# 2017 Crop Residue Burning Ozone State Implementation Plan Revision Amendment

Additional Photochemical Modeling Analysis

**State of Idaho**
**Department of Environmental Quality**
**Air Quality Division**
**1410 N. Hilton**
**Boise, ID 83706**

**October 2017**

Printed on recycled paper, DEQ, October 2017, PID SSIP, CA code 81992. Costs associated with this publication are available from the State of Idaho Department of Environmental Quality in accordance with Section 60-202, Idaho Code.

# Table of Contents

## List of Tables

# List of Figures

# Abbreviations, Acronyms, and Symbols

| | |
|---|---|
| **§** | section (usually a section of federal or state rules or codes) |
| **AIRPACT** | Air Information Report for Public Access and Community Tracking |
| **AMET** | Atmospheric Model Evaluation Tool |
| **$CH_4$** | methane |
| **CMAQ** | Community Multiscale Air Quality |
| **CO** | carbon monoxide |
| **$CO_2$** | carbon dioxide |
| **CRB** | crop residue burning |
| **DEQ** | Idaho Department of Environmental Quality |
| **EPA** | United States Environmental Protection Agency |
| **FB** | fractional bias |
| **FE** | fractional error |
| **FHWA** | Federal Highway Administration |
| **HMS** | Hazard Mapping System |
| **ID** | Idaho |
| **IDAPA** | Refers to citations of Idaho administrative rules |
| **km** | kilometer |
| **LAR** | Laboratory for Atmospheric Research (WSU) |
| **MADIS** | Meteorological Assimilation Data Ingest System |
| **MATS** | Modeled Attainment Test Software |
| **MCIP** | Meteorological-Chemistry Interface Processor |
| **MDA8** | maximum daily 8-hour average |
| **MEGAN** | Model of Emissions of Gases and Aerosols from Nature |
| **MNB** | mean normalized bias |
| **MNGE** | mean normalized gross error |
| **MODIS** | Moderate Resolution Imaging Spectroradiometer |
| **MOVES** | Motor Vehicle Emissions Simulator |
| **MOZART** | Model for Ozone And Related Chemical Tracers |
| **NAAQS** | National Ambient Air Quality Standards |
| **NEI** | National Emissions Inventory |
| **NO** | nitric oxide |
| **$NO_2$** | nitrogen dioxide |
| **$NO_x$** | nitrogen oxides |
| **NRMC** | Northwest Regional Modeling Consortium |
| **$PM_{2.5}$** | particulate matter with an aerodynamic diameter of 2.5 micrometers or less |
| **ppb** | parts per billion (aka ppbv) |
| **ppbv** | parts per billion by volume |
| **ppm** | parts per million |
| **SIL** | significant impact level |
| **SIP** | state implementation plan |
| **SMA** | smoke management area |
| **SMOKE** | Sparse Matrix Operator Kernel for Emissions |
| **UT** | Utah |
| **UW** | University of Washington |
| **VMT** | vehicle miles traveled |
| **VOC** | volatile organic compound |
| **WRF** | Weather Research and Forecasting |
| **WSU** | Washington State University |

# Executive Summary

In 2008, Idaho created a new crop residue burning (CRB) program as a result of a court settlement and negotiations between regulators, environmental health advocates, and growers. The Idaho Department of Environmental Quality (DEQ) submitted the new program as a State Implementation Plan (SIP) revision, and the revision was approved by the United States Environmental Protection Agency (EPA) and became effective September 2008 (73 FR 44915). The 2008 Idaho statute (Idaho Code §39-114) and rule (IDAPA 58.01.01.621.01) implemented the program and limited burning at 75% of the National Ambient Air Quality Standard (NAAQS). This rule prohibited approving agricultural burning when ozone concentrations were greater than 56 parts per billion (ppb). DEQ has managed the CRB program for several years under this threshold limitation, and days with atmospheric conditions conducive to good smoke management were often excluded because of this threshold. When EPA modified the 8-hour ozone NAAQS in 2015 to 0.070 parts per million, the original Idaho rule, if left unchanged, would have restricted any agricultural burning at 52.5 ppb. An ozone concentration of 52.5 ppb is approaching background ozone levels in Idaho and would limit the effectiveness of Idaho's smoke management program. In the 2016–2017 negotiated rulemaking process, DEQ modified the Idaho rule allowing CRB to 90% of the 8-hour ozone NAAQS.

Changing the Idaho rule to 90% of the NAAQS for ozone only, which represents a 63 ppb ozone concentration, was pursued to ensure the program continues to protect public health and air quality while allowing CRB as an agricultural practice when it will not jeopardize public health. This change applies to lands outside the five Idaho tribal reservation boundaries only. A cessation threshold of 63 ppb provides (at a minimum) a 7 ppb cushion for protecting the 2015 8-hour ozone NAAQS. In reality most burning occurs on days with lower ozone concentrations and thus the actual buffer to protect the NAAQS is greater than 7 ppb. In this analysis, we conservatively assumed the smallest possible buffer of 7 ppb.

DEQ drafted the *2017 Crop Residue Burning Ozone State Implementation Plan Revision* (2017 CRB SIP) to demonstrate that CRB, as it occurs in Idaho, has and will continue to meet all requirements of the Clean Air Act and will not cause or significantly contribute to a NAAQS violation. In support of the 2017 CRB SIP, this amendment provides additional evidence that when operating under the new rule, Idaho's CRB program will not cause or contribute to a violation of the ozone NAAQS at any locations in and around Idaho.

This report describes the modeling approach (including model selection, episode selection, boundary and initial conditions), emission inputs, meteorological model evaluation, photochemical model evaluation, diagnostic evaluation of modeled fire plume rise, and assessment of CRB impacts on the maximum daily averaged 8-hour (MDA8) ozone at all locations in and around Idaho. Model performance for meteorological inputs and the photochemical model met EPA recommendations for use in regulatory demonstrations.

This air quality analysis evaluated potential CRB impacts on ozone concentrations through four modeling runs, a base-case or background simulation without Idaho's CRB emissions and three different scenarios for the CRB program:

- **Background emissions analysis—**A modeling analysis for the July 8–September 26, 2013, episode with all emissions sources except Idaho CRB sources, including all wildfires and all the agricultural burning in other states and tribal areas outside Idaho's CRB program.
- **Scenario 1: 2013 actual CRB emissions—**Actual crop residue burns in the CRB program that occurred during the July 8–September 26, 2013, episode. This scenario provided the 2013 base case for CRB emissions in Idaho before the new rule (i.e., burning was not allowed in this scenario for any burn area or county in which the ozone MDA8 was forecasted to be over 56 ppb, 75% of the 2008 NAAQS).
- **Scenario 2: 2013 burning under the new rule—**This scenario adds burning on additional days allowed under the new rule. To simulate the base year 2013 episode as it would occur under the new rule, this scenario includes the Scenario 1 actual burns plus "hypothetical burn" median emissions that could have also occurred under the new rule when the model predicted a concentration between 56 ppb and 63 ppb.
- **Scenario 3: maximum daily burning—**To ensure that the maximum existing/historical daily burning levels are assessed, the burns simulated in Scenario 2, (including both the actual burns and hypothetical burns under the new rule) were grown by adding emissions needed to bring each county up to the historical maximum 1-day emissions for that county.

DEQ does not anticipate any increase in annual emissions resulting from this rule change, but rather the same emissions spread out over more good burn days, resulting in lower overall impacts. Scenario 3 was chosen as a possible worst-case scenario for each day, but the total acres are not intended to reflect a greater seasonal burn acreage.

In Scenario 1, model results indicate that the highest CRB contribution to the MDA8 from any actual burning during July 8–September 26, 2013, was 1.8 ppb. This result is consistent with the findings of the 2017 CRB SIP. Scenario 2 simulated the actual burn days plus the days opened up for burning under the new rule. This result caused some increased ozone MDA8 contributions on new days and in new counties in the range of 0–0.4 ppb, but the maximum contribution observed was still 1.8 ppb. It appears that the days with ozone in this range (56–63 ppb) had lower CRB ozone impacts due to improved vertical mixing and transport on the additional warm, sunny days. Scenario 3 burn emissions reflect an increase in the Scenario 2 burn emissions (by county) to reflect the maximum one-day burn acreage that has ever occurred in the CRB program since its inception in 2008. The maximum 8-hour ozone impacts from CRB under this maximum day scenario were 4.0 ppb. The background ozone during this maximum impact day was 49 ppb, but for this worst-case evaluation, we assume an MDA8 ozone concentration of 63 ppb, so the combined worst-case MDA8 ozone concentration with a maximum CRB contribution of 4.0 ppb is estimated to be 67 ppb. This is a conservative result due to the conservatism built into the model plume rise treatment, conservative emission factors used, and the application of historical maximum daily burn acreages used in Scenario 3.

The observed, monitor-based design values were around 61–62 ppb in the rural areas, 65 ppb in the semi-urban areas of Meridian and Logan and 69 ppb in Boise. The modeled $4^{th}$-high background concentrations in areas of daily maximum CRB impacts average 57 ppb with a maximum of 64, in close agreement with the rural and semi-urban monitors.

The photochemical modeling described in this report demonstrates that the value of the ozone NAAQS will not be violated even once under DEQ's CRB program, when operating under the new rule. This conclusion is consistent with DEQ's 2017 CRB SIP that determined a maximum 2 ppb CRB contribution to the observed monitoring concentrations over the last five years of the program. In addition, because fields are typically burned only once per year and none of the modeled daily highest MDA8 values occurred at the same location twice, the 4th highest CRB contribution under the new rule was 0.15 ppb, well below EPA's 1.0 ppb significant impact level.

# 1 Introduction

This amendment provides additional air quality analysis that supports the *2017 Crop Residue Burning Ozone State Implementation Plan Revision* (2017 CRB SIP) and further demonstrates that the Idaho Department of Environmental Quality's (DEQ's) proposed rule change will not cause or significantly contribute to a violation of the 2015 ozone National Ambient Air Quality Standard (NAAQS). DEQ's proposed rule change, underlined below, revises the program concentration threshold for ozone:

> **621. BURN DETERMINATION.**
>
> [Effective February 28, 2018] This version would become effective on a date certain by which EPA will have approved the SIP. DEQ anticipates approval of the SIP by February 28, 2018.
>
> **01. Burn Approval Criteria**. The Department shall develop a Crop Residue Operating Guide to use in assisting in the determination of burn approvals. The permittee shall obtain initial approval from the Department for the proposed burn at least twelve (12) hours in advance of the burn. The permittee shall confirm, with the Department, the approval the morning of the proposed burn. The Department may shorten this time frame if meteorological or other applicable conditions change that will impact the air quality during the proposed burn period. To approve a permittee's request to burn, the Department must determine that ambient air quality levels do not exceed ninety percent (90%) of the ozone national ambient air quality standard (NAAQS) and seventy-five percent (75%) of the level of any other national ambient air quality standards NAAQS on any day and are not projected to exceed such level over the next twenty-four (24) hours, and ambient air quality levels have not reached, and are not forecasted to reach and persist at, eighty percent (80%) of the one (1) hour action criteria for particulate matter under Section 556 of these rules. . .

The form of the 2015 ozone NAAQS is the 3-year average of the 4th-highest *maximum daily averaged 8-hour* (MDA8) ozone concentration. To violate the NAAQS, the MDA8 concentration at any location would have to exceed 70 parts per billion by volume (ppbv) more than three times in 1 year, on average, over 3 years.

DEQ has determined in the 2017 CRB SIP, that CRB has never produced enough additional ozone to exceed 70 ppbv at any monitor even once, thus the probability of doing it four times in 1 year at a single location, averaged over three consecutive years is extremely low. The modeling demonstration shows that this is true even when modeling the maximum historical county-level burn days in the 9 years of the program.

Supporting documentation is provided in the following appendices:

- Appendix A. AIRPACT5 Emissions Inventory
- Appendix B. Memorandum: Methods and Results for Preparation of the Wildland Fire Emissions Inventory for the AIRPACT5 Domain from July through September 2013
- Appendix C. CRB Emissions Factors and Burn Activity for Each Scenario
- Appendix D. Assessment of Meteorological Simulations for 2013 and 2015 CRB Modeling Episodes
- Appendix E. Plume Rise Diagnostic Evaluation
- Appendix F. Evaluation of CMAQ Photochemical Transport Model
- Appendix G. Detailed Results of the CRB Impact Analysis

## 1.1 Modeling Approach

As stated in the 2017 CRB SIP, this rule change does not increase emissions, or acres burned on a daily or annual basis, and should be considered a minor SIP revision because it only changes a decision-making threshold that will improve overall smoke management (the primary goal of any successful smoke management program).

DEQ conducted this analysis approach using modeling systems and inputs developed and tailored specifically for forecasting air quality in the Pacific Northwest. These operational systems are operated by the Northwest Regional Modeling Consortium (NRMC), which funds the University of Washington (UW) to operate the Weather Research and Forecasting (WRF) model, and the NW-AIRQUEST Consortium, which funds Washington State University (WSU) to operate the Community Multiscale Air Quality (CMAQ) model in an operational forecast system called Air Information Report for Public Access and Community Tracking (AIRPACT5). These operational forecast systems are not inherently of the same nature as a retrospective/reanalysis modeling approach, but DEQ believes that due to more than 15 years of operating these WRF and CMAQ systems, updating emissions to best reflect Pacific Northwest sources, testing submodules to produce the best meteorological and air quality forecasts, the WRF/AIRPACT5 system typically performs at a level, without reanalysis, that would be acceptable for SIP-level nonattainment demonstrations. In addition, it is one of the tools that is used for ozone forecasting to guide Idaho’s CRB program decisions so this modeling demonstration, although significantly updated with improved emissions inventories, will be consistent with the operational model.

## 1.2 Modeling Protocol and Deviations

A modeling protocol was prepared and shared with the modeling team including United States Environmental Protection Agency (EPA) Region 10 representatives. The final version of the protocol was not definitive until fairly late in the modeling effort due to uncertainties; however, the latest version was distributed in June 2017. This was the point when the model infrastructure and emissions were defined but before the CRB impact modeling occurred.

The modeling protocol was followed in all the major elements with one exception. DEQ originally anticipated using the Modeled Attainment Test Software or MATS (Abt Associates 2010) because (1) it is often used, per EPA guidance, in nonattainment demonstrations; (2) it is designed to reduce the effect of model bias in the results; and (3) it is a good tool to use in developing an unmonitored area analysis. As the modeling project proceeded, and DEQ looked more carefully into MATS, we realized that it does a good job using model grids to interpolate between monitors to reduce model bias between monitors; however, there are only three ozone monitors in Idaho, a geographically huge and complex region, and interpolation would likely not be effective in such a case. Due to the topographic divisions resulting from mountain ranges and river valleys, there is usually only one or at most two ozone monitors in a single contiguous airshed, and this is not adequate for developing spatially adjusted model surfaces as MATS does for unmonitored areas. In addition, DEQ found that the model bias is very low so the need for bias correction, another advantage of MATS, is also less important. Finally, DEQ is primarily trying to determine the relative contribution from one source category, CRB, by difference, rather than trying to predict an absolute concentration for comparison to the NAAQS, as is done in an attainment demonstration. DEQ discussed these issues with EPA, Region 10, and they concurred that MATS would be less useful in our situation, and agreed that its utility may be limited in this project. No other significant deviations from the modeling protocol occurred.

## 1.3 Modeling Demonstration Participants and Roles

The participants and their roles in this modeling project are listed in Table 1.

**Table 1. Participants and their roles in this modeling demonstration project.**

| Participating Person/Organization | Role |
|---|---|
| Idaho DEQ Air Quality Program | Project sponsor, objectives and management.<br>Emission Inventory support.<br>CRB program database interpretation and additional support in understanding the program and program operations. |
| Idaho DEQ Technical Services Division | Project planning, model implementation and updating, emission inventory assistance, MOVES modeling, meteorological and air quality model performance evaluation, attainment testing and reporting. |
| University of Washington, Atmospheric Science Department | Development of operational WRF system and originators of WRF meteorological inputs provided to WSU for input to the AIRPACT modeling system. |
| Washington State University, Laboratory for Atmospheric Sciences | Development of operational AIRPACT5 air quality forecast system and system components. WSU provided DEQ with archived boundary conditions, Sparse Matrix Operator Kernel Emissions - ready emissions for most source categories, and Meteorological-Chemistry Interface Processor meteorological fields (informed by the UW WRF outputs) for episode periods simulated by DEQ. |
| United States Environmental Protection Agency | EPA supports the WRF and AIRPACT5/CMAQ regional modeling operations through the NRMC and NW-AIRQUEST consortia. EPA staff provided input and suggestions on this project as it proceeded. |
| Sonoma Technology | Provided wildfire and prescribed fire emissions from SMARTFIRE2/BlueSky for the AIRPACT5 domain during DEQ's base year (2013) episode. |
| United States EPA/Sonoma Technology | Wildfire and prescribed fire emissions from SMARTFIRE2/BlueSky for the Soda Fire in August 2015. Sonoma generated a 2015 nationwide wildfire emissions inventory for EPA based on the 2014 National Emissions Inventory methods. EPA authorized Sonoma to release the Soda Fire emissions files from this work product to DEQ before EPA's full release of the data. |

## 1.4 Conceptual Model

### 1.4.1 Air Quality in Idaho

All ozone monitor measurements in and around Idaho are below the ozone NAAQS of 70 ppb. The urban areas around Boise; Spokane, Washington; and Salt Lake City, Utah, all generally have somewhat higher ozone levels than the rural and remote areas in the state, including the areas with the most CRB acreage which are located in central Idaho, north and south Magic Valley and eastern Idaho. The ozone monitoring data in and around Idaho and the latest 3-year design values are described in the 2017 CRB SIP.

### 1.4.2 Ozone Formation in Traditional Urban Nonattainment Areas

Ozone nonattainment areas are typically formed in the vicinity of large urban areas where the nitrogen oxides ($NO_x$) and volatile organic compounds (VOCs) mix, transport downwind on the predominant afternoon winds, and react to produce enhanced ozone over a number of hours in the afternoon. The typical ozone formation scenario that comes to mind when atmospheric scientists think of urban nonattainment areas is described here because that conceptual model is different from the ozone formation due to wildfires and crop residue burning. In urban areas, the source area is broad, reflecting the entire densely populated area; its location is fixed; and its emissions are more or less constant, except for relatively minor seasonal and day-of-week variations. Finally, since the location is fixed, a predominant afternoon wind often brings the broad, oxidant rich, urban plume over the same downwind locations nearly every day. Thus, the higher MDA8 ozone concentrations typically occur on numerous days at the same location, a requirement for causing a NAAQS violation under the form of the standard. Wildfires and crop residue burning both differ from this conceptual model in both the spatial extent of the ozone-rich plume, frequency of occurrence and duration. Wildfires have a smaller source area and plume dimension and do not occur year-round but may persist for weeks or months causing ozone and other smoke impacts in a small region for part of one year. CRB is characterized by even smaller plumes in variable locations, rarely causing significant impacts at the same location twice in one year. In addition, the short nature of CRB burns, typically less than 1 or 2 hours, results in impacting a single location (e.g. a residence) for only one day and for only a small fraction of the 8-hour average used to compute the MDA8 ozone concentrations as required for comparison to the NAAQS.

### 1.4.3 Ozone Formation from Wildfires

All biomass fires emit primary particulate matter smaller than 2.5 micrometers in aerodynamic diameter ($PM_{2.5}$) (i.e., smoke particles) as well as carbon monoxide (CO), carbon dioxide ($CO_2$), VOCs, and $NO_x$, including nitric oxide (NO) and nitrogen dioxide ($NO_2$). Following release of these pollutants and early in the life of the resulting plume, before it has travelled very far, the NO reacts with ozone already existing in the background ambient air forming $NO_2$, and largely depleting the ozone. In addition, when the smoke is still thick and opaque, it may block the solar ultraviolet light necessary for fresh photochemical ozone production. As a result, ozone is known to be reduced in the near field. As the plume or smoke parcel is transported downwind, it undergoes a number of changes. First, it is dispersed and diluted, reducing the concentrations of all species. In addition, aerosol particles “age” or grow, as semi-volatile organic gases cool and condense on the surface of the smoke particles. As the smoke plume disperses, the $NO_2$ levels become more conducive to oxidant production, and the solar ultraviolet light begins to produce photochemical oxidants such as hydroxyl radicals, aldehydes, and ultimately ozone. More detailed information on ozone formation in biomass burning plumes is provided in the 2017 CRB SIP.

### 1.4.4 Ozone Formation from Crop Residue Burns

Ozone can be produced in all biomass burning plumes; however, the impact of the ozone production depends on the size of the fire(s) and of the resulting plume(s), quantity of woody smoldering-prone fuels, quantities of ozone precursors present in the plume after transport and dilution, and VOC/$NO_x$ environment into which the plume is dispersing and mixing. Thus, the relative impact depends on the fuel type, the meteorological conditions leading to plume transport and dilution and the photochemical environment into which it is mixing. Individual fires may produce relatively narrow plumes that are isolated and may sweep over a given location (e.g., a monitor or receptor) for only a very brief time. The time of plume impact is typically limited by the horizontal width of the plume, reflecting the cross-wind dimension of the field being burned, and by the persistence of the transport wind, while the axial dimension of the plume (in the direction of travel) is limited primarily by the duration of the fire. For example, a crop burn that lasts 30 minutes and is not prone to extensive smoldering will typically only produce a plume that passes over any location in little more than 30 minutes at most. The horizontal dimension and axial dimension of the plume determine the duration of any ozone impact, its health effects, and its contribution to the MDA8 ozone concentration. As a result, crop residue burning in Idaho typically results in a very limited plume impact compared to wildfires because the dimensional limitations greatly mitigate the 8-hour averaged ozone concentration that would impact citizens or would be measured or modeled. Crop fields and multiple field configurations are rarely if ever burned twice in the same year, so the 4-high contribution from CRB is greatly limited and the only realistic scenario for contribution is for a single maximum impact day contributing to the existing background 4th-highest MDA8 concentration. Nevertheless, when numerous fields are burned in one area, the potential for cumulative contributions to the 8-hour averaged ozone may be increased. It is therefore important to simulate large burn day scenarios when numerous fields may cause overlapping ozone contributions.

## 1.5 Modeling Approach Summary

The modeling described in this report was conducted to evaluate the enhanced ozone production that may result from agricultural burning in Idaho under DEQ's CRB program. Since ozone production is highly dependent on the environment into which ozone precursors are released, DEQ obtained the modeling system used for forecasting ozone, AIRPACT5, and updated the most important sources of ozone precursors in Idaho during the ozone season: vegetation, motor vehicles, and wildfires. After the modeling infrastructure was complete, DEQ evaluated potential CRB impacts on ozone concentrations through four modeling runs, a base-case or background simulation without Idaho CRB emissions and three CRB scenarios:

- **Background emissions analysis—**A modeling analysis for the July 8–September 26, 2013, episode that included all emissions sources except Idaho CRB sources, including all wildfires and all the agricultural burning in other states and tribal areas outside DEQ's CRB program. This provides the background concentrations against which the three CRB emission scenarios were compared to determine ozone contributions due to CRB emissions.
- **Scenario 1: 2013 actual CRB emissions**—Actual crop residue burns in the CRB program that occurred during the July 8–September 26, 2013, episode. This provided the 2013 base case for CRB emissions in Idaho before the new rule (i.e., burning was not allowed in this scenario for any burn area or county in which the ozone MDA8 was forecasted to be over 56 ppb, 75% of the 2008 NAAQS).
- **Scenario 2: 2013 burning under new rule—**This scenario adds burning on additional days allowed under the new rule. To simulate the base year 2013 episode as it would occur under the new rule, this scenario includes the Scenario 1 actual burns plus

"hypothetical burns" that would have also occurred under the new rule when the model predicted a concentration between 56 ppb and 63 ppb. Emissions representing the median daily average burn acreage for each county were added to any county on any day in which the background ozone was in this range. The median represented the same month as the additional day to account for seasonal variability.

- **Scenario 3: Maximum daily burning—**To ensure that the maximum existing/historical daily burning levels are assessed, the burns simulated in Scenario 2, (including both the actual burns and hypothetical burns under the new rule) were grown by adding emissions needed to bring each county up to the historical maximum 1-day emissions for that day and county. To implement a maximum day scenario, each of the days (by county) that produced additional ozone (> 0.2 ppb) in the Scenario 2 simulation was selected and the emissions for that county/day and for adjacent counties that may have contributed on the same day, were also grown to the maximum 1-day historical emissions level for those counties. The details for all three scenarios are provided in Appendix C.

The maximum daily simulation is made to provide a worst-case daily emissions scenario that leads to maximum ozone formation and is not intended to suggest that more acres will be burned daily or annually, nor to allow any increase in burning beyond the historical levels for the program.

# 2 Model Selection

Ozone formation resulting from both anthropogenic and natural sources of VOC and $NO_x$ precursors is not a linear process, but rather a very complex process that depends on the transport and dispersion actions of the atmosphere as well as the hundreds of photochemical reactions that occur every second at every location and every elevation throughout the earth's atmosphere. EPA supports the public domain CMAQ model which has the largest community of developers and users world-wide and is commonly used for ozone and $PM_{2.5}$ nonattainment SIPs. Thus, DEQ has selected CMAQ and its supporting models, primarily the WRF (Weather Research and Forecast) model which provides weather parameters for every 4-km location through the Pacific Northwest, and the Sparse Matrix Operator Kernel for Emissions (SMOKE) emissions processor, which prepares the emissions inventory for CMAQ by applying the temporal and spatial allocations and speciation profiles for every source. The CMAQ model and the ancillary sub-models and other programs used to provide or process its inputs are described below.

## 2.1 Weather Research and Forecasting Model

DEQ used archived meteorological outputs from the WRF model, produced by UW in an operational mode and archived by WSU in the form of outputs from the Meteorological-Chemistry Interface Processor (MCIP) that was run operationally on the actual episode days for which DEQ modelled. The native WRF modeling operation is described in section 6.1.

## 2.2 AIRPACT5 Regional CMAQ Photochemical Model

DEQ conducted this weight-of-evidence analysis approach using modeling systems and inputs developed and tailored specifically for the Pacific Northwest by the NRMC (WRF) and NW-AIRQUEST (AIRPACT). AIRPACT version 5 became operational in December 2015. Meteorology and boundary condition input files (i.e., MCIP and BCON files) were available from the archived AIRPACT4 2013 operational model archive to drive DEQ's updated AIRPACT5 simulations for the modeling episodes described here, but the framework and other components, including the static portions of the EI are based on AIRPACT5.

These operational forecast systems are not used in a completely retrospective modeling approach often used for attainment demonstrations in nonattainment SIPs, but DEQ believes that through more than 15 years of operating these MM5/WRF and CMAQ systems, updating emissions to best reflect Pacific Northwest sources, testing submodules to produce the best meteorological and air quality forecasts, the WRF/AIRPACT5 system performs adequately to meet the performance criteria typical of regulatory applications as described in section 8. In addition, the WRF/AIRPACT5 system used for this analysis is very similar to the current WRF/AIRPACT5 systems used for the regional operational forecasts and for forecasting ozone levels used in Idaho's CRB burn calls. Value exists in using the same system for this ozone NAAQS evaluation as that used in the operational forecasts, as long as it meets the general performance benchmarks typically used in the regulatory application of such models (Simon et. al. 2012).

DEQ used the AIRPACT5 emission inventory for many of the source categories; however, the major emission categories for VOCs and $NO_x$ were updated for this project, including biogenic emissions using the latest version of Model of Emissions of Gases and Aerosols from Nature (MEGAN), on-road emissions using the latest version of the Motor Vehicle Emissions Simulator (MOVES) model, wildfires in the region using Smartfire2/BlueSky estimates of ozone precursor emissions, and the CRB emissions. After updating the emissions, DEQ evaluated both the WRF meteorological outputs and the CMAQ air quality model outputs using the same methods and the same performance evaluation benchmarks used for the more traditional SIP modeling efforts. DEQ believes, based on our performance evaluation and the many years of on-going performance and diagnostic analyses by UW and WSU that model performance is sufficient for the purposes of this study.

## 2.3 Sparse Matrix Operating Kernel for Emissions

WSU's LAR used SMOKE version 3.5.1 to process emissions for speciation of VOCs and $PM_{2.5}$ components and to spatially and temporally allocate the emissions by hour into 4-kilometer (km) grids throughout the domain.

## 2.4 Community Model for Air Quality

The central chemical and transport model used within AIRPACT5 is CMAQ. CMAQ is a Eulerian photochemical grid model developed under EPA funding. The version used in this analysis was CMAQ5.0.2.

# 3 Model Domain, Grid and Boundary Conditions

## 3.1 Model Domain

The model domain used in these simulations was the original WRF and CMAQ modeling domain that covers the Pacific Northwest including southern British Columbia and Northern California, Nevada, Utah, and portions of western Montana (Figure 1). The agricultural areas where crop residue burning is concentrated are shown in Figure 2. As shown in the figure, the crop agricultural areas (yellow) are in the broad valleys and plains and no significant crop residue burning occurs in the forested mountainous regions (dark green.) The population is also concentrated in the relatively flat areas (Figure 3), as are most of the $NO_x$ emissions (Figure 4), so the larger valley areas are of most concern in this modeling analysis. DEQ focused the Idaho portion of the model performance evaluation on these broad plains and large valley areas with less emphasis on the steeper mountain areas with deep narrow deep valleys where sources and receptors are scarce, where CRB does not occur, and where the 4-km WRF modeling is already known to be incapable of accurately capturing complex, terrain-channeled winds.


**Figure 1. WRF and AIRPACT5 4-km domain.**

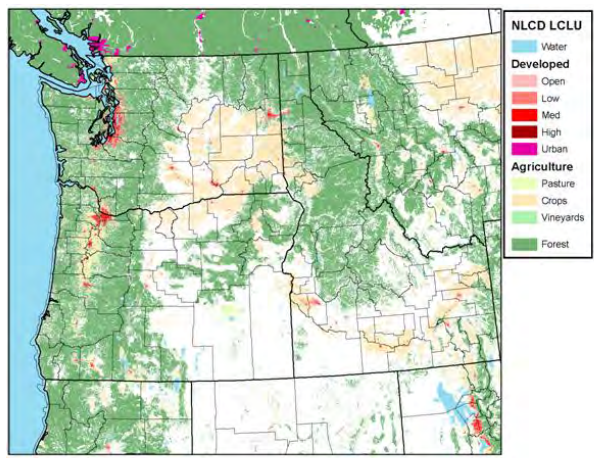



**Figure 2. Modeling domain including agricultural/crop areas where CRB activity occurs.**

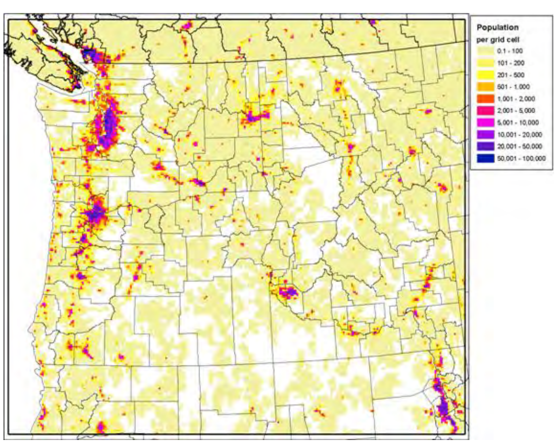



**Figure 3. WRF and AIRPACT domain showing population density.**

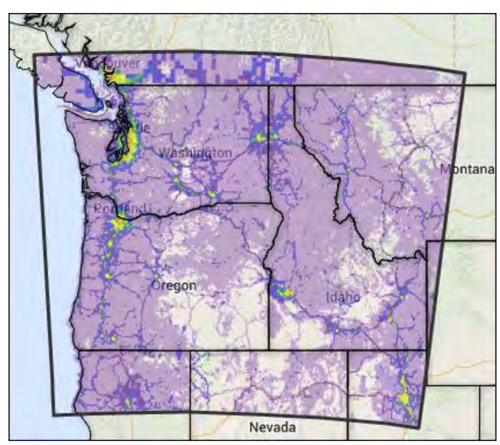



**Figure 4. WRF and AIRPACT domain showing $NO_X$ emissions density.**

## 3.2 Grid Resolution and Vertical Structure

The AIRPACT5 domain used in the CMAQ modeling uses a 4-km horizontal grid resolution. Due to archived MCIP outputs used in our modeling, The AIRPACT5 simulations produced by DEQ use a 21-layer vertical structure used in AIRPACT4 (Table 2). The horizontal grid resolution and vertical layers break up the entire modeling domain into "grid cells" that are the smallest portion of the model in which all processes are separately simulated (e.g., emissions, transport, and chemistry).

**Table 2. AIRPACT5 vertical layers (height above ground is approximate).**

| Model Layer | Pressure Relative to Ground Elevation (i.e., Sigma Level) | Height of Layer Top Above Ground (meters) |
|---|---|---|
| 0 | 1 | — |
| 1 | 0.995 | 40 |
| 2 | 0.99 | 80 |
| 3 | 0.9841 | 130 |
| 4 | 0.9772 | 185 |
| 5 | 0.9702 | 245 |
| 6 | 0.962 | 315 |
| 7 | 0.9525 | 395 |
| 8 | 0.9414 | 490 |
| 9 | 0.9284 | 600 |
| 10 | 0.9134 | 730 |
| 11 | 0.896 | 880 |
| 12 | 0.8759 | 1,060 |
| 13 | 0.8527 | 1,270 |
| 14 | 0.7608 | 2,150 |
| 15 | 0.6309 | 3,525 |
| 16 | 0.4594 | 5,675 |
| 17 | 0.2832 | 8,565 |
| 18 | 0.1595 | 11,450 |
| 19 | 0.0806 | 14,215 |
| 20 | 0.0312 | 16,865 |
| 21 | 0 | 19,425 |

## 3.3 Initial Conditions

Initial conditions were developed by beginning the simulation at 12 days before the start of the main episode on July 8 to allow for complete model "spin-up" and generation of realistic initial conditions on the first day of the main episode.

## 3.4 Boundary Conditions

Boundary conditions were provided for AIRPACT5 each day by the operational Model for Ozone And Related Chemical Tracers (MOZART) global photochemical model operated by the National

Center for Atmospheric Research in Boulder, Colorado (*https://www2.acom.ucar.edu/gcm/mozart*). They were archived along with the MCIP meteorological files and provided by WSU for DEQ's modeling episodes.

# 4 Episode Selection

DEQ selected two episodes as part of its demonstration of ozone contributions from crop residue burning: (1) Soda Fire—a largely rangeland fire with measured ozone impacts simulated as a diagnostic evaluation of plume rise and a limited check on model performance for a crop-like rangeland fire; and (2) the base episode—a base-year episode to simulate a more complete period including both the peak ozone formation period and the peak crop residue burning period, evaluated to quantify the potential ozone formation from crop residue burning.

## 4.1 Soda Fire Episode for Diagnostic Plume Rise Evaluation

While CMAQ photochemical modeling has been conducted widely to simulate the ozone formation from wildfires and other wildland burning, it has not, to our knowledge, been used in any major studies to predict ozone formation from crop residue burning. While the photochemical models have been demonstrated to be reasonably accurate for wildland fires involving woody fuels and forest combustion, such demonstrations have not been found for agricultural or crop residue burning. Some photochemical modeling has been conducted for rangeland fire (Craig et. al. 2013), which due to the preponderance of grasses is more like agricultural residue fire than woody forest fires. However, these studies involve much larger fires than a typical crop residue burning scenario and have not occurred in the Pacific Northwest under conditions representative of Idaho agricultural areas. While no major studies in our region involve ozone formation resulting from crops or grass burning are known, DEQ identified an episode involving a rangeland fire (i.e., Soda Fire) near Boise, Idaho, in August 2015 that clearly resulted in ozone impacts on at least 2 days, at two Boise area monitors (Figure 5). Moderate Resolution Imaging Spectro-radiometer (MODIS) satellite images show the Soda Fire plumes travelling north toward the Boise/Meridian area on August 12 (Figure 6). The time-series observations in Figure 5 show that the fire plume reaches the monitoring station during two short periods on August 12 and 14 when brief but significant ozone "peaks" appear, simultaneously with $PM_{2.5}$ "peaks." The unusual $PM_{2.5}$ peaks occurring at the same time indicate that it is the smoke plume from the Soda Fire causing the ozone increase or "spike" above the normal rising afternoon ozone pattern. While this case was not the subject of a special monitoring program or study, and a comprehensive dataset for all ozone precursors is not available, it did provide some value in testing the model plume rise and ozone formation for Idaho conditions. DEQ believes it provided some confidence that the modeling treatment of a "crop-like" range fire (including plume rise and the photochemical computations) are capable of simulating ozone formation from a crop-like fire with reasonable accuracy. By evaluating nonreactive species such as $PM_{2.5}$ and CO first, DEQ was able to adjust the plume rise method to ensure reasonable transport conditions. When that was accomplished, the ozone formation matched the monitored values very well, giving us confidence that the model was getting the right ozone concentrations for the right reasons.

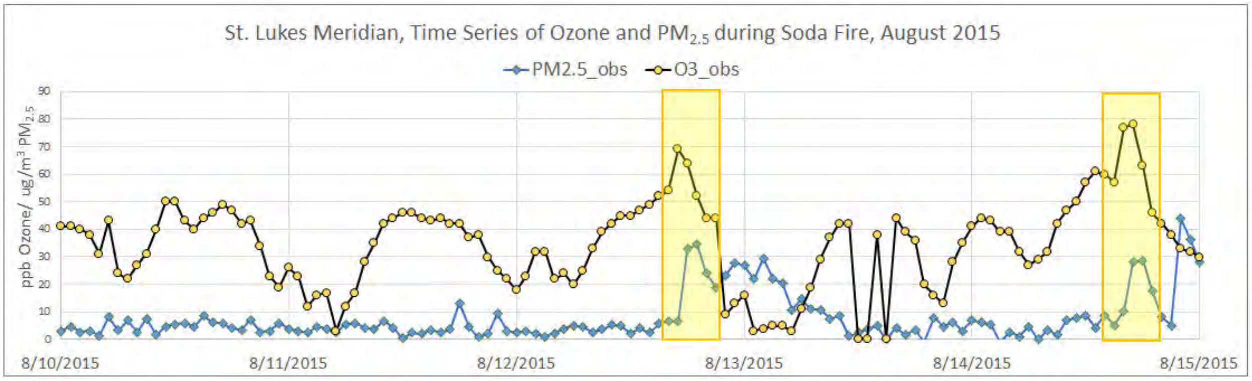



**Figure 5. Soda Fire ozone and $PM_{2.5}$ observations at the St. Luke's, Meridian monitor location with periods of plume contributions from fire shown in yellow boxes on August 12 and August 14, 2013.**

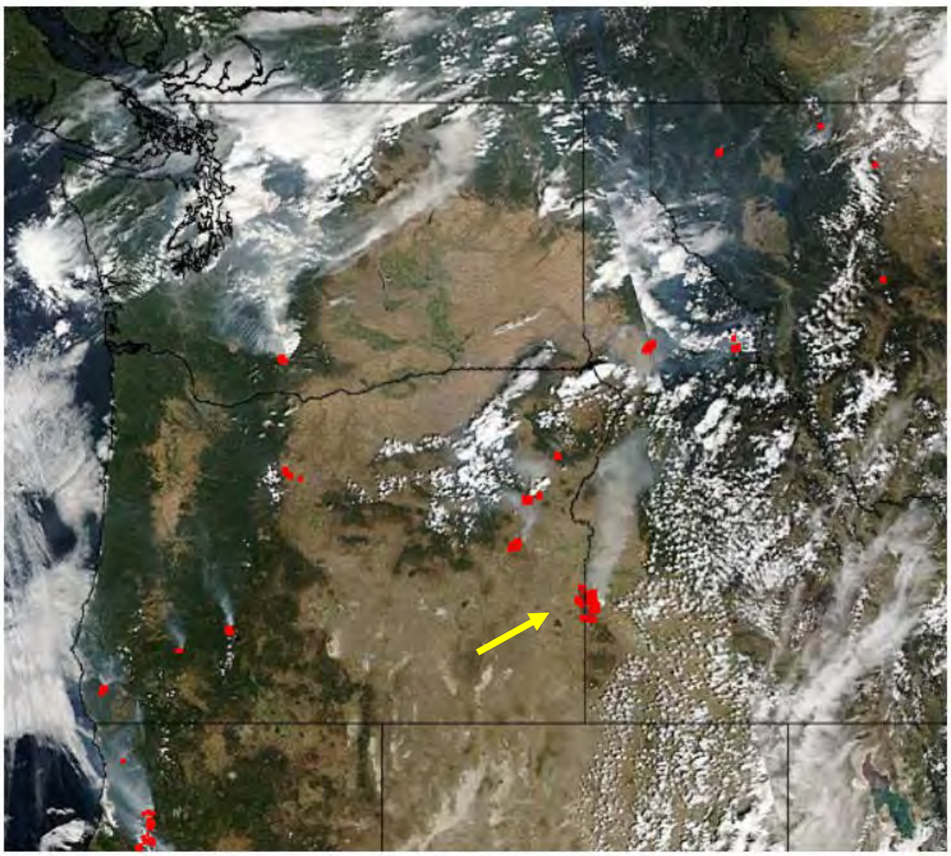


**Figure 6. MODIS Aqua image from around 1:45 p.m. August 12 local time showing fires and smoke from the Soda Fire (arrow) travelling north toward the Boise-Meridian area and the St. Luke's monitor.**

## 4.2 Base-Case Episode 2013 Ozone Season

The primary focus of this modeling study was to understand the level of ozone formation that may result from crop residue burning in Idaho, when the "no burn" program threshold limit is changed from 75% of the ozone NAAQS (52.5 ppbv) to 90% of the NAAQS (63 ppbv). To do this, a base-year modeling episode is needed that meets several desired criteria:

1. Represents conditions conducive to maximum ozone formation (i.e., the peak ozone season).
2. Represents days in which Idaho's Smoke Management Areas (SMAs) experience realistically large burn days in terms of total CRB acres burned in a single day.
3. Does NOT represent days in which Idaho's CRB program would not allow any significant burns due to (a) stormy weather; (b) red flag warnings; (c) significant wildfire smoke in the area; (d) forecasted rain, wet fuel, or poor dispersion; or (e) forecasted background ozone expected to exceed the program concentration threshold at which burning must stop (63 ppbv).
4. Is not so long that computing times are unacceptable.

DEQ selected an 81-day episode that meets these criteria from July 8 to September 26, 2013.

For the base-case modeling year, DEQ selected 2013 because (1) it is a year of unusually high ozone in the Pacific Northwest due to a persistent high-pressure ridge present over the region for much of the year; (2) it included a median level of crop residue burning in Idaho throughout the 9-year history of the program through 2016; and (3) it is only 1 year removed from the AIRPACT5 emissions year, 2014 (Otterson 2017).

Figure 7 shows the MDA8 ozone values for each day in 2013 for year-round monitoring stations (St. Luke's Meridian and Craters of the Moon ID and Logan, UT). Figure 8 show stations in and around Idaho (White Pine in Boise, ID and Cheney-Turnbull and Green Bluff, WA) that only monitor during the EPA-defined "ozone season" (May 1–September 30). The period of the ozone modeling episode is shown, in both figures, between the red dotted lines representing July 8 and September 26.

Figure 7 and Figure 8 show that the peak ozone season in and around Idaho is primarily June 27 through early September. There is a secondary period of elevated ozone from May 1 to May 15 resulting largely from stratospheric ozone intrusion and/or trans-Pacific transport of ozone precursors from Asia that influences the entire region. The photochemical conditions for surface-based local anthropogenic ozone formation are reduced during this period so it is not included in the simulation. The reduced potential for surface precursor emissions to produce ozone during the cooler seasons (September–April) is evidenced by the fact that ozone levels at the more rural monitors in this period (Craters of the Moon, Green Bluff, and Cheney) are higher, and ozone levels at the urban monitors (St. Luke's, White Pine, and Logan) are lower.

The CRB acres burned on each day in 2013 are shown in Figure 9. Typical of the burning seasons every year, there is some limited burning in the spring with most days below about 250–500 acres per Smoke Management Area (SMA), then burning drops to an insignificant level from about May 15 through about mid-July before harvest. After mid- to late-July growers begin to request authorization to burn, and the peak burn season lasts from mid-July until about September 20. In addition to the peak period of ozone formation, the selected modeling episode captures the portion of the burn season with most of the large burn days (i.e., the most acres per SMA in one day, the scenarios that should lead to the most ozone formation.)

Excessively long modeling episodes are resource intensive and result in unreasonably long computer run times, so the simulations must address only the most important periods. The selected base-year episode does this, although there are a few higher ozone days before July 8 and a few large burn days after September 26 that are not included in the episode. The periods just before and after the episode are not necessary for the following reasons:

- In the days before the July 8 start of the modeling episode, several elevated ozone days are found, mostly from June 28 to July 8. The episode does not include this small portion of the high ozone period. However, there is virtually no significant burning during this period (Figure 9 and Figure 10), so it is not useful to include it.
- In the days after September 26, the end of the modeling episode, there are still a small number of days with moderate burning levels, though much lower than during the episode. This period of agricultural burning is also not important to the objectives of this modeling study because the background ozone always drops sharply after mid-September due to lower temperatures, lower solar ultraviolet radiation, and lower precursor emissions from both vehicle fuel evaporation and from biogenic sources. The significantly lower ozone formation potential is seen in Figure 7, where no values exceed 47 ppb after September 26. Thus, the period after September 26 is also less important to the objectives of this study.

The selected modeling episode, July 8–September 26, 2013, meets the criteria identified above and captures all periods of greatest potential for ozone formation resulting from CRB activity, including the intersection of the high photochemical ozone period and the period of large burn days. DEQ believes that if no exceedances are found during this period they would also not occur in the other periods of the CRB season. To demonstrate that the 2013 annual burn pattern is very typical of all burn years, Figure 10 shows daily total burn acres for each SMA for all years of the DEQ's CRB program (2009–2016), excluding only the first year, which did not start until September and was atypical. Figure 10 also depicts the period of the 2013 modeling episode and shows that it also would be an appropriate episode to capture burn conditions for any year over the 2009–2016 time frame.

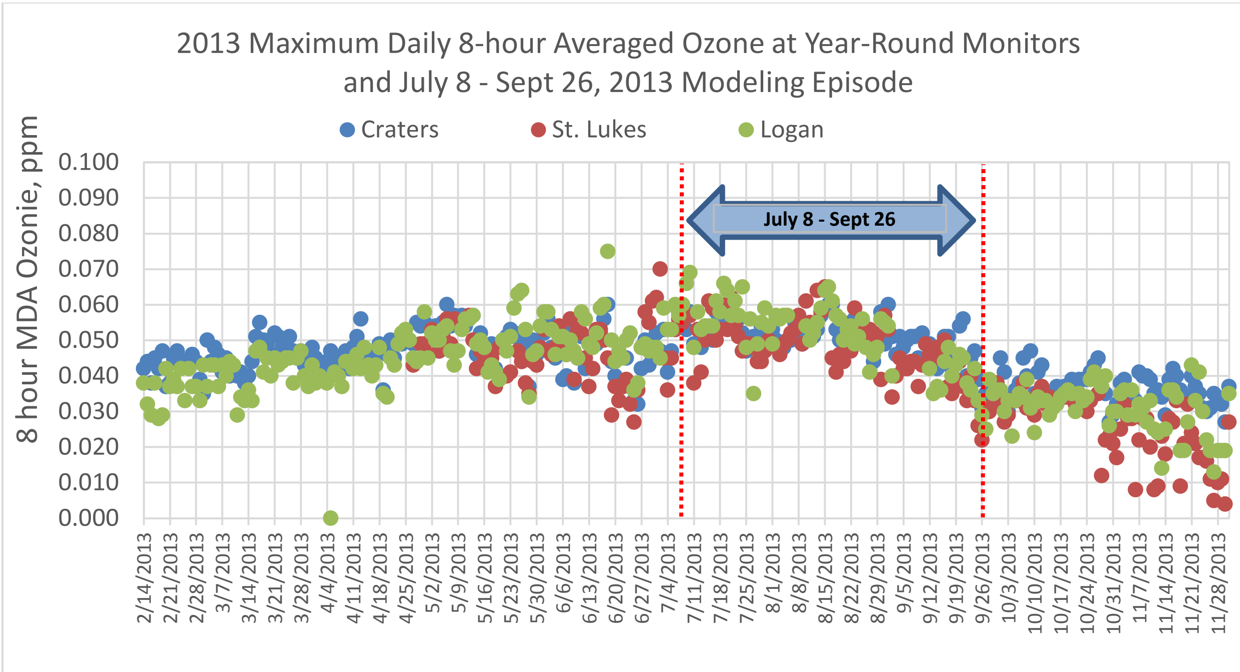



**Figure 7. The 2013 MDA8 ozone for year-round stations. The period of the base-year modeling episode, July 8–September 26, is shown by the arrow.**

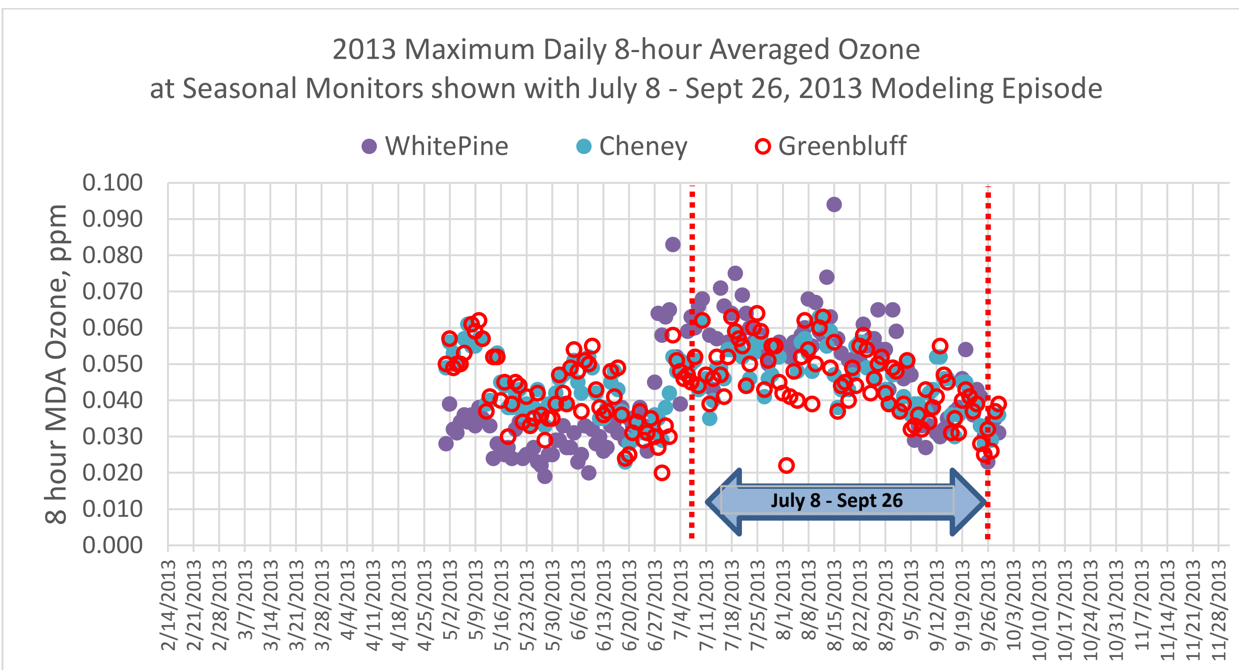



**Figure 8. The 2013 MDA8 ozone for stations that only operate May–September. The period of the base-year modeling episode, July 8–September 26, is shown by the arrow.**

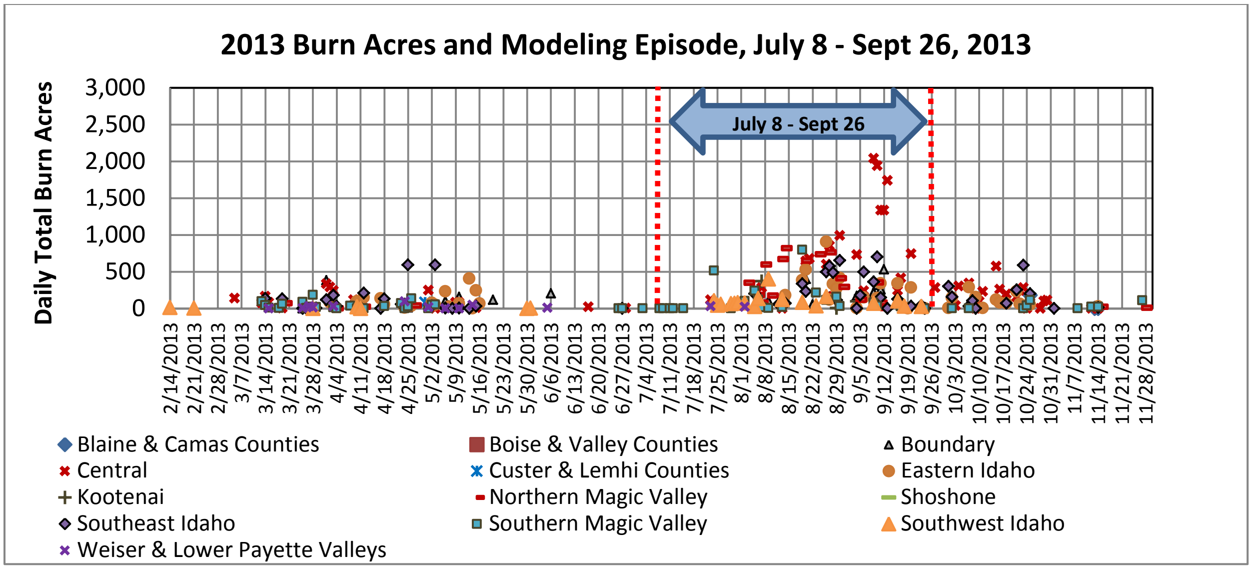



**Figure 9. Daily burn acres for Idaho's CRB program in 2013, by SMA.**

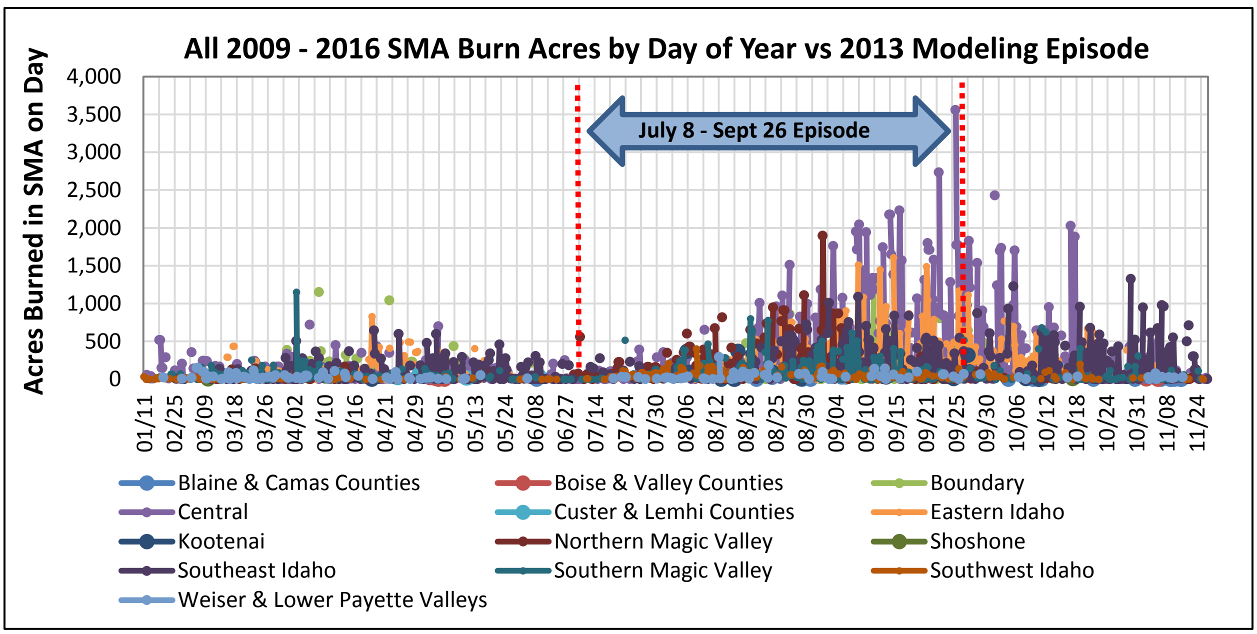



**Figure 10. Burn acres for all SMAs by day of year, 2009–2016. (Note: horizontal time scale differs slightly from the previous four figures.)**

# 5 Emission Inputs

The emissions of air pollutants from all anthropogenic and natural sources must be included in the CMAQ model to account for all of the atmospheric chemistry. Most importantly for ozone modeling, the emissions of ozone precursors $NO_x$ and VOCs from their major source categories should be complete and up to date. Carbon monoxide is also an ozone precursor but much less active in producing ozone than VOCs. The National Emissions Inventory (NEI) is produced by

EPA every 3 years and the 2011 NEI, adjusted or "grown," to represent 2014 served as the basis for most categories of emissions incorporated into the AIRPACT5 model.

The most critical emission categories for ozone precursors are the major categories that vary day to day. These categories were updated by DEQ specifically for the 2013 base-case episode and the 2015 Soda Fire episode using the latest model versions, including on-road (MOVES) emissions, biogenic emissions, wildfire emissions, and CRB emissions. These updated categories produced 93% of the VOCs and 64% of the $NO_x$ emissions in Idaho in the 2014 NEI. DEQ believes that the 7% fraction of VOCs and 36% of $NO_x$ emissions representing 2014 in the AIRPACT5 emission inventory (section 5.1) that were not updated for DEQ's simulations change very little over a 1-year period and are therefore reasonably well captured by the AIRPACT5 emission inventory described in section 5.1.

## 5.1 Point Sources and Other Nonpoint Anthropogenic Emissions

The AIRPACT5 modeling system uses a regional emissions inventory (Appendix A) developed by the NW-AIRQUEST regional modeling consortium (Otterson 2017). The on-road motor vehicle emissions, biogenic emissions, wildfire/prescribed fire emissions were all produced on a daily basis in the operational AIRPACT5 model runs because they all depend on varying activity and meteorological conditions, so these portions of the AIRPACT5 EI were updated by DEQ for this project. The updated components represent the largest sources of VOCs (93%) and $NO_x$ (64%) so they were re-generated for this project using the modeled temperature, solar radiation, and humidity conditions for each hour of the two DEQ modeling episodes. However, for point sources and many nonpoint or area source categories, the emissions are somewhat more static from day to day. These point source and more static nonpoint source categories in the AIRPACT5 inventory are described in Appendix A.

The AIRPACT5 inventory was focused on a 2014 inventory year so it is only 1 year removed from DEQ's 2013 base-case episode and 1 year removed from DEQ's 2015 Soda Fire episode. We believe this is a reasonable compromise for these smaller and more static emission categories. The larger categories of ozone precursor emissions that DEQ updated specifically for the 2013 base-case episode are described in the following sections.

## 5.2 Motor Vehicle Emissions

Motor vehicle emissions were estimated using the latest MOVES modeling, version 2014a, which is required by EPA for SIP and conformity purposes. MOVES on-road emissions were computed statewide for the 2011 and 2014 NEIs, and the 2011 emission factors are used in the operational AIRPACT system. However, motor vehicles are a major category of both VOC and $NO_x$ emissions, so DEQ produced a new MOVES2014a simulation for the 2013 ozone/CRB season episode, July 8–September 26. New meteorology for that period and the vehicle source population and other detailed input databases for the 2014 NEI, the latest available, were used in the new simulation. The 2014 NEI utilizes source population information from the 2014 vehicle registration database so it represents the vehicle mix existing within 6 months of the 2013 episode, and because the mix of vehicle types and age distributions change very little from year to year, the 2014 source populations are adequate.

The MOVES2014a updates completed for the NEI every 3 years require many months of data processing, and it is not feasible, nor required by EPA, to reanalyze them for each SIP modeling project. Traffic information from Idaho's statewide Automatic Traffic Recorders for the 2-year period 2013–2014 were used in the updated MOVES modeling, so the temporal patterns by vehicle and roadway types are representative of 2013 traffic conditions. The vehicle source population and vehicle mix also change only slightly from year to year. The source population is not a large change as it is mostly related to population growth, which is relatively flat, particularly in rural Idaho counties where CRB activity occurs. DEQ used the 2014 NEI on-road MOVEs inputs for the 2013 episode with the meteorology adjusted to 2013 episode meteorology, the vehicle miles traveled (VMT) adjusted to 2013 levels using statewide VMT data from the Federal Highway Administration's Highway Performance Measurement System database (FHWA 2017), and the vehicle population adjusted to 2013 levels based on assumption of constant VMT per vehicle. Similarly, the MOVES inputs used for the 2015 Soda Fire episode were also adjusted to 2015 meteorology, VMT, and vehicle population.

## 5.3 Biogenic Emissions

Vegetation and soils in both natural and cultivated areas are known to produce ozone precursors, including VOCs from plants and nitrogen oxides from soil bacteria. The quantity of emissions depend on the type of vegetation, temperature, and solar radiation. These emissions were specifically estimated for each location, vegetation mix, and meteorological condition by the MEGAN model, version 2.10 (Guenther et al. 2014), to calculate emission rates for numerous biogenic VOCs and nitrogen oxides. DEQ used MCIP conditions during the July 8–September 26, 2013, episode and the August 2015 Soda Fire episode to inform the MEGAN 2.10 biogenic emissions model, estimate emissions, and allocate them throughout the domain for each episode.

## 5.4 Wildfire Emissions

Wildfire emissions are incorporated into AIRPACT5 operationally by the SMARTFIRE2/BlueSky "framework" (Larkin et, al. 2009), a system of wildfire emissions and modeling programs designed to produce the best operational estimate for wildland fire emissions every day. In a forecast mode, the acres burned for the forecast day can only be estimated from the known acreages from the previous day. For more accurate incorporation of wildfire emissions in any reanalysis, including ozone precursors VOC and $NO_x$, the actual reanalyzed fire perimeters are a better approach for estimating fire size and making the best and most accurate emission estimates for each day of the modeling episode.

The most recent major reanalysis of wildfire and prescribed fire emissions nationwide was the 2014 NEI wildland fire emission inventory developed by Sonoma Technology for EPA. In addition, Sonoma Technology recently produced a 2015 national wildland fire emissions inventory for EPA following the 2014 NEI work and using the same methodology. They used the SMARTFIRE2/BlueSky fire emissions modeling system developed by the United States Forest Service AirFire group along with the National Oceanic and Atmospheric Administration's Hazard Mapping System (HMS) fire detection data to identify and verify fires, and the reanalyzed fire perimeters from Geospatial Multi-Agency Coordination operation to obtain accurate locations and burn acres for each day of the year (USGS 2017).

Sonoma Technology provided DEQ with the August 2015 Soda Fire emissions from their 2015 nationwide wildland fire emissions inventory previously developed under contract to EPA. In addition, for DEQ's 2013 modeling episode, July 8–September 26, DEQ contracted with the same staff at Sonoma Technology to produce the reanalyzed wildland fire emissions inventory for the AIRPACT5 domain using the same methods they employed in the recent 2014 NEI work and the nationwide 2015 wildland fire emissions inventory. The Sonoma Technology report describing the 2013 episodic wildland fire emissions development is included in Appendix B.

## 5.5 Crop Residue Burning Emissions

The crop residue burning database and 2013 episodic emissions development methods are summarized below and described in greater detail in Appendix C.

### 5.5.1 Burn Database for Idaho Agricultural Burns

Crop residue burning activity in Idaho has been documented by the DEQ CRB burn database since 2008. This database provides acres burned, crop type, date burned and location, all parameters necessary to model the CRB activity in State of Idaho managed areas. Annual CRB Program burning activity is shown in Figure 11. The median level of acreage burned throughout the history of the program occurred in 2013, the year selected for the model base-case episode. The burn database contains all burns permitted by the Idaho program. Each individual burn during the period July 8 – September 26, 2013 was explicitly modeled in Scenario 1 of the base-case episode.

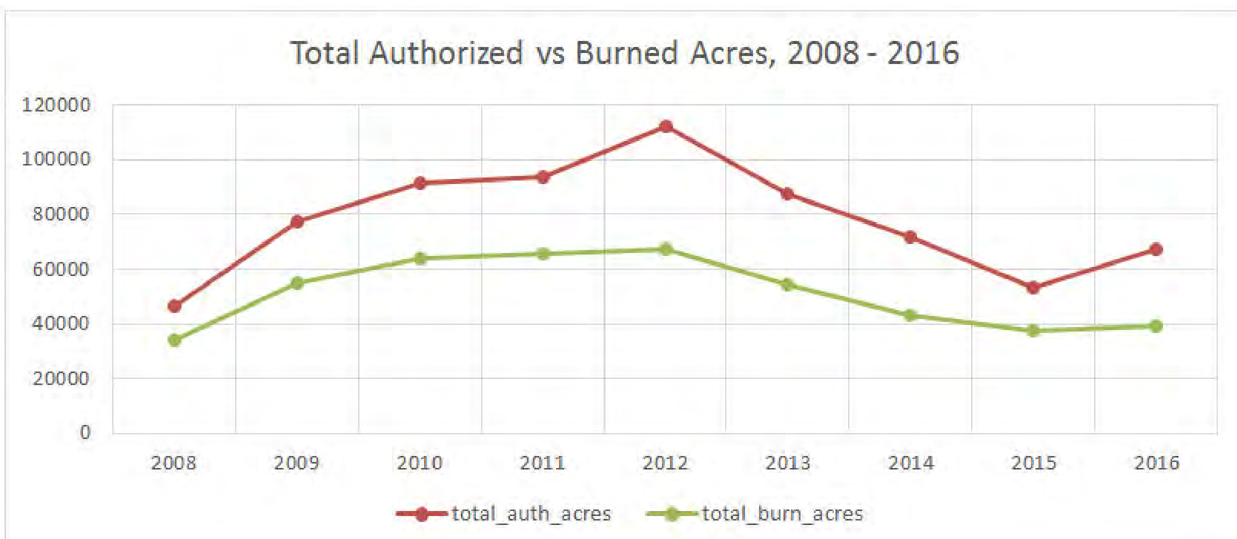



**Figure 11. DEQ agricultural burning database activity level, 2008–2016.**

### 5.5.2 Agricultural Burning Activity Outside DEQ Regulated Areas

Agricultural burning activity in Tribal areas and in the neighboring states can be more difficult to determine because less detail is retained by some burning programs in those areas. DEQ does not have authority for burning within Reservation boundaries (except for the Kootenai Tribal area) or other states, but for the purposes of model evaluation, it is important to include as much of the other background agricultural burn activity as possible, even though the resulting emissions are small in comparison to the wildfires occurring at the time. Operational forecast results in the AIRPACT5 daily operation exclude crop residue burning with the assumption that it does not significantly impact pollutant levels and cannot be reasonably included in a forecast model on a day-to-day basis.

For the 2014 NEI, EPA used satellite-based fire detections at agricultural land-use locations to identify the dates and locations of burns. Then average burn acreages were assumed for each state to allow them to quantify emissions. The 2014 NEI-based emissions are not available for DEQ's 2013 episode, so DEQ used HMS fire detects on agricultural land types provided by Sonoma Technology to approximate the 2014 NEI agricultural burning emissions inventory process. Crop residue burning emission factors and the state-averaged field acreages used by EPA in the 2014 NEI were then applied to the satellite-determined agricultural burns that coincided with field locations in the United States Department of Agriculture crop-type mapping system to estimate agricultural emissions in the other states and in Idaho's tribal areas within the modeling domain. DEQ estimated an HMS detection rate based on the known Idaho CRB activity and matching HMS detects for the Idaho burns to scale up the HMS detects in other areas. The HMS-based detects do not capture all agricultural fires, particularly smaller fires and fires on cloudy days; however, it was used by EPA in the 2014 NEI, and it is the best approach reasonably available for approximating the small amount of background ozone precursor concentrations due to other agricultural burning in the model (outside of DEQ's CRB program).

### 5.5.3 Crop Residue Burning Emission Factors

EPA recently inventoried all US agricultural burning emissions for the 2014 NEI. This effort included a careful review of crop residue burning emission factors by McCarty (2011) in which the emission factor literature was reviewed, and appropriate values were averaged together to develop robust multi-study averages. The 2011 and 2014 NEI used the McCarty (2011) values for crop residue burning nationwide (EPA 2016). Since this body of work is the most recent and best documented emission factor review in the past decade, and its nationwide use presumably resulted in widespread peer review, DEQ proposes to use the 2014 NEI (EPA 2016) emission factors, combustion efficiencies, and fuel loadings for the CRB emissions estimates.

DEQ reviewed regional field studies that measured emissions from cereal grain residue (Air Sciences 2003) and Bluegrass residue (Johnston and Golob 2004) to determine if these studies may provide better Idaho/Eastern Washington-specific emission factors that are more appropriate for Idaho crops. DEQ concluded that these studies were already included along with other studies in the McCarty (2011) factors, and that the studies focused on CO, $CO_2$, $CH_4$ and $PM_{2.5}$ and did not quantify either VOCs or $NO_x$ that are the precursors most important to this ozone modeling project. Thus, DEQ used 2014 NEI–McCarty (2011) values (EPA 2016) for all the CRB emission estimates.

The 2014 NEI factors did not include Bluegrass burning; however, the McCarty (2011) review did provide factors for Bluegrass. In fact, it appears that the latest set of factors published in the 2014 NEI Technical Support Document (EPA 2016) used the McCarty (2011) Bluegrass factors for the "Other Crops" and "Pasture/Grass" crop burns as all three sets of factors are identical. It appears that the Bluegrass factors are used for the other categories because they are the most conservative of the three. Consistent with EPA's approach, DEQ used the 2014 NEI "Other Crops" values (equal to McCarty 2011 Bluegrass factors) for all grass seed fields, pasture/grass fields, and all other crops in the DEQ database that are not explicitly included by name in the 2014 emission factor set. This assures a conservative set of emission factors.

### 5.5.4 Idaho CRB Emission Inventory for Specific Modeling Scenarios

To evaluate the potential impact of the new CRB rule to cause or contribute to a NAAQS violation, four simulations were made—a background simulation and three CRB emissions scenarios. The background simulation included all sources, including wildfires, except that the Idaho CRB emissions were not included. This simulation provided the background conditions into which Idaho's CRB program emissions were added. Three CRB emission scenarios were developed as described in Section 1.5 and in Appendix C:

- Scenario 1: 2013 actual CRB emissions
- Scenario 2: 2013 burning under the new rule
- Scenario 3: Maximum daily burning

# 6 Meteorological Inputs

The meteorological inputs and their performance in the 2013 modeling episode are summarized below and described in detail in Appendix D.

## 6.1 WRF/MCIP as Used in AIRPACT5 Inputs

The WRF meteorological model was operated by UW in an operational mode to produce the original AIRPACT model meteorological inputs for the 2013 base-year modeling episode from July 8 to September 26, and the August 2015 Soda Fire episode from August 6 to August 15. The native meteorological inputs from WRF were then processed by MCIP version 3.6 to generate the actual meteorological inputs used during the original AIRPACT4 operational forecast simulations. The archived MCIP and BCON files from 2015 and 2013 operational runs were provided by WSU for use in this analysis (Vaughn 2016). For each day, the met data from the forecast hours 8-32 of the 00Z WRF model run (i.e. the run starting at 00:00 UTC or Coordinated Universal Time) are utilized and then these segments of the meteorological outputs for each day are combined to cover the whole episode.

DEQ believes that the regional simulations in the WRF/AIRPACT5 systems are sufficiently accurate for this project due to many years of operating and tuning these systems. Thus, a time-consuming reanalysis of the WRF is not necessary.

The native WRF simulations were made using WRF version 3.4.1 beginning in December 2012 and ending with the September 16, 2013, 00Z run. The WRF modeling system was then migrated to WRF version 3.5 beginning with the September 16, 2013, 1200Z run (i.e., for the last 10 days of DEQ's July 8–September 26 episode) (UW 2017). The last 10 days of the episode represent a lower ozone period so the critical high ozone days are generally before the last 10 days. Lower burn acreages also occur after September 16. DEQ did not expect significant differences in meteorology inputs due to the change in WRF model version on September 16, and we did not detect any.

## 6.2 Meteorological Evaluation

The meteorological data can significantly affect the model results of photochemical transport modeling, so it is important to assess if the meteorological data are adequate for subsequent air quality simulations. The meteorological simulations were evaluated by comparing calculated statistics against model performance benchmarks for both simple terrain and complex terrain conditions. Based upon the evaluation of many meteorological and air quality applications, Emery et al. (2001) proposed a set of performance benchmarks for meteorological model performance, which have been adopted by the regulatory meteorological modeling community. However, these benchmarks are mostly for simulations over simple terrain. The meteorological simulations over complex terrain, such as the Rocky Mountains, are not expected to be as good as those for simple or flat, homogeneous terrain. Kemball-Cook et al. (2005) proposed benchmarks for complex terrain conditions. The benchmarks proposed by Emery et al. (2001) for simple terrain and by Kemball-Cook et al. (2005) for complex terrain, along with model performance results are shown in Table 3.

The model performance was first evaluated using observational data at all stations throughout the model domain ingested into EPA's Atmospheric Model Evaluation Tool (AMET) program by the NCEP Meteorological Assimilation Data Ingest System. Quantitative evaluation of domain-wide surface temperature, wind speed, and wind direction are shown in Table 3. This evaluation reveals that all the calculated statistics values met the model performance benchmarks available for complex terrain conditions and are appropriate for use in this study because the simulations cover a very complex terrain with many mountain ranges including the Rocky Mountains. Some statistical measures, such as temperature bias and wind direction bias, have even met the benchmarks for simple terrain conditions. To better reflect the simulations for the Idaho region, Table 3 also shows the meteorological performance for the high-quality National Weather Service sites in Idaho and in portions of other states near Idaho. Again, all the statistics calculated for the Idaho region have not exceeded the benchmarks available for complex conditions. Overall, the model evaluation demonstrates that the meteorological model performance is adequate for use as the input to the photochemical modeling in this study. The full meteorological model evaluation is provided in Appendix D.

**Table 3. Meteorological model performance and benchmarks for simple and complex terrain conditions, adopted by Emery et al. (2001) for simple terrain and Kemball-Cook et al. (2005) for complex terrain.**

| | Model Performance | | Benchmarks | |
|---|---|---|---|---|
| **Parameter** | **Entire Domain** | **Idaho Region** | **Simple Terrain** | **Complex Terrain** |
| Temperature bias | -0.16 | -0.24 | ≤ ±0.5 K | ≤ ±2.0 K |
| Temperature error | 2.15 | 2.15 | ≤ 2.0 K | ≤ 3.5 K |
| Mixing ratio bias | NA | NA | ≤ ±1.0 g/kg | NA |
| Mixing ratio error | NA | NA | ≤ 2.0 g/kg | NA |
| Wind speed bias | 0.58 | -0.43 | ≤ ±0.5 m/s | ≤ ±1.5 m/s |
| Wind speed RMSE[a] | 2.05 | 1.82 | ≤ 2.0 m/s | ≤ 2.5 m/s |
| Wind direction bias | 6.83 | 12.5 | ≤ ±10 degrees | NA |
| Wind direction error | 54.74 | 50.7 | ≤ 30 degrees | ≤ 55 degrees |

a. Root Mean Square Error (RMSE)

# 7 Limited Model Diagnostic Evaluation—Soda Fire

Following the meteorological evaluation, DEQ simulated ozone impacts from the Soda Fire in southwestern Idaho/southeastern Oregon in August 2015 to assess model performance for a rangeland wildfire that may approximate crop residue burning more appropriately than densely forested wildfires. This evaluation provided limited diagnostics of the plume rise estimated by the model. If the plume injection heights and transport of tracer species such as $PM_{2.5}$ and CO appear to be realistically simulated by the model, and the ozone production characteristics of this “crop-like” grass/shrub-land fire match the observed ozone concentrations, then we have greater confidence that both transport and chemistry are working well and the model is getting the right answer for the right reasons. This component of DEQ’s diagnostic model evaluation addresses the one area in CMAQ modeling that is most difficult and most uncertain. Such a diagnostic model evaluation is possible for the Soda Fire case because in addition to ozone monitoring, DEQ operates CO and $PM_{2.5}$ monitors at the St. Luke’s Meridian, ID site, just west of Boise. Observations of these species during the Soda Fire episode are shown in Figure 5 where simultaneous peaks of $PM_{2.5}$ and ozone represent the period when the plume is impacting the monitoring site.

Using the $PM_{2.5}$ and CO observations recorded at the St. Luke’s Meridian, ID monitoring site, and additional $PM_{2.5}$ observations at the Nampa, ID monitoring site, DEQ investigated the plume rise and dispersion/transport performance by AIRPACT5. Based on these monitoring observations, photos of the fire and its plumes, and literature reports of typical wildfire plume rise observations, DEQ found that the standard plume rise estimation methods in the BlueSky fire parameter inputs are not accurate for this type of fire and a modification was necessary to obtain the best performance for $PM_{2.5}$ and CO compared to the ground-level observations at the Meridian and Nampa monitors. Following adjustment of the plume rise estimation in the model, DEQ found that the modeled ozone predictions matched the observed ozone very well during the two periods when the Soda Fire plume was impacting the monitoring sites.

The adjustments to the plume rise algorithms were presented to the modeling community in the Pacific Northwest and received a positive preliminary review. Additional peer review is in progress; however, DEQ has evaluated its performance in three different analyses over hundreds of fires and found that its performance is more consistent with the literature than the existing treatment. The plume rise modification uses a correction for the area of a burn based on the methods used in the Western Regional Air Partnership's (WRAP's) *Deterministic and Empirical Assessment of Smoke's contribution to Ozone* (DEASCO3) modeling project which investigated fire contributions to ozone in the west (Air Sciences 2013). The modifications in processing the BlueSky fire data and three evaluations of it are described in greater detail in Appendix E. DEQ demonstrates that the modification results in fire emissions injected into the model at more realistic altitudes based on the literature (Val Martin et al. 2010), and as a result, both the tracer species and ozone predictions were improved. In addition, because the modification produces lower plume rise than the original method for CRB fires, the ozone production is conservative and suitable for this analysis of the maximum ozone impacts from CRB activity.

Following the meteorological and Soda Fire evaluations and plume rise adjustment, a more complete evaluation of the photochemical modeling system, including both wildland and crop residue fires was conducted using the July 8–September 26, 2013, base-case episode.

# 8 Photochemical Model Evaluation

Photochemical models used in a regulatory application, such as a SIP, are typically evaluated for overall ozone performance, according to EPA's modeling guidance (2014). The evaluation should include both an operational evaluation to demonstrate statistical model performance against observed concentration values and a diagnostic evaluation to ensure that the components of the model are performing reasonably well and the model is providing the right answers for the right reasons. The photochemical model statistical performance evaluation is briefly summarized in this section, but is more fully described in Appendix F.

## 8.1 Operational Evaluation

Similar to the meteorological model performance evaluation described in section 6.2, the CMAQ model air quality predictions for the 2013 base-year episode from July 8–September 26 were evaluated using AMET. Model performance statistics were computed for all ozone monitors in the domain as well as a subset focusing on those in Idaho. The model evaluation simulations included all source categories including the wildland fire emissions inventory prepared by Sonoma Technology and the crop residue burning for Idaho and other jurisdictions in the domain to provide a complete base-case source inventory.

EPA does not recommend or provide bright-line thresholds for acceptable model photochemical model performance because every modeling project has different objectives, uncertainties, and sensitivity to uncertainties (Simon et. al. 2012). Rather, the modeling guidance suggests comparing model performance to the universe of performance evaluations that are being obtained in the modeling community nationwide and globally. Recently, Adelman et al. (2014) proposed model performance criteria for ozone simulations, which use fractional bias (FB) and fractional error (FE). According to Adelman et al. (2014), the model performance is considered good if the statistics meet the following criteria.

Fractional bias (FB) ≤ ± 15%

Fractional error (FE) ≤ 35%

Table 4 shows that FB and FE calculated for both the entire domain and the Idaho sites are far below the criteria, indicating good model performance for ozone simulations.

The model performance was also conducted using the EPA's 1991 ozone modeling guidance performance goals, which were based on mean normalized bias (MNB) and mean normalized gross error (MNGE). The MNB and MNGE were first calculated for all sites across the domain, and then for the sites in Idaho (Table 4). As shown in Table 4, the calculated MNB and MNGE values have not exceeded their respective goals, ± 15% and 35%, again suggesting that the modeling system has simulated realistic ozone concentrations. While we noticed that the use of MNB and MNGE is not encouraged by some scientists (e.g., Simon et al. 2012) due to a potential issue around zero, they are still included in this study for completeness.

Simon et. al. (2012) reviewed performance evaluations for 69 photochemical modeling efforts that they found in the literature and summarized the results of those evaluations graphically for a number of bias and error statistics. When the DEQ's performance statistics (Table 4) are compared to the range of model bias and error statistics observed in the studies they reviewed, DEQ concludes that the AIRPACT5 system developed by WSU and updated by DEQ for this modeling study performs better than the majority of modeling efforts reviewed by Simon et al. (2012).

Overall, the model evaluation shows that the CMAQ model, using the updated AIRPACT5 system produced very good performance and can be used to investigate the CRB impacts on ozone concentrations for both the entire domain and Idaho region. More details of CMAQ evaluation are provided in Appendix F.

**Table 4. CMAQ ozone model performance.**

| Statistic | 2013 Base-Case Performance, Entire Domain | 2013 Base-Case Performance, Idaho Region | Acceptable Range (Adelman et al. 2014) |
|---|---|---|---|
| **Fractional Bias (FB) (%)** | **1.2** | **-3.5** | **≤ ± 15** |
| **Fractional Error (FE) (%)** | **17.8** | **16.7** | **≤ 35** |
| Mean Normalized Bias (MNB) (%) | 5.6 | -4.3 | ≤ ± 15 |
| Mean Normalized Gross Error (MNGE) (%) | 19.7 | 14.2 | ≤ 35 |
| Normalized Mean Bias (NMB) (%) | 0.9 | -5.3 | N/A |
| Normalized Mean Error (NME) (%) | 16.2 | 14.7 | N/A |
| Mean Bias (MB) (ppb) | 0.4 | -2.6 | N/A |
| Mean Error (ME) (ppb) | 6.9 | 7.4 | N/A |
| RMSE | 9.1 | 9.7 | N/A |

## 8.2 Diagnostic Evaluation

The Soda Fire limited evaluation of plume rise and transport was an important part of DEQ's overall diagnostic evaluation of the AIRPACT5 system (section 7 and Appendix E). It allowed DEQ to understand the reasonableness of the pollutant emissions, plume rise and transport processes based on the non-reacting species CO and $PM_{2.5}$, and to demonstrate that when modeled concentrations of those species match the observed time series values well, the ozone also performs well, indicating that the photochemical processes are functioning correctly.

DEQ believes that WRF and CMAQ configurations used in AIRPACT5 have undergone extensive diagnostic evaluation by university and agency scientists, including the AIRPACT5 performance evaluation and simulation of intensive monitoring campaigns conducted in the region over the years; therefore, the burden of additional diagnostic evaluation is lessened compared to typical stand-alone modeling efforts built "from the ground up" specifically for a SIP attainment demonstration. Because this modeling effort (1) is not for a nonattainment SIP but rather, for an activity that was established and approved by a SIP action in 2008, and which has never been found to exceed the NAAQS even once in Idaho, and (2) further supports the main SIP analyses and narrative, which definitively demonstrates that the NAAQS is not threatened, DEQ believes that no additional diagnostic evaluations are necessary. Additional diagnostic evaluations are not included in this report beyond the Soda Fire evaluation of plume rise described in Section 7 and Appendix E.

# 9 CRB Impact Analysis

The results of the CRB impact analysis are briefly described in this section for the three CRB emission scenarios with detailed results provided in Appendix G. The modeling results (section 9.1) address the maximum CRB contributions alone and the total ozone impacts when background ozone is added. In addition, locations of the maximum daily impacts are described in section 9.2 and the 4th-high background concentrations are discussed in section 9.3. Finally, for the purpose of assessing CRB significance, the 4th-high CRB-only contributions are included in section 9.4.

## 9.1 Maximum Daily CRB Impacts

The maximum daily CRB contribution at any point in the domain on any day should be less than the worst-case 7 ppb buffer between the burn cessation threshold (63 ppb) and the NAAQS value (70 ppb) to ensure that CRB activity cannot cause a violation of the standard.

On most days when the modeled CRB impacts occurred the background ozone was very low, averaging 50 ppb, so the "buffer" between the background ozone and the NAAQS is usually much greater than 7 ppb. The background ozone MDA8 concentrations and locations of all the maximum daily CRB contributions above a DEQ-selected *de minimis* threshold for analysis of 0.2 ppb are provided in Appendix G. Nevertheless, for a worst-case analysis, we must assume that the CRB activity should not contribute more than 7 ppb to ensure that the value of the NAAQS will not be exceeded under the new rule, even one time. This is the most conservative criterion and an important goal of DEQ's CRB program. The total MDA8 ozone concentrations must also remain below the NAAQS (70 ppb).

### 9.1.1 Scenario 1—2013 Actual CRB Emissions

In the actual CRB emissions case, the maximum ozone MDA8 contribution from CRB activity was 1.8 ppb, occurring in Minidoka County on August 12, 2013. The modeled background MDA8 ozone on this day was 49.4 ppb so the total MDA8 ozone concentration was estimated to be 51.2 ppb. The highest total MDA8 ozone concentration for any daily maximum CRB contribution over 0.2 ppb was 54.6 ppb on 7/26/2013.

This highest modeled CRB contribution (1.8 ppb) is consistent with the 2017 CRB SIP analysis of monitoring observations that found no ozone monitored MDA8 contributions above 2.0 ppb, in or around Idaho, that were potentially caused by CRB. The consistency between measurements and model is a strong indicator that this is approximately the maximum level of CRB contribution that historically has occurred. This 1.8 ppb maximum modeled contribution is well below the conservative 7 ppb buffer.

### 9.1.2 Scenario 2—2013 Burning Under New Rule

When the CRB program is operating under the new rule, burning will be permitted when ozone is in the 56–63 ppb range, as long as all other program requirements are met. DEQ tested the most likely effects of this rule by first identifying the days for each county in which the modeled MDA8 ozone concentration is in the 56–63 ppb range for any portion of the county, based on the background modeling simulation that includes all fires except Idaho CRB. Days in which the county would not have burned due to a high $PM_{2.5}$ level or a fire safety (high wind) day were excluded. In the end, 302 county-days were identified in addition to the Scenario 1 burns when burning could be allowed under the new rule. In reality, many of these days would not have had burns due to poor moisture or dispersion conditions or due to not receiving any burn requests, but all such counties and days were assumed in this scenario to have burns anyway. Next, hypothetical emissions were added to the model based on the monthly median acres burned for each identified county in the same month. In the absence of other spatial allocation information, the hypothetical added emissions were located based on the historical burn configuration for the median burn day for each county.

Scenario 2 results revealed that the 10 highest MDA8 concentrations in Scenario 1 were also the 10 highest days in Scenario 2. The highest contribution due to CRB burning in the Idaho program was 1.8 ppb on August 12, 2013, and the total MDA8 ozone concentration on this day was 51.2 ppb, the same as for Scenario 1. The highest total MDA8 ozone concentration for any daily maximum CRB contribution over 0.2 ppb in Scenario 2 was 60.9 ppb on 7/19/2013 as shown in Appendix G.

The highest additional MDA8 maximum contribution resulting from new burns allowed under the new rule was only 0.36 ppb in comparison to the 1.8 ppb for Scenario 1. DEQ believes that the maximum contribution for the new days is lower than for the actual 2013 burn days because the new days opened to burning under the new rule were typically warmer and sunnier (explaining the higher background ozone) and therefore resulted in greater vertical mixing and dispersion of the smoke and ozone precursors. Although not a factor simulated in this modeling, dryer fuels, higher combustion efficiencies and higher plume rise on the sunnier days likely also contribute to lower impacts of all pollutants on the new days opened up by the new rule. The finding of lower impacts, and the increased ability to spread the same burn acreage over additional days reflects DEQ's objective in opening these days to burning and explains why DEQ believes that overall the impacts of the program will be lessened for all pollutants due to more efficient combustion and more good dispersion days available for burning.

### 9.1.3 Scenario 3—Maximum Daily Burning Scenario

This scenario tested the ozone formation potential of CRB under higher emissions scenarios that reflect the largest burn day acreage that the program has seen in its 9-year history. To do this, the county-days having a CRB MDA8 ozone contribution of at least 0.2 ppb were identified and the emissions in the primary contributing county were increased to match the maximum recorded burn acres that occurred in that county in the history of the CRB program. A threshold for implementing the maximum day analysis of 0.2 ppb, well below the EPA's significant impact level (SIL) (1.0 ppb), was selected to ensure all potential significant impacts are captured without expanding the maximum day analysis to an unmanageable size. In addition to a conservative selection of primary impacting counties, up to two other nearby counties that may have contributed to that highest daily ozone contribution due to their proximity to the maximum impact location were also grown to reflect the maximum historical burn acreages for those counties.

The Scenario 3 results indicated that the highest Scenario 1 and 2 CRB contribution day, August 12, remained the highest day, but the previous high modeled MDA8 ozone contribution for that day of 1.8 ppb increased to 4.0 ppb due to the added emissions. The added emissions reflect a growth of acres burned in Northern Magic SMA from 673 acres in Scenarios 1 and 2 to 1,754 acres in Scenario 3. This highest ozone contribution resulting from the maximum recorded emission levels is still 3 ppb lower than the conservative 7 ppb buffer. As described above, the modeled background MDA8 ozone on this day was 49.4 ppb so the total ozone MDA8 concentration was 53.4 ppb, again indicating that the worst-case buffer is very conservative. The highest total MDA8 ozone concentration for any daily maximum CRB contribution over 0.2 ppb in Scenario 3 was 61.7 ppb on 7/19/2013, as shown in Appendix G.

## 9.2 Locations of Maximum CRB Impacts

The highest background ozone in Idaho and surrounding areas is found in the Boise and Salt Lake City/Logan urban areas (see 2017 CRB SIP, Appendix B for monitor design values). However, the maximum ozone impacts from crop residue burning in Idaho generally occur in the agricultural areas and do not typically extend into the urban areas: Very little burning occurs in the Boise area with a maximum 1-day acreage of 493 acres for the entire southwest SMA in Scenario 3 (Appendix C, Table 7). Ozone concentrations in Idaho also trend somewhat higher at higher elevations and exhibit a lower-to-higher gradient from the northwest to the southeast corner of Idaho. The locations of all CRB ozone impacts in the entire domain for each scenario are shown in "tile plots" in Appendix G. A review of the plots for the 4 highest contribution days for each scenario suggests the maximum values are extreme, well above other impacts on the days they occur, and are sparsely located throughout the state's agricultural areas with the highest values each day significantly higher than other values that typically occur on the same day. As a result, DEQ focused on the highest daily CRB contributions that occurred statewide for each day.

The locations of all the highest contribution values for Scenario 3 impacts over a DEQ-selected *de minimis* value of 0.2 ppb MDA8 are shown in Figure 12. The figure shows that the maximum daily CRB impacts are located in the rural/agricultural areas, typically far from the urban areas. In addition, it is important to note that because fields do not typically burn twice in one year, no one-day configuration of fields is the same as any other and as a result, no MDA8 daily maximum concentrations occur at the same location. This characteristic of CRB burning activity ensures that the highest contribution days would never, or only very rarely, contribute to a second significant impact at a single location in the same year. Thus, the highest CRB contributions tend to not be cumulative or repetitive at a single location such as a residence, school or monitor. This is a key point because NAAQS violations only occur at a single site and when multiple monitors exist in a county, the design value is examined separately for each site. The highest impact location (on August 12) is identified in Minidoka County (red triangle) and the locations of the maximum values above the EPA's SIL (1.0 ppb) are indicated separately (yellow triangles) from the remainder of the values below the SIL. Additional details for the model results for each scenario, including the background ozone levels at each location are included in Appendix G.

## 9.3 Modeled 4th-High MDA8 Background Ozone

Section 9.1 assesses CRB contributions compared to the worst case 7 ppb buffer. However, the only contributions that may cause a modeled exceedance of the NAAQS in the unmonitored areas are those that when added to the 4th-highest background MDA8 ozone concentration at a single location, and averaged over 3 years exceeds the NAAQS. While 3 full years were not modeled, the 4th-high background values in the 2013 modeling episode may provide an approximation of the background MDA8 design value without CRB contributions.

The monitor-based 3-year design values for the 2012–2014 period are also shown in Figure 12 for the monitors in the Idaho region. The monitor-based observed design values were 61–62 ppb at the rural sites in and around Idaho and around 65 ppb at the semi-rural sites (Meridian ID, St. Luke's site and Logan UT) while the highest observed MDA8 in this design period was the Boise White Pine monitor which represents a very small area influenced by urban conditions and is not near any significant CRB activity (the White Pine design value was 69 ppb for 2012–2014, 67 ppb for the 2013–2015 design value period, and 64 ppb in 2015).

The highest modeled 4th-high background MDA8 ozone at the locations of CRB maximum daily contributions are provided in Appendix G. However, if a 4th-high background concentration is higher than the burn cessation threshold for any scenario, then CRB would not have occurred in that area and could not have contributed additional ozone on that day. As a result, the estimation of design values using the 4th-high background values in a uniform manner is problematic. Therefore, the 4th-high background values at the point of each CRB maximum daily impact are provided in Appendix G to better characterize the background in CRB impact areas, but no attempt is made to construct total design values.

## 9.4 CRB Contribution 4th-High Concentrations

The purpose of this modeling analysis is to evaluate whether CRB activity under the new rule will *cause or significantly contribute* to a NAAQS violation. There are no NAAQS violations ever observed or modeled in Idaho, so *significant contributions* may be a moot point. Nevertheless, to better understand how the spatial variability of CRB impacts would mitigate any threat of NAAQS violations at a single residence or monitor, DEQ developed scripts to determine the 4th-high CRB-only contributions at all points in the state. The 4th-high CRB contribution at any grid cell for the Scenario 2 simulation (of burning under the new rule) is 0.15 ppb. This 4th-high contribution is well below the EPA's 1.0 ppb SIL for the ozone NAAQS (EPA 2016b). A similar 4th-high computation for the Scenario 3 maximum historical burn levels is not realistic because the highest historical burn levels would never occur on every burn day as simulated in Scenario 3.

## 9.5 Unmonitored Area Analysis

The unmonitored area analysis is required in traditional ozone nonattainment SIPs after attainment is demonstrated at the monitoring sites to ensure that all other locations (i.e., unmonitored areas) will also remain in compliance with the NAAQS. This demonstration is not a nonattainment SIP; however, the primary focus of this analysis is already in the unmonitored areas, involving all locations in Idaho and surrounding states, so a separate unmonitored area analysis is not needed.

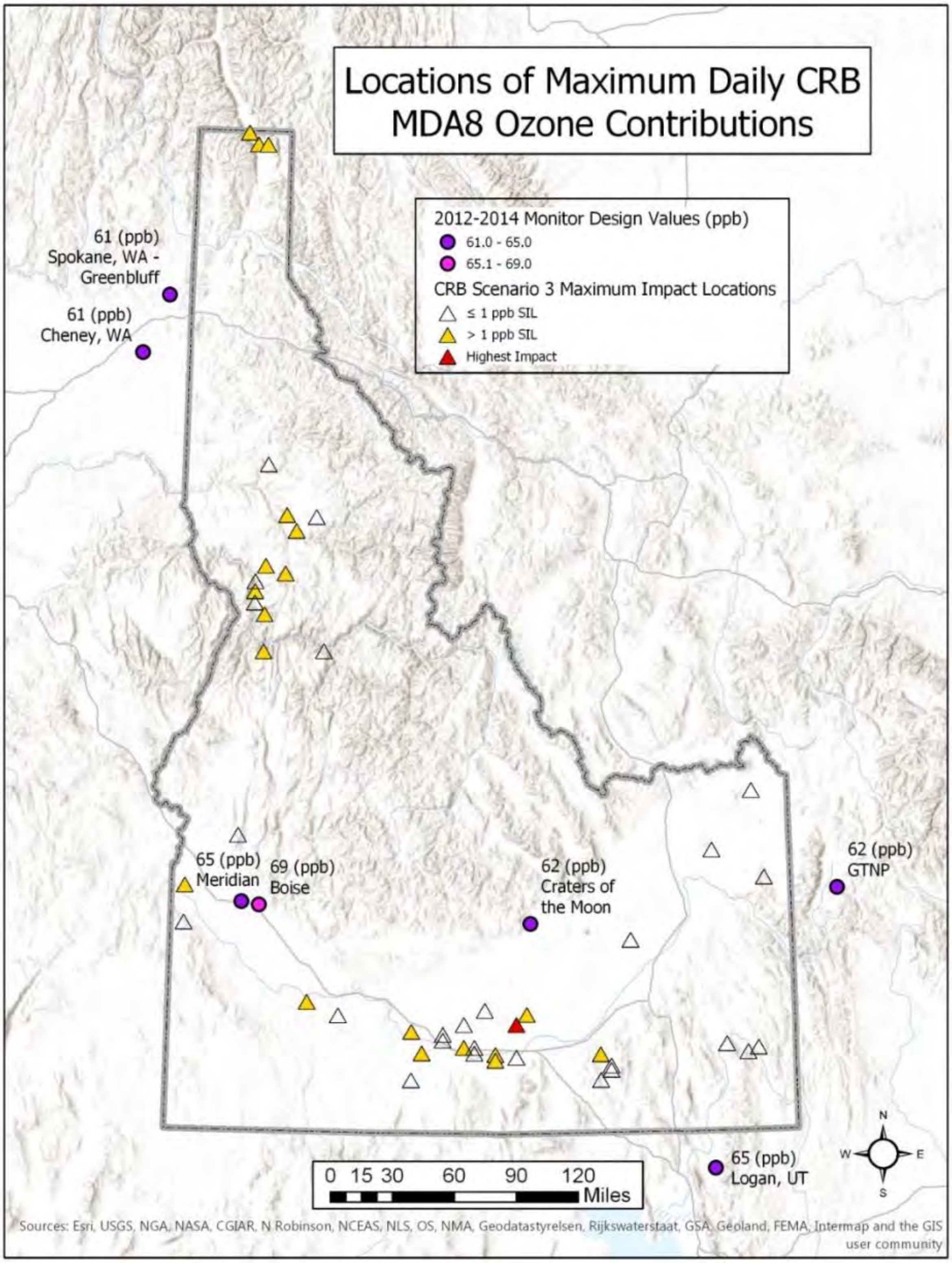



**Figure 12. Locations of the highest modeled MDA8 ozone contributions on each 2013 episode day in which the Scenario 3 CRB impacts exceed 0.2 ppb. The highest impact location (red triangle) was 1.8 ppb for Scenario 1 and 2 and 4.0 ppb for Scenario 3. No two daily impacts occurred at the same location (i.e., within the same 4 km grid cell). Monitor design values bracketing the 2013 model year are also shown.**

# 10 Summary and Conclusions

## 10.1 Summary of Modeling Results

This air quality modeling analysis provides additional evidence to the 2017 CRB SIP that further demonstrates DEQ's proposed rule change will not cause or significantly contribute to a violation of the 2015 ozone NAAQS. The 2017 CRB SIP requests that the point at which burning is not permitted change from 52 to 63 ppb. CRB burning is not allowed if the MDA8 ozone concentration is expected to exceed 63 ppb or 90% of the NAAQS. No increase in acres is requested or anticipated.

In addition to the 2017 CRB SIP monitoring-based evidence, DEQ estimated the contributions of Idaho's CRB program to ozone formation in and around the state using the AIRPACT5 regional modeling system and domain. The scenarios and results are summarized in Table 5:

**Table 5. Summary of modeling results: highest impact day for three CRB burn scenarios.**

| Modeling Scenario | Highest MDA8 Ozone CRB Contribution (ppb) | Modeled Background MDA8 Ozone Concentration on Same Day (ppb) | Total MDA8 Ozone Concentration on Same Day (a) (ppb) |
|---|---|---|---|
| Scenario 1—Actual 2013 burns | 1.8 | 49.4 | 51.2 |
| Scenario 2—With added burns when ozone is 52–63 ppb under the new rule | 1.8 | 49.4 | 51.2 |
| Scenario 3—With Scenarios 1 and 2 emissions grown to maximum historical county-level emissions | 4.0 | 49.4 | 53.4 |

Note (a): The highest total MDA8 ozone concentrations for any of the highest CRB contribution days >0.2 ppb in Scenarios 1, 2 and 3 were 54.6 ppb, 60.9 ppb and 61.7 ppb, respectively, as shown in Appendix G.

## 10.2 Review of CRB SIP Findings

The combined findings of the *2017 Crop Residue Burning Ozone State Implementation Plan Revision* and the results of the photochemical modeling reported in this amendment are summarized below.

### 2017 CRB SIP Revision

1. No increase in acres burned is requested or anticipated as a result of the new rule, only an increase in sunnier, drier days with greater vertical mixing that will lower the level of exposure to smoke and all the pollutants associated with it.
2. All Idaho ozone monitors are in compliance with the 2015 ozone NAAQS and the observed design values at rural monitors in and around Idaho where crop residue burning occurs range from 61 to 63 ppb.
3. An extensive search of all monitoring data, following two separate approaches, found no ozone impacts larger than 2 ppb that could be potentially be attributed to CRB burns. This is a level typical of day to day fluctuations (i.e., "noise"), and due to their

prevalence, DEQ did not investigate the potential CRB impacts at or below this level—true CRB contributions could be lower.

4. In San Joaquin Valley, CA where a very dense ozone monitoring network exists and where more acres are burned on some days than in Idaho or any other state, DEQ could find no evidence of ozone contributions from agricultural burning in the monitoring database for 2014, the NEI year used in the analysis to identify burn days.

## Analysis of Photochemical Modeling for the SIP Revision Amendment

1. Photochemical modeling of the 2013 burn season predicts a maximum potential CRB MDA8 contribution of 1.8 ppb for the actual burns over the 81-day episode (Scenario 1). This result is consistent with the monitoring data search (item 3 above), which found no CRB impacts greater than the approximate "noise" level of 2 ppb.
2. When the counties/days with ozone in the range 56–63 ppb are simulated in addition to the actual 2013 burns (Scenario 2), the maximum CRB contribution remains the same, 1.8 ppb. The new days opened up 302 additional county-days in this ozone range; however, conditions on those new days resulted in lower ozone contributions (0.36 ppb maximum) than in the Scenario 1 case which simulated 2013 actual burns with a 56 ppb "no burn "threshold.
3. When maximum historical county-level burn acres are simulated in all counties causing a Scenario 1 or 2 impact >0.2 ppb, the maximum 1-day MDA8 impact is estimated to be 4.0 ppb still well below the 7 ppb buffer.
4. When the CRB MDA8 ozone contributions are added to the modeled background for the same days, the total concentration is always well below the NAAQS, reaching a maximum of only 60.9 ppb under the new rule (Scenario 2) and 61.7 ppb under the maximum emissions case (Scenario 3).
5. Both observed and modeled 4th-high background ozone concentrations in rural and semi-urban Idaho reach 62 ppb to 65 ppb and average only 57 ppb at CRB impact locations based on the model. Thus, none of the maximum CRB MDA8 ozone contributions could ever result in a total design value that threatens the NAAQS.
6. The 4th-highest CRB-only contribution under the new rule (Scenario 2) is 0.15 ppb for the MDA8 ozone contribution, well below the EPA's 1.0 ppb SIL for the 2015 ozone NAAQS.

In conclusion, based on the monitoring observations analyzed in the 2017 CRB SIP Revision, and the photochemical modeling described in this amendment, the Idaho CRB program has never and will never cause or significantly contribute to a NAAQS violation. In addition, this modeling shows that the new days opened up by the new rule appear to result in lower ozone concentrations. DEQ believes the additional days should lower the impacts of all pollutants by spreading the same acreage over additional burn days with better dispersion conditions.

# References


Abt Associates, Inc. 2010. *Modeled Attainment Test Software: Users Manual.* Prepared for EPA, OAQPS. Bethesda, MD.

Adelman, Z., U. Shanker, D. Yang, and R. Morris. 2014. *Three-State Air Quality Modeling Study CAMx Photochemical Grid Model Final Model Performance Evaluation Simulation Year 2008*, Chapel Hill, NC and Novato, CA.: University of North Carolina at Chapel Hill and ENVIRON International Corporation.

Air Sciences 2013. DEASC$O_3$ Project Updates to the Fire Plume Rise Methodology to Model Smoke Dispersion, Memo prepared by Matt Mavko, Air Sciences Inc. and Ralph Morris, ENVIRON, Project No. 178-14, December 3, 2013.

Air Sciences, Inc. 2003. *Cereal-Grain Residue Open-Field Burning Emissions Study.* Portland, OR. *http://www.ecy.wa.gov/programs/air/aginfo/research_pdf_files/FinalWheat_081303.pdf*

Craig, K., D. Alrick, Y. Du, G. Erdakos, C. MacDonald, T. Gross, and D. Watson. 2013. *Use of Photochemical Grid Modeling to Quantify Ozone Impacts from Fire in Support of Exceptional Event Demonstrations.* Presented at the 12th Annual CMAS Conference, Chapel Hill, NC. October 28–30.

Emery, C., E. Tai, and G. Yarwood. 2001. *Enhanced Meteorological Modeling and Performance Evaluation for Two Texas Ozone Episodes*. Prepared for the Texas Natural Resource Conservation Commission. Novato, CA: ENVIRON International Corporation.

EPA (United States Environmental Protection Agency). 2014. Draft. *Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5. and Regional Haze*.

EPA (United States Environmental Protection Agency). 2016. Draft. *2014 National Emissions Inventory, version 1 Technical Support Document.* Research Triangle Park, NC.

EPA (United States Environmental Protection Agency). 2016b. "Guidance on Significant Impact Levels for Ozone and Fine Particles in the Prevention of Significant Deterioration Permitting Program," memorandum from Stephen D. Page, Director, Office of Air Quality Planning and Standards, August 1, 2016, Revised August 18, 2016.

FHWA (Federal Highway Administration). 2017. *Annual Vehicle Distance Traveled in Miles and Related Data - 2013 by Highway Category and Vehicle Type.* Table VM-1. *https://www.fhwa.dot.gov/policyinformation/statistics/2013/vm1.cfm*

Geunther, A., X. Jiang, T. Duhl, T. Sakulyanontvittaya, J. Johnson, and X. Wang. 2014. *MEGAN Version 2.10 User's Guide.* Pullman, WA: University of Washington.

Johnston, W.J. and C.T. Golob. 2004. *Quantifying Post-Harvest Emissions from Bluegrass Seed Production Field Burning.* Pullman, WA: Washington State University, Department of Crop and Soil Sciences.

Kemball-Cook, S., Y. Jia, C. Emery, and R. Morris. 2005. *Alaska MM5 Modeling for the 2002 Annual Period to Support Visibility Modeling*. Prepared for Western Regional Air Partnership (WRAP). Novato, CA: Environ International Corporation.

Larkin N.K., O'Neill S.M., Solomon R., Raffuse S., Strand T.M., Sullivan D.C., Krull C., Rorig M., Peterson J., and Ferguson S.A. (2009) "The BlueSky smoke modeling framework." Int. J. Wildland Fire 18 (8), 906-920 (doi:10.1071/WF07086).

Mass, C.F. et al. 2003. "Regional Environmental Prediction over the Pacific Northwest." *Bulletin of the American Meteorological Society.* 84: 1353–1366.

McCarty, J.L, 2011. "Remote Sensing-Based Estimates of Annual and Seasonal Emissions from Crop Residue Burning in the Contiguous United States." *Journal of the Air & Waste Management Association*. 61:1.22–34. DOI: 10.3155/1047-3289.61.1.22.

Otterson, S. 2017. "AIRPACT5 Emissions Inventory." NW-AIRQUEST Emissions Inventory Workgroup. Personal Communication to R. Hardy, DEQ.

Raffuse et. al. 2012. "An Evaluation of Modeled Plume Injection Height with Satellite-Derived Observed Plume Height." *Atmosphere*. 3(1): 103–123.

Simon, H., K. Baker, S. Phillips, and B. Timin. 2012. *Model Evaluation: Review of Current Science and Lessons Learned.* Presented to the 2012 Regional/State/Local Modeling Workshop. Chicago, IL.

Sonoma Technology. 2017. Methods and Results for Preparation of the Wildland Fire Emissions Inventory for the AIRPACT5 domain from July through September 2013, Technical Memorandum, Prepared by Sonoma Technology, Inc., May 24, 2017, prepared for Idaho Department of Environmental Quality, STI-917019-6741-TM.

USGS (United States Geological Survey). 2017. "Geospatial Multi-Agency Coordination." USGS Geosciences & Environmental Change Science Center, Lakewood, CO. Accessed 2017 by Sonoma Technology. *https://www.geomac.gov/about.shtml*

UW (University of Washington). 2017. "Pacific Northwest Mesoscale Model Weather Forecasts: Information." *http://www.atmos.washington.edu/wrfrt/info.html*

Val Martin, M. et. al. 2010. "Smoke Injection Heights from Fires in North America: Analysis of 5 Years of Satellite Observations." *Atmospheric Chemistry and Physics*. 10: 1491–1510.

Vaughn, J. 2016. MCIP and BCON archived MCIP and BCON model files for July1–September 26, 2013 modeling episode, personal communication, Joe Vaughan, Washington State University, Laboratory for Atmospheric Research, Pullman Washington, retrieved from AIRPACT archives 2016.

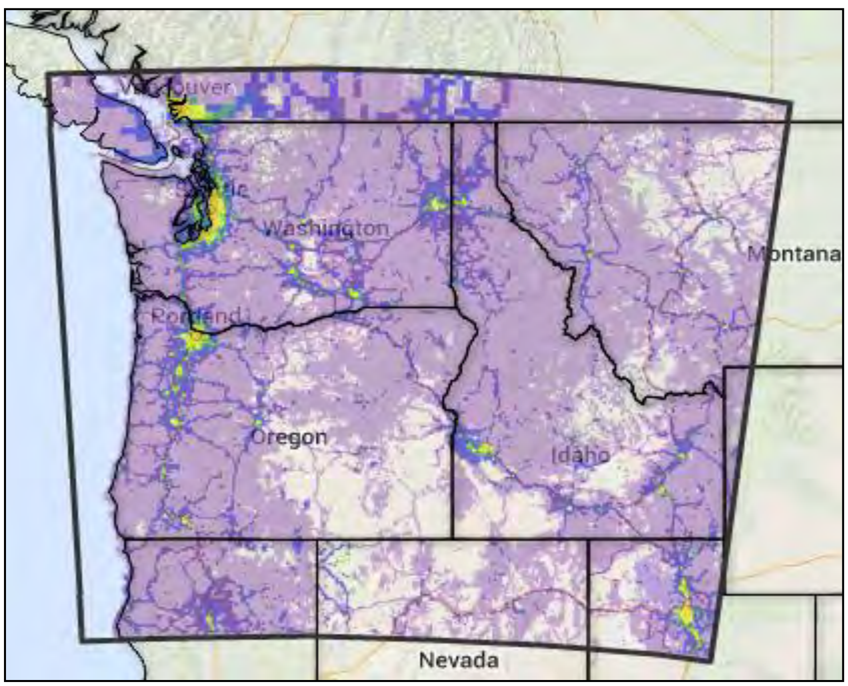
# Appendix A. AIRPACT5 Emissions Inventory

AIRPACT-5 Emissions Inventory

Note: The AIRPACT5 emission inventory is documented in this in-progress summary provided by NW-AIRQUEST, the regional consortium that supports the AIRPACT5 model.

Portions of the Emission Inventory were updated by Idaho DEQ for the purposes of the 2017 CRB SIP modeling project, including On-road emissions, biogenic emissions and both wildland fire and agricultural burning emissions, as described in the DEQ's *2017 Crop Residue Burning Ozone State Implementation Plan Revision Amendment* (September 2017).

DEQ has annotated those sections in this summary which were updated by Idaho DEQ and are described in DEQ's modeling report (The Amendment).




NW-AIRQUEST Emissions Inventory Workgroup

## Table of Contents



## Tables



## Figures

**AIRPACT-5 Emissions Inventory Update**

## 1 Project Description

The Air Information Report for Public Access and Community Tracking (AIRPACT) is a computerized system for predicting air quality (AQ) in Idaho, Oregon, and Washington. AIRPACT predicts air quality by calculating the chemistry and physics of air pollutants as determined by pollutant emissions within the context of the background, natural air chemistry and predicted meteorology. Pollutant emissions from many different sources are calculated, chemically classified, spatially located, and adjusted as appropriate by date, time of day and predicted temperature, precipitation, and solar light intensity.

Approximately every 3 years the pollutant emissions are updated to reflect current conditions. This is the fourth major update of the AIRPACT emissions inventory since work began in 2000. The emissions inventory update was accomplished through a workgroup made up of members of the Northwest International Air Quality Environmental Science and Technology Consortium (NW-AIRQUEST). Members from all Idaho, Oregon, Washington, Canada, and several local jurisdictions participate in the workgroup. Members have expertise in emissions inventories and/or air quality modeling.

This document describes the construction of the air quality modeling inventory from state, provincial, and national inventory information. Contact the individual agencies for detail on emissions estimation methods and sources they used to generate the emissions.

In addition to the new inventory, software and other updates were made to the AIRPACT system resulting in a new version of AIRPACT called AIRPACT-5. The software and other component updates are only addressed to the extent that they affected inventory development.

## 1.1 Geographic Domain

Pollutant emissions estimates were compiled and developed for a rectangular domain encompassing Idaho, Oregon, Washington, northern California, western Montana, northern Utah, northern Nevada, southern Alberta, southern British Columbia, and very small portions of Wyoming and Saskatchewan. The resolution of the meterological and emissions data within the domain is defined by the grid spacing within the domain. Domain parameters are:

Coordinate System: Lambert conformal conical
First Standard Latitude: 30 N
Second Standard Latitude: 60 N
Central Meridian: 121 W
Central latitude: 49 N
Southwest Corner Coordinates (x,y): -342, -942
Northeast Corner Coordinates (x,y): 798, 90
Grid Spacing: 4-km

Figure 1: AIRPACT-5 Domain

## 1.2 Inventory Year

AIRPACT-5 produces daily predictions of air quality. The closer the emissions are to the current year, the better the predictions will be. The inventory prepared for this update is expected to be used from approximately 2015 to 2017. The workgroup chose 2014 as the inventory year.

The 2010 or 2011 comprehensive inventories prepared to meet state, provincial, and national reporting requirements are the most current available for most emissions sources. Inventories for onroad and some nonroad mobile sources were prepared specifically for 2014. Fire emissions are calculated for a specific day's forecast using the most recent Satellite Mapping Automatic Reanalysis Tool for Fire Incident Reconciliation v2 (SMARTFIRE2) information as input to the BlueSky framework, and thus are not part of this historical inventory. Biogenic emissions are also calculated separately from this inventory, using the Model of Emissions of Gases and Aerosols from Nature (MEGAN).

## 1.3 Pollutants

AIRQUEST members decided upon a list of pollutants to model in AIRPACT-5. Toxics were chosen based on health, presence of monitoring data for verification, and importance in ozone chemistry. The toxics are treated as tracers, which means they do not participate in the atmospheric chemistry processes. The pollutants submitted by each jurisdiction and through calculations specific to AIRPACT-5 were classified according to the AIRPACT-5 pollutant list. For example, *reactive organic compounds (ROG)* were classified as *VOC*, and *benzo(a)pyrene* was classified as *PAH*. If more than one hydrocarbon class was estimated for the same source, only one was chosen for the inventory.

Three PM2.5 tracers are tracked in addition to total PM2.5. The tracers track diesel, gasoline, and woodsmoke PM2.5. The tracers were calculated by duplicating PM2.5 estimates for diesel, gasoline, and residential wood combustion processes as identified by SCC codes.

The SMOKE-MOVES processor was used for the onroad mobile inventory. Pollutant names may differ from those in the table below.

Adjustments were made to particulate emissions under certain conditions. PM10 and PM2.5 emissions are sometimes reported as primary, filterable, or condensable. By definition, primary is the sum of filterable and condensable. If there were filterable emissions for a process, but no primary emissions, the filterable and condensable were added together to represent primary emissions. Only primary emissions were used for the final inventory.

Inventories provided by the air agencies were checked for missing particulate matter data. If a process had PM10 emissions, but no PM2.5 emissions, or conversely if a process had PM2.5 emissions, but no PM10 emissions, then the missing size range was estimated from the existing PM using either (1) particle size distribution data, or (2) the simple assumption that PM10 = PM2.5.

Table 1: AIRPACT-5 Pollutant List

| Pollutant | AIRPACT-5 Name | Pollutant | AIRPACT-5 Name |
|---|---|---|---|
| **Full Chemistry Pollutants** | | **Toxic Tracers** | |
| CO | CO | Acetaldehyde | ACETALDEHYD |
| NH3 | NH3 | Acrolein | ACROLEIN |
| NOx | NOx | Arsenic | ARSENIC |
| PM10 | PM10 | Benzene | BENZENE |
| PM2.5 | PM2_5 | 1,3-Butadiene | BUTADIENE |
| SO2 | SO2 | Chromium & Hexavalent Chromium | CHROMIUM |
| TOG | TOG | Dichloromethane/Methyene Chloride | DICHLOROMET |
| VOC | VOC | Ethylbenzene | ETHYLBENZEN |
| | | Formaldehyde | FORMALDEHYD |
| | | Lead | LEAD |
| **PM2_5 Tracers** | | Mercury | Manganese |
| Diesel PM2.5 | DSPM2_5 | Mercury | MERCURY |
| Gasoline PM2.5 | GASPM2_5 | Naphthalene | NAPHTHALENE |
| Woodsmoke PM2.5 | WSPM2_5 | PAH | PAH |
| | | Toluene | TOLUENE |
| | | Xylenes | XYLENE |

### 1.4 Emissions Inventory Processing

AIRPACT-5 uses the Sparse Matrix Operating Kernel Emissions (SMOKE) emissions processor to prepare emissions for air quality modeling. This inventory was developed specifically to be used with SMOKE v3.5.1. Files describing emissions, spatial allocation, temporal allocation, and chemical speciation are required. These files all work together to produce gridded chemically speciated emissions estimates for each hour of the air quality prediction. This is accomplished by linking emissions to the information in the spatial, temporal, and chemical speciation files. The key information required for making the linkage includes county, SCC code, and pollutant. The SCC code is a code that describes the type of process that is generating the emissions, e.g. SCC code 10200902 is a wood-fired industrial boiler. All the files are discussed in sections 2 through 5.

Washington State University (WSU) developed a special module to work within the SMOKE framework to make hourly emissions adjustments based on meteorology for woodstoves. This module should improve the accuracy of emissions estimates from residential heating and are described in more detail later in this document.

The states and Canada provided their emissions estimates in either SMOKE-ready format or in EPA's Emissions Inventory System (EIS) Staging Table format. Emissions were converted to SMOKE's IDA format using Perl scripts.

## 2 Emissions

Emissions were prepared for point, nonpoint, nonroad mobile, and onroad mobile sources. Emissions from biogenic sources and fires were incorporated into AIRPACT-5 by WSU using separate processes (see Section 1.2).

The Idaho Dept. of Environmental Quality (IDEQ), Oregon Dept. of Environmental Quality (ODEQ), Washington Dept. of Ecology (WAECY), and Environment Canada (EC) provided most of the inventory data. Gaps in the inventory were filled with estimates from version 1 of EPA's 2011 National Emissions Inventory (NEI).

Each major emissions category is described below.

### 2.1 Point Sources

*SMOKE file PTINV*

For AIRPACT-5, point sources were defined as industrial, commercial or institutional stationary sources whose emissions are individually tracked and located with geographic coordinates. Most of the point sources are classified as major sources[a] though some sources counted in the point source inventory are smaller sources. Stationary sources which were not tracked individually were aggregated at the county or district level and compiled into the nonpoint inventory (see section 2.4). Airports and some individual rail yards and livestock farms had latitude and longitude coordinates. Because they could be accurately located, they were processed as point sources. Those without coordinates were processed in the nonpoint inventory (section 2.4).

The following data elements are required for the SMOKE point source file PTINV:

State/Province FIPS
County/District FIPS
Plant ID (Facility ID)
Point ID (Emissions Unit ID)
Stack ID (Emissions Release Point ID)
Segment ID (Emissions Process ID, preferred but may leave blank)
Plant Name (preferred but may leave blank)
SCC Code
Stack Height (ft)
Stack Diameter (ft)
Stack Temperature (degrees Fahrenheit)
Stack Flow Rate ($ft^3$/sec)
Stack Velocity (ft/sec)
SIC Code (must be 4-digit SIC)
Stack Latitude (decimal degrees)
Stack Longitude (decimal degrees)
Pollutant Code
Emissions (tons/yr preferred, but may be tons/day)

The states provided their point source data in SMOKE's flat file format (FF10), EPA's Emissions Inventory System (EIS) XML format, or the EIS format as processed into EPA's staging tables. Canadian inventories were provided in SMOKE-ready ORL format, using the most recently available national dataset (2006 base year). Using these common formats greatly reduced the effort required to combine and format inventories for SMOKE.

---

[a] In the USA, major point sources are those with the potential to emit 100 tons per year or more of any one criteria pollutant or a combination of criteria pollutants, and/or point sources with the potential to emit 10 tons per year or more of any single Hazardous Air Pollutant, or 25 tons per year or more of a combination of Hazardous Air Pollutants (Section 112, Clean Air Act).

The USA inventories were updated to account for any known major changes between the base year 2011 and the AIRPACT-5 target year of 2014. They were also checked for missing release point parameters. For release points, EPA's EIS system does not allow a release point to be identified as a stack unless all parameters are present. If a release point is missing parameters, or set as zero, SMOKE uses default stack parameters based on the SCC, using the SMOKE PSTK file. If no entry for the associated SCC exists in the PSTK file, the stack parameters are set as fugitive. The PSTK file was updated for this inventory so that a minimal number of sources would be modeled as fugitive. Fugitive parameters are:

- height = 3 m (approximate minimum value allowed in SMOKE)
- diameter = 0.2 m (maximum value for EPA's EIS)
- temperature = 295.4 K (a general ambient temperature)
- velocity = 4 m/s (minimum value for EPA's EIS)
- flow in $ft^3/s$ (calculated from diameter and velocity)

If the stack parameters are not missing or zero, SMOKE ensures that their values are within the allowed ranges. When a stack parameter falls outside of its associated range, SMOKE sets it to the top or bottom of the range. Note that a zero value is not treated as an out-of-range parameter, but is treated as a missing value. The allowed range for each stack parameter is as follows:

- Height: 0.5 to 2100 meters
- Diameter: 0.01 to 100 meters
- Exit temperature: 260 to 2000 K
- Exit velocity: 0.0001 to 500 m/s

#### 2.1.1 Border States

Emission estimates for states along the WA/ID/OR tri-state border (CA, MT, NV, UT, and WY) were acquired from the 2011 NEI.

#### 2.1.2 Canada

Environment Canada provided point source data. They did not provide valid SCC codes for many of the sources. As a substitute, they provided a facility-specific code. The SCC code is used to link to temporal and chemical speciation profiles. More detail about the SCC code substitutions may be found in the temporal and chemical speciation sections. It is noted here that for sources using facility-specific codes, Canada speciated the VOC emissions and provided the lumped species in the emissions files.

### 2.2 Onroad Mobile Sources **[On-road emissions were reanalyzed for the Idaho CRB SIP modeling 2013 episode]**

*SMOKE-MOVES Emissions Processor Files*

Onroad mobile source emissions come from exhaust, evaporation, and brake and tire wear. Vehicle refueling is covered in the nonpoint category. Some onroad emissions are dependent on the number of miles driven (e.g. exhaust), and others on the number of vehicles (e.g. start emissions, liquid leaks).

Onroad mobile emissions were calculated using the SMOKE-MOVES processor. SMOKE-MOVES combines EPA's onroad mobile source MOVES model emissions rate calculation processes with SMOKE's hourly gridded meteorology, and activity, spatial, temporal, and chemical speciation processes to produce hourly gridded emissions.

IDEQ led a special workgroup to develop the inputs and scripting required to integrate SMOKE-MOVES into AIRPACT-5. IDEQ and WSU performed the SMOKE-MOVES modeling and integration using inputs supplied by the states.

Figures 2.13 and 2.14 from the SMOKE 3.5.1 User's Manual show the processing steps to produce gridded, hourly, chemically speciated emissions. The speciation, temporal allocation, and gridding are discussed in sections 3 through 5. This section focuses on the MOVES emission rates and activity data. The basic onroad mobile calculation focusing on the emission rates and activity data is shown below:

$$E = (M \times Rgmi) + (V \times Rgpveh)$$

where E = emissions in g
M = vehicle miles traveled (VMT)
V = vehicle population (VPOP)
Rgmi = emission rate in g/mi
Rgpveh = emission rate in g/vehicle

Figure 2: MOVES Rate per Distance Processing Steps (Figure 2.13 SMOKE Manual)

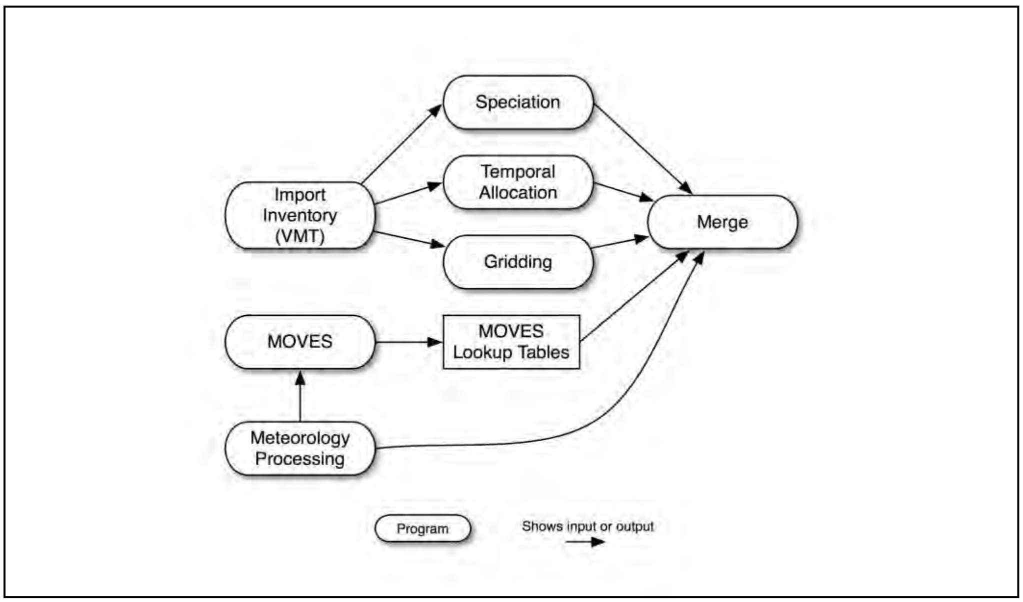
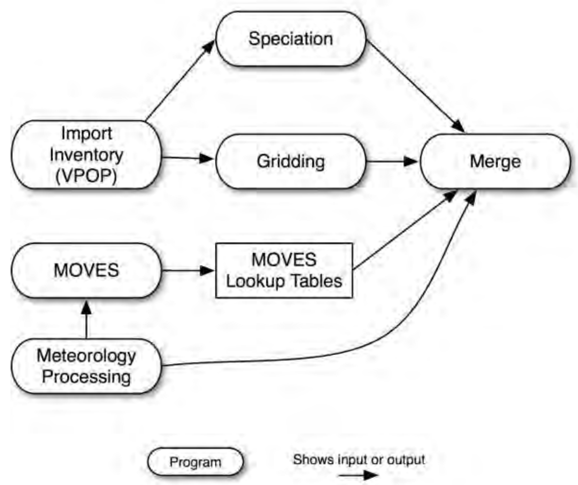



Figure 3: MOVES Rate per Vehicle and Rate per Profile Processing Steps (Figure 2.14 SMOKE Manual)




### 2.2.1 Emission Rates

Onroad mobile emission rates in g/mi and g/vehicle were calculated using the SMOKE-MOVES processor. Standard SMOKE-MOVES processing involves running MOVES within SMOKE each day based on the month, day of week, and forecast meteorology. Running in the standard mode was not possible due to long run times. Instead of running in the standard mode, the SMOKE-MOVES processor was used to generate emission factors (rate-per-distance, rate-per-vehicle, rate-per profile) that could be stored in static lookup tables. The emission factors can then be selected based on the road types, speeds and hourly forecast meteorology for each grid.

Some evaporative emissions (rate-per-profile) depend on the hour's temperature prediction, and on previous hourly temperatures. These factors were generated based upon typical seasonal profiles.

SMOKE-MOVES relies on the concept of reference counties and fuel months. Instead of running each county individually, counties with similar characteristics are grouped and one county in the group is run to represent itself and the other counties in the group. Months used in the runs are also grouped, and a reference month is chosen to represent each group based on similar fuel parameters. For all areas, January was chosen to represent November- April, and July was chosen for May-October.

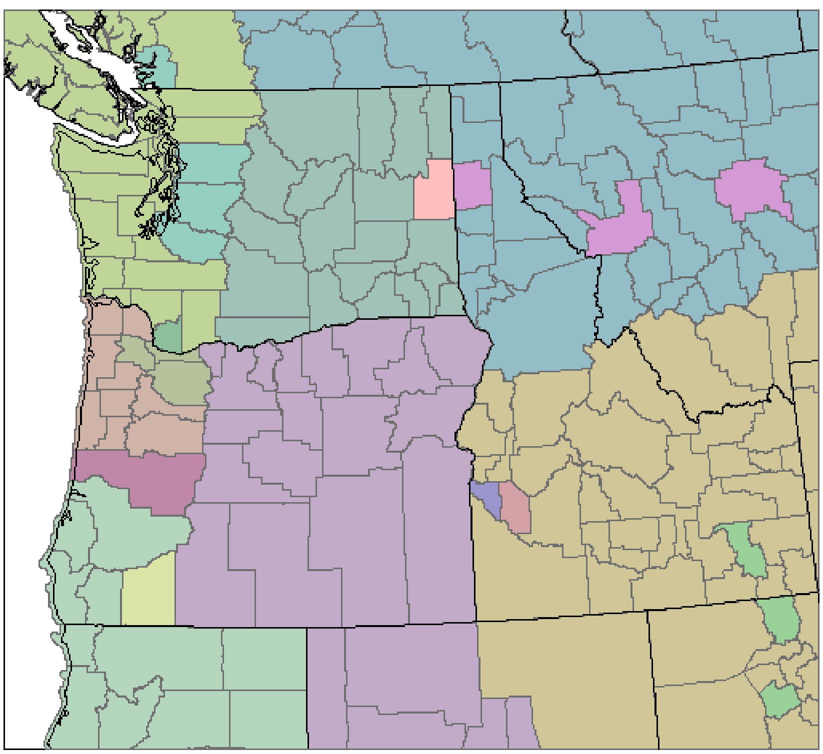
For each reference county and fuel month, the states provided MOVES model inputs for vehicle age distributions, fuel parameters, and I/M programs. The states identified reference counties for their states and for areas in the bordering states and Canada as shown in the table below.

Table 2: MOVES Representative Counties

| **Representative County** | **Representative County Group** |
|---|---|
| **Idaho** | |
| Ada | Urban with Ada County-Specific IM |
| Benewah | Rural with Northern Idaho Fuel Supply |
| Bannock | Urban with Southern Idaho Fuel Supply |
| Cassia | Rural with Southern Idaho Fuel Supply |
| Canyon | Urban with Canyon County-Specific IM |
| Kootenai | Urban with Northern Idaho Fuel Supply |
| **Oregon** | |

| | |
|---|---|
| Deschutes | Eastern Oregon - Rural - EOR Non IM with EOR Fuels |
| Douglas | S.W. Oregon - Rural - WOR Non IM with WOR Fuels |
| Jackson | Jackson County (Medford metro area) - Urban - IM with WOR Fuels |
| Lane | Eugene-Springfield - Urban- WOR Non IM with WOR Fuels |
| Linn | Willamette Valley/Coastal - Rural - WOR Non IM with WOR Fuels |
| Multnomah | Portland Metro - Urban - IM with Portland Fuels |
| **Washington** | |
| Clark | Clark IM with Portland Fuels |
| King | Puget Sound IM with WWA Fuels |
| Kitsap | WWA Non IM with WWA Fuels |
| Spokane | Spokane IM with EWA Fuels |
| Yakima | EWA Non IM with EWA Fuels |
| **CA, MT, NV, UT, and WY** | |
| OR - Deschutes | Eastern Oregon - Rural - EOR Non IM with EOR Fuels |
| ID - Benewah | Rural with Northern Idaho Fuel Supply |
| ID - Cassia | Rural with Southern Idaho Fuel Supply |
| OR - Douglas | S.W. Oregon - Rural - WOR Non IM with WOR Fuels |
| ID - Kootenai | Urban with Northern Idaho Fuel Supply |
| ID - Bannock | Urban with Southern Idaho Fuel Supply |
| **Canada** | |
| WA - King | Puget Sound IM with WWA Fuels |
| ID - Benewah | Rural with Northern Idaho Fuel Supply |
| WA - Kitsap | WWA Non IM with WWA Fuels |

Figure 4: MOVES Representative County Groupings



### 2.2.2 Activity Data: Vehicle Miles Traveled, Vehicle Population, Speed

The SMOKE-MOVES processor requires vehicle miles traveled (VMT), vehicle populations (VPOP), and speed by county or regional district, and SCC Code. The data were provided by the states, British Columbia, and Metro-Vancouver. MOVES default VMT and VPOP were used for the bordering states. Mainland British Columbia regional districts within the domain (excluding the Greater Vancouver Regional District) were used to develop per capita VMT and VPOP for the regional districts in Alberta.

The per capita values were multiplied by population in the districts to estimate VMT and VPOP, since they were not available for Alberta. Speeds used in Washington were used for the bordering states and Canadian regional districts.

## 2.3 Nonroad Mobile Sources, except Ships, Locomotives, and Aircraft

*SMOKE file ARINV*

Nonroad mobile sources (excluding ships, locomotives, and aircraft) are those which are included in EPA's NONROAD model. The model includes vehicles and equipment in the following categories:

| | | |
|---|---|---|
| Recreational | Agriculture | Underground Mining |
| Construction | Commercial | Oil Field |
| Industrial | Logging | Pleasure Craft |
| Lawn/Garden | Airport Support | Railroad |

The NONROAD model was used to estimate emissions. NONROAD requires information on fuels, temperatures, geographic areas, and timeframes. It outputs emissions in tons.

The following data elements are required for the SMOKE file ARINV:

State/Province FIPS
County/District FIPS
SCC Code
Pollutant Code
Emissions (tons/yr preferred, but may be tons/day)

### 2.3.1 USA

In the USA, version 2008a of NONROAD model was used. Emissions were run for each county for calendar year 2014. Because past work had shown that temperature did not affect emissions greatly, emissions were output as annual totals to simplify model runs.

The three states ran the NONROAD model using fuel and temperature parameters appropriate for their counties. Model runs for counties in the bordering states used fuel and temperature parameters from the onroad representative counties identified in Section 2.2. IDEQ staff did the model runs for Montana, Utah, and Wyoming. ODEQ staff did the runs for California and Nevada.

### 2.3.2 Canada

In Canada, nonroad mobile sources were estimated using the NONROAD model, version 2004. Environment Canada provided province-level emissions files for calendar year 2006 as SMOKE-ready files in ORL format.

## 2.4 Nonpoint Sources, (except Residential Wood Combustion), and Ships, Locomotives, and Aircraft

*SMOKE file ARINV*

Nonpoint sources include small stationary sources treated as county/district totals rather than individual sources (e.g., woodstoves, autobody shops), sources covering large areas (e.g., dust from agricultural tilling or roads), and sources of short duration (e.g. residential backyard burning). Ships, locomotives, and aircraft are nonroad sources, but they are documented here since their processing was identical to the nonpoint sources.

Residential wood combustion emissions were processed using special modules developed to adjust emissions according to the daily meteorological forecast. Residential wood combustion processing is described in section 2.5.

Several other sources were excluded from the nonpoint files because they were counted in other parts of the air quality modeling system. These were wildfire, agricultural burning, silvicultural burning, and biogenics.

All other non-point sources were processed using conventional SMOKE processes. The following data elements are required for the SMOKE file ARINV:

State/Province FIPS
County/District FIPS
SCC Code
Pollutant Code
Emissions (tons/yr preferred, but may be tons/day)

### 2.4.1 Idaho, Oregon, and Washington

IDEQ, ODEQ, and WA-ECY provided annual nonpoint emissions for their counties.

### 2.4.2 Border States

Emission estimates for the bordering states' counties were acquired from the 2011 NEI.

### 2.4.3 Canada

Emission estimates for Canada were acquired from their 2006 inventory.

### 2.4.4 Offshore Shipping Lane Emissions

NEI v.2 was used for offshore shipping.

## 2.5 Residential Wood Combustion

Annual emissions provided by states and/or the NEI were used for Residential Wood Combustion.

## 2.6 Biogenic Sources [**Biogenic emissions were reanalyzed for the Idaho CRB SIP modeling 2013 episode**]

Biogenic emissions are calculated at WSU on a daily basis, separate from this inventory, using the Model of Emissions of Gases and Aerosols from Nature (MEGAN).

## 2.7 Fire Sources [**All wildland fire and crop residue burning emissions were reanalyzed for the Idaho CRB SIP modeling 2013 episode**]

Wildfire and prescribed burn emissions are calculated separately from this inventory at WSU on a daily basis, using the US Forest Service BlueSky model (v3.5.1) and the Satellite Mapping Automatic Reanalysis Tool for Fire Incident Reconciliation v2 (SMARTFIRE-2).

# 3 Spatial Allocation

*SMOKE files SRGDESC (surrogate descriptions), AGPRO (spatial surrogates), AGREF (surrogate-to-source assignments), and COSTCY (country, state, county descriptions)*

AIRPACT-5 uses a 4-km grid spacing in the domain. Emissions estimates are allocated to each grid. Point sources are assigned to grids through their coordinates. Mobile and nonpoint sources cannot be specifically located; therefore, surrogates which can be specifically located are used to spatially allocate emissions. For example, pleasure craft cannot be individually located, but they can be assigned to grids containing open waters.

The SMOKE AGPRO file contains spatial allocations by grid for emissions surrogates. For the U.S., the allocations are the fractions of each surrogate in each grid within a county. For Canada, the allocations are the fractions of each surrogate in each grid within a province. Emissions sources (in ARINV files) are assigned to a surrogate through the spatial cross-reference file AGREF. The surrogates are used to spatially allocate the county total emissions by source to the grids.

The surrogates were assigned to grids using a variety of methods including the use of GIS software and customized scripts. Many shapefiles used to create surrogates were obtained from the EPA's 2003 (ftp://ftp.epa.gov/EmisInventory/emiss_shp2003/us/) and 2010 (ftp://ftp.epa.gov/EmisInventory/surrogates/shapefiles_2010/) surrogate datasets. Although other publicly available datasets were also used where appropriate.

## 3.1 Spatial Surrogates

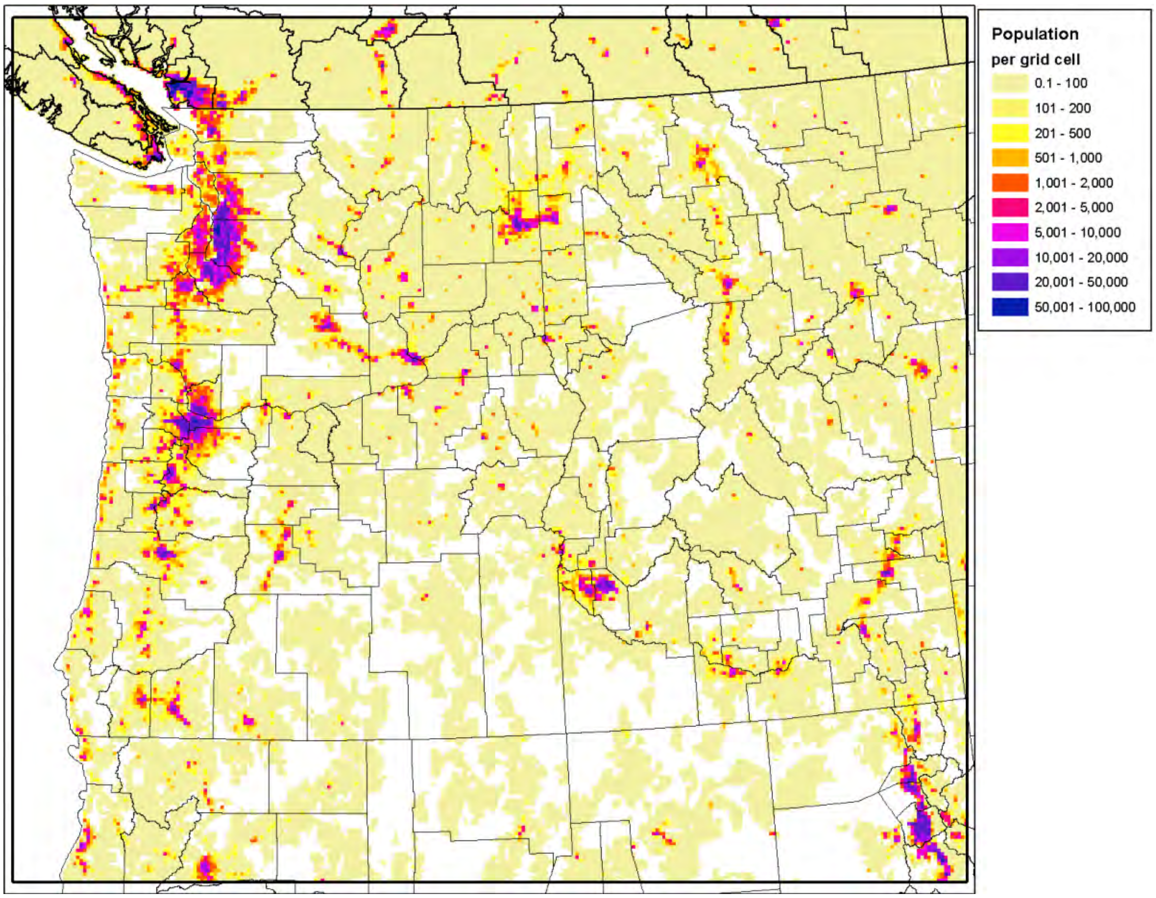
*SMOKE file AGPRO (spatial surrogates)*

Spatial surrogates are described below. Most are new for this AIRPACT-5 update. Please see Appendix A for details about how the surrogates were used in the inventory.

### 3.1.1 USA Population

The 2010 Census block data was used to allocate population and housing to grids.[1]

Figure 5: Total Population Per AIRPACT-5 Grid Cell



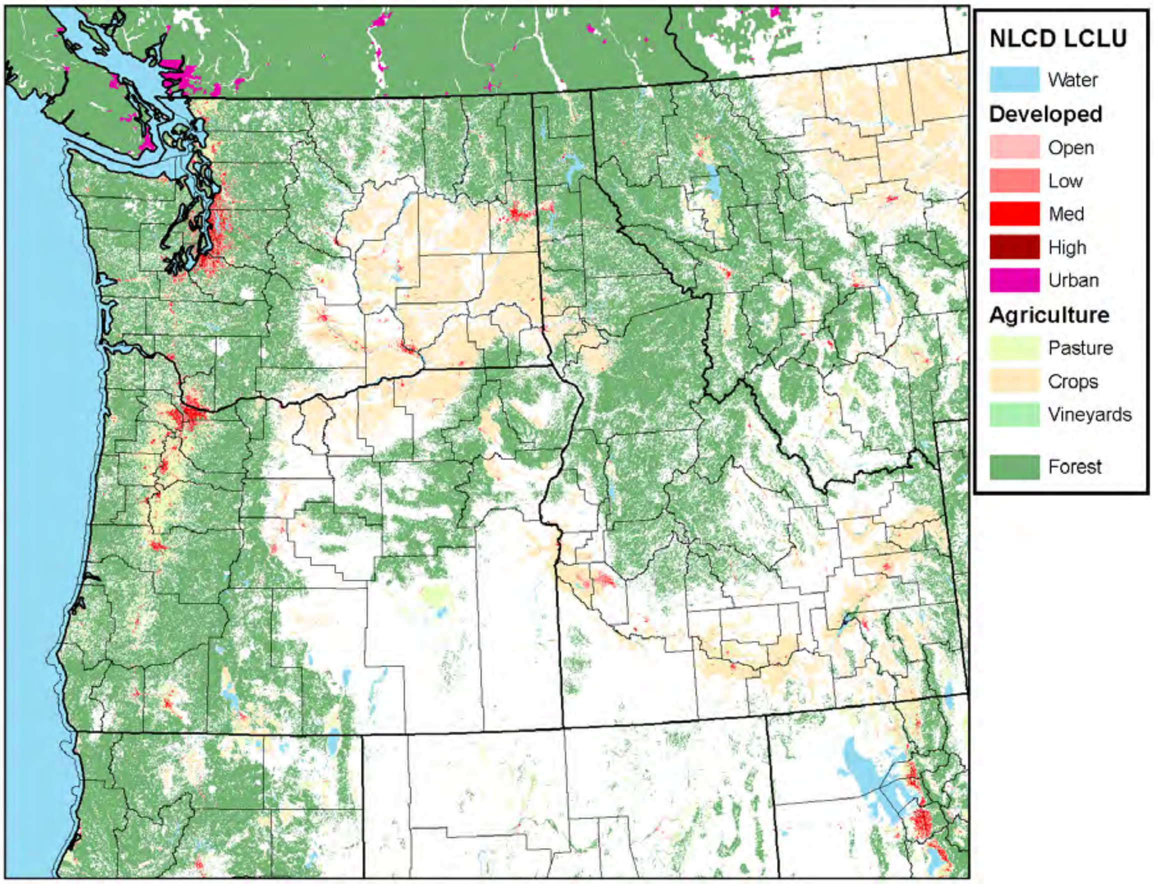

### 3.1.2 Population with Wood as Primary Heat Source

The 2012 American Community Survey 5-yr average[2] Census block group data for households using wood as their primary heat source was crossed with the 2006 National Land Class Database (NLCD)[3] low-intensity residential developed area to assign primary wood heating population to grids. This is the standard method recommended by EPA and is thought to be a better indicator of residential wood combustion than population, which was formerly used in AIRPACT-5.

### 3.1.3 USA Land Use and Land Cover

WA ECY developed grid assignments for land use and land cover from the NLCD: water, land, mines/quarries, forest, crop, pasture, vineyards, total agriculture, and developed (open, low, medium, and high intensity). Note that EPA considers low/med/high intensity developed areas as “residential” (e.g. low-intensity corresponds to single-family housing while high-intensity corresponds to apartments), but the classifications in the NLCD actually correspond to the percent of impervious surface, with housing as an example of the expected coverage in those areas.

Figure 6: Land Class / Land Use Categories in the AIRPACT-5 Domain




### 3.1.4 USA Vehicle Miles Traveled

Link-level VMT data was obtained from state transportation agencies (DOTs) and local metropolitan planning organizations (MPOs). The table below shows the area, agency, and year of link VMT. The MPO surrogates were used for all individual counties listed in the table below. All other counties were represented by the State DOT surrogates.

Table 3: Vehicle Miles Traveled Data Sources

| Dataset Coverage | Agency | VMT Year |
|---|---|---|
| Idaho, Statewide | Idaho Transportation Dept. (ITD)[4] | 2011 |
| Idaho - Ada and Canyon Counties | Community Planning Association of Southwest Idaho (COMPASS)[5] | 2014 |
| Oregon, Statewide | Oregon Dept. of Transportation (ODOT)[6] | 2006 |
| Oregon, METRO Portland (urban areas of Clackamas, Multnomah, Washington) | METRO (Portland)[7] | 2002 |
| Washington, Statewide | Washington State Dept. of Transportation (WSDOT)[8] | 2012 |
| Washington, King, Kitsap, Pierce, Snohomish Counties | Puget Sound Regional Council (PSRC)[9] | 2010 |
| Washington, Spokane County | Spokane Regional Transportation Council (SRTC)[10] | 2010 |
| Washington, Clark County | Southwest Regional Transportation Council (RTC)[11] | 2014 |
| Washington, Thurston, County | Thurston Regional Planning Council (TRPC)[12] | 2009 |

### 3.1.5 Railroads

EPA posted rail shapefiles and shape activity fractions for the 2011 NEI. The information was used to develop a spatial surrogate of rail density in gross ton-miles.[13]

### 3.1.6 Airports

Airports were treated as point sources. Most, if not all airport data was taken from EPA's NEI version 1.

### 3.1.7 Ports and Shipping Lane Emissions

EPA posted port and shipping lane shapefiles for the 2011 NEI. The shapes were weighted with average ship emissions of NOx, SO2 and PM2.5 to create a spatial surrogate of ship emissions.[14]

### 3.1.8 Sulfur Emissions Control Area Waters Outside County Boundaries

Grid assignments were developed for ship paths outside of county boundaries. The surrogate includes Canadian waters, and does not exclude any that may lie within British Columbia's boundaries. The surrogate was developed from GIS county boundary files and information prepared by Dr. James Corbett for the Sulfur Emissions Control Area (SECA) study 2010 projection (in raster format).[15, 16, 17] The surrogate is used to allocate open sea shipping emissions estimated in the SECA study.

### 3.1.9 FEMA

The Federal Emergency Management Agency (FEMA) estimates potential losses from disasters using the Hazus GIS dataset, which gives the total floor area of residential structures (derived from Census 2000) and non-residential structures (derived from Dun & Bradstreet 2006). The FEMA Hazus v2.1 GIS dataset was used to derive spatial surrogates for sub-classes and combinations of commercial, industrial, residential, institutional, and government.

### 3.1.10 Golf Courses

A spatial surrogate for golf courses was created using publicly available GPS data (http://www.poi-factory.com/node/29395) of the location of golf courses, weighted by the total holes of play at each course.

### 3.1.11 Wastewater Treatment Facilities

A spatial surrogate for wastewater treatment facilities was created using locations identified by the EPA's Permit Compliance System (PCS) and Integrated Compliance Information System (ICIS) databases (http://www.epa.gov/enviro/facts/pcs-icis/search.html).

### 3.1.12 Dry Cleaners

A spatial surrogate for dry cleaners was created using the EPA's 2003 surrogate dataset derived from the 2000 US Census.

### 3.1.13 Commercial Timber

A spatial surrogate for commercial timber removal was created using the EPA's 2003 surrogate dataset, derived from the 1995 USFS Forest Inventory and Analysis (FIA), which identifies over 20,000 point locations in the AIRPACT-5 domain that could be used to harvest timber.

### 3.1.14 Military Airports

A spatial surrogate for military airports was created using the US Department of Transportation's airport point locations listed in the 2014 National Transportation Atlas Database (http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_atlas_databa se/2014/point). These airport points were derived from the FAA's National Airspace System Resource Aeronautical Data Product. All airports with military operations were selected and weighted by the total annual military aircraft operations.

#### 3.1.15 Gas Stations

A spatial surrogate for gas stations was created using the EPA's 2003 surrogate dataset derived from business counts.

#### 3.1.16 Oil Refineries and Tank Farms

A spatial surrogate for oil refineries and tank farms was created using the EPA's 2003 surrogate dataset derived from FEMA HAZUS and updated using input from regional and state agencies.

#### 3.1.17 Canadian Surrogates

Environment Canada provided surrogates for Canadian sources. Surrogates are:

- Population
- Housing
- Agricultural
- Mining, Quarries and Oil
- Manufacturing
- Construction
- Digital Road Network
- Air Traffic Corridors
- Total Retail and Wholesale Sales
- Forestry and Manufacturing
- Mining and Manufacturing
- Railroad Network
- Forest Fire Activity

### 3.2 Spatial Cross-References

*SMOKE file AGREF (surrogate-to-source assignments)*
Emissions sources (in ARINV files) are assigned to a spatial surrogate through the spatial cross-reference file AGREF. See the Spatial Surrogate Workbook (Appendix A) for details.

## 4 Temporal Allocation

*SMOKE files [A/M/P]TPRO (month, day of week, and hourly weekday and weekend temporal profiles), [A/M/P]TREF (profile-to-source assignments)*

Emissions estimates are either expressed as tons per year or tons per day in the SMOKE emissions files (ARINV, PTINV). The estimates must be allocated by hour for air quality modeling. To allocate emissions by hour, temporal profiles are applied. The APTPRO (A = Area, P = Point) and MTPRO (M = Mobile) files contain temporal allocation profiles for sources defined in ARINV at the monthly, daily, and weekday/weekend hourly level. ATREF is the cross-reference file that assigns the temporal allocation profiles to the emissions sources by county, pollutant, and SCC code. For each of the profiles, the temporal allocations are defined as the portion of total profile activity occurring in the given timeframe.

Profiles and cross-references came from a variety of sources. The previous versions of AIRPACT's temporal profile files were used as a starting point. Portions of these AIRPACT temporal profiles were developed using EPA's NONROAD 2008 model, WSDOT urban traffic counters (2005, 2008),[18] WSU Woodstove survey (2001), WA agricultural statistics (2004), and WA business statistics (1996). For this EI update, special attention was given to mobile and residential wood combustion profiles and they were updated if necessary. Then, files provided by EPA for the 2011 base modeling platform were used to augment the files. Where there was crossover between AIRPACT's and EPA's information on profiles, the following method was used: if the AIRPACT profile had been developed using local data, we kept the AIRPACT profile. If we didn't have any specific data for an SCC, then we kept the EPA profile information. The EPA data included profiles for some SCCs that weren't previously in the AIRPACT files, even if those SCCs were not currently being used by AIRPACT, they were added to the file in case we use them in the future.

USA point sources were assumed to operate uniformly throughout the year, unless EPA's base modeling profile had a specific profile for the SCC. Environment Canada provided non-uniform temporal profiles for some of their point sources. The profiles were linked to facilities based on facility-specific codes which were substituted for SCC codes.

# 5 Chemical Speciation

*SMOKE files GSPRO (chemical speciation profiles), GSPRO_COMBO (chemical speciation profiles groups), (GSREF (profile-to-source assignments), GSCNV (conversion factors for VOC-to-TOG), INVTABLE (list of pollutants and characteristics)*

## 5.1 Speciation Profiles and Chemical Mechanism

*SMOKE file GSPRO (chemical speciation profiles)*

Speciation profiles provide estimates of the chemical composition of emissions which are necessary to to simulate air quality chemistry. For example, VOC emissions must be split among several more specific chemical species (i.e. speciated) based on the reactivity of the emissions. The distribution among the species is called a speciation profile. The composition of VOC and PM2.5 vary among different emissions sources; therefore, profiles have been developed for many different emissions sources. There are two major mechanisms for speciating emissions: SAPRC and Carbon Bond. The Carbon Bond (CB05) chemical mechanism was used for AIRPACT-5. Prior AIRPACT inventories used the SAPRC99 chemical mechanism.

Speciation profiles are contained in the GSPRO file. Emissions estimates for each source category (defined by SCC code) are assigned to the correct speciation profile through the cross-reference file GSREF. Most of the profiles and cross-references were obtained from EPA's 2011 modeling platform (version 6.2 and earlier versions). A few adjustments and additions were made primarily to accommodate nonroad and onroad mobile source modeling output.

The hydrocarbon profiles are given in terms of total organic gases (TOG). The emissions estimates are often expressed as VOC. The SMOKE file GSCNV provides conversion factors from VOC to TOG. It was reviewed and updated.

Environment Canada provided CB05 speciated VOC emissions for some of their point sources, so they were used for AIRPACT.

All the pollutants are specified in the SMOKE file INVTABLE. The file was reviewed and updated as needed.

# 6 Quality Control and Quality Assurance

Comparisons - inputs to SMOKE outputs, pollutant coverage across categories and geography, category coverage (by SCC) across geography. Gap filling. Mapping the surrogates. Use of SMOKE reports to summarize data. Other

# 7 Agency Roles

All agencies provided emissions and related data for their jurisdictions. All agencies participated in workgroup discussions and reviewed workgroup products. The products included the inventory and related spatial, temporal, and chemical speciation information. They also included the Inventory Preparation Plan (IPP) and final inventory documentation.

Tasks performed in addition to those mentioned above are listed below by agency.

## 7.1 Idaho DEQ

IDEQ led a special workgroup to develop the inputs and scripting required to integrate SMOKE-MOVES into AIRPACT-5. IDEQ and WSU performed the SMOKE-MOVES modeling and integration using inputs supplied by the states.

## 7.2 Oregon DEQ

ODEQ participated in designing and implementing QA processes.

## 7.3 Washington ECY

WA-ECY facilitated the workgroup meetings. With input from the workgroup members, WA-ECY wrote the IPP and compiled the final inventory documentation. WA-ECY formatted inventory and supporting data for the SMOKE emissions processor. WA-ECY participated in designing and implementing QA processes.

## 7.4 Washington State University

WSU implemented the woodstove temperature adjustment program. WSU integrated biogenic and fire emissions into the AIRPACT-5 system. WSU participated in designing and implementing QA processes. WSU implemented a new version of SMOKE, and chemical mechanism (CB05). WSU performs all the SMOKE model runs, ensuring all necessary data (e.g. meteorological forecast data) is available to the system.

Appendix A

Table A1: Description and source of the spatial surrogate codes (SSCs) used.

| CNTRY | SSC | Surrogate Description | Source | WEIGHT ATTRIBUTE |
|---|---|---|---|---|
| USA | 100 | Population | 2010 US Census | |
| USA | 110 | Housing | 2010 US Census | |
| USA | 120 | Urban Population | 2010 US Census | |
| USA | 130 | Rural Population | 2010 US Census | |
| USA | 140 | Housing Change and Population | 2010 US Census | 50/50 Average |
| USA | 150 | Residential Heating - Natural Gas | 2010 ACS | |
| USA | 160 | Residential Heating - Wood | 2010 ACS | |
| USA | 165 | 0.5 Res. Heating Wood + 0.5 Low Intensity Dev. | 2010 ACS + 2006 NLCD | 50/50 Average |
| USA | 170 | Residential Heating - Distillate Oil | 2010 ACS | |
| USA | 180 | Residential Heating - Coal | 2010 ACS | |
| USA | 190 | Residential Heating - LP Gas | 2010 ACS | |
| USA | 200 | Urban Primary Road Miles | tiger 2010 roads | MTFCC = S1100 |
| USA | 210 | Rural Primary Road Miles | tiger 2010 roads | MTFCC = S1100 |
| USA | 220 | Urban Secondary Road Miles | tiger 2010 roads | MTFCC = S1200 |
| USA | 230 | Rural Secondary Road Miles | tiger 2010 roads | MTFCC = S1200 |
| USA | 240 | Total Road Miles | tiger 2010 roads | |
| USA | 250 | Urban Primary plus Rural Primary | tiger 2010 roads | MTFCC = S1100 |
| USA | 260 | Total Railroad Miles | tiger 2010 railroads | |
| USA | 300 | Low Intensity Residential | 2006 NLCD | |
| USA | 301 | Med Intensity Residential | 2006 NLCD | |
| USA | 302 | High Intensity Residential | 2006 NLCD | |
| USA | 303 | Open Space | 2006 NLCD | |
| USA | 310 | Total Agriculture | 2006 NLCD | |
| USA | 312 | Orchards/Vineyards | 2006 NLCD | us_ag2k (61) |
| USA | 318 | Pasture Land | 2006 NLCD | |
| USA | 319 | Crop Land | 2006 NLCD | |
| USA | 320 | Forest Land | 2006 NLCD | |
| USA | 330 | Strip Mines/Quarries | 2006 NLCD | |
| USA | 340 | Land | 2006 NLCD | |
| USA | 350 | Water | 2006 NLCD | |
| USA | 400 | Rural Land Area | 2010 US Census | Recreational Area |
| USA | 500 | Commercial Land | FEMA HAZUS-MH 2.1 | COM(1-9) |
| USA | 505 | Industrial Land | FEMA HAZUS-MH 2.1 | IND(1-6) |
| USA | 510 | Commercial plus Industrial | FEMA HAZUS-MH 2.1 | COM(1-9) + IND(1-6) |
| USA | 512 | Commercial plus Residential | FEMA HAZUS-MH 2.1 | COM(1-9) + RES(1-4) |
| USA | 515 | Commercial plus Institutional Land | FEMA HAZUS-MH 2.1 | COM(1-9) + RES(5-6) + EDU(1-2) + REL1 |
| USA | 520 | Commercial plus Industrial plus Institutional | FEMA HAZUS-MH 2.1 | COM(1-9) + IND(1-6) + RES(5-6) + EDU(1-2) + REL1 |
| USA | 525 | Golf Courses plus Institutional plus Industrial | FEMA + GPS | 25%*COM3 + 10%*COM8 + 50%*EDU1 + 50%*EDU2 + 25%*IND1 + 25%*IND2 + 25%*IND6 + 10%*REL1 + SSC850 * 35,000 sqft/hole |
| USA | 527 | Single Family Residential | FEMA HAZUS-MH 2.1 | |
| USA | 530 | Residential - High Density | FEMA HAZUS-MH 2.1 | |
| USA | 535 | Residential + Commercial + Industrial + Institutional | FEMA HAZUS-MH 2.1 | |

| | | | | |
|---|---|---|---|---|
| | | + Government | | |
| USA | 540 | Retail Trade (COM1) | FEMA HAZUS-MH 2.1 | |
| USA | 545 | Personal Repair (COM3) | FEMA HAZUS-MH 2.1 | |
| USA | 550 | Retail Trade (COM1) plus Personal Repair (COM3) | FEMA HAZUS-MH 2.1 | |
| USA | 555 | Professional/Technical (COM4) plus General Government (GOV1) | FEMA HAZUS-MH 2.1 | |
| USA | 560 | Hospital (COM6) | FEMA HAZUS-MH 2.1 | |
| USA | 565 | Medical Office/Clinic (COM7) | FEMA HAZUS-MH 2.1 | |
| USA | 570 | Heavy and High Tech Industrial (IND1 + IND5) | FEMA HAZUS-MH 2.1 | |
| USA | 575 | Light and High Tech Industrial (IND2 + IND5) | FEMA HAZUS-MH 2.1 | |
| USA | 580 | Food, Drug, Chemical Industrial (IND3) | FEMA HAZUS-MH 2.1 | |
| USA | 585 | Metals and Minerals Industrial (IND4) | FEMA HAZUS-MH 2.1 | |
| USA | 590 | Heavy Industrial (IND1) | FEMA HAZUS-MH 2.1 | |
| USA | 595 | Light Industrial (IND2) | FEMA HAZUS-MH 2.1 | |
| USA | 596 | Industrial plus Institutional plus Hospitals | FEMA HAZUS-MH 2.1 | |
| USA | 600 | Gas Stations | 2000 CBP | |
| USA | 650 | Refineries and Tank Farms | State Agencies | |
| USA | 675 | Refineries and Tank Farms and Gas Stations | Custom | SSC 600 + 650 |
| USA | 720 | Military Airports | RITA.DOT.GOV | |
| USA | 800 | Marine Ports | 2010 NTAD | Berth |
| USA | 810 | Navigable Waterway Activity | ShippingLanes_NEI2011 | area weighted by NOx emissions from the NEI08v2 |
| USA | 850 | Golf Courses point locations | www.poi-factory.com | Golf Courses * Number of Holes |
| USA | 870 | Wastewater Treatment Facilities | EPA PCIS | |
| USA | 880 | Drycleaners | 2000 US Census | |
| USA | 890 | Commercial Timber | ~1998 USFS FIA | |
| USA | 999 | Unpaved Roads | Custom based on state files | Unpaved road locations weighted by rural population |
| USA | 2001 | AVMT, WSDOT 2012, Interstates | WA WSDOT | |
| USA | 2002 | AVMT, WSDOT 2012, Freeways/expressways, arterials, collectors | WA WSDOT | |
| USA | 2003 | AVMT, WSDOT 2012, Local roads | WA WSDOT | |
| USA | 2004 | Not used | WA WSDOT | |
| USA | 2030 | AVMT, ITD and IDEQ 2011, Rural Interstate | ID ITD and IDEQ | |
| USA | 2031 | AVMT, ITD and IDEQ 2011, Rural Principal Arterial | ID ITD and IDEQ | |
| USA | 2032 | AVMT, ITD and IDEQ 2011, Rural Minor Arterial | ID ITD and IDEQ | |
| USA | 2033 | AVMT, ITD and IDEQ 2011, Rural Major Collector | ID ITD and IDEQ | |
| USA | 2034 | AVMT, ITD and IDEQ 2011, Rural Minor Collector | ID ITD and IDEQ | |
| USA | 2035 | AVMT, ITD and IDEQ 2011, Urban Interstate | ID ITD and IDEQ | |
| USA | 2036 | AVMT, ITD and IDEQ 2011, Urban Principal Arterial | ID ITD and IDEQ | |
| USA | 2037 | AVMT, ITD and IDEQ 2011, Urban Minor Arterial | ID ITD and IDEQ | |
| USA | 2038 | AVMT, ITD and IDEQ 2011, Urban Collector | ID ITD and IDEQ | |
| USA | 2039 | AVMT, COMPASS TDM and IDEQ 2011, Rural Interstate | ID COMPASS and IDEQ | |
| USA | 2040 | AVMT, COMPASS TDM and IDEQ 2011, Rural Principal Arterial | ID COMPASS and IDEQ | |
| USA | 2041 | AVMT, COMPASS TDM and IDEQ 2011, Rural Minor Arterial | ID COMPASS and IDEQ | |
| USA | 2042 | AVMT, COMPASS TDM and IDEQ 2011, Rural Collector | ID COMPASS and IDEQ | |
| USA | 2043 | AVMT, COMPASS TDM and IDEQ 2011, Rural Local | ID COMPASS and IDEQ | |
| USA | 2044 | AVMT, COMPASS TDM and IDEQ 2011, Urban Interstate | ID COMPASS and IDEQ | |
| USA | 2045 | AVMT, COMPASS TDM and IDEQ 2011, Urban Principal Arterial | ID COMPASS and IDEQ | |

| | | | |
|---|---|---|---|
| USA | 2046 | AVMT, COMPASS TDM and IDEQ 2011, Urban Minor Arterial | ID COMPASS and IDEQ |
| USA | 2047 | AVMT, COMPASS TDM and IDEQ 2011, Urban Collector | ID COMPASS and IDEQ |
| USA | 2048 | AVMT, COMPASS TDM and IDEQ 2011, Urban Local | ID COMPASS and IDEQ |
| USA | 2049 | ADVMT, SWRTC 2014, Rural Interstate | WA SWRTC |
| USA | 2050 | ADVMT, SWRTC 2014, Rural Principal Arterial | WA SWRTC |
| USA | 2051 | ADVMT, SWRTC 2014, Rural Minor Arterial | WA SWRTC |
| USA | 2052 | ADVMT, SWRTC 2014, Rural Major Collector | WA SWRTC |
| USA | 2053 | ADVMT, SWRTC 2014, Rural Minor Collector | WA SWRTC |
| USA | 2054 | ADVMT, SWRTC 2014, Rural Local Access | WA SWRTC |
| USA | 2055 | ADVMT, SWRTC 2014, Urban Interstate | WA SWRTC |
| USA | 2056 | ADVMT, SWRTC 2014, Urban Other Fwy/Exp, no links | WA SWRTC |
| USA | 2057 | ADVMT, SWRTC 2014, Urban Principal Arterial | WA SWRTC |
| USA | 2058 | ADVMT, SWRTC 2014, Urban Minor Arterial | WA SWRTC |
| USA | 2059 | ADVMT, SWRTC 2014, Urban Collector | WA SWRTC |
| USA | 2060 | ADVMT, SWRTC 2014, Urban Local Access | WA SWRTC |
| USA | 2061 | PeakHr VMT, TRPC 2009, Rural Interstate | WA TRPC |
| USA | 2062 | PeakHr VMT, TRPC 2009, Rural Principal Arterial | WA TRPC |
| USA | 2063 | PeakHr VMT, TRPC 2009, Rural Minor Arterial | WA TRPC |
| USA | 2064 | PeakHr VMT, TRPC 2009, Rural Major Collector | WA TRPC |
| USA | 2065 | PeakHr VMT, TRPC 2009, Rural Minor Collector | WA TRPC |
| USA | 2066 | PeakHr VMT, TRPC 2009, Rural Local Access | WA TRPC |
| USA | 2067 | PeakHr VMT, TRPC 2009, Urban Interstate | WA TRPC |
| USA | 2068 | PeakHr VMT, TRPC 2009, Urban Other Fwy/Exp, no links | WA TRPC |
| USA | 2069 | PeakHr VMT, TRPC 2009, Urban Principal Arterial | WA TRPC |
| USA | 2070 | PeakHr VMT, TRPC 2009, Urban Minor Arterial | WA TRPC |
| USA | 2071 | PeakHr VMT, TRPC 2009, Urban Collector | WA TRPC |
| USA | 2072 | PeakHr VMT, TRPC 2009, Urban Local Access | WA TRPC |
| USA | 2073 | ADVMT, SRTC 2010, Rural Interstate | WA SRTC |
| USA | 2074 | ADVMT, SRTC 2010, Rural Principal Arterial | WA SRTC |
| USA | 2075 | ADVMT, SRTC 2010, Rural Minor Arterial | WA SRTC |
| USA | 2076 | ADVMT, SRTC 2010, Rural Major Collector | WA SRTC |
| USA | 2077 | ADVMT, SRTC 2010, Rural Minor Collector | WA SRTC |
| USA | 2078 | ADVMT, SRTC 2010, Rural Local Access | WA SRTC |
| USA | 2079 | ADVMT, SRTC 2010, Urban Interstate | WA SRTC |
| USA | 2080 | ADVMT, SRTC 2010, Urban Other Fwy/Exp, no links | WA SRTC |
| USA | 2081 | ADVMT, SRTC 2010, Urban Principal Arterial | WA SRTC |
| USA | 2082 | ADVMT, SRTC 2010, Urban Minor Arterial | WA SRTC |
| USA | 2083 | ADVMT, SRTC 2010, Urban Collector | WA SRTC |
| USA | 2084 | ADVMT, SRTC 2010, Urban Local Access | WA SRTC |
| USA | 2085 | ADVMT, PSRC 2010, Rural Interstate | WA PSRC |
| USA | 2086 | ADVMT, PSRC 2010, Rural Principal Arterial | WA PSRC |
| USA | 2087 | ADVMT, PSRC 2010, Rural Minor Arterial | WA PSRC |
| USA | 2088 | ADVMT, PSRC 2010, Rural Major Collector | WA PSRC |
| USA | 2089 | ADVMT, PSRC 2010, Rural Minor Collector, no links | WA PSRC |
| USA | 2090 | ADVMT, PSRC 2010, Rural Local Access | WA PSRC |
| USA | 2091 | ADVMT, PSRC 2010, Urban Interstate | WA PSRC |
| USA | 2092 | ADVMT, PSRC 2010, Urban Other Fwy/Exp | WA PSRC |
| USA | 2093 | ADVMT, PSRC 2010, Urban Principal Arterial | WA PSRC |
| USA | 2094 | ADVMT, PSRC 2010, Urban Minor Arterial | WA PSRC |
| USA | 2095 | ADVMT, PSRC 2010, Urban Collector | WA PSRC |

| | | | | |
|---|---|---|---|---|
| USA | 2096 | ADVMT, PSRC 2010, Urban Local Access | WA PSRC | |
| USA | 2097 | ADVMT, METRO_OR 2002, Rural Freeways and Ramps | OR METRO | |
| USA | 2098 | ADVMT, METRO_OR 2002, Rural Arterials | OR METRO | |
| USA | 2099 | ADVMT, METRO_OR 2002, Rural Locals | OR METRO | |
| USA | 2100 | ADVMT, METRO_OR 2002, Urban Freeways and Ramps | OR METRO | |
| USA | 2101 | ADVMT, METRO_OR 2002, Urban Arterials | OR METRO | |
| USA | 2102 | ADVMT, METRO_OR 2002, Urban Locals | OR METRO | |
| USA | 2103 | ADVMT, METRO_OR 2002 and ODOT 2006 Rural Arterials | OR METRO and ODOT | |
| USA | 2200 | Unpaved road miles in WA, DNR 1994 data - NOT USED | WA DNR | |
| USA | 2201 | AVMT, WSDOT 2012, Total all roads | WA WSDOT | |
| USA | 2202 | ADVMT, ITD and IDEQ 2011, Total all roads | ID ITD and IDEQ | |
| USA | 2203 | ADVMT, COMPASS TDM and IDEQ 2011, Total all roads | ID COMPASS and IDEQ | |
| USA | 2204 | ADVMT, SWRTC 2014, Total all roads | WA SWRTC | |
| USA | 2205 | PeakHr VMT, TRPC 2009, Total all roads | WA TRPC | |
| USA | 2206 | ADVMT, SRTC 2010, Total all roads | WA SRTC | |
| USA | 2207 | ADVMT, PSRC 2010, Total all roads | WA PSRC | |
| USA | 2208 | ADVMT, METRO_OR 2002, Total all roads | OR METRO | |
| USA | 2209 | ADVMT, ODOT 2006, Total all roads | OR ODOT | |
| USA | 2210 | ADVMT, METRO_OR 2002 and ODOT 2006 | OR METRO and ODOT | |
| USA | 2711 | Railroad Density in million gross Ton-miles, Railroad Class 1 | EPA | |
| USA | 2712 | Railroad Density in million gross Ton-miles, Railroad Classes 2 and 3 | EPA | |
| USA | 8001 | Marine ports, CMV hoteling and manuevering, diesel | ECY, Starcrest, EPA | |
| USA | 8002 | Marine ports, CMV hoteling and manuevering, residual | ECY, Starcrest, EPA | |
| USA | 8003 | Marine ports, all CMV operations, gasoline | ECY, Starcrest, EPA | |
| USA | 8021 | Shipping lanes, CMV underway, diesel | ECY, Starcrest, EPA | |
| USA | 8022 | Shipping lanes, CMV underway, residual | ECY, Starcrest, EPA | |
| CAN | 100 | Population | 2006 Canada Census | DAPOP2006 |
| CAN | 101 | total dwelling | 2006 Canada Census | DATDWELL20 |
| CAN | 102 | urban dwelling | 2006 Canada Census | DAURDWELL2 |
| CAN | 103 | rural dwelling | 2006 Canada Census | DARDWELL20 |
| CAN | 104 | Total Employment | 2006 Canada Census | TOTAL_LABO |
| CAN | 106 | ALL_INDUST | 2006 Canada Census | ALL_INDUST |
| CAN | 107 | Total urban population from Census 2006 | 2006 Canada Census | UA_POP |
| CAN | 108 | Total rural population from Census 2006 | 2006 Canada Census | RA_POP |
| CAN | 111 | Farms | 2006 Canada Census | FARMS |
| CAN | 113 | Forestry and logging | 2006 Canada Census | FORLOG |
| CAN | 114 | Fishing hunting and trapping | 2006 Canada Census | FISHHUTRAP |
| CAN | 115 | Agriculture and forestry activities | 2006 Canada Census | OTHAGRFOR |
| CAN | 116 | Total Resources | 2006 Canada Census | TOTRESOURC |
| CAN | 200 | Road Miles of Urban Primary Roads | NRN_CA | Class1 |
| CAN | 202 | Road Miles of Rural Primary Roads | NRN_CA | Class2 |
| CAN | 204 | Road Miles of Urban Secondary Roads | NRN_CA | Class3 |
| CAN | 206 | Road Miles of Rural Secondary Roads | NRN_CA | Class4 |
| CAN | 211 | Oil and Gas Extraction | 2006 Canada Census | OILGASEXTR |
| CAN | 212 | Mining except oil and gas | 2006 Canada Census | MINING2 |
| CAN | 213 | Mining and Oil and Gas Extract activities | 2006 Canada Census | OTHMINOILG |
| CAN | 219 | Mining-unspecified | 2006 Canada Census | MININGUNSP |
| CAN | 221 | Total Mining | 2006 Canada Census | TOTALMI3 |
| CAN | 222 | Utilities | 2006 Canada Census | UTILITIES |

| | | | | |
|---|---|---|---|---|
| CAN | 231 | Construction except land subdivision and land development | 2006 Canada Census | CONSTRUCT |
| CAN | 232 | Land subdivision and land development | 2006 Canada Census | LNDDEV |
| CAN | 233 | Total Land Development | 2006 Canada Census | TOTLND |
| CAN | 308 | Food manufacturing | 2006 Canada Census | FOODMANU |
| CAN | 309 | Beverage and tobacco product manufacturing | 2006 Canada Census | BEVTABMANU |
| CAN | 313 | Textile mills | 2006 Canada Census | TEXTILMILL |
| CAN | 314 | Textile product mills | 2006 Canada Census | TEXTILPROD |
| CAN | 315 | Clothing manufacturing | 2006 Canada Census | CLOTHMANU |
| CAN | 316 | Leather and allied product manufacturing | 2006 Canada Census | LEATHRMANU |
| CAN | 321 | Wood product manufacturing | 2006 Canada Census | WOODMANU |
| CAN | 322 | Paper manufacturing | 2006 Canada Census | PAPERMANU |
| CAN | 323 | Printing and related support activities | 2006 Canada Census | PRINTSUPRT |
| CAN | 324 | Petroleum and coal products manufacturing | 2006 Canada Census | PETCOLMANU |
| CAN | 325 | Chemical manufacturing | 2006 Canada Census | CHEMMANU |
| CAN | 326 | Plastics and rubber products manufacturing | 2006 Canada Census | PLASTCMANU |
| CAN | 327 | Non-metallic mineral product manufacturing | 2006 Canada Census | MINERLMANU |
| CAN | 331 | Primary Metal Manufacturing | 2006 Canada Census | METALMANU |
| CAN | 332 | Fabricated metal product manufacturing | 2006 Canada Census | FABMETMANU |
| CAN | 333 | Machinery manufacturing | 2006 Canada Census | MACHMANU |
| CAN | 334 | Computer and Electronic manufacturing | 2006 Canada Census | COMPUMANU |
| CAN | 335 | Electrical equipment appliance and component manufacturing | 2006 Canada Census | ELECTMANU |
| CAN | 336 | Transportation equipment manufacturing | 2006 Canada Census | TRANSPMANU |
| CAN | 337 | Furniture and related product manufacturing | 2006 Canada Census | FURNITMANU |
| CAN | 338 | Miscellaneous manufacturing | 2006 Canada Census | MISCMANU |
| CAN | 339 | Total Manufacturing | 2006 Canada Census | TOTMANU |
| CAN | 411 | Farm product wholesaler-distributors | 2006 Canada Census | FRMPRWSL |
| CAN | 412 | Petroleum product wholesaler-distributors | 2006 Canada Census | PETPRWSL |
| CAN | 413 | Food beverage and tobacco wholesaler-distributors | 2006 Canada Census | FBTPRWSL |
| CAN | 414 | Personal and household goods wholesaler-distributors | 2006 Canada Census | PERPRWSL |
| CAN | 415 | Motor vehicle and parts wholesaler-distributors | 2006 Canada Census | CARPRWSL |
| CAN | 416 | Building material and supplies wholesaler-distributors | 2006 Canada Census | BUILDPRWSL |
| CAN | 417 | Machinery equipment and supplies wholesaler-distributors | 2006 Canada Census | MACHPRWSL |
| CAN | 418 | Miscellaneous wholesaler-distributors | 2006 Canada Census | MISCPRWSL |
| CAN | 419 | Wholesale agents and brokers | 2006 Canada Census | WSLAGNT |
| CAN | 420 | Total Wholesale | 2006 Canada Census | TOTWSL |
| CAN | 441 | Motor vehicle and parts dealers | 2006 Canada Census | CARDEALER |
| CAN | 442 | Furniture and home furnishings stores | 2006 Canada Census | FURNITSTOR |
| CAN | 443 | Electronics and appliance stores | 2006 Canada Census | ELECTSTOR |
| CAN | 444 | Building material and garden equipment and supplies dealers | 2006 Canada Census | BUILDEALER |
| CAN | 445 | Food and beverage stores | 2006 Canada Census | FDBVDEALER |
| CAN | 446 | Health and personal care stores | 2006 Canada Census | HEALTHSTOR |
| CAN | 447 | Gasoline stations | 2006 Canada Census | GASSTOR |
| CAN | 448 | clothing and clothing accessories stores | 2006 Canada Census | CLOTHSTOR |
| CAN | 451 | Sporting goods hobby book and music stores | 2006 Canada Census | SPORTSTOR |
| CAN | 452 | General Merchandise stores | 2006 Canada Census | GENERSTOR |
| CAN | 453 | Miscellaneous store retailers | 2006 Canada Census | MISCSTOR |
| CAN | 454 | Non-store retailers | 2006 Canada Census | NONSTOR |
| CAN | 455 | Total Retail | 2006 Canada Census | TOTSTOR |
| CAN | 481 | Air transportation | 2006 Canada Census | AIRTRANS |
| CAN | 482 | Rail transportation | 2006 Canada Census | RAILTRANS |

| | | | | |
|---|---|---|---|---|
| CAN | 483 | Water Transportation | 2006 Canada Census | WATERTRANS |
| CAN | 484 | Truck transportation | 2006 Canada Census | TRCKTRANS |
| CAN | 485 | Transit and ground passenger transportation | 2006 Canada Census | PASSTRANS |
| CAN | 486 | Pipeline transportation | 2006 Canada Census | PIPETRANS |
| CAN | 487 | Scenic and sightseeing transportation | 2006 Canada Census | TOURTRANS |
| CAN | 488 | Support activities for transportation | 2006 Canada Census | SUPRTTRANS |
| CAN | 491 | Postal service | 2006 Canada Census | POSTAL |
| CAN | 492 | Couriers and messengers | 2006 Canada Census | COURIER |
| CAN | 493 | Warehousing and storage | 2006 Canada Census | STORAGE |
| CAN | 494 | Total Tranpsort and warehouse | 2006 Canada Census | TOTTRWH |
| CAN | 511 | Publishing and information services | 2006 Canada Census | PUBLISHSER |
| CAN | 512 | Motion picture and sound recording industries | 2006 Canada Census | MOVIEINDUS |
| CAN | 513 | Broadcasting and telecommunications | 2006 Canada Census | BROADCAST |
| CAN | 514 | Data processing services | 2006 Canada Census | DATASERV |
| CAN | 516 | Total Info and culture | 2006 Canada Census | TOTINFO |
| CAN | 521 | Monetary authorities - central bank | 2006 Canada Census | BANKS |
| CAN | 522 | Credit intermediation and related activities | 2006 Canada Census | CREDITSERV |
| CAN | 523 | Securities commodity contracts and other financial | 2006 Canada Census | SECURITIES |
| CAN | 524 | Insurance carriers and related activities | 2006 Canada Census | INSURANCE |
| CAN | 526 | Funds and other financial vehicles | 2006 Canada Census | MUTALFUNDS |
| CAN | 528 | Total Banks | 2006 Canada Census | TOTBANK |
| CAN | 531 | Real estate | 2006 Canada Census | REALESTATE |
| CAN | 532 | Rental and leasing services | 2006 Canada Census | RENTALSERV |
| CAN | 533 | Lessors of non-financial intangible assets (except copyrighted) | 2006 Canada Census | LESSORS |
| CAN | 534 | Total Realestate | 2006 Canada Census | TOTREAL |
| CAN | 541 | Professional scientific and technical services | 2006 Canada Census | PROFECTEC |
| CAN | 551 | Management of companies and enterprises | 2006 Canada Census | MANAGEMENT |
| CAN | 561 | Administrative and support services | 2006 Canada Census | ADMINSERV |
| CAN | 562 | Waste management and remediation services | 2006 Canada Census | WASTEMGMT |
| CAN | 611 | Education Services | 2006 Canada Census | EDUSERV |
| CAN | 621 | Ambulatory health care services | 2006 Canada Census | AMBUSERV |
| CAN | 622 | Hospitals | 2006 Canada Census | HOSPITALS |
| CAN | 623 | Nursing and residential care facilities (6231 to 6239) | 2006 Canada Census | NURSEFAC |
| CAN | 624 | Social assistance | 2006 Canada Census | SOCIALASS |
| CAN | 625 | Total Service | 2006 Canada Census | TOTSERV |
| CAN | 711 | Performing arts spectator sports and related industries | 2006 Canada Census | ARTINDUST |
| CAN | 712 | Heritage institutions | 2006 Canada Census | HERITAGE |
| CAN | 713 | Amusement gambling and recreation industries | 2006 Canada Census | RECINDUST |
| CAN | 721 | Accommodation services | 2006 Canada Census | ACCOMSERV |
| CAN | 722 | Food services and drinking places | 2006 Canada Census | RESTBARS |
| CAN | 723 | Total Tourism | 2006 Canada Census | TOTTOUR |
| CAN | 811 | Repair and maintenance | 2006 Canada Census | REPAIRMAIN |
| CAN | 812 | Personal and laundry services | 2006 Canada Census | PERSERV |
| CAN | 813 | Religious grant-making civic and professional and similar | 2006 Canada Census | RELIGUSERV |
| CAN | 814 | Private households | 2006 Canada Census | PRIVATHOUS |
| CAN | 815 | Total other services | 2006 Canada Census | TOTOSERV |
| CAN | 902 | military LTO | Airport_movements_2006 | SCC2275001 |
| CAN | 903 | Commercial LTO | Airport_movements_2006 | SCC2275020 |
| CAN | 904 | General Aviation LTO | Airport_movements_2006 | SCC2275050 |
| CAN | 905 | Air Taxi LTO | Airport_movements_2006 | SCC2275060 |
| CAN | 911 | Federal government public administration | 2006 Canada Census | FGOVADMIN |

| | | | | |
|---|---|---|---|---|
| CAN | 912 | Provincial and territorial public administration (9121 to 9129) | 2006 Canada Census | PGOVADMIN |
| CAN | 913 | Local municipal and regional public administration (9131 to 9139) | 2006 Canada Census | LMGOVADMIN |
| CAN | 914 | Aboriginal public administration | 2006 Canada Census | ABADMIN |
| CAN | 919 | International and other extra-territorial public administration | 2006 Canada Census | INTERADMIN |
| CAN | 920 | Total Government | 2006 Canada Census | TOTGOV |
| CAN | 921 | Commercial Fuel Combustion | 2006 Canada Census | COMFUEL |
| CAN | 922 | TOTAL DISTRIBUTION AND RETAIL | 2006 Canada Census | TOTDISRET |
| CAN | 923 | TOTAL INSTITUTIONAL AND GOVERNEMNT | 2006 Canada Census | TOTINSTGOV |
| CAN | 924 | Primary Industry | 2006 Canada Census | PRIMARY |
| CAN | 925 | Manufacturing and Assembly | 2006 Canada Census | MANASSEM |
| CAN | 926 | Distribtution and Retail (no petroleum) | 2006 Canada Census | DISRET |
| CAN | 927 | Commercial Services | 2006 Canada Census | COMSER |
| CAN | 928 | Commercial Meat cooking | 2006 Canada Census | COMCOOK |
| CAN | 932 | Railroads | CANRAIL | |
| CAN | 941 | Paved roads | paved4 | |
| CAN | 942 | Non paved roads | unpaved4 | |
| CAN | 945 | Commercial Marine Vessels | marine | SO2 |
| CAN | 948 | Forest | treesa | |
| CAN | 950 | Intersection of Forest and Housing | pop_trees_itsct3 | WOOD2 |
| CAN | 955 | Non paved roads and trails | unpaved5 | NONE |
| CAN | 960 | TOTBEEF | naesi_livestk | TOTBEEF |
| CAN | 965 | TOTBEEF | naesi_livestk | TOTBEEF |
| CAN | 966 | TOTPOUL | naesi_livestk | TOTPOULT |
| CAN | 967 | TOTSWIN | naesi_livestk | TOTSWINE |
| CAN | 968 | TOTFERT | naesi_fert | TOTFERT |
| CAN | 970 | TOTPOUL | naesi_livestk | TOTPOULT |
| CAN | 980 | TOTSWIN | naesi_livestk | TOTSWINE |
| CAN | 990 | TOTFERT | naesi_fert | TOTFERT |
| CAN | 996 | urban area 2001 | ua2001 | |

## References


1 2010 Census Redistricting Data (Public Law 94-171) Summary File, Technical Documentation/prepared by the U.S. Census Bureau, 2011. Census block information available from ftp website: http://www2.census.gov/census_2010/01-Redistricting_File--PL_94-171/. Files ss201.pl.zip (where ss = state abbreviation).

2 2012 American Community Survey 5-yr average. U.S. Census Bureau. http://www2.census.gov/acs2012_5yr/summaryfile/.

3 Multi-resolution Land Characteristics, National Land Cover Database. United States Geologic Survey. 2006, 30 m resolution.

4 Idaho Transportation Dept. data provided by Wei Zhang and Sara Strachan, Idaho Dept. of Environmental Quality. Aug 2014.

5 Community Planning Association of Southwest Idaho (COMPASS) data provided by Wei Zhang and Sara Strachan, Idaho Dept. of Environmental Quality. Shapefile *ROUNDED_b2014xy*. Aug. 2014.

6 Oregon Dept. of Transportation data provided by Jeffrey Stocum, Oregon Dept. of Environmental Quality. June 2008.

7 Portland METRO data provided by Jeffrey Stocum, Oregon Dept. of Environmental Quality. *PortlandMETROLinkData4Airpact.accdb*. May 2008.

8 Washington State Dept. of Transportation. http://www.wsdot.wa.gov/mapsdata/geodatacatalog/*. Shapefiles *TrafficSections2012, FunctionalClassSR, FunctionalClass_NonSR*.

9 Puget Sound Regional Council data provided by Rebecca King. *2010vmt_coordinates.xlsx*. Sept. 2014.

10 Spokane Regional Transportation Council data provided by Anna Ragaza-Bourassa. Shapefile *SRTC 2010 Base Model Final 040213_link*. Oct. 2013.

11 Southwest Regional Transportation Council data provided by Mark Harrington. *DOE_ClarkCo_VMT_140114.accdb*. Jan. 2014.

12 Thurston Regional Planning Council data provided by Clyde Scott. *PM_Peak_Hour_VMT_FT.xlsx* and shapefiles *emme_links.shp, emme_nodes.shp*. June 2014.

13 Railroad track shapefile and rail density information: *railway_20110921.zip and cmv_rail_shape cntyfractions.zip* (http://www.epa.gov/ttn/chief/net/2011inventory.html). Environmental Protection Agency.

14 Port and shipping lane shapefiles *2011_ports_shapefile* and *shippinglanes_112812_shapefile* (http://www.epa.gov/ttn/chief/net/2011inventory.html). NEI version 1 county emissions of NOx, SO2, and PM2.5 (ftp://ftp.epa.gov/EmisInventory/2011v6/flat_files/nonpoint/SmokeFlatFile_NONPOINT_20130911.csv.zip).

15 *Estimation, Validation, and Forecasts of Regional Commercial Marine Vessel Inventories*. Final Report. Submitted by James J. Corbett, P.E., Ph.D. and Jeremy Firestone, University of Delaware. Coauthored by Chengfeng Wang, Ph.D., California ARB. ARB Contract Number 04-346 and CEC Contract Number 113.111. Prepared for the California Air Resources Board and the California Environmental Protection Agency and for the Commission for Environmental Cooperation in North America. April 5, 2007

16 *North American Commercial Marine Vessel Emissions Inventory*. Prepared for State of California Air Resources Board, Research Division, PO Box 2815, Sacramento, CA 95812 and for the Commission for Environmental Cooperation in North America. Prepared by James J. Corbett, P.E., Ph.D and Chengfeng Wang, Ph.D. University of Delaware, College of Marine Studies, Newark, DE 19716-3501. (302) 831-0768. February 10, 2006.

17 *Estimation, Validation, and Forecasts of Regional Commercial Marine Vessel Inventories*. Tasks 3 and 4: Forecast Inventories for 2010 and 2020. Final Report. Submitted by James J. Corbett, P.E., Ph.D., University of Delaware. Coauthored by Chengfeng Wang, Ph.D., California ARB. ARB Contract Number 04-346. Prepared for the California Air Resources Board and the California Environmental Protection Agency. December 8, 2006.

18 Email from Guorong Liu, Washington State Department of Transportation to Sally Otterson, Washington State Department of Ecology. Transmitting spreadsheets with monthly, day-of-week, and hourly adjustment factors. monthfac_all.xls, dowfac_all.xls, hourfac_all.xls. Sept. 5, 2006.

# Appendix B. Memorandum: Methods and Results for Preparation of the Wildland Fire Emissions Inventory for the AIRPACT5 Domain from July through September 2013

Sonoma Technology, Inc.
Innovative Environmental Solutions

# Technical Memorandum

May 24, 2017 STI-917019-6741-TM

To: Rick Hardy, Idaho Department of Environmental Quality

From: Nathan Pavlovic and ShihMing Huang

**Re: Methods and Results for Preparation of the Wildland Fire Emissions Inventory for the AIRPACT5 domain from July through September 2013**

This work was done via Contract No. K167 with the Idaho Department of Environmental Quality (IDEQ). This technical memorandum describes the methods used to develop the AIRPACT WLFEI, which is the wildland fire emissions inventory for July through September 2013 for the AIRPACT5 modeling domain, in support of IDEQ's 2013 ozone modeling study. The methods used here are identical to those employed to create the U.S. EPA's 2014 Wildland Fire National Emissions Inventory (Huang et al., 2016), with two exceptions: (1) some fire activity data sources used in 2014 could not be used in this inventory, and (2) emissions were calculated for fires in the Canadian portion of the AIRPACT5 modeling domain for this inventory.

## Technical Approach

### Spatial and Temporal Domain

Emissions data were prepared for July through September 2013 for the AIRPACT5 modeling domain (**Figure 1**). The domain includes all of Idaho, Oregon, and Washington, portions of California, Montana, Nevada, Utah, and Wyoming, and portions of the Canadian provinces of Alberta, British Columbia, and Saskatchewan.


**Figure 1**. The AIRPACT5 modeling domain was used to constrain the area for which emissions were provided for the 2013 AIRPACT WLFEI. The domain boundary is shown in blue.

## Data Sources

The following data sets were used to develop the 2013 AIRPACT WLFEI:

- Fire activity inputs to SmartFire2
  - *Hazard Mapping System (HMS)* data were acquired from the National Oceanic and Atmospheric Administration (NOAA).
  - *ICS-209 Reports* in application (.exe) format[1] were acquired from the National Fire and Aviation Management Web Applications website. Upon execution, the application file created a Microsoft Access database containing the fire activity data. Data from the IMSR_IMSR_209_INCIDENTS_T table were used.

[1] http://fam.nwcg.gov/fam-web/sit/sit_2013.exe

  - *National Association of State Foresters (NASF)* fire information data were downloaded from the National Fire and Aviation Management Web Applications website.[2]
  - *Forest Service Activity Tracking System (FACTS)* fire information data were downloaded from the United States Forest Service (USFS) FSGeodata Clearinghouse website.[3]
  - *Geospatial Multi-Agency Coordination (GeoMAC) group* fire perimeter data were downloaded via the USGS GeoMAC wildland fire support website.[4]
  - *U.S. Department of the Interior (DOI)* wildland fire data were provided by the DOI Office of Wildland Fire (OWF).
  - *Fire Emissions Tracking System (FETS)* wildland fire information was obtained from the Western Regional Air Partnership (WRAP) through IDEQ. The FETS dataset included fire activity for five states: Idaho, Montana, Oregon, Washington, and Wyoming.
  - *U.S. Fish and Wildlife Service (FWS)* fire information data were requested from the FWS but could not be obtained. In other years, the data available from this source have been very sparse in the AIRPACT5 domain.

- Fuel moistures – Fire weather observation files (fdr_obs.dat) were acquired for each analysis day from the USFS archive.[5] Files were downloaded and used as inputs to the Fuel_Moisture_WIMS module in the BlueSky Framework (Du et al., 2013).
- Fuel loading – The Fuel Characteristic Classification System (FCCS) 1-km fuels shapefile and lookup table for the contiguous United States were provided by the USFS AirFire Team. The Alaskan FCCS 1-km fuels shapefile and lookup table were acquired from the USFS Fire and Environmental Research Applications Team's website.[6]
- Cropland Data Layer (CDL) – The CDL raster data set of crop-specific land cover data was obtained from the United States Department of Agriculture (USDA) National Agricultural Statistics Service website.[7] Downloaded data were used to identify agricultural fires from satellite detections in the United States.
- North American Land Change Monitoring System (NALCMS) 2010 Land Cover Data – The NALCMS land cover data were obtained from the Commission for Environmental Cooperation website.[8] Downloaded data were used to identify agricultural fires from satellite detections in Canada and to support calculation of volatile organic compound (VOC) and hazardous air pollutant (HAPs) emissions for Canadian fires.

[2] https://fam.nwcg.gov/fam-web/
[3] https://data.fs.usda.gov/geodata/edw/datasets.php
[4] http://rmgsc.cr.usgs.gov/outgoing/GeoMAC/
[5] http://www.wfas.net/archive/www.fs.fed.us/land/wfas/archive/
[6] http://www.fs.fed.us/pnw/fera/fccs/maps.shtml
[7] https://www.nass.usda.gov/Research_and_Science/Cropland/Release/
[8] http://www.cec.org/tools-and-resources/map-files/land-cover-2010

## Preparation of Fire Activity Data

SmartFire2 was used to process and reconcile fire activity data following the methods in Pollard et al. (2011). All fire activity data sets were reconciled using a single SmartFire reconciliation stream. For the 2013 AIRPACT WLFEI produced with SmartFire2, several steps were taken to quality-control the data and confirm that the algorithms and data sets incorporated into SmartFire2 worked appropriately.

***Before Running SmartFire2***

- We reviewed input data sets to identify data gaps.
- We identified fire incidents that appeared to be double-counted in individual data sets and removed duplicate records.
- We examined fires with long durations or conflicts between start date and report date to identify fires that may have erroneous start dates. Start dates later than report dates were replaced with the report dates.
- We reviewed fire locations to ensure that they fell within the United States or the portion of the AIRPACT domain covering Canada. Obvious errors in data entry such as the reversal of latitude and longitude were corrected where possible.
- We reviewed large and small fires in each data set for validity.
- We modified distant fires (in different states) with the same names to ensure that the events were not associated.
- We removed agricultural and pile burns from input data sets based on ground reports.

***After Running SmartFire2***

- We checked the location, fire type, duration, underlying fire activity input data, final shape, and final size for large fire events (i.e., area burned > 20,000 acres) to ensure that the results were reasonable. InciWeb and media reports were used to corroborate SmartFire2 output data in selected cases.
- We visually reviewed data for spatial errors.
- We ran self-intersections to identify overlaps between fire events and removed identified duplicates.
- We produced and reviewed summary statistics, tables, and plots of the 2013 fire inventory data.

After data reconciliation, SmartFire2 data were exported for the entire year. The data were reviewed for quality as described above, including the removal of agricultural fires. In the United States, fires that were reported by the HMS system only and that fell in crop cover type in the CDL land cover data set were identified as agricultural fires. In Canada, fires that fell in the NALCMS cropland land cover type were identified as agricultural fires. The location, date, and estimated size of agricultural fires were saved to a separate file and delivered to IDEQ separately from other fires. For non-agricultural fires, daily input files were generated for emissions calculation through the BlueSky Framework.

## Emissions Modeling

The BlueSky Framework provides several choices of models at each step of the smoke emissions modeling process. The model chain used for the contiguous United States, where FCCS fuel loading data are available, is summarized in **Table 1**. Consume 3.0 was used to calculate fuel consumption by the flaming, smoldering, and residual phases.[9] The Fire Emission Production Simulator (FEPS) module was customized for the BlueSky Framework to calculate HAP emissions for 34 pollutants (U.S. Environmental Protection Agency, 2016). The default method used by FEPS to calculate emission factors for $CO_2$, CO, $CH_4$, $PM_{2.5}$, $PM_{10}$, $NO_x$, $SO_2$, and $NH_3$ was used without modification. These emission factors are calculated based on combustion efficiency, which is the ratio of flaming to smoldering consumption (calculated by Consume). A fire with 100% flaming consumption is modeled with a combustion efficiency of 90%, while a 100% smoldering fire has a combustion efficiency of 76%. **Table 2** shows the range of possible effective emission factors for these species. Region-specific emission factors for HAPs, which do not vary with combustion efficiency, were provided by EPA. For several HAPs, emission factors are specific to flaming and smoldering combustion phases. The $PM_{2.5}$ emissions calculated by FEPS were post-processed to speciate elemental carbon, organic carbon, $SO_4$, $NO_3$, and $PM_{fine}$ using speciation factors provided by EPA.

**Table 1.** Model chain for the contiguous United States portion of the 2013 AIRPACT WLFEI development.

| Data Type | Model Used | Version Information |
|---|---|---|
| Fire activity data | SmartFire2 | Version 2.0, Build 42022 |
| Fuel moisture | Fuel_Moisture_WIMS v1 | As implemented in BlueSky Framework 3.5.1, revision 47693 |
| Fuel loading | FCCS v2 | |
| Fuel consumption | Consume v4.1 | |
| Emissions | Fire Emission Production Simulator v2 | |

[9] https://www.fs.fed.us/pnw/fera/research/smoke/consume/consume30_users_guide.pdf

**Table 2.** Theoretical effective emission factors (g/kg biomass consumed) calculated by FEPS for hypothetical fires with 100% flaming or 100% smoldering consumption.

| Species | 100% Flaming | 100% Smoldering |
|---|---|---|
| $CO_2$ | 1,650 | 1,390 |
| CO | 72 | 210 |
| $CH_4$ | 3.82 | 9.87 |
| $PM_{2.5}$ | 7.28 | 16.6 |
| $PM_{10}$ | 8.59 | 19.6 |
| $NO_x$ | 2.42 | 0.91 |
| $SO_2$ | 0.98 | 0.98 |
| $NH_3$ | 1.21 | 3.41 |
| VOC | 17.3 | 49.0 |

A different model chain was used for fires in Canada, as summarized in **Table 3**, because FCCS data are not available in these regions. The Fire Inventory from the National Center for Atmospheric Research (NCAR) (FINN) version 1 is capable of producing global emissions estimates for wildland fires and was therefore used to develop the emissions for Canada. FINN uses satellite-derived land cover data, along with estimated fuel loadings and emission factors, to model smoke emissions (Wiedinmyer et al., 2011). However, the emission factors of VOCs and HAPs are not available in FINN.

Emission estimates of VOCs and HAPs from wildland fires in Canada were based on carbon dioxide ($CO_2$) outputs from FINN. The average ratios of VOCs and HAPs to $CO_2$ for wildland fires in each land cover type available in the NALCMS land cover data set were calculated for the contiguous United States and applied to the $CO_2$ emissions of Canada fires to estimate VOC and HAP emissions. Heat emissions are not calculated in the FINN pathway. We calculated the heat release using the default heat content of 8,000 BTU per pound of fuel consumed.[10]

**Table 3.** Model chain for the Canada portion of the 2013 AIRPACT WLFEI development.

| Data Type | Model Used | Version Information |
|---|---|---|
| Fire activity data | SmartFire2 | Version 2.0, Build 42022 |
| Fuel loading | FINN v1 | As implemented in BlueSky Framework 3.5.1, revision 47693 |
| Fuel consumption | FINN v1 | |
| Emissions | FINN v1 | |

[10] SMOKE v4.5 uses the same default calculation. See page 168 of the SMOKE v4.5 documentation: https://www.cmascenter.org/smoke/documentation/4.5/manual_smokev45.pdf.

**Emissions Processing**

The following steps were applied to process fire activity data and estimate emissions for fires in the United States:

1. *Create BlueSky input file* – The daily input files for the BlueSky Framework (fire_locations_yyyymmdd.csv) were created from quality-controlled SmartFire2 output files and saved to the BlueSky Framework input directory. A summary file of fire events was also exported from SmartFire2 to provide the information on the data source for each event.
2. *Process through BlueSky Framework* – The BlueSky Framework is currently designed to process one day at a time. A shell script was used to process emissions one year at a time. The resulting files are daily BlueSky outputs.
3. *Process BlueSky outputs* – The BlueSky Framework produces three output files for each day. This project requires fire_locations_nei_yyyymmdd.csv, which contains the same data as the input file with additional calculated fields (fuel loadings, fuel consumptions, and emissions) appended to each fire record. The 2013 files include three data records per daily fire location to present emissions from flaming and smoldering combustion phases in addition to total emissions. The daily files were concatenated into a single file using a Python script.
4. *Post-process emissions* – There is a known issue in the Consume model: the algorithm does not behave properly for prescribed burns in areas with large duff depths. In such a case, Consume will overestimate the duff consumptions, resulting in considerably high emissions. A post-processing procedure was applied to each prescribed fire to scale down phase-specific consumptions and daily total emissions. The scaling factor for each prescribed fire was derived according to its location and duff consumption. This step-by-step process was followed:
   i. New duff consumption of each prescribed burn was re-calculated by setting a “cap” value for the duff consumption. For fires in the United States, the duff consumption cap was set to 20 tons per acre. This cap was developed in consultation with USFS and U.S. Department of Interior experts. For each fire, the exceedance in duff consumption was calculated by subtracting capped duff consumption from the original duff consumption.
   ii. The new total consumption of each prescribed burn was calculated by removing the exceedance in duff consumption from the original total consumption.
   iii. The scaling factor for each prescribed burn was calculated as the ratio of the new total consumption over the original total consumption.
   iv. Finally, the burn-specific scaling factor was applied to phase-specific consumption (flaming, smoldering, and residual) and daily emissions of all pollutants to compute new fuel consumption and emissions.
5. *Prepare wildland fire emissions inventory data* – The merged file of fire emissions was separated into daily fire location csv files for each state or province. In addition, these

files were processed using an R script to obtain the SMOKE FF10 daily and annual files for each state.

Emissions processing Steps 1 to 4 were omitted for Canada wildland fires because the model chain used in the BlueSky Framework was different. FINN does not require fuel moisture data, nor does it need daily fire activity input files. The activity data of fires in Canada were input into the BlueSky Framework in one single file and the output file, fire_locations.csv, contained the fuel consumptions and emissions data for all fires in the input file. The outputs were post-processed to estimate VOC and HAP emissions as described previously in the Emissions Modeling section, appended to the merged file of fire emissions, and finalized for this emissions inventory using Step 5.

## Summary of 2013 Wildland Fire Emissions Inventory (AIRPACT WLFEI)

We estimated that wildland fires occurring between July and September 2013 burned about 1.6 million acres in the AIRPACT5 domain and emitted over 240,000 tons of $PM_{2.5}$ (**Table 4**). These figures include all portions of fires that burned between July and September 2013, including area burned and emissions that occurred before or after the time period of interest. The areas burned by wild and prescribed fires are 1.6 million (97%) and 55,000 (3%) acres, respectively. Wildfire $PM_{2.5}$ emissions account for 97% and prescribed burns $PM_{2.5}$ emissions account for 3% of the total emissions in this inventory.

**Table 4.** Total area burned and total emissions of $PM_{2.5}$, CO, $SO_2$, $NO_X$, and VOCs for Idaho, Oregon, Washington, and the remainder of the AIRPACT5 domain. Totals are rounded to the nearest 100 acres or tons.

| | Total Area (Acres) | Total $PM_{2.5}$ (Tons) | Total CO (Tons) | Total $SO_2$ (Tons) | Total $NO_X$ (Tons) | Total VOC (Tons) |
|---|---|---|---|---|---|---|
| Idaho | 789,300 | 103,000 | 1,211,100 | 8,500 | 14,600 | 285,200 |
| Oregon | 356,900 | 50,900 | 587,000 | 4,500 | 8,400 | 138,600 |
| Washington | 171,200 | 16,600 | 194,100 | 1,400 | 2,500 | 45,800 |
| Remainder of Domain | 319,400 | 73,000 | 856,000 | 6,000 | 10,400 | 201,000 |
| Total | 1,636,700 | 243,500 | 2,848,100 | 20,400 | 35,900 | 670,600 |

In the 2013 AIRPACT WLFEI, emissions are distributed across the AIRPACT5 domain, with significant concentrations of emissions in central Idaho, southwestern Oregon, and northern California (**Figure 2**). **Figure 3** depicts the total monthly $PM_{2.5}$ emissions for each state or Canadian province for fires occurring in July through September 2013. Fire emissions were generally highest in each state during August 2013, though emissions were higher during July in Washington and during September in British Columbia. **Figure 4** depicts the area burned per square mile by county for wildland fires in AIRPACT WLFEI.

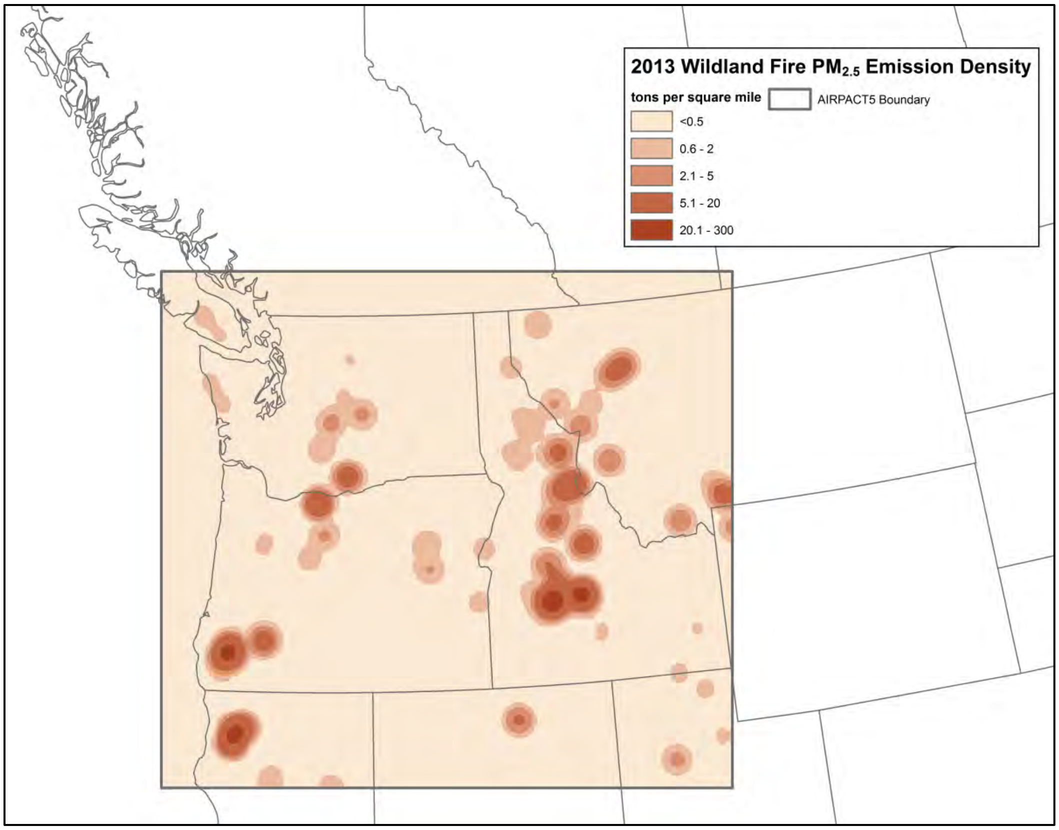



**Figure 2.** Wildland fire $PM_{2.5}$ emission density in the 2013 AIRPACT WLFEI.

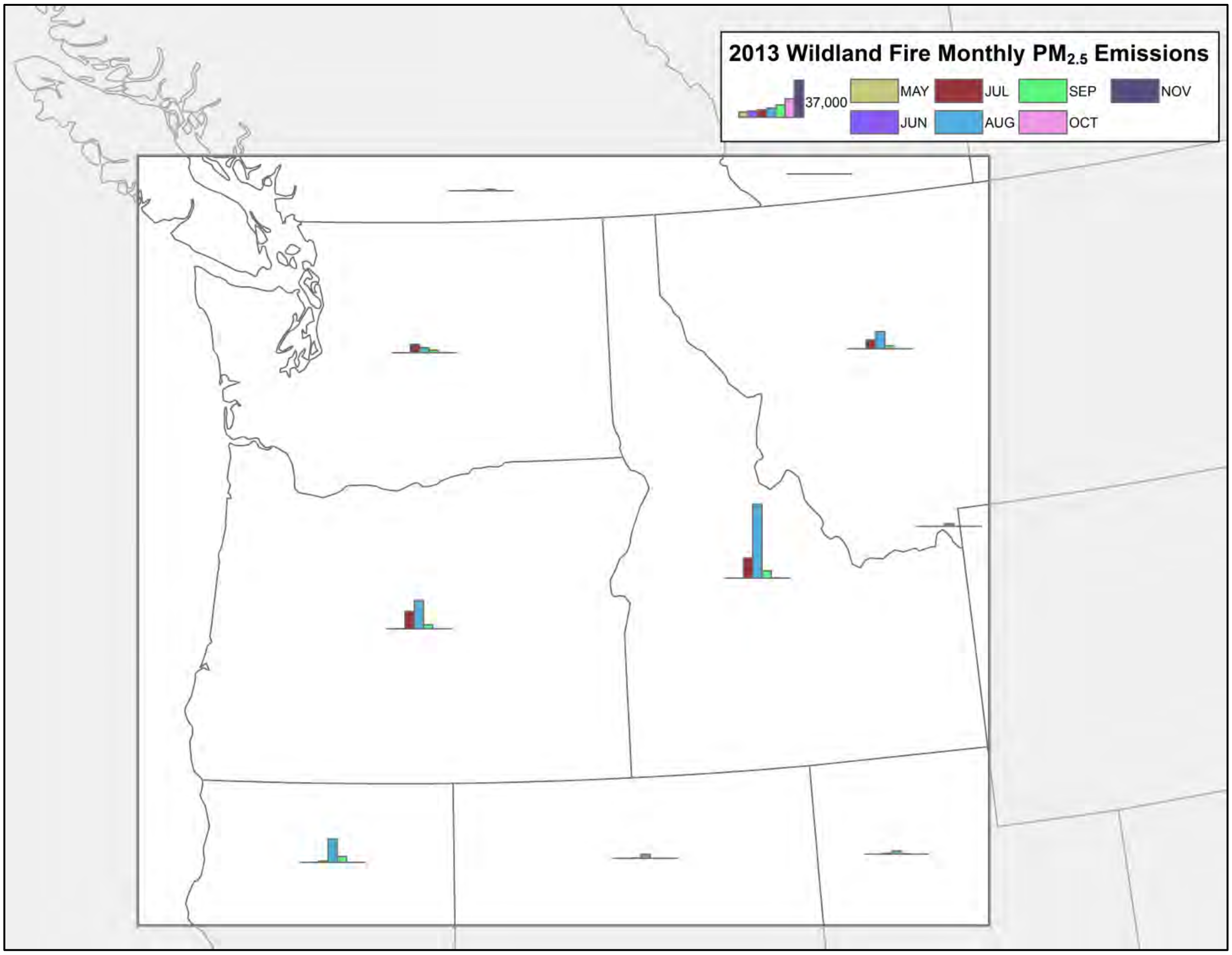



**Figure 3.** Total monthly $PM_{2.5}$ emissions (tons) from wildland fires by state or Canadian province, in the 2013 AIRPACT WLFEI. Data shown represent emissions from fires occurring in the AIRPACT5 domain only. Emissions outside of July through September were released by fire events where some portion burned during the July through September period of interest.

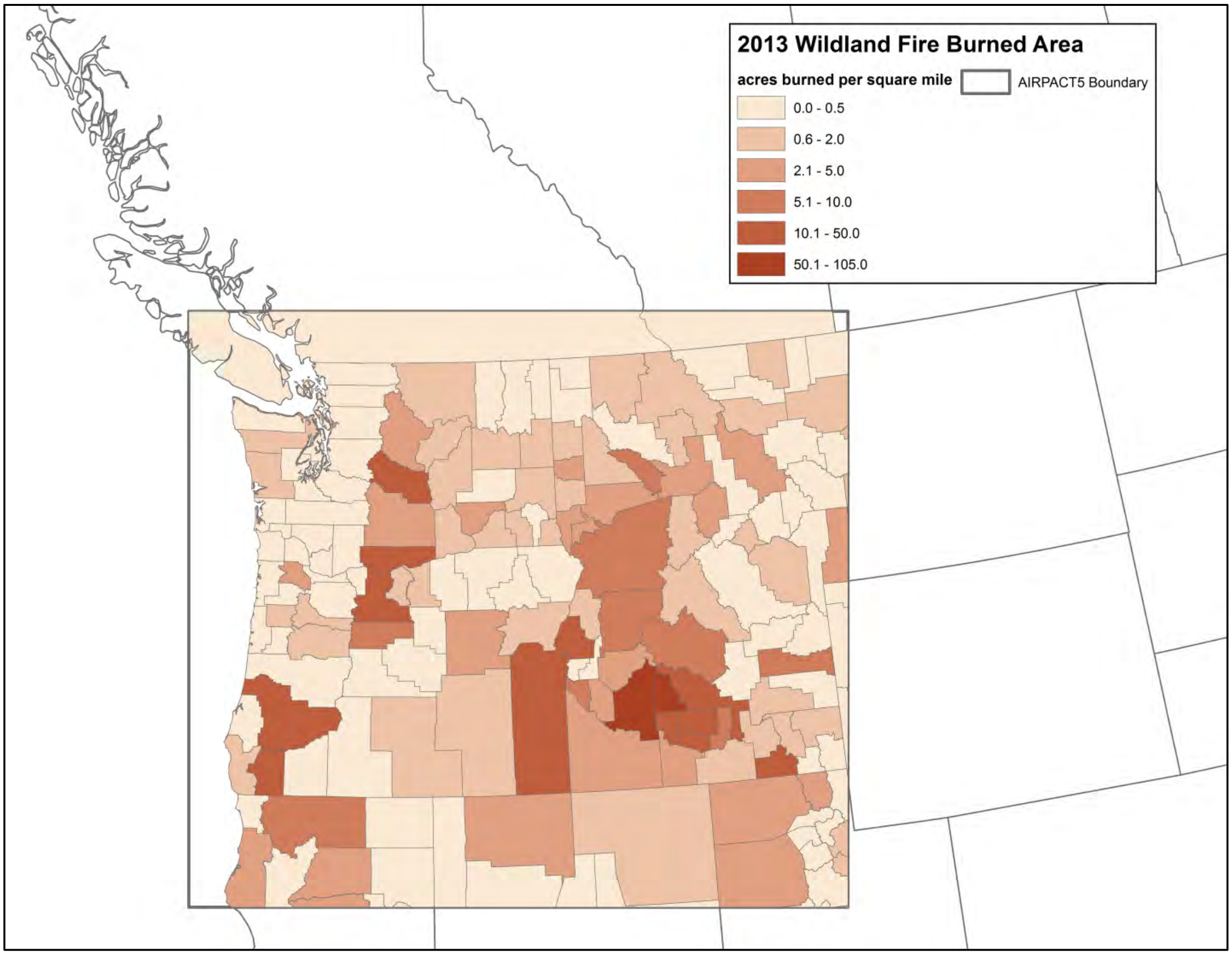



**Figure 4.** Wildland fire area burned (acres per square mile) by county, in the 2013 AIRPACT WLFEI. Area burned in Canada is shown as acres per square mile by province.

Area burned and $PM_{2.5}$ results by state or province and fire type are presented in **Figure 5**. Both area burned and $PM_{2.5}$ emissions are dominated by wildfires in all states and Canadian provinces in this inventory.

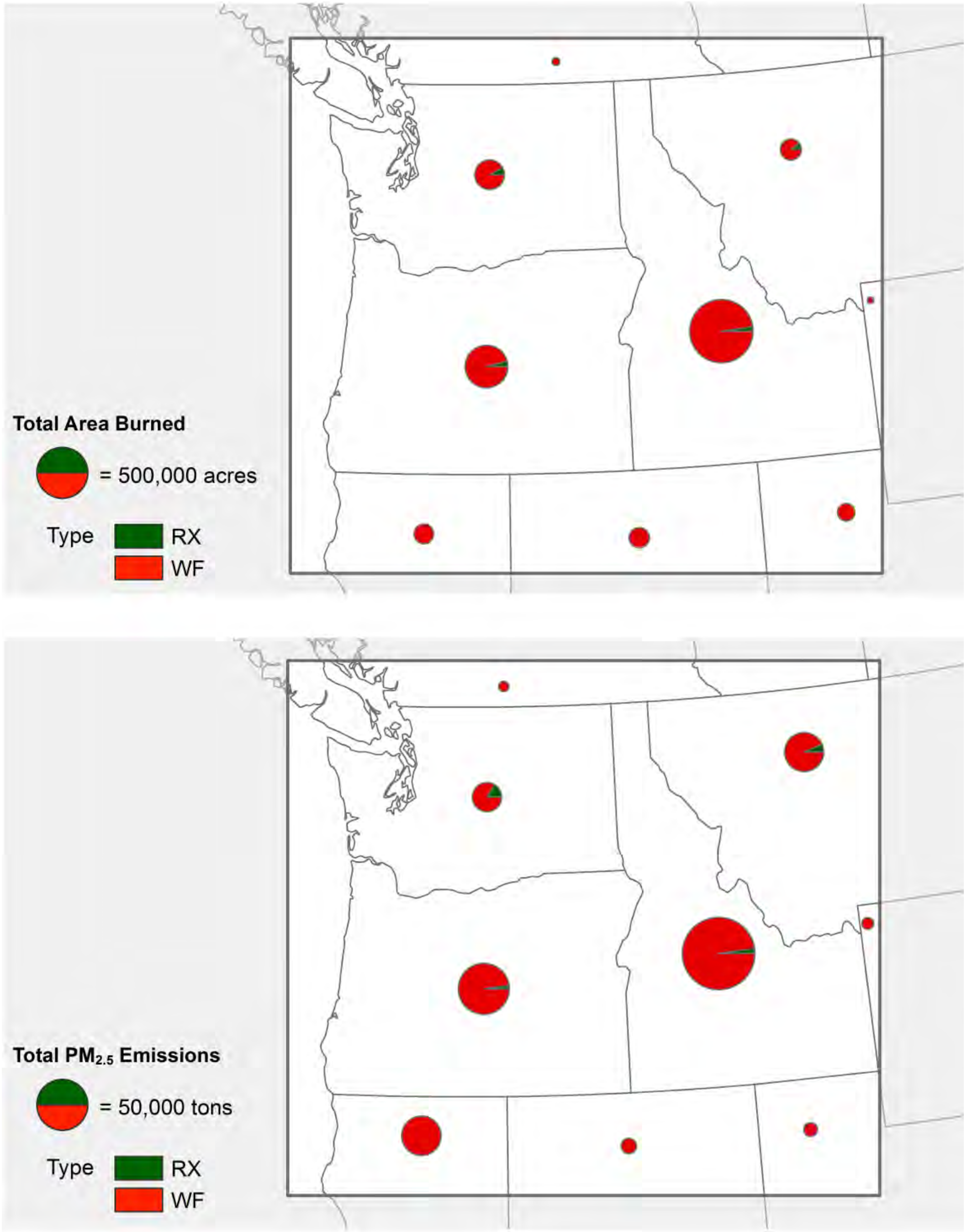



**Figure 5.** State or Canadian province totals of area burned (top) and $PM_{2.5}$ emitted (bottom) by fire type in the 2013 AIRPACT WLFEI. Pie sizes are proportional to state totals. Each pie consists of two components: prescribed fire (green; RX) and wildfire (red; WF).

The monthly patterns of total area burned and $PM_{2.5}$ emissions in the AIRPACT WLFEI are shown in **Figures 6 and 7**. In this inventory, fire activity and area burned peaked in August. The majority of prescribed burning that was reported for the AIRPACT5 domain between July and September occurred during September.

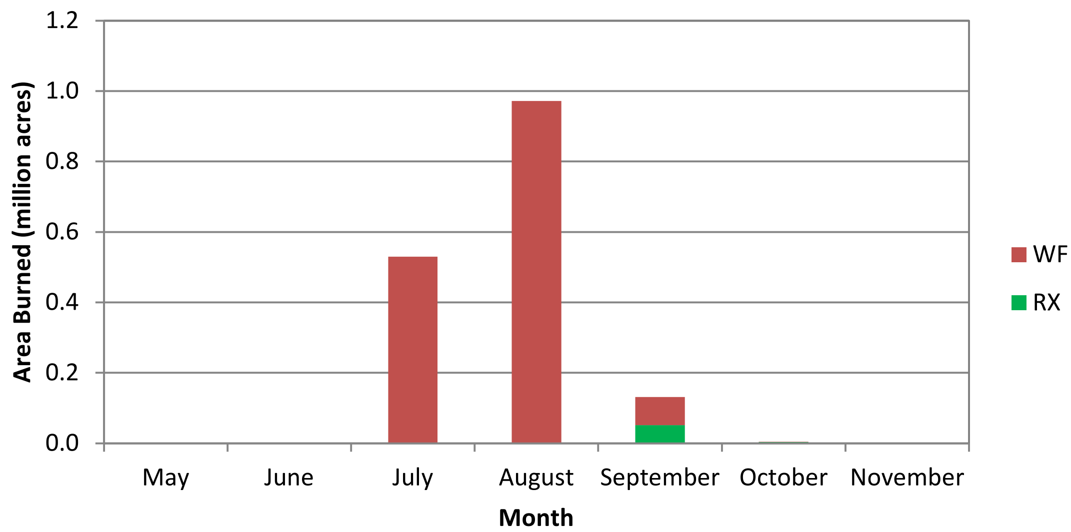



**Figure 6.** Monthly area burned by firetype, in the 2013 AIRPACT WLFEI. Red indicates wildfires and green indicates prescribed burns. Area burned outside of July through September indicates the area burned by fire events where some portion burned during the July through September period of interest.

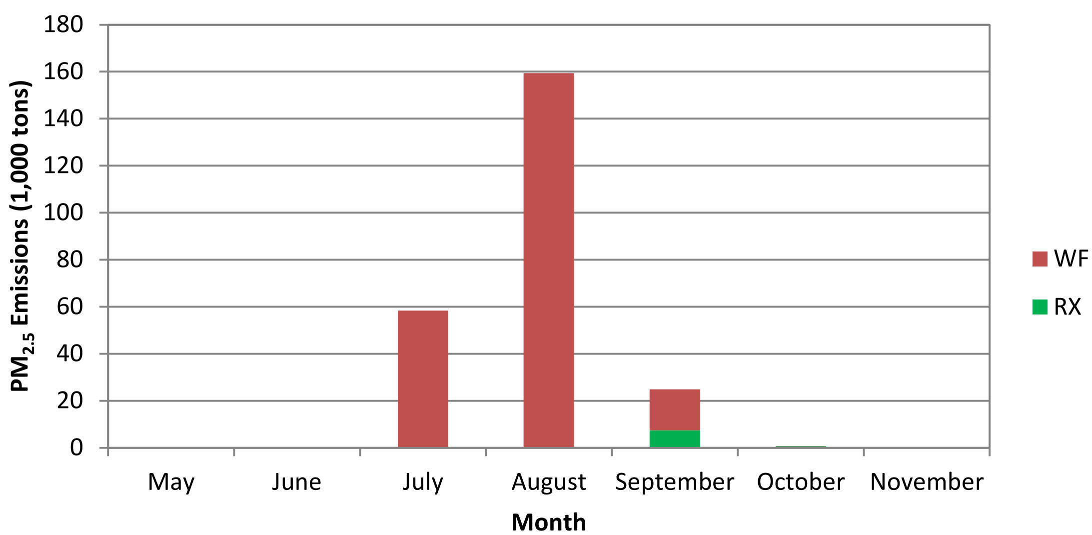



**Figure 7.** Monthly $PM_{2.5}$ emitted by fire type, in the 2013 AIRPACT WLFEI Red indicates wildfires and green indicates prescribed burns. Emissions outside of July through September were released by fire events where some portion burned during the July through September period of interest.

## Deliverables

The 2013 AIRPACT WLFEI is provided in the following formats:

- BlueSky fire location daily files for wild and prescribed fires by state and Canadian province

- SMOKE FF10 daily and annual files for wild and prescribed fires by state and Canadian province
- A compiled list of agricultural fires

In addition, U.S. state and Canadian province totals for July through September 2013 for the AIRPACT5 domain for wild and prescribed fires are provided in an Excel table.

## References


Du Y., Raffuse S.M., and Reid S.B. (2013) Technical guidance for using SmartFire2 / BlueSky Framework to develop national wildland fire emissions inventories. User's guide prepared for the U.S. Environmental Protection Agency, Research Triangle Park, NC, by Sonoma Technology, Inc., Petaluma, CA, STI-910414-5593, April 26.

Huang S., Pavlovic N., and Du Y. (2016) Technical documentation for the wildfire and prescribed fire portion of the 2014 National Emissions Inventory. Draft report prepared for the U.S. Environmental Protection Agency Emissions Inventory and Analysis Group, Durham, NC, by Sonoma Technology, Inc., STI-916054-6590-DR, October.

Pollard E.K., Du Y., Raffuse S.M., and Reid S.B. (2011) Preparation of wildland and agricultural fire emissions inventories for 2009. Technical memorandum prepared for the U.S. Environmental Protection Agency, Research Triangle Park, NC, by Sonoma Technology, Inc., Petaluma, CA, STI-910221-4231, October 6.

U.S. Environmental Protection Agency (2016) 2014 National Emissions Inventory, version 1. Draft technical support document, December. Available at https://www.epa.gov/sites/production/files/2016-12/documents/nei2014v1_tsd.pdf.

Wiedinmyer C., Akagi S.K., Yokelson R.J., Emmons L.K., Al-Saadi J.A., Orlando J.J., and Soja A.J. (2011) The Fire INventory from NCAR (FINN): a high resolution global model to estimate the emissions from open burning. *Geosci. Model Dev. Discuss.*, 3(doi:10.5194/gmd-4-625-2011), 2439-2476. Available at http://www.geosci-model-dev.net/4/625/2011/gmd-4-625-2011.pdf.

# Appendix C. CRB Emission Factors and Burn Activity for Each Scenario

# Appendix C—CRB Emission Factors and Burn Activity for Each Scenario

State of Idaho
Department of Environmental Quality
Air Quality Division
1410 N. Hilton
Boise, ID 83706

September 2017

Printed on recycled paper, DEQ, September 2017
PID SSIP, CA code 81992. Costs associated with
this publication are available from the State of Idaho
Department of Environmental Quality in accordance
with Section 60-202, Idaho Code.

# Table of Contents



# List of Tables

# 1 Introduction

The modeling inventory for the 2013 crop residue burning (CRB) modeling episode represents the period July 8–September 26, 2013. This period includes the largest CRB burning period and the highest ozone season. However, it does not represent a complete year and is not comparable to an annual emissions inventory (EI). This appendix describes the emission factors used in the episode, the Idaho CRB database used to construct Idaho's CRB EI, and the methods used to estimate CRB in other jurisdictions in the domain outside of the Idaho CRB program.

# 2 Emission Factors from the 2014 National Emissions Inventory

Emissions factors for CRB are generally based on field burn measurements and in some cases, controlled laboratory burns. The *Air Quality Modeling Technical Support Document for the 2015 Ozone NAAQS Preliminary Interstate Transport Assessment* (EPA 2016) reports on United States Environmental Protection Agency (EPA)-developed emissions for 2014 agricultural field burning and provides fuel loads, combustion completeness, and emissions factors for carbon monoxide (CO), nitrogen oxides ($NO_x$), sulfur dioxide ($SO_2$), particulate matter 2.5 and 10 ($PM_{2.5}$, $PM_{10}$), volatile organic compounds (VOC), and ammonia ($NH_3$). The emissions factors used in the 2014 National Emissions Inventory (NEI) are based primarily on a comprehensive review and averaging of all available factors by McCarty (2011), under contract to EPA for the 2011 NEI, and is the most recent and comprehensive set of emissions factors.

The emission factors subsequently used by EPA in the 2014 NEI do not specifically include all of the crop types reviewed in the 2011 NEI effort, nor those reported in the Idaho Department of Environmental Quality's (DEQ's) CRB burn permit database. The 2014 NEI documentation does provide an "Other Crops" category for any crops not specifically included and a "Pasture/Grass" category. Both categories have identical loads and factors to bluegrass, so it appears that EPA selected "Other Crops" and "Pasture/Grass" factors from the bluegrass values because they are the highest of any "Other Crops," while EPA's previous "Other Crops" factor in McCarty (2011) has slightly lower values that are no longer used. For this project DEQ used the 2014 NEI factors and methods.

DEQ reviewed two regional emissions factor studies of residue burning from Kentucky bluegrass seed (Johnston and Golob 2004) and cereal grain (Air Sciences 2003) to determine if they were more specific to Idaho and eastern Washington and therefore better suited to the Pacific Northwest region than the EPA factors. It appears that both studies were included in the average factors developed by McCarty (2011) so they are already incorporated in these factors. However, neither of these studies included the ozone precursors, $NO_x$ and VOC, in the emissions measurements so they do not contribute local/regional emissions knowledge most needed in this analysis, and the recent EPA factors are best used for consistency without deviation.

The emissions factors reported in the 2014 NEI documentation or the original McCarty (2011) compilation are shown in Table 1. Table 2 shows how the EPA/McCarty (2011) crop types are mapped to the DEQ burn database crop types.

**Table 1. Emissions factors used in the 2014 NEI (EPA 2016) and (last row, for bluegrass) in the 2011 NEI (McCarty 2011).**

| Crop Type | Fuel Load (ton/acre) | Combustion Completeness (%) | $PM_{2.5}$ (lb/ton) | $NO_X$ (lb/ton) | VOC (lb/ton) | CO (lb/ton) | $SO_2$ (lb/ton) | $PM_{10}$ (lb/ton) | $NH_3$ (lb/ton) |
|---|---|---|---|---|---|---|---|---|---|
| Corn | 4.2 | 0.75 | 9.9 | 4.6 | 6.6 | 106 | 2.38 | 21.4 | 19.3 |
| Wheat | 1.9 | 0.85 | 8.1 | 4.7 | 7.6 | 110 | 0.88 | 14.1 | 33.7 |
| Soybean | 2.5 | 0.75 | 12.4 | 6.3 | 12.0 | 128 | 3.13 | 17.7 | 44.9 |
| Cotton | 2.18 | 0.65 | 12.4 | 6.9 | 12.0 | 146 | 3.13 | 17.7 | 48.9 |
| Fallow | 2.18 | 0.75 | 12.3 | 5.6 | 12.0 | 128 | 2.34 | 17.0 | 16.2 |
| Rice | 3 | 0.75 | 4.7 | 6.2 | 5.0 | 105 | 2.77 | 6.6 | 26.2 |
| Sugarcane | 4.75 | 0.65 | 8.7 | 6.1 | 9.0 | 117 | 3.32 | 9.8 | 43.0 |
| Lentils | 2.94 | 0.75 | 12.3 | 5.6 | 12.0 | 128 | 2.34 | 17.0 | 39.8 |
| Other crops | 1.9 | 0.85 | 23.2 | 4.3 | 10.7 | 182 | 0.80 | 31.6 | 12.5 |
| Pasture/ grass | 1.9 | 0.85 | 23.2 | 4.3 | 10.7 | 182 | 0.80 | 31.6 | 12.5 |
| Bluegrass[a] | 1.9[b] | 0.85[b] | 23.2[a] | 4.3[a] | 10.7[b] | 182[a] | 0.80[a] | 31.6[a] | 12.5[b] |

a. Bluegrass was not explicitly reported in the 2014 NEI documentation (EPA 2016) but was provided in the original McCarty (2011) evaluation upon which the 2014 NEI is based and is used here. EPA uses the bluegrass factors for "Other Crops" and for "Pasture/Grass" in the 2014 NEI.
b. VOC and $NH_3$ values were not available in McCarty (2011) so the values for "Other Crops" are used for bluegrass for VOC and $NH_3$ values and for the fuel loading and combustion completeness.

**Table 2. Crosswalk from DEQ Agburn Database crop types to NEI (EPA 2014) and McCarty (2011) crop types.**

| DEQ Agburn Data Crop Type | Crop Type Assigned |
|---|---|
| Alfalfa | Other crops[a] |
| Cereal grain (wheat, barley) | Wheat |
| Corn | Corn[a] |
| CRP | Fallow[a] |
| Kentucky bluegrass | Bluegrass[b] |
| Legumes | Other crops[a] |
| Other | Other crops[a] |
| Other grass species | Bluegrass[b] |
| Pasture | Pasture_Grass[a] |
| Turf grass | Bluegrass[b] |

a. EPA 2014 NEI
b. McCarty (2011)
*Notes*: In the 2014 NEI documentation, Pasture/Grass NEI crop type factors and characteristics are identical to EPA's "Other Crops" category and both appear to come from bluegrass as all three are identical.

# 3 Idaho Crop Residue Burning Database

DEQ's CRB program acres burned during the 2013 modeling episode are shown in Table 3 for each Smoke Management Area (SMA). Days with no burning are excluded from the table.

**Table 3. Acres burned each day of the 2013 modeling episode by SMA.**

| Burn Date | Boundary | Central | Eastern Idaho | Kootenai | Northern Magic Valley | Southeast Idaho | Southern Magic Valley | Southwest Idaho | Weiser & Lower Payette Valleys | Total Acres |
|---|---|---|---|---|---|---|---|---|---|---|
| 07/08/2013 | | | | | | | 0.1 | | | 0.1 |
| 07/09/2013 | | | | | | | 0 | | | 0 |
| 07/11/2013 | | | | | | | 0 | | | 0 |
| 07/12/2013 | | | | | | | 0 | | | 0 |
| 07/15/2013 | | | | | | | 0 | | | 0 |
| 07/23/2013 | | 117.5 | | | | | | | 30 | 147.5 |
| 07/24/2013 | | | | | | | 514 | 106 | | 620 |
| 07/25/2013 | | | | | | | | 44 | | 44 |
| 07/26/2013 | | | | | | | | 59 | | 59 |
| 07/29/2013 | | | | | 65 | | 0 | 65 | | 130 |
| 07/30/2013 | | | | | | | | 70 | | 70 |
| 07/31/2013 | | | | | | | | 79 | | 79 |
| 08/02/2013 | | | | | 349 | | 102.2 | 76.5 | 23 | 550.7 |
| 08/05/2013 | | | | | 183 | 200 | 241 | 29 | | 653 |
| 08/06/2013 | | 96 | | | 81 | | 120 | 135 | | 432 |
| 08/07/2013 | | 283 | | 370 | 599 | 40 | 13 | | | 1305 |
| 08/09/2013 | 100 | | | | 176 | | 7 | 403 | | 686 |
| 08/12/2013 | | | | | 673 | 57 | | | | 730 |
| 08/13/2013 | | 0 | | | 818 | | 19 | 122 | | 959 |
| 08/14/2013 | | | 179 | | | 72 | | | | 251 |
| 08/19/2013 | | | 382.5 | | 651 | 337 | 798 | 86 | | 2255 |
| 08/20/2013 | 400 | 646 | 529 | | | 230 | | | | 1805 |
| 08/21/2013 | | 682 | | | | | | | | 682 |
| 08/22/2013 | 55 | | | | | | | | | 55 |
| 08/23/2013 | | | | | 736 | | 213 | 37 | | 986 |
| 08/26/2013 | | 602 | 904 | | 764.5 | 499 | 115 | 164 | | 3049 |
| 08/27/2013 | 164 | 854 | 120 | | | 577 | | | | 1715 |
| 08/28/2013 | | 164 | 330 | | | 490 | | | | 984 |
| 08/29/2013 | | 379 | 272 | 5 | 410 | 115 | 160 | | | 1341 |
| 08/30/2013 | | 993.4 | 413 | | 292 | 652 | 33 | | | 2383 |
| 09/04/2013 | 170 | 731 | 6 | 95 | 120 | 0 | | | | 1122 |
| 09/05/2013 | | | | | | 180 | | | | 180 |
| 09/06/2013 | | 240 | 150.5 | | | 495.7 | | | | 886.2 |
| 09/09/2013 | 218 | 2043 | | | 355 | 360.3 | 79.4 | 70 | | 3126 |
| 09/10/2013 | 317 | 1942 | 140 | | 79 | 702 | 35 | | | 3215 |
| 09/11/2013 | 260 | 1335 | 339 | | 5 | 150 | | | | 2089 |
| 09/12/2013 | 533 | 1337 | | | | | | | | 1870 |
| 09/13/2013 | | 1741 | | | | 0 | | | | 1741 |
| 09/16/2013 | | 247 | 339 | | | 126 | | 101 | | 813 |
| 09/17/2013 | | 413 | | | | | 28 | | | 441 |
| 09/18/2013 | | | | | | | | 30 | | 30 |
| 09/19/2013 | | 17 | 0 | | | | | | | 17 |
| 09/20/2013 | | 744 | 282 | | | 30 | | | | 1056 |
| 09/23/2013 | | | 12 | | | 42 | | 26 | | 80 |
| 09/24/2013 | | | 2 | | | 0 | 0 | | | 2 |

# 4 Agricultural Burns in the Domain Outside Idaho's Program

Because we do not have detailed information for agricultural burns in the domain outside the Idaho permit program, a more complex approach was necessary to estimate the burn activity. Once the burn acres were estimated, the emissions were computed following the same emissions estimation approach based on the 2014 NEI, as employed in Idaho's CRB inventory.

Sonoma Technology provided DEQ with a Hazard Mapping System (HMS)-detected burns dataset for the modeling episode for all satellite detected burns that occurred on agricultural land in the AIRPACT domain for the 2013 episode (Sonoma Technology 2017). This dataset was a byproduct from their wildland fire emissions inventory development work for DEQ (Appendix B); however, due to limitations of the HMS detection approach for agricultural fires, it is not complete. Agricultural burns are often not detected by the HMS system due to limitations of the satellite method and the generally smaller size of many agricultural burns. The analysis of Idaho's agricultural burns compared to Idaho burns known to have occurred based on the DEQ's CRB permit database for the same period showed that for the Idaho region, approximately 75% of the burns were missing in HMS dataset. Rather than using the HMS-detected burns directly for the non-DEQ burn areas, DEQ attempted to produce a better estimate for the non-Idaho CRB inventory, even though the regional CRB emissions are relatively small compared to wildfires and other source categories of ozone precursors. To account for missing burns from the HMS dataset, we developed an approach similar to the EPA 2014 NEI (EPA 2016), using the following steps:

1. Develop HMS miss and detect ratio using the Idaho CRB dataset (ratio = [Burn acres missed by HMS] / [Burn acres detected by HMS]).
2. Develop and estimate of the average size of HMS missed CRB fires using the Idaho CRB dataset.
3. Develop a daily temporal profile using the Idaho HMS missed CRB fires. This assumes that on a day-to-day basis, the weather system (and burn conditions) over Idaho is our best approximation for burn conditions in nearby agricultural areas in other states but near the Idaho border.
4. Develop a spatial surrogate of HMS missed acres outside of Idaho using HMS-detected acres. This assumes that HMS detects are in the same agricultural areas where we expect the nondetected fires to be (e.g., the CRB fires should be in the agricultural areas near the detected burns rather than in mountain, desert, or urban areas).
5. Develop a pool of known fire locations for each county outside of Idaho or each tribal area using HMS-detected fires outside of Idaho.
6. Calculate the total areas burned that are not detected by HMS outside of Idaho's CRB program by using the HMS misses/detects ratio generated using the ratios described above (item 1) from the Idaho CRB dataset.
7. Use the temporal profile developed from the Idaho HMS-missed CRB fires to temporally allocated acres of fires to each day. The Idaho HMS missed acres account for days known to have burns, when cloudy conditions may cause the burns to be missed throughout the region. We assume missed burns in other states near Idaho are correlated with the proportion of missed burns in Idaho. This accounts for greater ratio of missed acres on cloudy days, for example.
8. For each day, allocate acres to each county using the spatial surrogate (steps 4 and 5).

9. For each day, for each county, determine how many “missed” fires occur based on the total missed acres and the average missed fire size and begin to reconstruct the missed fires. Fires are not lumped together because that would alter the heat density and resulting plume rise.
10. Randomly choose a location for each constructed missed fire from the pool of fire locations in each county in outside of Idaho.
11. For each reconstructed “missed” fire, calculate consumption and emissions based on locations chosen and emission factors used in the Idaho CRB emission calculations.

The detected acres, estimated missed acres, and the total (detected + missed) acres that were modeled in DEQ’s 2013 base-case modeling episode are shown in Table 4. As a check on this approximation approach for CRB burned acreage outside the DEQ program, DEQ obtained the 2014 total crop and grass/pasture burning emissions for the July 8–September 26, 2014, period for Washington and Oregon, the only two states, other than Idaho that are 100% within the modeling domain. While the 2014 NEI is for a different year than the 2013 modeling episode and year-to-year variations may account for significant differences, it nevertheless provides a rough idea of the normal amount of burning for each state. The 2014 acreage burned during the July 8–September 26 period, were 87% of the 2013 modeled episode acres for Oregon and 68% of the modeled episode acres for Washington. This comparison is reasonable considering likely annual variation and serves the intended purpose of making a reasonable attempt to include all emission sources even for categories such as agricultural burning which do not produce significant ozone precursors capable of making a significant change in Idaho’s background ozone.

**Table 4. CRB burn acres estimated in AIRPACT5 modeling domain but outside of Idaho’s program.**

| State or Tribe | HMS Detected Acres | HMS Missed Acres | Total Modeled Acres |
|---|---|---|---|
| California | 800 | 2,360 | 3,160 |
| Coeur d'Alene Tribe | 8,130 | 23,984 | 32,114 |
| Fort Hall Tribe | 200 | 590 | 790 |
| Kootenai Tribe | 100 | 295 | 395 |
| Montana | 8,696 | 25,653 | 34,349 |
| Nevada | 500 | 1,475 | 1,975 |
| Nez Perce Tribe | 12,900 | 38,055 | 50,955 |
| Oregon | 12,138 | 35,807 | 47,945 |
| Utah | 800 | 2,360 | 3,160 |
| Washington | 19,000 | 56,050 | 75,050 |
| **Total** | **63,264** | **186,629** | **249,893** |

# 5 Idaho CRB Acres Burned for Specific Modeling Scenarios

The burn assumptions and the emissions related to the three CRB-specific modeling scenarios are described below, and the resulting acres estimated to be burned for each scenario are shown in Table 3, Table 6, and Table 7.

## 5.1 Scenario 1: Base Scenario—Under Previous Rule: Actual CRB

This scenario represents the actual burns that occurred in the 2013 episode when the old rule stopped burning for counties forecasted to be higher than 56 ppb. The daily acres burned in each SMA are shown in Table 3.

## 5.2 Scenario 2: Additional "Hypothetical" Acres Added Under the New Rule

This scenario reflects the actual 2013 burns included in the Scenario 1 inventory, plus additional burns and emissions added to any county on any day that its background ozone concentration is above 56 ppb and below 63 ppb in the background model simulation. The "hypothetical" new burn acreages are based on the median acres for the same county in the same month. The daily acres assumed burned for Scenario 2 in each SMA are shown in Table 6 and include Scenario 1 burns.

## 5.3 Scenario 3: Scenario 2 Burns Grown to Maximum Historical Burn Levels by Day

The emissions for counties causing any significant CRB contributions from the Scenario 2 analysis (> 0.2 ppb MDA8), based on the combined Scenario 1 "actual" and Scenario 2 "hypothetical" acres burned each day were "grown" to reflect the maximum burned acres ever recorded in the involved counties on the same day since the inception of the DEQ CRB program. This was accomplished by first identifying the maximum concentration and county in which the burns that caused the maximum were located. Any nearby counties that may have also contributed were also grown to their historical maximum emissions levels to ensure that the maximum impacts were re-created. The daily acres assumed burned for Scenario 3 in each SMA are shown in Table 7.

# 6 Total CRB Emissions for Modeling Episode

The emission factors are combined with the burned acres for each burn location on each day to generate the CRB emissions for the modeling episode. The emissions are then spatially and temporally allocated in the emissions preprocessor before the simulation. The total 2013 episode CRB emissions for the actual burns simulated in Scenario 1 are shown in Table 5 with the 2014 annual CRB emissions from the 2014 NEI, for a point of comparison (DEQ did not compute a complete annual EI for 2013 for this project but only for the modeling episode). The 2013 episodic emissions for ozone precursors VOC and $NO_x$ are within about 12% of the annual totals for 2014, reflecting that the modeling episode captures the majority of the emissions for a typical year, allowing for some year-to-year variation between 2013 and 2014.

**Table 5. Modeled CRB emissions (tons) for the July 8–September 26, 2013, actual burns modeled in Scenario 1, with 2014 NEI annual emissions for comparison.**

| Period | $PM_{2.5}$ | CO | $NO_X$ | VOC | $SO_2$ |
|---|---|---|---|---|---|
| 2013 Model Episode | 298 | 3648 | 147 | 250 | 29 |
| 2014 Annual CRB Emissions | 340 | 4123 | 166 | 286 | 34 |

**Table 6. Total burn acres by day for Scenario 2—actual 2013 burns and new days at 56–63 ppb.**

| Date | Blaine & Camas Counties | Boundary | Central | Eastern Idaho | Kootenai | Northern Magic Valley | Southeast Idaho | Southern Magic Valley | Southwest Idaho | Weiser & Lower Payette Valleys | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/8/2013 | | | | | | | | 0 | | | 0 |
| 7/9/2013 | | | | | | | | | | 25 | 25 |
| 7/10/2013 | | | | | | 353 | | 51 | 38 | | 442 |
| 7/15/2013 | | | | | | | | | 44 | 25 | 69 |
| 7/16/2013 | | | | | | | 60 | | | 50 | 110 |
| 7/17/2013 | | | | | | | 201 | 51 | 44 | | 296 |
| 7/18/2013 | | | | | | 353 | 60 | 51 | 44 | | 508 |
| 7/19/2013 | | | | 29 | | 421 | 201 | | | | 651 |
| 7/22/2013 | | | | | | 264 | 141 | 26 | | | 431 |
| 7/23/2013 | | | 118 | | | 157 | | | 82 | 30 | 387 |
| 7/24/2013 | | | | | | | 60 | 540 | 106 | | 706 |
| 7/25/2013 | | | | | | | 141 | 26 | 44 | | 211 |
| 7/26/2013 | | | | | | 225 | 141 | 51 | 97 | | 514 |
| 7/29/2013 | | | | | | 65 | | | 65 | | 130 |
| 7/30/2013 | | | | | | | | | 70 | | 70 |
| 7/31/2013 | | | | | | | | | 79 | | 79 |
| 8/2/2013 | | | | | | 349 | | 102 | 77 | 23 | 551 |
| 8/5/2013 | | | 298 | | | 183 | 548 | 315 | 193 | 43 | 1580 |
| 8/6/2013 | 95 | | 262 | 134 | | 81 | | 120 | 135 | | 827 |
| 8/7/2013 | 95 | | 283 | 41 | 370 | 599 | 228 | 87 | | | 1703 |
| 8/8/2013 | | | 132 | | | | | | | 83 | 215 |
| 8/9/2013 | | 100 | | | | 176 | | 7 | 493 | | 776 |
| 8/12/2013 | | 150 | | | 95 | 673 | 57 | 50 | | 43 | 1068 |
| 8/13/2013 | | 150 | 132 | | 95 | 861 | | 19 | 212 | | 1469 |
| 8/14/2013 | | | 132 | 624 | 95 | 445 | 413 | 124 | 55 | 40 | 1928 |
| 8/15/2013 | | | | 134 | | 168 | | | 55 | | 357 |
| 8/16/2013 | | | | | | 445 | | 50 | | 43 | 538 |
| 8/19/2013 | | | | 383 | | 651 | 425 | 798 | 86 | | 2343 |
| 8/20/2013 | | 400 | 646 | 529 | | | 230 | | | | 1805 |
| 8/21/2013 | | | 682 | | | | | | | | 682 |
| 8/22/2013 | | 55 | | | | | | | | | 55 |
| 8/23/2013 | | | | | | 736 | | 213 | 37 | | 986 |
| 8/26/2013 | | | 602 | 904 | | 765 | 499 | 115 | 164 | | 3049 |
| 8/27/2013 | | 164 | 854 | 120 | | | 577 | | | 97 | 1812 |
| 8/28/2013 | | | 164 | 330 | | | 490 | | | | 984 |
| 8/29/2013 | | | 379 | 272 | 5 | 410 | 143 | 160 | | | 1369 |
| 8/30/2013 | | | 993 | 413 | | 292 | 740 | 33 | | | 2471 |
| 9/3/2013 | | | | | | | 25 | | | | 25 |
| 9/4/2013 | | 170 | 731 | 6 | 95 | 120 | | | | | 1122 |
| 9/5/2013 | | | | | | | 205 | | | | 205 |
| 9/6/2013 | | | 240 | 151 | | | 496 | | | | 886 |
| 9/9/2013 | | 218 | 2043 | | | 355 | 360 | 79 | 70 | | 3126 |
| 9/10/2013 | | 317 | 1942 | 260 | | 79 | 1043 | 35 | | | 3676 |
| 9/11/2013 | | 260 | 1335 | 339 | | 5 | 150 | | | 8 | 2097 |
| 9/12/2013 | | 533 | 1337 | | | | 130 | 128 | | | 2128 |
| 9/13/2013 | 165 | | 1741 | 270 | 80 | 84 | 25 | | | | 2365 |
| 9/16/2013 | | 225 | 247 | 903 | | 19 | 548 | 184 | 145 | | 2271 |
| 9/17/2013 | | | 413 | 956 | | | 883 | 156 | | | 2408 |
| 9/18/2013 | 65 | | | 120 | | | 145 | | 30 | | 360 |
| 9/19/2013 | | | 17 | | | | | | 23 | | 40 |
| 9/20/2013 | | | 774 | 282 | | | 30 | | 72 | 69 | 1227 |
| 9/23/2013 | | | | 12 | | | 42 | | 26 | | 80 |
| 9/24/2013 | | | | 2 | | | | | | | 2 |

**Table 7. Total burn acres by day for Scenario 3—maximum historical acres burned.**

| Date | Blaine & Camas Counties | Boundary | Central | Eastern Idaho | Kootenai | Northern Magic Valley | Southeast Idaho | Southern Magic Valley | Southwest Idaho | Weiser & Lower Payette Valleys | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/8/2013 | | | | | | | | 0 | | | 0 |
| 7/9/2013 | | | | | | | | | | 25 | 25 |
| 7/10/2013 | | | | | | 353 | | 51 | 136 | | 540 |
| 7/15/2013 | | | | | | | | | 44 | 25 | 69 |
| 7/16/2013 | | | | | | | 60 | | | 50 | 110 |
| 7/17/2013 | | | | | | | 201 | 51 | 44 | | 296 |
| 7/18/2013 | | | | | | 353 | 60 | 51 | 44 | | 508 |
| 7/19/2013 | | | | 29 | | 759 | 201 | | | | 989 |
| 7/22/2013 | | | | | | 264 | 141 | 26 | | | 431 |
| 7/23/2013 | | | 118 | | | 157 | | | 82 | 30 | 387 |
| 7/24/2013 | | | | | | | 60 | 543 | 106 | | 709 |
| 7/25/2013 | | | | | | | 141 | 26 | 44 | | 211 |
| 7/26/2013 | | | | | | 225 | 141 | 51 | 248 | | 665 |
| 7/29/2013 | | | | | | 65 | | | 65 | | 130 |
| 7/30/2013 | | | | | | | | | 70 | | 70 |
| 7/31/2013 | | | | | | | | | 79 | | 79 |
| 8/2/2013 | | | | | | 349 | | 102 | 77 | 23 | 551 |
| 8/5/2013 | | | 298 | | | 183 | 548 | 591 | 193 | 43 | 1856 |
| 8/6/2013 | 95 | | 262 | 134 | | 81 | | 120 | 135 | | 827 |
| 8/7/2013 | 95 | | 283 | 41 | 370 | 614 | 228 | 87 | | | 1718 |
| 8/8/2013 | | | 132 | | | | | | | 83 | 215 |
| 8/9/2013 | | 1248 | | | | 176 | | 7 | 493 | | 1924 |
| 8/12/2013 | | 150 | | | 95 | 1754 | 57 | 50 | | 43 | 2149 |
| 8/13/2013 | | 150 | 132 | | 95 | 2140 | | 19 | 212 | | 2748 |
| 8/14/2013 | | | 132 | 624 | 95 | 2052 | 413 | 1057 | 55 | 40 | 4468 |
| 8/15/2013 | | | | 134 | | 649 | | | 55 | | 838 |
| 8/16/2013 | | | | | | 815 | | 50 | | 43 | 908 |
| 8/19/2013 | | | | 383 | | 651 | 928 | 798 | 86 | | 2846 |
| 8/20/2013 | | 1248 | 646 | 529 | | | 230 | | | | 2653 |
| 8/21/2013 | | | 1911 | | | | | | | | 1911 |
| 8/22/2013 | | 55 | | | | | | | | | 55 |
| 8/23/2013 | | | | | | 2503 | | 599 | 37 | | 3139 |
| 8/26/2013 | | | 602 | 904 | | 888 | 499 | 582 | 164 | | 3639 |
| 8/27/2013 | | 164 | 1970 | 120 | | | 577 | | | 97 | 2928 |
| 8/28/2013 | | | 164 | 330 | | | 490 | | | | 984 |
| 8/29/2013 | | | 379 | 272 | 5 | 410 | 143 | 160 | | | 1369 |
| 8/30/2013 | | | 1760 | 413 | | 292 | 740 | 33 | | | 3238 |
| 9/3/2013 | | | | | | | 25 | | | | 25 |
| 9/4/2013 | | 170 | 2038 | 6 | 95 | 120 | | | | | 2429 |
| 9/5/2013 | | | | | | | 205 | | | | 205 |
| 9/6/2013 | | | 240 | 151 | | | 1528 | | | | 1919 |
| 9/9/2013 | | 218 | 4252 | | | 355 | 360 | 79 | 70 | | 5335 |
| 9/10/2013 | | 317 | 2635 | 260 | | 79 | 1043 | 35 | | | 4368 |
| 9/11/2013 | | 260 | 2403 | 339 | | 5 | 150 | | | 8 | 3165 |
| 9/12/2013 | | 1248 | 1337 | | | | 130 | 128 | | | 2843 |
| 9/13/2013 | 165 | | 3585 | 270 | 80 | 84 | 25 | | | | 4209 |
| 9/16/2013 | | 225 | 247 | 903 | | 19 | 548 | 184 | 180 | | 2306 |
| 9/17/2013 | | | 413 | 956 | | | 883 | 156 | | | 2408 |
| 9/18/2013 | 65 | | | 120 | | | 145 | | 30 | | 360 |
| 9/19/2013 | | | 17 | | | | | | 23 | | 40 |
| 9/20/2013 | | | 774 | 282 | | | 30 | | 72 | 69 | 1227 |
| 9/23/2013 | | | | 12 | | | 42 | | 26 | | 80 |
| 9/24/2013 | | | | 2 | | | | | | | 2 |

# References

Air Sciences, Incorporated. 2003. *Cereal-Grain Residue Open-Field Burning Emissions Study.* Portland, OR. *http://www.ecy.wa.gov/programs/air/aginfo/research_pdf_files/FinalWheat_081303.pdf*

EPA (United States Environmental Protection Agency). 2016. *National Emissions Inventory, version 1, Technical Support Document* (DRAFT).

Johnston, W.J. and C.T. Golob. 2004. *Quantifying Post-Harvest Emissions from Bluegrass Seed Production Field Burning.* Pullman, WA: Washington State University, Department of Crop and Soil Sciences.

McCarty, J.L, 2011. "Remote Sensing-Based Estimates of Annual and Seasonal Emissions from Crop Residue Burning in the Contiguous United States." *Journal of the Air & Waste Management Association*. 61:1.22–34. DOI: 10.3155/1047-3289.61.1.22.

Pavlovic, N. and S. Huang, Sonoma Technology. 2017. Personal communication with Idaho Department of Environmental Quality.

# Appendix D. Assessment of Meteorological Simulations for 2013 and 2015 CRB Modeling Episodes

# Appendix D—Assessment of Meteorological Simulations for 2013 and 2015 CRB Modeling Episodes

State of Idaho
Department of Environmental Quality
Air Quality Division
1410 N. Hilton
Boise, ID 83706

September 2017

Printed on recycled paper, DEQ September 2017, PID SSIP, CA code 81992. Costs associated with this publication are available from the State of Idaho Department of Environmental Quality in accordance with Section 60-202, Idaho Code.

# Table of Contents



## List of Tables

## List of Figures

# Summary

In October 2015, the United States Environmental Protection Agency (EPA) released its new National Ambient Air Quality Standards (NAAQS) for ground-level ozone, which was decreased from 75 parts per billion (ppb) to the current 70 ppb. Accordingly, the Idaho Department of Environmental Quality (DEQ) modified its rule for crop residue burning (CRB) that allows farmers to burn their crop residues when ozone levels are not exceeding, or expected to exceed, 90% (rather than 75% based on DEQ's previous rule) of the updated ozone NAAQS. As part of a State Implementation Plan (SIP) demonstration, DEQ conducted a comprehensive photochemical modeling study to investigate the impact of Idaho's crop residue burning on ozone concentrations and to quantitatively assess if the revised Idaho CRB rule is still protective of the ozone NAAQS.

The meteorological data can significantly affect the model results of photochemical transport modeling. Our CRB modeling study used meteorological simulations of Weather Research and Forecasting (WRF) model that were subsequently processed by the Meteorology-Chemistry Interface Processor (MCIP). It is crucial to assess if the meteorological data are adequate for subsequent air quality simulations.

The meteorological simulations were evaluated by comparing calculated statistics against model performance benchmarks for both complex and simple terrain conditions, which were developed based on many "good" prognostic model simulations. The evaluations were conducted using the EPA's Atmospheric Model Evaluation Tool (AMET) for two episodes selected for the simulations in this study:

1. Episode #1 was July 8–September 26, 2013, which is the major episode for assessing the CRB impacts on ozone concentrations
2. Episode #2 was August 6–15, 2015. This episode was selected primarily to improve the simulation of fire plume rise and thus the fire impacts on air quality.

The model performance was first evaluated using observational data at all stations throughout the model domain ingested into the AMET program by the NCEP Meteorological Assimilation Data Ingest System (MADIS) system. Quantitative evaluation of domain-wide surface temperature, wind speed, and wind direction in the 2013 episode showed that the statistics values did not exceeded the model performance benchmarks for complex terrain conditions, which are appropriate for use in this study since the simulations cover a very complex terrain with many mountain ranges including the Rocky Mountains. To more closely concentrate on model performance for the Idaho region, the meteorological performance was then evaluated at high-quality National Weather Service sites in Idaho and in portions of other states near Idaho. Again, the statistics did not exceed the benchmarks for complex terrain conditions. Similar evaluations were conducted for the 2015 episode. The model evaluation showed that the meteorological model performance is adequate for use as the input to the photochemical modeling for both the 2013 and 2015 episodes for their respective objectives in this study.

# 1 Introduction

The Idaho Department of Environmental Quality (DEQ) drafted the *2017 Crop Residue Burning Ozone State Implementation Plan Revision* (2017 CRB SIP) to demonstrate that CRB, as it occurs in Idaho, has and will continue to meet all requirements of the Clean Air Act and will not cause or significantly contribute to a National Ambient Air Quality Standards (NAAQS) violation. In support of the 2017 CRB SIP, this amendment provides additional evidence that when operating under the new rule, Idaho's CRB program will not cause or contribute to a violation of the ozone NAAQS at any locations in and around Idaho.

DEQ conducted a comprehensive photochemical modeling study to investigate the impact of Idaho's crop residue burning on ozone concentrations. The CRB modeling study used meteorological simulations of Weather Research and Forecasting (WRF) model and Meteorology-Chemistry Interface Processor (MCIP). Since the meteorological data may significantly affect the model results of photochemical transport modeling, this report conducts an evaluation of the meteorological simulations to assess if they are adequate for subsequent air quality simulations.

# 2 Meteorological Simulations and Evaluation Approach

## 2.1 Model Selection

Ground-level ozone is a secondary pollutant produced primarily by chemical reactions of nitrogen oxides ($NO_x$) and volatile organic compounds (VOCs) in the presence of sunlight. The emissions from the crop residue burning can interact with $NO_x$ and VOCs from various natural and anthropogenic sources that may affect ozone concentrations. High $NO_x$ emissions primarily come from on-road and nonroad mobile as well as nonpoint sources. Large quantities of VOCs are emitted from the biogenic and nonpoint sources. In addition, the VOC emissions from the on-road and nonroad mobile sources are also very high in populated regions. The relative importance of anthropogenic and biogenic VOC emissions is dependent on the location: although biogenic emissions account for ~90% of nonmethane VOCs globally, anthropogenic emissions are more important in populated areas (Atkinson and Arey 2003; Guenther et al. 1995). Moreover, the transport of VOCs and $NO_x$ as well as their reaction products from these sources in neighboring states may also affect ozone concentrations in Idaho. Since the chemistry of $O_3$ with other pollutants is highly nonlinear, the accurate prediction of their concentrations resulting from certain sources is only possible if all relevant trace species are simulated in the same framework, including reactive radicals such as OH, photochemical processes, and cloud and secondary aerosol processes. This can only be achieved by the use of a comprehensive meteorological and chemical transport modeling system that can account for all relevant atmospheric chemistry in the target area. In addition to all these, the selection of modeling systems also needs to consider the operations of Idaho's CRB program, which uses ozone forecast by the WRF/AIRPACT5 meteorological and air quality forecasting system. The WRF/AIRPACT system can simulate complex chemical and physical processes involved in ozone chemistry and transport, so it is suitable for the CRB modeling study.

The development and operation of WRF/AIRPACT5 air quality forecasting system involve two organizations: The Northwest Regional Modeling Consortium (NWRMC) and the Northwest International Air Quality Environmental Science and Technology Consortium (NW-AIRQUEST). These two organizations are collaborative groups consisting of universities and environmental agencies in the region, including the University of Washington (UW), Washington State University (WSU), EPA, Idaho DEQ, Washington Department of Ecology, Oregon Department of Environmental Quality, the Nez Perce Tribe, and Environment and Climate Change Canada. The NWRMC funds UW to operate the WRF model (Mass et al. 2003), and the NW-AIRQUEST Consortium funds WSU to operate AIRPACT5 (Vaughan et al. 2004; Herron-Thorpe et al. 2010) and provide operational meteorological and air quality forecasts for the Pacific Northwest region. In the past 15 years, both the input files and model components of the WRF/AIRPACT system have been frequently updated to produce the best meteorological and air quality forecasts for the region. Given the more than 15 years of efforts to improve its performance for the Northwest region, DEQ believes that the WRF/AIRPACT system, which is utilized as a major forecasting tool in real-world CRB operations in Idaho, is its best option for the CRB modeling study. DEQ used the newest version of the WRF/AIRPACT modeling system in this study.

## 2.2 Meteorological Simulations

The WRF/AIRPACT5 system was developed by using complex meteorological and chemical transport models, including Weather Research and Forecasting (WRF) Model, Meteorology-Chemistry Interface Processor (MCIP), Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System, and Community Multi-scale Air Quality Model (CMAQ). This report focuses on the meteorological data output from the Meteorology-Chemistry Interface Processor (MCIP) that were driven with the simulations of the Weather Research and Forecasting (WRF) model.

Two episodes were selected for the CRB simulations in this study:

1. Episode #1 was July 8–September 26, 2013, which is the major episode for assessing the CRB impacts on ozone concentrations
2. Episode #2 was August 6–15, 2015. The original AIRPACT5 modeling system has shown poor performance in simulating the air quality impacts from fires. Therefore, this episode was selected to use the Soda wildfire, a rangeland wildfire that approximates crop residue burning and was observed by air quality monitors in the Boise region, to improve the simulation of fire plume rise and thus the fire impacts on the concentrations of air pollutants such as ozone and $PM_{2.5}$.

The WRF simulations were performed in an operational mode for both the 2013 base year and 2015 Soda fire episodes. The simulations used WRF version 3.4.1 for December 2012 through September 15, 2013, but switched to the WRF version 3.5 since September 16, 2013.

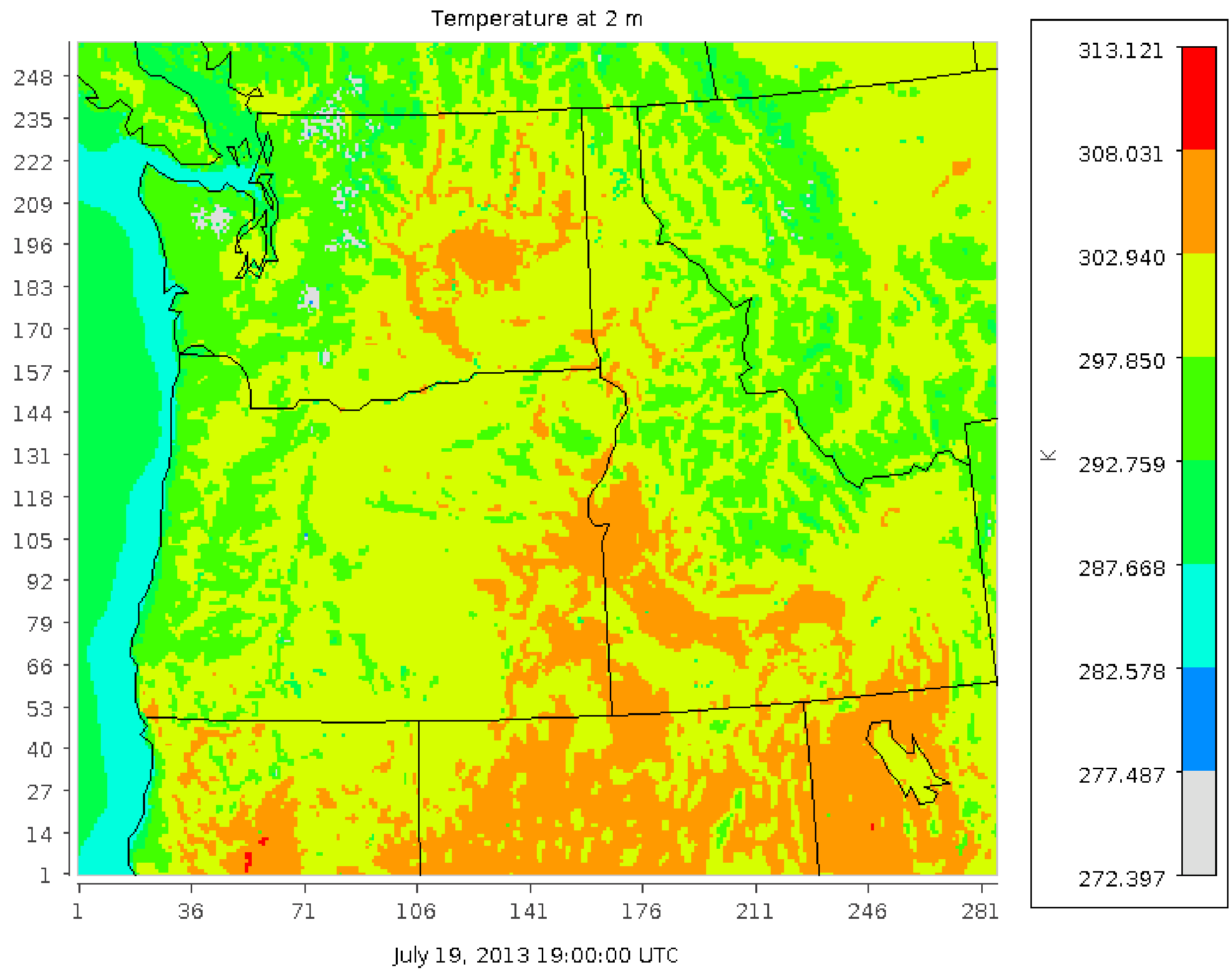



**Figure 1. The model domain with 2-m temperature on July 19 at 19:00:00 UTC.**

The WRF model makes available a suite of physics schemes, including radiation (RA), microphysics (MP), cumulus (CU), planetary boundary layer (PBL), and land-surface (LS) parameterizations. The meteorological simulations are very sensitive to different schemes (Li et al. 2015; Li et al. 2016). In the past 15 years, both the input files and model components of the WRF/AIRPACT system have been updated and optimized to produce the best meteorological simulations for the region. The parameterization schemes selected were the combination that yielded the most realistic simulations of meteorological variables. The model land use was derived from the United States Geological Survey (USGS) 24-category global dataset.

The meteorological data from the WRF model were then processed by the MCIP model (version 3.6) to generate the input files for the SMOKE/CMAQ models. Figure 1 shows the domain with 2-m temperature, which covers the entire Pacific Northwest, including all of Idaho, Oregon, and Washington, portions of California, Montana, Nevada, Utah, Wyoming, and portions of the Canadian provinces of Alberta, British Columbia, and Saskatchewan. This domain is adequate to account for the effect of regional pollution transport. The spatial resolution was set to 4 km, which can reasonably resolve the ozone formation and loss processes.

## 2.3 Statistical Benchmarks

Based upon the evaluation of tens of meteorological and air quality applications, Emery et al. (2001) proposed a set of performance "benchmarks" for meteorological model performance, which have been adopted by the regulatory meteorological modeling community. However, these benchmarks are mostly for simulations over "simple" terrain. The meteorological simulations over complex terrain, such as the Rocky Mountains, are not expected to be as good as those over simple, flat, homogeneous terrain. Therefore, Kemball-Cook et al. (2005) proposed "benchmarks" for "complex terrain" conditions. The benchmarks proposed for "simple terrain" conditions by Emery et al. (2001) and for "complex terrain" conditions by Kemball-Cook et al. (2005) are shown in Table 1.

**Table 1. Meteorological model performance benchmarks proposed by Emery et al. (2001) for simple terrain conditions and by Kemball-Cook (2005) for complex terrain conditions.**

| Parameter | Simple (✓) | Complex (✓) |
|---|---|---|
| Temperature Bias | ≤ ±0.5 K | ≤ ±2.0 K |
| Temperature Error | ≤ 2.0 K | ≤ 3.5 K |
| Mixing Ratio Bias | ≤ ±1.0 g/kg | NA |
| Mixing Ratio Error | ≤ 2.0 g/kg | NA |
| Wind Speed Bias | ≤ ±0.5 m/s | ≤ ±1.5 m/s |
| Wind Speed RMSE | ≤ 2.0 m/s | ≤ 2.5 m/s |
| Wind Direction Bias | ≤ ±10 degrees | NA |
| Wind Direction Error | ≤ 30 degrees | ≤ 55 degrees |

Statistical measures are typically calculated in the meteorological model evaluation for temperature, wind speed, and wind direction. Model performance metrics were calculated using modeled ($C_m$) and observed ($C_o$) values as well as the number of available pairs (N) (Li et al. 2013), and a few examples are given below:

Bias:

$$\mathrm{MB} = \frac{1}{N}\sum_{i=1}^{N}(C_m^i - C_o^i)$$

Error:

$$\mathrm{ME} = \frac{1}{N}\sum_{i=1}^{N}| C_m^i - C_o^i |$$

Root Mean Square Error (RMSE) is calculated as the square root of the mean squared difference in prediction-observation pairings.

$$RMSE = \left[ \frac{1}{N} \sum_{i=1}^{N} \left( C_m^i - C_o^i \right)^2 \right]^{1/2}$$

# 3 Model Performance for the 2013 Episode

Model evaluation for the meteorological variables simulated in the two episodes was conducted using the Atmospheric Model Evaluation Tool (AMET) v 1.2 (Appel et al. 2013). This tool is designed to ingest large quantities of meteorological observations and air quality observations for the purpose of evaluating the performance of MCIP and CMAQ. AMET matches the model output for particular locations to the corresponding observed values, and the pairings of modeled and observed values are then used to evaluate the model's performance. This section focuses on the model performance for the 2013 episode, and section 4 describes the performance of meteorological simulations for the 2015 episode.

## 3.1 Sites in the Entire Domain

The domain of the CRB modeling study, shown in Figure 1, covers a very complex terrain with many mountain ranges including the Rocky Mountains. It is, therefore, appropriate to compare the model performance with the benchmarks for complex terrain conditions proposed by Kemball-Cook et al. (2005), which are shown in Table 1. All the variables (i.e., surface temperature, wind speed, and wind direction) listed in the benchmarks for complex terrain conditions are quantitatively evaluated across the domain.

### 3.1.1 Surface Temperature

Figure 2 and Figure 3 show, respectively, the temperature bias and error calculated using data for all sites in the domain during the 2013 episode. The figures illustrate that on average, the biases and errors are small across the entire domain. Table 2 shows the benchmarks for both simple and complex terrains along with the calculated statistics of surface temperature for all sites in the domain during the 2013 episode. The calculated temperature bias is smaller than its benchmark for both simple and complex terrain conditions. In Table 2, the temperature error calculated using data for all sites in the domain during the 2013 episode is far below its benchmark for complex terrain conditions. It is evident that the model evaluation shows that the model performance for temperature well meets its benchmarks for complex terrain conditions, indicating adequate performance for use as the input to the photochemical modeling in this study.

**Table 2. Statistics of surface temperature for all sites in the domain during the 2013 episode.**

| Parameter | Simple (✓) | Complex (✓) | All Domain |
|---|---|---|---|
| Temperature Bias | ≤ ±0.5 K | ≤ ±2.0 K | -0.16 (✓) |
| Temperature Error | ≤ 2.0 K | ≤ 3.5 K | 2.15 (✓) |

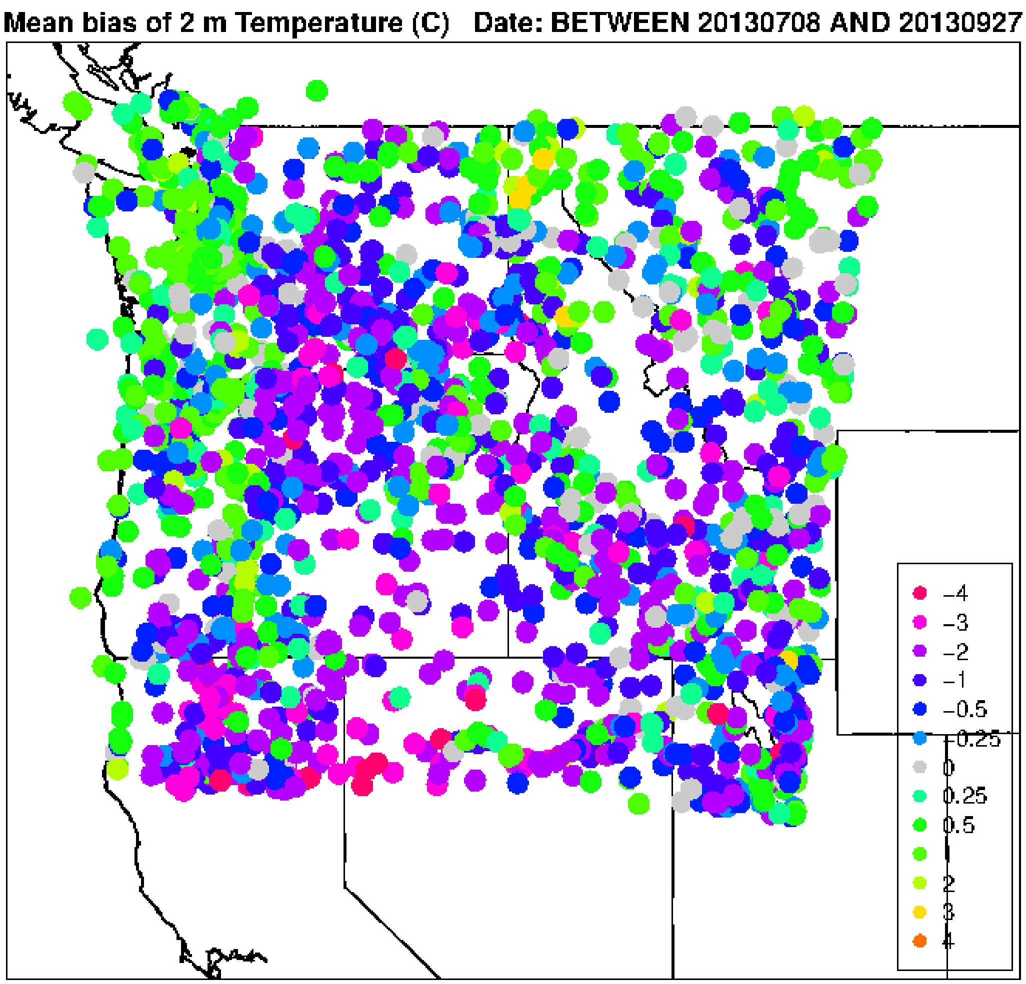



**Figure 2. Bias of surface temperature for all sites in the domain during the 2013 episode.**

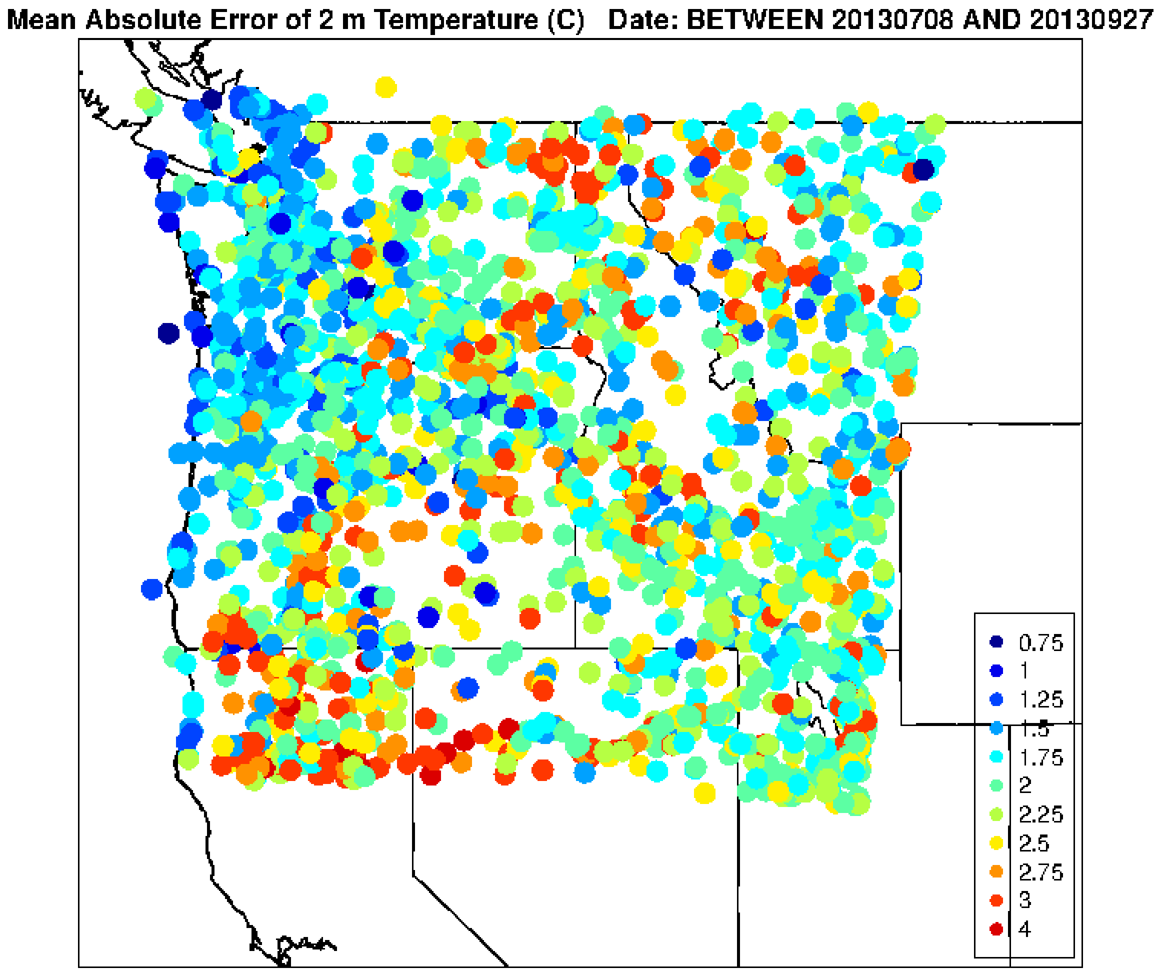



**Figure 3. Error of surface temperature for all sites in the domain during the 2013 episode.**

Figure 4 shows a summary plot of surface temperature for all sites in the domain during the 2013 episode. This summary plot contains an extensive list of model performance metrics and displays for all sites across the domain. These performance metrics include the number of data points used, correlation coefficient, standard deviation, and three types of bias and error. Graphical displays include a scatter plot, a comparison of the bias and mean absolute error (MAE) as a function of the observed quantity, and box plots of the distribution of the observed and predicted temperature. All the model performance metrics and graphical displays confirm that the simulated surface temperature compares well with the observations at sites across the domain.

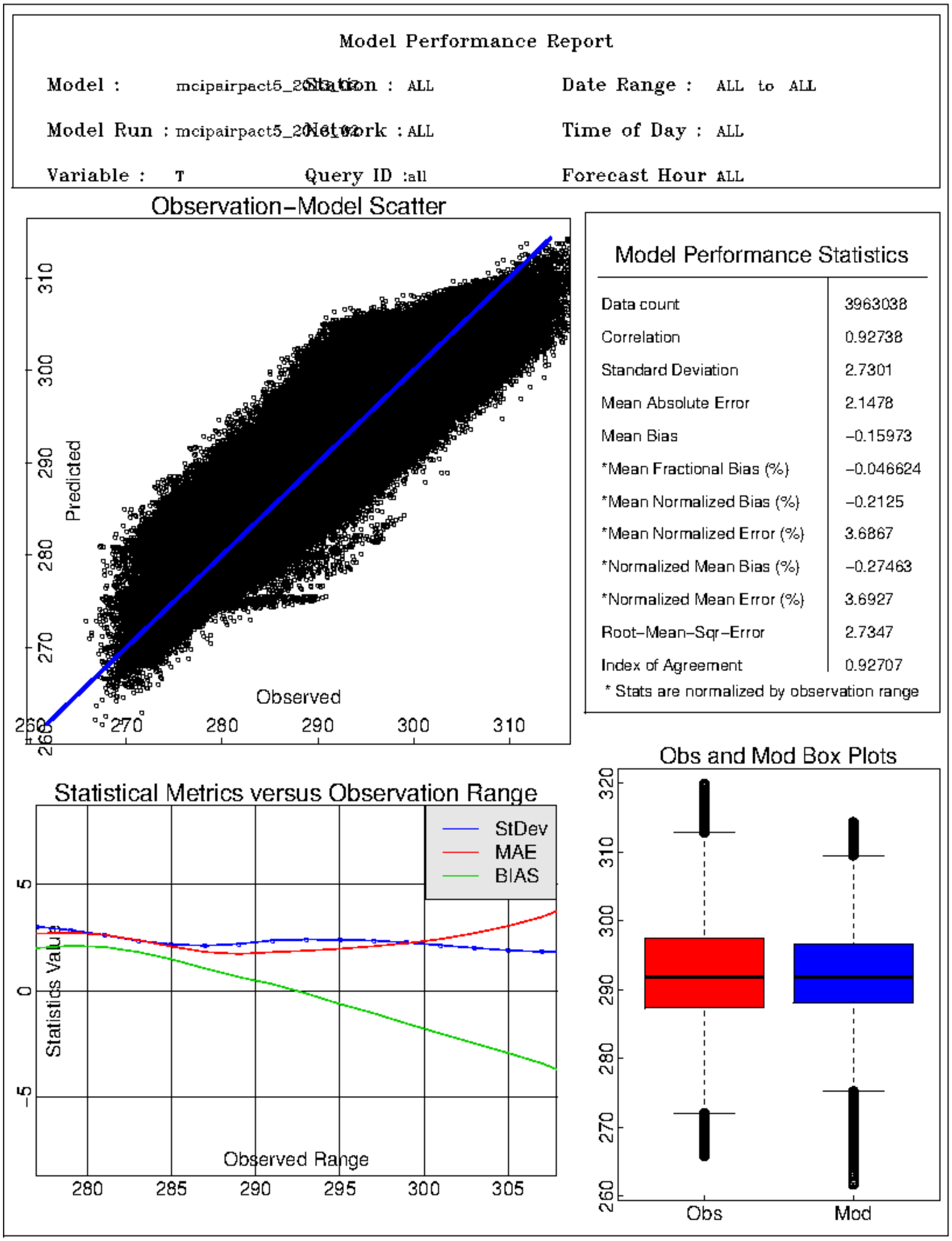



**Figure 4. Surface temperature for all sites in the domain during the 2013 episode.**

### 3.1.2 Wind Speed

Figure 5 and Figure 6 show, respectively, the bias and RMSE of wind speed for all sites in the domain during the 2013 episode. The figures illustrate that on average, the biases and RMSE are small across the entire domain. Table 3 shows the benchmarks for both simple and complex terrain conditions along with the calculated statistics of wind speed for all sites in the domain during the 2013 episode. Both bias and RMSE of wind speed are far below its benchmarks for complex terrain conditions, indicating that the model performance for wind speed meets its benchmarks for use in photochemical modeling of this study.

**Table 3. Statistics of wind speed for all sites in the domain during the 2013 episode.**

| Parameter | Simple (✓) | Complex (✓) | All Domain (m/s) |
|---|---|---|---|
| Wind Speed Bias | ≤ ±0.5 m/s | ≤ ±1.5 m/s | 0.58 (✓) |
| Wind Speed RMSE | ≤ 2.0 m/s | ≤ 2.5 m/s | 2.05 (✓) |

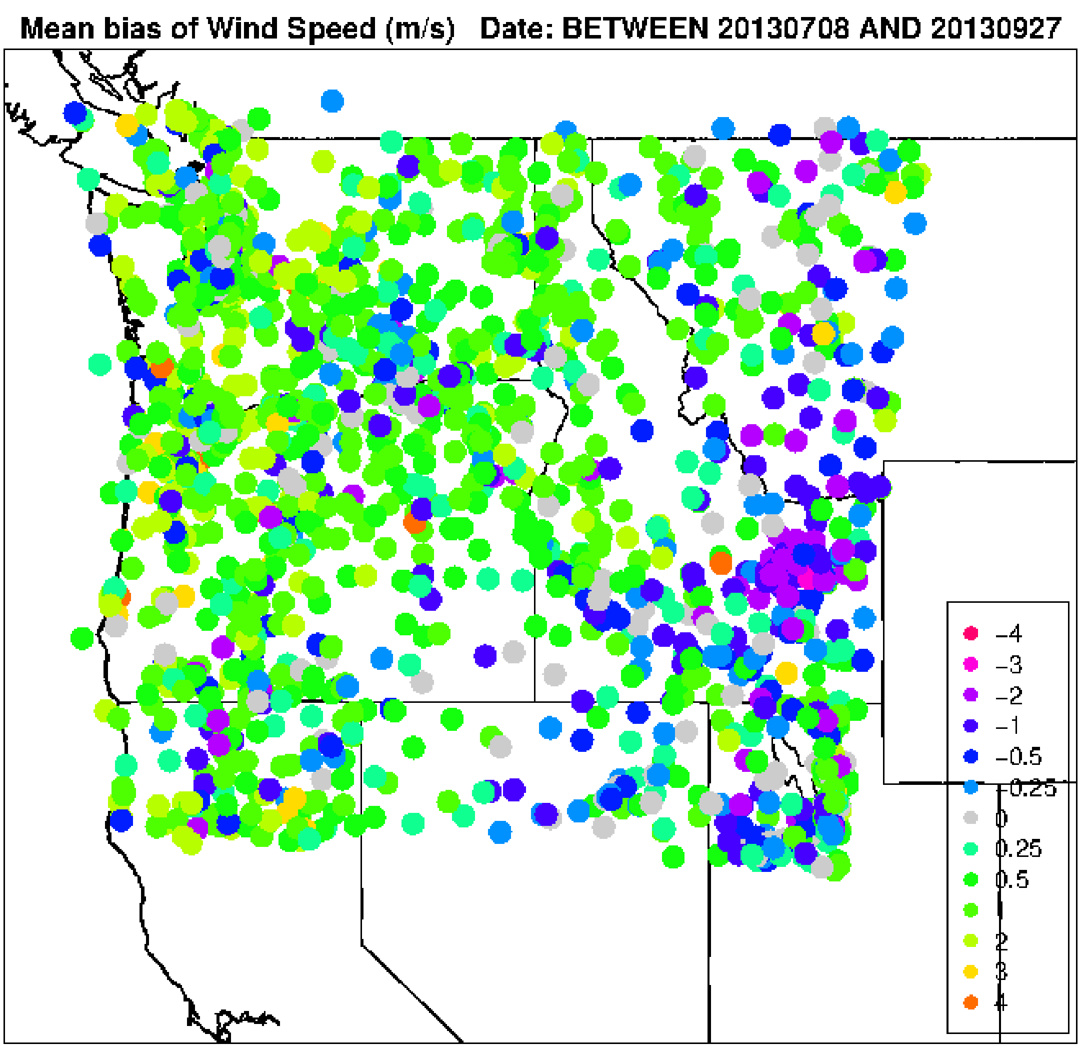



**Figure 5. Bias of weed speed for all sites in the domain during the 2013 episode.**

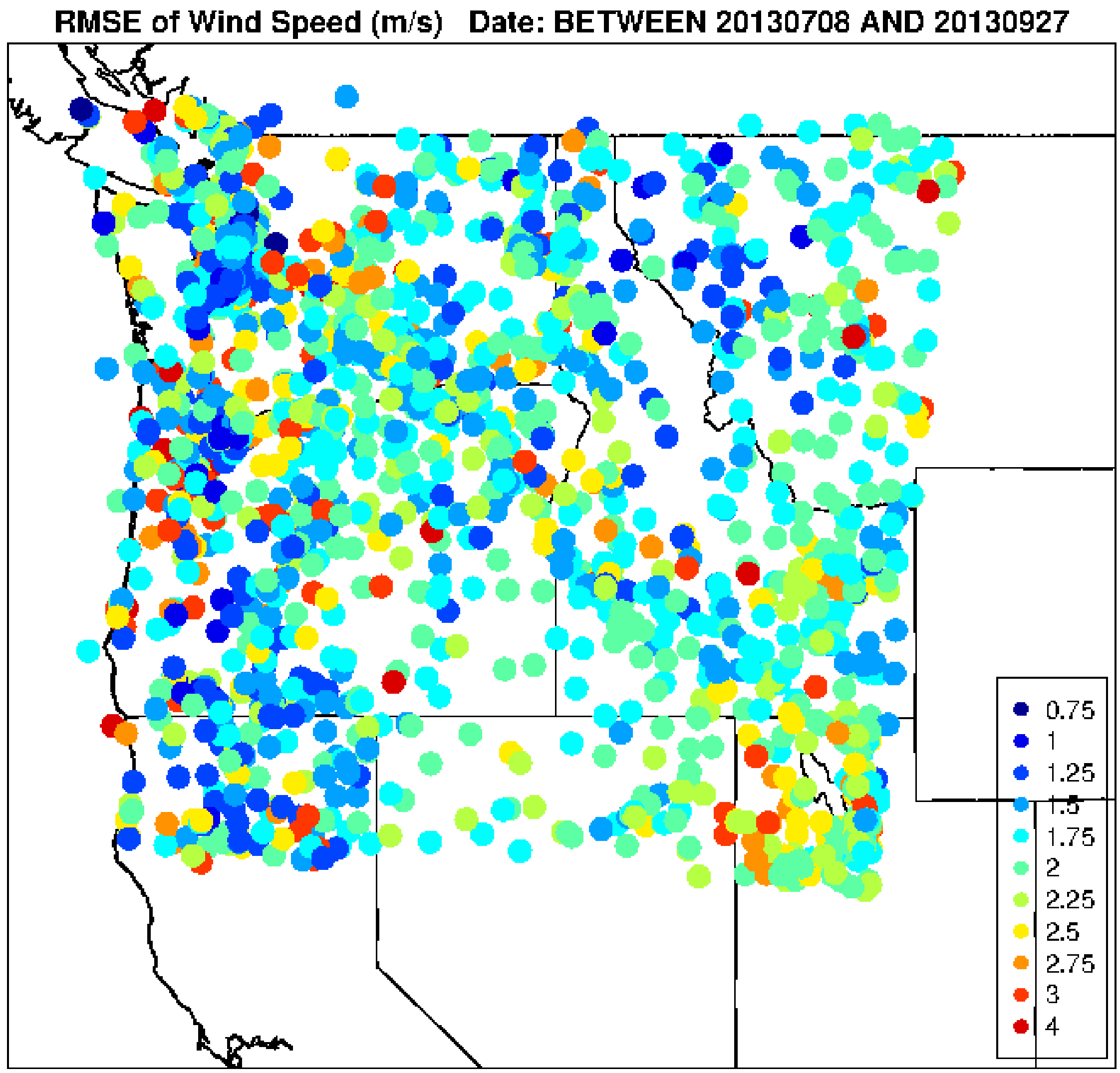



**Figure 6. RMSE of wind speed for all sites in the domain during the 2013 episode.**

Figure 7 shows a summary plot of wind speed for all sites in the domain during the 2013 episode. Again, all the model performance metrics and graphical displays demonstrate that the simulated wind speed compares well with the observations across the domain.

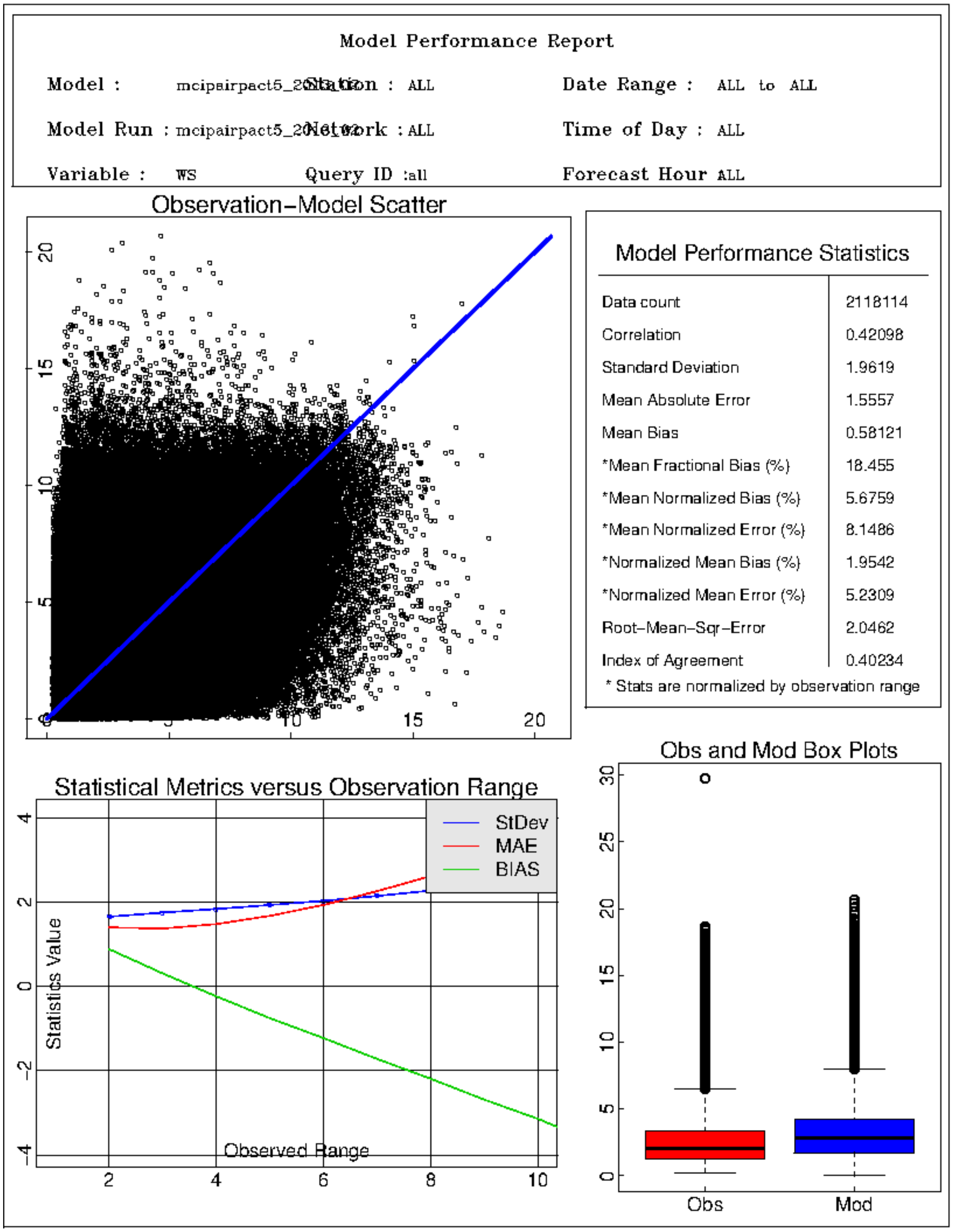



**Figure 7. Wind speed for all sites in the domain during the 2013 episode.**

### 3.1.3 Wind Direction

Figure 8 and Figure 9 show, respectively, the bias and error of wind direction for all sites in the domain during the 2013 episode. Table 4 shows the benchmarks for both simple and complex terrain conditions along with the calculated statistics of wind direction across the domain during the 2013 episode. The calculated bias is even smaller than its benchmark for simple terrain conditions. While the error of wind direction is relatively large, it is still marginally below its benchmark for complex terrain conditions. The summary plot shown in Figure 10 also indicates that the model performance for wind direction meets its benchmarks for complex terrain conditions.

It should be noted that wind direction error may affect the photochemical model performance in comparison to fixed ozone monitoring sites. However, if that evaluation is adequate, then wind direction error is not a critical parameter because the crux of DEQ's modeling is in the unmonitored areas where wind direction is largely irrelevant—DEQ is evaluating all impacts due to CRB burning that occur anywhere in the domain and the direction of the wind and resulting locations of the impacts are relatively unimportant for that purpose.

**Table 4. Statistics of wind direction for all sites in the domain during the 2013 episode.**

| Parameter | Simple (✓) | Complex (✓) | All Domain |
|---|---|---|---|
| Wind Direction Bias | ≤ ±10 degrees | NA | 6.8 (✓) |
| Wind Direction Error | ≤ 30 degrees | ≤ 55 degrees | 54.7(✓) |

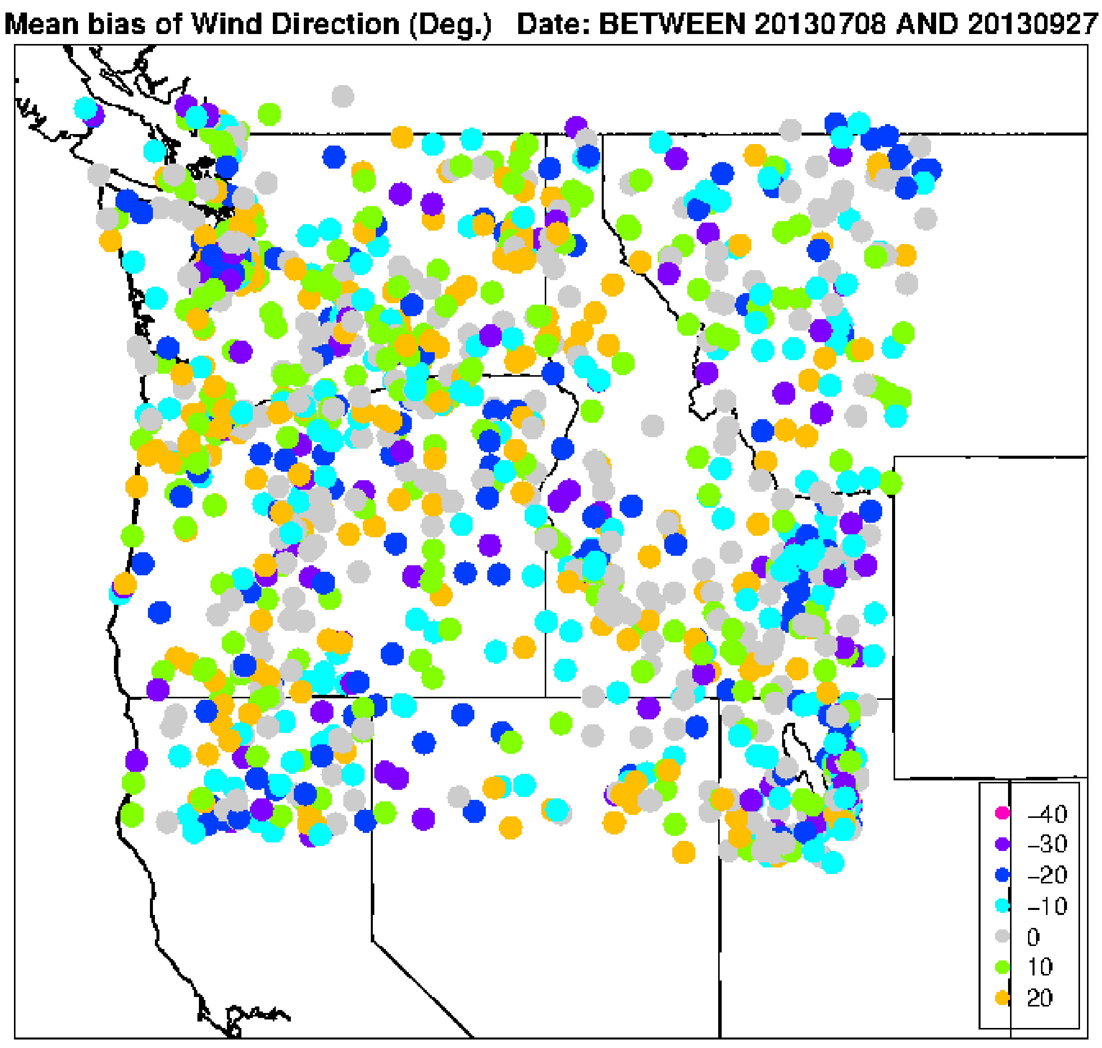



**Figure 8. Bias of wind direction for all sites in the domain during the 2013 episode.**

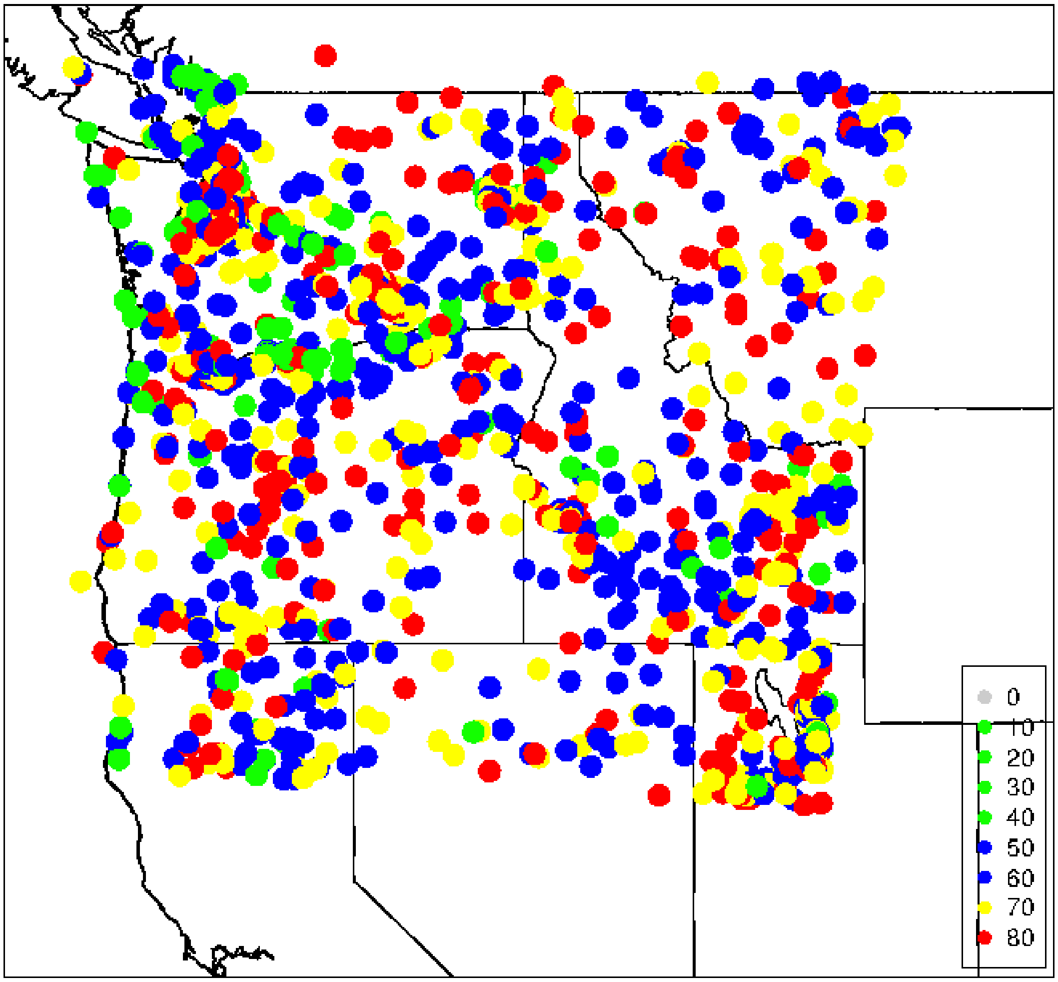



**Figure 9. Error of wind direction (Deg.) for all sites in the domain during the 2013 episode.**

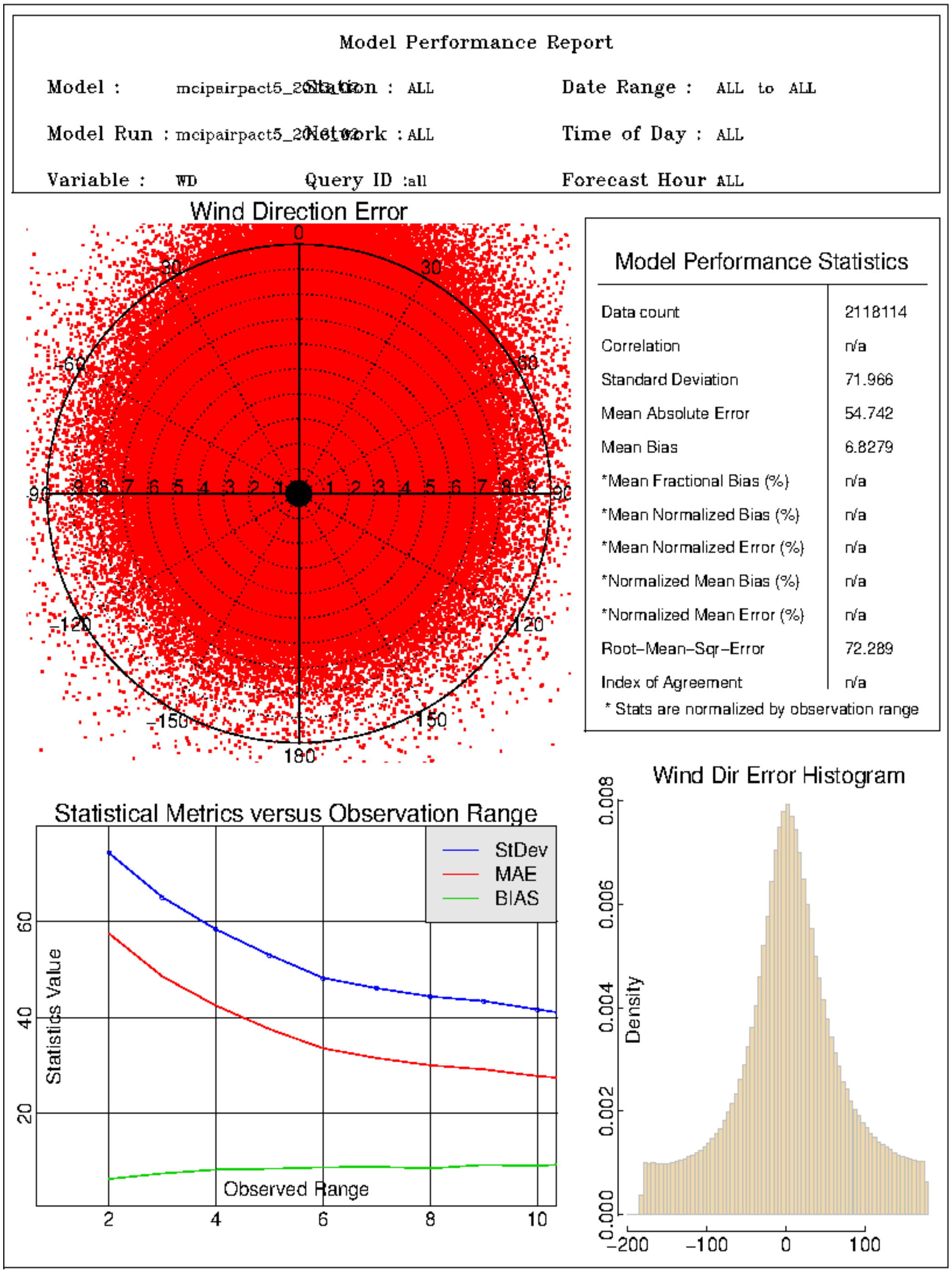



**Figure 10. Wind direction for all sites in the domain during the 2013 episode.**

## 3.2 Idaho and Neighboring NWS Stations

To assess the model performance for the Idaho region, all the variables (i.e., surface temperature, wind speed, and wind direction) listed in the benchmarks for complex terrain conditions proposed by Kemball-Cook et al. (2005) are evaluated at 24 National Weather Service sites in Idaho and in portions of other states near Idaho. The National Weather Service sites were selected because of their high-quality measurement data.

### 3.2.1 Surface Temperature

Figure 11 and Figure 12 show, respectively, the temperature bias and error calculated using data observed at the National Weather Service sites around the Idaho region during the 2013 episode. The figures show that the biases and errors are small at the Idaho sites. Table 5 compares the calculated statistics of surface temperature for the Idaho sites during the 2013 episode against the benchmarks for both simple and complex terrain conditions. The calculated temperature bias is smaller than its benchmark for both simple and complex terrain conditions, and the temperature error is far below its benchmark for complex terrains. The model performance for temperature at the Idaho sites easily meets the benchmarks for complex terrain conditions, indicating good performance for use as the input to the photochemical modeling in this study.

**Table 5. Statistics of surface temperature for the Idaho sites during the 2013 episode.**

| Parameter | Simple (✓) | Complex (✓) | Idaho Sites (K) |
|---|---|---|---|
| Temperature Bias | ≤ ±0.5 K | ≤ ±2.0 K | -0.24 (✓) |
| Temperature Error | ≤ 2.0 K | ≤ 3.5 K | 2.15 (✓) |

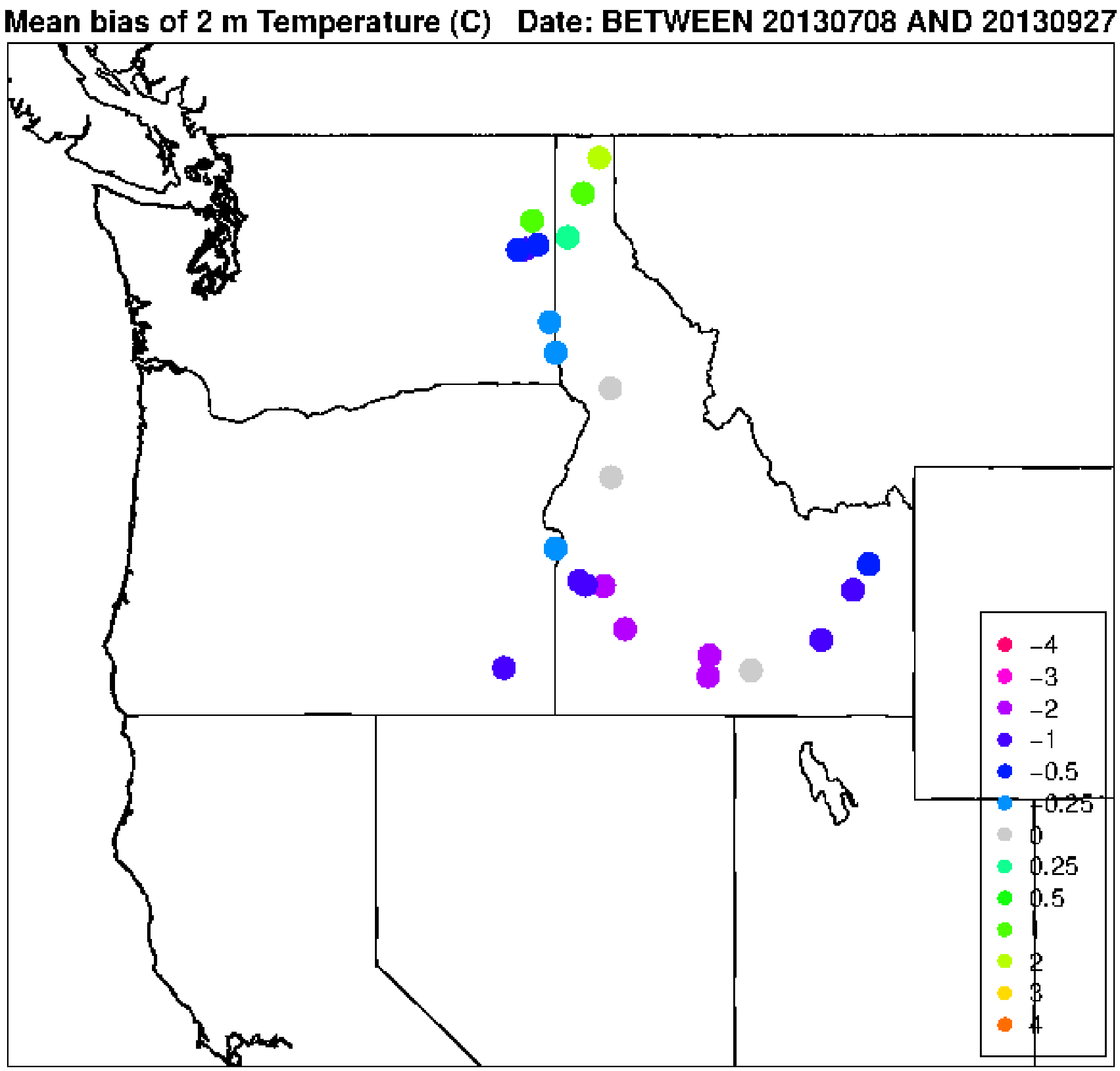



**Figure 11. Bias of surface temperature for the Idaho sites in the domain during the 2013 episode.**

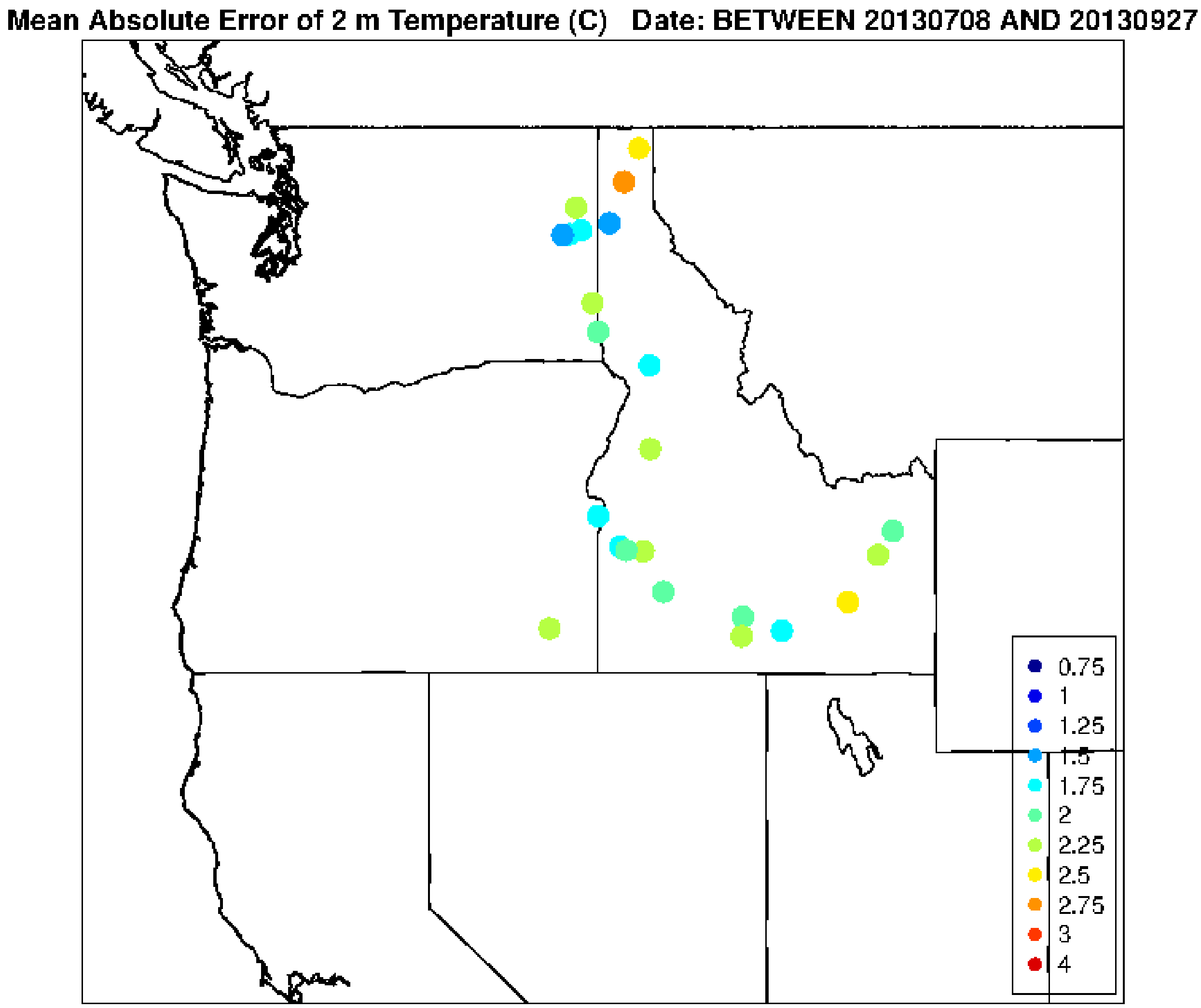



**Figure 12. Error of surface temperature for the Idaho sites in the domain during the 2013 episode.**

Figure 13 shows a summary plot of surface temperature for the Idaho sites during the 2013 episode. Again, all the model performance metrics and graphical displays show that the simulated surface temperature compares well with the observations at the Idaho sites.

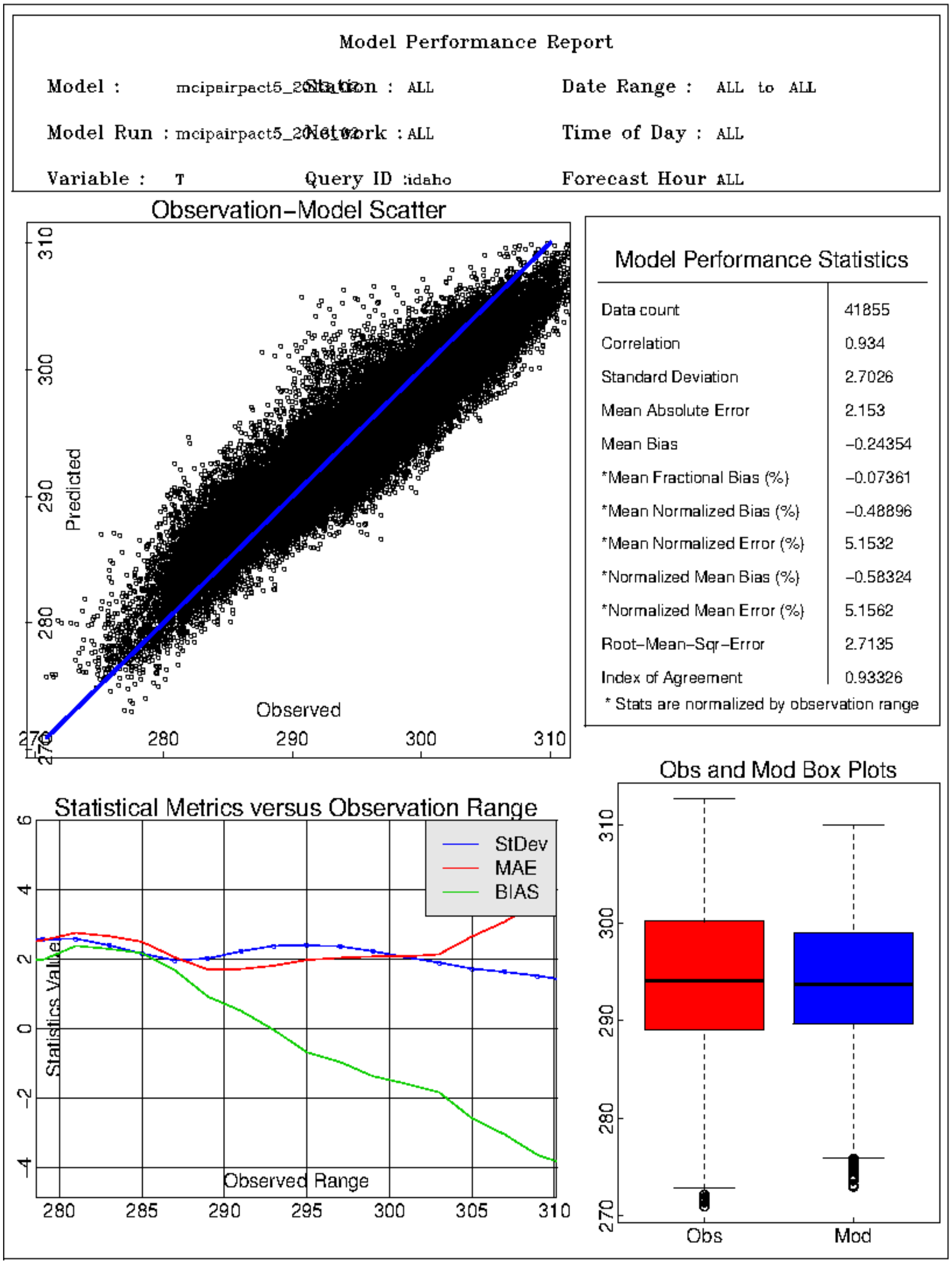



**Figure 13. Surface temperature for the Idaho sites in the domain during the 2013 episode.**

### 3.2.2 Wind Speed

Figure 14 and Figure 15 show, respectively, the bias and RMSE of wind speed for the Idaho sites during the 2013 episode. The figures illustrate that on average, the biases and RMSE are small across the Idaho sites. Table 6 shows that both bias and RMSE of wind speed are below its benchmark for complex terrains, indicating that the model performance for wind speed meets its benchmarks for use in subsequent chemical transport modeling.

**Table 6. Statistics of wind speed for the Idaho sites during the 2013 episode.**

| Parameter | Simple (✓) | Complex (✓) | Idaho Sites (m/s) |
|---|---|---|---|
| Wind Speed Bias | ≤ ±0.5 m/s | ≤ ±1.5 m/s | 0.58 (✓) |
| Wind Speed RMSE | ≤ 2.0 m/s | ≤ 2.5 m/s | 2.04 (✓) |

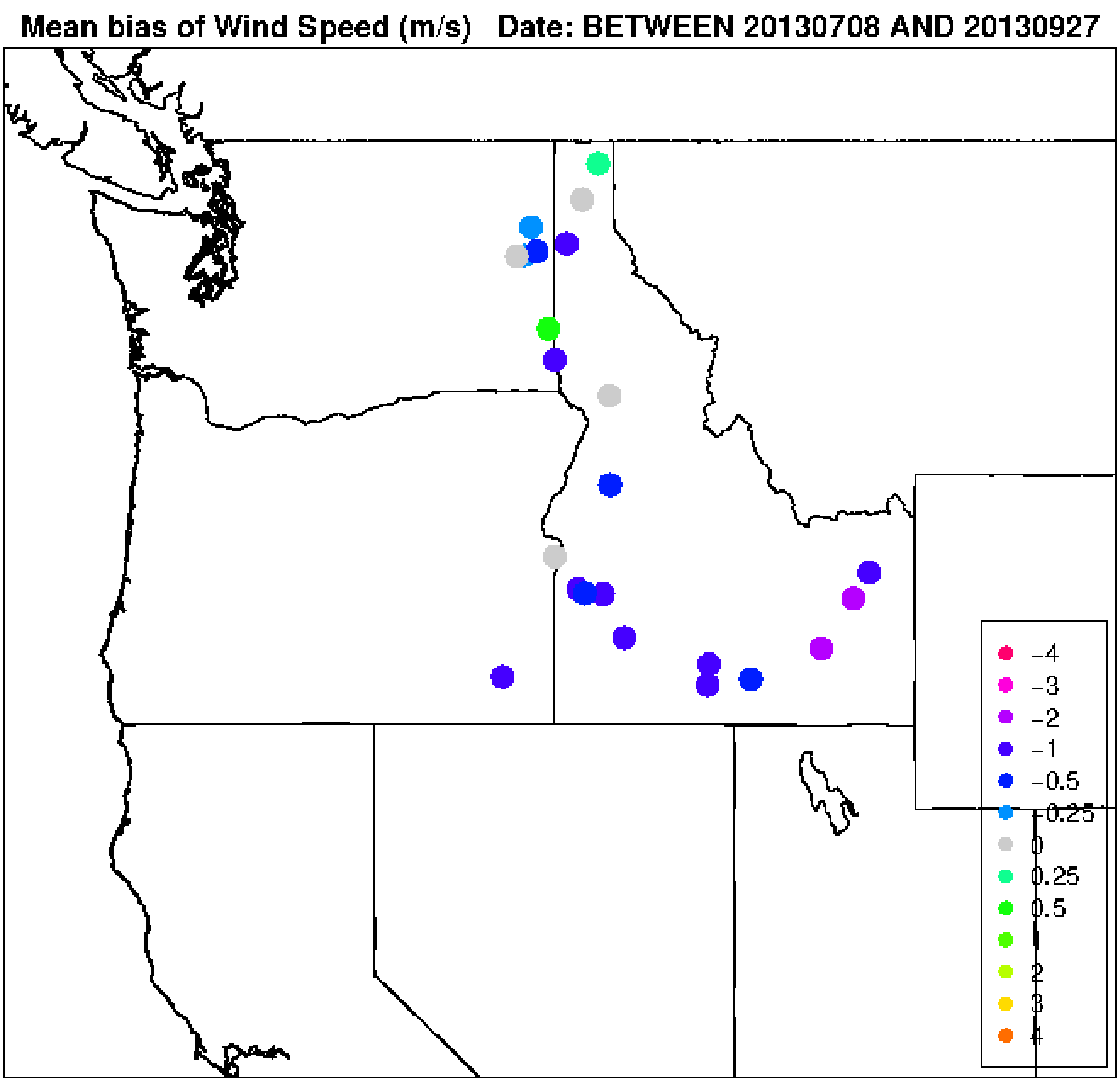



**Figure 14. Bias of wind speed for the Idaho sites in the domain during the 2013 episode.**

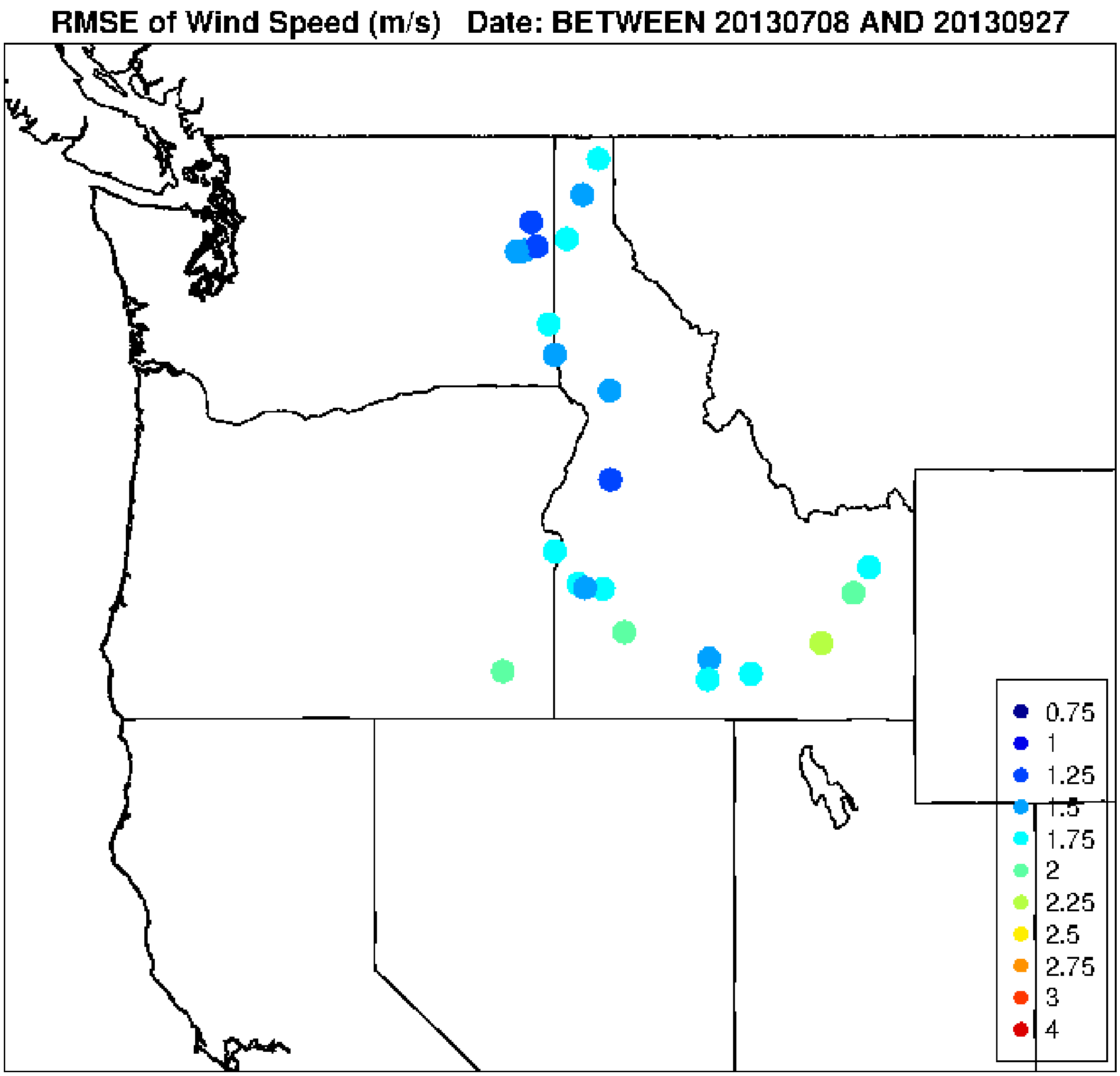



**Figure 15. RMSE of wind speed for the Idaho sites in the domain during the 2013 episode.**

Figure 16 shows a summary plot of wind speed for the Idaho sites during the 2013 episode. Again, all the model performance metrics and graphical displays demonstrate that the simulated wind speed compares well with the observations at the Idaho sites.

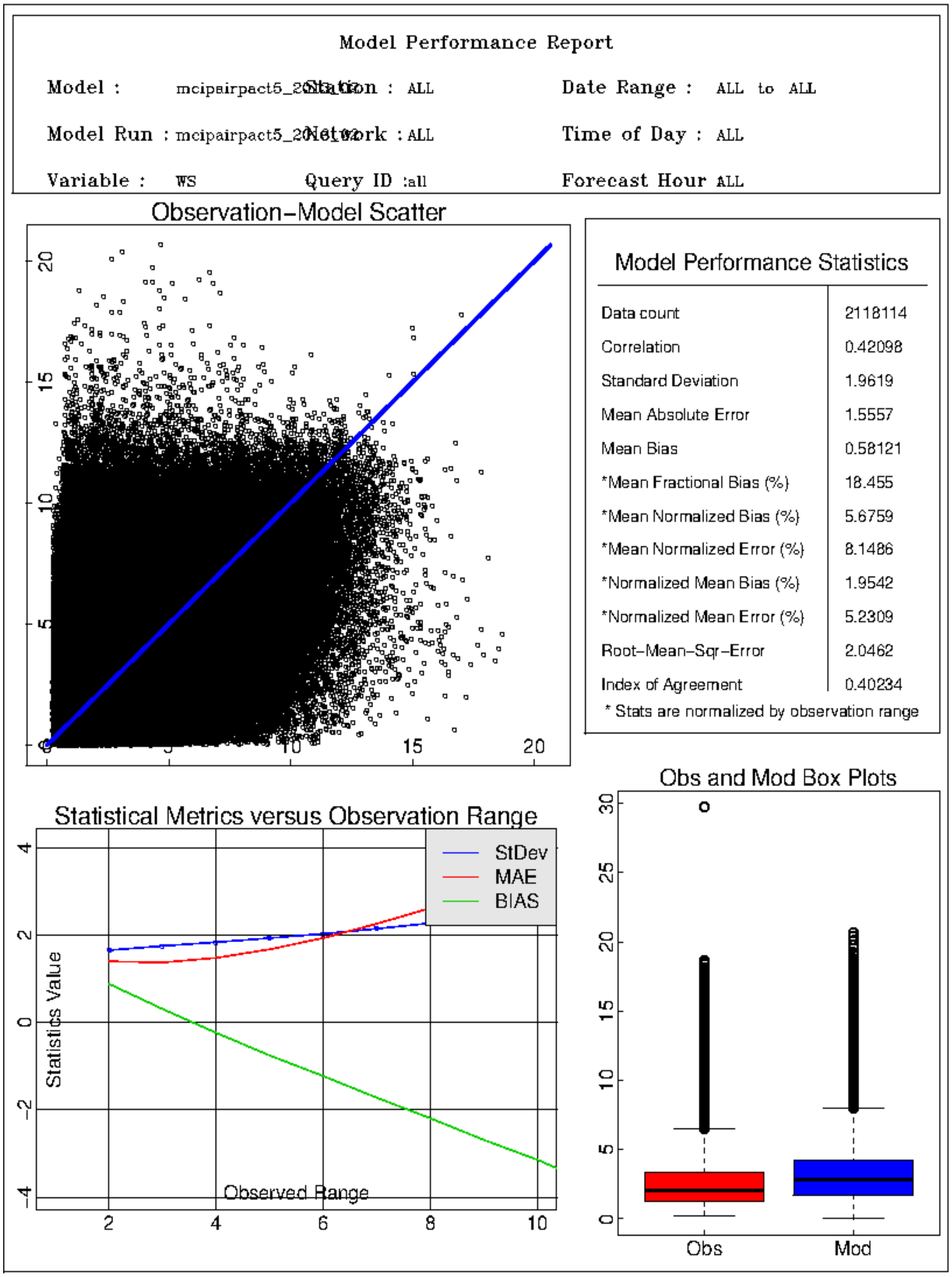



**Figure 16. Wind speed for the Idaho sites in the domain during the 2013 episode.**

### 3.2.3 Wind Direction

Figure 17 and Figure 18 show, respectively, the bias and error of wind direction for the Idaho sites during the 2013 episode. Table 7 compares the calculated statistics of wind direction for the Idaho sites during the 2013 episode with the benchmarks for both simple and complex terrain conditions. The calculated bias is a little bigger than its benchmark for simple terrain conditions, but no criterion was proposed for wind direction bias under complex terrain conditions. While the error of wind direction is relatively large, it is still below its benchmark for complex terrain conditions. The summary plot shown in Figure 19 also indicates that the model performance for wind direction meets its benchmarks available for complex terrain conditions.

**Table 7. Statistics of wind direction for the Idaho sites during the 2013 episode.**

| Parameter | Simple (✓) | Complex (✓) | Idaho Sites |
|---|---|---|---|
| Wind Direction Bias | ≤ ±10 degrees | NA | 12.5 (✓) |
| Wind Direction Error | ≤ 30 degrees | ≤ 55 degrees | 50.7(✓) |

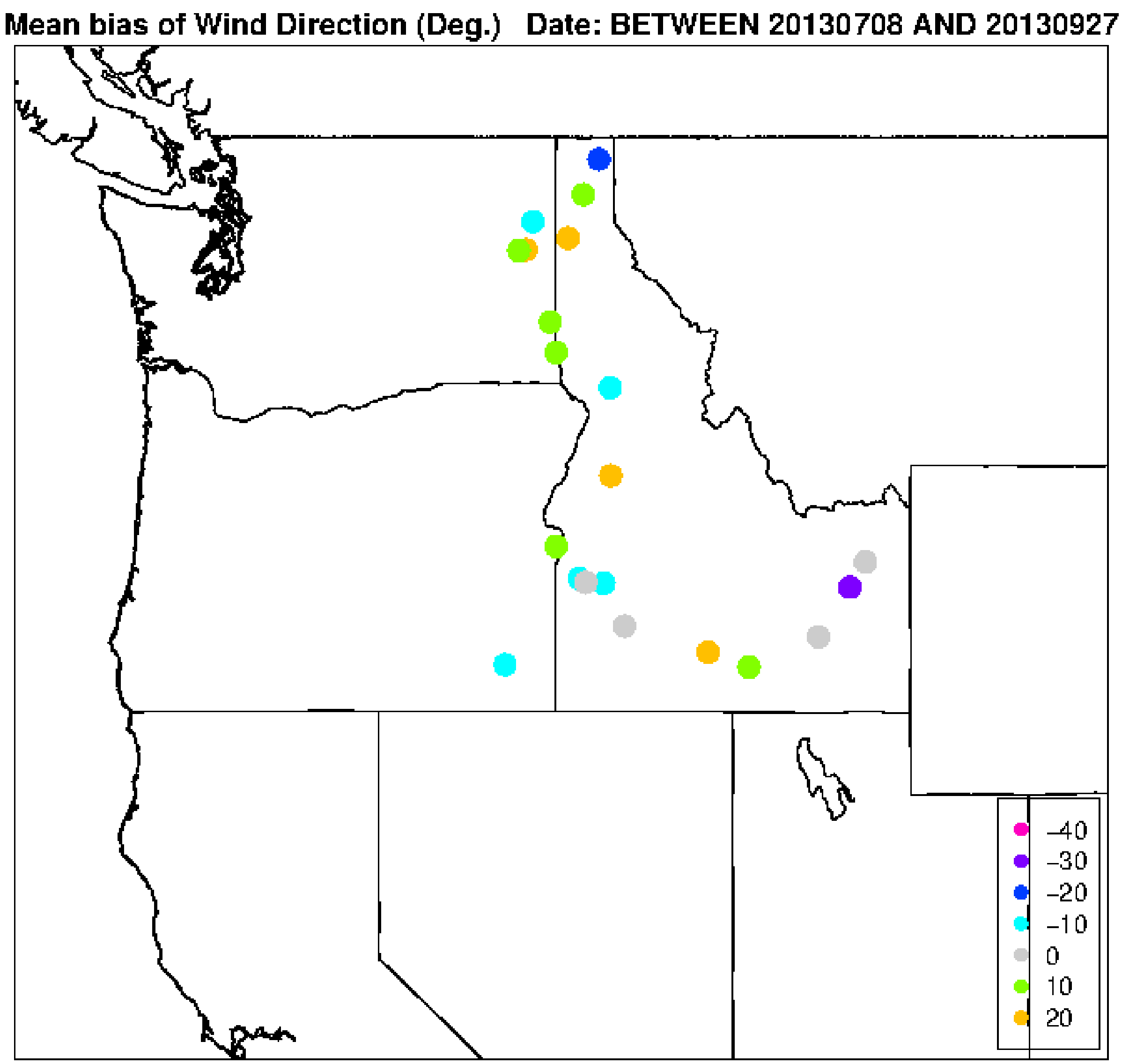



**Figure 17. Bias of wind direction for the Idaho sites in the domain during the 2013 episode.**

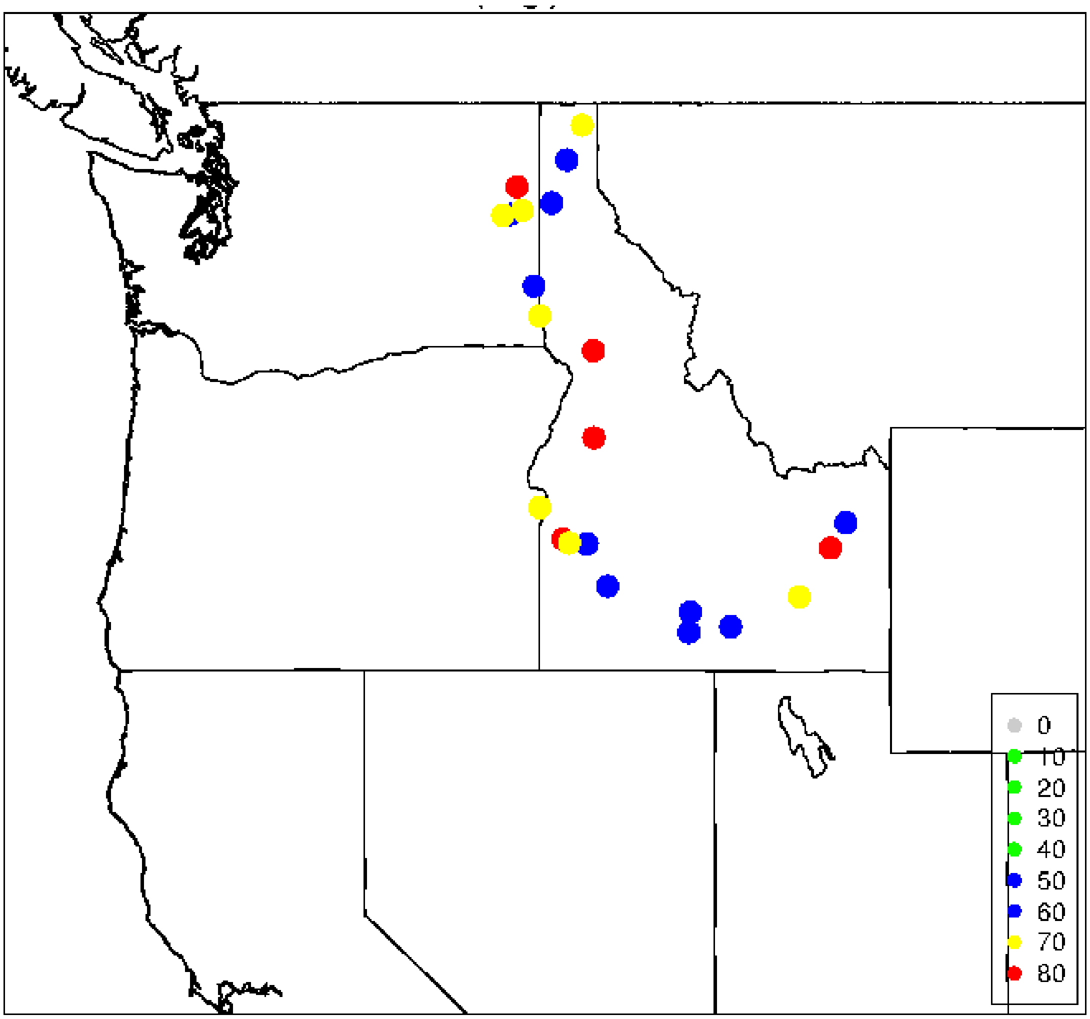



**Figure 18. Error of wind direction (Deg.) for the Idaho sites in the domain during the 2013 episode.**

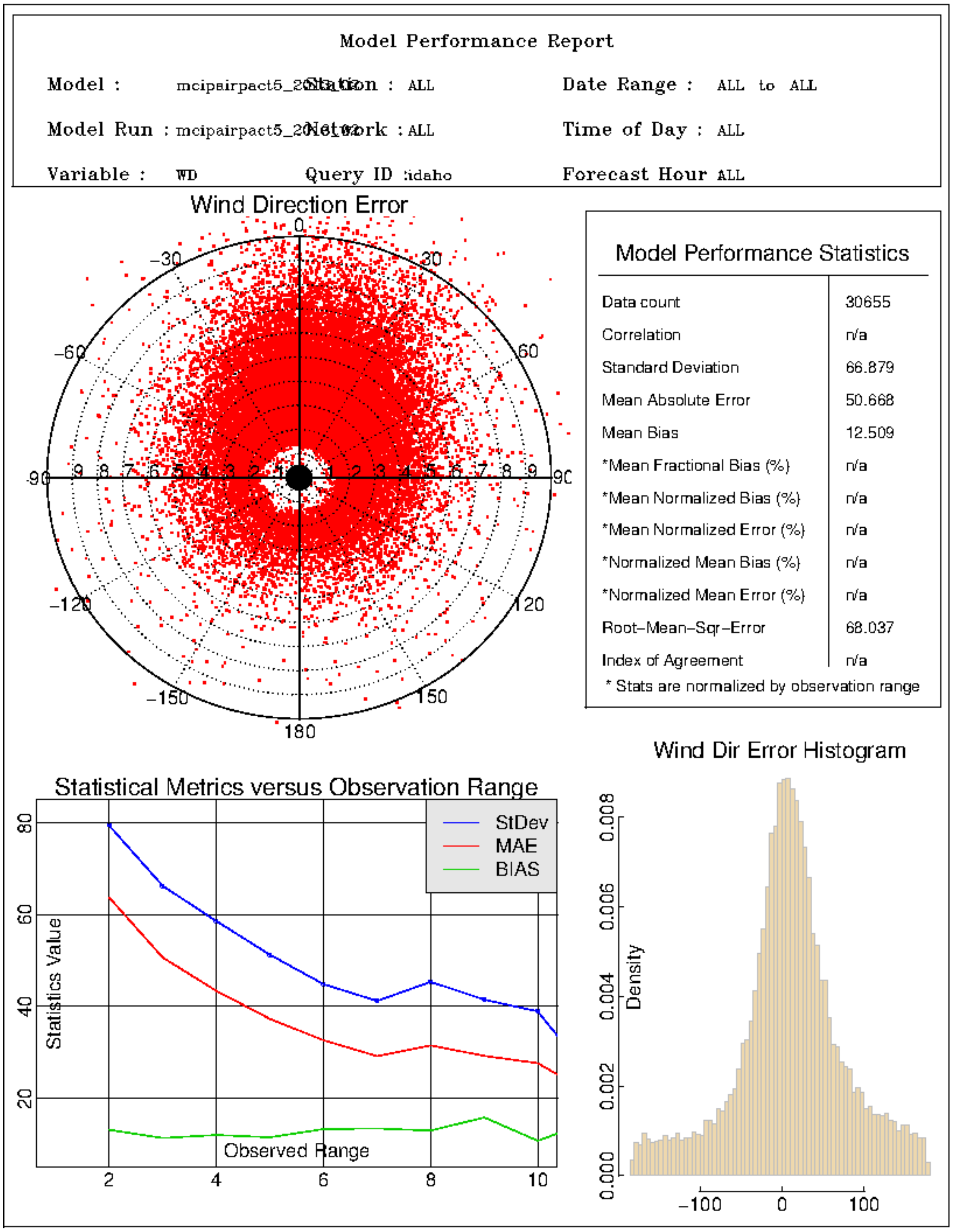



**Figure 19. Wind direction for the Idaho sites in the domain during the 2013 episode.**

## 3.3 Summary of the 2013 Meteorological Data

The model performance for the 2013 episode was first evaluated using observational data at all stations throughout the model domain ingested into EPA's Atmospheric Model Evaluation Tool (AMET) program by the NCEP Meteorological Assimilation Data Ingest System (MADIS). Quantitative evaluation of domain-wide surface temperature, wind speed, and wind direction is shown in Table 8, which reveals that all the calculated statistics values have met the model performance benchmarks available for complex terrain conditions. Some statistical measures, such as temperature bias and wind direction bias, have even met the benchmarks for simple terrain conditions. To better reflect the simulations for the Idaho region, Table 8 also shows the meteorological performance for the high-quality National Weather Service sites in Idaho and in portions of other states near Idaho. Again, all the statistics calculated for the Idaho region have met the benchmarks available for complex terrain conditions. Overall, the model evaluation demonstrates that the meteorological model performance is adequate for use as the input to the photochemical modeling in this study.

**Table 8. Meteorological model performance for the 2013 episode and benchmarks for simple and complex terrain conditions, adopted by Emery et al. (2001) for simple terrain and by Kemball-Cook et al. (2005) for complex terrain.**

| Parameter | Model Performance | | Benchmarks | |
|---|---|---|---|---|
| | Entire Domain | Idaho Region | Simple Terrain | Complex Terrain |
| Temperature Bias | -0.16 | -0.24 | ≤ ±0.5 K | ≤ ±2.0 K |
| Temperature Error | 2.15 | 2.15 | ≤ 2.0 K | ≤ 3.5 K |
| Mixing Ratio Bias | NA | NA | ≤ ±1.0 g/kg | NA |
| Mixing Ratio Error | NA | NA | ≤ 2.0 g/kg | NA |
| Wind Speed Bias | 0.58 | -0.43 | ≤ ±0.5 m/s | ≤ ±1.5 m/s |
| Wind Speed RMSE | 2.05 | 1.82 | ≤ 2.0 m/s | ≤ 2.5 m/s |
| Wind Direction Bias | 6.83 | 12.5 | ≤ ±10 degrees | NA |
| Wind Direction Error | 54.74 | 50.7 | ≤ 30 degrees | ≤ 55 degrees |

# 4 Model Performance for the 2015 Episode

This section focuses on the performance of meteorological simulations for the 2015 episode.

## 4.1 Sites in the Entire Domain

All the variables (i.e., surface temperature, wind speed, and wind direction) listed in the benchmarks for complex terrain conditions are quantitatively evaluated across the domain for the 2015 episode.

### 4.1.1 Surface Temperature

Figure 20 and Figure 21 show, respectively, the temperature bias and error calculated using data for all sites in the domain during the 2015 episode. The figures illustrate that the biases and errors are small across the entire domain. Table 9 shows the benchmarks for both simple and complex terrain conditions along with the calculated statistics of surface temperature for all sites in the domain during the 2015 episode. The calculated temperature bias is smaller than its benchmark for both simple and complex terrain conditions. In Table 9, the temperature error calculated using data for all sites in the domain during the 2015 episode is far below its benchmark for complex terrain conditions. In short, the simulated temperature meets its benchmarks for complex terrain conditions, indicating adequate performance for use as the input to the photochemical modeling in this study.

**Table 9. Statistics of surface temperature for all sites in the domain during the 2015 episode.**

| Parameter | Simple (✓) | Complex (✓) | All Domain |
|---|---|---|---|
| Temperature Bias | ≤ ±0.5 K | ≤ ±2.0 K | -0.06 (✓) |
| Temperature Error | ≤ 2.0 K | ≤ 3.5 K | 2.15 (✓) |

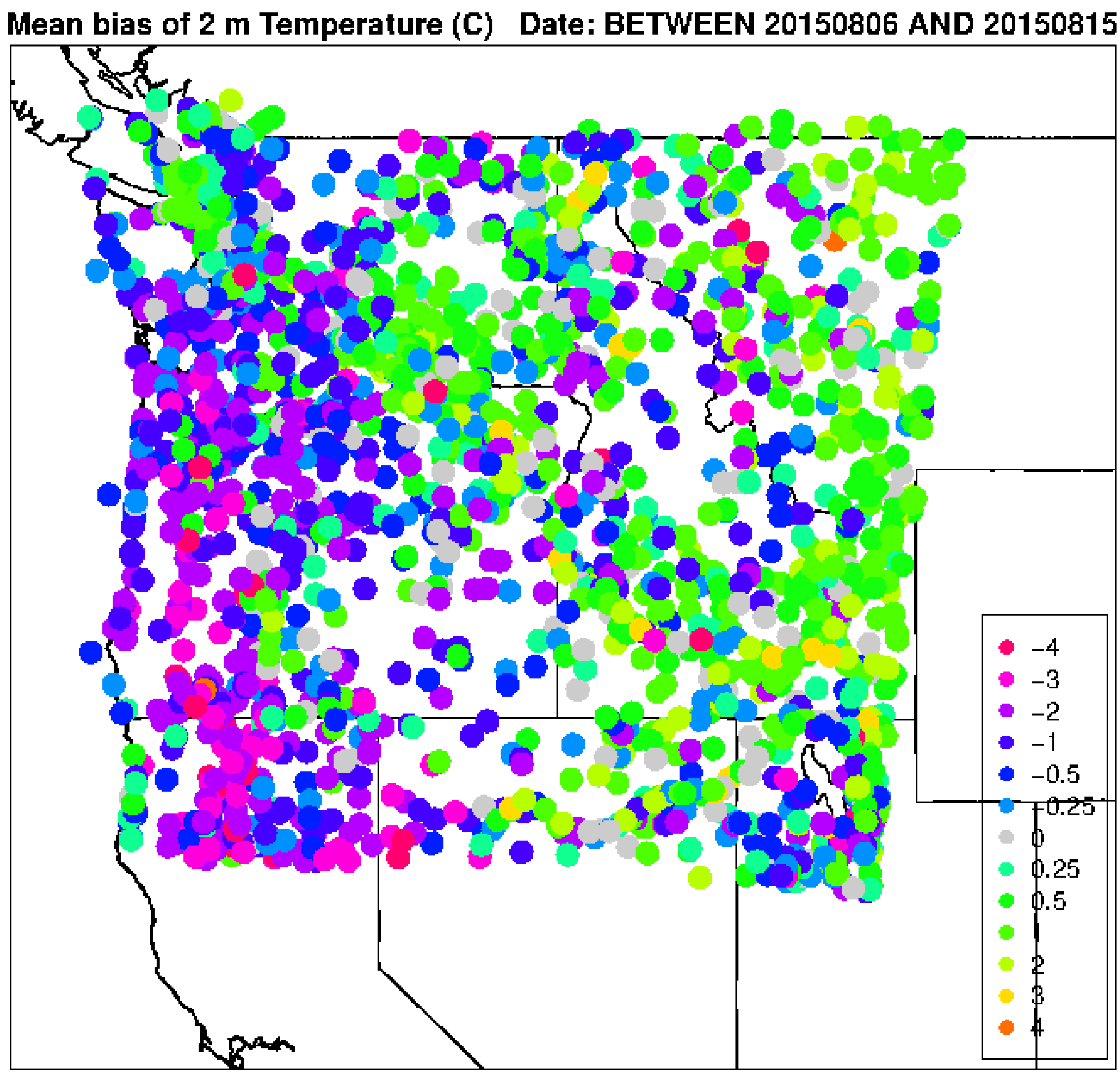



**Figure 20. Bias of surface temperature for all sites in the domain during the 2015 episode.**

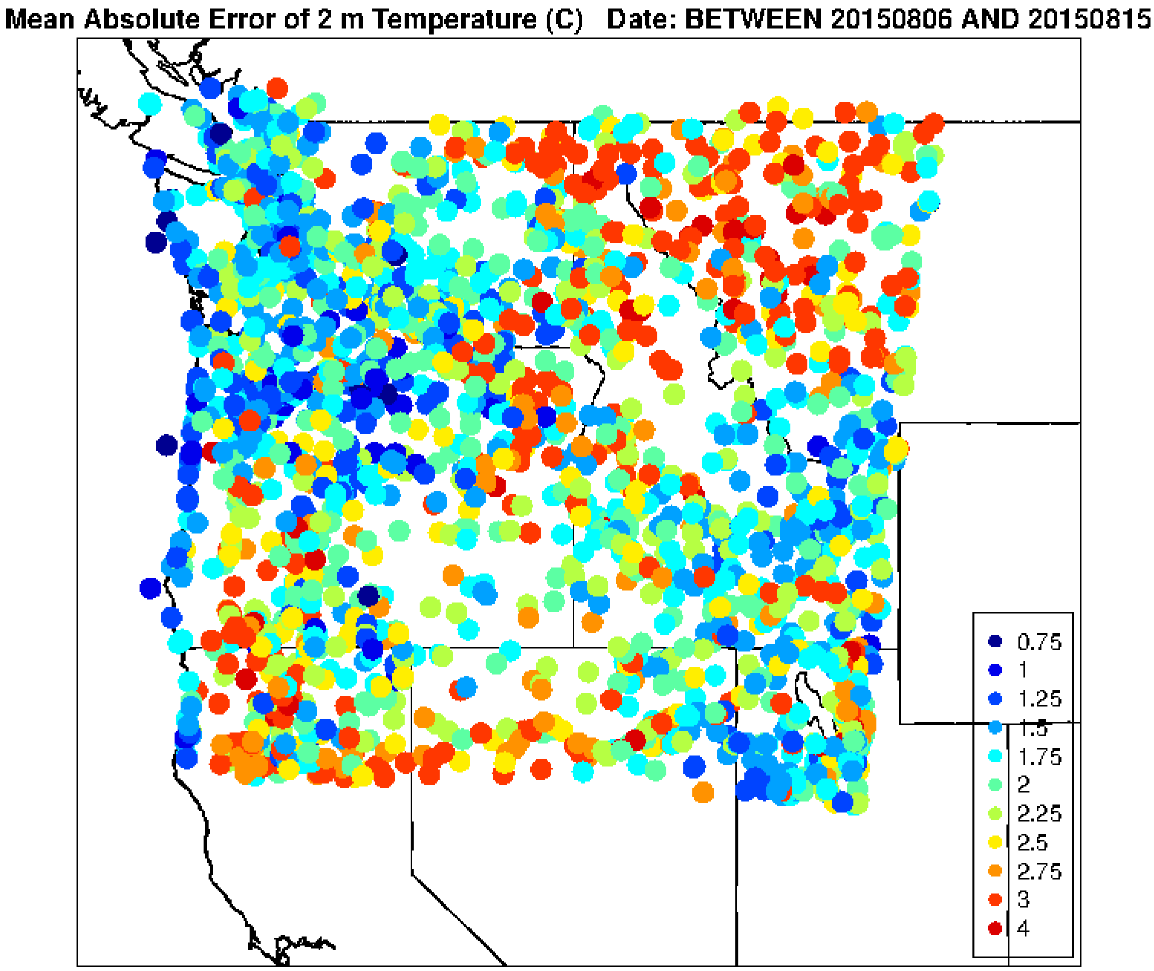



**Figure 21. Error of surface temperature for all sites in the domain during the 2015 episode.**

Figure 22 presents a summary plot of surface temperature for all sites in the domain during the 2015 episode. In the summary plot, all the model performance metrics and graphical displays confirm that the simulated surface temperature compares well with the observations at sites across the domain.

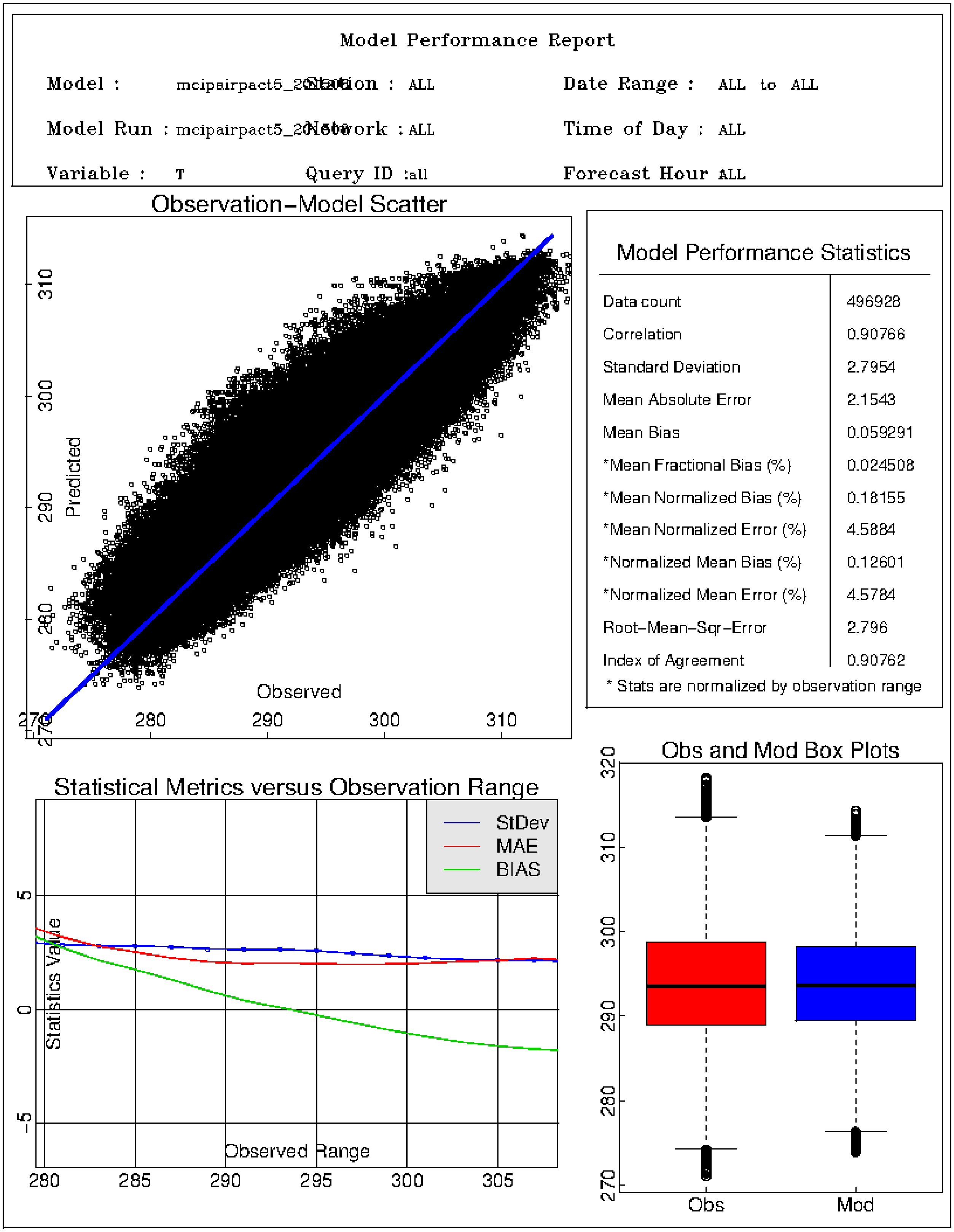



**Figure 22. Surface temperature for all sites in the domain during the 2015 episode.**

### 4.1.2 Wind Speed

Figure 23 and Figure 24 show, respectively, the bias and RMSE of wind speed for all sites in the domain during the 2015 episode. The figures illustrate that the biases and RMSE are small across the entire domain. Table 10 shows the benchmarks for both simple and complex terrain conditions along with the calculated statistics of wind speed for all sites in the domain during the 2015 episode. Both bias and RMSE of wind speed have met the benchmarks for complex terrain conditions, indicating that the model performance for wind speed meets its benchmarks for use in the subsequent photochemical modeling of this study.

**Table 10. Statistics of wind speed for all sites in the domain during the 2015 episode.**

| Parameter | Simple (✓) | Complex (✓) | All Domain (m/s) |
|---|---|---|---|
| Wind Speed Bias | ≤ ±0.5 m/s | ≤ ±1.5 m/s | 0.83 (✓) |
| Wind Speed RMSE | ≤ 2.0 m/s | ≤ 2.5 m/s | 2.14 (✓) |

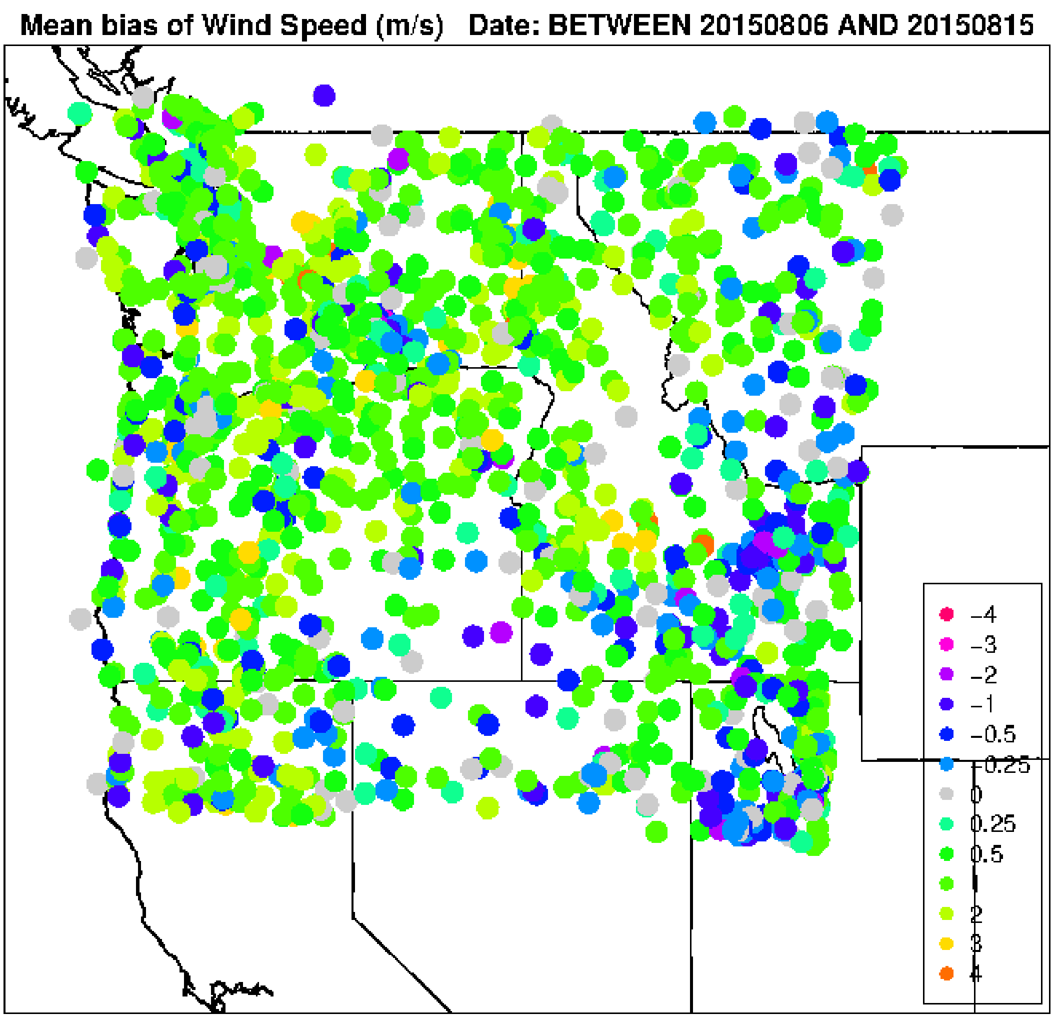



**Figure 23. Bias of weed speed for all sites in the domain during the 2015 episode.**

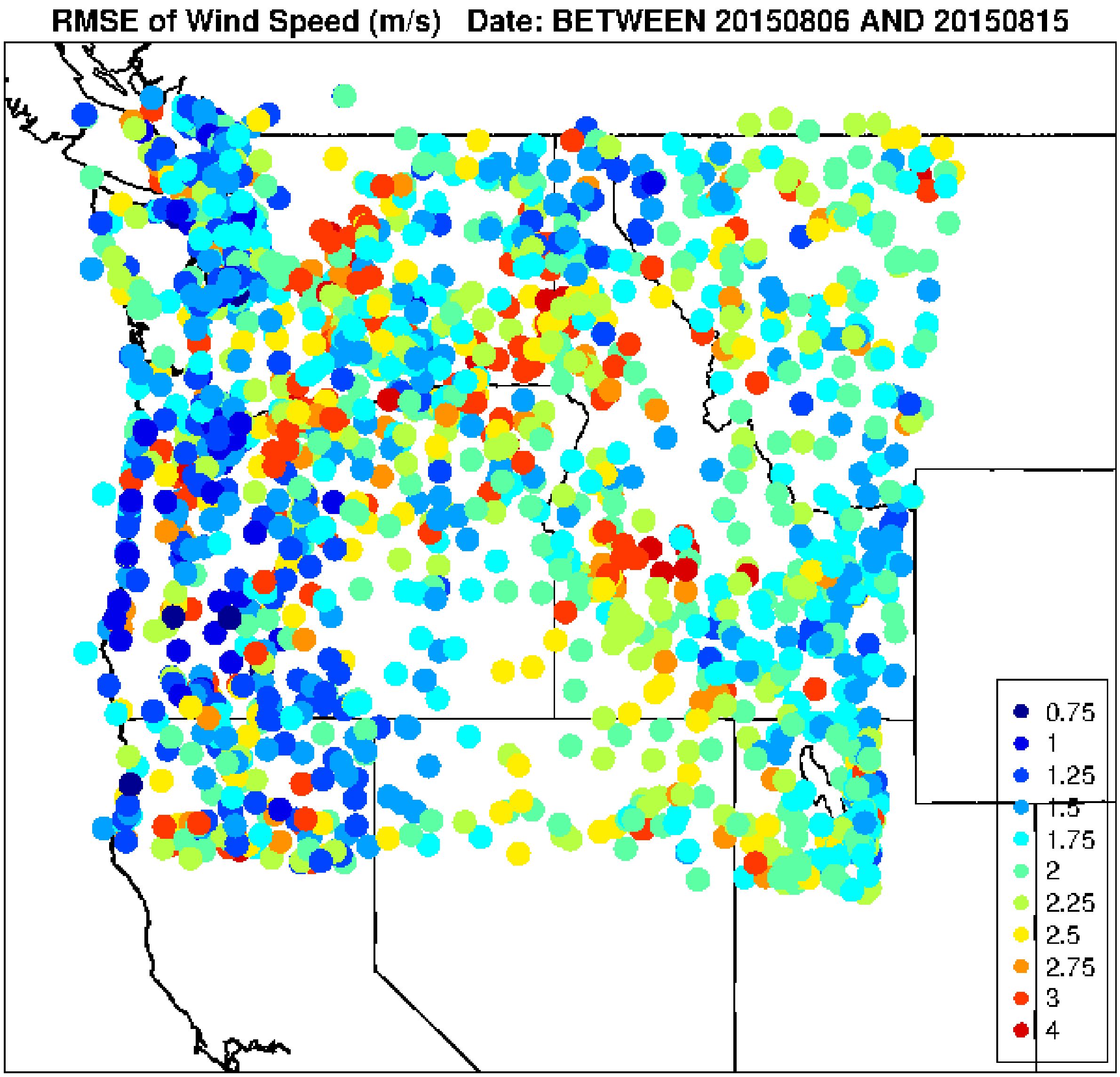



**Figure 24. RMSE of wind speed for all sites in the domain during the 2015 episode.**

Figure 25 shows a summary plot of wind speed for all sites in the domain during the 2015 episode. All the model performance metrics and graphical displays demonstrate that the simulated wind speed compares well with the observations across the domain.

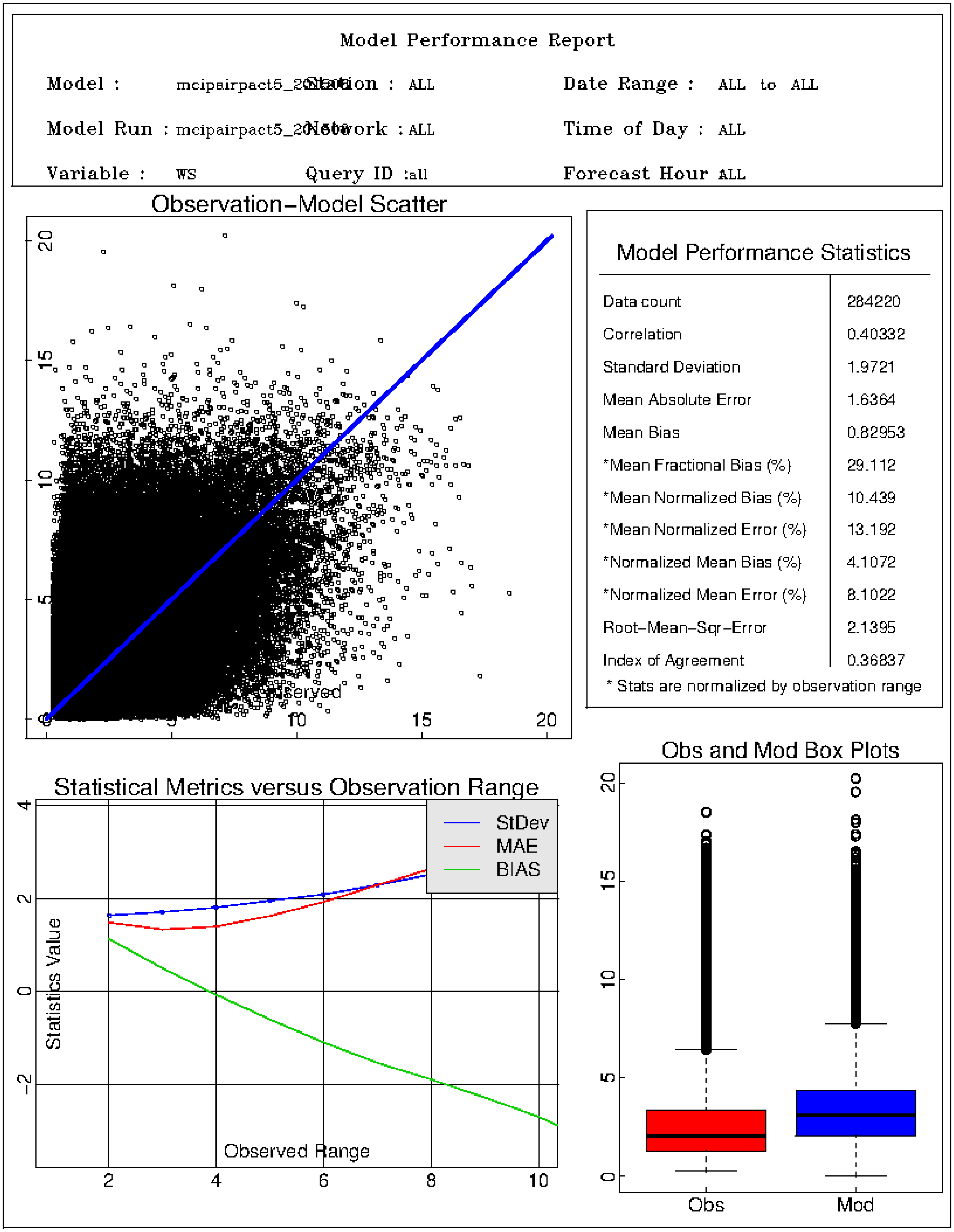



**Figure 25. Wind speed for all sites in the domain during the 2015 episode.**

### 4.1.3 Wind Direction

Figure 26 and Figure 27 show, respectively, the bias and error of wind direction during the 2015 episode for all sites in the domain. Table 11 shows the benchmarks for both simple and complex terrain conditions along with the calculated statistics of wind direction during the 2015 episode across the domain. Table 11 and Figure 28 show that the calculated bias is even smaller than its benchmark for simple terrain. The error of wind direction is a little higher than its benchmark for complex terrain. However, the benchmarks were not designed to necessarily give a passing or failing grade to a particular application, but these benchmarks can help understand how poor or good the model simulations are relative to other applications over various regions. In this episode, the error of wind direction is very close to its benchmark for complex terrain conditions.

**Table 11. Statistics of wind direction for all sites in the domain during the 2015 episode.**

| Parameter | Simple (✓) | Complex (✓) | All Domain |
|---|---|---|---|
| Wind Direction Bias | ≤ ±10 degrees | NA | 5.58 (✓) |
| Wind Direction Error | ≤ 30 degrees | ≤ 55 degrees | 56.6 |

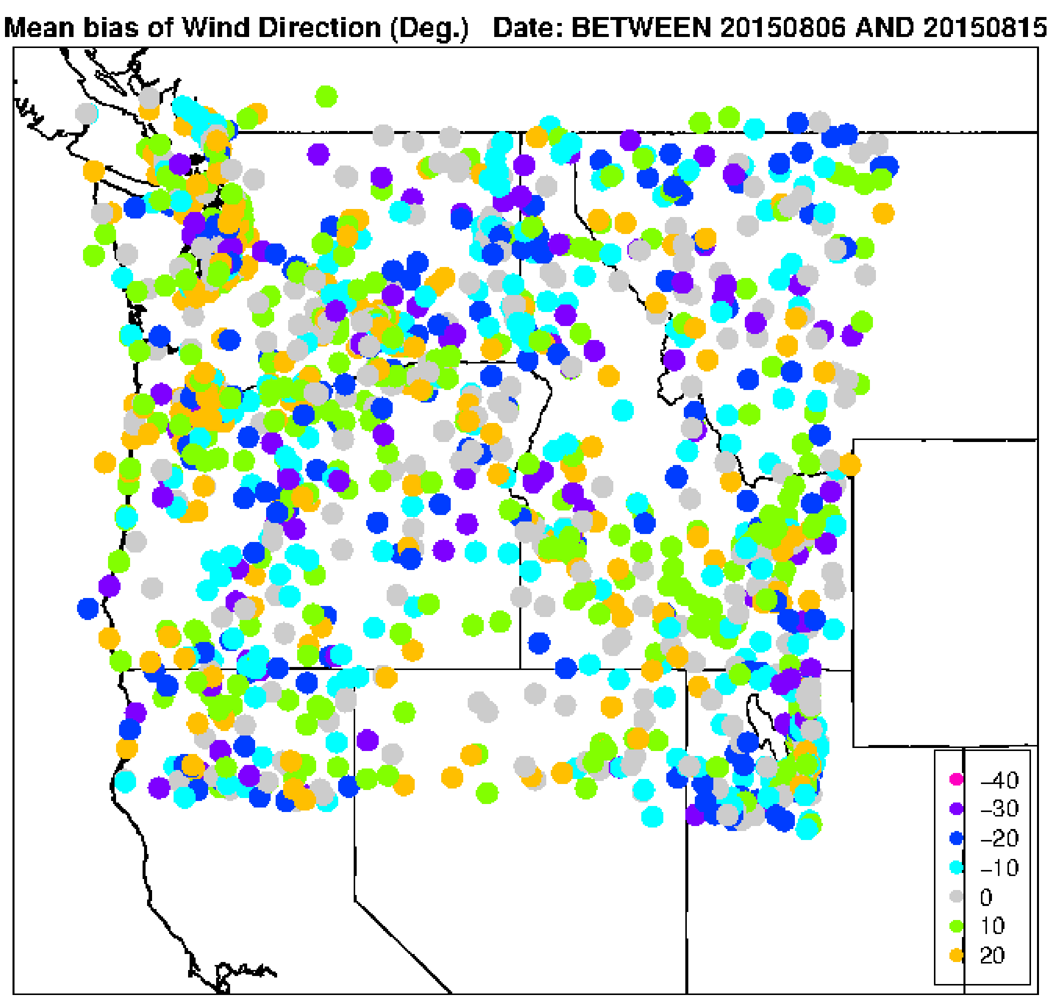



**Figure 26. Bias of wind direction for all sites in the domain during the 2015 episode.**

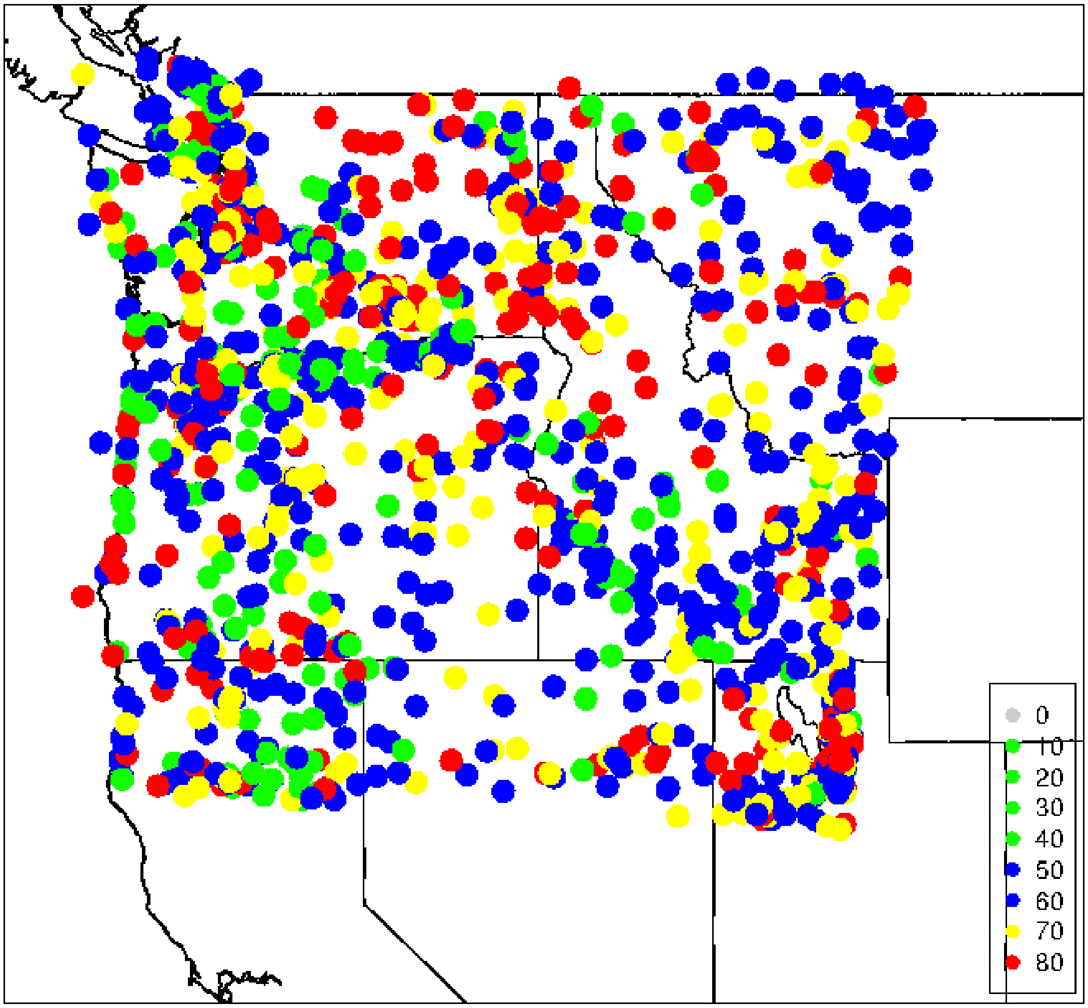



**Figure 27. Error of wind direction (Deg.) for all sites in the domain during the 2015 episode.**

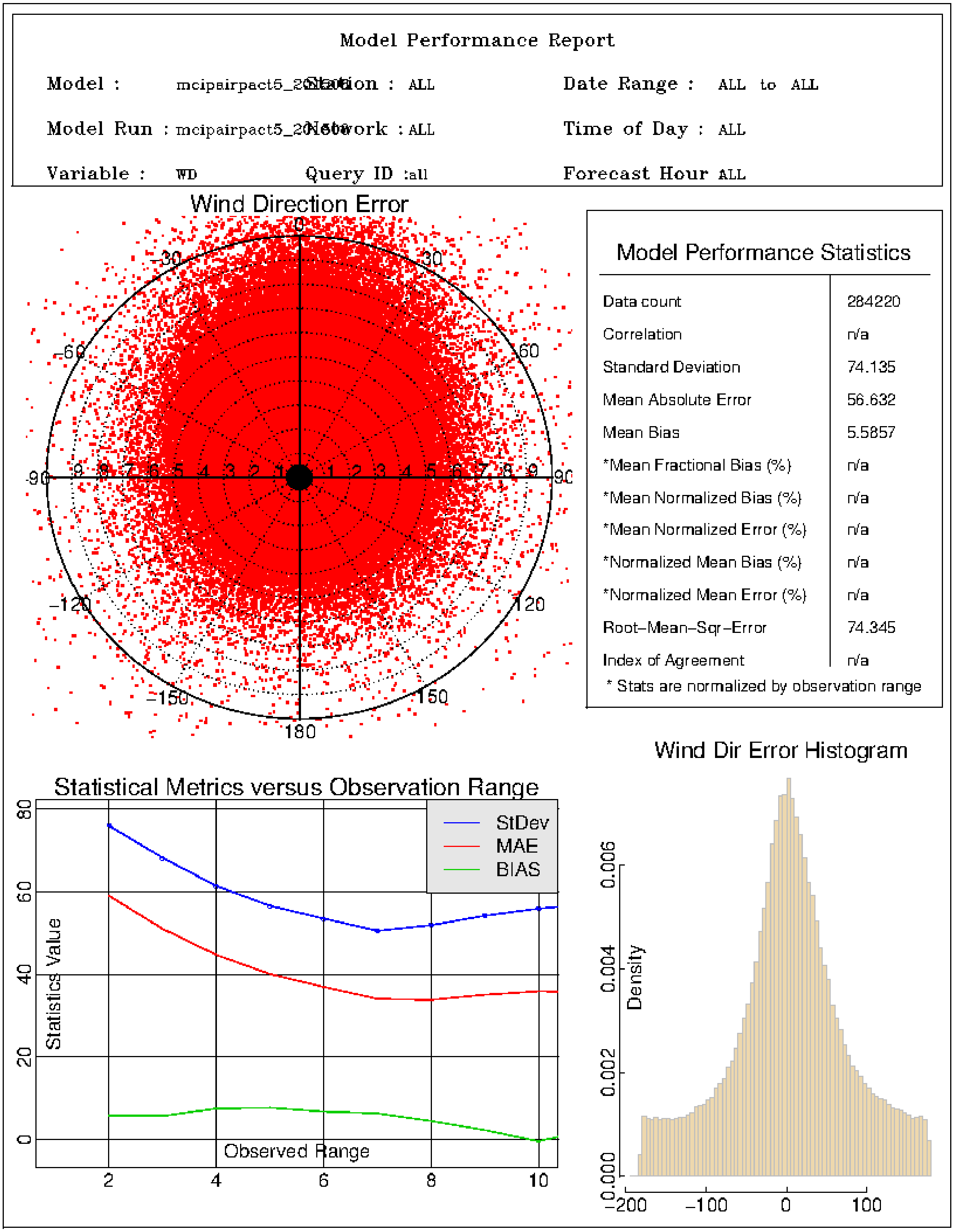



**Figure 28. Wind direction for all sites in the domain during the 2015 episode.**

## 4.2 Idaho and Neighboring NWS Stations

To assess the model performance for the Idaho region, all the variables (i.e., surface temperature, wind speed, and wind direction) listed in the benchmarks for complex terrain conditions proposed by Kemball-Cook et al. (2005) are evaluated at 24 National Weather Service sites in Idaho and in portions of other states near Idaho for the 2015 episode.

### 4.2.1 Surface Temperature

Figure 29 and Figure 30 show, respectively, the temperature bias and error calculated using data observed at the National Weather Service sites around the Idaho region during the 2015 episode. In these figures, the biases and errors are small at the Idaho sites. Table 12 compares the calculated statistics of surface temperature for the Idaho sites during the 2015 episode against the benchmarks for both simple and complex terrain conditions. The calculated temperature bias is smaller than its benchmark for both simple and complex terrain conditions, and the temperature error is far below its benchmark for complex terrain conditions. The model performance for temperature at the Idaho sites meets its benchmarks for complex terrain conditions, indicating adequate performance for use as the input to the photochemical modeling in this study.

**Table 12. Statistics of surface temperature for the Idaho sites during the 2015 episode.**

| Parameter | Simple (✓) | Complex (✓) | Idaho Sites (K) |
|---|---|---|---|
| Temperature Bias | ≤ ±0.5 K | ≤ ±2.0 K | -0.80 (✓) |
| Temperature Error | ≤ 2.0 K | ≤ 3.5 K | 2.19 (✓) |

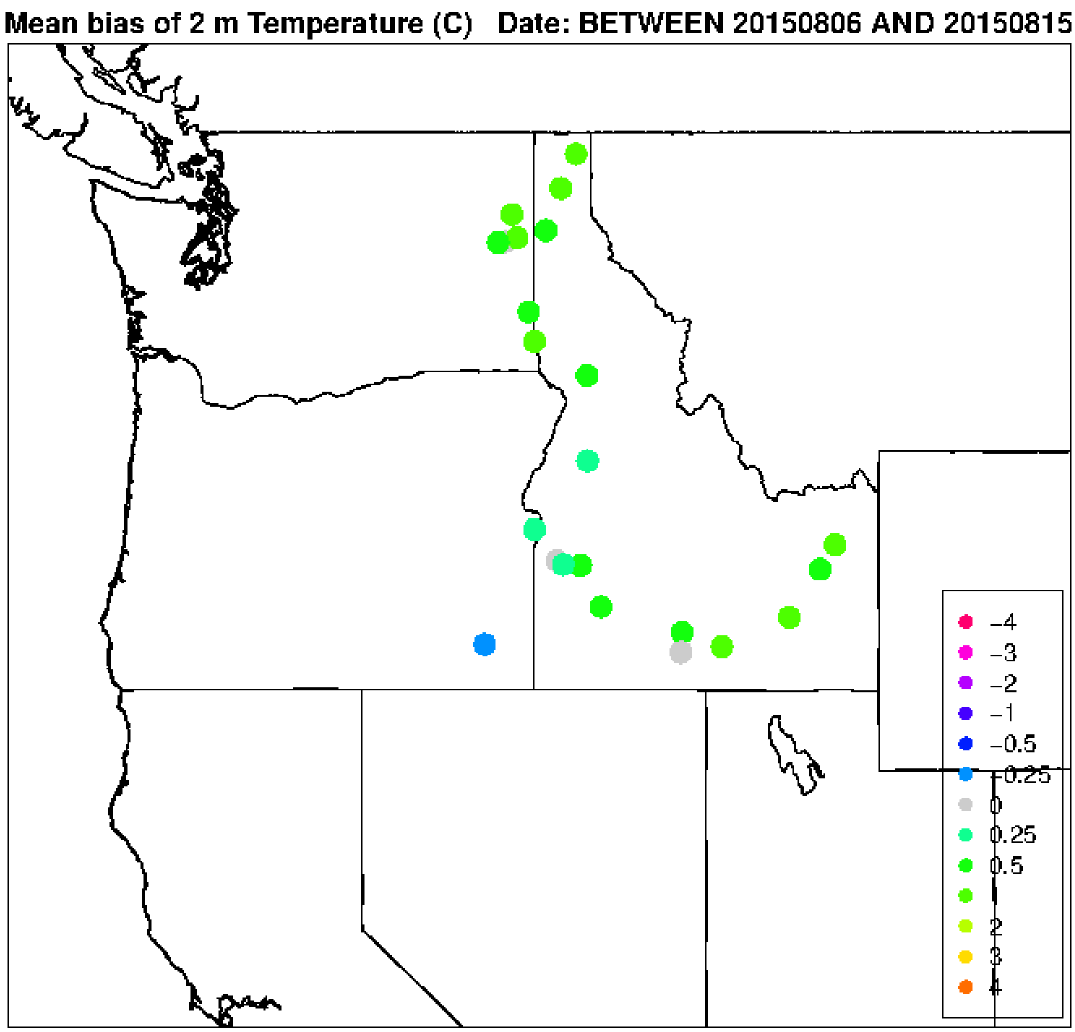



**Figure 29. Bias of surface temperature for the Idaho sites in the domain during the 2015 episode.**

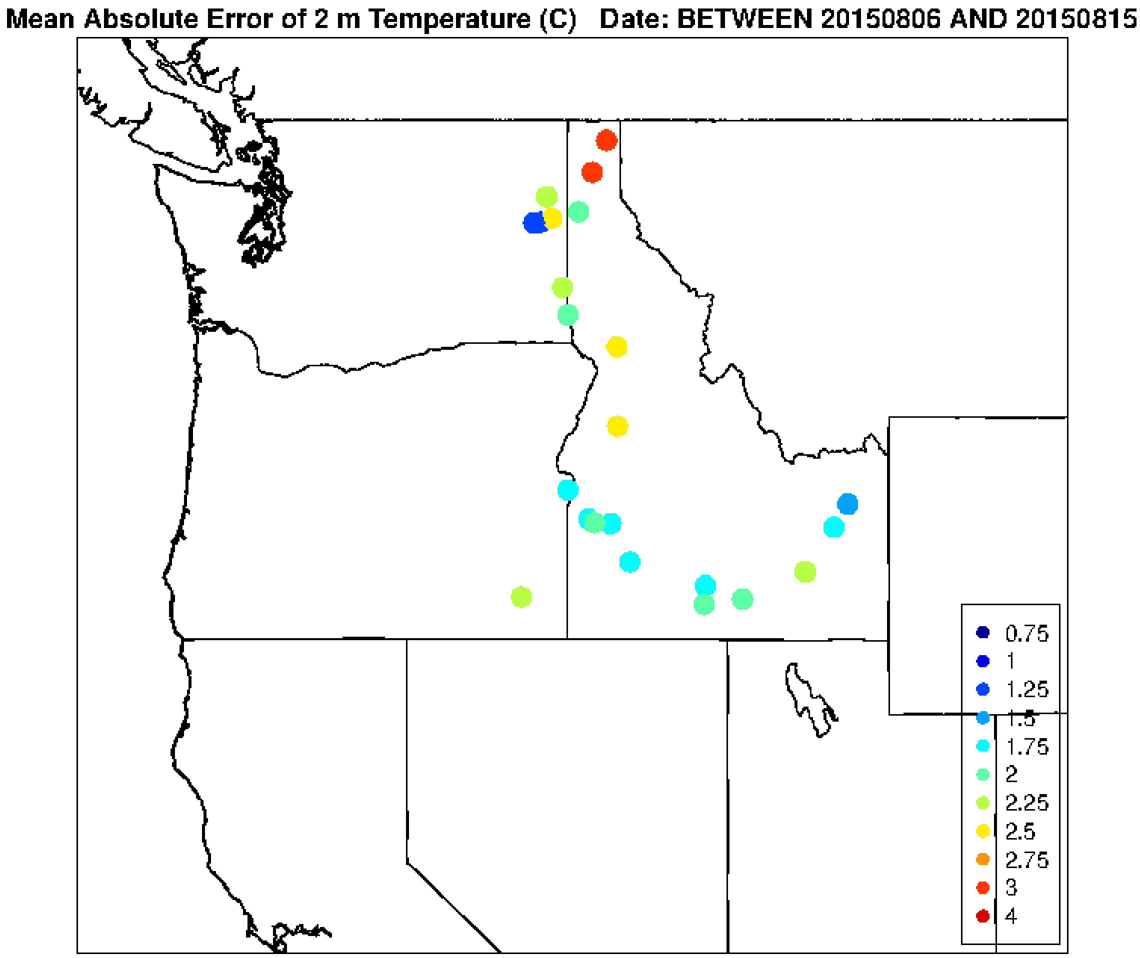



**Figure 30. Error of surface temperature for the Idaho sites in the domain during the 2015 episode.**

Figure 31 presents a summary plot of surface temperature for the Idaho sites during the 2015 episode. Again, all the model performance metrics and graphical displays confirm that the simulated surface temperature compares well with the observations at the Idaho sites.

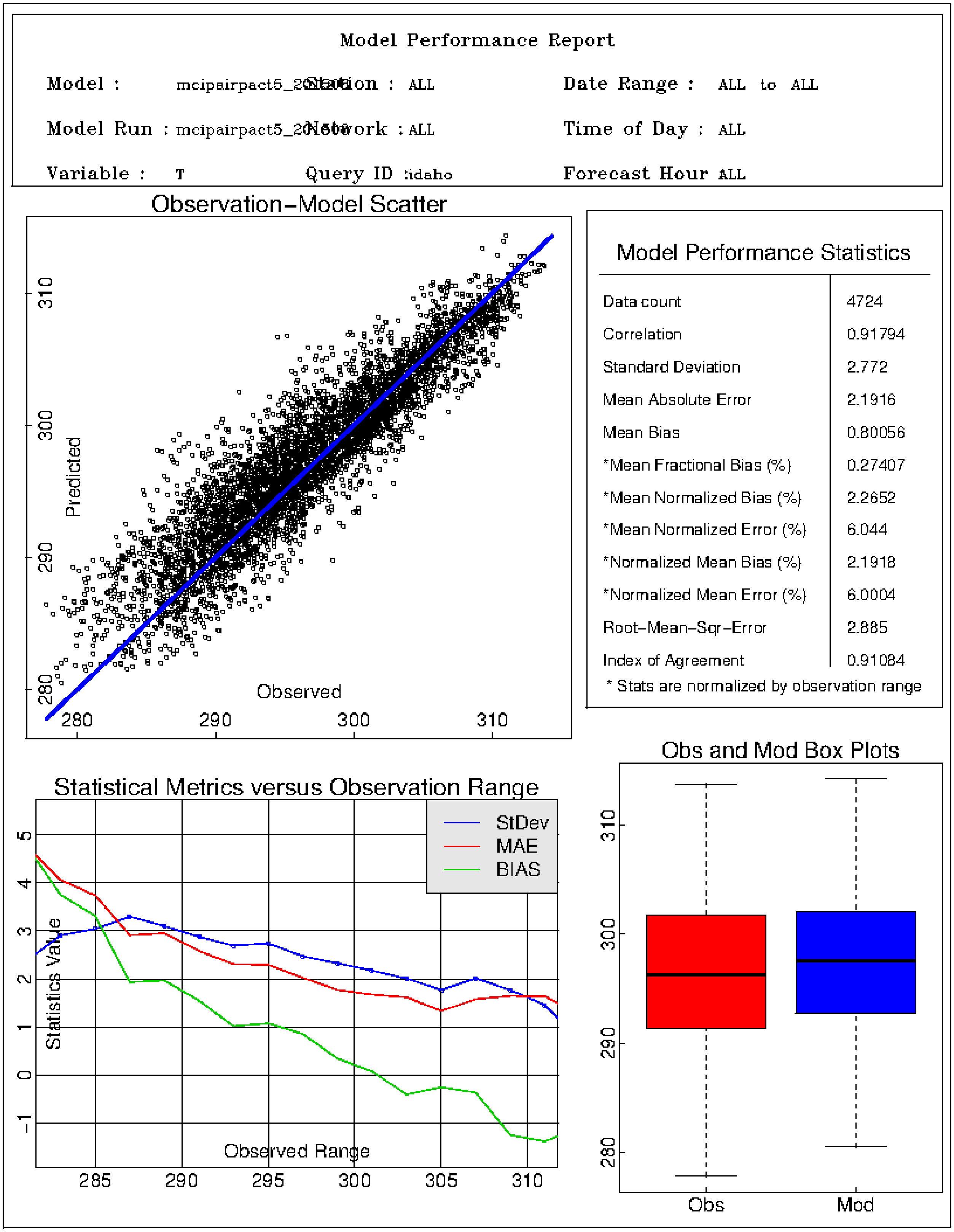



**Figure 31. Surface temperature for the Idaho sites in the domain during the 2015 episode.**

### 4.2.2 Wind Speed

Figure 32 and Figure 33 present, respectively, the bias and RMSE of wind speed for the Idaho sites during the 2015 episode. Table 13 shows that both bias and RMSE of wind speed have not exceeded its benchmarks for both simple and complex terrain conditions, indicating that the model performance for wind speed easily meets its benchmarks for use in subsequent chemical transport modeling.

**Table 13. Statistics of wind speed for the Idaho sites during the 2015 episode.**

| Parameter | Simple (✓) | Complex (✓) | Idaho Sites (m/s) |
|---|---|---|---|
| Wind Speed Bias | ≤ ±0.5 m/s | ≤ ±1.5 m/s | -0.15 (✓) |
| Wind Speed RMSE | ≤ 2.0 m/s | ≤ 2.5 m/s | 1.97 (✓) |

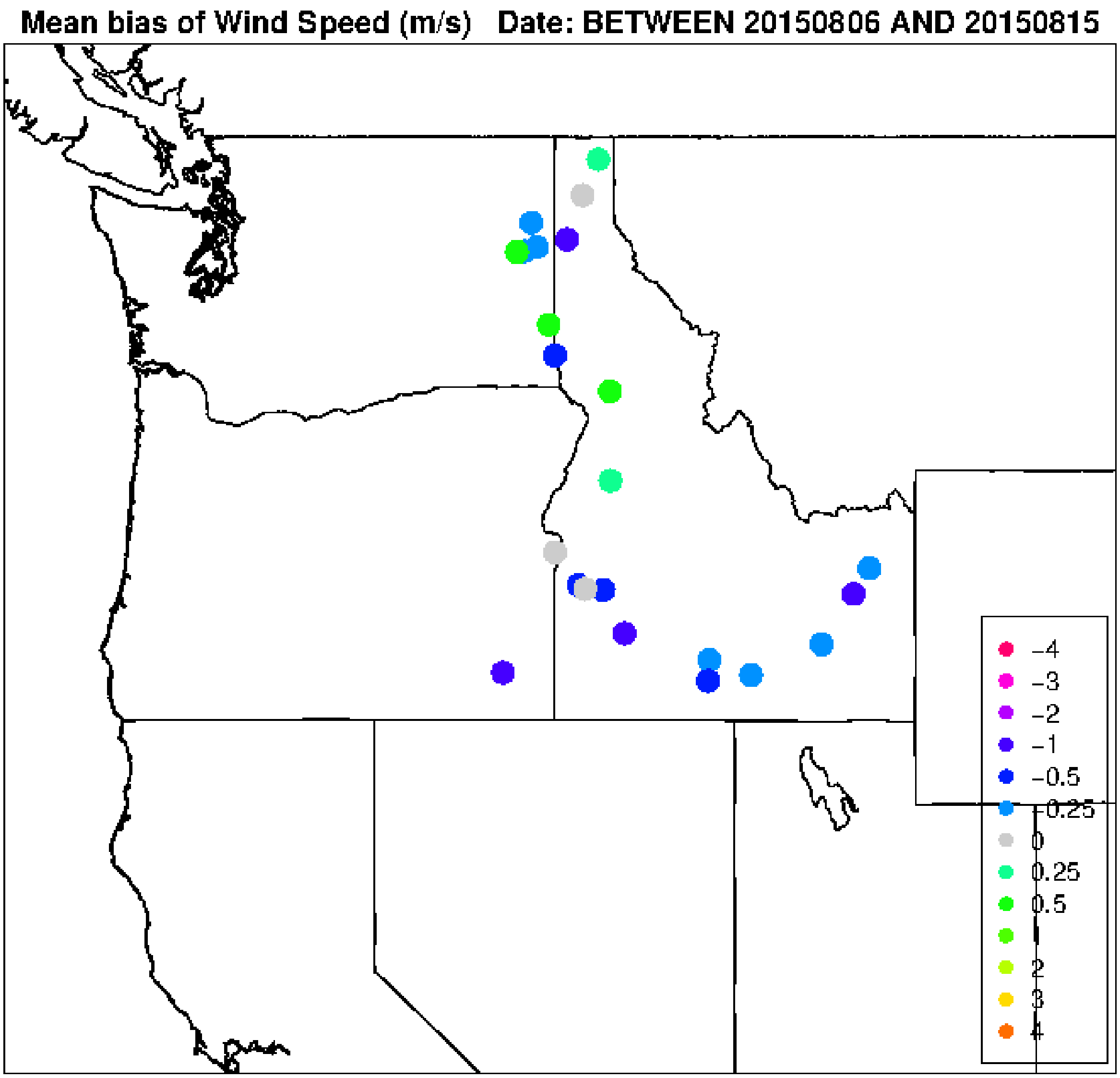



**Figure 32. Bias of wind speed for the Idaho sites in the domain during the 2015 episode.**

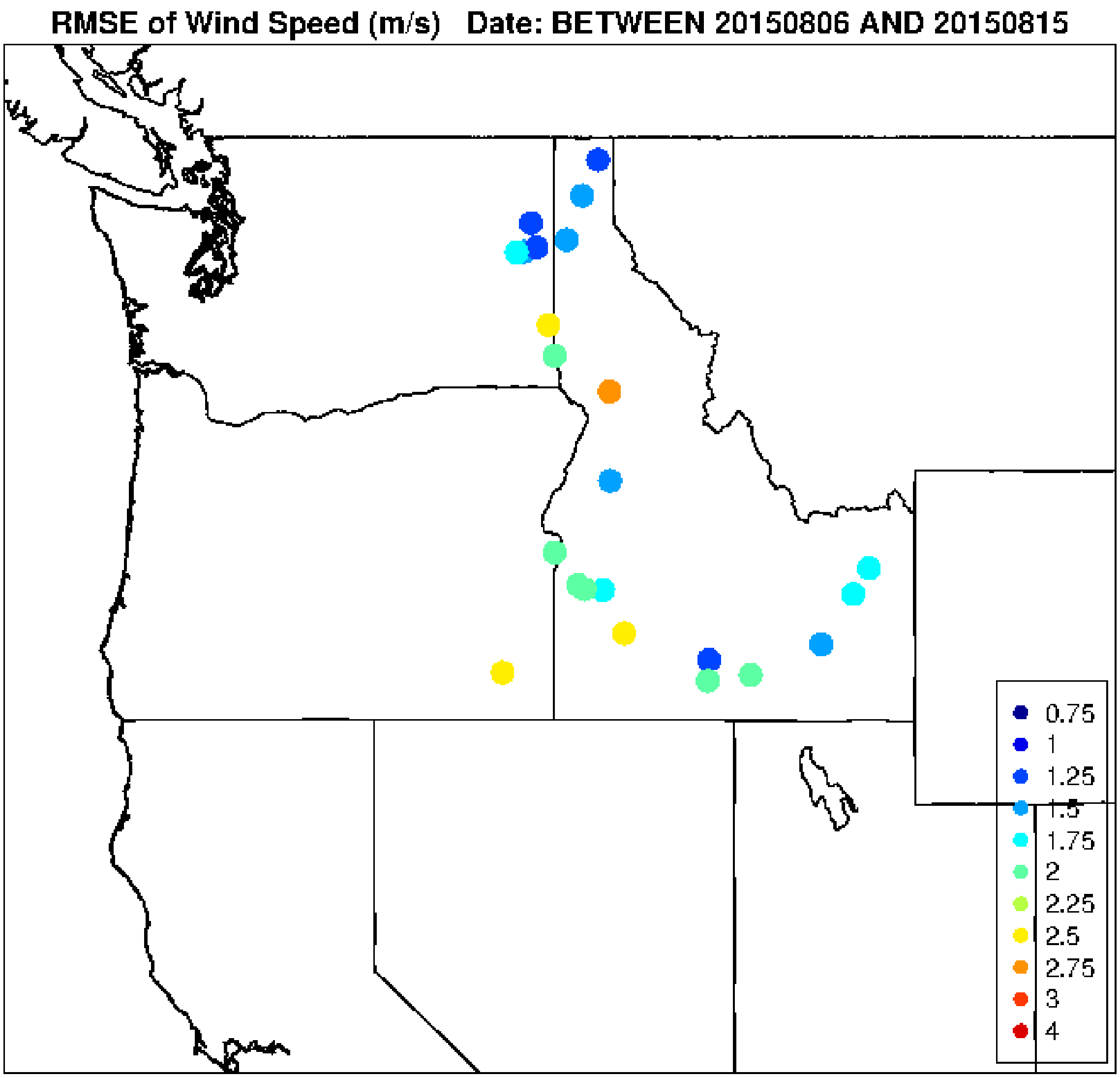



**Figure 33. RMSE of wind speed for the Idaho sites in the domain during the 2015 episode.**

Figure 34 shows a summary plot of wind speed for the Idaho sites during the 2015 episode. Again, all the model performance metrics and graphical displays demonstrate that the simulated wind speed compares well with the observations across the domain.

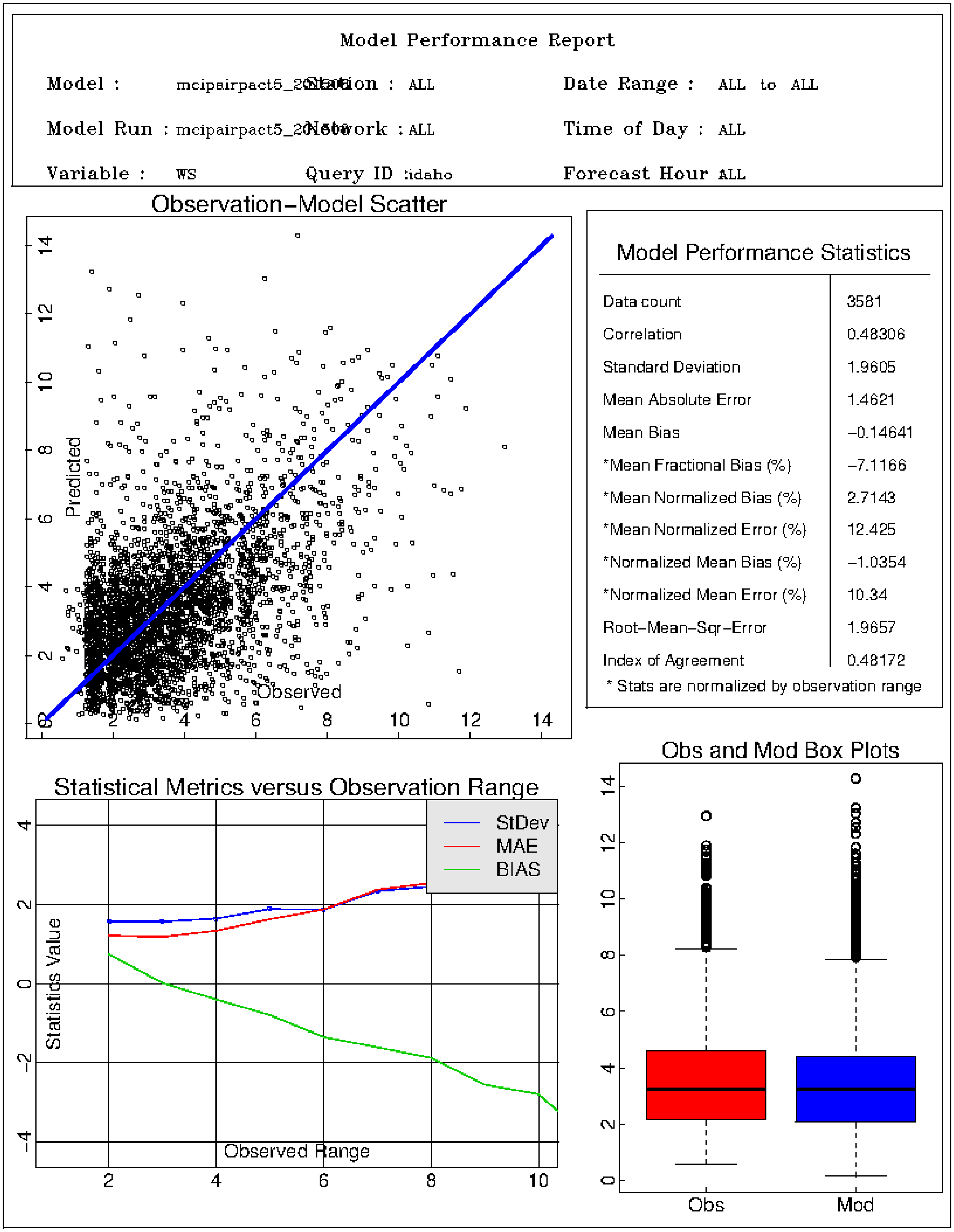



**Figure 34. Wind speed for the Idaho sites in the domain during the 2015 episode.**

### 4.2.3 Wind Direction

Figure 35 and Figure 36 present, respectively, the bias and error of wind direction for the Idaho sites during the 2015 episode. Table 14 compares the calculated statistics of wind direction for the Idaho sites during the 2015 episode with the benchmarks for both simple and complex terrain conditions. Table 14 along with the summary plot shown in Figure 37 show that the error of wind direction is a little higher than, but close to its benchmark for complex terrain conditions.

**Table 14. Statistics of wind direction for the Idaho sites during the 2015 episode.**

| Parameter | Simple (✓) | Complex (✓) | Idaho SItes |
|---|---|---|---|
| Wind Direction Bias | ≤ ±10 degrees | NA | 10.3 (NA) |
| Wind Direction Error | ≤ 30 degrees | ≤ 55 degrees | 56.0 |

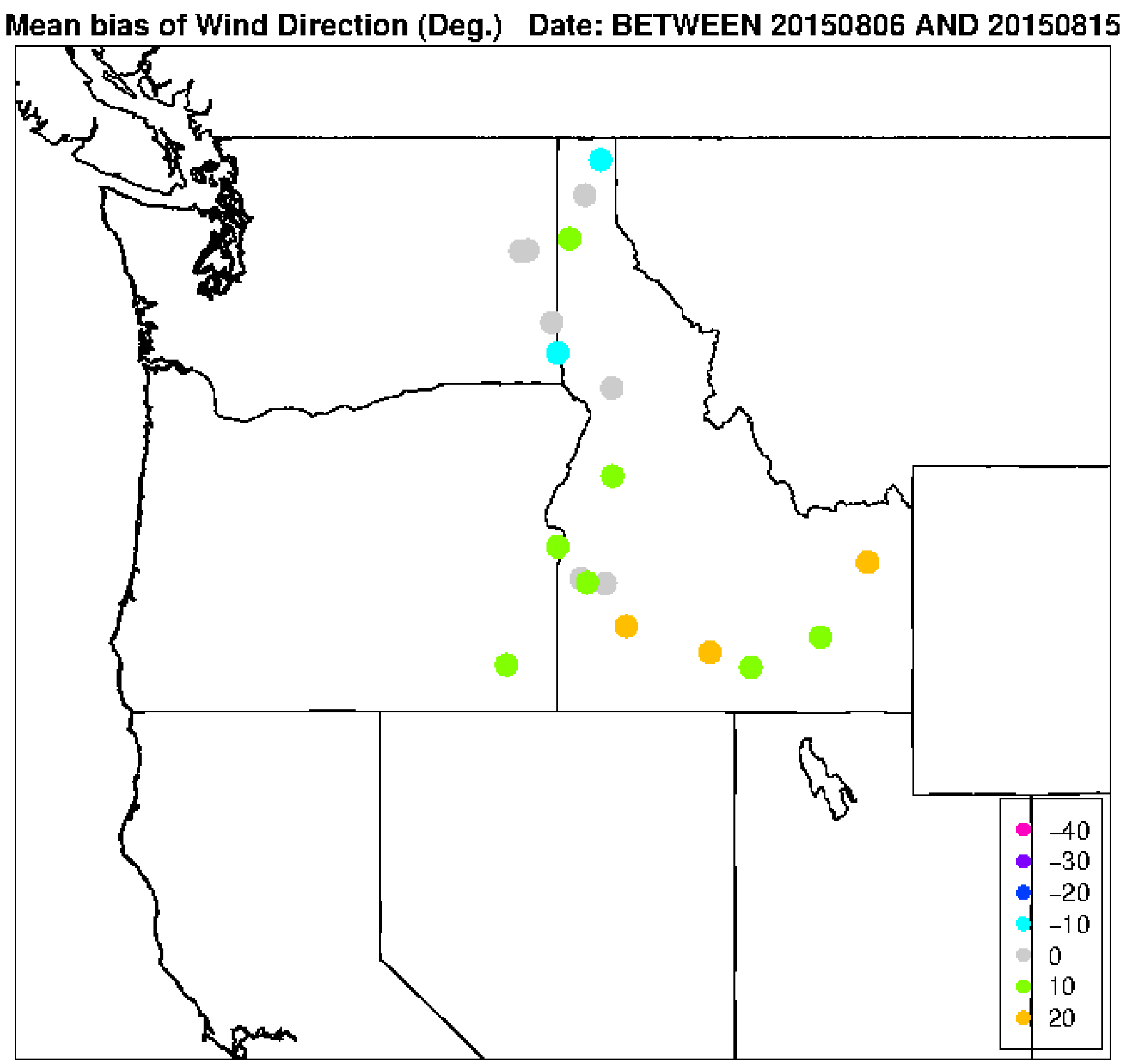



**Figure 35. Bias of wind direction for the Idaho sites in the domain during the 2015 episode.**

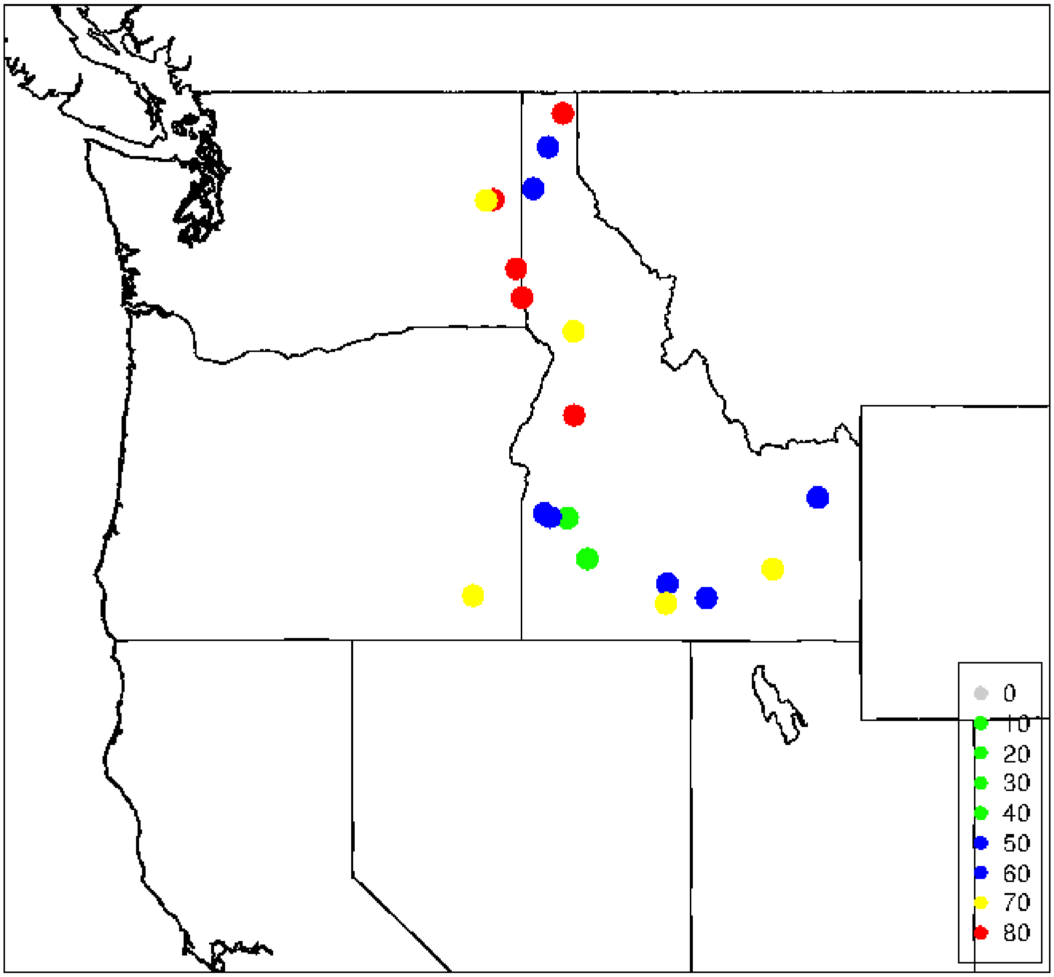



**Figure 36. Error of wind direction (Deg.) for the Idaho sites in the domain during the 2015 episode.**

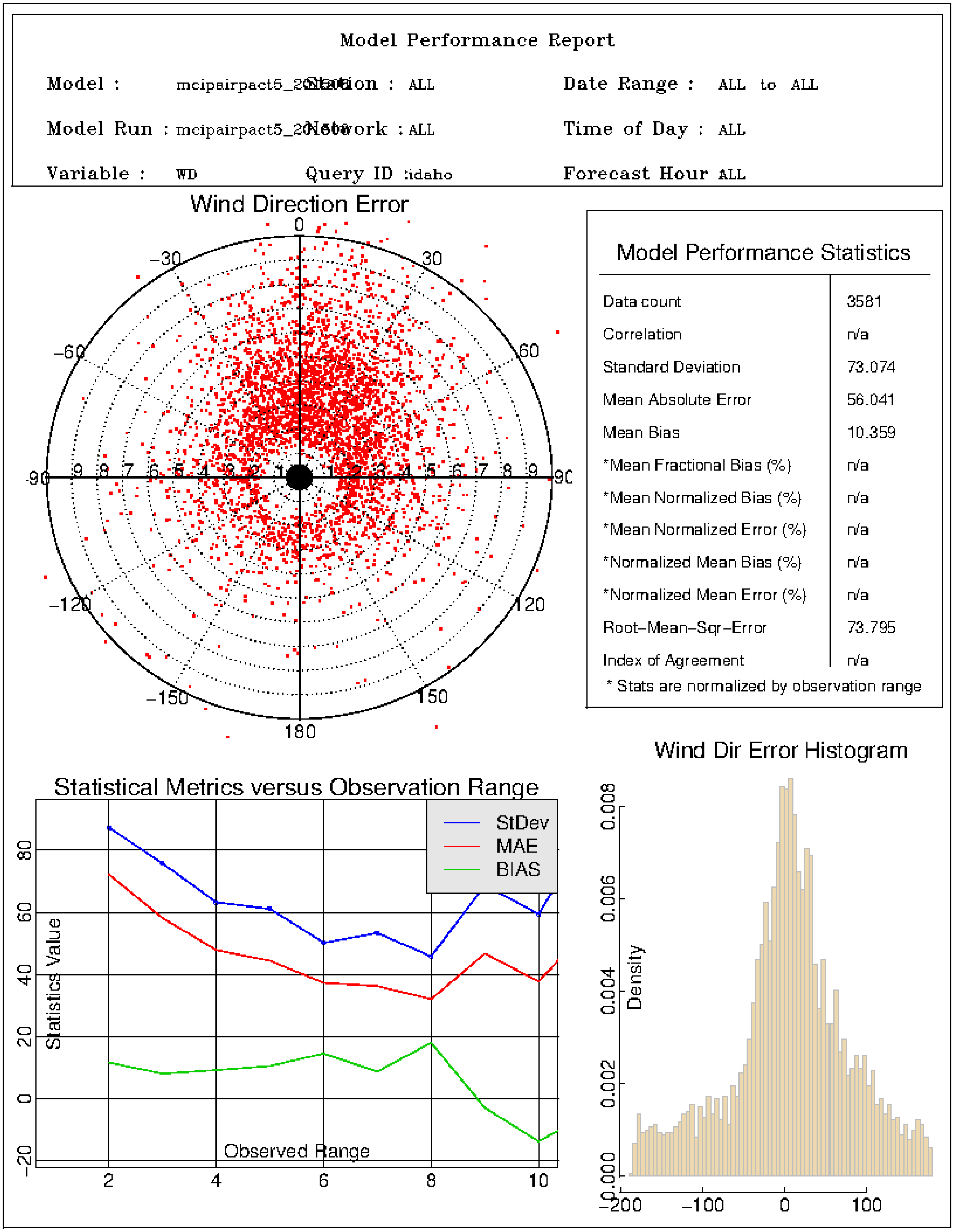



**Figure 37. Wind direction for the Idaho sites in the domain during the 2015 episode.**

## 4.3 Summary of the 2015 Meteorological Data

The model performance for the 2015 episode was first evaluated using observational data at all stations throughout the model domain ingested into EPA's Atmospheric Model Evaluation Tool (AMET) program by the NCEP Meteorological Assimilation Data Ingest System (MADIS). Quantitative evaluation of domain-wide surface temperature, wind speed, and wind direction is shown in Table 15, which reveals that all the calculated statistics for surface temperature and wind speed have not exceeded the model performance benchmarks for complex terrain conditions. To better reflect the simulations for the Idaho region, Table 15 also shows the meteorological performance for the high-quality National Weather Service sites in or near the Idaho region. Again, all the statistics calculated for temperature and wind speed in the Idaho region have not exceeded the benchmarks for complex terrain conditions. However, the error of wind direction for both the entire domain and the Idaho region is a marginally higher than its benchmark for complex terrain conditions. It is well known that the benchmarks were not designed to necessarily give a passing or failing grade to a modeling study, but they were designed to help understand the model performance with respect to the modeling objectives. Moreover, the 2015 episode is not focused so much on CRB ozone impacts, but rather is primarily used to improve the plume rise simulations using the $PM_{2.5}$ and CO predictions from the Soda fire. Since wind direction does not play a significant role in the Soda fire plume rise, DEQ believes that the simulations for the 2015 episode are adequate for its purpose.

**Table 15. Meteorological model performance for the 2015 episode and benchmarks for simple and complex terrain conditions, adopted by Emery et al. (2001) for simple terrain and by Kemball-Cook et al. (2005) for complex terrain.**

| Parameter | Model Performance | | Benchmarks | |
|---|---|---|---|---|
| | Entire Domain | Idaho Region | Simple Terrain | Complex Terrain |
| Temperature Bias | -0.06 (✓) | -0.80 (✓) | ≤ ±0.5 K | ≤ ±2.0 K |
| Temperature Error | 2.15 (✓) | 2.19 (✓) | ≤ 2.0 K | ≤ 3.5 K |
| Mixing Ratio Bias | NA | NA | ≤ ±1.0 g/kg | NA |
| Mixing Ratio Error | NA | NA | ≤ 2.0 g/kg | NA |
| Wind Speed Bias | 0.83 (✓) | -0.15 (✓) | ≤ ±0.5 m/s | ≤ ±1.5 m/s |
| Wind Speed RMSE | 2.14 (✓) | 1.97 (✓) | ≤ 2.0 m/s | ≤ 2.5 m/s |
| Wind Direction Bias | 5.58 (✓) | 10.3 (NA) | ≤ ±10 degrees | NA |
| Wind Direction Error | 56.6 | 56.0 | ≤ 30 degrees | ≤ 55 degrees |

# 5 Concluding Remarks

This CRB modeling study has two episodes:

1. Episode #1 was July 8–September 26, 2013, which is the major episode for assessing the CRB impacts on ozone concentrations
2. Episode #2 was August 6–15, 2015. This episode is primarily used to improve the simulation of fire plume rise and thus the fire impacts on air quality.

The meteorological simulations for both episodes were evaluated in this report. For the 2013 episode, which is the major episode for the CRB SIP demonstration, the statistics of all evaluated variables (i.e., surface temperature, wind speed, and wind direction) have met the model performance benchmarks for complex terrain conditions for all sites across the entire domain as well as for the Idaho sites, indicating that the meteorological simulations for the 2013 episode are adequate for use in the photochemical modeling of this CRB SIP demonstration. For the 2015 episode, the statistics calculated for temperature and wind speed in both the entire domain and the Idaho region have met the benchmarks for complex terrain conditions. However, the error of wind direction for both the entire domain and the Idaho region is marginally higher than its benchmark for complex terrain conditions. These benchmarks were not designed to necessarily give a passing or failing grade, but rather to help understand the model performance in comparison to project objectives and to other studies over various regions. Moreover, the 2015 episode is not the major episode for the CRB SIP demonstration. Instead, it is only used to improve the plume rise simulations using the Soda fire. Given the fact that wind direction does not play a significant role in the Soda fire plume rise and its error is close to the benchmark, DEQ believes that the meteorological data for the 2015 episode are also adequate for the Soda fire plume rise simulations.

## References


Appel, Y., Y. Gilliam, and U. Shankar. 2013. "Atmospheric Model Evaluation Tool (AMET) v1.2 User's Guide." Research Triangle Park, NC: EPA. https://www.cmascenter.org/amet/documentation/1.2/AMET_Users_Guide_v1.2.1.pdf.

Atkinson, R. and J. Arey. 2003. "Atmospheric Degradation of Volatile Organic Compounds." *Chemical Reviews.* 103(12): 4605–4638.

Emery, C., E. Tai, and G. Yarwood. 2001. "Enhanced Meteorological Modeling and Performance Evaluation for Two Texas Ozone Episodes." Prepared for the Texas Natural Resource Conservation Commission, by ENVIRON International Corporation.

Guenther, A., C.N. Hewitt, D. Erickson, R. Fall, C. Geron, T. Graedel, P. Harley, et al. 1995. "A Global Model of Natural Volatile Organic Compound Emissions." *Journal of Geophysical Research: Atmospheres.* 100(D5): 8873–8892.

Herron-Thorpe, F.L., B.K. Lamb, G.H. Mount, and J.K. Vaughan. 2010. "Evaluation of a Regional Air Quality Forecast Model for Tropospheric NO 2 Columns Using the OMI/Aura Satellite Tropospheric NO 2 Product." *Atmospheric Chemistry and Physics*. 10(18): 8839–8854.

Kemball-Cook, S., Y. Jia, C. Emery, and R. Morris. 2005. "Alaska MM5 Modeling for the 2002 Annual Period to Support Visibility Modeling." Western Regional Air Partnership, Regional Modeling Center. September.

Li, R., S.-Y. Wang, and R.R. Gillies. 2016. "A Combined Dynamical and Statistical Downscaling Technique to Reduce Biases in Climate Projections: An Example for Winter Precipitation and Snowpack in the Western United States." *Theoretical and Applied Climatology*. 124(1–2): 281–289.

Li, R., C. Wiedinmyer, K.R. Baker, and M.P. Hannigan. 2013. "Characterization of Coarse Particulate Matter in the Western United States: A Comparison between Observation and Modeling." *Atmospheric Chemistry and Physics*. 13(3): 1311–1327.

Li, R., J. Jin, S.-Y. Wang, and R.R. Gillies. 2015. "Significant Impacts of Radiation Physics in the Weather Research and Forecasting Model on the Precipitation and Dynamics of the West African Monsoon." *Climate Dynamics*. 44(5–6): 1583–1594.

Mass, C.F., M. Albright, D. Ovens, R. Steed, M. MacIver, E. Grimit, T. Eckel, et al. 2003. "Regional Environmental Prediction over the Pacific Northwest." *Bulletin of the American Meteorological Society*. 84(10): 1353–1366.

Vaughan, J., B. Lamb, C. Frei, R. Wilson, et al. 2004. "A Numerical Daily Air Quality Forecast System for the Pacific Northwest." *Bulletin of the American Meteorological Society*. 85(4): 549.

# Appendix E. Plume Rise Diagnostic Evaluation

# Appendix E—Plume Rise Diagnostic Evaluation

2015 Soda Fire Modeling Episode

**State of Idaho**
**Department of Environmental Quality**
**Air Quality Division**
**1410 N. Hilton**
**Boise, ID 83706**

**September 2017**

Printed on recycled paper, DEQ, September 2017.
PID SSIP, CA code 81992. Costs associated with
this publication are available from the State of Idaho
Department of Environmental Quality in accordance
with Section 60-202, Idaho Code.

# Table of Contents



## List of Tables



## List of Figures

# 1 Introduction

The Idaho Department of Environmental Quality (DEQ) drafted the *2017 Crop Residue Burning Ozone State Implementation Plan Revision* (2017 CRB SIP) to demonstrate that CRB, as it occurs in Idaho, has and will continue to meet all requirements of the Clean Air Act and will not cause or significantly contribute to a National Ambient Air Quality Standards (NAAQS) violation. In support of the 2017 CRB SIP, this amendment provides additional evidence that when operating under the new rule, Idaho's CRB program will not cause or contribute to a violation of the ozone NAAQS at any locations in and around Idaho.

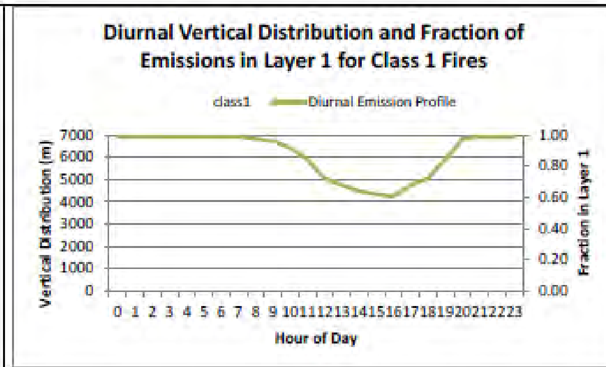
The photochemical modeling of CRB must be evaluated to ensure that emissions and plume injection heights for the burns are reasonable and provide estimated concentrations that compare well to the observed (i.e., monitor-based) pollutant concentrations. This study evaluates the reasonableness of the plume rise or plume injection heights in the CMAQ model (AIRPACT5) compared to the literature and ground-level pollutant measurements that are highly dependent on the plume heights simulated in the model.

DEQ used the 2015 rangeland Soda Fire in a diagnostic evaluation of the plume rise estimates produced by the standard BlueSky-to-SMOKE-to-CMAQ modeling process. As is well known in the fire modeling community (Raffuse et al. 2012; Zhou et al. 2017), the plume rise, or height at which fire pollutants are injected into the model layers, can be problematic when modeling fire emission sources. This appendix describes the evaluation and modified approach for simulating plume rise in SMOKE.

# 2 Plume Rise Problems

Plume rise is a critical component in fire modeling, and it will dramatically change how emissions disperse and transport. The fire modeling approach in DEQ's modeling effort started with BlueSky/Smartfire2 framework (Raffuse et. al. 2009; Larkin et. al. 2009); then the SMOKE emissions preprocessor was used to prepare fire inputs for the CMAQ simulations (Pouliot et al. 2005). DEQ selected a rangeland fire (2015 Soda Fire) with monitor impacts near Boise to evaluate the plume rise reasonableness of this standard approach. During our diagnostic evaluation of the Soda Fire impact on $PM_{2.5}$ and $O_3$ monitors in Boise area, we identified two plume rise-related problems in the existing modeling system. First, the smoldering fraction was too low, and second, the plume rise was too high causing extremely low concentrations compared to ground-level monitors. These two problems are confirmed by literature research, including the largest and most widely peer reviewed western fire modeling project in recent years, the DEASCO3 project conducted by the Western Regional Air Partnership (WRAP). In their final report, *Deterministic and Empirical Assessment of Smoke's Contribution to Ozone* (DEASCO3) (WRAP 2013), they show much higher smoldering fractions and much lower plume rise (than observed using the BlueSky/Smartfire-to-SMOKE process) (Figure 1 and Figure 2). In addition, Raffuse et al. (2012) reported that the standard model approach overestimates the plume rise for large fires, such as the Soda Fire (Figure 3). NW-AIRQUEST also found $PM_{2.5}$ concentrations downwind of wildfires simulated in the AIRPACT5 modeling system are too low as a result of the modeled plume rise being too high (AIRPACT5 2017).

| Class | Virtual Acreage |
|---|---|
| 1 | < 10 |
| 2 | 10 – 100 |
| 3 | 100 – 1000 |
| 4 | 1000 – 5000 |
| 5 | >= 5000 |



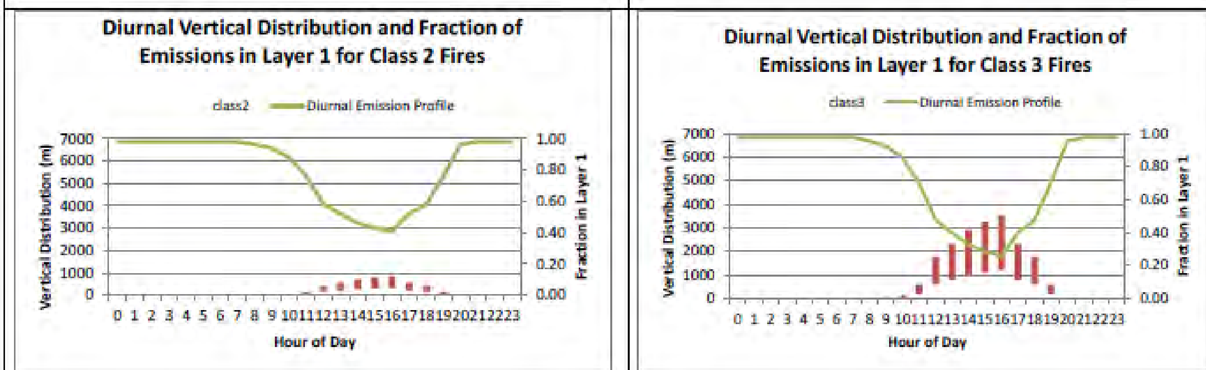




**Figure 1. Diurnal vertical distribution and fraction of emissions in Layer 1 for Class 1 to 3 fires.**

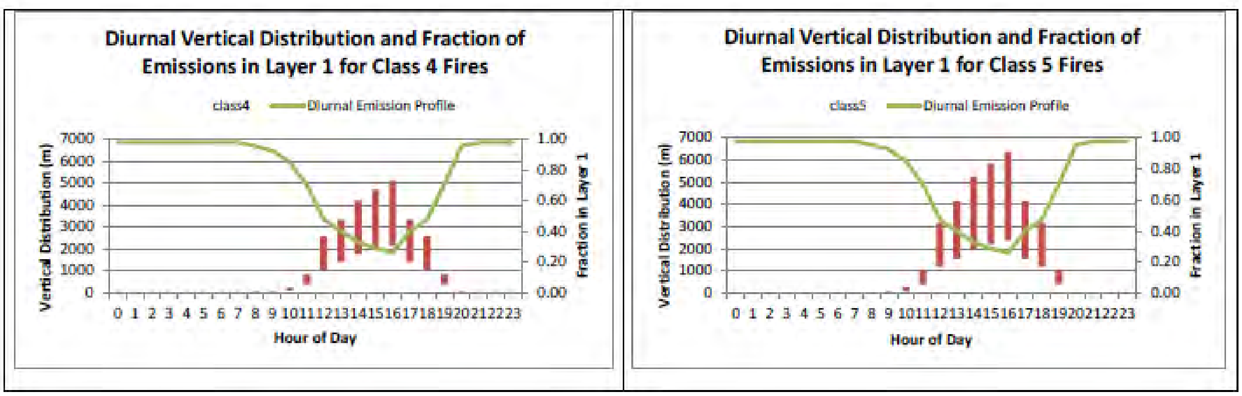



**Figure 2. Diurnal vertical distribution and fraction of emissions in Layer 1 for Class 4 to 5 fires.**

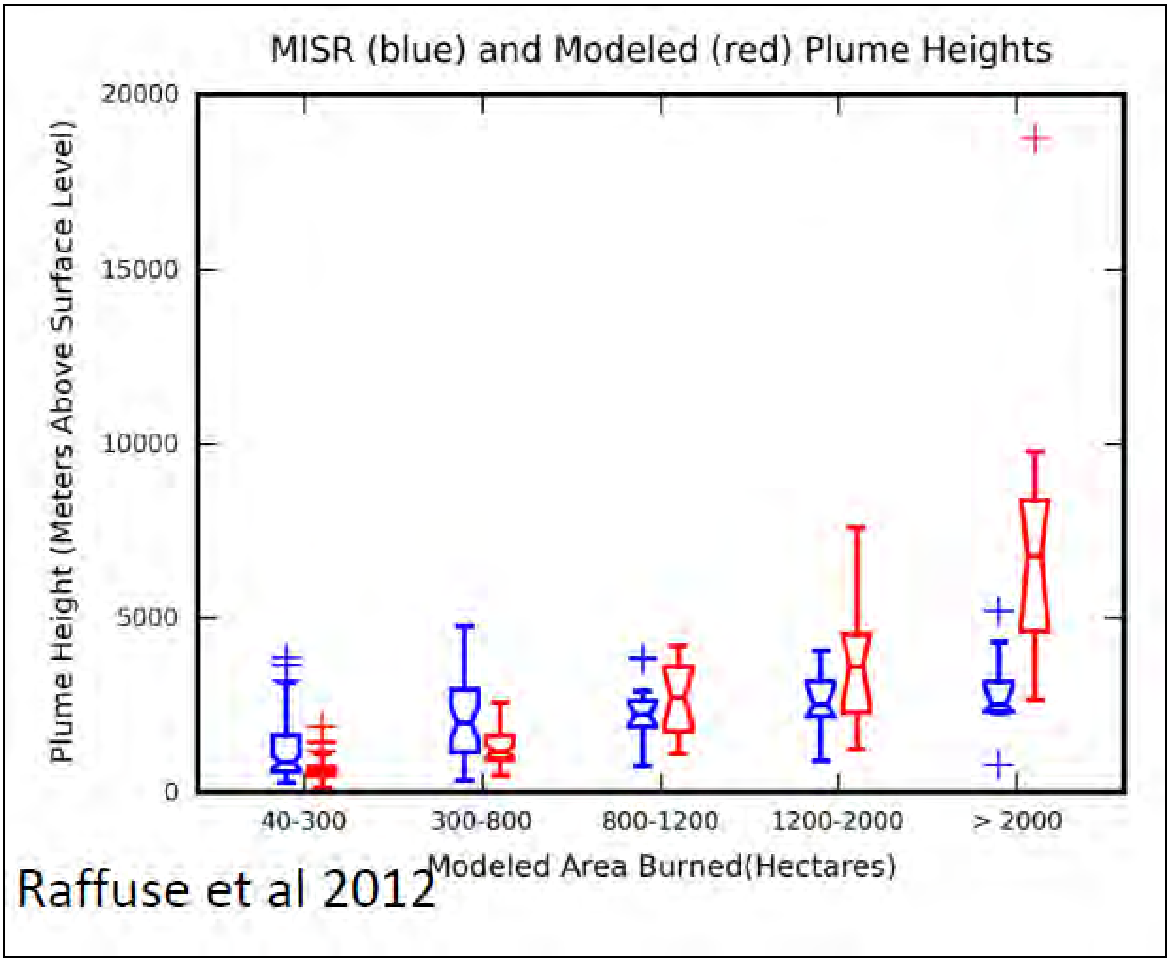



**Figure 3. Observed plume heights versus modeled plume heights from Raffuse et al. 2012.**

# 3 Solution

After extensive research and investigation of the SMOKE source code that generates plume rise and determines vertical emission distribution, DEQ developed a solution to solve the two identified problems.

## 3.1 Generating Plume Rise and Smoldering Fraction in SMOKE

In the SMOKE process, the plume rise is generated using the Briggs plume rise algorithm, which was originally designed for point sources (stacks) with much smaller diameters. First, SMOKE determines the plume top and plume bottom. Second, it determines the smoldering fraction or the fraction of fuel consumption associated with smoldering fuels. Third, it injects the smoldering portion of emissions into the model layers between ground level and the plume bottom and injects flame portion of emissions between plume bottom and plume top. The two key inputs for this process (other than meteorological conditions) are heat flux and area burned. Heat flux is used in the first step, which is the plume rise calculation to determine plume top and plume bottom. The area burned is used in the second step, which is the smoldering fraction determination process. These steps are totally separated in the model, and the area burned is not considered in the plume rise calculation.

## 3.2 Smoldering Fraction

In the SMOKE process for fire emissions, the smoldering fraction is a function of area burned, as shown in Figure 4 (Pouliot et al. 2005). It produced unrealistic smoldering fraction for our Soda Fire simulation compared with historical statistical approach shown in DEASCO3 report (Figure 1 and Figure 2). Flyover video observations also indicated higher smoldering fraction and lower plume rise (Figure 5). To solve the problem, we first predetermined the smoldering fraction using data in DEASCO3 report for different fire classes and produced a virtual area using the function derived from the function used in SMOKE (Figure 4). Then the virtual area was used as input in SMOKE process. It preserves the predetermined smoldering fraction in SMOKE process.

$$BE_{size} = 0.0703 * \ln(acres) + 0.3 \tag{2}$$

where $BE_{size}$ = buoyant efficiency
acres = fire size in acres

The smoldering fraction ($S_{fract}$) was calculated from the Bouyant efficiency as follows:

$$S_{fract} = 1 - BE_{size}.$$

**Figure 4. Smoldering fraction determination in SMOKE.**

**Figure 5. Soda Fire, August 12 flyover.**

## 3.3 Plume Rise

In the SMOKE process, plume rise calculation only uses heat flux as input, and the area burned is not in the equation. This is reasonable for point sources with small diameters, for which it was originally designed, but it is not realistic for fires with large areas burned. As Air Sciences (2013) suggested, "1,000,000 British Thermal Units (BTUs) released over 100,000 acres is not equivalent, in terms of plume rise, to the same amount of heat released over 10,000 acres." To address this problem, the virtual heat concept, a function of flaming phase heat and area burned as shown in Figure 6, is introduced. The virtual heat is then used as input in the SMOKE emissions allocation process. This approach uses three different methods for different sizes of fires. For very small fires (<= 1 acres), the "Briggs Plume Rise" method from the BlueSky framework is reasonable (Pouliot et al. 2005). For fires that are 1,000 acres in size and larger, a method inspired by Air Sciences (2013) "Flaming Phase Consumption Index," which classified fire plumes in the DEASCO3 project was used. It considers fire density and multiple flame fronts associated with large wildland fires. For fires or subfires whose size is between the BlueSky and DEASCO3 methods, a linear interpolation between the two cutoff points is used.

**Definition:**

- VH : Virtual Heat
- FPH : Flame Phase Heat (maximum heat)
- AR : Area burned

**If AR <= 1 acre :**

$$VH = FPH$$

**If AR > 1 and < 1001 acres :**

$$VH = \frac{FPH}{\sqrt{AR}} + \left(FPH - \frac{FPH}{\sqrt{AR}}\right) * \left(\frac{1001 - AR}{1000}\right)$$

**If AR >= 1001 acres :**

$$VH = \frac{FPH}{\sqrt{AR}}$$

**Figure 6. Virtual heat treatment.**

## 4 Soda Fire Results

After the solution was employed within SMOKE for our 2015 Soda Fire simulation, the result was a dramatically improved model performance for nonreacting "tracer species" as shown in Figure 7 and Figure 8 for $PM_{2.5}$, and Figure 9 and Figure 10 for $O_3$. The legend entry for "SMOKE method" indicates the simulation uses the standard fire modeling system without change. The legend entry for "New method" indicates the simulation applies our solution described above. The Soda Fire impact is observed on August 12, 2015. For $PM_{2.5}$, at both St. Luke's Meridian and Nampa, ID sites, the "New method" has a good agreement with observation, but the original "SMOKE method" dramatically underestimated the Soda Fire impacts on August 12.

The good agreement between the modeled and observed $PM_{2.5}$ indicates that the plume rise, transport, and plume dilution are simulated with reasonable accuracy. The next step, once proper transport and dilution is confirmed, is to assess the model's performance in duplicating the photochemical processes of $O_3$ formation.

For $O_3$, at both the St. Luke's and White Pine sites, "New method" shows that the Soda Fire impacts match the observed magnitude and shape of the Soda Fire impact peaks very well, while the "SMOKE method" did not.

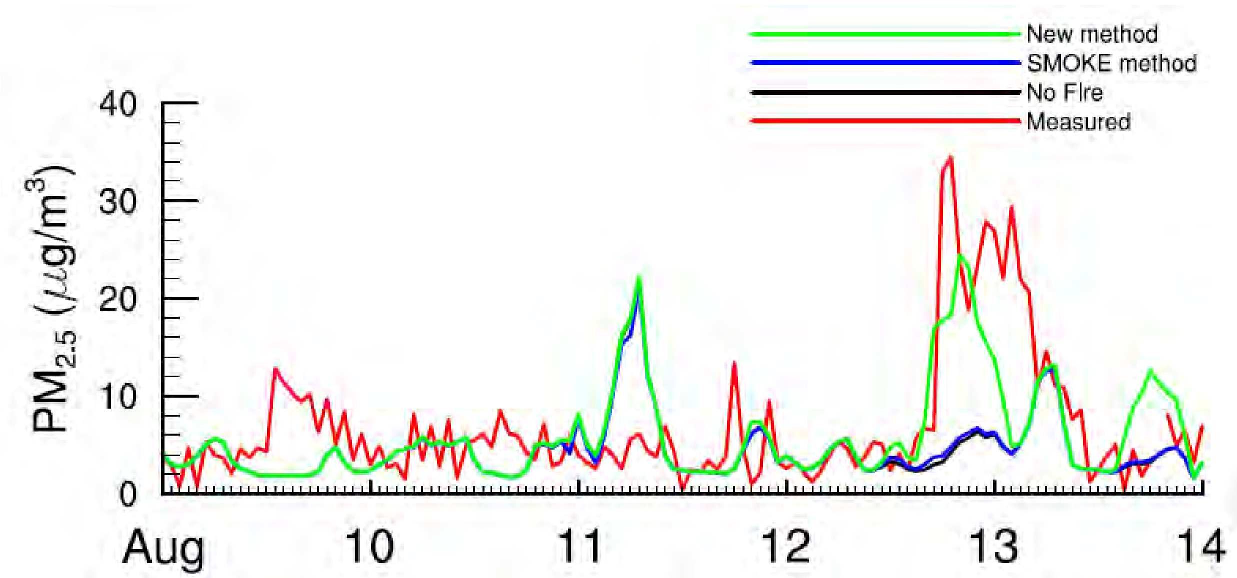



**Figure 7. $PM_{2.5}$ time series at St. Luke's ("SMOKE method" is original simulation and "New method" is the simulation with the DEQ solution applied).**

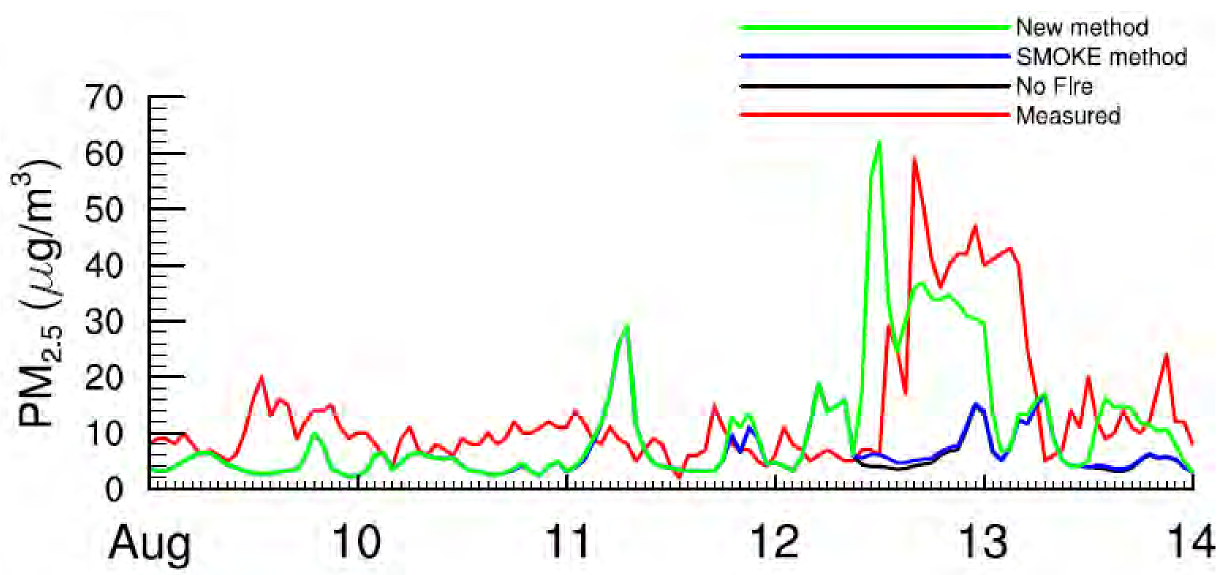



**Figure 8. $PM_{2.5}$ time series at Nampa ("SMOKE method" is original simulation and the "New method" is the simulation with the DEQ solution applied).**

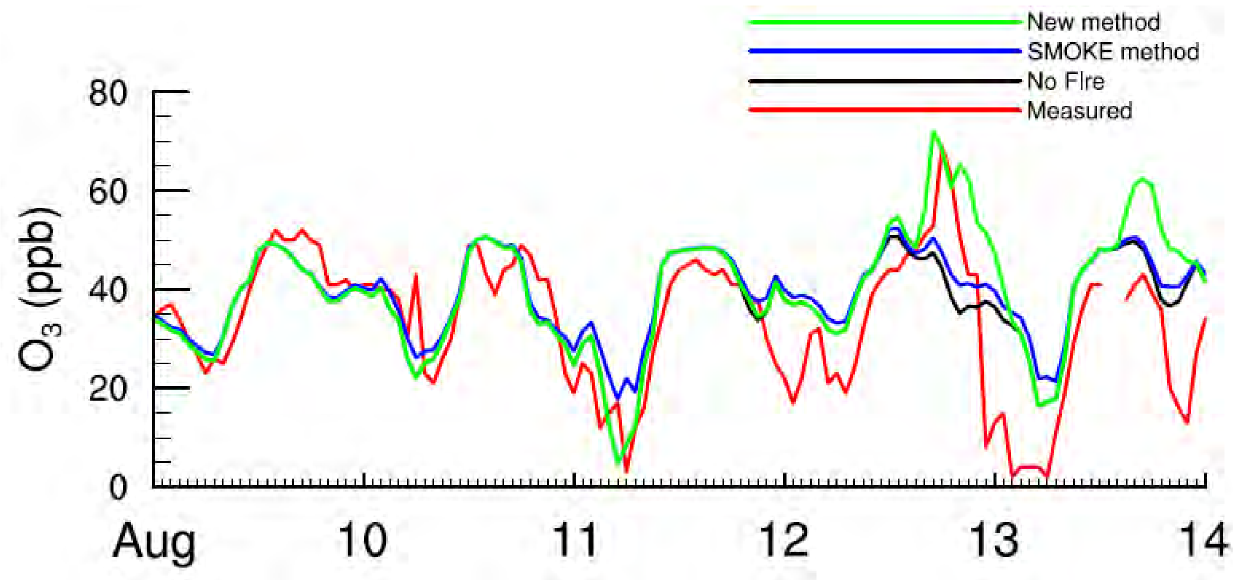



**Figure 9. Ozone time series at St. Luke's, Meridian, ID site ("SMOKE method" is the original simulation and "New method" is the simulation with the DEQ solution applied).**

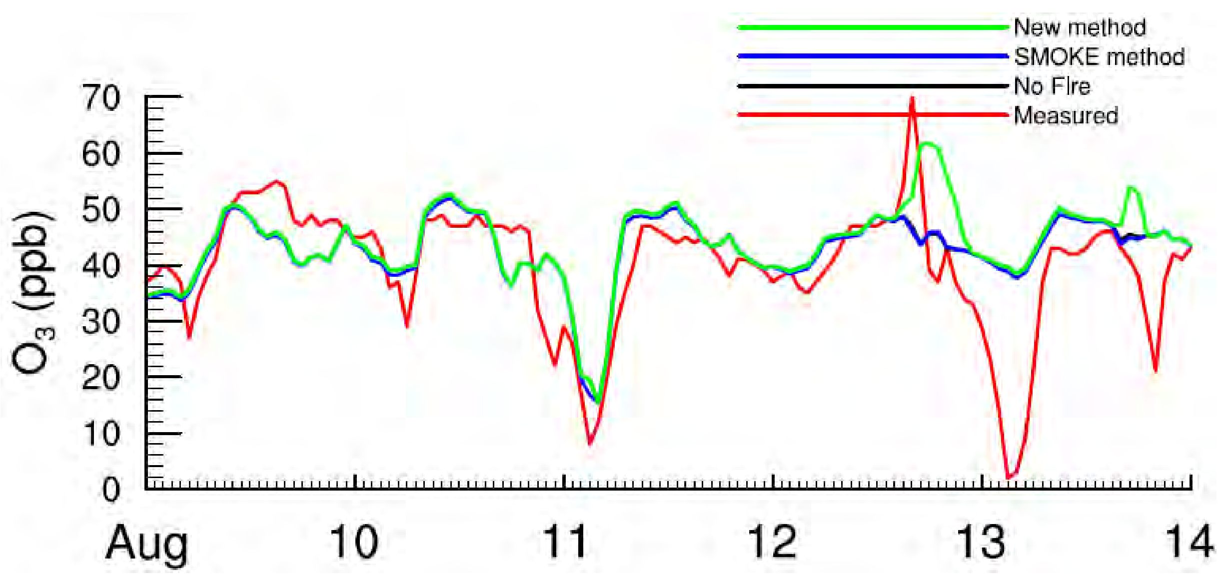



**Figure 10. Ozone time series at White Pine ("SMOKE method" is original simulation and "New method" is the simulation with the DEQ solution applied).**

# 5 Plume Rise Results in 2013 Episode

In DEQ's 81-day 2013 ozone modeling episode (July 8–September 26), the new method was applied to both wildfires and CRB fires, and the plume injection heights were captured to evaluate plume rise performance. In Figure 11, we compare hourly plume injection heights for more than 2,000 modeled wildfire plumes, or plume "cores," and more than 200 CRB fire plumes in the DEQ 2013 episode simulation with a study of satellite plume rise values over a 5-year period (Val Martin et. al. 2010) (*Smoke injection heights from fires in North America: analysis of 5 year of satellite observation*). The "2013 WF Modeled Plume Tops" represents wild fire plume tops and "2013 CRB Modeled Plume Tops" represents plume tops for all the CRB fires, distinguished from the wildfires by their presence in the afternoon burn window rather than 24 hours per day. As shown in Figure 11, in general, there are good agreements between the Val Martin study and the DEQ 2013 simulation although the plume top distributions are shifted slightly higher for wildfires and slightly lower for CRB compared to the "Forest Temperate" and "Cropland" plume injection heights, respectively in the Val Martin study. The DEQ plume top injection heights are also more consistent with the satellite measured plume heights than the modeled plume heights in the Raffuse et al. (2012) study, reproduced in Figure 3. In both comparisons, the CRB plume heights in DEQ's simulations are slightly lower, and this is expected to result in slightly higher precursor concentrations, and therefore, slightly higher levels of ozone enhancement at ground level, as reflected in Figure 10 and Figure 11.

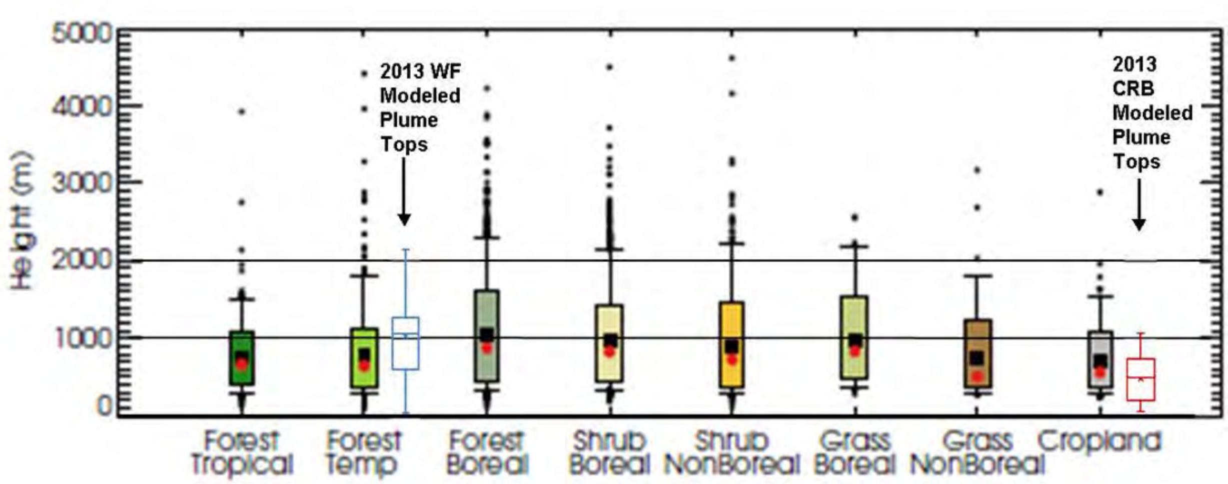



**Figure 11. Comparison of 2013 modeled plume injection heights to Val Martin et al. (2010). In both the Val Martin boxes and DEQ's WF and CRB boxes, the box indicates the interquartile distribution (25% to 75% of the values, while the "error bars" represent the 5% and 95% points in the distribution.**

# 7 Limited Comparison to RARE Agburn Study

The 2013 modeling episode includes the period of a special CRB study conducted by EPA, Washington State University, the Missoula AirFire Laboratory, and others (Zhou et al. 2017). The fire burns in the RARE agburn study occurred during DEQ's 2013 episode, but the burns included in the RARE study were not fully captured in DEQ's process for non-Idaho burns. However, for the single RARE study field burn on August 19, the DEQ simulation and RARE study did both include the burn. Actual burn parameters and the modeled parameters for the August 19 field burn are shown in Table 1 along with the resulting plume rise observed during the field study compared to that modeled using the DEQ's plume rise adjustment method. Table 1 shows the plume rise produced by our new method is a slightly lower but bounded by minimum and maximum observed heights during the burn. (The instrument used in the field study produces a minimum and maximum height for each time instance, which gives bounding estimates for plume height). Thus, the observed minimum and maximum plume heights are consistent with what we obtained in our 2013 episode simulation. While this is a very limited comparison, the results confirmed that the plume rise produced by the simulation using the new method is in good agreement with the observed plume rise for one case included in the EPA RARE study.

**Table 1. Limited comparison to RARE agburn study for one common CRB fire (Burn #1, August 19, 2013).**

| Parameter/Result | EPA Agburn Study Observed Parameters and Plume Rise | DEQ 2013 Simulated Parameters and Modeled Plume Rise |
|---|---|---|
| Field size (acres) | 163 | 163 |
| Crop type | Kentucky Bluegrass | Kentucky Bluegrass |
| Fuel consumption (tons) | 161 | 263 |
| Resulting plume rise (height above ground in meters) | Minimum Height ~670<br>Maximum Height ~2400 | Plume Top ~1300 |

# 8 Conclusion

DEQ diagnostically evaluated the existing modeling system to assess its handling of fire plume rise in the Soda Fire simulation and discovered poor model performance due to two plume rise related problems: (1) the smoldering fraction was too low, and (2) the plume rise was too high, resulting in very low ground-level concentrations. After investigating and examining the SMOKE algorithms and source code, a modified method was developed to address the problems. The new method shows not only a good model performance in Soda Fire simulation but also a reasonable comparison to EPA's agburn field study, and good comparison of plume top distributions between satellite observations reported by Val Martin et al. (2010) and the plume injection heights from our 2013 fire season modeling episode. The new method and Soda Fire results were presented at the 2017 NW-AIRQUEST annual meeting in June 2017 and at a subsequent AIRPACT-FIRE meeting for peer review. Both meetings generated positive feedback, and the new method is currently proposed for adoption in the AIRPACT5 regional forecast model.

## References

Air Sciences. 2013. DEASC$O_3$ Project Updates to the Fire Plume Rise Methodology to Model Smoke Dispersion. Memo prepared by Matt Mavko, Air Sciences Inc. and Ralph Morris, ENVIRON. Project No. 178–14. December 3.

Pouliot, G., T. Pierce, W. Benjey, S. O'Neill, and S. Ferguson. 2005. *Wildfire Emission Modeling: Integrating BlueSky and SMOKE*. Presented at 14th International Emission Inventory Conference: Transforming Emission Inventories Meeting Future Challenges Today. Las Vegas, NV. April 11–14.

Larkin N.K., S.M. O'Neill, R. Solomon, S. Raffuse, T.M. Strand, D.C. Sullivan, C. Krull, M. Rorig, J. Peterson, and S.A. Ferguson. 2009. "The BlueSky Smoke Modeling Framework." *Int. J. Wildland Fire.* 18(8): 906–920. DOI:10.1071/WF07086).

Raffuse et. al. 2012. "An Evaluation of Modeled Plume Injection Height with Satellite-Derived Observed Plume Height." *Atmosphere.* 3(1): 103–123.

Raffuse S.M., D.A. Pryden, D.C. Sullivan, N.K. Larkin, T. Strand, and T. Solomon. 2009. "SMARTFIRE Algorithm Description." Paper prepared for the US Environmental Protection Agency, Research Triangle Park, NC, by Sonoma Technology, Inc., Petaluma, CA, and US Forest Service, AirFire Team, Pacific Northwest Research Laboratory, Seattle, WA. STI-905517-3719.

Val Martin, M. et al. 2010. "Smoke Injection Heights from Fires in North America: Analysis of 5 Years of Satellite Observations." *Atmospheric Chemistry and Physics*. 10: 1491–1510.

Washington State University. 2017. "AIRPACT5. Air-Quality Forecasting for the Pacific Northwest." 5th Generation. (*http://lar.wsu.edu/airpact/index.html*)

Zhou, L., K. Baker, S. Napelenok, G. Pouliot, R. Elleman, S. O'Neill, S. Urbanski, and D. Wong. 2017. *Modeling Crop Residue Burning Experiments and Assessing the Fire Impacts on Air Quality* (Manuscript in Preparation).

# Appendix F. Evaluation of CMAQ Photochemical Transport Model

# Appendix F—Evaluation of CMAQ Photochemical Transport Model

**State of Idaho**
**Department of Environmental Quality**
**Air Quality Division**
**1410 N. Hilton**
**Boise, ID 83706**

**September 2017**

Printed on recycled paper, DEQ, September 2017, PID SSIP, CA code 81992. Costs associated with this publication are available from the State of Idaho Department of Environmental Quality in accordance with Section 60-202, Idaho Code.

# Table of Contents



# List of Tables



# List of Figures

# Summary

Crop residue burning (CRB) may contribute to air quality concerns. To achieve our twin goals of protecting public health from smoke impacts and permitting crop residue burning under certain conditions, the State of Idaho developed a CRB rule that has been used since 2008. However, in October 2015, the United States Environmental Protection Agency (EPA) changed its National Ambient Air Quality Standards (NAAQS) for ground-level ozone from 75 parts per billion (ppb) to 70 ppb. Based on the 2008 CRB rule, this change in ozone NAAQS would have reduced the ozone threshold from 56 ppb to 52 ppb for agricultural burning, leading to fewer burning days and possible elevated daily impacts. Therefore, the Idaho Department of Environmental Quality (DEQ) modified the CRB rule that allows crop residue burning when ozone levels are not exceeding, or expected to exceed, 90% or 63 ppb (rather than 75% or 52 ppb in the original 2008 rule) of the updated ozone NAAQS.

To add to the weight of evidence for the State Implementation Plan (SIP) demonstration, DEQ conducted a comprehensive photochemical modeling study to investigate the impact of Idaho's crop residue burning on ozone concentrations and to quantitatively assess if the revised Idaho CRB rule is still protective of the ozone NAAQS.

This report conducts an evaluation of the photochemical simulations to assess if they are adequate for studying the CRB impacts on ozone concentrations. The evaluation was conducted by comparing the computed CMAQ performance statistics against the proposed model performance criteria for ozone simulations. DEQ first used the model performance criteria proposed by Adelman et al. (2014) for ozone simulations, which use Fractional Bias (FB) and Fractional Error (FE). According to Adelman et al. (2014), the model performance is considered good if the statistics meet the following criteria.

Fractional Bias (FB) $\leq \pm 15\%$
Fractional Error (FE) $\leq 35\%$

Model performance statistics were computed for all ozone monitors in the domain as well as a subset focusing on those in Idaho. Evaluation shows that Fractional Bias (FB) and Fractional Error (FE) calculated for both the entire domain and the Idaho sites are far below the criteria, indicating good model performance for ozone simulations.

The model performance was then evaluated using EPA's 1991 ozone modeling guidance performance goals, which were based on Mean Normalized Bias (MNB) and Mean Normalized Gross Error (MNGE). The MNB and MNGE were first calculated for the entire domain, and then for the sites in Idaho. The evaluation also shows that the calculated MNB and MNGE values have not exceeded their respective goals, ± 15% and 35%, again suggesting that the modeling system has simulated realistic ozone concentrations. Actually we noticed that the use of MNB and MNGE is not encouraged by some scientists (Simon et al. 2012) due to a potential issue around zero; however, they do not seem to be an issue in this study and are still included for completeness.

In addition to the statistics metrics used to compare with the proposed performance criteria, DEQ also calculated additional performance metrics, including Normalized Mean Bias (NMB), Normalized Mean Error (NME), Mean Bias (MB), Mean Error (ME), and Root Mean Square

Error (RMSE). The performance metrics show that our model performance is much better than most of the photochemical studies over the United States or Canada documented in 69 peer-reviewed articles compiled by Simon et al. (2012).

Overall, the model evaluation shows that the CMAQ model has good performance and therefore can be used to investigate the CRB impacts on ozone concentrations for both the entire domain and Idaho region.

# 1 Introduction

The Idaho Department of Environmental Quality (DEQ) drafted the *2017 Crop Residue Burning Ozone State Implementation Plan Revision* (2017 CRB SIP) to demonstrate that CRB, as it occurs in Idaho, has and will continue to meet all requirements of the Clean Air Act and will not cause or significantly contribute to a National Ambient Air Quality Standards (NAAQS) violation. In support of the 2017 CRB SIP, this amendment provides additional evidence that when operating under the new rule, Idaho's CRB program will not cause or contribute to a violation of the ozone NAAQS at any locations in and around Idaho.

DEQ conducted a comprehensive photochemical modeling study to investigate the impact of Idaho's crop residue burning on ozone concentrations. In this report, DEQ conducts an evaluation of the photochemical simulations to assess if they are adequate for studying the CRB impacts on ozone concentrations.

# 2 Simulations and Performance Criteria

## 2.1 Model Simulations

Ground-level ozone is a secondary pollutant produced primarily by chemical reactions of nitrogen oxides ($NO_x$) and volatile organic compounds (VOCs) in the presence of sunlight. $NO_x$ and VOCs emitted from agricultural burning can interact with emissions from other various natural and anthropogenic sources that can affect ozone concentrations. High $NO_x$ emissions primarily come from on-road and nonroad mobile as well as nonpoint sources. Large quantities of VOCs are emitted from biogenic and nonpoint sources. In addition, VOC emissions from on-road and nonroad sources are also very high in populated regions. The relative importance of anthropogenic and biogenic VOC emissions is dependent on the location: although biogenic emissions account for ~90% of nonmethane VOCs globally, anthropogenic emissions are more important in populated areas (Atkinson and Arey 2003; Guenther et al. 1995). Moreover, the transport of VOCs and $NO_x$ as well as their reaction products from these sources in other states may also affect ozone concentrations in Idaho. Since the chemistry of $O_3$ with other pollutants is highly nonlinear, predictions of the changes in their concentrations under the various control scenarios is only possible if all relevant trace species are simulated in the same framework, including reactive radicals such as OH, photochemical processes, and cloud and secondary aerosol processes. This can only be achieved by the use of a comprehensive chemical transport model that can account for all relevant atmospheric chemistry in the target area. In addition to all these, the selection of modeling systems also needs to consider the operations of Idaho's CRB program, which uses ozone forecasts by the Air Indicator Report for Public Awareness and Community Tracking (AIRPACT) version 5 forecasting system. The AIRPACT5 system can simulate complex chemical and physical processes involved in ozone chemistry and transport, so it is suitable for the CRB modeling.

The development and operation of Weather Research and Forecast model (WRF)/AIRPACT5 air quality forecasting system involve two organizations: the Northwest Regional Modeling

Consortium (NWRMC) and Northwest International Air Quality Environmental Science and Technology Consortium (NW-AIRQUEST). These two organizations are collaborative groups consisting of universities and environmental agencies in the region, including the University of Washington, Washington State University, the U.S. Environmental Protection Agency (EPA), Idaho DEQ, Washington Department of Ecology, Oregon Department of Environmental Quality, the Nez Perce Tribe, and Environment and Climate Change Canada. The NWRMC funds the University of Washington (UW) to operate the WRF model (Mass et al. 2003), and the NW-AIRQUEST Consortium funds Washington State University (WSU) to operate AIRPACT5 (Vaughan et al. 2004; Herron-Thorpe et al. 2010) to provide operational meteorological and air quality forecasts for the Pacific Northwest region. In the past many years, both the input files and model components of the WRF/AIRPACT system have been updated to produce the best meteorological and air quality forecasts for the region. Given the enormous efforts of the universities and environmental agencies to improve its performance for the Northwest region, DEQ believes that the WRF/AIRPACT system, which is utilized as a major forecasting tool in real-world CRB operations in Idaho, is its best option for the CRB modeling study. DEQ used the newest version of the WRF/AIRPACT modeling system in this study.

WRF/AIRPACT5 air quality forecasting system consists of a number of complex components, including the WRF model, the Meteorology-Chemistry Interface Processor (MCIP), the Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System, and the Community Multiscale Air Quality (CMAQ) Modeling System. This report focuses on the evaluation of photochemical transport modeling by CMAQ, and the evaluation of the meteorological simulations by WRF and MCIP is provided in Appendix D.

The photochemical transport modeling requires emissions, which were processed by the SMOKE (version 3.5.1) model before being used as input to the CMAQ model in this study. The emissions used in the simulation were based on the newest emission inventories utilized in the AIRPACT5 system with a number of key updates. The biogenic emissions were calculated specifically for the simulations in this study using the Model of Emissions of Gases and Aerosols from Nature (MEGAN version 2.10). Similarly, the on-road mobile emissions were simulated using the latest version of the Motor Vehicle Emissions Simulator (MOVES version 2014a) model. The emission inventories for the wildfires and prescribed fires in the region were developed by Sonoma Technology for this study, as described in Appendix B. The emissions from crop residue burning were also estimated in this study and the details are provided in Appendix C. In addition, DEQ also developed a new plume rise treatment to improve the vertical distribution of fire emissions injected into the model and thus ensure reasonable dispersion and transport. This new treatment was evaluated using the 2015 Soda fire episode as described in Appendix E.

To account for the effect of regional pollution transport, the domain of the photochemical simulations, shown in Figure 1, covers the entire Pacific Northwest, including all of Idaho, Oregon, and Washington, portions of California, Montana, Nevada, Utah, Wyoming, and portions of the Canadian provinces of Alberta, British Columbia, and Saskatchewan. The spatial resolution was set to 4 km, which can reasonably resolve the ozone formation and loss processes. Table 1 shows the vertical structure of the simulations with 21 vertical layers. The episode selected for studying the CRB impact on ozone concentrations was July8-September 26, 2013, which covers a period of both highest ozone concentrations and maximum CRB activities.

Before this major episode, the modeling system was run for 12 days which were used as model "spin-up" and are excluded in this evaluation analysis. Boundary conditions for the photochemical simulations were provided by the results of a global chemical transport model: Model for OZone And Related chemical Tracers (MOZART).

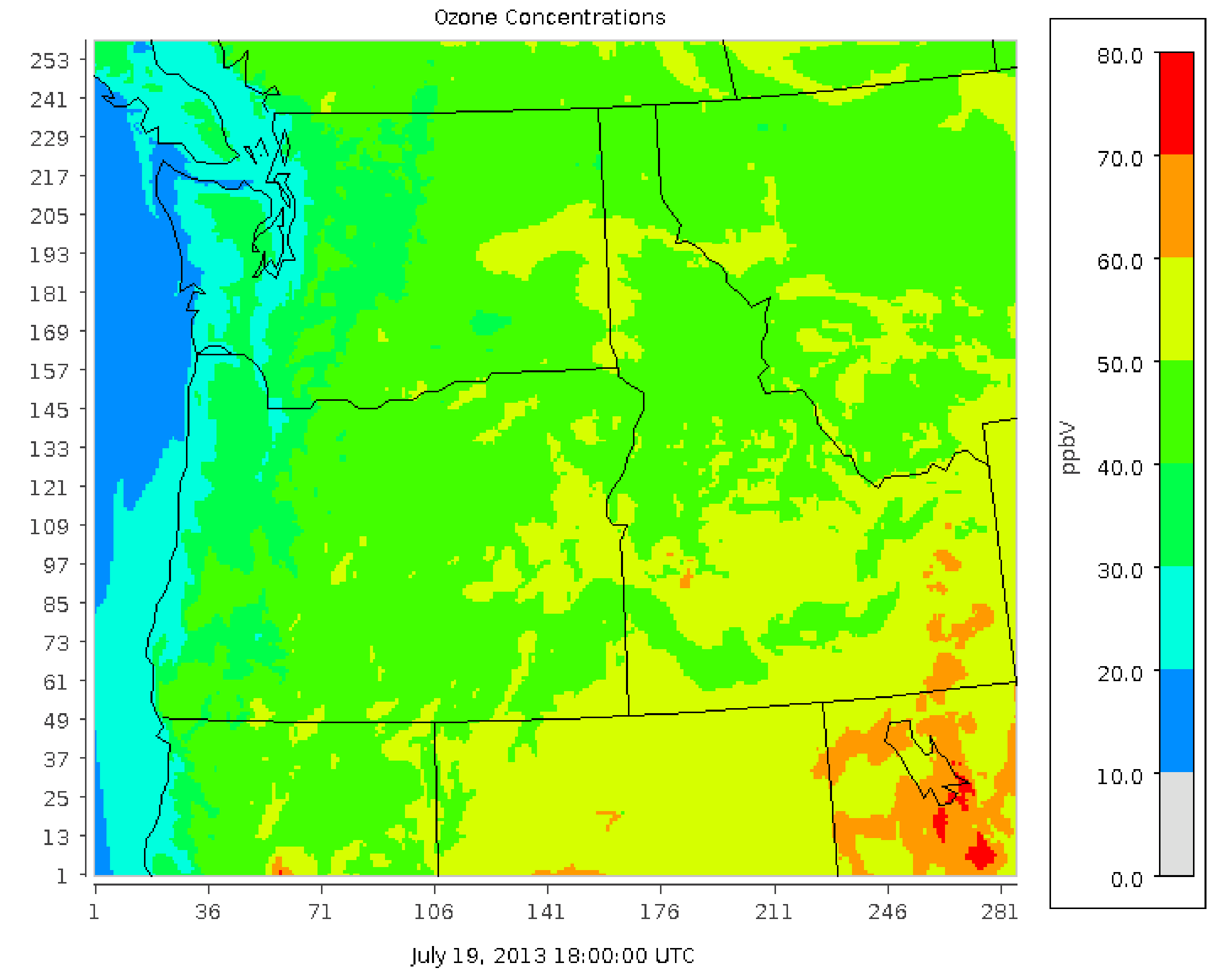



**Figure 1. The model domain with surface ozone concentrations on July 19 at 18:00:00 UTC.**

**Table 1. Vertical layers in the CMAQ model.**

| Layer | Sigma Level | Approximate Height Above Ground (m) |
|---|---|---|
| 0 | 1 | — |
| 1 | 0.995 | 40 |
| 2 | 0.99 | 80 |
| 3 | 0.9841 | 130 |
| 4 | 0.9772 | 185 |
| 5 | 0.9702 | 245 |
| 6 | 0.962 | 315 |
| 7 | 0.9525 | 395 |
| 8 | 0.9414 | 490 |
| 9 | 0.9284 | 600 |
| 10 | 0.9134 | 730 |
| 11 | 0.896 | 880 |
| 12 | 0.8759 | 1,060 |
| 13 | 0.8527 | 1,270 |
| 14 | 0.7608 | 2,150 |
| 15 | 0.6309 | 3,525 |
| 16 | 0.4594 | 5,675 |
| 17 | 0.2832 | 8,565 |
| 18 | 0.1595 | 11,450 |
| 19 | 0.0806 | 14,215 |
| 20 | 0.0312 | 16,865 |
| 21 | 0 | 19,425 |

## 2.2 Model Performance Criteria

Model evaluation for the CMAQ photochemical model simulations was conducted using the Atmospheric Model Evaluation Tool (AMET) v 1.2 (Appel et al. 2013). This tool is designed to ingest large quantities of meteorological observations and air quality observations for the purpose of evaluating the performance of WRF, MCIP, and CMAQ through statistical comparisons to the measured values.

Recently, Adelman et al. (2014) proposed model performance criteria for ozone simulations, which use Fractional Bias (FB) and Fractional Error (FE). According to Adelman et al. (2014), the model performance is considered good if the statistics meet the following criteria.

Fractional Bias (FB) $\leq \pm 15\%$
Fractional Error (FE) $\leq 35\%$

The performance criteria for ozone simulations proposed by Adelman et al. (2014) were first used in the CMAQ model evaluation. Then, the CMAQ performance statistics were also compared to the U.S. EPA's 1991 ozone modeling guidance performance goals, which were based on Mean Normalized Bias (MNB) and Mean Normalized Gross Error (MNGE) with their perspective goals of $\leq \pm 15\%$ and $\leq 35\%$.

It should be noted that all complex photochemical models cannot capture all processes, especially episodic nature of human activities such as traffic jams, and use parameterizations of complex processes. Therefore, all the photochemical simulations inevitably have biases. The performance criteria were not designed to give a passing or failing grade, but to help compare results across different modeling studies.

# 3 Results

## 3.1 Statistics Metrics and Spatial Distribution

The CMAQ performance for ozone simulations in the 2013 episode was evaluated using observational data at all AQS ozone monitors in the domain as well as a subset focusing on those in Idaho ingested into the U.S. EPA's the Atmospheric Model Evaluation Tool (AMET) program (Appel et al. 2013). The results are presented in Table 2, which shows that Fractional Bias (FB) and Fractional Error (FE) calculated for both the entire domain and the Idaho sites have met the ozone performance criteria proposed by Adelman et al. (2014), indicating good model performance for ozone simulations. Figure 2 and Figure 3 show, respectively, the Fractional Bias and Fractional Error of ozone concentrations at all sites across the domain that have at least 75% of valid data during the 2013 episode. In Figure 2, the Fractional Bias is small across the entire domain, and particularly small with the values below ± 5% at all three Idaho sites: St. Luke's in Meridian, White Pine in Boise, and Craters of the Moon. Figure 3 shows that the Fractional Error is also small across the entire domain, with all sites in or near Idaho having FE values below 25%, which have met the ozone performance criterion (≤ 35%) proposed by Adelman et al. (2014). In Idaho, the FE value is lower at a rural site (i.e., Craters of the Moon) than the urban sites (i.e., St. Luke's and White Pine). The evaluation indicates that the photochemical modeling system performs well for ozone simulations and is adequate for studying the CRB impacts on ozone concentrations.

Table 2 also compares the calculated CMAQ ozone statistics against the U.S. EPA's 1991 ozone modeling guidance performance goals, which were based on Mean Normalized Bias (MNB) and Mean Normalized Gross Error (MNGE). The MNB and MNGE were first calculated for all sites across the domain, and then for the sites in Idaho. The comparisons also show that the calculated MNB and MNGE values have met their respective goals, ± 15% and 35%, again suggesting that the modeling system has simulated realistic ozone concentrations. While we noticed that the use of MNB and MNGE is not encouraged by some scientists (e.g., Simon et al. 2012) due to a potential issue around zero, they are still included in this study for completeness.

In addition to the statistics metrics used to compare with the proposed performance criteria, DEQ also calculated additional statistics metrics, including Normalized Mean Bias (NMB), Normalized Mean Error (NME), Mean Bias (MB), Mean Error (ME), and Root Mean Square Error (RMSE). The results are also included in Table 2. The spatial distributions of these metrics are shown in Figures 4-8. These figures and Table 2 show that these bias and error metrics are also small.

Simon et al. (2012) collected model performance metrics from 69 peer-reviewed articles that applied photochemical models over the United States or Canada in research, regulatory or forecasting applications. In comparison to the range of reported performance metrics compiled by Simon et al. (2012), our CMAQ model performance is much better than most of the studies. This provides further confidence in our photochemical modeling for this CRB study.

Overall, the model evaluation shows that the photochemical modeling has met the model performance criteria for ozone simulations, and is adequate for studying the CRB impact on ozone concentrations in this study.

**Table 2. CMAQ model performance.**

| Statistic | 2013 Base-Case Performance, Entire Domain | 2013 Base-Case Performance, Idaho Region | Acceptable Range (Adelman et al. 2014) |
|---|---|---|---|
| **Fractional Bias (FB) (%)** | **1.2** | **-3.5** | **≤ ± 15** |
| **Fractional Error (FE) (%)** | **17.8** | **16.7** | **≤ 35** |
| Mean Normalized Bias (MNB) (%) | 5.6 | -4.3 | ≤ ± 15 |
| Mean Normalized Gross Error (MNGE) (%) | 19.7 | 14.2 | ≤ 35 |
| Normalized Mean Bias (NMB) (%) | 0.9 | -5.3 | N/A |
| Normalized Mean Error (NME) (%) | 16.2 | 14.7 | N/A |
| Mean Bias (MB) (ppb) | 0.4 | -2.6 | N/A |
| Mean Error (ME) (ppb) | 6.9 | 7.4 | N/A |
| RMSE | 9.1 | 9.7 | N/A |

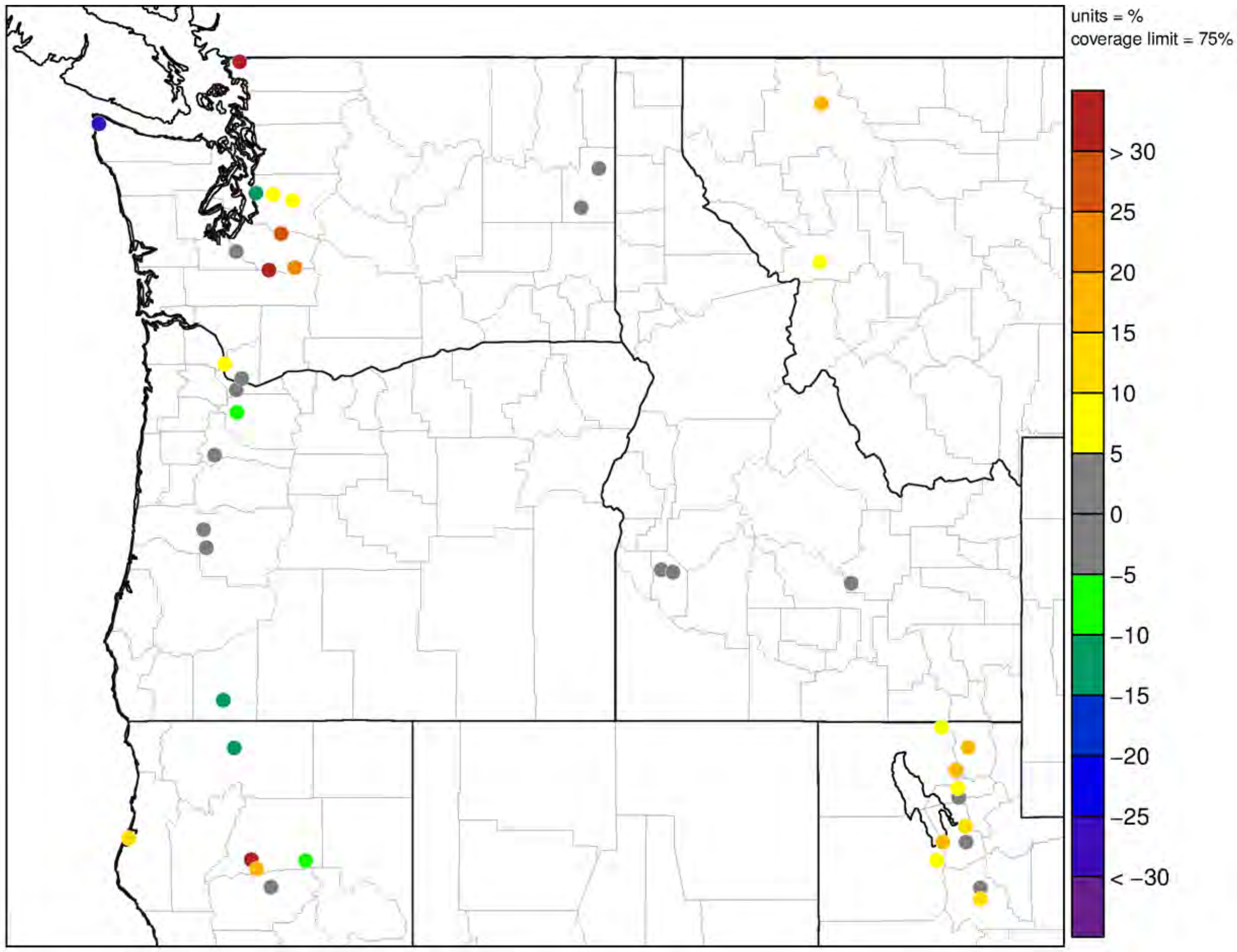



**Figure 2. Fractional bias (FB) (%) of ozone concentrations at all sites across the domain during the 2013 episode.**

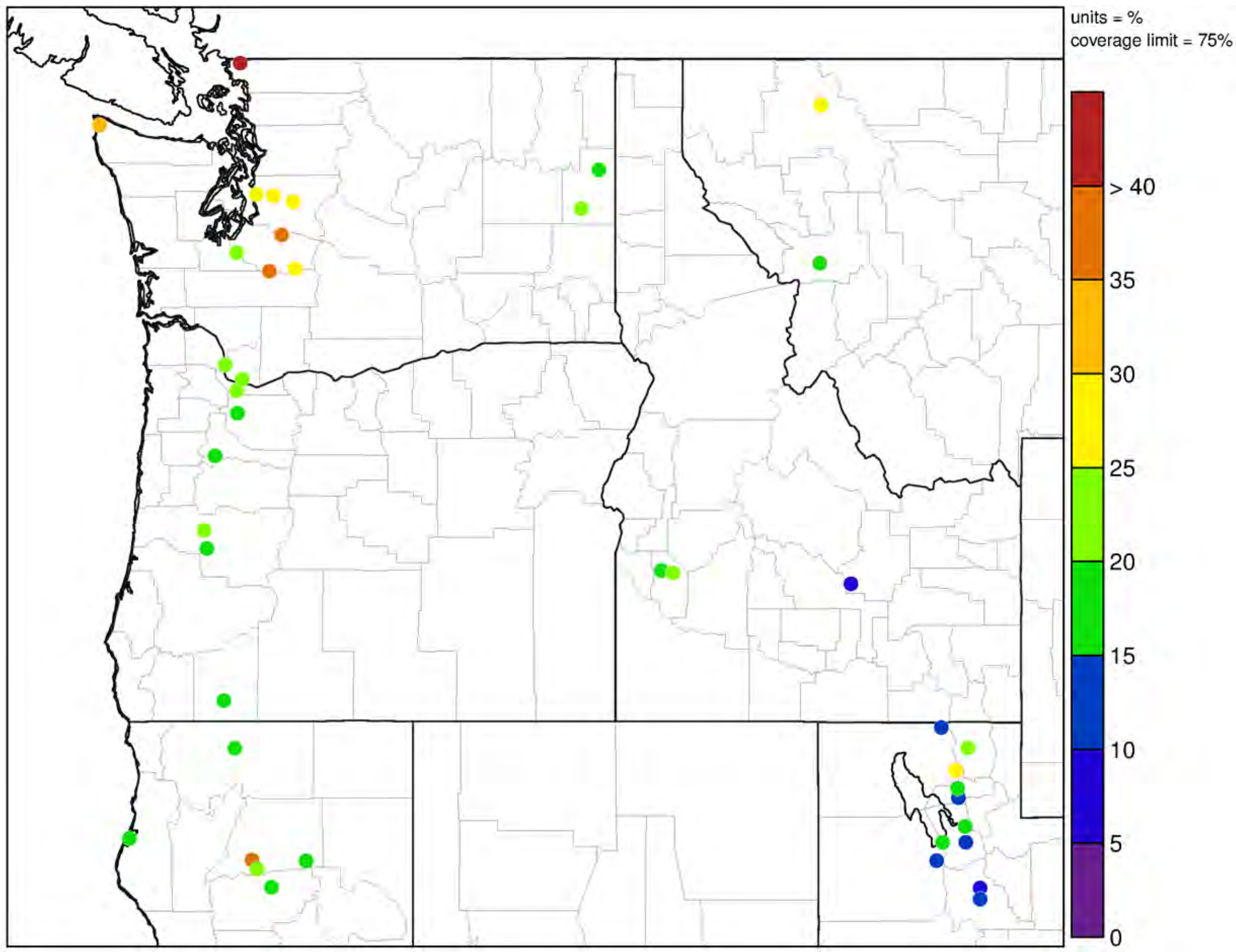



**Figure 3. Fractional error (FE) (%) of ozone concentrations at all sites across the domain during the 2013 episode.**

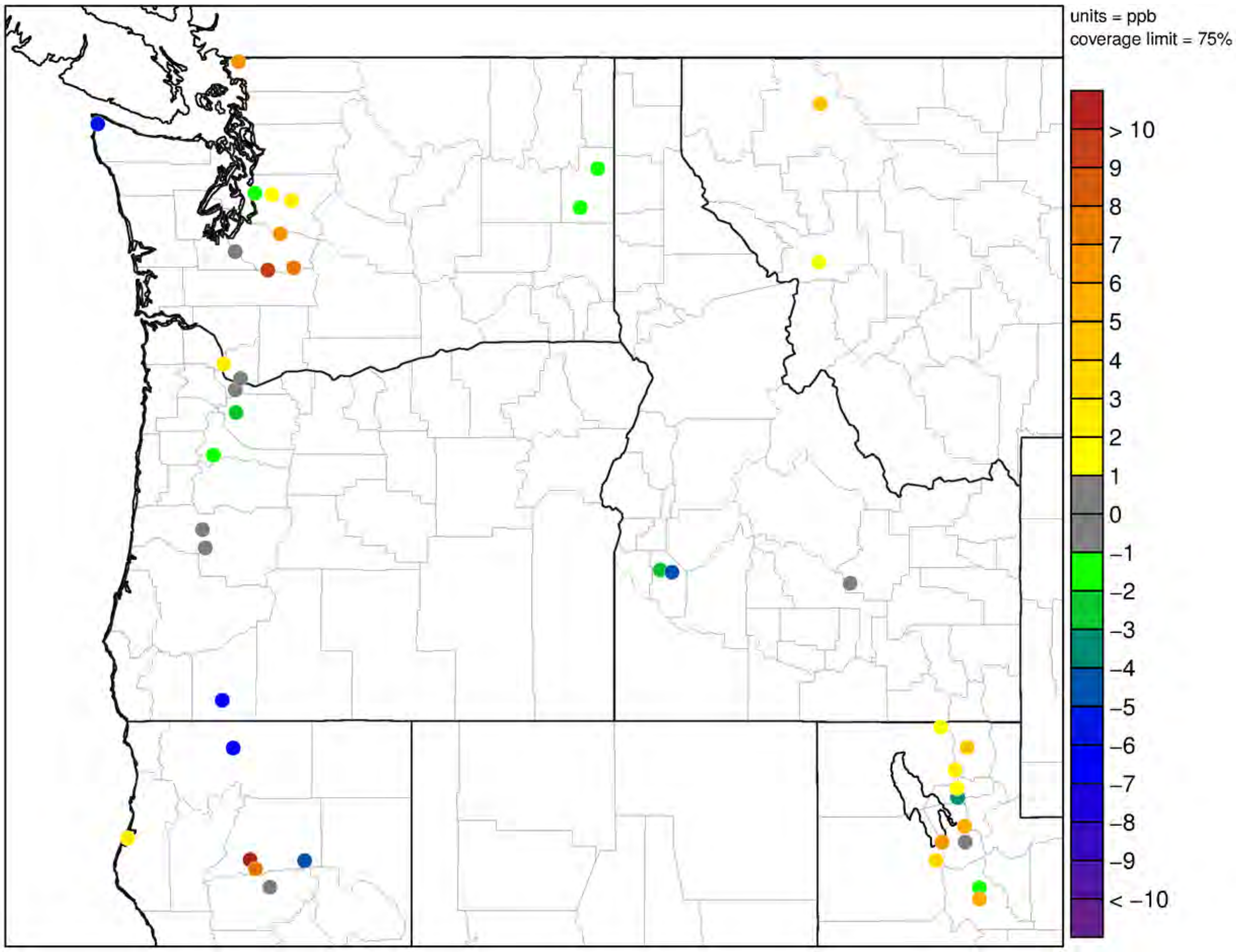



**Figure 4. Mean bias (MB) (ppb) of ozone concentrations at all sites across the domain during the 2013 episode.**

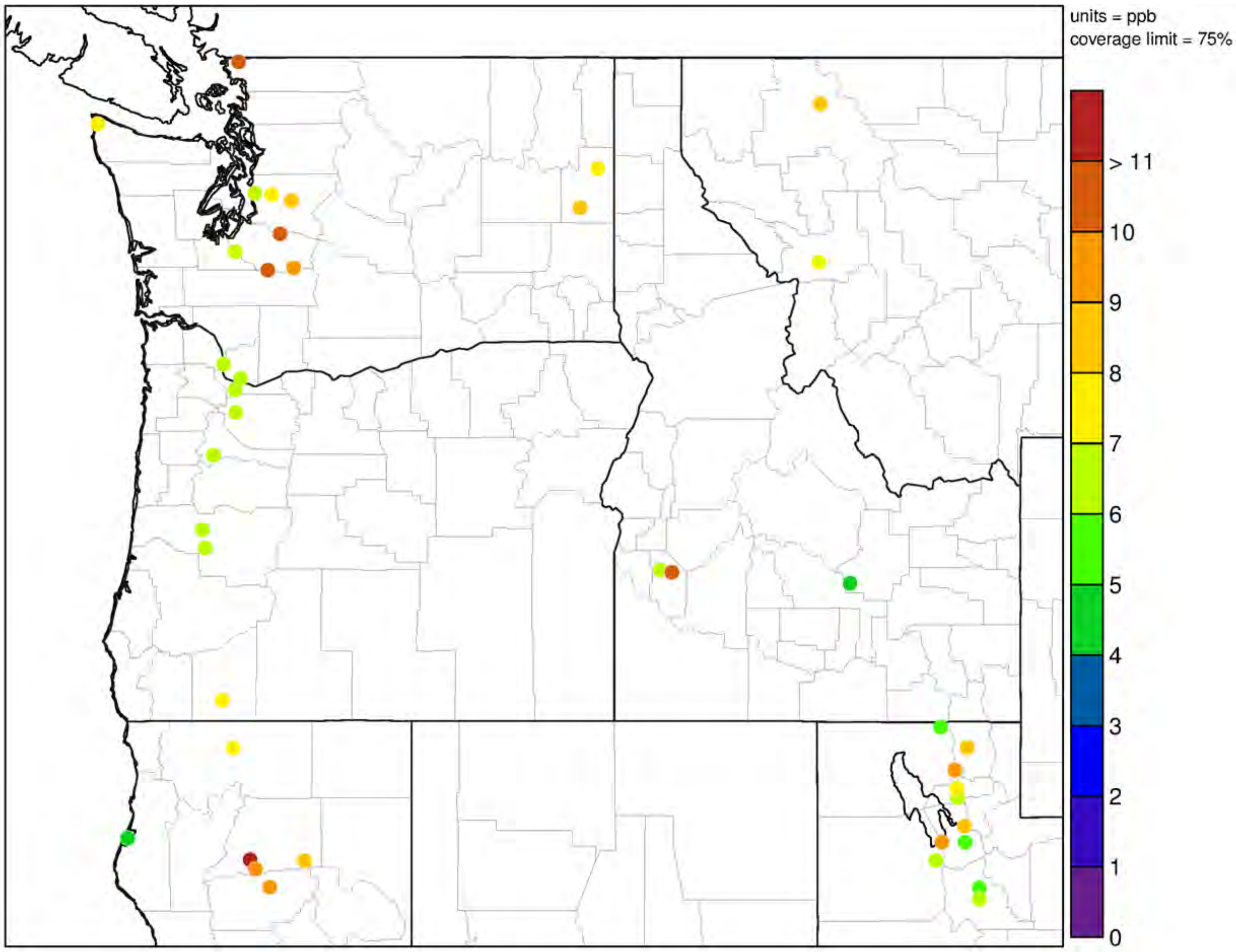



**Figure 5. Mean error (FE) (ppb) of ozone concentrations at all sites across the domain during the 2013 episode.**

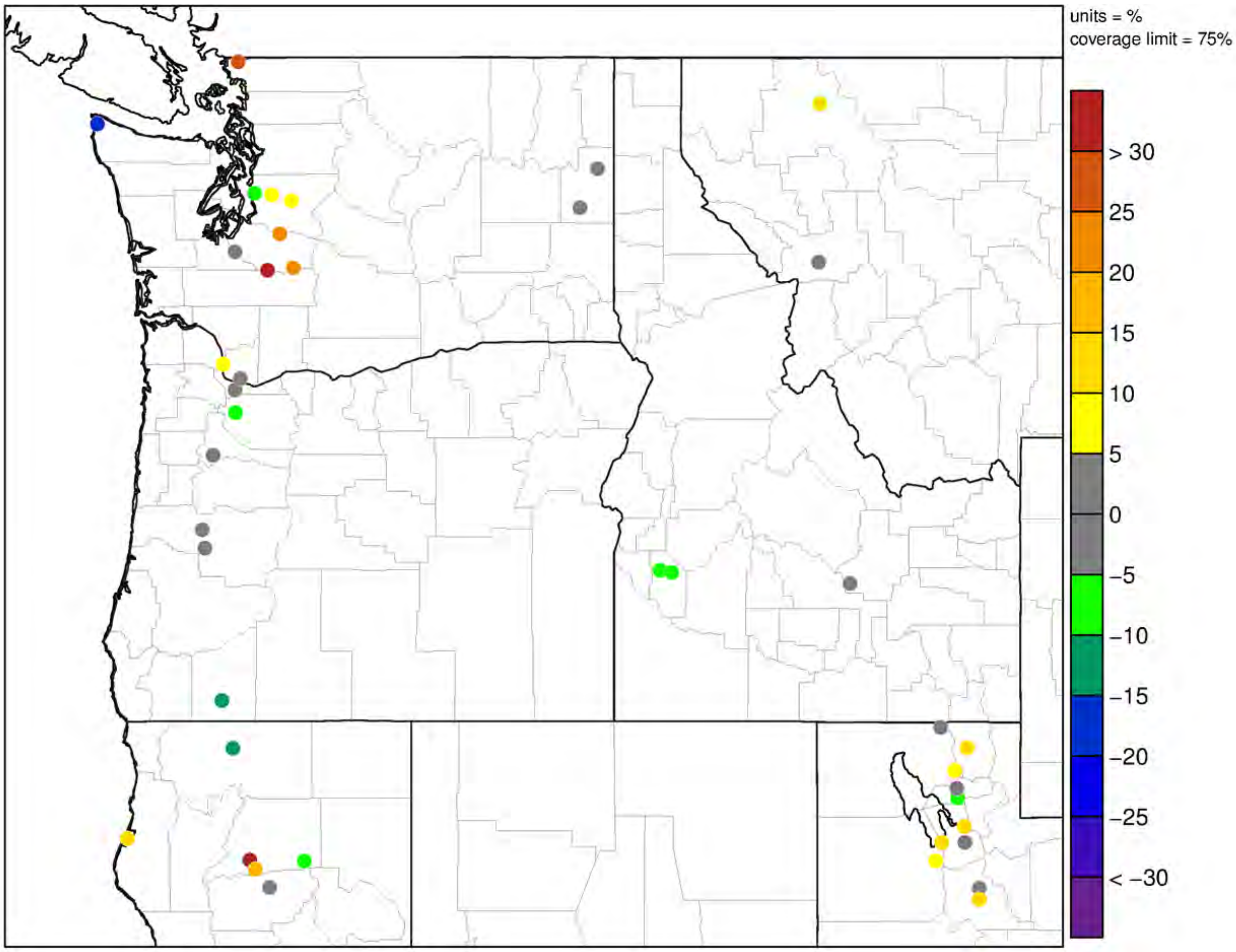



**Figure 6. NMB(%) of ozone concentrations at all sites across the domain during the 2013 episode.**

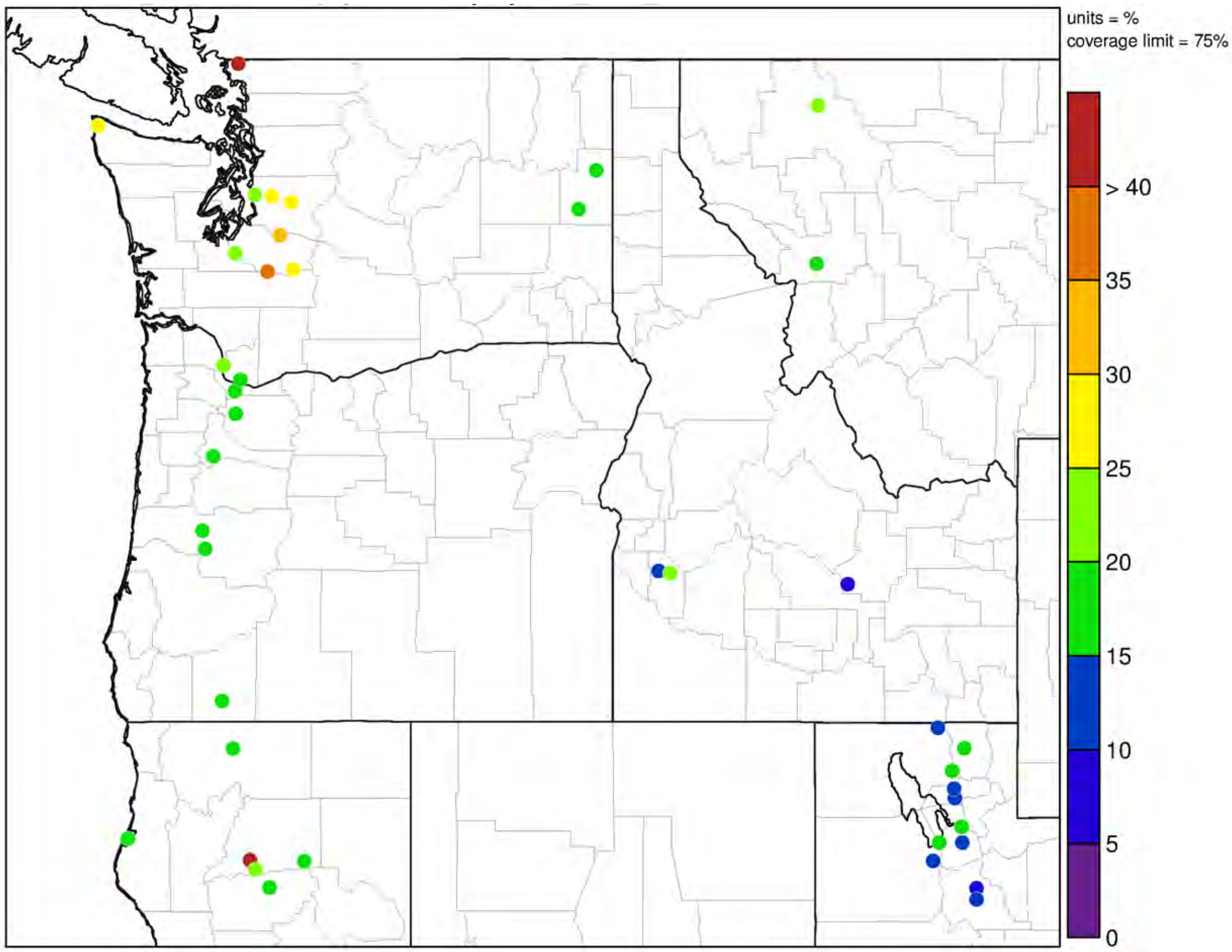



**Figure 7. NME (%) of ozone concentrations at all sites across the domain during the 2013 episode.**

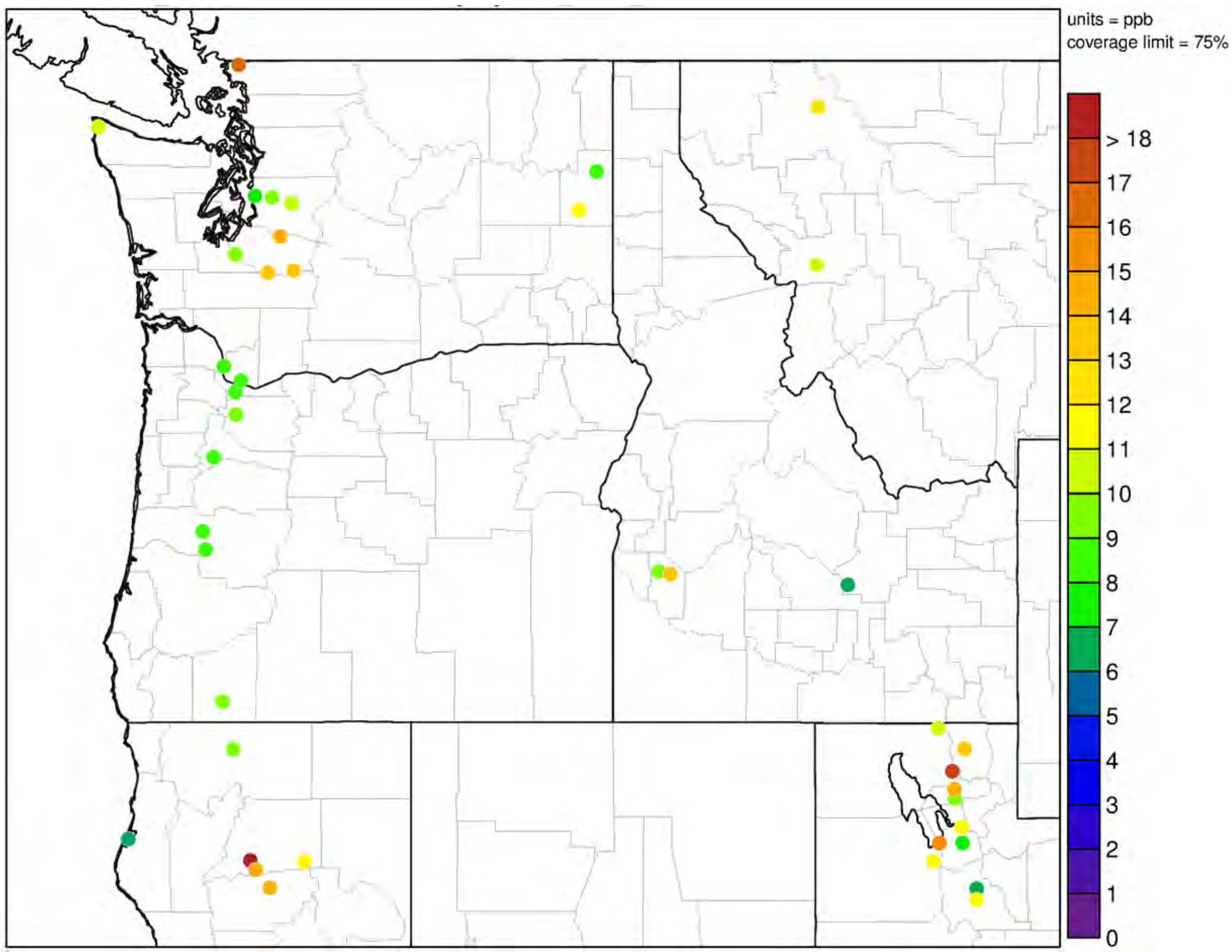



**Figure 8. RMSE of ozone concentrations at all sites across the domain during the 2013 episode.**

## 3.2 Time Series

In addition to the spatial figures, DEQ also evaluated the time series. Figure 9 shows the time series of modeled and observed daily maximum 8-hour ozone concentrations (ppb) averaged over all sites across the domain. In general, the CMAQ model tracked the temporal variability of the observed ozone concentrations very well. While the agreement between the modeled and observed ozone concentrations is good for the 2013 episode, there are some considerable biases around September 12-14, 2013. These biases, as shown in Figure 10, still appear in the simulation when the Idaho CRB emissions are removed, suggesting that these are systematic biases that do not affect the impacts of Idaho CRB on ozone concentrations.

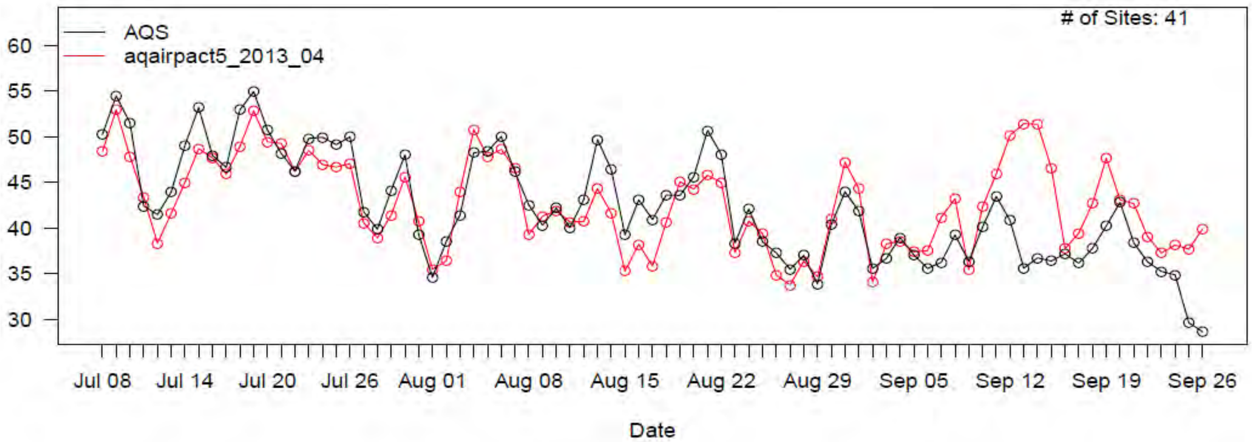



**Figure 9. Time series of CMAQ-modeled and observed daily maximum 8-hour ozone concentrations (ppb) averaged over all sites across the domain in the scenario driven by all emission sources.**

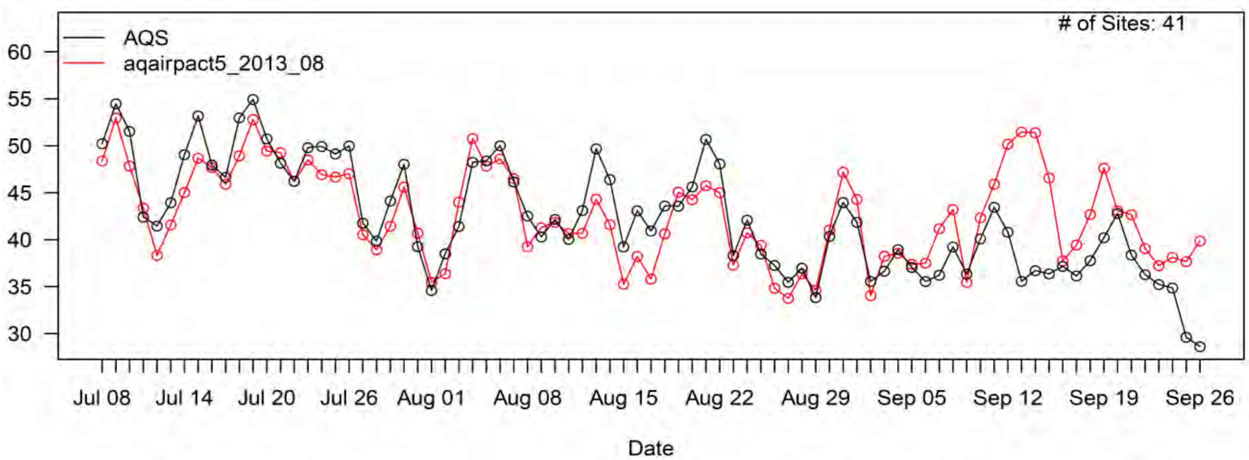



**Figure 10. Time series of CMAQ-modeled and observed daily maximum 8-hour ozone concentrations (ppb) averaged over all sites across the domain in the scenario driven by all emission sources except Idaho agricultural burning.**

## 3.3 Box and Scatter Plots

Figure 11 presents a box plot of CMAQ-modeled and observed daily maximum 8-hour average ozone concentrations in the scenario driven by all emission sources. The figure shows good agreement between the distributions of modeled and observed ozone concentrations in all the three months, with a slight underestimate in July and August but a slight overestimate in September, 2013.

Figure 12 shows a scatter plot that compares CMAQ-modeled and observed daily maximum 8-hour average ozone concentrations in the scenario driven by all emission sources. This figure, again, confirms a good agreement between the CMAQ-modeled and observed ozone concentrations.

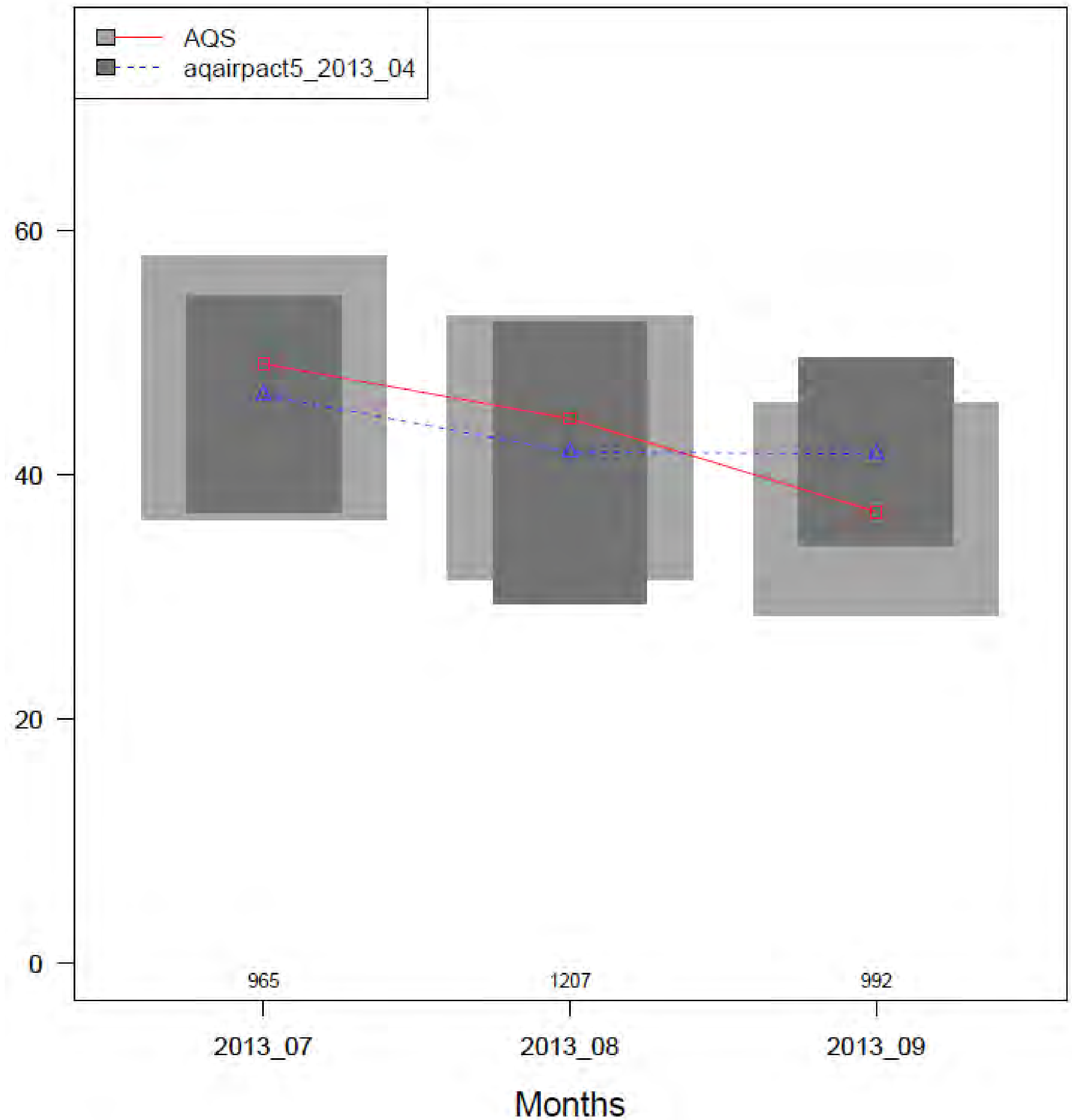



**Figure 11. Box plot of CMAQ-modeled and observed daily maximum 8-hour average ozone concentrations (ppb) in the scenario driven by all emission sources.**

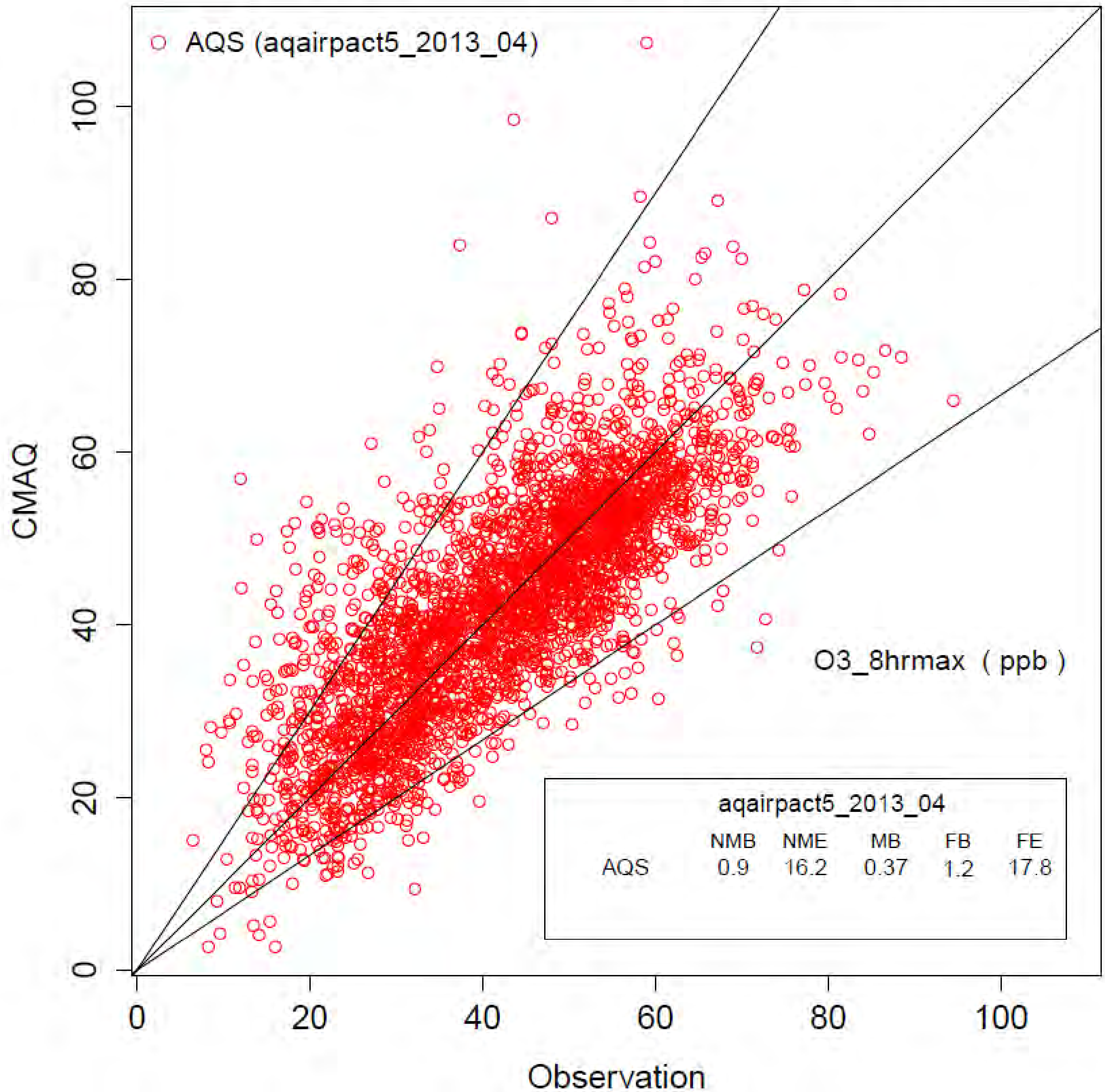



**Figure 12. Comparison of CMAQ-modeled and observed daily maximum 8-hour average ozone concentrations (ppb) in the scenario driven by all emission sources.**

# 4 Conclusions

The ozone simulations for the 2013 episode, which is the major episode for the CRB SIP demonstration, were evaluated in this report. The evaluation shows that the statistics of photochemical simulations have not exceeded the ozone performance criteria for the entire domain as well as for the Idaho sites, indicating good performance of the photochemical simulations. The time series, box, and scatter plots further confirm that the photochemical model well reproduced the observed ozone concentrations in the 2013 episode. Given its good ozone performance revealed by the evaluations, the CMAQ modeling system can be used to study the CRB impacts on ozone formation in this SIP demonstration.

## References

Adelman, Z., U. Shanker, D. Yang, and R. Morris. 2014. “Three-State Air Quality Modeling Study CAMx Photochemical Grid Model Final Model Performance Evaluation Simulation Year 2008.” Chapel Hill, NC and Novato, CA.: University of North Carolina at Chapel Hill and ENVIRON International Corporation.

Appel, Y., Y. Gilliam, and U. Shankar. 2013. “Atmospheric Model Evaluation Tool (AMET) v1.2 User’s Guide.” Research Triangle Park, NC: U.S. EPA. https://www.cmascenter.org/amet/documentation/1.2/AMET_Users_Guide_v1.2.1.pdf.

Atkinson, R. and J. Arey. 2003. “Atmospheric Degradation of Volatile Organic Compounds.” *Chemical Reviews.* 103(12): 4605–4638.

Guenther, A., C.N. Hewitt, D. Erickson, R. Fall, C. Geron, T. Graedel, P. Harley, et al. 1995. “A Global Model of Natural Volatile Organic Compound Emissions.” *Journal of Geophysical Research: Atmospheres*. 100(D5): 8873–8892.

Herron-Thorpe, F.L., B.K. Lamb, G.H. Mount, and J.K. Vaughan. 2010. “Evaluation of a Regional Air Quality Forecast Model for Tropospheric NO 2 Columns Using the OMI/Aura Satellite Tropospheric NO 2 Product.” *Atmospheric Chemistry and Physics*. 10(18): 8839–8854.

Mass, C.F., M. Albright, D. Ovens, R. Steed, M. MacIver, E. Grimit, T. Eckel, et al. 2003. “Regional Environmental Prediction over the Pacific Northwest.” *Bulletin of the American Meteorological Society*. 84(10): 1353–1366.

Simon, H., K.R. Baker, and S. Phillips. 2012. “Compilation and Interpretation of Photochemical Model Performance Statistics Published between 2006 and 2012.” *Atmospheric Environment*. 61: 124–139.

Vaughan, J., B. Lamb, C. Frei, R. Wilson, et al. 2004. “A Numerical Daily Air Quality Forecast System for the Pacific Northwest.” *Bulletin of the American Meteorological Society*. 85(4): 549.

# Appendix G. Detailed Results of the CRB Impact Analysis

# Appendix G—Detailed Results of the CRB Impact Analysis

2013 Modeling Episode

State of Idaho
Department of Environmental Quality
Air Quality Division
1410 N. Hilton
Boise, ID 83706

September 2017

Printed on recycled paper, DEQ, September 2017. PID SSIP, CA code 81992. Costs associated with this publication are available from the State of Idaho Department of Environmental Quality in accordance with Section 60-202, Idaho Code.

## Table of Contents



## List of Tables



## List of Figures

# 1 Introduction

Detailed results of the crop residue burning (CRB) impact analysis are provided in this appendix for the three CRB impact scenarios modeled by the Idaho Department of Environmental Quality (DEQ) in support of the 2017 CRB State Implementation Plan (SIP) revision.

The new rule being evaluated in this modeling effort changes the burn cessation point in the DEQ CRB program from 52 ppb (75% of the National Ambient Air Quality Standards [NAAQS]) to 63 ppb (90% of the NAAQS). In 2013, the year of the modeling episode the cessation point was 56 ppb, 75% of the 2008 ozone NAAQS. The potential for CRB impacts to contribute to concentrations in excess of NAAQS can therefore be assessed by examining two model results: (1) the CRB-only contribution results and (2) total MDA8 ozone concentrations obtained when the CRB contributions are added to the background MDA8 ozone concentration that occurs at the same location and same day.

CRB contributions to the maximum daily averaged 8-hour ozone concentration (MDA8) predicted in this modeling exercise must be below a worst-case buffer of 7 ppb to demonstrate that the 70 ppb NAAQS will not be threatened by the rule change to the 63 ppb cessation threshold. In addition, to further demonstrate that the Idaho CRB activity cannot cause a total ozone MDA8 concentration above the NAAQS, the background ozone.

The results reported in this appendix are based on the following 4 simulations:

- **Background emissions analysis—**A modeling analysis for the July 8–September 26, 2013, episode with all emissions sources except Idaho CRB sources, including all wildfires and all the agricultural burning in other states and tribal areas outside Idaho's CRB program. This simulation provided the background ozone concentrations.
- **Scenario 1: 2013 actual CRB emissions—**Actual crop residue burns in the CRB program that occurred during the July 8–September 26, 2013, episode. This scenario provided the 2013 base case for CRB emissions in Idaho before the new rule (i.e., burning was not allowed in this scenario for any burn area or county in which the ozone MDA8 was forecasted to be over 56 ppb, 75% of the 2008 NAAQS).
- **Scenario 2: 2013 burning under the new rule—**This scenario adds burning on additional days allowed under the new rule. To simulate the base year 2013 episode as it would occur under the new rule, this scenario includes the Scenario 1 actual burns plus "hypothetical burn" median emissions that could have also occurred under the new rule when the model predicted a concentration between 56 ppb and 63 ppb.
- **Scenario 3: maximum daily burning—**To ensure that the maximum existing/historical daily burning levels are assessed, the burns simulated in Scenario 2, (including both the actual burns and hypothetical burns under the new rule) were grown by adding emissions needed to bring each county up to the historical maximum 1-day emissions for that county.

# 2 CRB Contribution Results

CRB contributions for the three modeled scenarios are presented in detail in this section for the 81-day modeling episode, July 8–September 26, 2013. Tile plot maps for the 4 highest CRB contribution days for each Scenario 1 through 3 are reflected in Figure 1 through Figure 3. These modeled contribution maps represent each CRB scenario output at every grid cell in the domain after subtraction of the base-case background simulation values that include all sources except Idaho CRB burns. It is important to note that the maximum CRB contribution on each of the 4 highest days (for all scenarios) is very isolated and is always much higher than CRB impacts in all other locations in the state. As a result, the maximum statewide MDA8 value for each day, identified in the model-generated caption below each map can be used for each day to ensure the highest values are captured, without expending resources analyzing and processing an excessively large data set including much lower contribution values that do not influence the analysis of maximum impacts.

CRB contribution results for all daily maximum MDA8 ozone concentrations over a DEQ-selected *de minimis* threshold of 0.2 ppb are provided in ranked order for Scenario 1 through 3 in Table 1 through Table 3, respectively. This threshold is 1/5th of the EPA's 1.0 ppb Significant Impact Level (SIL) for ozone so values below this level do not merit further analysis.

The maximum CRB MDA8 ozone contribution was 1.8 ppb on August 12, 2013, for both Scenario 1 and Scenario 2. The top ten Scenario 1 CRB contributions were also the top ten Scenario 2 contributions indicating that the additional emissions added to the new 302 county-days opened up by the new rule did not cause higher concentrations than the top ten existing actual burns simulated in Scenario 1. DEQ believes this is because the new Scenario 2 burns generally occurred on warmer, sunnier days, which not only cause the ozone to be in the range 56–63 ppb, but also provided increased vertical mixing and better dispersion of ozone precursors. The effects of drier fuels, more efficient combustion and higher plume rise, would also likely contribute to lower ozone formation on these new days under the new rule, but such effects are not captured by the modeling and are not reflected in these results. The primary advantage of the new rule is more opportunity to spread out the same number of acres on additional days, therefore lowering impacts of ozone precursors as well as all other pollutants that occur in biomass plumes.

Under Scenario 3, the emissions for all burns included in Scenario 1 and Scenario 2 were grown to reflect the emissions levels for the maximum historical burn acreages, in the 9-year history of the CRB program for the counties where they occurred. The highest CRB contribution in the Scenario 3 results, presented in Table 3, also occurred on August 12; however, the added maximum historical emissions resulted in a maximum MDA8 ozone contribution from CRB of 4.0 ppb, at the same location of the previous highest CRB contributions (1.8 ppb) from Scenario 1 and 2. This maximum contribution is still well below the worst-case buffer of 7 ppb.

# 3 Background Concentrations

The "background without CRB" MDA8 ozone concentrations at the location of each maximum daily MDA8 CRB contribution are also shown for Scenario 1 through 3 in Table 1 through Table 3 respectively, along with the location and the maximum CRB contributions for each day. The CRB contributions are added to the background concentrations at the same point to provide the "Total MDA8 $O_3$ with CRB" concentrations.

For Scenario 1 (Table 1) which simulated the actual burns as they occurred in 2013, the background ozone concentrations are all below 56 ppb because the previous rule, in effect in 2013, did not allow burning to occur when the ozone was forecast to be above 56 ppb. The average background MDA8 ozone concentration for Scenario 1 was 46.9 ppb and the maximum background MDA8 was 54.2 ppb. For Scenario 2, which simulated the 2013 program as if the new rule was in place, allowing burns to proceed at ozone levels up to 63 ppb, the average background MDA8 ozone concentration was 47.8 ppb and the maximum was 60.9 ppb. The Scenario 3 case, which grew the emissions to reflect the maximum historical CRB emissions for each Scenario 1 and 2 ozone impact, resulted in the same maximum background MDA8 concentration (60.9 ppb) but the average background increased to 48.0 ppb.

# 4 4th-High "Design Value" Background Concentrations

In a traditional nonattainment SIP, a modeled "design value" concentration using the form of the standard is typically compared to the NAAQS to assess whether the attainment plan will be successful in bringing the area back into compliance. The design value concentration is the 4th-high MDA8 ozone concentration for each year or ozone season, averaged over 3 years. For this case, since no monitored or modeled concentrations exceed the NAAQS anywhere in Idaho, a conservative surrogate for the design value might be constructed by adding the maximum CRB contribution to the modeled 4th-high background concentrations at the point where the impacts occurred. However, this approach presents a problematic comparison to the NAAQS for any background 4th-high concentration over 63 ppb, for example, the highest 4th-high background concentration of 64.3 ppb (on 9/6/2013). The maximum CRB contribution cannot be added to any 4th-high background concentration that is 63 ppb or higher to produce a realistic design value under the CRB program after the rule change because the program does not allow burns to occur at or above 63 ppb, so there would be no CRB allowed and no CRB contribution to add to the 4th-high value. For 4th-high background MDA8 ozone concentrations below 63 ppb, the predicted maximum CRB contribution could occur, and if added to the 4th-high background, could be considered as a surrogate for the design value.

A similar issue occurs for Scenario 1 when the burn cessation point was 56 ppb—any 4th-high background concentration above 56 ppb cannot be used to construct a valid design value because burns would not have been allowed above 56 ppb so CRB could not have contributed in those cases. DEQ does not have the 4th-high concentrations for the Scenario 1 through 3 simulations. Nevertheless, the modeled 4th-high background concentrations for the episode at every maximum daily CRB impact location in Scenarios 1 through 3 are provided in Table 1 through Table 3 respectively, to provide background benchmarks for comparing the total MDA8 ozone concentrations estimated for each day of CRB impact (>0.2 ppb).

# 5 CRB Significance

The purpose of the DEQ modeling project in support of the 2017 CRB SIP revision is to demonstrate that the CRB activity in the Idaho program will not *cause or significantly contribute to a violation* of the NAAQS. The results reported in sections 2–4 above indicate that CRB activity in Idaho has never caused a violation of the ozone NAAQS (Scenario 1), will not do so under the new rule (Scenario 2), and would not do so even if the maximum historical burn acres were repeated on any of the CRB impact days with a contribution over 0.2 ppb. Thus, CRB could never *significantly contribute* to a violation that has never or will never occur. Nevertheless, the significance of this source category and the influence of its characteristic of not repeating significant impacts at the same location, may be of interest.

The EPA recently developed SILs including a SIL for ozone (*Guidance on Significant Impact Levels for Ozone and Fine Particles in the Prevention of Significant Deterioration Permitting Program*, from Stephen D. Page, Director, Office of Air Quality Planning and Standards, August 1, 2016, Revised August 18, 2016):

> *Each SIL value is based on the level, averaging period and statistical form of its corresponding NAAQS. For example, for ozone the recommended SIL value is based on the 4th highest daily maximum 8-hour concentration, averaged over 3 years. The derived value from the air quality variability analysis is 1.0 parts per billion (ppb), and we recommend the case-by-case application of this value as the SIL for the 8-hour ozone NAAQS.*

To evaluate whether CRB activity by itself could *significantly contribute* to a violation of the NAAQS requires alternative analysis of the model outputs. DEQ developed scripts to determine the 4th-highest CRB contribution at each location in the model for the 2013 episode. While it cannot be averaged with other values over 3 years, it remains the best choice for comparison to the SIL that is available. Due to the nature of CRB impacts, rarely causing large impacts in the same location, this is a reasonable surrogate. The 4th-highest CRB contribution at any location in the domain is 0.15 ppb for the Scenario 2 simulation of conditions under the new rule. This is well below the 1.0 ppb SIL for ozone. A similar calculation is not realistic for the Scenario 3 maximum historical emissions simulation because, in reality, these maximum burn levels occurred only once in 9 years, not for every maximum impact location on every burn day in the ozone season (episode) as modeled in Scenario 3.

**Table 1. Scenario 1 daily maximum impacts >0.2 ppb from CRB contributions for 2013 burns.**

| Date | Scenario 1 CRB Actual 2013 Contribution (ppb) | Lat (deg) | Long (deg) | Background without CRB (ppb) | Total MDA8 $O_3$ with CRB (ppb) | 4th-high Background O3 without CRB (ppb) |
|---|---|---|---|---|---|---|
| 8/12/2013 | 1.8 | 42.76 | -113.7 | 49.4 | 51.2 | 62.3 |
| 9/12/2013 | 1.2 | 48.91 | -116.3 | 39.6 | 40.8 | 56.3 |
| 8/27/2013 | 0.9 | 45.99 | -116.1 | 43.1 | 44 | 57.2 |
| 9/10/2013 | 0.9 | 45.78 | -116.3 | 42.2 | 43.1 | 55.4 |
| 8/30/2013 | 0.7 | 45.62 | -116.2 | 34.4 | 35.1 | 55.1 |
| 9/4/2013 | 0.7 | 45.91 | -116 | 40.4 | 41.1 | 56.9 |
| 8/5/2013 | 0.6 | 42.56 | -114.6 | 50.9 | 51.5 | 55.8 |
| 8/7/2013 | 0.6 | 42.86 | -114 | 52.3 | 52.9 | 61.6 |
| 8/13/2013 | 0.6 | 42.83 | -113.6 | 50.6 | 51.2 | 58.2 |
| 9/9/2013 | 0.6 | 46.36 | -116 | 41.4 | 42 | 53.9 |
| 9/11/2013 | 0.6 | 45.36 | -116.2 | 48.7 | 49.3 | 55.9 |
| 9/13/2013 | 0.5 | 46.21 | -115.9 | 48.1 | 48.6 | 53.7 |
| 7/26/2013 | 0.4 | 42.91 | -115.7 | 54.2 | 54.6 | 59.5 |
| 8/9/2013 | 0.4 | 48.91 | -116.4 | 44.6 | 45 | 55.9 |
| 8/19/2013 | 0.4 | 43.35 | -112.6 | 44.7 | 45.1 | 60.2 |
| 8/20/2013 | 0.4 | 48.99 | -116.5 | 41.5 | 41.9 | 52.6 |
| 7/24/2013 | 0.3 | 42.37 | -114.7 | 49.2 | 49.5 | 57.7 |
| 8/14/2013 | 0.3 | 43.05 | -112.5 | 47.7 | 48 | 57.8 |
| 8/21/2013 | 0.3 | 45.85 | -116.3 | 42.6 | 42.9 | 56.2 |
| 9/6/2013 | 0.3 | 42.55 | -112.9 | 48 | 48.3 | 64.3 |
| 7/18/2013 | 0.2 | 42.53 | -113.7 | 53.9 | 54.1 | 58.6 |
| 7/23/2013 | 0.2 | 42.76 | -114.2 | 53.8 | 54 | 60.8 |
| 8/2/2013 | 0.2 | 42.6 | -114.1 | 45.3 | 45.5 | 58.2 |
| 8/6/2013 | 0.2 | 43.45 | -116.9 | 51.9 | 52.1 | 58.8 |
| 8/23/2013 | 0.2 | 42.51 | -113.9 | 52.7 | 52.9 | 58 |
| 8/26/2013 | 0.2 | 42.69 | -114.4 | 50.4 | 50.6 | 56.5 |
| 9/16/2013 | 0.2 | 43.71 | -116.9 | 42.6 | 42.8 | 55.4 |
| 9/20/2013 | 0.2 | 46.67 | -116.2 | 49.7 | 49.9 | 51.1 |

Note for Tables 1-3: Column 1 is the date of impact; Column 2 is the MDA8 ozone contribution from CRB for Scenario; Column 3 is Latitude of impact in degrees; Column 4 is Longitude in degrees; Column 5 is the modeled background MDA8 ozone concentration at the day and location of the impact; Column 6 is the total MDA8 Ozone concentration including CRB (Column 2 + Column 5); Column 7 is the modeled 4th-high background MDA8 ozone concentration for the episode at the location of the impact in Column 2.

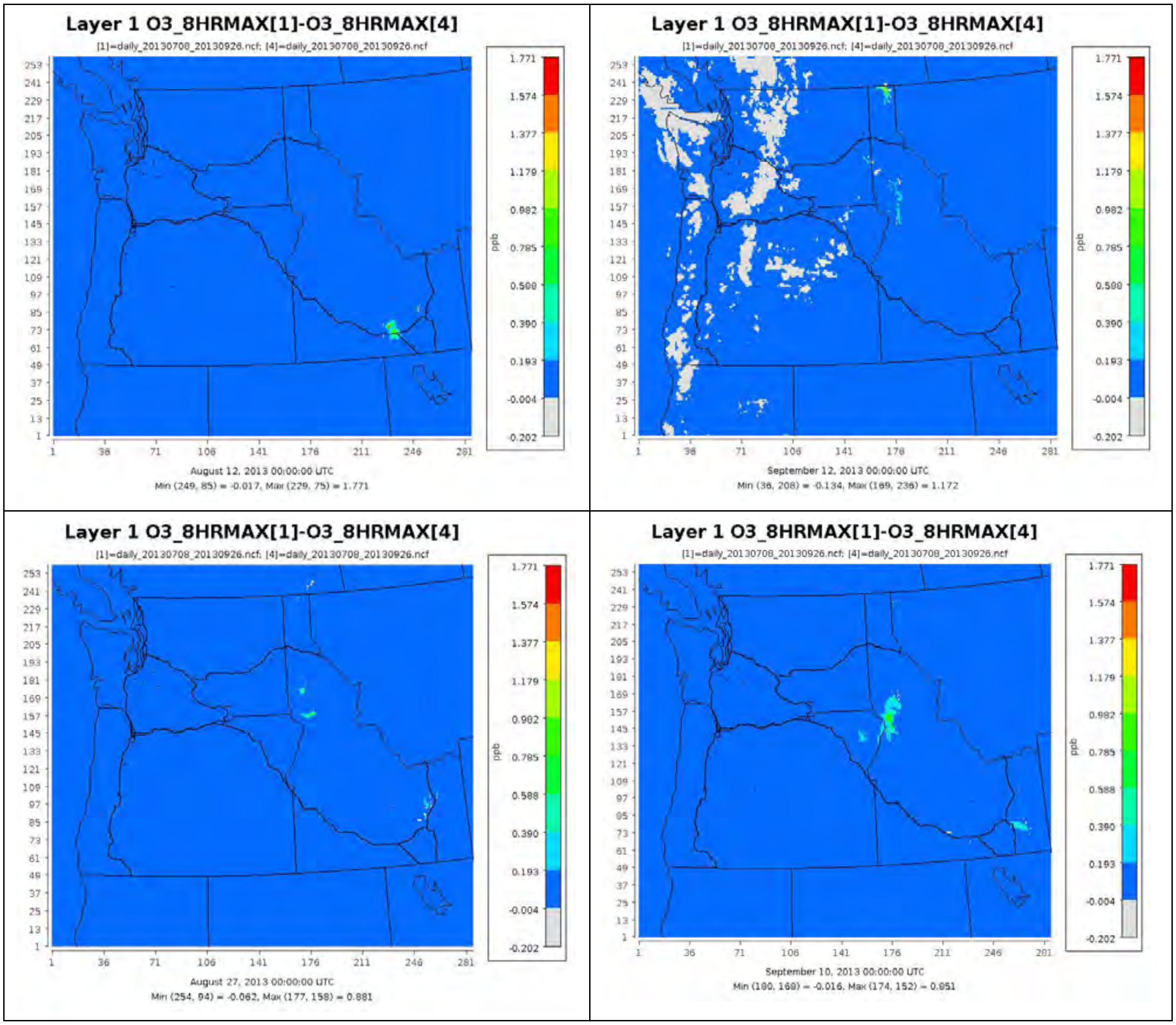



**Figure 1. Scenario 1 model results for four highest CRB contribution days, 1st high on August 12, 2nd high on September 12, 3rd high on August 27, and 4th high on September 10, 2013. Maps show the CRB Scenario 1 simulation with background, including all other sources, subtracted. Negative values reflect minor variation in background that is subtracted.**

**Table 2 Scenario 2 daily maximum impacts >0.2 ppb from CRB contributions the under new rule.**

| Date | Scenario 2 CRB Contribution Under New Rule (ppb) | Lat (deg) | Long (deg) | Background without CRB (ppb) | Total MDA8 $O_3$ with CRB (ppb) | 4th-high Background O3 w/out CRB (ppb) |
|---|---|---|---|---|---|---|
| 8/12/2013 | 1.8 | 42.76 | -113.7 | 49.4 | 51.2 | 62.3 |
| 9/12/2013 | 1.2 | 48.91 | -116.3 | 39.6 | 40.8 | 56.3 |
| 8/27/2013 | 0.9 | 45.96 | -116.2 | 43.1 | 44.0 | 57.2 |
| 9/10/2013 | 0.9 | 45.78 | -116.3 | 42.2 | 43.1 | 55.4 |
| 8/30/2013 | 0.7 | 45.62 | -116.2 | 34.3 | 35.1 | 55.1 |
| 9/4/2013 | 0.7 | 45.91 | -116 | 40.4 | 41.1 | 56.9 |
| 9/11/2013 | 0.6 | 45.36 | -116.2 | 48.7 | 49.3 | 55.9 |
| 8/5/2013 | 0.6 | 42.56 | -114.6 | 50.9 | 51.5 | 55.8 |
| 8/7/2013 | 0.6 | 42.86 | -114 | 52.3 | 52.9 | 61.6 |
| 8/13/2013 | 0.6 | 42.83 | -113.6 | 50.6 | 51.2 | 58.2 |
| 9/9/2013 | 0.6 | 46.32 | -116 | 41.3 | 41.9 | 53.9 |
| 9/13/2013 | 0.5 | 46.21 | -115.9 | 48.1 | 48.6 | 53.7 |
| 7/26/2013 | 0.4 | 42.91 | -115.7 | 54.2 | 54.7 | 59.5 |
| 8/20/2013 | 0.4 | 48.99 | -116.5 | 41.5 | 41.9 | 52.6 |
| 8/19/2013 | 0.4 | 43.35 | -112.6 | 44.7 | 45.1 | 60.2 |
| 8/9/2013 | 0.4 | 48.91 | -116.4 | 44.6 | 45.0 | 55.9 |
| 7/10/2013 | 0.4 | 43.71 | -116.9 | 51.4 | 51.8 | 56.2 |
| 7/19/2013 | 0.3 | 42.6 | -114.2 | 60.6 | 60.9 | 59.3 |
| 7/24/2013 | 0.3 | 42.37 | -114.7 | 49.2 | 49.6 | 57.7 |
| 8/15/2013 | 0.3 | 42.71 | -114.7 | 55.2 | 55.6 | 55.6 |
| 8/21/2013 | 0.3 | 45.85 | -116.3 | 42.6 | 42.9 | 56.2 |
| 8/14/2013 | 0.3 | 42.55 | -113.9 | 55.8 | 56.1 | 57.8 |
| 8/16/2013 | 0.3 | 42.69 | -114.4 | 55.8 | 56.1 | 57.7 |
| 9/6/2013 | 0.3 | 42.55 | -112.9 | 48.0 | 48.3 | 64.3 |
| 8/23/2013 | 0.2 | 42.51 | -113.9 | 52.7 | 53.0 | 58 |
| 8/26/2013 | 0.2 | 42.56 | -114.1 | 50.3 | 50.5 | 56.5 |
| 9/16/2013 | 0.2 | 43.71 | -116.9 | 42.6 | 42.9 | 55.4 |

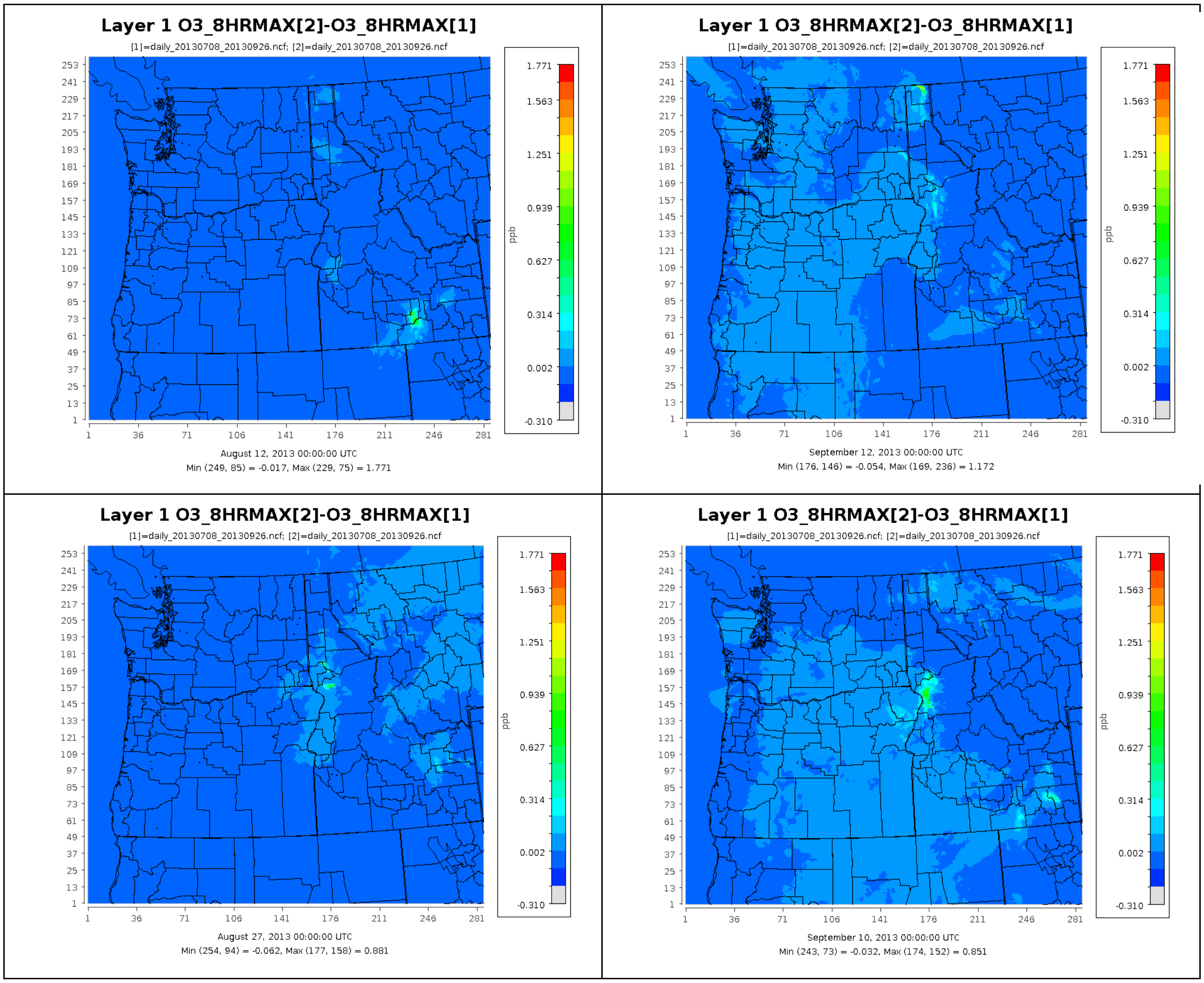



**Figure 2. Scenario 2 model results for four highest CRB contribution days, 1st high on August 12, 2nd high on September 12, 3rd high on August 27, and 4th high on September 10, 2013. Maps show the CRB Scenario 2 simulation with background, including all other sources, subtracted. Negative values reflect minor variation in background that is subtracted.**

**Table 3. Scenario 3 daily maximum impacts > 0.2 ppb from CRB historical maximum emissions.**

| Date | Scenario 3 CRB Historical Max Contribution (ppb) | Lat (deg) | Long (deg) | Background without CRB (ppb) | Total MDA8 $O_3$ with CRB (ppb) | 4th-high Background O3 w/out CRB (ppb) |
|---|---|---|---|---|---|---|
| 8/12/2013 | 4 | 42.76 | -113.7 | 49.4 | 53.4 | 62.3 |
| 8/9/2013 | 3.8 | 48.91 | -116.4 | 44.6 | 48.4 | 55.9 |
| 8/14/2013 | 2.5 | 42.55 | -113.9 | 55.8 | 58.3 | 57.8 |
| 9/12/2013 | 2.4 | 48.91 | -116.3 | 39.6 | 42 | 56.3 |
| 9/4/2013 | 2.2 | 45.91 | -116 | 40.4 | 42.6 | 56.9 |
| 8/27/2013 | 2 | 45.96 | -116.2 | 43.1 | 45.1 | 57.2 |
| 8/23/2013 | 1.6 | 42.51 | -113.9 | 52.7 | 54.3 | 58 |
| 7/26/2013 | 1.4 | 42.91 | -115.7 | 54.2 | 55.6 | 59.5 |
| 9/11/2013 | 1.4 | 45.36 | -116.2 | 48.7 | 50.1 | 55.9 |
| 9/13/2013 | 1.4 | 46.21 | -115.9 | 48.1 | 49.5 | 53.7 |
| 8/13/2013 | 1.3 | 42.83 | -113.6 | 50.6 | 51.9 | 58.2 |
| 9/10/2013 | 1.3 | 45.78 | -116.3 | 42.2 | 43.5 | 55.4 |
| 8/30/2013 | 1.2 | 45.62 | -116.2 | 34.3 | 35.5 | 55.1 |
| 7/10/2013 | 1.1 | 43.71 | -116.9 | 51.4 | 52.5 | 56.2 |
| 7/19/2013 | 1.1 | 42.6 | -114.2 | 60.6 | 61.7 | 59.3 |
| 8/5/2013 | 1.1 | 42.56 | -114.6 | 50.9 | 52 | 55.8 |
| 8/15/2013 | 1.1 | 42.71 | -114.7 | 55.2 | 56.3 | 55.6 |
| 8/20/2013 | 1.1 | 48.99 | -116.5 | 41.5 | 42.6 | 52.6 |
| 9/9/2013 | 1.1 | 46.32 | -116 | 41.3 | 42.4 | 53.9 |
| 9/6/2013 | 1 | 42.55 | -112.9 | 48 | 49 | 64.3 |
| 8/16/2013 | 0.9 | 42.69 | -114.4 | 55.8 | 56.7 | 57.7 |
| 8/21/2013 | 0.9 | 45.85 | -116.3 | 42.6 | 43.5 | 56.2 |
| 8/19/2013 | 0.8 | 43.35 | -112.6 | 44.7 | 45.5 | 60.2 |
| 8/7/2013 | 0.6 | 42.86 | -114 | 52.3 | 52.9 | 61.6 |
| 8/26/2013 | 0.4 | 42.56 | -114.1 | 50.3 | 50.7 | 56.5 |
| 7/24/2013 | 0.3 | 42.37 | -114.7 | 49.2 | 49.5 | 57.7 |
| 9/16/2013 | 0.3 | 43.71 | -116.9 | 42.6 | 42.9 | 55.4 |
| 7/18/2013 | 0.2 | 42.53 | -113.7 | 53.9 | 54.1 | 58.6 |
| 7/23/2013 | 0.2 | 42.76 | -114.2 | 53.8 | 54 | 60.8 |
| 8/2/2013 | 0.2 | 42.6 | -114.1 | 45.3 | 45.5 | 58.2 |
| 8/6/2013 | 0.2 | 43.45 | -116.9 | 51.9 | 52.1 | 58.8 |
| 8/28/2013 | 0.2 | 43.97 | -111.8 | 41.2 | 41.4 | 59.8 |
| 9/14/2013 | 0.2 | 45.37 | -115.6 | 44.4 | 44.6 | 59 |
| 9/20/2013 | 0.2 | 46.67 | -116.2 | 49.7 | 49.9 | 51.1 |

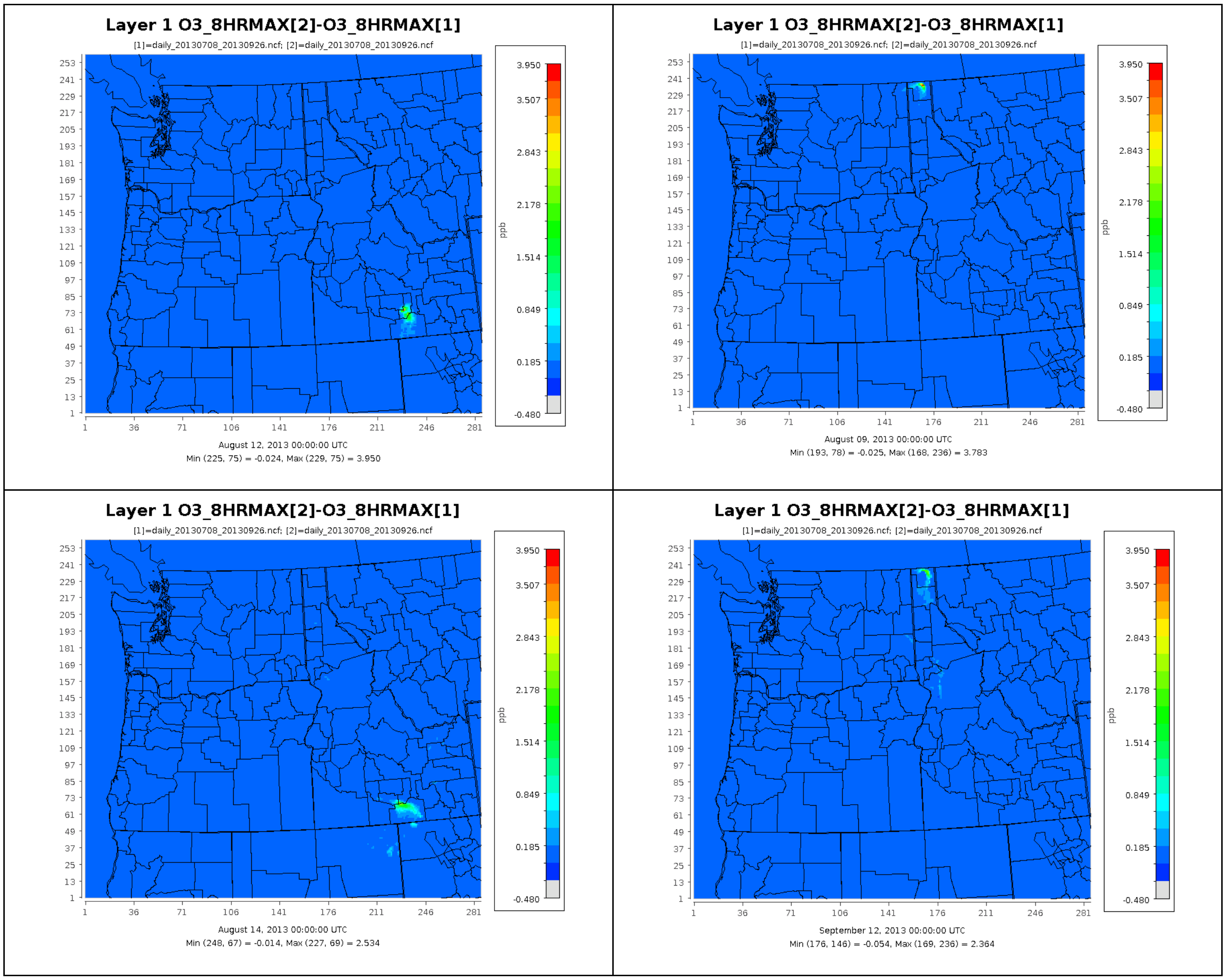



**Figure 3. Scenario 3 model results for four highest CRB contribution days, 1st high on August 12, 2nd high on August 9, 3rd high on August 14, and 4th high on September 12, 2013. Maps show the CRB Scenario 3 simulation with background, including all other sources, subtracted. Negative values reflect minor variation in background that is subtracted.**

# Appendix H. Public Participation and Public Comments

**CERTIFICATE OF HEARING**

**SUBJECT:** 2017 Crop Residue Burning Ozone State Implementation Plan Revision Amendment

**LOCATION:** DEQ Conference Center, 1410 N. Hilton, Boise, Idaho

**HEARING DATE:** October 18, 2017

The undersigned designated hearing facilitator hereby certifies that on the 18th day of October, 2017, a public hearing was held on the 2017 Crop Residue Burning Ozone State Implementation Plan Revision Amendment, at the DEQ conference center in Boise, Idaho. The hearing commenced at 3:00 p.m. and was adjourned at 3:30 p.m. No members of the public attended the hearing.

Notice of this hearing appeared in the Idaho Statesman on September 18, 2017. This publication was timely made and other necessary notice requirements have been met.

DATED this 18th day of October, 2017

P J Wilson

Paula J. Wilson
Hearing Facilitator

IDAHO CONSERVATION LEAGUE

208.345.6933 • PO Box 844, Boise, ID 83702 • www.idahoconservation.org

10/16/2017

Tanya Chin
Air Quality Division
DEQ State Office
1410 N. Hilton
Boise, ID 83706

Mary Anderson
DEQ State Office
Air Quality Division
1410 N. Hilton
Boise, ID 83706

Submitted via email: tanya.chin@deq.idaho.gov and mary.anderson@deq.idaho.gov

**RE: Revision to Draft Air Quality Implementation Plan for Crop Residue Burning**

Dear Ms. Chin and Ms. Anderson:

Thank you for the opportunity to comment on DEQ's proposed revisions to the air quality implementation plan for crop residue burning (CRB) amendment.

Since 1973, the Idaho Conservation League has been Idaho's leading voice for clean water, clean air and wilderness—values that are the foundation for Idaho's extraordinary quality of life. The Idaho Conservation League works to protect these values through public education, outreach, advocacy and policy development. As Idaho's largest state-based conservation organization, we represent over 25,000 supporters, many of whom have a deep personal interest in protecting Idaho's air quality.

The proposed changes to the SIP, including this amendment, remain incomplete due to lacking appropriate analyses on the potential impacts this decision could have on public health. DEQ continues to assume that compliance with the NAAQS equates to protection for public health. This is contrary to the most recent scientific findings, as detailed in our previously submitted comments (attached), which highlight that the NAAQS are not sufficient in protecting human health, particularly when cumulative impacts from multiple pollutants are assessed. The DEQ is charged with protecting public health. If compliance with the NAAQS is insufficient at achieving this then they must cease relying on the NAAQS as a means to satisfy their obligation.

Further, DEQ continues to claim throughout the revision amendment that these changes were pursued in order to simultaneously protect public health and retain fire as an agricultural tool. However, DEQ entirely omits that this decision goes against the recommendations of multiple professional health organizations and all the public health advocates who participated in the rulemaking process (see attached). This information provides vital context necessary for the public to adequately scrutinize the impact this decision would have on their personal health and peace of mind. Whenever DEQ makes claims that this change will protect public health they should also include language stating that leading professional medical organizations disagree with this conclusion.

In summary, we disagree with this proposed SIP revision, even after reviewing this revision amendment. Should you have any questions regarding our concerns or if we can provide you with any additional information on this matter please do not hesitate to contact me at 208-345-6933 ext. 23 or ahopkins@idahoconservation.org.

Sincerely,

Austin Hopkins
Conservation Associate

CC:

Randall Ruddick, ruddick.randall@epa.gov
Air Planning Unit, Office of Air and Waste
USEPA REGION 10
1200 Sixth Avenue
Seattle, WA 98101

Debra Suzuki, suzuki.debra@epa.gov
Air Planning Unit Manager, Office of Air and Waste
USEPA REGION 10
1200 Sixth Avenue
Seattle, WA 98101

Tim Hamlin, hamlin.tim@epa.gov
Director, Office of Air & Waste
USEPA REGION 10
1200 Sixth Avenue
Seattle, WA 98101

IDAHO CONSERVATION LEAGUE

208.345.6933 • PO Box 844, Boise, ID 83702 • www.idahoconservation.org

9/7/2017

Tanya Chin
Air Quality Division
DEQ State Office
1410 N. Hilton
Boise, ID 83706

Mary Anderson
DEQ State Office
Air Quality Division
1410 N. Hilton
Boise, ID 83706

Submitted via email: tanya.chin@deq.idaho.gov and mary.anderson@deq.idaho.gov

**RE: Draft Air Quality Implementation Plan for Crop Residue Burning**

Dear Ms. Chin and Ms. Anderson:

Thank you for the opportunity to comment on the draft air quality implementation plan for crop residue burning (CRB).

Since 1973, the Idaho Conservation League has been Idaho's leading voice for clean water, clean air and wilderness—values that are the foundation for Idaho's extraordinary quality of life. The Idaho Conservation League works to protect these values through public education, outreach, advocacy and policy development. As Idaho's largest state-based conservation organization, we represent over 25,000 supporters, many of whom have a deep personal interest in protecting Idaho's air quality.

As presented, this proposed SIP revision is incomplete due to lacking appropriate analyses on the potential impacts this decision could have on public health. DEQ should analyze the scenarios discussed herein prior to submittal of this revision to the EPA.

Our detailed comments are attached to the end of this letter. Please do not hesitate to contact me at 208-345-6933 ext. 23 or ahopkins@idahoconservation.org if you have any questions regarding our comments or if we can provide you with any additional information on this matter.

Sincerely,

Austin Hopkins
Conservation Associate

CC:

Randall Ruddick, ruddick.randall@epa.gov
Air Planning Unit, Office of Air and Waste
USEPA REGION 10
1200 Sixth Avenue
Seattle, WA 98101

Debra Suzuki, suzuki.debra@epa.gov
Air Planning Unit Manager, Office of Air and Waste
USEPA REGION 10
1200 Sixth Avenue
Seattle, WA 98101

Tim Hamlin, hamlin.tim@epa.gov
Director, Office of Air & Waste
USEPA REGION 10
1200 Sixth Avenue
Seattle, WA 98101

## Analysis of Cumulative Effects on Public Health

The proposed SIP revision remains incomplete as it fails to analyze realistic effects on public health from the cumulative impacts of comingling of all pollutants present in the air. DEQ presents this change as a "minor SIP revision" with no effect on emissions and therefore no change in impact to public health. However, classifying this change so narrowly fails to capture the full impact this decision could have on public health and thus fails to meet applicable requirements set forth in the Clean Air Act (CAA).

DEQ asserts that the proposed changes would not cause or contribute to a violation of the 2015 8-hour ozone NAAQS or interfere with any other applicable CAA requirement. While DEQ's SIP revision document focused heavily on compliance with the ozone NAAQS, they have failed to provide sufficient justification that remaining CAA requirements would not be violated. Specifically, the CAA's declaration codifies the requirement to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population. 42 U.S.C. § 7401(b)(1).

Implicit in the requirement to protect air quality in the interest of public's health is a need to determine how proposed changes will realistically affect the air people breathe. The air we all breathe has numerous constituents present, and numerous studies have highlighted the legal and scientific need to analyze pollutants in aggregate (see Behles (2010)[1], Fann et. al (2012)[2]). A proposed altering of a tolerable allowance for one pollutant must be analyzed in the context of its relation with other pollutants. This is contrary to DEQ's approach of focusing solely on ozone, with no regard to the effect elevated ozone levels could have in combination with pollutants such as $PM_{2.5}$ or $PM_{10}$.

While DEQ is proposing only to change the ozone threshold, this revision would have far greater implications on public health beyond simply ozone. DEQ has yet to demonstrate that this change will not increase risks to the public's health. Until such time that this demonstration is complete DEQ should not approve this revision.

## Adverse Effects to Human Health Below NAAQS

DEQ repeatedly argues that this change is not likely to result in a violation of the ozone NAAQS and is therefore protective of human health. This presumption however is counter to recent scientific studies that have demonstrated human health effects at and

---

[1] Deborah Behles. (2010). *Examining the Air We Breathe: EPA Should Evaluate Cumulative Impacts When It Promulgates National Ambient Air Quality Standards.* Pace Environmental Law Review. Vol. 28. Iss. 1.
[2] Neal Fann, Lamson A.D., Anenberg S.C., Wesson K., Risley D., and Hubbel B.J. (2012). *Estimating the*

[2] Neal Fann, Lamson A.D., Anenberg S.C., Wesson K., Risley D., and Hubbel B.J. (2012). *Estimating the *National Public Health Burden Associated with Exposure to Ambient PM2.5 and Ozone.* Society for Risk Analysis. Vol. 32. No. 1. doi: 10.1111/j.1539-6924.2011.01630.x

well below established NAAQS. For example, Kim et al. (2011)[3] showed that exposure of healthy young adults to 0.06 ppm ozone for 6.6 hours causes a significant decrement of FEV(1) – an indicator to the degree of obstruction in the lungs – and an increase in neutrophilic inflammation in the airways. There are two critical components one must consider when reviewing these results. First, this test was conducted on healthy young adults, which are among the most resilient population to air pollution. Sensitive populations such as youth, elderly, or those with respiratory or cardiovascular impairments would respond more negatively to these tests. Second, these results were generated in a lab and are entirely independent of any other pollutant that would otherwise be present in the natural world (see previous comment).

In a similar study, Bell et al. (2006)[4] analyzed the exposure–response curve for ozone to understand the risk of premature mortality at low concentrations and the adequacy of current ozone regulations. The authors utilized multiple methods in their analysis, including a linear approach and subset, threshold, and spline models. The authors concluded their study with the following summary:

> "…our nationwide study provides strong and consistent evidence that daily changes in ambient O3 exposure are linked to premature mortality, even at very low pollution levels, including an idealized scenario of complete adherence to current O3 regulations. We also found robust evidence of this relationship between O3 exposure and mortality when we used data that included only O3 levels nearing background concentrations, which typically range from 10 to 25 ppb (Fiore et al. 2003, 2004)[5]. Therefore, any anthropogenic contribution to ambient O3, however slight, still presents an increased risk for premature mortality."

Lastly, the authors provide a cautionary note that pollution levels below air quality regulatory standards should not be misinterpreted as safe for human health.

These studies both indicate that reliance solely on the NAAQS to protect public health is inadequate. DEQ is obligated to protect public health using the best available science, therefore the current SIP revision should be deemed inadequate due to its reliance on the ozone NAAQS to protect public health. The revision should be redone with

---

[3] Kim CS, Alexis NE, Rappold AG, Kehrl H, Hazucha MJ, Lay JC, Schmitt MT, Case M, Devlin RB, Peden DB, Diaz-Sanchez D. (2011). *Lung function and inflammatory responses in healthy young adults exposed to 0.06 ppm of ozone for 6.6 hours*. American Journal of Respiratory and Critical Care Medicine. doi: 10.1164/rccm.201011-1813OC

[4] Michelle L. Bell,1 Roger D. Peng,2 and Francesca Dominici. 2006. "The Exposure–Response Curve for Ozone and Risk of Mortality and the Adequacy of Current Ozone Regulations." Environmental Health Perspectives. doi: 10.1289/ehp.8816

[5] Fiore A, Jacob DJ, Liu H, Yantosca RM, Fairlie TD, Li Q. 2003. "Variability in surface ozone background over the United States implications for air quality policy." J Geophys Res Atmos. 10.1029/2003JD003855.; and Fiore A, Jacob D J, Liu H, Yantosca RM, Fairlie TD, Li Q. 2004. Correction to "Variability in surface ozone background over the United States implications for air quality policy." J Geophys Res Atmos. 10.1029/2004JD004567.

consideration given to both established and emerging science on the detrimental effects ozone can have on public health.

**Lack of Review of Alternative Options**

DEQ's introductory sentence states: "The goal of any smoke management program is to protect public health by reducing smoke impacts from allowable forms of open burning while protecting the NAAQS and maintaining fire as a tool." We are concerned that DEQ appears to be prioritizing maintaining fire as a tool over the protection or air quality and the public's health.

During the EPA's rulemaking to tighten the ozone NAAQS, leading medical societies and health organizations, including the America Medical Association, American Lung Association, American Academy of Pediatrics, American Thoracic Society, and American Heart Association all urged EPA to adopt a more protective ozone standard of 60 ppb, based on evidence that ozone harms people's health at (and even below) that level. Dkt-2720, -3863[6]. DEQ's proposal would thus allow burning to occur even when ozone pollution already exceeds (or is expected to exceed) a level deemed unsafe by medical professionals. It is unclear why DEQ, whose decisions should be based on sound science and informed by leading experts, would choose to ignore multiple preeminent medical societies and health organizations.

In addition to the dismissal of medical experts, DEQ also never considered any alternatives to field burning. According to DEQ, the impetus for this revision is due to the difficulties in denying burns because of ozone when all other atmospheric conditions were ideal for smoke dispersion. Yet, if there were no smoke to begin with DEQ wouldn't have to worry about ambient ozone concentrations and the decision would become infinitely easier. Despite this alternative approach, DEQ appears to not have even considered alternatives to field burning such as those prepared for the State of Washington's Department of Ecology[7] or the Fire Emissions Joint Forum of the Western Regional Air Partnership[8].

First and foremost, DEQ is tasked with protecting public health. This SIP revision should be researched, prepared, and reviewed in that context. In its present form, the proposed revisions succeed at preserving fire as a tool, but are inadequate in terms of assuring protections for public health. DEQ should not approve the current revision, and instead prepare a document that focuses first on the protection of all Idahoans, then on the tools

[6] All "Dkt" references are to document numbers in EPA docket EPA-HQ-OAR-2008-0699 (e.g., "Dkt-0405" means EPA-HQ-OAR-2008-0699-0405).
[7] *See* ALTERNATIVES to AGRICULTURAL BURNING, available: http://www.ecy.wa.gov/programs/air/aginfo/research_pdf_files/AlternativesAgBurn.pdf
[8] *See* VOLUME I: NON-BURNING MANAGEMENT ALTERNATIVES ON AGRICULTURAL LANDS IN THE WESTERN UNITED STATES and VOLUME II: NON-BURNING MANAGEMENT ALTERNATIVES AND IMPLEMENTATION PLAN STRATEGIES, available: https://deq.utah.gov/Pollutants/R/regionalhaze/rhsip/docs/2006/05May/VolumeII-NonburningAgLandFinal.pdf

and strategies available to deal with crop residue. The redone analysis should include considerations of alternatives to burning such as those detailed in the aforementioned studies.

## Figure 1 is Misleading

Figure 1 in the SIP revision document shows the six criteria air pollutants and their corresponding AQI values at 75% and 90% of each respective NAAQS. DEQ is utilizing this figure to show that 75% of the ozone NAAQS is the only value that falls within the "good" air quality index range, whereas 75% of the NAAQS for all other pollutants reside in the "moderate" range of the air quality index. We feel this figure is misleading and should be either removed or discussed within the appropriate context.

It appears this figure is utilizing the recently updated 2015 NAAQS for ozone. It is therefore likely that ozone is the pollutant that has most recently undergone a NAAQS review and has subsequently been made more stringent based upon a greater understanding of ozone. As the science of air pollution emerges, it is not uncommon for standards to become more stringent as scientists develop better understandings of the risk to public health. Thus, the lower value of ozone could be indicative of a trend in which all criteria pollutants become more stringent during their upcoming NAAQS review. DEQ should discuss Figure 1 in this context, rather than attempting to utilize it to justify weakening ozone protections.

## Approval of Burning on Poor Ambient Air Quality Days

Table 10 lists five (5) burn days that corresponded to MDA8 values greater than the 95$^{th}$ percentile MDA8 at nearby monitoring sites. DEQ goes on to justify how these elevated events were attributable to either wildfires (e.g. Boise exceedances on 8/13/2013) or regionally high ozone concentrations due to lower troposphere/stratosphere intrusions (e.g. Washakie, UT event on 5/1/2015). For both the Boise and Washakie event, the MDA8 was recorded to be 74 ppb and 67 ppb, respectively. These values are greater than both the existing and proposed ozone threshold for burn approval. We are therefore confused as to how burning on these days was ever initially approved, as DEQ is expressly prohibited from approving burns when ambient air quality levels are exceeding, or are expected to exceed, seventy-five percent (75%) of the level of any national ambient air quality standard (NAAQS) on any day. Idaho Code 39-114(3)(a). We ask that DEQ provide details and justification as to how the decision to allow burning on these days was made, as well as details on what measures are in place to ensure that the approval of burns on inappropriate days doesn't happen again.

## Additional Context Needed in Section 7.2

Section 7.2 states that DEQ works with an advisory committee representing a broad range of interests to discuss issues and obtain valuable feedback on the program's implementation and improvement. This section should note that in preparing these changes DEQ disregarded the committee's recommendation on a SIP revision. Further, DEQ should note that all of the environment and public health advocates resigned from the advisory board as a result of these proposed changes to DEQ's CRB program. Inclusion of this information is consistent with DEQ's goal of running a transparent program.

**Reporting Requirements in Section 7.6**

DEQ outlines the surveillance and documentation components of their smoke management program. This section should also detail the reporting requirements for staff responsible or associated with any burn decision. For example, DEQ states that seasonal smoke coordinators observe burning activity on days when burning is approved in their counties or regions. However, through e-mail contact with Ms. Mary Anderson of DEQ, we learned that DEQ doesn't keep track of the number of burns observed nor reports this information to the public.

DEQ states they adhere to *Section 4.5.4 – Field Observation* of the Crop Residue Burning Program Operating Guide for determining which fields will be observed. However, the public is left unaware of whether this requirement was fulfilled unless record keeping and reporting are included as part of this program. Running a program that was transparent to the public was a key component to the original agreement reached in 2007. Public reporting on which burns were observed by DEQ staff is therefore well within the scope of DEQ's CRB program and should clearly be codified in this SIP revision.

**Received via DEQ general online comment website:**

Note: It was not clear that this was a comment on the CRB ozone SIP, but DEQ is treating it as such.

**Subject:**

**Name:**

Brent Thomson

**Email:**

Sacajawea208@aol.com

**Affiliation:**

Retired Chemical Engineer and Hotelier

**Comments:**

I am concerned about combustion of grass and forests which produce dioxins.
Dioxin is limited severely in paper manufacturing.
It is the most toxic, long lasting chemical associated with Agent Orange.
Most of the dioxin in the atmosphere today appears to be the result of burning grass, yard waste, and forest fires.
The quantity of dioxins does not even appear to be considered as a risk in this evaluation of grass burning.
I think it should be evaluated before permits are issued.
Brent Thomson

**Thank you:**

DEQ's Response to Comments on the 2017 Crop Residue Burning Ozone State Implementation Plan Revision Amendment

| Commenter 1 – Austin Hopkins ICL | Commenter 2 – Brent Thomson | |
|---|---|---|
| | | |

| Commenter | Comment | Response |
|---|---|---|
| **1** | The proposed changes to the SIP, including this amendment, remain incomplete due to lacking appropriate analyses on the potential impacts this decision could have on public health. DEQ continues to assume that compliance with the NAAQS equates to protection for public health. This is contrary to the most recent scientific findings, as detailed in our previously submitted comments (attached), which highlight that the NAAQS are not sufficient in protecting human health, particularly when cumulative impacts from multiple pollutants are assessed. The DEQ is charged with protecting public health. If compliance with the NAAQS is insufficient at achieving this then they must cease relying on the NAAQS as a means to satisfy their obligation. | In the original SIP Revision, DEQ summarizes how all applicable requirements of the Clean Air Act are addressed. The CAA does not require States to evaluate additive effects of pollutants. A NAAQS standard is designed to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly, with an adequate margin of safety. EPA set the 2015 ozone standard after looking at all available scientific data. While there have been some studies that look at the combined effects of pollutants on public health, EPA continues to evaluate each criteria pollutant individually. The Idaho SIP demonstrates how DEQ will implement those standards in Idaho.<br><br>This change will strengthen protections from field burning as it will help decrease the impact of burns on public health by utilizing burn days when smoke dispersion (adequate smoke lift, proper mixing, appropriate air movement and direction, etc.) is good or better during times when ozone forecast is expected to reach between 75% and 90% of the ozone NAAQS. |
| **1** | Further, DEQ continues to claim throughout the revision amendment that these changes were pursued in order to simultaneously protect public health and retain fire as an agricultural tool. However, DEQ entirely omits that this decision goes against the recommendations of multiple professional health organizations and all the public health advocates who participated in the rulemaking process (see attached). This information provides vital context necessary for the public to adequately scrutinize the impact this decision would have on their personal health and peace of mind. Whenever DEQ makes claims that this change will protect public health they should also include language stating that leading professional medical organizations disagree with this conclusion.<br>In summary, we disagree with this proposed SIP revision, even after reviewing this revision amendment. | This comment is outside the scope of this SIP Revision Amendment and therefore no changes will be made to the document.<br><br>DEQ did not receive any comments from professional medical organizations during the negotiated rulemaking or on these SIP revisions.<br><br>DEQ disagrees that it disregarded the recommendations of the public health advocates of the CRB Advisory Committee. The recommendation agreed upon at the 2017 annual Committee meeting was to enter into negotiated rulemaking to modify IDAPA 58.01.01.621.01 as it relates to the requirement of 75% of the NAAQS. That is what this proposed SIP revision does.<br><br>DEQ properly followed IDAPA 58.01.23 and the Idaho Administrative Procedures Act to ensure the negotiations were open and transparent. No decisions were made without listening to all participants in the negotiating group. All comments were considered. |
| **2** | I am concerned about combustion of grass and forests which produce dioxins.<br>Dioxin is limited severely in paper manufacturing.<br>It is the most toxic, long lasting chemical associated with Agent Orange.<br>Most of the dioxin in the atmosphere today appears to be the result of burning grass, yard waste, and forest fires.<br>The quantity of dioxins does not even appear to be considered as a risk in this evaluation of grass burning.<br>I think it should be evaluated before permits are issued. | This comment is outside the scope of this SIP Revision and therefore no changes will be made to the document.<br>This Plan revision does not increase emissions from permitted Kentucky Bluegrass residue or other grass species residue burning.<br>Commenter is encouraged to review EPA's most updated National Dioxin Monitoring Network report, EPA/600/R-13/183F (August 2013), for additional information. DEQ has assessed the carcinogenic and non-carcinogenic risk of post-harvest grass residue burning. The carcinogenic and non-carcinogenic risk for a resident in Idaho is very low. |

**Idaho Statesman**
The Newspaper of the Treasure Valley
IDAHOSTATESMAN.COM
PO Box 40, Boise, ID 83707-0040



# LEGAL PROOF OF PUBLICATION

| Account # | Ad Number | Identification | PO | Amount | Cols | Lines |
|---|---|---|---|---|---|---|
| 263916 | 0003281364 | LEGAL NOTICE NOTICE OF 30-DAY PUBLIC C | CropResideueBurn | $169.76 | 2 | 96 |

**Attention:** TANYA CHIN

IDAHO DEPT OF ENVIRONMENTAL QUALITY
1410 N HILTON ST
BOISE, ID 837061253

**LEGAL NOTICE**

**NOTICE OF 30-DAY PUBLIC COMMENT PERIOD REGARDING A 2017 CROP RESIDUE BURNING OZONE STATE IMPLEMENTATION PLAN REVISION AMENDMENT.**

**PROPOSED ACTION:** The Idaho Department of Environmental Quality (DEQ) is proposing to submit a 2017 Crop Residue Burning Ozone State Implementation Plan (SIP) Revision Amendment to the US Environmental Protection Agency (EPA). This amendment further demonstrates that Idaho's proposed rule revision to update the crop residue burning (CRB) ozone requirements meets the requirements of Section 110(l) of the Clean Air Act. The public comment period for the original SIP revision closed on September 14th. This amendment provides additional evidence in support of the original submittal.

**BACKGROUND:** The CRB Program has been implemented by DEQ since 2008. One aspect of the program requires that, prior to approving a crop residue burn, DEQ must determine that 1) air quality is not exceeding 75% of any NAAQS, and 2) air quality is not projected to exceed such level during the next 24 hours. Fine particulate matter (PM2.5) is the pollutant most directly affected by crop residue burning. There are days when PM2.5 concentrations are not a concern, but ozone concentrations exceed or are projected to exceed 75% of the ozone NAAQS. As a result, there are fewer days when DEQ can approve crop residue burns despite the fact that 1) the weather conditions exhibit good smoke dispersion characteristics, and 2) DEQ technical staff expect the burns to have minimal impact on ambient ozone concentrations (NAAQS). Therefore, burning may not be allowed on good burn days even when the burn is not predicted to cause or significantly contribute to a violation of the ozone NAAQS.

Through the negotiated rulemaking process, DEQ developed a rule that gives DEQ the authority to approve crop residue burning when ozone levels are not exceeding, or expected to exceed, 90% rather than 75% of the ozone NAAQS only. This new 90% level is still protective of the ozone NAAQS, and also provides farmers the ability to burn while following smoke management best practices. The DEQ rule improves overall smoke management by modifying a decision making threshold to provide greater flexibility on available burn days. The increased flexibility will lead to greater air quality protection.

**PUBLIC COMMENT AND HEARING:** The public comment period will last from September 18 to October 18, 2017. Questions regarding the public comment process should be directed to:
Tanya Chin, Department of Environmental Quality, 1410 N. Hilton, Boise, ID 83706, tanya.chin@deq.idaho.gov, or 208-373-0440.
A public hearing will be held:

October 18, 2017 at 3 pm MST
DEQ State Office
Conference Room A
1410 N. Hilton
Boise Idaho

The meeting location will be accessible to persons with disabilities, and language translators will be made available upon request. Requests for these accommodations must be made no later than five (5) days prior to the meeting date. For arrangements, contact Tanya Chin.

**AVAILABILITY OF MATERIALS:** The document "2017 Crop Residue Burning Ozone State Implementation Plan Revision Amendment" is available for public review on DEQ's website at http://www.deq.idaho.gov/news-public-comments-events/

Printed materials will be made available upon request at the DEQ state office.

**SUBMISSION OF WRITTEN COMMENTS–ASSISTANCE ON TECHNICAL QUESTIONS:** Anyone may submit written comments regarding the document. To be most effective, comments should address air quality considerations and include support materials where available.

Please reference the document title listed above when sending comments or requesting information. Comments should focus on whether Idaho has met the Clean Air Act requirements under Section 110(l) or whether this change interferes with the attainment of the NAAQS or any other applicable requirement of the Clean Air Act.

For technical assistance on questions concerning this document, please contact Mary Anderson at (208) 373-0202 or mary.anderson@deq.idaho.gov.

All written comments concerning this document must be directed to and received by the undersigned on or before 5:00 p.m., MST/MDT, October 18, 2017.

DATED this 18th day of September, 2017.
Tanya Chin

JANICE HILDRETH, being duly sworn, deposes and says: That she is the Principal Clerk of The Idaho Statesman, a daily newspaper printed and published at Boise, Ada County, State of Idaho, and having a general circulation therein, and which said newspaper has been continuously and uninterruptedly published in said County during a period of twelve consecutive months prior to the first publication of the notice, a copy of which is attached hereto: that said notice was published in The Idaho Statesman, in conformity with Section 60-108, Idaho Code, as amended, for:

1 Insertions

Beginning issue of: 09/18/2017

Ending issue of: 09/18/2017

Janice Hildreth
(Legals Clerk)

STATE OF IDAHO )
.SS
COUNTY OF ADA )

On this 18th day of September in the year of 2017 before me, a Notary Public, personally appeared before me Janice Hildreth known or identified to me to be the person whose name subscribed to the within instrument, and being by first duly sworn, declared that the statements therein are true, and acknowledged to me that she executed the same.

Anna Gomm
Notary Public FOR Idaho
Residing at: Boise, Idaho

My Commission expires: 08/17/2022

ANNA GOMM NOTARY PUBLIC STATE OF IDAHO