West-wide Jumpstart Air Quality Modeling Study

Final Project Report and Modeling Results

August 20, 2014

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Funding from State of NM, BP, and National BLM Air Program

Oversight by western states, local air agencies, federal land managers, EPA regional and national offices

EPA national Ozone Standard

- Measured at ground station sites, highest 8-hour average each day
- 4th highest values each year are averaged over 3-year periods to determine compliance (e.g., 2007-09, 2008-10)
  - Statistic is called a “Design Value” for that site for that time period
- Current Ozone health standard level is 75 ppb
- EPA (re)considering revised Ozone health standard in a range of 60 to 70 ppb
- EPA also considering a secondary Ozone standard for ecosystem protection
  - Growing season / daylight hours-weighted cumulative metric

What are (some of) the sources and control issues in the West related to new Ozone standard(s)?

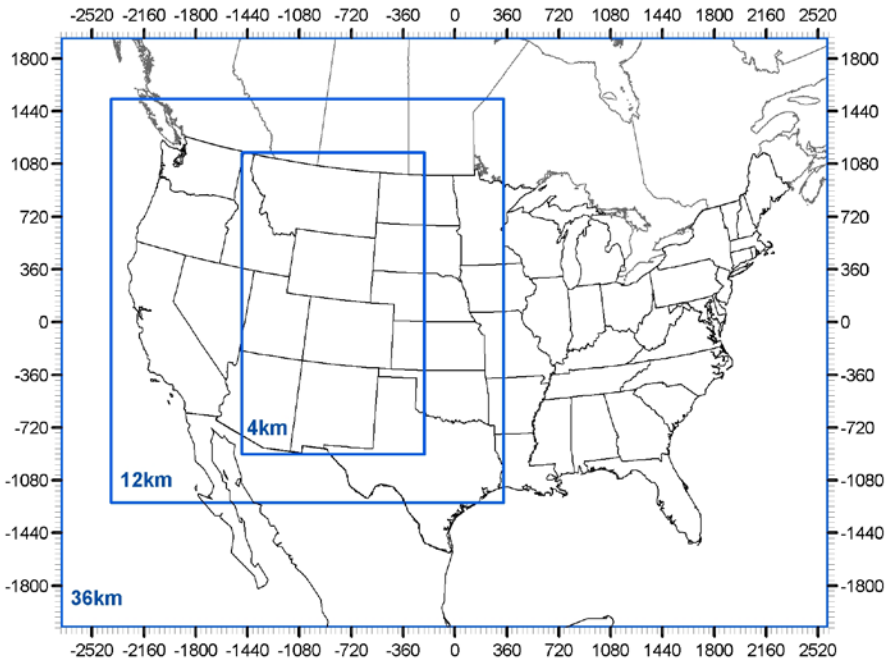
- Urban and rural reactivity
- Transport and formation – how much / how important?
- Public lands with large biogenic emissions and fire activity
  - How to characterize for effects of drought and climate variation ?
- Federal and state mobile fuel and tailpipe controls
- Upstream Gas NSPS rules in place in 2015
  - Industry practices changing rapidly, e.g., green completions
- Point sources (dominated by EGUs for SO_2, NO_x)
  - Significant NO_x BART by ~2018
  - Less coal-fired electricity supply due to climate change rule?
  - 17+ million acres of public lands leased in last 5 years for O&G exploration and production

Introduction

- West-wide Jump-start Air Quality Modeling Study (WestJumpAQMS) was initiated in late 2010 to:
  - Develop the next generation of regional air quality modeling databases for ozone, $PM_{2.5}$, visibility and deposition planning in the western U.S.
  - Provide information on the role of interstate and international transport to ozone and $PM_{2.5}$ under current and potential future NAAQS
  - Assess contributions of major source categories (e.g., point, O&G, mobile, et cetera) to air quality in the West
  - Provide detailed information to the community

Overview of Approach

- 2008 Modeling Database
  - 36 km CONUS
  - 12 km WESTUS
  - 4 km IMWD
- WRF meteorological; CAMx photochemical; SMOKE emissions models
- 2008 WRAP Phase III O&G emissions
- 2008 NEI emissions
- Model Evaluation
- Sensitivity Tests



Modeling Domain

- State-Specific and Source Category-Specific Ozone and $PM_{2.5}$ Source Apportionment Modeling

WestJumpAQMS Products

- Final Report
  - 15 Electronic Appendices
  - Response-to-Comments
- Ammonia Emissions Recommendations Memo
- Modeling Protocol
  - Response-to-Comments
- WRF Application/Evaluation Report
  - Evaluation down to individual monitoring site
  - Response-to-Comments

- 16 Technical Memorandums on Emissions

1. Point Sources
2. Area + Non-Road
3. On-Road Mobile

4a-e. Oil and Gas (5 geographic areas)

5. Fire (WF, Rx & Ag)
6. Fugitive Dust
7. Off-Shore Shipping
8. Ammonia
9. Biogenic

11 Mexico/Canada

12. Sea Salt and Lightning
13. Emissions Modeling Parameters

All information on WestJumpAQMS website

WestJumpAQMS Progress Webinars

- June 20, 2013: 2008 Database Development
- July 26, 2013: State-Specific Source Apportionment
- August 29, 2013: Source Category-Specific Source Apportionment
- Interactive agenda from WestJumpAQMS Final Project Report meeting, Denver, CO – September 25, 2013
- **Presentations and all project materials at: http://www.wrapair2.org/WestJumpAQMS.aspx**

Ozone, PM, Deposition, and Visibility Source Apportionment Resources from WestJumpAQMS

http://www.wrapair2.org/WestJumpAQMS.aspx

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WestJumpAQMS - Reports

West-Wide Jump-Start Air Quality Modeling Study (WestJumpAQMS) – Final Report (PDF 15MB), September 30, 2013

- Response-to-Comments for Draft Final Report (PDF 1MB), September 30, 2013

List of Appendices and directions for use (PDF)

Appendix A: CSAPR-Type Analysis for 2008 Upwind State Highest Contribution to Average and Maximum Ozone Design Values at any Monitoring Site in up to 5 Downwind States using MATS (XLSX 1MB)

Appendix B: State Contributions to Daily Maximum 8-Hour Ozone Concentrations on 10 Highest Modeled Ozone Days in 2008 by Monitoring Site (XLSX 19MB)

Appendix C: Spatial Maps of State-Specific Anthropogenic Emissions Contributions to Highest and Fourth Highest Modeled Daily Maximum 8-Hour Ozone Concentrations during 2008 Greater than 76 (current NAAQS), 70, 65, 60 (potential future NAAQS) and 0 (maximum contribution) ppb across the 12 km WESTUS and 36 km CONUS Domains (ZIP 37MB) **(corrected files posted February 7, 2014)**

Appendix D: CSAPR-Type Analysis for 2008 Upwind State Highest Contribution to Annual $PM_{2.5}$ Design Values in up to Five Downwind States using MATS (XLSX 12MB)

Appendix E: State Contributions to Modeled Annual PM2.5 Concentrations in 2008 by Monitoring Site (XLSX 23MB)

Appendix F: CSAPR-Type Analysis for 2008 Upwind State Highest Contribution to 24-Hour $PM_{2.5}$ Design Values in up to Five Downwind States using MATS (XLSX 12MB)

Appendix G: Spatial Maps of Modeled State-Specific Anthropogenic Emissions Contributions to Highest (1stmax) and Eighth (8thmax) Highest 24-Hour $PM_{2.5}$ Concentrations during 2008 greater than 35 (current NAAQS), 30, 25, 20 and 0 (maximum contribution) $\mu g/m^3$ (ZIP 13MB) **(corrected files posted February 7, 2014)**

Appendix H: Source Category-Specific Contributions to 8-Hour Ozone Design Values at Monitoring Sites in the 4 km Detailed Source Apportionment Domain (DSAD) using MATS and Maximum Contribution to 8-Hour Ozone Design Values in Each DSAD State (CO, NM, UT and WY) due to Major Source Categories using MATS (XLSX 1MB)

Appendix I: Source Category-Specific Contributions to Ten Highest Modeled Daily Maximum 8-Hour Ozone Concentrations at Monitoring Sites in the 4 km Detailed Source Apportionment Domain (DSAD) (XLSX 2MB)

Appendix J: Source Category-Specific Contributions to Annual $PM_{2.5}$ Design Values at Monitoring Sites in the 12 km WESTUS Domain using MATS (XLSX 2MB)

Appendix K: Source Category-Specific Contributions to Modeled Annual $PM_{2.5}$ Concentrations ($\mu g/m^3$) at Monitoring Sites in the 12 km WESTUS Domain (XLSX 4MB)

Appendix L: Source Category-Specific Contributions to 24-Hour $PM_{2.5}$ Design Values at Monitoring Sites in the 12 km WESTUS Domain using MATS (XLSX 2MB)

Appendix M: Source Category-Specific Contributions to Ten Highest Modeled 24-Hour $PM_{2.5}$ Concentrations ($\mu g/m^3$) at Monitoring Sites in the 12 km WESTUS Domain (XLSX 10MB)

Appendix N: Annual Sulfur and Nitrogen Wet and Dry Deposition at IMPROVE Monitors by Species (XLSX 1MB)

Appendix O: Western State-Specific Modeled Contributions to Visibility Impairment at IMPROVE Monitoring Sites for Modeled Worst (W20) and Best (B20) 20% Days during 2008 (ZIP 46MB)

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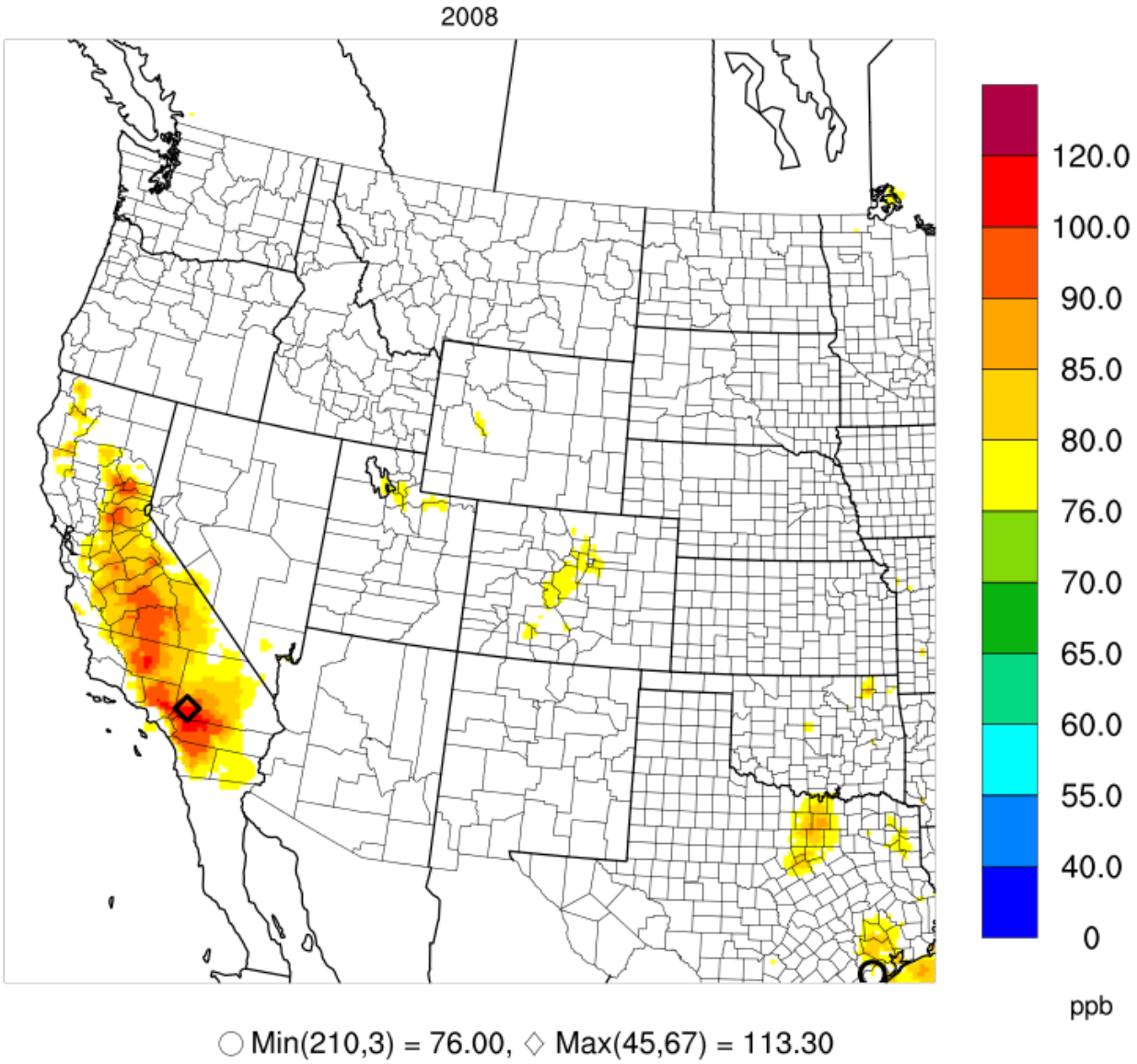
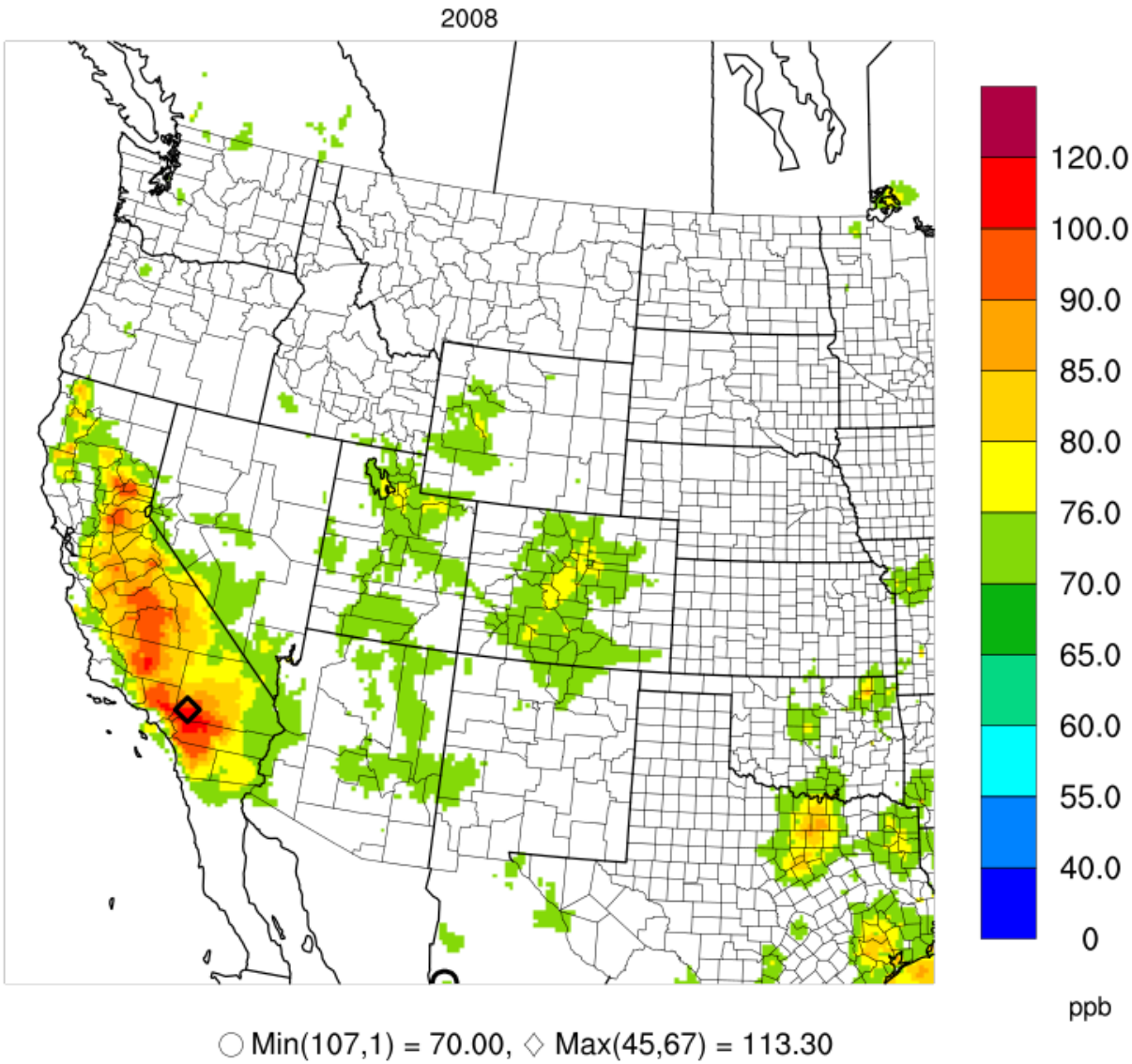
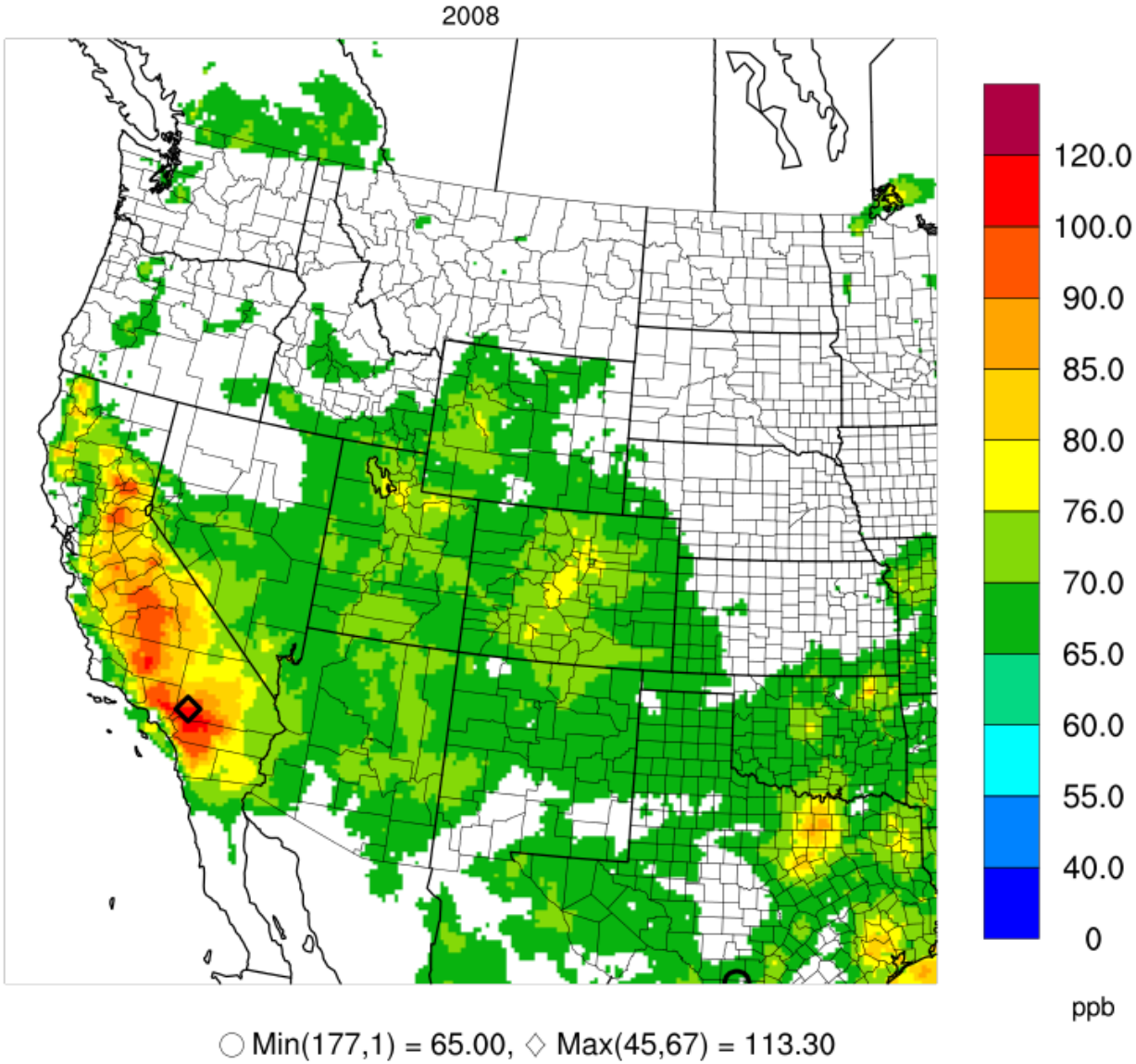
Ozone Attainment Test Software – Unmonitored Area Analysis with Design Value (2006-2010) ≥ 76 ppb



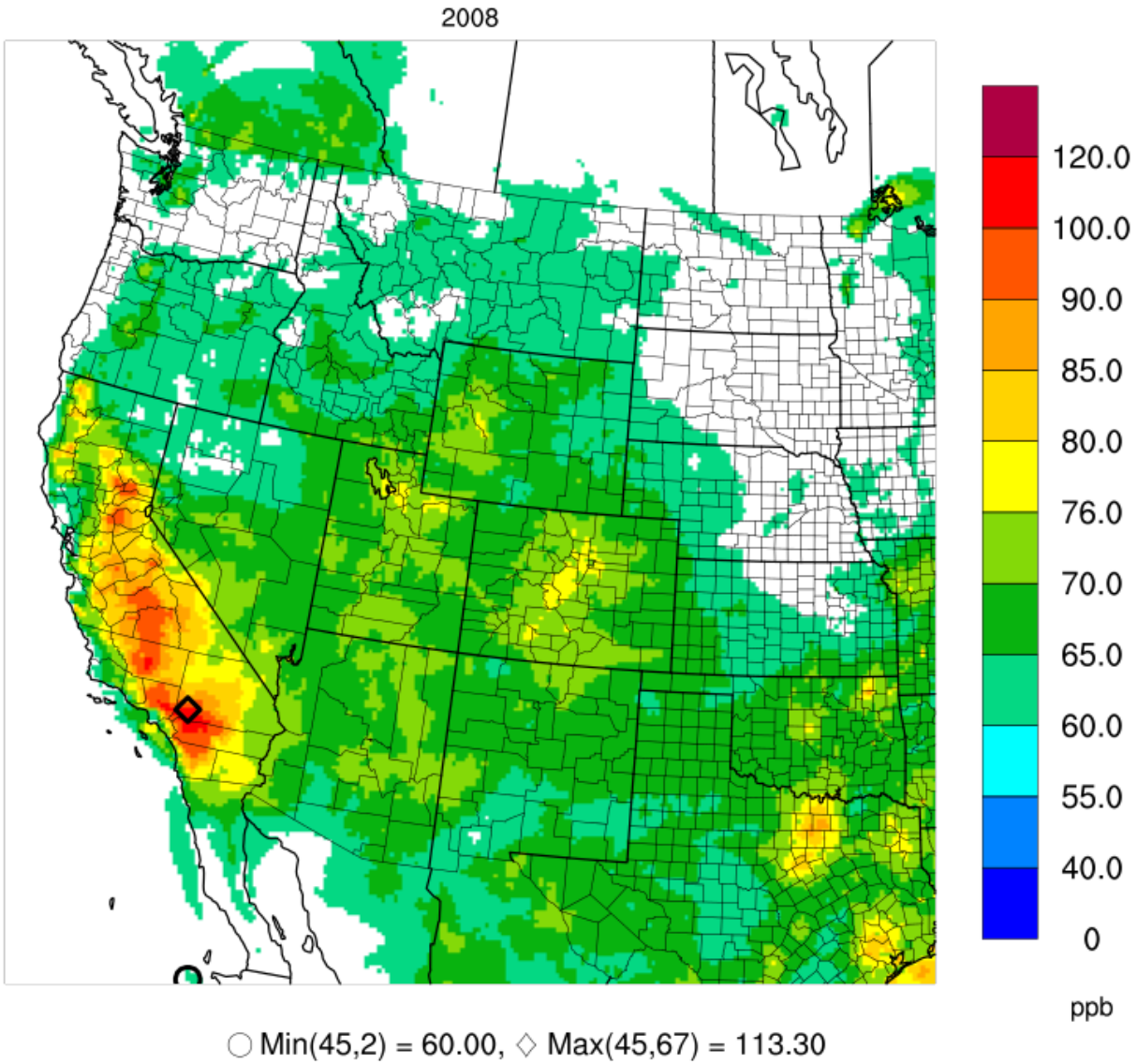
Ozone Attainment Test Software – Unmonitored Area Analysis with Design Value (2006-2010) ≥ 70 ppb



Attainment Test Software – Unmonitored Area Analysis with Design Value (2006-2010) ≥ 65 ppb



Ozone Attainment Test Software – Unmonitored Area Analysis with Design Value (2006-2010) ≥ 60 ppb

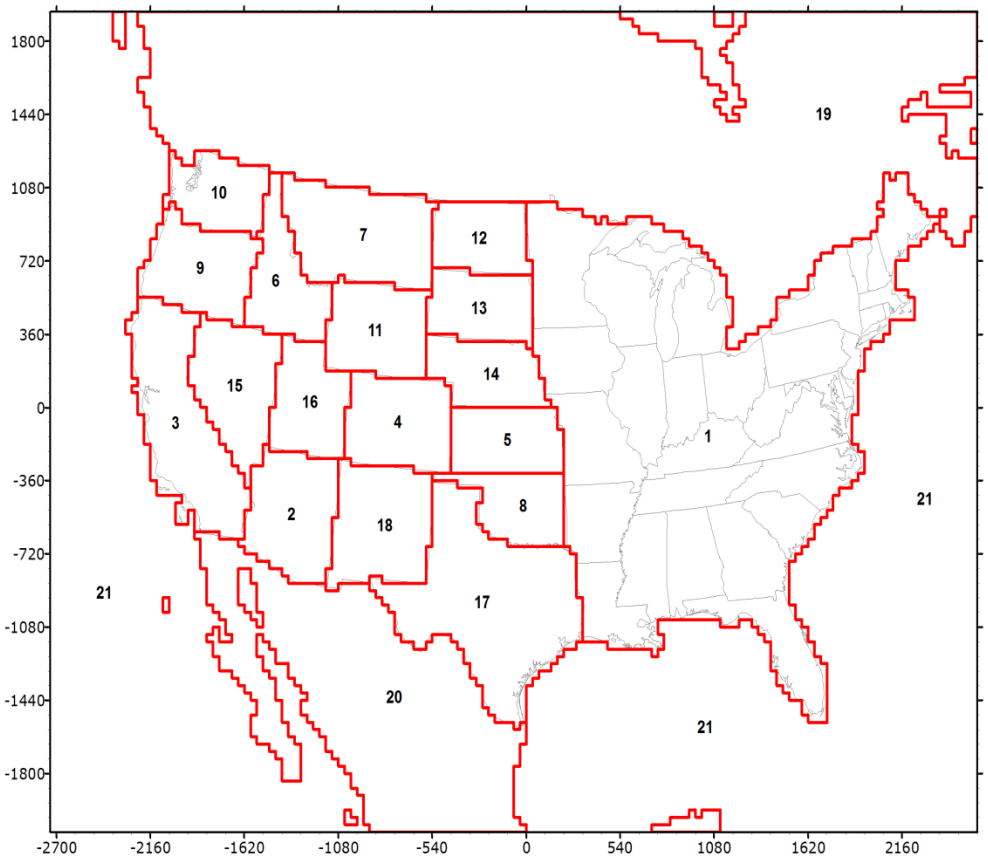


State-Specific Ozone Source Apportionment

- Purpose: To provide information on the role of ozone transport to exceedances of the current and potential future ozone NAAQS in the western U.S.
- Approach: Analyze ozone apportionment several ways:
  1. Upwind state contribution to downwind state nonattainment using Cross State Air Pollution Rule (CSAPR-type) approach
     - Use EPA method for projecting ozone Design Values (RRFs)
  2. State contributions to modeled high ozone DMAX8 ozone at monitors in 12 km WESTUS domain
     - Spatial extent of modeled state contributions to 1stmax and 4thmax DMAX8 ozone greater than current and potential future NAAQS
     - Source category analysis (Natural, Fires & Anthropogenic)
  3. Detailed Source Category-Specific Source Apportionment
     - 6 key source categories across 4 states in intermountain West
     - 2-way nesting between model domains

State-Specific Ozone Source Apportionment

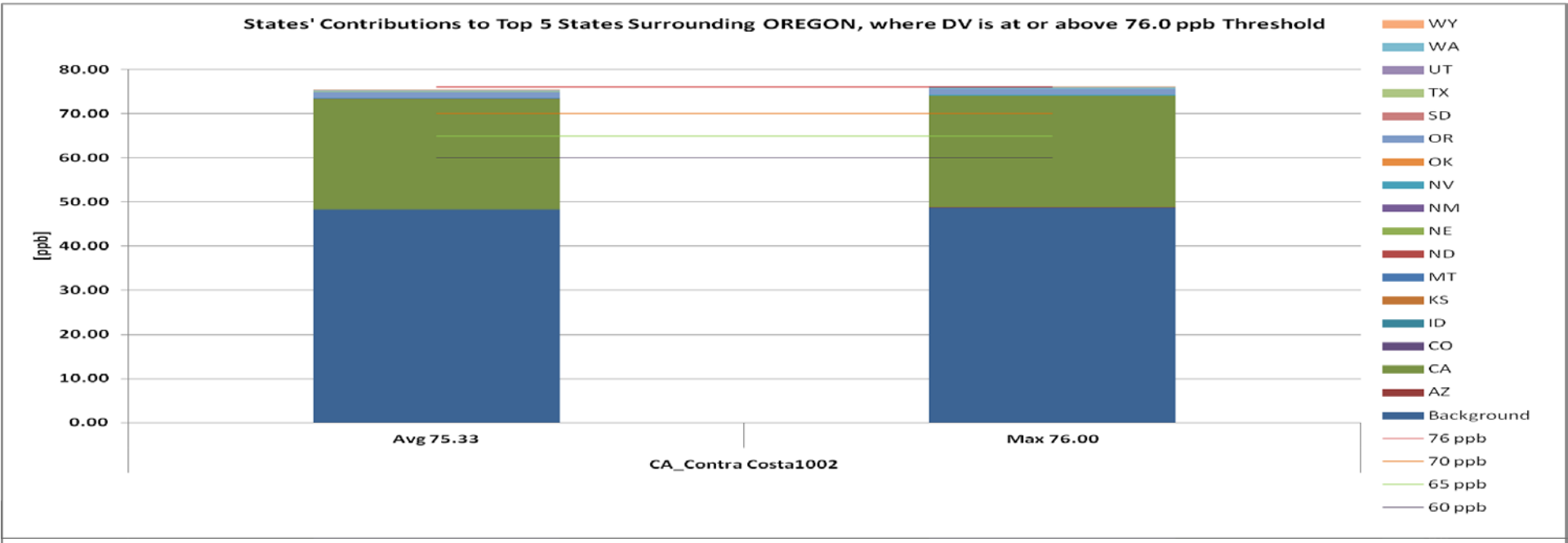
- 2008 36/12 km Base
- 17 Western States
  - Plus EasternUS, Can, Mex & Off-Shore
- 5 Source Categories
  - Natural (Biogenics+Lightning+WBDust+SeaSalt)
  - WF, Rx and Ag Fires
  - Anthropogenic
- 107 Source Groups (21 x 5 + 2)
  - 4 Extra Species for each Group
    - 428 additional species
    - Standard Model = 70 species
    - Computationally Demanding

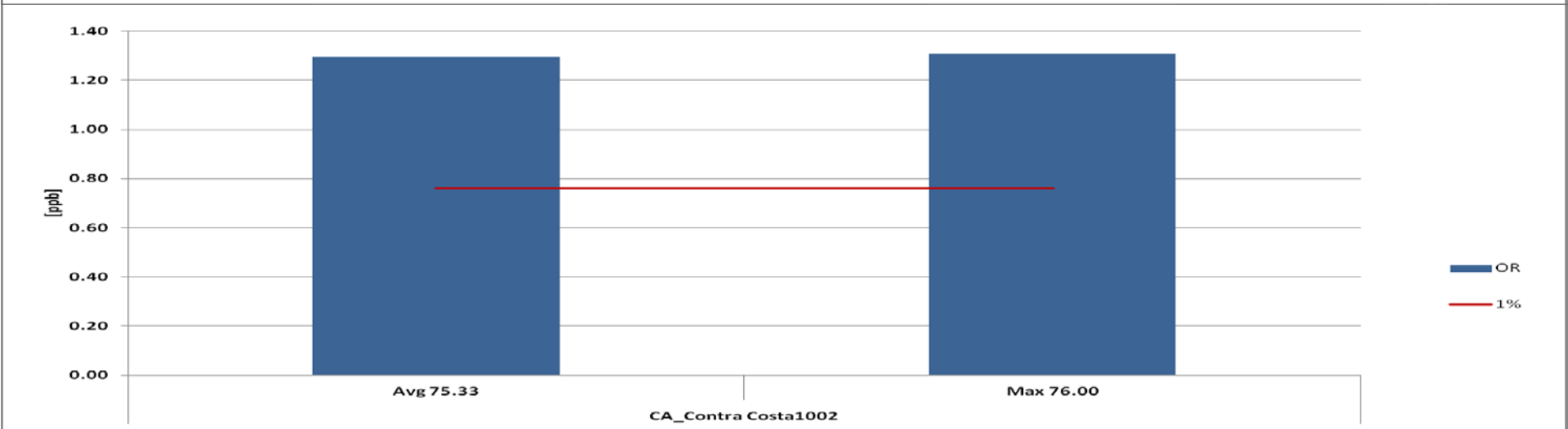


CSAPR-Type Analysis for current (76 ppb) and potential future (70 and 65 ppb) NAAQS levels

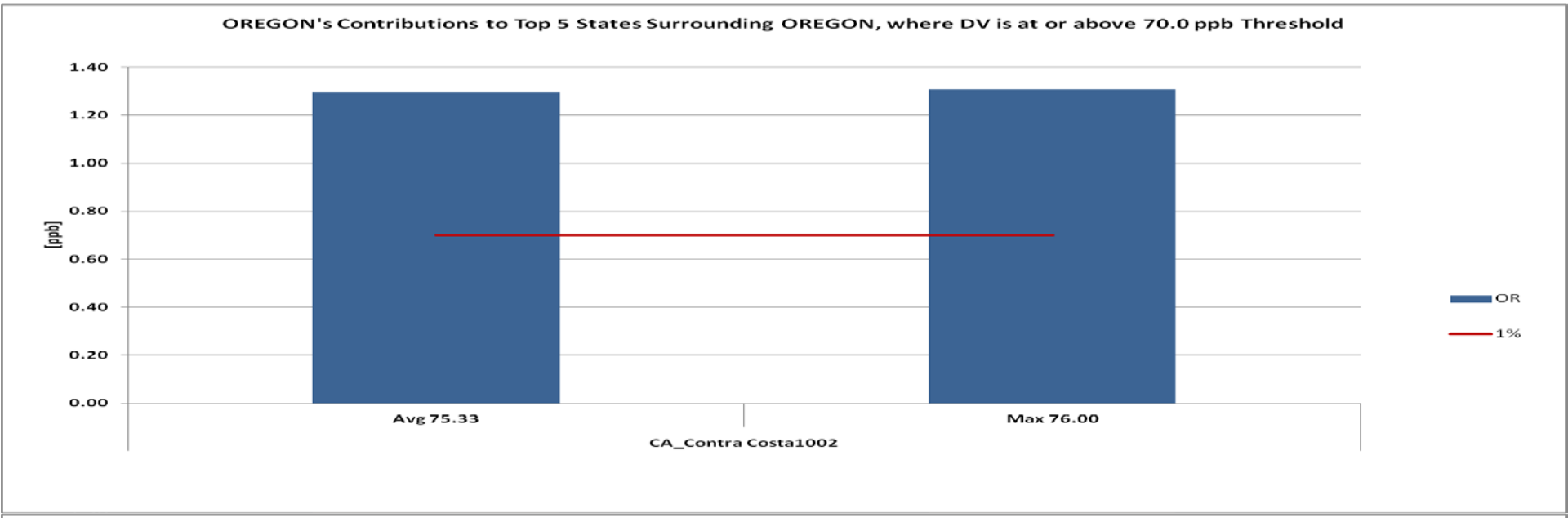
- CSAPR looked at contributions to:
  - Average Design Value = Average of DVs from 2006-2010
  - Max Design Values = Max DVs from 2006-2010
- 136 ozone monitors in 12 km WESTUS domain with Average Design Value exceeding 76 ppb NAAQS
  - 86 sites (63%) in California
- For 17 upwind western states examine 2008 contribution to DMAX8 ozone Design Value in downwind states
  - CSAPR used a 1% NAAQS significance threshold (≥0.76 ppb)
- This analysis is for 2008 and is not a regulatory analysis that would have to examine a future year

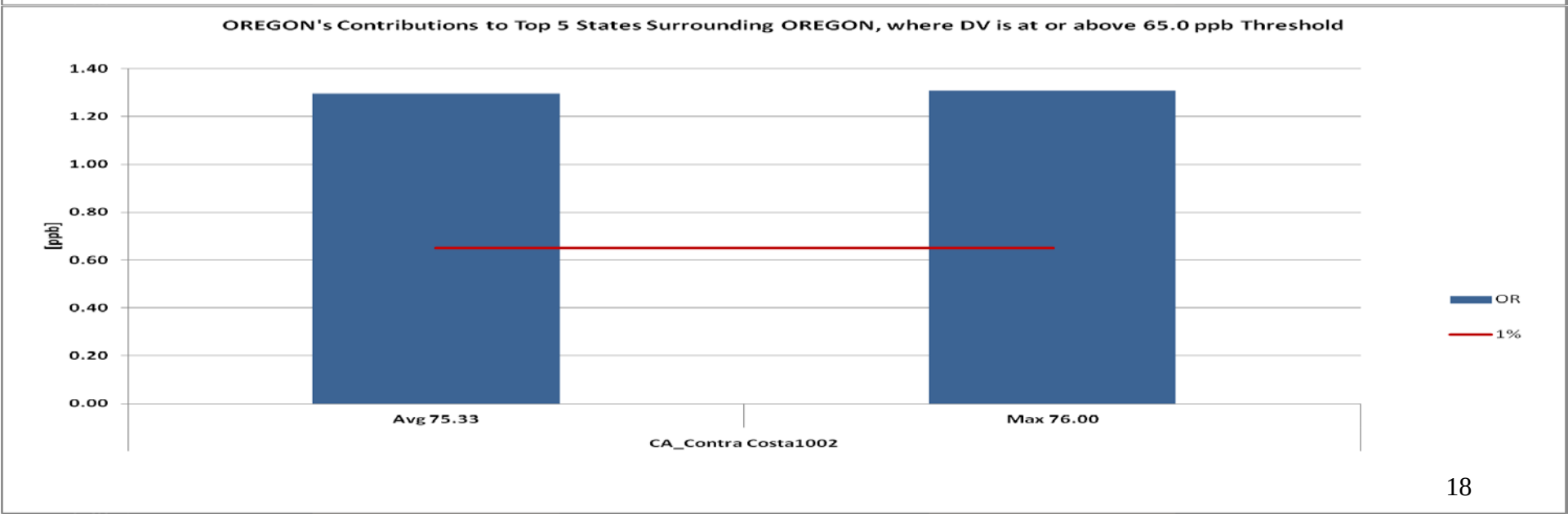
Oregon CSAPR-Type Ozone Analysis for current 75 ppb NAAQS (from WestJumpAQMS Appendix A)



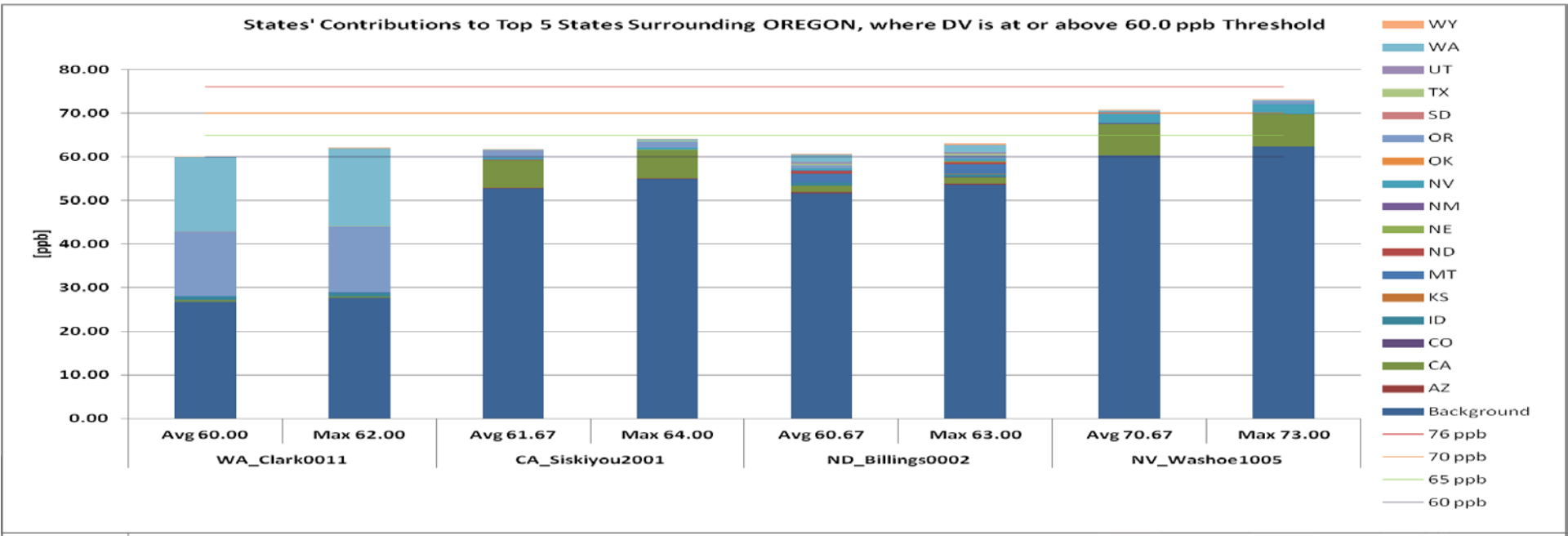


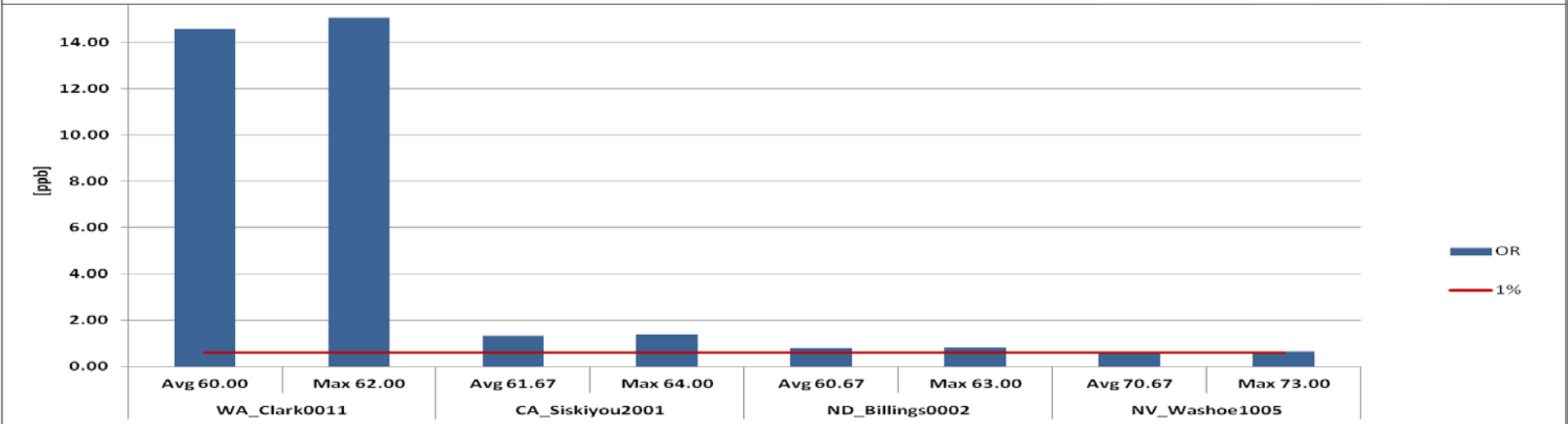
Oregon CSAPR-Type Ozone Analysis for potential 70 and 65 ppb NAAQS (from WestJumpAQMS Appendix A)



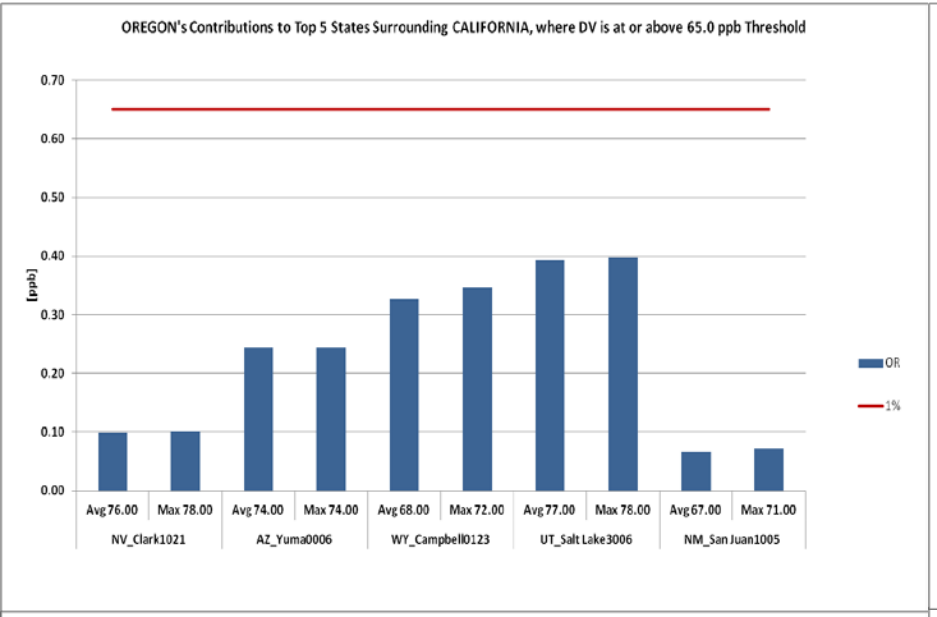


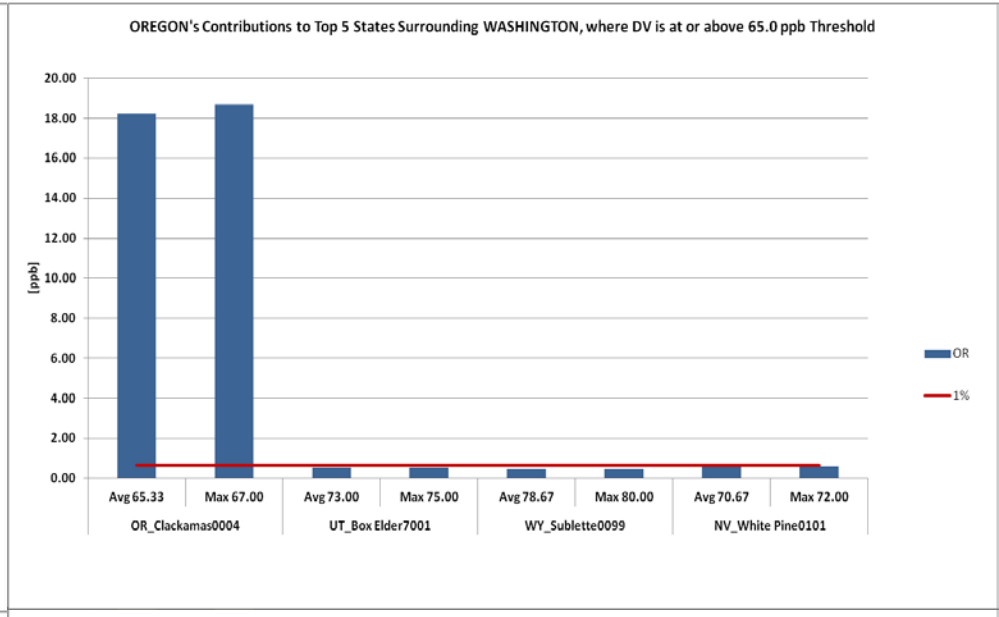
Oregon CSAPR-Type Ozone Analysis for potential 60 ppb NAAQS (from WestJumpAQMS Appendix A)

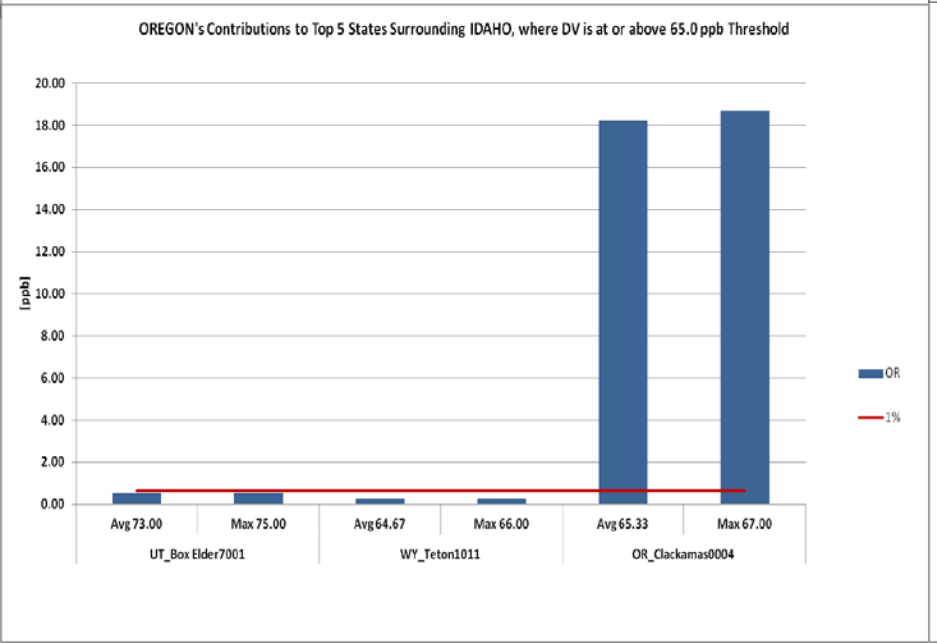


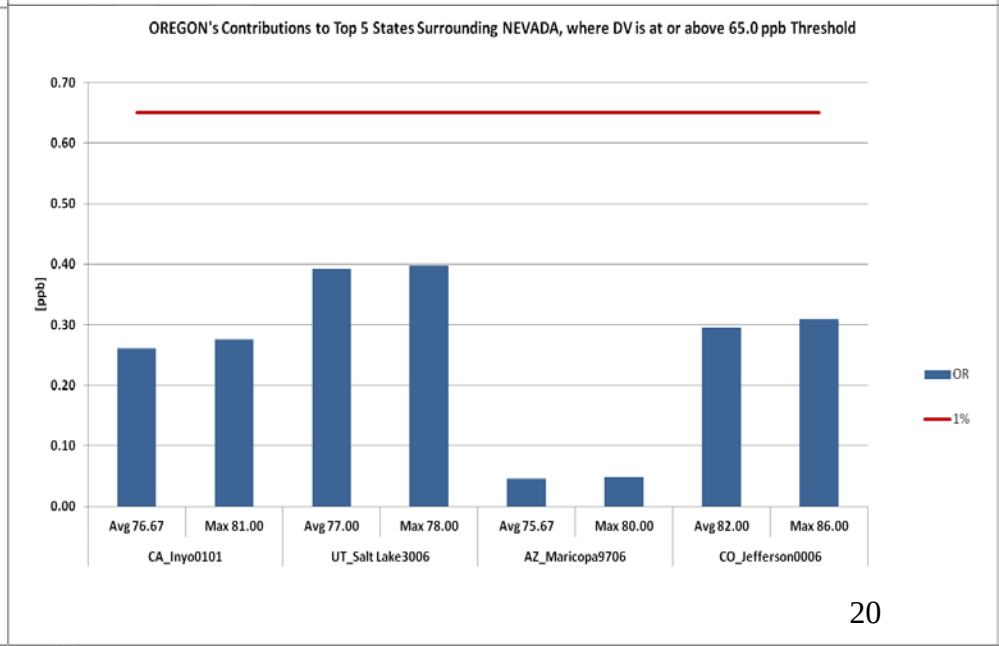


Oregon CSAPR-Type Ozone Contribution Analysis in "states near OR" at potential 65 ppb NAAQS (from WestJumpAQMS Appendix A)



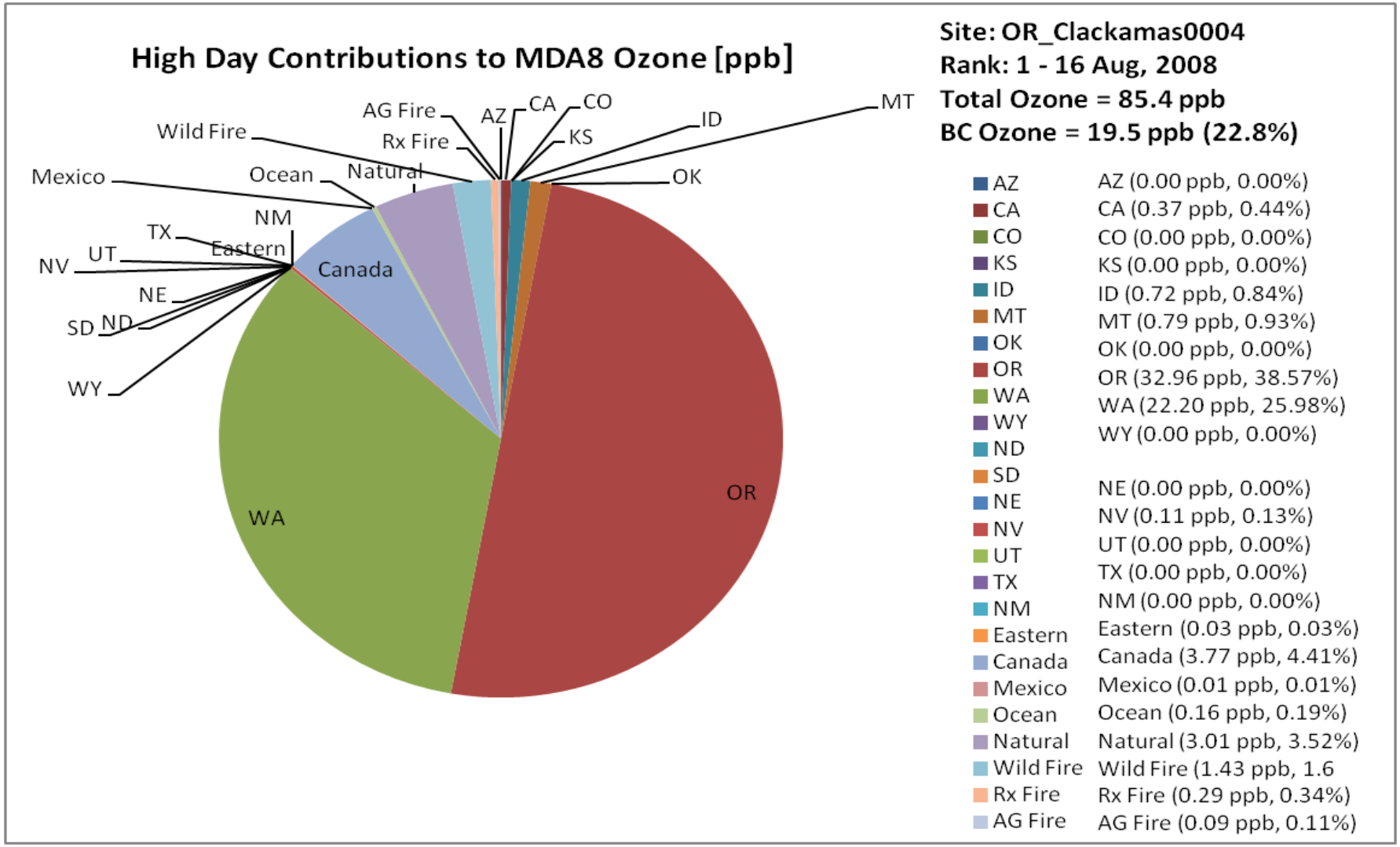






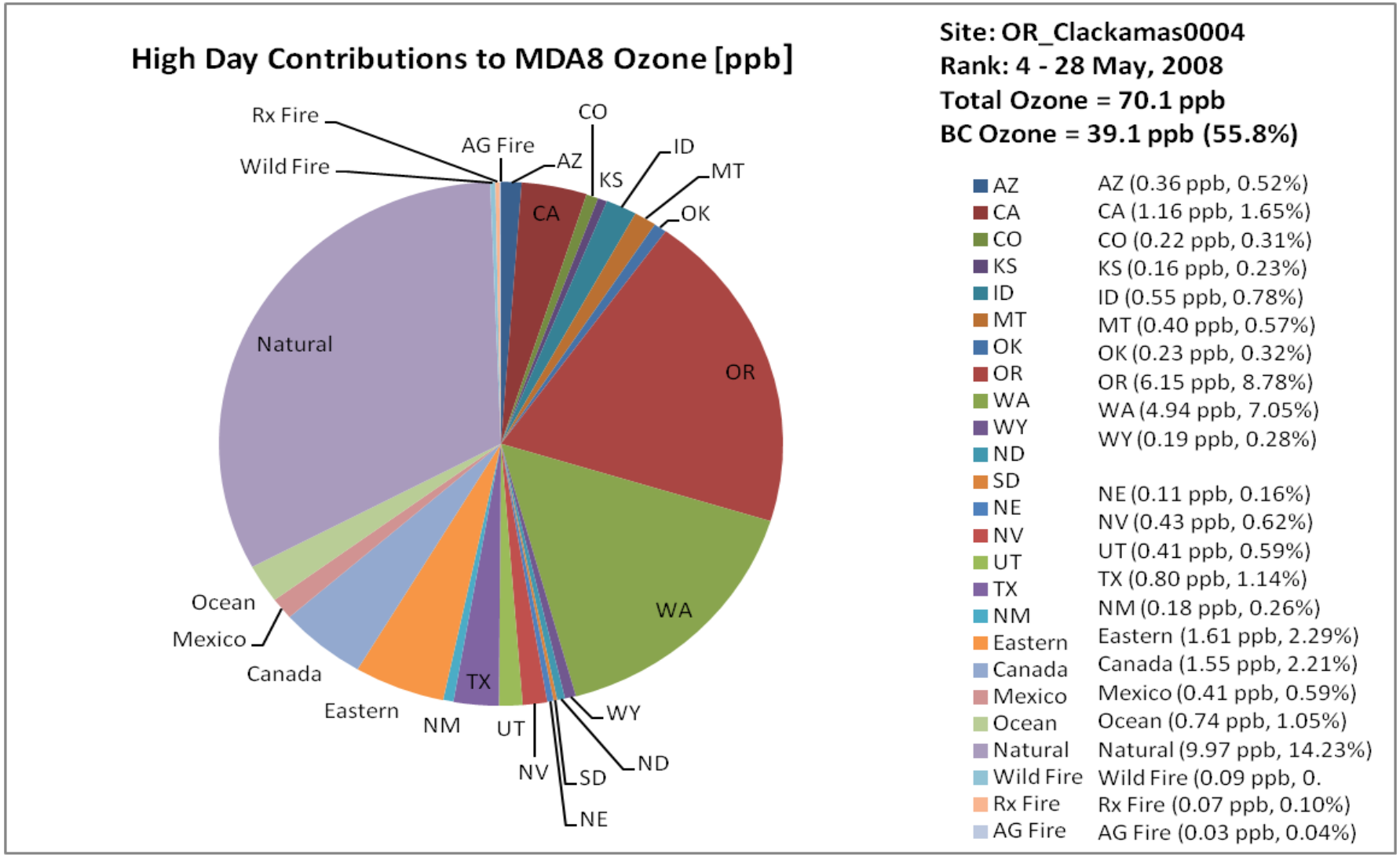
State Contributions to Modeled 10 Highest DMAX8 Ozone Days (from WestJumpAQMS Appendix B)

Highest Modeled DMAX8 Day at Spangler Road, Portland metro area



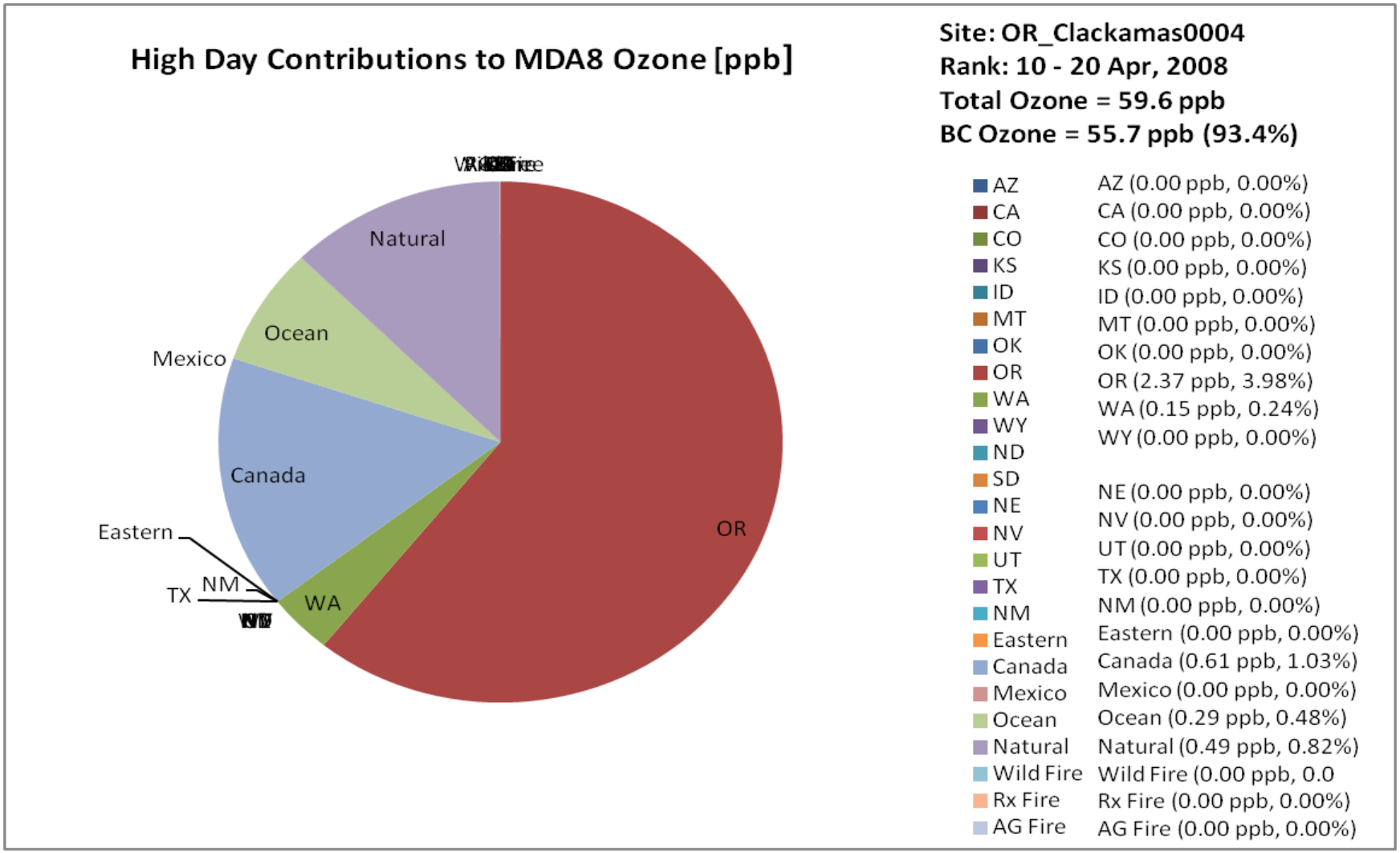
State Contributions to Modeled 10 Highest DMAX8 Ozone Days (from WestJumpAQMS Appendix B)

4th Highest Modeled DMAX8 Day at Spangler Road, Portland metro area



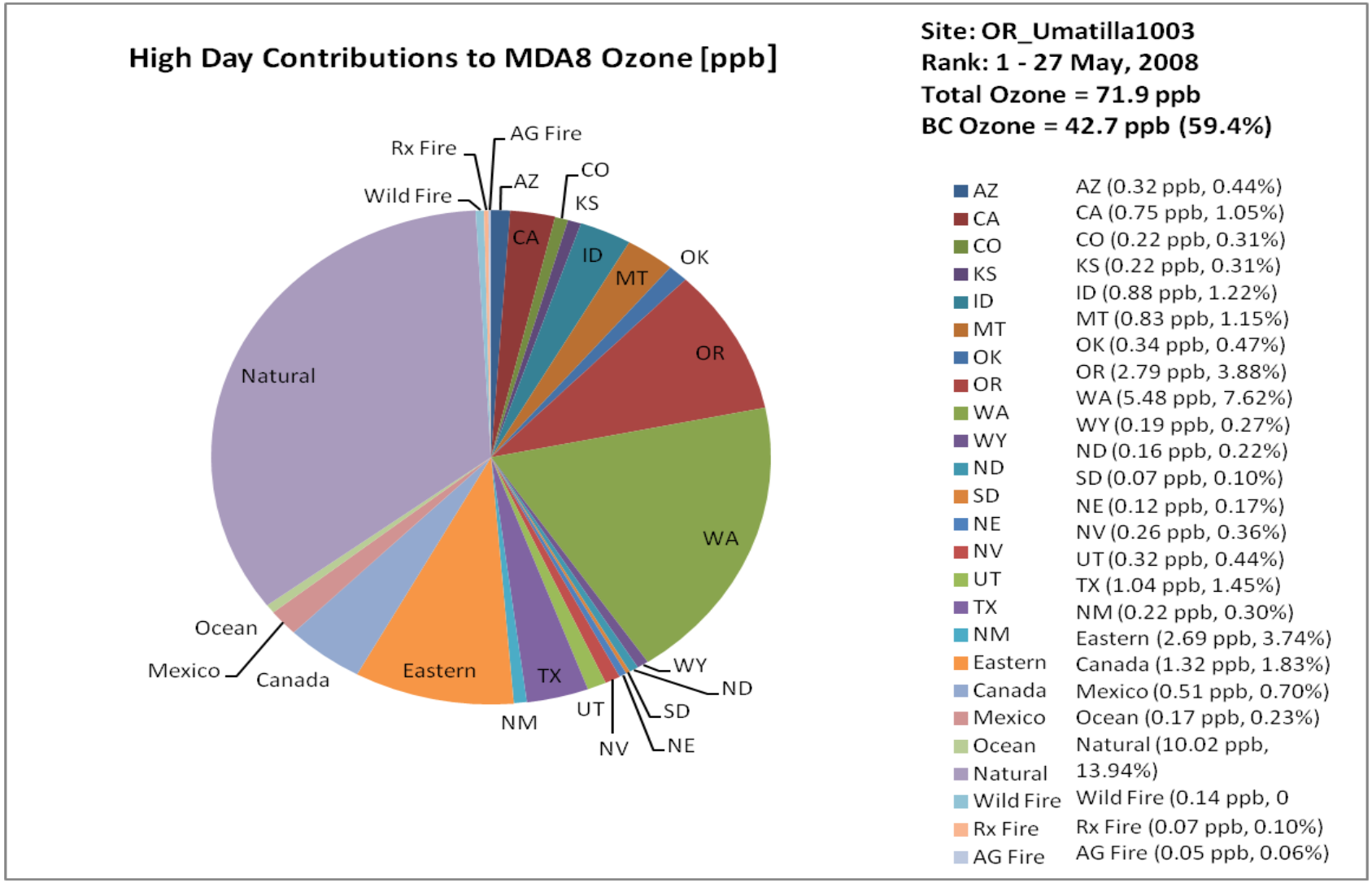
State Contributions to Modeled 10 Highest DMAX8 Ozone Days (from WestJumpAQMS Appendix B)

10th Highest Modeled DMAX8 Day at Spangler Road, Portland metro area



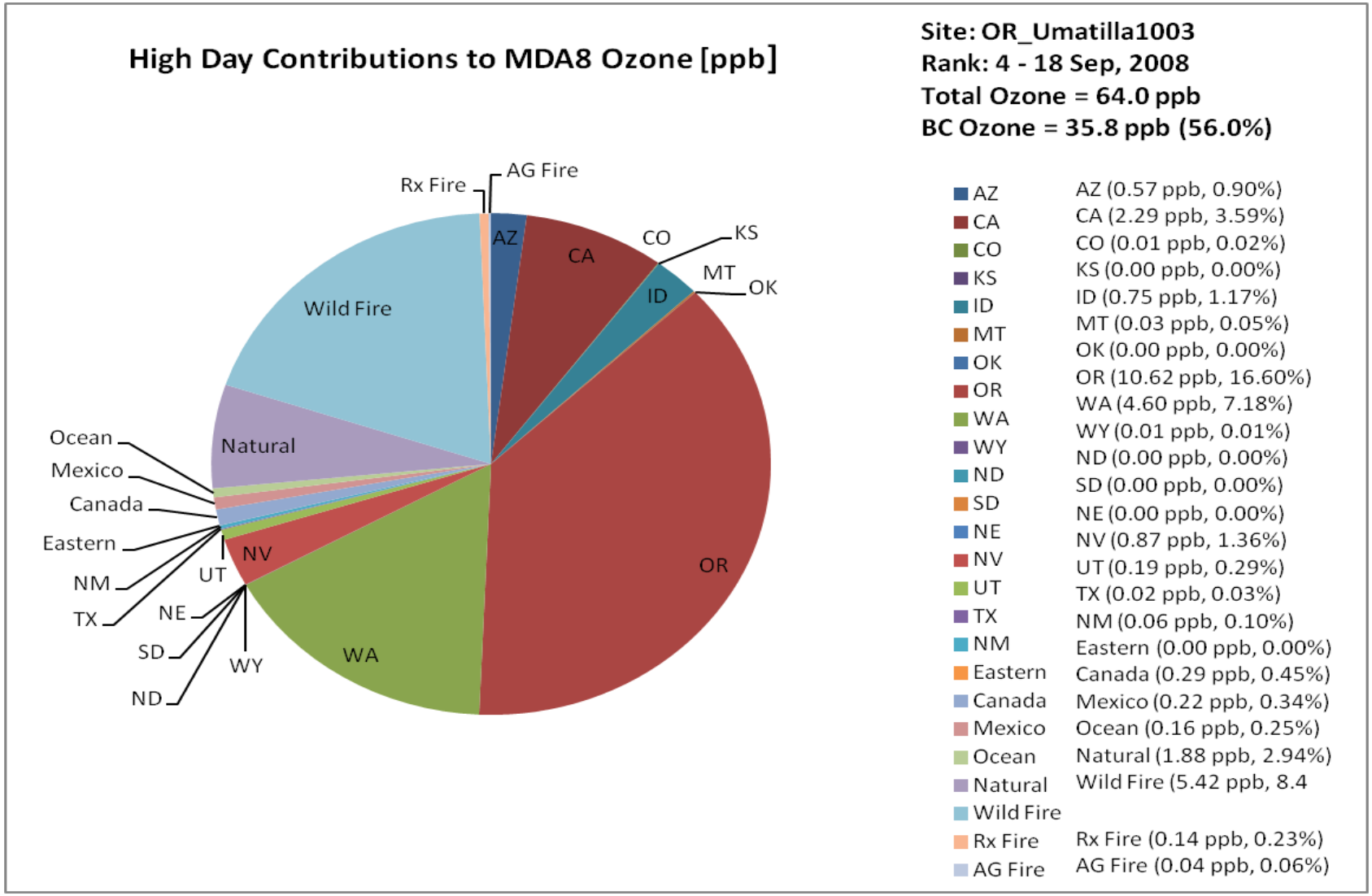
State Contributions to Modeled 10 Highest DMAX8 Ozone Days (from WestJumpAQMS Appendix B)

Highest Modeled DMAX8 Day @ Hermiston Municipal Airport



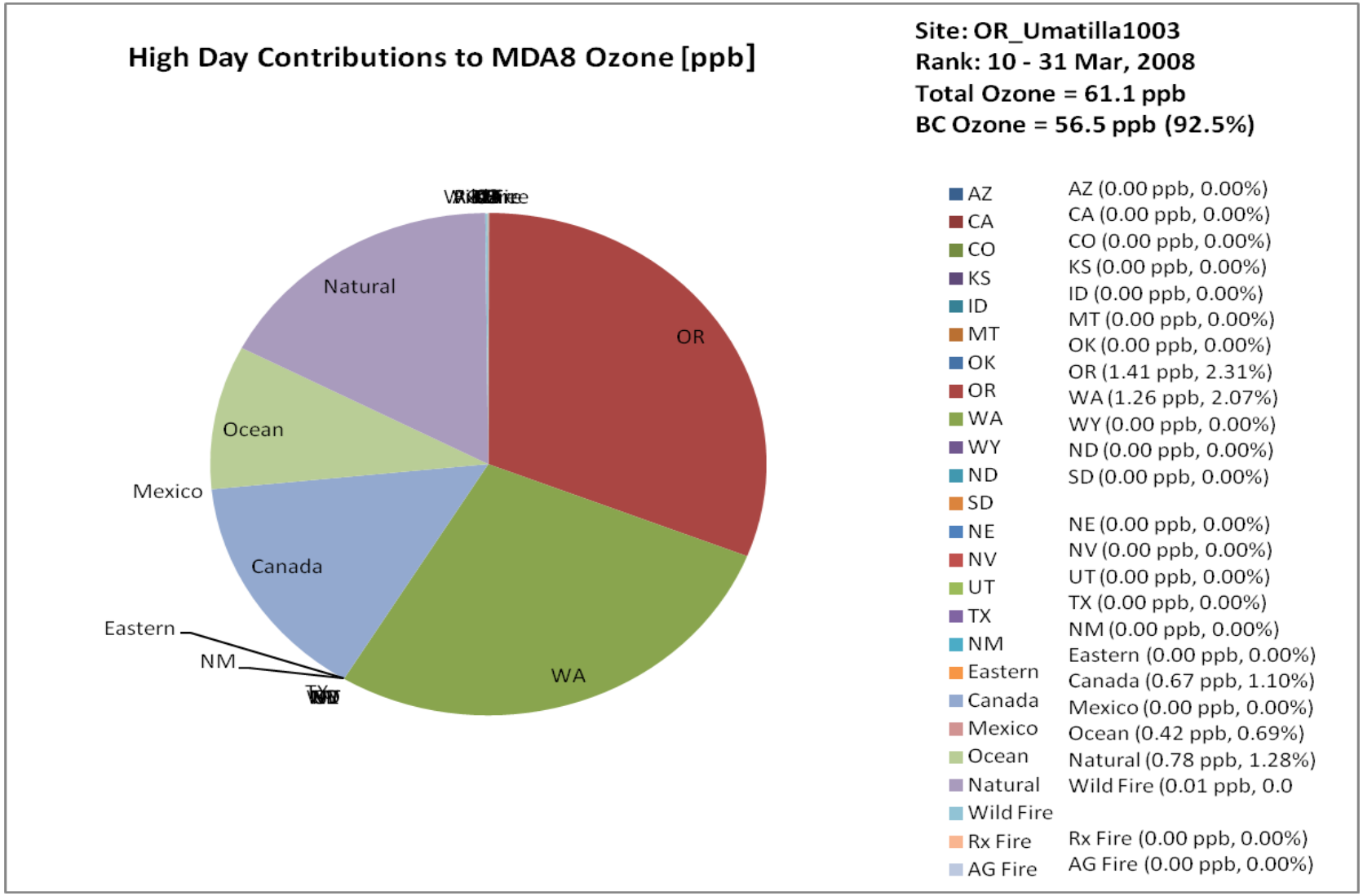
State Contributions to Modeled 10 Highest DMAX8 Ozone Days (from WestJumpAQMS Appendix B)

4th Highest Modeled DMAX8 Day @ Hermiston Municipal Airport



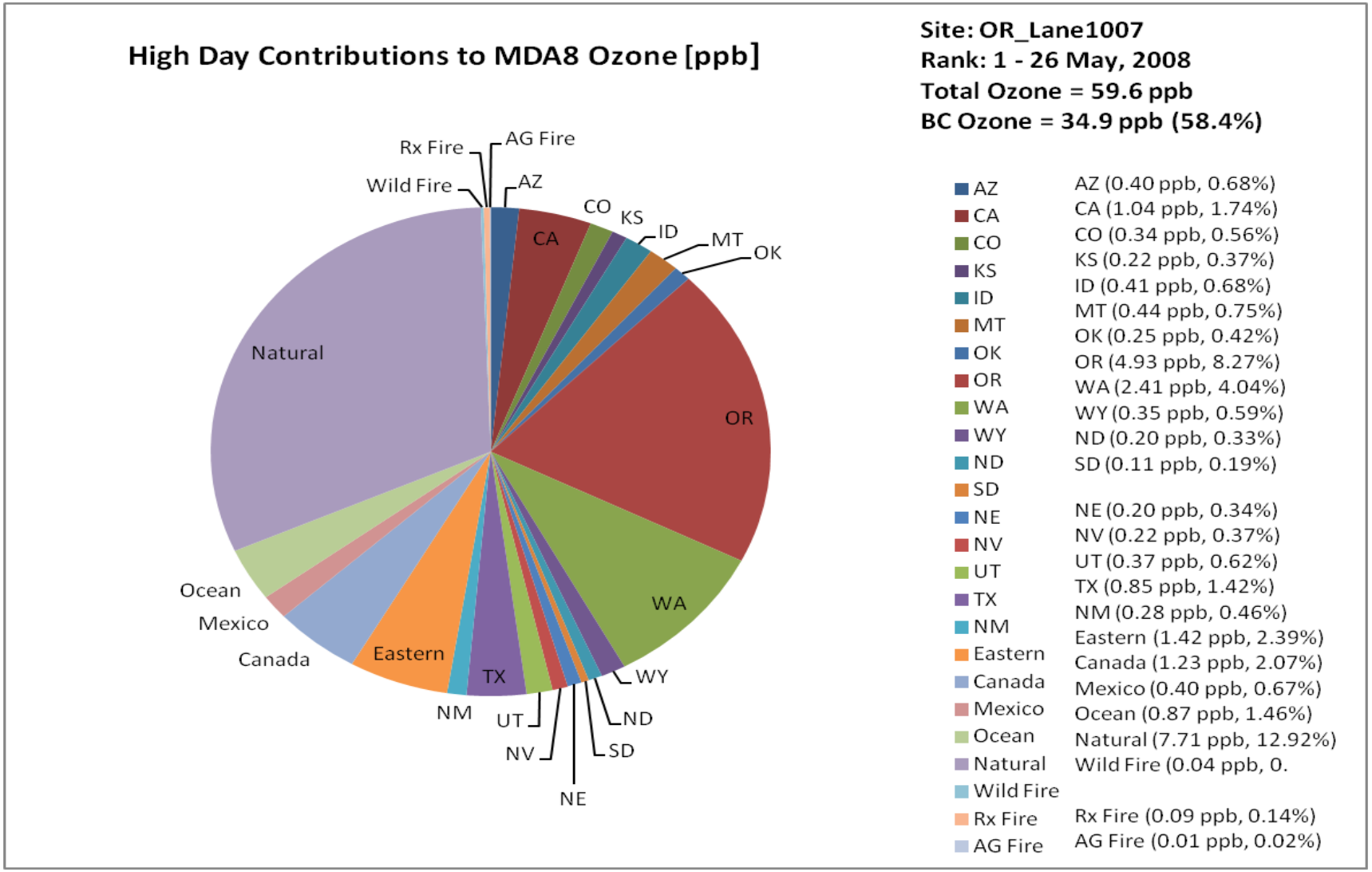
State Contributions to Modeled 10 Highest DMAX8 Ozone Days (from WestJumpAQMS Appendix B)

10th Highest Modeled DMAX8 Day @ Hermiston Municipal Airport



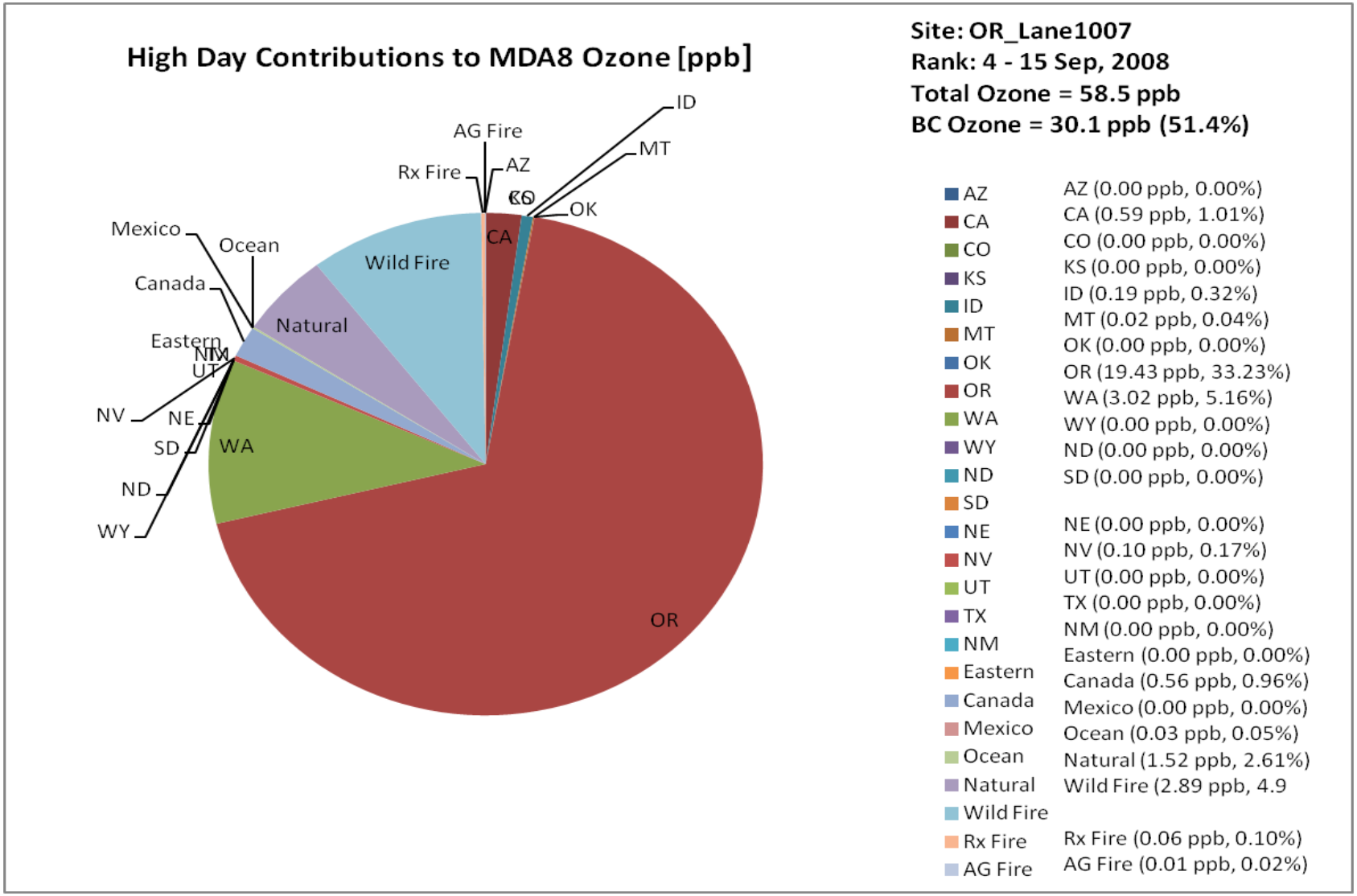
State Contributions to Modeled 10 Highest DMAX8 Ozone Days (from WestJumpAQMS Appendix B)

Highest Modeled DMAX8 Day @ Saginaw, Lane County



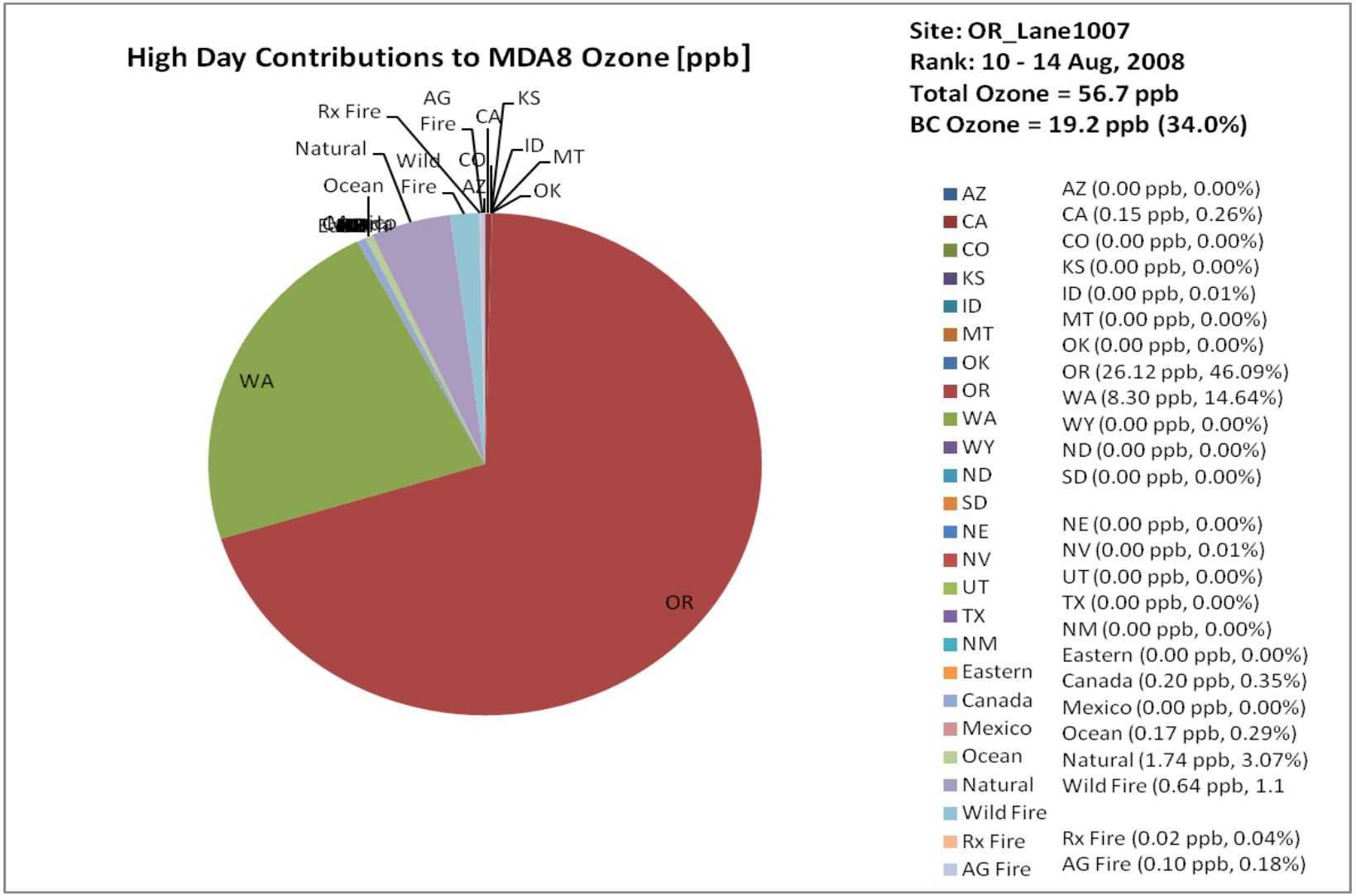
State Contributions to Modeled 10 Highest DMAX8 Ozone Days (from WestJumpAQMS Appendix B)

4th Highest Modeled DMAX8 Day @ Saginaw, Lane County



State Contributions to Modeled 10 Highest DMAX8 Ozone Days (from WestJumpAQMS Appendix B)

10th Highest Modeled DMAX8 Day at Saginaw, Lane County



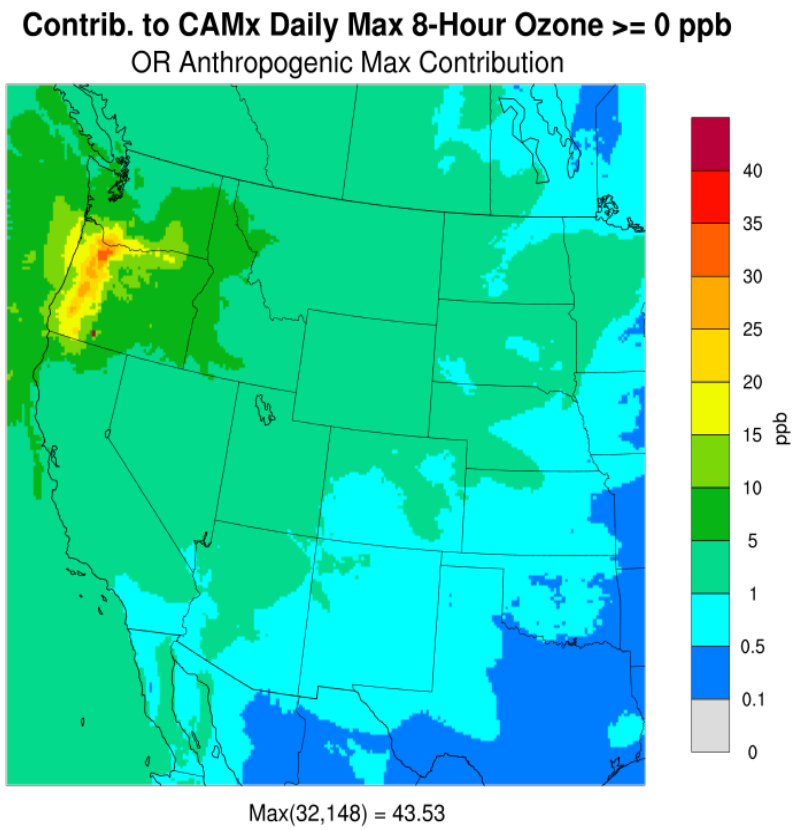
Spatial Distribution of State Ozone Contributions

- Spatial distribution of state's ozone contribution to DMAX8 ozone concentrations greater than or equal to:
  - 76 ppb (current NAAQS)
  - 70 ppb; 65 ppb and 60 ppb (potential future NAAQS)
  - 0 ppb (highest contribution in year)
- Two types of metrics:
  1. Maximum modeled contribution to Highest and 4th Highest DMAX8 ozone (from WestJumpAQMS Appendix C)
  2. Attainment Test Unmonitored Areas projection contribution to 8-hour ozone design value (not shown in this presentation)
- Examples for Oregon next:
  - Maximum contribution to highest DMAX8 ever and at 76 ppb (current NAAQS)
  - Maximum contribution to 4th high DMAX8 for 76, 70, 65, and 60 ppb

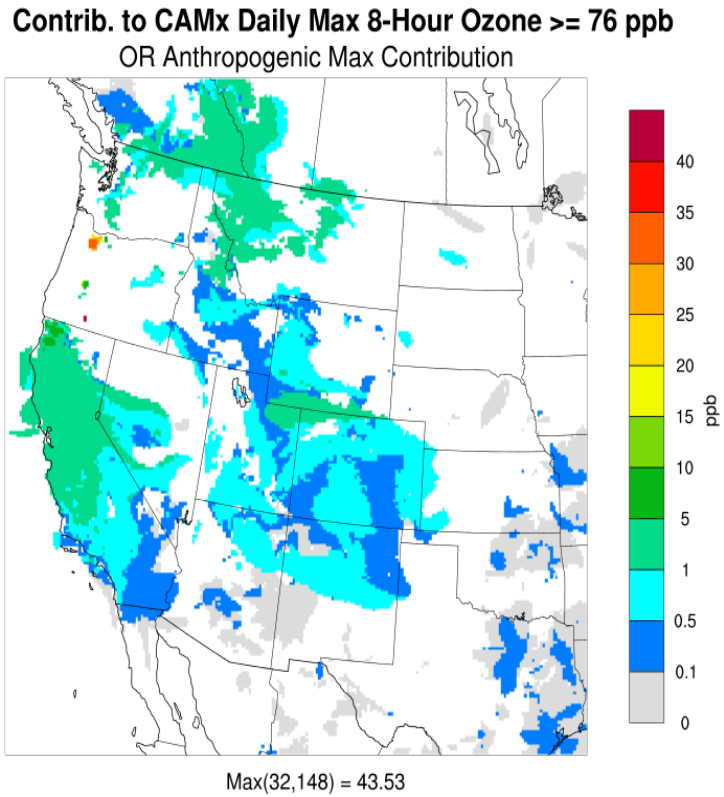
2008 Oregon 8-Hour Ozone Contribution

from WestJumpAQMS Appendix C

Highest Modeled Contribution

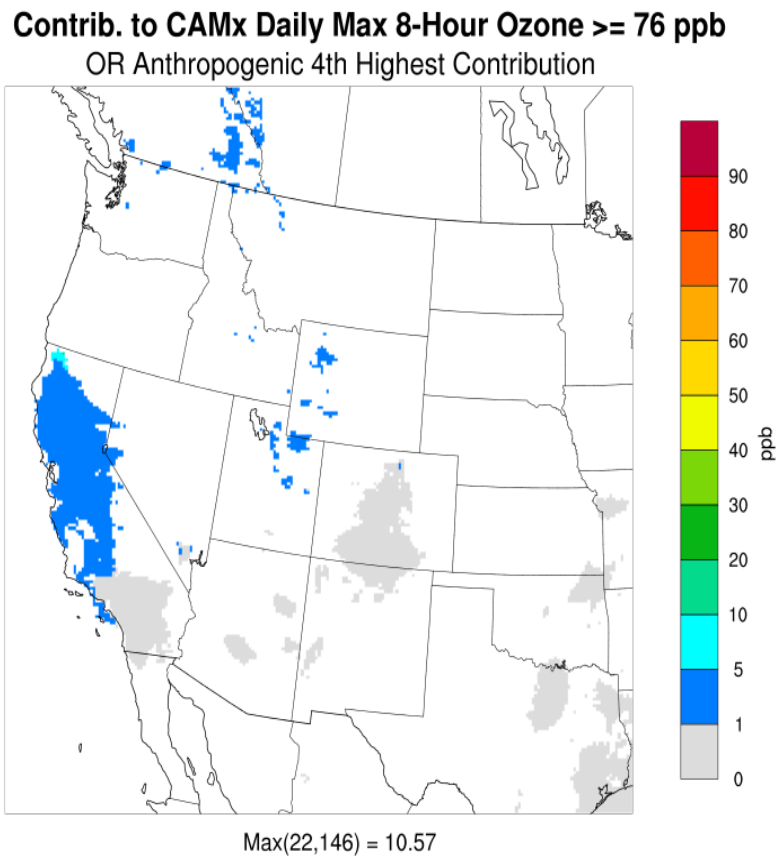


Modeled DMAX8 Ozone ≥ 76 ppb

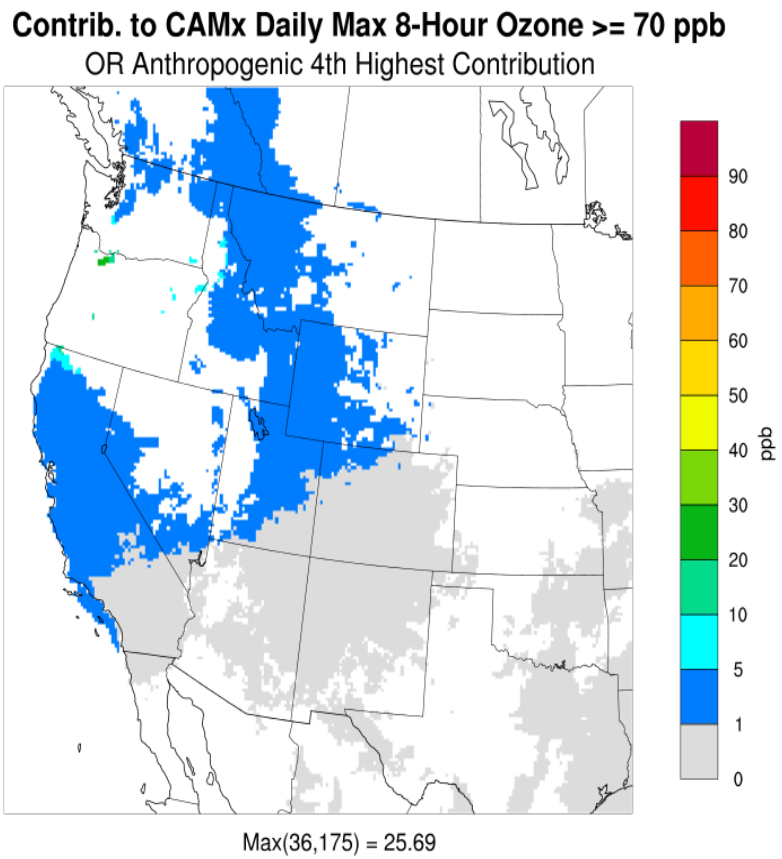


2008 Oregon Contribution to 4th High DMAX8 Ozone
from WestJumpAQMS Appendix C

4th Highest DMAX8 Ozone ≥ 76 ppb

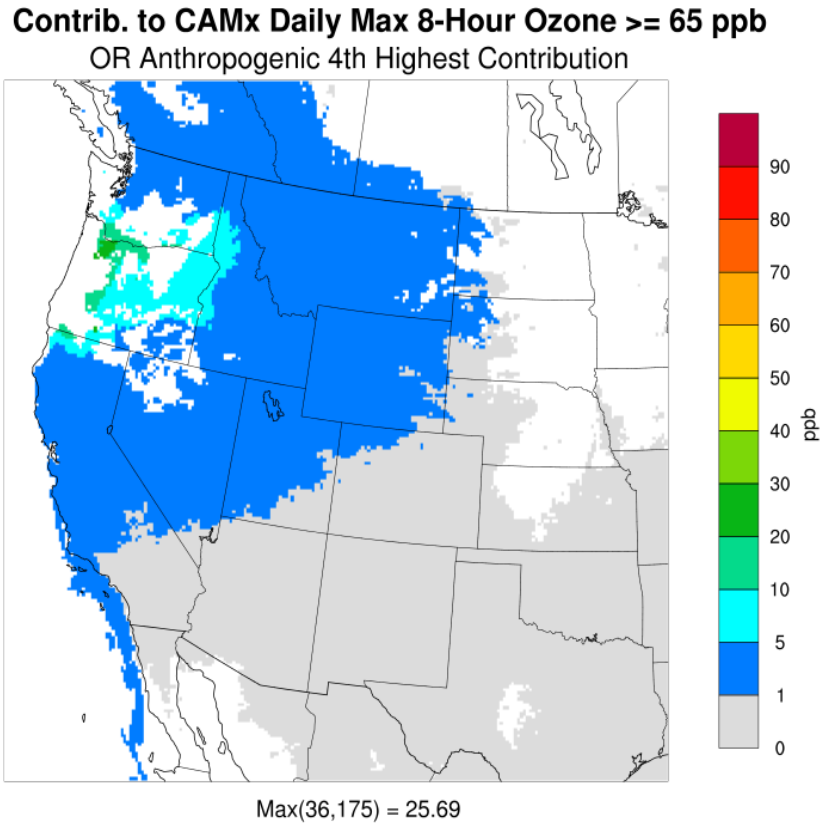


4th Highest DMAX8 Ozone ≥ 70 ppb

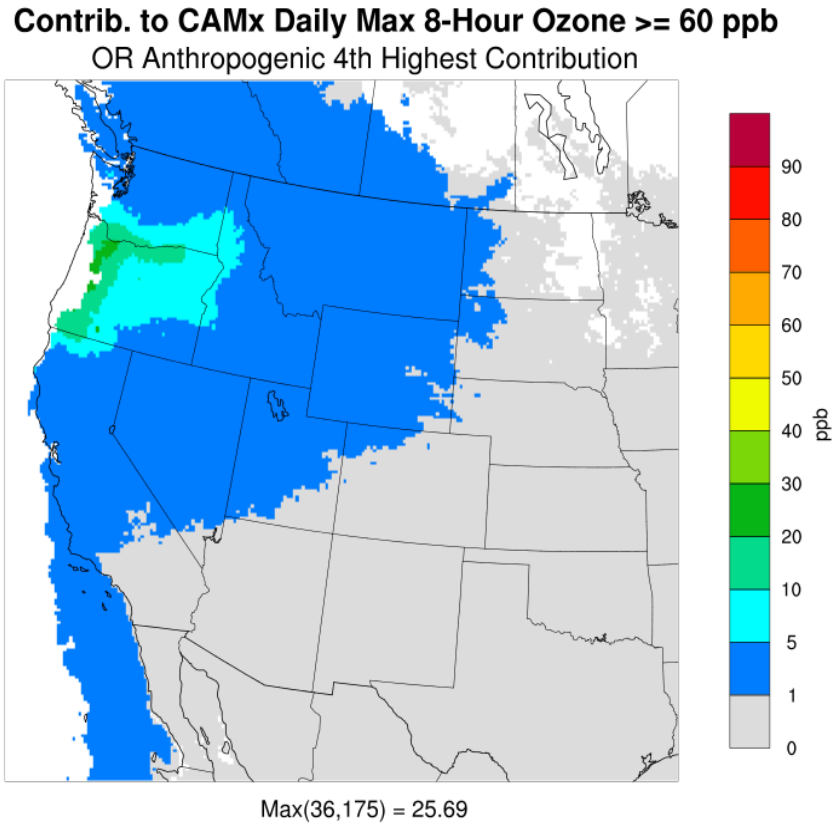


2008 Oregon Contribution to 4th High DMAX8 Ozone
from WestJumpAQMS Appendix C

4th Highest MAX8 Ozone ≥ 65ppb

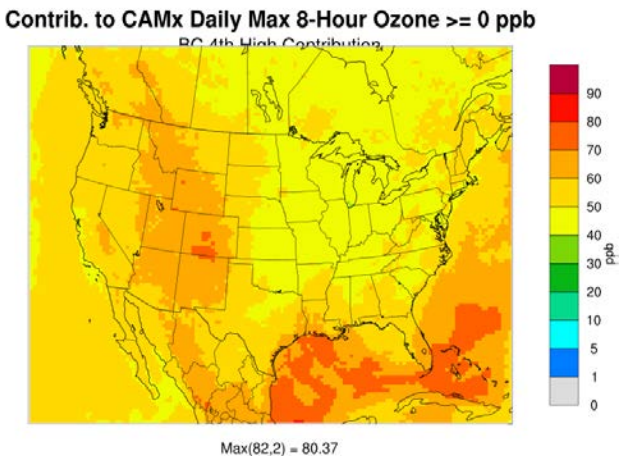


4th Highest DMAX8 Ozone ≥ 60 ppb

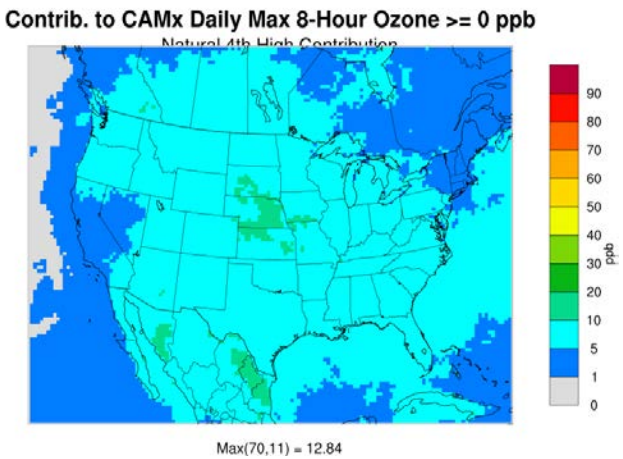


“Other Sources” Max Contrib. 4th High DMAX8 Ozone

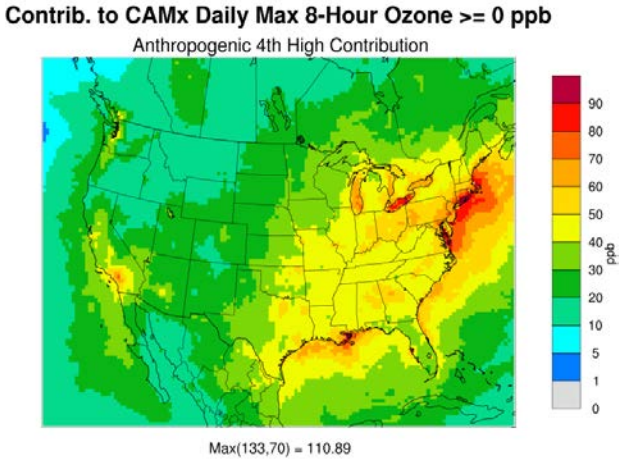
Boundary Conditions

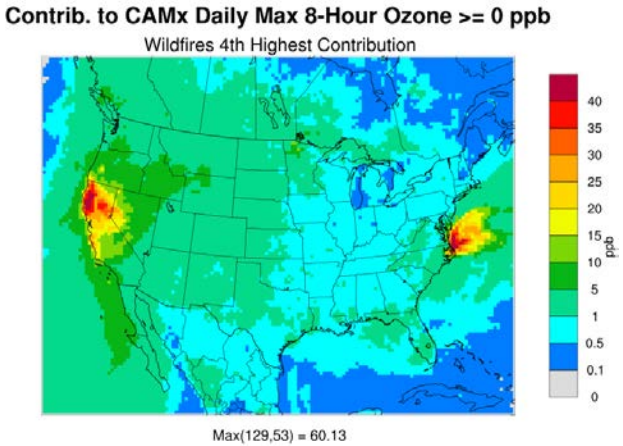


Natural

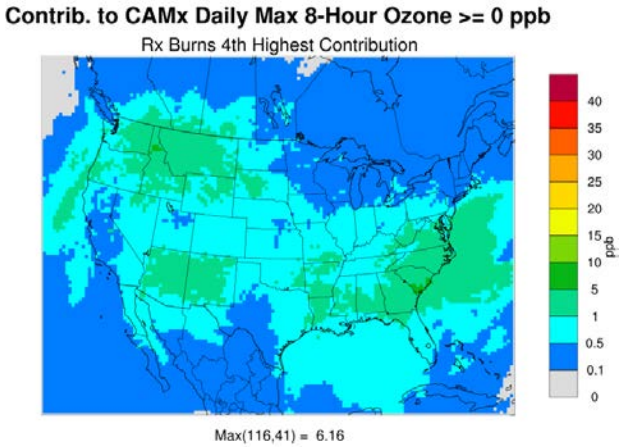


Anthropogenic

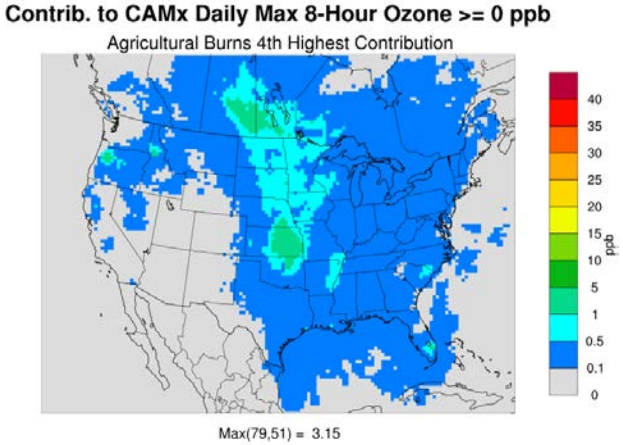




Wildfire

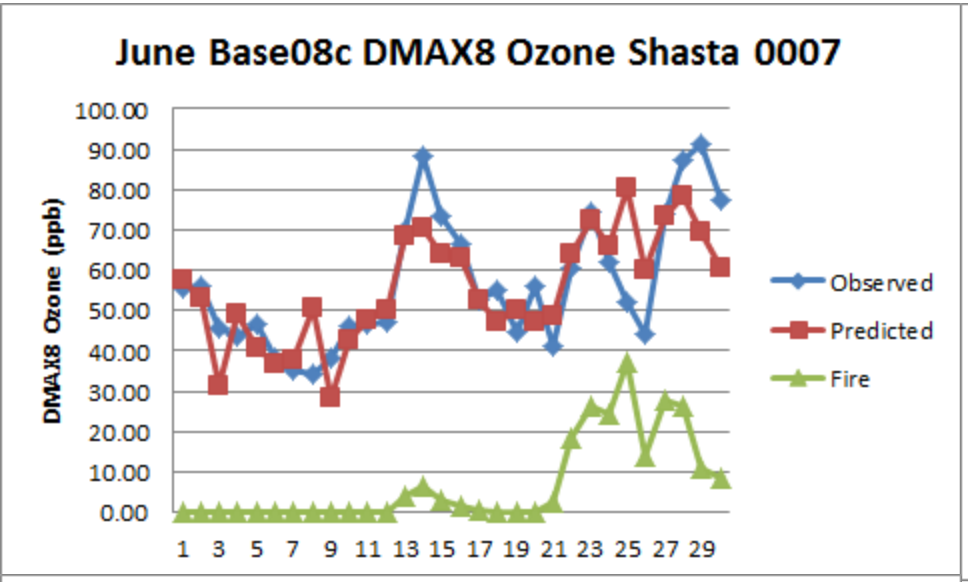


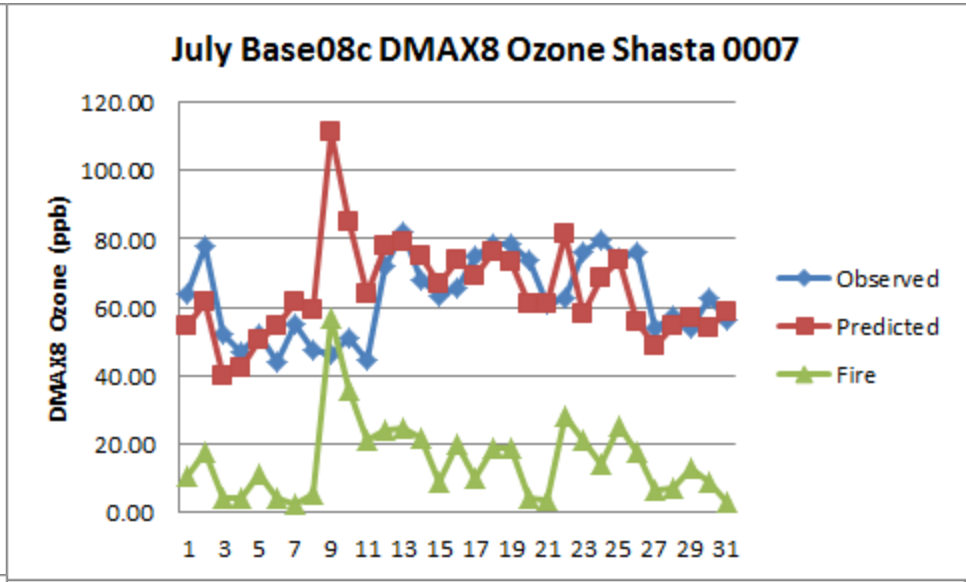
Prescribed Fire

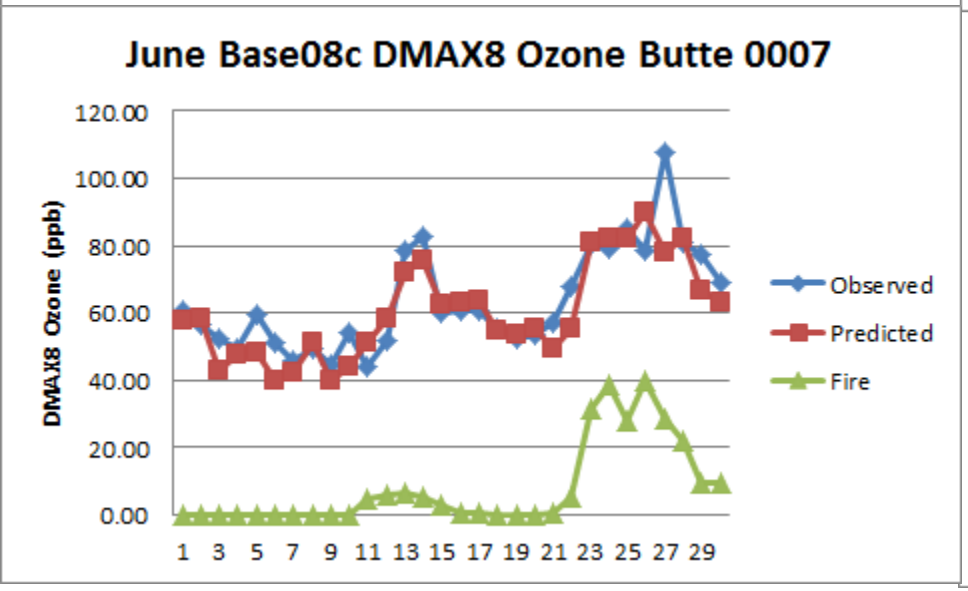


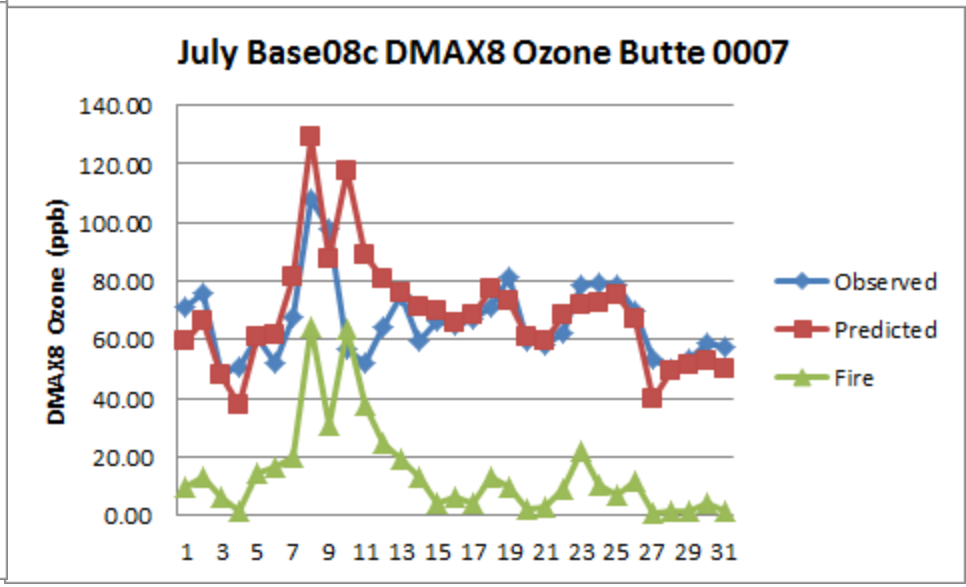
Agricultural Fire

Northern California Wildfires June-July 2008

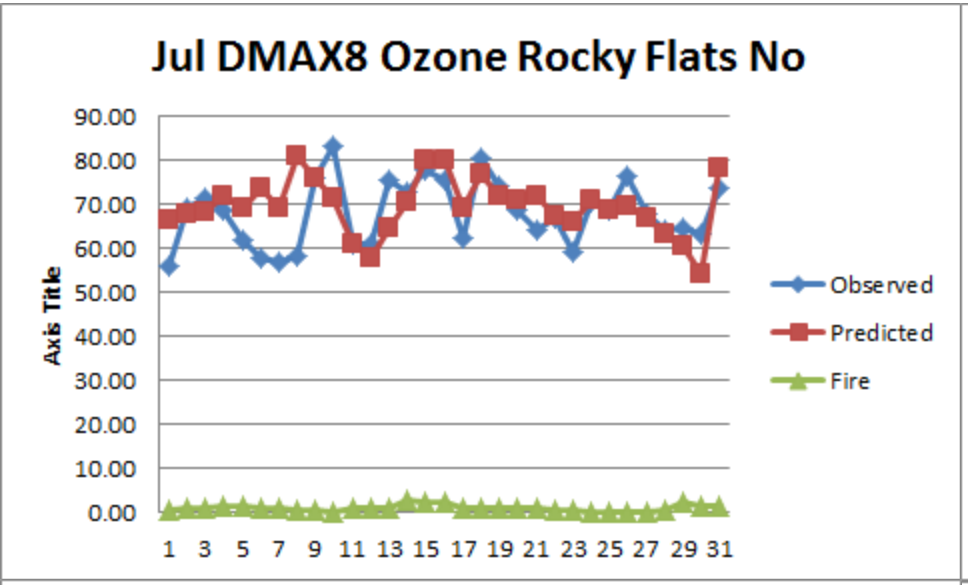


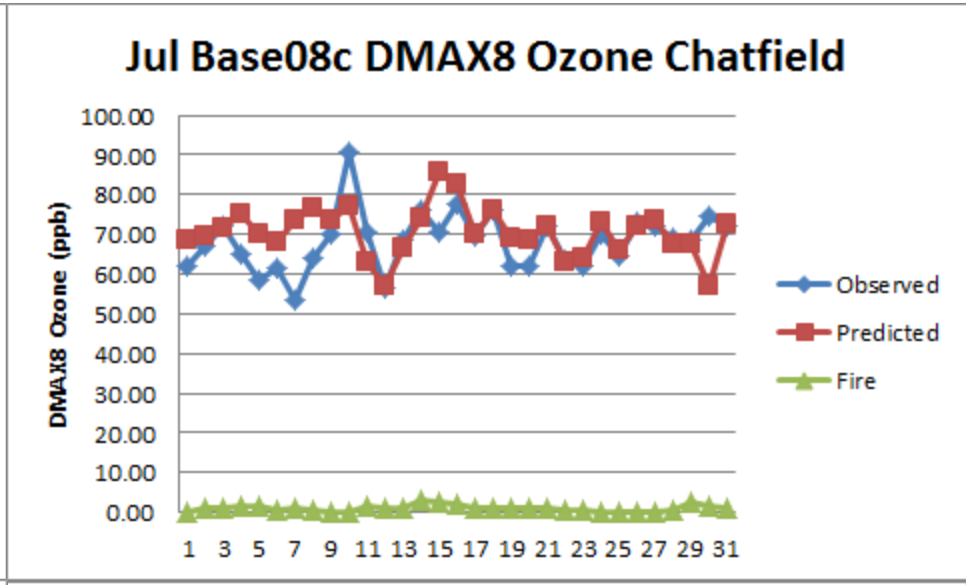


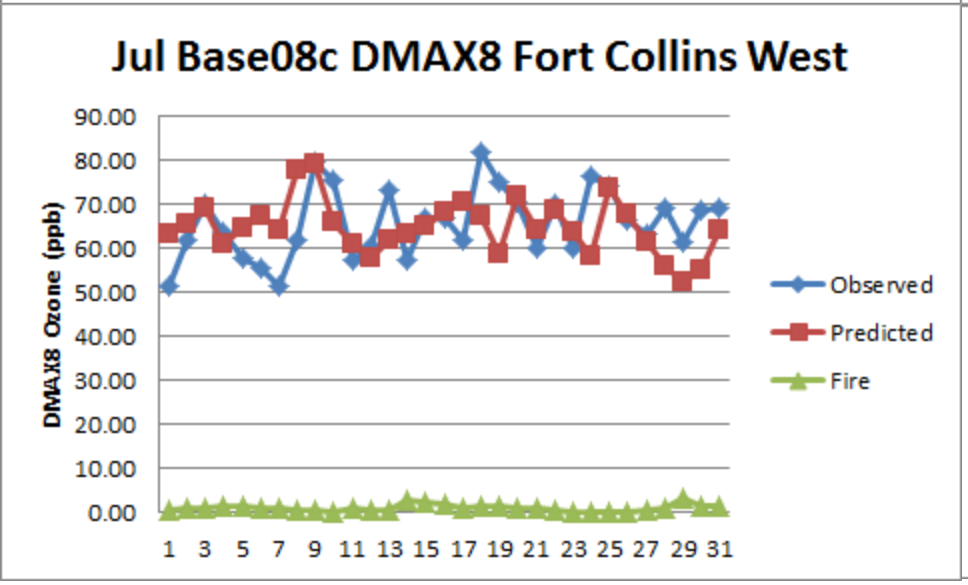


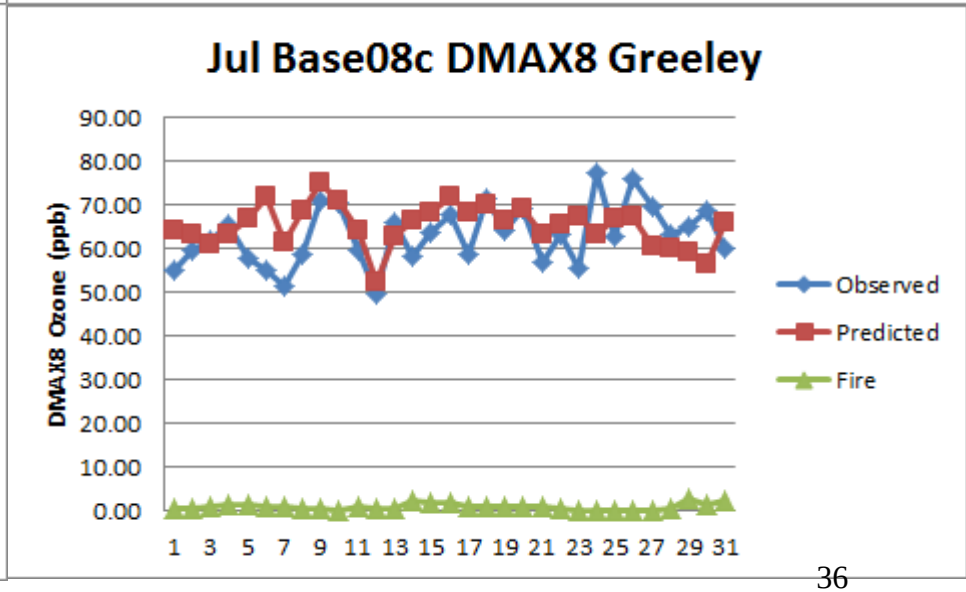


Denver Ozone Monitors July 2008



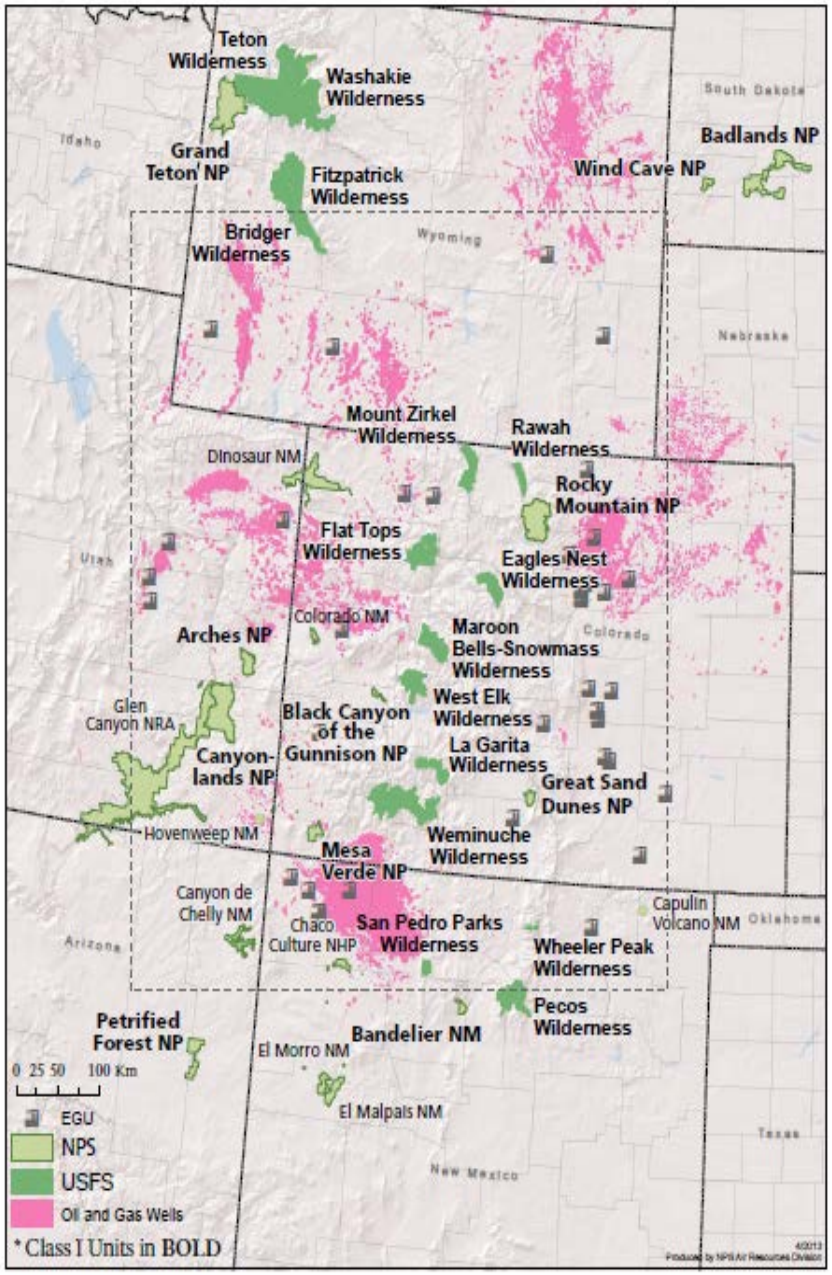






Pilot Study - Detailed Source Category-Specific Ozone Source Apportionment

- Six Source Categories:
  - Natural (Biogenic, Lightning, Sea Salt & WBD)
  - Fires (WF, Rx, & Ag)
  - Upstream Oil and Gas (O&G)
  - Point Sources (EGU & Non-EGU)
  - Mobile Sources (on-road, non-road & CMV)
  - Remainder (Area/Non-Point)
- Ozone Apportionment
  - May-Aug 2008
  - 36/12/4 km Domains
  - 4 States (CO, NM, UT & WY)

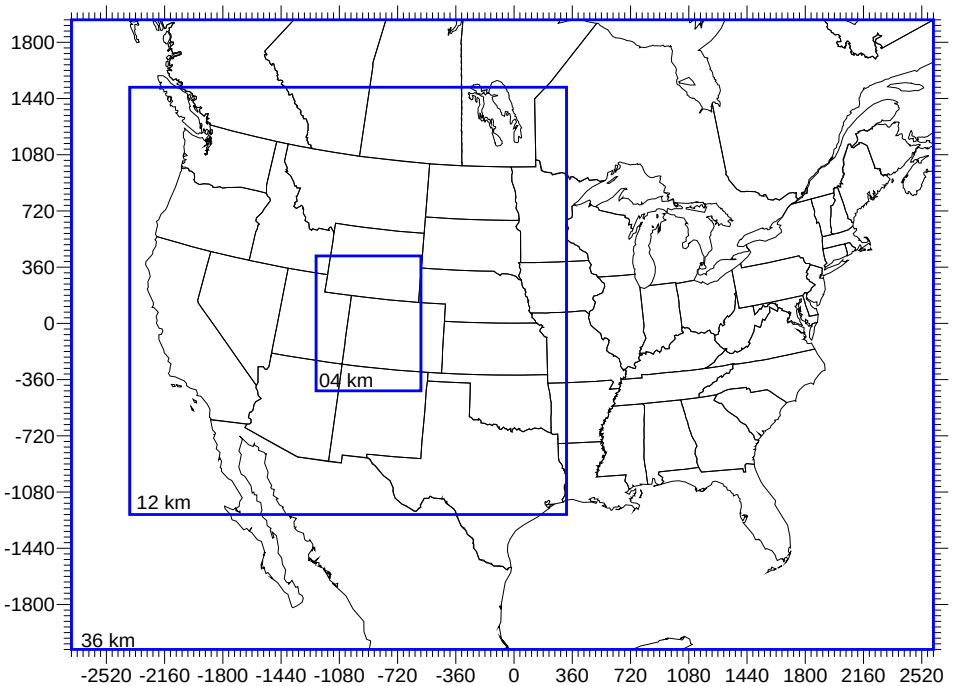


Pilot Study - Ozone Source Category-Specific Source Apportionment

← 4 km Detailed Source Apportionment Domain

36/12/4 km Two-Way Grid Nesting

(Results in Appendix I on WestJumpAQMS webpage)



CAMx Modeling Domain

36 km : 148 x 112 (-2736, -2088) to (2592, 1944)
12 km*: 227 x 230 (-2388, -1236) to (336, 1524)
04 km*: 164 x 218 (-1228, -436) to (-572, 436)

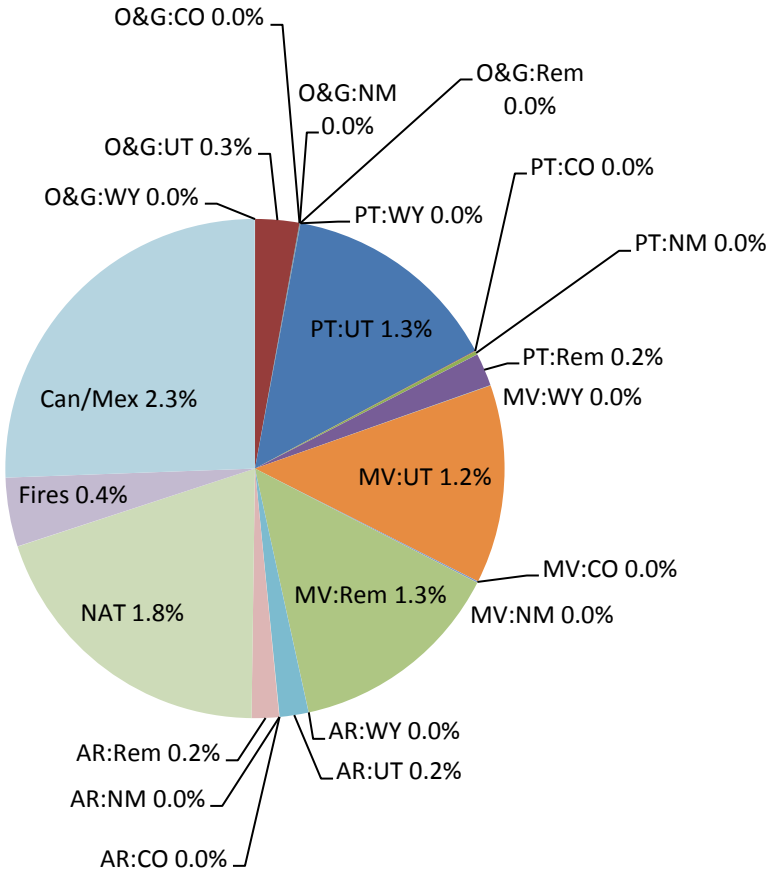
* includes buffer cells

Detailed Pilot Study: 2008 4th Highest Modeled Contribution to Ozone
(from WestJumpAQMS Appendix I)

Canyonlands NP, UT site

Contributions to MDA8 Ozone [ppb] at UT_San Juan0101

Rank (4) 05/11/08; Model = 71.2 ppb; Obs = 63.6 ppb; Bias = +12.0%; BC = 64.7 ppb (90.9%)



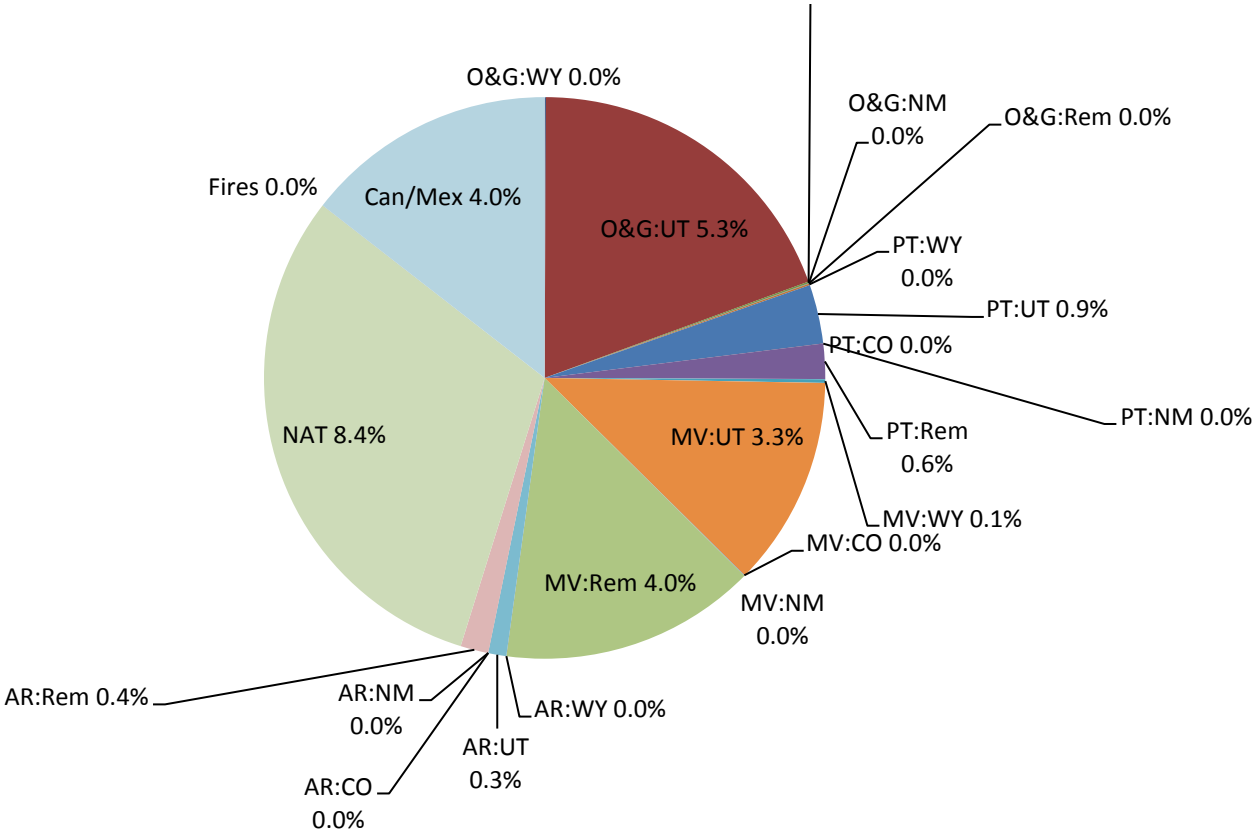
Detailed Pilot Study: 2008 4th Highest Modeled Contribution to Ozone

(from WestJumpAQMS Appendix I)

Contributions to MDA8 Ozone [ppb] at UT_Uintah1003

Vernal, UT site
Modeled Rank (4) on 06/13/08

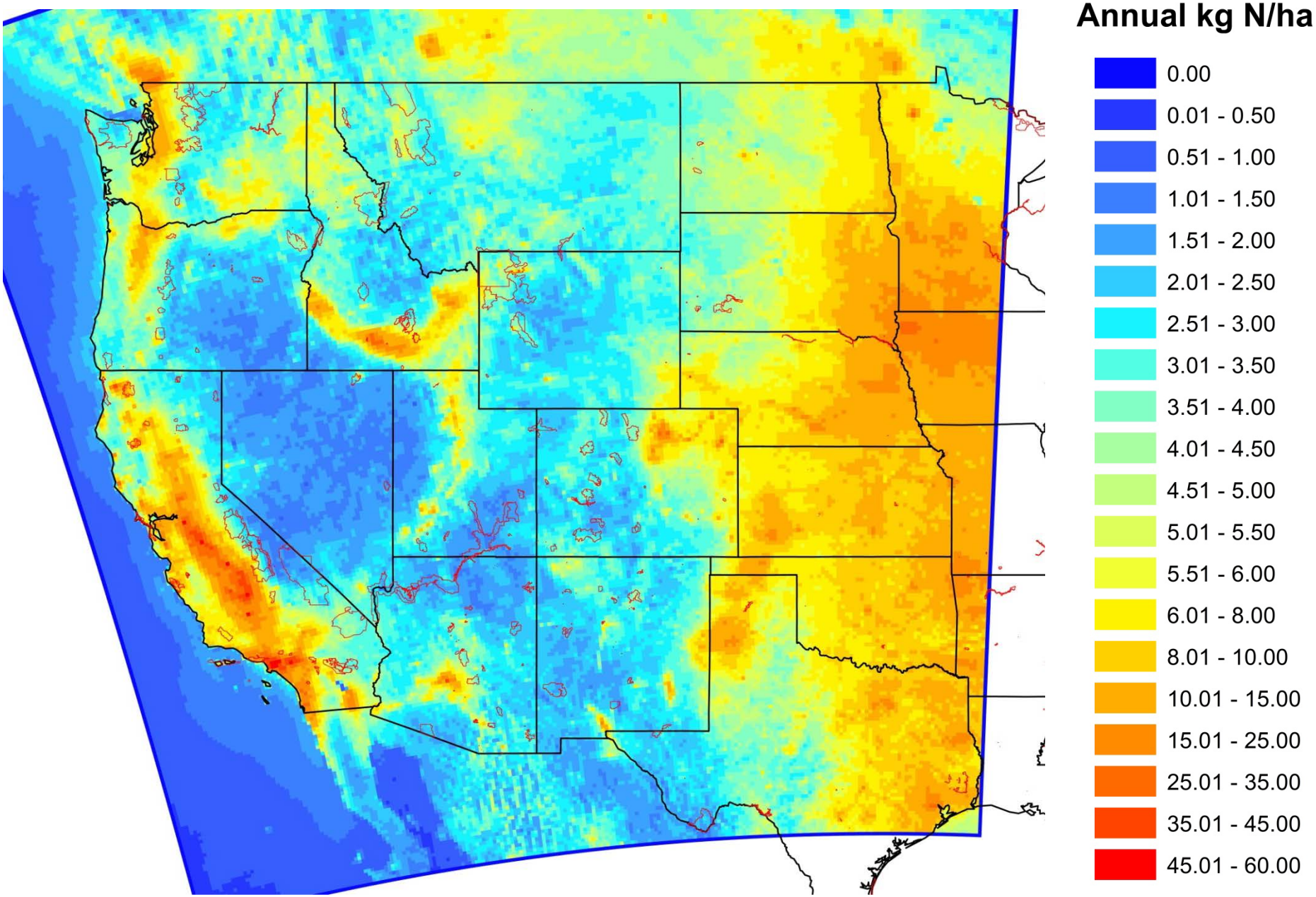
no ambient observations, site was not installed



Summary of WestJumpAQMS 2008 Modeling Results for Oregon

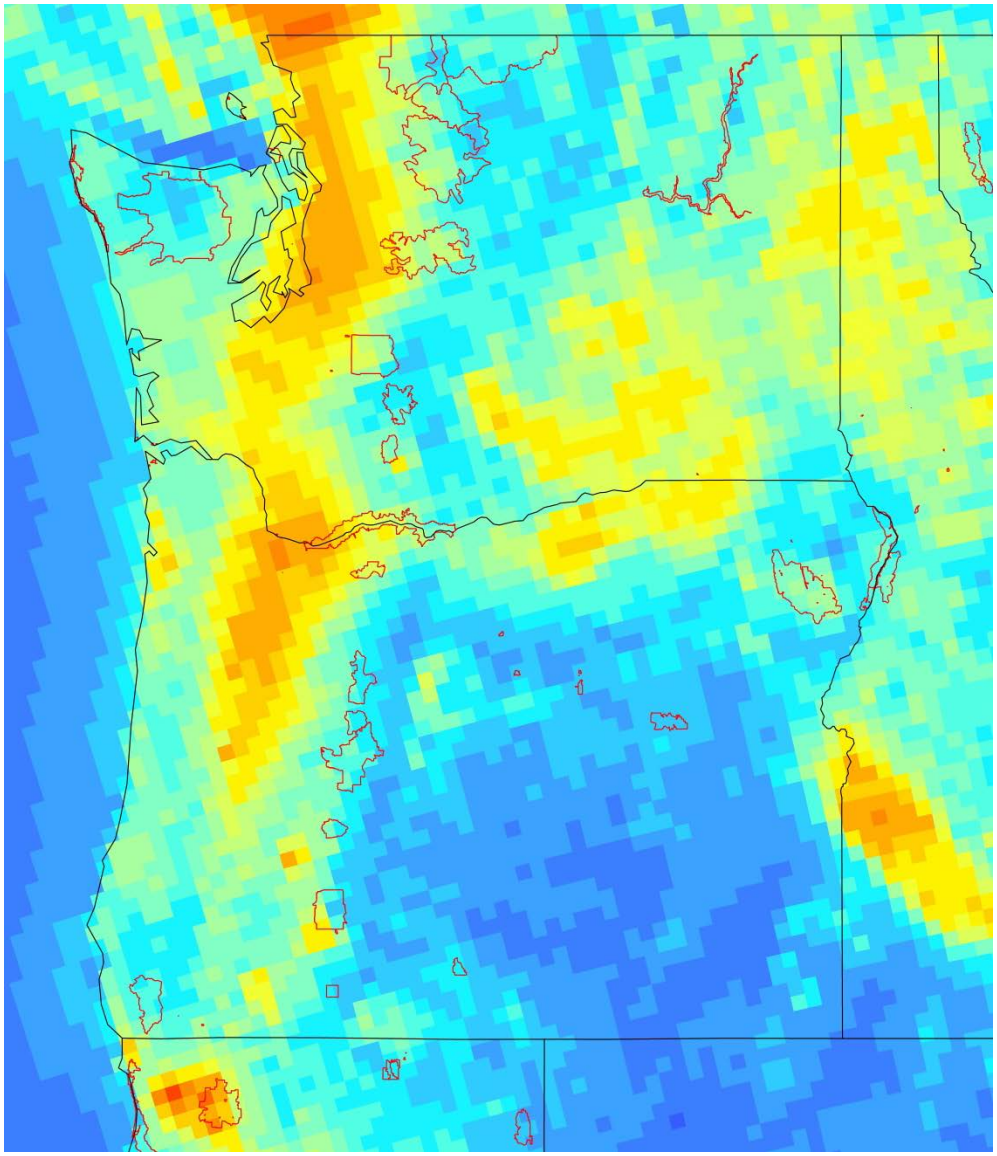
- Shown earlier
  - Examples of Upwind Ozone Contribution to highest and 4th highest, and 10th highest modeled days at 3 monitor sites across OR (shown earlier, from Appendix B)
- Next
  - Nitrogen Deposition Analysis
  - Thanks to Tammy M. Thompson, CIRA, and Michael G. Barna, NPS for modeling results and slides

WestJumpAQMS Modeled Total Nitrogen Deposition



Class 1 & 2 Areas outlined in Red. Total N includes wet & dry deposition of all species.

WestJumpAQMS Modeled Total Nitrogen Deposition



Class 1 & 2 Areas outlined in Red. Total N includes wet & dry deposition of all species.

Total Modeled Nitrogen Deposition Includes:

- Organic Nitrogen Species: PAN, RNO_3 (model chemistry includes organic N formed from biogenic VOCs)
- Dry Deposition Other Oxidized Nitrogen: NO, NO_2, N_2O_5, HONO, HO_2NO_2
- Dry Deposition Ammonia (NH_3)
- Wet Deposition Other Oxidized Nitrogen: NO, NO_2, N_2O_5, HONO, HO_2NO_2
- Dry Deposition of Nitric Acid (HNO_3)
- Particulate Nitrate (NO_3^-): Wet and dry
- Particulate Ammonium (NH_4^+): Wet and dry

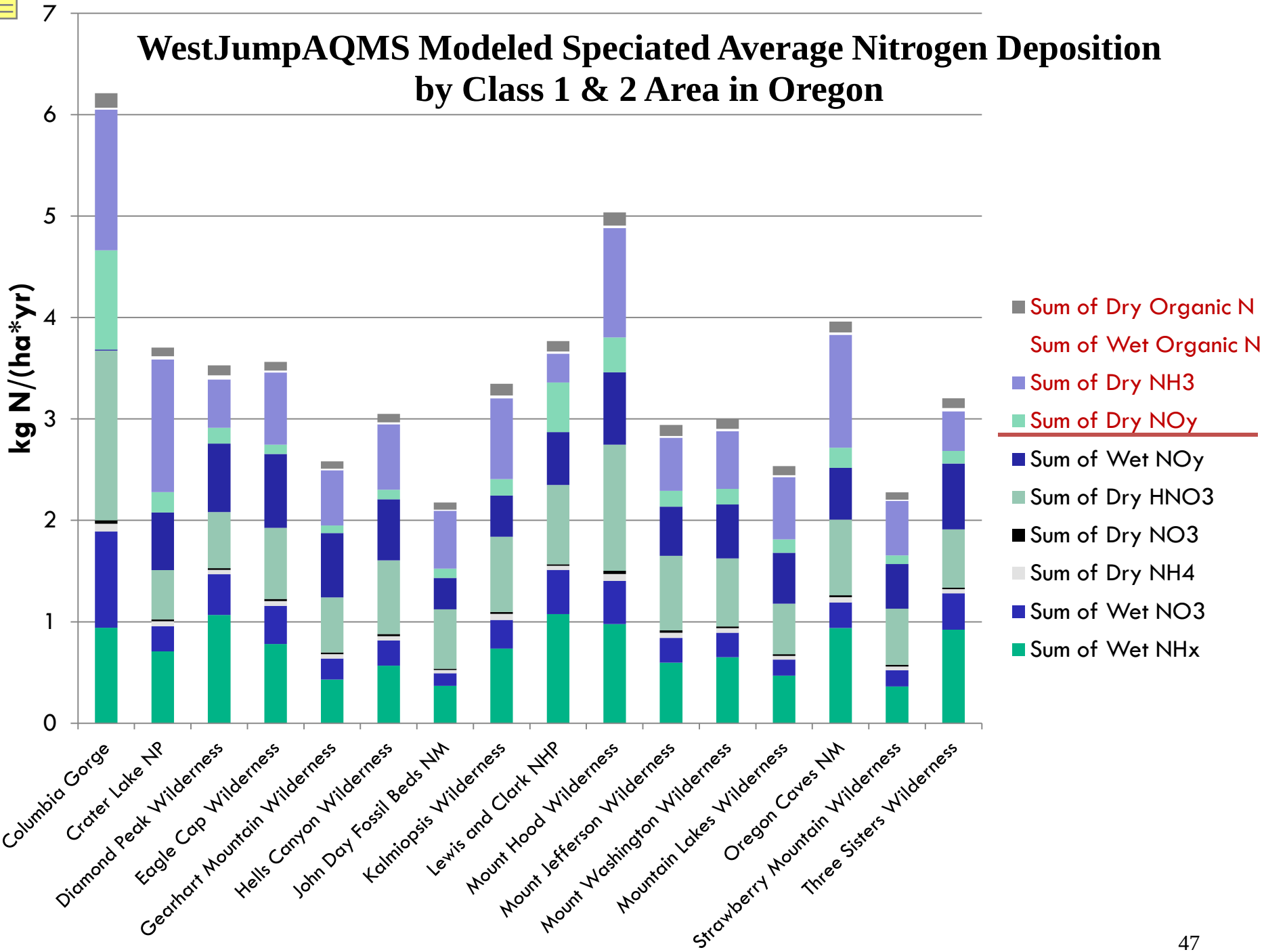
Total Measured Nitrogen Deposition Includes:

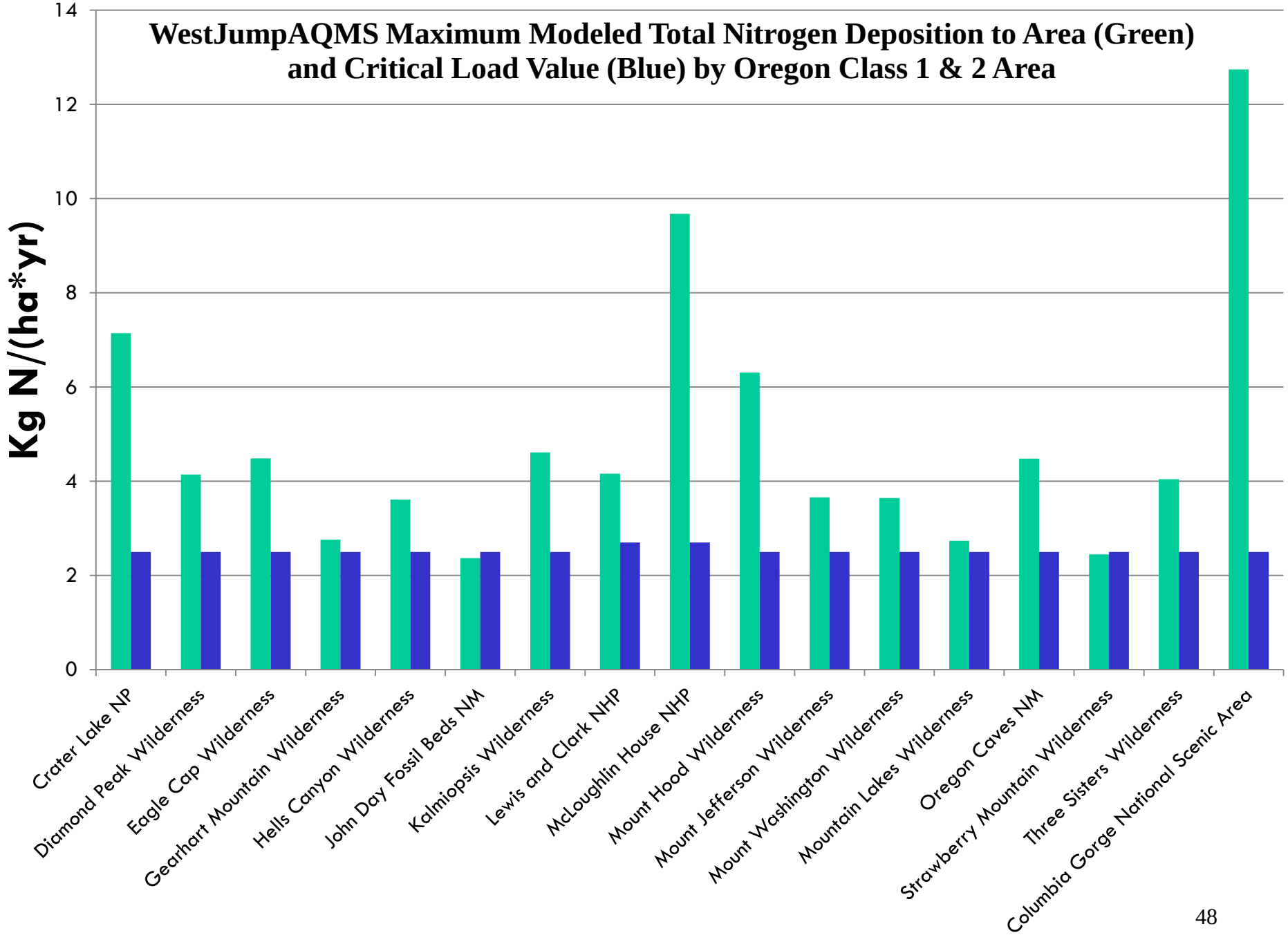
- ~~Organic Nitrogen Species: PAN, RNO_3 (model chemistry includes organic N formed from biogenic VOCs)~~
- ~~Dry Deposition Other Oxidized Nitrogen: NO, NO_2, N_2O_5, HONO, HO_2NO_2~~
- ~~Dry Deposition Ammonia (NH_3)~~
- Wet Deposition Other Oxidized Nitrogen: NO, NO_2, N_2O_5, HONO, HO_2NO_2
- Dry Deposition of Nitric Acid (HNO_3)
- Particulate Nitrate (NO_3^-): Wet and dry
- Particulate Ammonium (NH_4^+): Wet and dry

Nitrogen deposition measurement data is incomplete

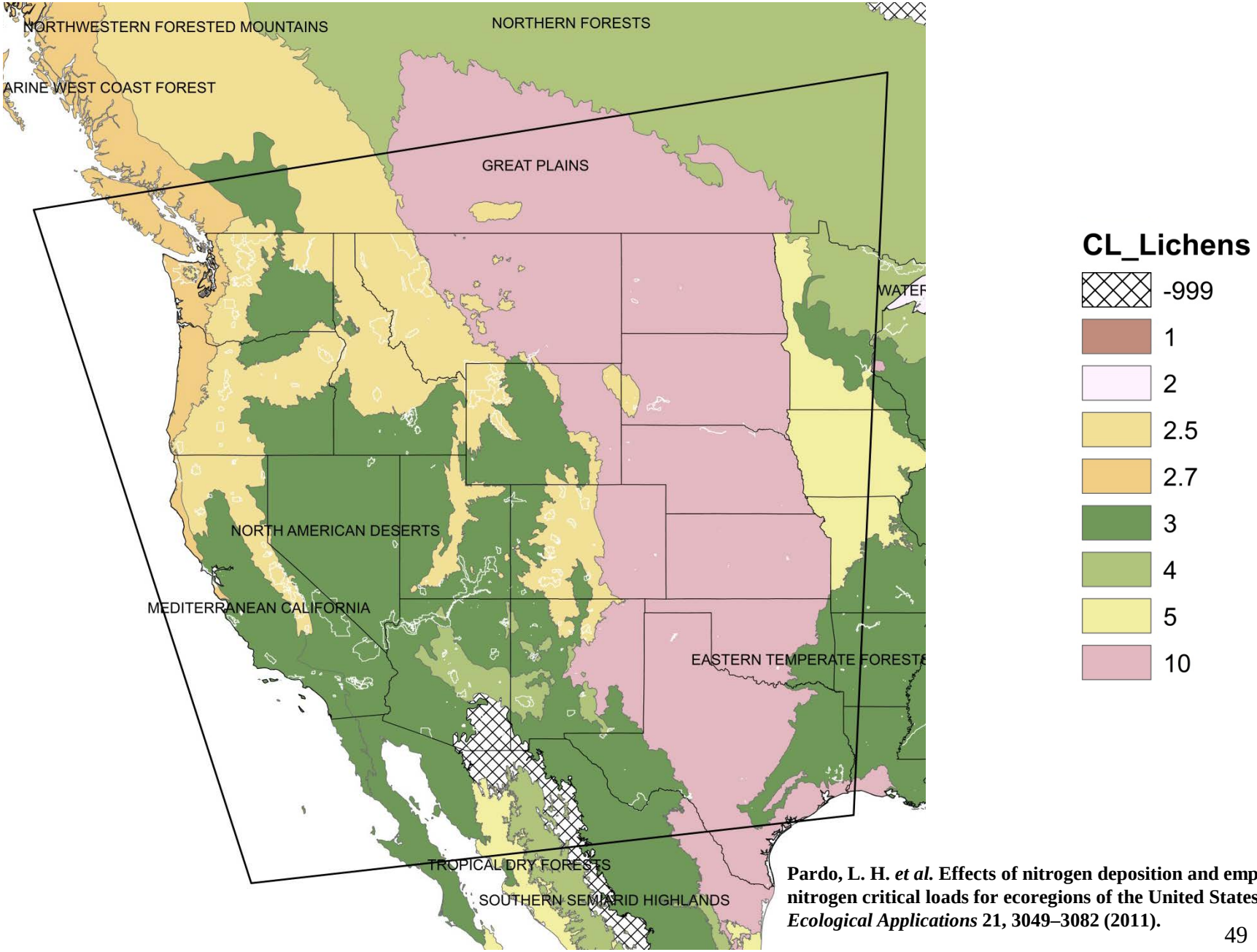
- Chemical Transport Models (e.g., CAMx) capture the bulk of total Nitrogen Deposition (although CAMx is missing reduced organic nitrogen and includes limited oxidized organic nitrogen – both expected to be small)
- Many Critical Load values are estimated using measurement data, some with scaling factors to account for “missing” N, others incorporate modeling data, still others leave data as is with caveats
- Efforts to close this gap continue, including the creation, in 2010, and subsequent expansion of the Ammonia Monitoring Network (AMoN)

WestJumpAQMS Modeled Speciated Average Nitrogen Deposition by Class 1 & 2 Area in Oregon




WestJumpAQMS Maximum Modeled Total Nitrogen Deposition to Area (Green) and Critical Load Value (Blue) by Oregon Class 1 & 2 Area
Kg N/(ha*yr)
0
2
4
6
8
10
12
14
Crater Lake NP
Diamond Peak Wilderness
Eagle Cap Wilderness
Gearhart Mountain Wilderness
Hells Canyon Wilderness
John Day Fossil Beds NM
Kalmiopsis Wilderness
Lewis and Clark NHP
McLoughlin House NHP
Mount Hood Wilderness
Mount Jefferson Wilderness
Mount Washington Wilderness
Mountain Lakes Wilderness
Oregon Caves NM
Strawberry Mountain Wilderness
Three Sisters Wilderness
Columbia Gorge National Scenic Area

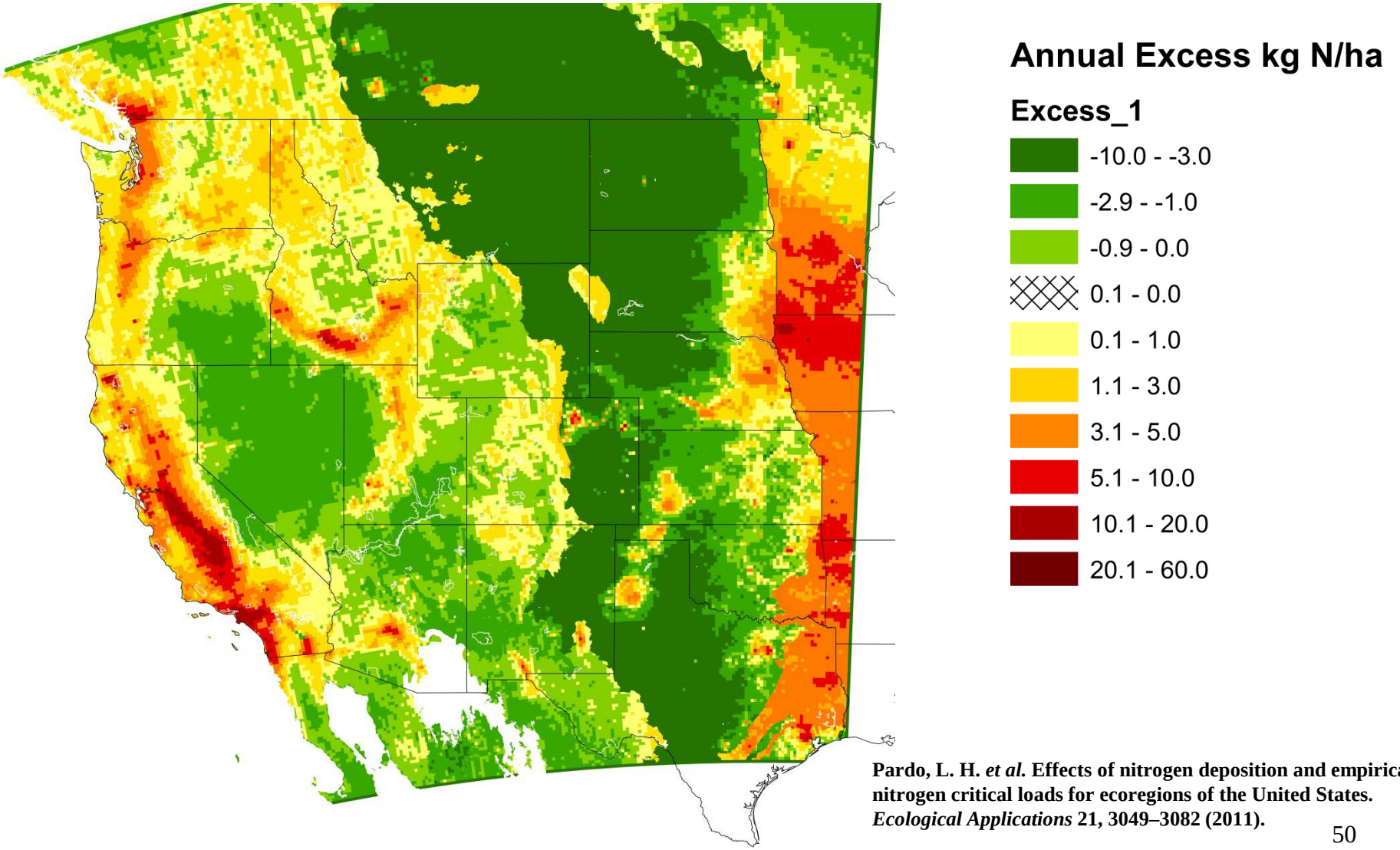
Critical Load by Eco-Region (kg N/ha)



Pardo, L. H. *et al.* Effects of nitrogen deposition and empirical nitrogen critical loads for ecoregions of the United States. *Ecological Applications* 21, 3049–3082 (2011).

Nitrogen Deposition Excess

Total Modeled Nitrogen Wet & Dry Deposition (all species) - Critical Load



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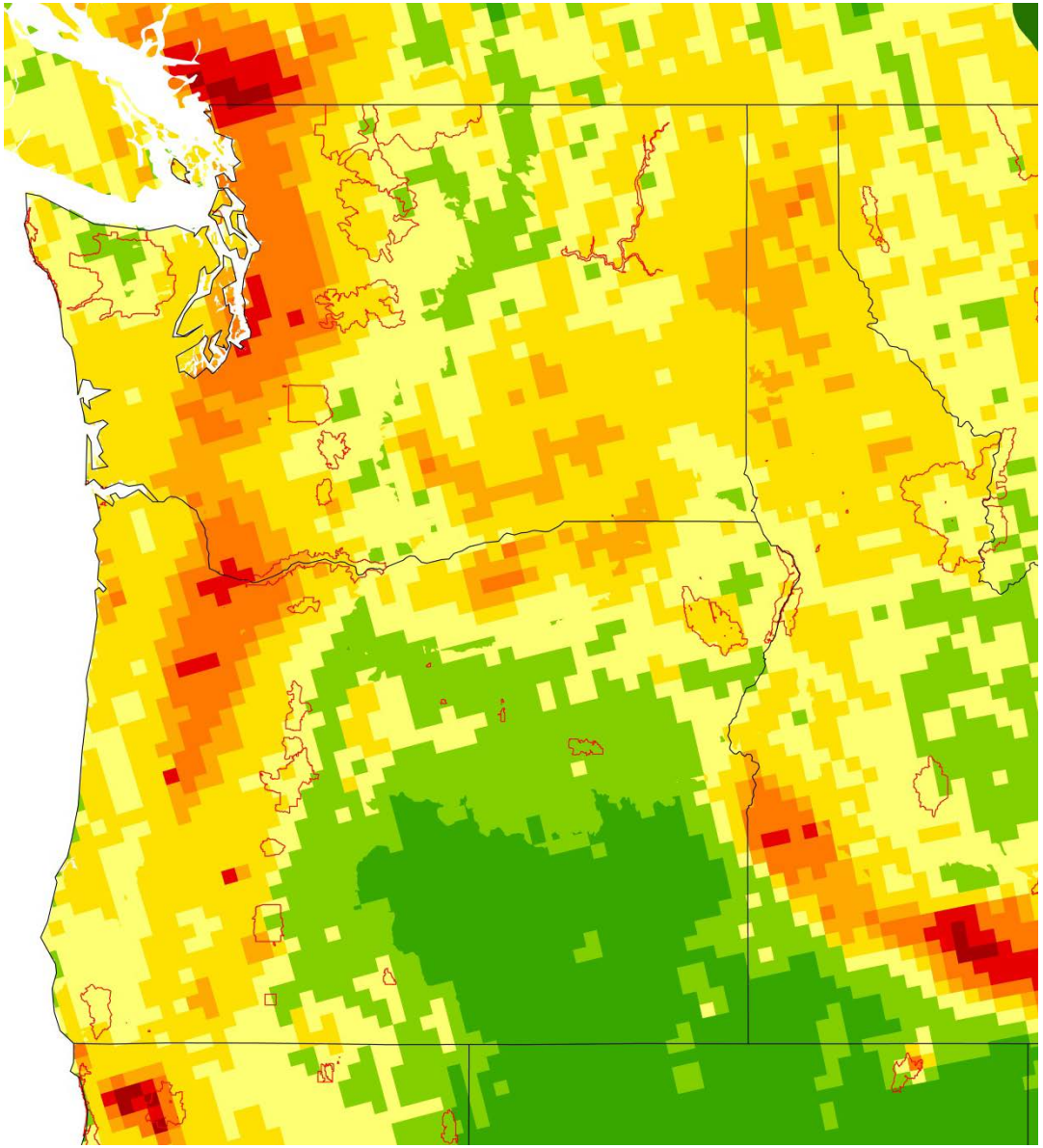


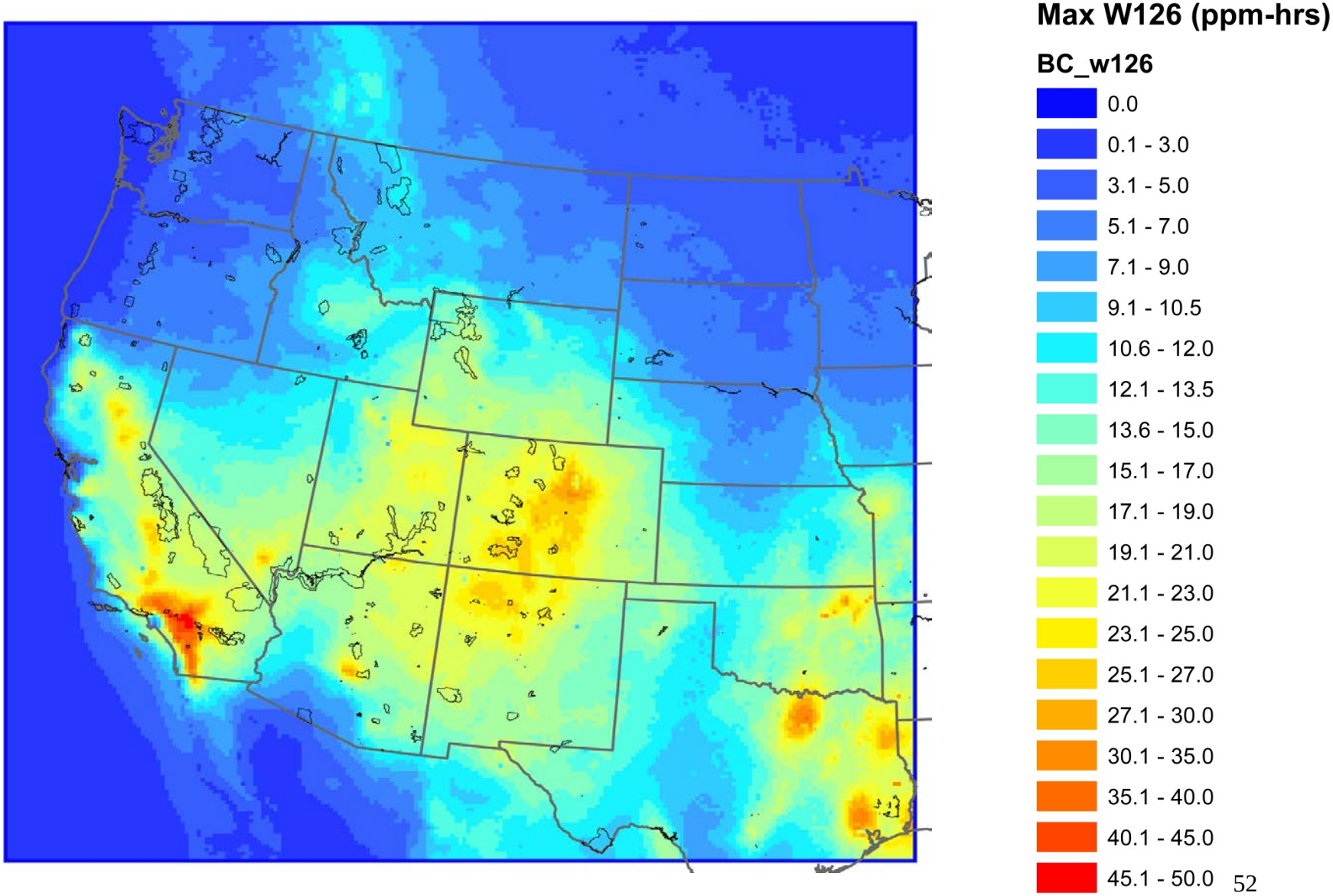
Annual Excess kg N/ha

Excess_1

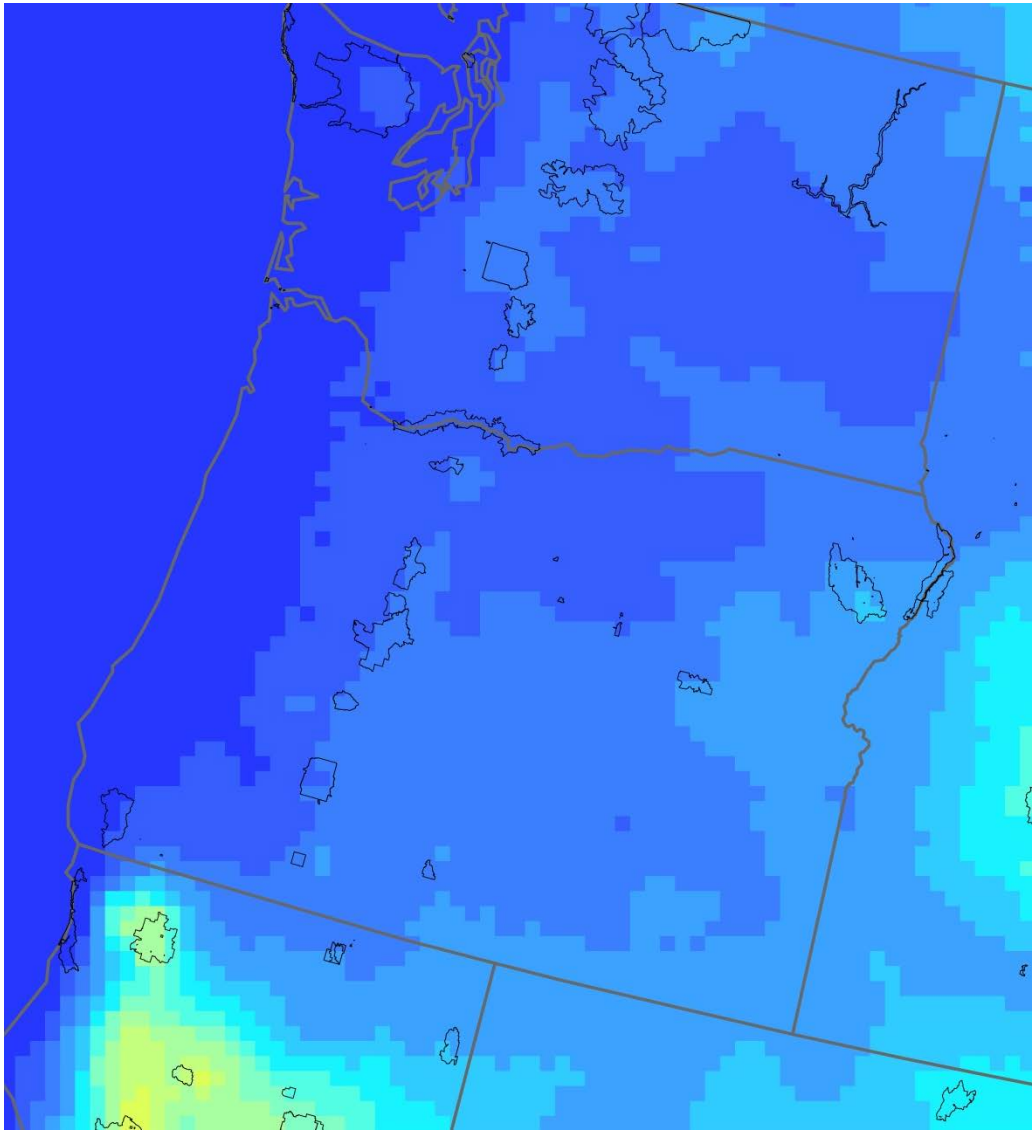
- -10.0 - -3.0
- -2.9 - -1.0
- -0.9 - 0.0
- 0.1 - 0.0
- 0.1 - 1.0
- 1.1 - 3.0
- 3.1 - 5.0
- 5.1 - 10.0
- 10.1 - 20.0
- 20.1 - 60.0

Pardo, L. H. *et al.* Effects of nitrogen deposition and empirical nitrogen critical loads for ecoregions of the United States. *Ecological Applications* 21, 3049–3082 (2011).

WestJumpAQMS Maximum Ozone Season W126 (ppm-hrs)



WestJumpAQMS Maximum Ozone Season W126 (ppm-hrs)

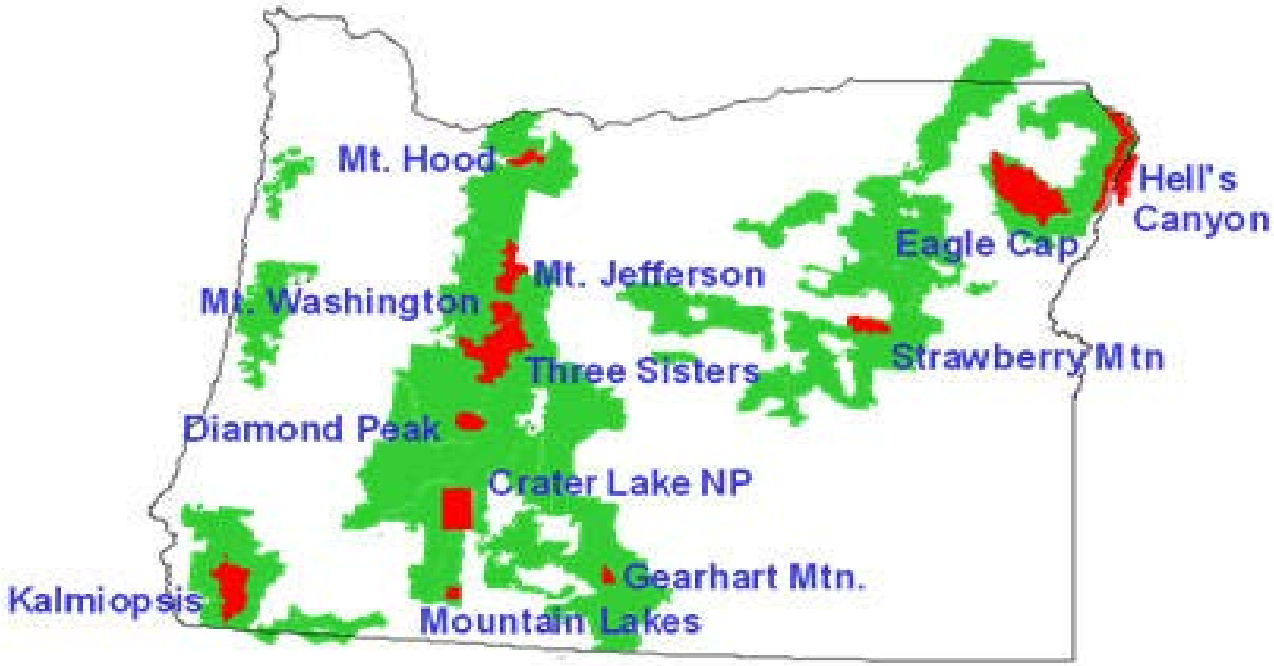


Max W126 (ppm-hrs)

BC_w126

- 0.0
- 0.1 - 3.0
- 3.1 - 5.0
- 5.1 - 7.0
- 7.1 - 9.0
- 9.1 - 10.5
- 10.6 - 12.0
- 12.1 - 13.5
- 13.6 - 15.0
- 15.1 - 17.0
- 17.1 - 19.0
- 19.1 - 21.0
- 21.1 - 23.0
- 23.1 - 25.0
- 25.1 - 27.0
- 27.1 - 30.0
- 30.1 - 35.0
- 35.1 - 40.0
- 40.1 - 45.0
- 45.1 - 50.0

Oregon Class I Areas



Oregon progress report is due to EPA by …?

Next regional haze full control SIP due July 2018

WestJumpAQMS modeling is the starting point for 2011 or 2014 base year, 2018 progress check, and 2028 projection modeling.

WestJumpAQMS Benefited From

- WRAP Regional Modeling Center (2002 Platform)
- Four Corners Air Quality Task Force (2005 Platform)
- Continental Divide-Creston EIS (2005/2006 Platform)
  - NEPA O&G EIS using PGM for far-field AQ/AQRV
- Denver Ozone SIP Modeling and Follow-On
- 2008 National Emissions Inventory (2008 NEIv2.0)
  - Cornerstone to 2008 emissions
- WRAP Phase III O&G Emissions Study
  - Projected to 2008 plus add Permian Basin
- WESTAR-funded MEGAN Biogenic Emissions Enhancement Study
- DEASCO$_3$ 2008 Fire Emissions

Benefited from WestJumpAQMS

- Colorado Air Resource Management Study (CARMMS)
  - 2008 4 km Modeling Platform
- Deterministic & Empirical Assessment of Smoke's Contribution to Ozone (DEASCO$_3$)
  - 2008 36/12 km Modeling Platform
- PMDETAIL -- Smoke contributions to PM
- Three-State Data Warehouse (3SDW) and Three-State Air Quality Study (3SAQS)
  - 2008 36/12/4 km Modeling Platform; Test database for 3SDW
- Additional Follow-On Studies
  - NPS, BLM, etc.

Thanks –

Tom Moore, WRAP Air Quality Program Manager
Western States Air Resources Council (WESTAR)

e: tmoore@westar.org | o: 970.491.8837

Western Regional Air Partnership | www.wrapair2.org