Western U.S. Regional Ozone Modeling

EPRI ENV-Vision Conference
Washington, DC
May 11, 2016

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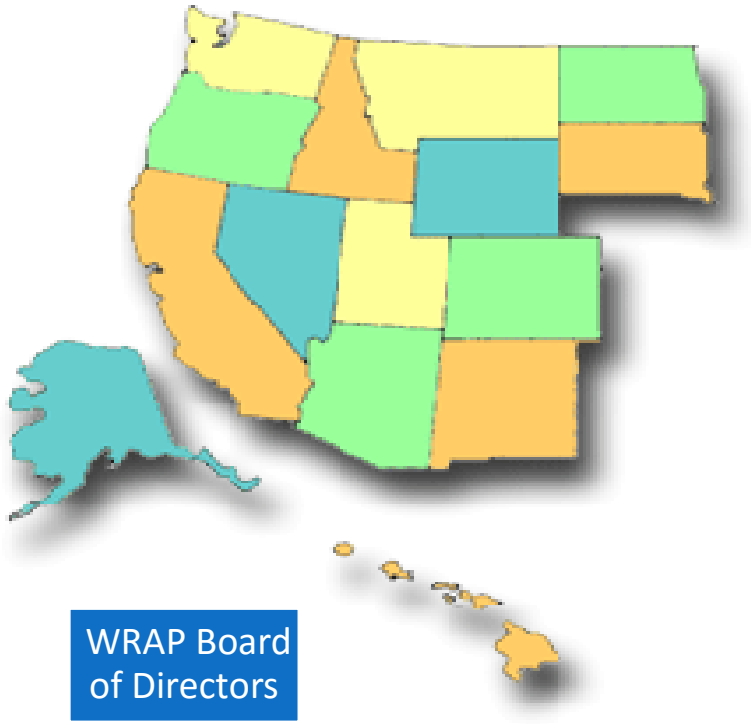
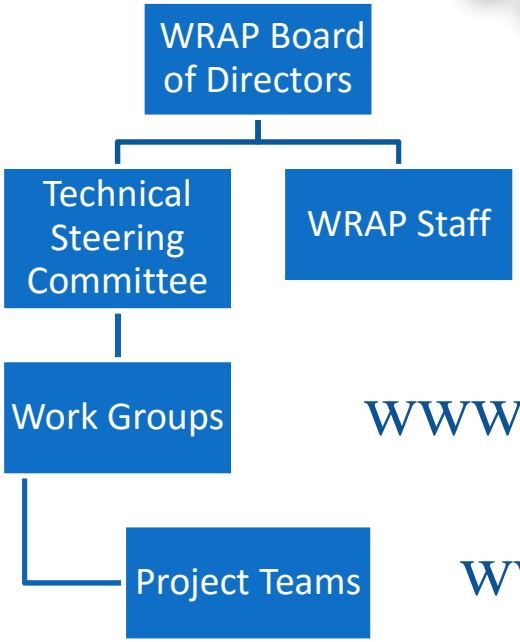
WESTAR Council

WESTAR-WRAP





www.westar.org

www.wrapair2.org

NAAQS Implementation and Maintenance

- Data for future infrastructure and transport SIPs

Exceptional Events

- Develop technical support data and analysis protocols

Implementation of Regional Haze SIPs

- Identify and execute technical work needed for 20~~18~~21 plans

Needs of sub-regional groups of states

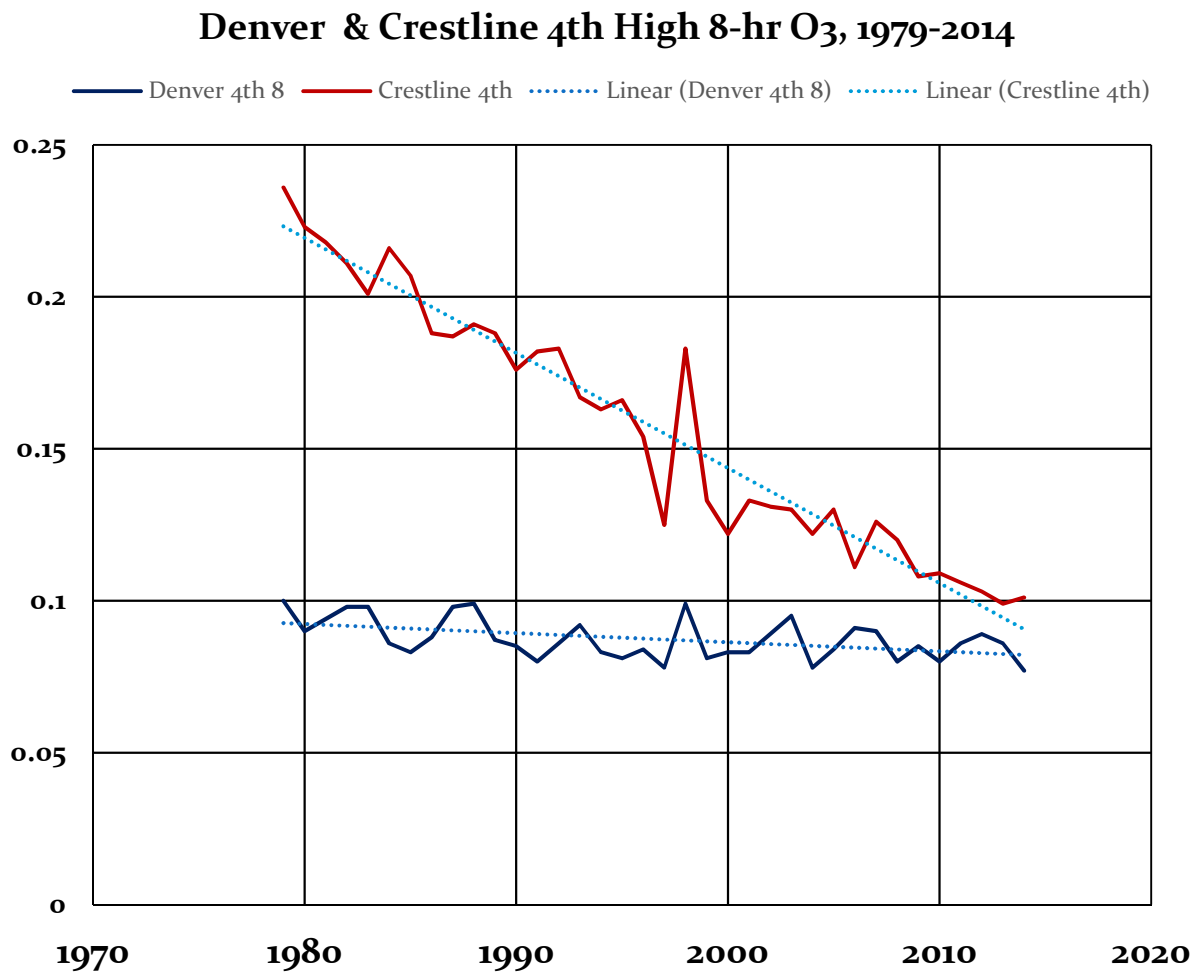
- Currently oil and gas, fire
- Similar efforts in past – dust, BART, other topics

O3 trends at high elevation sites in Western U.S.

Flat O3 trend in Denver

Need to understand roles of:

- International and interstate transport
- Wildfires
- Stratospheric O3
- Population growth
- Oil and gas development
- Seasonal variation



Sources of O_3 in the Western U.S.

O_3 Source	Meteorological Characteristics	Chemical characteristics	CAA Controllable
Local photochemical buildup	Stagnation, high temperatures.	CO/NOx/VOCs/PM consistent with local sources	Y
Regional transport (domestic sources)	Regional transport from major source regions (e.g., California) - currently not well characterized	CO/NOy/VOCs consistent with upwind sources + chemistry	Y
Upper trop/Lower strat intrusions (UTLS)	Post-cold front Broad spatial distribution (high O_3 in non-urban areas)	Very dry air.	N
Very long-range transport (VLRT)	Important at higher elevation. Subsidence and mixing into the boundary layer can enhance local concentrations.	Dry. Can be hard to distinguish from UTLS without good chemical data.	N
Wildfire smoke	Warm. Can be stagnant or not. Can be regional or large distant fires.	Chemistry complex & different from typical urban. O_3 enhancements not always seen. O_3-PM often poorly correlated. PM/CO/NOy always well correlated and ratios very different from typical urban.	N

Data Warehouse and Modeling Center
http://views.cira.colostate.edu/tsdw/

Background / Boundary Conditions evaluations:

MOZART
GEOS-Chem
(now adding AM3)

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Observations vs. Boundary Condition / Background Monthly Mean MDA8 Ozone

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Animations of Modeled Daily Max Concentrations

Background contribution
Difference plots for background minus U.S. sources

O3, NO_x, CO, $PM_{2.5}$

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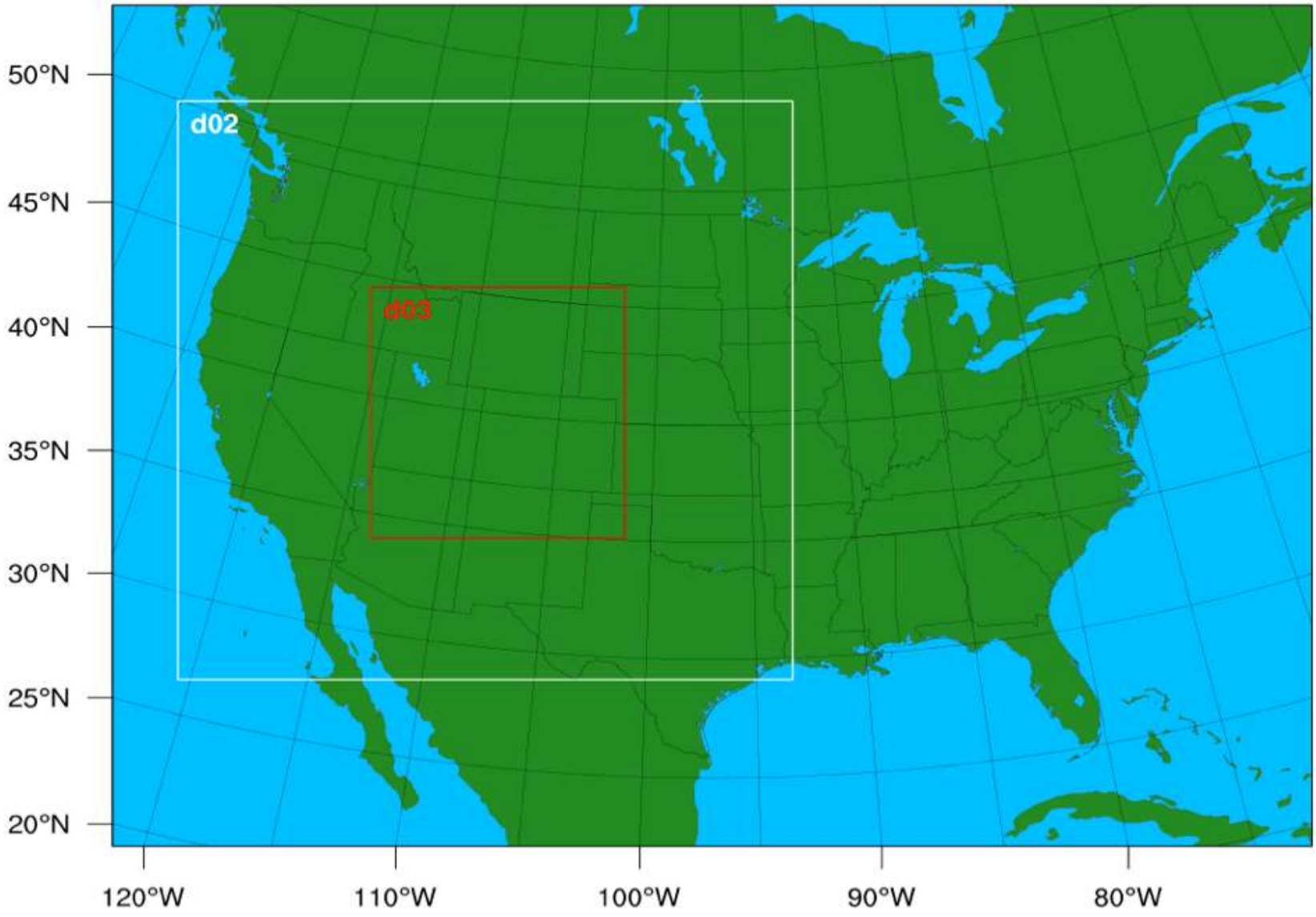
Animations of Daily Max Concentrations for O3 and Dust Boundary Tracers

Boundary conditions plots:

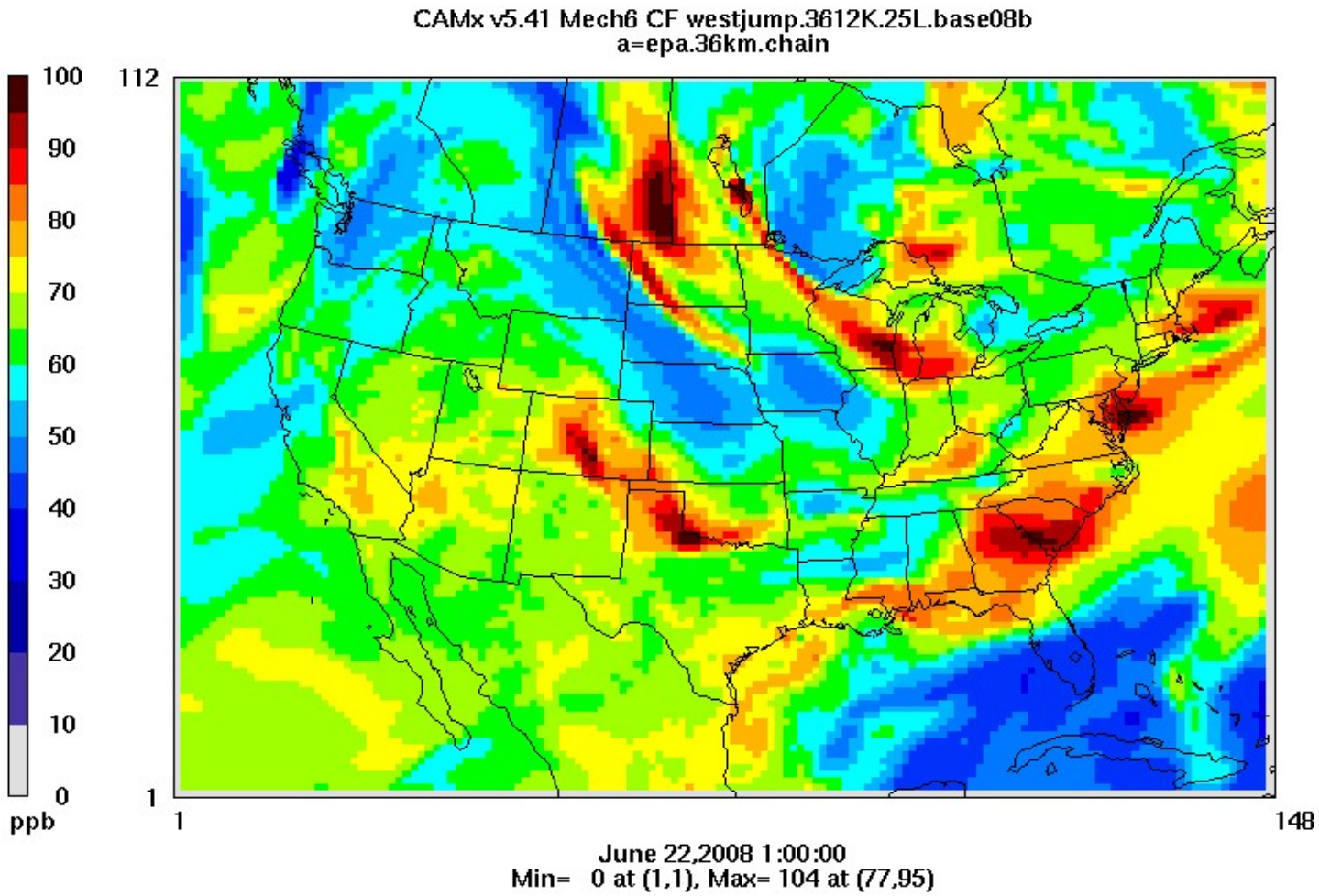
O3, Ox (O3+NO+NO2+PAN)
Coarse Dust (CCRS), Fine PM (FPRM+FCRS)

IWDW-WAQS nested 36/12/4-km WRF/CAMx and CMAQ domains



O3 in upper free troposphere is determined primarily by transport from boundaries

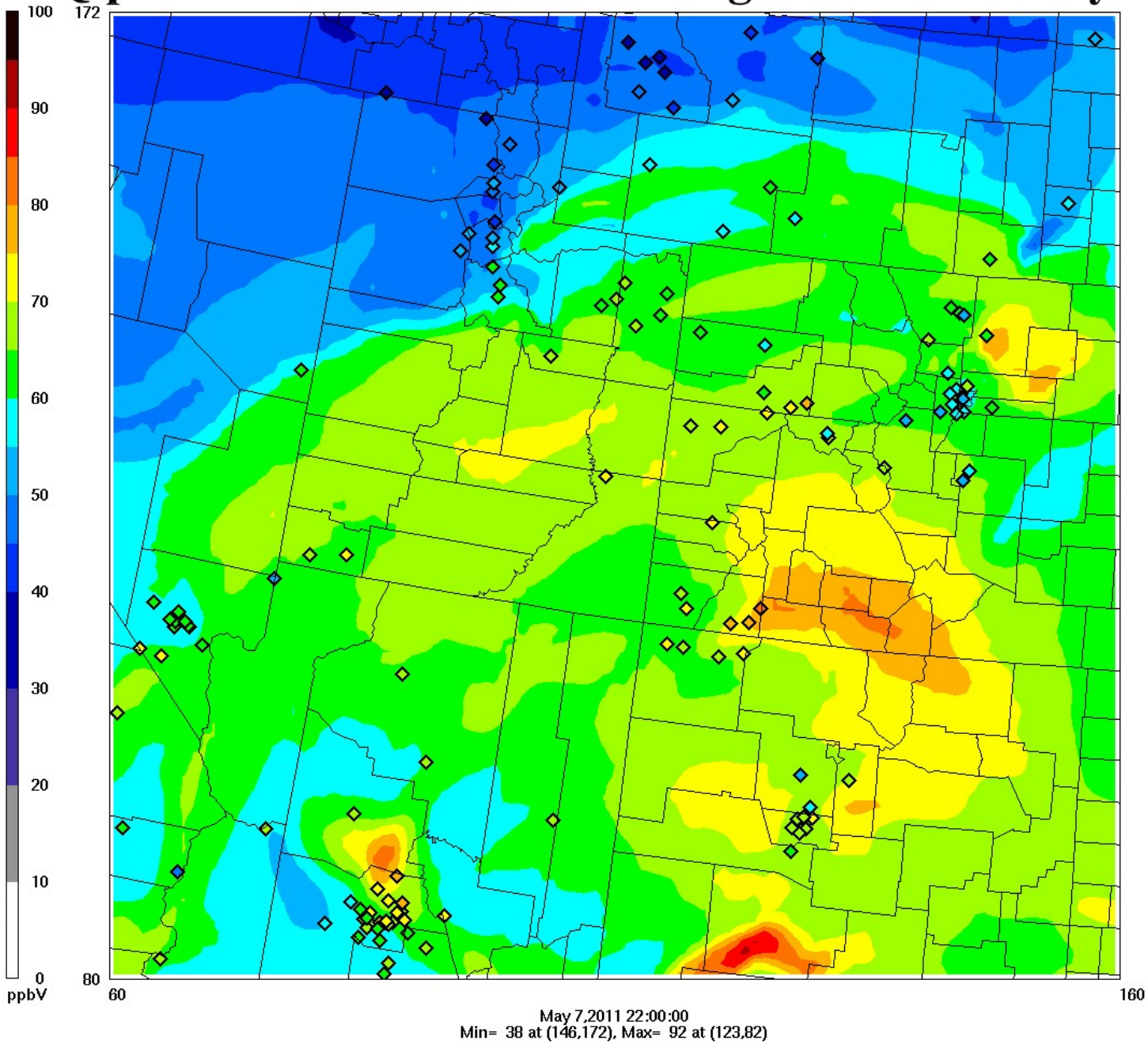
O3 animation in Layer 21 (6-7 km) 6/22-7/4/2008



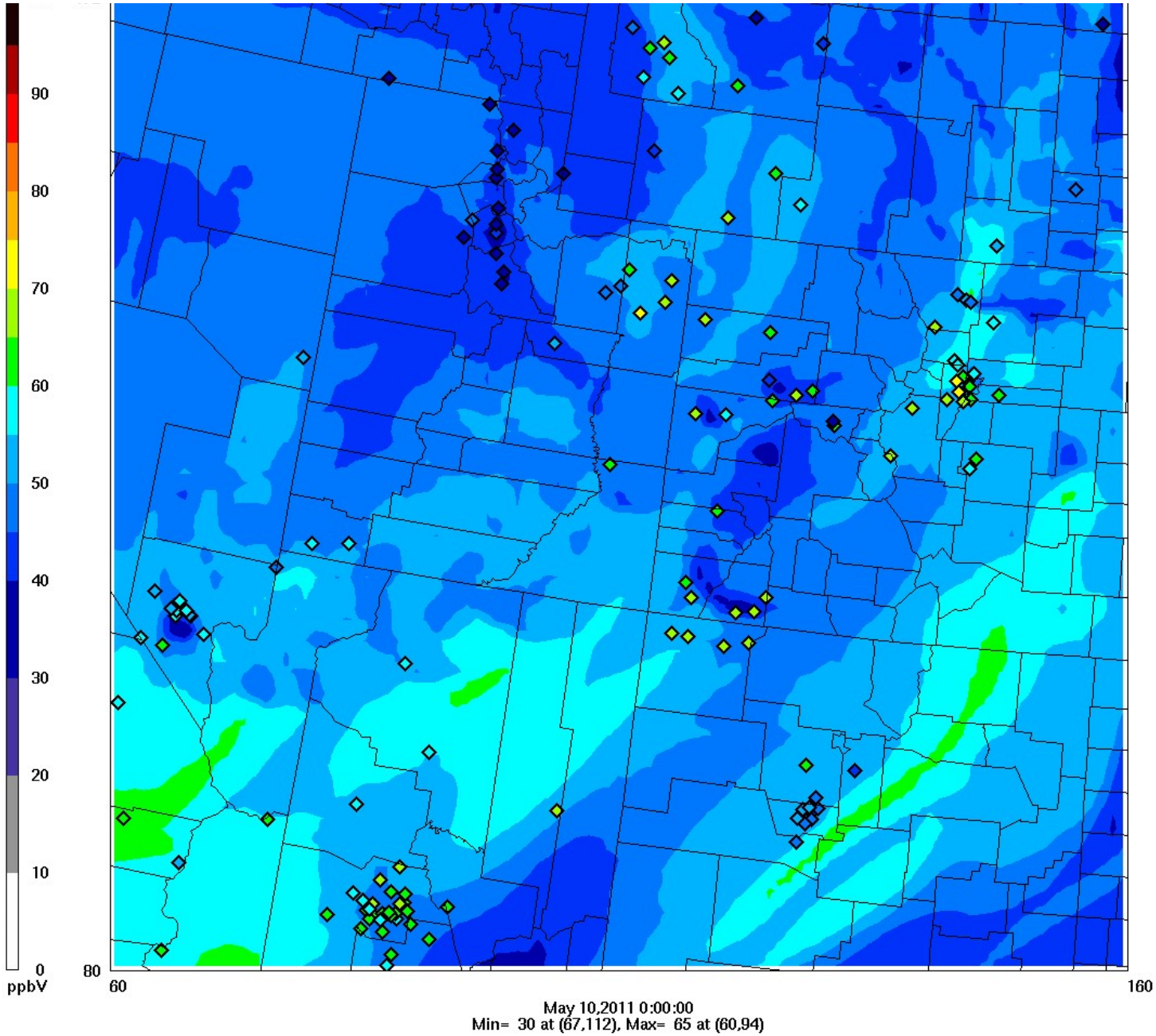
Case Study
Preliminary results from 2011 CMAQ Modeling

- BC data derived from GEOS-Chem.
- Ran both CAMx and CMAQ
- Larger set of rural O3 data available in 2011 from the IWDW-WAQS air quality study.
- What can we learn from spatial patterns of model performance for hourly O3 data?
- How do these results inform the discussion of needs for additional monitoring and modeling work?

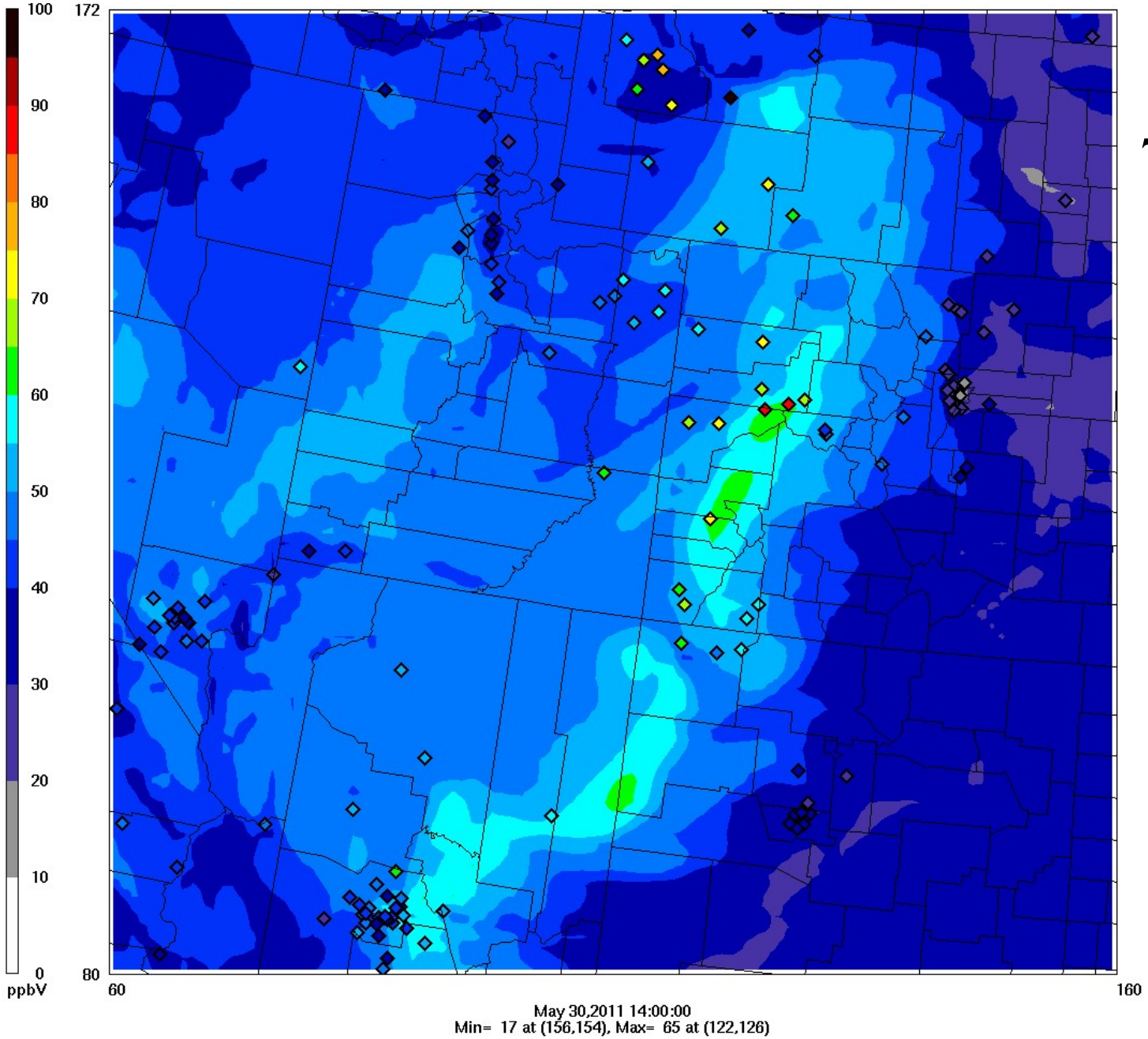
CMAQ performs well for elevated regional O3 on May 7, 3 pm



CMAQ biased low for elevated regional O3 on May 9, 5 pm LDT

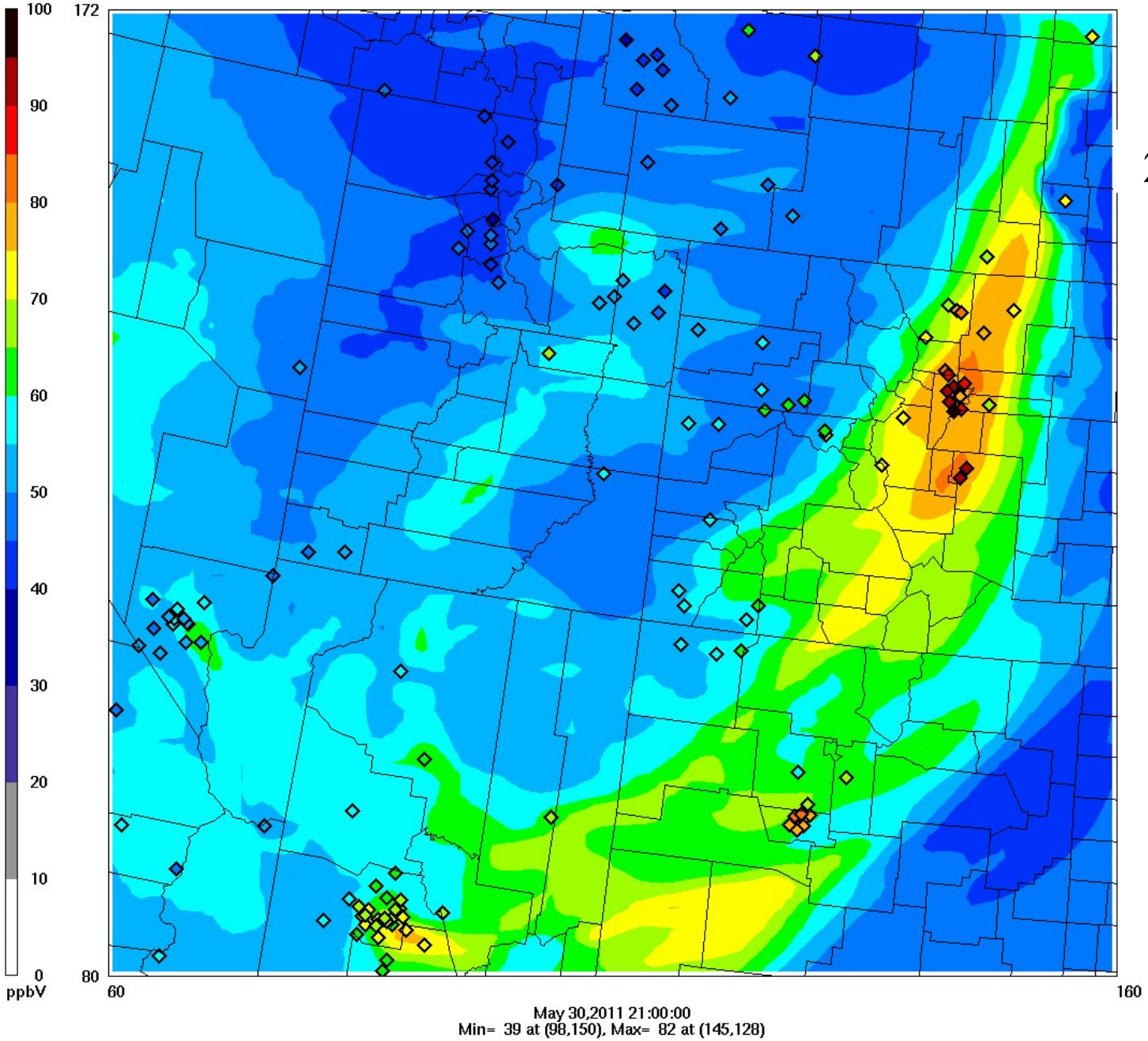


CMAQ biased low in morning at rural sites on May 30



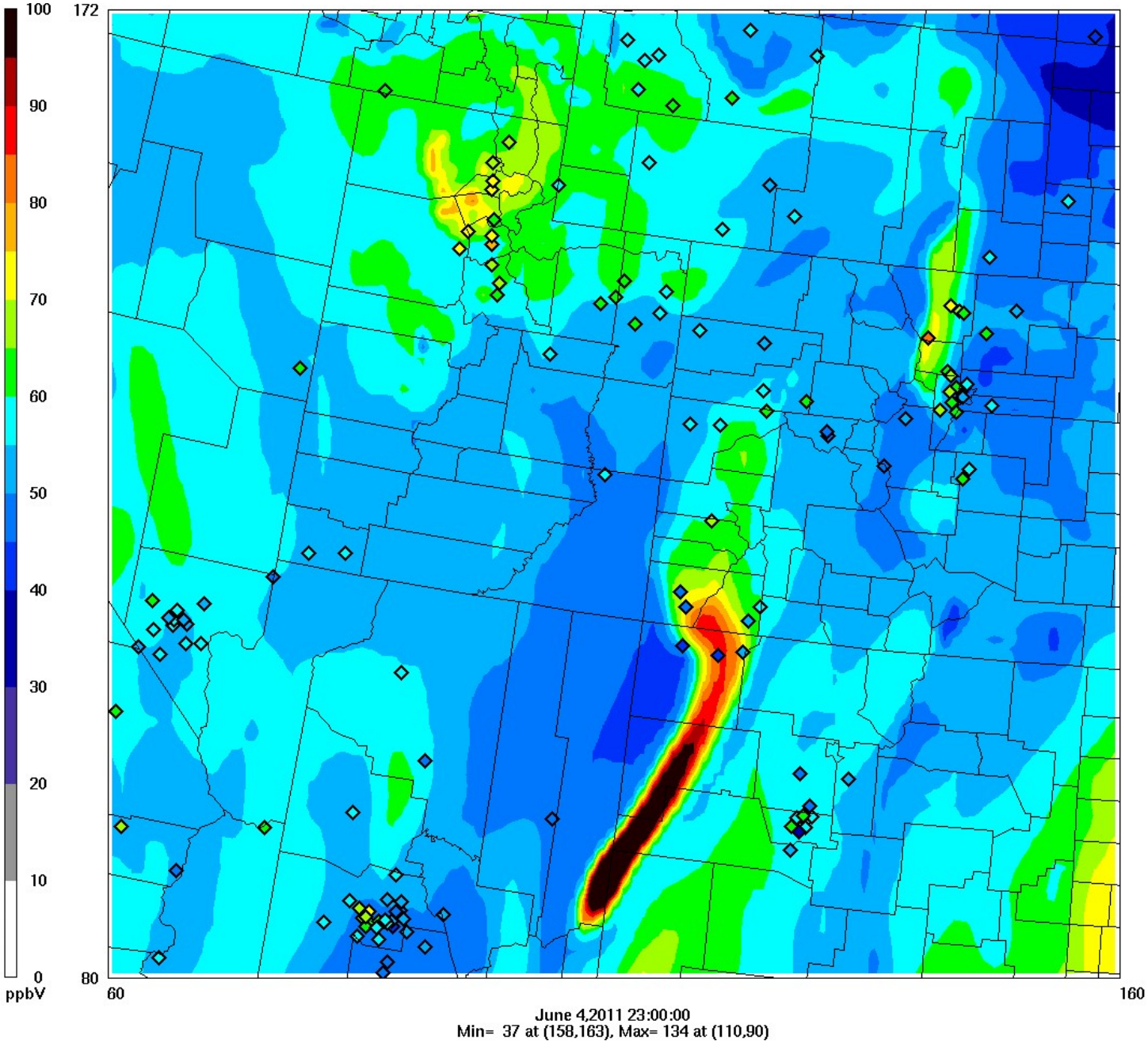
7 am LDT

CMAQ matches the regional high O3 on May 30, low bias at urban sites



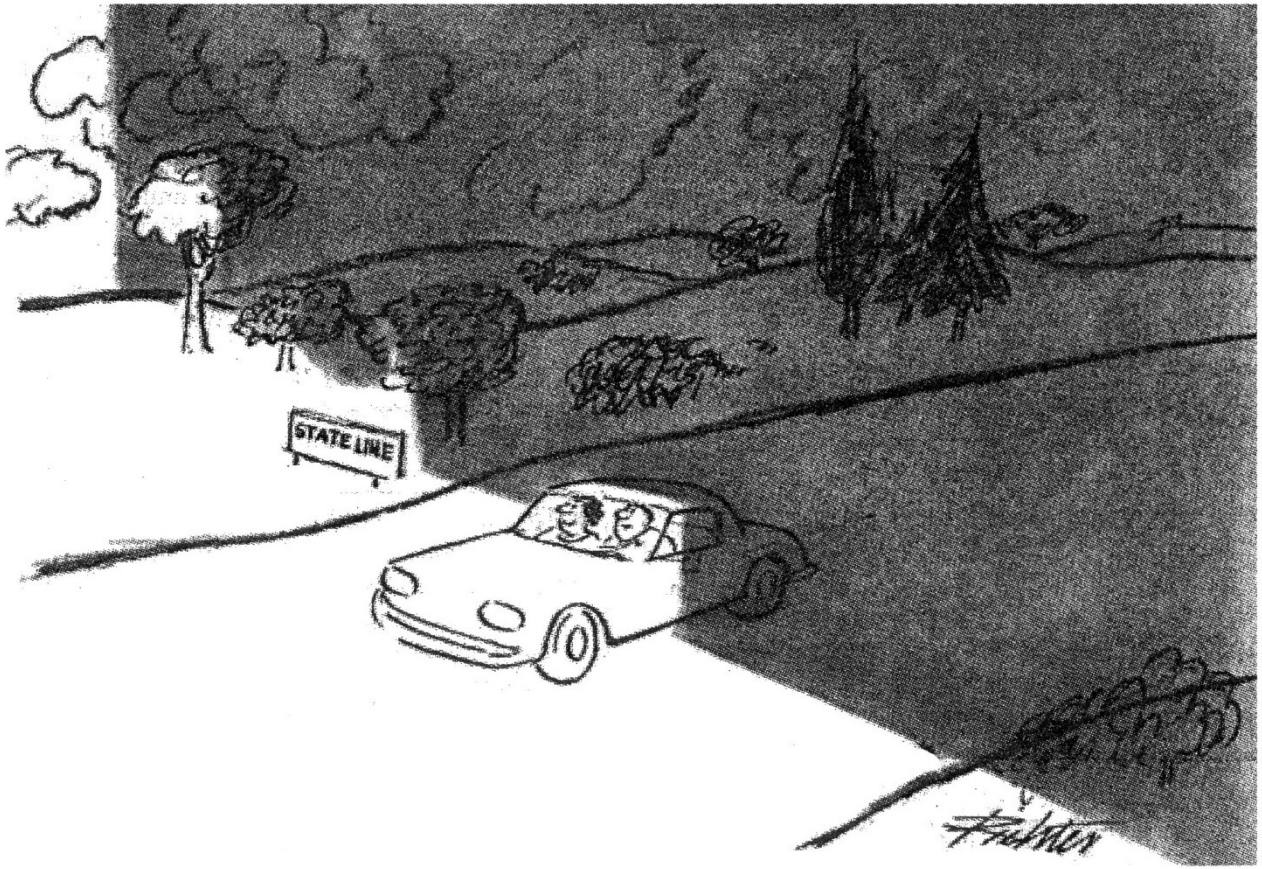
2 pm LDT

CMAQ biased high for wildfire O3 in June



Strategies for Improving the State of the Science for modeling O3 in the western U.S.

- More monitoring data to improve characterization of background O_3 and to evaluate the accuracy of model-based estimates of USB:
  - More measurements to improve characterization of vertical O_3 profiles.
  - Network of O_3 LIDAR vertical profiles (NASA TOLNET pilot study)
  - More ground based O_3 and precursor measurements in rural areas.
- Perform comprehensive model evaluation studies using new monitoring data to assess contributions to background O_3.
  - Do global models accurately estimate BC inflow?
  - Do regional models accurately simulate natural sources of O_3 from wildfires and biogenic precursors?
  - Do regional models accurately simulate vertical mixing of O_3?
  - ***Need improved projections of future emissions for uncontrollable sources as well as trends in global O3***.
- Increase state/federal & planner/researcher collaborations to improve modeling and data analysis for O3 transport, wildfires, and stratospheric intrusion.



"They have very strict anti-pollution laws in this state."

Five Ozone Planning Needs – western U.S.

1. Ozone NAAQS planning – (realistically) requires photochemical modeling for SIP attainment demonstrations for nonattainment areas.
2. Ozone transport SIPs – photochemical source apportionment modeling is tool of choice to quantify U.S. Ozone background as well as transport between states and jurisdictions.
3. Identification of Ozone exceptional events caused by stratospheric intrusion and wildfires – can require variety of observations & data analysis, supplemented with global / regional scale photochemical models and regression models.
4. Identification of international transport of Ozone for §179B demonstrations: requires nested global and regional scale photochemical modeling to evaluate international transport of Ozone.
5. Identification of §182 Rural Transport Areas – combination of data analysis and photochemical modeling.

In the West under CAA, whom to do which ?

Alone or together ?

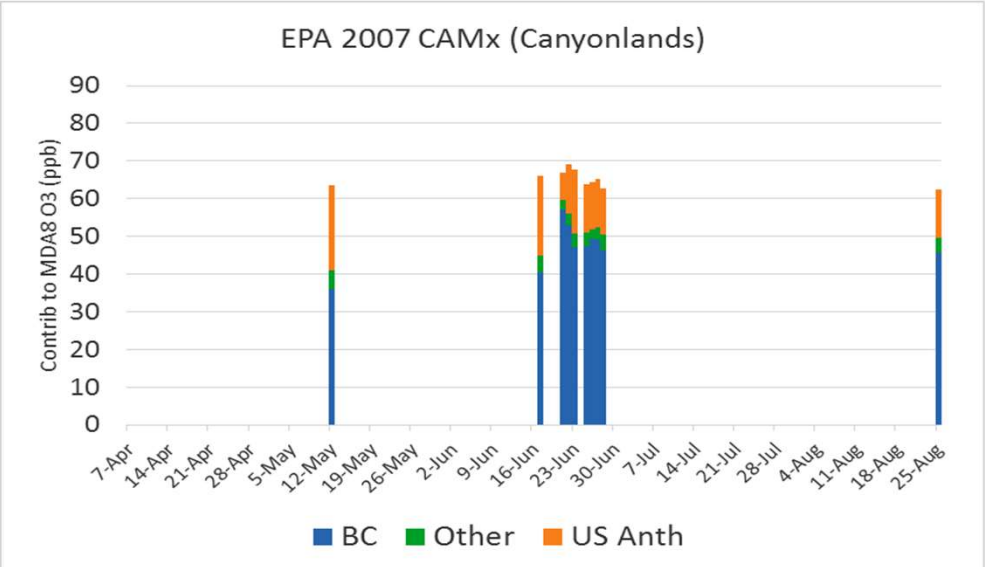
- States/Locals

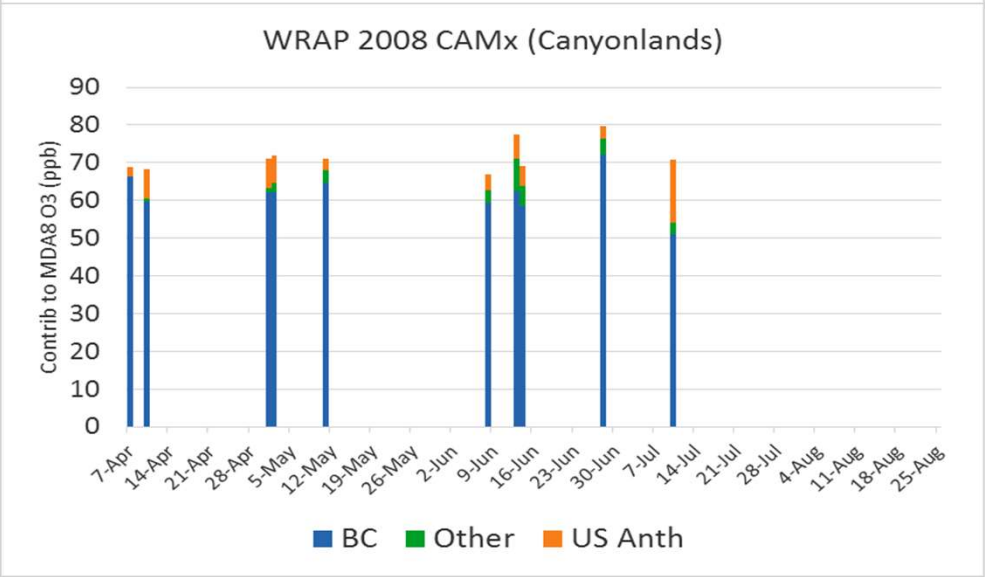
- Regional

- Federal

Uncertainty in model estimates of U.S. Background

CAMx simulations for 2007 and 2008 at Canyonlands National Park – Eastern UT



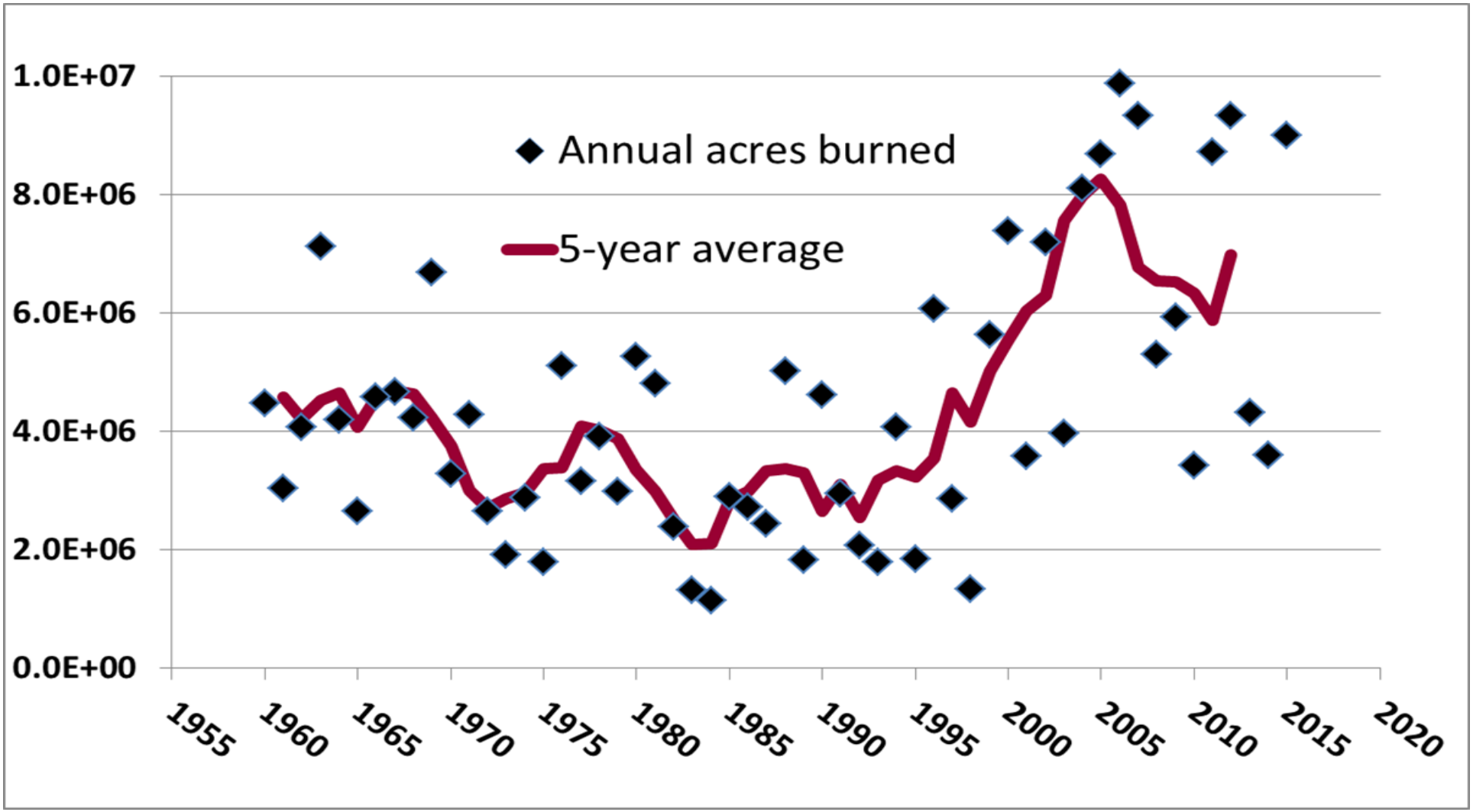


EPA 2007 CAMx model platform: Background contributions of 36-57 ppb; still substantial U.S. anthropogenic contribution to ozone.

WRAP WestJumpAQMS 2008 CAMx model platform: Background contributions of 50-72 ppb, much larger than OAQPS modeling.

Same methodology - reasons for modeled differences are not fully understood

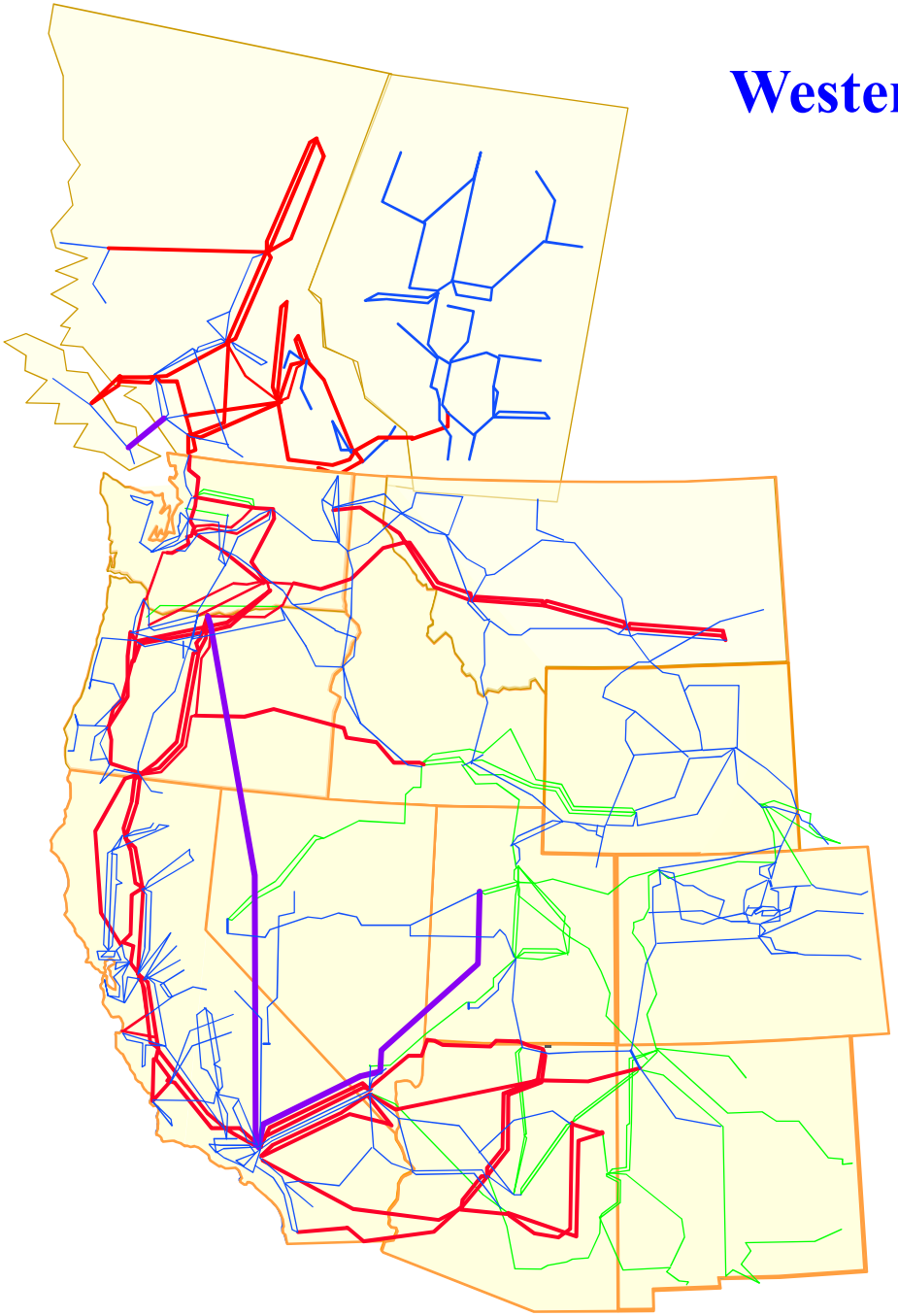
Area Burned for U.S. Wildfires (NIFC)



The last decade has seen a significant increase in the area burned. Approximately 70% of these fires are in the Western U.S.

More than 75% of areas with visibility protection are in the WESTAR-WRAP region

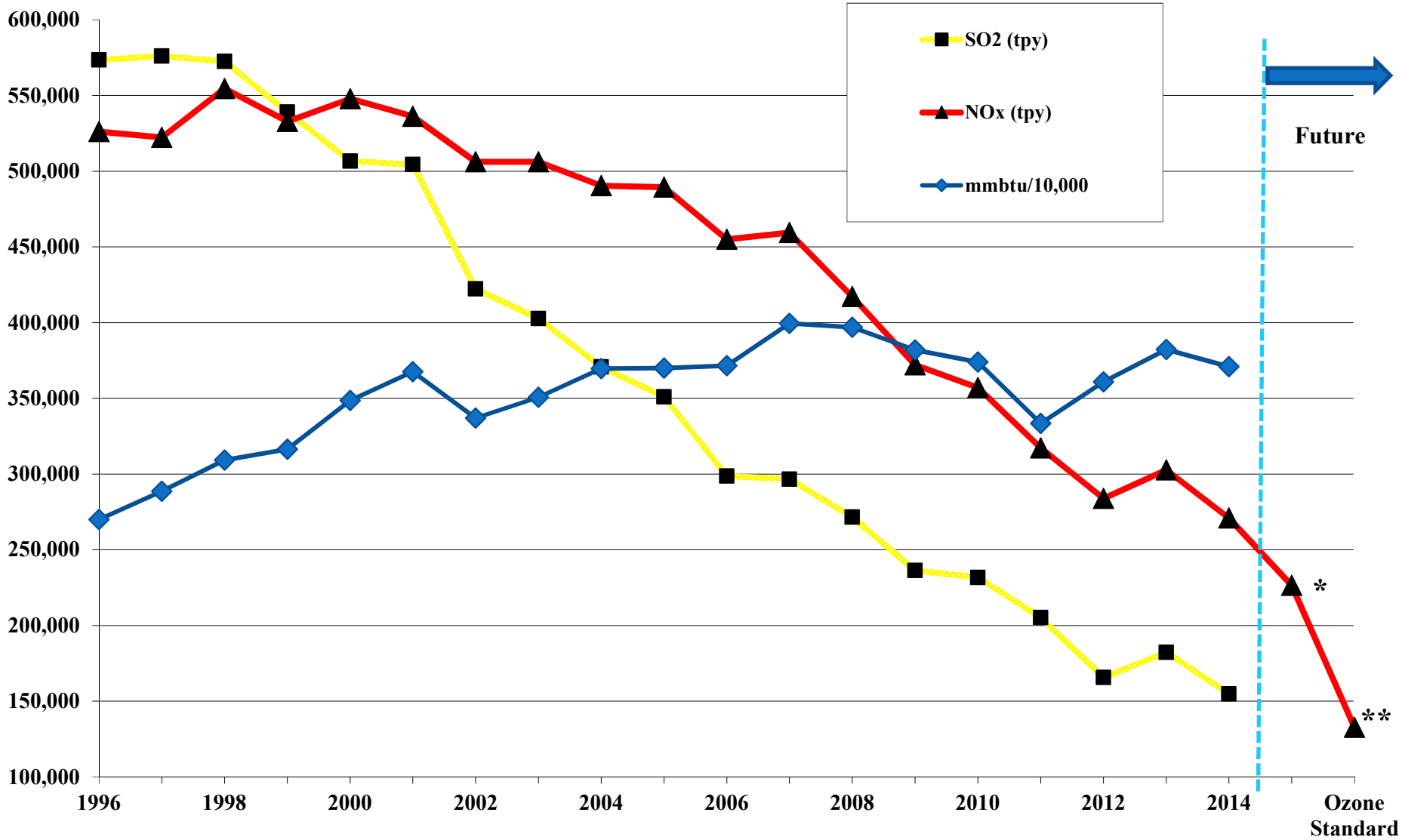
Western Electrical Interconnect



WECC
Existing Transmission System

	230 kV HVAC
	345 kV HVAC
	500 kV HVAC
	± 500 kV HVDC

Western Interconnect Fossil Fuel Power Plant Emissions



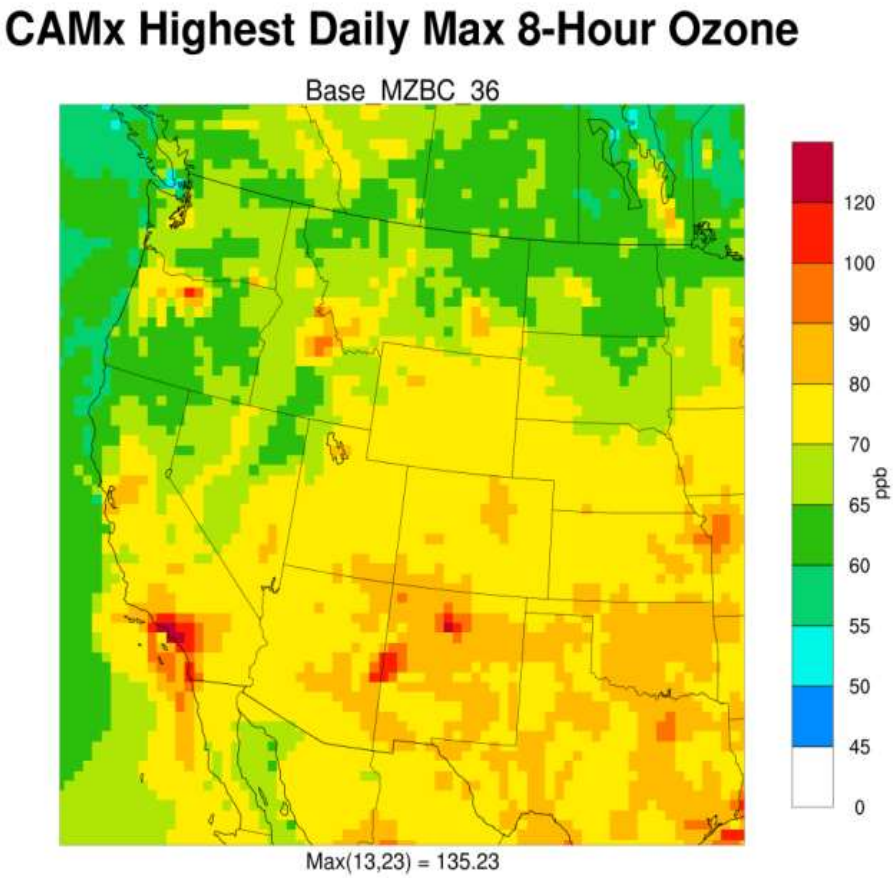
1996 through 2014 data from EPA data for fossil fuel-fired electrical generating units in the 11-state Western Interconnect

* Additional NOx reductions estimate - BART controls from Regional Haze baseline planning

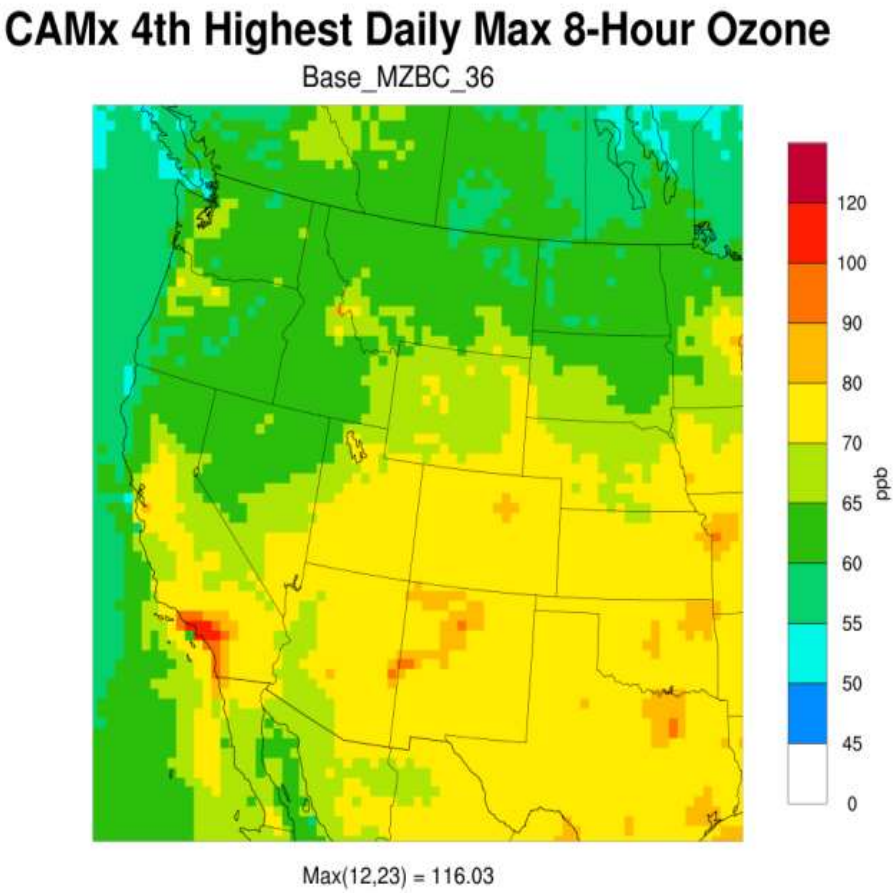
** Further NOx reductions estimate from applying maximum post-combustion controls to all remaining units

IWDW-WAQS 2011b Ozone base case - Mozart global model as BCs

modeled 1st high



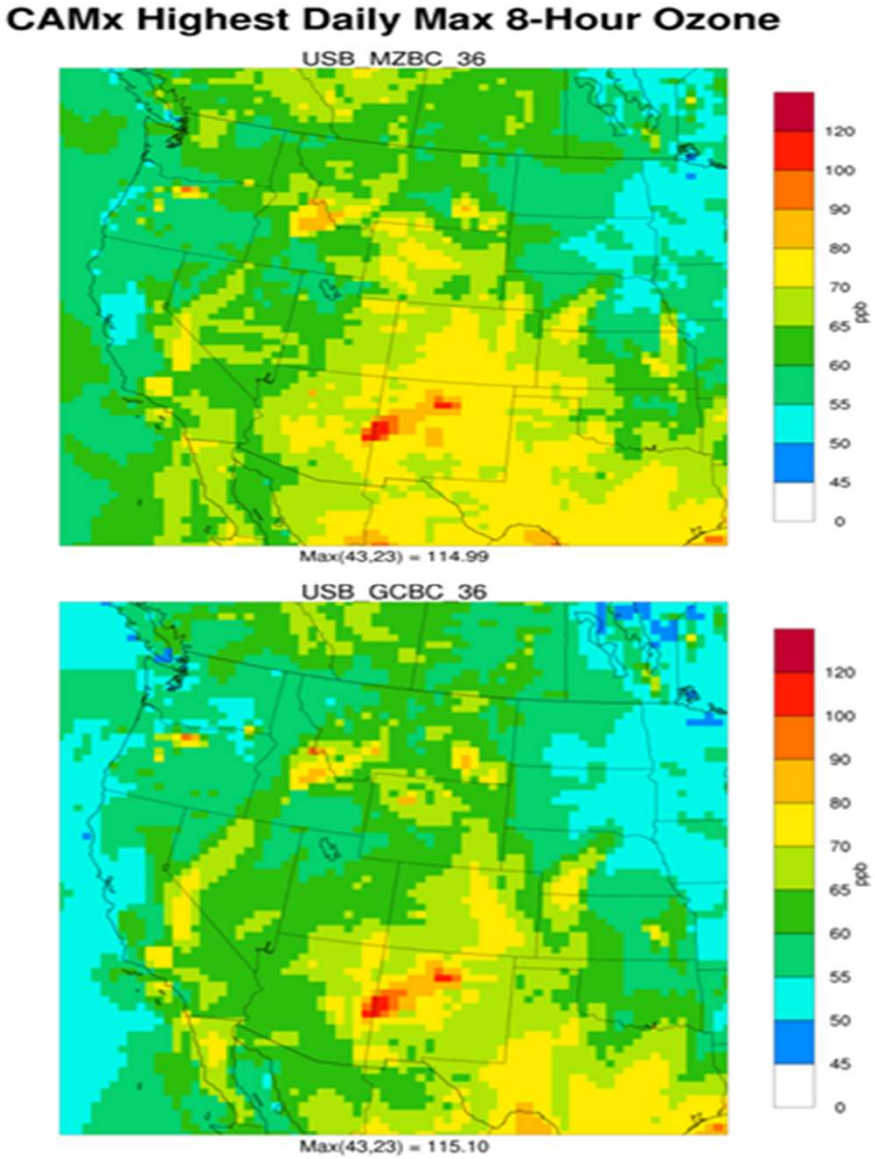
modeled 4th high



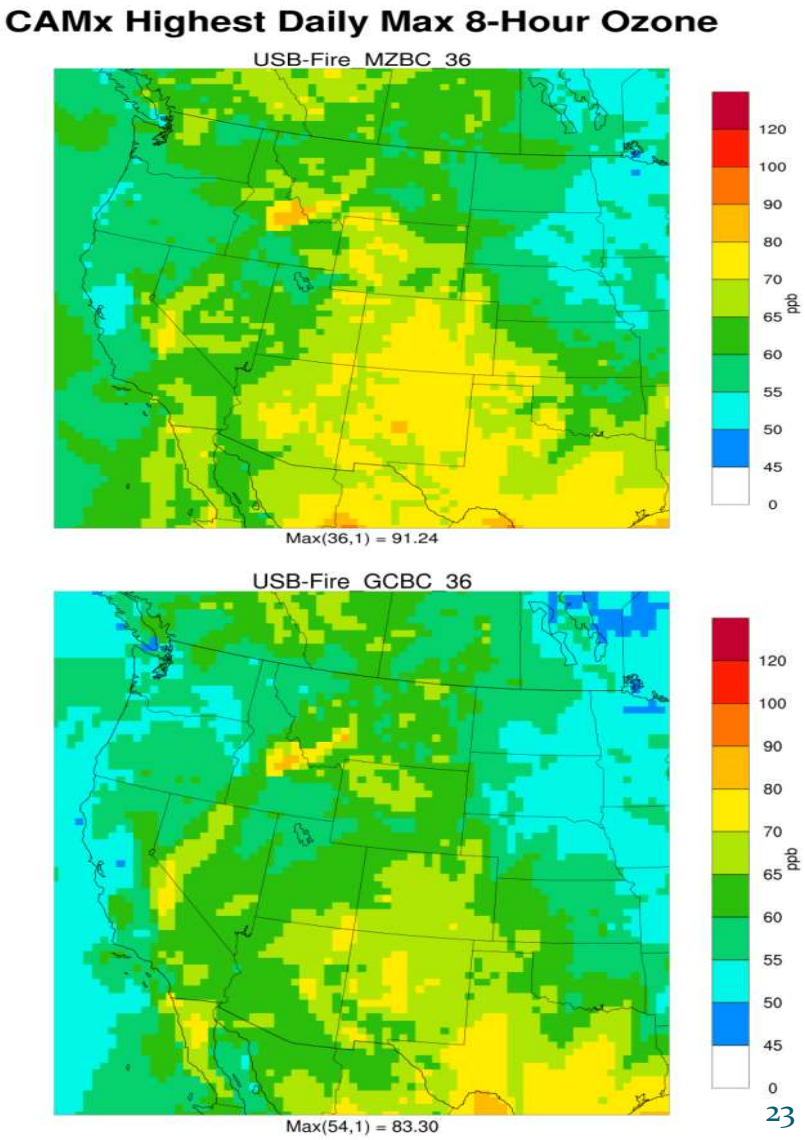
Highest Modeled Ozone Max 2011b platform

Mozart top, GeosCHEM bottom

USB contribution



USB-Fires

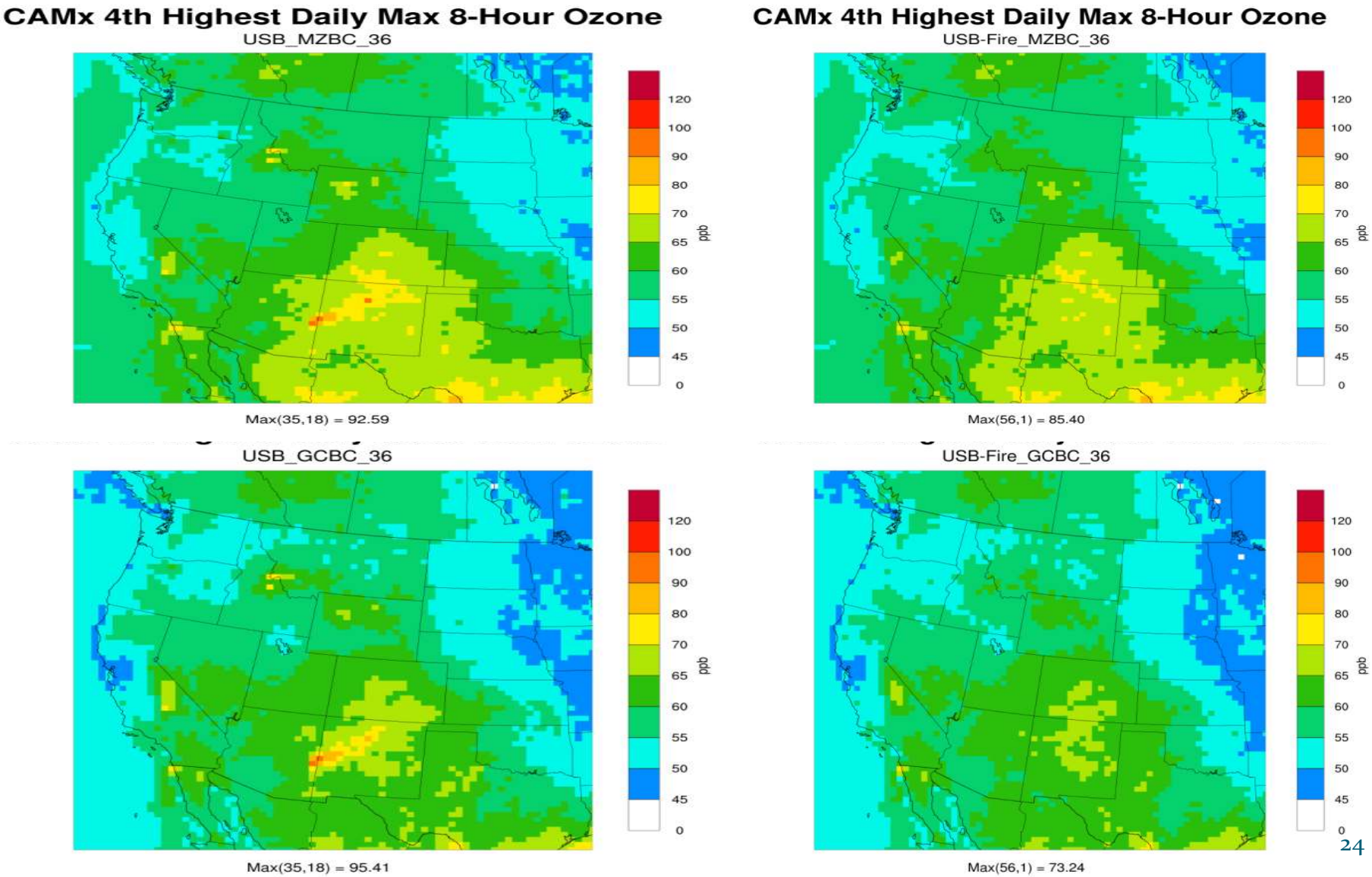


4th Highest Modeled Max 2011b platform

Mozart top, GeosCHEM bottom

USB contribution

USB-Fires



Acknowledgements

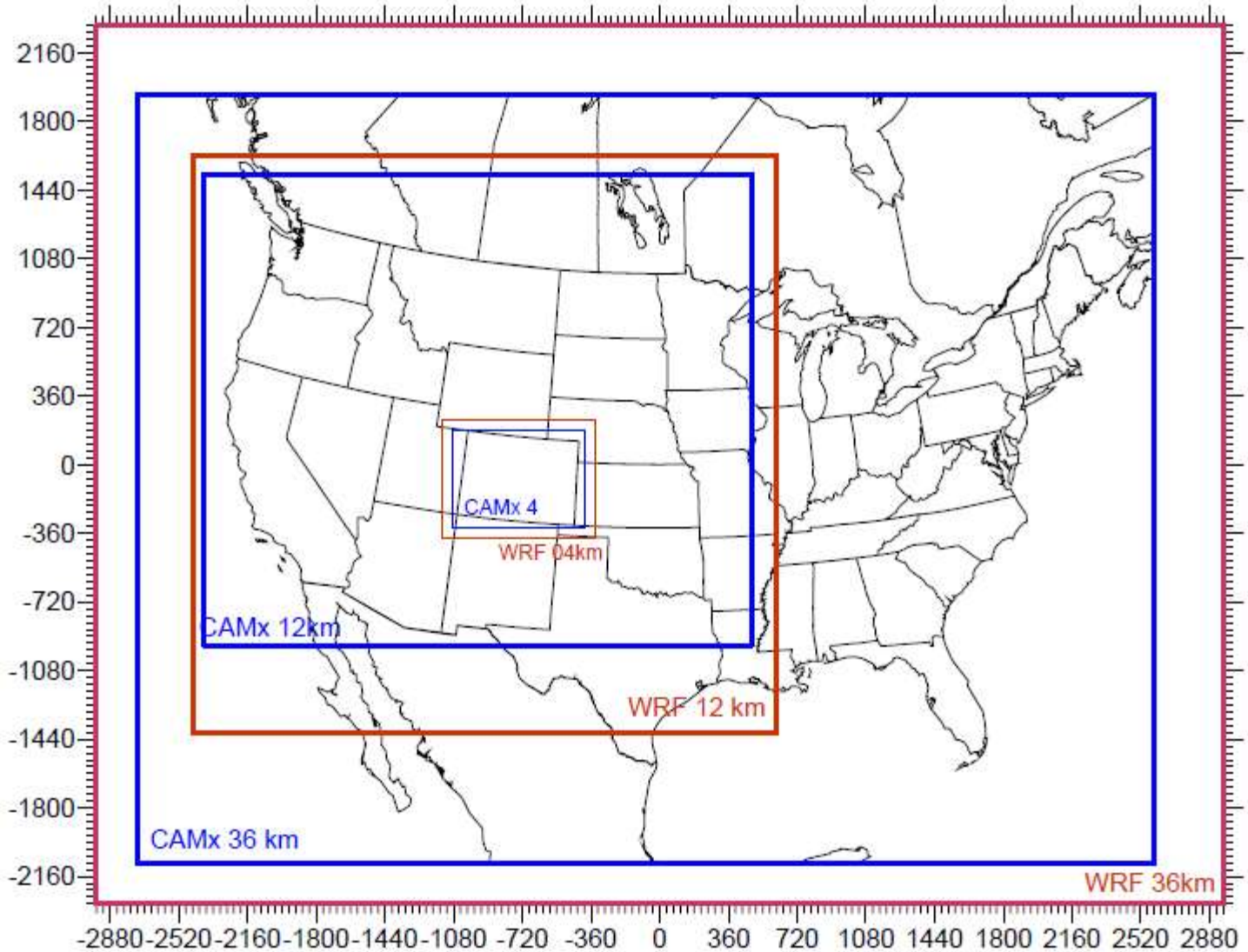
- Ralph Morris and colleagues, Ramboll-Environ
- Zac Adelman and colleagues, UNC
- Gail Tonnesen, EPA R8
- Dan Jaffe, UoW
- State and federal cooperators – IWDW-WAQS

Extra Slides

IWDW-WAQS USB Modeling Simulation Description

- 3 2011b annual USB+Natural sources using just the 36 km CONUS domain. The runs invoke OSAT source apportionment (not APCA) with the following 5 Source Categories:
  - Mexico, Canada and Offshore Shipping (MCO) anthropogenic emissions.
  - Natural emissions (Biogenic, Lightning NOx, SS and WBD)
  - Open Land Fires (combined WF, Rx and Ag fires).
  - Initial Concentrations (IC)
  - Boundary Conditions (BC)
- These 3 use different sets of Boundary Conditions (BCs): MOZART (MZ) with dust cap; GEOS-Chem (GC) and AM3 (AM). Also conducted CAMx 2011b 36 km Base Case (all emissions) and Clean CAMx 36/12 km run using MZBC.
  - Base_MZBC_36 run (no OSAT) performed to run MATS with Clean_MZBC_36 run.
  - Clean_MZBC_3612 run (No OSAT) will be run after the 36 km runs so we can determine the importance of the 12 km WESTUS domain for Clean simulations.
- IWDW-WAQS Round 3 2011 Source Apportionment Modeling Specifications

Nested 36/12/4-km WRF/CAMx Domains

Lateral BC from Global Models

25 CAMx layers from the surface to the lower stratosphere.