

# Comparing estimates of visibility improvement at Class I areas based on IMPROVE data analysis and photochemical model simulations

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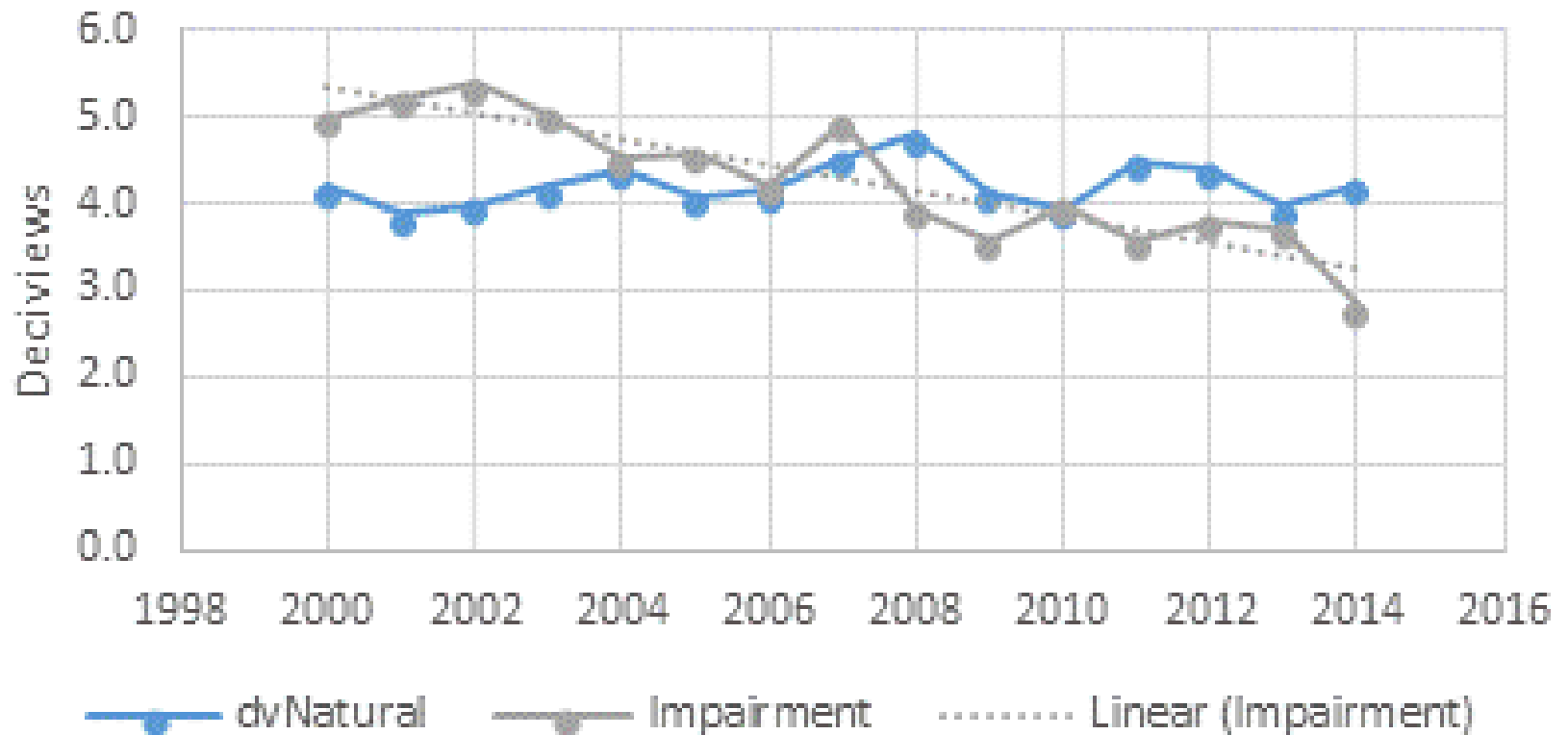
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Jackson Hole WY

# Regional Haze Rule Proposed New Procedures for Tracking Visibility

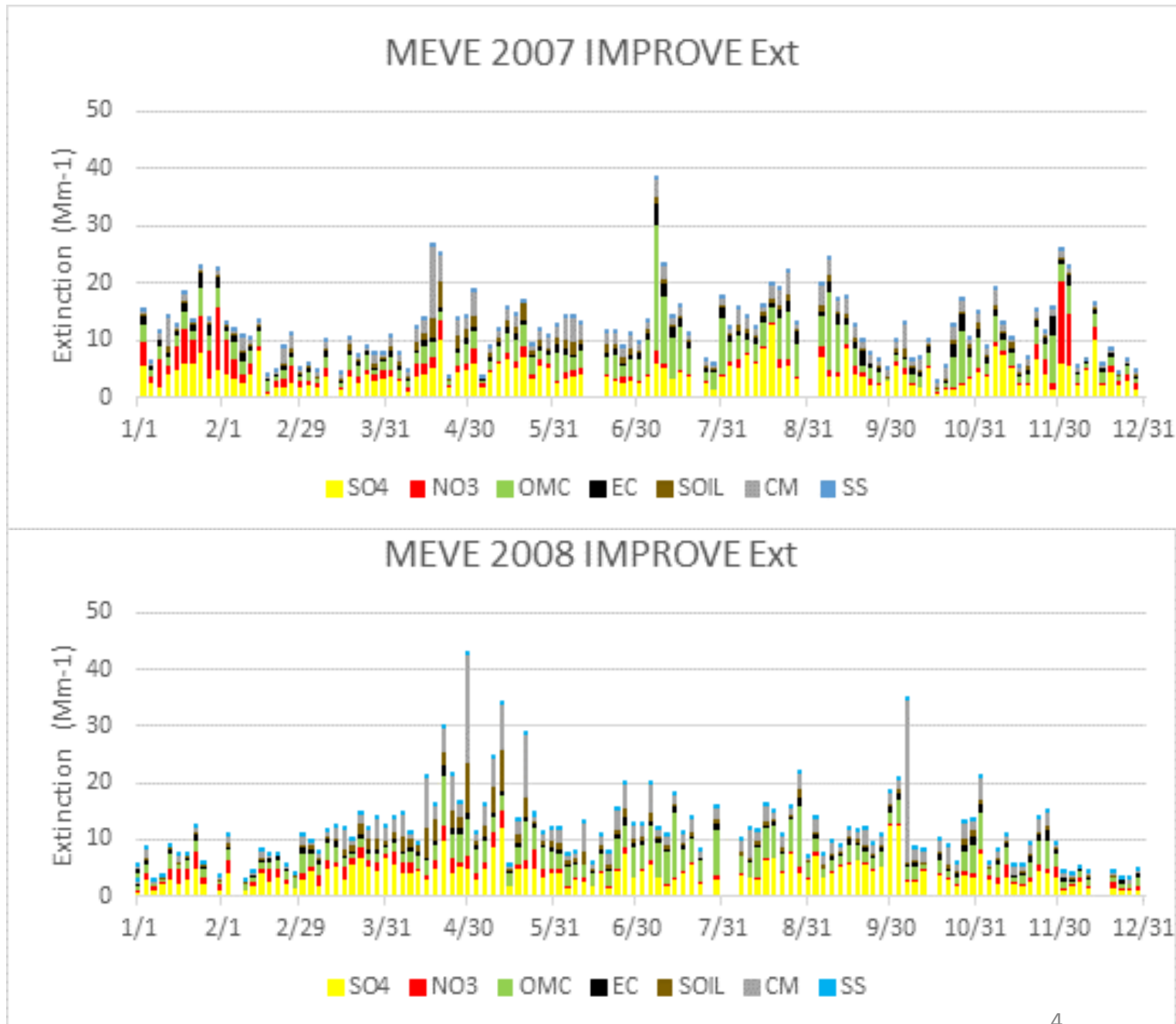
- Analysis of IMPROVE data and estimates of natural haze are used to estimate anthropogenic visibility impairment for each day at each Class I area.
- Impairment is evaluated in deciviews for the averages of the 20% most impaired days and the 20% best visibility days for each year and for the 5-year rolling average.
- The uniform rate of progress (URP) is a straight line from the baseline 5 year average 20% most impaired days (from 2000 to 2004) to zero impairment in 2064.
  - Data analysis is used to apportion light extinction to natural and anthropogenic sources **for each day of IMPROVE data**, and daily impairment is calculated as:  
Impairment (deciviews) =  $10 * \ln(\text{total extinction} / \text{natural extinction})$ .
  - The estimate of natural haze for the 20% most impaired days can be calculated each year and can change over time.
- Days with large natural haze (wildfires, dust storms) have poor visibility but low impairment and therefore will be excluded from the most impaired days and from the planning process. **This is an important message to communicate to the public.**

# EPA Analysis of Natural Haze and Impairment at Mesa Verde, CO, 2000 to 2014

MEVE trends in Natural Haze and Impairment on Worst 20% days

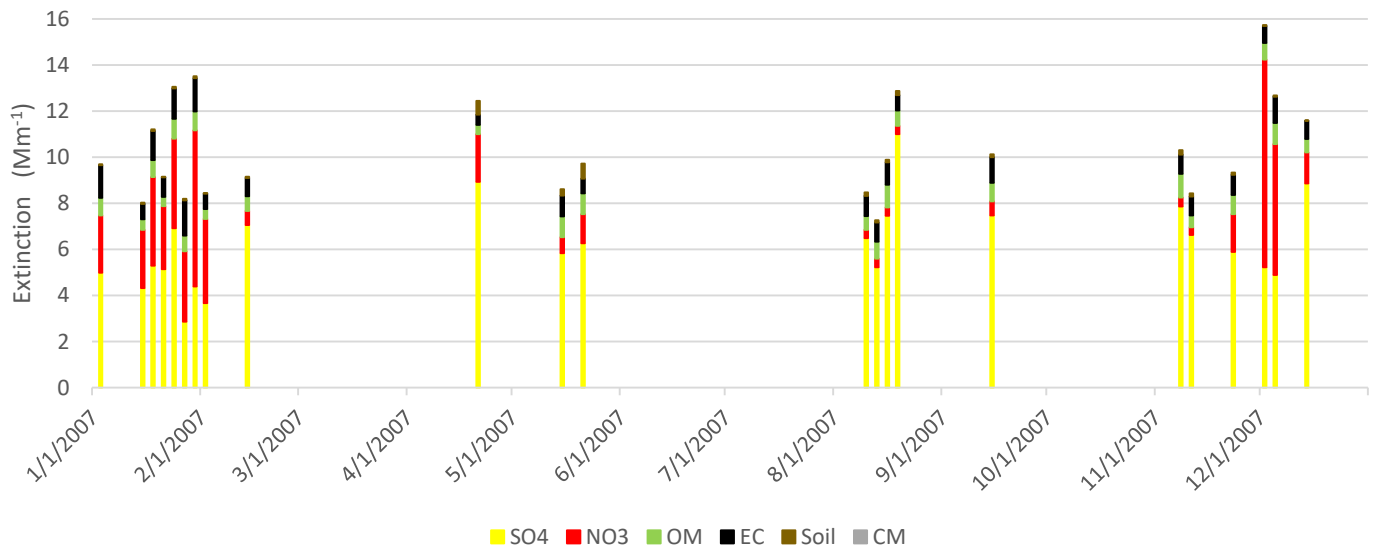


Larger nitrate contribution to total IMPROVE extinction at Mesa Verde in 2007 vs. 2008.

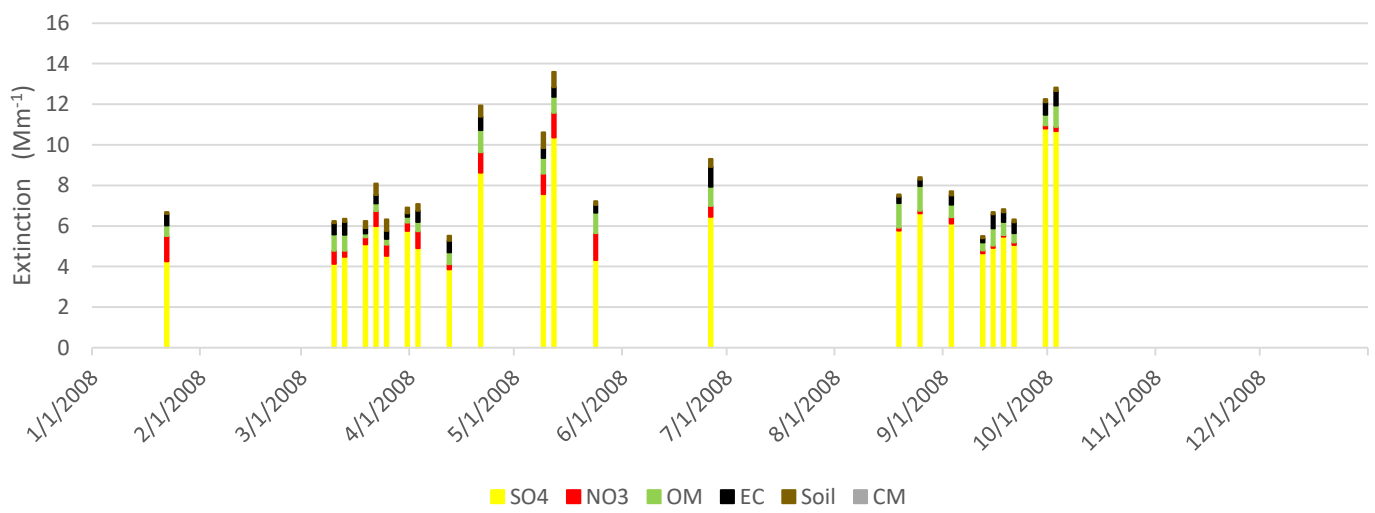


- There is interannual variability in species contributions to impairment, probably caused by variability in meteorological conditions and transport patterns.
- Selection of year to model might affect RPG results.
- Recommend evaluating more sites.

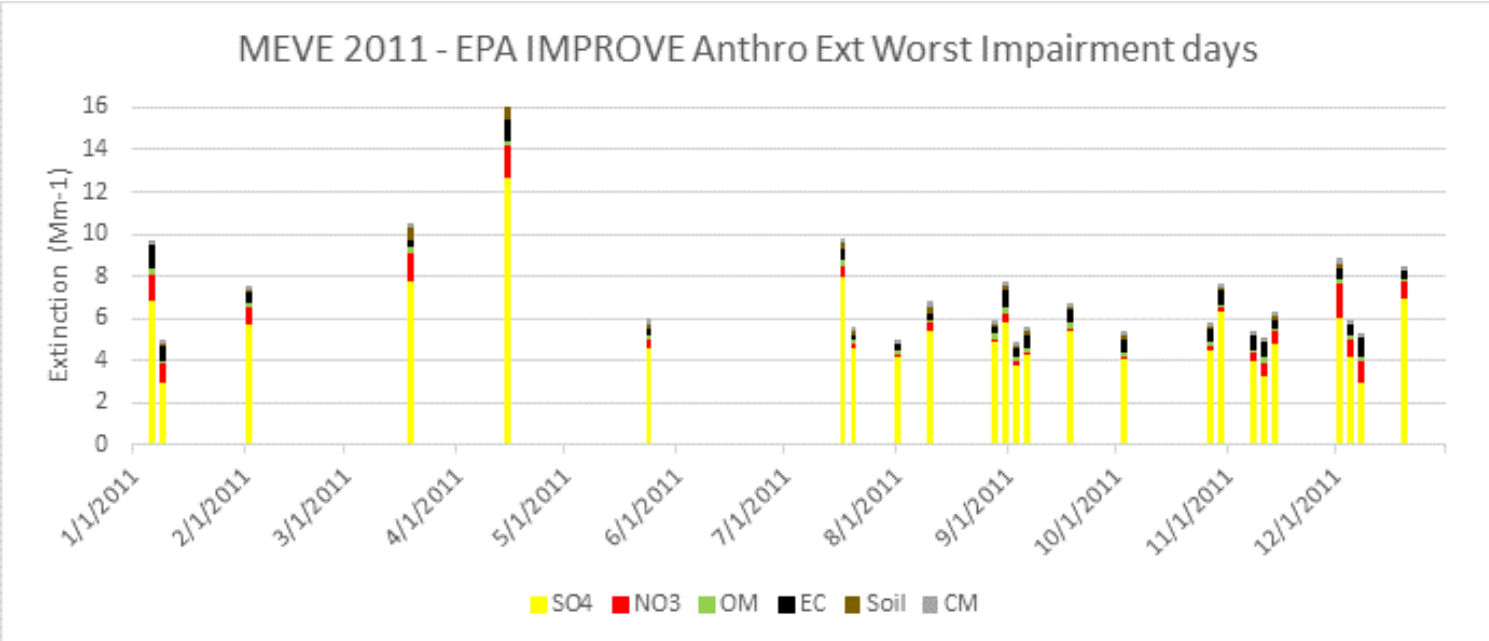
MEVE 2007 - EPA IMPROVE Anthro Ext Most Impaired days



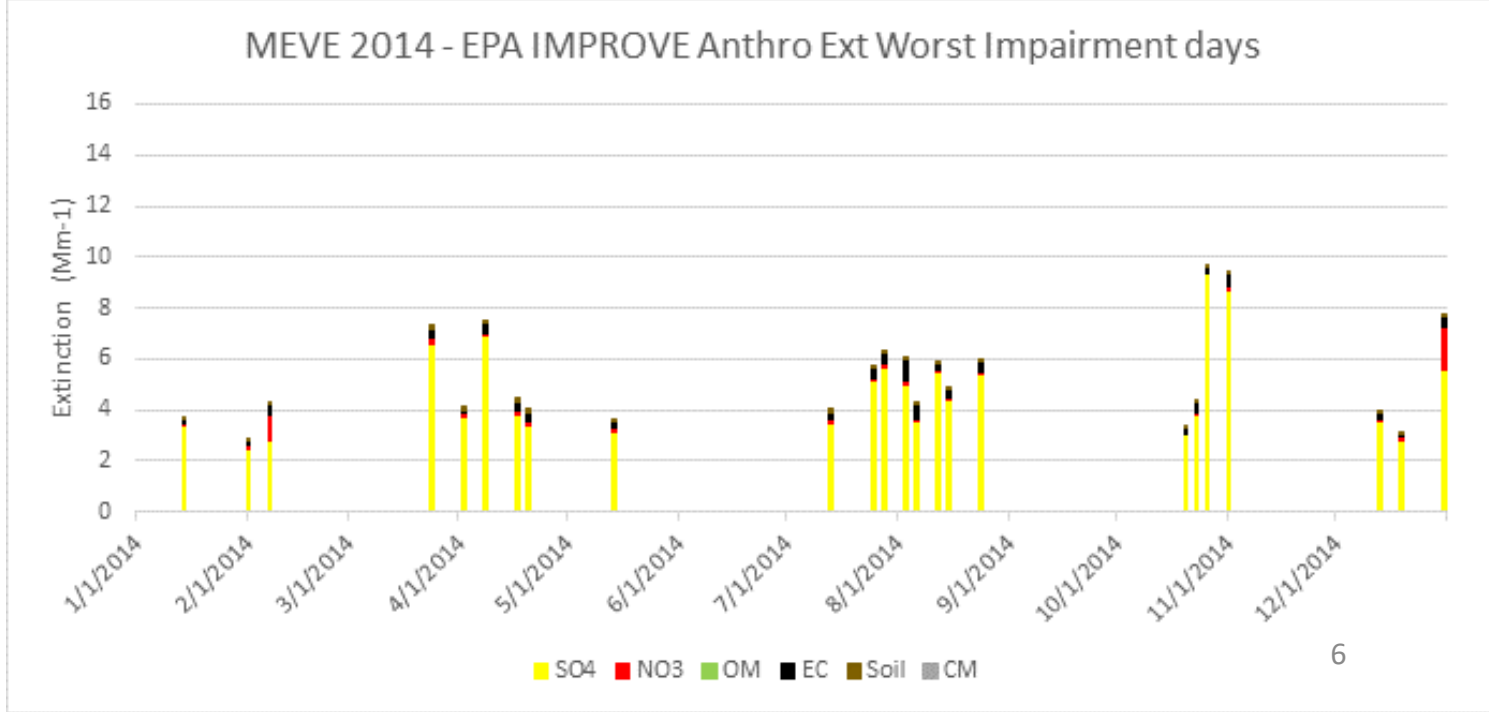
MEVE 2008 - EPA IMPROVE Anthro Ext Most Impaired days



- 2011 and 2014 are more similar to 2008 but with even lower NO3 in 2014.

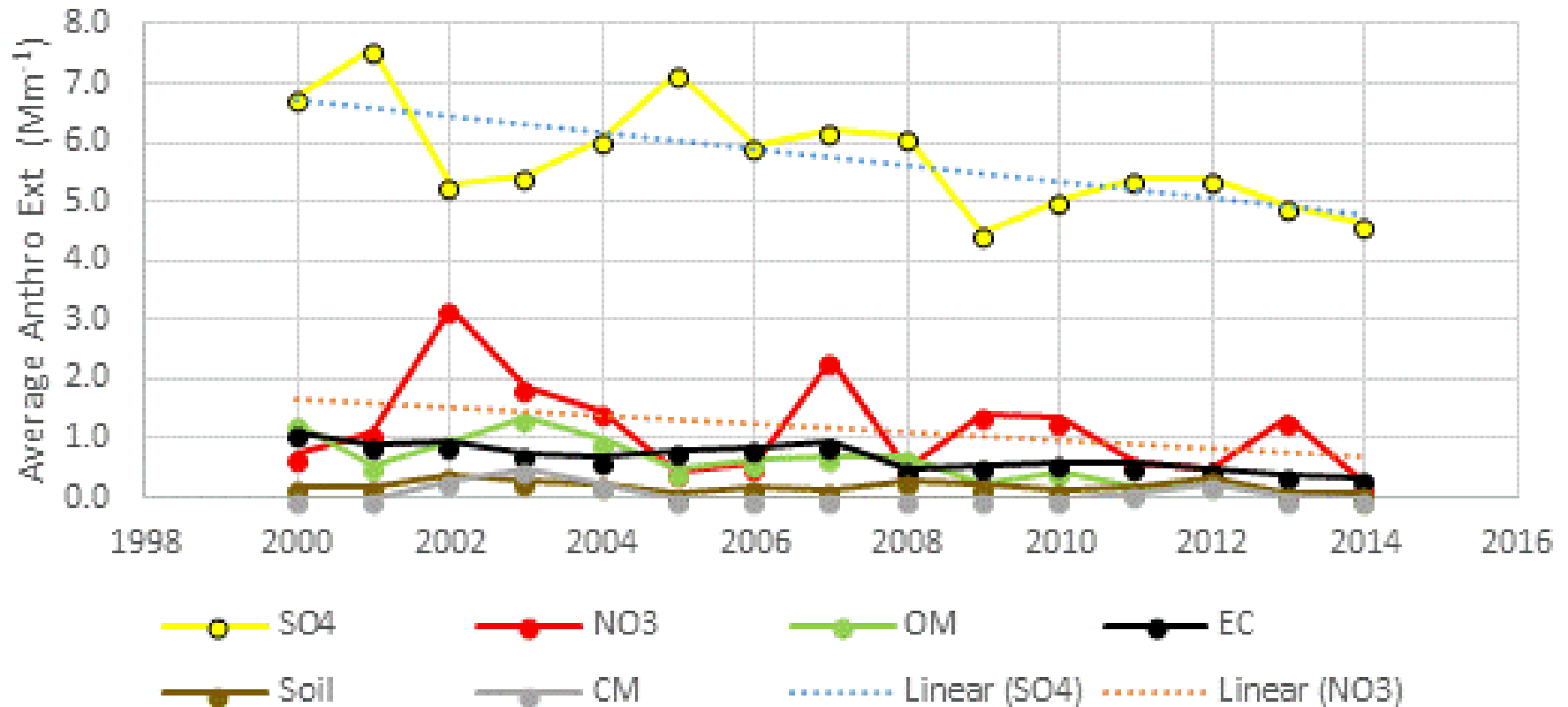


- Need to evaluate more sites.



# Trends in EPA estimates of anthropogenic contributions to extinction at Mesa Verde

MEVE Average EPA Anthro Ext on worst 20 days

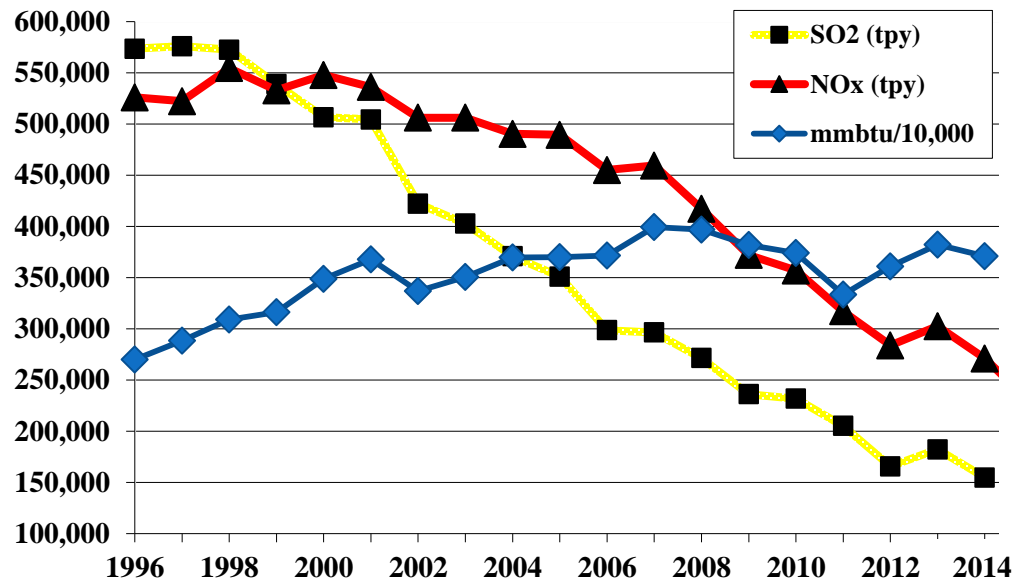


# Western Interconnect Fossil Fuel Power Plant Emissions

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

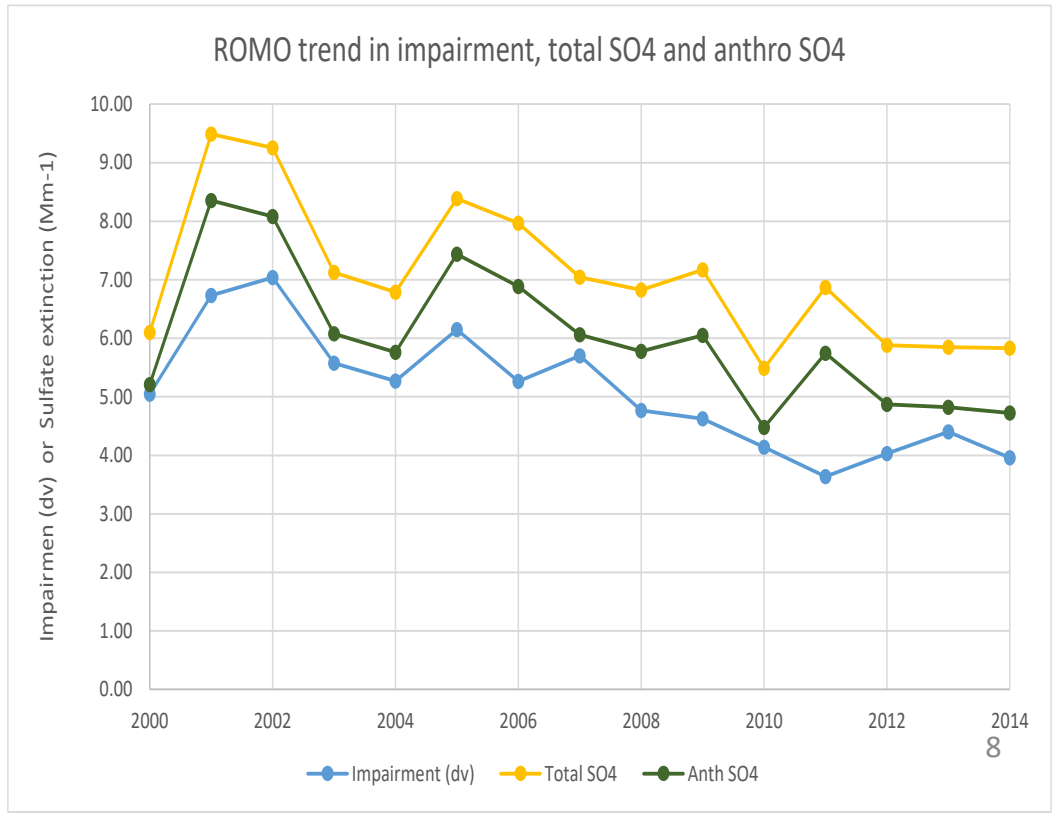
\* Additional NOx reductions estimate - BART controls from Regional Haze baseline planning

\*\* Further NOx reductions estimate from applying maximum post-combustion controls to all remaining units (Plot from WRAP)



## Trends in IMPROVE data at ROMO

Trend in sulfate extinction and total anthropogenic impairment based on EPA analysis for average of the 20% most impaired days

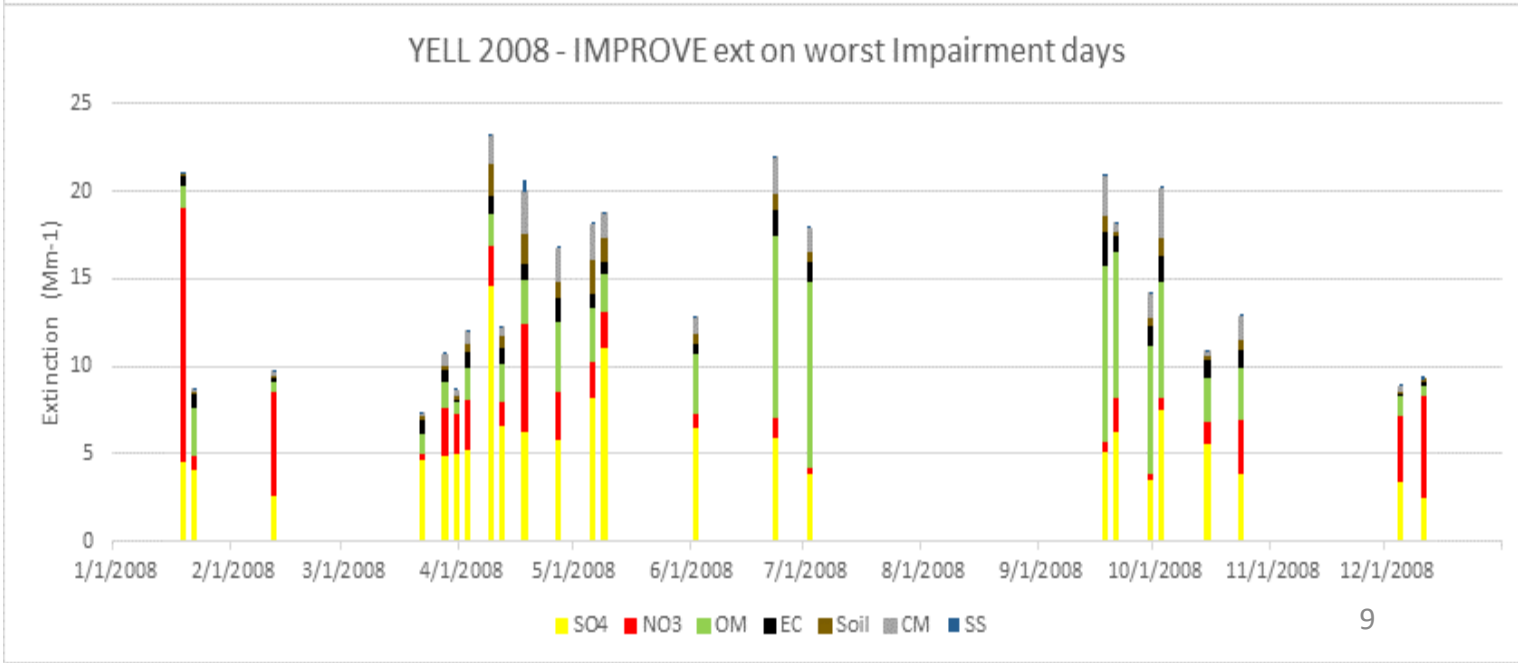
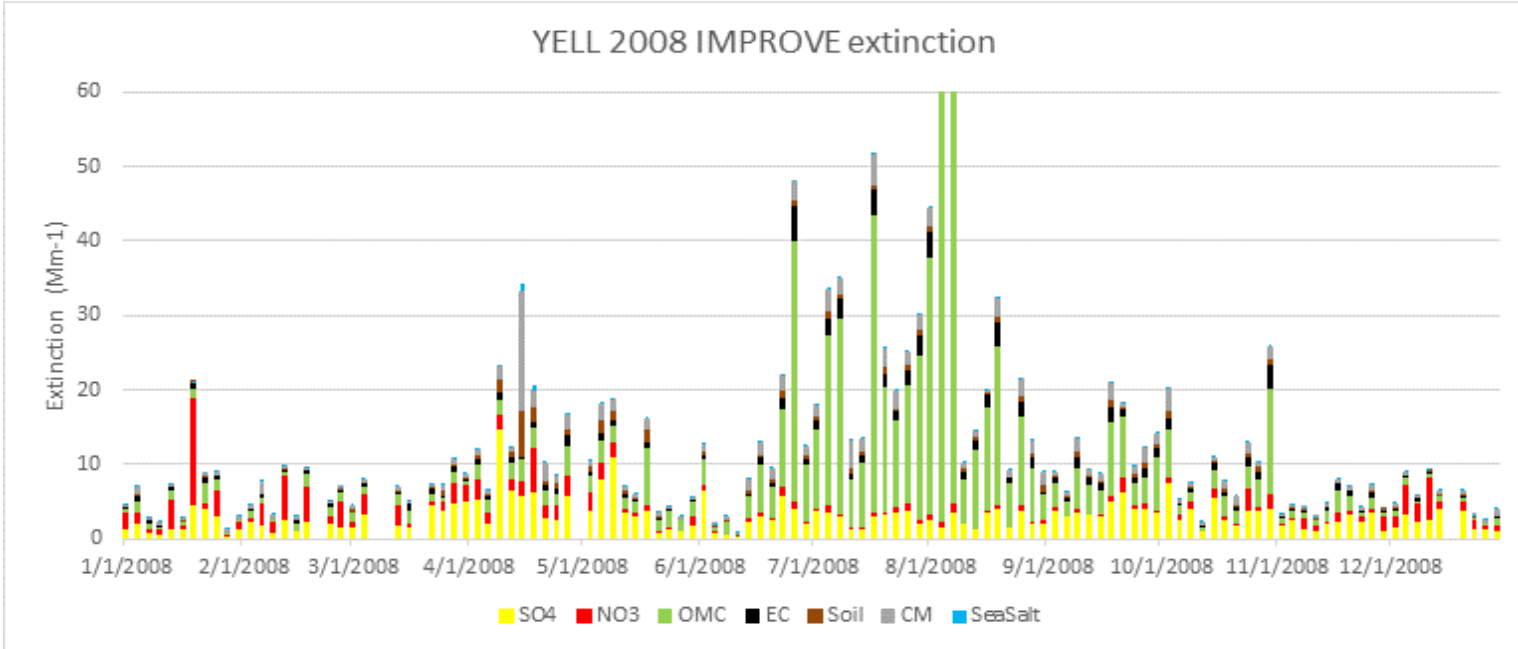




# Yellowstone 2008

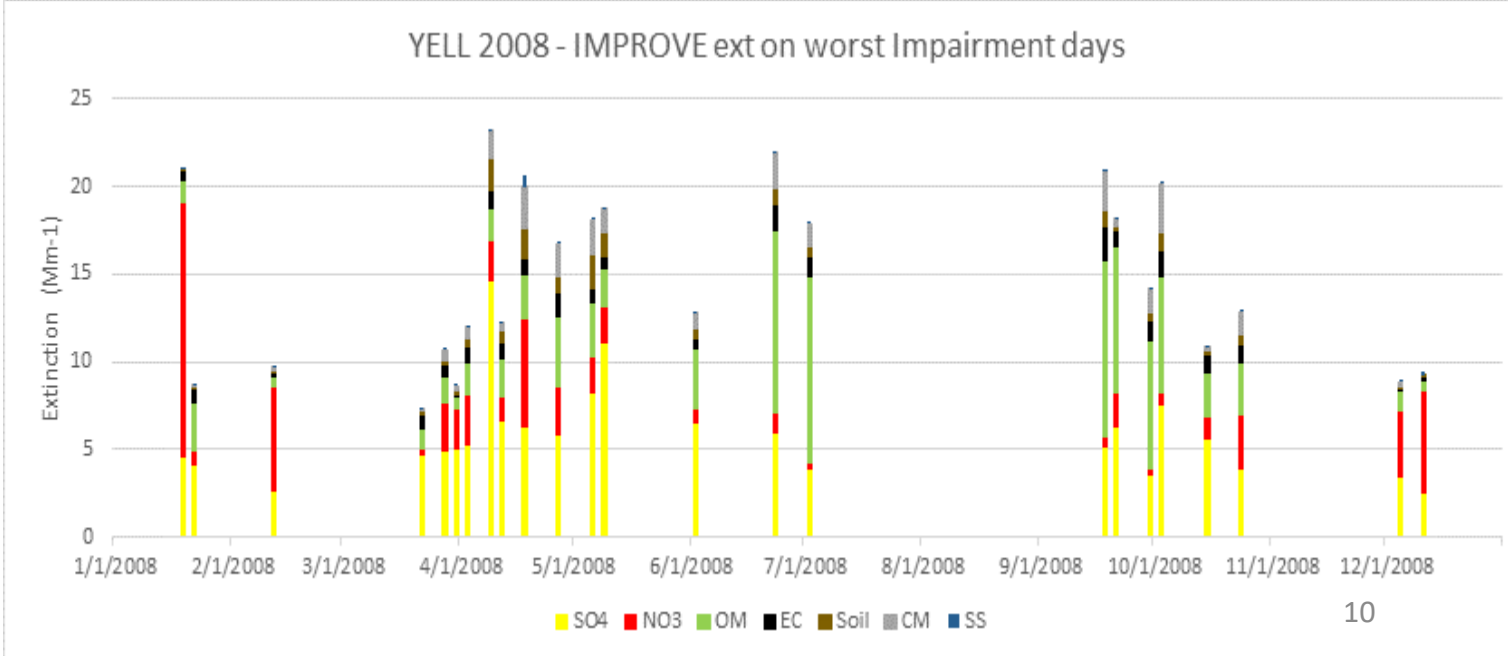
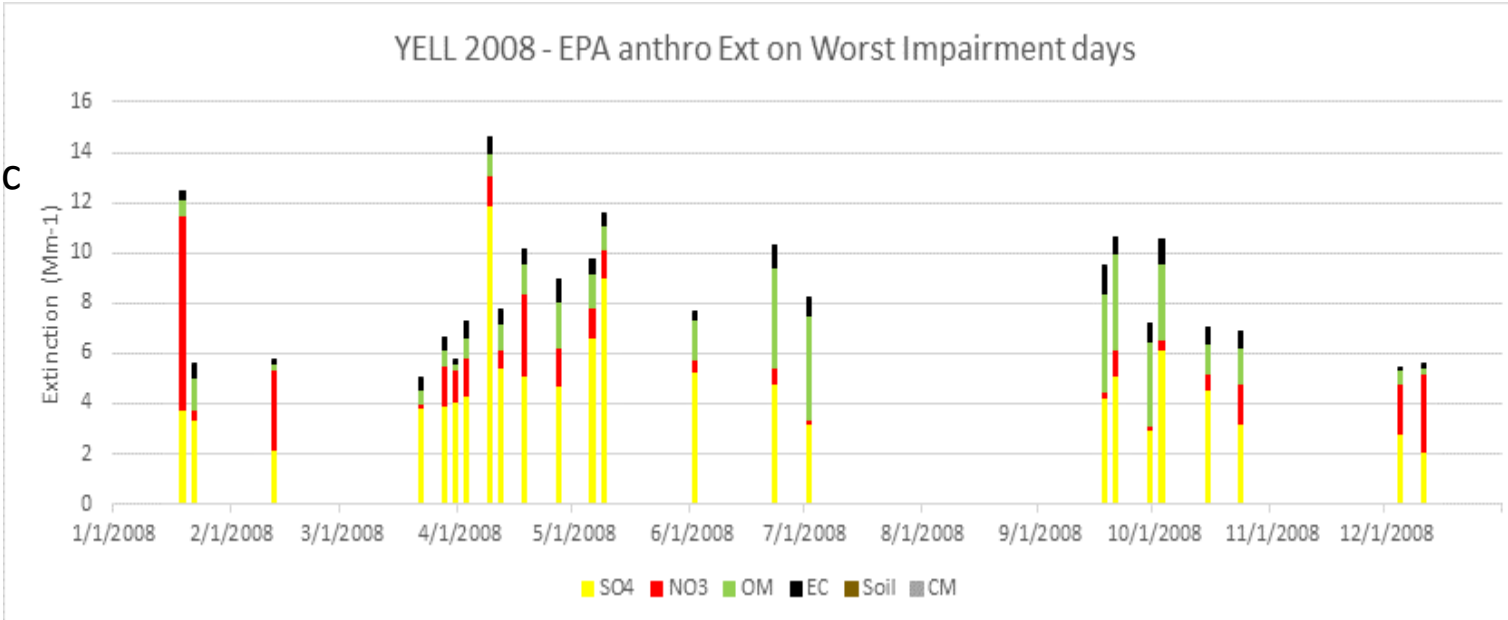
Wildfires from  
mid June to  
October, 2008.

EPA most  
impaired days  
include some  
days with  
wildfire  
influence.



EPA analysis attributes large fraction of OM and EC to anthropogenic sources on days with smaller but significant impact from wildfires.

Alternative approaches to identify extreme events are needed.



# Improving Estimates of Natural Haze

- Calculating day specific anthropogenic impairment using IMPROVE data requires an estimate of natural and anthropogenic fractions for each day.
- The new approach to exclude wildfires and dust storms is a significant improvement, but we still use the Trijonis estimates for routine contributions to natural haze.
- Suggestions for additional analysis:
  - Can we improve the method used to quantify wildfire contributions?
  - Evaluate the EPA assumption that natural haze for each species is a constant proportion of the observed IMPROVE species.
  - How does EPA data analysis of natural PM compare to modeled natural PM?
  - Can the IMPROVE steering committee lead the effort to update natural haze estimates?

# Using models to evaluate reasonable progress goals (RPG)

- The RHR requires states to develop a Long Term Strategy (LTS) for reducing emissions to make progress toward natural visibility in each planning period. Photochemical model simulations are used to simulate the LTS and to determine the Reasonable Progress Goal (RPG):
  - Model simulations for a baseline period (e.g., 2014) and for 2028 are used to calculate visibility impairment in 2028.
  - Modeled impairment is then compared to the URP in order to set the RPG. If the RPG is above the URP, additional analysis is required.
- Concerns with the use of models:
  - Modeled impairment is affected by model bias and by uncertainty in natural haze and international transport. How closely does the modeled impairment match the estimates of impairment based on our analysis of the IMPROVE data?
  - If modeled impairment is less than our estimate based on an analysis of the IMPROVE data, the model estimates of RPG will show slower progress.
  - Does this approach accurately characterize the cumulative benefits of emissions reductions before the 2014 baseline period?

# Western U.S. CAMx Modeling Results Available from WRAP and the Western Air Quality Study/Data Warehouse

- WestJumpAQMS CAMx modeling with source apportionment for 2008.
  - ✓ Available at <http://www.wrapair2.org/WestJumpAQMS.aspx>
- Western Air Quality Study Modeling for 2011.
  - 2011 Base Case Simulations with CAMx Source Apportionment.
    - ✓ Available at <http://views.cira.colostate.edu/TSDW>
  - Zero U.S. Anthropogenic emissions simulations using boundary conditions from three different global models: MOZART, GEOS-Chem, AM3.
    - ✓ Available at <http://views.cira.colostate.edu/TSDW/>

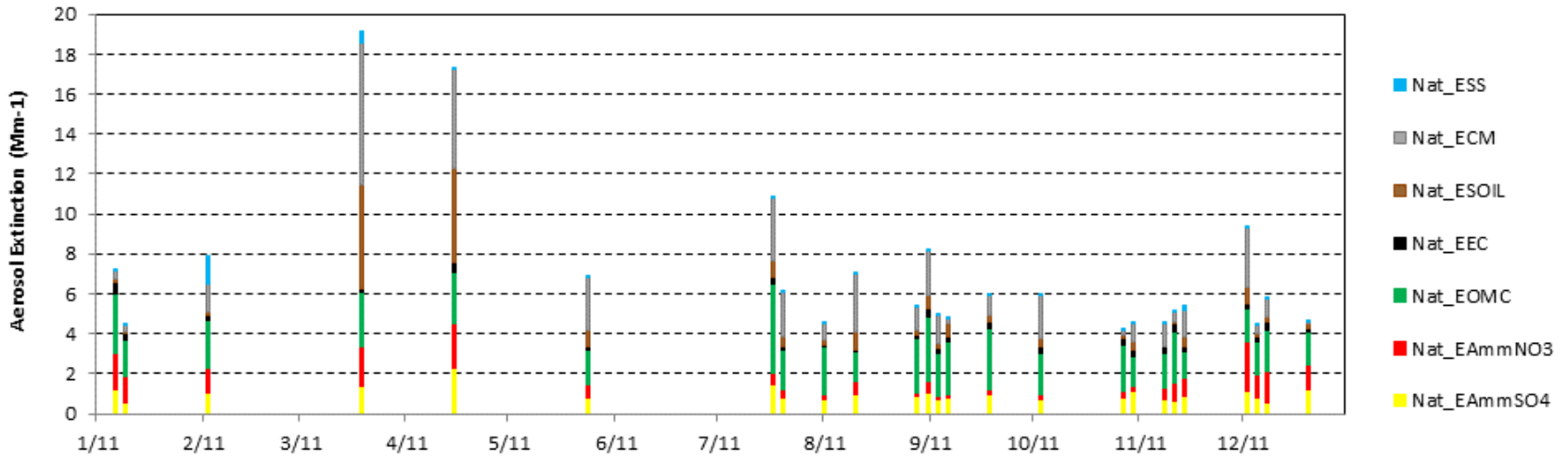
# WAQS 2011 Model Simulations of US Background compared to EPA Natural estimates

- WAQS CAMx simulations with zero US Anthropogenic emissions using boundary conditions from: MOZART, GEOS-Chem and AM3.
- See Morris et al. presentation for additional details on CAMx simulations.
- EPA natural estimate are from analysis of IMPROVE data.
- Note that model simulations also include international anthropogenic emissions but natural estimates do not. Need additional model simulations with zero international anthropogenic emissions for direct comparison.
- Comparison of modeled US Background to EPA estimates of natural haze:
  - All three models predict much greater USB SO<sub>4</sub>.
  - All three model predict less USB NO<sub>3</sub>, soil and coarse mass.
  - Models predict greater USB OMC in summer and less in winter.

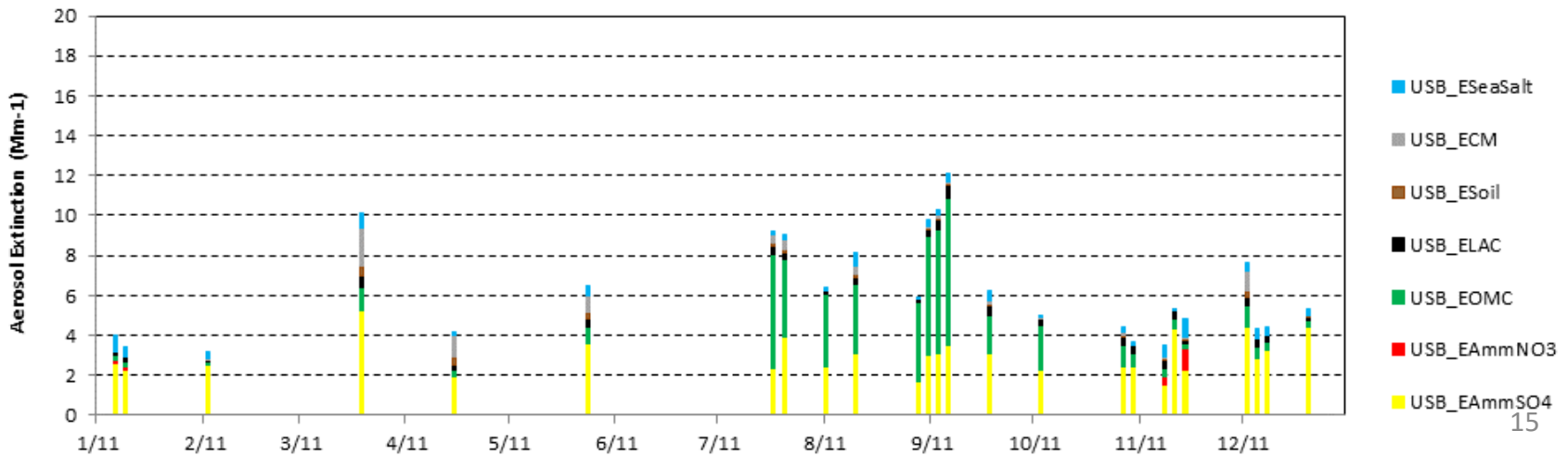
# Comparison of natural haze estimates to model USB

At Mesa Verde, CAMx predicts greater uncontrollable SO<sub>4</sub>, and less uncontrollable NO<sub>3</sub>, soil and coarse mass.

## EPA's Natural Aerosol Extinction (MEVE1)

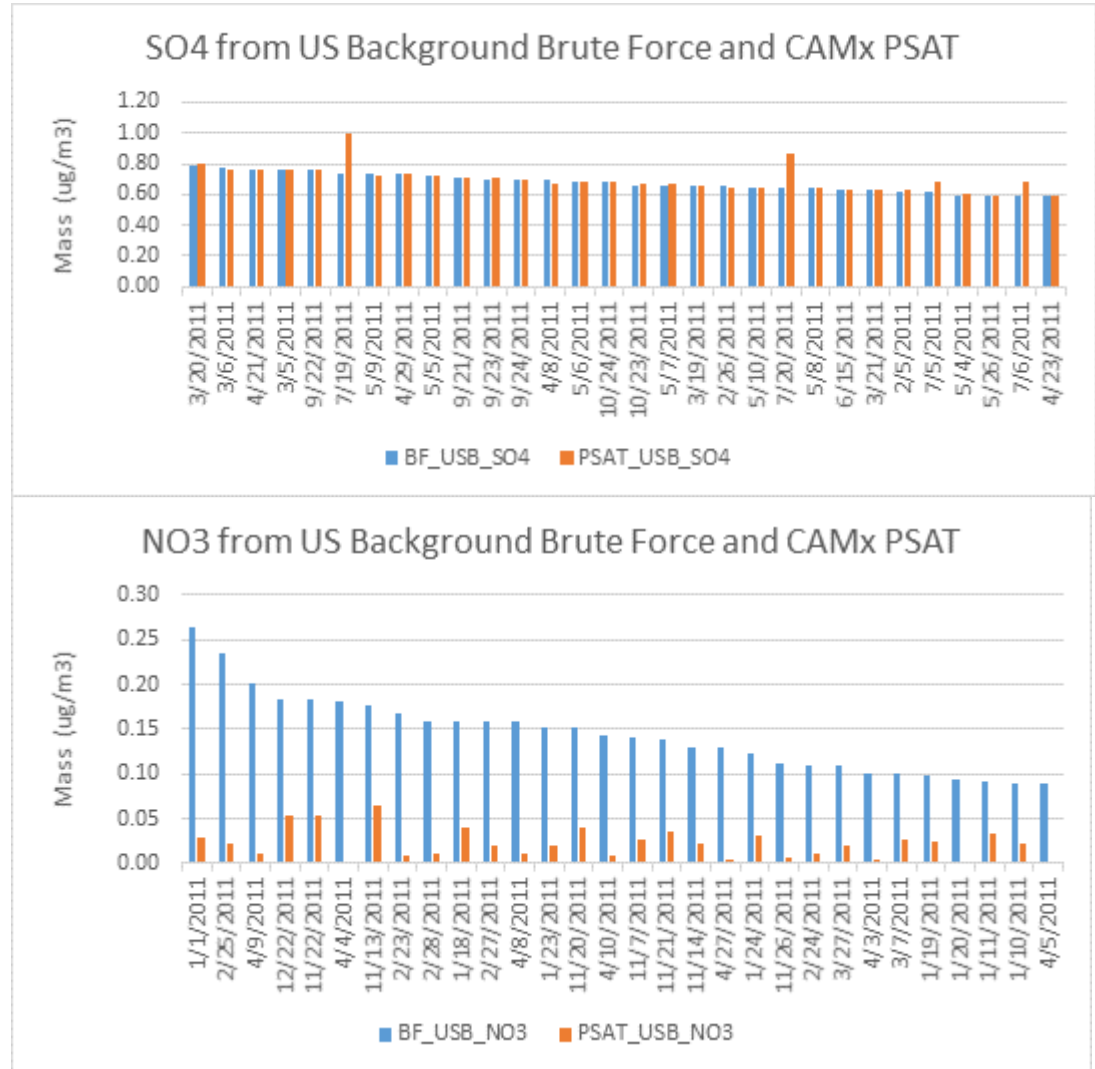


## CAMx MZBC USB Aerosol Extinction (MEVE1)



# Comparison of WAQS CAMx PSAT to CAMx Brute Force simulations of US Background

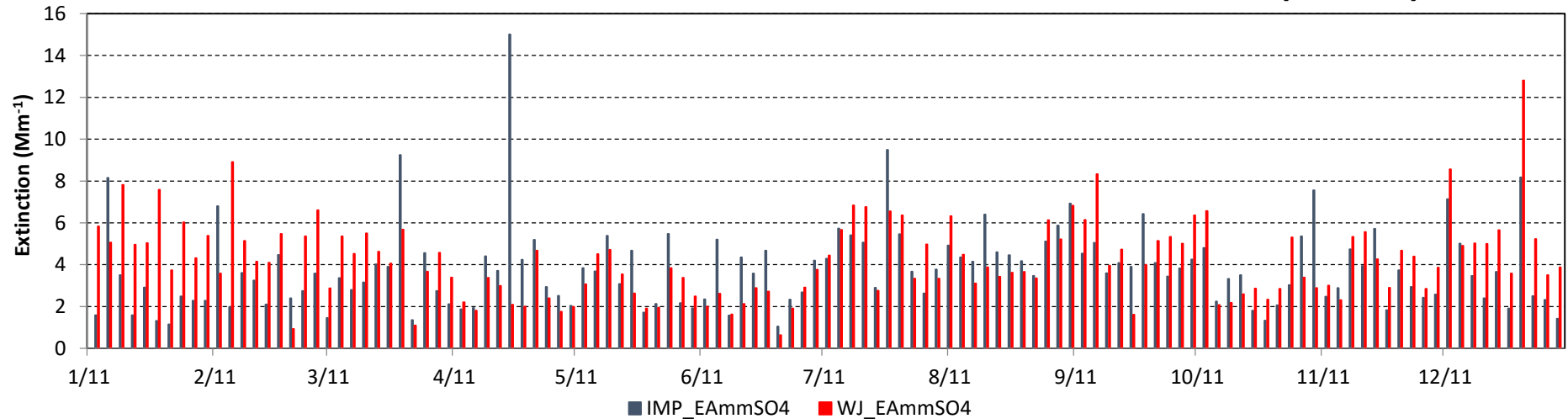
- CAMx PSAT results are very similar to brute force zero-out results for SO<sub>4</sub> and EC.
- CAMx PSAT predicts smaller contributions to USB NO<sub>3</sub> compared to simulations with zero US anthro emissions because ammonium nitrate is assumed to be in instantaneous equilibrium with gaseous HNO<sub>3</sub> and NH<sub>3</sub>.
- Locally produced HNO<sub>3</sub> rapidly replaces international HNO<sub>3</sub> in the PSAT aerosol tracer.



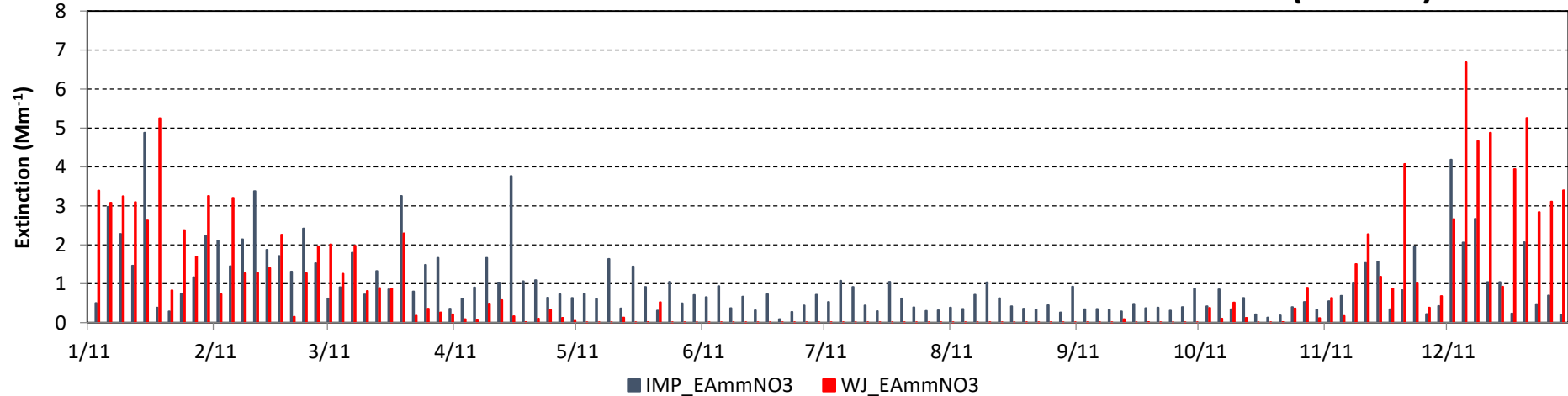


# WAQS CAMx has seasonal bias for Sulfate and Nitrate

## Ammonium Sulfate Extinction: IMPROVE and CAMX (MEVE1)

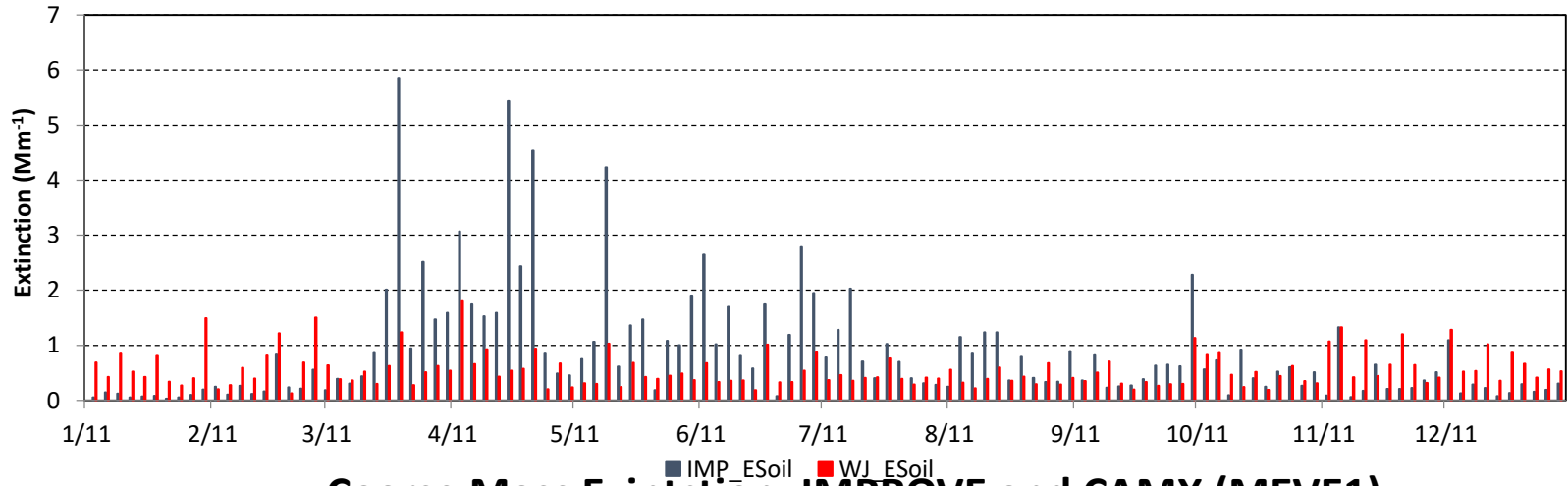


## Ammonium Nitrate Extinction: IMPROVE and CAMX (MEVE1)

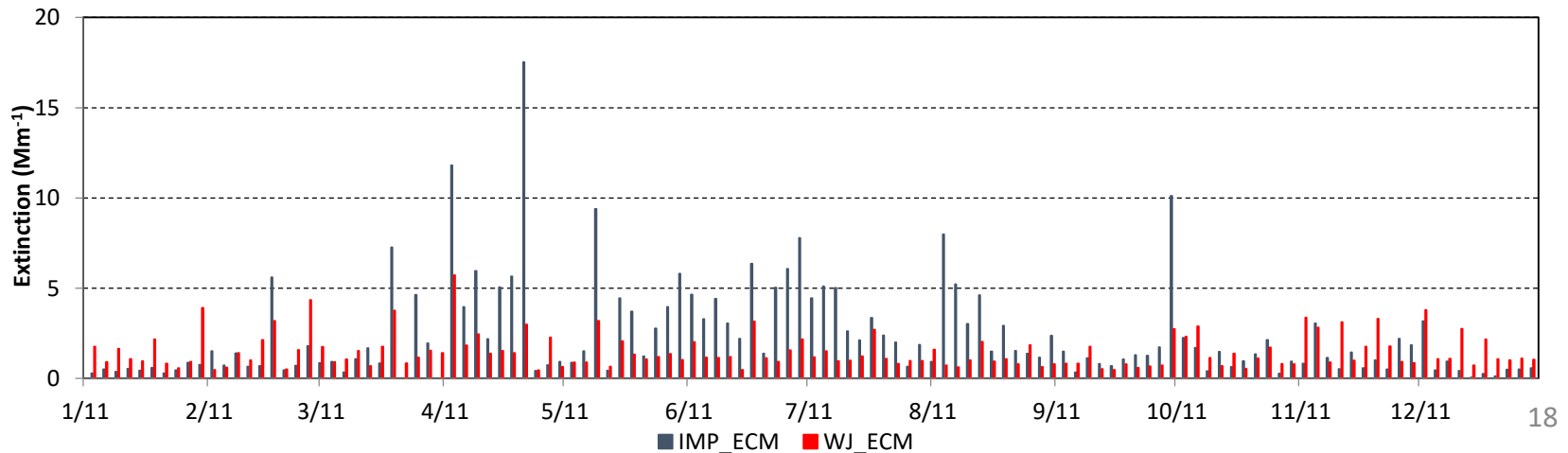


Soil and Coarse Mass: **WAQS** CAMx is biased low on the highest concentration days, and is biased high on low days. CAMx also predicts a large anthropogenic fraction on the low concentration days.

Soil Exintction: IMPROVE and CAMX (MEVE1)



Coarse Mass Exintction: IMPROVE and CAMX (MEVE1)



# Adjusting Modeled impairment predictions using the IMPROVE data

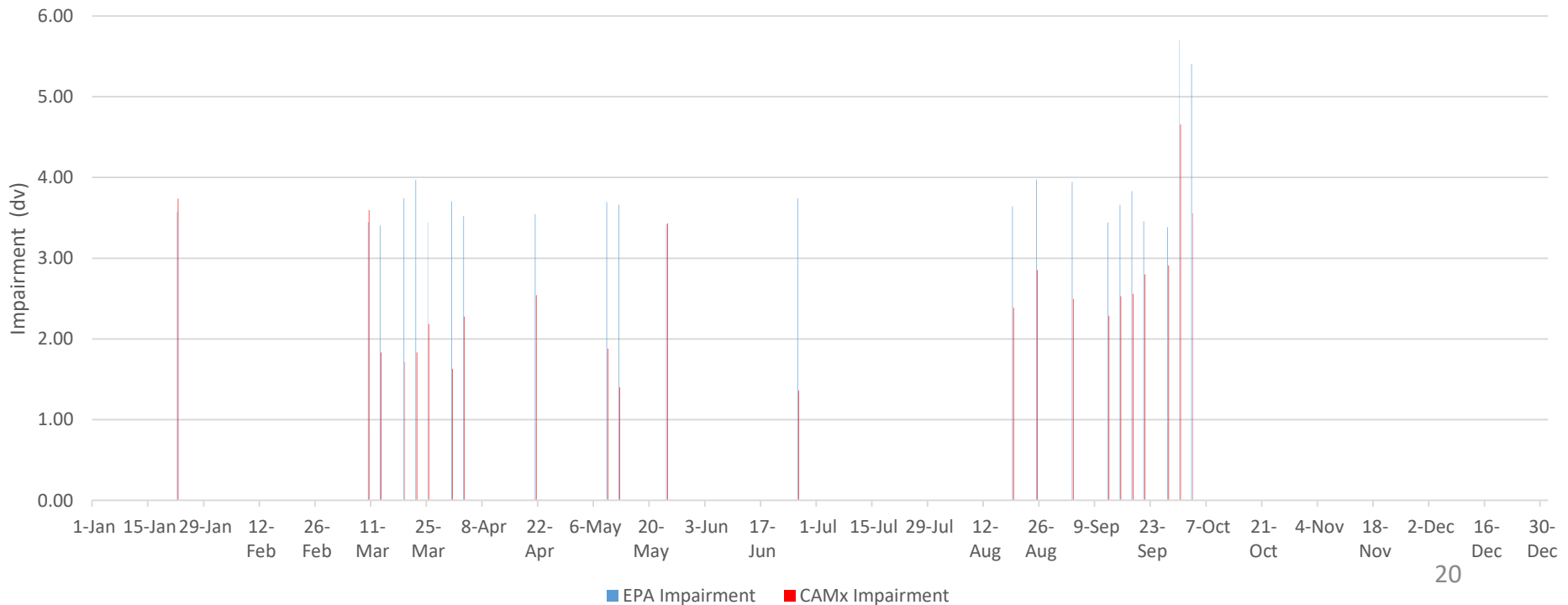
- Use model source apportionment results to calculate the percent U.S. anthropogenic contribution to extinction for each modeled day.
- Select the most impaired days in the EPA IMPROVE analysis and multiply each IMPROVE species by the model percent U.S. to estimate the modeled impairment for each day.
- Compare the EPA analysis of impairment using the IMPROVE data for each day to the modeled U.S. impairment.
- Compare the species contributions to impairment in the EPA analysis versus the model results.
- Results are available for WRAP and WAQS CAMx PSAT simulations for 2008 and 2011.

At Mesa Verde NP in 2008, the WestJump CAMx modeled U.S. impairment is significantly lower than the impairment estimated based on IMPROVE data. The average impairment for the 20% most impaired days is 3.8 dv for the EPA estimate compared to 2.5 dv CAMx. Thus, if we eliminated all US anthropogenic emissions CAMx would still be 1.3 dv above the URP in 2064.

The difference in estimates of impairment can result from four factors:

- 1) International anthropogenic impairment is not included in the modeled U.S. impairment.
- 2) Uncertainty in the modeled CAMx estimates of anthropogenic or natural extinction.
- 3) Uncertainty in the IMPROVE data analysis split between anthropogenic and natural extinction.
- 4) Uncertainty in the Trijonis estimate of natural visibility conditions..

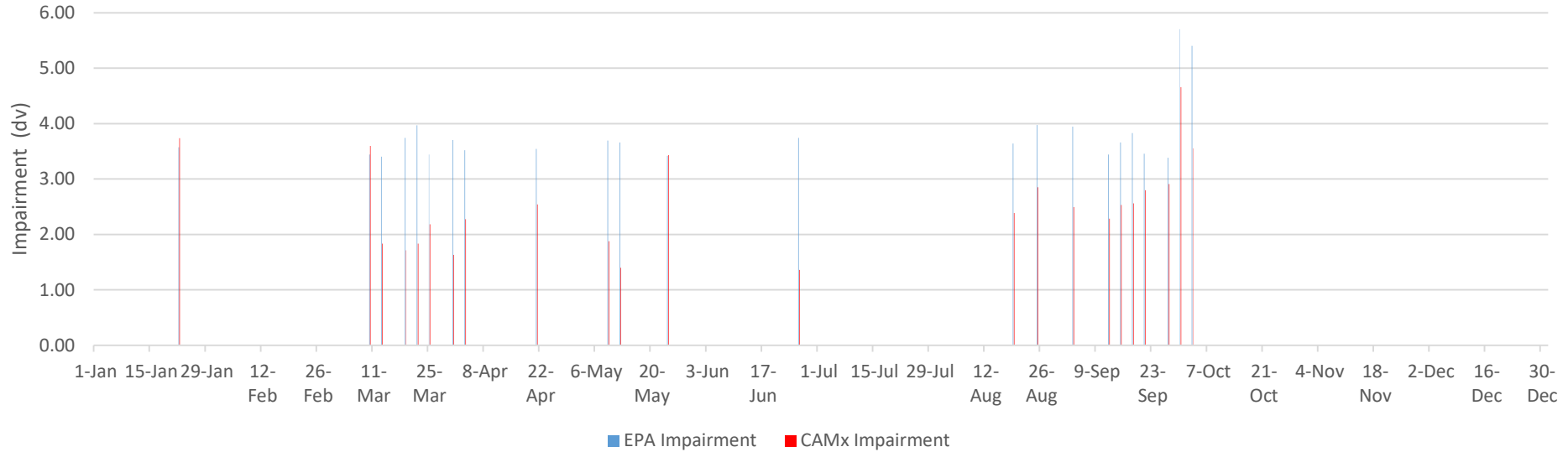
MEVE 2008 EPA Impairment vs. CAMx US Impairment



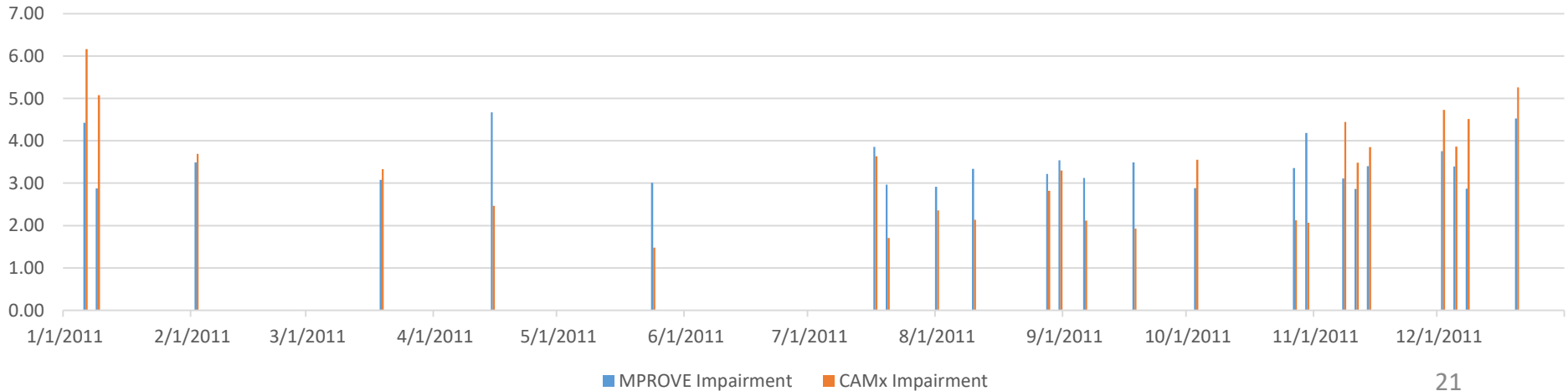
# Mesa Verde 2008 and 2011

Average impairment on most impaired days is similar in the 2011 WAQS CAMx analysis and the EPA analysis, but species contributions differ (see next slide).

### MEVE 2008 EPA Impairment vs. CAMx US Impairment

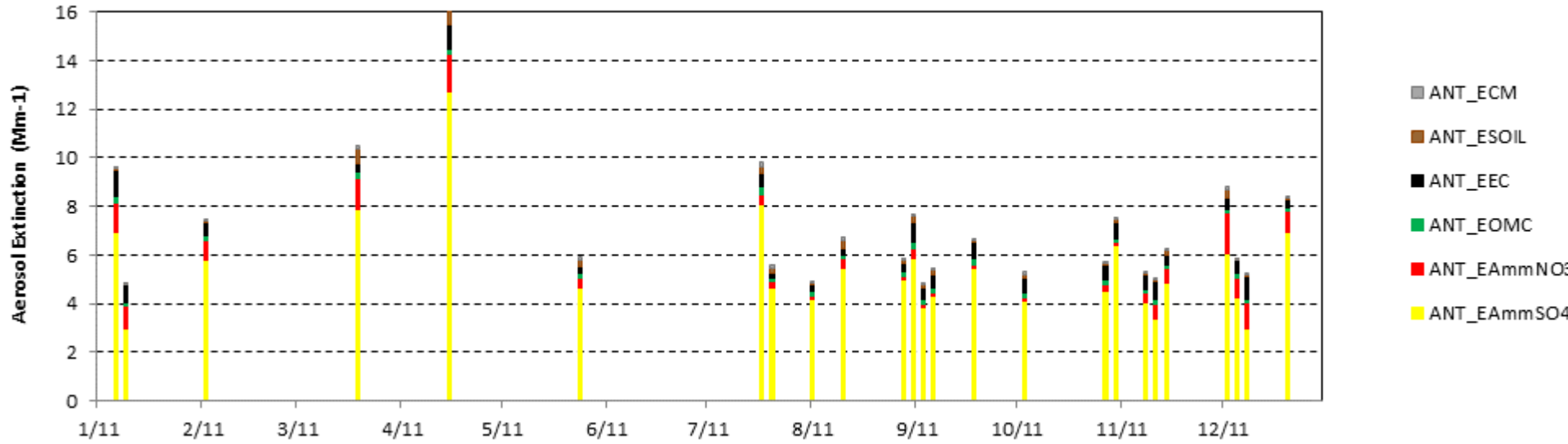


### Mesa Verde 2011 EPA Impairment vs. CAMx U.S. Impairment

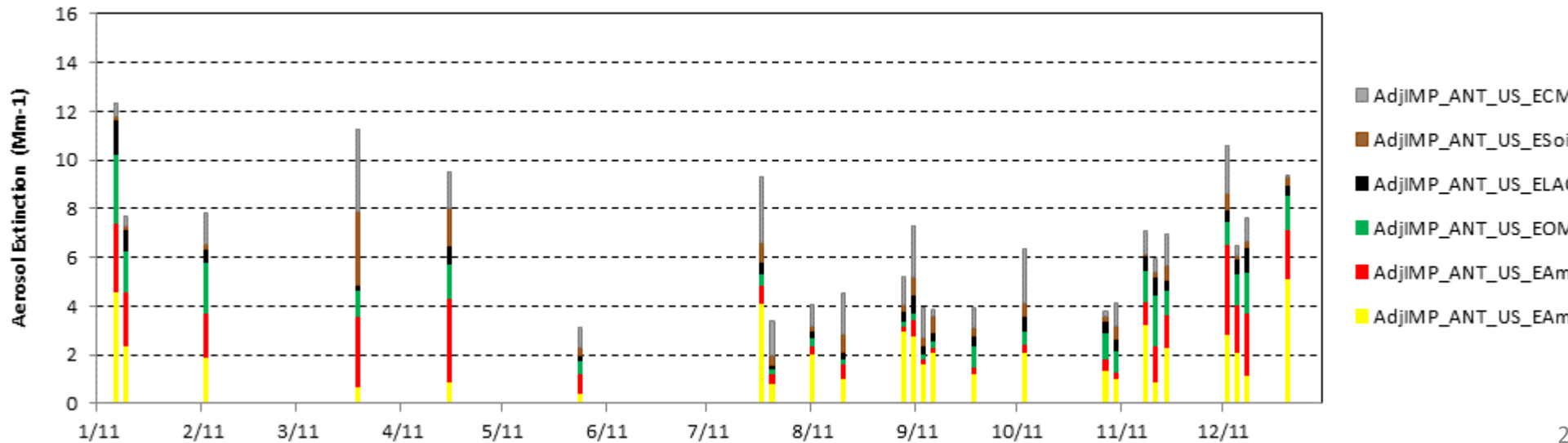


Top plot is EPA analysis of IMPROVE data anthropogenic impairment, bottom plot is 2011 WAQS CAMx PSAT US Controllable percentages multiplied by IMPROVE data.

**EPA's Anthropogenic Aerosol Extinction on 20% most impaired days (MEVE1)**

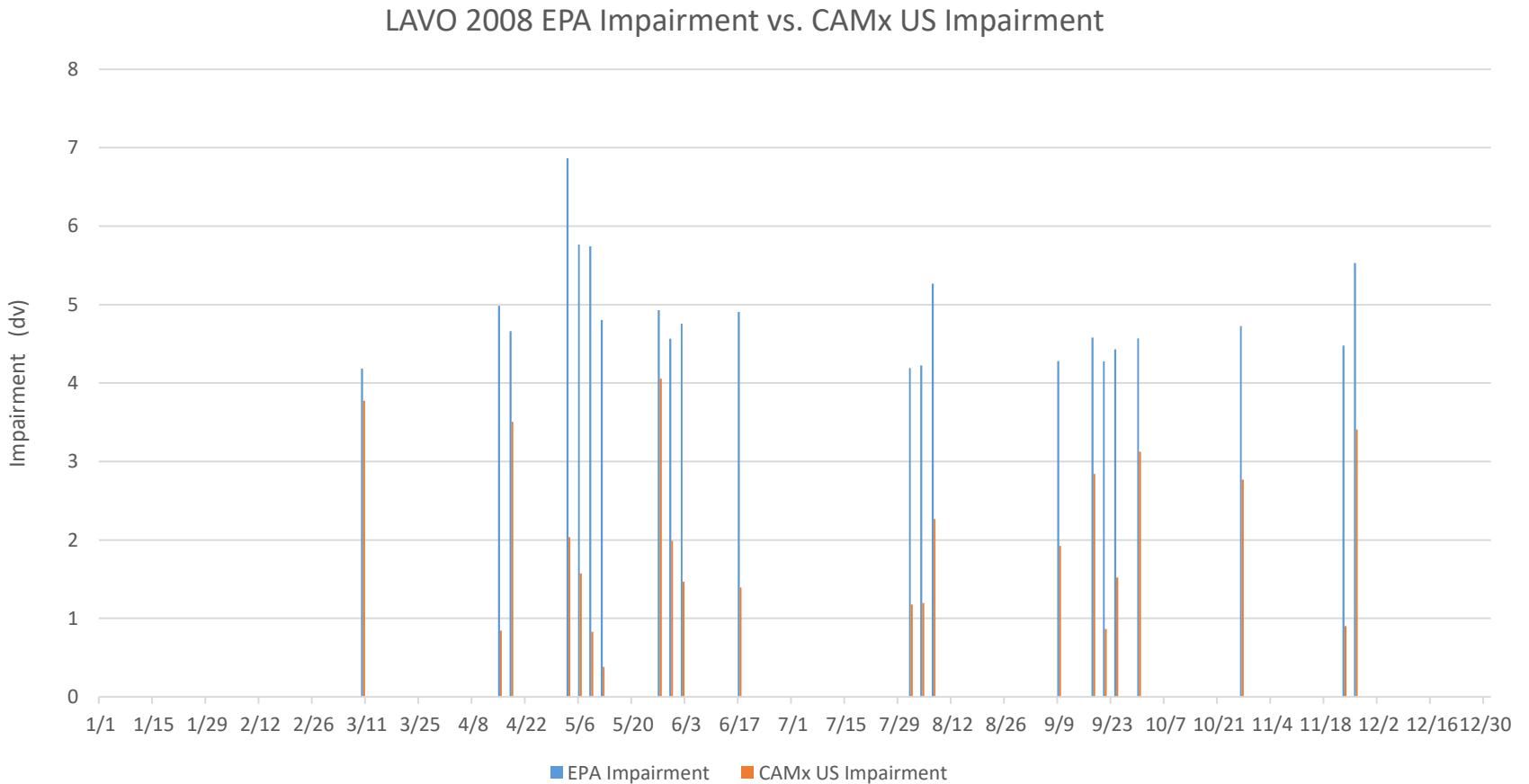


**Apportioned Controllable Aerosol Extinction on 20% most impaired day (MEVE1)**



# Lassen Volcanic National Park, 2008

The average impairment for the EPA 20% most impaired days is 4.85 dv compared to 1.99 dv WestJump CAMx US impairment.

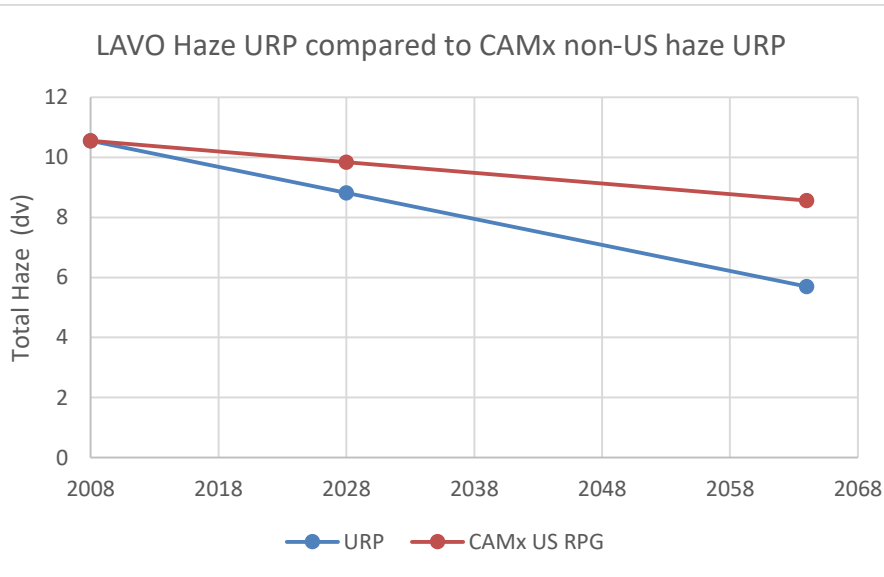


## Lassen Volcanic National Park, 2008

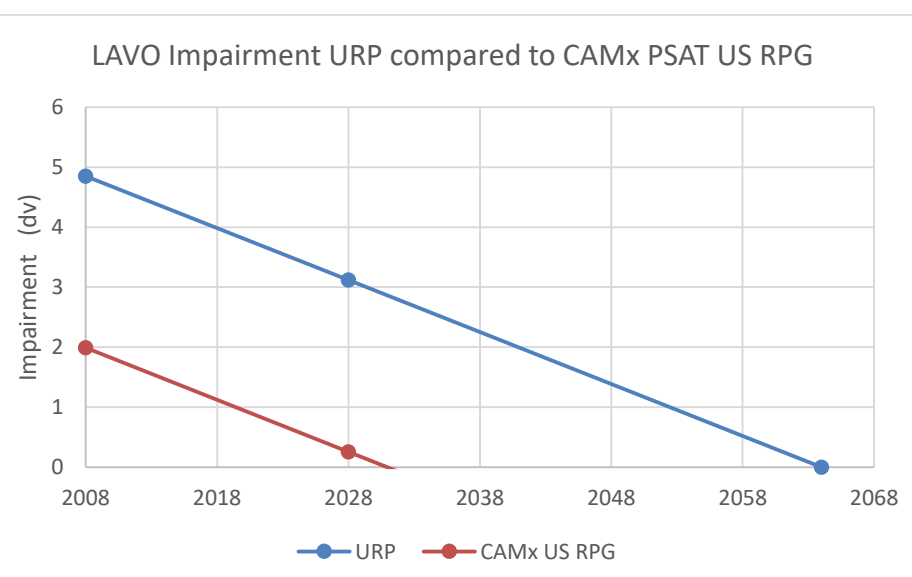
Based on the EPA 20% most impaired days average of 4.85 dv, the URP goal in 2028 is 3.12 dv impairment, or a reduction of 1.73 dv. WestJump CAMx PSAT results indicate that the maximum possible reduction with zero US anthropogenic emissions is 1.99 dv, so US emissions would have to be close to zero in 2028 for the RPG to be on or below the URP.

However, results from CAMx PSAT simulations will differ compared to CAMx sensitivity simulations of the LTS in 2028, and it is uncertain how reliably CAMx PSAT approximates progress compared to CAMx sensitivity simulations.

Linear rate of progress in CAMx US impairment compared to the IMPROVE URP



CAMx US impairment level that must be modeled to be on the URP



Note: The average natural conditions on the 20% most impaired days is 5.7 dv, so the total haze level in 2008 is  $5.7 + 4.85 = 10.55$  dv



# Using Models to Evaluate Cumulative Progress since 2002

The RHR defines the baseline period as 2000-2004. For purposes of modeling the second planning period, one option is to use a more recent baseline year (e.g. 2014). How do we quantify the cumulative visibility progress of emissions reductions from 2002 to 2014?

- One option is to assume that the trend in the estimated anthropogenic component of the IMPROVE data accurately characterizes the cumulative benefits of emissions reductions from 2002 to 2014.
- Modeling results presented here and the comparison of the SO<sub>2</sub> emissions to the IMPROVE sulfate trend both suggest that the analysis of the IMPROVE data might not accurately reflect cumulative reductions in U.S. impairment since 2002.
- Another option is to use a baseline model year of 2002 and evaluate the modeled RPG relative to total modeled U.S. anthropogenic contributions.

# Recommended Next Steps: Evaluation of Impairment

- Evaluate model results and EPA IMPROVE analysis for more IMPROVE sites. Results presented here are based on just a few sites.
- Reconsider the method used to split IMPROVE nitrate and sulfate into natural and anthropogenic fractions:
  - Should natural SO<sub>4</sub> and NO<sub>3</sub> be proportional to anthropogenic?
  - Explore other methods to quantify fire contributions to haze.
- In future model runs, we should split the BC contribution into international natural and anthropogenic contributions. This will allow explicit quantification of modeled international anthropogenic impairment.
- Use global/regional natural simulations to compare with IMPROVE analysis of natural haze.

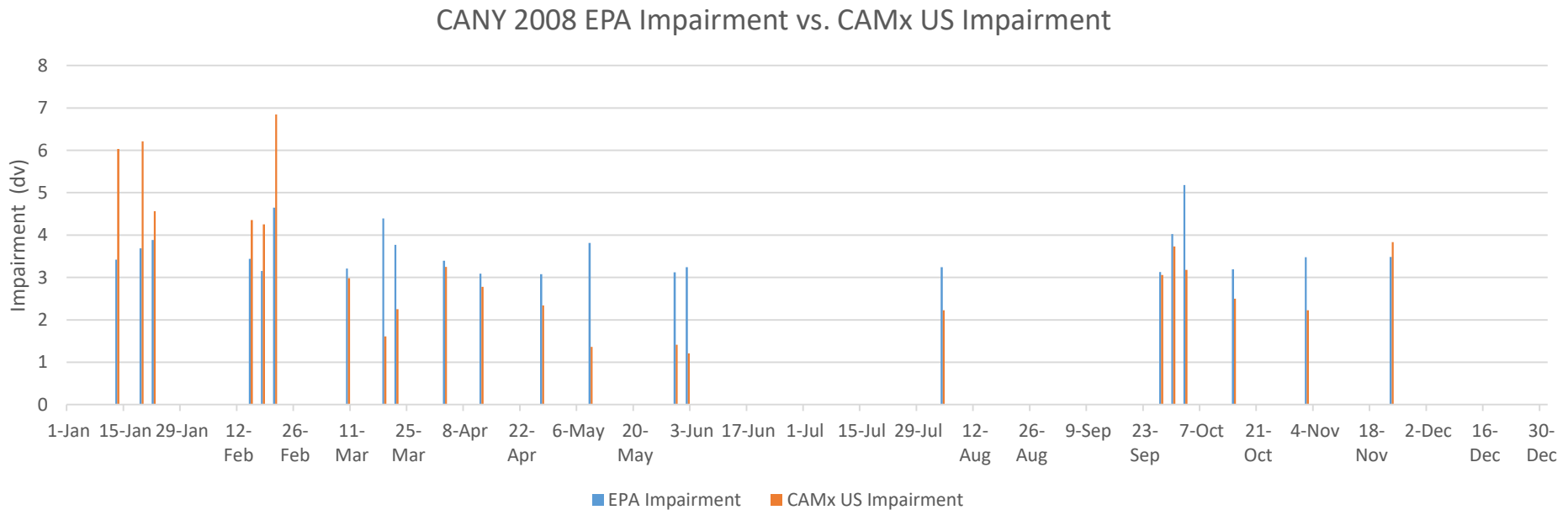
# Recommended Next Steps: Using Models to evaluate RPG

- For sites where modeled US impairment differs significantly from the estimate of impairment based on the IMPROVE data, consider alternate ways to compare the RPG to the URP, e.g., use the NPCA recommended approach of reducing US anthropogenic impairment to zero, or ... other options?

# Extra slides

## Canyonlands, 2008

The average impairment for the EPA 20% most impaired days is 3.6 dv compared to 3.3 dv CAMx US impairment. However, there are large seasonal differences in the impairment. CAMx has much larger nitrate impairment in winter and smaller impairment from sulfate in spring and summer.



## Rocky Mtn National Park, 2008

The average impairment for the EPA 20% most impaired days is 4.73 dv compared to 4.67 dv CAMx US impairment. The seasonal nitrate and sulfate differences are similar to Canyonlands.

ROMO 2008 EPA Impairment vs. CAMx US Impairment

