U.S. DEPARTMENT OF ENERGY | Office of Science

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Evaluation of WRF-Chem Simulations of Carbonaceous and Inorganic Aerosols

Jerome Fast, Vinoj Velu, Ying Liu, Manish Shrivastava, and Rahul Zaveri

- Utilize **extensive measurements** collected during the **CalNex and CARES** campaigns to evaluate regional predictions (Δx = 4 km) of aerosol mass, composition, size distribution, and optical properties

'clean' conditions observed → *challenging for models to accurately represent 'clean' conditions*

- Understand the sources of uncertainties associated with **simulated aerosol radiative forcing** over California
- Determine the relative importance of **long-range transport** and **local emission sources** on aerosol loading and radiative forcing

Weather Research Forecasting (WRF) Model

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

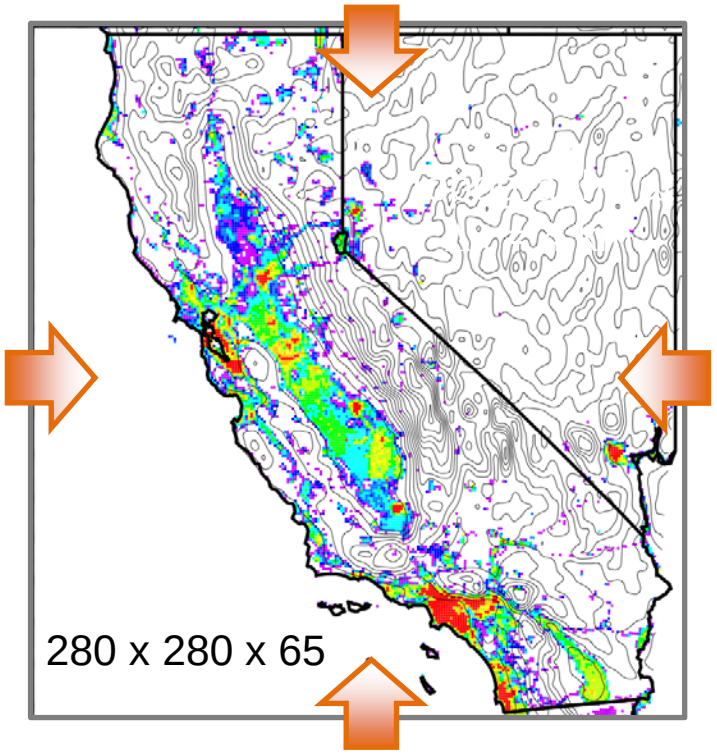
Meteorology:

- Boundary Layer: MYJ
- Land Surface: Noah
- Radiation: RRTMG
- Microphysics: Morrison
- Convection: new Kain-Fritsch
- IC/BC: GFS + analysis nudging

Chemistry:

- Trace Gases: SAPRC
- Photolysis: FTUV
- Aerosols: **MOSAIC, 8 size bins,**
- **Volatility Basis Set approach for SOA**
- Direct effect on, indirect effect off
- Wet Scavenging: **off**
- IC/BC: **MOZART**

Simulation Period:
May 1 – June 30, 2010

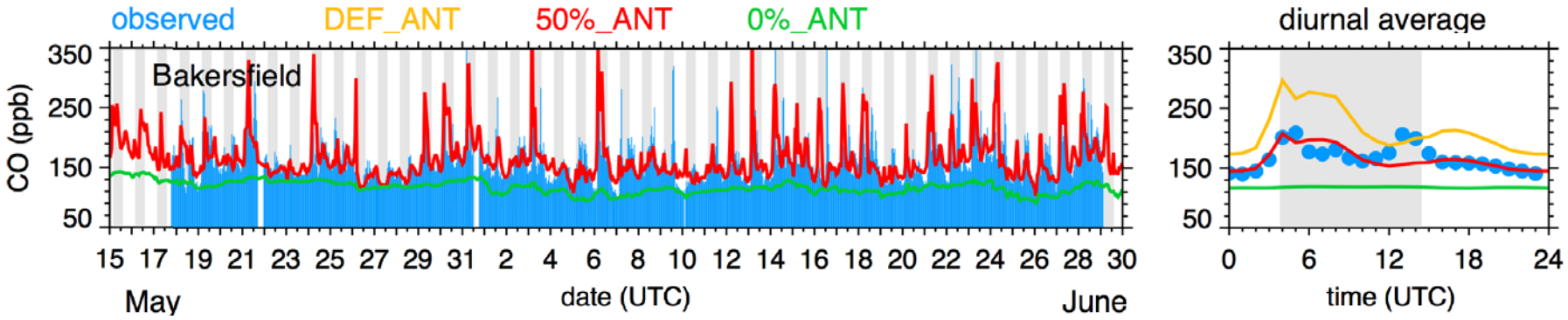


Effects of Long-Range Transport of Trace Gases and aerosols from Global Model

Four WRF-Chem Simulations

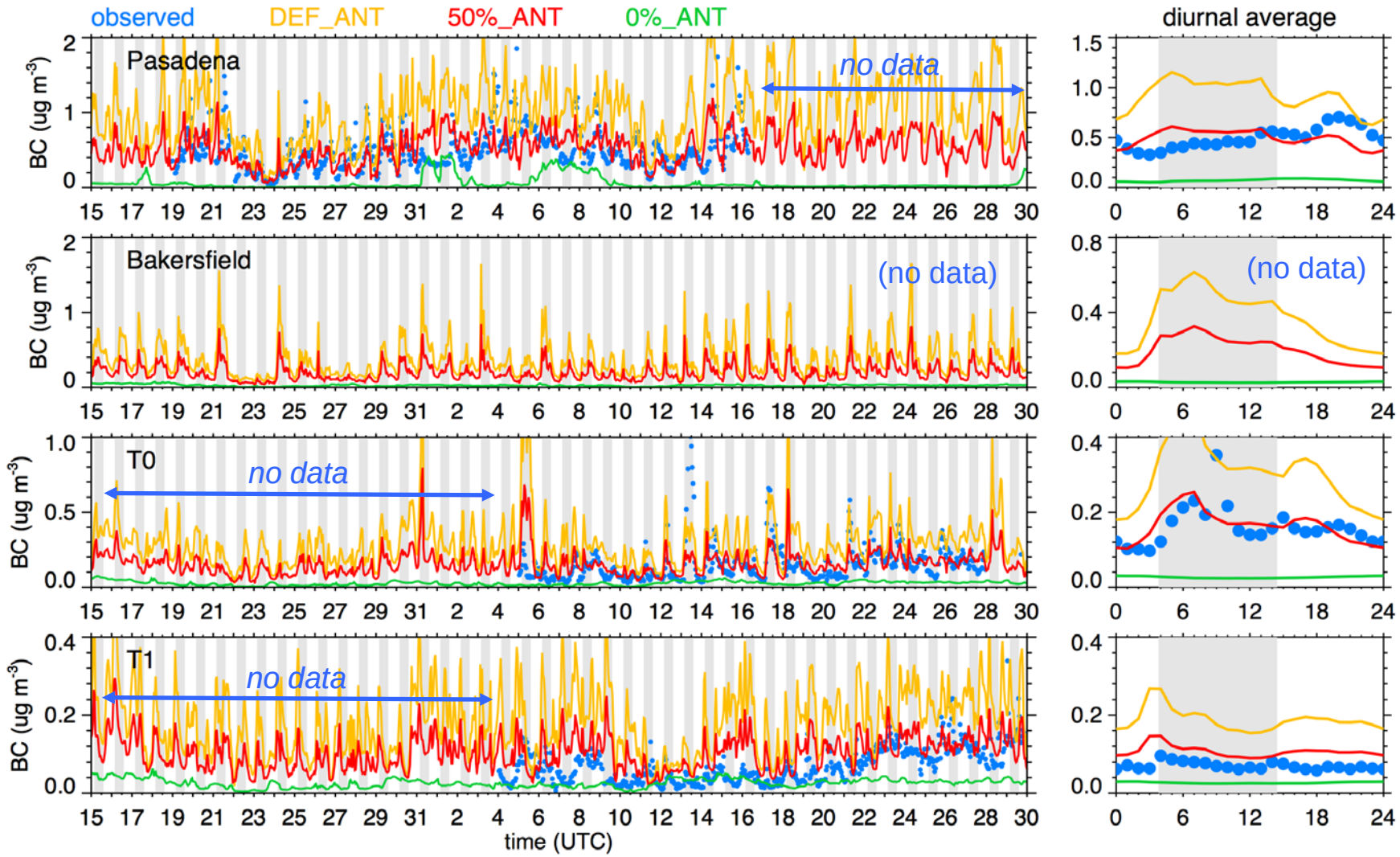
- **Default:** CARB 2008 inventory — DEF_ANT
- **Sensitivity 1)** 50% CARB inventory (except SO_2 and NH_3) — 50%_ANT
- **Sensitivity 2)** no anthropogenic emissions — 0%_ANT
- **Sensitivity 3)** same as 1), but MOZART aerosol for boundary conditions reduced by 50% — 50%_LBC

- Initial simulations (as well as other modeling studies) suggest that CARB 2008 inventory is too high, especially for CO, NOx, POA, and BC
- For example at Bakersfield:



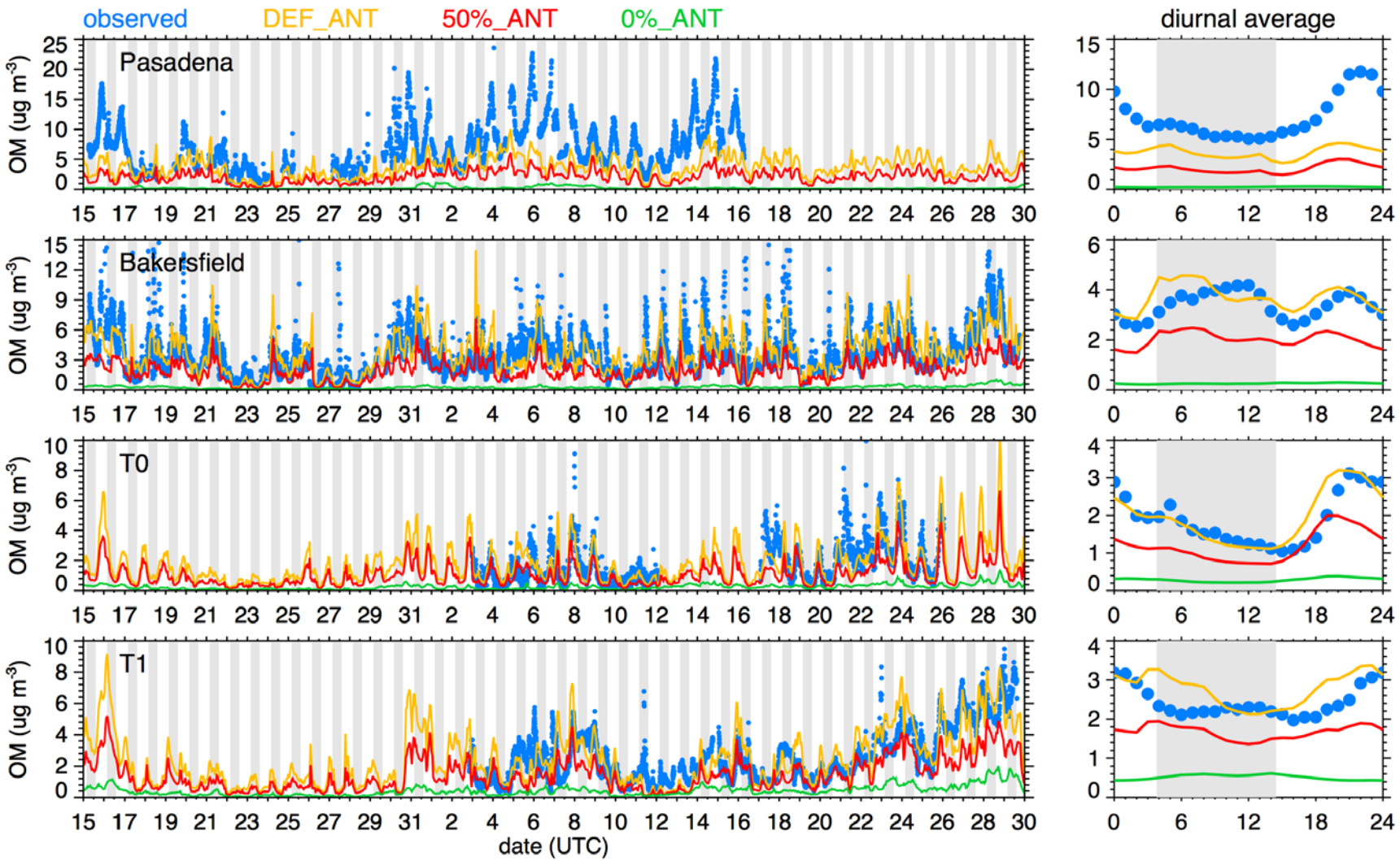
Results: Aerosols

Black Carbon at the Supersites



- Simulated BC improved when anthropogenic emissions reduced by 50%, but correlation could be improved

Organic Matter at the Supersites

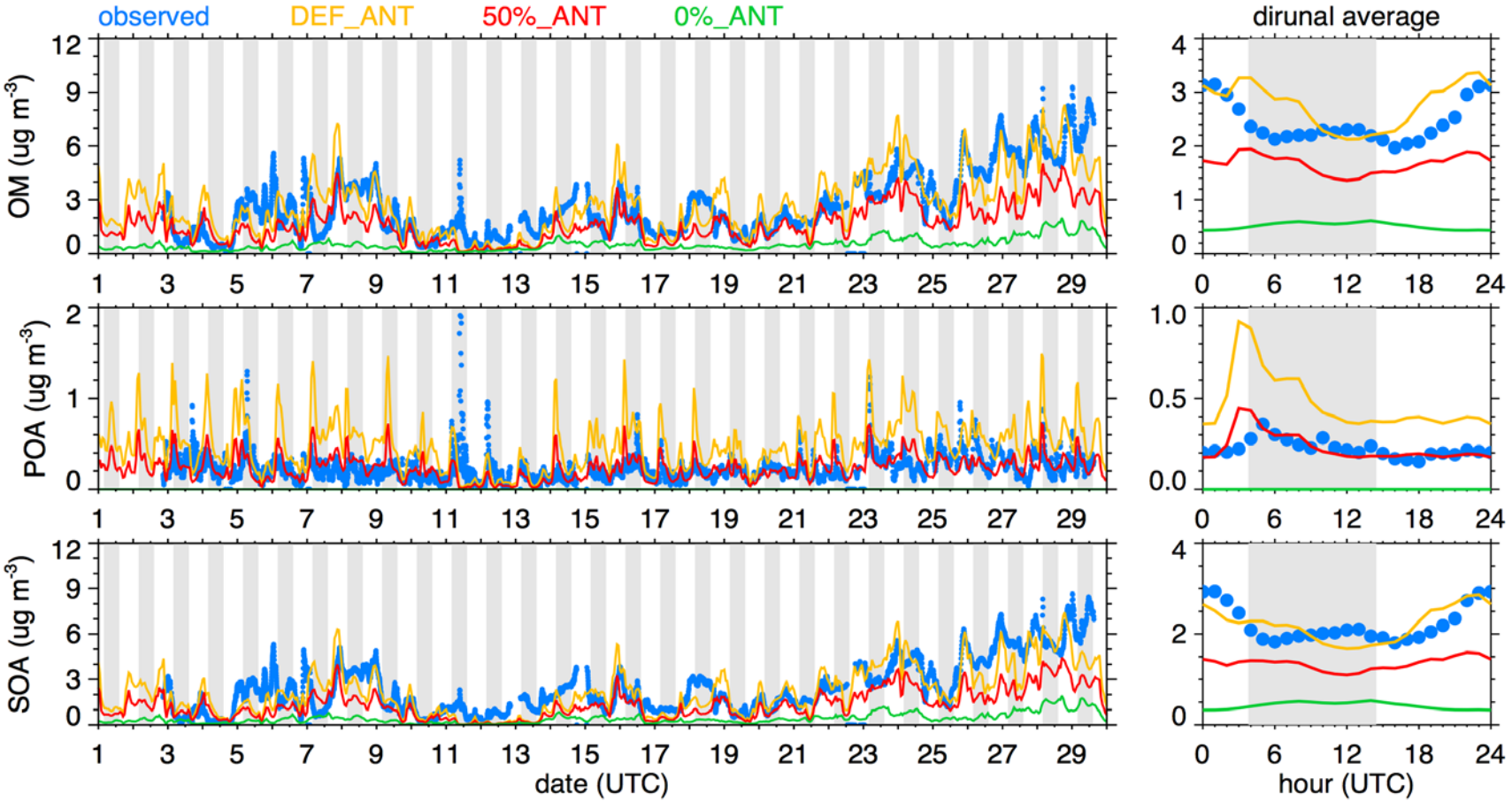


- Simulated OM too low when anthropogenic emissions reduced by 50%, but need to examine **components** of organic aerosols …

Organic Aerosol Components at T1

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Use of Postive Matrix Factorization to Determine POA and SOA from Aerosol Mass Spectrometer (AMS) data

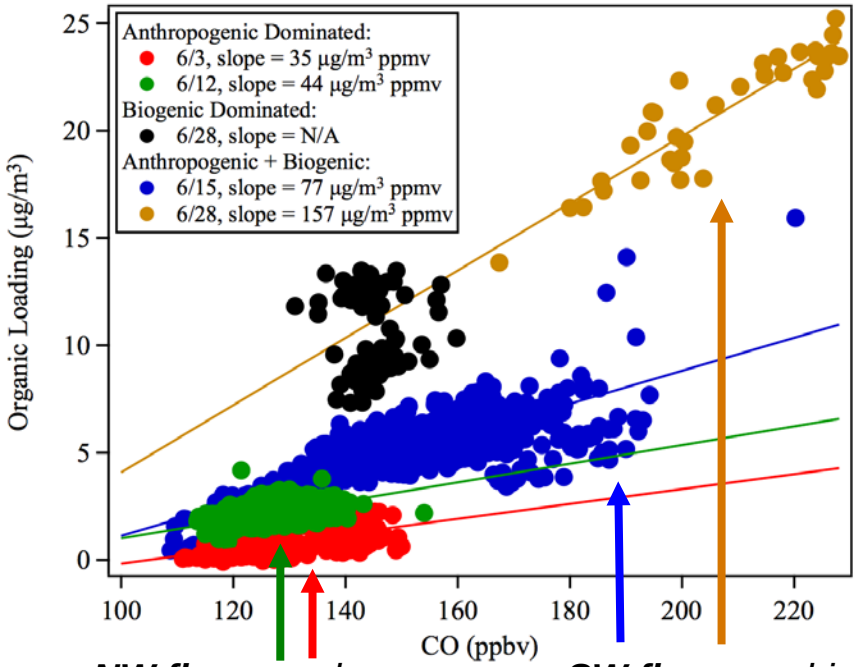


- Simulated POA from 50%_ANT in better agreement with PMF analysis
- Simulated SOA too low, missing **anthropogenic-biogenic interactions**

Role of Anthropogenic-Biogenic Interactions

- Shilling et al., ACP (2013) use G-1 AMS and PTR-MS data to show that OM is enhanced when anthropogenic and biogenic emissions mix together

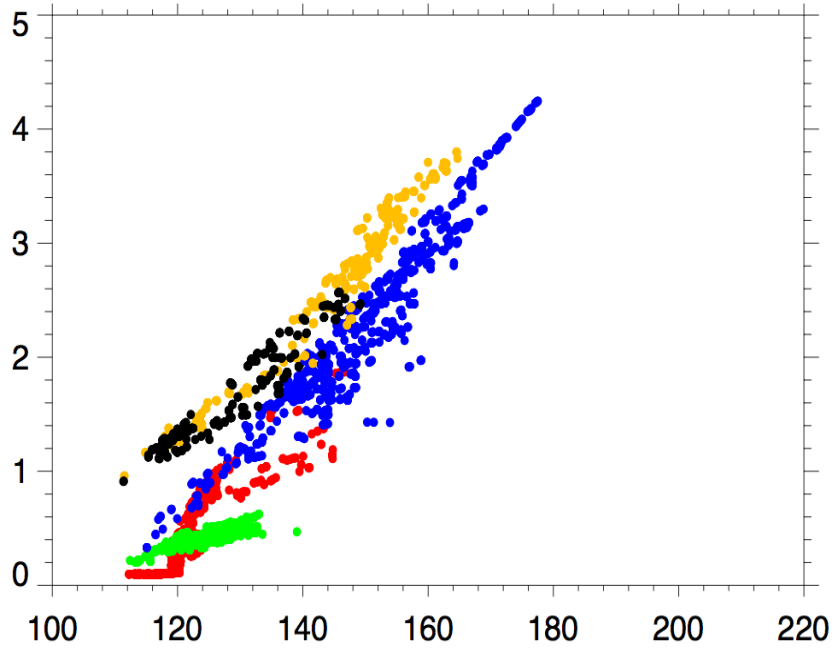
slope give measure of SOA production efficiency



***NW flow** over low biogenic emission regions*

***SW flow** over high biogenic emission regions*

Current WRF-Chem Simulation (50%_ANT)



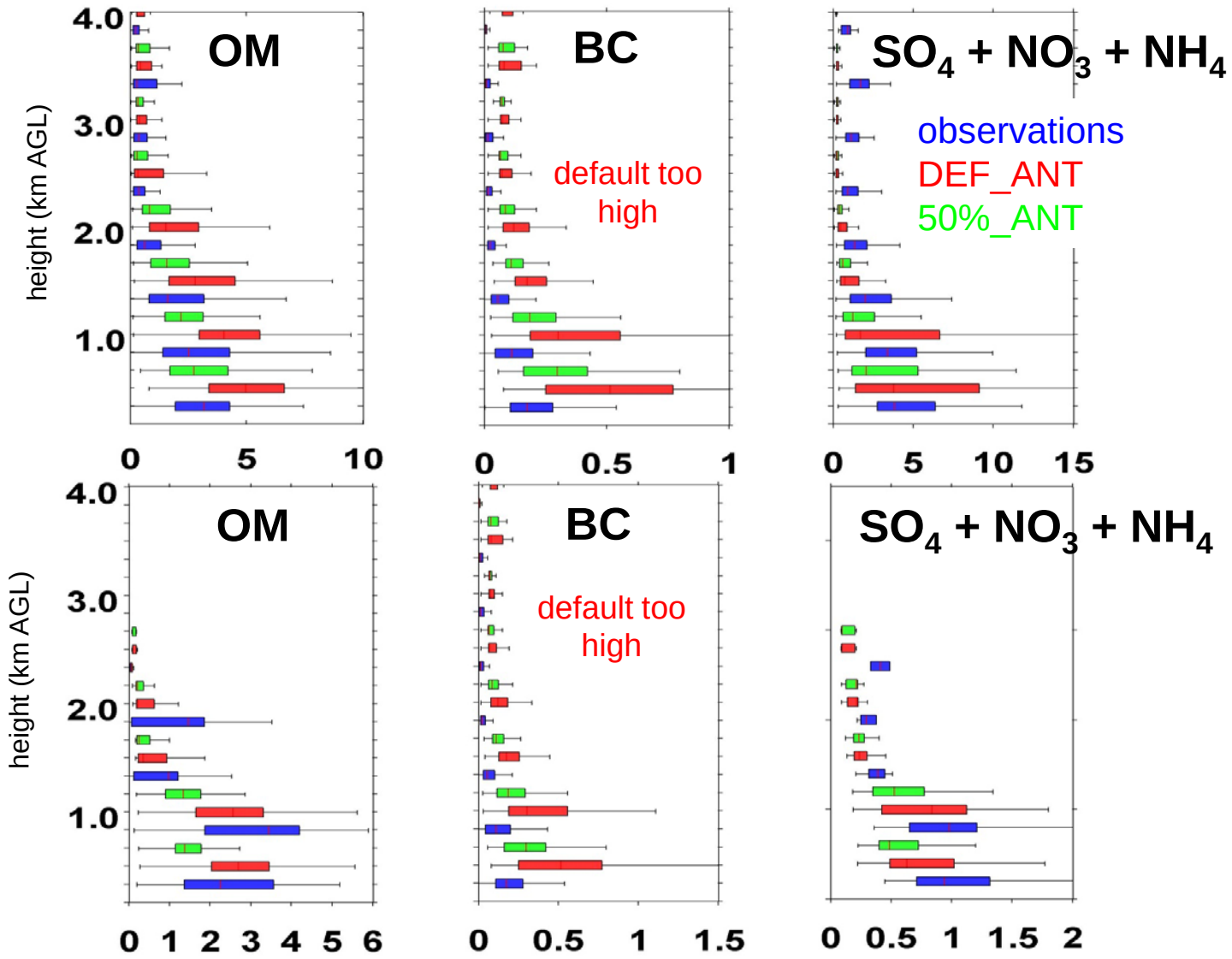
- Chemistry associated with this enhancement is not well known, and therefore not represented by treatments of SOA formation

Aerosol Composition Aloft

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

P-3B flights within +/- 0.5 degrees of Pasadena

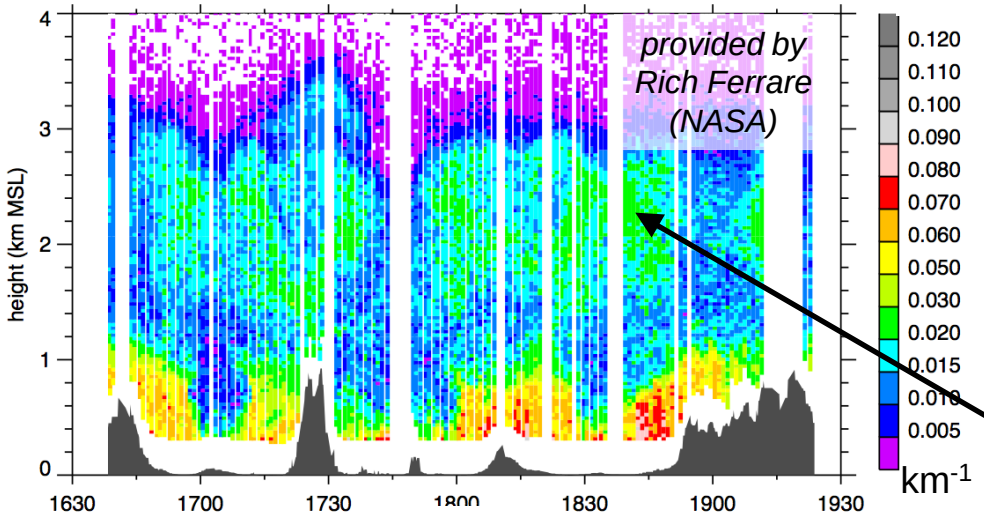
G-1 flights within +/- 0.5 degrees of T0



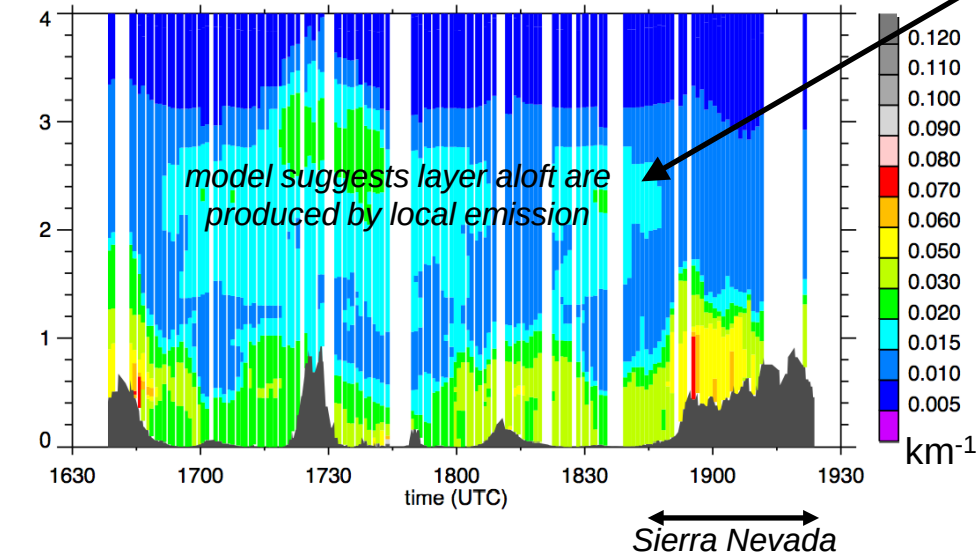
Extinction Profiles – Sacramento Valley

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

High Spectral Resolution Lidar – June 27

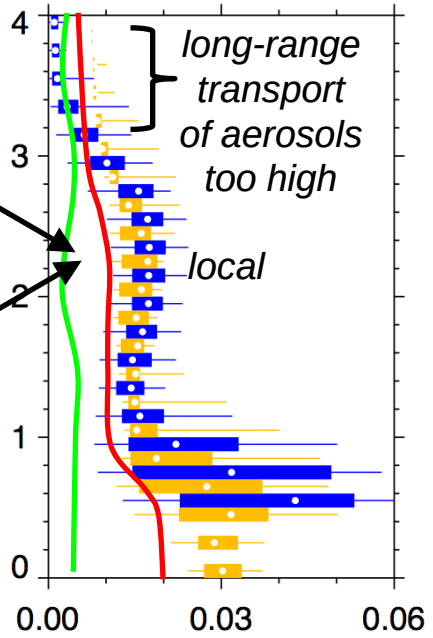


Simulated Extinction



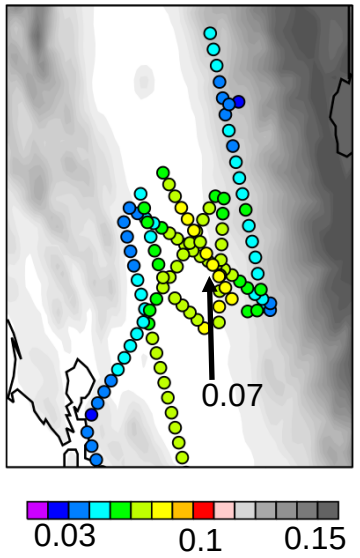
Percentiles

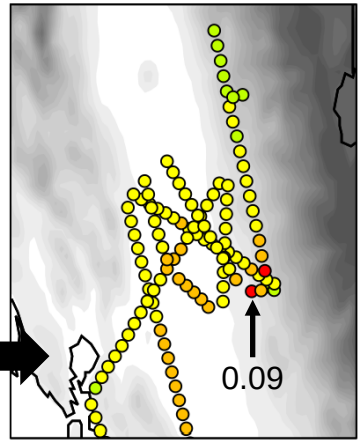
observed
DEF_ANT
50%_ANT
0%_ANT



long-range transport errors lead to positive biases in AOT

Observed AOT



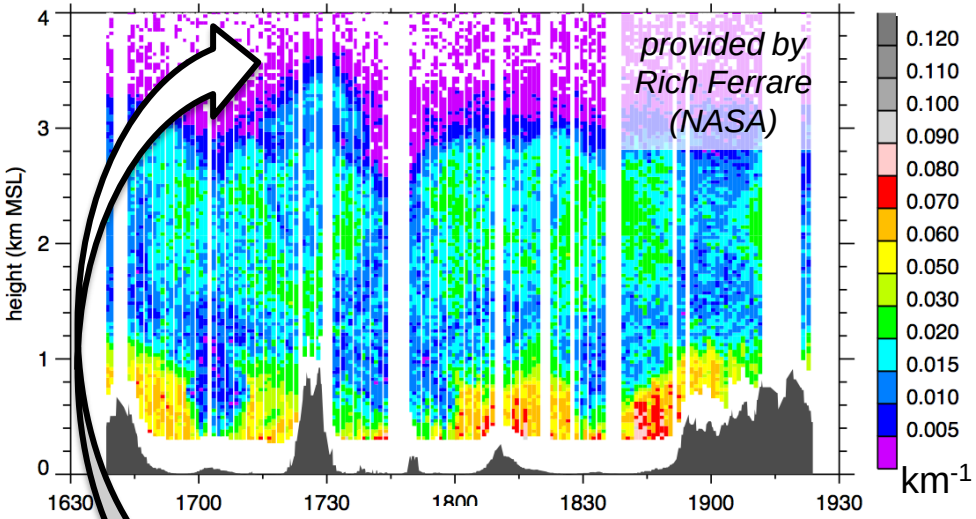


Simulated AOT

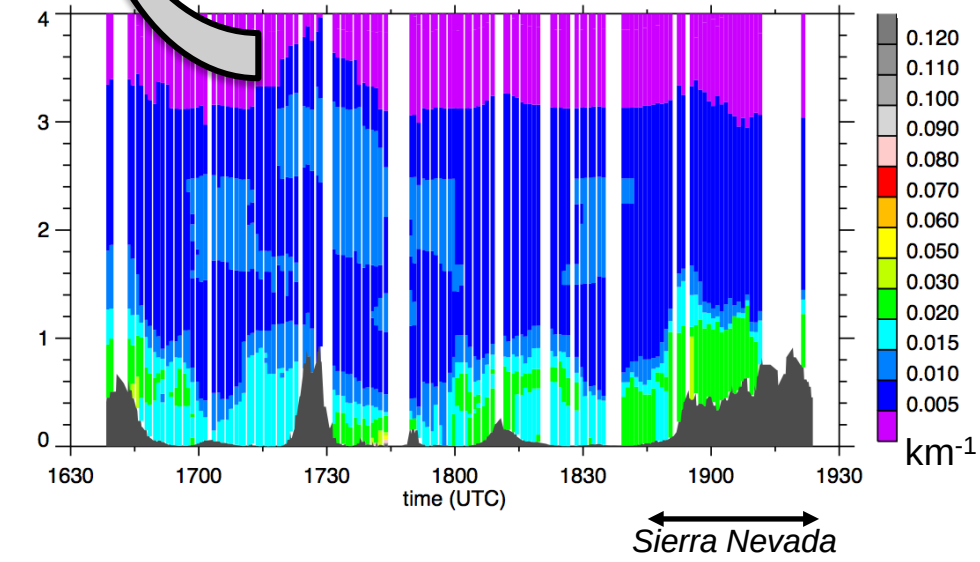
Extinction Profiles – Sacramento Valley

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

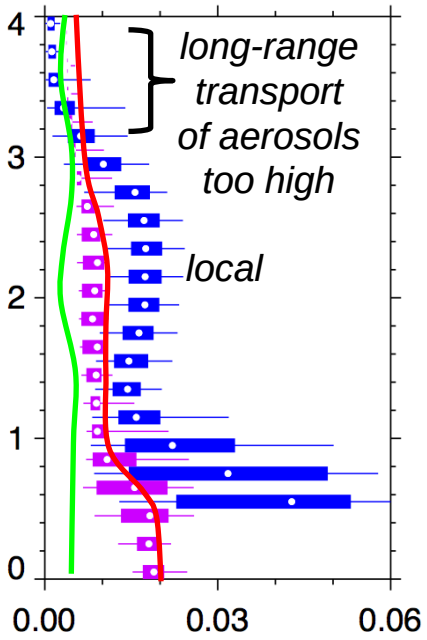
High Spectral Resolution Lidar – June 27



Simulated Extinction

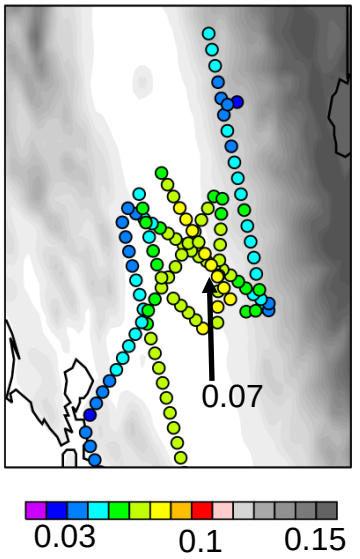


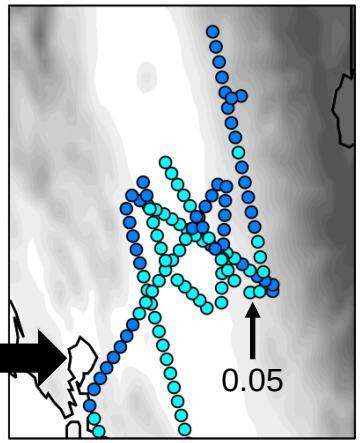
Percentiles



AOT now lower than observed, consistent with BL aerosols

Observed AOT





Simulated AOT

Summary

- Model is able to capture general spatial and temporal variations in aerosols reasonably well; however, simulated …
  - ***BC*** *too high unless emission rates reduced*
  - ***OM*** *too low (uncertainties in SOA), especially in southern CA*
  - ***SO_4*** *too low in southern CA , better represented in northern CA*
  - ***NO_3*** *too low everywhere, but better represented in southern CA*
- Spatial variations in extinction and AOT agree reasonably well with Lidar, errors in magnitude consistent with errors seen with in-situ data
- Emission inventories **are not** the only source of error
  - ***Long-range transport*** *of aerosols likely too high (both dust and anthropogenic)*
  - *Adjustments in emissions likely* ***depends on region***
- High bias in long-range transport leads to a positive bias in AOT and thus total radiative forcing (bias in transport offset to some extent by low bias in local aerosol sources)