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Simulated Carbonaceous and Inorganic Aerosols and their Effect on Radiation during the CalNex and CARES Campaigns in California

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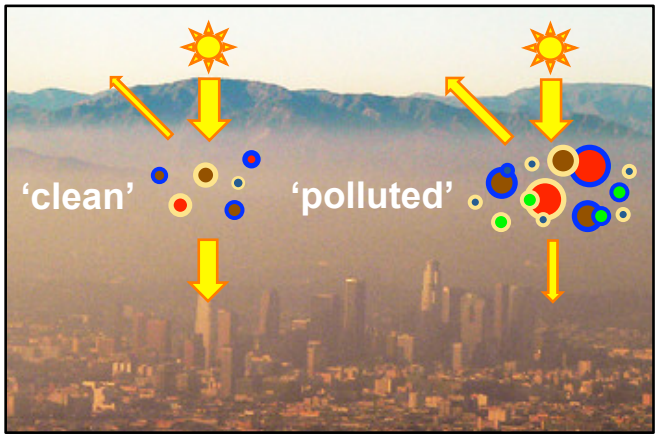
13th Annual WRF Users' Workshop, 28 June 2012

Objectives

- Quantify the uncertainties associated with modeling the aerosol direct effect by using the extensive meteorological, trace gas, and aerosol data collected over California during May – June 2010
  - *Emissions of primary aerosols (BC, POA) and gas-phase aerosol precursors*
  - *Treatment of the aerosol lifecycle, particularly secondary aerosol formation (SO_4, NO_3, NH_4, SOA)*
  - *Treatment of aerosol optical properties, particularly coating of black carbon*



- Assess the relative role of anthropogenic and natural aerosols on direct and indirect radiative forcing over California

- This presentation provides an **preliminary evaluation** of one version of WRF-Chem as a first step to reaching the above goals

CalNEX and CARES: Aircraft / Ship

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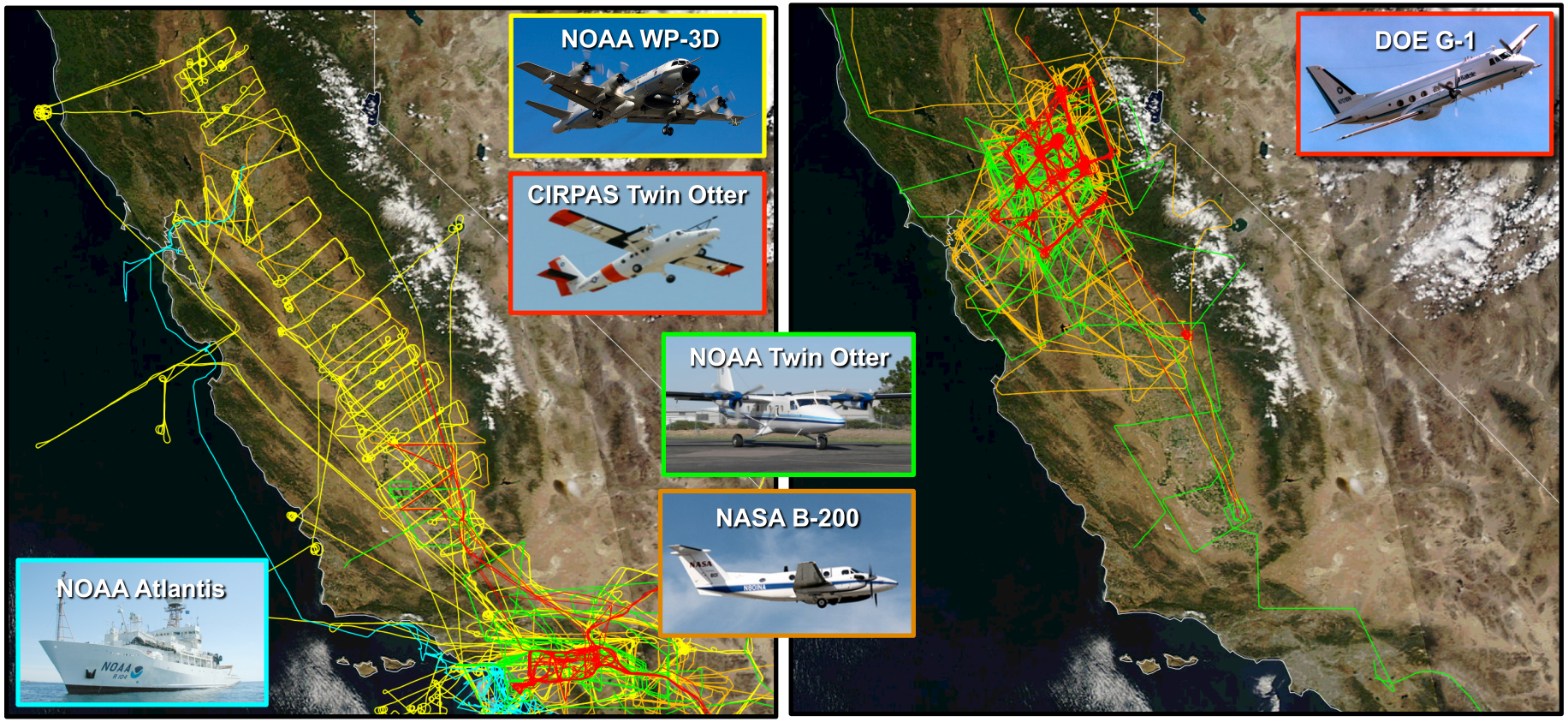
CalNEX Flight Paths
May 4 – June 20

CARES Flight Paths
June 3 - 28

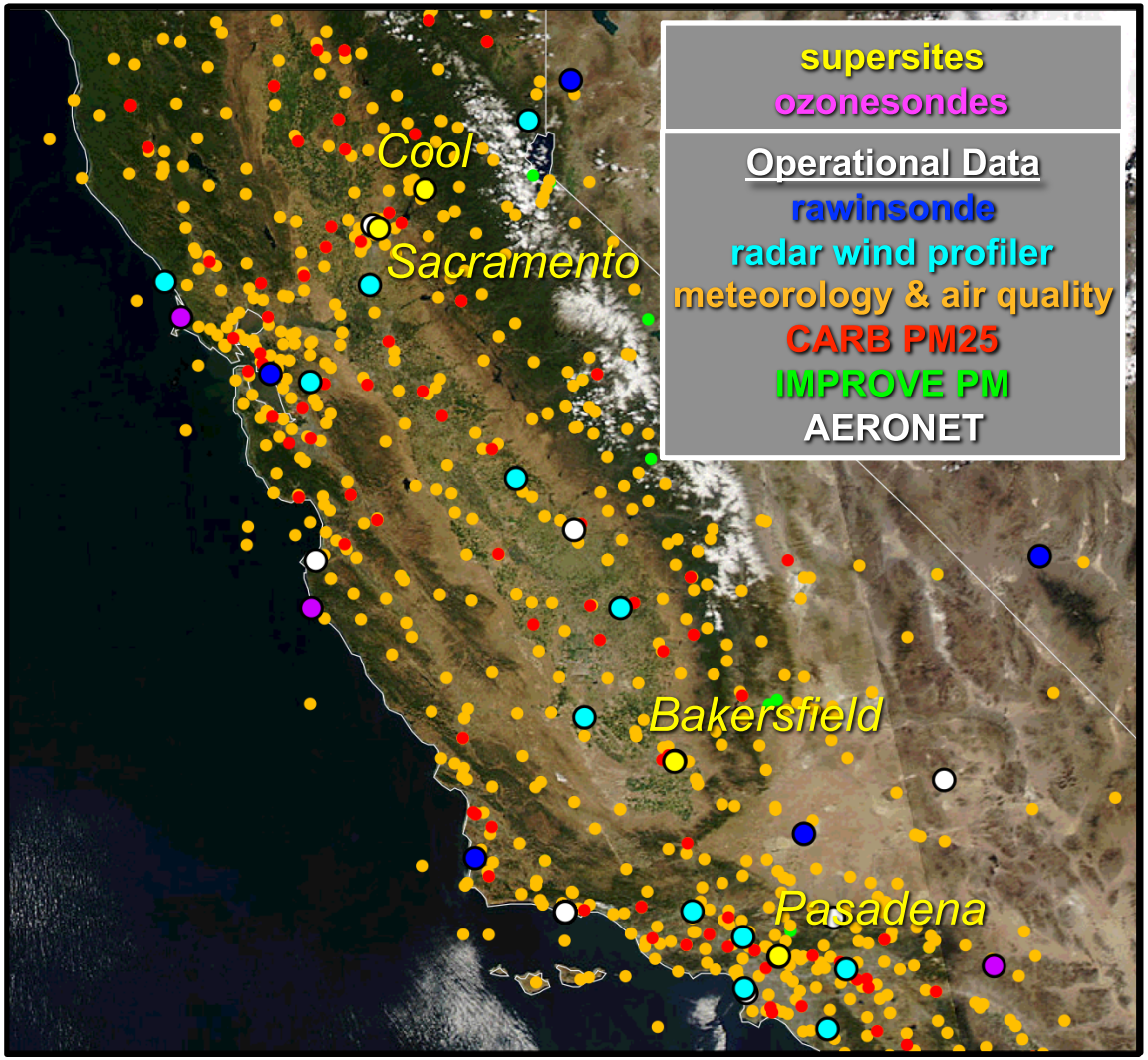


complimentory studies

mostly southern California ⟷ ***mostly northern California***

some overlap in time

CalNEX and CARES: Surface



- Four primary sites with a wide range of instrumentation, e.g.
  - AMS
  - SP2
- Extensive routine measurements of meteorological, air quality, and column integrated aerosol optical property quantities

Aerosol Modeling Testbed (AMT)

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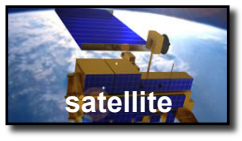
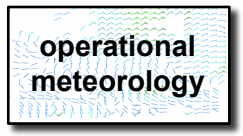
Development of a Evaluation Testbed Case for the Community

Test and Compare Process Modules

CARES





+

CalNex

coming soon

Testbed Case

Software Extraction, Statistics, Graphics

available in a couple of weeks

ARM CLIMATE RESEARCH FACILITY
Data Archive
http://www.arm.gov

Scientist

WRF and WRF-Chem Community

WRF-Chem v3.3.1 Configuration

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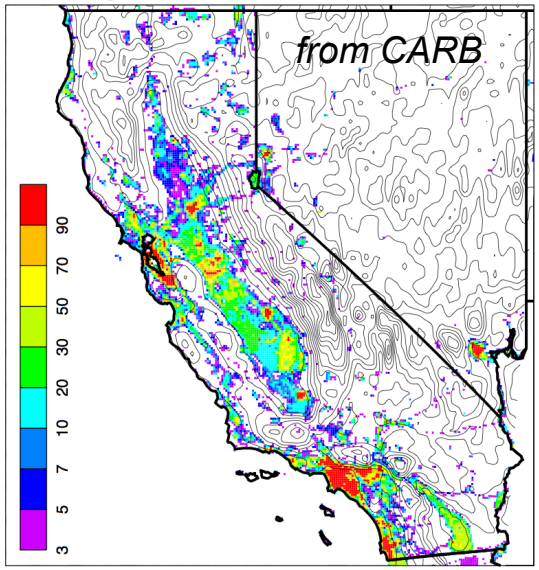
Meteorology:

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

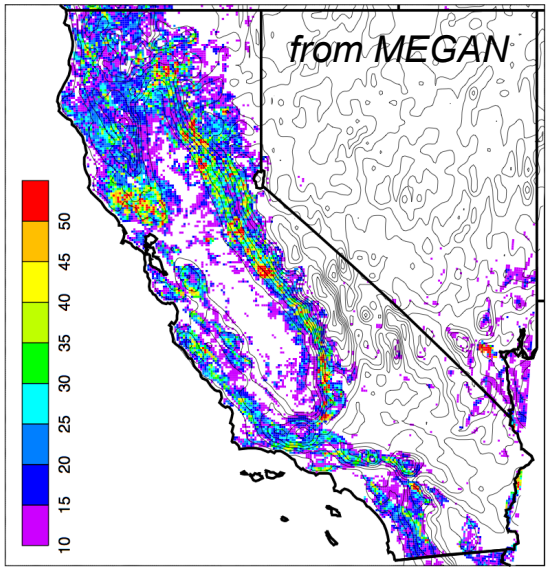
Chemistry:

- Trace Gases: SAPRC
- Photolysis: FTUV
- Aerosols: MOSAIC, 4 size bins, VBS SOA
- Direct effects on, indirect effects off
- Wet Scavenging: off
- IC/BC: MOZART

Anthropogenic VOC Emissions



Biogenic Isoprene Emissions



May 1 – June 30, 2010
Dx = 4 km, 65 vertical levels

- **Anthropogenic** emissions from CARB 2008 inventory; trace gases reduced by 33%
- On-line **biogenic** emissions from MEGAN
- On-line **sea-salt** emissions
- Currently off: on-line **dust** emissions, **biomass burning** emissions

Effect of Aerosols Solar Radiation

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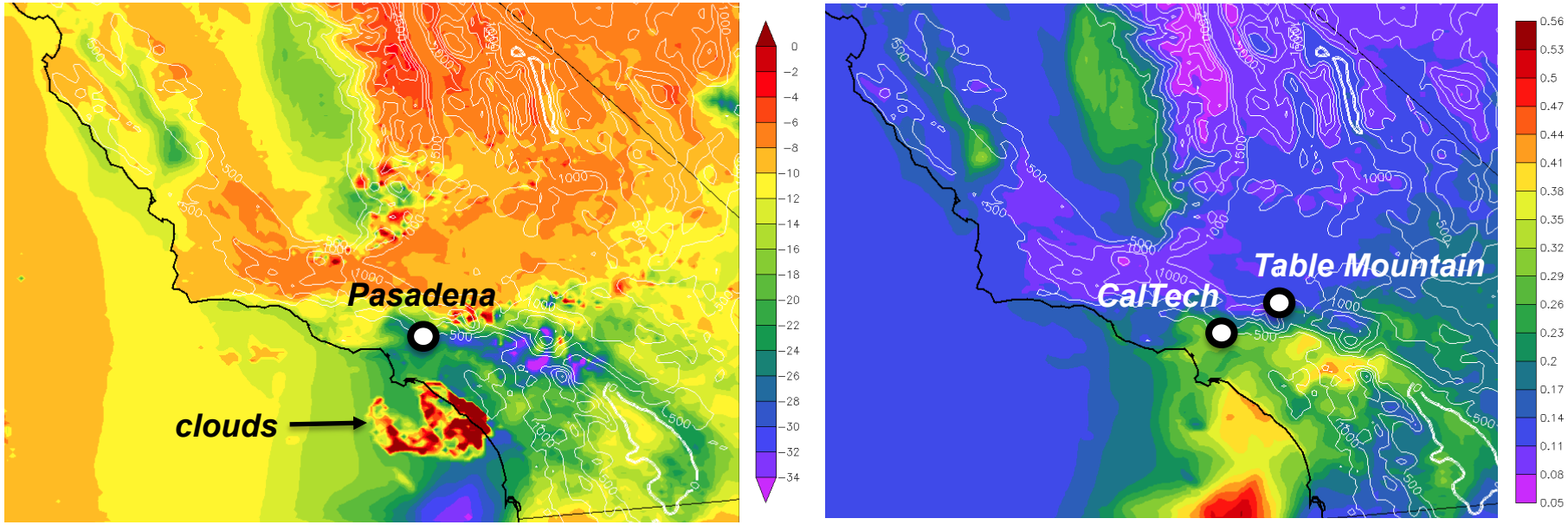
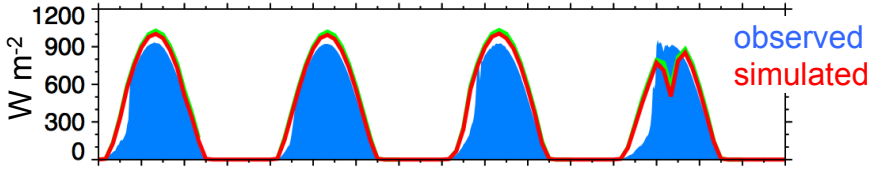
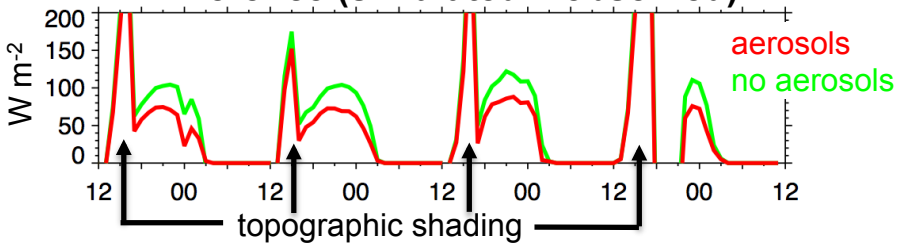
D Shortwave Radiation 21 UTC, 5 June 2010 **AOD 400 nm**



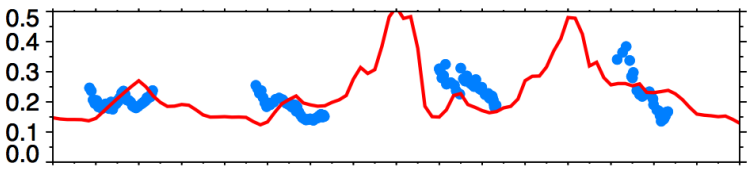
Solar Radiation at Pasadena, June 5 – 9



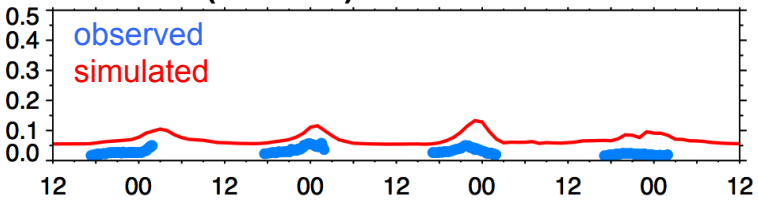
Difference (simulated – observed)



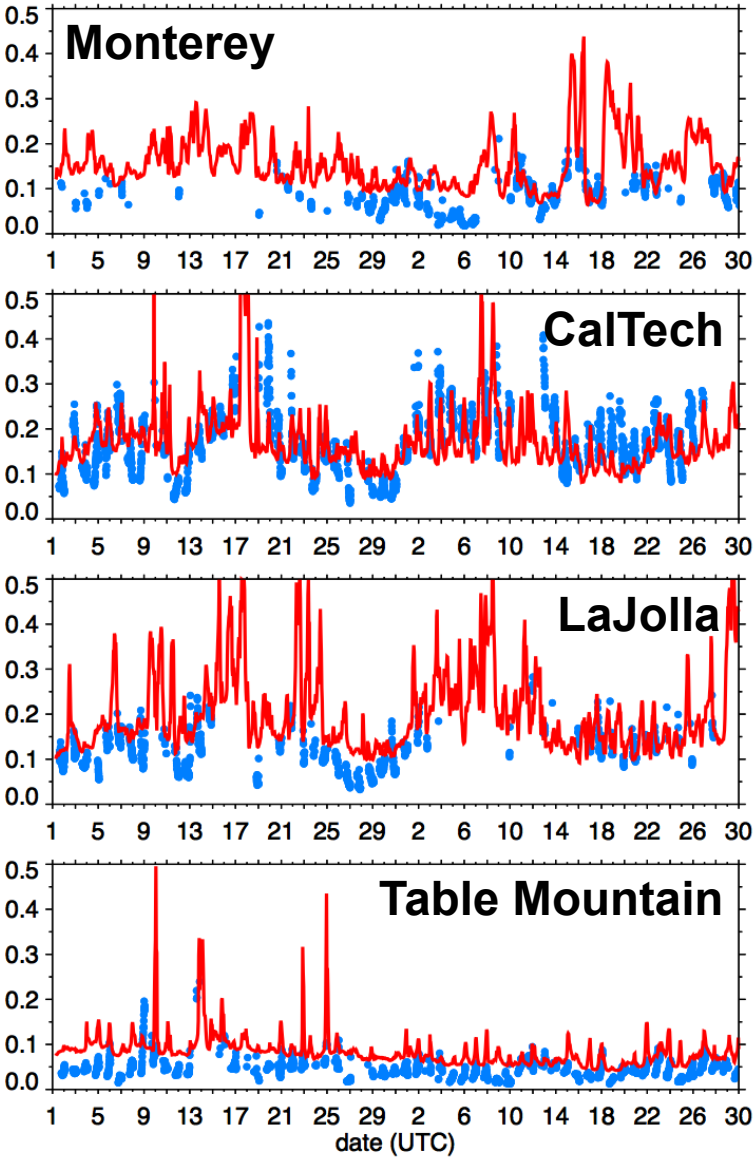
AOD (500 nm) at CalTech, June 5 - 9

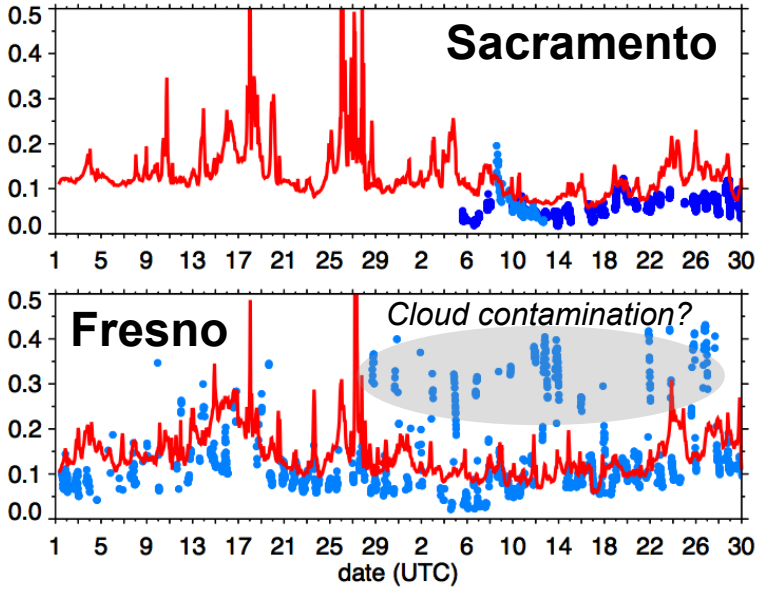


AOD (500 nm) at Table Mountain



AOD over Two-Month Period





- Differences in AOD among sites simulated reasonably well, but …
- AOD usually too high, except at CalTech

Spatial Variability of Extinction – Sacramento

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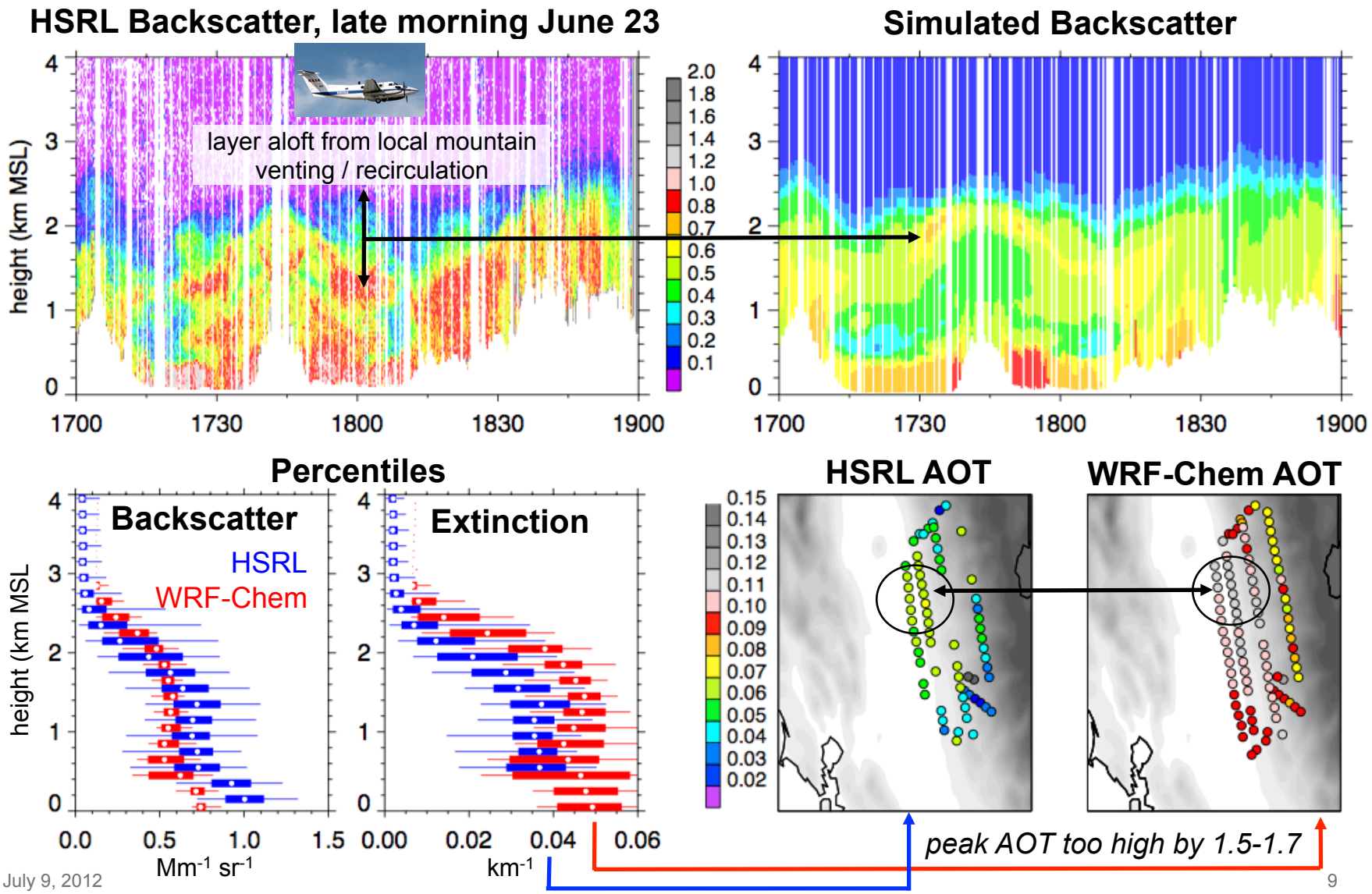

Spatial Variability of Extinction – Sacramento

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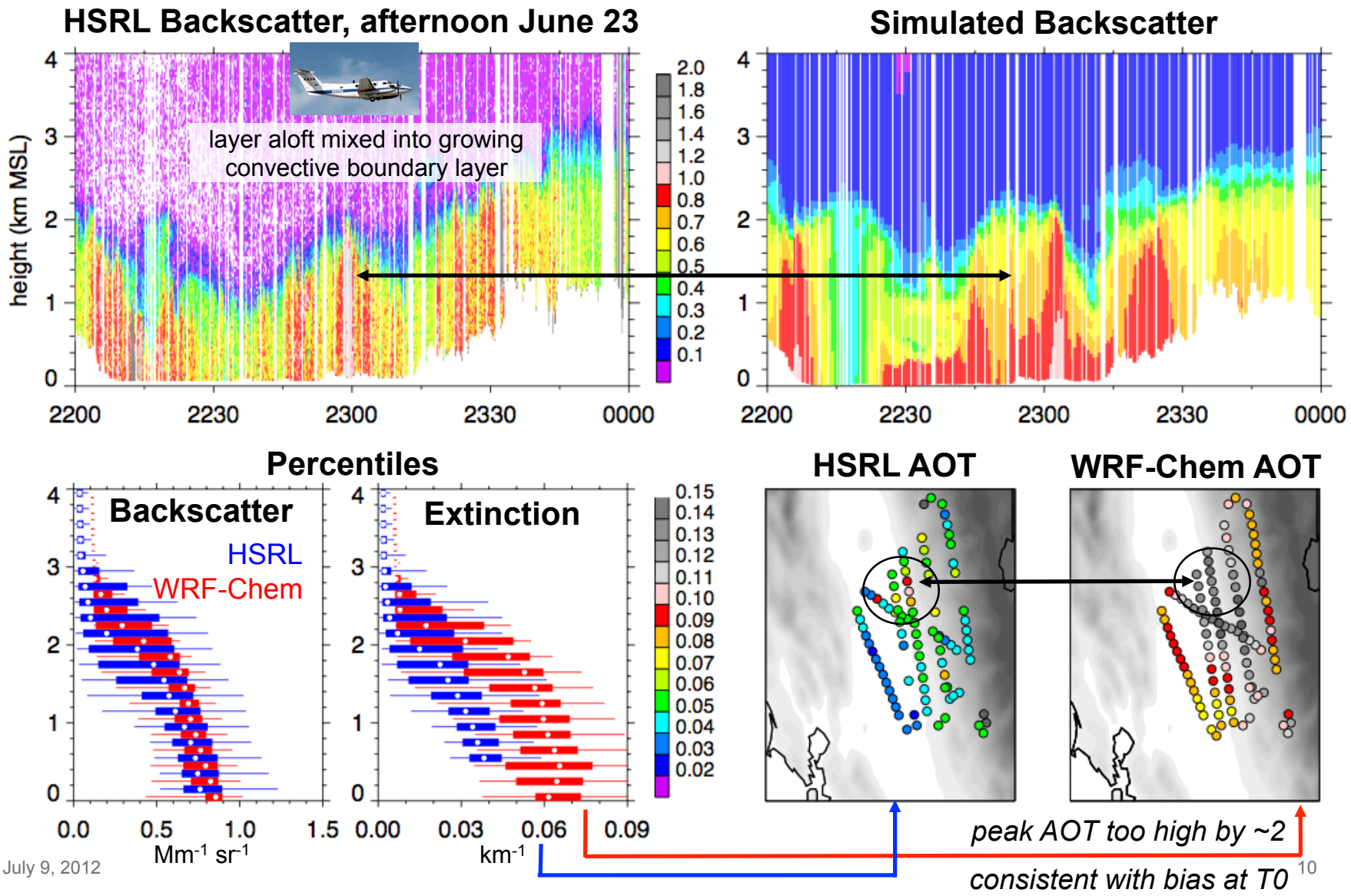
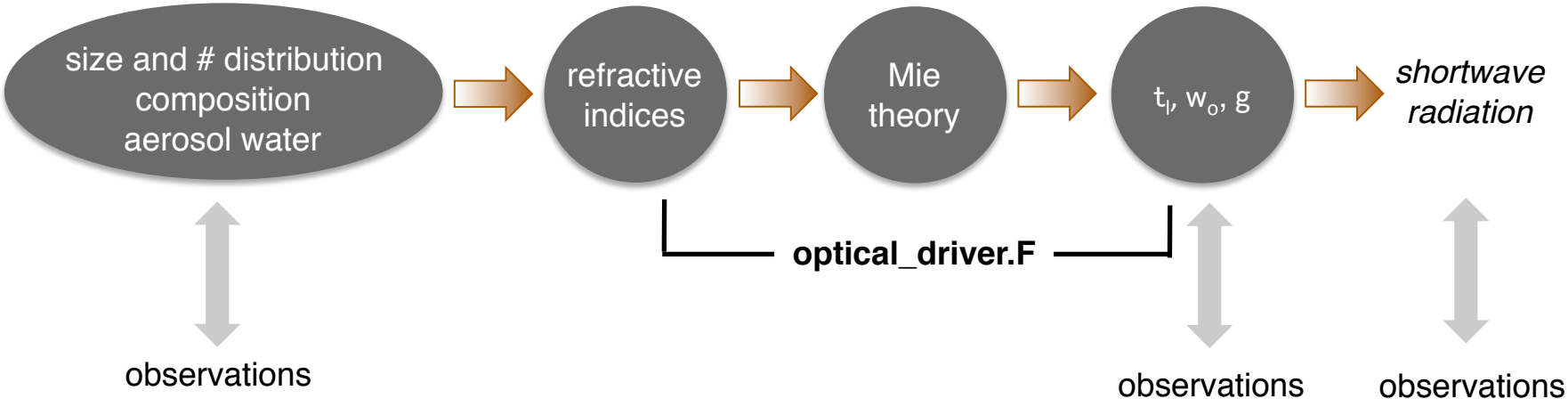
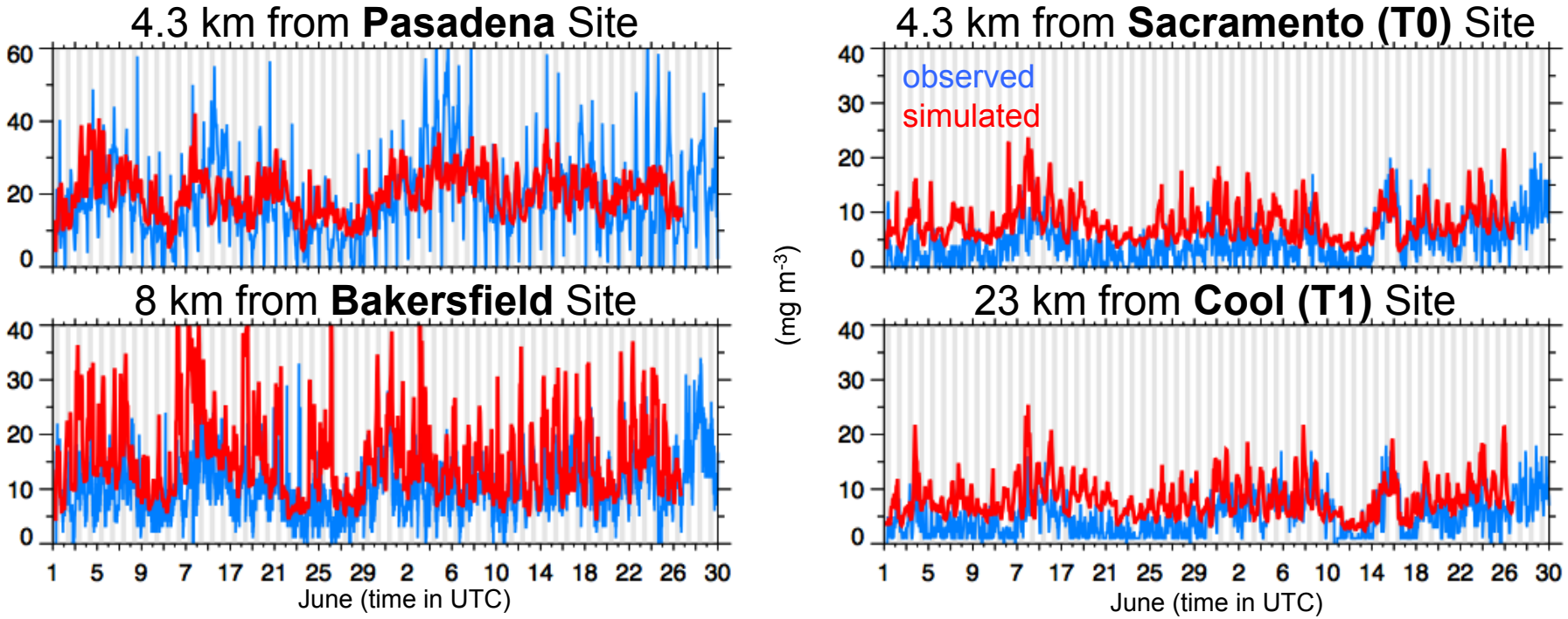


Now What?

- Even though simulated AOD is reasonable at Pasadena supersite, the simulated impact on radiation is too low. Why?
- Simulated AOD and extinction usually too high elsewhere when compared with AERONET and aircraft lidar measurements, but model biases among both sets of measurements are consistent
- What are the primary uncertainities in aerosol mass, composition, and optical properties (including Idependence) that contribute to biases in AOD, single scattering albedo, and asymmetry factor?



PM2.5 at Operational Sites



	bias	RMSE	r
Pasadena	1.4	11.1	0.34
Bakersfield	6.0	9.1	0.48
Sacramento	3.7	5.3	0.39
Cool	3.4	5.2	0.33

- Total simulated PM concentrations are usually too high
- Model has some skill for multi-day variability, but errors at shorter time scales lead to lower correlation coefficients

Operational vs Supersite PM

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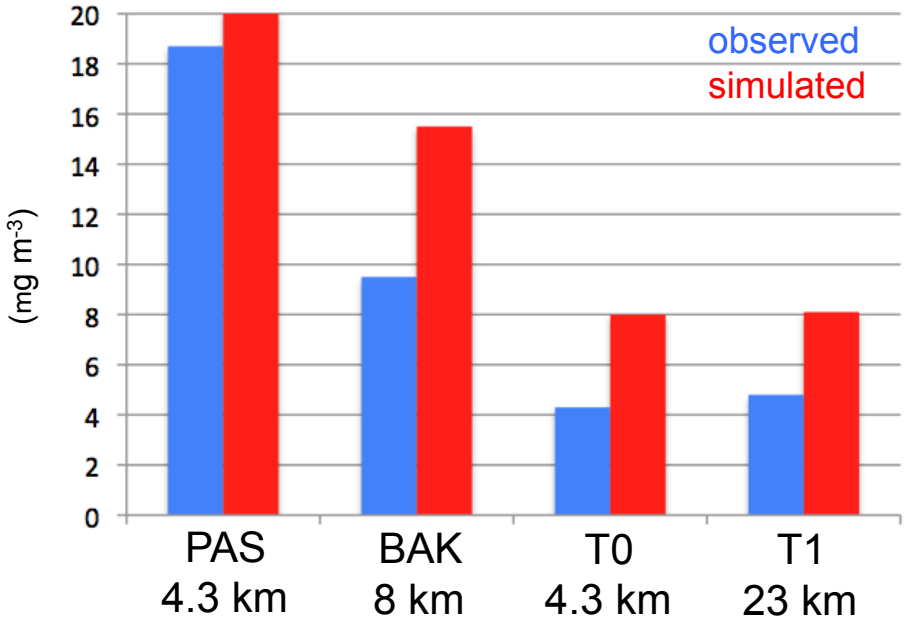
Operational Total PM2.5 Mass

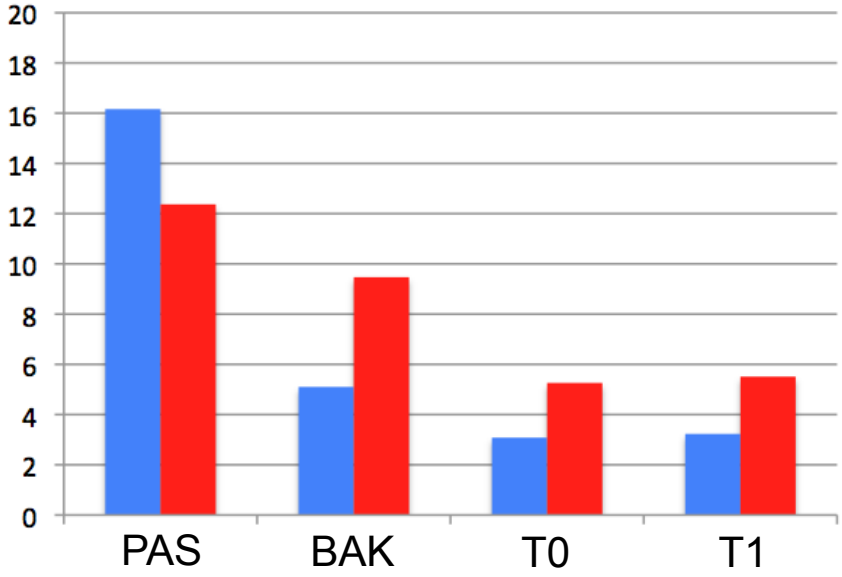
BAM, < 2.5 mm



"nearby" operational stations

Field Campaign AMS + SP2 Mass

AMS < 1 mm, SP2 < 2.5 mm



more mass ⟷ consistent ⟷ less mass

Aerosol Composition – Pasadena Site

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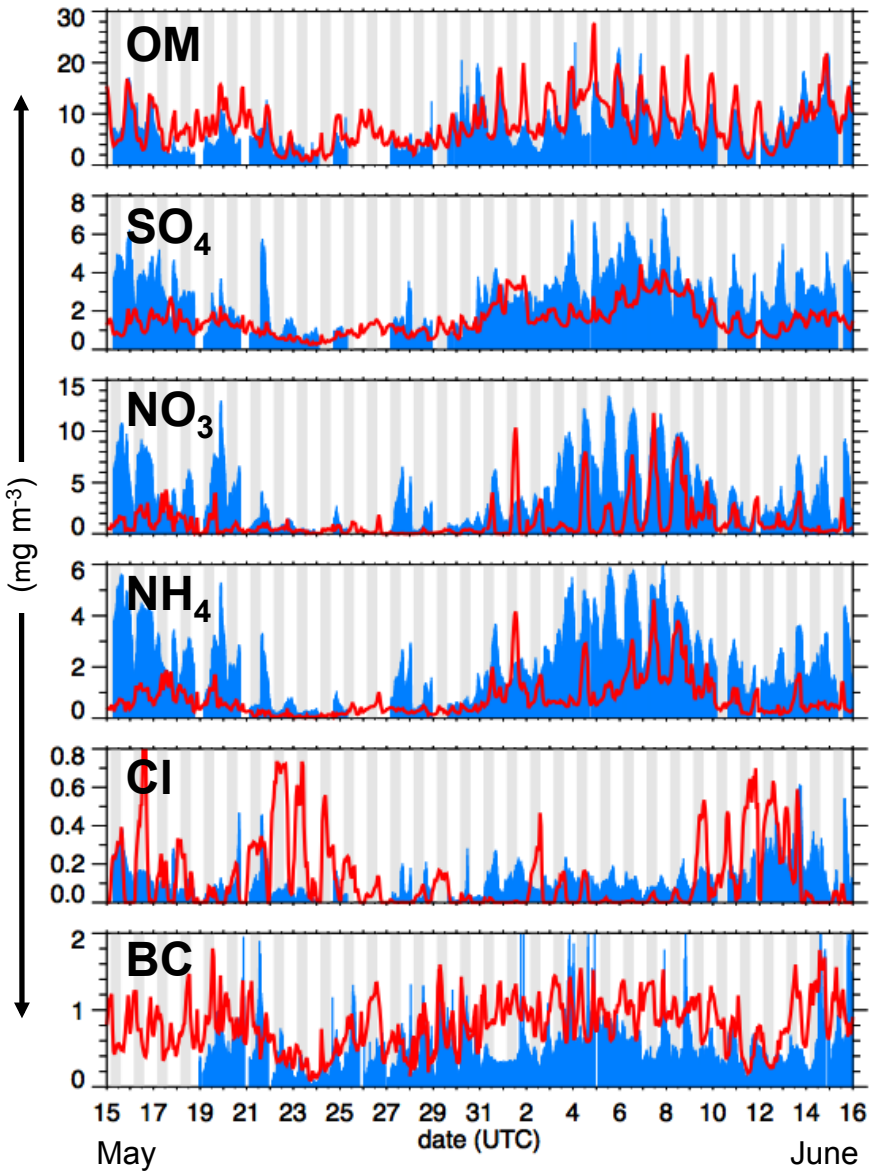

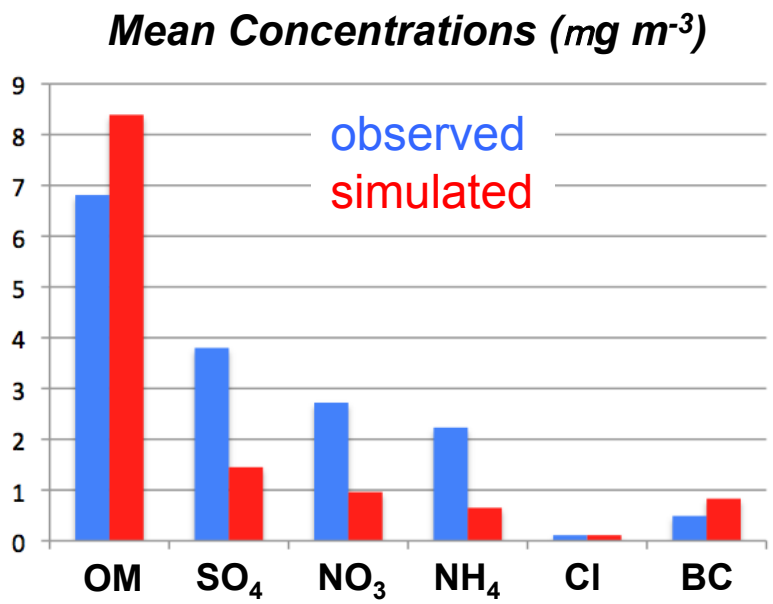

Simulated Quantities

- OM very similar to measurements
- Multi-day and diurnal variability in SO_4, NO_3, and NH_4 similar to observed, but too low overall and missing some peaks
- BC usually too high

Data Sources: Jose Jimenez, James Allen

Surface Aerosol Composition – Supersites

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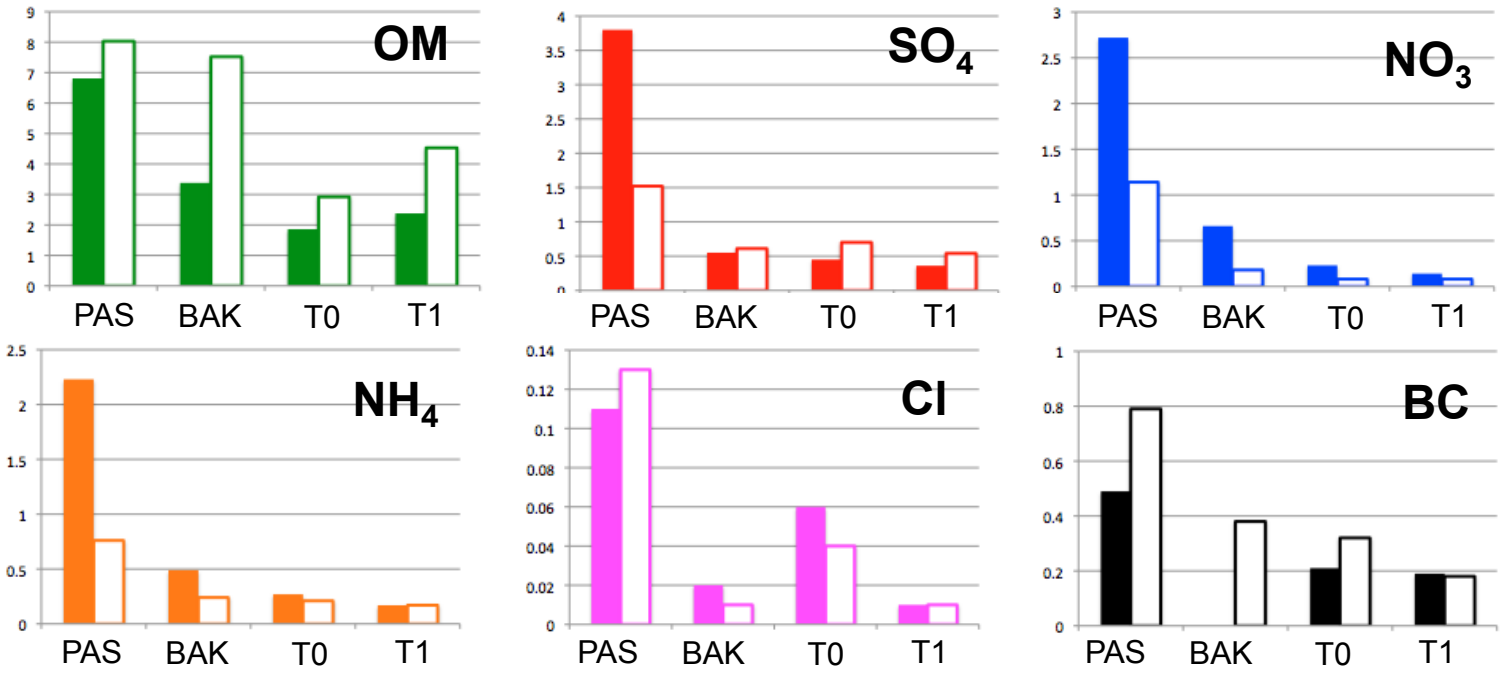
Mean Concentrations (mg m^{-3}) *solid = observed, white = simulated*



Simulated Quantities

- OM too high at Bakersfield, T0, and T1
- SO_4 similar to observed at Bakersfield, T0, and T1, but too low at Pasadena
- NO_3 too low at all sites by factor of 2 - 2.5
- Temporal variation of SO_4, NO_3, and NH_4 similar to measurements

Data Sources: Jose Jimenez, James, Allen, Lynn Russell, Chen Song, Qi Zhang, Random Subramanian

Organic Aerosol Components

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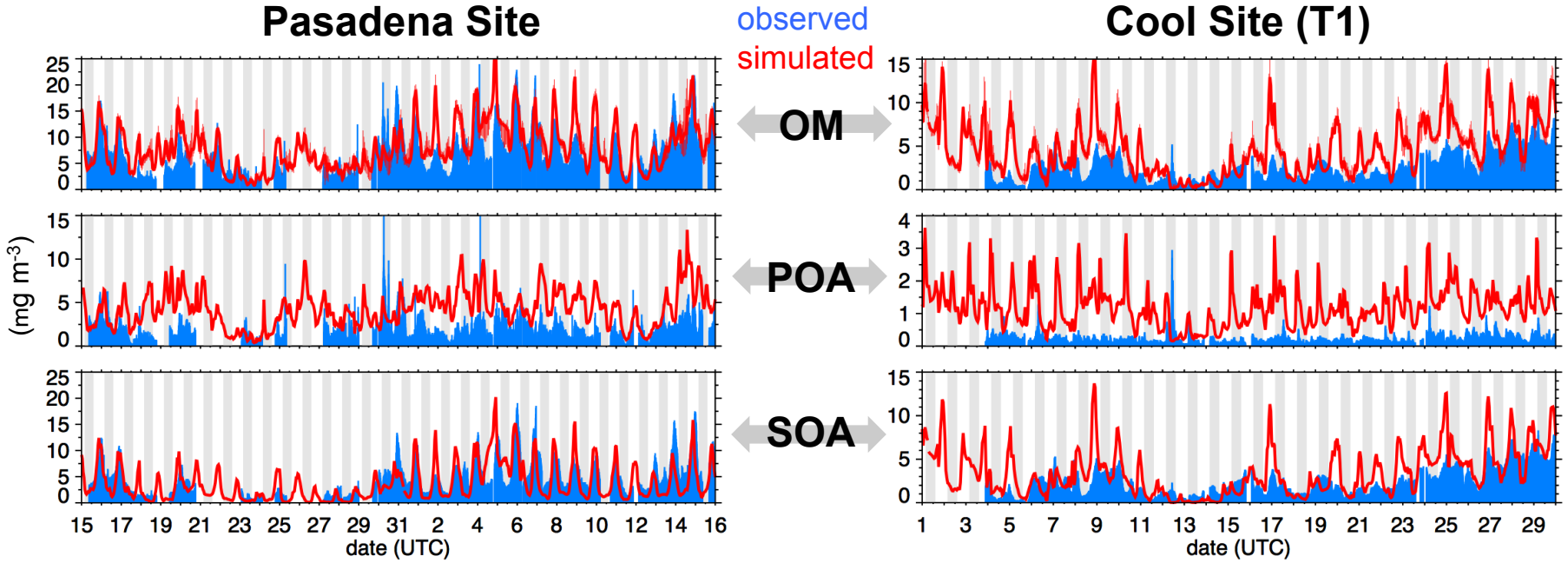
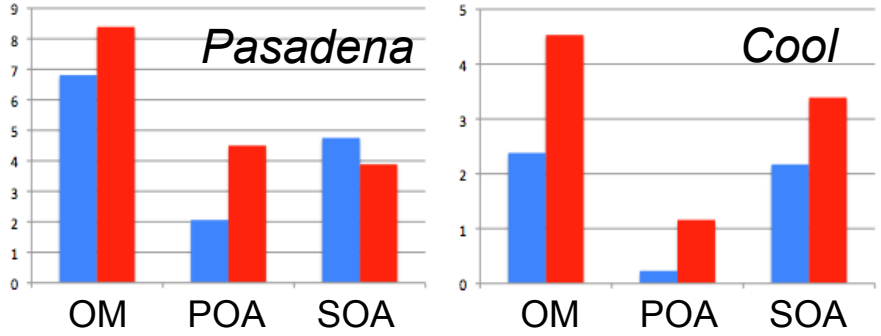


Mean Concentrations (mg m^{-3})



Simulated Quantities

- Temporal variability well predicted
- POA emissions too high ?
- Assumption of 6.5 * POA emissions for semi-volatile and intermediate volatility species likely too high
- Agreement at Pasadena likely fortuitous

Data Sources: Jose Jimenez, Qi Zhang

Aircraft Aerosol Composition – May 31

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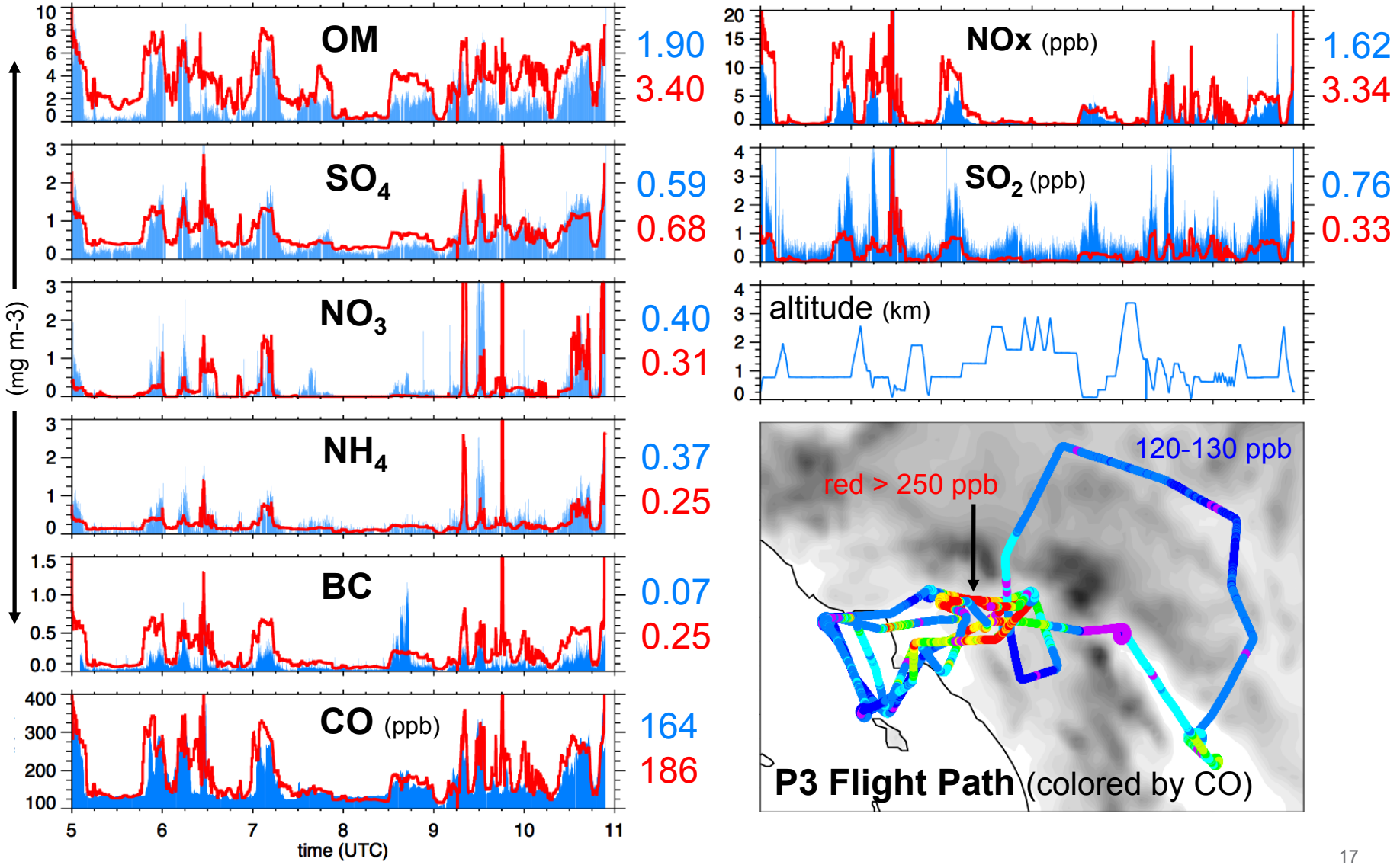

Data Sources: Ann Middlebrook, John Holloway, Joshua Schwartz, Tom Ryerson

Summary

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- CalNex + CARES is an excellent resource to evaluate aerosols
- Aerosol concentrations were “low”, but simulating the effect of aerosols on radiation needs to work well for both clean and extreme conditions
- Reason for the differences between observed and simulated shortwave radiation still under investigation
- Simulated PM and AOD too high: OA and BC too high, but inorganics (SO_4, NO_3, NH_4) too low
  - OA: model assumptions for VBS
  - BC: emissions likely too high
  - Inorganics: combination of meteorology and emissions
- Account for measurement uncertainties

Acknowledgements: Support provided by NOAA’s Climate Program and DOE’s Atmospheric System Research (ASR) program. Thanks to the many investigators for participating in campaigns and providing data.

Extra Slides

All P3 Flights

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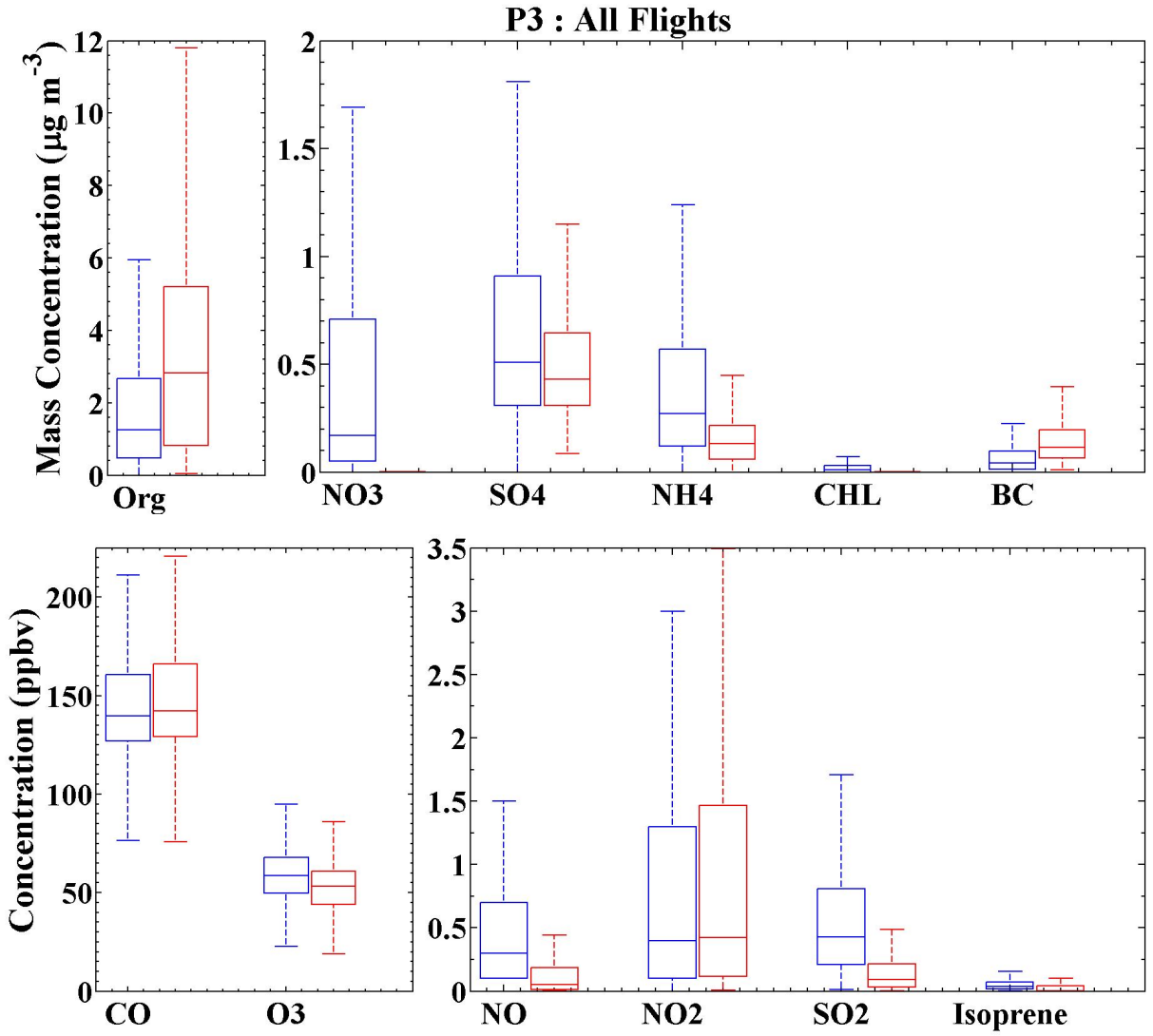
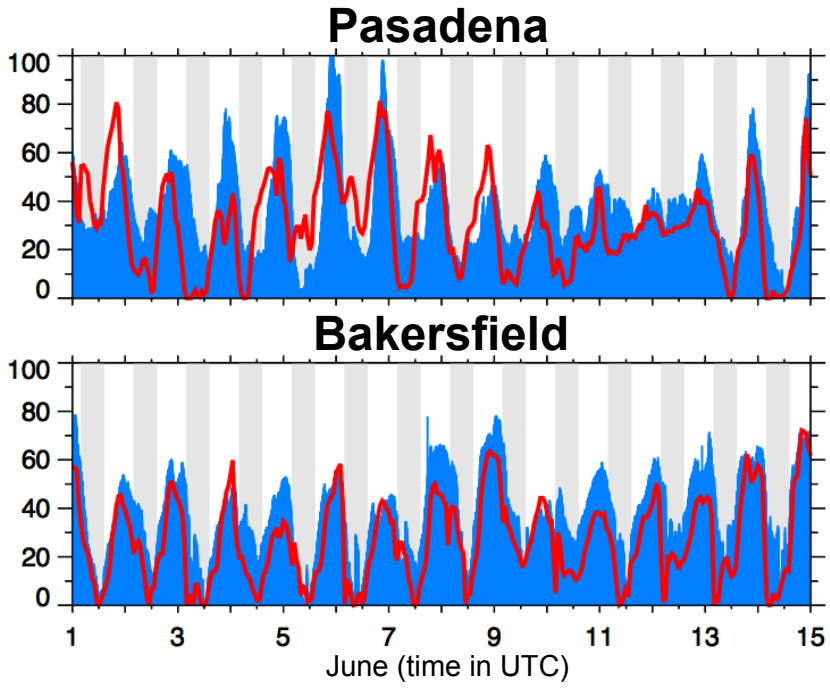
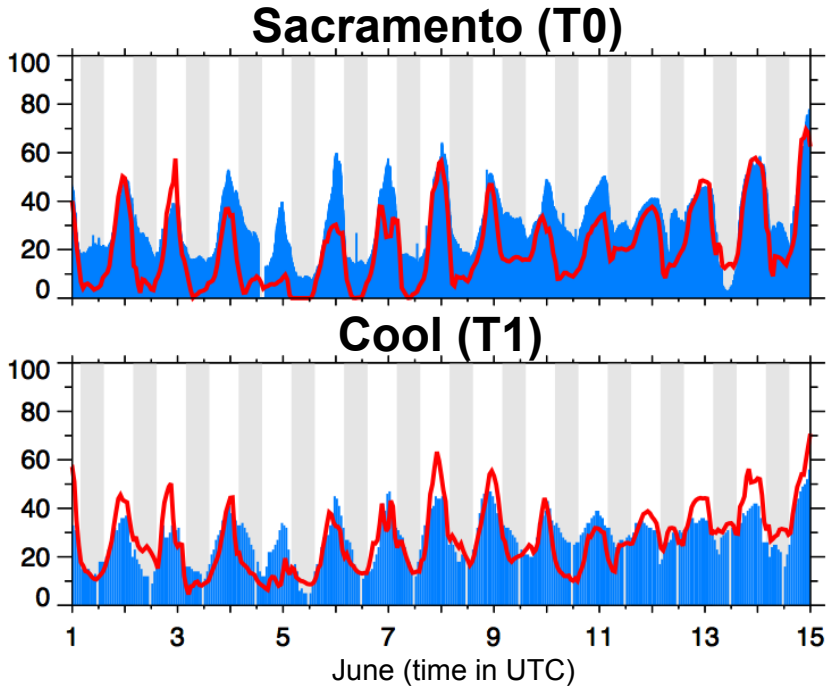
Aerosols

Gases



Regional Photochemistry - Ozone





Spatial Variability of Extinction – Los Angeles

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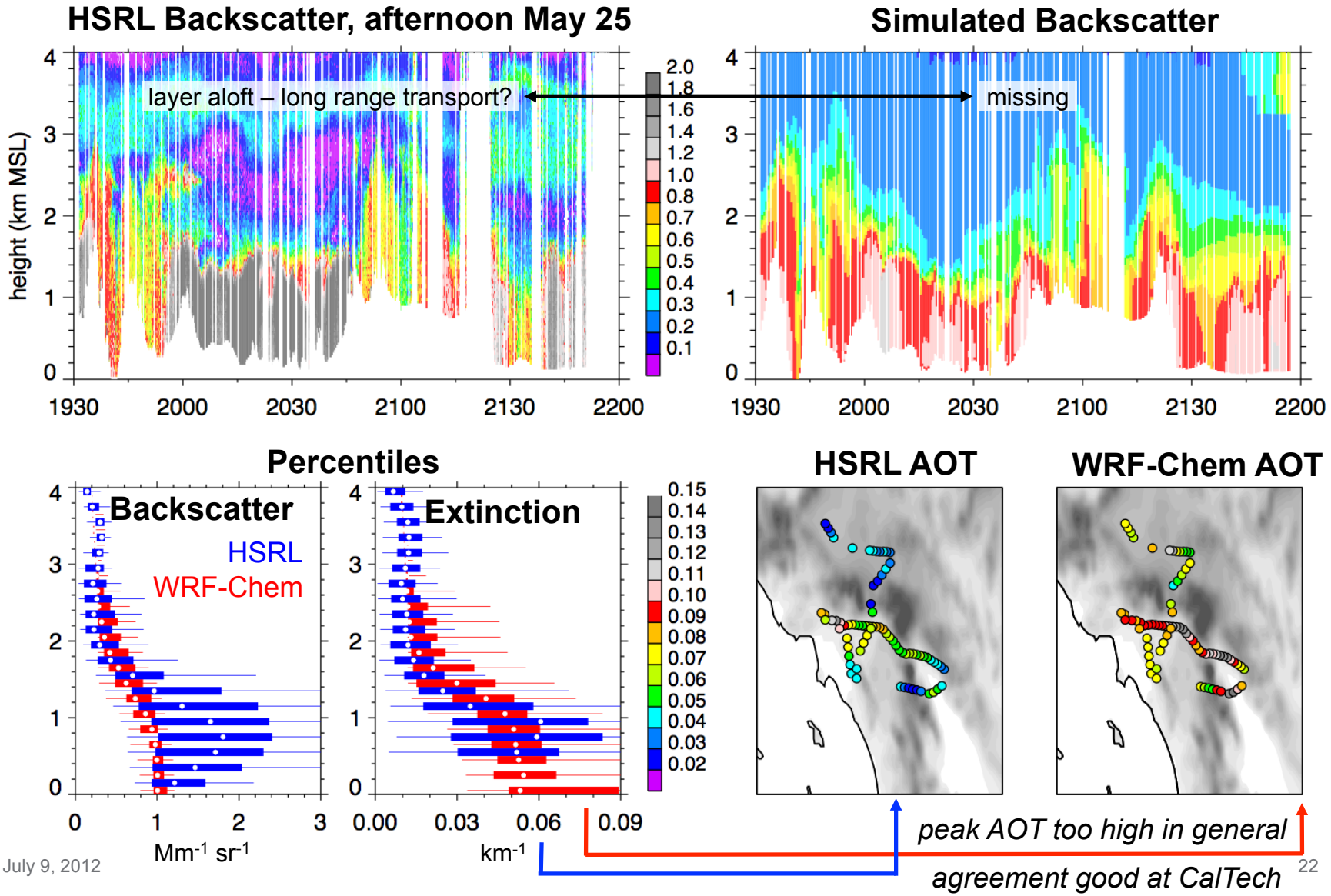

Aircraft Aerosol Composition – June 16