Constraining aerosol surface loadings by combining multi-angular and polarimetric remote sensing with a chemical transport model

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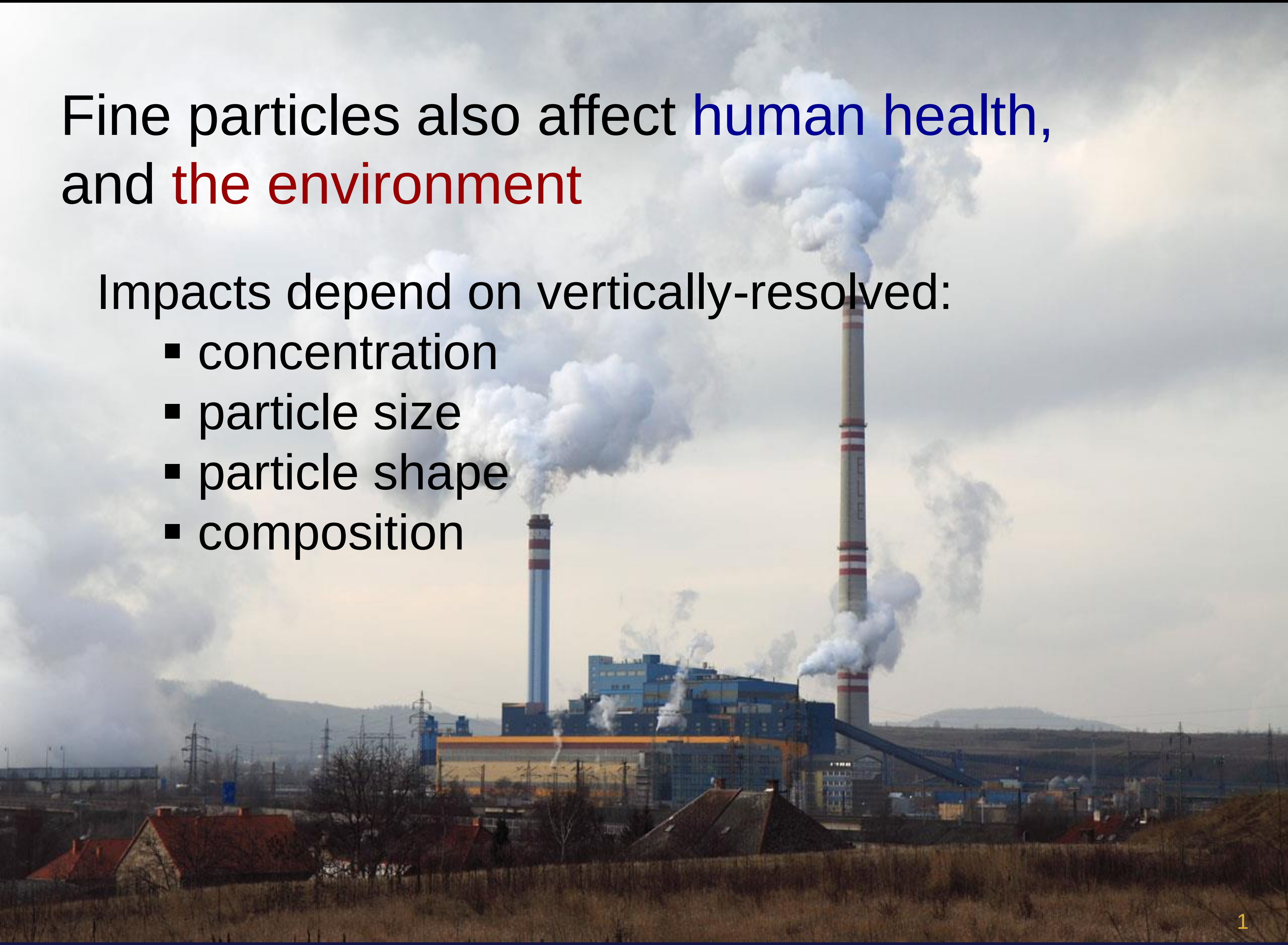
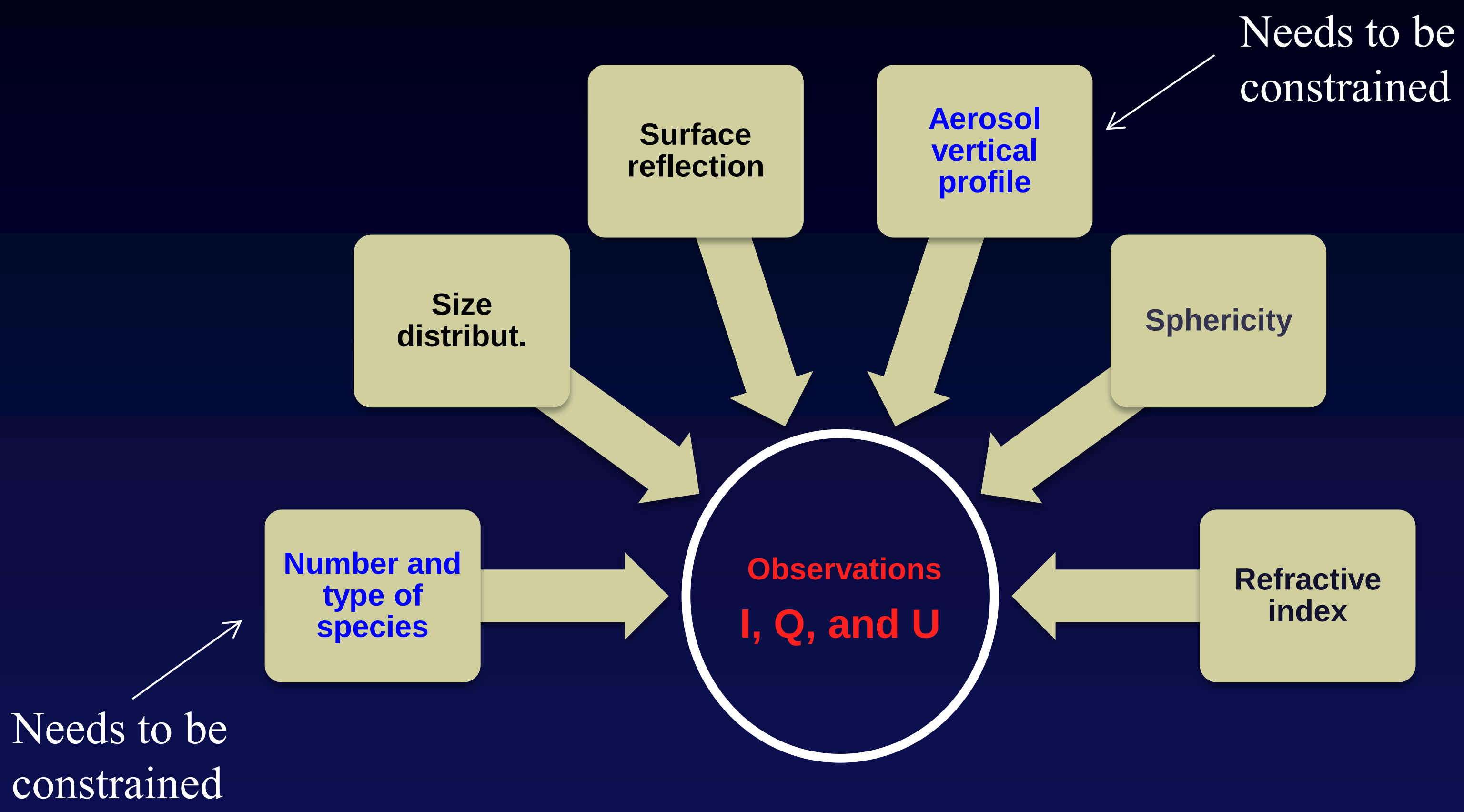
Fine particles also affect human health, and the environment

Impacts depend on vertically-resolved:

- concentration
- particle size
- particle shape
- composition

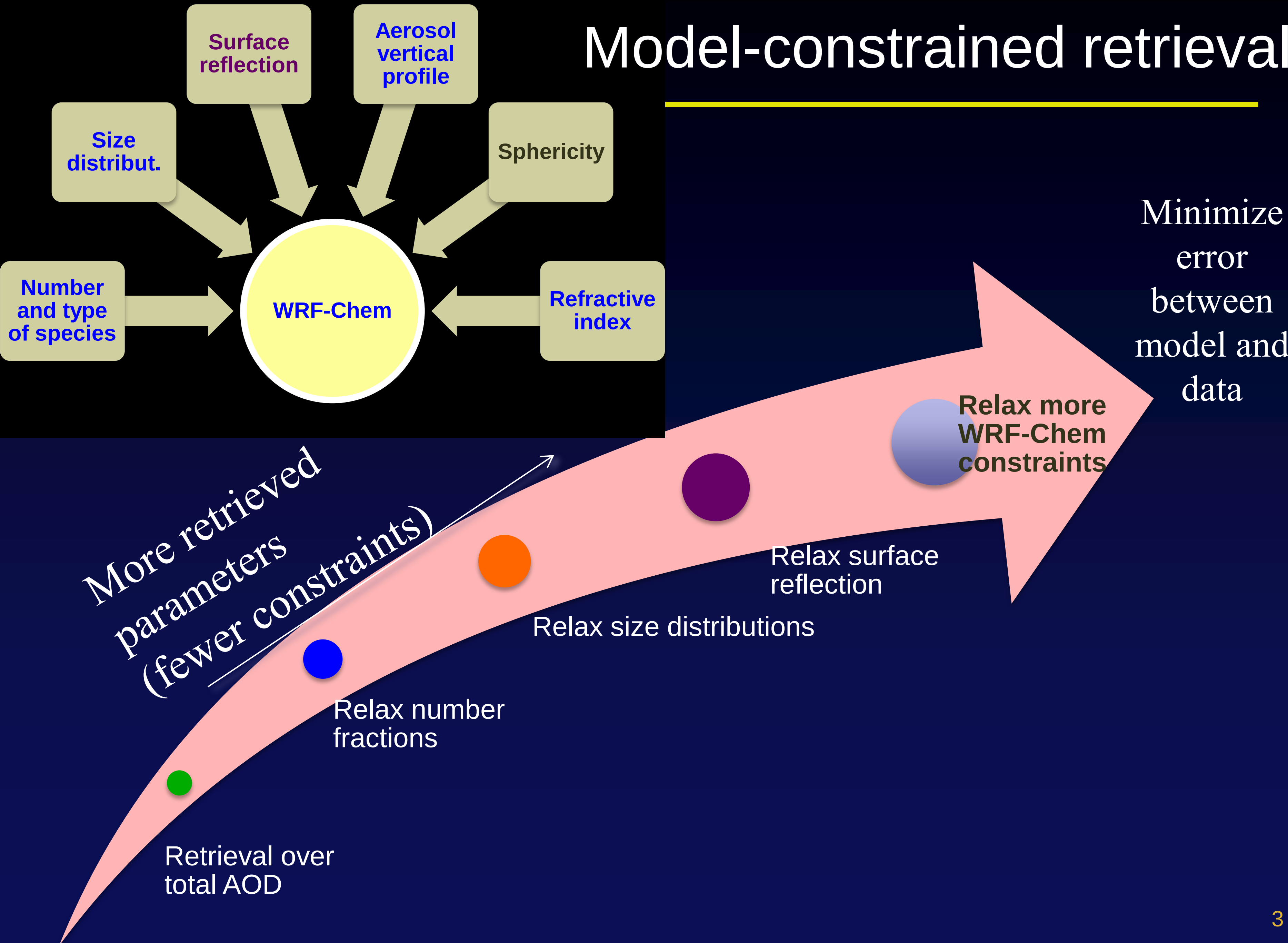


What multi-angular polarimetry can add?



"…algorithms utilizing high-accuracy polarization as well as radiance measurements are much less dependent on the availability and use of a priori information and can be expected to provide a physically based retrieval of aerosol characteristics…" (Mishchenko and Travis, 1997)

Model-constrained retrieval



AirMSPI instrument

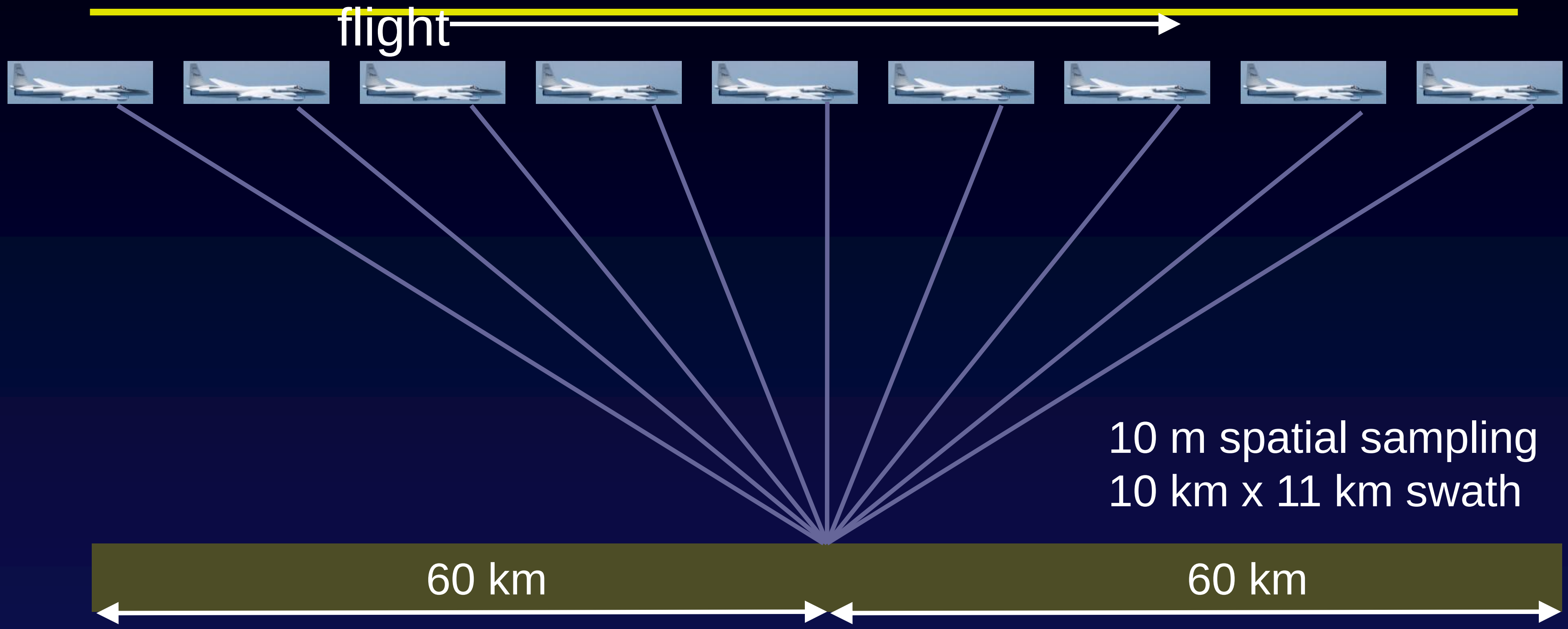
Spectral bands: 355, 380, 445, 470*, 555, 660*, 865*, 935 nm (*polarimetric)

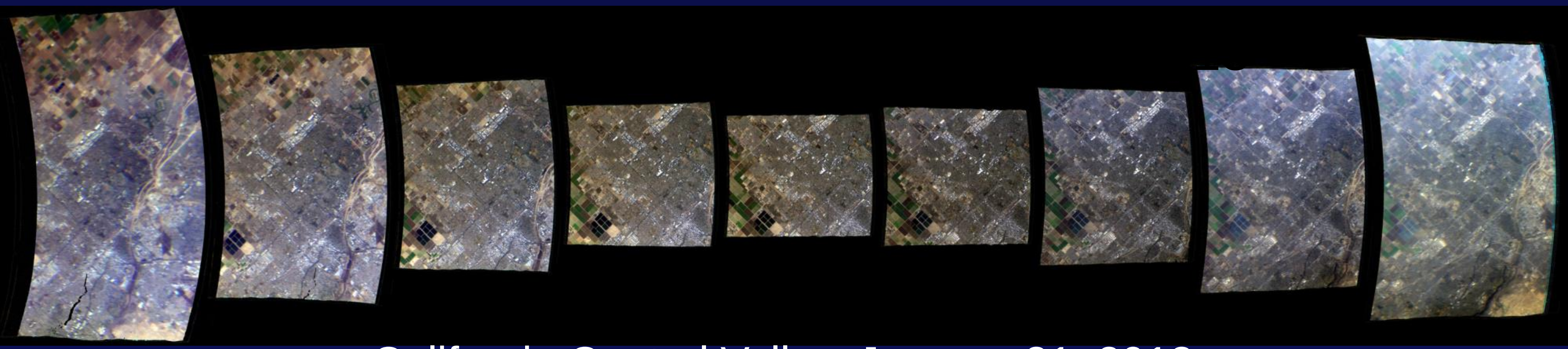
Two Types of Sampling: Step-and-Stare and Continuous Sweep

Flies in nose of NASA ER-2

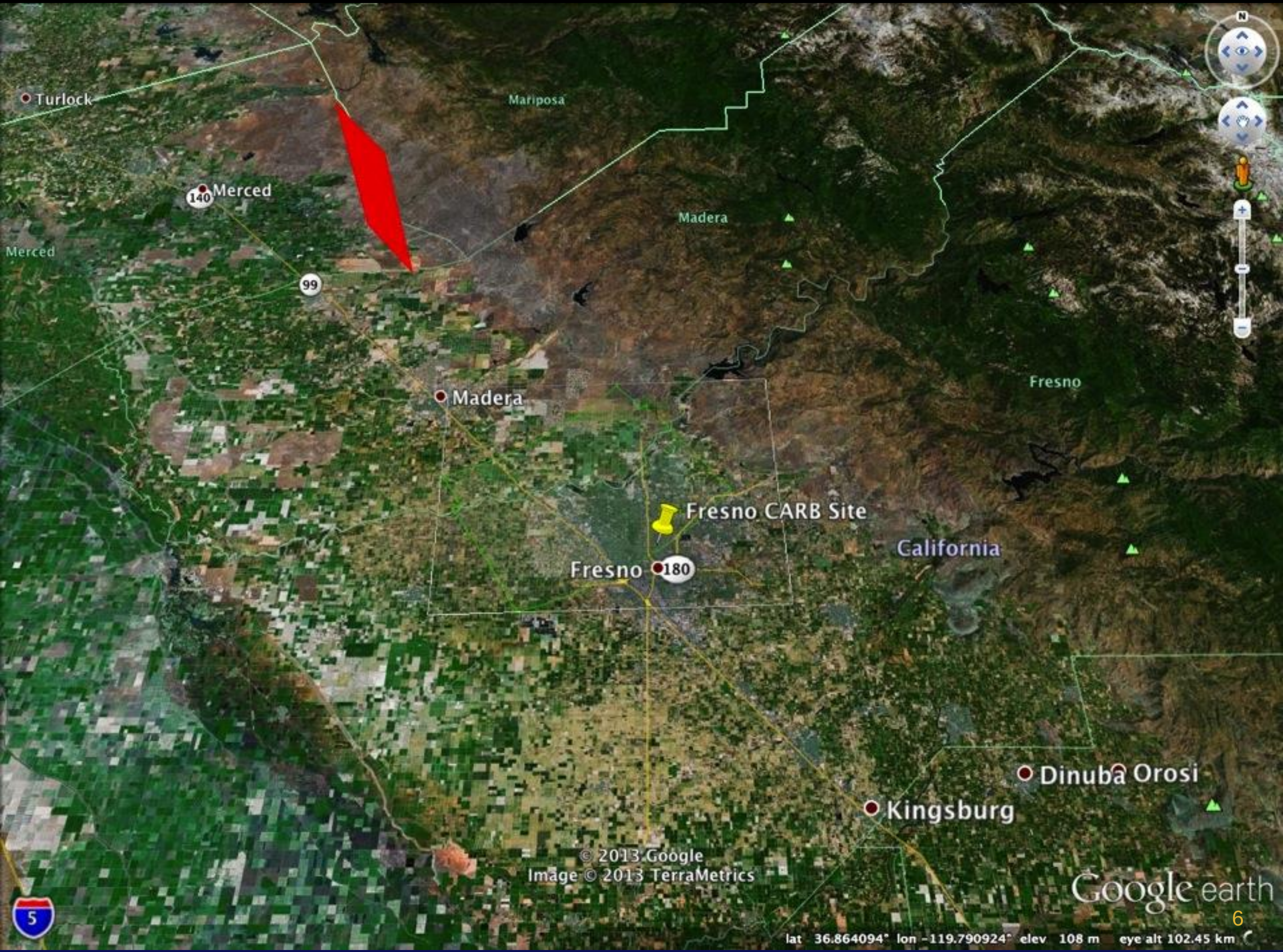
Has flown: Oct 2010, Aug/Sep 2011, Jan 2012, Jul/Aug 2012, Jan/Feb 2013 (PODEX), May 2013, Aug/Sept 2013 (SEAC[4]RS), Oct 2013, April/May 2014

AirMSPI step and stare





California Central Valley, January 31, 2013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Merced
140
Madera
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Fresno
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California
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Google earth
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lat 36.864094° lon -119.790924° elev 108 m eye alt 102.45 km

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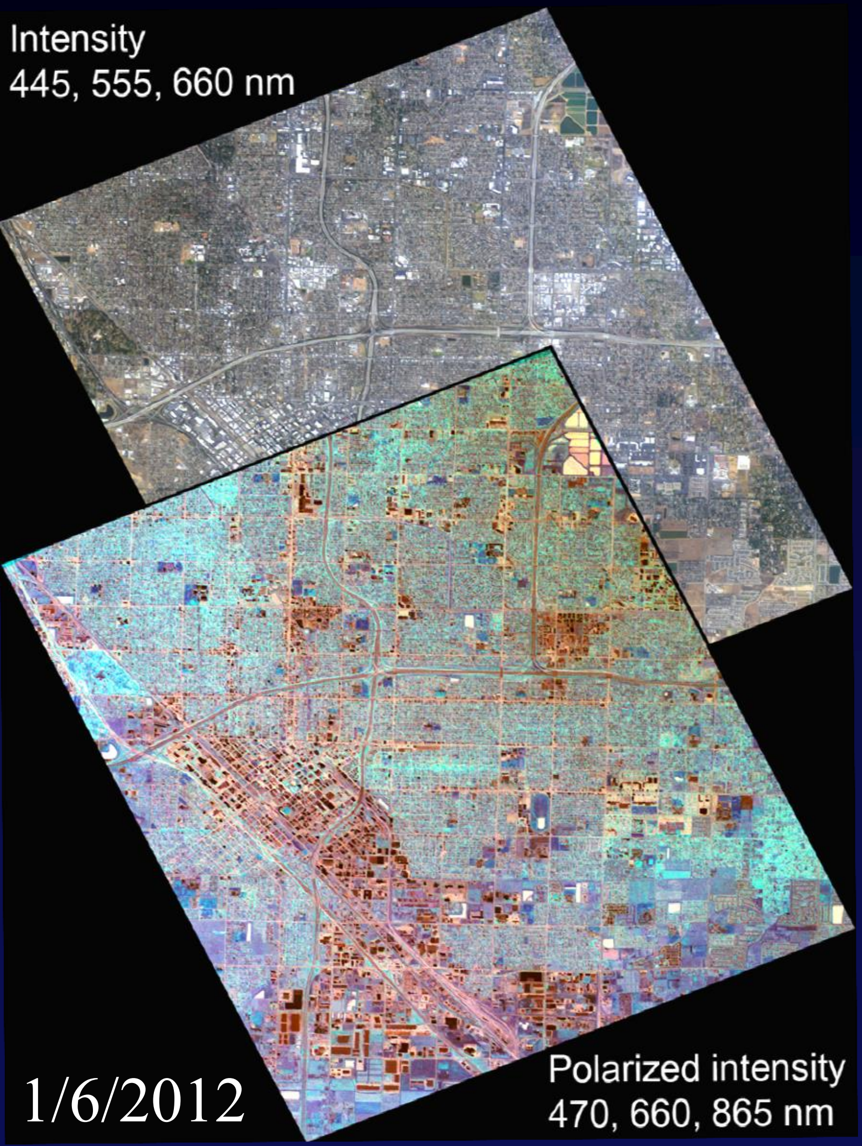
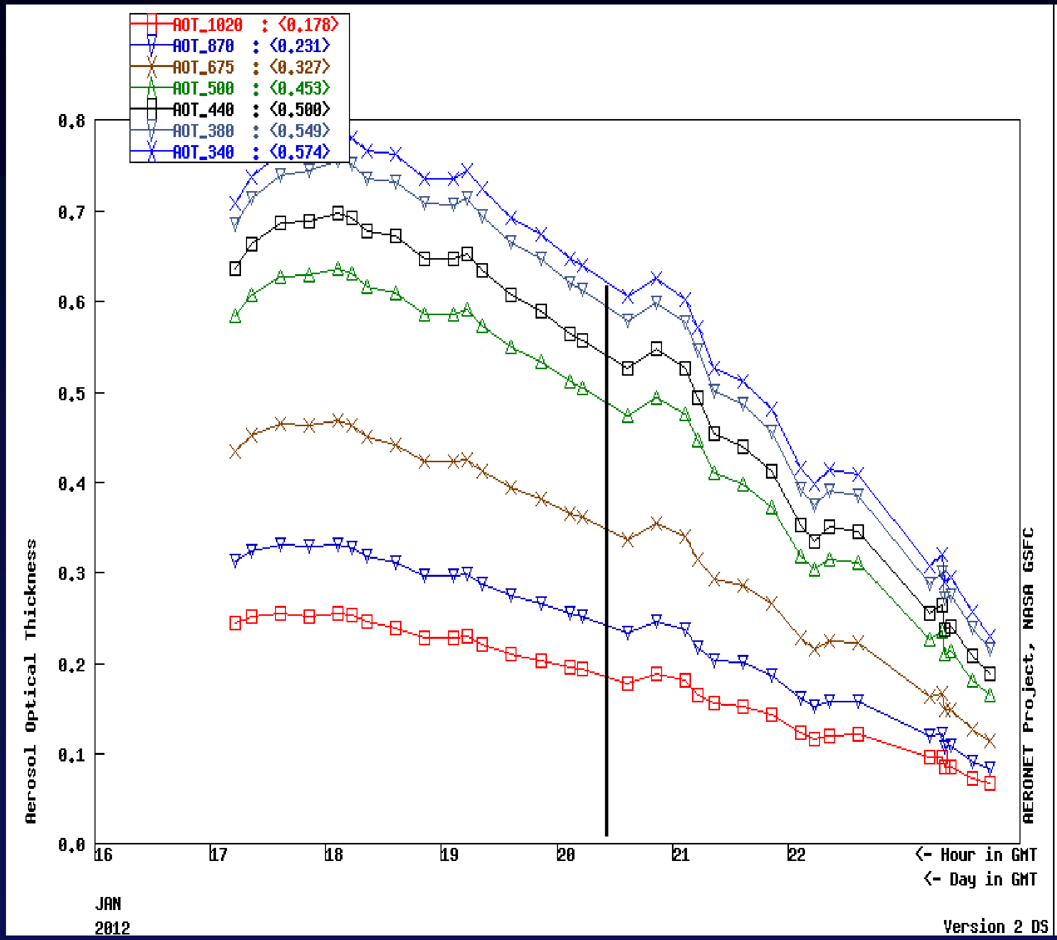
Case study: Pollution over Fresno – Jan 6, 2012





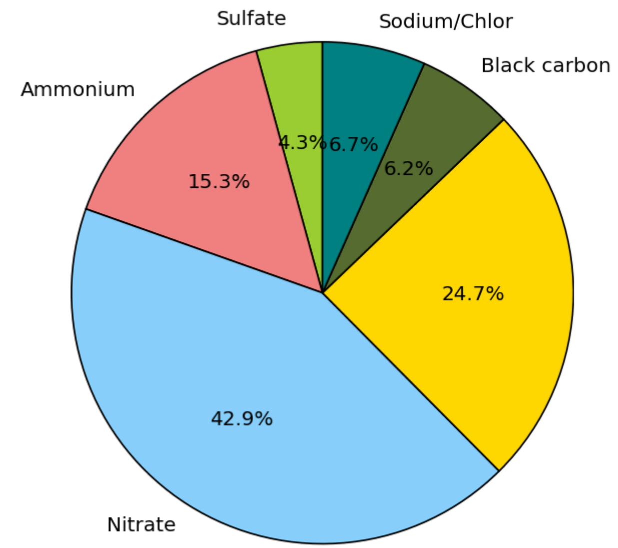
AirMSPI overpass 20:19:23

WRF/Chem aerosol module (MADE)

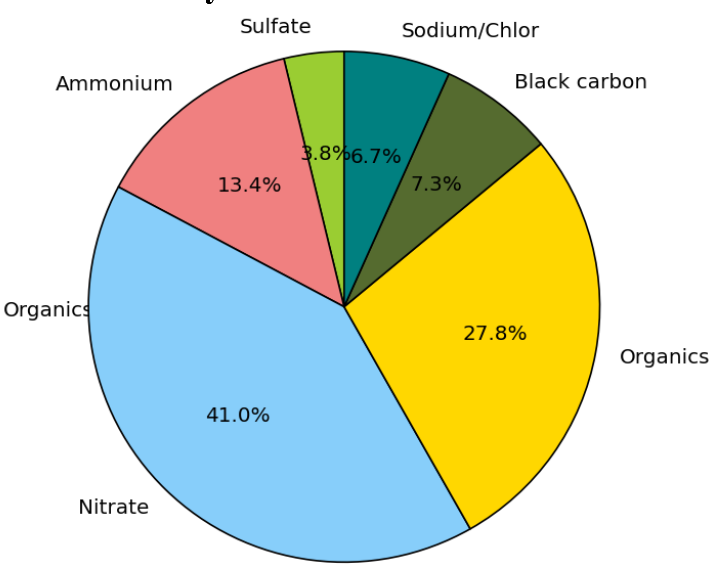
- 3 log-normal aerosol modes: Aitken, accumulation, coarse (no nucleation), mode width σ is fixed
- Accumulation and aitken modes:
  - Antropogenic SOA, POA
  - Biogenic SOA, elemental carbon (soot)
  - Sulfate, Nitrate, Ammonia, sea salt
  - Primary PM (PM2.5)
- Coarse aerosol
  - Anthropogenic primary coarse (coal, cement, etc)
  - Sea salt
  - Soil particles (mineral dust)

Pollution over Fresno – WRF Chem species

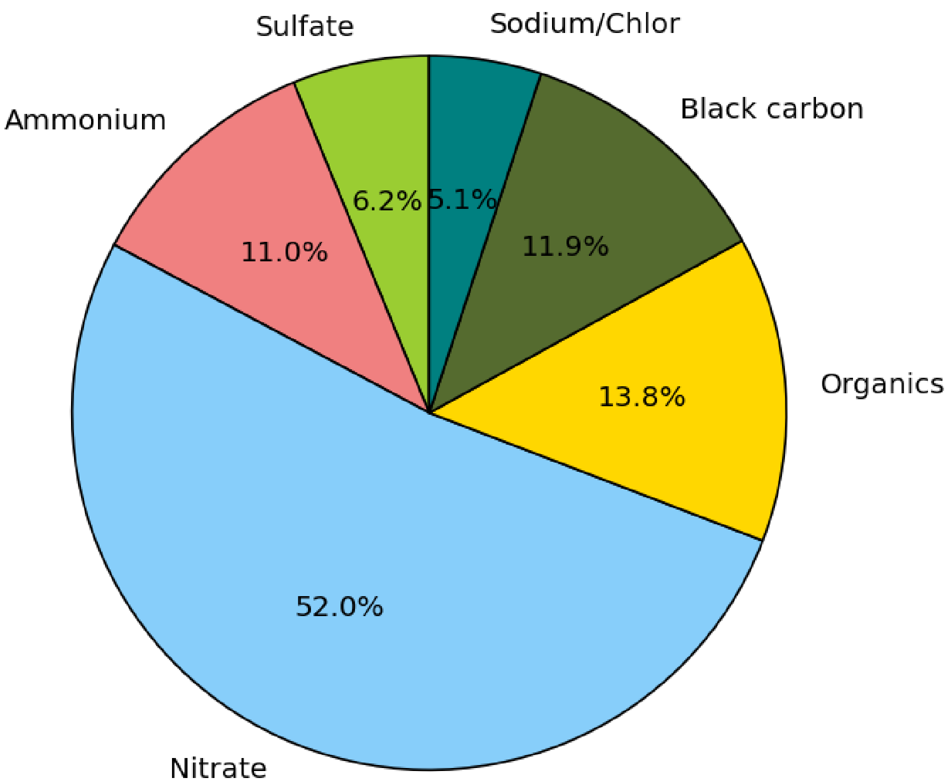
January 1 – surface Network data



January 7 – surface Network data

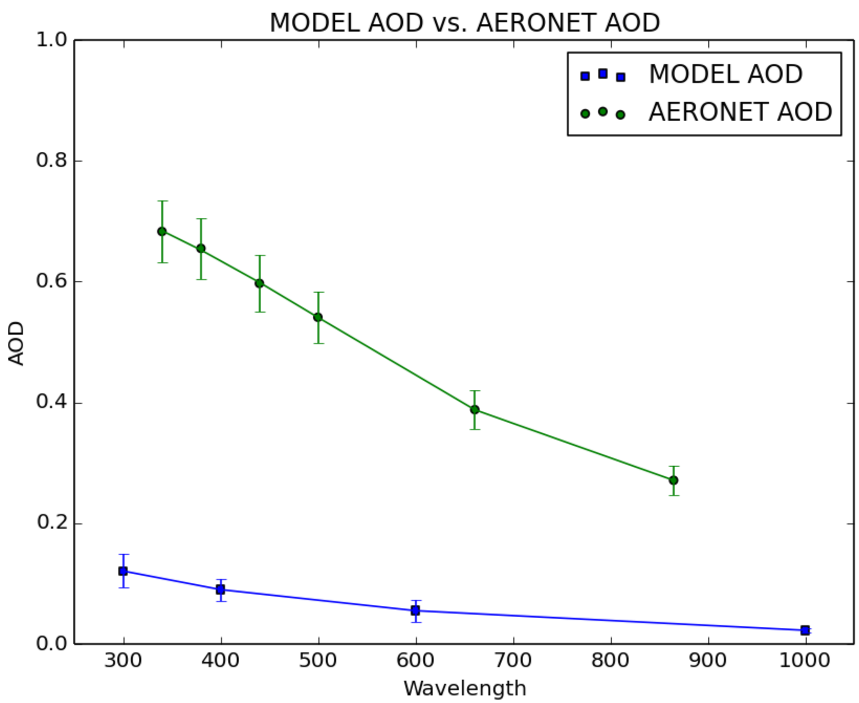


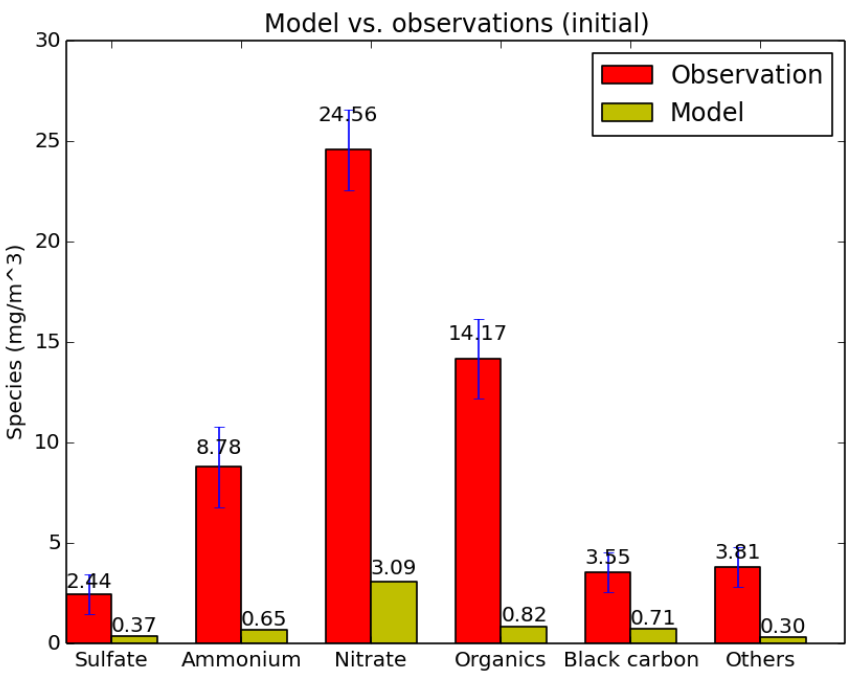
January 6 – WRF-Chem speciation



Chemical Transport models (CTM) do well in predicting the types of aerosols present at a given location and time

Pollution over Fresno – WRF Chem AOD/PM2.5



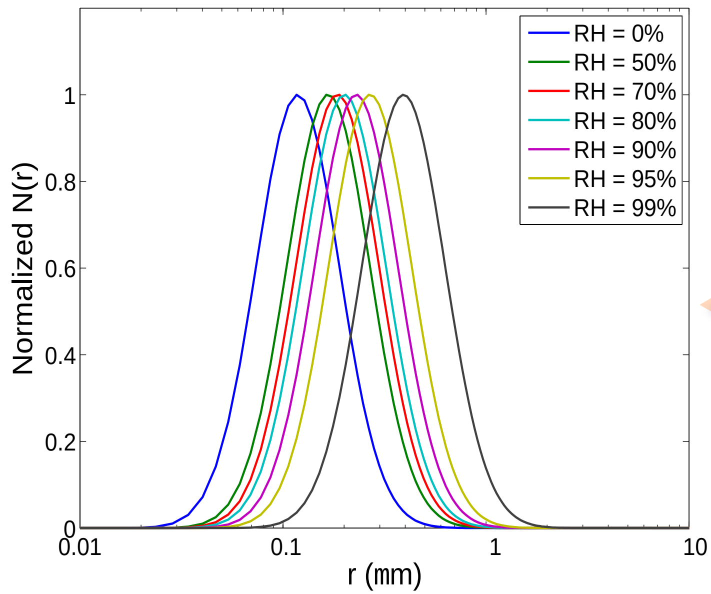


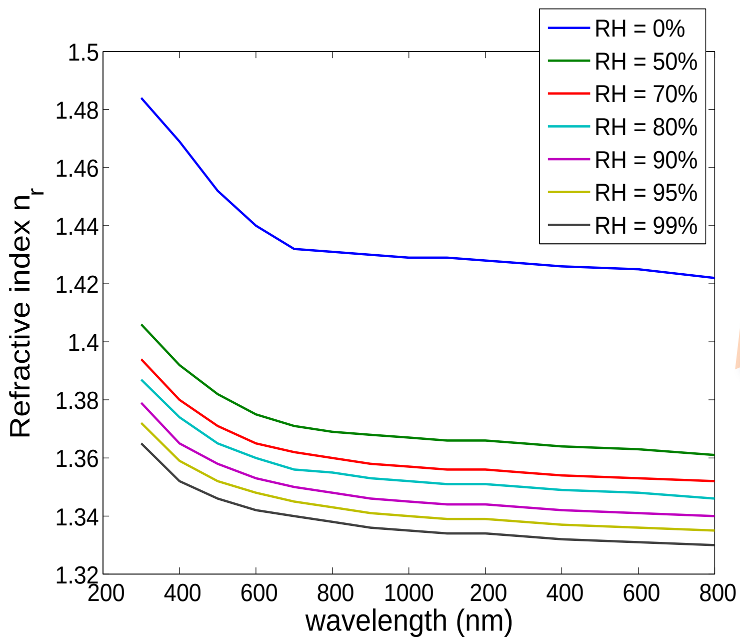
Large uncertainties currently exist in WRF-Chem (and other chemical transport models) estimates of the concentration the various aerosol species (e.g., black carbon, sulfate, dust, etc.).

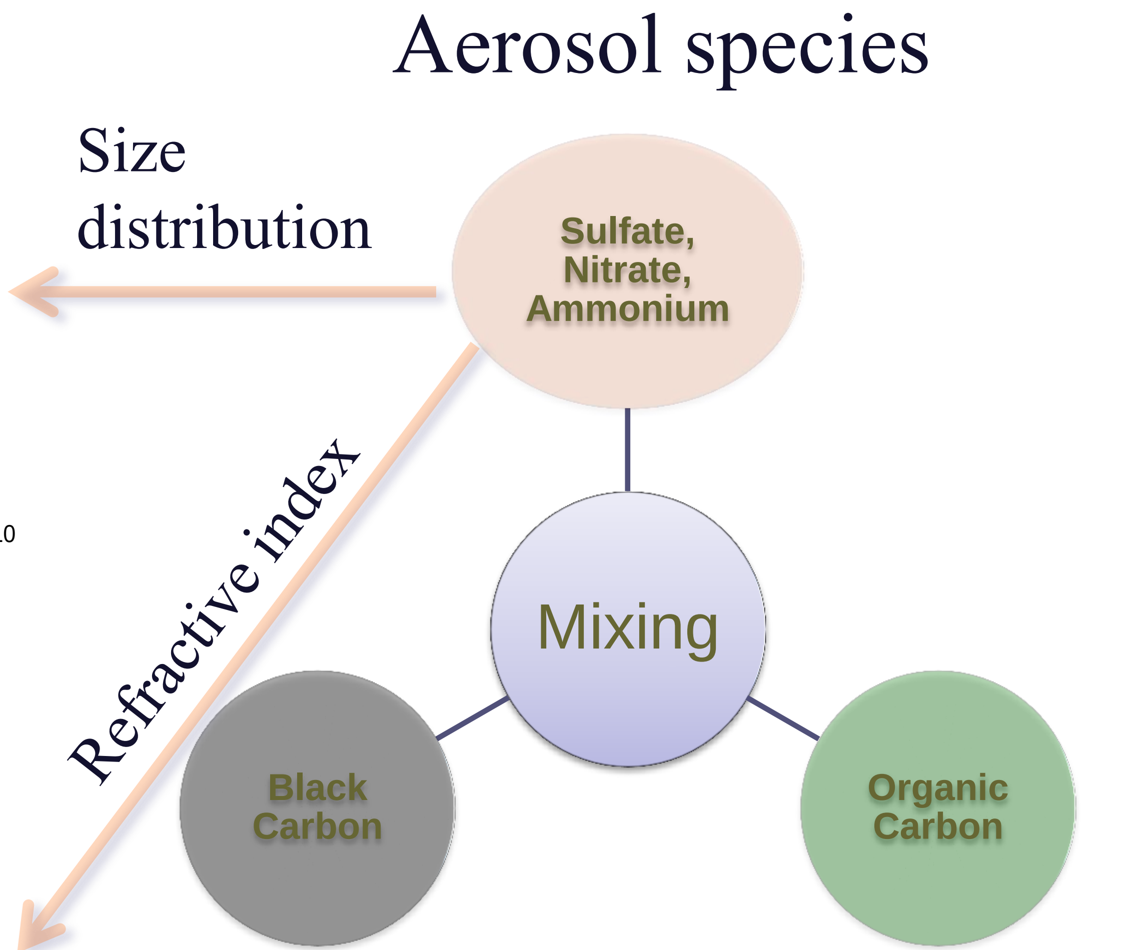
Model-constrained aerosol retrieval assumptions

- Retrieval is based on a Markov Chain vector radiative transfer code and optimized inversion
- Band width effect and O_3 absorption ignored
- Surface reflection retrieved assuming AERONET aerosol properties
- Species limited to (SO_4, NO_3, NH_4), BC, and OC
- Species optical properties are defined by WRF-Chem
- Species vertical profile based on WRF-Chem
- Mean radius derived from WRF-Chem

WRF-Chem aerosols – optical characteristics

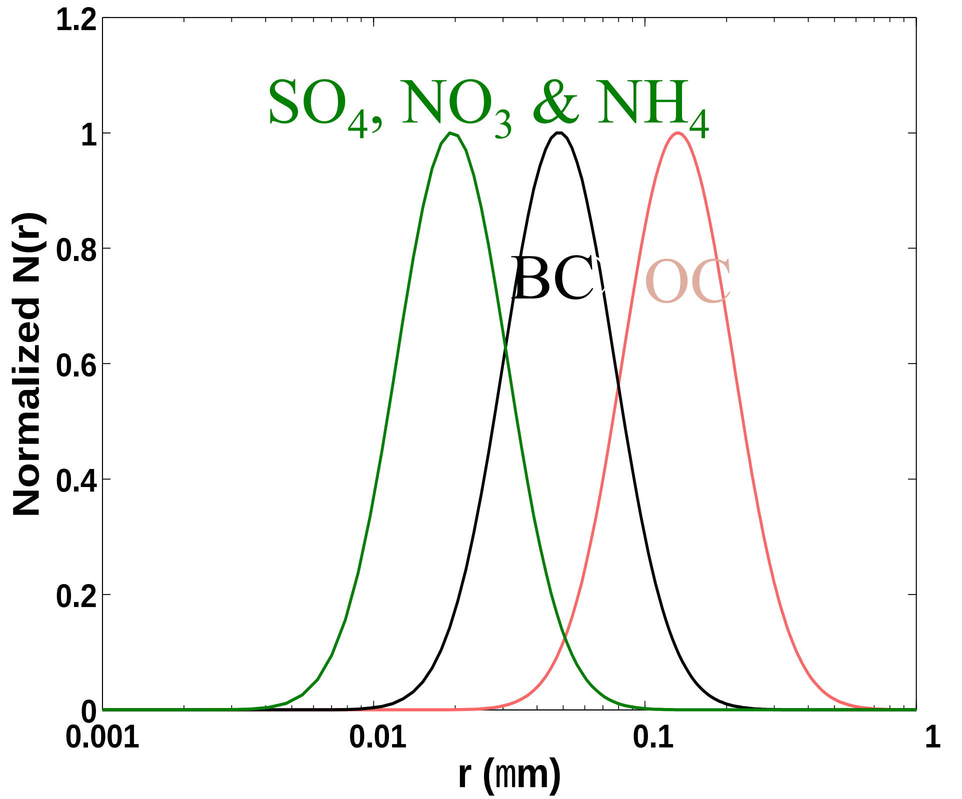




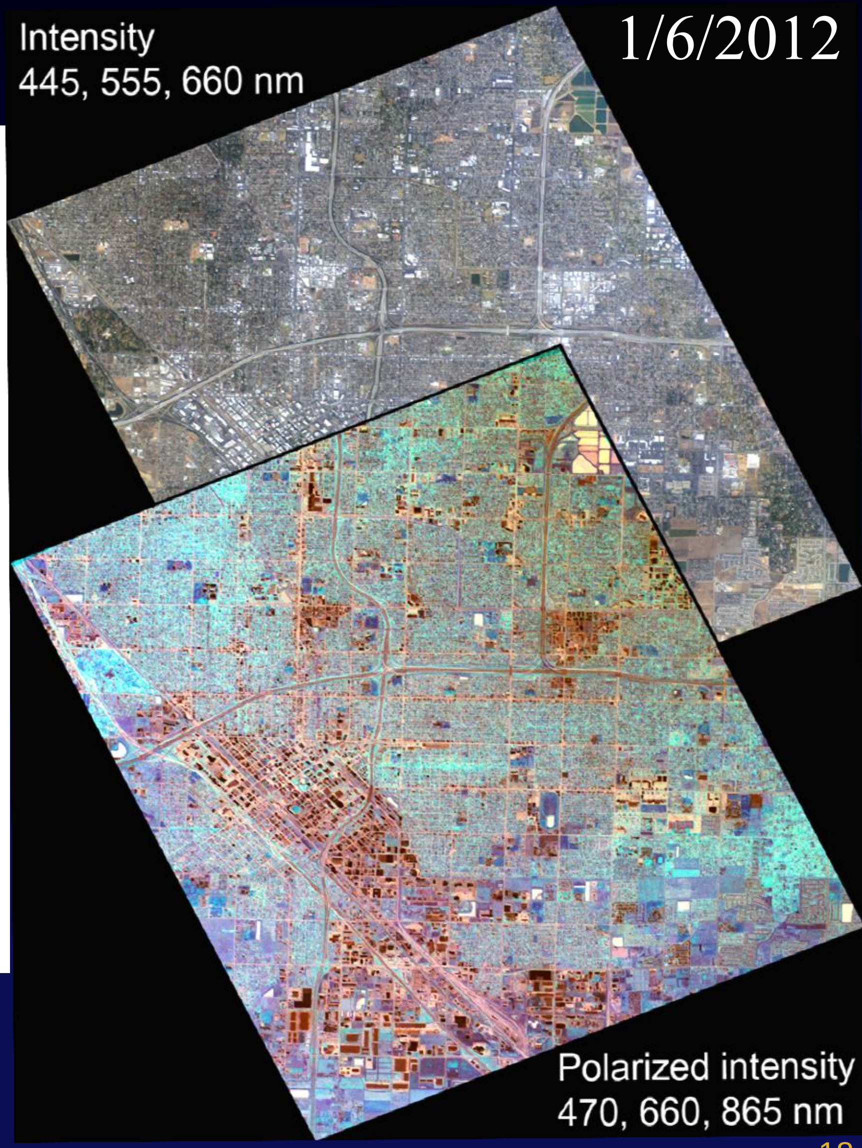


Pollution over Fresno

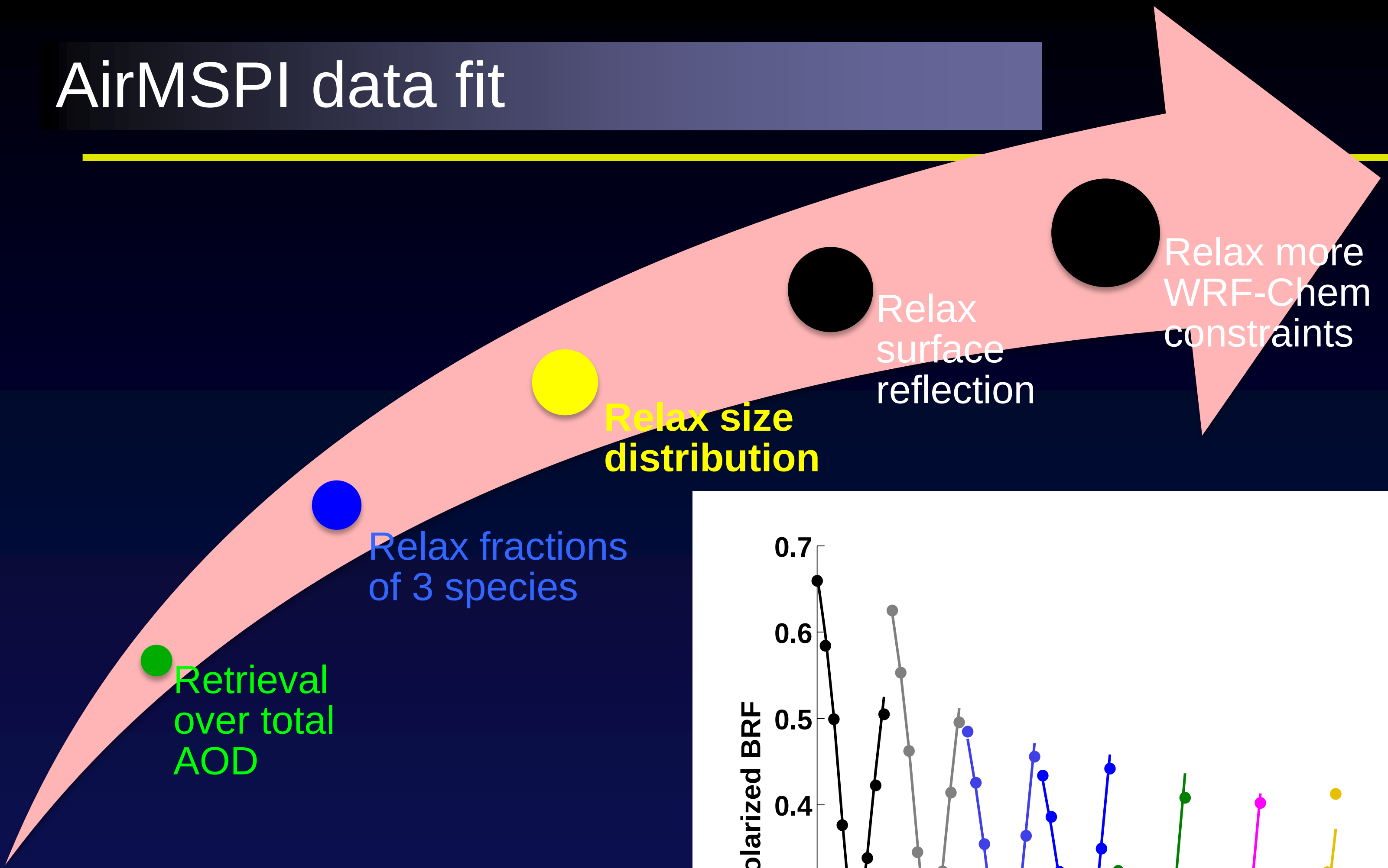
Accumulation mode of each species

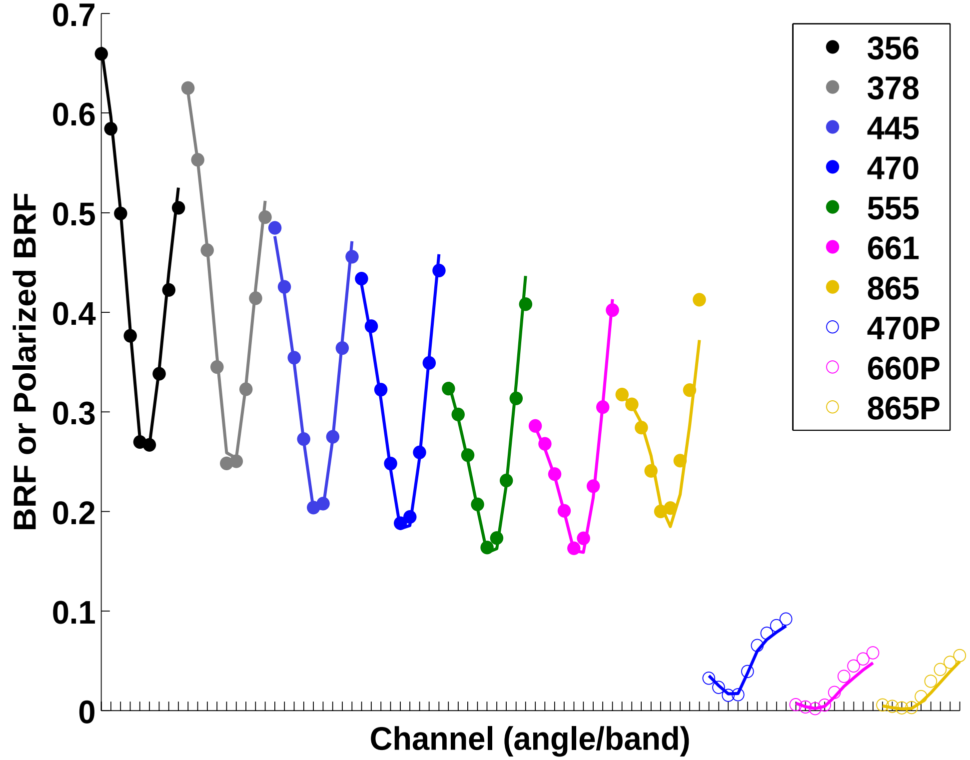


RH = 30%

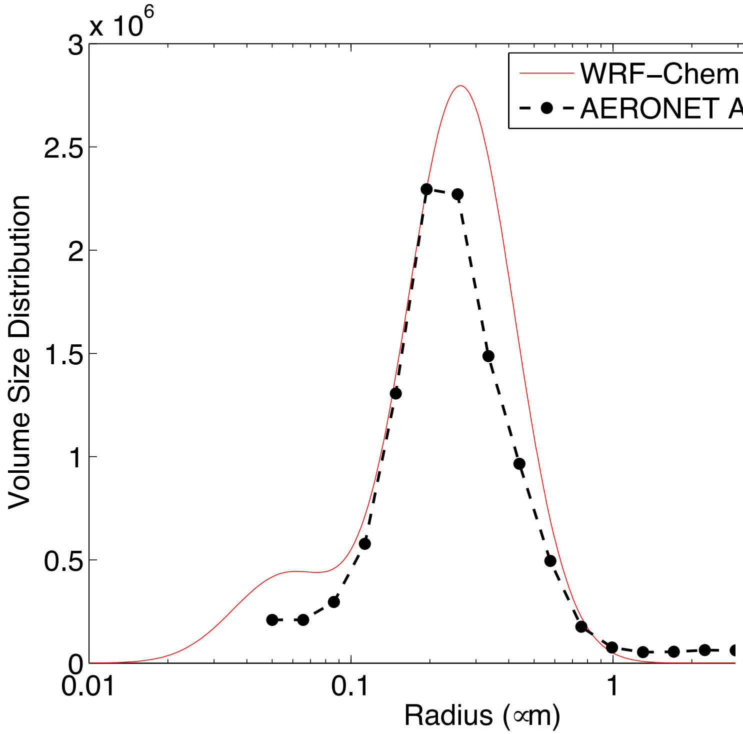


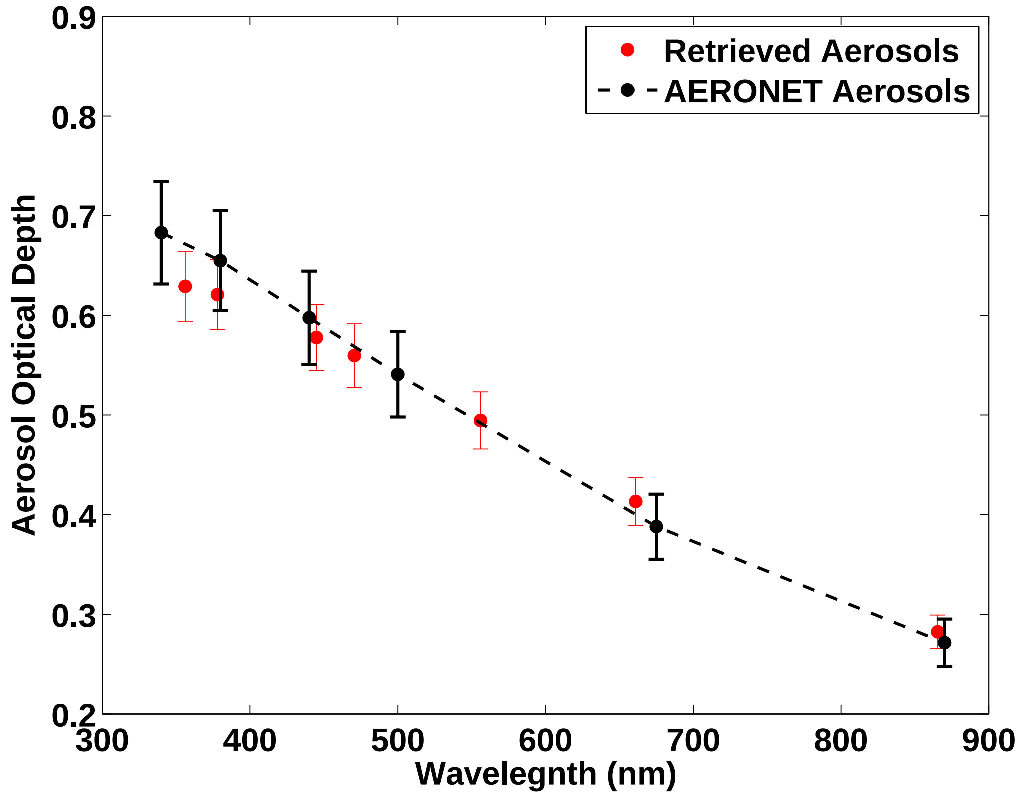
AirMSPI data fit



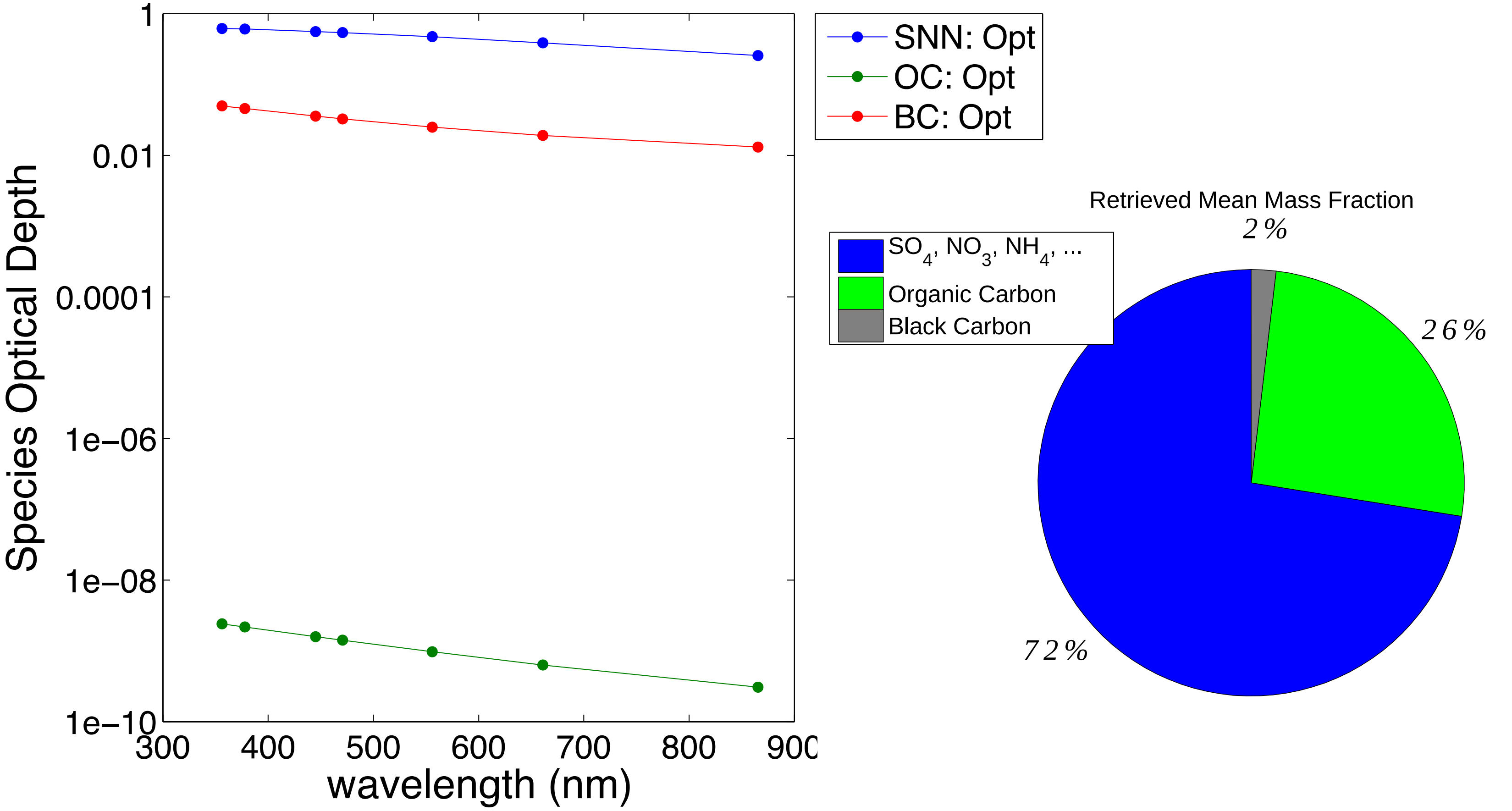


AERONET comparison

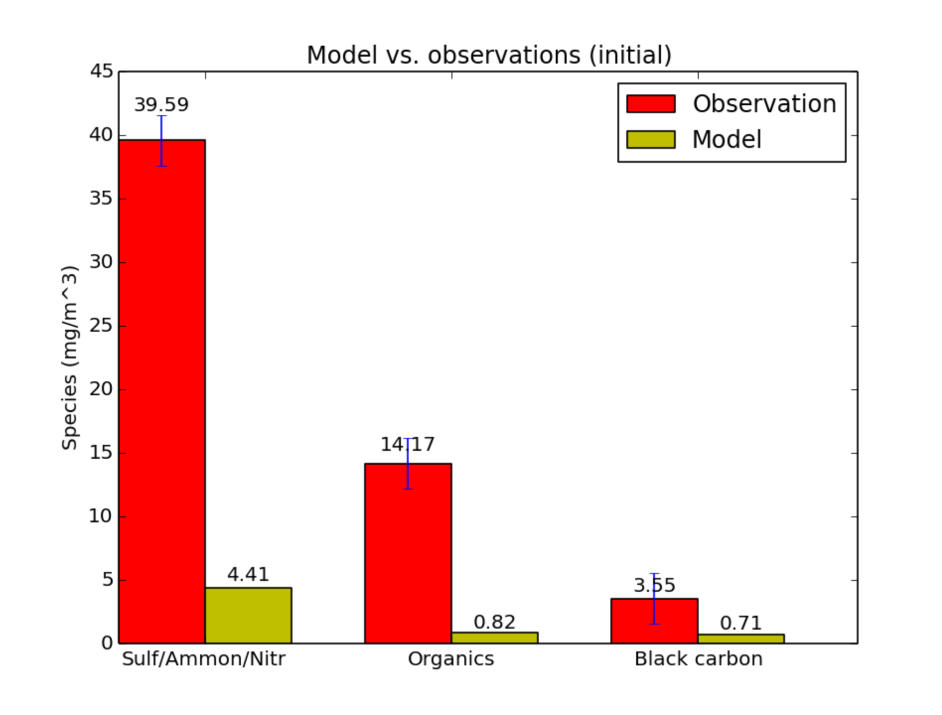


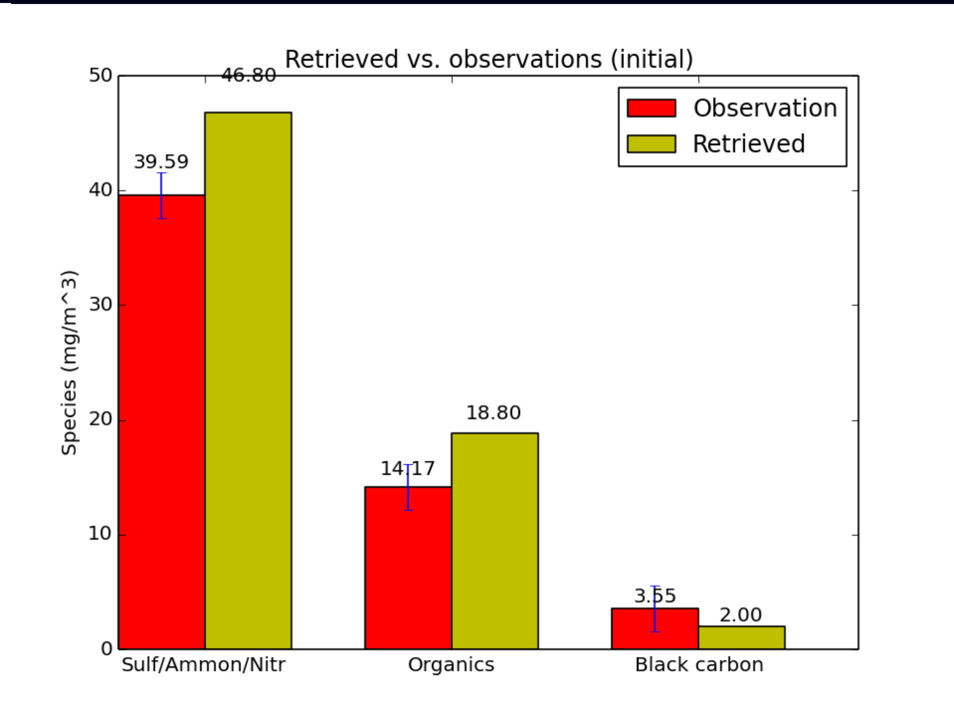


Retrieved speciated AOD – Fresno pollution



Retrieved speciated PM (WRF-constrained)





Observations – daily averaged; model and retrieval at 20:00 and 20:19:43 UTC correspondingly

Multiangular polarimetric observations constrained by WRF-Chem model are promising tool for retrieval $PM_{2.5}$ by particle species (sulfate, nitrate, organic carbon, black carbon, dust)

Concluding remarks

- Quantitative determination of PM distributions, trends, sources, and types is necessary for measuring and predicting exposure and toxicity.
- Advanced remote sensing technologies improve our sensitivity to particle type.
- Conversion of column AOD and fractional AOD to $PM_{2.5}$ species requires a chemical transport model to account for vertical distribution and integrating the data with *in situ* measurements to “train” the retrievals and remove biases.
- The next major advance will be to partition $PM_{2.5}$ by particle species (sulfate, nitrate, organic carbon, black carbon, dust) using polarimetric observations.