Predictions of Aerosols Downwind of Mexico City using a Fully-Coupled Meteorology-Chemistry-Aerosol Model

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Objectives

Examine particulate evolution downwind of Mexico City:

- Initially focus on transport between Mexico City and T1 & T2
- Evaluate model with extensive measurements (surface, aircraft, satellite)
- Use model to "fill-in" data voids and examine particulate evolution further downwind MILAGRO measurements

Quantify effect of aerosols on radiation in the region:

- Do models predict the correct regional variations?
- If so, are the values produced for the right reasons?
- What are major uncertainties in radiative forcing?
- What is the "footprint" of Mexico City on downwind radiative forcing?
- In collaboration with Alma Hodzic (NCAR), determine the relative contribution of anthropogenic and biomass burning to radiative forcing.

Model

WRF-chem:

- Weather Research Forecasting (WRF) model for meteorology
- photochemistry: CBM-Z
- Aerosols: MOSAIC, sectional approach for size distribution (8 bins)
- Boundary conditions from MOZART (in the future)
- Fully-coupled meteorology, chemistry, aerosols, that includes aerosol-radiative feedbacks
- 2 simulations: March 6 - 13 & March 17 - 22, both contain periods of SW ambient winds favorable for transport towards T1 & T2

Meteorology:

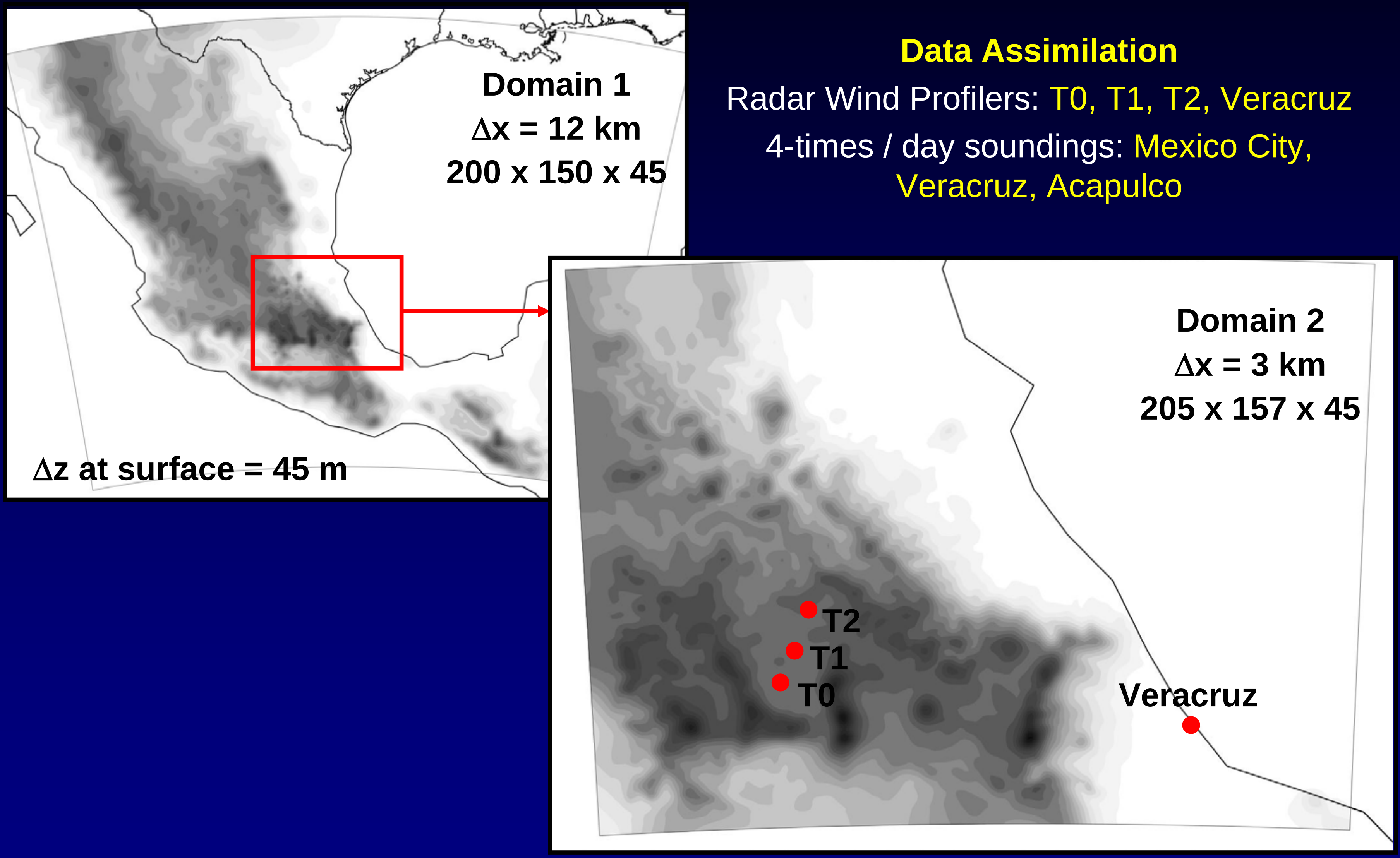
- Boundary conditions from GFS analyses
- Four-dimensional data assimilation using observations
- YSU boundary layer parameterization
- Lin et al. microphysics
- Goddard shortwave and RRTM longwave radiation schemes

Domains

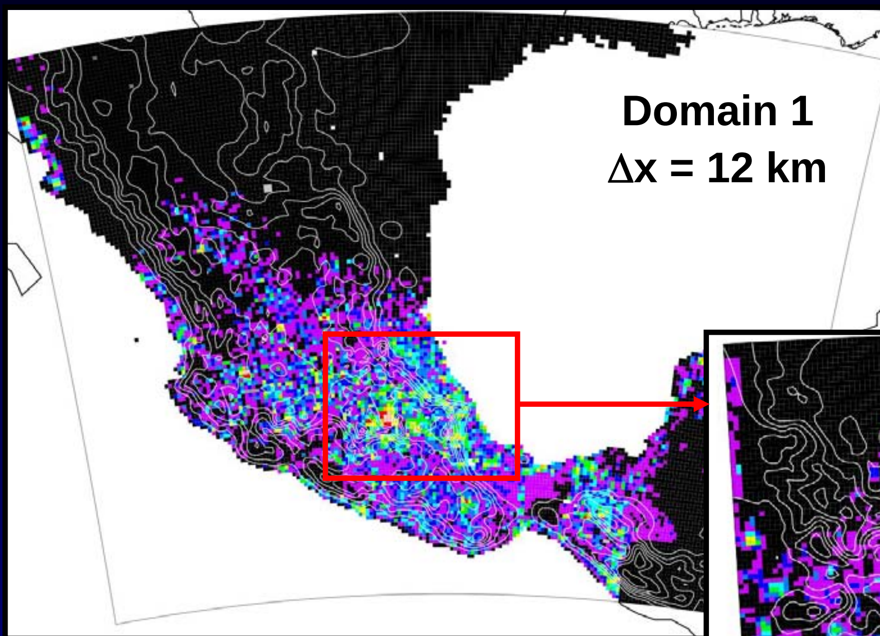
Data Assimilation

Radar Wind Profilers: T0, T1, T2, Veracruz

4-times / day soundings: Mexico City, Veracruz, Acapulco



Emission Rates



Emission Rates

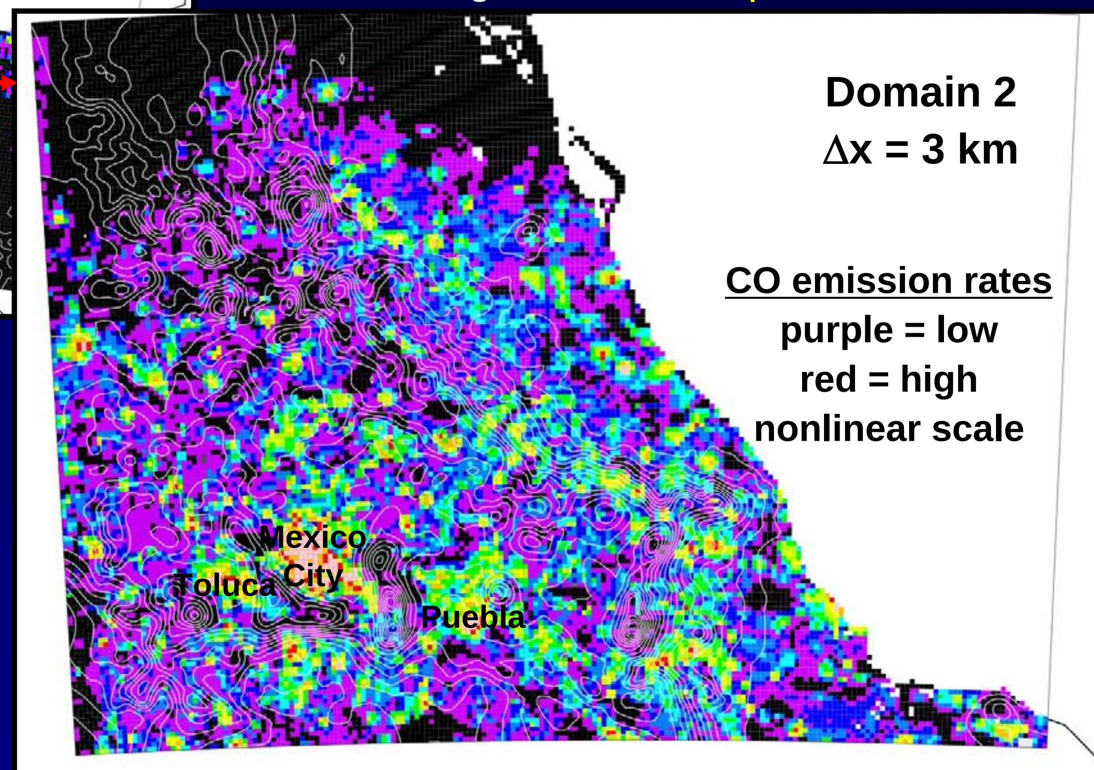
Anthropogenic: NEI99

Biomass Burning: MODIS hotspot

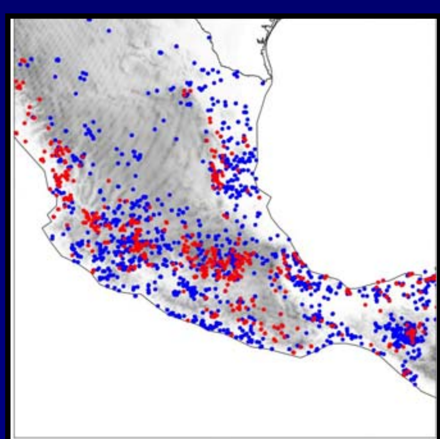
Dust: f(u*)

Volcanic: SO_2 estimated

Biogenic: none at present



Fires detected by MODIS



MCMA 2000: 6,033 tons PM2.5 / yr

MCMA 1999: 24,308 tons PM2.5 / yr

Results

Results are preliminary

and, only a sample are presented here when compared with various measurements during MILAGRO

First examine parameters aerosol radiative parameters:

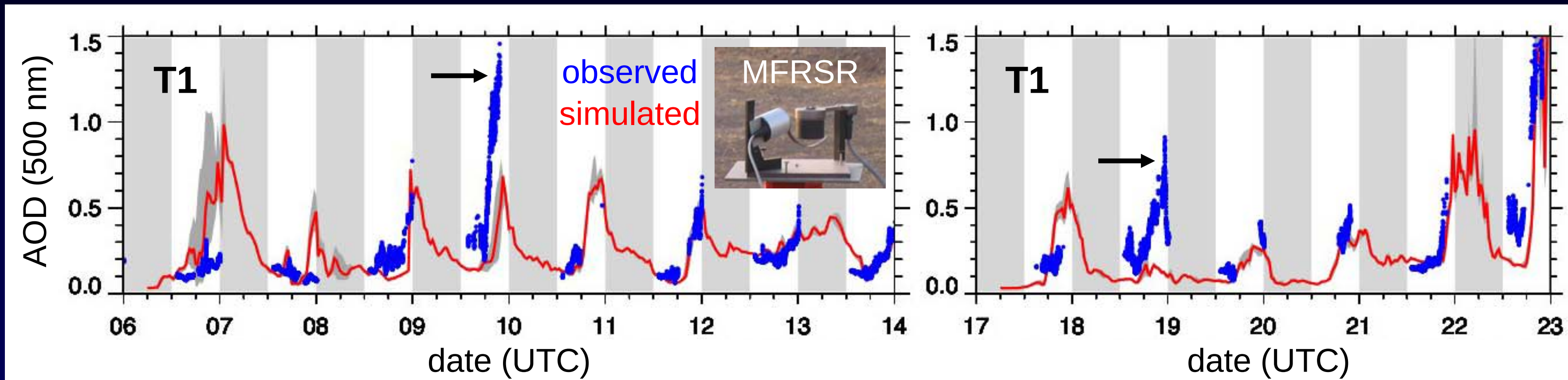
- Aerosol optical depth, $\tau(\lambda,z)$
- Single scattering albedo, $\omega_o(\lambda,z)$

$\omega_o = k_s / (k_a + k_s)$, where
k_s = scattering coefficient and
k_a = absorption coefficient

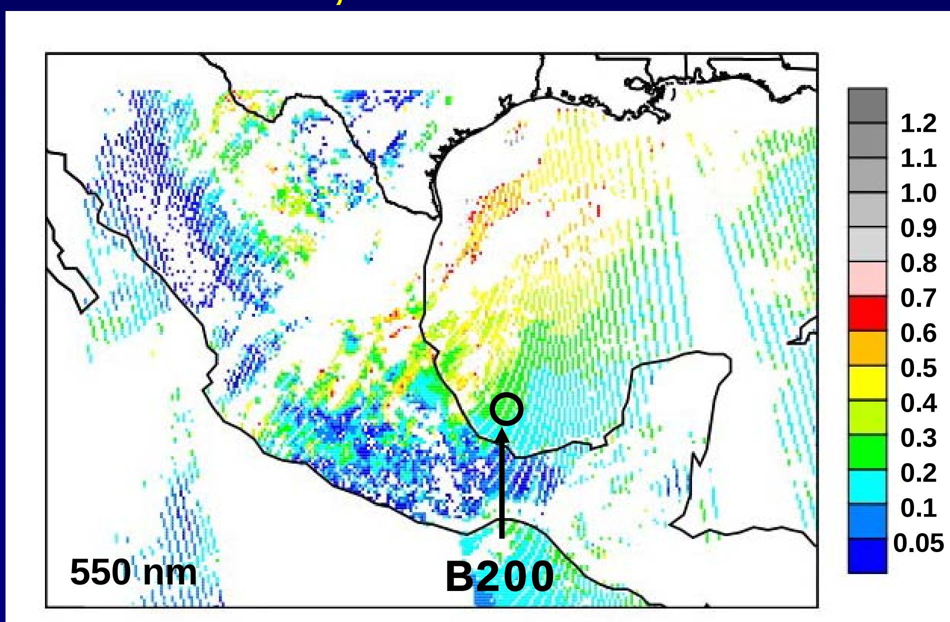
Then, examine factors that affect aerosol radiative parameters:

- Mass - *more mass* ➔ *bigger radiative impact*
- Composition - *relative amount of black carbon* ➔ k_s *&* k_a
- Size distribution - *largest effects near 0.4* μm

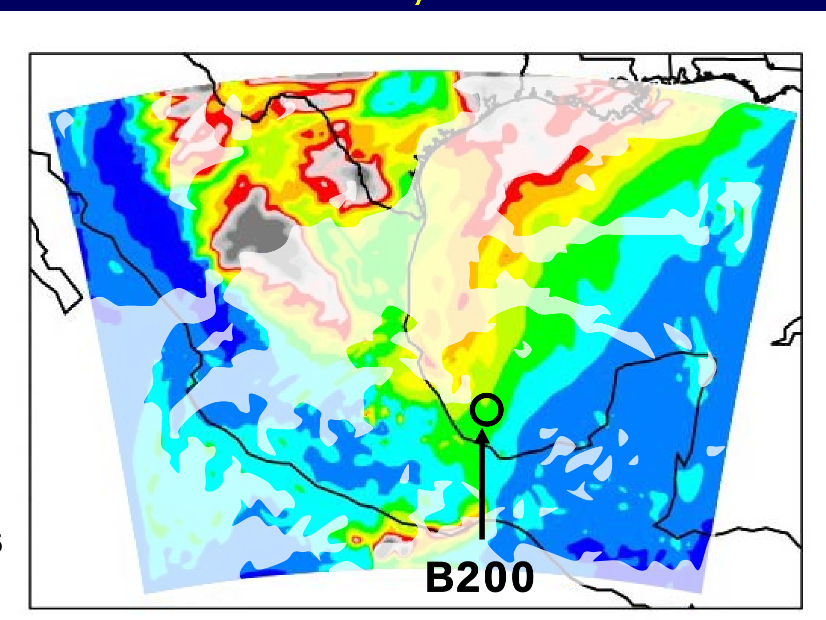
Aerosol Optical Depth



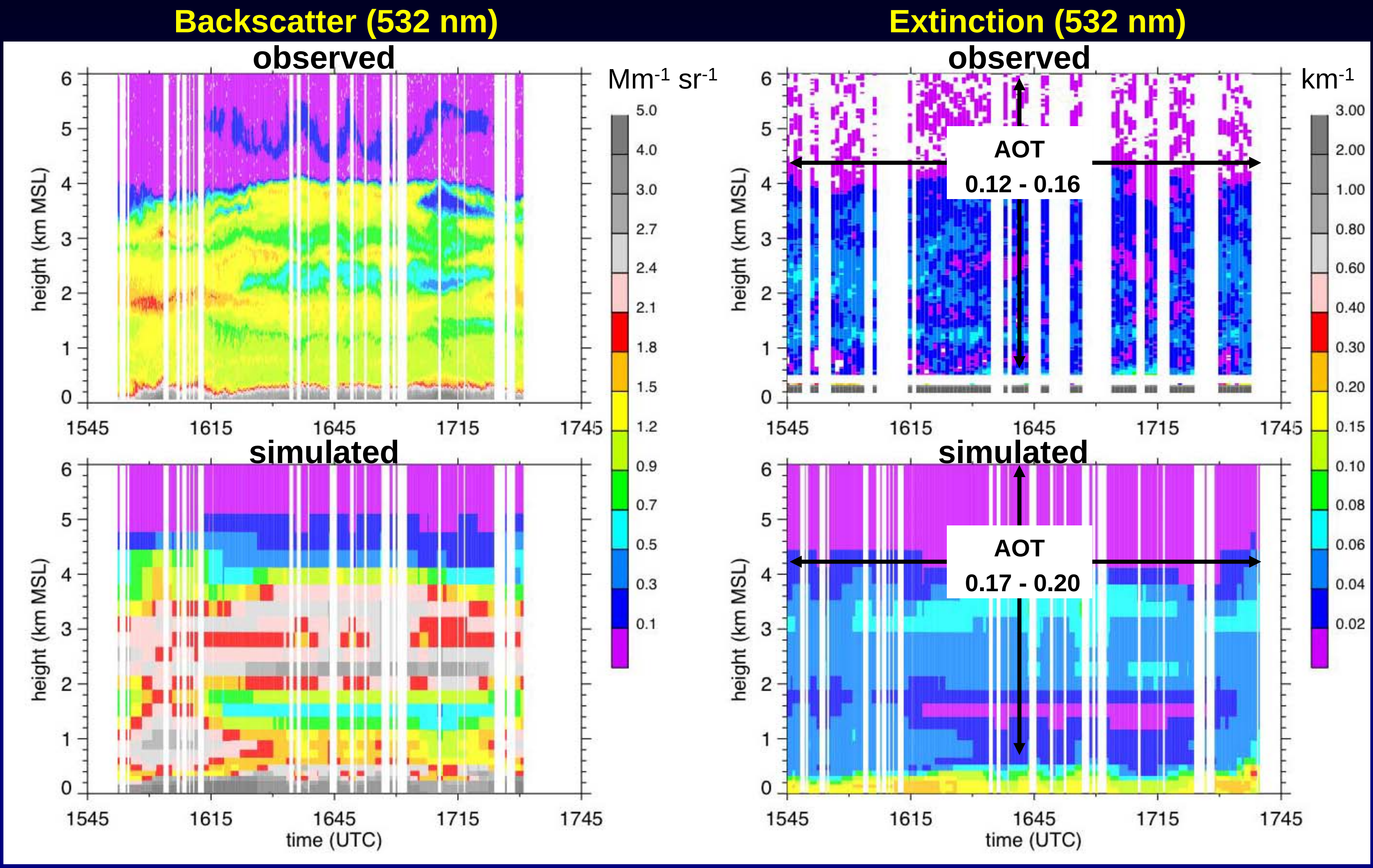
MODIS AOD, ~1930 UTC March 10



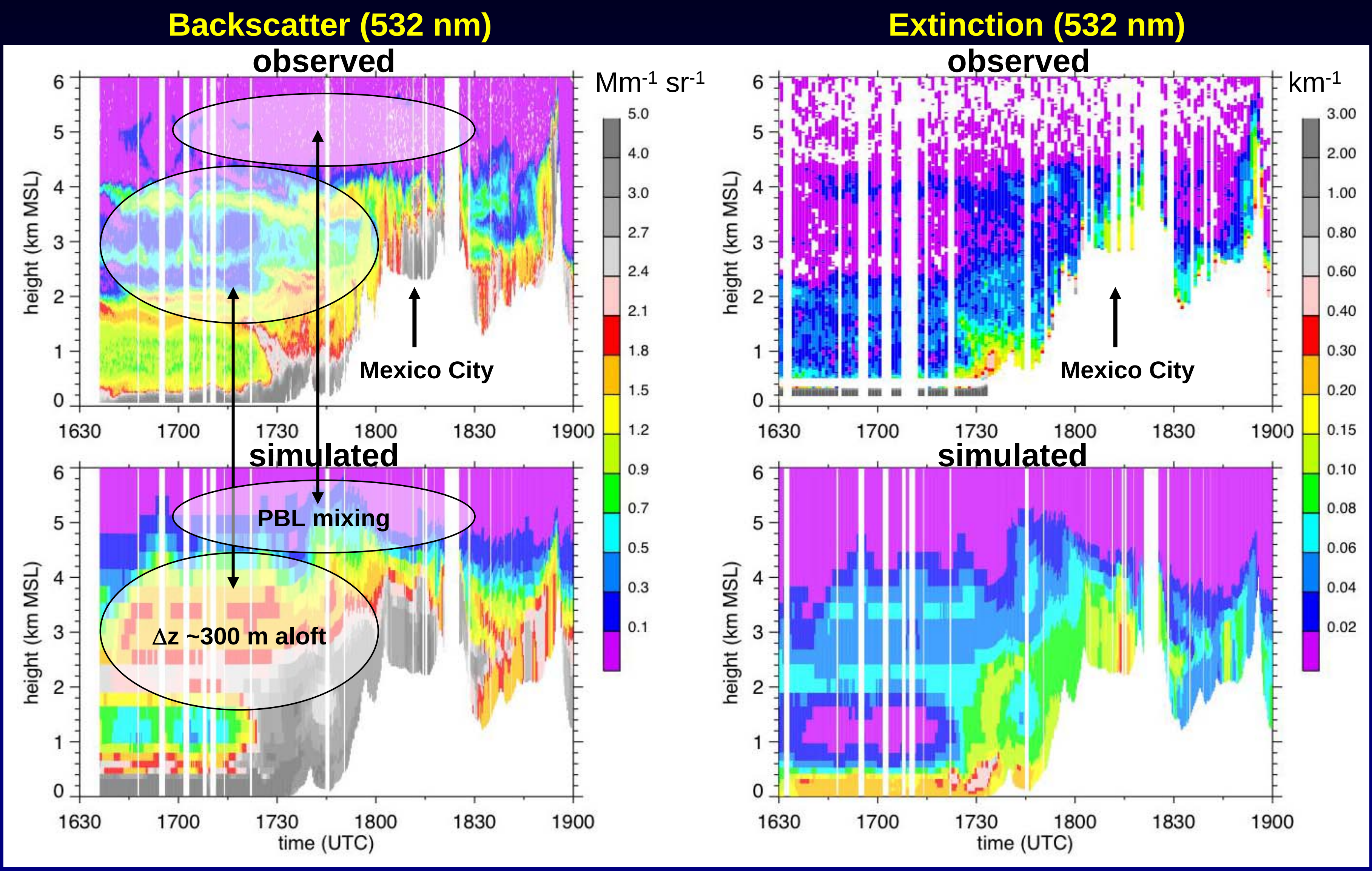
Simulated AOD, 20 UTC March 10



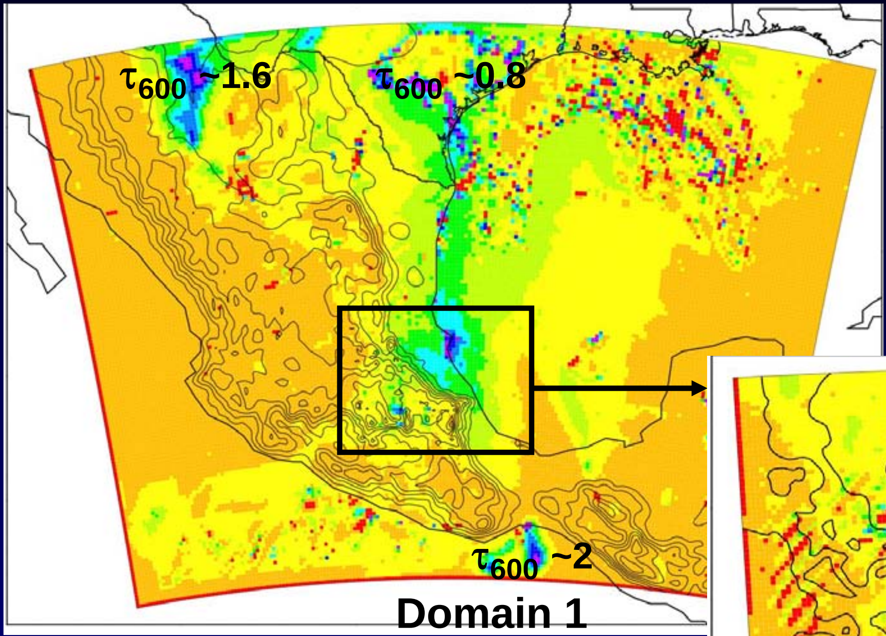
B200 Lidar, March 10



B200 Lidar, March 12

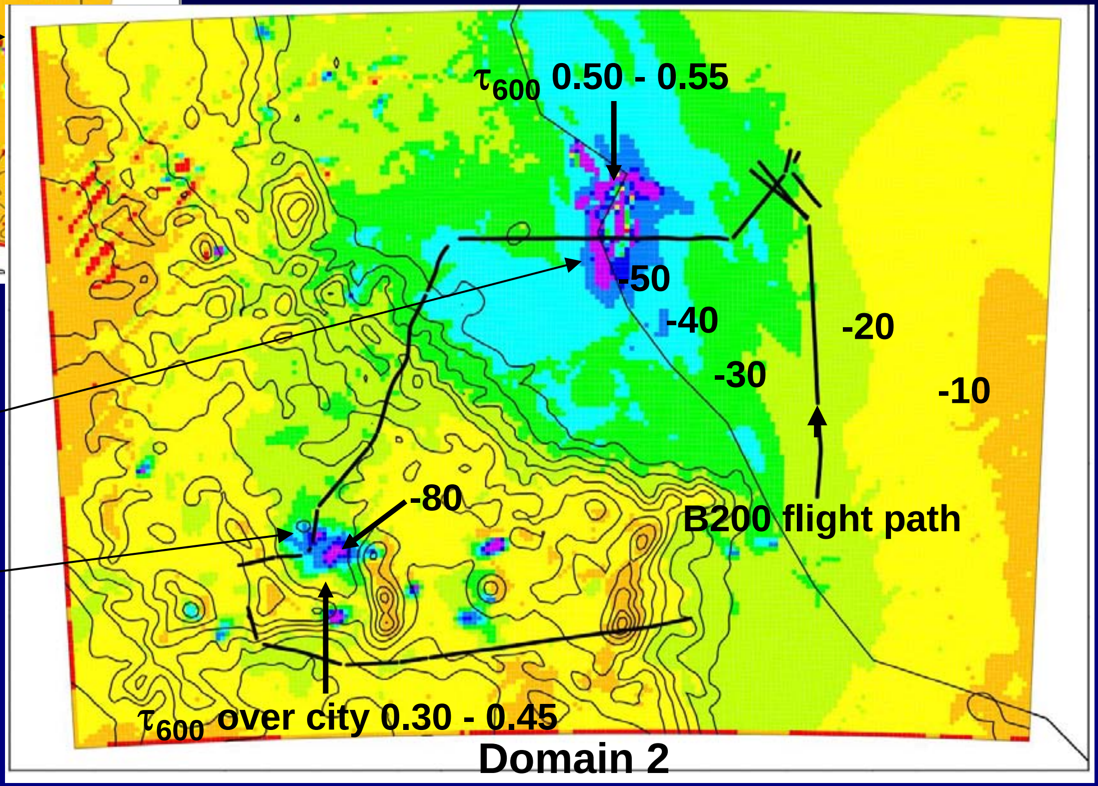


Mexico City “Footprint”

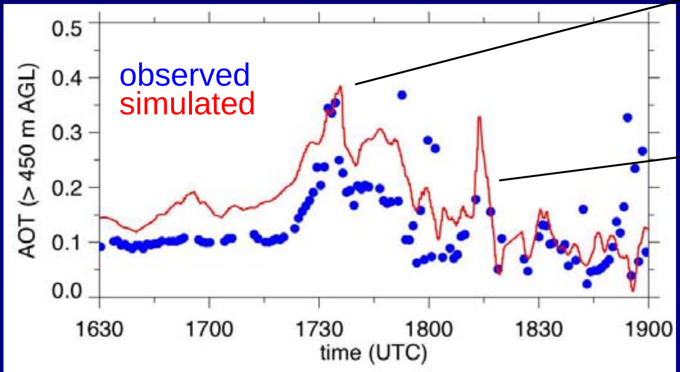


$\Delta SW\downarrow$ ($W\ m^{-2}$) 18 UTC March 12

simulation with feedback -
simulation without feedback

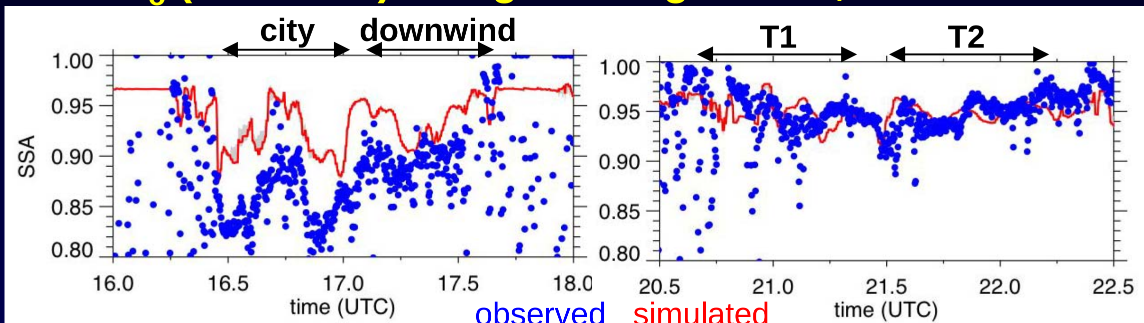


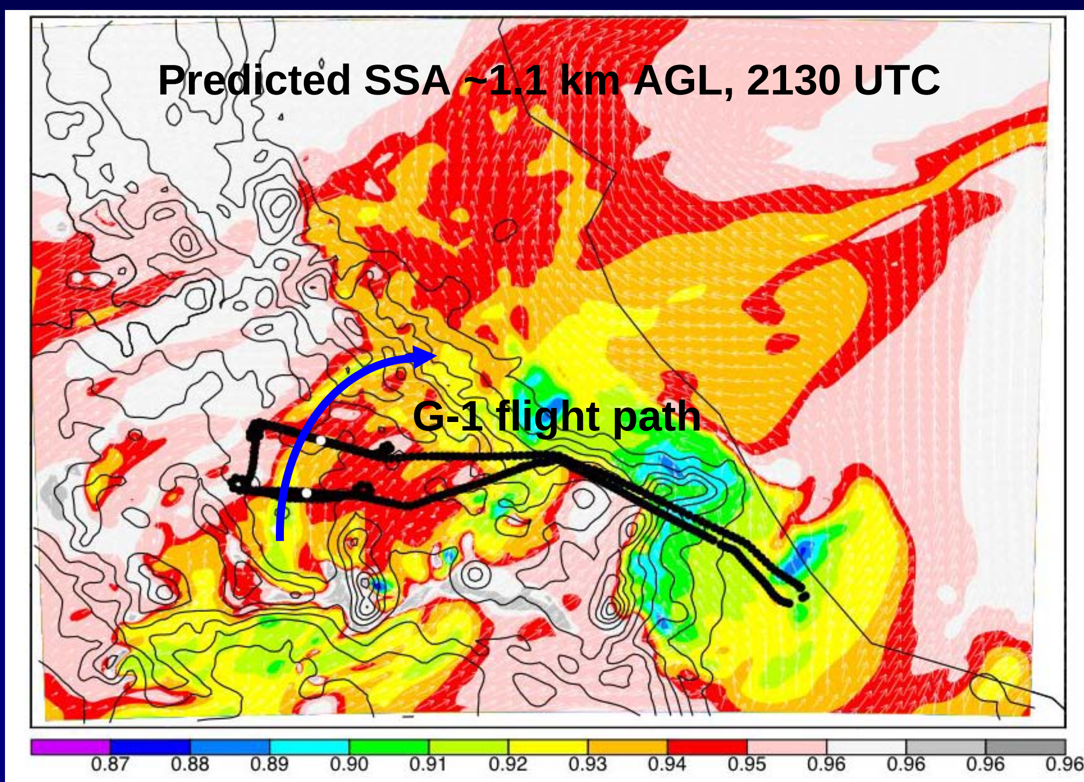
AOT along B200 Flight Path

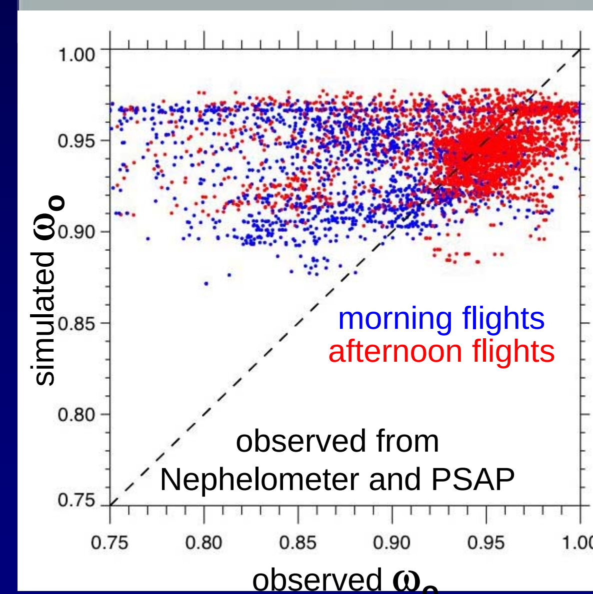


Single Scattering Albedo

ω_o (550m nm) along G-1 Flight Path, 20 March







- simulated ω_o better during afternoon
- errors likely the result of an under-prediction of elemental carbon

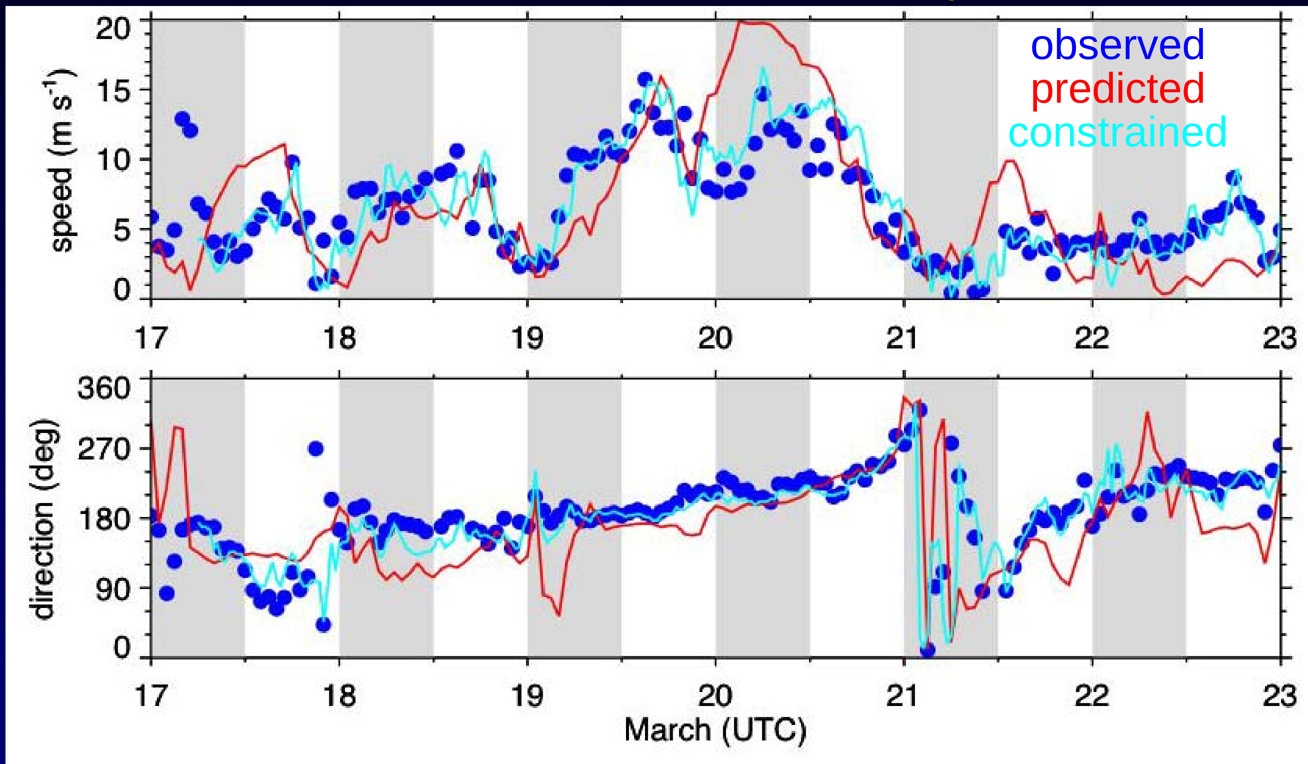
Comments

- In general, a qualitative agreement between predicted and observed magnitude and spatial variations in τ and ω_o, but …
- there are still relatively large errors at times.
- When the predictions agree with the observations, is the model getting the right answer for the right reason?
- When the predictions differ with the observations, what are the factors contributing to these errors?

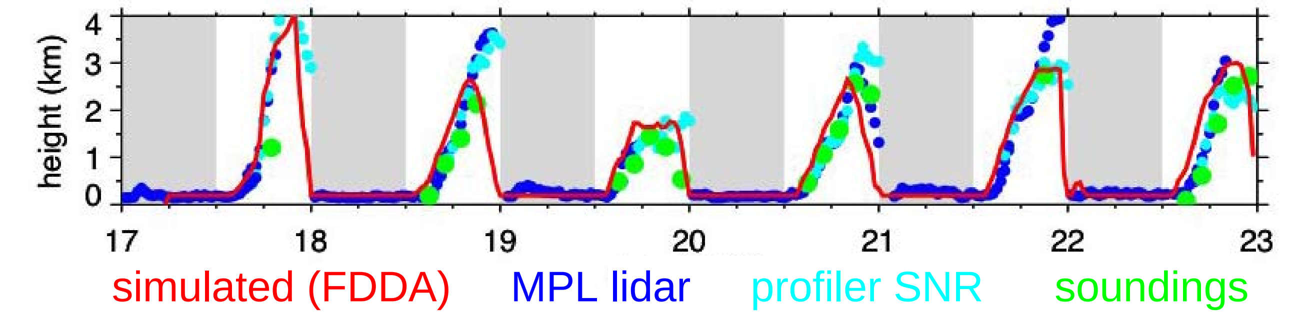
➔ Need to examine predicted meteorology and chemistry that affect particulate evolution as well as particulate mass, composition and size distribution that affects aerosol optical properties

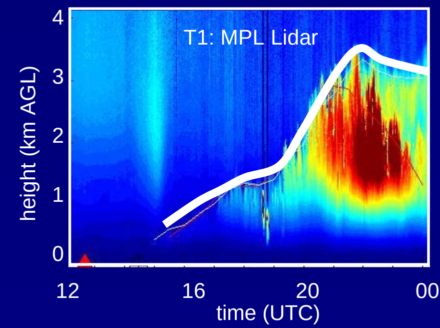
Transport and Vertical Mixing

Observed and Simulated Winds at T1, ~2190 m AGL



Observed and Simulated PBL Depth at T1

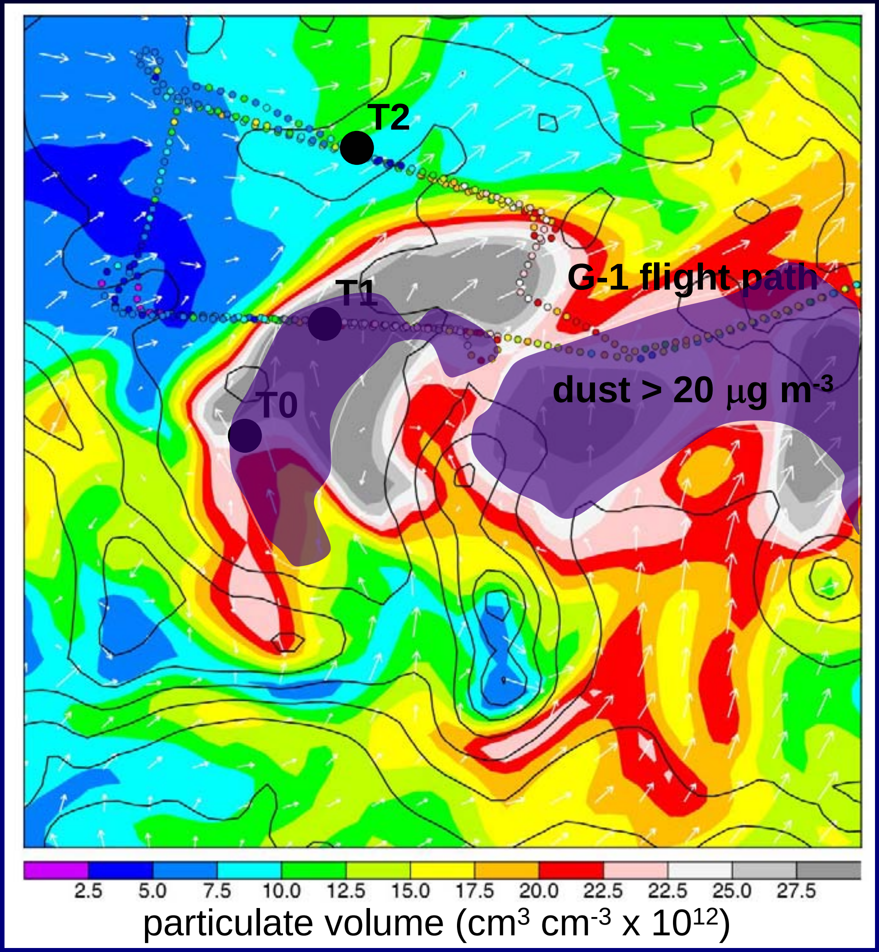




Spatial Variability

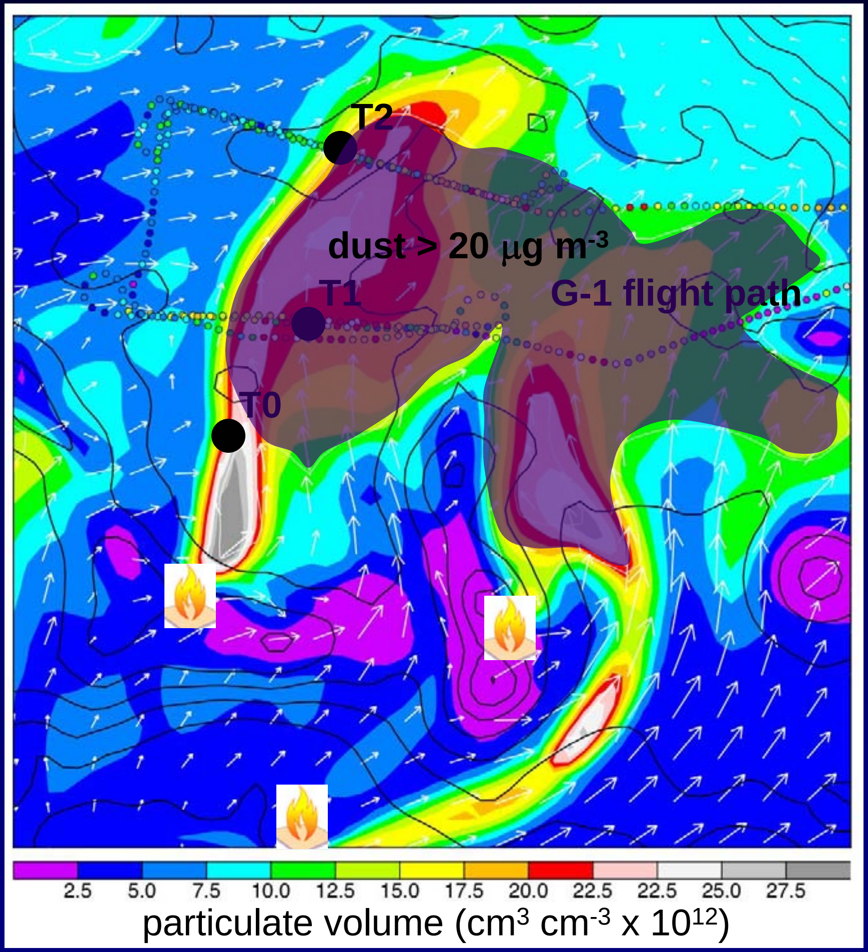
Predicted Particulate Plume ~800 m AGL

2300 UTC March 9



mix of urban and dust sources

2130 UTC March 20

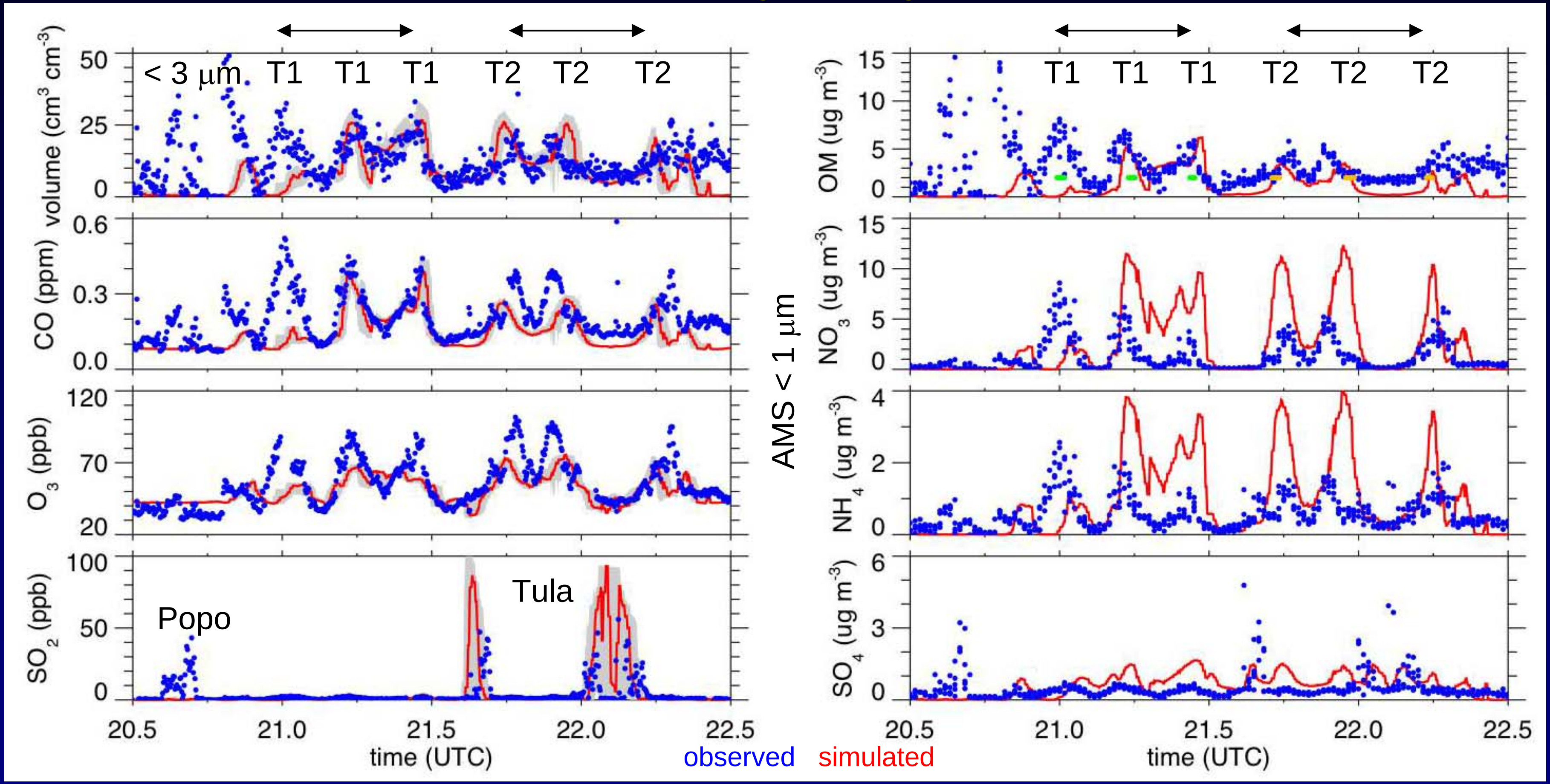


mix of urban, biomass burning, and dust sources

predicted spatial variations in particulate volume consistent with G-1 measurements

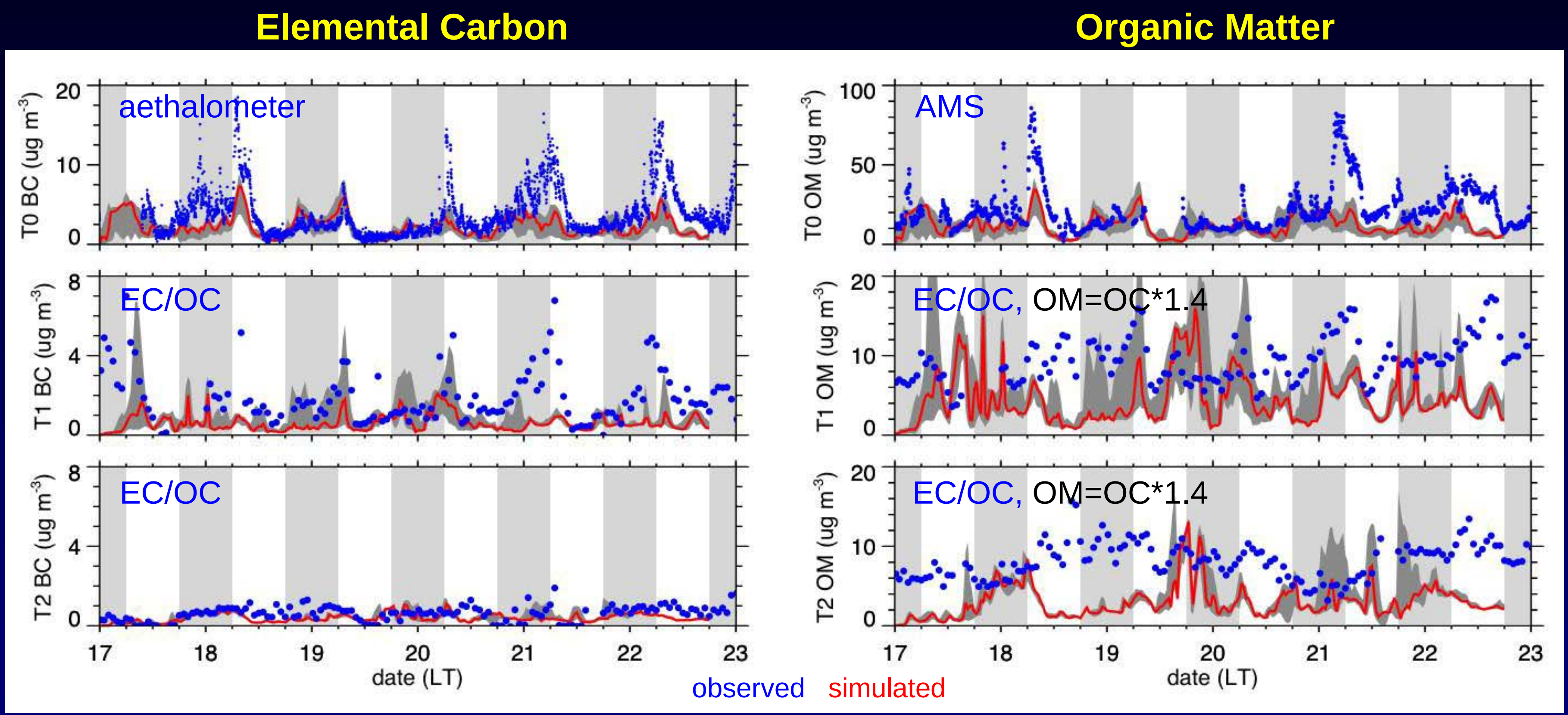
Composition Aloft

Observed and Simulated Values along G-1 Flight Path, Afternoon of March 20



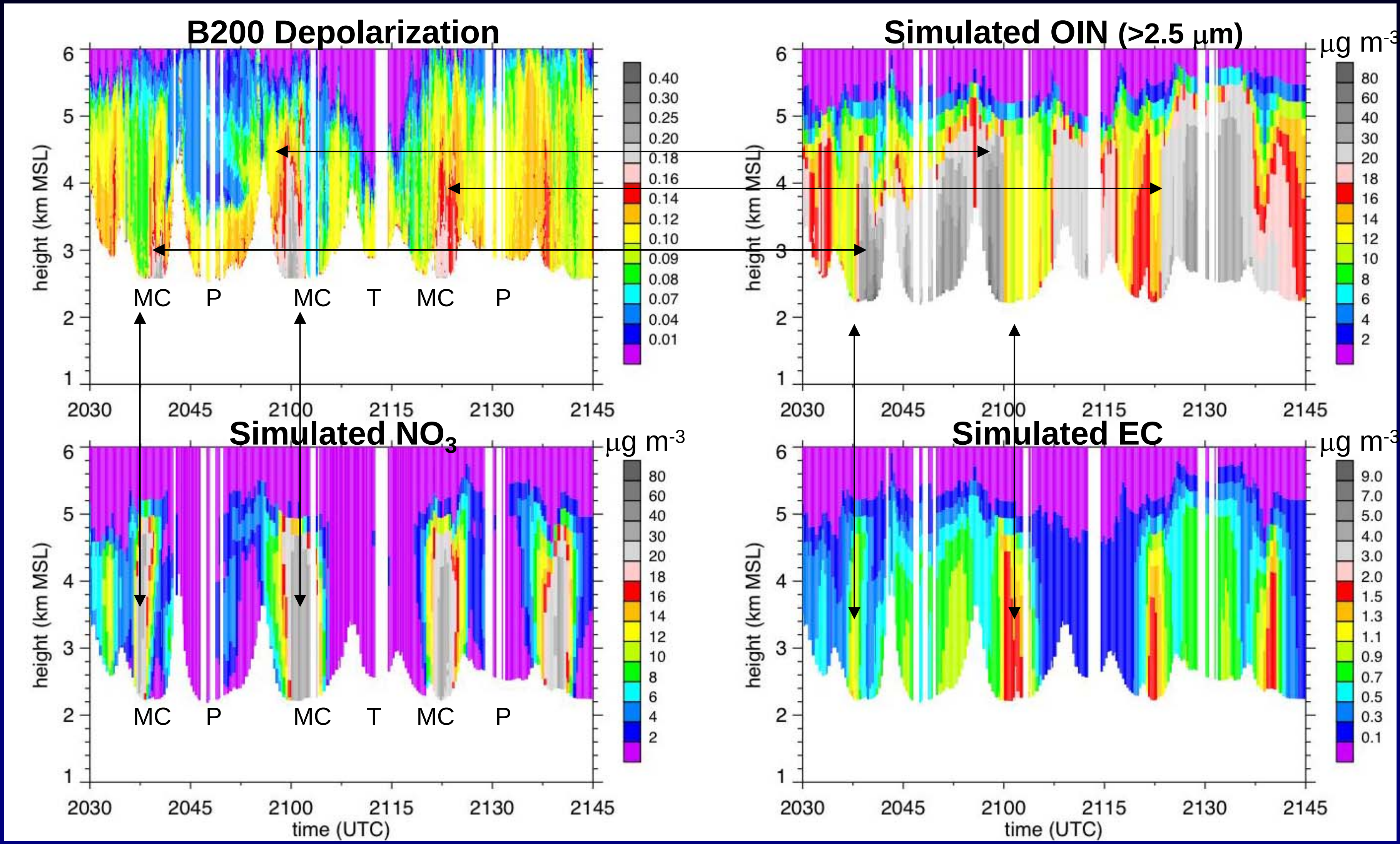
- predicted OM likely too high considering model has no SOA
- NO_3 and NH_4 too high and O_3 too low since predicted NOx too high
- SO_2 predicted well around Tula, but predicted SO_4 occurred further downwind
- inconsistency between particulate volume and mass from AMS?

Surface Composition



- Predicted variations in time agree best with T0 observations
- OM predictions at T0 may suggest POA emissions too high,
- Not a good correlation of EC and OM at T1 and T2
- Predicted OM at T1 and T2 too low as expected since the model has no SOA
- OM higher at surface that aloft as measured by G-1

B200 Lidar, March 9

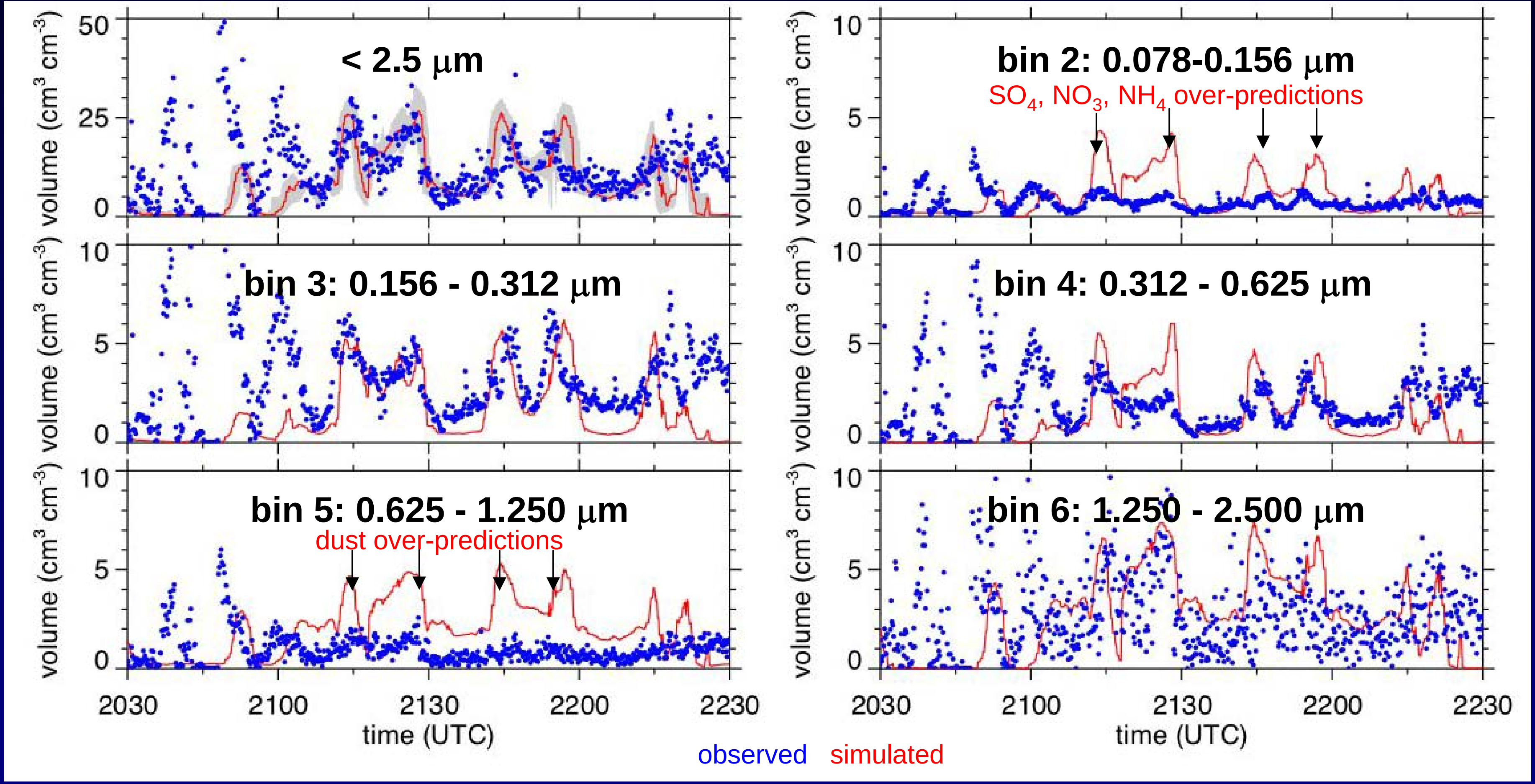


Lidar suggests strong horizontal variations in particulate composition across valley

Simulated urban and dust particulates often consistent with Lidar depolarization

Size Distribution

PCASP Particulate Volume Distributed over MOSAIC Size Bins



Dust emission parameterization produces too much dust < 1.25 μn

Over-predictions in SO_4, NO_3, and NH_4 in bin 2 do not occur during morning flights

Modeling Issues

Uncertainties in Emissions:

- Consistency between urbanized area in 2006 and emissions
- Biomass burning - MODIS hotspot counts missing events
- Dust source regions
- Composition of anthropogenic particulate emissions

Transport and Vertical Mixing:

- Despite data assimilation, small errors affects pollutant transport and complicated comparisons at T0, T1, T2
- Do errors in layering over Gulf affect radiative forcing downwind?

Secondary Organic Aerosols:

- Compare predicted OM with measured primary OM estimates
- Need a viable SOA treatment in the model

Optical Properties:

- Errors in mass & composition predictions affect τ and ω_o
- Treatment is likely to be important too (e.g. internal vs external mixing)

Uncertainties in Data:

- Need to account for these when comparing to modeled values

Acknowledgements

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