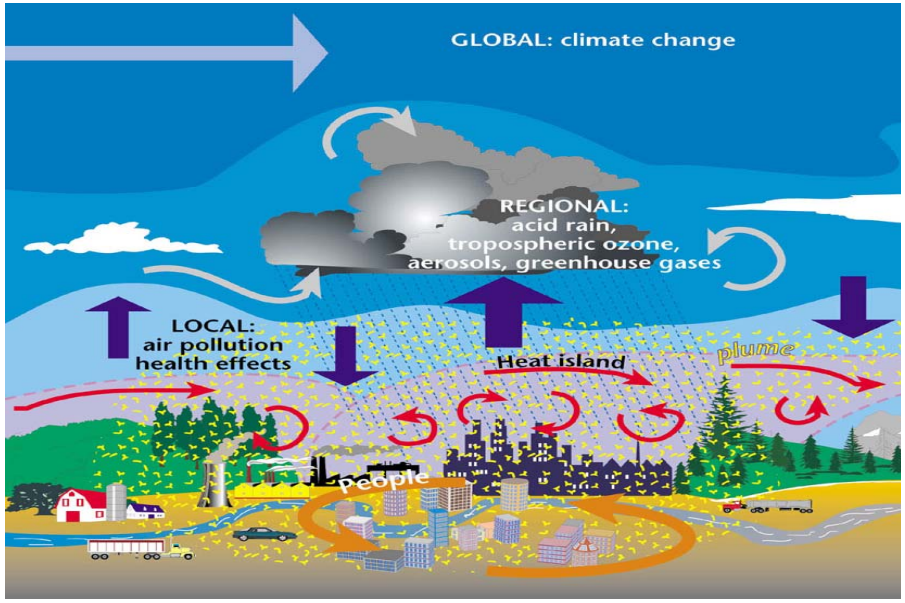
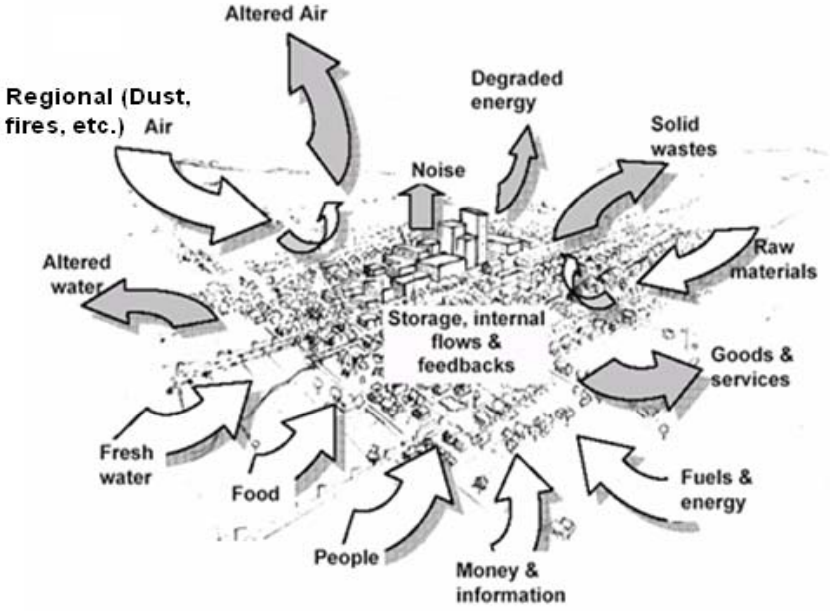
Models are an Integral Part of ABC Studies

- Field experiment planning
- Provide 4-Dimensional context of the observations
- Facilitate the integration of the different measurement platforms
- Evaluate processes (e.g., role of biomass burning, wet removal, heterogeneous chemistry….)
- Evaluate emission estimates (bottom-up as well as top-down)
- Scenario analysis/attribution studies

GAW Urban Research Meteorology and Environment
GURME project





T. Oke

How large are their footprints?

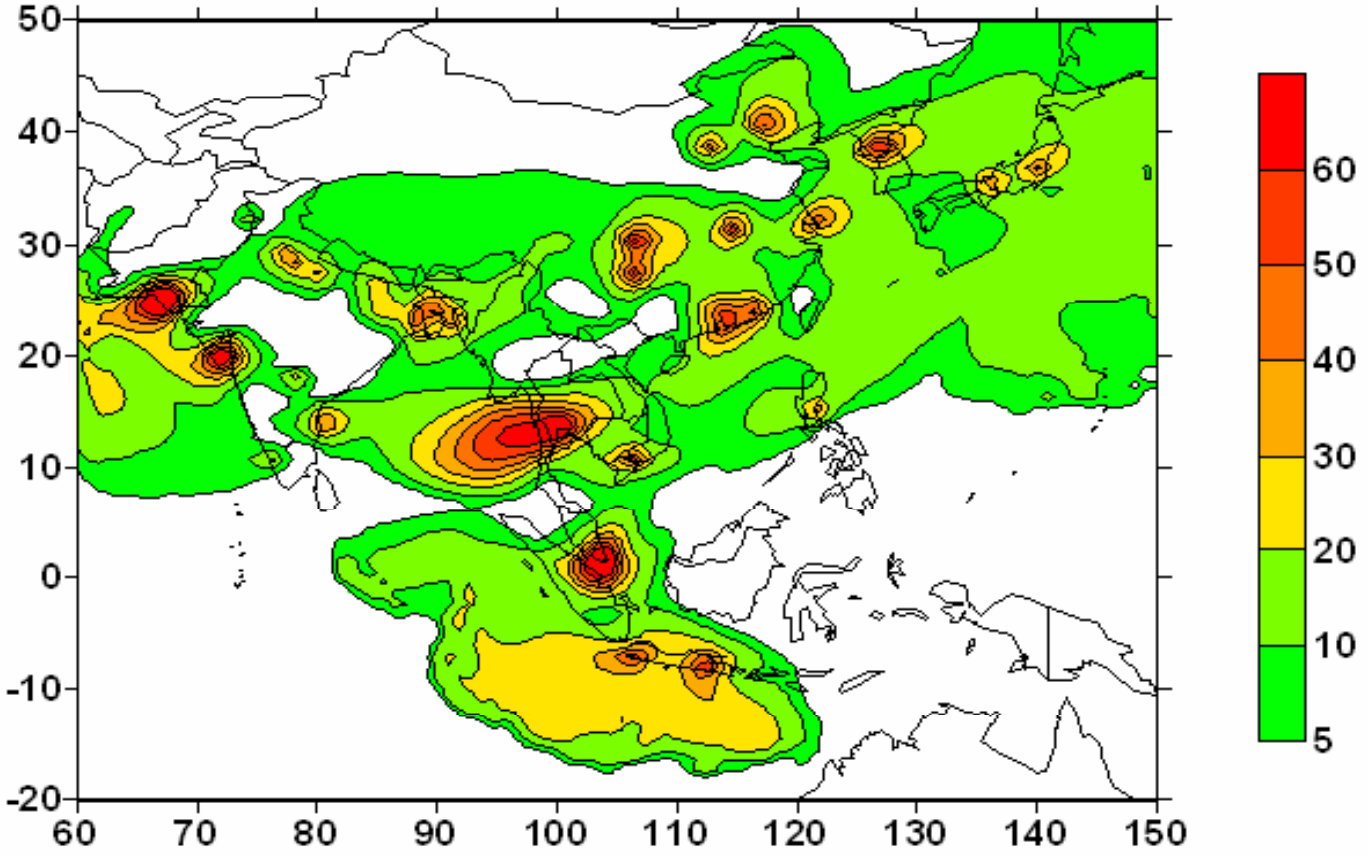
Air pollution in city clusters

- High levels of primary and secondary airborne pollutants lead to the development of an “air pollution complex”;
- Unique in scale and complication;
- Constraint factor to social – economic development ;
- Air quality improvement: regional coordination for joint implementation.

Mega-City "Footprints" Can Be Large

Percentage Contribution to Total Sulfur Deposition due to SO_2 Emissions from Megacities in Asia, (1975-2000)

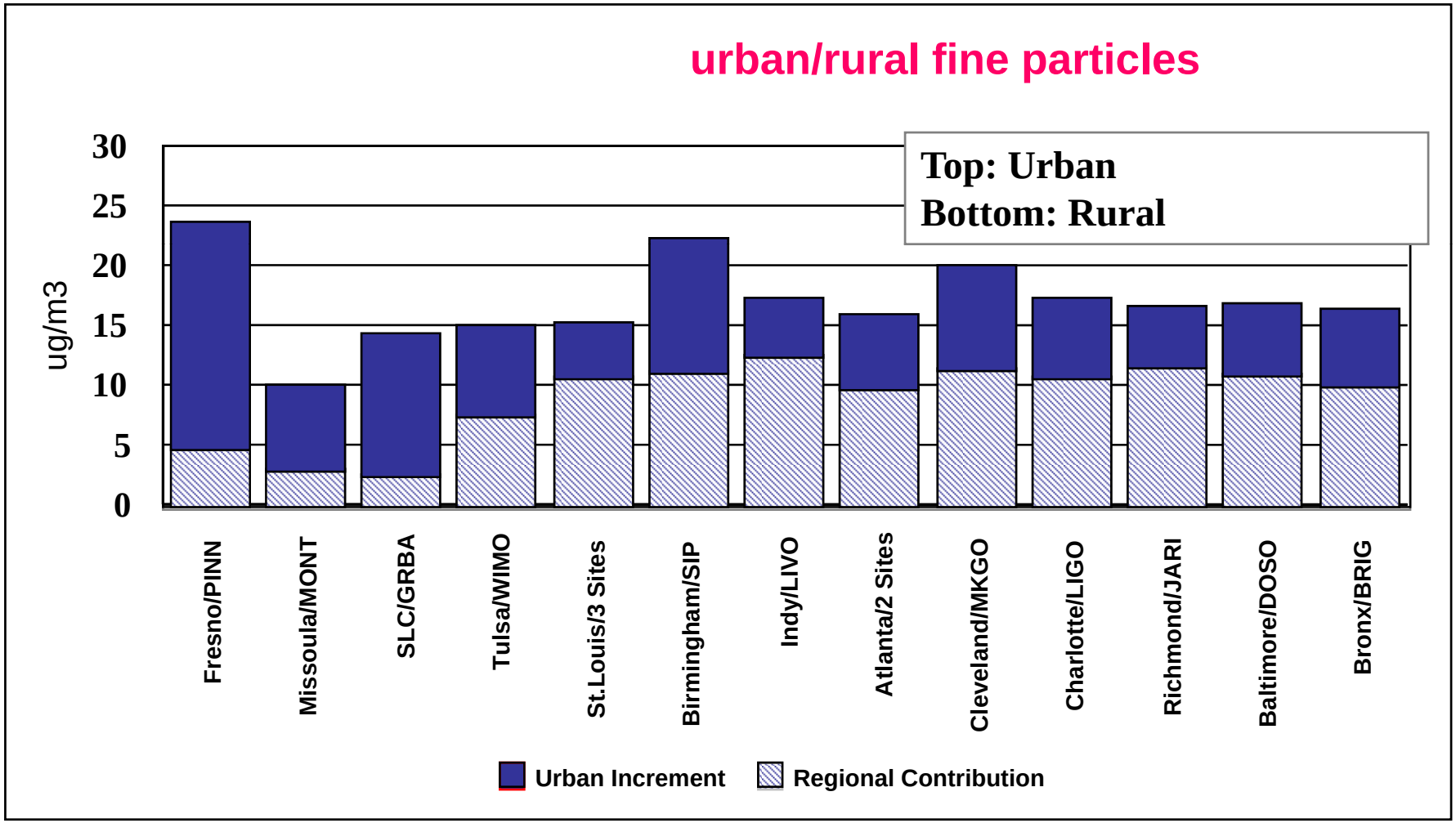
Megacities account for 11% of emissions and occupy <1% of land area



25yr Annual Average Total Sulfur Deposition Originating from Urban Asia

Guttakundi et al., Atmos. Env., 2003; JGR, 2006

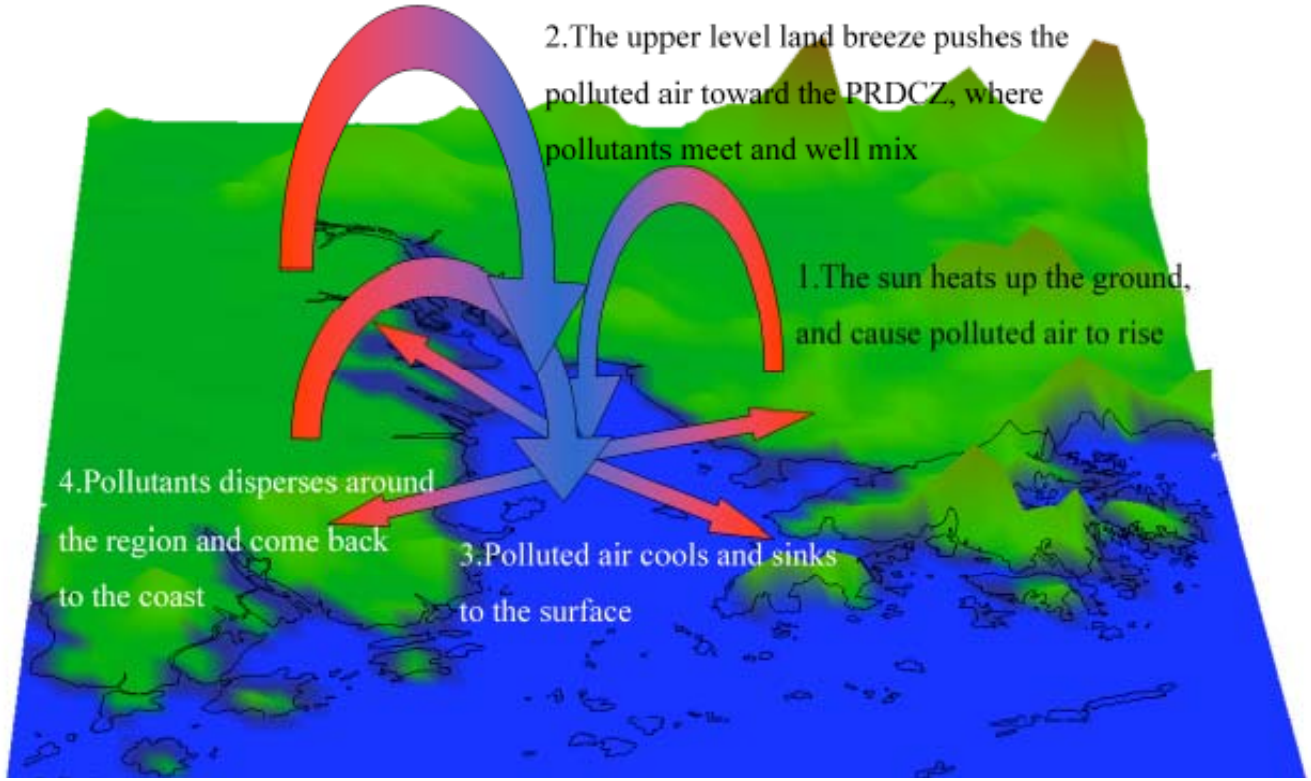
Regional Transport Is a Major Fraction of $PM_{2.5}$ and Ozone in Urban Centers and is Key to Devising Control Strategies



12-month average PM2.5 mass from speciation samplers

Reference: 2002 EPA Trends Report http://www.epa.gov/air/airtrends/chem_spec_of_pm2.5_b.pdf

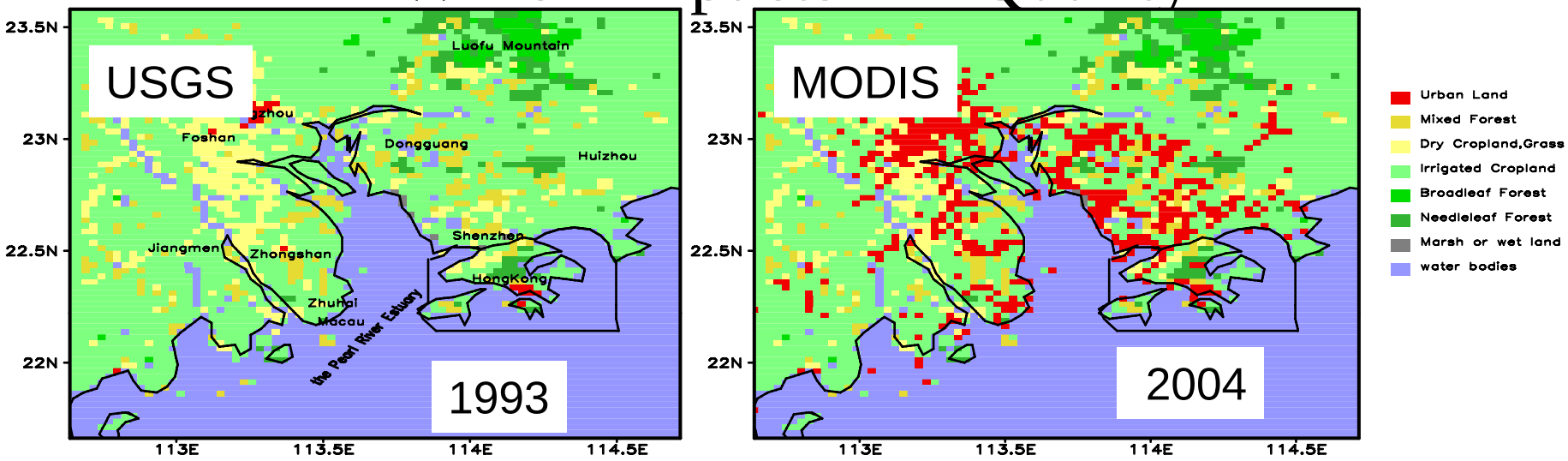
Impacts of Urban Heat Islands on Meteorological Conditions



Urban heat islands reduce the strength of nocturnal land-breeze (return flow from land to sea), so air pollutants tend to accumulate over land.

Lo, Lau, Chen, Fung, 2006 (*J. Appli. Meteor. And Climate*)

Urbanization Also Impacts Atmospheric Physics – Which Impacts Air Quality



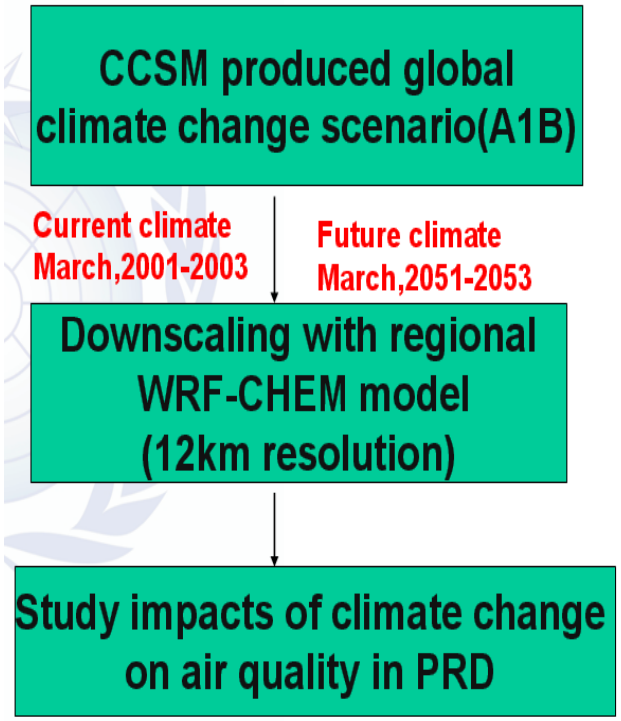
Urban heat islands reduce the strength of nocturnal land-breeze (return flow from land to sea), so air pollutants tend to accumulate over land.

Lo, Lau, Chen, Fung, 2006 (*J. Appli. Meteor. And Climate*)

- **Influences of urban expansion on increase temperature and decrease wind speed, PBL depth increase more in the day time than that in the night time.**
- **Areas with main O_3 concentrations increase (from 2 to 6 ppb), coincident with the areas of increased temperature and decreased wind speed, PBL depth also plays an important role in the daytime vertical transport**

Wang X.M. et al. (2007, Tellus -B)

Future Climate Change on O_3



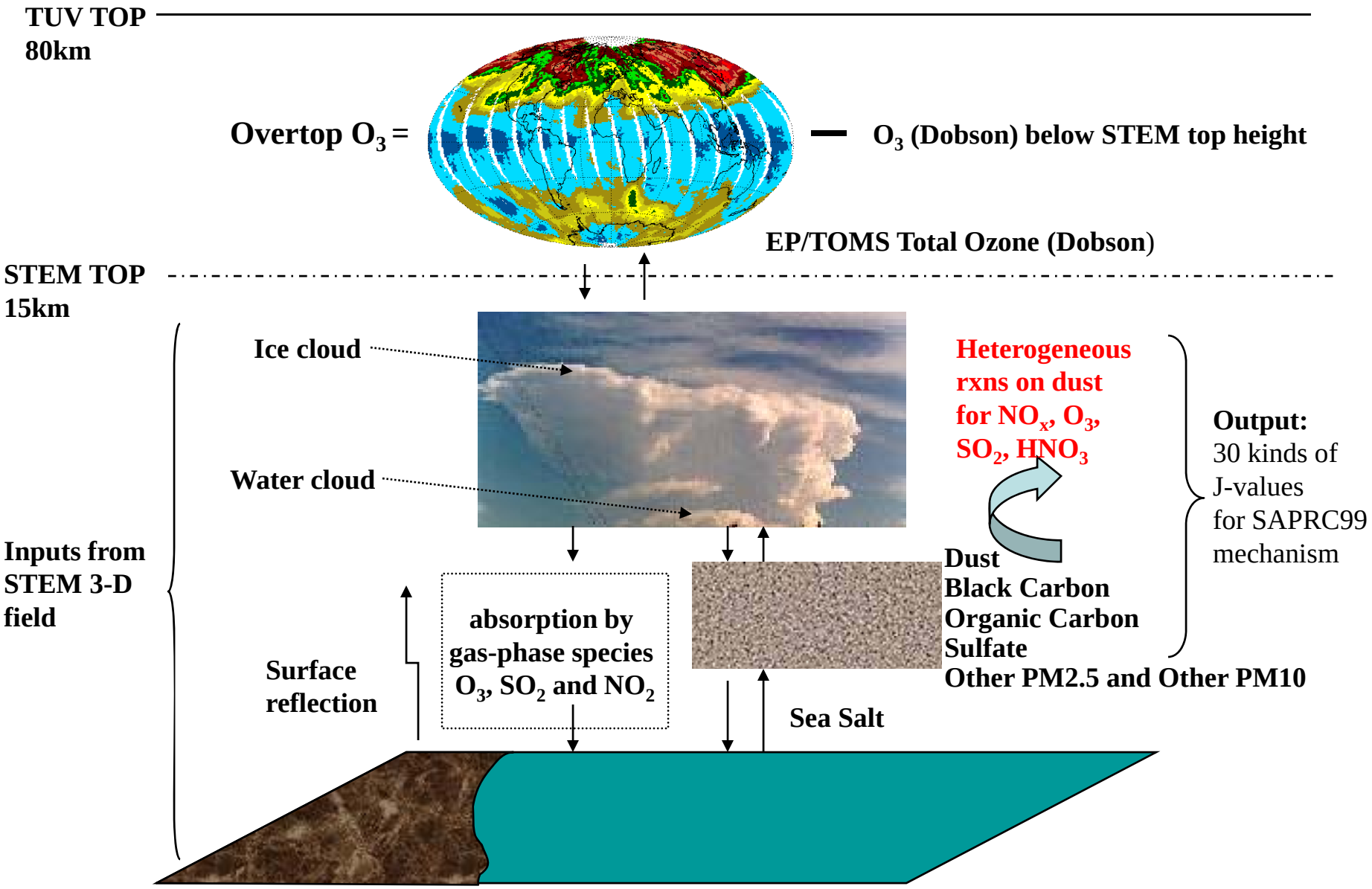
Community Climate System Model(CCSM3) with 1.4 degree

Weather Research and Forecasting model with Chemistry (WRF-CHEM)

Findings

- **Future climate change has significant influence on O3 in the PRD**
- **Temperature decrease up to -1.0 C (3%)**
- **Downward solar radiation increase up to 12%**
- **Decreased water vapor mixing ratio up to 10%**
- **Less frequent rainfall (0-6 days per month)**
- **Stagnation events increase up to 2 days per month**
- **Unvented hours increase up to 2 hours per day**
- **Mean ozone concentration increase up to 6 ppbv, about 20% in the future.**

Aerosols Are a Key Component in Urban Environments -- Impacting Chemistry and Physics



Introduction

- Experimental Setup
- Model performance and improvements.
- Regional Effect on Ozone Production Regimes.
- Effect of aerosol loading in ozone formation.
- Conclusions

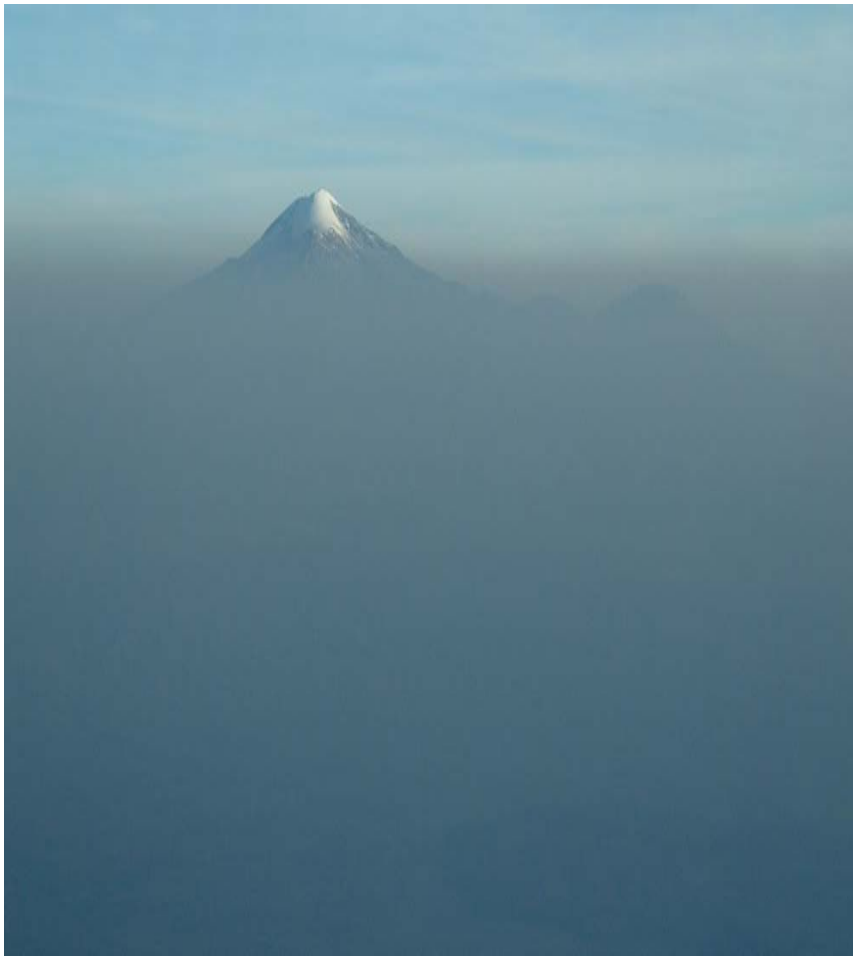
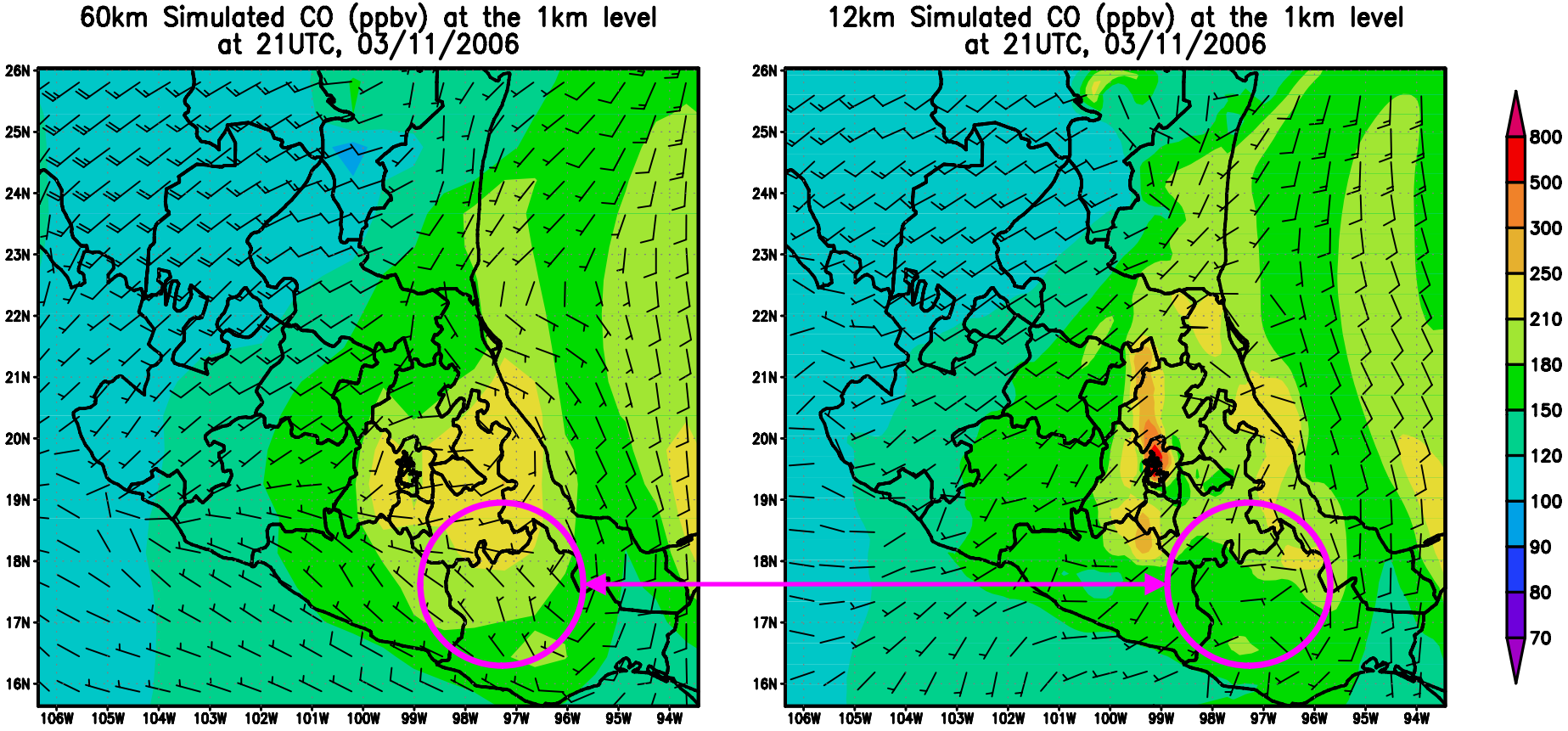


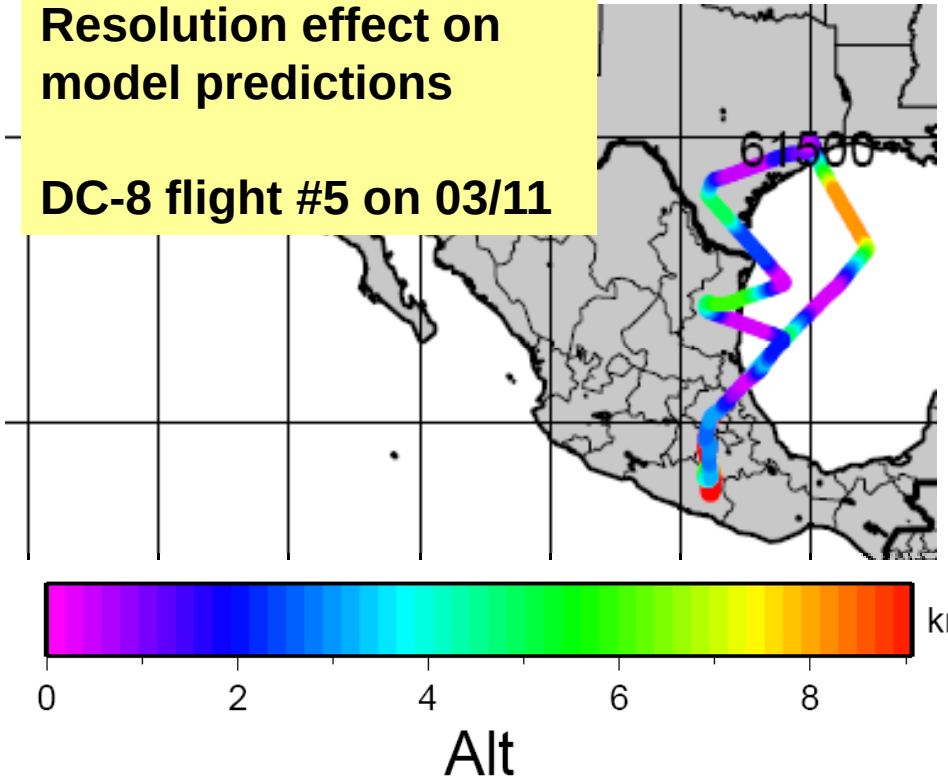
Photo Credit: Frank Flocke.

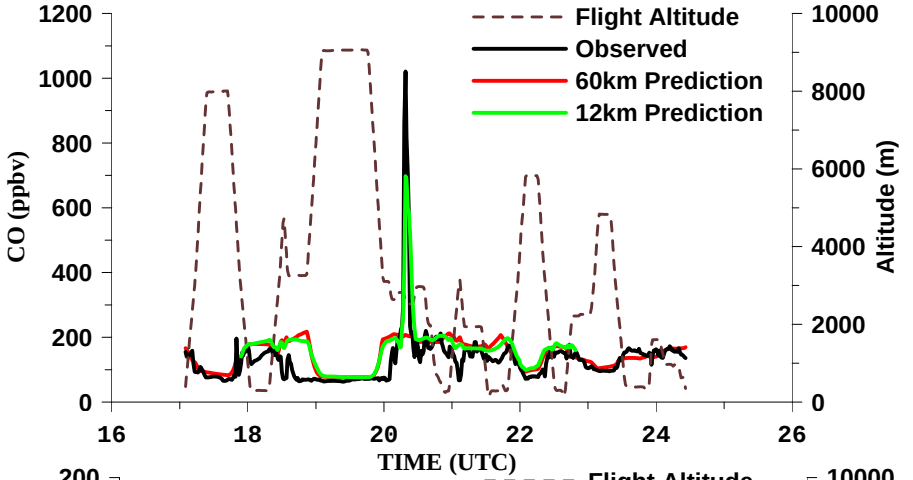


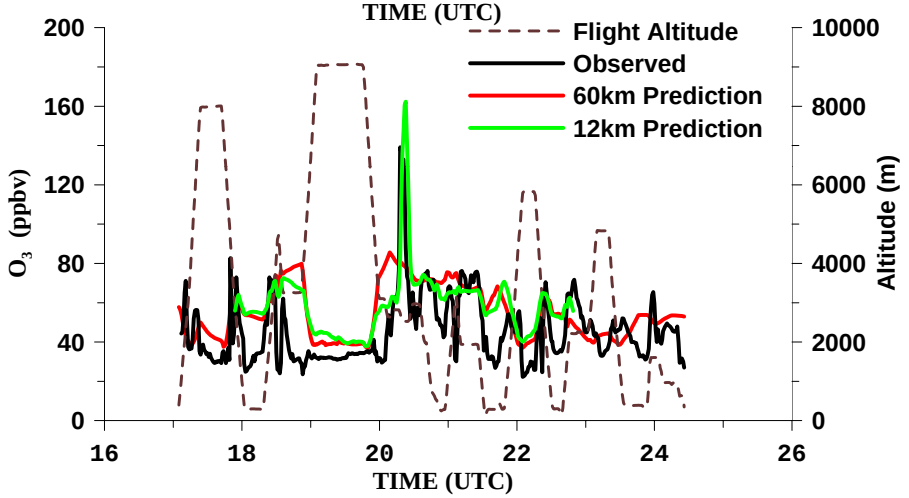
The high-resolution simulation yield different results not only due to the improved resolution of emissions, but also due to the terrain/landuse and wind field.

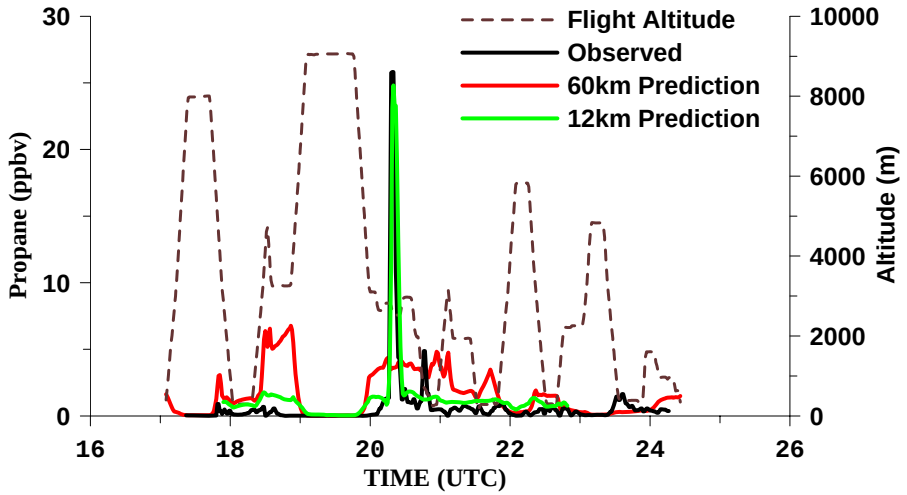
Resolution effect on model predictions

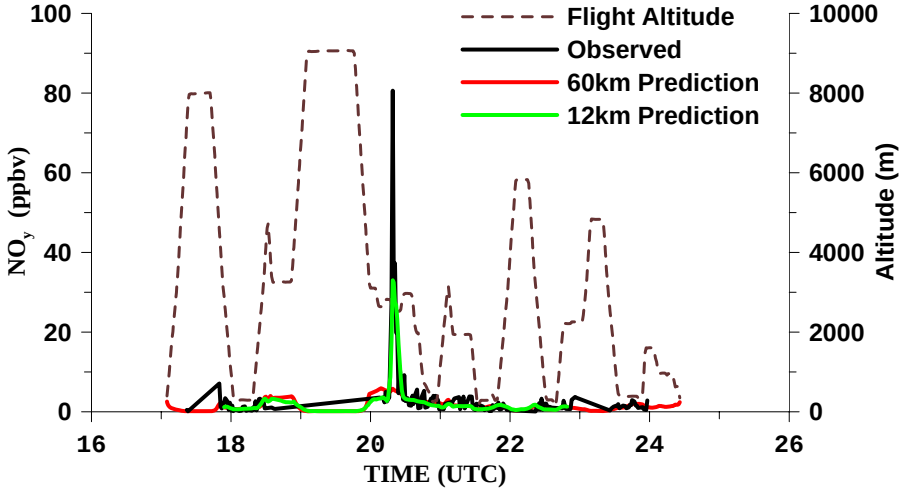
DC-8 flight #5 on 03/11





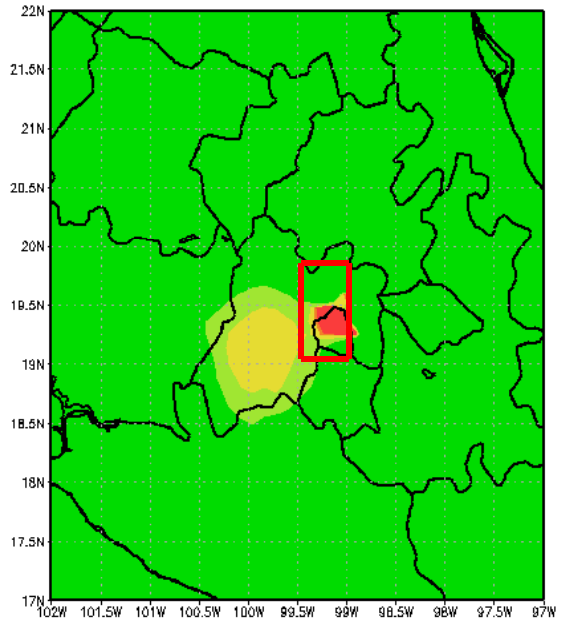


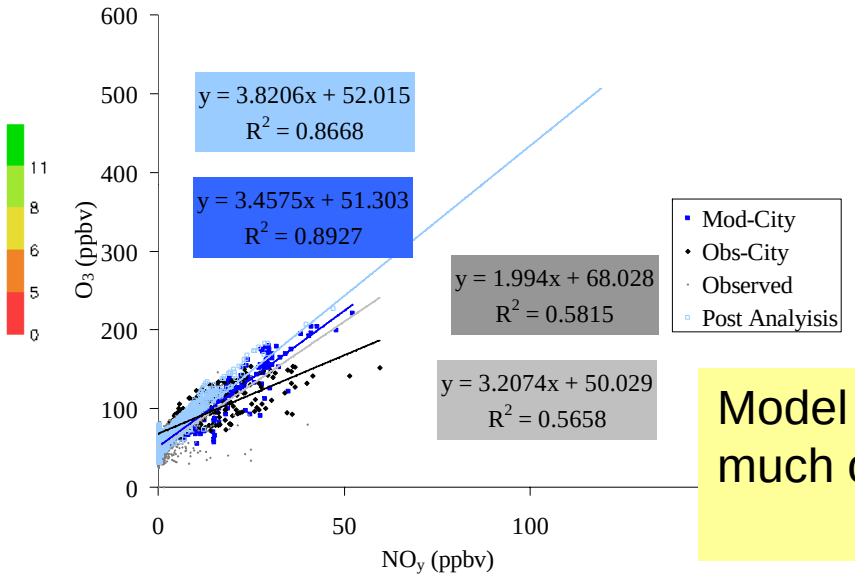




Modeled and observed indicator ratios.

All data :3.8 (mod) and 3.2 (obs).
City Loop: 3.5 (mod) and 2 (obs)

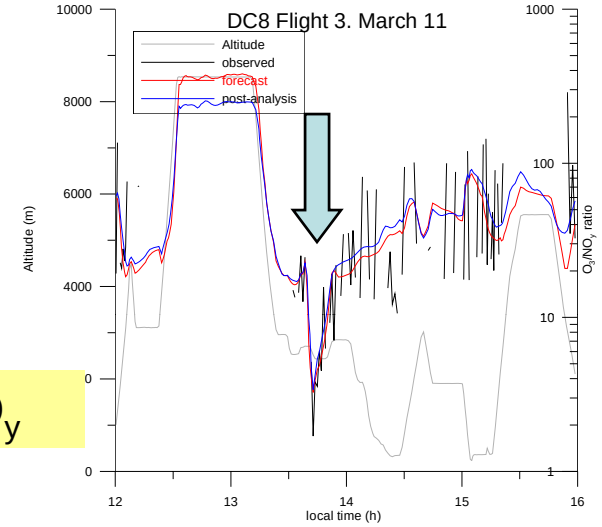




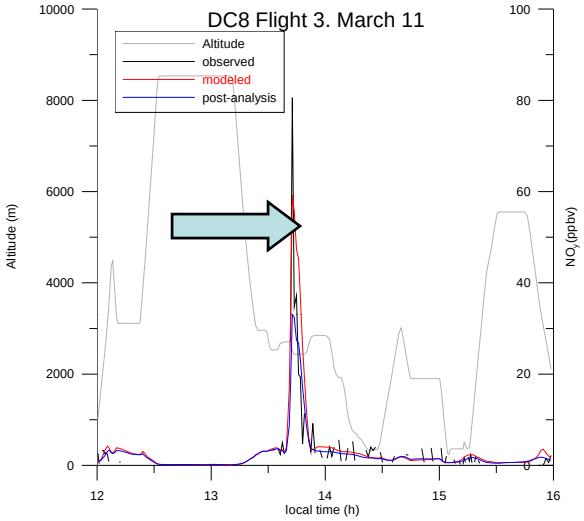
Model makes too much ozone in city.

Figure 5. Left Panel: Modeled mean daytime O_3/NO_y ratios for STEM 2k3 12km run. Red represents VOC limited conditions, Green represents NO_x limited conditions. Right panel: measured and modeled O_3 vs. NO_y. Blue: Post analysis. Gray: Observed.

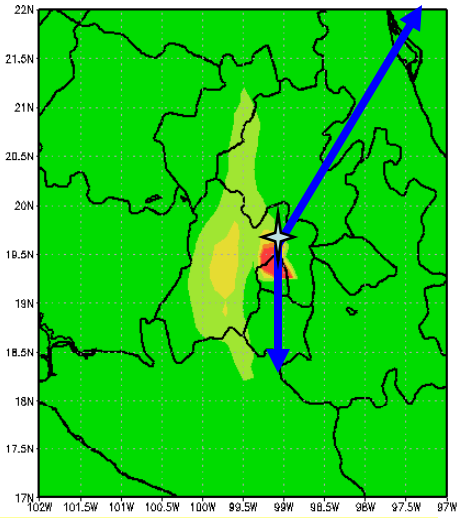
MC Influence: March 11, VOC limited conditions.



O_3/NO_y



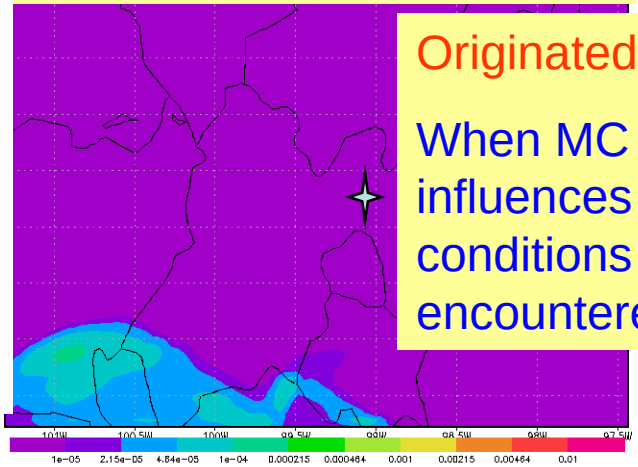
NO_y



GrADS: COLA/IGES

Modeled O3/NOy

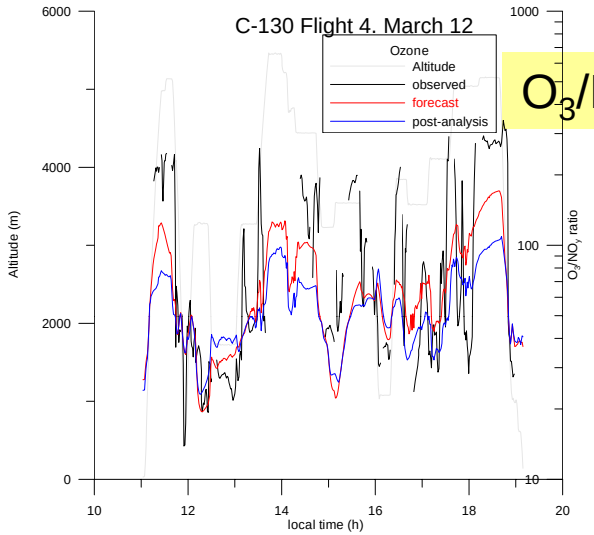
Adjoint sensitivity on point along DC-8 path



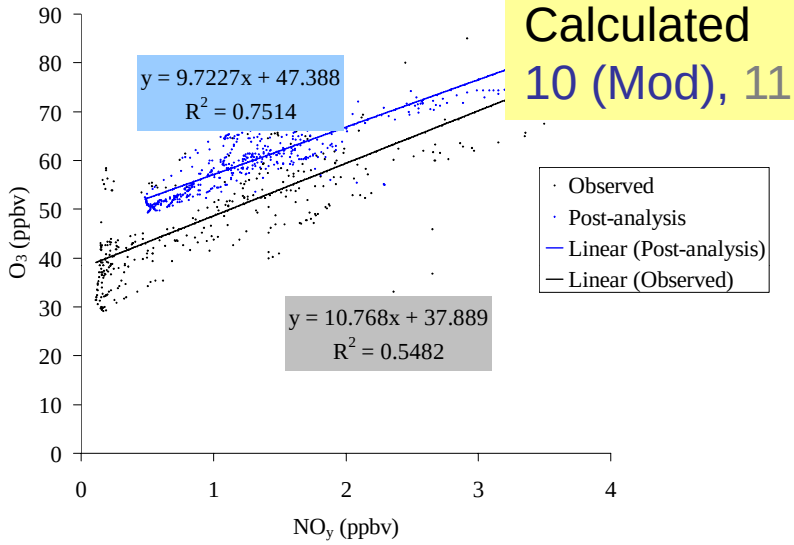
Originated in Mexico City.

When MC outflow influences region, VOC lim conditions can be encountered.

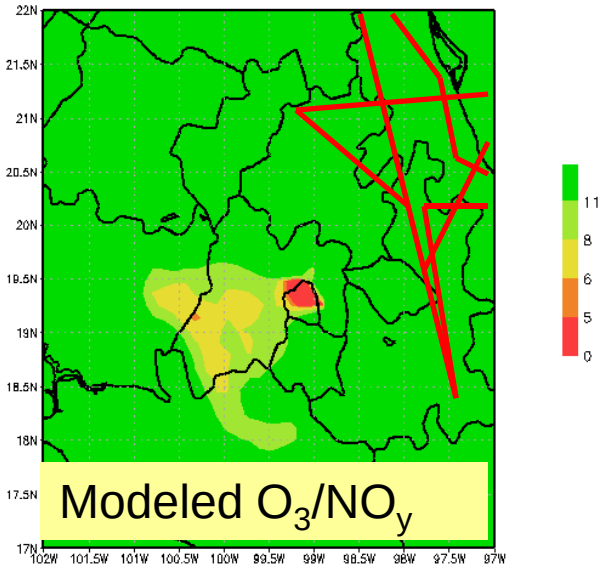
No MC influence: March 12, NO_x limited conditions.



O_3/NO_y



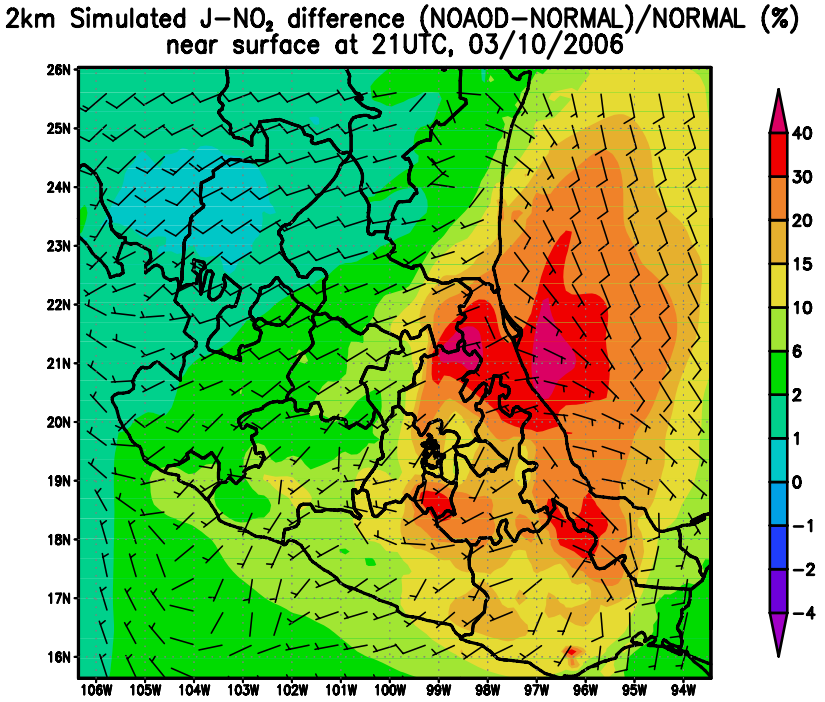
Calculated Slope: 10 (Mod), 11 (Obs)

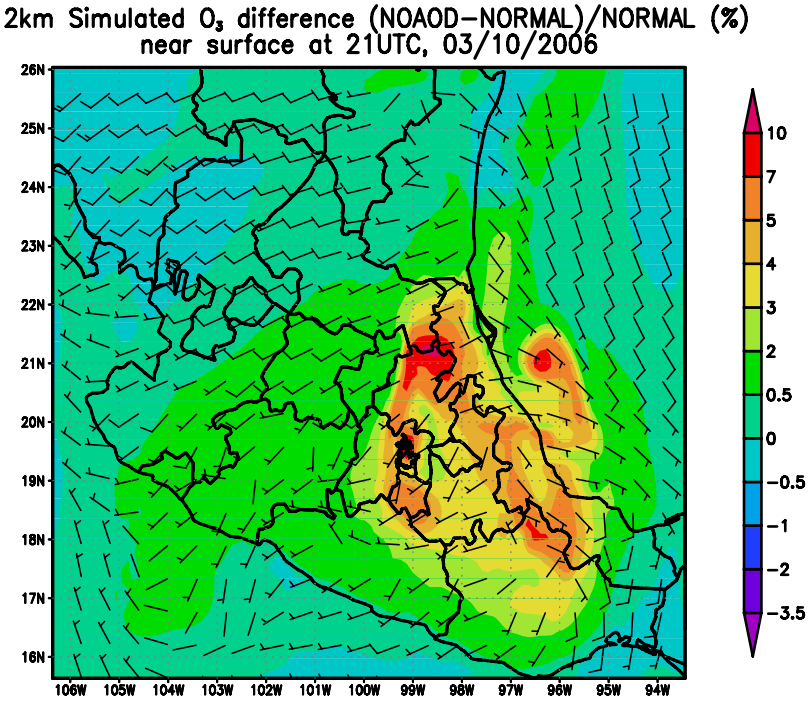


Modeled O_3/NO_y

Mexico City influence to West. NO_x limited conditions are sampled.

Impact of Aerosols on Mexico City Photochemistry – Milagro Period





J-NO2 **O3**

% Difference (without aerosol – with)/with

Due to the Complexity and Uncertainties in Calculating the Sources, Formation, Transport and Removal of Aerosols in the Atmosphere, a Closer Integration of Observations and Models is Needed

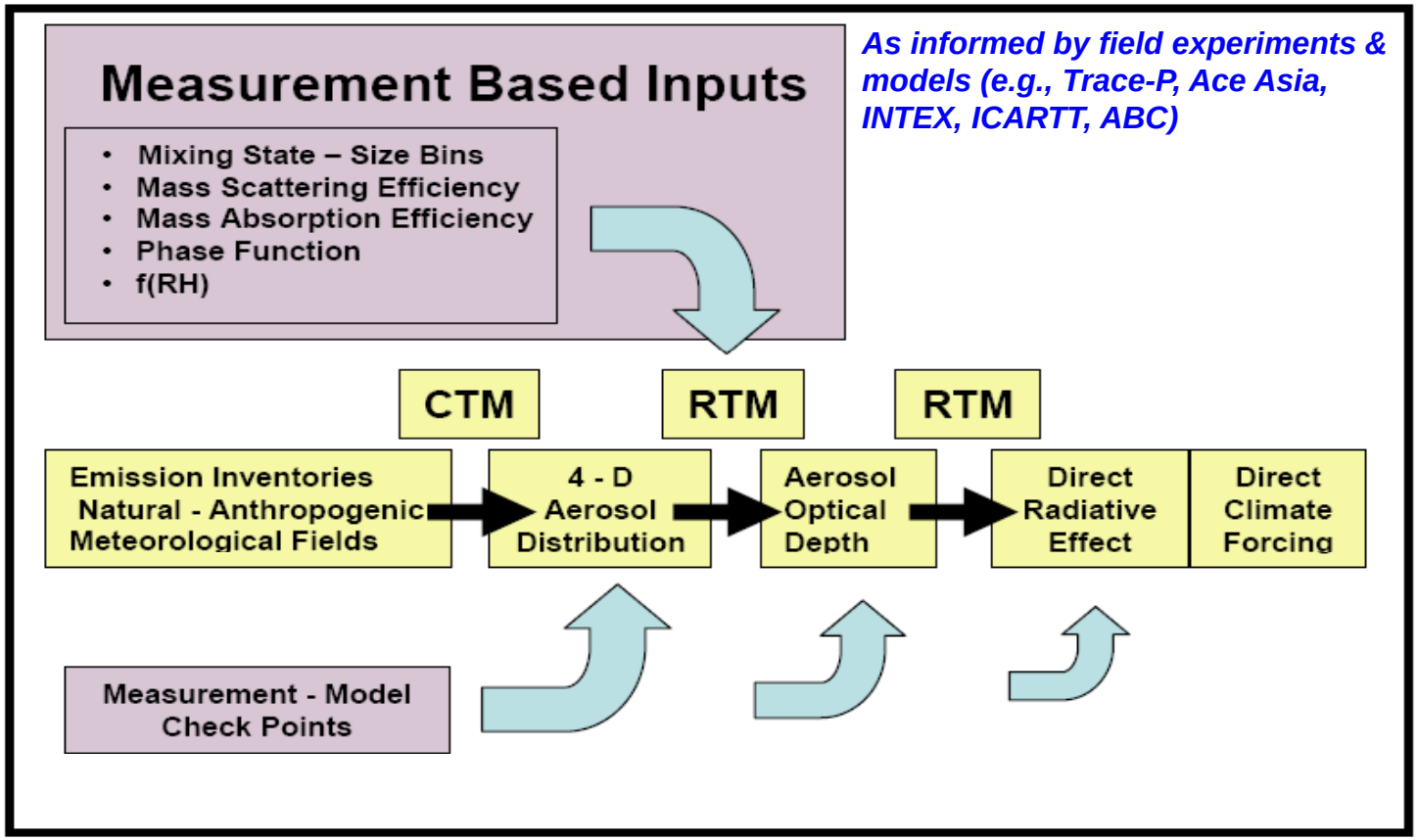
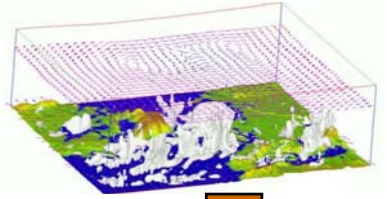


Figure 1. Schematic of the approach taken here to calculate the direct radiative effect (DRE) and direct climate forcing (DCF) and to narrow their uncertainties. Emission inventories and meteorological fields were used in CTMs to calculate dry 4-D aerosol distributions. The RTMs used these distributions and in-situ measurement based optical properties to calculate aerosol optical depth, DRE and DCF. Measurements and model output were compared at three points in the process.

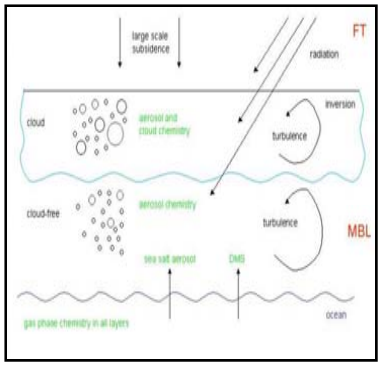
Bates et al., ACPD, 2005

Air Quality Modeling: Improving Predictions of Air Quality (analysis and forecasting perspectives)

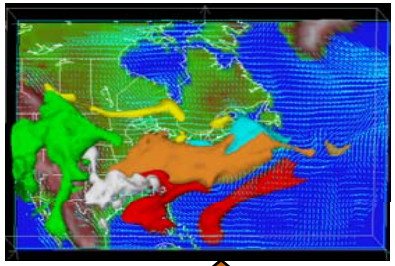
Met model



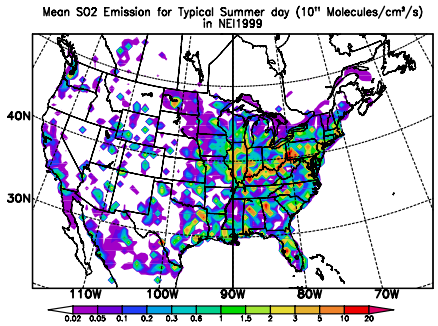
Chemical, Aerosol, Removal modules



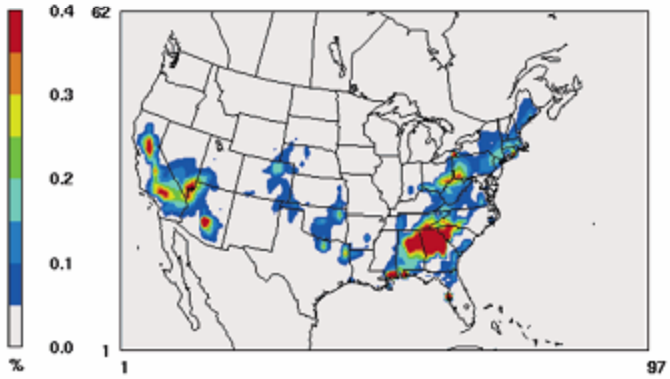
CTM



Emissions

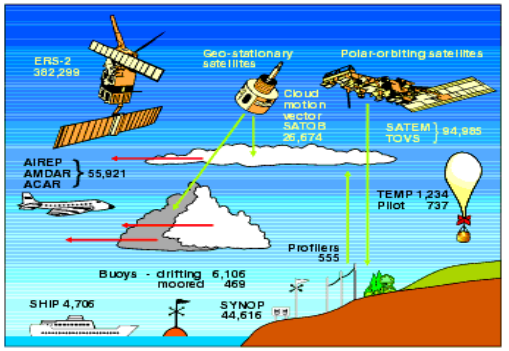


Predicted Quantity: e.g., *ozone AQ violation*

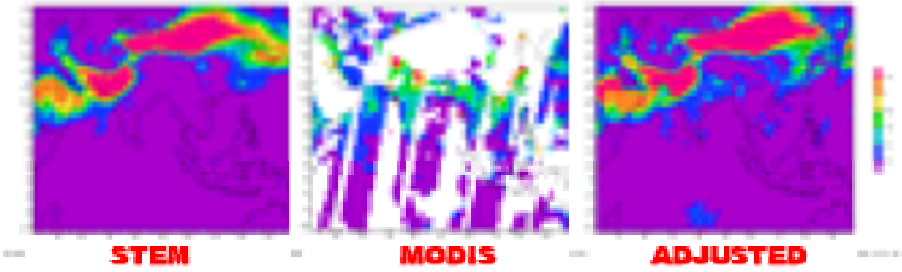


Constrained Fields Through Assimilation

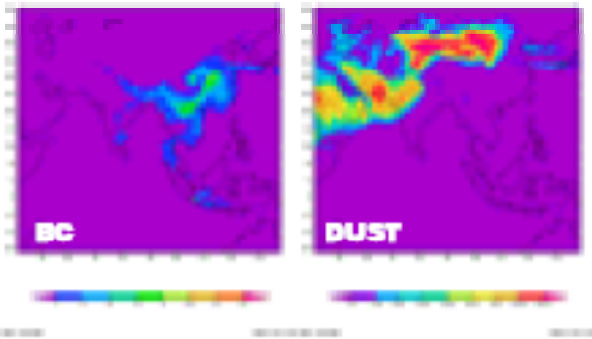
Observations



Initial Condition Adjustment



24 hr STEM Run



Computing of 2D AOD* from 3D STEM's concentrations field according with IPCC table

The adjustment is for both large mode and fine mode AOD

Modeled fine mode AOD: **OC, BC, SULF** (these species are considered as representative of anthropogenic portion of the aerosol, see table 5)

*the same procedure has been adopted for the estimation of the SSA (see table 9)

5-yr Mean Aerosol Mass

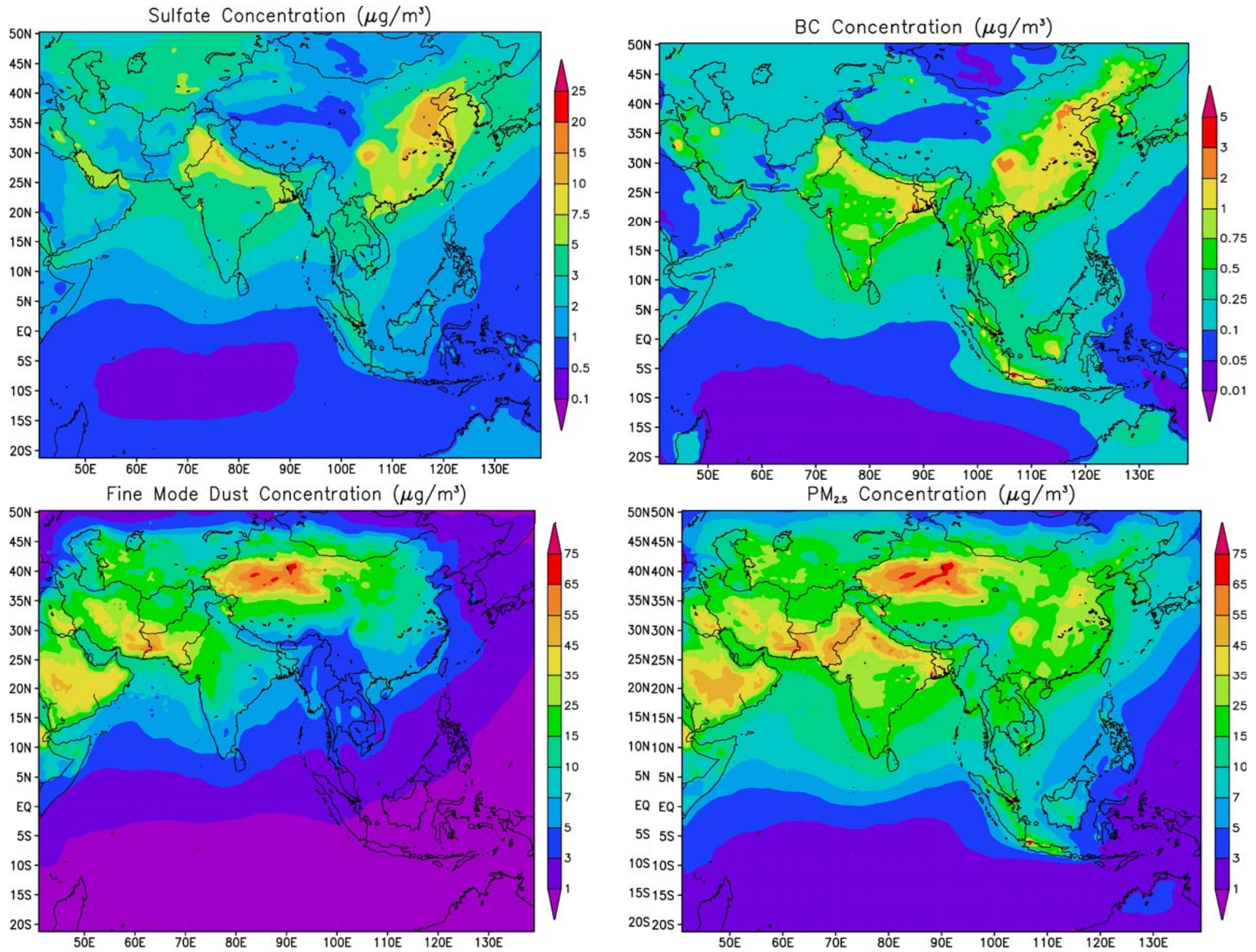
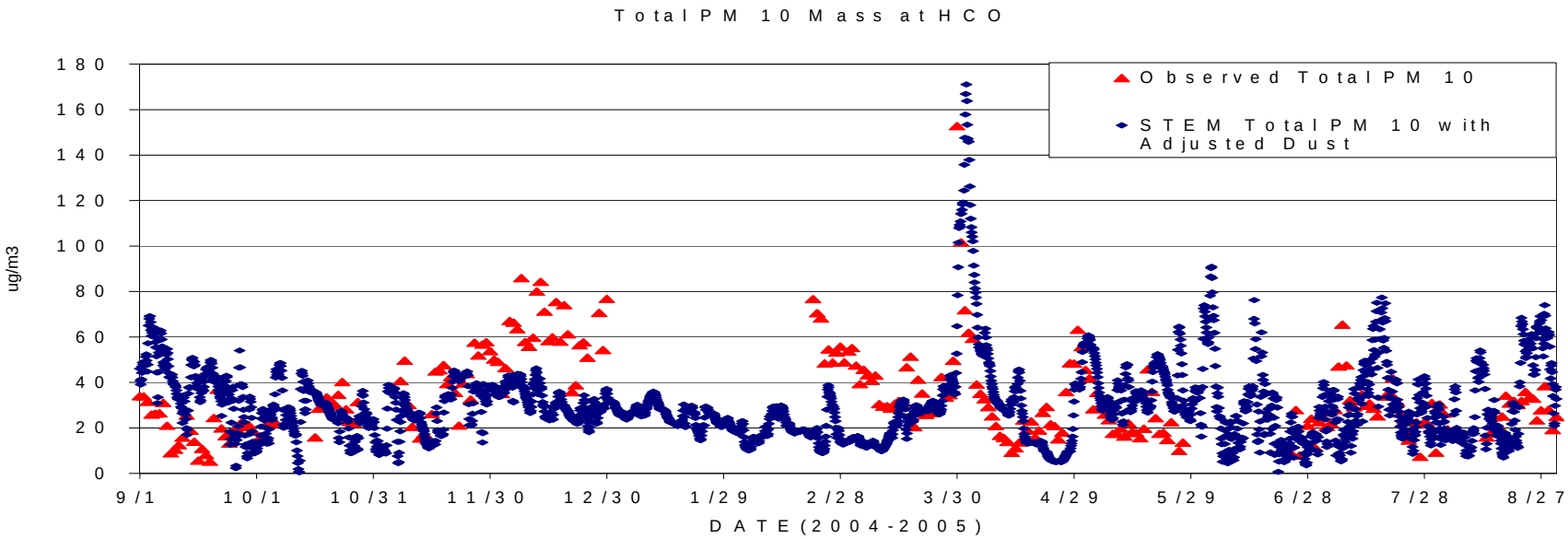
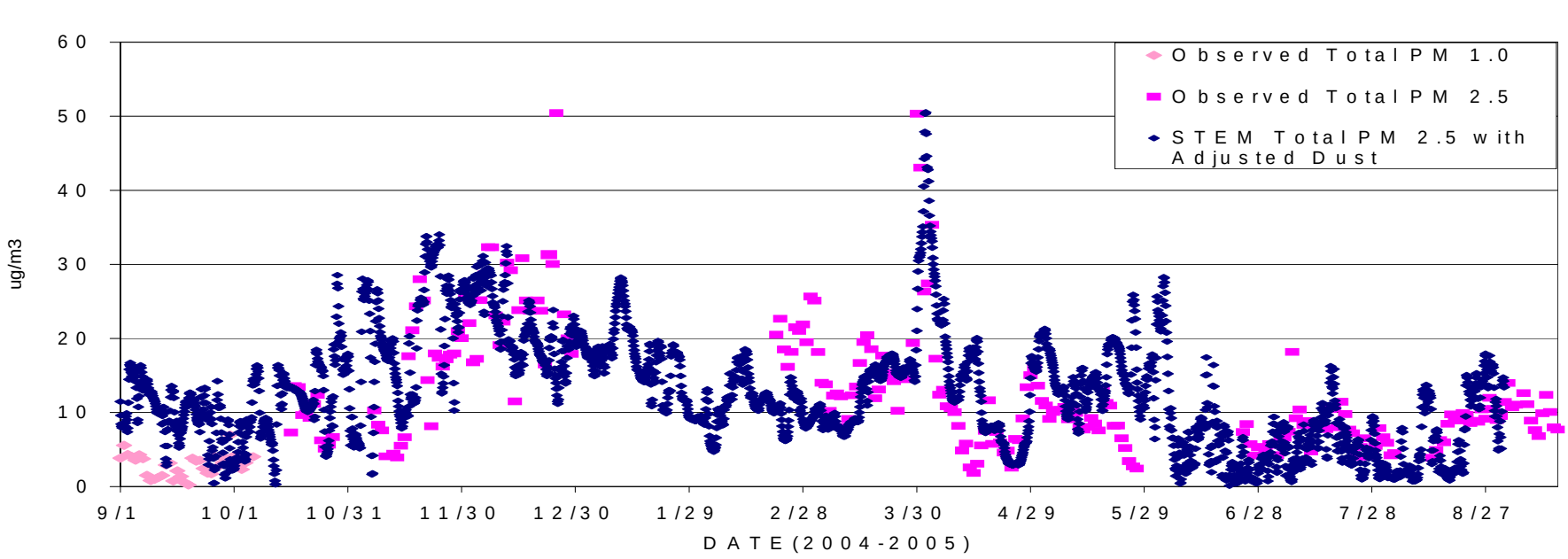
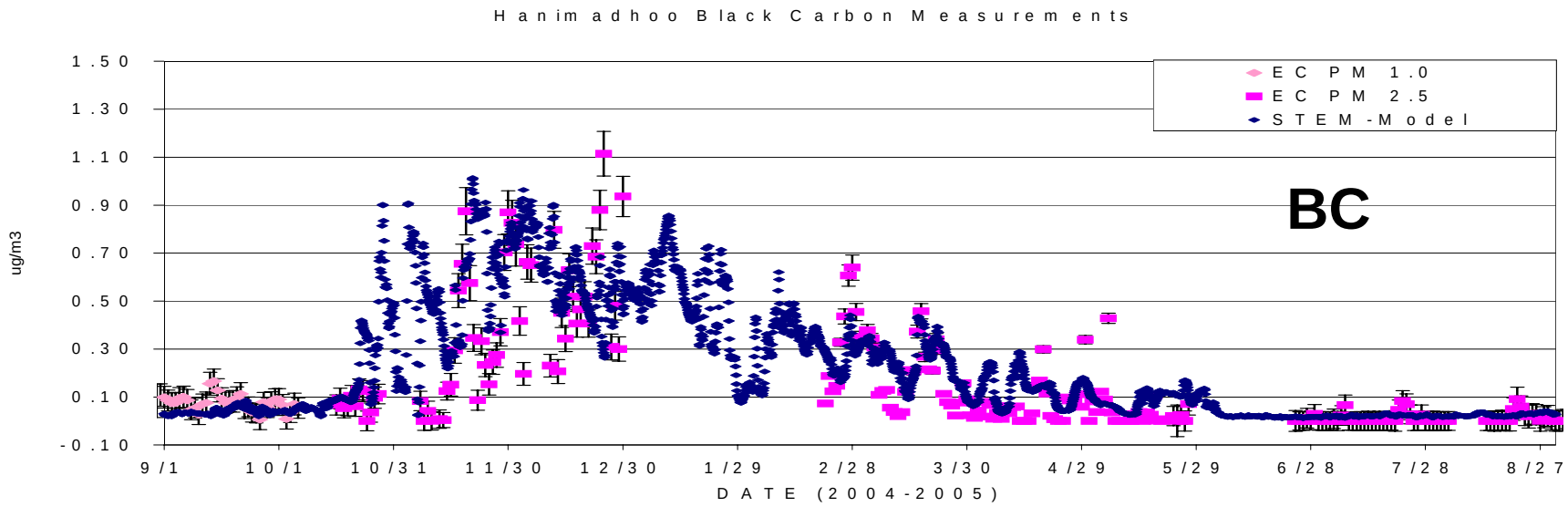


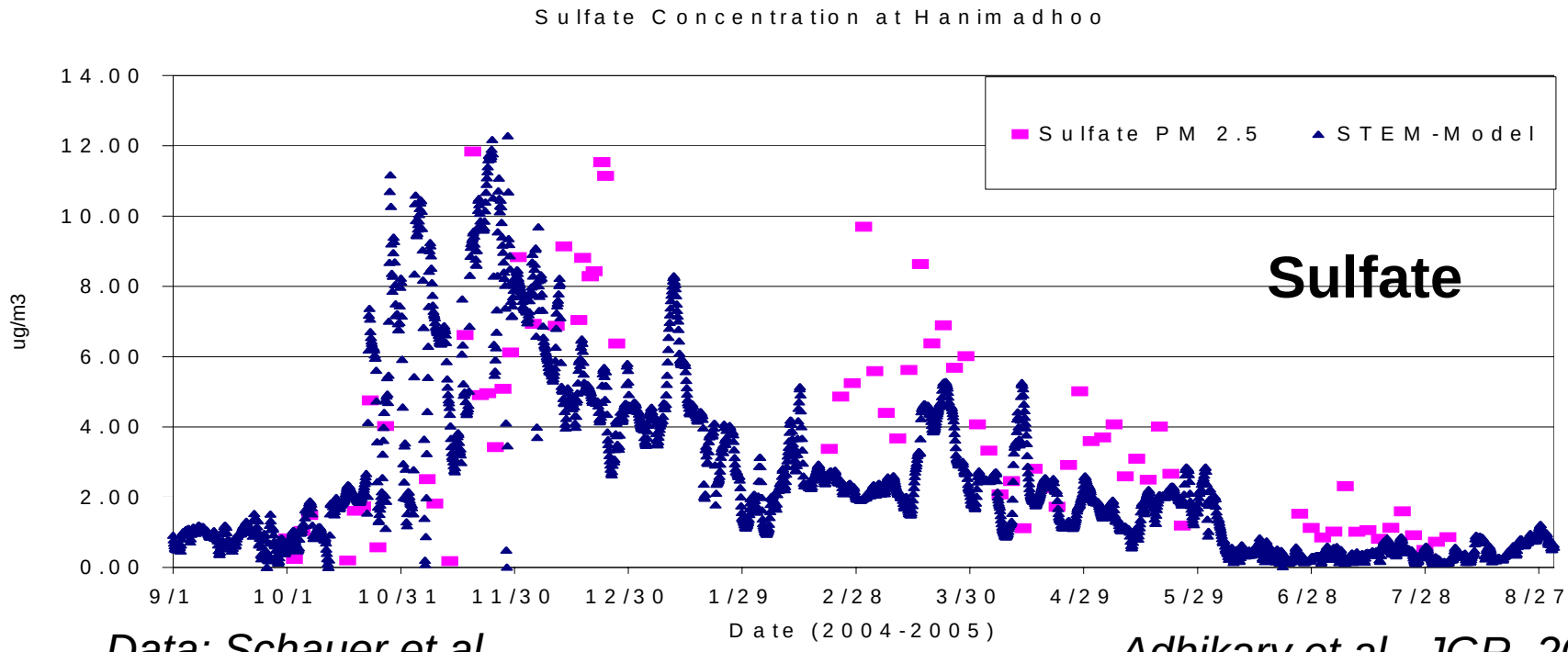
Fig 2

HCO PM10 and PM2.5





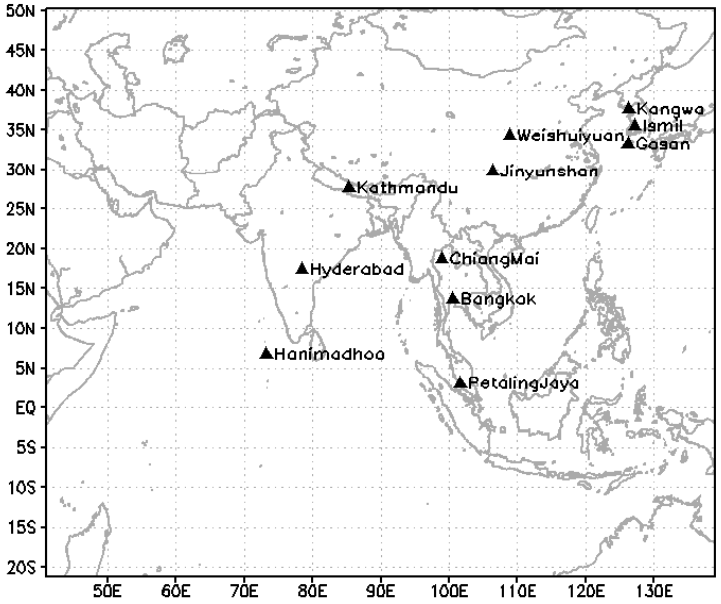


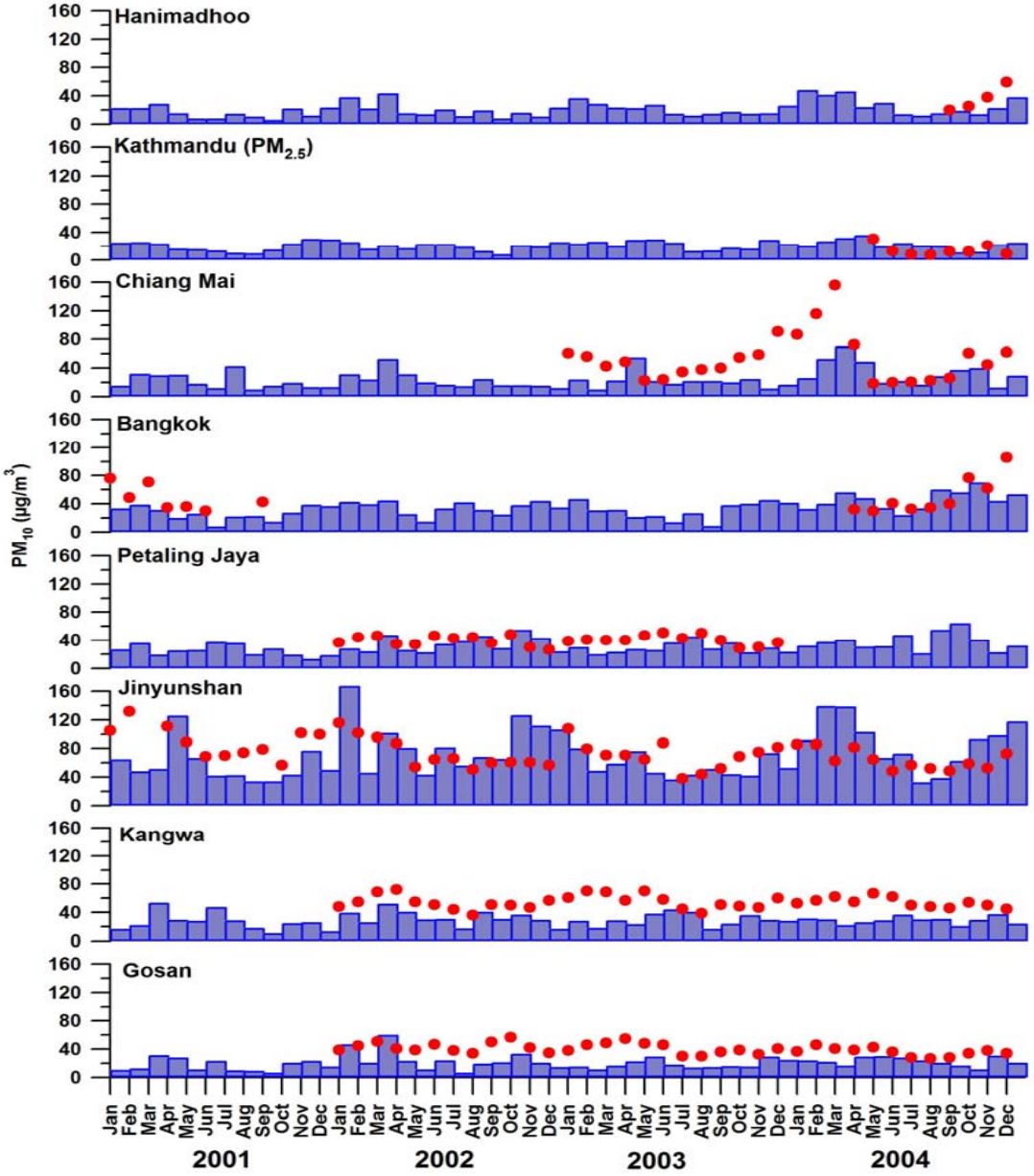


Data: Schauer et al

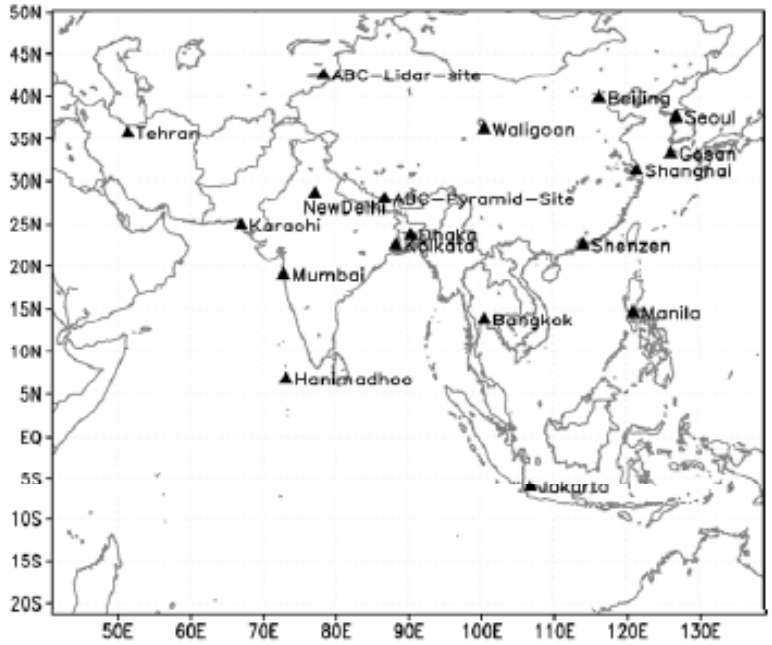
Adhikary et al., JGR, 2007

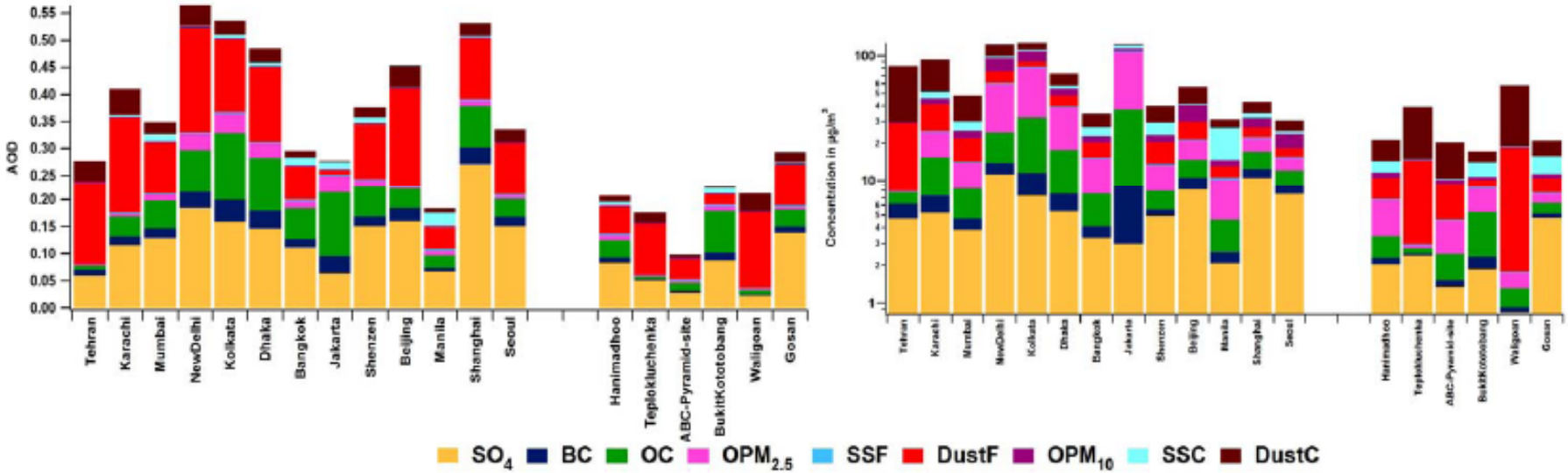
PM10 Observations and Predictions (ABC and EANET Sites)



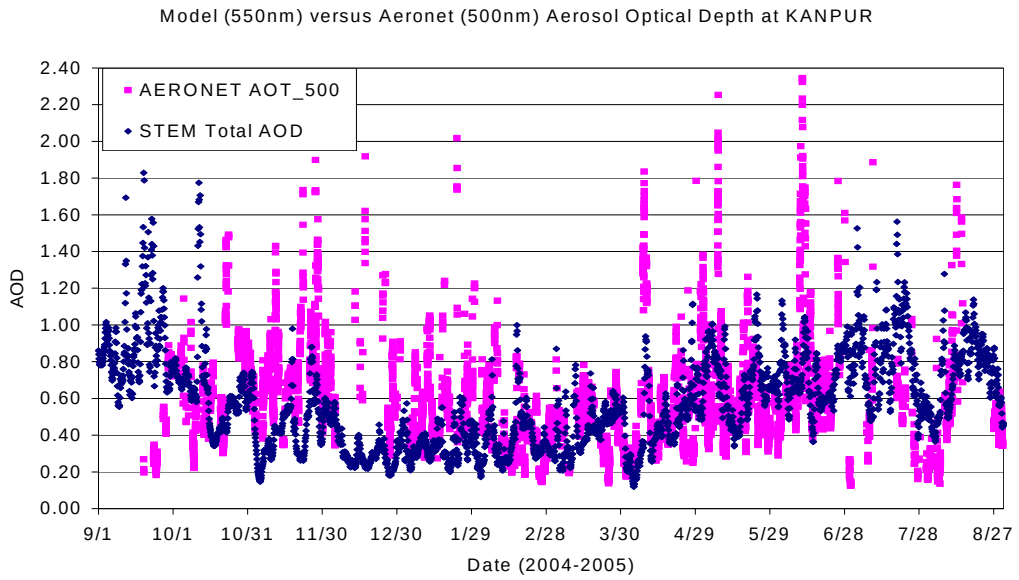


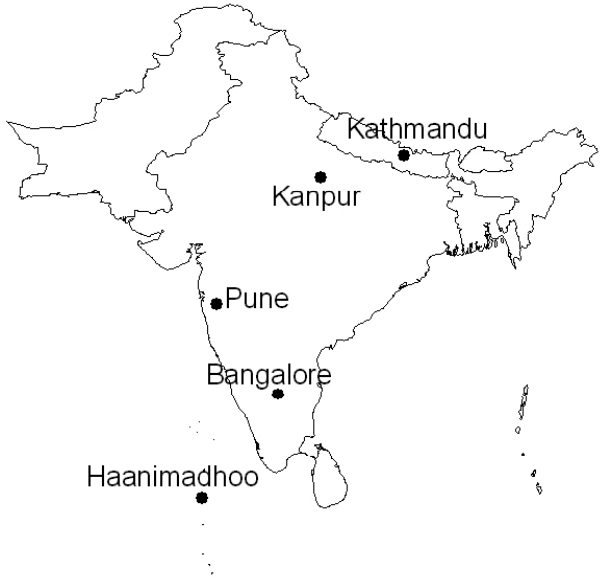
5-yr Mean AOD and PM Levels



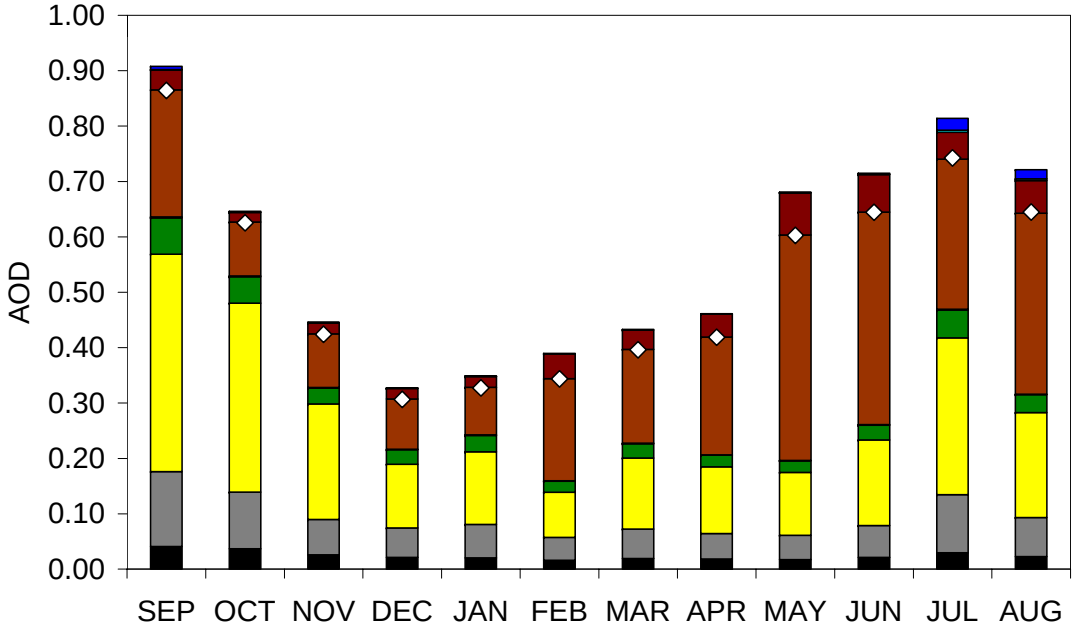


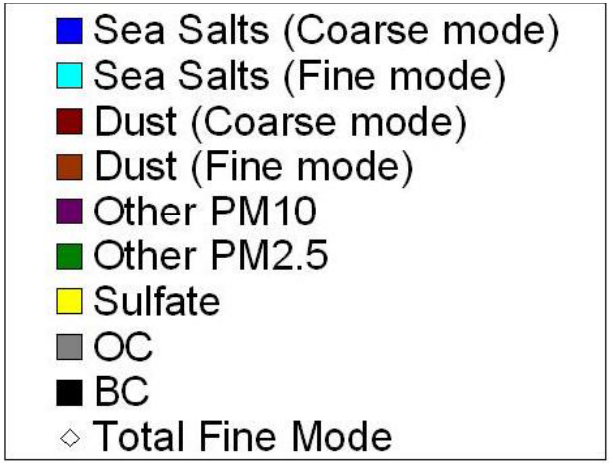
Kanpur
AOD Results





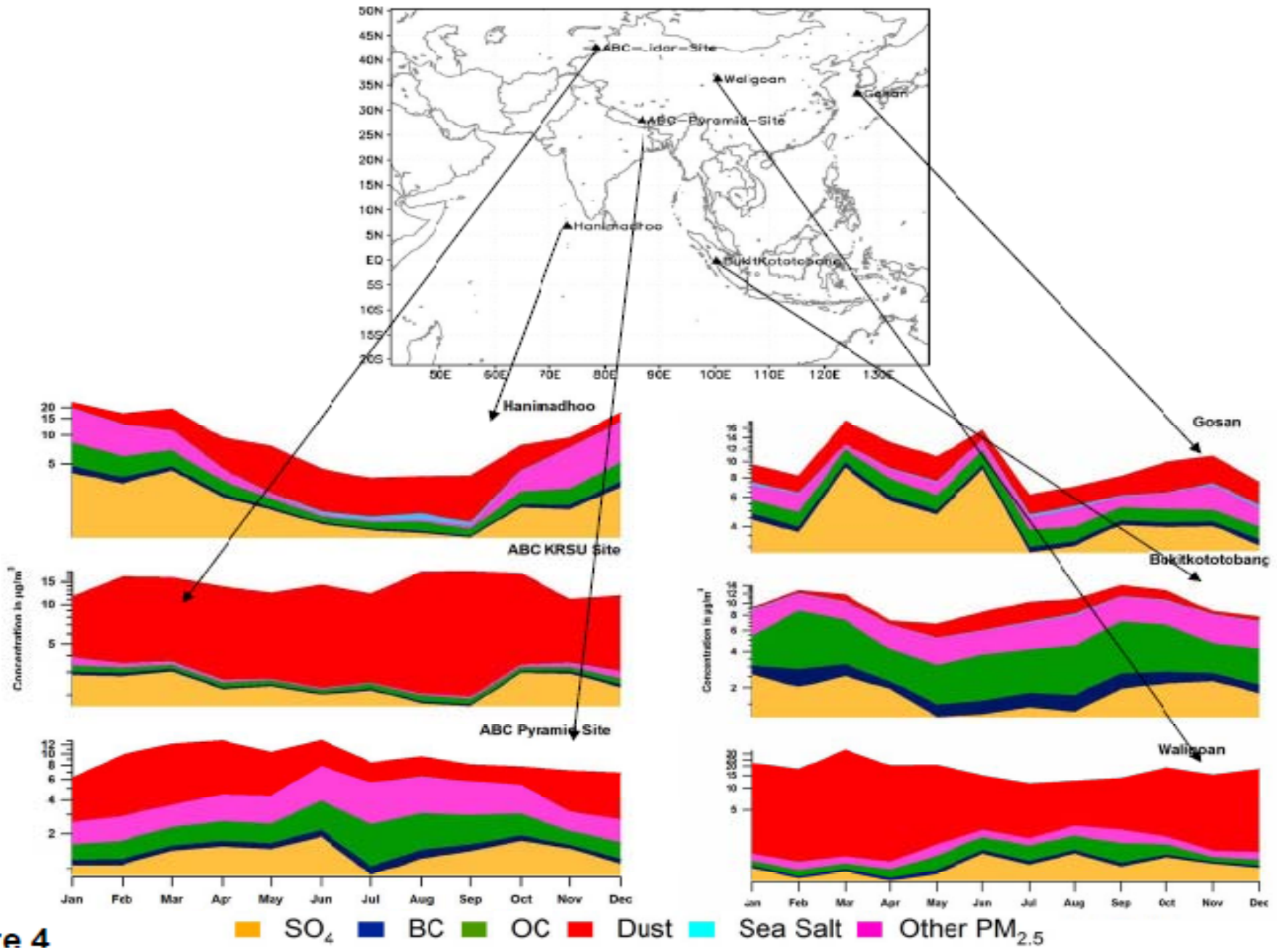
Model Predicted Total AOD at KANPUR





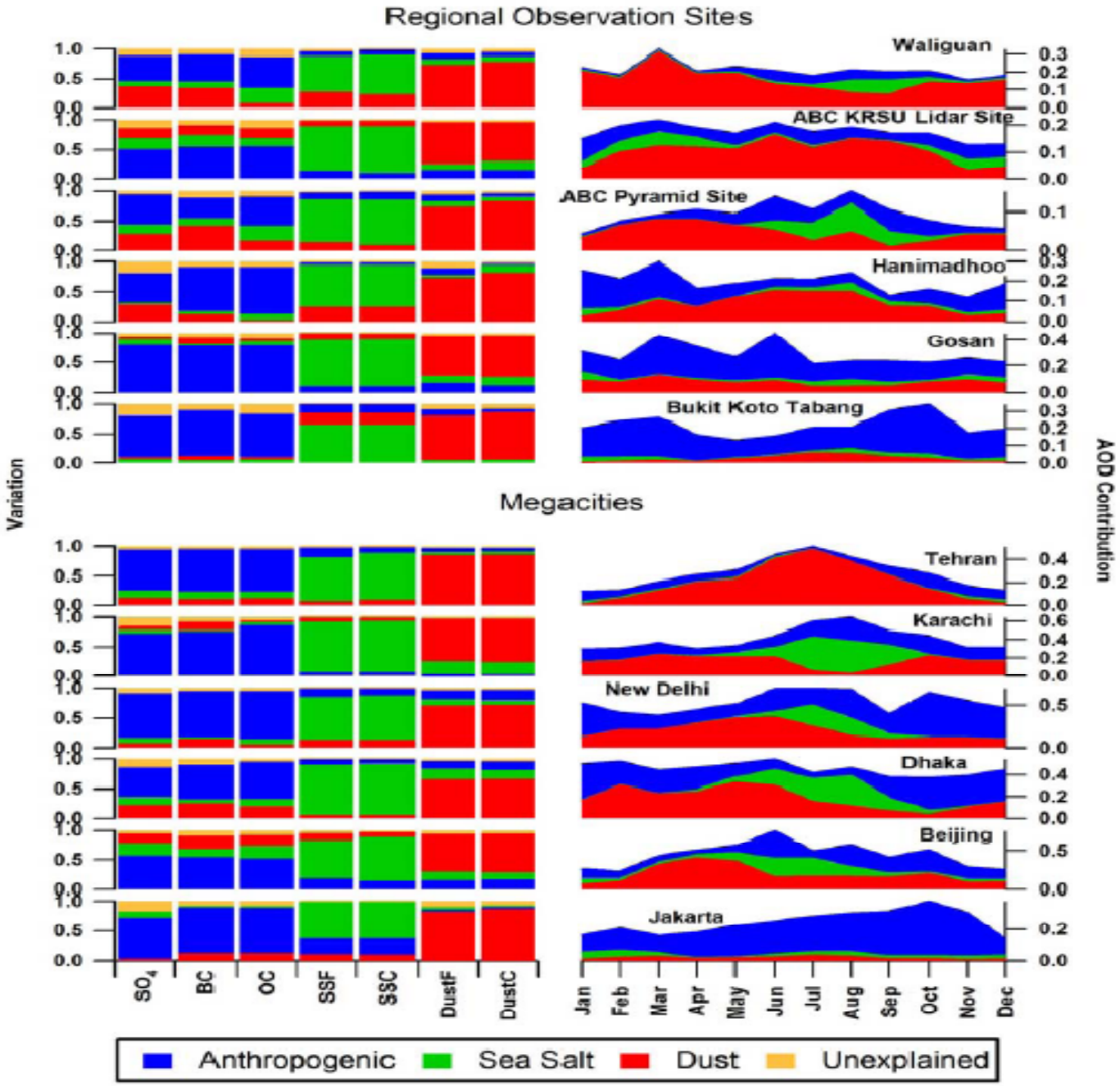
Adhikary et al., JGR, 2007

5-yr Mean Seasonal Variation of PM 2.5



igure 4

PMF Analysis of Model Results



Models are an Integral Part of ABC Studies

- Field experiment planning
- Provide 4-Dimensional context of the observations
- Facilitate the integration of the different measurement platforms
- Evaluate processes (e.g., role of biomass burning, wet removal, heterogeneous chemistry….)
- Evaluate emission estimates (bottom-up as well as top-down)
- Scenario analysis/attribution studies