Gregory R. Carmichael
College of Engineering
Center for Global & Regional Environmental Research, University of Iowa

68 faculty/16 departments/
6 colleges

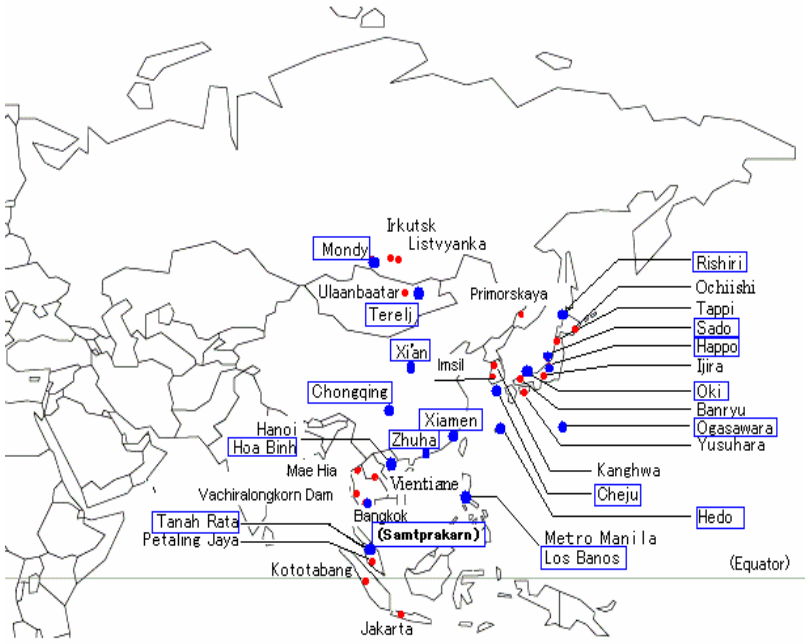
MICS-Asia < *M*odel *I*nter*C*omparison *S*tudy in *Asia* >

Main goal **Evaluation of model performance to make an international common understanding and improve air pollution modeling in East Asia**

Nine different regional models

Observations:

- EANET (47 sites) (gas, aerosol, deposition)
- Ozonesondes
- Trace-P Obs.
- Special obs. (aerosols)
- Met obs (sondes and surface)
- (daily & monthly analysis)
- Special Section of *Atmospheric Environment (8 papers)*



Completed MICS I & II

MICS-Asia: Next Steps

- Continue our MICS collaborations for Phase 2.x -- exciting papers ….
- Contribute to HTAP – strengthen connection to the global and policy receptive elements --
- Transition to MICS-III, to tackle important regional issues (megacities and connections to climate) and continue to build collaboration base.

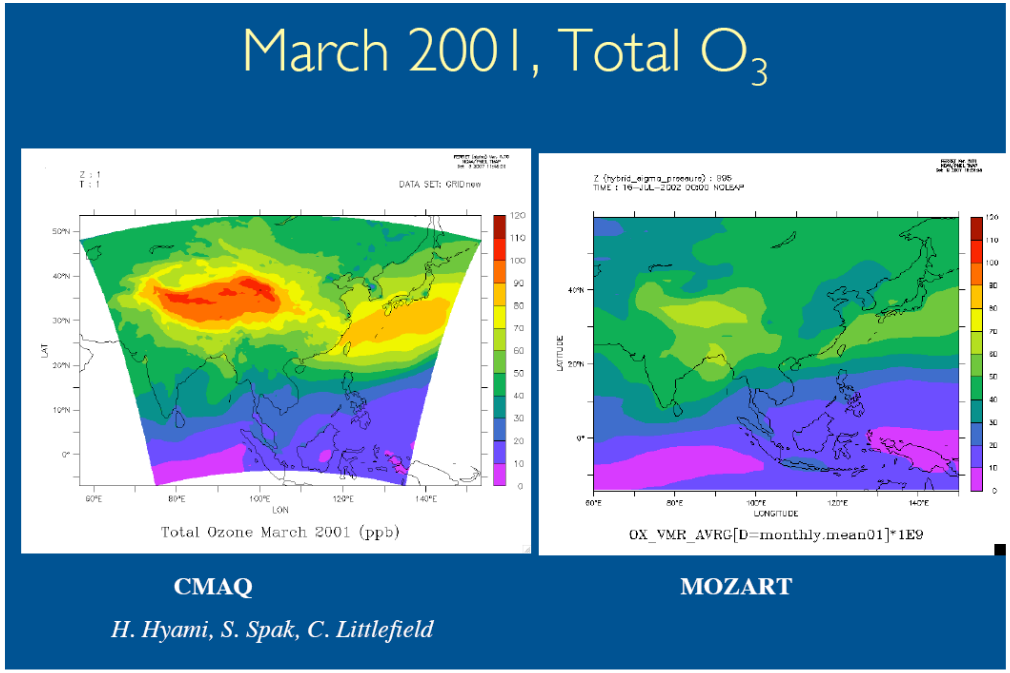
MICS ←→ HTAP – activities for 2008

Tasks: Evaluate the effects of resolution & BCs on regional ozone and PM predictions.

-Further analyze ozone and PM concentration metrics for GCTM and RCTM calculations.

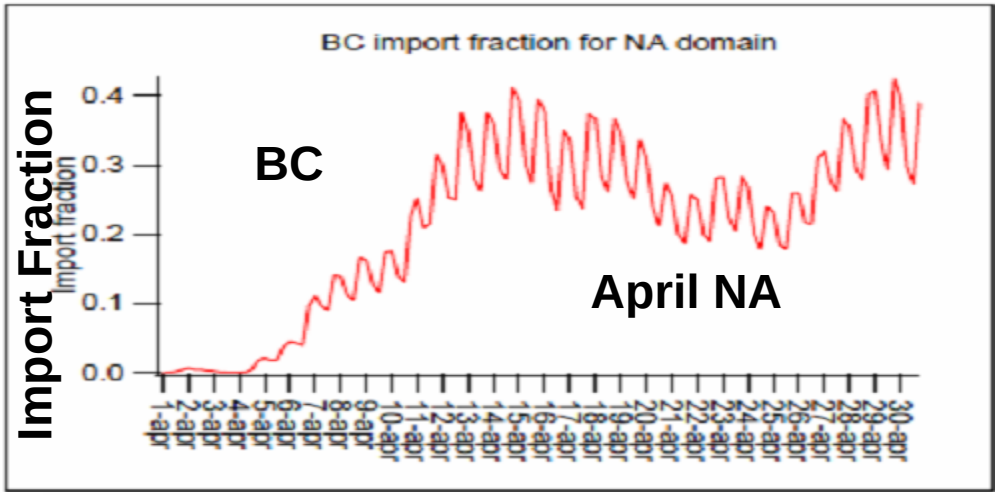
-Calculate export fluxes (across altitude & longitudes) for GCTM and RCTM calculations.

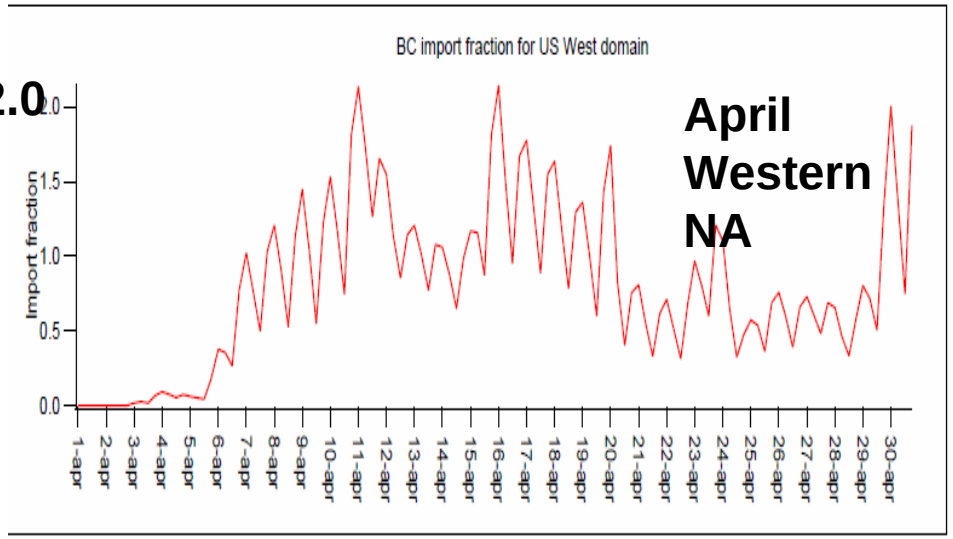
-Utilizing current MICS results and new simulations using subset of HTAP results, analyze domestic response simulations for grid resolution effects.

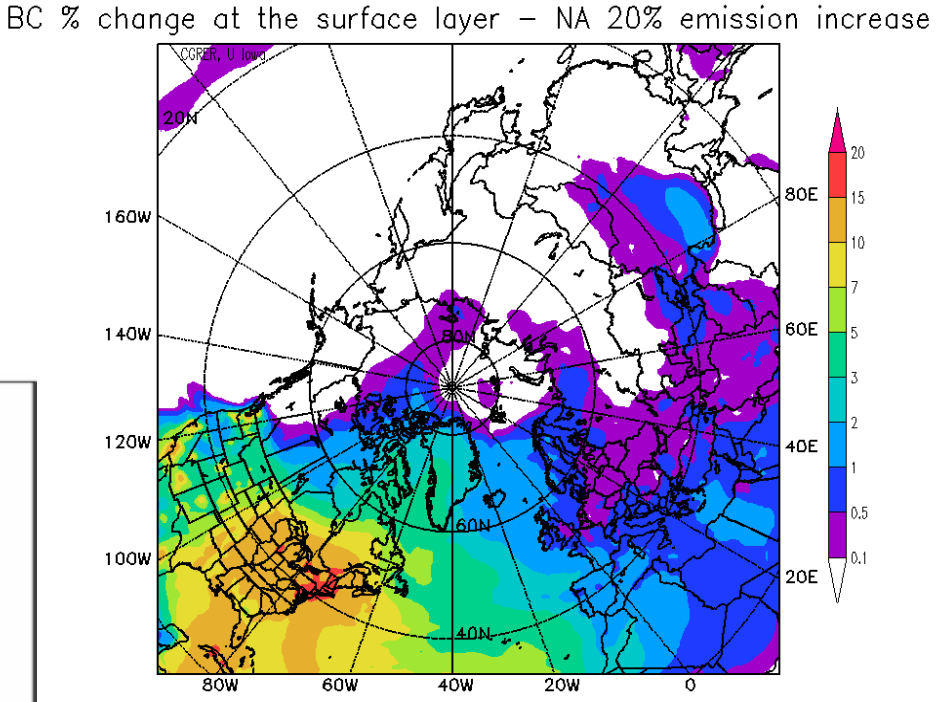


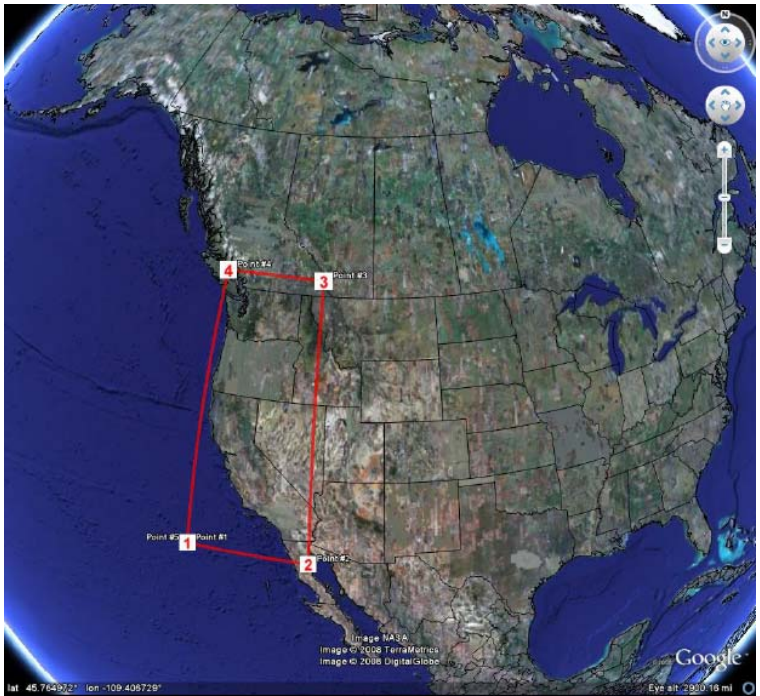
Source Receptor Relationships for HTAP Regions

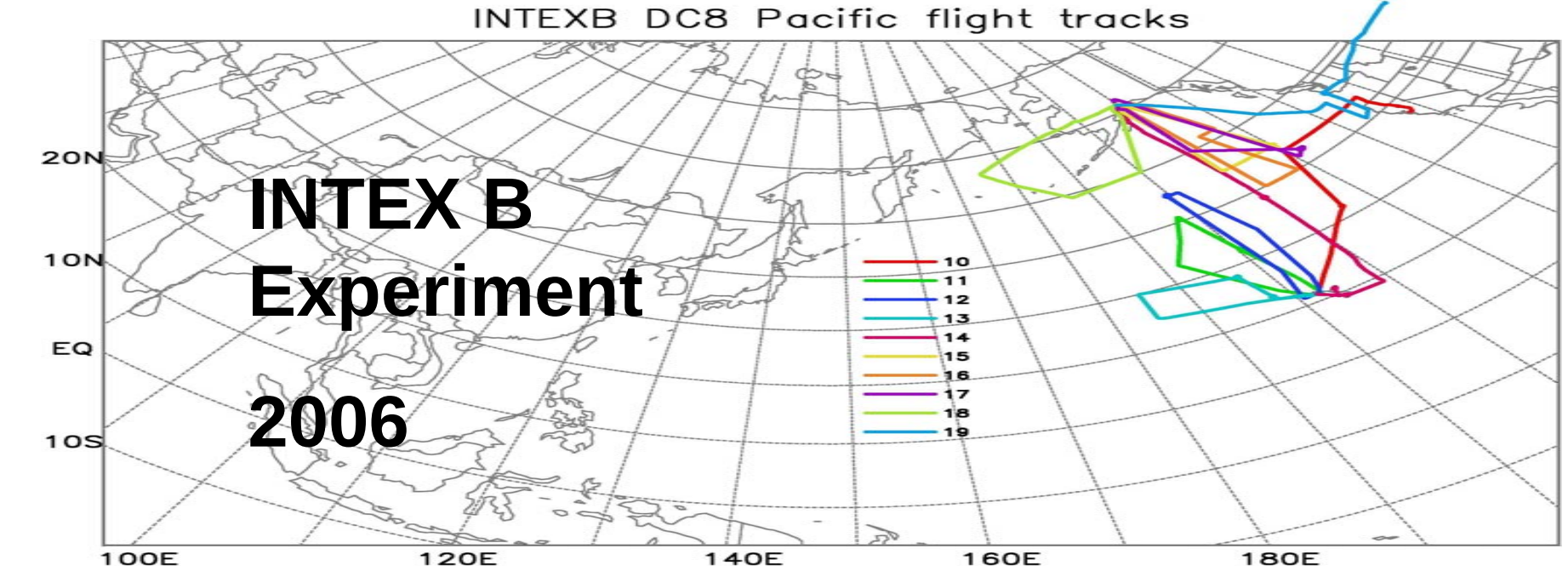
April-September 2008 NASA -ARCTAS



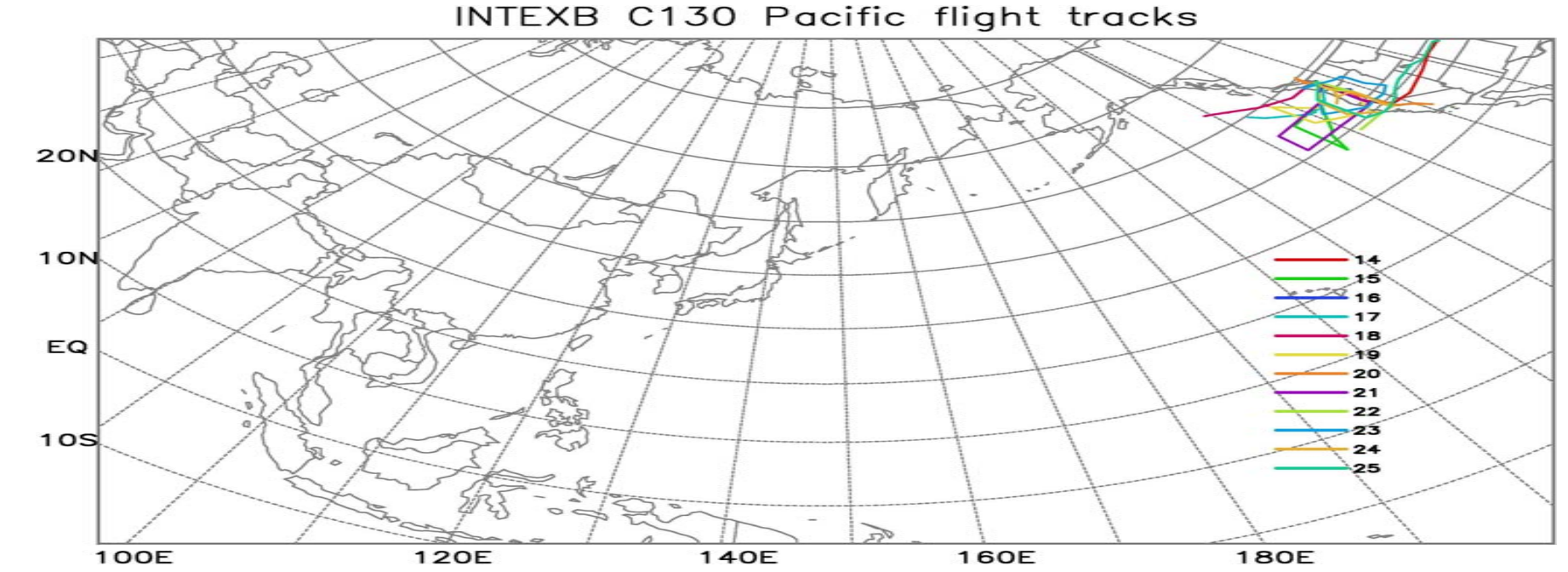








INTEX B Experiment 2006



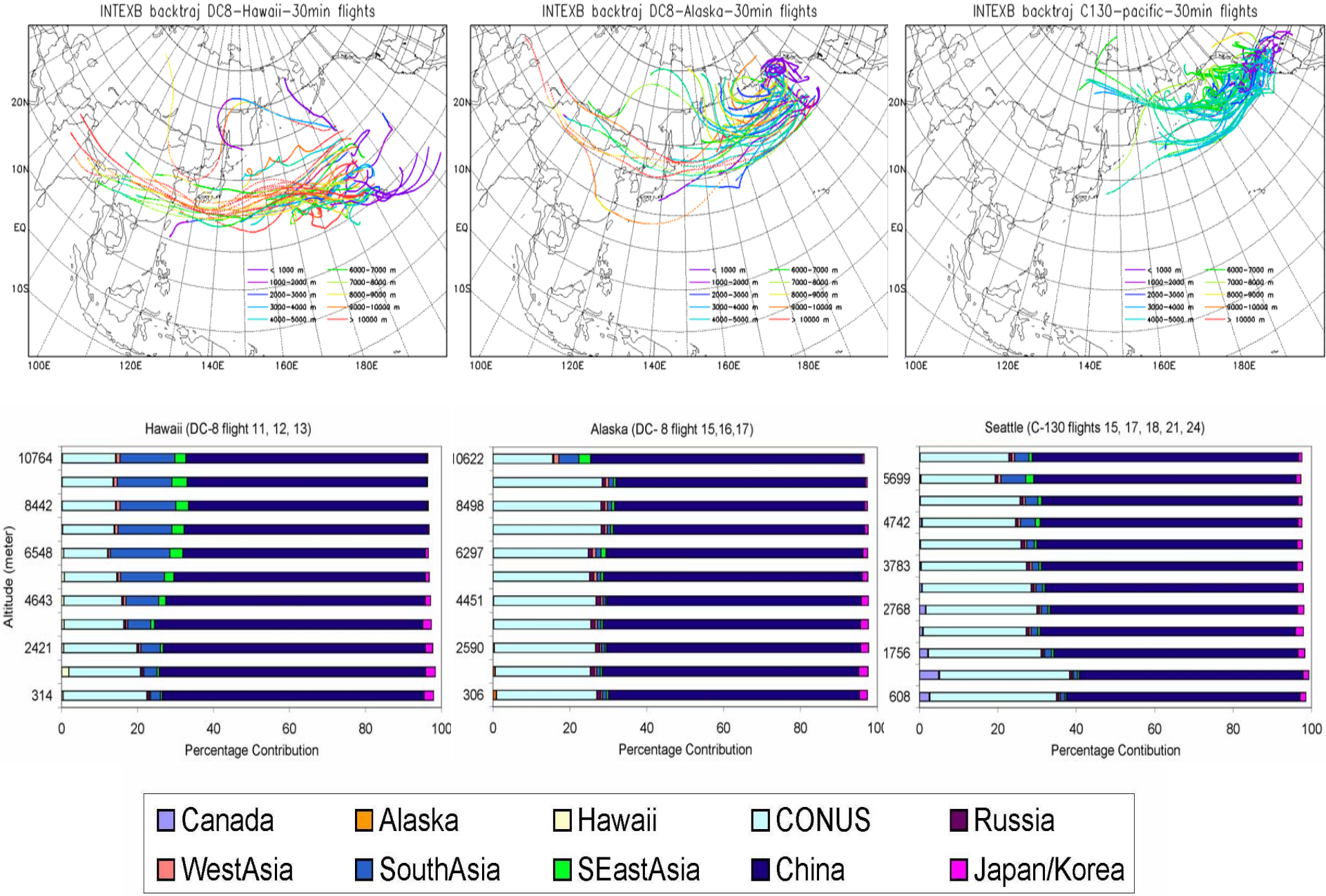
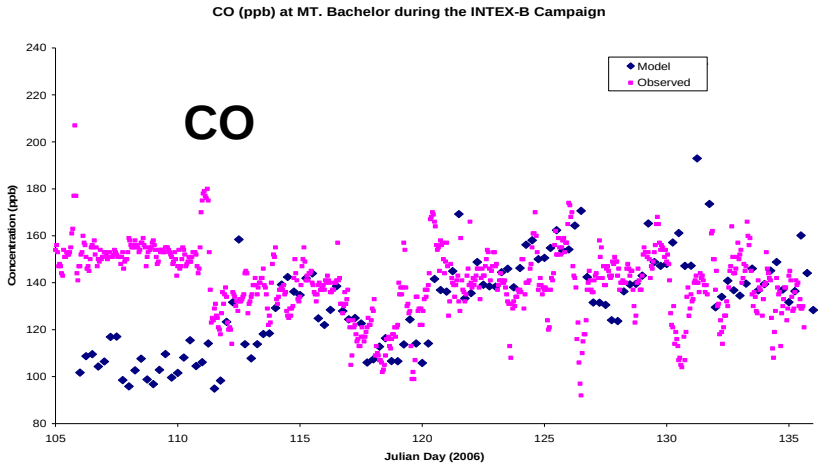
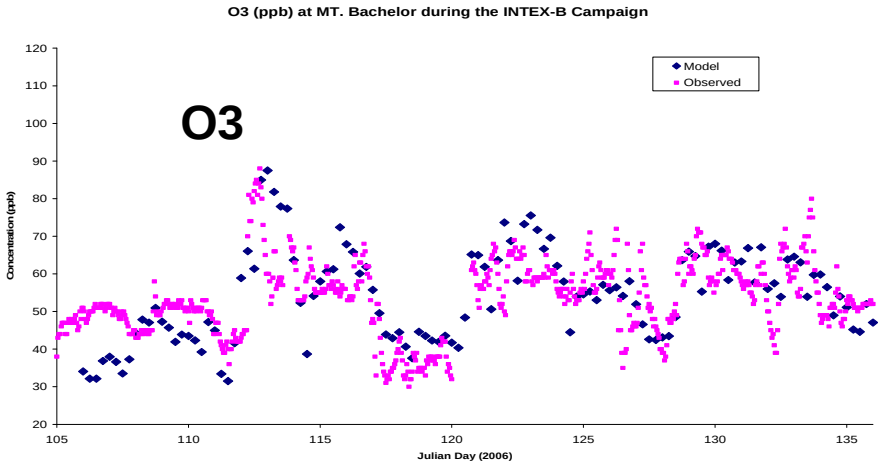
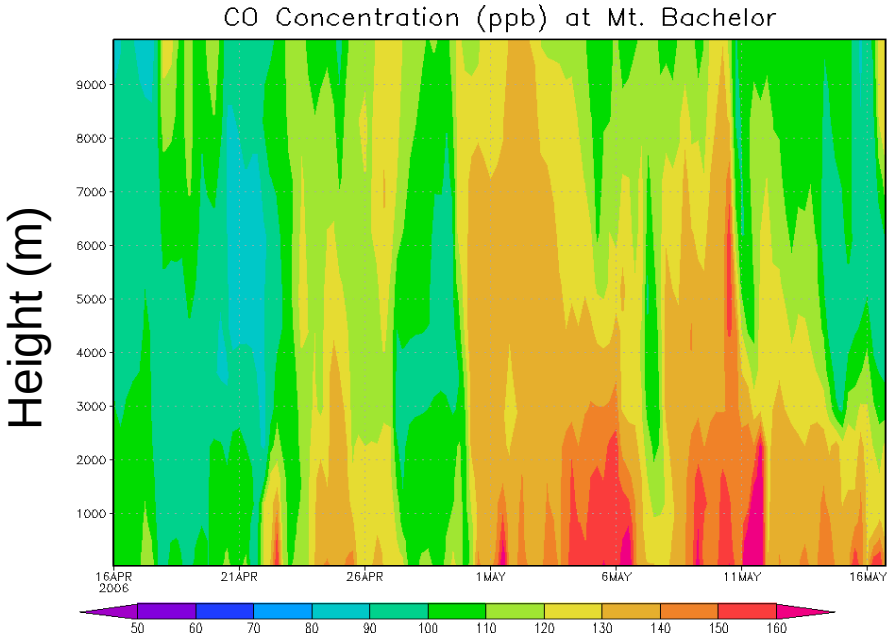

INTEXB backtraj DC8-Hawaii-30min flights
INTEXB backtraj DC8-Alaska-30min flights
INTEXB backtraj C130-pacific-30min flights
20N
10N
EQ
10S
100E
120E
140E
160E
180E
< 1000 m
1000-2000 m
2000-3000 m
3000-4000 m
4000-5000 m
6000-7000 m
7000-8000 m
8000-9000 m
9000-10000 m
> 10000 m
Hawaii (DC-8 flight 11, 12, 13)
Alaska (DC- 8 flight 15,16,17)
Seattle (C-130 flights 15, 17, 18, 21, 24)
Altitude (meter)
10764
8442
6548
4643
2421
314
10622
8498
6297
4451
2590
306
5699
4742
3783
2768
1756
608
0
20
40
60
80
100
Percentage Contribution
Percentage Contibution
Canada
Alaska
Hawaii
CONUS
Russia
WestAsia
SouthAsia
SEastAsia
China
Japan/Korea

Figure 3

Recent NASA Experiments Enhances Observations to Test Models







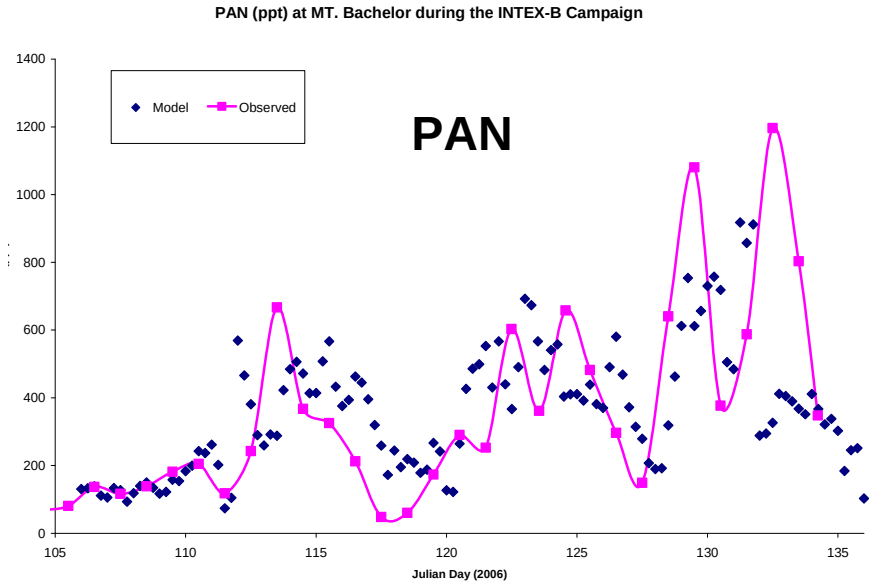
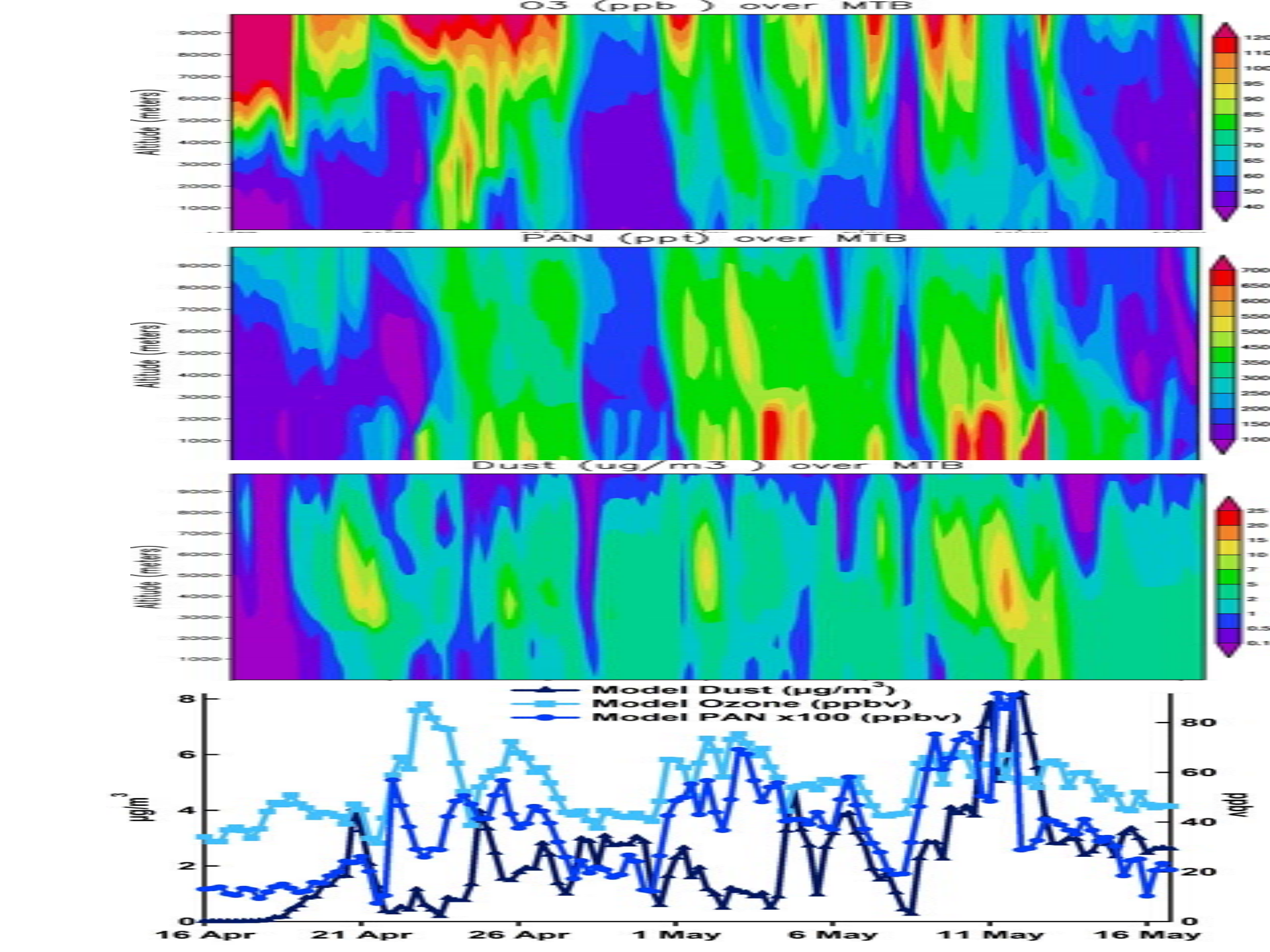
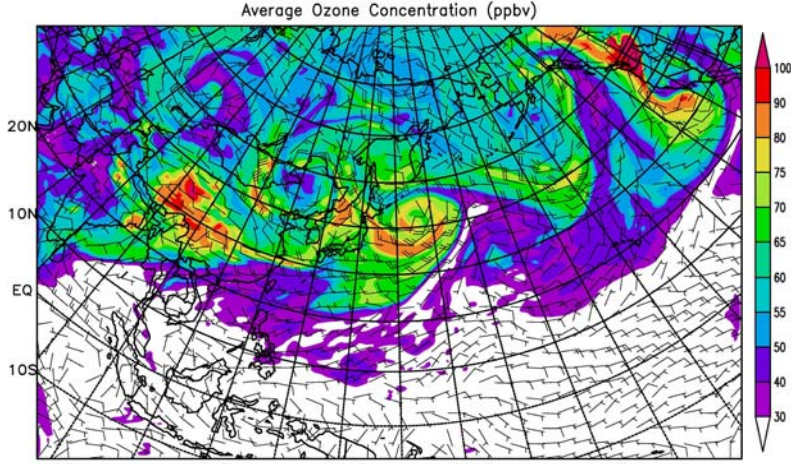
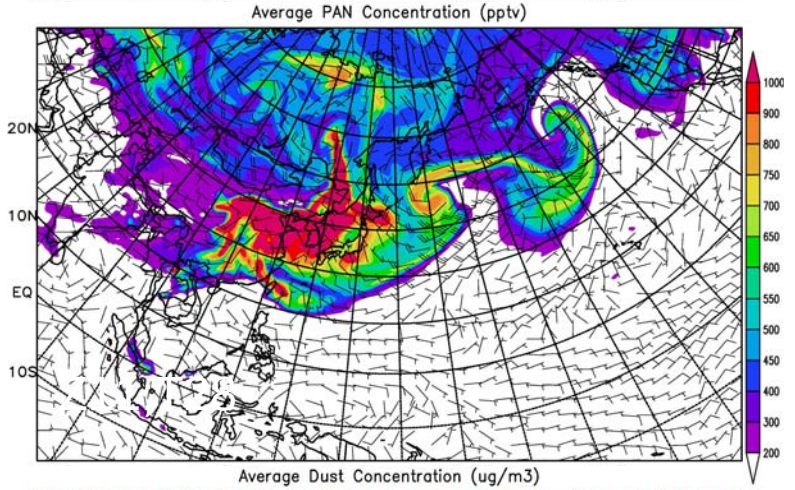
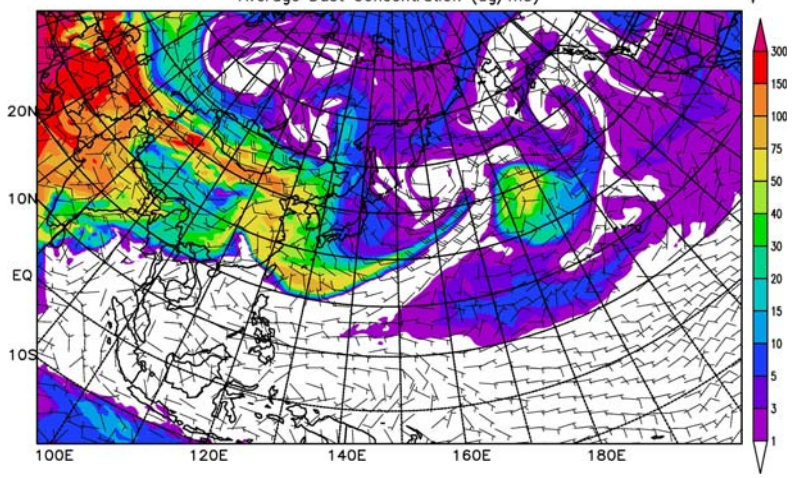


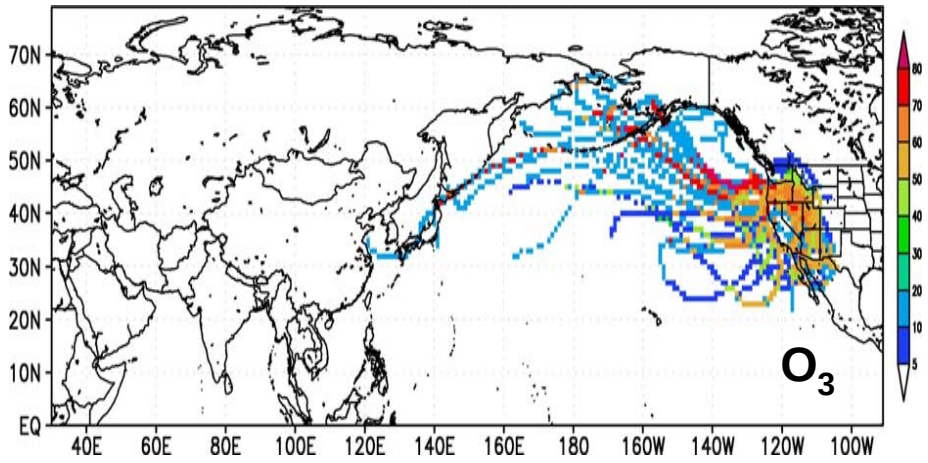
Figure 13. Comparison of the STEM model prediction versus observed trace gaseous at Mt. Bachelor, OR.

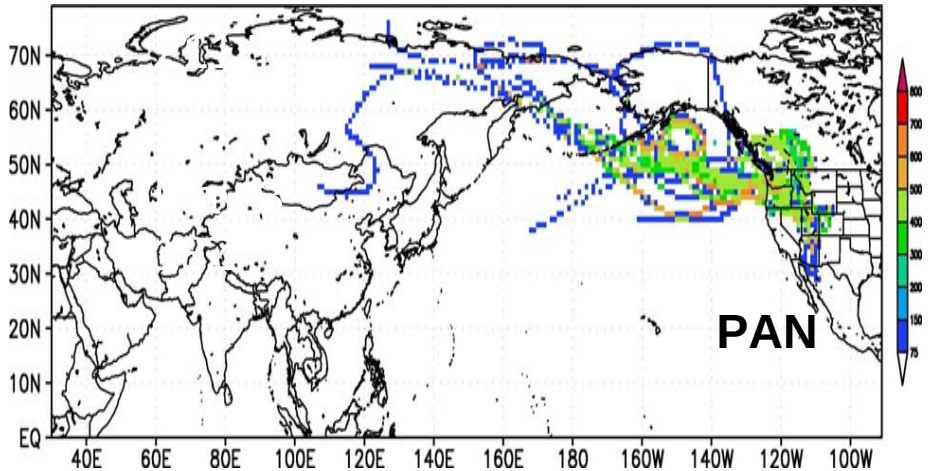

O3 (ppb) over MTB
PAN (ppt) over MTB
Dust (ug/m3) over MTB
Altitude (meters)
Model Dust (µg/m3)
Model Ozone (ppbv)
Model PAN x100 (ppbv)
µg/m3
ppbv
16 Apr
21 Apr
26 Apr
1 May
6 May
11 May
16 May

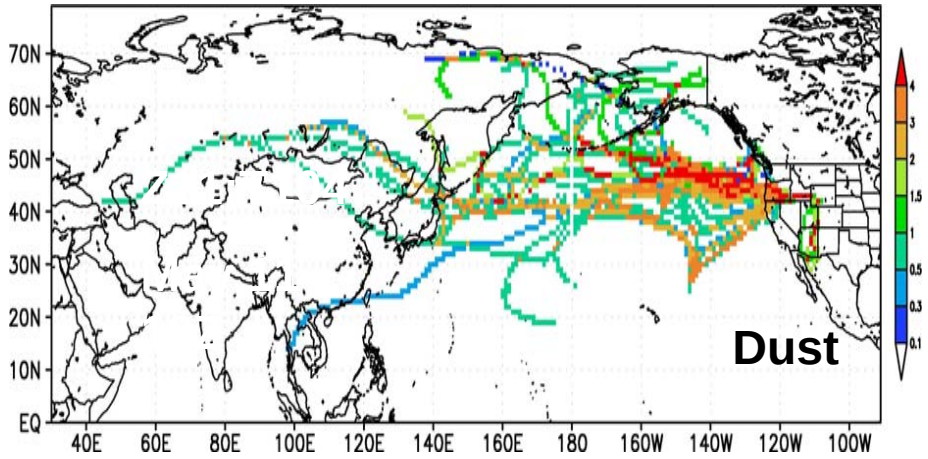

Average Ozone Concentration (ppbv)
20N
10N
EQ
10S
100
90
80
75
70
65
60
55
50
40
30


Average PAN Concentration (pptv)
20N
10N
EQ
10S
1000
900
800
750
700
650
600
550
500
450
400
300
200


Average Dust Concentration (ug/m3)
20N
10N
EQ
10S
100E
120E
140E
160E
180E
300
150
100
75
50
40
30
20
15
10
5
3
1


70N
60N
50N
40N
30N
20N
10N
EQ
40E
60E
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
O3


70N
60N
50N
40N
30N
20N
10N
EQ
40E
60E
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
PAN


70N
60N
50N
40N
30N
20N
10N
EQ
40E
60E
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
Dust

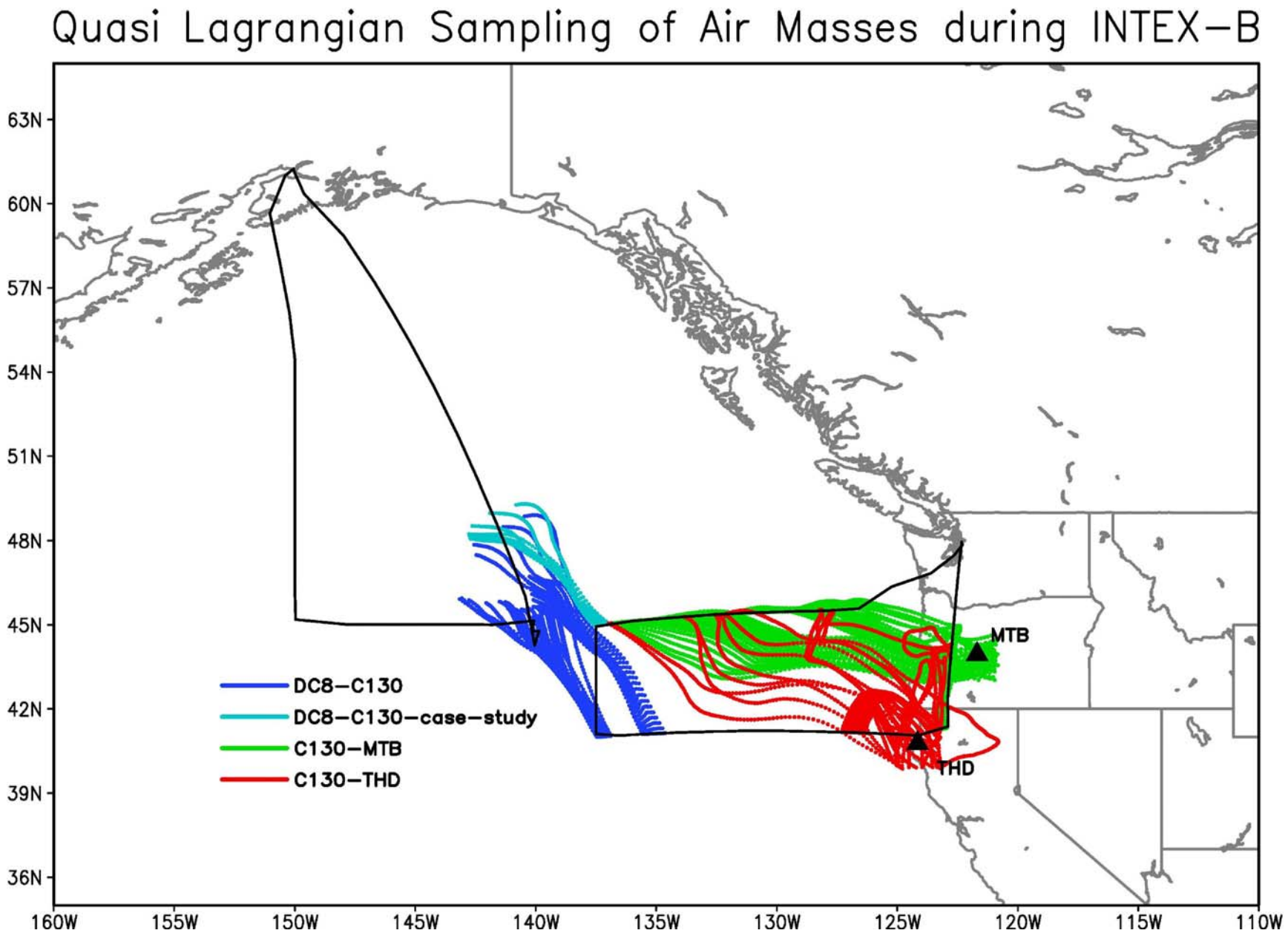
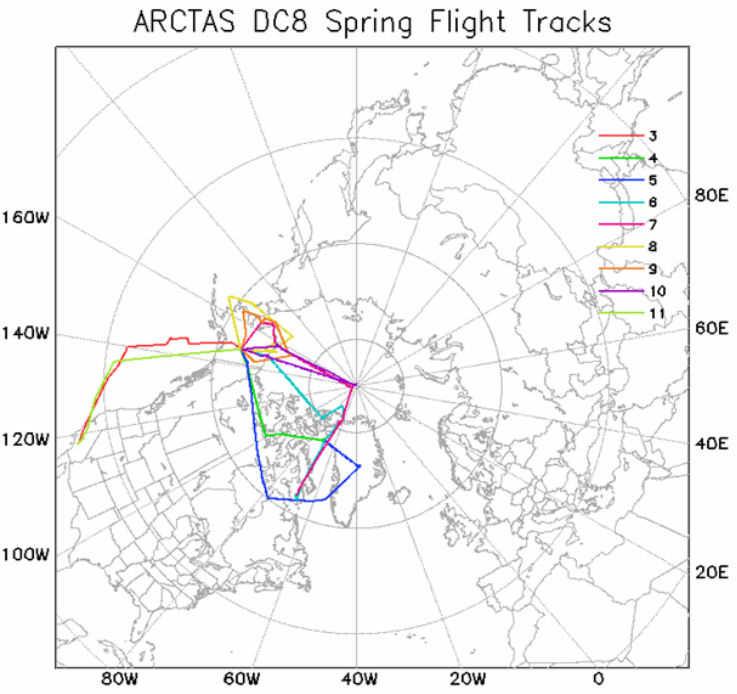
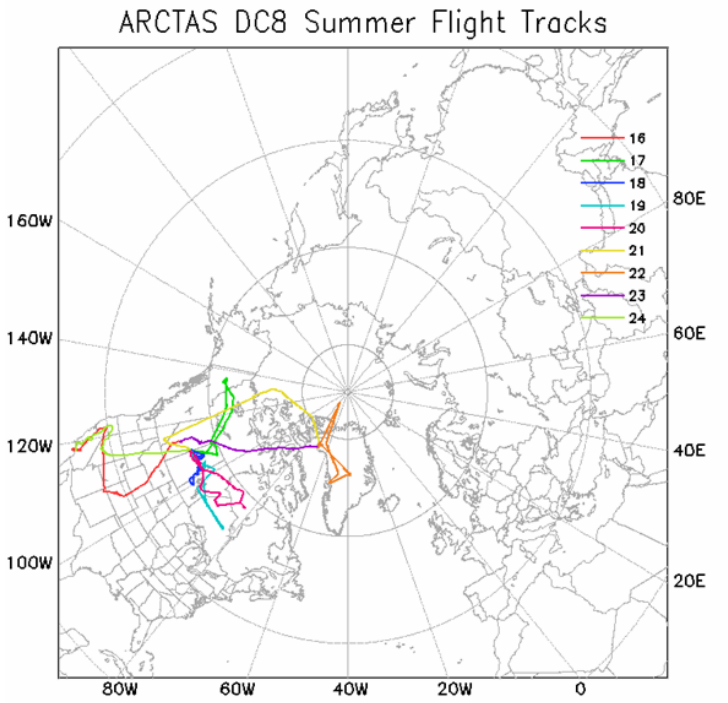

Quasi Lagrangian Sampling of Air Masses during INTEX–B
63N
60N
57N
54N
51N
48N
45N
42N
39N
36N
160W
155W
150W
145W
140W
135W
130W
125W
120W
115W
110W
DC8–C130
DC8–C130–case–study
C130–MTB
C130–THD
MTB
THD

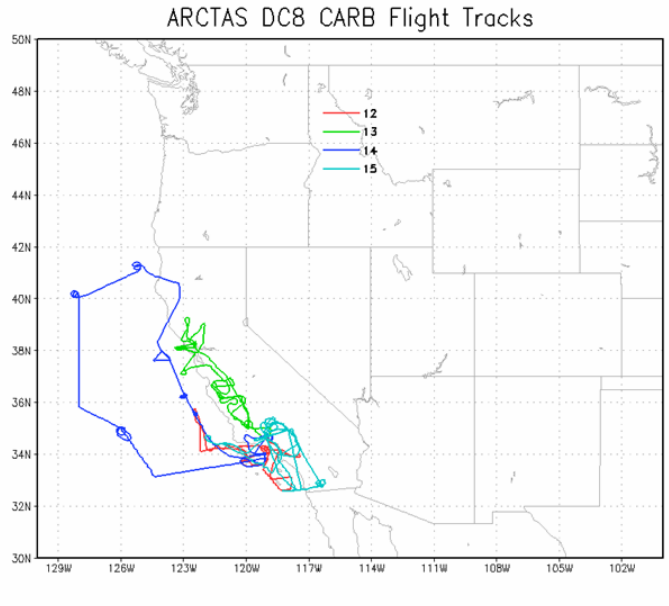
Figure 15





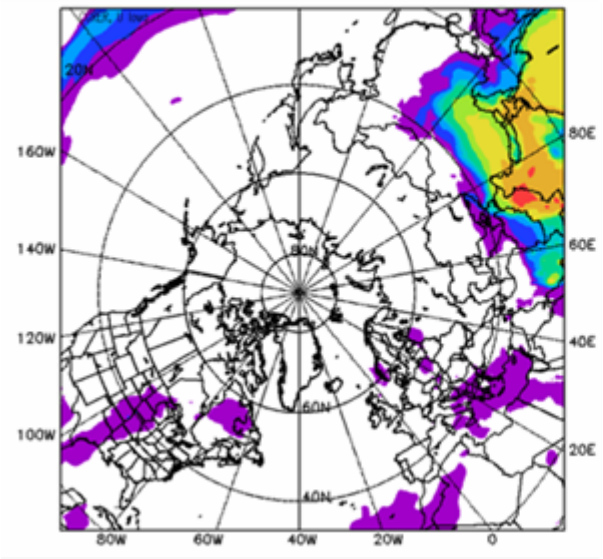
ARCTAS Experiment

April-July 2008

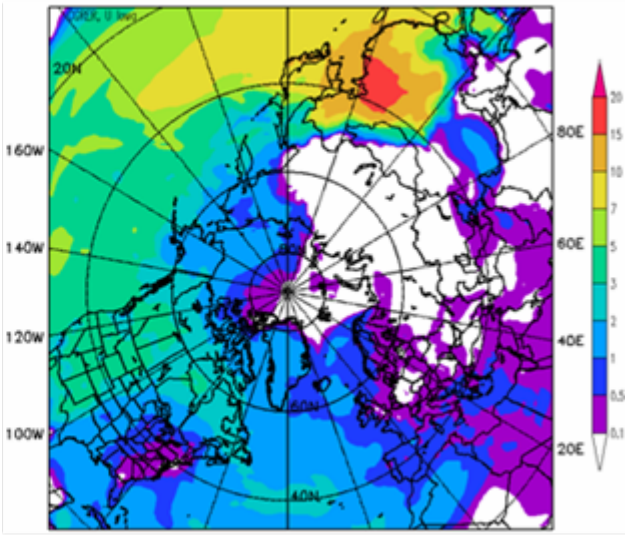


S/R to Arctic April 2008

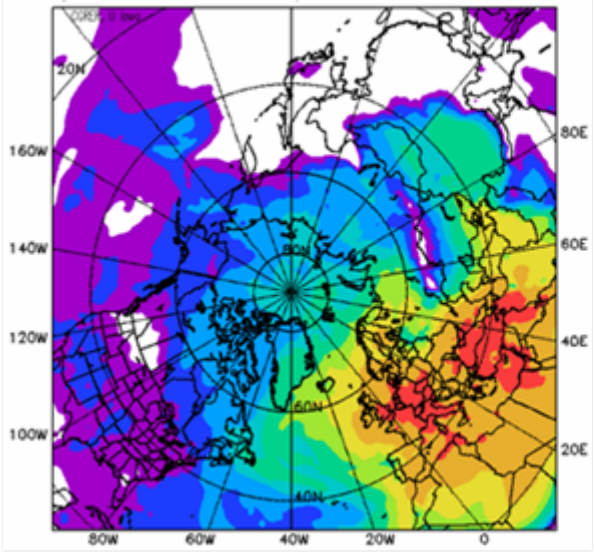
SA 20%



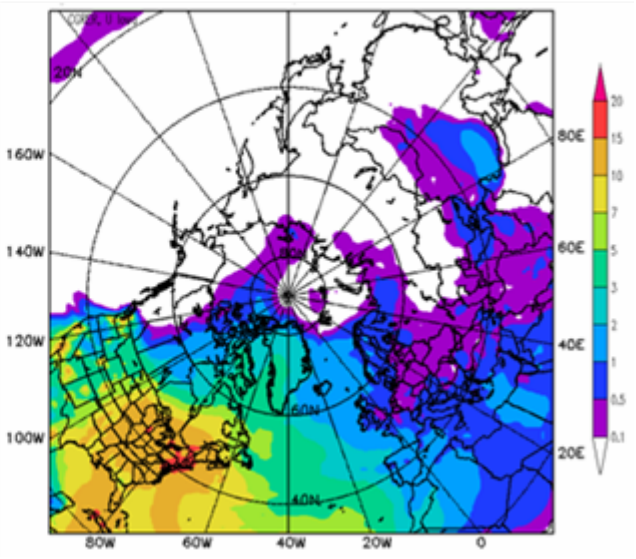
EA 20%



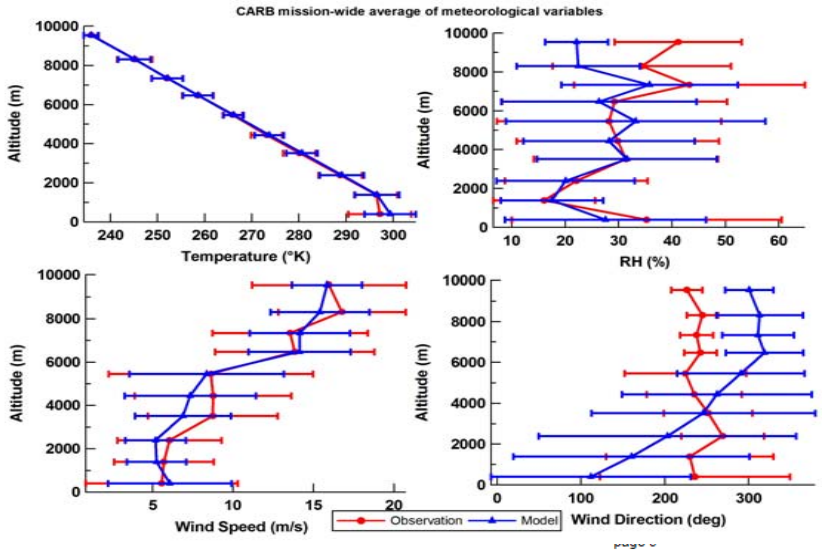
EA 20%

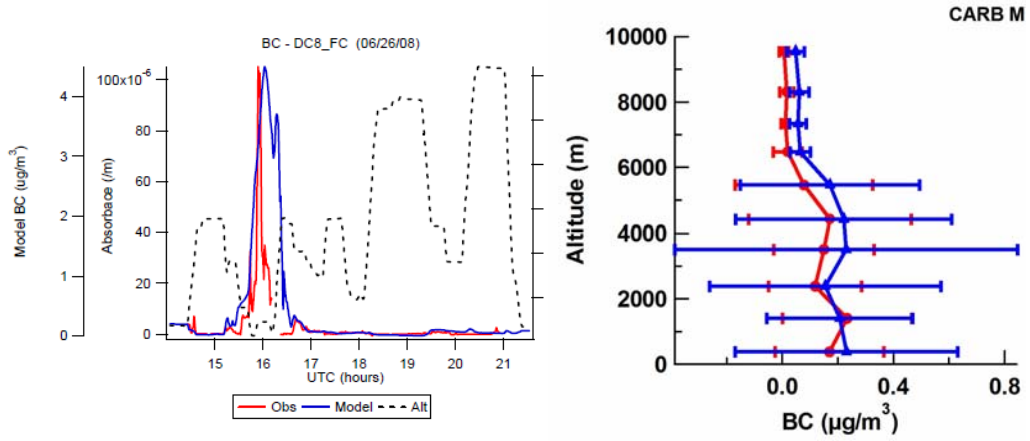


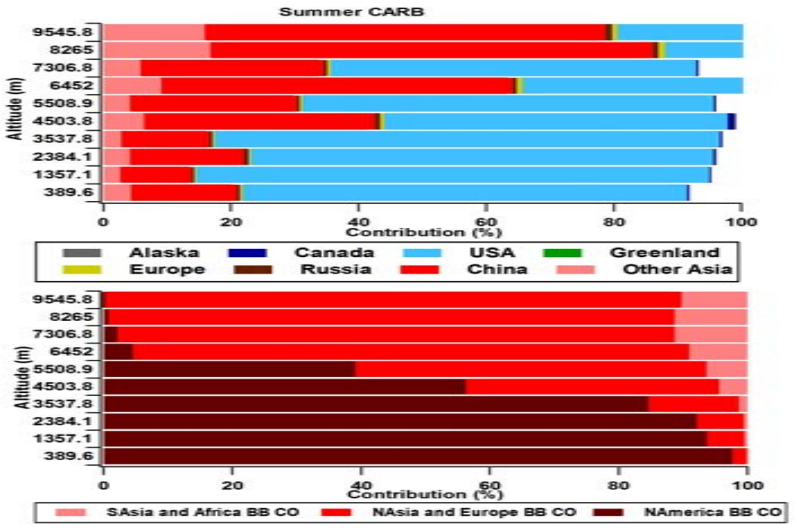
NA 20%

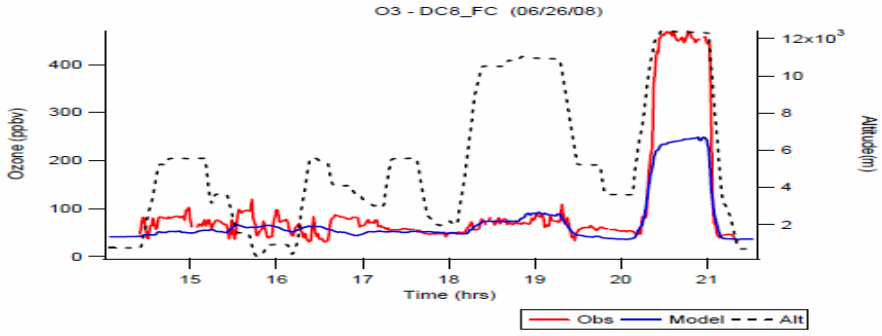


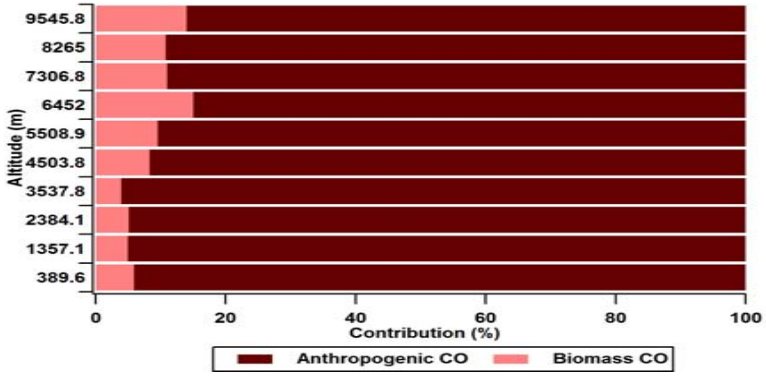
U Iowa Regional Modeling and S/R Analysis for California



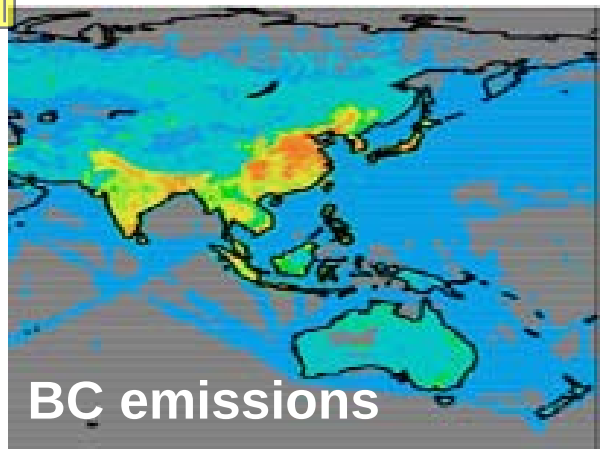


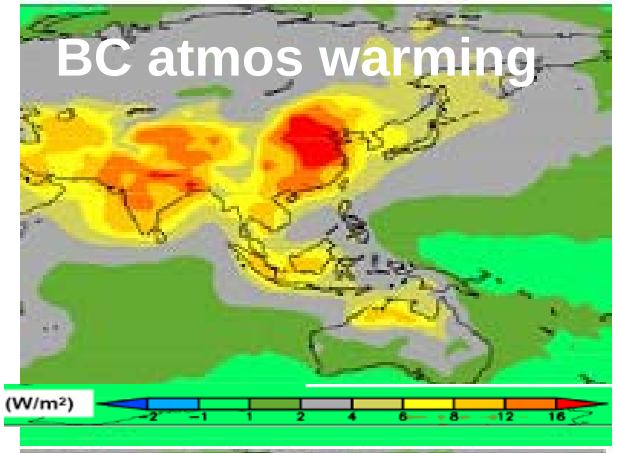


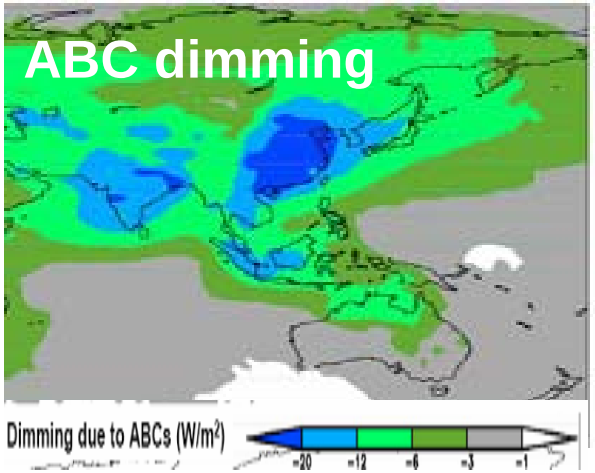




Atmospheric Brown Clouds (ABCs) and Megacities -- An Estimated 3 Billion Persons Live Under ABCs – Implications for urban environments and beyond







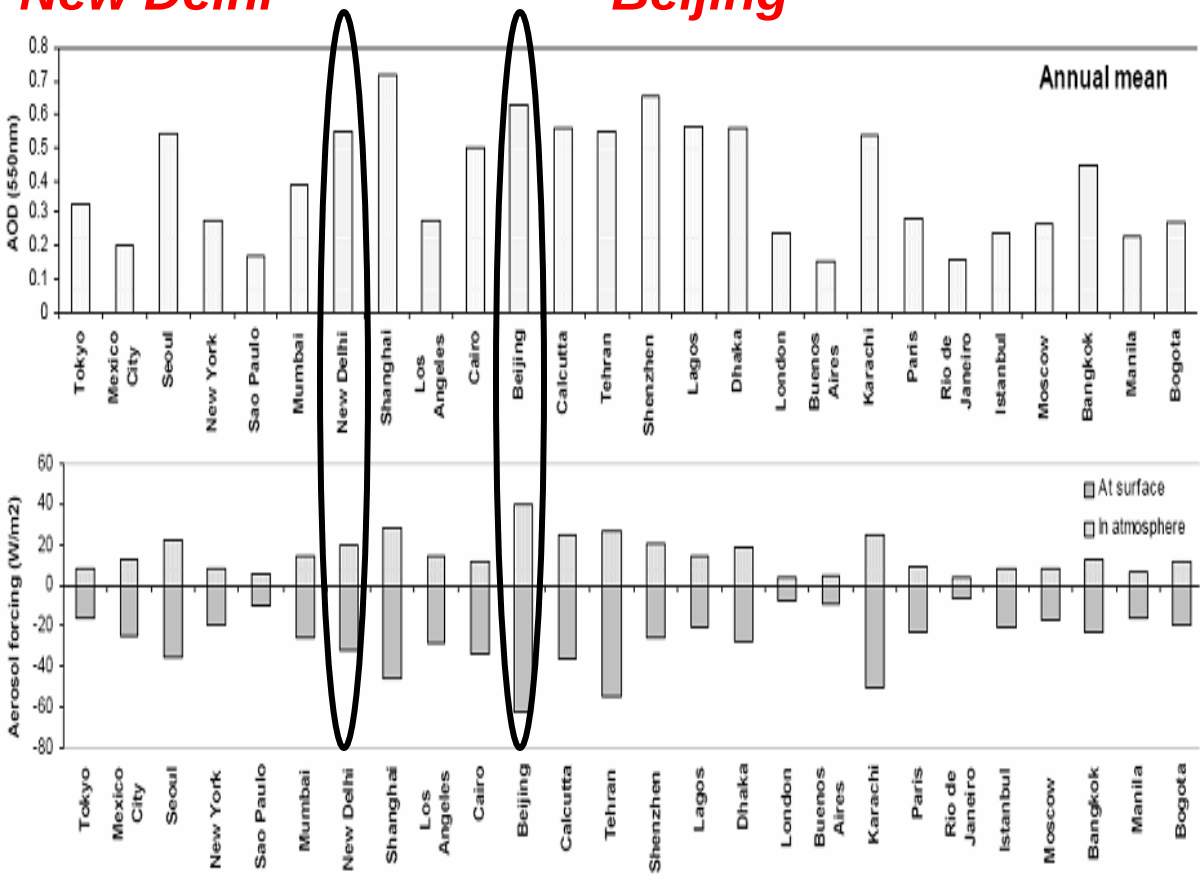
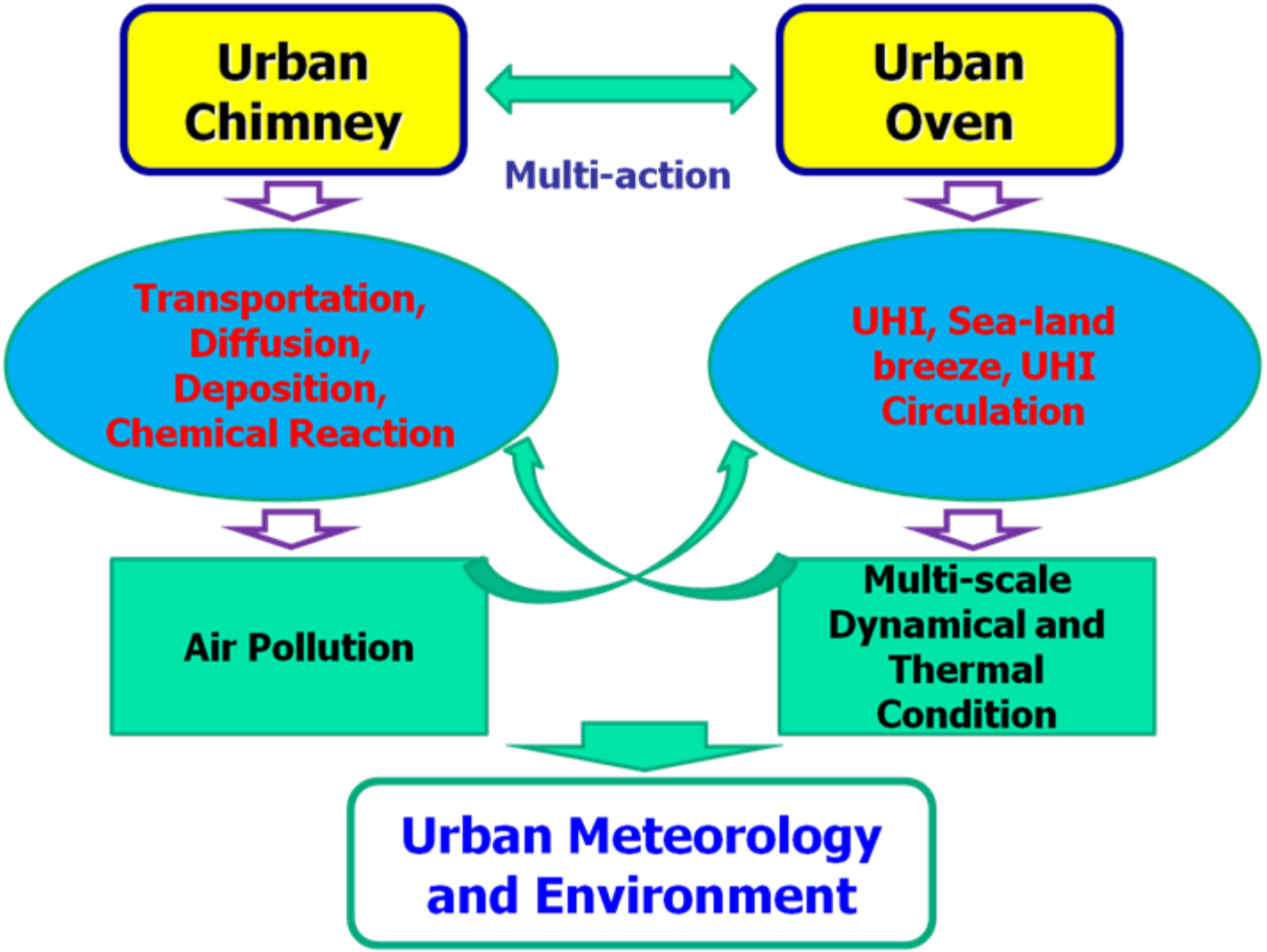
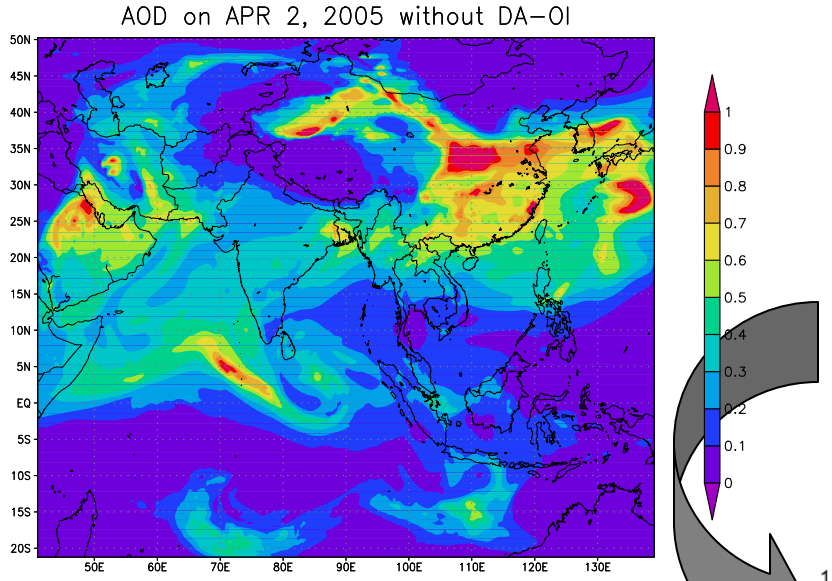


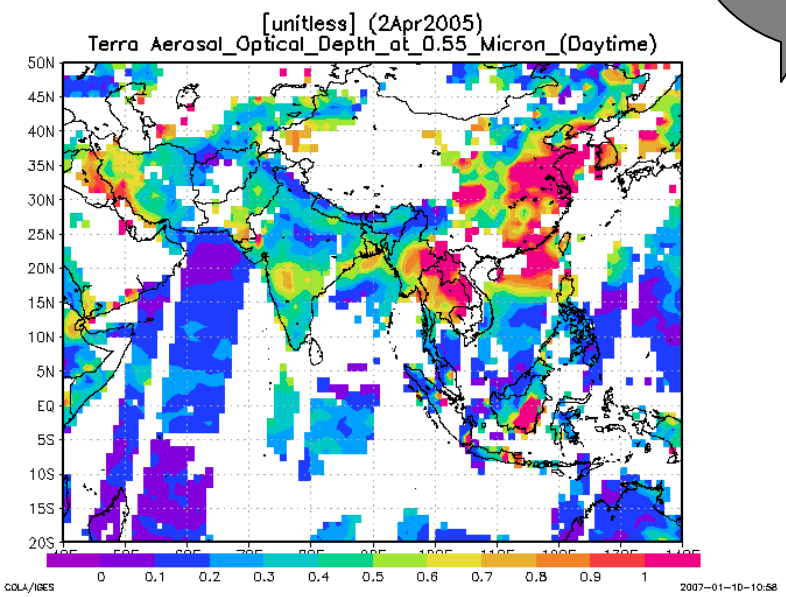
Figure Source: V. Ramanathan, and G. Carmichael, Nature Geoscience, 2008

To understand characters and trends of interactions between the two effects and provide relative products which show the integrated impacts from the two effects to the public are the new frontiers for urban met service.



Assimilation of MODIS AOD to Produce Constrained Fields for Climate Calculations





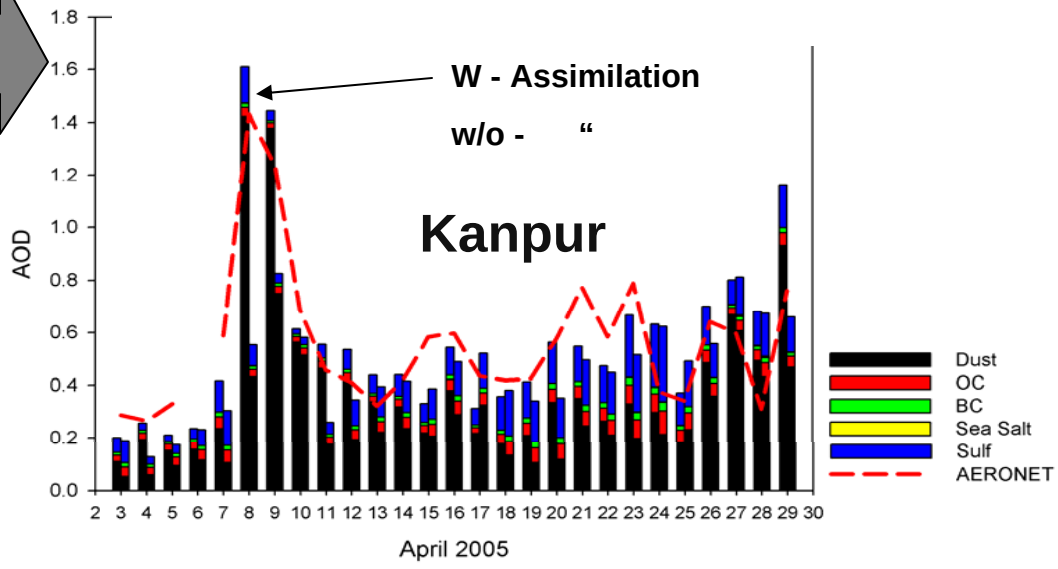
How to optimally adjust individual aerosol quantities given AOD (sulfate, BC, OC, dust, sea salt)?

- AOD by itself not unique

- Fine mode fraction helps

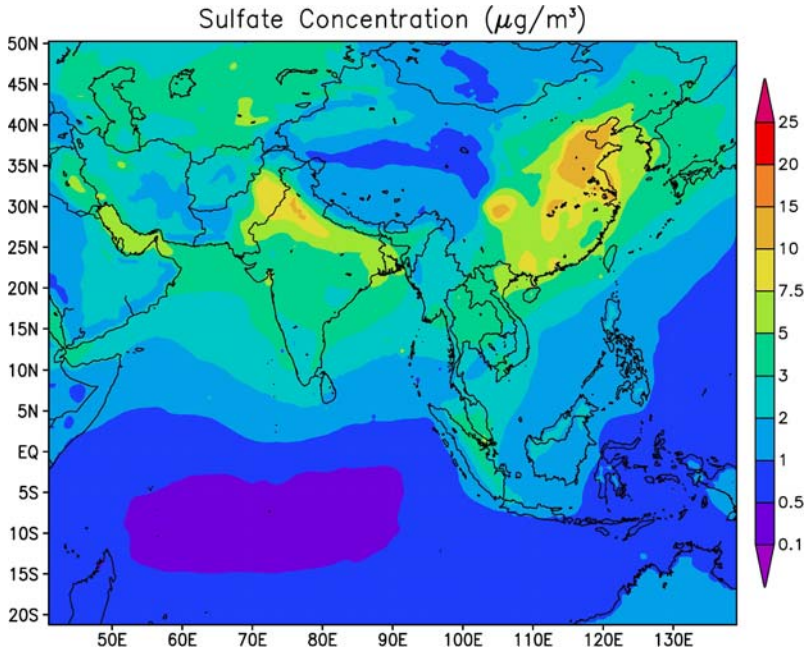
- SSA gives info to adjust abs vs scat.

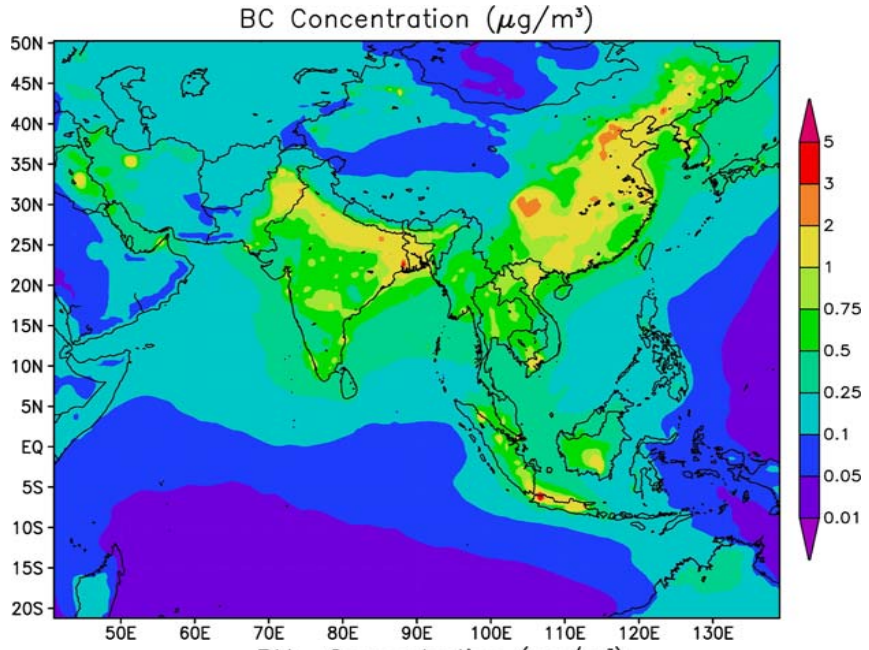
Technique: Collins, W. D., et al. (2001),, *JGR*, *106*, 7313-7336

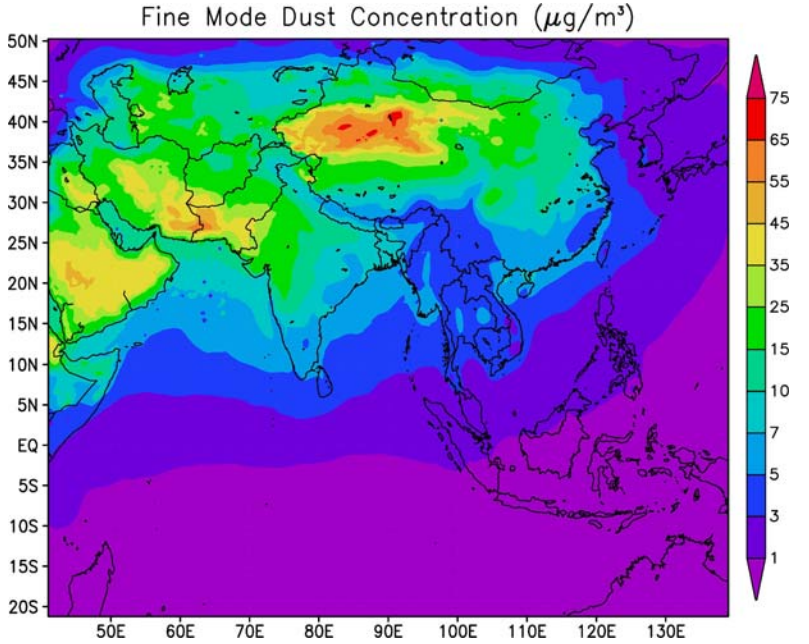


Adhikary et al., 2007,2008

5-yr Mean Aerosol Mass







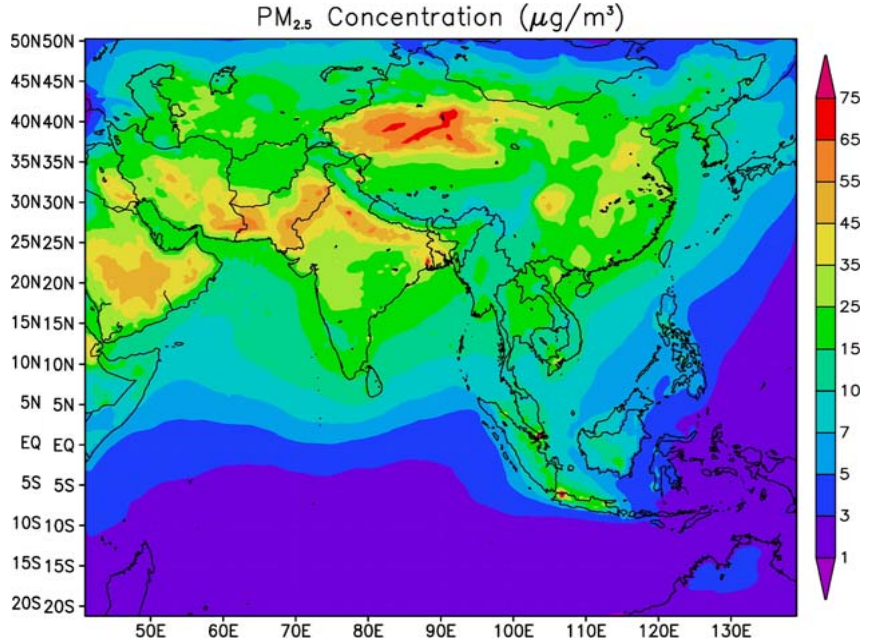
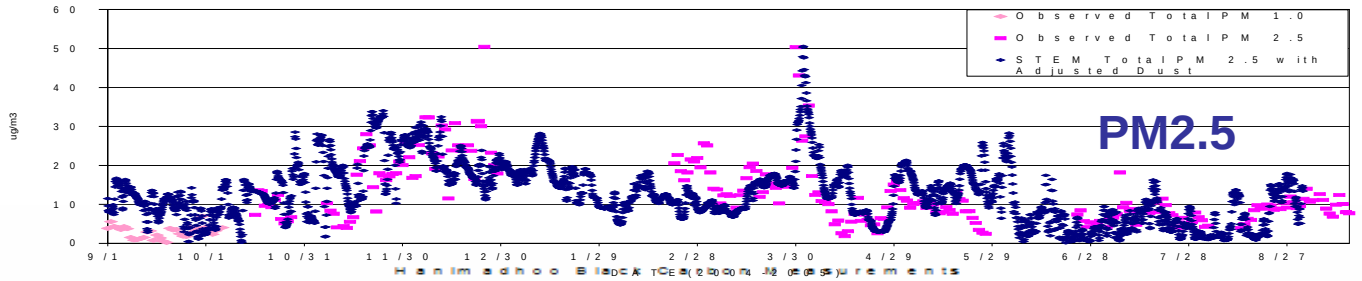
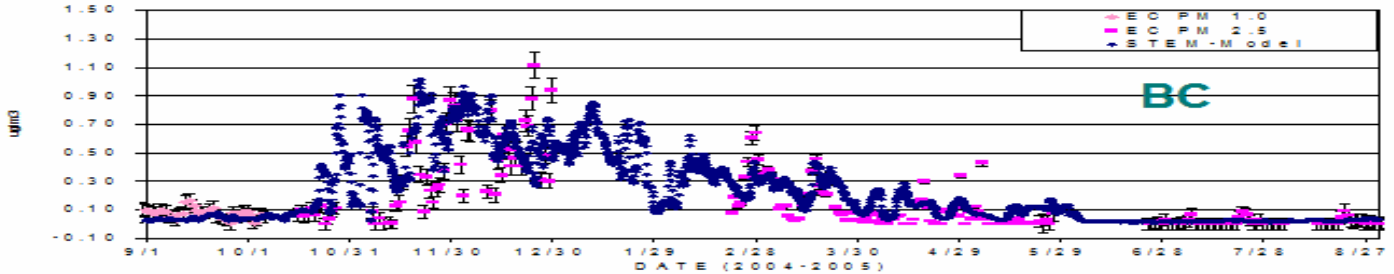


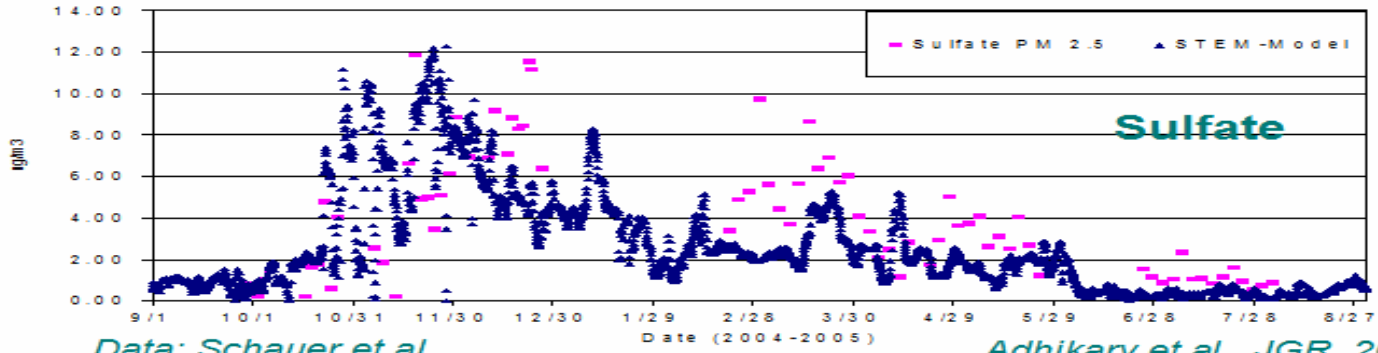
Fig 2

Observed and Predicted PM at the Maldives ABC Site





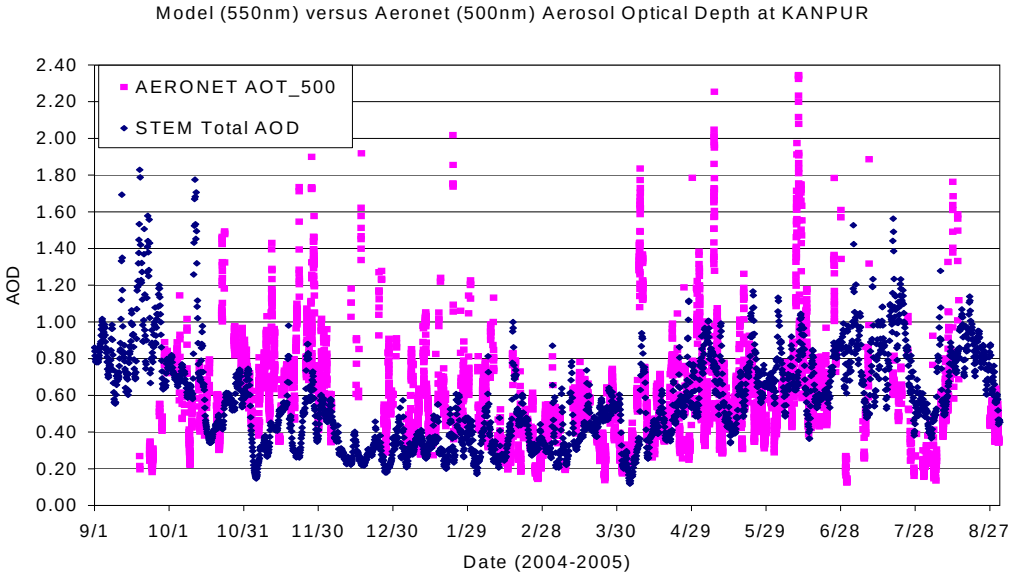
Sulfate Concentration at Hanimadhoo

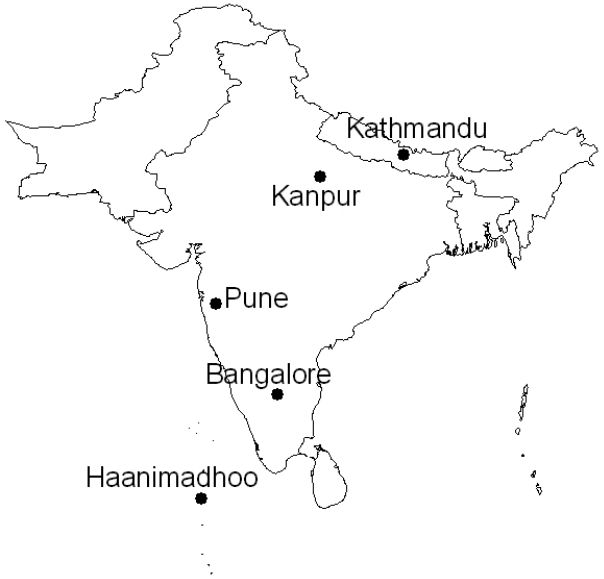


Data: Schauer et al

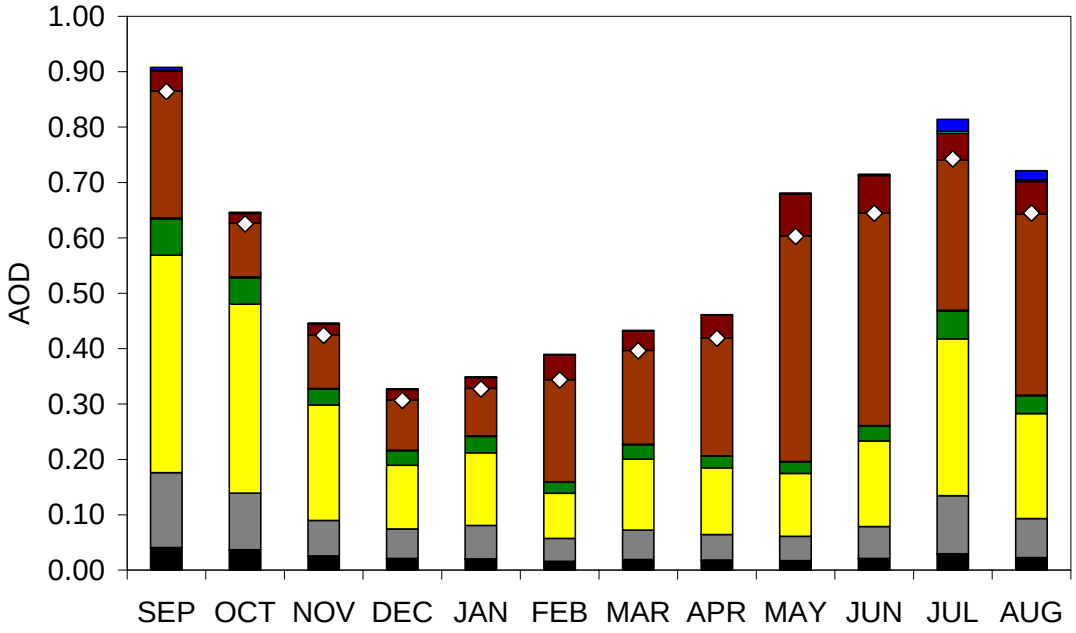
Adhikary et al., JGR, 2007

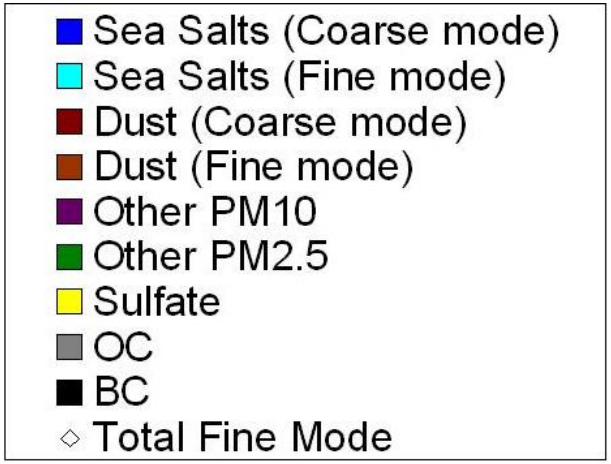
Kanpur AOD Results





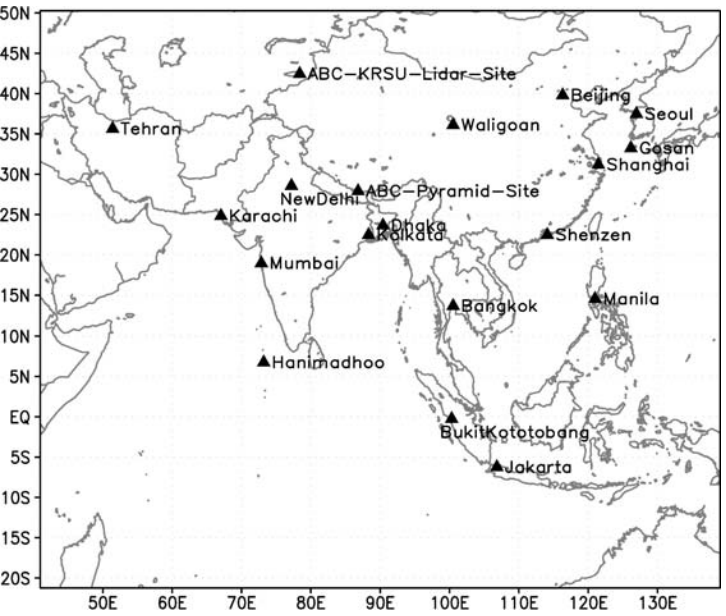
Model Predicted Total AOD at KANPUR

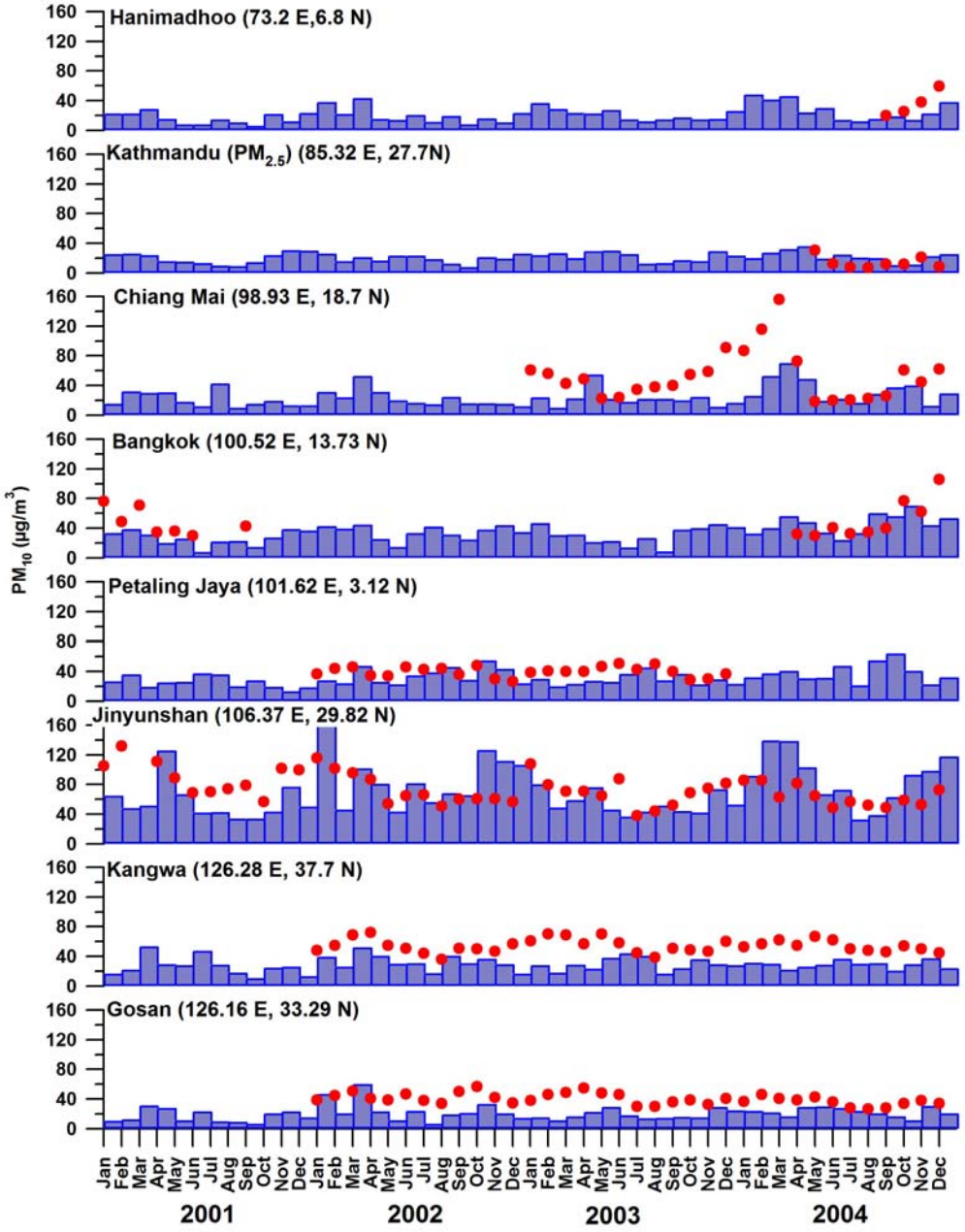




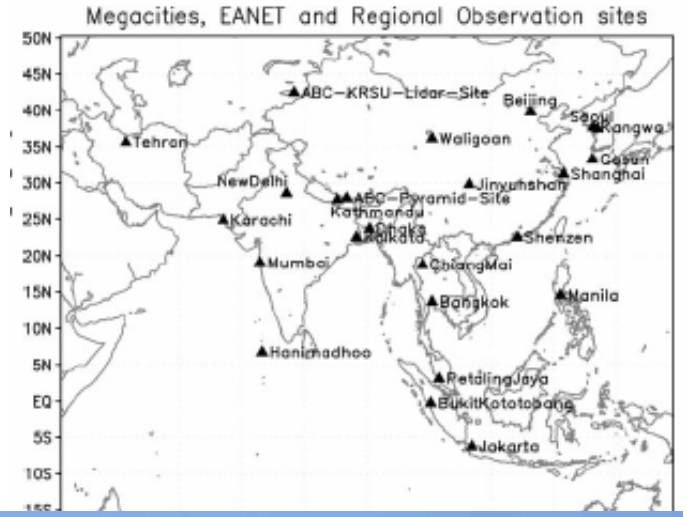
Adhikary et al., JGR, 2007

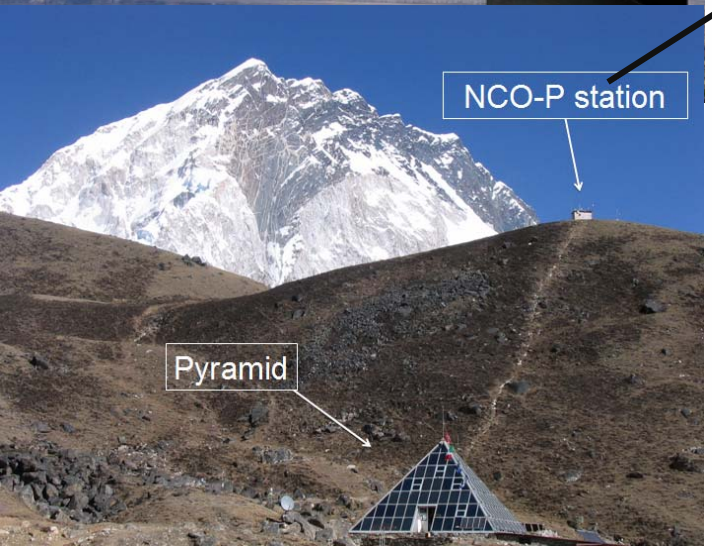
Comparison with EANET and ABC sites

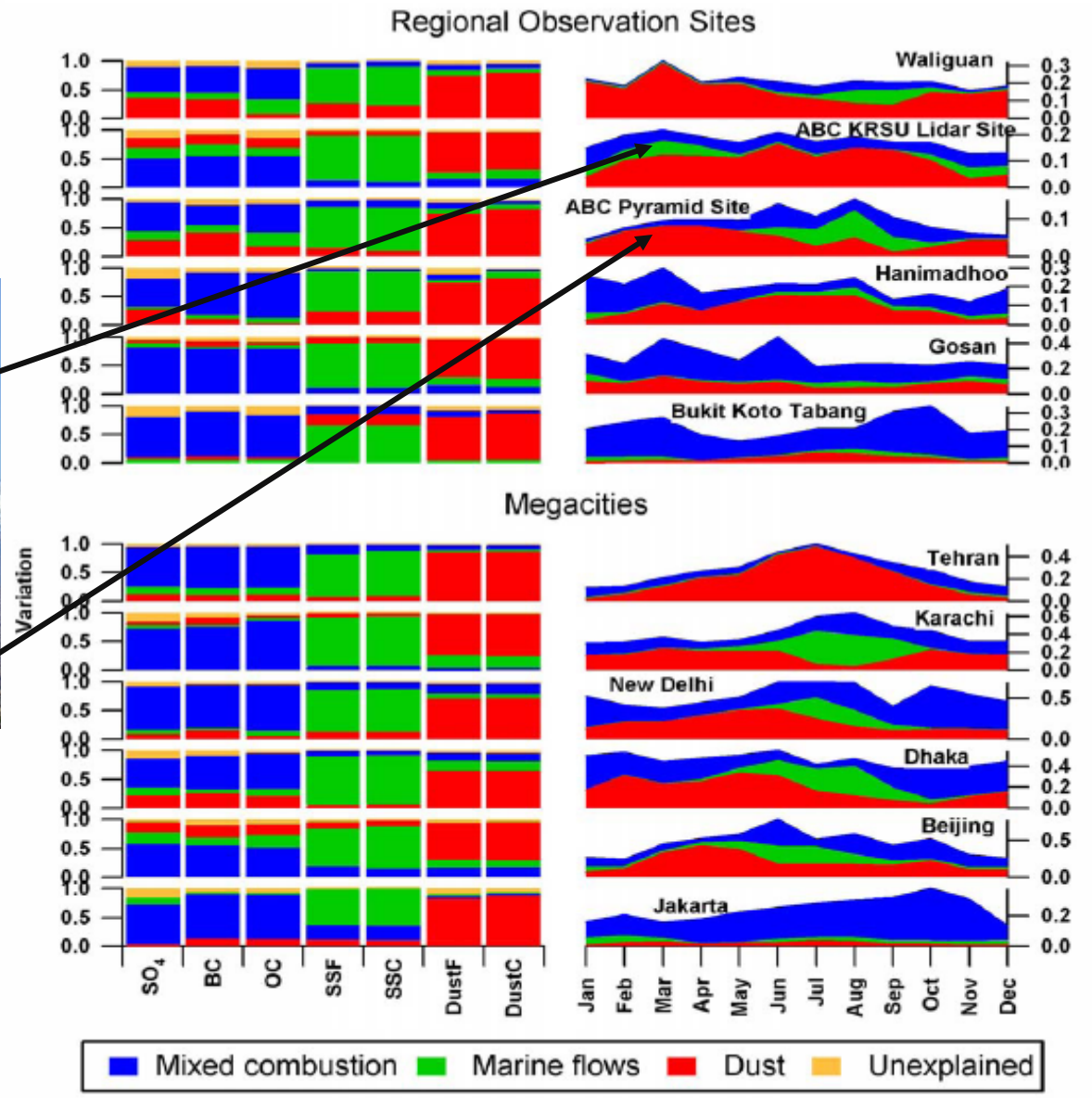




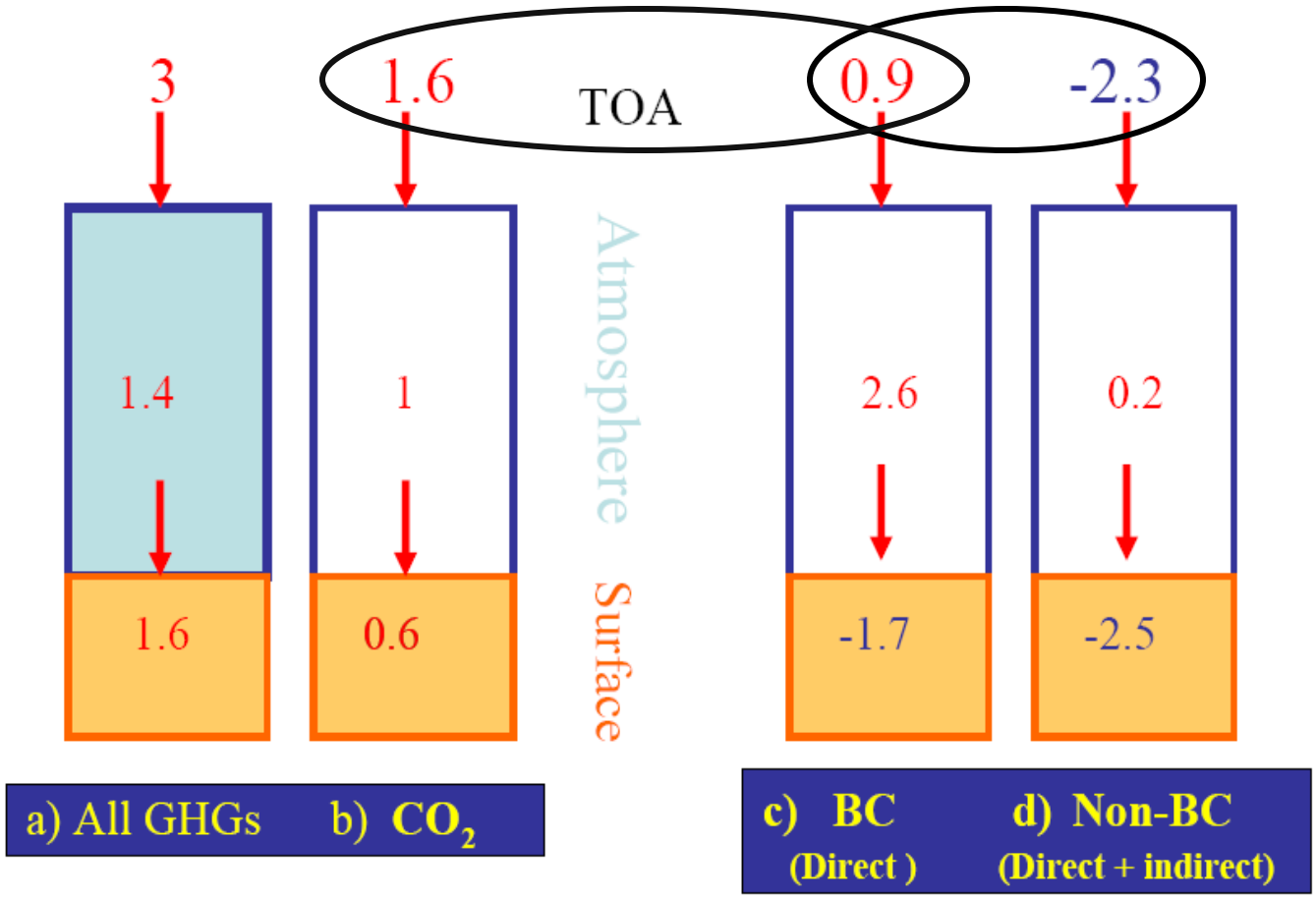
Seasonal Analysis of 5-yr Mean AOD (PMF)







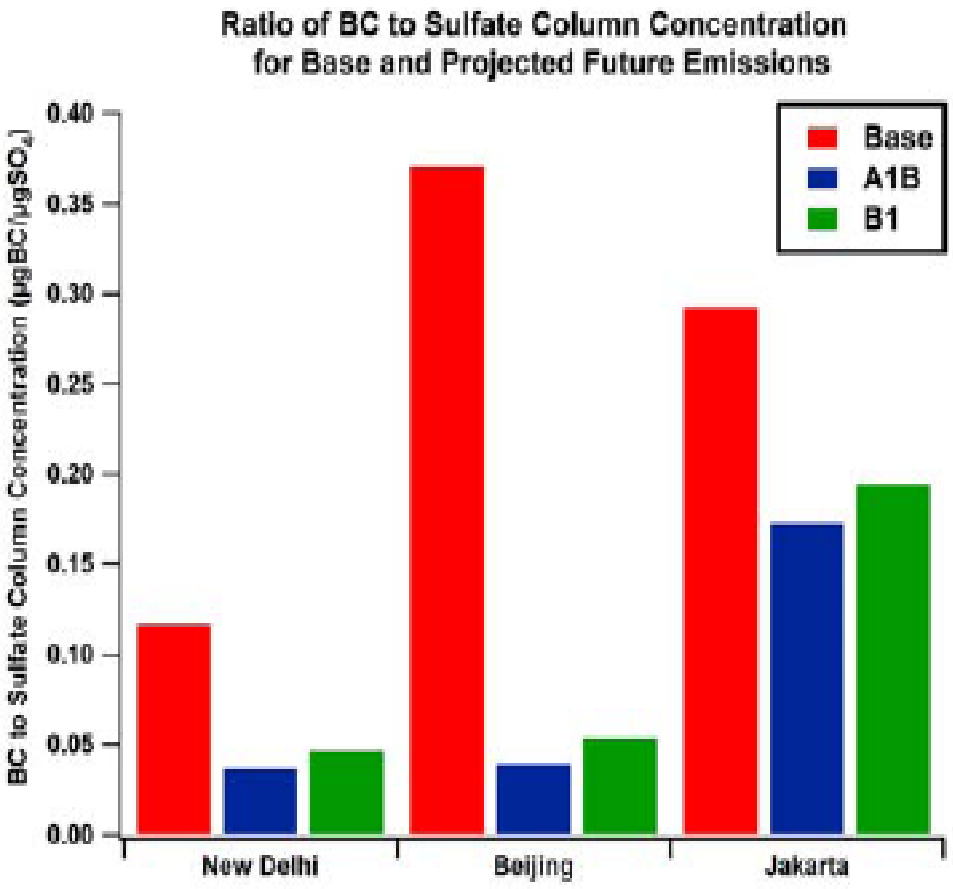
ABCs Mask ~ 50% of Warming



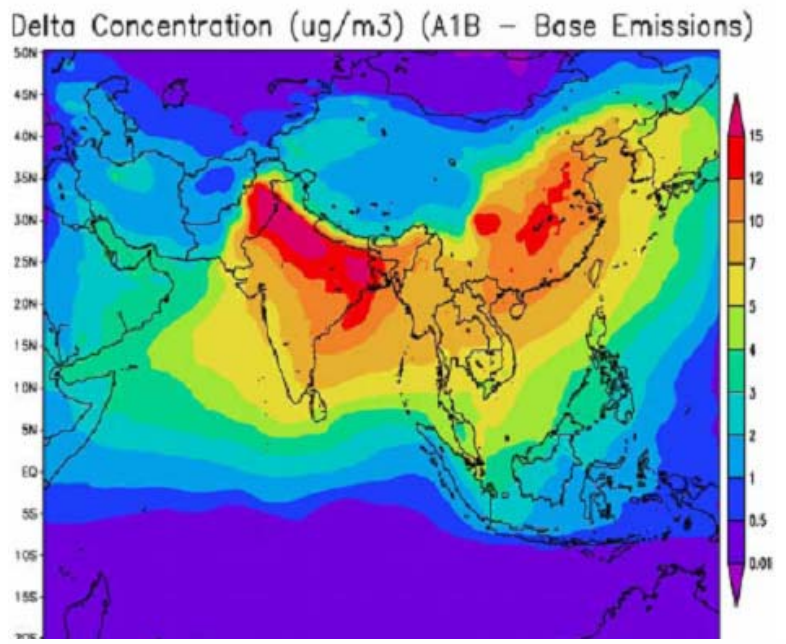
- **BC is ~55% of CO_2 and has a much shorter lifetime**
- **Regional climate, hydrologic, agriculture, and health impacts of ABCs in Asia are summarized in a series of UNEP-ABC reports Nov. 2008.**

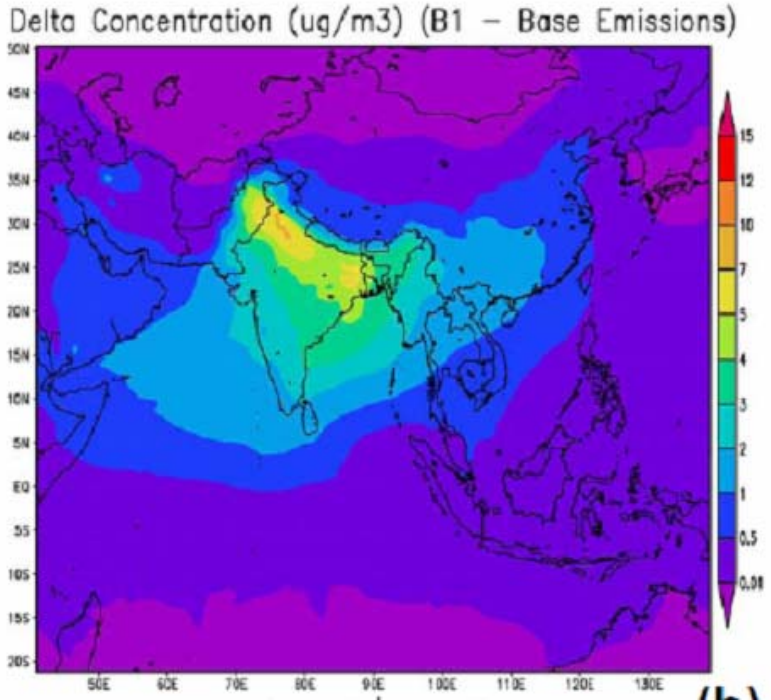
Figure Source: V. Ramanathan, and G. Carmichael, *Nature Geos*. 2008

Under IPCC Scenarios the BC to Sulfate Ratios Decrease …BUT



Future Changes in PM2.5





EXPO 2010

Better City, Better Life

WMO has confirmed officially its participation.

The WMO/CMA pavilion is planned to have three components:

- Multi-hazard early warning demonstration
- Integrated global observing system
- Classroom setup (workshops etc)

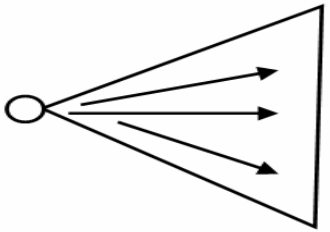
Other agreed activities:

Second World Conference on Broadcast Meteorology

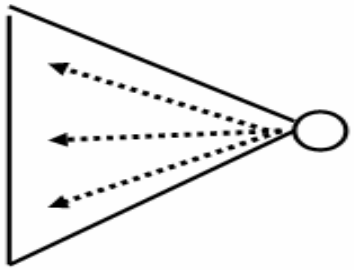
Plan for GURME demonstration in the Pavilion!

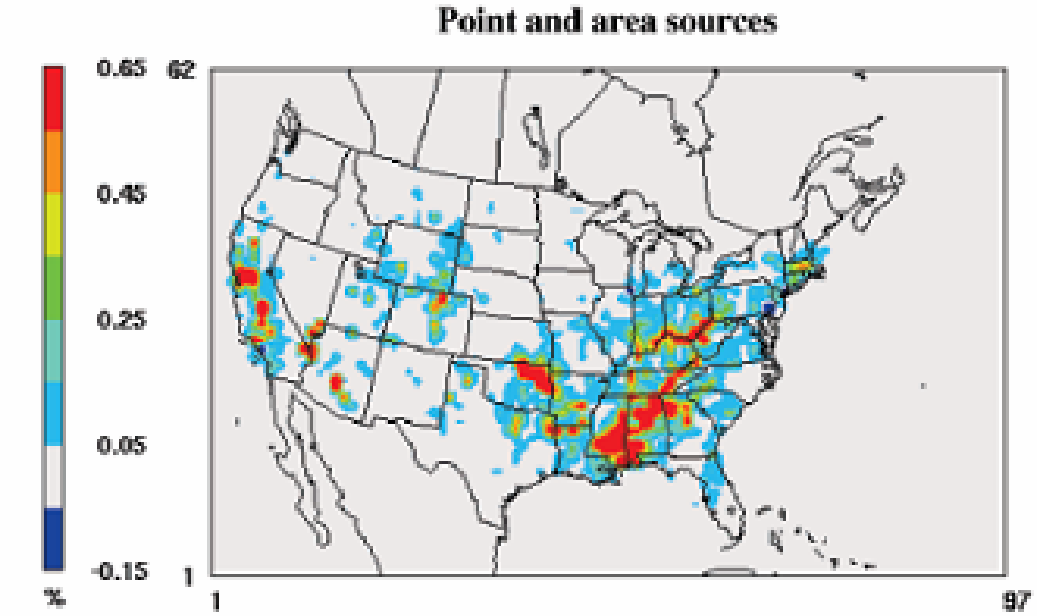
Source/Receptor Calculations: Per

Source-oriented approach - Direct sensitivity analysis.



Receptor/target-oriented approach - Adjoint sensitivity analysis.





Adjoint analysis, ozone violation wrt to emission

Adjoint Analysis at Global Scale Gives Important estimates of Contributions

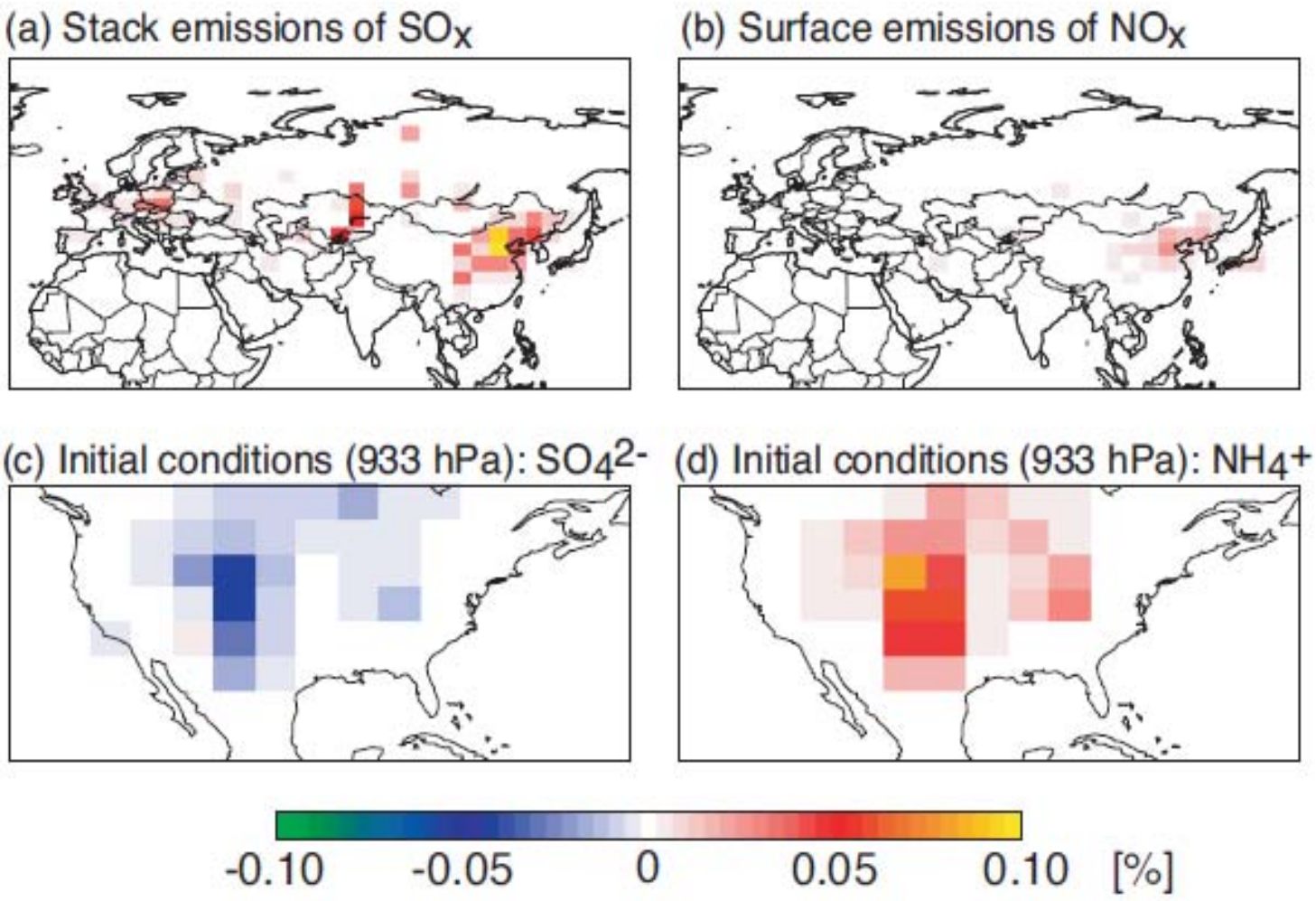


Fig. 4. Normalized sensitivities of the cost function in April with respect to **(a)** stack SO_x emissions, **(b)** NO_x surface emissions, **(c)** SO_4^{2-} initial conditions, and **(d)** NH_4^+ initial conditions. Note the scale is from –0.1% to +0.1%.

Henze et al., 2008

MICS-Asia Phase Ⅲ (Modeling and Emission Inventories)

”Multi-scale model (Global, regional, urban)”

Draft Plan

Scales: Mega-cities, City clusters:

Japan (Tokyo and Osaka Metropolitan areas)
Increase of ozone conc. despite of NOx and VOC reduction,

China (Beijing, Pearl River Delta: Hundred-Million Yen Project, Shanghai-EXPO2010)

Thailand (VOCs emission is controlled by Environmental Standard and then photochemical ozone)

Scales: Regional and global

Source/Receptor analysis at regional scales

Increase of annual average concentration of ozone
- Decline of crops and forests (AOT40)
- Global warming

Passive sampler campaign (Workshop and observation in EANET sites)

Collaborating with

EANET, HTAP, WMO GAW Urban Research Meteorology and Environment (**GURME**) Programme, IGAC and others

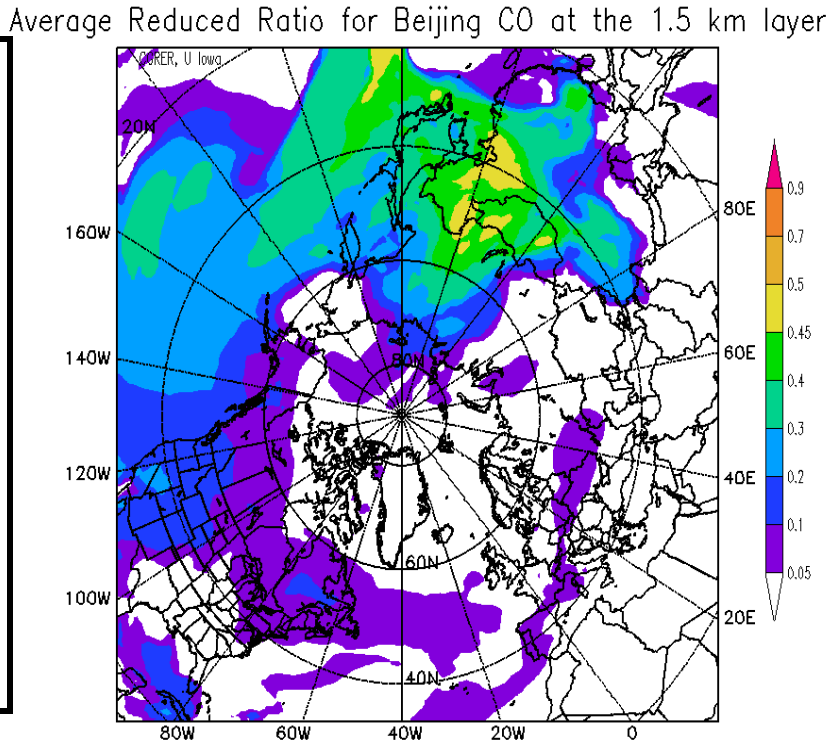
Collaborations welcomed and needed !!

Over what scales can we quantify the impact of megacities?

What can we learn from the Beijing Olympics?

(Tsinghua Univ, Argonne, Iowa, NASA Goddard)

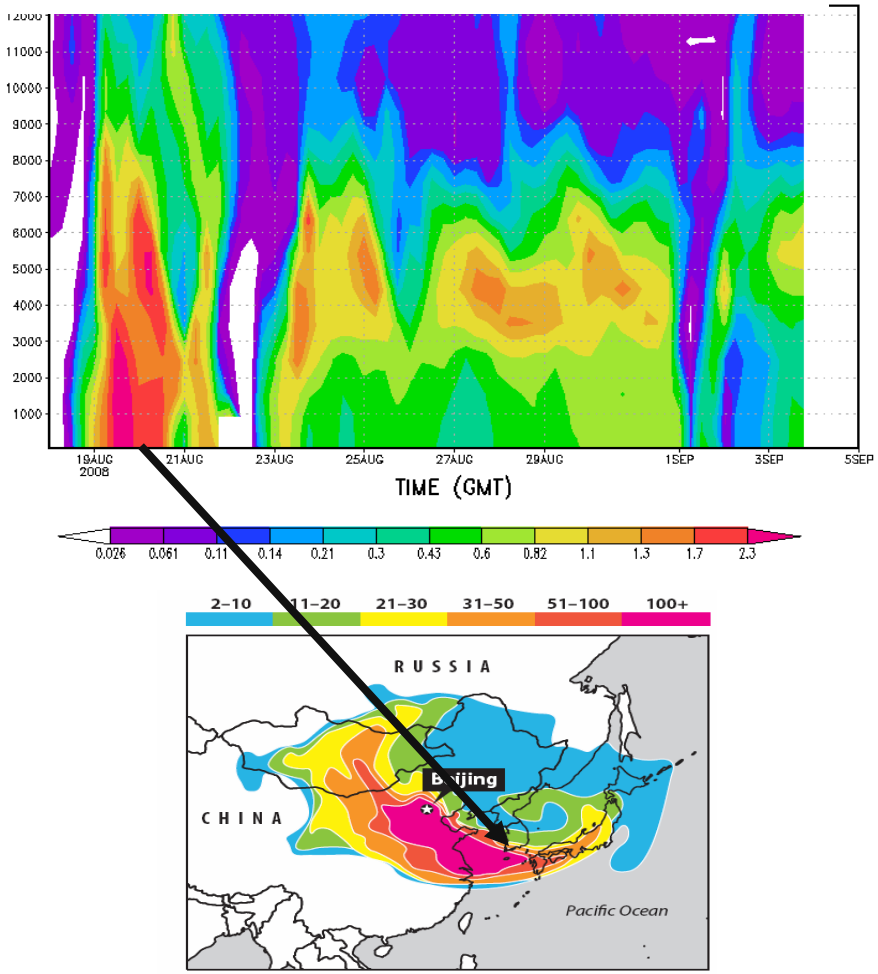
- ✓**Making forecasts of the Beijing Control Zone.**
- ✓**2 forecasts @ regional and hemispheric scales: Normal emissions + Estimated impact of controls; BC and BC/S decrease**
- ✓**Combine inventory analysis, satellite, models to estimate emissions.**



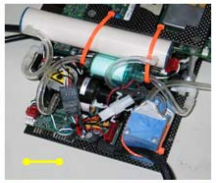
Aug1-24 Avg

Cheju ABC Plume-Asian Monsoon Experiment (CAPMEX) –NSF/KOSEF

Beijing Plume Influence at Cheju



UAS instruments



Optical Particle Counter (580 g)
→ N_{OPC}; 0.3 < D_p < 3 µm

[=] 1 inch

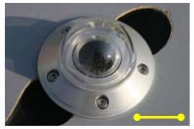
Condensation Particle Counter (870 g) → N_{CN}; D_p > 10 nm

Aethalometer (820 g)
→ absorbing aerosol

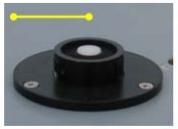
T/RH probe (50 g)
→ Temperature & RH

Aerosol inlet & splitter (150 g)
→ unbiased aerosol sampling

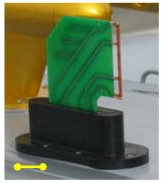
Cloud Droplet Spectrometer (1.4 kg) → distr. 1 < D < 50 µm



Pyranometer (190 g)
→ irradiance 0.3 – 2.8 µm



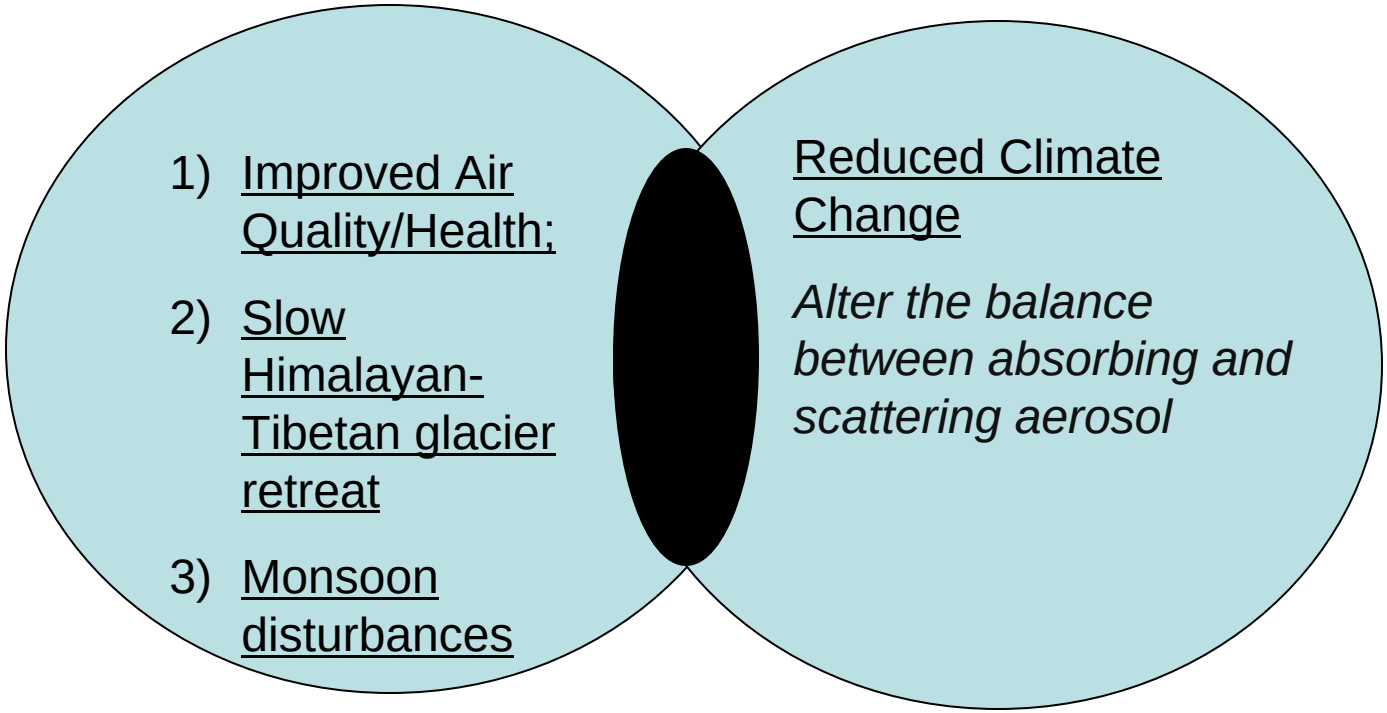
PAR radiometer (45 g)
→ irradiance 400 – 700 nm



LWC probe (450 g)
→ Cloud water (g m^{-3})

Gust probe (400 g) & video camera (280 g)
→ turbulence & cloud targeting

Reducing the Impacts of ABCs Co-benefits



Win/Win Strategy

+ **Decrease PM2.5**

+ Decrease BC faster than Sulfate aerosol

BC Focused Controls Have Significant Health (and Climate) Benefits and Opportunities

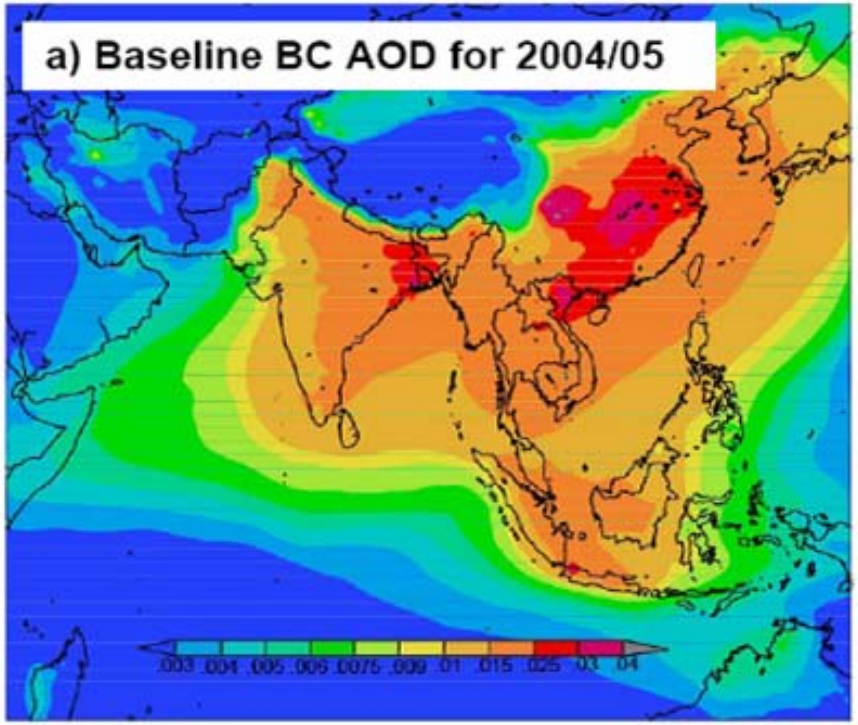
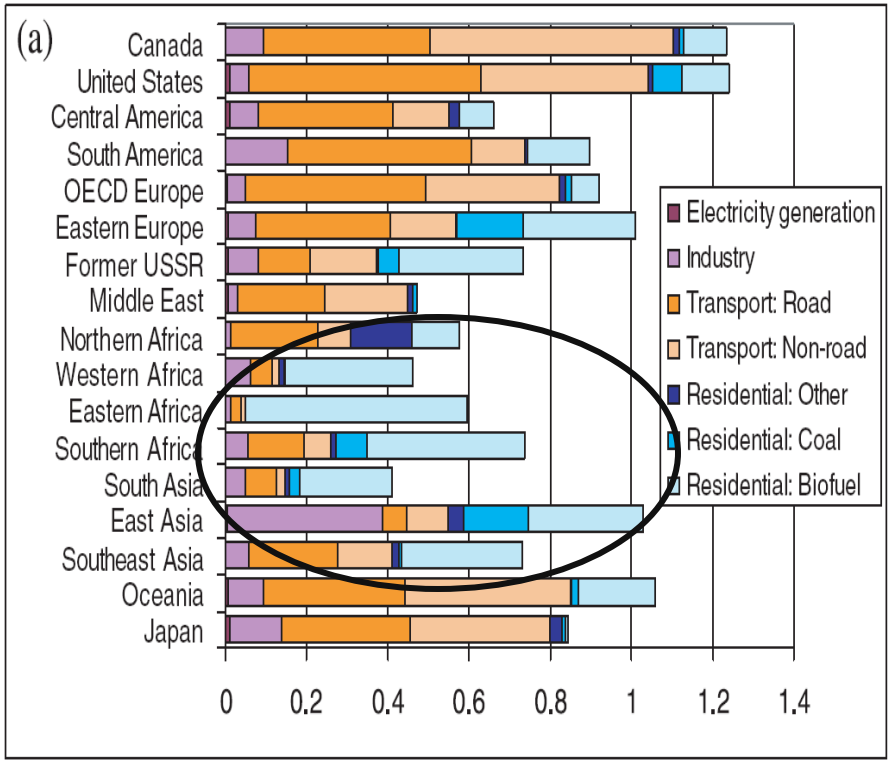


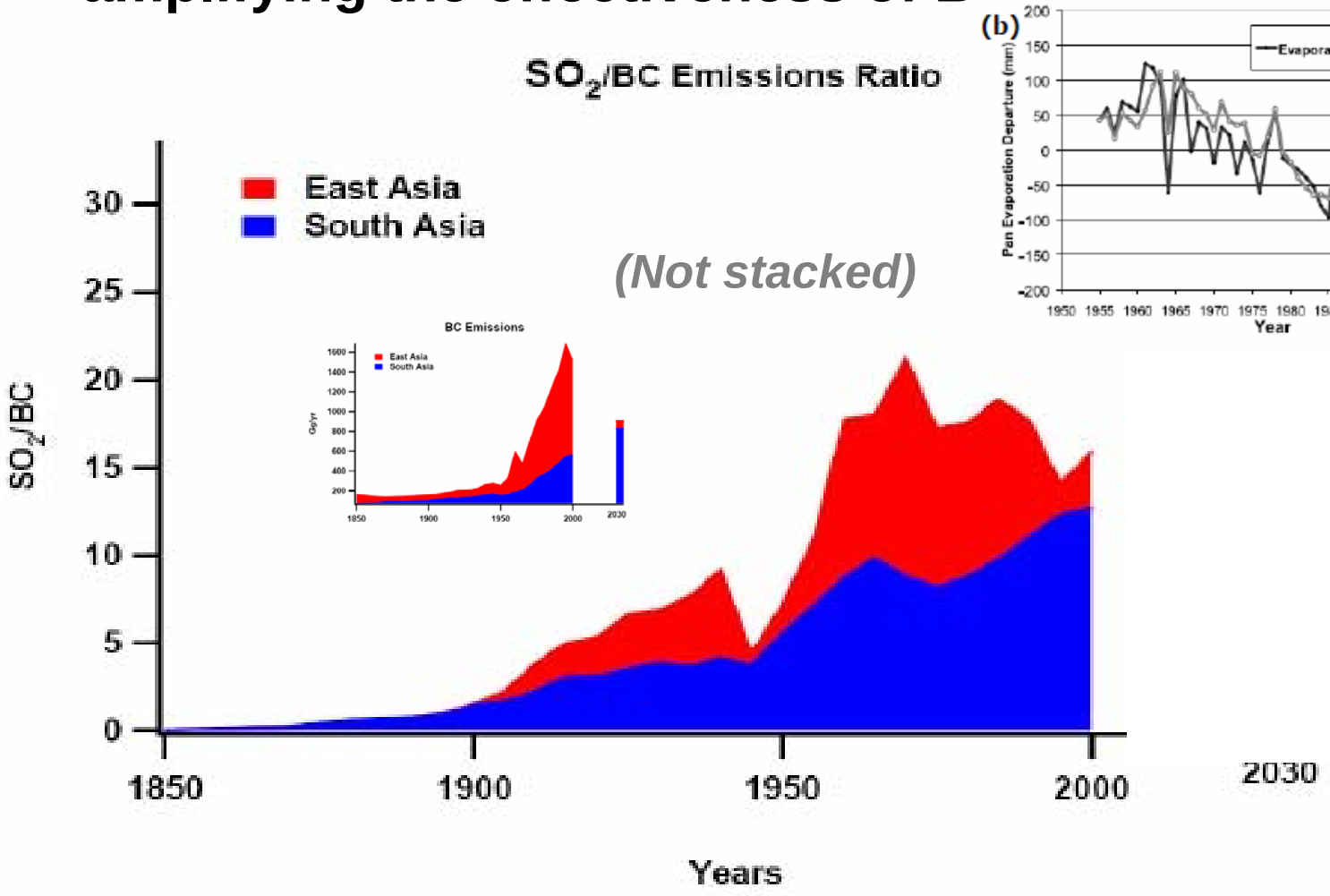
Figure Source: Adhikary et al., *JGR*, 2008



Bond et al., ERL, 2007

Biofuels are a significant source in many regions

With strategies in Asia recognizing the climate and AQ importance of BC, the non-BC to BC ratio would likely decrease in the future, more quickly in East Asia, amplifying the effectiveness of B



Ohara, et al., ACP, 2007; Bond et al., GBGC, 2007; Stern, Chemosph., 2005; Streets et al., JGR, 2004

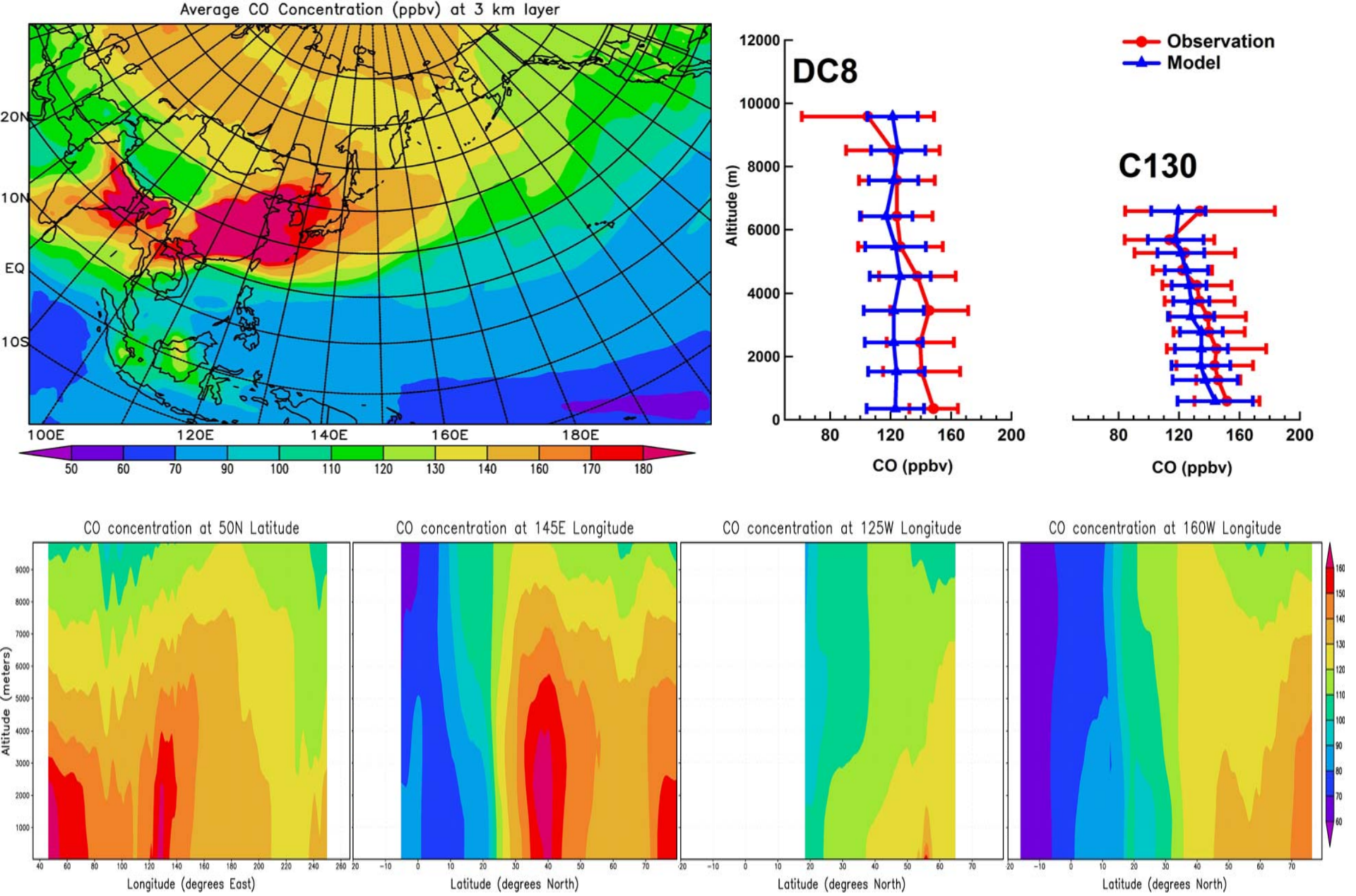
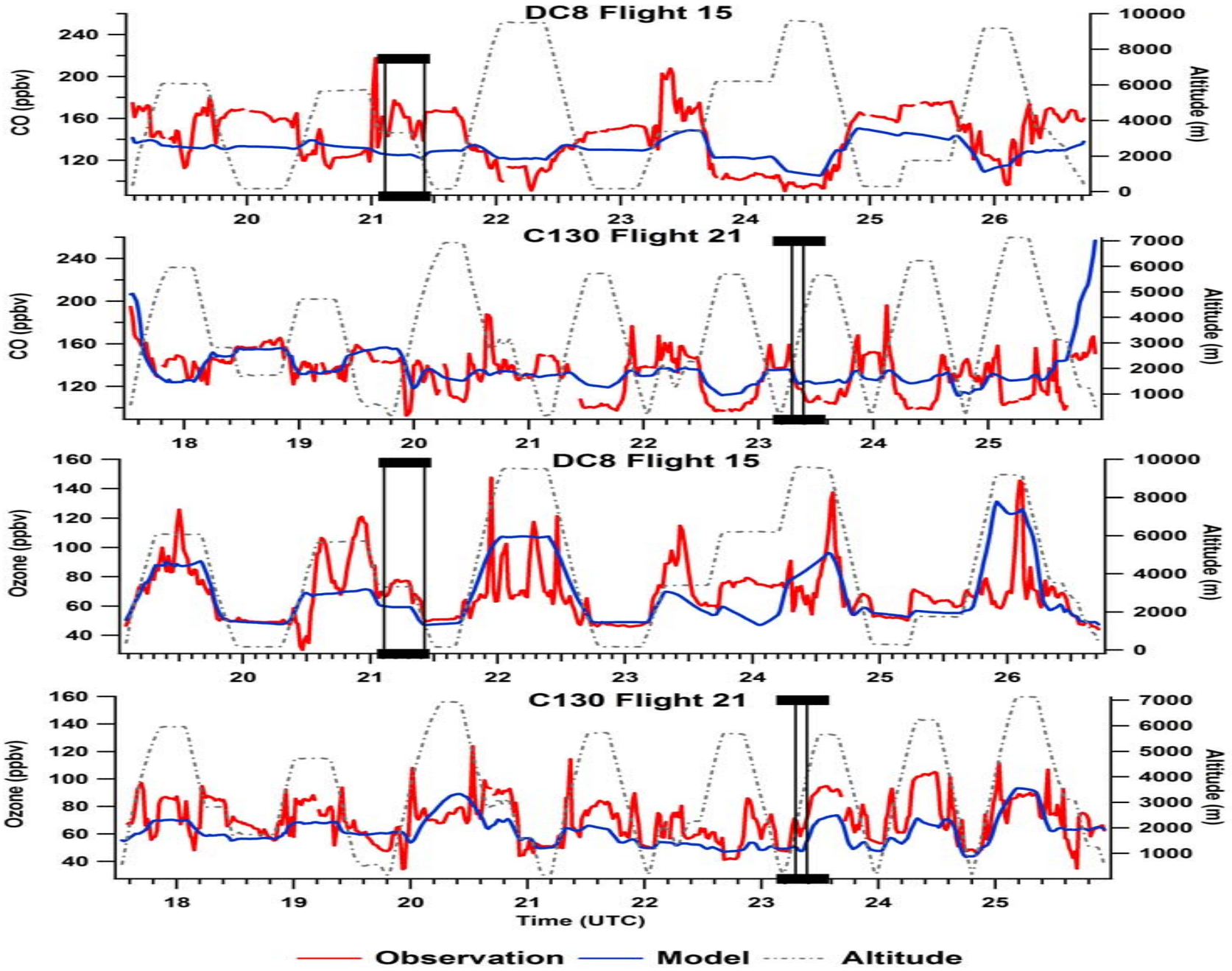
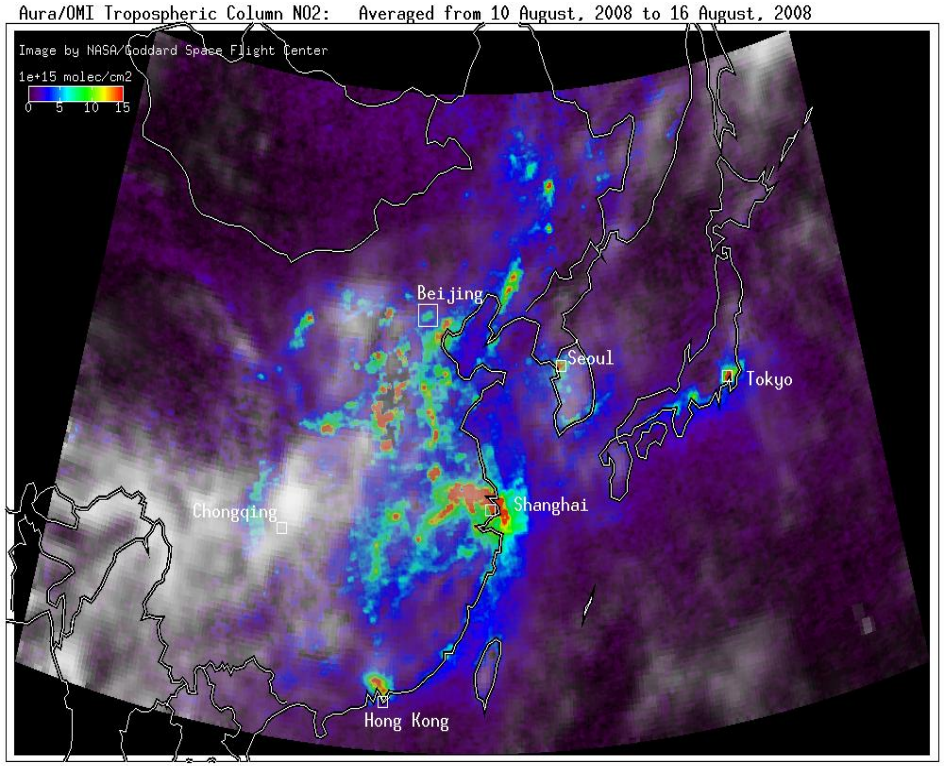

Average CO Concentration (ppbv) at 3 km layer
20N
10N
EQ
10S
100E
120E
140E
160E
180E
50
60
70
90
100
110
120
130
140
160
170
180
DC8
C130
Observation
Model
Altitude (m)
CO (ppbv)
CO concentration at 50N Latitude
CO concentration at 145E Longitude
CO concentration at 125W Longitude
CO concentration at 160W Longitude
Altitude (meters)
Longitude (degrees East)
Latitude (degrees North)

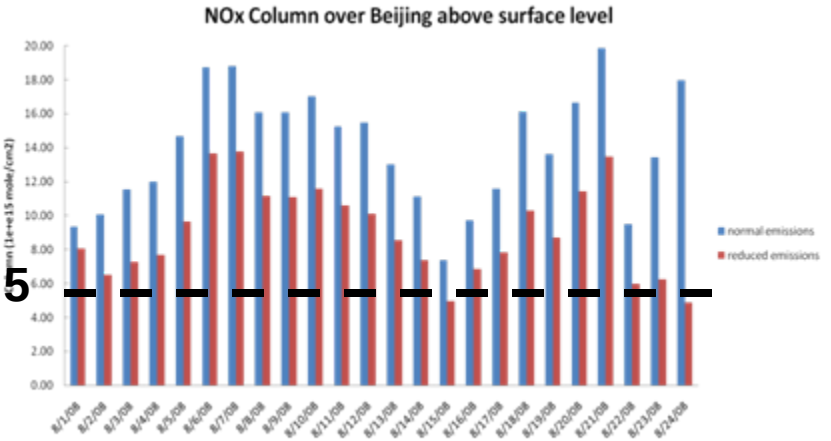
Figure 2

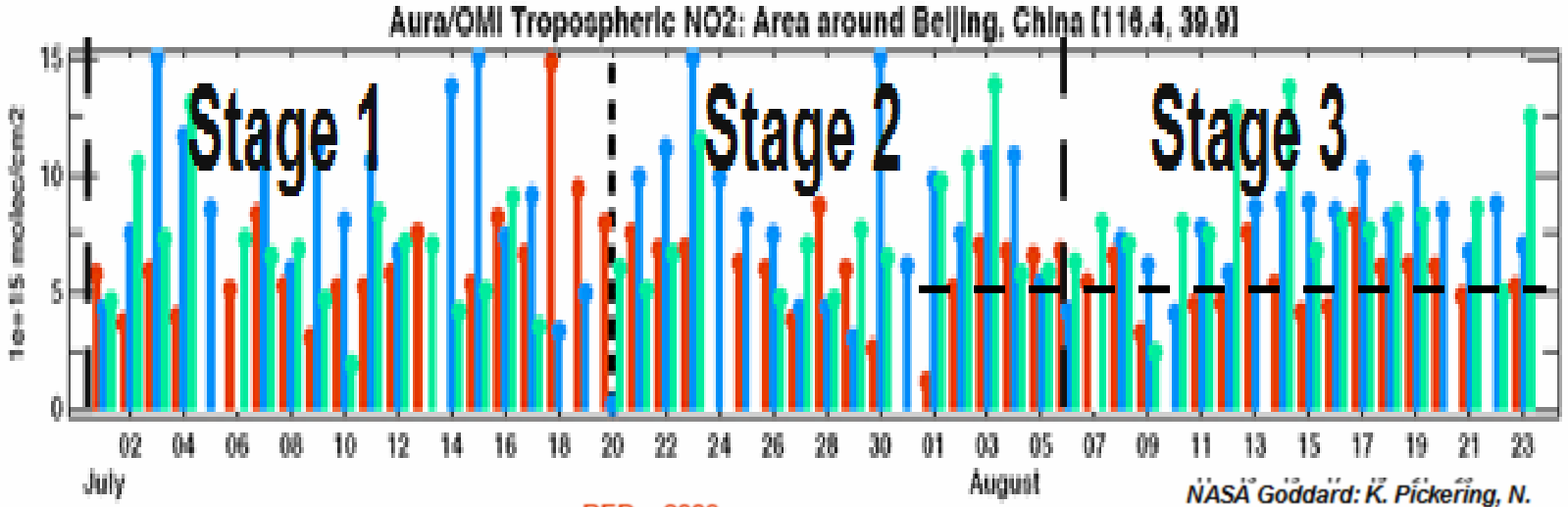

DC8 Flight 15
CO (ppbv)
Altitude (m)
C130 Flight 21
CO (ppbv)
Altitude (m)
DC8 Flight 15
Ozone (ppbv)
Altitude (m)
C130 Flight 21
Ozone (ppbv)
Altitude (m)
Time (UTC)
Observation
Model
Altitude

Preliminary Analysis of NO2 and SO2 Columns.

Over what scales can we detect the signal?; to what extent can we attribute the signal?



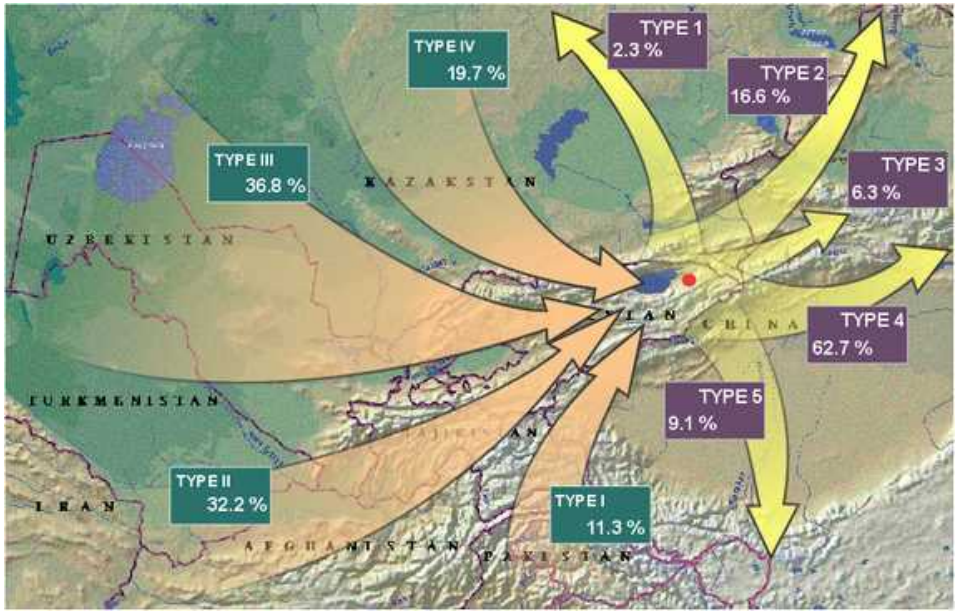




NASA Goddard: K. Pickering, N. Krotkov, J. Gleason, J. Witte, A. Prados, and M. Schoeberl.

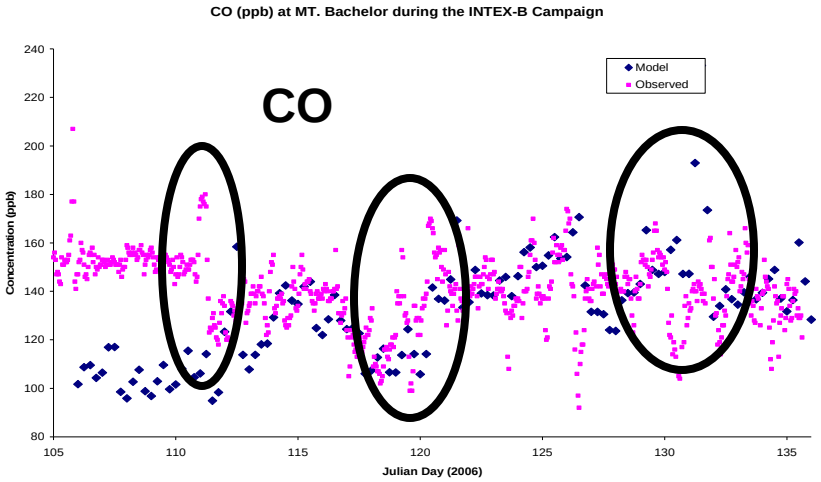
Central Asia is a Region of Growing Interest – A New ABC Site is being Established.

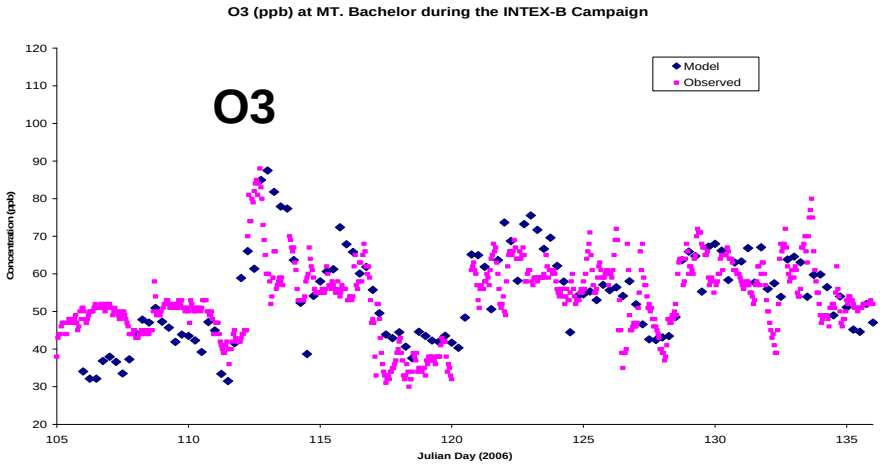
Collaborators Welcomed!

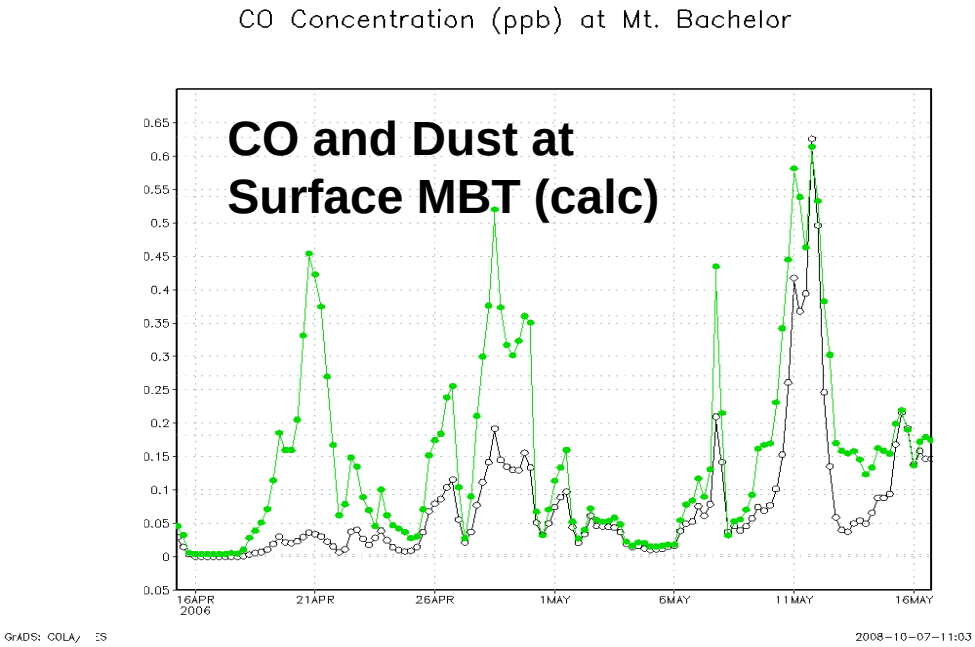


Trajectories of long range transport at height 3500 m over sea level

Recent NASA Experiments Enhances Observations to Test Models







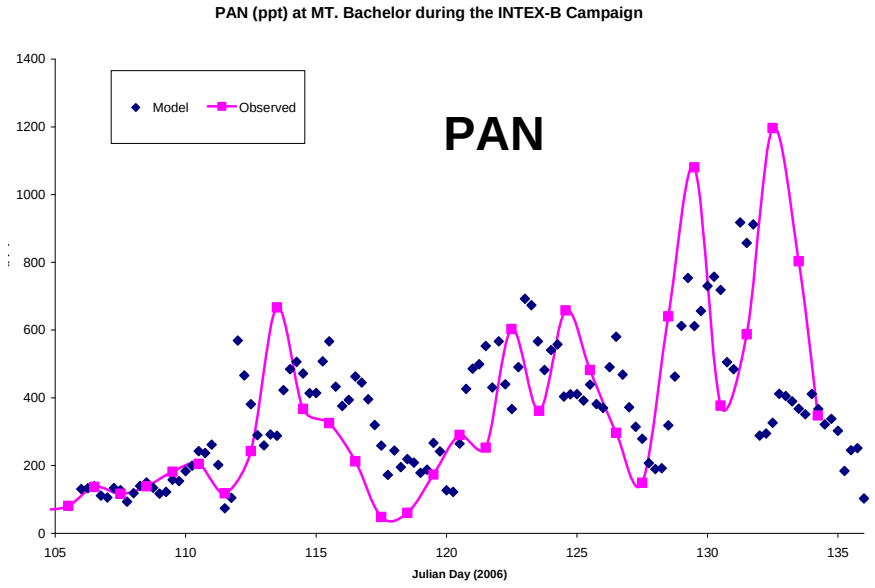


Figure 13. Comparison of the STEM model prediction versus observed trace gaseous at Mt. Bachelor, OR.