Improving process understanding of transpacific transport: Insights from space and high-resolution models

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Questions? Come to find me!

1. Introduction

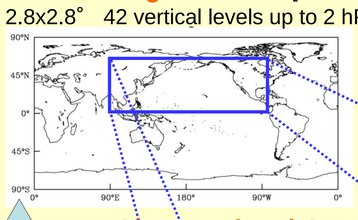
Both synoptic and mesoscale processes play important roles in global air pollution transport and associated impacts on air quality. Transpacific transport of trace gases and aerosols requires further process-based studies, in particular the role of mesoscale processes on pollution export from Asia [*Lin et al., 2010*], chemical processing over the Pacific, and the mixing of background air into the surface over the western North America through land-sea breezes and orographic flow [*Parrish et al, 2009*].

High-resolution observations and multi-scale model simulations may provide insights into the interaction of synoptic and mesoscale processes:

- Gradient of urban-suburban-rural emissions and ozone formation regimes
- The signal of emission perturbations on ground-level ozone
- Contribution of background ozone transport to surface air quality
- Provide the most relevant information for local urban planners

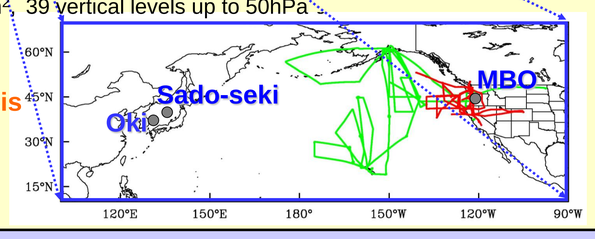
2. Multiscale model simulations and observations

MOZART-4 global CTM [*Emmons et al., 2010*]
2.8x2.8° 42 vertical levels up to 2 hPa



GFS/FNL global analysis

WRF-Chem regional CTM [*Grell, et al., 2005; Fast et al., 2006*]
60x60 km², 39 vertical levels up to 50hPa



Consistent emissions:

- INTEX-B 2006 Asian emissions [*Zhang et al., 2009*]
- NEI2005 for North America [*Mckeen, S.*]
- MEGAN online calculation of biogenic VOC emissions [*Guenther et al, 2006*]

WRF-Chem physics:

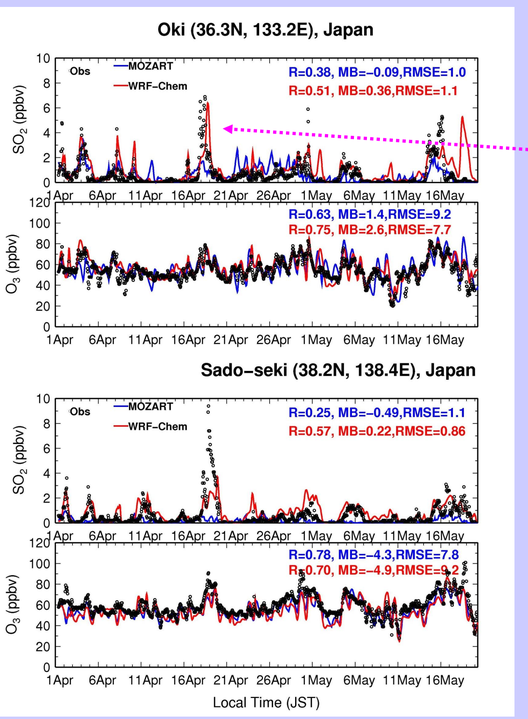
- CBM-Z/MOSAIC gas-phase/aerosol chemistry
- Fast-J photolysis scheme
- Grell-Devenyi cumulus
- Noah land surface model

In-situ observations:

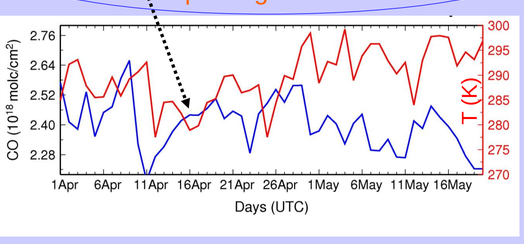
- EANET [*Akimoto, H.*]
- INTEX-B **DC8** and **C130** [*Singh et al., 2009*]
- Mt. Bachelor (2700 a.s.l.) [*Jaffe, D., Thornton, J.*]

3. Asian pollution outflow, transpacific transport, and import to North America

Continental outflow events

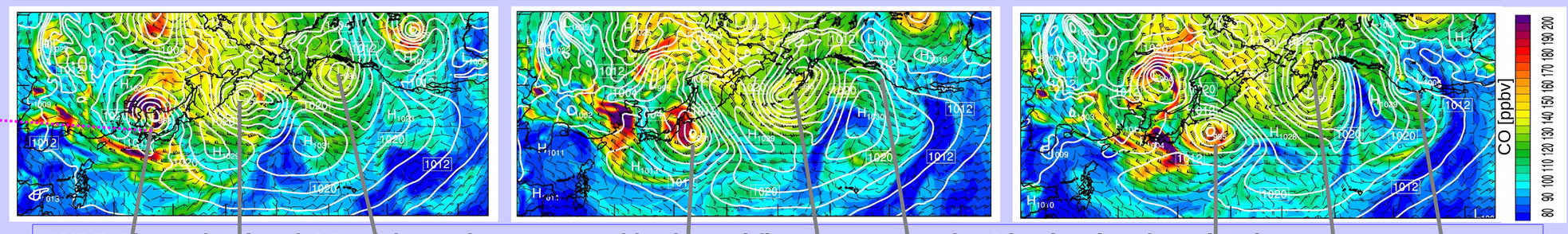


Drop of surface temperature indicates cold front passages.

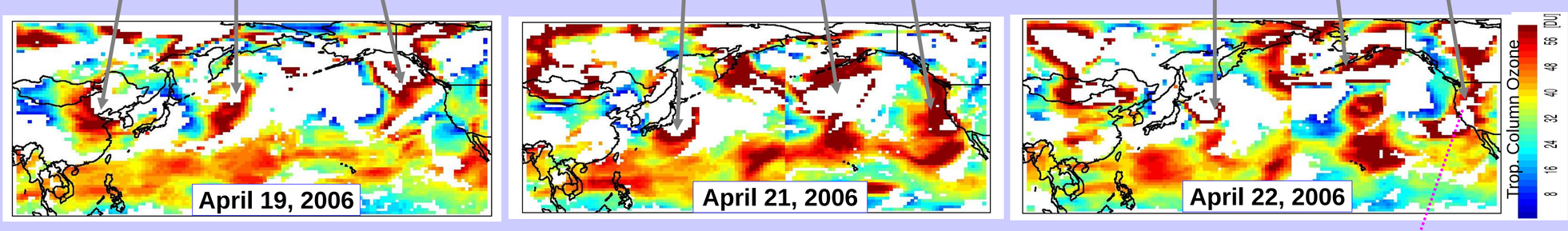


Daily variations of total CO columns (20-55N, 125-150E) and surface temperature (34-40N, 114-120E) retrieved from the AIRS instrument on board the Aqua satellite.

Transfer of polluted air masses among multiple warm conveyor belts across the Pacific



WRF-Chem simulated CO mixing ratios (colors) **and horizontal fluxes** (arrows) **at the 4-km level and sea level pressure** (white contours)



Ozone transport as seen by daily maps of Aura OMI/MLS tropospheric column ozone

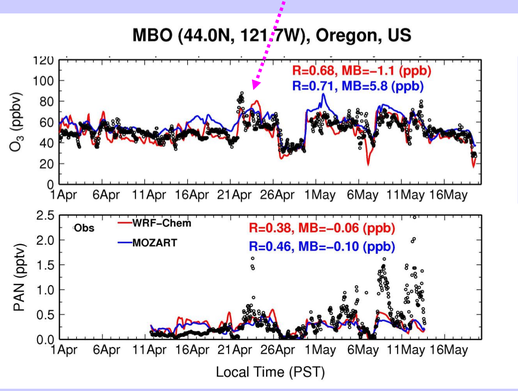
Observational constraints:

The figures illustrate the export of a highly-polluted air mass from Asia to North America during April 18-24, 2006. This event was first sampled at the EANET ground sites on the west coast of Japan, then transported across the Northern Pacific as illustrated in the daily maps of tropospheric column ozone retrieved from the OMI/MLS instruments aboard the Aura satellite [*Ziemke et al., 2006*], and finally arrived at the Mt. Bachelor ground site over the Western U.S. on April 22-24.

Transport mechanism:

The WRF-Chem model simulation suggests that two warm conveyor belts (WCB) were involved in the transport of pollution from Asia to North America, consistent with a previous finding using trajectory analysis [*Cooper et al, 2004*]. The pollutants were lofted by one WCB over the east Asian coast, carried by a second WCB across the Pacific, and then subsided into the lower free troposphere over the western U.S. by a high-pressure system. The WCBs likely also entrain ozone from the stratosphere.

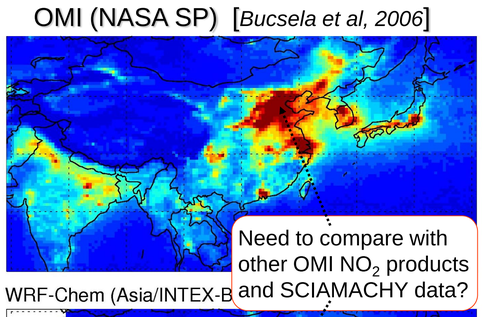
Ozone enhancements at Mt. Bachelor, Oregon, US



4. Regional to urban features of ozone formation regimes and precursor emissions

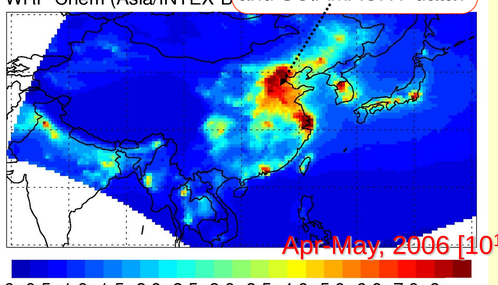
Tropospheric NO_2 columns

OMI (NASA SP) [*Bucsela et al, 2006*]



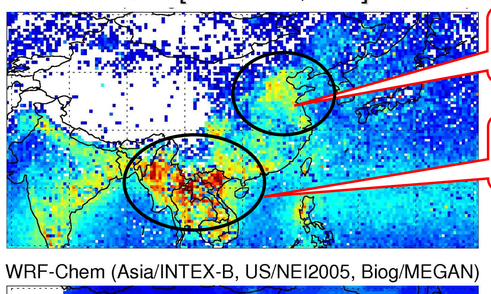
Need to compare with other OMI NO_2 products and SCIAMACHY data?

WRF-Chem (Asia/INTEX-B



Tropospheric HCHO columns

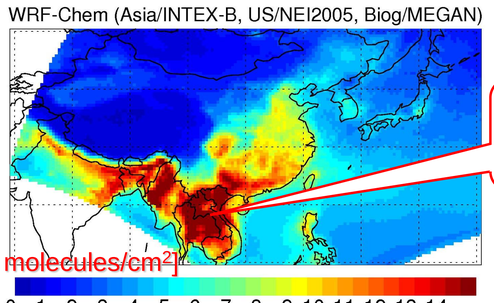
OMI [*Kurosu et al, 2004*]



anthropogenic signal

Biogenic or fire signal

WRF-Chem (Asia/INTEX-B, US/NEI2005, Biog/MEGAN)



Overestimate of isoprene emissions?

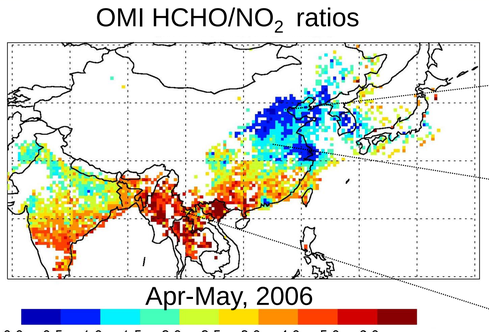
Apr-May, 2006 [10^{15} molecules/cm^2]

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 5.0 6.0 7.0 8.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Ozone control strategies for China from space?

OMI $HCHO/NO_2$ ratios



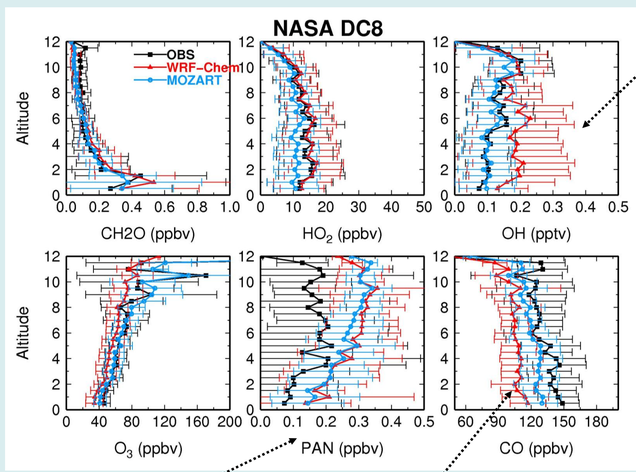
Recommended $HCHO/NO_2$ ratio index:
[*Martin et al., 2004, Duncan et al., 2010*]

Megacities: $HCHO/NO_2 < 1$
→ Ozone formation is VOC-limited
→ VOC control is more effective for ozone reduction

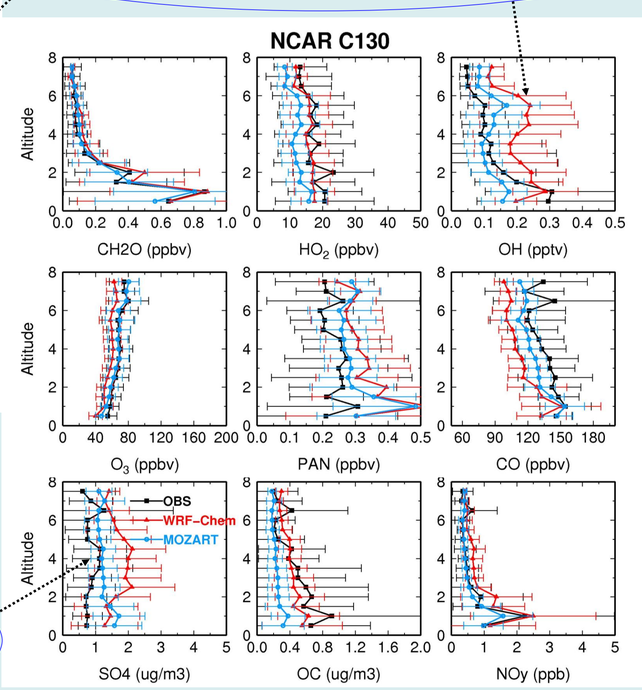
Suburban regions: $1< HCHO/NO_2 < 2$
→ Ozone formation is in the transition from the VOC-limited to NO_x-limited regimes
→ Both NO_x and VOC controls are effective

Active isoprene emission regions: $HCHO/NO_2 > 2$
→ NO_x control is more effective for ozone reduction

5. Probing into model uncertainties



WRF-Chem OH is biased high by a factor of two



Errors in isoprene contribute to PAN overestimate?

Consistent with OH overestimate

WRF-Chem reproduces the sulfate enhancement between 2-5 km well, but overestimates the magnitude, likely due to oxidation of SO_2 by OH

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