Constraining tropospheric CO using ensemble-based data assimilation

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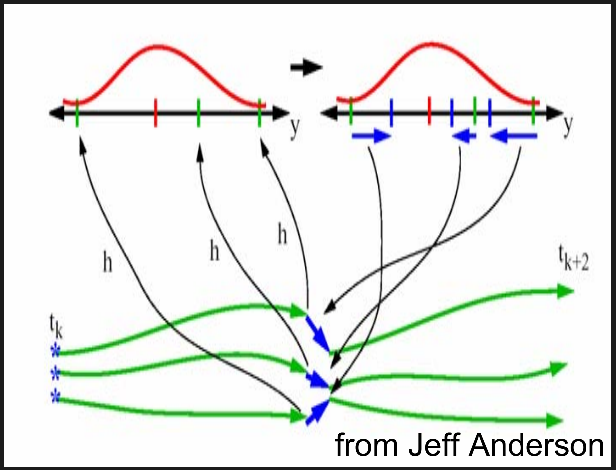
NCAR Data Assimilation Research Testbed (NCAR DART)

DART is an ensemble Kalman filter software package being developed at NCAR/DARes (http://www.image.ucar.edu/DAReS).

Supports low order models (L63, L84, L96, L2004...), global models like NOAA/CDC PE model, CAM 2.0, 3.0, 3.1, GFDL FMS/AM/MOM3, MIT GCM, NCEP GFS, regional models like WRF, EPA CMAQ, intermediate models like ROSE and Cane-Zebiak 5



EnKF Scheme

Users include:

Government and Private Industries (GFDL, CDC, CIRES, NRL, NSSL, SAMSI, Livermore, George Mason, CalTech, COLA, Argonne, JPL, Bell Labs)

Universities (Wisconsin, MIT, Utah Colorado, Arizona, Oklahoma, Princeton, Chicago, Berkeley, Purdue, Istanbul Technical University, CU Denver, ETH Zurich, Warsaw University, Seoul National Univ., Kobe University, Aachen Univ., UNC Charlotte, Virginia Tech, Illinois, Delft, Courant, Washington, Duke)

Global Chemical Data Assimilation System (DART/CAM)

GCTM (CAM)

Community Atmosphere Model (CAM3.1.1) with simplified CO chemistry
(used the finite-volume dynamical core at 2^{o}x2.5^{o} horizontal & 30 vertical levels)

→ ensembles of CO total emissions (based on MOZARTv4 standard emission)
→ ensembles of CAM initial conditions (based on previous CAM climatological runs)

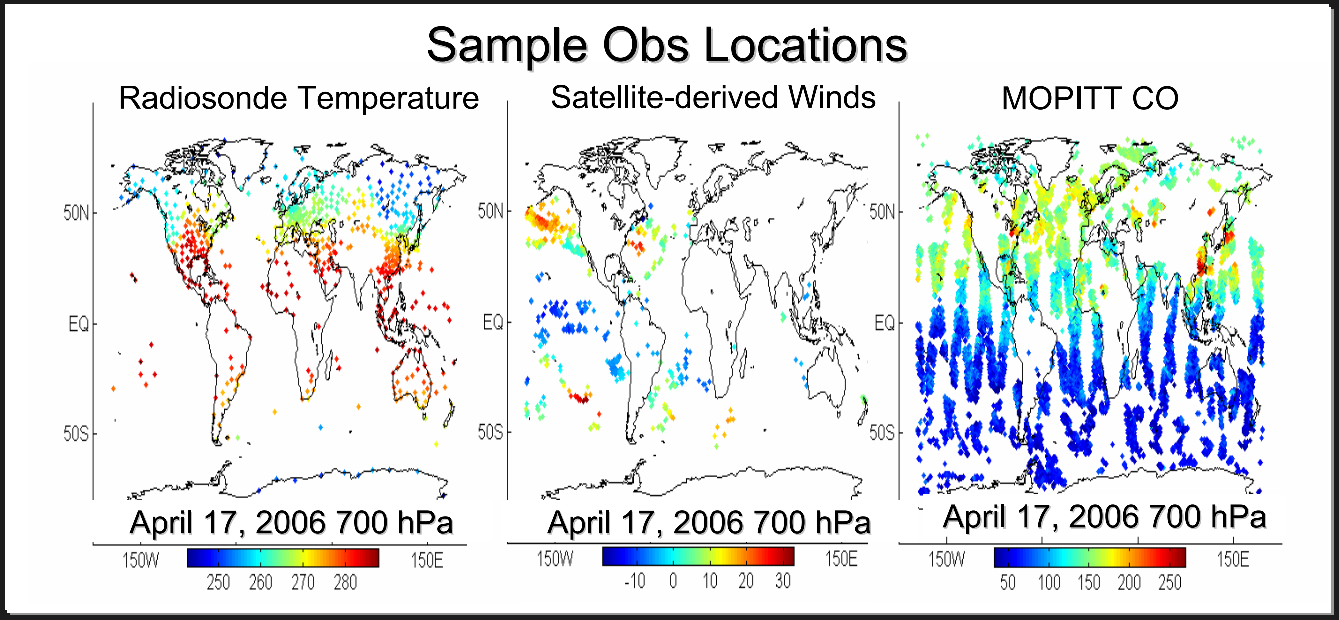
EnKF Package (DART)

DART with temperature (T), horizontal winds (U,V), specific humidity (Q), cloud ice, cloud water, and CO as state variables

Observations

NCEP BUFR (used a subset that includes radiosonde T, U,V and satellite U,V)

MOPITT CO retrievals (used 700 hPa for now)



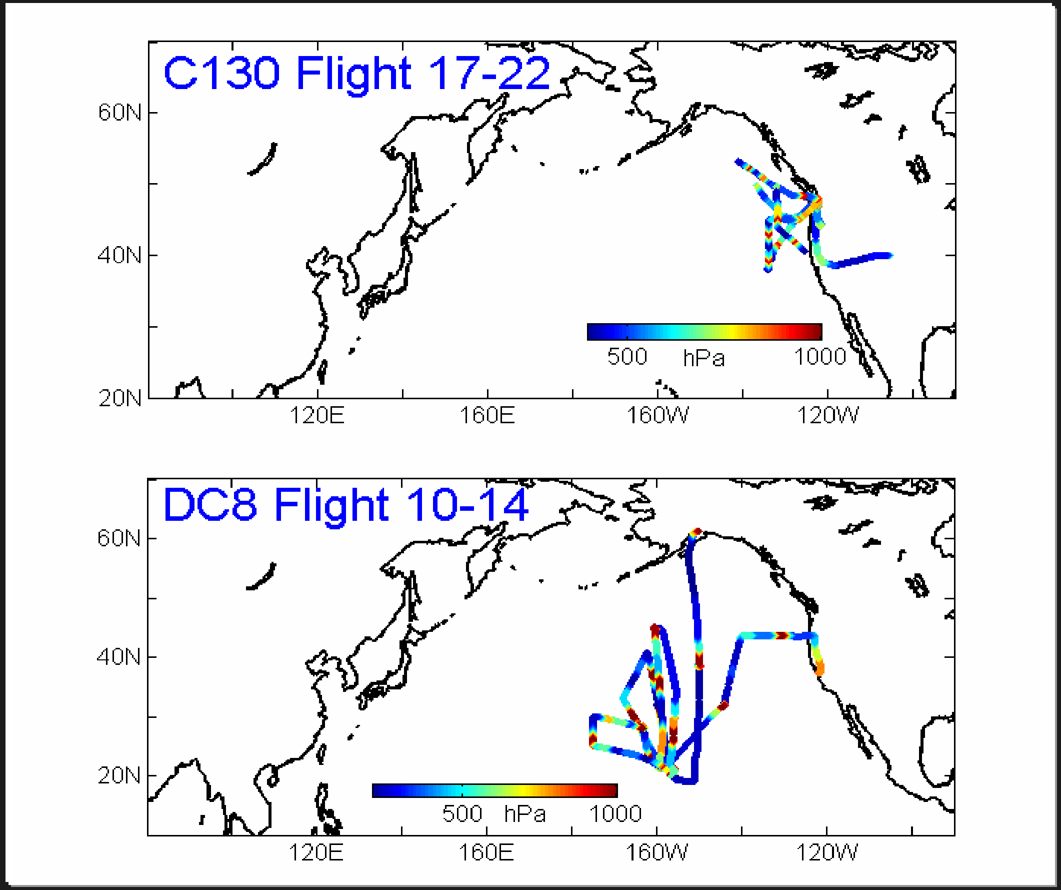
INTEX-B Field Campaign

The NASA Intercontinental Chemical Transport Experiment B 2nd phase (INTEX-B) was aimed at sampling the Asian pollution outflow over Hawaii, Alaska and Seattle during April and May 2006.

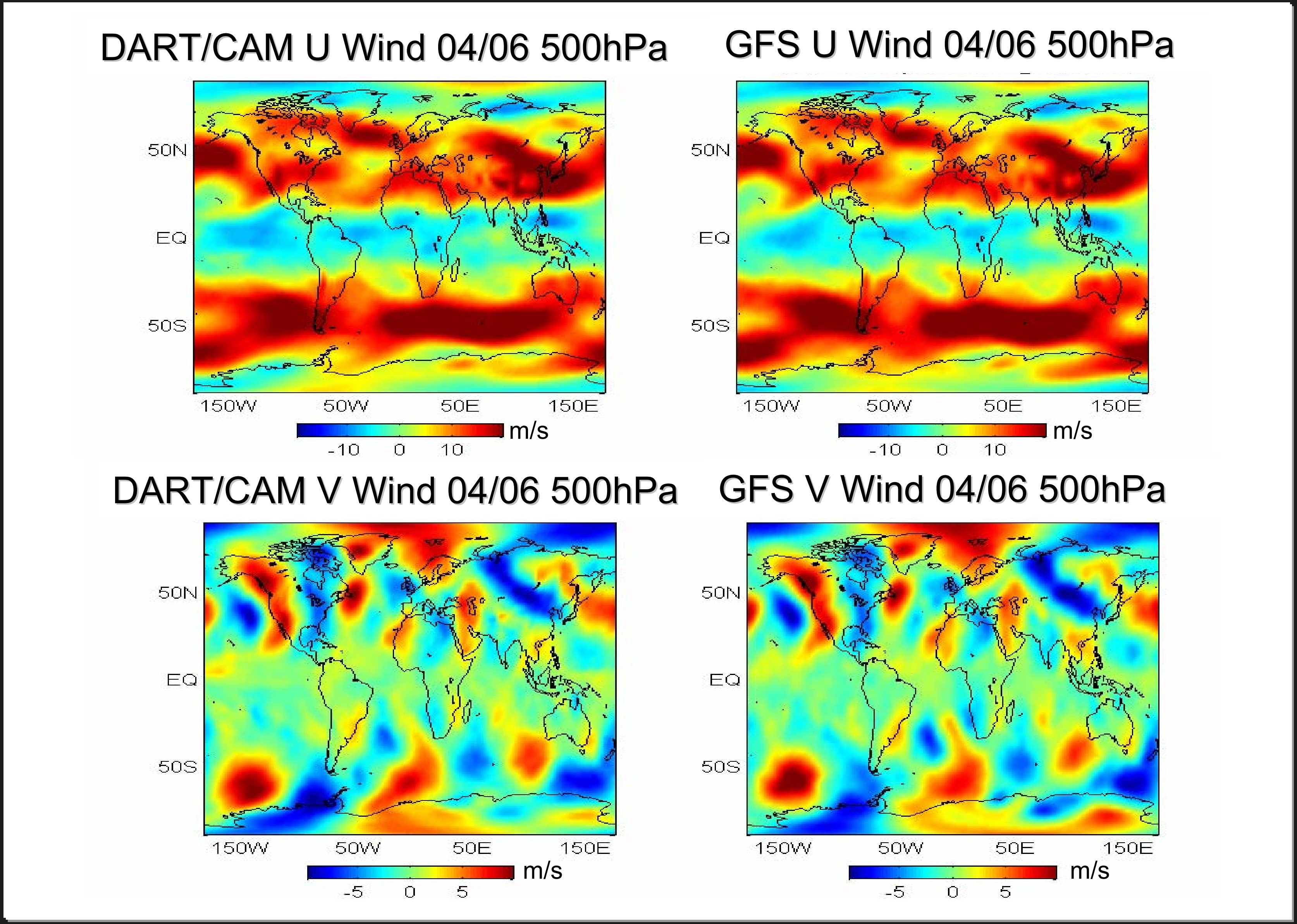
→ Regional to global chemical transport models (GCTMs) were used extensively to aid in flight planning (i.e. chemical forecasts).

→ Opportunity to verify model performance and assimilation system.

Flight tracks during the first half of INTEX-B

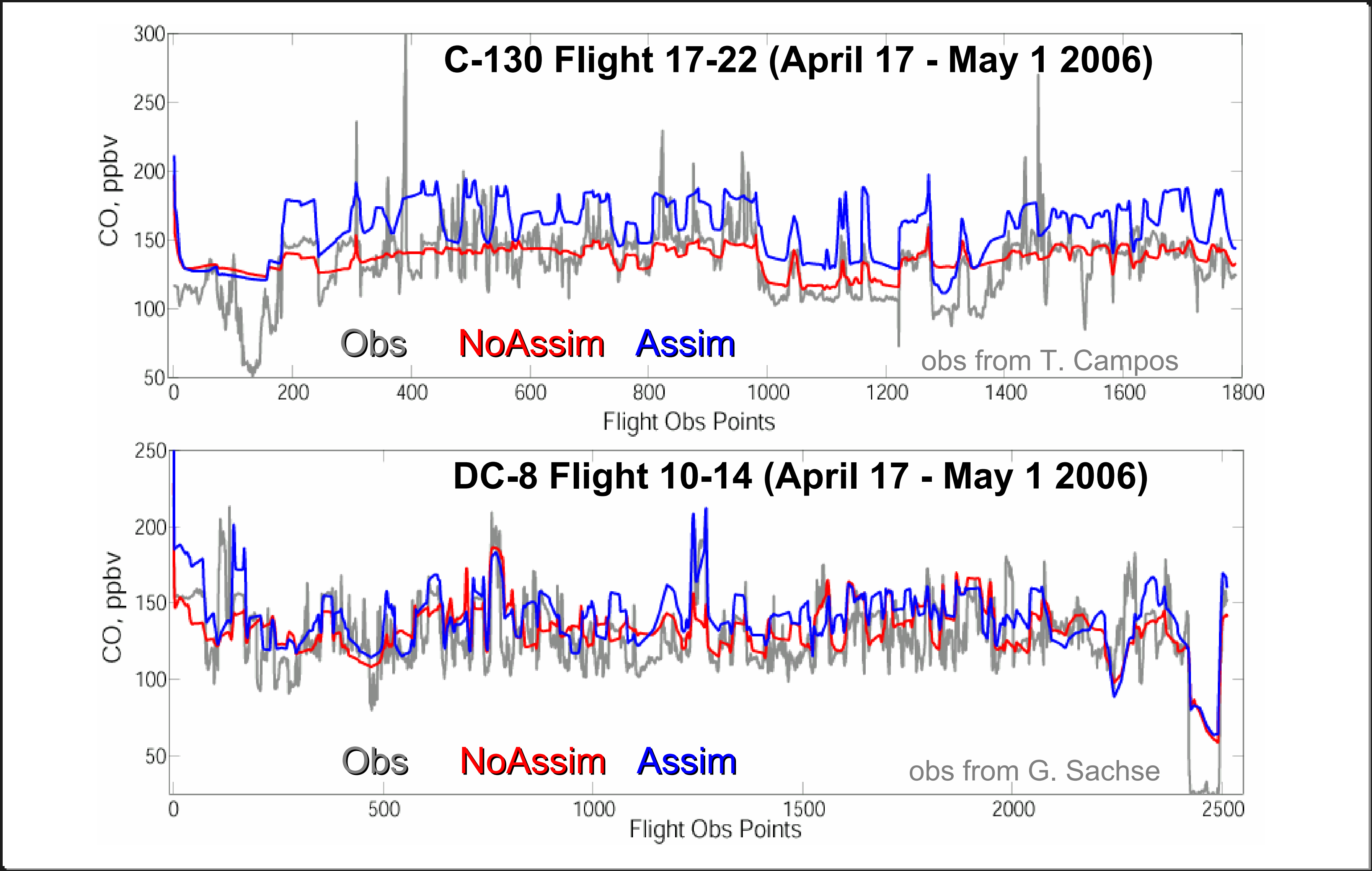


DART/CAM vs GFS Winds



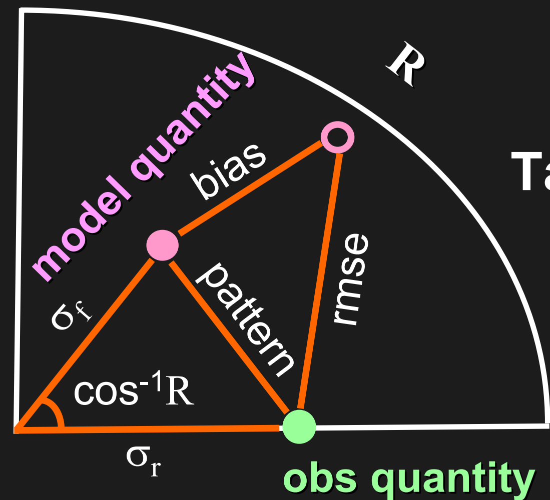
Similarity offers confidence on DART/CAM representing realistic tracer transport.

DART/CAM CO vs INTEX-B CO



Observed CO variability and gradients during INTEX-B are better captured by the model using MOPITT CO assimilation.

Alternative Approach to Illustrate Model Skill



Taylor Diagram

A measure of skill is typically plotted as contours.
Here, skill is defined as:

$$S = \frac{4(1+R)^4}{\left(\hat{\sigma}_f + 1/\hat{\sigma}_f\right)^2 (1+R_0)^4}$$

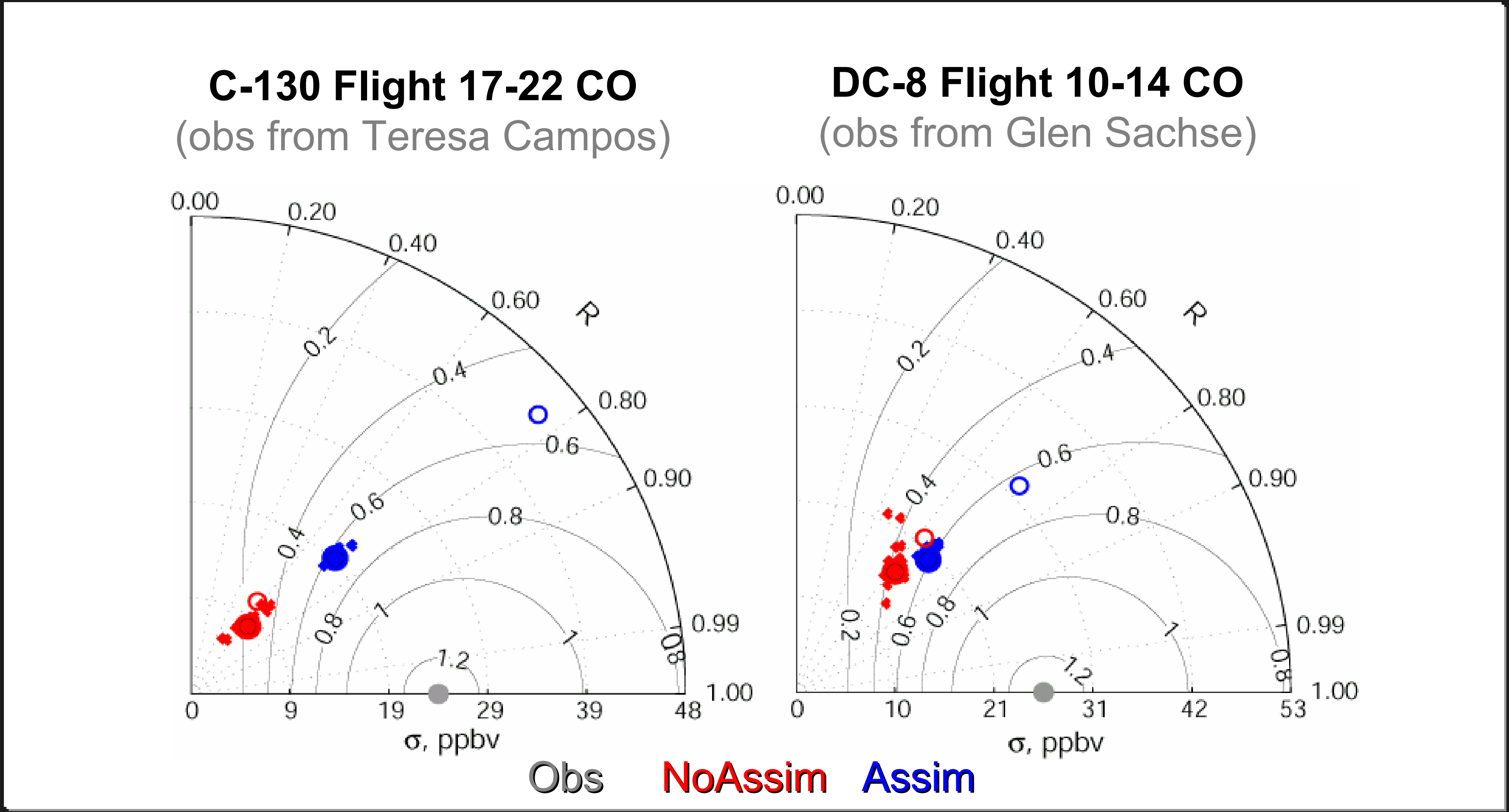
$R \sim$ correlation, $R_0 \sim 0.9$

$\sigma_f \sim$ model sigma

$\sigma_r \sim$ obs sigma

$\hat{\sigma}_f = \sigma_f / \sigma_r$

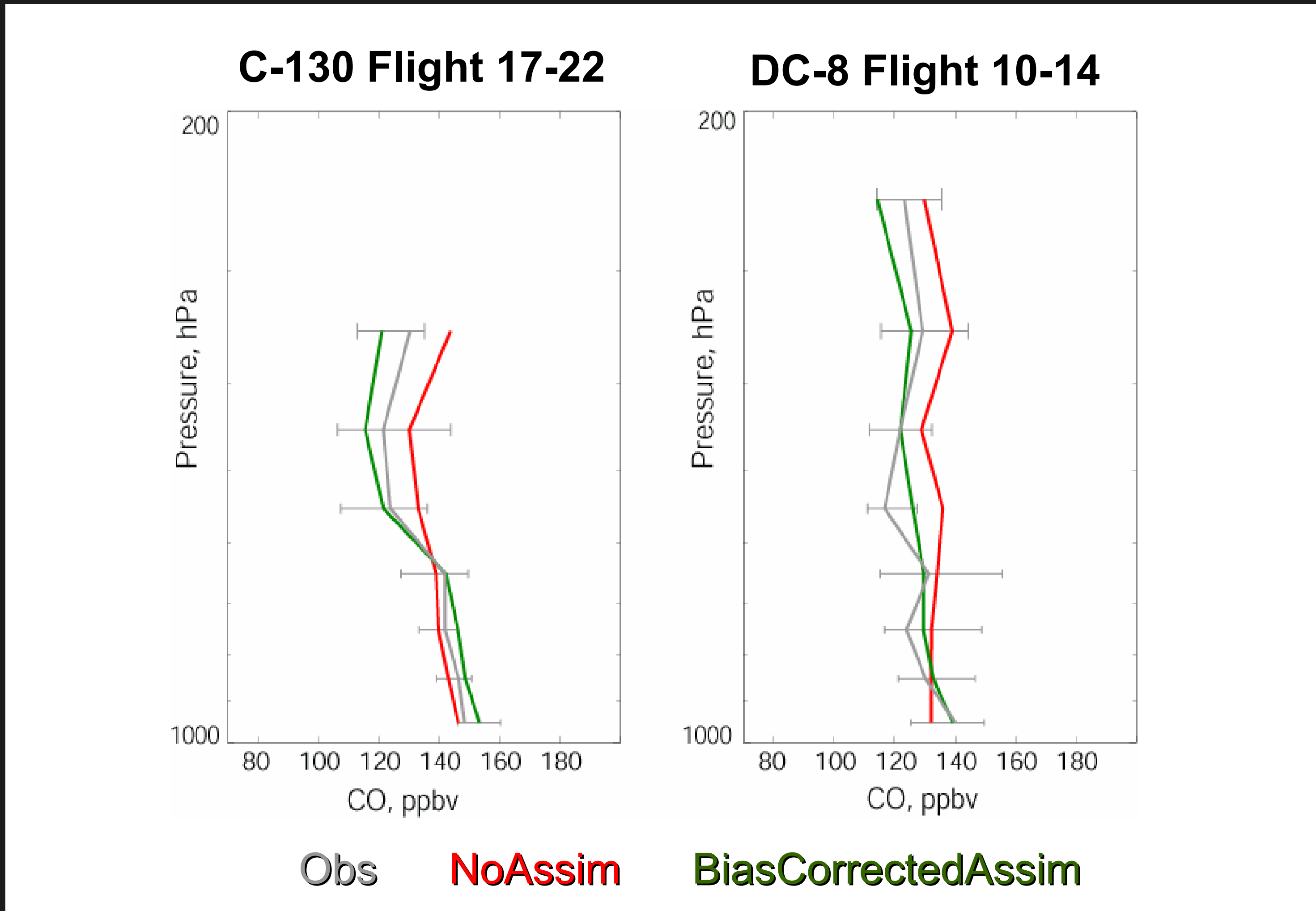
Assimilation vs No Assimilation



→ Assimilation improves the pattern statistics (from skill of ~0.2 to a skill of ~0.6)

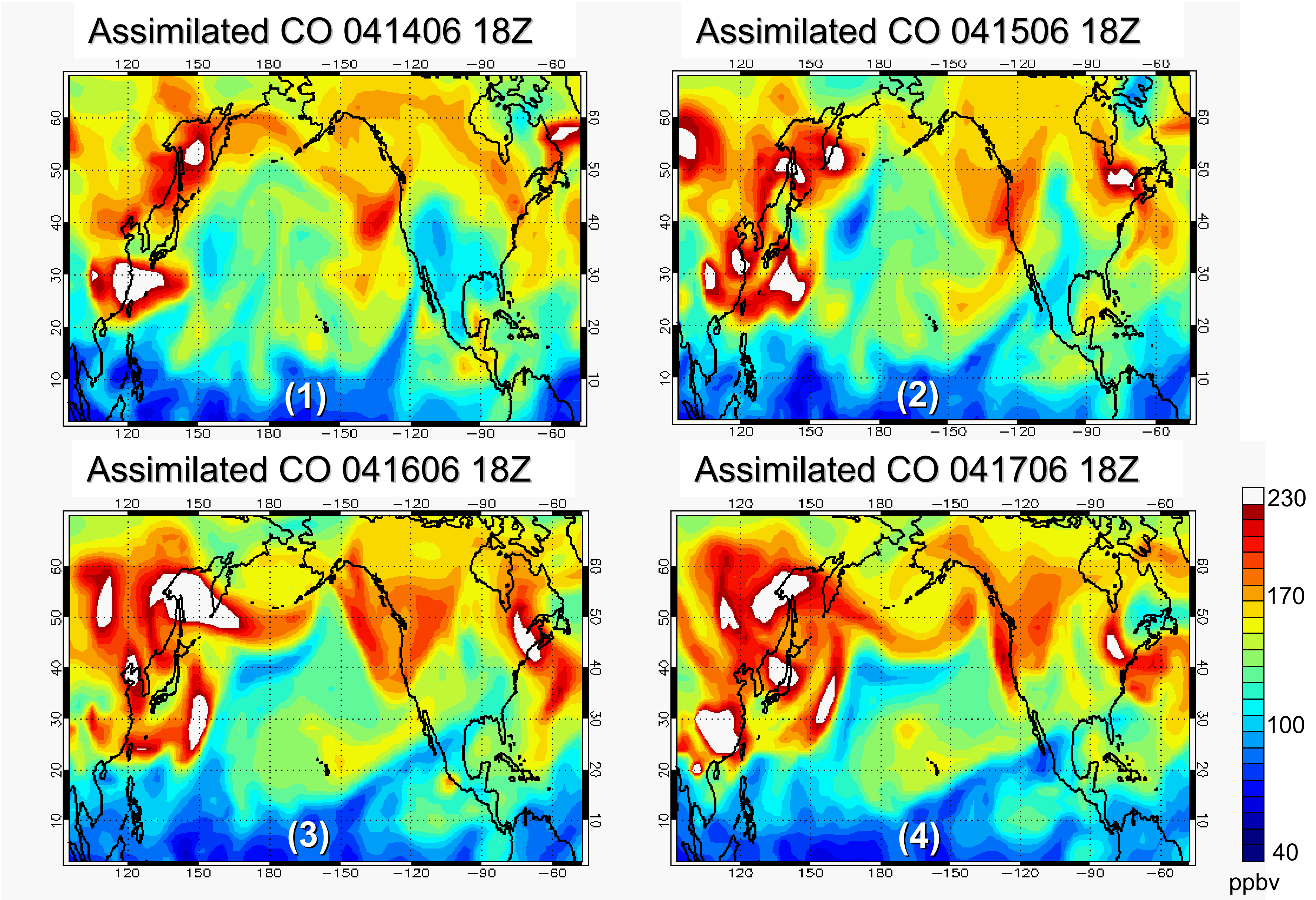
→ Clear indication of increased bias in assimilated CO relative to no assimilation, indicating that MOPITT is positively biased (~18%±12% for C130, 10%±15% for DC8), consistent with Emmons et al, 2004.

Median Vertical Profiles For All Flights

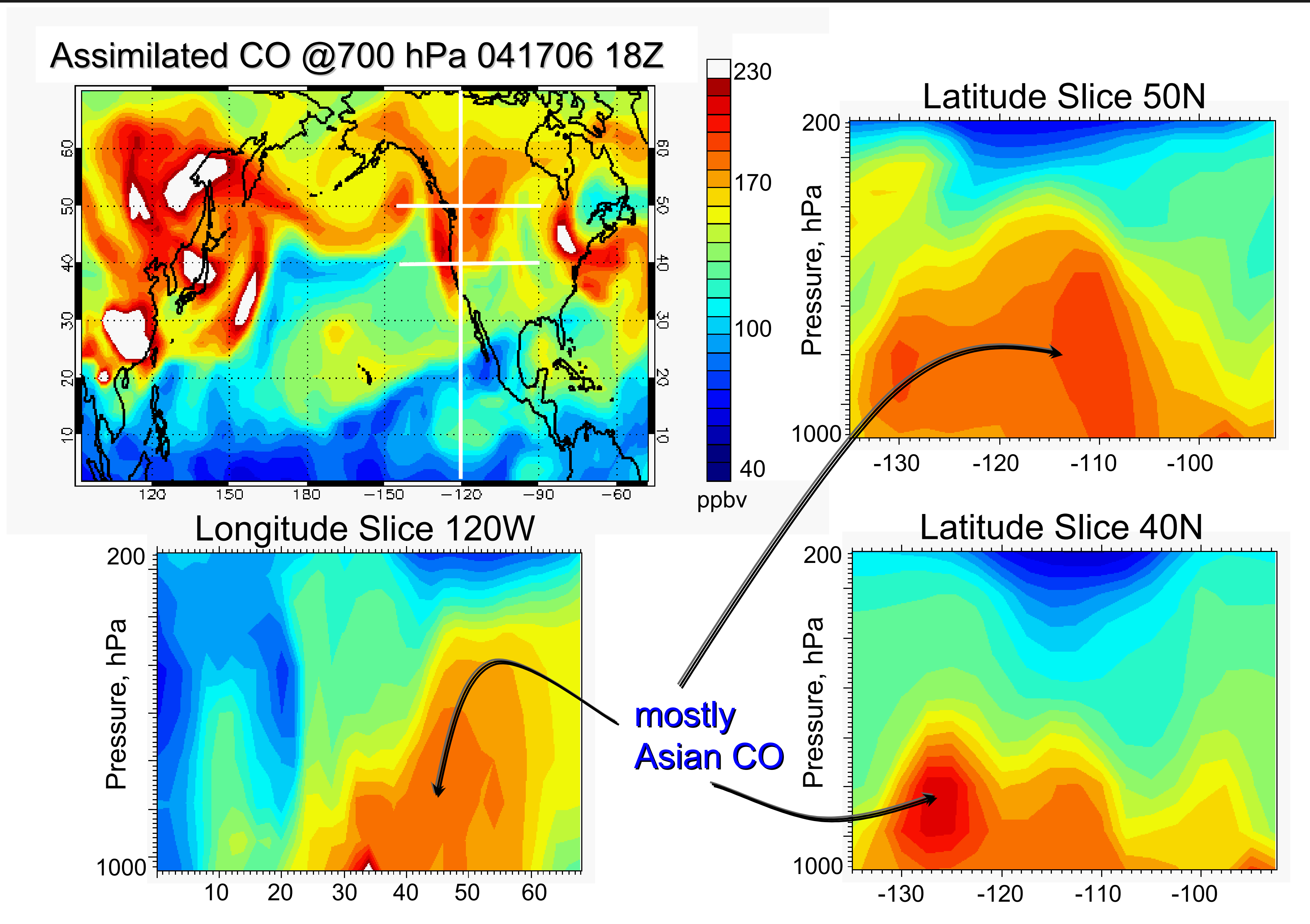


Assimilation also improves the modeled vertical structure of CO.

Episodic Impact of Asian Pollution to North America

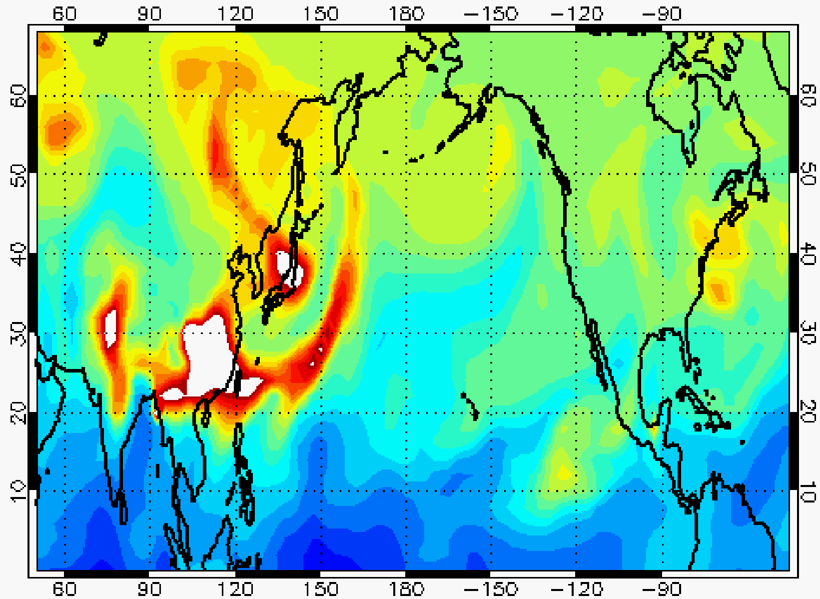


Impact of Asian Pollution to North America



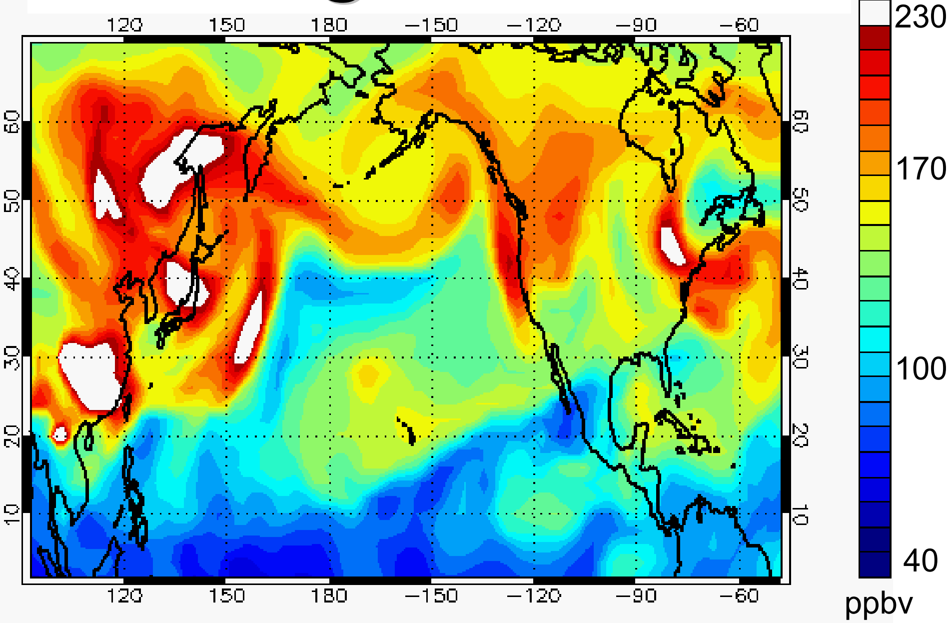
Impact of Assimilation in Modeled CO

No Assimilation @700 hPa 041706 18Z



Assimilating MOPITT CO provides important constraints to regional CO distribution in the troposphere.

Assimilation @700 hPa 041706 18Z



Suggests the utility of assimilation in providing better initial/boundary conditions to regional CO forecasts.

Summary

- A global chemical data assimilation system has been implemented at NCAR using CAM (chem) and DART.

- Such system is verified using INTEX-B CO data and shows significant improvements in CO model skill.

- Constraining tropospheric CO using the assimilation system potentially provides important information in improving regional air quality forecasts (e.g. need for better initial/boundary conditions).

Acknowledgements

1) We especially thank Louisa Emmons (NCAR/ACD) for providing GFS/MZ4 simulation and assimilation

2) NCAR MOPITT, Teresa Campos (INTEX-B) and Glenn Sachse (INTEX-B) for CO data

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Impact of Assimilation in Modeled CO