Using AIRS CO 1DVAR retrievals to evaluate processes in chemical models: Progress Report

Joanna Joiner (GSFC 613.3)
Arlindo da Silva (GSFC GMAO)
Bryan Duncan (GSFC 613.3)
Huisheng Bian (GSFC 613.3)
Pete Colarco (GSFC 613.3)
Partha Bharracharjee (GMU)

Outline

- Background: AIRS 1DVAR CO algorithm
- Comparison with
  - GMI
  - GMAO on-line GOCART
  - updated GCM GOCART
- Non-linearity issue for AIRS retrievals
- Comparisons of GMI with MOZAIC CO
- Conclusions

AIRS CO retrieval

- 3 EOS instruments provide information about CO from thermal IR (4.6 μm) – MOPITT, AIRS, TES
- All use different methods in cloudy scenes; Here, we use cloud-clearing method (reconstruct clear-column radiances using adjacent fields-of-view)
- AIRS attributes
  - widest swath (best single day coverage)
  - low noise
  - data available in near-real-time (limited channel selection)
- All instruments provide ~1+ pieces of information in the vertical, low sensitivity near the surface

What is 1DVAR and why use it?

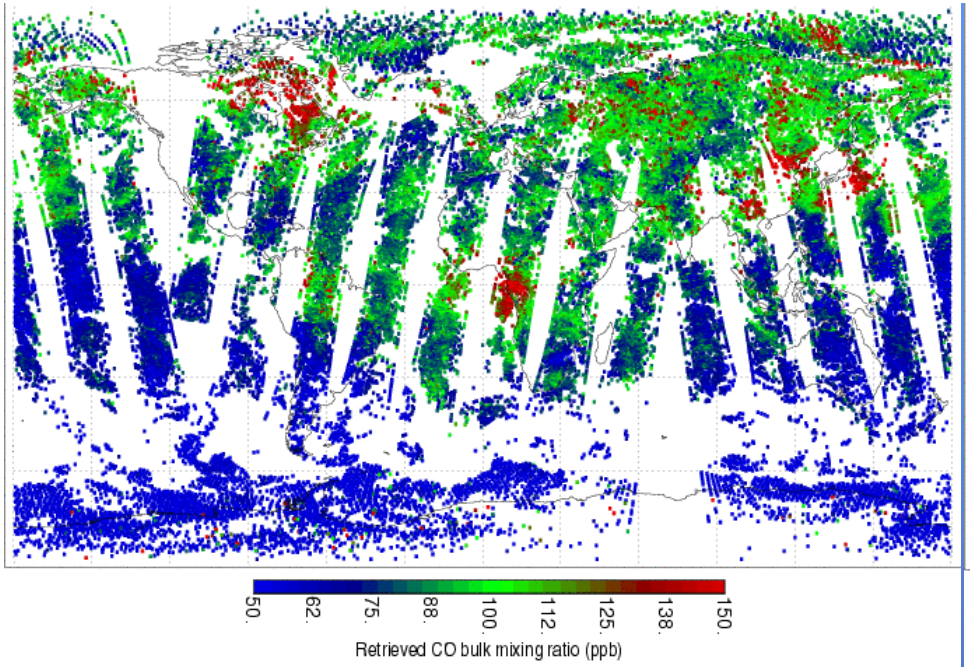
- 1DVAR refers to a variational (VAR) profile retrieval (1D) that use a first guess (background) from an assimilation system
- Flexible:
  - can use first guess from any number of models or fixed *a priori*
  - Can run interactively or passively
- Models may provide best guess of vertical profile and linearization point (latter is large source of error)
- Increments (retrieval – first guess) show where model is consistent (or not) with observed radiances
- Straight-forward to compare different model runs
- Relatively cheap (CO retrieval performed separately from T, q, cloud-clearing that is more computationally intense but need only be done once), takes ~40 mins/day on a single processor
- Natural progression towards assimilation
- Must be careful with interpretation when using nadir thermal IR!

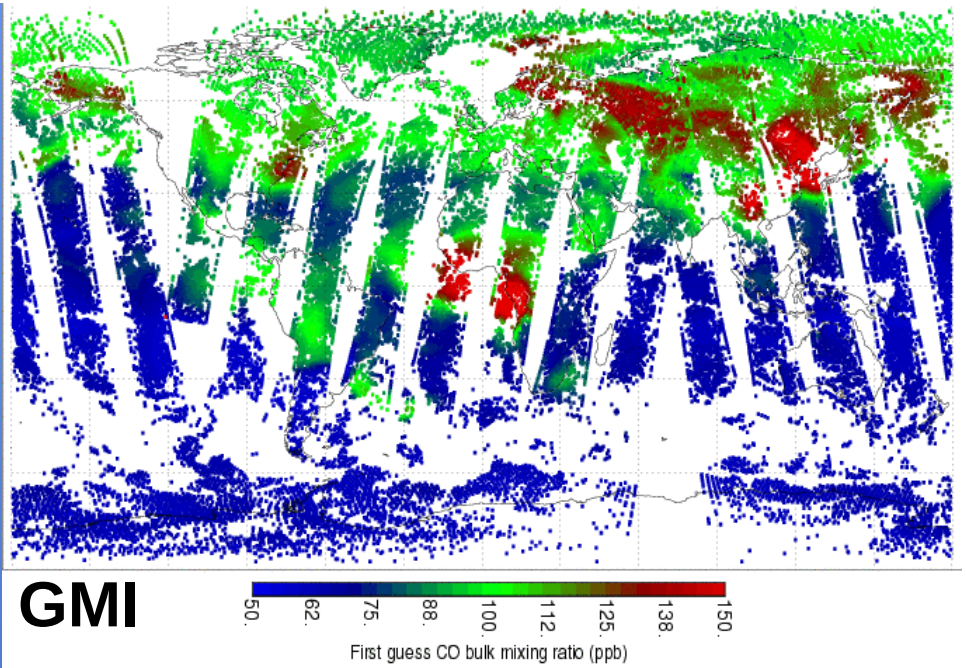
To compare AIRS with models, we develop an appropriate 1D projection operator

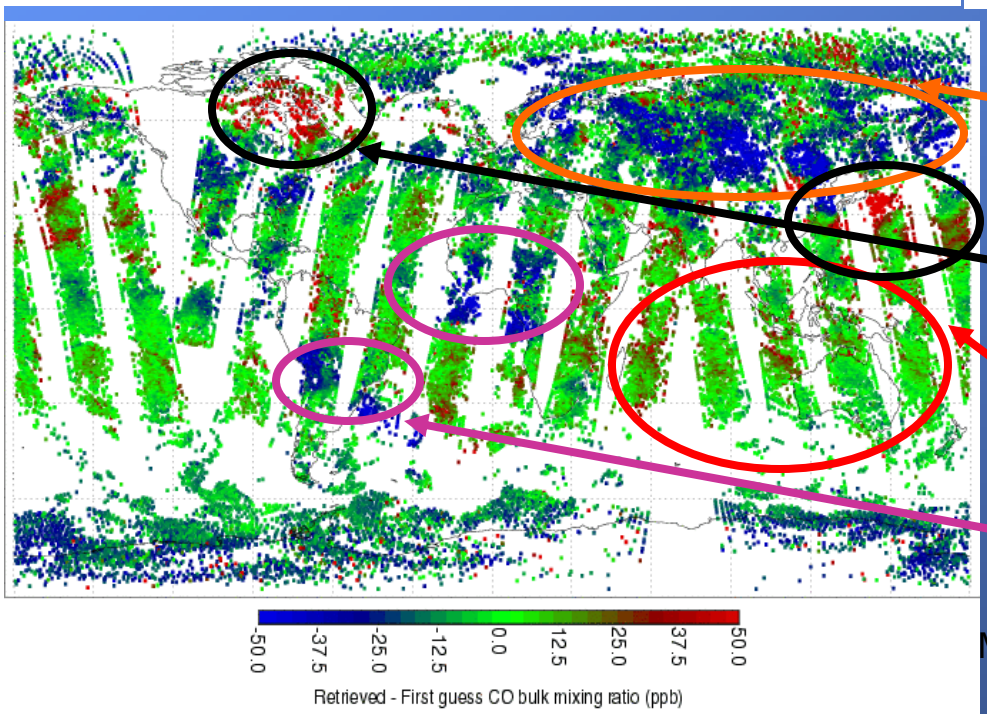
- For a retrieval with ~1 piece of information, this collapses the vertical information into a single number with appropriate units (pick an operator such that the effect of *a priori* is limited).
- For simplicity, we have chosen a weighted average the CO mixing ratio (actually ln q_{CO}) over the shape of the Jacobian of the most strongly absorbing AIRS CO channel
- This “AIRS-averaged” mixing ratio can be computed for both the retrieval and model.
- Comparing this quantity is more straightforward than comparing mixing ratio at a single level or “applying the averaging kernel” which provides profiles that look much like the first guess

Models: 2004-2005

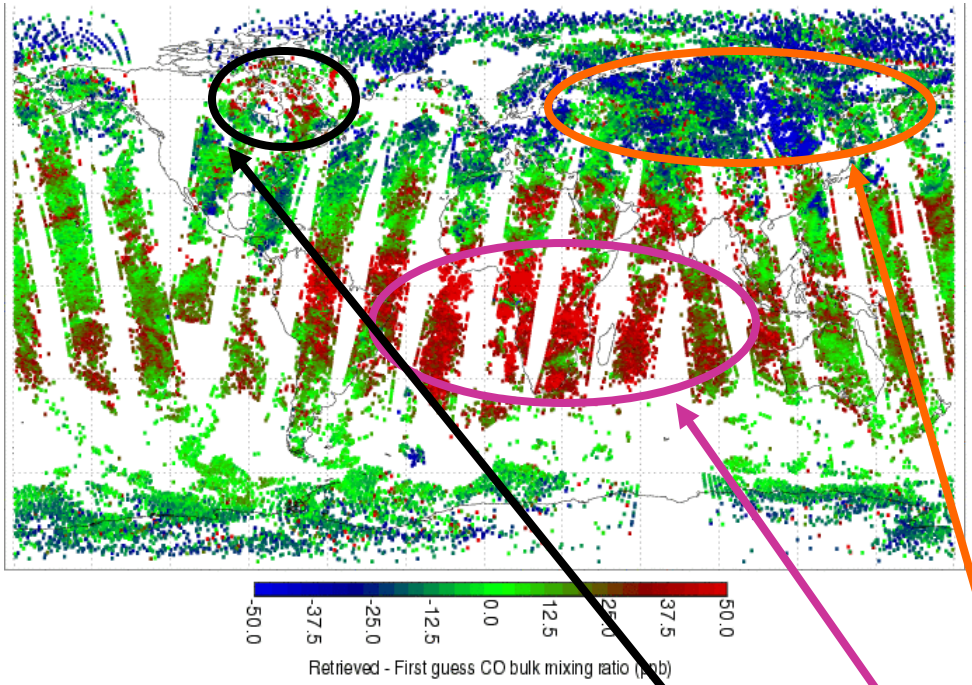
- GMI (The apple)
  - Detailed chemistry
  - Off-line transport: driven by meteorological fields from GMAO (NASA Global Modeling and Assimilation Office) GEOS-4 data assimilation system (DAS)
  - Horizontal Resolution: 2 X 2.5 degree, Top 52hPa, 19 levels
  - Fossil fuel emissions from 1995; climatological biomass burning
- GEOS online-GOCART (old version) (The carrot)
  - Parameterized CO chemistry
  - On-line transport (within the GEOS-4 general circulation model) run in replay mode without initializing humidity from analyses (model runs with its internal moisture field)
  - Horizontal resolution: 1 X 1.25 degree, Top 0.01hpa, 32 levels
  - Biomass burning estimated using EOS Terra and Aqua MODIS real-time fire counts normalized to GFED data set (accounts for daily variability)
- GEOS GCM GOCART (updated version) (The potato)
  - Updated sources, chemistry
  - On-line transport using free-running GCM
  - Horizontal resolution: 1 X 1.25 degree, Top 0.01hpa, 55 levels
  - Biomass burning emissions GFED V2 data set for 2004

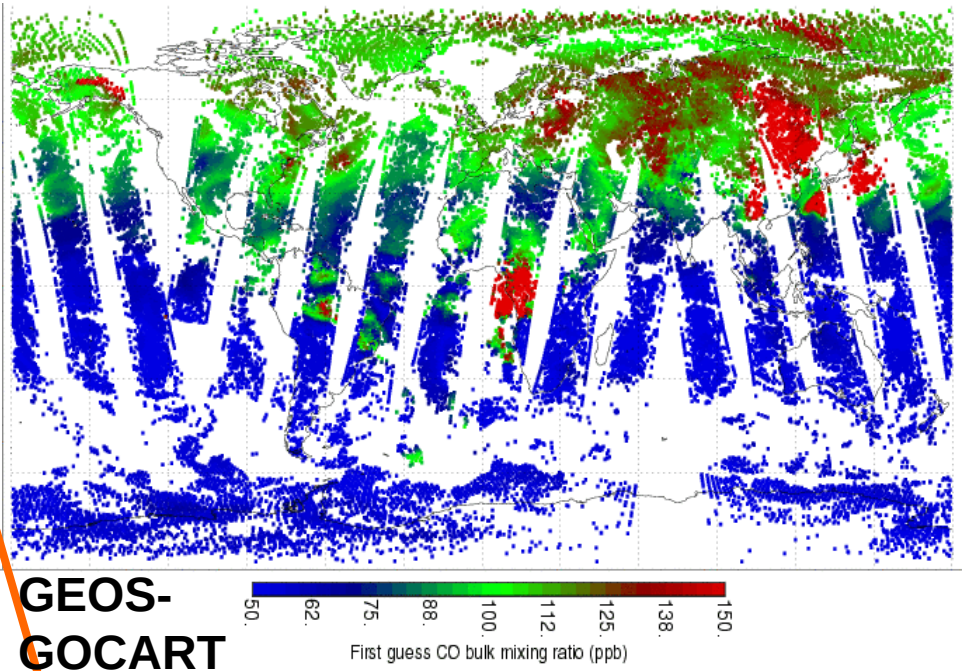




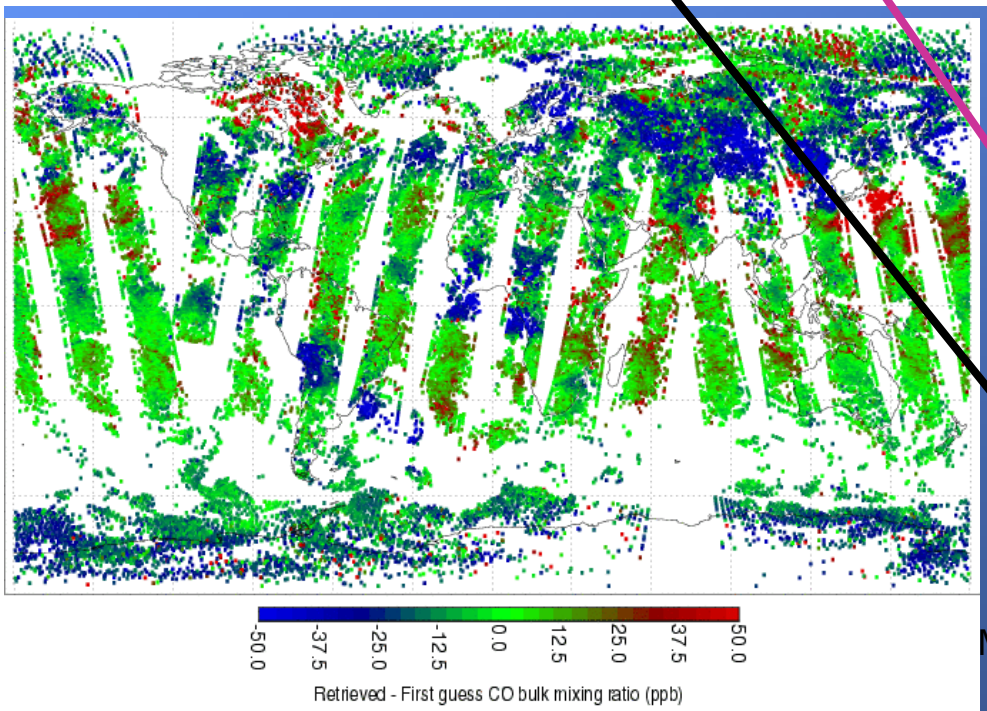


- Too high in altitude and/or amount CO over parts of Asia, N. America, Europe (excessive convection)
- Missing enhanced CO from Alaska fires
- Overall good agreement throughout much of tropics.
- Too high in altitude and/or amount CO from Africa and S. America biomass burning

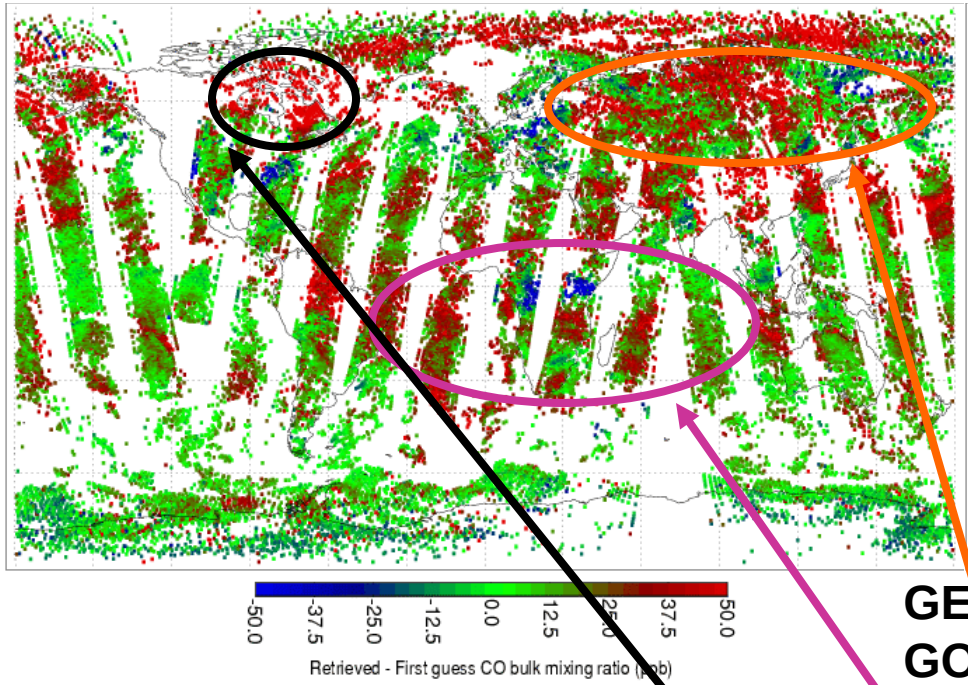


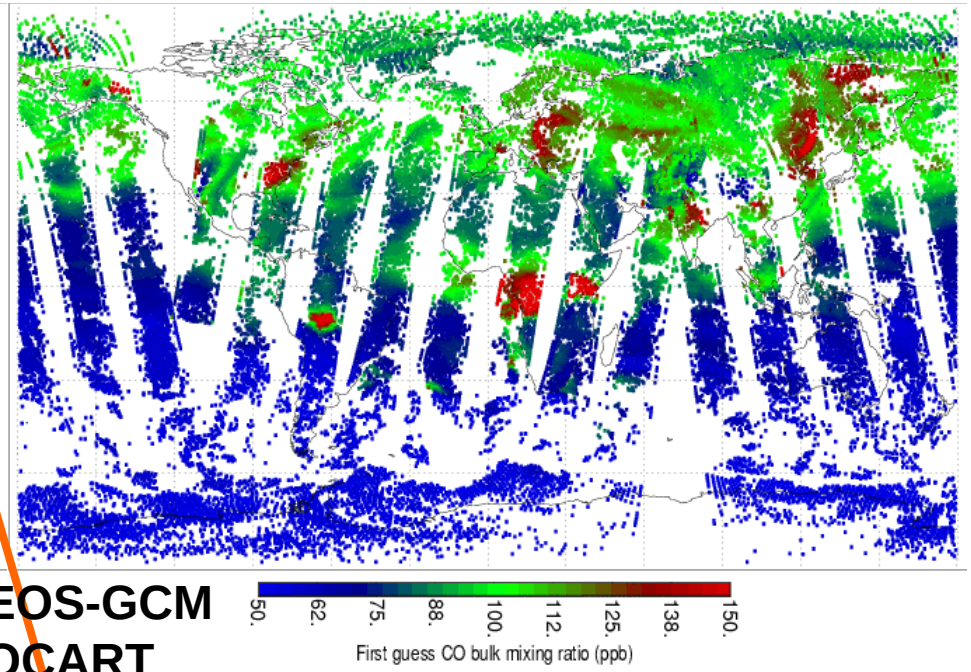


GEOS-GOCART

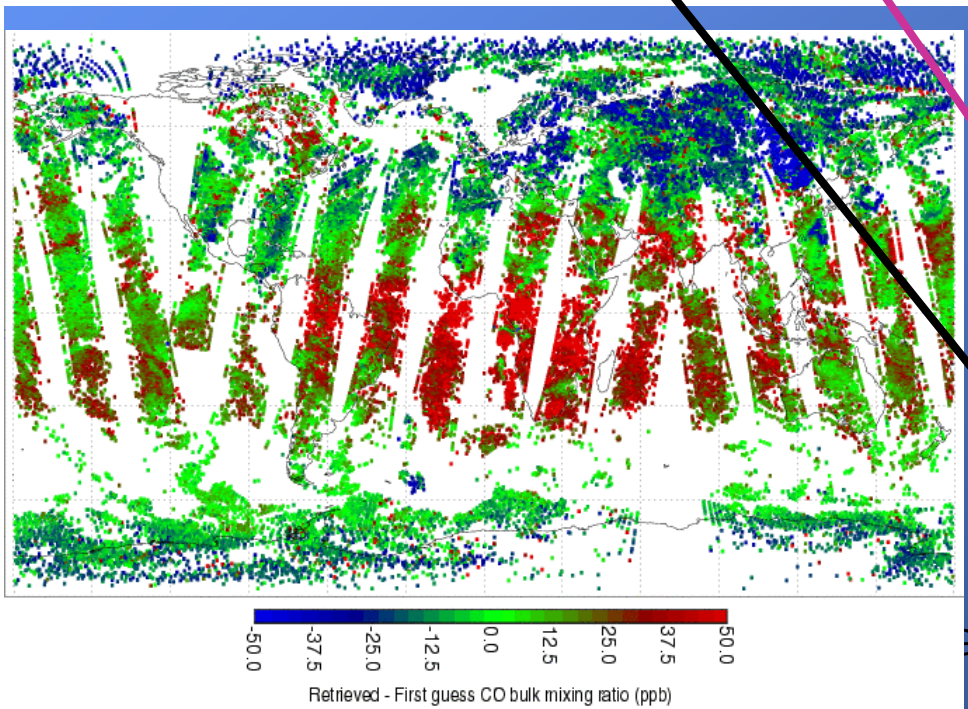


- CO to high in altitude and/or amount in parts of Asia, Europe
- CO too low in altitude and/or amount in tropics (GFED V2 emissions too low), plume model from S. Freitas being implemented to give correct injection height
- Does a somewhat better job with transport from Alaska fires

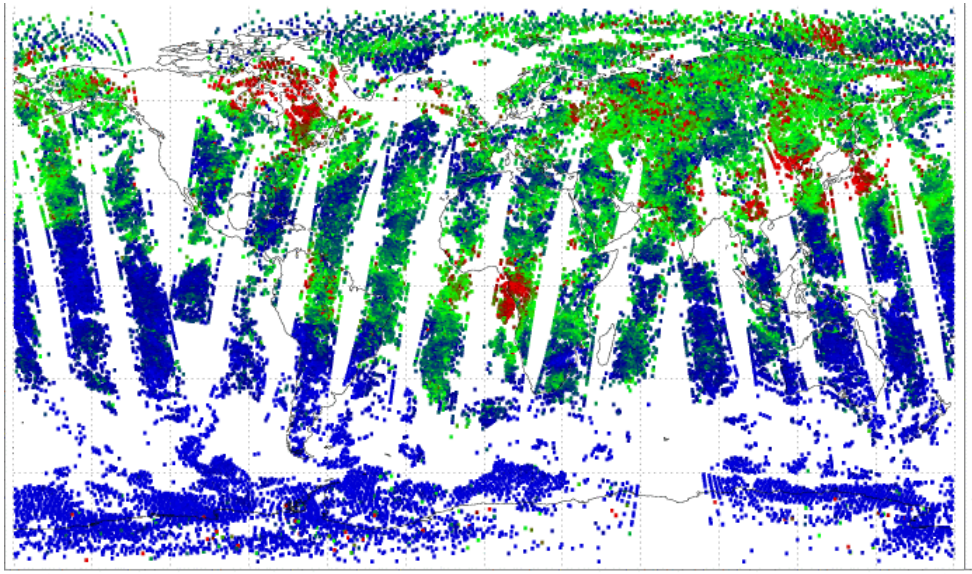




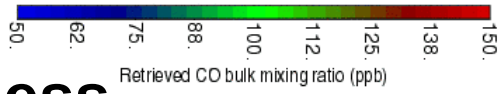
GEOS-GCM
GOCART

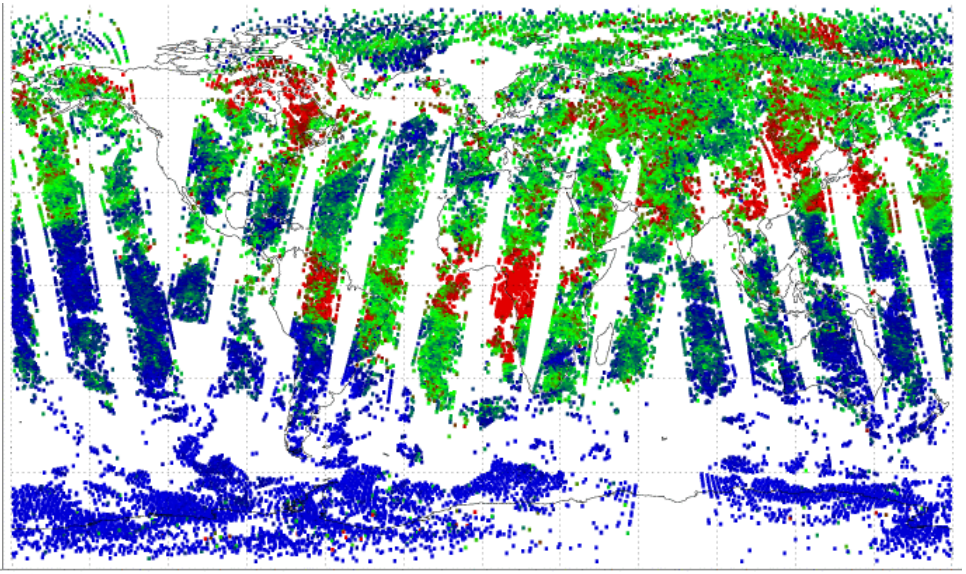


- CO now a bit low in altitude and/or amount in parts of Asia (GCM vs DAS? Other deficiencies in sources/chemistry?)
- Improvements in tropics, still a bit low in altitude and/or amount in tropics (GFED V2 emissions too low over S. America)
- QFED with daily variability doing better than GFED with transport from Alaska fires

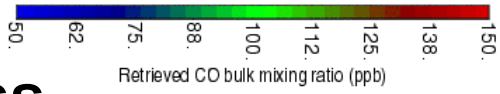


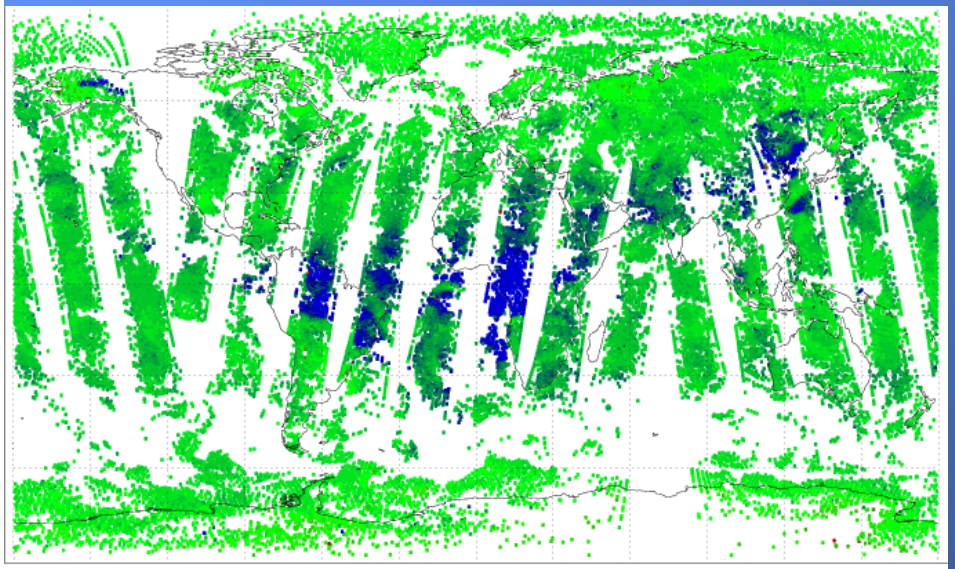
GMI first guess



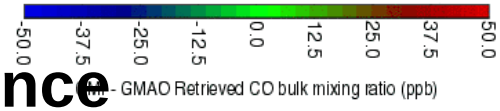


GOCART first guess



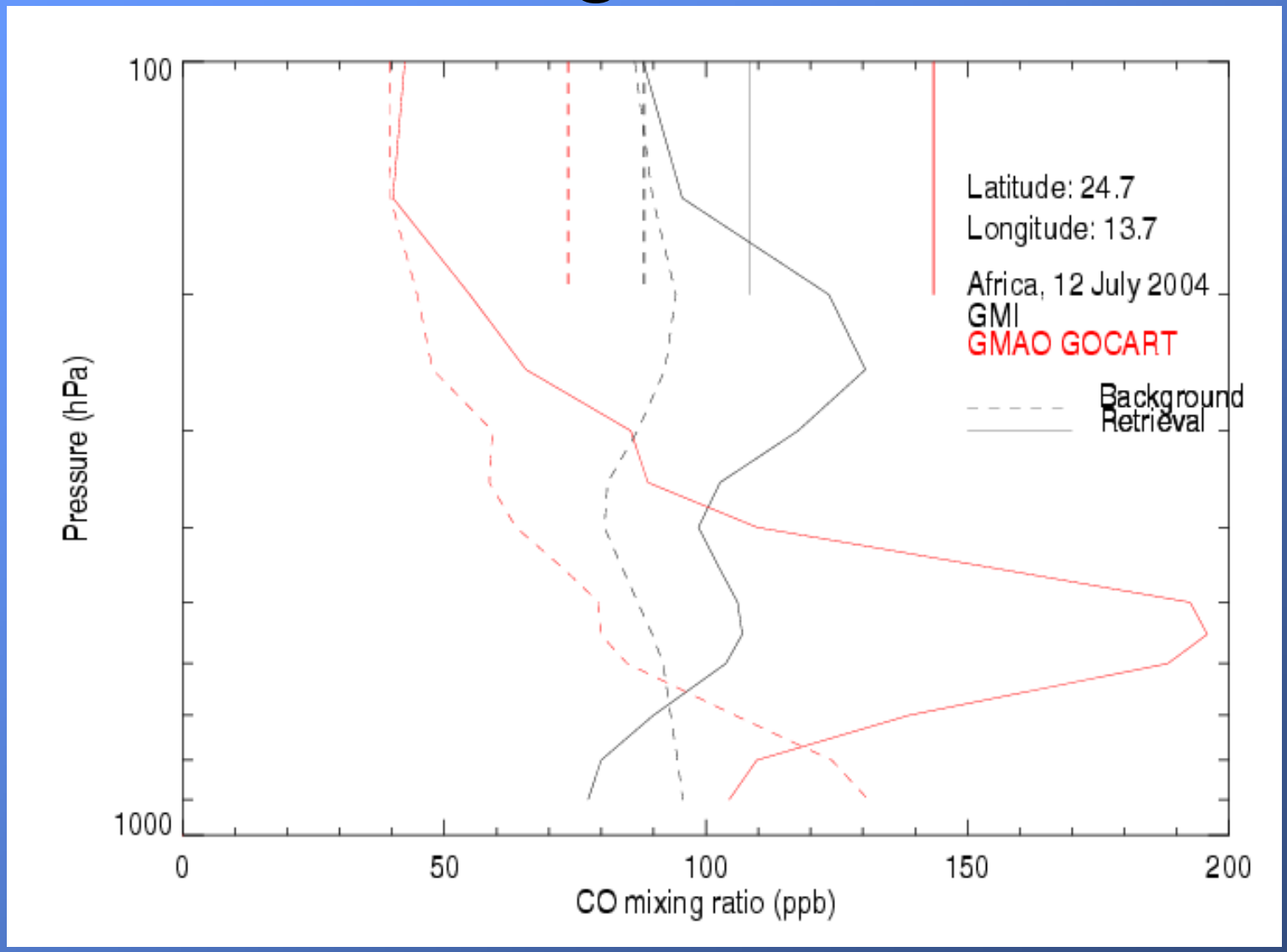


Difference

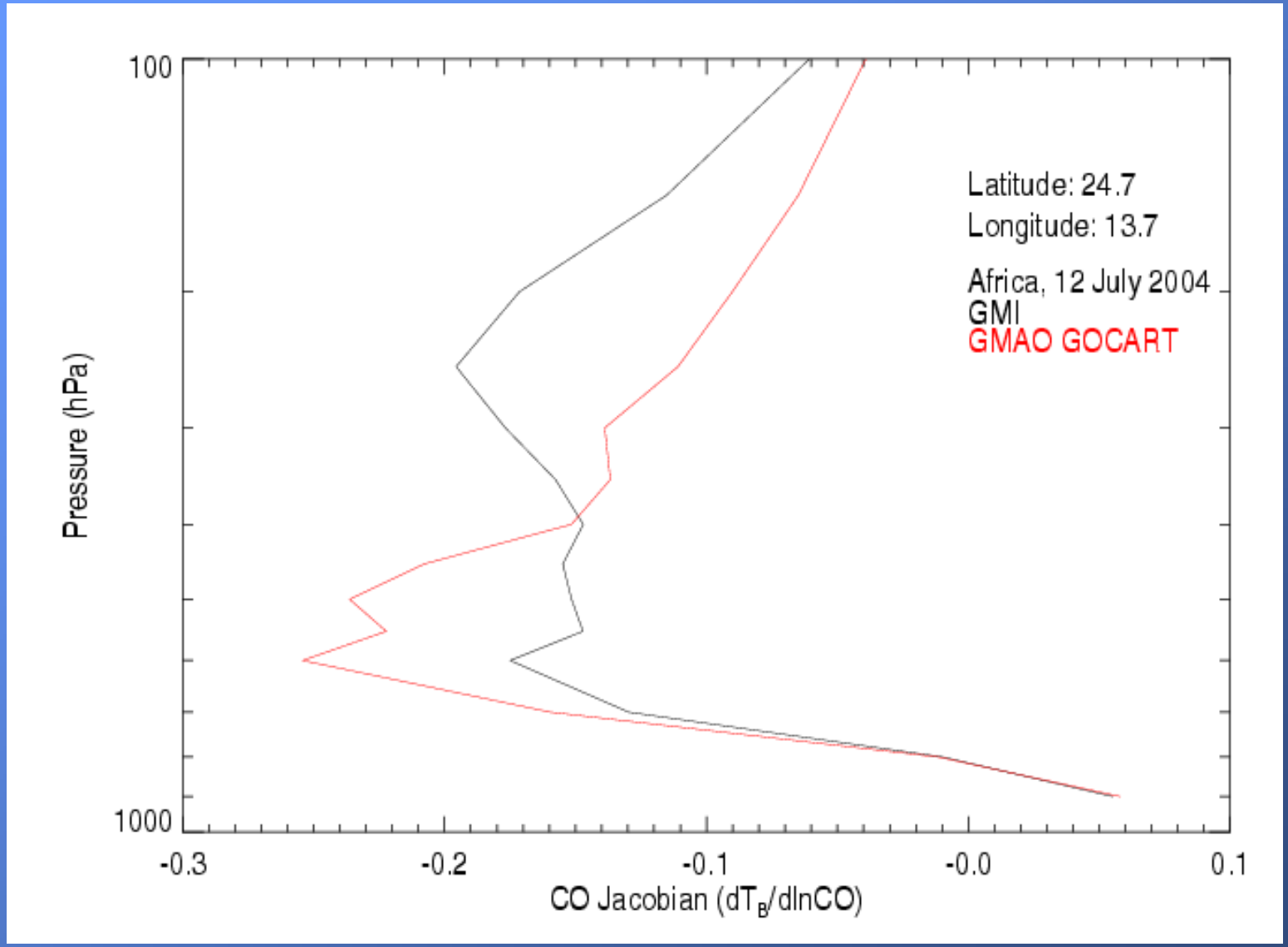


- Retrieved amounts differ significantly (~30+%) due to linearization (profile) dependence of first guess

Effect of first guess on retrieval



Non-linearity effect on Jacobians



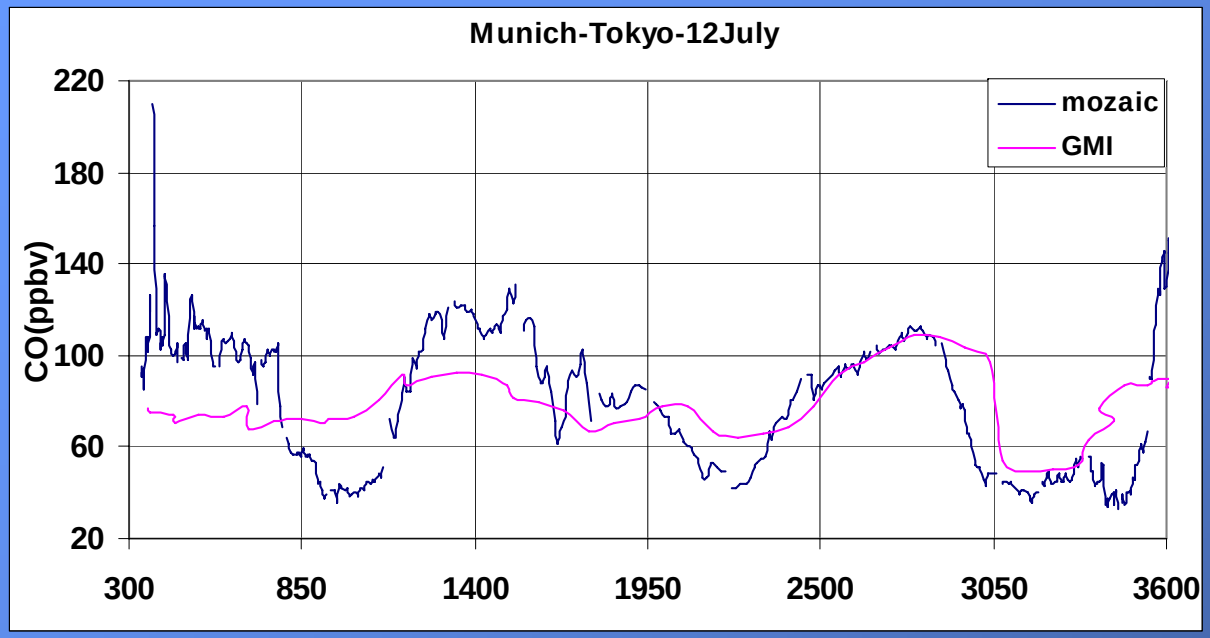
Summary of AIRS CO comparisons

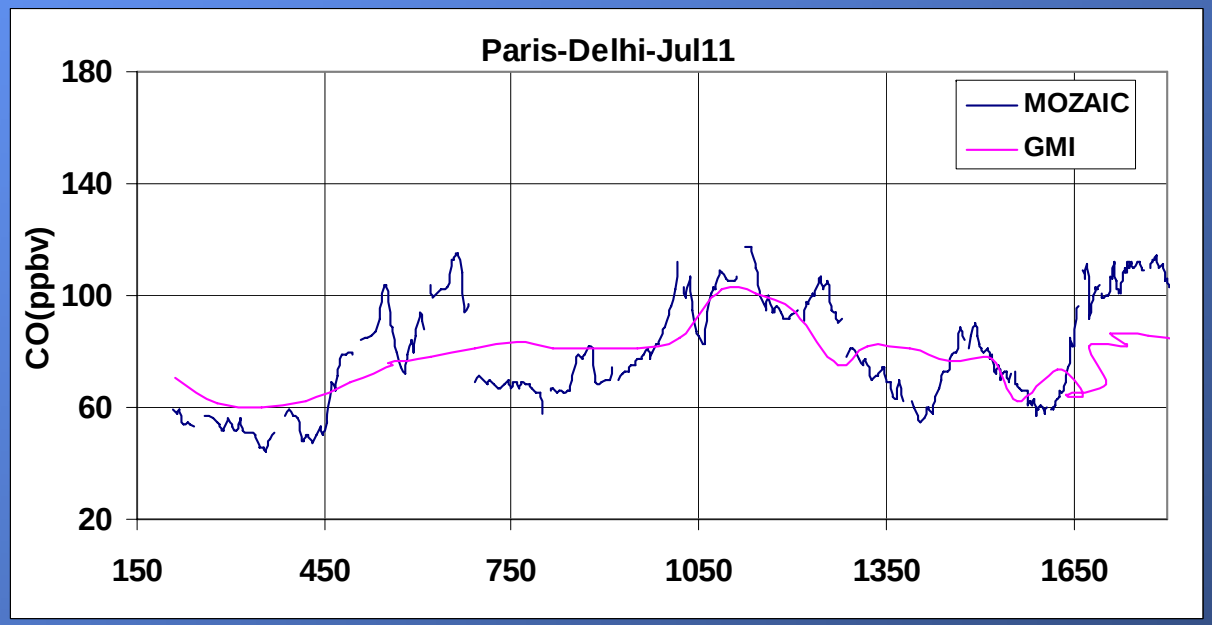
- AIRS CO 1DVAR is a useful tool for comparing different model runs, evaluating specific processes
- We have identified some strengths and shortcomings in both GMI and GMAO-GOCART runs; ongoing work to combine assets of both
- We must bear in mind the limitations of satellite data and be careful not to overinterpret (non-linearity error is significant)

MOZAIC

- Started in 1993 by European community to measure atmospheric composition
- Autonomous instruments deployed aboard long-range passenger airliners AIRBUS A340-300
- Regularly measures O_3, water vapor, CO, NO_y
- Daily 12-15 flights
- Vertical profiles : Surface to 12 km, takeoff and landing sites
- Along track: Cruising altitude (~200 hPa)

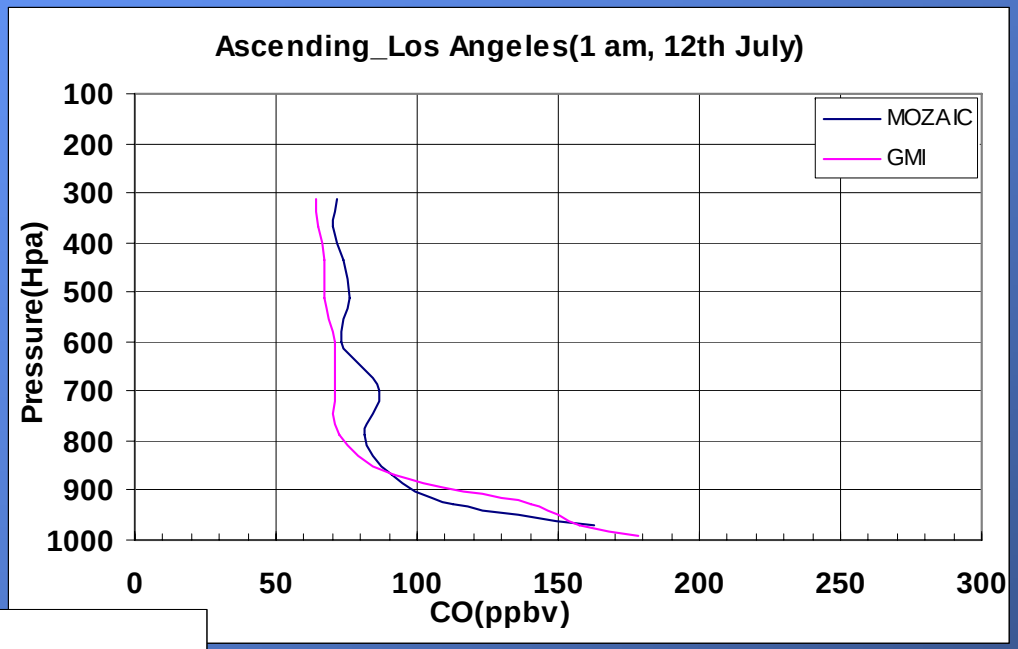
Along-track comparisons with MOZAIC

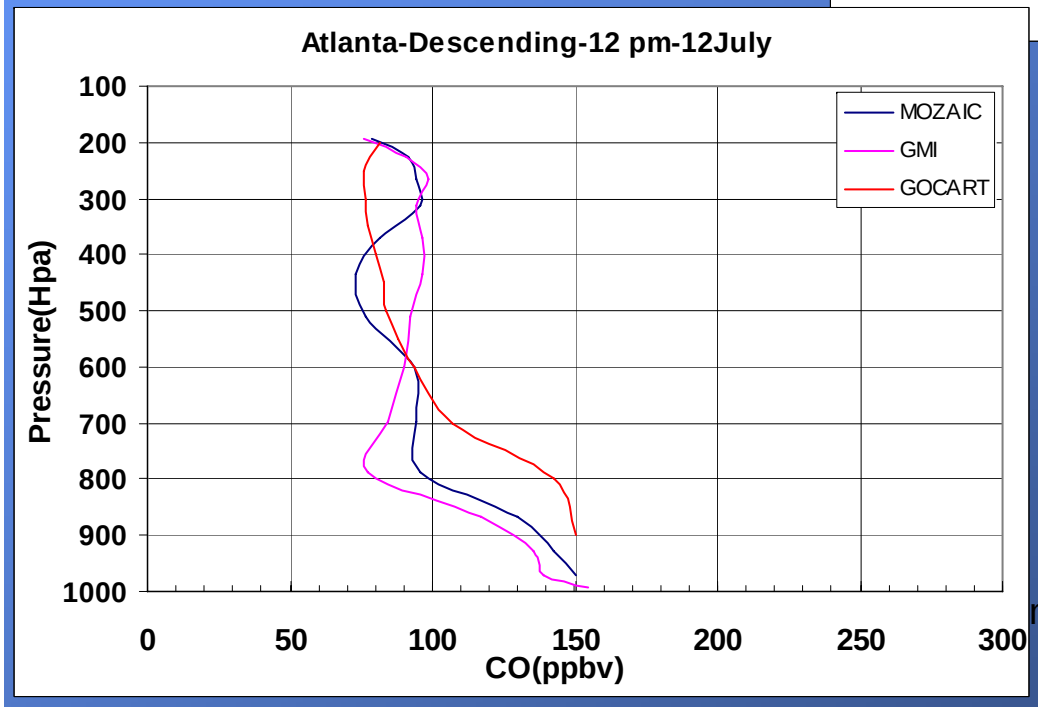




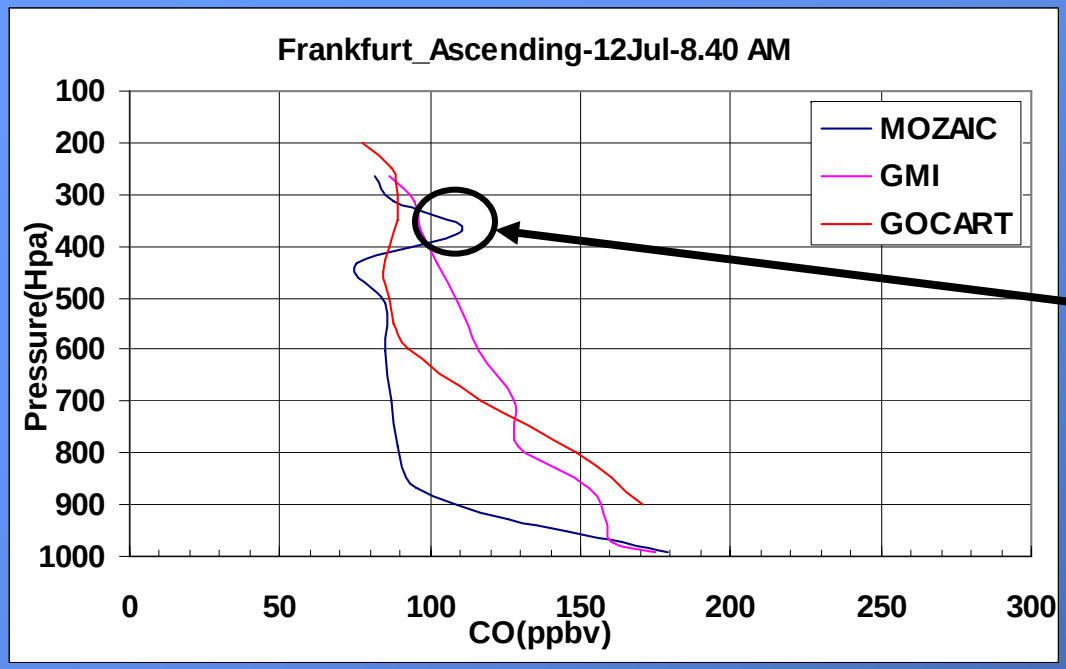
Vertical Profiles on 12h July, 2004, MOZAIC smoothed

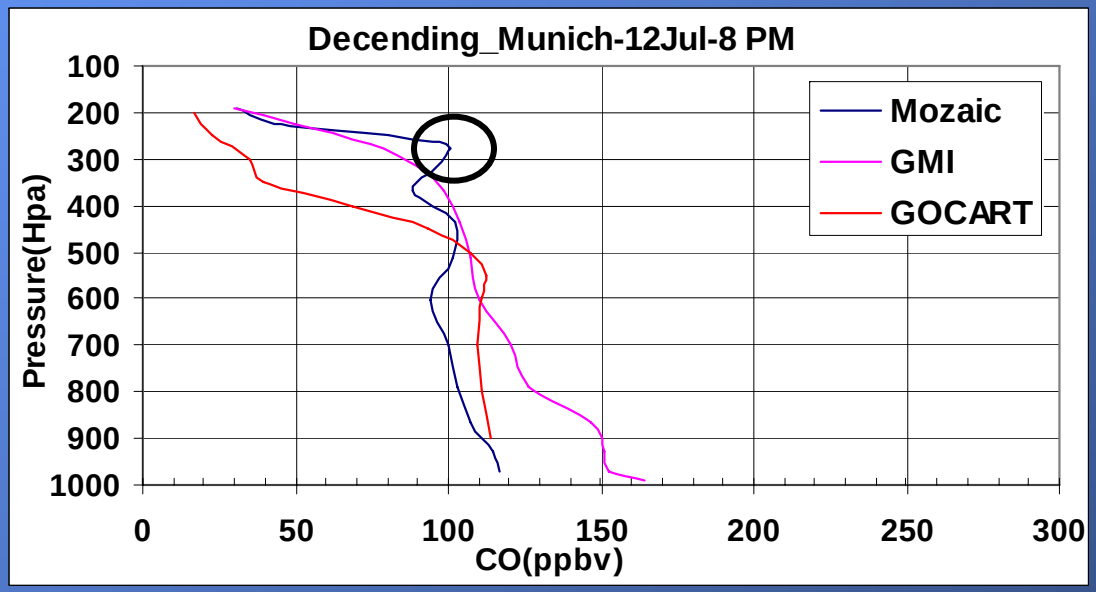
LA





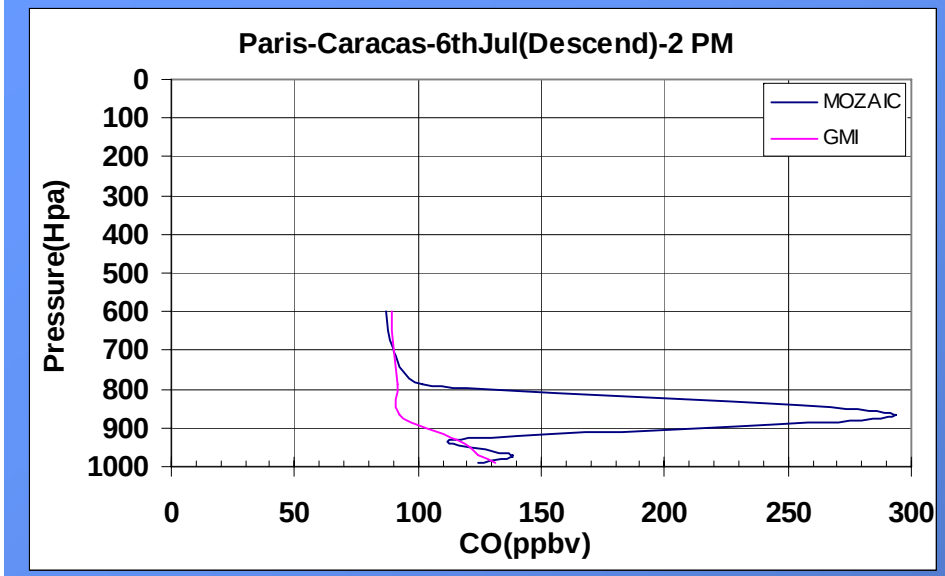
Atlanta

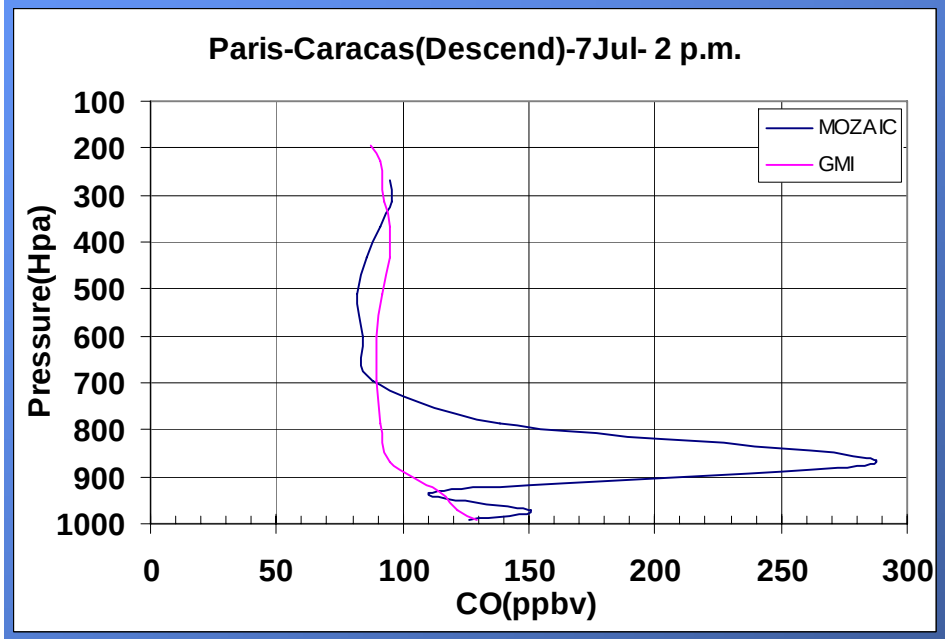




Morning and evening flights show UT enhancement over Europe – transport of CO from biomass burning areas in Canada (not simulated by either model).

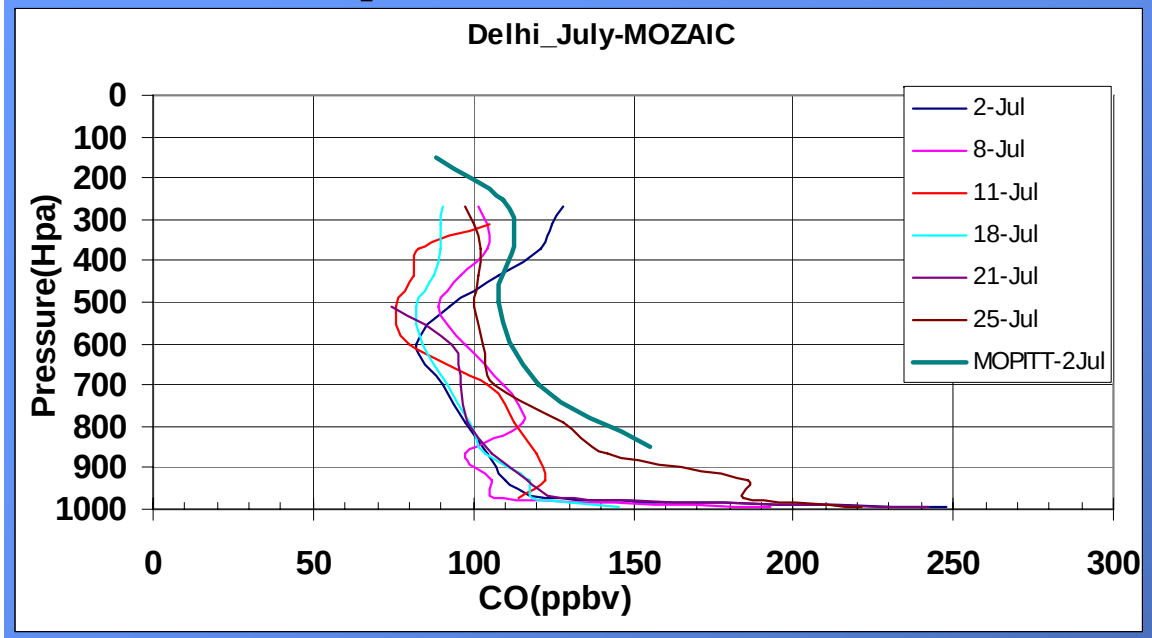
GMI (local noon) overestimates CO in free troposphere as compared with both morning and evening flights.





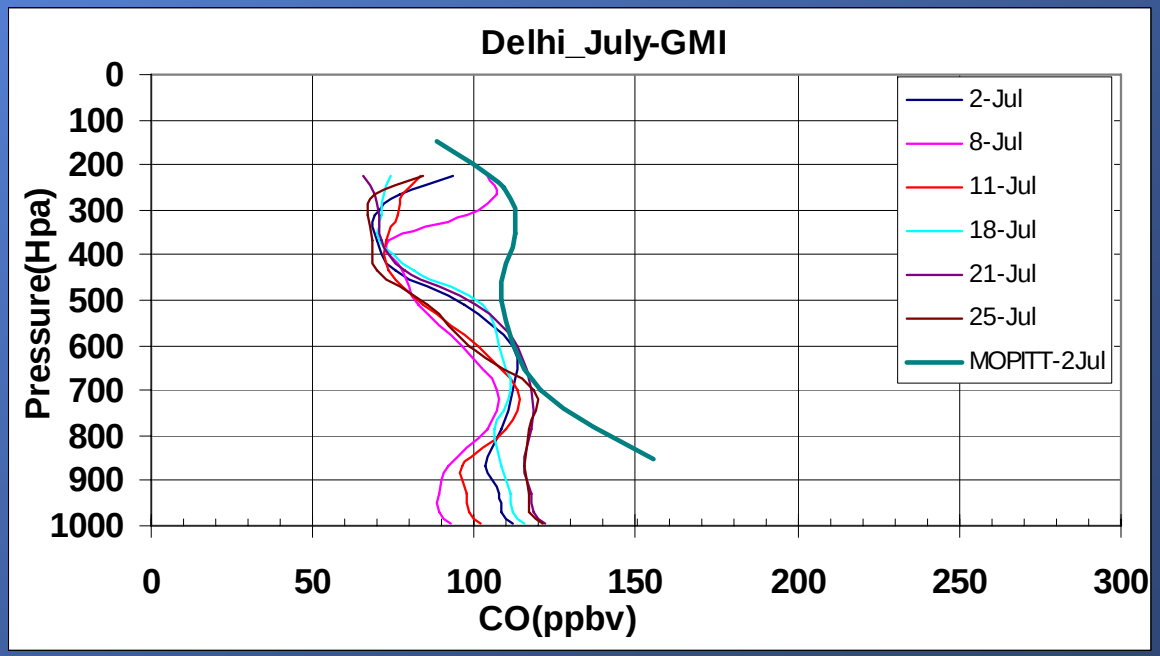
Transport of CO from biomass burning over Amazon region to Caracas (low altitudes)

Vertical profiles over Delhi on individual days

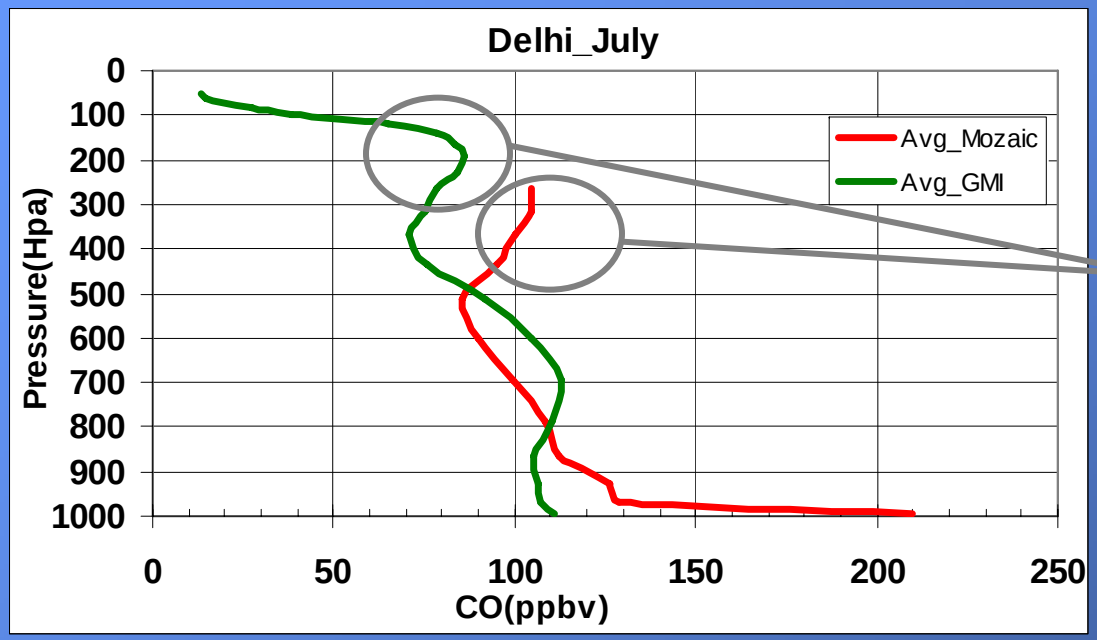


Very few MOPITT data over Delhi due to high amounts of cloud cover

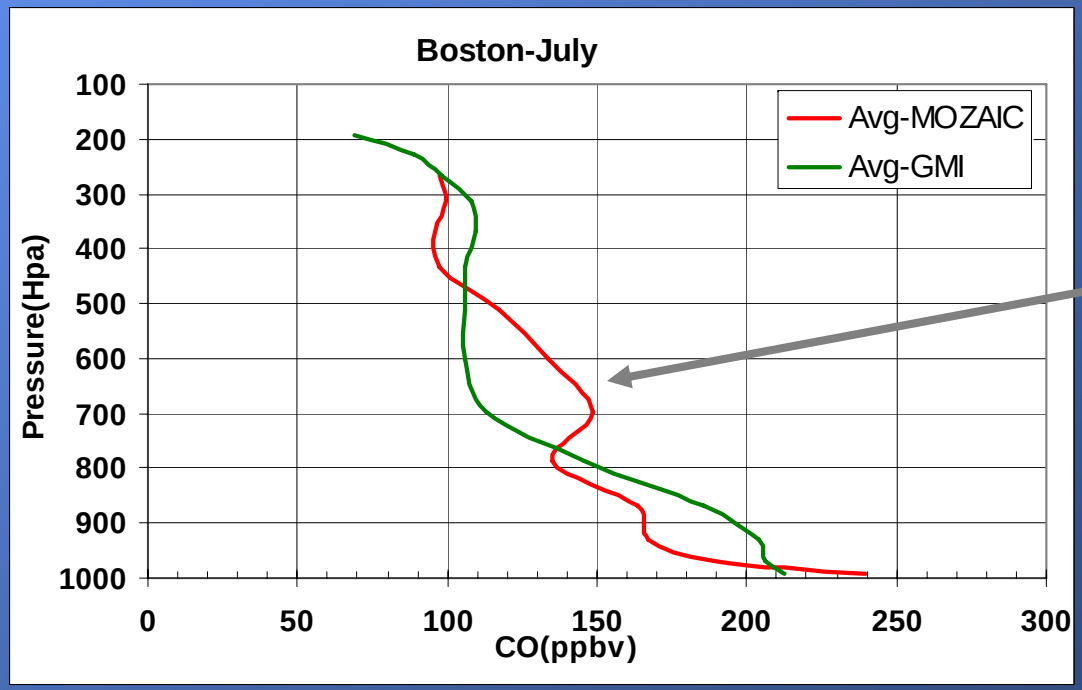
MOPITT appears to be a bit too high



Monthly Averages of MOZAIC and GMI



Convective lifting of CO: enhanced layer is higher in GMI



Enhanced layer from in middle troposphere from Canadian fires (not simulated in GMI)

Summary of MOZAIC comparisons

- GMI captures boundary layer enhancements well in some, but not all urban areas
- GMI CO amounts too high throughout the free troposphere over Frankfurt (consistent with AIRS result)
- UT lifted CO layer too high over India (convection too strong in DAS)
- GMI CO looks pretty good in the UT/LS
- As expected (using climatology), transport from biomass burning not correctly captured

Ongoing work

- Evaluate AIRS retrievals using MOZAIC, etc.
- AIRS can be used to evaluate:
  - plume model
  - near-real-time emissions (derived with MODIS fire counts) versus monthly mean, climatology
  - different meteorological forcing (DAS, forecast, DAS with non-cycled humidity, free-running GCM)
  - on-line vs off-line transport
  - parameterized vs detailed chemistry
  - effect of horizontal resolution
- Implement near-real-time AIRS CO (interactive) retrievals/assimilation
- Run 1DVAR AIRS retrievals for entire Aqua period and make data set publicly available