Assimilation of Compact Phase Space Retrievals (CPSRs) in WRF-Chem/DART

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Overview

- Assimilation of trace gas retrievals
- Phase space retrievals
- Compact phase space retrievals (CPSRs)
- WRF-Chem/DART
- Case study: Assimilate CPSRs for CONUS June 2008
- Summary and Conclusions

Assimilation of Trace Gas Retrievals

- Air quality is an important national/international issue.
- Air quality forecasts require observations.
- In situ observations are spatially and temporally sparse.
- Remotely sensed (satellite observations) are relatively abundant.
- Question whether to assimilate radiances or retrievals.
- Retrievals are inverse solutions to the RTE that identify the "optimal" trace gas profile that yields the observed radiance profile.

Assimilation of Trace Gas Retrievals

- The retrieval equation:

$$y_r = Ay_t + \left(I - A\right) y_a$$

- Challenges with assimilating retrievals:
  i. Data sets have large amounts of data with low information content per observation.
  ii. Observation error covariance contains off-diagonal terms.
  iii. The retrievals contain contributions from the retrieval prior.
- Prior work has focused on ii and iii. Relatively little work on i. Joiner and Da Silva (1998) and Migliorini et al. (2008) are two such papers.

Phase Space Retrievals

- Joiner and Da Silva (1998):
  - First proposed using information content to reduce the number of retrieval observations
  - Project retrievals onto null space of different operators [$(I\text{-}A)$, E_s, and E_m] – called "null space filtering."
- Migliorini et al. (2008):
  - Remove retrieval prior contribution with "quasi-optimal" subtraction

$$y_r - \left(I - A\right) y_a = A y_t$$

  - Neglect quasi-optimal retrievals whose forecast error variance was smaller than the corresponding observation error variance.

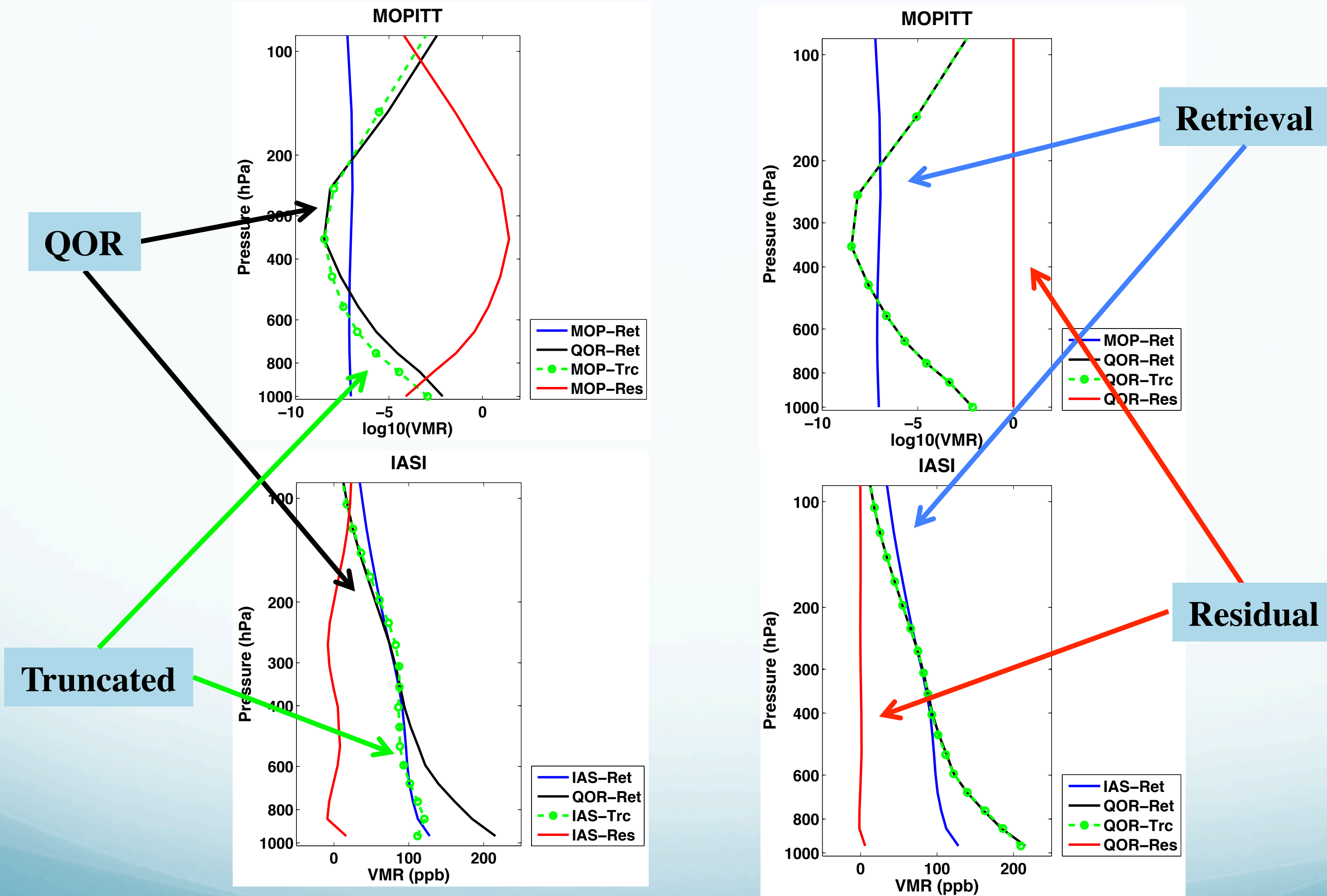
Compact Phase Space Retrievals

- Mizzi et al. (2015):
  - Notice that in

$$y_r - \left(I - A\right) y_a = A y_t$$

  the left singular vectors of *A* span its range.
  - *A* is singular so the "quasi-optimal" retrieval projects completely onto the leading left singular vectors.
  - That projection compresses the system but the transformed error covariance may not be diagonal.
  - So rotate/diagonalize the system with an SVD of the transformed observation error covariance.
  - Compression factor depends on the difference between the number of rows and rank of *A* (~66% MOPITT and ~80% IASI).

CPSR Properties

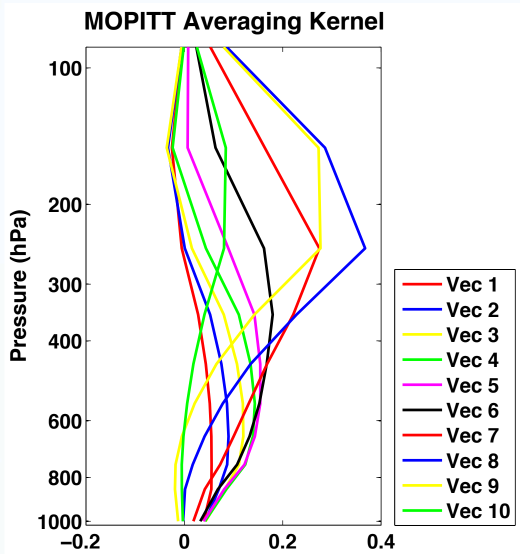


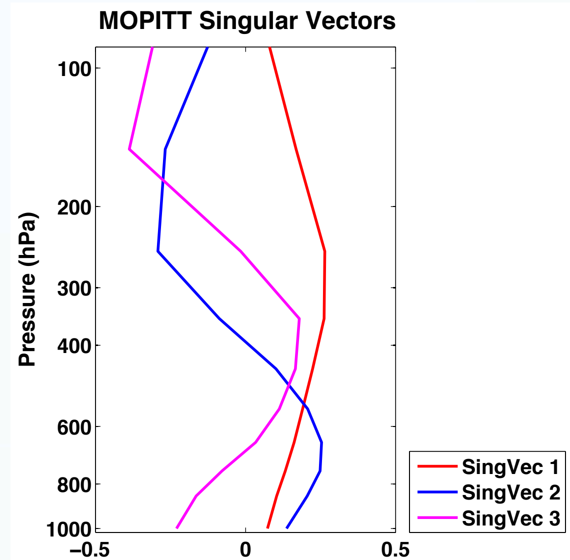
CPSR Properties

Averaging Kernels

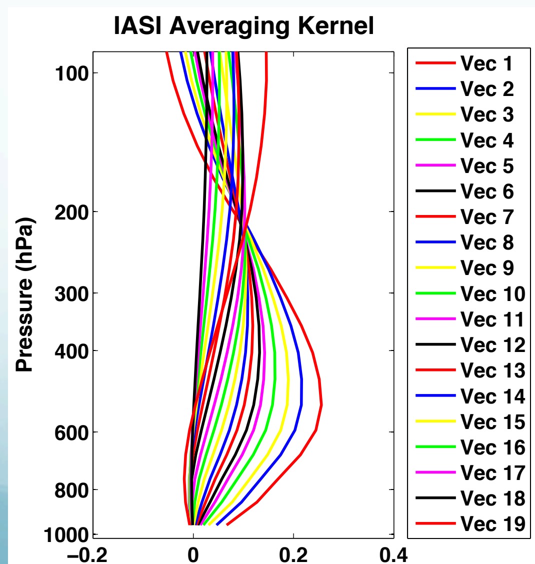
Leading Singular Vectors

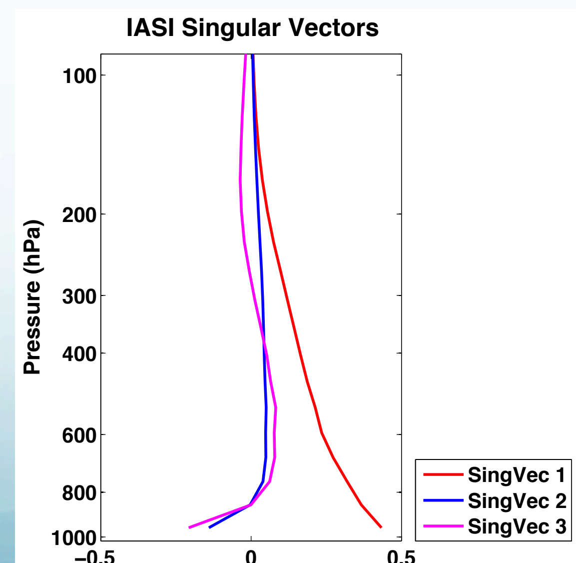
MOPITT





IASI





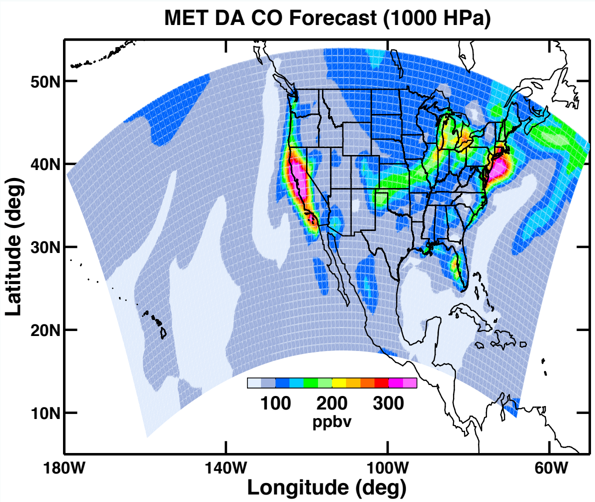
WRF-Chem/DART (Poster P-69)

- **WRF-Chem** is WRF with online chemistry that simulates emission, transport, mixing, and chemical transformation of atmospheric trace gases and aerosols.
- **WRF-Chem** developed and maintained by NOAA/ESRL, DOE/PNNL, and NCAR/ACOM.
- **WRF-Chem** added as a model in **DART** (available to community as β-test).
- **DART** – Data Assimilation Research Testbed developed and maintained by NCAR/IMAGe.
- **DART** is a flexible software environment for exploring different assimilation methods, models, and observations.

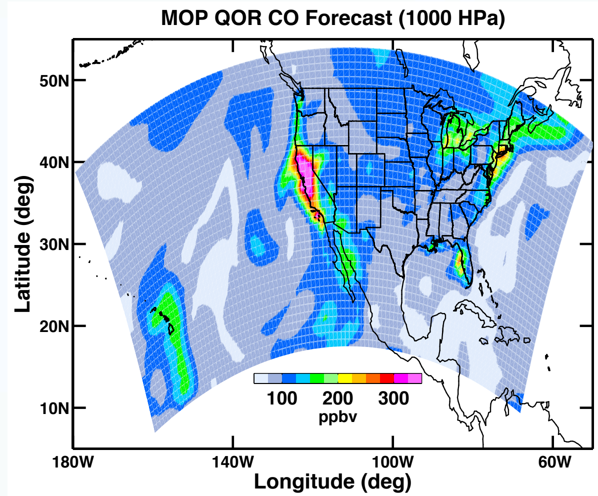
Experimental Setup

- **WRF-Chem/DART** cycling with conventional meteorological observations and **MOPITT** and **IASI CO** retrieval profiles.
- 6 hr cycling (00Z, 06Z, 12Z, and 18Z)
- CONUS grid with 101x41x34 grid points and 100 km resolution
- 20-member ensemble
- Results for June 1 - 30, 2008 cycling experiments (112 cycles)
- Three experiments:
  - Exp 1: PREPBUFR conventional obs
  - Exp 2: CO retrieval profiles and PREPBUFR conventional obs
  - Exp 3: Repeat Exp 2 with CPSRs.
- See Mizzi et al. (2015) GMD for details.

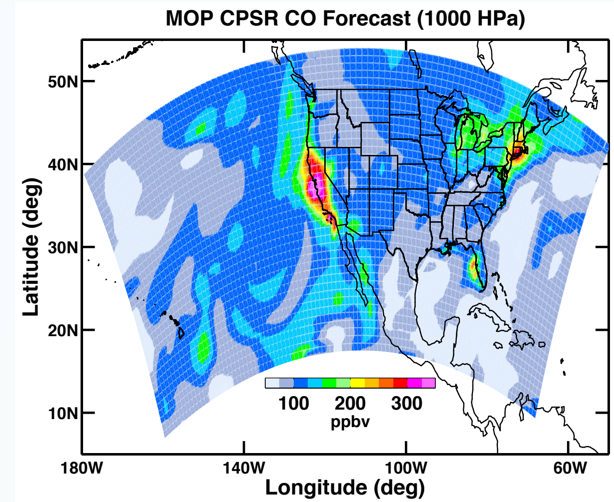
Experimental Results



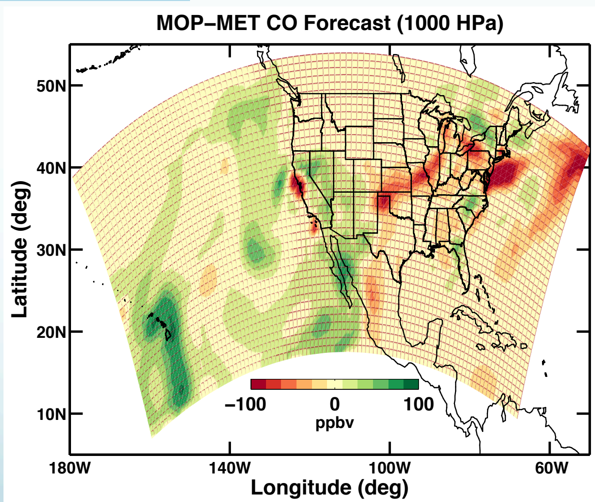
MET Only



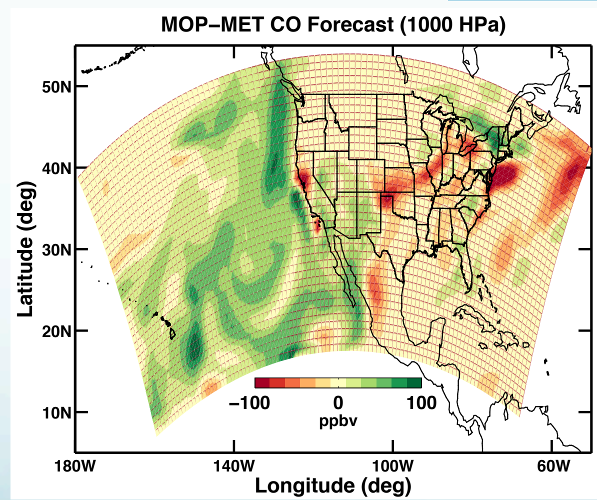
MET and CO-QORs



MET and CO-CPSRs



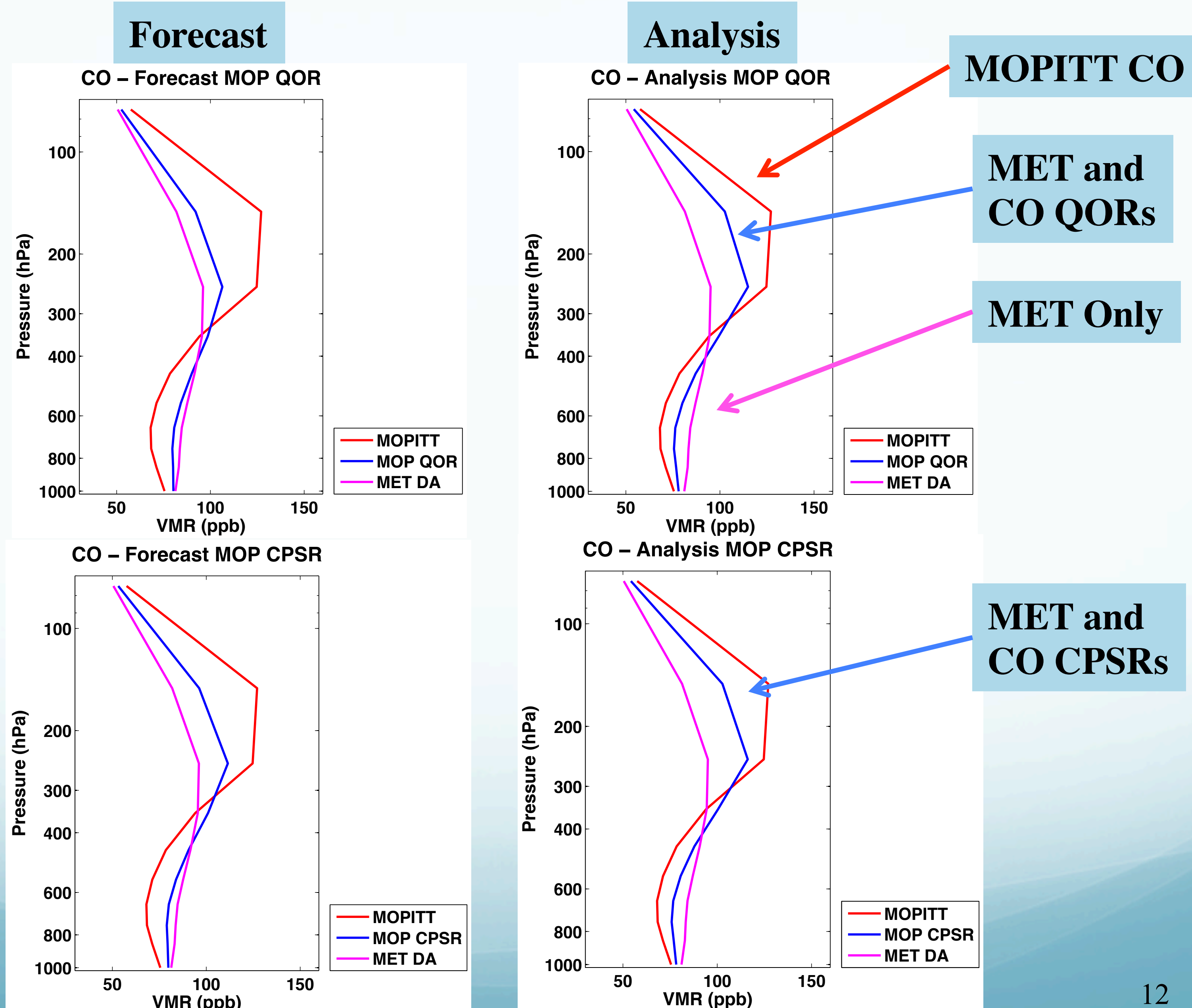
QOR-MET Diff



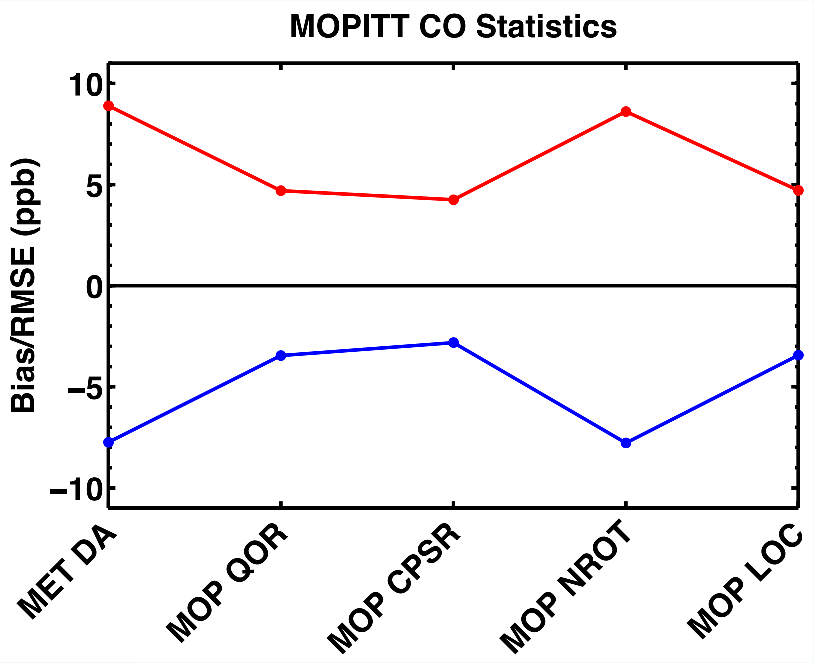
CPSR-MET Diff

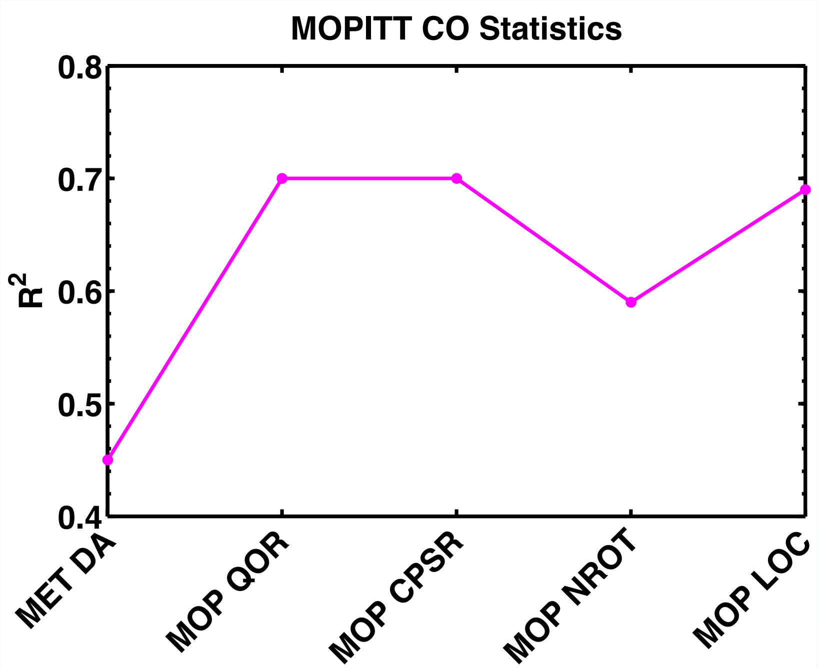
CO (ppb) at ~1000 hPa (18 UTC June 28, 2008)

Vertical Profiles



Verification





RMSE – red curve
Bias – blue curve
R2 – magenta curve

Summary and Conclusions

- **WRF-Chem/DART** available as β-test release.
- Assimilation of MOPITT CO improves CO analysis and forecast.
- Assimilation of MOPITT CO CPRSs performed as well of better that assimilation of retrievals.
- Use of CPSRs reduced computational costs by ~35%.
- CPSRs can be obtained for retrievals from any optimal estimation algorithm and can be used with correlated or uncorrelated errors.

Questions ?