Assimilation of Compact Phase Space Retrievals (CPSRs): Comparison with Independent IAGOS and IASI Observations and Assimilation of Retrieval Partial Profiles

Arthur P. Mizzi[*], David Edwards[*],

and Jeffrey Anderson[#]

(mizzi@ucar.edu)

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* NCAR/Atmospheric Chemistry Observations and Modeling Laboratory, Boulder, CO
# NCAR/Institute for Mathematics Applied to Geosciences, Boulder, CO

Overview

- Background
- Compact phase space retrievals (CPSRs)
- Assimilation of retrieval full profiles as CPSRs
- WRF-Chem/DART
- Comparison with independent IAGOS and IASI observations
- Extension of CPSRs to assimilation of retrieval partial profiles
- Summary and Conclusions

Assimilation of Trace Gas Retrievals

- Air quality is an important national and international issue.
- Air quality forecasts require observations.
- In situ observations are spatially and temporally sparse.
- Remotely sensed – satellite observations are relatively abundant.
- 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 Retrieval Full Profiles

- The retrieval equation:

$$\boldsymbol{y_r = A y_t + (I - A) y_a + \epsilon}$$

with error covariance $\boldsymbol{E_m}$.

- 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: Joiner and Da Silva (1998); Migliorini et al. (2008) focused on ii and iii. Mizzi et al (2016a) introduced CPSRs to addressed i to iii.

Compact Phase Space Retrievals (CPSRs)

- Mizzi et al. (2016a):
  - Notice that in

$$\boldsymbol{y_r - (I - A)y_a - \epsilon = Ay_t}$$

the left singular vectors of $\boldsymbol{A}$ 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 depends on difference between the number of rows and rank of $\boldsymbol{A}$. (~66% MOPITT and ~80% IASI)

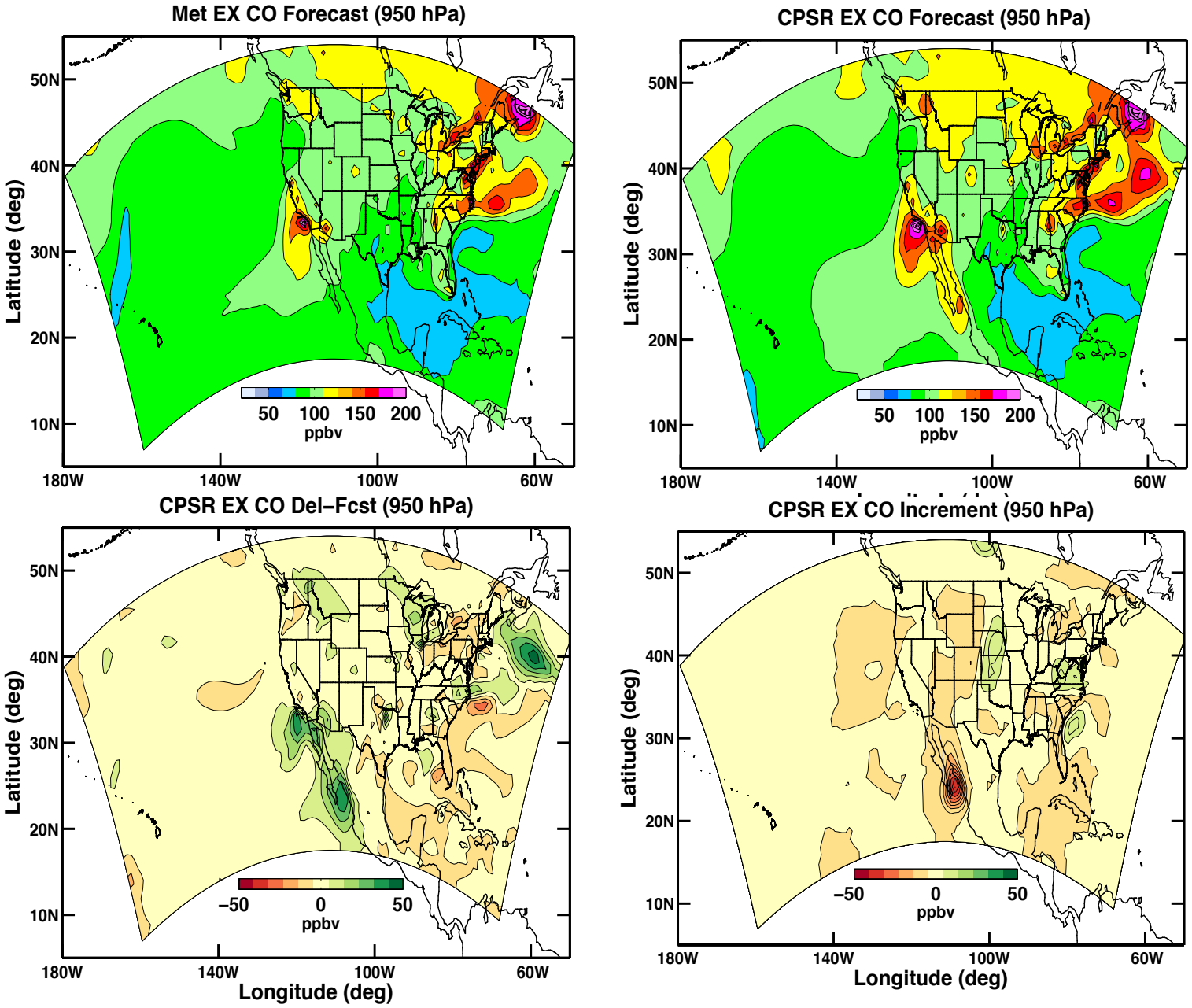
WRF-Chem/DART (Poster P20)

- **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/ACD.
- **WRF-Chem** added as a model in **DART** (available to community as β-test).
- **DART** – Data Assimilation Research Testbed developed and maintained by NCAR/DAReS.
- **DART** is a flexible software environment for exploring different assimilation methods, models, and observations.

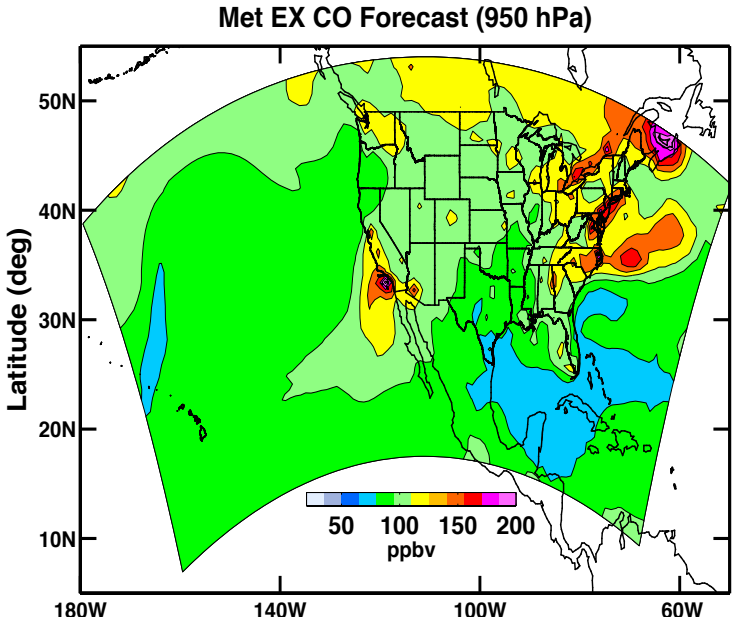
Experimental Setup

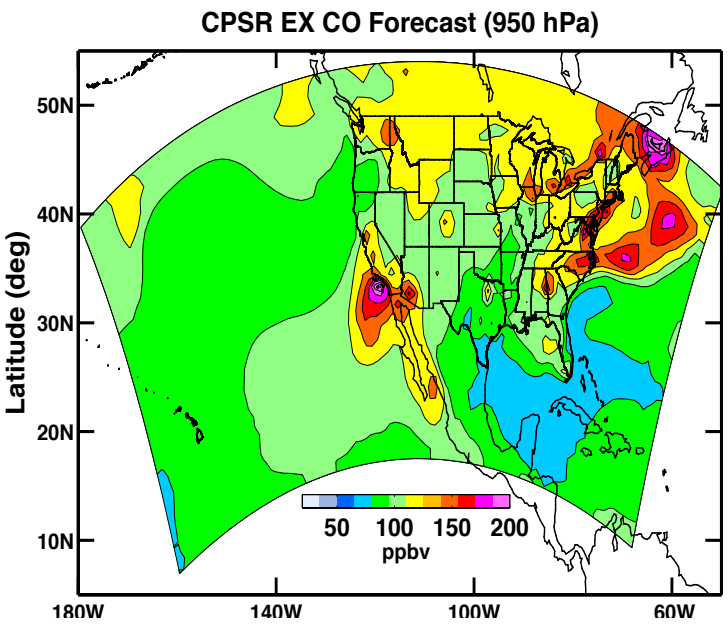
- **WRF-Chem/DART** cycling with conventional meteorological observations and **MOPITT** and **IASI CO** retrieval profiles.
- 6 hr cycling (00Z, 06Z, 12Z, and 18Z)
- CONUS grid with 101x41x34 grid points and 100 km resolution
- 20-member ensemble
- Results for June 1 - 10, 2008 cycling experiments (~40 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. (2016a) GMD and Mizzi et al. (2016b) [under internal review] for more details.

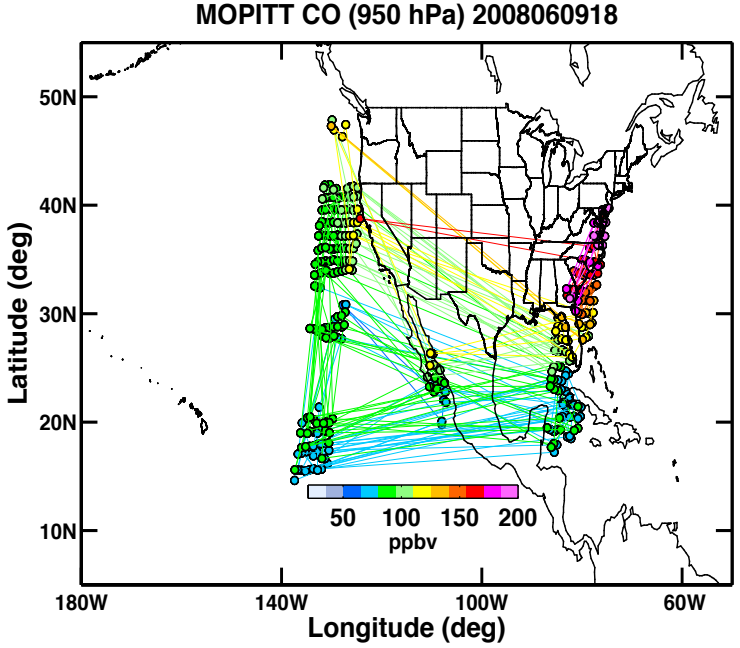
June 19, 2008 18 UTC (Retrieval Full Profiles)

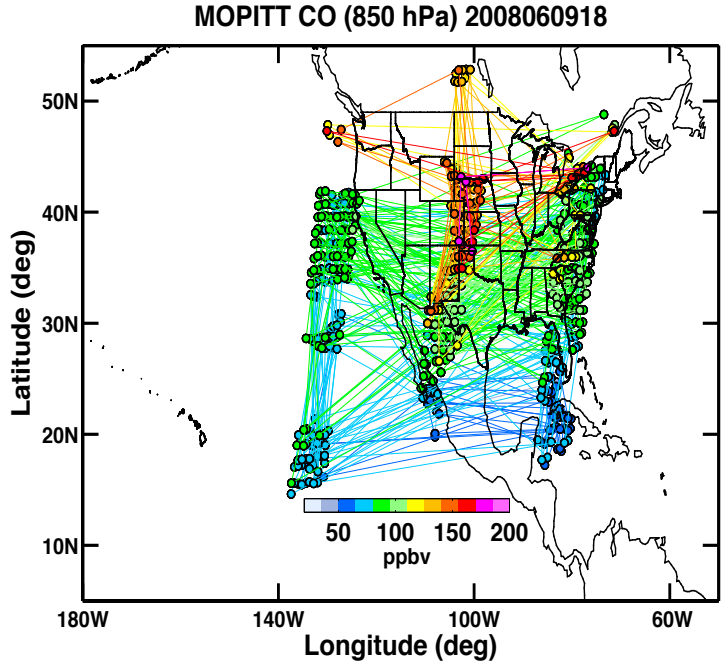


Comparison with MOPITT CO

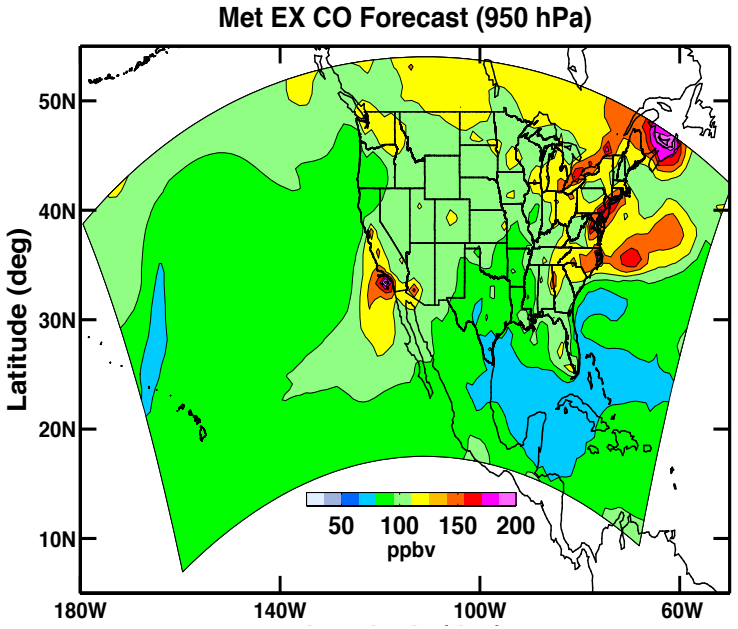


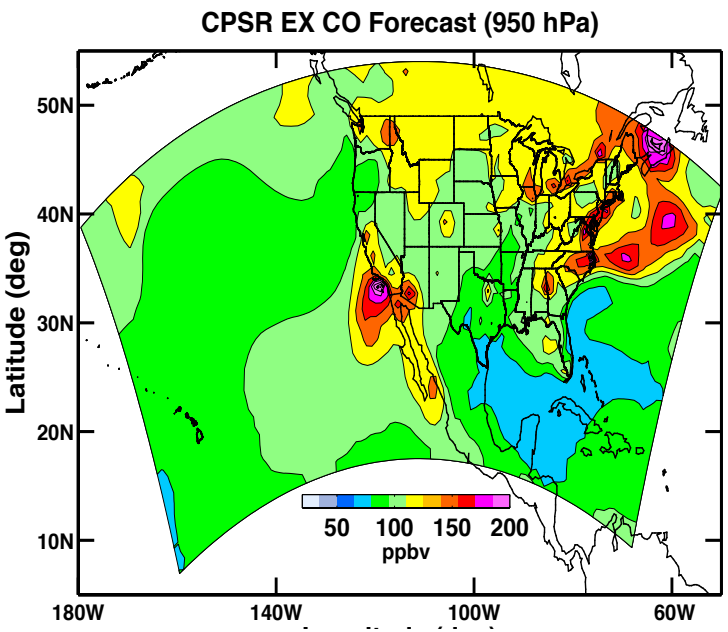


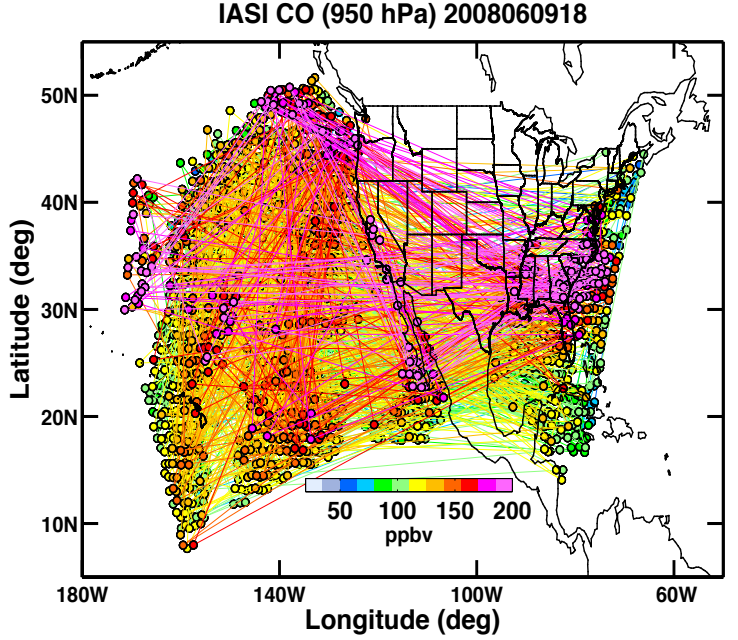


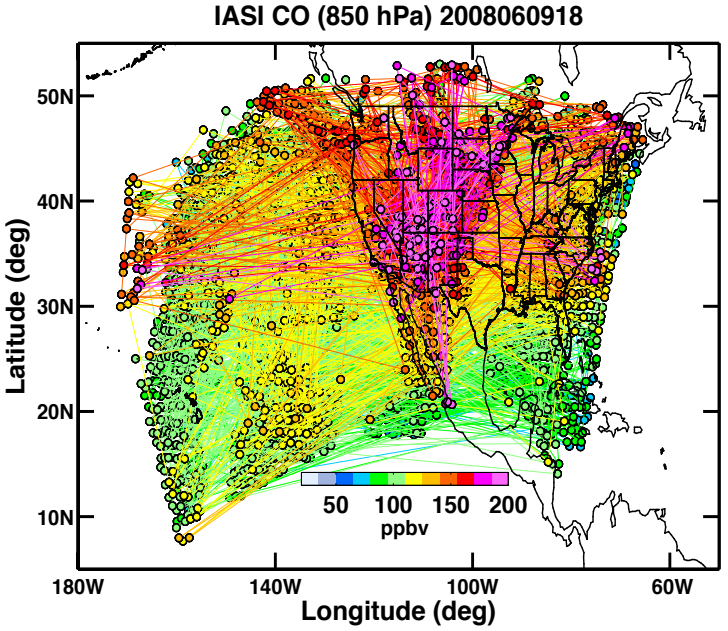


Comparison with IASI CO

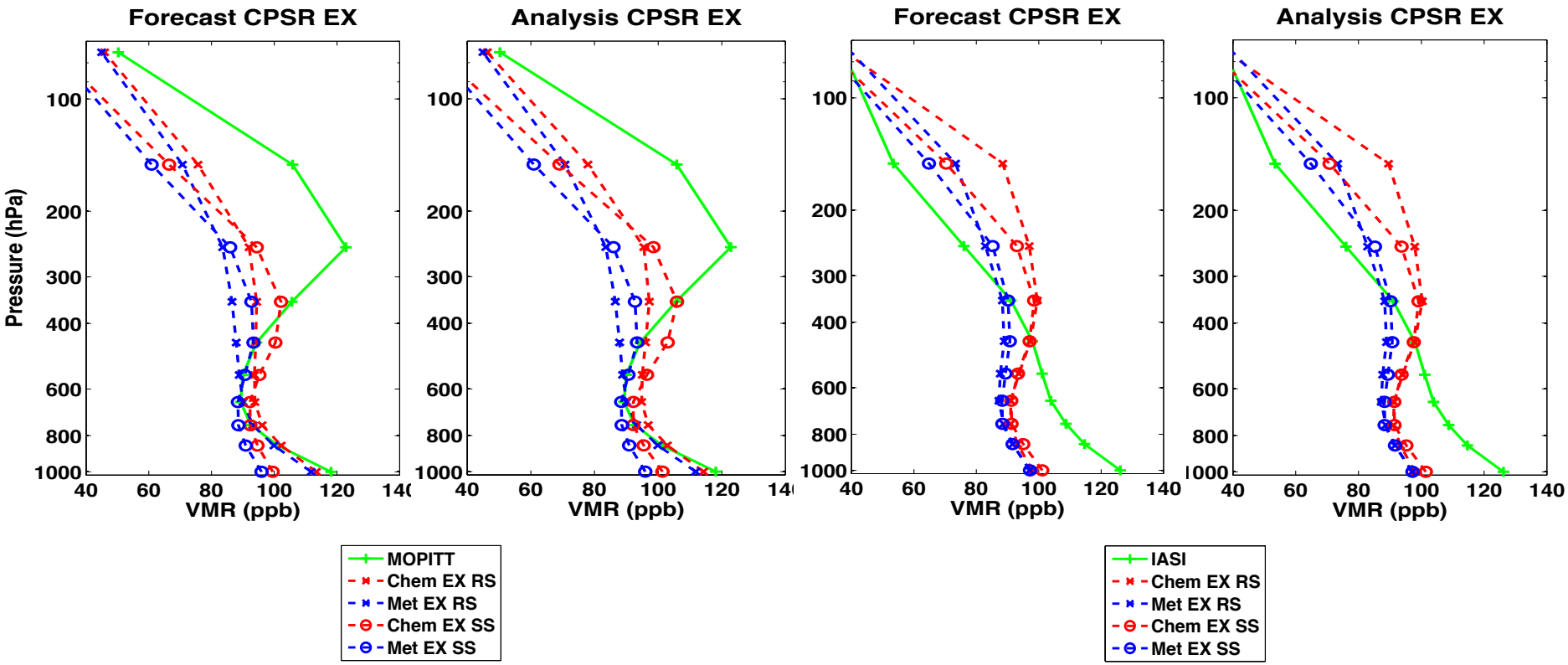








Vertical Profiles (Retrieval Full Profiles)



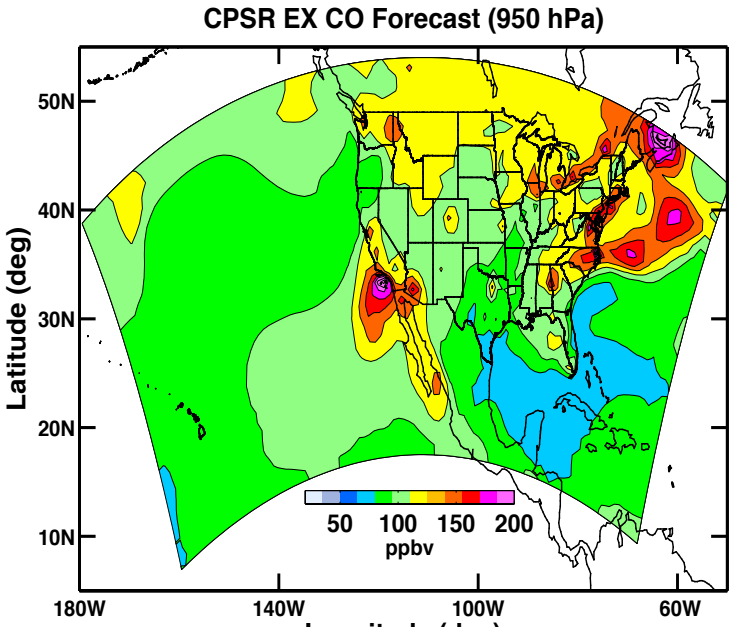
CPSR Extension to Retrieval Partial Profiles

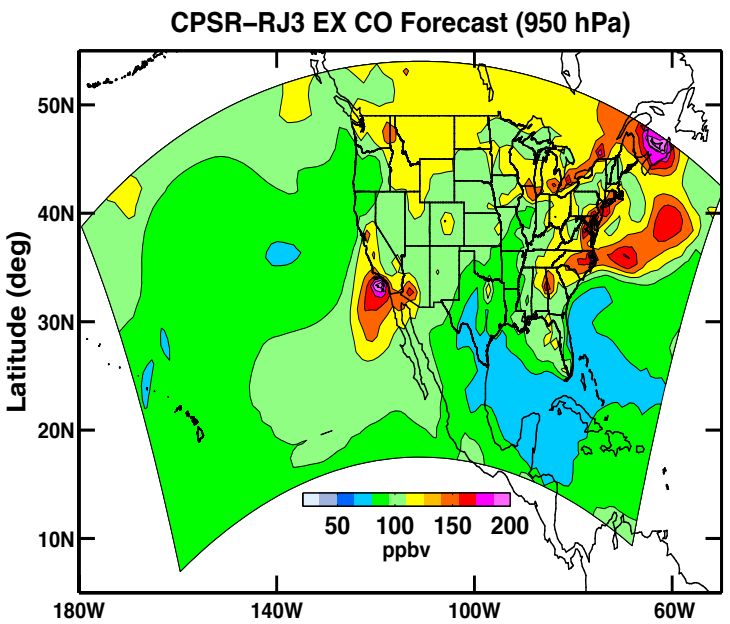
➢ Mizzi et al. (2016b):

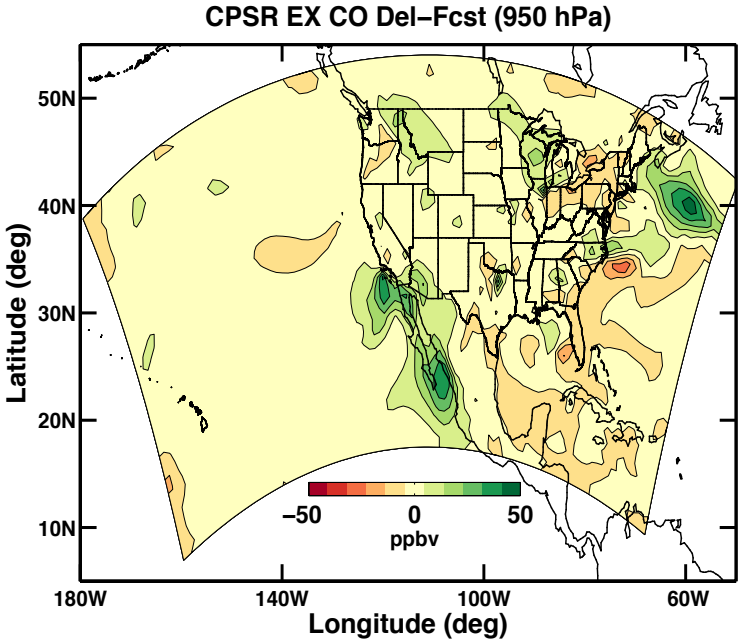
$$\boldsymbol{y_r - (I - A)y_a - \epsilon = Ay_t}$$

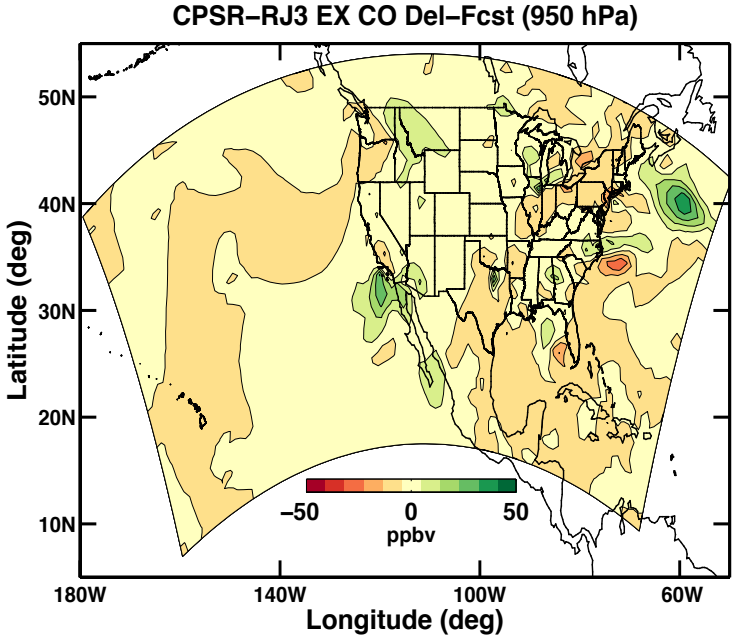
- Discard $\boldsymbol{m}$ elements of $\boldsymbol{y_r}$. The resulting dimension is $\boldsymbol{n - m}$.
- Discard the corresponding elements of $\boldsymbol{y_a}$, the corresponding row of $\boldsymbol{A}$, and the corresponding rows and columns of $\boldsymbol{E_m}$.
- $\boldsymbol{A}$ was a square $\boldsymbol{n \times n}$ matrix. It is now a rectangular $\boldsymbol{(n - m) \times n}$ matrix. Thus, assimilation of retrieval partial profiles is called "CPSRs applied to rectangular systems."
- The rest of the derivation follows Mizzi et al. (2016a) due to our use of SVDs for the "compression" and "diagonalization" transformations.

CPSR Extension to Retrieval Partial Profiles

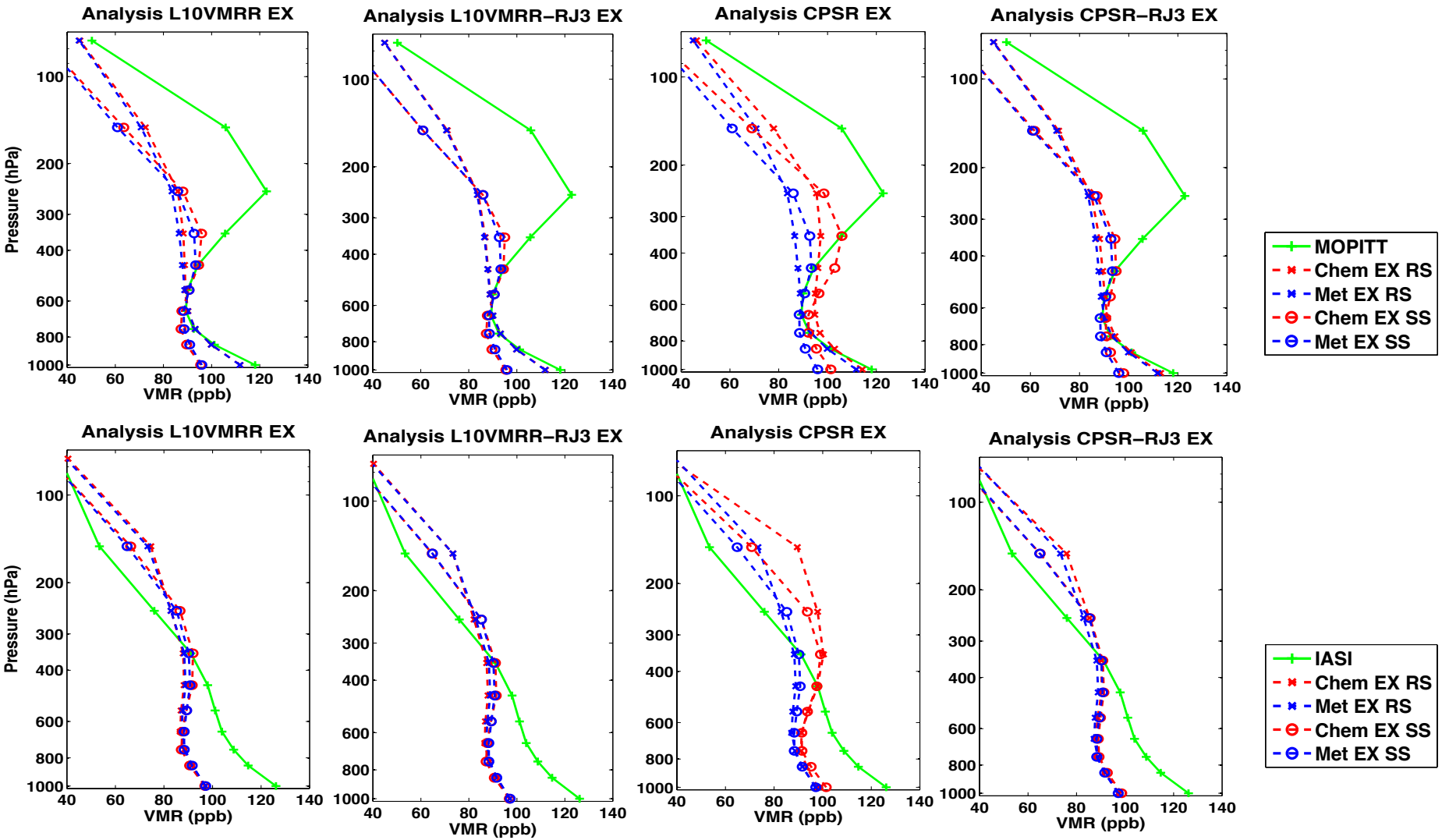




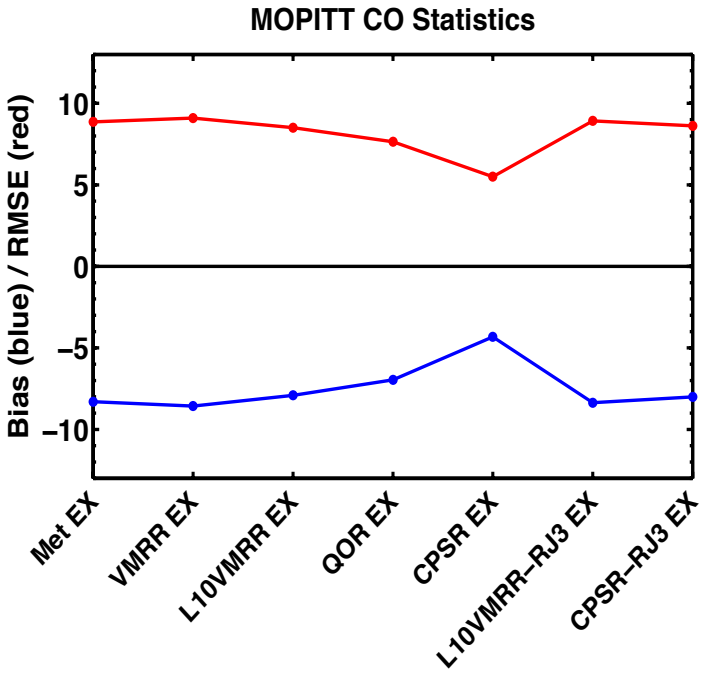


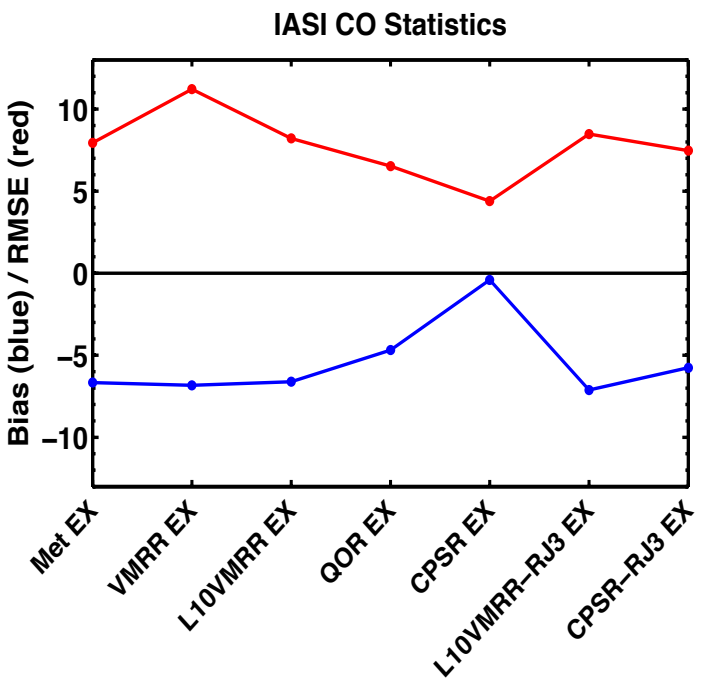


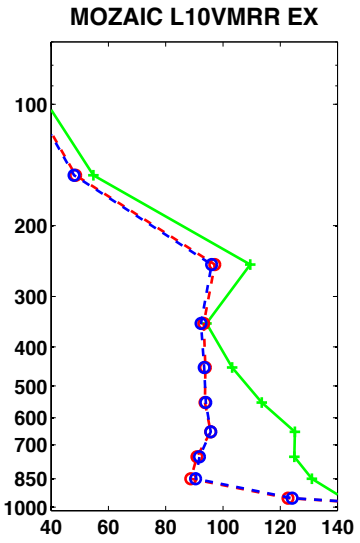
CPSR Extension to Retrieval Partial Profiles

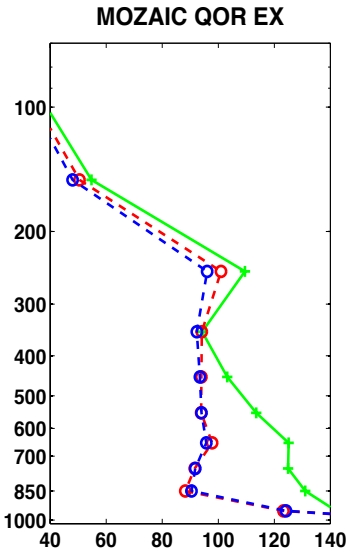


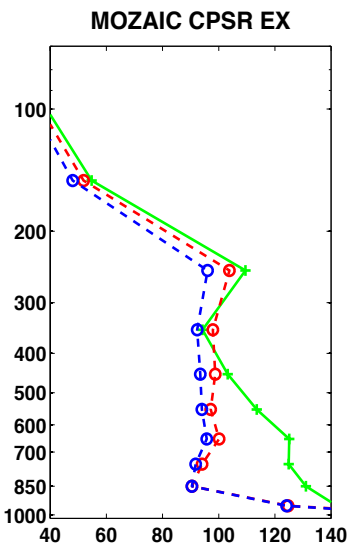
Verification (Retrieval Partial Profiles)

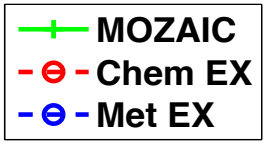










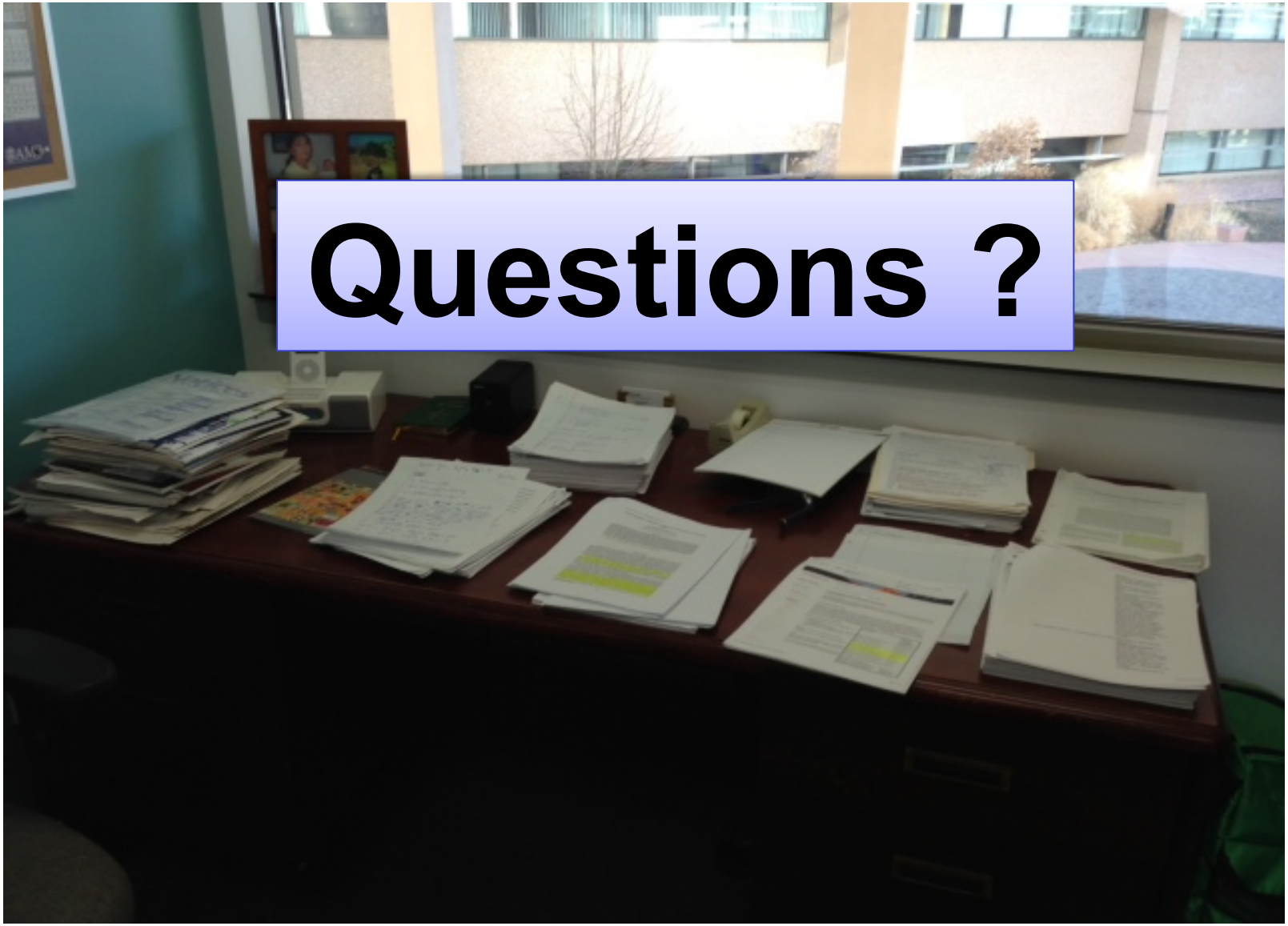


Summary and Conclusions

- Comparison of MOPITT CPSR CO assimilation/forecast results with MOZAIC in situ and IASI retrieval CO observations confirms that CPSRs improve the WRF-Chem/ DART CO analysis fit and forecast skill at ~50% reduction in computation cost compared to assimilation of raw or quasi-optimal retrievals.
- Extended CPSRs to assimilation of retrieval partial columns to enable discarding of retrieval elements with known error.
- Data discard experiments show that assimilation of retrievals has remote (outside the assimilation vertical localization domain) due to the averaging kernels and/or the phase-space transform functions.

References

- Mizzi, A. P., A. F. Arellano, D. P. Edwards, J.L. Anderson, and G. G. Pfister: Assimilating compact phase space retrievals of atmospheric composition with WRF-Chem/DART: A regional chemical transport/ensemble Kalman filter data assimilation system. *Geosci. Model Dev.*, 9, 1-14, 2016a.
- Mizzi, A. P., D. P. Edwards, and J. L. Anderson: Assimilating compact phase space retrievals (CPSRs): Comparison with independent observations (MOZAIC in situ and IASI retrievals) and extension to assimilation of retrieval partial profiles. [*under internal review*], 2016b.


Questions ?