# Preliminary Results of the GEOS-Chem/LETKF Data Assimilation System

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## ◆ Abstract

We developed a new GEOS-Chem data assimilation system based on Local Ensemble Transform Kalman Filter (LETKF), and performed an observation system simulation experiment (OSSE) for geostationary satellite and one-month assimilation experiment with CO profiles observed by MOPITT to validate the assimilation system.

- The OSSE and one-month experiments shows that GEOS-Chem/LETKF works very well.
- Ensemble generation affects CTM assimilation results (not shown).
- The OSSE indicates that observations by geostationary satellite with NIR and TIR sensors are required for better CO forecasting over the East Asia. Polar-orbit satellite with TIR only (i.e. MOPITT) is insufficient to improve (even 1-day) forecasting.
- Bias-aware (BA) method is implemented in the GEOS-Chem/LETKF. Near the emission region, BA is useful and important.
- Assimilation increase CO concentration at the surface over urban areas, and reduce significantly at the upper level (700hPa).
- Validation with independent in-situ data shows better agreement with assimilation results.

## ◆ Model and Method

### ■ GEOS-Chem (v8-03-01)

Resolution: 2 x 2.5, L47.

### ■ Local Transform Ensemble Kalman Filter (LETKF)

One of Square Root Filters (SRF).
Solve analysis ensemble perturbation by linear combination of forecast ensemble perturbation with eigenvalue decomposition.

### ■ Ensemble Generation

Relative Residual Error (RRE), Time-Lagged Ensemble (TLE) and Randomly Perturbed Emission (PRE) are available.

### ■ Target species

CO (Another species are also available in the GEOS-Chem/LETKE)

## ◆ OSSE with Geostationary Satellite

(E. Asia, May, 2006)

### ■ Experiment Setting

Period: 5-6 May 2006 (1-day assimilation and 1-day forecasting)
Ensemble Generation: RRE
Observations: Pseudo-observations derived from 'true' simulation.
[two orbits]: Geostationary (GEO) and Polar-orbit (LEO)
[two sensors]: Near Infra Red (NIR) and Thermal IR (TIR)

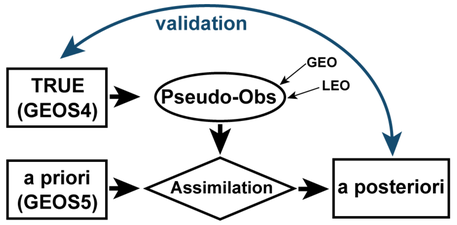


Fig. 1 Schematic of the OSSE experiment.

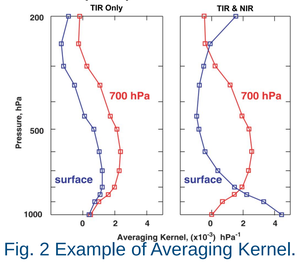


Fig. 2 Example of Averaging Kernel.

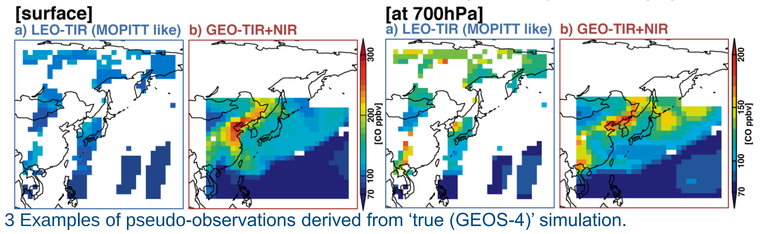


Fig. 3 Examples of pseudo-observations derived from 'true (GEOS-4)' simulation.

## ■ Assimilation Results

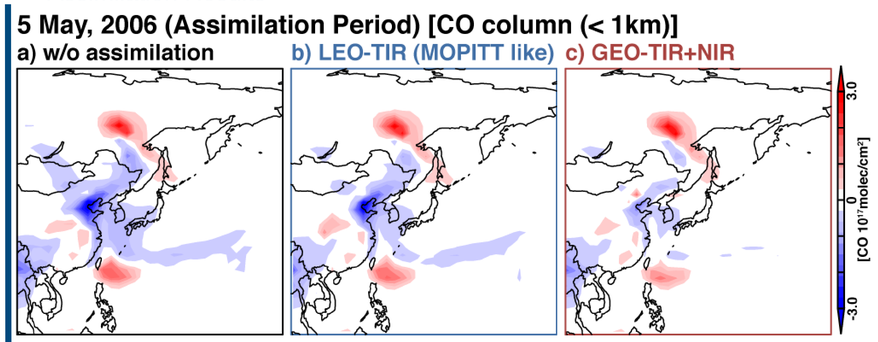


Fig. 4 Deviations from 'true (GEOS-4)' CO field during assimilation period.

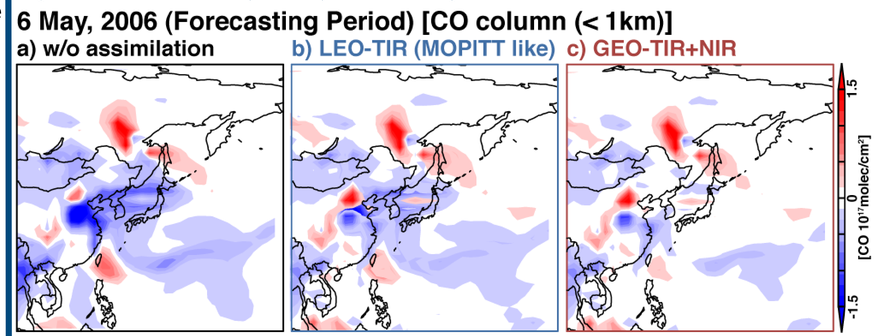


Fig. 5 Deviations from 'true (GEOS-4)' CO field during forecasting period.

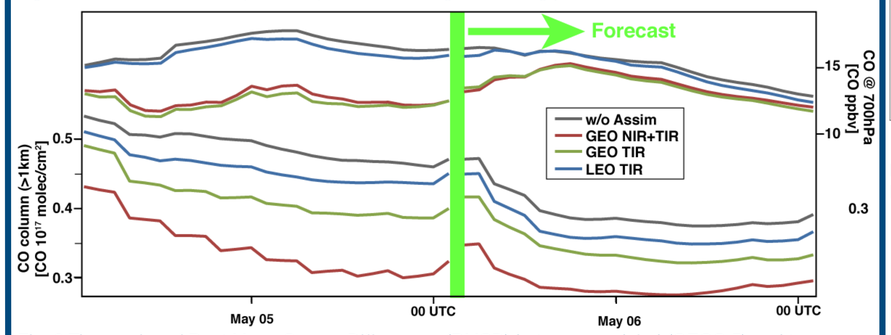


Fig. 6 Time series of Root Mean Square Differences (RMSD) between modeled (GEOS-5) and true (GEOS-4).

Assimilation by GEO with NIR and TIR shows better improvement even in forecasting period.

### ■ Bias-Aware (BA) Method

Simplified bias-aware (BA) method (Dee 2005) is implemented in the GEOS-Chem/LETKF. Figure 7 shows bias estimated by the BA assimilation.

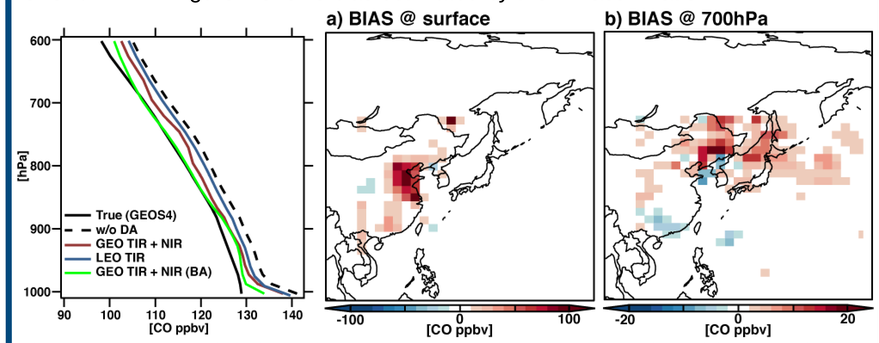


Fig. 7 Results of BA assimilation. Left panel shows comparison of vertical profiles. Right panels show monthly averaged biases at the surface and 700hPa.

## ◆ 1-month assimilation with MOPITT profile

(N. America, July, 2006)

### ■ Experiment Setting

Assimilation period: 1-month assimilation (July, 2006)
Observation: MOPITT CO profiles (Level3, Version4)
Ensemble generation: RRE + RPE

### ■ Assimilation Results

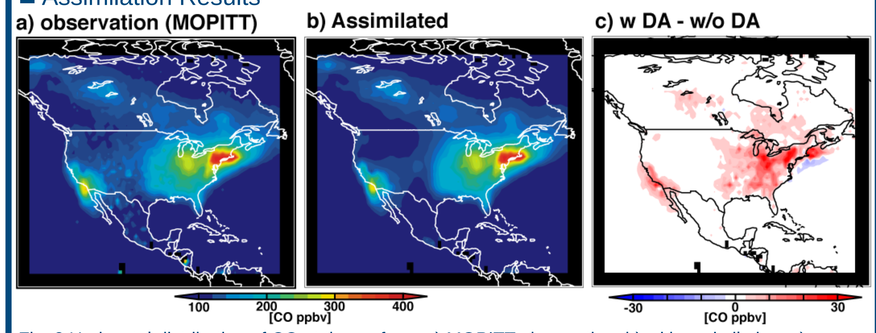


Fig. 8 Horizontal distribution of CO at the surface. a) MOPITT observation, b) with assimilation, c) increment between with and without assimilation.

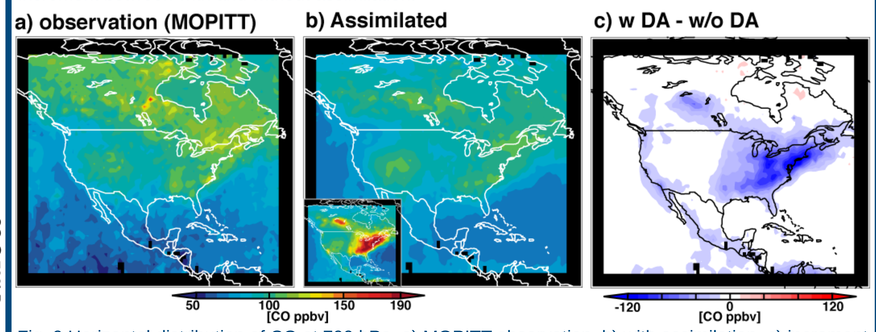


Fig. 9 Horizontal distribution of CO at 700 hPa. a) MOPITT observation, b) with assimilation, c) increment between with and without assimilation.

Assimilation results show good improvements: especially, at 700hPa, model's over-estimate is considerably reduced. At the surface, the assimilation increases CO concentration over urban areas.

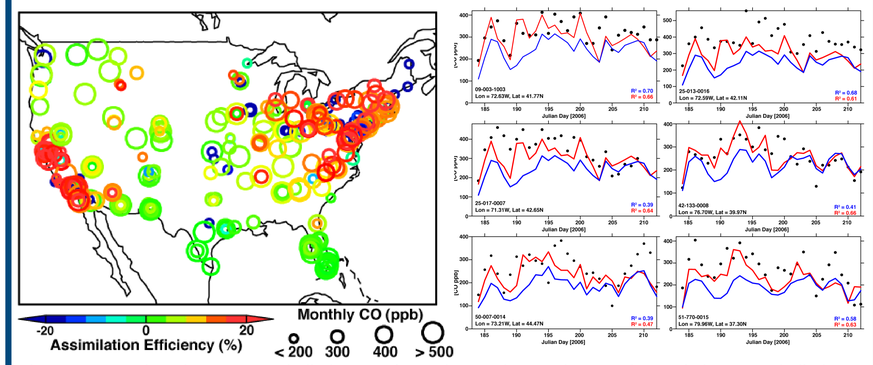


Fig. 10 Comparison between assimilation results and EPA observations. Left panel shows assimilation efficiency at each observation site derived from daily modeled and observed CO concentrations. Right panels show comparisons of CO time series. Assimilation efficiency is derived from (RMSDf – RMSDa) / RMSDf. RMSDf and RMSDa are RMSD for w/o and with assimilation, respectively: Positive assimilation efficiency means better agreement.

An independent validation is performed with EPA in-situ observations. In spite of coarse model space resolution and less sensitivity of MOPITT observations to the surface CO, assimilation results show good improvements: 279 of 340 (82%) sites show better agreements. Sites with lower monthly CO (< 200 ppb) tend to show worse agreements.