Assimilation of satellite precipitation data with EFSO

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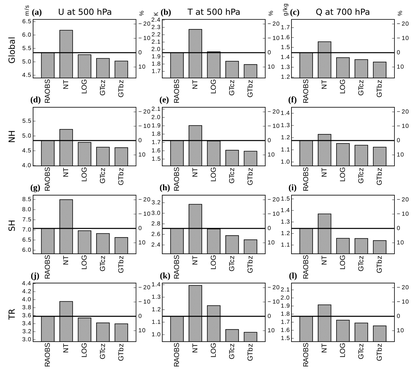
Precipitation assimilation

TRMM Multisatellite Precipitation Analysis (TMPA) / NCEP GFS model (Lien et al. 2016a,b)

- The effective precipitation assimilation was achieved by:
  - Using the local ensemble transform Kalman filter (LETKF).
  - Applying Gaussian variable transformation to both observation and model precipitation data.
  - A quality control (QC) criterion requiring enough background ensemble members have non-zero precipitation.

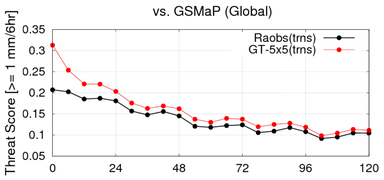
RAOBS: Conventional radiosonde only
NT: Raobs + TMPA without transformation
Log: Raobs + TMPA with the Logarithm transformation
GTcz, GTbz: Raobs + TMPA with the Gaussian transformation (two different methods)

Average 24-h forecast errors

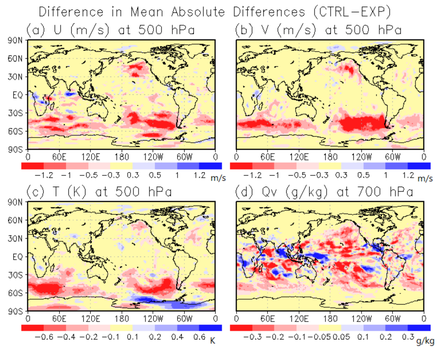


Global Satellite Mapping of Precipitation (GSMaP) / NICAM model (Kotsuki et al. 2016, under review)

- Use previous 1-month data (instead of long-term climatology) to define Gaussian transformation.
- Perform "inverse transformation" to obtain a model-consistent precipitation analysis.
- Precipitation forecasts are also improved.



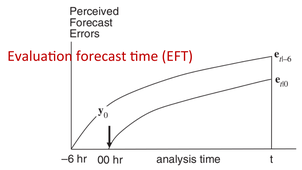
Improvement of 5-day precipitation forecast by precipitation assimilation



Improvement of winds, temperature, and moisture variables by precipitation assimilation (red: improvement; blue: degradation)

Ensemble forecast sensitivity to observation (EFSO)

- Kalnay et al. (2012) and Ota et al. (2013) computed forecast sensitivity to observation (FSO; Langland and Baker 2004) within the ensemble Kalman filter framework.
- Advantages:
  - Easy to compute; do not need linearization of models.
  - Applied to all types of ensemble data assimilation systems.



(Kalnay et al. 2012)

Reduction in forecast errors (in terms of a given norm)

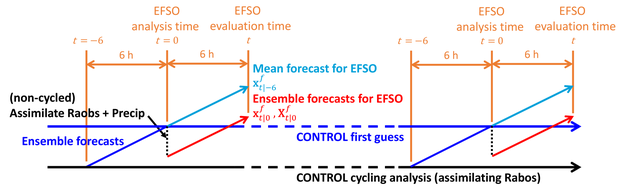
$$\Delta e_{t2} = e_{t|0t2} - e_{t|-6t2} = e_{t|0tT} C e_{t|0} - e_{t|-6tT} C e_{t|-6}$$

$$\cong 1/K - 1\ \delta y_{tT}\ R_t^{-1}\ Y_{ta}\ X_{t|0tf}\ T\ C(e_{t|0} + e_{t|-6})$$

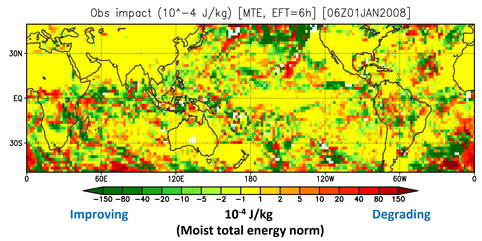
Using EFSO to accelerate assimilation development *(Lien et al. 2016, in preparation)*

- **Step 1**: Conduct an "offline" (not cycled) DA experiment, assimilating most of available new observation data with no or minimal QC. Obtain large samples of EFSO data for the new observations (i.e., precipitation).
- **Step 2**: Compute the average per-obs EFSO and the percentage of beneficial observations conditionally sampled based on various factors that can be potentially used to formulate QC criteria for data selection, such as location, time, satellite channels, data quality flags, and model background conditions.
- **Step 3**: Verify the QC criteria by applying them in cycled observing system experiments (OSEs).

Step 1: EFSO samples

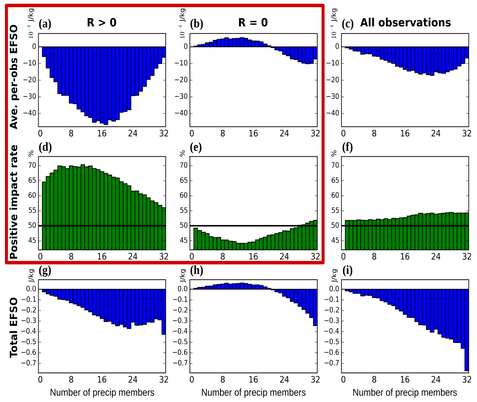


One time EFSO snapshot



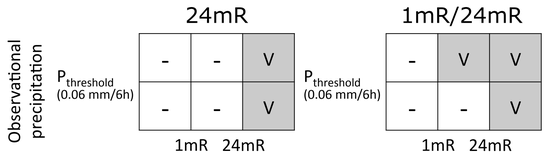
- Evaluation forecast time (EFT): 6 hours.
- Sample: Year 2008 every 30 hours (skip every 4 of 5 cycles).
  - 292 times; ~ 2.9×10^6 samples are obtained.

Step 2: EFSO statistics

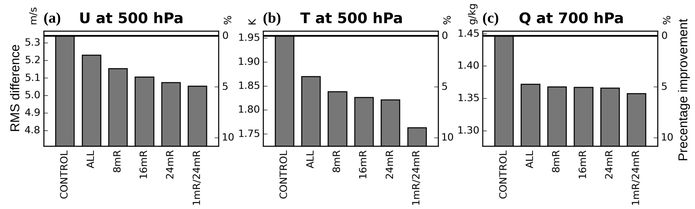


- First column (R>0 observations): The average per-obs EFSO is all beneficial, but it is most beneficial when about half of the ensemble forecasts are precipitating. The percentage of the beneficial observations are very high.
- Second column (R=0 observations): When the number of precipitating members is less than 20, assimilating the R=0 observations has a detrimental effect. It only becomes beneficial when most of the ensemble members are (wrongly) precipitating.

Step 3: OSE for verification



Average 24-h forecast errors



1mR/24mR: The best result we obtained based on the EFSO guidance.

Summary

- The NASA's TMPA and the JAXA's GSMap satellite precipitation data are successfully assimilated into different global models.
- The effective precipitation assimilation is achieved by: 1) the LETKF 2) Gaussian variable transformation 3) proper QC criteria.
- We demonstrate the use the EFSO to efficiently analyze the assimilation impact of precipitation data. The results are consistent with OSEs.
- This method can be easily applied to any data from new observing systems (Lien et al. 2016, in preparation).