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Ensemble-based Data Assimilation of TRMM/GPM Precipitation Measurements

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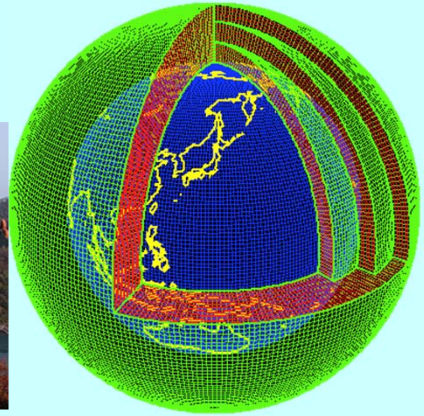
Data Assimilation (DA)

Observations

Numerical models

Data Assimilation

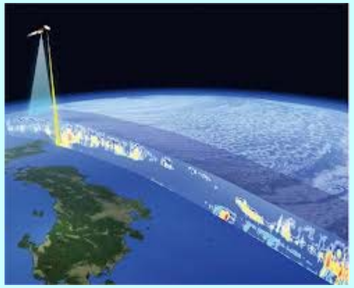


Data assimilation best combines observations and a model, and brings synergy.

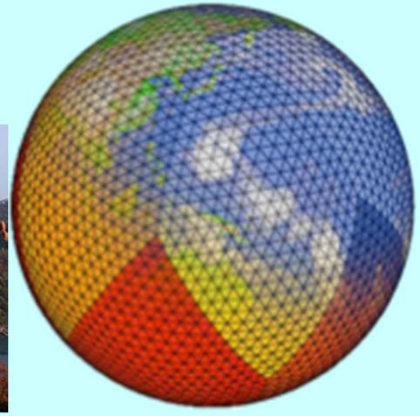
Project Overview

TRMM/GPM

NICAM



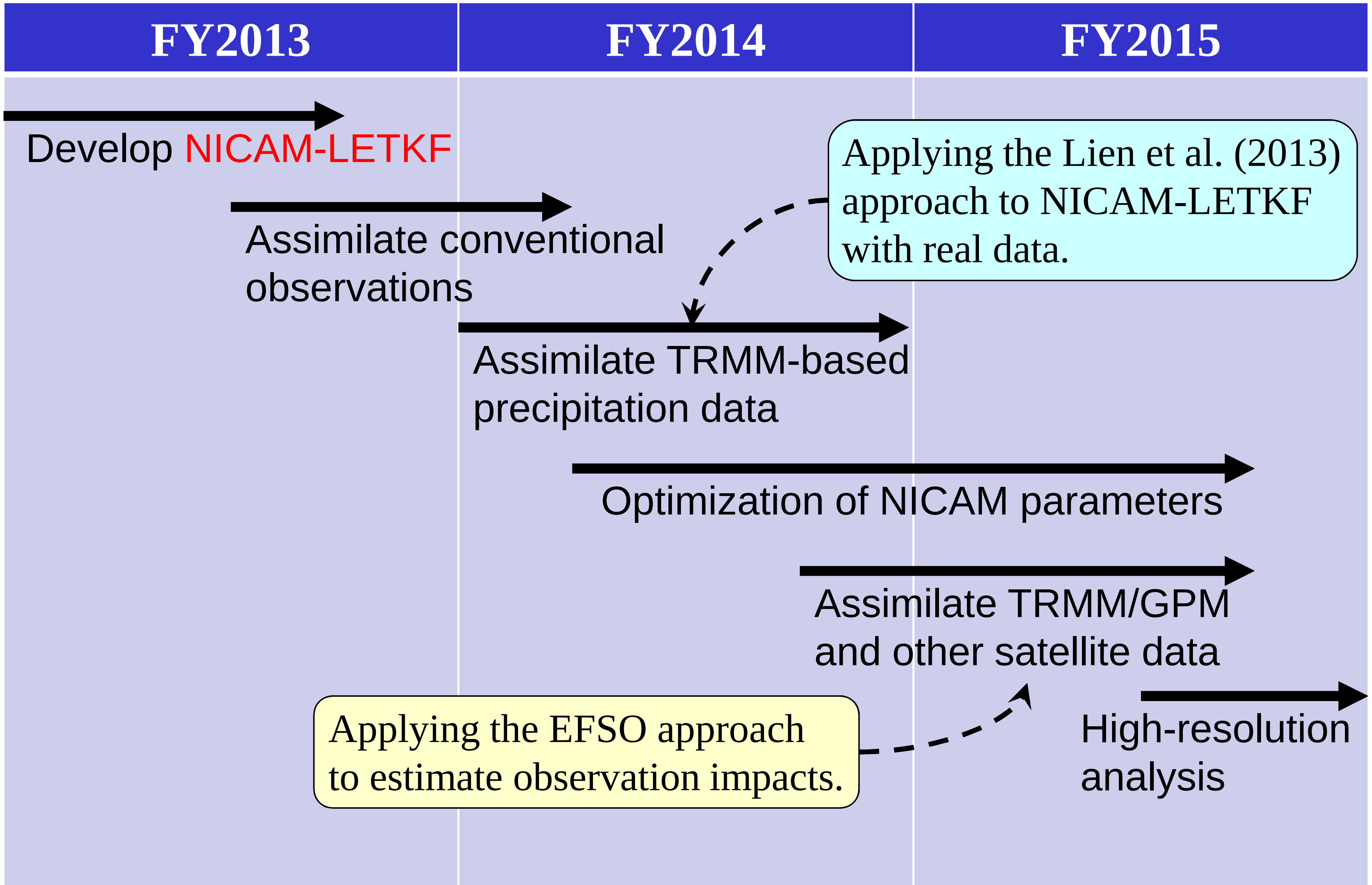
LETKF



Local Ensemble Transform Kalman Filter
(Hunt et al. 2007)

Goal: Look for most effective use of TRMM/GPM precipitation measurements.

Research plans

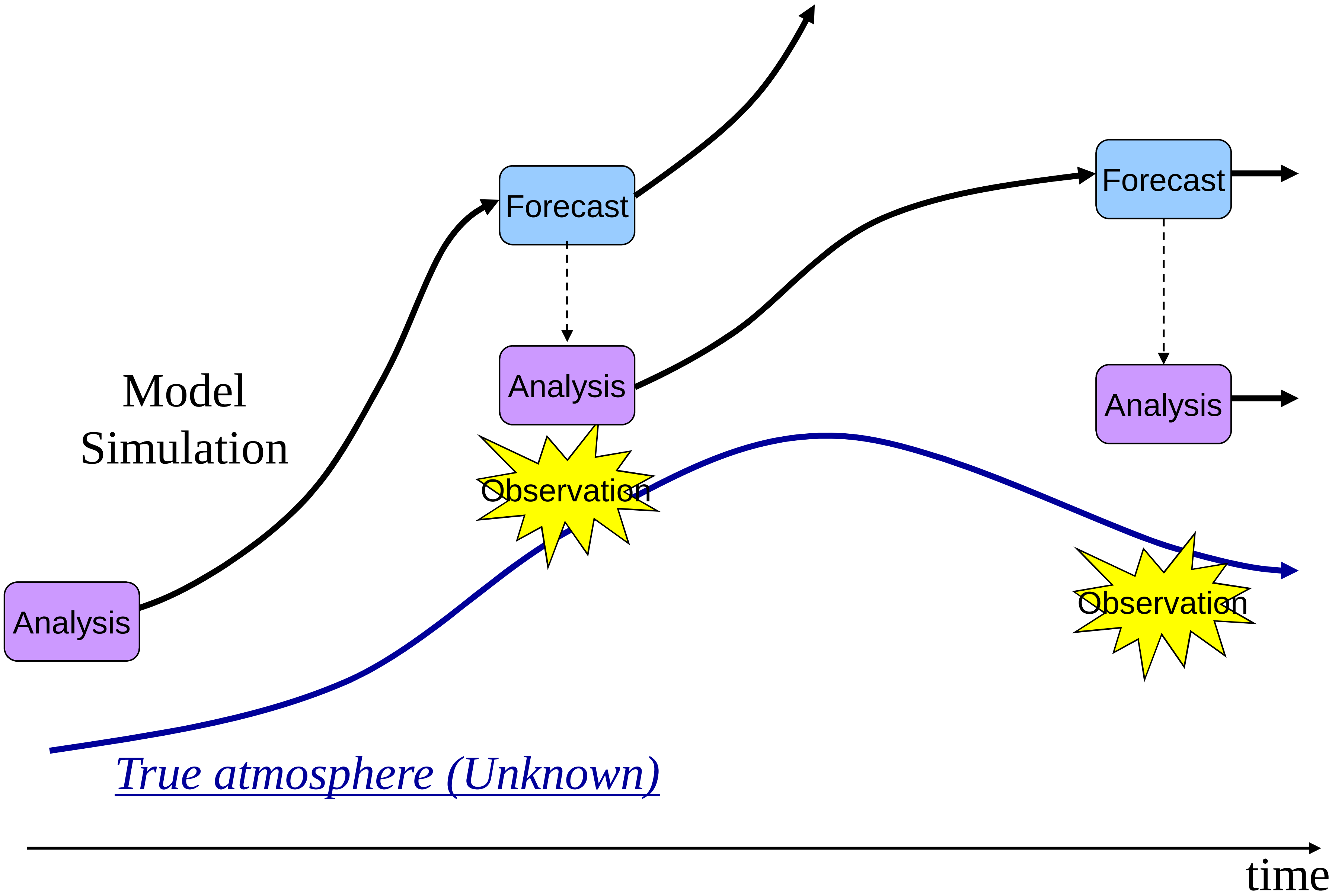


FY2013 List of Achievements

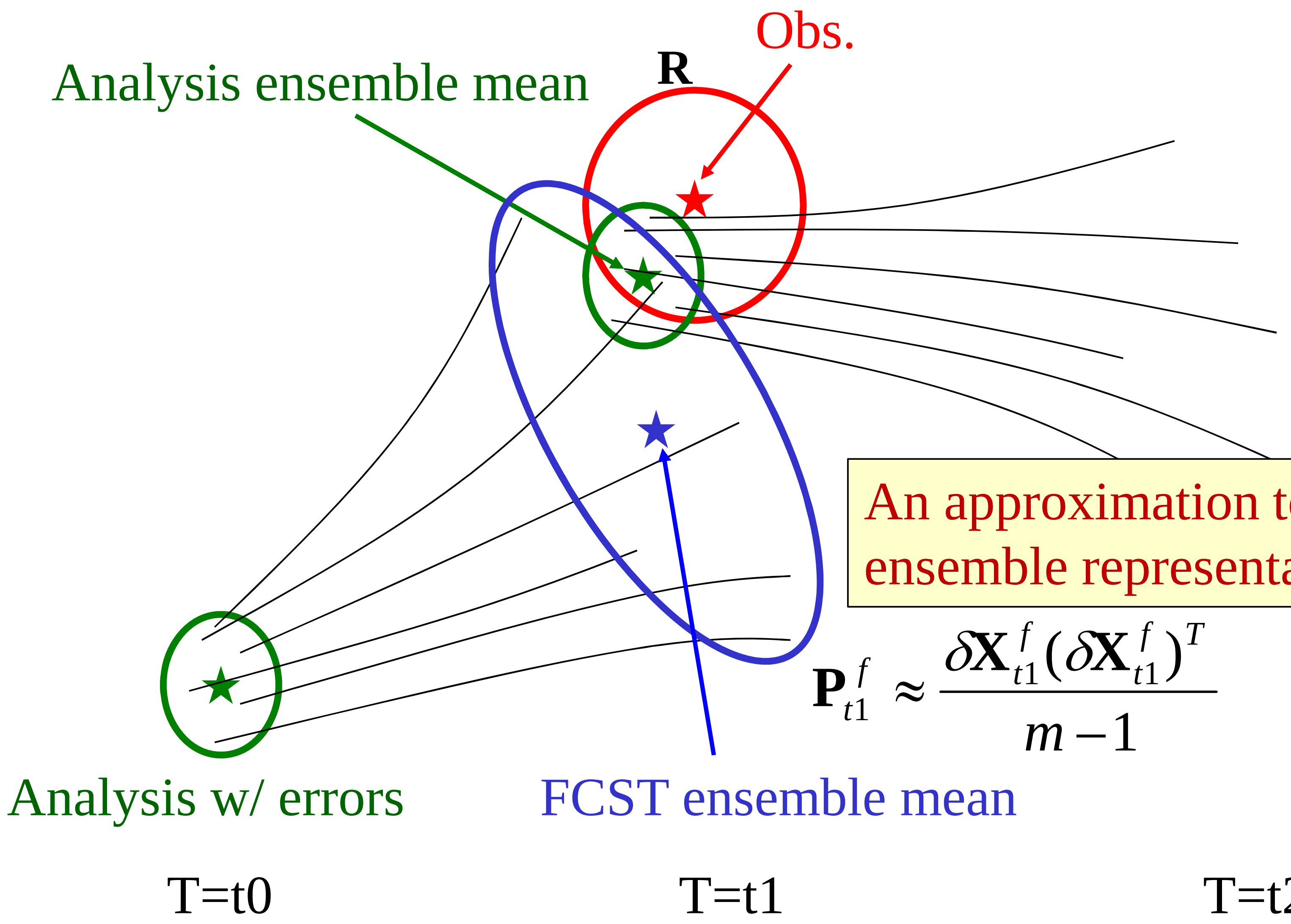
- NICAM-LETKF prototype system developed
  - Successfully tested with perfect-model OSSEs
- Real observations successfully assimilated
  - NCEP PREPBUFR
  - Reasonable performance with Glevel-6 (112 km) and Glevel-7 (56 km) resolutions
- Precipitation assimilation methodology explored **(U. Maryland)**
  - A conceptual paper published (***Lien et al. 2013***)
  - TRMM-based precipitation product (TMPA) successfully assimilated with GFS-LETKF

NICAM-LETKF

Numerical Weather Prediction (NWP)



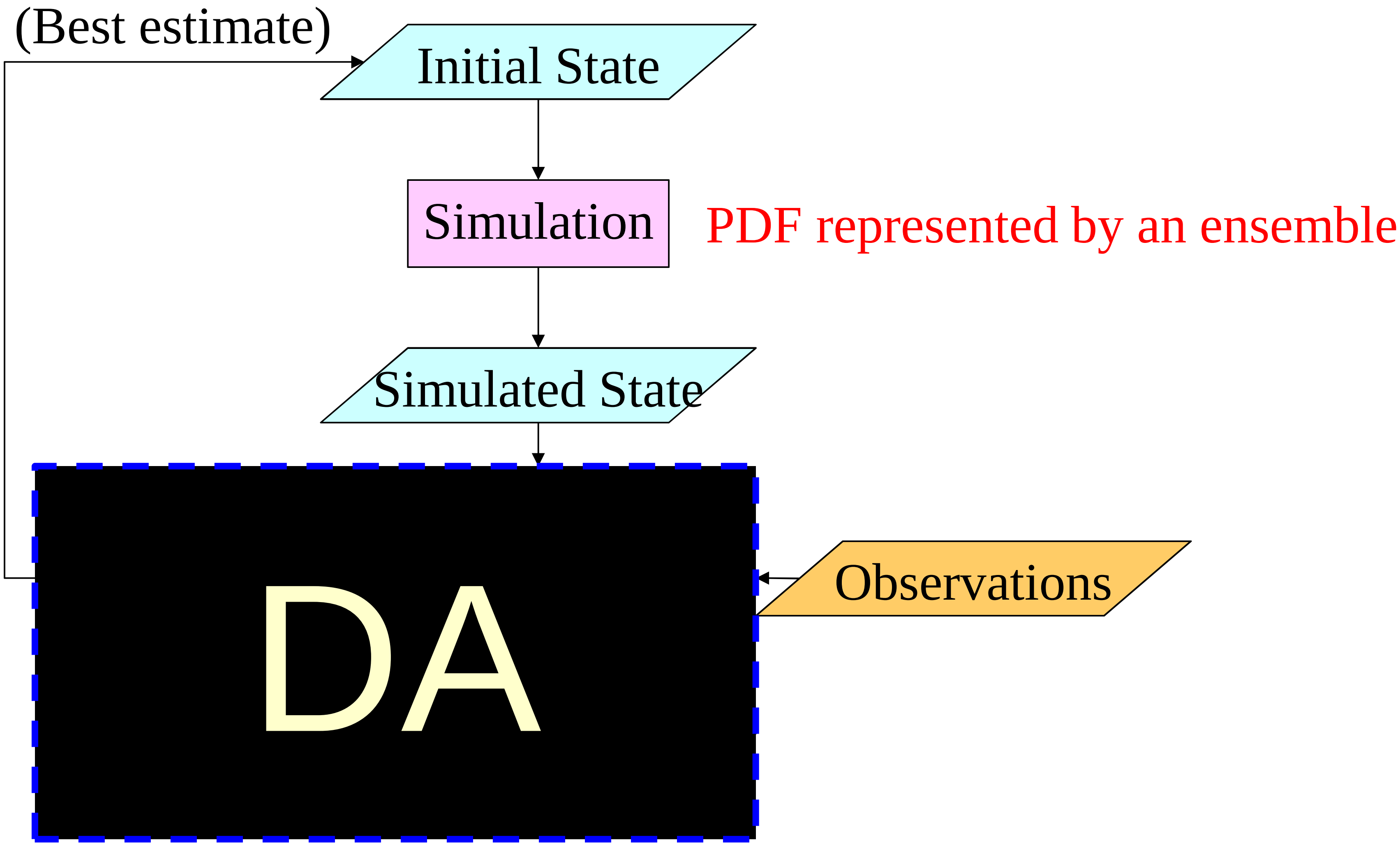
We consider the evolution of PDF



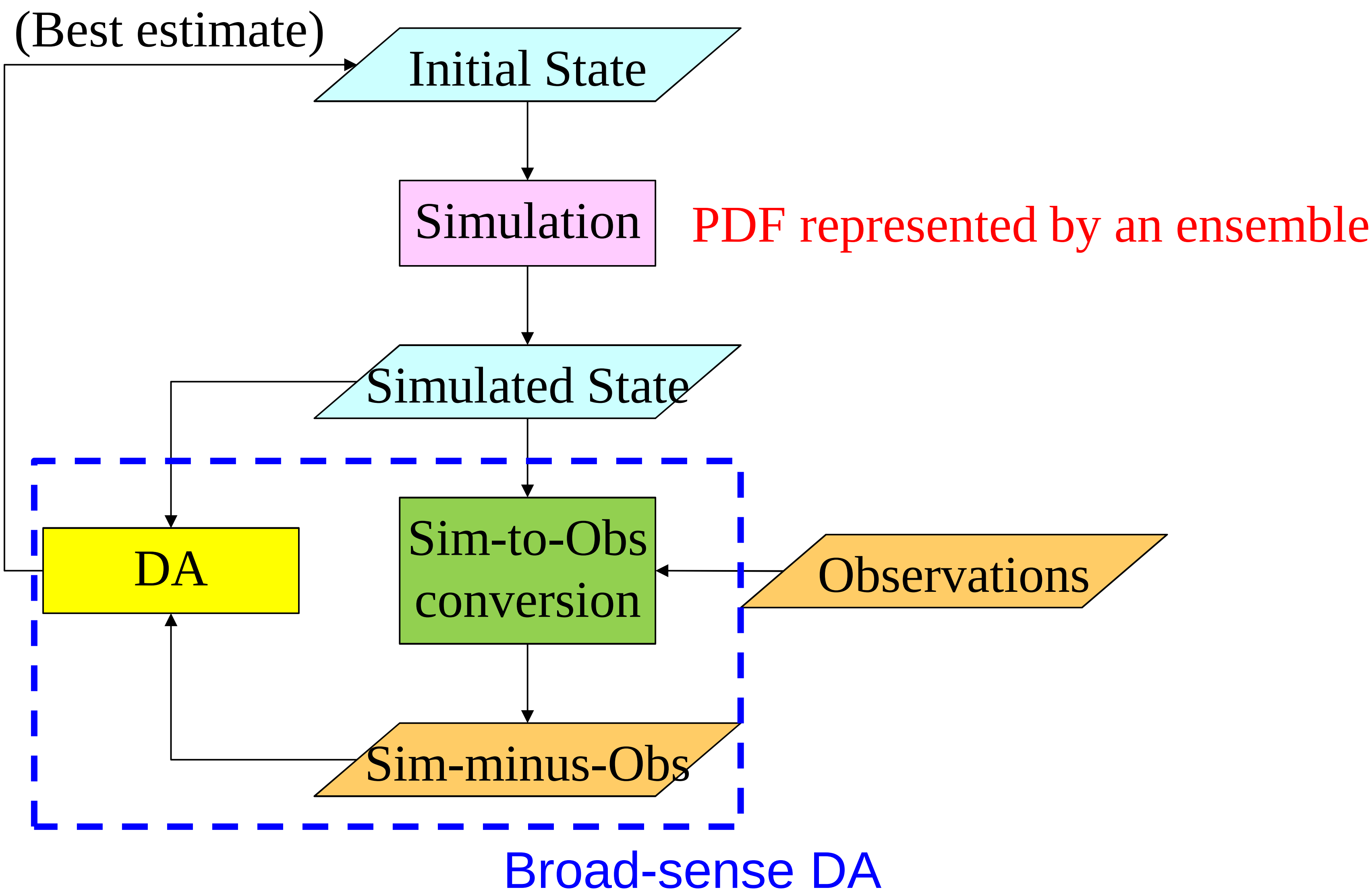
An approximation to KF with ensemble representations

$$\mathbf{P}_{t1}^{f} \approx \frac{\delta \mathbf{X}_{t1}^{f} (\delta \mathbf{X}_{t1}^{f})^{T}}{m-1}$$

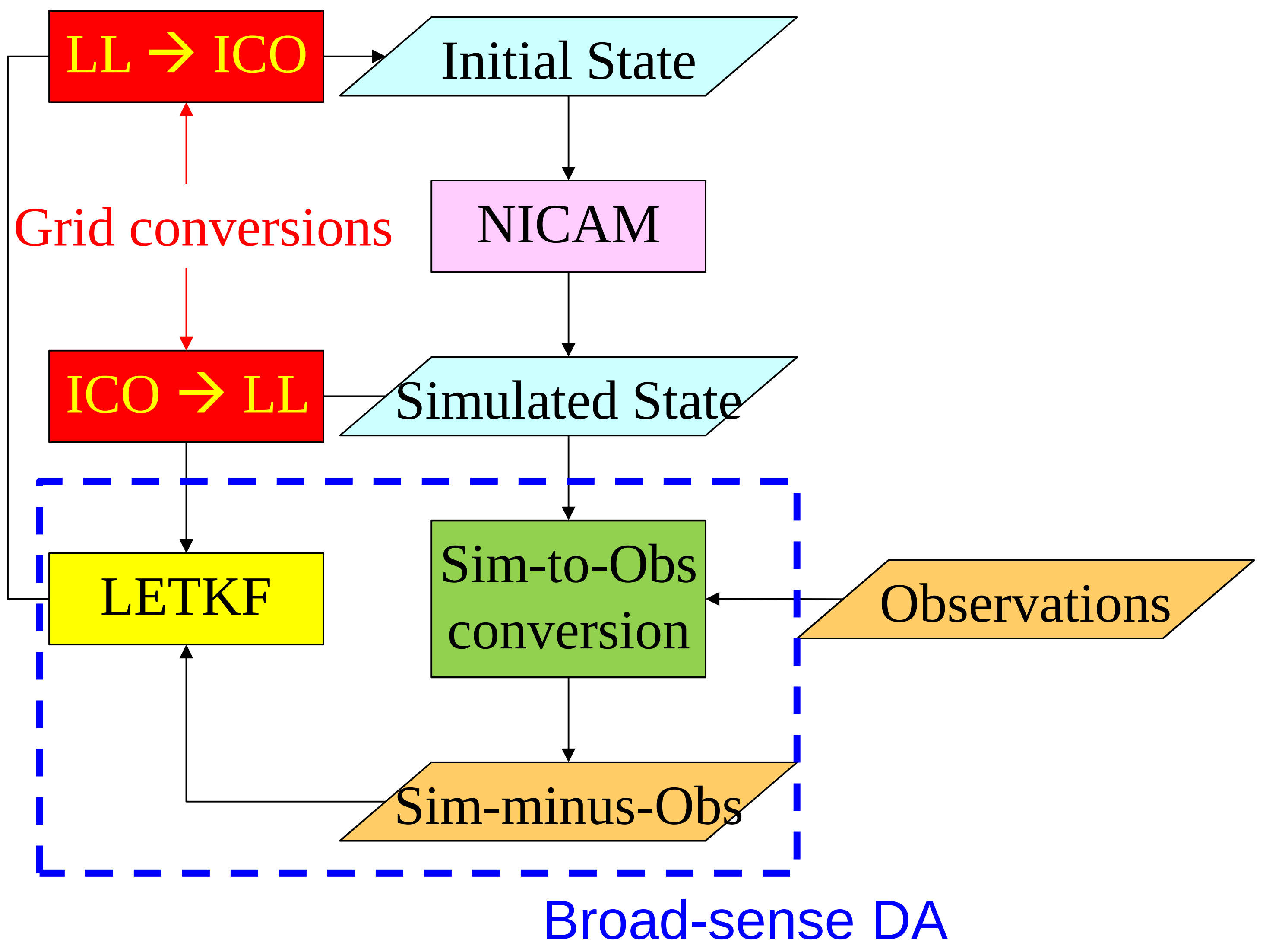
Flow chart of DA



Flow chart of DA

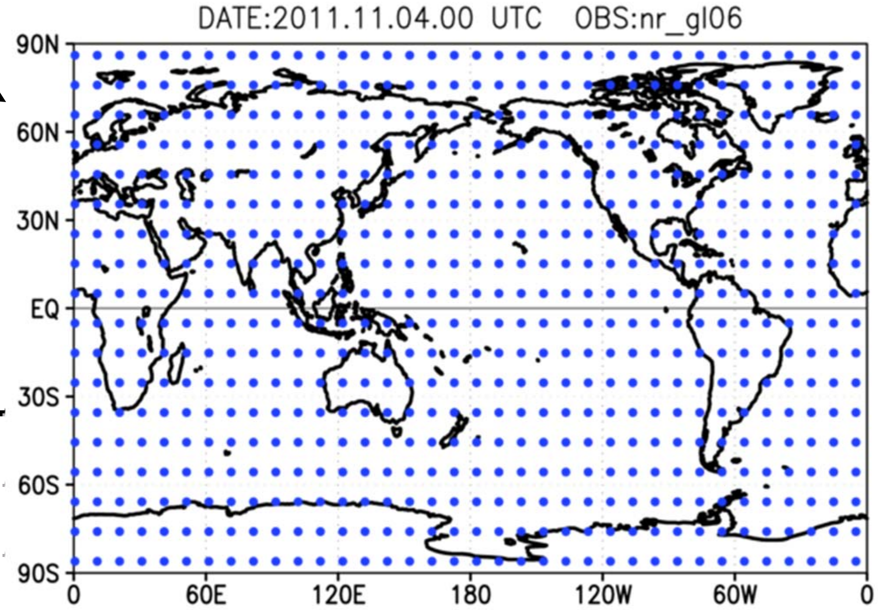


NICAM-LETKF Prototype

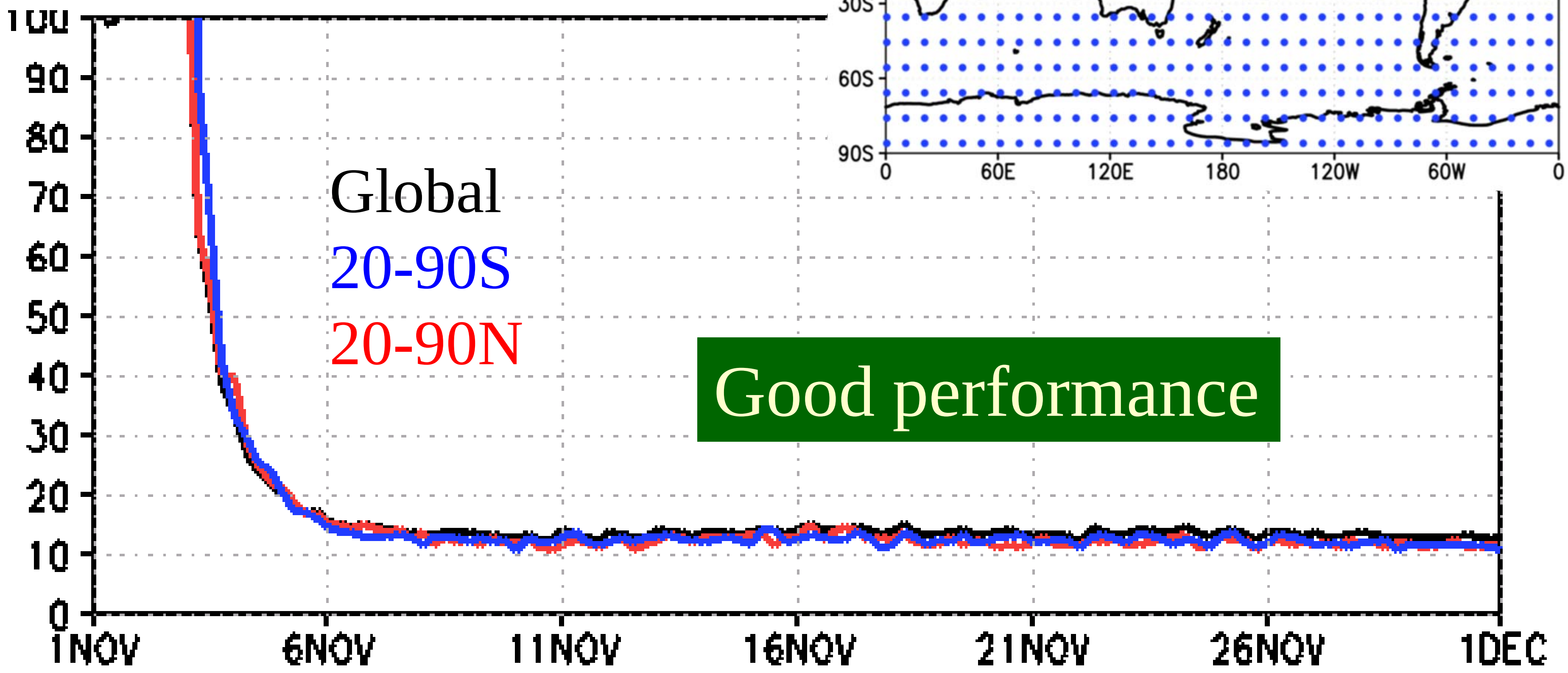


Results from perfect-model OSSE

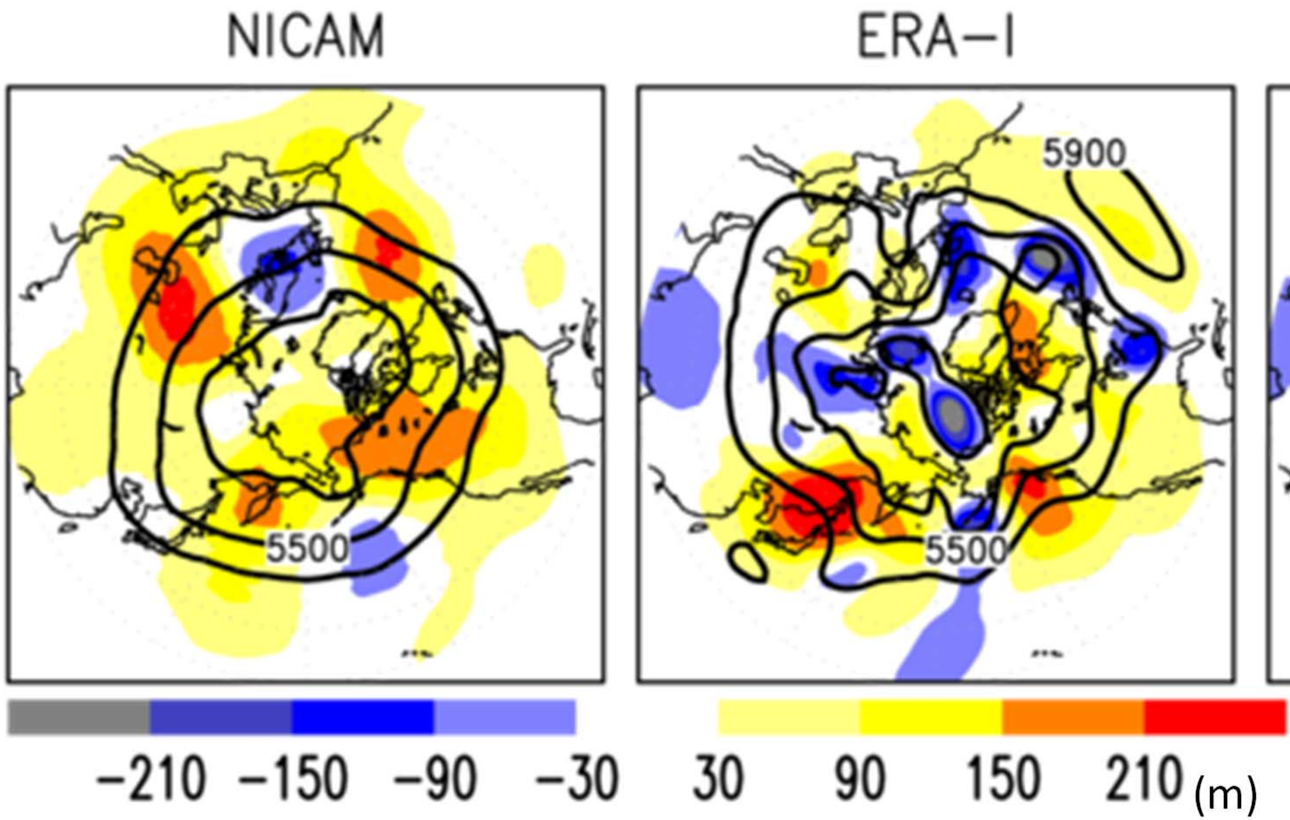
Observing network



500-hPa Height RMSE (m)



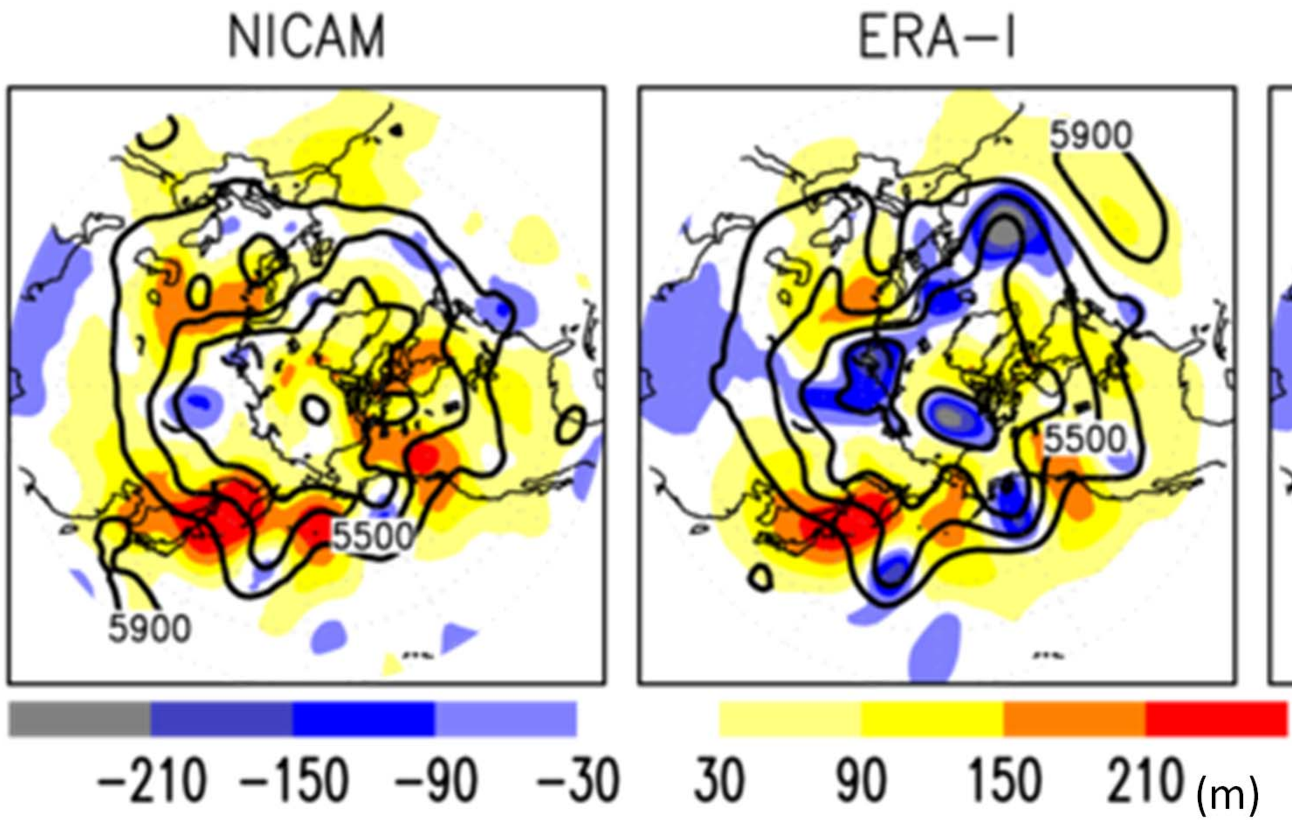
With real observations (Initial: Day 0)



2011/11/01 00UTC
Initial time (Day 0)

Lat: 20-90N

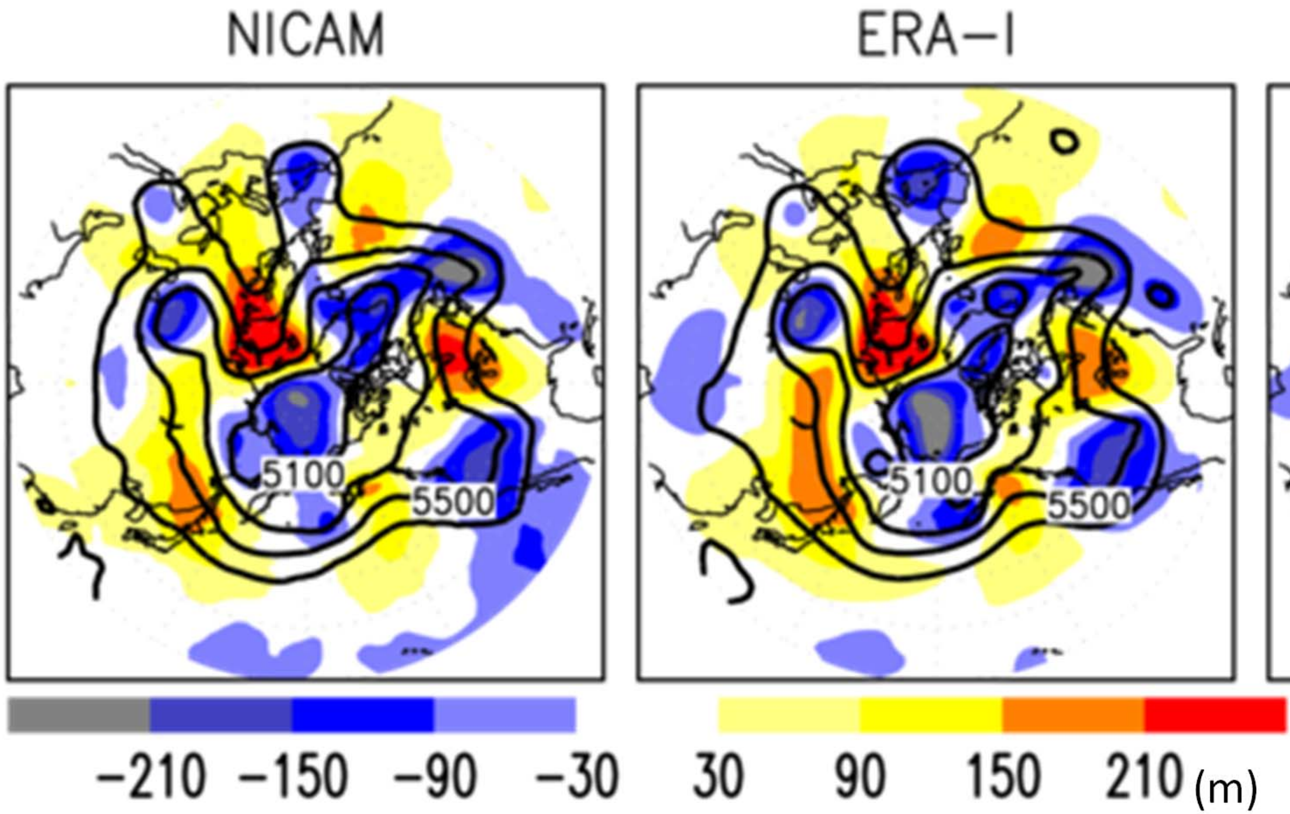
With real observations (Day 1)



2011/11/02 00UTC
Day 1

Lat: 20-90N

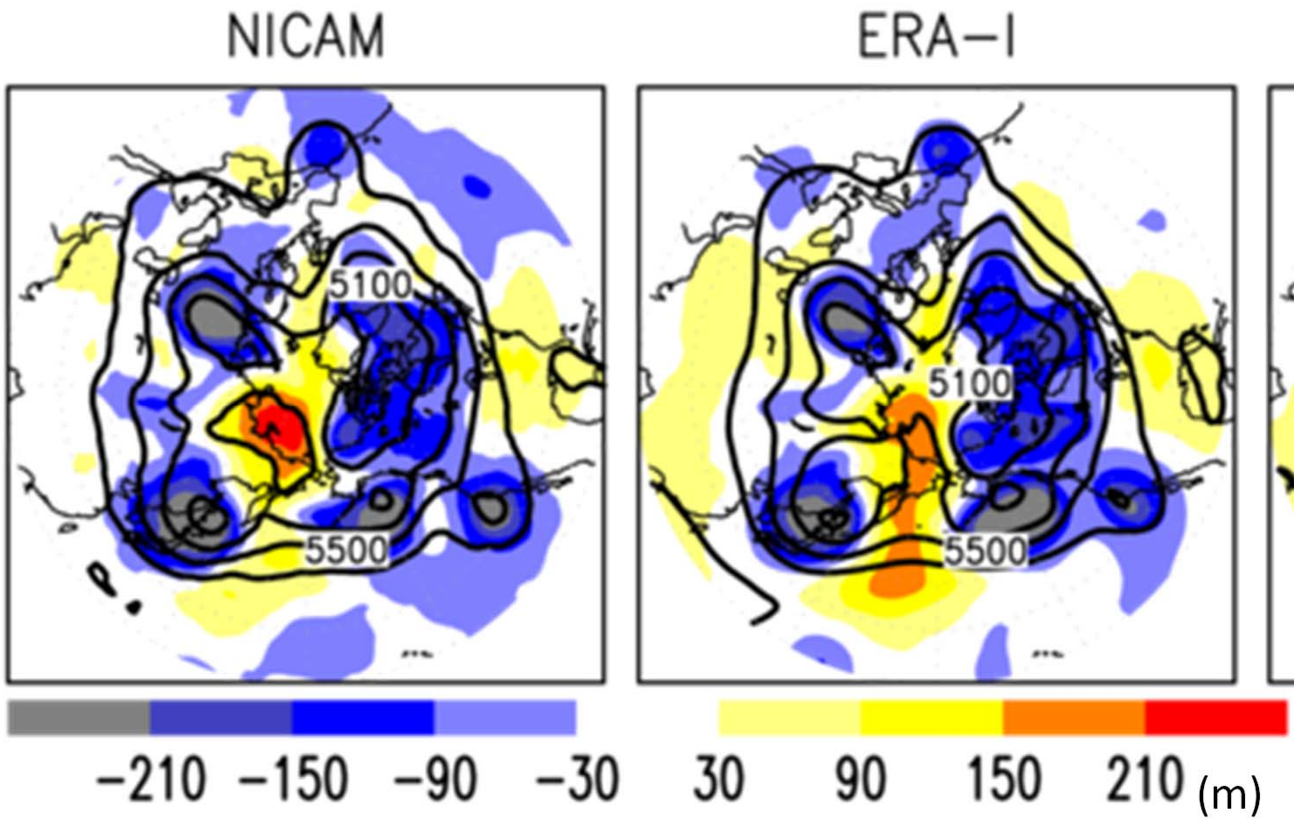
With real observations (Day 5)



2011/11/06 00UTC
Day 5

Lat: 20-90N

With real observations (Day 20)



2011/11/21 00UTC
Day 20

Lat: 20-90N

LETKF analysis is more suitable to NICAM.

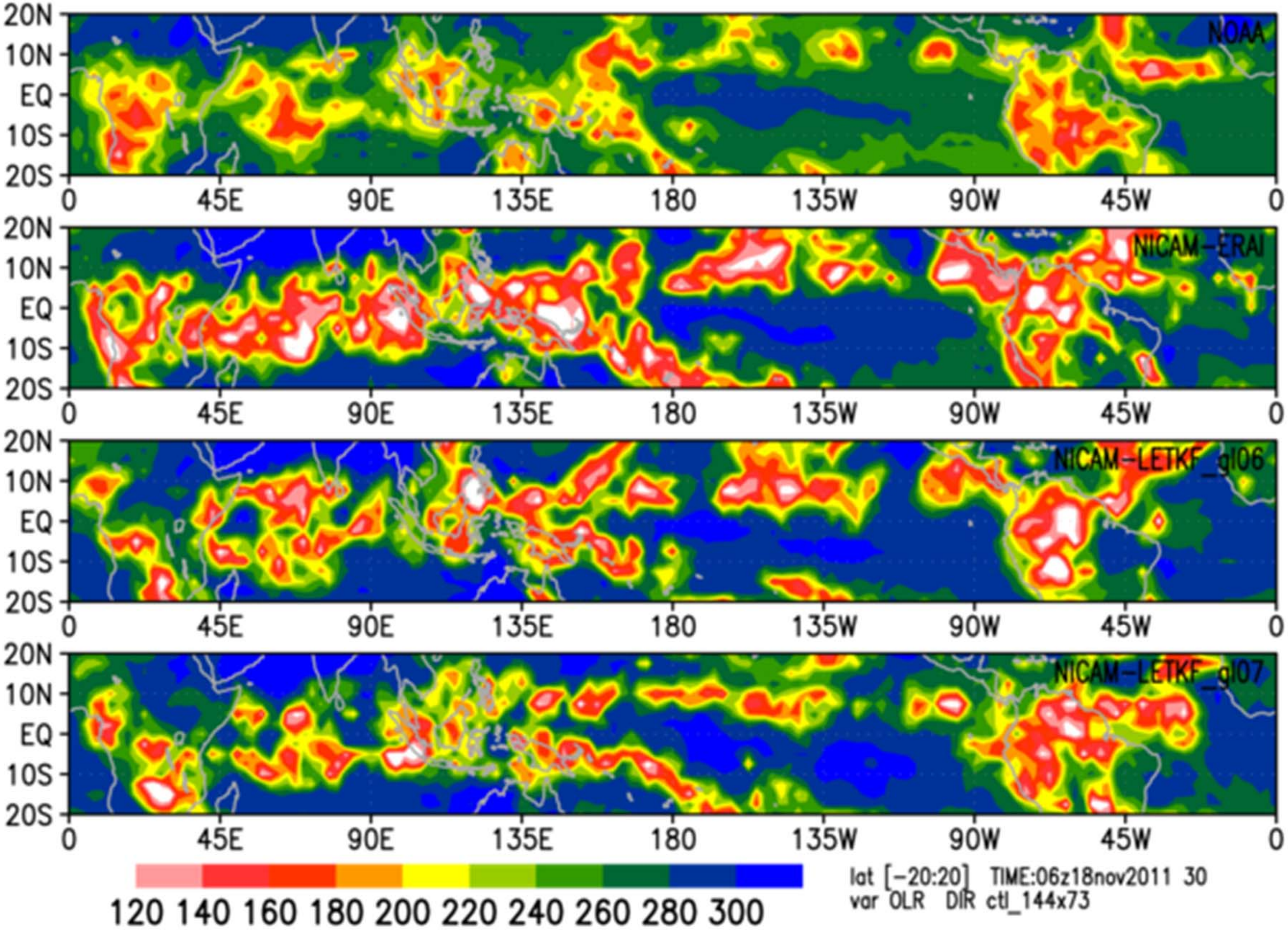
gl9 (14km) 30-h forecast OLR showing NICAM's spin-up

NOAA Analysis

NICAM initialized by ERA-I

LETKF -gl6 (112km)

LETKF -gl7 (56km)



PRECIP ASSIMILATION

Challenges of precip. assimilation

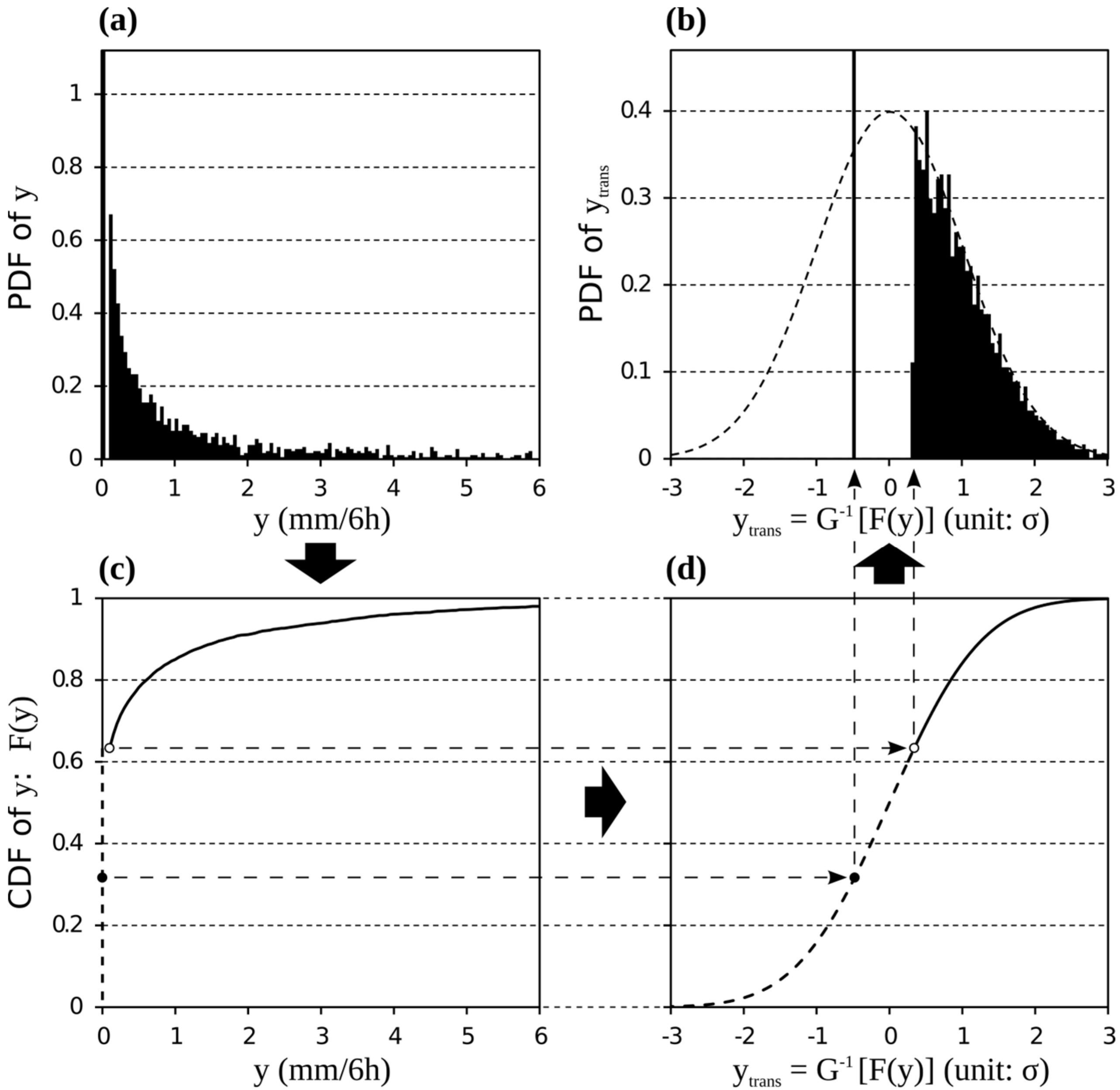
- Previous studies (e.g., *Tsuyuki 1996*; *Mesinger et al. 2006*) succeeded in forcing the model precipitation to be close to the observed values.
- However, the model forecasts tend to lose their additional skill after a few forecast hours.
- Major difficulties (*Bauer et al. 2011*):
    1. Linear representation of moist physical processes for variational data assimilation
    2. Non-Gaussianity of precipitation variable

An approach to precip. assimilation

- Major difficulties (*Bauer et al. 2011*):
  1. Linear representation of moist physical processes for variational data assimilation
  2. Non-Gaussianity of precipitation variable
- Approach
  1. Using LETKF (or other EnKF methods) avoids linear representation of moist physics.
  2. Applying empirical Gaussian transformation
  3. Considering background PDF (requiring precipitating members)
- Lien et al. (2013) tested the approach and obtained promising results.

Lien, G.-Y., E. Kalnay, and T. Miyoshi, 2013: Effective Assimilation of Global Precipitation: Simulation Experiments. *Tellus*, **65A**, 11915.

Example of precipitation distribution in DJF near Maryland



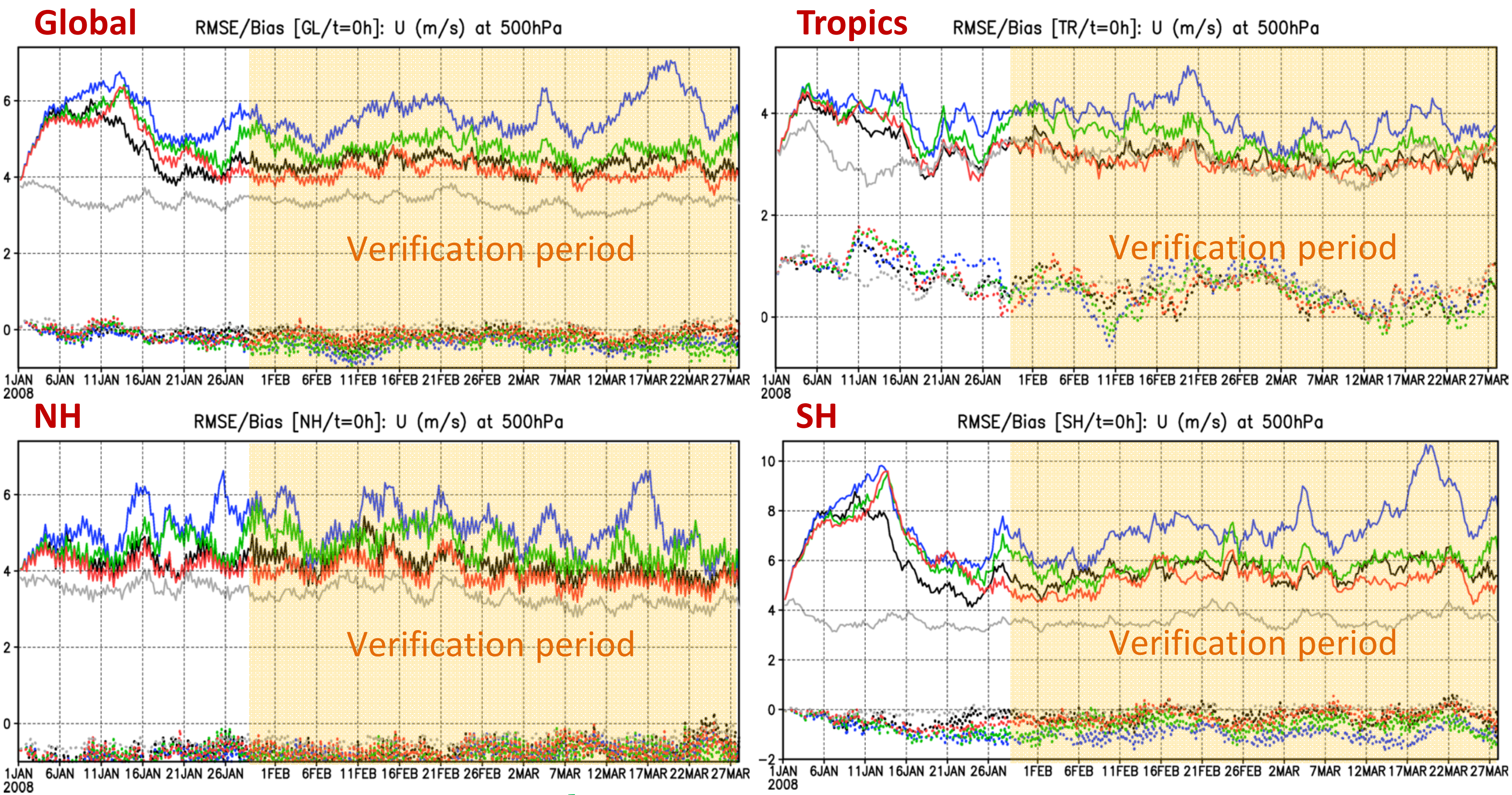
Lien et al. (2013)

Most recent results from Guo-Yuan Lien and Eugenia Kalnay

REAL TMPA AND GFS-LETKF

Lien and Kalnay succeeded in assimilating TMPA.

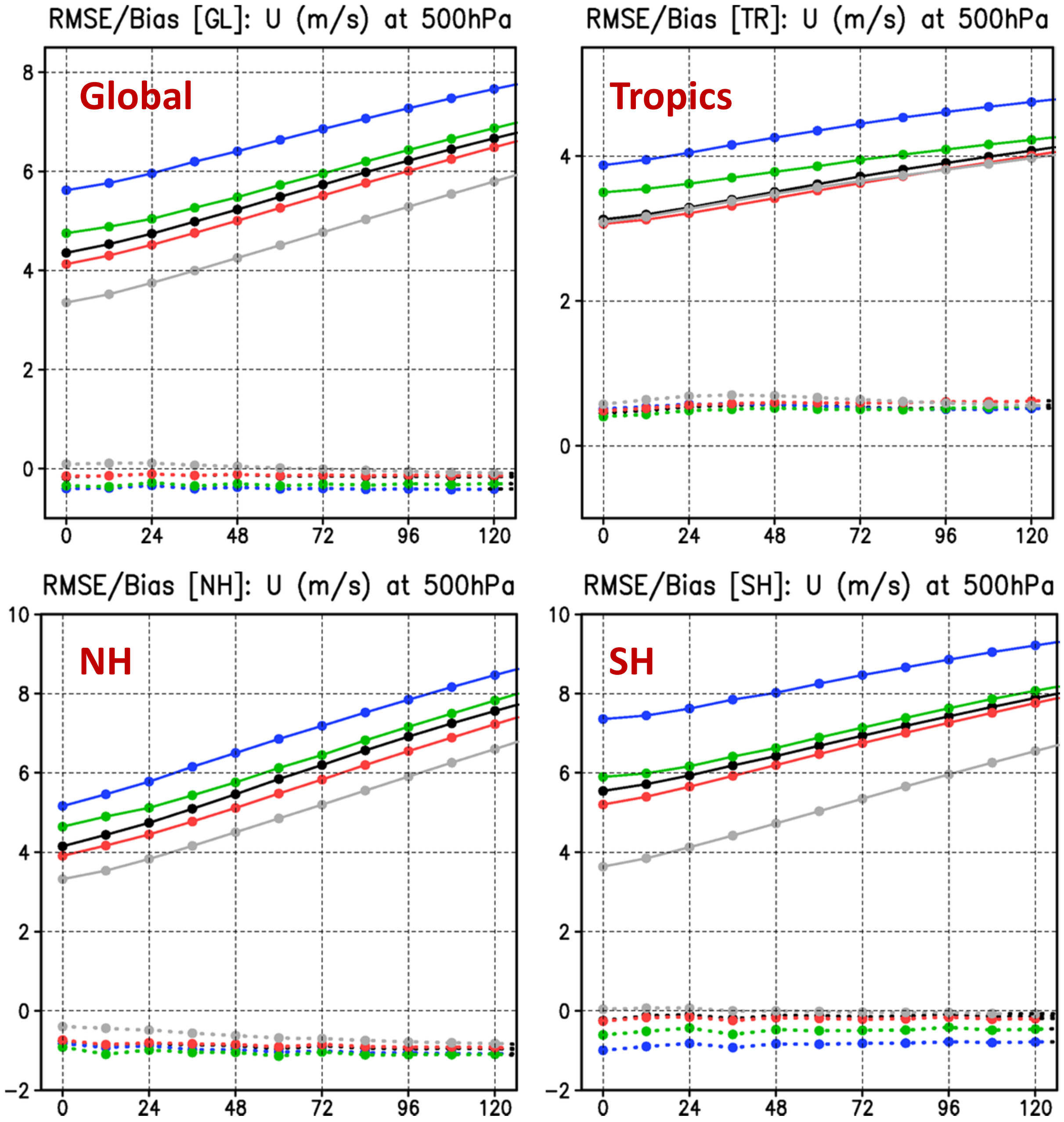
3-month time series: Analysis U (m/s) at 500 hPa, error relative to ERA-int.



Raobs
Raobs_TMPA
Raobs_TMPA_Log
Raobs_TMPA_GT
Conv

Solid lines: RMS error
Dashed lines: Bias

5-day forecasts were improved.



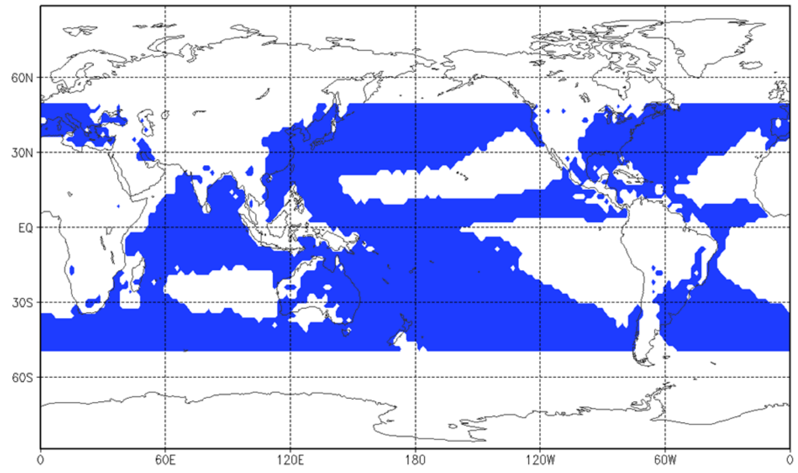
2-month average
U at 500 hPa

Solid lines: RMS error
Dashed lines: Bias

Raobs
Raobs_TMPA
Raobs_TMPA_Log
Raobs_TMPA_GT
Conv

What did we do?

- Improved QC
  - Corr[TMPA, GFS] > 0.45



  - Requiring background 24 members are raining (out of 32)

ENSEMBLE-BASED OBS IMPACT

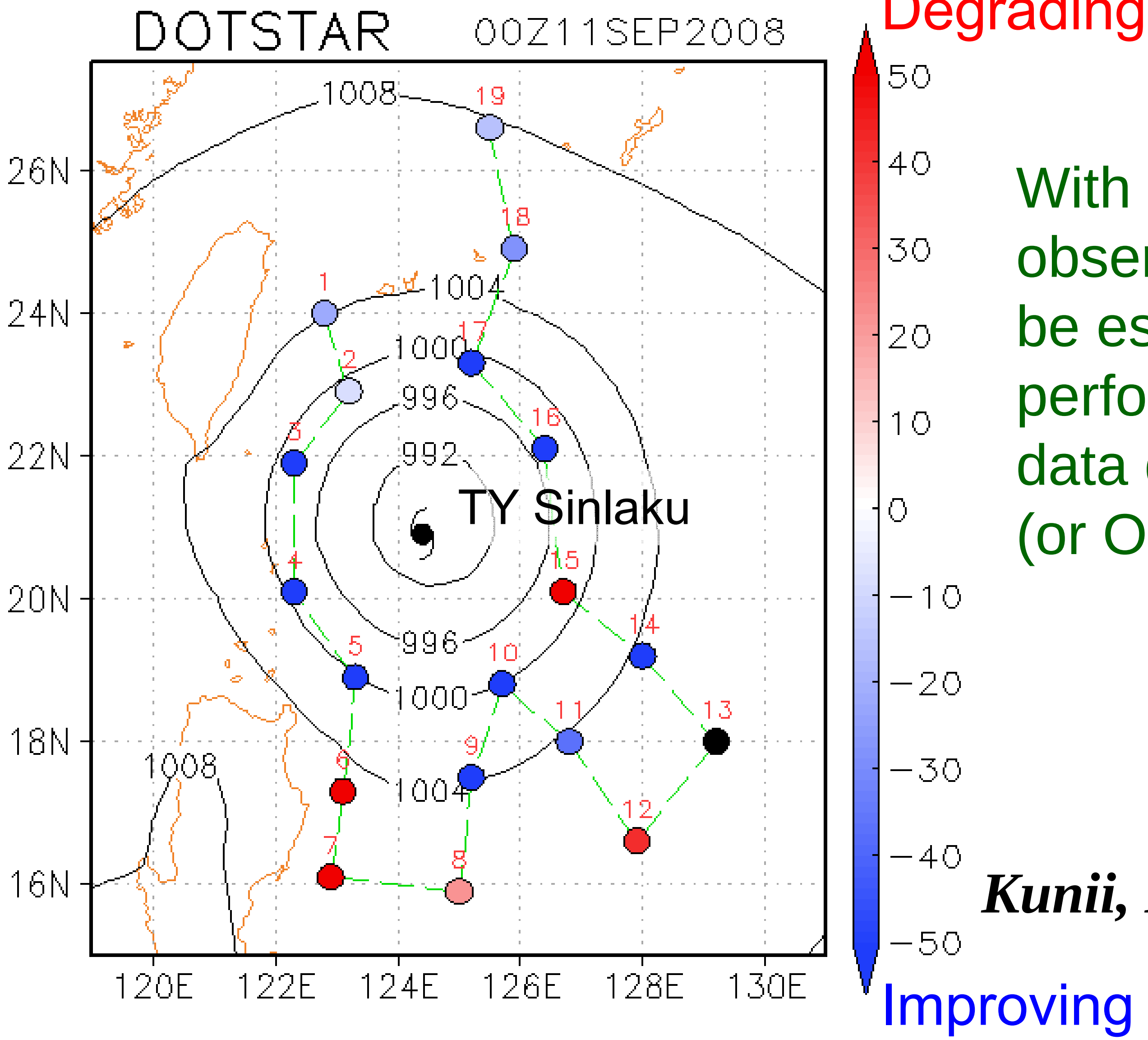
Kunii, Miyoshi and Kalnay (2012, *Mon. Wea. Rev.*)

Kalnay, Ota, Miyoshi and Liu (2012, *Tellus*)

Ota, Kalnay, Miyoshi and Derber (2013, *Tellus*)

Forecast Sensitivity to Observations (FSO)

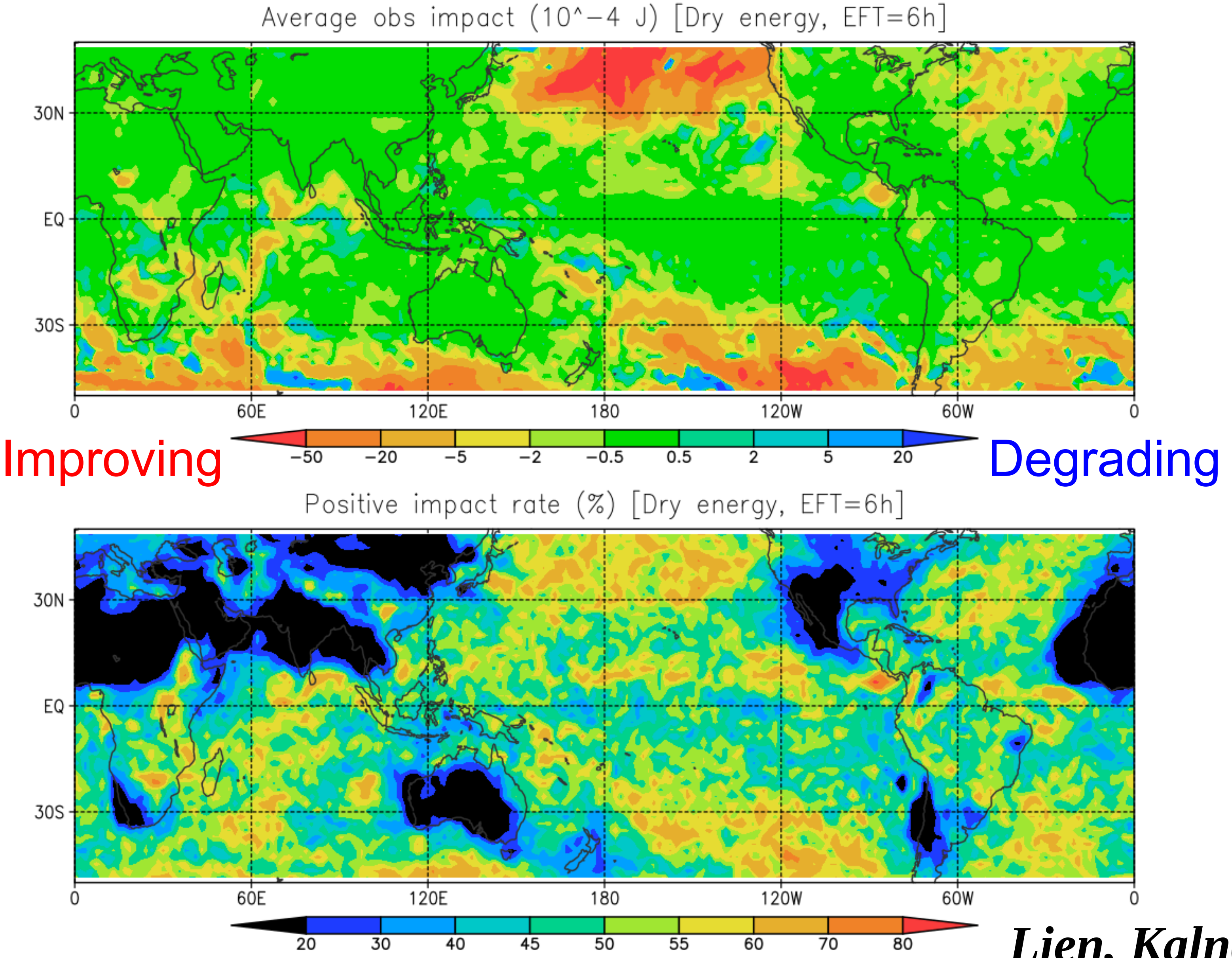
Estimated observation impact



With FSO approaches, observation impacts can be estimated without performing expensive data denial experiments (or OSEs).

Kunii, Miyoshi, Kalnay (2012)

Impact of TMPA on GFS forecasts



Lien, Kalnay (2014)

Research plans