Local Ensemble Transform Kalman Filter Experiments with the NCEP Global Numerical Weather Prediction Model

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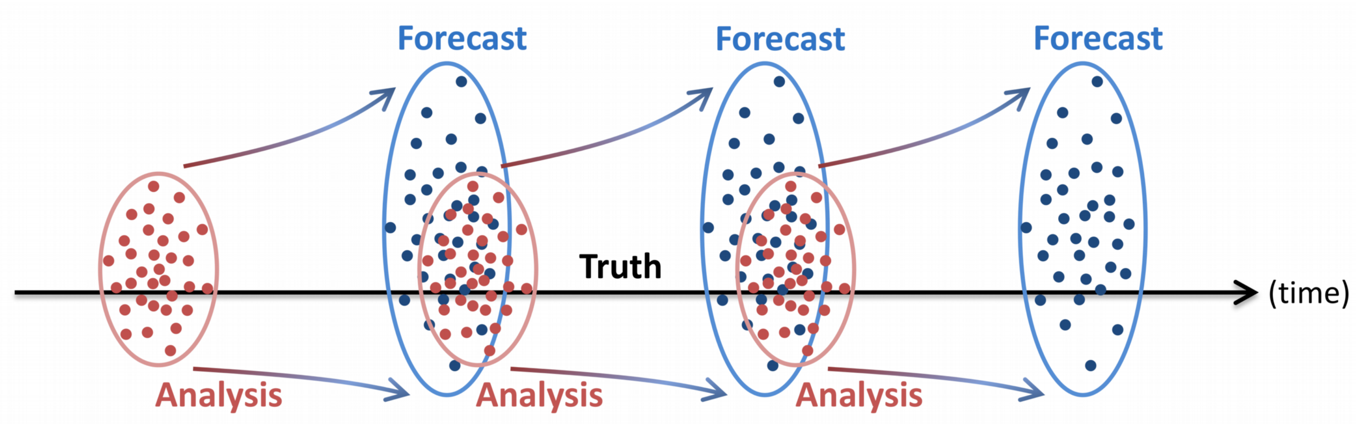
Introduction

- The Local Ensemble Transform Kalman Filter (LETKF) is an ensemble Kalman filter (EnKF) data assimilation scheme that performs the computations in ensemble space and in each local domain.
  - An efficient and accurate data assimilation algorithm.
  - Flow-dependent background error covariance.
- The core code of LETKF has been coupled with several atmospheric and oceanic models and satisfactory performance has been delivered.
  - SPEEDY model (Miyoshi 2005) / SPEEDY-C model (Kang et al. 2011, 2012)
  - WRF model (Miyoshi and Kunii 2012; Yang et al. 2012)
  - GFS model (Szunyogh et al. 2008)
  - Earth simulator (Miyoshi and Yamane 2007)
  - Mars model (Greybush et al. 2012)

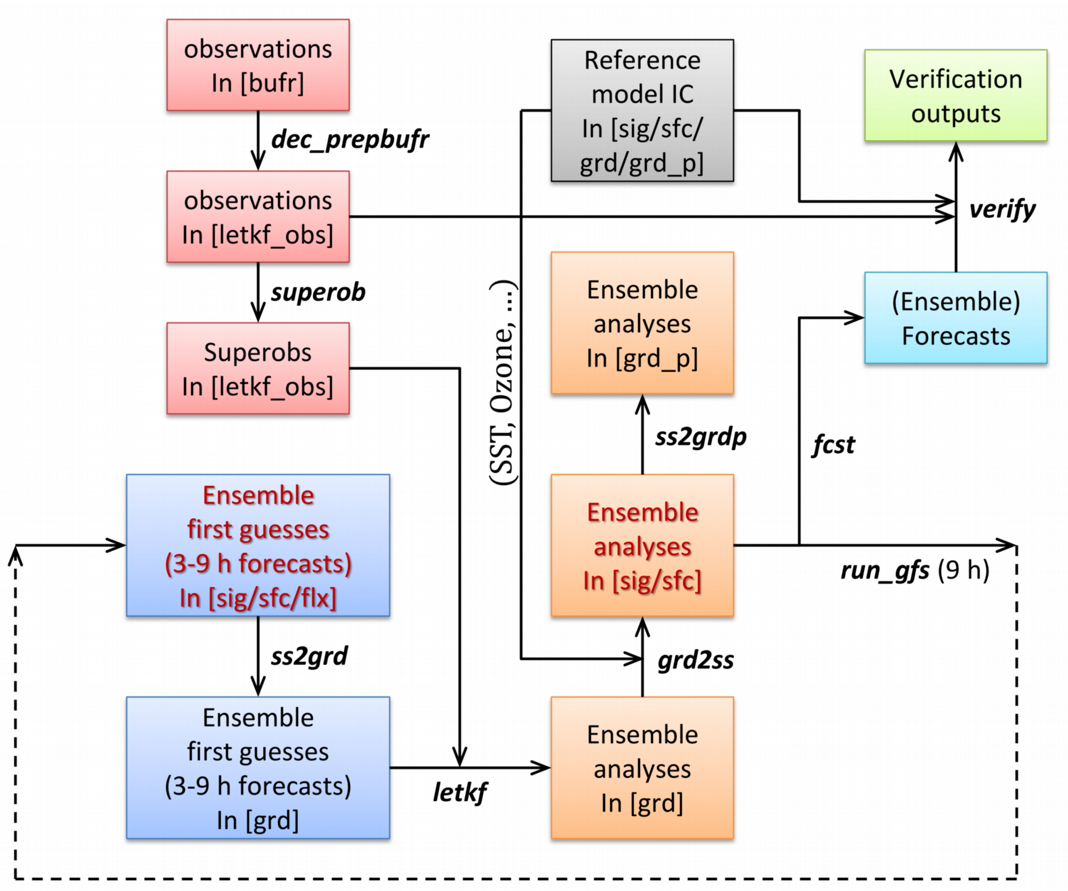
Ensemble Kalman filter



System design

- Model: National Centers for Environmental Prediction (NCEP) Global Forecasting System (GFS) model.
  - Resolution: T62L64.
- Observation data: NCEP PREPBUFR.
  - Contains all types of conventional observations.
  - No radiance data.
- Four-dimensional LETKF (4D-LETKF).
  - Assimilate observations within 3-9 forecast hours.
- Reference model initial condition: NCEP Climate Forecast System Reanalysis (CFSR).

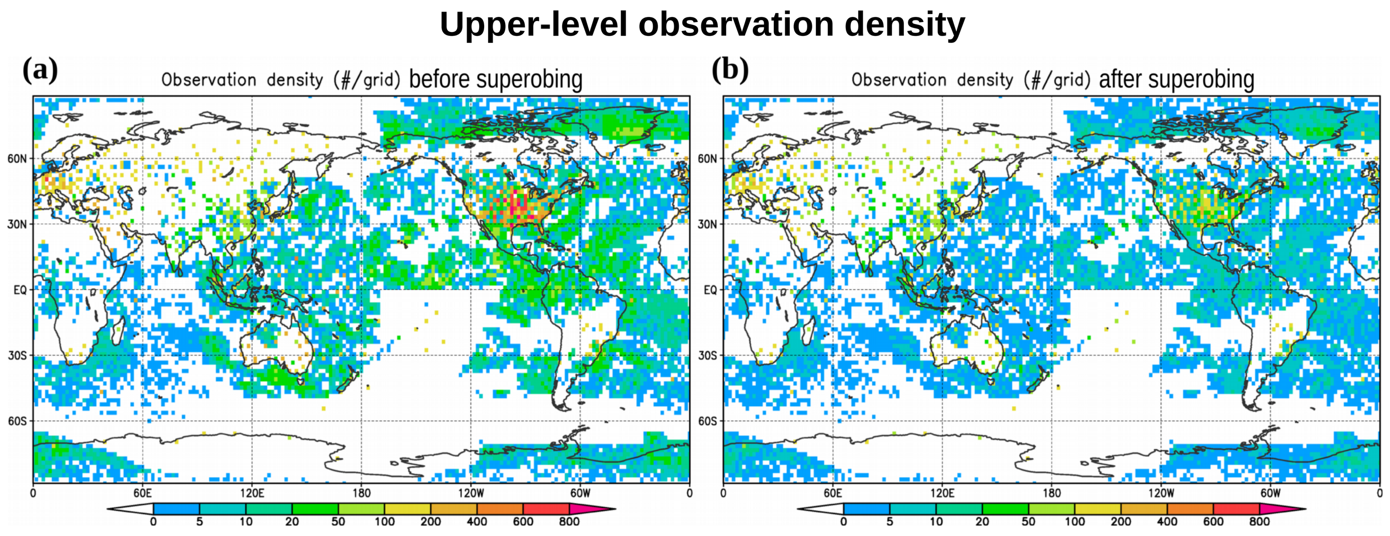
Flow chart



Superobing / Thinning

- The original PREPBUFR data are extremely dense in some particular locations, such as the continental United States and the Europe.
- Main idea: keep at most only one observation per (3-D) model grid point/observation type/variable during one assimilation window.
  - Reduce the inflation factor due to many observations.
  - Reduce the total observation numbers by about one third.

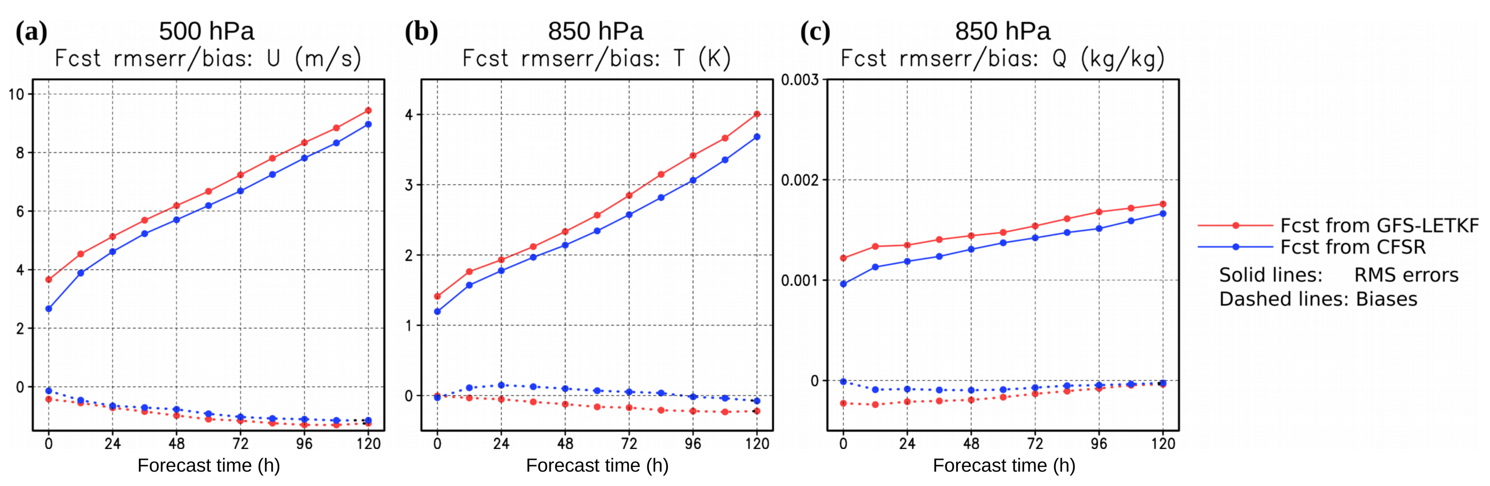
Upper-level observation density



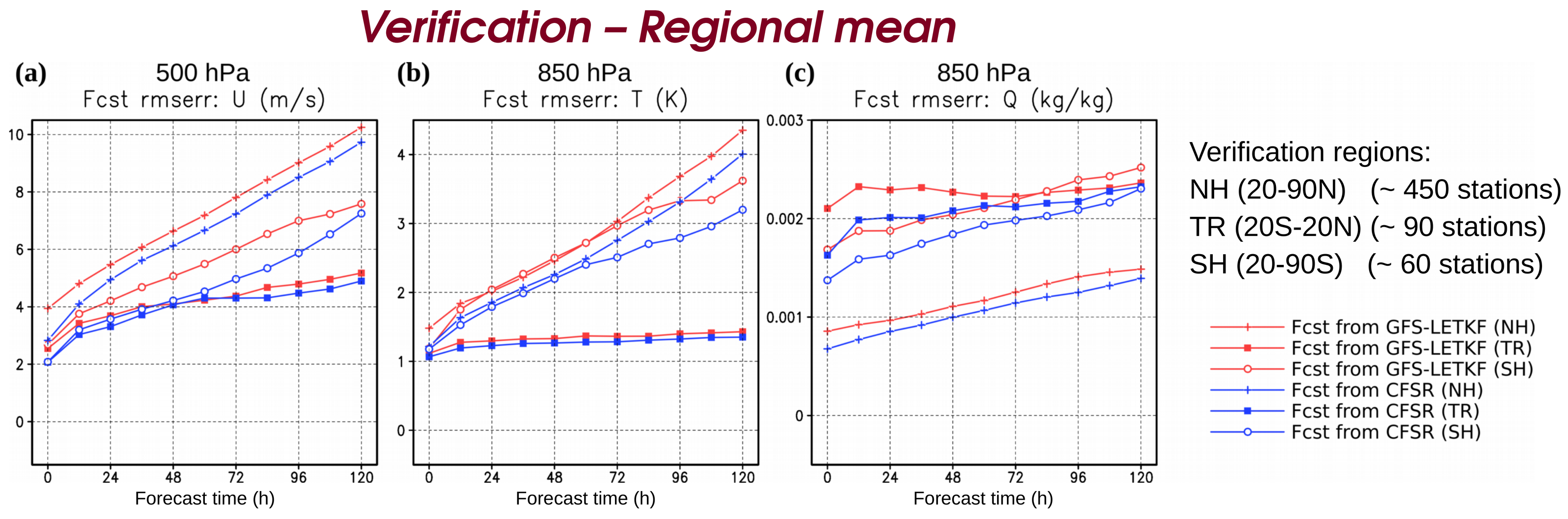
Results

- Spin up from a random initial ensemble at 01 January 2008.
- Mean analysis/forecast errors/biases verified against rawinsonde observations (~ 600 stations globally) during the 01~10 February 2008 period (10 days) are shown.
- 5-day forecasts at T62L64 every cycle.
  - Initialized from GFS-LETKF analyses.
  - Initialized from CFSR (for comparison), which uses satellite radiance data.

Verification – Global mean

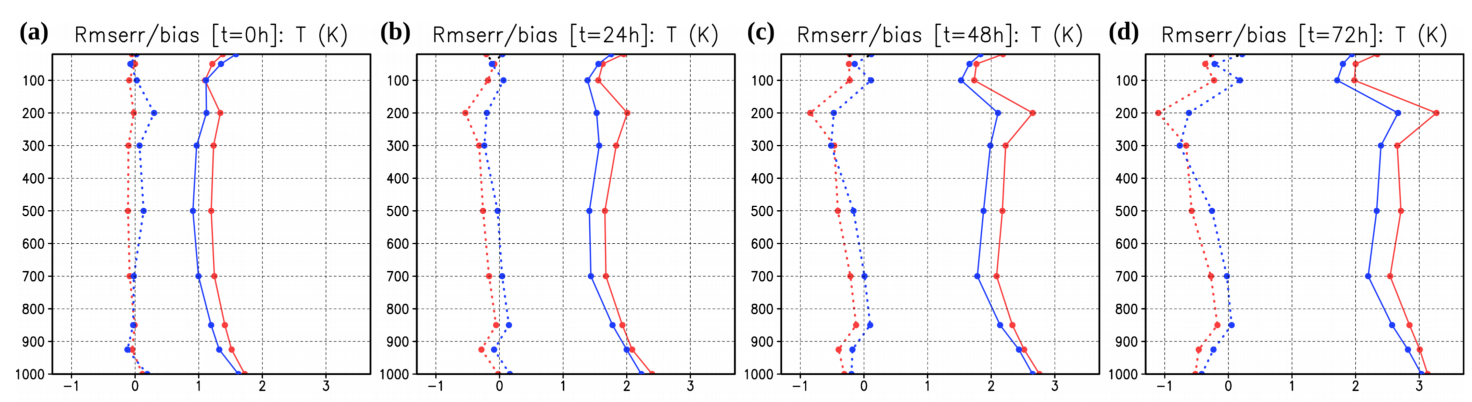


Verification – Regional mean

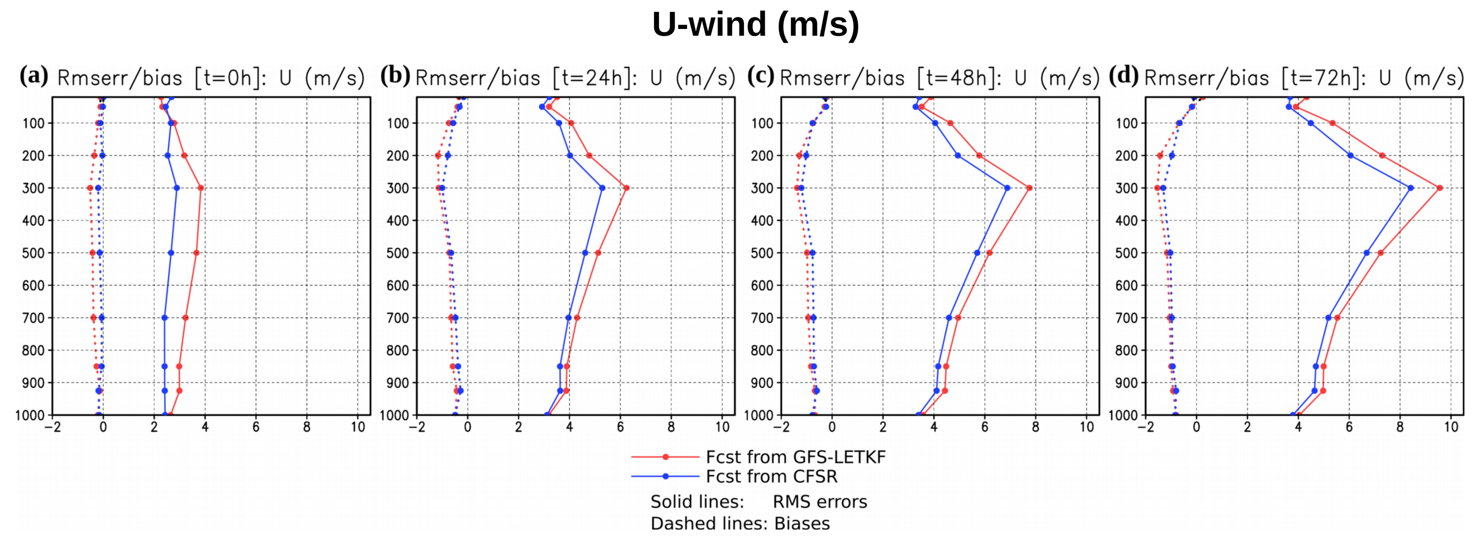


Verification – Vertical structure

Temperature (K)



U-wind (m/s)



Computational time (sec)

Nodes (processors)	Ensemble GFS forecasts	Superobing / Thinning	LETKF at 00Z, 12Z	LETKF at 06Z, 18Z	Other tasks (data conversion, IO)	Average time of one 6-h cycle
2 (16)	707	38	379	281	236	1547
4 (32)	359	37	226	166	137	886

Conclusion

- A 4D-LETKF is coupled with the NCEP GFS model.
- The system has been tested on a Linux cluster at a T62L64 resolution, assimilating real observations from NCEP PREPBUFR data.
- A resolution-dependent superobing/thinning procedure has been newly developed and is shown to be essential for the GFS-LETKF system.
- Verification results indicate that the system can reach reasonable 0-5 day forecast accuracy as compared to forecasts initialized from the CFSR using the same T62L64 GFS model.
  - The CFSR is expected to be better because it has been made with satellite radiance data and also at a much higher resolution.
- Future plan:
  - Satellite radiance data assimilation.
  - Precipitation data assimilation.