LETKF-NMMB
Hybrid EnVar-NMMB data assimilation

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How it started, motivation and idea

Verification of cloud related variables like cloud top temperature and cloud water vapor from NMMB against 6.2μm and 10.8μm satellite products gives low scores for first 12 h of forecast (Kasic and Lompar, 2015).

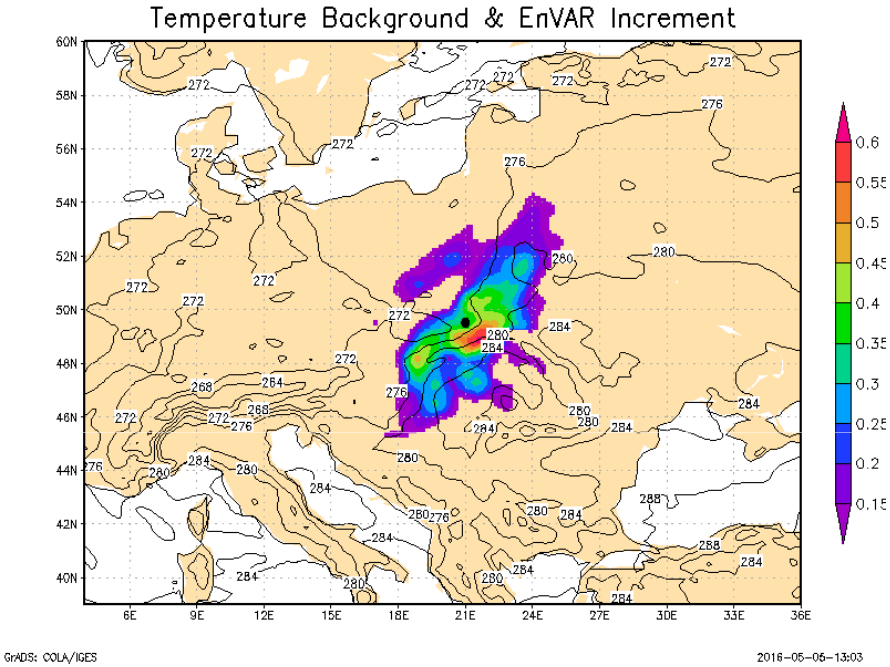
Improvement of very short forecast (first 12h) and extreme weather events of high resoultion regional model using contribution from ensemble spread.

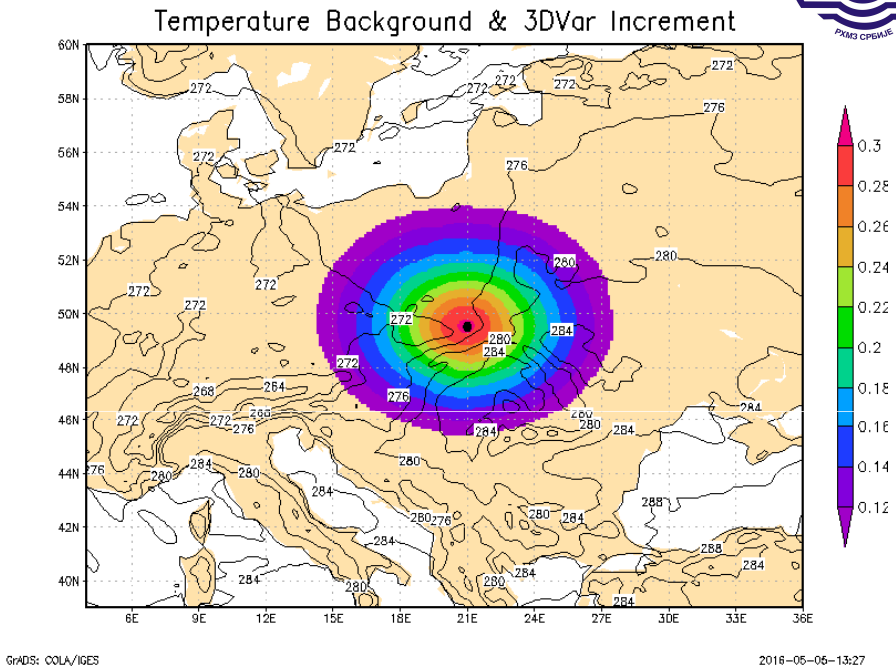
Comparison VAR vs EnKF

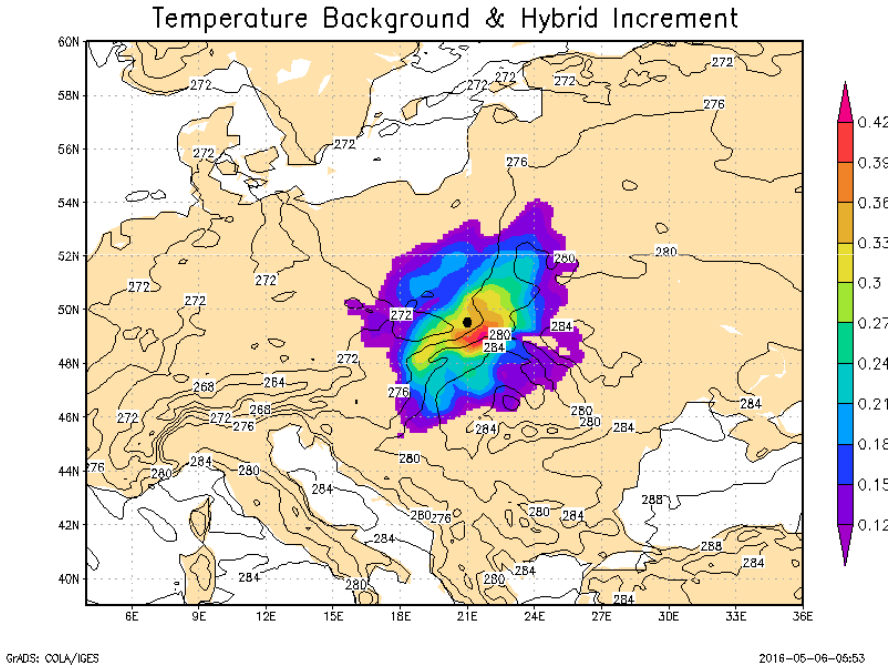
Forecast model	Predict evolution of mean.	Ensemble. Predict evolution of typical state.
Background error	Calculated from climatology data. Static**. :-(**	Calculated from ensemble. Flow dependent**. :-)**
Background error covariance	Full rank **:-)**	Low rank **:-(**
4D	Yes. But TLM and ADJ are needed.	Yes. Background error cov. et every time in ass. win. comes from ens. estimate.
Linear model	Yes**. :-(**	Not needed**. :-)**
Adjoint model	Yes. **:-(**	Not needed**. :-)**
Covariance model	Significant effort for developing**. :-(**	Effort to keep the ensemble spread matching the error.
Ability to fit detailed obs	Limited by resolution of simplified model.	Limited to fewer data (in a local region) then ensemble members. :-(
Non-Gaussian observational error	Allowed if differentiable.	Not allowed. But tricks for assimilation of obs such as precipitation have been developed (Lien 2013.)

Single Observation Example

Temperature observation at 850 mb in an area of a high temperature gradient





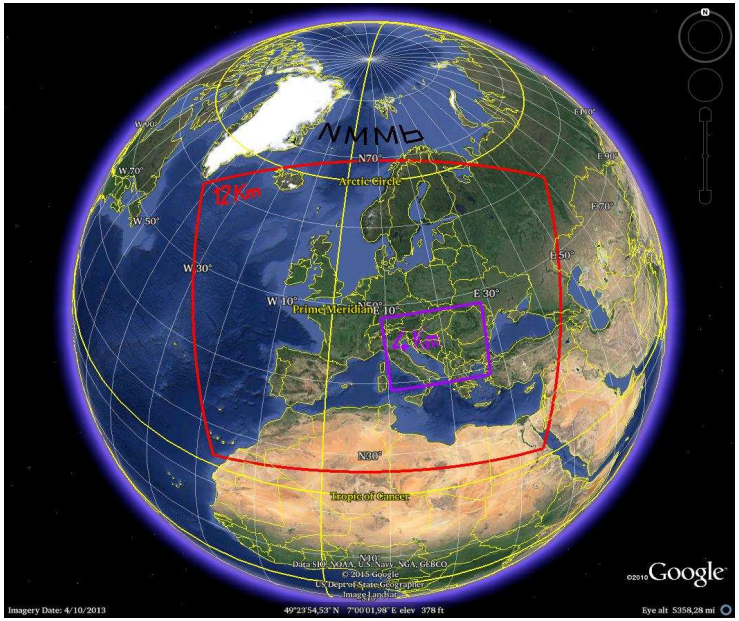


System components

NEMS-NMMB

Non-hydrostatic multi-scale model on B-grid (Janjic and Gall, 2012.)

Operational model in RHMSS with 3 domains



GSI-LETKF

- Local Ensemble Transform Kalman Filter (Hunt, et all. 2007)
- A flavor of EnKF
- Works inside of GSI system (use GSI operators)
- Model independent
- Observation assimilated simultaneously at every grid box
- Almost 100% parallel
- 4D LETKF extension, no TLM or ADJ needed
- Computes the weights of the ensemble forecasts explicitly
- 3DVar from GSI
- Obs. Operators - GSI

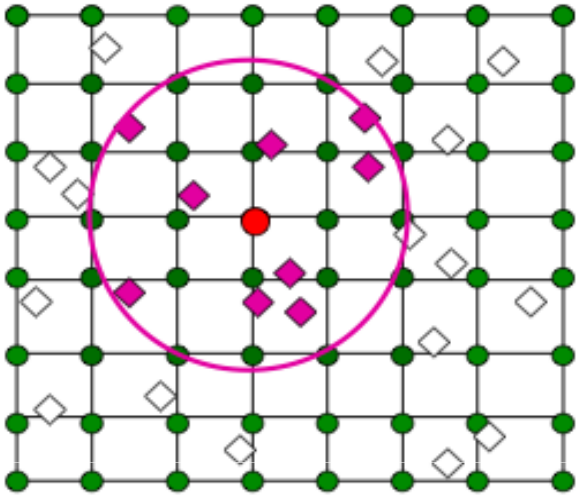
System setup

- **Model:**
  - **4 km horizontal resolution**
  - **64 vertical levels**
  - **LBC from ECMWF's EPS**

- **51 ensemble members**
  - **Multi physics within ensemble members**

- **EnKF localization**
  - **200 km in horizontal**
  - **3h in time**

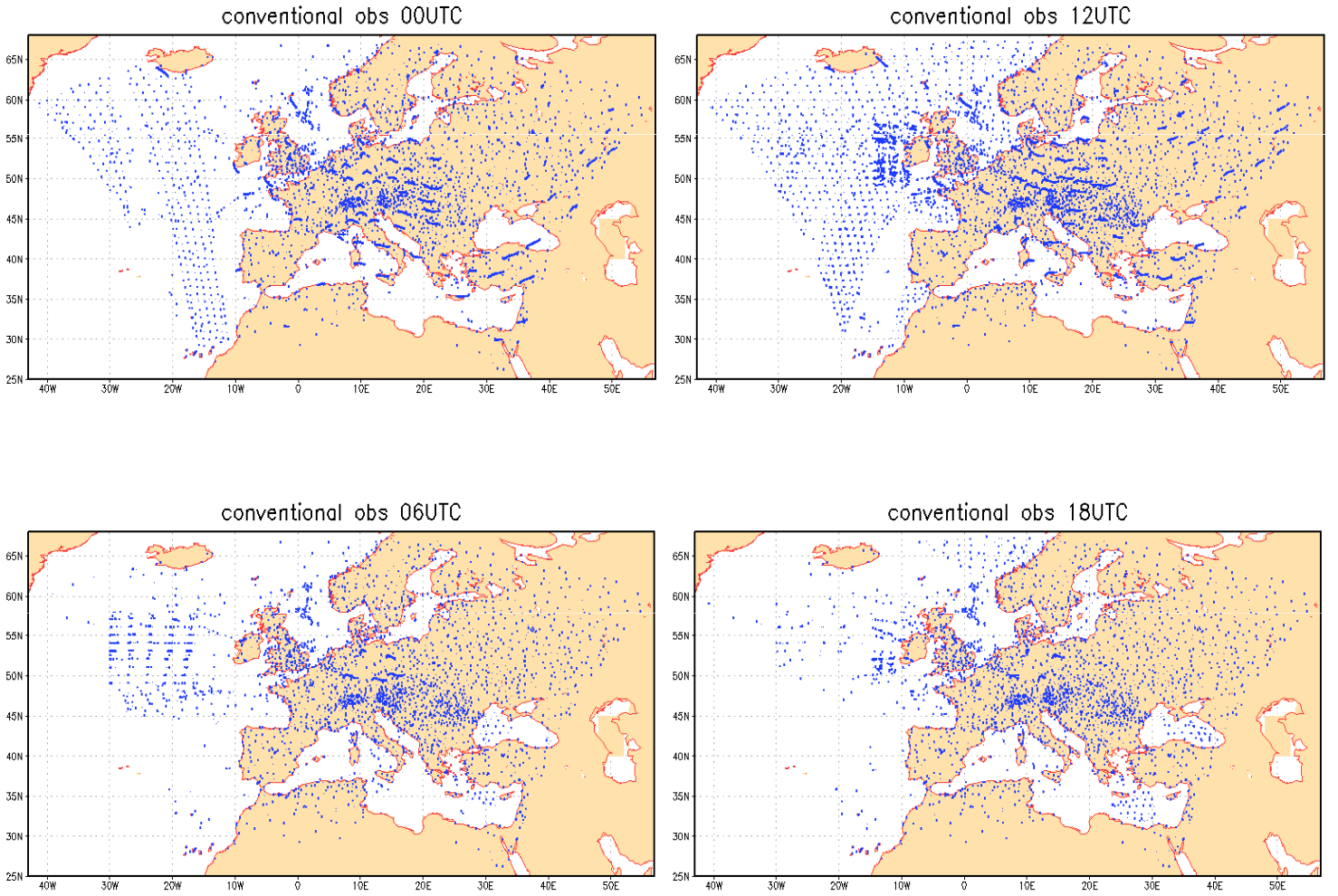
- **Assimilation cycle is 6 h, with 3h assimilation window**



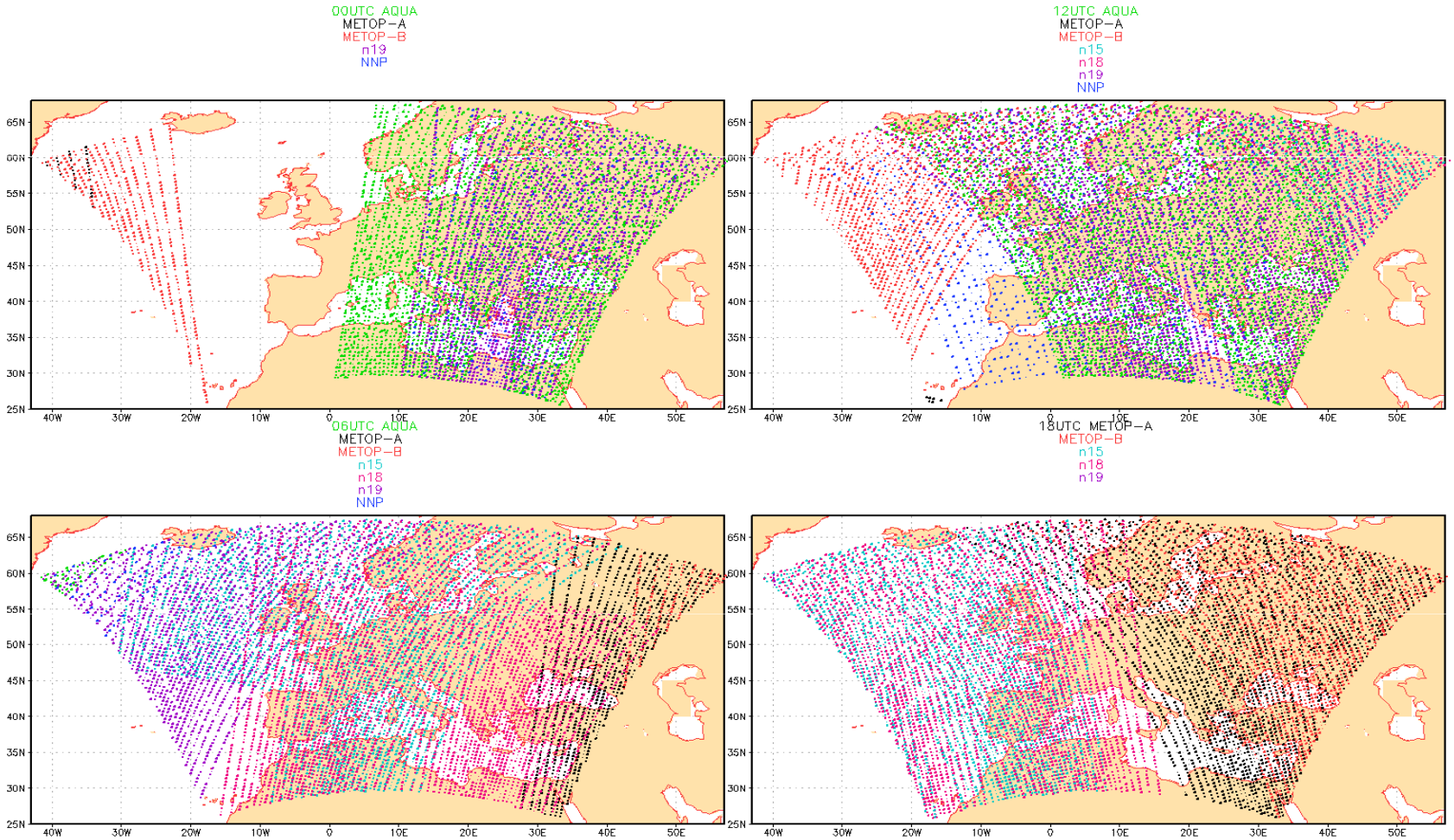
Observations

- Conventional:
  - ADPUPA, ADPSFC, SFCSHP, AIRCFT and remote sensing of wind (ie. SATWND)
- Satellite radiances:
  - METOP-A: AMSUA, IASI, HIRS4, MHS
  - METOP-B: AMSUA, IASI, HIRS4, MHS
  - AQUA: AMSUA, AIRS
  - NNP: AMSUA, HIRS4, CRIS, ATMS, MHS
  - NOAA n15: AMSUA
  - NOAA n18: AMSUA, MHS
  - NOAA n19: AMSUA, HIRS4, MHS
  - MSG m10: SEVIRI
- GPS RO

Distribution of conventional observation assimilated



Distribution of satellite radiances assimilated

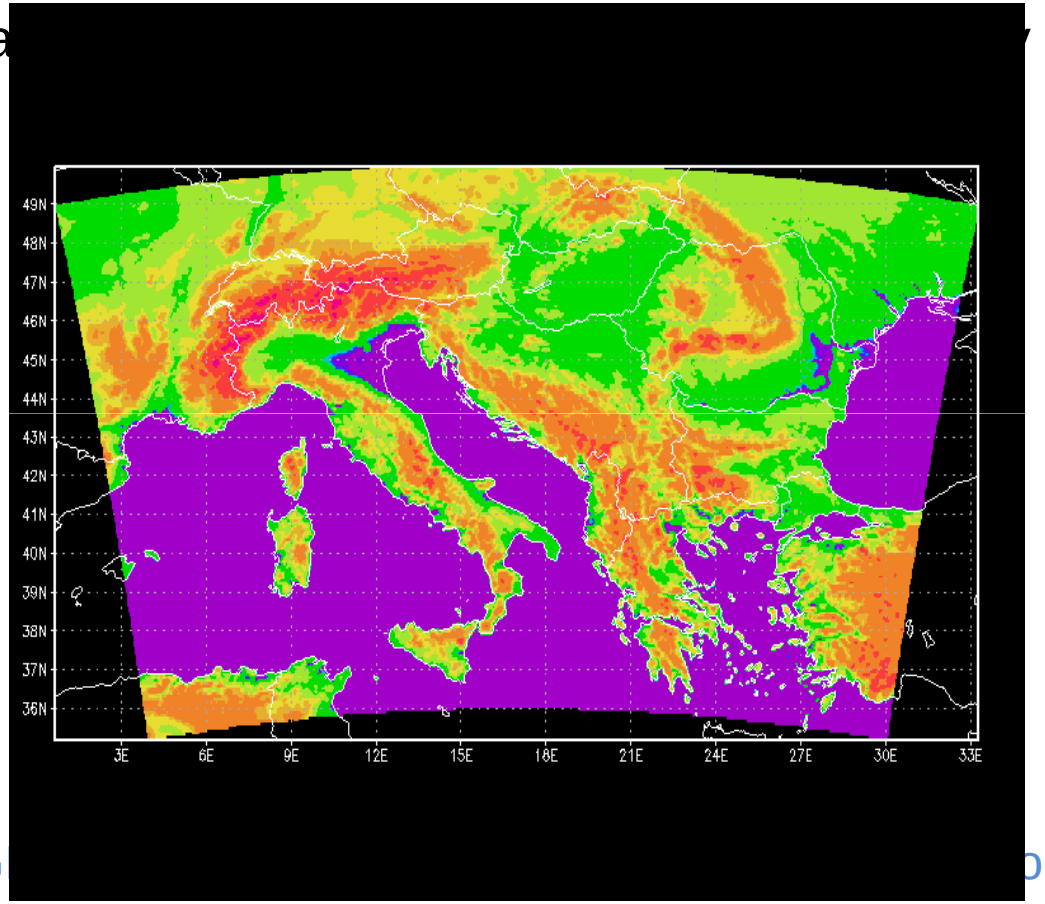


Testing period and initial results

- DA system has been tested previously on 12km model domain because of its small computational costs (in period from February to July 2016).

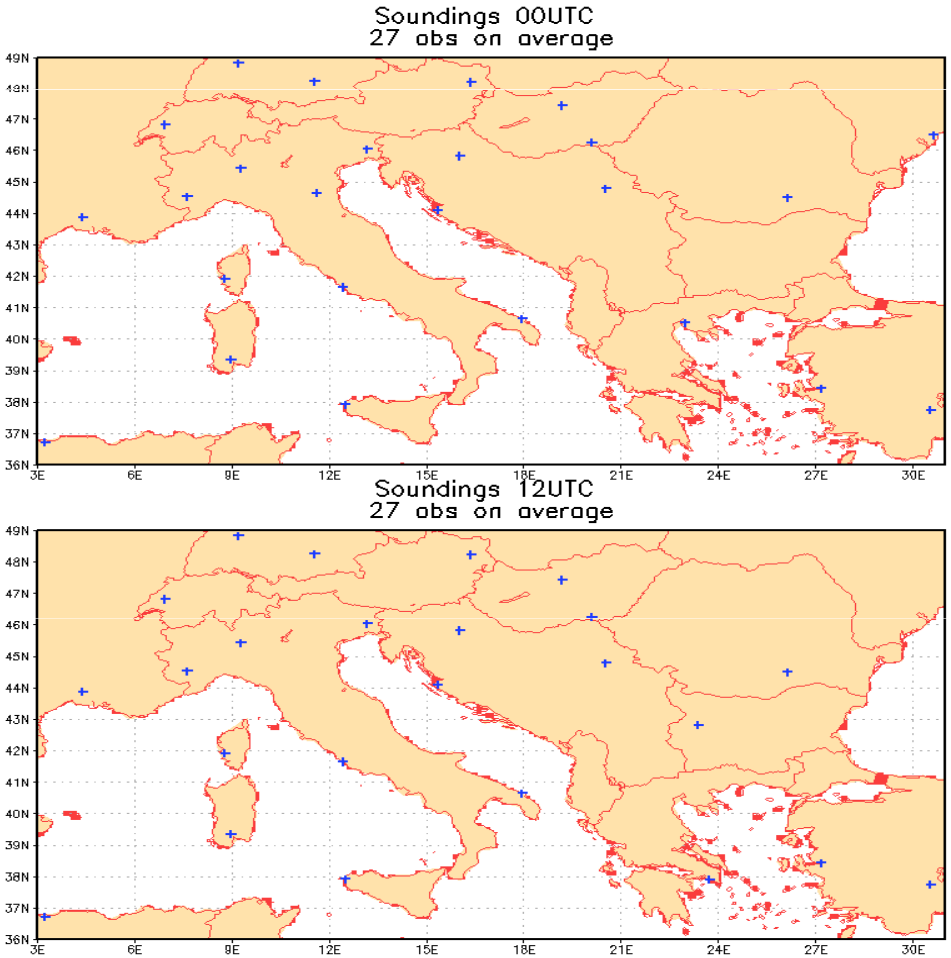
- Testing of DA system for 4 km domain started on 15th Jun 2016.

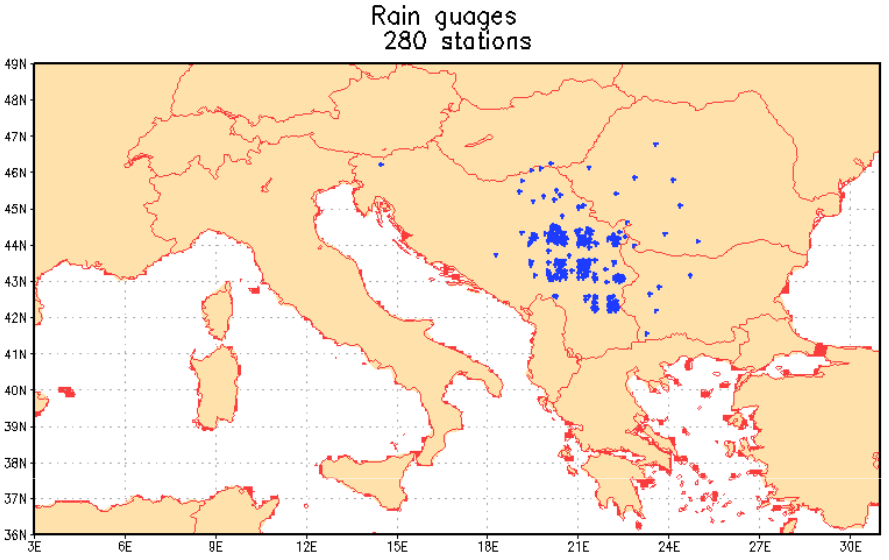
- Results and verifica 2016 will be presented.



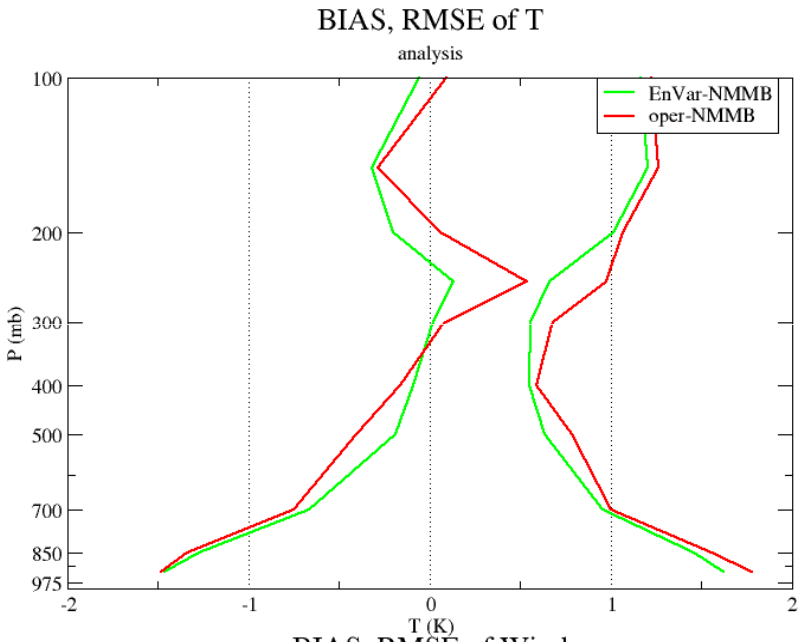
Verification using soundings and rain gauges

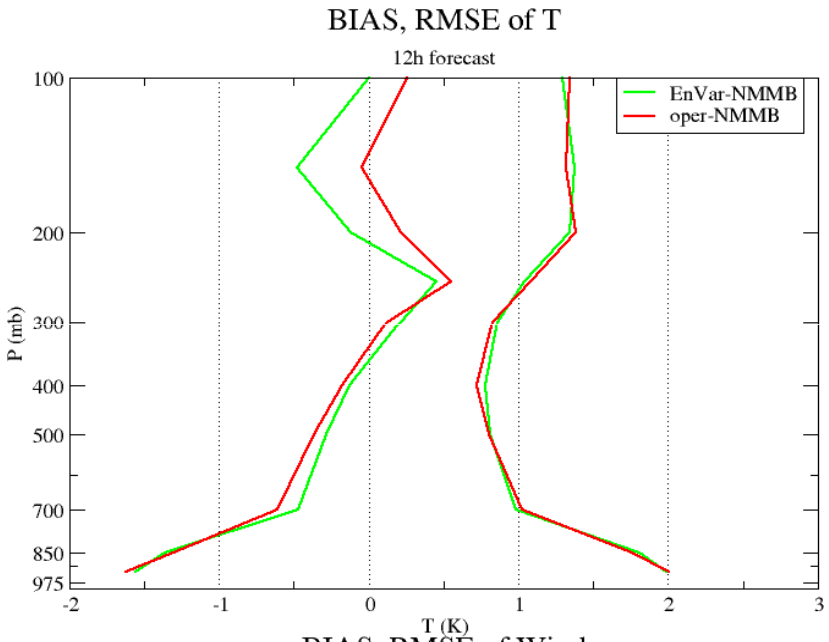
observation density

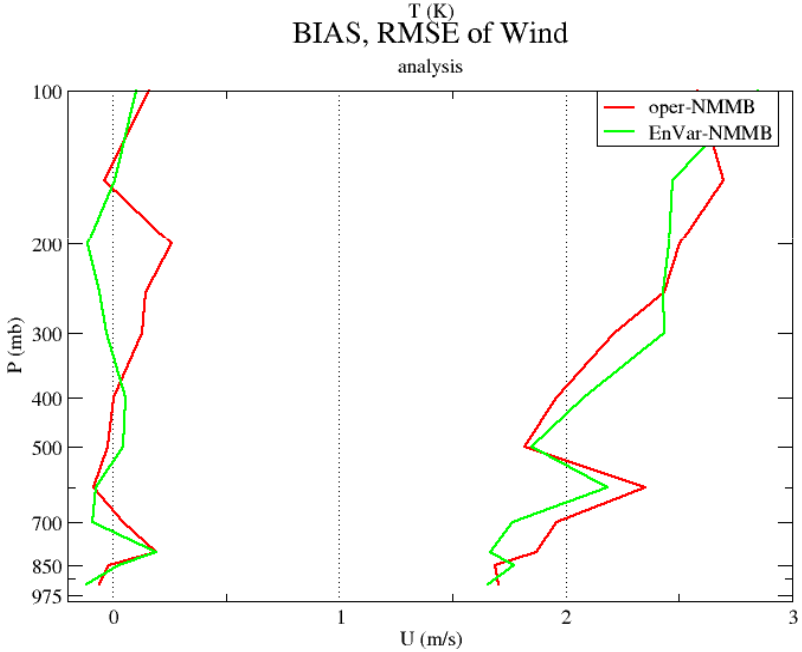


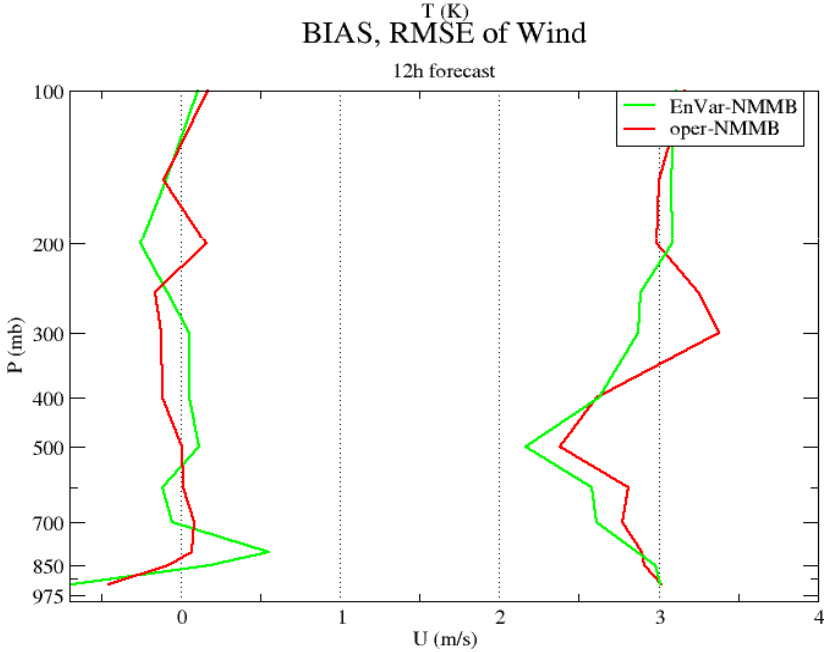


Analyses and +12h forecast error

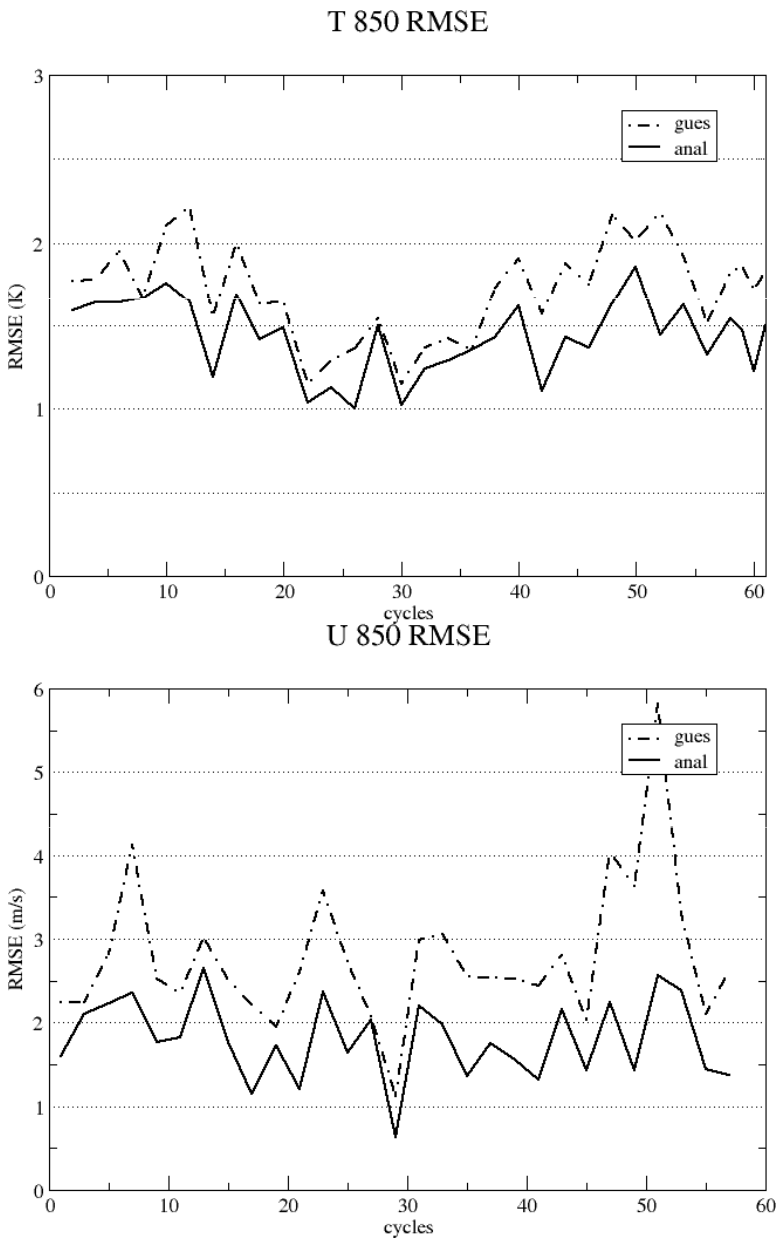




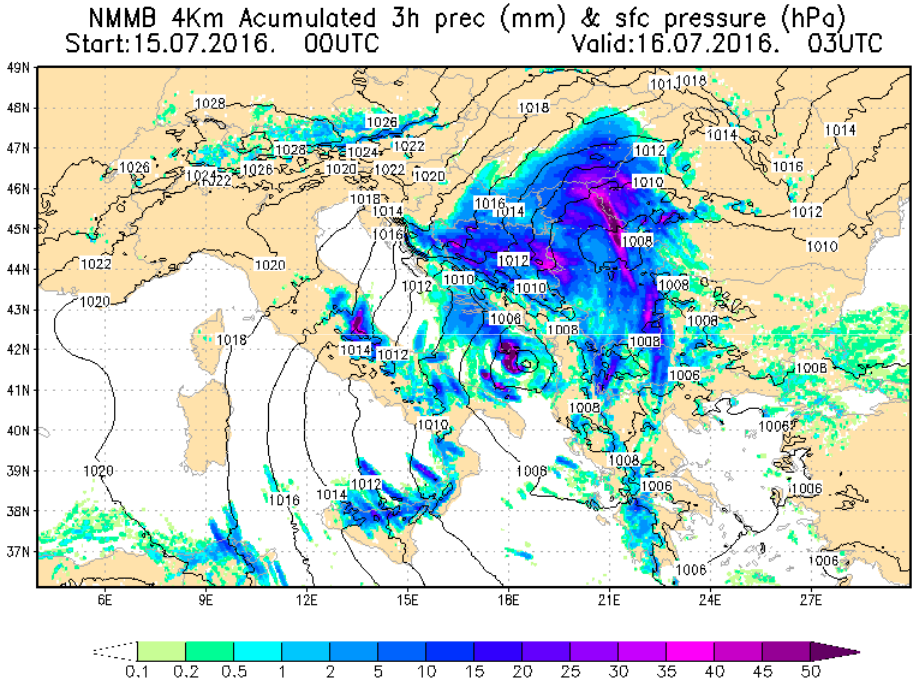




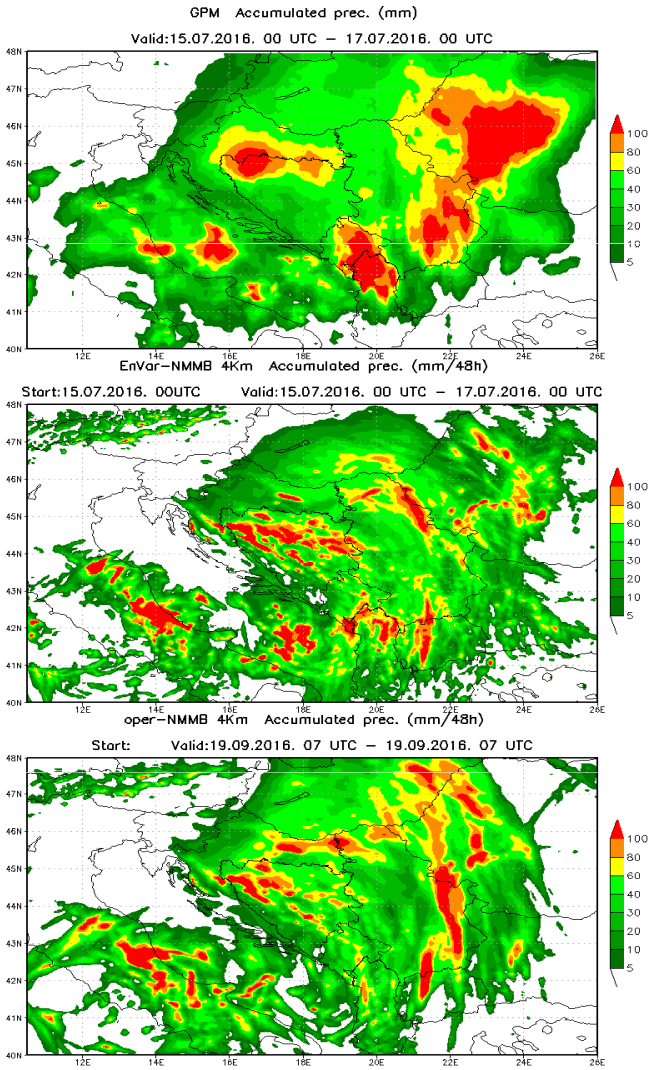
Time series of 6-h forecast (guess) and analysis (anal)

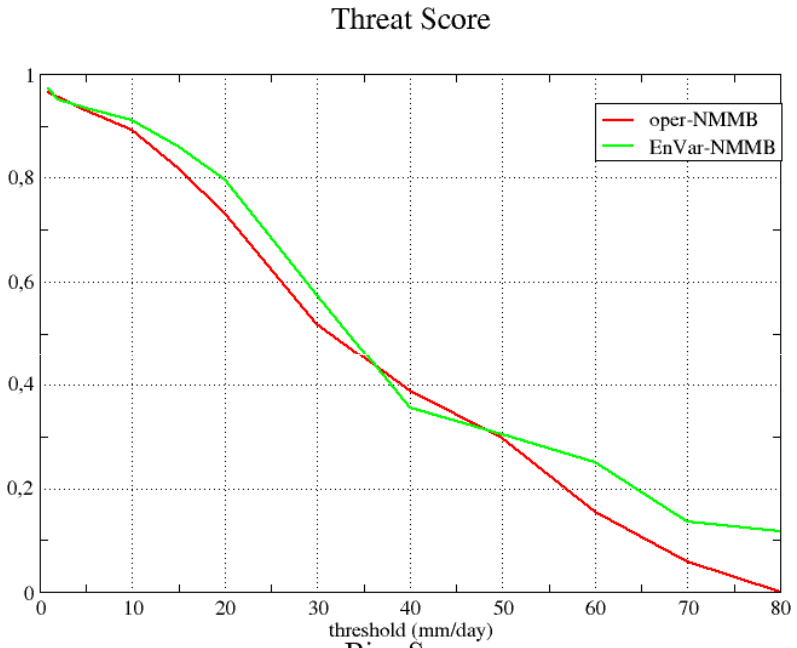


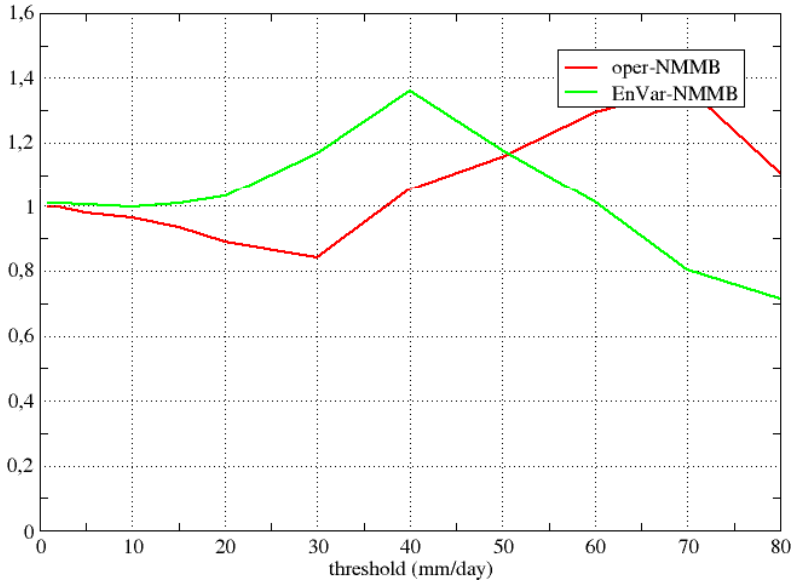
- RMSE relative to radiosonde observations
- Period from 1 July 2016 to 17 July 2016.



Heavy rain event in July 2016







Future plans

- Combining 4D LETKF and 3DVar to 4D EnVar in which observations are treated at times when are observed. The main advantage of 4DVar. Work is currently in progress.

  - Natural extension of 3DEnVar
  - No need to develop **TLM** and **ADJ**
  - Make use of 4D ensemble to perform 4D analysis
  - Highly **scalable** and computational **inexpensive**

- Assimilation of radar wind observation and radar reflectivity is also possible within this system. No work has been done so far but we hope it will start in following year(s).

Acknowledgments

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Development Testbed Center

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UMD, Weather&Chaos Group

We have been using ECMWF's EPS for boundary conditions

All work has been conducted on ECMWF's Cray supercomputer. Paul Dando, with his advices made migration of NMMB model and DA system to CCA painless.

References

- Developmental Testbed Center, 2015: Ensemble Kalman Filter (EnKF) User's Guide for Version 1.0.
- M. Dillon, et all. Application of the WRF-LETKF Data Assimilation System over Southern South America: Sensitivity to Model Physics. Weather and Forecasting February 2016, Vol. 31, No. 1 Published online on 11 Nov 2015.
- EMC, NCEP, NOAA. GDAS (Global Data Assimilation System). Presentation to NCEP Director March 17. http://www.emc.ncep.noaa.gov/gmb/noor/4dGFS/synergy%20announcementjan08.htm
- Hunt, et, all, 2007: Efficient data assimilation for spatiotemporal chaos: A local ensembletransform Kalman filter. Physica D, 230, 112-126,doi:10.1016/j.physd.2006.11.008.
- Janjic Z., and R. L. Gall 2012., Scientific documentation of the NCEP nonhydrostatic multiscale model on the B grid (NMMB). Part 1 Dynamics. NCAR Technical Note NCAR/TN-489+STR, doi:10.5065/D6WH2MZX.
- E. Kalnay, Atmosperic Modeling, Data Assimilation and Predictability. Cambridge University Press, 7th printing 2011.
- E. Kalnay, Some Ideas for Ensemble Kalman Filtering, NOAA, Climate Test Bed Joint Seminar Series, IGES/COLA, Calverton, Maryland, 3 December 2008.
- Kasic B., M. Lompar, 2015: Verification of NMMB model using METEOSAT SEVIRI data, 37th EWGLAM and 22nd SRNWP Meeting http://srnwp.met.hu/Annual_Meetings/2015/download/tuesday/prezentacija11.pdf
- Kistler, R., E. Kalnay, W. Collins, S. Saha, G. White, J. Woollen, M. Chelliah, W. Ebisuzaki, M. kanamitsu, V. Kousky, H. van den Dool, R. Jenne, and M. Fiorino, The NCEP/NCAR 50-Year reanalysis: monthly means CD-ROOM and documentation. Bull. Amer. Meteor. Soc. 82. 247-268.
- Lien, G.-Y., E. Kalnay, and T. Miyoshi, 2013: Effective assimilation of global precipitation: Simulation experiments. Tellus A, 65, 19915. doi:10.3402/tellusa.v65i0.19915
- A. Lorenc, The potential of the ensemble Kalman filter for NWP – a comparison with 4D-Var, Q. J. R. Meteorol. Soc. (2003), 129, pp 3183-3203.
- A. Lorenc, Development of the Met Office's 4DEnVar System. The 6th EnKF Workshop Agenda, May 18-22, 2014.Beaver Hollow Conference Resort, Buffalo, New York.
- T. Miyoshi and M. Kunii, Using AIRS retrivals in the WRF-LETKF system to improve regional numerical weather prediction, Telus A 2012. 64, 18408.
- The ECMWF, Ensemble Prediction System. http://www.ecmwf.int/sites/default/files/elibrary/2012/14557-ecmwf-ensemble-prediction-system.pdf