The CNMCA Operational LETKF Data Assimilation System: recent developments

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CNMCA - EnKF DA (*Bonavita, Torrisi and Marcucci, Q.J.R.M.S.,2008,2010)*

- ***OPERATIONAL SINCE 1 JUNE 2011*** to initialize the 7km COSMO-ME model

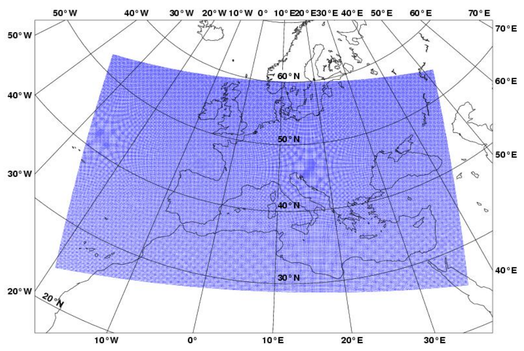
CNMCA is the first meteorological centre which uses operationally a pure EnKF DA to initialize a deterministic NWP model

- ***LETKF Formulation*** *(Hunt et al,2007)*

Analysis Ensemble Mean $\overline{\mathrm{x}}^{\mathrm{a}} = \overline{\mathrm{x}}^{\mathrm{b}} + X^{b}\overline{w}^{a}$ $\quad \overline{\mathrm{w}}^{\mathrm{a}} = \tilde{P}^{a} Y^{bT} R^{-1}(y - H(x^{b}))$ $\quad \tilde{\mathrm{P}}^{\mathrm{a}} = \left[(m-1)I + Y^{bT} R^{-1} Y^{b}\right]^{-1}$

Analysis Ensemble Perturb. $\mathrm{X}^{\mathrm{a}} = X^{b} W^{a}$ $\quad \mathrm{W}^{\mathrm{a}} = \left[(m-1)\tilde{P}^{a}\right]$ $\quad \mathrm{Y}^{\mathrm{b}} = \left[(H(x_1^b) - \overline{H(x^b)}),....,(H(x_m^b) - \overline{H(x^b)})\right]$

- 6-hourly assimilation cycle
- 40 ensemble members + deterministic run with 0.09° (~10Km) grid spacing (COSMO model), 45 hybrid z-sigma vertical levels (top at ~27km)
- (T,u,v,pseudoRH,ps) set of control variables
- Observations: RAOB/TEMP, PILOT, SYNOP, SHIP, BUOY, VAD/Wind Profilers, AMDAR-ACAR-AIREP, MSG3-MET7 AMV, MetopA-B scatt. winds, NOAA/MetopA AMSUA radiances+ LandSAF snowmask,



Model and sampling errors are taken into account using:

- "Relaxation-to-Prior Spread" Multiplicative Inflaction according to Whitaker et al (2010)

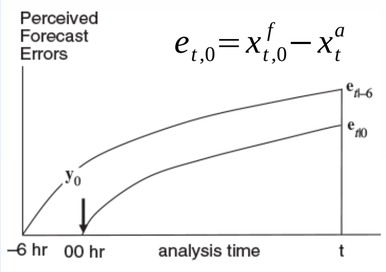
an. pert. $\mathbf{x}'_{\mathrm{a}} = \mathbf{x}'_{\mathrm{a}} \sqrt{\alpha \frac{\sigma_{\mathrm{b}}^2 - \sigma_{\mathrm{a}}^2}{\sigma_{\mathrm{a}}^2} + 1}$ $\quad \alpha = 0.95$ $\quad \sigma^2$ = variance

- Additive noise from EPS
- Lateral Boundary Condition Perturbation using EPS
- Climatological Perturbed SST
- Adaptive selection radius using a fixed number of effective observations (sum of obs weights)

CHANGES IN THE OPERATIONAL CNMCA-LETKF (since 4 june 2013)

- COSMO replaces HRM model
- Assimilation of radiosoundings (RS) with space / time displacement
- Humidity bias correction for Vaisala RS (solar corr.)
- AMSU-A radiances assimilation over sea and land
- Additive noise from IFS forecasts instead from model climatology

FORECAST SENSITIVITY TO OBSERVATIONS



Following Kalnay et al. (2012) the observation impact on the reduction of forecast error is:

$$J = \Delta e^2 = e^T_{t,0} C e_{t,0} - e^T_{t,-6} C e_{t,-6}$$

$$\Delta e^2 \approx 1/(K-1)\left[y_0 - H\left(x^b_{0,-6}\right)\right]^T R^{-1} Y^a_0 X^{f\,T}_{t,0} C\left(e_{t,0} + e_{t,-6}\right)$$

C = square norm to be used (moist total energy norm)

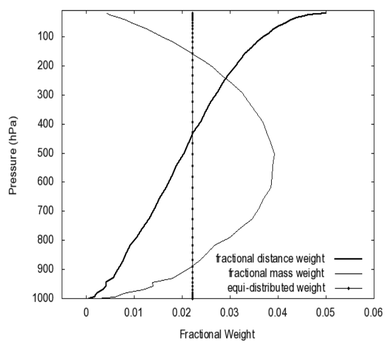
TEST WITH DIFFERENT VERTICAL WEIGHTS FOR THE ENERGY NORM

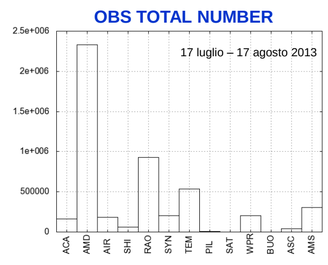
$$E = 1/2 \Sigma_{i,j,k} \Delta A_j \Delta \sigma_{i,j,k} \left(u'^2 + v'^2 + aT'^2 + bq'^2 + cp_s'^2\right)$$

Fractional mass $\quad \Delta \sigma_{i,j,k,fd} = \Delta p_{i,j,k} / \left(ps_{i,j} - p_t\right)$

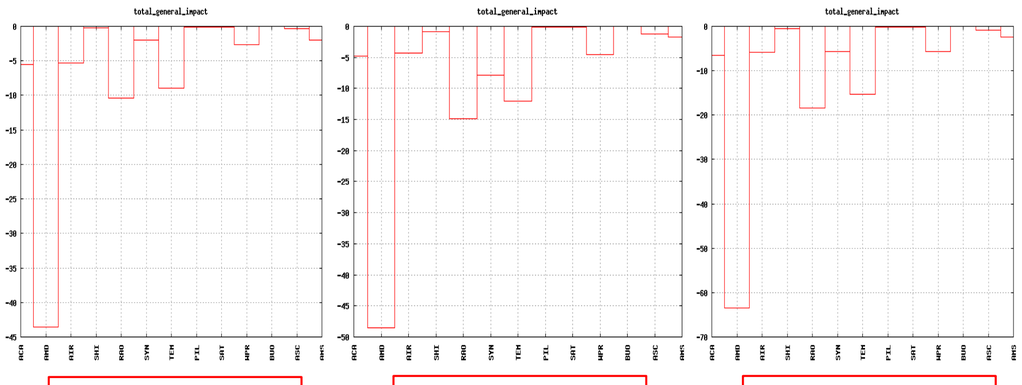
Fractional dist $\quad \Delta \sigma_{i,j,k,fm} = \Delta z_{i,j,k} / \left(zs_{i,j} - z_t\right)$

Equi-distributed $\quad \Delta \sigma_{i,j,k,eq} = 1/45$





17 luglio – 17 agosto 2013



Equi-distributed | Fractional distance | Fractional mass

CURRENT DEVELOPMENTS

Investigation of two different approaches to evaluate the observation impact in the DA system:

-**Method proposed in Todling (2012)**

The method uses an observation-space metric to estimate the observation impact on forecast using differences of observation-minus-forecast residuals obtained from consecutive forecasts.

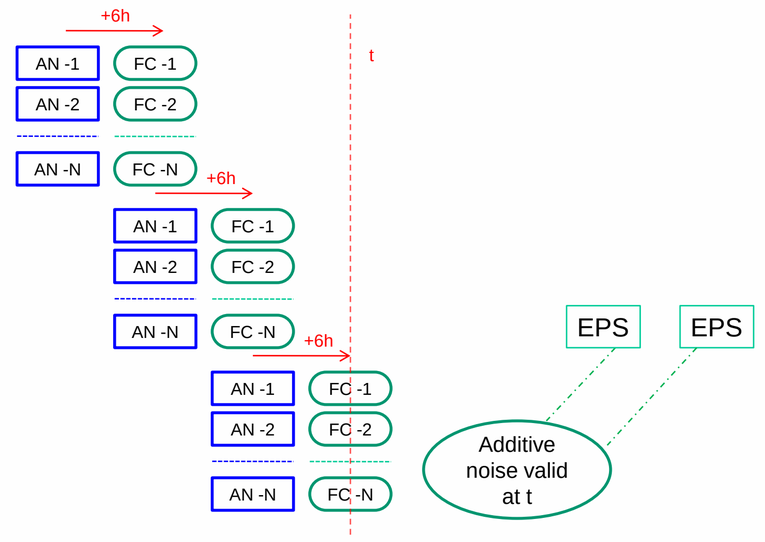
- **DFS method (Liu et al. 2009)**

The method uses the diagonal value of the influence matrix to estimate the sensitivity of observations (information content) on analysis. It has been firstly proposed for variational techniques and then generalised for ensemble based methods.

SELF-EVOLVED ADDITIVE NOISE FORMULATION

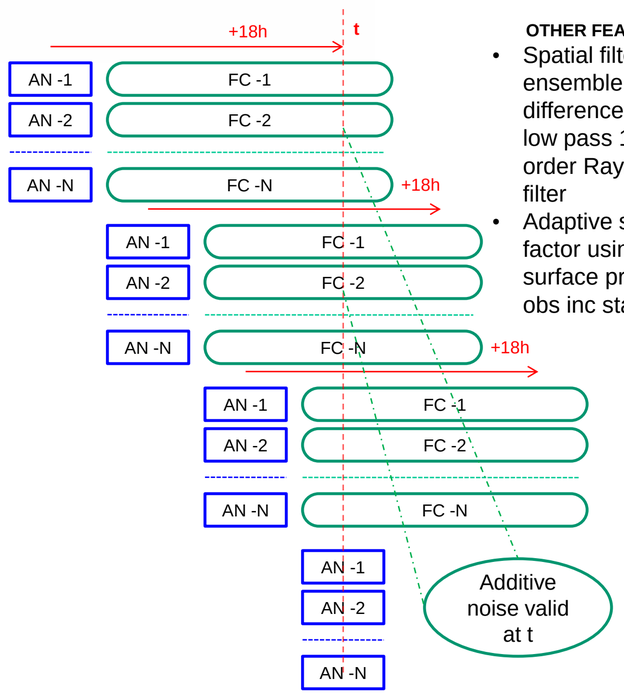
CURRENT FORMULATION (EPS ADDITIVE NOISE)

- It has recently substituted the climatological noise
- Differences between EPS ensemble forecasts valid at the analysis time are computed and interpolated on the COSMO grid
- The mean difference is removed to yield a set of perturbations that are scaled and used as additive noise
- EPS additive noise is not consistent with COSMO model errors statistics



NEW FORMULATION (SELF EVOLVING ADDITIVE NOISE)

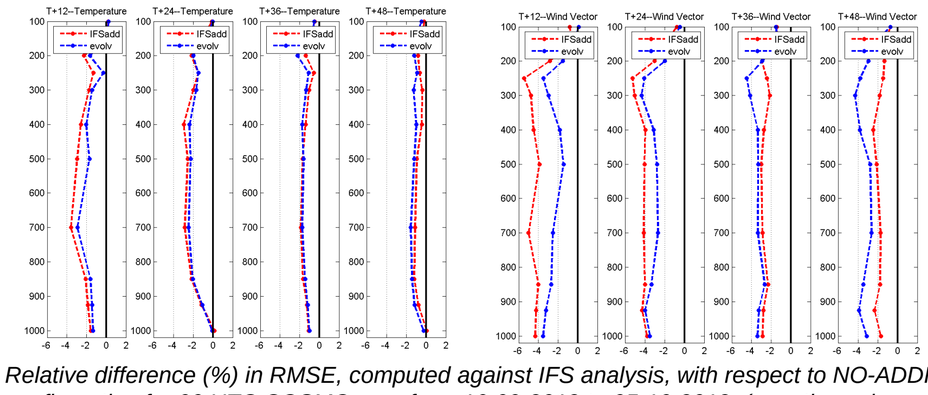
- Basic idea of Mats Hamrud (ECMWF)
- Differences between ensemble forecasts valid at the analysis time are calculated
- The mean difference is subtracted to yield a set of perturbations that are scaled and used as additive noise
- The ensemble forecasts are obtained by the same ensemble DA system extending the end of the model integration.
- The self-evolving additive perturbations are consistent with model errors statistics
- This is a a flow-dependent noise that may have a component that will project onto the growing forecast structures having probably a benificial impact on spread growth and ensemble-mean error



OTHER FEATURES

- Spatial filtering of ensemble difference using a low pass 10th order Raymond filter
- Adaptive scaling factor using the surface pressure obs inc statistics

EPS ADDITIVE vs SELF EVOLVING ADDITIVE



Relative difference (%) in RMSE, computed against IFS analysis, with respect to NO-ADDITIVE configuration for 00 UTC COSMO runs from 16-09-2012 to 05-10-2012 (negative value = positive impact)

- A positive impact of the "self evolving additive" is found at all forecast times with respect to the "no-additive" run
- The "self-evolving additive noise" outperformes the "EPS additive" formulation at day 2
- Further investigation is needed

NEXT-FUTURE DEVELOPMENTS :

- Comparison of the self-evolving additive inflation vs Stochastics physics
- COSMO-ME Short-Range EPS based on CNMCA-LETKF (experimentally running)
- Dynamical retrieved MW land emissivity under testing
- ATMS radiances, Oceanscat2 winds, MetopB AMSUA-MHS, GPS delays monitored
- Shorter assimilation cycle
- Further tuning of model error representation (cov. localization, bias correction,etc.)