Recent Work on CNMCA COSMO-LETKF Data Assimilation System

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Outline

- Recent changes in operational CNMCA LETKF system
  - -> COSMO model (operational since June 2013)
  - -> Assimilation of radiosoundings in BUFR
  - -> Assimilation of AMSUA radiances
  - -> Additive noise from IFS
- Ongoing developments
  - -> Assimilation of MHS radiances
  - -> Self-evolving additive noise and stochastics physics
  - -> Forecast Sensitivity to Observations
- Future developments

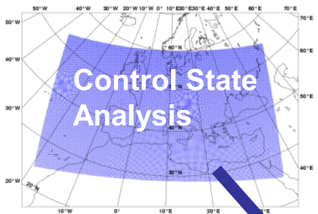
Changes in CNMCA LETKF system

COSMO LETKF is operational at CNMCA since June 2013.
Some changes in the new LETKF system were done with respect to old one based on HRM:

- COSMO model (tuning and adaptation)
- Space and time displacement in radiosoundings (only BUFR messages)
- Humidity bias correction for Vaisala RS (solar corr.)
- AMSU-A radiances over sea and land
- Additive noise from IFS forecasts instead from model climatology

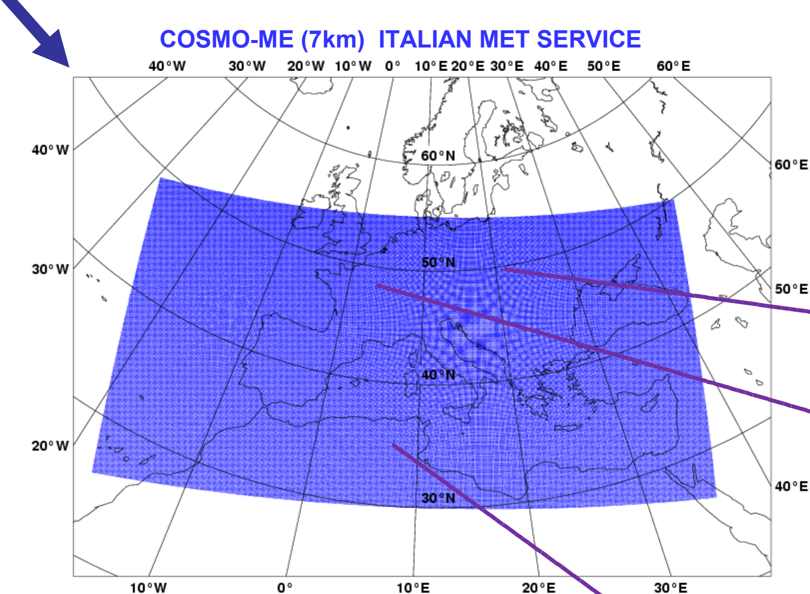
CNMCA NWP SYSTEM since 1 June 11

Ensemble Data Assimilation:



10 km
45 v.l.

LETKF analysis ensemble (40+1 members) every 6h using TEMP, PILOT, SYNOP, SHIP, BUOY, Wind Profilers, AMDAR-ACAR-AIREP, MSG3-MET7 AMV, MetopA-B scatt. winds, NOAA/MetopA AMSUA radiances
+ Land SAF snow mask,
IFS SST analysis once a day

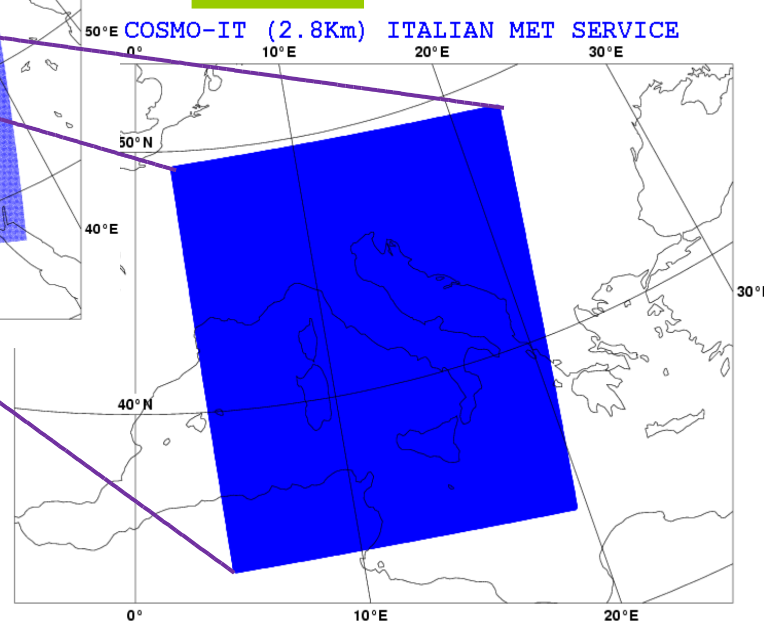


7 km
40 v.l.

- compressible equations
- parameterized convection

2.8 km
50 v.l.

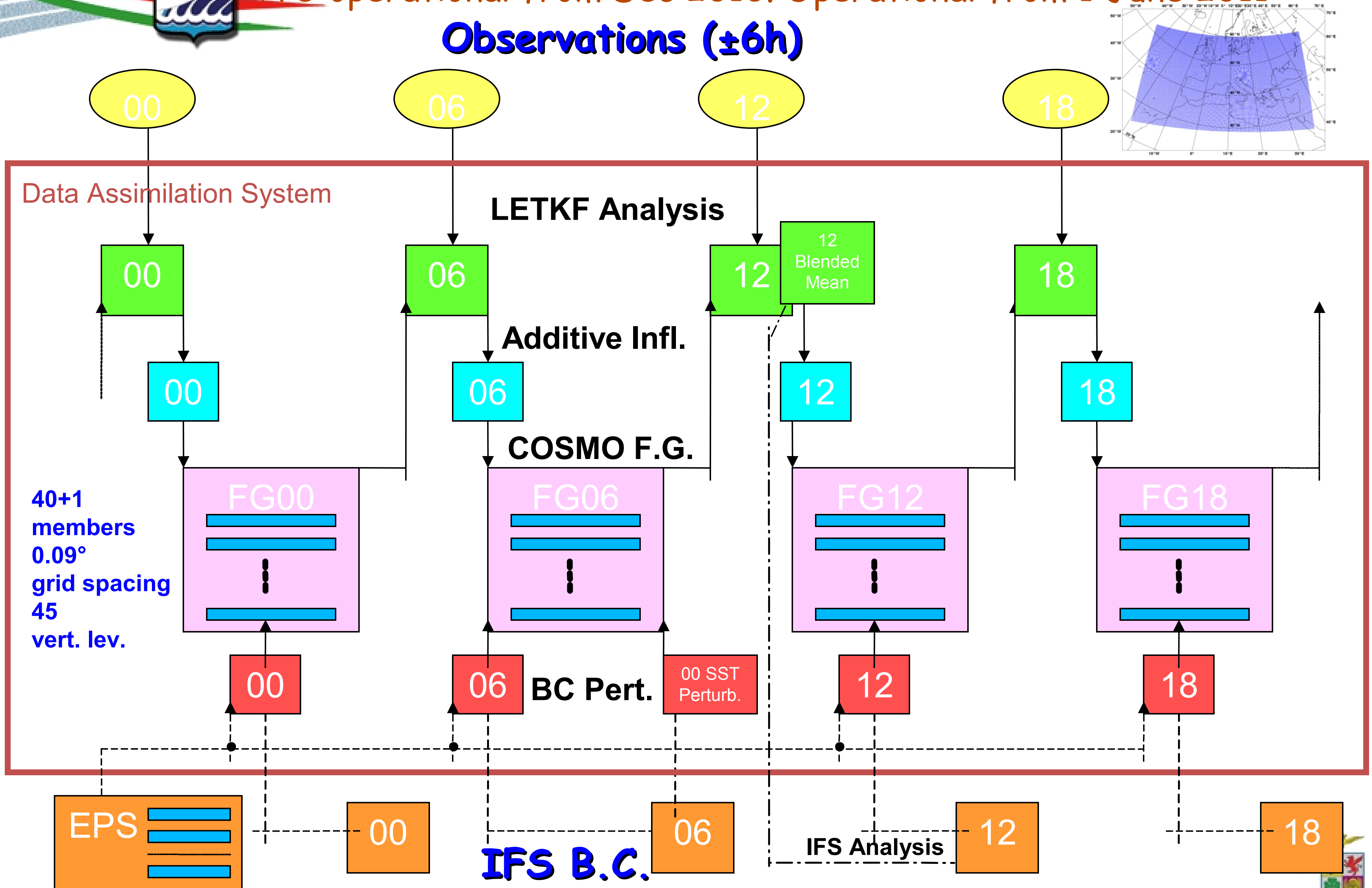
- compressible equations
- explicit convection



Local Area Modelling: COSMO

CNMCA LETKF DA SYSTEM

Pre-operational from Dec 2010. Operational from 1 June 2011



COSMO model in CNMCA-LETKF

- HRM hydrostatic model is subtituted by COSMO non-hydrostatic model in CNMCA LETKF system taking into account of that:
  - The model top is raised from $^{235}_{92}$21.5km ($^{235}_{92}$43hPa) to $^{235}_{92}$26km ($^{235}_{92}$18hPa) using 45 vertical levels to reduce the influence of the sponge layer (upper levels Rayleigh damping zone)
  - Initial pressure perturbation fields are derived using the hydrostatic balance equation

- A long period of parallel runs was performed showing very small differences in the results

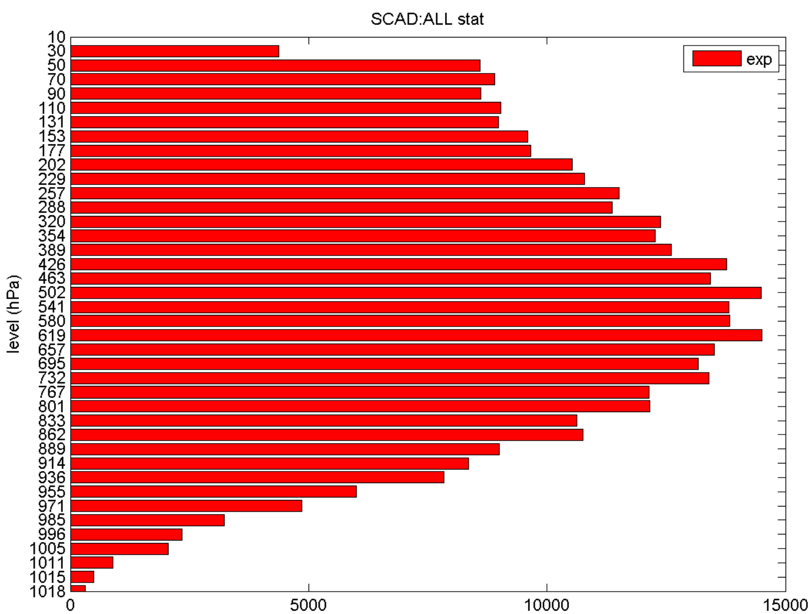
- COSMO is the prognostic model in the operational CNMCA-LETKF system since 4 June 2013

Radiosounding Assimilation

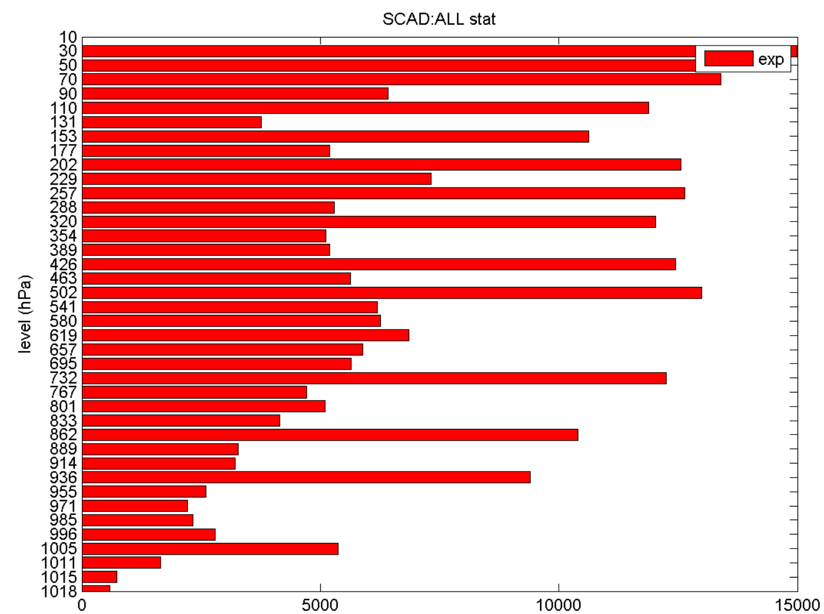
RAOB in BUFR are operationally assimilated in CNMCA LETKF system. TEMP messages having the same identifier of BUFR ones are discarded. Time and space displacements are taking into account. The same vertical thinning of aircraft data is applied to reduce the large amount of data in the upper levels.

Assimilation
Period
5 May2013
25 June 2013

BUFR

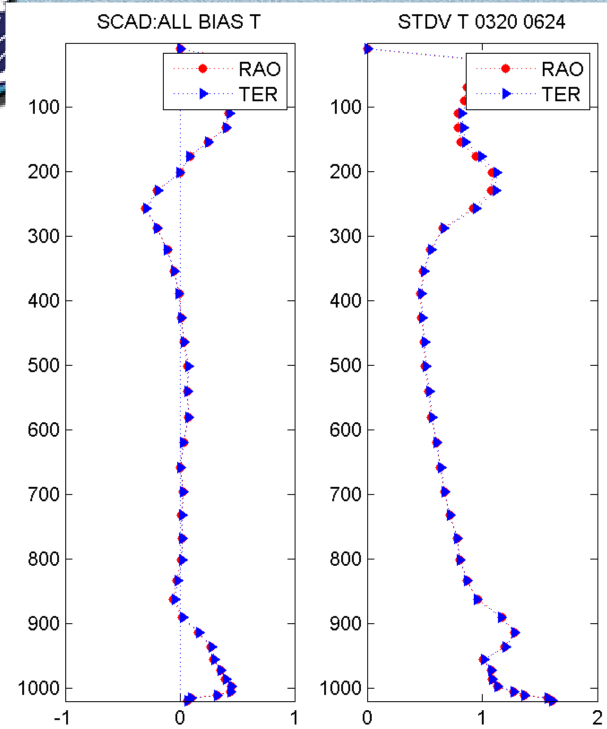


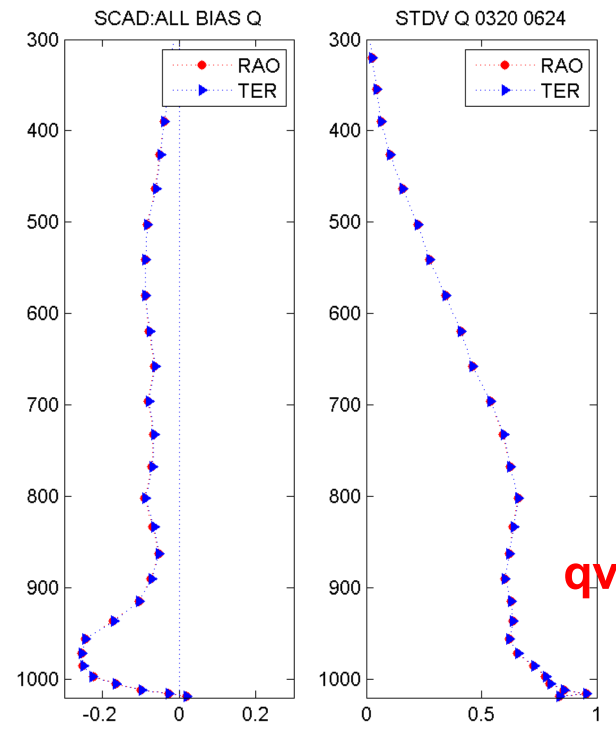
TEMP



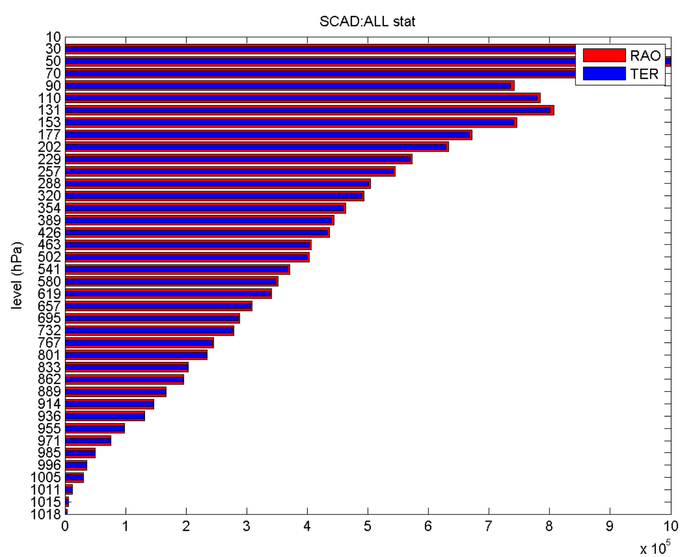
RAOB (RAO) vs RAOB "no displacement" (TER)

T





qv

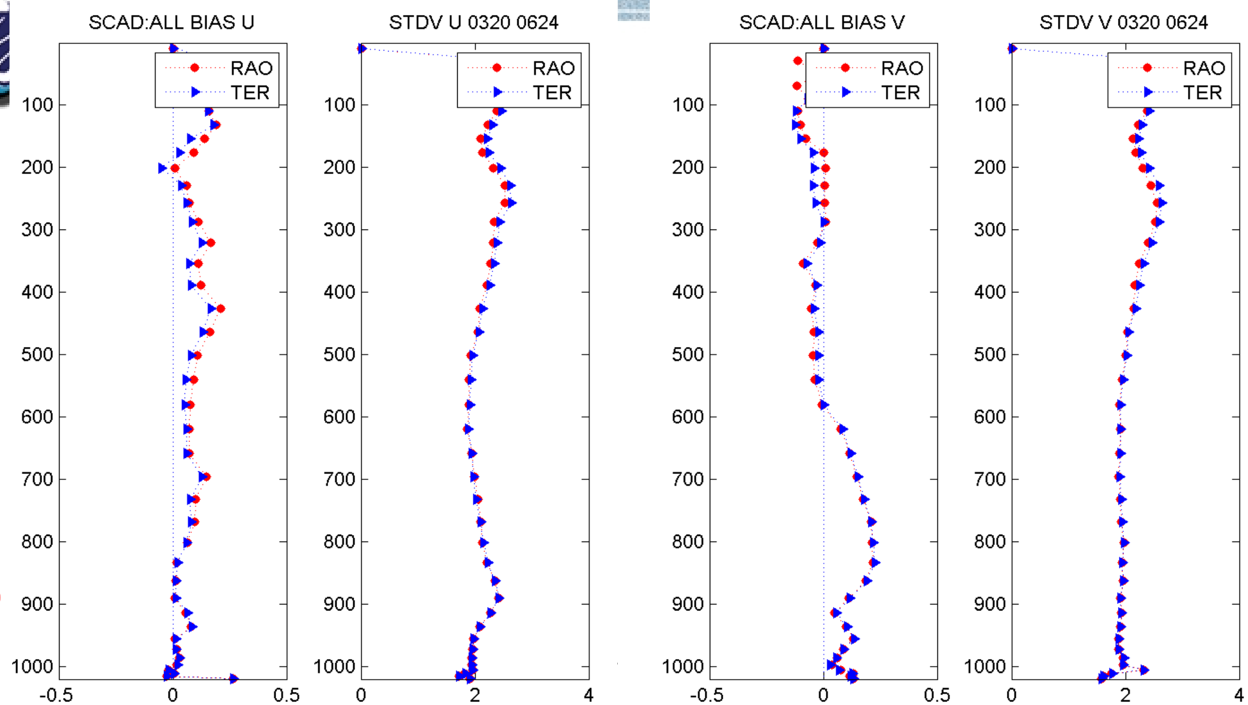


Monitoring using CNMCA COSMO-LETKF system

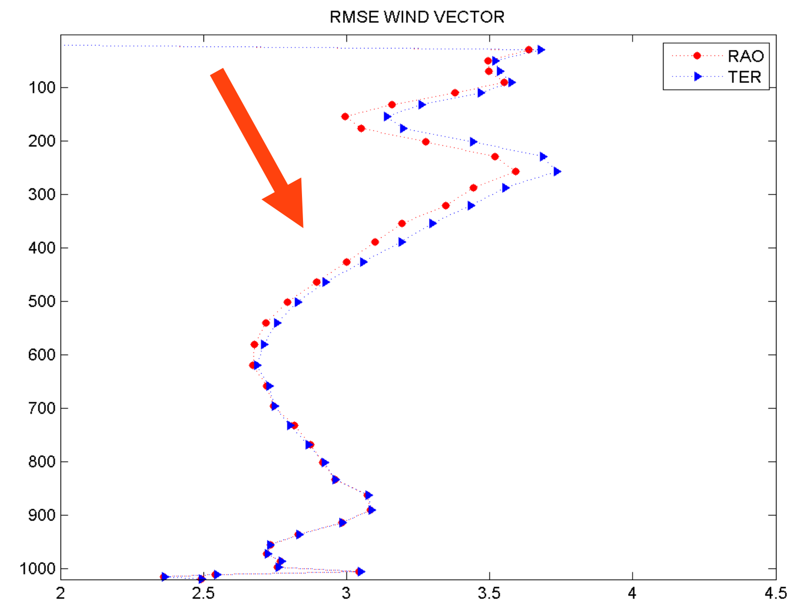
From 20 march 2013 to 24 june 2013

RAOB (RAO) vs RAOB "no displacement" (TER)

U-WIND



V-WIND

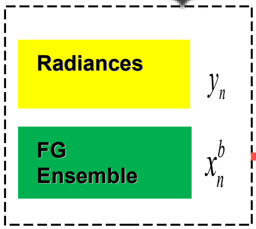


Wind Vector

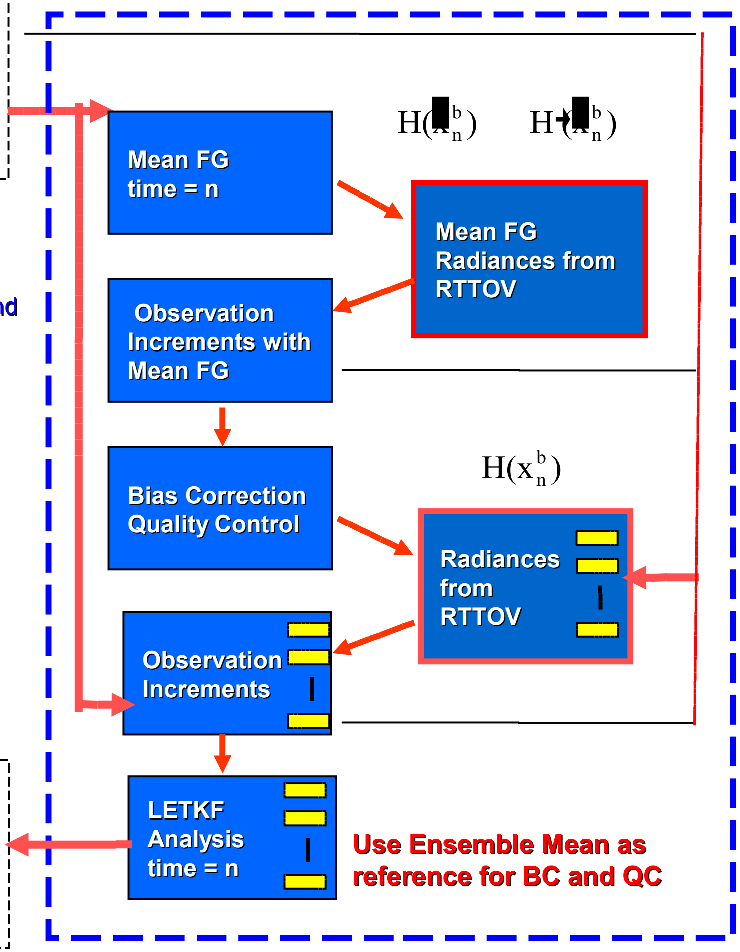
Monitoring using CNMCA COSMO-LETKF system

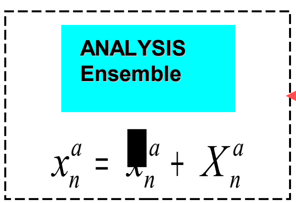
From 20 march 2013 to 24 june 2013

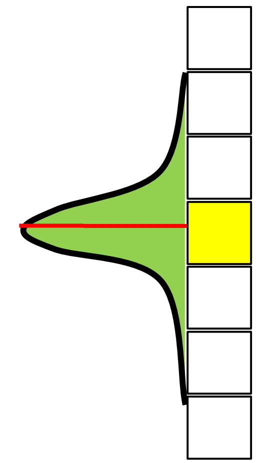
AMSUA rad. assimilation



- Obs from NOAA16-18-19 and MetOpA
- RTTOV v 10.2
- Off Line Dynamic Bias Correction
- Obs Error 0.2-0.35 °K (no FOV 1-3 and 28-30)
- Horizontal thinning 100 km
- Channels 5-9
- Rain check on CH 4:
  1.5 °K over SEA
  1. °K over LAND
- Grody LWP check
- CH5-6 discarded over high orography







Weighting function
(transmittance vert. derivative)

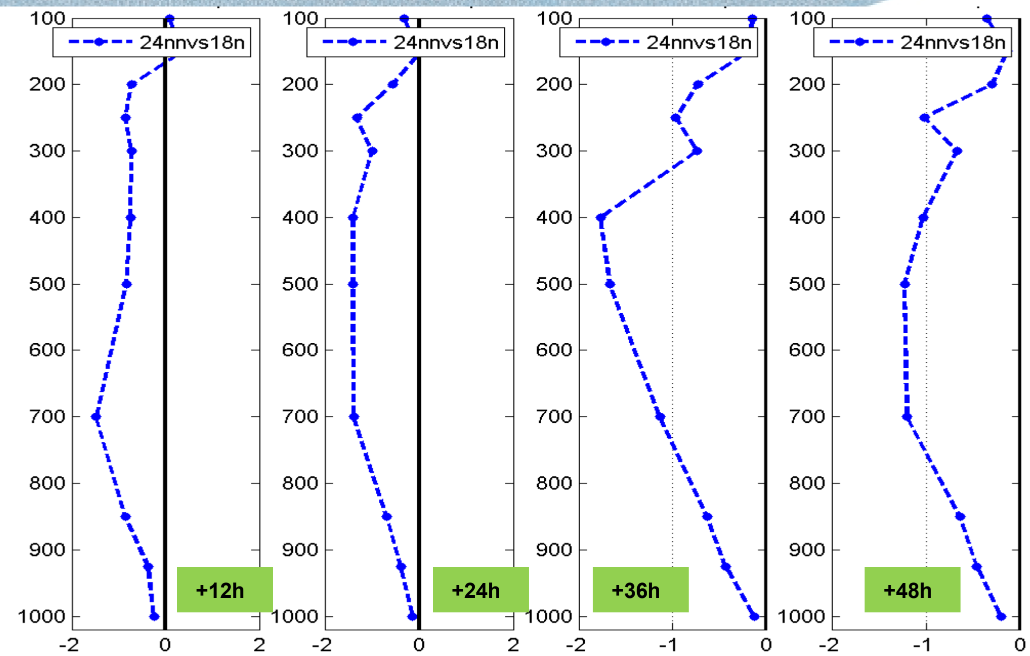
$$w_k = (\tau_{v,k-1} - \tau_{v,k}) / (\ln(p_k) - \ln(p_{k-1}))$$

MAXIMUM-BASED METHOD

- AMSU-A are treated as "single-level" obs
- Assign radiance to the pressure level obtained by a weighted average using the normalized weighting function (WF) larger than 0.8

Impact of AMSUA rad assimilation

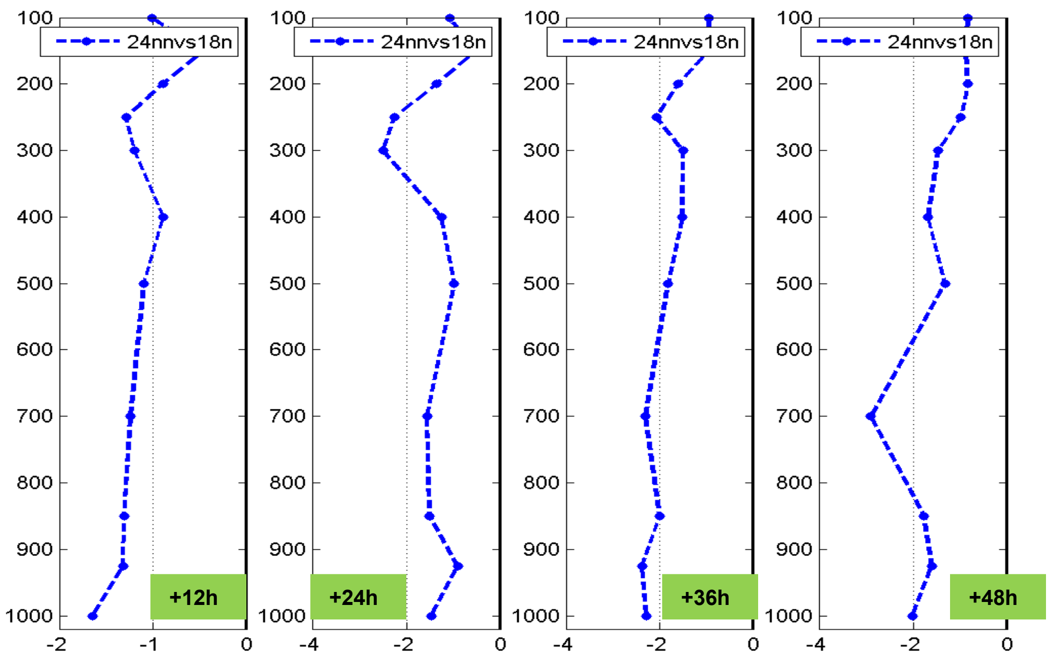
TEMPERATURE



Relative difference (%) in RMSE computed against IFS analysis for 00 UTC COSMO runs from 16-09-2012 to 05-10-2012

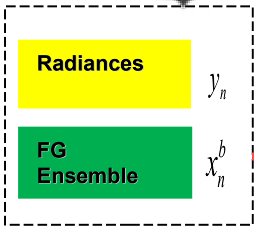
negative value = positive impact

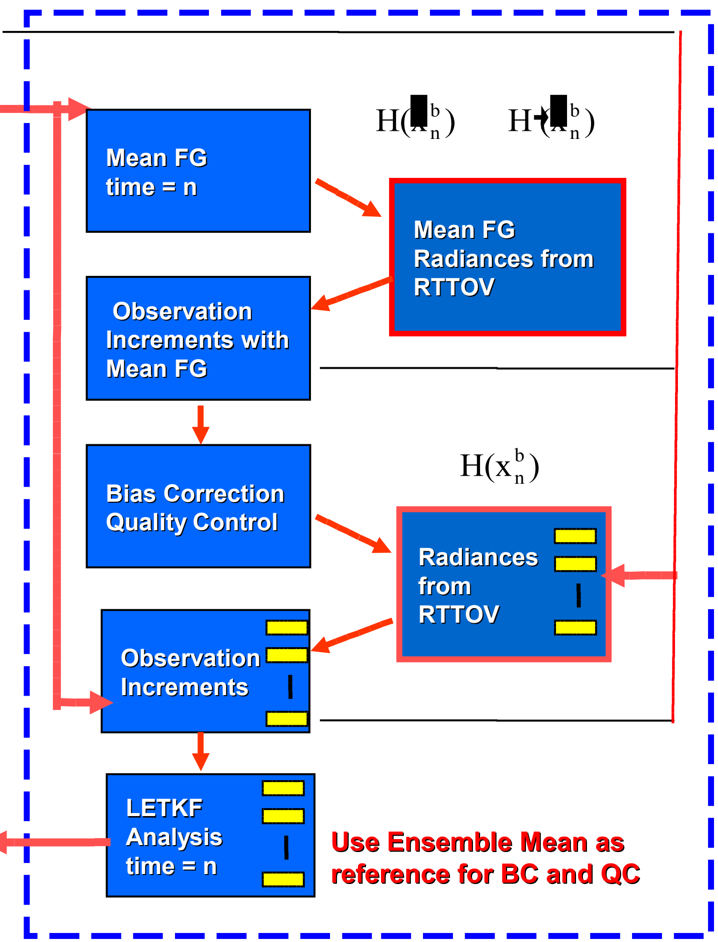
WIND VECTOR

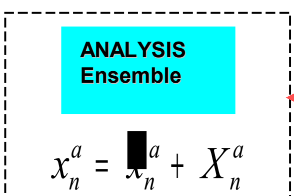


*CLEAR **POSITIVE** IMPACT OF **AMSUA** ASSIMILATION ON THE WHOLE COLUMN*

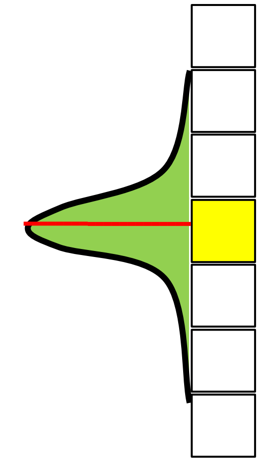
MHS rad. assimilation







- Obs from NOAA16-18-19 and MetOpA
- RTTOV v 10.2
- Off Line Dynamic Bias Correction
- Obs Error 2 °K (no FOV 1-8 and 83-90)
- Horizontal thinning 120 km
- Channels 3-4
- Rain check on CH 2: 5 °K
- Discarded over high orography



Weighting function (transmittance vert. derivative)

$$w_k = (\tau_{v,k-1} - \tau_{v,k})/(\ln(p_k) - \ln(p_{k-1}))$$

MAXIMUM-BASED METHOD

- MHS are treated as “single-level” obs
- Assign radiance to the pressure level obtained by a weighted average using the normalized weighting function (WF) larger than 0.8

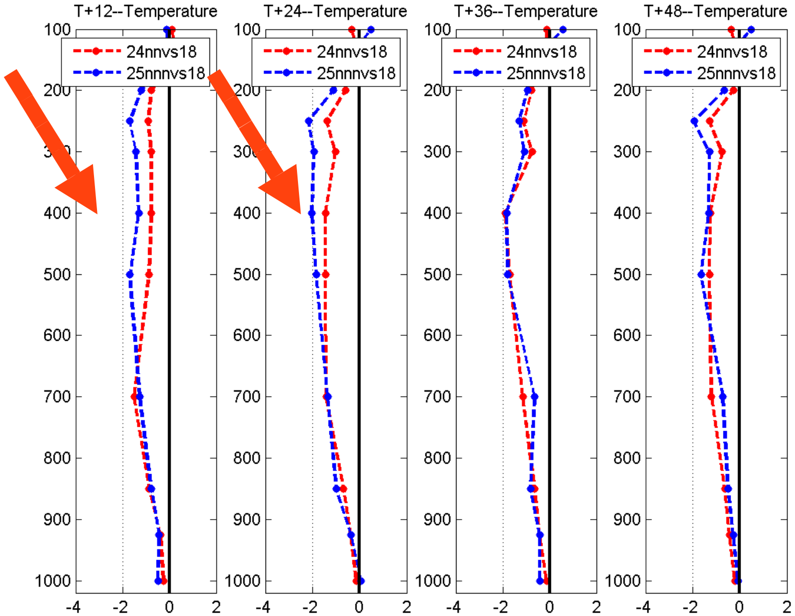
MHS rad. assimilation

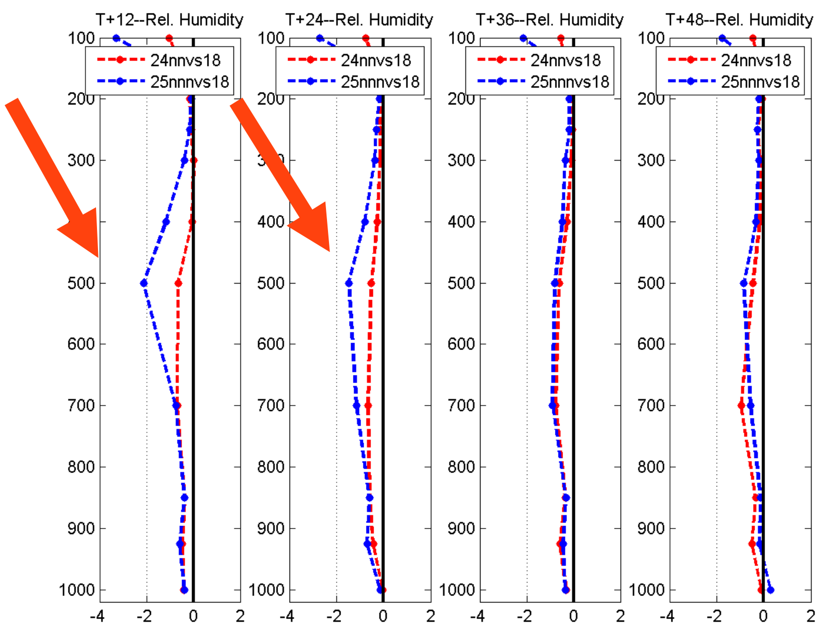
Relative difference (%) in RMSE computed against IFS analysis for 00 UTC COSMO runs from 16-09-2012 to 05-10-2012

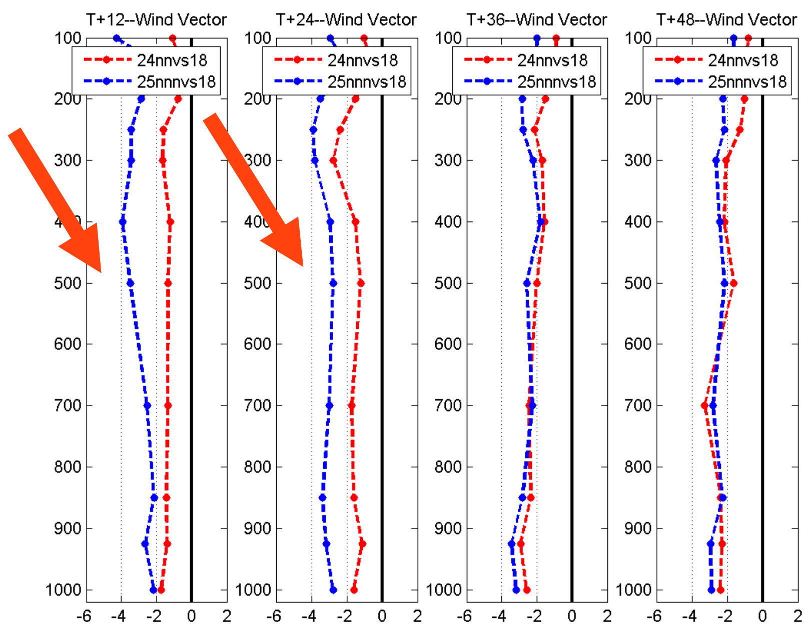
negative value = positive impact

MHS+AMSU

AMSU







New Additive Noise

Another additive inflaction formulation (noise added to each analysis ensemble member) is needed for COSMO-LETKF since:

- The previous version of CNMCA-LETKF used a climatological additive noise based on HRM model.
- A climatological forecast database for COSMO at 0.09° and 45 v.l. is not available on the current integration domain
- Climatological additive inflaction has the technical disadvantage to require an "enough" long period of 36/48h forecasts (need to re-run the model or to interpolate old runs to the new resolution)

Moreover:

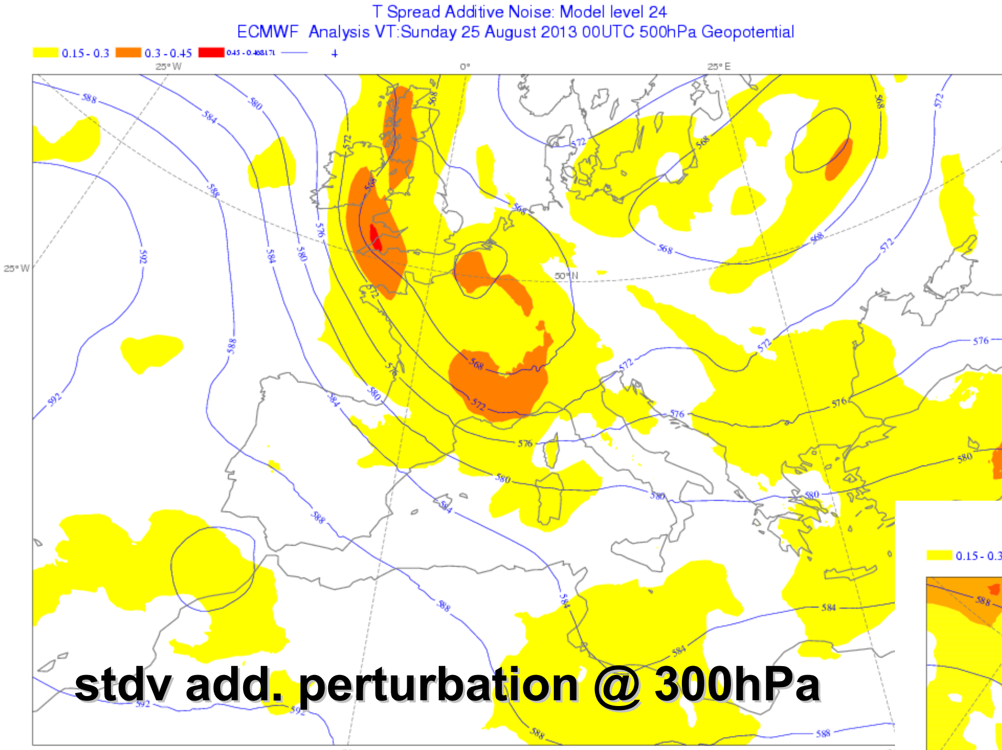
- A deficiency of climatological additive perturbations is that they are not dynamically conditioned to project onto the growing forecast structures (no relevance of flow of the day). It may take a while to project strongly.

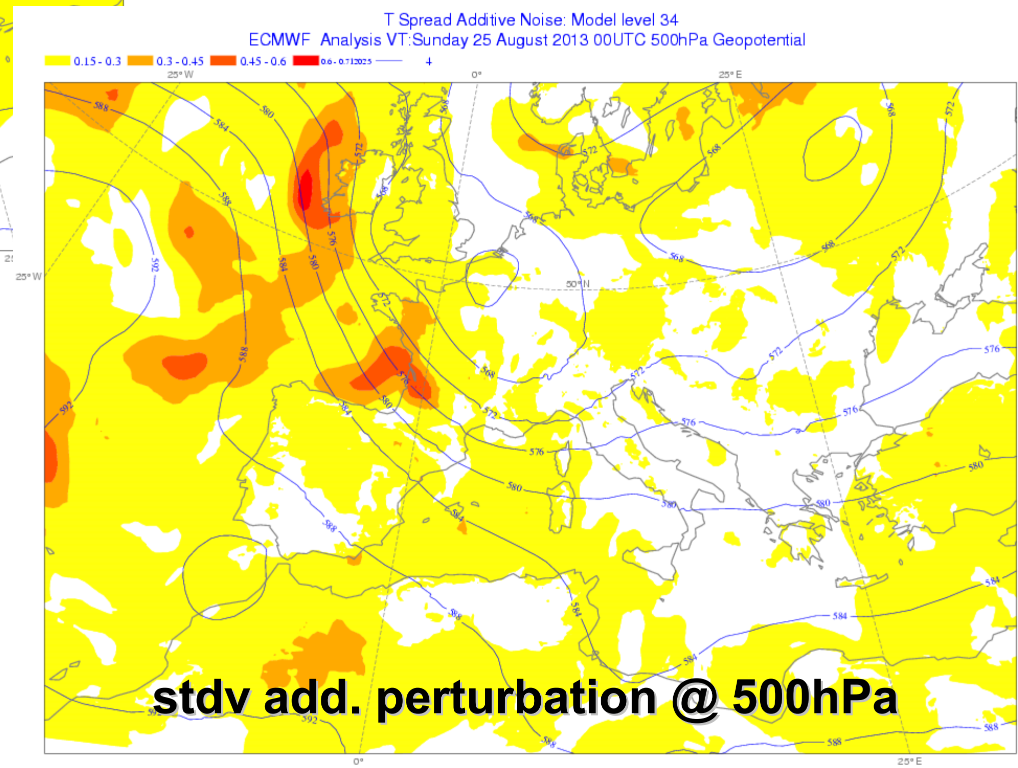
Additive Noise from IFS

- The difference between EPS ensemble forecasts valid at the analysis time is computed and interpolated on the COSMO grid (36h and 12h at 00/12UTC run and 42h and 18h at 06/18UTC run)
- EPS forecasts on pressure levels are currently used.

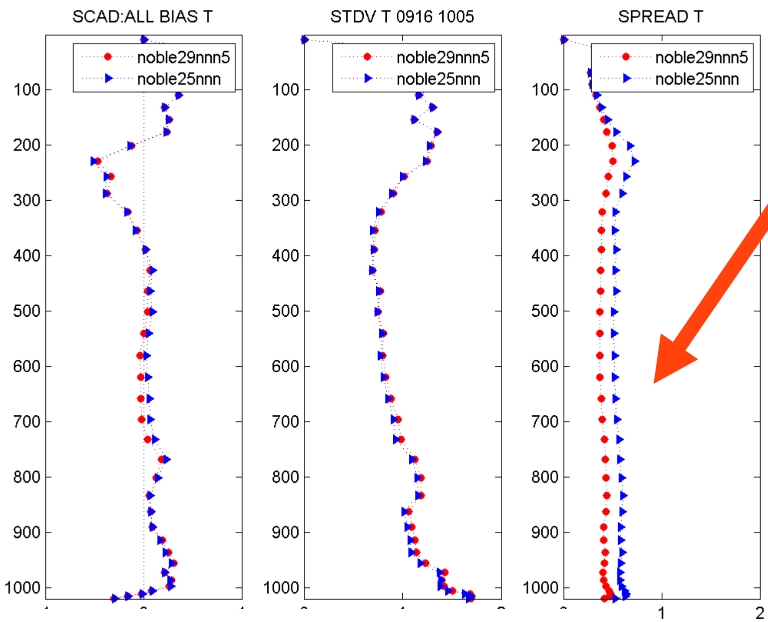
- The mean difference is removed to yield a set of perturbations that are scaled and used as additive noise.
- This additive noise, derived from IFS model, is not consistent with COSMO model errors statistics, but it may temporarily substitute the climatological one (avoiding a decrease of the spread in the CNMCA COSMO-LETKF).

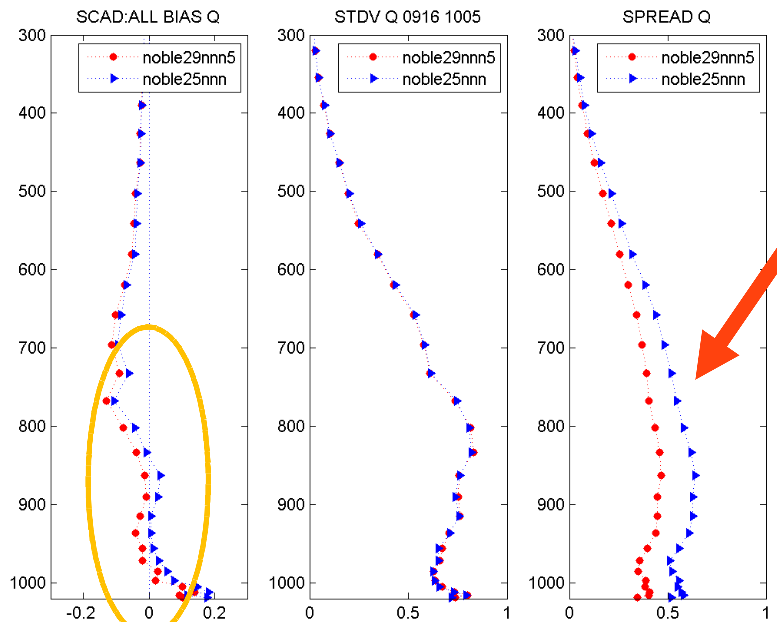
Additive Noise from IFS

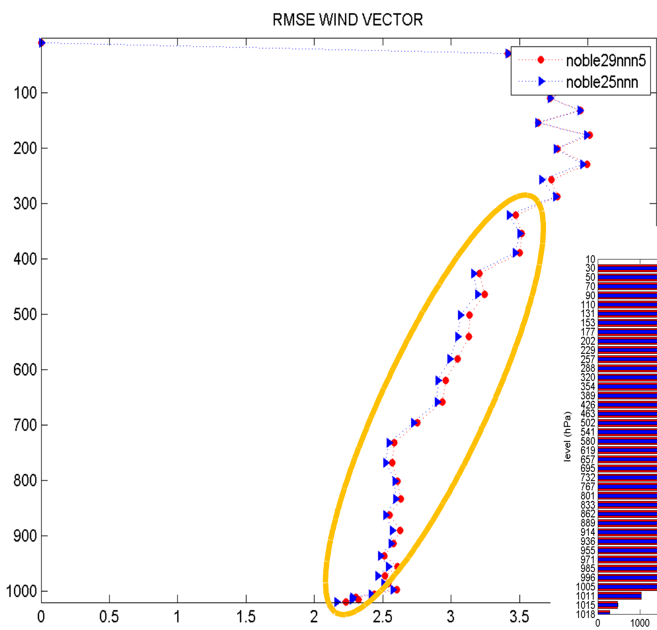


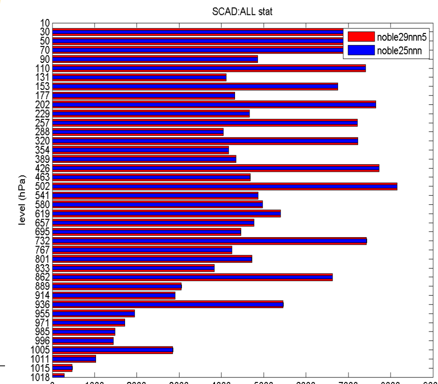


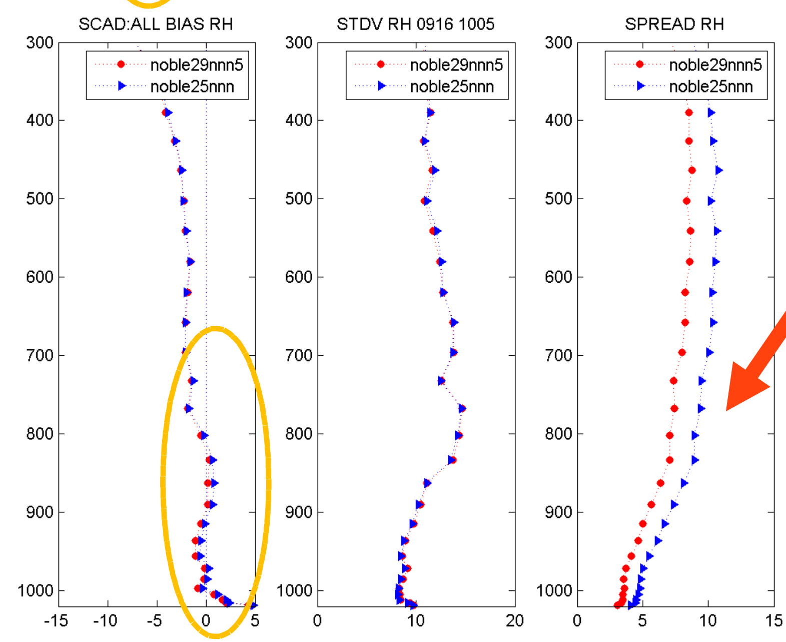
OBS INCREMENT STATISTICS (RAOB)
NO ADDITIVE VS IFS ADDITIVE





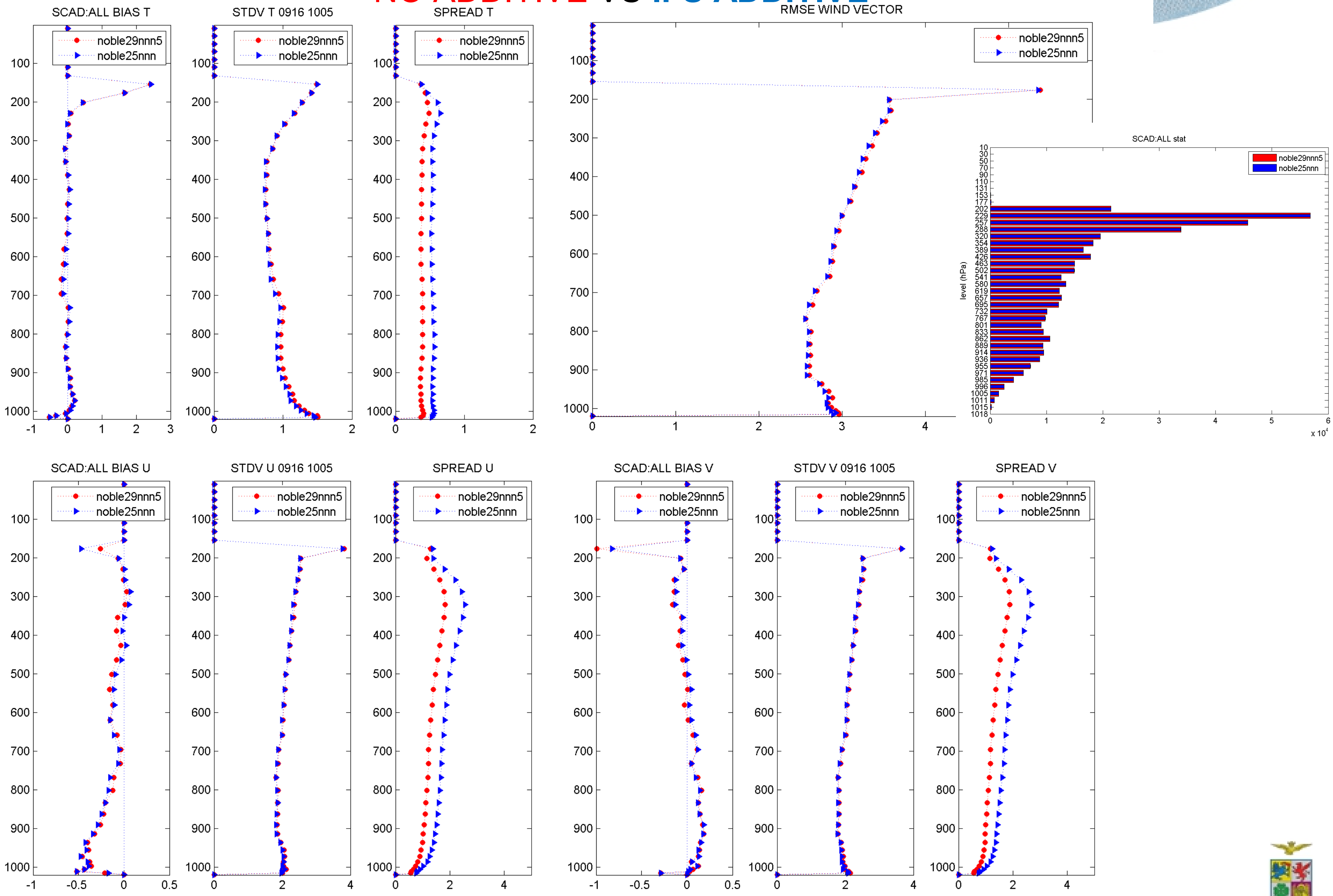






OBS INCREMENT STATISTICS (AIRCRAFT)

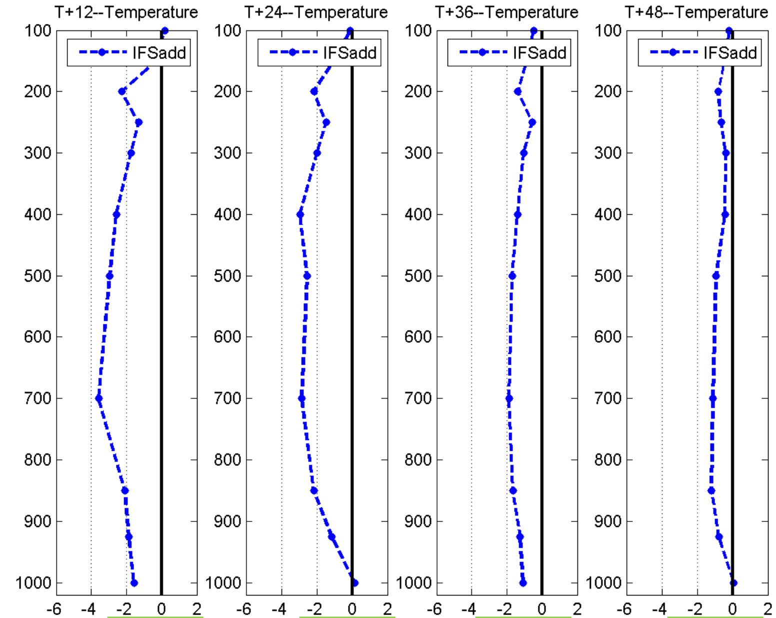
NO ADDITIVE VS IFS ADDITIVE



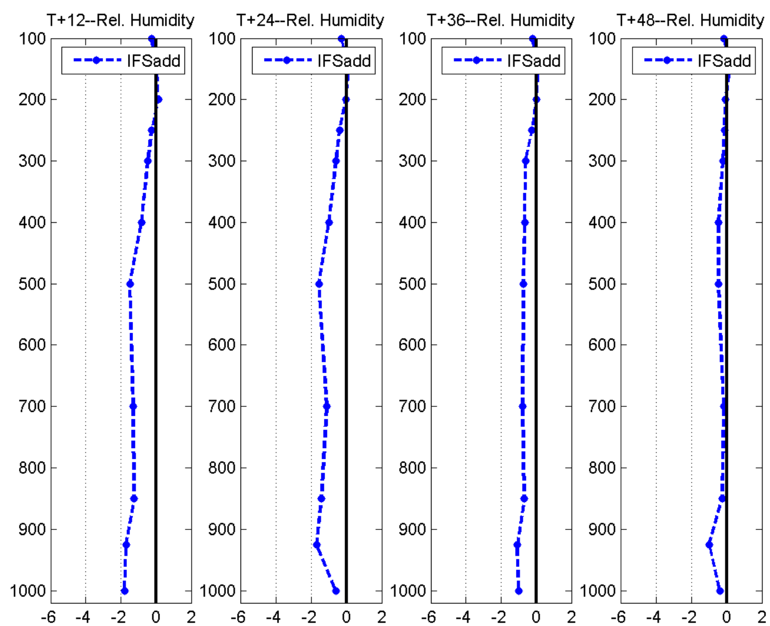
Additive Noise from IFS

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

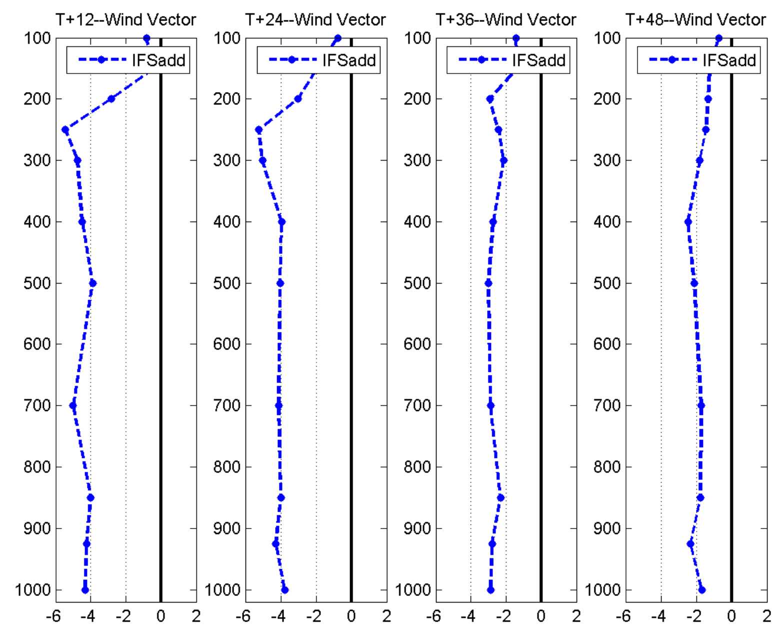
negative value = positive impact



+12h | +24h | +36h | +48h



+12h | +24h | +36h | +48h



Additive Noise from IFS

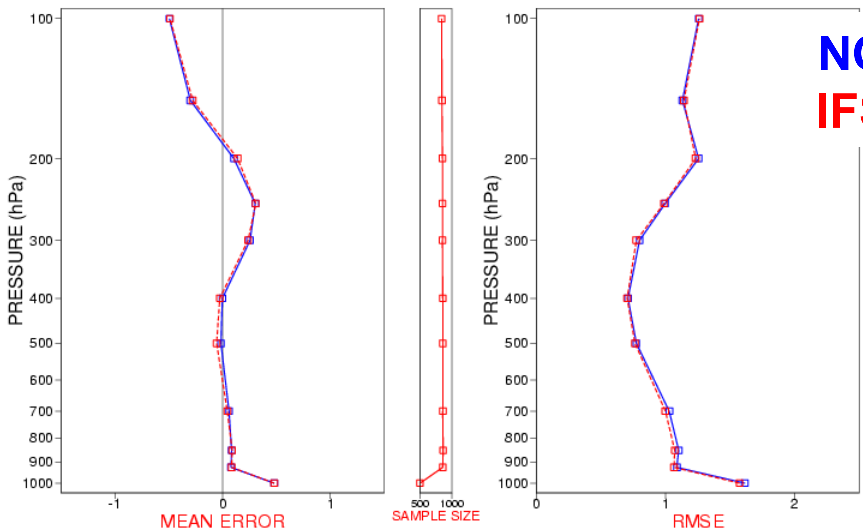
FORECAST VERIFICATION AGAINST RAOB

17sept 2012 – 5oct 2012

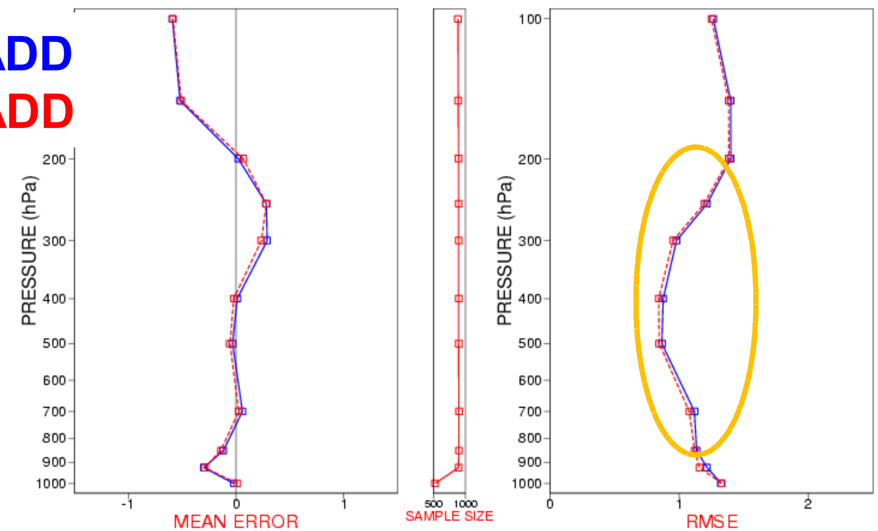
NO ADD

IFS ADD

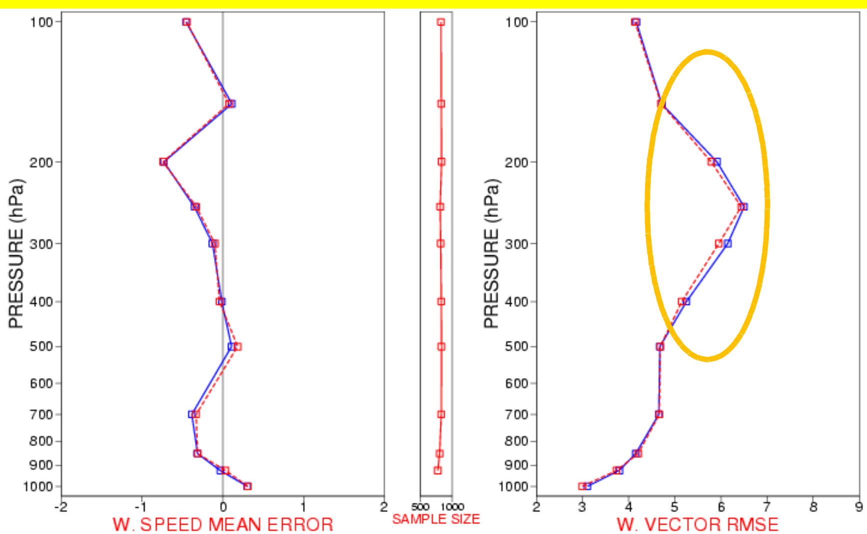
Temperature 00UTC FC+12h



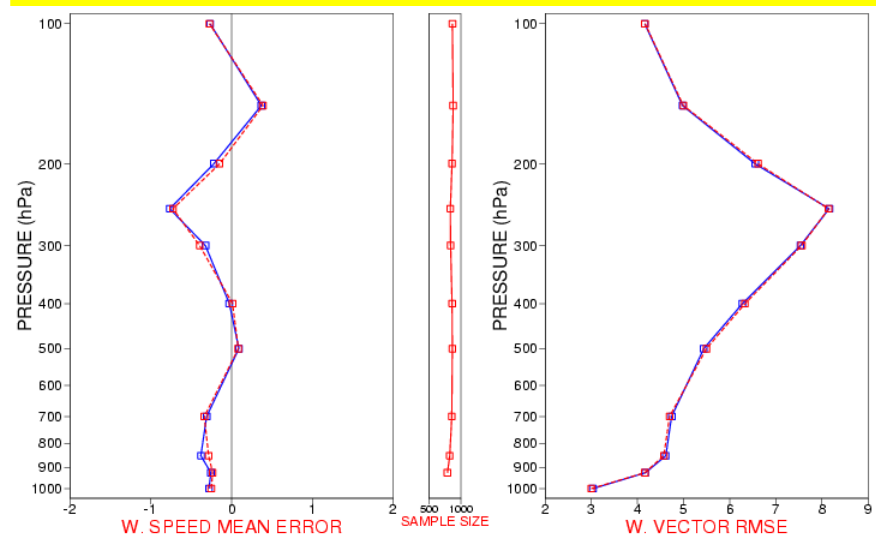
Temperature 00UTC FC+24h



Wind 00UTC FC+12h



Wind 00UTC FC+24h

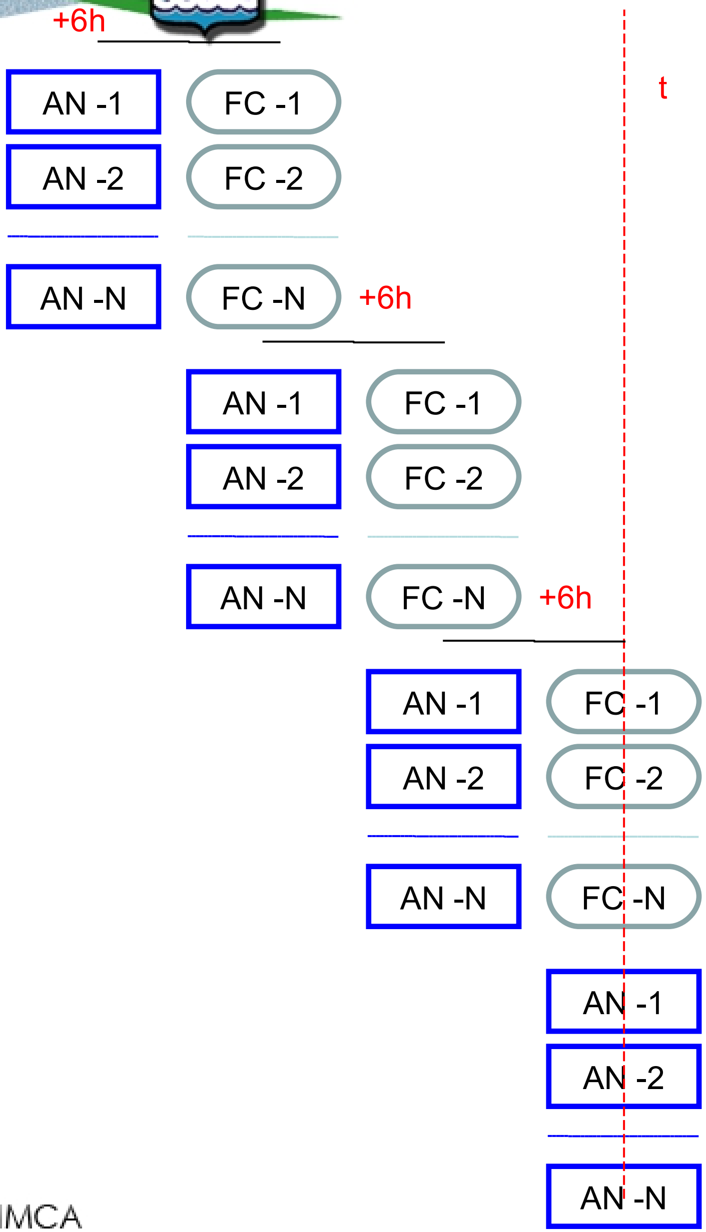


Self-Evolving Additive Noise

- A new additive inflaction formulation is needed, because IFS additive noise is not consistent with COSMO model errors statistics.
- The self-evolving additive inflaction (idea of Mats Hamrud – ECMWF) was chosen. The idea is different from the evolved additive noise of Hamill and Whitaker (2010)
- Difference between ensemble forecasts valid at the analysis time is 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 both consistent with model errors statistics and a flow-dependent noise
- The error introduced during the first hours may have a component that will project onto the growing forecast structures having probably a benificial impact on spread growth and ensemble-mean error

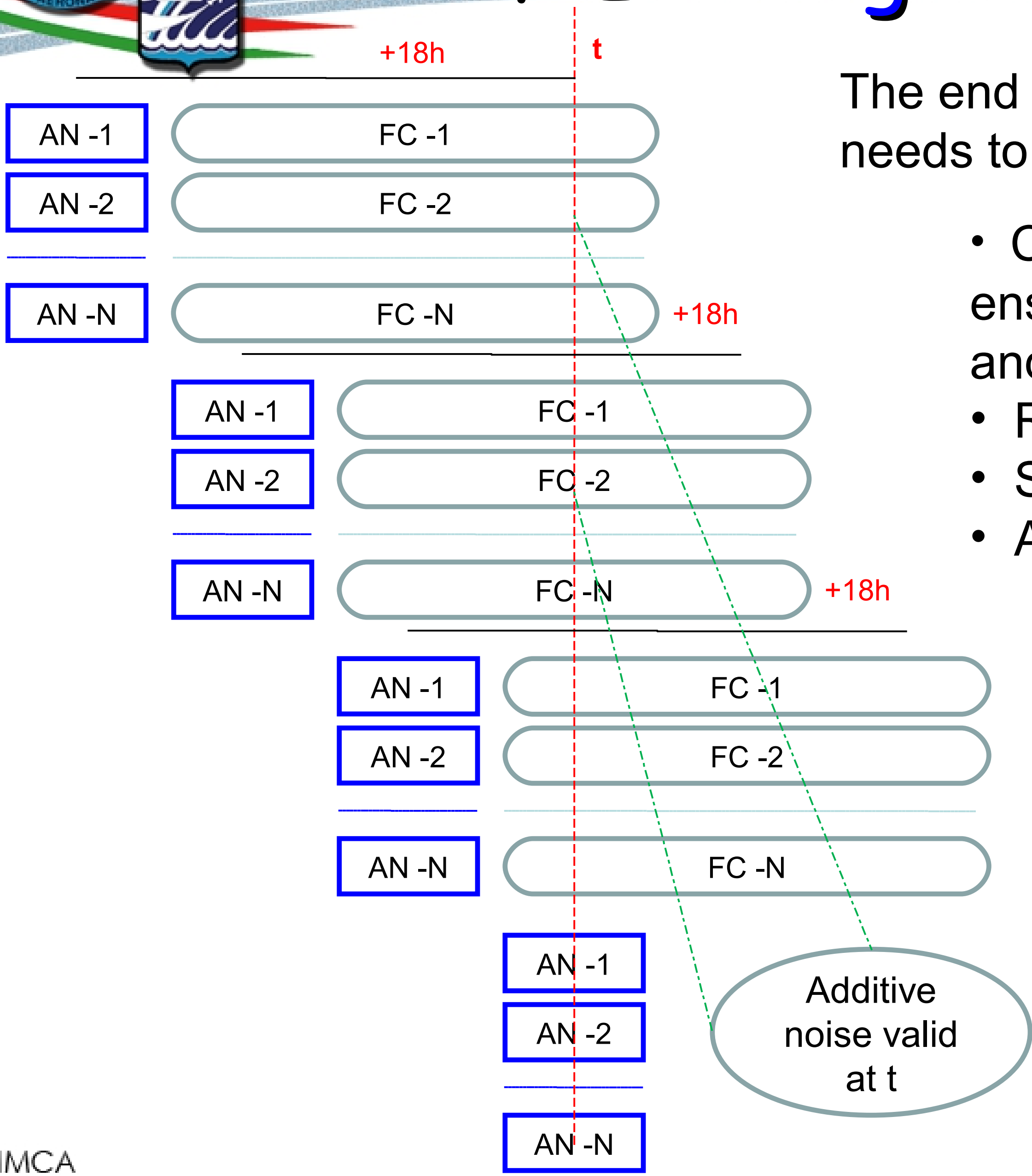
Self-Evolving Additive Noise



- Compute the difference of ensemble forecasts (i.e. 18h and 12h) valid at t
- Remove the mean difference
- Scale the perturbations
- Add to the T analysis

Additive noise valid at t

Self-Evolving Additive Noise



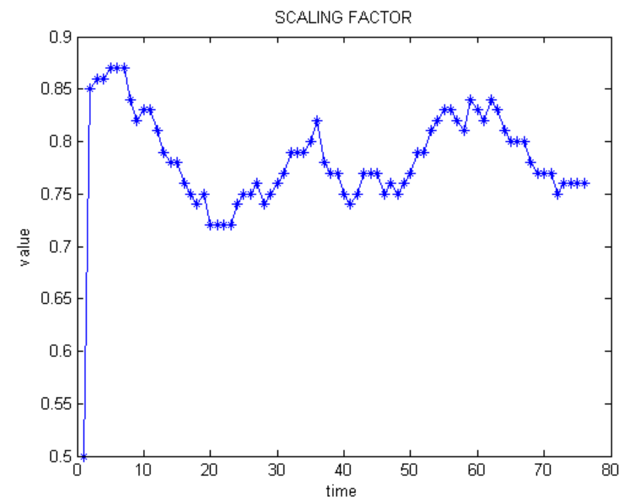
The end of model forecast integration needs to be extend

- Compute the difference of ensemble forecasts (i.e. 18h and 12h) valid at time t
- Remove the mean difference
- Scale the perturbations
- Add to the t analysis

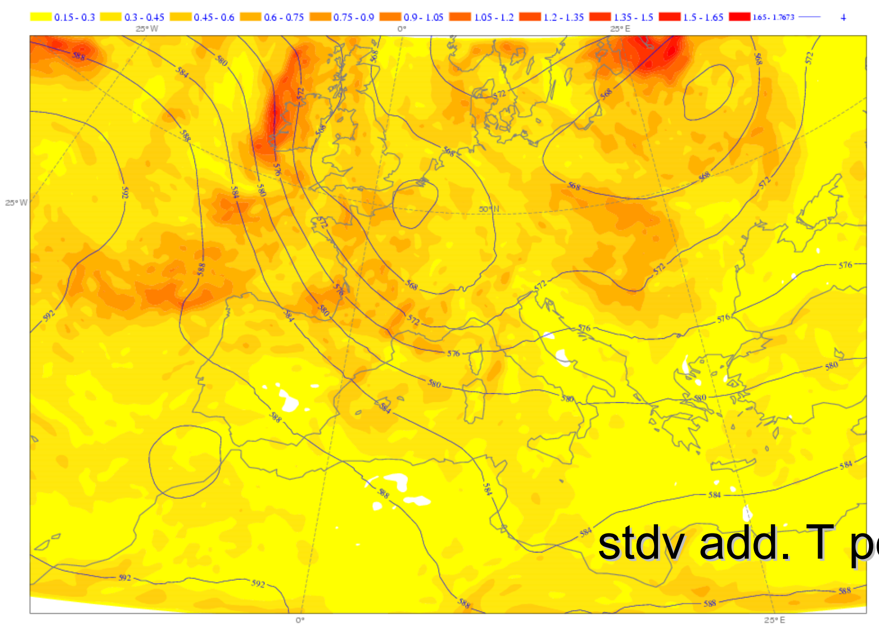
Self-Evolving Additive Noise

Other features in the current version:

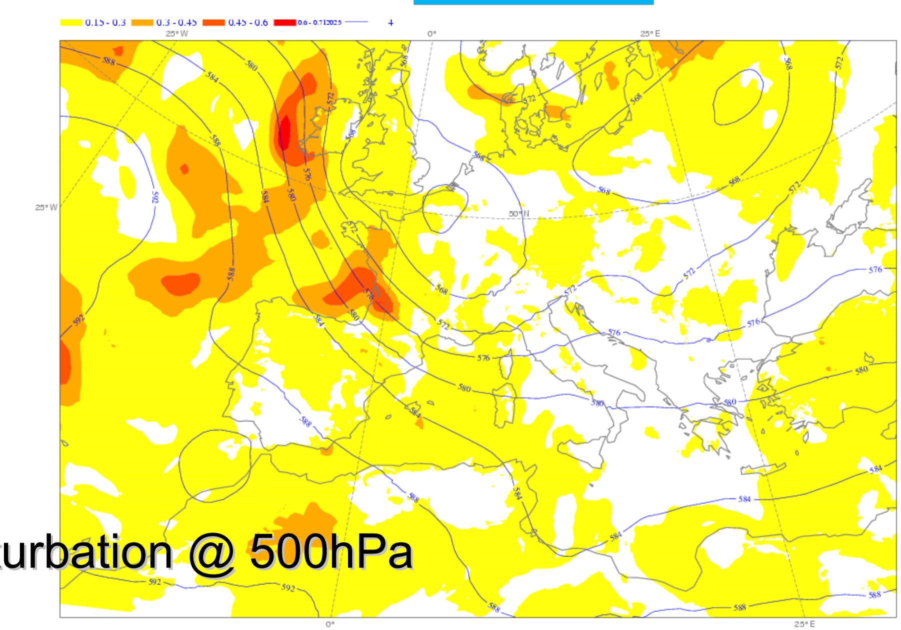
- 12h-6h forecast differences
- spatial filtering of ensemble difference using a low pass 10th order Raymond filter
- Adaptive scaling factor using the surface pressure obs inc statistics



SELF EV. ADD

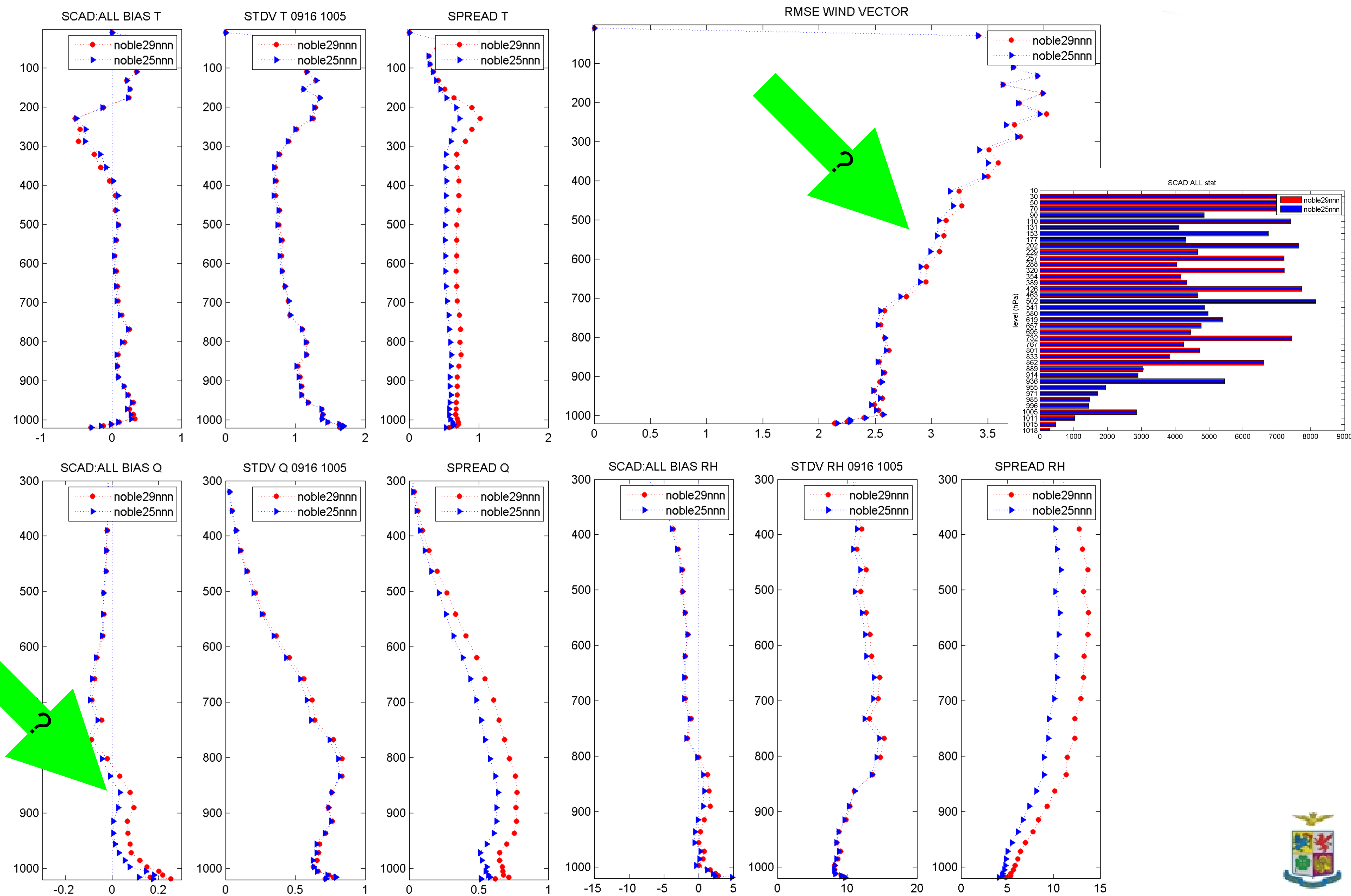


IFS ADD

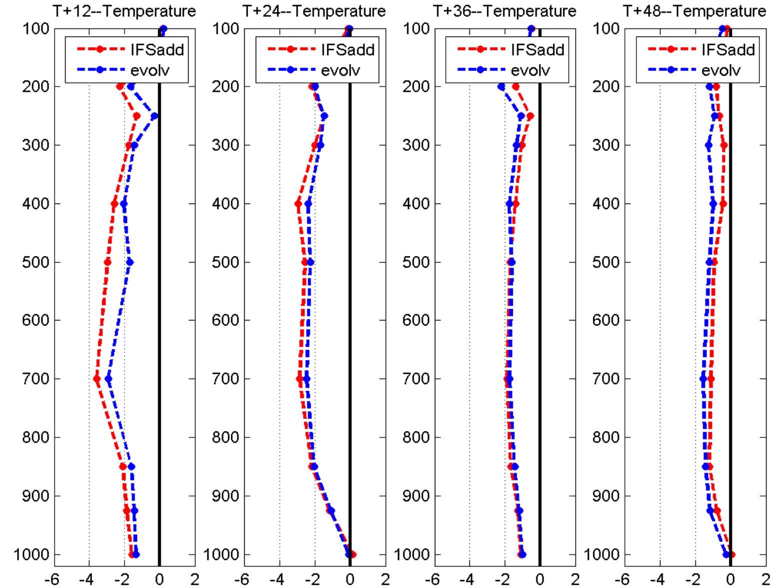


stdv add. T perturbation @ 500hPa

OBS INCREMENT STATISTICS (RAOB)
SELF-EVOLVING ADD. VS IFS ADDITIVE



Self-Evolving Additive Noise



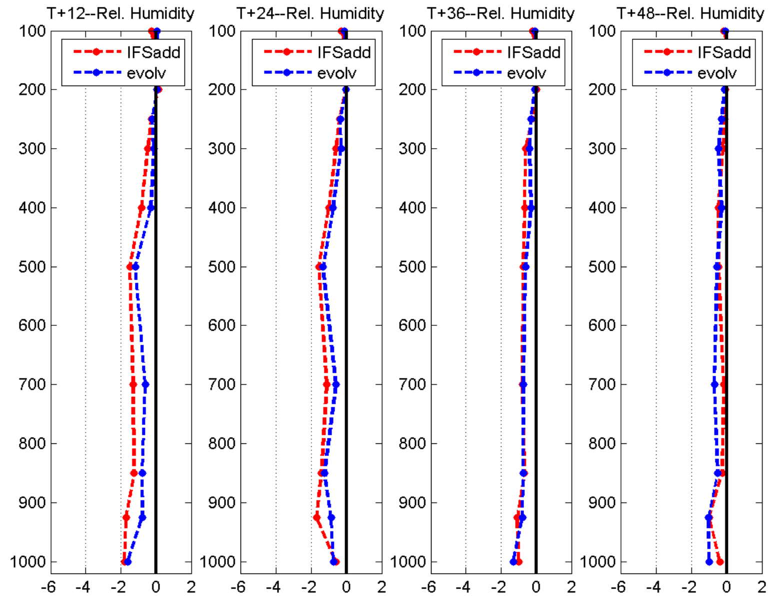
Relative difference (%) in RMSE, computed against IFS analysis, with respect to IFS-ADDITIVE run for 00 UTC COSMO runs from 16-09-2012 to 05-10-2012

negative value = positive impact

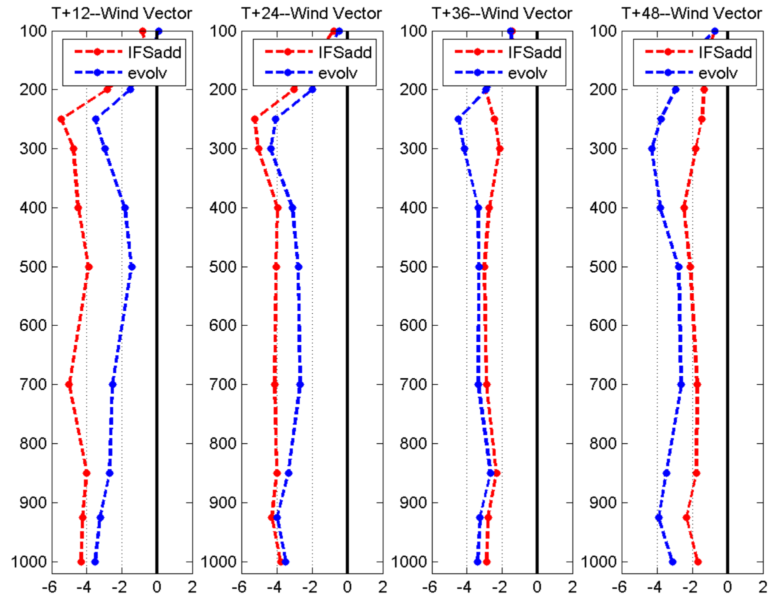
IFS ADD

SELF EV. ADD

+12h **+24h** **+36h** **+48h**



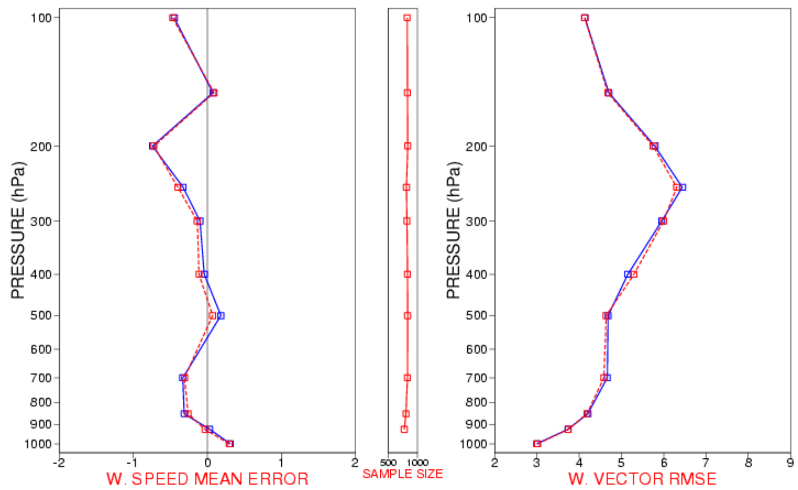
+12h **+24h** **+36h** **+48h**



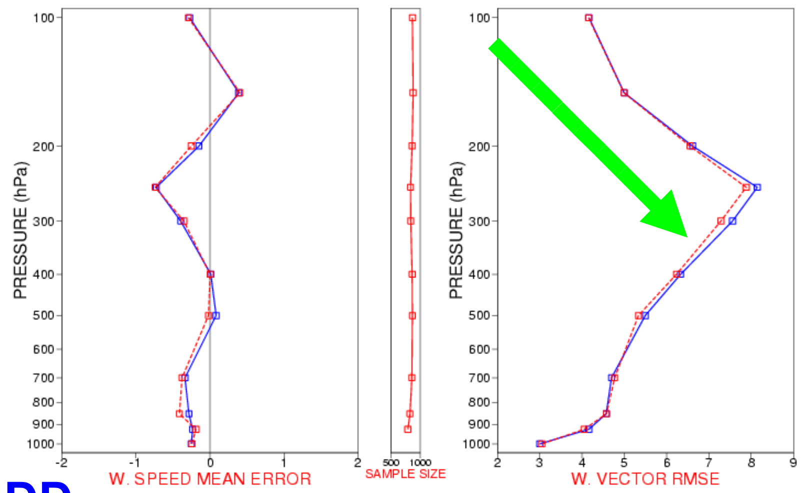
Self-Evolving Additive Noise

FORECAST VERIFICATION AGAINST RAOB 17sept 2012 – 5oct 2012

WIND 00UTC FC+36h



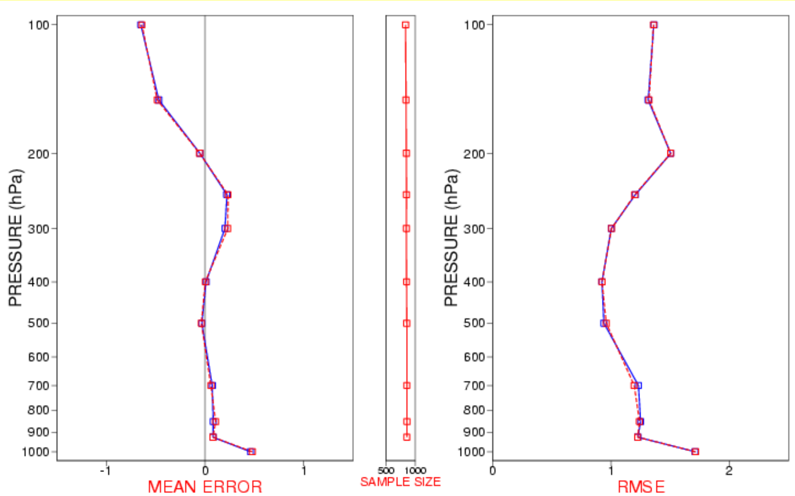
WIND 00UTC FC+48h



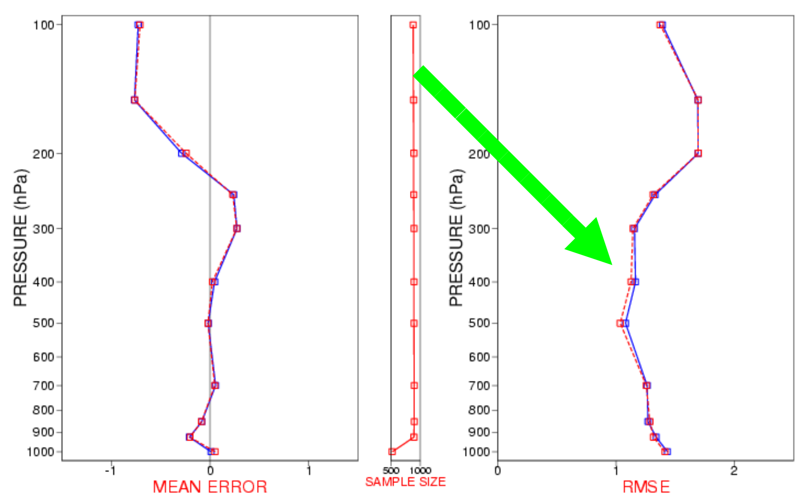
IFS ADD

SELF EV. ADD

T emperature 00UTC FC+36h

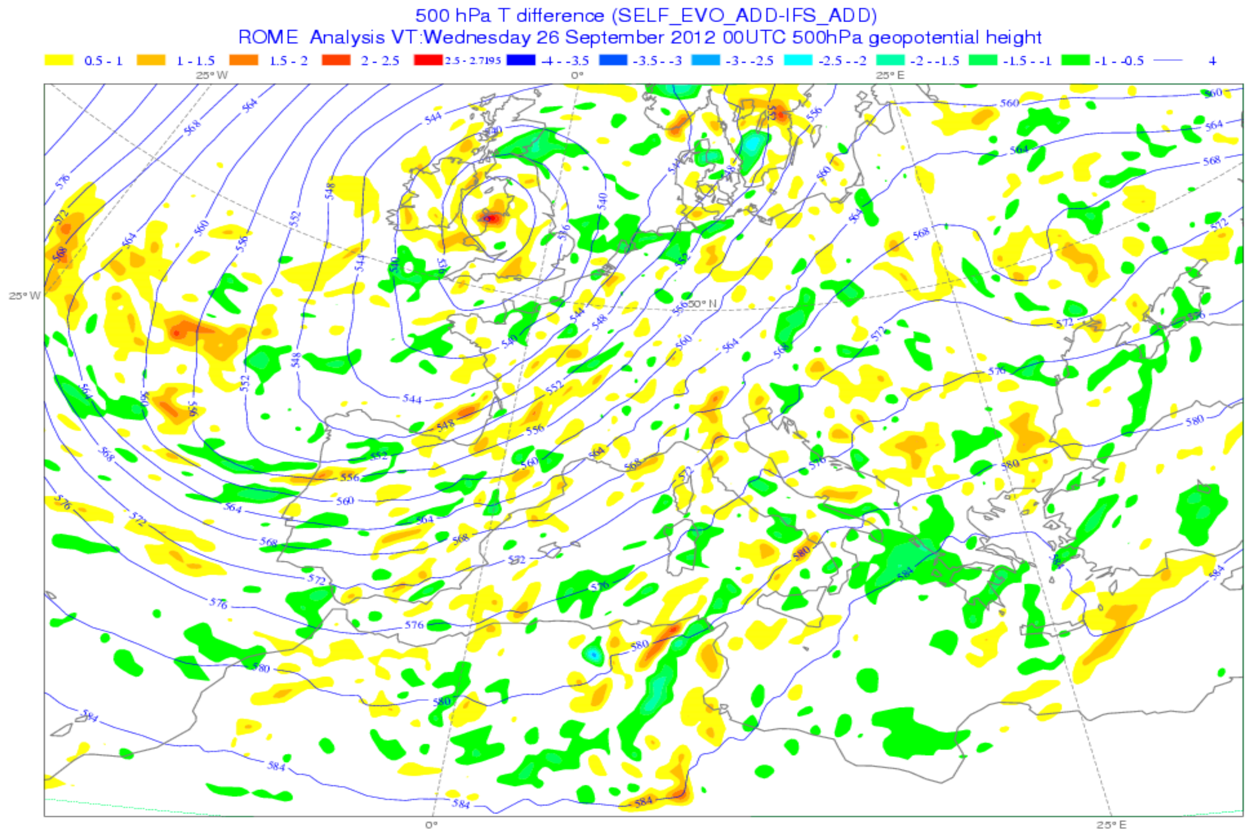


T emperature 00UTC FC+48h



Self-Evolving Additive Noise

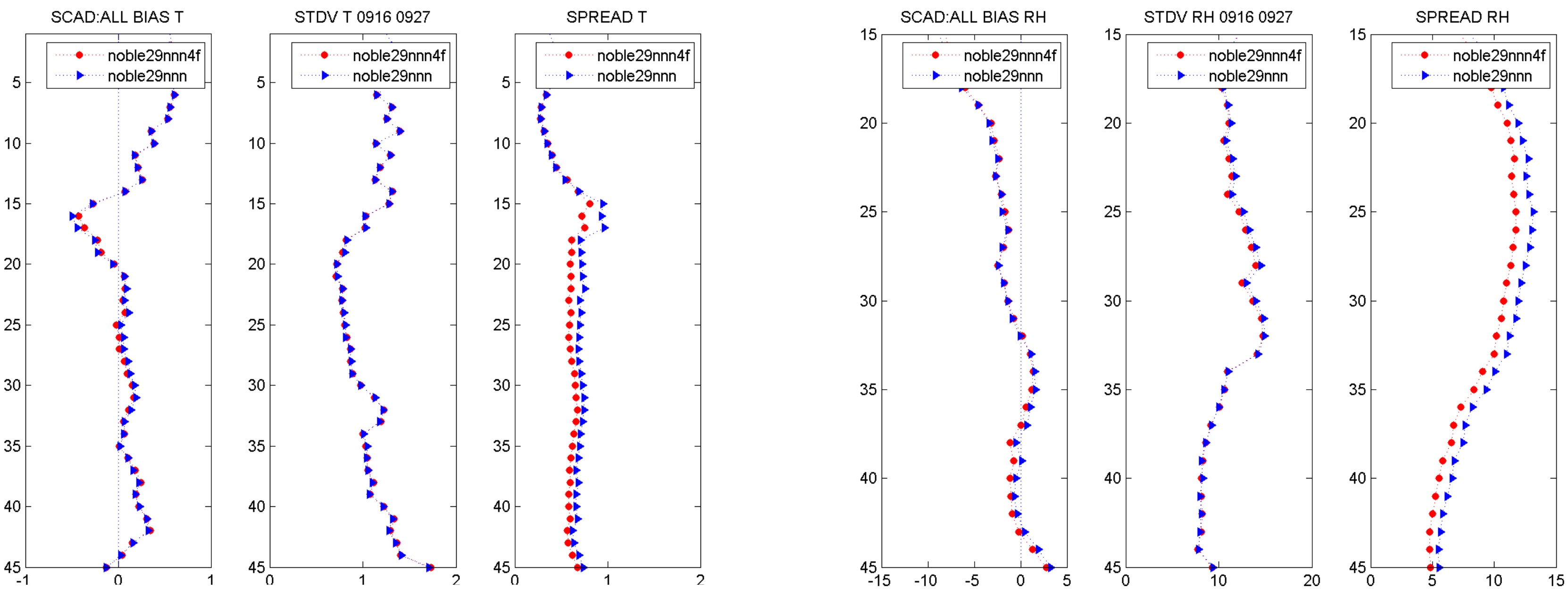
ANALYSIS@500hPa: SELF EVOLVING ADDITIVE – IFS ADDITIVE

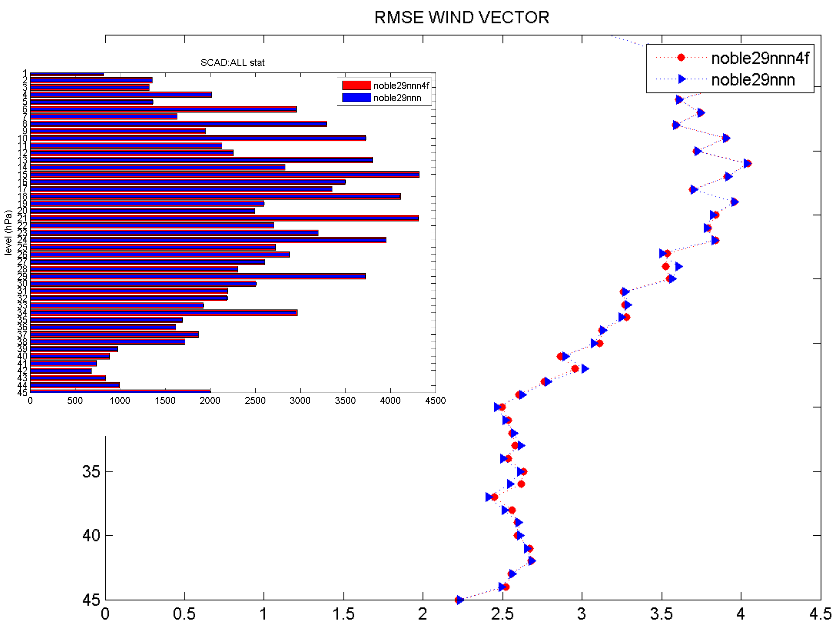


The impact of the self-evolving additive on COSMO day 2 forecast is larger than those of additive from IFS.
More work is needed to understand the slight worsening in day 1 forecast.

Future experiments:
- tuning of scaling factor and smoothing
- test of no adaptive scaling factor
- use of 18h – 12h ensemble forecast difference

OBS INCREMENT STATISTICS (RAOB)
STOCHASTIC PHYSICS VS SELF-EVOLVING ADDITIVE

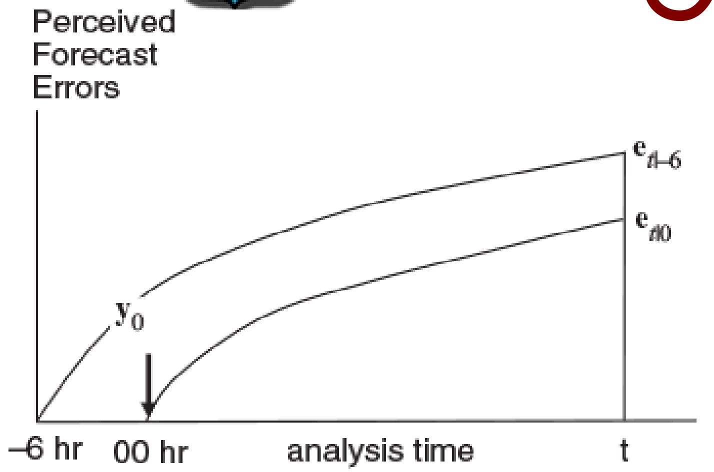




STOCHASTIC PHYSICS SETTINGS:
stdv=0.25, range=0.5
box 2.5° x 2.5°, 3 hour
interp. in space and time
no humidity check

The impact on COSMO forecasts of SP seems to be smaller than those of self-evolving additive (preliminar result)

Forecast Sensitivity to Observations



$$e_{t,0} = x^f_{t,0} - x^a_t$$

The only difference between $e_{t,0}$ and $e_{t,-6}$ is the assimilation of obs at 00 hr:

$$x^a_0 - x^b_{0,-6} = K(y_0 - H(x^b_{0,-6}))$$

Observation impact on the reduction of forecast error:

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

Kalnay et al. (2012)

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

where C defines the square norm to be used (moist total energy norm)

This method does not require the adjoint of M and K and it can be applied to every ENKF technique

Forecast Sensitivity to Observations

Moist total energy norm

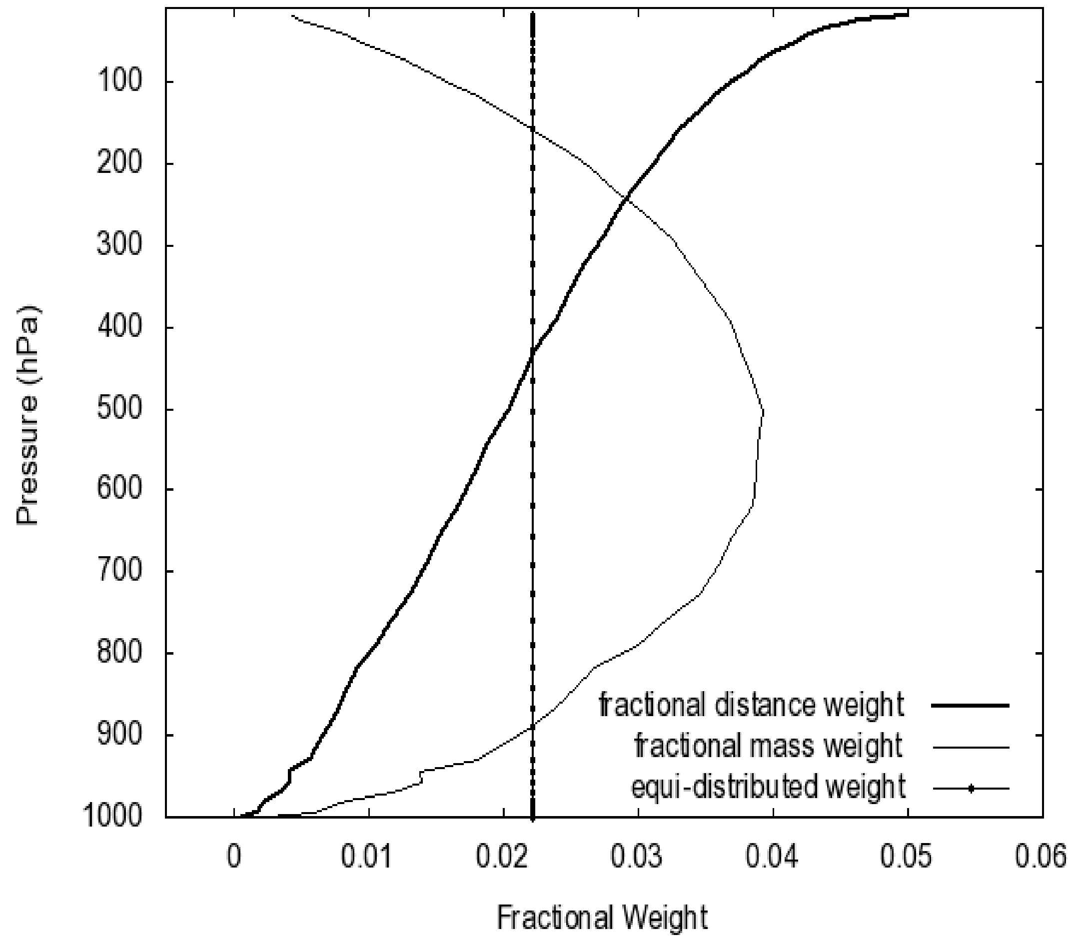
$$E = 1/2\,\Sigma_{i,j,k} \Delta A_j \Delta \sigma_{i,j,k} \left(u'^2 + v'^2 + aT'^2 + bq'^2 + cp_s'^2\right)$$

Different vertical weights were considered for the E-norm

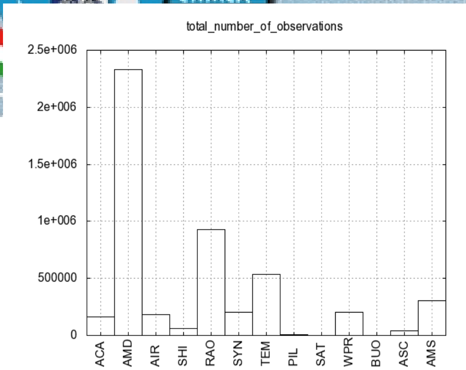
$$\Delta \sigma_{i,j,k,fd} = \Delta p_{i,j,k} / (ps_{i,j} - p_t)$$

$$\Delta \sigma_{i,j,k,fm} = \Delta z_{i,j,k} / (zs_{i,j} - z_t)$$

$\Delta \sigma_{i,j,k,eq} = 1/$ 1/Nlev

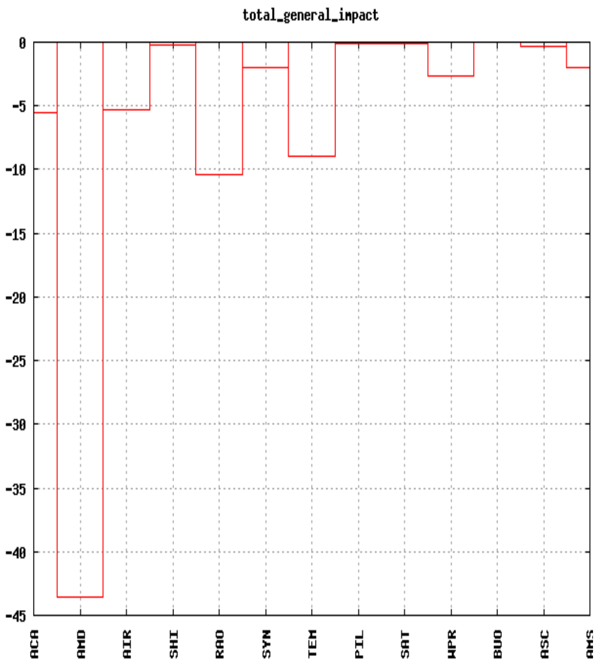


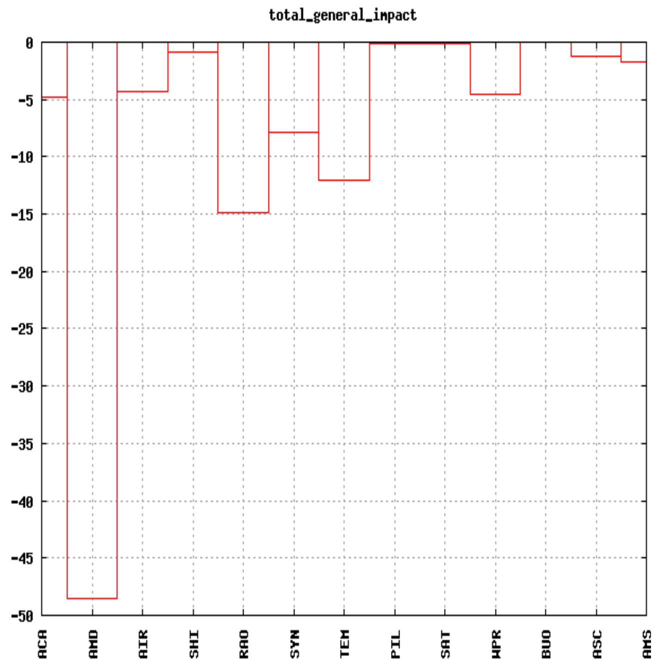
Forecast Sensitivity to Observations

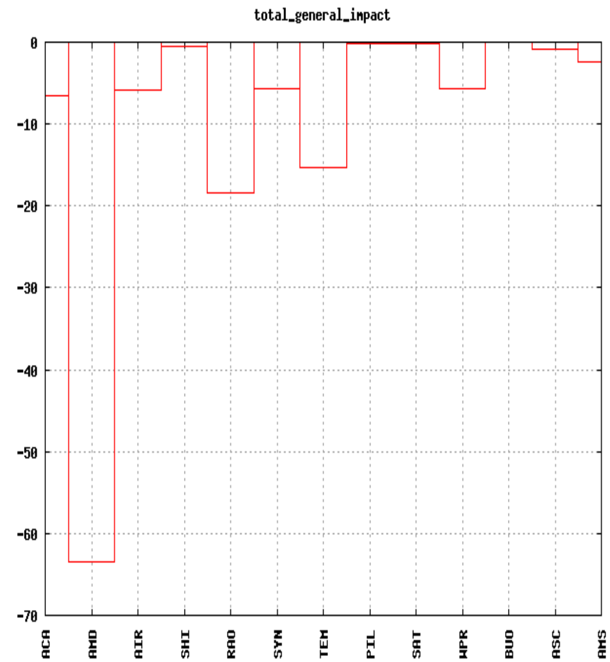


Total impact

17 luglio – 17 agosto 2013







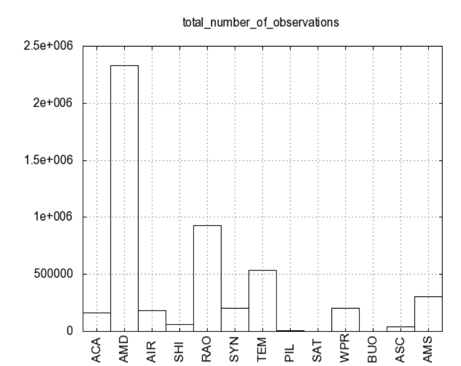
Equi-distributed

Fractional distance

Fractional mass

Forecast Sensitivity to Observations

Singular impact



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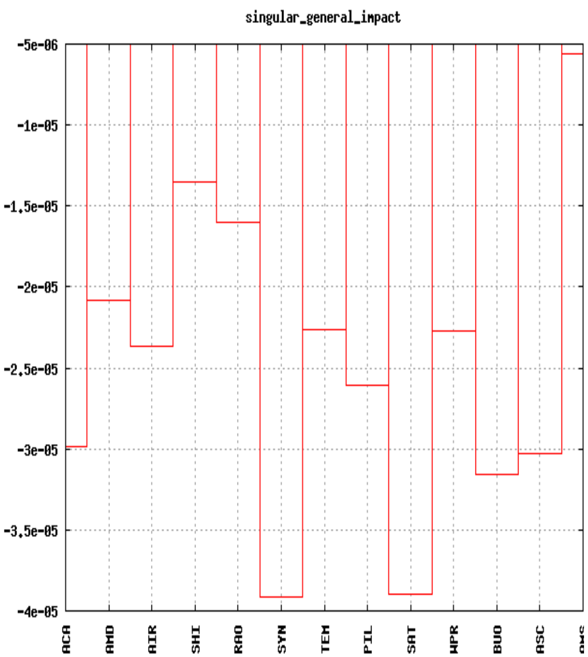

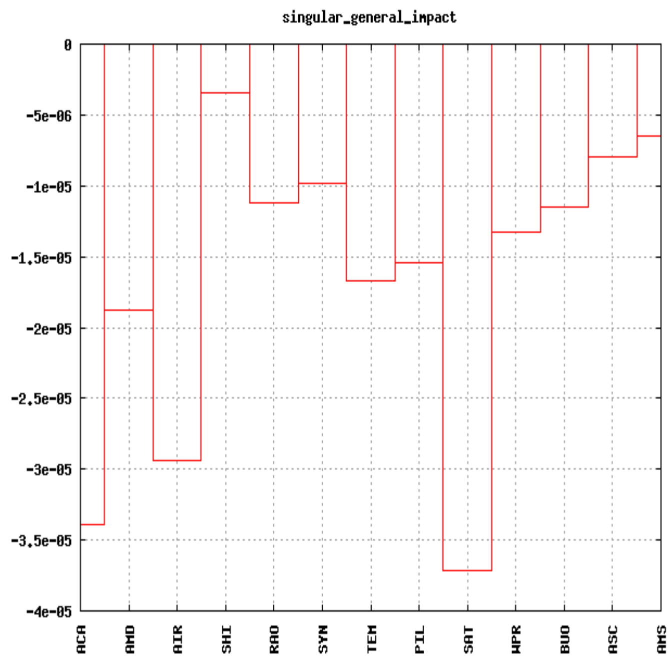

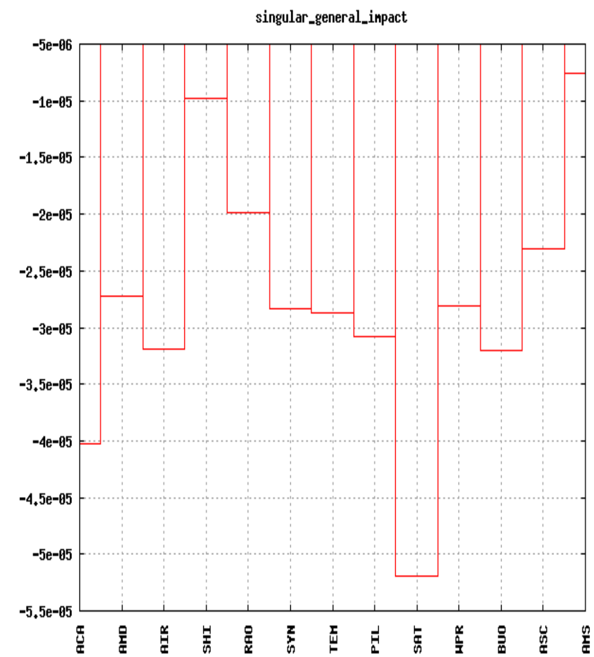

Equi-distributed

Fractional distance

Fractional mass

Current and future developments

- Assimilation of MHS is under investigation
- Self-evolving additive inflaction / Stochastics physics
- Pseudo-relative humidity as analysed variable
- COSMO-ME Short-Range EPS based on LETKF is experimentally running
- ATMS radiances, Oceanscat2 winds, MetopB AMSUA-MHS are monitored along with GPS delays.
- Dynamical retrieved MW land emissivity
- Shorter assimilation window
- Further tuning of model error representation (tuning of cov. localization, bias correction, etc.)

Thanks for your attention!