



Recent work on the treatment of model error in the CNMCA-LETKF system

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Outline



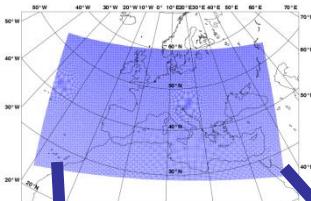
- Implementation of the LETKF at CNMCA
- Treatment of model error in the CNMCA-LETKF
 - The Self Evolving Additive Noise: different formulations
 - Forecast verification over 30-days test period
 - Test with SPPT
- Summary and future developments





CNMCA NWP SYSTEM since 1 June 11

Ensemble Data Assimilation:



10 km
45 v.l.

LETKF
Analysis

Control State
Analysis

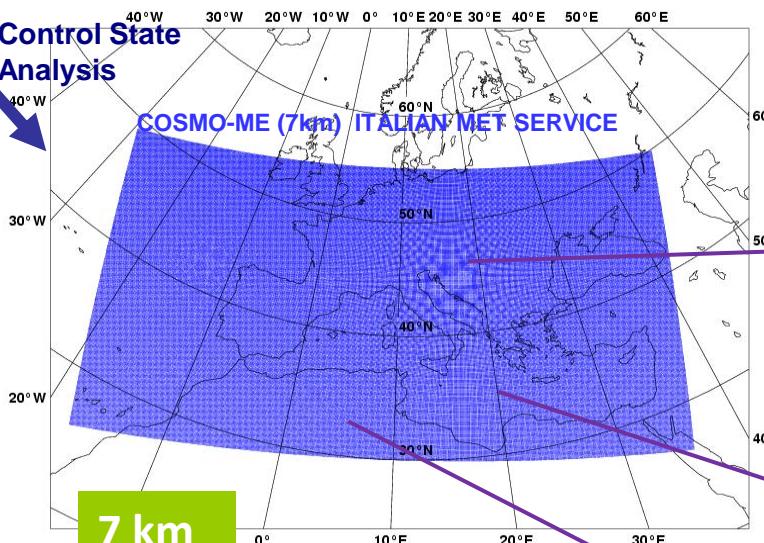


COSMO-ME EPS
(pre-operational)

LETKF analysis ensemble (40+1 members) every 6h using
RAOB (also 4D), PILOT, SYNOP, SHIP, BUOY, Wind Profilers,
AMDAR-ACAR-AIREP, MSG3-MET7 AMV, MetopA-B/Oceansat2 scatt. winds, NOAA/MetopA-B
AMSUA/MHS/ATMS radiances
+ Land SAF snow mask,
IFS SST analysis once a day

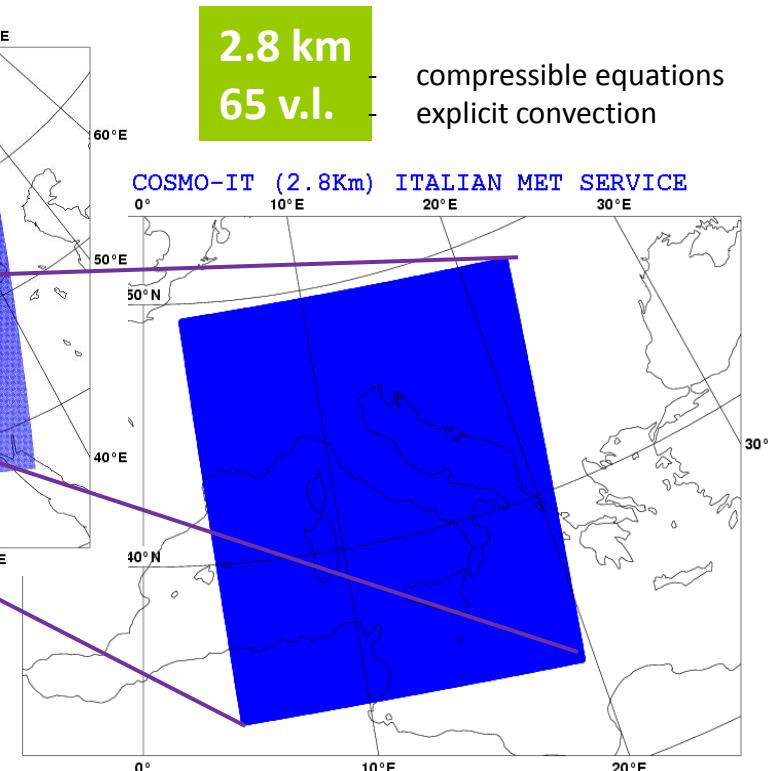
2.8 km
65 v.l.

- compressible equations
- explicit convection



7 km
40 v.l.

- compressible equations
- parameterized convection





Treatment of model error

In the **operational CNMCA-LETKF** implementation, model errors and sampling errors are taken into account using:

- Multiplicative Inflation: Relaxation to Prior Spread according to Whitaker et al (2012)

$$\text{an. pert. } \mathbf{x}_a' = \mathbf{x}_a' \sqrt{\alpha \frac{\sigma_b^2 - \sigma_a^2}{\sigma_a^2} + 1} \quad \alpha = 0.95 \\ \sigma^2 = \text{variance}$$

- Additive Noise from EPS (next slide)
- Lateral Boundary Condition Perturbation of determ. IFS using EPS
- Climatological Perturbed SST





Additive Noise from EPS

First (!not last) solution:

- 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)
- The mean difference is removed to yield a set of perturbations that are globally 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).





Self-Evolving Additive Noise

AIM: Find additive perturbations that are both consistent with model errors statistics and a flow-dependent noise

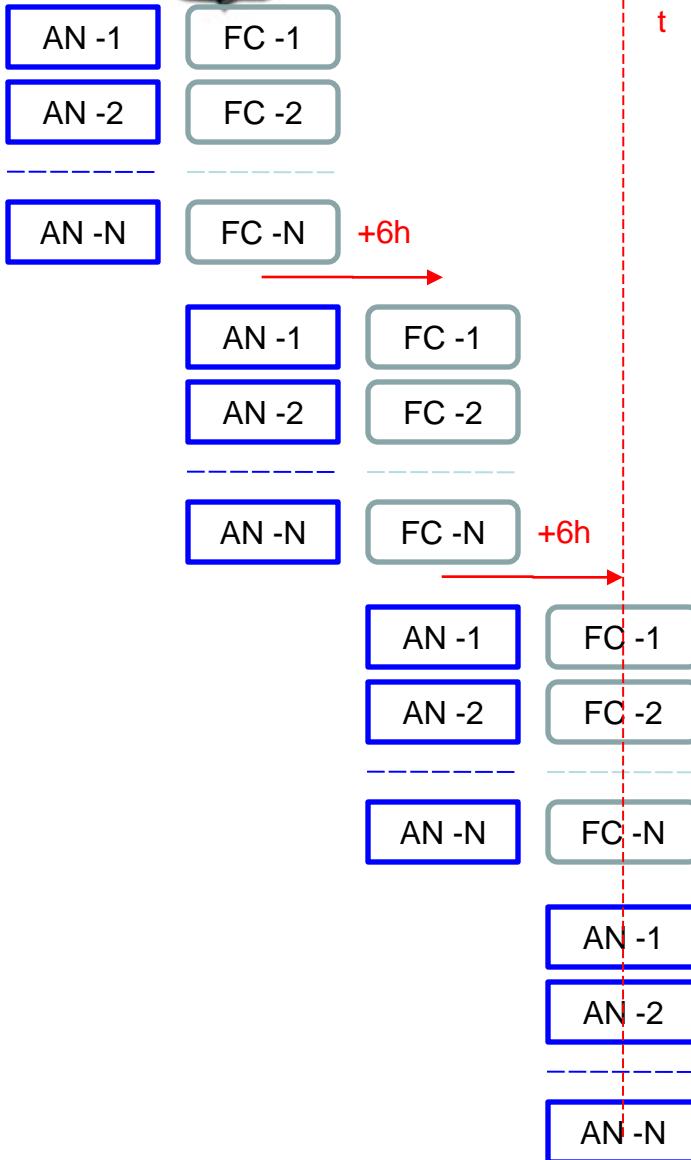
The self-evolving additive inflation (idea of Mats Hamrud – ECMWF) is chosen. The idea is different from that of the evolved additive noise of Hamill and Whitaker (2010)

- The difference between ensemble forecasts valid at the analysis time is calculated. The mean difference is then 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.
- This can be considered as a “blending” of two sets of perturbations, that should increase the “dimension” of the ensemble (i.e. 6h and 12h perturbations)
- The error introduced during the first hours may have a component that will project onto the growing forecast structures having probably a beneficial impact on spread growth and ensemble-mean error





Self-Evolving Additive Noise



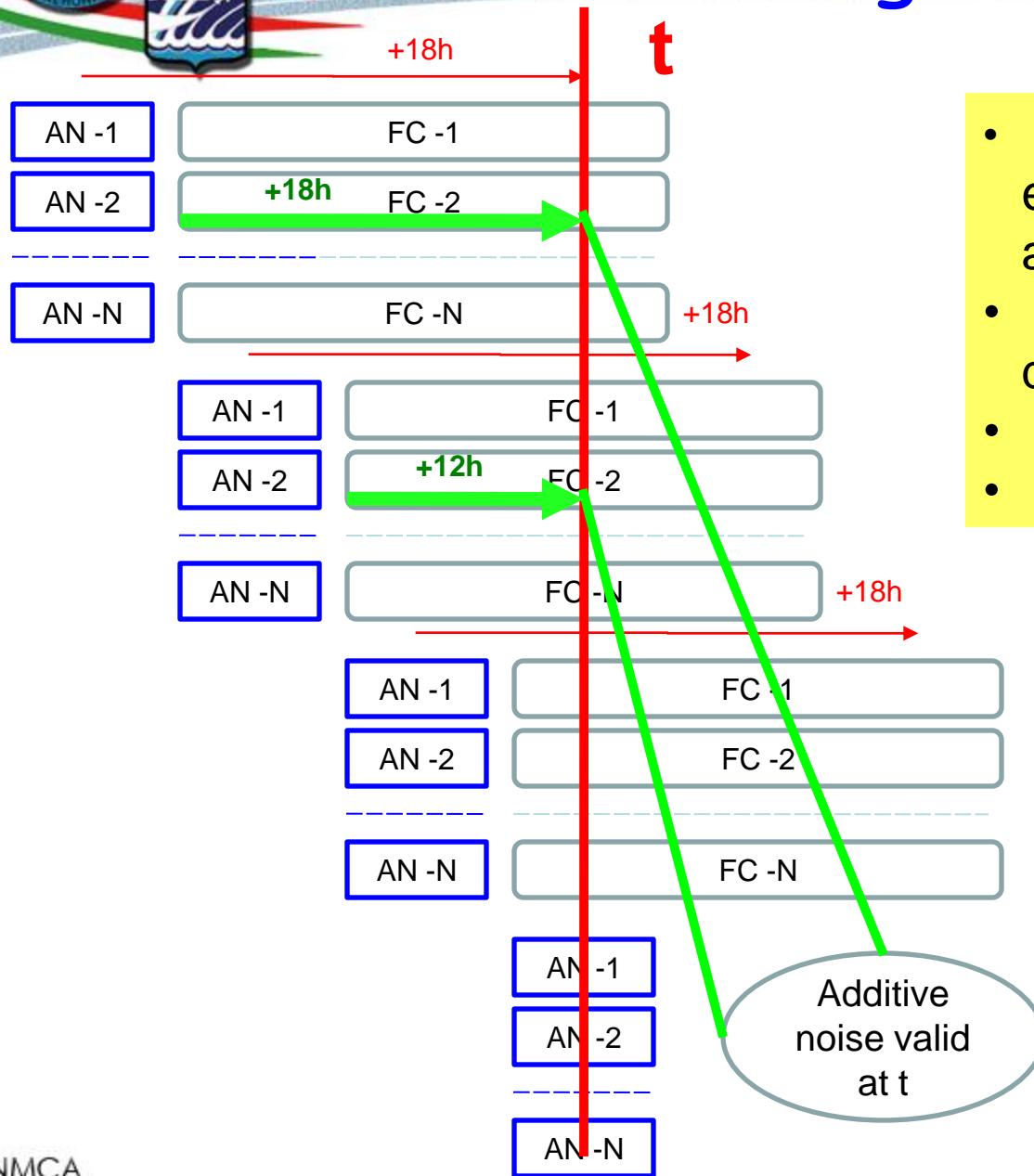
Additive
noise valid
at t

The end of model forecast integration needs to be extend





Self-Evolving Additive Noise



- 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





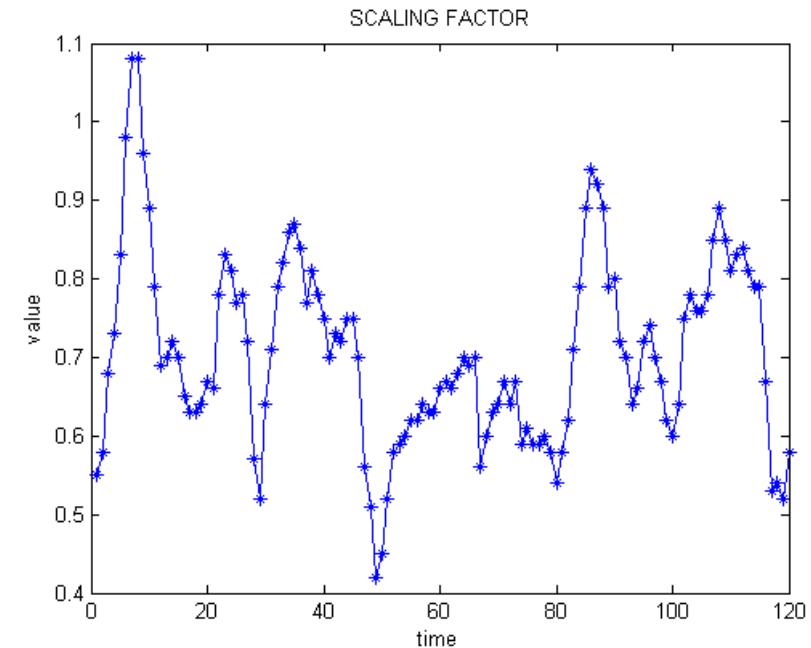
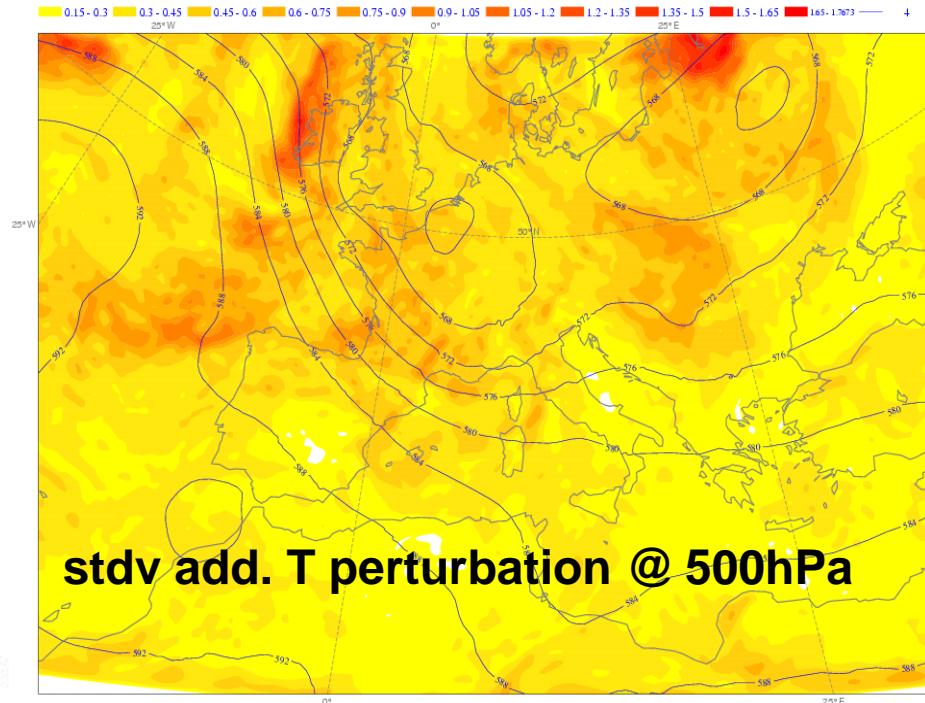
Self-Evolving Additive Noise

Features of first version:

$$\mathbf{x}_i^a \leftarrow \mathbf{x}_i^a + \alpha \mathbf{x}_i^n,$$



- 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 $R=0$





Self-Evolving Additive Noise

Can we get some benefit increasing the time difference between forecasts ?

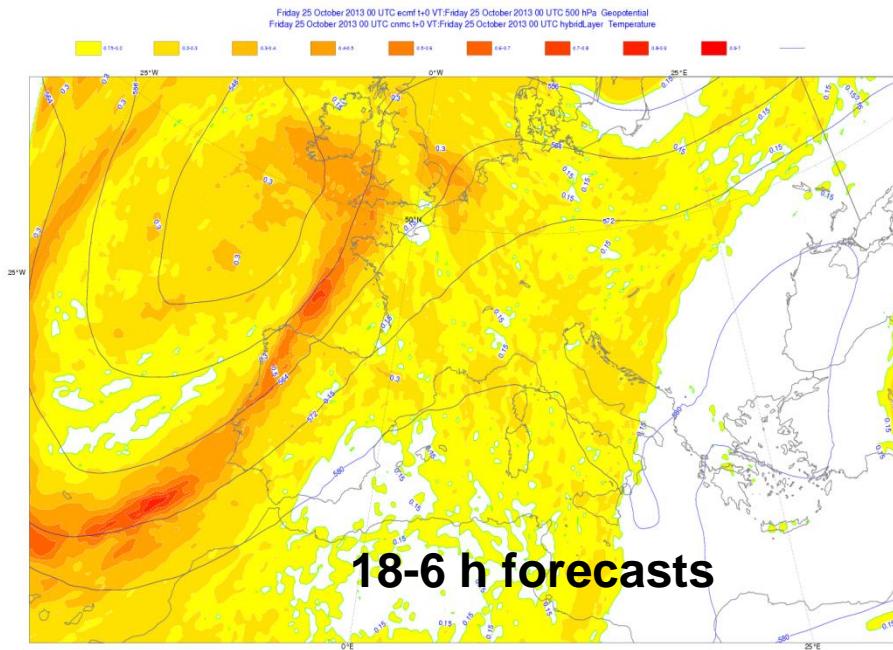
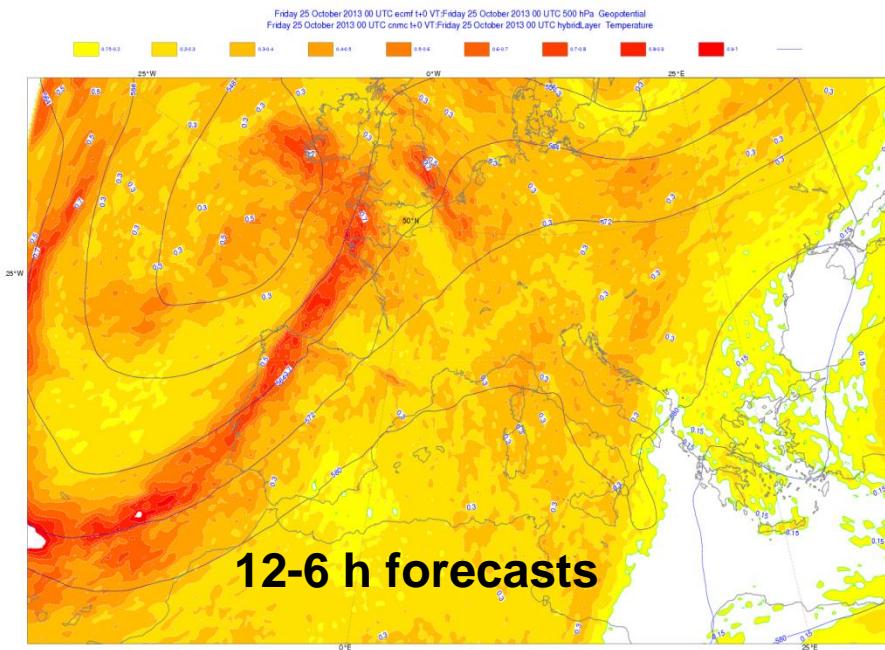
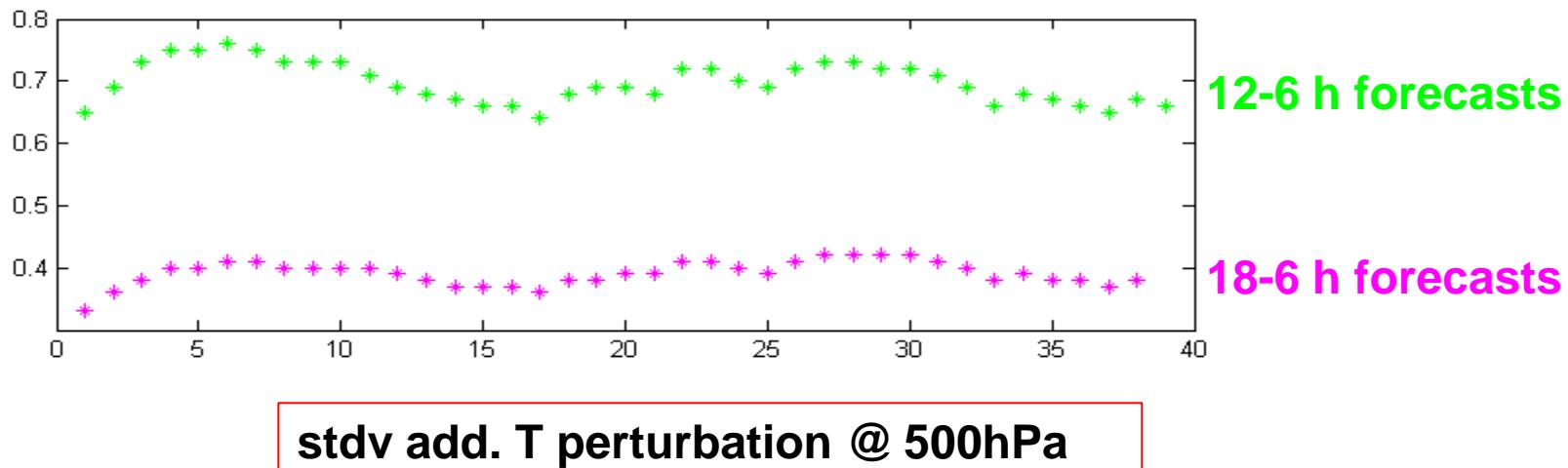
EXP1: perturbations from 12h - 6h forecast differences

EXP2: perturbations from 18h - 6h forecast differences



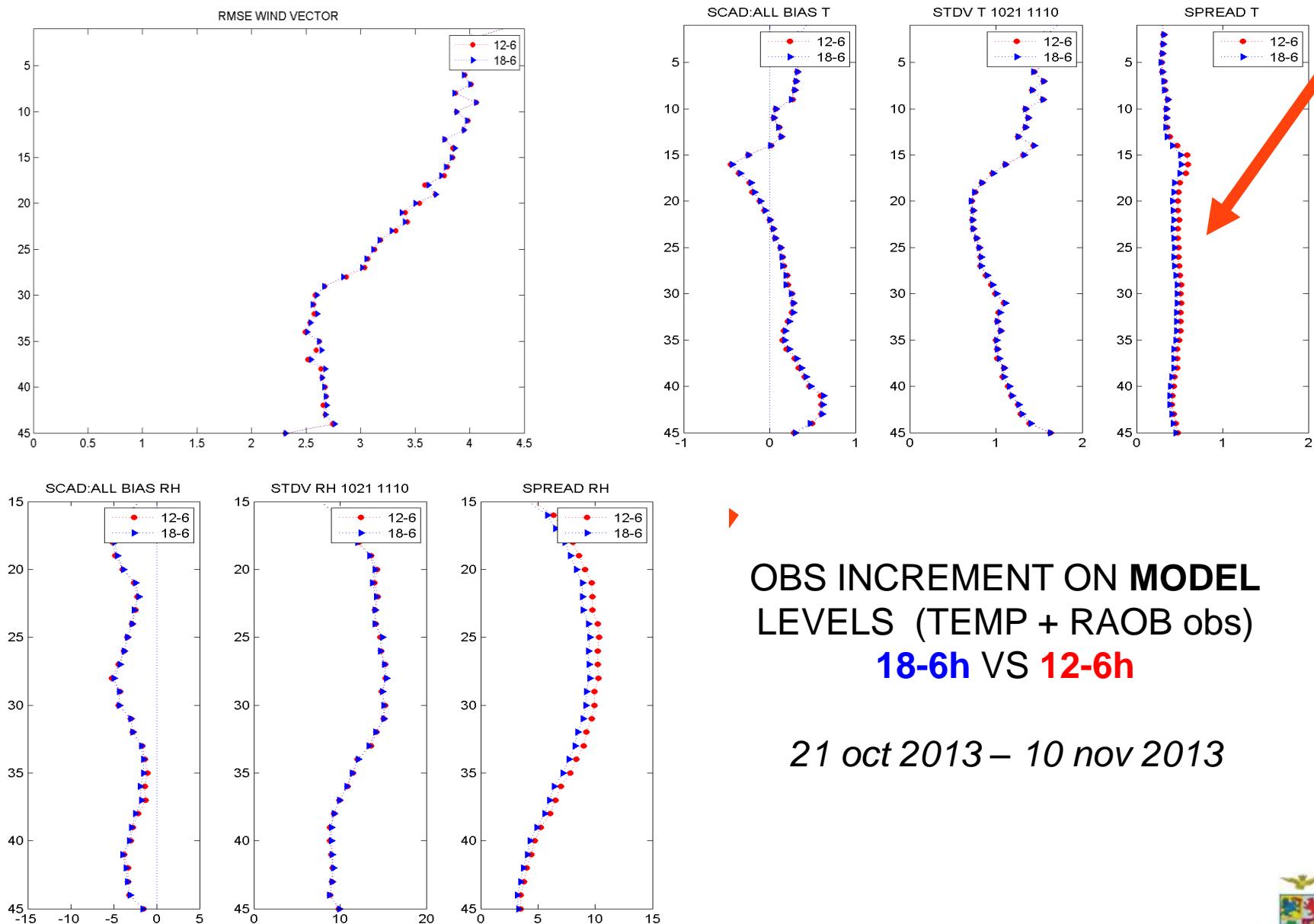


Self-Evolving Additive Noise



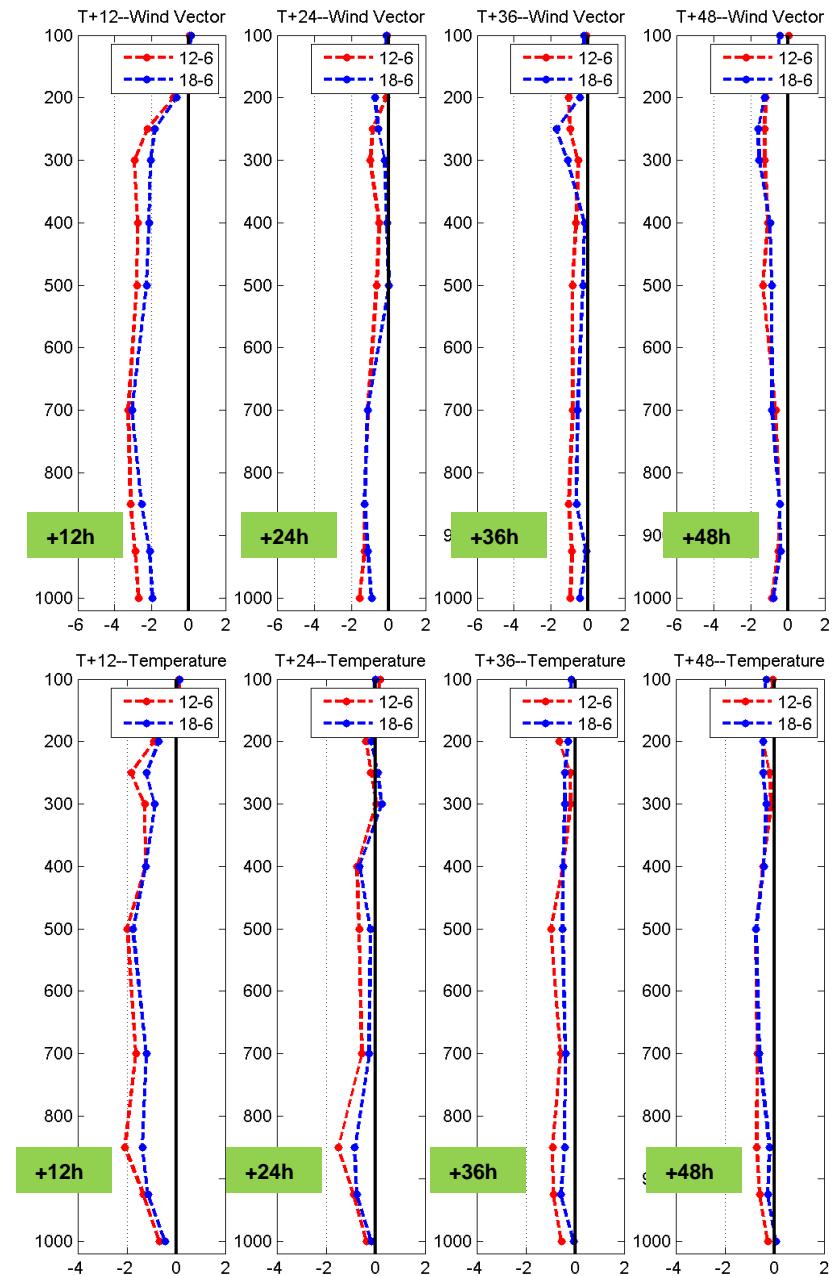
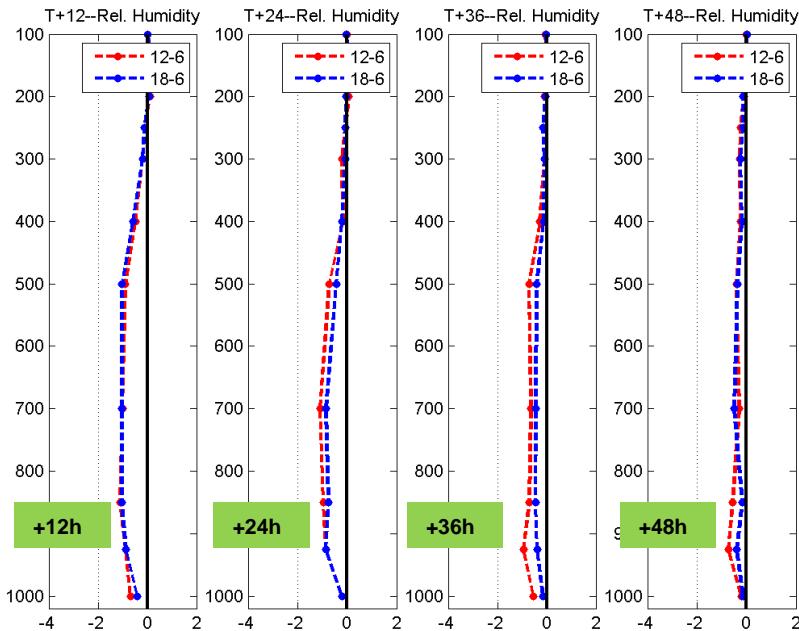


Obs Increment Statistics





Relative difference (%) in RMSE,
computed against IFS analysis, with respect
to **NO-ADDITIVE** run
for 00 UTC COSMO runs from
21-oct 2013 to 10 nov 2013
negative value = positive impact





Self-Evolving Additive Noise

Experiments on estimation of scaling factor

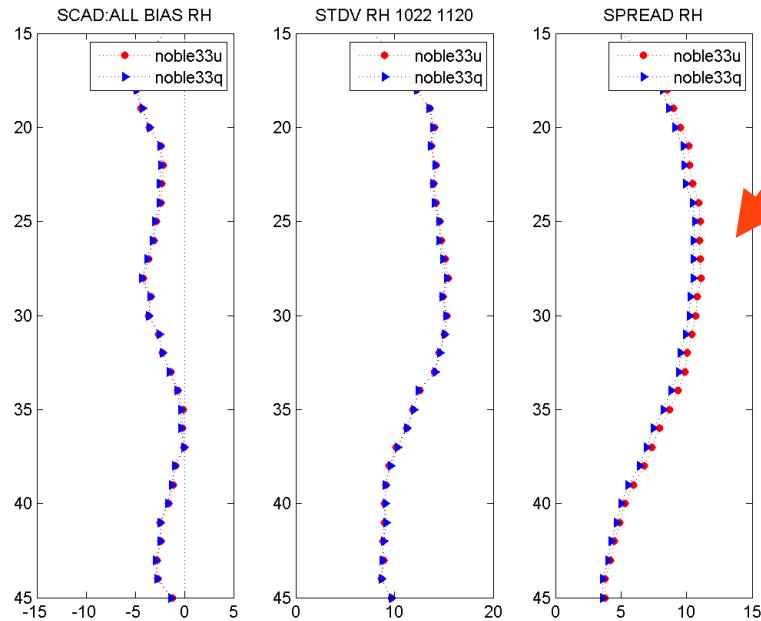
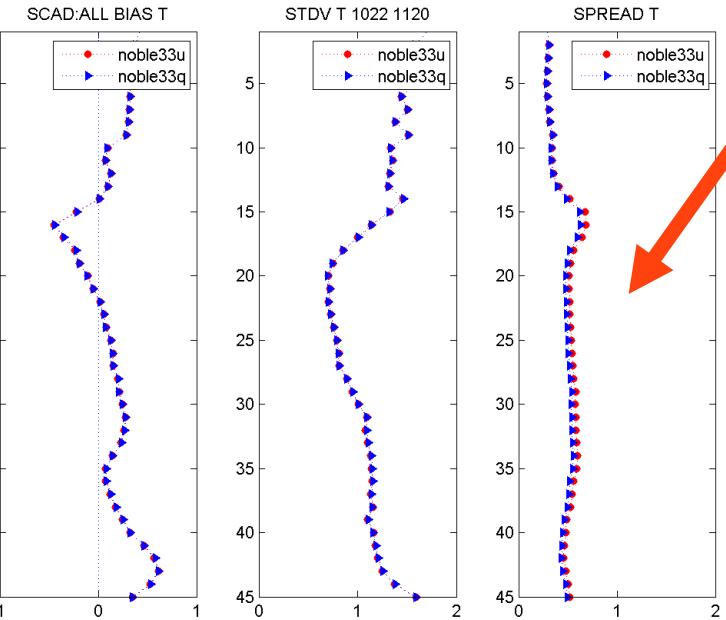
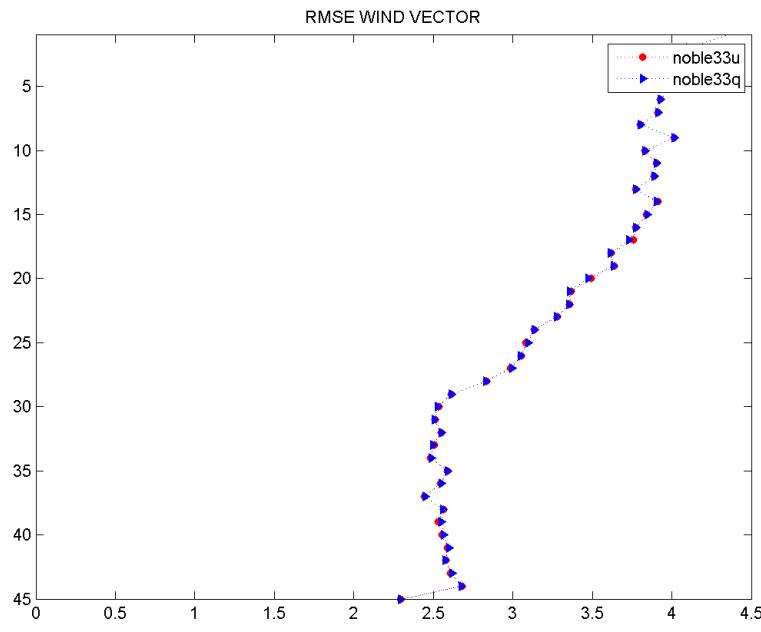
$$\frac{\text{Additive Noise}}{\text{Perturbation}}$$

- EXP1:** $R = 0$, perturbations from 12h - 6h forecast differences
- EXP3:** $R = 0.3$, perturbations from 12h - 6h forecast differences





Obs Increment Statistics



OBS INCREMENT ON MODEL
LEVELS (TEMP + RAOB obs)
EXP1 VS EXP3

21 oct 2013 – 20 nov 2013

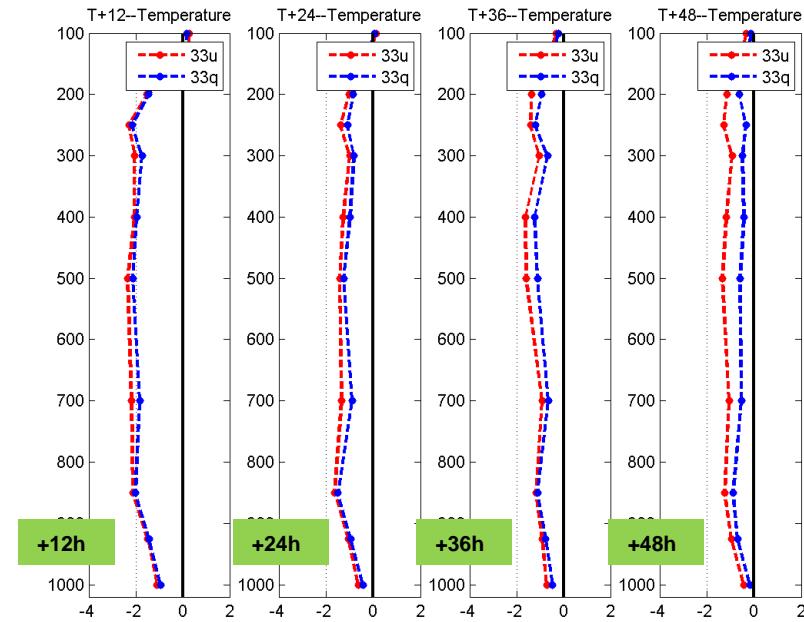
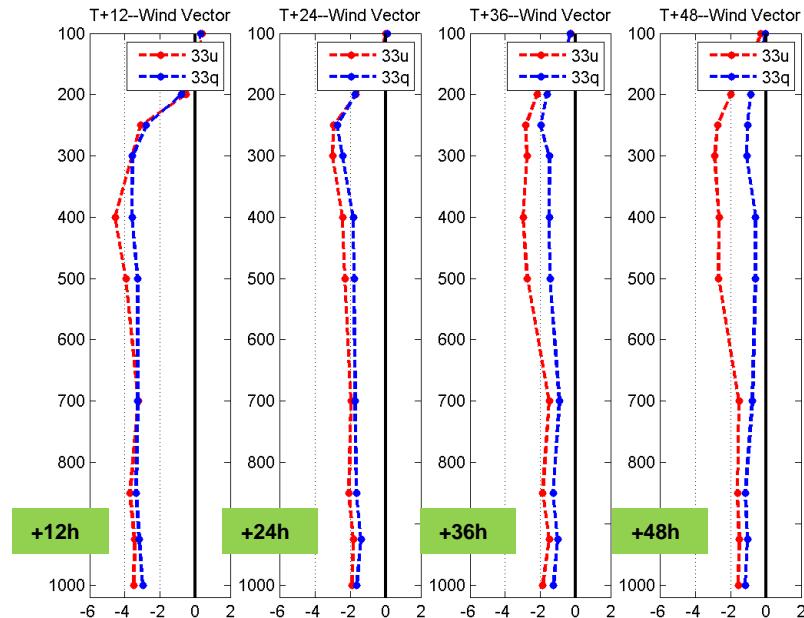
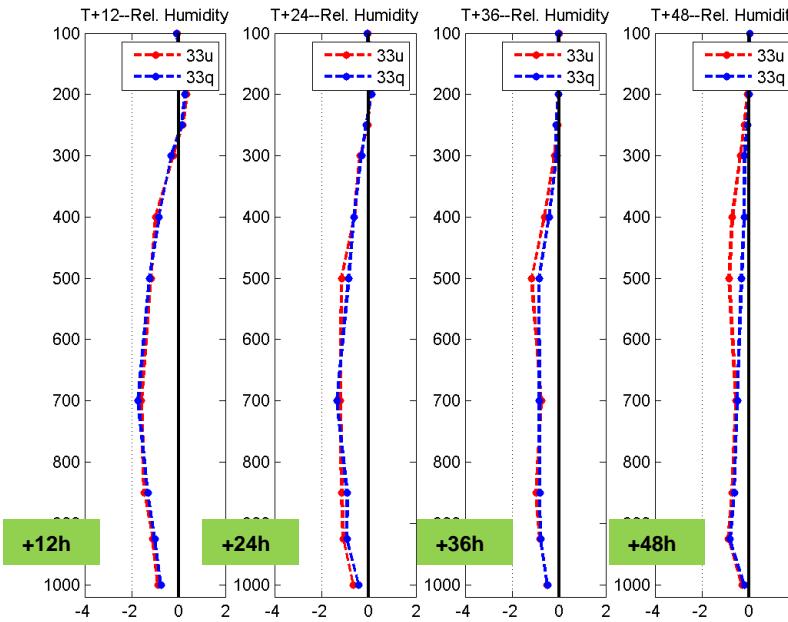




Forecast verification

Relative difference (%) in RMSE,
computed against IFS analysis, with respect
to **NO-ADDITIVE** run
for 00 UTC COSMO runs from
21-oct 2013 to 20 nov 2013
negative value = positive impact

EXP1 vs EXP3

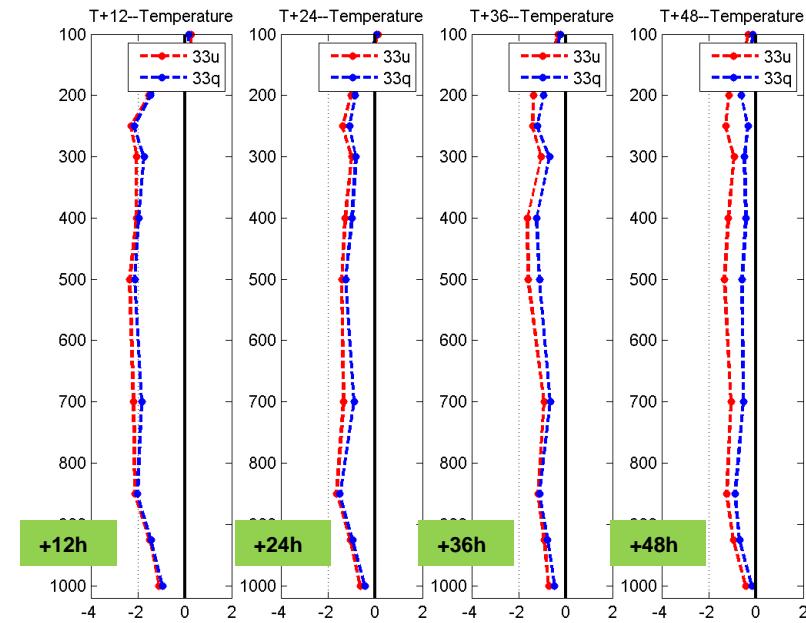
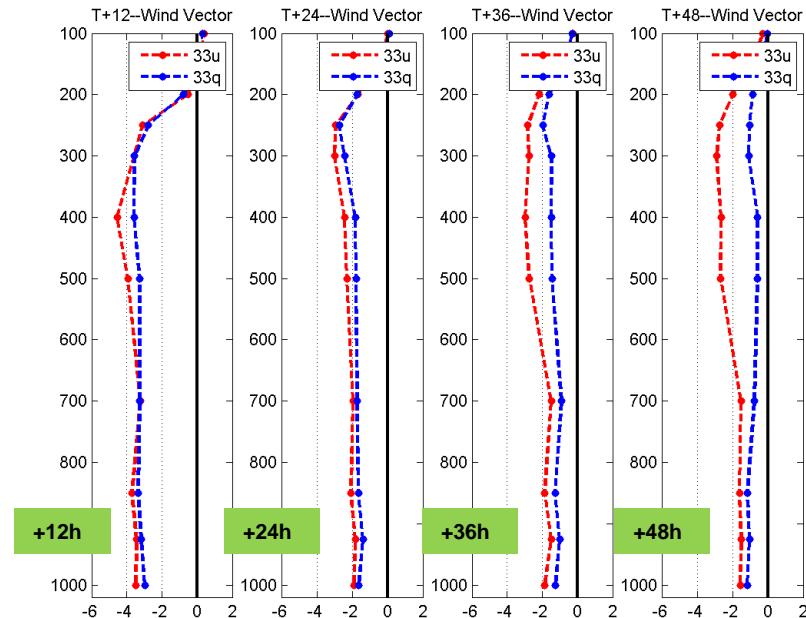
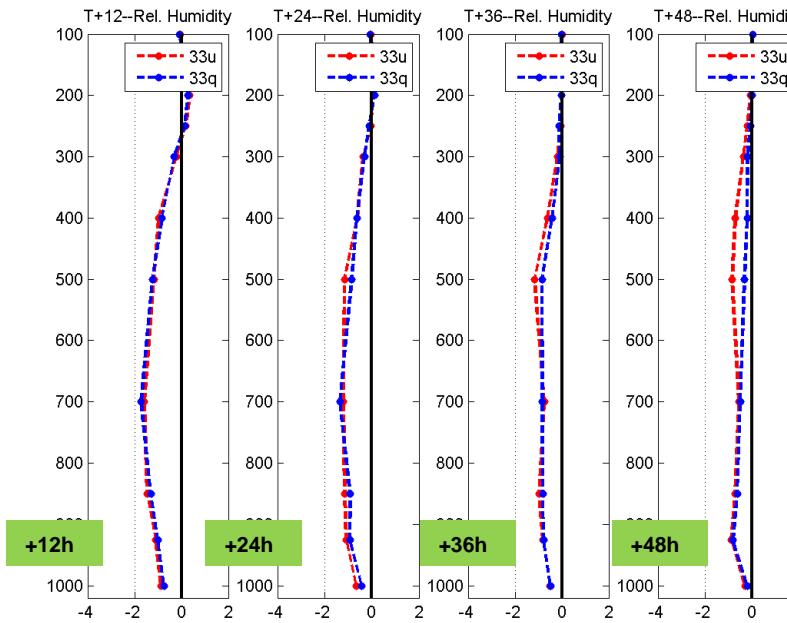




Forecast verification

Relative difference (%) in RMSE,
computed against IFS analysis, with respect
to **NO-ADDITIVE** run
for 00 UTC COSMO runs from
21-oct 2013 to 20 nov 2013
negative value = positive impact

EXP1 vs EXP3





Self-Evolving Additive Noise

Experiments on estimation of scaling factor

$$\frac{\text{Additive Noise}}{\text{Perturbation}}$$

- EXP1:** $R = 0$, perturbations from 12h - 6h forecast differences
- EXP3:** $R = 0.3$, perturbations from 12h - 6h forecast differences
- EXP4:** as EXP3 with temporal smoothing at same time (00,06,12,18 UTC)

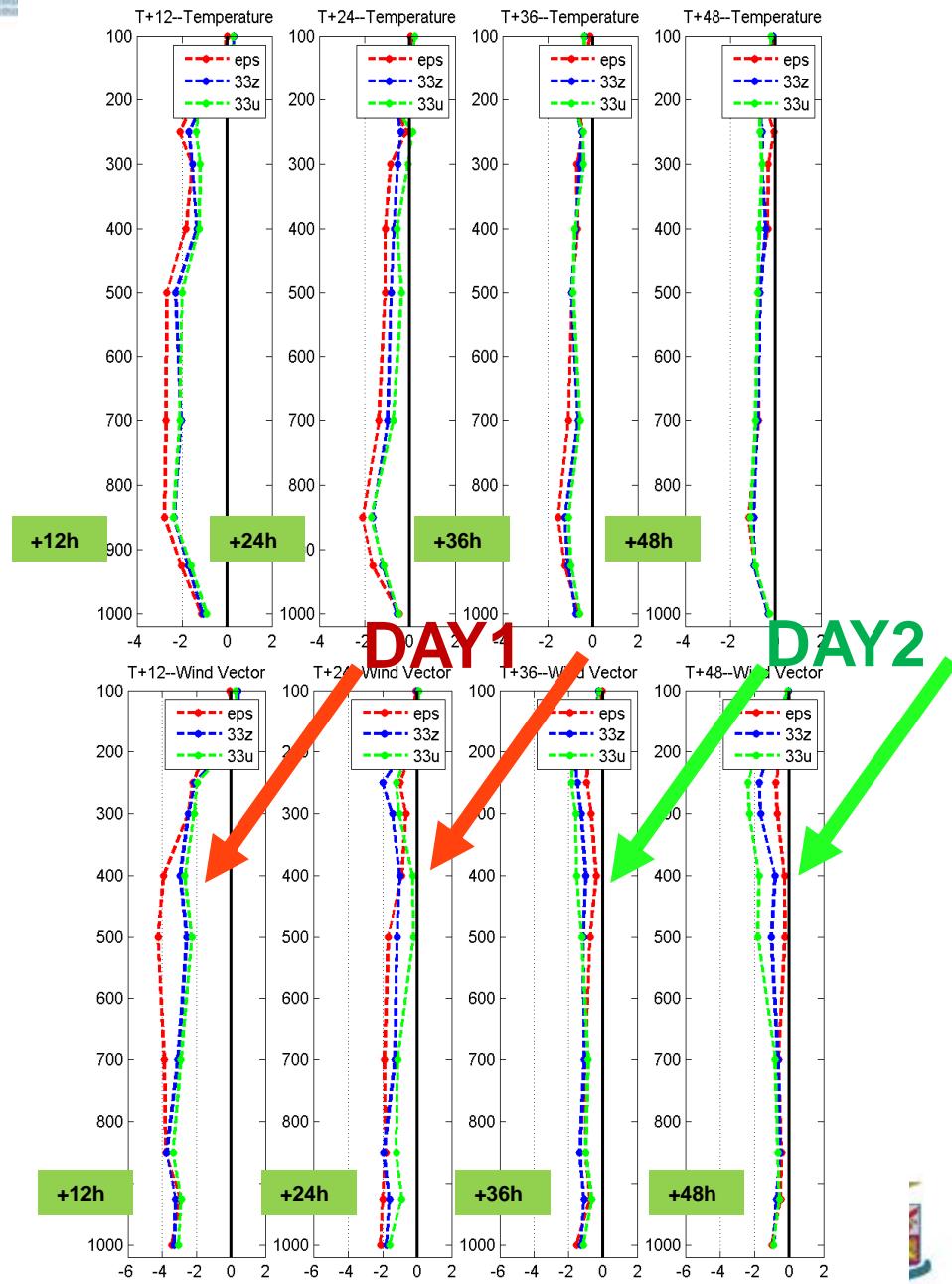
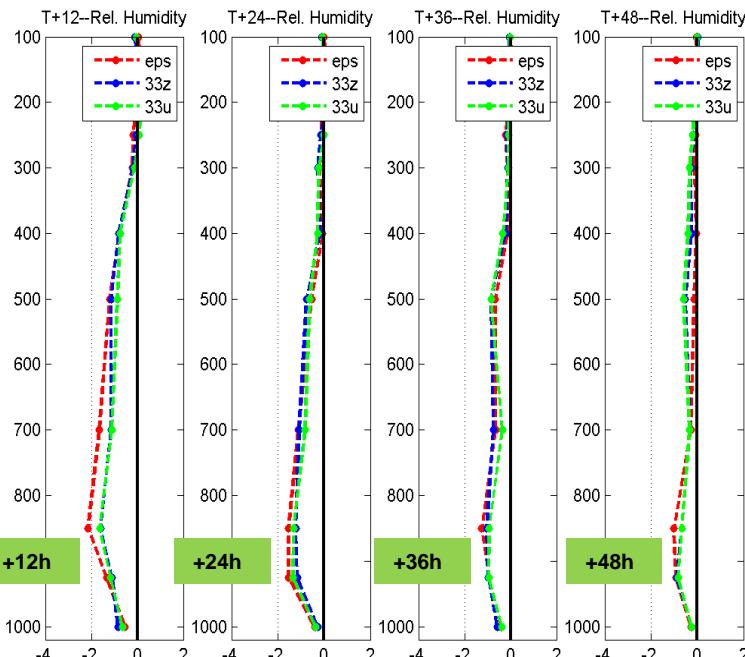




Forecast Verification

Relative difference (%) in RMSE,
computed against IFS analysis, with respect
to NO-ADDITIVE run
for 00 UTC COSMO runs from
22 oct 2013 – 10 nov 2013
negative value = positive impact

EPS, EXP1, EXP4

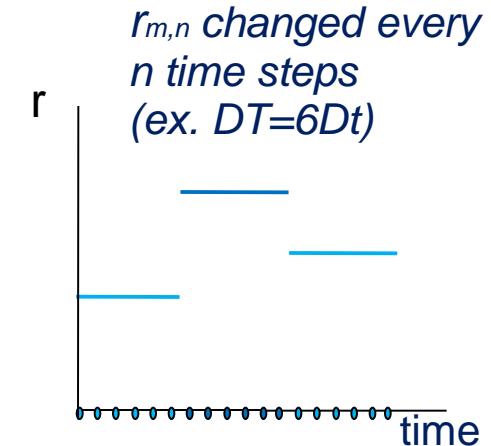
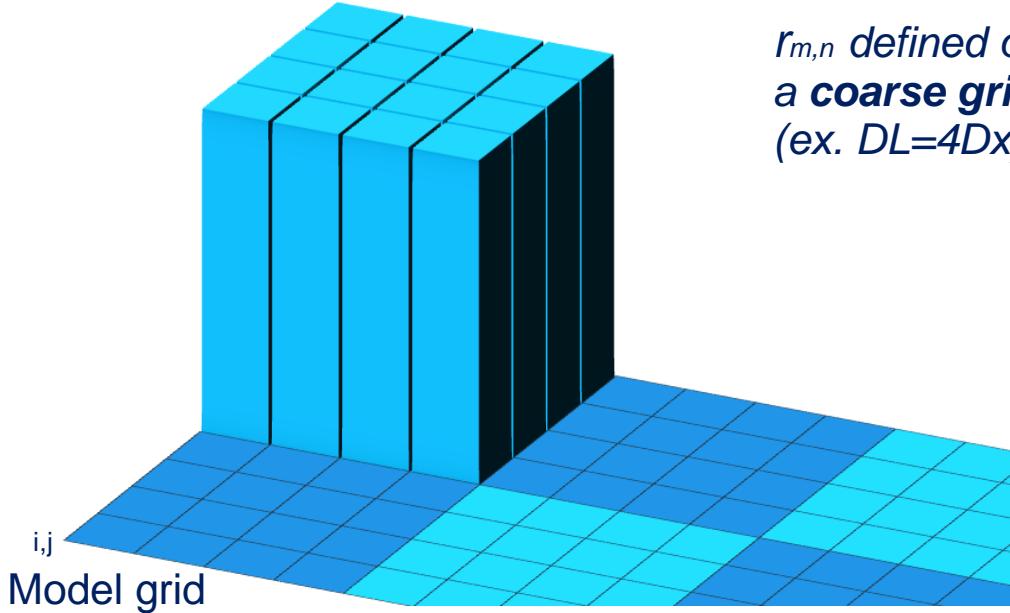




Stochastic Perturbed Physics Tendency

- Model uncertainty could be represented also with a stochastic physics scheme (Buizza et al, 1999; Palmer et al, 2009) implemented in the prognostic model
- This scheme perturbs model physics tendencies by adding perturbations, which are proportional in amplitude to the unperturbed tendencies X_c :

$$X_p = (1 + r \mu) X_c$$



COSMO Version (by Lucio Torrisi)

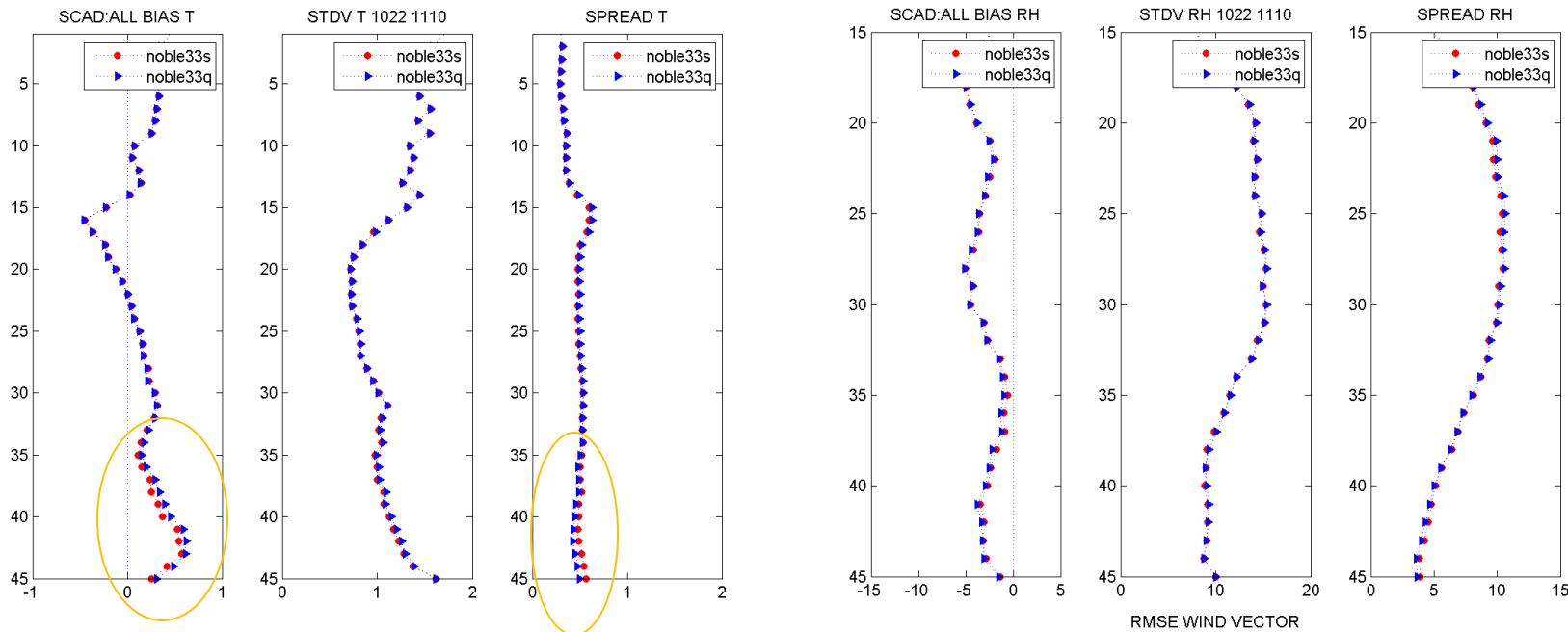
Random numbers are drawn on a horizontal coarse grid from a Gaussian distribution with a stdv (0.1-0.5) bounded to a certain value (range = $\pm 2\text{-}3$ stdv) and interpolated to the model grid to have a smoother pattern in time and horizontally in space. Same random pattern in the whole column and for u, v, t, qv variables.



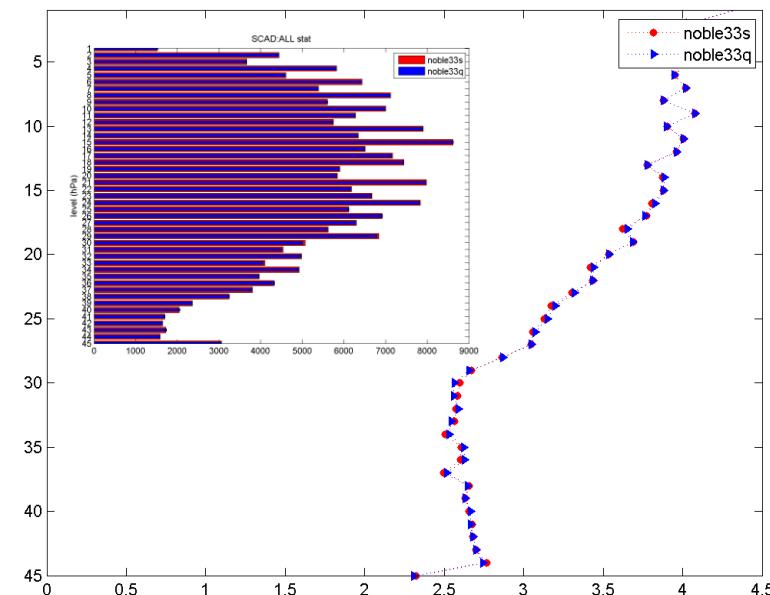


OBS INCREMENT STATISTICS (RAOB)

STOCHASTIC PHYSICS VS SELF-EVOLVING ADDITIVE

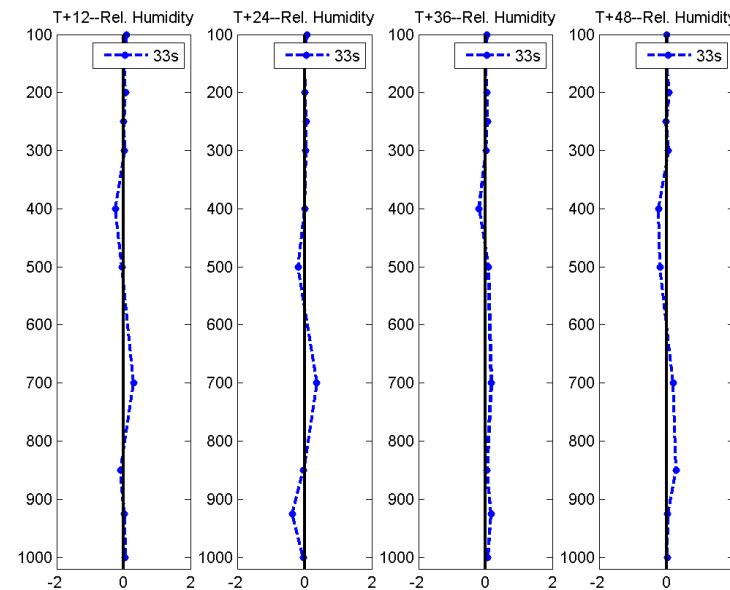
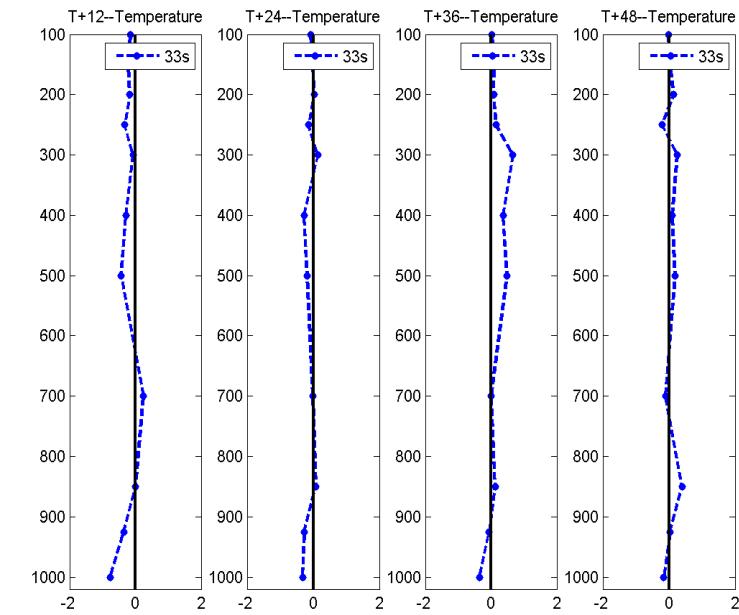


22 OCT 2013 – 20 NOV 2013

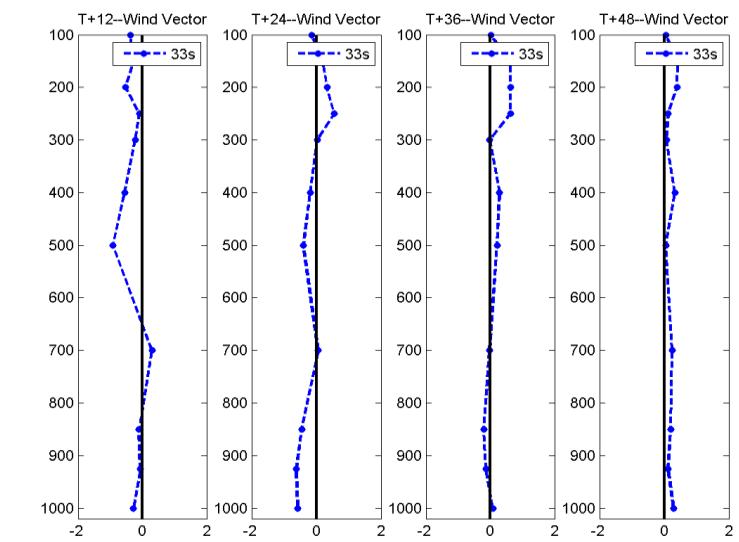




Forecast Verification



Relative difference (%) in RMSE, computed against IFS analysis, with respect to
ELF EVOLV ADD run for 00 UTC COSMO runs from 22 OCT–10 NOV 2013
negative value = positive impact



SPPT SETTINGS:
stdv=0.4, range=0.8
box $5^\circ \times 5^\circ$, 6 hour
interp. in space and time
no humidity check
T U V qv tendencies
No tapering near surface
IMODE_RN=1 (=0 FOR OLD)

SPPT seems to have a neutral/little negative impact if used in combination with self ev. add.





Summary and future steps

- “Self evolving additive noise” perturbations are both consistent with model errors statistics and a flow-dependent noise
- Additive noise computed using differences of forecasts with larger time distance (i.e. 18-6h) is computationally expensive and does not improve the scores
- Further tuning of the 12-6 h forecast (filter and scaling factor) is planned
- A combination of self evolving additive noise and SPPT has been tested, but no impact is obtained (further tuning!)





Thanks for your
attention!

