Recent developments for CNMCA LETKF

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CNMCA, Italian National Met Center

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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 the recent version of the SPPT
- Assimilation of new observations (ATMS and GPS)
- Summary and future developments

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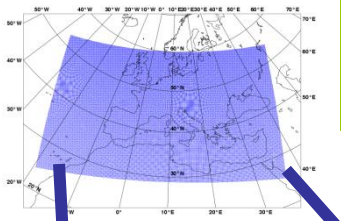
CNMCA NWP SYSTEM since 1 June 11

Ensemble Data Assimilation:

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

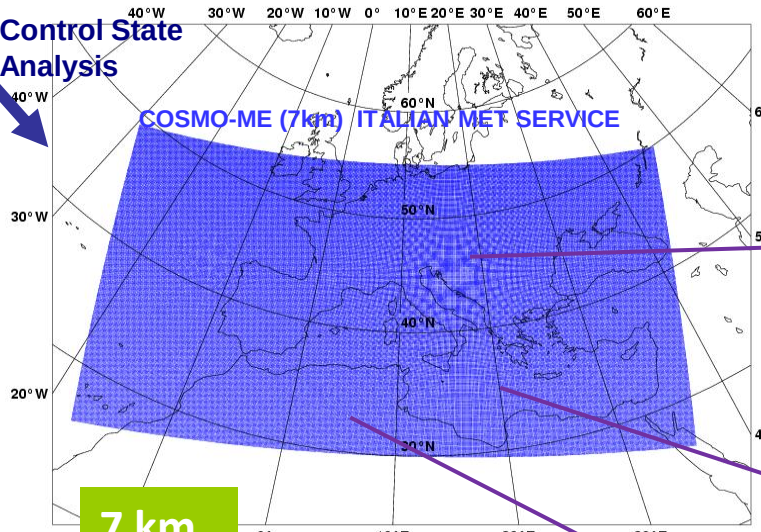


10 km
45 v.l.

LETKF Analysis

Control State Analysis

COSMO-ME EPS
(pre-operational)

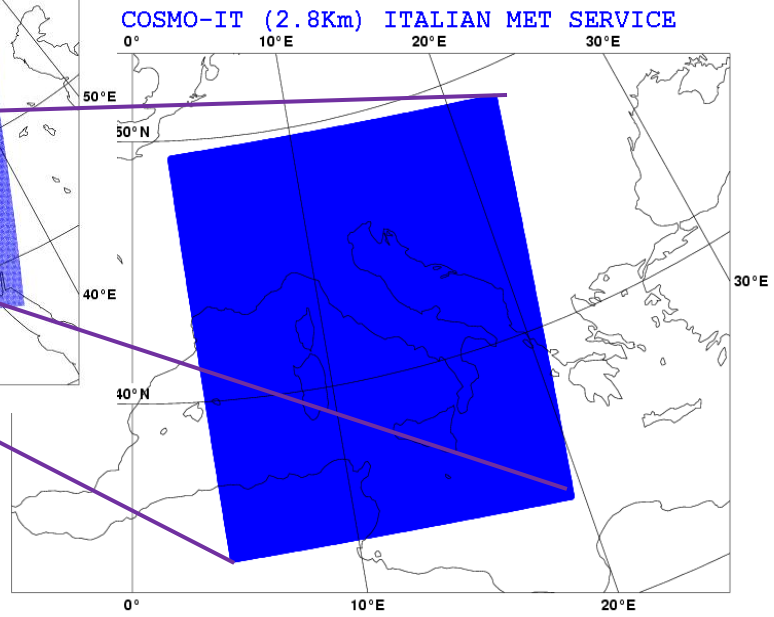


7 km
40 v.l.

- compressible equations
- parameterized convection

2.8 km
65 v.l.

- compressible equations
- explicit convection



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Treatment of model error

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

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

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

σ2 = variance

- Additive Noise from EPS (climat. noise before june 2013)

an. memb. $$\mathbf{x}_i^a \leftarrow \mathbf{x}_i^a + \alpha \mathbf{x}_i^n, \quad \alpha \mathbf{x}_i^n \sim N(0, \mathbf{Q})$$ α Scale factor

$\mathbf{x}_i^n$ 36-12h/42-18h forecast differences valid at analysis tyme

- Lateral Boundary Condition Perturbation of determ. IFS using EPS

- Climatological Perturbed SST

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Additive Noise from IFS

First (!not last) solution:

The 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).

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

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Self-Evolving Additive Noise

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

- The dfference 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 set 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 benificial impact on spread growth and ensemble-mean error

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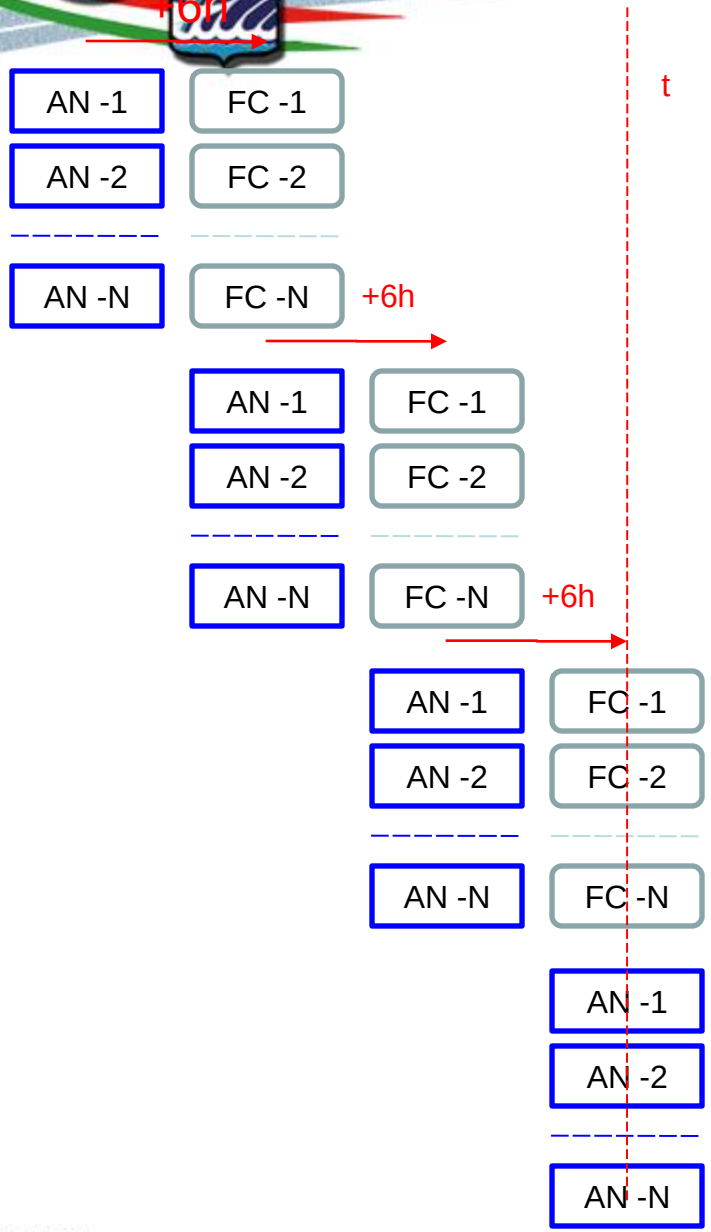
Self-Evolving Additive Noise



Additive noise valid at t

The end of model forecast integration needs to be extend

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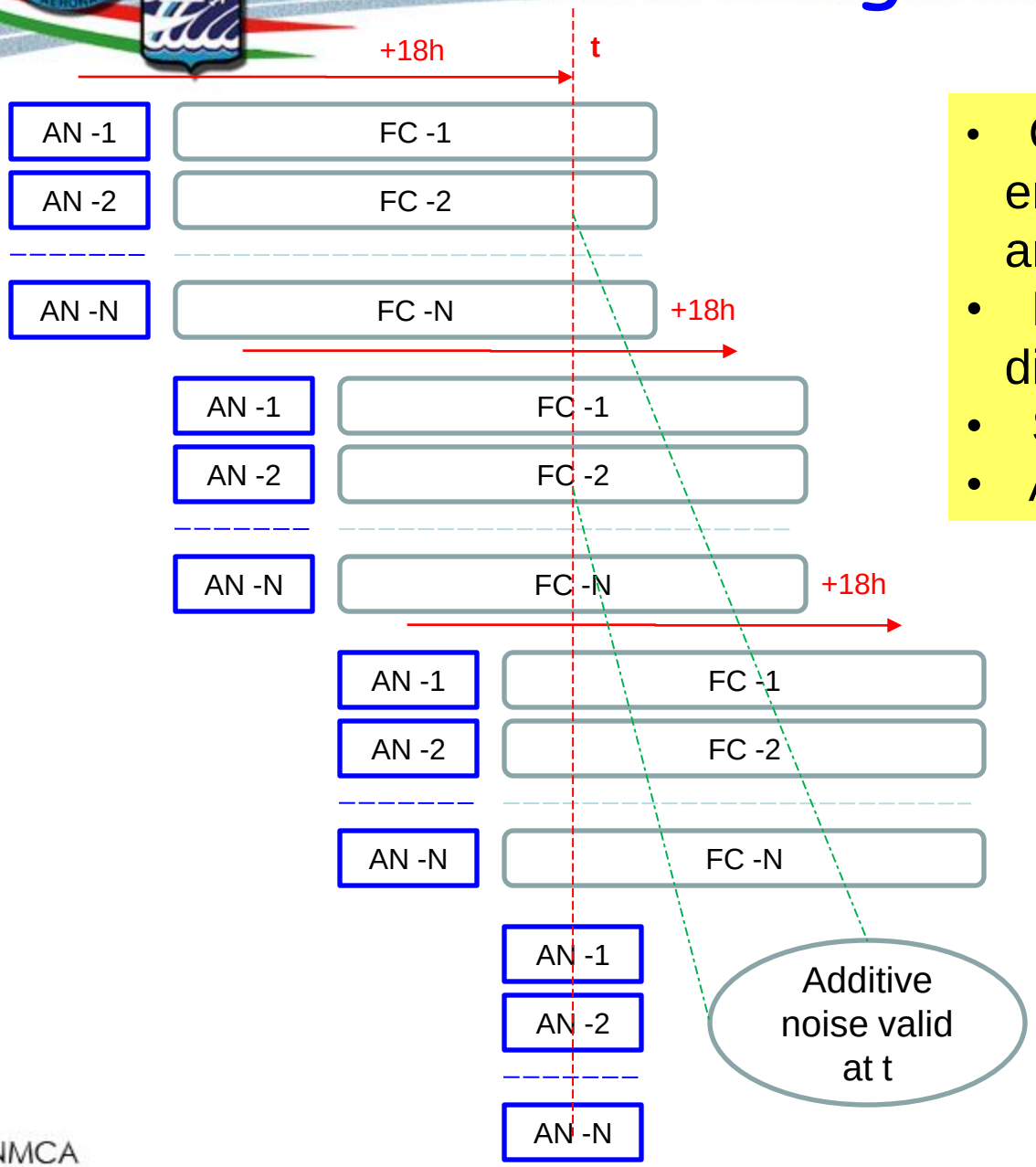
Self-Evolving Additive Noise



- 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

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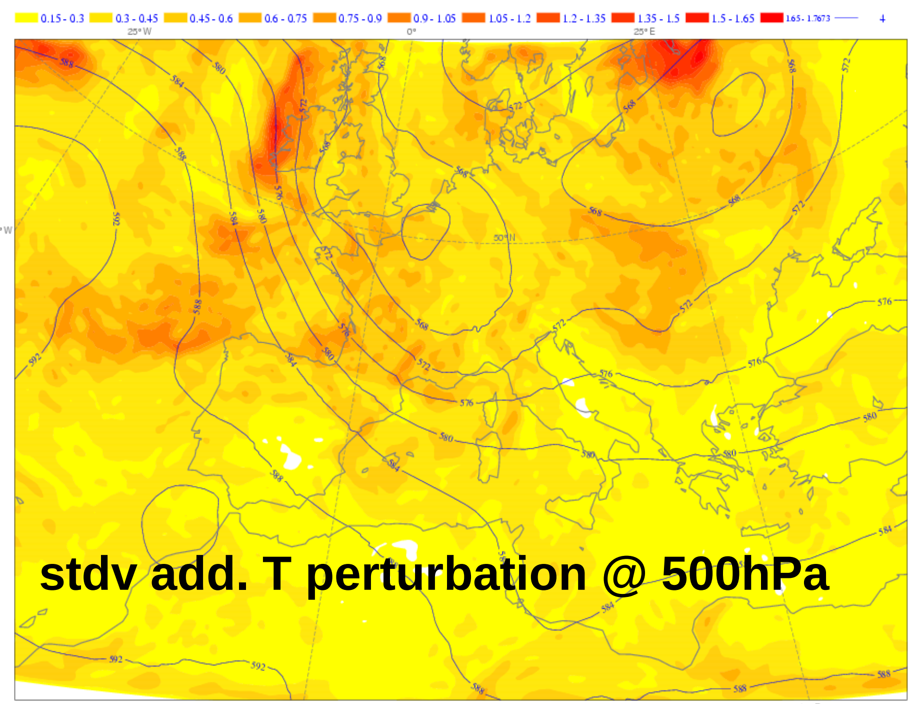
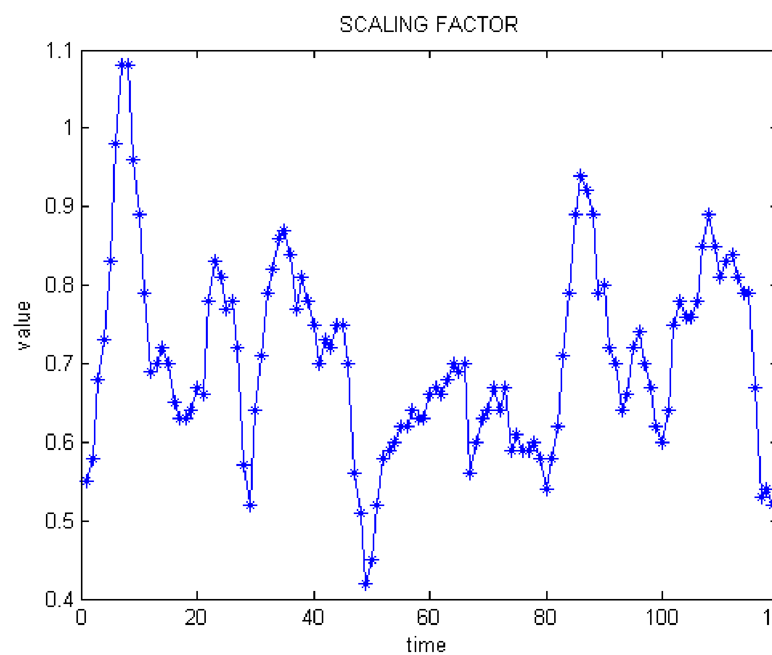
Self-Evolving Additive Noise

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

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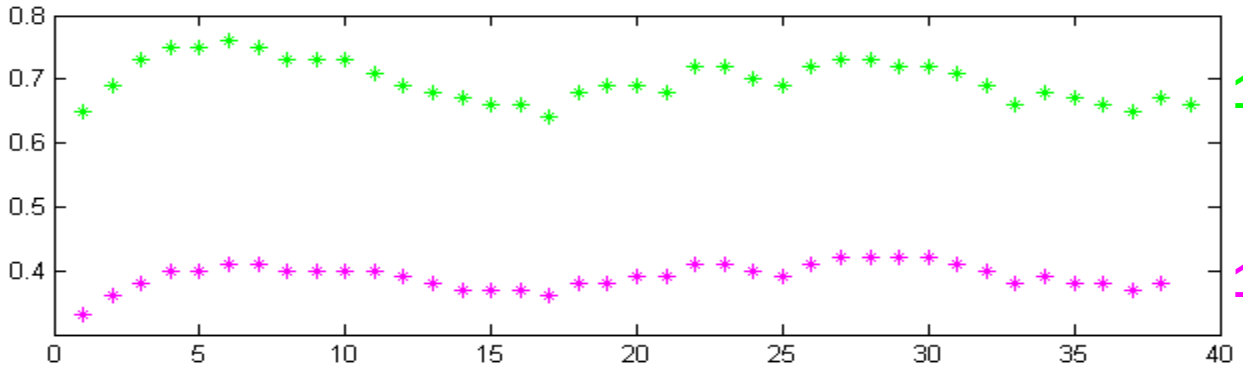
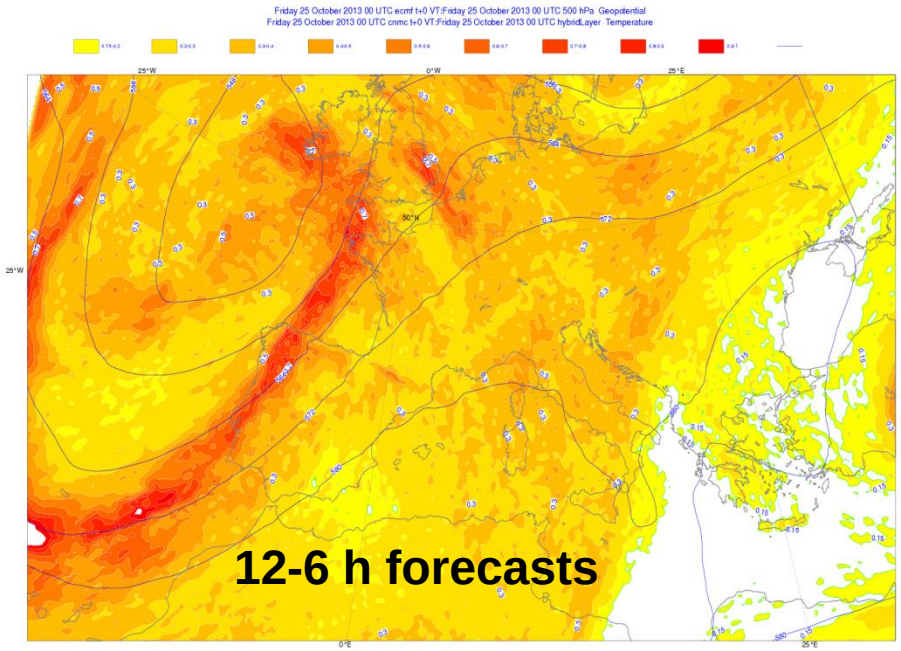
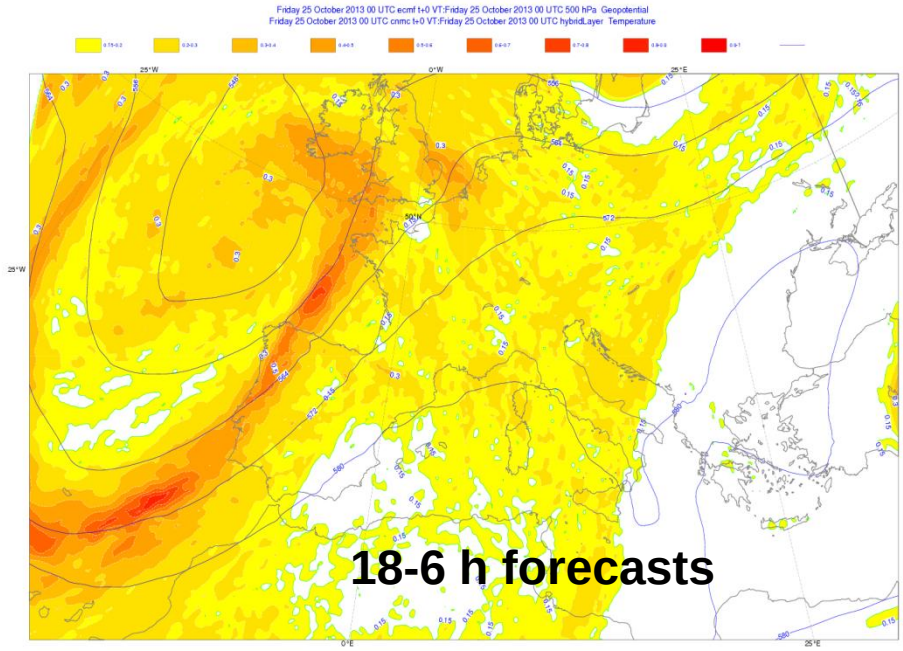
Self-Evolving Additive Noise

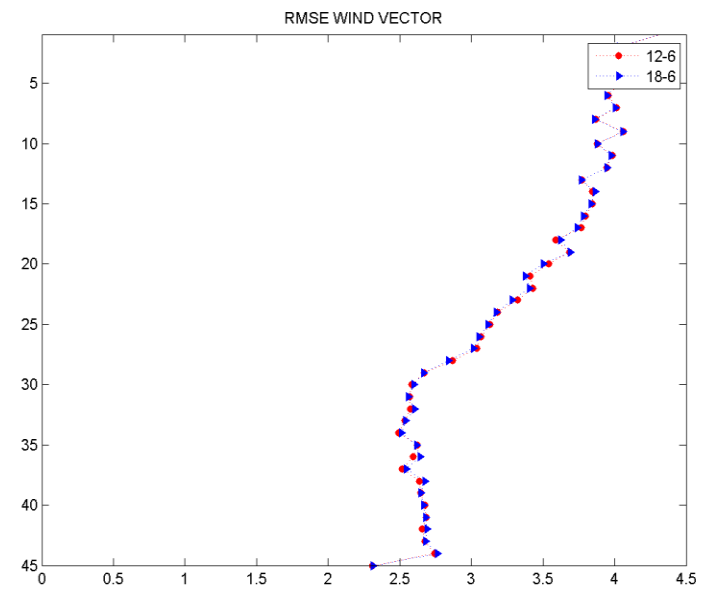


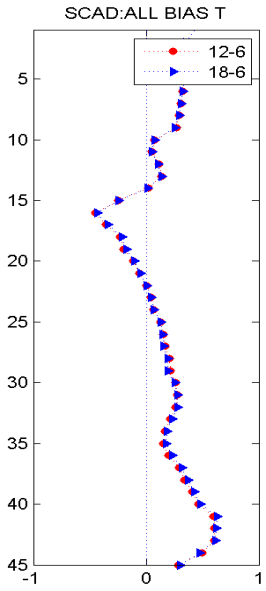
stdv add. T perturbation @ 500hPa

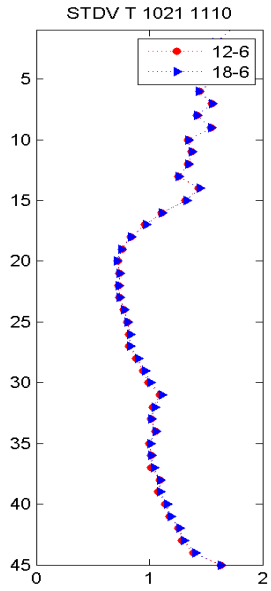


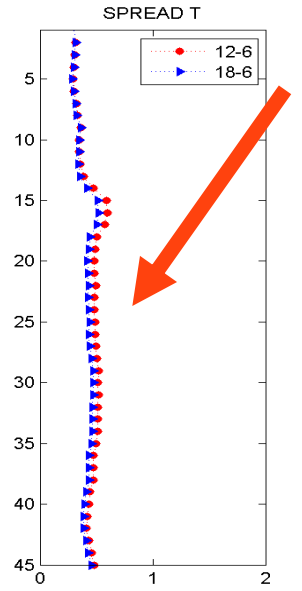


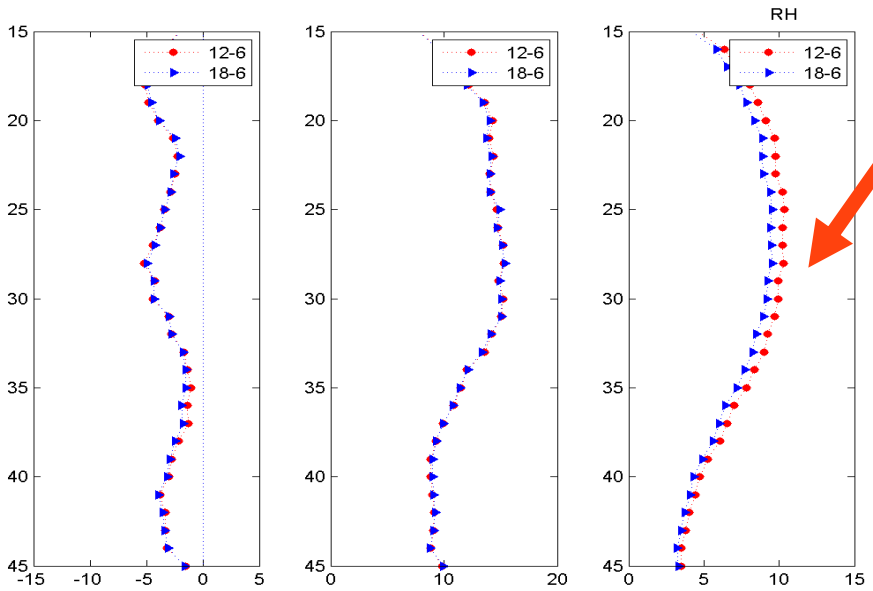
Obs Increment Statistics











OBS INCREMENT ON **MODEL** LEVELS (TEMP + RAOB obs)
18-6h VS **12-6h**

21 oct 2013 – 10 nov 2013

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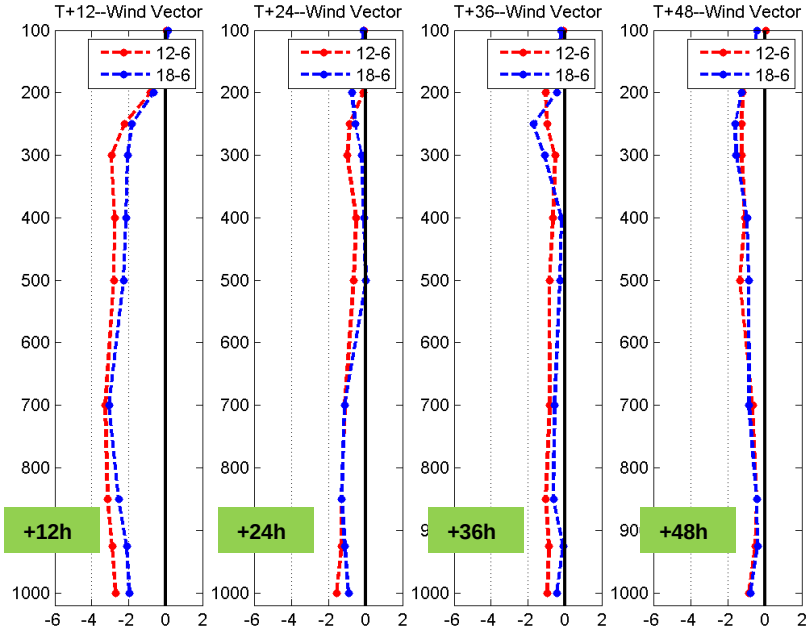
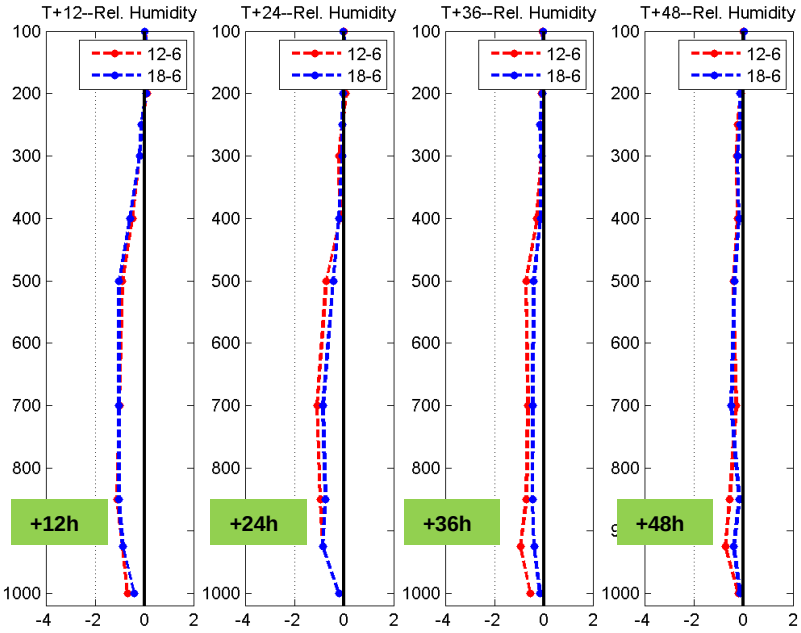
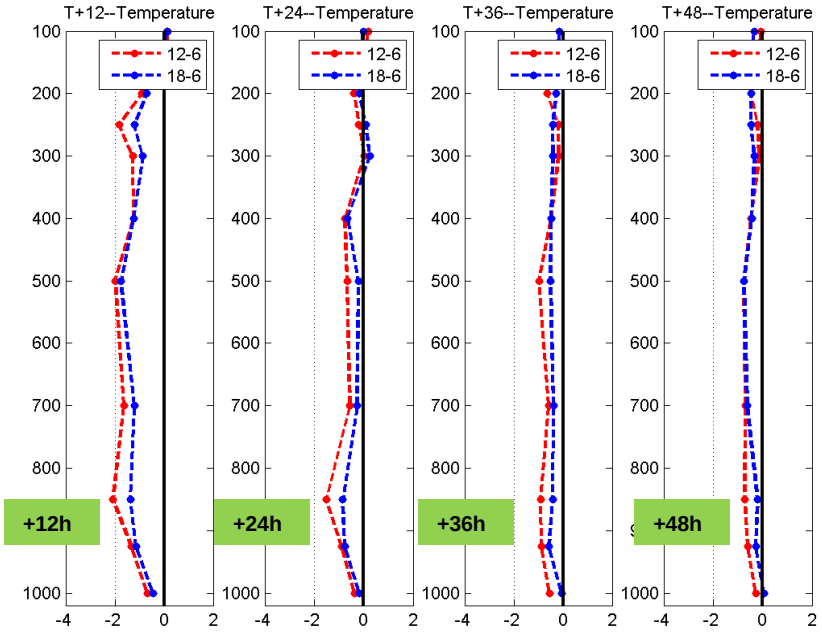
Forecast verification

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







Self-Evolving Additive Noise

Experiments on estimation of scaling factor

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)

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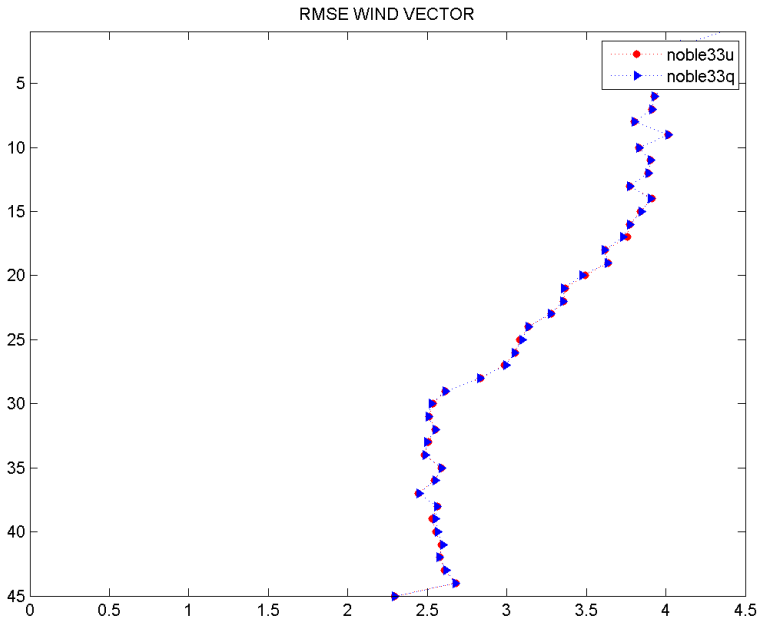
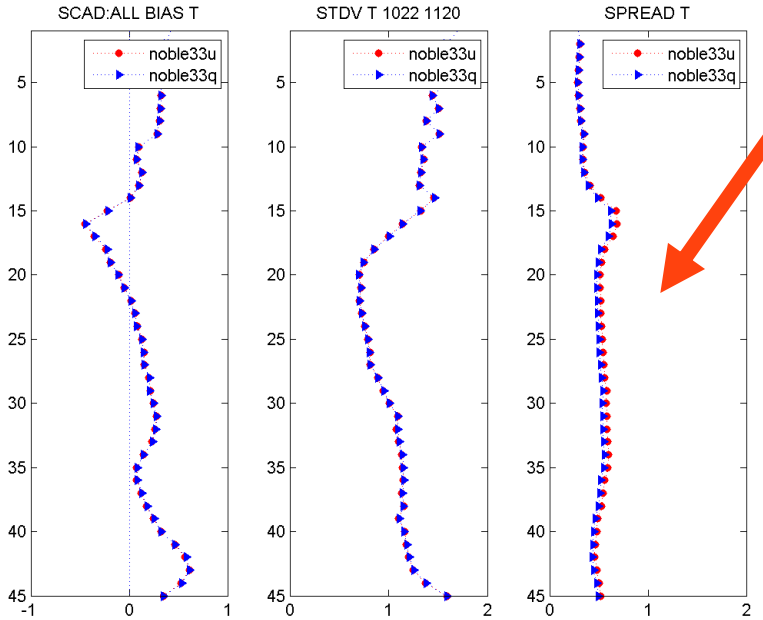
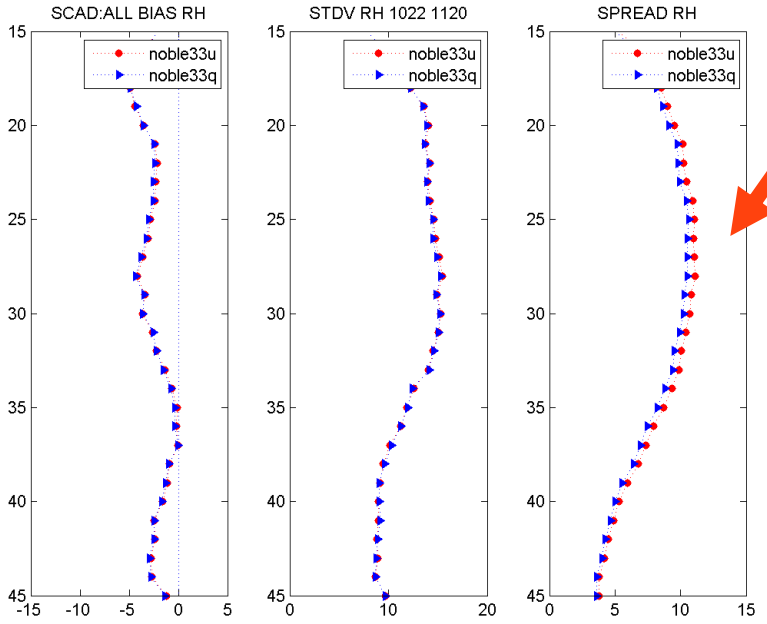
Obs Increment Statistics







OBS INCREMENT ON **MODEL** LEVELS (TEMP + RAOB obs)
EXP1 VS **EXP2**

21 oct 2013 – 20 nov 2013

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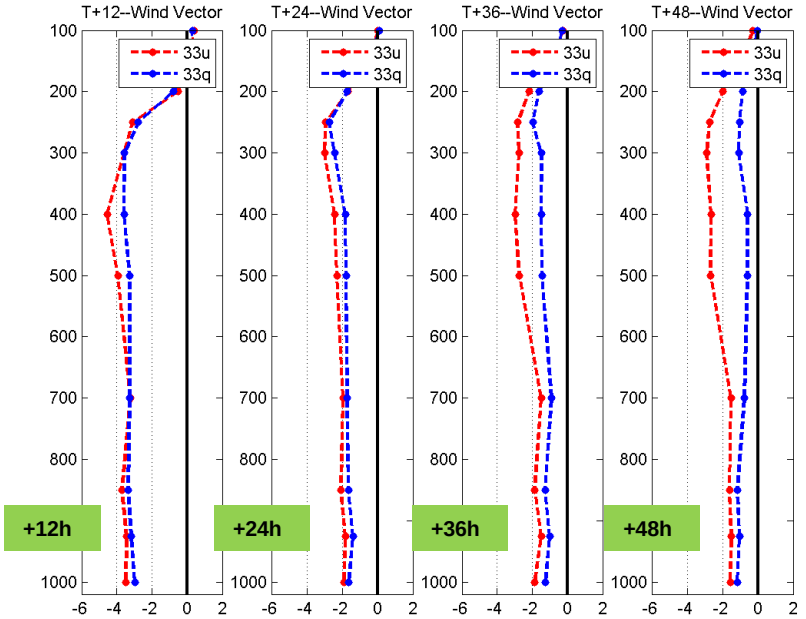
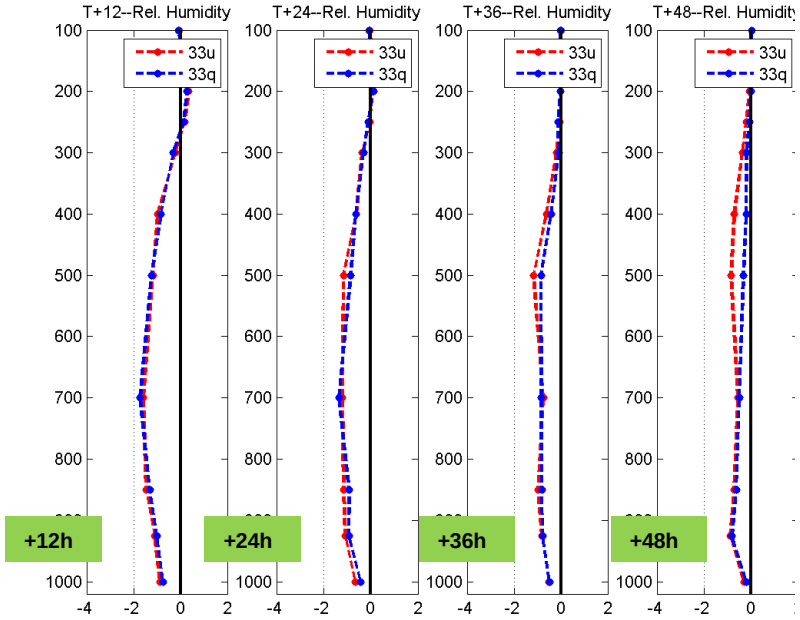
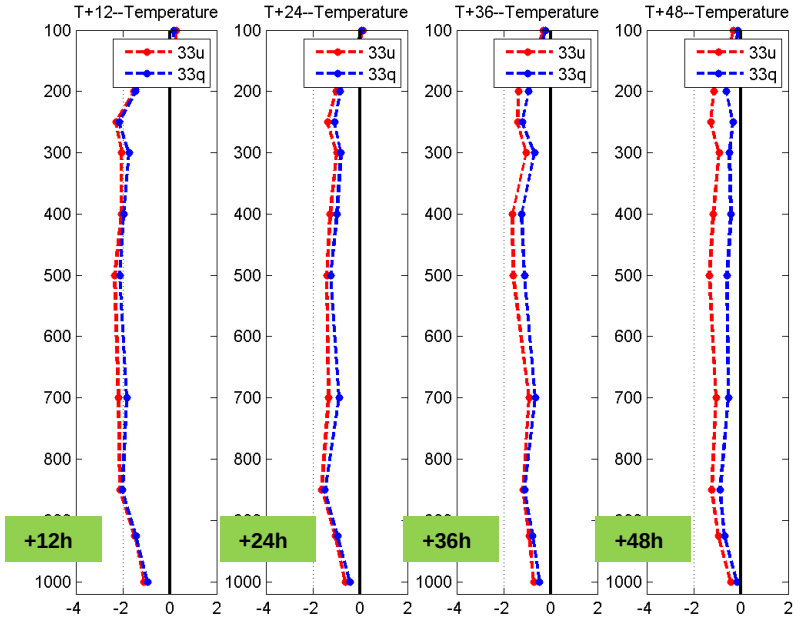
Forecast verification

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







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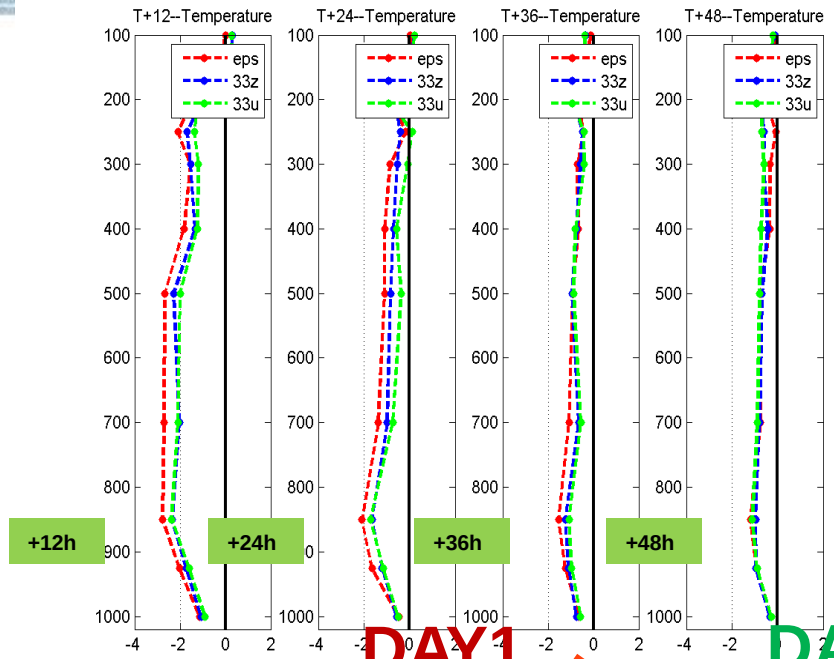
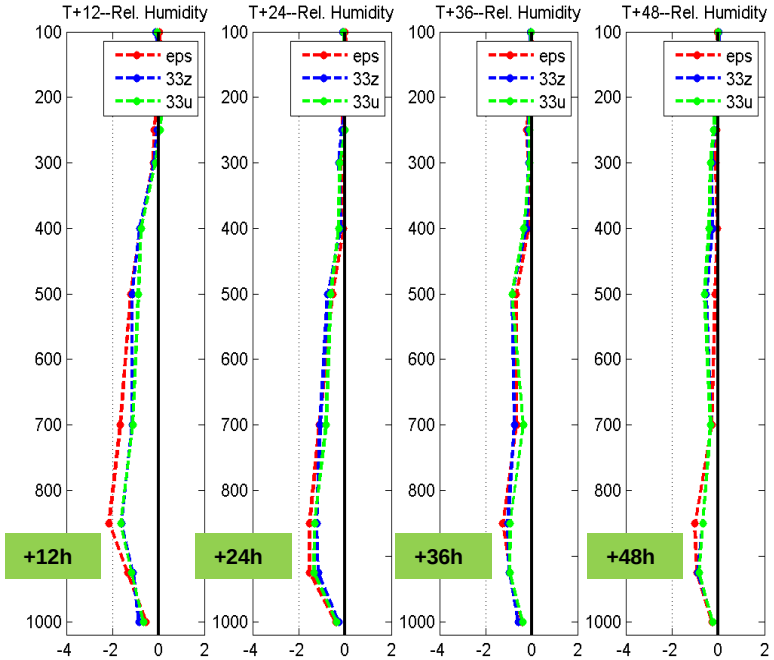
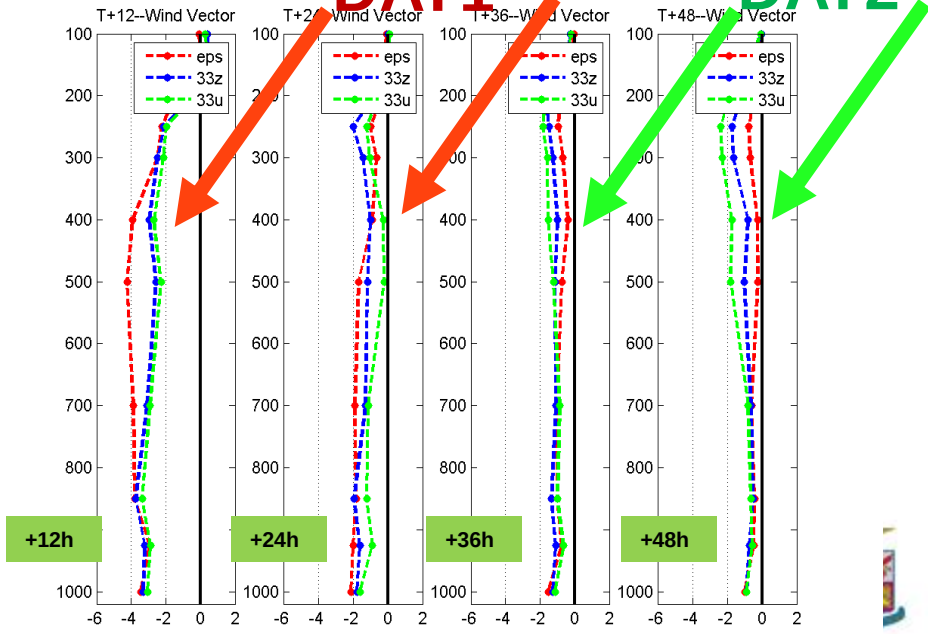
Forecast Verification

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







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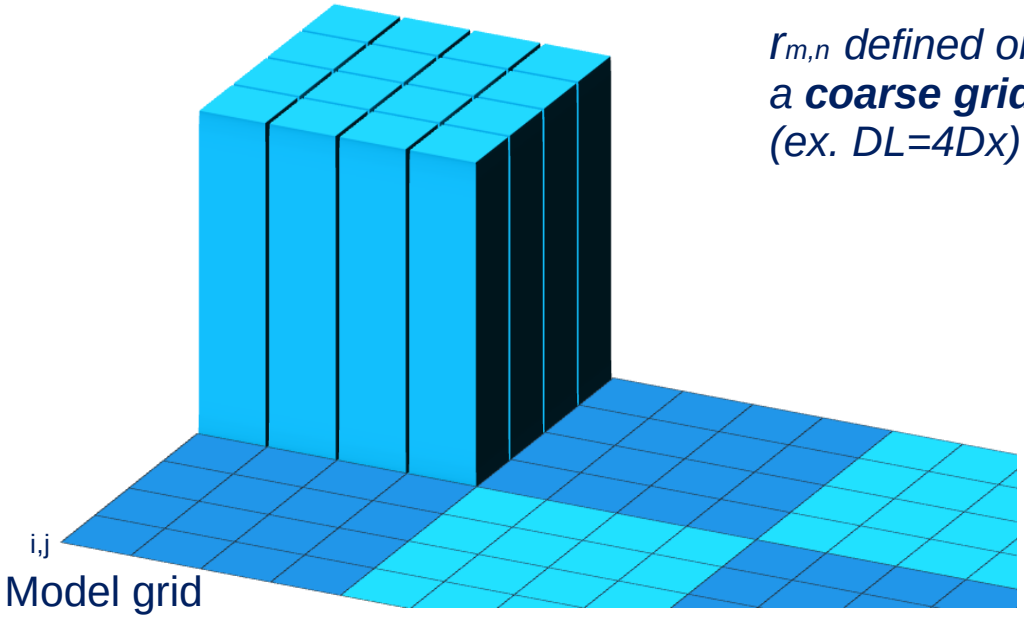
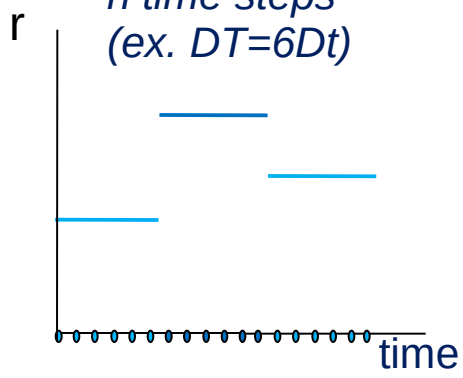
Stochastic Perturbed Physics Tendency

- 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 **Xc**:

$$Xp=(1+r\,\mu)Xc$$



$r_{m,n}$ *defined on a* ***coarse grid*** *(ex. DL=4Dx)*



$r_{m,n}$ *changed every n time steps (ex. DT=6Dt)*

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= ± 2-3 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.

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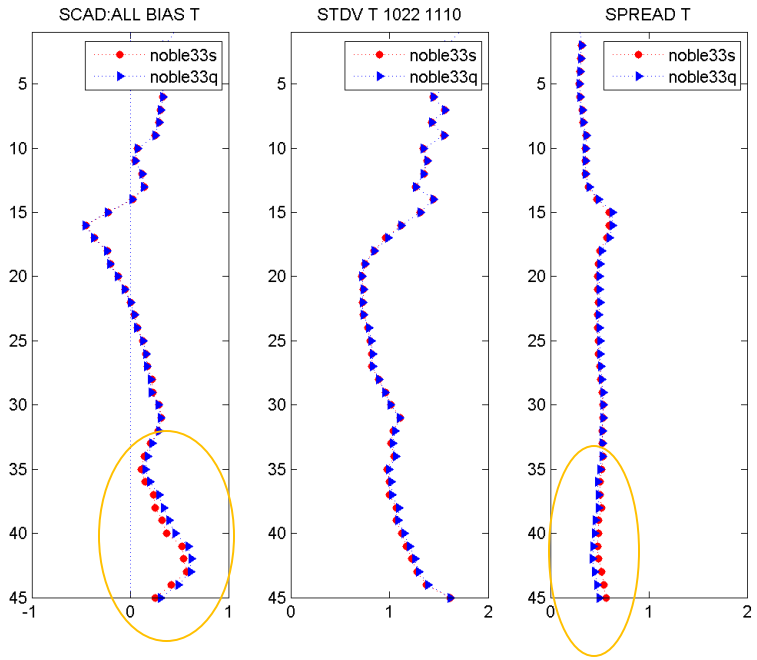
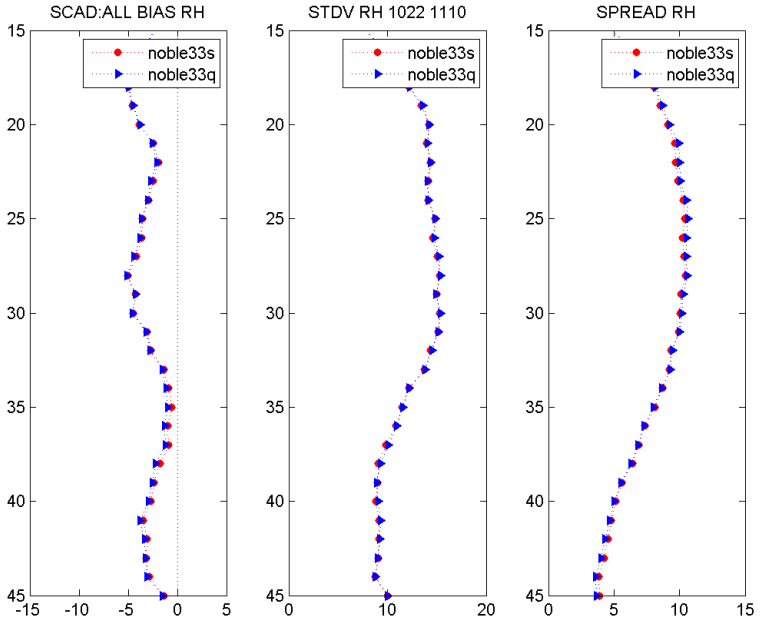
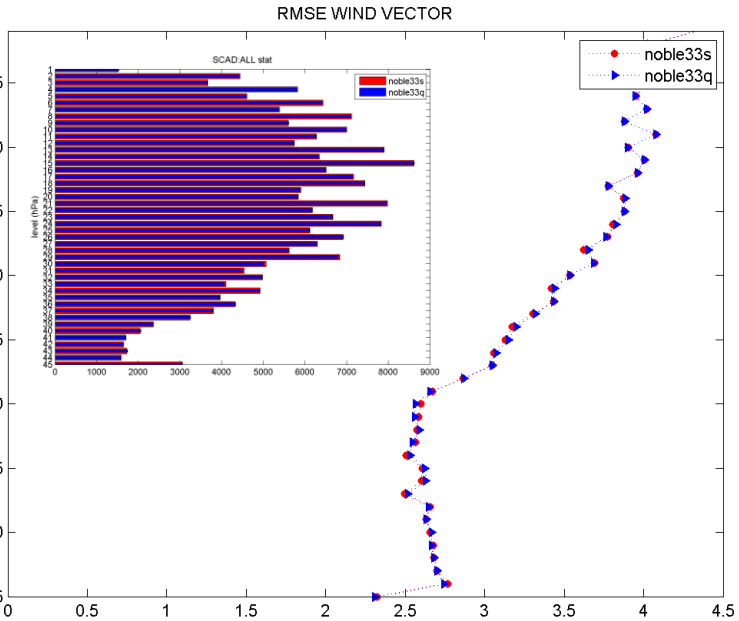
OBS INCREMENT STATISTICS (RAOB)
STOCHASTIC PHYSICS VS SELF-EVOLVING ADDITIVE





22 OCT 2013 – 20 NOV 2013



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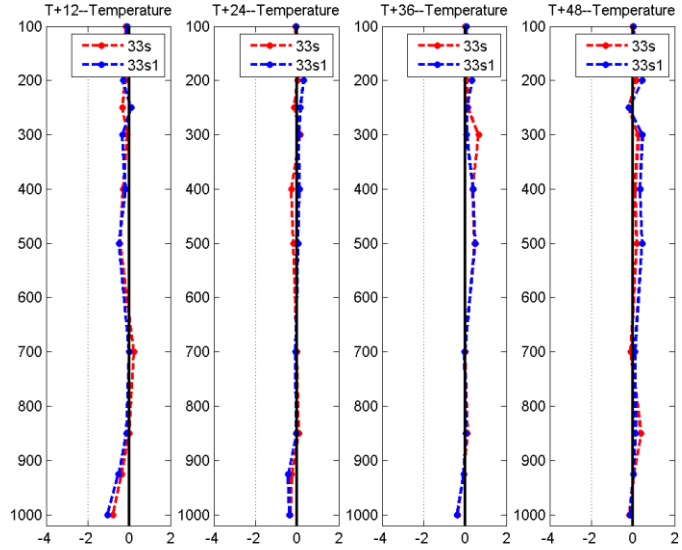
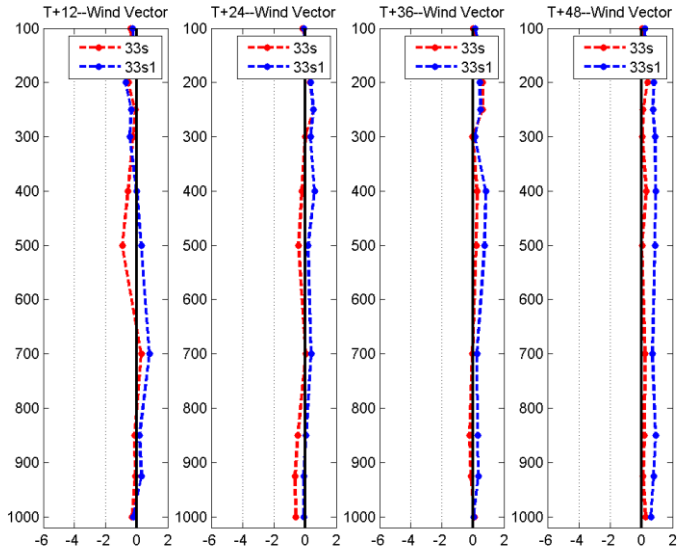
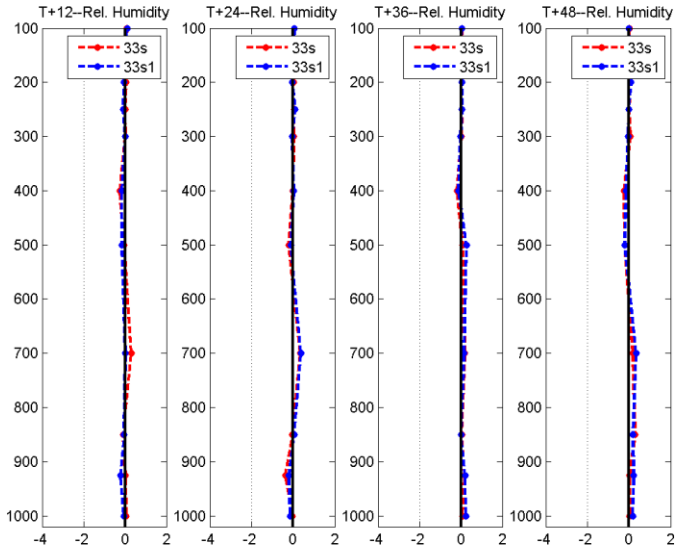
Forecast Verification



NEW
vs
OLD





Relative difference (%) in RMSE, computed against IFS analysis, with respect to SELF 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° x 5°, 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)

The most recent version of SPPT is slightly better than the old one.
SPPT seems to have a neutral/little negative impact if used in combination with self ev. add.

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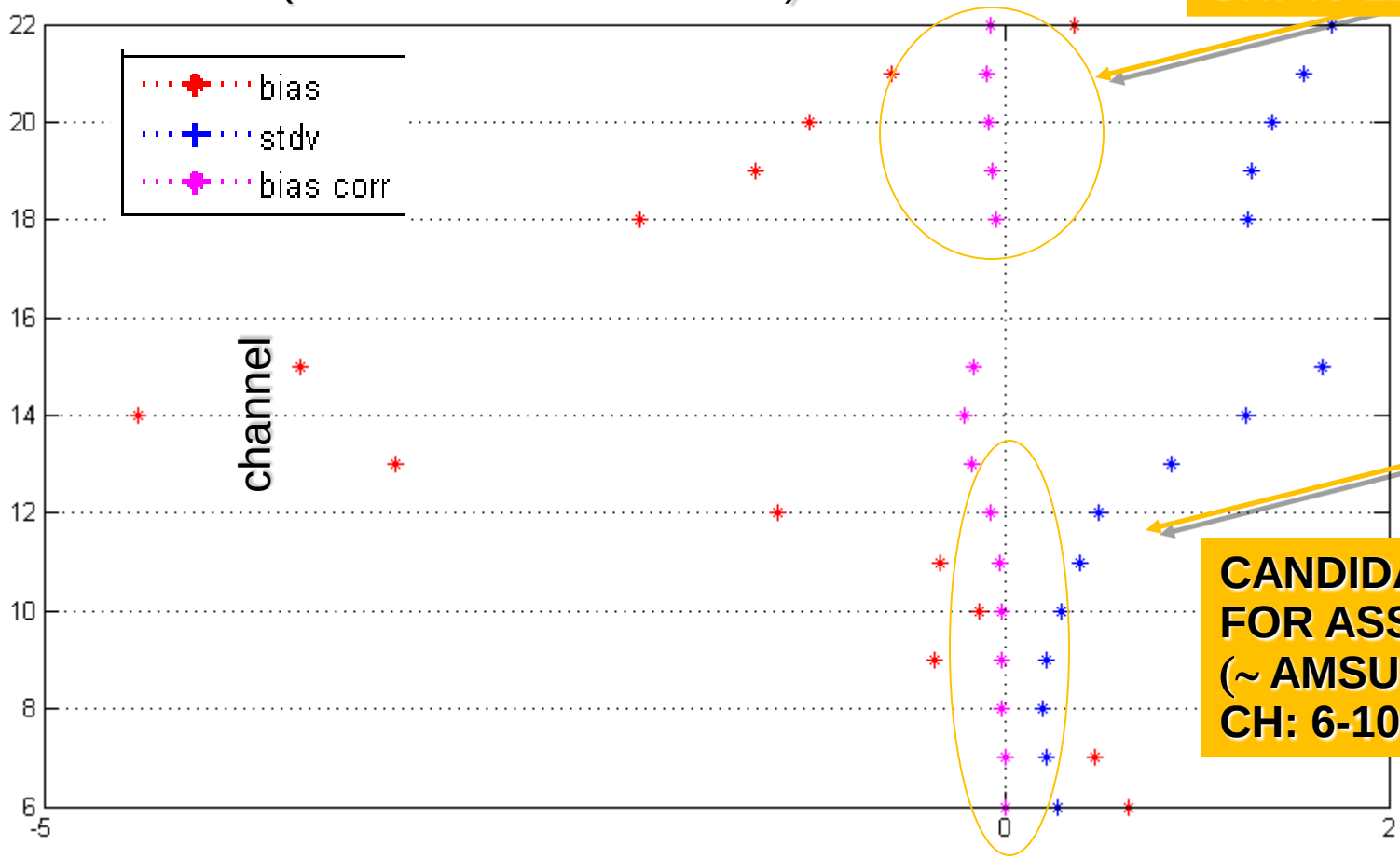
ASSIMILATION OF NEW OBS

ATMS

3x3 FOV spatial average
most recent statistics (MONITORING over SEA)



CANDIDATES FOR ASSIMIL. (~ MHS) CH: 19-22

CANDIDATES FOR ASSIMIL. (~ AMSU-A) CH: 6-10

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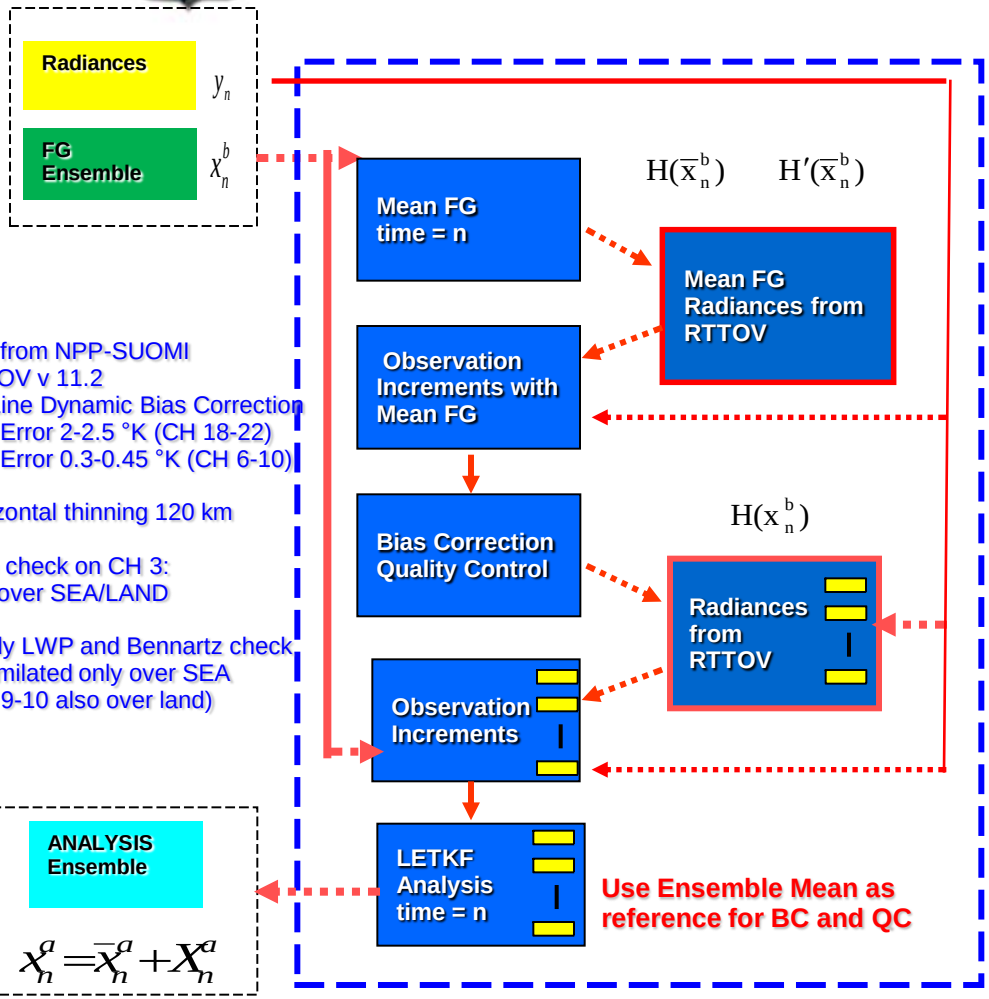
ATMS rad. assimilation

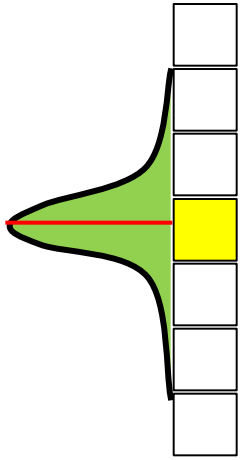


- Obs from NPP-SUOMI
- RTTOV v 11.2
- Off Line Dynamic Bias Correction
- Obs Error 2-2.5 °K (CH 18-22)
- Obs Error 0.3-0.45 °K (CH 6-10)

- Horizontal thinning 120 km

- Rain check on CH 3: 5 °K over SEA/LAND

- Grody LWP and Bennartz check
- Assimilated only over SEA (CH 9-10 also over land)



Weighting function (transmittance vert. derivative)

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

MAXIMUM-BASED METHOD

- ATMS 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

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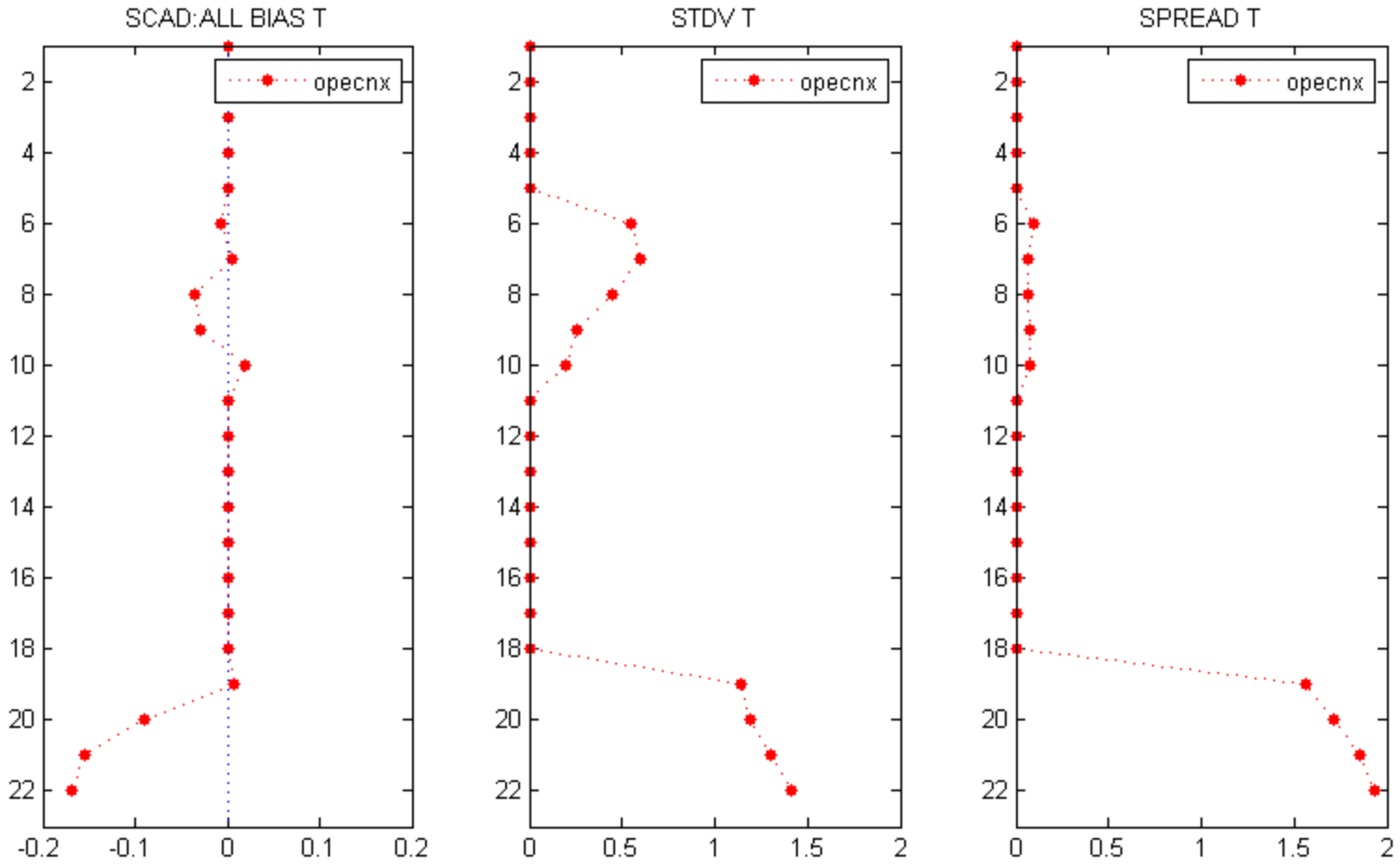
Obs Increment Statistics



Observation Increments Statistics from 12 aug 2014 to 3 sept 2014
(asimilated over SEA, channel 9-10 also over land)

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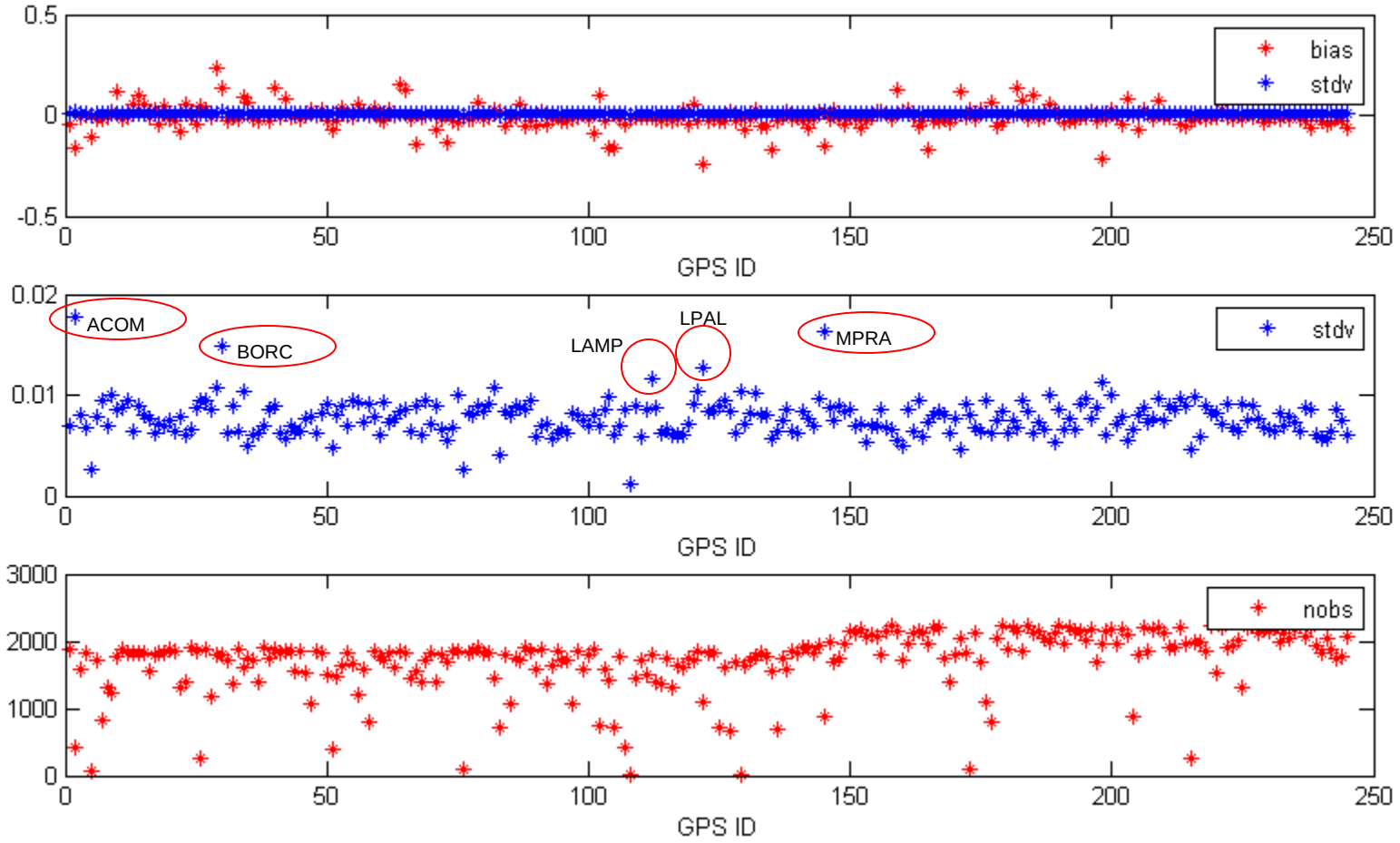
Italian GPS stations monitoring statistics (ZTD)

Period : 1-28 february 2014

Monitoring using CNMCA-LETKF system



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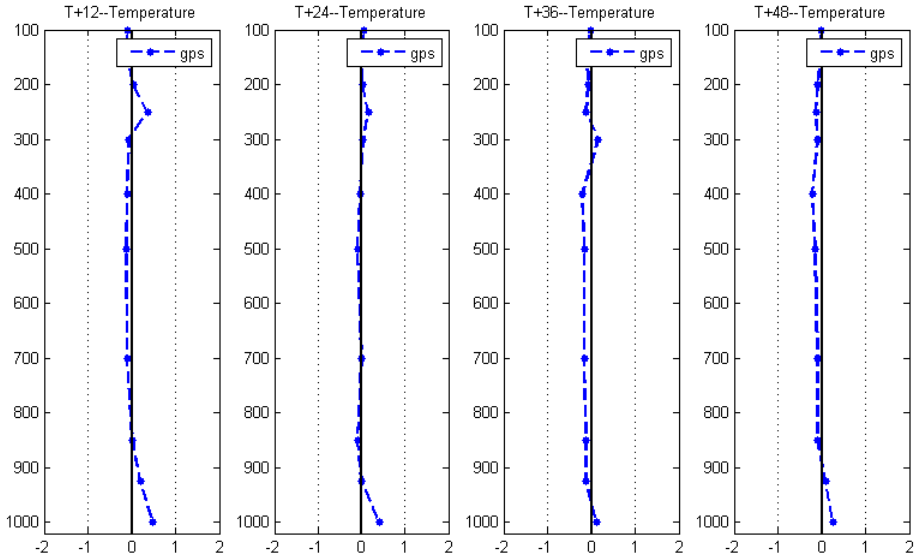
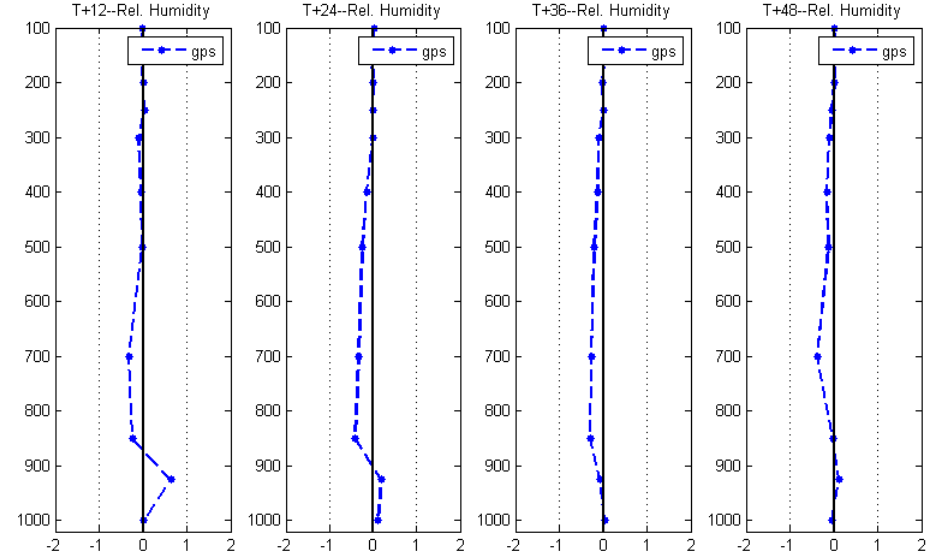
GPS Stations Assimilation

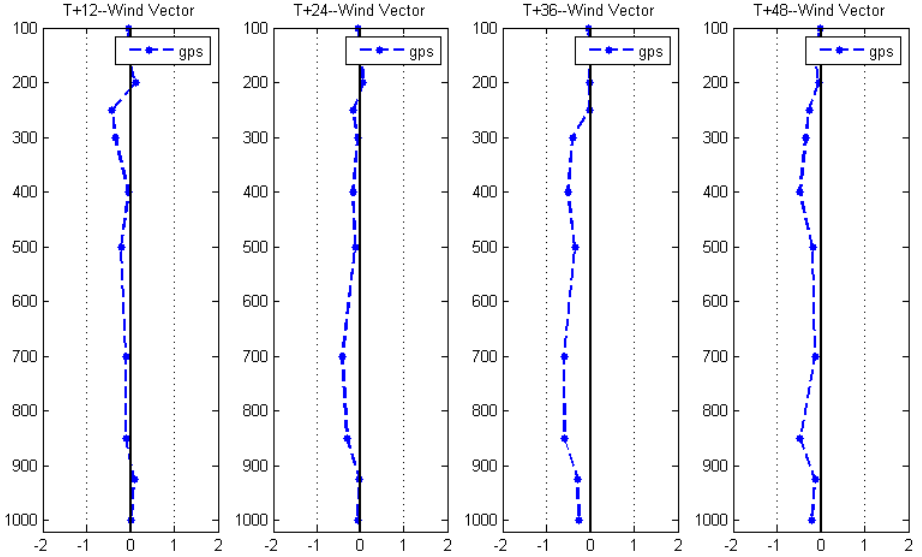
Thinning=60km

Relative difference (%) in RMSE computed against IFS analysis for 00 UTC COSMO runs from 11-01-2014 to 30-01-2014

negative value = positive impact







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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!)
- ATMS obs are already operationally assimilated, as soon as possible also GPS (bias corrected)
- On november (??) the EUMETSAT fellowship will start … first test of KENDA!

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Thanks for your attention!

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