The use of COSMO model in the CNMCA Operational LETKF System: First Results

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14° COSMO-General Meeting, Roma, 10-13 September 2012

Outline

- The 5th EnKF Workshop
- The CNMCA Ensemble Data Assimilation System (LETKF)
- Comparison HRM-COSMO LETKF:
  - COSMO model settings
  - Observation increment statistics
  - COSMO-ME objective verification
- Conclusions and future developments

Session 5: Operational Implementations

Session chair: Lucio Torrisi

Center	Scheme	Use	Operations	Presentation
CMC	EnKF (Stochastic)	- EPS initialization	January 2005	Oral
NCEP	Hybrid (3DVAR/EnSRF)	- Deterministic forecast	May 2012	Oral (sess. 2)
UKMO	Hybrid (4DVAR/ Local ETKF)	- Deterministic forecast - EPS Perturbations	July 2011 June 2006	Oral
MF	EDA (Ensemble of 4DVAR)	- Initial B variances in 4DVAR - EPS initial perturbations together with SV	July 2008 December 2009	-
ECMWF	EDA (Ensemble of 4DVAR)	- Initial B variances in 4DVAR - EPS initial perturbations together with SV	May 2011 June 2010	Oral
CNMCA (Italy)	Regional EnKF (LETKF)	- Deterministic forecast	June 2011	Poster

Ensemble Kalman Filter DA

- At CNMCA the **LETKF** (Hunt et al. 2007) formulation was chosen, because algorithmically simple to code, intrinsically parallel, etc.
- The analysis is done in the space of the ensemble perturbations and computed separately at each grid point selecting only the obs in a vicinity. This explicit localization reduces the problem dimensionality and the spurious correlations between distant locations due to limited ensemble size

Analysis Ensemble Mean $\qquad \overline{x}^a = \overline{x}^b + \mathbf{X}^b \, \overline{w}^a$

Analysis Ensemble Perturb. $\qquad X^a = \mathbf{X}^b \, W^a$

Analysis Ensemble $\qquad x^a = x^b + \mathbf{X}^b \, w^a$

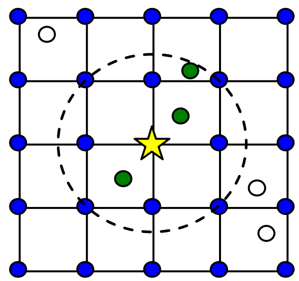
$$\overline{w}^a = \tilde{P}^a Y^{bT} R^{-1} (y - H(\overline{x}^b))$$

$$\tilde{P}^a = [(m-1)I + Y^{bT} R^{-1} Y^b]^{-1}$$

$$Y^b = [(H(x_1^b) - \overline{H(x^b)}), \ldots\ldots, (H(x_m^b) - \overline{H(x^b)})]$$

$$W^a = [(m-1)\tilde{P}^a]$$

$$w^a = W^a + [\overline{w}^a, \ldots\ldots, \overline{w}^a]$$



– ensemble mean analysis is the linear combination of forecast ensemble states which best fits the observational dataset
– analysis ensemble members are locally linear combinations of background ensemble members

CNMCA LETKF Implementation

- 40+1 member ensemble at 0.09°(~10Km) grid spacing (HRM model), 40 hybrid p-sigma vertical levels (top at 10 hPa)
- 6-hourly assimilation cycle run and (T,u,v,qv,ps) as a set of control variables
- Observations: RAOB, SYNOP, SHIP, BUOY, AIREP, AMDAR, ACAR, AMV (MSG, MET7), WindPROF, SCAT(METOP), AMSU-A (METOP,NOAA) radiances (very soon)
- Horizontal localization with 800 Km circular local patches (obs weight smoothly decay with a pseudo-gaussian function of hor. distance)
- Vertical localization to layers whose depth increases from 0.2 scale heights at the lowest model levels to 2. scale heights at the model top (obs weight smoothly decay with a pseudo-gaussian function of scale height)
- Adaptive selection radius using a fixed number of effective observations (sum of obs weights)
- Daily blending of the mean upper level analysis with the IFS analysis to compensate the limited satellite data usage

Covariance Inflation

In the 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)

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

- Climatological Additive Noise

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

$\mathbf{x}_i^n$ randomly selected, 48-24h forecast differences

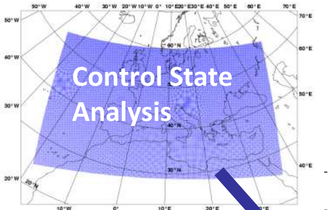
- Lateral Boundary Condition Perturbation using EPS

- Climatological Perturbed SST

CNMCA NWP SYSTEM since 1 June 11

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

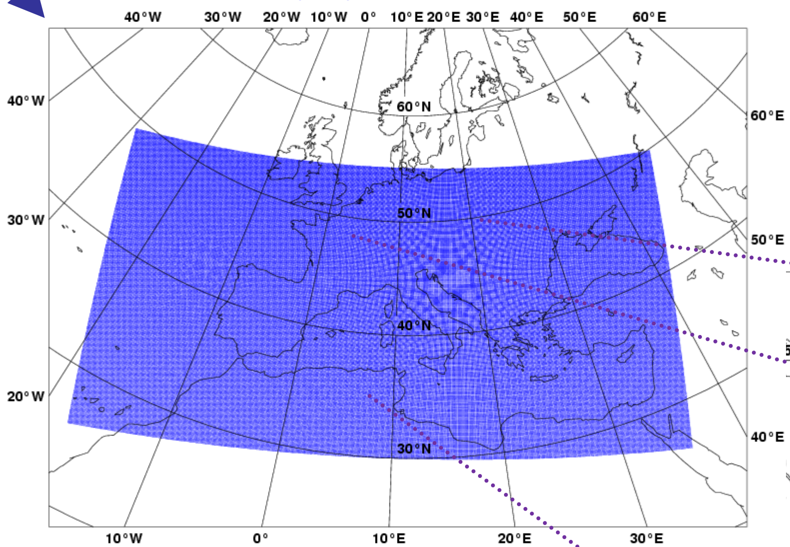
Ensemble Data Assimilation:



10 km
40 v.l.

HRM hydrostatic model
parameterized convection

COSMO-ME (7km) ITALIAN MET SERVICE



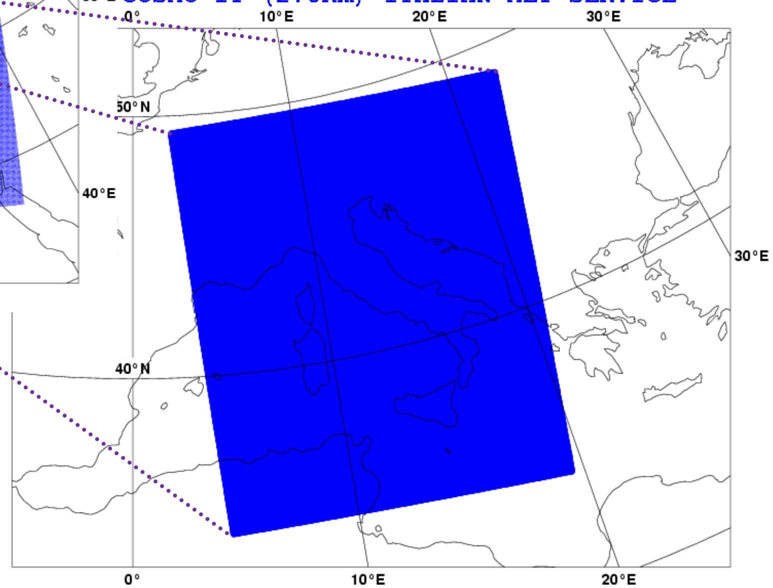
7 km
40 v.l.

compressible equations
parameterized convection

2.8 km
50 v.l.

compressible equations
explicit convection

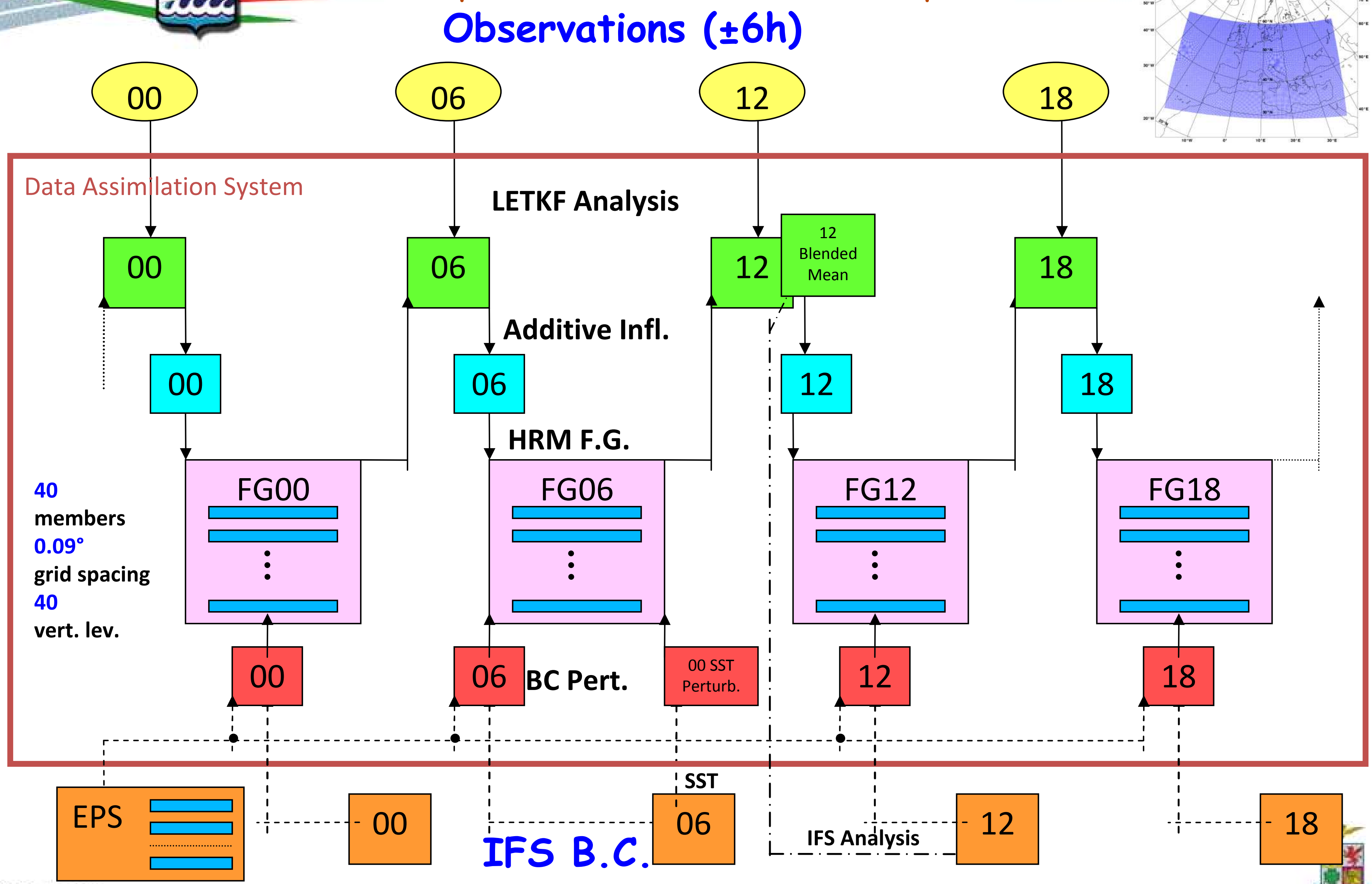
COSMO-IT (2.8Km) ITALIAN MET SERVICE



Local Area Modelling: COSMO

CNMCA LETKF DA SYSTEM

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

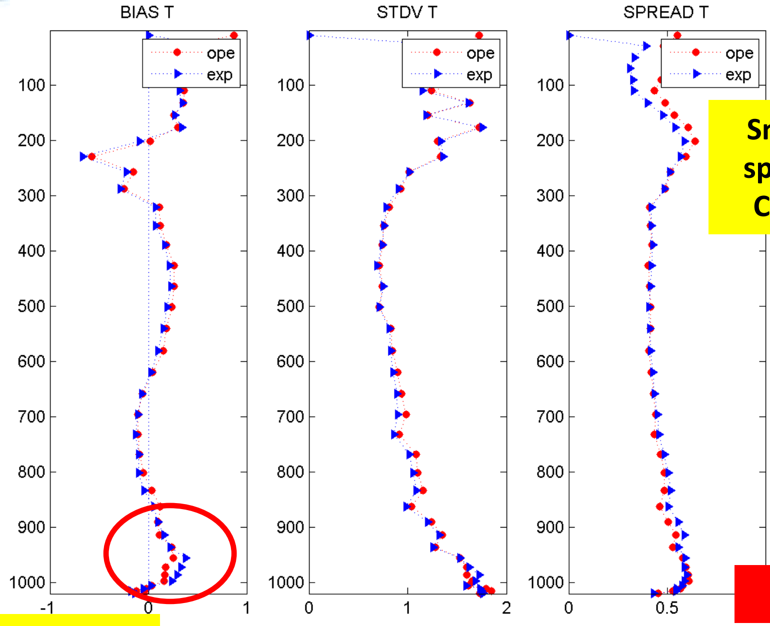


COSMO model in CNMCA-LETKF

- 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 ~21.5km (~ 43hPa) to ~26km (~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
- The CNMCA-LETKF system using COSMO model is experimental running since February 2012 with basicly the same settings of the operational one
- Observation increment statistics (obs-BG) is continously monitored and deterministic forecasts from this system are objectively verified against conventional observations

HRM vs COSMO LETKF

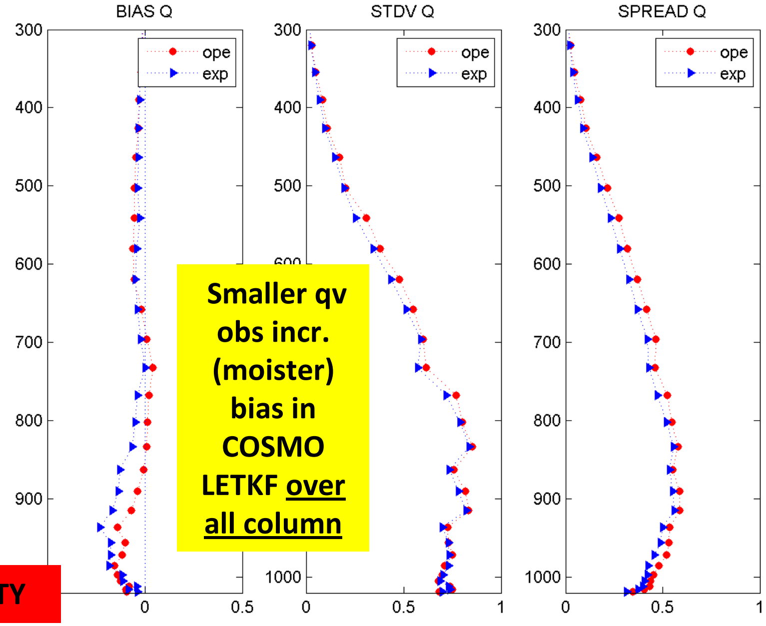
TEMPERATURE



Smaller T spread in COSMO

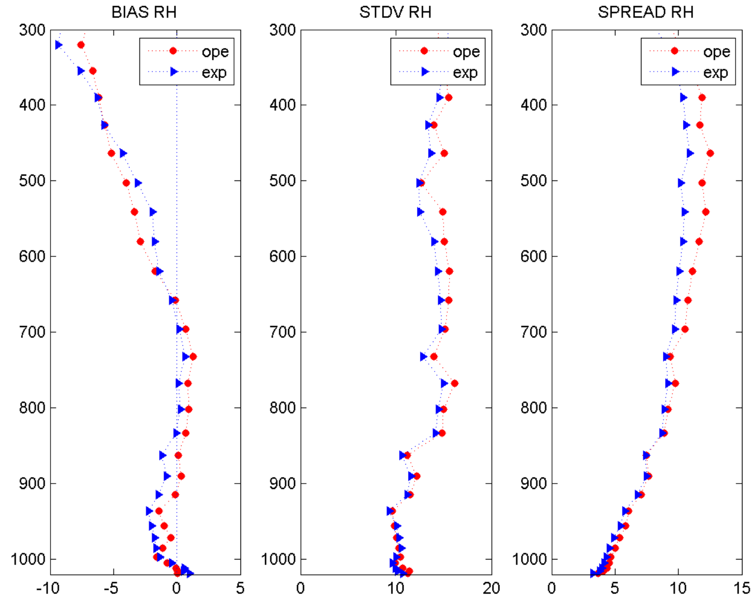
Larger T obs incr. (colder) bias in COSMO LETKF

SPEC. HUMIDITY



Smaller qv obs incr. (moister) bias in COSMO LETKF over all column

REL. HUMIDITY

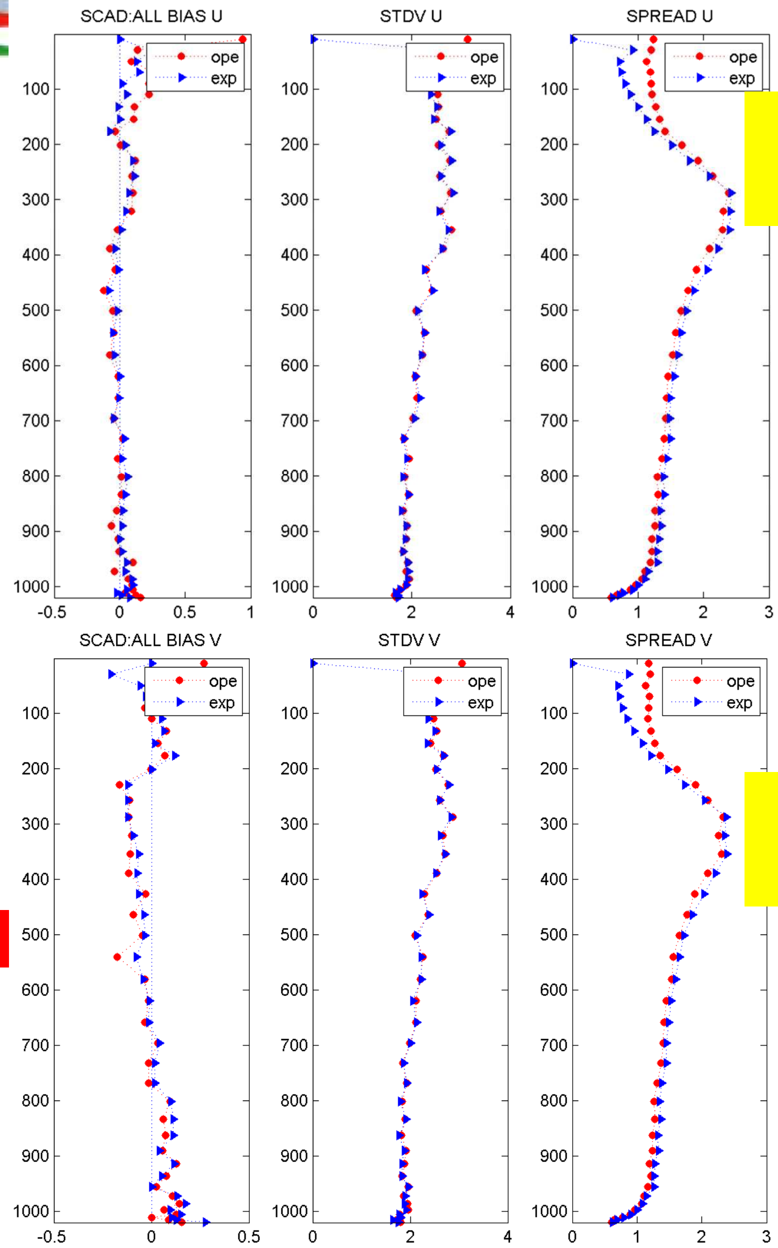


RAOB obs increment statistics (obs-BG ensemble mean) on 40 levels from 28 apr 2012 to 01 jun 2012 (00 06 12 18 UTC)

HRM vs COSMO LETKF

U - WIND

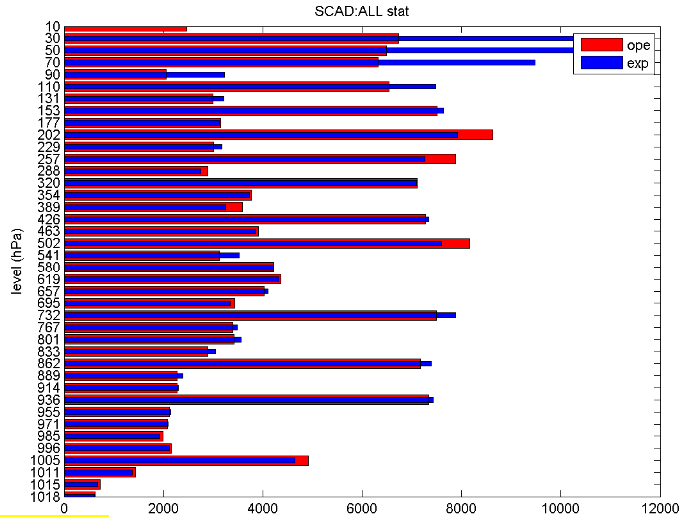
V - WIND



Smaller u spread in COSMO

Smaller v spread in COSMO

STATISTICS

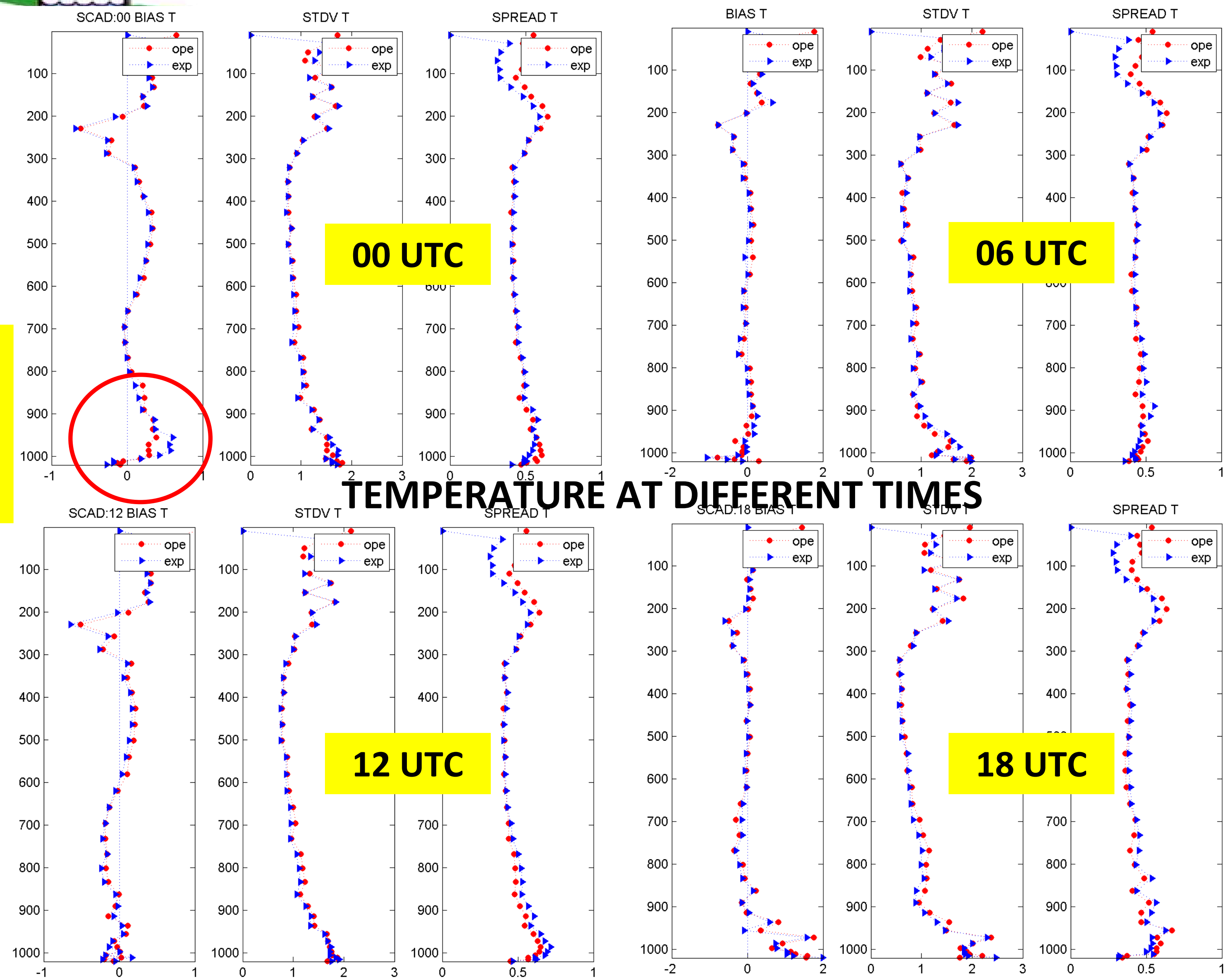


RAOB obs increment statistics on 40 p-levels from 28 apr 2012 to 01 jun 2012 (00 06 12 18 UTC)

HRM vs COSMO LETKF: 00UTC

RAOB obs increment statistics on 40 p-levels from 28 apr 2012 to 01 jun 2012

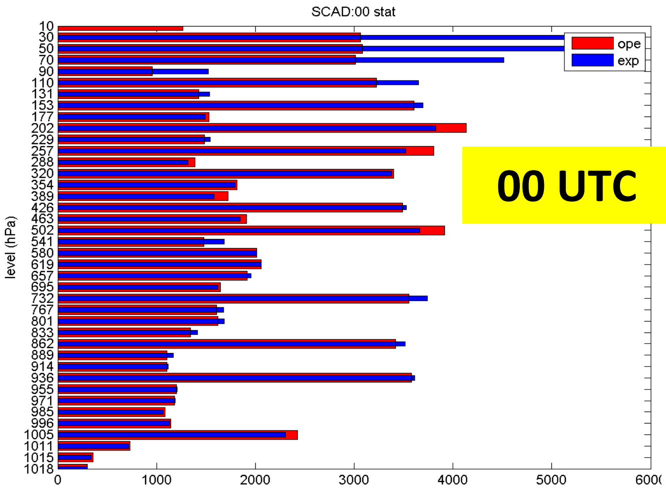
Larger T obs incr. (colder) bias in COSMO LETKF

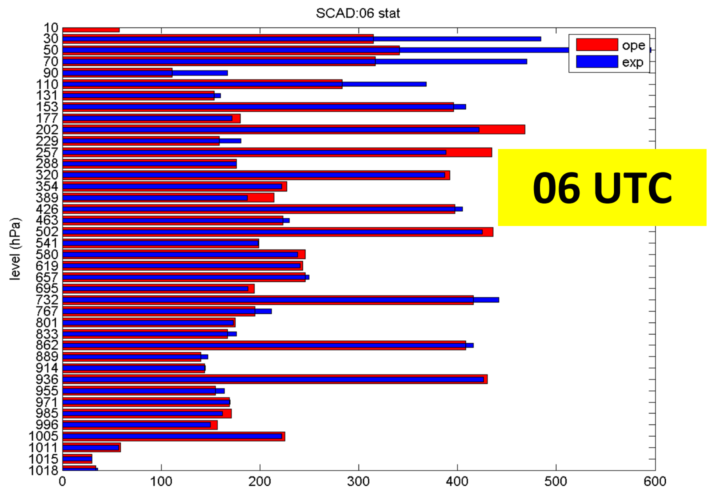


HRM vs COSMO LETKF

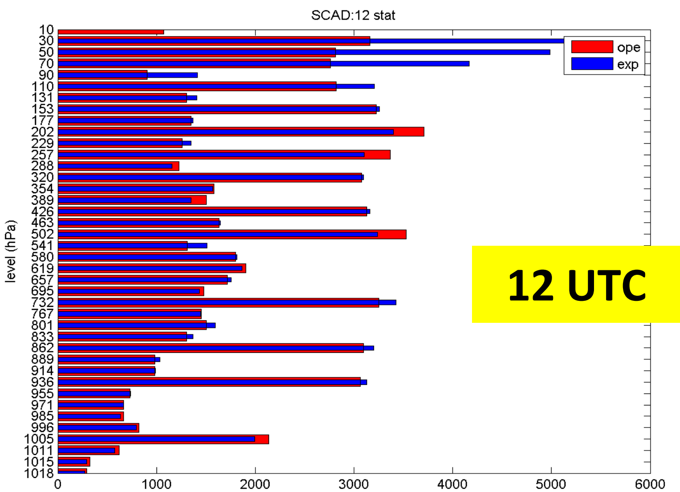
RAOB obs increment statistics on 40 p-levels from 28 apr 2012 to 01 jun 2012

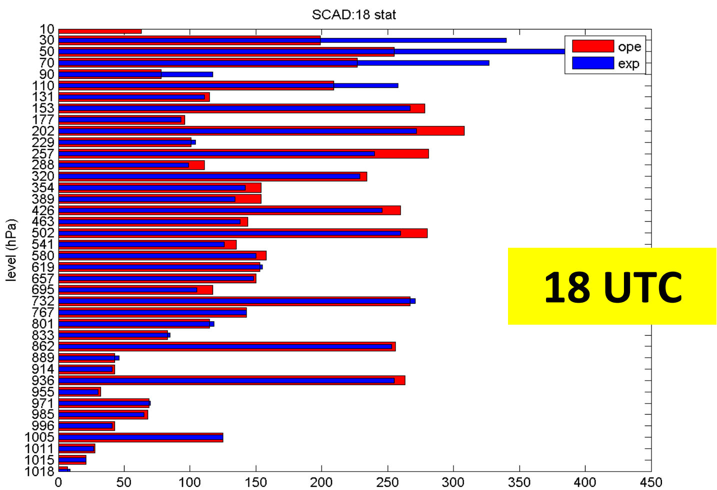
Sample Size





TEMPERATURE AT DIFFERENT TIMES

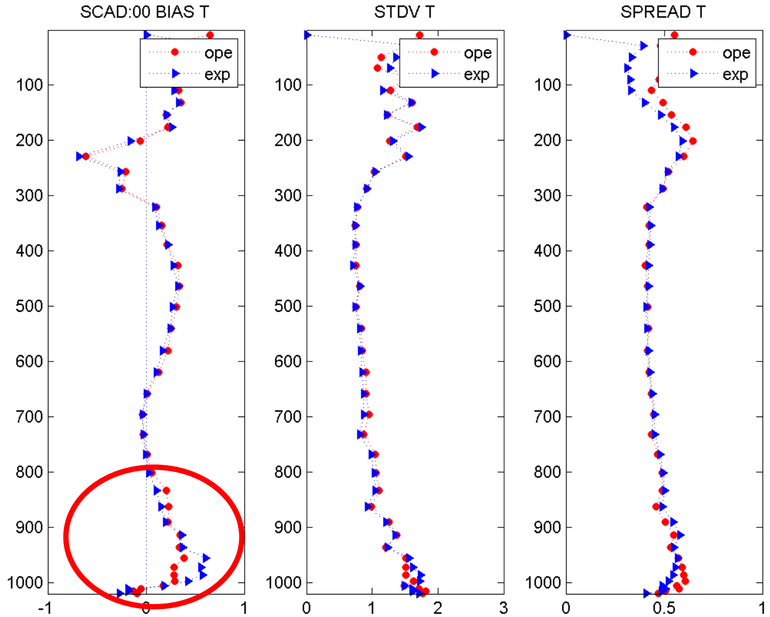




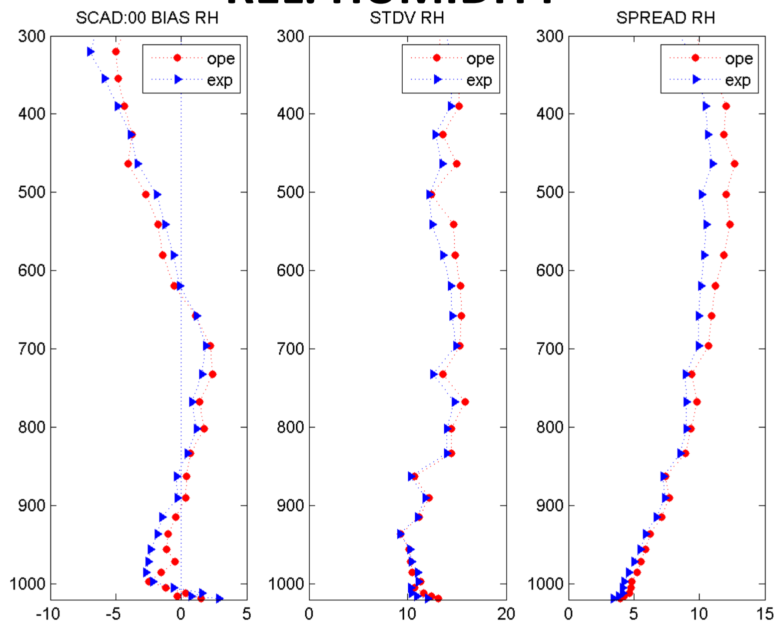
Small sample size at 06 and 18 UTC

HRM vs COSMO LETKF: 00UTC

TEMPERATURE

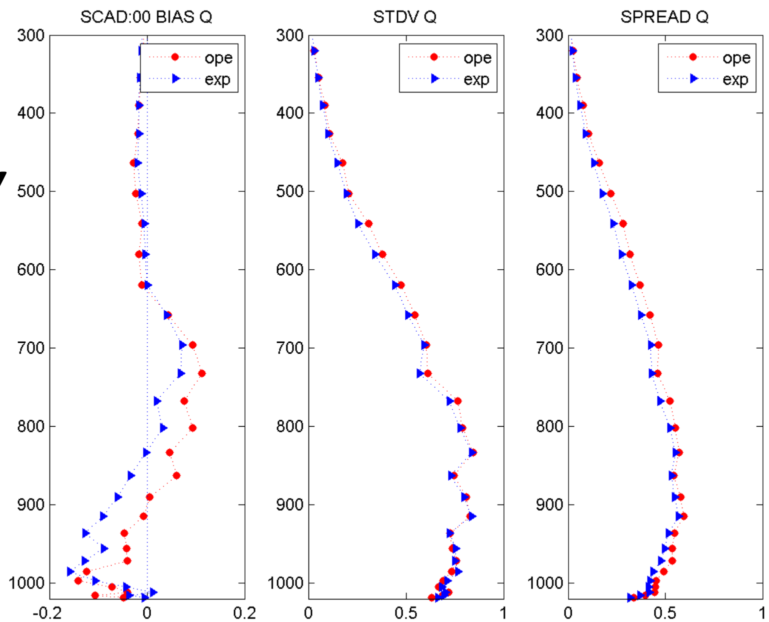


REL. HUMIDITY



Larger T obs incr. (colder) bias in COSMO LETKF

SPEC. HUMIDITY

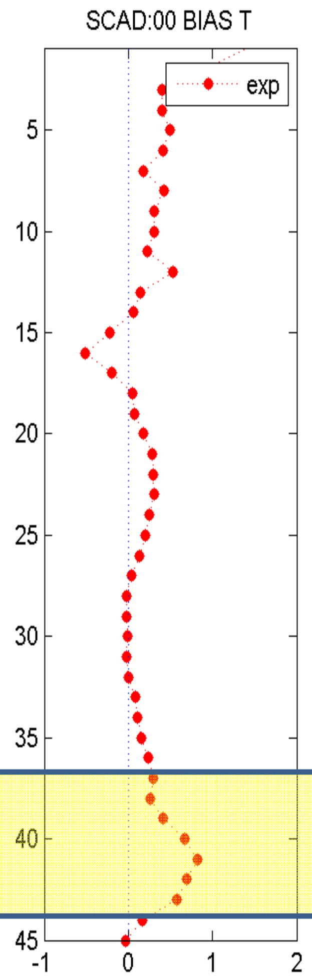


RAOB obs increment statistics on 40 p-levels from 28 apr 2012 to 01 jun 2012 at 00UTC

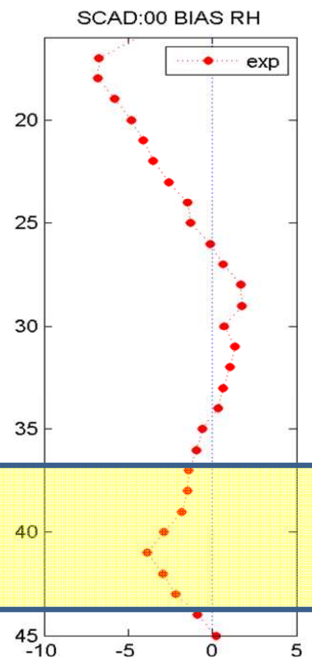
HRM vs COSMO LETKF: 00UTC

Nocturnal Colder Bias in COSMO Background Ensemble Mean

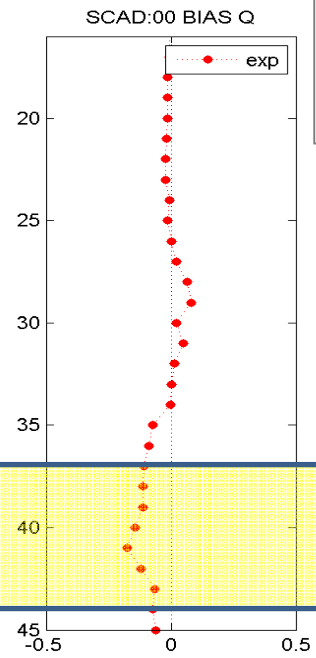
TEMPERATURE



REL. HUMIDITY



SPEC. HUMIDITY



RAOB obs increment statistics on 45 COSMO model levels from 28 apr 2012 to 01 jun 2012 at 00UTC

LARGER TEMPERATURE OBS INCR. (COLDER) BIAS LAYER

Looking at "daily" statistics a two days period has been selected

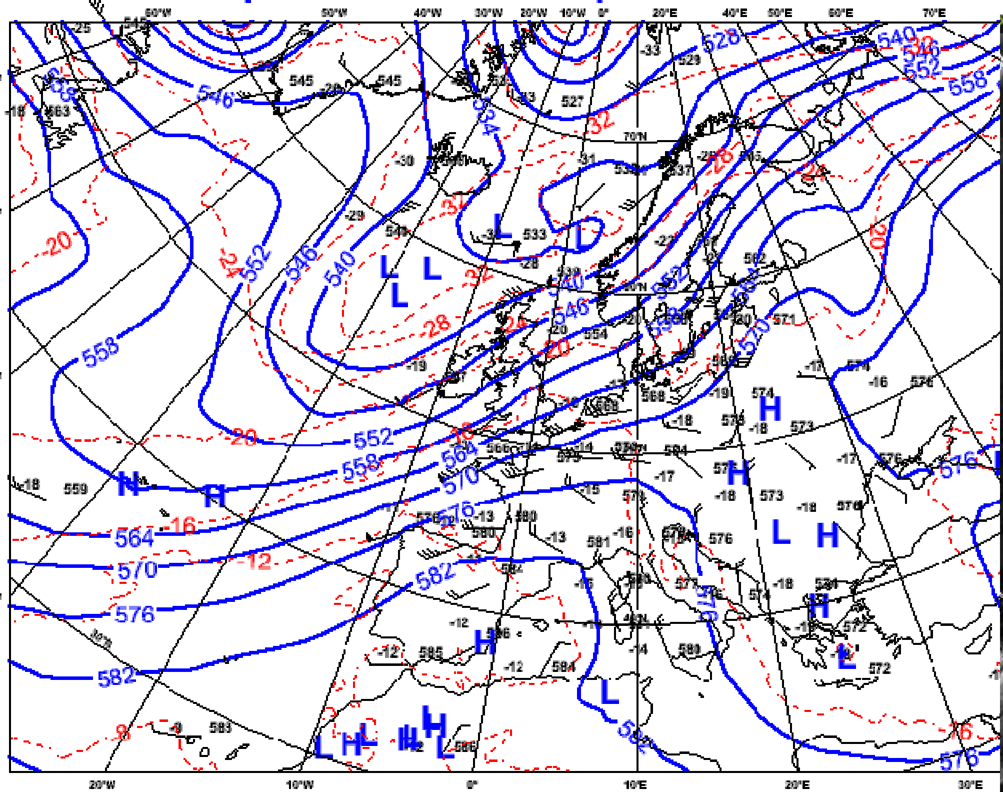
10-11 may 2012 → CASE STUDY

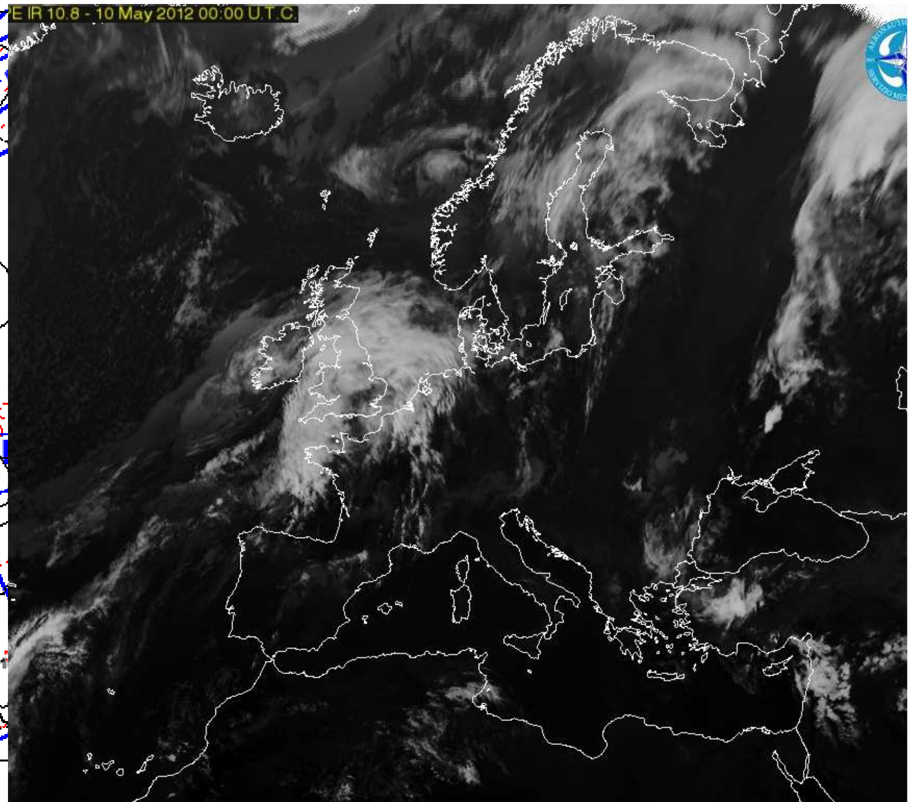
COSMO LETKF: 00UTC

10-11 May 2012 CASE STUDY

Upper level ridge over SW Europe → Subsidence → Stable condition

ROME Analysis VT:Giovedi 10 Maggio 2012 00UTC
Geopotenziale 500 hPa + Temperatura 500 hPa n.a.

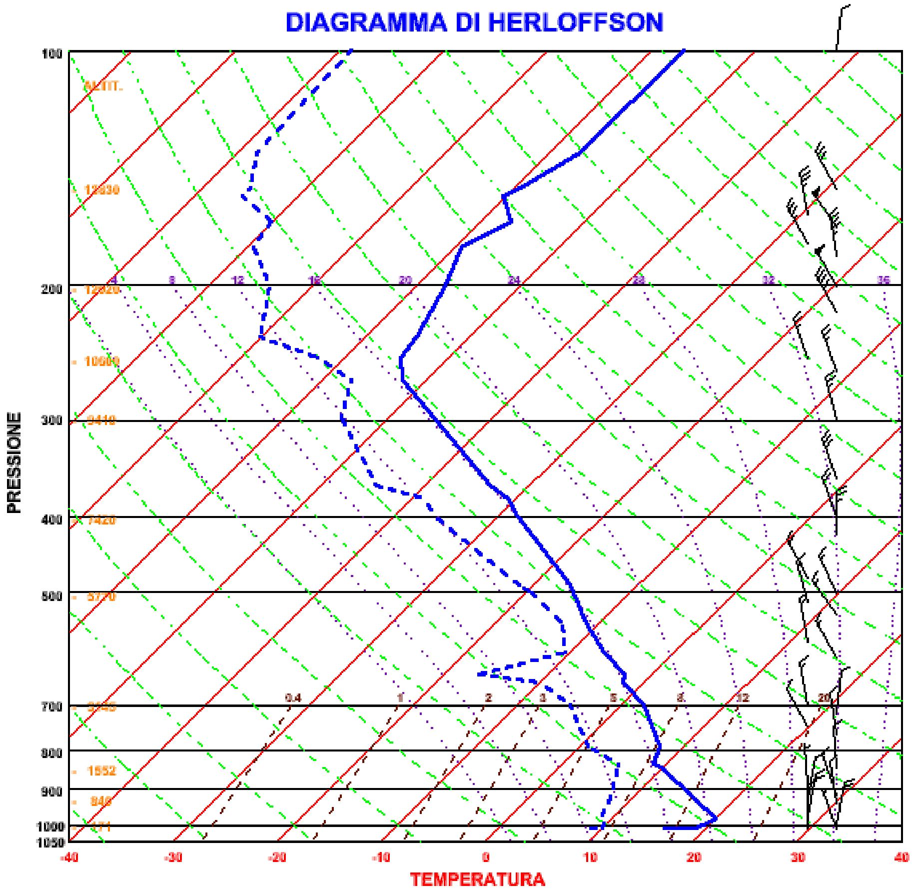




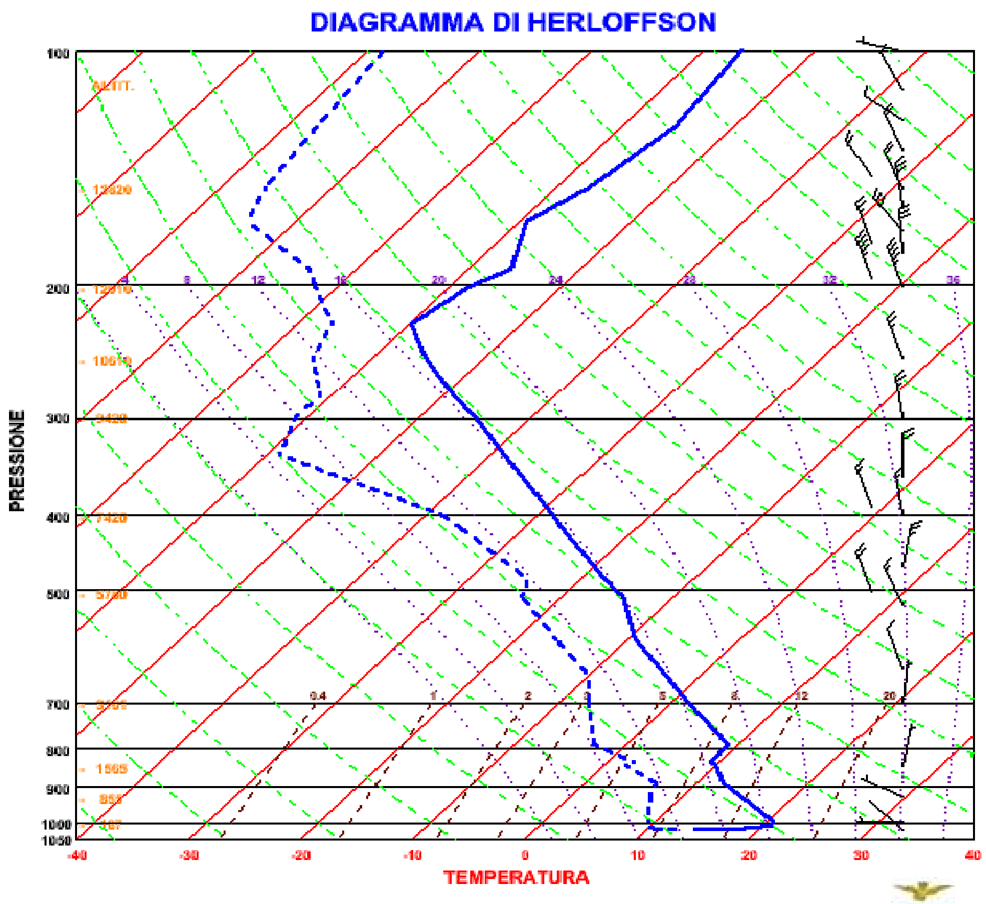
HRM vs COSMO LETKF: 00UTC

10 May 2012 00 UTC

Pratica di Mare (16245)

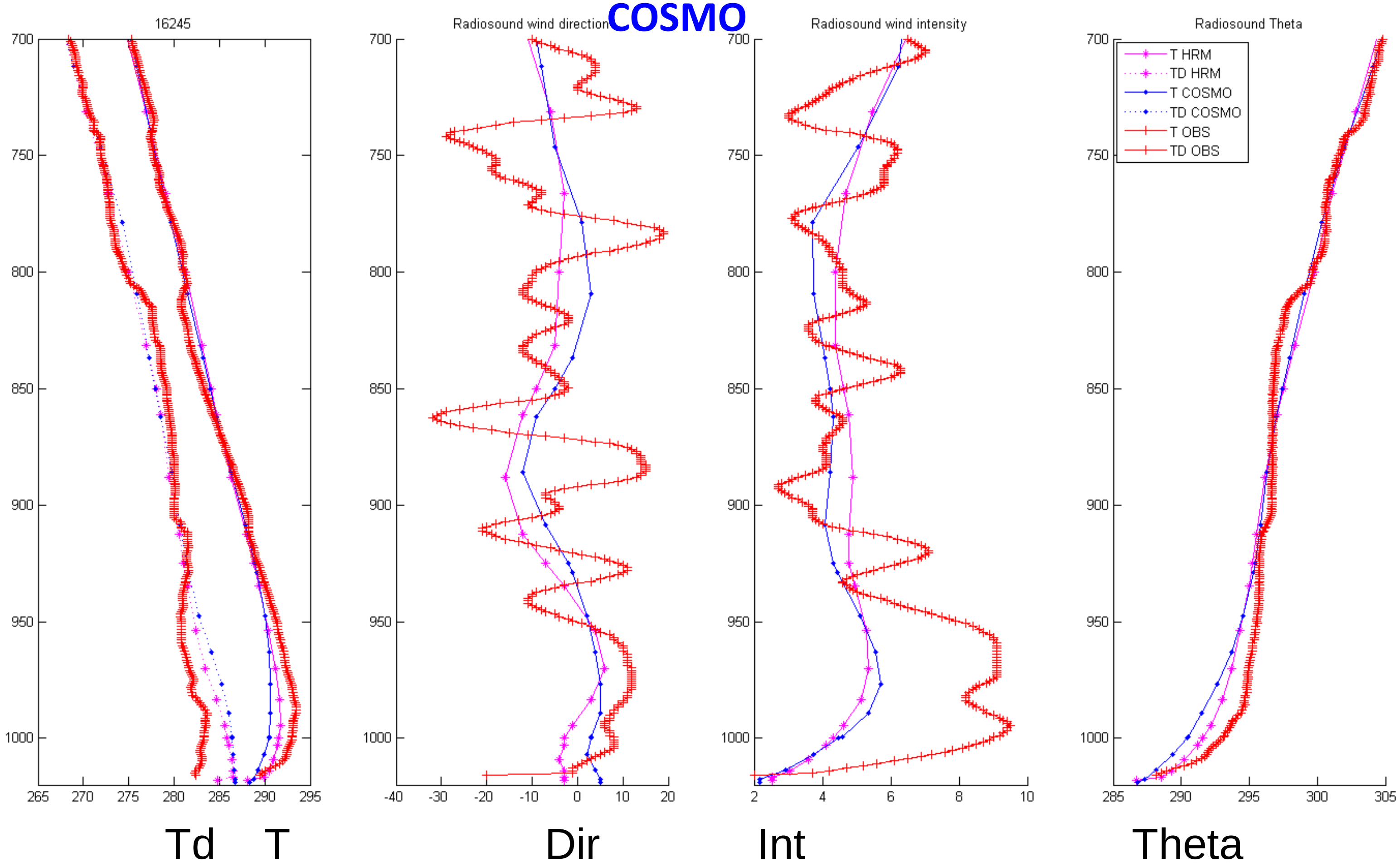


S.Pietro Capofiume (16144)



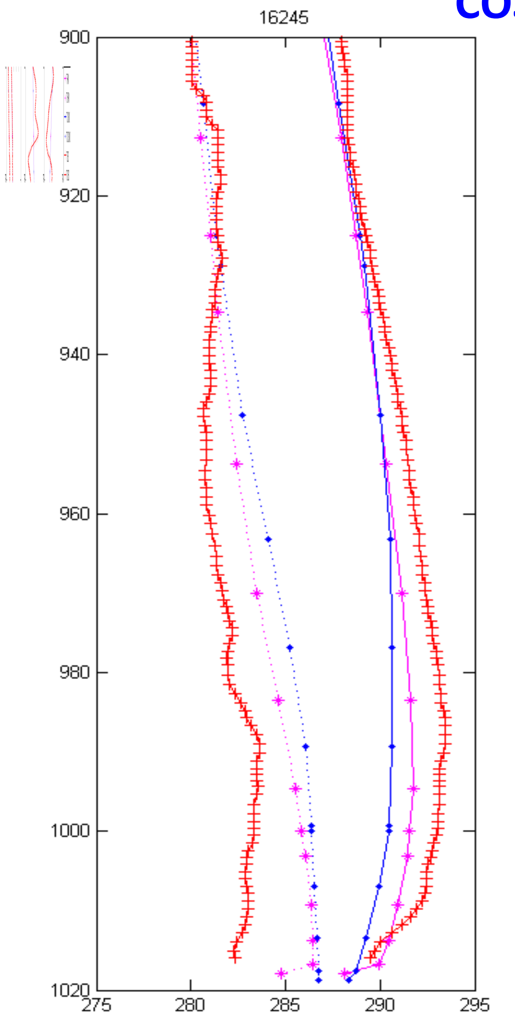
HRM vs COSMO LETKF: 00UTC

PRATICA DI MARE RAOB 20120510 00UTC HRM VS COSMO

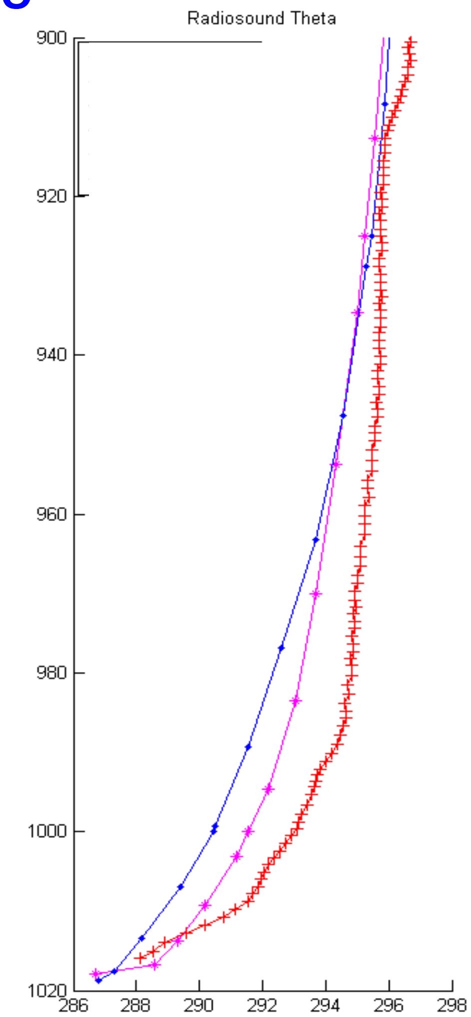


HRM vs COSMO LETKF: 00UTC

PRATICA DI MARE RAOB 20120510 00UTC HRM VS COSMO



Td T

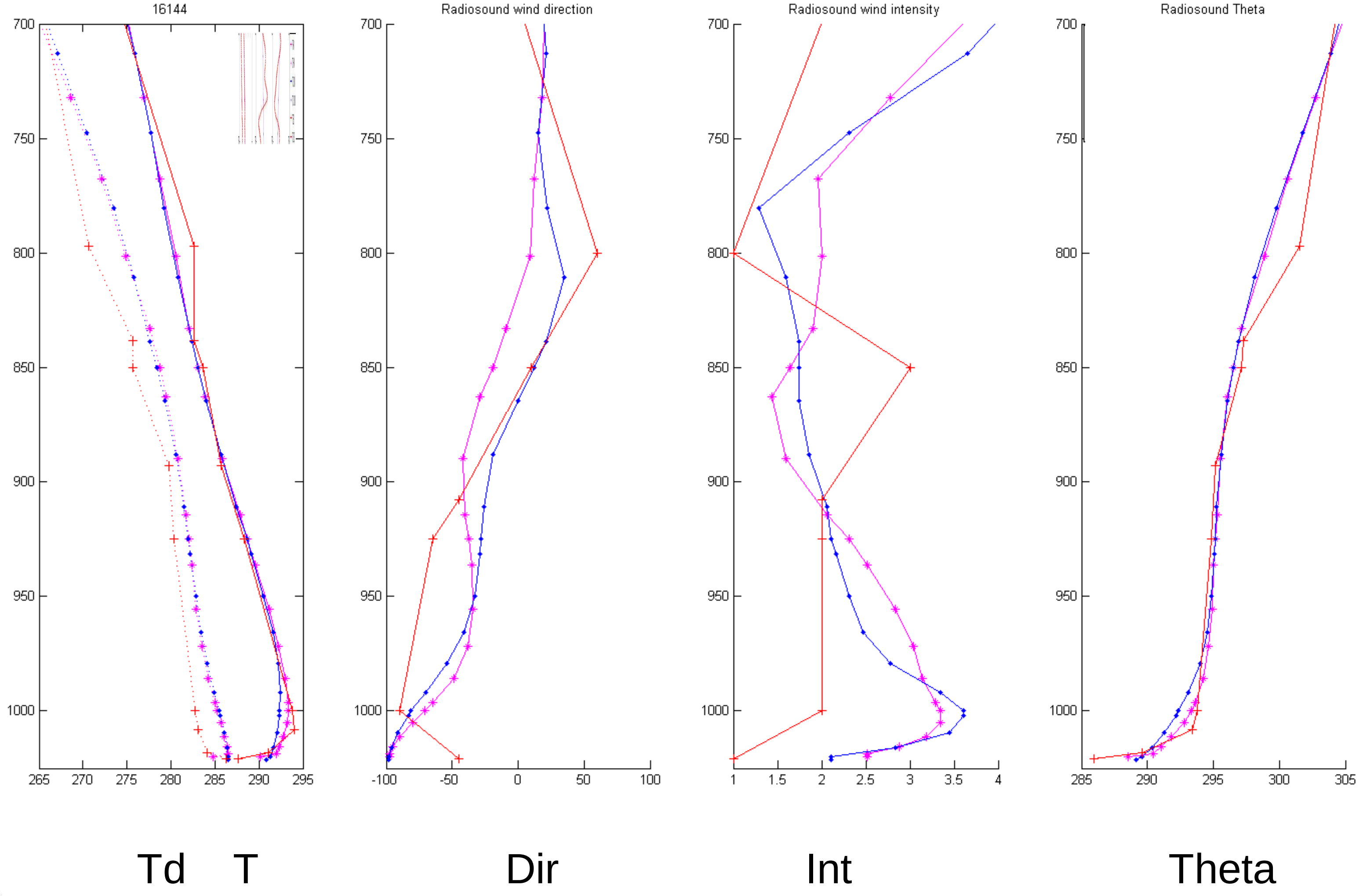


Theta

The strong cooling thermal inversion is not well represented using COSMO model.
HRM makes a better job!

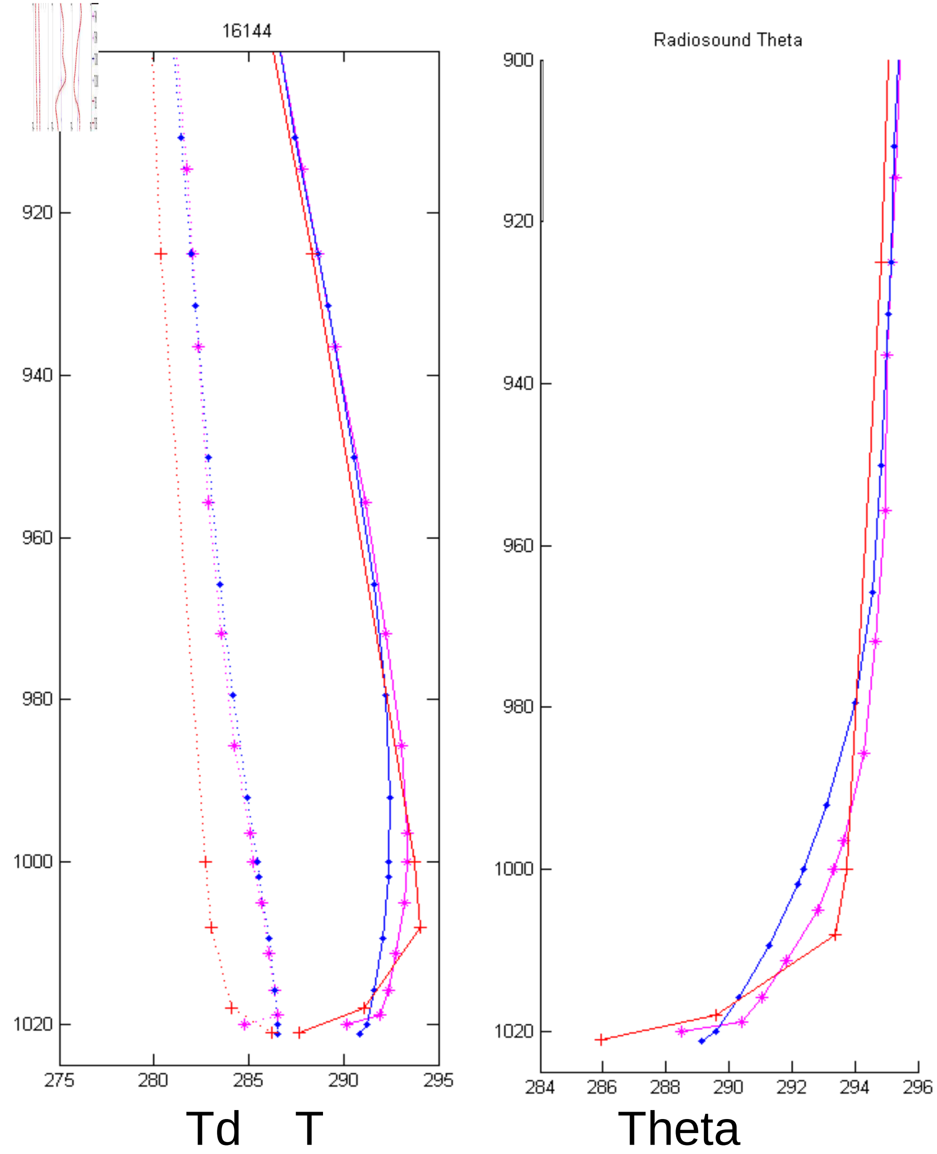
HRM vs COSMO LETKF: 00UTC

S.PIETRO CAPOFIUME RAOB 20120510 00UTC HRM VS COSMO



HRM vs COSMO LETKF: 00UTC

S.PIETRO CAPOFIUME RAOB 20120510 00UTC HRM VS COSMO



The strong cooling thermal inversion is not well represented using COSMO model. HRM is slightly better.

COSMO LETKF: 00UTC

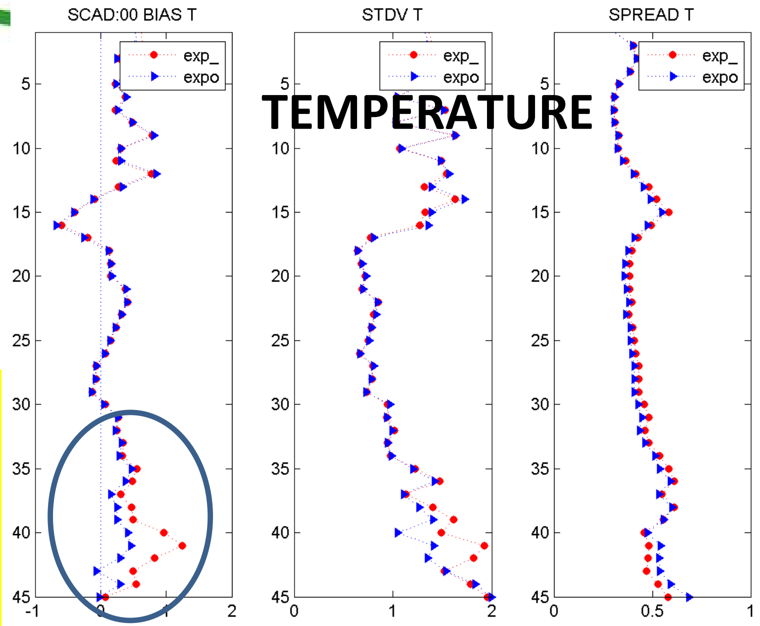
Sensitivity to the turbulence scheme

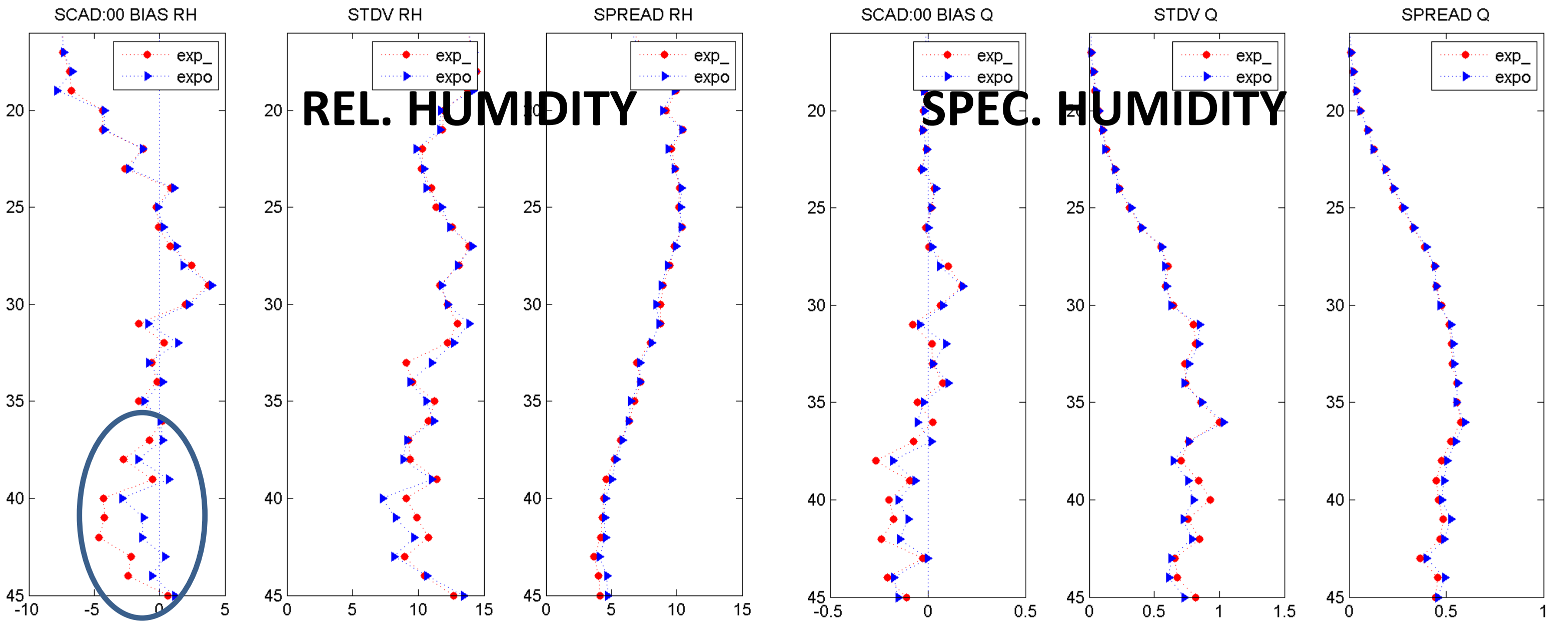
10-11 May 2012 CASE STUDY

RAOB obs increment statistics on 45 COSMO model levels at 00UTC

OLD (DIAG. TKE) VS OPE (PROG. TKE) TURBULENCE SCHEME

Larger T obs incr. (colder) bias using the oper. turbulence scheme

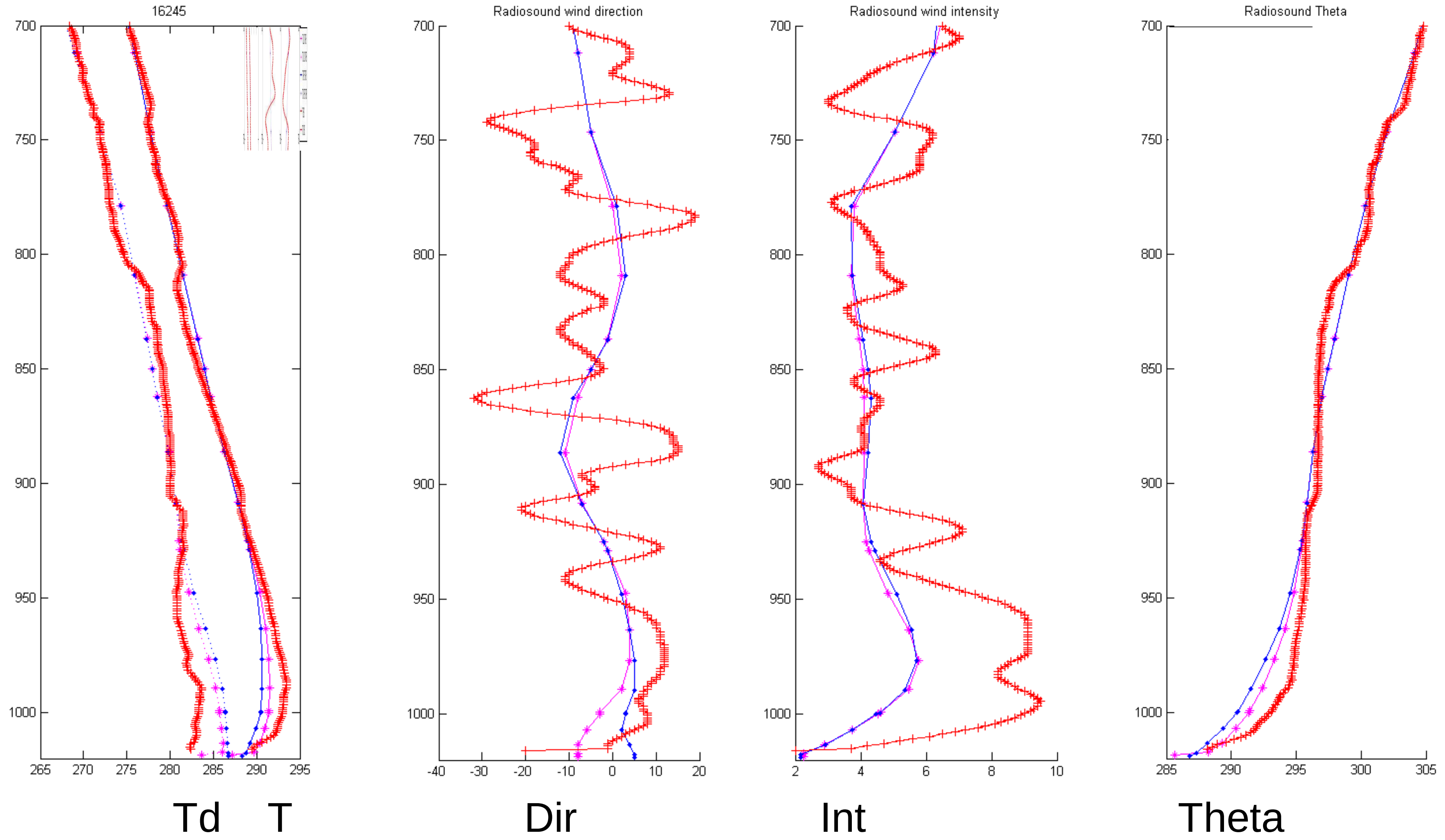




COSMO LETKF: 00UTC

Sensitivity to the turbulence scheme

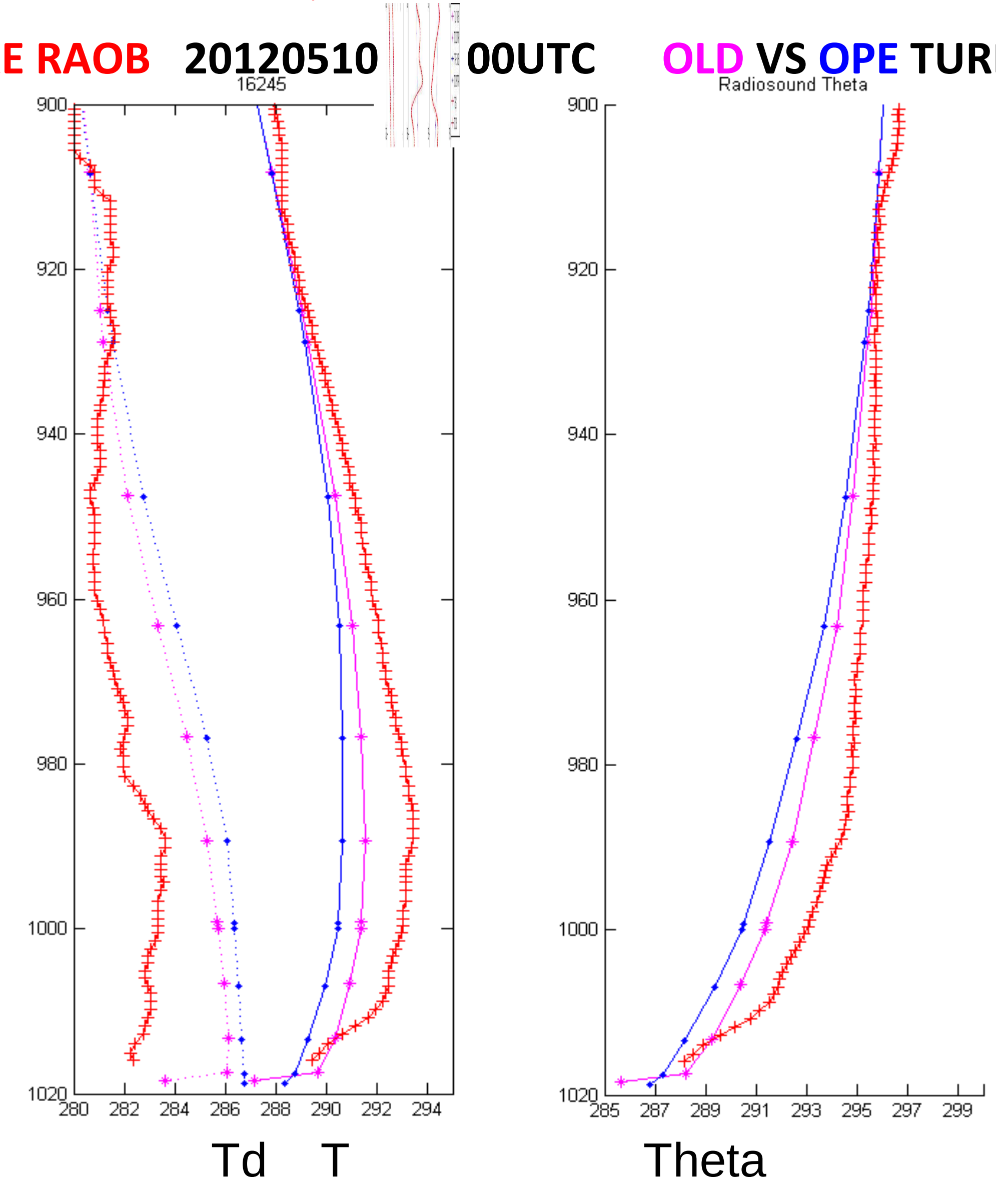
PRATICA DI MARE RAOB 20120510 00UTC OLD VS OPE TURBULENCE SCHEME



COSMO LETKF: 00UTC

Sensitivity to the turbulence scheme

PRATICA DI MARE RAOB 20120510 00UTC **OLD VS OPE TURBULENCE SCHEME**

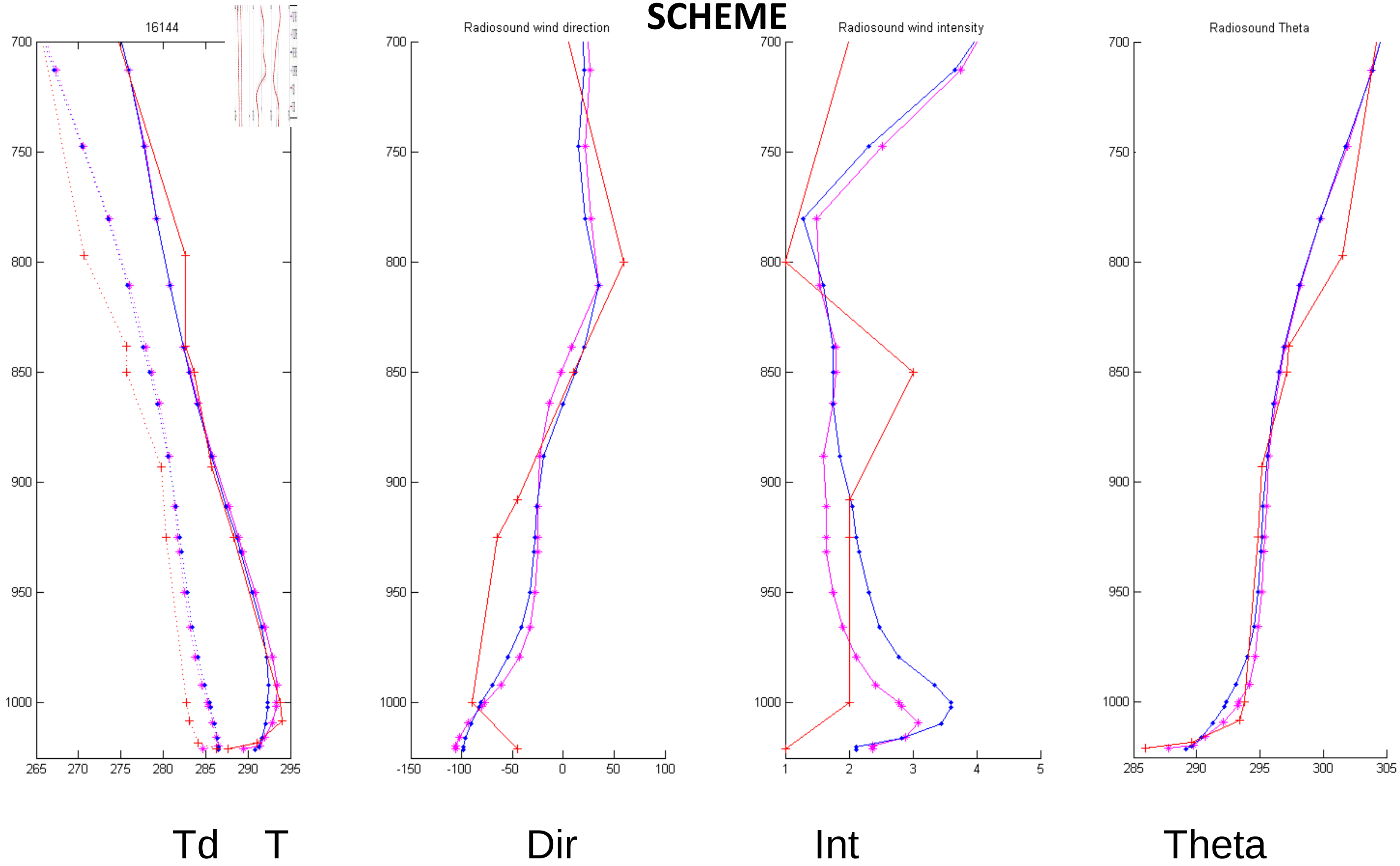


The strong cooling thermal inversion is not well represented in COSMO using the prognostic TKE (ope) turbulence scheme. COSMO with the diagnostic TKE (old) scheme makes a slightly better job.

COSMO LETKF: 00UTC

Sensitivity to the turbulence scheme

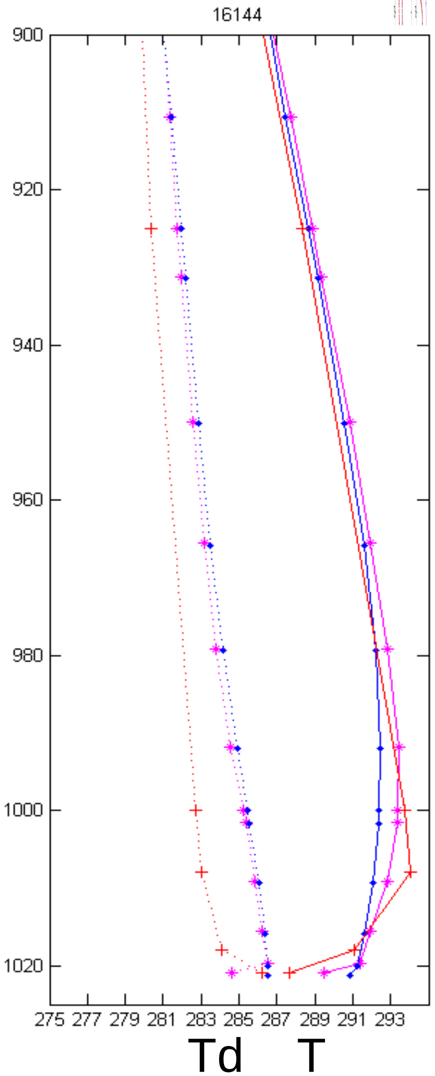
S.PIETRO CAPOFIUME RAOB 20120510 00UTC OLD VS OPE TURBULENCE SCHEME

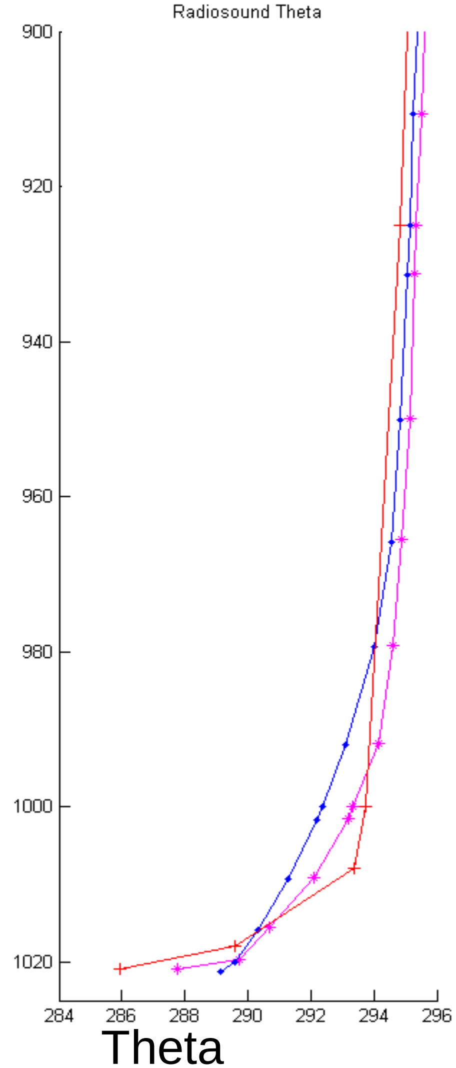


COSMO LETKF: 00UTC

Sensitivity to the turbulence scheme

S.PIETRO CAPOFIUME RAOB 20120510 00UTC OLD VS OPE TURBULENCE SCHEME

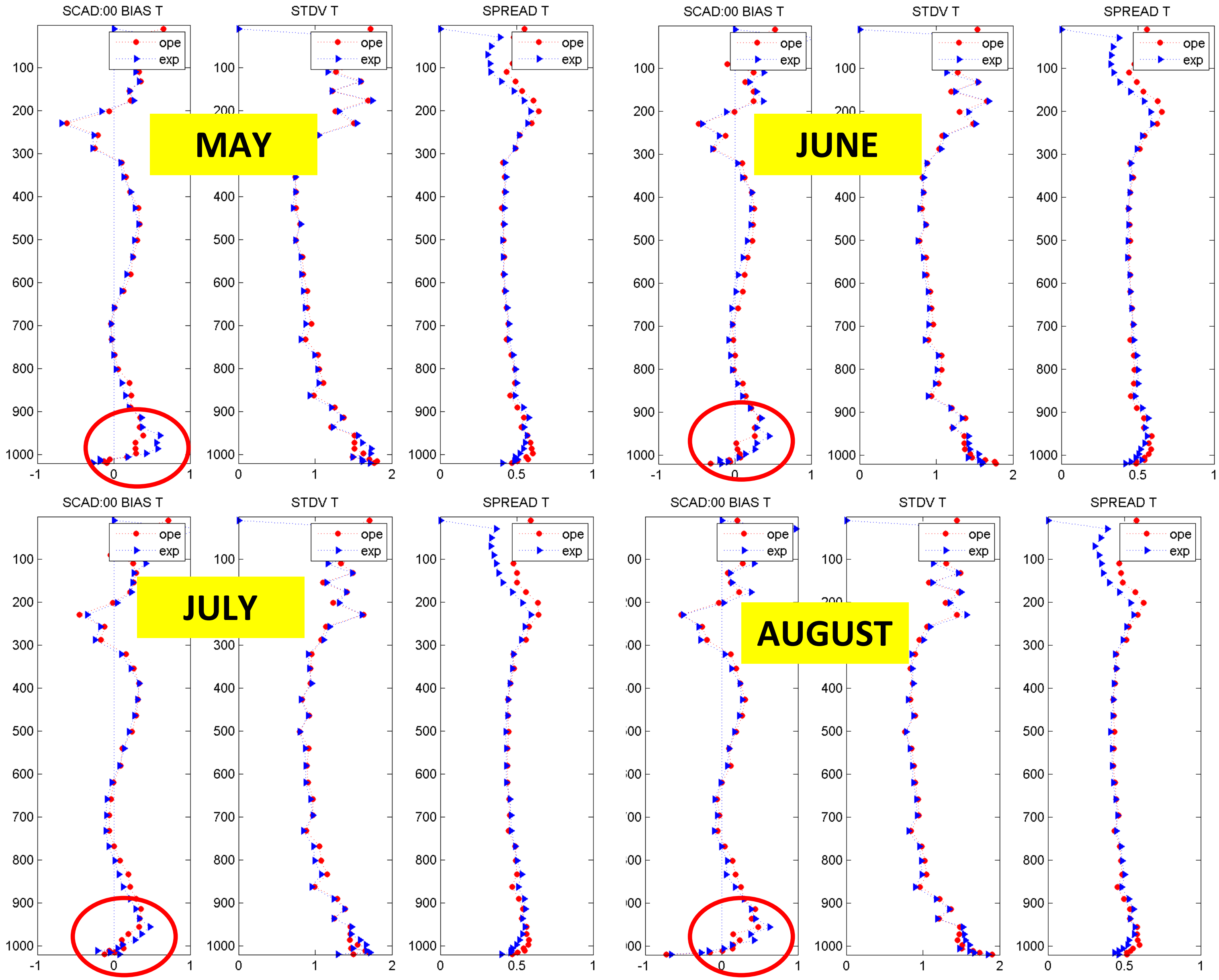




The strong cooling thermal inversion is not well represented in COSMO using the prognostic TKE (ope) turbulence scheme. COSMO with the diagnostic TKE (old) scheme makes a slightly better job.

HRM vs COSMO LETKF: 00 UTC

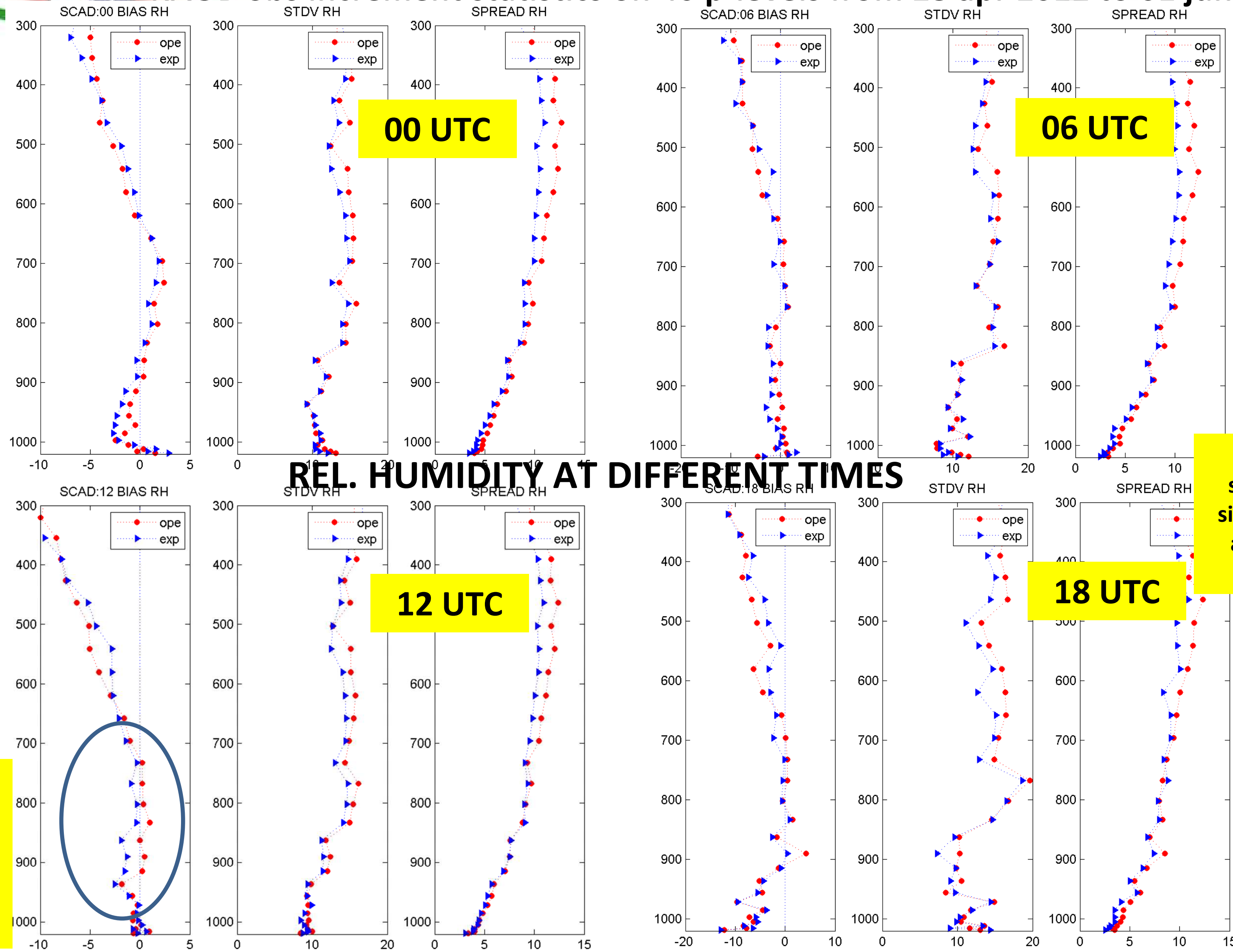
TEMPERATURE *MONTHLY STATISTICS*



The problem disappears in the summer months.

HRM vs COSMO LETKF

RAOB obs increment statistics on 40 p-levels from 28 apr 2012 to 01 jun 2012

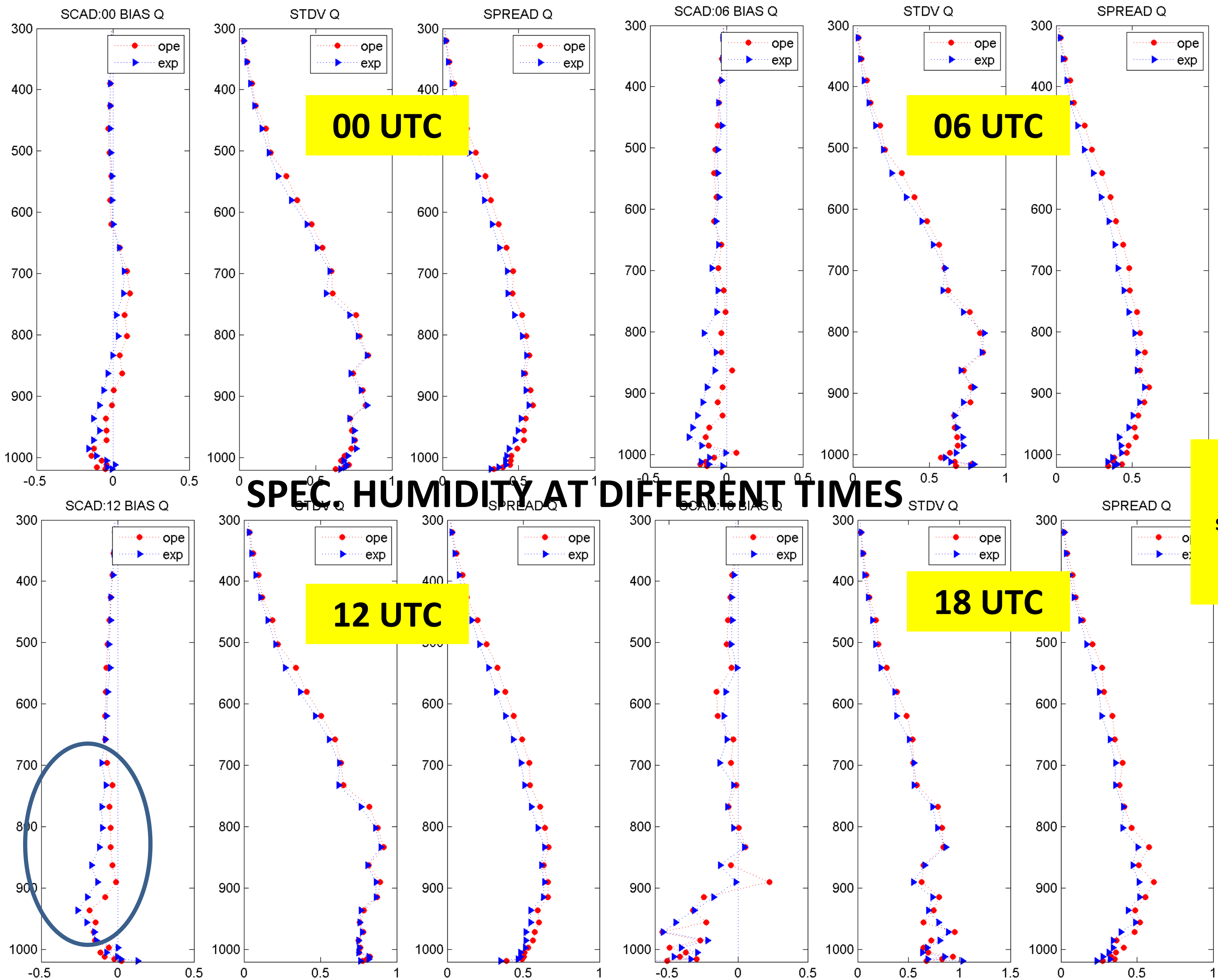


Small sample size at 06 and 18 UTC

Smaller RH (moister) bias in COSMO LETKF

HRM vs COSMO LETKF

RAOB obs increment statistics on 40 p-levels from 28 apr 2012 to 01 jun 2012



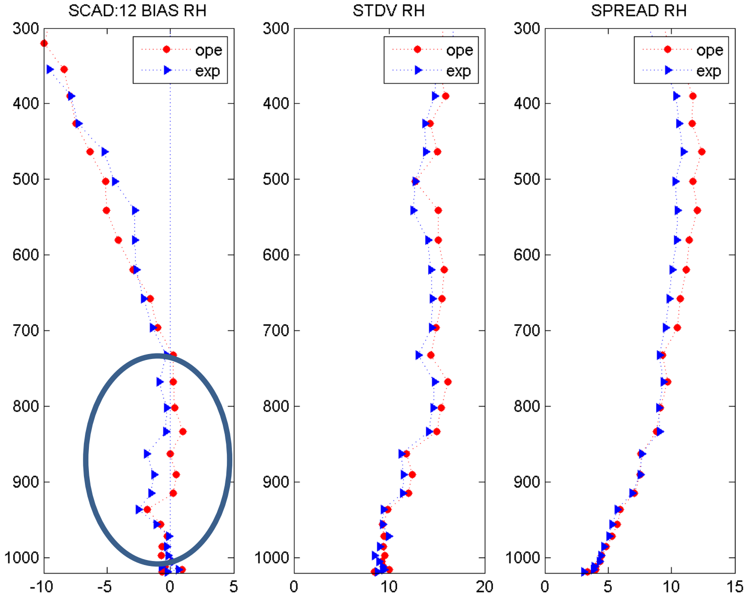
Small sample size at 06 and 18 UTC

Smaller qv obs incr. (moister) bias in COSMO LETKF

HRM vs COSMO LETKF: 12 UTC

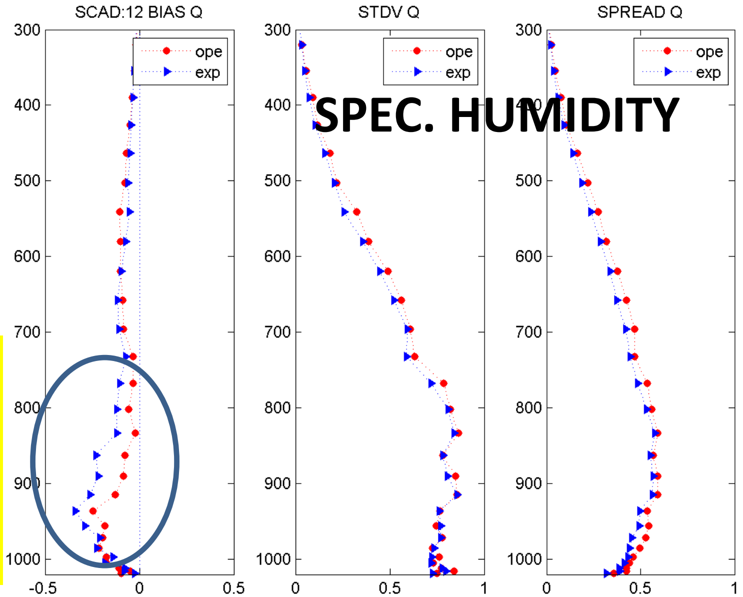
RAOB obs increment statistics on 40 p-levels from 28 apr 2012 to 01 jun 2012 at 12UTC

REL. HUMIDITY



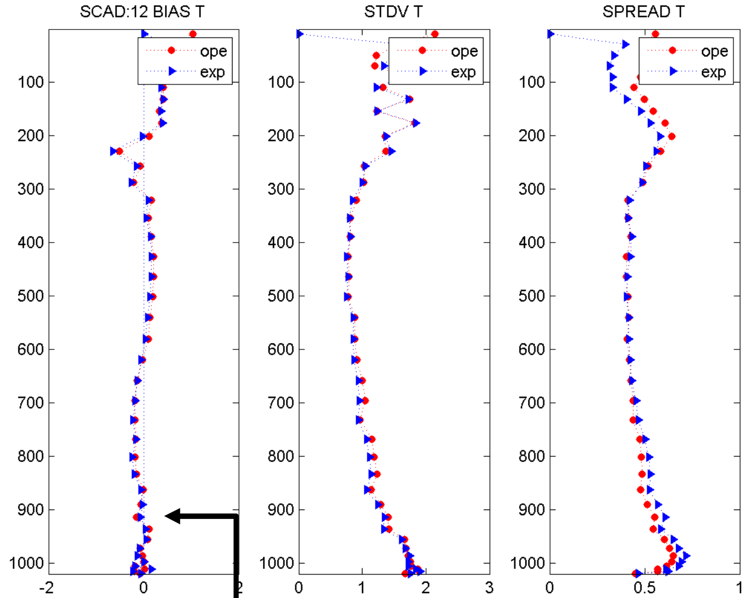
Smaller RH obs incr. (moister) bias in COSMO LETKF

SPEC. HUMIDITY



Smaller qv obs incr. (moister) bias in COSMO LETKF

TEMPERATURE

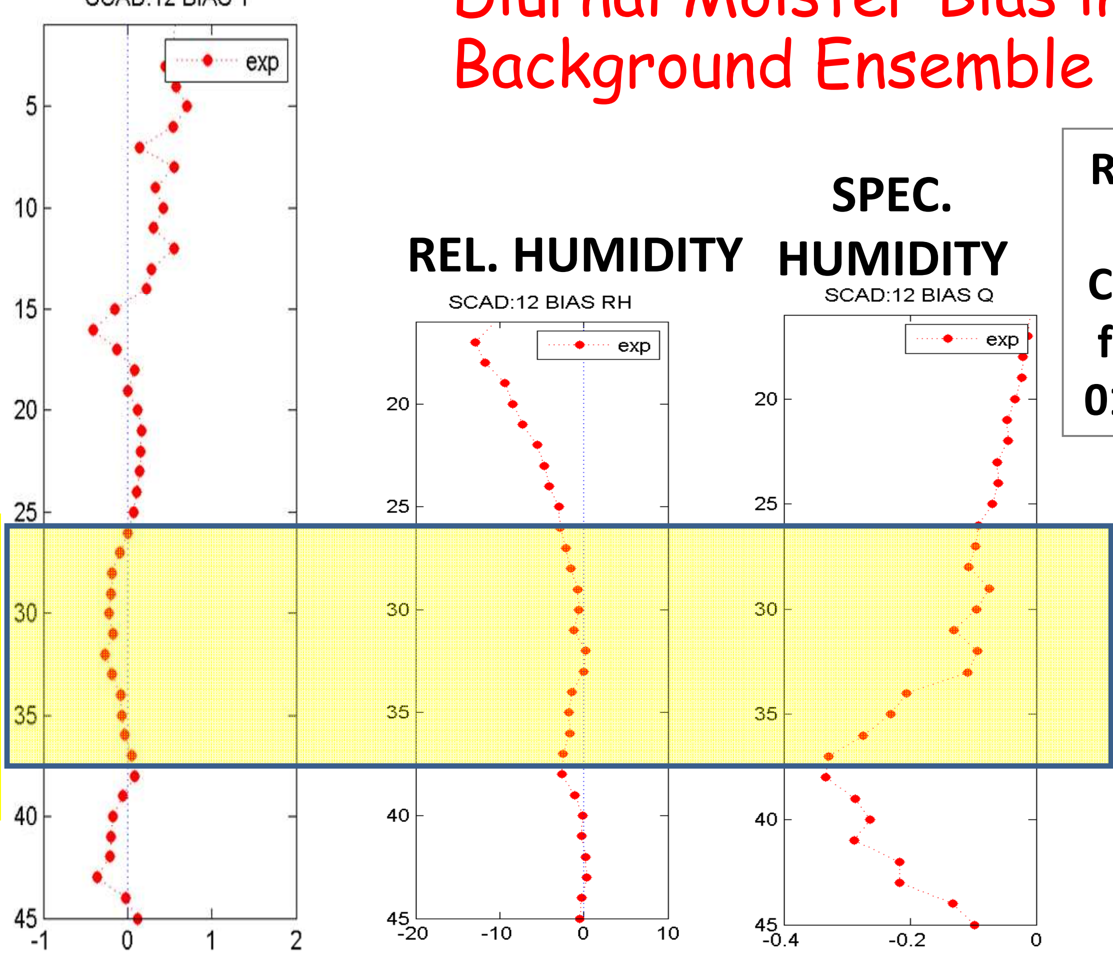


NO TEMPERATURE OBS INCR. BIAS

HRM vs COSMO LETKF: 12 UTC

Diurnal Moister Bias in COSMO Background Ensemble Mean

TEMPERATURE **REL. HUMIDITY** **SPEC. HUMIDITY**



SMALLER HUMIDITY OBS INCREMENT (MOISTER) BIAS LAYER

RAOB obs increment statistics on 45 COSMO model levels from 28 apr 2012 to 01 jun 2012 at 00UTC

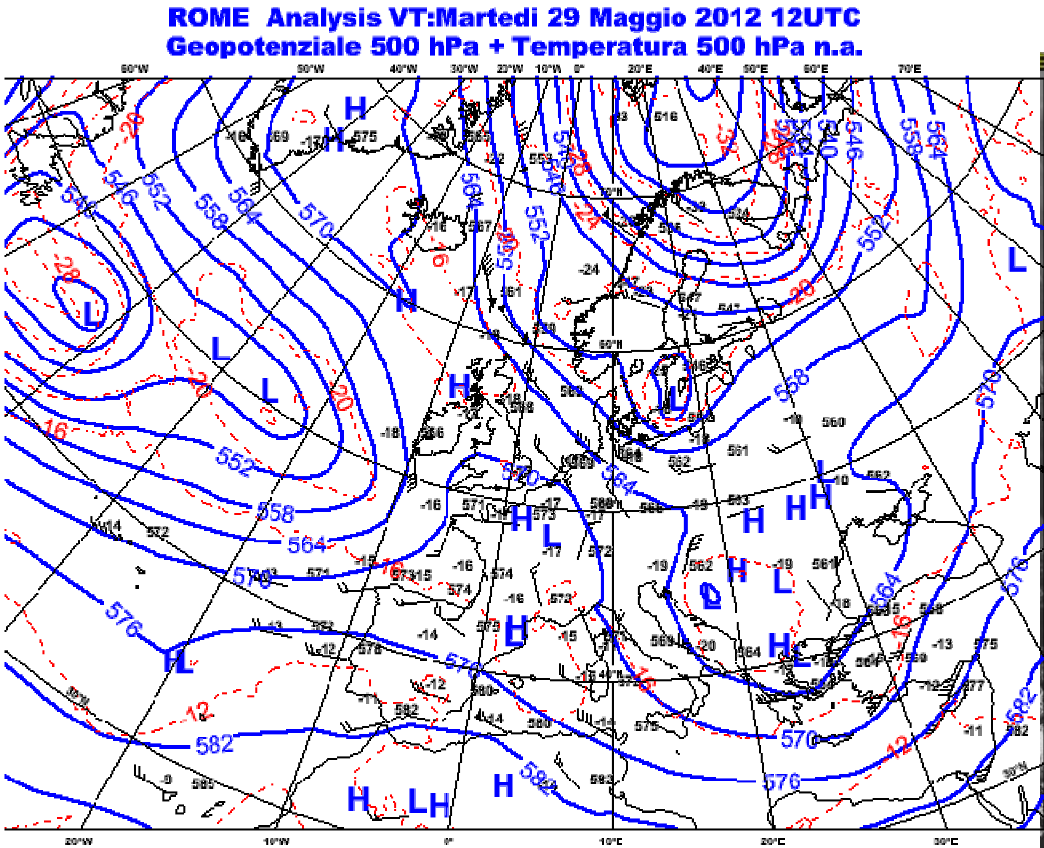
Looking at “daily” statistics a two days period has been selected

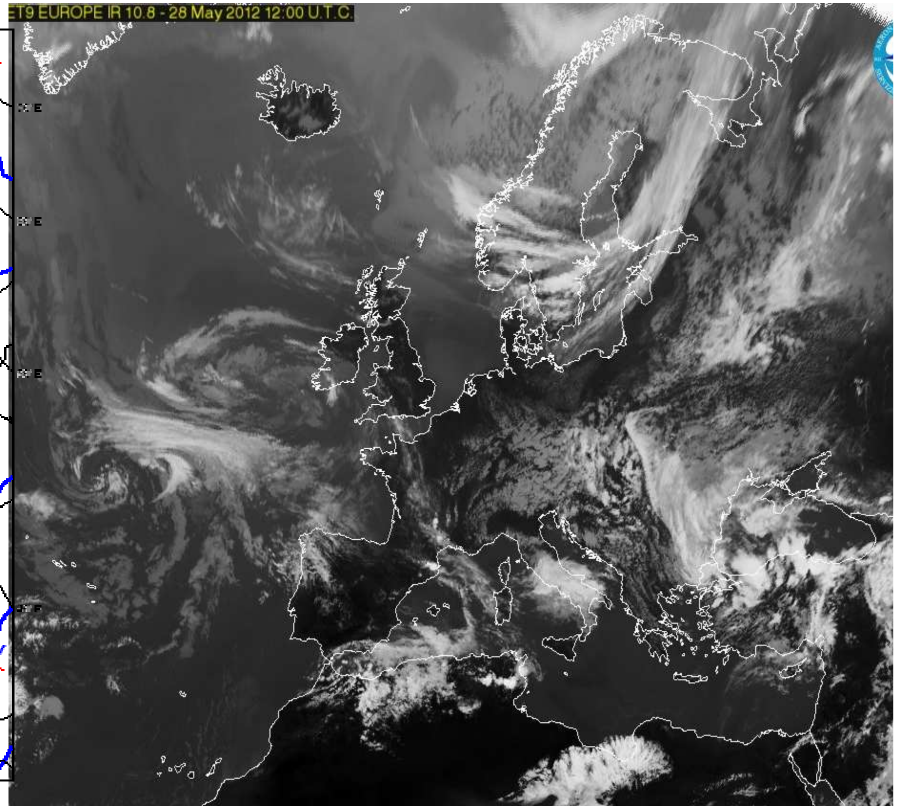
28-29 may 2012 → CASE STUDY

COSMO LETKF: 12 UTC

28-29 May 2012 CASE STUDY

Weak cyclonic circulation over SE Europe → Unstable condition





COSMO LETKF: 12 UTC

Sensitivity to the turbulence scheme

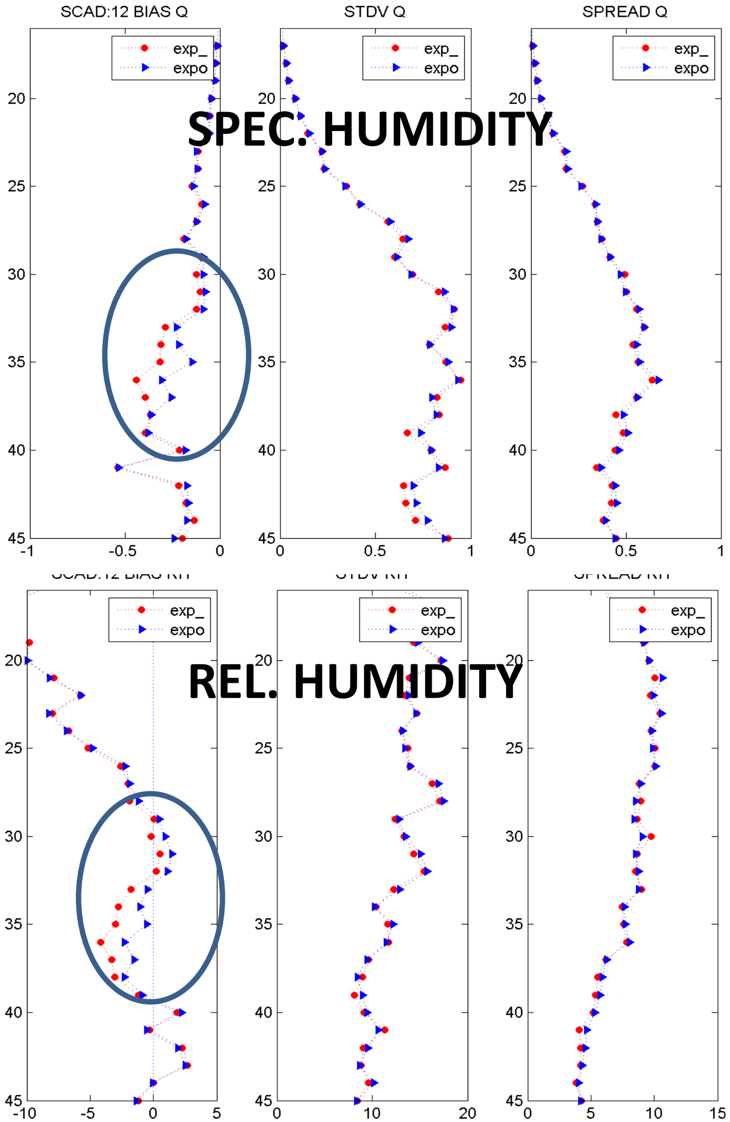
28-29 May 2012 CASE STUDY

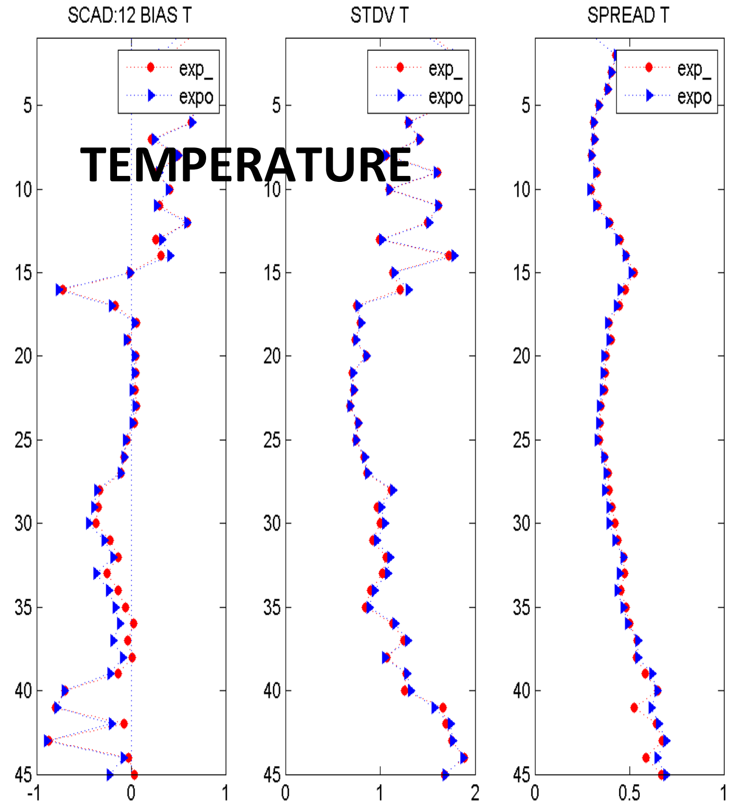
RAOB obs increment statistics on 45 COSMO model levels at 12 UTC

OLD (DIAG. TKE) VS OPE (PROG. TKE) TURBULENCE SCHEME

Smaller qv obs incr. (moister) bias using the oper. turbulence scheme

Smaller RH obs incr. (moister) bias using the oper. turbulence scheme





COSMO LETKF: 12 UTC

Sensitivity to the convection scheme

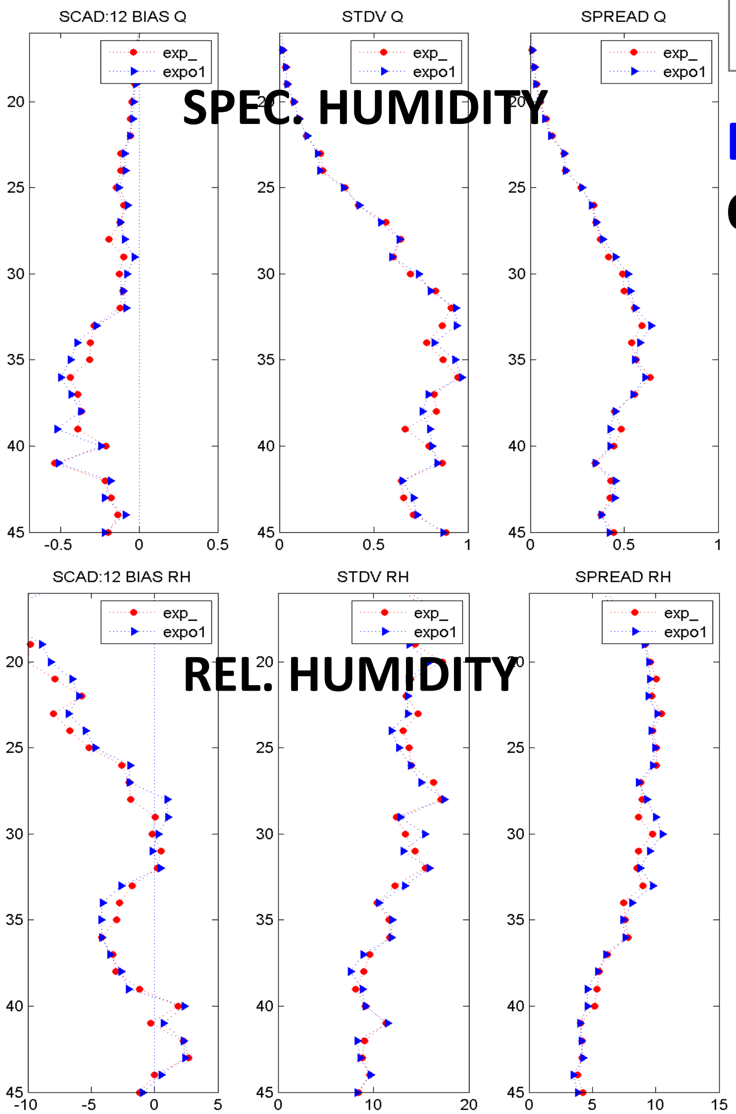
28-29 May 2012 CASE STUDY

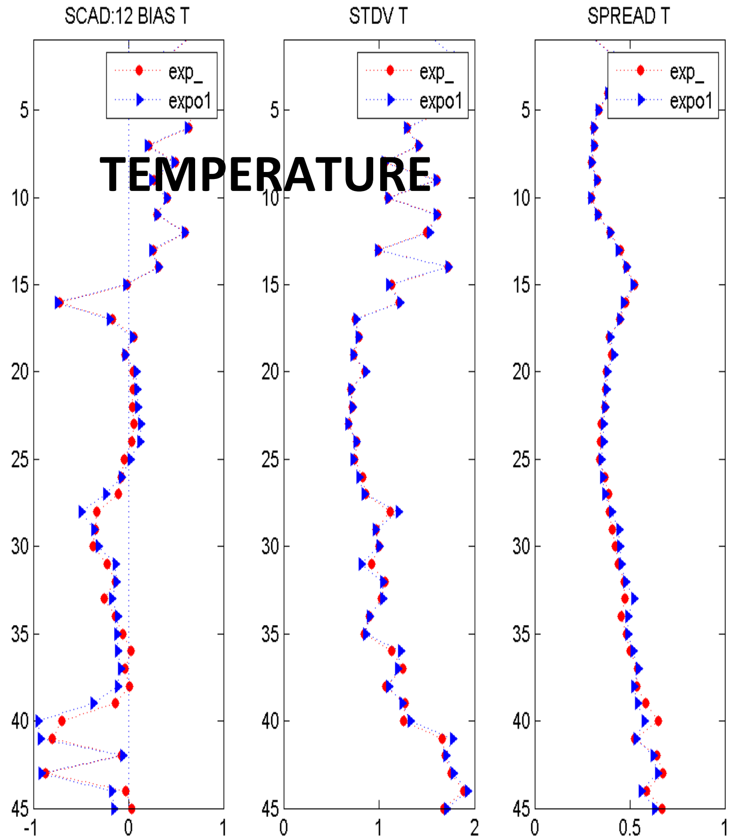
RAOB obs increment statistics on 45 COSMO model levels at 12 UTC

EXP (KAIN-FRITSCH) VS OPE (TIEDTKE) CONVECTION SCHEME

Smaller qv obs incr. (moister) bias using the exp KF convection scheme.

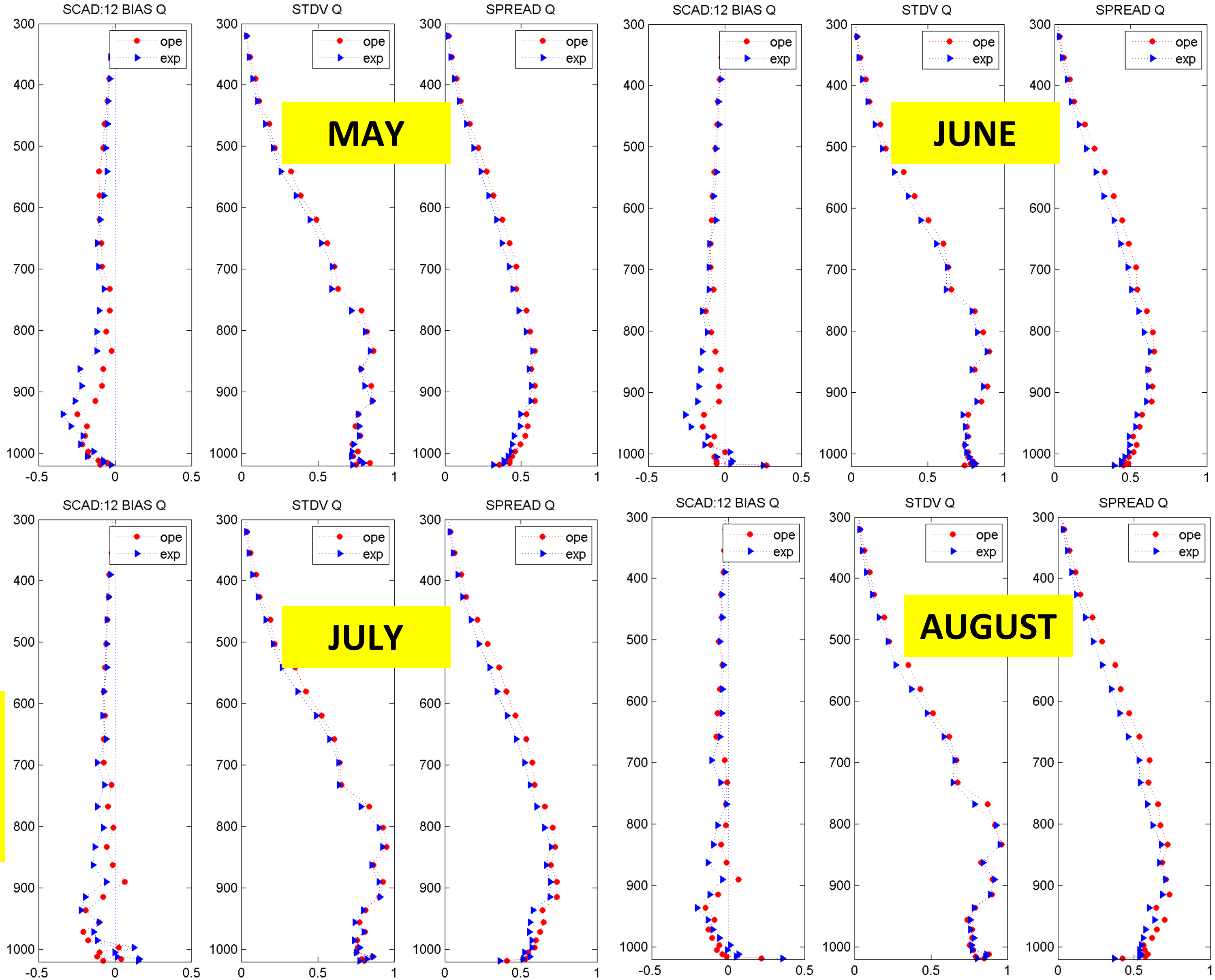
The use of Kain-Fritsch scheme deteriorates the BG ensemble mean





HRM vs COSMO LETKF: 12 UTC

SPEC. HUMIDITY *MONTHLY STATISTICS*



The problem is present in the period under examination.

Summary of Results

From observation increment statistics :

Nocturnal larger negative temperature bias near the surface in COSMO-LETKF background ensemble mean

- COSMO-LETKF with TKE prognostic turbulence scheme tends to produce less intense cooling thermal inversion than the HRM-LETKF (even if it does not well reproduce the observed situation).

Is the prognostic TKE scheme too diffusive ?

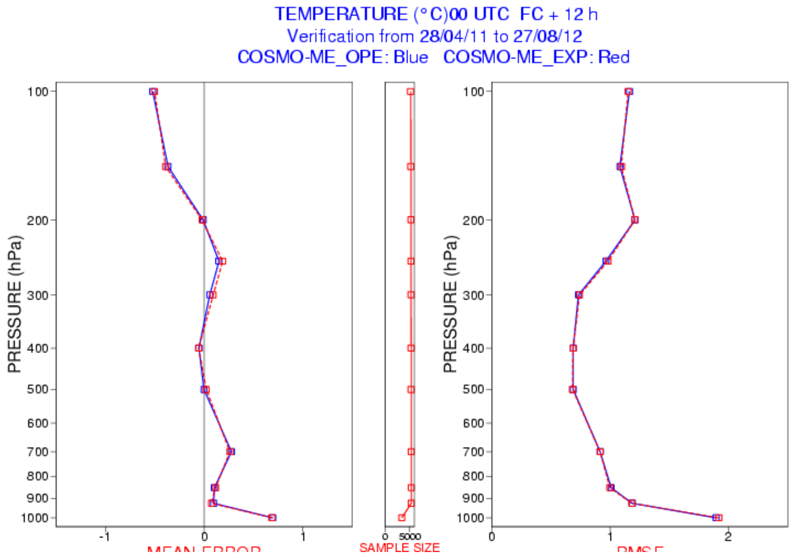
- The use of the old turbulence scheme slightly improves the performance of COSMO-LETKF background ensemble mean near the surface

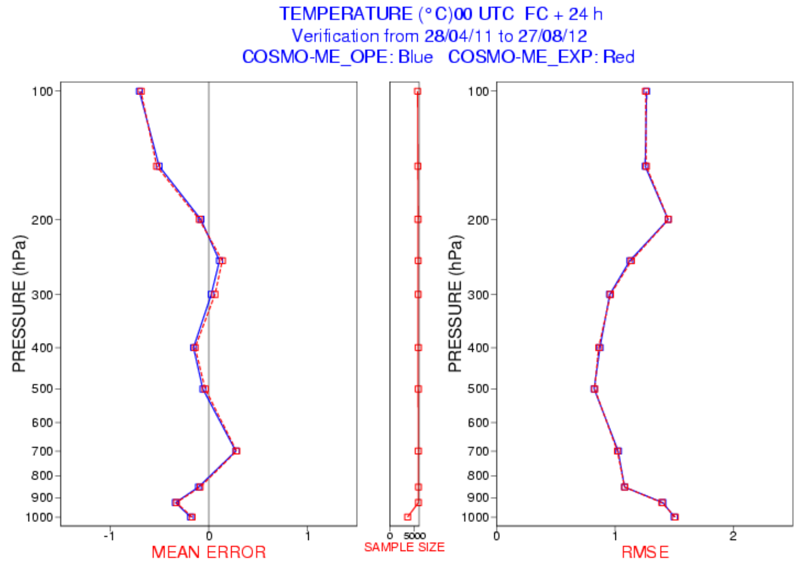
Diurnal larger positive humidity bias in the middle-lower troposphere using COSMO model

- COSMO-LETKF with TKE prognostic turbulence scheme tends to moisten the troposphere more than the HRM-LETKF.
- The use of the old turbulence scheme seems to have a very small positive impact
- The use of the Kain-Fritch convection scheme does not improve the performance of COSMO-LETKF background ensemble mean

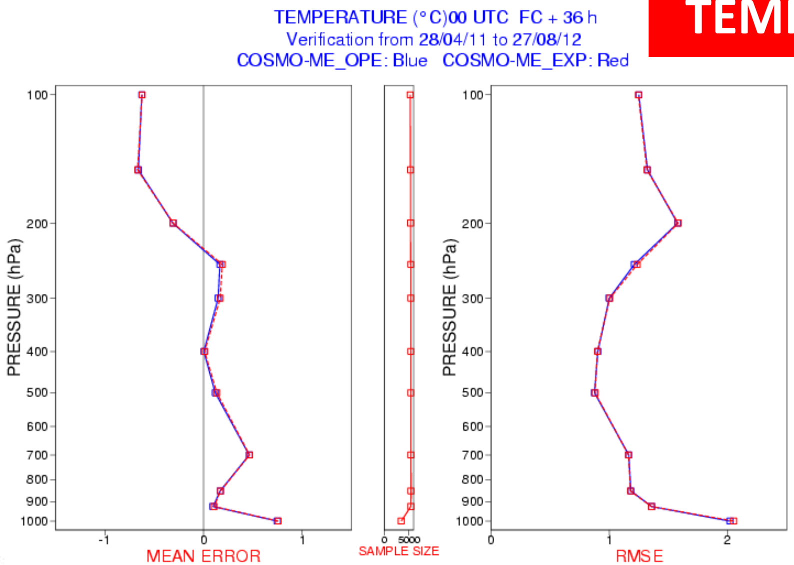
HRM vs COSMO LETKF: 00 UTC

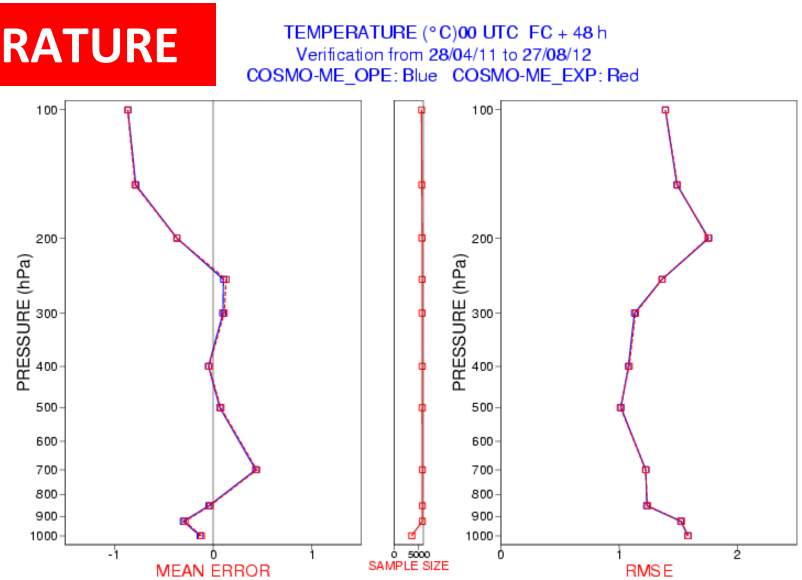
COSMO-ME OBJECTIVE VERIFICATION AGAINST RAOB





TEMPERATURE

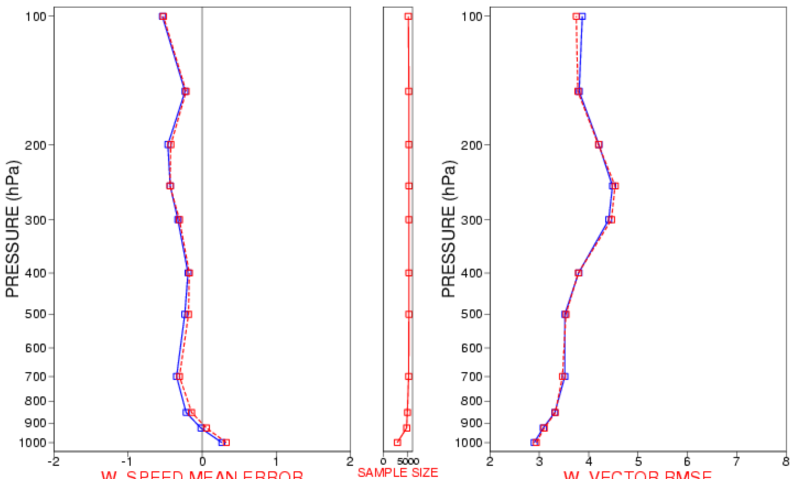




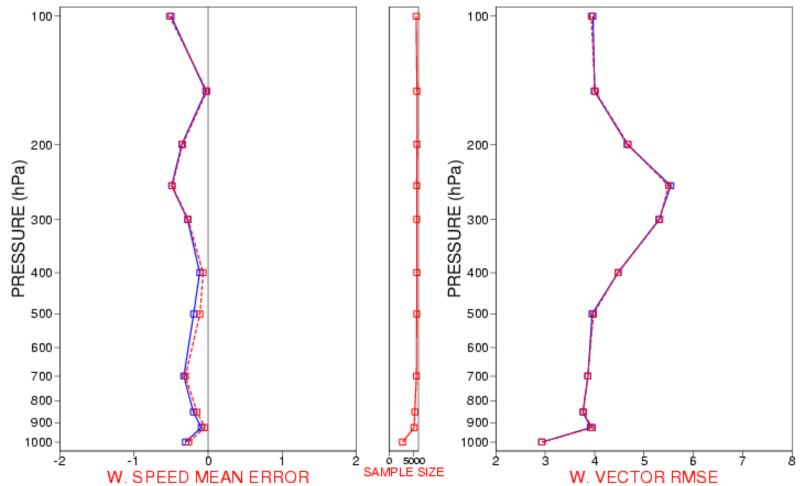
HRM vs COSMO LETKF: 00 UTC

COSMO-ME OBJECTIVE VERIFICATION AGAINST RAOB

WIND (m/s) 00 UTC FC + 12 h
Verification from 28/04/11 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red

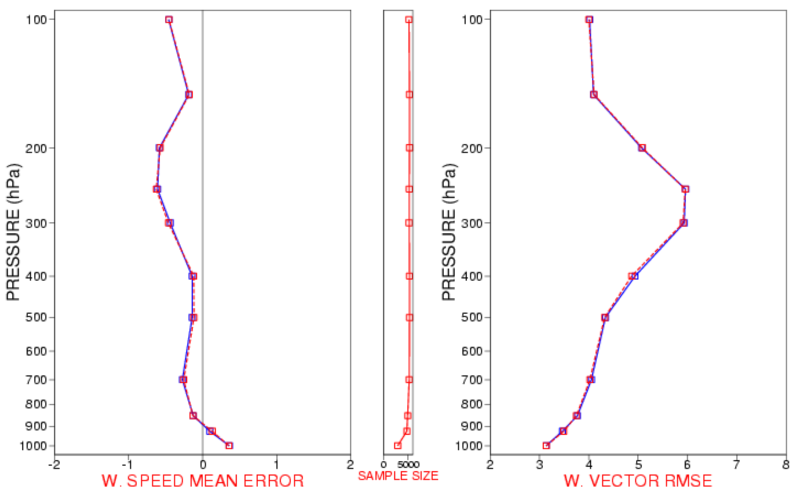


WIND (m/s) 00 UTC FC + 24 h
Verification from 28/04/11 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red

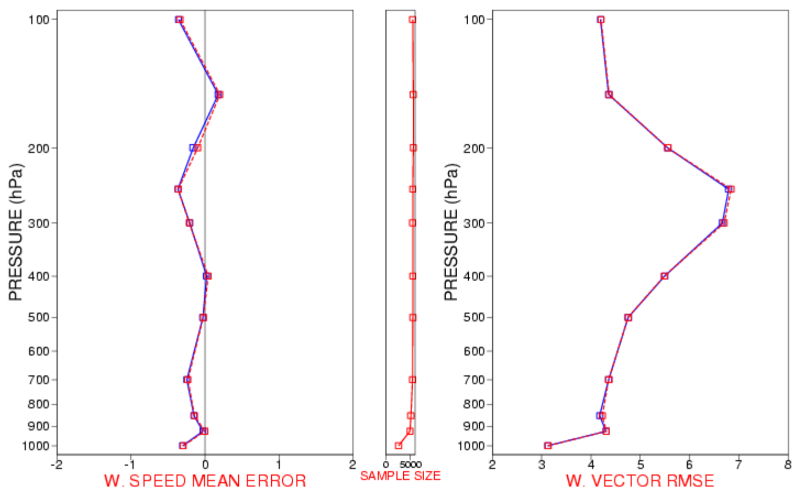


WIND

WIND (m/s) 00 UTC FC + 36 h
Verification from 28/04/11 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red



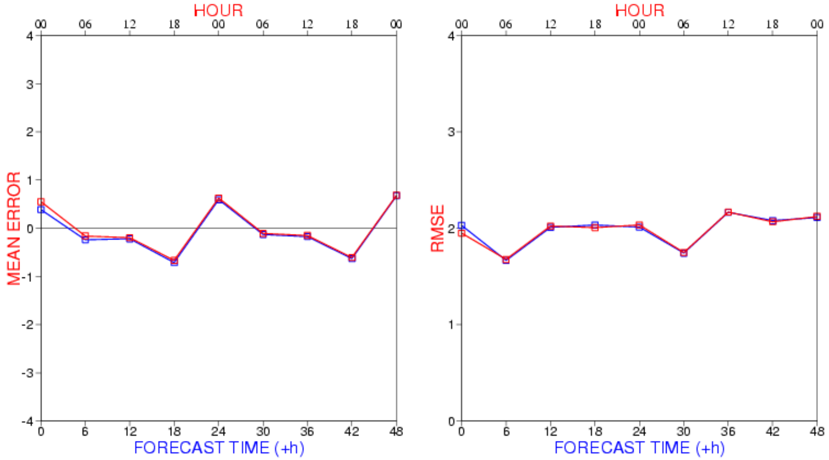
WIND (m/s) 00 UTC FC + 48 h
Verification from 28/04/11 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red



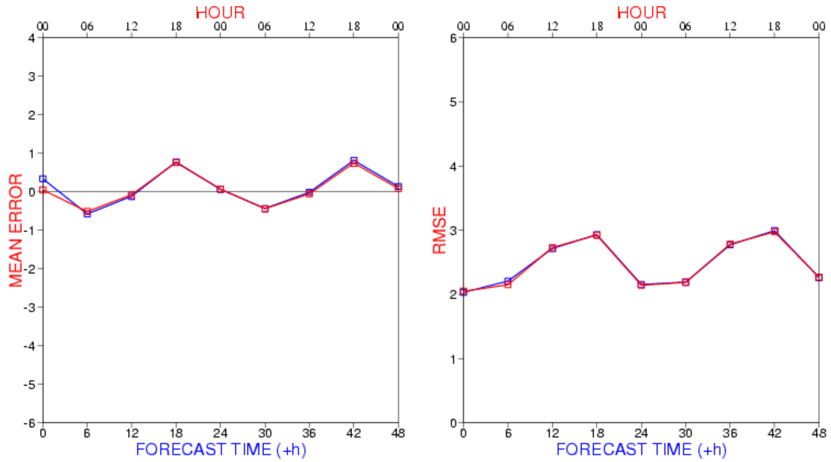
HRM vs COSMO LETKF: 00 UTC

COSMO-ME OBJECTIVE VERIFICATION AGAINST SYNOP

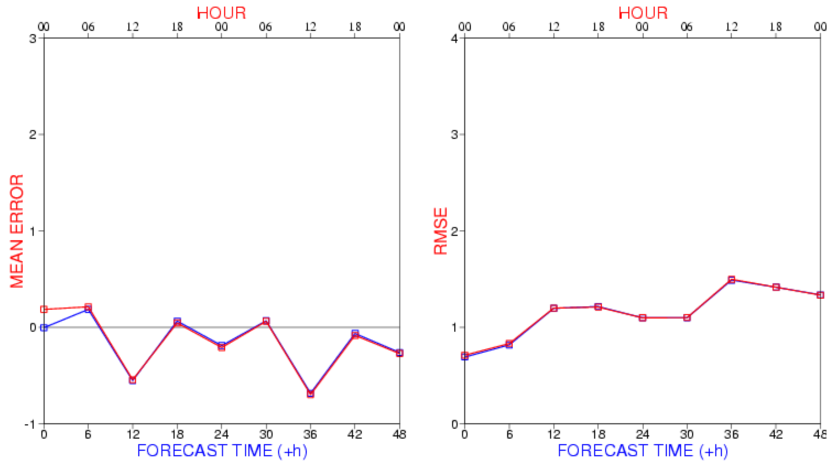
TEMPERATURE (° C) - 00 UTC RUN
Verification from 28/04/12 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red



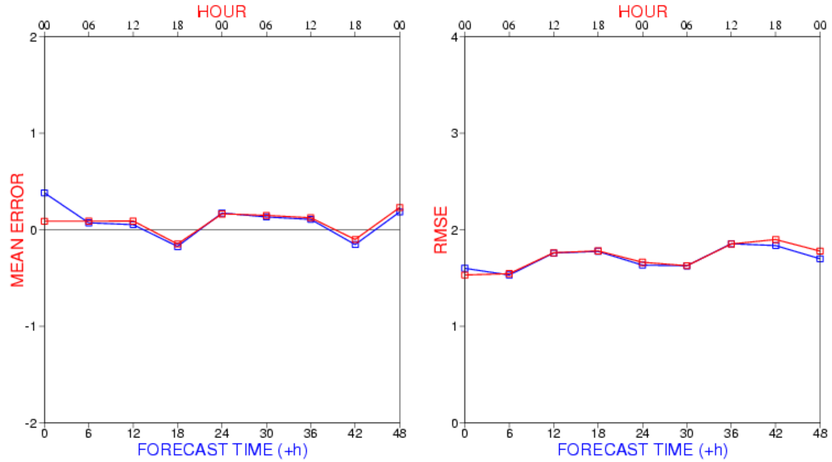
DEW POINT(° C) - 00 UTC RUN
Verification from 28/04/12 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red



MSL PRESSURE (hPa) - 00 UTC RUN
Verification from 28/04/12 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red

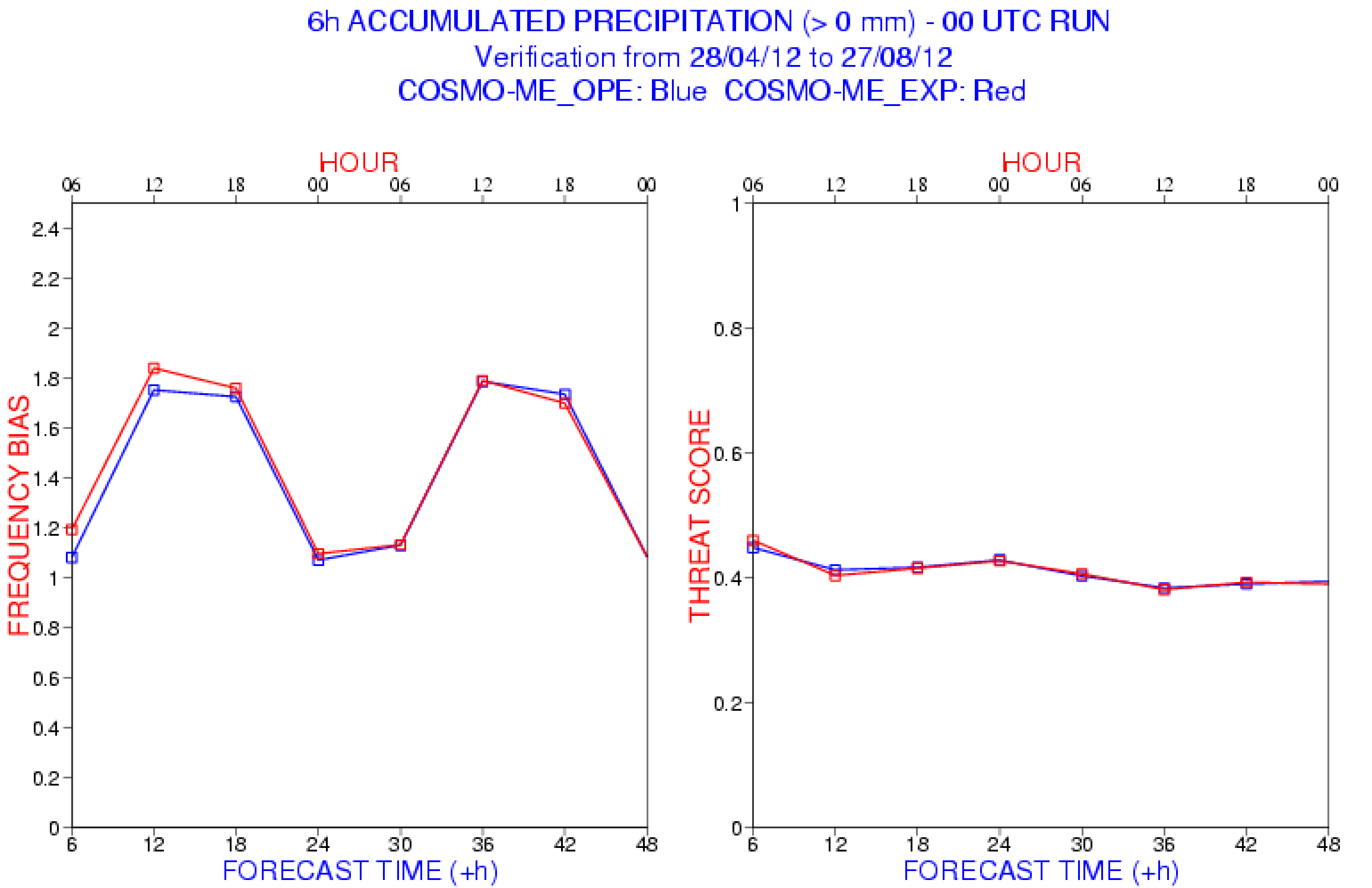


WIND SPEED (m/s) - 00 UTC RUN
Verification from 28/04/12 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red



HRM vs COSMO LETKF: 00 UTC

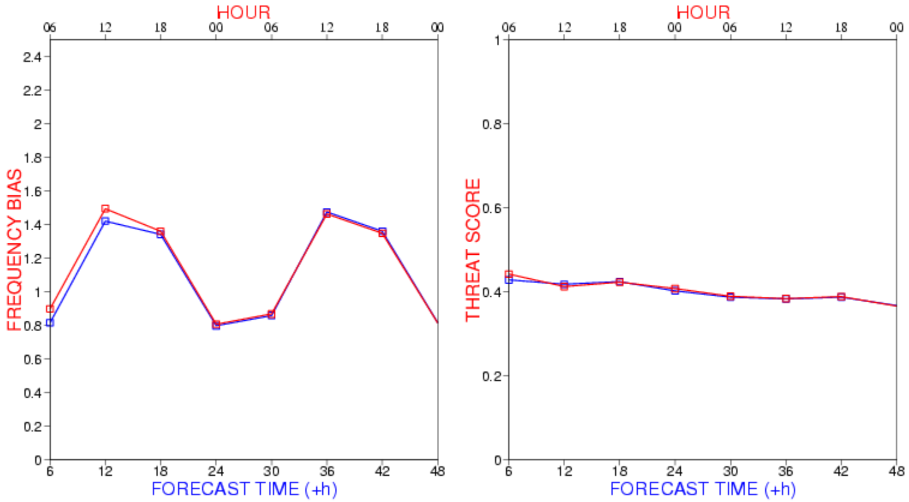
6h ACCUMULATED PRECIPITATION



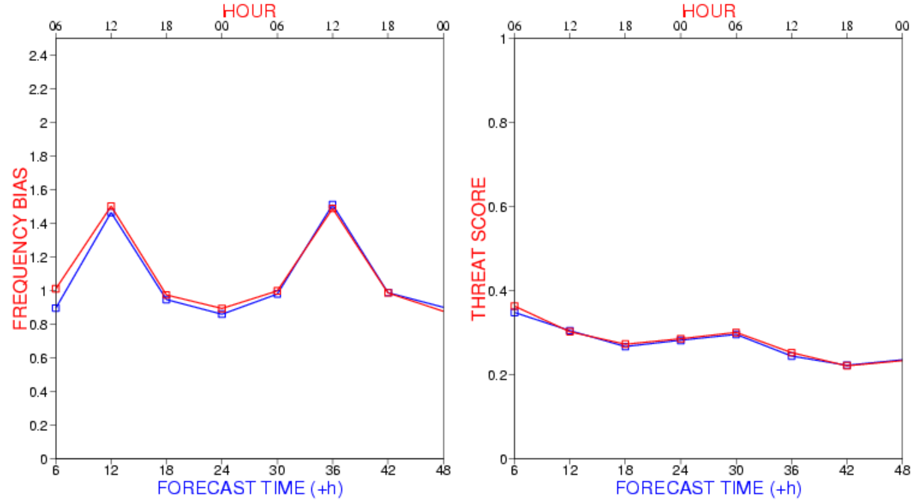
HRM vs COSMO LETKF: 00 UTC

6h ACCUMULATED PRECIPITATION

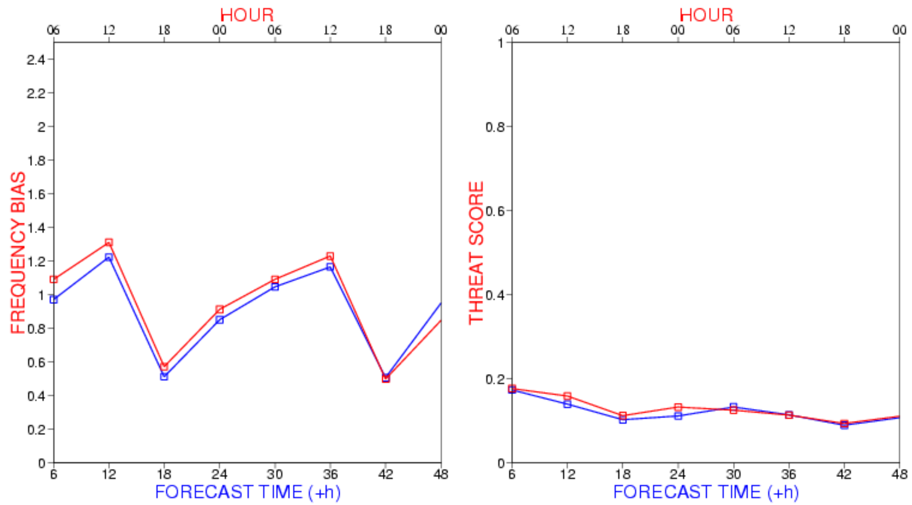
6h ACCUMULATED PRECIPITATION (> 0.1 mm) - 00 UTC RUN
Verification from 28/04/12 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red



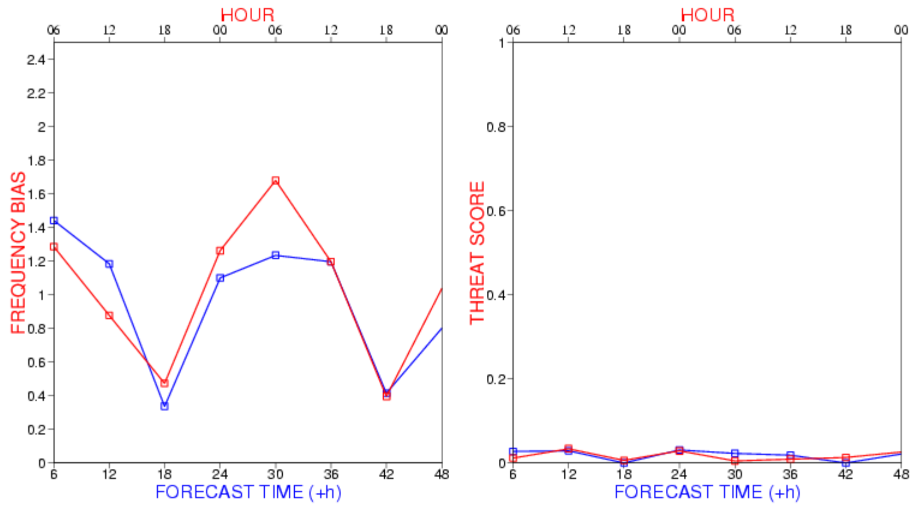
6h ACCUMULATED PRECIPITATION (> 2 mm) - 00 UTC RUN
Verification from 28/04/12 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red



6h ACCUMULATED PRECIPITATION (> 10 mm) - 00 UTC RUN
Verification from 28/04/12 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red



6h ACCUMULATED PRECIPITATION (> 30 mm) - 00 UTC RUN
Verification from 28/04/12 to 27/08/12
COSMO-ME_OPE: Blue COSMO-ME_EXP: Red



Conclusions

- CNMCA has planned to substitute HRM with COSMO model in its ensemble data assimilation (LETKF) system, which is used operationally to initialize the deterministic COSMO-ME model
- COSMO-LETKF and HRM-LETKF performances were compared for spring-summer 2012
- Observation increment statistics shows two well-known deficiencies. COSMO model is too humid and the prognostic TKE turbulence scheme is not able to reproduce correctly the strong cooling inversion in spring.
- Objective verification of COSMO-ME forecasts from both LETKF systems shows no significant differences, except for a very slight precipitation over-estimation using COSMO-LETKF

Future Developments

- Comparison of COSMO and HRM-LETKF in fall-winter period
- Assimilation of AMSU-B/MHS and IASI retrievals
- Use of KENDA and contribution to its improvement

- Tests with shorter assimilation window
- Further tuning of model error representation (tuning of cov. localization, self-evolved additive noise, bias correction, etc.)
- Implement a Short-Range EPS based on LETKF

Thanks for your attention!