# Meteorological experience from the Olympic Games of Torino 2006

ARPA PIEMONTE

12th COSMO General Meeting

Moscow, 6-10 September 2010

# Summary

- Multimodel general Theory
- Models & Variables
- Multimodel calculation: case of precipitation
- Recommendations
- Sample of results
- Comments
- Other PPT used in ARPA Piemonte (now)
- References

# Multimodel general Theory

As suggested by the name, the Multimodel SuperEnsemble method requires several model outputs, which are weighted with an adequate set of weights calculated during the so-called training period.

The simple Ensemble method with bias-corrected or biased data respectively, is given by

$$S = \overline{O} + \frac{1}{N}\sum_{i=1}^{N}\left(F_i - \overline{F_i}\right) \quad (1) \qquad \text{or} \qquad S = \overline{O} + \frac{1}{N}\sum_{i=1}^{N}\left(F_i - \overline{O}\right) \quad (2)$$

The conventional SuperEnsemble forecast (Krishnamurti et. al., 2000) constructed with bias-corrected data is given by

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number of models (N)

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$i^{th}$ model forecast

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mean forecast

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observation mean

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Multim. weights

The calculation of the parameters $a_i$ is given by the minimisation of the mean square deviation

$$G = \sum_{k=1}^{T} \left(S_k - O_k\right)^2$$

by derivation $\left( \frac{\partial G}{\partial a_i} = 0 \right)$ we obtain a set of $N$ equations, where $N$ is the number of models involved:

$$\begin{pmatrix} \sum_{k=1}^{T} \left(F_{1_k} - \overline{F_1}\right)^2 & \sum_{k=1}^{T} \left(F_{1_k} - \overline{F_1}\right)\left(F_{2_k} - \overline{F_2}\right) & \cdots & \sum_{k=1}^{T} \left(F_{1_k} - \overline{F_1}\right)\left(F_{N_k} - \overline{F_N}\right) \\ \sum_{k=1}^{T} \left(F_{2_k} - \overline{F_2}\right)\left(F_{1_k} - \overline{F_1}\right) & \sum_{k=1}^{T} \left(F_{2_k} - \overline{F_2}\right)^2 & & \vdots \\ \vdots & & \ddots & \vdots \\ \sum_{k=1}^{T} \left(F_{N_k} - \overline{F_N}\right)\left(F_{1_k} - \overline{F_1}\right) & \cdots & \cdots & \sum_{k=1}^{T} \left(F_{N_k} - \overline{F_N}\right)^2 \end{pmatrix} \bullet \begin{pmatrix} a_1 \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ a_N \end{pmatrix} = \begin{pmatrix} \sum_{k=1}^{T} \left(F_{1_k} - \overline{F_1}\right)\left(O_k - \overline{O}\right) \\ \vdots \\ \vdots \\ \sum_{k=1}^{T} \left(F_{N_k} - \overline{F_N}\right)\left(O_k - \overline{O}\right) \end{pmatrix}$$

We then solve these equations using Gauss-Jordan method.

# *Models & Variables*

## Olympic Games

- COSMO-I7 (00UTC + 12UTC)
- COSMO-7 (00UTC + 12UTC)
- COSMO-EU (00UTC + 12UTC)
- ECMWF-IFS (00UTC + 12UTC)

## Operational Use

- COSMO-I7 (00UTC + 12UTC)
- COSMO-ME (00UTC + 12UTC)
- ECMWF-IFS (00UTC + 12UTC)

**T2m, Rh2m, W10m, Precipitation**

# Multimodel calculation: case of precipitation

| model 1 | model 2 | model 3 | model 4 | model 5 | model 6 | model 7 | model 8 |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |

Only 2 models out of 8 give some precipitation for the given point and forecast time. Probably the best forecast should be no precipitation.

SuperEnsemble ever gives a result!

$$S = \overline{O} + \sum_{i=1}^{N} a_i \left(F_i - \overline{F_i}\right)$$

How to avoid this precipitation overestimation?

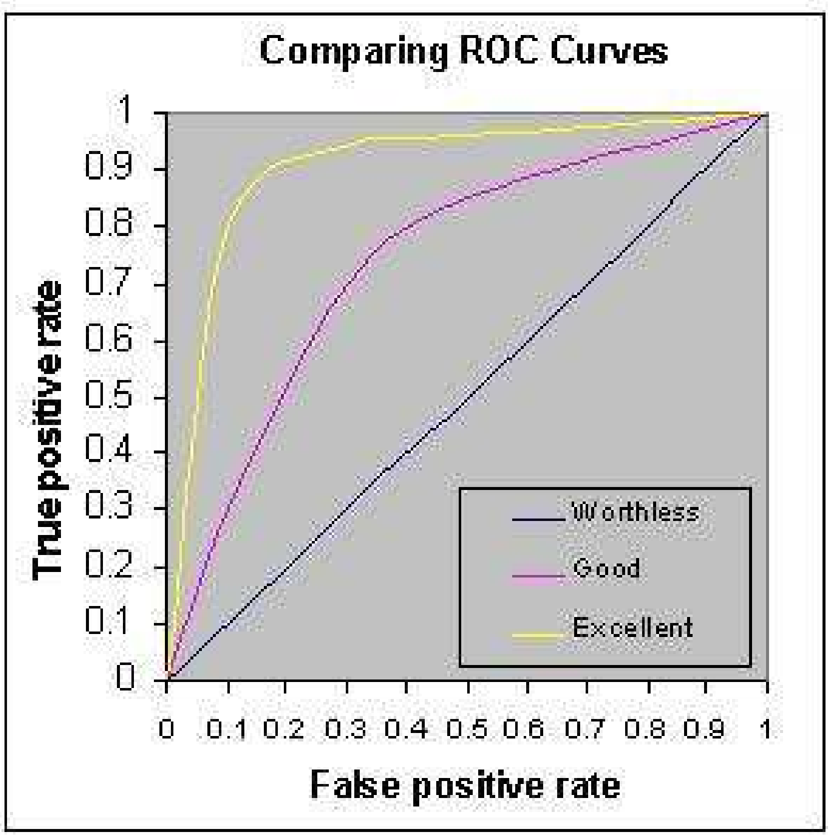
# ROC (Receiver Operating Characteristic)

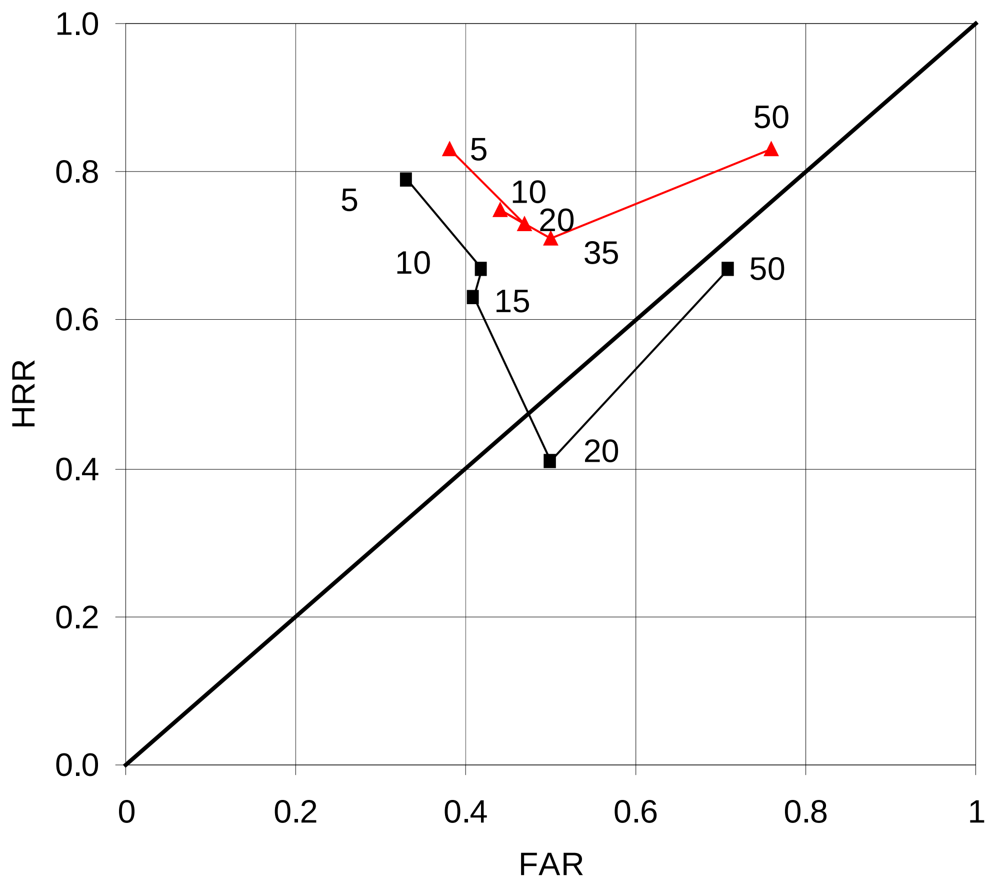
***False alarm ratio***

$$FAR = \frac{false\ alarms}{hits + false\ alarms}$$

***Probability of detection (hit rate HRR)***

$$POD = \frac{hits}{hits + misses}$$



How we calculate the global ROC of Multimodel:

| model 1 | model 2 | model 3 | model 4 | model 5 | model 6 | model 7 | model 8 |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |

For each model in the training period we calculate the HRR and FAR

$FAR_1$ $FAR_2$ $FAR_3$ $FAR_4$ $FAR_5$ $FAR_6$ $FAR_7$ $FAR_8$

$HRR_1$ $HRR_2$ $HRR_3$ $HRR_4$ $HRR_5$ $HRR_6$ $HRR_7$ $HRR_8$

Then we calculate the Multimodel FAR and HRR by combining the given values with respect to what models are forecasting now:

$$FAR_{MM} = FAR_1 \bullet (1-FAR_2) \bullet (1-FAR_3) \bullet (1-FAR_4) \bullet FAR_5 \bullet (1-FAR_6) \bullet (1-FAR_7) \bullet (1-FAR_8)$$

$$HRR_{MM} = HRR_1 \bullet (1-HRR_2) \bullet (1-HRR_3) \bullet (1-HRR_4) \bullet HRR_5 \bullet (1-HRR_6) \bullet (1-HRR_7) \bullet (1-HRR_8)$$

IF $FAR_{MM} >= HRR_{MM}$ Multimodel SuperEnsemble is put to 0

# Recommendations

Many tests have been performed in the years:

- different combination of models (LAMs alone or LAMs and ECMWF)
- different numbers of models (00UTC or/and 12UTC runs)
- different kind of training period (fixed or dynamical)
- different lengths of the training period
- comparisons among SuperEnsemble, PoorMenEnsemble and Kalman filter

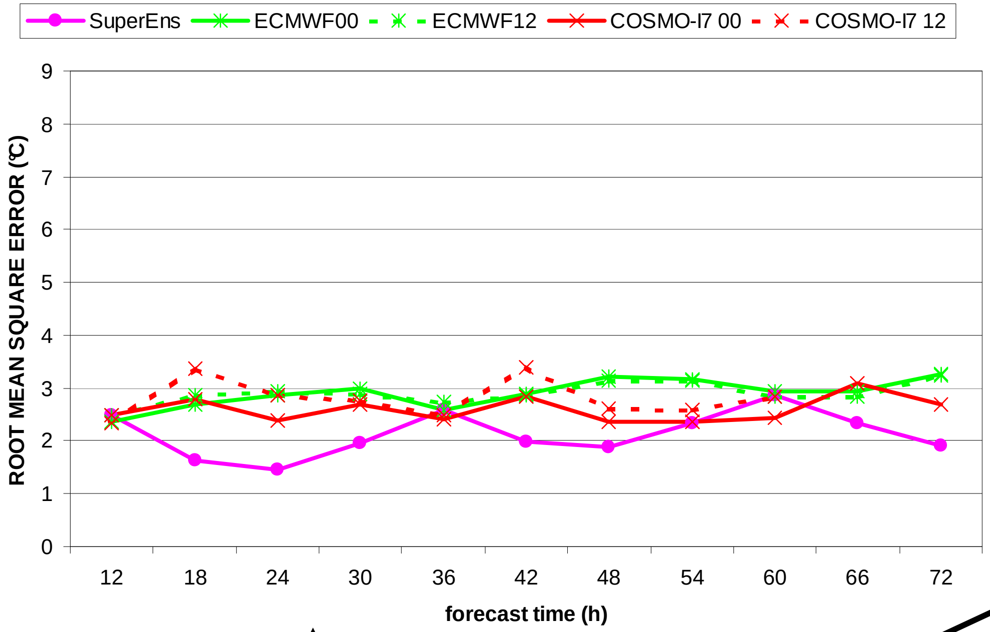
And the answers are:

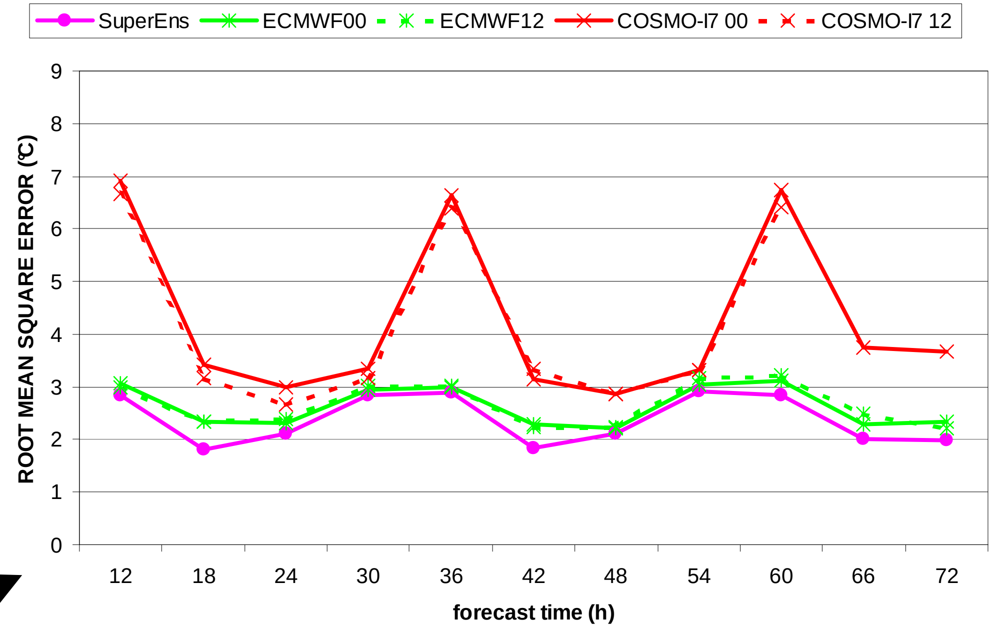
# *Recommendations*

- ECMWF model MUST be included
- there is an added value up to 6/8 models
- the dynamical training permits to take into account the seasonal variation of the model performances
- the minimum lengths (for the models and the area we use !!!) are:
  - 90 days for T2m, Rh2m and W10m
  - 180 days for precipitation
- SE works better than PME and (concerning temperature) is basically equivalent to Kalman filter applied to ECMWF model. The advantage is that the same algorithm it can be applied to other variables (precipitation)

PIEMONTE Arpa Agenzia Regionale per la Protezione Ambientale

# Sample of results

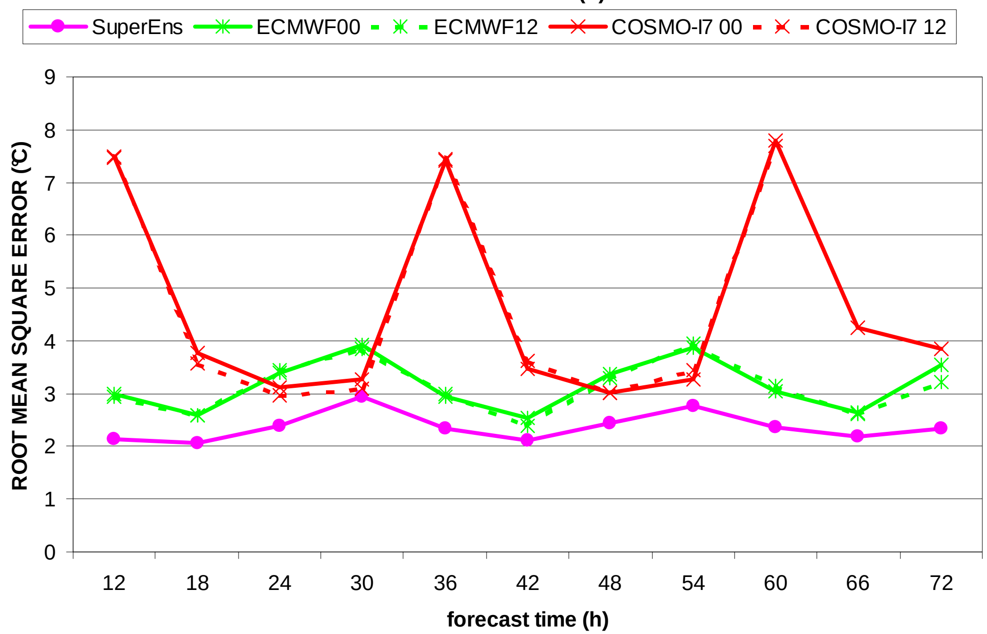



0-700 m

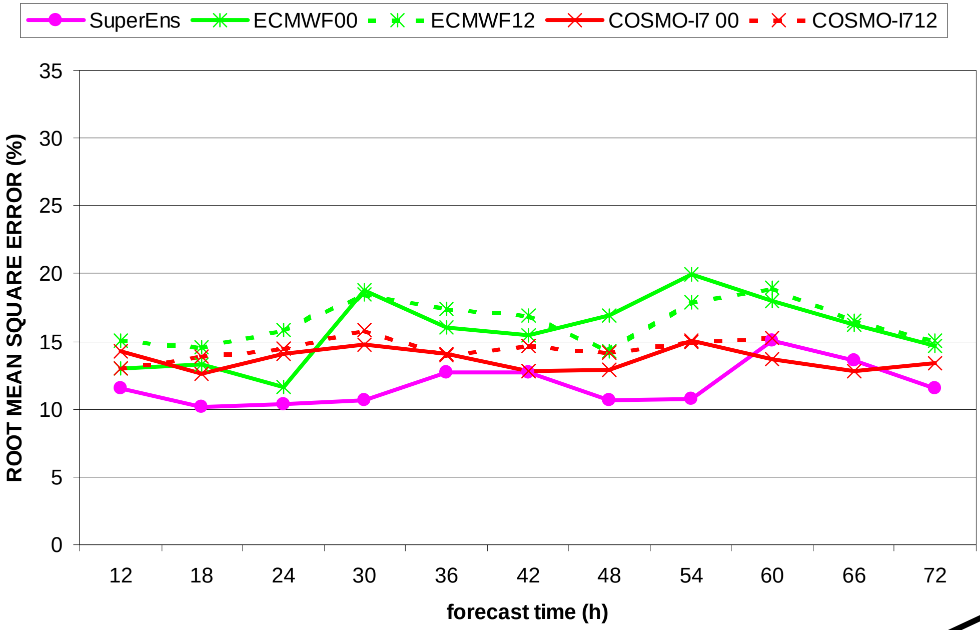
700-1500 m

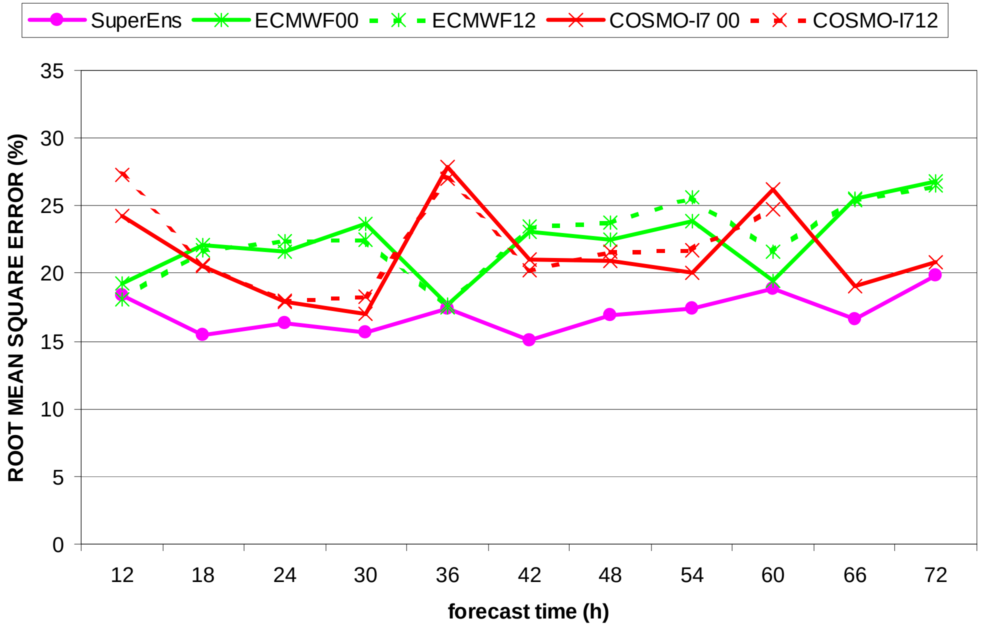
1500-3500 m




RMSE of T2m during February and March 2006 in Piemonte region

# Sample of results

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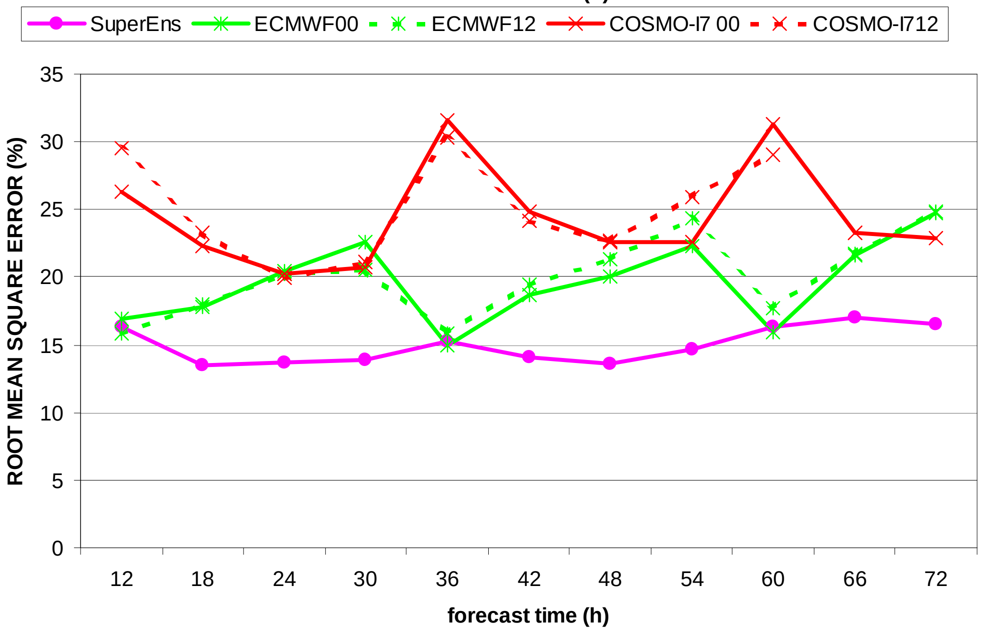
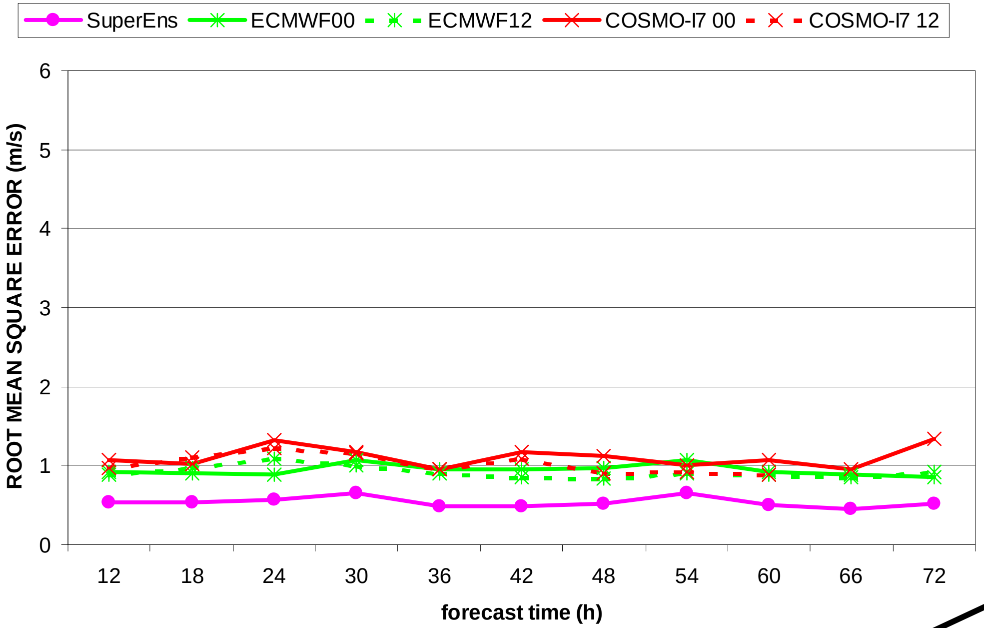
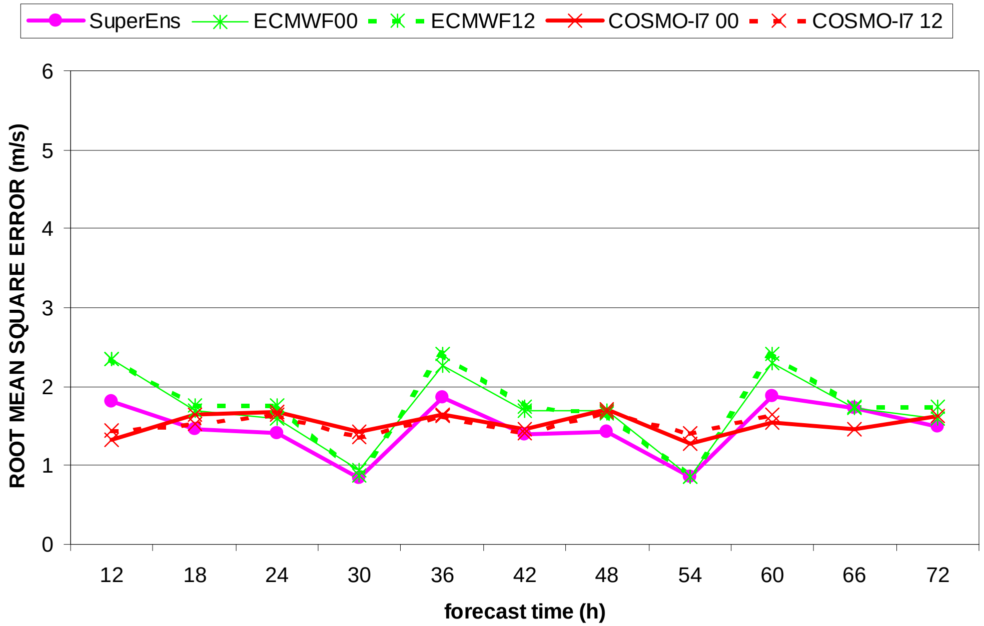
1500-3500 m




RMSE of RH2m during February and March 2006 in Piemonte region

# Sample of results

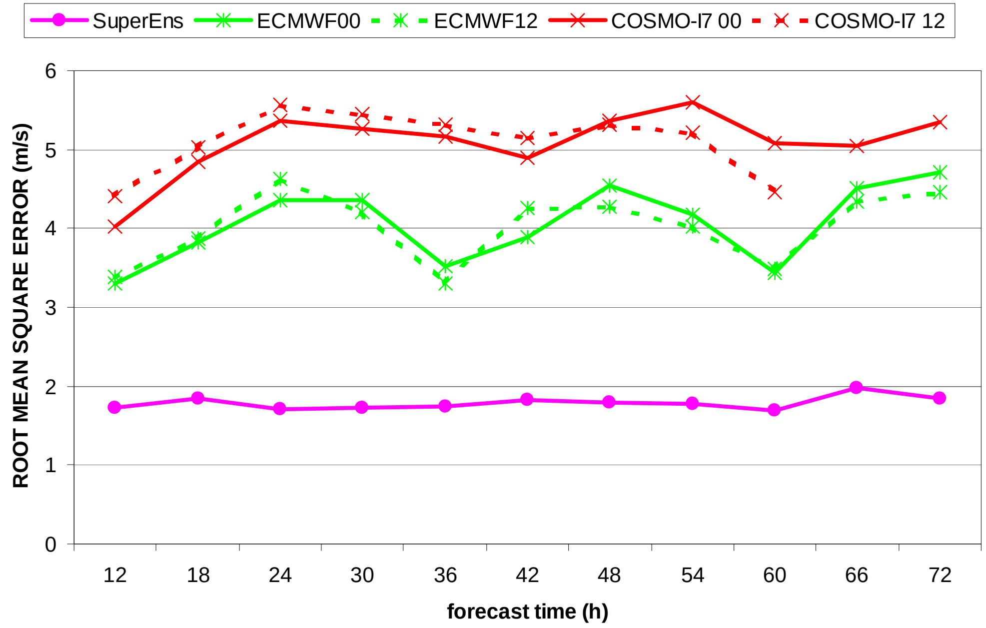



0-700 m

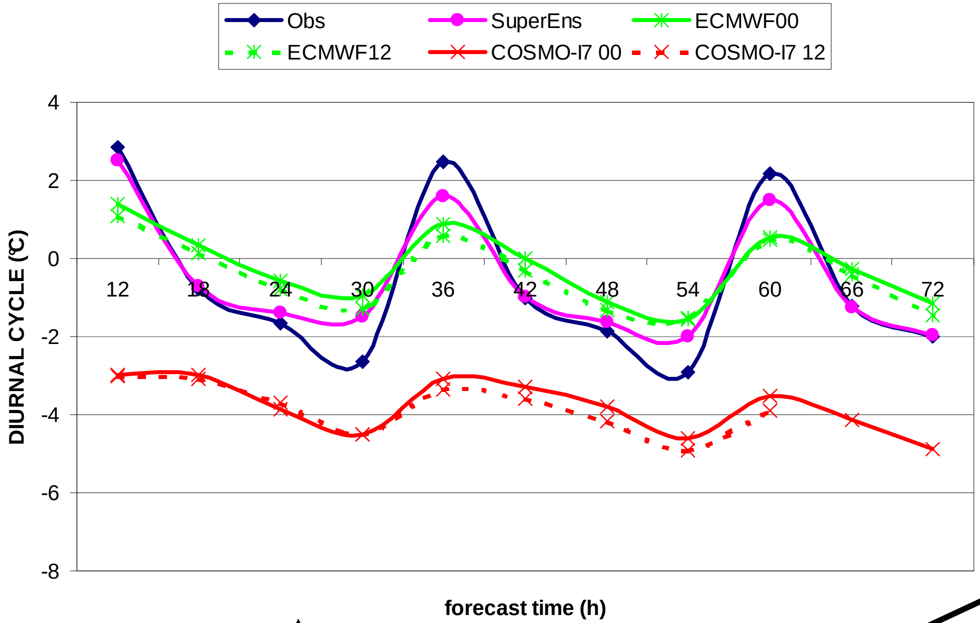
700-1500 m

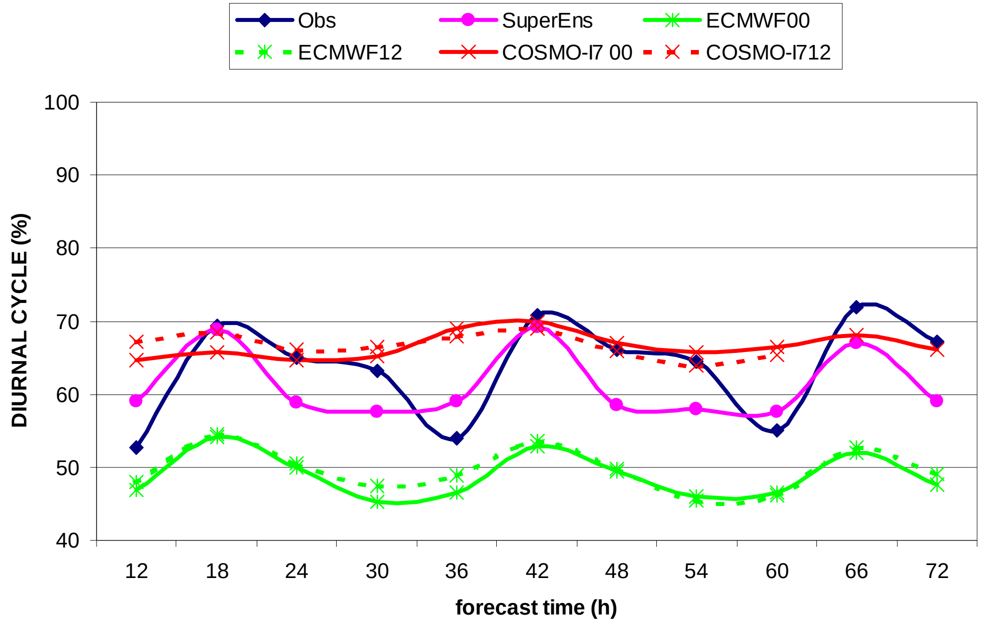
1500-3500 m




RMSE of W10m during February and March 2006 in Piemonte region

# Sample of results

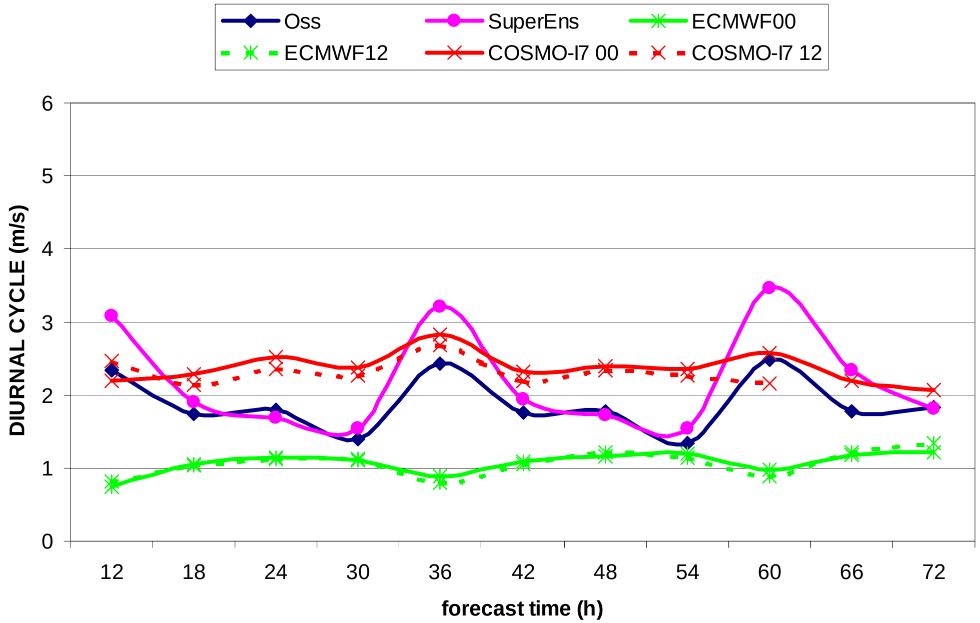



T2m

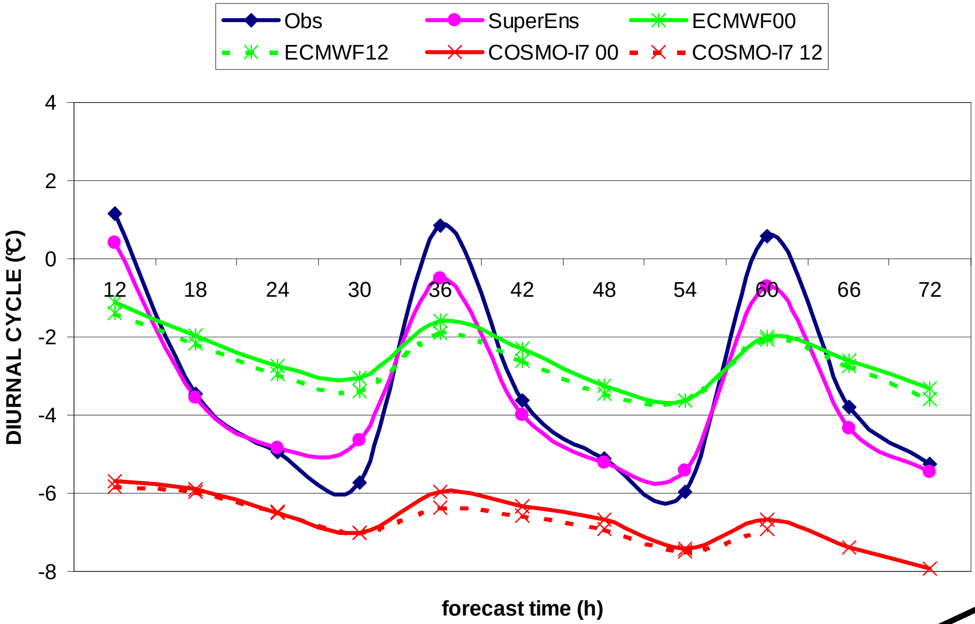
RH2m

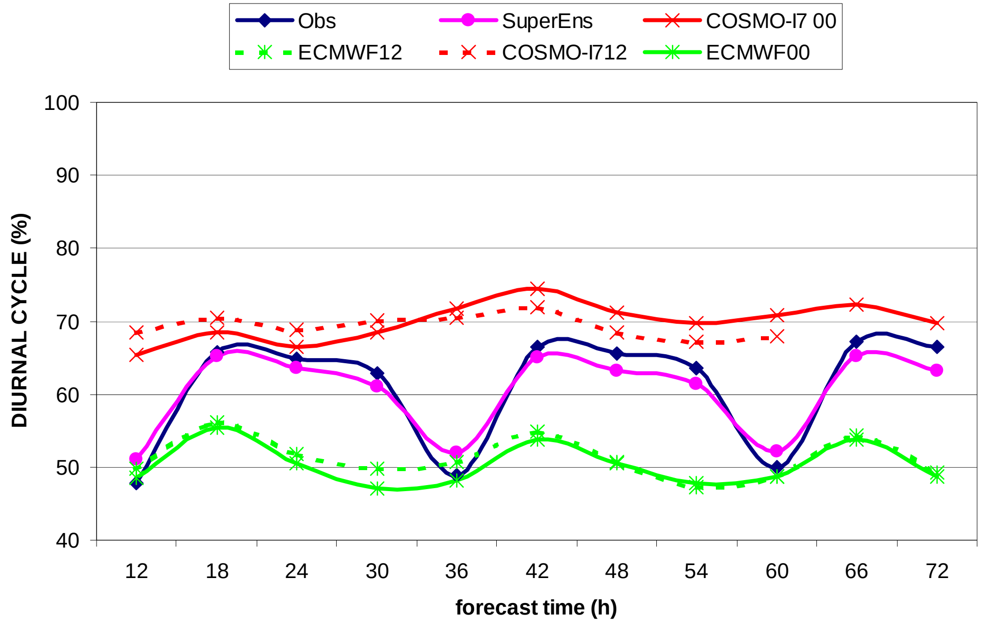
W10m




Diurnal cycle during February 2006 in Piemonte region between 700 and 1500 m

# Sample of results

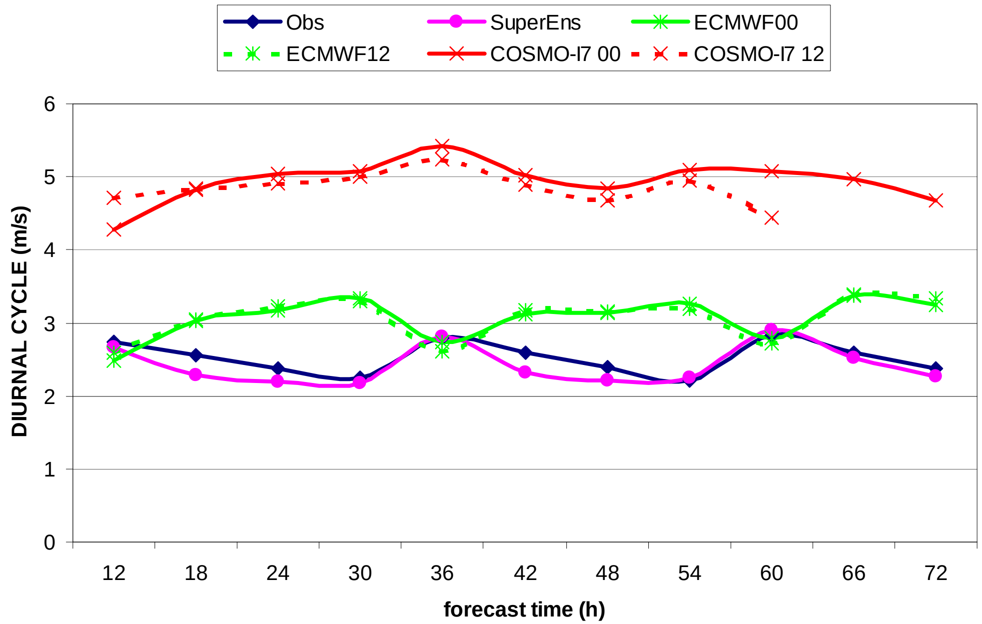



T2m

RH2m

W10m




Diurnal cycle during February 2006 in Piemonte region between 1500 and 3500 m


# Sample of results

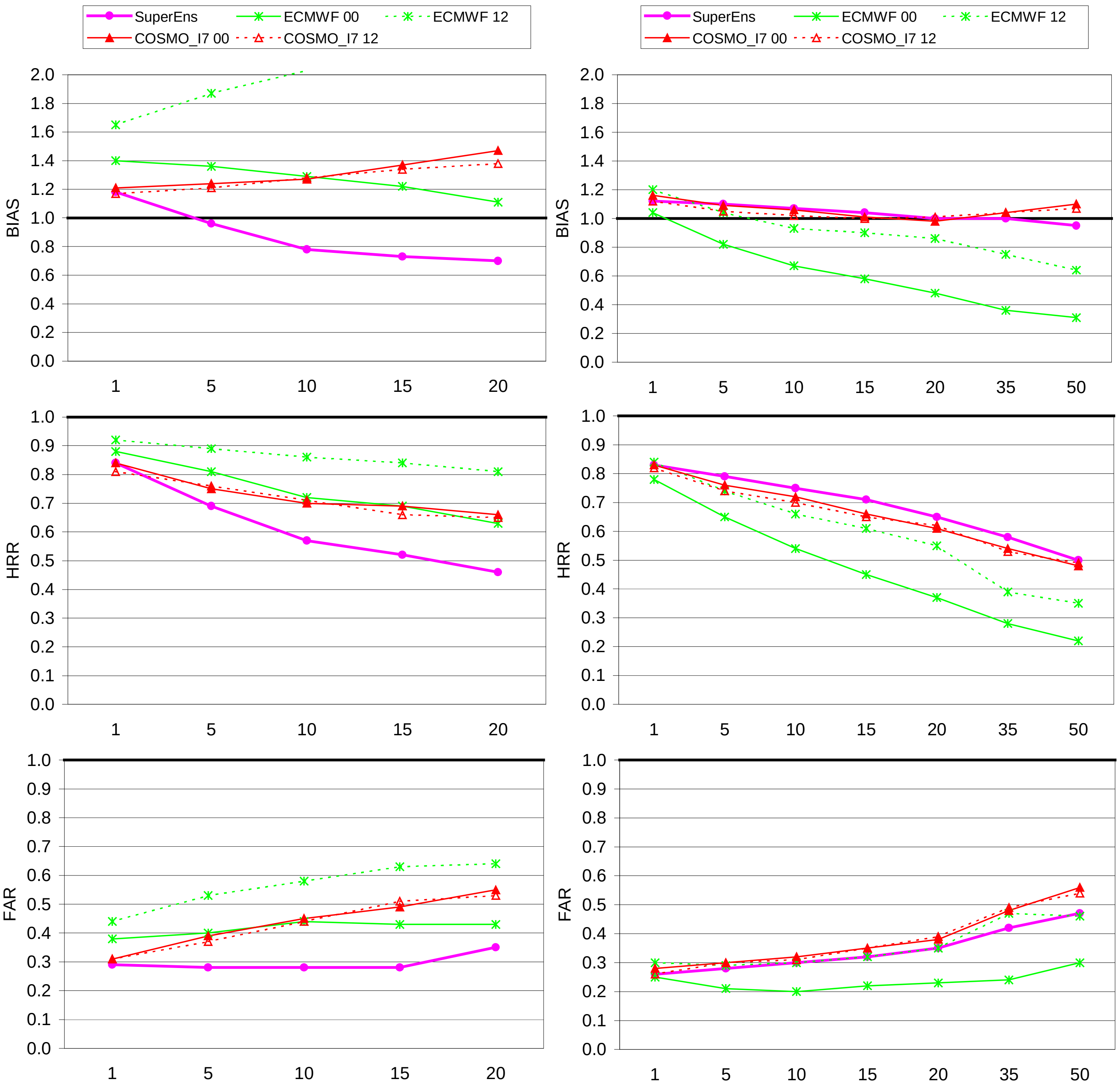
Precipitation verification indices for:

- Multimodel SuperEnsemble
- ECMWF IFS 00 UTC
- ECMWF IFS 12 UTC
- COSMO-I7 00 UTC
- COSMO-I7 12 UTC

as a function of the threshold (mm) for +12h/+36h forecasts. Average values (left) and maximum values (right).

Period: September 2006-August 2008

Area: Piemonte



# Sample of results

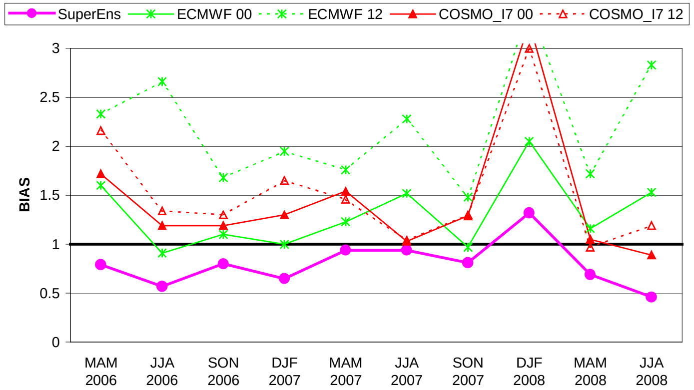
Precipitation verification indices for:

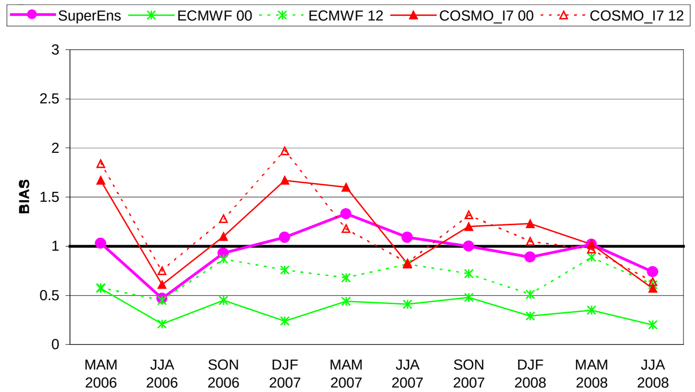
- Multimodel SuperEnsemble
- ECMWF IFS 00 UTC
- ECMWF IFS 12 UTC
- COSMO-I7 00 UTC
- COSMO-I7 12 UTC

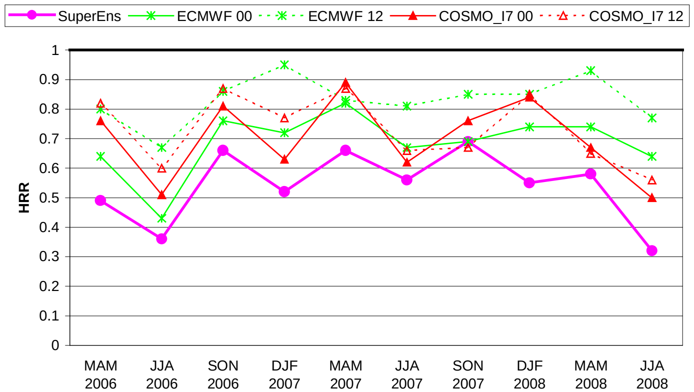
as a function of the season for +12h/+36h forecasts. Average values, threshold 10 mm (left) and maximum values, threshold 35 mm (right).

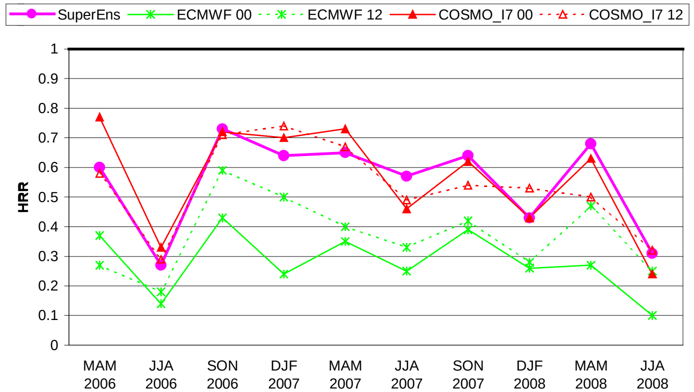
Period: September 2006-August 2008

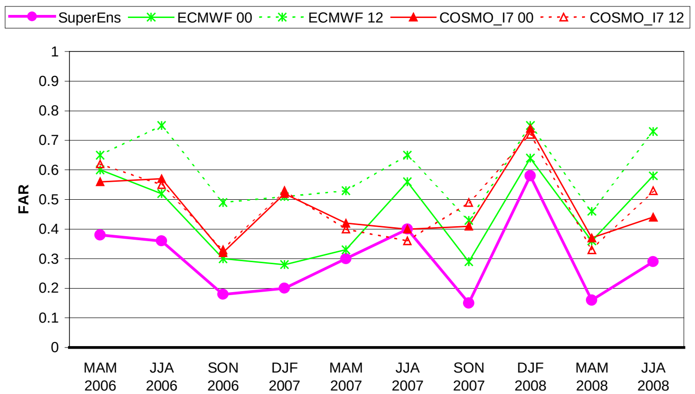
Area: Piemonte

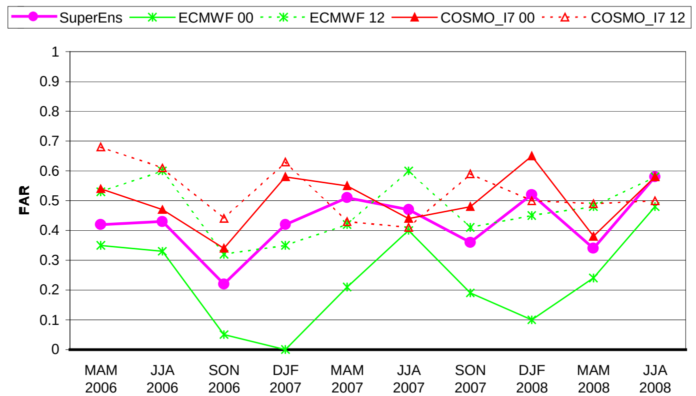


# Comments

***Temperature***

• Over the plains the temperature forecasts are acceptable, but in the mountains, mean errors of up to 6/7 °C occurred. The post-processing method enabled a considerable improvement in the forecasts for all the considered venues. The improvement is particularly evident in the mountains, where the mean error was reduced to values below 1 °C, while the RMSE was usually below 2 °C

• In general, the Kalman filter was slightly less “biased”, with mean error values always close to zero, indicating that, in general, the values were neither overestimated nor underestimated. On the other hand, the Multimodel SuperEnsemble, despite slightly larger bias, reported lower values for the RMSE, indicating smaller errors than the Kalman filter

# Comments

***<u>Other variables (Wind and Relative Humidity)</u>***

- The DMO of COSMO-I7 was useful for estimating wind gusts, but for the average wind field, SuperEnsemble was more reliable. The breeze conditions in the mountains were not “seen” at all by the models (and therefore by any kind of post-processing…)
- The DMO underestimates RH in the valleys and over the plains, but with the SuperEnsemble technique we could correct this trend

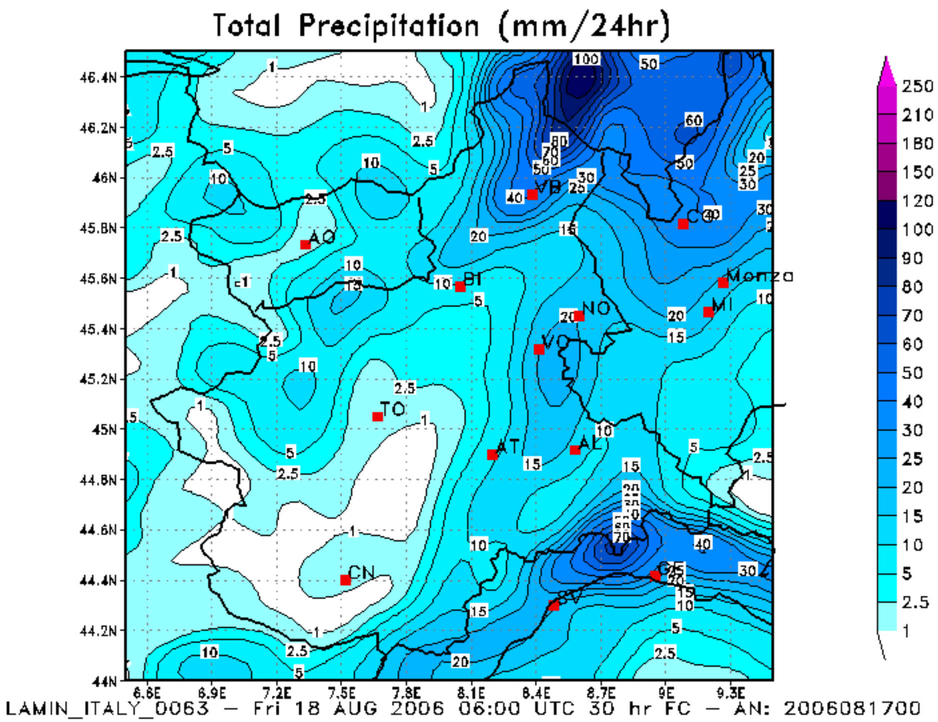
# Comments

## ***Precipitation***

- SuperEnsemble error is more stable than Direct Model Output
- SuperEnsemble gives better results than Ensemble and Poor-Man Ensemble
- Training period: the longest the better (basically for statistics reasons, but for a larger area it should be easier)
- The ROC correction works correctly

# Other PPT used in ARPA Piemonte (now)

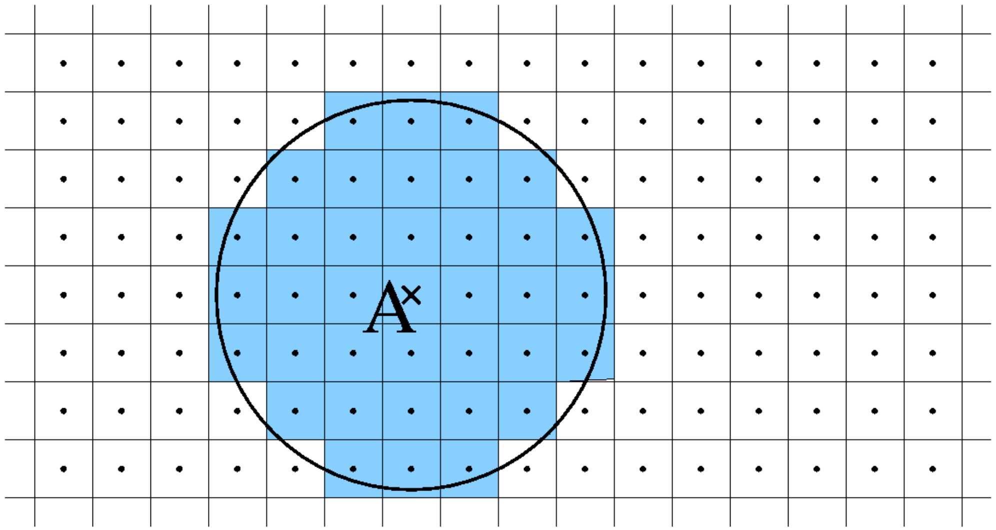
- The DMO of COSMO-I2 might contain a considerable amount of noise !
- Experienced forecasters interpret output from a very high resolution deterministic forecast in a *probabilistic* way

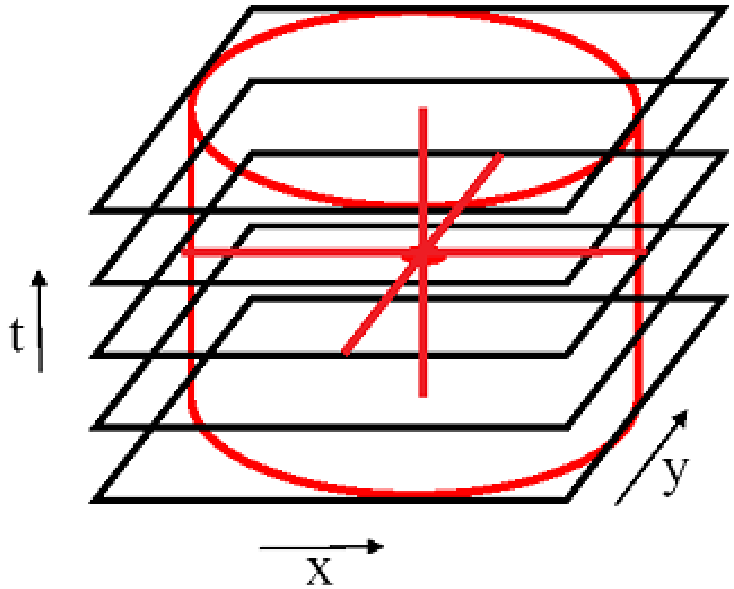



← "high probability of some heavy near Ticino and Toce valley ", ***not*** "82 mm of rain will fall in x,y"

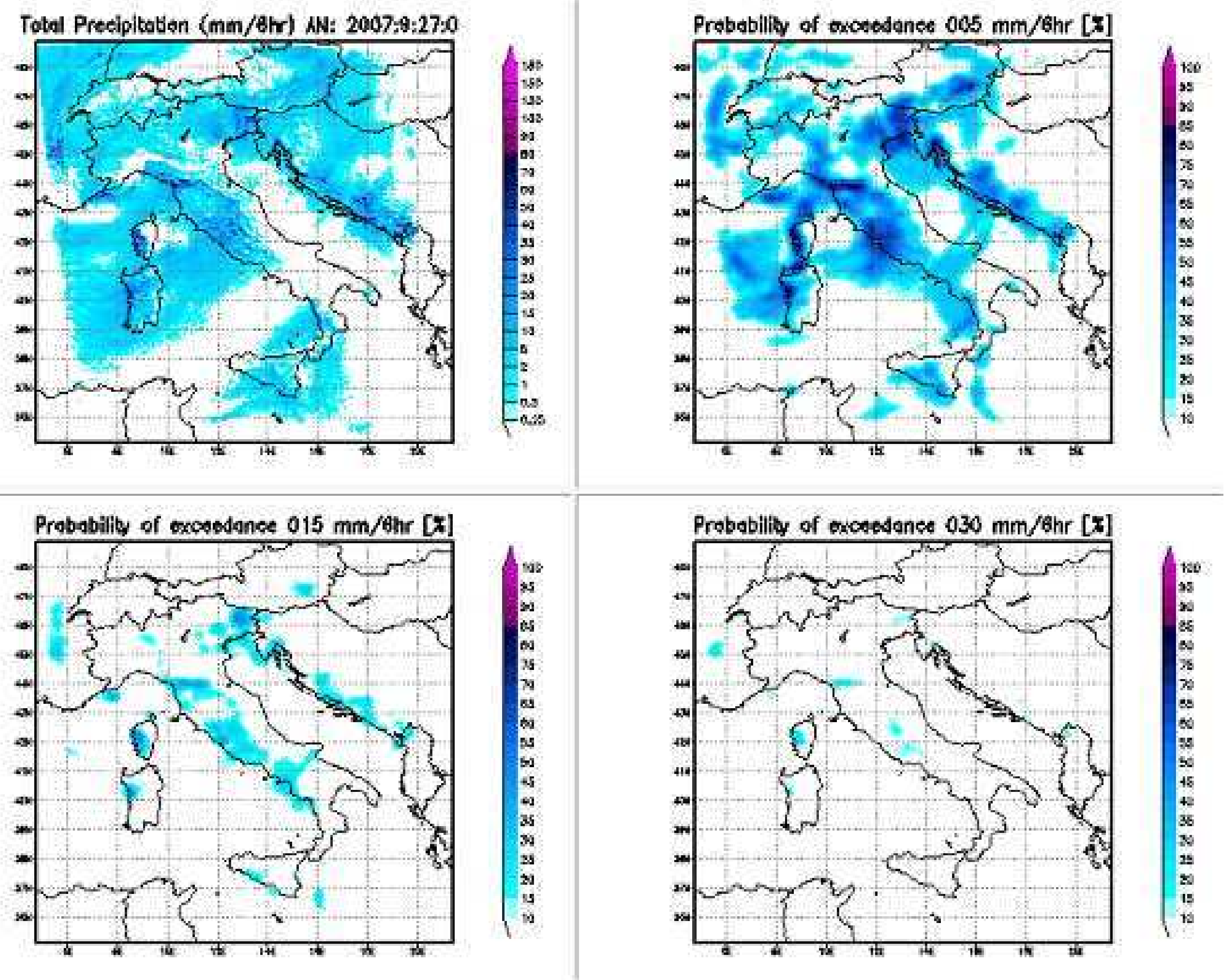
Neighbourhood method (Theis et al., 2005) applied to COSMO-I2.

Forecasts within a neighbourhood in space & time constitute a sample of the forecast at grid point A, given the hypothesis that spatial and temporal uncertainties are independent.




The radius, the shape and the time extension must be calibrated empirically.




Of course here we have a problem with verification

↓

Need for very high resolution (in space and time) observations

↓

Only eye-ball verification at the moment

# References (SuperEnsemble)


- Krishnamurti, T.N., Kishtawal, C.M., Larow, T., Bachiochi, D., Zhang, Z., Williford, C.E., Gadgil, S., Surendran, S., “Multi-Model SuperEnsemble Forecasts For Weather And Seasonal Climate”. J. Climate, 13, 4196-4216, 2000.
- Cane, C., and Milelli, M., "Multimodel SuperEnsemble technique for weather parameter forecasts in Piemonte region", Nat. Hazards Earth Syst. Sci. (NHESS), 10, 265-273, 2010
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# References (Neighbourhood Method)


- Theis, S., Hense, A., and Damrath, U., “Probabilistic precipitation forecasts from a deterministic model: a pragmatic approach”. Meteorological Applications, 12, 3, 257-268, 2005
- Kaufmann, P., “Post-processing of the aLMo Precipitation with the Neighbourhood Method”. COSMO Newsletter No. 7, 57-60, 2007
- Turco, M., and Milelli, M., "Towards Operational Probabilistic Precipitation Forecast", COSMO Newsletter No. 9, 56-62, 2009



**Thank you for the attention and…**

**GOOD LUCK FOR YOUR OLYMPIC GAMES !**