COMPARING DIFFERENT METEOROLOGICAL ENSEMBLE APPROACHES FOR HYDROLOGICAL PREDICTIONS

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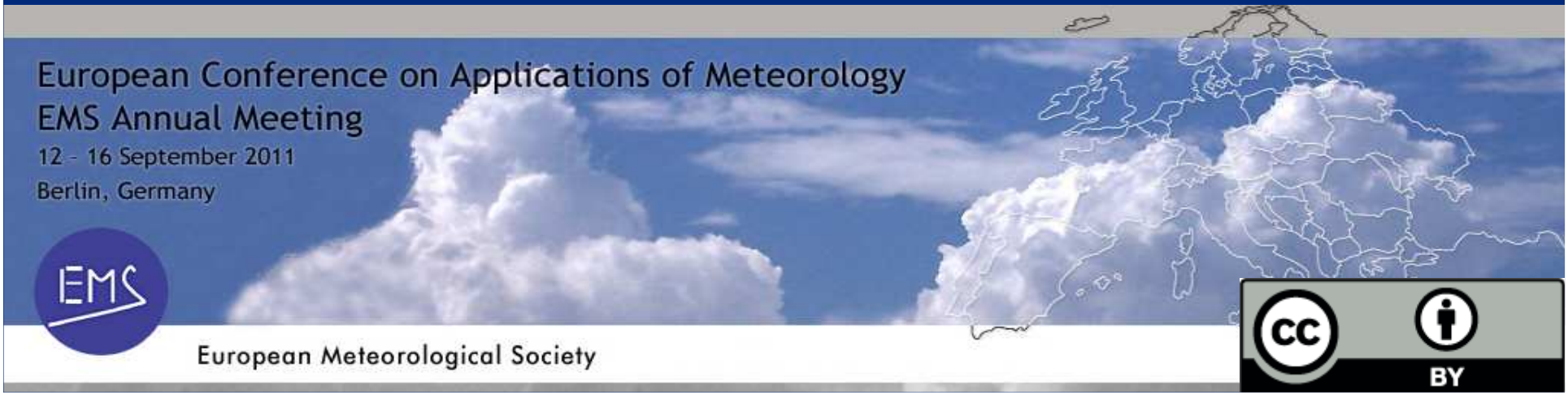


FRAMEWORK

Coupled meteo-hydrological modelling for discharge forecasting in small and medium-sized catchments.
Uncertainty in QPF may be relevant for hydrological applications → ensemble forecasting approach in order to provide a probabilistic prediction.

MOTIVATIONS

Comparing two ensembles approaches, based on mesoscale meteorological models, focusing on the short/medium range forecasting.
Both ensembles provide different meteorological scenarios to be used as an input for the same hydrological model.

The uncertainty propagates along the meteo - hydrological forecasting chain, providing a more informative and probabilistic prediction.

The performance of the ensembles is evaluated in terms of both rainfall and discharge predictions, for a recent severe episode affecting the Reno river basin, located in Northern Italy.

TWO ENSEMBLE APPROACHES

1) A **multi-model ensemble** (15 members), based on three mesoscale models:

- **BOLAM** (developed and implemented at ISAC CNR)
- **COSMO** (COnsortium for Small scale MOdelling) implemented by ARPA-SIMC
- **WRF** (Weather Research and Forecasting Model) implemented by ISAC CNR

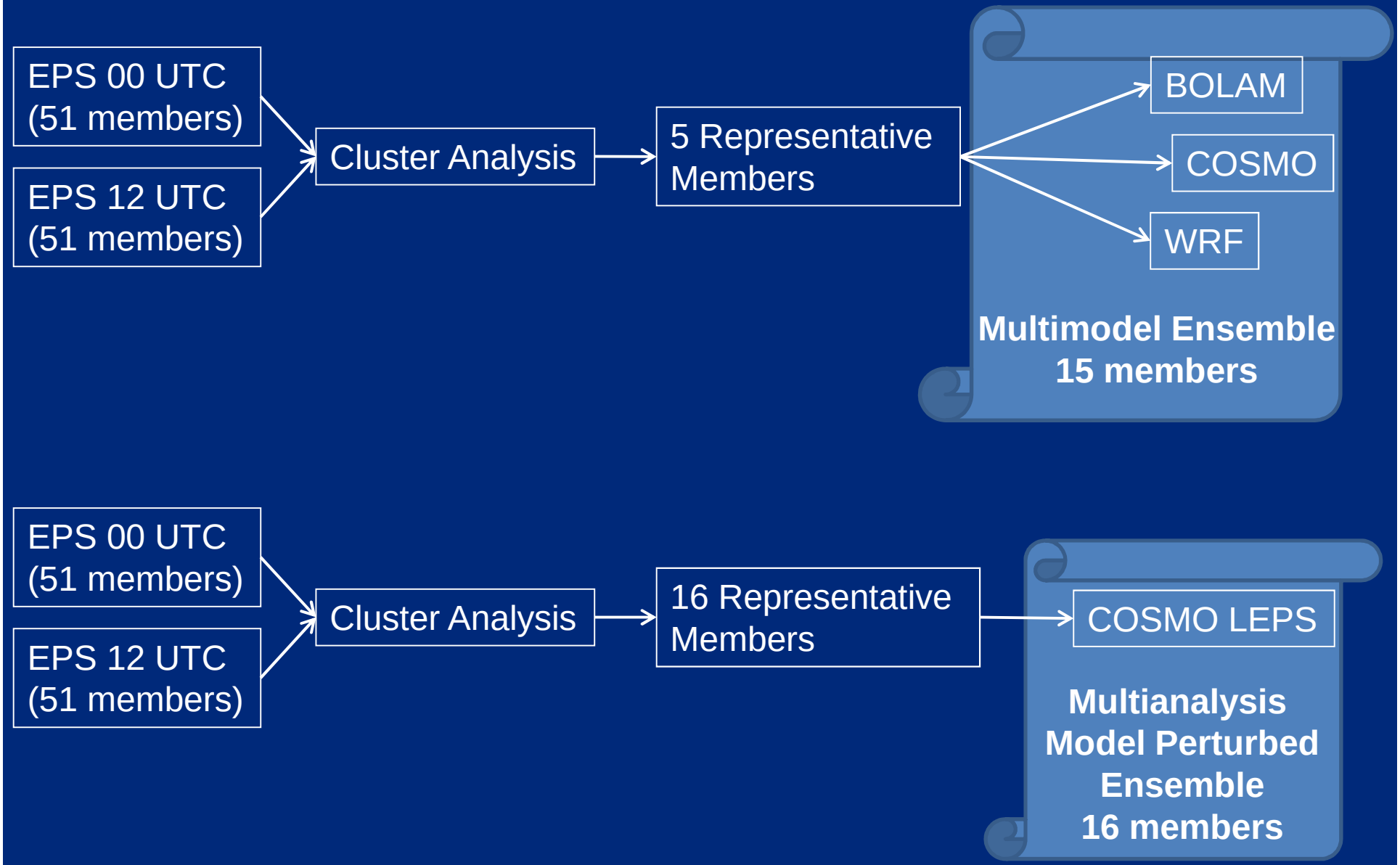
each of them initialized by 5 representative members of EPS-IFS.

2) A single-model approach, based on **COSMO-LEPS** (Limited-area Ensemble Prediction System) ensemble, the operational forecasting system with the COSMO model, driven by 16 representative members of EPS-IFS.

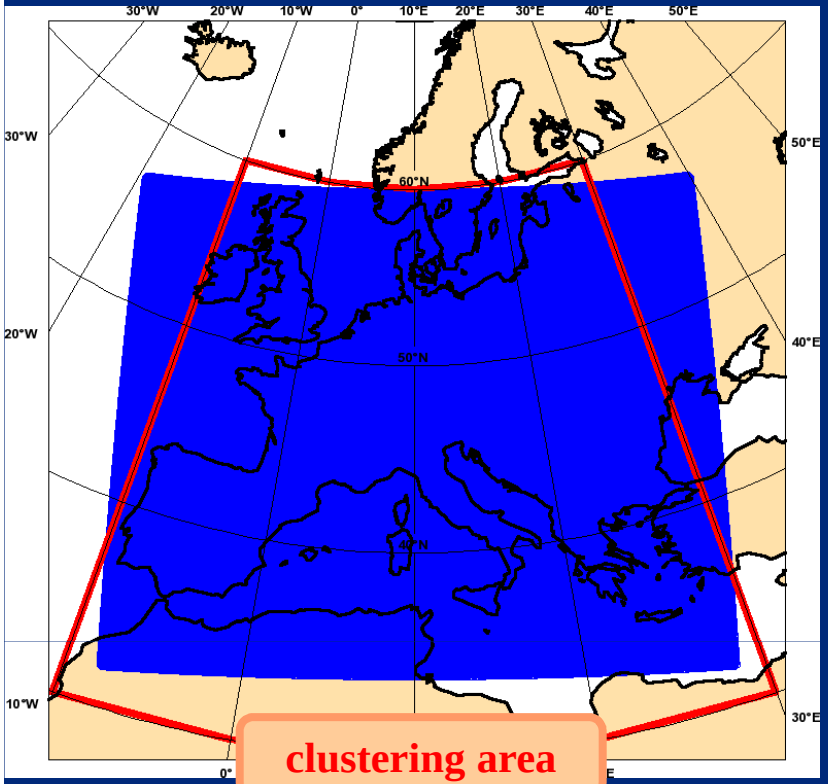
- ➢Similar integration domains
- ➢Similar horizontal resolution (7-8 km)
- ➢Same number of ensemble members (almost)
- ➢Real-time forecasting application using the same driving global ensemble prediction system of ECMWF (IFS-EPS)

TOPKAPI distributed rainfall-runoff model for discharge prediction

BUILDING THE ENSEMBLE: SELECTION OF REPRESENTATIVE MEMBERS (3)



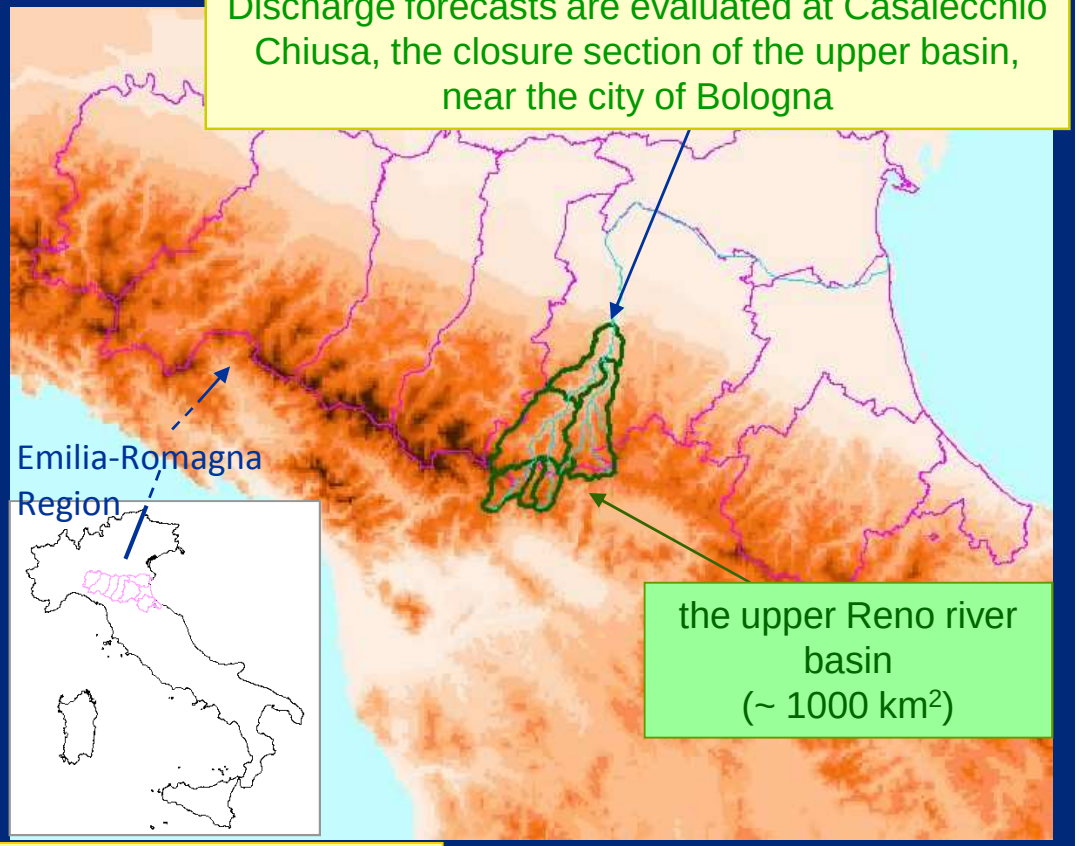
Common integration domain



AREA OF INTEREST

Reno river basin: location and characteristics

Discharge forecasts are evaluated at Casalecchio Chiusa, the closure section of the upper basin, near the city of Bologna



basin response time

~ 10-12 h at Casalecchio

~ 36 h at the outlet

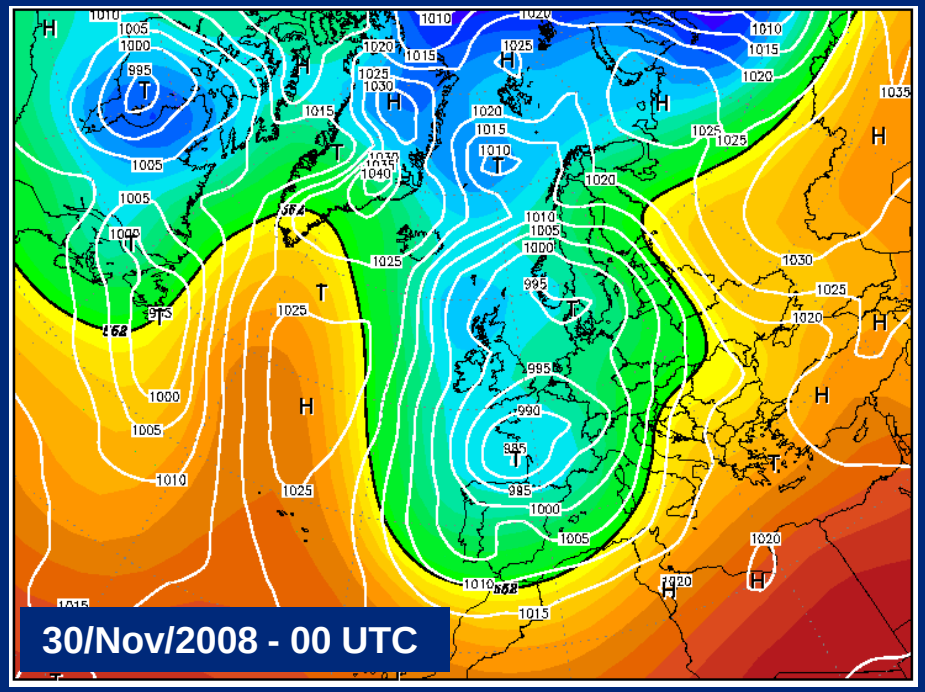
Alert thresholds:

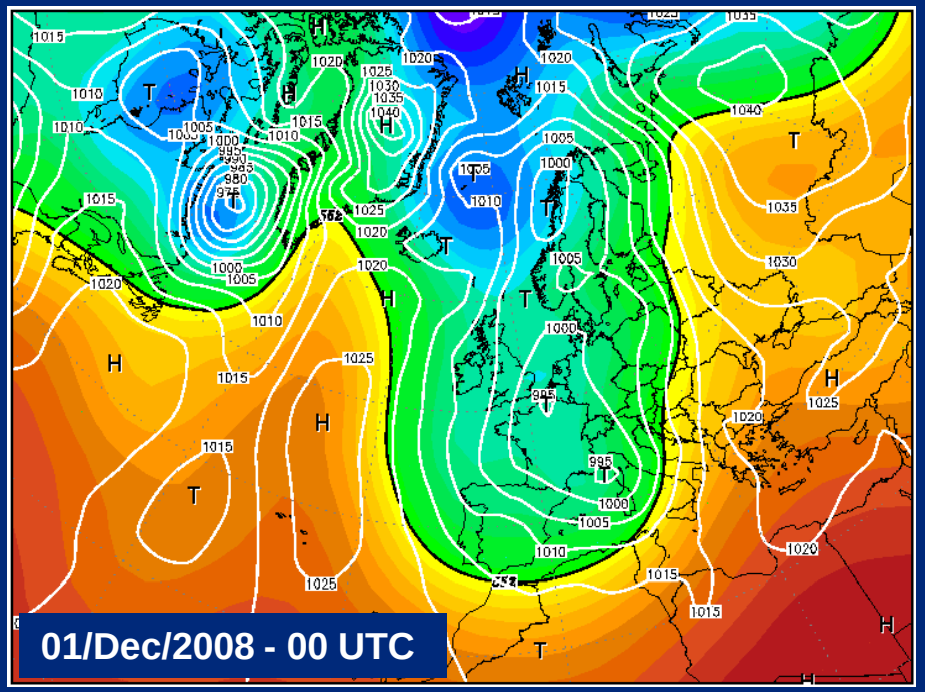
0.8 m (~ 80 m^3/s) *warning*

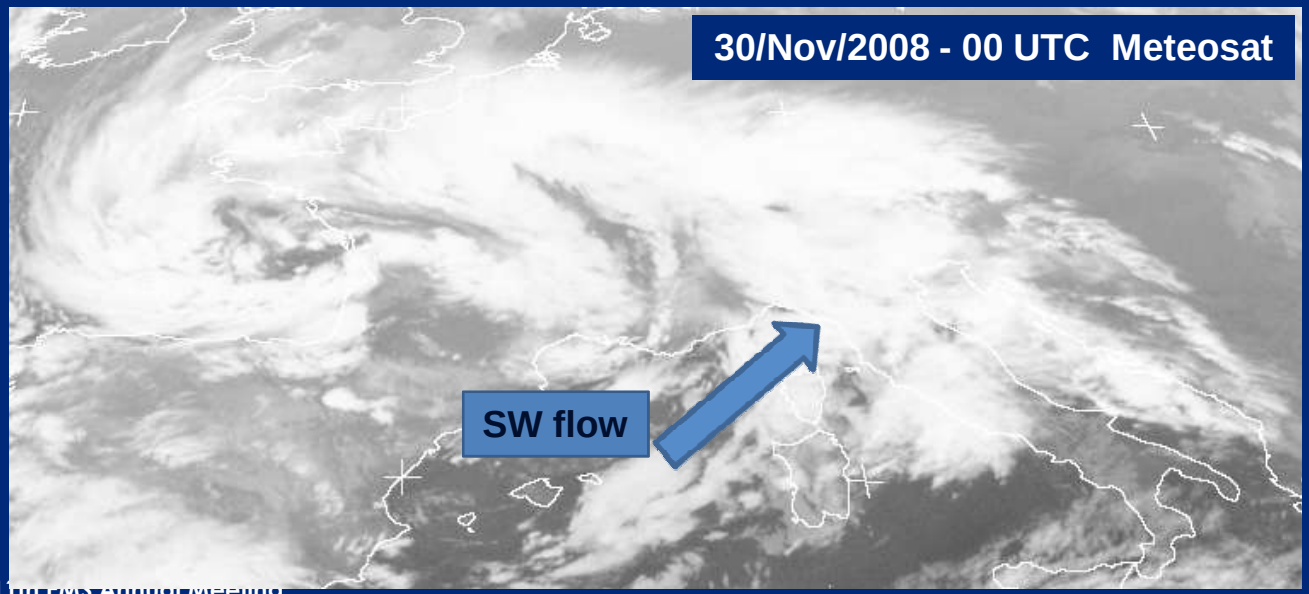
1.6 m (~ 630 m^3/s) *alarm*

SYNOPTIC OVERVIEW OF THE EVENT - 29 Nov - 2 Dec 2008

500 hPa geopotential height and sea level pressure







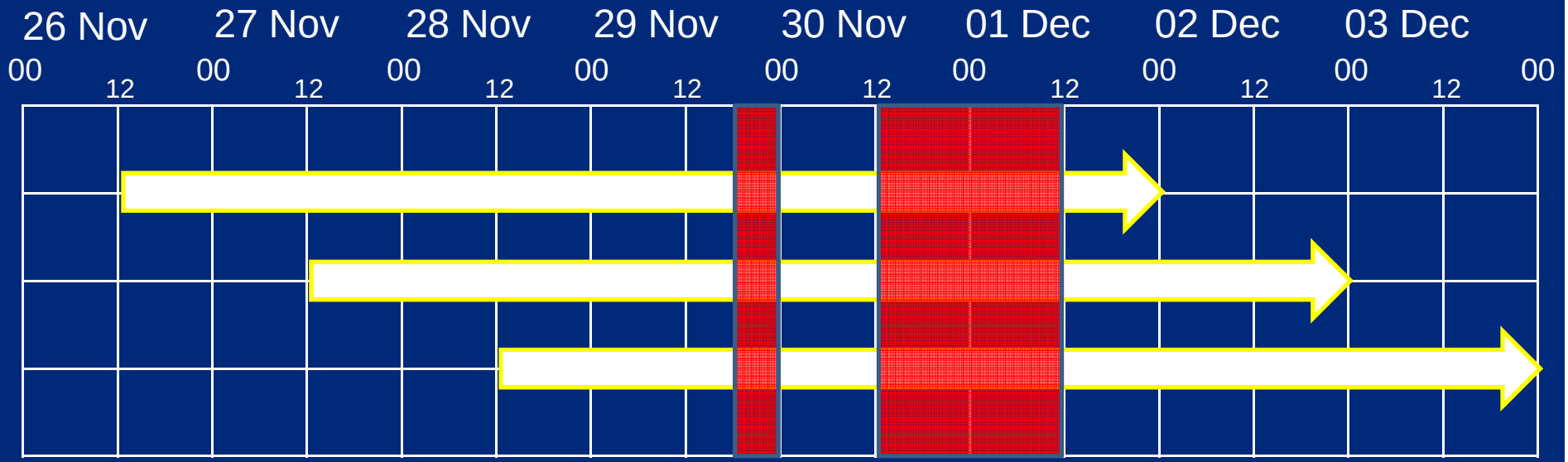
-Deep trough elongated N-S associated with cold air moving toward the Mediterranean.
-Several frontal systems moving in the cyclonic circulation over western Mediterranean.
-Warm air advection on the east side of the trough, sustained by intense southerly moist flow.
-Lee orographic cyclogenesis (Genoa low) in the second part of the event.
-Blocking over Eastern Europe.

ENSEMBLES PERFORMANCE

METEOROLOGICAL PERSPECTIVE

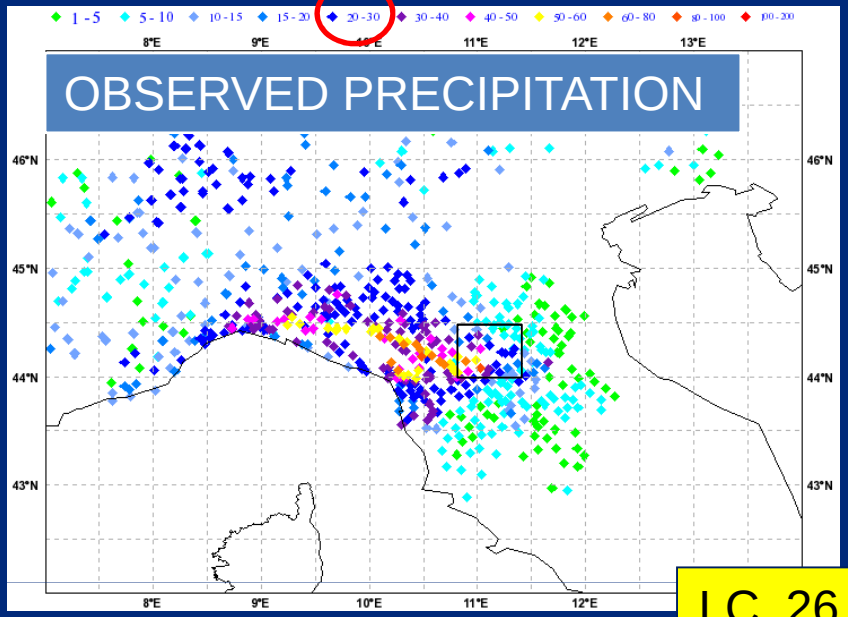
Two analysed periods of intense precipitation
29 November 18 - 00 UTC
30 November 12 UTC - 01 December 12 UTC

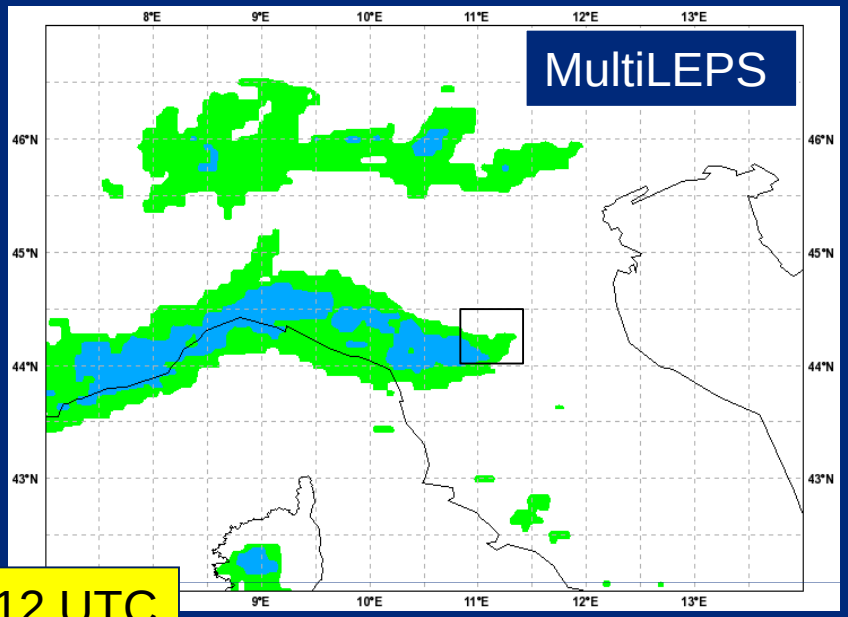
Probability Maps: precipitation exceeding fixed thresholds
- 20 mm/6h (for 29 Nov. 2008)
- 50 mm/24h (for 30 Nov. 2008)



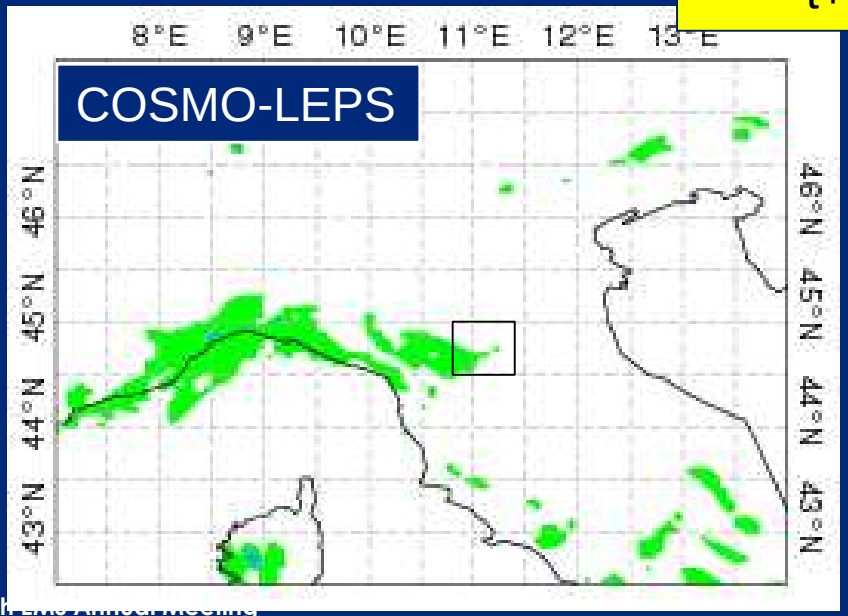
Three initialization times, 24-h apart

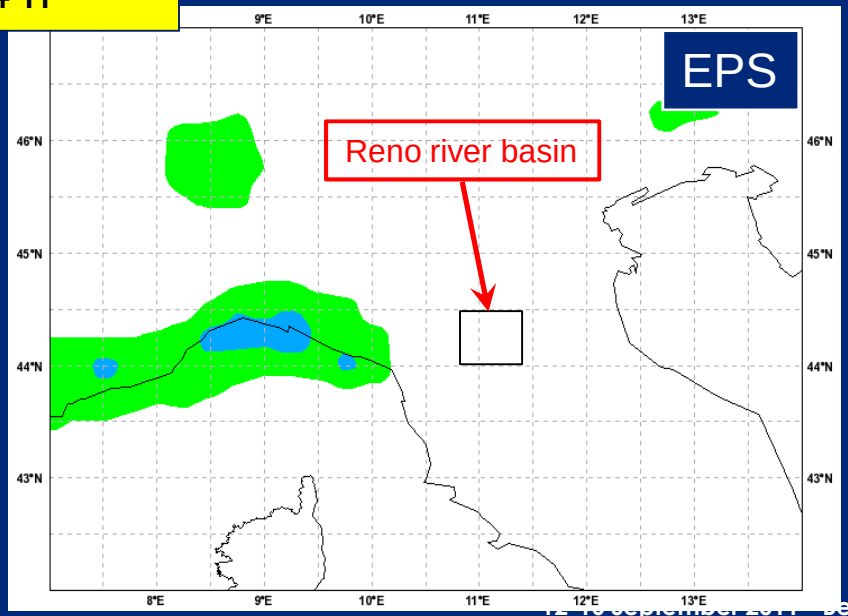
29 November 2008 18-24 UTC
Probability Total Precipitation > 20mm/6h





I.C. 26 Nov 12 UTC
t+78-84 h





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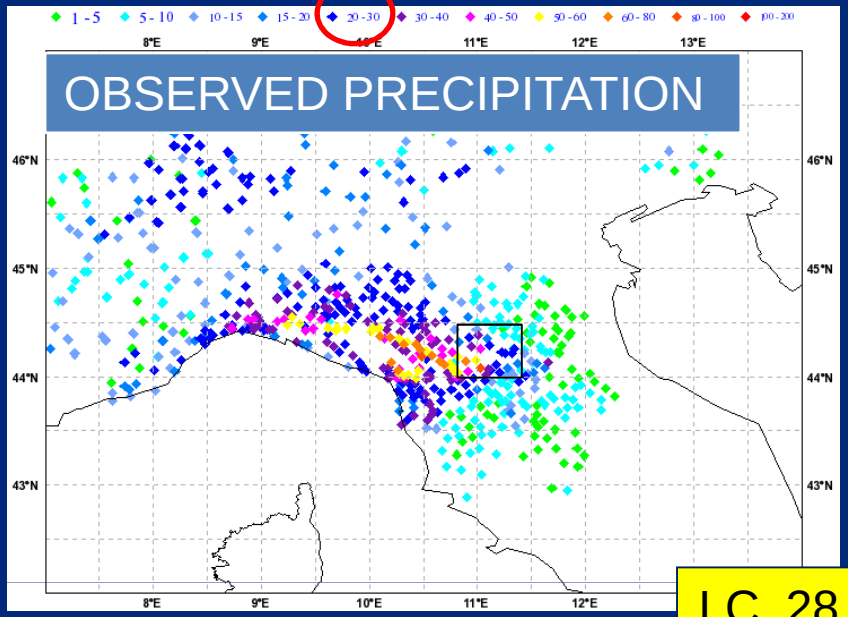
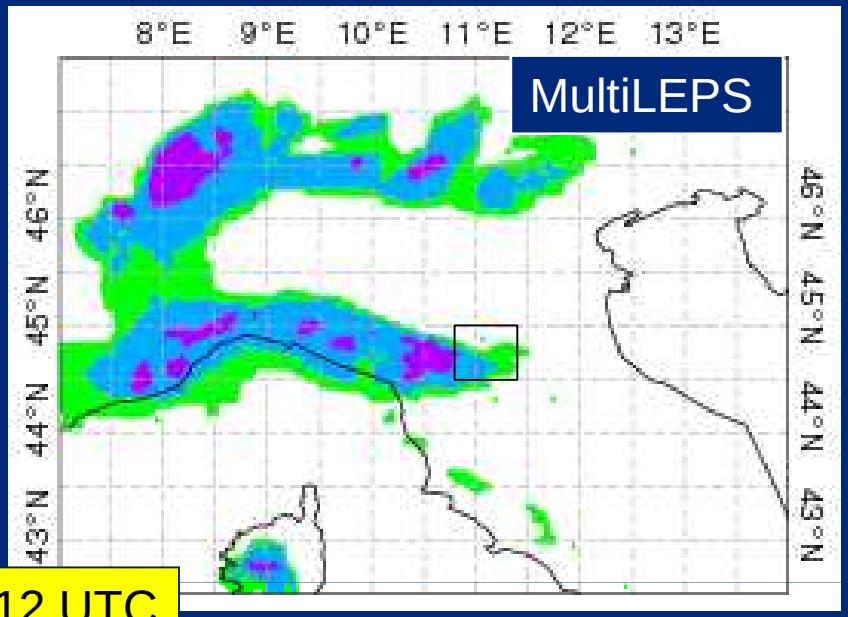
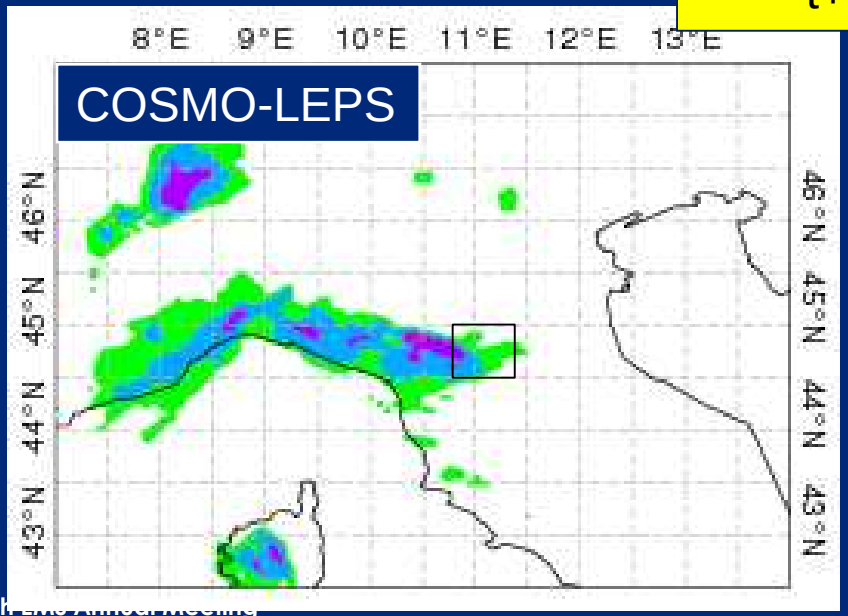
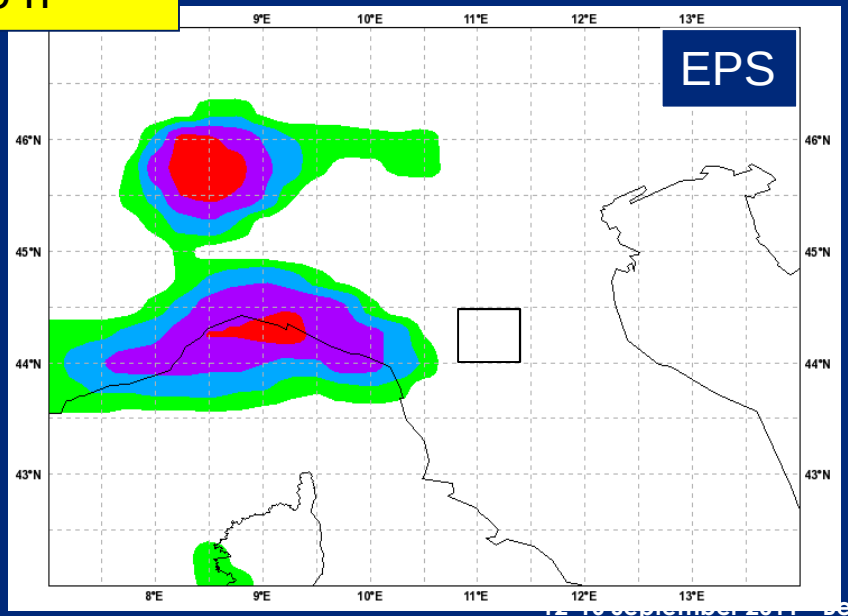


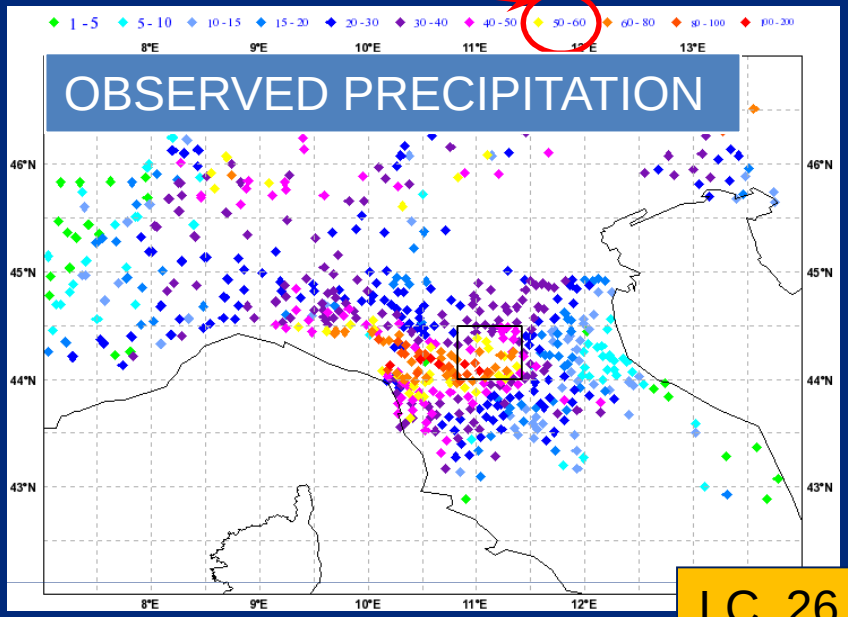


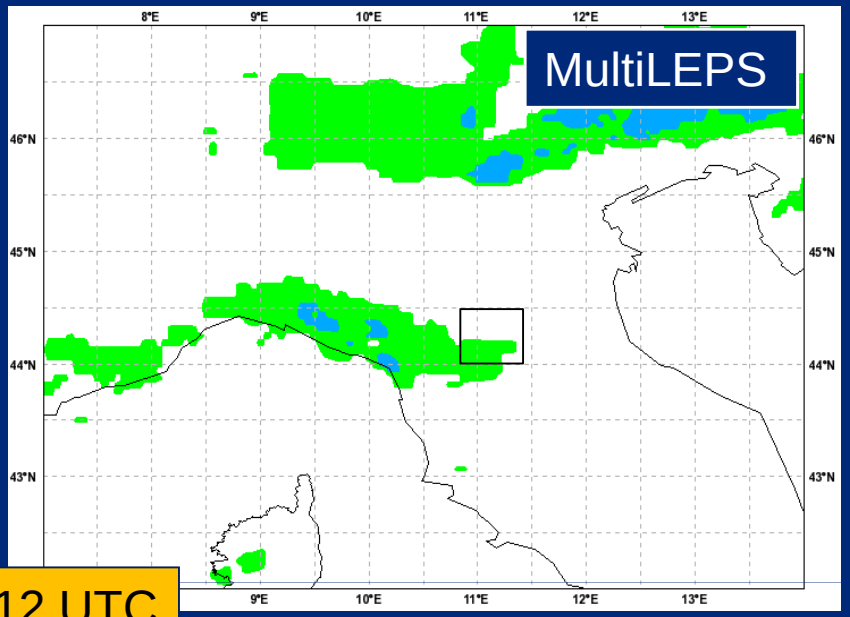
I.C. 28 Nov 12 UTC
t+30-36 h



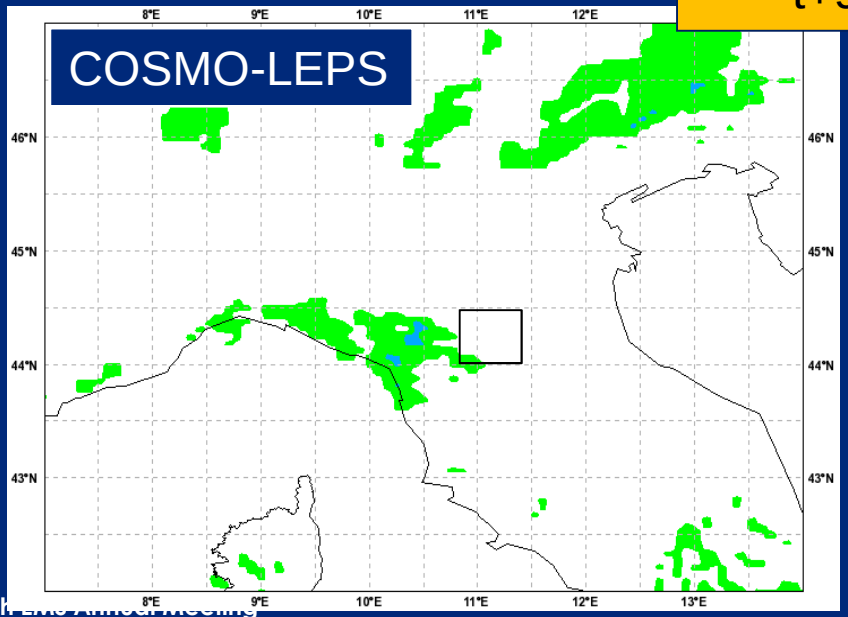


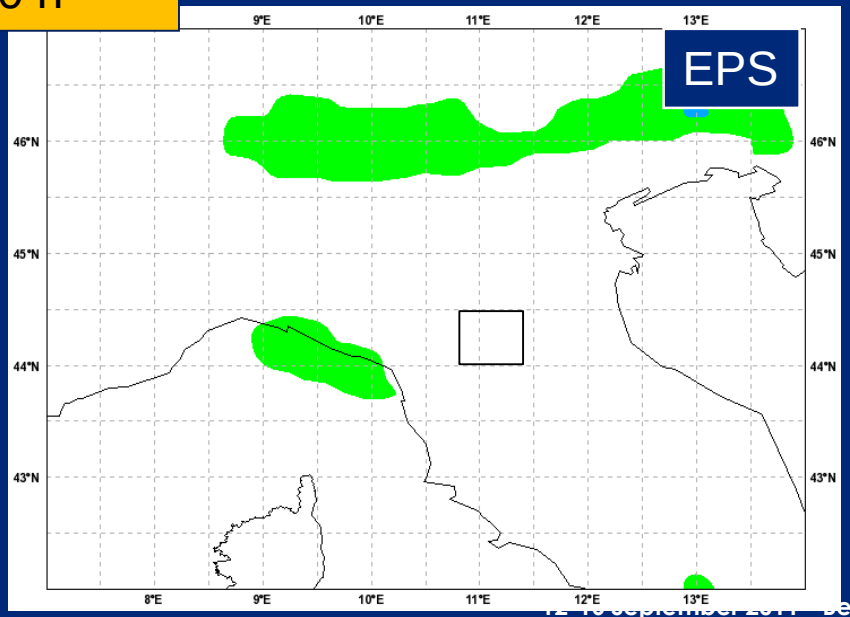
30 November 2008 12 UTC - 1 December 2008 12 UTC
Probability Total Precipitation > 50mm/24h





I.C. 26 Nov 12 UTC
t+96-120 h





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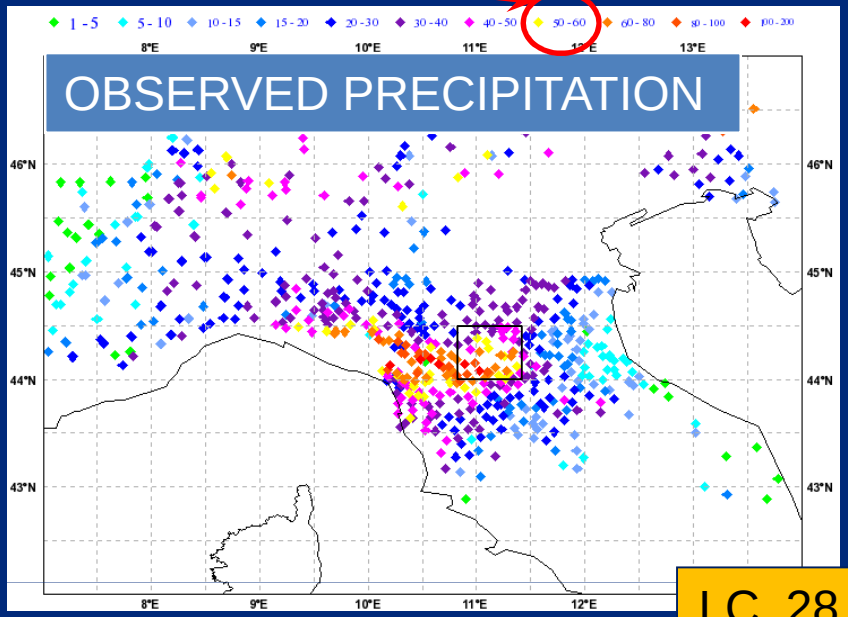
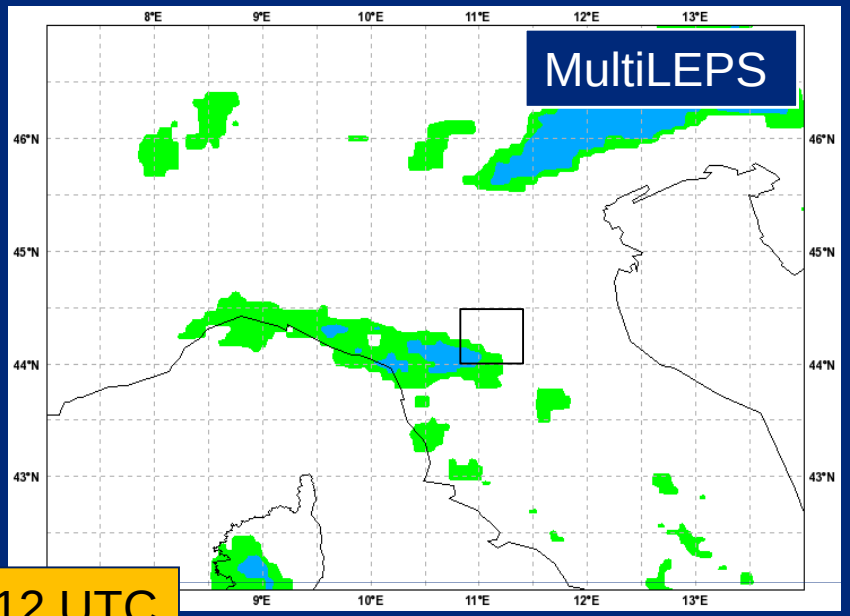
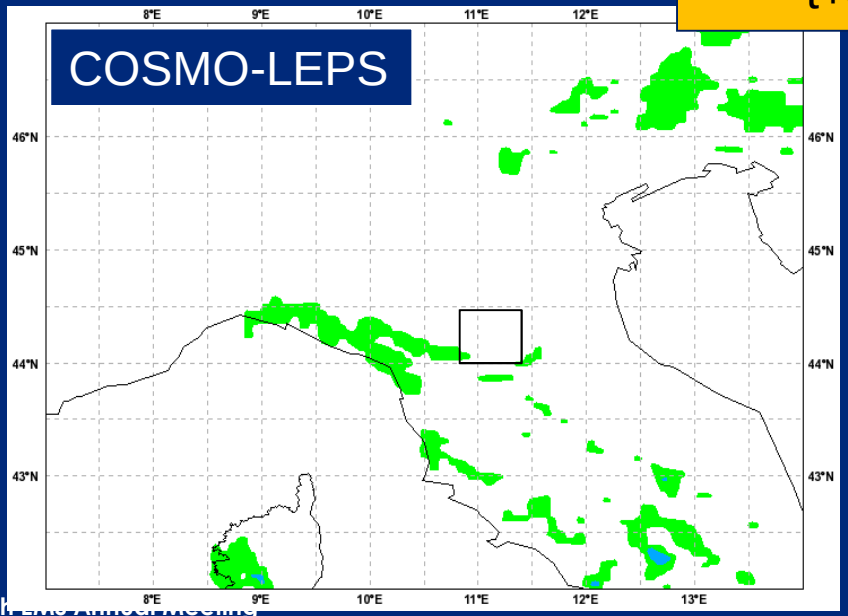
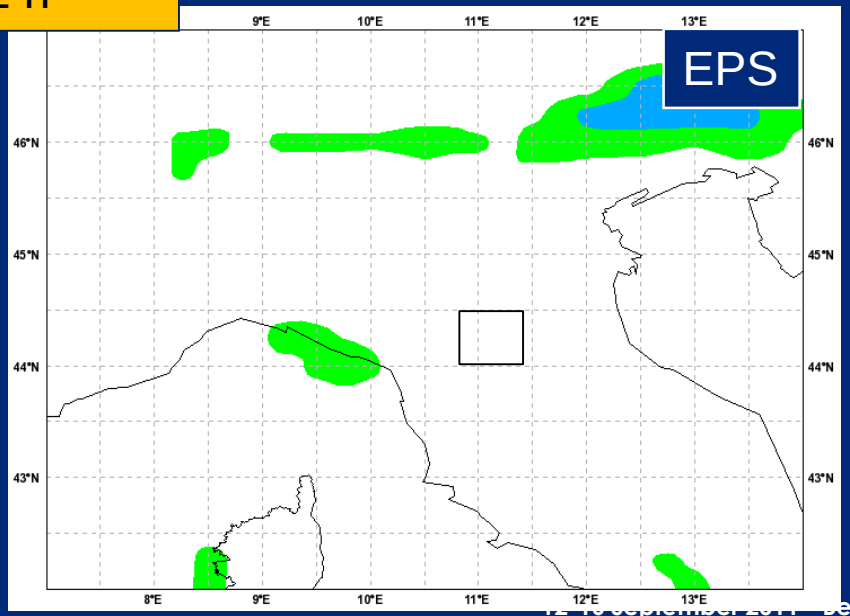




I.C. 28 Nov 12 UTC
t+48-72 h





SOME CONSIDERATIONS:

- The shorter the forecast range, the higher the probability of having intense precipitation over the Reno river basin (as expected) especially for the first 6h analysed period.
- ECMWF EPS probability maps provide little evidence of high precipitation over the Reno river basin, even at short forecast range. This highlights that structural model deficiencies (low resolution, orography representation) cannot be accounted for by this kind of ensemble approach. Higher resolution models are needed => added value of LAM ensembles.
- 6h probability maps (shorter forecast ranges, shorter period): in the Multimodel LEPS forecasts generally broader areas are indicated as probably affected by heavy precipitation, showing more uncertainty in the forecast. Though, the greater degree of diversity of the Multimodel LEPS members provides useful additional information.
- 24h probability maps (longer forecast ranges, longer period): only the Multimodel LEPS indicates some relevant probability of heavy precipitation on the target basin.
- The probability of intense precipitation over the Reno river basin issued by the Multimodel LEPS progressively increases as the forecast range decreases, thus improving the confidence in the prediction as the event approaches. The Multimodel LEPS identifies the Reno river basin as areas likely to be affected by intense precipitation more than 3 days in advance.

A DEEPER ANALYSIS OF THE MULTIMODEL ENSEMBLE RESULTS ....still meteorology

- subjective/qualitative evaluation of QPF

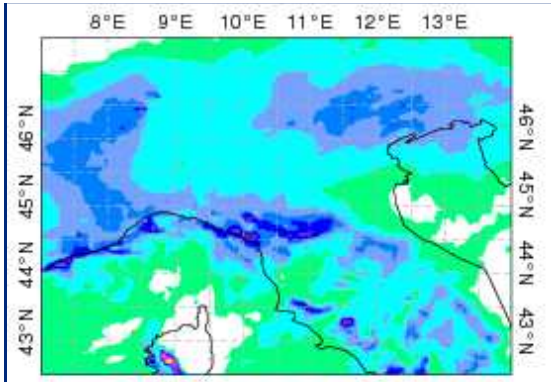
- try to explain the good performance?

- evaluate the impact of boundary conditions wrt model characteristics at different forecast ranges

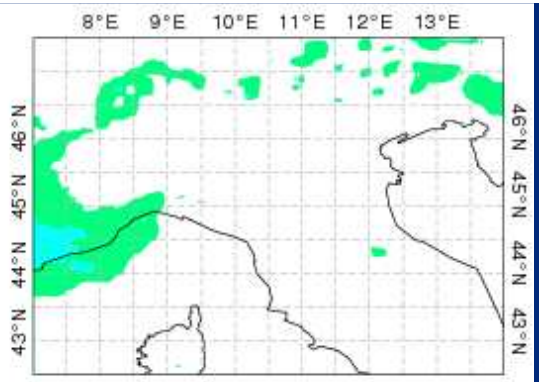
COSMO

I.C. 26 Nov 12 UTC

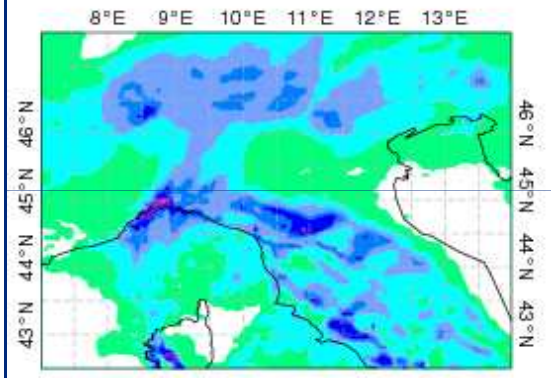
t+78-84 h



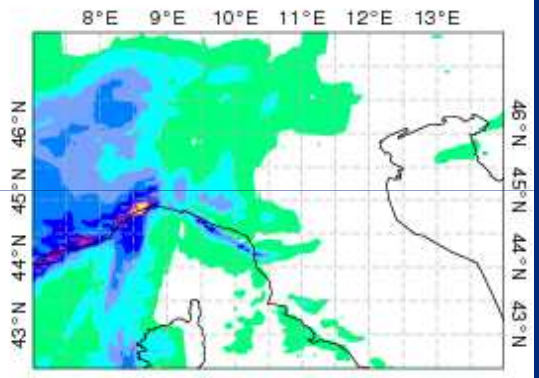
m3



m12

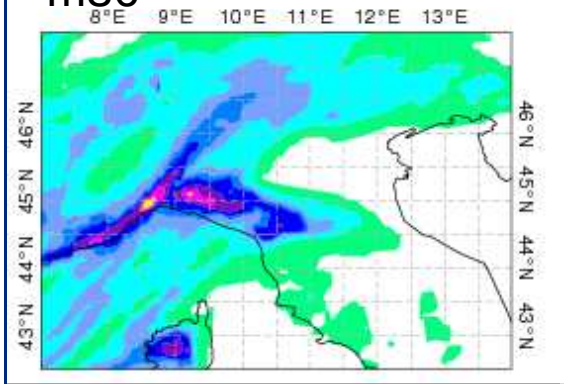


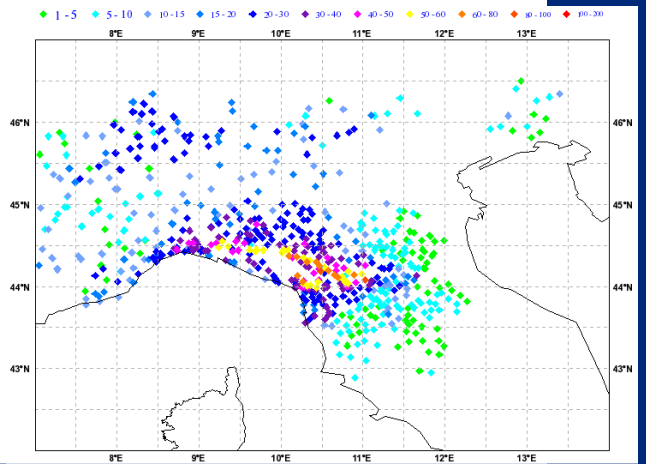
m23

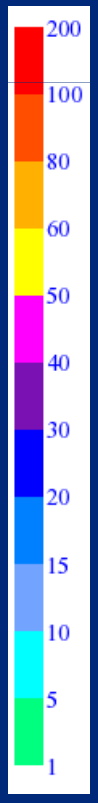


m35

m36





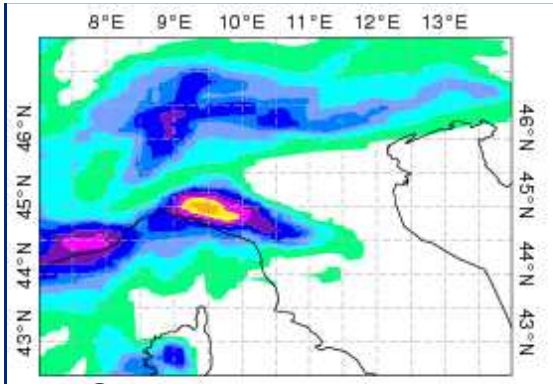


- underestimation over Apennine
- **best: 36** (then 23 and 3)
- **worst: 12**

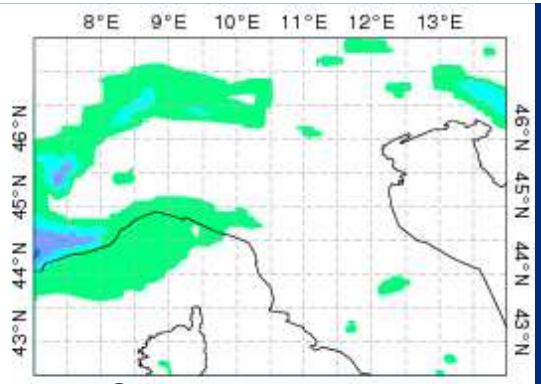
BOLAM

I.C. 26 Nov 12 UTC

t+78-84 h



m3



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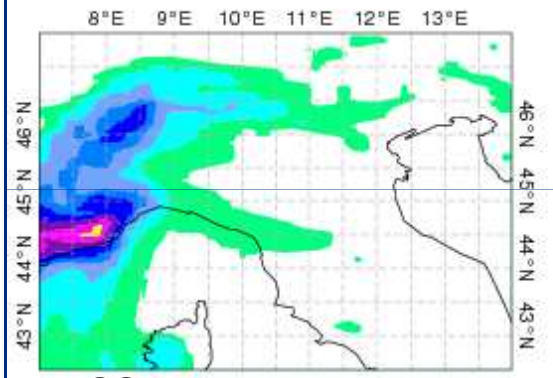

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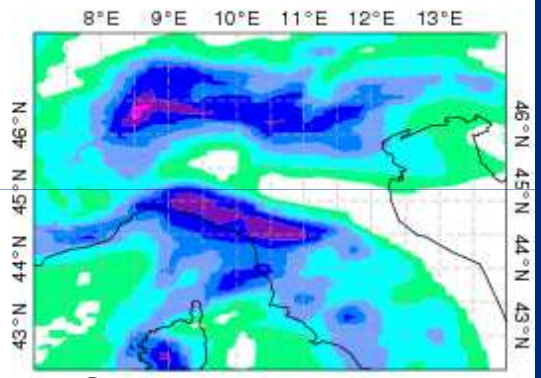
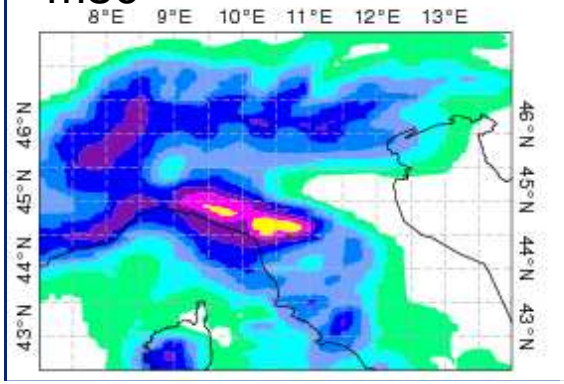
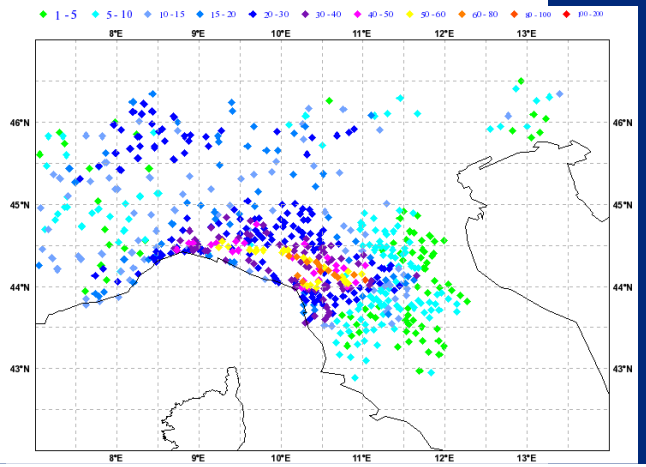


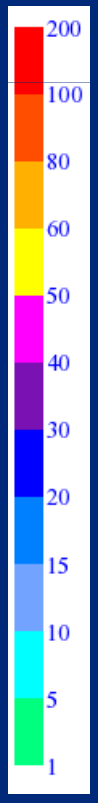
m35

m36





- good (overestimation over E-Alps)
- **best: 36** (then 3 and 35)
- **worst: 12**

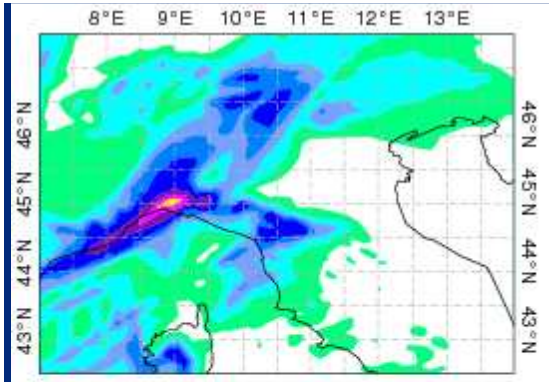


WRF

I.C. 26 Nov 12 UTC

t+78-84 h

- underestimation over Apennine
- **best: 3 or 36** (then 35)
- **worst: 12**



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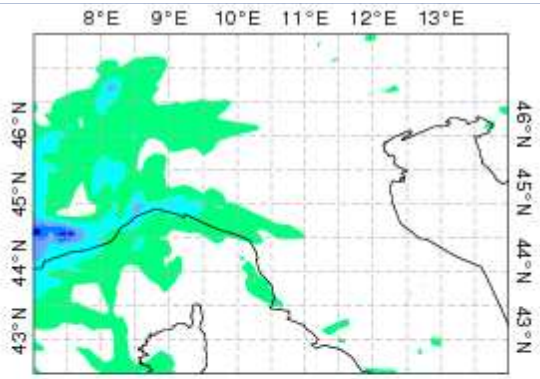
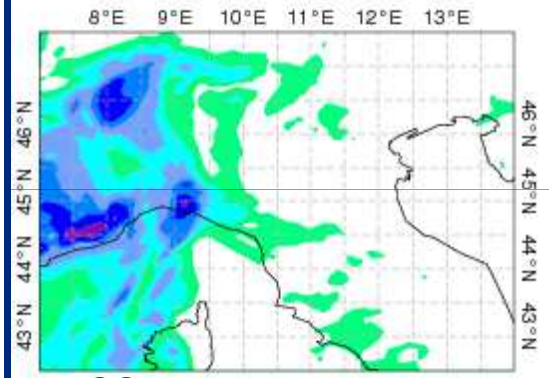


m12



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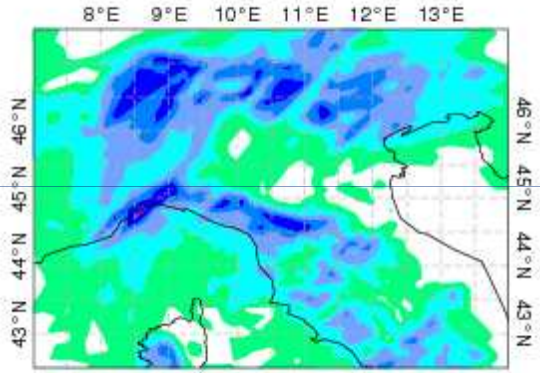
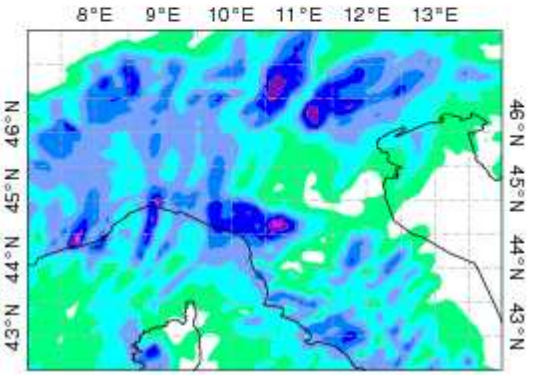
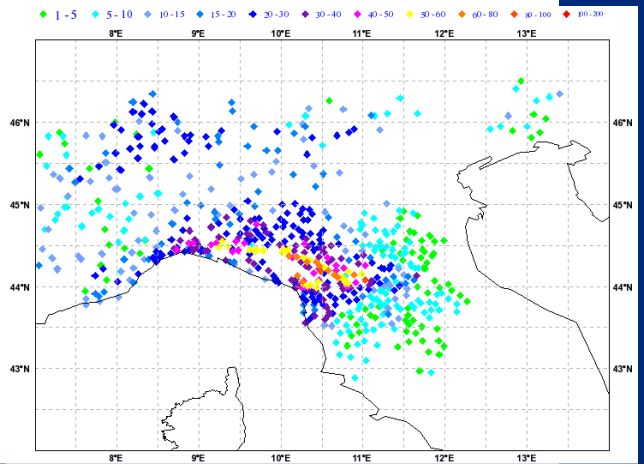
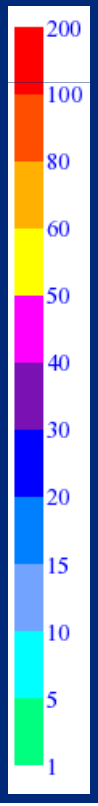


m35

m36

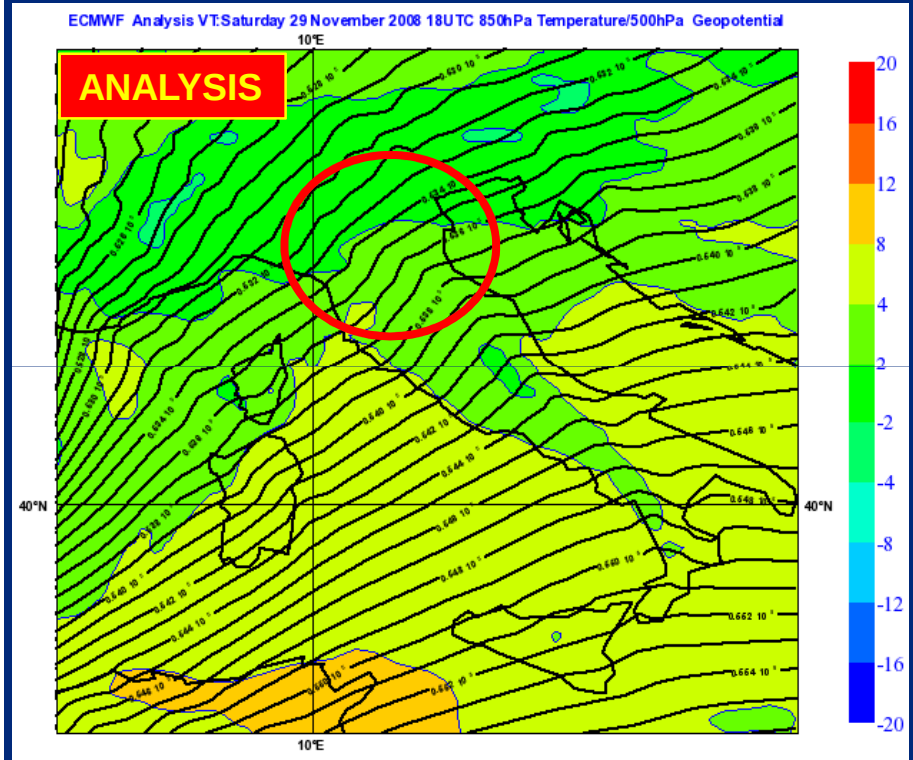


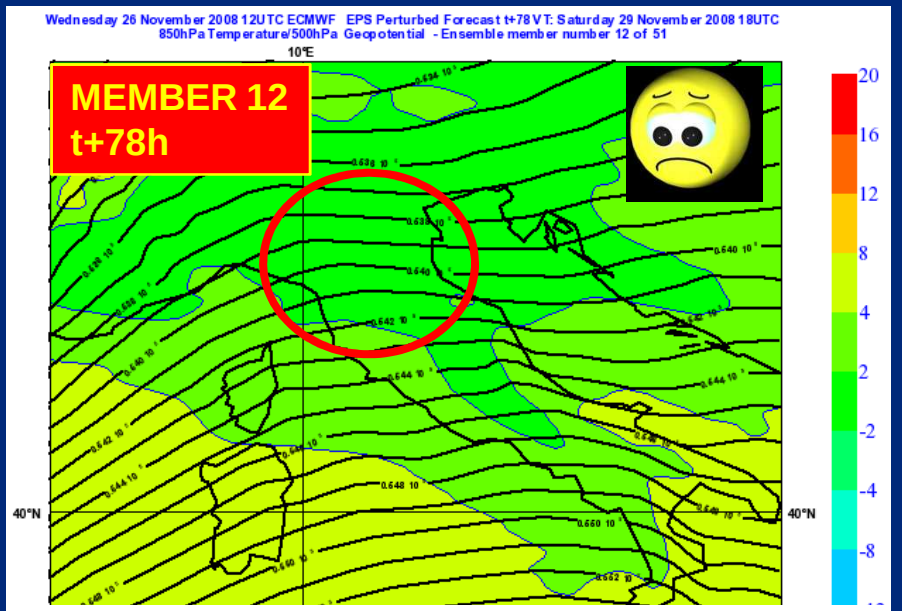


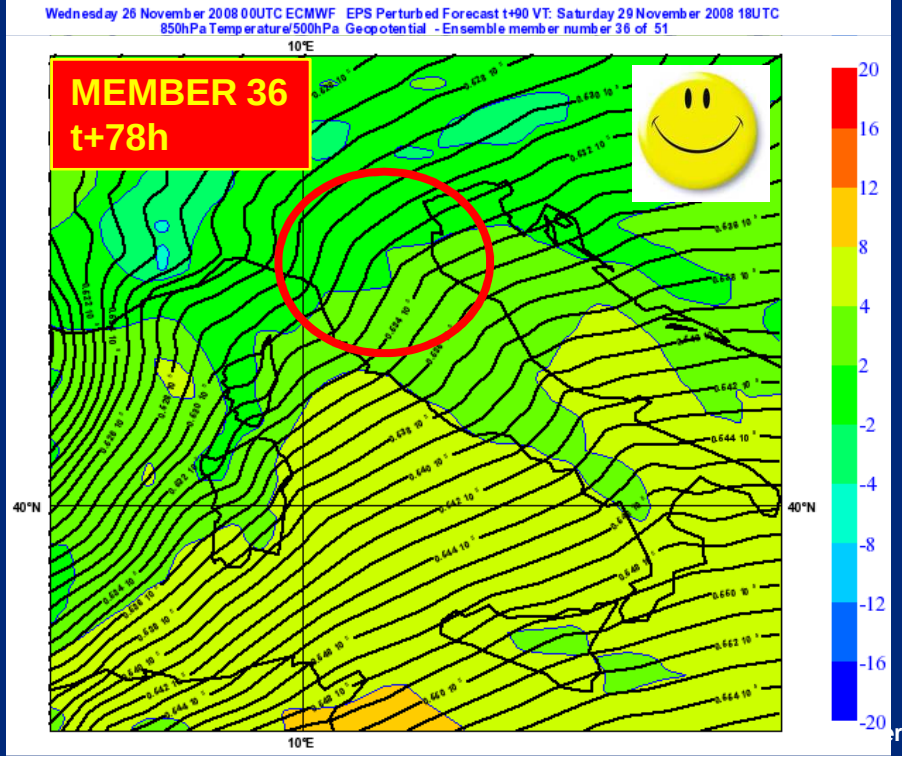


Forecasts driven by member 12 provide bad rainfall predictions at long range!

Large scale ECMWF fields
GPH 500hPa & T@850hPa
at 18 UTC, 29 Nov 2008







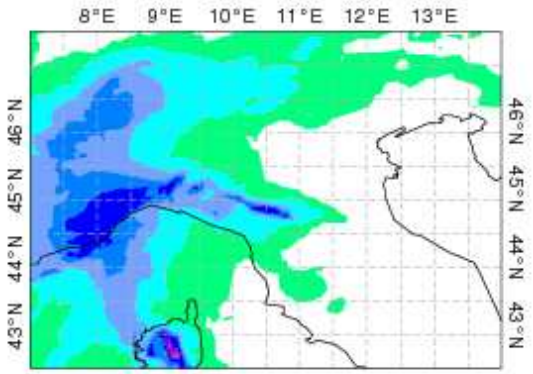
At long forecast range (day 3-5) the quality of the multi-model ensemble members is dominated more by the boundary conditions than by the model used for the integration.

COSMO

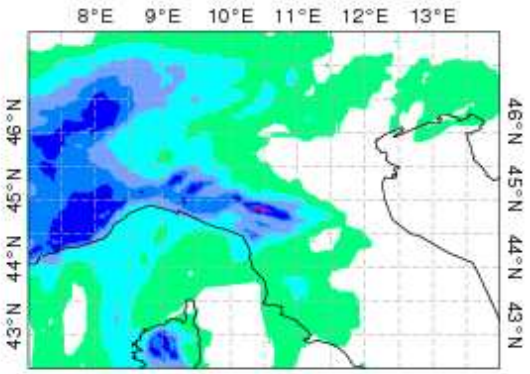
I.C. 28 Nov 12 UTC

t+30-36 h

- underestimation over Apennine
- best: 45 (then 26 and 15)
- worst: 5



m5



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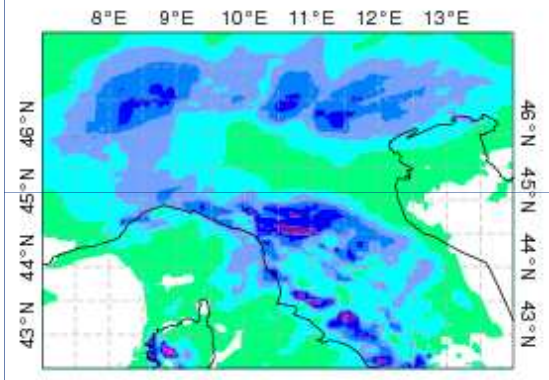

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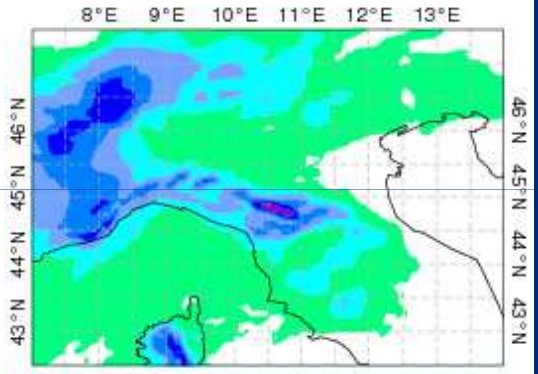

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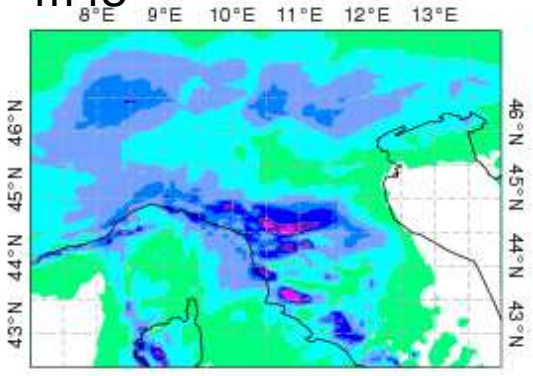
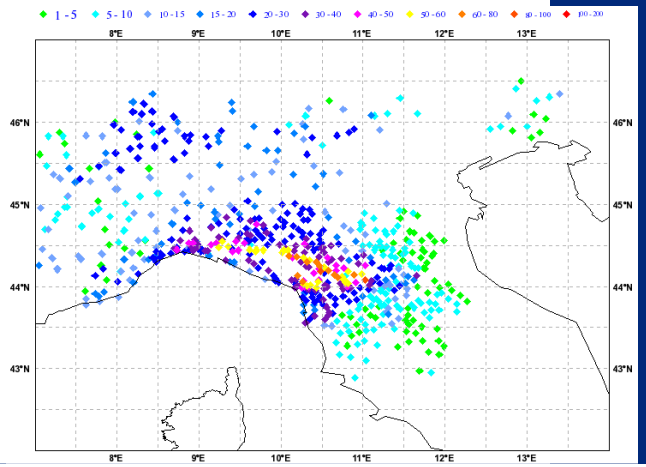
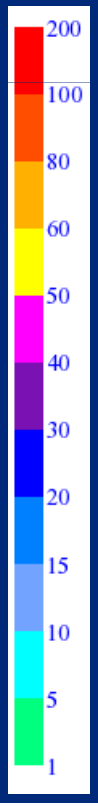
m45





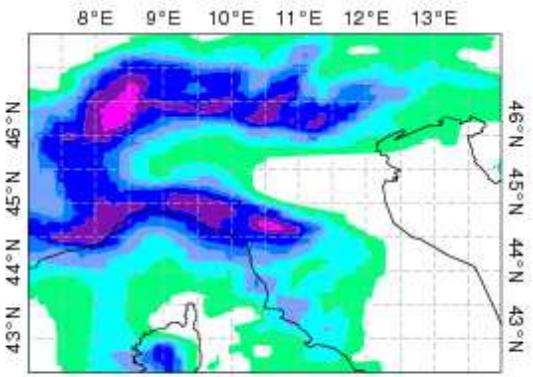


BOLAM

I.C. 28 Nov 12 UTC

t+30-36 h

- overestimation over Alps
- best: 15 (then 45)
- worst: 44



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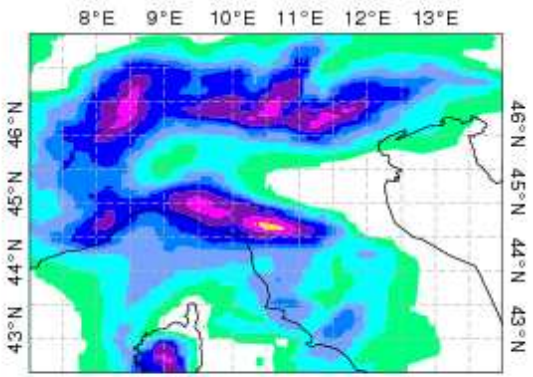

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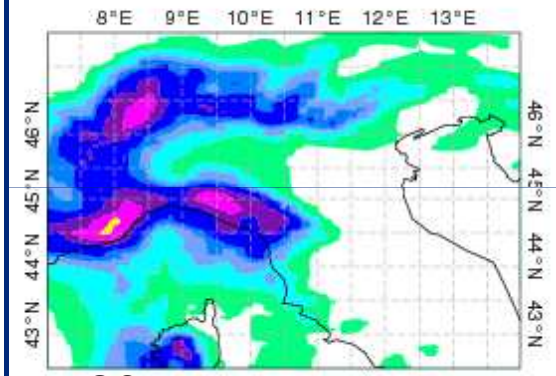

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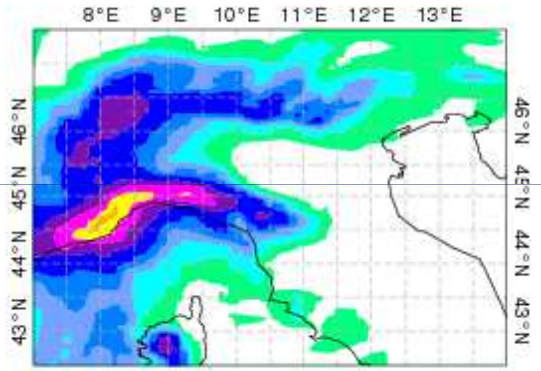
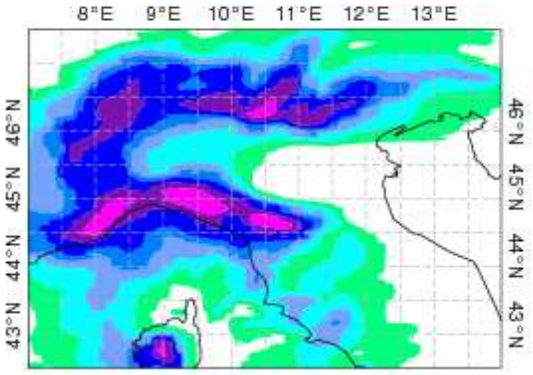
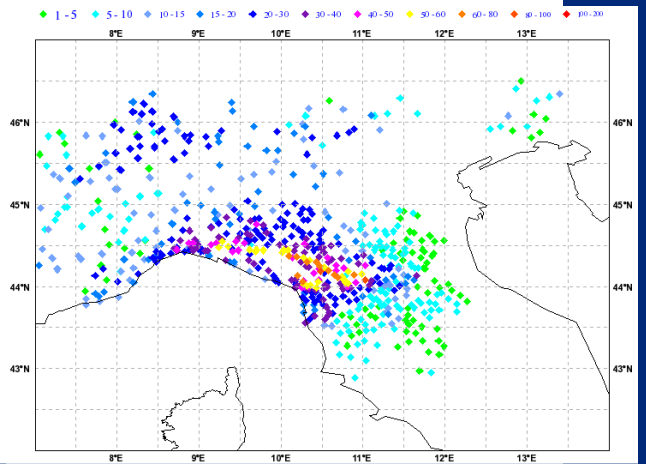
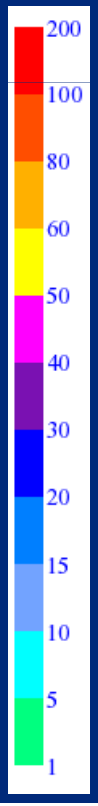


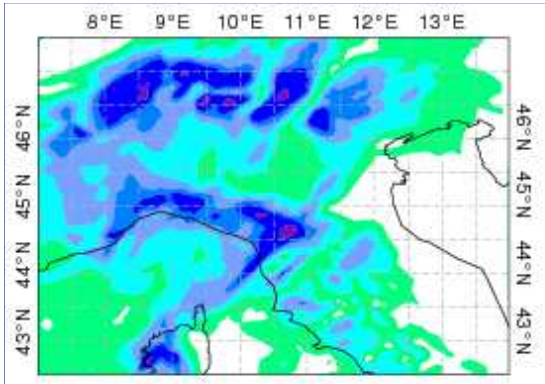
m44

m45









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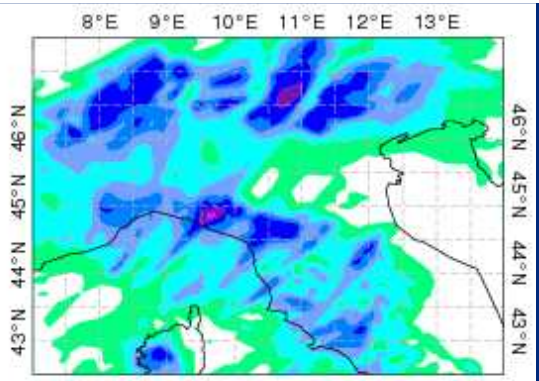

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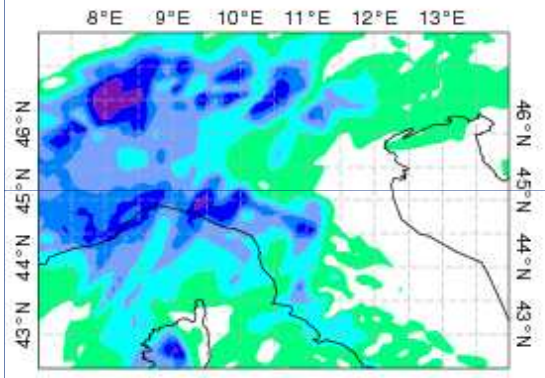

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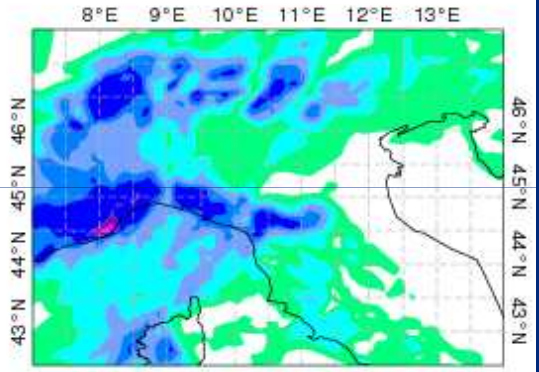

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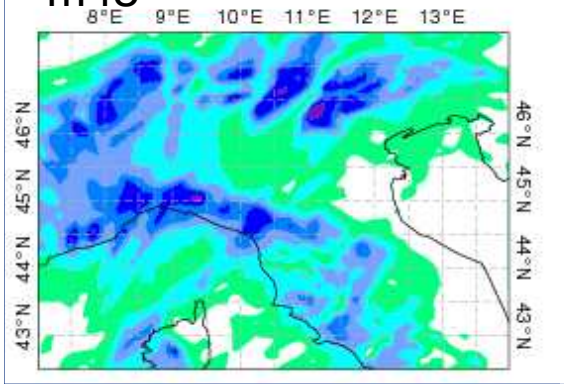
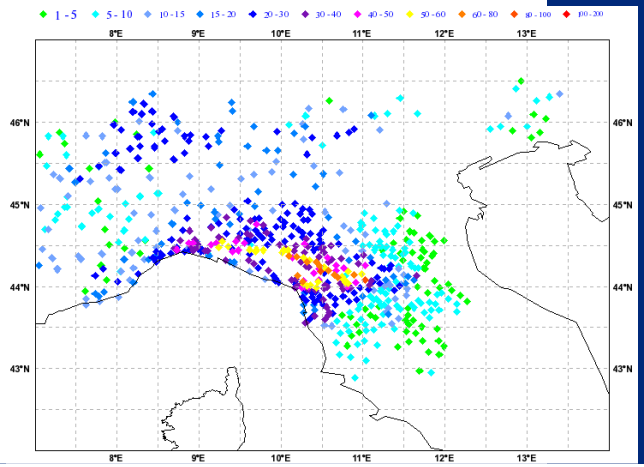
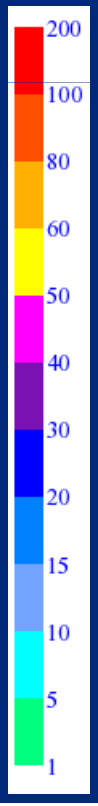






WRF

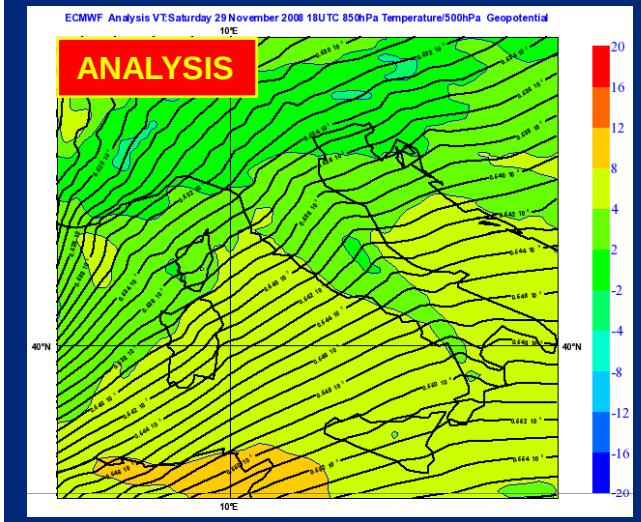
I.C. 28 Nov 12 UTC

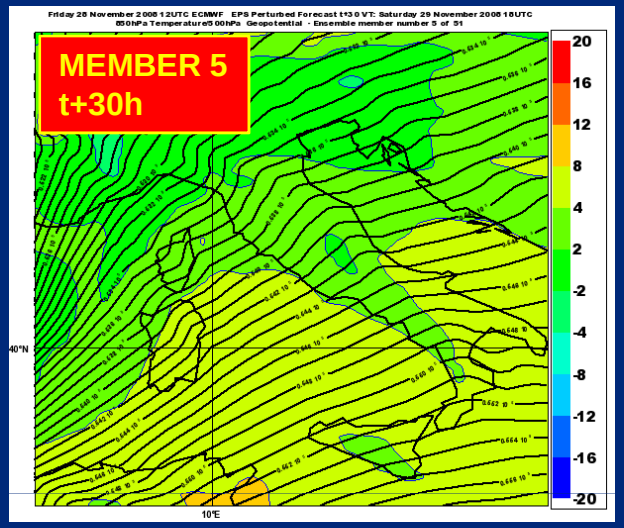
t+30-36 h

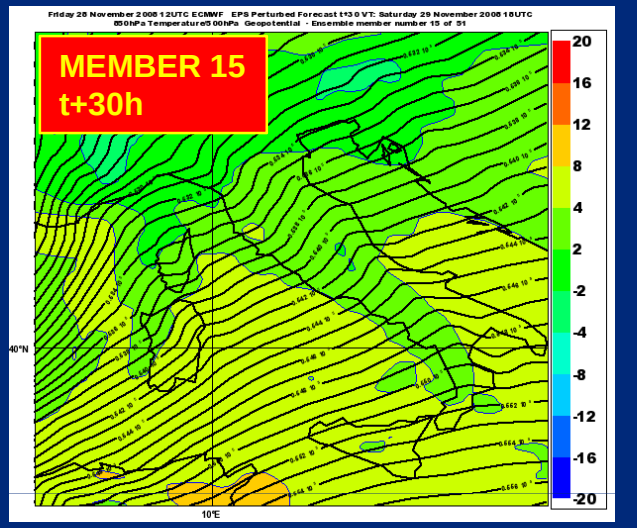
- underestimation over Apennine
- members quite similar
- best: 5
- worst: 45

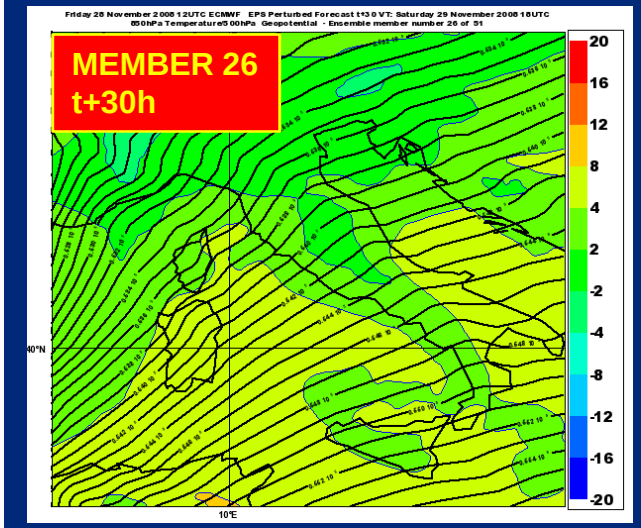
- Large variability among forecasts issued by different models
- Weak variability among the 5 forecasts issued by each single model

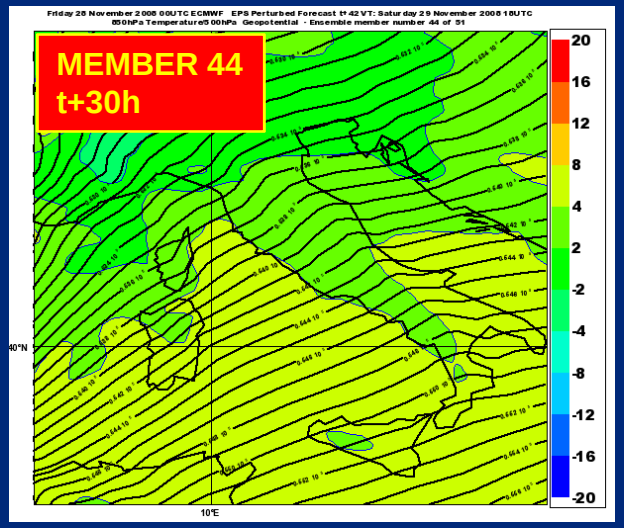
Large scale ECMWF fields - GPH 500hPa & T@850hPa - at 18 UTC, 29 Nov 2008

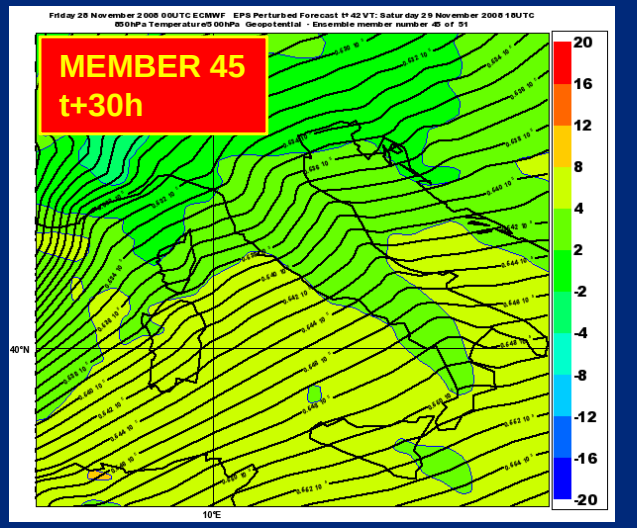












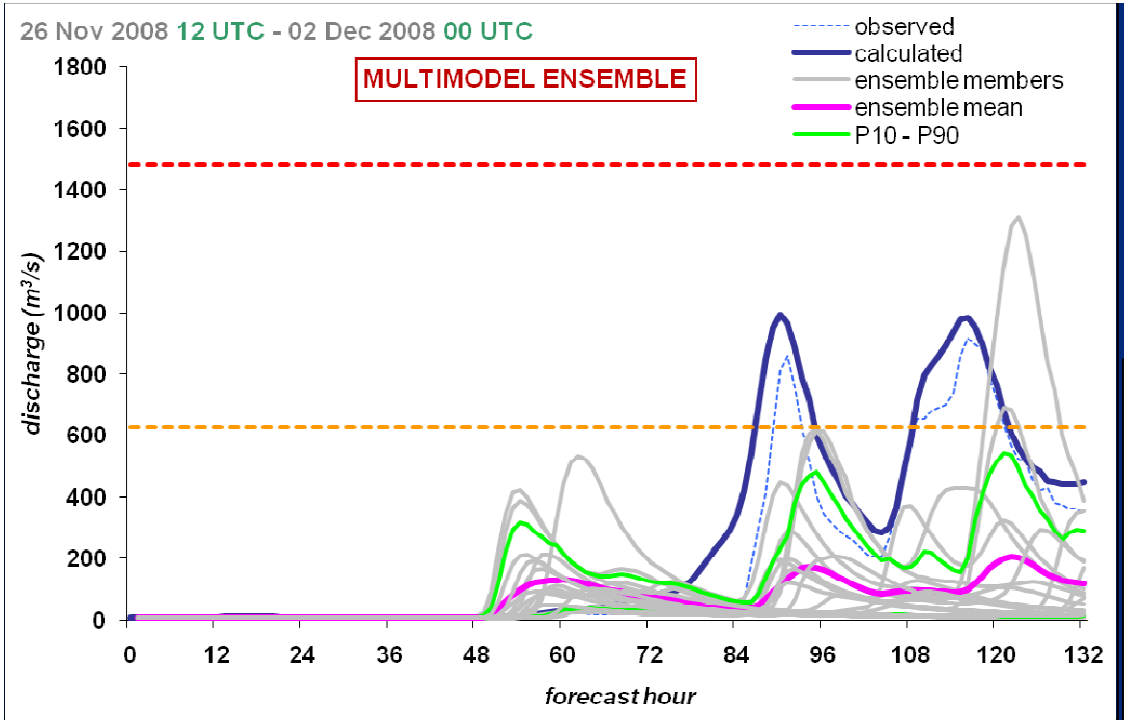
- The large scale conditions are similar (short-range forecast!) and the spread of the ensemble is provided by the different characteristics of the models

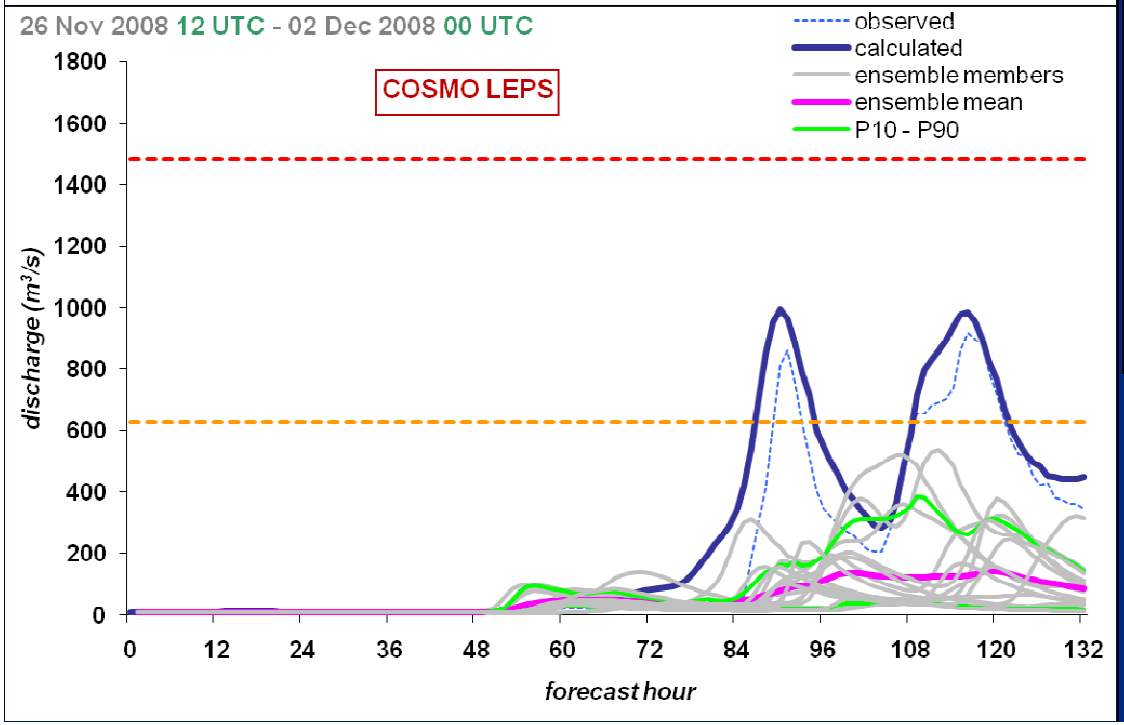
DISCHARGE FORECASTS

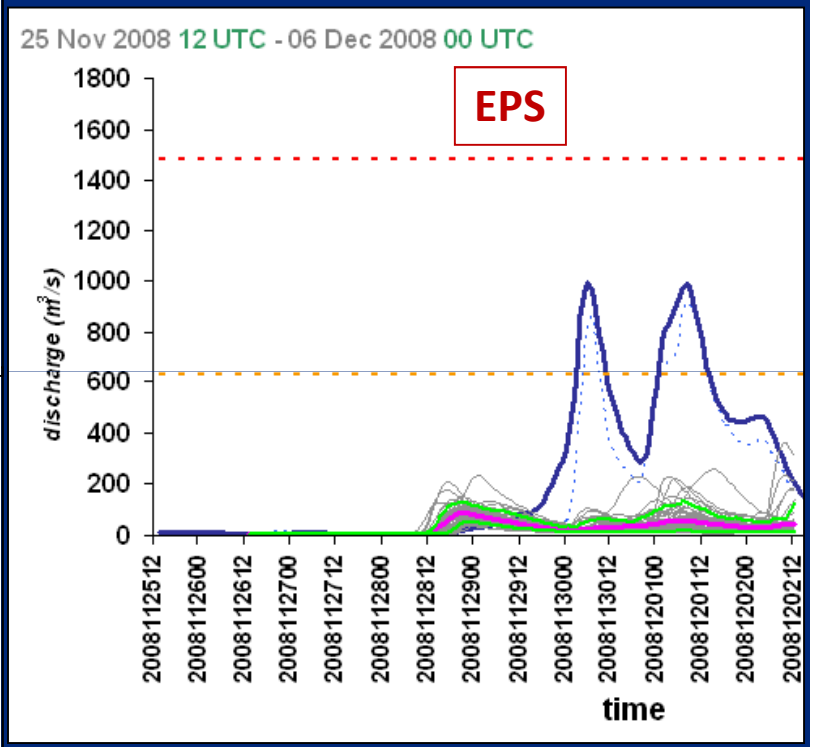
HYDROLOGICAL PERSPECTIVE

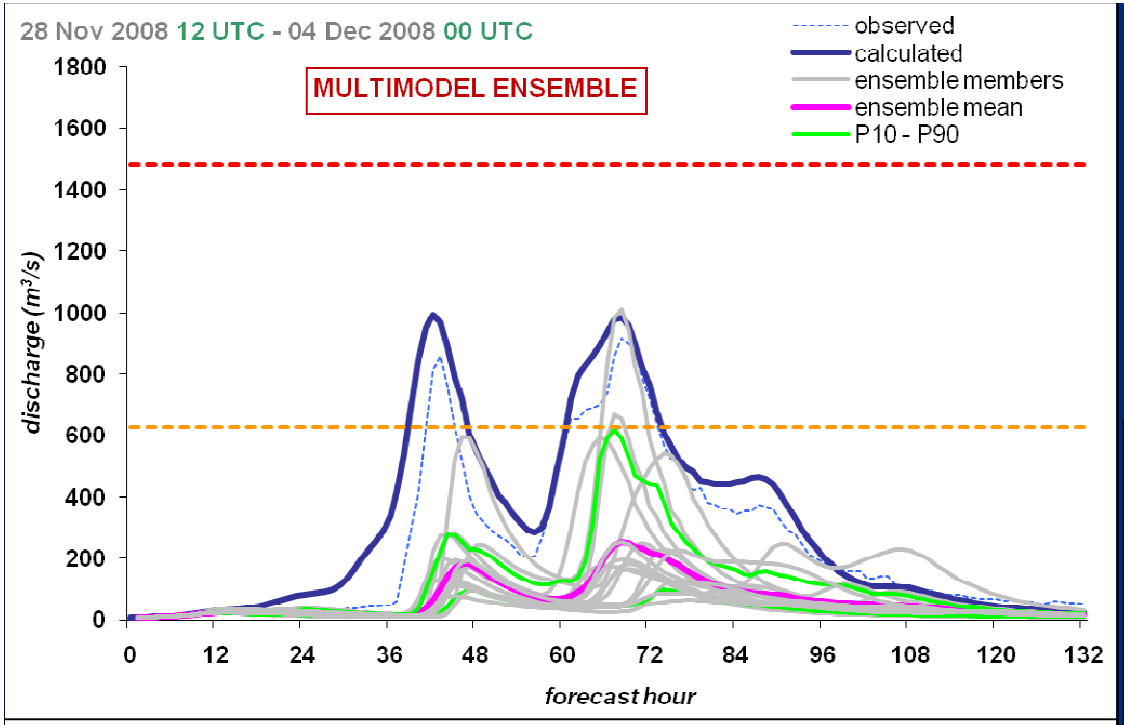
... back to small scale (basin scale)

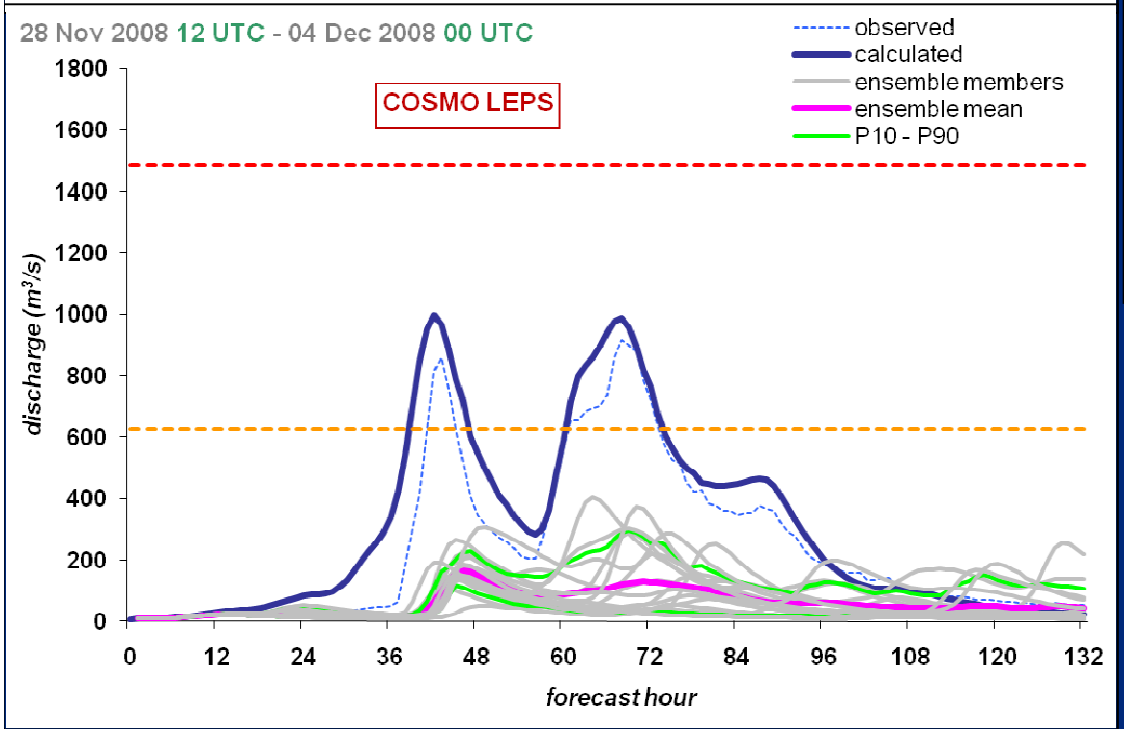
I.C. 26 Nov 12 UTC
Long forecast range



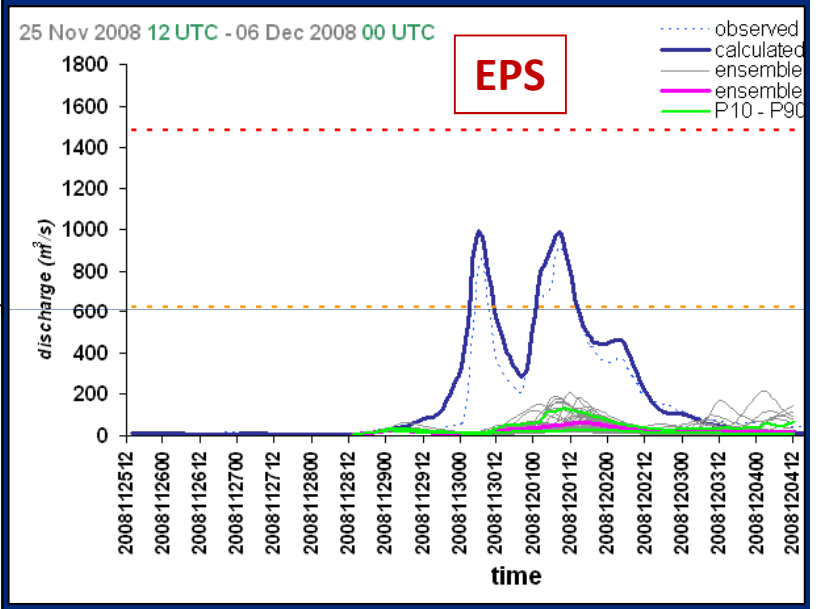




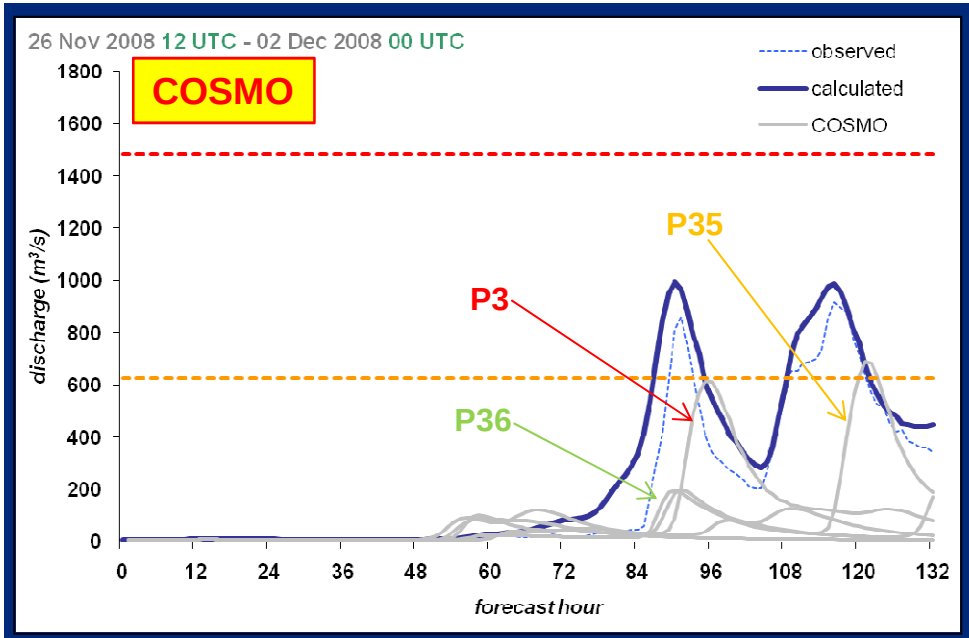


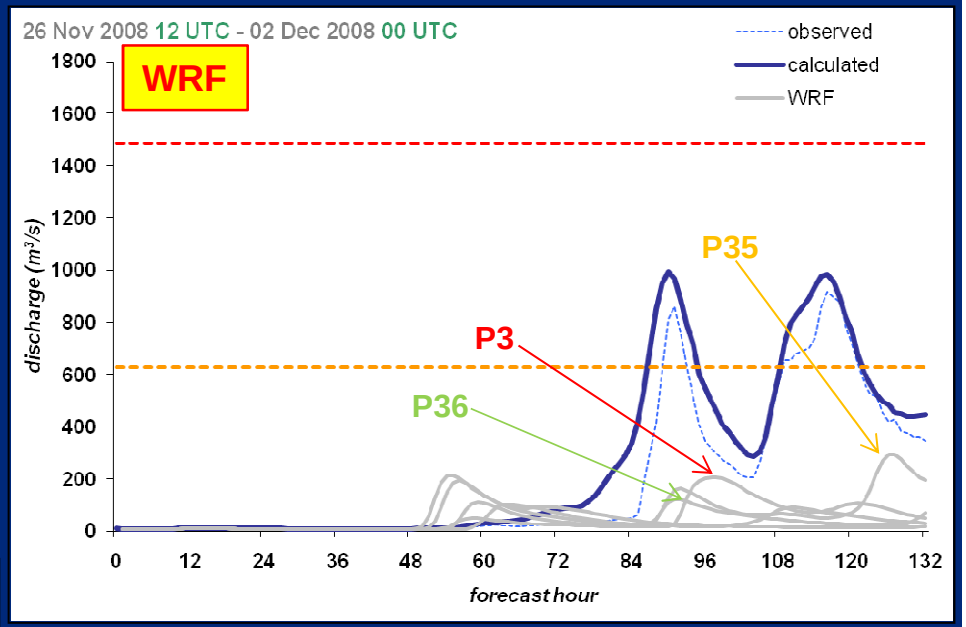


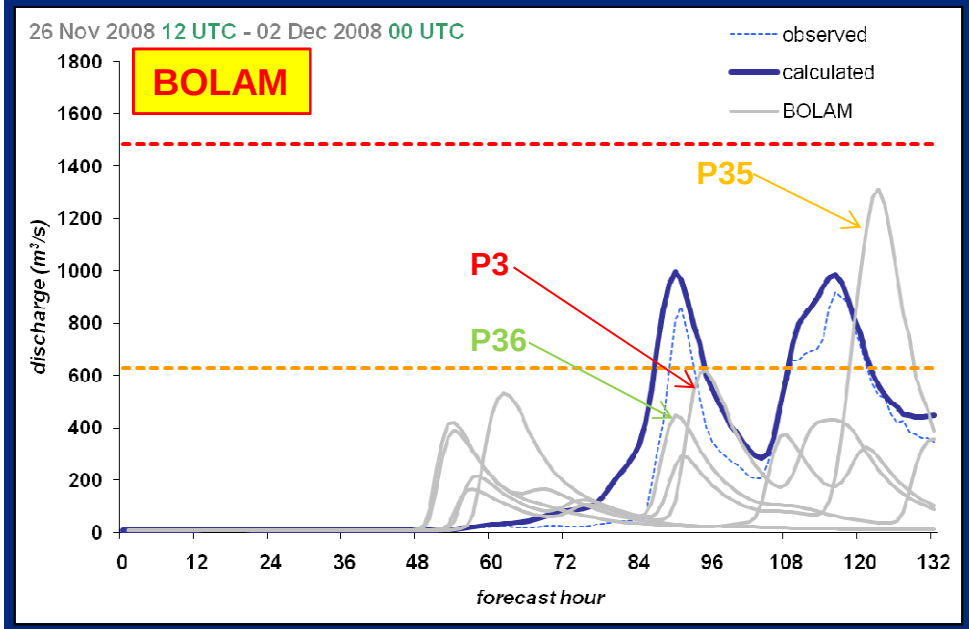
I.C. 28 Nov 12 UTC
Short forecast range

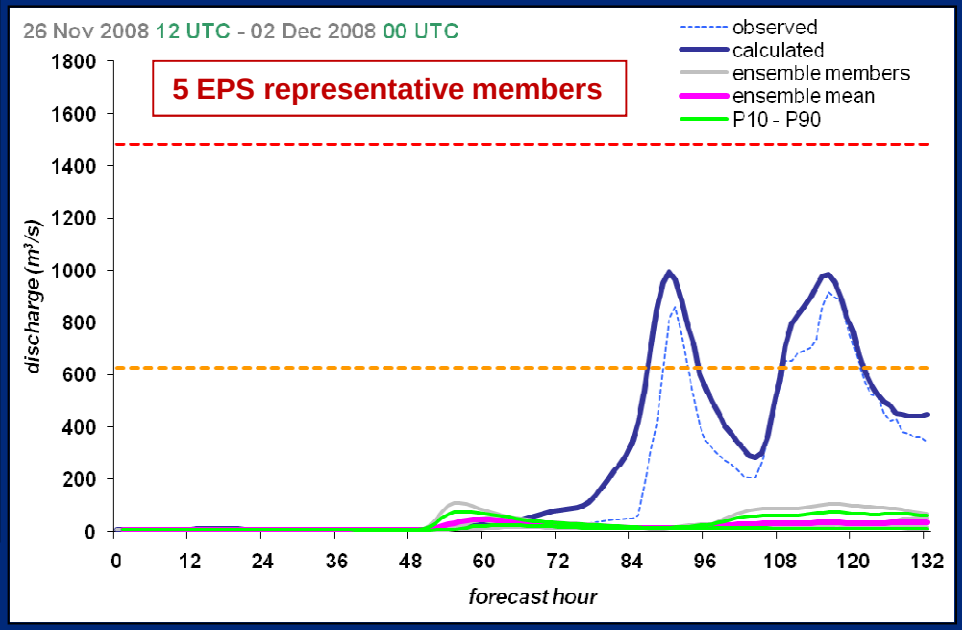


I.C. 26 Nov 12 UTC
Long forecast range

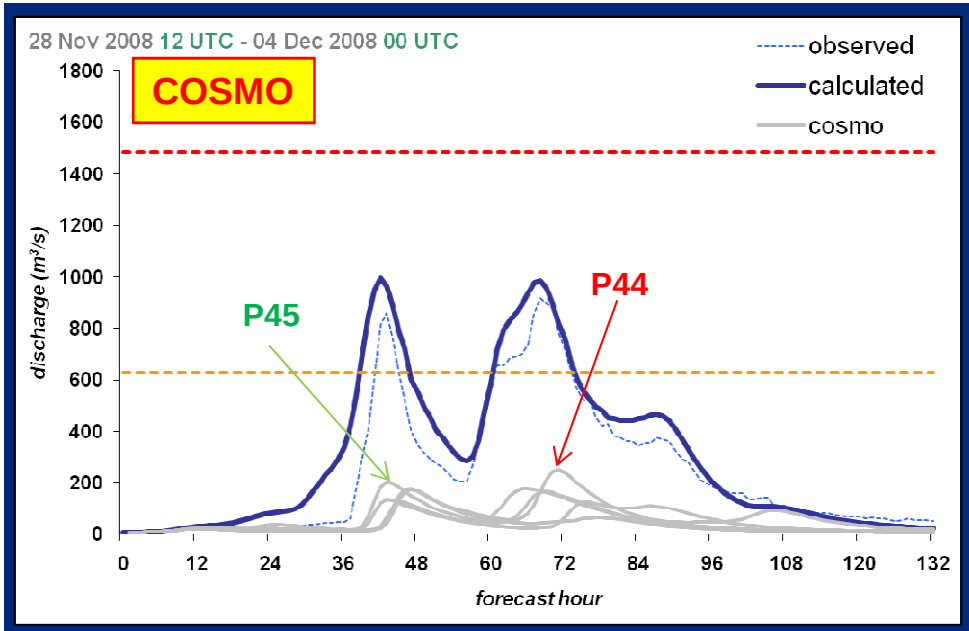


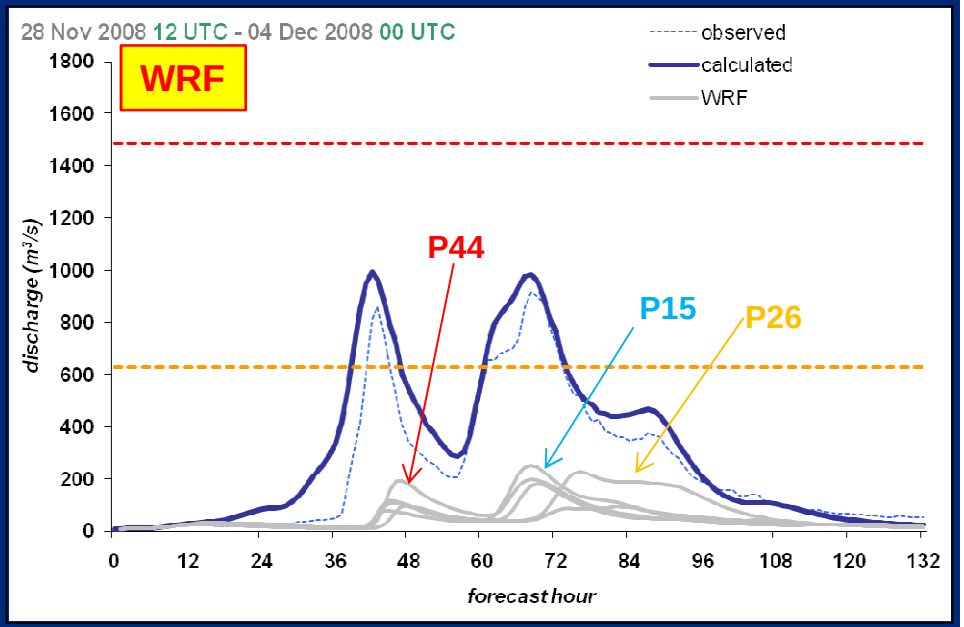


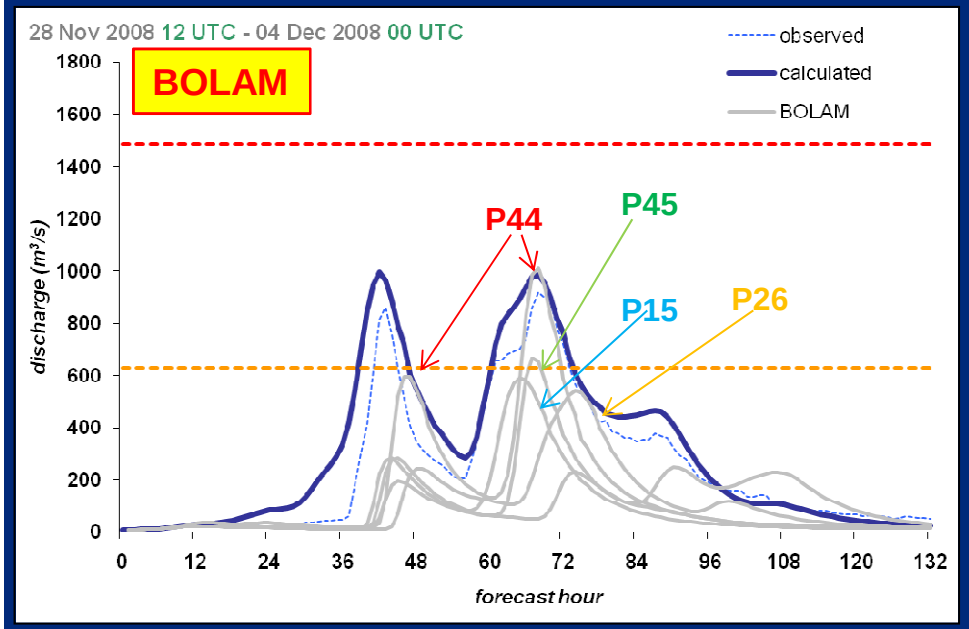


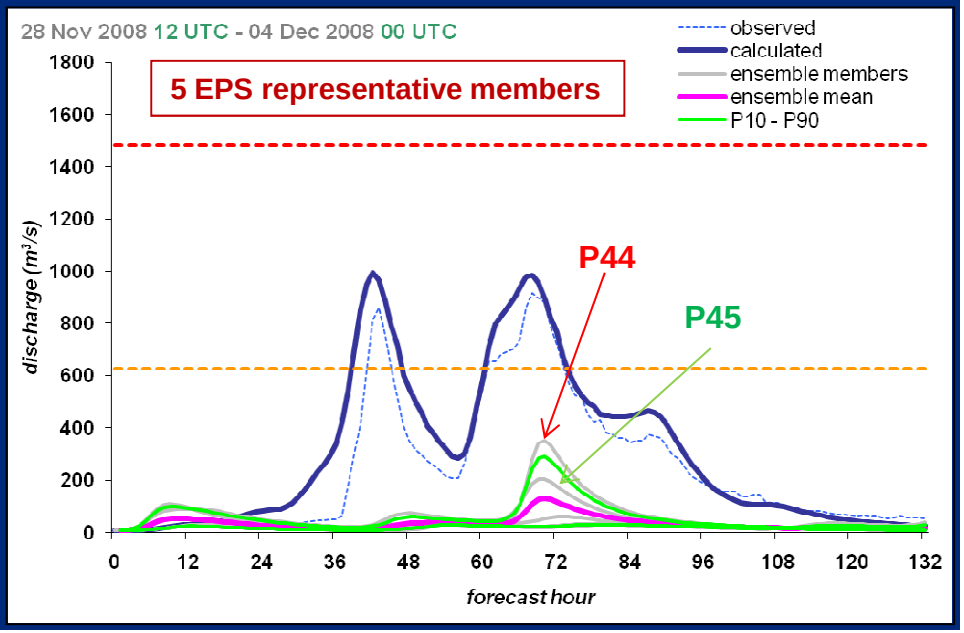


I.C. 28 Nov 12 UTC
Short forecast range









CONCLUSIONS

• Both mesoscale ensemble approaches remarkably improve the forecast quality in terms of both probability of precipitation and discharge prediction, with respect to the “driving” global model ensemble.
• Structural model deficiencies (low resolution, orography representation) cannot be accounted for by coarse resolution ensembles. Higher resolution models are needed => added value of LAM ensembles.
• Multimodel LEPS provides better results with respect to COSMO-LEPS, being characterized by a larger spread at short range due to different model characteristics. At longer forecast range, the similar behaviour of the Multimodel LEPS members indicates the relevant impact of the boundary conditions. The greater degree of diversity of the Multimodel LEPS members is the added value of the multi-model approach with respect to single-model COSMO-LEPS.

This results is limited to this single case study!!!

FUTURE PLANS

• Testing sensitivity to clustering analysis (e.g. clustering interval)
• Further case studies!
• Testing convection-resolving model ensemble for short range application.


THANKS !!!