Meteo-hydrological predictions: testing different ensemble approaches

S. Davolio[1], T. Diomede[2], C. Marsigli[2], M. M. Miglietta[3], A. Montani[2] A. Morgillo[2]

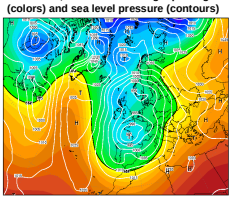
[1]Institute of Atmospheric Sciences and Climate – National Research Council (ISAC – CNR), Bologna, Italy
[2]Hydro-Meteo-Climate Service of Emilia-Romagna ARPA-SIMC, Bologna, Italy
[3]Institute of Atmospheric Sciences and Climate – National Research Council (ISAC – CNR), Padova, Italy

INTRODUCTION AND MOTIVATIONS

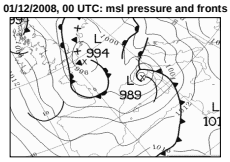
For medium-sized catchments, characterized by short response times, hydrological predictions have to rely on quantitative precipitation forecasts (QPFs) issued by meteorological models. In order to represent the uncertainty inherent to QPFs, which can be relevant at the scales of interest for hydrological purposes, the ensemble forecasting approach is becoming a common practice to provide multiple precipitation scenarios to be used as the input for a hydrological model. Here the hydrological model TOPKAPI is used to propagate the uncertainty in the flood forecasts, providing probabilistic hydrological prediction.
Two different ensemble approaches are tested in a real-time configuration:
1.COSMO-LEPS, the operational Limited-area EPS of the COSMO Consortium, which has been developed to combine the advantages of global-model ensembles with the high-resolution details gained in limited-area-model integrations, so as to improve the Late-Short (t+48h) to Early-Medium (t+132h) range forecasts of severe weather events.
2.A multi-model forecasting system based on four mesoscale models (BOLAM, COSMO, MOLOCH and WRF), implemented at different horizontal resolutions, ranging from 8 to 2.5 km. It is aimed at improving short range forecasts (up to t+72h) of intense precipitation
COSMO-LEPS may provide an alert window between 3 and 5 days in advance. The high resolution multi-model ensemble may provide a more accurate timing and magnitude of the event.

SYNOPTIC SITUATION

30/11/2008, 00 UTC: 500 hPa geop. height (colors) and sea level pressure (contours)

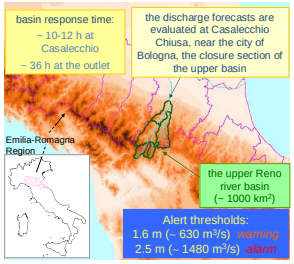


01/12/2008, 00 UTC: msl pressure and fronts



-Deep trough elongated from North to South and associated with cold air moving toward the Mediterranean;
-Several frontal systems moving in the cyclonic circulation over western Mediterranean
-Warm air advection on east side of the trough, sustained by intense southerly moist flow;
-Blocking over Eastern Europe
-Lee orographic cyclogenesis in the second part of the event

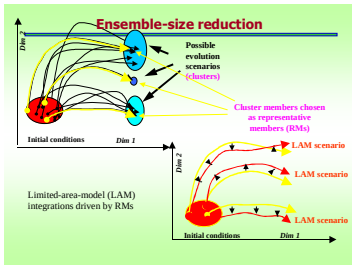
TARGET AREA

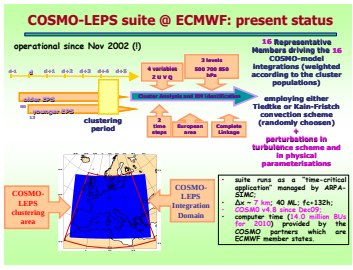


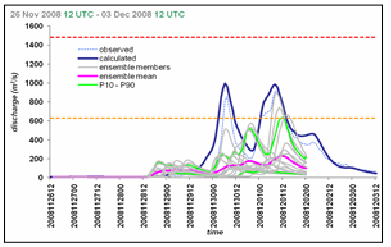
THE HYDROLOGICAL MODEL: TOPKAPI
Distributed physically based model (Todini and Ciarapica, 2002)

COSMO-LEPS Limited-area Ensemble Prediction System

- COSMO-LEPS is based on the non-hydrostatic limited-area-model COSMO.
- The different model runs are nested on some selected members of the ECMWF Ensemble Prediction System (EPS), chosen by means of an ensemble-size reduction technique based on a Cluster Analysis.
- The selected EPS "representative" members provide both initial and boundary conditions to COSMO integrations (16 members at 7 km horizontal resolution).



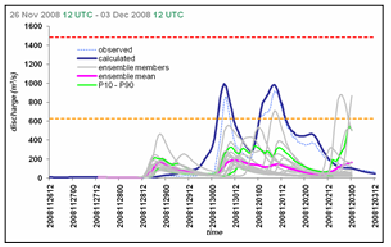




0 +24 +48 +72 +96 +120 +144 +168
Forecast range (h)

STARTING DATE: 26/11, 12 UTC

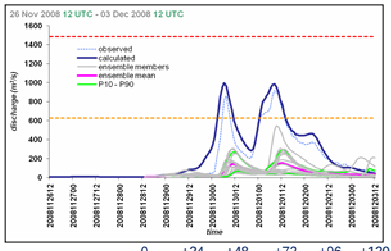
- At 5-days COSMO-LEPS forecasts three discharge peaks, with three members (and the 90th percentile) exceeding the lower warning threshold only in correspondence of the 2nd observed peak.
- Most of the members strongly underestimate the two calculated peaks.
- The ensemble mean does not provide a useful indication of the occurrence of the events.
- None of the single members predicted two peaks.



0 +24 +48 +72 +96 +120 +144
Forecast range (h)

STARTING DATE: 27/11, 12 UTC

- Closer to the event, the uncertainty in the timing of the peaks is even increased.
- Only one member reaches the lower warning threshold, the totality of the ensemble members underestimates the discharge.



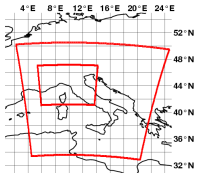
0 +24 +48 +72 +96 +120
Forecast range (h)

STARTING DATE: 28/11, 12 UTC

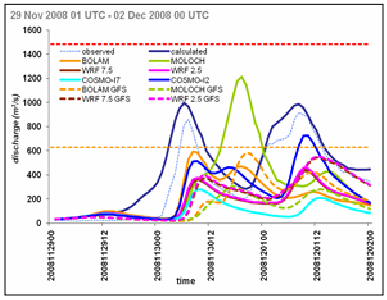
- At 3-days COSMO-LEPS shows a good agreement in the timing of the discharge peaks, but the magnitude of the event is greatly underestimated.
- None of the members exceeds the lower warning threshold.

Multi-model/Multi-analysis Ensemble

MODEL	Horizontal Resolution (km)	Grid points	Levels	Initial/boundary conditions	Nesting Procedure
BOLAM	8	200 x 240	42	ECMWF analyses/forecasts	/
BOLAM	8	200 x 240	42	GFS analyses/forecasts	/
MOLOCH	2.8	240 x 240	50	BOLAM	1-way nesting
LM7	7	234 x 272	41	ECMWF analyses/forecasts	/
LM2.8	2.8	246 x 240	41	LM7	1-way nesting
WRF7.5	7.5	200 x 240	42	ECMWF analyses/forecasts	/
WRF7.5	7.5	200 x 240	42	GFS analyses/forecasts	/
WRF2.5	2.5	244 x 238	42	WRF7.5	2-way nesting



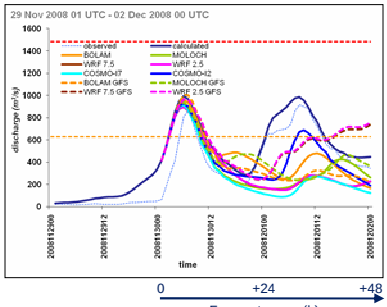
MODEL INTEGRATION DOMAINS



0 +24 +48 +72
Forecast range (h)

STARTING DATE: 29/11, 00 UTC

- Large spread in the 72 h discharge forecasting range especially after the first peak, both in terms of timing and amount. Only 2 members exceed the lower warning threshold.
- The runs driven by IFS generally reproduce the two-maxima structure, although the discharge is underestimated.
- COSMO-I2 reproduces the second peak quite well (at t=+60 h), correctly exceeding the lower warning threshold.
- The MOLOCH run shows a different behaviour, predicting only one peak with a discharge value close to the observed peaks, but in the afternoon of 30/11 (at t=+42 h). A small peak at this time is forecasted also by BOLAM and COSMO-I2.
- The runs driven by GFS confirm the scenario forecast by the IFS-driven runs, still underestimating the amount.
- The GFS-WRF run reproduces better the amount of the second peak (at t=+60 h) with respect to IFS-WRF.



0 +24 +48
Forecast range (h)

STARTING DATE: 30/11, 00 UTC

-Large spread in the timing of the second peak.
-Although at shorter forecast range (+36 h) the model runs still underestimate the second discharge peak. Only COSMO-I2 and GFS-WRF reach the lower warning threshold.
- The GFS-WRF run shows an increase of the discharge after 12 UTC, 01/12 differently from the other runs, due to overestimation of the rainfall.

CONCLUSIONS

- The **COSMO-LEPS** provides a weak indication of the possibility to exceed the lower warning threshold 4-5 days ahead.
- The **COSMO-LEPS** predicts a much better timing 3 days ahead, but does not give correct indications about the intensity of the event.
- The **multi-model ensemble** provides an indication of the possible occurrence of an event exceeding the lower warning threshold, even if with great variability in timing, 2-3 days ahead of the event.
- As for the **multi-analysis multi-boundary** contribution, the use of GFS instead of IFS as initial condition improves the results in some cases and thus adds information to the ensemble.
- Forecasters experience and attitude are fundamental for a correct interpretation of probabilistic predictions at different lead times.

REFERENCES

- Diomede T., S. Davolio, C. Marsigli, M. M. Miglietta, A. Moscatello, P. Papetti, T. Paccagnella, A. Buzzi and P. Malguzzi, 2008: Discharge prediction based on multi-model precipitation forecasts. *Meorol. Atmos. Phys.* **101**,245-265.
- Davolio S., M. M. Miglietta, T. Diomede, C. Marsigli, A. Morgillo and A. Moscatello, 2008: A meteo-hydrological prediction system based on a multi-model approach for precipitation forecasting. *Nat. Hazard Earth Syst. Sc.* , **8**, 143-159.
- Marsigli C., Montani A. and Paccagnella T., 2008: A spatial verification method applied to the evaluation of high-resolution ensemble forecasts. *Meteorological Applications*, **15**, 125-143.
-Todini E., Ciarapica L., 2002: The TOPKAPI model. In: Mathematical Models of Large Watershed Hydrology, ed. by Singh VP, Frevert DK. Littleton, Colorado, USA: Water Resources Publications, 914 pp