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Evaluating the uncertainty of hydrological model simulations coupled with meteorological forecasts at different spatial scales

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Abstract

In recent years, the interest in the prediction and prevention of natural hazards related to hydro-meteorological events has increased the challenge for numerical weather modeling, in particular for limited area models, to improve the Quantitative Precipitation Forecasts for hydrological purposes. In this study a hindcast for some precipitation events, occurred in Piemonte region and in the Maggiore Lake basin, is analyzed to evaluate how the uncertainty of meteorological forecasts influences the performance of hydrological predictions at different spatial scales. This hydro-meteorological chain includes both probabilistic forecasting based on ensemble prediction systems and deterministic forecasts based on high resolution atmospheric models. The hydrological model used to generate the runoff simulations is the rainfall-runoff distributed FEST-WB model, developed at Politecnico di Milano.

Keywords: Hydro-meteorological chain; hydrological model uncertainty; Map-D-Phase; QDF; ensemble hydrological forecast.

1. Main text

Over the last twenty years severe river floods have occurred in Europe, causing thousands of deaths and billion Euros in insured economic losses. Weather forecast, coupled to hydrological model to realize a forecasting cascade, can be used to decide on an early water-system control action to prevent or reduce problems with floods, droughts or water quality. Therefore, coupling meteorological and hydrological models became a great issue and challenge in the scientific community during the last decade.

To reduce the impact of floods through early warning system, in 2003 the European Commission started the development of a European Flood Alert System (EFAS) to provide medium-range flood simulations across Europe. Other international programmes dealing with these topics were HEPEX, AMPHORE (Application des Methodologies de Previsions Hydrometeorologiques Orientees aux Risques Environnementaux), RAPHAEL (Runoff and Atmospheric Process for flood Hazard forecasting and control), the European COST Action 731 (Propagation of Uncertainty in Advanced Meteo-Hydrological Forecast System), the Mesoscale Alpine Programme (MAP), and the D-PHASE (Demonstration of Probabilistic Hydrological and Atmospheric Simulation of Flood Events) (Zappa et al. 2008), where recent improvements in the operational use of an end to end forecasting system, consisting of atmospheric models, hydrological prediction systems, nowcasting tools and warnings for end users, were shown (Ranzi et al., 2009).

Quantitative Precipitation Forecast (QPF) is the most difficult task of meteorological models and can affect significantly the reliability of flood forecasting system. Furthermore complexity arises over mountainous areas, since Numerical Weather Prediction (NWP) is complicated by orographic effect.

In order to quantify uncertainty of flood prediction, the hydrological community is increasingly looking at the use of Ensemble Prediction System (EPS) instead of single (deterministic) forecasts for flood warning. From hydrological perspective, the use of EPS, as input to a hydrological model, is an important tool to produce river discharge predictions (Pappenberger et al., 2005) and to assess uncertainty involved in forecasting precipitation.

In this analysis the hydrological ensemble forecasts are based on the 16 meteorological members, provided by COSMO-LEPS model (by ARPA Emilia-Romagna) with 5 day lead-time and a horizontal resolution of 10 km and deterministic hydrological forecasts, provided by MOLOCH weather model (by ISAC-CNR) with a horizontal resolution of 2.2 km, nested into BOLAM, based on GFS initial and boundary conditions with 48 h lead-time.

The hydrological model used to generate the runoff simulations is the rainfall-runoff distributed FEST-WB model, developed at Politecnico di Milano. The observed data to run the control simulations were supplied by ARPA-Piemonte, which uses the same model every day for nowcasting monitoring and as a civil-protection tool.

The study is focused on Piemonte region and Maggiore Lake basin, an alpine basin between North-West of Italy and Southern Switzerland. In order to demonstrate the research progress on coupling meteorological and hydrological models, some precipitation events occurred in the recent years were re-analysed in this area, which was unfortunately affected by frequent flood events during the two last decades (1993, 1994, 1996, 2000, 2002, and 2008).

First step in this research is to value the sensitivity of hydrological model, which uses a finer spatial resolution (1 km), forced with meteorological data, coming from observed weather stations, aggregated at different spatial and time scales. Therefore it is presented how the meteorological forecasts are efficient into hydrological forecasting system at different days in advance, how the ensemble predictions are powerful to evaluate the uncertainty of the QPF which affects the Quantitative Discharge Forecast (QDF) and the whole hydro-meteorological alert system.

In fact, in some cases, an error of meteorological forecast can be compensated by an error of hydrological model and vice versa; an overestimation or an underestimation of weather models can be enhanced or covered by hydrological model performance. Even if the QDF seems equal to the river discharge measured at basin close sections, this is a crucial point which increases more the uncertainty in hydrological forecast.

Further, it was focus the attention on key role of air temperature which is a crucial feature in determining the partitioning of precipitation in solid (snow) and liquid phase (rainfall) that can affect the river discharge prediction in autumn and winter seasons in the alpine region.

Finally, in order to control the quality of the hydrological predictions in the short and medium range, statistical methods and skill scores are used to calculate the hydro-meteorological chain performance and how the ensemble forecasts can help the users for decision making in management situations. The introduction of alert codes appears to be another useful tool for decision makers to give them a spread of forecasted QDFs, coming from different weather and hydrological models with the probability of event occurrence.

2. References

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