FLASH FLOOD FORECASTING WITHIN THE PREVIEW PROJECT : HIGH-RESOLUTION HYDROMETEOROLOGICAL SIMULATIONS

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Keywords: *PREVIEW, flash flood, high-resolution models, quantitative precipitation forecast, quantitative discharge forecast*

1. FLASH FLOOD FORECASTING WITHIN PREVIEW

PREVIEW (**PREV**ention, **I**nformation and **E**arly **W**arning) is a European Commission FP6 Integrated Project which aims at developing, on a European level, new geo-information services for natural and industrial risk management. The different themes are atmospheric risks (plain floods and flash floods, fires and windstorms), geophysical risks (earthquakes and volcanoes, landslides), man made risks (nuclear and chemical accidents.)

Within the flood platform of the project, a specific action is dedicated to Mediterranean flash floods. Its aim is to improve the very short-range forecast of Mediterranean flash-floods over medium basins, based on the next generation European high-resolution Numerical Weather Prediction (NWP) models. Partners involved in this action are Météo-France/CNRM (France), ARPA Piemonte (Italy), LTHE (France), NOA-IERSD (Greece), Meteo-Swiss (Swiss) and Noveltis (France).

The project is composed of two distinct phases. The 2-year Phase 1 took end in April 2007. It was dedicated to the assessment of usefulness of kilometric scale atmospheric model forecast for hydrological applications as well as the development of hydro-meteorological coupled systems based on high-resolution atmospheric models and hydrological models adapted to the fast hydrological response of Mediterranean catchments. In Phase 2 (April 2007 to December 2008), the technical know-how obtained in Phase 1 will be useful to assess the added value and development of specific end-user oriented products.

2. EXPERIMENTAL DESIGN

2.1 Flash-flood Cases

The Cévennes-Vivarais region (Southeastern France) and the Italian Piedmont (North Italy) have been chosen as pilot sites. Their small to medium catchments are very prone to flash floods and both regions are well instrumented with operational observation systems. Five recent flash flood events which have occurred on those areas have been studied during Phase 1. Concerning Cevennes – Vivarais region, three events with recorded precipitation above 150 mm a day were selected. The first one took place from the 1st to the 3rd of December 2003 with 3-day accumulated rainfall reaching more than 300 mm that occurred over a very moistened soil. This leaded to a major flood of the Rhône river. Another event occurred in the beginning of September 2005. From the 5th to the 6th, heavy rainfall (up to 300 mm in two days locally) leaded to almost saturated water soil and was followed by another day of intense precipitation the 8th (about 220 mm in 24 h). This second heavy rainfall event triggered flash-flood in the small catchments of Gardon, Ceze and Ardeche rivers. The last one, less severe, occurred the 4th November 2004 with daily precipitation of about 150 mm.

Concerning the Italian cases, the first event began the 4th of June 2002 with daily precipitation reaching 300 mm causing landslides and flooding. Then, from the 1st to the 2nd of September 2002, a heavy rainfall episode affected the lowlands and the North-eastern sector of Piedmont and caused damages mainly by flooding of some small hydrological basins.

2.2 High-resolution atmospheric forecasts

Four non-hydrostatic atmospheric models have been used to simulate these cases: MM5 (Dudhia, 1993) for NOA, COSMO-2km (Swiss version of Lokal Modell (Doms and al, 1999) developed within the COSMO consortium) for MeteoSwiss, Meso-NH (Lafore et al, 1998) for Météo-France and COSMO-LAMI (Italian version of Lokal Modell) for Arpa Piemonte. Each atmospheric model runs a domain at 2-3 km horizontal resolution. Two runs by day (starting at 00 UTC and 12 UTC) have been performed with a forecast range up to 18 hours at least.

A reference set of experiments (called hereafter CTRL) using the large scale operational global model analyses (ECMWF, NCEP, ARPEGE) as initial conditions has first been built up. Then, to seek for the sensitivity to initial conditions, experiments starting from mesoscale data analyses (3Dvar ALADIN, 3Dvar MM5, COSMO nudging, etc) have been performed (SET2 or SET3).

2.3 Hydrological coupling

2.3.1 1-way coupling

The simplest basic approach of coupling hydrological and meteorological models is one-way coupling. The hourly precipitation forecasts produced by atmospheric models are supplied as input to the hydrological model to forecast discharge. A control run using observed rain gauge rainfall as input has been carried out for comparison. Two hydrological models are used: TOPMODEL (Beven and Kirkby, 1979) on French catchments, FEST (Mancini, 1990; Montaldo et al, 2004) on Italian ones.

2.3.2 1.5-way coupling

An intermediate coupling (called ***1.5-way coupling***) has also been tested. It consists of using the FEST hydrological model forced by the observed precipitation prior to the flash-flood event during typically a one-month period in order to produce estimations of soil moisture. Then these soil moisture estimations are used as initial surface conditions for atmospheric runs; the hydro-meteorological coupled system running in a one-way mode during the flash-flood event forecast.

2.3.3 2-way coupling

A full 2-way coupling has been developed between the hydrological model TOPMODEL and the surface scheme (SurfEx) of the MESON-NH model. The hydrological model performs the lateral soil water distribution over the catchments and diagnosed saturated areas, from which the surface scheme simulates the surface run-off. Then, surface runoff and deep drainage are routed on the hillslopes and in the river to the catchment's outlet. So total discharges are simulated. Moreover, more realistic soil moistures are expected for the meteorological simulations. Full 2-way MESO-NH/SURFEX/TOPMODEL coupling experiments will be performed during PREVIEW Phase 2. For the current phase 1, the hourly precipitation forecast from MESO-NH has been supplied as input to the 2-way coupling SURFEX-TOPMODEL system (e.g. no feedback of the improved soil moisture field on the atmospheric model).

3. RESULTS

3.1 Quantitative Precipitation Forecast (QPF)

A web interface has been developed for comparison and scoring facilities. It allows each partner to compare QPF between different models and experiments by plotting on the same area and with the same colour scale either 2m temperatures or 1h, 6h, 18h accumulated precipitation. Figure 1 provides an example of comparison for the September 2005 French case. Moreover, it is possible to compute on a given area scores for verification of QPF : classical scores such as BIAS, Mean Error Root Mean Squared Error, correlation coefficient (R^2) and categorical ones for instance Probability Of Detection (POD), False Alarm Ratio (FAR), Equitable Threat Score (ETS). The scores have been computed and compared for all the atmospheric simulations and for the 6-h and 18-h accumulated rainfall.

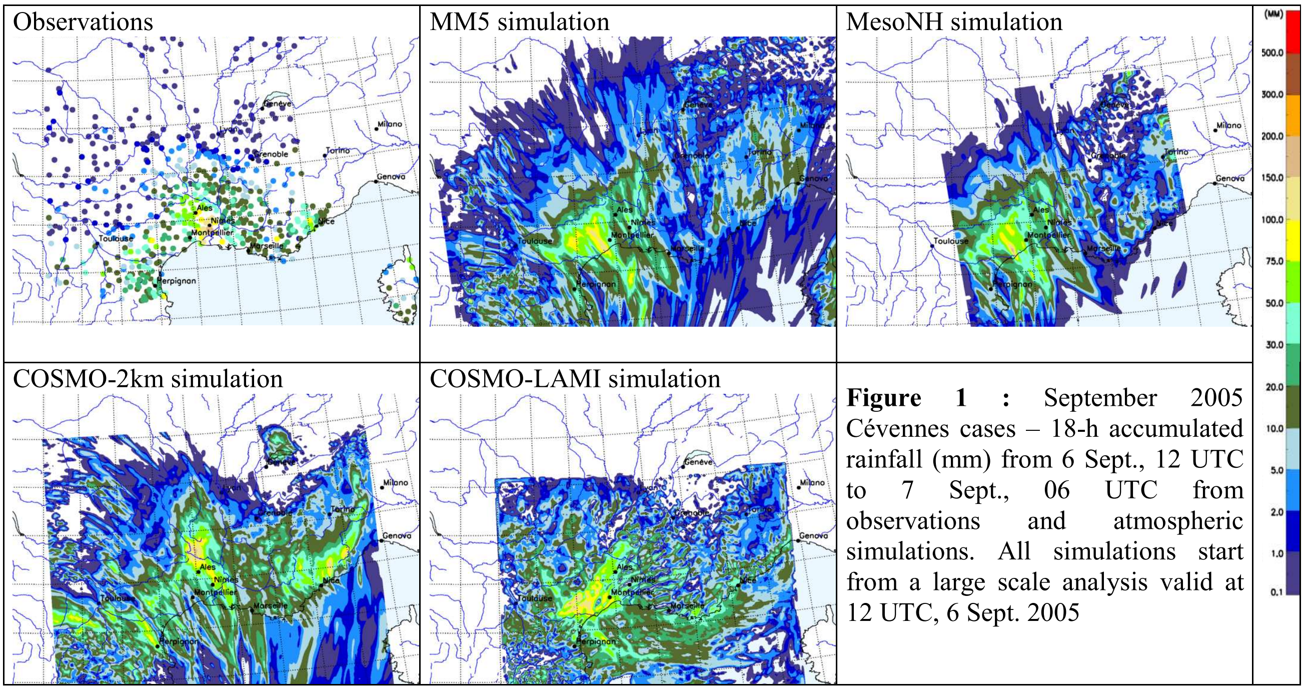

Figure 1 : September 2005 Cévennes cases – 18-h accumulated rainfall (mm) from 6 Sept., 12 UTC to 7 Sept., 06 UTC from observations and atmospheric simulations. All simulations start from a large scale analysis valid at 12 UTC, 6 Sept. 2005

Scores on precipitation show that it is not possible to point out that a model is better than the others; indeed, performance of the atmospheric models are really case-dependent. Model can have very good scores for a run and then very bad ones for another. Figure 2 also highlights that some cases are easier to simulate than the others (weaker BIAS). Then looking for the impact of using a mesoscale data analysis to initialise the runs (SET2 or SET3), it doesn't systematically improve the scores. Note that a more thorough analysis for the COSMO-2km model can be found in Dierer et al (2007) in this conference proceeding volume.

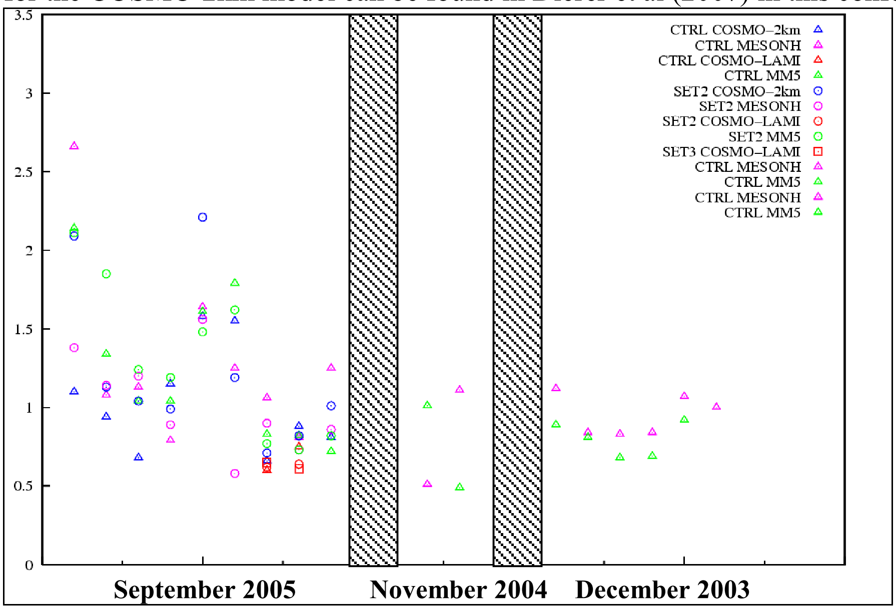

Figure 2 : BIAS obtained for all 18h-accumulated rainfall of all runs of the Cevennes experiments

3.2 Quantitative Discharge Forecast (QDF)

Another way to assess the quality of meteorological simulations is to use them as input to hydrological models as done for example by Chancibault et al (2006). The FEST hydrological model was used for the simulation of Italian Piedmont cases. The peak discharge mean relative error for the COSMO-LAMI simulations are presented in Table 1. One can notice that QDF are generally biased to underestimation due to QPF errors. Using the 1.5 way coupling system to specify the initial soil moisture of the atmospheric model (SET 4) doesn't improve the results, although the soil moisture fields produced by FEST are significantly different from the COSMO-LAMI one (see Sanna et al (2007) in this proceeding volume for details).

Improvements of the surface scheme of the atmospheric model seem to be required to fully exploit the detailed and more realistic moisture field provided by the 1.5 way coupling.

Lelay and Saulnier (2007), in this conference proceeding volume, detail the QDF verification when using the 1-way approach with TOPMODEL for the French Cevennes cases and for all the available atmospheric simulations. The Cevennes case of September 2005 was also simulated with the 2-way SURFEX/TOPMODEL coupled system using observed raingauge observations (kriged field) and QDF coming from Meso-NH simulations as input. Figure 3 shows the Nash coefficient at the main outlet of the Gard (Rémoulins), Cèze and Ardèche (St Martin) rivers. The Nash coefficient is improved when the 2-way system uses as input the MESO-NH simulation starting from a mesoscale data analysis (SET2) instead of a large scale analysis (CTRL). Note however that the Nash coefficient is weak for the Ardèche catchment even when it is forced by observed rainfall, pointing out that some calibration of the system is still needed. In particular, the system is very sensitive to the initial moisture soil conditions and to the speed of water in rivers and on hillslopes (not shown).

Input data	Initial time of forecast	Peak discharge Mean Relative Error
Spatial interpolation of raingauge observations	5 June 2002, 00UTC	-0.54
	5 June 2002, 12UTC	0.02
	1 Sept. 2002, 12 UTC	-0.02
CTRL QPF from COSMO-LAMI	5 June 2002, 00UTC	-0.90
	5 June 2002, 12UTC	-0.73
	1 Sept. 2002, 12 UTC	-0.99
SET4 QPF from COSMO-LAMI	5 June 2002, 00UTC	-0.91
	5 June 2002, 12UTC	-0.70
	1 Sept. 2002, 12 UTC	-0.98

Table 1 : Peak discharge mean relative error when the FEST hydrological model is forced by observed and simulated hourly rainfall for the two Piedmont cases

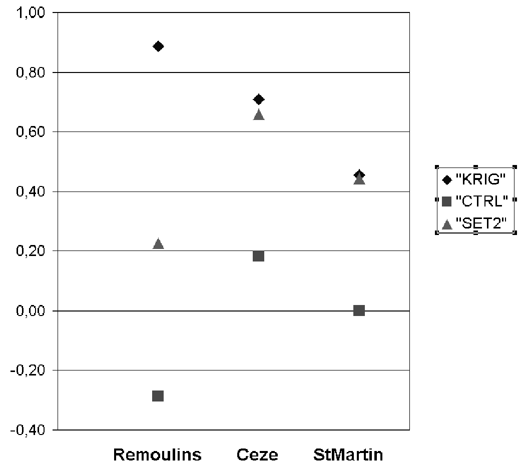

Figure 3 : September 2005 case – Nash efficiency for SURFEX/TOPMODEL simulations using as input: kriged raingauge data (KRIG); CTRL MESO-NH rainfall; SET2 MESO-NH rainfall.

4. SYNTHESIS AND PERSPECTIVE

Phase 1 of PREVIEW has assessed value of high-resolution rainfall forecasts both from a classical QPF scoring approach and from an hydrological response analysis for 5 past events over the Southeastern France and the Italian Piedmont. Even though errors in location and in intensity in the forecast rainfall fields exist, it seems that there are some relevant information in the hydrological responses (QDF), considering not too small catchments and a regional approach. Within Phase 2 of PREVIEW, end-user products will be developed considering the limitations and possibilities of the high-resolution atmospheric models. Full 2-way MESO-NH/SURFEX/TOPMODEL experiments will be also performed, allowing to test the impact of more realistic soil moisture content on the atmospheric simulations.

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