SENSITIVITY STUDY ON ASSIMILATION OF NON-GTS DATA AND SOIL MOISTURE INITIALIZATION

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Abstract: This study is worked out in the framework of the PREVIEW (PREVention, Information and Early Warning) project, part of the EU Sixth Framework Program and, in particular, inside the WP4340 (Very Short Range Flash-Flood Laboratory). The purpose is the improving of the very short-range forecast of Mediterranean flash floods over medium-sized basins, on the base of the next generation of European high-resolution NWP models, by means of the assimilation of non-GTS stations from the ARPA Piemonte very high-resolution network. In this work we present the impact of non-GTS data assimilation and soil moisture initialization in high-resolution models.

Keywords: *COSMO, PREVIEW, data-assimilation, flash-floods, high resolution data-network, soil moisture initialization, high resolution limited area models.*

1. INTRODUCTION

Flash-floods are one of the most common natural hazards in the Western Mediterranean region, where, during recent years, all the countries had to face with intense episodes and their consequences. This kind of phenomena is triggered by an intense rainfall over small catchments (typically more than 200 mm in less than 6 hours over catchments ranging typically from 100 to 1000 km^2) and the main cost is in terms of human lives, because its rapidity does not permit the actuation of alert procedures. For these reasons the forecasting of flash floods requires dedicated tools to cope with these smaller time and spatial scales.

Piemonte is one of the pilot regions of the PREVIEW project, where flash-flood test cases have been chosen and where impact of non-GTS data assimilation and soil moisture initialisation in high-resolution models (2.8 km horizontal resolution) will be investigated.

The hydrological model is FEST-WB (Flash-flood Event-based Spatially-distributed rainfall-runoff Transformation plus Water Balance), a high resolution model mainly designed for flood simulations. The meteorological model is the COSMO-LAMI (COnsortium for Small-scale MOdelling Limited Area Model Italian), the Italian version of the model developed inside COSMO, an over-national consortium coordinating the cooperation of the national and regional weather services of Germany, Italy, Switzerland, Greece, Poland and Romania (see http://www.cosmo-model.org/ for a more comprehensive description).

2. MODELS CHARACTERTISTICS

The FEST-WB hydrological model is a high resolution, distributed, complete model mainly designed for flood simulations. Water and energy budget are calculated at local scale with a simplified physical approach that allows solving an effective analytical numerical scheme. Soil parameterization comes from regional soil and land-use maps at 1 km resolution. The soil moisture model is based on the water conservation equation in the superficial soil layer; effects of elevation, slope inclination and solar radiation influx fields are carefully accounted for.

The COSMO model is based on non-hydrostatic, fully compressible hydro-thermodynamical equations. Prognostic variables are horizontal and vertical wind components, pressure perturbation, temperature, specific humidity, cloud water and ice content, specific water content of rain, snow and graupel and turbulent kinetic energy. Generalized terrain-following height coordinates with rotated geographical coordinates are used. Model equations are solved on an ARAKAWA C grid with user-defined vertical grid staggering. They are spatially discretized with second-order finite differences. Time integration uses as default leapfrog scheme (horizontally explicit, vertically implicit); in the 2.8 km version, the time integration uses a two-time 2nd order Runge-Kutta split-explicit scheme. Moist convection is parameterized using a mass-flux scheme with an equilibrium closure based on moisture convergence (Tiedtke, 1989) for simulations with 7 km grid size, while for very high-resolution simulations moist convection is not parameterised but for shallow convection.

3. SELECTED TEST CASE AND EXPERIMENTAL DESIGN

The test case presented in this work was selected among a series of flash-flood events investigated within the framework of PREVIEW project. In June 2002, heavy precipitation and thunderstorms affected the North-Western zones of Piemonte from Tuesday 4 June 2002 to Wednesday 5 June 2002. These precipitations caused landslides, erosions and floodings in the area between Canavese valleys (province of Turin) and Ossola Valley (province of Verbania). The alert code for localized hydrological risk condition was activated by Arpa Piemonte during this episode. The event interested mainly the Northern sector of the Piemonte on Wednesday 5 June, reaching its maximum intensity at about 18 UTC.

A mesoscale four-dimensional data assimilation (hereafter FDDA) and short-term forecasting system has been developed and tested. The assimilation method is based on the Newtonian relaxation technique where model solutions are nudged towards individual observations (Stauffer and Seaman, 1990 and Stauffer and Seaman, 1994). The system tested here is based on a first run at resolution of 7 km and without data assimilation to provide boundary and initial conditions (hereafter ICs and BCs respectively) to a finer nested grid at 2.8 km resolution, 222x200 size and 45 vertical levels. This first run is carried out using the ICs and BCs provided by the IFS T_L511 (ECMWF meteorological model, about 100 km horizontal resolution). Then a set of four assimilation/forecast (12h assimilation and 24h forecast) cycles is conducted by varying data assimilated and nudging parameters:

1) CTRL is the “control” version without data assimilation;
2) SET2 is run with assimilation of GTS radiosoundings and non-GTS data from the Piemonte Region high-density ground network. Sea level pressure, 2m humidity and 10m wind measurements are assimilated using the same nudging parameters of the operational version, which is at coarser resolution (7 km) and optimized for a less dense station network. This suite is characterized by a strict limitation on anemometric stations which must be located at less then 100 m above the mean sea level. Over Piemonte region this implies that only two stations can be used in the assimilation cycle;
3) SET3 is like SET2 but with nudging parameters adjusted in order to fit into a denser network. Moreover also 2m temperature (hereafter T2m) is assimilated and limitation on wind stations assimilation is removed;
4) SET4 is like SET3 but with soil moisture IC field replaced by one simulated with FEST.

SET3 and SET4 are referred to as fine-adjusted configuration experiments.

4. RESULTS

Model results are presented focusing on 18h-cumulated precipitation field and T2m. In the considered runs the 12h-assimilation cycle starts at 00UTC of 5 June while forecast starts at 12UTC of 5 June.

Precipitation data are verified computing the statistical indices of frequency bias (FBIAS) and Equitable Threat Score (ETS) (Wilks, 2006). Observed and forecast precipitation contingency tables are computed by assigning to each grid point the nearest weather station of the Piemonte Regional data network. Results are presented only for the event maximum intensity, reached at 18UTC of 5 June 2002.

T2m data are verified by means of daily cycles, Mean Error (ME) and Root Mean Square Error (RMSE). Statistical indices are computed assigning to each grid point the nearest network weather station. Results are presented in terms of time series along the 24 hour forecast period, vertical profiles and daily cycles.

Figure 1 shows model results for precipitation. SET2 data show no improvement with respect to CTRL, while SET3 and SET4 data show biases closer to one and higher values of the ETS. The fine-adjusted assimilation of non-GTS data seems then to give better results. Comparison between SET3 and SET4 data shows no significant variations: in this case the use of a better soil moisture adds no value to the forecasts.

Figure 2 shows results for T2m, with ME on the left panel and RMSE on the right one. CTRL presents a clear underestimation of T2m in the first 9 forecast hours, while in the last 6 forecast hours the model seams to overestimate the observations. The effect of data assimilation in SET2 is an even larger underestimation of T2m in the first 9 hours, while SET3 and SET4 strongly reduce the model bias. Contemporarily RMSE is considerably reduced in SET3 and SET4 with respect to both CTRL and SET2. The overall effect of data-assimilation is however limited to the first forecast period.

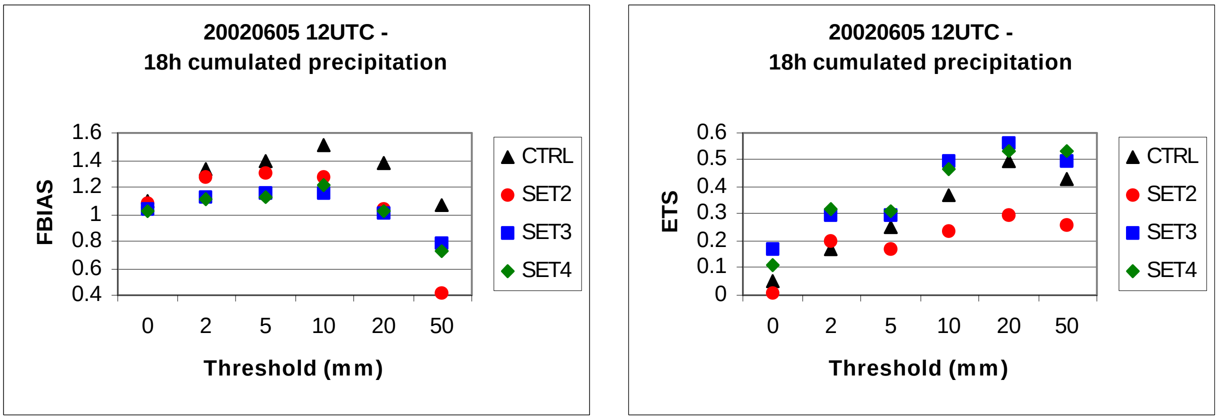

Figure 1: 18h cumulated precipitation. Left: Frequency Bias. Right: Equitable Threat Score. CTRL, SET2, SET3, SET4 data are plotted by black triangles, red circles, blue squares and green diamonds respectively. Titles refer to forecast initial date.

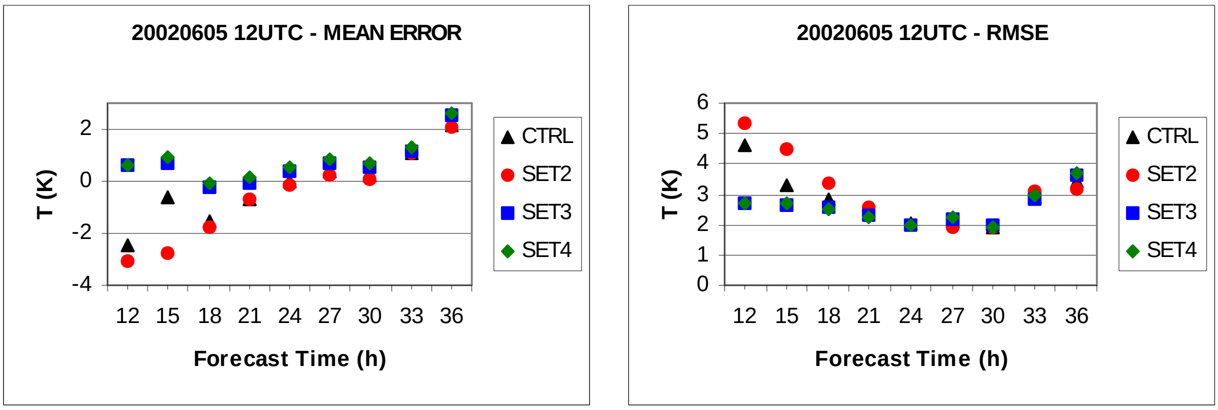

Figure 2: Three-hourly verification statistics for T2m. Left: Mean Error. Right: Root Mean Square Error. In both panels black triangles represent CTRL, red circles SET2, blue squares SET 3 and green diamonds SET 4 respectively. Titles refer to forecast initial date.

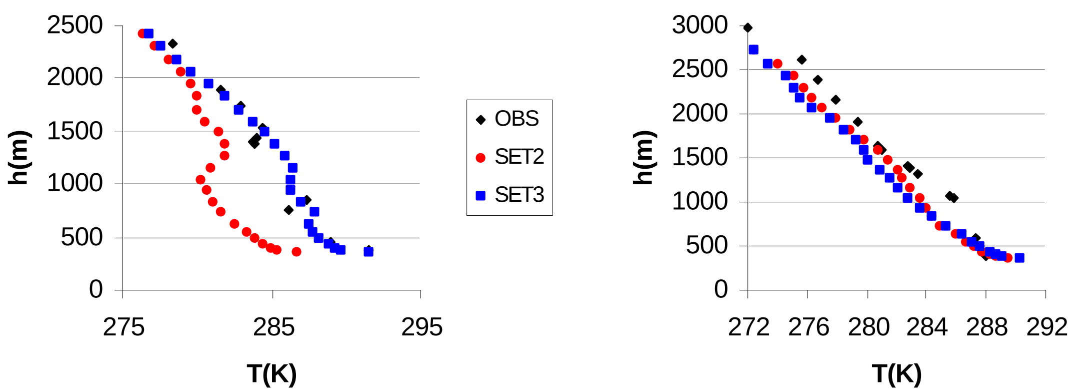

Figure 3: Temperature vertical profile at CUNEO GTS station. Left: analysis time. Right: 12th forecast hour. In both panels black diamonds represent OBS, red circles SET2, blue squares SET3.

Figure 3 shows vertical profiles of temperature observed and forecasted at CUNEO GTS station. Left panel shows the profiles at analysis time, that is at the end of the 12h assimilation cycle. SET3 better follows the observed trend with respect to SET2. Right panel shows results after 12h forecast: there are not appreciable differences between the two experiments sets (and this confirms that after 12 hours the effect of the nudging vanishes). The result is nevertheless noticeable because it shows that fine-adjusted surface data assimilation does not destroy the vertical profile as observed by Stauffer and Seaman with a coarser resolution (Stauffer and Seaman, 1990). In this case SET4 results are not shown since the difference with respect to SET3 is negligible.

Figure 4 shows the diurnal cycle of the forecast period for SET2, SET3 (chosen as the best experimental suite) and observed T2m. SET3 clearly shows a trend significantly nearer to the observed one.

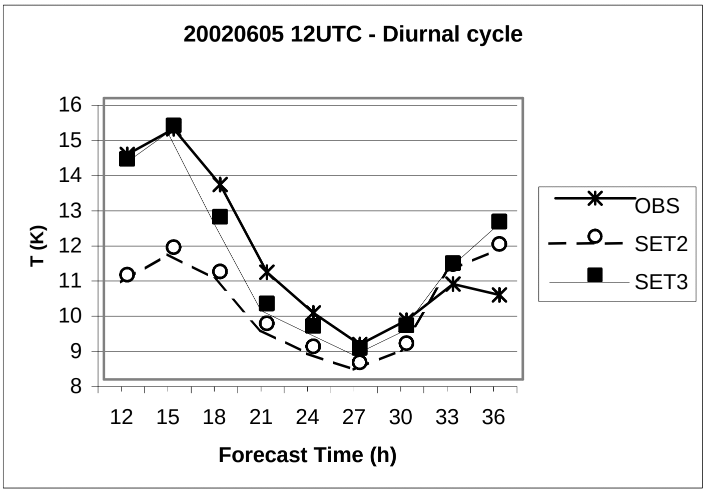

Figure 4: diurnal cycle of the 24h forecasted T2m: stars with continuous line represent observations, white circles with large dotted line represent SET2, black squares with dotted line represent SET3. Title refers to forecast initial date.

5. CONCLUSIONS

Sensitivity simulations are performed for a flash-flood event on Piemonte Region by changing model ICs, nudging parameters and data assimilated in a mesoscale FDDA system. Results show a significant improvement in T2m, at least within the first 9 forecast hours, using the fine adjusted configuration, while there is no evidence of enhancement of model performances by substituting the IC soil moisture field with the one simulated by FEST. As far as 18h-cumulated precipitation field is considered, fine adjusted configurations produce better results for all the considered threshold.

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