PREDICTABILITY OF A STRONG PRECIPITATION EVENT; A CASE STUDY AND AN INVESTIGATION OF MODEL SENSITIVITY

Mark Žagar, Kay Šušelj, Janez Polajnar

Environmental Agency of Slovenia, Vojkova 1b, SI-1000, Ljubljana, Slovenia
E-mail: mark.zagar@gov.si

Abstract: For a convective event, simulated rainfall intensity is compared to the observations at a minute-time-scale. Temporal intermittency and peak intensities are found to be similar to the rain-gauge data, when the model is forced with analysis at the lateral boundaries. Predictability of the same event, estimated on the basis of several simulations starting on different initial large-scale analysis and with forecast lateral boundary conditions, is found to be very low, meaning that accurate predictions of this and similar events at 36 – 48 hour ranges are unlikely.

Keywords: *Strong precipitation, convection, COAMPS™, floods*

1. INTRODUCTION

Predicting strong precipitation events in mountainous regions is a challenge, especially if the rainfall is of a convective type. A significant portion of efforts during the MAP project was focused on heavy precipitation, including convection. However, quite limited predictability of size and location of convective events is still generally acknowledged.

The present paper attempts to further enlighten some aspects of modelling heavy convective rain events at very high resolution. Special care is taken about the temporally variable nature of observed rainfall intensity. In order to gain insight into the model's ability of reproducing the observed precipitation, numerical output is generated with extremely high frequency, down to one minute. In contrast to the parameterized convection, where the numerical models merely produce the rain in order to remove excessive moisture and energy, brought from the large-scale, it can be shown that the nature of resolved precipitation in a state-of-art model is in fact quite similar to the observed one. Another aspect which we investigate here is the sensitivity of the model to initial and lateral boundary conditions, leading to a correct or faulty simulation of heavy convective rainfall.

Modelled precipitation is evaluated here against rain-gauge records with five minute frequency. Additional standard atmospheric observations were also used. We compared the temporal evolution of the observed discharge of a river to that obtained by a hydrological model fed with observed and modelled precipitation.

2. THE CASE OF 9-10 OCTOBER 2004

During these two days, moderate westerly-south-westerly winds prevailed through the mid-troposphere above the south-eastern Alps. A combination of relatively moist and warm, Mediterranean air mass below and cool air aloft offered favourable conditions for sporadic development of locally strong convective rain. More persistent rainfall was only observed along the most exposed slopes, oriented normally to the wind direction. Most of the rainfall occurred between 18 UTC of October 9 and 6 UTC of October 10. This 12 hours is the period we chose for comparison of modelled and observed rainfall. Up to 80 mm of rain accumulated at several rain-gauges inside the catchments of Gradaščica river, shown in Fig. 1 and denoted by the green bounding line. This was enough to trigger some flooding of the river in its lower stream. Previous days rainfall that caused the soil to be rather wet and unable to act as a reservoir for additional rain, contributed to the flooding event even though the total rainfall during the 12 hours of interest was not particularly abundant, at least not for this geographical region.

3. MODELLING APPROACH

The simulations were performed with the COAMPS™ atmospheric model (Hodur, 1997), version 3.1.1. The computational domain with two further nests is shown in Fig.1. Horizontal resolution of the outer grid was 9 km, while it was 3 km and 1 km in the two inner nests. One-way only nesting was used. 40 levels were non-uniformly distributed in the vertical with 20 of them below 1500 m above ground and the lowest level at 5 m above ground. The time-step was 30 s for the 9 km grid, resulting in 3.33 s in the inner, 1 km grid. All simulations were initialized by the ECMWF operational analyses, while for the time-evolving lateral boundary conditions either the ECMWF analyses, or ECMWF operational forecasts were used. In the former case boundaries were updated every 6 hours, while in the later case the update frequency was 3 hours.

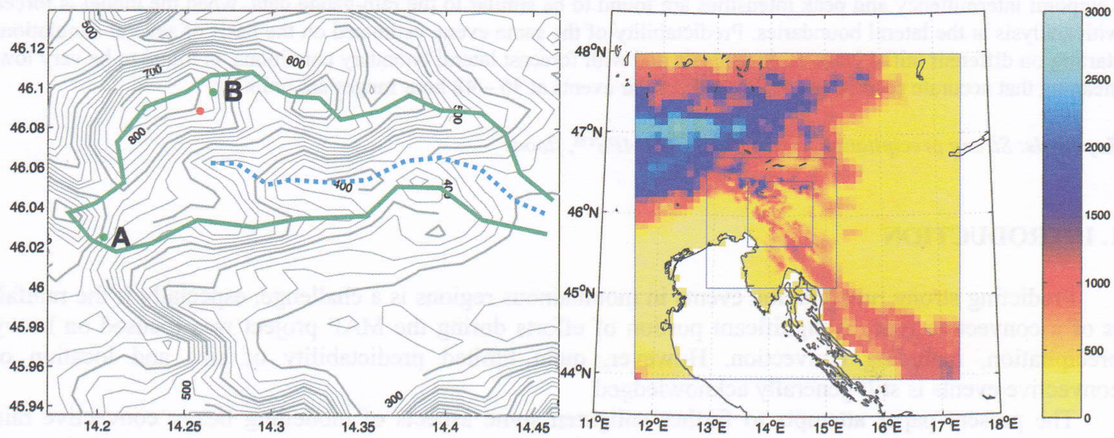

Figure 1: Left - detailed topography around the Gradaščica river and its catchments (blue and green line) and locations of the rain-gauge (red dot) and two points in the model (green dots, see reference in text for details. Right – domain set-up for the simulations and model's topography.

4. DISCUSSION OF THE RESULTS

Two aspects of modelling of convective rainfall are investigated here: spatial and temporal intermittency of convection, and its predictability, i.e. sensitivity to initial and lateral boundary conditions.

Figure 2 shows the temporal evolution of rainfall intensity in the model versus the observed one. Note that the rain-gauge data frequency is 5 minutes while for the model it is 1 minute. Points A and B refer to the locations, denoted in Fig. 1. Location A is the point in the 1 km model grid which is nearest to the rain-gauge, while the location B, 8 km away, is the one with the maximum of the simulated rainfall within the boundaries of the Gradaščica river catchments in the model run with analyzed LBC's. It is evident that the nature of precipitation in the model resembles well the observed one. Rain intensity of separate showers, as well as their duration, are quite similar. Of course the onsets of the simulated showers are sporadically distributed, although the relative minimum with around 1 hour duration is indicated in the simulated intensity, and point A. At the point B in the model the simulated rainfall resembles the real one to a somewhat smaller extent.

On Fig. 3 the radar image from the Lisca radar (located about 70 km east of the rain-gauge) is shown for 00 UTC on 10 October, i.e. nearest to the time of the maximum observed intensity. Location of the area of interest is denoted by the red circle.

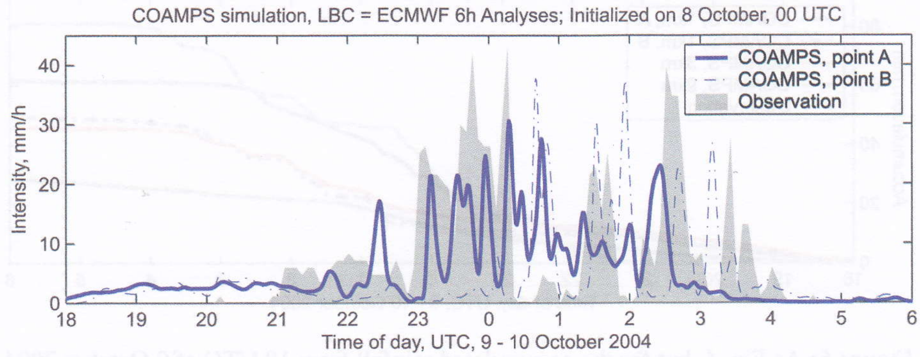

Figure 2: Temporal evolution of the rainfall intensity in mm/h between 18 UTC of 9 October and 06 UTC of 11 October 2004, as simulated with the model at 1 km resolution (blue lines) and the observed intensity (grey shaded area).

What concerns the accumulation of precipitation during the 12 hours between 18 UTC of October 9 and 06 UTC of October 10, we first examine the influence of horizontal model resolution to the simulated values. As seen in Figs. 4 and 5, where rain intensity and accumulations, respectively, in 9 km, 3 km and 1 km model grids are compared to the observations at the rain-gauge, it is evident that the jump in resolution from 9 km to 3 km changes more the amount of rainfall at one location, than the subsequent jump from 3 to 1 km. One can also notice how in principle correct the timing of the rainfall in the simulation at 9 km resolution is, although the intensity and total accumulation are much underestimated. It is here where the effect of analysed boundary conditions most probably plays the main role. It is interesting, however, how the simulation on the intermediate resolution shifts the maximum rainfall in time.

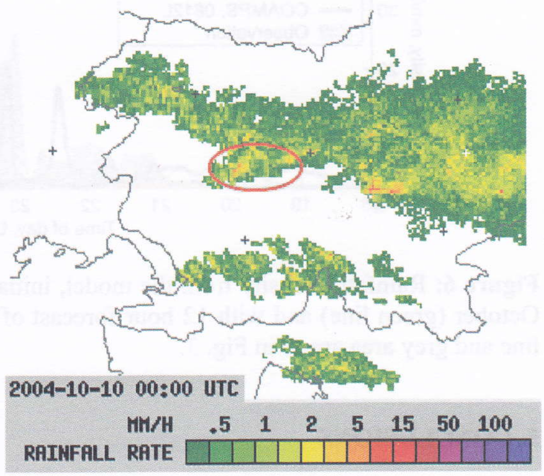

Figure 3: 10 October 2004, 00 UTC, radar image of the rainfall intensity.

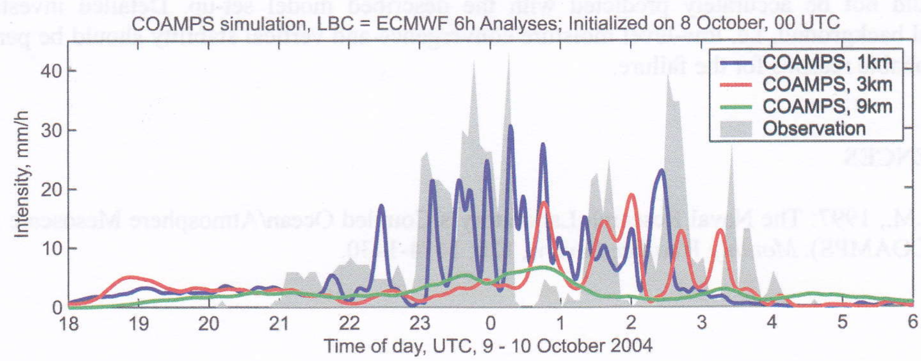

Figure 4: Rainfall intensity from the model nests with different resolution, compared to the observations.

Finally, the influence of the lateral boundaries and of the initial state of the model is demonstrated in Fig. 6, where the observed rainfall intensity is plotted together with that from the COAMPS model at 1 km resolution, run with the ECMWF operational forecast fields as the lateral boundary conditions. It is evident that apart from an indication of possible convective event, neither the onset time nor amount of rain could be predicted with reasonable accuracy.

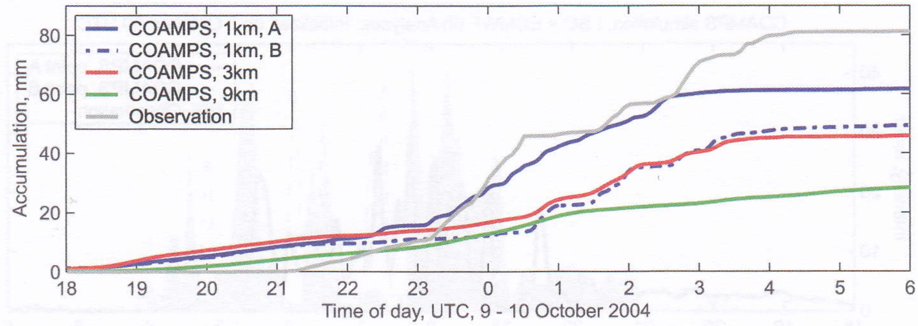

Figure 5: As Fig. 4, but for the accumulated rainfall from 18 UTC of 9 October 2004.

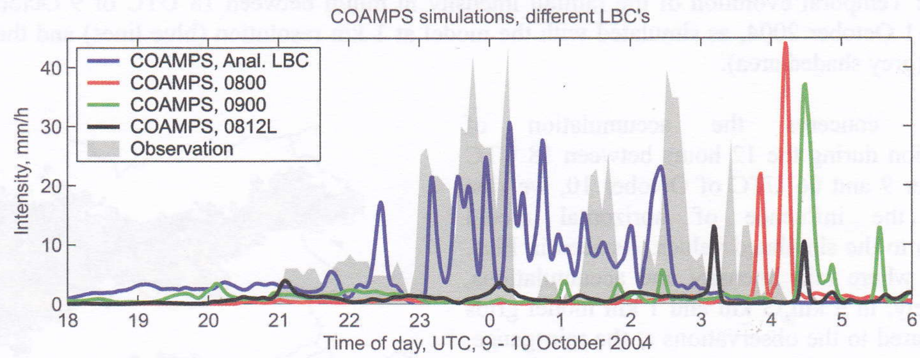

Figure 6: Rainfall intensity from the model, initialized on 00 UTC analysis of 8 October (red line), of 9 October (green line) and with 12 hour forecast of the ECMWF model, started 8 October, 12 UTC. Blue line and grey area are as in Fig. 3.

5. CONCLUSIONS

Simulations of a convective event using a high-resolution NWP model showed that the large-scale analyses, used as initial and lateral boundary conditions, contain enough information for the model to produce correct intensity, time of onset, and location of maximum convective rainfall of as small dimensions as a few kilometres only. However, using a large-scale forecast fields as initial and LBC the event could not be accurately predicted with the described model set-up. Detailed investigation of dynamical background, i.e. low-level moisture convergence and vertical stability should be performed to reveal probable reasons for the failure.

REFERENCES

Hodur, R.M., 1997: The Naval Research Laboratory's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). *Monthly Weather Review*, **125**, 1414-1430.