HIGH RESOLUTION SIMULATION OF A SEVERE BURA EVENT USING NONHYDROSTATIC NUMERICAL MODEL

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Abstract: Bura is strong and gusty wind common for the eastern Adriatic coast, with the most severe events beneath southern part of Velebit mountain. Due to traffic significance of the area and the fact that bura has strong impact on traffic, it is necessary to forecast the bura speed, onset and duration. A mesoscale nonhydrostatic numerical weather prediction model MM5 is employed in order to test and verify the model capabilities of forecasting wind speeds and spatial variabilities on very fine domain resolution of 1 km. During the winter 2003-2004 several bura events were recorded. The longest bura event, taking place from 22-25 December 2003 is analyzed. The model results are compared with the measured data taken from four automatic stations located on different altitudes along the slopes of Velebit. It is found that the model is able to predict onset duration and end of a bura episode with a reasonable accuracy. It is also found that the model is able to reproduce small scale bura variability.

Keywords – *MM5, bura, high-resolution, numerical modeling*

1. INTRODUCTION

Bura is strong and gusty wind with high horizontal and vertical variability common for the eastern Adriatic coast. The most severe events occur beneath the southern slopes of Velebit mountain. This region of Croatia became infamous due to frequent closures of the highway during winter because of bura. There were five automatic wind-measuring stations located along the highway. Two of the stations were located on the slope of the mountain, one was in the lowlands while the two were located on both sides of Maslenica bridge where the highest wind speeds were recorded. The highest wind speed ever recorded in Croatia was 69 m/s measured at the Maslenički most 1 station on the Maslenica bridge on 21 December 1998 (Bajić 2005).

The most severe bura event of the winter 2003-2004 occurred from 22 to 26 December with maximum wind gusts exceeding 60 m/s at most of the automatic stations. The maximum recorded 10-minute mean wind speed was 40.9 m/s and maximum gusts of 62.7 m/s were measured at Maslenički most 1 station. This event is modeled with MM5 limited area model on very fine scale. Due to the turbulent nature of bura the recorded wind speeds show significant difference on all stations regardless of the relative closeness - horizontal distance between the two most distant ones is less than 10 km and stations on Masenica bridge are only a few hundred meters apart.

In order to test the abilities of MM5 mesoscale model to reproduce the variability of bura at 1 km resolution, we compared the modeled results with the wind speeds measured at four stations along the highway in the lee of Velebit during the period from 22 to 26 December 2003.

2. MODEL DESCRIPTION

The PSU/NCAR MM5v3 is a non-hydrostatic fully compressible model (Grell et. al 1995). It employs terrain influenced pressure based vertical coordinate. Detailed model description is given in Grell et. al (1995). The model used two two-way nested grids with the coarse one having 3 km grid spacing while

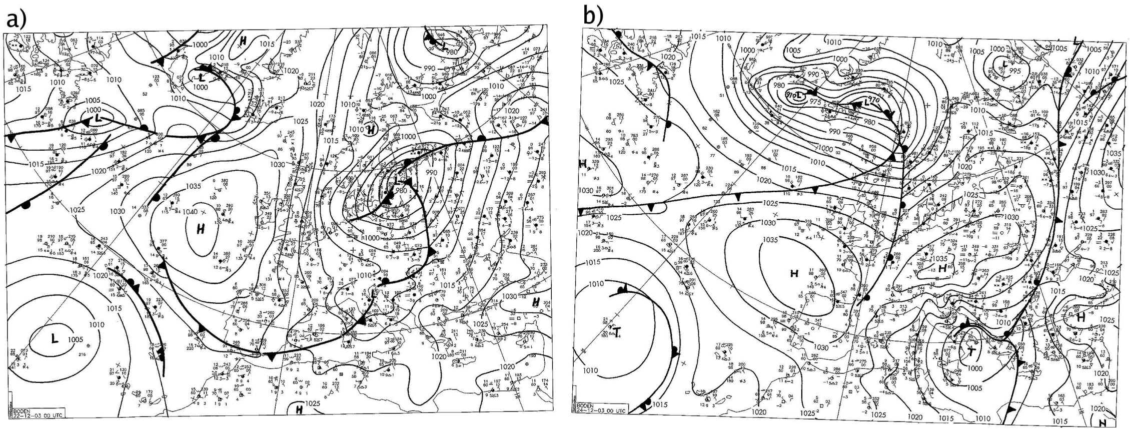

Figure 1. Analysis of the mean sea level pressure over Europe on 22 December 2003 – 00 UTC(a), 24 December 2003 – 00 UTC(b) (from Europaeischer Wetterbericht Deutscher Wetterdienst)

the fine grid had 1km grid spacing, with 30 vertical levels from ground up to 100 hPa. The distribution of vertical levels provided greatest resolution in the PBL.

Eta PBL parameterization based on Mellor-Yamada level 2.5 scheme was employed (Mellor and Yamada 1979). No convection parameterization was used since model resolution is sufficient to explicitly resolve convection. The surface energy budgets were computed using a 5 layer soil model. Moist processes were treated with Reisner graupel explicit cloud microphysical scheme. Rapid Radiative Transfer Model for shortwave and longwave radiation calculation was used. Upper non-reflecting radiative boundary condition was employed to prevent spurious reflections from the model top.

The model was initialized using ALADIN/HR forecasts. ALADIN/HR setup is described in Ivatek-Sahdan and Tudor (2004) Lateral boundary conditions were updated every 1h. All forecasts started at 00 UTC, and lasted for 48 hours. In order to capture entire bura event we made five runs starting from 22 to 26 December at 00 UTC every day. Only first 24 hours of each simulation are used to compare modeled results with the observations.

3. SYNOPTIC SITUATION

Synoptic situation on 22 December 2003 00 UTC (Fig. 1a) was characterized by a deep cyclone in northern Europe with the center of 980 hPa over Latvia and anticyclone (1040 hPa) west of Ireland and Great Britain. Center of shallow cyclone was over the north Adriatic. Cold air outbreak from north reached the Adriatic region during the early morning hours of 22 December 2003, which correspond to bura onset. On 24 December 2003 (Fig. 1b) a warm front divided the Atlantic anticyclone, which moved eastward. The Adriatic cyclone became deeper. Those two systems produced strong pressure gradient in the northern Adriatic. Such situation induced strong northeaster flow, which sustained extreme bura on the eastern Adriatic. The situation lasted until late 25 December when the systems moved further east.

4. RESULTS AND DISCUSSION

The model results were compared with the 10-minute mean wind speeds measured at the four automatic stations. There was another station on the slopes of Velebit but it was working only two hours in the bura episode so its data were not used. Ledenik station (Fig. 2a.) is located on the slopes of Velebit, Božići (Fig. 2b.) is located in the lowlands, while auMaslenički most 2 (MM2) Fig. 2d. and Maslenički most 1 (MM1) Fig. 2c. stations are located at both sides of Maslenica bridge. There are a lot of data missing from Ledenik station but the station managed to capture beginning, maximum and end of the

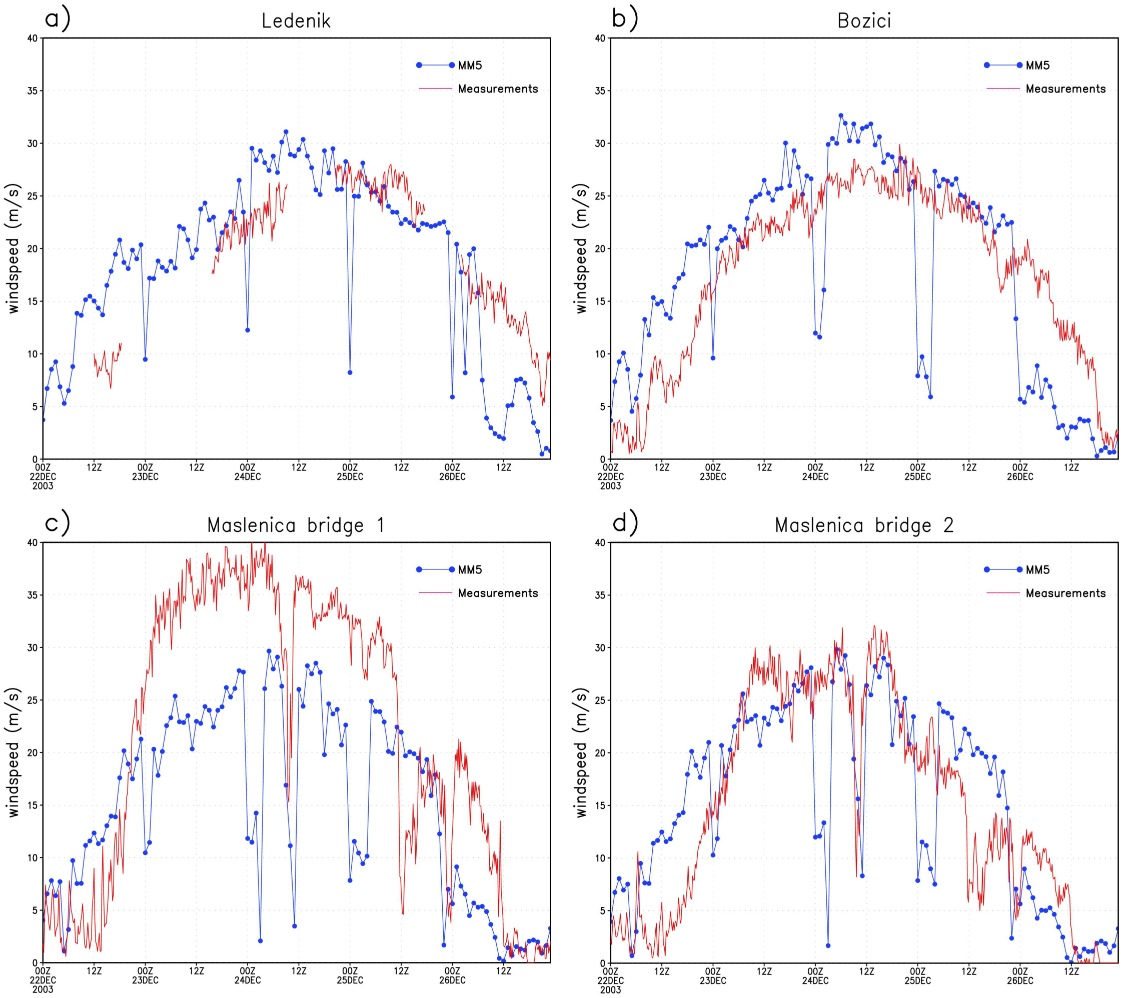

Figure 2. Time series of measured (red) and modeled (blue) wind speed (m/s) from 22 December 00 UTC to 26 December 00 UTC. at the locations of Ledenik (a), Božići (b), Maslenički most 1 (c) and Maslenički most 2 (d).

episode. There is a clear distinction in wind speed patterns between stations on Maslenica bridge and the two other stations. At Maslenica bridge bura had its maximum during 23 and 24 December on (Fig. 2c, 2d) while on Ledenik and Bozici the maximum wind speeds occurred during 24 December (Fig. 2a, 2b).

Low values of the modeled wind speed on Fig. 2 at 00 UTC every day are due to model reinitialization.

For Ledenik and Božići stations (Fig. 2a, 2b) the model is in good agreement with the observations. The best agreement is from 23 – 26 December. Model predicted bura onset almost 12 hour too early (at the beginning of 22nd, and overestimated actual wind speeds up to 5 m/s. During the next two days of the discrepancy with the measurements at these two stations was less than 5 m/s (Fig. 2a, 2b). During the 25th the agreement with the measurements was very good with differences less than 3 m/s. Late in the 25th the model performance got worse, it predicted end of bura more than 12 hours too early. Predicted maximum wind speed was 3 m/s too high.

At Maslenica the bridge model performance is not as good as for the previous two measuring stations. This is due to very complex orography at this location. Comparing the measurements on MM1 and MM2 and keeping in mind that those two stations are less than 500 m apart it understandable that the model can not reproduce such variability. The modeled wind speeds at these two stations are the same (Fig. 2c, 2d) because they are represented with a single grid point. As can be seen from Fig. 2c model underestimates observed wind speeds at MM1 up to 15 m/s but the predicted time of maximum wind speed correctly corresponded the observed one. Agreement with the observations on MM2 station is much better than at MM1 (Fig. 2d). The best agreements is during 23rd and 24th. During this period maximum discrepancy was less than 5m/s except from 00 UTC to 04 UTC on 24th but this is probably due to reinitialization. The model managed to reproduce significant wind speed decrease at 11 UTC on 24th when the wind speed suddenly decreased from 25 m/s to 8 m/s. The model gave the minimum one hour too late but the speed was accurate. There are however other brief minimae predicted by the model at 3 UCT on 24th and 3 UTC on 25th which were not observed (Fig. 2d). It is authors opinion that those minimae are also indluenced by model reinitialization. During the end of bura episode the model performance on MM1 and MM2 stations (Fig. 2c, 2d) is better than at Ledenik and Božići (Fig. 2a, 2b) stations.

5. CONCLUSIONS

The model is able to reproduce some of the spatial and temporal variability of bura wind. It is however not able to resolve very small scale variability which is observed at MM1 and MM2 stations. This is due to limited resolution of the model orography. It is found that MM5 model can be an useful tool for studying fine scale phenomena related to bura.

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