SEVERE ADRIATIC BURA EVENT FROM 14 TO 15 NOVEMBER 2004

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Abstract: We investigated the dynamics and structure of a severe bura event. Apart from the routine meteorological data, in this study, the wind data from three ultrasonic anemometers were used for the first time. The episode was modeled by the mesoscale model MM5. In the analyses of the model results, particular emphasis is given to establishment of the spatial structure of the potential vorticity (*PV*), and, its comparison with *PV* fields from previous bura studies. Due to well-known bura gustiness, also examined is the ability of the mesoscale model to predict the bura wind gusts.

Keywords - *bura, numerical model, potential vorticity, wind gusts, northern Adriatic*

1. INTRODUCTION

A severe bura event occurred at northern Adriatic during 14 – 15 November 2004. It was accompanied by material damages in the region. Although the bura wind blows rather frequently in that area, cases as strong as this one are rare. We will thus perform high resolution numerical simulations in order to examine the occurrence and development of the bura flow in details.

2. SYNOPTIC CONDITIONS

The synoptic conditions were characterized with the cyclone centered over the North Africa, and, anticyclone over the eastern part of Northern Atlantic. Both disturbances extended throughout the entire troposphere. A prominent feature of the North Atlantic anticyclone was its persistence. Starting from 4 November 2004 at 12 UTC, at 500 hPa level it is found west of Portugal as a cutoff from a northwestward oriented ridge of Rossby wave, while at lower levels it is positioned west of France.
By 14 November 2004 at 06 UTC both disturbances strengthened. While strengthening, cyclone had moved north-eastward and its centre was positioned over the Tyrrhenian Sea. Simultaneously, the associated anticyclone had elongated towards the east. Therefore, a high north-south synoptic pressure gradient established. The increase in the pressure gradient, together with further eastward elongation of anticyclone and further northeastward movement of the cyclone, continued throughout 14 November.
Above synoptic pattern is generally favorable for the development of bura, and it resembles to mean pressure field patterns associated with bura wind.

3. WIND DATA

Wind measurements were performed at four measuring sites (Fig. 1): Zagreb-Horvatovac (Z), Senj (S), Vratnik (V), and Krk-Bridge (K). Three WindMaster ultrasonic anemometers recorded the wind data at resolutions of 0.25 s (points S and V), and 1 s (point Z), respectively. Positions of points S and V are extremely favorable for the bura occurrence. Point K, which is also according to climatological analysis generally exposed to strong bura, was equipped with an automatic meteorological station, reported mean wind values determined from the 10-minute measurement intervals starting 10 minutes prior to the round hour.

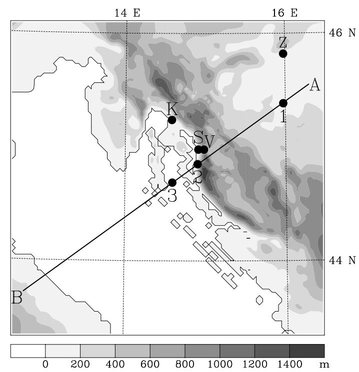

Figure 1. Topography of the investigated 300 x 300 km^2 area. Points Z, S and V correspond to locations of ultrasonic anemometers, while K is the location of automatic meteorological station. At line AB, which is parallel to bura flow, points 1-3 are selected as representative of conditions over the mainland (1), downstream of the coastal mountain crests (2), and over the sea (3), respectively.

4. NUMERICAL SIMULATIONS

Atmospheric fields were simulated with a nonhydrostatic version of MM5 model (Grell et al., 1995). A three nested domains: 2700 x 2700 km^2, 900 x 900 km^2 and 300 x 300 km^2, with corresponding horizontal grid increments of 27 km, 9 km and 3 km, respectively, were employed. Each domain had 36 vertical levels. Selected bura episode was investigated in the smallest domain, while two larger domains were used only to produce boundary and initial conditions for the domain with the finest horizontal resolution.

The simulation was performed for the period from 12 November 2004 at 00 UTC (01 LST) to 15 November 2004 at 18 UTC (19 LST). The model was driven with the ECMWF operational analysis data, which are available for every 6 hours.

5. RESULTS AND DISCUSSION

The model results revealed that over the mainland strong surface temperature gradients perpendicular to the coastline (Fig. 2), and, hence, strong pressure gradients, were established. These were accompanied with an advection of the cold and dry air (which was also found farther aloft) and a consequent strong bura event (Fig. 2).

Examination of the modeled along-bura (NE-SW) vertical cross sections (Fig. 3(a)) revealed a different pattern of stability stratification compared with another strong bura episode (Klaić et al., 2003). In the previous study, the strengthening of the bura was accompanied with the increase of static stability in the lowermost atmospheric layer. On the contrary, results of this study show the formation of an elevated stable layer, while lowermost layers were less stable or even unstable. The elevated stable layer intensified after the bura onset. In time, as the persistent cold air advection continued, this stable layer extended vertically.

Consequently, previously investigated strong bura episode (Klaić et al., 2003) was characterized with prominent temporal transition of subcritical to supercritical airflow within the bura layer, which is in accordance with the behavior of stratified airflow over an obstacle. On the contrary, results of this study did not clearly reveal hydraulic nature of the flow within the bura layer.

For both, previously investigated and this strong bura episode the static stability was the strongest in narrow region above the major lee slope adjacent to the sea (see densely spaced and steeply lowering isentropes above x ≈ 200 km in Fig. 3(a)). Further, for both episodes wind reversal aloft was present only in the first part of the bura episode.

Results also showed an interesting pattern of the air pressure with a prominent disturbance in the period between approximately 12th and 48th hour of the simulation. The above pressure disturbance was the most pronounced for the point 1 where the pressure amplitude of about 10 hPa was found. Further investigation of atmospheric conditions revealed that it can be attributed to short-living mesocyclone which moved fast eastward over the middle Adriatic.

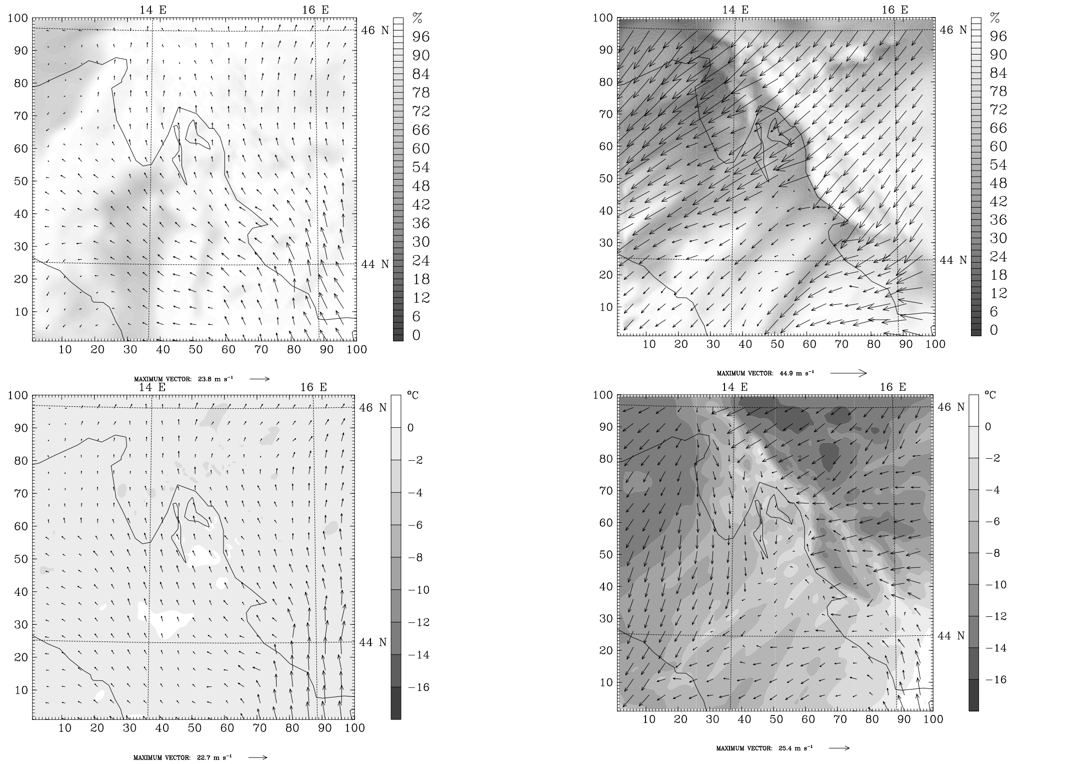

Figure 2. Modeled fields prior to *bur*a onset (13 November 2004 at 00 UTC, left) and during the bura episode (14 November 2004 at 06 UTC, right). Upper panels: relative humidity and horizontal wind fields at 850 hPa level. Lower panels: temperature and horizontal wind fields at 700 hPa level.

Figure 3(b) shows model predicted *PV* field. Downstream-elongated *PV* anomalies that mark the shear lines between the individual jets and wakes (Grubišić, 2004), are found in pairs of positive and negative filaments (banners). As the bura strengthens, anomaly amplitudes increase. Positions of predicted *PV* banners are in excellent agreement with those obtained by Grubišić, thus confirming the role of the upwind topography in banners formation. Further, both along-bura and transversal dimensions of individual banners agree well with the above study. However, the maximum predicted *PV* amplitude was even greater than 14 PVU, while for the episode investigated by Grubišić it was up to 6 PVU.

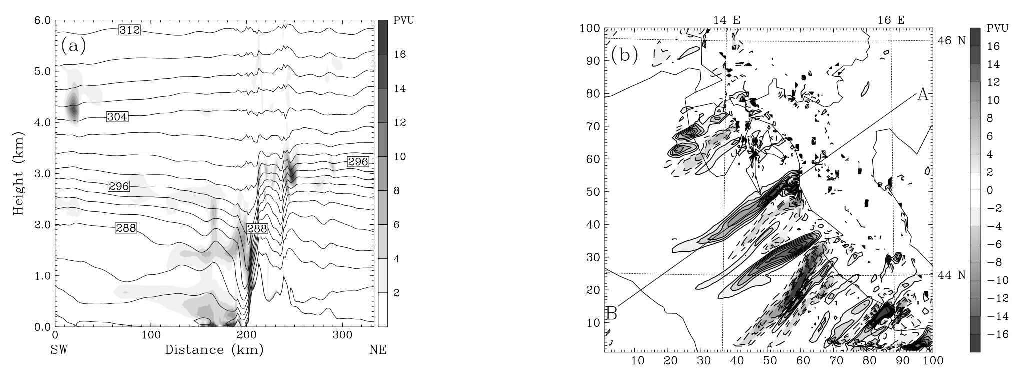

Figure 3. (a) Modeled along-bura vertical cross-section of potential temperature (K) and potential vorticity (PVU) for 14 November at 00 UTC. The base of the cross-section is the line AB in Fig. 1. (b) Modeled potential vorticity field (PVU) at 700 m ASL for 14 November at 12 UTC. Regions of positive and negative potential vorticity are surrounded with full and dashed lines, respectively.

In searching for the possibility to predict maximum wind gusts, we applied a method of Brasseur (2001) modified by Belušić and Klaić (2004). Figure 4, which shows results for three sites exposed to bura (K, S and V) and one without bura (Z), shows that bura gust estimates agree well with the measurements. Further, specifically for the bura flow, upper bound tends to overlap with the gust estimate, while for the site Z, where there is no bura flow, the upper bound and the gust estimate are clearly separated. Above results further support a conclusion of Belušić and Klaić that due to the dynamical structure of bura flow, bura gust simply equals to maximum wind speed within the bura layer.

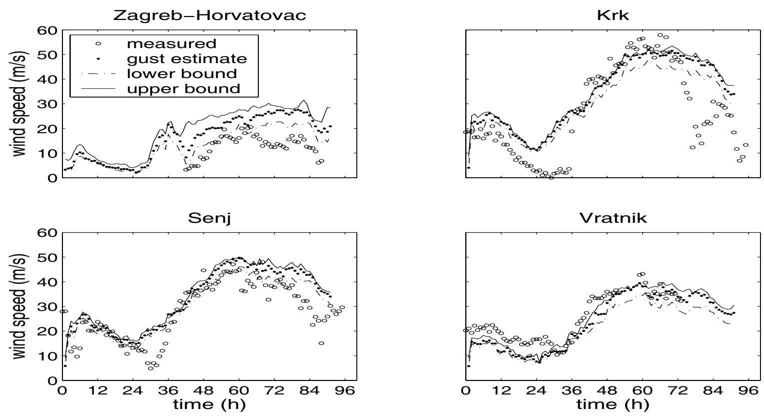

Figure 4. Measured vs. estimated gusts for the period from 00 UTC 12 November to 18 UTC 15 November. Positions of Zagreb-Horvatovac (Z), Krk (K), Senj (S), and Vratnik (V) are shown in Fig. 1.

4. CONCLUSION

The model reproduced well the pressure gradient establishment and the consequent onset and the strength of investigated strong bura event. Advection of the cold and dry air was found not only within the bura layer, but also far above the ground. Further, wind reversal aloft (not shown here) was present only at the bura onset and its developing stage.

Predicted *PV* banners further support the orographic generation mechanism of *PV* proposed by Grubišić (2004). Along-bura dimensions of individual *PV* banners were of the order of magnitude of 100 km, thus indicating a downstream advection of *PV* anomaly. Vertically they extended up to 2-4 km. A comparison of transversal dimensions of individual banners with the results of previous study (Klaić et al., 2003) suggests a noticeable sensitivity to model resolution.

Finally, the bura gusts can be estimated well by the method proposed by Belušić and Klaić (2004).

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