SODAR AND RADIO SOUNDING MEASUREMENTS AT ZADAR, CROATIA

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Abstract: A new data acquisition system is employed at Zadar, eastern Adriatic coast, to measure local coastal and orographic flows during winter-spring 2004/05. Although different data types and measuring philosophy correspond to sodar and radio sounding, through boundary layer these often well relate to each other. The latter depends on the amount and intensity of small-scale variability in the wind stratification. The data comparison is substantiated via Numerical Weather Prediction (NWP) model ALADIN. During synoptical and mesoscale flow forcing a coastal low-level jet (LLJ) often occurs. Further the possibility of LLJ prediction with operationally used NWP model is explored.

Keywords: *sodar, radio sounding, LLJ*

1. INTRODUCTION

Low-level jet (LLJ) is one of the phenomena detected in the Croatian area during Alpine experiment (ALPEX, March-April 1982) and many others case experiments of bura events (e.g. Jurčec, 1992; Tutiš, 2002). In stable boundary layer (SBL), in the lowest 2 to 10 m, winds can have very complex characteristics with the direction depending on local orography and speed governed by buoyancy, friction, entrainment etc. Nevertheless, higher in SBL synoptic and mesoscale forcing becomes important (Stull, 1988) and the wind speed can increase with height, reaching a maximum near the top of the SBL. Investigations have shown that there are many causes for LLJ (e.g. Kraus et al., 1985); and some of those are related to sea- and land-breeze (de)coupling with anabatic and katabatic flows and to some synoptic events such as bura in our case. Our study also shows the occurrence of LLJ at Zadar site, which is driven orographically and with bura flow. The main goal of this work was to compare radio sounding, sodar and NWP data in a couple of mesoscale and synoptic regimes characteristic for this area.

2. MEASUREMENTS AND NWP MODEL USED

Radio soundings data are performed in Zadar since 2002 twice a day at 12 and 00 UTC. Data are measured in the first 5 min, every 30 s in next 15 min, and every 1 min until the end of sounding path. Crossing the boundary layer along a skewed path within a few minutes provides a 'snapshot'-like profile that can be a limiting factor (e.g. Parlange and Brutseart, 1989). If the time response of the radiosonde instruments is too long, some sharp changes in the profiles can be misrepresented.

Sodars provide continuous vertical soundings by vertically emitting sound pulses and deriving the output information from the frequency and amplitude of the atmospheric echoes. Besides wind speed and direction other information about the characteristics and structure of boundary layer turbulence are provided. Depending on the sodar model, maximum measurement ranges are between several hundred meters and more than a kilometre. In Zadar the Scintec MFAS sodar is used. Its measurement range is set from 40 to 700 m. Averaging and output intervals are set to 10 minutes, and space resolution is 20 m.

ALADIN is a spectral hydrostatic limited area NWP model for short-range forecasts, and operational model set-up is described in Ivatek-Šahdan and Tudor (2004). We have used prognostic data from pseudotemp format on the model level in the grid point, which represents Zadar. Vertical resolution is not uniform and the levels are around: 17 m, 65 m, 143 m, 251 m,..., 1673 m, 1977 m, 2306 m etc. Space differences gradually increase with height, resulting in higher vertical resolution near the surface.

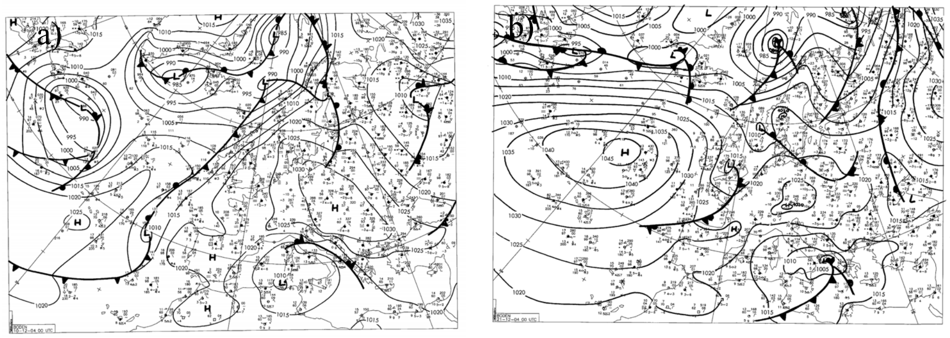

Figure 1. Synoptic situation on a) 10 December 2004 at 00 UTC and b) 21 December 2004 at 00 UTC.

3. RESULTS

Development of LLJ is analysed in two case studies, Fig. 1. Synoptic situation on 9-10 December 2004, Fig. 1a) was characterised with a cyclone over the Mediterranean and anticyclone over the continent. Additionally, E-SE flow was intensified by the orography. On 20-22 December 2004, Fig. 1b), there was a flow crossing the mountains due to low pressure above the sea and yielding bura-flow characteristics.

The ability of ALADIN model to predict diurnal development of LLJ is shown in Figs. 2 and 3 where vertical profiles are compared with radio soundings for 00 and 12 UTC in Zadar, Croatia. These results are further compared with the sodar data shown in Fig 4.

On 9 December 2004 the model predicted development of LLJ at 250 m in the afternoon with wind speed around 13 m/s at 21 UTC, while the radio sounding measurements at 12 UTC indicate LLJ of 5 m/s which is two time less than in the model. This can be compared with the sodar results in Fig 4 a) and obviously the model over predicted wind speed at 12 UTC. Further, the sodar shows development of LLJ of approximately 15 m/s after 18 UTC between 50 and 250 m which is in agreement with the model results. There is also sodar observation of another afternoon LLJ development with wind speeds > 20 m/s in the layer between 400-700 m. This secondary LLJ was not detected by the soundings or predicted by the model.

The next day, 10 December 2004, the radio sounding at 12 UTC shows LLJ of 15 m/s at 300 m, and the model has the similar profiles as the day before. The sodar shows similar vertical structure before the sunrise as the previous day, with two LLJ's separated with 200 m thick layer of wind speeds < 5 m/s.

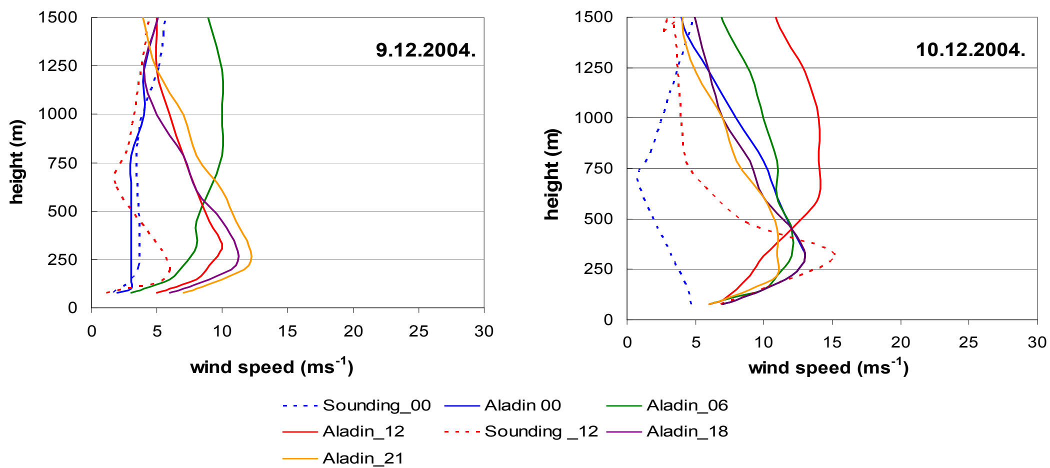

Figure 2. Vertical profiles of wind speed measured with radio sounding (dashed) and wind speed diurnal course predicted with ALADIN model (solid) for 9 and 10 December 2004 in Zadar, Croatia.

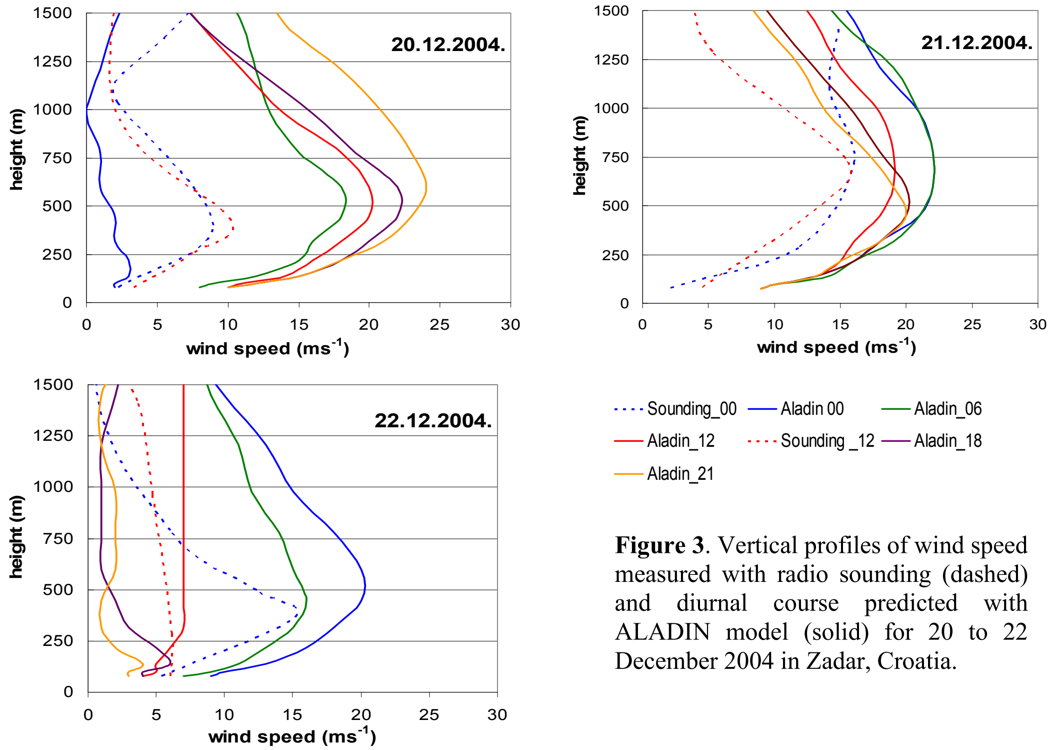

Figure 3. Vertical profiles of wind speed measured with radio sounding (dashed) and diurnal course predicted with ALADIN model (solid) for 20 to 22 December 2004 in Zadar, Croatia.

Between 7 and 12 UTC wind speeds are around 12 m/s and more-less uniform throughout the vertical. Later in the afternoon the sodar shows increase of wind speeds > 20 m/s from 300 to 700 m.

Second case is shown with the sounding and the model in Fig. 3, and with the sodar in Fig 4b). On 20 December 2004 the model indicates diurnal increase of LLJ at 500 m from wind speeds of 16 m/s at 6 UTC to 24 m/s at 21 UTC. The soundings show similar profiles at 00 and 12 UTC having LLJ with wind speeds 8-10 m/s at 300 m height. The sodar indicates LLJ at the same heights and intensity as the soundings but also have wind speeds > 10 m/s at and above 500 m. After 6 UTC the sodar measures wind speeds from 10 to 20 m/s in the layer 200 to 700 m. The next day, the soundings, the sodar and the model indicate LLJ with significantly increased wind speeds. After 12 UTC the sodar shows speed > 25 m/s. On 22 December, the sodar wind speeds are around 15 m/s across the profile and in the afternoon these decrease to > 10 m/s on levels > 400 m. The radio sounding at 00 UTC also indicates speeds > 10 m/s around 400 m.

4. CONCLUSIONS

The sodar and the radio sounding measurements are compared in two cases containing LLJ near Zadar. It is shown that soundings, performed operationally twice a day, do not give adequate representations of LLJ. However, the sodar data shows LLJ development and its daily dynamics. On 9 December 2004 two LLJs developed after the sunset, which was not detected by the soundings. On 20 December 2004 the maximum wind speed lowered from the morning toward the end of the day. The next day supergeostrophic winds between 20-30 m/s starting from 300 m are observed with the sodar but fully missed by the soundings. Since, on 21 December 2004, bura flow was observed at surface with in situ wind measurements, this jet can be connected with it (Tutiš, 2002).

The model results are in good agreement with the sodar results. Nevertheless, ALADIN underestimates the observed wind speeds but it captures good daily tendencies of the LLJ. This means that this NWP model can be used in prediction of LLJ but higher maxima can be expected.

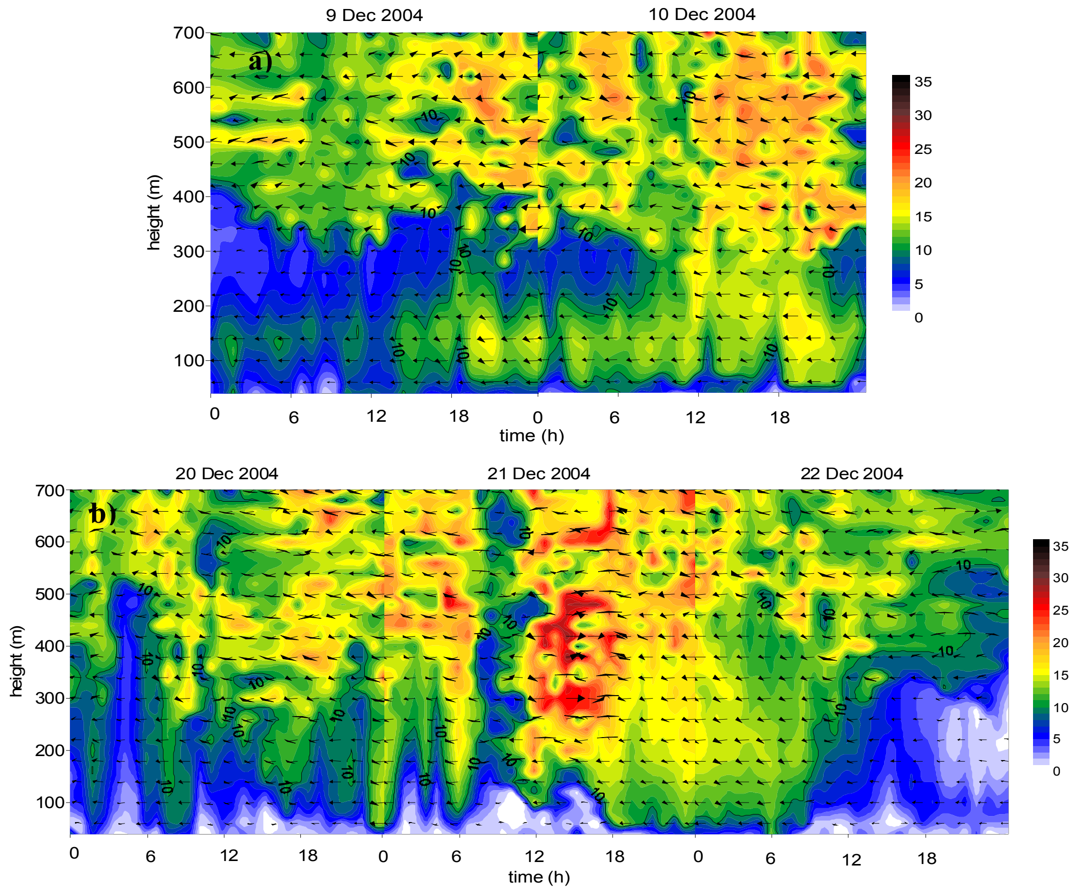

Figure 4. Sodar wind speeds and direction measurements for a) 9-10 December 2004 and b) 20-22 December 2004 at Zadar, Croatia.

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