CHARASTERISTICS OF THE NEAR-SURFACE TURBULENCE DURING A BORA EVENT

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Abstract: Wind velocity at the town of Senj was measured at 13 m above the ground with a 3D ultrasonic anemometer operating at 4 Hz sampling frequency. The severe bora case that occurred on 07 January and lasted to 11 January 2006 is analyzed here. This data set is used for evaluation of the turbulent kinetic energy, *TKE*, and its dissipation rate, ε. Some considerations about defining turbulent perturbations of the bora wind speed are pointed out. The inertial dissipation method for estimation of ε is used. The empirical length scale parameter for this event is estimated with respect to ε and *TKE*.

Keywords: bora wind, inertial dissipation technique, turbulent kinetic energy, dissipation rate, mixing length-scale

1 INTRODUCTION

Bora (locally *bura*) is a downslope windstorm that blows from the northeastern quadrant in the lee of the coastal mountains when the relatively cold northeasterly flow impinges on the Dinaric Alps (e.g. Yoshino, 1976; Grisogono and Belušić, 2009). Belušić and Klaić (2006) analyzed bora case with gusts speed maxima > 60 m s^{-1}. They found that the values of turbulent kinetic energy (*TKE*) can surpass 30 J kg^{-1}.

TKE dissipation rate (ε) describes dissipation of *TKE* by molecular viscosity into the heat. Improvements needed for a more faithful turbulence parameterization in e.g. air-pollution and dispersion calculations during bora events require a more detailed understanding of bora turbulence (e.g. Baklanov and Grisogono, 2007). This is impossible without a more complete knowledge of *TKE* and ε. Piper and Lundquist (2004) evaluated ε related to the cold front. Their results are compared with those derived here with the respect to the mean streamwise velocity component, giving also credibility to this study.

2 DATA AND METHODS

The 3D wind speed measurements were performed in the town of Senj (44.99°N, 14.90°E, 2 m above MSL) at a height of 13 m above the ground with the WindMaster ultrasonic anemometer (Gill Instruments). The anemometer records the data with a sampling frequency f = 4 Hz. The observed bora episode extends from 07 to 11 January 2006 (4 day time series). The coordinate system is rotated in the mean wind direction (55°). Figure 1 depicts the measured 4 day time series of the streamwise velocity component with 1 hr mean superimposed.

We used the inertial dissipation method (IDM) for evaluation of ε (e.g. Večenaj et al., 2007). Using Taylor's hypotheses of frozen turbulence (e.g. Stull, 1988), ε can be evaluated from:

$$\varepsilon = \frac{2\pi}{\overline{U}}\left[\frac{f^{5/3} S_u(f)}{\alpha}\right]^{3/2} \qquad (1)$$

where $\overline{U}$ is a mean streamwise velocity component, $S_u(f)$ is the spectrum and α is the Kolmogorov constant.

Starting from the local one-and-a-half-order closure, ε can be parameterized in numerical models using the mean value of *TKE* (e.g. Mellor and Yamada, 1974):

$$\varepsilon = \frac{TKE^{3/2}}{\Lambda} \qquad (2)$$

where $TKE = \frac{1}{2}\left(\overline{u'^2} + \overline{v'^2} + \overline{w'^2}\right)$ and u', v' and w' are turbulent perturbations of the streamwise, transverse and vertical velocity components, respectively, while bars represent a suitable averaging. The parameter Λ is the empirical length scale that is closely related to the size of dissipating turbulent eddies.

3 RESULTS

The relationship between the standard deviation of the streamwise velocity component (σ_u), and $\overline{U}$ in the surface layer is usually linear (e.g. Stull, 1988), which was shown by Belušić et al. (2006) to be valid for the local bora turbulence. Moving averages with lengths from 1 min to 1 h are subtracted from the entire 4 day bora episode to determine the perturbations. Then a power law of the form (3a) is fitted to the scatter diagrams of σ_u

vs. $\overline{U}$ for different moving averages. Expecting b to be 1, Fig. 2 shows that the closest value for $b \approx 1$ is achieved for the 1 min moving average. Therefore, we use the 1 min moving average for determination of the local turbulence perturbations in this bora episode. From (2) it follows that $\varepsilon \propto TKE^{1.5}$. This relation is tested by fitting the (3b) power law to the ε vs. *TKE* scatter diagram of 1 h mean values for the entire bora episode. This fit gives coefficient d and parameter $\Lambda = (c)^{-1}$ to be 1.3 and 60 m, respectively.

$$\sigma_u = a\left(\overline{U}\right)^b \quad (3a); \qquad \varepsilon = c(TKE)^d \quad (3b)$$

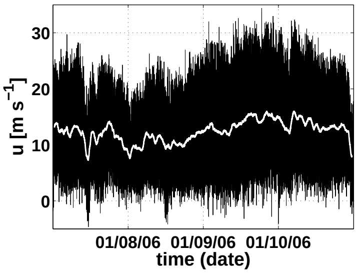

Figure 1. A 4 day raw 4 Hz data time series (07 to 11 January 2006) of the streamwise-wind component measured in Senj, with the 1 h mean superimposed.

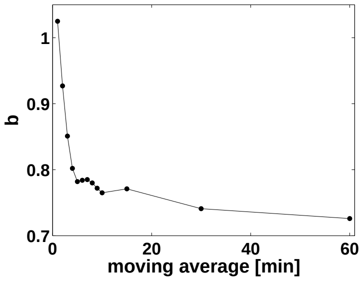

Figure2. The power coefficients b from (3a) for different moving averages subtracted from the entire bora episode.

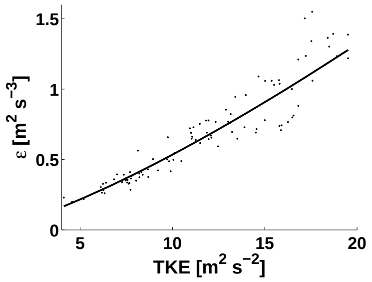

Figure3. Scatter plot ε vs. *TKE* for the entire bora episode. Solid line is the fit with the *a priori* unknown coefficients c and d from (3b).

4 CONCLUSIONS

Our data suggest that the 1 min moving average may be recommended for determination of the local turbulence perturbations for bora. Estimations of ε using IDM agree well with those of Piper and Lundquist (2004) with respect to the mean streamwise velocity component. In this bora episode ε is proportional to $TKE^{1.303}$. This model explains 91 % of ε vs. *TKE* variance. From (3b) it follows that $\Lambda \approx 60$ m.

Many current state-of-the-art models use Blackadar length-scale parameterization which would for this situation give $\Lambda \approx 25$ m. This is derived on the basis of the vertical *TKE* profiles from Belušić and Klaić (2004), using MEMO 6 mesoscale model to simulate several bora events. The same result is obtained using the WRF-ARW model with Mellor-Yamada-Janjic turbulence parameterization scheme. The model-based Λ obviously underestimates Λ derived here from *TKE* and ε values. This may imply the inadequacy of the Blackadar type of parameterizations for the bora related turbulence.

Future work related to the near-surface bora turbulence will include the 4 Hz data analysis of a variety of the bora episodes, categorized by their nature (type), severity (strength) and seasonal period. In this way, a comprehensive picture of the bora related near surface turbulence will be revealed.

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