Longitudinal roll vortices in the bora wind

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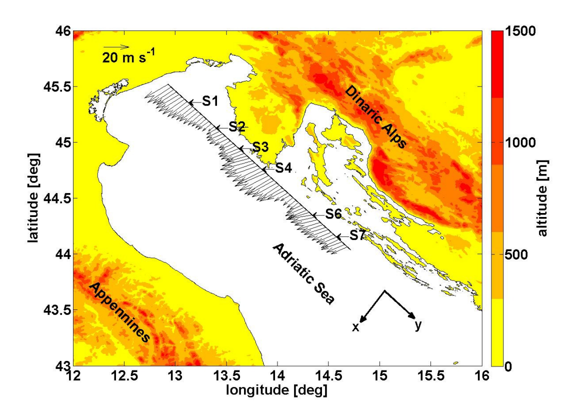

Figure 1. Wind vectors averaged over 1.6 km along the lower flight leg (370m a.s.l., 1504–1539 UTC 7 Nov 1999) with the release positions of dropsondes indicated. Reference wind vector is shown in the top left corner. Coordinate system is denoted in the bottom right corner

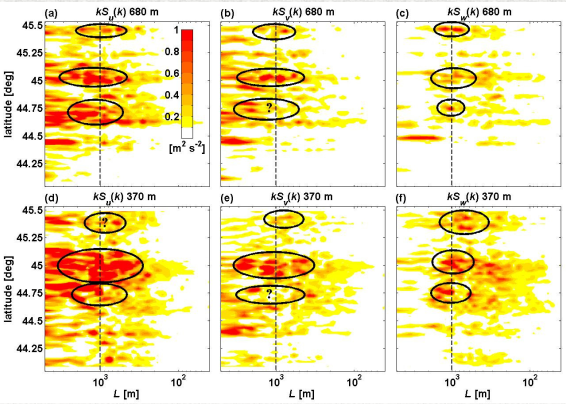

Figure 2. Spatial structure of the weighted energy spectra along the upper (top panels) and lower (bottom panels) flight leg for *u* (left), *v* (middle) and *w* (right) wind components. A noticeable increase in energy at the horizontal scale of approximately 1 km is present in all plots around the latitude of 45 degrees.

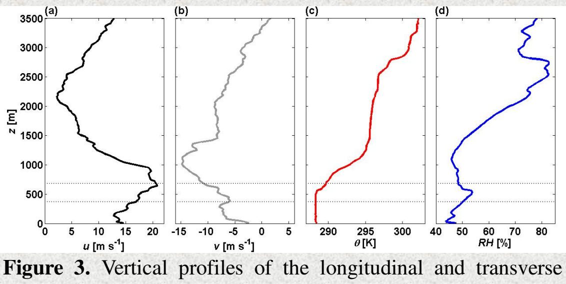

Figure 3. Vertical profiles of the longitudinal and transverse wind components, potential temperature and relative humidity from the dropsonde S3 (Fig. 1).

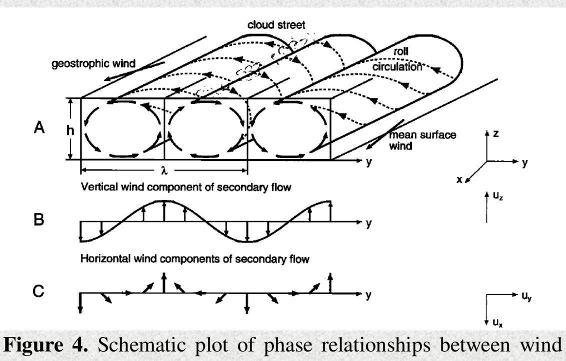

Figure 4. Schematic plot of phase relationships between wind components in roll vortices. (A) Three-dimensional view. (B) Transverse variation of the vertical wind component. (C) Transverse variation of the horizontal wind vector (from Alpers and Brummer 1994).

1. INTRODUCTION

- **Longitudinal roll vortices (LRV): quasi-2D vortices that strongly affect the atmospheric boundary layer (ABL) fluxes (LeMone 1976) ➔ vertically limited by the top of the ABL (z_i) and have horizontal wavelengths (*L*) 2–12 x larger than vertical scale**
- **BORA: cold air outbreak over the warm Adriatic Sea ➔ suitable conditions for the appearance of LRV ➔ their existence during bora has never been considered**
- **LRV are typically associated with the presence of the ubiquitous cloud streets (CS) ➔ NOT the case for bora due to its downslope nature with descending dry air which results with the cloud-free conditions ➔ their existence in the bora flows is not obvious**
- **We present aircraft observations above the Adriatic Sea that despite the absence of CS suggest the existence of LRV in bora**

2.DATA

- **Mesoscale Alpine Program (MAP) Intensive Observation Period 15 (IOP 15) on 7 Nov 1999 ➔ NCAR Electra aircraft ➔ 3 flight legs (Fig. 1) from 1347 to 1539 UTC:**
  - **leg 1 (NW → SE): 1347–1420 UTC ≈ 4200 m a.s.l. ➔ + 6 dropsondes**
  - **leg 2 (SE → NW): 1429–1501 UTC ≈ 680 m a.s.l.**
  - **leg 3 (NW → SE): 1504–1539 UTC ≈ 370 m a.s.l.**
  - **(legs 1–3) 25 Hz sampling ➔ dy ≈ 4 m**

3. RESULTS

- **Peaks in the wind velocity energy spectra appear at $L \approx 1$ km at several locations along the flight legs (Fig. 2), but the dominant peak at lat ≈ 45° is evident in all wind components and at both flight legs ➔ the most likely location of LRV ➔ segment between 44.90 and 45.05 degrees is chosen for further analysis**
- **θ from the S3 dropsonde (Fig. 1) released closest to the chosen interval indicates the ABL height of about 600 m (Fig. 3); however, the aircraft data suggests that the inversion base is above the upper flight leg ➔ hence we estimate the ABL height as z_i = 700 m ➔ the roll aspect ratio (wavelength/ABL height) is $L/z_i = 1.4$ ➔ somewhat smaller than reported in the literature**
- **The spatial structure of LRV yields specific phase relationships between different wind components (e.g. Hein and Brown 1988) ➔ Fig. 4 depicts an idealized system that indicates that expected phase angles are (Chen et al. 2001): $\Phi_{vw} = \pm 90°$; $\Phi_{uw} = \pm 180°$**
- **Figure 5 shows the coherence and phase angle for all combinations of the three wind components for our data at both heights ➔ the peak in coherence at *L* of 1 km is present for all combinations of components at 370 m, and for *v* and *w* at 680 m**
- **At 370 m (≈ in the middle of the LRV layer) *u* and *w* are 180° out of phase, while *v* and *w* are in phase ➔ indication that LRV are tilted in the crosswind direction**
- **In accordance with the theory, the phase angle between *v* and *w* changes to 90 degrees at 680 m, which is near the top of the roll layer**
- **The absence of CS is due to the RH being close to 50% below 1.5 km (Fig. 3) 🡐 descending dry air governed by a large-amplitude or breaking mountain wave**

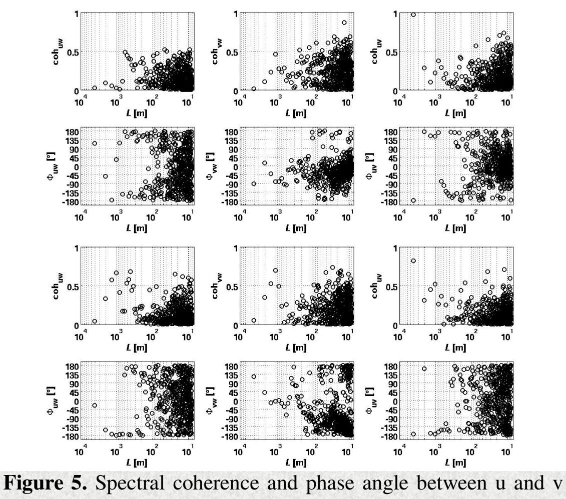

Figure 5. Spectral coherence and phase angle between u and v (left), v and w (middle) and u and v (right) wind components. Top two rows are for the higher flight leg (680 m) and the bottom two rows are for the lower flight leg (370 m).

4. CONCLUSIONS

- **Aircraft measurements of the bora wind above the Adriatic indicate the existence of LRV with *L* of 1 km and L/z_i of 1.4 ➔ the lower limit of the boundary between quasi-two-dimensional rolls and 3D convective cells ➔ possibility that the organized structures are in fact 3D cells**
- **A way to inspect this scenario would be to compare spectral characteristics of the wind velocity between the along-wind and cross-wind flight patterns (Hein and Brown 1988) ➔ the quasi-2D LRV structures should have a unique spectral peak in the cross-wind flight direction that does not appear in the along-wind direction**
- **No ABL flights parallel to the bora direction during the MAP experiment ➔ this possibility cannot be examined at present**

References

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