Numerical simulation of low-level jets during the Perdigão field campaign 2017

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Introduction

- The Perdigão field campaign 2017 provides a comprehensive data set of meteorological observations in the atmospheric boundary layer (ABL) over complex terrain including the interaction of the flow with a single wind turbine (Fig. 1)
- Nocturnal low-level jets (LLJ) from NE were frequently observed by lidars and met-masts during the measurement period
- Gravity waves (GW) are induced by the double-ridge topography
- The correct simulation of LLJs is difficult, but important for wind power production

Research questions:

- Can the LLJs be simulated correctly with a numerical model?
- What are typical wavelengths of the observed GWs?

Figure 1: Perdigão SW ridge with wind turbine. Photo taken by N. Wildmann.

Model Set-up

- WRF ARW version 3.8
- **Long run:**
  - Simulation over 1.5 months (30.4. to 18.6.)
  - D1 (dx=5 km), D2 (dx=1 km), Fig.2a
  - Double ridge not resolved
- **Short runs:**
  - Simulations over 12 hours (18 UTC to 6 UTC)
  - D3 (dx=200m) and D4 (dx=40 m) in LES mode
  - ASTER topography (30 m resolution, Fig. 2b)
  - CORINE land-use data set (100 m res., Fig. 2c)
  - Vertical levels: dz=40 m below 1000 m AGL
  - **CTRL** run: roughness length from CORINE data set
  - **ROUGH** run: additional friction term applied on 1st model level in D3 and D4, representing the trees in the domain

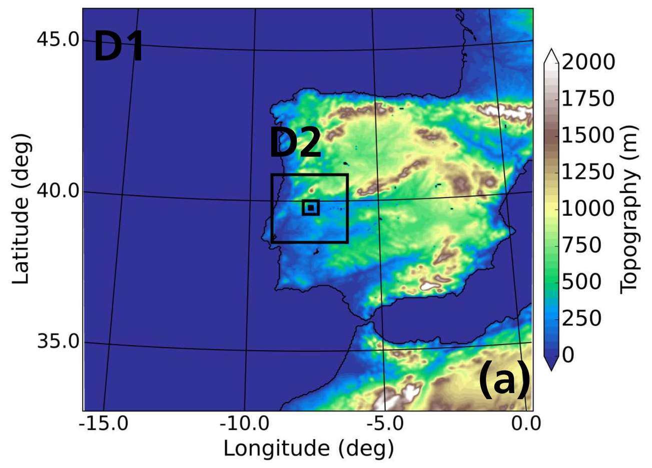
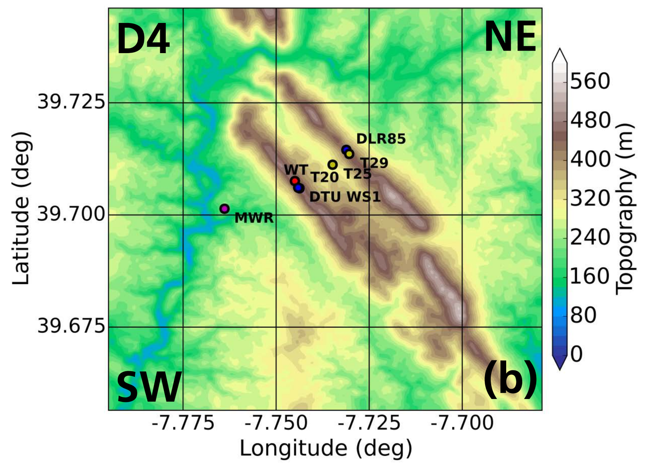
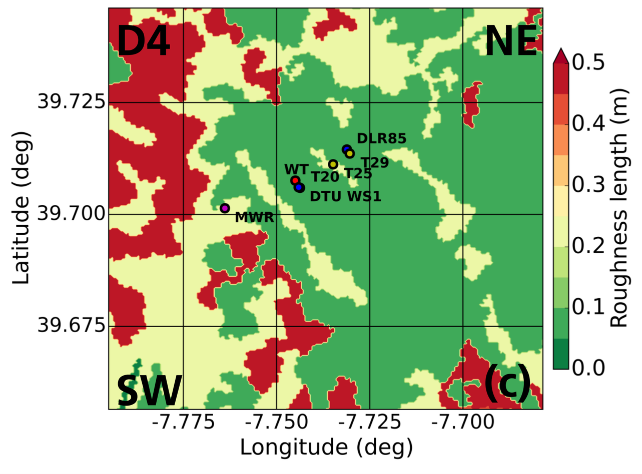


Figure 2: Model domains D1 – D4. Locations of the wind turbine (WT), DLR lidar (DLR85), DTU lidar (DTU WS1), DLR microwave radiometer (MWR) and 100m towers (T20, T25, T29) are marked by coloured dots in c.





WRF long run

- WRF long run captures ABL-flow well under various synoptic conditions in spite of missing valley topography (Fig. 3 a,b)
- NE-flows occur during calm synoptic conditions: e.g., May 7 & 8
- Max wind speeds too high, probably due to small CORINE z_0 values (Fig. 3 c,d)

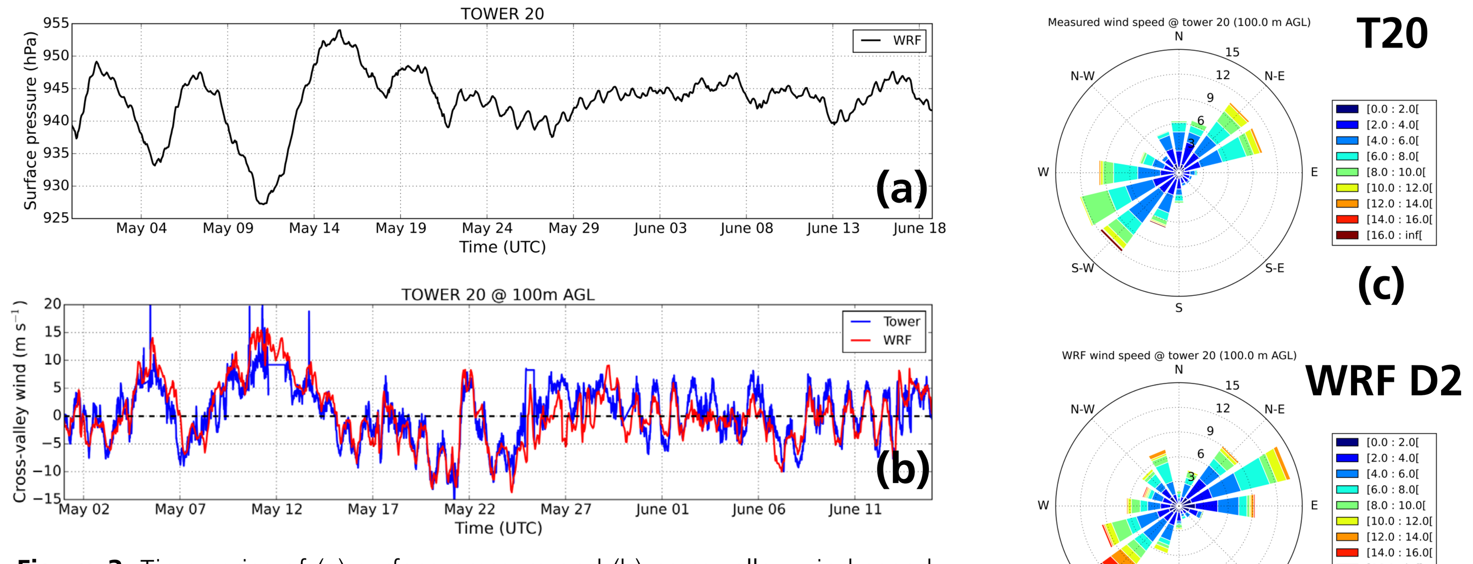


Figure 3: Time series of (a) surface pressure and (b) cross-valley wind speed at 100 m AGL at the SW ridge for WRF D2 run and tower observations (T20). The distribution of wind speed at T20 is shown in (c) and (d).

WRF short runs

- The combined lidars DTU-WS1 and DLR-85 indicate the formation of trapped lee waves over the double ridge on May 7 and 8 (Fig. 4)
- **May 7:** Strong upstream wind (~6.5 ms^{-1}) and weak wind shear (thick jet layer) induce longer horizontal wavelength with λ~1.5 km and $Fr \approx 1.2$ (Fig. 4 a & 6 c)
- **May 8:** Thin jet layer with strong shear but weaker wind (~4.2 ms^{-1}) (Fig. 5 b) results in shorter wavelengths of λ~0.5 - 0.7 km and $Fr \approx 0.7$ (Fig. 4 b)
- **CTRL run:** LLJ too strong (up to 12.8 ms^{-1} on May 8), poor representation of GW (Fig. 6 d)
- **ROUGH run:** Improved ABL-structure (Fig. 6 b,e), but on May 8 LLJ still too thick and wavelength too long (λ ~1.5 km) (Fig. 6 e,f)

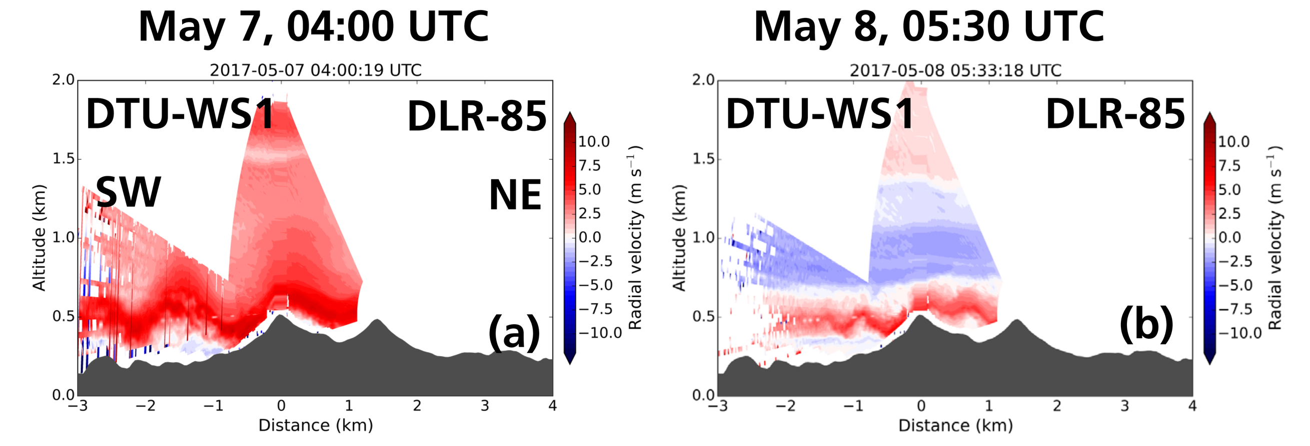


Figure 4: Radial velocities from lidars DLR-85 on NE ridge and DTU-WS1 on SW ridge Positive wind speeds indicate flow away from lidar.

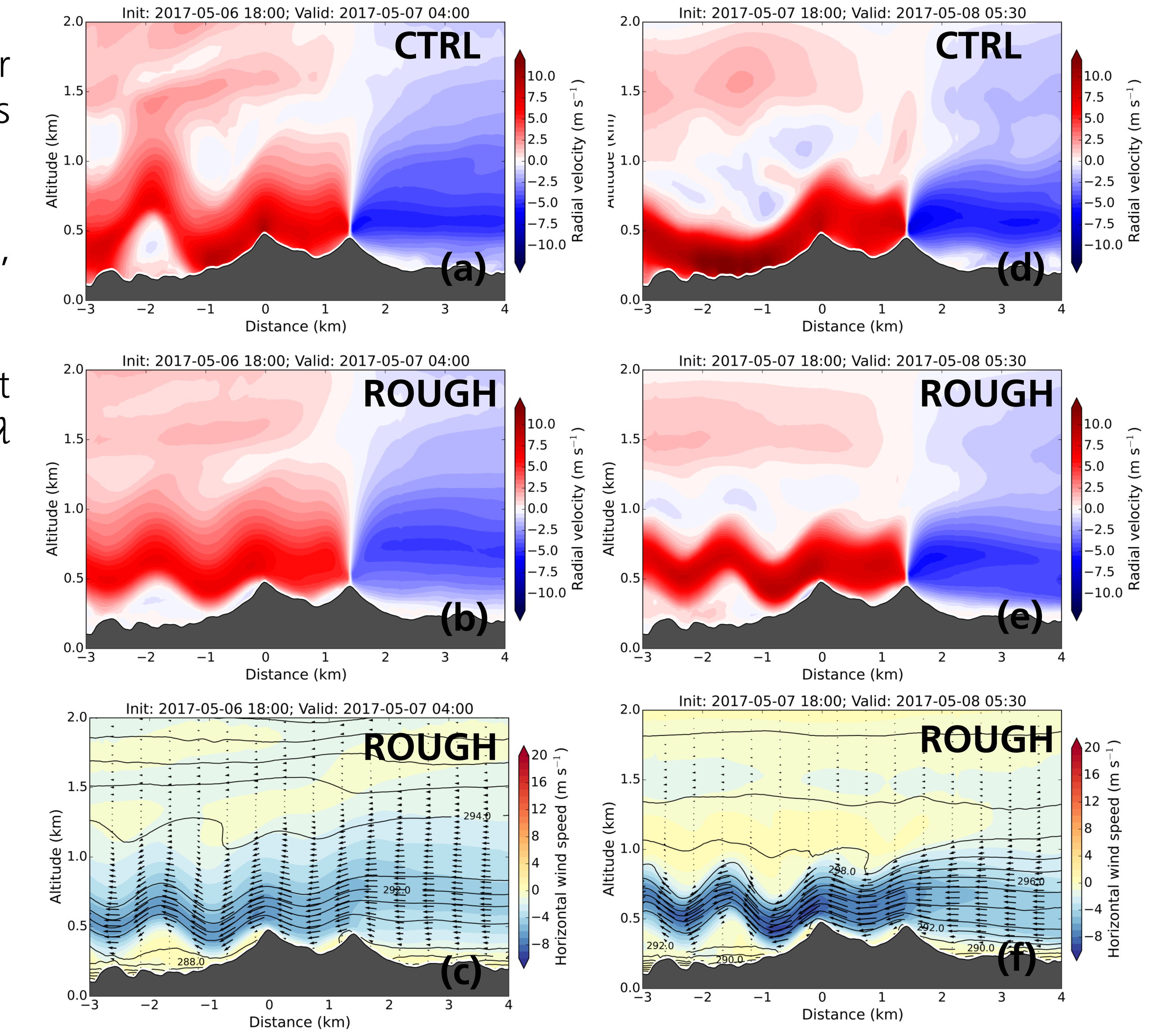


Figure 6: WRF D4 simulations of the LLJ situations. Radial velocities as seen by a virtual lidar DLR-85 are plotted in a, b, d, and e. The flow parallel to the lidar cross section is shown in c and f.

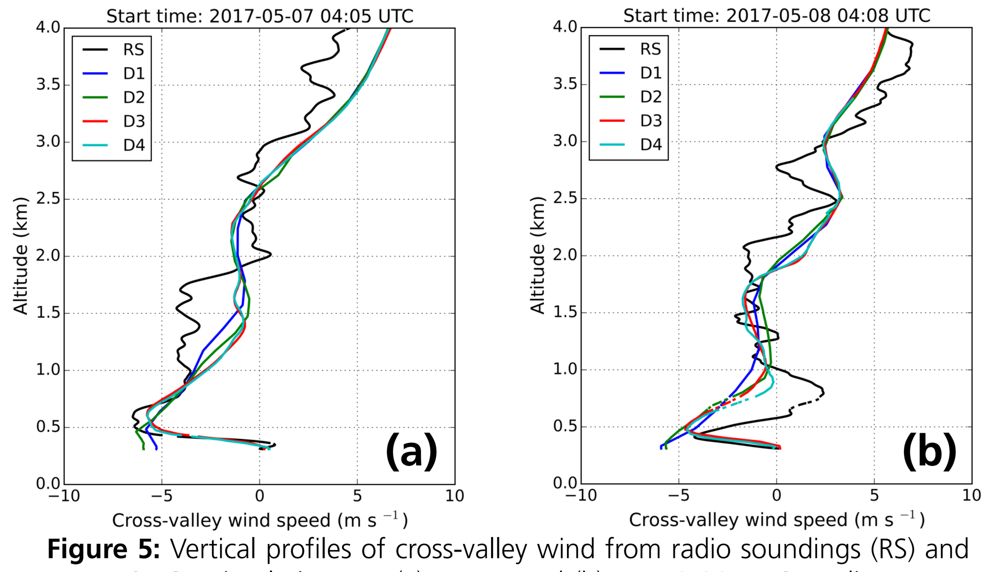


Figure 5: Vertical profiles of cross-valley wind from radio soundings (RS) and WRF ROUGH simulations on (a) May 7 and (b) May 8 2017. Soundings were kindly provided by NCAR EOL (K. Young).

Conclusion

- WRF captures the basic flow features; upper winds well represented even in coarse resolution and in a long run
- Roughness lengths from CORINE data set significantly too small
  - ⇨ Wrong ABL structure with extremely high surface winds and missing trapped lee waves in the CTRL run
- Additional friction term on 1st model level improves simulated jet
  - ⇨ Further sensitivity runs with corrected roughness lengths necessary
- **Outlook**:
  - Nested domain D5 with dx=8m and parameterized wind turbine to simulate WT-wake under different ABL conditions
  - Repeat WRF long run with horizontal resolution of 200m (D3) to resolve double-ridge

Acknowledgements

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