Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2018-847-RC1, 2018

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Characterization of flow recirculation zones in complex terrain using multi-lidar measurements" *by* Robert Menke et al.

Anonymous Referee #1

Received and published: 29 September 2018

This paper reports measurements over a double ridge from a range of instruments (sonic anemometers on 100 m wind masts, Doppler lidars, etc.) made during the Perdigao field campaign in Portugal. The study focuses mostly on the occurrence of flow separation in the lee of the upwind hill, because of the importance for wind-power applications of the decrease of mean wind speed and increase of turbulence intensity that accompanies flow separation (and its effect on the downwind hill). The manuscript represents a substantial contribution to scientific progress, within the scope of ACP, being especially relevant due to the novel and comprehensive data gathered using state-of-the-art equipment. These data are processed and interpreted appropriately, although a number of improvements are possible (see below). The scientific approach, methodology and assumptions seem overall sound, and are described and discussed

Printer-friendly version

Discussion paper

in an adequate, clear and balanced way, including allusions to previous work and use of references. Relevant results and conclusions supported by them are presented. The paper is concise, well-structured, clear, and well written. The title reflects the contents of the paper, and the abstract provides a good summary. The quality and number of figures and tables seems appropriate (for the content as it currently stands). The equations, symbols and units are properly defined and used. Although I will suggest some additions that require new calculations and possibly new figures, these should be straightforward to obtain from the existing data, so the paper is likely to require only minor revisions prior to publication.

General comment

Analysis of the collected data could be a bit more comprehensive, specifically regarding conditions under which flow separation is expected. These conditions may be estimated from simple, mostly linear, theories of flow over orography. Even ignoring boundary layer effects (which would complicate the picture considerably), flow separation can be viewed as an outcome of flow deceleration by the orography. Two paradigms may be considered in this problem. For neutral flow, nonlinearity may be quantified by (h/a) (the orography steepness), where h and a are typical height and width for the orography, and the flow perturbation scales as U(h/a), where U is the incoming wind speed. For substantially stratified flow, on the other hand, nonlinearity is quantified by (Nh/U), where N is the Brunt-Vaisala frequency of the incoming wind, and the horizontal flow perturbation scales as (Nh). The authors consider Ri as a relevant parameter, but overlook the sensitivity of the flow to (Nh/U), which would be equally easy to test and is even more basic (since it does not involve vertical derivatives of U). From the results presented in the paper, one gets the impression that neutral flow always causes flow separation (theoretically, this is predicted by (h/a), which is fixed by the orography), but in statically stable conditions the important nonlinearity parameter becomes instead (Nh/U), which might explain the absence of wave breaking detected when Ri>0, i.e. Nˆ2>0. With this conceptual framework, the fact that flow separation occurs for high wind speeds may be explained by the consequent smallness of (Nh/U). The role currently played by Ri, in my view, is primarily distinguishing between unstable or neutral flows, on the one hand, and stable flows, on the other, but it is not obvious that the wind shear effect contained in Ri has much relevance. This is one of the reasons why I suggest that the scaling with (Nh/U) be tested.

Specific comments

Page 1, lines 21-22: "flow acceleration and channeling effects, the formation of lee waves, and flow recirculation (Stull, 2012) which are not captured well by a linearized flow model". The word "well" is essential for this passage not to be grossly inaccurate. Linear models, with a structured atmosphere, are capable of predicting lee waves (Teixeira and Miranda, 2017), and can even give qualitative indications about flow channelling and recirculation (Teixeira, 2017). Linear models are almost the only way to obtain systematic scalings for the flow variables, and that should be recognized more in this passage.

Page 4, line 5: "Range gates". It is not obvious to the reader what these mean exactly. Please add a brief description.

Page 6, lines 4-5: "[in order to calculate the Richardson number] we calculate the difference between the wind speed measured by the 100 m sonic and at the ground level, 0 m, where the wind speed is assumed to be zero". I assume that in this calculation and that of the vertical potential temperature gradient used to evaluate Ri the authors adopt linear interpolation in Eq. (1) (these details are not specified). The range of heights over which this calculation is performed is most likely in the surface layer. Since the profiles of both wind speed and potential temperature in that layer are logarithmic to a first approximation, it might be more accurate to determine Ri based on the logarithmic finite-difference approximation described by Arya (2001), Eq. (11.22). If this is not appropriate, please justify why.

Figures 5 and 6: following my suggestions in the General Comment above, it would be probably useful to produce figures similar to these, but where Ri on the horizontal axis is replaced by (Nh/U), or U/(Nh). This should give some additional physical insight into the flow behaviour.

Page 9, lines 2-3: "Recirculation is more likely to occur during unstable or neutral atmospheric conditions (Ri<0) than for stable conditions (Ri>0) for both SW and NE winds". The interpretation presented in my General Comment, along with plotting the data as a function of (Nh/U), might be able to shed some light as to why this happens. In terms of the behaviour with Ri, what appears to matter (see below) is the sign of Nˆ2, more than the detailed value of Ri. Perhaps this could be recognized and discussed.

Page 9, lines 13-18: Flow separation is discussed with relation to the height and steepness of the ridges. It is also noted that the southwest slope of the soutwest ridge is steeper than the northeast slope of the northeast ridge. However, for flow separation in southwest flow what should be most important is the steepness of the northeast slope of the southwest ridge (because separation occurs downwind of obstacles) and for northeast flow the steepness of the southwest slope of the northeast ridge. The authors should check whether the steepnesses of these slopes are consistent with this physical interpretation of the results.

Figure 8: the reverse flow speed is presented as a function of the upstream flow speed. As is consistent with my General Comment above, this tests a scaling for neutral flow, where the velocity perturbation scales as u $\sim$ U(h/a). This scaling is likely to be applicable, in Fig. 8, to the points that have Ri<0 (i.e. Nˆ2<0), because they will generate no orographic gravity waves. For points that have Ri>0 (i.e. Nˆ2>0), orographic gravity waves will occur, and the corresponding stratified scaling may apply, namely u $\sim$ (N h). So, it would be interesting to produce a figure similar to Fig. 8, but with (Nh) in the horizontal axis. Perhaps a better collapse will be obtained for points with Nˆ2 (although there are definitely many other processes going on, most prominently boundary layer effects). Even if this scaling with (Nh) does not work very well (for example, due to an insufficiently strong stratification), it is interesting to compare the two scalings.

References

Teixeira, M. A. C. (2017) Diagnosing lee wave rotor onset using a linear model including a boundary layer. Atmosphere, vol. 8, 5.

Teixeira, M. A. C. and Miranda, P. M. A. (2017) Drag associated with 3D trapped lee waves over an axisymmetric obstacle in two-layer atmospheres. Quarterly Journal of the Royal Meteorological Society, vol. 143, 3244-3258.

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2018-847, 2018.