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Atmospheric Measurement Techniques
Discussions

Interactive comment on "Evaluation of wake influence on high-resolution balloon-sonde measurements" *by* J. Faber et al.

J. Faber et al.

jens.faber@io-warnemuende.de

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Reply to the anonymous review 2

We are grateful for the effort undertaken by the reviewer and like to thank her/him for the constructive recommendations. A point-by-point answer is given below.

What is actually a typical wake effect on measurements of turbulence (or other quantities like temperature or humidity)? Please provide more information about this to the unexperienced reader.

Thanks very much for your suggestion. We have added the following paragraph to the introduction that highlights the impact of wake created turbulence.

"On measurements of turbulent velocity fluctuations, the wake from the balloon can hardly be distinguished from atmospheric turbulence of the same strength. With our LITOS instrument we found that the spectral shape of the velocity fluctuations does not allow a distinction between atmospheric turbulence and wake. Depending on the payload-balloon distance, we found dissipation rates created by the balloon's wake between 10^{-4} W kg^{-1} and 10^{-2} W kg^{-1}. In terms of aviation turbulence categories, these dissipation rates correspond to "light" and "moderate" turbulence using the scaling of Sharman et al. (2014). Wake effects from the ropes holding the gondola show consistently "severe" turbulence intensities around and 10^{-1} W kg^{-1}. Accordingly, these effects should not be neglected for turbulence measurements from rising balloons. For standard radiosondes Kräuchi et al. (2016) report a warm bias of 1 K on average for a daytime sounding in the stratosphere. Furthermore, moisture from the balloon's skin will lead to a wet bias of stratospheric humidity if the sensor is in the balloon's wake."

The manuscript seems to provide examples both of increased turbulence and decreased turbulence in the wake (figure 3; page 11, line 5-9; page 11, line 12-13).

According to our understanding, the strength of wake related turbulence depends on the payload-balloon distance and possibly on the size of the balloon or the ascent rate. We found kinetic energy dissipation rates from 10^{-4} W kg^{-1} to 10^{-2} W kg^{-1}. This, however, is not related to the strength of atmospheric turbulence. Therefore, atmospheric turbulence may be weaker as well as stronger than wake related turbulence. In order to point this out, we changed the paragraph following page 11, line 7:
"We like to stress, however, that the data underlying Figure 1 show only one exemplary case of a turbulent altitude bin. Under different atmospheric conditions, LITOS measured atmospheric turbulence ranging from 0.001 mW kg^{-1} to 100 mW kg^{-1}. In contrast, we typically find dissipation rates between 0.01 mW kg^{-1} and 1 mW kg^{-1} for balloon-wake induced turbulence. However, during previous measurements with lower payload-balloon distances we measured wake induced turbulence stronger than 10 mW kg^{-1} (data not shown here)."

At several places in the manuscript it is stated that the wake does not have a clear outer boundary. Rather, one would expect, a continuous transition from a perturbed region to an unperturbed region. On the other hand you use the notation "inside the wake" and "outside the wake" throughout the manuscript. And you introduce e.g. the "radius of the wake" (page 10, line 11). This is not consistent and should be clarified.

We are sorry for our inconsistent terminology on this matter. To our understanding, there is a clear outer boundary of the wake. However, the transversal distance of the outer boundary of the wake to the wake's centre will change depending on the downstream distance from the balloon. This is, because the outer boundary of the wake is shaped by larger eddies. A visualisation of the flow in a turbulent wake showing a fairly clear outer boundary is given in Jang and Lee (2008, Figure 11b). Even though we expect a clear outer boundary, we cannot state its distance from the wake centre for a given downstream distance to the balloon due to the chaotic flow in the wake. This is one of the main reasons to take a probabilistic approach in our wake detection algorithm. The sentence on page 3, lines 3-7 has been changed to:
"Furthermore, we consider that the diameter of the balloon's wake changes on short time scales of a few seconds due to the production of larger vortices. Furthermore, its mean diameter increases on longer timescales in the order of several 10 seconds. Since the balloon's contour resembles a sphere during flight, we can refer to fundamental experiments done in wind tunnels (e.g. Riddhagni et al., 1971; Gibson and Lin, 1968). An informative visualisation of such a flow can be found in Jang and Lee (2008, Figure 11)."
Other discussions of the outer boundary of the wake have been amended accordingly.

Most analysis in the paper is done in terms of likelihood for instruments to encounter the wake of the balloon (or of the payload chain). What would desirable for balloon researchers is a more "deterministic" algorithm that provides a rather clear statement Yes or No about being influenced by a wake effects in a given situation. Do the authors see any way forward towards developing such a "deterministic" analysis tool?

We fully agree with the reviewer that a deterministic tool to determine whether the balloon's gondola is inside or outside the wake would be highly desirable. Unfortunately however, we do not see a way to create such a tool using radiosonde wind data. The main reason for this conclusion is that the uncertainty in the payload-wake distance ($\Delta_{d_{\text{p-wake}}}$) is in the same order of magnitude as the payload-wake distance ($d_{\text{p-wake}}$). From our point of view this requires an uncertainty analysis, which is done in our probabilistic approach. The uncertainty in the position of the balloon ($\Delta_{\text{X}_{\text{bal}}}$) could only be reduced by using an additional GPS receiver attached to the balloon. The uncertainties in the radiosonde wind measurement (Δ_{U}) and in the payload position ($\Delta_{\text{X}_{\text{p}}}$) however, could be generally reduced by enhancing precision and sampling rate of the radiosonde. Nevertheless, these measures would still not remove the uncertainty in the diameter of the wake (as discussed in the previous point). In conclusion, one could reduce the uncertainties in the calculation with a high technical effort, but would still not be able to fully avoid a probabilistic approach. Therefore, we assume that our approach provides a helpful compromise between usability and certainty in the prediction.

On page 11, line 12-13, you refer to probabilities exceeding 95% as "wake affected within uncertainty". Would you not consider significantly lower probabilities (e.g. 80% or 60%) as being "wake affected within uncertainty". What is the significance of the number 95%?

Our aim is to sort out all data bins that are not most certainly wake free. Therefore, we only use turbulence measurements from altitude bins showing $P_{\text{wake}} < 5\,\%$. From our point of view a significantly lower confidence level (accepting turbulence measurements with $P_{\text{wake}} \gg 5\,\%$) would illicitly increase the risk of misinterpreting wake created turbulence for atmospheric turbulence. Accordingly, we define altitude bins with a wake probability above 95 % as wake affected in order to be consistent with our definition of wake free altitude bins. To make our wording more precise, we removed "within uncertainty" from page 11, line 13 of the manuscript.

Related to the above questions: On page 4, line 18, you refer to a measurement un-

perturbed by ant wake effect. How do you know this?

We know that there are no wake effects on this measurement, because we measured on a descending balloon with our sensors pointing downward. Accordingly, all parts of the payload are located downstream of our sensors. Therefore, the sensors cannot be hit by the wake from these objects.

It would be instructive if you in your conclusions formulated some general advice for balloon researcher about how to deal with wake effects.

Thank you very much for pointing this out. We added the following sentence to our conclusion:
“For research purposes where the complete avoidance of any wake influence is crucial (e.g. turbulence measurements, high accuracy temperature soundings), we strongly recommend to measure on a descending balloon with the sensor pointing downward.”

Some minor comment:
Om page 3, lines 9, 12, 15: It is unclear what "their" refers to in this paragraph. It somehow refers to "other studies" in line 8. Please clarify the formulations.

Thanks for identifying this issue. We changed the sentences to:
“The most common method to obtain energy dissipation rates from radiosonde temperature profile has been adapted from oceanic sciences by Luce et al. (2002) and Clayson and Kantha (2008). It is frequently referred to as the “Thorpe analysis”. Energy dissipation rates are inferred from the vertical displacement (Thorpe displacement) of an air parcel compared to a statically stable profile (Wilson et al., 2010, 2011). Typically, for a standard radiosonde the distance between the balloon and the sensor is between 30 m and 55 m. This makes the measurements susceptible to distortions from the balloon’s wake (e.g. Jumper and Murphy, 2001; Kräuchi et al., 2016). Hence, our wake evaluation tool may be used to assess the likelihood of wake influence for every altitude bin of a Thorpe analysis turbulence retrieval, depending on the balloon-payload distance of the instrument.”

On page 9, line 9-12, you introduce the amplitude of the balloons horizontal motion. It would be instructive to provide the reader with some typical numbers for this amplitude, e.g. for the LITOS case.

We have added the following statement to the text:
“Typically, D_{bal} is below 10 m. In the case of the LITOS launch from 29 January 2016 (discussed in Section 3.1.4) the mean amplitude in the critical and supercritical Reynolds number range is 6.3 m.”

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