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Interactive comment on "Modeling the ascent of sounding balloons: derivation of the vertical air motion" *by* A. Gallice et al.

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We would like to thank the reviewer for taking the time to examine our manuscript, and for his(her) very helpful suggestions. Below we give our detailed responses to the points raised.

General Comments

1. In the paper, we discuss the model in the case of night flights only. As the reviewer kindly suggests, this should be mentioned in the abstract and the conclusion for clarity, and we have now done this. Provided that solar radiation is treated as a diffusive process, the model could be adapted to simulate daytime soundings

too. In this case, the mean heat diffusion coefficient would have to be increased to take also radiation into account. To this end, quantitative assessments of the contribution of solar radiation to the heating of the balloon should be performed as a function of altitude. This would also depend on solar zenith angle, and cloud cover. The application of the model to daytime soundings is therefore not trivial and calls for a further study, preferably including measurements of the temperature within the balloon.

2. A short assessment of the model accuracy in terms of balloon altitude forecasting is presented in the paragraph starting at line 11 of page 3989. In this paragraph, the forecasted balloon altitude at burst time is compared with the measured one for all of the 10 LUAMI flights. Following the suggestion of the reviewer, we have also adjusted the manuscript to present an overall comparison of the forecasted and measured balloon trajectories. Figure 7 has been renamed as Fig. 7(a), and we have now added Fig. 7(b) to present the predicted and forecasted balloon trajectories in the case of LUAMI flight L005.

3. The suggestion of the reviewer to link Sections 2.3.1 and 2.3.2 to Sect. 2.3.3 is very pertinent. However, we did not do so in the paper because of our great uncertainties regarding the relevant phenomena (atmospheric turbulence intensity, balloon non-spherical shape, lift-induced drag, ...) explaining the departure of the LUAMI drag curves from the drag curves by Achenbach and Son et al. The general S-shape of the balloon ascent rate as a function of altitude can actually be explained by Eq. (3). Due to the diffusion of heat inside the balloon, the difference between the mean balloon temperature and the atmospheric temperature remains approximately constant over the troposphere and the stratosphere separately. Under this condition, it can be shown that the ascent rate of the balloon is proportional to the $-1/6$ power of the atmospheric density (e.g. see Eq. (2.100) at page 60 of Yajima et al. (2009), where $\tilde{f}$ and $\tilde{T}$ are constant in regard of the fact that the temperature difference between balloon and the atmosphere is con-

stant). This explains why the balloon ascent rate increases with altitude over the troposphere and the stratosphere separately. The decrease in the ascent rate at the tropopause results from the sudden increase in the potential temperature. This can be interpreted as the balloon being suddenly colder than its environment and therefore decelerating, until its temperature difference with the surrounding atmosphere stabilises and its ascent rate increases again as the $-1/6$ power of the atmospheric density. We have now added text to explain the general shape of the observed profiles.

4. Performing a sensitive study is difficult in the present case, in the sense that the model is self-consistent. The balloon drag curve is derived from the measurements using the model itself. As such, even a wrong estimation of the balloon radius can lead to a satisfactory estimation of the ascent rate, since the derived drag curve will counterbalance the error in the balloon radius. It is therefore in principle hard to say which one of the drag coefficient or the balloon radius is more important for future improvements. In practice however, the drag coefficient appears to be the most critical point. Contrary to the diffusion of heat inside the balloon, the dynamics of the drag coefficient remains poorly understood. In particular, its variation with altitude and the different mechanisms contributing to it are still unclear. Moreover, a shift of the balloon drag curve is observed to affect more strongly the profile of the balloon ascent rate than a variation of the diffusion coefficient. We therefore recommend that the dynamics of the drag coefficient are investigated more thoroughly in the future, which is stated in the conclusion of our manuscript.

Specific Comments

1. The drag coefficient is “defined with respect to S” for a given drag force, in the sense that the choice of the reference area is a priori not unique and only a matter of convention. To each different choice of a reference area corresponds a

different definition of c_D, since the drag force must be the same in the end. In our case, we decided to work with the cross-sectional area of the sphere with same volume as the balloon for convenience. Once the reference area is defined, c_D only depends on the Reynolds number, the turbulence intensity of the atmosphere and the shape of the object (but not its cross-section). We have now clarified this point in our manuscript.

2. Our results do indeed only apply to TX1200 balloons launched at night. We tried to apply our model to TX2000 balloons (the two removed flights mentioned in the paper) and obtained a different experimental drag curve. As compared to the TX1200 balloons, the values of c_D were lower in the troposphere and much higher in the stratosphere. We also tried to apply the model to daytime soundings, which revealed a strong impact of solar radiation on the values of c_D. Given a suitable set of night time soundings, and using the methods we describe here, it would be possible to calibrate this model to represent a different type of balloon, and indeed we hope that interested readers will carry out this exercise to apply the model to their own balloon of choice.

3. We are afraid we badly formulated our sentence. What we meant is that the presence of a parachute and a payload would increase the drag coefficient of the balloon because of their oscillations at the end of the cable. However, we do take into account the masses of the parachute and the payload when calculating the total mass of the balloon. This has now been made clearer in the manuscript.

4. We also had the idea to try third- and forth-order polynomials to fit the drag curves, which unfortunately did not prove successful (it was actually even worse).

References

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