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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Defintion of "banner clouds" based on time lapse movies" *by* J. H. Schween et al.

J. H. Schween et al.

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We are grateful to the two reviewers for their constructive and helpful remarks. In response we carefully revised various parts of the manuscript. Below we provide a point by point description how we accounted for the referees' criticism.

General remark

Reviewer 2 writes that the paper does not extend the scientific knowledge in a significant and scientific way. Of course, to some degree this is a matter of view and judgement rather than a fact. This is our reply.

Banner clouds are a complex phenomenon in space and time. For the first time, this

paper documents the space-time structure of these clouds by use of time lapse movies. This possibility has recently become available through modern online journals such as ACP. Quite literally this *adds an entire new dimension* to the documentation of banner clouds compared with any previous such effort. In combination with our discussion of various theoretical concepts as well as available meteorological observations (wind, temperature, radiosonde profiles), we present *at least two new results* which we have not found anywhere in the scientific literature. The first one (as reviewer 2 admits himself) is that the occurrence of banner clouds is not restricted to peaked mountains. Rather, they can just as well occur on quasi two-dimensional ridges. Second, our work provides evidence that banner clouds are more complex than thought before: there is a quasi-continuous transition between banner clouds (originating primarily from dynamical effects due to the strong cross wind) and more convective clouds (originating primarily from buoyancy). This finding is based on our method using movies to analyze the temporal behaviour. It lends a posteriori justification for a paper which defines the phenomenon, and this is what we aim to provide here.

Based on these facts and considerations, in our view the paper certainly contains enough scientific novelty such as to justify a pulication in ACP.

Referee 1

- We deliberately refrain from giving a typical size of the banner cloud, because our observations suggest that both length and depth strongly vary in response to the meteorological situation. This is now stated explicitly in the revised text at the end of section 3.
- We added some information regarding the statistics of banner clouds at Mount Zugspitze at the end of section 3.
- We added information regarding the wind and the static stability for each of the

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examples in the corresponding figure caption.

- The issue of the windward-leeward asymmetry is explicitly addressed in section 2. The most important aspect is the flow field, which is strongly asymmetric featuring one vortex (or two vortices) in the lee only. The vertical displacement due to the vortex (due to the vortices) is stronger than the vertical displacement on the windward side owing to the need of the air to flow over the mountain, thus favoring cloud formation in the lee. This point is now made explicitly in the revised version in the middle of section 2.

- We have recently started to study the physical mechanisms with the help of numerical modeling. This will allow us to put speculations about the mechanisms on a stronger footing. As the reviewer anticipates, it is planned to report about this research in an upcoming publication.

Referee 2

- General remark:
  One part of this comment is addressed above under "general remark". Regarding the other part, we followed the referee's suggestion and provided more observational data regarding the environmental conditions.

- Introduction:
  We included the reference of Houze (1993).

- Existing theories 1:
  We enhanced the discussion of the phenomenon of pairs of vortices in the lee of a three-dimensional mountain in section 2, including a reference to Smolarkiewizc and Rotunno (1989).

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- Existing theories 2:
  This section has been extended providing an additional argument which makes the theory of mixing fog appear less likely.

- Existing theories 3:
  This remark regarding the role of local valley circulations is very interesting. However, since slope winds and valley winds are thermally driven wind systems, we argue that they should not be seen as primary cause for a banner cloud. Thus, in our discussion of criterion IV we essentially exclude such circulation systems as the primary cause for banner clouds, although we do not exclude that they may contribute to the formation and modify the appearance.

- Orography at Mount Zugspitze:
  We included a new paragraph at the end of section 3 adding statistical information regarding the banner clouds at Mount Zugspitze. Unfortunately, our project did not permit the installation of more than one webcam. Nevertheless, from the available time lapse movies as well as from eye observations (taken regularly by the staff of the weather station at the summit of Mount Zugspitze) we can state that the depth and length of a banner cloud varies grately and it is hard to define a “typical size”. Rather, the appearance of the banner cloud sensitively depends on the meteorological conditions.

- Definition of banner clouds, 1:
  This is a good idea! We followed the reviewer’s suggestion and combined item 1 and 2 of the original definition into one item.

- Definition of banner clouds, 2:
  We agree with the reviewer that item IV is a contentious one, and this is explicitly admitted in the text. Note, however, that deliberately this item is separated from the other ones by some text, suggesting that the last item has a somewhat different quality (i.e. contains a theoretical concept). As we argue later in section 5,

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we believe that this last criterion is necessary in order to define banner clouds in situations which would be ambiguous otherwise.

- section 5.1, line 13:
  We now avoid the term “eddy turnover time” and, instead, refer to the time it takes a parcel in order to travel a distance corresponding to the cloud extent. This avoids reference to any vortex and is therefore more straightforward.

- section 5.1, line 16:
  We added the wind observations from the met-station at Zugspitze summit. Of course it would be of interest to know the wind shear at the ridge, but unfortunately we do not have wind measurements at different levels around the mountain. The possible role of wind shear is discussed in section 2.

- section 5.1:
  In the revised text we explicitly discuss the inversion seen in the radio sounding. It turns out that this does not preclude convective type clouds at the altitude of the Zugspitze summit.

- section 5.5 - now 5.3:
  The referee’s remark makes us aware that here is some potential for confusion. We actually admit that this case is an ambiguous one: there are arguments both in favour and against a banner cloud. Accordingly we changed the title of this subsection to ‘An ambigous case’ and thoroughly revised the entire section. In addition we changed the order of the examples in section 5. Former section 5.5. (‘not a banner cloud’) is now 5.3, former sections 5.3 (‘Transition from a banner cloud to a convective cumulus cloud’) and 5.4 (‘Different condensation levels’) were shifted backwards and are now accordingly sections 5.4 and 5.5.

- section 5.6:
  The arguments of the referee nicely demonstrate the point made in the glossary

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of Meteorology, namely that it is difficult to tell the difference between blowing snow and banner clouds. We revised the section and added two arguments, both of which are based on meteorological observations, and both of which are in favor of blowing snow. So we are confident that we do see blowing snow and not just a very thin banner cloud.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 9995, 2006.