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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Do gravity waves significantly impact PSC occurrence in the Antarctic?" *by* A. J. McDonald et al.

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1 General remarks

The article aims at quantifying the contribution of gravity waves (GW) to the formation of PSCs at southern polar latitudes during winter. This is an interesting (and largely open) issue, as it is classically thought that, in contrast with the Northern Hemisphere, large-scale temperatures in the southern polar vortex are cold enough to widely trigger the formation of PSCs and that extra meso-scale temperature disturbances (induced by gravity waves) are not really needed. Still, recent studies (referred in the article) have shown that this classical view may be somehow in default, and that gravity waves can actually play an effective role in the formation of PSC in the Southern Hemisphere. The authors combine three sources of data:

- POAM III extinction to detect the presence of (specifically Type I) PSCs, as well as stratospheric water vapour mixing ratios,
- UKMO analyses to infer the temperatures in the polar stratosphere,
- and, CHAMP GPS/Radio-occultation temperature profiles to estimate the amplitude of temperature pertubations produced by gravity waves.

The main result of the article is that gravity waves play a relatively marginal role throughout winter, with the exception of the early winter during which they can contribute up to 40% of the observed PSCs.

As stated above, I think the article tackles an interesting scientific issue, and does it with an original approach. I have however noted a number of concerns or remarks, which address both the results themselves and the way the article is written. Some of them may alter the main conclusion of the article. I therefore think that these remarks need to be taken into account before publication. Once this job done, I would support the publication of the article.

2 Major issues

1. On a formal point of view, the article could be much better organized. The major concerns are with:
    - the Introduction: A (too) large part of the introduction is devoted to the review of various articles that deal with the possible impact of gravity waves in the formation of PSCs. However, the structure of this discussion is not very clear. It begins on p3404, l6, with 3 articles that support the importance of gravity waves. Then on p3405, l7, there is a discussion on NAT nucleation with (on l18) an example of an article that does not support the

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need for gravity waves. But just after (p3405, l25), the authors come back with another article in favor of gravity waves. The discussion could be easier to follow, if it would deal in a sequential (and separate) way with first, examples of GW or non-GW PSCs, and then microphysical issues, and if the transitions between these two parts were clearly stated (instead of "Work as shown..." on page 3405, l7)

- The use of repetitions that tend to weigh down the text (and sometimes also to complicate the reading of it without necessity). For instance, the sentence on p3408, l3, is very similar to the one 10 lines above (p3407, l19), and can therefore be safely removed ; the way temperature thresholds are computed is stated on p3411, but recalled without necessity on p3414, l12. Examples like these are numerous (I try to mention other ones in specific points below, but I urge the authors to make a careful reading of their text to remove these repetitions).
- the use of reference. Very often, the authors goes into fine details of the articles that they cite (which demand them to allow one paragraph for every article), whereas one sentence that would synthetize the main outcomes of those references could be enough. Examples are found in the Introduction: the 3 articles on p3404 or the Parrondo et al (2007) on p3407.

2. On the results themselves, I have 4 important concerns:

   - the first one is associated with the sampling of the POAM III instrument. This sampling (more specifically, the variation with time of the latitude observed by POAM) is illustrated late in the article in Fig 8a. First, to my opinion, this graphic should be put much earlier in the article, in Section 2, where the authors present the dataset they will use. Then, a thorough discussion of the effect of this very specific sampling on the principal results of the article is lacking: one single short paragraph before the conclusion is devoted to this

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issue. For instance, it is stated several times in the article that the Antarctic Peninsula is considered as a "hotspot" for gravity waves. The Antarctic Peninsula is roughly located between 65°S and 75°S. Those latitudes are not observed by POAM after early August. More generally, after early August POAM III observations only occur over the Plateau, where the activity of gravity waves is expected to be very small. Could this sampling thus explain the **temporal** variation in the reported gravity wave impact on PSC generation ?

- the second one is associated with the "observational filter" of the Champ instrument. The radio occultation technique implies an integration along the line of sight of the Champ instrument, which will average some gravity-wave perturbations. The wave perturbations in the Champ temperature profiles are thus certainly underestimated, as are consequently the results in terms of percentage of PSC produced by GW (Figure 9). This effect is never mentionned in the article.
- I have another reason to think that the figures mentionned in this article actually underestimate the effect of gravity waves: the article does not deal with Type II PSC (which demand colder temperatures that Type I, and for which mesoscale disturbances can therefore be important). This should be more clearly stated in the title of the article (Type I PSC instead of PSC)
- I was very confused by Figure 6 (see specific points below). I am not sure to fully understand what is represented. However, the authors use this figure to support their hypothesis that GWs are mainly important in early winter, so that it is very important that some clarifications can be obtained.

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3 Specific points

- p3402, l26: I would rephrase: "The impact of wave-induced temperature perturbations causing enhanced PSC formation..." Note that I am not sure of the conclusion stated in this sentence (see POAM sampling above).
- p3403, l22: Rather than the seasonal relationship between temperature and PSC, I think that it is the cold temperature over wide areas that has led to less focus on gravity wave impact.
- l27: the recent Eckerman et al (2009) should be cited in complement to Höpfner et al. 2006 (note that Höpfner is mispelled many times in the article, including the bibliography).
- p3404, l23: Hertzog et al. (2008) emphasize the particular role of the Antarctic Peninsula.
- p3406, l1: "Mountain" -> "mountain" (and throughout the rest of the article). Furthermore the results from Svendsen et al. (2005) are relevant for the Artic: it is not obvious if the inclusion of mountain waves would have the same impact in the Antarctic.
- p3407, l6: Luntama et al (2008) has a nice illustration of the spurious ECMWF oscillations in temperature (that change with the year).
- p3408, l20: Rephrase "Research based on POAM III observations..." The description of the temporal sampling of POAM III should be placed here.
- p3409, l15 and 16: I do not understand the end of this sentence, as it is stated on the same page l6 that "in this study we do not differentiate between Type Ia and Ib PSC. This has to be clarified.

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- p3410, l3: idem. Is this second algorithm used (in which case, its description has to be more detailed) or not ?
- l10: this is another important point: I have understood from this paragraph that the methodology used here cannot address the effect of gravity waves on the formation of optically thick PSCs. Am I correct ? This is another important underestimation of the effect of gravity waves.
- l15: It should be worth beginning a new subsection here devoted to Champ. The discussion on the Champ observational filter in terms of gravity waves should be placed here.
- p3411, l15: This is the 3rd times in the same paragraph that it is stated that the Hanson and Mauersberger (1988) formula is used.
- p3412, l4: I do not agree: the standard deviation of a binomial distribution reads sqrt[n.p.(1-p)]... Can you explain more clearly the formula that is written in your article ?
- l11: I do not agree with the sentence that begins at the end of this line. The correspondence between PSC occurence and temperature is far from direct: both family of contours cross each other...
- p3413, l7: Another explanation could be a cold bias of the UKMO analysis. Could the authors give a reference on the accuracy of UKMO analyses at southern polar latitudes ? Or Figure 7 can be placed around here to discuss this issue.
- p3414, l12: This has already been stated.
- l17: This sentence can be removed, as the difference between Type Ia and Ib PSCs is not addressed in this paper.

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- p3415, l6: Could you be more specific about "statistical" ? Have you constructed a Champ-based temperature climatology (including mean and disturbances) ? What are the independent variables: latitude, longitude, altitude, time ?
- l10: to be put before !
- Figure 6 and the associated discussion in pages 3415-3417: I have difficulties in understanding this figure. First, there is one star per month in the upper panel. Does it mean that the Champ PSC occurrences are monthly values ? This is linked to the "climatology" above, and has to be more clearly stated. Second, I am very confused by the lower panel. My understanding (after many hesitations) is the following. The blue line is the relative difference between the blue and red curves in the upper panel, but the green stars is not the difference between the green stars and the red curve in the upper panel. Otherwise, the lower panel green stars would have no reason to be systematically above 0 (see for instance August and September). It seems that they represent the additional effect of gravity waves in allowing the Champ profile to cross T_{NAT}. Am I right ? If I am, this has first to be (at least) more clearly explained, but then I do not understand the values reported in Figure 9: how can GW account for 40% of PSCs in June (according to Figure 9), while they only contribute to a "Delta_occurrence" of a few percent in the same month (according to Figure 6). Really, this is an important issue ! Without understanding the meaning of these green stars in the lower panel, it is very difficult to follow the associated discussion.
- p3416, l2: I don't know what is "this value".
- l9: what do "that" stands for ?
- l20: Your results also tend to show that T_{STS} is a better proxy. Why not using T_{STS} here instead of T_{NAT} ? Note also that the sentence "This may be explained..." is almost identical to the one that begins on p3413, l21.

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- last paragraph: the information contained here is almost identical to the one provided in page 3414, l14-16.
- p3417: the paragraph that begins on l4 is meant to show that the difference between Champ and UKMO PSC occurrence cannot be due to a bias in the UKMO analyses. While important, I think this paragraph belongs more to the "Discussion" section than to the "Results" themselves. Furthermore, the aim of the comparison shown in figure 7 should be emphasized before the description of the figure itself.
- p3418, and Figure 9: There is also a marked longitudinal structure in July. Do you have any clue ?
- p3418, l24: I think I have understood the meaning of this sentence, but it has to be rephrased: it seems that a verb is lacking after "if only". On the associated Figure 9, I do not understand why there are 4 symbols per month ???
- p3419, l1-3: this has to be discussed in closer relation with the POAM sampling.
- l5: The sentence "This may..." is almost identical to the one in the previous page, l9.
- l10-12: I am not sure that a quantitative comparison with what happens in the Arctic is very relevant. The temperature of both vortices, and the underlying topography, are quite different.

4 Figures

- Figure 1 (and many others): please indicate the unity of the values in the color bar: here "(K)" for instance.

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- Figure 3: Please recall in the caption that the UKMO temperatures are interpolated on the locations of POAM observations.
- Figure 5: Where do the small-scale oscillations in the Champ (green) profile at 13-14 km come from ? The text reports that the vertical resolution of Champ is 1.4 km...
- Figure 6: Note that the colors referred to in the caption do not correspond to the graphic.
- Figure 8: "(b)" -> "(lower panel)"

5 Further References

- Hertzog, A., G. Boccara, R. A. Vincent, F. Vial, et Ph. Cocquerez, Estimation of gravity wave momentum flux and phase speeds from quasi-Lagrangian stratospheric balloon flights. 2: Results from the Vorcore campaign in Antarctica, *J. Atmos. Sci.*, **65**, 3056-3070, 2008.
- Luntama et al., Prospects of the EPS GRAS mission for operational atmospheric applications, *Bull. Am. Meteorol. Soc.*, **89**, 1863-1875, 2008.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 3401, 2009.