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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "A study of the dynamical characteristics of inertia–gravity waves in the Antarctic mesosphere combining the PANSY radar and a non-hydrostatic general circulation model" *by* Ryosuke Shibuya and Kaoru Sato

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Reviewer #3,

The authors greatly appreciate the reviewer's critical reading of our manuscript and constructive comments. We have revised the manuscript as much as possible following the reviewer's comments. Responses to each comment are described in the following. The pdf version is also attached as the supplement pdf.

Response to comments: Start your abstract with one sentence about the general pur-

pose of this study.

We have added a sentence to explain the general purpose of this study at the beginning of the abstract.

P2L11 than those from the radar observations. P3L20 physically-based

We have revised the sentences.

P3L24 to show that this is a general problem quote also one Korean paper, e.g. Choi et al., JAS, 2011 P4L5 also McLandress et al., JAS, 2012 and Garcia et al., JAS 2017

We have added the references into the text.

P4L20 It is not the mesosphere which is the harsh environment. Revert order Due to the harsh environment in the Antarctic it is still challenging there to perform observations of the mesosphere.

We have revised the sentence.

P5L19 Mesosphere data for CRISTA would be Preusse et al., JASTP, 2006 (omit Preusse et al 1999, and Eckermann and Preusse 1999) P5L20 There is a new reference for climatological data of GWMF in Ern et al., ESSD, 2018. The inferred GW climatology is freely available. P5L24 Observational filter: Alexander, GRL, 1998 is the first, Alexander et al, QJRMS, 2010 the most comprehensive discussion of the observational filter. The observational filter for MLS is first introduced by Wu and Waters, GRL, 1996 and the one for infrared limb sounders (CRISTA, SABER) by Preusse et al., JGR, 2002. Anyway, if you want one reference, probably Alexander et al, QJRMS, 2010 is best.

We have changed the references. Thank you very much for your kind instructions.

P7L8 There are comparisons between modeled and observed GWs in the MLT in the frame of DeepWave, e.g. Eckermann et al., JAS, 2016. Please be more precise what is really not existing. P7L28 2 sentences: Pansy is capable ... when ... . This high resolution is unique in .... P8L1 Just as a comment (no change requested): Provided you can resolve spatial and temporal scales related to non-hydrostatic waves. Otherwise the feature also may cause problems. P9L18 that we use (present tense for the innvestigation, cf. L21) P10L9 which is P10L15 resolution P11L5 In order to adequately simulate ... (omit finely) P11L20 As a result the ... or Accordingly P13L4 gaps -> jumps ? 19. F2 line-of-sight or perhaps here an abbreviation LOS might be easier to read, actually P13L15 () to the end of sentence

We have revised the sentences.

P13L22 Really? A very crude check for the order of magnitude. The overall residence time in the MLT is half a year, hemsiphere-to-hemisphere, which corresponds to 1m/s. In addition, you are close to the pole, south of the acceleration region which should lessen the value. Please give an expected value with reference for comparison.

The line-of-sight velocity by the north beam is V_N=v sinâĄąθ+w cosâĄąθ, where θ = 10°. Assuming that w=0, v=V_N/sinâĄąθ =0.174×V_N. Since V_N at heights from 60 km to 70 km ranges from -6 m/s to -2 m/s in Fig. 2, v ranges from about -1 m/s to -0.3 m/s, which is roughly consistent with the order of the magnitude of the mesospheric residual circulation. However, as mentioned in the main text, the observational data from the PANSY radar are only available in the daytime during this period. As a result, the simple average of V_N inevitable includes the effects of the diurnal and the semidiurnal tides. Thus, a larger amount of the observational data, as Sato et al., (2017) is likely required to a quantitative discussion. The main test has been revised to avoid the above discussion (P14, L1-3).

P14L6 Using again a simplified argumentation: wavelengths there are 10km, so you are some 7 cycles above ground (likely more because of varying wind speeds). This means that you need to know your background atmosphere to an accuracy better than 5-10%. Deviating phases seem not that unexpected after all.

According to my previous paper (Shibuya et al., 2017), wave structures observed in the

Antarctic mesosphere consists of wave packets whose vertical scales is about 20 km to 30 km. Thus, the possible reason for the deviating phases is that the propagation path of the wave packet simulated in NICAM on May 13 is unrealistic, since the large-scale fields likely do not remain sufficiently close to the reanalysis data after such a long simulation time. The main text has been revised to clarify this point (P14, L9-14).

P14L12 this method -> the method

The sentence has been revised.

P14L13 Start with introducing that you use a variational approach and that you illustrate this first with a well-matching example.

An illustration of the estimation method by a simple case with cosâĄąãĂŰiπ(2z-t)ãĂŮ has been added as a supplement figure. In addition, the main text has been revised (P15, L6-8). The supplement figure (S1) is attached as the figure.

25. P14L15/16 Please clarify the difference between the two L

One of the two symbol has been changed.

26. P16L1 shorter -> longer

We apologize for this mistake which may have led to the unnecessary confusion. The sentence has been revised.

27. P16L3 and shift the energy from shorter, unresolved scales to the shortest resolved scales. A reference for that, though in different context, would be Lane and Knievel, JAS, 2005. I have seen things like this also occur in other models. For instance, the high-resolution WACCM and also some Canadian simulations show very pronounced ring-like convective GWs over the whole tropics. In principle such features are known from storms like the Hector (Darwin, Australia), but the scales in case of the model are several 100km and for that we have no experimental evidence. Still, why waves with wavelengths longer than 1000km should be overestimated, remains a bit puzzling.

Anyway, that you see similar waves in radar and model is encouraging for the further investigation of the waves.

Thank you very much for your comment about the very nice reference. A discussion about the overestimation of wave amplitude in NICAM has been added to Section 5 (P30, L3-23).

28. F5 slightly increase the distance between the two panels

The configuration of the figure has been changed.

29. P16L10 gap -> jump

The sentence has been revised.

30. P16LL20 Which data are assimilated into MERRA? Likely there is very little guidance by observations above 50km, so you cannot use MERRA as truth either (though it is some confirmation that both show the same basic features), i.e. you know that you have the general features right, but which of the two actually comes closer to reality in the details you do not know.

According to Sakazaki et al., (2012, JGR), radiances from TOVS and Advanced TOVS, and from EOS-Aqua are assimilated but only up to 50 km. Nevertheless, it is inferred that the overestimation of the zonal wind in NICAM is confirmed at heights from 35 km to 50 km. To clarify this point, an explanation about the data assimilation technique of MERRA has been added in Section 2.2.2.

31. P17L19 Linear gravity wave theory is based on the ansatz [equation] 32. P17L20 relationship -> relation 33. P18L2 since you have both I think being precise would be better: vertical flux of horizontal momentum and horizontal flux ... 34. Please check that all variables(frequency omega, intrinsic frequency nhat{nomega} are defined in the text. 35. P19L5 and superpressure balloon and satellite observations.

The sentences have been revised.

36. F7 contour lines versus coast lines The coast lines are very weak the contour lines are bold. By that it is very difficult to make out the geographic features. In particular for the lower three rows contour lines do not make sense as the structures are much too fine scale to follow them uphill and hence get additional quantitive information. Better omit them. It may also be worthwhile not to use a contour filling algorithm but plot for each grid point a little area with the color code of that value (tile-like).

The figure 7 has been revised by removing contours and making the coast lines thicker.

37. P19L17 also Hertog et al 2008 38. P20LL2 Please use a few lines to explain, why this is consistent (consistent with a westward-poleward and westward-equatorward horizontal flux of horizontal momentum at low / high latitudes) This is qualitative, though. 39. 4.2 Spectral analysis 40. F8 to one day and half a day 41. P21L3 -5/3 is steeper than -1

The sentences have been revised.

42. What puzzled/intrigued me in these figures: I think it would be good to give a general guidance: At the left edge one finds signatures of what apparently are planetary waves (Rossby waves). On he right side there is the GW branch. However, GWs may have ground-based frequencies lower than f because of Doppler shift, i.e. peaks on the left side of the red line might still be associated with GWs. A few sentences for orientation would probably be helpful for the reader.

The sentences about the other branch (likely due to planetary waves) and the effect of the doppler shift have been added (P22. L12-14).

43. P24L14 also Kalisch et al., JGR, 2014 44. P25L5 topographic -> orographic ; also follow-on sentences: topographies -> orography

The sentences have been revised.

45. P25L20 Geller et al makes kind of the destinction that models resolving scales substantially smaller than 1000km are what we now call GW allowing models, but that

are definitely not small-scale GWs. Maybeone could use a terminology like <100km small scale (not contained here) 100km<Lh<1000km mesoscale and Lh>1000km large scale

Although the numerical diffusion is too strong to fully calculate gravity waves with wavelength less than 100 km (small-scale GWs), the effect of small-scale GWs is not entirely removed in the results. Thus, the terminology has been changed from “small-scale” to “small-to-medium-scale”.

46. P29L13 stops -> stalls

The sentence has been revised.

47. P28LL1 If you approach a critical level than as you say the group velocities tend to zero. What kind of simultaneously happens is that the vertical wavelength decreases, that the ratio of kinetic and potential energy shifts towards kinetic energy (rotationalpart of the GW wind increases) and that the satuartion limit decreases (the saturation limit of GWMF is proportional to the third power of the vertical wavelength). In addition, knowing that the horizontal wavelength is very long, i.e. mÂżk, you can do a simple estimate for c_gh/c_gz. Assuming that k is changing its value much less than m, one can argue that the propagation would be more and more oblique as the critical level is approached. I think all this is in favor of your argumentation of accumulating GWs from the north in a region where omega approaces f. The peak is much more evident in the wind than in the temperature and momentum flux spectra. The propagation direction would become very oblique (very horizontal) before the wave than stalls in that horizontal direction and would thus not be dissipated before it becomes visible in the spectra.

Thank you very much for your fruitful comment. The sentences about the difference of the spectra between the winds and the momentum flux has been added based on the above theoretical explanation (P30, L3-23).

48. P30L18 I think that reads a bit wrong: It is the first simulation with that model but not the first long term simulation for this altitude range.

As mentioned in the introduction, in my knowledge, this is the first long-term simulation using the “non-hydrostatic” GCM.

49. P31L4 Also, the or In addition, ... at the beginning of sentence 50. P31L11 Here in the summary clarify again: ... peaks at ground-based frequencies ...vised.

The sentences have been revised.

Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2018-1023/acp-2018-1023-AC3-supplement.pdf

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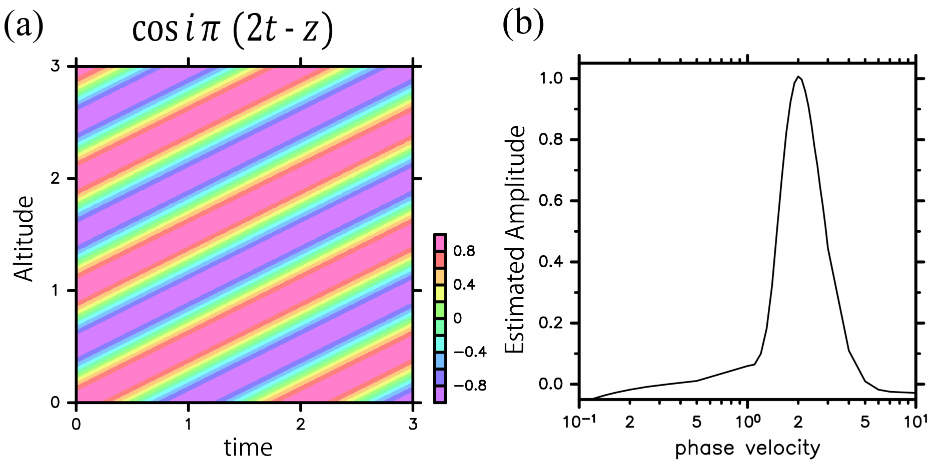

Fig. 1. S1. (a) A time-height section of cosâĄąãĂŰiπ(2z-t)ãĂŮ. (b) the estimated wave amplitude of cosâĄąãĂŰiπ(2z-t)ãĂŮ as a function of the vertical phase velocity.