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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Geographical distributions of mesospheric gravity wave activity before and after major sudden stratospheric warmings observed by Aura/MLS" *by* Klemens Hocke et al.

Anonymous Referee #2

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General comments:

This study shows geographical maps of gravity wave activity in the mesosphere through standard deviations of geopotential height (GPH) obtained by Aura/MLS observation. This method is also applied for the investigation of the difference of gravity wave activity before and after three major sudden stratospheric warmings. Observational evidence of mesospheric gravity wave activity itself is quite interesting and is inherently important to understand the momentum budget in the middle atmosphere.

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Discussion paper

However, it seems that there are some problems for publication of this paper. One of the fundamental points is that the results are not carefully discussed and less convincing, in particular, in Section 4; for example, the differences of the gravity wave activities before/after SSW are not clearly separated by their intra-seasonal change despite their long average period – 30 days (albeit the authors try to discuss in Fig. 4). In other word, the SSW signals, which are considered as a change associated with SSW in this manuscript, seems to be mixed-up with the seasonal change shown in Fig. 4. On the other hand, the description of the methodology is not enough in Section 2 to convince readers that the method based on GPH perturbations would be reliable. In addition, in my knowledge, the upper stratospheric and mesospheric gravity wave activity averaged in August shown in Section 3 have been already examined by several previous studies. However, there is no appropriate reference, and this blurs novelties of the results using the high-resolution Aura/MLS data.

Overall, I cannot recommend this article for publication and would suggest re-submit with extensive revisions.

Major comments: 1. (Critial) The authors state that a decrease of gravity wave activity in the Southern summer hemisphere in the lower and middle mesosphere seems to be associated with the SSW of January 2006 in Section 4.1, and this is a new result. In my opinion, this discussion is not correct, since the decrease of the gravity wave activity in the Southern summer hemisphere is also seen in Fig. 4. This means that the decrease of the gravity wave activity is caused by the seasonal change of the background wind and/or of gravity wave sources such as convection/jet front. Because the authors use 30-day intervals for the statics, the effect of the SSW should be carefully distinguished from the seasonal change with “no SSW” years. For example, it is interesting that the gravity wave activity is enhanced at 0.01 hPa and 0.0022 hPa in the northern polar region after SSW in Fig. 3, which is not confirmed in Fig. 4. It is natural to think that this change is caused by the sudden disruption of the polar vortex. Thus, it may be better to define the effects of the SSW as anomalies from the seasonal change in no

SSW years. This point is related to Major comment 2.

2. (Critial) As mentioned in Major comment 1, it is important to elucidate the (intra-)seasonal change of gravity wave activity without SSW. In this manuscript, why do the authors test the seasonal change only in 2010/2011 winter? It would be better that such seasonal change should be constructed by averaging at least several years. Is this related to the limitation of the time-range in the used dataset? Please clarify that.

3. (Critial) In Section 2, the authors should explain the reason why the GPH perturbation is a better measure of gravity wave activities. At least, the comparison between the temperature perturbation and GPH perturbation of Aura/MLS should be shown as one figure. The reason why temperature perturbation is less reliable is described only based on the absence of the Southern Atlantic Anomaly, but this is not convincing. Please explain, or try to discuss this through the observational mechanism of Aura/MLS.

4. (Critial) About Section 3: In my knowledge, the enhanced gravity wave activity over and leeward of the Andes is not a new result. For example, Alexander (1998, JGR) showed maps of observed gravity wave radiance variances by the MLS observations at an altitude of 53 km, while Jiang et al. (2005, Advanced in Space research) also showed MLS normalized radiance variance map at 80 km. Walterscheid and Christensen (2016, JGR) showed maps of average wintertime standard deviations of the temperature profile over the altitude range 95-115 km using SABER temperature observation, while John and Kumar (2012, Clim. Dyn.) also showed global maps of gravity wave potential energies in the 60-80 km using SABER data. If the advantage of the methodology proposed by this study is high-resolution horizontal sampling, what is a new finding which has not been reported by the above previous studies? Or, is this just a confirmation of the obtained gravity wave activities by the proposed (new) method? Please clarify this point. The gravity wave activities likely caused by tropical convection have also been described by the observational studies, and the propagation paths are well examined by some modeling studies (for example, Sato et al., 2009,

JRL).

5. (Critial) It would be quite interesting to show that the horizontal maps of gravity wave activities along the edge of the polar vortex. However, the authors should pay careful attention to the reason why such an asymmetry cannot be found in 2006 and 2009 SSW. If the authors suggest that the stationary structure of the planetary waves, please show the time-series of the planetary wave structure.

6. Why the standard deviation of GPH perturbation shown in Fig. 1 does not significantly vary in the altitude direction? Does the GPH perturbation have similar meaning to the potential energy of gravity waves? If so, why doesn't the geographical distribution become diffusive in the upper mesosphere expected by the wave breaking mechanism?

Minor comment:

1. Page 2, line 4: why the periods of the inertia-gravity waves are limited to 24 hour? Due to the Doppler shift, the (ground-based) period can be longer than 24 hour.

2. Page 2, line 5: whey the periods of medium-frequency gravity waves are limited for 1 to 3 hours? Is there any derivation of the period range for gravity waves with horizontal wavelengths between 150 km and 300 km?

3. Page 2, line 12: Non-orographic gravity waves are not simply categorized as "tropospheric" gravity waves, since spontaneously generated gravity waves also originate from the upper part of the jet core (in the stratosphere)

4. Page 2, line 31: ". . .beyond, although recent modeling studies reveals propagation paths of gravity wave which focus into the polar night get (Sato et al., 2009, GRL; Shibuya and Sato, 2018, ACP)

5. Page 4, line 7: please delete a blank before "a measure"

6. Page 4, line 31: how frequently does the orbit of Aula/MLS cross a latitude-longitude

grid? I mean, how many times are data sampled per day at a latitude-longitude grid?

7. Page 5, line 5: Please add ")" at the end of the sentence.

8. Page 5, line 9: what do you mean by the "background"? Please clarify what has been done in the detrend process.

9. Page 5, line 24: In this sentence, the purpose of this study is to obtain the "rough" geographic distribution of gravity waves. This is controversial to the motivation using the high-resolution dataset.

10. Page 5, line 33: Is this value representative in the stratosphere or the mesosphere? And what is the season?

11. Page 6, line 23: I disagree with this sentence. I don't think that the horizontal sampling does have an impact to the horizontal map greatly. If so, please show 3 point-running averaged Aura/MLS map and confirm whether the map becomes diffusive as expected.

12. Page 5, line 27: The gravity wave propagation is not only filtered by the background wind, but is refracted by the gradient of the background wind.

13. Page 7, Line 28: To me, the difference between Fig 2a and 2d and that between Fig. 2b and 2e seems comparable.

14. Page 9, line 27: Why did the authors show the PV structure for 20-31 December (12 days), not for 30 days as the statics of the gravity waves? In addition, it would be better to use ERA5 reanalysis dataset and MERRA2 reanalysis dataset, since these datasets include the stratosphere up to 1 hPa, which may be suitable for the purpose of this study.

15. Page 10, line 6: This sentence is not convincing. One of the reasons why the gravity wave fields seems to be diffuse is because large-amplitude gravity waves are easy to collapse due to the wave breaking mechanism.

16. Page 11, line 2: “since it does not. . .”

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