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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Satellite observations of middle atmosphere gravity wave activity and dissipation during recent stratospheric warmings" *by* Manfred Ern et al.

Anonymous Referee #3

Received and published: 8 June 2016

RECOMMENDATION: minor revision

SUMMARY STATEMENT: The paper is devoted to satelite observations of gravity wave (GW) properties during sudden stratospheric warmings (SSW). It describes in detail GW temperature fluctuations and estimates the absolute momentum flux and its divergence. The findings are interpreted adequately, only the discussion should be clarified in some points and slightly extended. In recognition of the overall quality of the work I suggest: minor revision.

MAJOR COMMENTS:

1) Title: In the title you use the terms "activity and dissipation" which both are well

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defined. None of them are observed directly, instead you make estimates of GW momentum flux and its divergence. I suggest to rather refer to "properties" instead.

2) Residual circulation: The basic changes of temperature and wind structure during SSWs can be understood in terms of residual circulation, which is in first instance driven by PWs in the stratosphere and by GWs in the mesosphere. In particular, the zonal-mean zonal wind does not react on the zonal wave drag (as in the QBO) but on the associated poleward flow and vertical motion, inducing dynamical warming and thermal wind changes. As lined out in Hitchcock & Shepherd (2013), there are acting different portions of PWs and GWs on the vertical motion which arranges the wind and temperature fields. When, for example, the GW drag (GWD) appears at the upper flank of the stratospheric eastward jet, the link is through the dynamic warming by breaking westward GWs. In this understanding, the re-formation of the eastward polar jets is not "likely" an effect of the residual circulation, but "basically". Please, see specific comments on page 15 and 16 and remove misunderstandable formulations.

3) Thermal structures: While the aspects of GW generation and propagation are well discussed with relation to the wind, I suggest to add some remarks on the GW impact on the temperature fields. In view of the above, the primary effect of the wave forcings is in a change of residual vertical motion and related dynamical warming. Such patterns should be identified in Fig. 2 and could also be used for a validation of the GW potential drag. In my perception, a part of the GWD in the lower mesosphere is missing which forces the stratopause in the 50 - 70 km altitude range. Please, comment in that.

MINOR COMMENTS

General comments: 1) In the formulae background temperature should be amended with a subscript Zero, as it as done for the background density (see eq. 1, 3) 2) Adjust the timing information between text and figures. For example you refer in page 20, line 26 to 11 - 26 February 2011, but the left column in fig. 7 actually is "119213-110228". There are some more cases like this.

Specific comments: page 1, line 10: The central date is defined as the first day of westward wind. If you refer to the first days after, you should write "when the wind HAS reversed from... (usually AFTER the central...)...". Please, specify. page 8, line 15 and 16: subscribe "0" to background temperature –> T_0 page 9, line 19: "before" –> "recently" page 11, line 28: subscribe "0" to background temperature –> T_0 page 12, line 23: By definition Polar-night Jet Osciallations (PJO) are based on polar-cap temperatures which is not necessarily associated to planetary wave amplitudes. Insofar ", i.e. when the... maximizes." is not obvious and I suggest to delete this part. page 14, line 12: The amplitude of a conservatively propagating GW does not only depend on density but on wind, too. If you extend the sentence like "... conservatively in a constant wind, this amplitude..." it is correct. page 14, line 14: The conserved quantity is pseudomemoentum flux, which is the same like momentum flux only for mid-frequency GWs. page 15, line 32 (see major comment 2): According to Matsuno, the SSW-related changes in residual circulation in the stratosphere are a result of anomalous breaking planetary waves (PWs). After this perturbation, the polar stratosphere becomes cold again and the PWs re-arrange the normal residual circulation. GWs dominate circulation in the mesosphere and are involved in the formation of apparently downwelling cooling/warming patterns - see Fig. 4 of Hitchcock & Shepherd (2013). Corresponding patterns you see clearly in your temperature plots of Elevated Stratopause (ES) or PJO events, f.e. Fig. 2h. Comparing it with Fig. 5h there is missing the down-reaching cold branch of positive GWD just after the central day. May be it is a matter of the observational data material? The following ES-related warm branch with enhanced negative GWD instead can be identified. page 16, line 6 (see major comment 2): This paragraph is misunderstandable, too. The stratosphere is cold without waves, it is slightly warmed through the PW-driven residual circulation. After the SSW it breaks down and the stratosphere is colder than before. In the mesosphere, the GW-driven branch of residual circulation enforce the stratopause. During SSW, the GWs dissappear (or may change sign) and it becomes cold there. When the winter comes back, GWs rearrange the stratopause. Insofar, the residual circulation drives the thermal structure of the

mesosphere and not vice versa.

REFERENCES:

Hitchcock, P. & T. G. Shepherd, 2013: Zonal-mean dynamics of extended recoveries from stratospheric sudden warmings. J. Atmos. Sci. 70, 2: 688 - 707. doi:10.1175/JAS-D-12-0111.1.

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