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Atmospheric Chemistry and Physics Discussions

# *Interactive comment on* "How Does Downward Planetary Wave Coupling Affect Polar Stratospheric Ozone in the Arctic Winter Stratosphere?" *by* Sandro W. Lubis et al.

**Anonymous Referee #1**

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**REVIEW: How Does Downward Planetary Wave Coupling Affect Polar Stratospheric Ozone in the Arctic Winter Stratosphere? by S. W. Lubis, V. Silverman, K. Matthes, N. Harnik, N-E. Omrani and S. Wahl**

In this manuscript the authors show that Downward Wave Coupling (DWC) events impact high-latitude stratospheric ozone in two ways: 1) reduced dynamical transport of ozone from low to high latitudes during individual events and 2) enhanced springtime chemical destruction of ozone via the cumulative impact of DWC events on polar stratospheric temperatures. The authors motivate the study by highlighting the focus



of previous work on the role of upward propagating waves. The results presented here broaden the scope of the impact of wave-mean flow interaction on stratospheric ozone by highlighting the key role of wave reflection. The authors make a convincing case supporting and extending previous published work.

My recommendation is that this manuscript should be published with minor revisions which are outlined in greater detail below.

## 1 General comments:

- I strongly recommend a reorganization of the figures in the main manuscript and the supplementary material. While it will not change the results of the paper I feel it would greatly improve the readability of the manuscript and highlight the key points in a simpler way. This would also reduce the total number of figures by 2. My recommendation is the following:
  - Figure 1: Show pressure-time plots of VT, EPFD, Psi, dtheta/dt for the DWC events where VT and EPFD panels are taken from the old fig. S1. This would remove the duplication of figures in fig. S1 and focus the reader on the dynamics of DWC events with a consistent set of axes.
  - Repeat the new fig.1 in fig. S1 for positive heat flux events.
  - Figure 2: combine the 2 line plots in the current fig.1 with the line plot in the current fig. 4. Again this would aid the reader with a consistent panel format in the figure.
  - Figure 3: Move the current fig. 2 to new fig. 3.
  - Figures 4: Don't change

- Figures 5-8: Repeat the new organization from figs. 1-4 for the model.

- While the authors focus on wave-1 heat flux events, there is no mention of wave-2. How do the results in the first part of the paper compare to a similar analysis using wave-2 for both positive and negative heat flux events? Do reflective winters exhibit more extreme negative wave-2 events and vice versa for absorptive winters? Shaw and Perlwitz 2014 use the total eddy heat flux in their analysis of the role of DWC on stratospheric temperatures suggesting that wave-2 might also be important.

**2 Specific comments:**

- In terms of the definition of reflective winters, why not simply use the previously published definition from Perlwitz and Harnik 2003 based on the zonal-mean zonal wind shear? This index likely encapsulates both $U$ and $m^2$ criteria used here in a simple way. How does the PH03 shear index look when plotted next to the time series in figure 9?

- Are reflective winters dominated by DWC events? Similarly do "absorptive" winters contain a large amount of extreme positive heat flux events? Quantifying whether the individual events defined in section 1 occur in the seasons defined in section 2 would add additional support to the cumulative argument.

- I'm not sure I completely agree with the argument in the footnote of page 11 motivating the authors' removal of SSW's during "reflective" winters. It would be good if the authors could address the following points:

  - SSW's are effectively a continuum that depends on the definition threshold (e.g. Butler et al. 2015 BAMS fig. 4), and so the current definition includes



    years that contain events that are very close to satisfying the SSW criteria, which would contribute to the season being "absorptive" when it is defined as "reflective".
  - Doesn't the fact that seasons with SSW's can have increased wave reflection call into question the definition of "reflective" and "absorptive" winters based on the seasonal mean wind and wave geometry?
  - If you include SSW years but keep the rest of the definition the same, do you get similar results? Perlwitz and Harnik 2003 did not exclude SSW years.

- L198-200: Is there a difference when time averaging from day -10 to +5 from figure 1b (i.e. all days not only significant days)?

- L343-344: How do you calculate m2 and l2? everyday and then average or from the average U and T? Does it make a difference? Are the results sensitive to the meridional/vertical averages and thresholds used in the definition?

- L364-365: Why is a wider meridional wave guide favorable for upward wave events? Presumably a narrower waveguide would focus wave activity polewards rather than equatorwards enhancing the positive heat fluxes. This seems to run counter to previous literature which argues that a strong poleward shifted vortex is conducive to upward wave activity (McIntyre 1982 and others).

- L412-413: What is meant by "sharpened gradients of ozone" and their relationship to dynamical terms? In addition, it seems that in the reflective winters during MA there are anomalous positive heat fluxes enhancing the climatological transport of ozone. This runs counter to the expectation during "reflective" winters.

- Figures 3 and 7: Why not simply plot all the data in the scatter plot instead of contours? The contours seem unnecessarily complicated and plotting the entire time series would allow the reader to see the large correlations from the full time series quoted in the text.

- Figure 14: I'm not sure the current schematic is helping to succinctly convey the dynamical mechanisms detailed in the text. I suggest either streamlining it or completely removing it since it is not very helpful in its current iteration.

**3 Technical corrections:**

L34: Suggest changing "it represents" to "proportional to"

L49: "increases" should be "increased"

L137: "transform" should be "transformed"

L138: Suggest putting the equation number from Andrews et al. 1987

L140: I suggest adding a sentence linking Equation 1 and 2, i.e. the first 3 RHS terms in equation 2 sum to the 2nd RHS term in equation 1. Same for chemistry and analysis terms.

L155: Suggest also citing Dunn-Sigouin and Shaw 2015 for the event definition

L159: Suggest citing Shaw et al. 2010 for period of maximum vertical wave coupling.

L22: Fig. "2e" should be "2f"



L237: "circular" should be "oval"

L270: You could also add the point that the historical time series is short and so you can get a more robust sample of events in the model to support the reanalysis dynamics.

L307-309: Perhaps mention that the detailed analysis of why the model terms are biased is beyond the scope of the article.

L321-322: Suggest mentioning the correlation for the entire data set in the model as was done for reanalysis data

L341: "ozones" should be "ozone"

L361-362: "due to enhanced DWC events": could also be due to enhanced equatorward refraction and a lack of upward propagation

L398-399 and L409: Why "not shown"?

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