

Interactive comment on “The wintertime two-day wave in the Polar Stratosphere, Mesosphere and lower Thermosphere” by D. J. Sandford et al.

D. J. Sandford et al.

Received and published: 21 December 2007

We would like to thank the anonymous referees and Luis Millan-Valle for their comments and suggestions. We have revised the paper and believe it is significantly stronger as a result.

The specific replies follow.

Referee 1

Page 14751, line 16: the description "from values as small as about 20 m²s² in 2001 and 2004 to values as large as about 75 m²s² in 2002" seems not to be correct.

Corrected to read 8220; from values as small as about 30 m²s² in 2003 (zonal component) and 2004 to values as large as about 100 m²s² in 2002 (meridional compo-

nent)8221;

Page 14755, line 10: Does the "E2 two-day wave planetary wave" (This expression sounds strange. I think it should be written as "E2 two-day planetary wave") derive from the baroclinic instability? It should be helpful to include some explanations for the source of the planetary wave, as the main subject of this paper is the 8217;winter-time8217; two-day wave as written in the title.

"E2 two-day wave planetary wave" changed to "E2 two-day planetary wave". We have included a more detailed explanation of the two suggested excitation mechanisms in the discussion.

Figure 5: There is a difficulty to know the regions where the wind velocity exceeds 52 ms8722;1. I cannot find the "dashed lines" except very obscure ones, and I think the "dashed lines" are the "solid lines" which I can see clearly. The authors should correct the description. Moreover, something like mesh or screen should be added to the region where the wind velocity exceeds 52 ms8722;1, as it is difficult to know which side of the lines exceeds the threshold wind velocity.

We have added an additional figure to make this part of the results more clear. Figure 5 is now changed to include figure 5a, the original contour plot without regions indicated, figure 5b to show the zonal mean winds and figure 5c, which takes the data of 5a but shades in the regions where the wind meets the Charney-Drazin criteria for the E2 wave.

Referee 2

It is less surprising that the variance of the wind minimizes during the periods of wind reverse during the equinoxes. The authors use a band-pass filter to reveal oscillations with periods between 1.5 and 3.4 days, but they did not describe its characteristics. This is a relatively broad filter (36 to 81.6 h). The period of the two-day wave varies between 42 and 56 h. E.g. Manson et al. 2004 employed a

24 day window to achieve this resolution for the 2-day period. According to the signal theory, the filter here corresponds to a window in the order of only 5 days.

An explanation of the characteristics of the filter used has been included: This filter type offers a steeper 8220;roll-off8221; characteristic than Butterworth filters, albeit with more ripple. The 99

The filter width has been reduced in a re-analysis. Because, as the referee pointed out, the period of the two-day wave varies between about 42 and 56 hour, we used a filter that passes periods between 36 and 62.4 hours.

The first paragraph of 3. Results belongs in 2. Data analysis and should be moved.

Paragraph moved as suggested.

In the mesopause region one important diabatic heat source is chemical heat. Particularly in the domain above 90 km the heating rate is determined by transport of latent chemical heat from the lower thermosphere triggered by planetary waves. During sudden stratospheric warmings (SSW) and in their aftermath, drastic changes of this rate occur (see e.g. Sonnemann et al. 2006, JASTP 68, 2012-2025, Figure 5d). These changes feed back to the dynamics. Ward et al. 1997, Geophys. Res. Lett. 24, 1127-1130, observed a Q2DW in the green line of atomic oxygen in a height where the concentration variation can only be explained by the transport of atomic oxygen by winds. Kulikov, 2007, J. Geophys. Res. 112, D02305, doi:10.1029/2005JD006845 investigated the influence of a Q2DW on nonlinear photochemical oscillations. He found a periodic transport of minor constituents by vertical wind associated with the wave and he stated this mechanism may lead to a phase locking of the photochemical oscillation to the wind oscillation. The paper cannot give an answer to the question, how the behaviour of the Q2DW influences the feedback between dynamics and chemistry, but the problem could be mentioned in the chapter 4. Discussion.

We have modified the introduction to place the 2-day wave in a slightly broader context. Specifically, 8220;The Q2DW is known to interact with and modulate the tides of the mesosphere (e.g. Teitelbaum and Vial, 1991 and Mitchell et al., 1996) and may also impact the photochemistry of this region (e.g. Kulikov, 2007).8221;

Fig. 5 seems to indicate that SSWs prevent a Q2DW in accordance with the Charney-Drazin theorem because the mean zonal wind speed decreases during this time or even re-verses for major SSWs. Looking at the SSW statistics, one will find that in 2005 a major warming occurred in the beginning of March and no SSW occurred in the winter 2006/7. However, in the winter 2005/6 a minor warming occurred in the beginning of January 2006, succeeded by a major SSW on January 20, 2006. The figure exactly reflects this behaviour. Dickinson 1968, Month. Weath. Rev., 96(7), 405-415, recalculated the Charney-Drazin theorem using spherical coordinates. His values differ somewhat (they are larger for wave number 2) from those of Charney-Drazin and should be employed in the paper. The lines in Fig.5 are not dashed. It would also be better to use 12 ticks instead of 10 for the time axis to conform to the number of months.

A new figure, Figure 6, has been introduced which shows the zonal mean zonal winds at the upper level of the UKMO stratospheric assimilated data set. The major stratospheric warmings are marked on the figure. The text of the results section has been modified to indicate this: 8220;Further, the occurrence of major sudden stratospheric warmings has the effect of reversing the zonal mean winds at high latitudes. Therefore, when a major stratospheric warming is present the E2 two-day wave should not be able to propagate as the wind regime will not satisfy the Charney-Drazin criterion.8221;

The Dickinson 1968, recalculations of the Charney-Drazin theorem would be more accurate. However, for the use made of it here, we feel the simple original Charney-Drazin theorem is adequate.

Referee 3

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8230;they suggested that this wave is one of a series of waves generated by instabilities in the winter polar jet. However, to be generated by instabilities, the mode has to be trapped in the source region. Fig. 5 shows that the E2 two-day wave has the strongest amplitudes at the altitude 60 km and decrease in the amplitude above this level. This means that the E2 two-day wave is not propagating. However, it is capable of penetrating from the source region (the stratosphere) up to the heights of the mesosphere and lower thermosphere.

The text has been modified to read 8220;The amplitudes maximise around the stratopause suggesting that the wave may be evanescent above this height8221;.

Correspondence between the strongest polar stratospheric jet and the maxima of the E2 two-day wave amplitude indicates simply that the strongest jet is more unstable. To identify the source regions of the E2 two-day wave, it should be helpful to show the latitude-time cross section of the background wind in the stratosphere (for instance, at the higher level of the UK Met Office data). If the instabilities in the winter polar jet are responsible for the E2 two-day wave generation, this wave has to be strongly suppressed during stratospheric warming events.

Good point. A latitude-time cross section has been introduced in Figure 6 and times of major stratospheric warmings marked. The E2 two-day wave is indeed strongly suppressed during major stratospheric warmings. There are two possible reasons for this. Firstly, the occurrence of major stratospheric warmings means that the wind regime will not satisfy the Charney-Drazin criterion for an E2 two-day wave, and therefore should not allow propagation, even if such a wave were still excited. Secondly, the excitation of the wave itself by regions of negative potential vorticity on the poleward side of the stratospheric polar vortex will no longer happen as the polar vortex breaks up. These reasons have been included in the manuscript.

Short Comment: L. Millan-Valle

I believed some explanations for some of the terms introduced will be helpful for the reader. For instance, it should be explained what is the meaning of a wave wavenumber, what is a Meteor Radar, and an explanation for the period of 2 days of the wave (if available).

An explanation of the term 8220;wave number8221; has been included in the second paragraph of the introduction. More references to detailed descriptions of the Esmine meteor radar and the Meteor radar technique have been included. The period of 2 days is explained in the beginning of the results section which refers to five complete cycles of the wave occurring in a 10 day segment of time, therefore one wave cycle occurs about every 48 hours (i.e. two-days).

Apart from that it would be useful to know what amplitude of temperature variation is associated with these waves.

This is beyond the scope of the present paper, but could be done using MLS or SABER temperature data.

Fig 1b, should say something among the lines of, as for figure 1a for meridional winds.

Figure captions for figures 1a and 1b are together.

Finally, note that the data in the analysis has also been updated to November 2007.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 14747, 2007.

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