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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Tropical cooling in the case of stratospheric sudden warming in January 2009: focus on the tropical tropopause layer" *by* K. Yoshida and K. Yamazaki

Anonymous Referee #1

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This paper explores global dynamical phenomena during 2009 associated with temperature changes in the tropical upper troposphere and lower stratosphere (UTLS), including a sudden warming which peaks on January 26. Several of the diagnosed connections are quite interesting, including the relationship between wave activity flux near Alaska, the sudden warming in the stratosphere, radiation of a wave train in the UTLS toward Amazonia, and subsequent modification of the tropical UTLS. The temporal evolution over the planet in 3D is characterized well, with analysis including refractive index and 3D wave activity fluxes. Attribution of the causes of changes in local upwelling to selected regions of wave driving is explored using the transformed Eulerian mean approach. The basic mechanisms of meridional overturning and Rossby

wave train propagation seem valid. However, cooling in the tropics begins around January 10, at the same time that the high latitudes being to warm, so it is recommended to describe the meridional overturning as co-evolution of tropical and extratropical phenomena. It is also recommended that the differences between causes of rising motion in different altitude regions in the tropics be emphasized, as it highlights the complexity of causal attribution. In particular, it seems that subtropical monsoons, synoptic waves in the subtropical UTLS, and synoptic/planetary waves in the extratropical stratosphere each provide separate wave driving that has significant effects on different layers of the tropical stratosphere. This paper highlights the interconnectedness of phenomena in an interesting way and uses appealing and useful diagnostices. I recommend publication with minor revision. The following comments follow the approximate order of encountering them in the manuscript, with more significant issues highlighted by asterisks.

1. p2265, line 26- Please state the geographical location of the seesaw pattern of convection - it approximately zonally symmetric?

2. p2266, line 24: Please state the horizontal resolution and the vertical resolution in the upper troposphere and lower stratosphere (refer to 2.6).

3. p2267, line 14: Since ECMWF data are being analyzed, it might be good to directly evaluate the diabatic heating term, which would then help diagnose whether the vertical heat fluxes are reasonable. This would also help resolve whether convective bursts can *cause* cooling in the TTL, or if only extratropical wave drag can cause such cooling.

4. p2267, line 18: Are the first and fourth terms always small? Is it self-consistent to leave out the fourth term on the rhs of (1) but explicitly discuss the importance of F_1ˆ(phi) for the EP flux? (They represent the same term in the TEM transformation, where it is subtracted from the temperature equation and added to the zonal momentum equation.)

5. p2268, line 16: The TEM equations apply on a sphere and the flow need not be

quasi-geostrophic, just hydrostatic.

*6. Fig. 1 interpretation: There is a tropical warm anomaly centered at 50-70 hPa during January 1-16, which precedes the warming. It would be interesting to explore the geographical distribution of this warm anomaly and try to see how it could relate to a planetary wave connection to higher latitudes. Maybe there is a tropical precursor to the high latitude development. Note that the cooling near 10 hPa begins on January 10 at low latitudes at the same time as warming begins at high latitudes. (p.2272, l.1 states that the change begins on January 18, but that is in the middle of the transition.) On p. 2272, l16-17 The upward flow begins around 12 January, peaking near 19 January.

*7. Fig. 2 interpretation: The vertical motion changes at 10 hPa seem decoupled from those at 125 and 150 hPa, while the changes seen at 70 and 100 seem to act independently also. This seems to reduce the likelihood that far-field wave driving patterns exclusively control tropical upwelling ("the extratropical gyroscopic pump"). For example, p.2273, l23-24: If div F_1ˆz from NH forcing above 80 hPa controls tropical ascent in the stratosphere, please show this term and show what altitude ranges and times are influenced this way. On p. 2274,l5 it is stated that "tropical ascent is driven by global forcing below 90 hPa", so that the stratospheric pump "has only a minor influence on vertical flow between 150 and 100 hPa". On p.2276, l.2-5 it states that wave driving in the low latitude subtropics is the main factor inducing tropical upwelling in the UTLS. Doesn't this imply that the "extratropical pump" is not the primary factor? How does this fit in with vertical fluxes of heat in the tropics? Please reconcile and clarify your views on the timing and forcing locations for vertical motion events in the tropics. If possible, it would be good to pin down the geographical location of enhanced ascent, for linking with OLR.

8. p.2274, l7: What is the physical interpretation of boundary forcing in the TEM set?

9. p.2275, l20: Here it is stated that eddy forcing in the SH troposphere has an insignificant effect on the tropical tropopause layer, but Fig. 7a shows significant influence with

upward motion at 200 and 150.

10. p.2276, l26: From *10* January ...

11. p.2278, l23: Please link to Fig. 10c. It looks to me like upward motion is induced off Baja California, but the OLR minimum is over Amazonia. Is an extended wave train connecting the two regions?

12. p.2280, l14-15: Is it possible to describe more about how the vertical heat fluxes relate to the structure of wave/monsoon structures in the tropical UTLS?

13. p.2280, l18-19: If subtropical wave driving is the proximal cause, then the SW was not the cause of tropical cooling.

14. Figure 6 caption: Please clarify the difference between what is being shown in the upper versus lower panels.

15. Fig. 8: Tropical upwelling at 100 hPa is large on 18 January, larger than on 26 January, and it happens before the peak of the SW.

16. Fig. 10: Please plot to 10S so can see tropical upwelling and relate to Fig. 11.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 2263, 2011.