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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "A global non-hydrostatic model study of a downward coupling through the tropical tropopause layer during a stratospheric sudden warming" *by* N. Eguchi et al.

N. Eguchi et al.

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Thank you for reviewing our manuscript. The authors understood three major points pointed out by reviewer#1. Along the comments and suggestions from two reviewers, almost of them were corrected and modified, including figures.

[Specific (major) comments]

First, I wonder what the overall contribution from this study is and how significant it is. The authors state that they investigate changes in convection during SSW using the NICAM data (l. 27, p. 6805). It will be much more useful to clarify what is the

scientific question(s) that remains unanswered in the previous studies and is targeted in this investigation. The statements in and around the paragraph read as the target question is "are the previous observational and GCM results reproduced by the NICAM for the SSW?". An- other possibility is that the authors aim to diagnose the thermodynamic budget of the changes in the tropical troposphere ("how do the changes in the tropical troposphere including clouds occur thermodynamically"), which is difficult with observational or GCM data. In any case, however, it may not be sufficient in originality and significance if the authors just describe the changes (some part of the present results repeat/confirm their previous results) and show that they are thermodynamically consistent. (This is related to the next point.)

Reply: We added the following sentence for the explanation of the present purpose at l.22-24, p.3 of the revised manuscript (attached as Supplement).

"Further, to investigate the adiabatic and diabatic parameters in the TTL are necessary to clarify a coupling process between the stratosphere and troposphere through the thermo-dynamic balance."

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Second, I do not well understand, from the paper, what is the key dynamical or physical process(es) for the convective changes to occur during the SSW. It seems that this study still lacks presenting direct evidence for such a key process(es). For example, what does determine the particular locations and timing (time scale) of the convective changes in response to the SSW (or wave-driven upwelling in the tropical LS). Exploring such a key process(es) will be an essential point that is worthwhile for a serious investigation on this topic.

Reply: The region where the convective response is apparent is the region where the deep convective activity is seen in climatology. However, it is difficult to say exact region for a particular event, because of the internal variability of the atmosphere. For discussion of regional response, ensemble mean simulation is indispensable, which will be able to do in near future.

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It also seems uncertain to me how the upper level ice (cirrus) clouds in the TTL occur in period 2. Can you be more specific about how the destabilization in the TTL prompts the cloud formation by referring to a direct or existing result(s)?

Reply: Upward motion around the tropopause produces cooling and decrease of static stability in the upper TTL. As a consequence, deep convective activity extends higher in the TTL as indicated by vertical velocity in the Figure 1. A time-latitude section of ice clouds is added to the revised manuscript as Figure 2d.

Attached Figure 1: (top) Time-height section of normalized vertical wind (color shading) and negative value of static stability are shown by contours. (bottom) Longitude-Pressure section of vertical wind during periods i and ii.

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Why do such clouds tend to be absent in period 3 even when the LS temperatures are low (Fig. 2a,b)?

Reply: The cirrus clouds were not absent at period 3 (January 21-27). It is shown in Figure 2d of the revised manuscript.

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Third, I sometimes feel it difficult to follow the authors' logic flow (or terminology) in places through the manuscript. I think that the authors will need to better distinguish the followings: refer to existing results in the literature, describe direct results from the materials, derive consequences of present and/or existing results, and make suggestions/speculations.

Reply: Along the comment, we rechecked and modified the descriptions in Sections 3 and 4 to make clear the mechanism found by the present study (e.g., l.9-27, p.10).

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Some notable examples are found in the third paragraph in Section 4, whereas other examples also exist. "Vertical velocity in the LS is mainly driven by extratropical planetary waves," Is there any direct evidence for this statement given in this paper? Or, if this is based on an existing knowledge, then please provide a reference(s).

Reply: This is an existing and basic knowledge of Brewer-Dobson circulation (e.g., Andrews et al. 1987). Reference to the recent studies is added to the revised manuscript. (l.11, p.10 in the revised manuscript)

Andrews, D., J. R. Holton and C.B. Leovy, Middle atmosphere dynamics, Academic press, 1987, p.489.

Ueyama, R., Gerber, E.P., Wallace, J.M., and Frierson, D.M.W, The role of high-latitude waves in the intraseasonal to seasonal variability of tropical upwelling in the Brewer–Dobson circulation, J. Atmos. Sci., 70, 1631–1648, doi:http://dx.doi.org/10.1175/JAS-D-12-0174.110.1175/JAS-D-12-0174.1, 2013.

Abalos, M., W.J. Randel and E. Serrano, Dynamical forcing of sub-seasonal variability in the tropical Brewer-Dobson circulation, J. Atmos. Sci., in press, 2014. (e-View doi: http://dx.doi.org/10.1175/JAS-D-13-0366.1)

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"reflected in the location of the strongest LS upward motion between 20S and 30S," Is there any result showing that the strongest LS upwelling occurs in these latitudes? Figure3a will not support this claim, as it just plots a correlation.

Reply: The sentence was removed from the revised manuscript. Generally, the upwelling branch of BD circulation is located at off equatorial summer hemisphere, for this case is south of the equator.

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"but that in the UT was controlled mainly by deep convection (between 10S and 20S)," The word “controlled” will be too strong. The results just show that the upwelling and DH (deep convection) occur at similar locations (Figs. 3a,b and 5). Other results or knowledge will be needed to draw this statement.

Reply: The word was changed from ‘controlled’ to ‘affected’. (l.12, p.10 in the revised manuscript)

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"while the vertical velocity in the TTL was affected by both upwelling in the LS (a branch of the stratospheric meridional circulation) and convection, which is able to reach to the TTL." The phrase (“the TTL vertical velocity was affected by the LS upwelling”) sounds awkward. The next sentence makes better sense: “The enhanced upwelling in the LS during the SSW event can intrude deeper into the TTL”.

Reply: The sentence was removed.

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[Specific (minor) comments]

Section 3.1; The authors seem to use the word "cooling" for two meanings: when temperature tendency is negative, and when temperature is lower (e.g., than normal). It is simple and straightforward to use each word only for one meaning. If the authors focus on the temperature tendency, it will be useful to display a plot for that.

Reply: Along the comment, the "cooling (warming)" related with temperature tendency was changed to "negative (positive) temperature tendency".

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l. 27, p. 6808; I’d like to confirm that the serial correlation of the time series is taken into account in calculating the significance of the correlation of the vertical wind (Fig.3a). Namely, the daily mean data for the 30 days should not have an actual degree of

freedom of 30 in the statistical test. Unless this effect is considered, the result may be much weaker than the authors expect. Displaying time-latitude sections of the zonal mean vertical wind at a few key levels should be useful to sense its variations.

Reply: Figure 2 shows the time-latitude section of vertical velocity at several altitudes. It is shown that the upward velocity in the southern hemisphere increased after 13 January at 5, 12 and 20 km, although the increasing of upward velocity at the middle troposphere (5km) delayed than that in the upper layers. The vertical lines show the date that the zonal mean vertical wind at 20 km had just started negative as shown in Figure 4d. On the other hand, the temporal variation of latitudinal structure of vertical velocity at 17km (around 100hPa) are not clear. In fact, these features can be seen in Figure 3a, therefore they did not be included in the manuscript but the explanation was added. (l.5-6,p.7 in the revised manuscript)

Attached Figure 2: Time-latitude sections of vertical velocity at 20 km (top-left), 17 km (top-right), 12 km (bottom-left) and 5 km (bottom-right) from January 1 to 31. The vertical lines show the date.

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l. 5, p. 6810; It does not seem convincing to me why the authors choose the 20S-5N range for Fig. 4. Figure 3a seems to imply that anomalous vertical wind has strong latitudinal dependence (including sign changes) in these latitudes. Taking the latitudinal average in 20S-5N will lead to a strong cancellation of such anomalous vertical wind signals. Time-latitude sections of the vertical wind will be useful again.

Reply: Because the convection accompany downwelling area in its neighborhood, to get a mean upward velocity of a large scale circulation such as of Hadley circulation, average is taken over the tropics of the summer hemisphere. However the figures were modified by the average between 20S and equator, because of focusing to highlight the southern hemisphere change.

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l. 16, p. 6810; How do the authors find these terms “major”? It will be needed to say something like “we find that these terms make major contributions in the equation in our preliminary calculations (not shown).”

Reply: It is the basic knowledge [text book of Andrews et al.,1987] and the order analysis also shows that the two terms are dominant.

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l. 19, p. 6810; The equation should be for the zonal mean temperature tendency. If so, please denote some symbol for the zonal mean.

Reply: Along the comment, the equation is modified. (l.15, p.8 in the revised manuscript)

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l. 2, p. 6811; The authors point out the close correspondence between the adiabatic cooling and heat flux time series (Fig. 4c,d). How is this result consistent with the study of Polvani and Waugh (2004, J. Climate)? They showed the importance of cumulating or averaging the poleward eddy heat flux (in time) in the lower stratosphere for obtaining high correlations of the heat flux with the 10 hPa NAM index.

Reply: The eddy heat flux is used as a proxy of wave forcing. Roughly speaking, the eddy heat flux is related with zonal wind "tendency" or temperature "tendency". On the other hand, to analyze the variation of polar vortex, they need to INTEGRATE eddy heat flux.

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Fig. 2; It will be useful to match all panels in Fig. 2 with those in Fig. 1 in terms of the quantities plotted, and axis ranges. Some panels could be separated into another figure.

Reply: The authors think that we did not need to be same figures at both Figures 1 and 2, because Figure 1 only shows the characteristics of the atmospheric change when the SSW occurs in real atmosphere.

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Fig. 2c; Is it possible to show cloud fractions of deep convective and cirrus clouds separately?

Reply: Figure showing the variation of ice cloud (Figure 2d) was added together with the explanation to the revised manuscript.

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Why do some plots use height (km) and others use pressure (hPa)? It is simpler to use either one, if possible.

Reply: Both the pressure and altitude labels were put on the vertical-axis in each figure.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/14/C4437/2014/acpd-14-C4437-2014-supplement.pdf

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 6803, 2014.

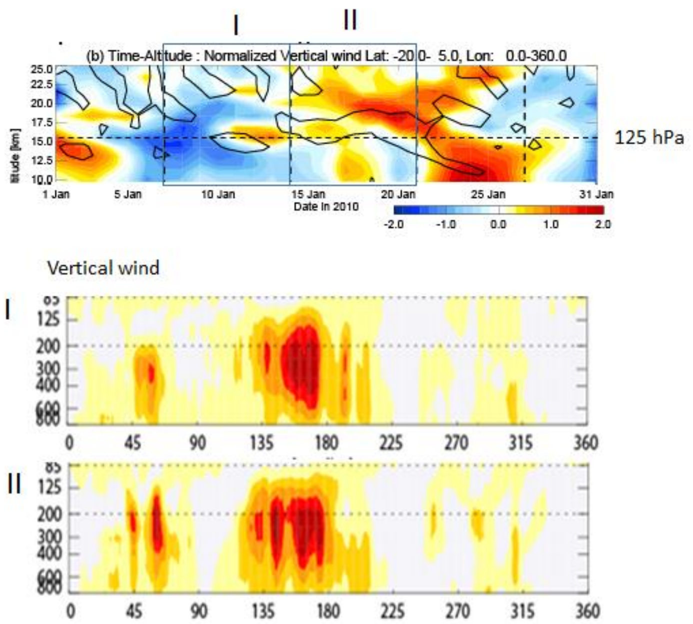

Fig. 1. (top) Time-height section of normalized vertical wind (color shading) and negative value of static stability shown by contours. (bottom) Longitude-Pressure section of vertical wind during periods i&ii

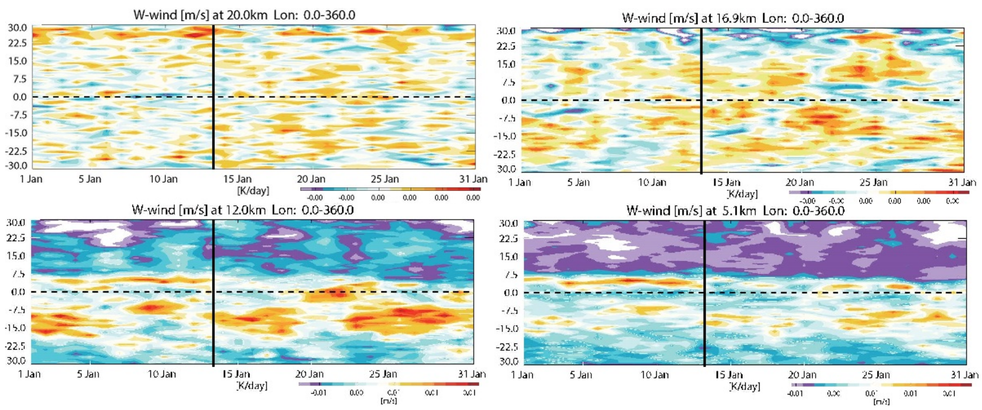

Fig. 2. Time-latitude sections of vertical velocity at 20 km (top-left), 17 km (top-right), 12 km (bottom-left) and 5 km (bottom-right) from January 1 to 31. The vertical lines show the date.