Weather Clim. Dynam. Discuss., referee comment RC2
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Comment on wcd-2022-34

Anonymous Referee #2

Referee comment on "The stratosphere: a review of the dynamics and variability" by Neal Butchart, Weather Clim. Dynam. Discuss., https://doi.org/10.5194/wcd-2022-34-RC2, 2022

Excellent review, very enjoyable to read. A briefly and clearly expressed overview of fundamentals on global structure and large scale dynamical variability of the stratosphere. There are only a few locations where the presentation, the structure of the sections, the reference to recent reviews would benefit improvements, as highlighted hereafter. Based on these considerations, my recommendation is minor revision.

This review is about the mean structure and large scale dynamical variability of the stratosphere. The review provides the background theoretical understanding of stratosphere dynamics, and briefly describes its early historical evolution. The review focuses later on, on the SSW and QBO phenomena.

Given the global approach, part of the structure of the review is not optimal. This is my major comment. Because material of section 2 "Extratropical stratosphere", such as the hemispheric-scale mean meridional overturning circulation, the equations of section 2.2, Figure 7 with its large STD over the Equator, do not really fit under the header "Extratropical stratosphere". Please consider first a section on global theoretical and observational background, and thereafter distinguish between extratropical and tropical stratosphere.

L12: "or at least a second layer to the Earth’s atmosphere" unclear, possibly redundant.

L20: The subdivision of a lower (troposphere) and middle atmosphere (everything above) has limitations, in recognition of the strong two-way dynamical coupling between the troposphere and stratosphere. The two-way coupling is mentioned later on in the introduction, where it can be consequently noted that to divide the atmosphere in the lower and middle atmosphere is not necessary the best view, when considering atmospheric dynamical processes.

L37-40: In the stratosphere there is "variability of dynamical origins" at other scales of motions, e.g., the ubiquitous gravity waves that drive the QBO, or that may condition the stratospheric vortex, for instance. Although the review focus is on the most distinctive phenomena, it would be worth, however, to highlight that not covered are the important workings of gravity waves, and possibly refer to a recent review on them, if any.

L40: Maybe it is somewhat unfortunate for this review that SSWs have been very recently reviewed (Baldwin et al 2021). Please explain why we need a new review on SSW so close to the one of Baldwin et al 2021? What does this review adds and what is the difference in focus, perspective or else?

L51: "this dynamical forcing" unclear

Section 2: Although in the stratosphere "dynamics" does lead to (large) departures from radiative balance, the mean structure of the middle atmosphere is fundamentally dominated by radiative forcing (i.e., the summer easterlies and winter westerlies). Please consider being more explicit to pass this message very early in the section, instead of later on along the writing (i.e., L98: "underlying annual cycle throughout the extratropical stratosphere is fundamentally a radiatively driven phenomenon")

L81 "In this situation" not clear.

L85 "eastward circumpolar vortex" Given that commonly used is as well the term "westerlies" please consider to add in a note that here the "eastward and westward" terms are used, instead of the respective "westerlies" and "easterlies", as more commonly done in practical meteorology.

Figure 2: Section 2.1 starts with "Unlike the troposphere", but then the troposphere is not discussed. That is fine overall, but it may be worth to further the distinction of the troposphere and the stratosphere, with very briefly explaining why there are westerlies year around in the troposphere, as show in the figure, which could actually be extended to 1000 hPa. Indeed, unclear why bottom at ~500 hPa?

Figure 3: Possibly a time mean state would be a better example than a daily field, given that there might be January days in the NH with a rather circular vortex.

Figure 4: Consider a more holistic approach and include the troposphere (extend the plots to ~1000 hPa) to help in illustrating how dynamically coupled are these layers.

L172-173 "gravity waves tend not to break until the mesosphere" possibly good to note that orographic gravity waves, and in the SH in general, may break in the stratosphere, something not always appreciated.

Figure 7: similarly as above, my suggestion is to be more comprehensive and to show the troposphere. Added value would be to briefly point out differences and similarity in the variability of these layers.

L202-210: In general discussion of figure 7 needs to be improved, indeed noting as well the large inter annual variability centred at the Equator. This is another example that it would be worth to consider an easy restructuring of the review, first considering the global background of theoretical and observational aspects, and then deal with SSW and QBO.

L206: "This is what is expected for variability resulting from Rossby wave forcing from the troposphere." Unclear. Why should be SH October monthly STD similar to the NH winter monthly STD, on the basis of forcing from the troposphere?

L481: "(starting with Boville (1984))" substitute commas to the brackets (to avoid double brackets)

L495: "models simulate occurrences SSWs reasonably well" occurrence with the meaning of frequency or of their fundamental dynamics? The fundamental dynamics of the SSWs is known to be captured by models since some time (e.g. Charlton et al J. Climate, 20, 470-488, 2007). However, at that time, the modelled SSW frequency was diagnosed low. What is the current status on modelling the SSW frequency in climate models?

Section 6: The first paragraph is more general than the "Middle and high latitudes". Consider moving it above the section 6.1 title, as mini-introduction to the topic.

L599: Kidston et al., 2015 is, as well, another review. Please mention that it is a review.

L604: Please consider the seminal work of Perlwitz and Graf, 1995, "The statistical connection between tropospheric and stratospheric circulation of the Northern hemisphere in winter", J Climate, 8, 2280-2295.

L614 "(Kidston et al., 2015, and ref. therein)" Please do report the key works instead,

given they very importance in demonstrating via controlled model experiments the downward influence. In alternative, it would be necessary to write that the topic is not here reviewed, because already done in Kidston et al.

L615: Confusing the reference to the EOF at this stage, given that the previous paragraph ends with a "genuine physical downward influence" found in model experiments, results which are independent on EOFs. Consider revising and better connecting these paragraphs.

In general, a mechanism for downward influence was reviewed by Kidston et al., 2015, Box 1. It would make sense to critically comment on that review, and if anything new has surfaced since that time, please report.

L644 Please start a new paragraph for the SH. Concerning the SH, of interest would be to distinguish the two time scales over which downward influence has been found: the long time scales (trends) related to ozone depletion and the intra-seasonal time scale (by Lim et al etc.).