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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The advective Brewer-Dobson circulation in the ERA5 reanalysis: variability and trends" *by* Mohamadou Diallo et al.

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Review on:
"The advective Brewer-Dobson circulation in the ERA5 reanalysis: reanalysis and trends", ACPD, 2020, by Diallo, M. et al..

In their paper, Diallo et al. compare several variables which are used to analyse the BDC of the new ERA5 reanalysis data with ERAinterim data. The authors show that the structures of the ERA5 BDC pretty much resemble those of ERAi, but also that there are nuanced differences that are important to consider. Some of the points, like the fairly large difference of tropical upwelling in the lower stratosphere and the clear

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Discussion paper

difference in the trends can become crucial for future interpretations of stratosphere dynamics and transport. The paper is well-written, it is relevant and important for research on stratospheric dynamics and it fits for ACP.
I am very much in favour of publication of the article in ACP, however, only after several major and a number of minor revisions that I list below. In my opinion, in the paper the authors oftentimes conclude too quickly, without having considered all possibilities and processes. This concerns also one of the major conclusions, where the authors state that tropical upwelling is 40% smaller in ERA5 due to gravity wave forcing (see below). Moreover, the length of the paper could easily be reduced (I give advice below), and at one point the paper loses its main focus (the comparison of ERA5 and ERi) without a good reason. I also strongly suggest to include statistical significance tests for proper interpretation of the results, to somewhat revise the conclusion section and to slightly change the title. Please see my major and minor points listed below and also consider the technical issues that I list at the bottom.

Best wishes
Roland

Major issues:

- P1L12-13 and P25L12-13: I did not believe this statement when I first read the abstract and I still don't do so having read the whole paper. Commonly the contribution of gravity waves on tropical upwelling is around 30% here (see Butchart et al. 2010). Stating that a weaker GW forcing reduces tropical upwelling by 40% does not go together with that. The statement seems to base on the sentence "The contribution of the planetary waves to the tropical upwelling differences is less evident" on P21L1-2 (and P26L23), which you use to entirely disregard any PW contribution or anything else. I think what could help to separate the contri-

butions of planetary and GW waves here could be a downward control (Haynes et al. 1991) analysis, but on the basis of patchy Fig. 10, the statement seems adventurous to me. Moreover, how well do the tropopauses fit together between ERAi and ERA5? The differences seem strongly altitude-dependent. This and also Fig. 2b made me think of a possible vertical shift between the reanalyses, that could contribute to the upwelling differences, too.

- In all plots where you calculate the difference between ERAinterim and ERA5 you need to add the statistical significance of the differences. In some regions and/or for some variables, the variability may be so large that the mean differences are not meaningful or small differences might be overseen despite their significance. Please add significance to all those plots and revise your text accordingly. In many occasions (e.g. P26 L16,L24,31) you even mention significance, but it has never been shown.

- P7L26-27 and P25L13-14: ”suggesting a stronger advective BDC“ That statement seems much too general and in some sense even wrong, because you already showed, that in the tropics, the upwelling is weaker. Often tropical upwelling is used as a proxy for the advective BDC in the whole stratosphere.
  As the stronger downwelling is limited to the high latitudes, this might be related to the polar vortex strength, which has some impact on high latitude downwelling. But the polar vortex differences between ERAi and ERA5 are not discussed in the paper. I am not saying you should analyse it, and include plots, but there should be a discussion about it, separating the different regions. The topic only appears very briefly in the very last sentence of the paper. In my opinion this is much too late and too briefly discussed, it should be included properly in the analysis and discussion.

- The paper is quite long and not every analysis is really needed for the conclusions. I think some of the figures (or panels) do not contribute anything to the

final conclusions. I therefore suggest to go through the paper starting from the back, analysing each conclusion with respect to which figures are really needed for that. The rest can be banished to a supplement, where I would also move the figures that now are in the appendix.
For example: P25L14-18: If this is all the outcome from the seasonal climatologies, I think the analysis of the seasonal climatologies can be reduced drastically, and most of the figures can be moved to a supplement. Also, I am not sure if Fig. 3 is needed at all for the conclusions.

- Until section 4, the paper always focuses on the comparison between ERAi and ERA5. In section 4, at first only the ERA5 trends (streamfct and wave drag trends) are analysed, and then the mass flux trend is compared between ERA5 and ERAi again. I do not understand why you do not stick to the comparison between the reanalysis products, as it seemed to me that this is the focus of the paper. I suggest to include the ERA5-ERAi streamfct and wave drag comparison here as well, to keep the theme of the paper. Moreover, I suggest to reflect that theme also in the title of the paper, maybe something like:
”Comparison of the advective Brewer-Dobson circulation between ERA5 and ERAinterim reanalysis: climatology, variability and trends“.
And I particularly suggest to add ”climatology“, because that is what most of the paper deals with (annual and seasonal climatologies).

- The discussion and conclusion section almost completely lacks the connection to literature and it also does not point out what the implications of the study are. I think both these points can easily be addressed. The literature is already outlined nicely in the introduction. The implications can include what the present study means for older conclusions about the BDC based on ERAi data (or model simulation results that are nudged or prescribed to ERAi dynamics), and what now can be assessed better, or more precisely, or differently with ERA5. This would be nice for closing remarks of the paper.

Minor issues:

- P3L11: “the strength of the BDC”. Do you mean the change of the strength here or really the strength? If the latter, I think the statement is out of place here, since you talk about trends in this paragraph.
- P3L13: remove “reanalyses and for”. There were no reanalyses analysed in that study.
- P4L11-12: I assume that the ability to better resolve (macro-scale) meteorological features is mainly du to the higher resolution, and not “apart from that“. Hence, please reformulate the sentence.
- Sect. 2.2: Please consider the QJRMS paper by Eichinger and Sacha, (2020). You have to be very cautious with which w^* you use for your analyses. As you do all your calculations in log-pressure coordinates, you may make a mistake when you calculate the w^* trends because in log-pressure coordinates, the trends of the pressure levels (i.e. the temperature trends and thereby the trend in the scale-height, which you implicitly neglect using the log-pressure formulae) is not considered. In that paper, we propose using the goepotential coordinates. However, for your streamfunction trends, you should be fine, because the H cancels out when you use the log-pressure density (Sect. 4.2 of the paper). But you also calculate some w^* trends at the end where it certainly matters. And I am not exactly sure if it is important for the variability calculations. Please make sure your analyses do not include the error.
- P7L4: Remove the overbar over w^*, it is not zonal mean here. But throughout the paper, use the overbar when zonal mean is shown and no overbar if it is general. And note somewhere that the overbar stands for zonal mean.

- Fig. 2: Why 15·σ? The 15 seems very arbitrary, can you explain why you chose it? And why not adding such a measure of uncertainty also to a,b,c? It would be helpful when interpreting the results (see also my major point about statistical significance)

- P10L9: But according to Fig. 2e, that is only true between 35 and 40 km, not everywhere above 20 km.

- P11L14-16: Note that ... polar regions. I do not understand what you try to say with that sentence. I suggest to remove it.

- P11L19-24: The description of the differences is unclear to me:
  - In DJF, I only see a small negative patch in the UTLS and more negative fields in the SH mid to high latitudes. The conclusion in L21 therefore bases on wrong facts.
  - I also do not see the positive differences between 40S and 0, where are you there? Still in DJF?
  The differences generally barely exceed the tropopause, or are just much smaller in the stratosphere, as the mass streamfunction is much smaller there too. So the color bar is maybe not really suitable, and moreover, it would be very helpful here to see statistical significance.
  The statement that the residual circulation is stronger in ERA5 seems wrong. Firstly, you already showed that upwelling is weaker, secondly Fig. 4c shows the opposite.
  Please clarify and correct these points.

- P11L25-27: I do not understand what you mean by ”horizontal shift here. Can you elaborate on this please.

- P14L23: “stronger westerly and easterly shear“ I can not quite see that. Can you please describe where/ guide the eye a bit?

- P14L25: ”into the troposphere below the tropopause .... does not propagate that far downward“
  I can not see that. Only some seasonal pattern is stronger in the upper troposphere in ERA5. Can you please explain this more precisely, and/or rephrase the sentence.
- P14L29-30: Halting, complicated sentence, please rephrase.
- P17L6-7: Can you rephrase this sentence please, I think this is important, but I do not understand it.
- P19L1: Why competing? Both these points are accelerating the BDC, right?
- P19L4-5: According to what I can see from the figures, this statement is probably right, but why do you not show the differences figures in that case, as you do for all other figures? (see also my major point on that)
- P20L7: ”less evident, but stronger“ How can that be? That does not seem right to me. It would be clearer if you would show the differences.
- P20L22: ... can induce meridional wind ”changes”. (provide a citation for this please, maybe Holton et al. 1995. Also for line 25-27)
- P20L30: this description is not clear to me, please rephrase it.
- P20L31-33: Please rephrase this sentence, it is confusing. Why planetary and gravity wave together in the second part of the sentence? Did you not want to separate the two forcings here?
- P22L4-5: “the difference in the net forcing....” This sentence seems obsolete to me, that is what you analyse here, not a result.

- P22L15-33: Figures that are not shown should not be described in detail and analysed in detail as here. As the paper is quite long already, I do not ask you to show the figures, but rather to move the description and the figures to the supplement and write in the main text only the most important outcome of these figures with a quick reference to the supplement.
- P23L7-8: The trend around the tropopause seems like being caused by the tropopause rise (which is part of stratospheric shrinking). The circulation moves upward. Please reformulate, keep the Sacha citation, but add for example Oberländer-Hayn et al. (2016) and Vallis et al. (2015).
- P23L29: Provide an uncertainty range of the trend (e.g. 1σ)
- P23L23: "not significant", what test did you perform? Significant on what level?
- P23L32-34: please rephrase, it does not disappear, it is simply not present in ERA5, in contrast to ERAi. This is indeed a very important point, because it has been standing in contrast to what GCMs simulate. It should be described/discussed with references in the last section.
- Fig. 11: Panel a: Please do not show these white (undefined) areas in the troposphere, instead, modify the colour bar such that it includes -inf and +inf, so that at least the sign can clearly be seen.
  Panels b-d: What are the contour lines here?
  Add an estimate of the significance of the trends, and the units to the colour bars.
- caption Fig. 12: replace "trend" with "linear regression lines" (both times).
- P26L28: Please provide a citation for ERA5 here.
  Also, remove the last part of the sentence (from ", which is" onward) or clarify what was done there and make it more precise.

- P26L32: But this acceleration has not been observed! Observations show a non-significant deceleration (Engel eta. 2009, 2017). The acceleration has been shown in model simulations.
- P26L33-34: This sentence simplifies the problem too much. Please revise it.

Technical issues:

- P1L7: The comparison of .... shows very good....
- P1L9: ...and in the...
- P1L13: ...due to weaker gravity wave forcing at....
- P1L20: ...(BDC, e.g. ...
- P1L21: ... has received a lot of interest ...
- P2L2: remove “most effectively”
- P2L7: (the so-called surf zone)
- P2L16: ... and small-scale waves
- P2L23: greenhouse gas .... ozone deplet**ing** substances
- P2L24-26: ... variability, QBO and ENSO, which affecting the temperature structure and thus the tropical upwelling and extratropical downwelling in the stratosphere
- P2L27: ... in wave propagation...
- P2L31: remove “would”

- P2L32: ...negative stratospheric temperature...
- P4L5and6: change “better” to “higher”
- P4L8: ... for the 2000...
- P4L18: I guess you mean UTC here.
- P4L28: p_S (small letter)
- P4L29: velocity. ...
- P5L3: ... is the Lagrangian...
- P5L17: Θ is the potential...
- P6L10: ... to maintain steady ...
- P610-11: brackets around citations (use citep)
- P6L17: I guess this should be $\phi(z')$
- P6L24: Used as a ...
- P7L1: ... in detail and applied in numerous...
- P7L8: ... which are the...
- P7L17: ... seasonal means of ...
  This appears also below (P7L28 and caption Fig. 1, maybe more.)
- P7L27: 0.5 mm·s^{-1}. (The dot between mm and s!). And that wrong dot appears many times again in the paper, e.g. P7L31, Fig. 2, Fig. 4, please correct throughout the paper

- For a quick look at the figures, I would appreciate the units of the variable attached to each color bar, rather than (only) in the caption.
- caption fig. 1: black
- Fig. 2 d,e,f: Relative ”differences” in ...
- Fig. 2 overbar over w
- caption Fig. 2: ... the differences of $\overline{w^*}$ between .... relative to the annual mean.
- caption Fig. 3: Monthly mean $\overline{w^*}$ at 70 hPa as function of latitude and time.
- P10L3: of $\overline{w^*}$
- P10L5: and L16: in $\overline{w^*}$ (please correct that throughout the paper)
- P11L20: ... between 0 and ...
- P11L21: ... and is consistent...
- P11L25: You mean “Fig. 4g-i”
- P11L28: the two reanalysis in Fig. 5,...
- P11L32: ...between ERA5 and... (remove “the” here, and please do that throughout the paper)
- Caption Fig. 4: boreal winter / boreal summer
- Caption Fig. 4: You describe differences in contour lines, but I do not see any difference in the colour bar, so what do you mean?
- Caption Fig. 5: boreal winter / boreal summer

- P14L3: years
- P14L7: average
- P14L8: ...for the full...
- P14L: ... major modes of ...
- P14L15 interannual time-scales
- P15L1: driving of the
- P16L11: i.e.
- P16L15: of the secondary
- Caption Fig. 7. Missing full stop after (10)
- caption Fig. 8: I guess the common abbreviation for standard deviation is “std“
- P18L1: remove ”regions of“
- P18L2: while the QBO
- P18L2: remove ”again“
- P18L3: altitudes
- P18L9: conditions
- P20L8: stream-function
- P20L13-14: ...with less ...
- P20L15: remove ”out“

- P20L19: driving of the
- P20L22: Assuming zonal momentum...
- P20L23: ... the meridional residual wind...
- P22L11:... the non-orographic gravity wave ...
- P22L11: So ERA5 does... please rephrase the sentence
- P22L15: seaonal differences
- P23L9: ...trend provides an...
- P23L10: remove ”in ERA5“ (that is the case not only in ERA5)
- P23L15: planetary wave breaking
- P23L18: remove ”we also note that“
- P23L22: ERA-Interim shows a ...
- P23L32: the
- P25L4: replace ”including“ with ”in particular“
- P25L10: induced modulations
- P25L16: seasonal mean

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