Answer to Roland Eichinger's comments on "The advective Brewer-Dobson circulation in the ERA5 reanalysis: climatology, variability and trends" by Mohamadou Diallo et al.

Dear Editor-in-Chief, Peter H. Haynes,

We are submitting our revised article titled "'The advective Brewer-Dobson circulation in the ERA5 reanalysis: climatology, variability and trends". We thank the Reviewer #1 for already accepting the manuscript as it is and the Reviewer #2 for detailed and well thought-out minor comments, which helped to further improve the paper. We have made substantial changes to the manuscript in order to thoroughly address the Reviewers' suggestions and comments. Main changes concern:

- We have substituted the panels (c, d) in the fig 11 by the differences between ERA5 and ERAi as suggested by Reviewer #1, a new figure showing these results and the related discussion.
- rephrasing of several paragraphs in order to clarify the manuscript.

With these changes, we are convinced that the paper has been significantly improved and is highly relevant for a wide-ranging journal like *Atmospheric Chemistry and Physics*. Please see below our answers point by point to all reviewers comments and suggestions.

Reviewers comments are in bold, followed by our respective replies. Changes in the manuscript are in blue, allowing them to be tracked easily.

Kind regards,
Mohamadou Diallo (on behalf of the co-authors)

Roland Eichinger, Reviewer #2 (Comments to Author):

Minor issues:

1. ***P1L4: ...inter-annual variability, climatology and trends...***

   We have rephrase it.

2. ***P1L4: ...with the predecessor ERA-Interim...***

   We have rephrased the sentence.

3. ***P1L13: The statement that the GW forcing is the reason for all of the changes here is too absolute, at least you need to add a mainly, because planetary waves also have a significant contribution here. But see my points below that explain the topic.***

   The contribution of planetary wave is significant but weaker than the gravity wave as clearly shown by the differences in Fig. 11. Most importantly, the contribution of planetary wave occurs either below the tropopause or far from the regions known as important for wave driving the upwelling branch of the BDC. We have clarified it.

4. ***P1L13-14: ... at the equatorward upper flank of the subtropical jet.***

   We have rephrased it.

5. ***P1L17: ... with observed and modeled BDC changes.***

   We have rephrased it.

6. ***P2L28: ozone depleting substances***

   We have rephrased it.

7. ***P3L4: ... consistent with observed negative ...***

   We have rephrased it.

8. ***P3L30: ...includes extensive improvements...***

   We have rephrased it.

9. ***P4L14: exchange order of "80km" and "31km", for consistency***

   We have rephrased it.

10. ***P4L18: Can you be more specific than "higher up"?***

    We have rephrased it.

11. ***P4L19: Through the higher spatial and.... are a better..., a better .... . Moreover, data from many recent satellite instruments are now additionally assimilated.***

    We have rephrased it.

12. ***P4L29: remove "h"***

    We have rephrased it.

13. ***P7L21: ...normalized coefficients the QBO and ....***

    We have rephrase it.

14. ***P8L10: three distinct regions of the stratosphere (tropical pipe, mid-latitude surf zone and polar regions***

    We have rephrased it.

15. ***P8L19: remove "at 95% confidence interval"***

    We have removed it.

16. ***P8L31: To quantify the circulation differences***

    We have rephrased it.

17. ***P8L33: The vertical w* profiles***

    We have rephrased it.

18. ***P8L34: in the w* structure***

    We have rephrased it.

19. ***P9 caption Fig.1: Write more compact: "...annual (a-c), DJF (d-f) and JJA (g-i) mean ..." and remove the two sentences below (the same applies to caption of Fig. 4 and Fig. 5)***

    We have rephrased it.

20. ***P9 caption Fig.1: ... . Grey line indicates the zero w* contours. Grey dots ...***

    We have rephrased it.

21. ***P10 Caption Fig. 2: ... (b) tropical ...***

    We have rephrased it.

22. ***Fig. 2: Change header of figures: Tropical upwelling is a mass flux, but here you show w*, the residual vertical velocity.***

    We decided to keep the wording as is.

23. ***Fig. 2: State in the captions or text what latitude bands you use, or if you use the turnaround latitudes to determine the regions of up- and downwelling (or did I miss that?).***

    This is already stated clearly in the text (Page 9, line 28-30). We have also added it in the caption.

24. ***P10L1: the relative w* differences***

    We have rephrased it.

25. ***P10L2 the large-scale downwelling differences***

    We have rephrased it.

26. ***P11 caption Fig.3: remove "together with"***

    We have rephrased the sentence.

27. ***P11 caption Fig.3: horizontal lines indicate.***

    We have rephrased it.

28. ***P11 caption Fig.3: climatologies. (remove "from the ERA5 and ERA-Interim reanalyses respectively")***

    We have removed it.

29. ***P11L5 Change "errorbars" to "the uncertainties" or to "variability is"***

    We have rephrased it.

30. ***P11L15 of the w* differences between***

    We have rephrased it.

31. ***P12L7: remove "remarkably"***

    We have removed it.

32. ***P12L11-12: stream-function upwelling in the tropical pipe and the mid-latitude surf zone is weaker in ERA5 than in ...***

    We have rephrased it.

33. ***P15L1 with the w* differences***

    We have rephrased it.

34. ***P15L12: remove "remarkably"***

    We have remove it.

35. ***P15L25: "increase with increasing: sounds odd. Maybe: "increase with enhanced"***

    We have rephrased it.

36. ***P15L16f: Rephrase sentence to: "Therefore, the use of...drag parameterization in ERA5 likely is the cause of..."***

    We have rephrased it.

37. ***P15L30: Rephrase sentence to: "In ERA-Interim, Rayleigh drag was applied as a substitute..."***

    We have rephrased it.

38. ***P15L30f: Rephrase sentence to: "For ERA5, a Warner and McIntyre (2001) type nonorographic spectral gravity wave scheme was introduced and hence the Rayleigh drag could be switched off."***

    We have rephrased it.

39. ***P16L3: ... agree well in phase ...***

    We have rephrased it.

40. ***P16L11: ... (Fig. 7c, d). Westerly shear reduces....***

    We have rephrased it.

41. ***P17L15: one of the major***

    We have rephrased it.

42. ***P17L23: ...in w* and ψ*, the regression analysis...***

    We have rephrased it.

43. ***P17L28: ...in w* show...***

    We have rephrased it.

44. ***P17L29: ...in w* show...***

    We have rephrased it.

45. ***P19 caption Fig.8: Remove "horizontal"***

    We have rephrased it.

46. ***P19 Fig.8: Add overbars to w*, also in other figures, and also to ψ* in captions and figures.***

    With the matlab version that we have, it is not possible to put the overbar in the figures. We have decided to keep it as it is.

47. ***P20L5: Change "therefore" to "thereby"***

    We have rephrased it.

48. ***P21L4-5: ...reveals larger negative w* anomalies than ERA-Interim, which is likely due to the differences in wave activity(...).***

    We have rephrased it.

49. ***P21L11: Change "This" to "These"***

    We have rephrased it.

50. ***P21L30 and L31 (two times): remove "would" and change "weaken" to "weakens"***

    We have rephrased it.

51. ***P23L5 while the ... upper stratosphere. I dint think that sentence make sense as it is, better revise it.***

    We have rephrased it.

52. ***P23L6 remove "previously reported"***

    We have rephrased it.

53. ***P23L8 "difference is less evident". But there are still significant differences in the lower stratosphere, that should be mentioned. Moreover, there are strong PW differences in the upper troposphere, but I know these are not meant here (still they could be mentioned, and stated that they are not meant for this or that reason). However, the text must therefore be cautiously revised as to whether the upper troposphere, or the lower stratosphere is meant. Here, you state UTLS and that is not correct. Also in Line 11 you incorrectly state UTLS, please go through the entire text to make it more precise.***

    Please see item 3 above. We have rephrased the text accordingly.

54. ***P23L13: ... two reanalyses are governed by differences in the contribution of both the planetary and...***

    We have rephrased it.

55. ***P23L19 ...based on the non-orographic gravity wave parameterization...***

    We have rephrased it.

56. ***P23L20 remove the sentence "This means that... any longer" (that is clear)***

    We have removed it.

57. ***P23L26 and L35: the gravity wave breaking differences are mostly in the lower stratosphere. There are also clear differences in planetry wave forcing, the strongest in the upper tropopshere, but also some in the lower stratosphere. Please take that into account here, and add it to the text and be precise about the regions, as written above.***

    Thank for this comments. note that wave breaking near the equatorward upper flank of the subtropical jet are the ones that initially drive the upwelling branch of the BDC. In this region GW contribution is the dominant one and the area of significant is even much larger than the planetary wave. The planetary wave contribution are significant but weaker than compared to the gravity wave contribution near the upper flank of the subtropical jet. In addition, the PW contribution as you notice is below the tropopause or outside of this key region. We have rephrased it and clarified it.

58. ***P23L30 ...in both hemispheres, but can be seen in a much larger ...***

    We have removed it.

59. ***P24 Figure 11: I think you must (additionally) show the differences here, because I cannot everywhere see what you state. I see it in the SH, but in the NH, the differences are not large enough to see the differences by eye. Moreover, this will help you to quantify the contributions of GWs and of planetary waves and then you can in the text more clearly discuss how much which contribution is.***

    We have changed the Fig 11 by substituting the ERA-interim panel by the different between ERA5 and ERA-Interim. The text has been modified accordingly.

60. ***P24 Figure 11: You need to explain why you chose 70 hPa. It is easily explainable citing that 70 hPa is traditionally (citing Butchart et al. (2010), Hardiman et al. (2014)...) used, and Dietmuller et al. 2018 (https://doi.org/10.5194/acp-18-6699-2018) show that 70 hPa works best for AoA and for RCTT in an inter-model correlation for almost all the stratosphere. Moreover, as all your other figures show geometric altitude, for reference, state what 70 hPa more or less refers to in km altitude.***

    Thanks for the suggestion. Actually, we had already justified the use of 70hPa for the figure 2 (Page 11, Line 3-5) and all these references were already cited in the manuscript. We have added also at Page 23, Line 33-35.

61. ***P24L3: correct UTLS as mentioned above***

    We have rephrased it.

62. ***P25L1-2 I think this sentence is somewhat too general, please specifiy it at least concerning the altitude and moreover, state that there are also significant differences in PW driving that contribute there, although somewhat smaller than the gravity wave changes.***

    We have removed it.

63. ***P25L13: "boundary layer" is not a process, maybe write boundary layer physics if that is what is meant.***

    We have removed it.

64. ***P25L20 change "projections" to "simulations"***

    We have removed it.

65. ***P25L22 remove "at 95%"***

    We have removed it.

66. ***P25L30 I think you want to refer to panel g in Fig. 10 here. The patterns here also indicate that the effect is stonger in the SH than in the NH, which goes together with the BDC differences.***

    The figure reference was not correct. It was fig. 12 here. We have changed it.

67. ***P25L31 "MAINLY by enhanced gravity wave breaking"***

    We have removed it.

68. ***P26 figure 12: Mention in the caption that the differences are not significant on the 95% level anywhere here if that is correct. If not, include the dots.***

    We have mentioned that time in the text and also added to the caption.

69. ***P26L1: Change "Eichinger and Sacha 2020" to "Sacha et al 2019", that fits better***

    We have rephrased it.

70. ***P26L6: ... using stratospheric age of air and its spectrum...***

    We have rephrased it.

71. ***P27L9: Here you can add the Eichinger and Sacha 2020 citation***

    We have rephrased it.

72. ***P27L10-11: remove: "at 95% using student t-test with two tail distribution"***

    We decided to keep it as it is because it's good to remind it in the conclusion.

73. ***P27L18 and 19: Provide the std declaration behind the number in brackets with unit. I.e. that way: ($\sigma = 0:053 kg/s/dec$)***

    We have changed by adding the sigma directly to the trend as plus/minus uncertainty.

74. ***P27L20 ... but it is significant and between 10% and 20% below 70 hPa. This indicates that....***

    We decided to keep it as it is.

75. ***P27L27 In our comparisons...***

    We have rephrased it.

76. ***P27L27 Remove "a remarkably"***

    We decided to keep it as it is because the structure of the circulation agreed remarkably well actually.

77. ***P27L31-32 I guess you are only talking about the deep branch (or the downwelling regions) here, include that to the sentence, otherwise it is very confusing***

    We are talking about the overall BDC and then region region by region. We decided to keep it as it is.

78. ***P27L33-34: Again, that statement is much to absolute for me. At least you must add a mostly or alike in front of the gravity wave, because planetary waves also contribute significantly.***

    We have rephrased it.

79. ***P28 caption Fig. 13: A trend is a scalar, while the lines you show here are functions. Therefore, change "trend" to "linear regression lines" (twice).***

    For consistency with the discussion in our regression section, and to be more accurate, we replaced "trend" with "linear trend".

80. ***P28L13: change "a very" to "show"***

    We have added the missing verb.

81. ***P29L9: I think "less evident" is not a good way to put it, as the differences are after all significant. But with the difference of the downward control analysis you can make this statement more quantitative.***

    We have rephrased it accordingly to the Fig. 11 which confirm that the GW contribution dominates.

82. ***P29L11 larger than what? You forgot to clearly state what reanalysis is larger here, and in the following which BDC in the UTLS is stronger. Moreover, as discussed above, UTLS is not the term you want to use here. Revise also this complete section w.r.t. that inaccuracy.***

    We have rephrased it.

83. ***P29L12: Therefore, these differences ...***

    We have rephrased it.

84. ***P29L17: Change "Even not" to "Although not"***

    We have rephrased it.

85. ***P29L17f remove "with the student t-test"***

    We have rephrased it.