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Interactive comment on “Simulation of the isotopic composition of stratospheric water vapour – Part 2: Investigation of HDO/H_2O variations” *by* R. Eichinger et al.

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*Reply to referee #1

GENERAL REMARKS

- *this is a nice study evaluating a global climate model with isotopic fractionation* *for HDO. The goal of the manuscript is to better understand the mechanisms by which air gets into the stratosphere. The paper in its present form is only partially successful in this regard. It needs major revisions to be publishable in ACP. The sensitivity study of methane effects is good. My general critique of the manuscript is two fold. First, the description of monsoon impacts is confusing, and second the summary is more confusing with a discussion of lofted ice. I think the authors should think about a sensitivity study to remove the isotopic effects of lofted ice to prove their point. I think a further sensitivity study of lofted ice effects on delD could be conducted to clarify this: perhaps both globally and over the ASM region: lofted ice delD could just be set to the environmental delD to remove any lofted ice effect, and then differences performed.*

Thank you for your valuable comments and suggestions. Please find below our reply to your specific points.

SPECIFIC COMMENTS

- Page 29460 L8: *no comma necessary*

  1. Thank you, will be corrected.

- Page 29460 L13: *effects...have a damping....(plural)*

  2. Thank you, will be corrected.

- Page 29463 L23: *can you add a sentence on how realistic the energy budget and hydrologic cycle is relative to observations? Nudged climate models need not represent reality very well. This is probably in the other paper, but please state here.*

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3.1 Hydrological cycle: The hydrological cyle of the basemodel ECHAM5 has been evaluated e.g. in Hagemann et al. (2006). Jöckel et al. (2006) state that the modifications introduced by the MESSy system, as well as by the application of the T42L90MA resolution and nudging, produces a hydrological cycle similar to the results by Hagemann et al. (2006) and consistent with observations. With respect to the water isotopologues, this has indeed been done extensively in Part 1 of the article. We will include some sentences with additional references in the revised manuscript.

3.2 Energy budget: Yes, "nudging" changes the energy budget of the model (e.g. through clouds). However, the nudging applied here does not include "wave zero" in the spectral space (i.e., it is applied without "nudging" the global mean temperature), which minimises this effect. The reason to "nudge" the model for the present study was to achieve a representation of the interannual variation in dynamics (e.g., w.r.t. ENSO, NAO etc.) which is as realistic as possible to be able to compare directly with observations.

- Page 29464 L22: *for figure 1, what is the correlation coefficient?*

  4. Thank you, we forgot that, the (Pearson's) correlation between HALOE/MIPAS and EMAC is R^2=0.502. We will include it.

- Page 29465 L5:*'determining' : not proper grammar. "Both determined by Tropospehere-stratosphere exchange processes" would be better*

  5. Thanks for reading carefully, will be corrected

- Page 29465 L9:*is anticorrelated (not opposing).*

  6. Thanks, will be corrected

- Page 29466 L25: *I do not think the tape recorder figures are helpful : you could remove figure 3 & 4 and just show figure 5.*

7. We disagree on that point. The tape recorder figures nicely show that the earlier fade-out of the δD(H_2O) tape recorder (compared to the H_2O tape recorder) is due to chemical isotope effects. This is particularly interesting as a follow-up for the studies in the companion paper (Part 1) and is not obvious from figure 5 only. Moreover, they show more clearly that in the upper levels the high δD(H_2O) values show a QBO signal and that this signal disappears in the second simulation. Therefore, we prefer to keep these images.

- Page 29467 L15: *affected more strongly*

8. Thank you, we will correct that.

- Page 29470 L5: *but lower temps would imply more negative DelD.*

9. Please see 13

- Page 29470 L11: *but the rest of the hemisphere also has relatively high delD at these altitudes and latitudes: could it be that the ASM is just making a region of low delD on a high delD background because it is warmer?*

10. Please see 13

- Page 29470 L16: but these two monsoons have very different structures and water vapor signals : I believe randel and park among others deal with this. I do not think simple averages can be compared in this way.

11. Thank you, among other issues, this leads us to delete the image, please also see 13

- Page 29470 L25: but the earlier figure shows that the high values are adjective from the lower stratosphere around the ASM anti-cyclone. Would that not be the cause?

12. Please see 13

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- Page 29472 L7: to me they look pretty similar up to 23 km or so. I do not think this supports the argument that one is more influential than the other: they are similar. Also: you correlate the NAM over the anticyclone with the ASM downstream.

  13. Thank you, these are important points.
  Considering this and also the comments of the second referee we decided to restructure Sects. 5 and 6:
  We will remove large parts of Sect. 5, including Fig. 9 and the entire Sect. 5.2. Instead, we will include an analysis of cloud and convection effects on the δD(H_2O) tape recorder based on additional sensitivity simulations. The main question addressed in this section will then no longer be the influences of the two monsoon systems, but rather if the in-mixing (of old stratospheric air) or the cloud/convective effects are (to what extent) responsible for the δD(H_2O) tape recorder. The question about the role of the two different monsoon systems, however, will still be addressed in the analysis and the revised discussion.
  Due to the interhemispheric differences of lofted ice and its influence on δD(H_2O) in stratospheric water vapour, the ice lofting analysis (Sect. 6) will be used as motivation at the start of the section.

- Page 29473 L16: *please explain here the mechanism: does this mean there is more lofted ice in the N hemisphere. I also think and analysis of DJF would be useful to see if the asymmetry holds in the cold season with low delD (large depletion).*

  14. Yes, there is more lofted ice in the NH. That is due to the greater land mass and hence stronger convection plus the monsoon systems. The attached figures for DJF (13 and 14) support this point. Here, these patterns can not be observed. We will add these Figs. and clarify the analysis.

- Page 29474 L19: *the enhancement is at 18 km in figure 12. Does convection in the model penetrate to this altitude? You must have some convective mass flux* *output from the model available. What can you say about the relative mass of ice injected from delD?*

15. No, convection does not penetrate up to 18 km in the model, it rather stays below the tropopause. The isotopical enrichment of water vapour due to convection is basically limited to the upper troposphere. However, this isotopically enriched water vapour is then further transported (monsoon outflow and isentropic transport) into the tropical stratosphere. The enhancement (that blob) at 18 km in Fig. 12 you are referring to, is a (maybe misleading) artefact, caused by the seasonal averaging. The mass of ice injected directly into the stratosphere is extremely low, but a slight increase would have a large effect on δD(H_2O). Thus, more ice injection in the model would produce results closer to observations (see Part 1). Hence the conclusion that the convection scheme may be responsible for the appearing differences between model and observations (later on). We will revise the text and add explanations in order to eliminate the causes for these misunderstandings.

- Page 29476 L7: *but you just said it was due to horizontal transport, and now it is due to ice lofting? I think a bit more analysis is warranted here. Or clarification, it sounds like you are talking about the same region.*

16. Water vapour is isotopically enriched through convective ice lofting during the monsoon season, but only up to the upper troposphere (at least in the model). From here on, monsoonal outflow and isentrope parallel transport is responsible for the advection of this isotopically enriched water vapour into the tropical stratosphere, where it experiences vertical transport. We will add a sentence to make this transport connection clear.

- Page 29476 L22: *how do you NSNOW the convection scheme is in error. You are discussing discrepancies with observations: please show the discrepancies.*

17. Indeed we do not have proof for that. Here we refer to Fig. 11 in Randel et

al. (2012). Together with the other cited studies this leads to these assumptions. We will revise the text and clarify that this ”could” be an explanation

- Page 29477 L3: *since you have done this for methane HDO sources, I was expecting you to do the same thing for convective HDO: why not run a sensitivity test to determine what the lofted ice does to HDO? You could revert ice coming out of convection to the environment, and that would allow you to discern the signal.*

  18. Thank you very much for this suggestion. Instead of Sect. 5.2 we will now include an additional analysis, please see Point 13.

References

- Hagemann, S., Arpe, K., and Roeckner, E.: Evaluation of the hydrological cycle in the ECHAM5 model, J. Climate, 19, 3810–3827, 2006.
- Jöckel, P., Tost, H., Pozzer, A., Brühl, C., Buchholz, J., Ganzeveld, L., Hoor, P., Kerkweg, A., Lawrence, M. G., Sander, R., Steil, B., Stiller, G., Tanarhte, M., Taraborrelli, D., van Aardenne, J., and Lelieveld, J.: The atmospheric chemistry general circulation model ECHAM5/MESSy1: consistent simulation of ozone from the surface to the mesosphere, Atmos. Chem. Phys., 6, 5067–5104, 2006

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 29459, 2014.

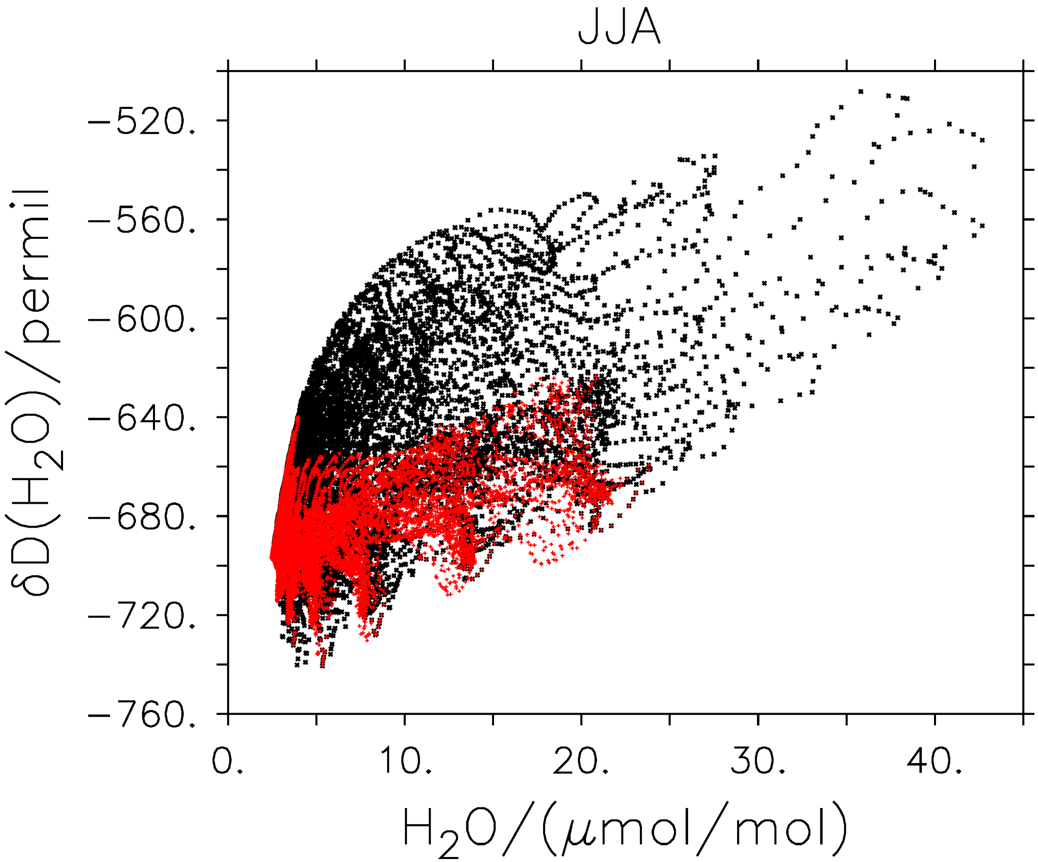

Fig. 1. Relation between H2O and dD(H2O) from 14 to 20 km in JJA between 10N and 40N (black crosses) and between 40S and 10S (red crosses), averaged over the 21 years of the EMAC simulation.

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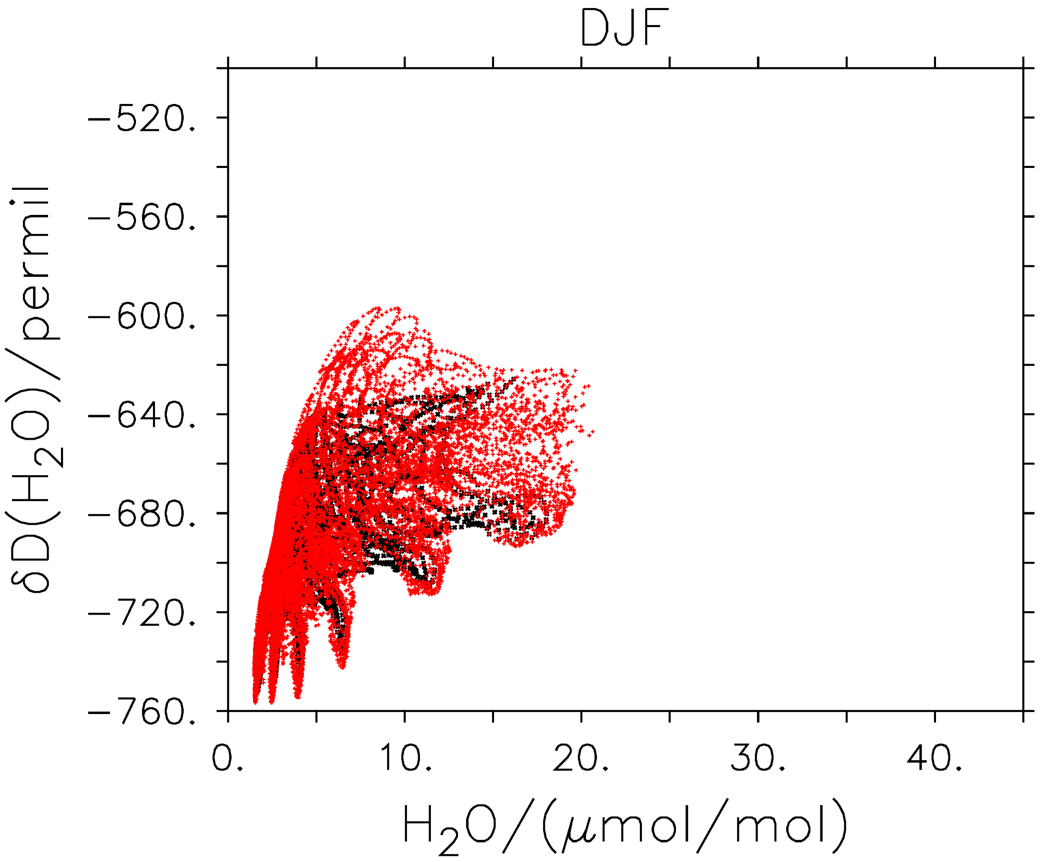

Fig. 2. Relation between H2O and dD(H2O) from 14 to 20 km in DJF between 10N and 40N (black crosses) and between 40S and 10S (red crosses), averaged over the 21 years of the EMAC simulation.

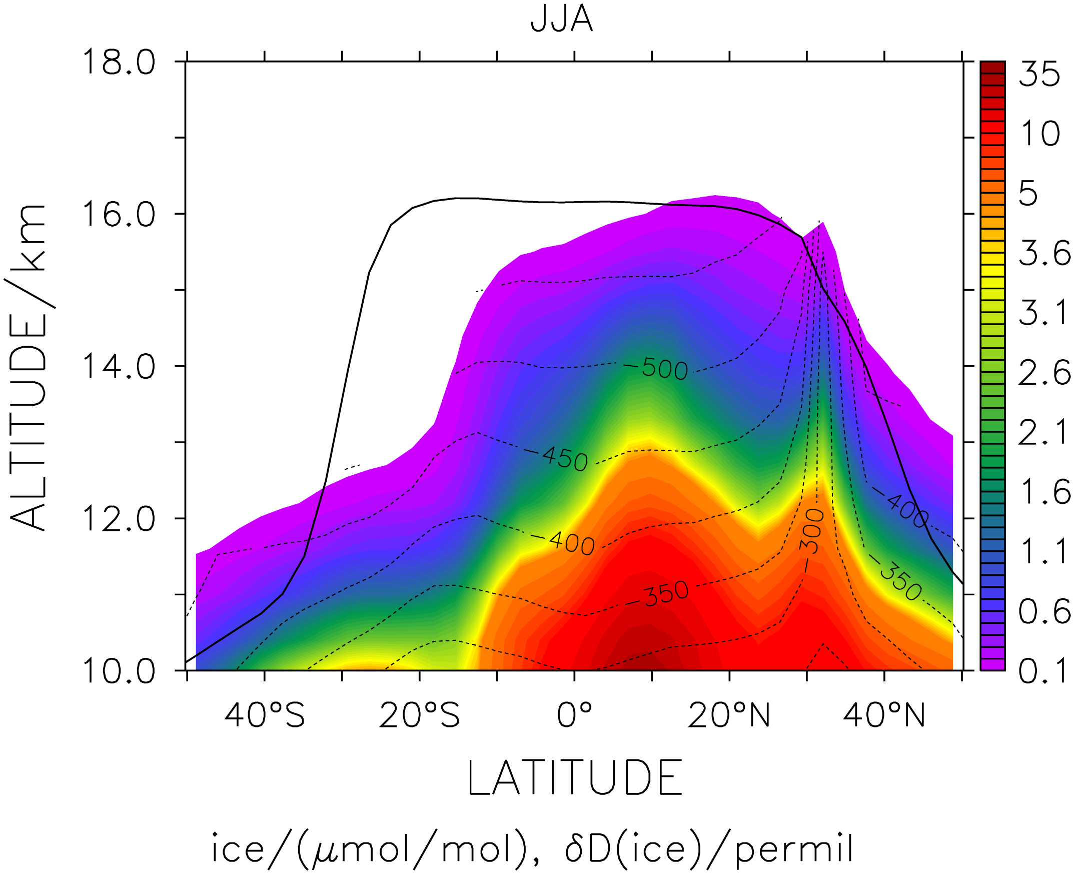

Fig. 3. Ice water content (colours) and dD(ice) (dashed contour lines) in JJA and tropopause height (solid black line), averaged over the 21 years of the EMAC simulation.

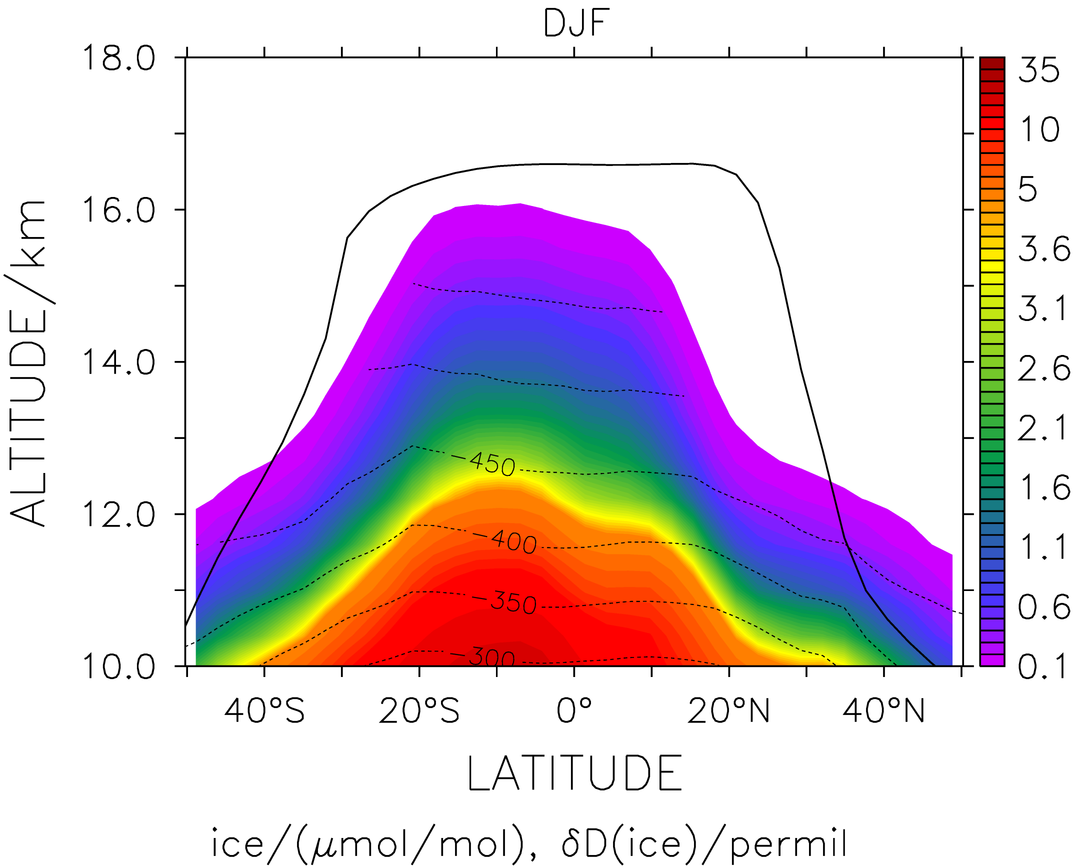

Fig. 4. Ice water content (colours) and dD(ice) (dashed contour lines) in DJF and tropopause height (solid black line), averaged over the 21 years of the EMAC simulation.

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