Review of Extier et al

December 14, 2023

The paper has been improved by the revisions. I still have many comments. I think they can be fixed easily, but they are numerous.

- l 12: "δ^2H and $\delta^{17}O$ water isotopes" -> "$^1H^2H^{16}O$ and $^1H_2^{17}O$ water isotopes"
- l 18: "Models and the..." -> "Models. The main isotopic effects and the latitudinal gradient are properly modeled, similarly to previous water isotope-enabled General Circulation Models."
- l 32: "the δ^2H and $\delta^{18}O$ isotopic ratios of precipitation" -> "the δ^2H and of precipitation"
- l 32: "ice cores" -> "polar ice cores" (things are different in tropical ice cores)
- l 34: ", and following ... latitudes": remove, I don't understand what it means.
- l 50: "experiment" -> "experimental"
- l 74: "plant lipids wax" -> "plant lipids" or "plant wax"
- l 76: "waters" -> "water"
- l 82: missing empty line
- l 85: "allows estimations of past regional and qualitative changes" -> "allows qualitative estimations of past regional changes"
- l 93: remove Risi et al 2010, which was not coupled. Rather look for HadCM or GISS references.
- l 99: "works" -> "work"
- l 107: "still appears quite suitable" -> "is suitable"
- l 107: add a sentence on other existing isotope-enabled intermediate complexity models: CLIMBER? Speedier?
- l 125: clarify what are the layers: from which level to which level? Are 800, 500 and 200 hPa the middle of the layers?
- l 138: Merlivat and Jouzel 1979 reference here is out of place. They don't say they look at precipitable water.
- l 138: recall that the moisture is assume to be only in the first layer.
- l 147: this part is still not clear. All isotope-enabled GCMs adopt the same kind of equation to calculate R_E, even though there is vertical discretization of water and isotopes in these models. So I don't think the lack of vertical discretization in iLOVECLIM is what justifies the formula for R_E. I advice to clarify what are the consequences of the lack of vertical discretization. e.g. is there a systematic bias in R_a? "solution adopted by Roche (2013)" is misleading, since the same formula was used in all isotope-enabled GCMs, already long before 2013.
- l 164: clarify the 3 types of precipitation: e.g. how about large-scale snow? Do you mean convective rain, large-scale rain, and snow?

- l 165: "values at 650, 800 and 650 hPa": it was previously written that there was no vertical discretization for water isotopes? Please clarify.
- l 166: "fractionation schemes" -> "fractionation coefficients"?
- l 166: "fractionation" -> "equilibrium fractionation"? same l 168?
- l 167: "enhanced kinetic fractionation at high latitude": do you mean the supersaturation effect? If so, please clarify this, and replace Merlivat and Jouzel 1979 by [Ciais and Jouzel, 1994].
  General: How do you account for the kinetic effect associated with the supersaturation at cold temperature? Do you use a linear function of supersaturation as a function of temperature like in all GCMs? Please explain.
- l 166-168: this sentence is really not clear. Please replace it by a clear equation, or remove.
- l 227: "annual mean" -> "annual-mean"
  Same l 506.
- Fig 2: make text in the keys larger. Same Fig 3
- Fig 3: precise if the values are monthly values. If the case, it represents both spatial and seasonal variations
- l 277: "with a correlation coefficient of ... 0.99" -> "with a correlation coefficient of 0.99"
- l 303: "and could be used...": I would replace by ". The same caution should be required for iLOVECLIM as for other GCMs when investigating past changes in d-excess."
- Fig 4 is wrongly named Fig 2; problem with the numbering of all figures starting here.
- Discussion around Fig 4: in GCMs, d-excess in high latitudes is very sensitive to the parameterization of supersaturation. Is it also the case here? Or are temperatures not cold enough?
- l 356: "even if ... fit" -> "with most of the data fitting"
- l 402: "composition" -> "ratio". General rule: the ratio is a number, the composition is a qualitative property.
- l 404: " to see if ... precipitation." -> "because this is where the amount effect is observed."
- l 411: "secondary evaporation": what does this mean? Does it mean the rain evaporation? But it was written this process is ignored in iLOVECLIM?
- l 414: "delay" -> "advance"?
- The fact that iLOVECLIM can simulate the amount effect deserves to be discussed. [Lee and Fung, 2008, Risi et al., 2008, Risi et al., 2021] show the key role of rain evaporation in the amount effect. [Field et al., 2010] even shows that disabling the fractionation during rain-vapor interactions suppressed the amount effect in a GCM. The capacity of iLOVECLIM to simulate the amount effect without this fractionation is thus surprising. In contrast, several studies give an integrated water budget perspective to the amount effect [Lee et al., 2007, Moore et al., 2014], which could explain the capacity of iLOVECLIM to simulate the amount effect.
- Fig 8: why normalizing the values? Is this hiding a problem with the amplitude in iLOVECLIM? I would advice to show the real value, for transparency.
- Fig 7: Why is LMDZ alone on its plot? Why is the x-axis unit different for the two plots? I suggest to use the same precipitation unit for all observations and models and plot everything on the same plot. If too busy, then add observations on each plot as a reference.
- l 441: again, what does 650 hPa mean? Is this an interlayer level?
- sec 3.2.2: why comparing iLOVECLIM with only one GCM? It's OK but needs to be justified: e.g. is LMDZ representative of all other GCMs?

- LMDZ is too enriched at cold temperatures with respect to observations, for reasons given in [Cauquoin et al., 2019]
- l 458: “with fractionation during continental recycling”: no! even without fractionation during continental recycling, the continental effect is observed, as shown by all isotope-enabled GCMs. It is due to the fact that over land, the enrichment of the low-level vapor by evaporation is weaker than over the ocean. Over land, not all the precipitation goes back to the atmosphere, so heavy isotopes are preferentially lost by runoff (e.g. [Pierrehumbert, 1999] for a simple model of this effect). The fractionation during bare soil evaporation only very slightly enhanced the continental effect [Haese et al., 2013, Risi et al., 2016]. For the observed continental effect, cite [Rozanski et al., 1993].
  l 470: “”Even if... fractionation”: remove, since the fractionation during bare soil evaporation is not responsible for the continental effect.
- Why documenting the continental effect in the tropics? It is largest at mid and high latitudes. In the tropics, it is weak [Salati et al., 1979, Worden et al., 2021] or even reversed (more enriched over land) [Levin et al., 2009], due to strong evapo-transpiration. I would have expected the same plot for mid and high latitudes.
- l 478: “more complex”: is it really more complex than in LMDZ? Any reference to justify this assertion? The main difference between LMDZ and ECHAM seems to be the horizontal resolution, not the complexity of its parameterization.
- l 515: I don’t understand the logic: why the “absence of sea ice ... would lead to fractionation during sea ice formation”?
- l 518: “more depleted d-excess” -> “lower d-excess”
  l 521: “as well highly depleted” -> “very low”
  General rule: the vapor is depleted, but the $\delta^{18}O$, the d-excess or the ^{17}O-excess are low.
- l 544: “observation” -> “observations” or “dataset”
- l 560: “than d-excess” -> “as the d-excess maximum”
- l 573: “with the conservation of” -> “with a reasonable simulation of”
- l 579: “that has a too important” -> “with an excessive”
- l 580: “isotopes-enabled” -> ”isotope-enabled”
- l 581: “a good accordance of” -> “with good agreement”

References

[Cauquoin et al., 2019] Cauquoin, A., Risi, C., and Vignon, É. (2019). Importance of the advection scheme for the simulation of water isotopes over antarctica by atmospheric general circulation models: A case study for present-day and last glacial maximum with lmdz-iso. *Earth and Planetary Science Letters*, 524:115731.

[Ciais and Jouzel, 1994] Ciais, P. and Jouzel, J. (1994). Deuterium and oxygen 18 in precipitation: isotopic model, including cloud processes. *J. Geophys. Res.*, 99:16,793–16,803.

[Field et al., 2010] Field, R. D., Jones, D. B. A., and Brown, D. P. (2010). The effects of post-condensation exchange on the isotopic composition of water in the atmosphere. *J. Geophy. Res.*, 115, D24305:doi:10.1029/2010JD014334.

[Haese et al., 2013] Haese, B., Werner, M., and Lohmann, G. (2013). Stable water isotopes in the coupled atmosphere-land surface model ECHAM5-JSBACH. *Geoscientific Model Development*, 6:1463–1480, doi: 10.5194/gmd–6–1463–2013.

[Lee and Fung, 2008] Lee, J.-E. and Fung, I. (2008). "Amount effect" of water isotopes and quantitative analysis of post-condensation processes. *Hydrological Processes*, 22 (1):1–8.

[Lee et al., 2007] Lee, J.-E., Fung, I., DePaolo, D., and Fennig, C. C. (2007). Analysis of the global distribution of water isotopes using the NCAR atmospheric general circulation model. *J. Geophys. Res.*, 112:D16306, doi:10.1029/2006JD007657.

[Levin et al., 2009] Levin, N. E., Zipser, E. J., , and Cerling, T. E. (2009). Isotopic composition of waters from Ethiopia and Kenya:Insights into moisture sources for eastern Africa. *J. Geophys. Res.*, 114:D23306, doi:10.1029/2009JD012166.

[Moore et al., 2014] Moore, M., Kuang, Z., and Blossey, P. N. (2014). A moisture budget perspective of the amount effect. *Geophys. Res. Lett.*, 41:1329–1335, doi:10.1002/2013GL058302.

[Pierrehumbert, 1999] Pierrehumbert, R. T. (1999). Huascaran delta18O as an indicator of tropical climate during the Last Glacial Maximum. *Geophys. Res. Lett.*, 26:1345–1348.

[Risi et al., 2016] Risi, C., Bony, S., Ogée, J., Bariac, T., Raz-Yaseed, N., Wingate, L., Welker, J., Knohl, A., Kurz-Besson, C., Leclerc, M., Zhang, G., N, B., Santrucek, J., Hronkova, M., David, T., Peylin, P., and Guglielmo, F. (2016). The water isotopic version of the land-surface model ORCHIDEE: implementation, evaluation, sensitivity to hydrological parameters. *Hydrology: Current Research*, 7:DOI: 10.4172/2157–7587.1000258.

[Risi et al., 2008] Risi, C., Bony, S., and Vimeux, F. (2008). Influence of convective processes on the isotopic composition (O18 and D) of precipitation and water vapor in the Tropics: Part 2: Physical interpretation of the amount effect. *J. Geophys. Res.*, 113:D19306, doi:10.1029/2008JD009943.

[Risi et al., 2021] Risi, C., Muller, C., and Blossey, P. (2021). Rain evaporation, snow melt, and entrainment at the heart of water vapor isotopic variations in the tropical troposphere, according to large-eddy simulations and a two-column model. *J. Adv. Model. Earth Sci.*, 13(4):e2020MS002381, DOI: https://doi.org/10.1029/2020MS002381.

[Rozanski et al., 1993] Rozanski, K., Araguas-Araguas, L., and Gonfiantini, R. (1993). Isotopic patterns in modern global precipitation. *Geophys. Monogr. Seri., AGU*, Climate Change in Continental Isotopic records.

[Salati et al., 1979] Salati, E., Dall'Olio, A., Matsui, E., and Gat, J. (1979). Recycling of water in the Amazon basin: An isotopic study. *Water Resources Research*, 15:1250–1258.

[Worden et al., 2021] Worden, S., Fu, R., Chakraborty, S., Liu, J., and Worden, J. (2021). Where does moisture come from over the congo basin? *Journal of Geophysical Research: Biogeosciences*, 126(8):e2020JG006024.