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Geoscientific Model Development Discussions

Interactive comment on "From climatological to small scale applications: Simulating water isotopologues with ICON-ART-Iso (version 2.1)" *by* Johannes Eckstein et al.

Anonymous Referee #1

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Review of "From climatological to small scale applications: Simulating water isotopologues with ICON-ART-Iso (version 2.1)", submitted to GMD by Eckstein et al. Paper number GMD-2017-280

This papers describes the implementation of water isotopologues and water tracers into ICON, a new global non-hydrostatic model, along with an assessment of initial results from the model.

Assessment:

The paper does a good job of describing ICON and the implementation of water tracers and isotopologues into the model and its physical parameterizations. The valida-

tion studies move from surface precipitation to mid-tropospheric vapor to upper tropospheric vapor and provide a good picture of how the model captures isotopic variations. I suggest below that the different schemes for isotopic exchange between rain and vapor might be better evaluated in a situation where measurements of deuterium excess are available and also in the lower troposphere where most rain evaporation occurs.

Recommendation: Minor revisions.

Major comment:

1. Why perform the sensitivity study on the parameterizations for isotopic exchange during evaporation from rain on water vapor in the upper troposphere? Also, since rain evaporation predominantly happens in the lower troposphere, I would argue that this sensitivity study be performed either for precipitation or for near-surface/lower-tropospheric vapor. Since rain evaporation is a non-equilibrium process, I would expect differing parameterizations to have the strongest impact on deuterium excess rather than deltaD or delta18O.

In this paper, measurements of deuterium excess are only available for the GNIP data, so that this would argue for the evaporation test to be applied on that data. Alternately, a recent dataset of isoptopic measurements in water vapor (Benetti et al, 2017, Scientific Data, https://doi.org/10.1038/sdata.2016.128) might provide a reasonable constraint on isotopic values over the ocean surface. I would suggest that the authors try out the evaporation scheme sensitivity study for the GNIP data and possibly also for this vapor dataset (perhaps using climatological monthly values for the appropriate locations). If they help differentiate between the performance of the two evaporation parameterizations, I would suggest that the CARIBIC comparison only apply to the standard model and the evaporation test applied to lower-tropospheric vapor or precipitation.

Minor comments (5/26 means page 5, line 26):

2/30: I think that this statement should be qualified as "isotopologue enabled _global_ models", since COSMOiso (Pfahl et al, 2012) and SAM (Blossey et al, 2010) are non-hydrostatic.

3/15-20: Might it be useful to specify a few sample grid resolutions here for the different applications of ICON?

5/eqn 2: I find the choice of alpha_eq < 1 to be surprising, but if this is carried consistently throughout the code, I suppose it fine. If one looks at Majoube (1971), for example, one finds log(alpha_18O) = 1.137e3/Tˆ2 - 0.4156/T - 2.0667e-3, which if my computations are correct yields 0.0117. This suggests alpha itself is greater than one. Still, as I said, if this interpretation of alpha is applied consistently through the code, that seems okay, but be careful to comment things well so that the next coder who is accustomed to alpha > 1 is not confused. I would suggest that the variable might be renamed to something other than alpha to avoid confusion in the future. Checking these equations against those in Blossey and Stewart required a lot of careful attention, with the alpha switching meaning between those papers and this one.

6/eqn 6: First, I am a bit worried by equation 6 with the saturation vapor deficit in the denominator since this will go to zero in the cloud. Of course, the evaporation rate of the standard isotope will also go to zero, but careful coding is required when dividing small numbers by similarly small numbers. Secondly, this equation seems to shut off isotopic exchange between rain and vapor in saturated conditions. This doesn't seem to happen in COSMOiso as described by Pfahl et al (2012, equations 4-5). Perhaps, the implementation in ICON preserves isotopic exchange in saturated conditions. If so, this should be mentioned in the text.

6/eqn 7: While this expression seems consistent with equation 7 from Blossey et al, the denominator is needlessly obscure. The quantity in parenthesis in the denominator can be written as (1 + b_l)/ (ˆlD \rho_{l,\infty}ˆ*). I would advocate putting the (1+b_l) in the denominator and putting the ˆlD next to the f and the \rho_{l,\infty}ˆ* at the end.

Also, my impression from looking at both Stewart and Blossey is that they are working

from the same basic equations. I'm guessing that if the formula for ˆl S_xˆ{evap} were plugged into equation 6, something very close to equation 7 would emerge, though with the (hD/lD)ˆn in place of the combination of the diffusivity ratio and ventilation factor ratio. There is probably a way of writing these two equations so that they are easy to compare by eye and don't require a lot of algebra.

Last, note that alpha>1 in equation 7 and alpha<1 in equation 6, unless my algebra was wrong.

7/eqn 10: Shouldn't that be ˆlf/ˆhf in the denominator? Maybe eta could be defined as the product of the diffusivity and ventilation factor ratios: (ˆhD/ˆlD) * (ˆhf/ˆlf) to simplify this formula and also equation 7.

8/6-7: Could the sentence "Evaporation of precipitation ..." be rephrased? The effects of evaporation on buoyancy and the resulting cold pools is certainly important, but it is important for other reasons as well. Thinking of isotopic applications, Risi et al (2008, JGR, doi:10.1029/2008JD009943) suggest that the recycling to vapor from downdrafts into the boundary layer could play a role in the amount effect. As this vapor is affected by rain evaporation and re-equilibration in the downdraft, evaporation could be an important process for this isotopic application as well.

9/sec 3: Are these simulations free-running or are they nudged to reanalysis fields (wind, temperature, surface pressure) to preserve the "observed" meteorology? It's worth making this clear, because isotope-enabled global models are often run in nudged configurations to produce a sort of isotope reanalysis (e.g., Steen-Larsen et al, 2017, JGR, http://dx.doi.org/10.1002/2016JD025443).

13/fig 2: I realize that Vienna is the home of the IAEA, but does it really provide much information that isn't in the Karlsruhe plot? Is it worth having both here when they're so similar? Removing one location might enable the panels to be larger and more readable, which seems desirable.

14/25: I think that the threshold for cloud-affected grid points should perhaps be set much lower. I would advocate for 50% at most and think of 10% as a better characterization of the almost-cloud-free conditions that would be ideal for a IASI retrieval.

16/19: Suggested re-wording "This _may be_ partly due to evaporation of rain drops ...". There could be other things contributing to these changes in the 4-6km layer where IASI is most sensitive, so that I would suggest less certainty here. I think of rain evaporation as being most prominent below cloud base, less so in the mid-troposphere, though I am happy to be corrected on this.

Typographic suggestions:

1/6: "... measurements _of_ precipitation ..."

1/12: "... as well as _that of all_ tropical data ..."

2/1: "It is the strongest green house gas (...) _and_ distributes energy through the release of latent (...), while liquid and frozen particles influence the radiative balance (...)." I don't think "to name only three ..." is needed.

2/13-15: Possible rephrasing: "Measurements of the isotopic content of vapor first required cryogenic samplers (Dansgaard, ...), but in the last 15 years laser absorption spectroscopy has made in situ measurements possible (citations)."

6/6: "ilead" —> "lead"

9/2: "presents"

9/19: comma before "respectively".

10/2: Remove "timestep" after "convection". It's unnecessary.

10/15: Try to avoid starting a sentence with a symbol when possible. Suggested rephrasing: "Two months after initialization, q_{init} ..."

10/24: "... importance of this parameterization in the _simulations at this resolution._"

In other simulations with the same model or at other resolutions, this parameterization might not have the same role.

10/25: To make this flow better, suggested rephrasing: "The situation is different in northern hemisphere summer (...). Land areas in the northern hemisphere (bottom right) themselves supply a substantial fraction ..."

12/11: Move d-excess definition here: "... and d-excess (= deltaD - 8 delta18O) in precipitation." and remove the sentence on lines 13-14.

14/2: "in approximately" –> "at a height of approximately"

20/20: "Thirty output files ..." At the start of a sentence, spell out the number (or rephrase to avoid having it at the start).

21/1: "... from each file, and 200 ..." This is a compound sentence, so that there should be a comma before the "and".

21/2: "to consider" –> "corresponding to"

21/2-3: "The resulting probability distributions are shown in the right panels of Fig. 7 (...) together with the samples along the paths of flights 309-310." I think this is more clear for the reader.

24/24: "proofs" –> "proves"

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