



Interactive comment on “Stable water isotopes in the coupled atmosphere–land surface model ECHAM5-JSBACH” by B. Haese et al.

B. Haese et al.

Barbara.Haese@awi.de

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We would like to thank referee 2 for their comments which have helped to improve the submitted manuscript. Below we answer each comment in turn. Please find attached the manuscript in a revised form.

Reviewer: This paper presents a set of sensitivity tests for an isotope AGCM with and without a detailed land surface isotopic parameterization. The authors incorporated prognostic isotopic reservoir (soil moisture) and corresponding fractionation process associated with evaporation from soil and plant into JSBACH, and quantify the impact of adding these processes. The work is not new in the community (there are a few similar studies with different climate models), but in this particular model, it is the first report. However, I strongly suspect that there are significant errors which would largely

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influence their final conclusion. Without fix the problems, I do not think the paper is worth to be judged.

Reply: We thank the reviewer for the critical evaluation of our presented work. After receiving the two reviews on our manuscript, we have carefully checked all parts of the model code and indeed discovered a major coding error, however different than the reviewer anticipated. As a consequence, we had to conduct all experiments with a new model version and the results have substantially changed. We actually had a bug in the program, even if a different than expected. We conducted all the experiments again and came to completely different results. Please find the new results in the new version of the paper.

Reviewer: The first error is in Equation (3). The author multiplies $R^{\hat{x}}_{res}$ to the whole right hand side, but this does not make sense at all (e.g., vapor isotope, $q^{\hat{x}}_{vap}$ is be multiplied by soil moisture isotopic ratio $R^{\hat{x}}_{res}$). In the correct form, $R^{\hat{x}}_{res}$ should be multiplied with the second term in the parenthesis ($\alpha^{\hat{x}}(T) \cdot h \cdot q_{sat}$). All relevant studies use this way. If this way is wrong, the authors need to justify their way more clearly. Because of this error, the isotopic ratio of evaporation is over estimated. Therefore the precipitation isotope ratio is enriched in many places.

Reply: In the former version of the manuscript, we mixed up the description of the equations implemented for the noF (no fractionation over land surface) and FE (fractionation of evaporation from bare soil only, over land surface) simulations. This has been corrected in the new manuscript version. Furthermore, we now explain in more detail the equations describing the evaporation and transpiration from the different land surface water reservoirs as well as the related equations for calculating the isotopic composition of the water fluxes. (Please see the modifications in Sec. 2.1)

Reviewer: Secondly, in Equation (3) again, the dew should not be physically represented with this form. There is no physical link between dew formation and the soil moisture. Dew is simply the over saturation of water vapor, so that equilibrium fraction-

ation should be used. This error also has negligible impact to the conclusion.

Reply: We agree with the reviewer and implemented equilibrium fractionation for dew formation in the model. The description of this process in the rewritten manuscript version has been changed to: "Dew formation occurs in ECHAM5-JSBACH if the vapor of the lowest model layer q_{vap} is larger than the saturated specific humidity q_{sat} . For this case, we assume the equilibrium fractionation between the dew and the surrounding vapor." (please see Sect. 2.1 I. 224)

Reviewer: Third, in Equation (4). The authors misunderstand the meaning of fractionation with transpiration. Yoshimura et al. (2006) implemented fractionation in transpiration, but against the leaf water, not to the soil moisture. Because the leaf water is very small pool, isotopic enrichment in the leaf water would occur instead of isotopic depletion of transpired vapor. Moreover, R^x_{ws} must not be placed in this position anyway (same as the first error).

Reply: We agree with the reviewer on this topic and rate the effect of fractionation on the transpired vapor as rather small, in general. However, in JSBACH, the hydrology inside of the plants leading to transpiration is not explicitly described. E.g., the model does not contain any leaf water reservoir. The transpiration through plants is simply calculated as a potential evaporation flux of soil water multiplied by a transpiration efficiency factor (please see Eq. 5 in the revised manuscript). The experiment FET is a pure sensitivity study performed to analyze what happens if the entire evapotranspiration flux from soil reservoir would fractionate. For example, with the FET experiment we are able to detect where recycled water plays an important role over land surfaces. But we are totally aware that this sensitivity study does not mimic the natural process. We added a more detailed model description regarding this FET setup at sect. 2.1 I. 216 of the revised text:

"Since the hydrology inside the plants is not described by ECHAM5-JSBACH, the transpired water is modeled as a potential transpiration flux:

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$$T = p \cdot C_V \cdot |v_h| \cdot S^{-1} (q_{vap} - q_{sat})$$

The factor S^{-1} is the transpiration efficiency, which includes among others the stomatal resistance of canopy. A detailed description can be found in DKRZ (1992). Gat (1996) has shown that there is no fractionation between isotopes as roots take up water. This leads to the model assumption that the isotopic composition (R^x_{veg}) inside the plants is identical to the isotopic composition of the soil water ($R^x_{ws} = R^x_{veg}$). If we assume no fractionation occurring during transpiration, the transpiration isotope flux is calculated as follows:

$$T^x = R^x_{ws} \cdot p \cdot C_V \cdot |v_h| \cdot S^{-1} (q_{vap} - q_{sat})$$

To estimate the potential maximum fractionation effect for the combined evapotranspiration flux over land surface, we perform an additional sensitivity study. Here we assume that the equilibrium fractionation occurs during both evaporation and transpiration. As JSBACH model does not resolve the hydrology inside the plants and does not simulate the amount of leaf water, we assume that the whole amount of transpired water can fractionate. This leads to the altered Eq. 10:

$$T^x = p \cdot C_V \cdot |v_h| \cdot S^{-1} (q^x_{vap} - (R^x_{ws} \cdot q_{sat}) / \alpha^x(T)).$$

We are aware that this sensitivity study does not mimic the natural process of isotope changes during transpiration (e. g. described by Sachse et al., 2012). Nevertheless we rate it as a useful for estimating upper limit of isotope changes related to the simulated evapotranspiration in ECHAM5-JSBACH."

Reviewer: With these three critical errors, I believe that their results became totally meaningless. For example, the soil moisture isotopic ratio became depleted at high latitude by having evaporative fractionation (Fig 9) is totally unreasonable. This time I hesitate to comment about all the results since they will be dramatically changed with the right formulations. Here I don't mean that the previous formulations are "right", but at least if new formulation is proposed, more supportive evidence should be shown.

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Reply: As stated above, the model results have substantially changed after correcting the coding error. Based on our new findings, the model description, the result part, and the conclusion have been rewritten.

Reviewer: Final point, I really like the sensitivity test with different kinetic fractionation parameterizations. However, the author did not write detailed specification of the tests. Please describe both kinetic fractionations with equations. Then the results would be relevant to the readership.

Reply: The sensitivity test with different kinetic fractionation parameterizations are now described in more detail and the relevant equations are given in the revised manuscript, please see sect. 2.1 l. 187:

“First, we assume that the same kinetic fractionation factor as for evaporation over the ocean can be used over land as well:

$$\alpha_k = 1 - \lambda k,$$

with $k = 0.006$ if $|V_s| \leq 7$ [m/s], and $k = 0.000285|V_s| + 0.00082$ if $|V_s| > 7$ [m/s], $\lambda = 1$ for ^{18}O , and $\lambda = 0.88$ for D . Here V_s is the horizontal wind speed on the surface and λ describe the ratio of the isotope molecular diffusivity in air. In this approach α_k is depending on the molecular and turbulent resistance of water vapor and has been described in detail by Merlivat and Jouzel, 1979. The second approach is presented by the study Mathieu and Bariac, 1996. Where α_k is calculated as the n th power of the molecular diffusivity ratio in air:

$$\alpha_k = 1 / ((d_v / d^x_v)^n), \text{ with } d_v \text{ (} d^x_v \text{)}$$

as the vapor diffusivity in air (vapor diffusivity of the isotopic species x). The exponent n includes the influence of the turbulent and molecular resistance and we use, as suggested by (Riley et al., 2002), $n = 0.67$.”

References:

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Please also note the supplement to this comment:

<http://www.geosci-model-dev-discuss.net/5/C1566/2013/gmdd-5-C1566-2013-supplement.pdf>

Interactive comment on *Geosci. Model Dev. Discuss.*, 5, 3375, 2012.

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