

Anna Martin and her co-authors implemented the land surface and vegetation model JSBACHv4 into the ECHAM/MESSy Atmospheric Chemistry (EMAC) model. JSBACH is now available as an independent MESSy submodule and can be used instead of the previous soil water bucket model, which is integrated in the SURFACE submodel.

The authors describe how they integrated JSBACH into MESSy and also describe the various processes of JSBACH and how these are divided into different subroutines/functions/files in the MESSy infrastructure.

For the optimization of the previously used parameters in SURFACE, tuning was carried out with the help of numerous EMAC simulations.

A detailed evaluation of JSBACH in comparison to SURFACE was carried out using different observation and reanalysis data (MODIS, GPCP and ERA5-Land). The evaluation shows that JSBACH achieves significantly better results in some cases. In particular TWS, LAI and the precipitation are now closer to the observational data (at least the mean). Other physical variables such as LST or albedo are simulated similarly as with SURFACE. In addition, JSBACH now includes new physical variables such as FaPAR, GPP or NPP, which allow additional accuracy of the soil properties and in particular the properties of the vegetation.

All in all, the authors show a very successful integration of JSBACH into the MESSy infrastructure. EMAC and probably also IMAC (ICON/MESSy), are thus taking a further successful step towards a holistic comprehensive earth system model.

The paper is therefore of great scientific importance and significance.

The scientific quality of the paper is very good. It is written clearly and has a logical and structured structure. The model simulations and evaluations are well described and reasonable. The description of JSBACH in EMAC is very well described and the necessary evaluation is presented in detail. All EMAC simulations and evaluations should be easy reproducible. The complete model code is available in a GitLAB at DKRZ.

I can therefore recommend the paper for publication in any case and have only a few comments that should be taken into account (although many of them are only suggestions, where the authors can decide for themselves whether they want to implement them):

**Comments/Remarks/Suggestions:**

Line 2: "the soil water bucket model" → "the soil water bucket model included in the SURFACE submodel"

Line 8: "coupled model" → "new coupled model (EMAC/JSBACH)"

Line 9: "MODIS" → "Moderate Resolution Imaging Spectroradiometer (MODIS)"

Line 15: I would move the sentence "The LAI climatology in EMAC has been substituted with a refined method for directly calculating LAI" to line 6

Lines 16/17: I would remove here the sentence "FaPAR and GPP exemplify two of the many additional variables made available through JSBACH in EMAC", but insert a sentence in the area of line 4 to 7, describing which variables are now new in EMAC (not included in SURFACE before).

Lines 20 to 23: “This improvement can be attributed to a general increase in soil moisture and water storage in deeper soil layers, leading to a reduction in normalised root mean square error (NRMSE) and a closer alignment of simulated TWS with observations, mitigating the previously widespread problem of soil drought.” → “This improvement can be attributed to a general increase in soil moisture and water storage in deeper soil layers, and a closer alignment of simulated TWS with observations, mitigating the previously widespread problem of soil drought.”

Line 23: I would either remove the sentence “The correlation of TWS and observations is 0.251 and the average global difference is 0.052m water”, because that sounds contradictory (due to the very low correlation and the fact that the means are not mentioned) to the previous sentence or alternatively mention also the means 1.13m (model) and 1.078m (ERA5).

Line 24: “We show that the numerous newly added components strongly improve the land hydrology, e.g. soil moisture; while surface parameters, which were mostly prescribed according to climatologies, remain similar.” → “We show that the numerous newly added components strongly improve the land surface, e.g. soil moisture, TWS, and LAI, while surface parameters, as LST, surface albedo or  $Rad_{TOA}$ , which were mostly prescribed according to climatologies, remain similar.”

Line 34: “Gutiérrez et al., 2021”. I think this is not the correct citation for the Annex II of IPCC, 2021. The correct citation (also in the literature) is in my opinion an mention in the document itself: IPCC, 2021: Annex II: Models [Gutiérrez, J.M., A.-M. Tréguier (eds.)]. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 2087–2138, doi:10.1017/9781009157896.016

Line 37: “... (Roeckner et al., 2006)” → “... ,Roeckner et al., 2006)”

Line 37: “However, all physical parameterisations from ECHAM have been replaced ...”. I find this sentence misleading, as the parameterizations were not replaced in most cases, but rather outsourced to certain submodels and where appropriate supplemented there with further parameterizations. It is better described in the lines 124/125.

Line 46: “(LPJ-GUESS)” → “(LPJ-GUESS, Forrest et al., 2020)”

Line 49: “documented” → “described”

Line 51: “(Reick et al., 2021)” → “(Reick et al., 2013, 2021)”

Line 59: “SURFACE” → “the MESSy submodel SURFACE”

Line 67: “document” → “describe”

Line 69: “evaluation” → “corresponding evaluation”

Line 73: “Reick et al. (2013)” → “Reick et al. (2013, 2021)”

Line 75: “Briefly summarized, on the technical side ...” → “On the technical side ...”

Line 86: “The ICON-Land infrastructure allows a clear separation of the physical processes used in JSBACHv4.” → “In the case of the ICON-Land infrastructure a clear separation of the physical processes used in JSBACHv4 is allowed.”

Line 87: “defined via gross and net primary productivity and photosynthesis” → “defined via gross (GPP) and net primary productivity (NPP) and photosynthesis”

Lines 91/92: Please add a sentence that different land cover types are listed in Table A2.

Line 99: “jsbach” → “JSBACH”

Lines 108/109: I would make a paragraph here (before JSBACH).

Line 129: “In future simulations where JSBACH is used, the SURFACE submodel must be switched off in the namelist setup.” → “In the case JSBACH is used, the SURFACE submodel must be switched off.”

Line 141: “The simulation based on the default parameters ...” → “The simulation using JSBACH based on the default parameters ...”

Lines 144/145: “... Table S2 of the Supplement. Simulation 2 and 31 were not completed due to server failures and were excluded from the analysis.” → “Table S2 of the Supplement (simulations 2 and 31 were not completed due to server failures and were excluded from the analysis).”

Line 148: “ERA5/ERA5-Land monthly averaged data” → “ERA5-Land monthly averaged data”

Lines 160/161: In my opinion you should write two or three sentences more here regarding the results in Table 3. What criteria were applied to decide which parameter sizes were selected?

Line 173: “standard 11 tile setup” → “standard tile setup”

Lines 207/208: I would make a paragraph here (before “LST”)

Line 208: “(shown in red in Fig. 1)”. In my case this is not red, rather brown. Perhaps don't mention the colours, in my opinion this is not necessary. I would write “(see Fig.1 and Table 6)”.

Line 209: “0.743 K warmer than REF”. According to Table 6 it has to be “0.816 K”.

Line 211: “0.946” → “0.947” and “0.943” → “0.944” (according to Table 6)

Line 212: “-0.012” → “-0.013”. Probably the reason is the rounding ...

Line 213: “ Wm-2 ” → “ Wm<sup>-2</sup> ”

Lines 239/240: (Muñoz Sabater, 2019, 2021) → “(Muñoz Sabater, 2019)”. The both datasets Muñoz Sabater, 2019 and Muñoz Sabater, 2021 were combined into one data set.

Line 246: “is lower everywhere” → “is lower than REF everywhere”

Line 258: “warmer land surface” → “warmer global land surface”

Line 261: “tropics, subtropics” → “tropics/subtropics”

Line 262: “in both simulations” → “in the EMAC/JSBACH and the EMAC/SRF simulation”

Line 283: Also evaporation?

Line 293: “In Fig. 7 the difference of TWS between EMAC/JSBACH and ERA5 is shown.” → “In Fig. 7 the difference of TWS between EMAC/JSBACH and EMAC/SRF to ERA5 is shown.”

Line 293ff, Fig.6/Fig.7: I would change the numbers of the two figures, Figure 7 to Figure 6 and Figure 6 to Figure 7, so that they appear in the text in the correct order.

Line 295: “Russia” → “Western Russia”

Line 295: "EMAC/JSBACH overestimates TWS almost everywhere, except for high elevated regions" → "EMAC/JSBACH overestimates TWS almost everywhere, independent of the season, except for high elevated regions"

Line 298: → Fig.7 (right panels)

Line 299: "... than the EMAC/SRF results, which is also visible in Fig. 6." → "... than the EMAC/SRF results. This is also visible in Fig. 6. where the globally averaged TWS trend is illustrated."

Line 300: "The TWS of the EMAC/SRF simulation is lower everywhere ..." → "The TWS of the EMAC/SRF simulation (Fig. 7) is lower everywhere ..."

Line 302: "-0.68 m lower than the one derived from reanalysis data." → "-0.684 m lower than the one derived from reanalysis data (see Table 6). In EMAC/JSBACH the global average of TWS is  $1.13 \pm 0.706$  m which is, with a difference of 0.052m, significantly closer to ERA5 ( $1.078 \pm 0.56$ m)."

Line 304: "computed" → "simulated"

Line 310: "0 °C" → "0 °C"

Line 325: I would make a paragraph here (after "... (2021).")

Line 327: "?Schaaf and Wang," → "Schaaf and Wang,"

Lines 330-332: "During summer, EMAC/JSBACH shows a slight overestimation in the Northern Hemisphere and an underestimation in the Southern Hemisphere. In the winter months the opposite applies, underestimation in the Northern Hemisphere and overestimation in the Southern Hemisphere." This is only true for different parts of the Northern Hemisphere and Southern Hemisphere. Please be more specific.

Line 336: "Fig.8" → "Fig.8 (right panels)"

Line 355: "0.907" → "0.907 (Table 6)"

Line 355: "ERA5 and EMAC/JSBACH" → "EMAC/JSBACH and ERA5"

Line 356: "... of EMAC/JSBACH Rad<sub>TOA</sub> during ..." → "... of EMAC/JSBACH Rad<sub>TOA</sub> in comparison to ERA5 during ..."

Line 370: "correlation" → "anti-correlation"

Line 387ff/Fig.10/Fig.11: I would also here change the numbers of the two figures, Fig. 10 to Fig. 11 and Fig. 11 to Fig.10, so that they appear in the text in the correct order.

Lines 388: "... in the simulation results in comparison ..." → "... in the EMAC/JSBACH simulation in comparison ..."

Line 390: "... is 0.042 mm day<sup>-1</sup>." → "... is 0.042 mm day<sup>-1</sup> (2.738 to 2.696 mm day<sup>-1</sup>, see Table 6)." This makes it easier to classify the size of the difference.

Lines 427/428: : I would make a paragraph here (after "... grid.")

Line 427: "... is -0.212 m<sup>2</sup> m<sup>-2</sup> lower ..." → "is -0.212 m<sup>2</sup> m<sup>-2</sup> (1.187 to 1.399, see Table 6) lower ..."

Line 431: "The zonal average shows" → "The zonal averages (Fig. 12 right panels) shows"

Line 516: "0.056% ± .4e - 05%" → "0.056% ± 4e-04%"

Line 518: “Results indicate that the LST derived from the newly coupled model is on average 1.546°K colder compared to the LST derived from ERA5.” → “Results indicate that the LST derived from the newly coupled EMAC/JSBACH model is on global average 1.546 K colder compared to the LST derived from ERA5 (using the old SURFACE submodel, the globally averaged LST was 0.816 K warmer).”

Line 520: “the reanalysis” → “the ERA5 reanalysis”

Line 525: “are among many other newly introduced variables”. I would list them all here.

Table 1: “NPP” → “Net primary productivity (NPP)”

Table 3: In the case that the abbreviation of a physical quantity (e.g.  $HFLX_{sensible}$ ) are not explained (long form) in the main text, explain them here at least in the caption

Table 6:

- For the precipitation there is the value  $2.738 \pm 3.382$  (EMAC/JSBACH) and  $3.025 \pm 3.279$  (EMAC/SRF). That cannot be, or? The standard deviation is larger than the mean. This would lead to negative precipitation values ...
- Maybe this is not so important, but I would prefer it to see the observational data repeated in the 2nd part of the table.

Table A1: Why do you have two times the number 1 and two times the number 11 here?

Table S2 (Supplement):

- It is not totally clear that the numbers in the EMAC/SRF and in the CTRL rows are the default values. Maybe you can write this in the caption. Furthermore, if the value appears in the table, it would also be good to write “default” there. For example in run 4 instead of “0.85” for zasic write “default”. Perhaps the latter is also sufficient to make it clear.
- Please also write in the caption that the simulations 2 to 35 were performed with EMAC/JSBACH.
- What is the difference between CTRL and the runs 4, 8, 20, and 22? Maybe I don’t see it, but are these not all the simulation setups? In Table S3 and S4 are the same results in the case of the simulations 4, 8, 20 and 22. But the results differ to the CTRL simulation. Why is this so?
- Why do you write “EMAC/JSBACH” instead of “16” in the case of run 16. That is confusing. If you want to express that this is the best choice of parameters, please also write this in the caption.

Fig. 5:

- “low cloud cover (lcc), medium cloud clover (mcc) and high cloud cover (hcc)” are not shown.
- “The blue background colour indicates values averaged over the polar climate zone (latitudes  $> 66.5^\circ$ ), the green background colour indicates values averaged over the temperate climate zone (latitudes between  $40^\circ$  and  $66.5^\circ$ ), and the red background colour indicates values averaged over the tropical and subtropical climate zone (latitudes  $< 40^\circ$ )” □ “The upper panels indicates values averaged over the polar climate zone (latitudes  $> 66.5^\circ$ ), the mid panels values averaged over the temperate climate zone (latitudes between  $40^\circ$  and  $66.5^\circ$ ), and the bottom panels values averaged over the tropical and subtropical climate zone (latitudes  $< 40^\circ$ ).”

## References:

1) “Gutiérrez, J M., A.-M. T. e., Masson-Delmotte, V., P. Z. A. P. S. C. C. P. S. B. N. C. Y. C. L. G. M. G. M. H. K. L. E. L. J. M. T. M.-T. W.O. Y. R. Y., and (eds.), B. Z.: Annex II: Models, p. 2087–2138, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA,, <https://doi.org/10.1017/9781009157896.016>, 2021”

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„IPCC, 2021: Annex II: Models [Gutiérrez, J M., A.-M. Tréguier (eds.)]. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 2087–2138, doi:10.1017/9781009157896.016”

2) “Hersbach, H., B. B. B. P. B. G. H. A. M. S. J. N. J. P. C. R. R. I. S. D. S. A. S. C. D. D. T. J.-N.: ERA5 monthly averaged data on single levels from 1940 to present, Copernicus Climate Change Service (C3S) Climate Data Store (CDS), <https://doi.org/10.24381/cds.f17050d7,615>, 2023.”

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“Hersbach, H., Bell, B., Berrisford, P., Biavati, G., Horányi, A., Muñoz Sabater, J., Nicolas, J., Peubey, C., Radu, R., Rozum, I., Schepers, D., Simmons, A., Soci, C., Dee, D., Thépaut, J.-N. (2023): ERA5 monthly averaged data on single levels from 1940 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS), DOI: 10.24381/cds.f17050d7 (Accessed on DD-MMM-YYYY)”

3) “Muñoz Sabater, J.: ERA5-Land monthly averaged data from 1981 to present, <https://doi.org/10.24381/cds.68d2bb3>, 2019.

Muñoz Sabater, J.: ERA5-Land monthly averaged data from 1950 to 1980, <https://doi.org/10.24381/cds.68d2bb3>, 2021”

→

“Muñoz Sabater, J. (2019): ERA5-Land monthly averaged data from 1950 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). DOI: 10.24381/cds.68d2bb30 (Accessed on DD-MMM-YYYY)”