Dr. Qiang Wang
Topical Editor
Geoscientific Model Development
February 26th 2019

Manuscript reference No. GMD-2018-91

Dear Dr. Qiang Wang,

Please find attached a revised version of the manuscript, **The Brazilian Earth System Model version 2.5: Evaluation of its CMIP5 Historical Simulation**, which we would like to resubmit for publication in Geoscientific Model Development.

We appreciate the opportunity to improve the manuscript.

Following your suggestion, a complete English editing of the reviewed manuscript was performed by a native English speaker scientist with publishing experience. The English certificate editing certificate is attached. All the changes in the text based on the reviewers' suggestions and on the English editing are marked in green (included text) and red (deleted text) in the "WithChangeTrack" manuscript.

The manuscript English editing involved grammar, phrasing, and punctuation. Much of the editing involved articles and some word order changes to improve the flow and readability. The most substantial feature of the editing was the use of different tenses. It was edited in such a way that operations performed by the most in the past, which led to figures, are now in the past tense - as they happened once in the past. In contrast, when these operations showed or confirmed a feature or ability of the model that is ongoing, it is maintained in the present tense.

In the following pages are our most important point-by-point revisions.

- Page 9, Line 2

  Based on the second comment of the reviewer #2 the following text: “The ocean stand-alone runs for 71 years (13 years period of ocean model spin-up forced by climatological atmospheric fields plus 58 years period forced by interannually varying atmospheric fields). Then a spin-up of the fully coupled model is done for 100 years. The ocean and atmosphere states at the end of this 100 years long integration are used as the initial condition for the piControl simulation. The piControl simulation shows stable conditions after a fast adjustment over the first 13 years of simulation (figure not shown).” has been replaced by “The ocean stand-alone ran for 71 years (a 13-year period of ocean model spin-up forced by climatological atmospheric fields plus a 58-year period forced by interannually varying atmospheric fields). Next, a spin-up of the fully coupled model was performed for 100 years. The oceanic and atmospheric states at the end of this 100-year-long integration were used as the initial conditions for the piControl simulation. The versions of the model differ slightly in the 100-year spin-up and the piControl run, in the parameterizations of the land ice albedo and in the cloud microphysics. For its initial conditions, the historical simulation used information about the 14th year provided by the piControl simulation. The piControl simulation showed stable conditions following a fast adjustment over the first 13 years of simulation (figure not shown). Therefore, it is assumed that the historical simulation had a spin-up of 113 years.”

- Page 13, Line 18

  Based on the second comment of the reviewer #1, the following text has been included: “The net radiation imbalance at TOA is related to significant loss of energy at TOA both from the outgoing long-wave radiation and outgoing short-wave radiation.”

- Page 21, Line 7

Based on the first comment of the reviewer #2 the following text: "To evaluate how the global ocean profile evolves throughout the simulation, it is computed the depth-time Hovmöller diagrams of global mean ocean temperature and salinity departures from their respective initial conditions (Fig. 13). Here initial conditional means the value of the first year of simulation, in this case, the year 1850. The prominent warming occurs from the surface up to 400 m depth (Fig. 13a). This warming is more significant at the end of the simulation (~0.6 ℃ comparing with initial conditions) and is likely to be related to the global warming of the planet and consequential increasing heat flux from the atmosphere into the ocean. In deeper waters, from 1500 m up to the ocean floor, there is a weaker warming, indicating that the ocean is gaining heat mainly in the upper layers. Between 500-1500 m depth, it is observed a cooling tendency respective to initial conditions. The ocean salinity slightly increases below 1000 m depth and from 1935 the increase reaches 0.04 PSU between 1500 and 3000 m depth compared with the initial values (Fig. 13b). Above 1000 m depth there is a significant freshening of the ocean waters, with the surface waters salinity decreasing up to 0.18 PSU at the end of the simulation. Such tendency can mean that the ocean is still drifting from its initial conditions in the Historical simulation." has been replaced by "To evaluate how the global ocean profile evolves throughout the simulation, depth-time Hovmöller diagrams of global mean ocean salinity and temperature departures from their respective initial conditions were calculated (Fig. 13a and 13b) in the historical simulation. Here, "initial condition" indicates the value of the first year of the simulation, in this case, 1850. The ocean salinity slightly increased below a depth of 1000 m and from 1935 on, the increase reached 0.04 PSU between depths of 1500 and 3000 m compared with the initial values (Fig. 13a). Above a depth of 1000 m, there was a significant freshening of the ocean waters, with the surface water salinity decreasing up to 0.18 PSU by the end of the simulation. Concerning ocean temperature, prominent warming occurred from the surface up to a depth of 400 m (Fig. 13b). This warming was more significant at the end of the simulation (~0.6 ℃ compared with the initial conditions) and was mostly caused by the ocean warming drift in the model. Fig. 13c shows the same diagram for a piControl simulation (during the period in which both simulations were performed in parallel), which also shows the ocean drift feature. However, the ocean temperature anomalies above 600 m reach approximately 0.6 ℃ in the historical simulation, whereas they only reached approximately 0.4 ℃ in the piControl. This difference of 0.2 ℃ between the two simulations is likely due to the global warming of the planet and consequential increasing heat flux from the atmosphere into the ocean (Fig. 13d). In deeper waters, from 1500 m down to the ocean floor, there was weaker warming, indicating that the ocean is gaining heat mainly in its upper layers (Fig. 13b). Between the depths of 500−1500 m, a cooling tendency was observed relative to the initial conditions. Such a tendency could indicate that the ocean is still drifting from its initial conditions in the historical simulation."

- Page 22, Line 20

Based on the fourth comment of the reviewer #2 the following text: "The AMOC in the BESM-OA2.5 historical experiment has the typical structure described in Lumpkin and Speer (2007), with the main layers well depicted in the appropriated depths (Figure 14a)." has been replaced by "The AMOC in the BESM-OA2.5 historical experiment showed the typical structure described in Lumpkin and Speer (2007), with the upper layer of the upper cell, which is the northward flux, depicted at the appropriate depth, from the surface down to ~1000 m (Fig. 14a). However, the upper cell simulated by BESM-OA2.5 was too shallow compared with the RAPID measurements (McCarthy et al., 2015). The depth of the upper cell was 2500 m in the model, whereas the measurements show its depth at ~4500 m. This shallow upper cell of the AMOC is a common feature of state-of-the-art climate models (see Menary et al., 2018). In the deep ocean, the model accurately simulated the Antarctic Bottom Water flowing northwards over the Atlantic Ocean floor."

- Page 24, Line 1

Based on the comment 3.3 of the reviewer #2 the following text has been included: "Figure 15 shows the mean sea ice concentration simulated by BESM-OA2.5 for the end of the winter and the summer seasons for each hemisphere over the period 1971−2000. The thick black lines represent the 15 % climatological values for the period 1971−2000 given by the 20CRv2 Reanalysis. The sea ice concentration at the end of the Arctic winter was overestimated in the Atlantic, specifically north of Scandinavia (Fig. 15a). However, at the end the Arctic summer, the sea ice concentration was underestimated (Fig. 15b). At the end of the Antarctic summer, the model showed a significant underestimation of the sea ice concentration (Fig. 15c), whereas at the end of the Antarctic winter, the model generally overestimated the extension of the sea ice concentration over the Southern Ocean (Fig. 15d). Such seasonal sea ice concentration variations are likely related to the radiative net bias inherent in the model at high latitudes, which results in the generation of higher sea ice extensions during the winter season in each hemisphere compared with those from the Reanalysis dataset and excessive sea ice melting during the summer season in each hemisphere."

- Page 40, Line 20

It has been included the following text: "Author contributions SFV conducted the analyses and wrote the manuscript, under the supervision of PN. PN, EG, VC, MBJ, ALM, SNF, JPB, PK worked in the development of the new version of the model. VC and MBJ conducted the experiments. All the authors contributed the revision of the manuscript."

- Page 41, Line 9

It has been included the following text: "MBJ is supported by a grant funded by FAPESP (2018/06204-0)."

- Page 43, Line 7

It has been deleted the following reference: "Anthes, R. A.: A Cumulus Parameterization Scheme Utilizing a One-Dimensional Cloud Model, Mon. Weather Rev., 105(3), 270–286, doi:10.1175/1520-0493(1977)105<0270:ACPSUA>2.0.CO;2, 1977." Through a review of the atmospheric model, it has been concluded that the reference is not appropriated.

- Page 43, Line 14

It has been deleted the following reference: "Arakawa, A. and Schubert, W. H.: Interaction of a Cumulus Cloud Ensemble with the Large-Scale Environment, Part I, J. Atmos. Sci., 31(3), 674–701, doi:10.1175/1520-0469(1974)031<0674:IOACCE>2.0.CO;2, 1974." Through a review of the atmospheric model, it has been concluded that the reference is not appropriated.

- Page 50, Line 24

It has been included the following reference: "Menary, M. B., Kuhlbrodt, T., Ridley, J., Andrews, M. B., Dimdore-Miles, O. B., Deshayes, J. et al.: Preindustrial control simulations with HadGEM3-GC3.1 for CMIP6., J. Adv. Model. Earth Syst., 10, 3049–3075, doi:https://doi.org/10.1029/2018MS001495, 2018." It has been suggested by reviewer #2.

- Page 54, Line 5

It has been included the following reference: "Tarasova, T. A. and Fomin, B. A.: Solar Radiation Absorption due to Water Vapor: Advanced Broadband Parameterizations, J. Appl. Meteorol., 39(11), 1947–1951, doi:10.1175/1520-0450(2000)039<1947:SRADTW>2.0.CO;2, 2000." Through a review of the atmospheric model, it has been concluded that the reference is the correct one.

- Page 54, Line 8

It has been deleted the following reference: “Tarasova, T. A., Barbosa, H. M. J. and Figueroa, S. N.: In- corporation of new solar radiation scheme into CPTECGCM. Instituto Nacional de Pesquisas Espaciais Tech. Rep. INPE-14052-NTE/371, 44 pp. [Available online at http://mtc-m15. sid.inpe.br/col/sid.inpe.br/iris%401915/2006/01.16.10.40/doc/publicacao.pdf, 2006.” Through a review of the atmospheric model, it has been concluded that the reference is not appropriated.

- Page 55, Line 14

It has been included the following reference: “Webster, S., Brown, A. R., Cameron, D. R. and P.Jones, C.: Improvements to the representation of orography in the Met Office Unified Model, Q. J. R. Meteorol. Soc., 129(591), 1989–2010, doi:10.1256/qj.02.133, 2003.” Through a review of the atmospheric model, it has been concluded that the reference is the correct one.

- Page 58

Figure 1 has been improved. The revised figure shows the 100 years of coupled spin-up run. Based on the second comment of the reviewer #2.

- Page 74

Figure 13 has been improved. It has been suggested by reviewer #2 (comment 1).

- Page 75, Line 1

"Depth-time Hovmöller diagrams of global average ocean temperature and salinity anomalies from the respective initial conditions (IC). Here the initial conditions are taken from the 1th year. The diagrams are based on annual average time series simulated by the Historical simulation over the period 1850-2005 (156 years). The thick black line represents the zero contours. Note that the vertical scales are different above and below 1000 m." has been replaced by "Depth-time Hovmöller diagrams of the global average ocean (a) salinity and (b) temperature anomalies from the respective initial conditions (IC). Here, the initial conditions were taken from the first year for (a, b) historical simulation and from the 14th year for the (c) piControl simulation. The map shown in (d) presents the difference between the temperature anomalies of the historical simulation relative to the piControl. The diagrams are based on annual average time series simulated by the historical simulation over the period 1850–2005 (156 years) and by the piControl simulation over the period 14–169 years (156 years). The thick black line represents the zero contours. Note that the vertical scales are different above and below 1000 m."

- Page 78

A new figure has been included (Figure 15). It has been suggested by reviewer #1 (comment 3.3).

- Page 78, Line 3

It has been included the following text: "BESM-OA2.5 mean sea ice concentrations for March (a, c) and September (b, d) for each hemisphere. The solid black lines show the 15 % mean sea ice concentration from the 20CRv2 Reanalysis. The average values were computed over the period 1971–2000 for BESM-OA2.5 and 20CRv2. The concentrations are presented as percentages."