Response to Review of "Description and basic evaluation of BNU-ESM version 1" ***by*** **D. Ji et al.**

We first thank the reviewer for his/her insightful comments, which helped us clarify and greatly improve the paper. Comments from the reviewer are in black, and our responses are in blue.

General comments:

In this manuscript the authors document the Beijing Normal University Earth System Model and its climate simulation performance. The model consists of components adopted from various modeling centers in the world, with a number of modifications. The simulations of the climate mean and temporal variability from intraseasonal, annual, interannual to decadal scales demonstrate that the model performs reasonably well. The major problems that exist in other models also appear in this model, including double ITCZ, weak MJO and warm SST biases in the eastern part of the oceans. Putting together a comprehensive model, even with existing model components, is a tremendous effort. The BNU-ESM is a participant of the CMIP5 project, and its simulations have been examined in a number of studies as referenced in the manuscript. Thus, it is very useful for the global modeling and climate change communities to have a thoroughly documented reference in the literature. This study is timely for this purpose, and is suitable for publication in GMD. The paper is well organized and well written. I suggest publication with minor revision.

Minor comments:

1. I suggest using the full name of the model in the title, i.e., change "BNU-ESM" to "Beijing Normal University Earth System Model".

Agree. We will change the title to "Description and basic evaluation of Beijing Normal University Earth System Model (BNU-ESM) version 1" in the final revised paper.

2. I suggest adding the climatological mean fields from observations in Figs. 3 and 4. This will give a better sense of the model simulation performance.

Agree. Student t-test was also performed to show the significance of the SST and precipitation bias according to the minor comment 8 and 9 from reviewer#2. The following are revised figures:

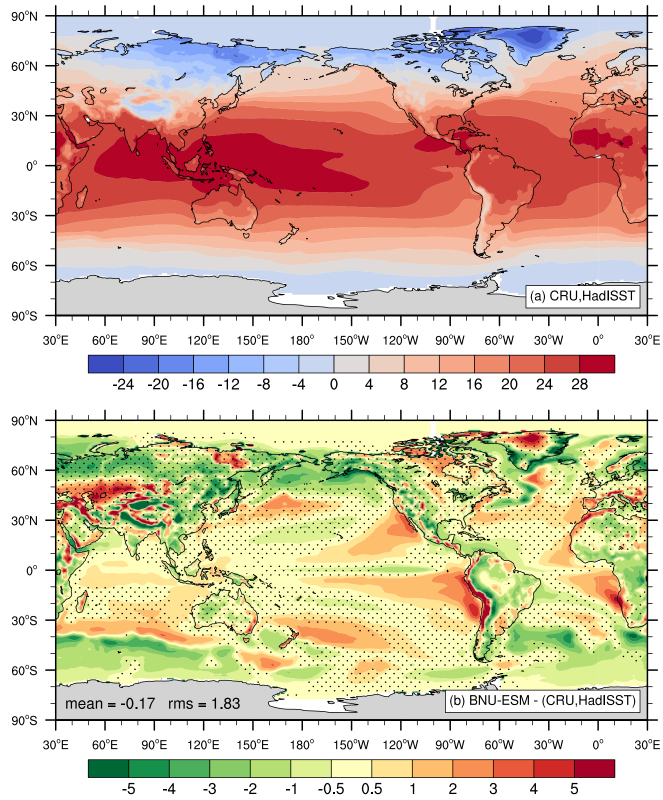

Figure 3. Climatological mean surface temperature from the 0.5°×0.5° CRU TS 3.1 (Harris et al., 2013) and 1°×1° HadISST (Rayner et al., 2003) observations (a) for the period 1976-2005. Annual mean surface temperature bias (°C) of BNU-ESM relative to the CRU TS 3.1 and HadISST data sets for the period 1976-2005 (b). All data sets are regridded to 1°×1° resolution. Dotted area indicates non-significant regions at the 95% confidence level.

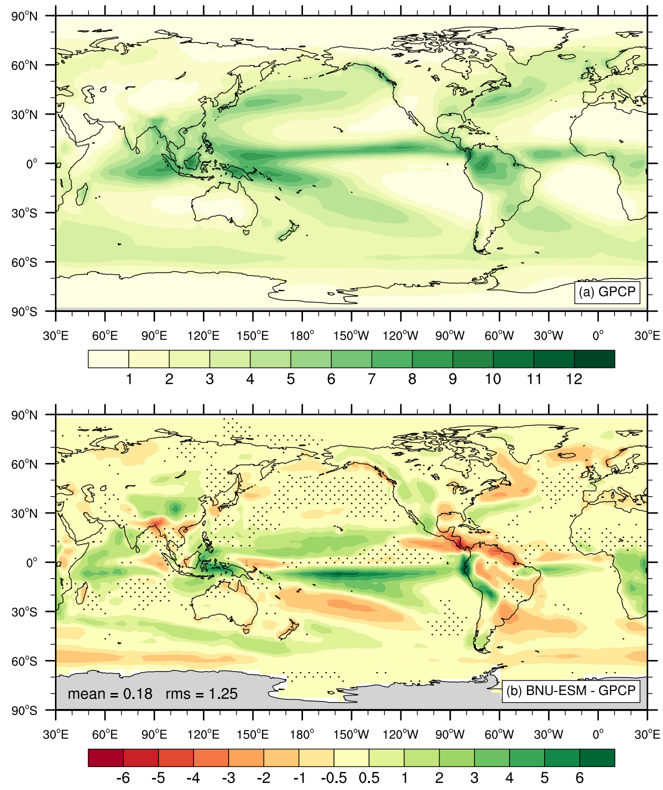

Figure 4. Climatological mean precipitation from the GPCP observations (a) and annual mean precipitation bias (mm/day) of BNU-ESM relative to the GPCP climatology for the period 1979-2005 (b). Dotted area indicates non-significant regions at the 95% confidence level.

3. The simulations of basic fields such as temperature, specific humidity, circulation and clouds are an important metric for GCMs. I suggest that the authors add a sub-section 4.2, which describes the zonal mean T, q, zonal wind from reanalysis and deviations from that of the model simulation (height-latitude cross section), and global distribution of cloud fraction compared with some observational products.

Agree. The following sub-section will be added in the final revised paper to describe the mean atmospheric state and its deviations from reanalysis:

Figure R1 shows the zonally averaged mean atmospheric temperature, zonal wind and specific humidity for the *historical* simulation of the BNU-ESM and its deviations from the ERA-Interim reanalysis (Dee et al., 2011). The air temperature in the troposphere is in general cold for both boreal summer and winter, especially during the boreal summer (Fig. R1a). Near the polar tropopause (about 250 hPa) there is a relatively large cold bias up to 8 K over the Arctic during JJA, and up to 10 K over the Antarctica during DJF. This tropospheric cold bias is one common problem in many CMIP5 models (Charlton-Perez et al., 2013; Tian et al., 2013). In the lower polar troposphere during JJA, there is a notable cold bias over the Antarctic. In the stratosphere, the very low winter temperature at 50 hPa in the Southern Hemisphere associated with the polar night jet is overestimated in the model.

With respect to zonally averaged winds (Fig. R1b), the seasonal mitigation of the northern tropospheric jet is well captured in the simulation, but the westerlies at 200 hPa in this jet are too strong by up to 4 m/s during DJF and 8 m/s during JJA compared with ERA-Interim reanalysis. The southern tropospheric jet during DJF is also too strong by up to 12 m/s. While the westerlies from the surface to about 100 hPa at 60° S during DJF are weak relative to the reanalysis. The westerly wind maximum in the Southern Hemisphere during JJA extends upward into the stratosphere at higher latitudes as is observed. In the stratosphere, the polar-night jets in both hemispheres are shifted slightly polewards relative to the reanalysis. Over the equator in the upper tropopause the model overestimates the easterly velocities, the largest biases occur at roughly 50 hPa.

Fig. R1c shows the modeled zonally averaged specific humidity and their differences relative to the ERA-Interim reanalysis shown as percentages because the relative error provides a better measure of the water vapor's impact on the radiative transfer than does the absolute errors (Soden et al., 2005). The model can simulate the strong meridional and vertical gradients in tropospheric specific humidity that decrease with both latitude and altitude. For example, the specific humidity decreases from around 14 g/kg at 1000 hPa near the equator to around 1 g/kg at 1000 hPa near the poles and around 0.5 g/kg at 300 hPa over the equator. In comparison with ERA-Interim reanalysis, the model has a moist tendency in the southern tropical upper troposphere (above 700 hPa) and a slightly dry tendency in the tropical lower troposphere. In terms of relative difference, the model's dry bias in the tropical lower troposphere approaches 15%, and the wet bias in the tropical upper troposphere approaches 50%. This humidity bias pattern is also presented in many CMIP5 models (Tian et al., 2013).

Clouds are always a major source of uncertainty in climate models. In BNU-ESM the total cloud fraction is generally underestimated (Fig. R2a), the global mean value for the years 1976-2005 of the *historical* simulation gives a bias of -14% with a RMSE of 18% compared with the ISCCP observational dataset. A notable exception is Antarctica where there are too many clouds. The tropical central eastern Pacific and southern Africa also have more clouds than observations. The latitudinal averaged cloud fraction bias within the tropics and subtropics is much lower than at higher latitudes (Fig. R2b), and is similar to results from the original CAM3.5 and CAM4 at $2^{o}\times 2^{o}$ degree horizontal resolution (Neale et al., 2013). At the same time, the liquid water in clouds over ocean is generally exaggerated in the simulation (Fig. R2c), and is particularly pronounced in the extratropical storm track regions.

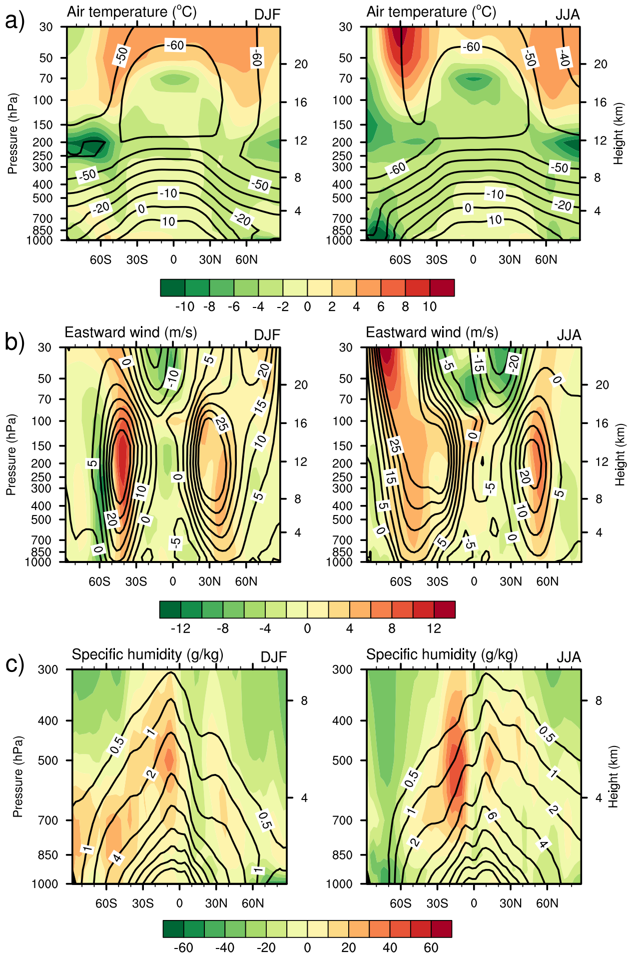

Figure R1. Zonally averaged air temperature (a), zonal wind (b) and specific humidity (c) climatology from BNU-ESM *historical* simulation (black contours) and bias relative to the ERA-Interim climatology (color filled, color bar is of same units except as % for specific humidity) for 1986-2005.

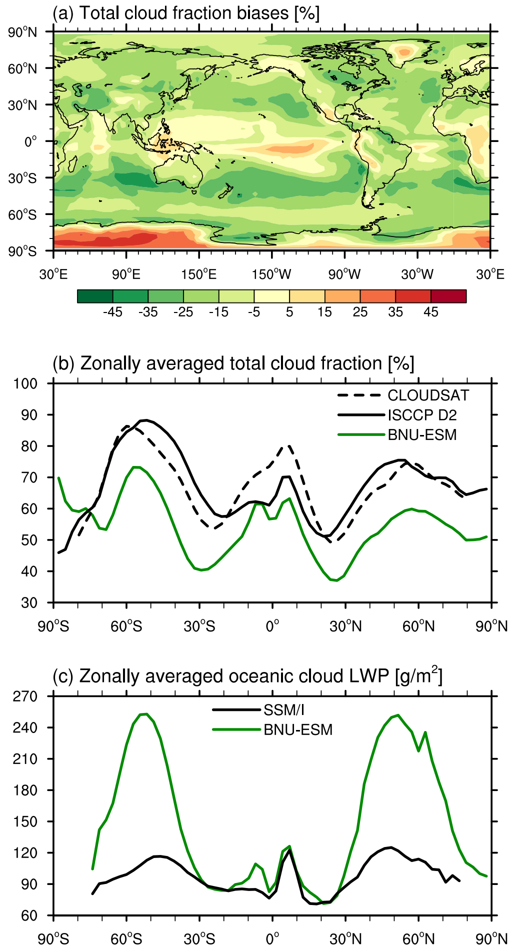

Figure R2. (a) Total cloud fraction bias relative to ISCCP D2 retrievals (Rossow and Schiffer, 1999; Rossow and Dueñas, 2004). (b) Zonally averaged total cloud fraction compared with ISCCP D2 retrievals and CLOUDSAT retrievals (L'Ecuyer et al., 2008.) (c) Zonally averaged total liquid water path (LWP) compared with SSM/I retrievals (Wentz, 2000, 2013) over oceans.

4. P. 3, L2. Change "much cooperation" to "collaboration".

Agree.

"…with much cooperation from several model development centers in China…"

Revised to:

"…with collaboration from several model development centers in China…".

5. P. 4, L3. Add "Zhang, 2002;" after "Zhang and McFarlane, 1995;"

Agree.

"…with a revised Zhang-McFarlance deep convection scheme (Zhang and McFarlane, 1995; Zhang and Mu, 2005a)."

Revised to:

"…with a revised Zhang-McFarlance deep convection scheme (Zhang and McFarlane, 1995; Zhang, 2002; Zhang and Mu, 2005a)."

6. P. 4, L21-22. Add "Data for" before "all" and change "published" to "stored".

Agree.

"All CMIP5 and GeoMIP simulations completed by BNU-ESM have been published on an Earth System Grid Data Node…"

Revised to:

"Data for all CMIP5 and GeoMIP simulations completed by BNU-ESM have been stored on an Earth System Grid Data Node…".

7. P. 7, L9. Replace the reference "Zhang and McFarlane, 1995" by "Zhang, 2002". Zhang (2002, JGR) first modified the Zhang-McFarlane scheme.

Agree. We will replace this reference.

8. P. 8, L22. Add "," after "that is". L24, change "a little" to "slightly".

Agree.

"…in which the penetrating solar radiation is equal to zero for snow-covered ice, that is most of the incoming sunlight is absorbed near the top surface. The visible and near infrared albedos for thick ice and cold snow are set to 0.77, 0.35, 0.96 and 0.69 respectively, a little smaller than the…"

Revised to:

"…in which the penetrating solar radiation is equal to zero for snow-covered ice, that is, most of the incoming sunlight is absorbed near the top surface. The visible and near infrared albedos for thick ice and cold snow are set to 0.77, 0.35, 0.96 and 0.69 respectively, slightly smaller than the…".

9. P. 11, L2. Add "is" after "there".

This should be at P. 12, L2.

"Note that there no land cover change related to (anthropogenic) land use…"

Revised to:

"Note that there is no land cover change related to (anthropogenic) land use…"

10. P. 13, L15. Change “coast” to “coastal”.

Agree.

“probably due to coast winds that are not favorable for…”

Revised to:

“probably due to coastal winds that are not favorable for…”

11. P. 13, L19. Add “Oceans” after “Pacific”.

Agree.

“Negative SST biases are mainly found in South Atlantic, South Indian, and subpolar North Pacific.”

Revised to:

“Negative SST biases are mainly found in South Atlantic, South Indian, and subpolar North Pacific Oceans.”

12. P. 16, L20. Change “averaged” to “average”. L21, delete “anomalously”.

Agree. We also compared the surface wind stress with another reanalysis according to reviewer 2 minor comment 14.

“One notable bias is that the annual averaged zonal wind stress from about 35°S to 55°S latitudes over ocean is 42.8% anomalously stronger compared with NCEP reanalysis products…”

Revised to:

“One notable bias is that the annual average zonal wind stress from about 35°S to 55°S latitudes over ocean is 23.2% stronger compared with ERA-Interim reanalysis and 42.8% stronger compared with NCEP reanalysis…”

13. P. 17, L10. Delete “to” after “reach”.

Agree.

“North Atlantic deep-water circulation can reach to most of the ocean bottom between 30°N and 60°N.”

Revised to:

“North Atlantic deep-water circulation can reach most of the ocean bottom between 30°N and 60°N.”

14. P. 19, L1. Change “demonstrated in the simulation;” to “simulated,”

Agree.

“Meanwhile, the northward propagation in summer can be realistically demonstrated in the simulation;”

Revised to:

“Meanwhile, the northward propagation in summer can be realistically simulated;”

15. P19, L14-16. “While. . .40 days.” This is not a complete sentence. One way to change it is to combine it with the preceding sentence: As with BNU-ESM. . .(Kim et al. 2009), while . . .

Agree and thanks.

“As with BNU-ESM, the power spectra maximum produced by CCSM3.5 using its default convection parameterization is also greater than 80 days (Kim et al., 2009). While spectra computed by Zhang and Mu (2005b) for CCM3 adopting the same convection parameterization scheme as BNU-ESM, peaks at approximately 40 days.”

Revised to:

“As with BNU-ESM, the power spectra maximum produced by CCSM3.5 using its default convection parameterization is also greater than 80 days (Kim et al., 2009), while spectra computed by Zhang and Mu (2005b) for CCM3 adopting the same convection parameterization scheme as BNU-ESM peaks at approximately 40 days.”

16. P 19, L17. Suggest changing the sentence to “. . .climate model to simulate realistic MJO depends not only on its convective parameterization, but also on interactions between...” It’s incorrect to say it does not depend on convective parameterization because it DOES.

Agree and thanks.

“These studies suggest that the ability of a climate model to simulate realistic MJO does not depend simply on its convective parameterization, but likely depends upon interactions between convection and other physical processes in the model."

Revised to:

"These studies suggest that the ability of a climate model to simulate realistic MJO depends not only on its convective parameterization, but also on interactions between convection and other physical processes in the model."

17. P. 21, L10. Add "that" between "with" and "from".

Agree.

"…compared with from HadISST observations."

Revised to:

"…compared with that from HadISST observations."

18. P 25, L22. A model is not a diagnostic tool. You can change "diagnostic" to "modeling".

Agree.

"BNU-ESM has proven to be a useful diagnostic tool…"

Revised to:

"BNU-ESM has proven to be a useful modeling tool…"

References:

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Wentz, F. J.: "SSM/I Version-7 Calibration Report", Remote Sensing Systems, Santa Rosa, CA. Available online at http://www.remss.com/papers/tech_reports/2012_Wentz_011012_Version-7_SSMI_Calibration.pdf (last access: May 2014), 2013.