Reply to Reviewer #2

Thank you very much for your interest in FGOALS-f3 and its simulation performance for tropical cyclones activities. Your valuable comments and suggestions have help us to improve the quality of manuscript, and we have learned a lot from your suggestions. The following is our point-by-point reply to your comments.

Comments:

This paper serves as documentation of the tropical cyclone activity simulated by the FGOALS-f3 models submitted to the HighResMIP subproject. While there is little unexpected in the comparison of low to high resolution models, it is important to have such individual model results in the literature. I recommend that it be sent to the authors for some fairly minor revisions that I describe in detail below.

1. **Section 3.1:** Figure 2. It is difficult to synthesize by eye the biases in figure 2. I would like to see either a bar chart figure or a table with observed and simulated TC counts both globally and by ocean basin.

   Thank you for your valuable suggestion. We have added a table (Table 4) showing the observed and simulated tropical cyclone counts, both globally and by ocean basin.

Table 4. Observed and simulated average tropical cyclone number, both globally and by ocean basin, in the northern Indian (NI), western Pacific (WP), eastern Pacific (EP), northern Atlantic (NA), southern Indian Ocean (SI), southern Pacific (SP) and southern Atlantic (SA) oceans.

Data source	Global	NI	WP	EP	NA	SI	SP	SA
IBTrACS	82.67	4.05	26.24	15.00	13.85	14.25	9.14	0.14
FGOALS-f3-L	53.14	1.98	25.04	3.96	7.54	7.34	6.83	0.45
FGOALS-f3-H	67.72	3.25	27.46	10.00	11.83	8.63	6.09	0.46

2. **Figure 4.** Please note that the bias in the min pressure/max wind speed is worse in the North Atlantic than in the western Pacific in the high-resolution model. Why is this?

Thank you for your question. As shown in Figure 4, the bias in tropical cyclone intensities in the NA are greater than those in the WP. We did not tune the model for specific regions. However, to comply with the HighResMIP rule “The experimental set-up and design of the standard resolution experiments will be exactly the same as for the high-resolution runs”, we tried to keep the model setting consistent when the horizontal resolution was increased from 100 to 25 km. It is possible that the strong tropical cyclone event in the NA is still not well resolved at 25 km resolution in FGOALS-f3. There was still a negative bias in the tropical cyclone count in the NA when the horizontal resolution increased from 100 to 25 km. Another possible reason is related to the Resolving Convective Precipitation (RCP) scheme (Bao and Li, 2020) used in FGOALS-f3. The RCP scheme calculates convective and stratiform precipitation at the grid scale, which is clearly different from the traditional convective parameterization. Current studies indicate that the sub-grid parameterization in convective schemes is sensitive to the simulated intensities of tropical cyclones even when the horizontal resolution of GCMs is increased to 25 km (Murakami et al., 2012; Lim et al., 2015). We think that FGOALS-f3 with the RCP scheme does not give the best performance at 25 km and it is worth increasing the horizontal resolution (e.g., 1/8°) to verify this assumption.

References:

Bao, Q. and Li, J.: Progress in climate modeling of precipitation over the Tibetan Plateau, Natl. Sci. Rev., 7, 486-487, https://doi.org/10.1093/nsr/nwaa006, 2020.

Murakami H, Wang Y, Yoshimura H, et al. Future changes in tropical cyclone activity projected by the new high-resolution MRI-AGCM. Journal of Climate, 2012, 25(9): 3237-3260.

Lim Y K, Schubert S D, Reale O, et al. Sensitivity of tropical cyclones to parameterized convection in the NASA GEOS-5 model[J]. Journal of Climate, 2015, 28(2): 551-573.

3. **Lines213-215**: "Neither the single peak in the number of tropical cyclones in the northern Atlantic (peak month September), eastern Pacific (peak month August) and southern Pacific (peak month February) oceans nor the double peak in the northern Indian Ocean (peak months May and November) could be reproduced in FGOALS-f3-L." I don't think this is actually correct, although the low-resolution model does not produce the magnitude of these peaks, it does appear to replicate the timing of the seasonal cycle. This would be more apparent by normalizing figure 6 by the number of storms per basin. Admittedly, the Southern Pacific does appear to be delayed.

   Thank for your valuable suggestion. We agree with your view about the seasonal cycle of the tropical cyclone number. Although FGOALS-f3-H generates more tropical cyclone counts in each basin, FGOALS-f3-L replicates the timing of the seasonal cycle. The seasonal cycle with normalized tropical cyclone counts is a good method by which to compare the simulation of the seasonal cycle of tropical cyclones between FGOALS-f3-L and FGOALS-f3-H. So, as suggested, we have added a figure in the supplementary material to show the normalized seasonal cycle of tropical cyclones in each basin. We have added the sentence as "Although FGOALS-f3-H can produce more tropical cyclone counts in the peak month in each basin, both FGOALS-f3-L and FGOALS-f3-H appeared to replicate the timing of the seasonal cycle when we normalized the results of the tropical cyclone seasonal cycle (Figure S1)" at lines 233–235.

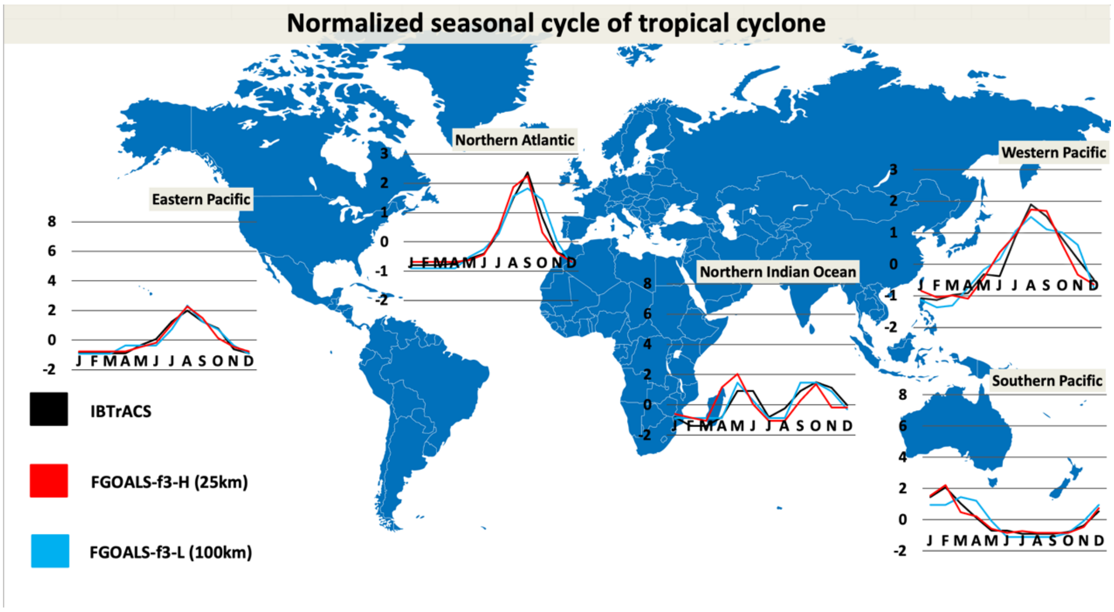

Figure S1. Seasonal cycle of tropical cyclones with zero-mean normalization in the western Pacific, southern Pacific, northern Indian, northern Atlantic and eastern Pacific oceans (units: number of cyclones) during the time period 1991–2014.

4. **Lines 226-229:** It is a bit of a stretch to claim that the interannual correlation of ACE is improved with resolution in WP and NA as the differences are very small in figure 9. In fact, given that the correlation in interannual counts changes a fair amount in figure 8, one might expect that the ACE correlation should change even more, given the dependence on the square of peak wind speed and the differences in that field between resolutions. A more interesting quantity might be simply the average ACE per basin.

The average accumulated cyclone energy (ACE) is an interesting quantity with which to compare the intensity of tropical cyclones in each basin. As suggested, we have added a table (Table 5) to show the average ACE between the observations and simulations.

Table 5. Observed and simulated averaged ACE (units: 104 kt) in the northern Indian (NI), western Pacific, eastern Pacific, northern Atlantic (NA), southern Indian (SI), southern Pacific (SP) and southern Atlantic (SA) oceans.

Data source	NI	WP	EP	NA	SP
IBTrACS	24.21	258.75	137.42	133.13	67.58

FGOALS-f3-L	12.13	170.47	7.83	69.38	60.30
FGOALS-f3-H	32.08	247.66	43.66	89.10	61.21

5. **Section 3.3:** Grammar. Instead of "The extreme position of precipitation", you mean "The position of extreme precipitation". Figure 9 is quite interesting. It may be clearer to express the bias in terms of an angle and radial distance. It does appear that the radial distance is quite good. Any thoughts on the error in angle? Also, the diameter of the eye would appear to be only one or two grid cells. It should be mentioned that although an eyewall is present, it is not resolved at this resolution

Thank you for your correction. "The position of extreme precipitation" is the correct meaning and we have changed this sentence from "The extreme position of precipitation" to "The position of extreme precipitation" at line 255. Chen et al. (2006) found that the vertical wind shear and storm motion are the two most important factors contributing to asymmetries in rainfall in tropical cyclones. We therefore think the error in the angle is due to the biases in the wind shear and storm motion when the intensity of the tropical cyclone reaches a maximum in FGOALS-f3. The non-hydrostatic dynamical core used in FGOALS-f3 and the limited air–sea coupling processes (Kim et al., 2018) (AMIP) also contribute to this error. We have therefore modified the statement at lines 262–266 to "Chen et al. (2006) found that the vertical wind shear and storm motion are the two most important factors contributing to rainfall asymmetries in tropical cyclones. The biases in the vertical wind shear and storm motion in FGOALS-f3 may affect the angle of the horizontal structure of tropical cyclones. The non-hydrostatic dynamical core used in FGOALS-f3 and the limited air–sea coupling processes (Emanuel et al., 2013; Kim et al., 2018) (AMIP) also contribute to the error".

References:

Chen, Shuyi S., John A. Knaff, and Frank D. Marks Jr. "Effects of vertical wind shear and storm motion on tropical cyclone rainfall asymmetries deduced from TRMM." Monthly Weather Review, 2006, 134.11: 3190-3208.

Kim D, Ho C H, Park D S R, et al. The relationship between tropical cyclone rainfall area and environmental conditions over the subtropical oceans. Journal of Climate, 2018, 31(12): 4605-4616

Emanuel, K., and Sobel, A. Response of tropical sea surface temperature, precipitation, and tropical cyclone-related variables to changes in global and local forcing, Journal of Advances in Modeling Earth Systems, 2013, 5(2), 447-458.

6. **Section 4:** In my view, the biggest source of difference between TC activity in the two models comes from the storm tracker. Despite the threshold adjustment table 3 (which is quite small), the trackers such as used here (or in TempestExtremes) are generally going to miss the weak storms in the low-resolution models. Trackers such as TRACK show much higher storm counts in low resolution models (see Roberts et al.). So, while the improvements in MJO and GPI are interesting, it is hard to claim that they are responsible for the higher TC counts when there is such a strong dependence on the choice of storm tracker. You may consider shortening these sections.

   Thank you for your valuable suggestion. Although we examined the sensitivity of thresholds in our tracker, which is not very sensitive to the threshold of wind speed and vorticity, we did not take into account the biases of different trackers (e.g., TempestExtremes, TRACK and TSTORM). It is a good idea to reduce the uncertainty in the recognition of tropical cyclones in GCMs. The work of Roberts et al. (2020a; 2020b) is outstanding in revealing the errors caused by different methods in the simulation and projection of tropical cyclones. As suggested, we have added a discussion about the different trackers at lines 336–339: “However, the difference between the tracking algorithms—such as TRACK (Hodges et al., 2017), TSTORM (Zhao et al., 2009) and TempestExtremes (Ullrich et al., 2017, 2021)—are also an important factor in the uncertainties in tropical cyclone simulations. Cross-validation of the performance of tropical cyclone simulations with multiple tracking algorithms is necessary in future research (Roberts et al., 2020)”. We agree with your suggestion that the GPI and MJO are not unique, dominant factors. We have therefore rewritten these sections of the paper.

References:

Hodges, Kevin, Alison Cobb, and Pier Luigi Vidale. "How well are tropical cyclones represented in reanalysis datasets?." Journal of Climate 30.14 (2017): 5243-5264.

Roberts, Malcolm John, et al. "Projected future changes in tropical cyclones using the CMIP6 HighResMIP multimodel ensemble." Geophysical research letters 47.14 (2020a): e2020GL088662.

Roberts, Malcolm John, et al. "Impact of model resolution on tropical cyclone simulation using the HighResMIP–PRIMAVERA multimodel ensemble." Journal of Climate 33.7 (2020b): 2557-2583.