Response to Comment on “Impact of Shifting Patterns of Pacific Ocean Warming on North Atlantic Tropical Cyclones“

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Abstract

The comments by Lee et al. (2009) on Kim et al. (2009) are not germane to the basic issues discussed in our study. The comparisons use different metrics, accrue statistics for different regions in the North Atlantic for different time periods in the annual cycle. Furthermore, their experiments match poorly both observations and other experiments.

Lee et al. (hereafter, LWE) raise two critiques of Kim et al. (*1*, hereafter, KWC09): (i) of the 5 CPW years reported in KWC09, only 1969 has significantly greater-than-average TC activity, (ii) the shifting pattern of tropical Pacific SST forcing has no coherent influence on the Atlantic Basin atmospheric circulation. With respect to point (i), LWE use a different region, different periods and different metrics in their comparisons. With respect to point (ii), which they support with model experiments, we obtain different results from our own numerical experiments that show considerable and consistent changes to the Atlantic circulation. Overall, the comments made by LWE are not particularly applicable to KWC09.

(i) <u>Phenomenon, domain, period and metric choice</u>: While KWC09 focused on the comparison between Central Pacific Warming (CPW) and East Pacific Warming (EPW), LWE compare TC activity differences between CPW and climatology. KWC09, in discussing differences in TC number between CPW and EPW, for the interpretation of TC frequency (Figure 2 in KWC09), noted that "*There is a clear difference between the number of cyclones forming during EPW and EPC events, as noted earlier (ref), but there is almost as large a difference between the EPW and CPW events. The Accumulated Cyclone Energy also shows the overall cyclone activity is larger in CPW events than EPW events (as shown in supplementary information)*" and "*We have shown that there are significant differences between the frequency and tracks of cyclones during EPW compared to CPW events*". LWE, on the other hand, compare number of TCs and ACE during CPW compared with climatology (LWE, Table 1) rather than a comparison with EPW. They also discuss the number of hurricanes and major hurricanes which are not mentioned in KWC09 at all.

LWE concentrates on different regions from our study. KWC09 showed above-average track density across the Caribbean, the Gulf of Mexico and the east coast of the U.S. On the other hand, LWE calculate the cyclonic activity in the "Intra America Sea (IAS)" for each of the CPW years, and show only 1969 showing significant positive anomaly. We are confused with the definition of IAS and exactly how the storms are counted. Figure 1 below shows the observed track density anomaly for individual years that LWE deem an ‘insignificant’ increase. It is very clear that 2004 has a large positive anomaly that is even larger than 1969 across the Caribbean, the Gulf of Mexico. Clearly, there is some muddling between the statistics used by LWE and the location of TCs.

We believe that the main reason for the discrepancy between KWC09 and LWE is the large domain that is used for the IAS calculation. The domain (especially the Caribbean, 90ºW-60ºW and 10ºN-20ºN in LWE) includes the regions where KWC09 showed a *decreased* activity. Further, the LWE computes statistics for the June to November period compared to August to October in KWC09. While the additional 3 months used by LWE are not the active portion if TC season, it confuses the comparison between the two analyses.

(ii) Factors changing the large scale circulation: LWE argues that the TC activity in 1969 and 2004 is greatly influenced by the size of the Atlantic warm pool (AWP) and not by the remote SST forcing associated with a CPW. LWE perform numerical experiments in the tropical Pacific by prescribing the SST for two CPW years (1969 and 2004) that show large differences in atmospheric response. One of the CPW years (2004) resembles the pattern of the EPW year. However, absent from LWE are scientific explanations that support their conclusions. In KWC09 it was concluded that the atmospheric response over the Atlantic Basin is related to the shift of the Walker circulation associated with a westward location of the Pacific warming as occurs in a CPW. The impact of such a shifting pattern of topical SST on the change of Walker circulation and its global climate impact have been accepted in other recent studies (*2, 3, 4*). To understand the results of LWE’s experiments, we compare their simulation with observations. Observations show that the vertical wind shear has been reduced over the MDR both in 1969 and 2004 but this reduction is *not* replicated in their simulations.

As a further check, we have examined the sensitivity of zonal winds over the Atlantic to SST forcing in the tropical Pacific through series of numerical experiments performed by using the International Centre for Theoretical Physics (ICTP) AGCM (*5*). A description of the ICTP AGCM, as well as other recent applications, can be found in recent studies (*6*, *7*). In the control run (26 years), the model is forced by fixed monthly varying climatological SSTs. Sensitivity experiments are conducted by superimposing a SST heating anomaly as in KWC09 (Figure 1) on the climatological fields to replicate EPW, CPW and EPC periods. The SST anomalies are prescribed only in the tropical Pacific with climatological SST values used elsewhere. The vertical zonal wind shear anomalies for the three experiments are displayed in Figure 2. The three model experiments generally agree with the observed atmospheric response over the North Atlantic for CPW, EPW and EPC. In particular, the vertical shear anomaly with CPW forcing decreases over the MDR compared to EPW in a manner consistent with KWC09.

In summary, LWE make comparisons that are not germane to the basic issues listed in KWC09. The comparisons are for a different location using different metrics over uncommon periods. Their experiments do not relate to observations nor to our numerical experiments which are consistent with other studies.

References and Notes

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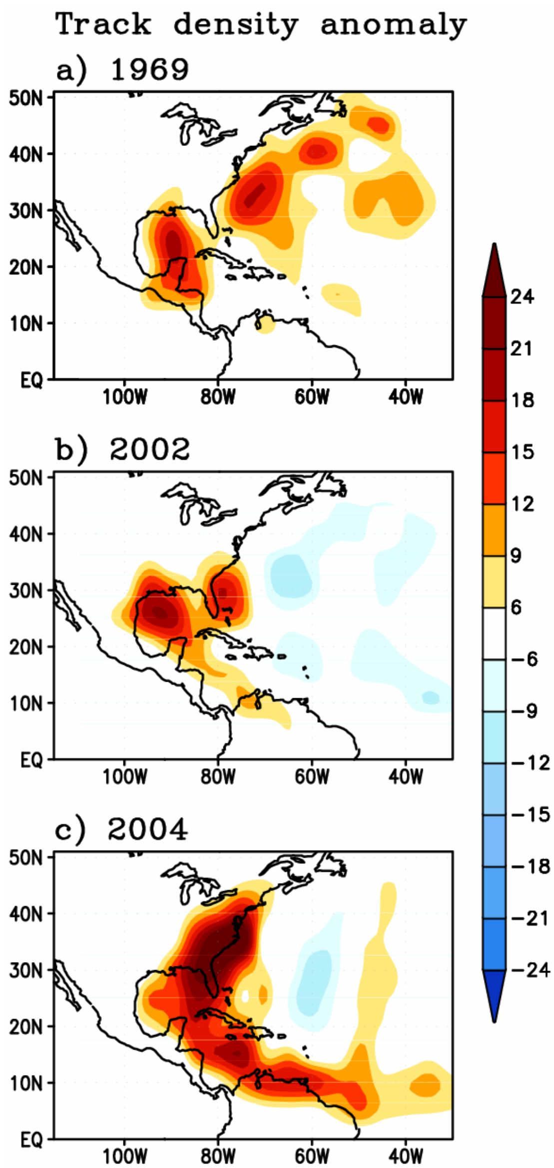
Figure Captions

Figure 1: Composites of track density anomaly (multiplied by 10) during the August-October period for CPW years; (a) 1969, (b) 2002, and (c) 2004.

Figure 2. Composites of simulated wind shear (difference in zonal wind speed between 200 and 850 hPa, m s^{-1}) anomalies during the August-October period for (a) EPW, (b) CPW, and (c) EPC experiment. The box shows the main development region of tropical cyclones.



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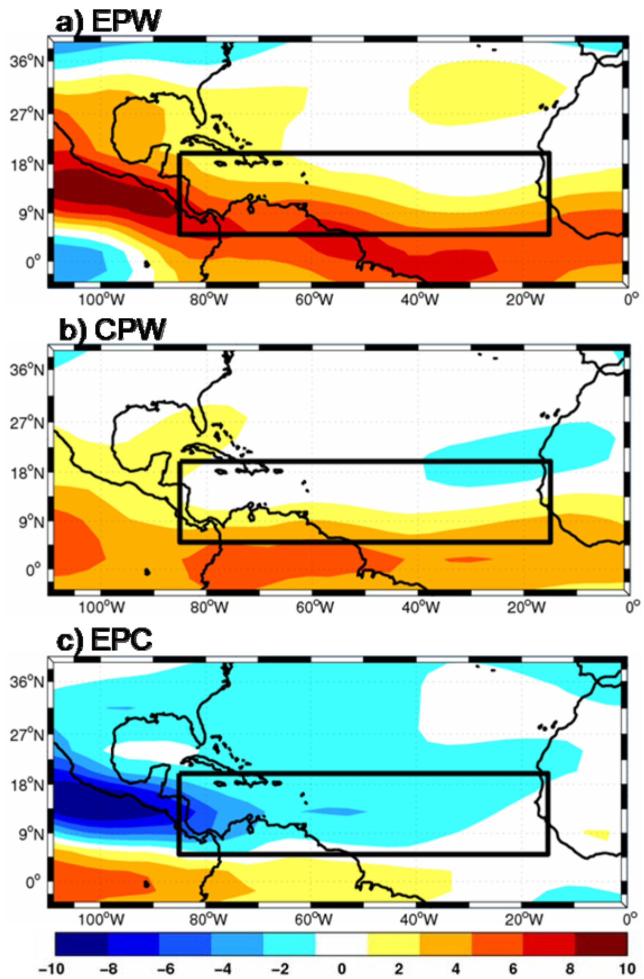

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