Supporting Information for

Roles of interbasin frequency changes in the poleward shifts of maximum intensity location of tropical cyclones

Il-Ju Moon¹, Sung-Hun Kim¹, Phil Klotzbach², and Johnny C. L. Chan³

¹Typhoon Research Center, Jeju National University, Jeju 690-756, Republic of Korea
²Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado 80523, USA
³Guy Carpenter Asia-Pacific Climate Impact Centre, School of Energy and Environment, City University of Hong Kong, Hong Kong

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S1. Data dependency and limitations

The present analysis has been done for TCs that are of at least tropical storm (TS) strength with maximum wind speeds (MWS) of more than 17 m s\(^{-1}\), which is different from KEV who includes tropical depressions (TD) with MWS of less than 17 m s\(^{-1}\) in their analysis of the global best track data. KEV also used a globally homogenized record of intensity taken from the Advanced Dvorak Technique Hurricane Satellite (ADT-HURSAT) data set, which is limited to only TCs with intensities of at least hurricane or typhoon strength (MWS of more than 33 m s\(^{-1}\), Kossin \textit{et al} 2013).

The estimated poleward trends and main factors contributing to the trends may be sensitive to the data and TC intensity used as the minimum threshold in the analysis. To test the sensitivity, the analyses of Fig. 1–3 are repeated using the best track data including TD as in KEV. The results reveal that the general patterns of the poleward trends and dominant factors contributing to the trends in each hemisphere are consistent with the present results, but the contribution of the pure migration contributions in the NH as well as the global trends considerably increased (see figure S1 and S2; table S1). When we include TDs in the analysis, the pure migration contribution increased from 8\% to 35\% in the NH and from 36\% to 51\% in the global trend, in which the contributions from the intrabasin pure migration are now comparable to those from the interbasin frequency change. These results are qualitatively consistent with those of KEV that included TDs in their analysis, although KEW more emphasized the contribution of the intrabasin poleward migration. However, it should be noticed that the impact of the interbasin frequency change on the poleward trends is still robust (with 99\% confidence; see Figure S2(f)) even though the use of a different TC data threshold yielded a significant increase in the contribution of the intrabasin poleward migration.

In general it is difficult to estimate the intensity of TDs mainly because TDs have no eye, do not typically have the organization or the spiral shape of more intense storms, and live for a short period (Kossin \textit{et al} 2013). For these reasons, the RSMC-Tokyo regional center under the World Meteorological Organization (WMO), which takes the responsibility of producing TC best tracks in the western North Pacific, does not provide intensity information for TDs. Therefore, it is prudent to exclude TDs in the present analysis due to accuracy issues, although the choice of the minimum threshold in TC intensity data is subjective (Landsea \textit{et al} 2010).
In the extended TC data going back to the 1950s before satellite imagery, the low latitude TCs over the open ocean might have been missed preferentially compared to higher latitude ones closer to the North American and Asian continents, as the latter would have been more completely observed. This may contribute to some of the trends toward lower latitudes of LMI positions from the 1950s to around 1980 in figure 5(d). However, considering that the limitations in TC observations could exist in both the NA and EP during the period, we cannot deny the possibility that the earlier equatorward trend of LMI position in figure 5(d) is real as a result of the clear long-term opposite trends of both TC frequency and VWS (a crucial index related to TC genesis) between the two basins (figure 5(c) and 5(d)).

Additional references:
Kossin J P, Olander T L, and Knapp K R 2013 Trend analysis with a new global record of tropical cyclone intensity J. Clim. 26 9960–9976
Landsea C W, Vecchi G A, Bengtsson L and Knutson T R 2010 Impact of duration thresholds on Atlantic tropical cyclone counts J. Clim. 23 2508–2519
Figure S1. (a), (b), (c), As in figure 1. (d), (e), (f), As in figure 3. G, H, I, As in figure 4, but including tropical depressions. Poleward migration of the LMI latitude away from the equator (a, b, c), comparisons between frequency contribution and pure migration contribution in the shifting trend of LMI latitude towards the poles (d, e, f), and migration trends of the LMI latitude after removal of the frequency contributions in the North Atlantic and the eastern North Pacific (g, h, i).
Figure S2. As in figure 2, but including tropical depressions.
Table S1. As in table 1, but including tropical depressions.

|                  | WP | NA | EP | NI | SI | SP | NH | SH | GLB | IH |
|------------------|----|----|----|----|----|----|----|----|-----|----|
| **Linear trend of LMI latitude (km decade⁻¹)** | 31.2 | -1.5 | 8.8 | -47.0 | **62.9** | 53.0 | 43.3 | 56.0 | **51.2** | **99.2** |
|                  | (58%) | (16%) | (24%) | (82%) | **(98%)** | **(77%)** | **(88%)** | **(94%)** | **(98%)** | **(98%)** |
| **Clim.-mean latitude of LMI** | 19.7°N | 25.1°N | 16.2°N | 16.5°N | 16.3°S | 17.9°S | 19.6°N | 16.9°S | 18.8° | - |
| **Linear trend of frequency percentage (% decade⁻¹)** | -1.8 | **3.1** | -1.2 | **1.6** | -0.4 | -1.3 | 1.7 | -1.7 | - | - |
|                  | (88%) | **(99%)** | (85%) | **(99%)** | (52%) | (83%) | (94%) | (94%) | - | - |
| **Clim.-mean frequency percentage (%)** | 31.5 | 14.7 | 18.2 | 6.6 | 18.2 | 10.8 | 71.0 | 29.0 | - | - |