Cause of the Recent Tendency of Tropical Cyclones Approaching Coasts as Revealed by HighResMIP-PRIMAVERA Simulations

Fumiaki Ogawa,[a]* Shoshiro Minobe,[a] Malcolm J. Roberts,[b] Rein Haarsma,[c] Dian Putrasahan,[d] Christopher D. Roberts,[e] Enrico Scoccimarro,[f] Laurent Terray,[g] and Pier Luigi Vidale.[h]

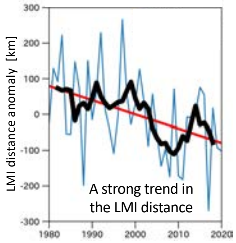
[a] Hokkaido University, Japan. [b] Met Office, U.K. [c] The Royal Netherlands Meteorological Institute, Netherlands. [d] MPI for Meteorology, Germany. [e] ECMWF, U.K. [f] CMCC, Italy. [g] CERFACS, France. [h] University of Reading, U.K.

*Corresponding author: fumiaki.ogawa@sci.hokudai.ac.jp

1. Motivation

- Tropical cyclone paths have been extended meridionally in recent decades (ref. 1).
- Tropical cyclones (TC) developing over the ocean threaten society when they approach land.
- **The mean distance of TC location from the closest shoreline at lifetime maximum intensity (LMI) is getting shorter in the recent 40 years (ref. 2, fig.1).**

▼ **Figure 1.** Observed annual-mean LMI distance and its 5-year running mean.



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As only one realization, the cause is unclear; **external forcing vs natural variability.**

External forcing:
- Impact on global spatial distribution of TC (ref. 3).
- Hadley Cell expansion (ref. 1).

Natural variability:
- Pacific Decadal Oscillation (PDO) changes the atmospheric circulation (ref. 2).
- ENSO impacts the TC genesis and intensity over the western North Pacific (ref. 4).

Aim of this study: identify the cause of the observed LMI trend through a multi-model data analysis.

2. Data and method

- We analyzed outputs of **High-resolution global multi-model ensemble simulations prepared by the PRIMAVERA project** according to the CMIP6 **HighResMIP protocol** (ref.5, table 1).
- TC tracking data are publicly available for the models (ref. 6), reanalysis (ref. 6), and observation (IBTrACS; ref. 7).
- We calculate the instantaneous distance using these tracking data and discuss the reproducibility of the trend in LMI distance on the following assumption;

  AGCM ensemble mean captures SST forcing.
  CGCM ensemble mean captures external forcing (global warming).

▼ Table 1. Models and reanalysis data used in this study. Resolutions indicate the atmospheric grid spacing at the equator.

Model	Version	Resolution (km)	Reanalysis	Resolution (km)	Period
CMCC-CM	2-VHR4	0.25° × 0.25° (28)	ERA-Interim	TL255 (113)	1979–2016
	2-HR4	1° × 1° (100)			
CNRM-CM	6-1-HR	TL359 (55)	ERA5	TL1279 (44)	1979–2018
	6-1	TL127 (156)			
EC-Earth	3P-HR	TL511 (39)	MERRA2	Cubed sphere (71)	1980–2017
	3P	TL255 (78)			
HadGEM	3-GC31-HM	N216 (39)	JRA-55	TL319 (78)	1958–2014
	3-GC31-MM	N96 (93)			
MPI-ESM	1-2-XR	T255 (52)	CFSR	T382 (54)	1979-2016
	1-2-HR	T127 (100)			

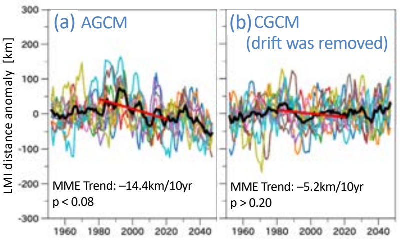
3. Results

3-1. Simulated annual mean time series of the LMI distance

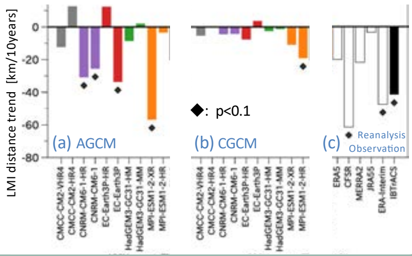
- AGCM : Significant trend is reproduced for both MME and 4/10 simulations (Figs. 2a, 3a, 3c).
- CGCM : No significant trend for MME, and the time-evolution is very different from each other.

➡ **Importance of natural SST variability on the LMI trend, not global warming.**

▼ **Figure 2.** 5-year running mean evolution of global-mean LMI distance. Colors: Individual models, Black : Multi-model ensemble mean (MME)



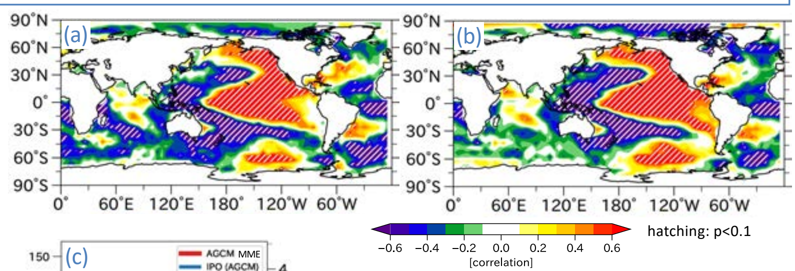
▼ **Figure 3.** Linear trend of LMI distance (1981– 2020) for individual models shown in Figure 3, reanalysis, and observation.

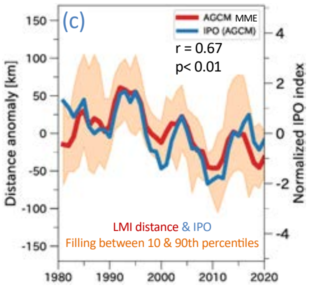


3-2. Association of the LMI distance trend with SST variability; IPO

- SST anomaly associated with the global-mean LMI distance (Fig. 4a) anomaly shows a similarity to the natural SST variability pattern known as **Inter-decadal Pacific Oscillation** (**IPO**, fig. 4b, ref. 8)
- Correlation between the detrended LMI distance and IPO for AGCM (fig.4c) is 0.67 (p<0.01).
- **IPO shows a negative trend during 1981-2020** (fig. 4c).

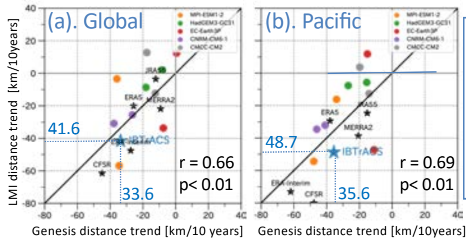
▼ **Figure 4.** (a) Correlation between annual-mean SST and the AGCM MME mean LMI distance for 1981-2020. (b) IPO pattern. (c) Time series of AGCM MME mean LMI distance anomaly and IPO index for 1981-2020. 5-year running mean was applied.





3-3. Process at work in variations of LMI distance; TC genesis locations

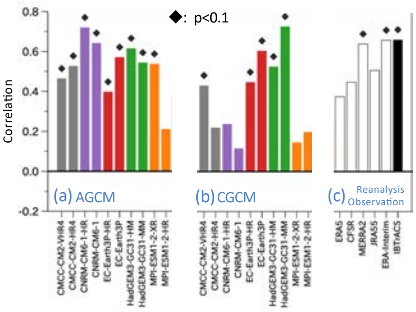
- Trends of LMI distance and the genesis distance are highly correlated for both global and Pacific averages (Fig. 5).
- The global mean trends reflects the Pacific basin. In the Pacific basin, the mean annual TC genesis number in IBTrACS (1981-2020) is 59.7, which is 70.1% of the entire globe (85.2).
- For IBTrACS, the genesis-distance trend explains 80.8% of the LMI-distance trends for the global domain and 73.1% for the Pacific domain.
- **Due to the closer location of TC genesis to land, the LMI locations also became closer.**



◀ **Figure 5.** Scatter plots of genesis distance trend (vertical axis) versus LMI distance trend (horizontal axis) for IBTrACS, reanalysis, and individual AGCMs.

3-4. Association between the TC genesis distance and IPO

- Focusing on the Pacific basin, **IPO strongly influences the decadal-scale variation in the location of TC genesis locations,** which was found through the observation, AGCM, and CGCMs (Fig.6).
- This association plays **a vital role in variations of LMI distance.**



◀ **Figure 6.** Correlation between the detrended genesis distance averaged for the Pacific (100E-70W, 90S-90N) and IPO (1981–2020). 5-year running mean was applied.

4. Summary

- **Our HighresMIP data analyses revealed that the cause of the recent tendency of TCs approaching coasts is the natural SST variability known as IPO, not the global warming.**
- **IPO impacts on the TC genesis locations over the Pacific basin, thereby influences the LMI distance.**
- **The observed LMI trend is not expected to continue in the future.**

References
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