Robust Future Projections of Global Spatial Distribution of Major Tropical Cyclones and Sea Level Pressure Gradients

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1. Background & Scientific Question

Intense tropical cyclones (TCs), such as major TCs (≥50m s^{-1}), caused substantial societal impact all over the world.

Addressing possible future changes in regional occurrence of major TCs remains a challenge for the science community for several reasons.

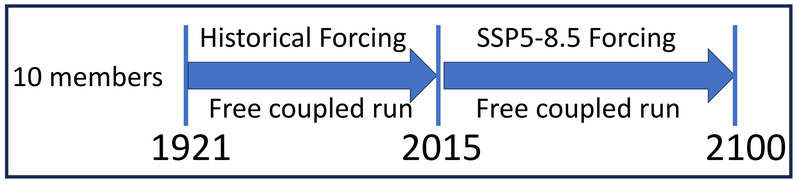
- Low horizontal resolution employed in most global dynamical
- To isolate the effect of anthropogenic forcing from internal noise is difficult especially for the rare vents of major TCs
- There are substantial variations in projections of regional TC occurrence among climate models

To tackle those challenges, we use **SPEAR_HI** and **MRI-AGCM3.2S** that reasonably simulate the frequency of occurrence of major TCs globally.

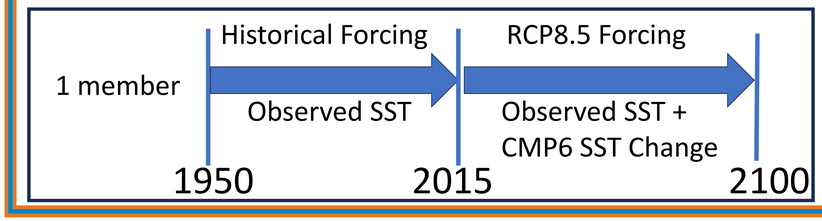
The aim of this study is to find robust future changes in frequency of occurrence of major TCs by the two high-resolution models and quantify associated storm hazards such as wildfires caused by the intense winds.

2. Models and Experiments

SPEAR_HI (High-resolution coupled model developed at GFDL)
25-km atmosphere and land-surface coupled with 100-km ocean and ice components

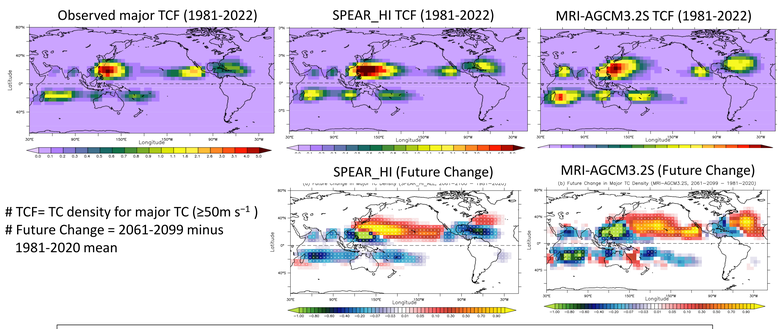


MRI-AGCM3.2S (20-km mesh Atmosphere model developed at MRI)
20-km atmosphere (Mizuta et al. 2012; Murakami et al. 2012)



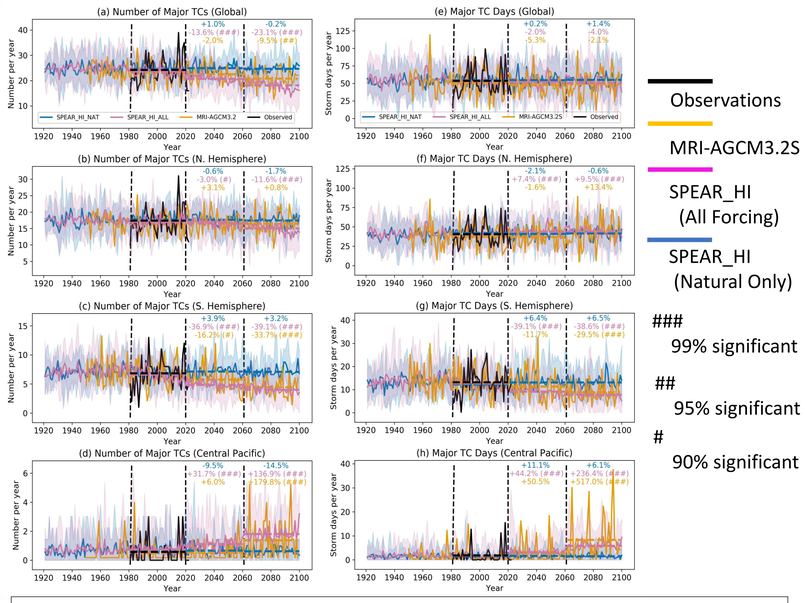
3. Projected Changes in Major TCs

Major TC density (Major TCF)



- Both models simulate reasonable major TCF in the historical period
- Both models project similar spatial pattern of major TCF changes

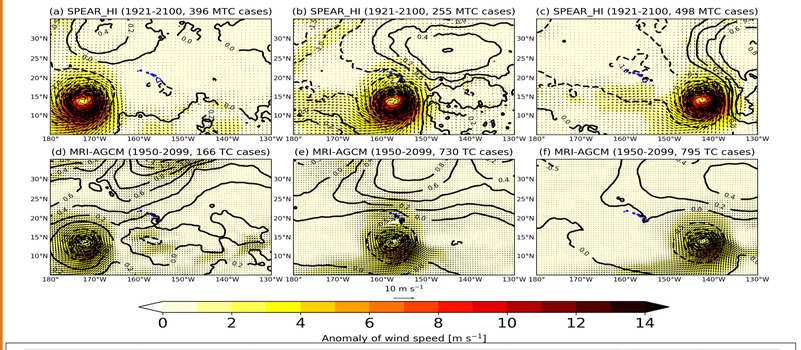
Time Series of major TC number and major storm days



- Both models project significant decrease in number of major TCs (Fig. a)
- The decrease is more in the Southern Hemisphere than in the Northern Hemisphere (Fig. b, c)
- Both models projects unchanged storm days of major TCs globally (Fig. e).
- Major TCs increases substantially in the Central Pacific including Hawaii (Fig. d, h)

4. Increased Frequency of Abrupt Change in SLP Gradient

Composite of SLP and wind anomaly when major TCs are located near Hawaii



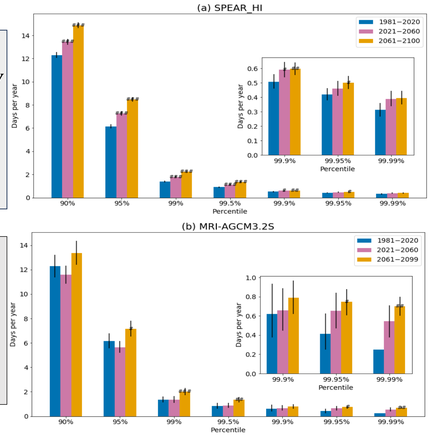
- Increasing frequency of Major TCs will increase the frequency of abrupt change in meridional SLP gradient, leading to abrupt occurrence of strong wind (and wildfire)

Simulated frequency of extreme events of abrupt increases in SLP gradient near Hawaii

$$SLPG = \overline{SLP_a}^{25°N}_{160-155°W} - \overline{SLP_a}^{15°N}_{160-155°W}$$

$$TSLPG = \frac{SLPG(t) - SLPG(t-dt)}{dt}$$

dt= 24 hours

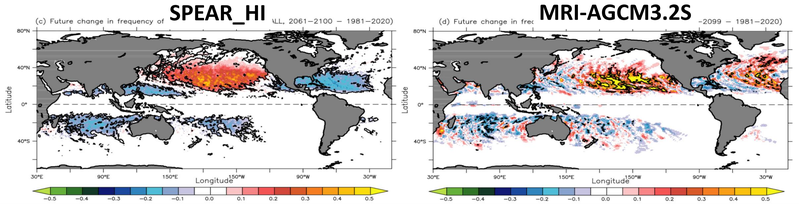


We determined threshold values for several percentiles (e.g., 90th, 95th, 99th, 99.5th, 99.9th, 99.95th, and 99.99th percentiles) using the TSLPG data for the present-day period of 1981–2020 for reference.

- Robust increases in extreme TSLPG events near Hawaii
- The increases indicate projected increase in the frequency of events of rapid intensification in wind speed within 24 hours, and associated increase in the occurrence of wildlife associated with Hurricane Dora in 2023

Simulated frequency of extreme events of abrupt increases in SLP for each grid

Future changes in frequency of 99.95% TSLPG events



- Both models project robust spatial patterns of change in extreme TSLPG events
- Increasing occurrence in the central Pacific and diminishing occurrences in the Gulf of Mexico, Caribbean Sea, and broad open oceans in the Southern Hemisphere

5. Conclusions

1. The two independent high-resolution global climate models can project robust future changes in the spatial patterns of the frequency of occurrence of major TCs attributable to increased anthropogenic forcing.
2. The projected increase in frequency of occurrence of major TCs would also lead to increased frequency of occurrence of abrupt rise in the SLP meridional gradient within 24 hours, which in turn would lead to increased frequency of sudden onset of strong winds and possible wildfire events, as seen during Hurricane Dora in 2023.