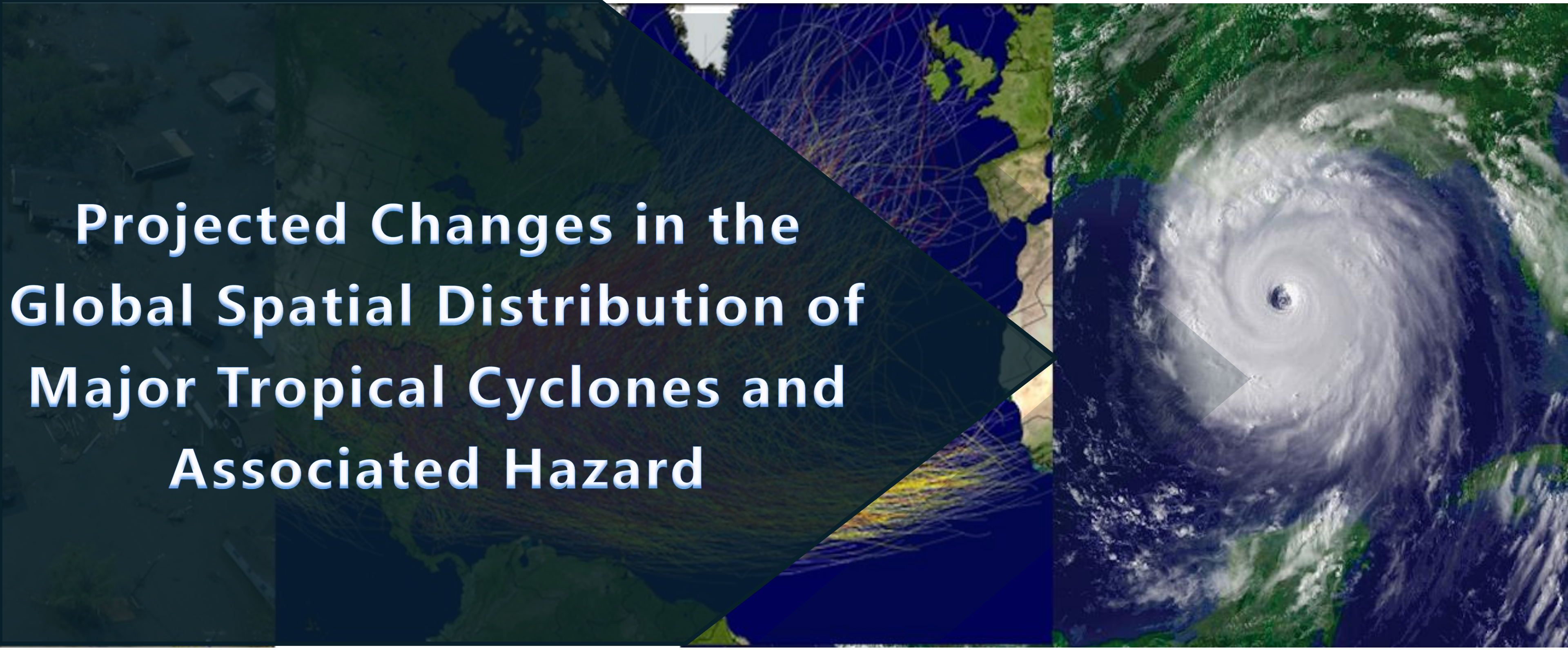


Projected Changes in the Global Spatial Distribution of Major Tropical Cyclones and Associated Hazard

Hiro Murakami[1], **W.F. Cooke**[1], **R. Mizuta**[2], **H. Endo**[2], **K. Yoshida**[2], **S. Wang**[3], **P.-C. Hsu**[4]

[1]*Geophysical Fluid Dynamics Laboratory, NOAA, USA*

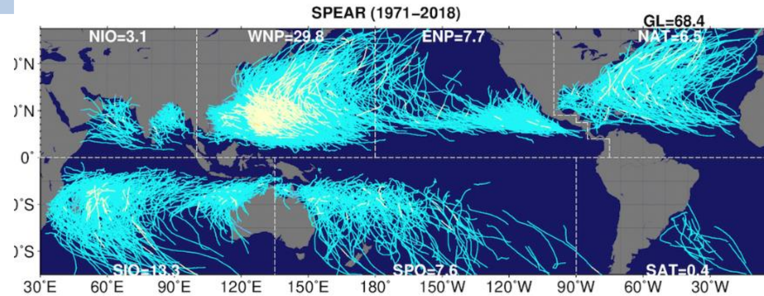
[2]*Meteorological Research Institute, Japan*

[3]*University of Delaware, USA*

[4]*Nanjing University of Information Science and Technology, China*

GFDL-SPEAR –Dynamical Global Atmos & Ocean Coupled Model–

GFDL-SPEAR
Delworth et al. (2020)



A modified version of AM4 (atmosphere) & MOM6 (ocean) & SIS2 (ice) & LM4 (land)

50-km mesh cubed-sphere atmosphere & land components coupled with **1°** ocean & sea ice components

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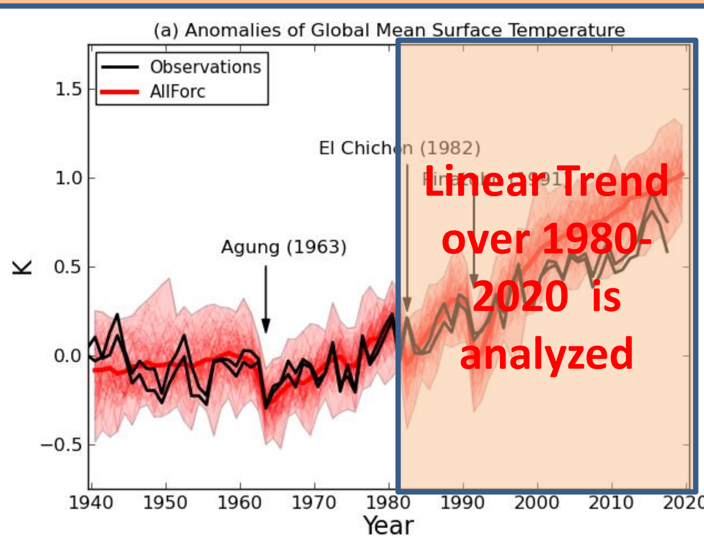
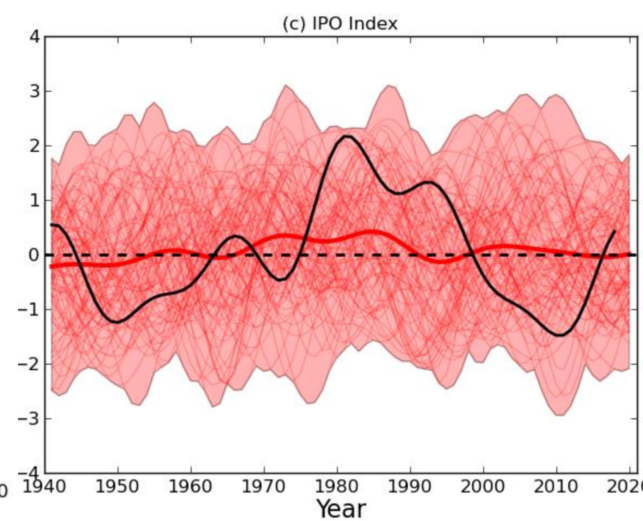
Large Ensemble: 1921-2100: Historical + Future simulations by prescribing external forcing (greenhouse gases, aerosols, ozone, and volcanic forcing)
30 ensemble members





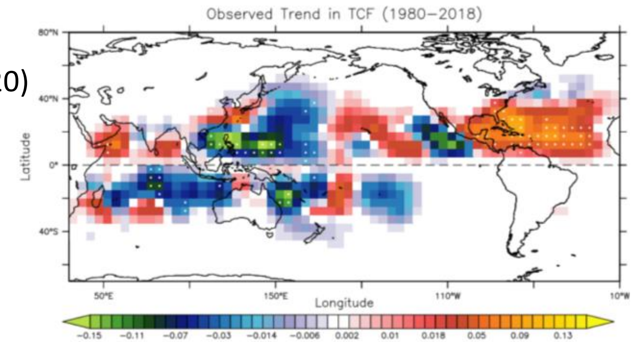
Detecting historical changes in TC activity (SPEAR_MED)

Q: Have global TCs already been affected by anthropogenic forcing over the past 40 years?

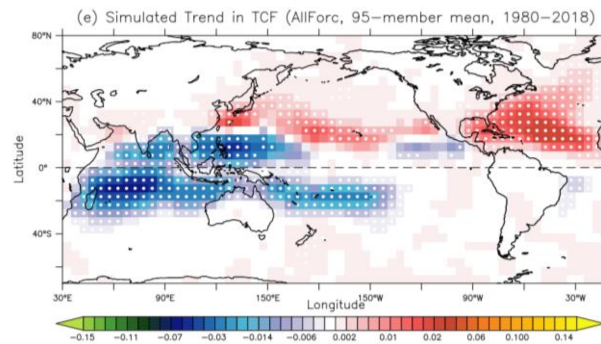
Experiments:

- All forcing (1850-2100, various scenarios)
- Fixed aerosol historical experiment (1921-2020)
- Pre-industrial experiment (~1000 years)
- Transient doubling CO_2

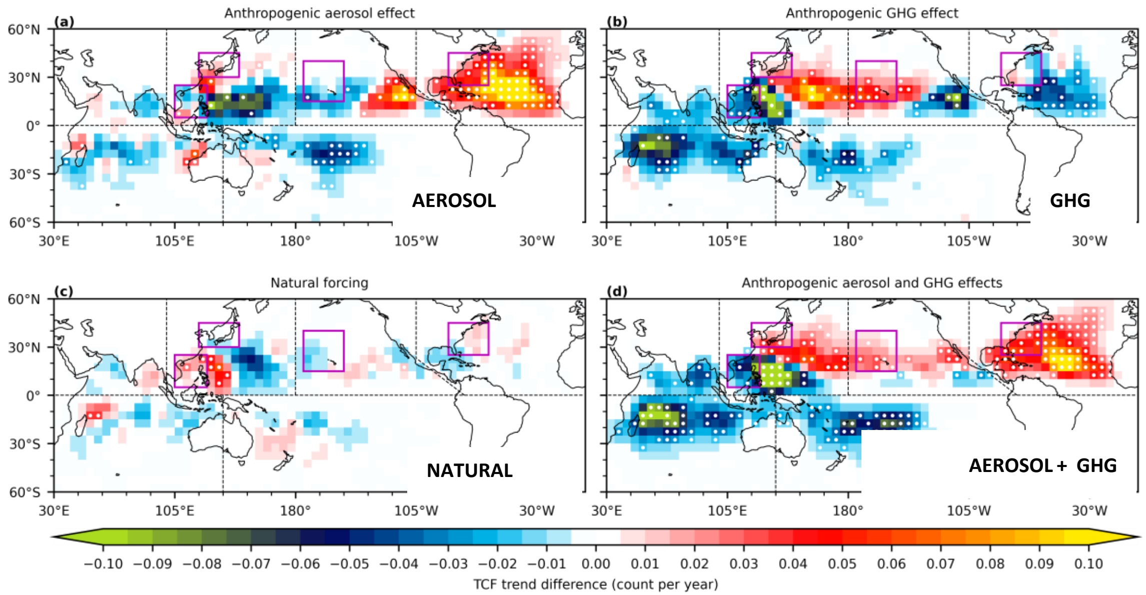
Observed Trend in TC density (1980-2018)



Large-ensemble simulations



Murakami et al. (2020, *PNAS*)



Combinations of various single or multiple external forcing experiments revealed:

US east coast	Aerosol ☞ TC Density ⇧
Hawaii	GHG ☞ TC Density ⇧
South China Sea	GHG ☞ TC Density ⇩
Japan-Korea	GHG + Aerosol ☞ TC Density ⇧

S. Wang et al. (2023, *npj Climate*)

Motivation

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

*About **85%** of the total TC damage has been caused by the major TCs in the United States*

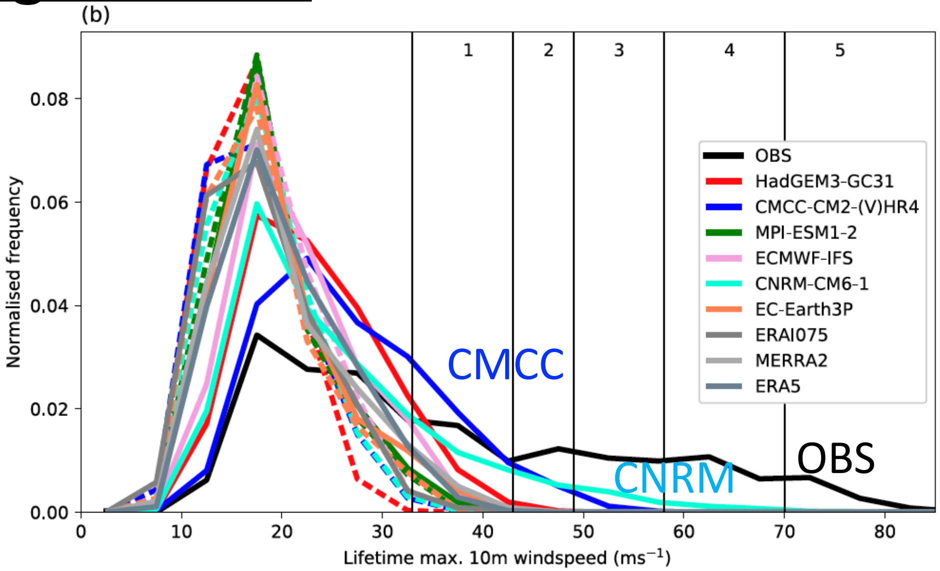
It is vital to identify where the occurrence of major TCs will increase in the future.

A Challenge

Low horizontal resolution is employed in most global dynamical climate models

Insufficient Major TC Simulations by Dynamical Climate Models

HighResMIP

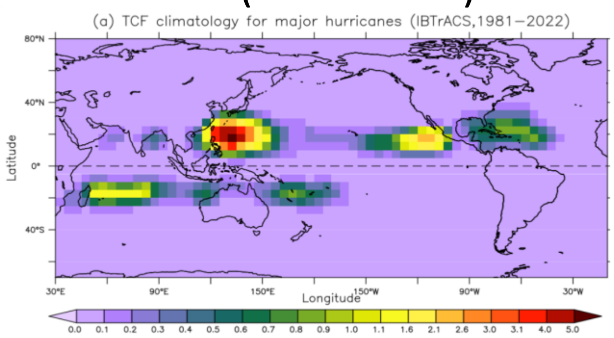


Only two HighResMIP models simulates major TCs.

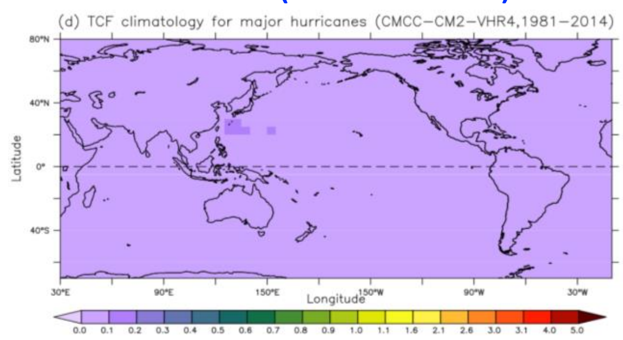
Roberts et al. (2020, *J. Climate*)

Major TC Density (Counted on 5° x 5° grid cells)

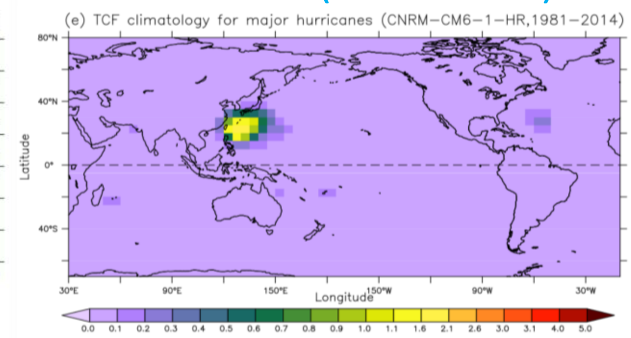
OBS (1981-2022)



CMCC (1981-2014)



CNRM (1981-2014)



The two HighResMIP models critically underestimate major TC density

SPEAR_HI (High-resolution coupled model developed at GFDL)

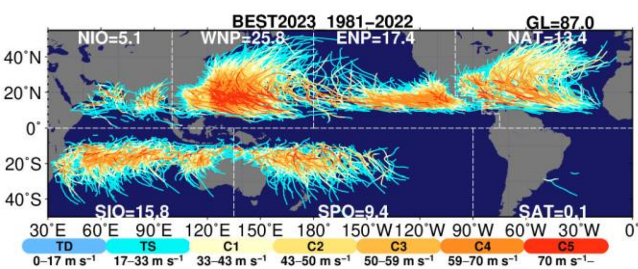
25-km atmosphere and land-surface coupled with 100-km ocean and ice components

MRI-AGCM3.2S (20-km mesh Atmosphere model developed at MRI)

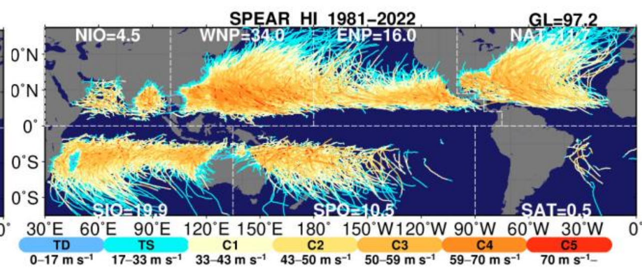
20-km atmosphere (Mizuta et al. 2012; Murakami et al. 2012)

TC Tracks with TC intensity

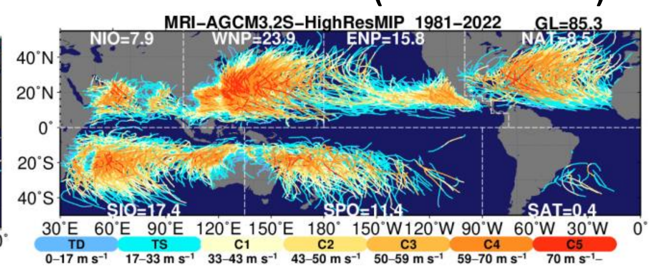
OBS (1981-2022)



SPEAR_HI (1981-2022)

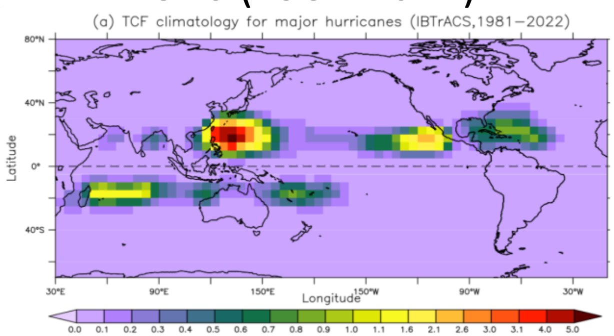


MRI-AGCM3.2S (1981-2021)

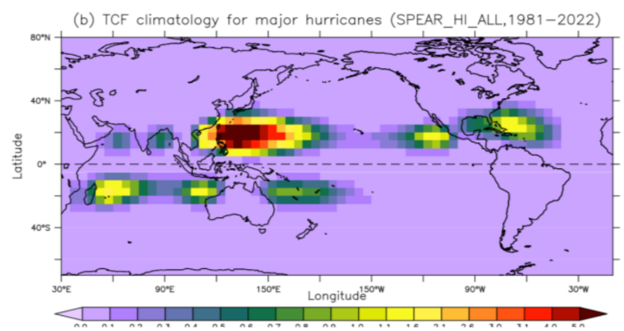


Major TC Density (Counted on 5° x 5° grid cells)

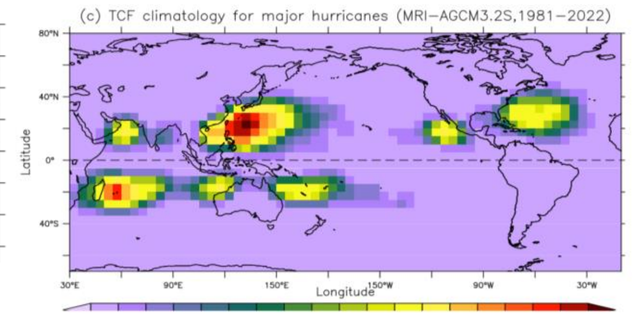
OBS (1981-2022)



SPEAR_HI (1981-2022)



MRI-AGCM3.2S (1981-2021)



2. The Aim of This Study

The aim of this study:

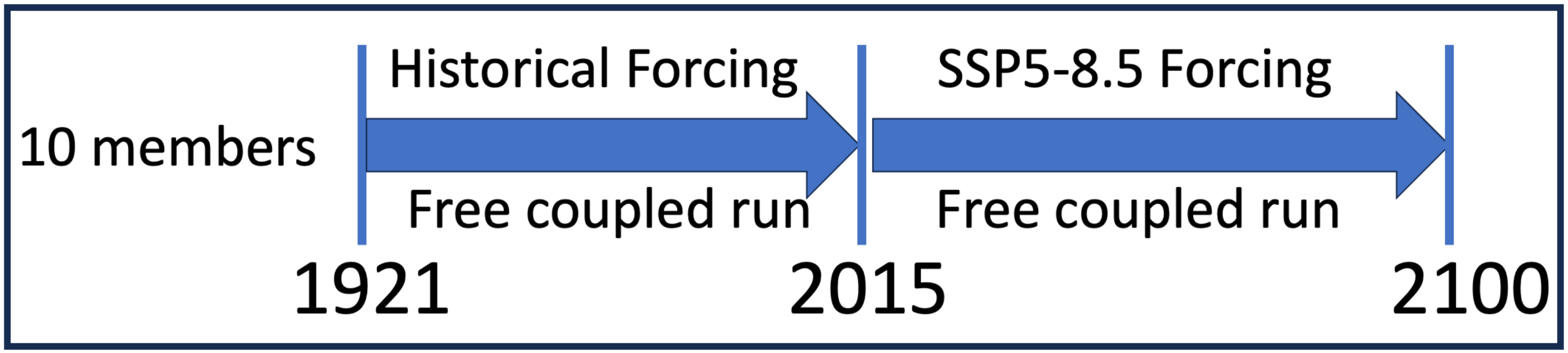
1. To identify if there are robust future changes in spatial pattern of frequency of occurrence of major TCs (≥50m s^{-1}), by the two independent high-resolution models.
2. To quantify associated storm hazards such as wildfires caused by the intense winds caused by major TCs.

The aim of this study:

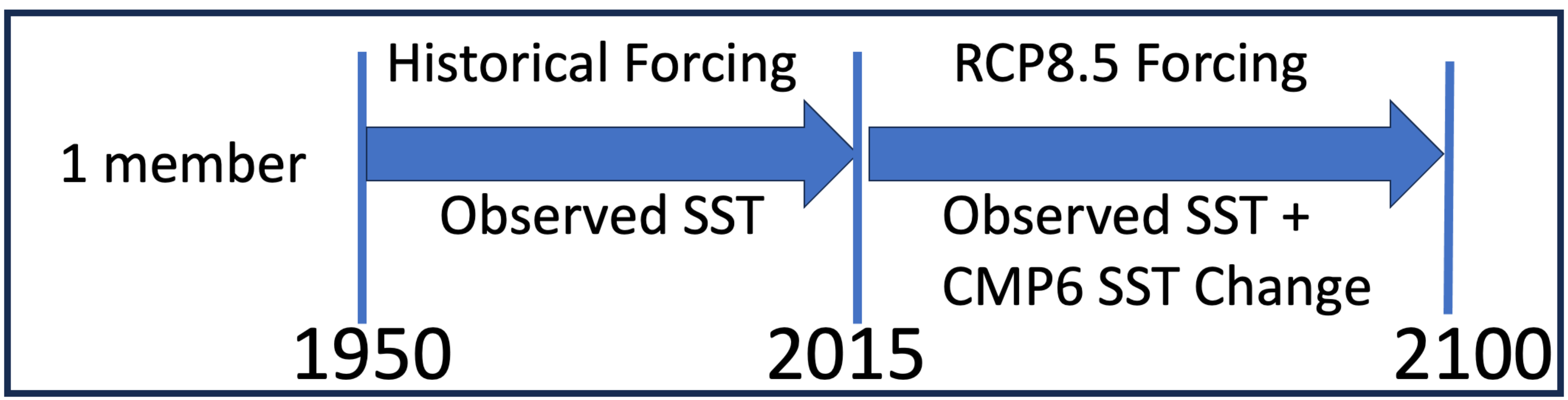
1. To identify if there are robust future changes in spatial pattern of frequency of occurrence of major TCs ($\geq$50m s^{-1}), by the two independent high-resolution models.
2. To quantify associated storm hazards such as wildfires caused by the intense winds caused by major TCs.

Climate Experiments

SPEAR_HI (25-km mesh coupled model developed at GFDL)



MRI-AGCM3.2S (20-km mesh Atmosphere model developed at MRI)



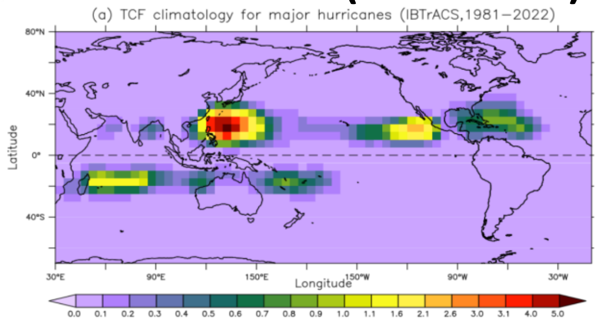
Future Change = 2061-2099 minus 1981-2020 mean

Projected Future Changes in Major TC Density

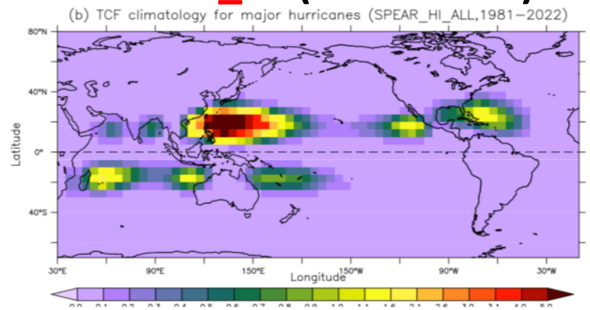
Major TC density (Major TCF, ≥50m s^{-1})

SPEAR_HI: 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

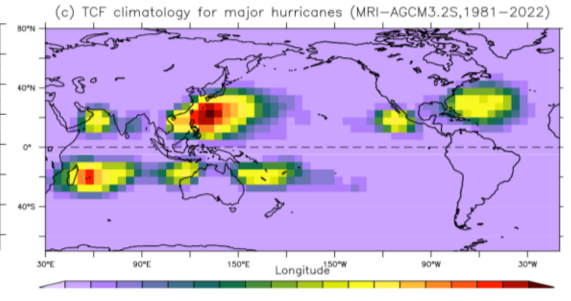
Observations (1981-2022)



SPEAR_HI (1981-2022)



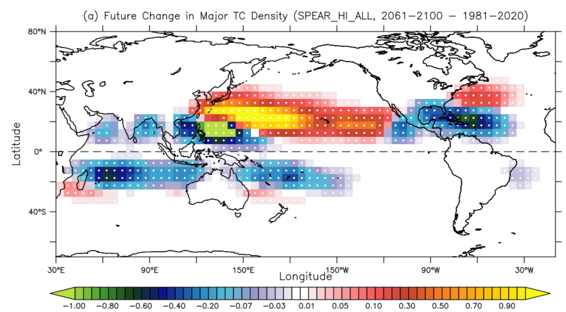
MRI-AGCM3.2S (1981-2022)



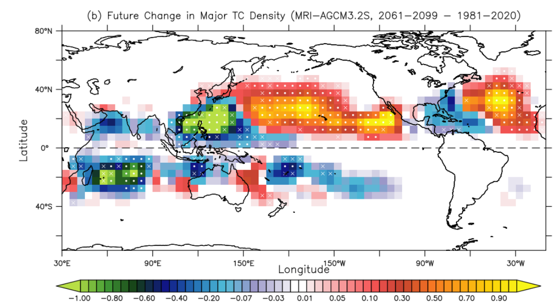
Major TC Density (≥50m s^{-1})

Future Change = 2061-2099 minus 1981-2020 mean

Future Change



Future Change



Both models project similar spatial patterns of changes in major TC density

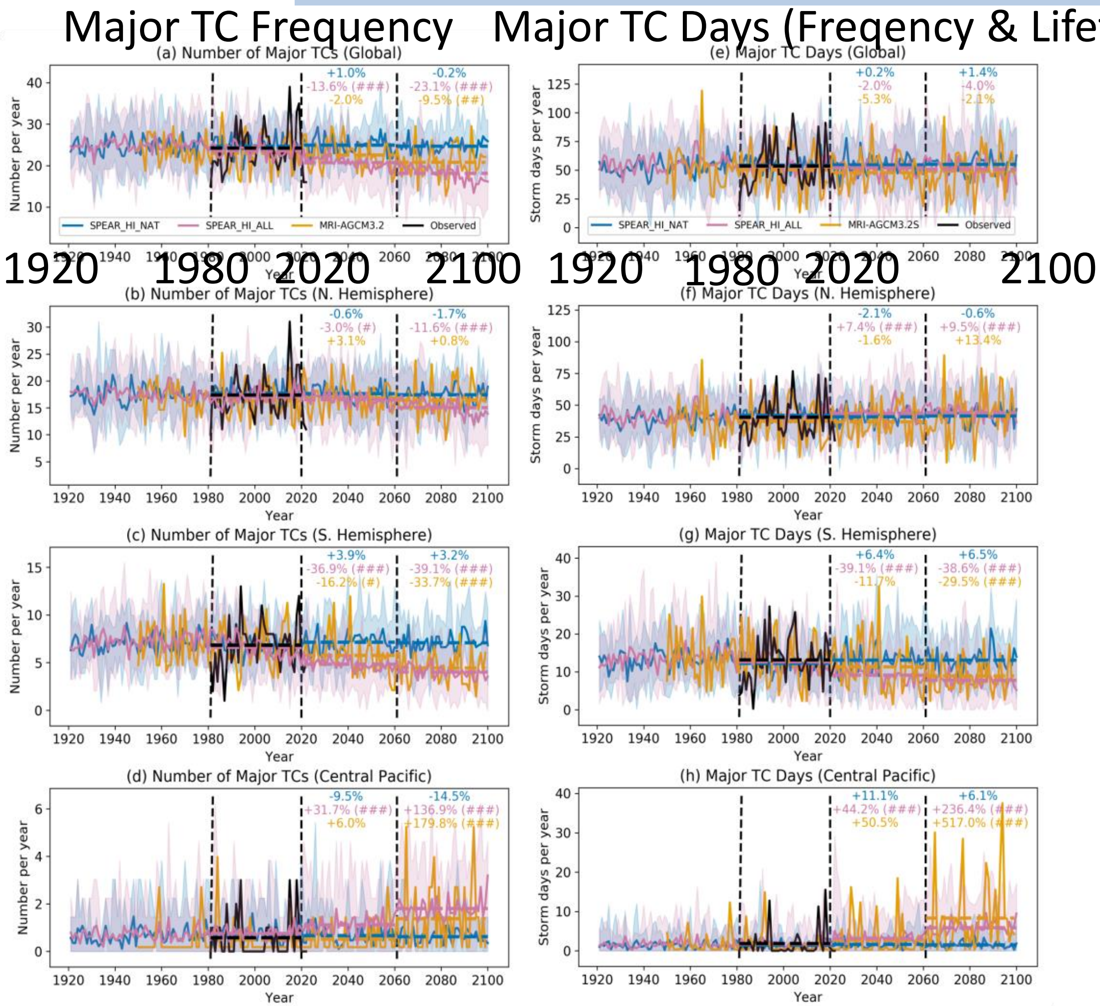
Time-series of Major TC Frequency and Storm Days

Global

NH

SH

Central Pacific



Observations

MRI-AGCM3.2S

SPEAR_HI (All Forcing)

SPEAR_HI (Natural Only)

99% significant

95% significant

90% significant

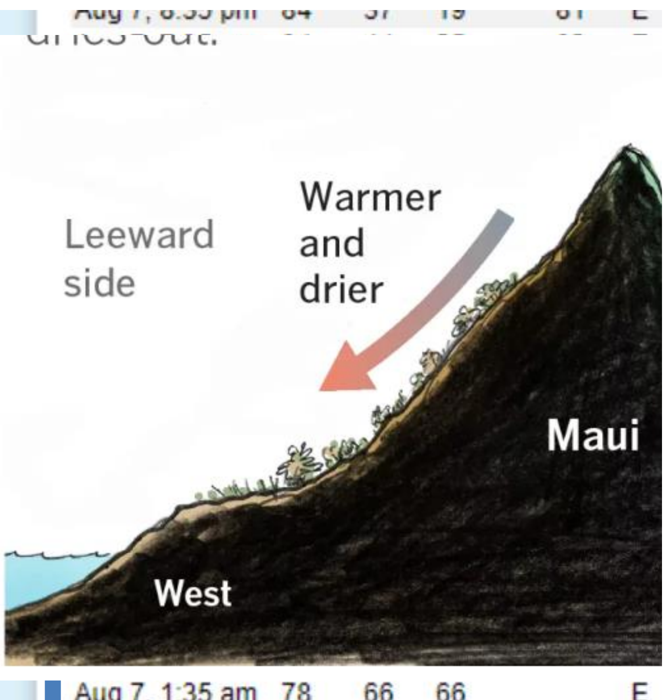
- Both models project a significant decrease in the frequency of global major TCs
- The decrease is more in the Southern Hemisphere than in the Northern Hemisphere
- Both models project unchanged storm days of major TCs globally
- Major TCs increase substantially in the Central Pacific including Hawaii

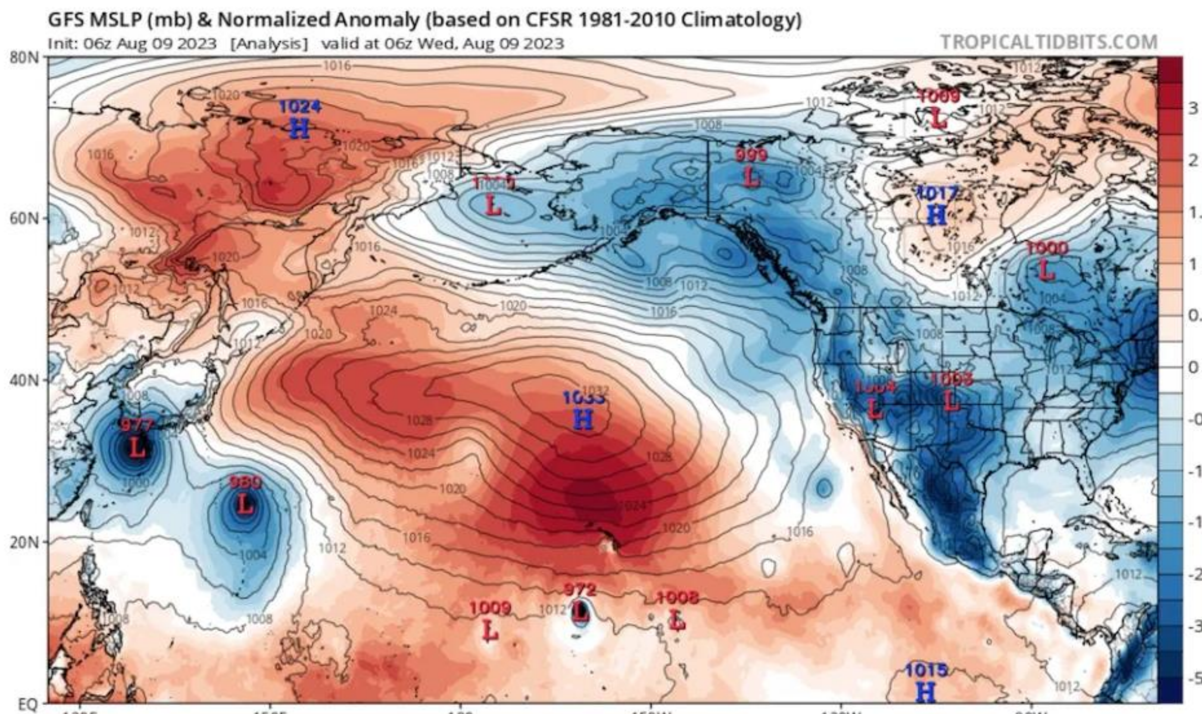
The aim of this study:

1. To identify if there are robust future changes in spatial pattern of frequency of occurrence of major TCs ($\geq$50m s^{-1}), by the two independent high-resolution models.
2. To quantify associated storm hazards such as wildfires caused by the intense winds caused by major TCs.

Hurricane Dora and Wildfire in Maui (2023)

Aug. 8-9, 2023.
At least 36 deaths in Lahaina



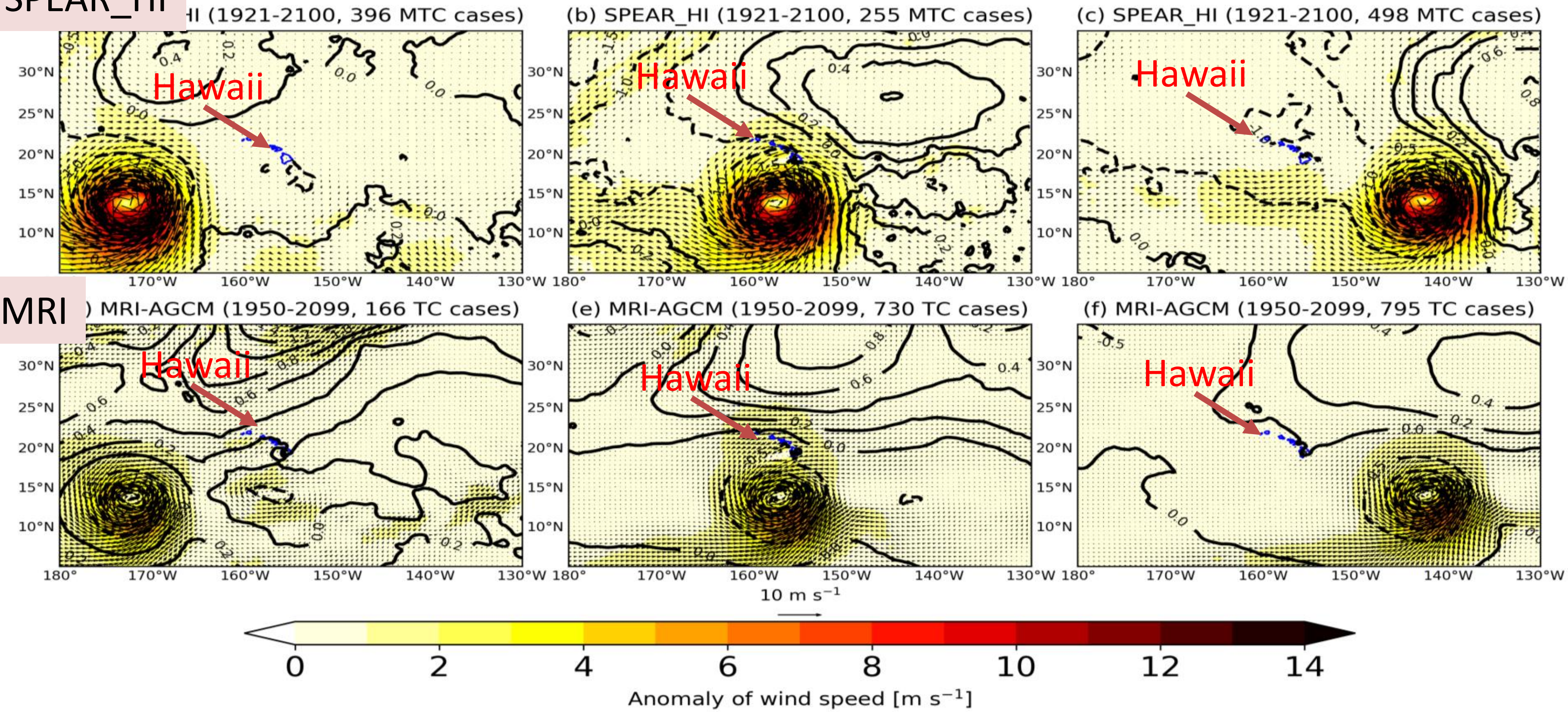


Influence of Major TCs on Remote Sea Level Pressure

Contours: SLP Anomaly (2 hPa interval for negative and 0.2 hPa interval for positive values)
Shadings: Wind Speed Anomaly

SPEAR_HI

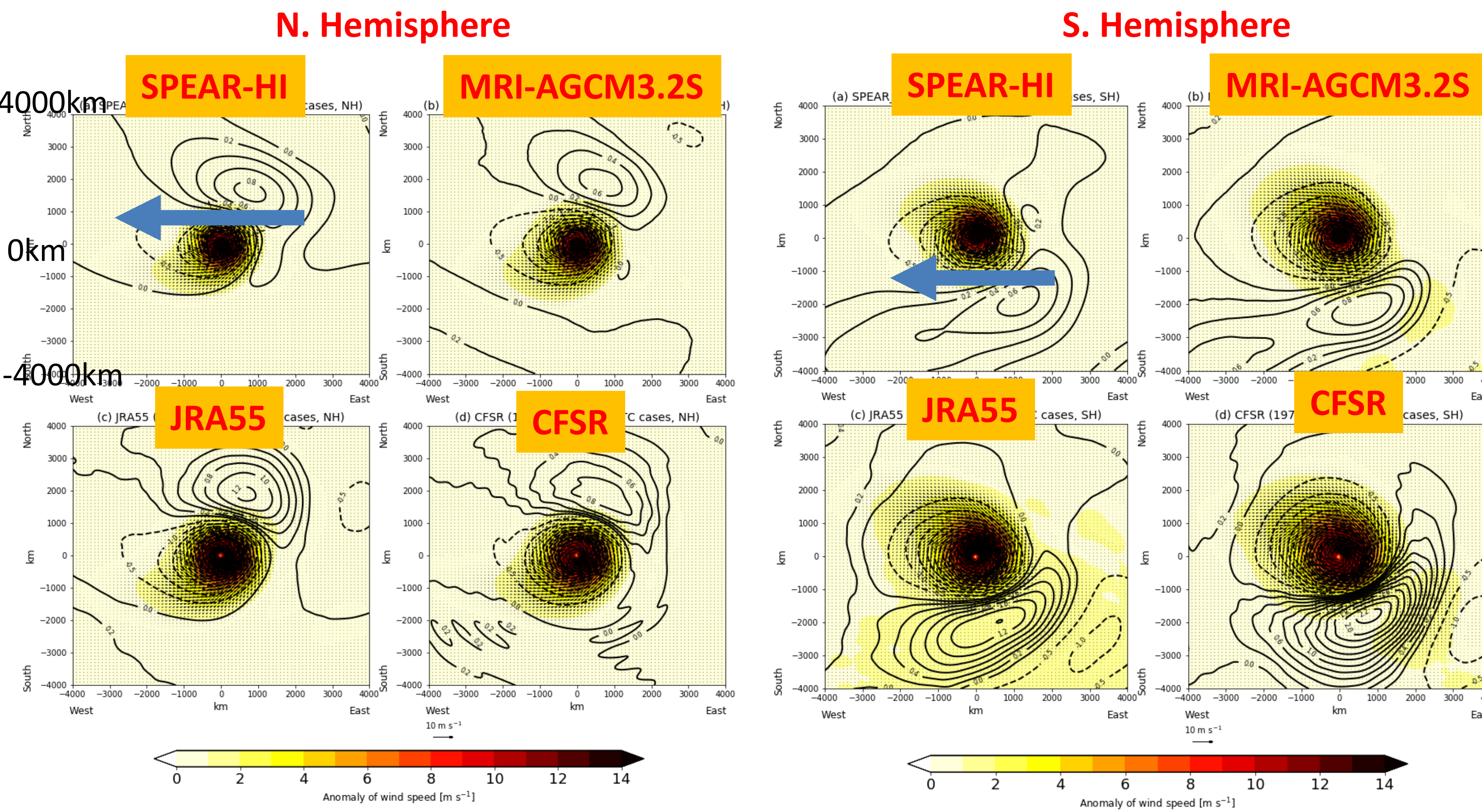
MRI



A Major TC transfers low PV at lower latitudes to higher latitudes, generating positive SLP anomaly to the Northeast, resulting in a strong meridional SLP gradient

Influence of Major TCs on Remote Sea Level Pressure

Contours: SLP Anomaly (2 hPa interval for negative and 0.2 hPa interval for positive values)
Shadings: Wind Speed Anomaly



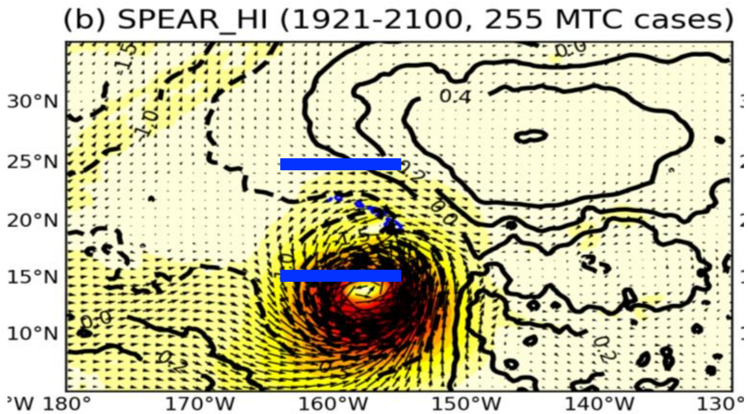
It can be seen in reanalysis data and occur everywhere

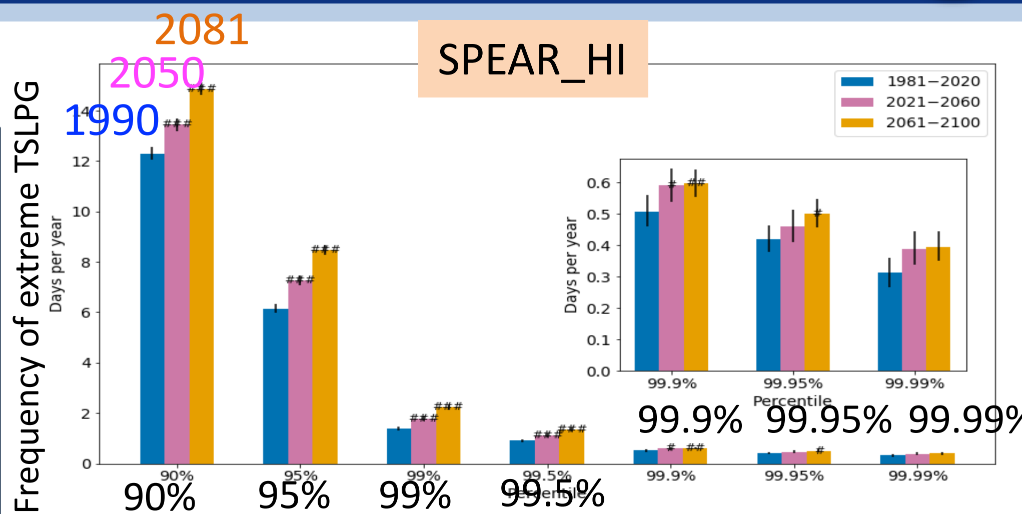
6. Simulated frequency of extreme events of abrupt increases in SLP gradient near Hawaii

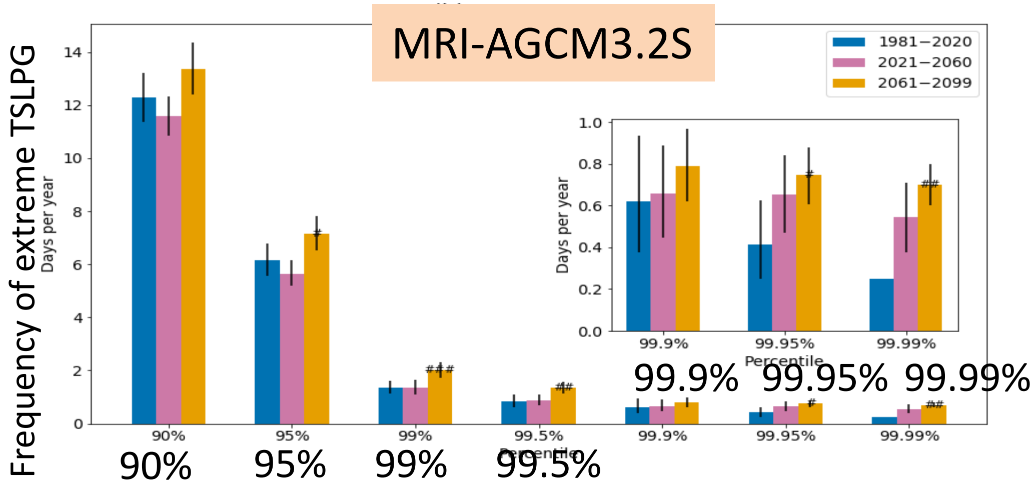
$$SLPG = \overline{SLP_a}^{25°N}_{160-155°W} - \overline{SLP_a}^{15°N}_{160-155°W}$$

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

dt= 24 hours







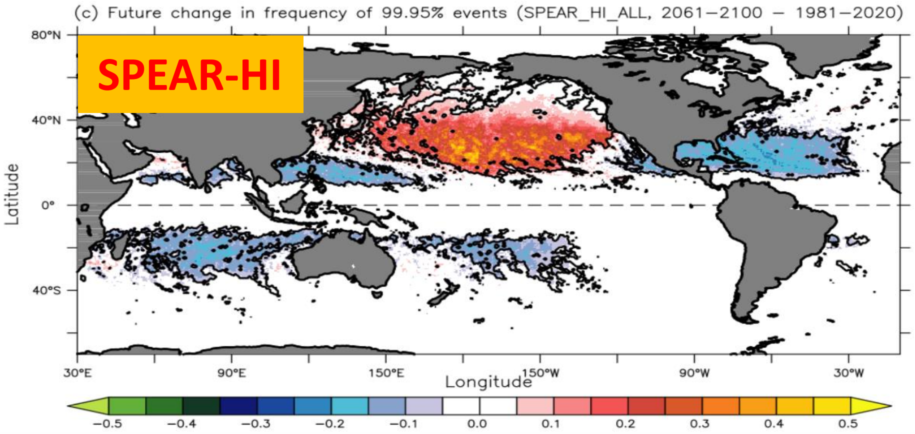
- Robust projected increases in extreme TSLPG events near Hawaii
- The increases indicate a projected increase in the frequency of events of rapid intensification in wind speed within 24 hours and associated increase in the occurrence of wildlife associated with Hurricane Dora in 2023

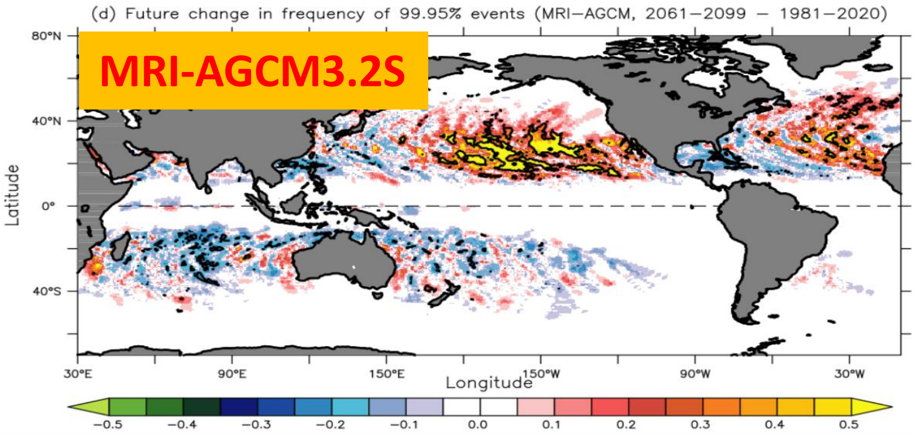
Simulated frequency of extreme events of abrupt increases in SLP for each grid

Projected changes in the frequency of extreme TSLPG events on a global scale

90 percentile threshold

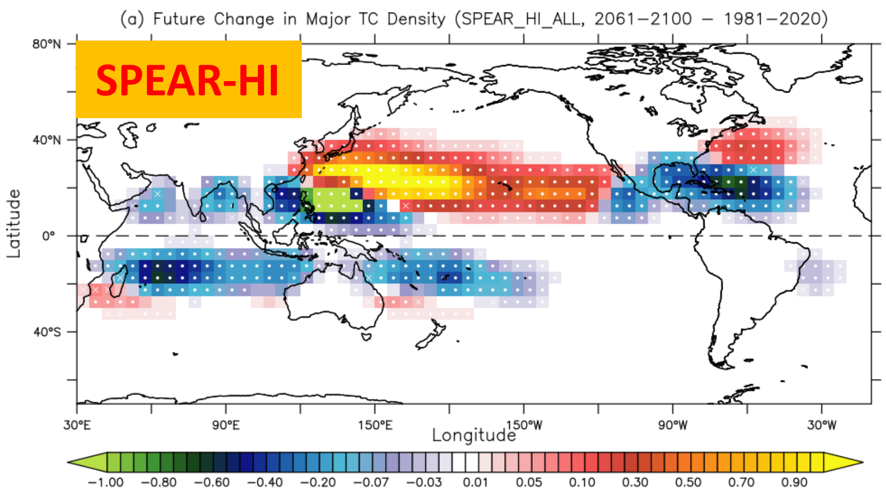
Future (2061–2100) minus present-day (1981–2020)

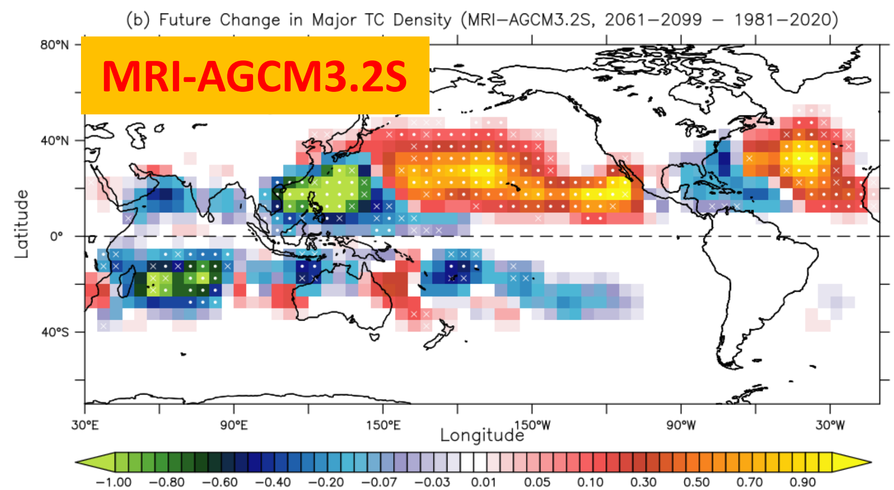




Projected future changes in the frequency of occurrence of major TCs (50 m s^{-1})

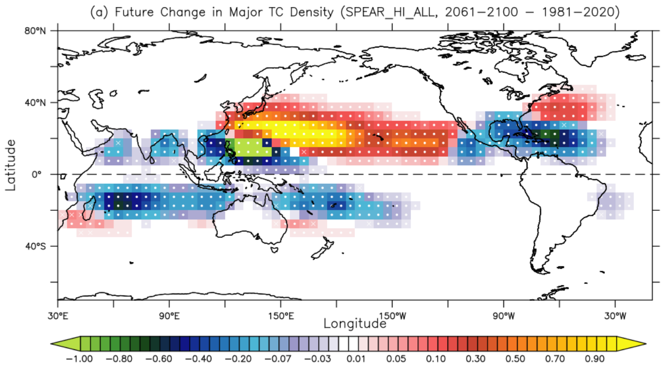
Future (2061–2100) minus present-day (1981–2020)

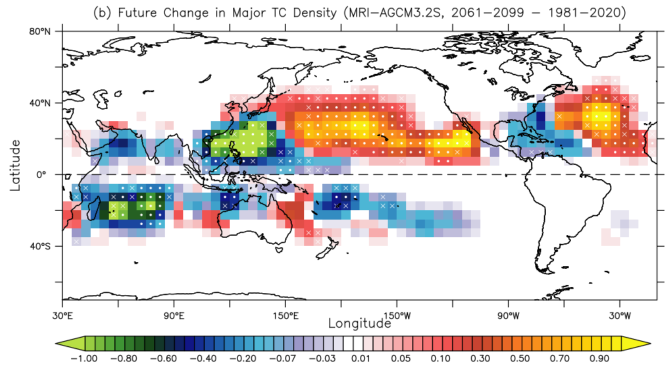




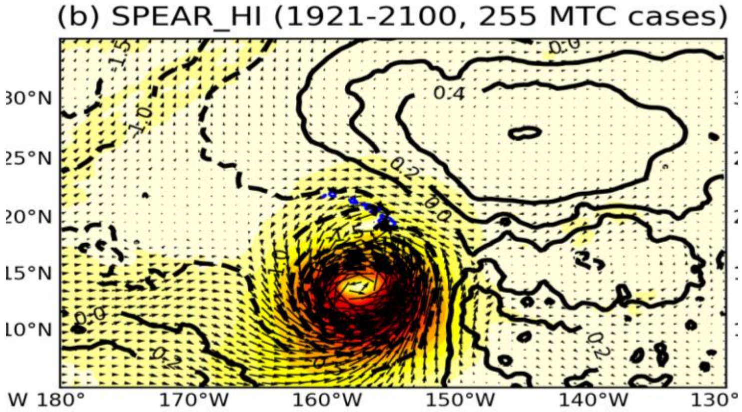
Takeaway

1. Robust future changes in the spatial pattern of major TC density





2. The hazard risk exists even when a major hurricane is positioned far away



Murakami et al. (2024, under review)

Seeking for a New Postdoc (Just Posted This Morning!)

Princeton University and NOAA-GFDL will hire a postdoctoral researcher.

Seasonal to decadal variability of extreme precipitation events associated with tropical cyclones

Scope:

1. To identify the effects of **anthropogenic climate changes and natural variability** on the frequency and intensity of extreme precipitation events related to tropical cyclones

2. To determine the **predictability** of tropical cyclone-induced extreme precipitation events over seasonal to decadal timescales associated with anthropogenic forcing and natural variability.

Applications submitted by **July 15th** for priority consideration, but open until August 1st

Please apply through the Princeton AOS web page:
Contact me (Hiroyuki.Murakami@noaa.gov)