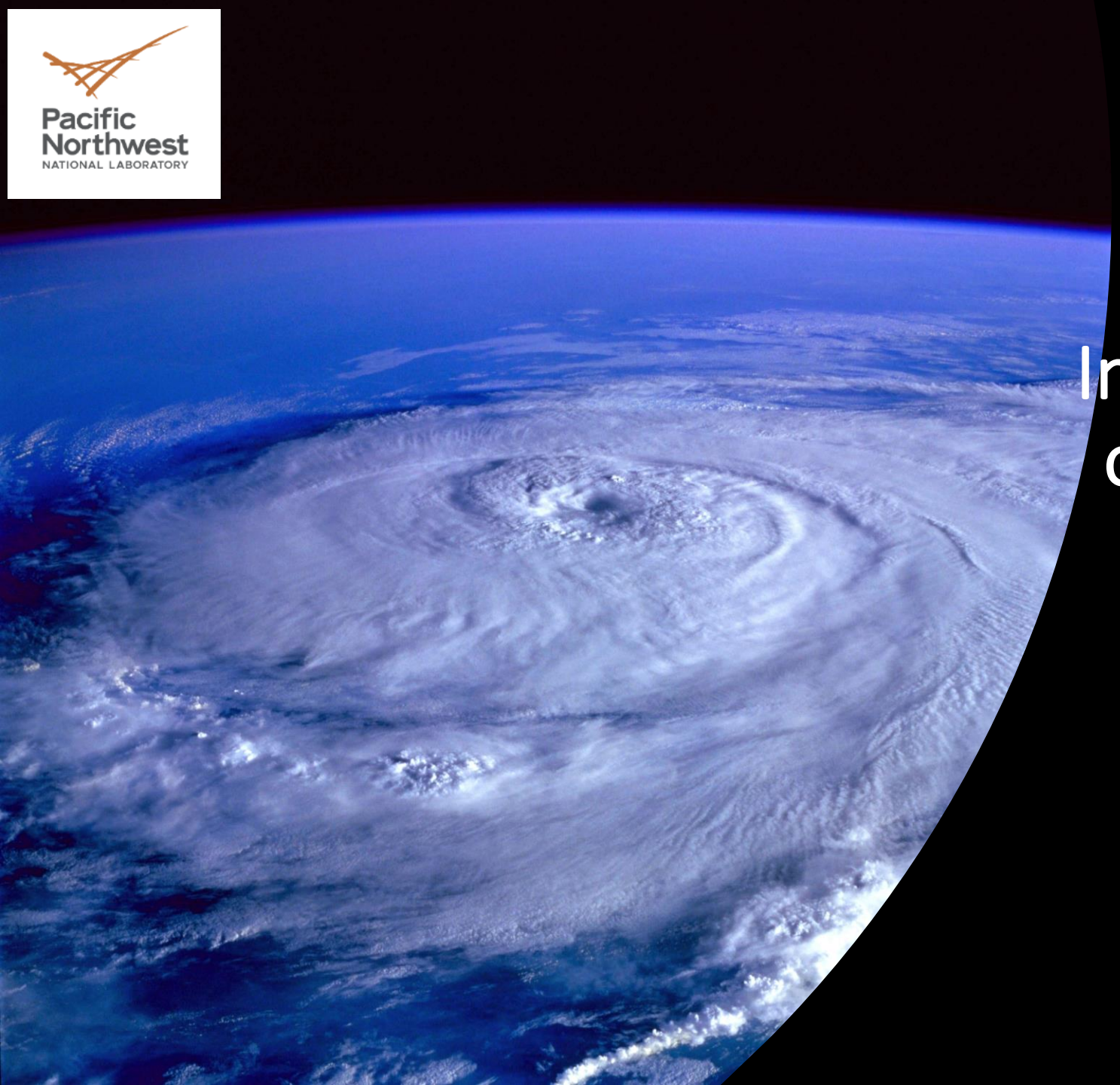


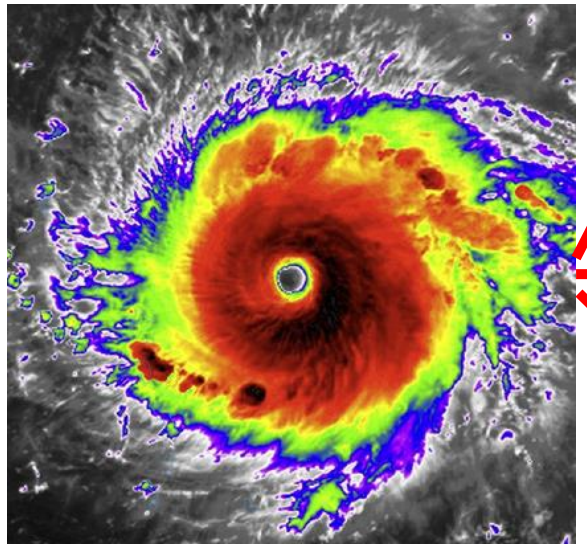
Increasing tropical cyclone outer size in the western North Atlantic

Karthik Balaguru,
Pacific Northwest National Laboratory

EESM PI Meeting, Aug 7, 2024

Why examine TC size?

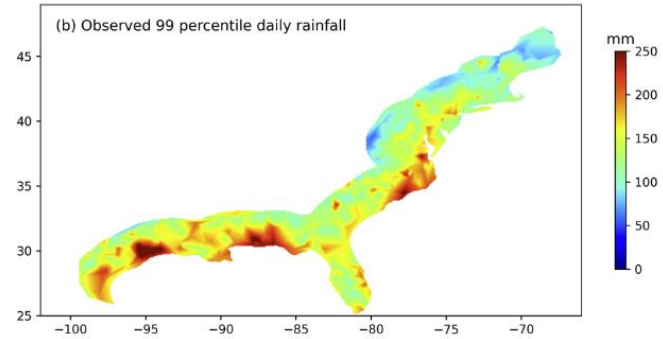
- Changes in various aspects of TCs have been considered in the past (eg. intensity, frequency, intensification rate, precipitation, forward moving speed, etc.)
- However, potential changes in TC size haven't been explored.
- Likely due to the relatively short record of observed TC size.



Source: NOAA

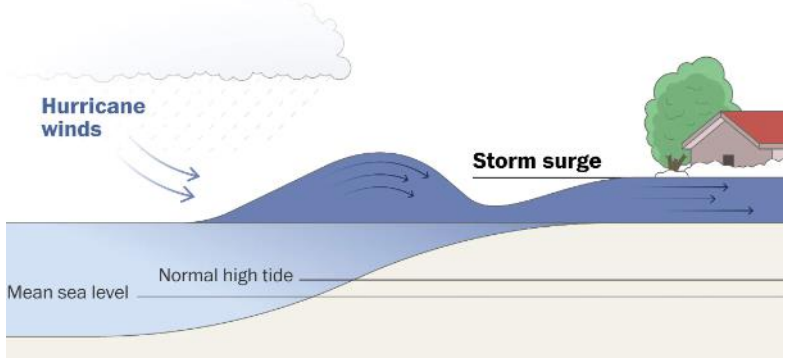
1) Area and duration of storm-force winds

2) Precipitation



(Xu et al, 2024)

3) Storm surge



Sandy – A prime example

image source: NASA

(b)	Disaster type	Year	Country	Economic losses (in US$ billion)
1	Storm (*Katrina*)	2005	United States	163.61
2	Storm (*Harvey*)	2017	United States	96.94
3	Storm (*Maria*)	2017	Puerto Rico	69.39
4	Storm (*Irma*)	2017	United States	58.16
5	Storm (*Sandy*)	2012	United States	54.47
6	Storm (*Andrew*)	1992	United States	48.27
7	Storm (*Ike*)	2008	United States	35.63
8	Wildfire	2019	United States	24.46
9	Storm (*Ivan*)	2004	United States	24.36
10	Drought	2012	United States	21.79

source: WMO

image source: US Airforce

Outline

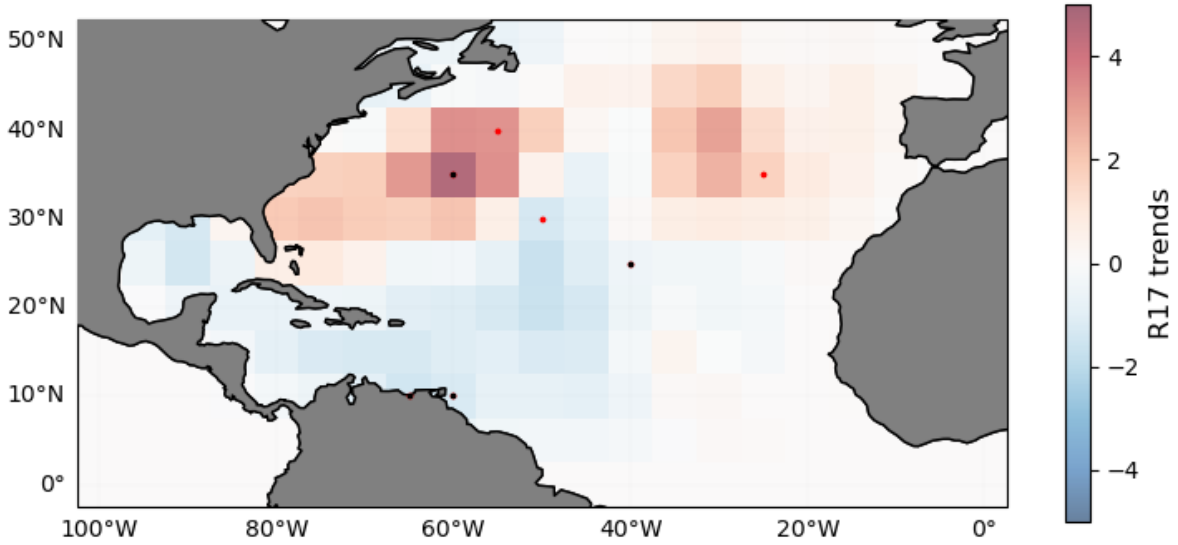
1) **Observational changes in TC outer size and environment**

2) **Can climate models reproduce these changes?**

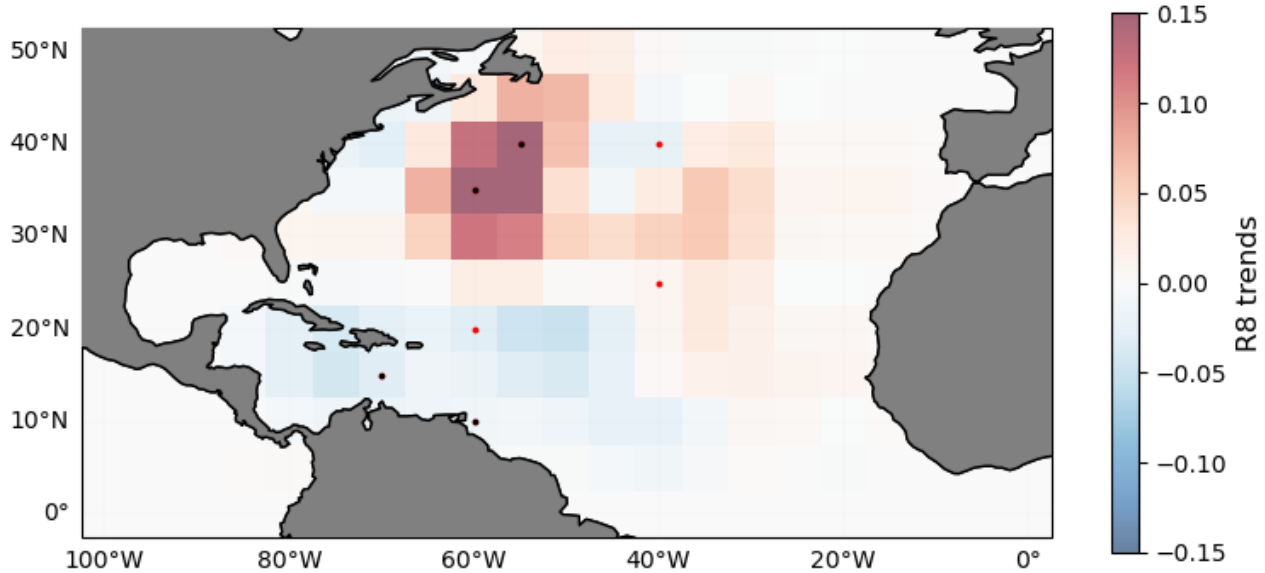
3) **Implications and future directions**

1: Observations

R17 trends Obs (2004-2022), HURDAT2



R8 trends (2004-2022), ERA5

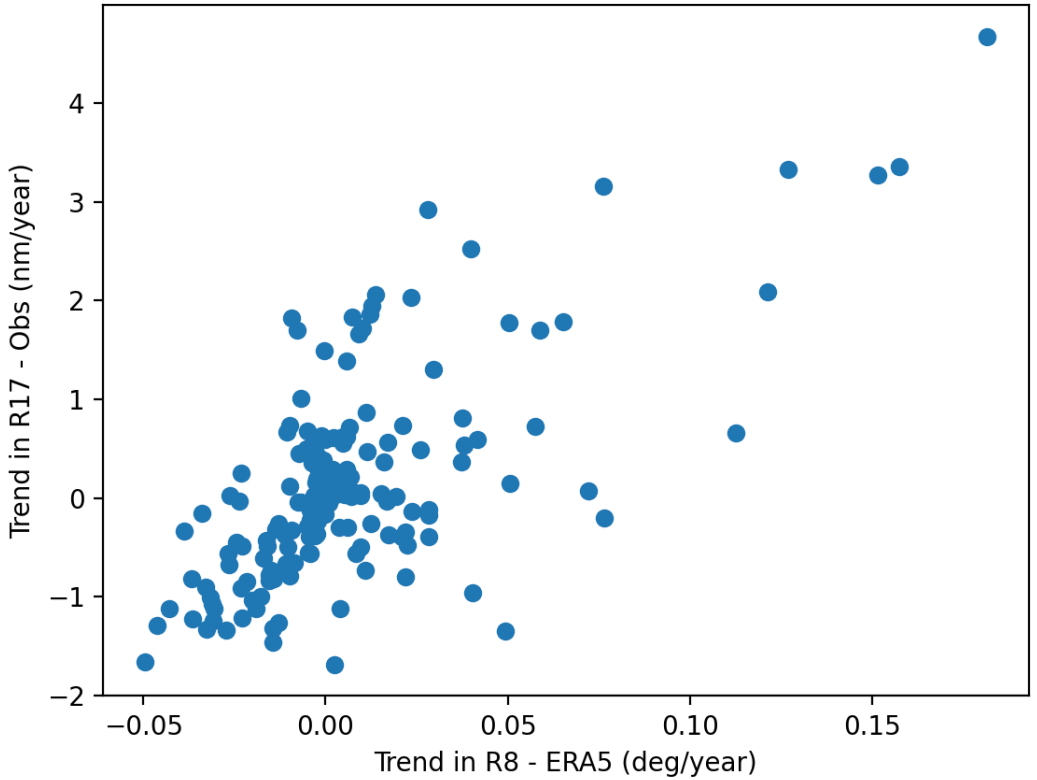


Storms tracked using *TempestExtremes* (Ullrich et al, 2021)

SyCLoPS: 100 hPa RH, DPSH, 850 hPa Temp

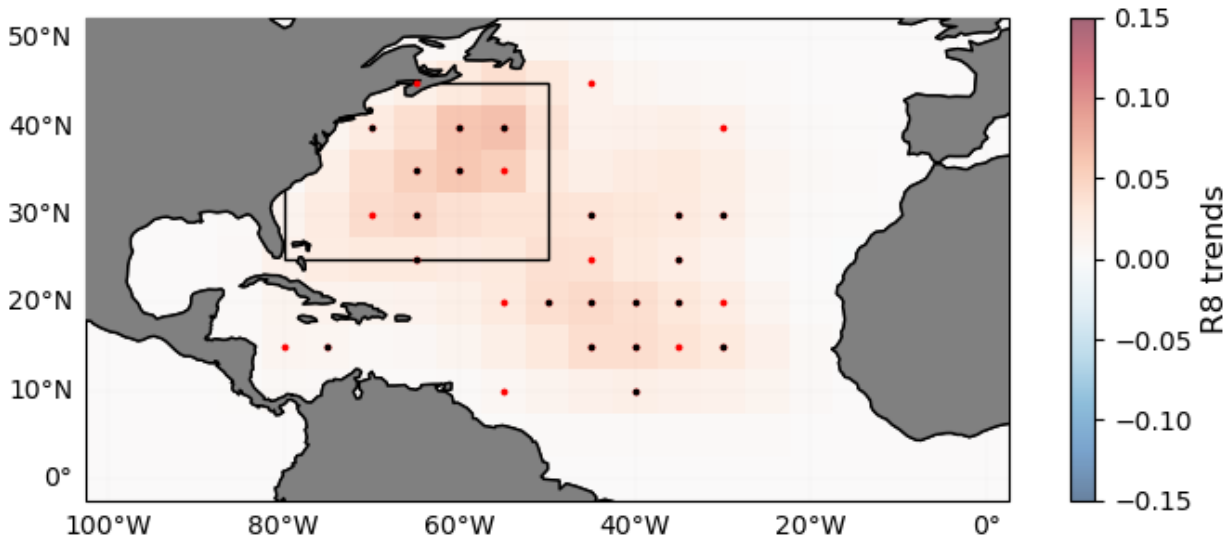
(Han and Ullrich, 2024)

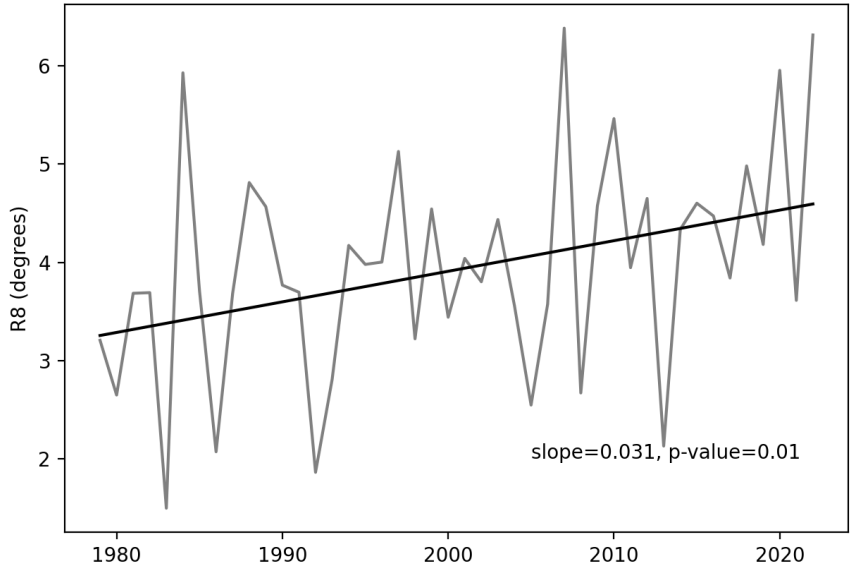
pattern correlation: 0.69, variance explained: 48%

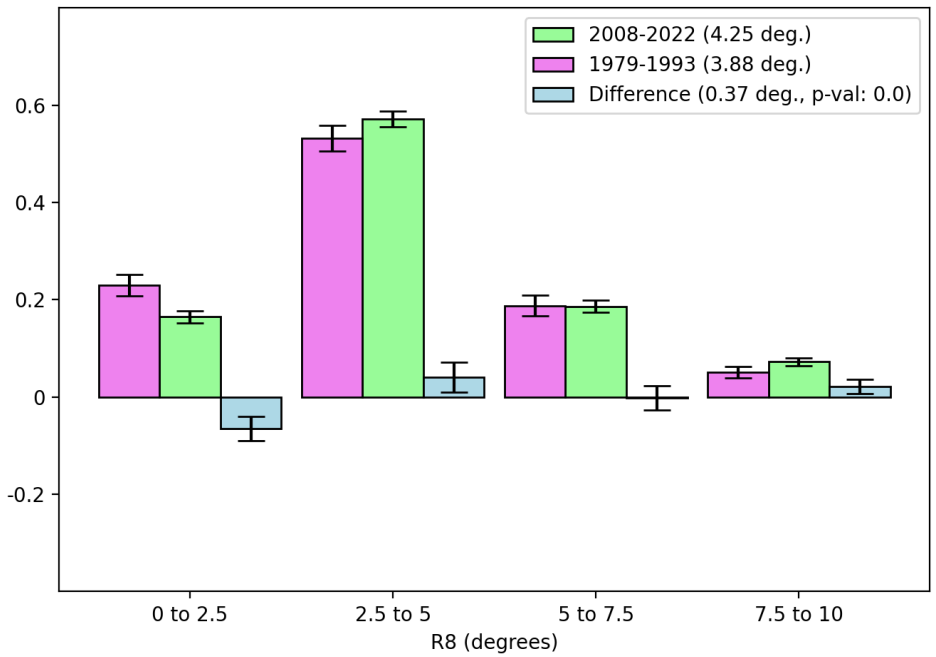


To the west of 55W where size data is more reliable

pattern correlation: 0.79, variance explained: 62%







Trend = 0.031, p-value = ~0.01 based on the Mann-Kendall test

Compared to the early period, R8 increased by about ~10% over the later period.

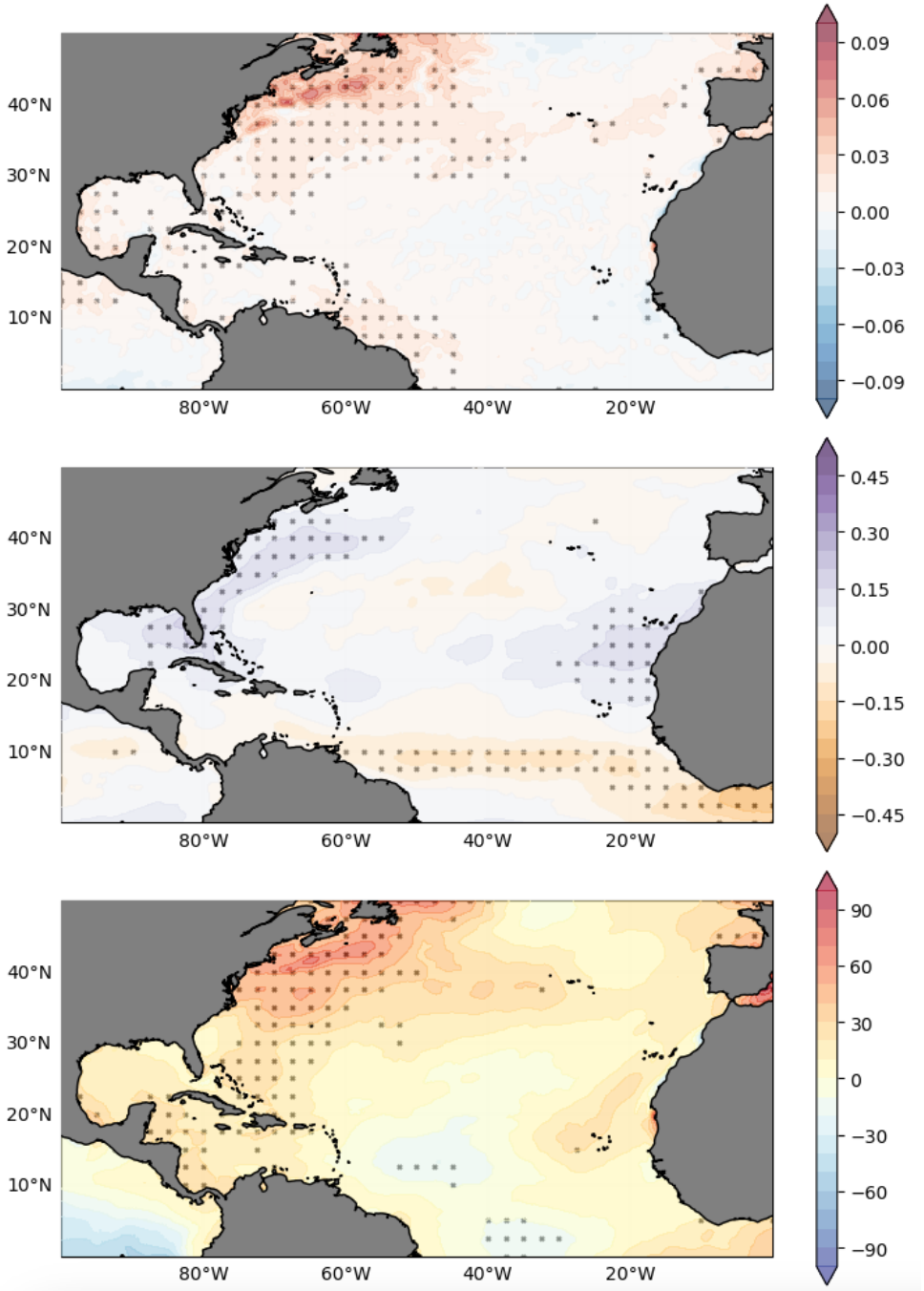
Environmental trends

- Previous studies have indicated that storm outer size may be related to the thermodynamic state of the environment (Eg. Emanuel (1986), Khairoutdinov and Emanuel (2013), Wang and Toumi (2022), Wang and Chavas (2024)).

- Trends in relative SST, mid-tropospheric relative humidity (RH600) and the gross moist instability (GMI) were examined.

- Environment has become more favorable over the western North Atlantic, especially in the sub-tropics.

ERA5 reanalysis (1979-2022)



Relative SST trends

RH600 trends

GMI trends

2: Climate model

Atm and land: 25 -> 100 km

Ocn and sea-ice: 14 -> 60 km

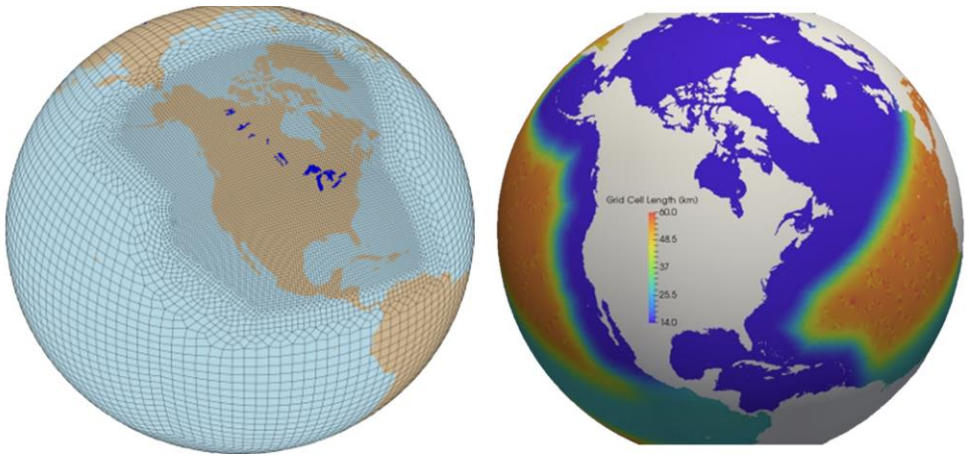
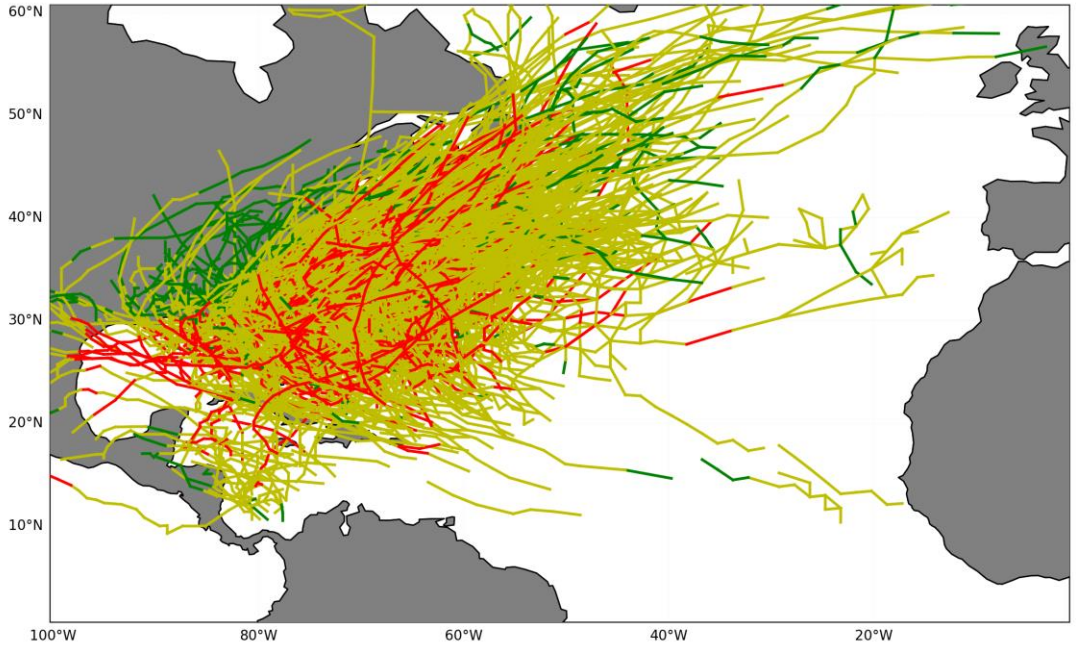


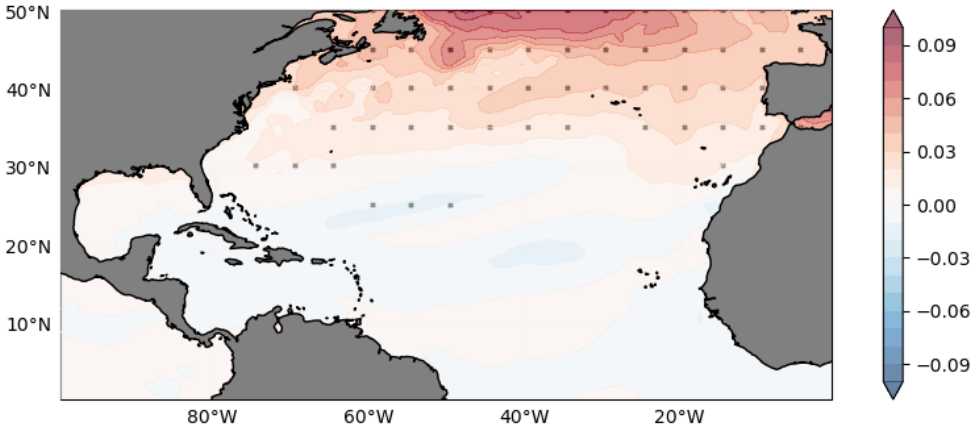
Image source: E3SM.org



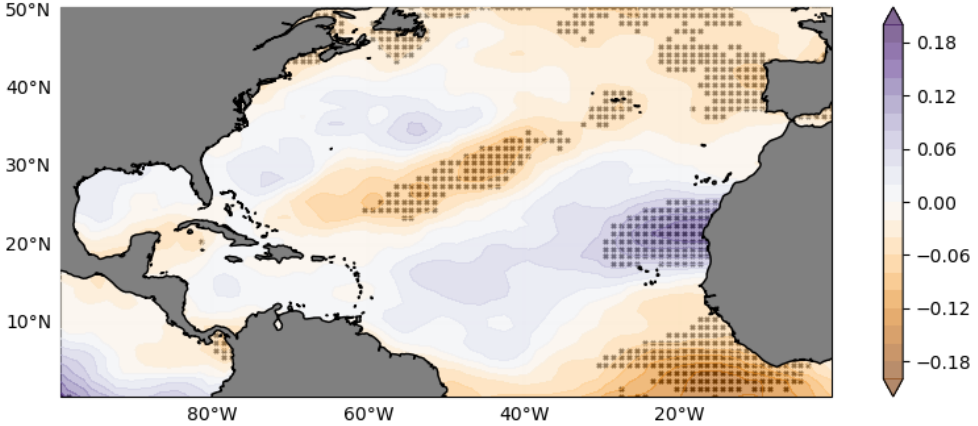
E3SM NARRM simulations

- Analyzed ***North American Regionally Refined Model*** (NARRM) simulations to support observations.
- 3-member ensemble of historical simulations (1850-2014) were used.
- TCs were tracked in the model using TempestExtremes.
- North Atlantic TC activity under-represented in NARRM.
- But storms are produced in the Western Atlantic, reach a maximum intensity of Category 4.

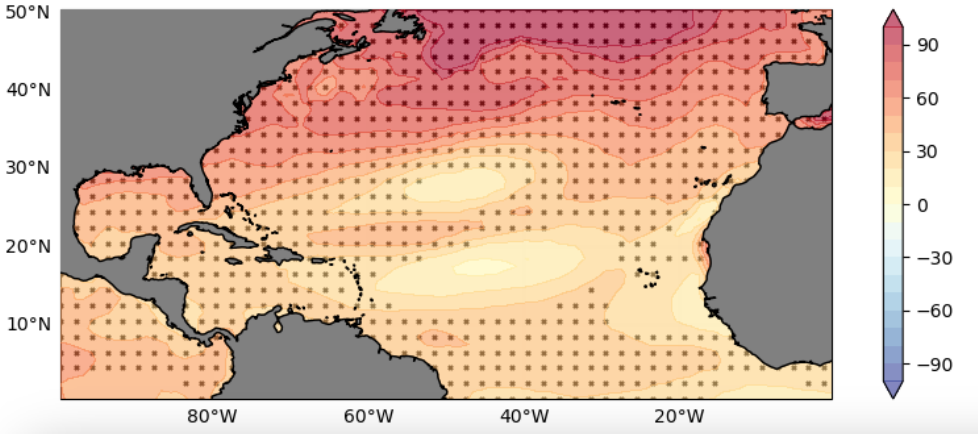
E3SM – simulations (3-member ensemble): 1979-2014



Relative SST trends

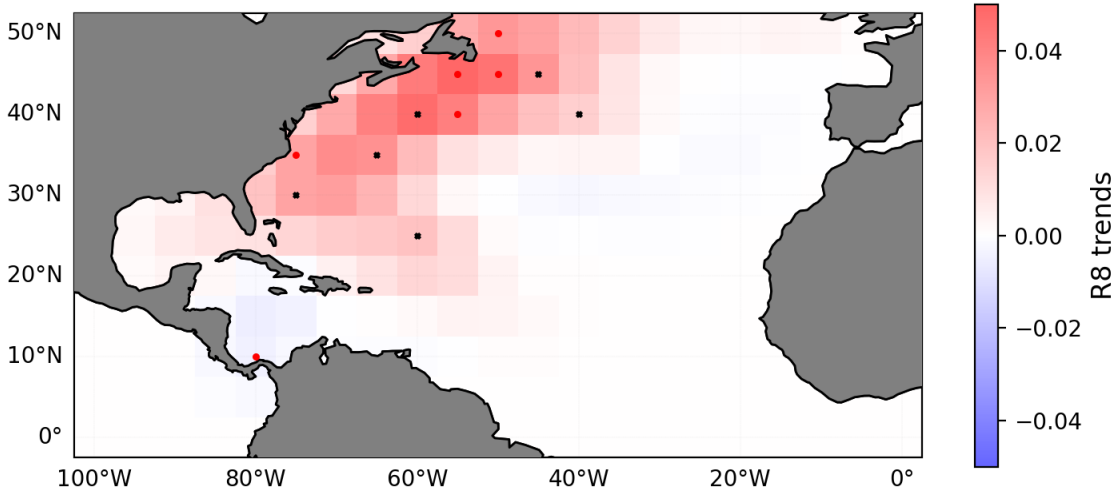


RH600 trends



GMI trends

R8 trends



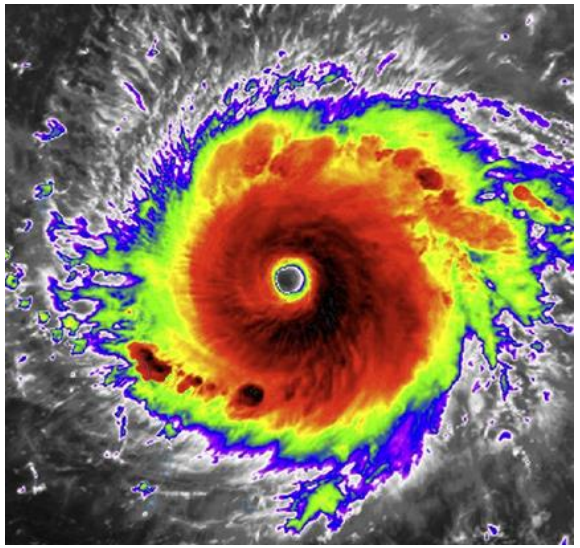
E3SM NARRM broadly captures the spatial pattern of trends in the environment and TC size.

3: Future directions

a: Physical mechanisms

Past research suggests that storm size may be influenced by the environment.

Most previous studies used idealized settings (eg. uniform SST warming)



There is also some evidence to indicate that storm size may be controlled by its initial state.

It remains unclear what determines the initial vortex size

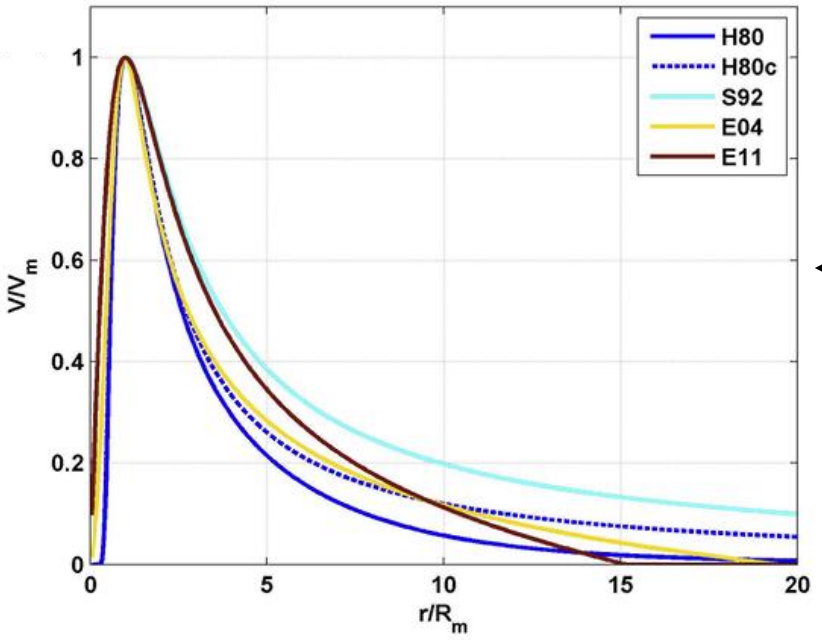
- **High-resolution modeling studies with more realistic settings are needed**
- **Efforts such as storm-tracking in HighResMIP (eg. Roberts et al. 2019) should be encouraged to include metrics of TC size**

b: Impact assessment models

Storm surge - The single largest cause of death from TCs

Storm surge $\propto V_{max}^2 \cdot R_{50} \cdot S^a \cdot L_{30}$ Islam et al. (2021)

Intensity **Size** **Translation** **Bathymetry**



Lin and Chavas (2012)

In most parametric wind models, the radial profile is a function of central pressure deficit, maximum wind speed, radius of maximum wind and latitude.

Develop new models (eg. using ML/AI) for storm structure that can take the ambient environment into consideration.

c: Datasets of storm size

NHC's best track data includes TC size metrics since 2004 : ~20 years of data

↓

Not sufficient for robust analysis

↓

Here we attempted to address this using: HURDAT2 + ERA5 + TempestExtremes + SyCloPS

↓

Source: NASA

Develop new datasets of storm size, leveraging advanced AI and additional data, such as longer-term homogenous records of satellite observations.

Thank you