

Long-Term Changes in Atlantic Tropical Storms and Hurricanes: Observed Frequency and Predictability

Hui Wang¹, Arun Kumar¹, Lindsey Long^{1,2}, Wanqiu Wang¹, Yutong Pan^{1,2}, Wenhong Li³, Rongqing Han⁴, Knut L. Seip⁵

¹NOAA Climate Prediction Center; ²Innovim; ³Duke University; ⁴CMA National Climate Center; ⁵Oslo Metropolitan University

1. Background

Tropical cyclones with different intensities may respond to climate change differently. Here we examine the long-term change in Atlantic tropical cyclones by grouping them into tropical storms (less intense than hurricanes), minor hurricanes (Category 1 and 2 hurricanes) and major hurricanes (Category 3–5). The goals are:

- 1) To document the long-term changes in tropical cyclones with different intensities,
- 2) To examine their relationships to large-scale atmospheric and oceanic environment, and
- 3) To assess potential predictability of tropical storms, minor and major hurricanes.

2. Data and Methods

Observational data (1948–2019)

- Atlantic named storms (NS), hurricanes (H), major hurricanes (MH), and accumulated cyclone energy (ACE)
- Sea surface temperature (SST): NOAA ERSSTv5
- Vertical wind shear (U200–U850): NCEP–NCAR Reanalysis
- Climatology (30 years): 1981–2010

Methods

Categorize Atlantic tropical cyclones in two different ways.

Table 1

	Traditional	Non-Overlapping
Named Storm (NS) Wind ≥ 39 mph		Tropical Storm (TS) 39 ≤ Wind ≤ 73 mph
Hurricane (H) Wind ≥ 74 mph		Minor Hurricane (MinH) 74 ≤ Wind ≤ 110 mph
Major Hurricane (MH) Wind ≥ 111 mph		Major Hurricane (MH) Wind ≥ 111 mph

3. Results

Correlation: 1948–2019

	ACE	NS	H	MH	ACE
MH		0.69	0.86	0.86	ACE
MinH	0.03		0.77	0.57	NS
TS	0.17	0.16		0.74	H
ACE	0.86	0.37	0.24		MH
	MH	MinH	TS	ACE	

Table 2

74% + 14% + 6% = 94% (variance)

* **Bold:** Correlations above the 99% significance level.

- ACE is highly correlated with NS, H, and MH.
- NS, H, and MH are highly correlated with each other.
- **TS, MinH, and MH are largely independent.**
- **MH contributes most to the ACE interannual variance.**

Long-term changes

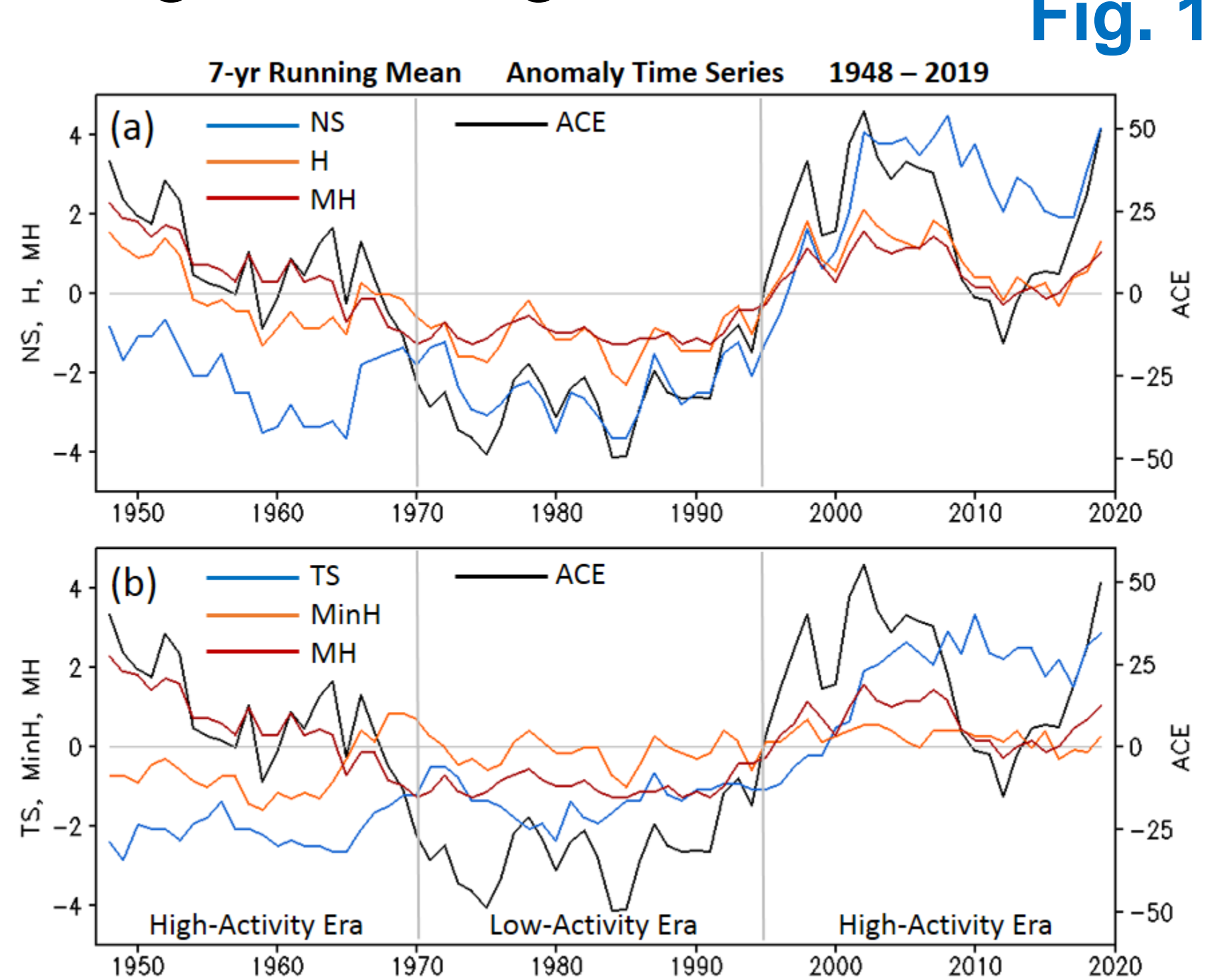


Fig. 1

Fig. 1. Anomaly time series of 7-year running mean (a) ACE, named storms (NS), hurricanes (H), and major hurricanes (MH), and (b) tropical storms (TS), minor hurricanes (MinH), and MH from 1948 to 2019. The 72 years are classified into two high-activity eras and one low-activity era, based on ACE values.

Figure 1b shows different long-term changes in TS, MinH, and MH.
MH: Multi-decadal variation **MinH:** No significant change
TS: Significant increase since 2000. There might be weak storms missed in early years, which could affect the long-term change in TS.

Relationships between SST and tropical cyclones

Fig. 2. Correlations between ASO SST and Atlantic tropical cyclones in different groups over the 72 years (1948–2019).

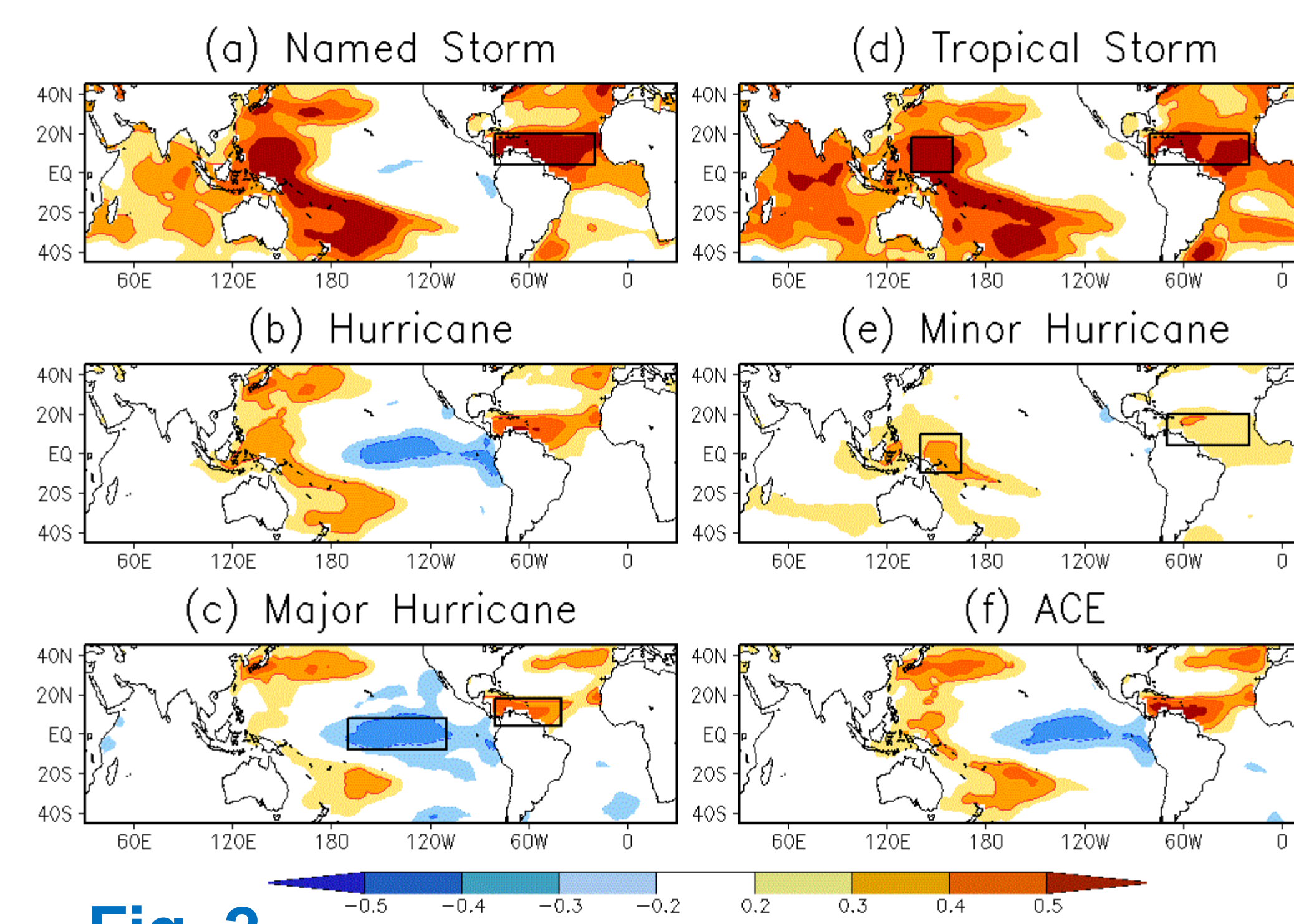


Fig. 2

Regions of high correlations used to create predictors:

- 2 SST predictors
- 1 wind shear predictor

Fig. 3. Correlations between ASO SST and the detrended tropical cyclones in the different groups over the 72 years.

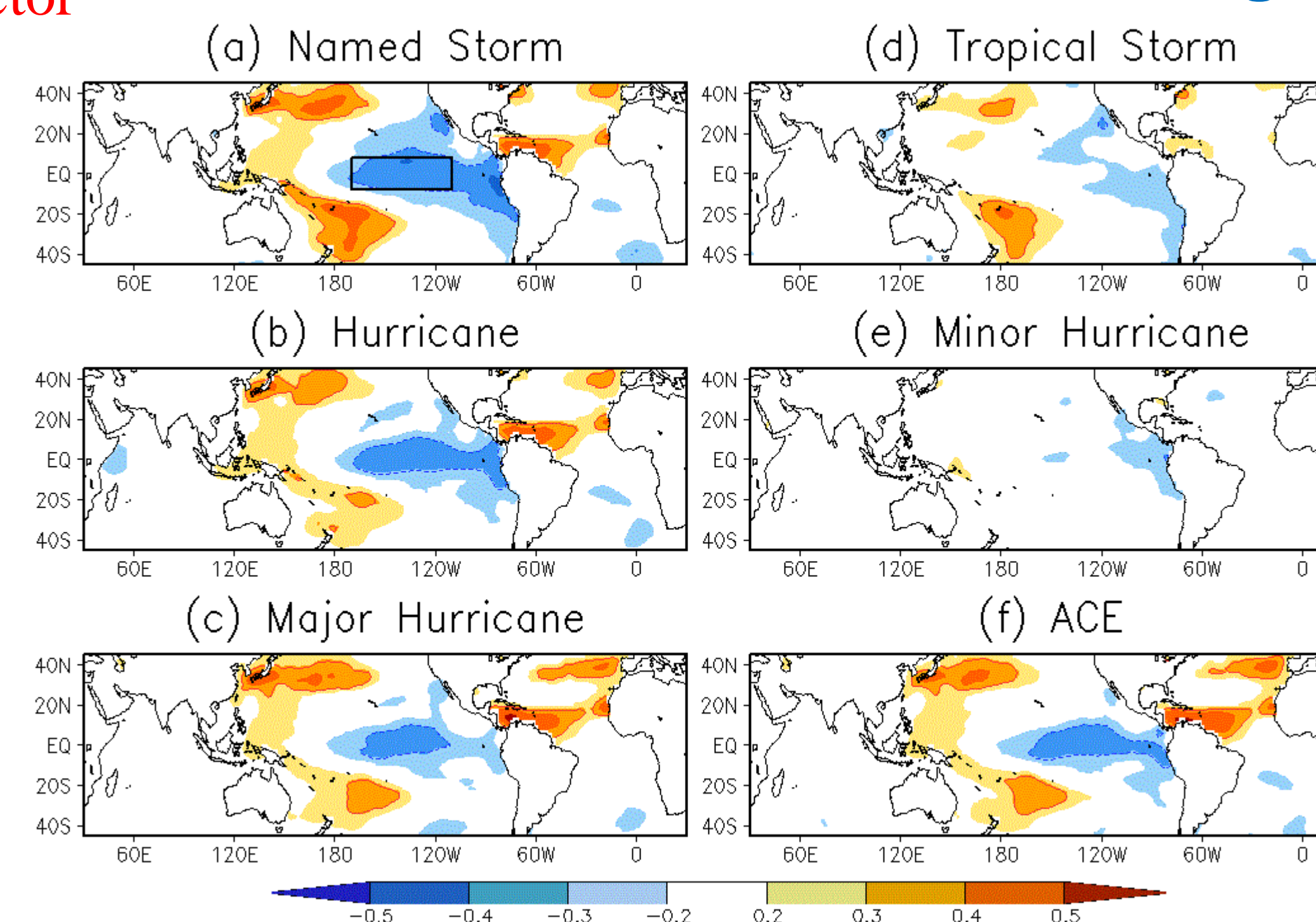


Fig. 3

Relationships between wind shear and tropical cyclones

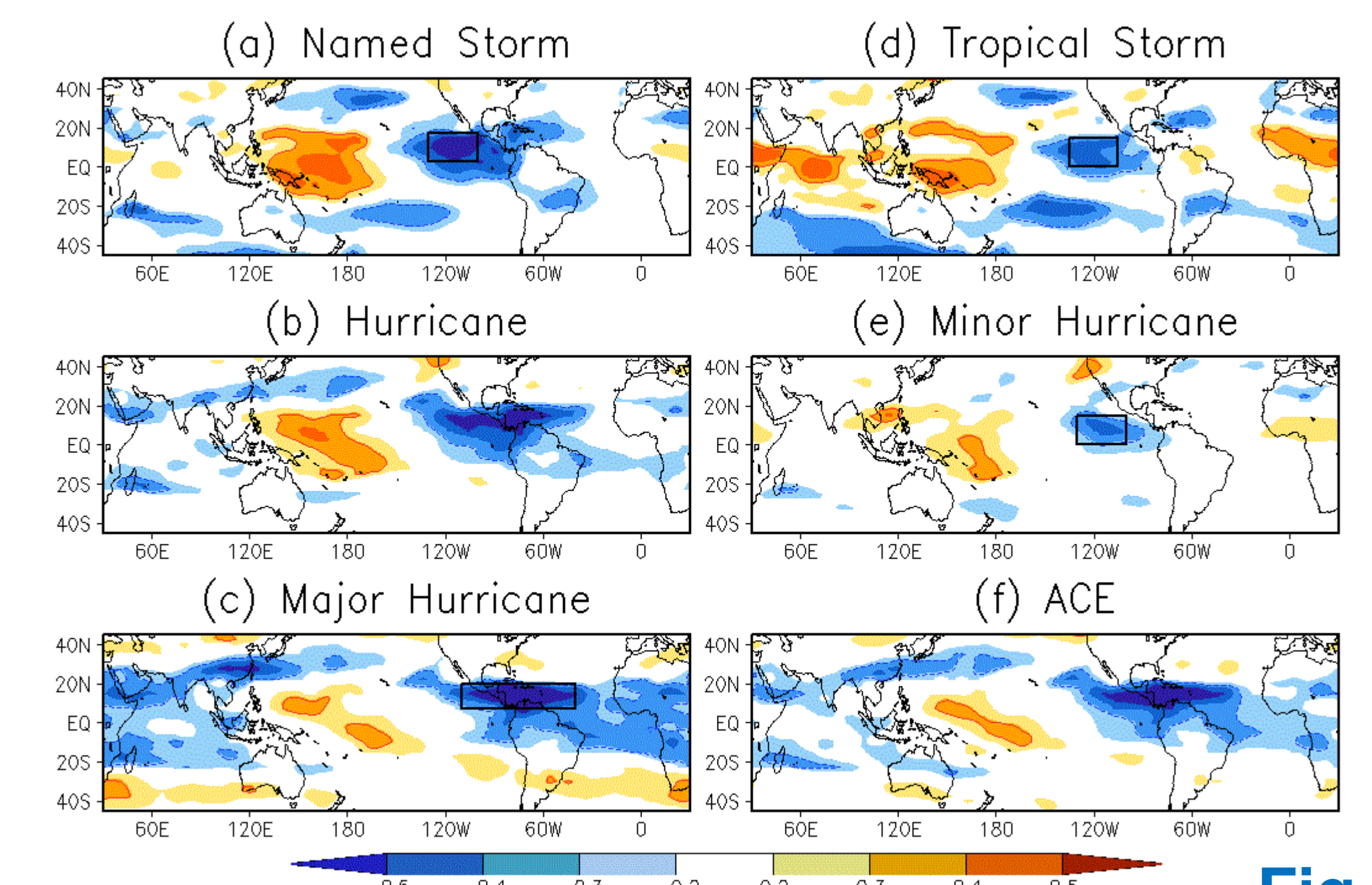


Fig. 4

Fig. 4. Correlations between ASO wind shear and Atlantic tropical cyclones in different groups over the 72 years from 1948 to 2019.

Potential predictability

Fig. 5. Time series of observed (black) and forecasted (red) tropical cyclone anomalies from 1984 to 2019, based on cross-validations with a multiple linear regression model, one wind shear predictor and two SST predictors. Green curve in (d) is the sum of forecasts of TS, MinH and MH. The anomaly correlation (AC) skill is also listed.

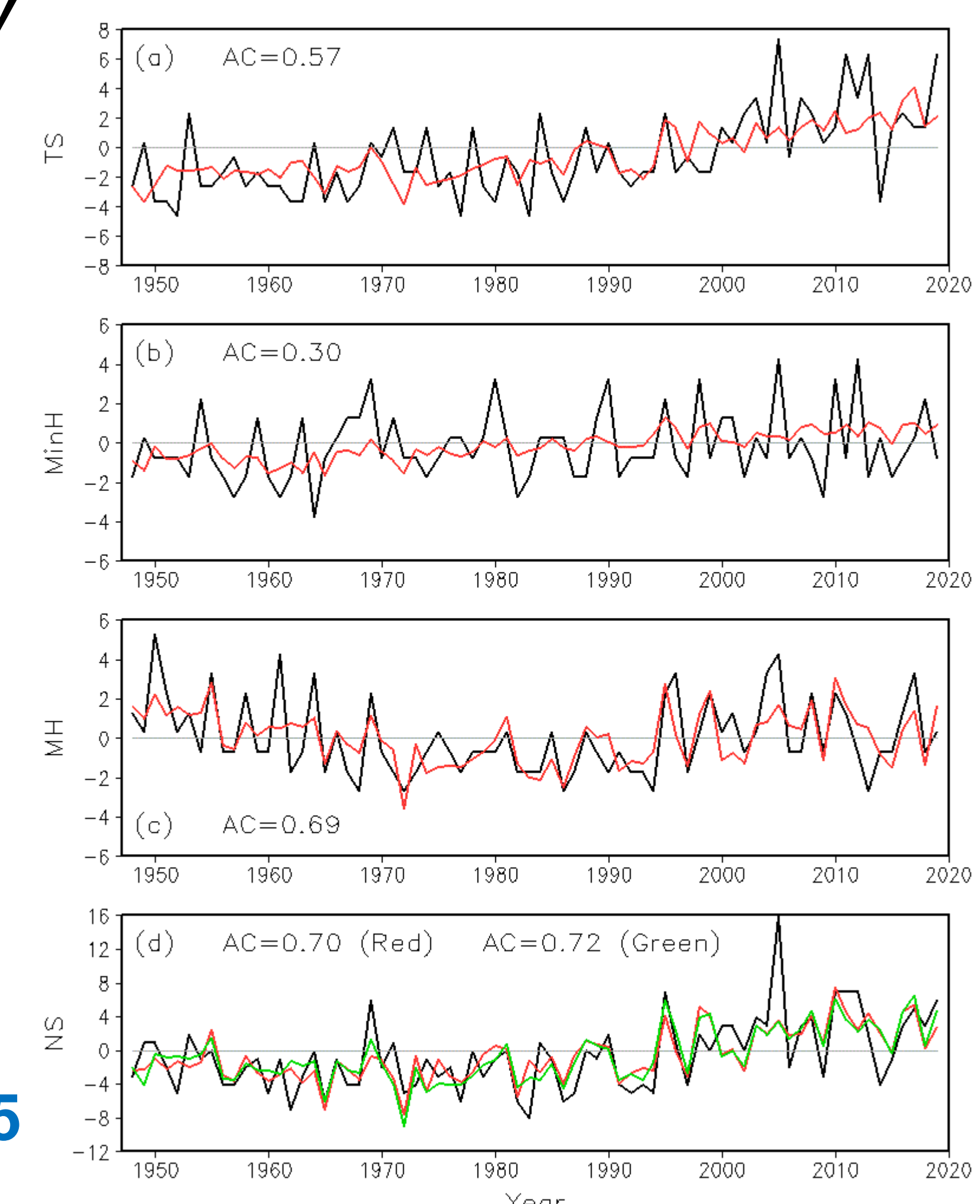


Fig. 5

4. Conclusions

- Atlantic tropical storms (TS), minor hurricanes (MinH) and major hurricanes (MH) experience different long-term changes, with an increasing trend, small variations, and multidecadal variations, respectively.
- The observed increasing Atlantic tropical cyclone activity in recent two decades is largely due to the increase in TS.
- TS, MinH, and MH show different relationships with SST and wind shear. Based on these relationships, MH has a high potential predictability and MinH has a low predictability.

Email Contact: hui.wang@noaa.gov