Multi-Year Prediction of Atlantic Tropical Cyclones

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Multi-Year Prediction of Atlantic TCs

- Compared to S2S prediction, multi-year prediction of TC activity is less well studied despite its significant value in various sectors (such as emergency management and insurance industry).
- Smith et al. (2010) showed that Atlantic hurricane frequency can be predicted at lead times of a few years using the Met Office Decadal Climate Prediction System (DePreSys)
- In a follow-up study, Dunstone et al. (2011) suggested that the Atlantic subpolar SST is an important source of multi-year predictability for the tropical Atlantic atmospheric circulation and Atlantic TCs.
- Vecchi et al. (2013) and Caron et al. (2014) emphasized the importance of the SST in the Atlantic Main Development Region (MDR) relative to the global tropics, and they skillfully predicted the Atlantic multi-year hurricane frequency using a Poisson regression model.
- *The mechanisms of multi-year predictability for Atlantic TC are not well understood.*
- *Most studies didn't detrend the data, and the linear trend can substantially inflate the prediction skill.*

Objective

- Present a skillful hybrid prediction model for Atlantic TC activity (TC and hurricane freq, landfall TC activity) using SST prediction from a large-ensemble, dynamical prediction dataset.
  - What is the relative importance of tropical and extratropical SST in the multi-year prediction of Atlantic TC activity?
  - How sensitive is the hybrid model to the ensemble size of the dynamic prediction?
  - Does ocean initialization help increase the prediction skill?
  - What are the possible underlying mechanisms for the skillful prediction?

A large ensemble of initialized decadal prediction

- The ensemble decadal prediction was carried out by the NCAR using the Community Earth System Model (CESM-DP) (Yeager et al. 2018).
- Consists of coupled atmosphere, ocean, land, and sea ice component models; approximately 1° horizontal resolution in all model components, too coarse to explicitly resolve TCs
- The dataset is comprised of 10-year prediction initialized on Nov 1 every year from 1954-2015 (62 years) and consists of 40 ensemble members.
- The CESM-DP uses the same code base, component model configurations, and radiative forcing as in the CESM Large Ensemble (CESM-LE; Kay et al. 2015), but the ocean and sea ice were not initialized in the CESM-LE.

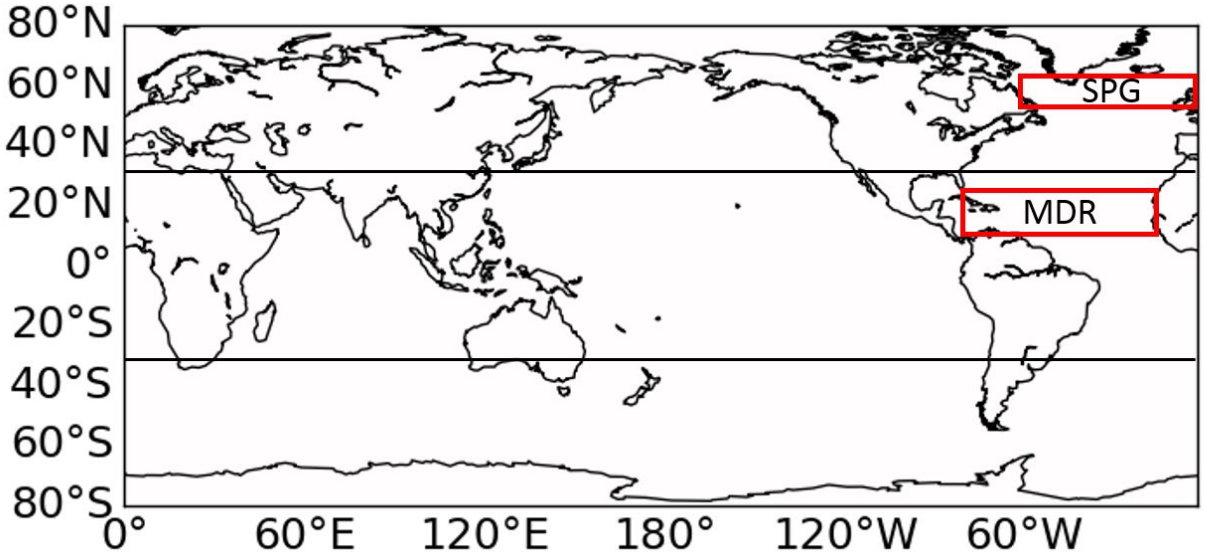
Hybrid Prediction

- TC indices (Jun-Nov):
  - basin-wide: TC frequency, hurricane (>= 64 knots) frequency, accumulated cyclone energy (ACE)
  - Landfalling: TC frequency, hurricane frequency
- A **Poisson** model for Atlantic TC activity (TC frequency, ACE, hurricane frequency, landfalling TC or hurricane frequency)

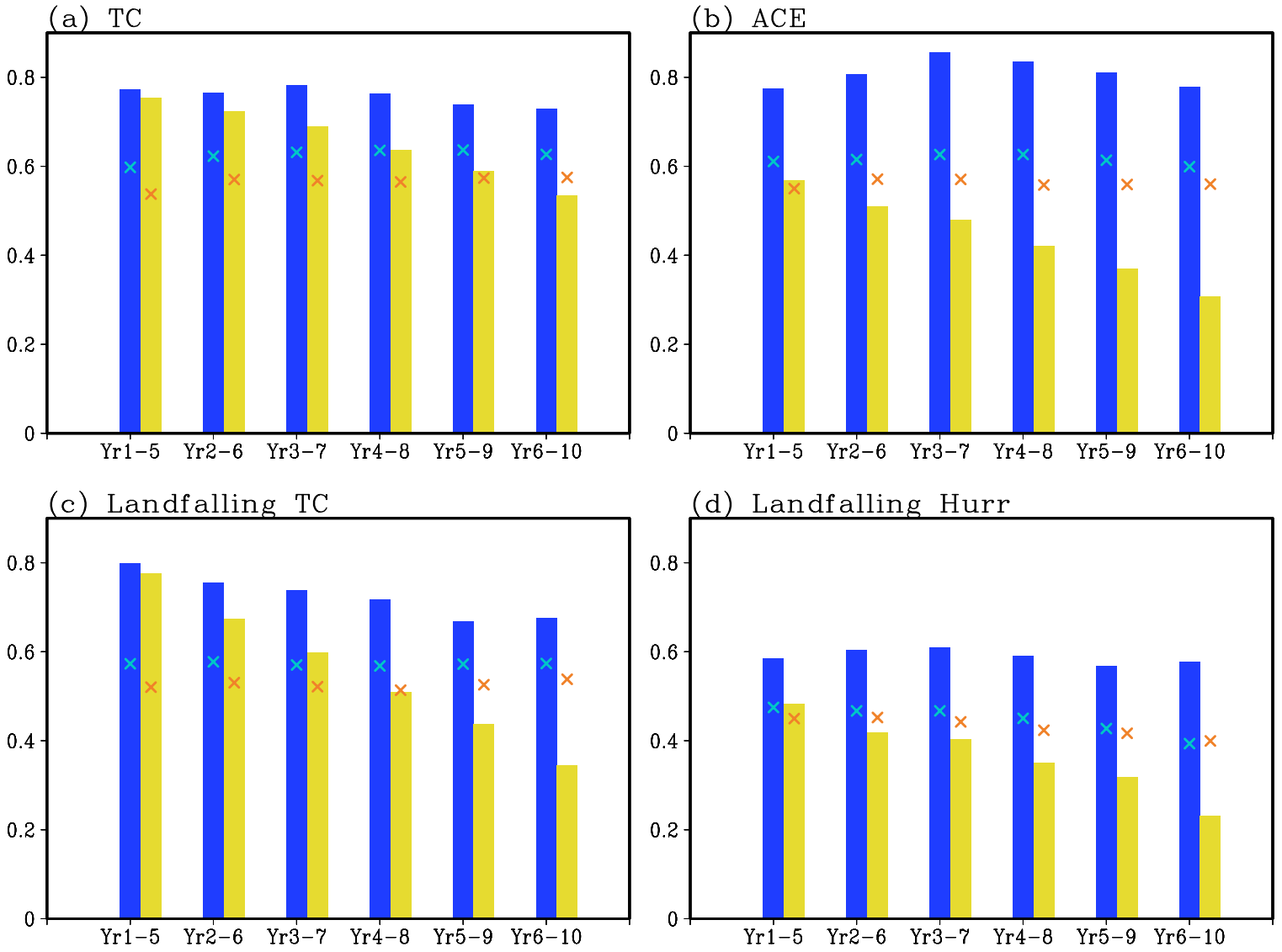
$$\lambda = \exp(a_0 + a_1 MDR + a_2 SPG)$$

where λ represents a TC index, MDR represent the MDR (10-20N, 20-80W) relative SST index, and SPG (50-60N, 10-50W) represents the subpolar Atlantic SST index.

- All data are **detrended**
- Prediction skill: assessed by the anomaly correlation coefficient (**ACC**) between the prediction and observation using leave-one-out against the IBTrACS data.
- We focus on 5-year mean, and the degree of freedom is adjusted following Chelton (1984)



ACC of Tropical Cyclone Prediction



Blue: two predictors, SPG+MDR SST;

Yellow: one predictor, MDR SST

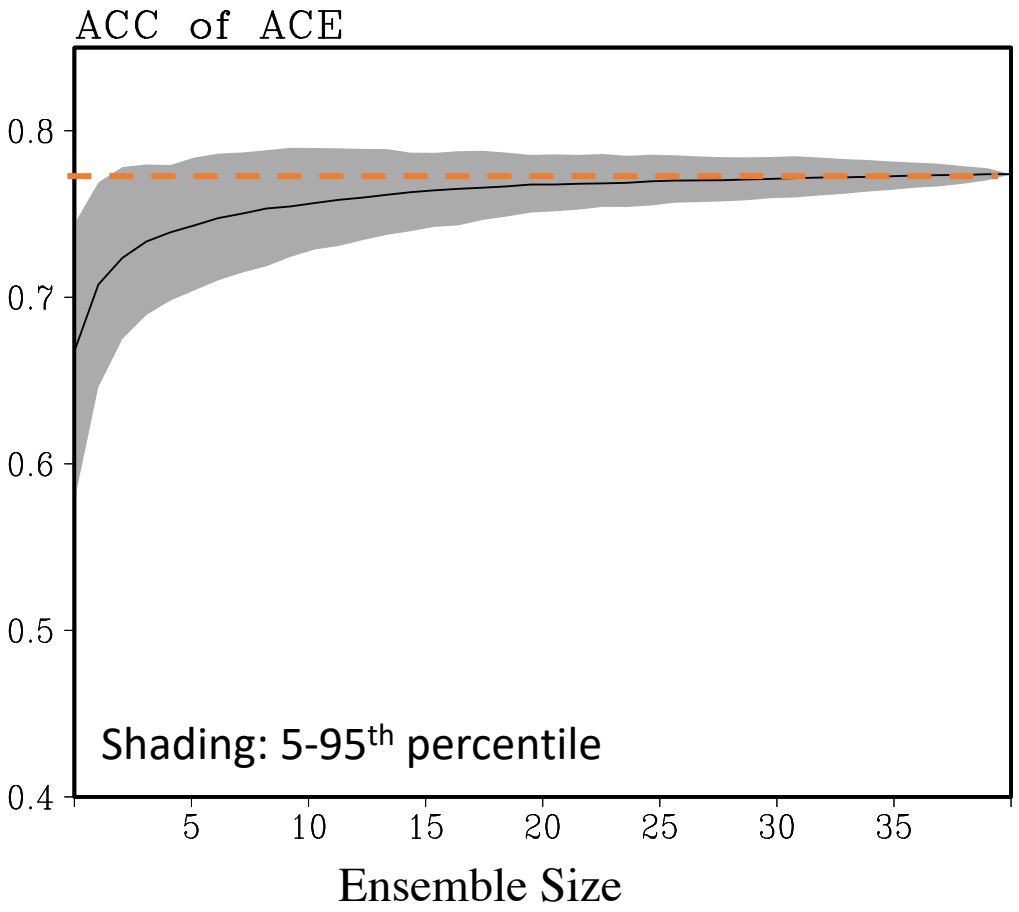
Zonal axis: lead times

Bars: ACC;

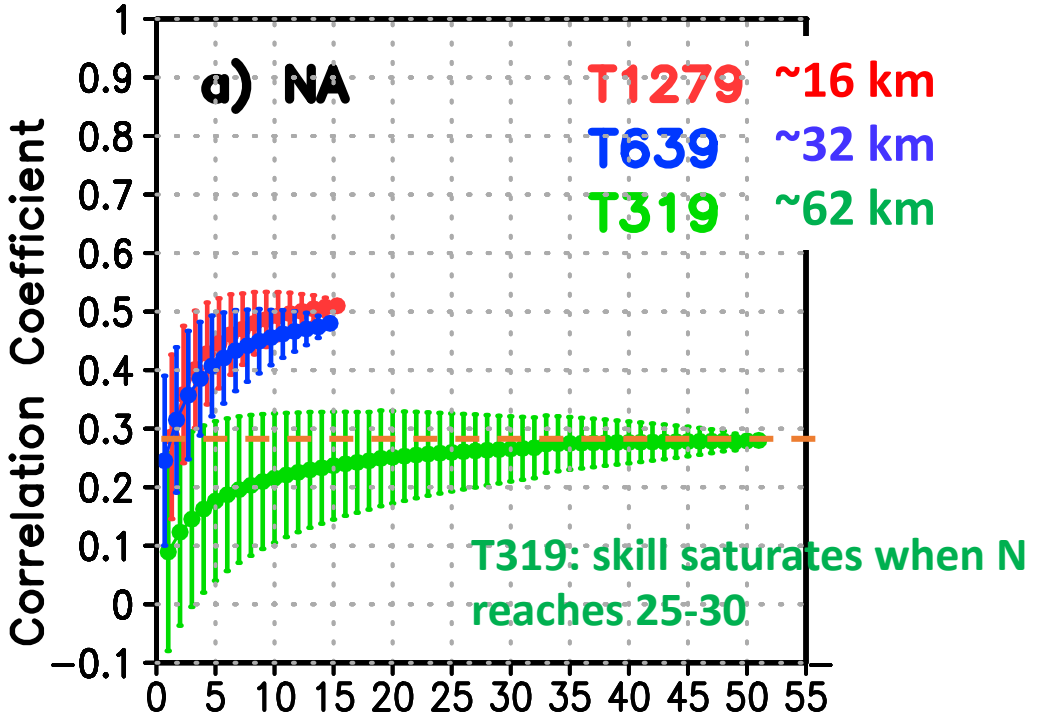
X: 95% confidence level with adjusted DOF

- The hybrid prediction employing MDR + SPG skillfully predicts TC activity
- The SPG predictor contributes to the prediction ACE and hurricane frequency.

Prediction Skill as a Function of Ensemble Size



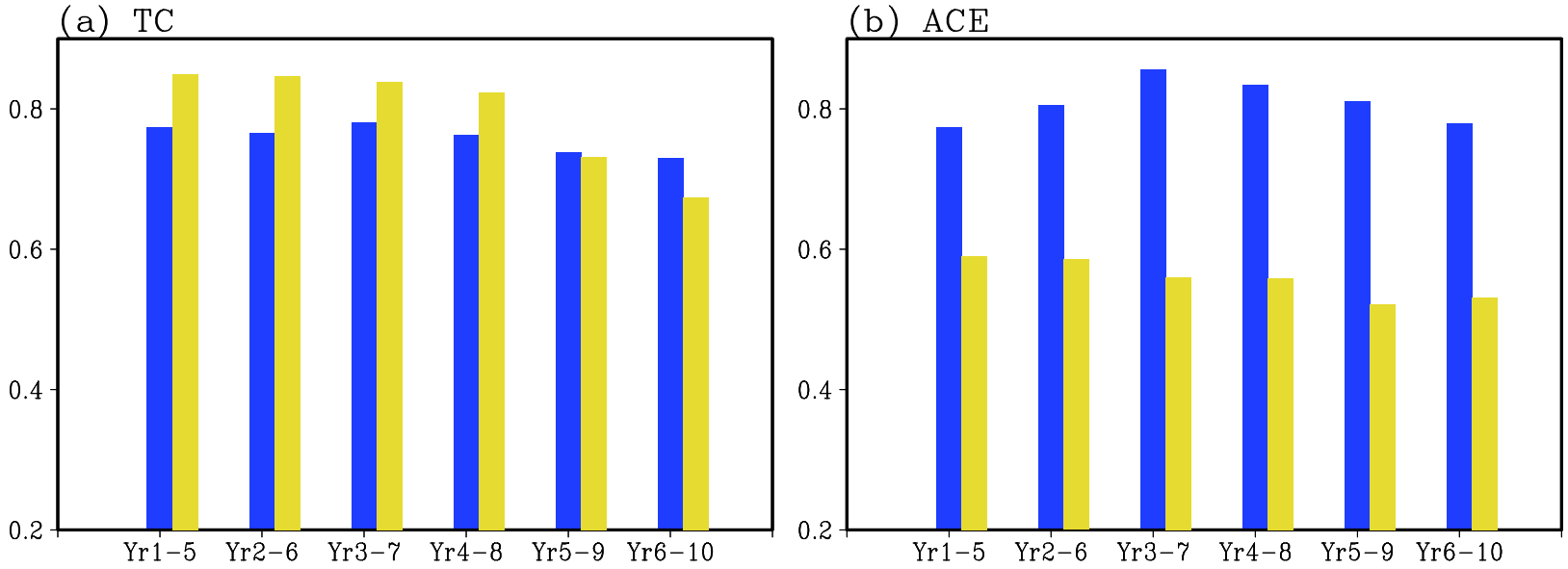
Dynamical seasonal prediction using ECMWF System 4



Manganello et al. (2016): Seasonal forecasts starting from May 1 for 1980-2011

The model skill increases sharply when the ensemble size is increased from 1 to 5, and saturates when the ensemble size is 15-20. The behavior is similar to the dynamic prediction by HR models.

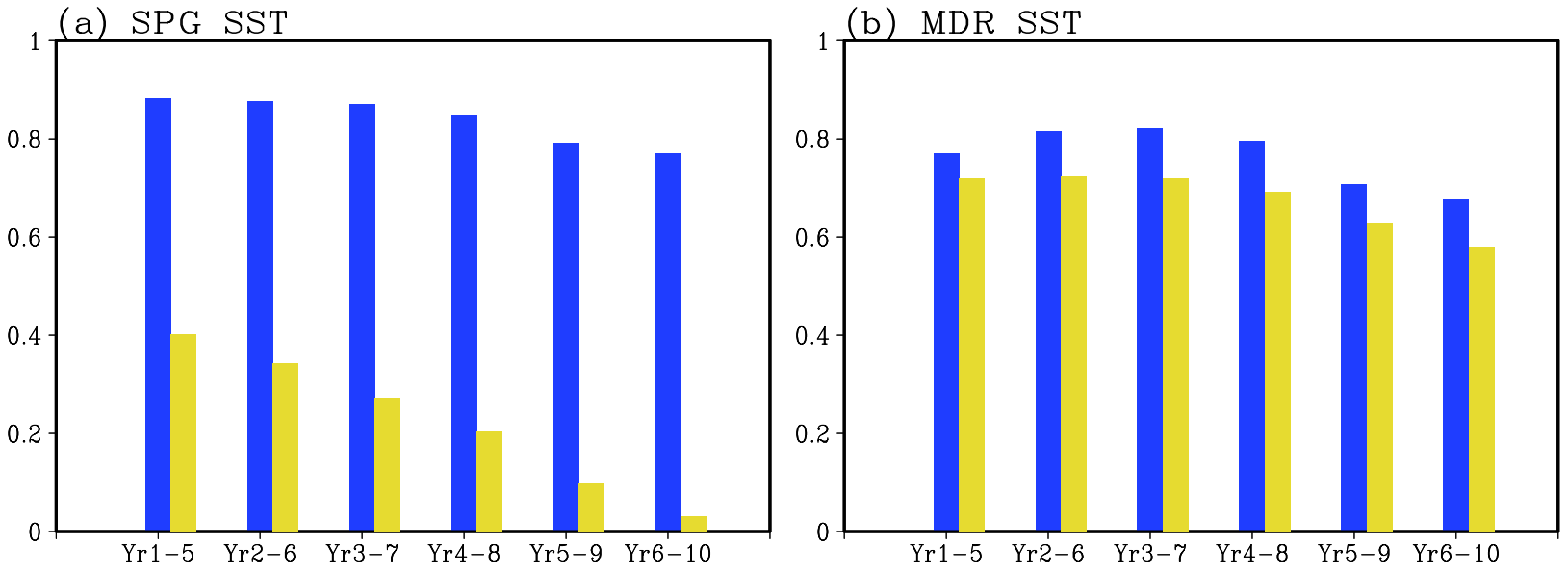
Initialized vs. uninitialized Predictions (two predictors: SPG + MDR)



Blue: initialized prediction, with the SST predictors derived from CESM-DP
Yellow: uninitialized prediction, with the SST predictors derived from CESM-LE

*Initialization of the ocean and sea ice doesn't substantially affect the prediction of TC frequency, but significantly increases the skill of ACE prediction.

Predictive Skill of the Predictors (SPG and MDR): CESM-DP vs. CESM-LE



Blue: initialized prediction, CESM-DP

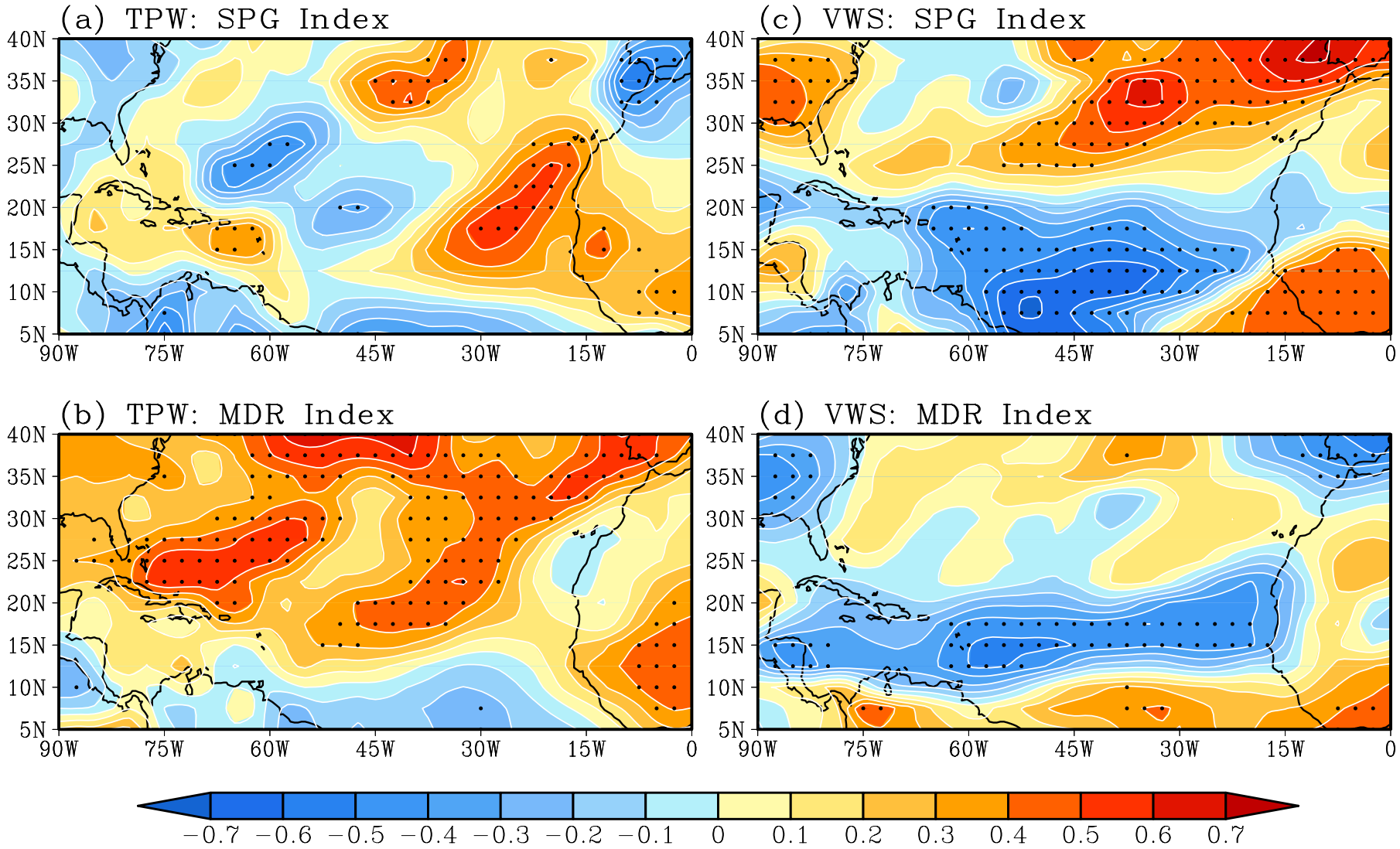
Yellow: uninitialized prediction, CESM-LE

Initialization (CESM-DP) significantly increases the skill of the SPG SST but doesn't substantially affect the MDR SST prediction. The prediction skill of hurricane frequency and ACE is more sensitive to SPG SST than the skill of TC frequency.

Large-scale Circulation Anomalies Associated with MDR vs. SPG SST: Partial Correlations (obv; Yr1-5)

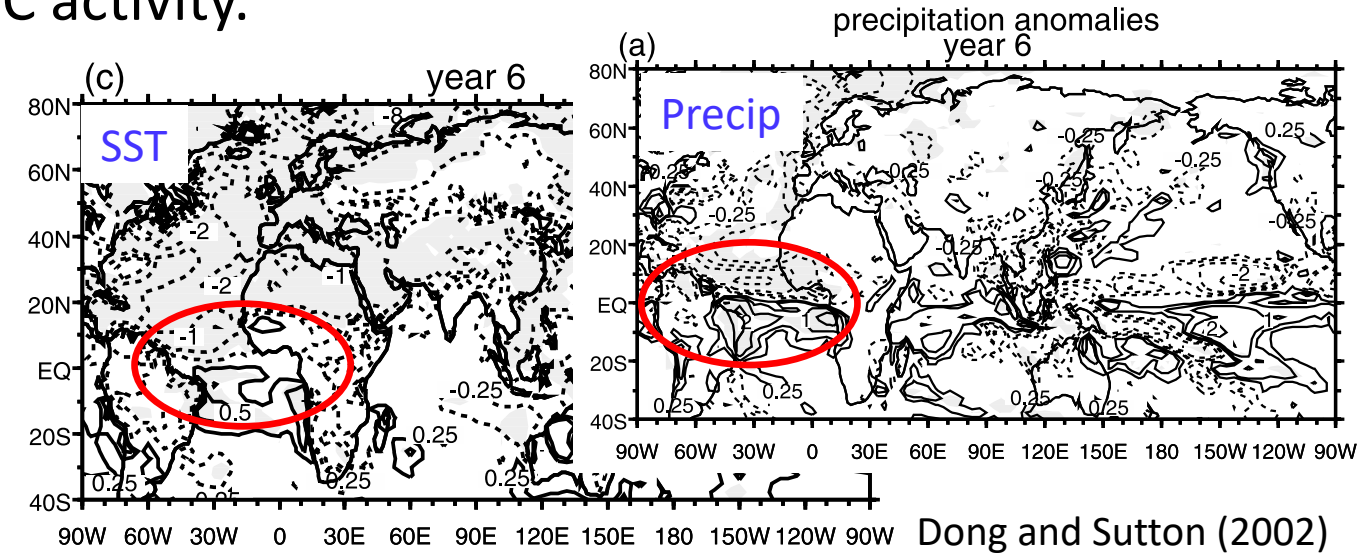
SPG SST

MDR SST



How does SPG SST affect the Tropical Atlantic:?

- Chiang et al. (2003) suggested that cooling/warming in the North Atlantic can induce a dipole SST pattern in the tropical Atlantic via wind-evaporation feedback and lead to a meridional displacement of the ITCZ.
- Dong and Sutton (2002) suggested that a sudden weakening in the Atlantic thermocline circulation induces dipolar SST anomalies in the tropical Atlantic and associated southward shift of the ITCZ.
- Smith et al. (2010) and Dunstone et al. (2011) suggested that the Atlantic subpolar SSTA may induce a latitudinal shift of the ITCZ and thus modulate Atlantic TC activity.

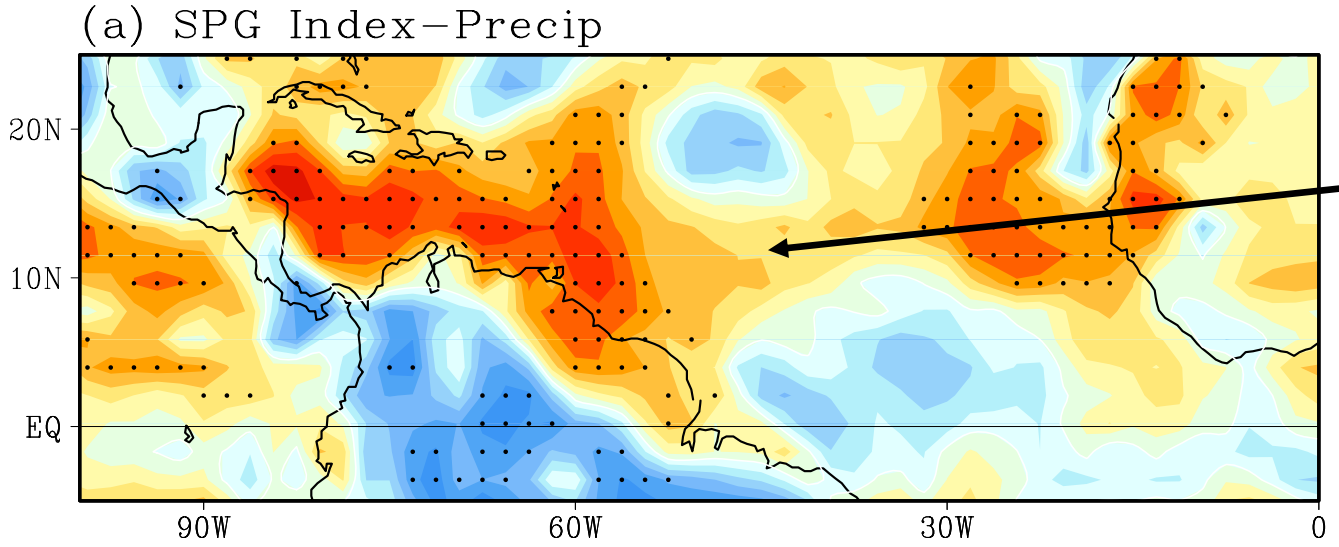


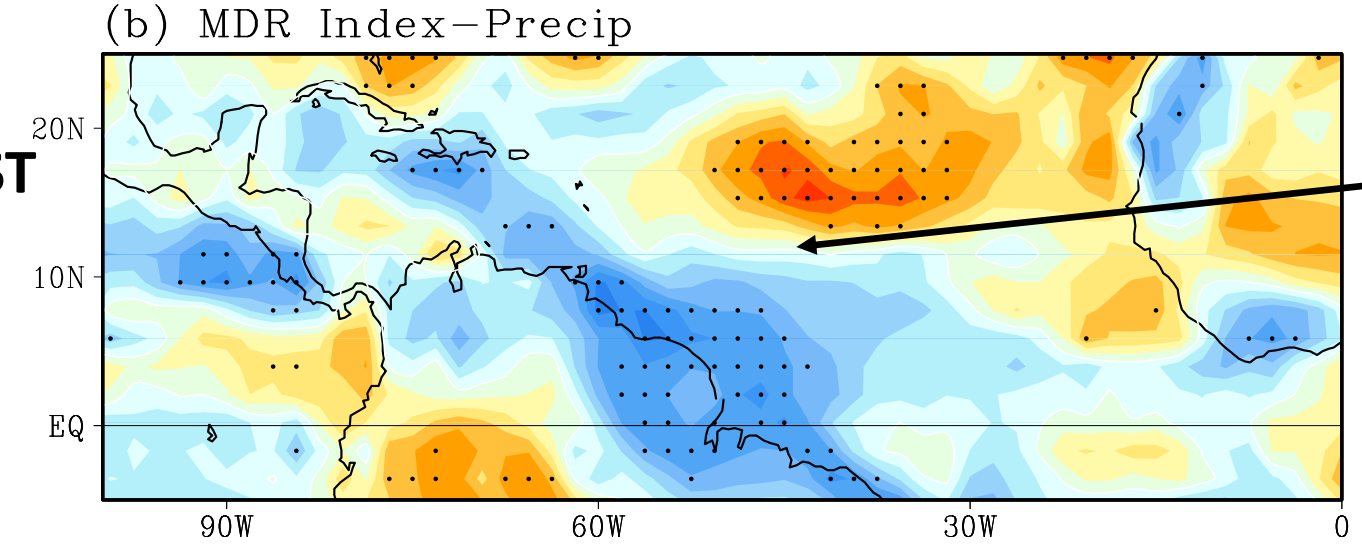
Dong and Sutton (2002)

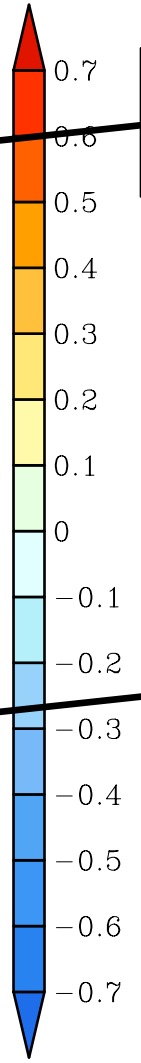
Partial Correlation of Precipitation with SPG vs. MDR SST (obv; Yr1-5)

SPG SST

MDR SST



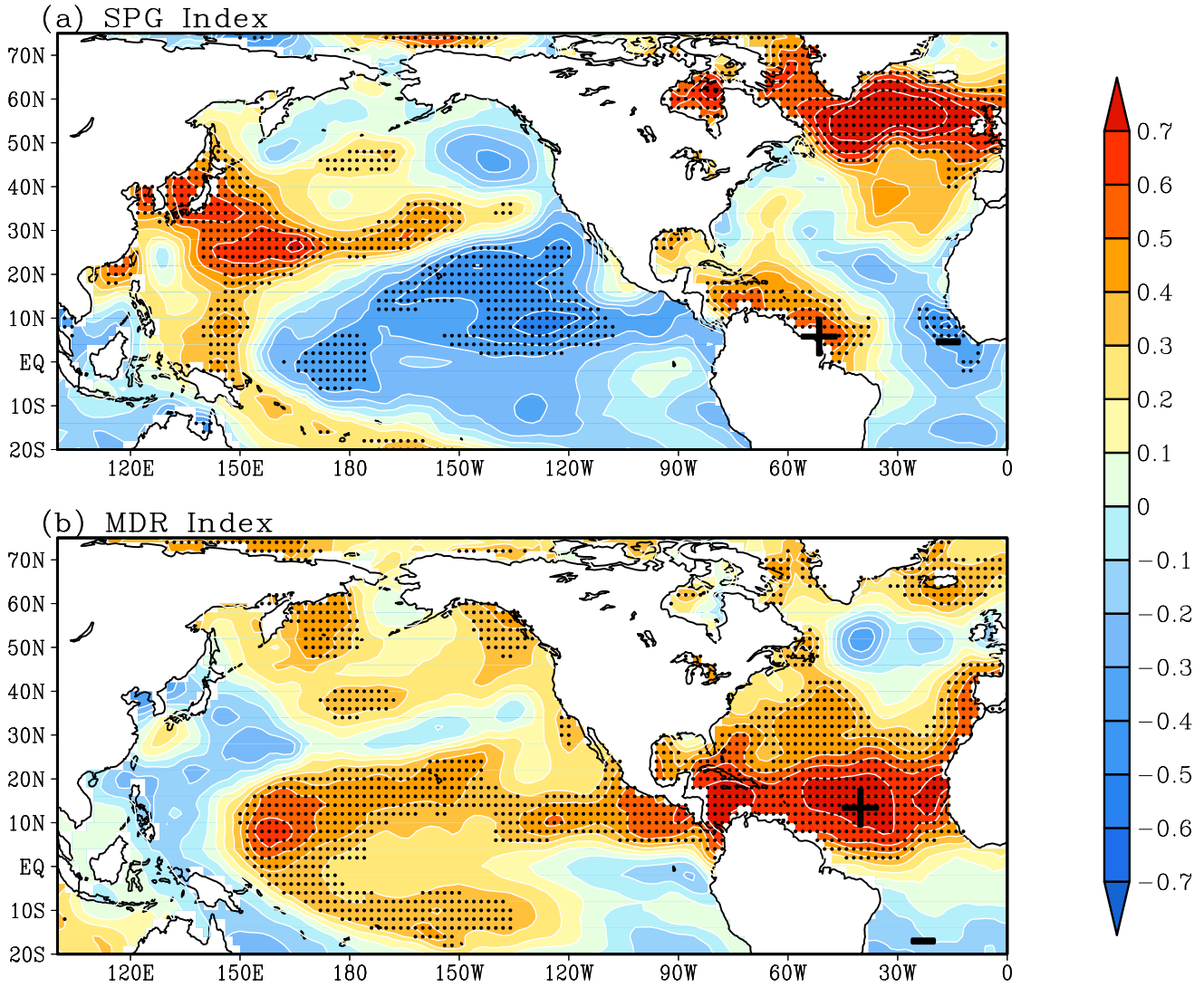




SPG SST: width and intensity change of the ITCZ

MDR SST: Latitudinal displacement of the ITCZ

Partial Corr. of SST with SPG vs. MDR Indices (ERSSTv5; YR1-5)

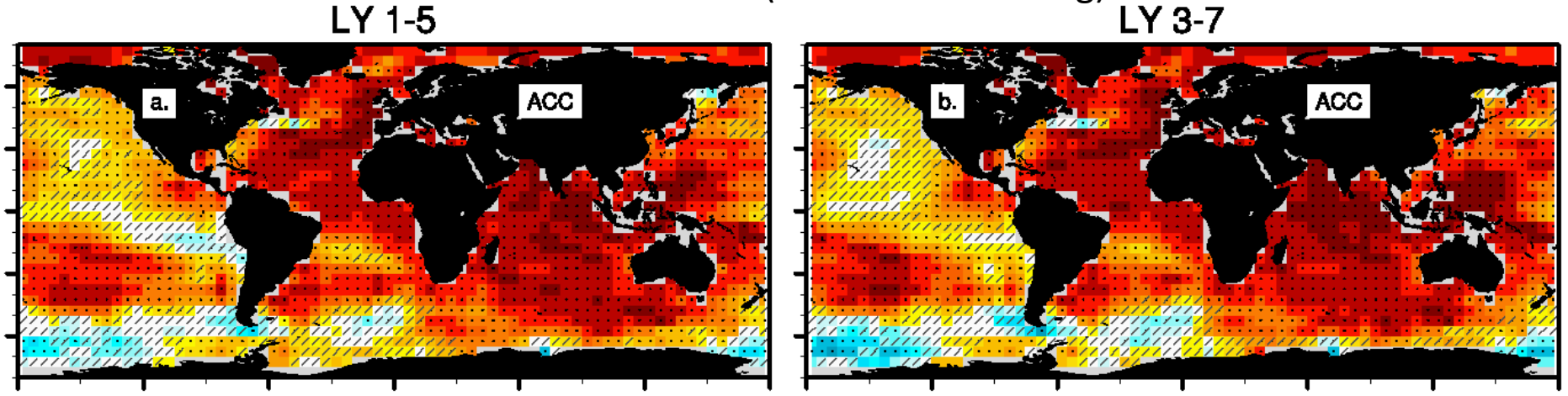


Correlation between the PDO and Atlantic TCs

	TC Freq.	Hurr. Freq.	ACE
Yearly data	**-0.39**	**-0.31**	**-0.29**
5-Yr Mean	**-0.63**	-0.44	-037

Bold: above 95% confidence level

ACC of SST between CESM-DPLE and ERASST (without detrending)



Yeager et al. 2018

Summary

- A skillful hybrid prediction model is developed to predict Atlantic TC activity using the CESM large ensemble decadal predictions.
- The prediction skill increases sharply when the ensemble size increases from 1 to 5 and saturates when the ensemble size reaches 15-20.
- Ocean initialization increases the prediction skill of hurricane freq. and ACE but doesn’t affect substantially the prediction of TC frequency.
- Compared to the prediction solely based on MDR SST, SPG SST provides added value to the prediction of ACE and hurricane frequency.
- SPG SST may affect the tropical Atlantic atmosphere and hurricane activity via the Pacific ocean (needs further testing).