Can we predict seasonal changes in high impact weather in the United States?

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Summary and Conclusion

Severe storms threaten lives throughout the United States (US) every year, suggesting that any predictive capability is of great societal benefit. While it is well recognized that predicting individual tornado outbreaks is only possible a few hours in advance, the large-scale background atmospheric conditions that influence the likelihood of tornado outbreaks may be more predictable.

Severe storms occur most readily when Convective Available Potential Energy (CAPE) and vertical wind shear both are large in a local environment. During May-June-July (MJJ), the evolution (not shown) and geographical location of CAPE is similar to the combination of CAPE and shear, and further, shear (climatology and variance) is weak (**Fig. 1**). Hence, in this study, CAPE is used as background state in which variations create conditions that are more or less favorable for severe weather occurrence (**Fig. 1 and Fig. 2**).

We analyzed 30 years of MJJ predicted CAPE from May 1st initialized forecasts from NCAR CCSM4. The forecasts were compared with observational estimates from North American Regional Reanalysis (NARR). The results show that an area-averaged SST anomaly in the Gulf of Mexico (GoM index) is a possible predictor for forecasting CAPE anomalies in the US: The warmer the SST in the Gulf of Mexico (GoM), the higher CAPE in the contiguous US during MJJ months (**Fig. 3**). The mechanism behind the correlation between GoM index and CAPE in the US is due to variations in moisture transport from the GoM to US (**Fig. 4**). Considering our current ability to predict SST in the GoM (**Fig. 5**) compared to the difficulty of predicting high-impact weather in the US, the findings are promising for the seasonal prediction of enhanced or decreased tornado activity in the US during MJJ using the GoM SST. This study further emphasizes that the influence of ENSO (contemporaneous as well as antecedent winter ENSO) in the Gulf of Mexico SST (and ultimately tornado activity in the US) is weak during MJJ, and there is no clear relationship between US CAPE and ENSO during MJJ (**Fig. 3**).

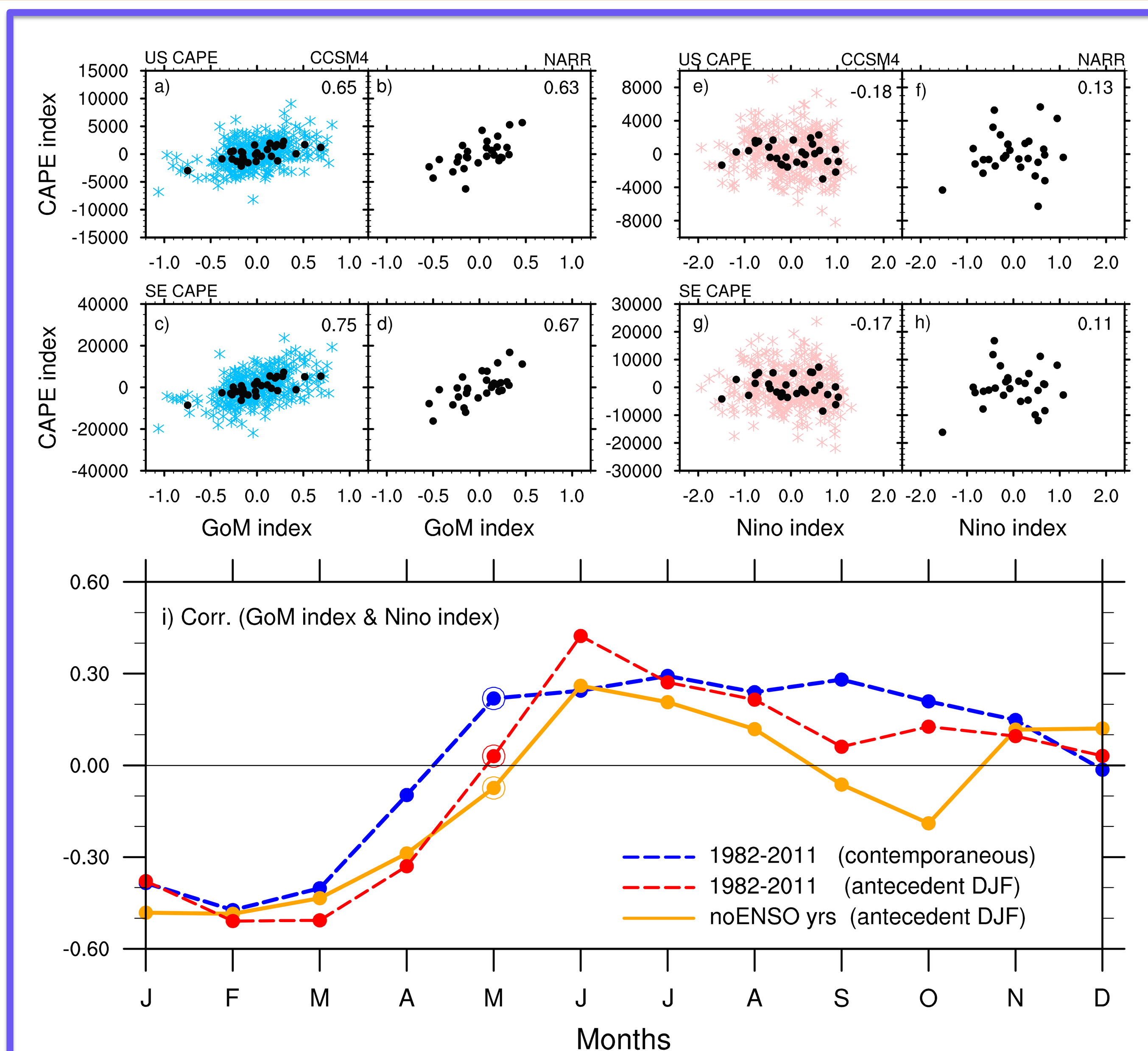

Fig. 3: (a-h) Scatter diagrams of CAPE indices (J/kg) with GoM (left) and Niño 3.4 (right) indices (°C) during MJJ from forecasts and observational estimates. The CAPE indices are calculated by averaging daily CAPE anomalies in the US (US CAPE) and in the southeast US (SE CAPE; 30-40°N, 85-100°W). The GoM index and Niño 3.4 index are each an area-averaged SST anomaly in their representative regions (20-30°N, 82-98°W; 120-170°W and 5ºS-5ºN). Individual forecast ensemble members are shown as colored asterisks, and the ensemble mean and NARR as black dots. The correlations between two indices are shown in the upper right corner in each box.
(i) Contemporaneous and antecedent ENSO influence on the Gulf of Mexico SST. Correlations are calculated first from all years 1982-2011 and second by excluding strong ENSO years. Strong ENSO years used are: 1982/1983, 1988/1989, 1997/1998, 2011/2012. Three-month mean values are used to calculate the correlation, for example, correlation shown in May (M) is calculated from SST anomalies during May-July months.

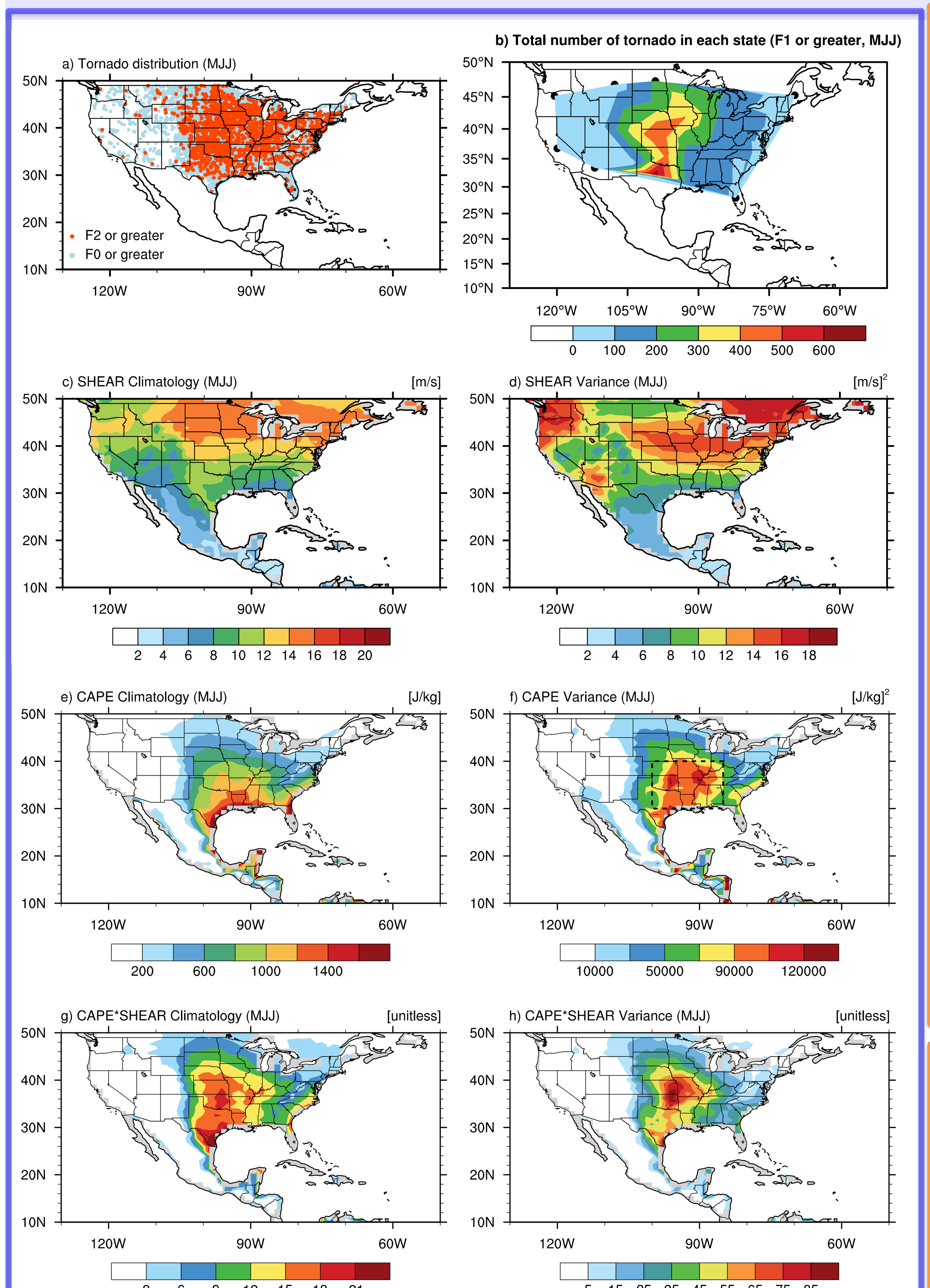

Fig. 1: (a-b) The distribution and total number of tornadoes during MJJ (May-June-July). Climatology and variance of (c-d) 0-6 km shear, (e-f) CAPE, and the (g-h) combination of CAPE and shear during MJJ.

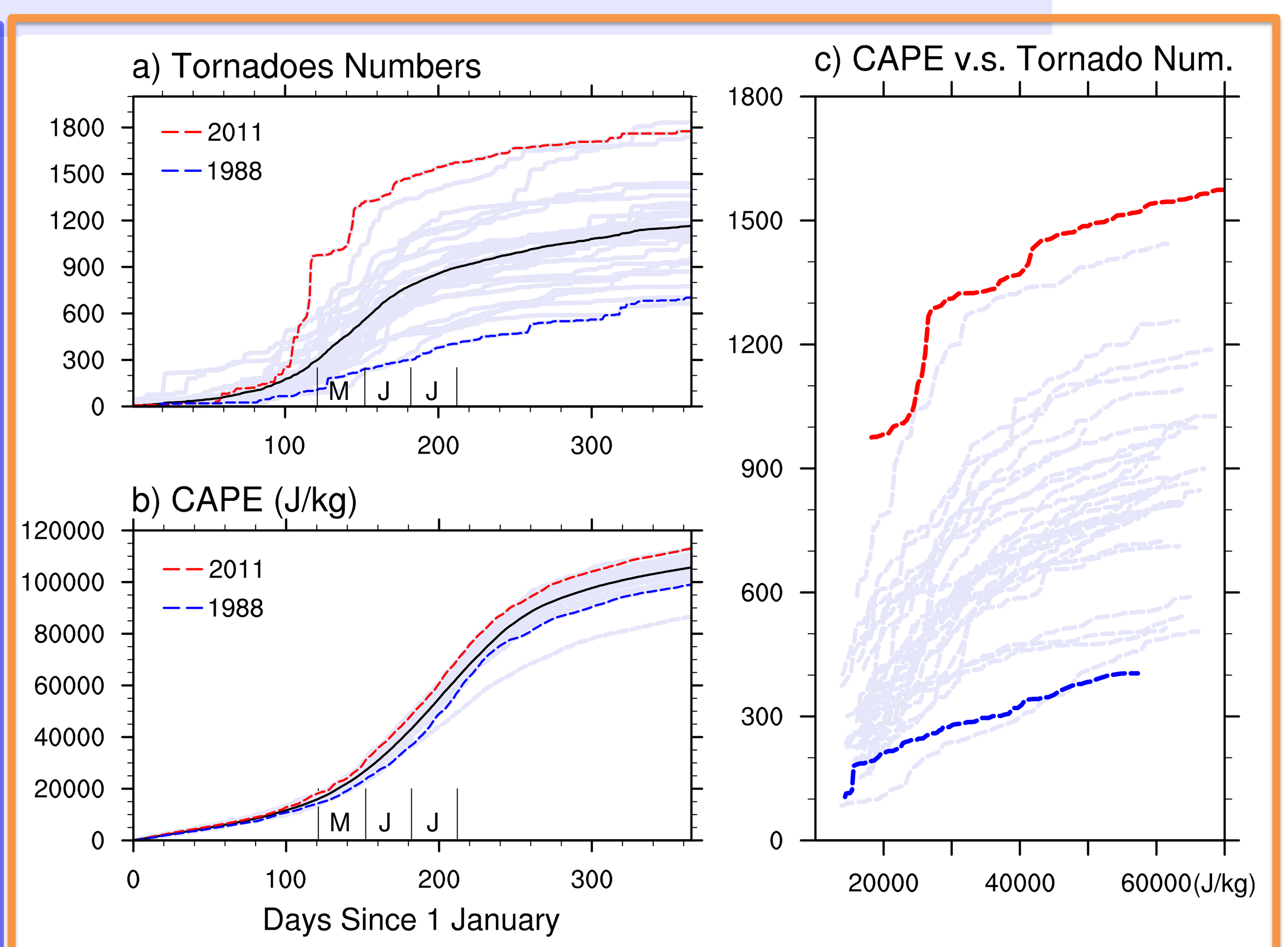

Fig. 2: Accumulated CAPE and accumulated number of tornadoes in the US for 1982-2011. The lavender shading represents (a) tornado numbers and (b) CAPE for each year, and the climatology is shown as a solid black line. Accumulated MJJ CAPE versus accumulated MJJ tornado numbers are shown in (c). Individual years 2011 (red) and 1988 (blue) are shown as dashed lines.

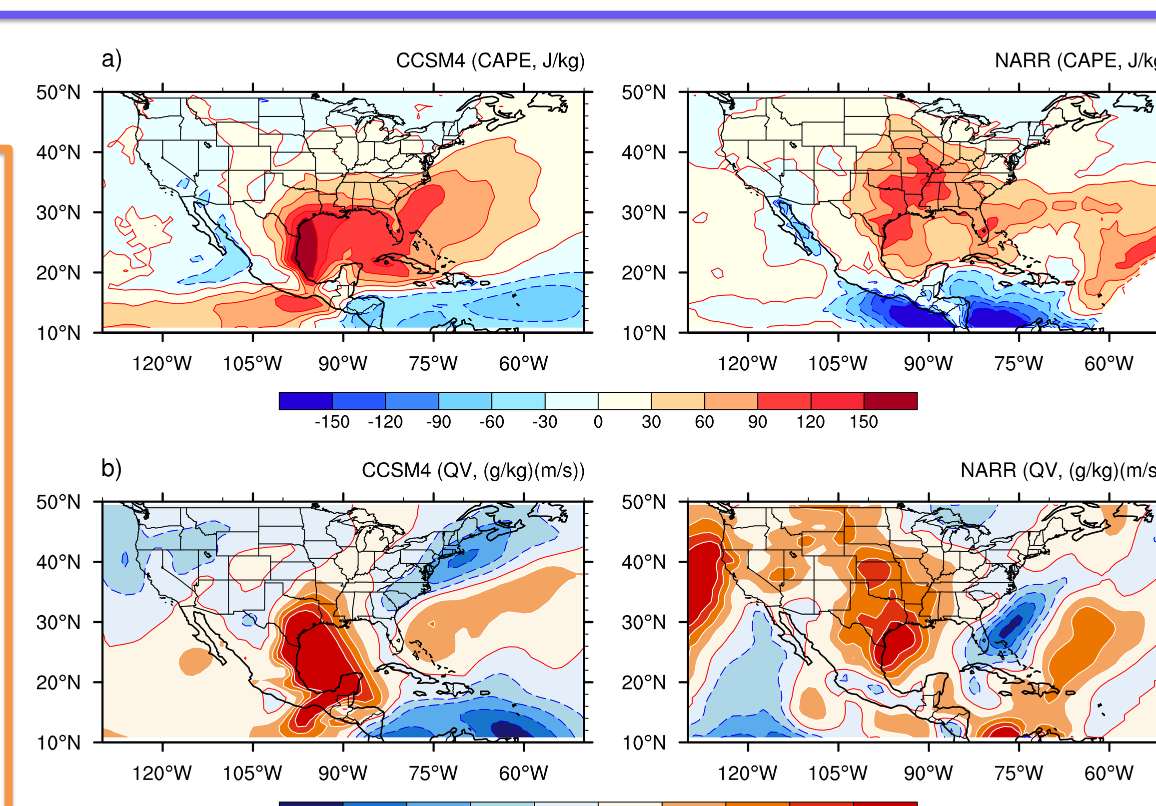

Fig. 4: (a) CAPE anomaly composite maps [J kg^{-1}] associated with warm SST anomaly in the Gulf of Mexico, in the CCSM4 forecasts (left) and NARR (right) for 1982-2011. MJJ CAPE anomalies were averaged for all years of positive GoM indices.
(b) Composite maps of northward moisture transports [QV, (g kg^{-1})(m s^{-1})] associated with warm SST anomaly in the Gulf of Mexico, in the CCSM4 (left) and NARR (right). The MJJ seasonal mean is accumulated from 1000 hPa to 850 hPa for all years of positive GoM indices.

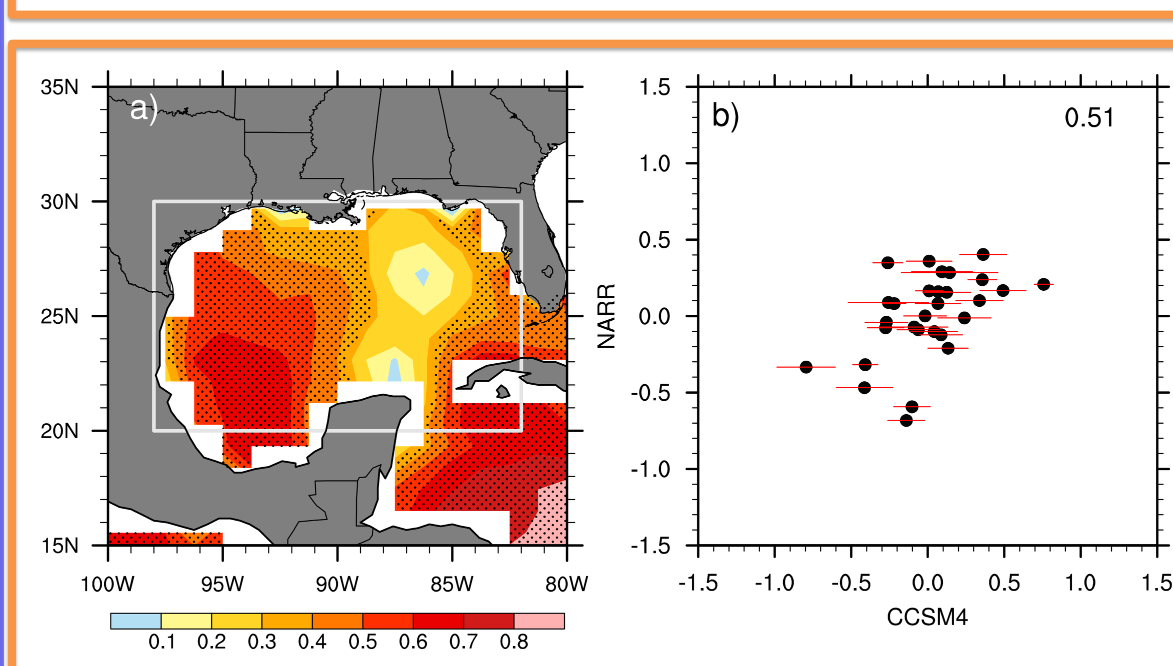

Fig. 5: Seasonal prediction skill of SST in the Gulf of Mexico. (a) Point-correlation between observed and predicted SST anomalies. The stippled areas are statistically significant at the 90% confidence level. (b) Scatter diagram of observed and predicted GoM index. The area used for calculating the GoM index is shown as a box in (a). Standard deviations of the individual forecast ensemble members are shown as red horizontal bars, and the ensemble mean is shown as black dots. The correlation between the two indices is shown in the upper right corner.

Acknowledgments

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