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 large 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 maybe more predictable.

Severe storms occur most readily when CAPE and vertical wind shear both are large in a local environment. During May-June-July, 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, Convective Available Potential Energy (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 May-June-July (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, 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 Gulf of Mexico to US (**Fig. 4, Fig. 5**). Considering our current ability to predict SST (**Fig. 6**) compared with the ability to predict the severe storms, the findings provide some hope for the seasonal prediction of high impact weather in the US. This study further shows that there is no clear contemporaneous relation between US CAPE and El Niño and the Southern Oscillation (ENSO) during the peak seasons (MJJ) of tornado activity in the US (**Fig. 3**).

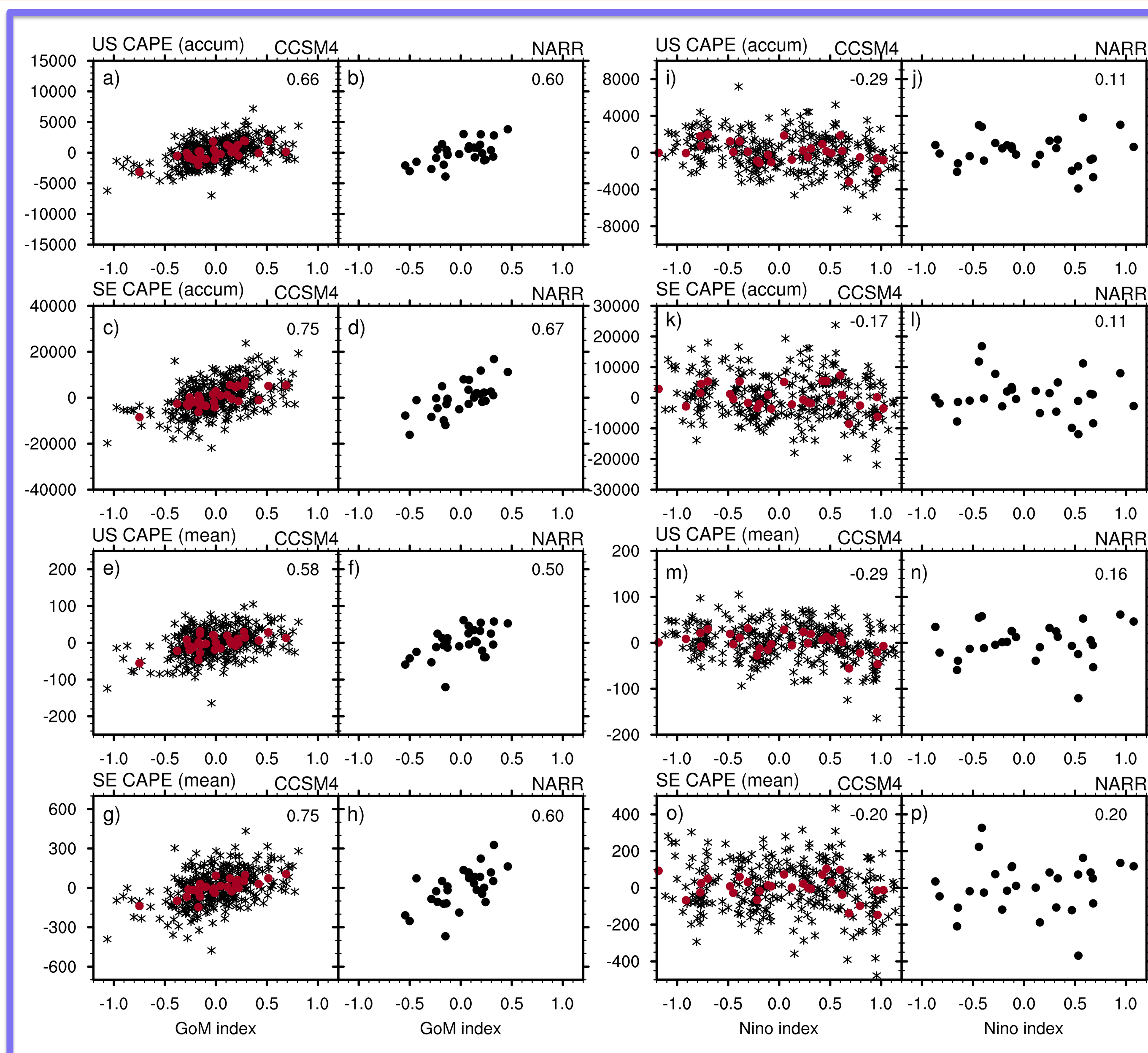

Fig. 3: Scatter diagrams of the CAPE indices with (a-h) the GoM index and (i-p) Niño 3.4 index. The GoM index is an area-averaged SST anomaly in the Gulf of Mexico. The CAPE index is calculated by averaging CAPE anomalies over the entire North America (US CAPE) and over the southeast of US (20-30°N, 230-270°W, shown as SE CAPE). Individual forecast ensemble members are shown as black asterisks and the ensemble mean is shown as red dots. The correlations between two indices are shown in the upper right corner in each box. The upper four panels show the MJJ accumulation of CAPE and the lower four panels show the MJJ mean CAPE.

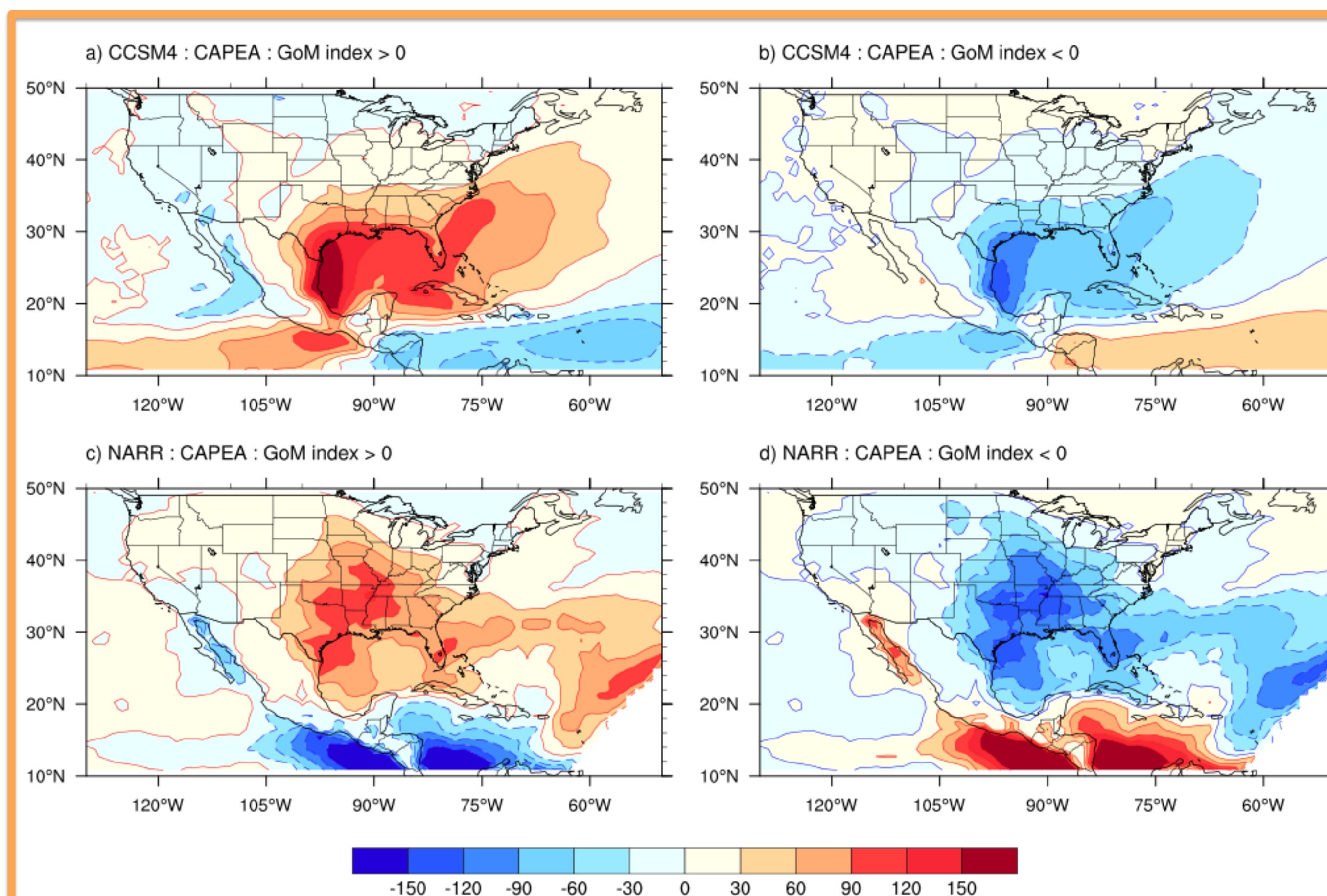

Fig. 4: The panels show CAPE anomaly composite maps [J kg^{-1}] associated with warm (left) and cold (right) SST anomaly in the Gulf of Mexico, in the CCSM4 forecasts (upper) and NARR (bottom) for the period 1982-2011. MJJ seasonal mean of CAPE anomalies were averaged for all years of positive (left) and negative (right) GoM indices.

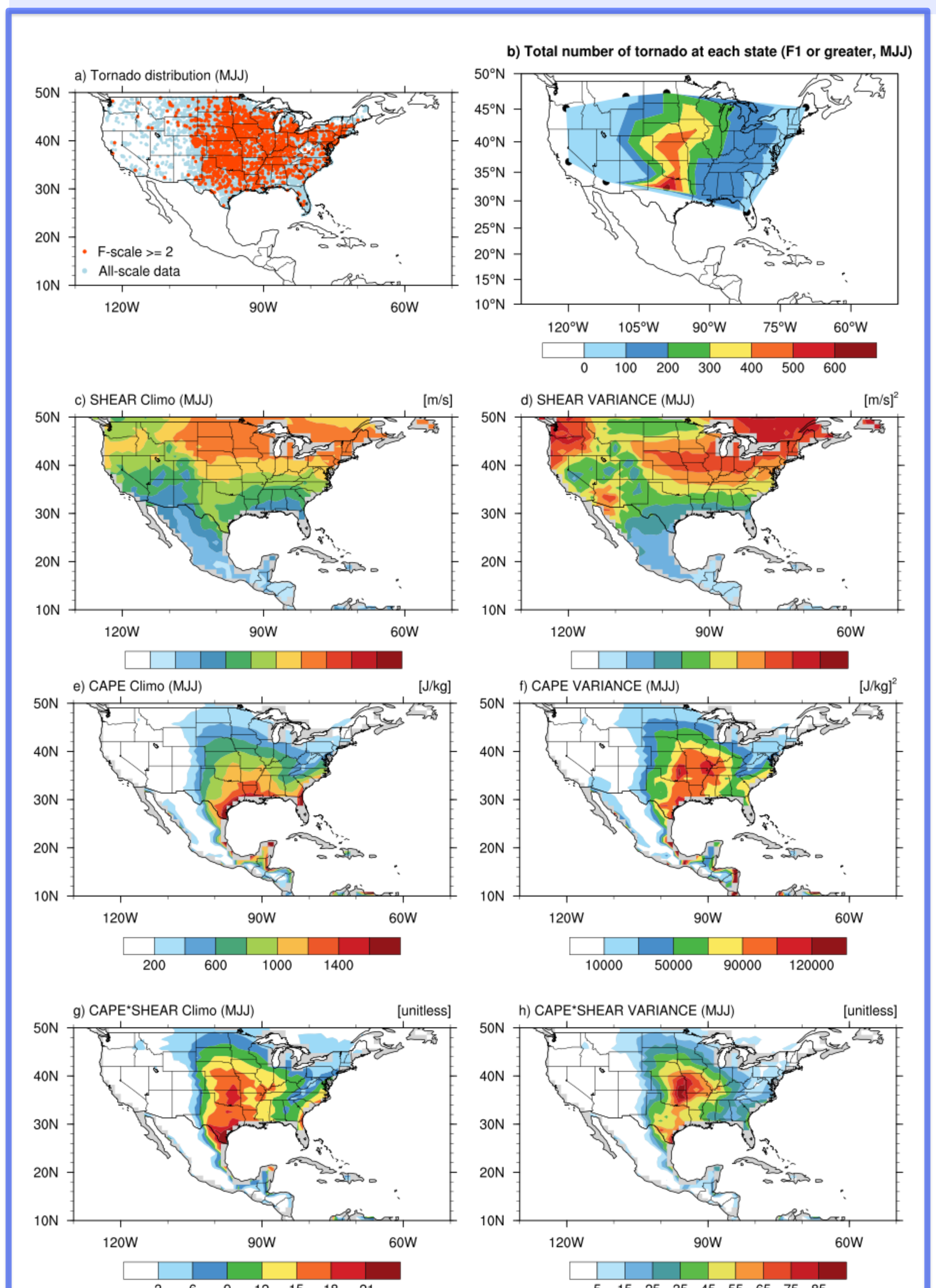

Fig. 1: (a-b) The distribution and total number of tornadoes during MJJ. Climatology and variance of (c-d) 0-6km shear, (e-f) CAPE, and the (g-h) combination of CAPE and shear during MJJ.

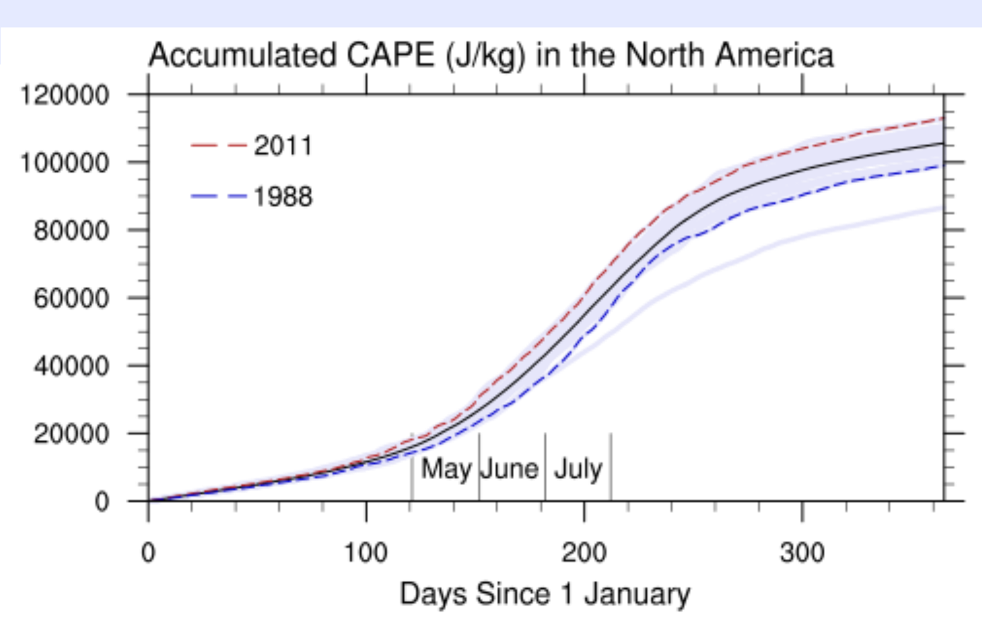

Fig. 2: The variation of area-averaged (10-50°N, 130°W-50°W) CAPE with a calendar day for each year 1982-2011 from NARR. Light purple shading: CAPE for each year, bold solid black: climatology.

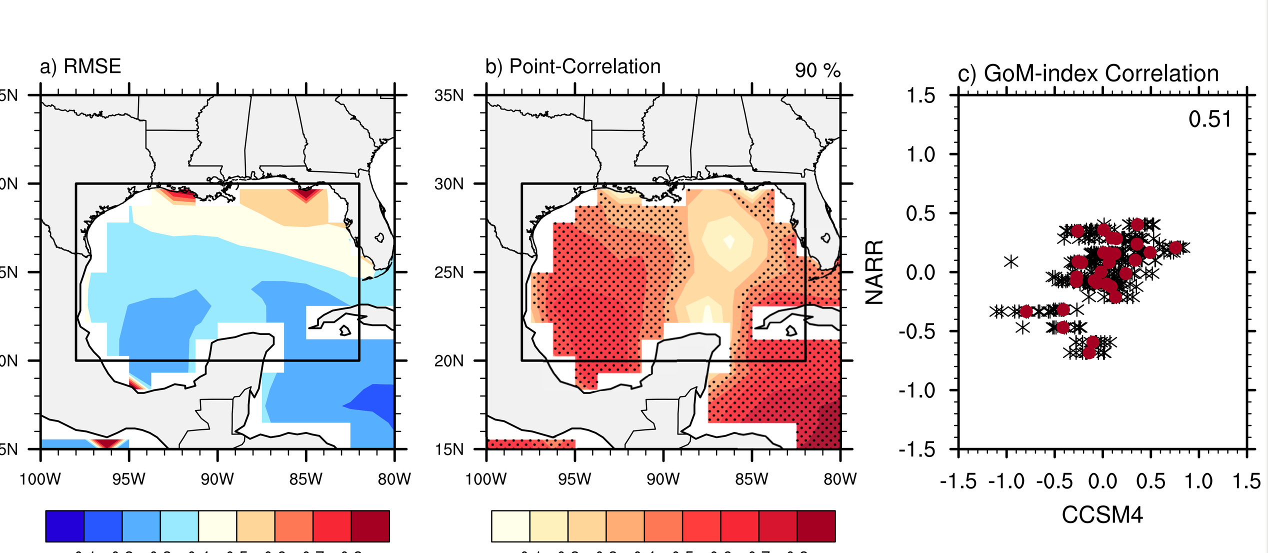

Fig. 6: (a) Root-mean-squared error (RMSE) and (b) point-correlation between NARR and CCSM4 SST anomalies. The stippled areas in Fig. 6b are statistically significant at the 90 % confidence level. Panel (c) shows GoM-index correlation. The area used for calculating the GoM-index is shown as a box in Fig. 6a-b. Individual forecast ensemble members are shown as black asterisks and the ensemble mean is shown as red dots. The correlations between two indices are shown in the upper right corner.

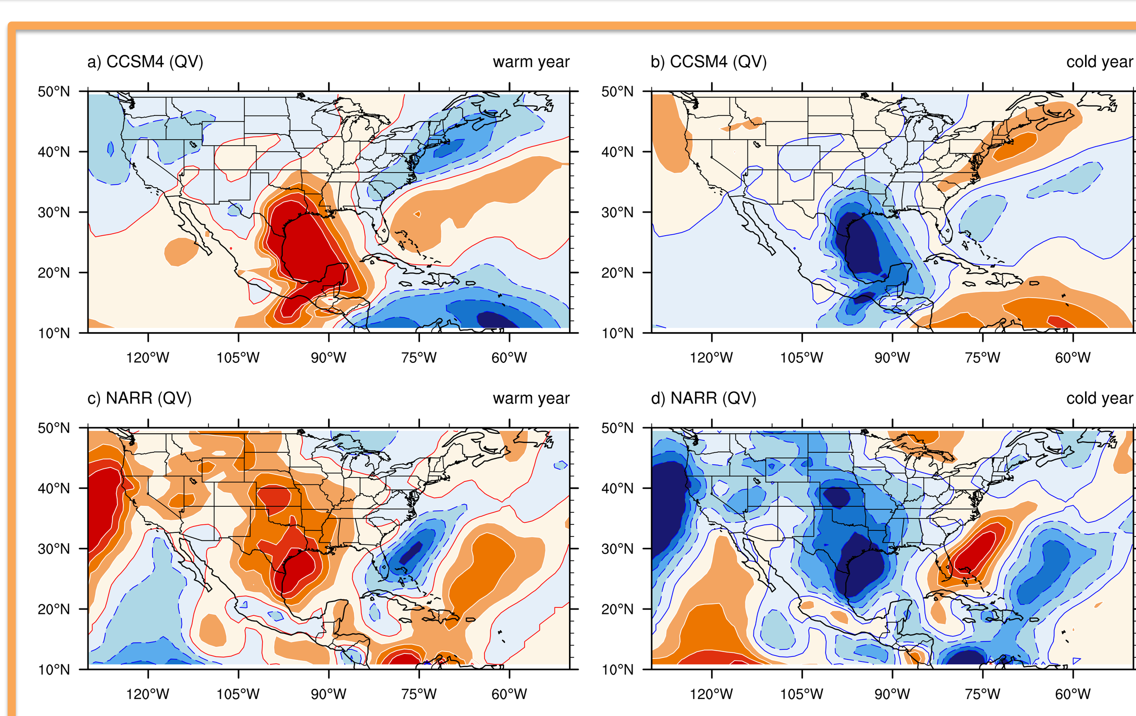

Fig. 5: The composite maps of northward moisture transports [QV, (g kg^{-1})(m s^{-1})] with warmer (left) and colder (right) than normal SST in the Gulf of Mexico. The MJJ seasonal mean is accumulated from 1000 hPa to 850 hPa for all years of positive (left) and negative (right) GoM indices.

Acknowledgments

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