Factors in Seasonal to Interannual Variability of U.S. Tornadic Activity

Philip Pegion[1,2], Martin Hoerling[1], and Thomas Hamill[1]

1-NOAA Earth System Research Laboratory / Physical Sciences Division
2- CIRES / University of Colorado

Motivation

- Due to the small spatial and time scales, tornado are not predictable beyond the timescales of minutes, but the environment in which they typically form are part of a large scale environment, which models can resolve and have a longer timescale of predictability

- We use a proxy index for tornadoes, which is an environment that based on a statistical analysis, where tornadoes are more probable.

Data

- Daily tornado reports from the SPC archive binned into daily 2.5x2.5 degree grids (NCEP/NCEP Reanalyisis grid)
- Favorable Tornado Days derived from the NCEP/NCEP Reanalysis
- HADISST monthly sea-surface temperature

Favorable Tornado Day Calculation

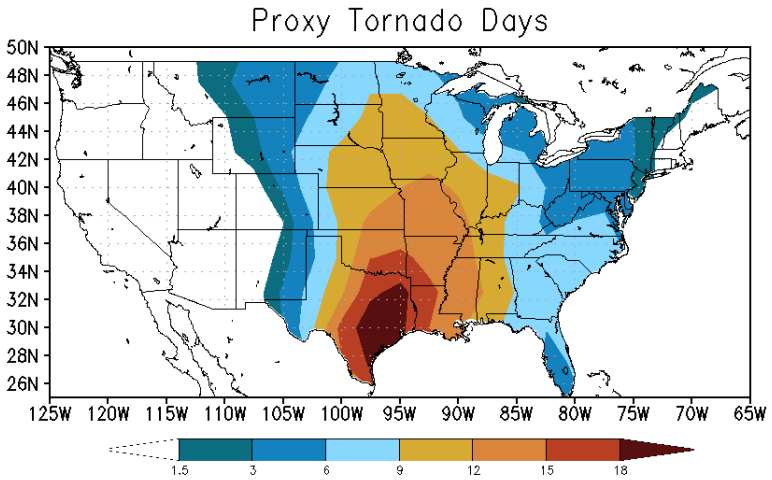
(Hamill et al 2005)

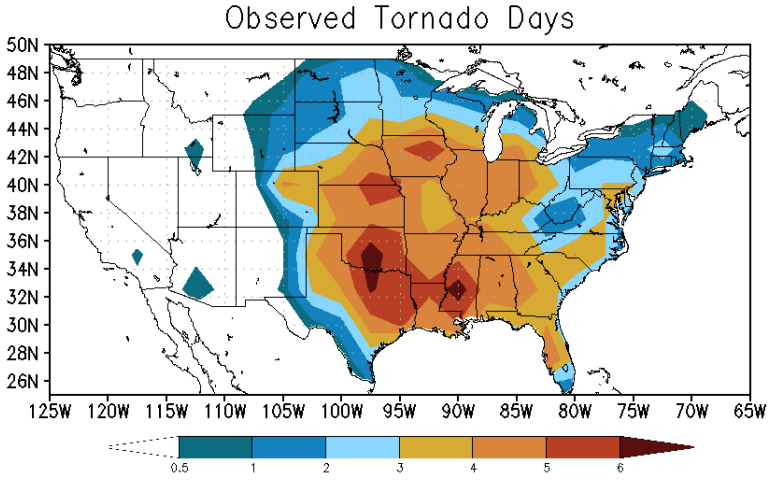
$$P(T \mid LI, shr) = 1.0 - \frac{1}{1 + e^{(b_0 + (b_1 * shr) + (b_2 * LI))}}$$

- Combination of sfc to 500 mb wind shear and lifted index.
- The weights b_0,b_1,and b_2 are determined through a logistic regression
- Additionally, we consider an environment favorable if there is upward vertical motion at 500 mb, and suppressed otherwise.
- A day is considered favorable in this study with the probability is 0.025

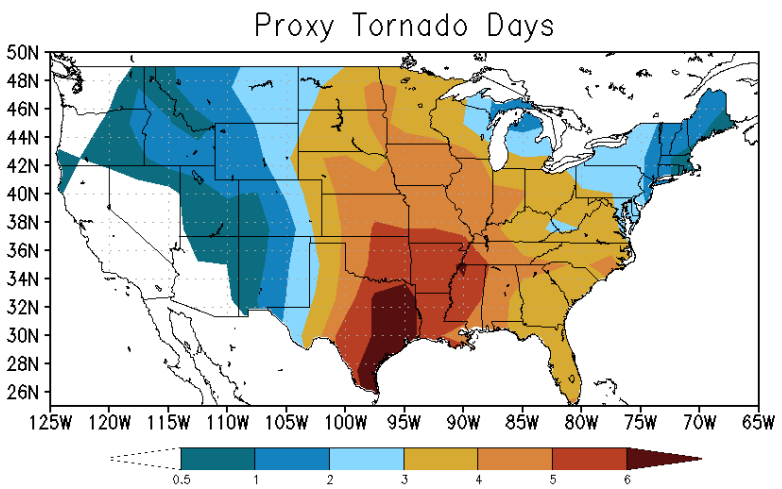
Spatial Climatology 1955-2010

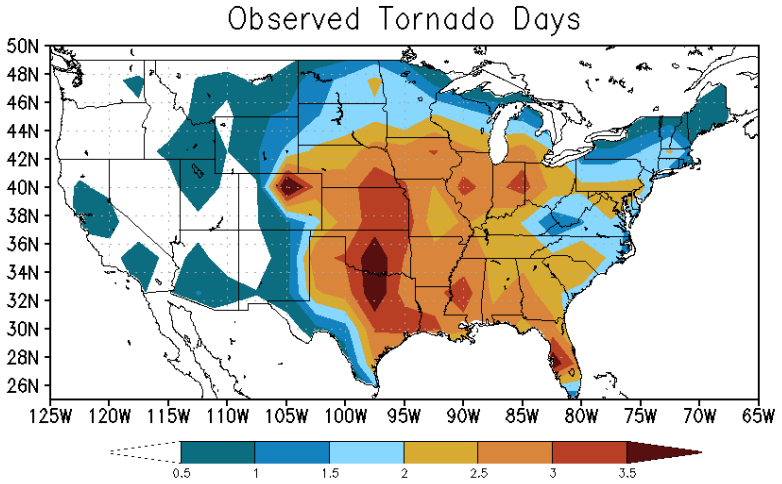
Mean





Standard Deviation

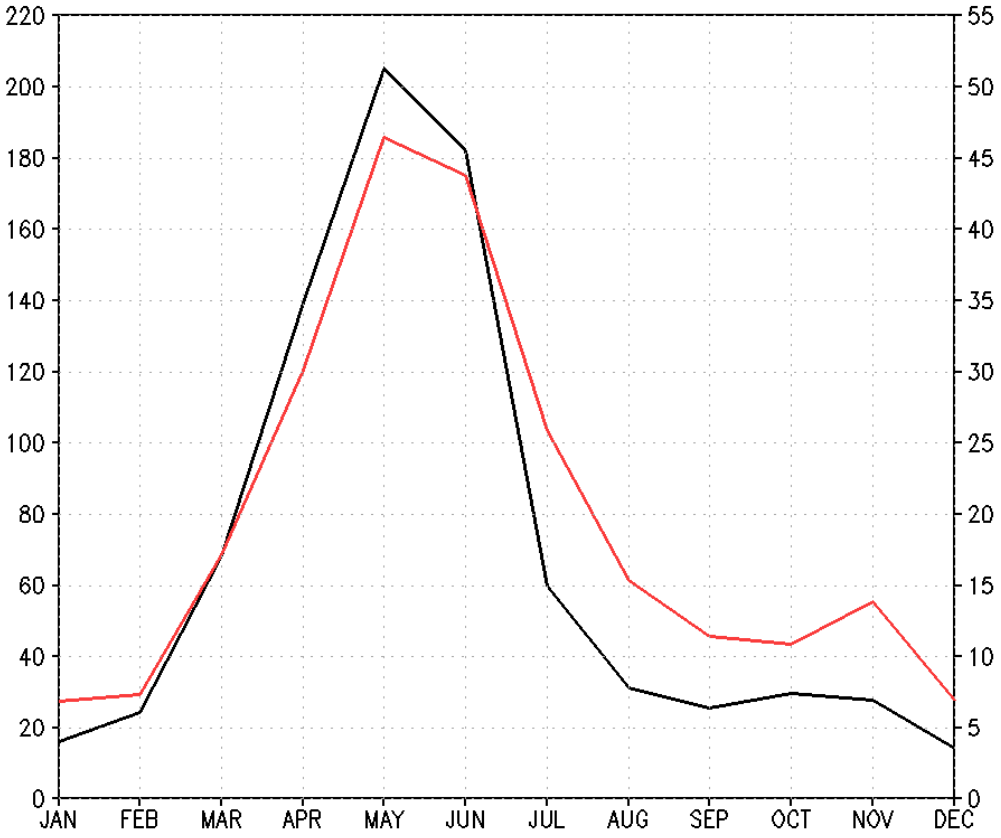




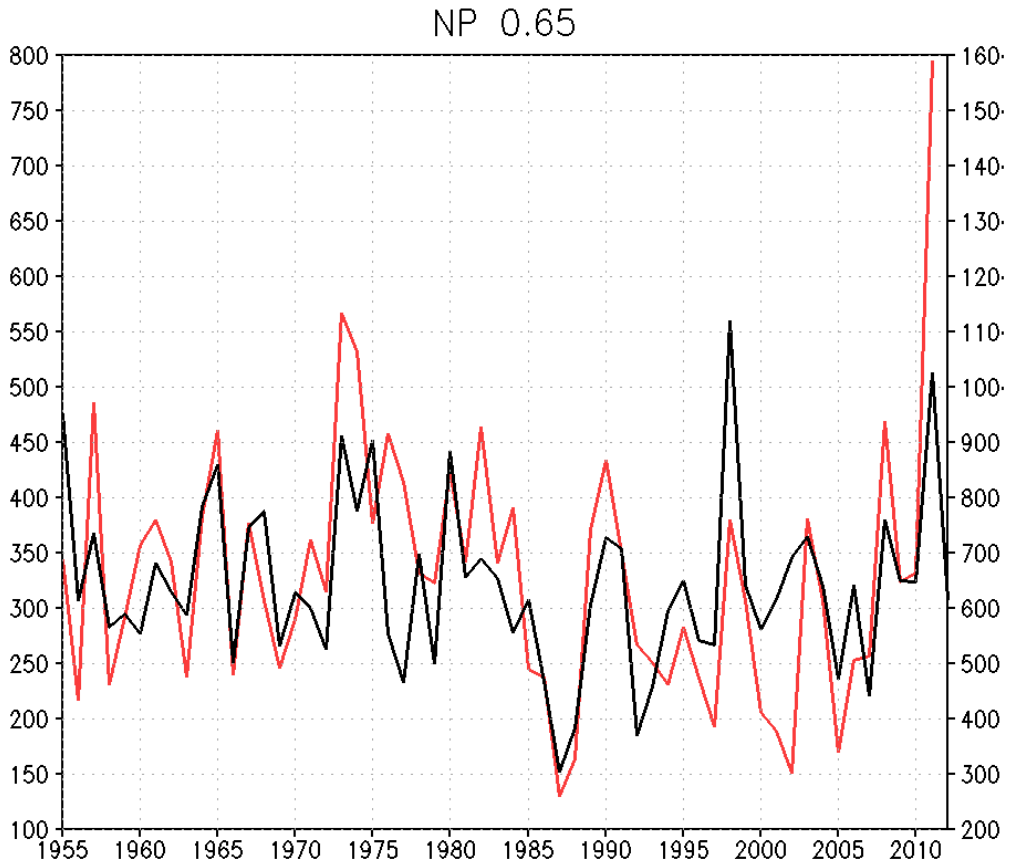
Seasonal Cycle of Favorable Days

Proxy Tornado Days

Observed Tornado Days



Interannual Variability (MAMJ)



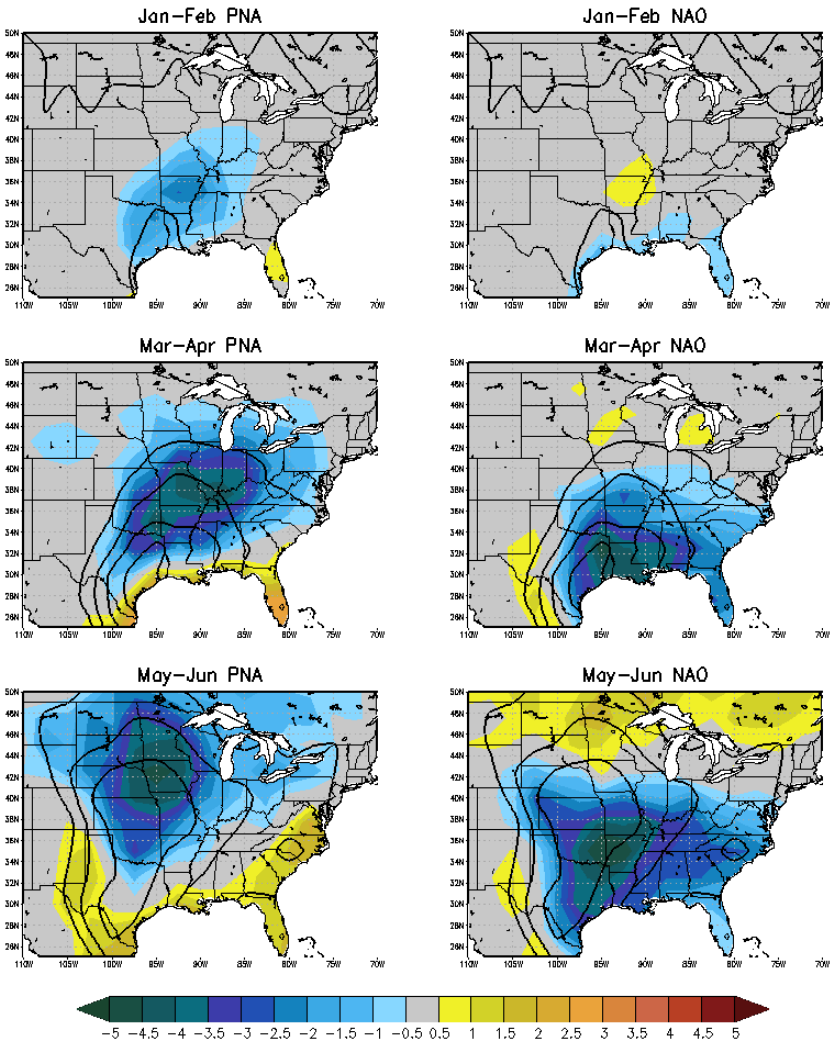
Corr:
0.60 1981-2010
0.65 1955-2011

Proxy Tornado Days
Observed Tornado Days

- Now that we have a ‘useful’ proxy for tornadoes, we can understand what the influence of the different modes of climate variability have.

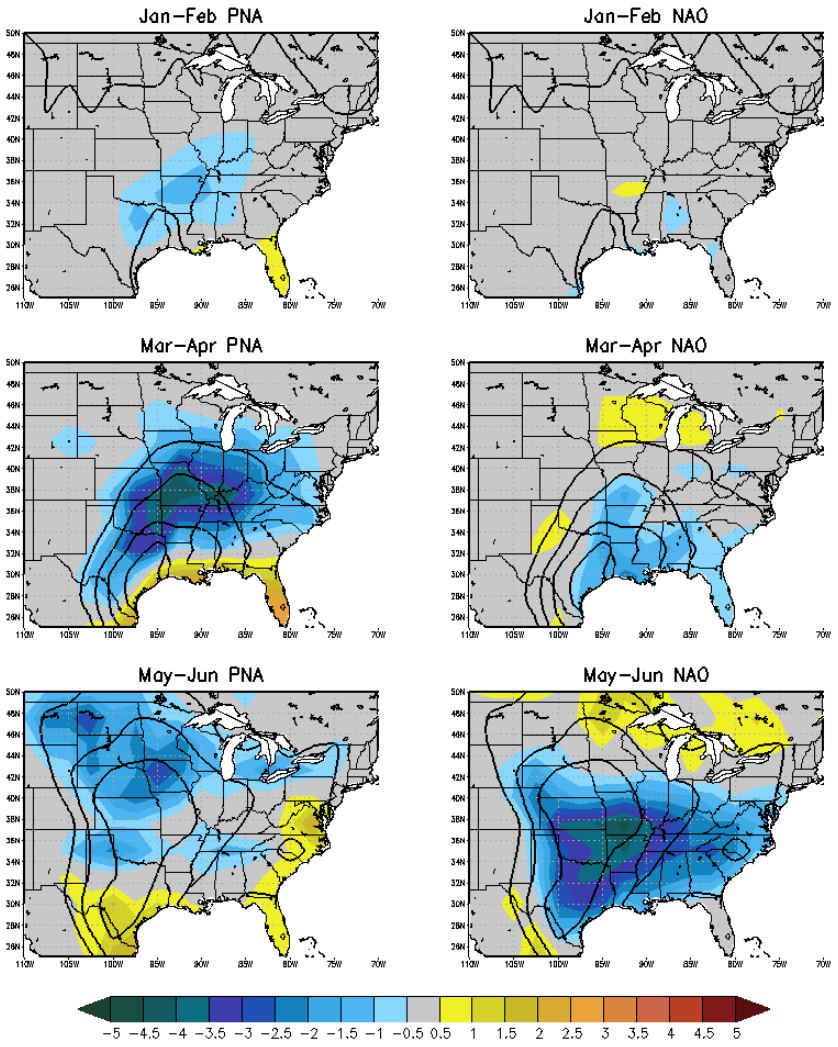
Daily composites of PNA/NAO index

Shading indicates the composite difference of the upper – lower tercile days



Contours:
Climatology
1 dy/month -1

Monthly composites of PNA/NAO index

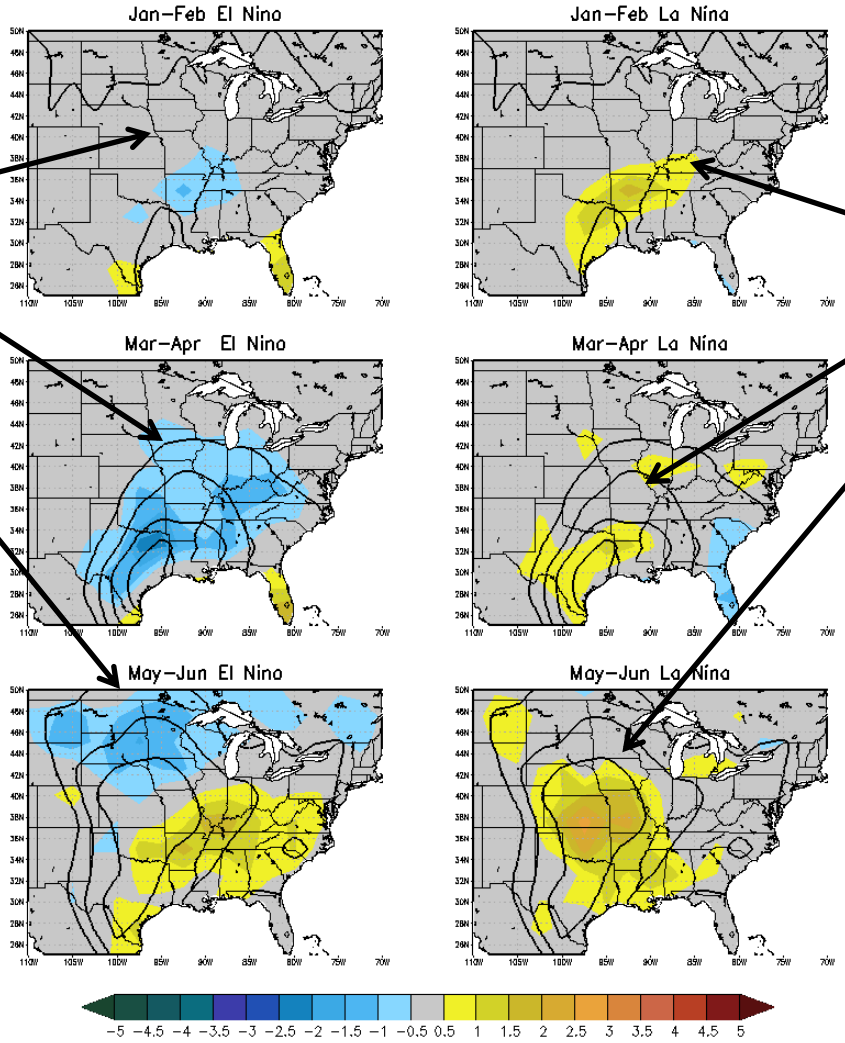


PNA and NAO
Indicies are averaged to Monthly means before Compositing is done on upper-lower terciles

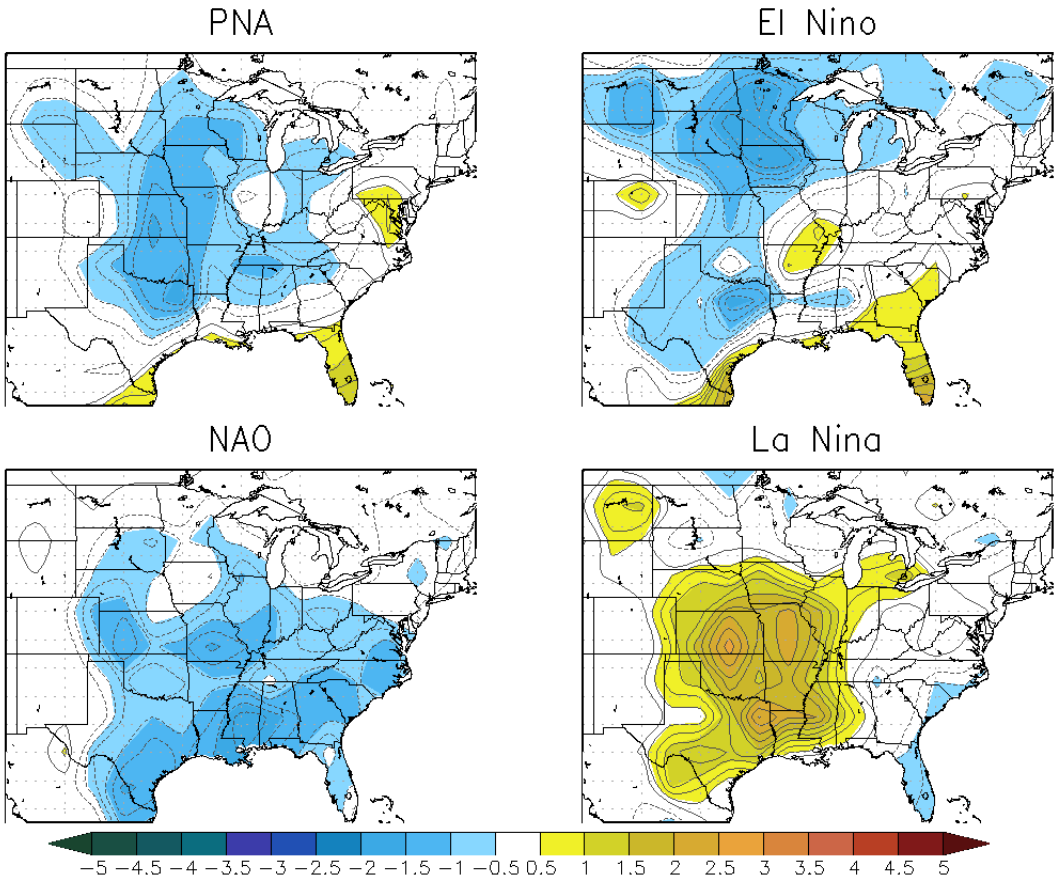
ENSO composites

El Niño suppresses Tornadoes

La Niña enhances Tornadoes



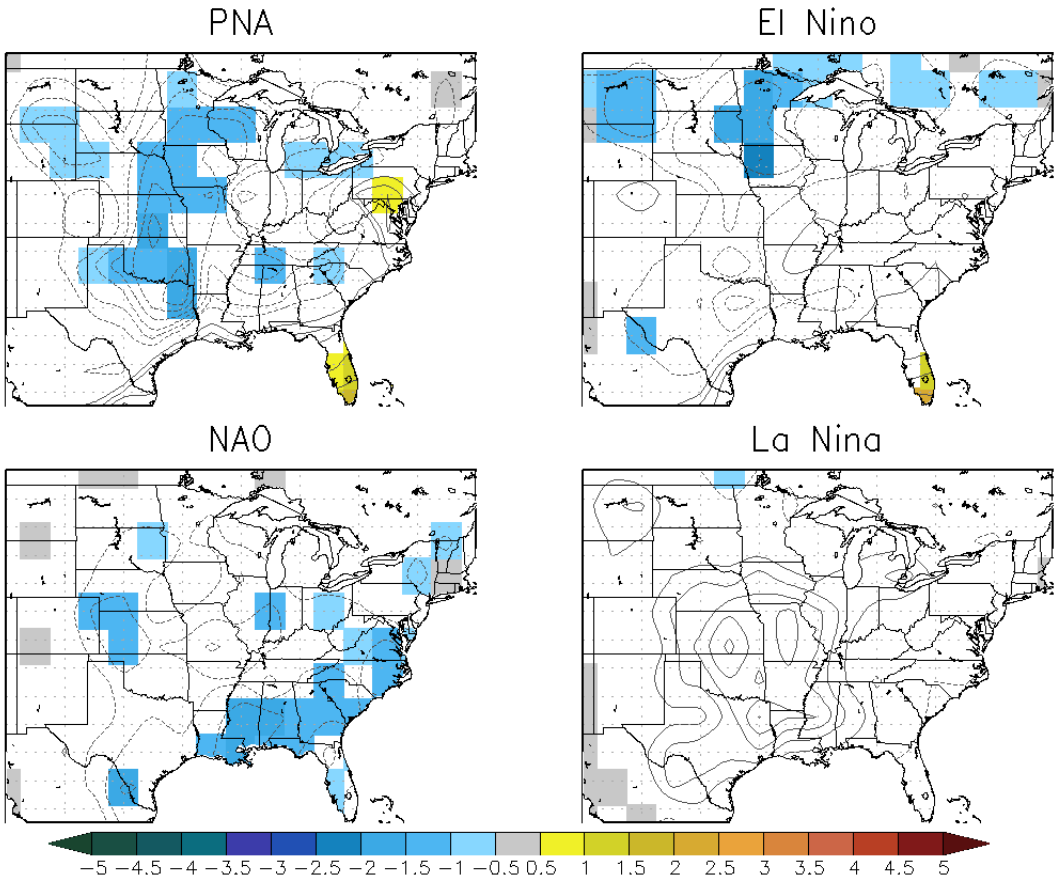
Tornado Season (Mar-Jun) Composite



ENSO composites are comparable in magnitude to the circulation indicies, but...

PNA & NAO index are composited off of seasonal mean indices

Tornado Season (Mar-Jun) Composite



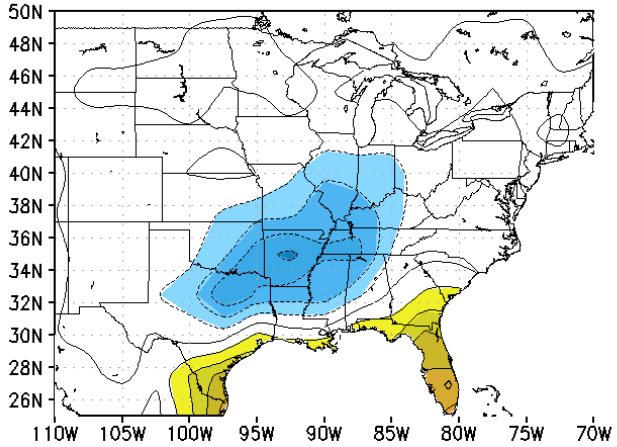
Most of the ENSO composite of not statistically significant during the spring.

Student-ttest applied: Shading indicates 90% confidence

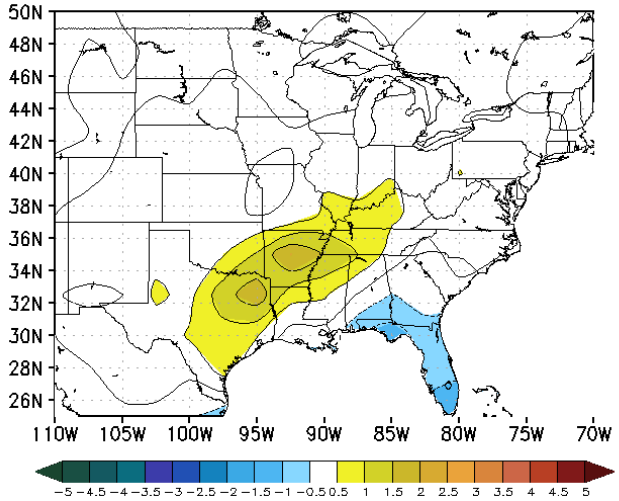
ENSO composites for JFM

Anomalies

El Nino

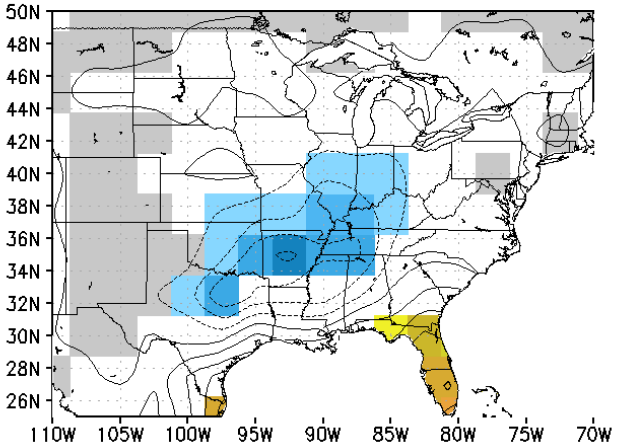


La Nina

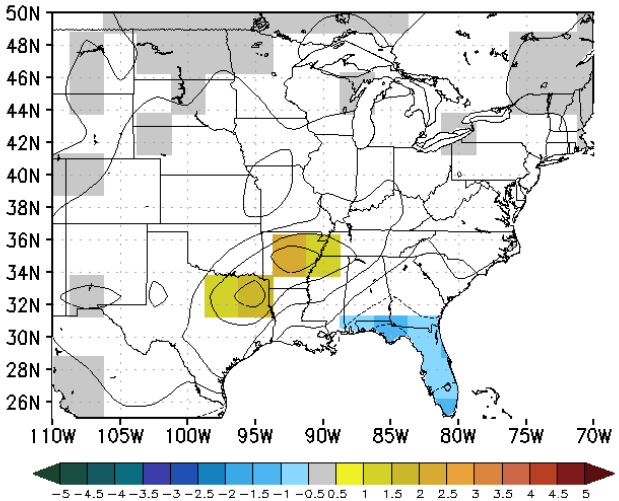


Significance Mask

El Nino



La Nina

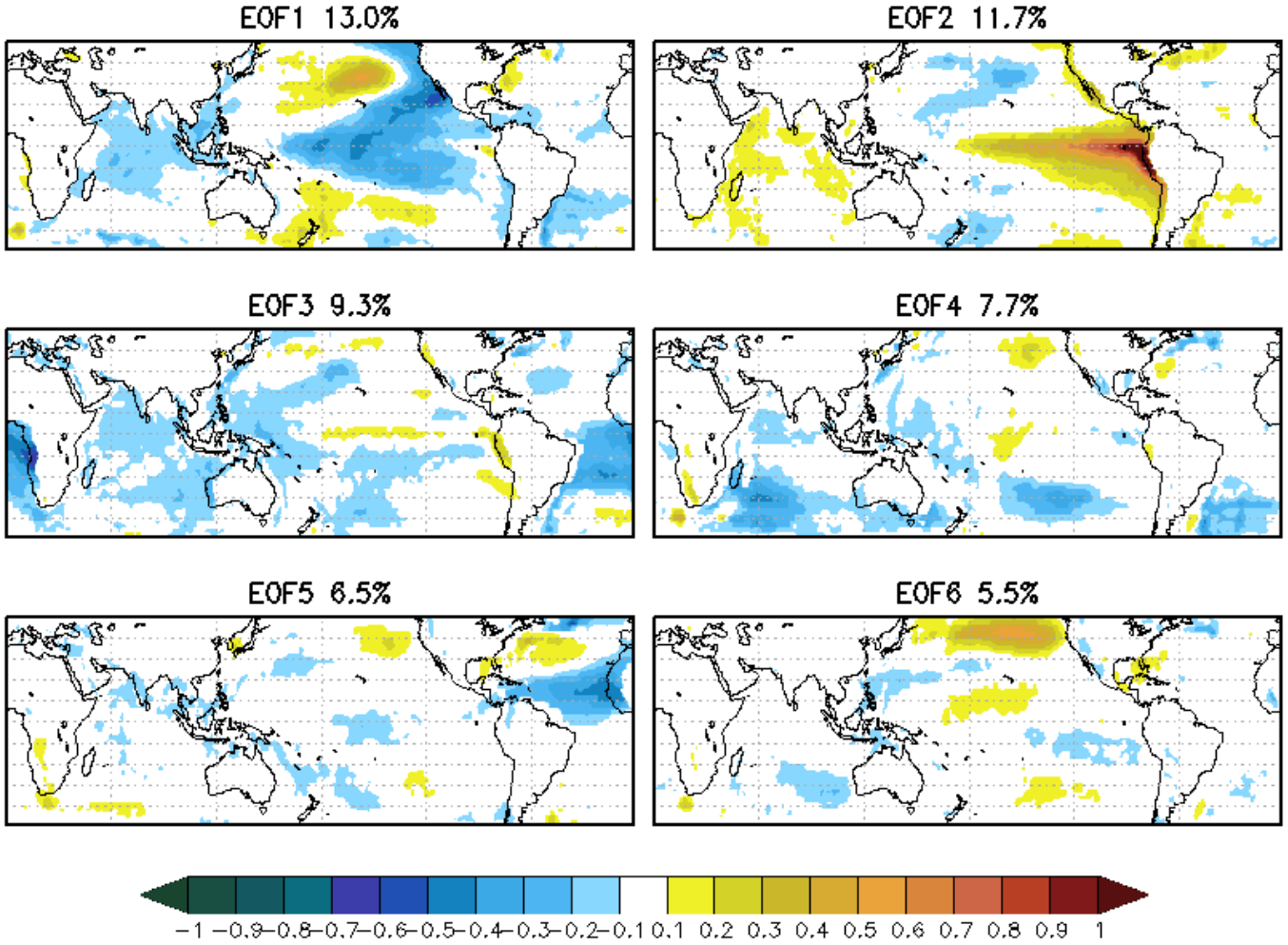


A larger portion of the composites are significant in the cold season.

What variability in favorable tornado days can be explained by changes in Sea-Surface Temperature?

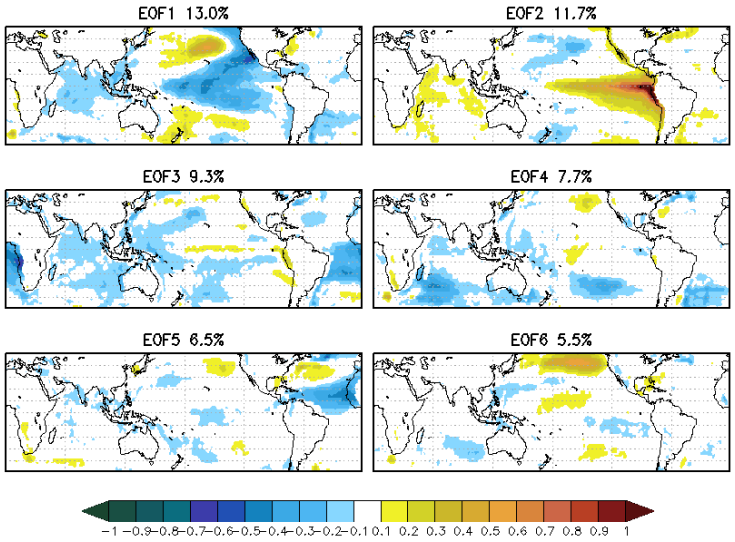
- thus potentially predictable at seasonal timescales.

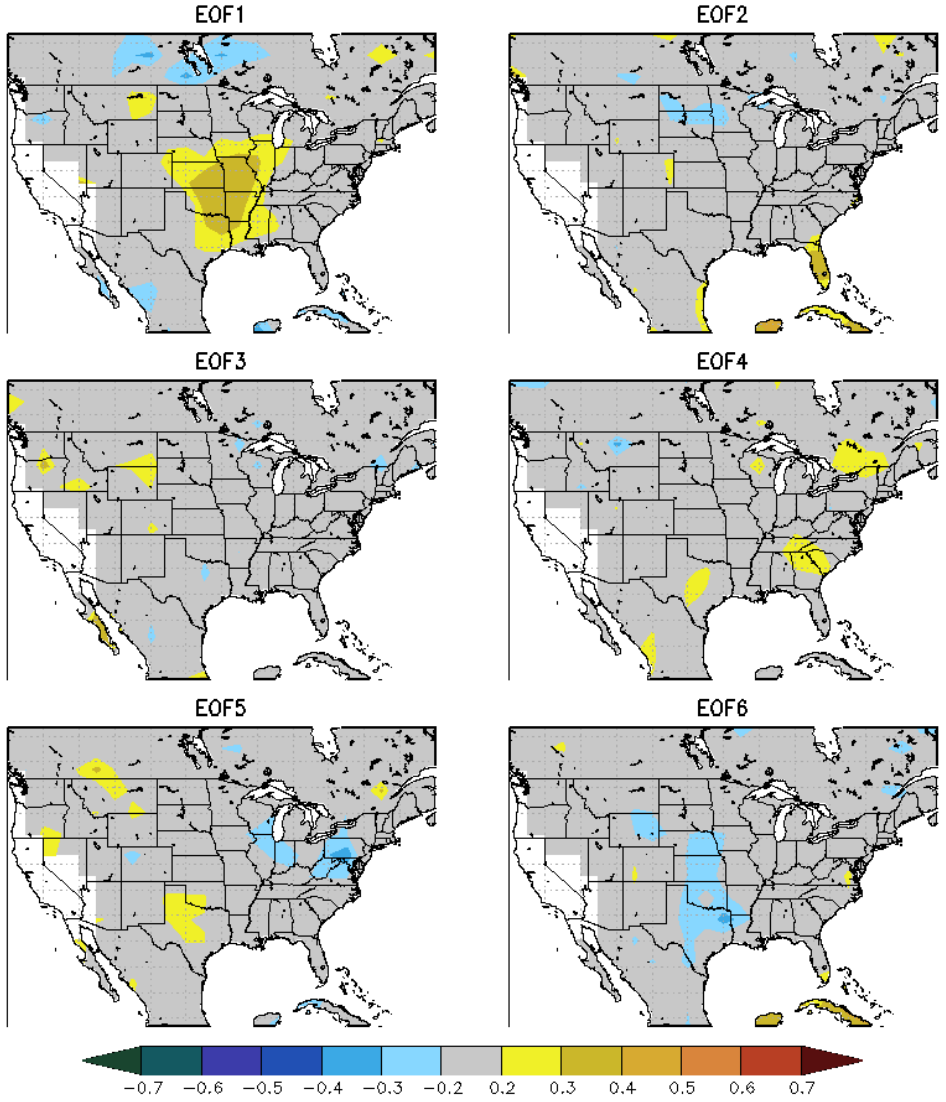
Rotated EOFs: MAMJ SST 1948-2011



Since springtime is the transition season of ENSO, it is represented by the first two rotated EOFS.

Temporal Correlation of Favorable tornado days with the leading patters on springtime SST variability



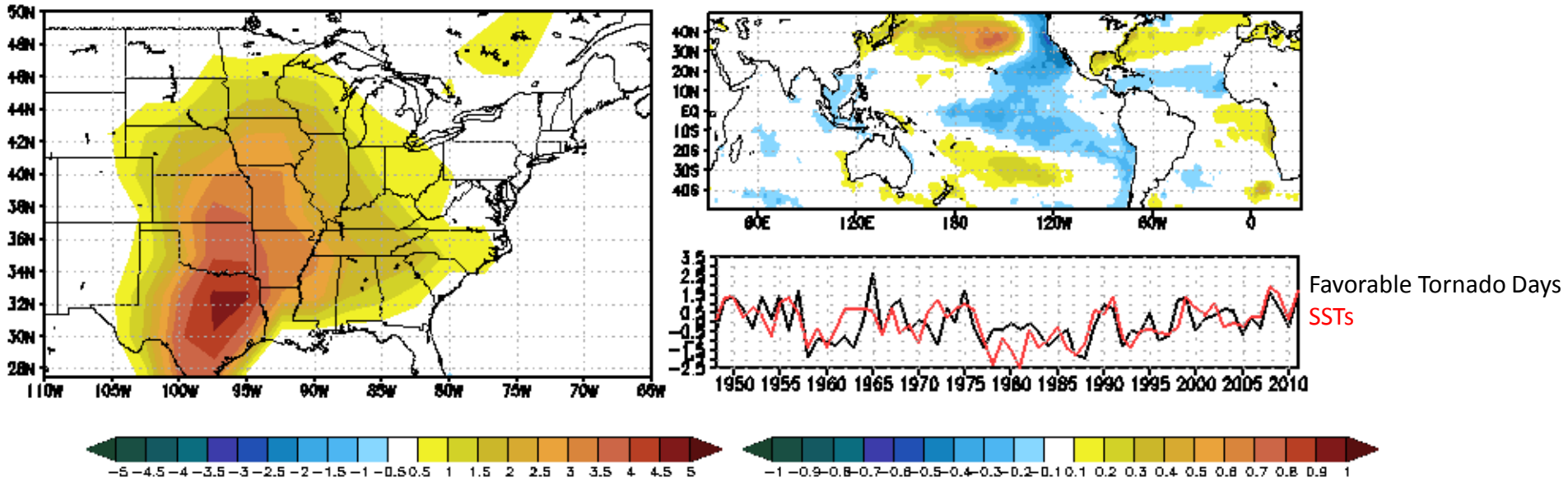


What other factors control the interannual variability of probable tornado environments?

- Canonical Correlation Analysis of Favorable Tornado Days and near Global SSTs.

CCA of Proxy Tornado Days & SST

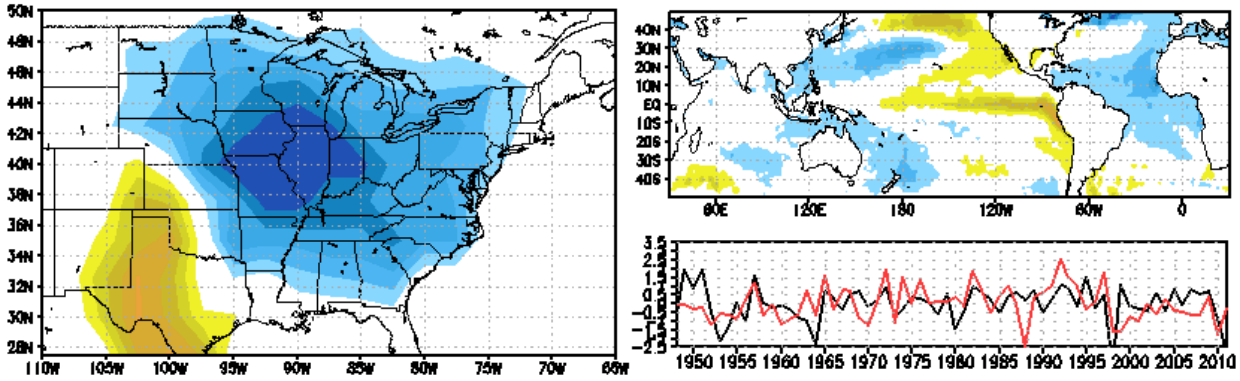
Favorable Tornado Days CCA #1 **Sea Surface Temperature**



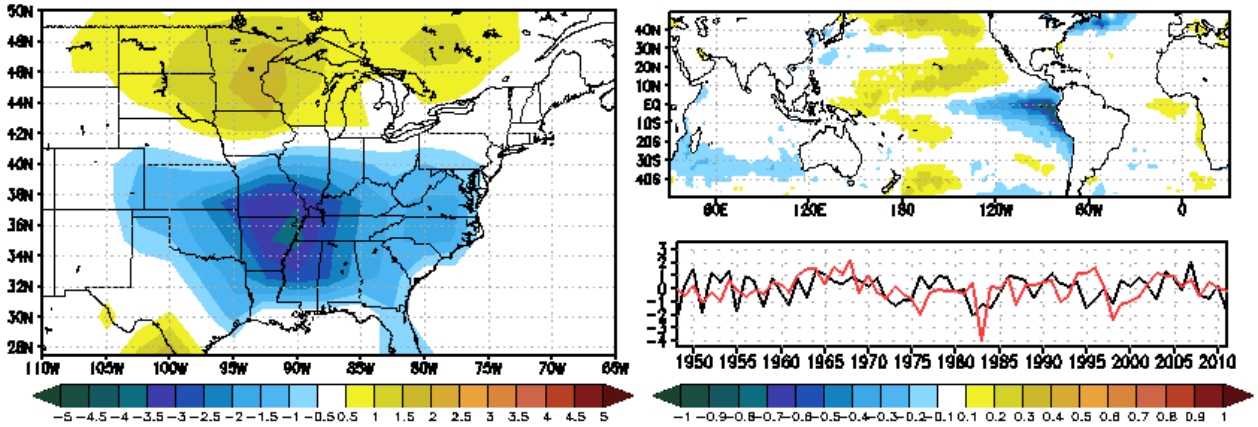
1st CCA is an amplification of climatology this is associated with a PDO like pattern. Homogeneous correlation is 0.56.

CCA of Proxy Tornado Days & SST

Favorable Tornado Days CCA #2 Sea Surface Temperature



Favorable Tornado Days CCA #3 Sea Surface Temperature



Favorable Tornado Days
SSTs

2nd and 3rd CCA's have much weaker correlations (0.29 and 0.20)

Conclusions

- The environment derived from the NCEP reanalysis is able to capture the spatial climatology, seasonal cycle and interannual variability of observed tornado days.

- Positive phases of both the PNA and NAO reduce the probability of tornadoes over much of the United States.

- The ENSO signal shows an increase risk during La Niña, and a decrease risk during El Niño over much of the US (SE US excluded).

- The relationship between tornado probability and SST anomalies is weak, but the prospect of being able to use these relationships as a forecasting tool needs to be explored.