Climatic Role of North American Low-Level Jets on U.S. Regional Tornado Activity

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36th CDPW

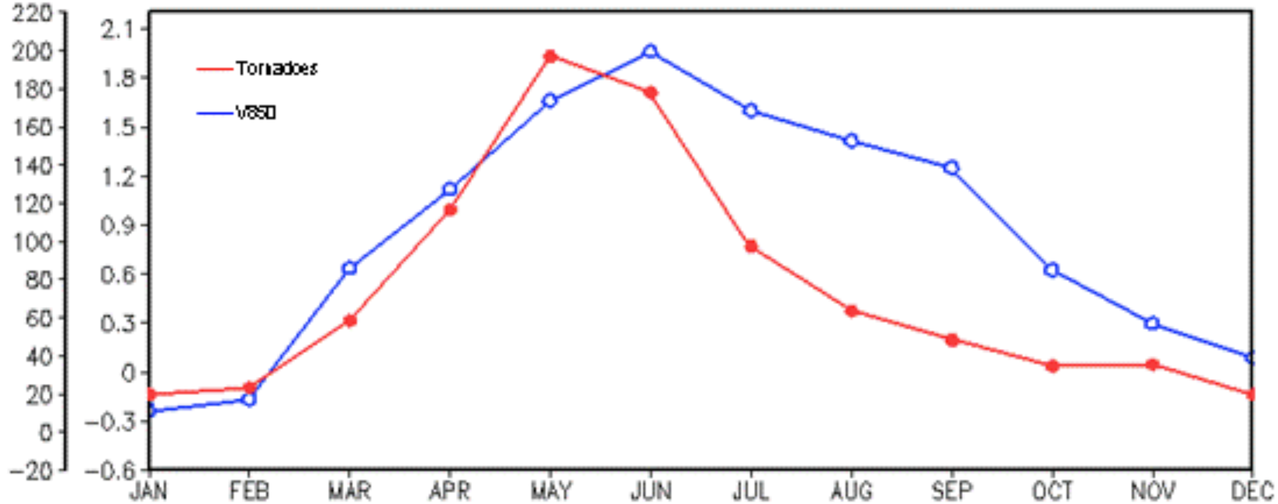
Motivation

- The Spring 2011 Tornado outbreaks caused devastating societal impacts with significant loss of life and property.
- Need for increased understanding, attribution, and prediction of seasonal tornadic activity.
- Previous observational studies indicate that ENSO linkages to spring U.S. tornado activity are weak.
- Local climate mechanisms that directly force variability in *regional* tornadic activity and their SST linkages remain to be characterized.
- NALLJs provide thermodynamic support and dynamic focusing mechanism for *Severe Climate* environment and provide a one-parameter assessment.
- Recent studies show mutidecadal variabilty and increasing interannual variability in warm season climate.

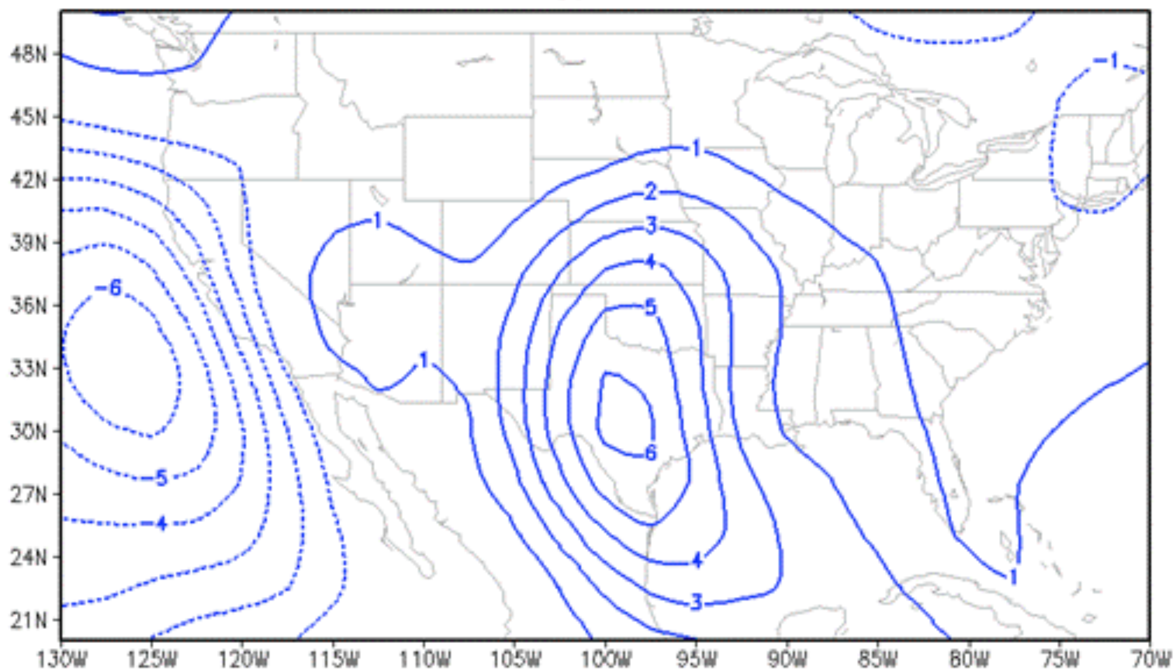
DATA

- SPC Severe Weather Database (SWD) for 1950-2010 for monthly tornado counts over the CONUS.
- SWD linearly detrended to ameliorate the effects of:
  - Changes in population & technology
  - Tornado assessment practices
  - National Weather Service guidelines
- NALLJ variability assessed via EOF analysis on AMJ meridional wind anomalies from NCEP/NCAR Reanalysis.
- Regional AMJ tornado anomalies formed by removing long term AMJ Climatology from each year's count.
- Regions defined based on NALLJ impacts.

V850 & Tornado Climatology U.S.



Climatology AMJ V850

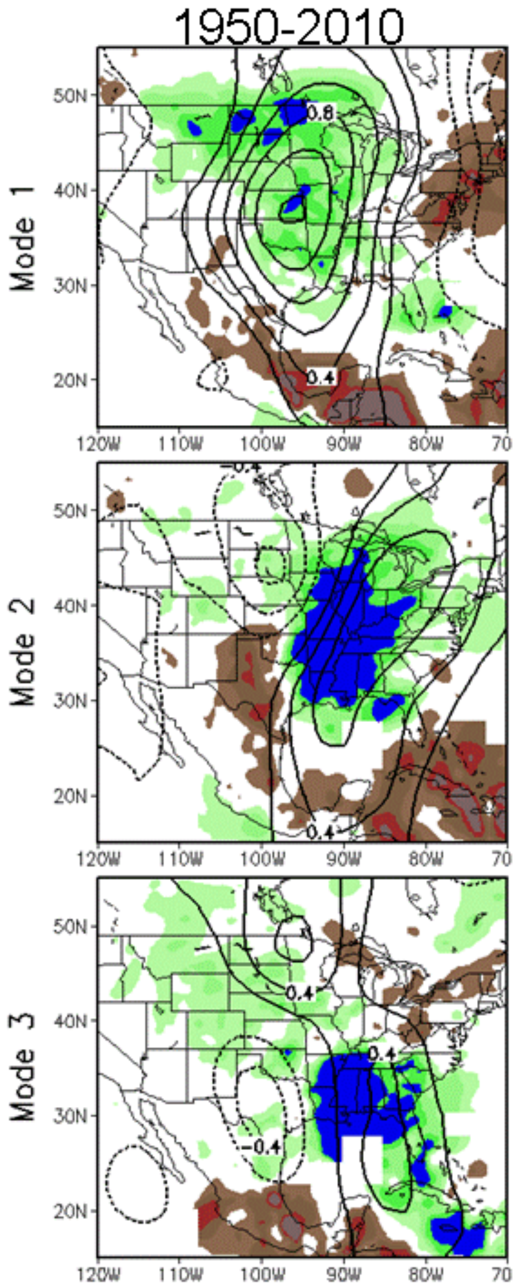


NALLJ Variability Modes & Precipitation

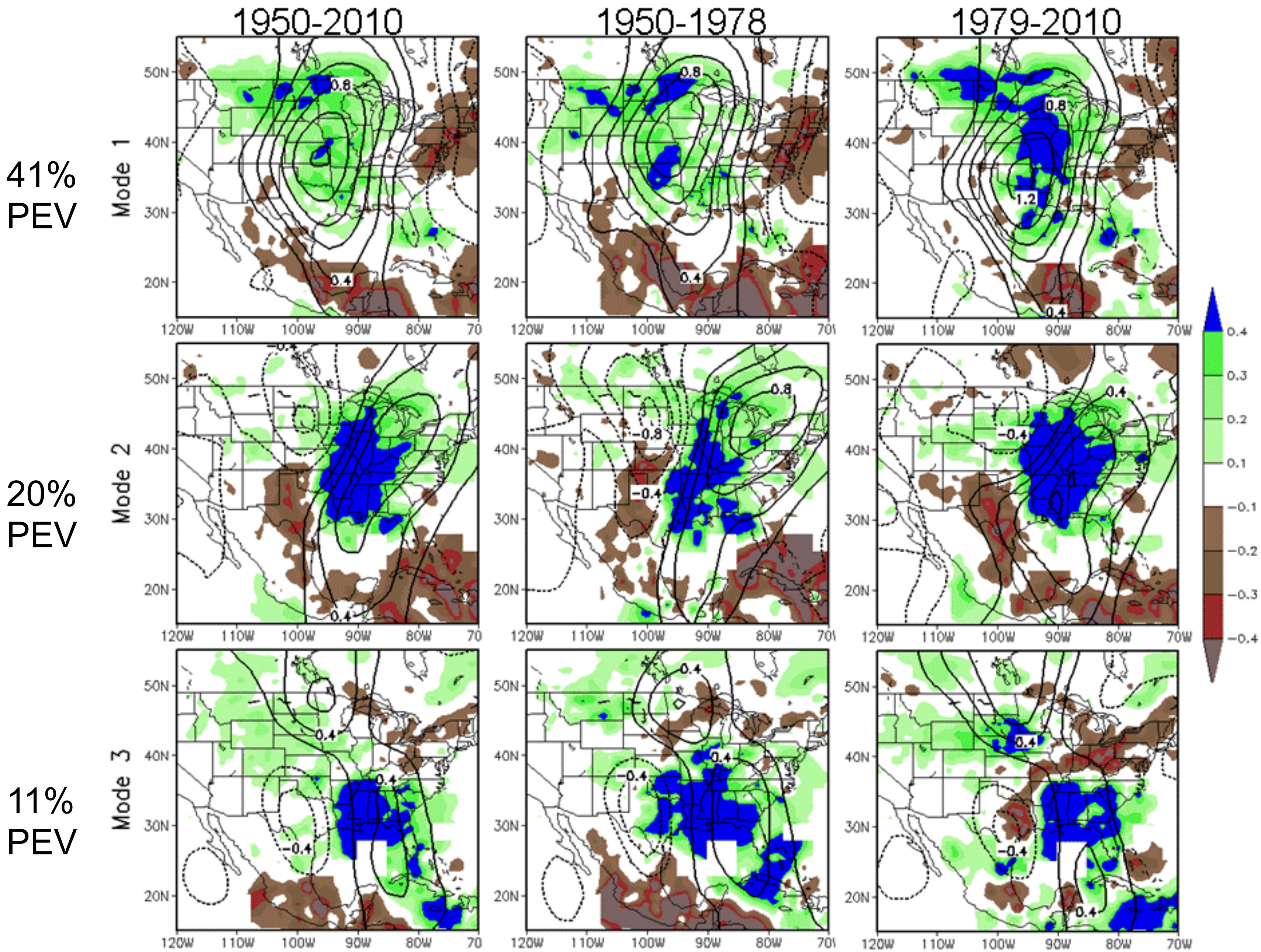
41%
PEV

20%
PEV

11%
PEV

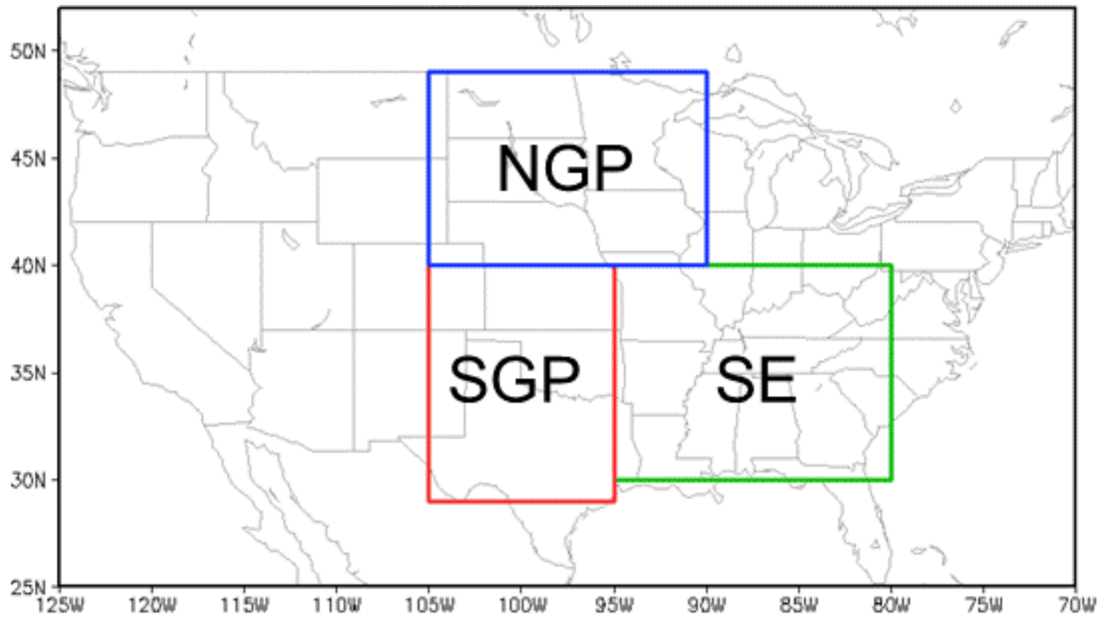


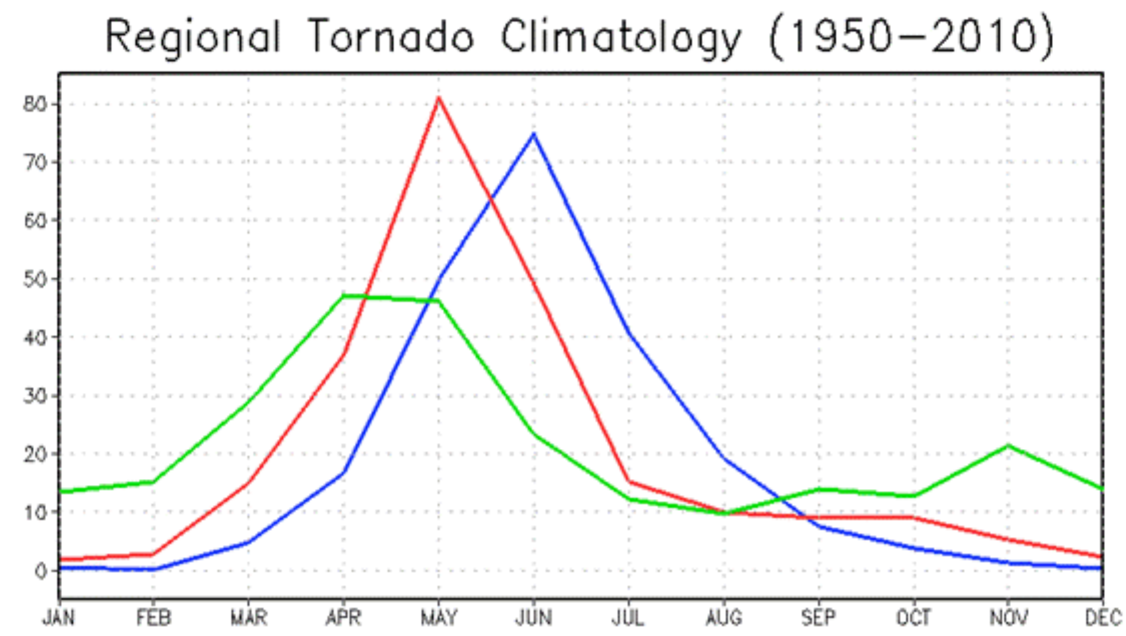
NALLJ Variability Modes & Precipitation



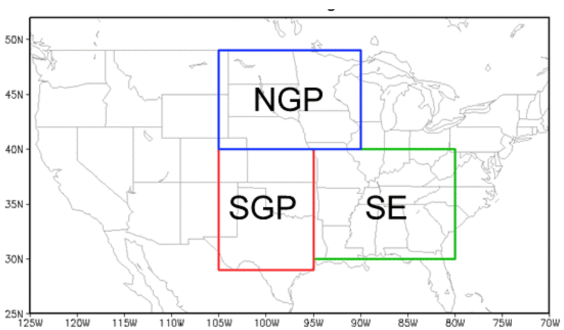
Tornado Regions

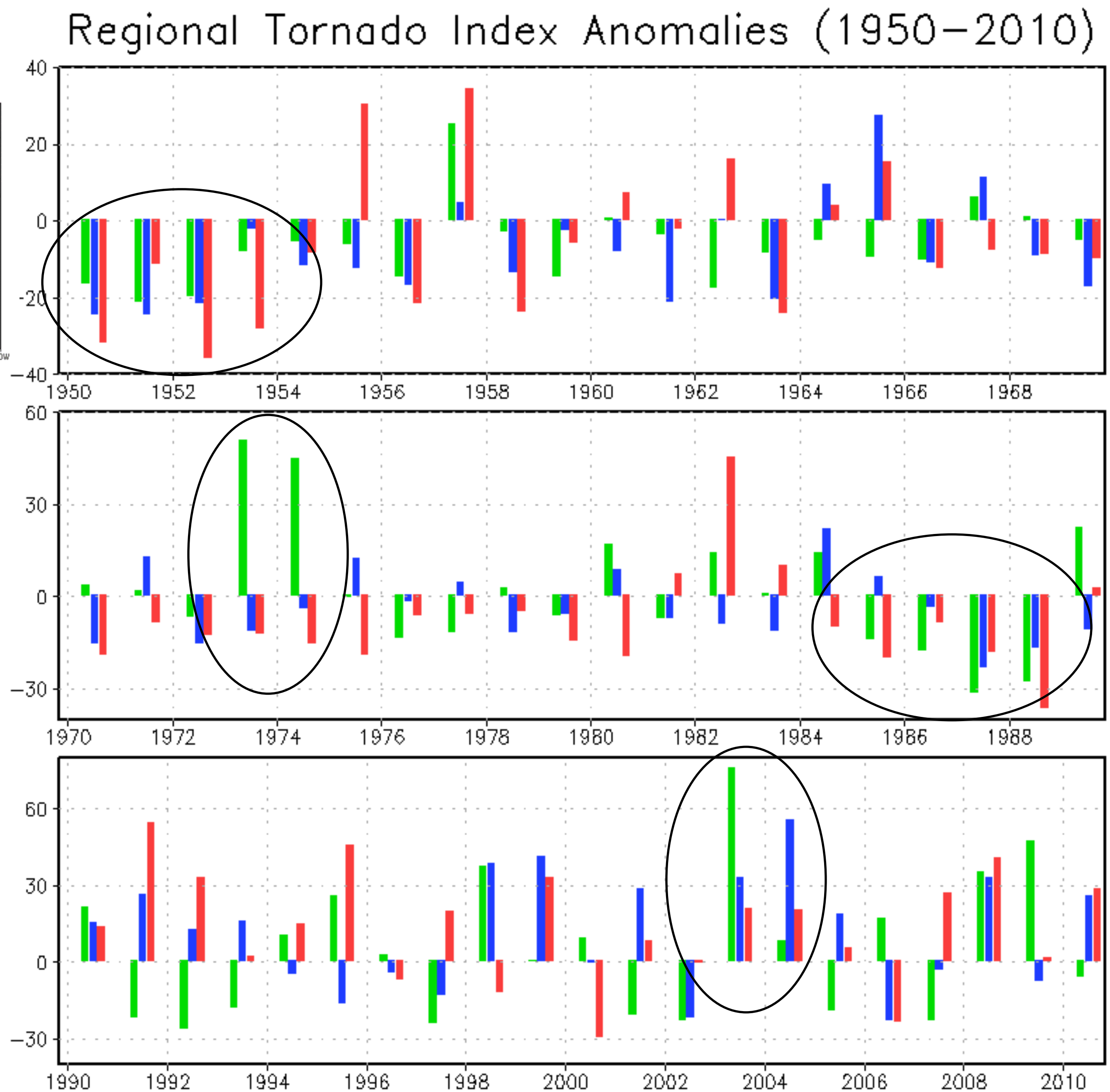
NGP: 40-49N 105-90W
SGP: 29-40N 105-95W
SE: 30-40N 95-80W





SE SGP NGP





Early period mostly negative especially early 1950's

1974 Super Outbreak

Late period more active Save late 1980's

2003-2004 active seasons

NALLJ PCs

PC1 interannual & decadal variability. Generally positive (negative) in early (late) period.

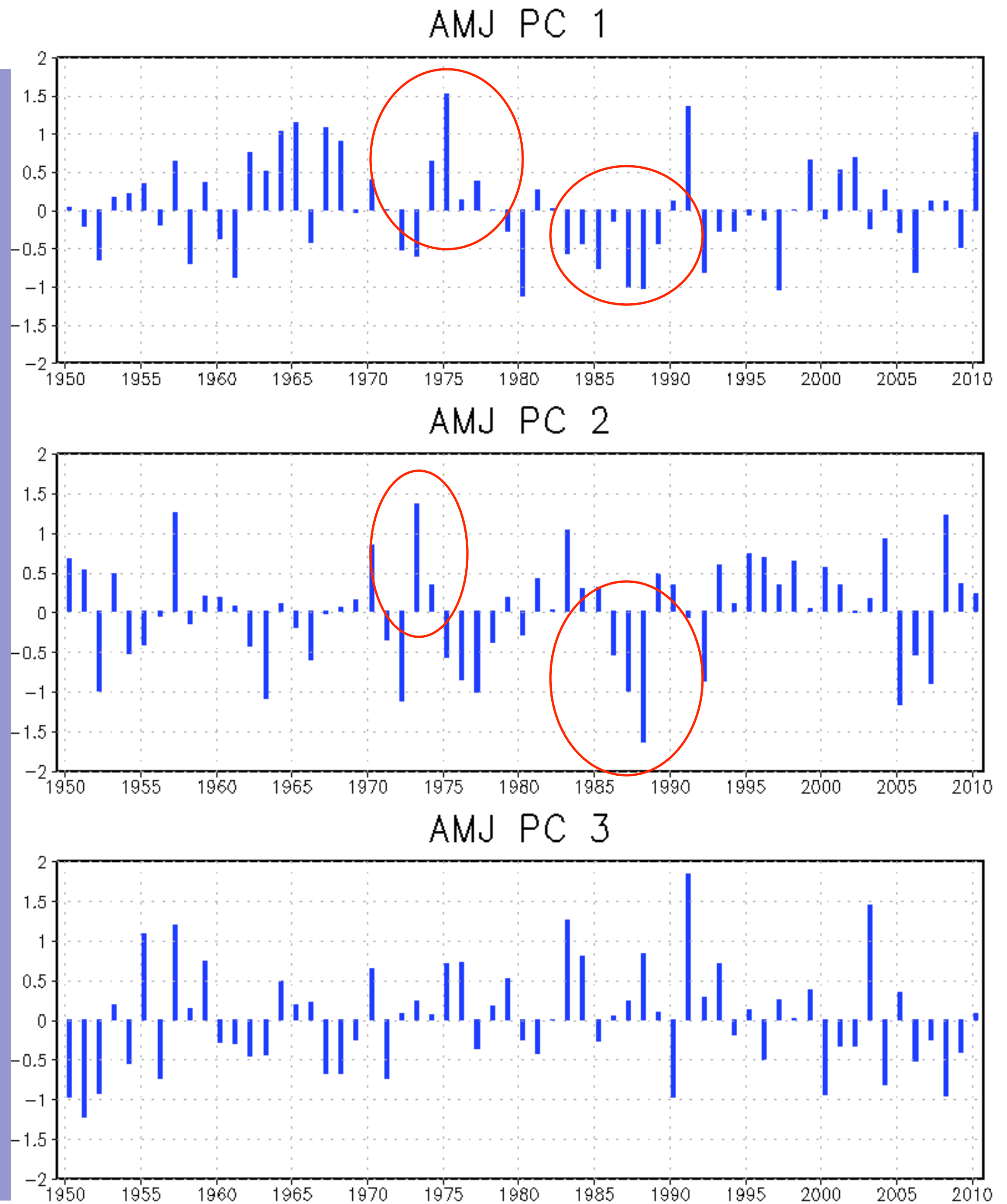
PC 2 interannual variability but many back to back years with same sign anomalies.

PC 2 strong during 1973 tornado season and may account for much of 1973 tornado anomaly.

Weaker in 1974, although 1974 was dominated by 1 super outbreak.

PC3 interannual variability

1980’s tornado hole had:
-PC1 -PC2 +PC3



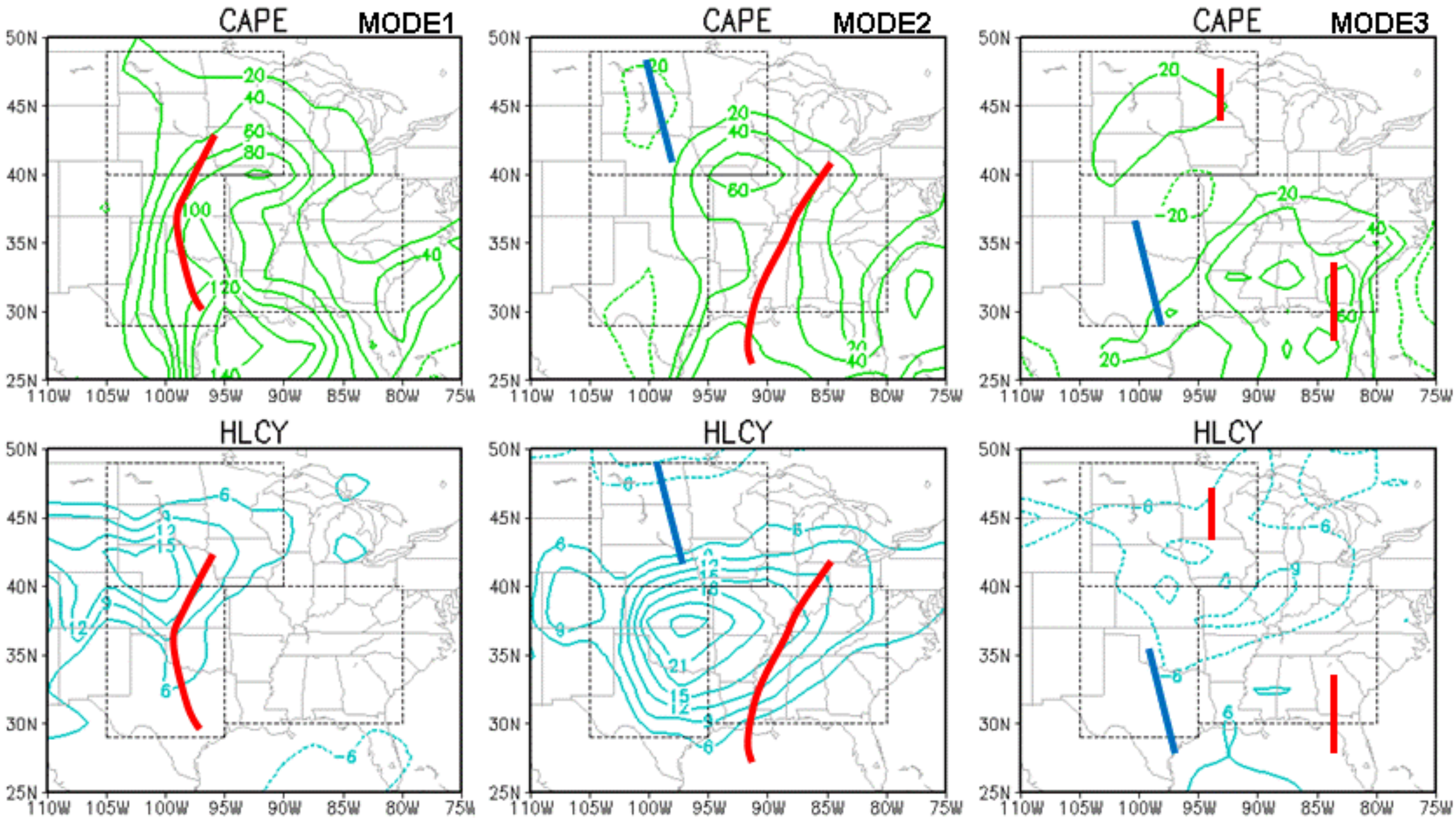
NALLJ & Tornado Correlations

	PC1	PC2	PC3
SE 50-78	-0.06	**0.53**	**0.32**
79-10	0.03	**0.47**	-0.15
NP 50-78	**0.65**	0.05	**0.33**
79-10	**0.49**	0.28	0.03
SP 50-78	**0.31**	0.13	**0.46**
79-10	**0.57**	0.25	0.13

Combined Influence of NALLJ Modes 1 & 2

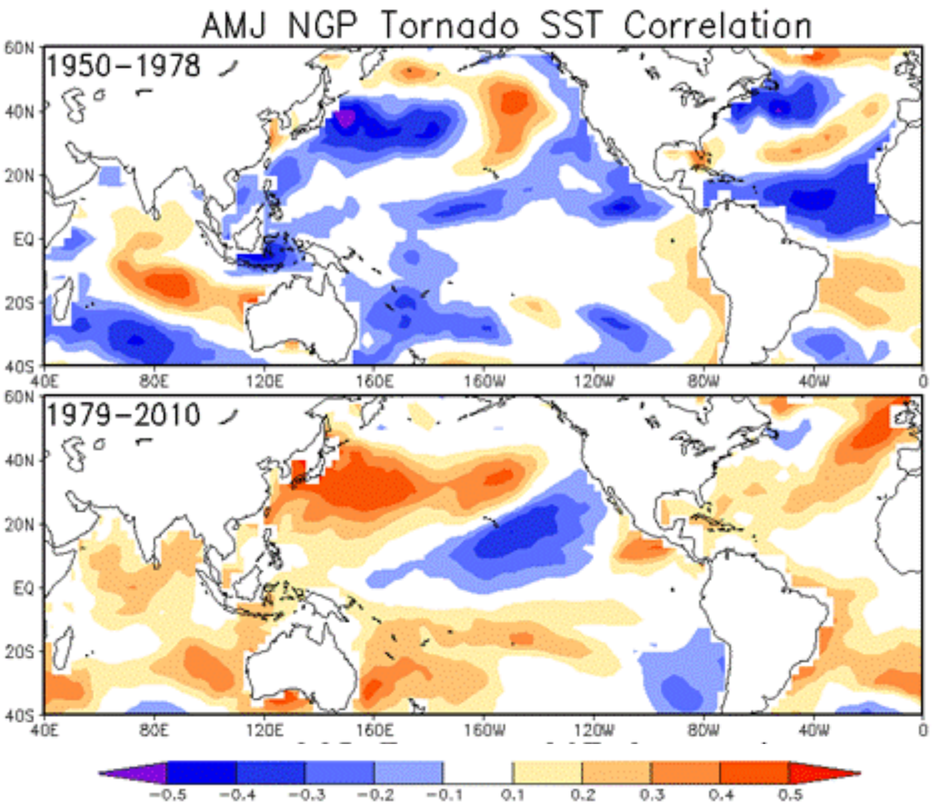
Seasons where both PC1 & PC2 are both Positive (Negative) and Tornado anomaly is also Positive (Negative)	PC1 & PC2 Both Positive	PC1 & PC2 Both Negative
At least one Region	14/18 + 78%	13/13 - 100%
All Regions	4/18 + 22%	9/13 - 69%

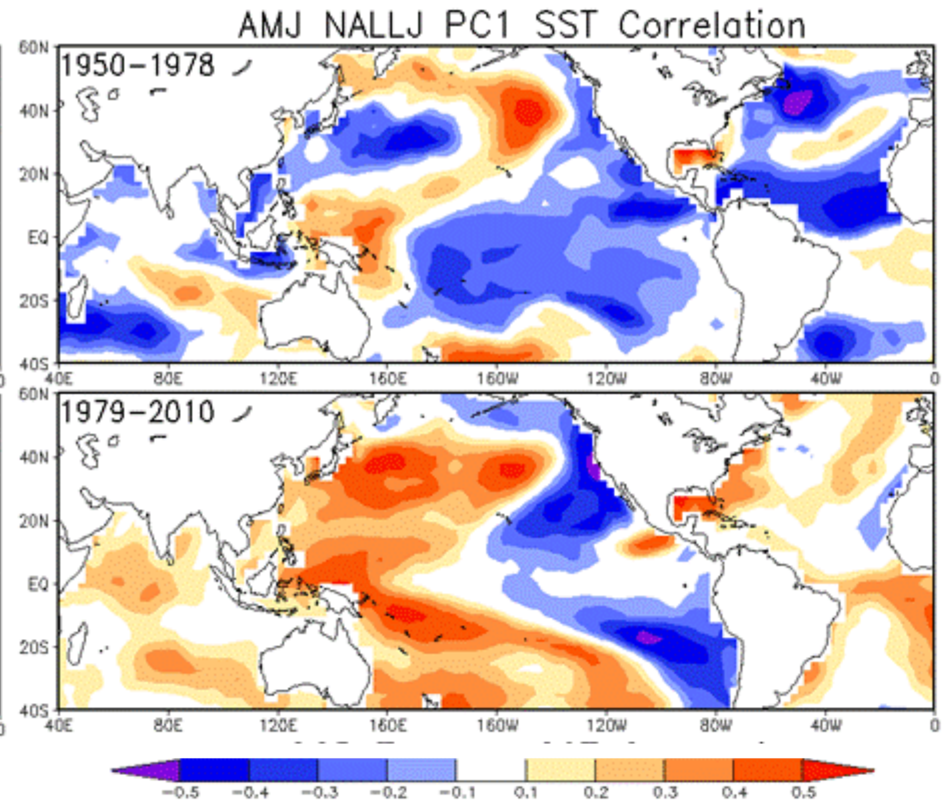
Tornadic Parameters from CFSR 1979-2010



Remote Influences

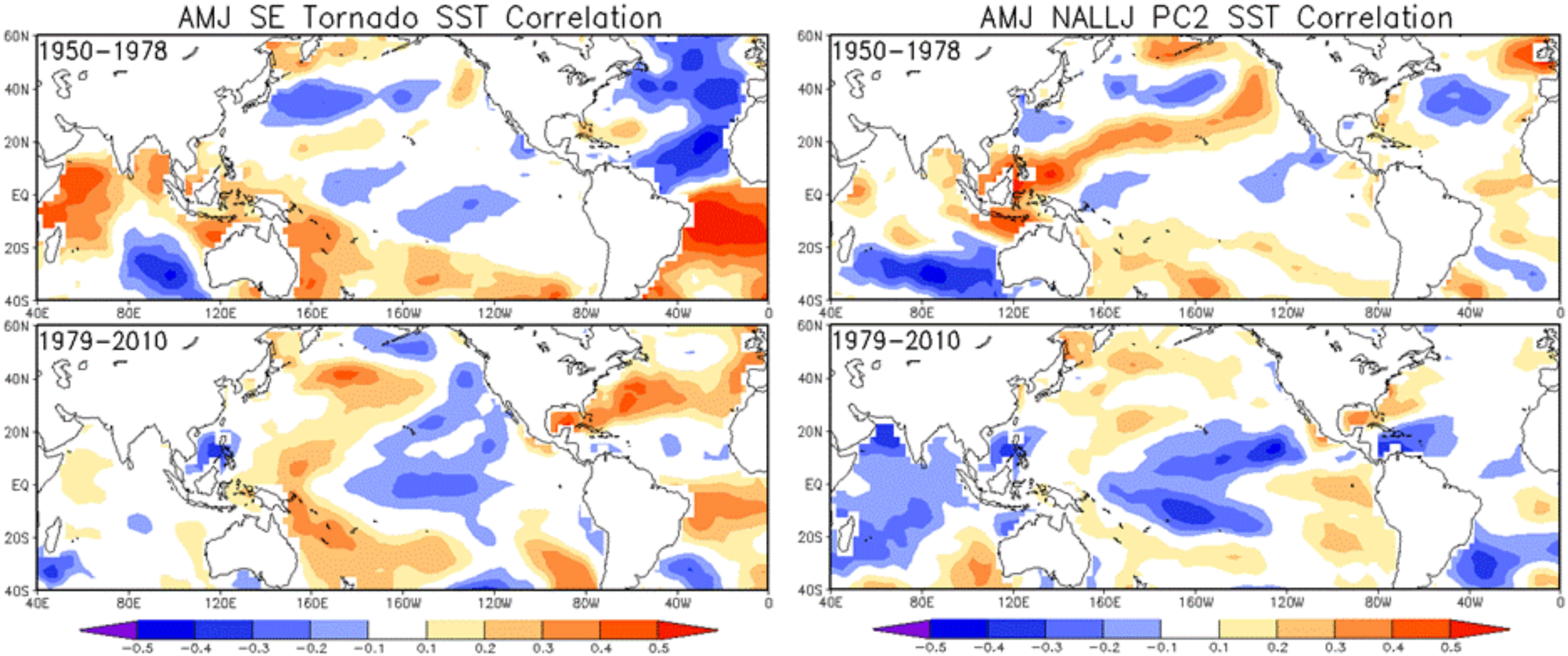
- SST anomalies offer prospects for attribution and prediction.
- ENSO linkages are inconclusive, demonstrating a weak connection to the CONUS.
- Compare and contrast the spatial patterns of global SST variability to regional tornado indices and NALLJ PCs during early and late epochs.
- Strategy assumes no a priori assumption regarding the structure of associated SST variability, the case and limitation when targeting connectivity to indices of ENSO.





AMO structure in early period (1950-1978) even in Pacific SST footprint

PDO structure (off equatorial) in recent period (1979-2010) most notable for NALLJ PC1. Is the PDO structure real?



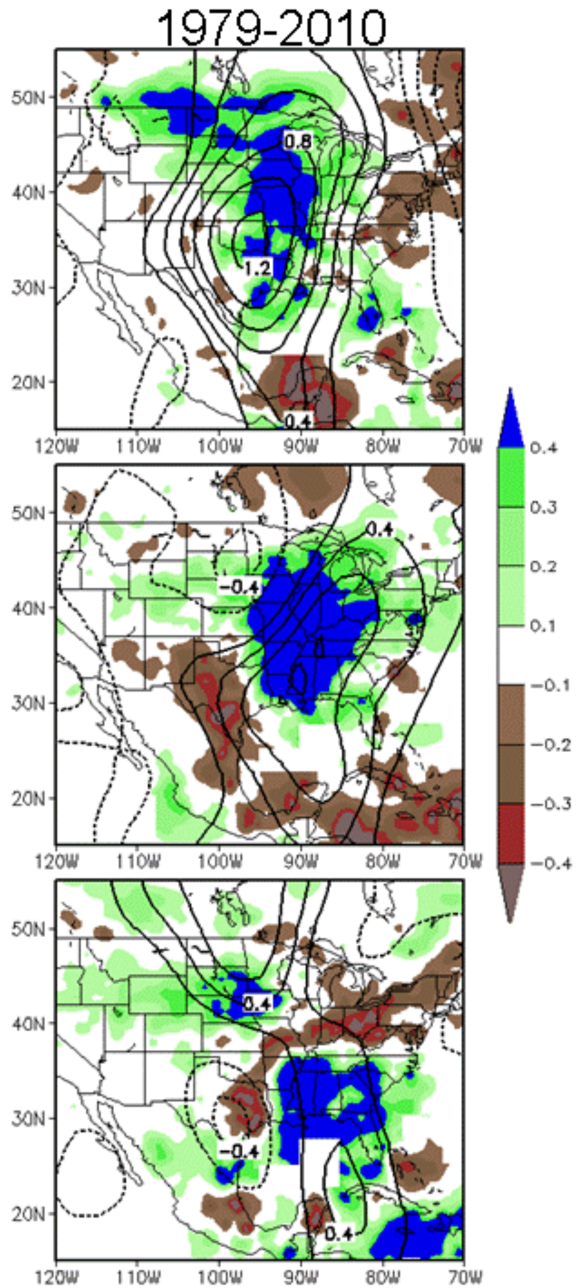
AMO structure in early period (1950-1978). Stronger in SE tornadoes than NALLJ PC2

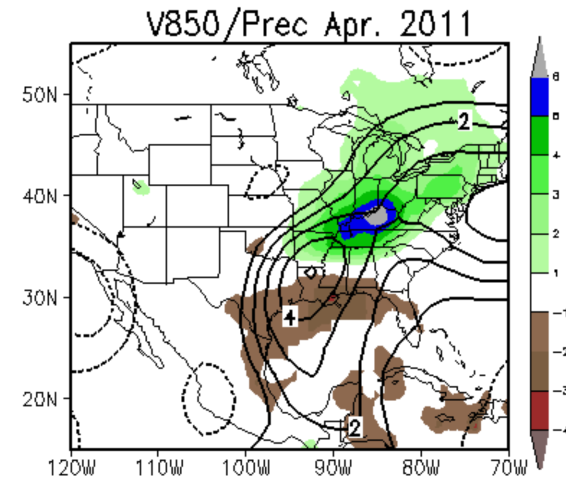
Weak central equatorial Pacific in SE tornadoes. NALLJ PC2 also exhibits a warm-east to cold-west dipole across the equatorial Pacific, reminiscent of the Trans Nino (TNI) SST structure. The TNI was recently linked to 7/10 strongest tornado outbreaks in the last 60 years.

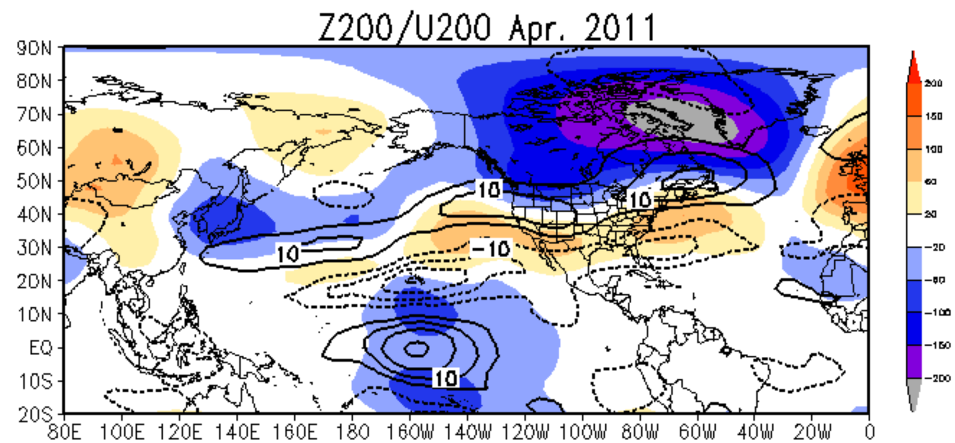
	PDO	AMO	TNI
PC1 50-78	-0.15	**-0.34**	0.13
79-10	**-0.52**	0.14	-0.20
PC2 50-78	0.21	-0.15	-0.02
79-10	0.13	0.06	**0.39**
PC3 50-78	0.25	-0.18	0.16
79-10	0.24	-0.10	0.04
NGP 50-78	0.04	-0.26	0.20
79-10	**-0.30**	0.22	0.00
SGP 50-78	0.08	-0.00	0.14
79-10	**-0.32**	0.05	-0.19
SE 50-78	0.16	**-0.39**	0.01
79-10	-0.22	0.23	0.07

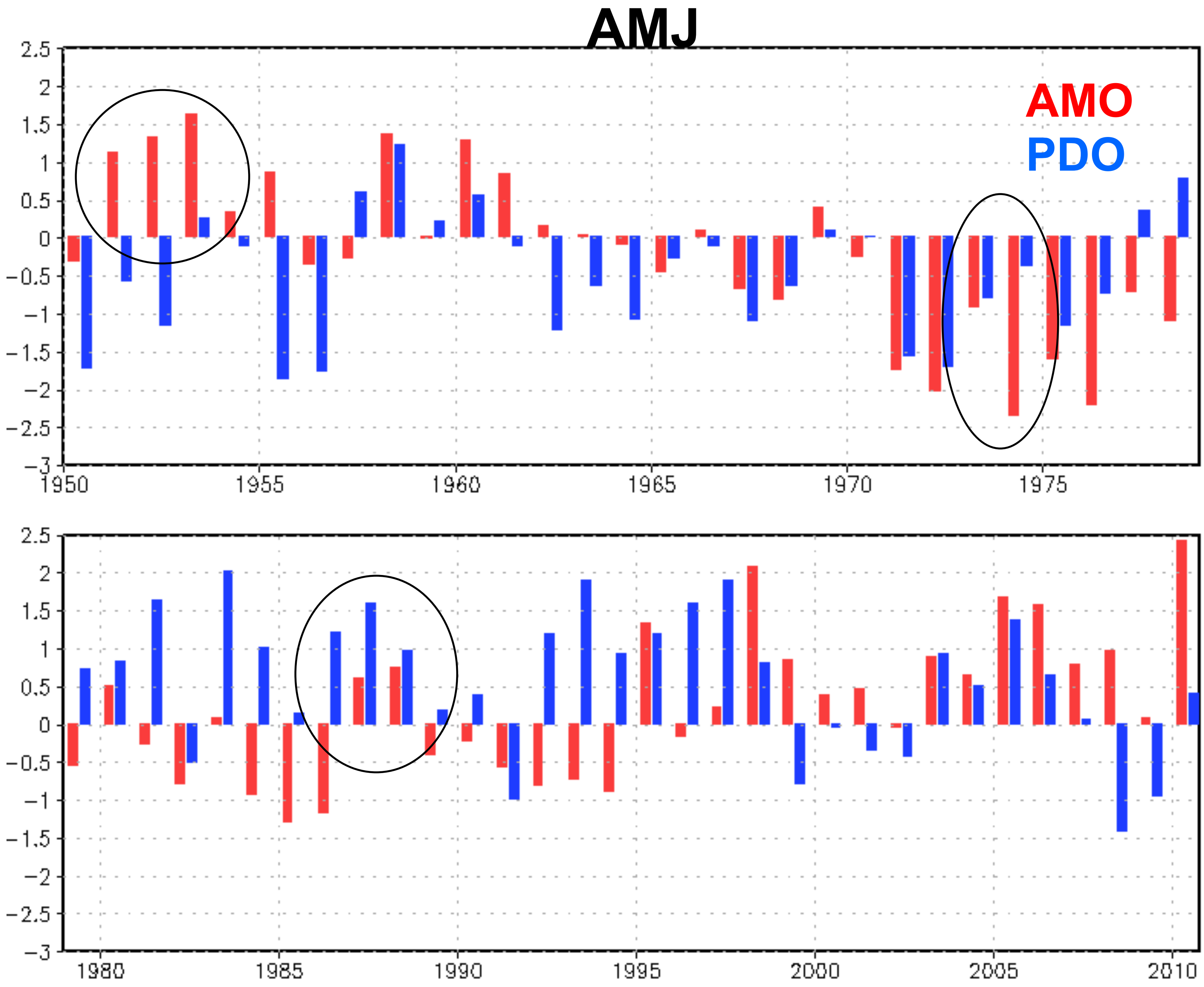
Closing Remarks

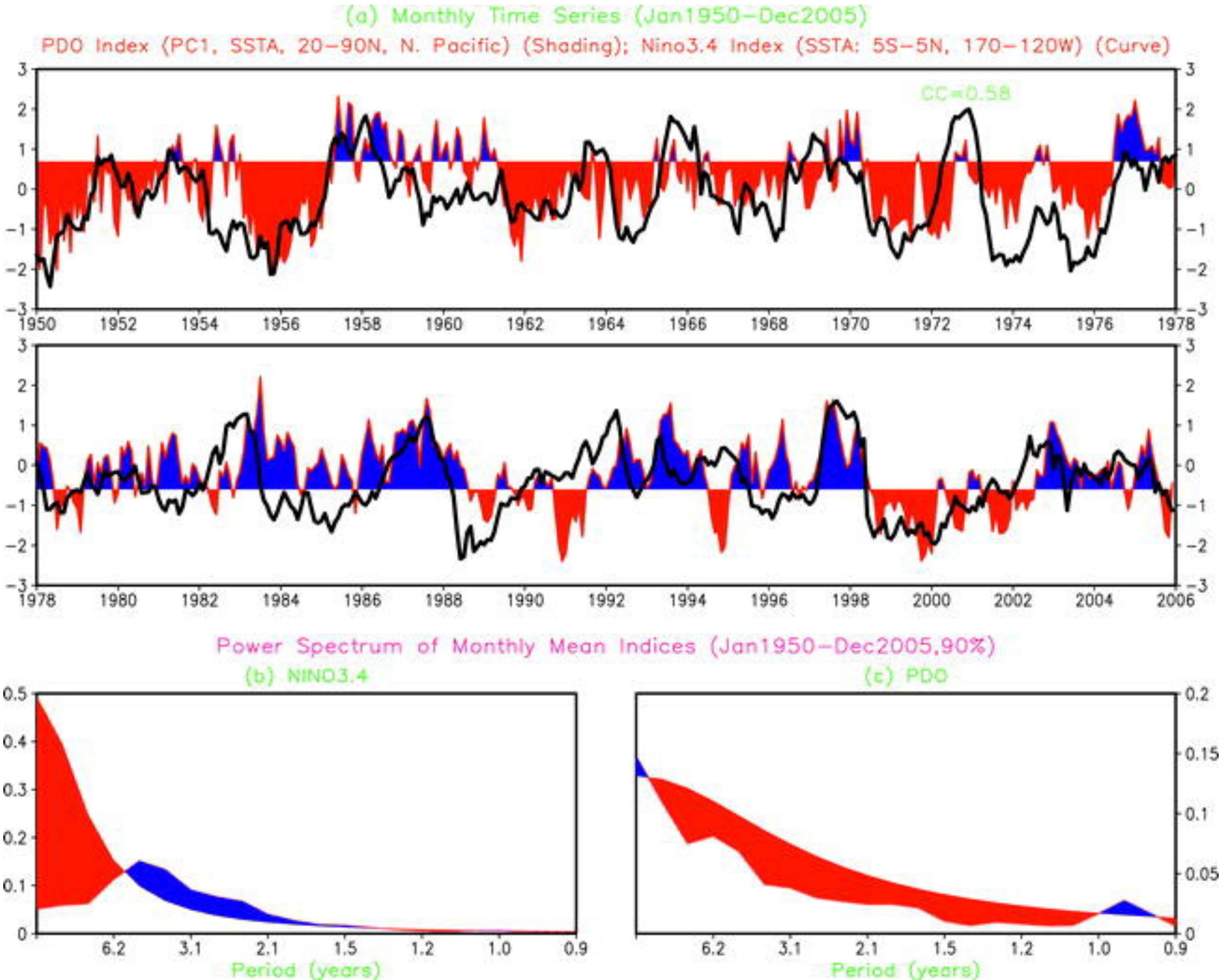
- NALLJ variability modes linked to regional U.S. tornadic activity.
- Mutlidecadal variation in the strength of the NALLJ - Tornado connection.
  - Highlighted by the SGP/PC1 correlation nearly doubling and PC3 influence weakening in the recent period.
  - Reflection of the southward shift of NALLJs in the recent period.
- SST Links show Atlantic variability (AMO) in the early period, with Pacific variability (ENSO/PDO) in the late period.
- SST attribution is challenging given the mixed modal structures.
- Model simulations and advanced statistical techniques may prove fruitful in understanding the relative roles of the various SST patterns.


1979-2010
0.8
1.2
0.4
-0.4
0.4
0.4
-0.4
0.4
50N
40N
30N
20N
120W 110W 100W 90W 80W 70W
0.4
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4


V850/Prec Apr. 2011
2
4
2
50N
40N
30N
20N
120W 110W 100W 90W 80W 70W


Z200/U200 Apr. 2011
10
10
10
-10
10
90N
80N
70N
60N
50N
40N
30N
20N
10N
EQ
10S
20S
80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W 60W 40W 20W 0

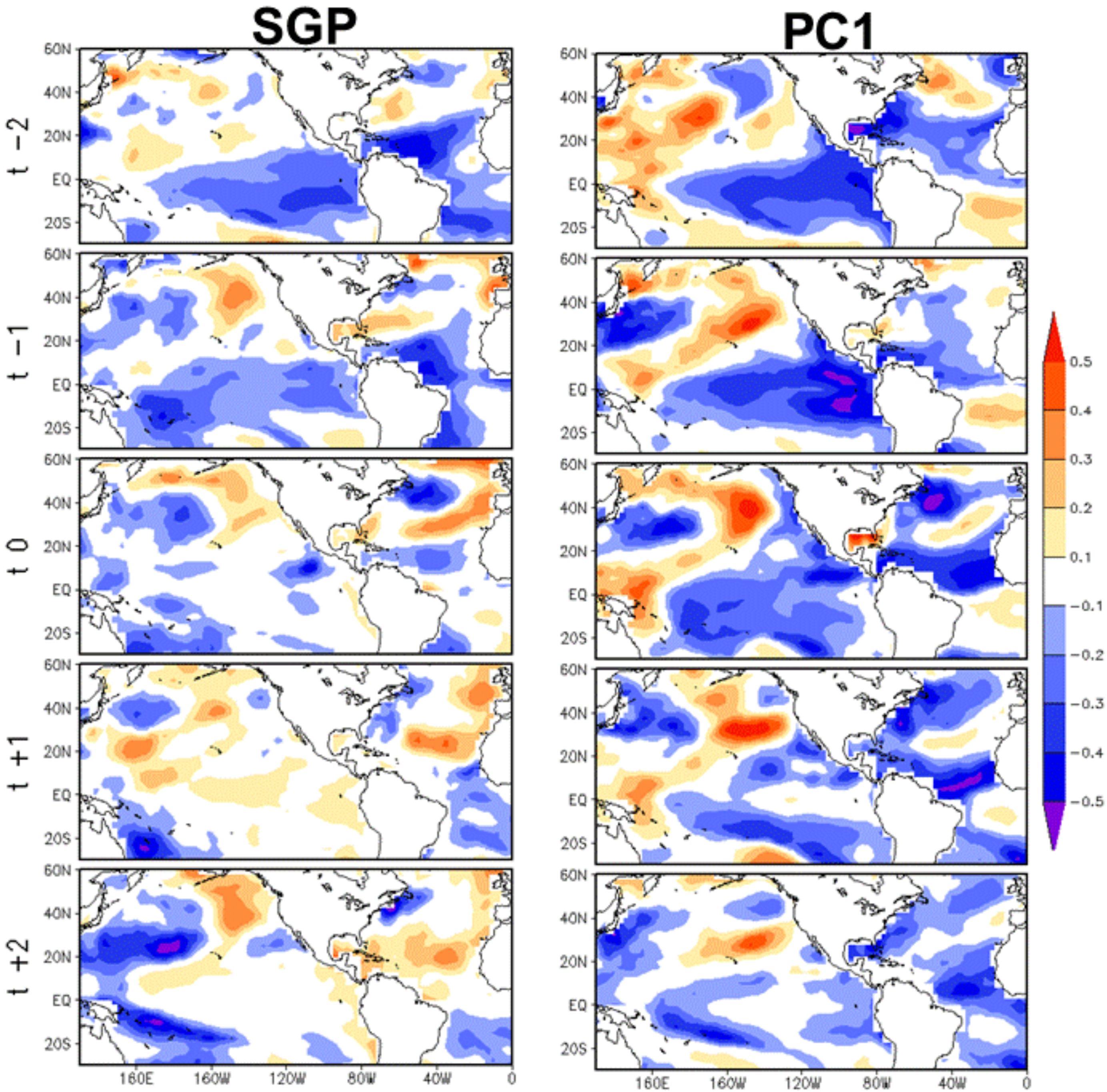

AMJ
AMO
PDO
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010



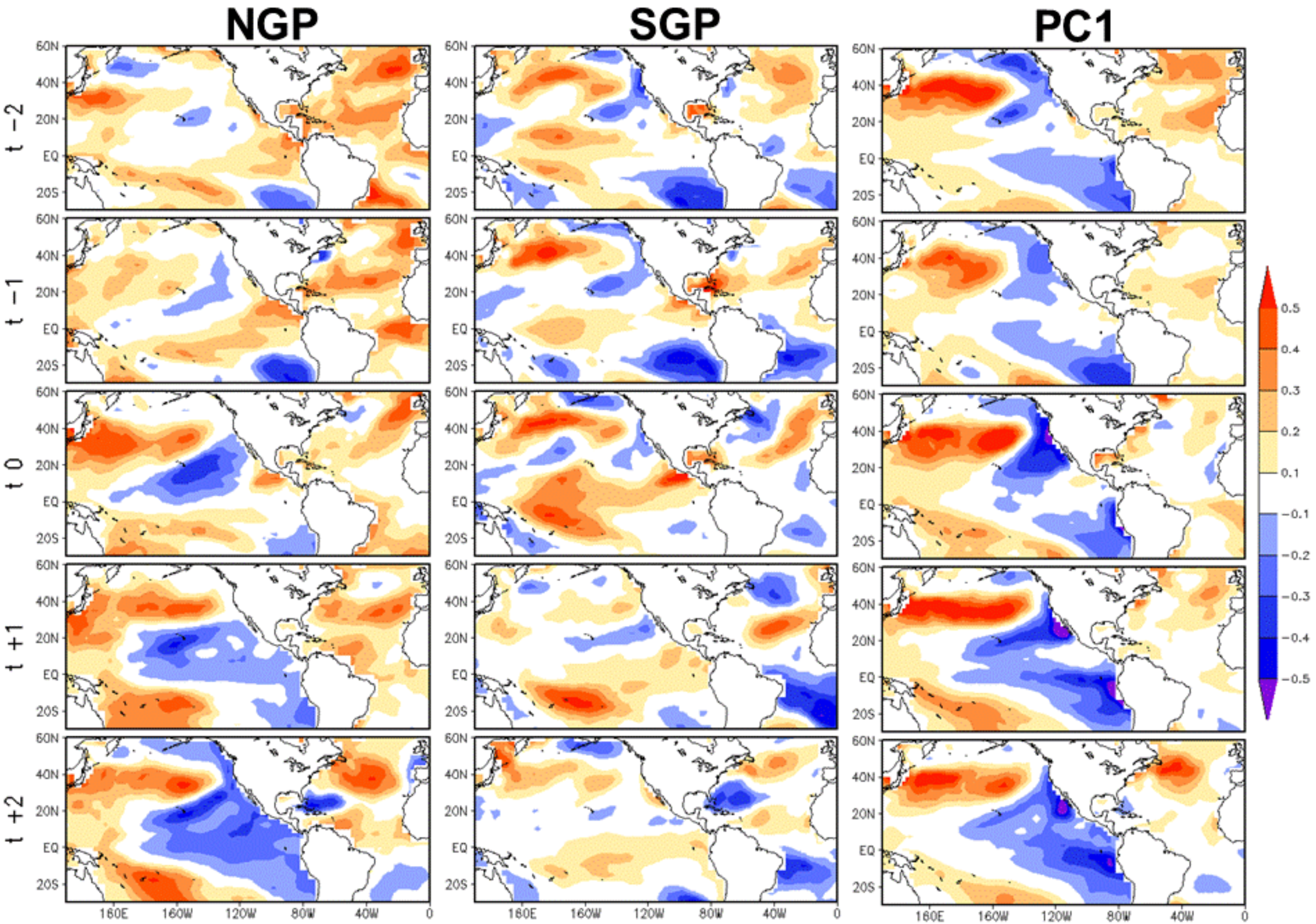
Hu and Huang 2009 J. Climate

SST Evolution

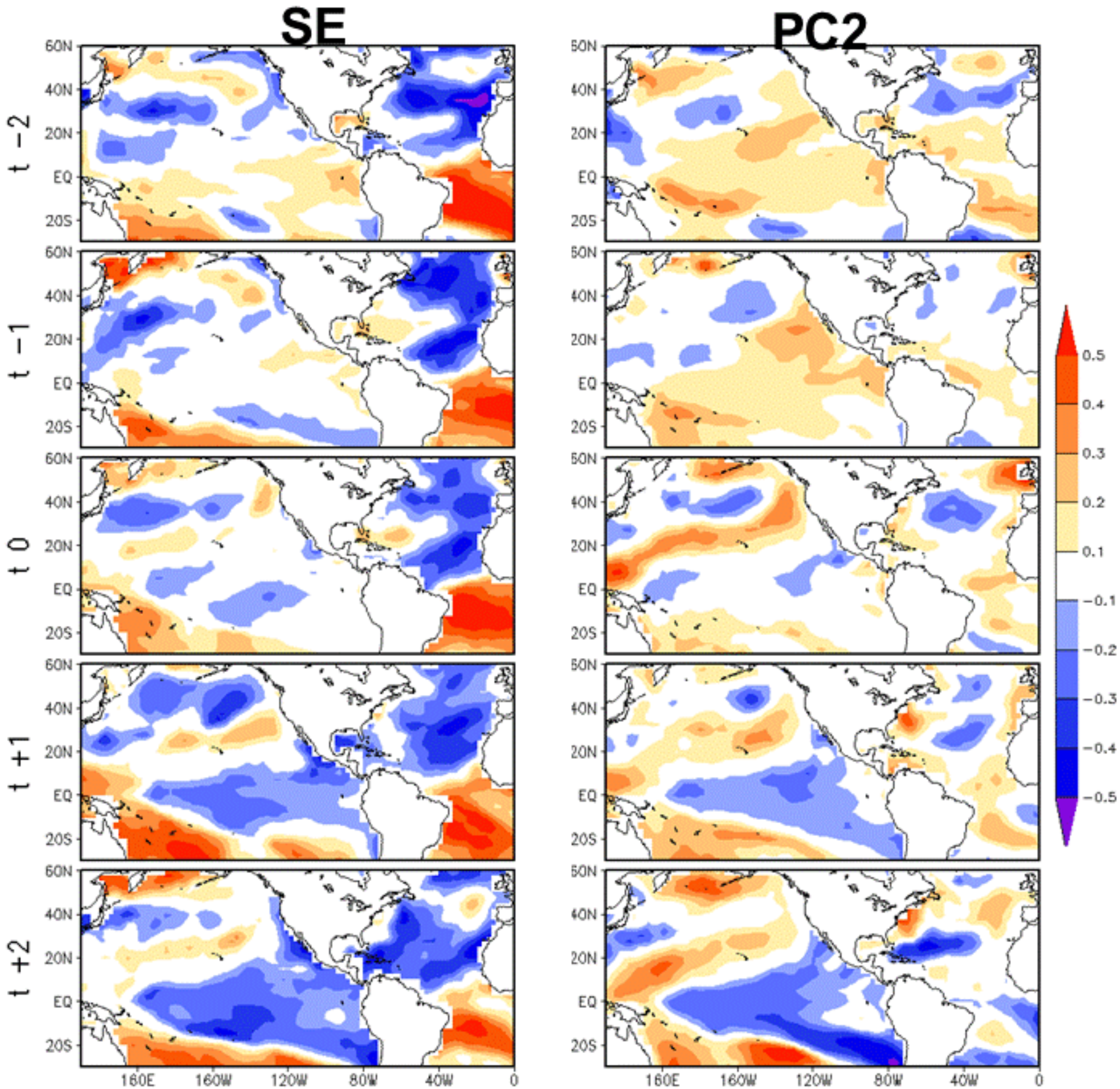
- Given our analysis season it can be difficult to attribute decadal-like SST over the Pacific to a purely decadal mode.
- Residual atmospheric forcing from previous season's ENSO may produce decadal-like SST variability over the north Pacific in spring (Atmospheric Bridge Paradigm).
- Although the observed contemporaneous ENSO connection is weak there may be a seasonal lag.
- Analyze lead lag correlations with 5 season window centered on AMJ.



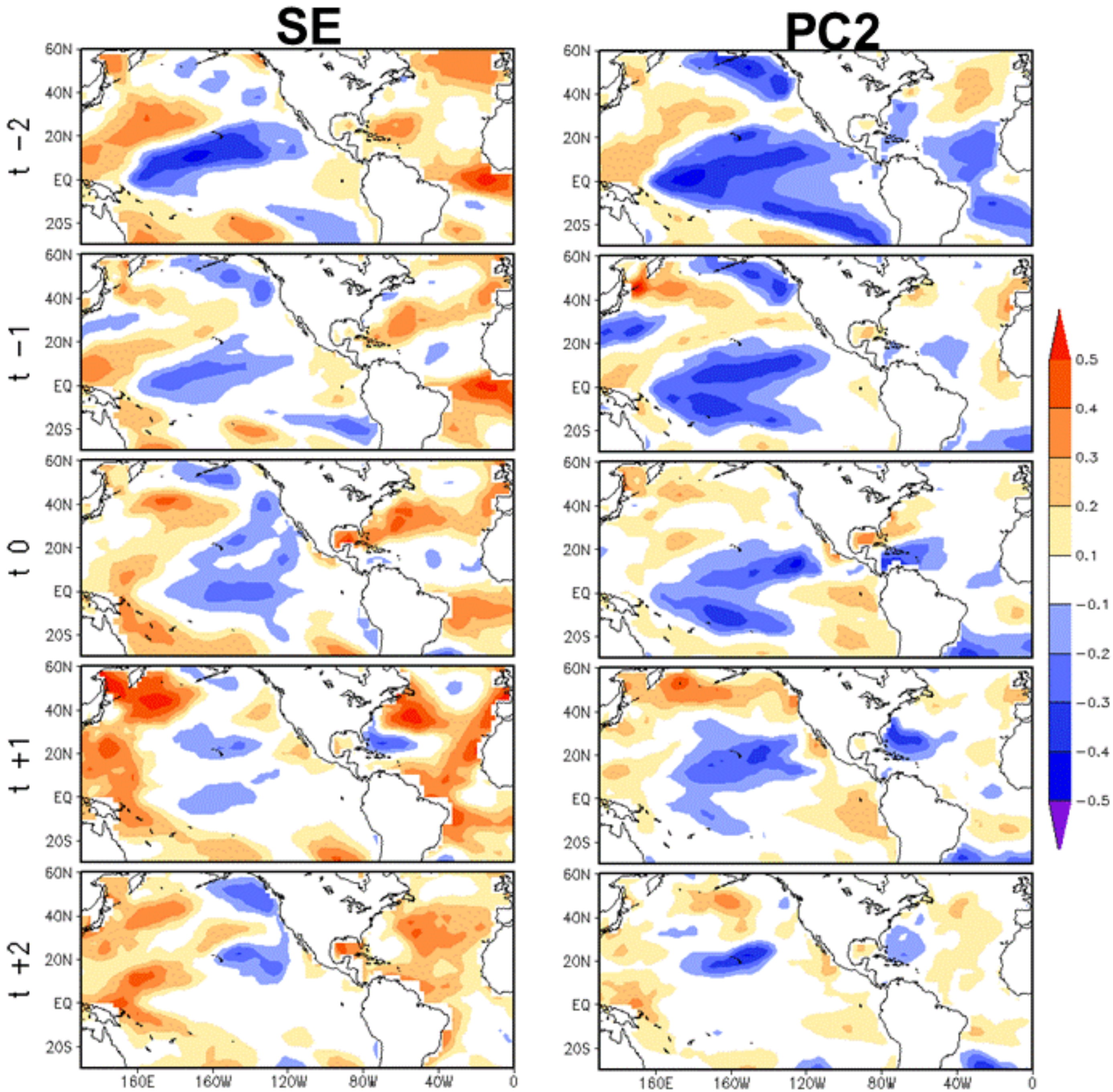
SGP
PC1
t −2
t −1
t 0
t +1
t +2
60N
40N
20N
EQ
20S
160E
160W
120W
80W
40W
0
0.5
0.4
0.3
0.2
0.1
−0.1
−0.2
−0.3
−0.4
−0.5



NGP
SGP
PC1
t −2
t −1
t 0
t +1
t +2
60N
40N
20N
EQ
20S
160E
160W
120W
80W
40W
0
0.5
0.4
0.3
0.2
0.1
−0.1
−0.2
−0.3
−0.4
−0.5



SE
PC2
t −2
t −1
t 0
t +1
t +2
60N
40N
20N
EQ
20S
160E
160W
120W
80W
40W
0
0.5
0.4
0.3
0.2
0.1
−0.1
−0.2
−0.3
−0.4
−0.5


SE
PC2
t −2
t −1
t 0
t +1
t +2
60N
40N
20N
EQ
20S
160E
160W
120W
80W
40W
0
0.5
0.4
0.3
0.2
0.1
−0.1
−0.2
−0.3
−0.4
−0.5

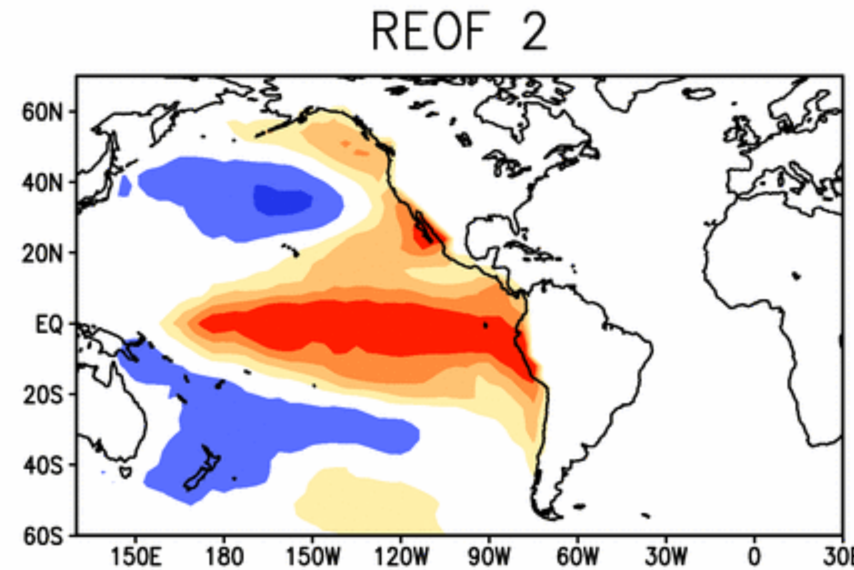
Idealized SST Simulations

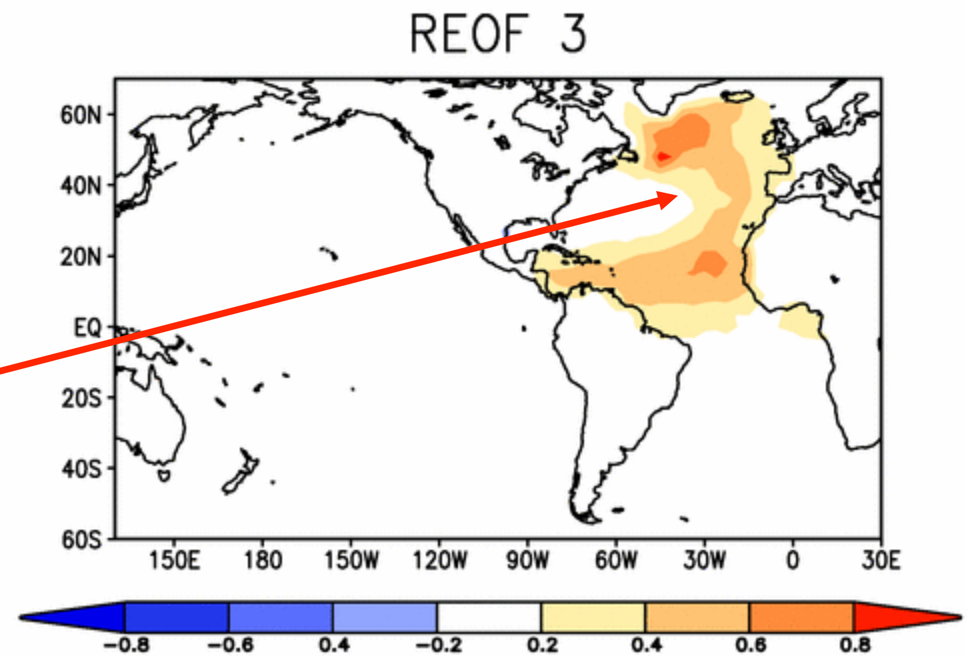
• SST forcing patterns gleaned from Rotated EOF analysis of annual mean SST anomalies for 1901-2004.

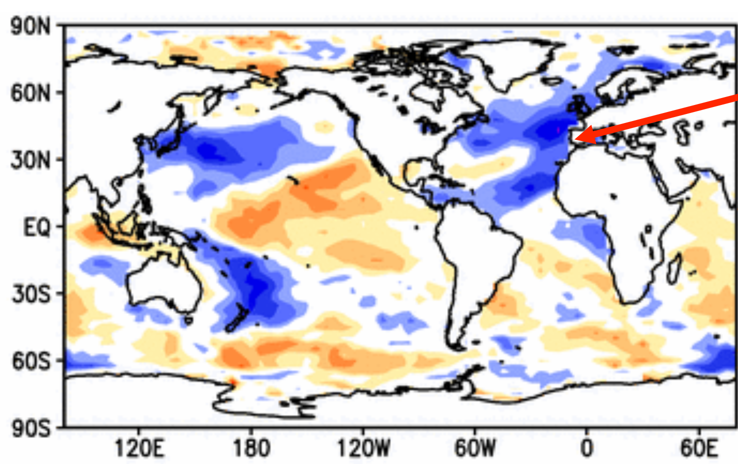
• Pacific pattern (20.5%)

• Atlantic pattern (5.8%)

• Models are forced with 2σ of all possible combinations and polarities of REOF patterns atop a monthly varying climatology for 50 years.







Seasonal Cycle of GPLLJ Responses
Under Various Forcing Polarities (50/35 Years)