Predictability of a North American tornado environment index from tropical Pacific SST and the Arctic Oscillation

Michael K. Tippett[1], Chiara Lepore[1], Michelle L. L'Heureux[2]

[1]Columbia University, [2]NWS/NCEP/Climate Prediction Center

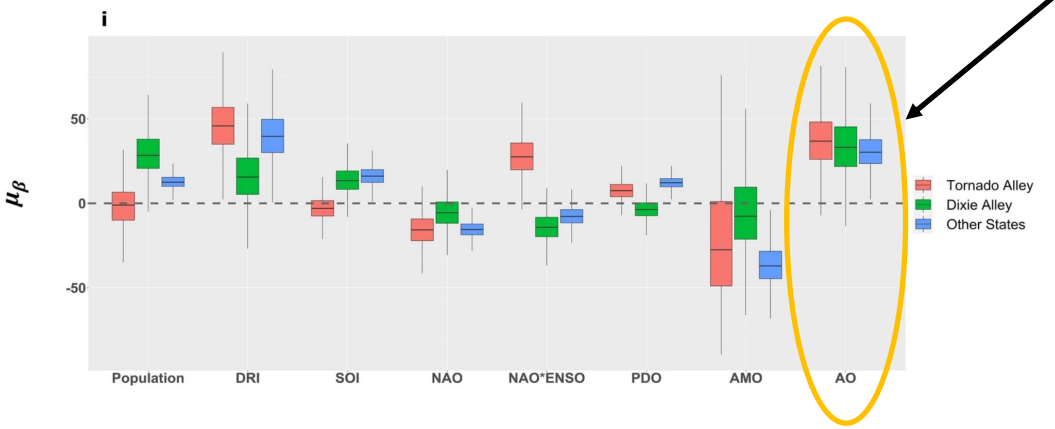
BONUS
3 “mistakes”

Summary

1. Review previous work with storm reports, reanalysis, etc.
   - More U.S. tornado activity during La Niña
   - Details are uncertain because:
     - ENSO signal is modest, tornadoes are sporadic
     - Sample size is small
2. We looked at a CFSv2-simulated tornado environment index (TEI)
   - TEI and its spread are larger during La Niña than El Niño
     - Implications for predictability depend on the predictability measure
   - ENSO and AO signals can be constructive or destructive
   - Sample size is large and details are robust
3. Monthly AO phase might have played a role in 2021’s relatively calm, despite La Nina, tornado season

Background

- More tornado activity during La Niña than El Niño
  - Except Florida
  - Reports, reanalysis, and models
  - Some indication of more uncertainty during La Niña
    - Molina et al., 2018, Moore, 2019.
- Less is known about the *positive* tornado / AO relation



Nouri, N., Devineni, N., Were, V. *et al.* Explaining the trends and variability in the United States tornado records using climate teleconnections and shifts in observational practices. *Sci Rep* **11,** 1741 (2021)

evolution of the regional environment
justification for such associations. This st
the literature, while also identifying a nu
Both the AO and NAO are relevant ac
SSTA/SSTADs are relevant on smaller
regional storm environment is largely re
which in turn influence deep- and low-

Brown, M. C., & Nowotarski, C. J. (2020). Southeastern U.S. Tornado Outbreak Likelihood Using Daily Climate Indices, *Journal of Climate*, *33*(8), 3229-3252.

TABLE 4. Correlations r^2 between NDJF and monthly tornado counts and ENSO or AO index time series. Italicized r^2 values indicate statistically significant correlations via the Pearson correlation test.

Teleconnection	NDJF	Nov	Dec	Jan	Feb
ENSO	*0.090*	0.011	0.003	0.059	*0.095*
AO	*0.168*	*0.104*	0.001	0.041	0.030

Childs, S. J., Schumacher, R. S., & Allen, J. T. (2018). Cold-Season Tornadoes: Climatological and Meteorological Insights, *Weather and Forecasting*, *33*(3), 671-691.

The Correlation between U.S. Tornadoes and Pacific Sea Surface Temperatures

CAREN MARZBAN

National Severe Storms Laboratory, Cooperative Institute for Mesoscale and Meteorological Studies, and Department of Physics, University of Oklahoma, Norman, Oklahoma

JOSEPH T. SCHAEFER

Storm Prediction Center, Norman, Oklahoma

(Manuscript received 10 December 1999, in final form 16 August 2000)

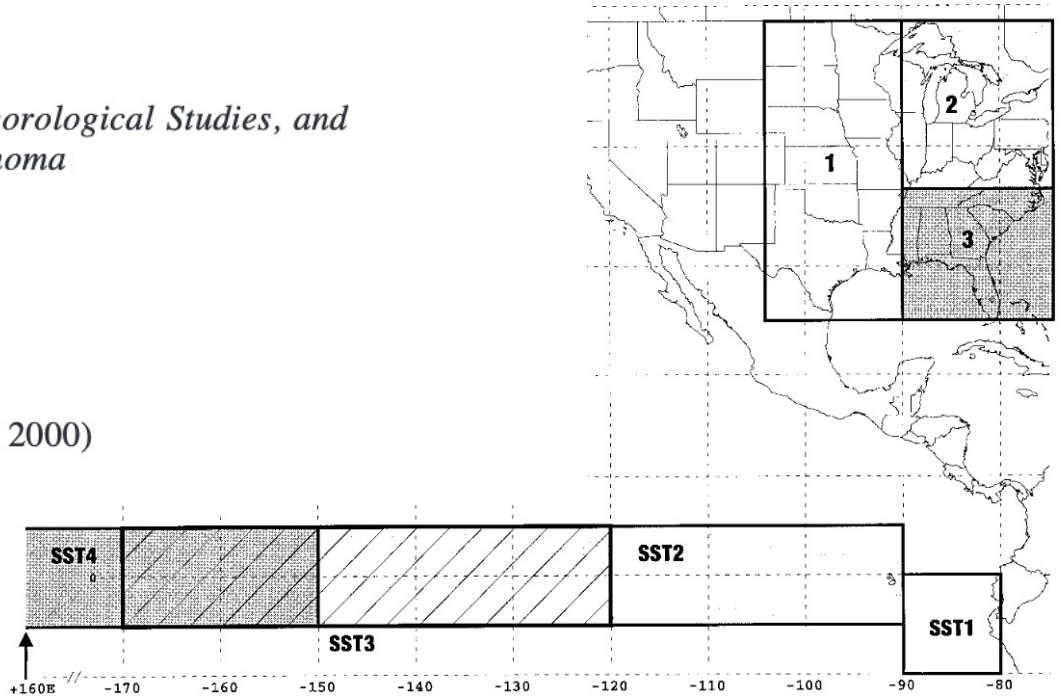


FIG. 1. The three regions of the United States, and the four zones in the Pacific.

Negative values of Kendall's tau

TABLE 2. Kendall's τ and its z statistic, (τ, z), for the correlation between between SST and (a) the number of tornadoes, and (b) the number of tornadic days. The bold font indicates the most significant correlation in the respective table.

	SST1	SST2	SST3	SST4
(a)				
Contiguous United States	(−0.03, −1,10)	(−0.05, −1.86)	(−0.05, −1.86)	(−0.04, −1.37)
Region 1: Tornado Alley	(−0.03, −1.21)	(−0.04, −1.37)	(−0.03, −1.18)	(−0.01, −0.25)
Region 2: Northeast United States	(−0.04, −1.51)	**(−0.06, −2.10)**	(−0.05, −1.70)	(−0.04, −1.41)
Region 3: Southeast United States	(−0.01, −0.48)	(−0.03, −1.04)	(−0.04, −1.41)	(−0.06, −2.04)
(b)				
Contiguous United States	(−0.02, −0.73)	(−0.03, −0.91)	(−0.02, −0.59)	(−0.02, −0.60)
Region 1: Tornado Alley	(−0.02, −0.86)	(−0.01, −0.33)	(+0.01, +0.27)	(+0.02, +0.87)
Region 2: Northeast United States	(−0.07, −2.62)	**(−0.08, −2.91)**	(−0.07, −2.35)	(−0.05, −1.73)
Region 3: Southeast United States	(−0.01, −0.39)	(−0.01, −0.20)	(−0.004, −0.14)	(−0.02, −0.65)

which the sea surface temperatures are assessed and the geographic region of the United States. In general, the correlations are negative, suggesting that a higher frequency of tornadoes and tornadic days is associated with cooler sea surface temperatures (La Niña). For instance,

All months

MWR, 2000

The Relation of El Niño–Southern Oscillation (ENSO) to Winter Tornado Outbreaks

A. R. Cook and J. T. Schaefer

NOAA/NWS Storm Prediction Center, Norman, Oklahoma

(Manuscript received 9 February 2007, in final form 26 November 2007)

El Niño

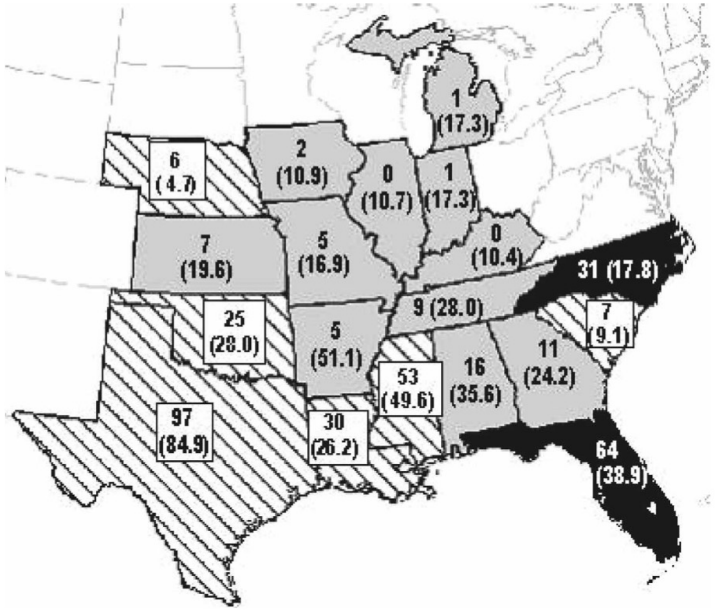


FIG. 10. Tornadoes occurring during EN winters by state. Numbers in parentheses are the expected values (independent of ENSO). Classifications of ENSO phase are made using the CPC ENSO phase classifications. States outlined in black experience greater than 125% of the expected number of tornadoes, while states outlined in gray experienced less than 75% of their expected value. States outlined in the stripes experience within 25% of the expected value of tornadoes.

La Niña

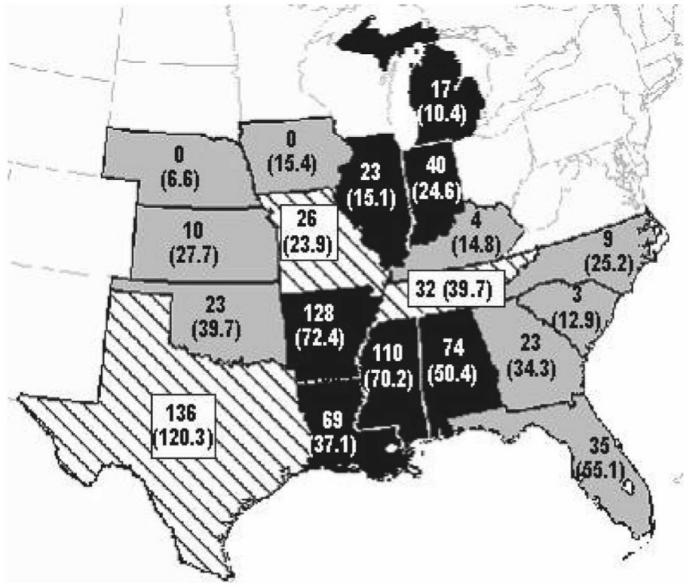


FIG. 12. Tornadoes occurring during LN winters by state, as in Fig. 10.

LESS

MORE

State-level resolution Jan–Mar

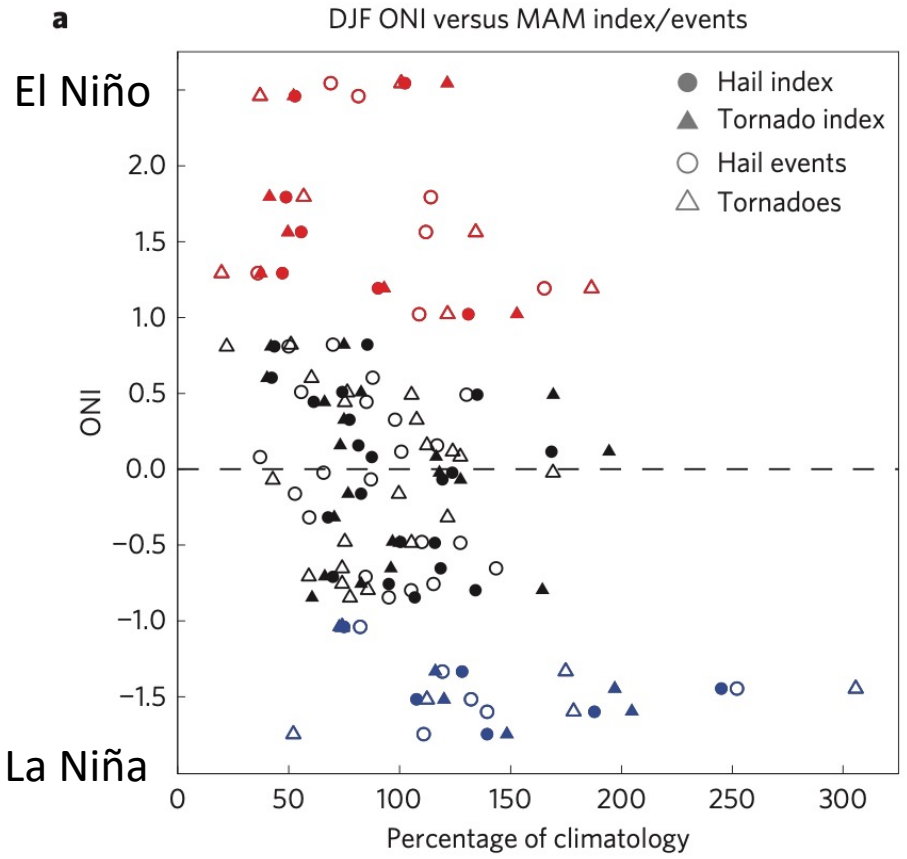
MWR, 2007

LETTERS
PUBLISHED ONLINE: 16 MARCH 2015 | DOI: 10.1038/NGEO2385 (2015)
nature geoscience

Influence of the El Niño/Southern Oscillation on tornado and hail frequency in the United States

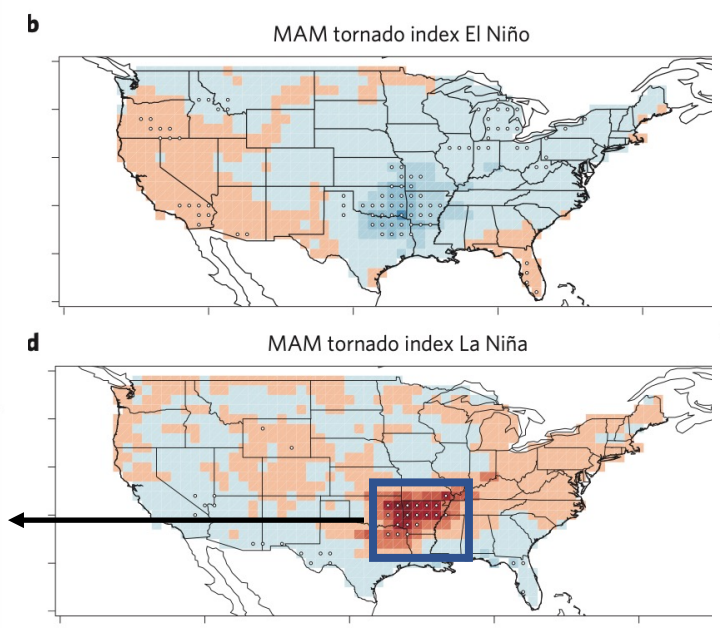
John T. Allen[1]*, Michael K. Tippett[2,3] and Adam H. Sobel[2,4]

El Niño

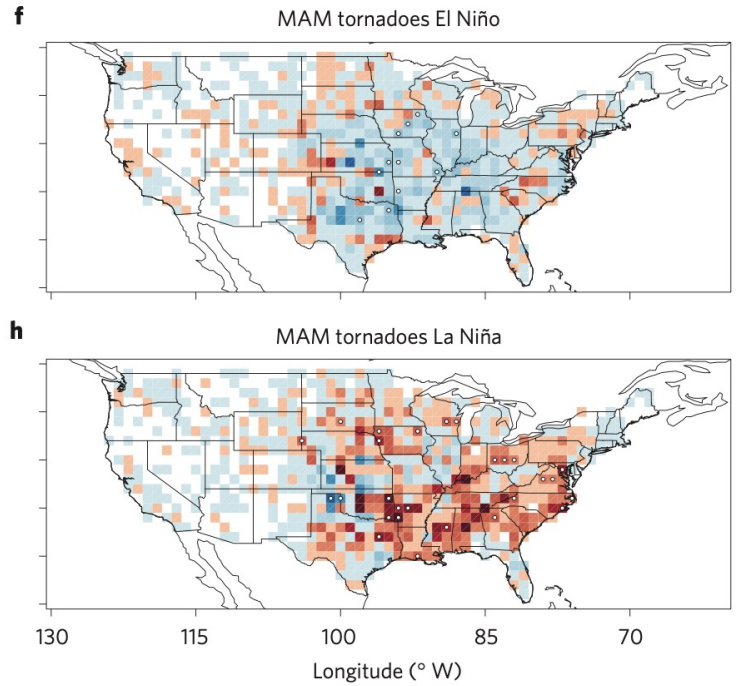


La Niña

Tornado Environment Index



Reports



El Niño
7 cases

La Niño
6 cases

1x1 grid

Mar-May

Issues/gaps/motivation

- A detailed estimate of the ENSO signal is difficult
  - Tornadoes are sporadic in time and space
    - Pool months together
    - Multi-state regions
  - Reliable tornado record is relatively short (since Doppler rollout)
  - Relatively few ENSO events
    - Each one contains signal & noise
    - Reanalysis is spatially smoother, but still just one sample per ENSO event
- Also hard to accurately to estimate what ENSO *doesn't* explain (noise)
  - Signal/Noise
- AO is probably more difficult because less persistent
- Some years (2021) don't turn out as expected.

2021

La Nina conditions

- **Above** average tornado expected

Jan tornado: *below* average

- AO -2.484

Feb tornado: *below* average

- AO -1.191

Mar tornado: **above** average

- AO 2.109

Apr tornado *below* average

- AO -0.204

May tornado average

- AO -0.161

Latest U.S. Tornado Statistics (AWIPS ID:STAMTS*)


```
ZCZC STAMTS ALL
NWUS21 KWNS 201238

TORNADO TOTALS AND RELATED DEATHS...THROUGH 19 OCT 2021
NWS STORM PREDICTION CENTER NORMAN OK
0738 AM CDT WED OCT 20 2021
```

	...NUMBER OF TORNADOES...						NUMBER OF TORNADO DEATHS					KILLER TORNADOES				
	..2021..		2020	2019	2018	3YR					3YR					3YR
	PREL	ACT	ACT	ACT	ACT	AV	21	20	19	18	AV	21	20	19	18	AV
JAN	16	-	86^	22	15	41^	1	7	0	0	2	1	3	0	0	1
FEB	11	-	42^	27	48	39^	3	1	1	2	1	1	1	1	2	1
MAR	191	-	83^	107	55	82^	7	25	23	0	16	2	3	1	0	1
APR	73	-	271^	272	130	224^	1	38	7	1	15	1	13	4	1	6
MAY	289	-	126^	510	170	269^	0	1	7	1	3	0	1	4	1	2
JUN	110	-	90^	177	155	141^	0	0	0	0	0	0	0	0	0	0
JUL	150	-	99^	101	92	97^	0	1	0	1	1	0	1	0	1	1
AUG	132	-	182^	78	81	114^	0	3	0	0	1	0	2	0	0	1
SEP	31	-	38^	85	108	77^	1	0	0	1	0	1	0	0	1	0
OCT	85	-	19^	65	123	69^	0	0	0	0	0	0	0	0	0	0
NOV	-	-	21^	16	83	40^	-	0	1	3	1	-	0	1	2	1
DEC	-	-	18^	57	66	47^	-	0	3	1	1	-	0	2	1	1
SUM	1088	---	1075^	1517	1126	1240^	13	76	42	10	41	6	24	12	9	15

```
*PRELIMINARY REPORTS.
^PRELIMINARY/INCOMPLETE VERSION OF FINAL COUNTS.
```

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2020	0.5	0.5	0.4	0.2	-0.1	-0.3	-0.4	**-0.6**	**-0.9**	**-1.2**	**-1.3**	**-1.2**
2021	**-1.0**	**-0.9**	**-0.8**	**-0.7**	**-0.5**	-0.4	-0.4	-0.5				

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

https://www.spc.noaa.gov/climo/online/monthly/newm.html

What we did

- Waited for decades more of data? No.
- “What would CFSv2 do?” method →
  - CFSv2 does ENSO but not tornadoes
  - Use the tornado environment index (TEI)
    - Function of monthly storm-relative helicity & convective precipitation
    - Previously documented relation with tornado reports
  - Compute TEI, Niño 3.4, and AO in CFSv2 hindcast/forecast data
    - ~8500 years of data for each month
    - Robust statistics

Published: 22 December 2016

What is the variability in US west coast winter precipitation during strong El Niño events?

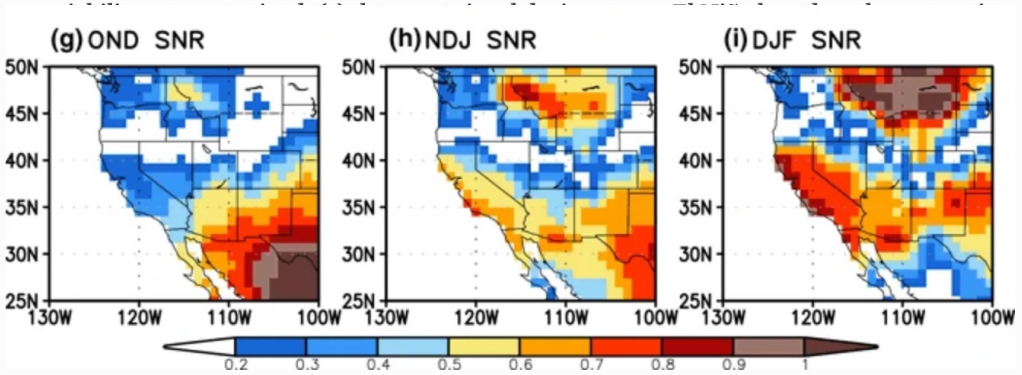
Arun Kumar & Mingyue Chen

Climate Dynamics **49**, 2789–2802 (2017) | Cite this article

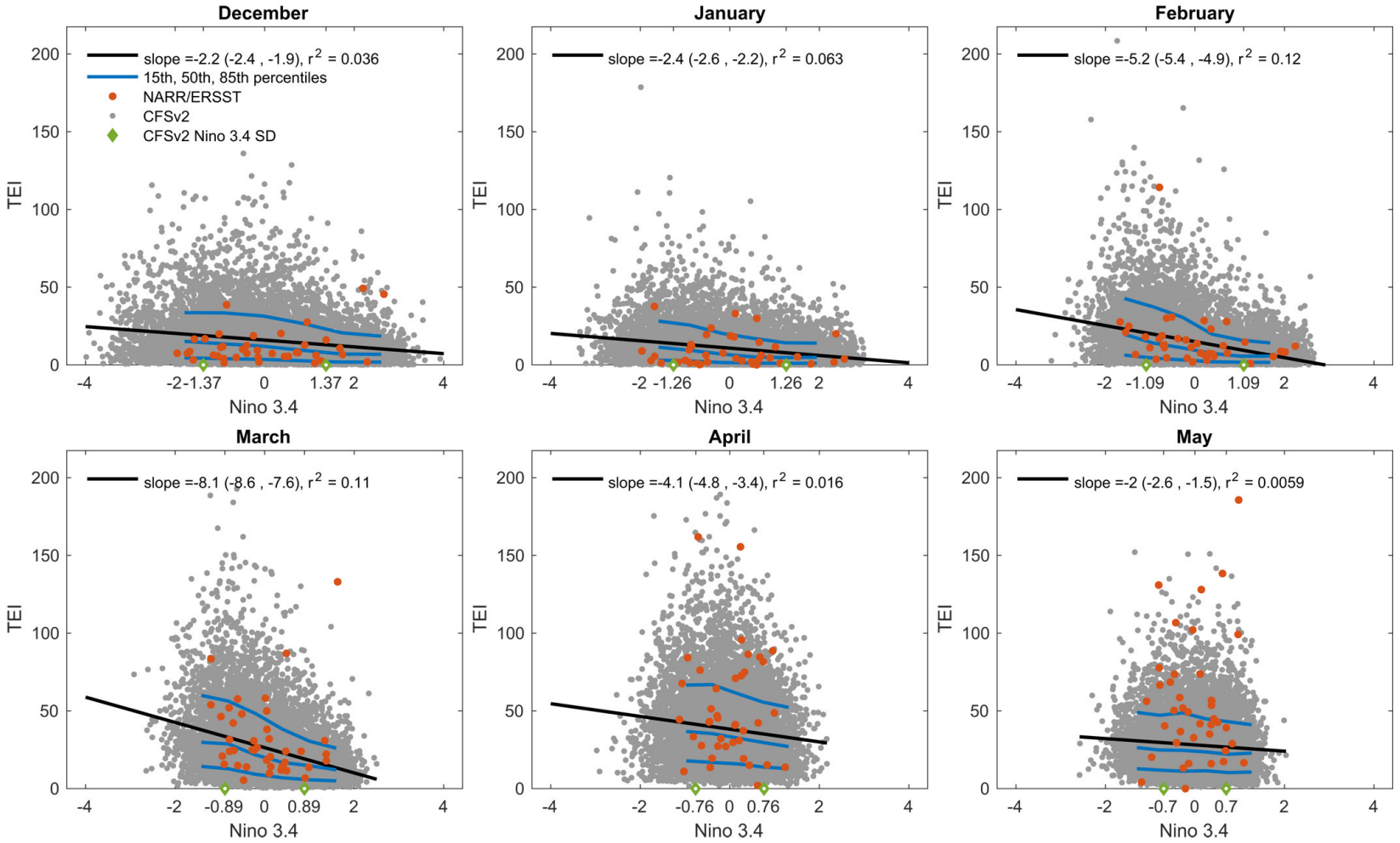
580 Accesses | **24** Citations | Metrics

Abstract

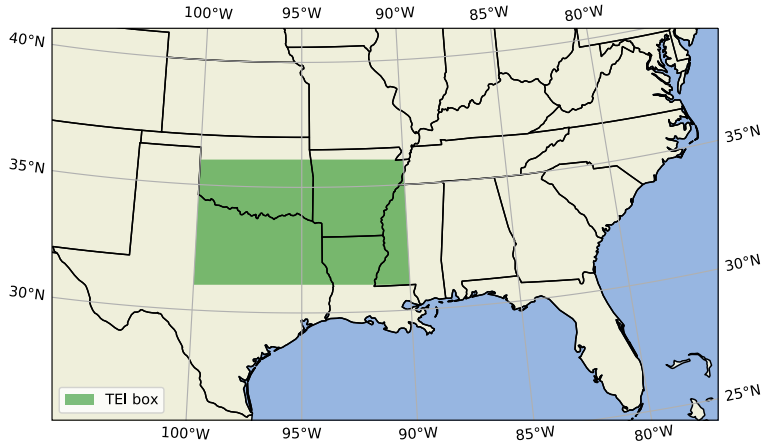
Motivated by the fact that the spatial pattern of the observed precipitation anomalies during 2015/16 winter (a year of strong El Niño) over the west coast of the US and that of the El Niño composite precipitation pattern had considerable differences, the variability in the winter precipitation during strong El Niño events is assessed. The analysis is based on a set of hindcasts (1982–2011) and real-time forecasts (2012–2015) from NCEP Climate Forecast System version 2 (CFSv2), and the following aspects for seasonal mean precipitation



What we found (in that box)



- Strongest ENSO/TEI signal in Feb & Mar
- TEI signal is linear in Niño 3.4 – **Same size signal** for El Niño and La Niña
- Noise (spread) is greater for La Niña than El Niño
- Similar to observations

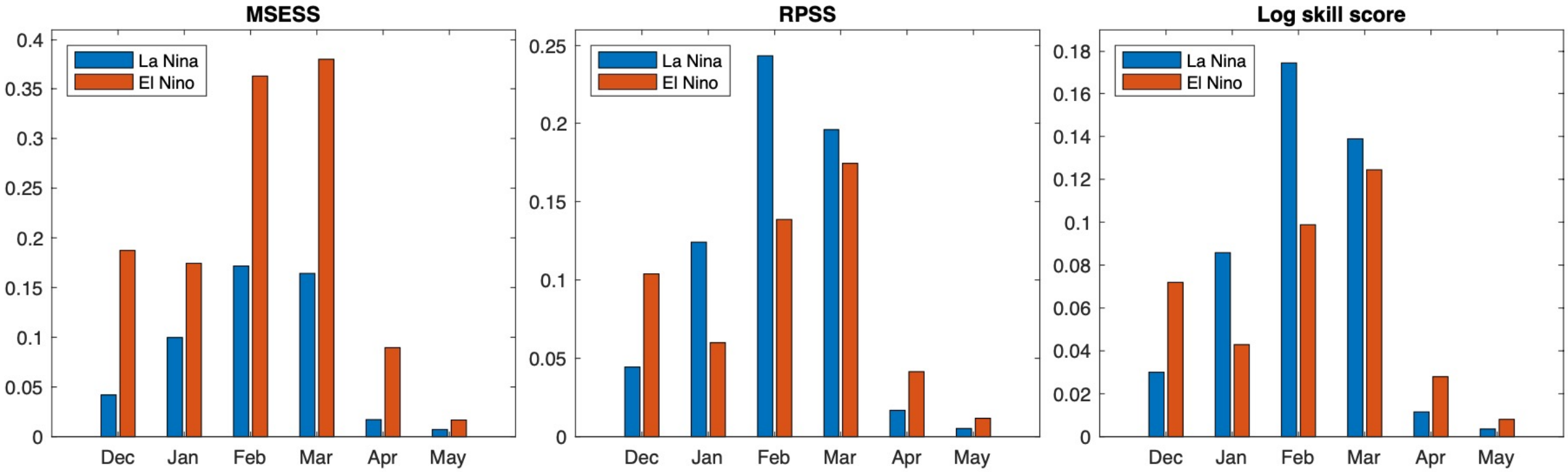


https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021GL094907

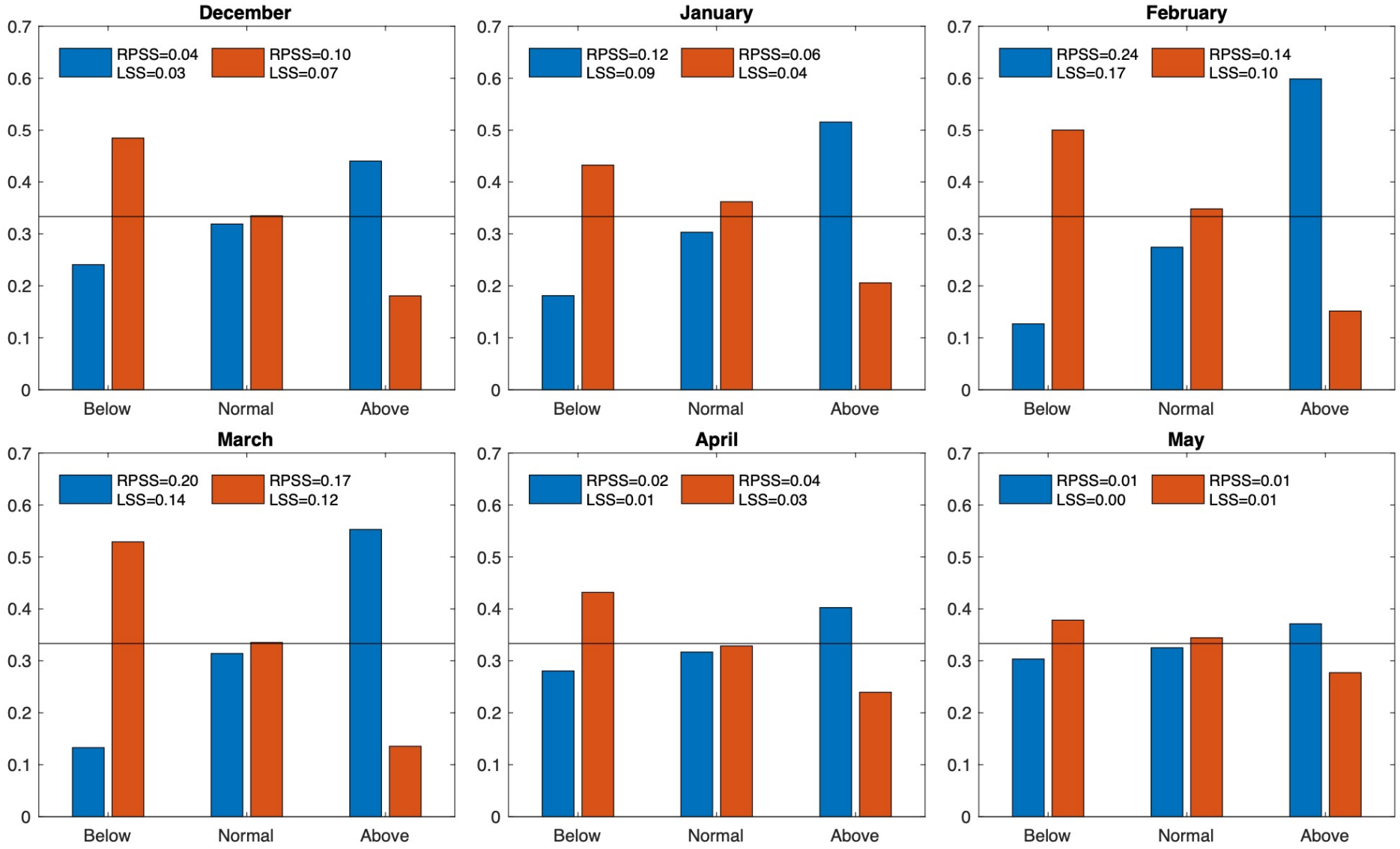
What are the implications for predictability/perfect model skill?

MSESS depends on Signal/Noise

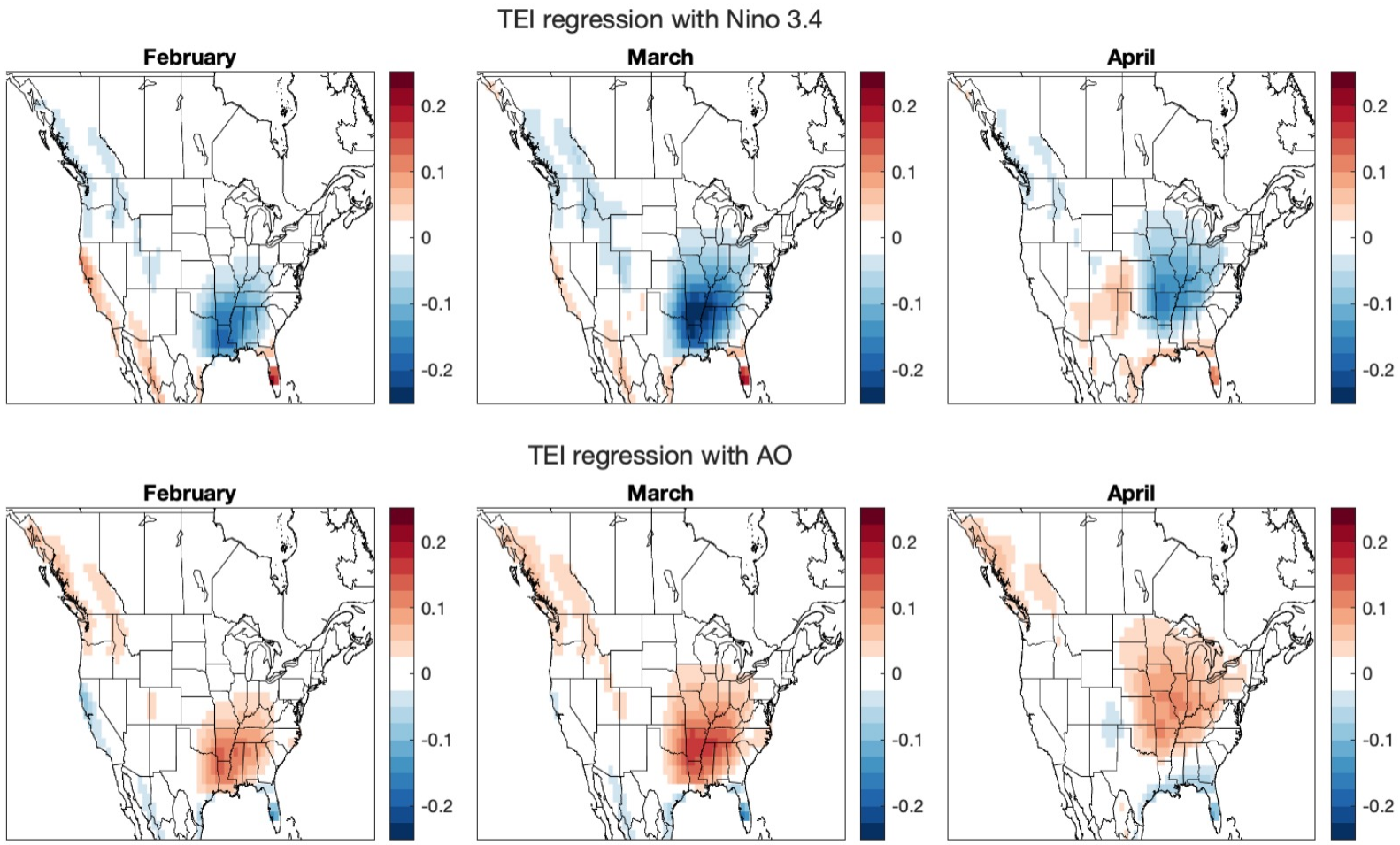
RPSS & LSS depend on probability shifts of below and above categories



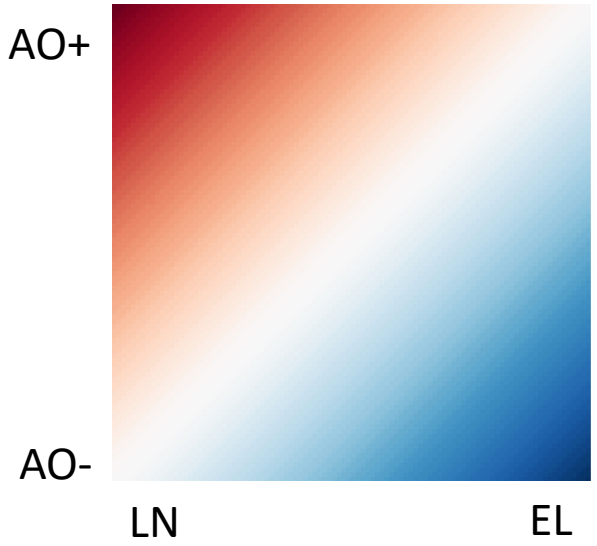
Probability shifts are indeed similar

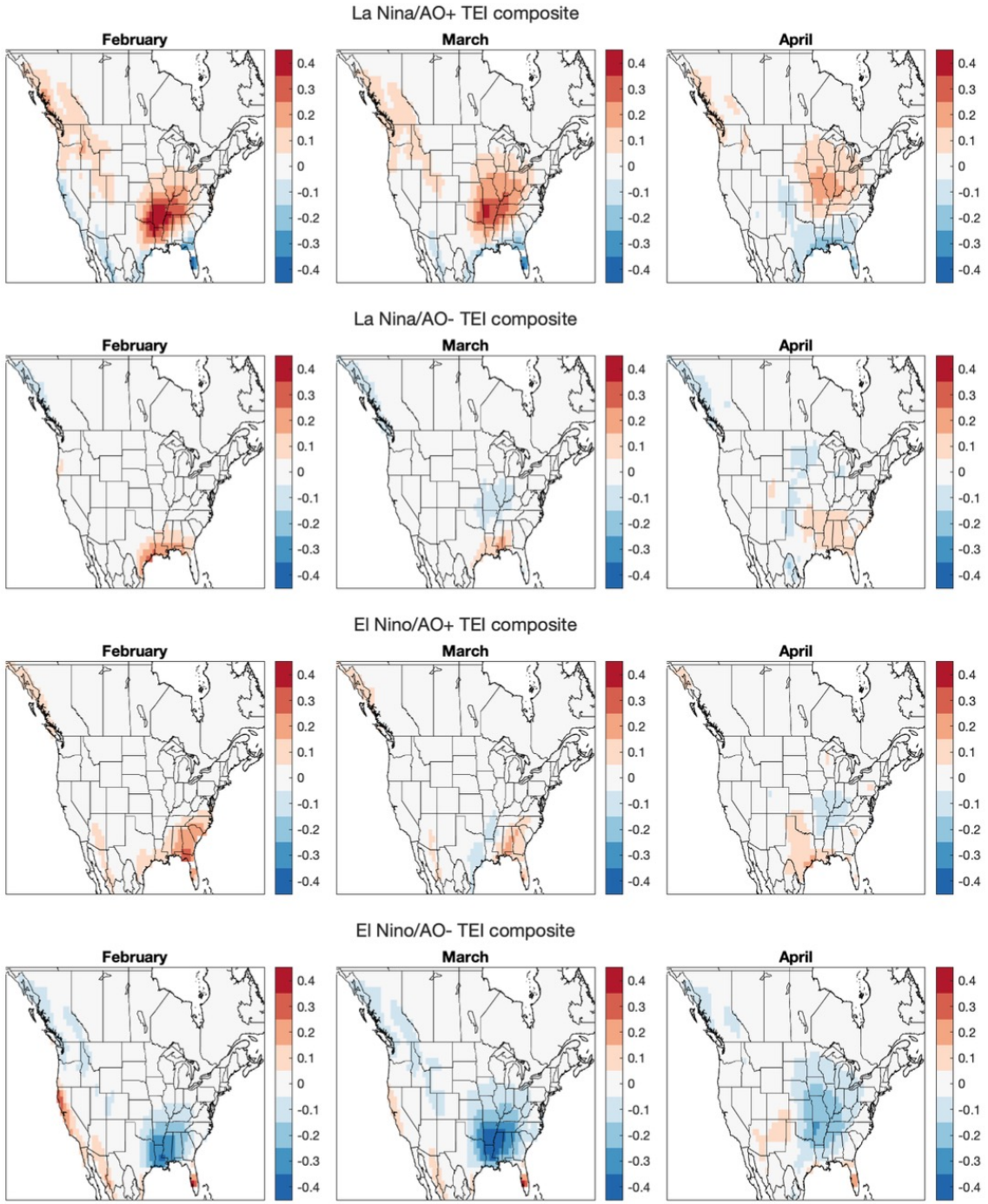


Competing ENSO/AO signals



Constructive and destructive interference of ENSO and AO signals





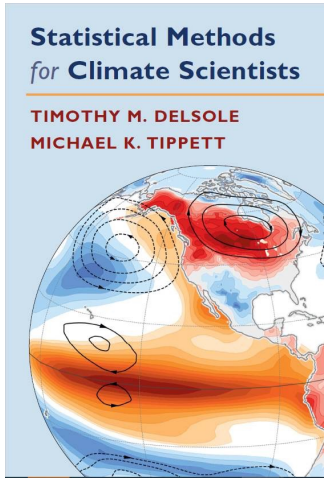
La Niña & AO+

La Niña & AO-

El Niño & AO+

El Niño & AO-

BONUS
3 “mistakes”



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2. We looked at a CFSv2-simulated tornado environment index (TEI)
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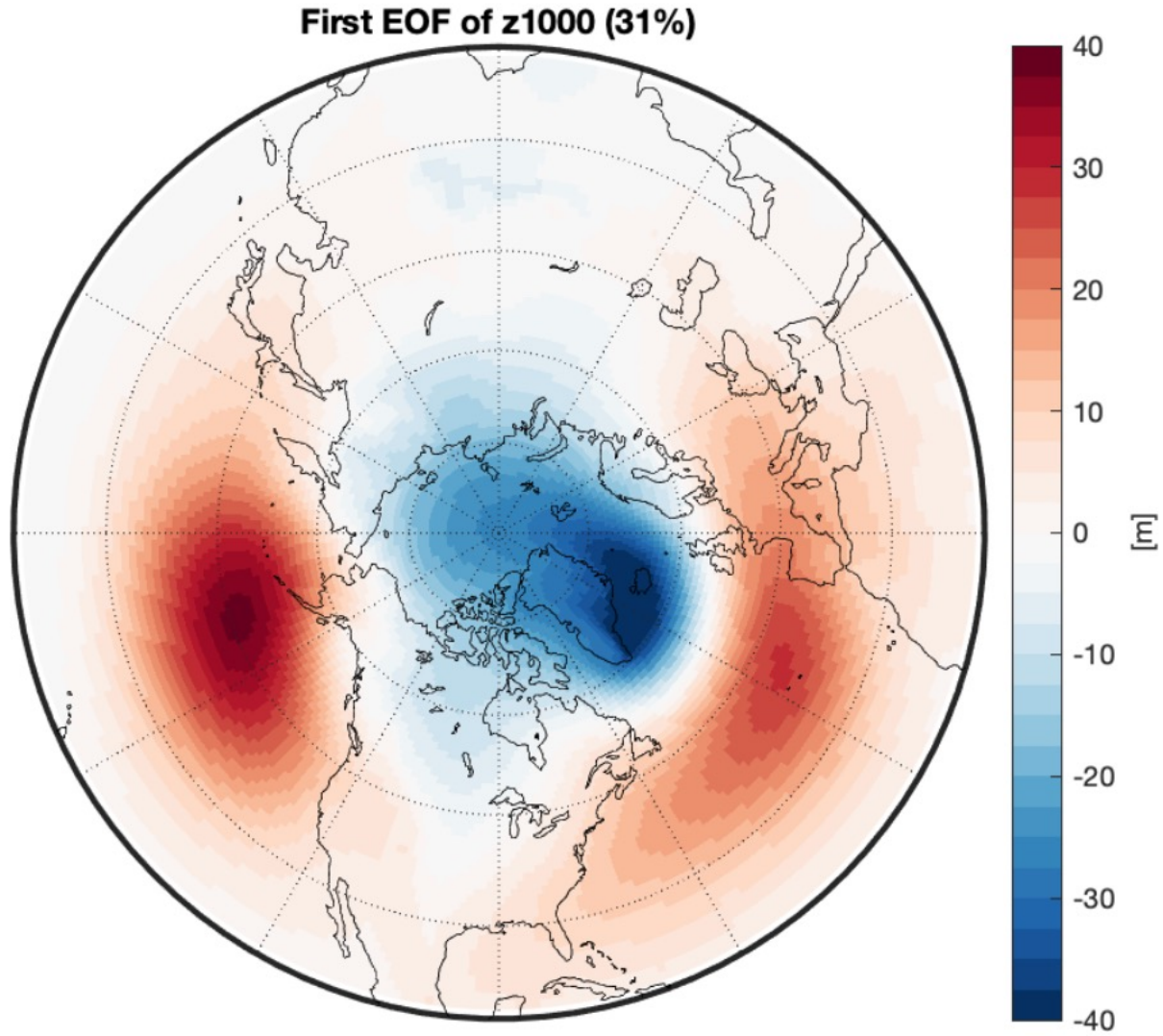
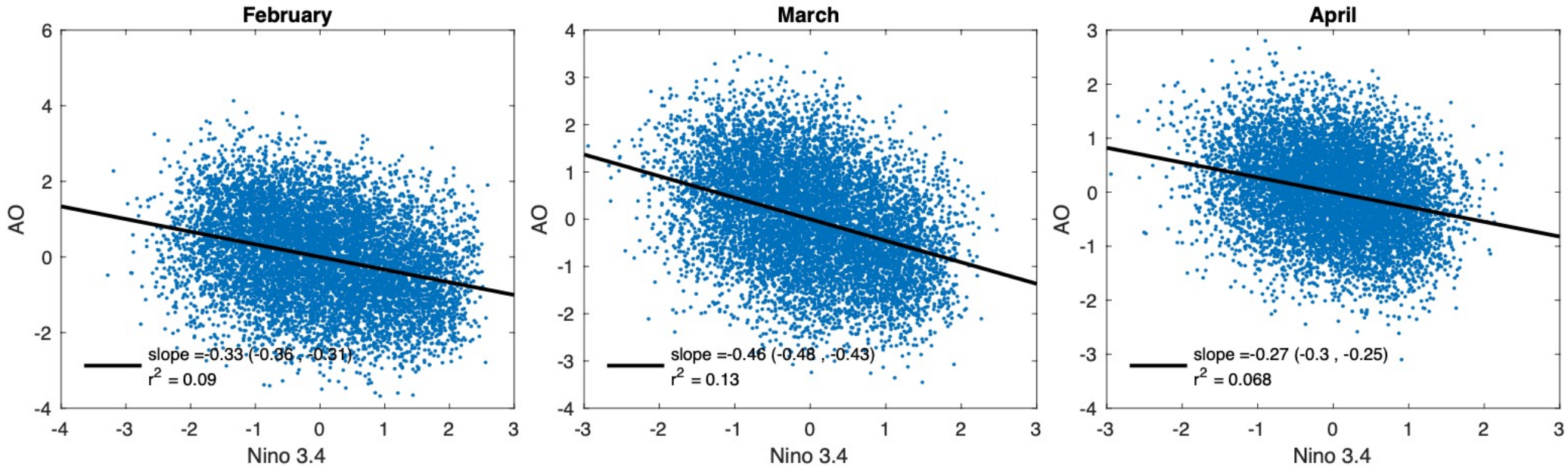
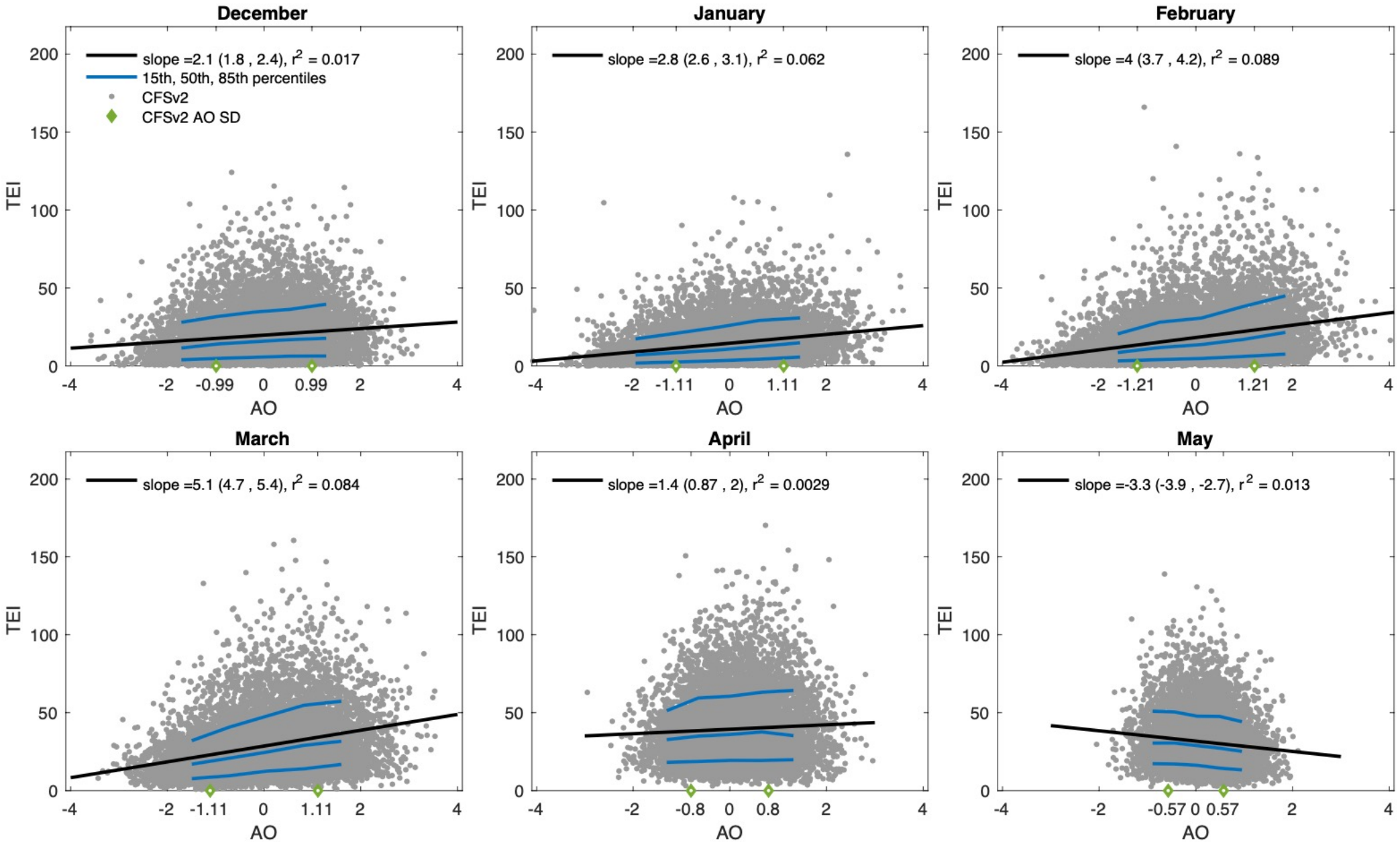

First EOF of z1000 (31%)
40
30
20
10
0
-10
-20
-30
-40
[m]


February
AO
Nino 3.4
slope =-0.33 (-0.36 , -0.31)
r2 = 0.09
March
AO
Nino 3.4
slope =-0.46 (-0.48 , -0.43)
r2 = 0.13
April
AO
Nino 3.4
slope =-0.27 (-0.3 , -0.25)
r2 = 0.068


December
slope =2.1 (1.8 , 2.4), r2 = 0.017
15th, 50th, 85th percentiles
CFSv2
CFSv2 AO SD
TEI
AO
-0.99
0.99
January
slope =2.8 (2.6 , 3.1), r2 = 0.062
-1.11
1.11
February
slope =4 (3.7 , 4.2), r2 = 0.089
-1.21
1.21
March
slope =5.1 (4.7 , 5.4), r2 = 0.084
-1.11
1.11
April
slope =1.4 (0.87 , 2), r2 = 0.0029
-0.8
0.8
May
slope =-3.3 (-3.9 , -2.7), r2 = 0.013
-0.57
0.57