Sources of seasonal extreme heat predictability diagnosed from the GFDL Seamless System for Prediction and EArth System Research (SPEAR)

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2024 CDPW-CPASW

March 26, 2024

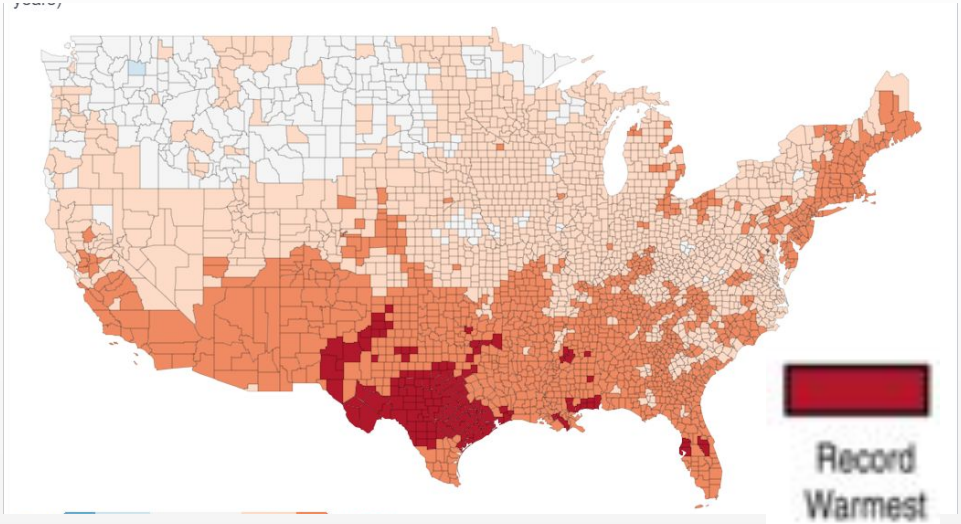
Record southern US heat: Summers of 2022 and 2023

- Record early summer (MJJ) Texas heat in 2022 and mid-summer (JJA) heat in southern Texas/Louisiana region in 2023

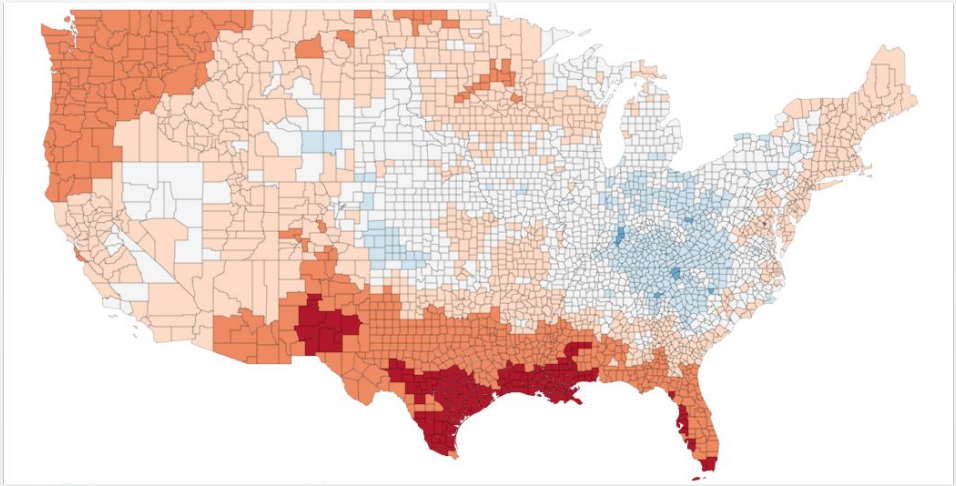
- <u>Impacts:</u>

✔ Records for energy demand
✔ Livestock and crops negatively impacted by drought
✔ Low river flows
✔ Record-setting fire weather
✔ Heat-related deaths

May – July 2022 Tavg Rank



June – August 2023 Tavg Rank



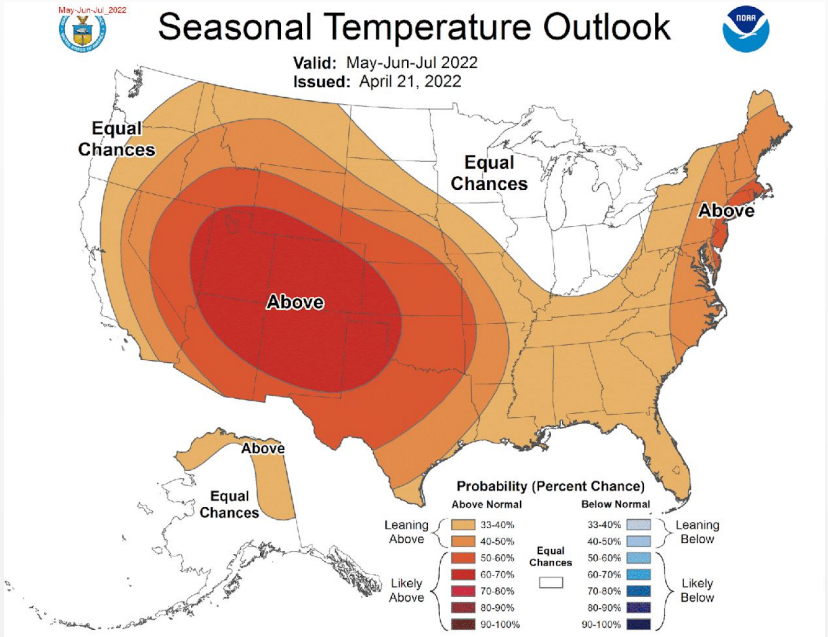
Source: NOAA NCEI

Questions to address

NOAA Climate Prediction Center (CPC) Temperature Outlooks

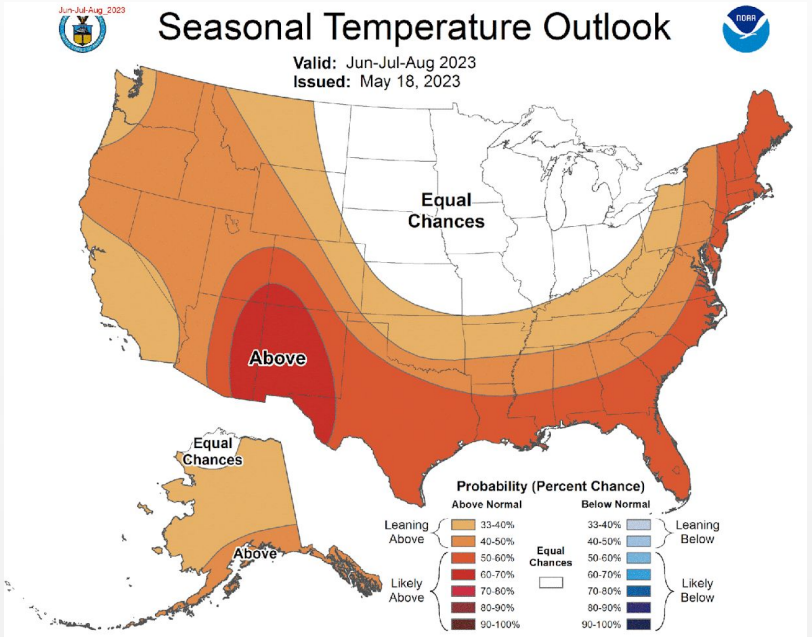
MJJ 2022

Issued 21 April 2022



JJA 2023

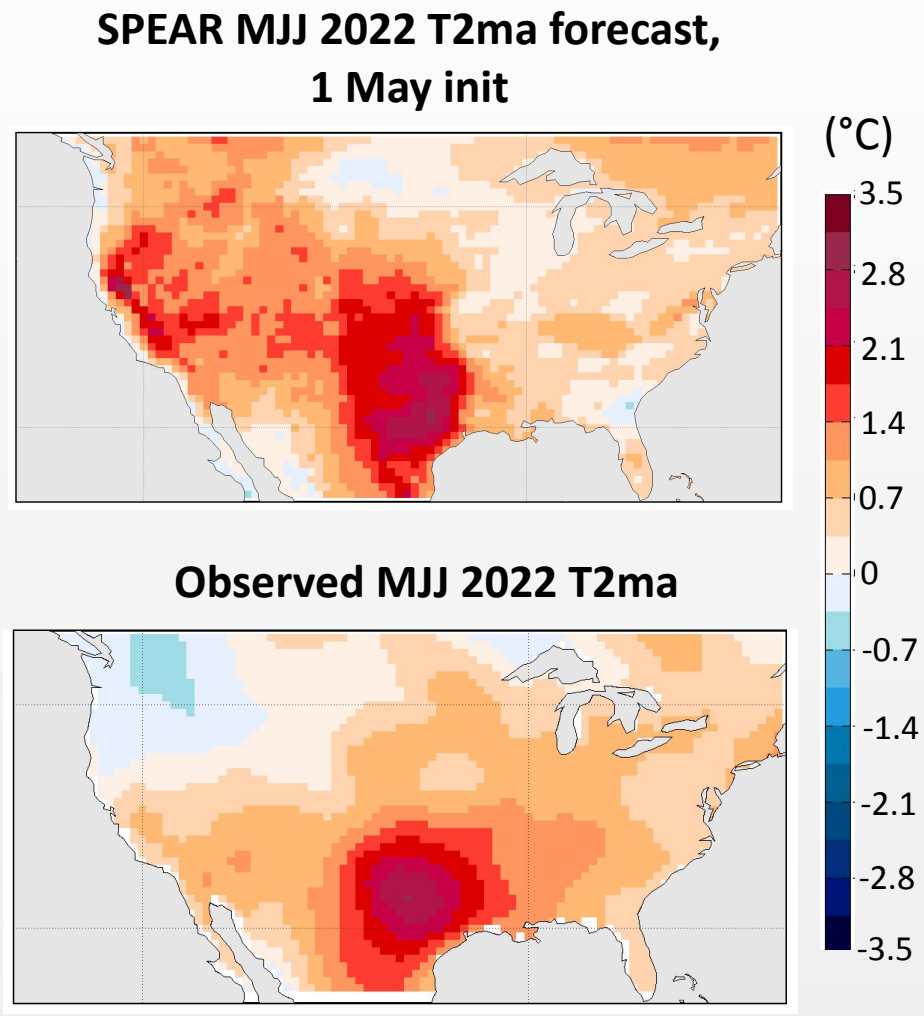
Issued 18 May 2023



1) How predictable were the recent seasonal US heat extremes?
2) What role did anthropogenic forcing play in the seasonal heat anomalies?
3) Were there other factors that could have given us advance warning of the elevated extreme heat probabilities?

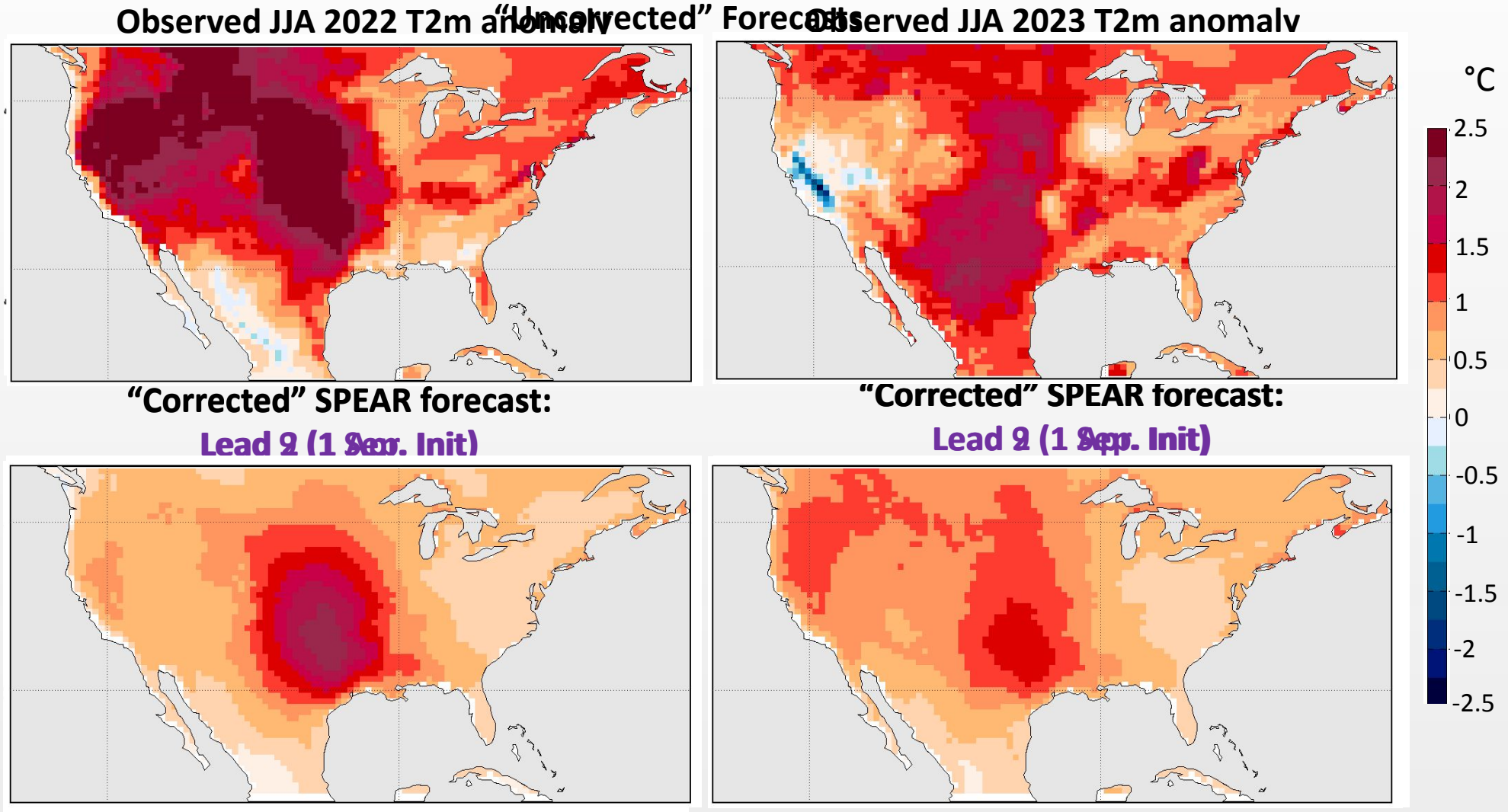
Seasonal Predictions with SPEAR

- **SPEAR** (Towards a Seamless System for Prediction and EArth System Research): GFDL's latest seasonal-to-decadal prediction system
- 50 km atmospheric, 1° ocean horizontal resolution (SPEAR_MED)
- **Real-time seasonal predictions**: 30-member monthly forecasts delivered to NOAA through the North American Multi-Model Ensemble (NMME) since February 2021
- **Retrospective forecasts**: 15-member ensembles back to 1991



BLUF: Evidence of some seasonal predictability for recent patterns of US summertime extreme heat

- Up to 9 months in advance for 2022
- About 2-4 months in advance for 2023

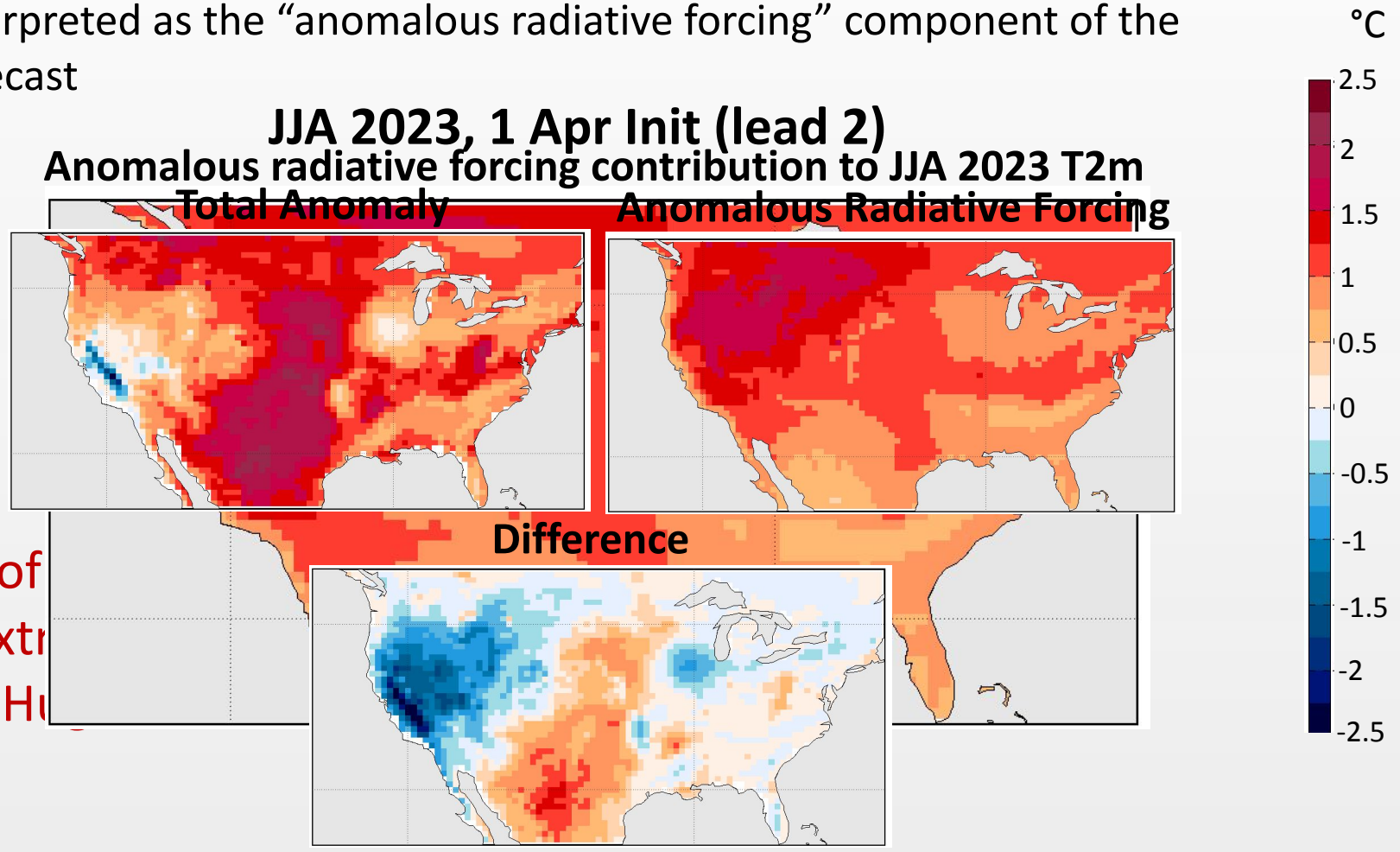


Is it just the trend?

What was the role of anthropogenic forcing in these forecasts of extreme heat?

Diagnosed from a **30-member SPEAR Large Ensemble** with historical radiative forcing but lacking initial condition information

- Interpreted as the "anomalous radiative forcing" component of the forecast

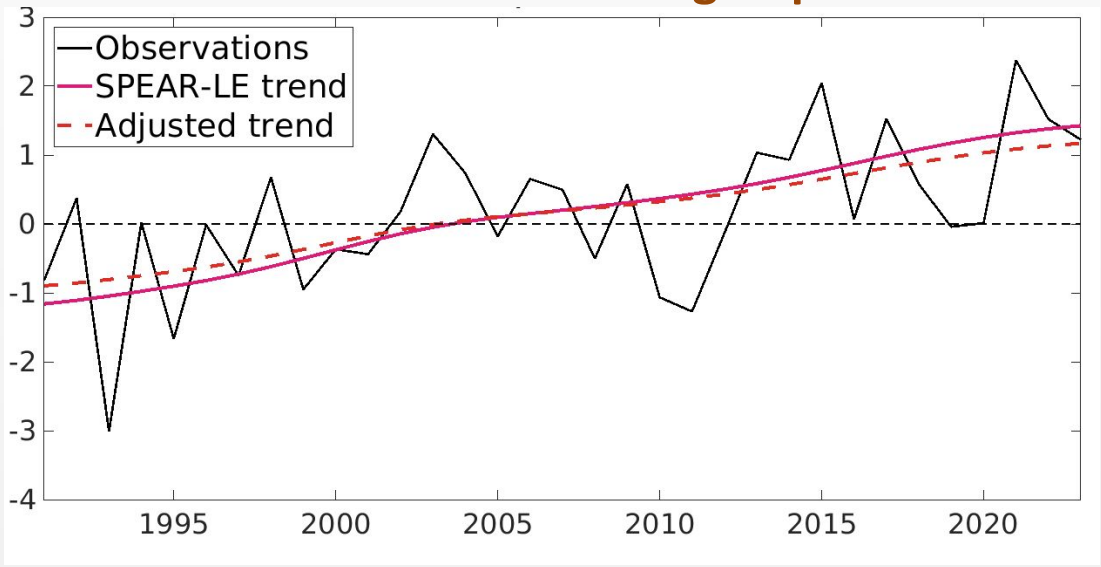


However, the trend of
summertime heat extr
strong in SPEAR (McH
2023)

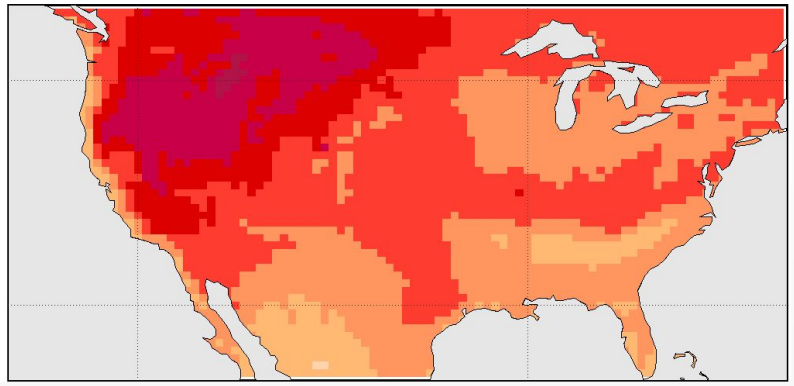
Correcting the trend: Regressing the observed JJA T2m on the radiative component from SPEAR

Linear regression correction: Reduces the anthropogenic contribution

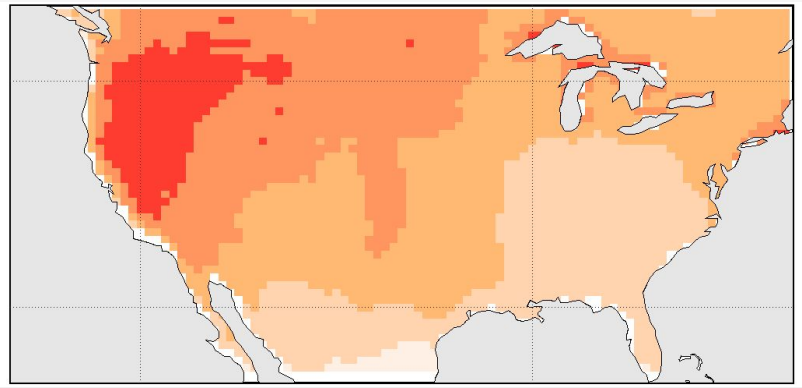
Western North America grid point

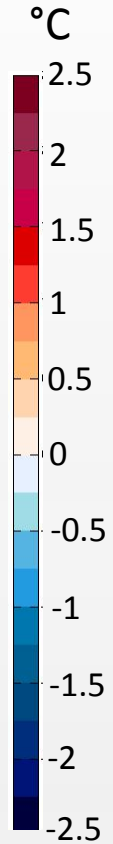


Original Trend Component for JJA 2023



Corrected Trend Component for JJA 2023





$$T_{cf} = T_f - T_{rad,SPEAR} + T_{rad,cal}$$

Corrected forecast

Original forecast

Trend component from SPEAR

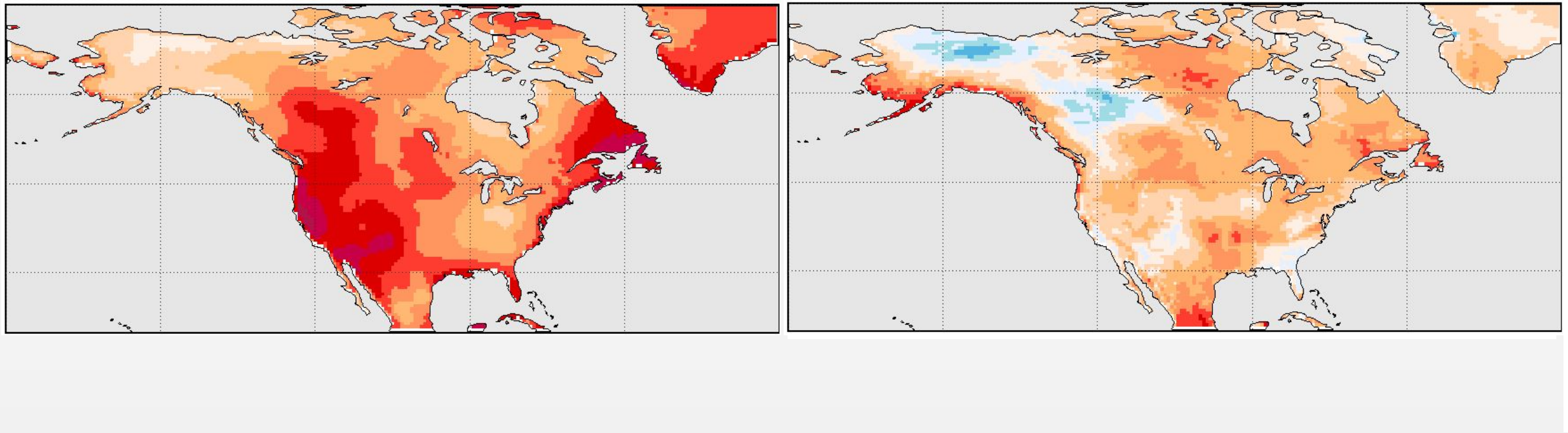
Linearly corrected trend

Beyond the trend: How much skill in summertime T2m?

Correlation Skill

Unitialized SPEAR-LE (Trend)

Trend-Removed: Leads 2-9



After trend removal, what are the sources of predictability?

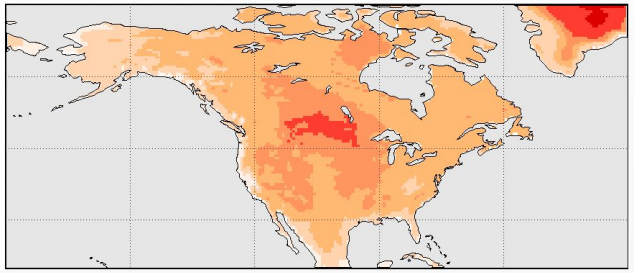
Average Predictability Time (APT) analysis: Determining patterns that **maximize predictability** (DelSole and Tippett 2009a,b)

- Similar to empirical orthogonal function (EOF) analysis but maximizing predictability integrated over all lead times instead of variance
- Previously applied to the seasonal prediction of North American summertime heat (Jia et al. 2022) and wintertime cold extremes (Jia et al. 2023)
- Here we apply APT analysis to North American JJA T2m predictions after removing the contribution from anomalous radiative forcing

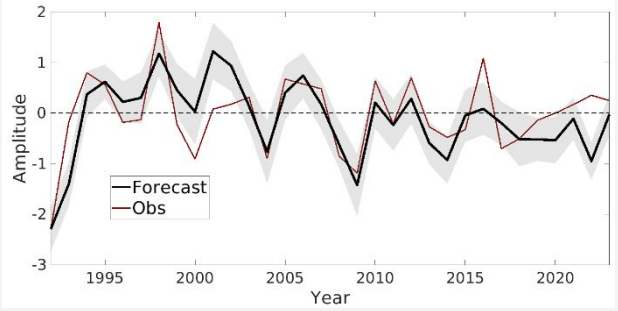
Decomposing the forecasts into the most predictable modes

Four skillfully predicted JJA T2m modes

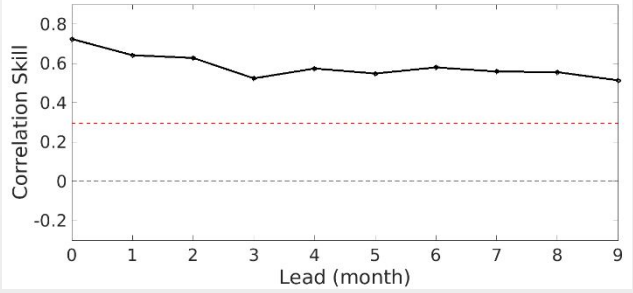
Mode 1 Pattern



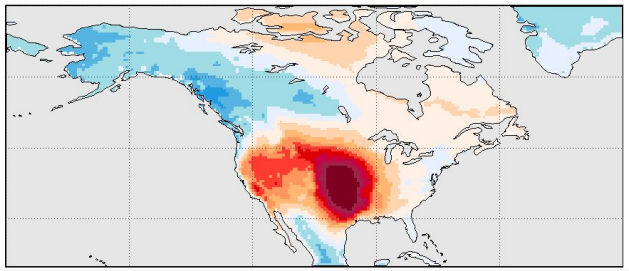
Time Series



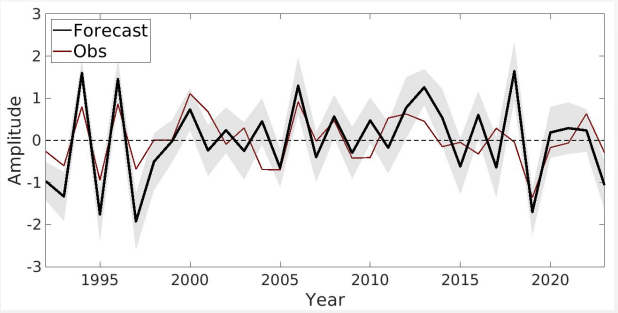
Skill



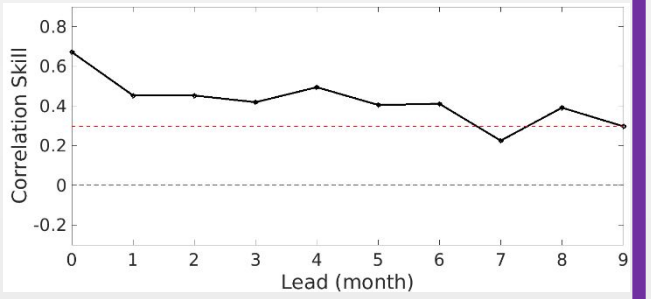
Mode 2 Pattern



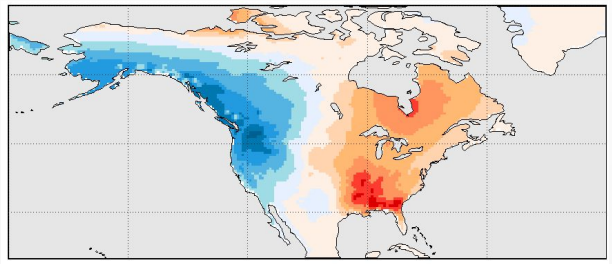
Time Series



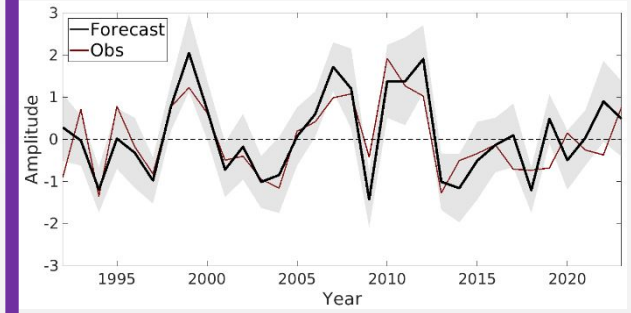
Skill



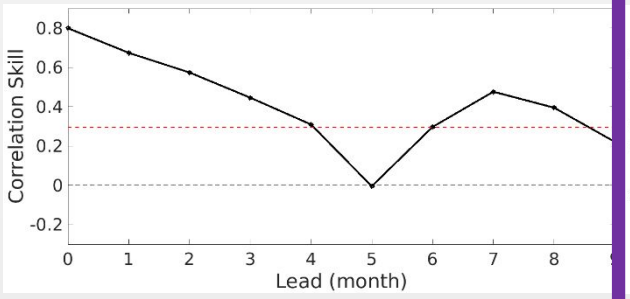
Mode 3 Pattern



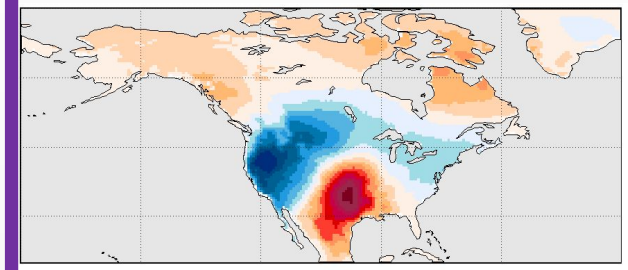
Time Series



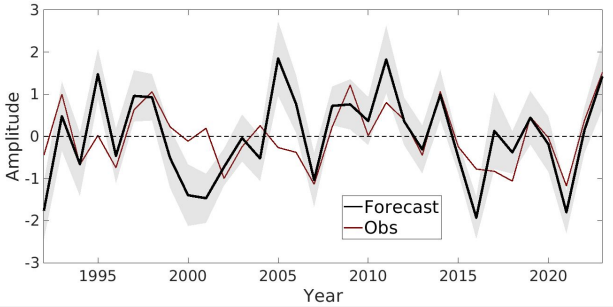
Skill



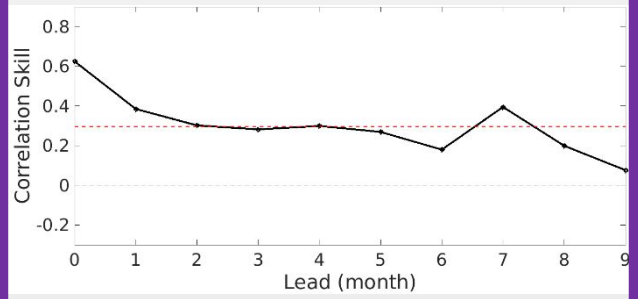
Mode 4 Pattern



Time Series



Skill



Reconstructing the forecasts from the most predictable modes

Reconstructing APT-filtered forecasts

$$T_{rf,l}(x,y) = \sum_{k}^{N} f_{k,l}\, p(x,y)_k$$

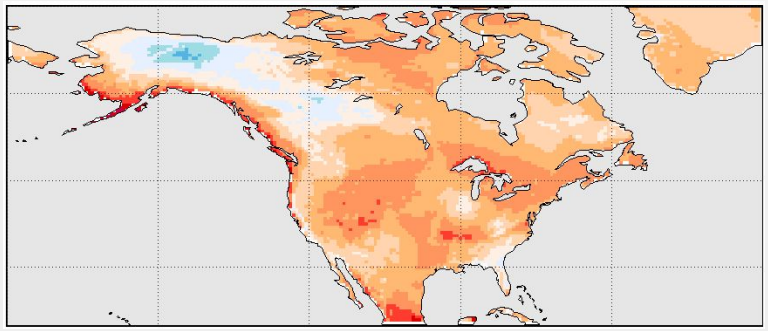
Reconstructed forecast (detrended) at lead *l*

Summation over modes with skill (*N* = 4)

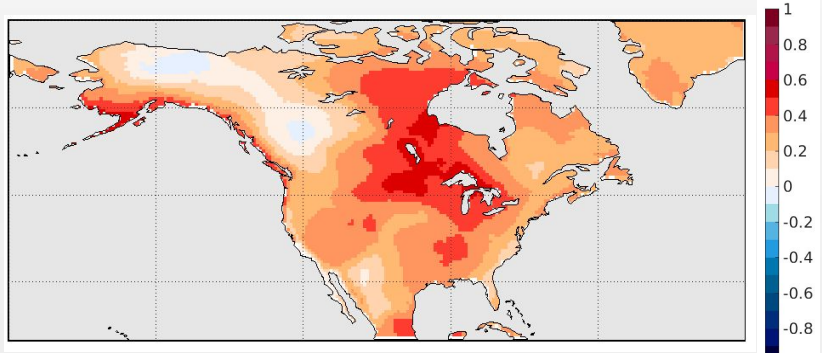
Predictable mode with amplitude

Average correlation skill of original versus APT-filtered forecasts

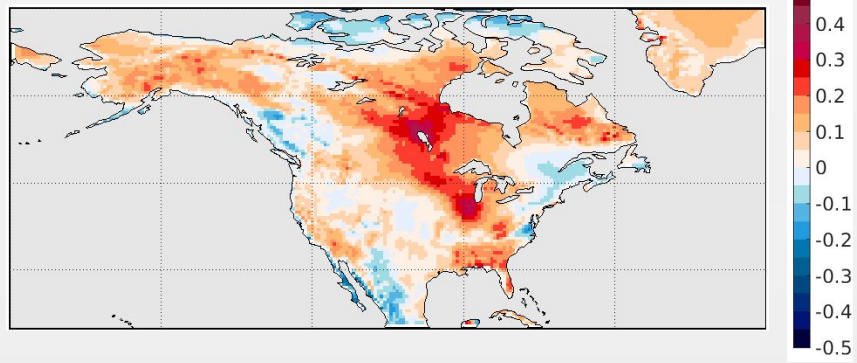
Original (After trend correction)



APT-filtered

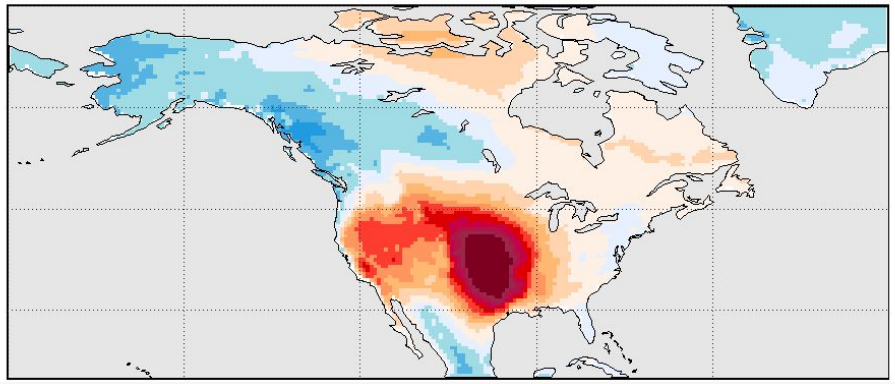


Difference (Filtered minus Original)



Mode 2: La Niña as a contributor to extreme Texas heat in 2022

Mode 2



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ENSO BLOG

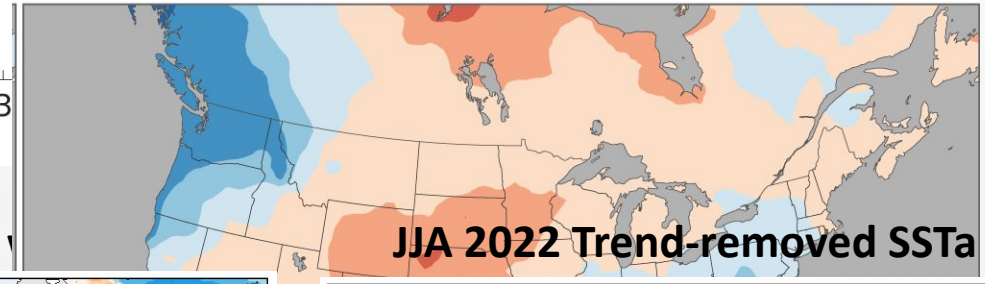
A blog *mostly* about monitoring and forecasting El Niño, La Niña, and their regional and global impacts...but sometimes about other climate phenomena that influence seasonal climate.

La Niña's delayed effect on sizzling Texas summers

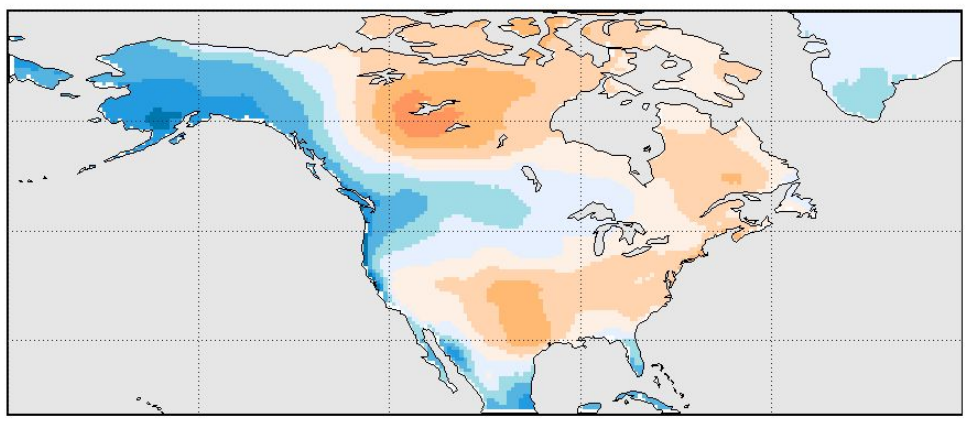
BY NAT JOHNSON
PUBLISHED AUGUST 25, 2022
COMMENTS: 6

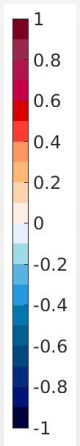
It's been a scorching summer in much of the US, but no state has sizzled more than Texas. Does this summer's unusually persistent La Niña bear some of the responsibility for the extreme heat? In this blog post, we'll try to figure that out!

When La Niña occurred the previous winter

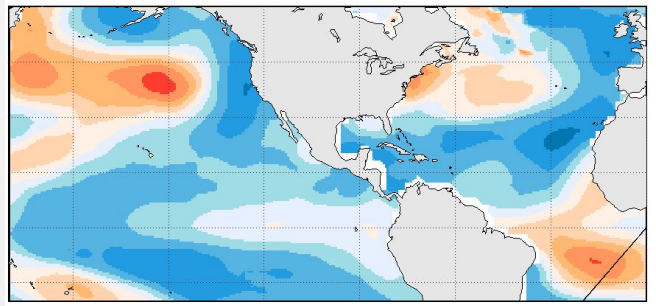


1 Sep correlation with JJA T2m (9 months lead)

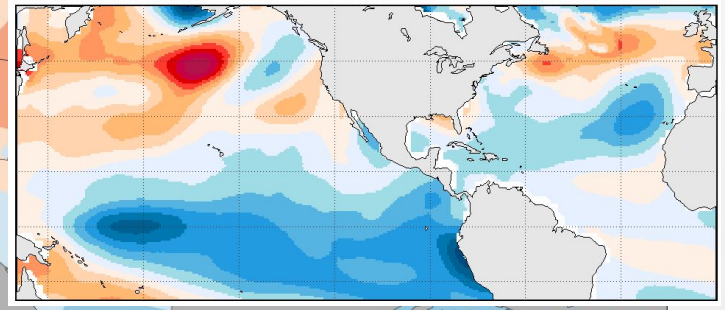


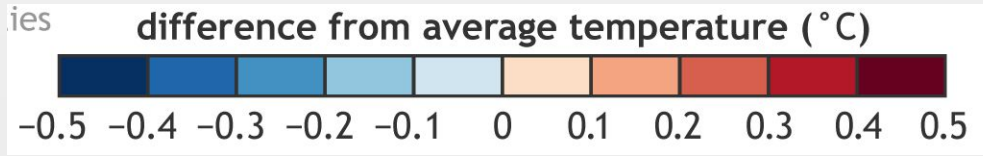


1 Sep correlation



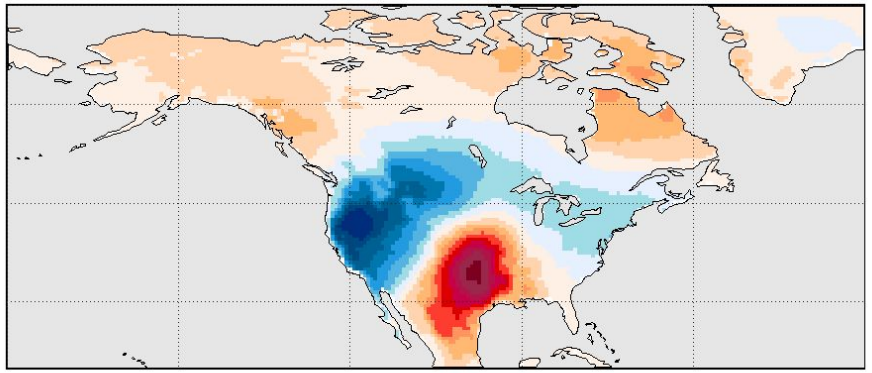
JJA 2022 Trend-removed SSTa

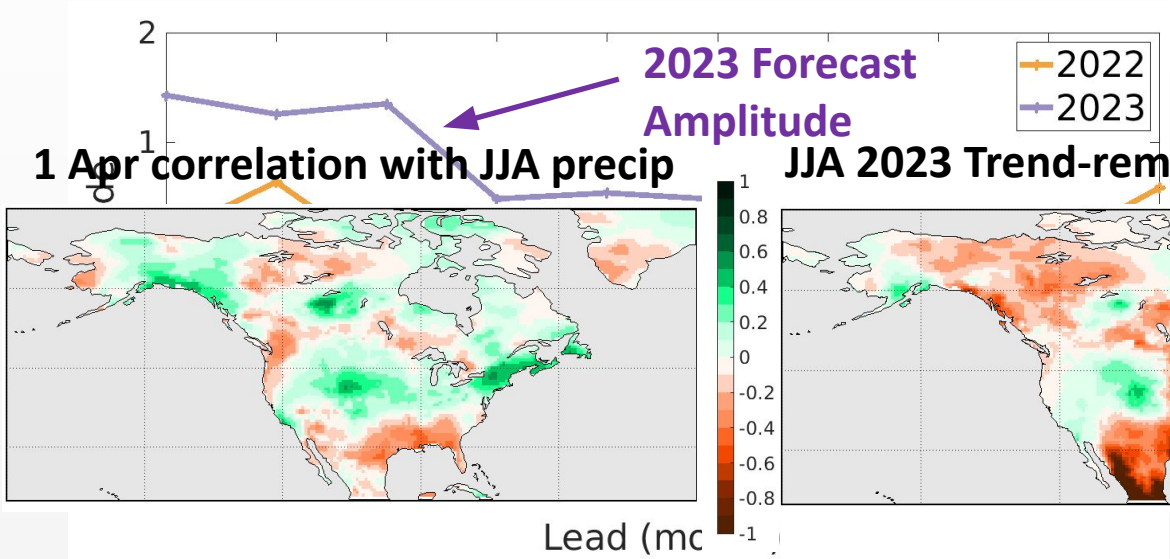




Mode 4: Atlantic/Gulf of Mexico SSTs as contributors in 2023?

Mode 4

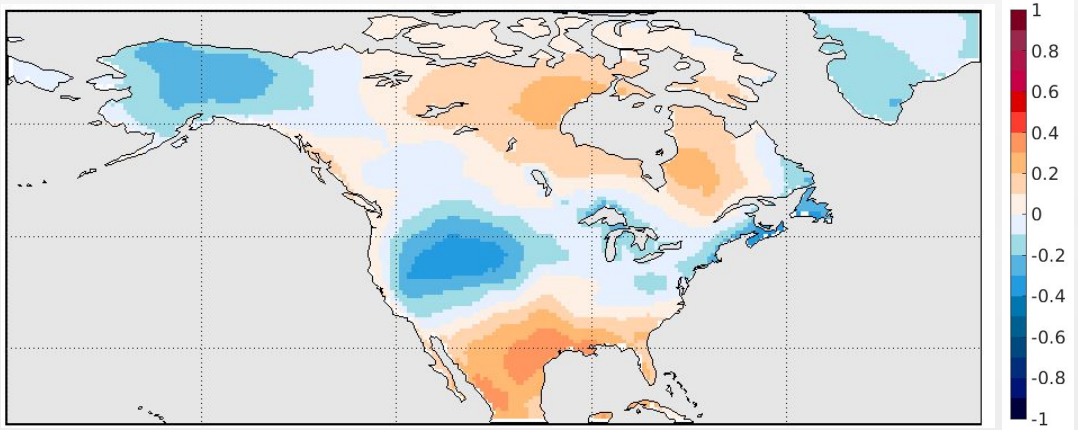




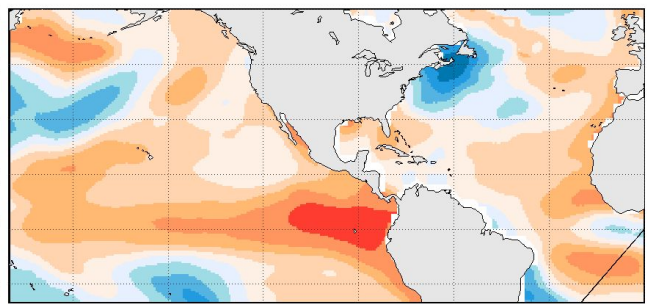
1 Apr correlation with JJA precip

JJA 2023 Trend-removed precipa

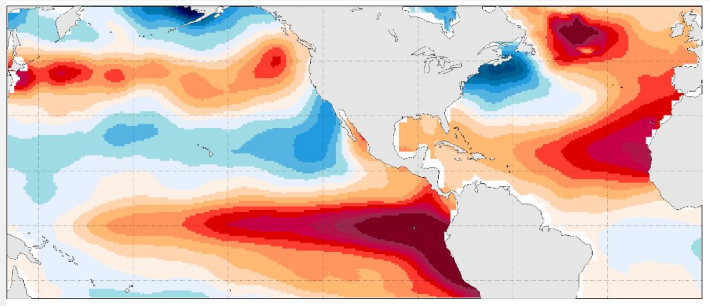
1 Apr correlation with JJA T2m (2 months lead)



1 Apr correlation with JJA SST



JJA 2023 Trend-removed SSTa



Key takeaways

- **Record southern U.S. summer heat** in both 2022 and 2023
- Patterns of anomalous heat **reasonably well predicted** in SPEAR: ~5-9 months for 2022 and ~2-4 months for 2023, especially after correcting for trend and filtering by most skillfully predicted modes
- **Patterns of seasonal predictability**: In addition to the long-term trend, average predictability time (APT) analysis reveals 4 skillfully predicted modes of North American summertime temperature
- **Sources of seasonal predictability (preliminary)**: anomalous Pacific (e.g., ENSO) and possibly Atlantic/Gulf of Mexico sea surface temperatures, preceding precipitation/soil moisture
- **Caveat**: Some of these results still need to be cross-validated

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