Identifying the Causes of Weather and Climate Events to Improve Predictions

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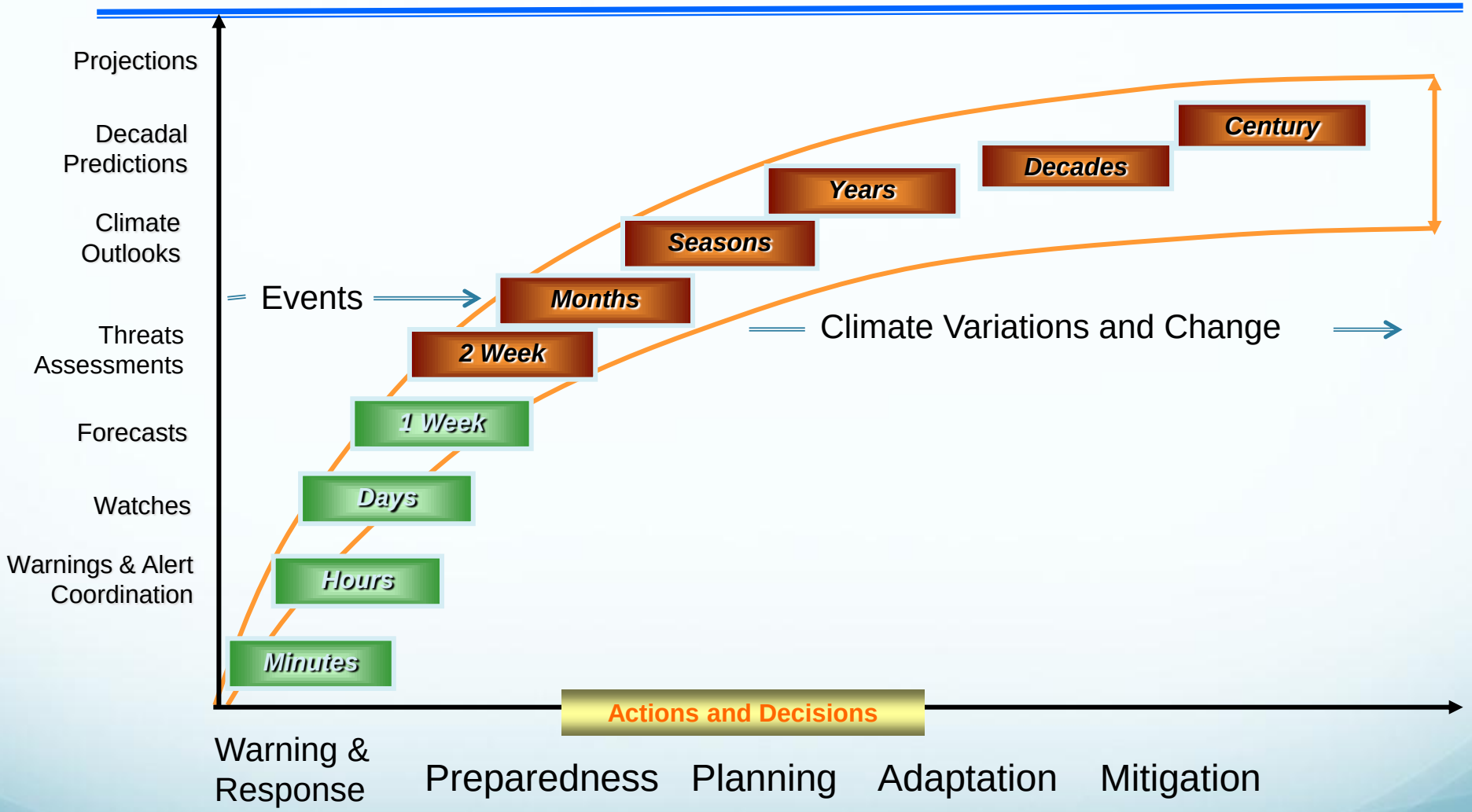
Information needs across time scales



Addressing needs to inform policy, planning and decision-making actions across time scales requires understanding how the occurrences of weather and climate-related *events* are conditioned by *climate variations and change.*

Framing questions

Most event attribution studies have been framed around one of two questions:

*What are the attributable **human influences** for an observed weather or climate event at some level of confidence?*

What are the most likely causes for an observed weather or climate event at some level of confidence?

The first question addresses needs of the IPCC and for informing long-term policy discussions, as well as other applications where attribution of human influence is the primary focus.

The second question considers roles of both human and natural factors in the event, including potentially predictable natural variations. The latter can be crucial for scientific understanding as well as for informing decisions, especially on shorter (I-SI) time scales.

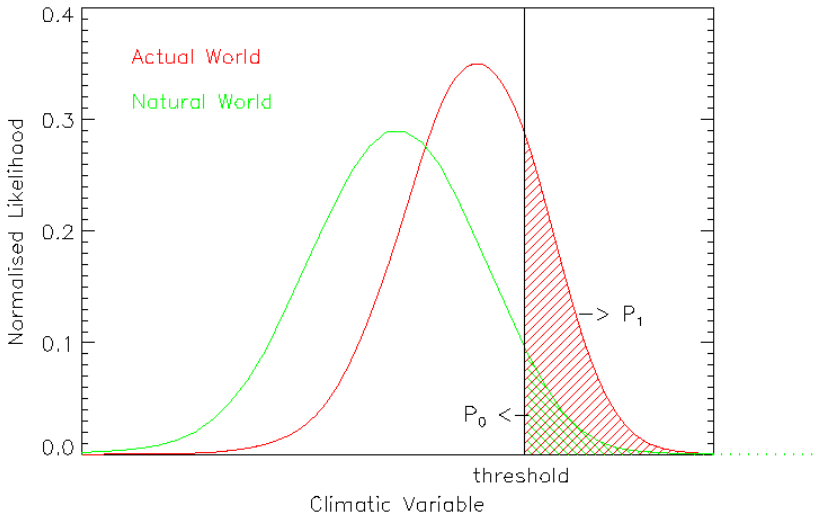
Two Approaches to Event Attribution: A Medical Analogy

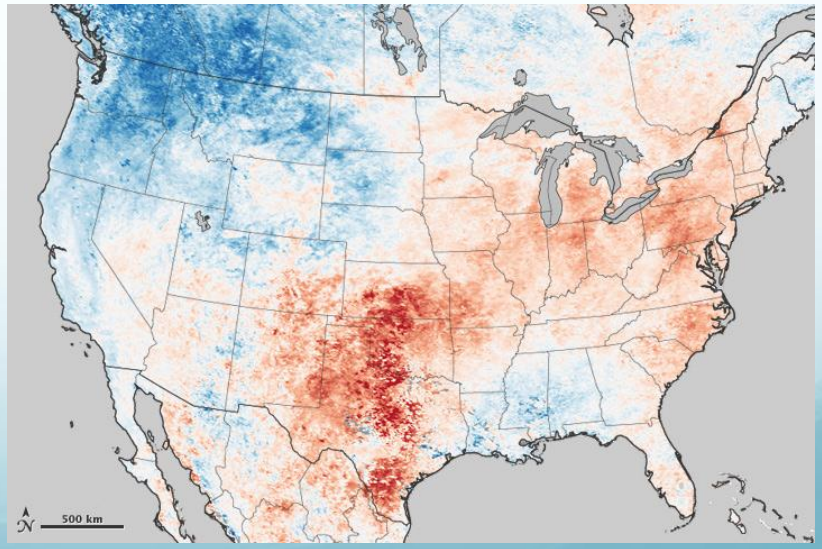
- **An epidemiological approach (population)**

  Obtain a statistical estimate of how a given factor, e.g., human-caused climate change, changes the probability (alters the *relative risk*) of an event defined by some threshold.

- **A diagnostic approach (individual)**

  Assess roles of potential contributing factors to an observed event through observational and diagnostic analysis and hypothesis testing (model experiments). A major goal is to improve *predictive understanding*.

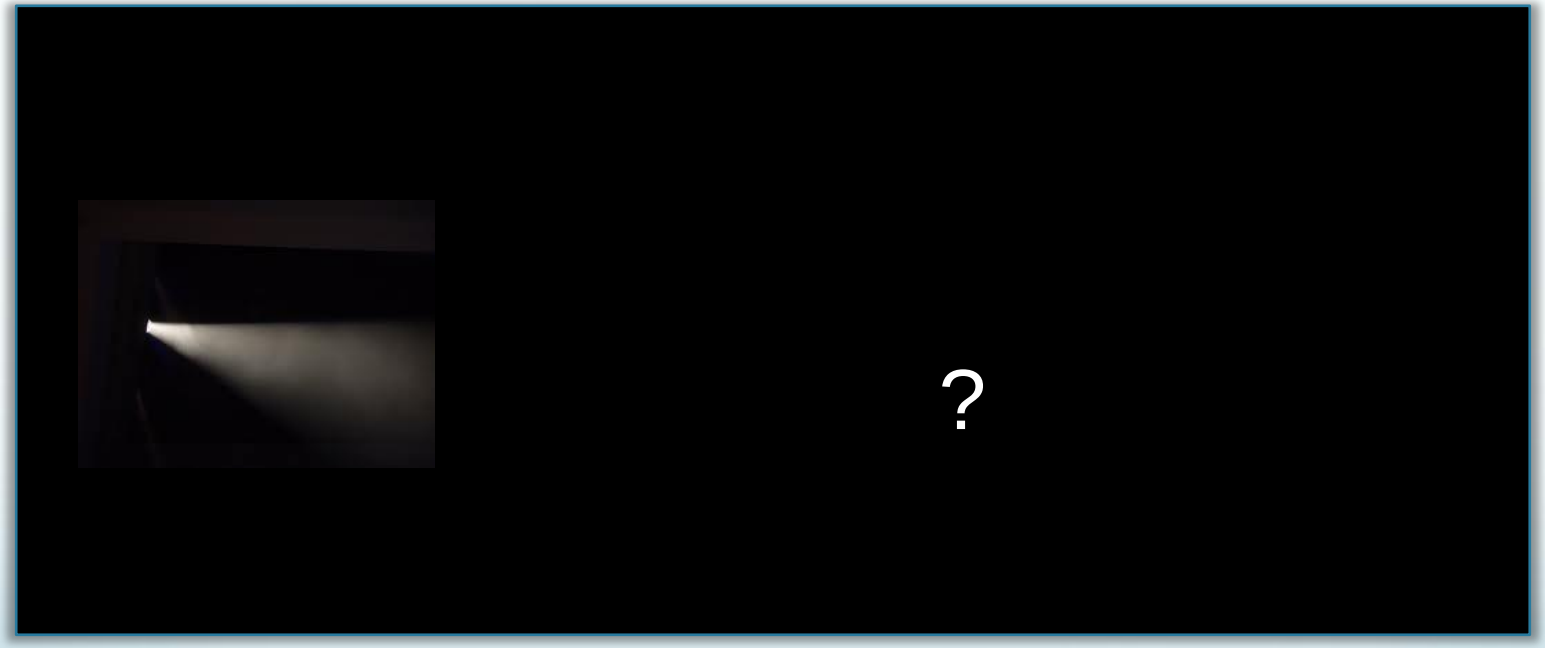




July 2011 T'sfc

A relevant proverb when beginning event attribution

It is very difficult to find a black cat in a dark room. Especially when there is no cat.



In attribution there is a fundamental need to consider alternative hypotheses.

Anatomy of an Extreme Event

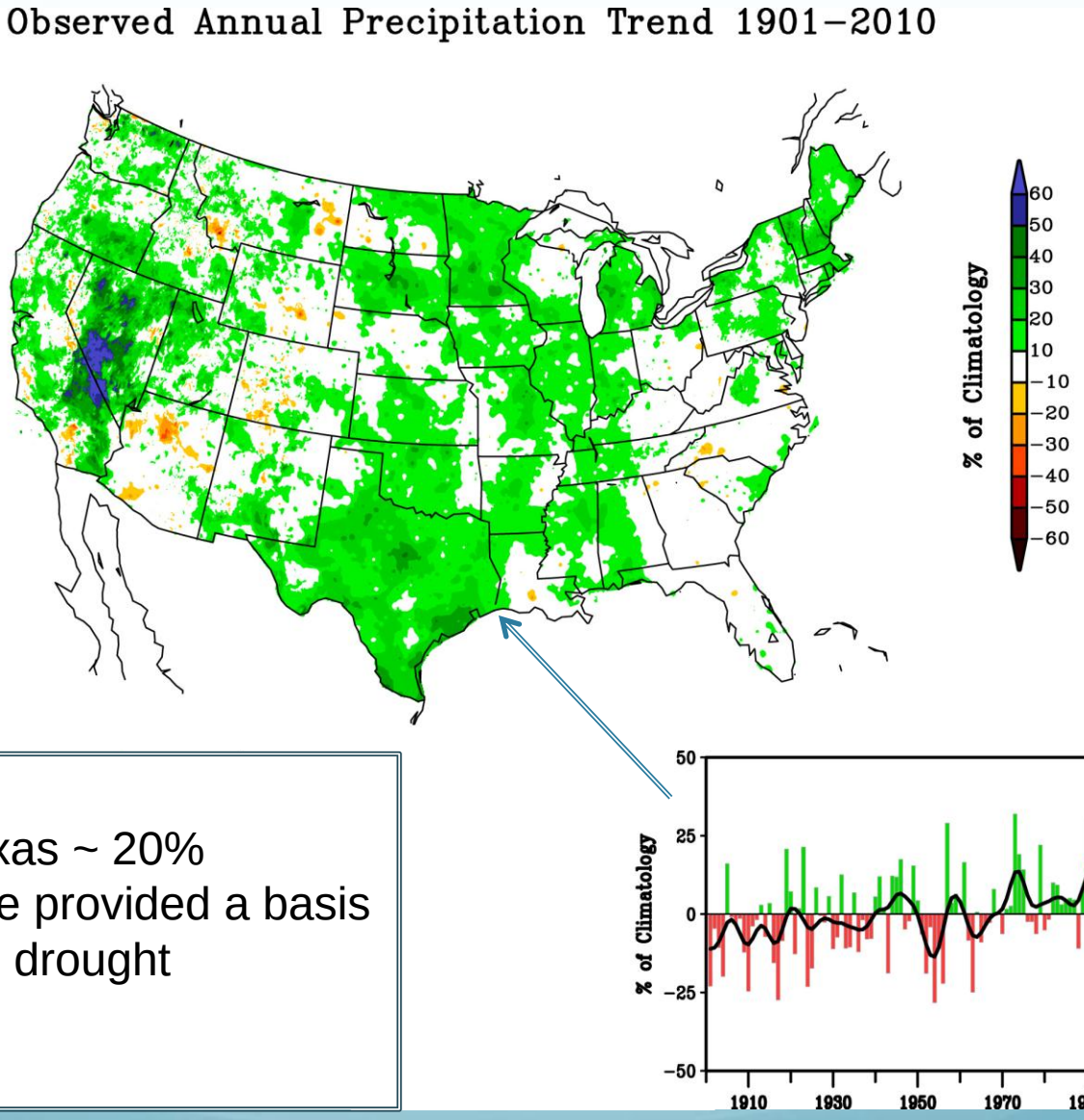
M. Hoerling, A. Kumar, R. Dole, J. Nielsen-Gammon, J. Eischeid, J. Perlwitz, X-W. Quan, T. Zhang, P. Pegion and M. Chen
(*J. Climate,* in press)

The 2010-2011 Texas drought and 2011 summer heat wave

What are possible contributing factors to the Texas drought and heat wave?

- **Anthropogenic forcing associated with increasing GHGs** (examine evidence for trends, model experiments)
- **Forcing associated with anomalous boundary conditions in SSTs, sea ice, soil moisture** … (consider observed conditions, historical and physical relationships, model experiments)
- Unforced internal variations (may include potentially predictable modes of variability)
- Others (land use and land cover changes, etc.)

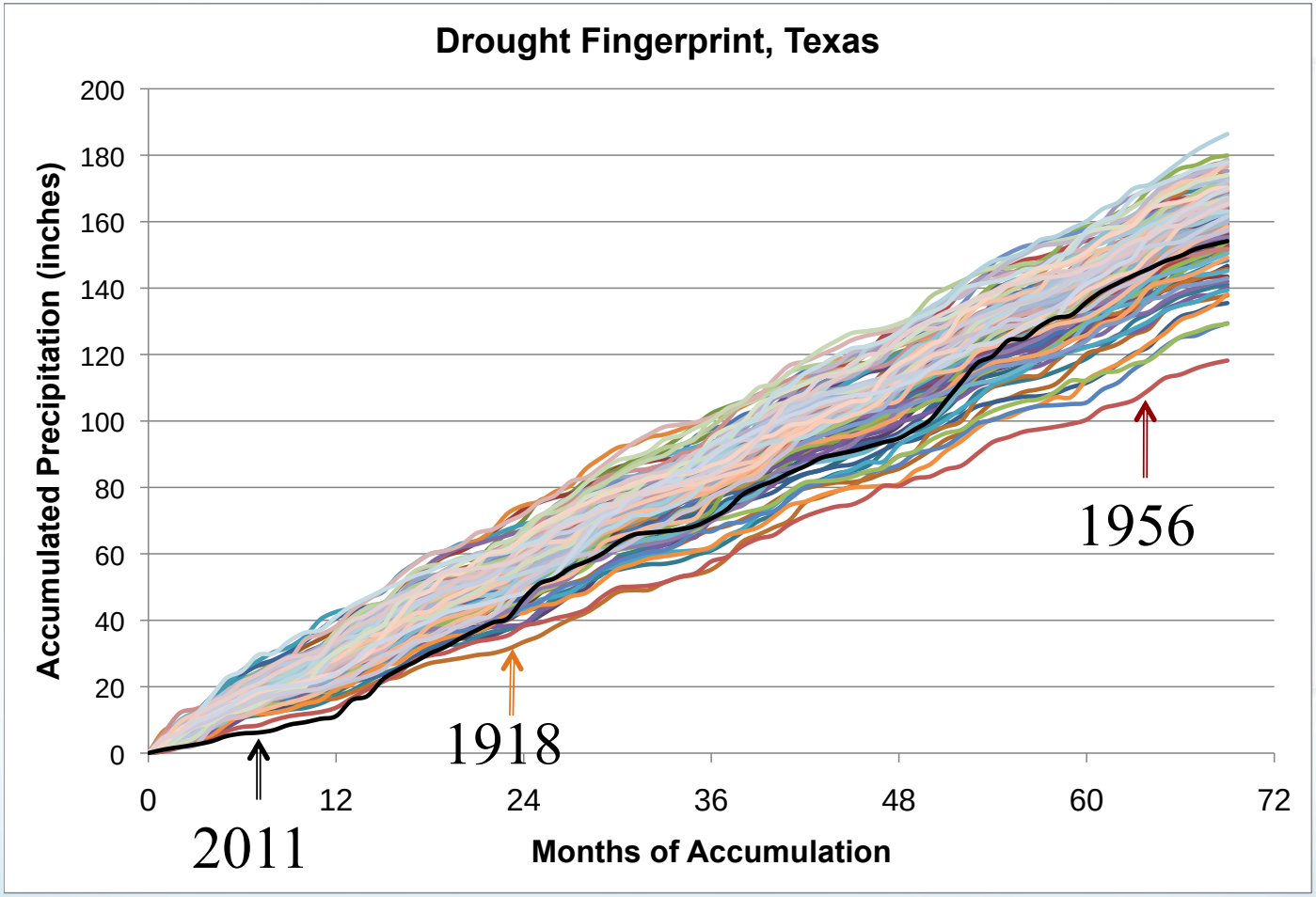
The 2010-11 Texas Drought: Is there evidence for a long-term drying trend?



No.

- Increase in Texas ~ 20%
- Would not have provided a basis for anticipating drought

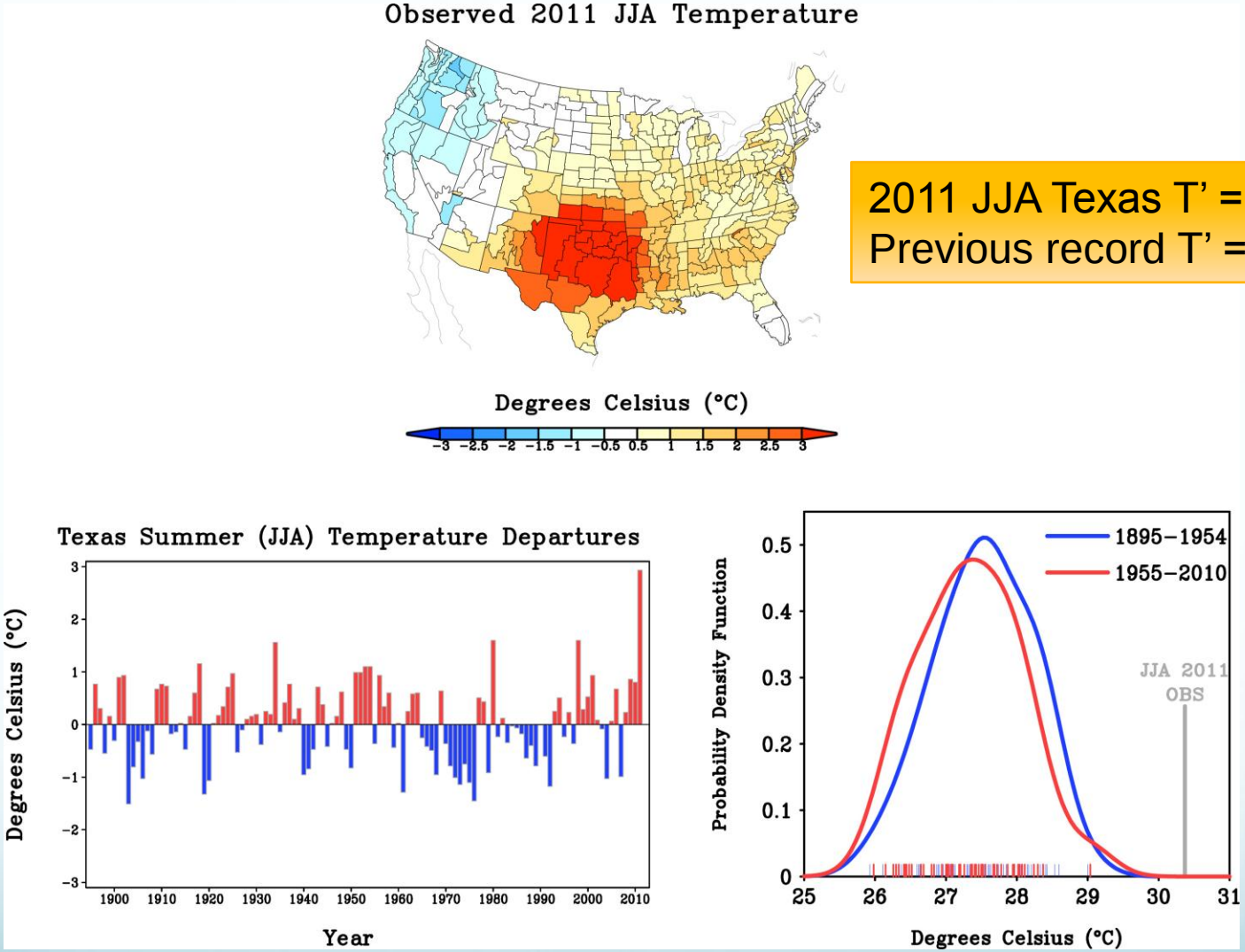
Or an emerging drought in the past several years?



Ending date (t = 0) - September 30 (Water Year)

- Drought began in Fall 2010
- Severe short-term (~1 year) drought

How about for summer temperatures?

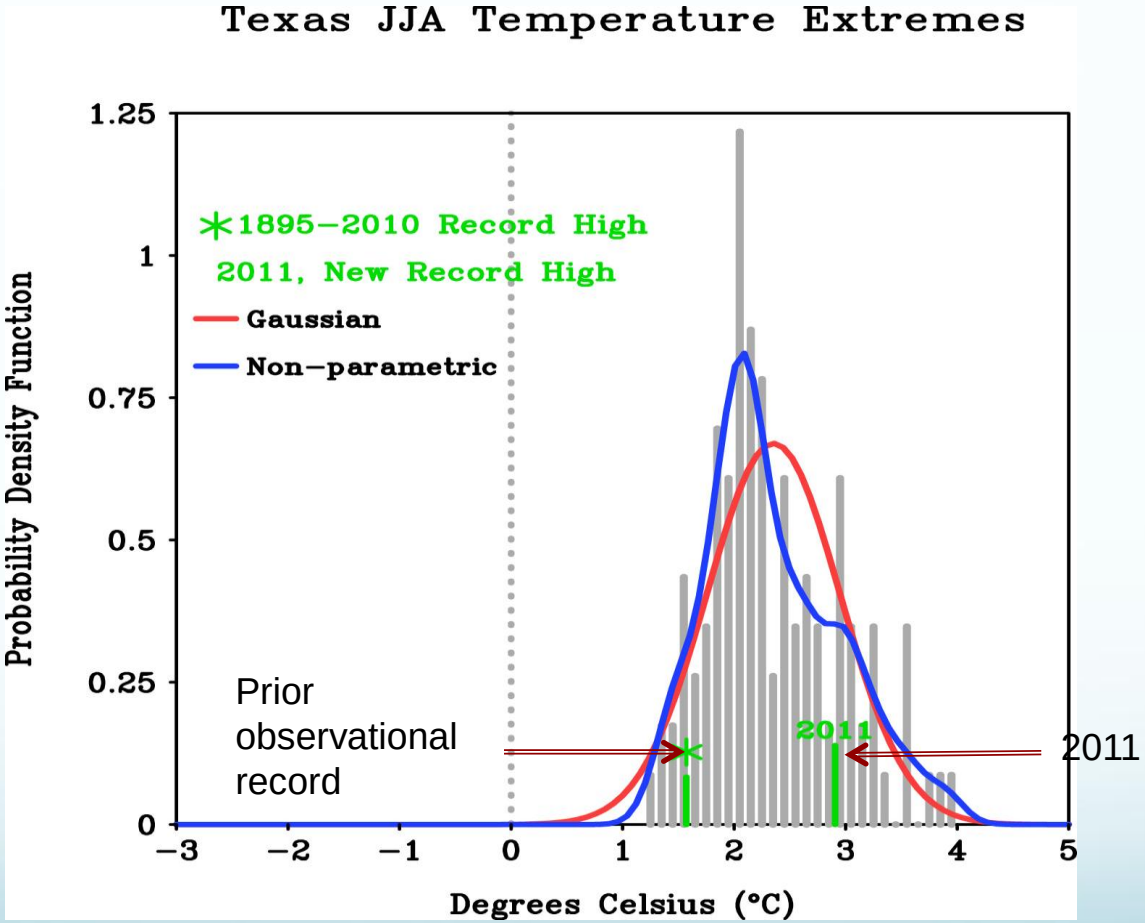


2011 JJA Texas T' = 2.9° C
Previous record T' = 1.6° C

Observational estimate of warming trend depends on time interval, ranging from ~ 0.6° C for 1981-2010 to ~ 0° C for periods starting prior to ~1950.

Was Human-Caused Climate Change **Necessary** to Produce Such an Intense Heat Wave?

Model results suggest that the answer is **No.**

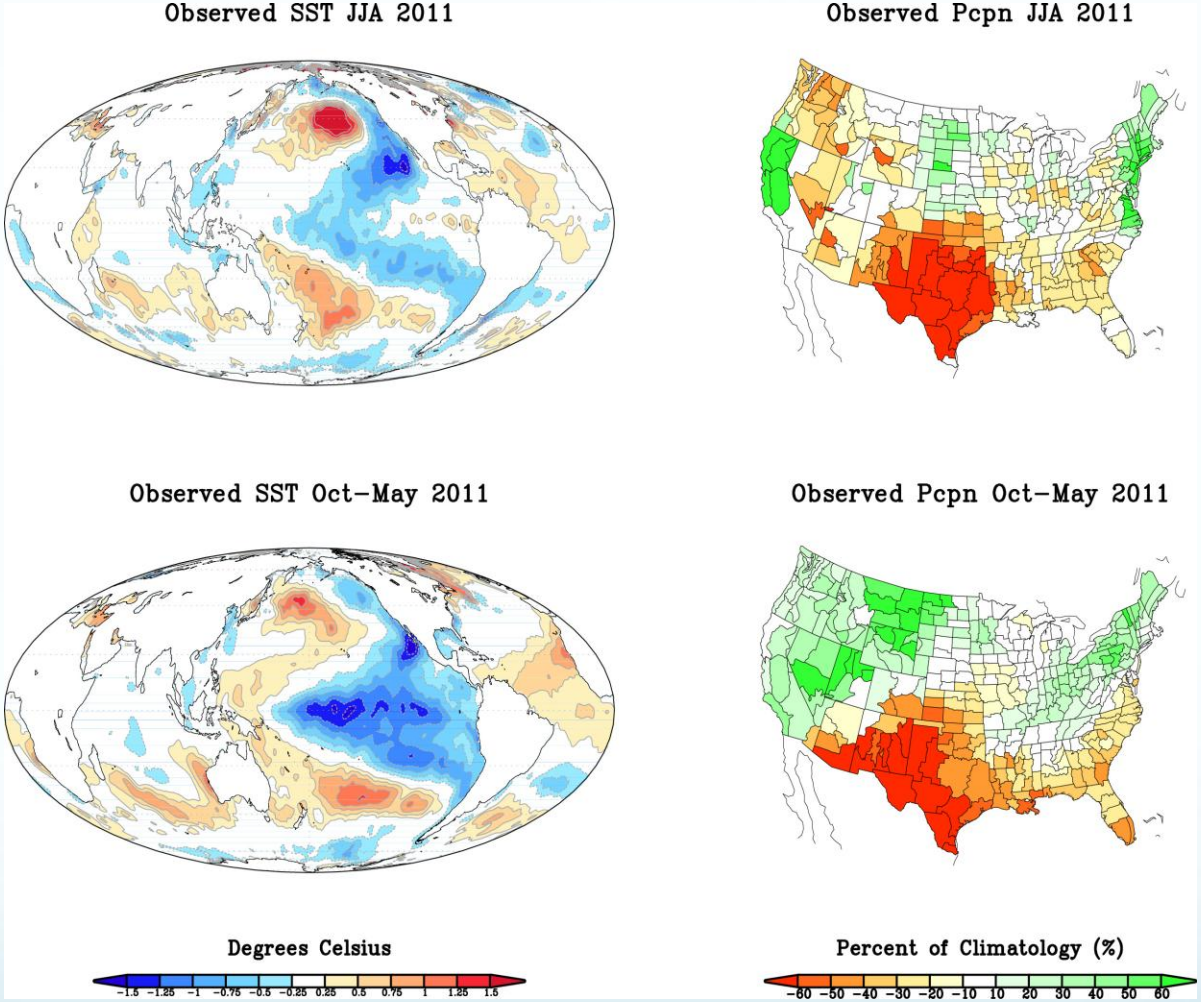


Distribution of warmest Texas summers occurring in 115 non-overlapping 100-year periods from CMIP5 **pre-industrial** simulations

Were observed ocean conditions favorable for drought?

Concurrent
Summer 2011

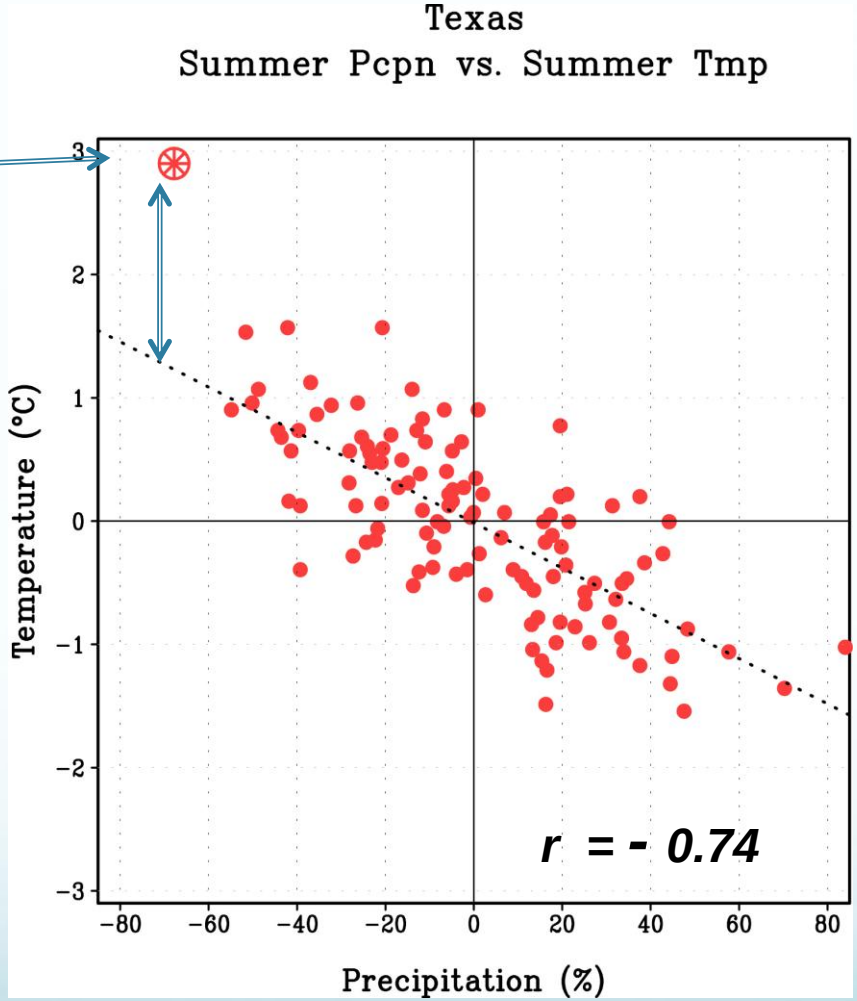
Preceding
Oct 2010-
May 2011



Yes. Preceding moderate La Niña event, decays by summer
Observed prior relationship between La Niña-Texas droughts
Known physical basis for this relationship.

What are observed relationships between Summer Precipitation and Temperature?

2011



Strong Relationship: “Dry-Warm”.

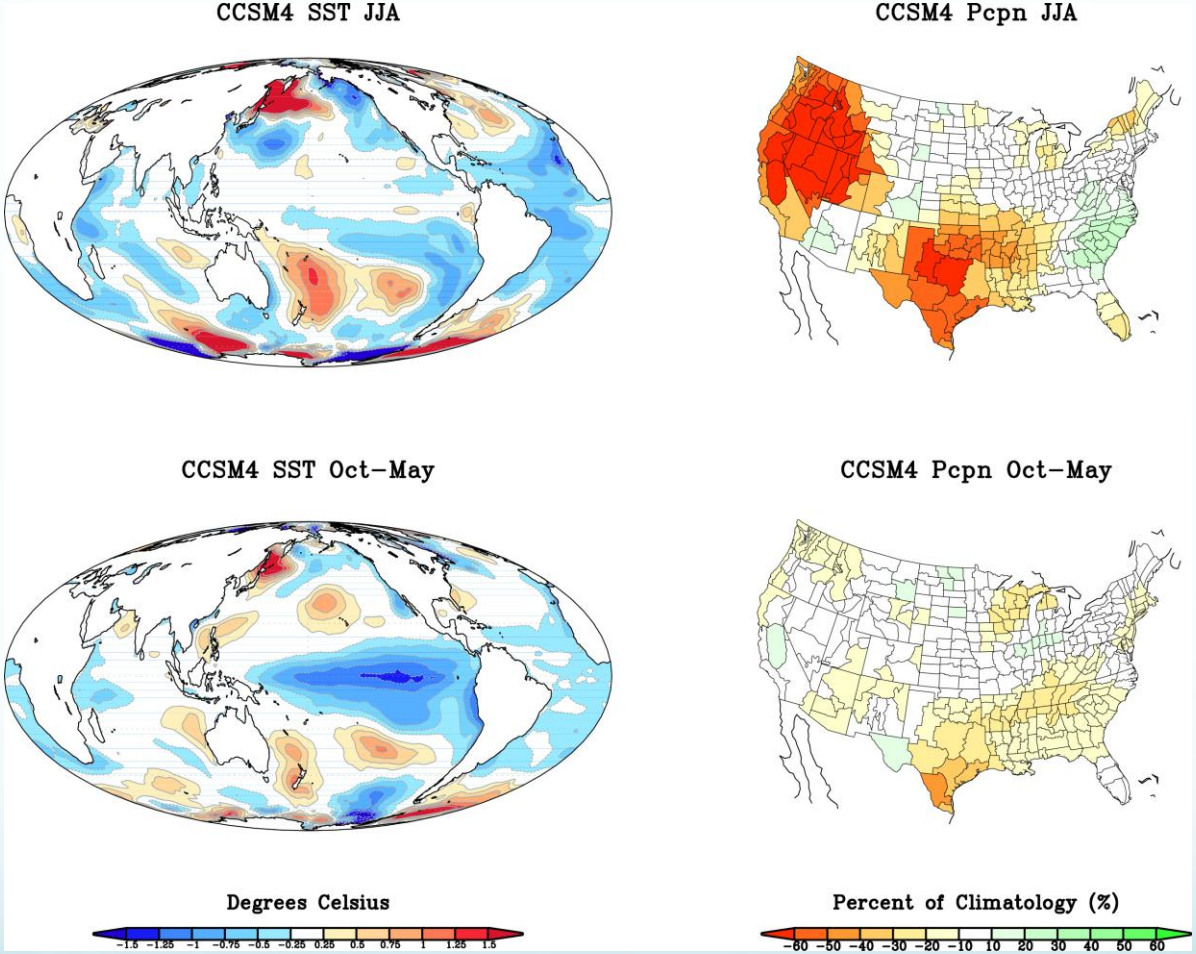
What Were Conditions Associated with Hot Texas Summers in Pre-industrial (Natural Variability) Runs?

Concurrent
Summer 2011

Preceding
Oct 2010-
May 2011

SSTs

Pcpn

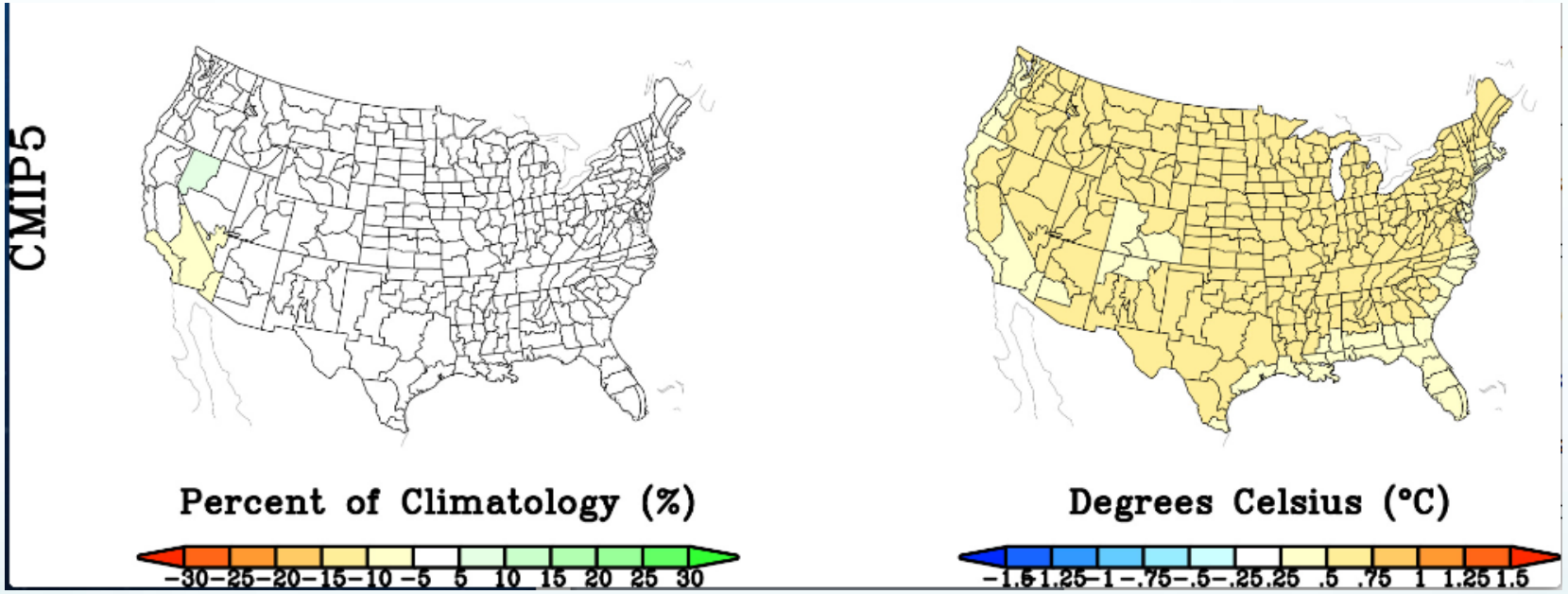


CCSM 1500-year pre-industrial run composites for “1-in-100 year” warm summers, which show preceding La Niña-like conditions and very dry conditions similar to observed relationships.

How might anthropogenic forcing have affected 2011 Summer Precipitation and Temperatures? (CMIP5)

Precipitation

Temperatures

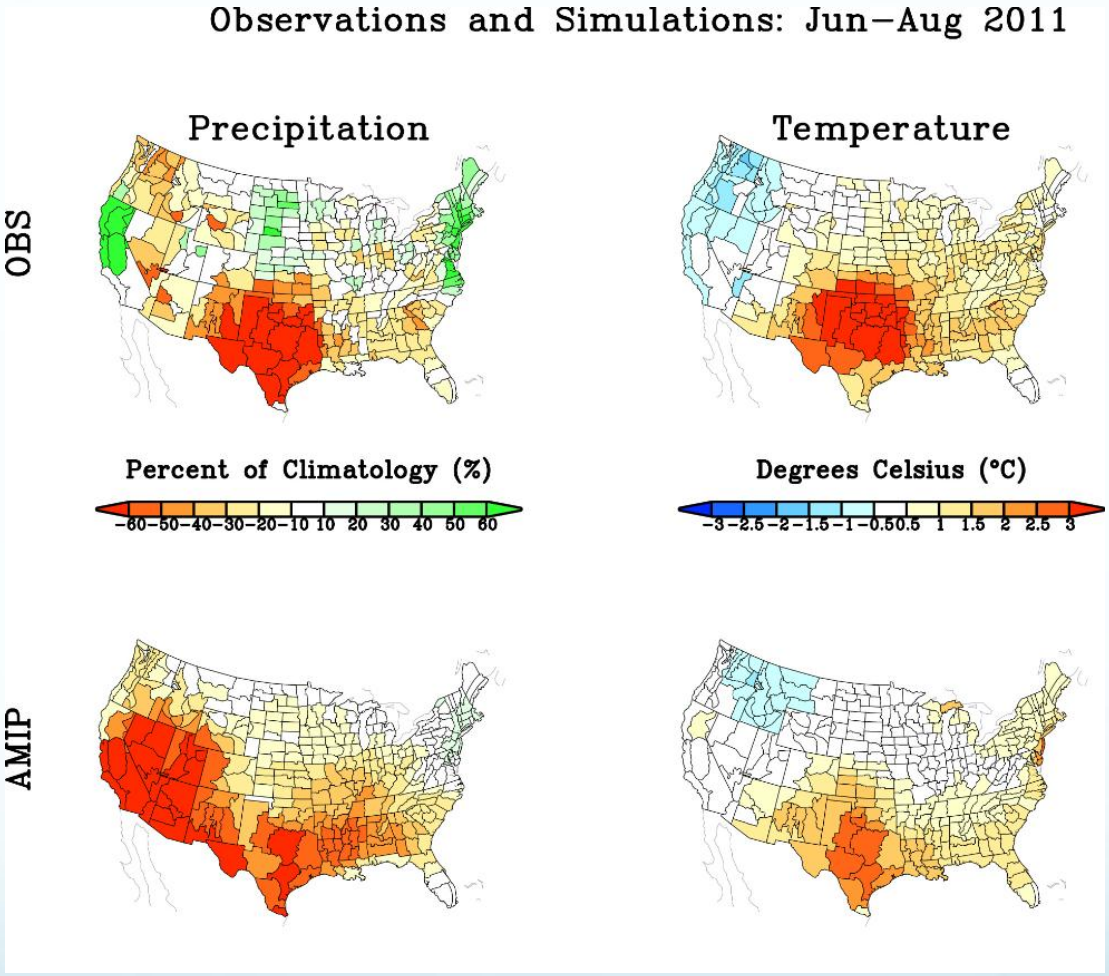


- No significant change in precipitation (no evidence for drought)
- Ensemble-mean of 20 CMIP5 models shows a nearly homogenous temperature pattern with ~ 0.6^{o} C warming over Texas.

What is the Response to observed SSTs?

Observations JJA

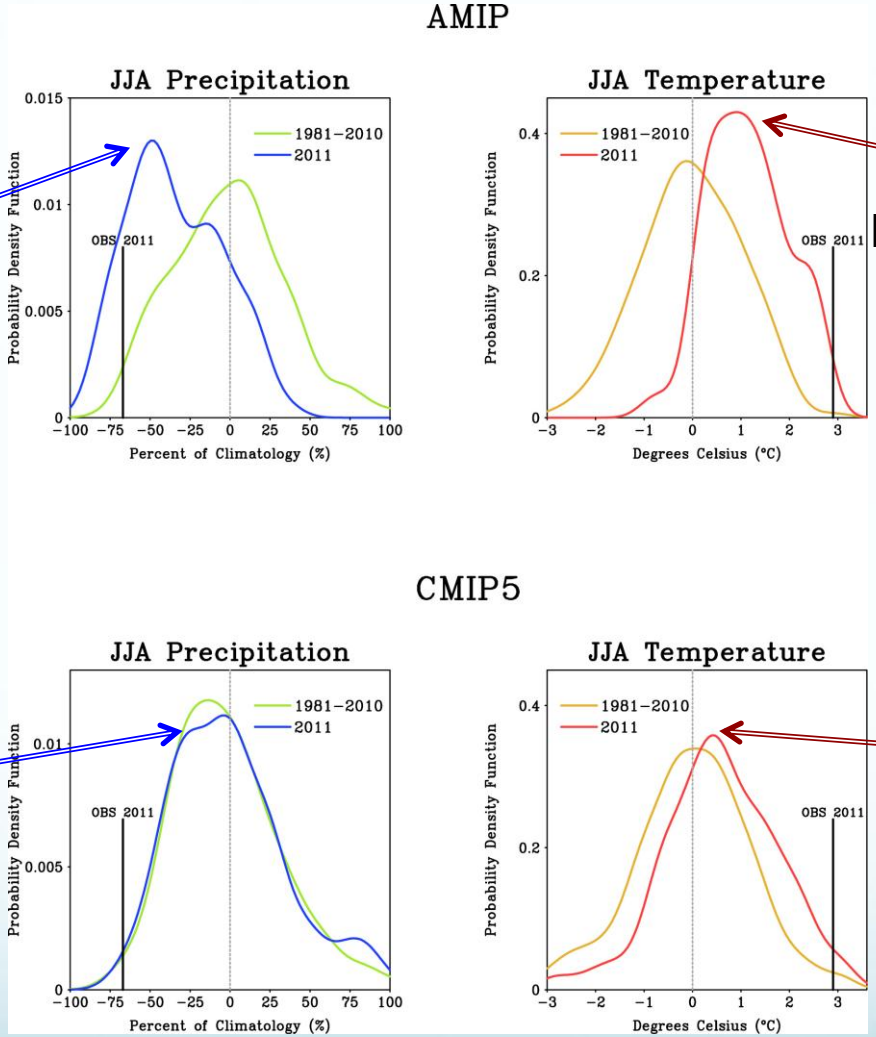
AMIP 80-member ensemble results



- Forcing from observed SSTs (and sea ice) produces drought over Texas and stronger, more regionally-focused warm anomalies

How do the distributions of precipitation and temperature change in response to forcings?

Response to SSTs (dry signal)



Response to SSTs (warming)

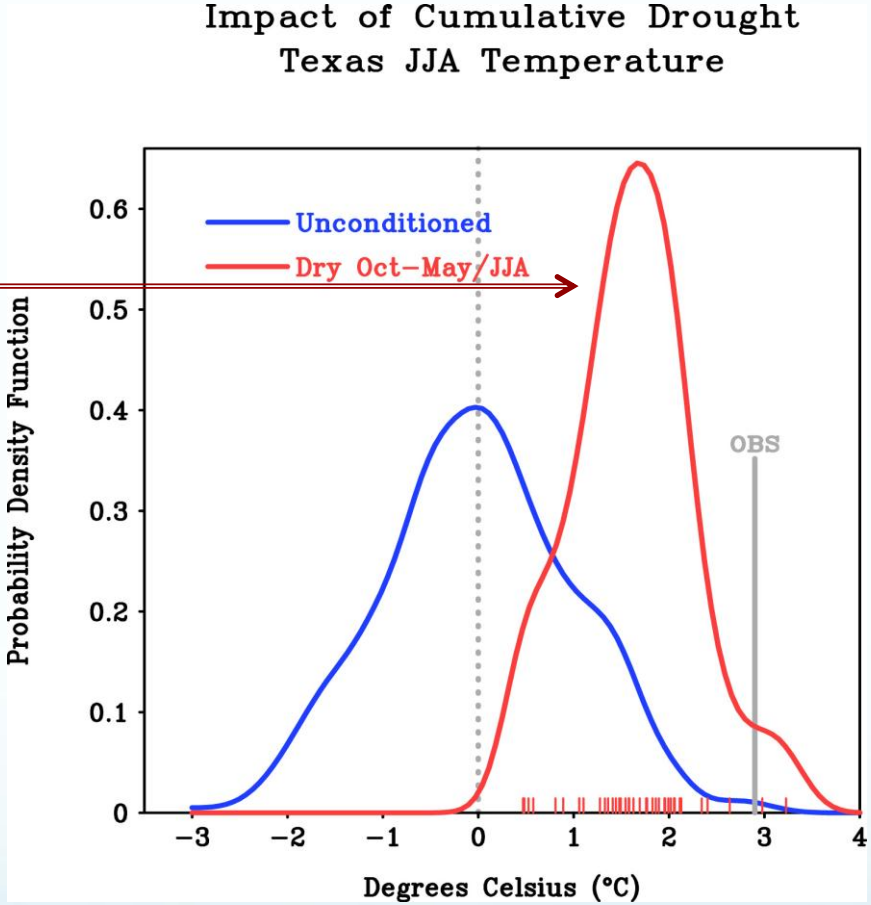
Response to GHG (no dry signal)

Response to GHG (warming)

- Observed SST patterns made drought far more likely
- Both anthropogenic (GHGs) and boundary forcings (SSTs) likely contributed to observed warm conditions

Beyond specific SSTs, did **prolonged** drought contribute to the exceptionally high temperatures?

Estimated PDF of Texas summer temperatures when the preceding and concurrent precipitation were both in lowest 20% of AMIP runs over years 1950-2010



Very likely yes.
Extreme warm summer temperatures were more likely in AMIP runs when both preceding and concurrent conditions are dry. This likely reflects effects of soil moisture depletion on surface energy balance.

Case Conclusions

- **It is very likely that virtually all the precipitation deficit is related to natural variability.** There is no evidence in either observations or CMIP5 simulations of a systematic shift toward drought. Forcing by SSTs, including by La Niña conditions, strongly increased the likelihood of severe drought.

- **Preceding and concurrent severe drought can explain much of the extremely warm summer temperatures.** Because of this, it is very likely that:

- **Natural causes account for most of the heat wave intensity.** It is very likely land-atmosphere feedbacks associated with extremely low soil moisture and desiccated vegetation contributed significantly to the extreme heat.

- **Anthropogenic warming is estimated to have provided an additional contribution to the observed heat wave magnitude** (~0.6^{o}C, or roughly 20%) . This warming increased the probability of achieving a record-breaking warm summer, but by itself was not the dominant cause.

The results suggest that the extreme Texas drought of 2010-11 was primarily due to natural causes. While anthropogenic climate change is not required to explain the extreme heat wave, it likely helped make what would have been an extremely warm summer even more exceptional.

Summary

- Framed event attribution around the question of identifying the most likely causes for an observed event.
- Provided an analogy between medical case diagnosis and physical-diagnostic event attribution.
- Illustrated this approach and findings for one case study, the recent Texas drought/heat wave.

Event attribution is key to developing predictive understanding.

Obtaining such understanding is a fundamental objective of Climate Diagnostics and Prediction Workshops, and more generally of climate science.