Understanding and Explaining Causes of Weather and Climate Related Extreme Events

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PSD’s Objective:
Provide physical explanation of the *magnitude* and probability of extreme events to assess their predictability

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A Tale of Two Extremes - The 2011 Texas Drought and Heat Wave

An Extreme Event with more than 7 Billion Dollar in Agricultural Loss Alone
What are possible contributing factors to the 2011 Texas drought and heat wave?

Analysis Approach

- Role of anthropogenic forcing (including increase in GHGs)
- Role of forcing associated with anomalous boundary conditions (SST, sea ice, soil moisture)
- Unforced internal variations
Observed Temperature and Precipitation Changes

Temperature
- ~ 0.6°C for 1981-2010
- ~ 0°C for periods starting prior to ~1950

Precipitation
- Century-scale trend towards wetter conditions for annual means
Role of Anthropogenic Forcing (based on 20 CMIP5 models)

- No significant change in precipitation
- Nearly homogenous temperature pattern over U.S.
- \( \sim 0.6^\circ C \) temperature increase over Texas (20%)
- Increase in probability for new temperature record from 3% to 6%
Anomalous Lower Boundary Conditions

**Concurrent**
Summer 2011

**Preceding**
Oct 2010 - May 2011

- Preceding moderate La Niña event that decayed by summer
- La Niña related preceding drought conditions

Hoerling et al. 2013
Role of SST patterns (GFS AMIP ensemble)

- Forced atmospheric response captures several regional features of 2011 climate conditions
- ~1.1°C temperature increase over Texas (40%)
- Increase in probability for new temperature record from 4% to 23%

Hoerling et al. 2013
Role of Prolonged Drought Conditions

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

- Extreme warm summer conditions were more likely in AMIP simulations when both preceding and concurrent conditions are dry.

Hoerling et al. 2013
Conclusions of Study

- No strong evidence for a detected change towards either hotter or drier summer based on historical records.
- Virtually all the precipitation deficits appear to be related to natural variability.
- Contributing factors to heat wave magnitude relative to 1980-2010:
  - ~40% due to a severe rainfall deficit (antecedent and concurrent season) related to anomalous SST (including La Niña)
  - ~20% due to human induced climate change
Was this event predictable?

- Forecasts initialized in May were able to anticipate much of the SST-enhanced risk for an extreme summer drought/heat wave over Texas.
Each Extreme Event has Different Predictive Attributes

**Atmospheric internal variability**
2010 Russian Heat Wave (Dole et al. 2011)

**Phenomena on all time scales from climate change to weather (including MJO event)**
2012 Midwest March Record Warmth (Dole et al. 2014)

**Ozone chemistry-climate interactions**
2011 Record Spring NAO (Karpechko, Perlwitz et al. 2014)

**Snow cover**
2013/2014 Upper Midwest Unusual Cold Winter (Wolter et al. 2015, submitted)