Drought: Large-Scale Drivers

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Pathways to Predictability

SST anomalies → Global-Scale Atmospheric Changes → Regional Forcing and land feedbacks → Local Impacts, user needs

- ENSO, PDO, AMO, warm pool variability, Global Warming, etc
- planetary waves, hydrological cycle, monsoons, Hadley Cell, Walker Circulation
- precipitation, soil moisture, snow, low level jets, dust, vegetation, land/atmosphere contrasts, changes in weather
- soil moisture, stream flow, precipitation, ground water, lakes, reservoirs
Issues:

- strength of the SST controls

- how does the response to SST vary in time (including seasonality)?

- what regions of SST (within an ocean basin) matter for the response?

- how do the responses to SST from the different ocean basins interact?

- What is the nature and role of unforced atmospheric variability?

- What is the role of land feedbacks and other local processes?
SST Signal/Total variance on Interannual Time Scales
As estimated from 5 AGCMs, 60 ensemble members: annual means (1979-2011)

T2m

Precipitation

Contour Intervals are different!

Illustrative Examples: Drought and Heat Waves over the US (2011 versus 2012)

Observed T2m

Some impact of SST in region of interest

Weak/no SST impact in region of interest

SST-forced warmth

Ensemble mean 12 GEOS-5 AMIP simulations
SST

2011
(a) JFM2011

2012
(d) JFM2012

(b) AM2011

(e) AM2012

(c) JJ2011

(f) JJ2012

°C

-2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5
JFM Impacts of Pacific SST

Warming both years!
JFM Impacts of Atlantic and Indian Ocean SST

T2m

2011

(b) Atl, JFM 2011

2012

(e) Atl, JFM 2012

Z250hPa

2011

(h) Atl, JFM 2011

2012

(k) Atl, JFM 2012

°C

Atl

Ind

Cooling

Warming

-4 -3 -2 -1 -0.5 -0.25 0.25 0.5 1 2 3 4 >

-90 -75 -60 -45 -30 -15 15 30 45 60 75 90 >
So What Matters for 2011 and 2012 JFM T2m Responses over the US in Terms of SST?

These drive continental-wide warming over the US in both years.

These act to **counteract** the warming over the US in 2011.

These act to **reinforce** the warming over the US in 2012.
Now focus on warm season

Observed T2m

Simulated T2m

Persistence? Land impacts?

Some impact of SST in region of interest

Weak/no SST impact in region of interest

MERRA

Ensemble mean 12 GEOS-5 AMIP simulations
2011 (southern Great Plains)

Surface Soil wetness

SST-driven Shift in PDF

Typical La Nina-driven drought

2012 (central Great Plains)

No obvious shift in PDF

Extreme events

What caused the extreme event in nature and a few of the simulations?

32 ensemble members, heavy black is ensemble mean, red is “observed”
Focus on Nature and Predictability of Late June Rossby Wave

“Constrained” Hindcasts (1 deg GEOS-5) forced to remain close to MERRA only in blue box

Blue box indicates region (atmos) important for initiation of Rossby Wave

Wave is produced if initialized on May 20 and given the correct forcing in east Asia

Wave is not predictable at one month lead time when initialized on May 20

Wave does not amplify without soil moisture feedback

Temporal Evolution of V250mb (40-60N): 2012

1 Aug
26 Jun
21 May
Lessons Learned

• There is more than just the canonical ENSO-driven drought: the other ocean basins matter at least in some cases
  – This can lead to dramatic differences in predictability depending on whether the responses cancel or reinforce

• The atmosphere only cares about SST anomalies in limited regions
  - Need to identify “hot spots” analogous to those found for land feedbacks

• The anatomy of the most extreme events (short term droughts and heat waves):
  – at least some longer-term preconditioning (e.g. from SST forcing), impacting the land
  – rapid development linked to internal atmospheric variability (e.g. Rossby waves) amplifying apparently in response to and interacting with soil moisture anomalies
Challenges

• Improve understanding and modeling of responses to SST in all Ocean Basins
• Improve SST predictions especially in Indian and Atlantic Oceans
• In general, need to better quantify what aspects of SST matter for regional responses
• At subseasonal time scales need to better understand the role and nature of atmospheric forcing in generating wave responses (these appear to be key to generating short term extremes especially during boreal summer)
• Need to better understand/simulate the local responses/interactions (especially land feedbacks)
• Need to better understand and quantity changes in predictability (forecasts of opportunity)
Recommendation for Joint CLIVAR/GEWEX Focus

Short term drought and heat waves (subseasonal to seasonal)

1) As an initial value problem
   challenge to extend skillful precipitation forecasts beyond one month
   need improved observations (e.g., soil moisture), higher model resolution, etc

2) As a decadal and climate change problem
   understand and distinguish decadal and climate change modulation of extremes
   are we getting the physical processes right (learn from (1))?  

Why this focus?
1) Huge societal impacts (thousands of deaths, impacts on agriculture, etc.)
2) Our best hope for improved predictions (subseasonal to seasonal)
3) Both ocean and land play pivotal roles for predictions and likely also as
   preconditioning agents at decadal and longer time scales