Climate Impacts of 2-year La Niña over North America

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Motivation

• El Niño has received more attention because its amplitude and impacts tend to be larger.

• But, La Niña maybe more important for US climate because:
  – 50% of La Niña events return on the 2\textsuperscript{nd} year, leading to more persistent drought over the southern tier of the US.
  – Stronger drought occurs during the second year of La Niña.
Multi-year La Niña events are very common

Okumura and Deser 2010
CCSM4 simulates realistic 2-year La Niña events

CCSM4 HadISST

SST anomaly (°C)

DiNezio and Deser 2014
Heat budget of Nino-3.4 anomalies
\[ \frac{\partial T'}{\partial t} = - \left( u' \frac{\partial T}{\partial x} + w' \frac{\partial T}{\partial z} + \frac{w}{\partial z} \right) - \frac{Q_{\text{air-sea}}}{\rho_0 c_p H} \]

Nonlinear delayed oscillator (NDO)
\[ \frac{\partial T'}{\partial t} = aT' - bT'(t - t_0) - cT' + \eta(t) \]

delayed thermocline feedback

DiNezio and Deser 2014
Two regimes

linear
1-year La Niña

non-linear
2-year La Niña

decreased heat content
increased heat content
decreased stratification
increased stratification

DiNezio and Deser 2014
La Niña droughts over N. America intensify during the second year

Composite of 4 events during 1982-2010.
Observational data: NOAA OISSTv2, GPCPv2 rainfall, and CPC soil moisture
Evolution of 2-year La Niña droughts

Composite of 8 events (1900-2008)
**Observed 2-year La Nina SST anomalies**
Composite of 8 observed events from 1900 to 2008

- Preceding El Niño
  - DJF°

- First year La Niña
  - DJF°+1

- Second year La Niña
  - DJF°+2

**Simulated 2-year La Nina SST anomalies**
Composite of 33 events simulated by CCSM4

- DJF°
- DJF°+1
- DJF°+2

**Surface temperature (°C)**

-2.5  -1.5  -0.5   0   0.5   1.5   2.5
**Observed 2-year La Niña SST anomalies**
Composite of 8 observed events from 1900 to 2008

- **preceding El Niño**
  - DJF$^0$

- **first year La Niña**
  - DJF$^+1$

- **second year La Niña**
  - DJF$^+2$

**Simulated 2-year La Niña rainfall anomalies**
Composite of 33 events simulated by CCSM4

- **DJF$^0$**
- **DJF$^+1$**
- **DJF$^+2$**
CAM4 GOGA rainfall anomalies
Composite of 9 events 1900-2007

CAM4 TOGA rainfall anomalies
Composite of 9 events 1900-2007
Simulated 2-year La Niña SST anomalies
Composite of 51 events simulated by CESM1-CAM5

Simulated 2-year La Niña rainfall anomalies
Composite of 51 events simulated by CESM1-CAM5
Simulated 2-year La Nina rainfall anomalies
Composite of 11 runs simulated by CAM5 forced with composite SSTs

Simulated soil moisture anomalies
Conclusions

• Observed intensification of La Nina drought on the second year.

• CAM4 and CAM5 do not simulate it very well.
  – Hypotheses:
    • CAM-simulated mid-latitude storms are not sensitive to Pacific SSTs.
      – Impact on US West Coast.
    • CAM rainfall is not sensitive to evaporation/soil moisture.
      – Impact on Southeastern US and TX
Thank you!
**Observed 2-year La Nina SST anomalies**
Composite of 8 observed events from 1900 to 2012

preceding El Niño
DJF^0

first year La Niña
DJF^+1

second year La Niña
DJF^+2

**Simulated 2-year La Nina SST anomalies**
Composite of 100 events simulated by CCSM4

DJF^0

DJF^+1

DJF^+2
CCSM4 simulates realistic 2-year La Niña events
Evolution of 2-year La Niña SST anomalies
Composite of 8 events (1900-2008)

SST anomaly (°C)