Climate Impacts of 2-year La Niña over North America

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CESM Paleoclimate Working Group
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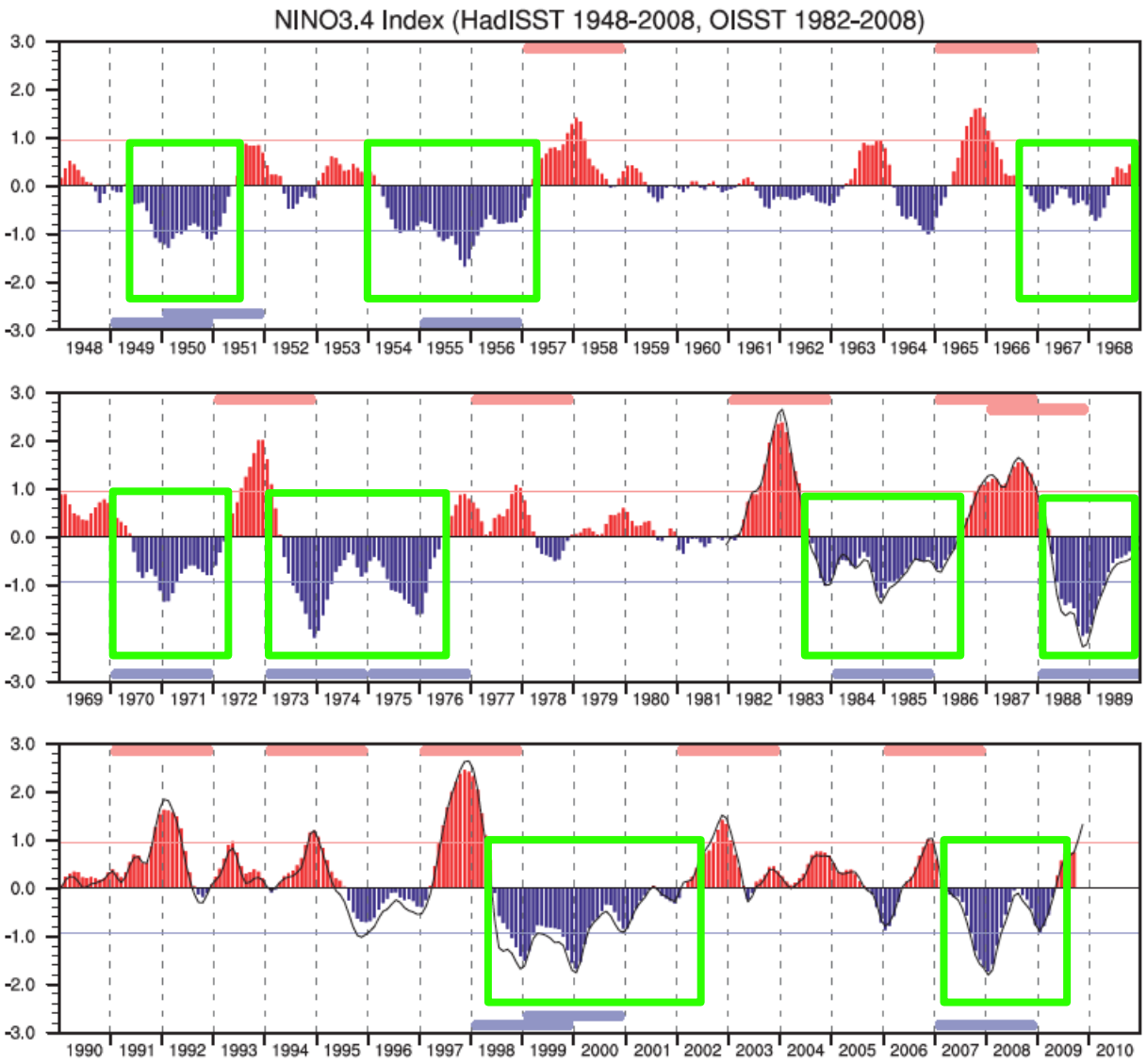
Motivation

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

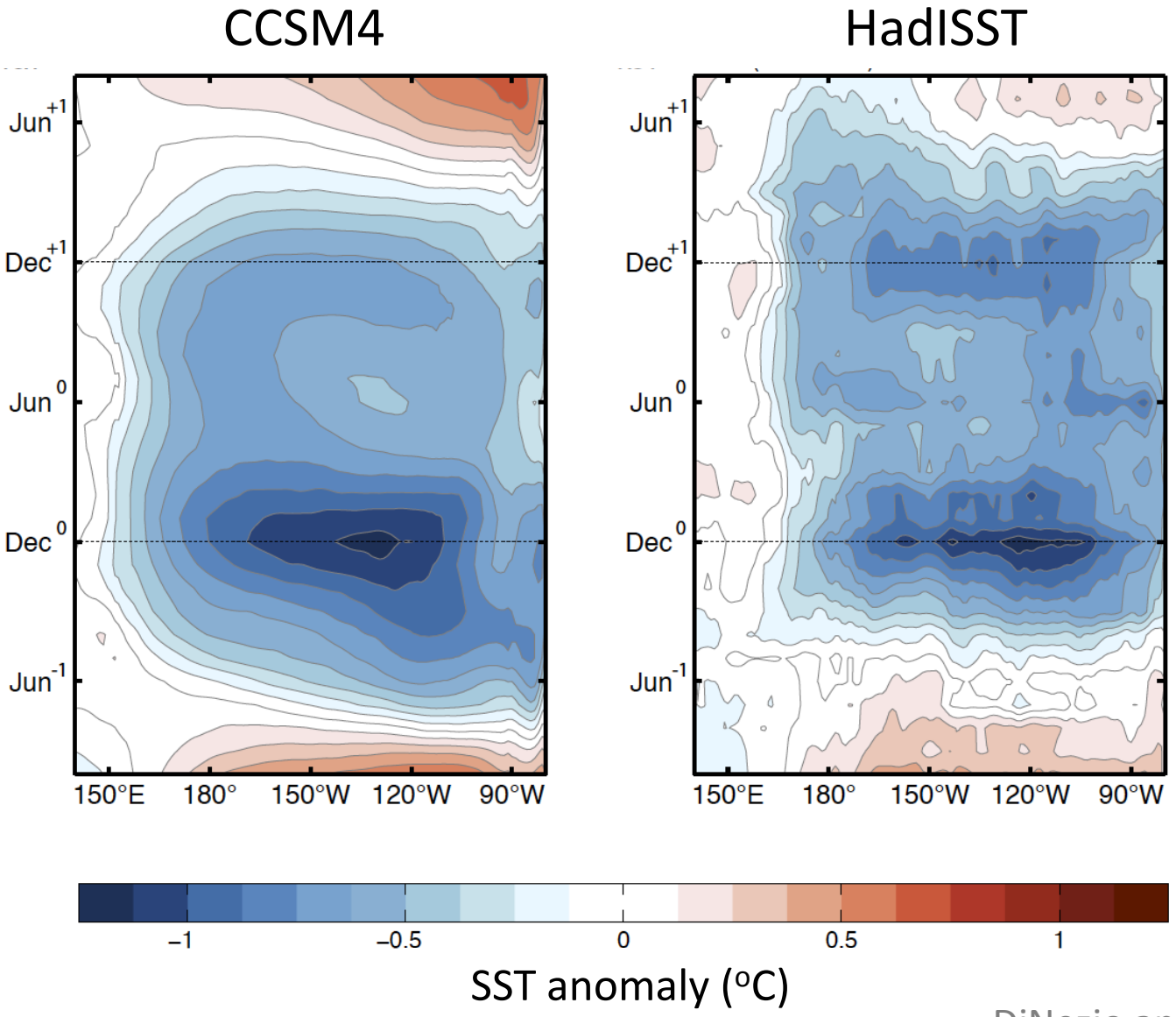
- But, La Niña maybe more important for US climate because:
  - 50% of La Niña events return on the 2nd year, leading to more persistent drought over the southern tier of the US.
  - Stronger drought occurs during the second year of La Niña.

Multi-year La Niña events are very common



Okumura and Deser 2010

CCSM4 simulates realistic 2-year La Niña events



DiNezio and Deser 2014

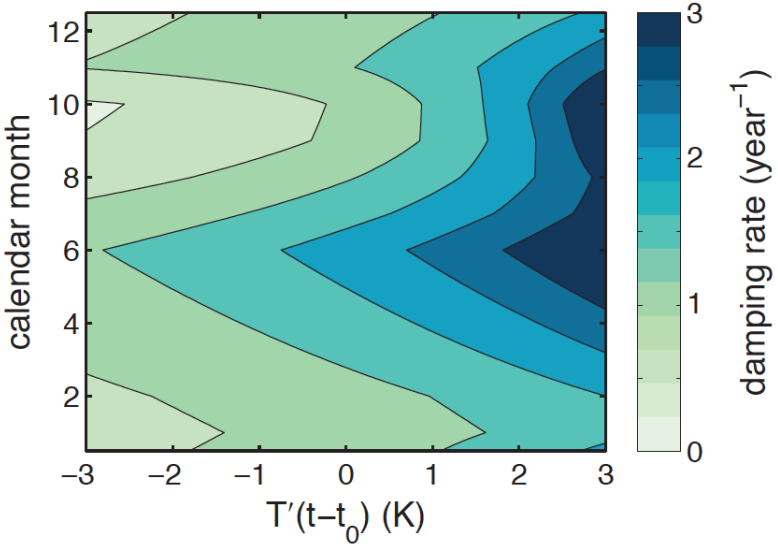
Heat budget of Nino-3.4 anomalies

$$\frac{\partial T'}{\partial t} = -\left(u' \frac{\partial \overline{T}}{\partial x} + w' \frac{\partial \overline{T}}{\partial z} + \overline{w} \frac{\partial T'}{\partial z} \right) - \frac{Q_{air-sea}}{\rho_0 c_p H}$$

Nonlinear delayed oscillator (NDO)

$$\frac{\partial T'}{\partial t} = aT' - bT'\left(t - t_0\right) - cT' + \eta(t)$$

delayed thermocline feedback

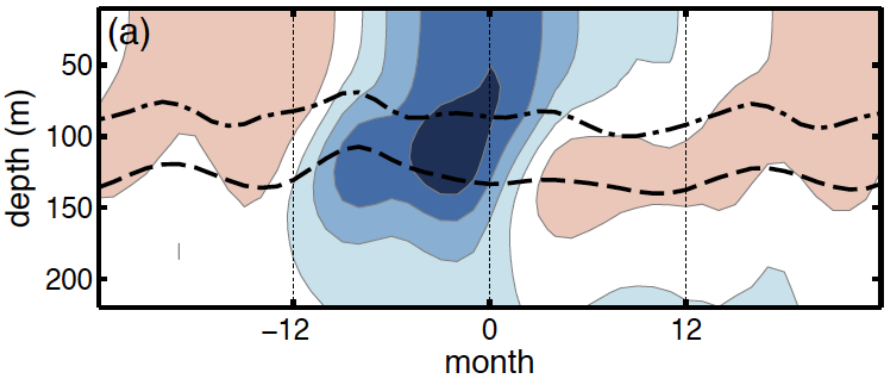


DiNezio and Deser 2014

Two regimes

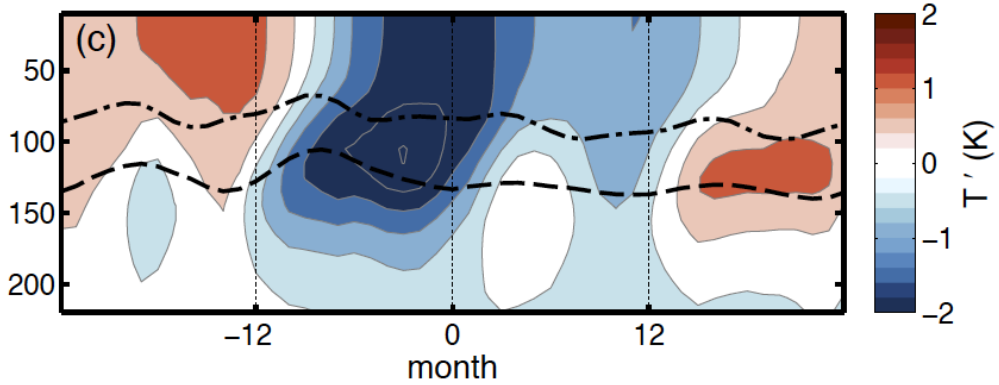
linear

1-year La Niña



non-linear

2-year La Niña



decreased heat content

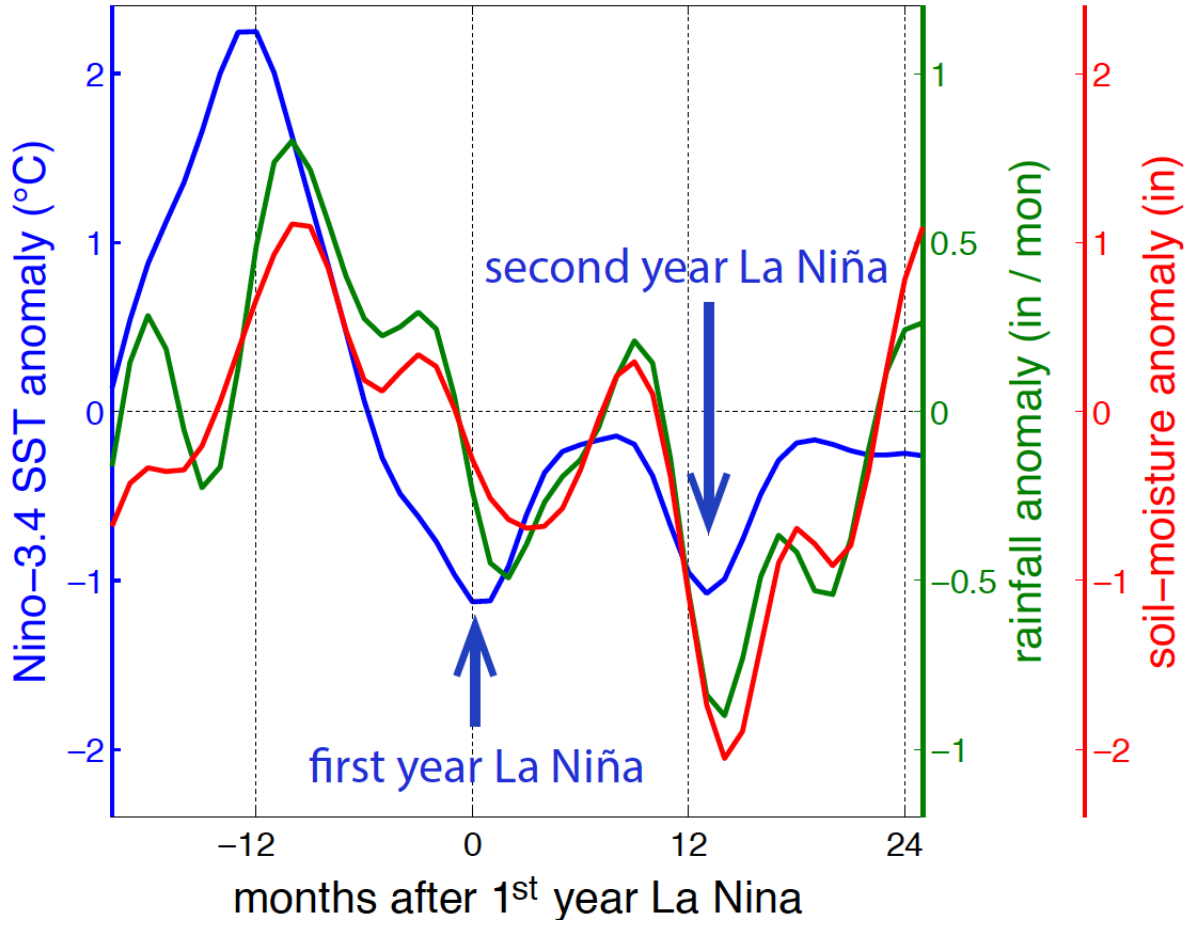
increased heat content

decreased stratification

increased stratification

DiNezio and Deser 2014

La Niña droughts over N. America intensify during the second year



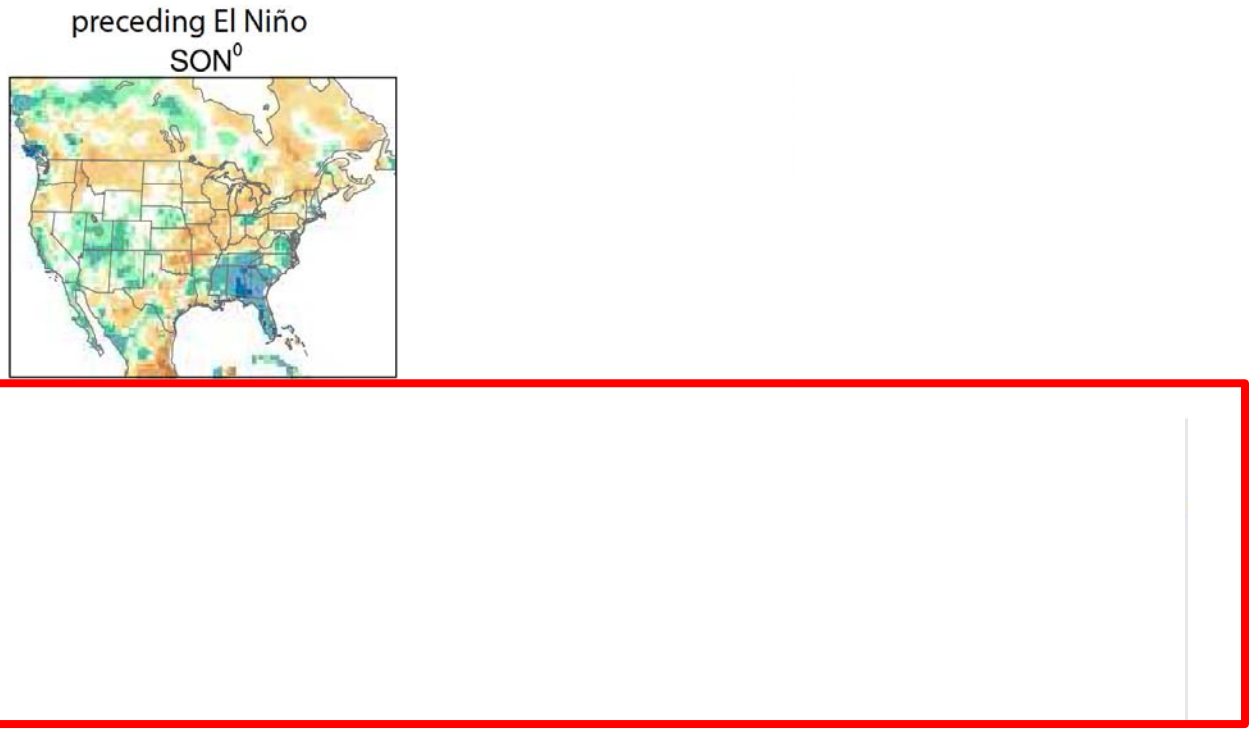
soil moisture over southern tier of the US (from GA to CA)

Composite of 4 events during 1982-2010.

Observational data: NOAA OISSTv2, GPCPv2 rainfall, and CPC soil moisture

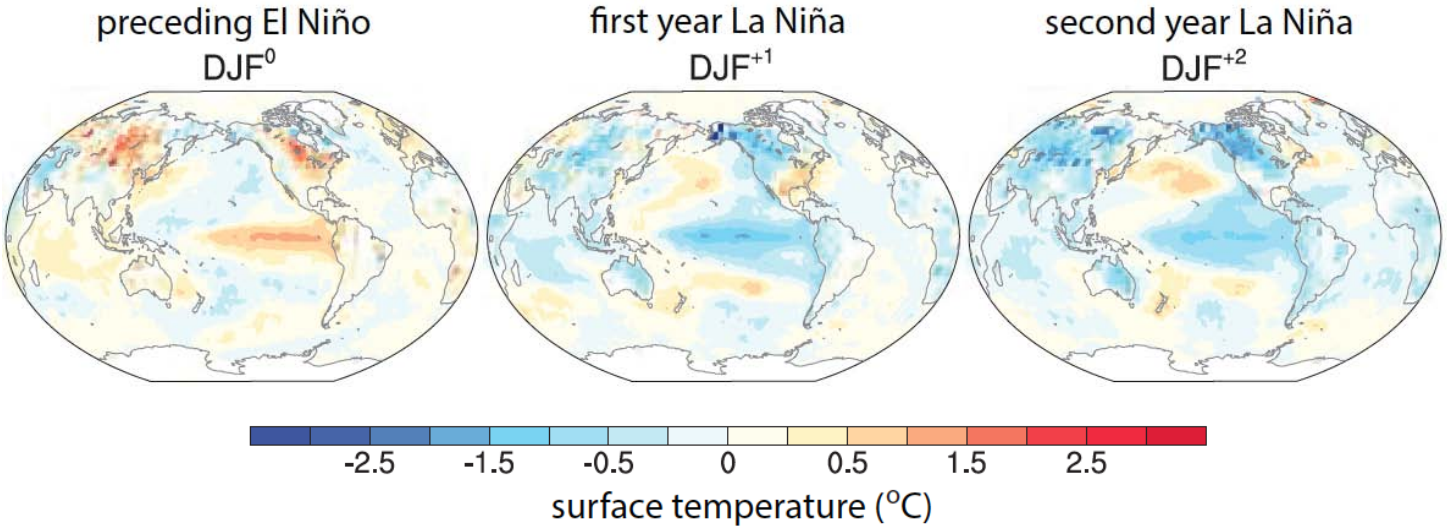
Evolution of 2-year La Niña droughts

Composite of 8 events (1900-2008)



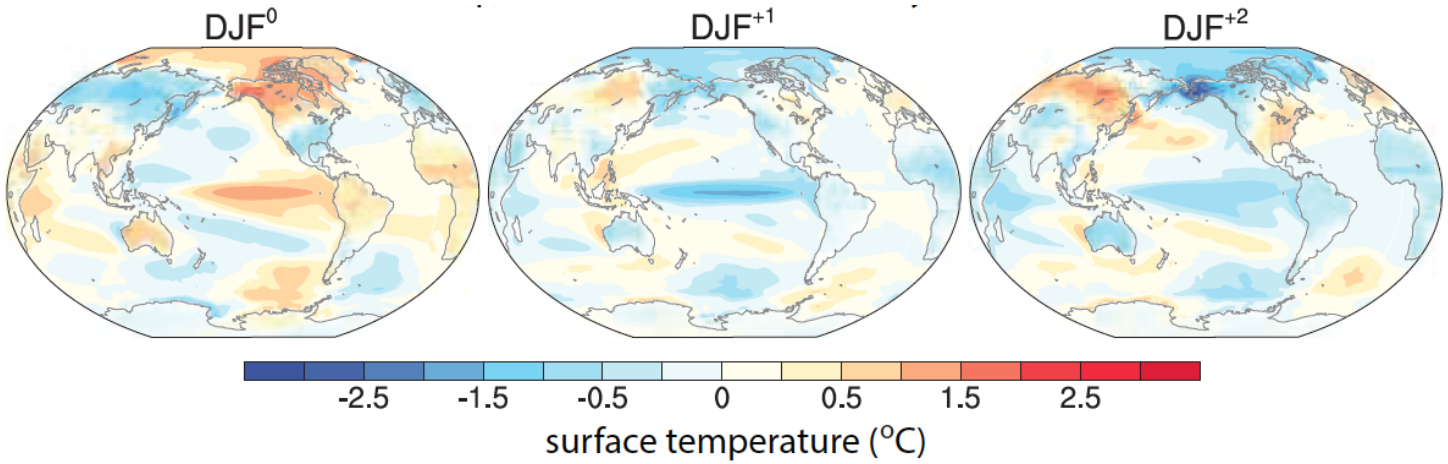
Observed 2-year La Nina SST anomalies

Composite of 8 observed events from 1900 to 2008



Simulated 2-year La Nina SST anomalies

Composite of 33 events simulated by CCSM4



Observed 2-year La Nina SST anomalies

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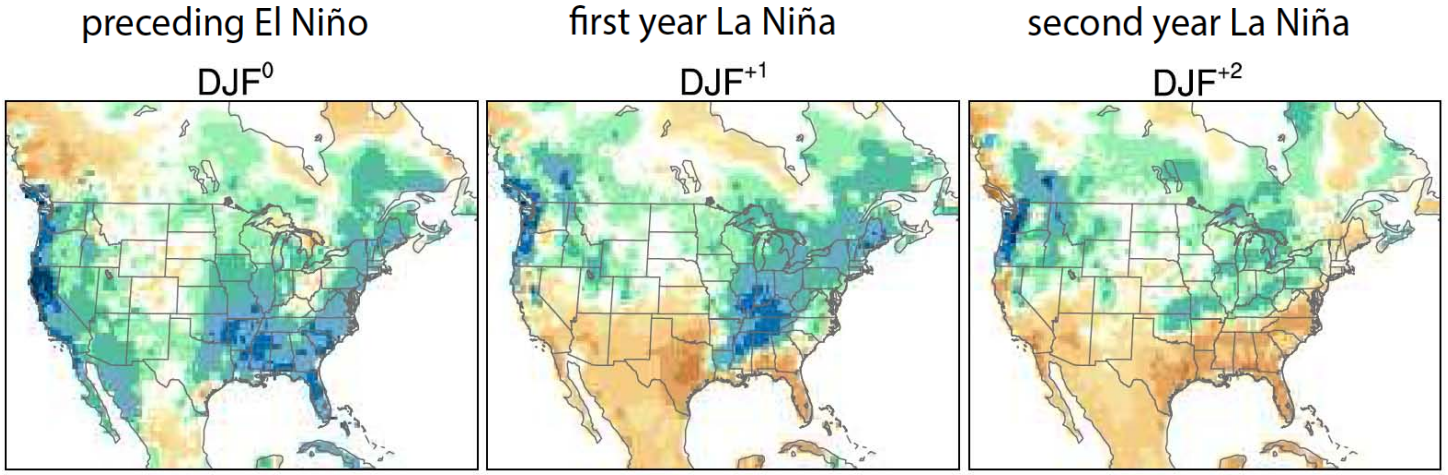
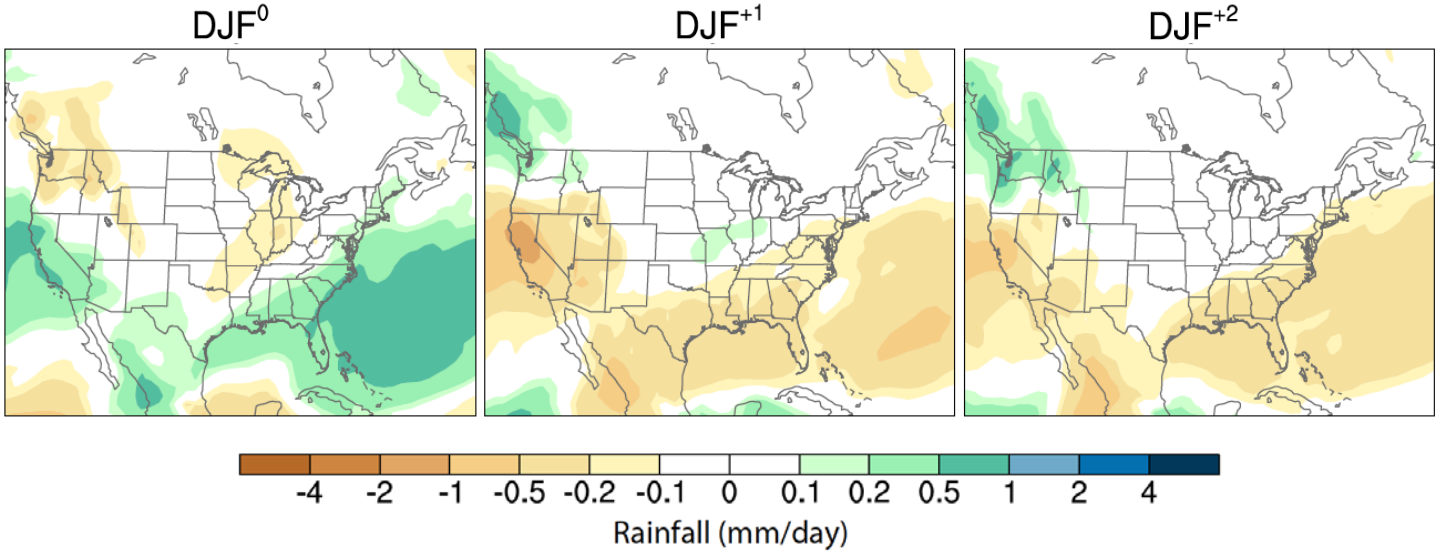


Simulated 2-year La Nina rainfall anomalies

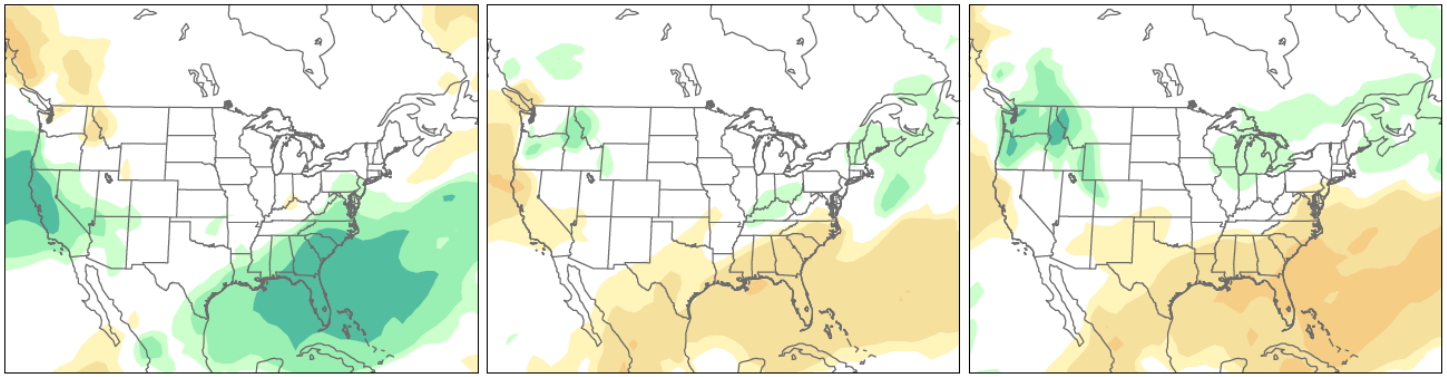
Composite of 33 events simulated by CCSM4



CAM4 *GOGA* rainfall anomalies

Composite of 9 events 1900-2007

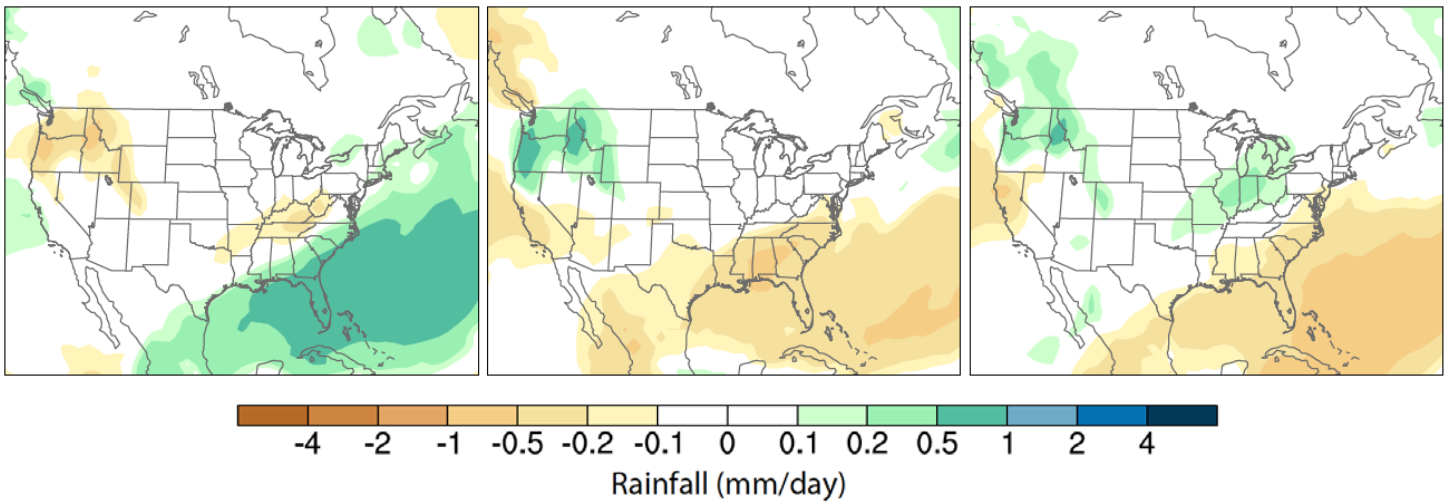
preceding El Niño DJF^{0} | first year La Niña DJF^{+1} | second year La Niña DJF^{+2}



CAM4 *TOGA* rainfall anomalies

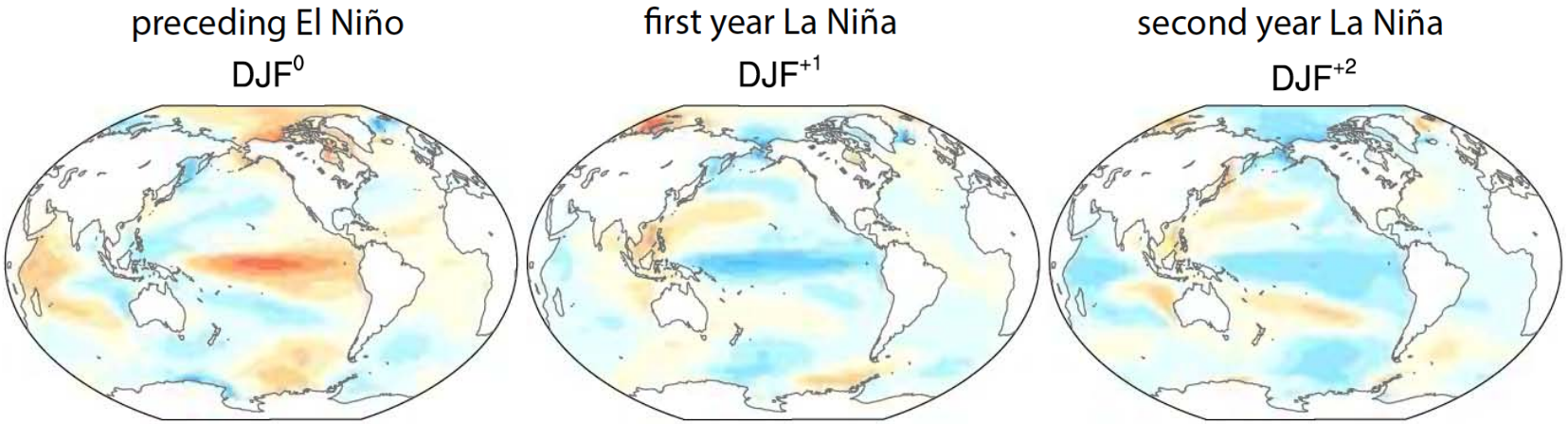
Composite of 9 events 1900-2007

DJF^{0} | DJF^{+1} | DJF^{+2}



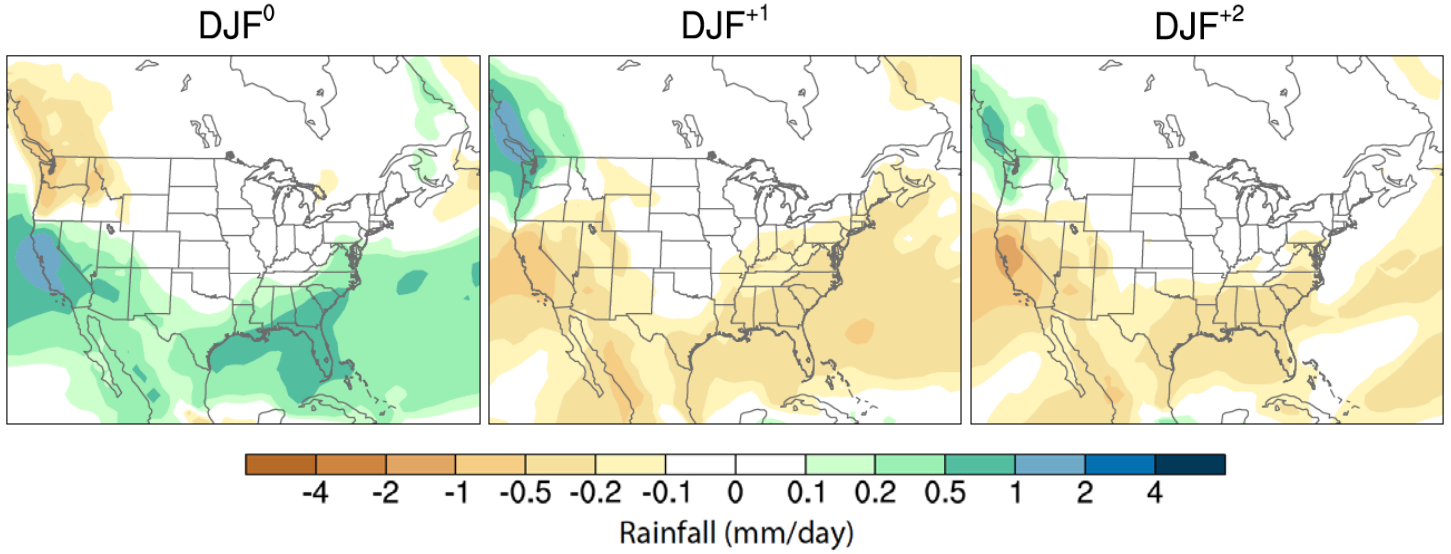
Simulated 2-year La Nina SST anomalies

Composite of 51 events simulated by CESM1-CAM5



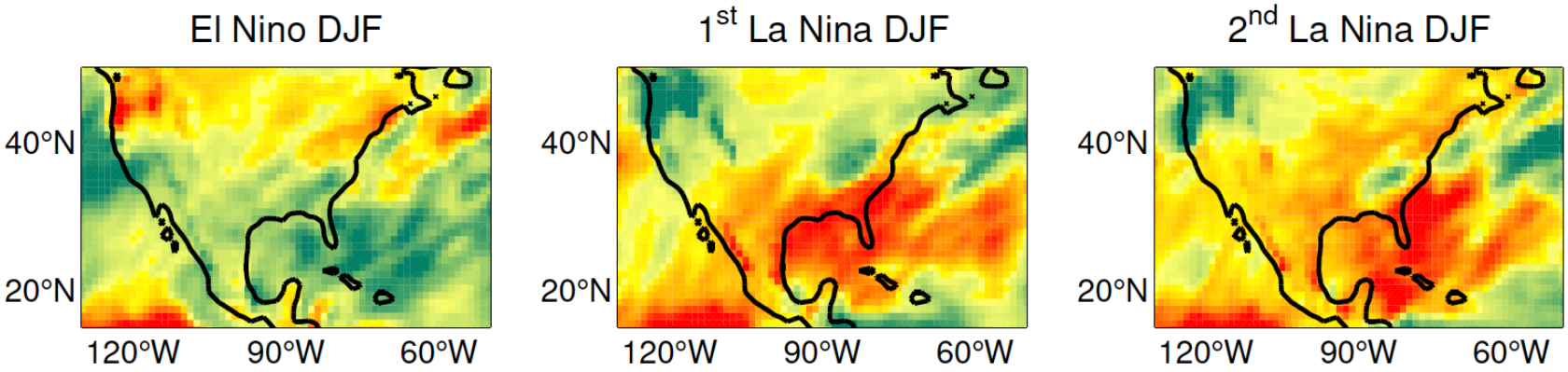
Simulated 2-year La Nina rainfall anomalies

Composite of 51 events simulated by CESM1-CAM5

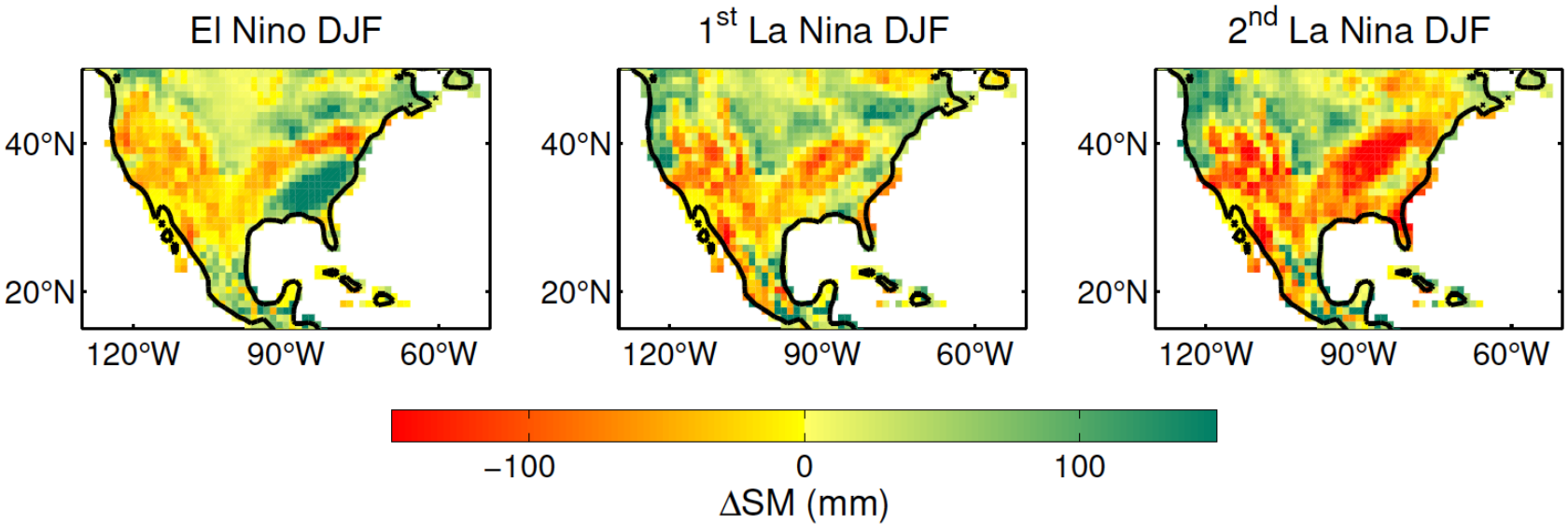


Simulated 2-year La Nina rainfall anomalies

Composite of 11 runs simulated by CAM5 forced with composite SSTs



Simulated soil moisture anomalies



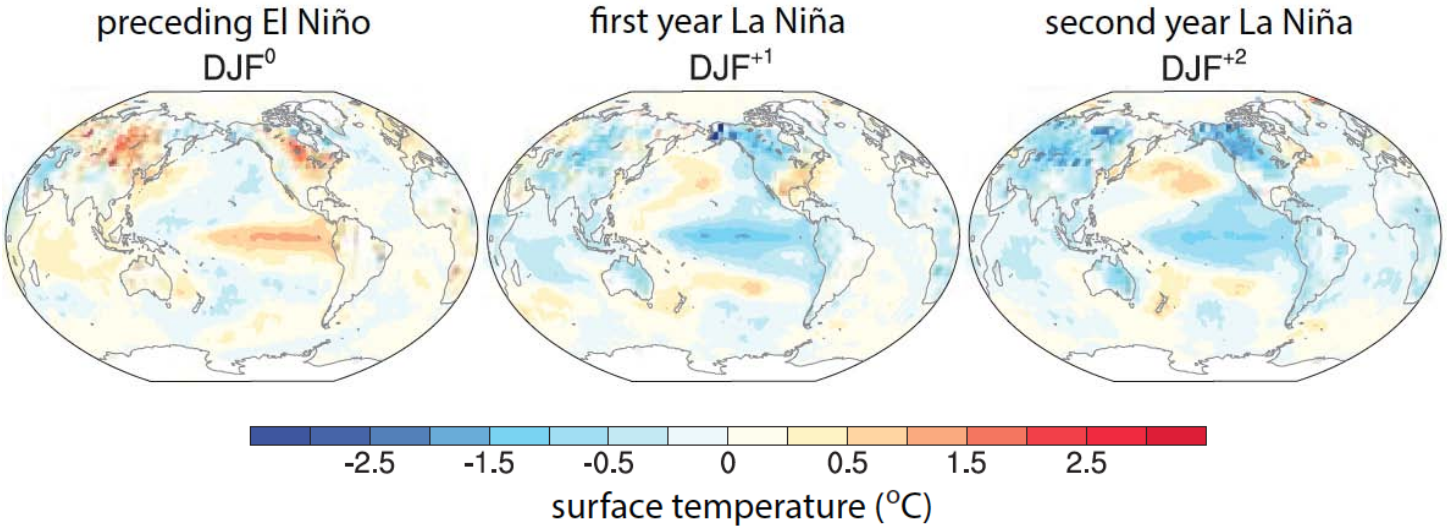
Conclusions

- 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!

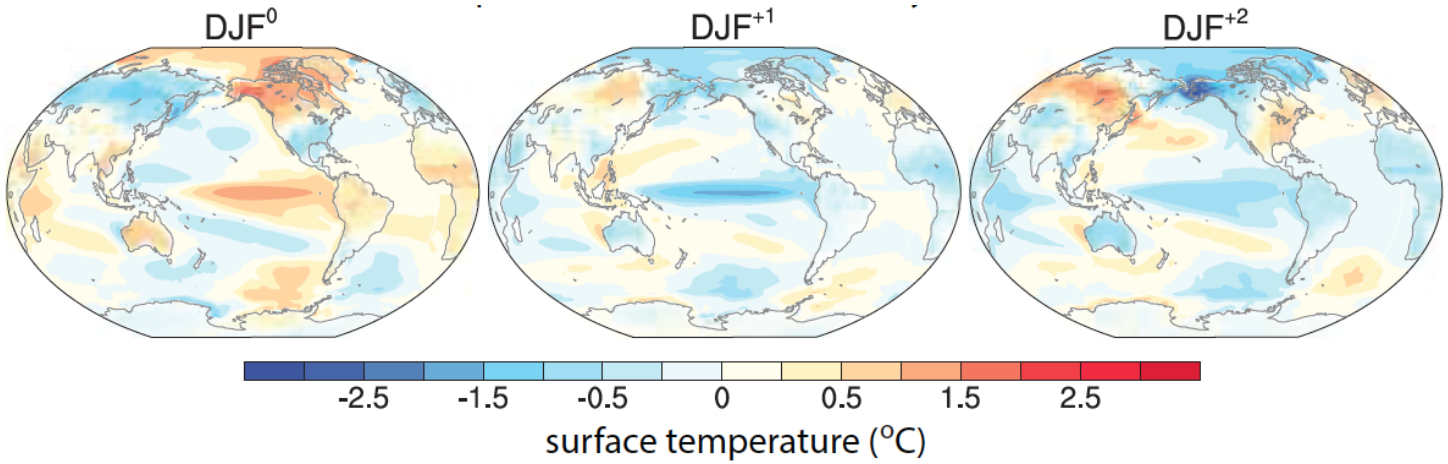
Observed 2-year La Nina SST anomalies

Composite of 8 observed events from 1900 to 2012



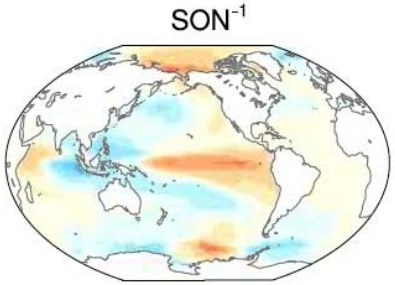
Simulated 2-year La Nina SST anomalies

Composite of 100 events simulated by CCSM4



CCSM4 simulates realistic 2-year La Niña events

preceding El Niño



time

-2.5 -1.5 -0.5 0 0.5 1.5 2.5

SST anomaly (°C)

time

Evolution of 2-year La Niña SST anomalies

Composite of 8 events (1900-2008)