Spring Land Surface and Subsurface Temperature Anomalies and Subsequent Downstream Late Spring-Summer Droughts/Floods in North America and East Asia

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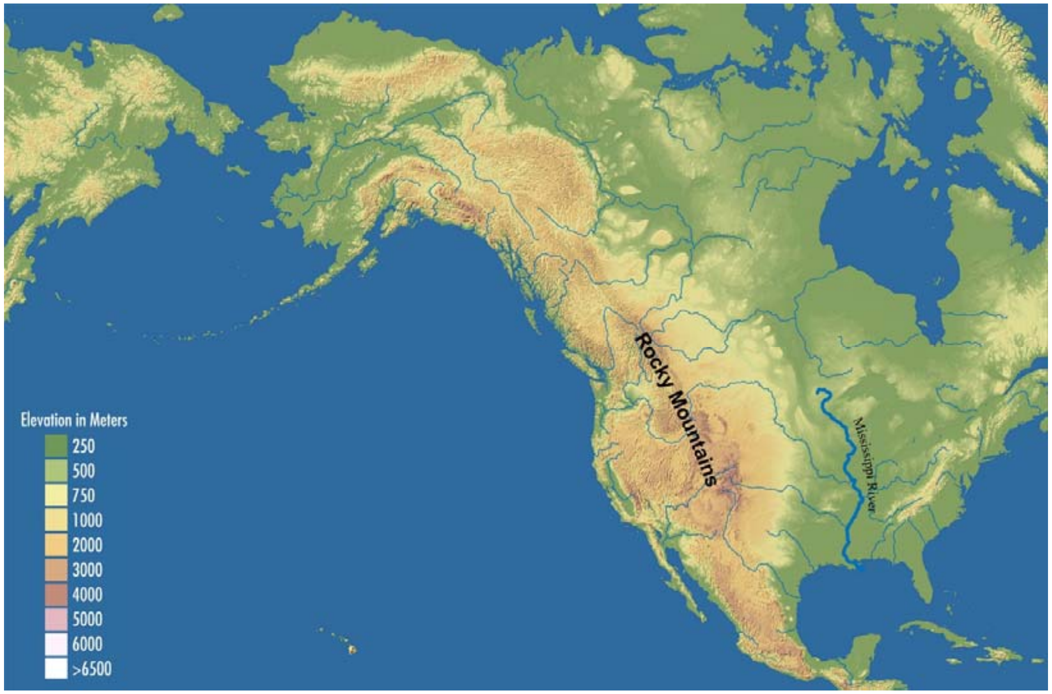
NOAA GAPP, CPPA Program (2001, 2007)
NSF Climate and Large-scale Dynamics (2014-)

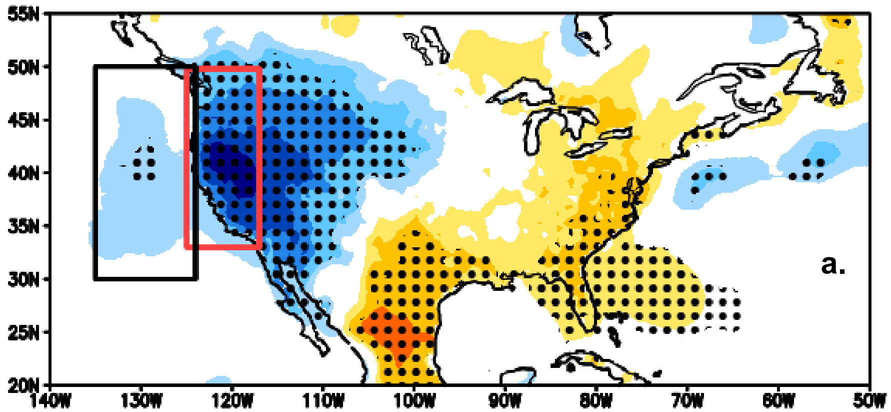
1). Background

North American Topography

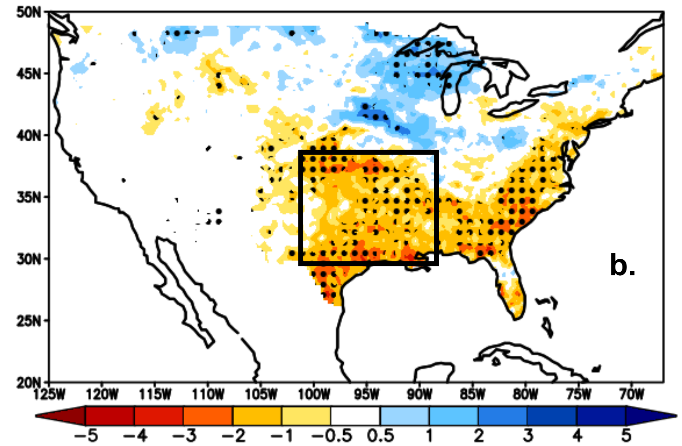


Observed differences between 9 coldest years and 9 warmest years (based on N.W. U.S. & S. E. Canada LST)

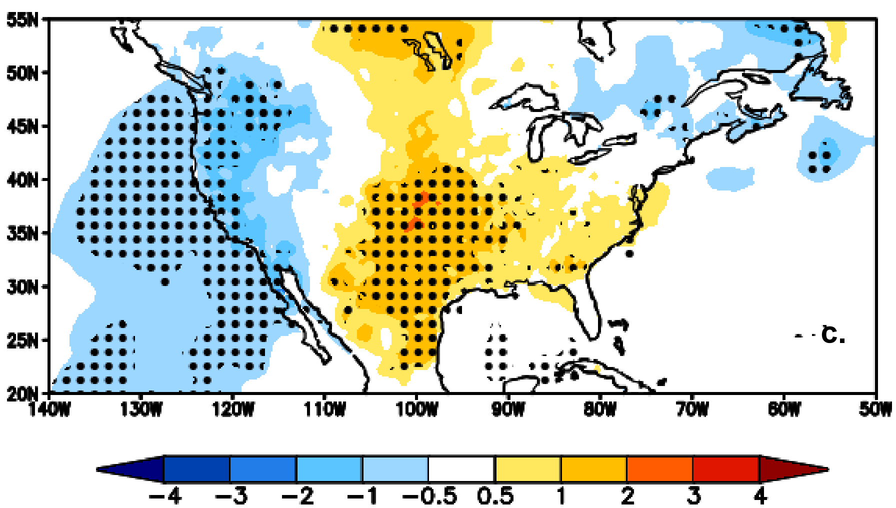
May Observed LST and **SST**



June Observed Precipitation

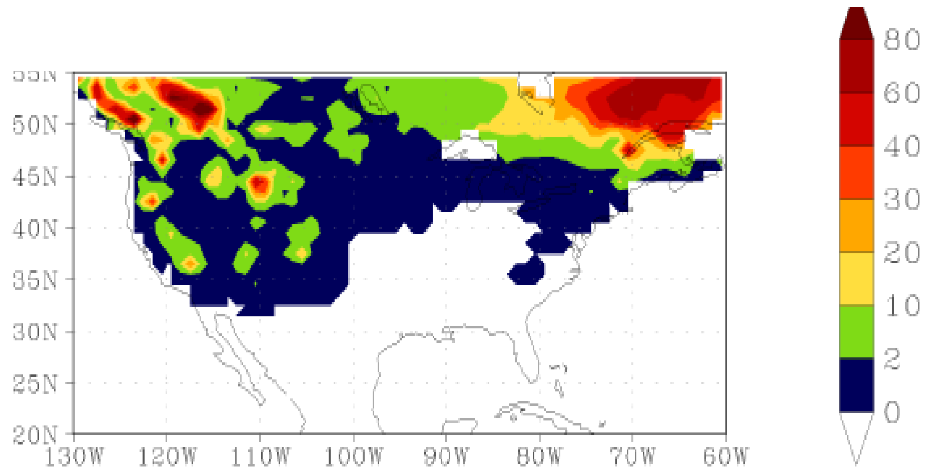


June Observed LST and SST

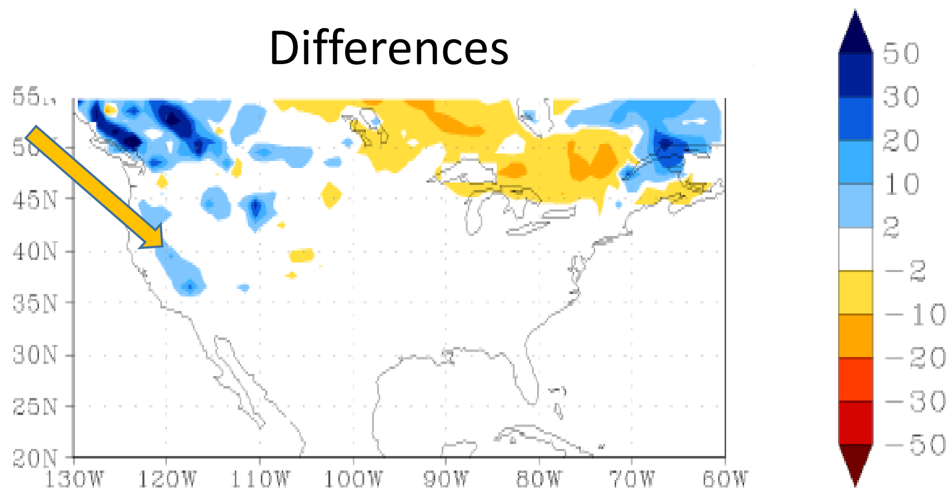


1) LST: land surface temperature
2) The dotted areas denote statistical significance less than α=0.1 level of t-test values.

Observed April snow water equivalent and its difference between Coldest and Warmest Years over West U.S.

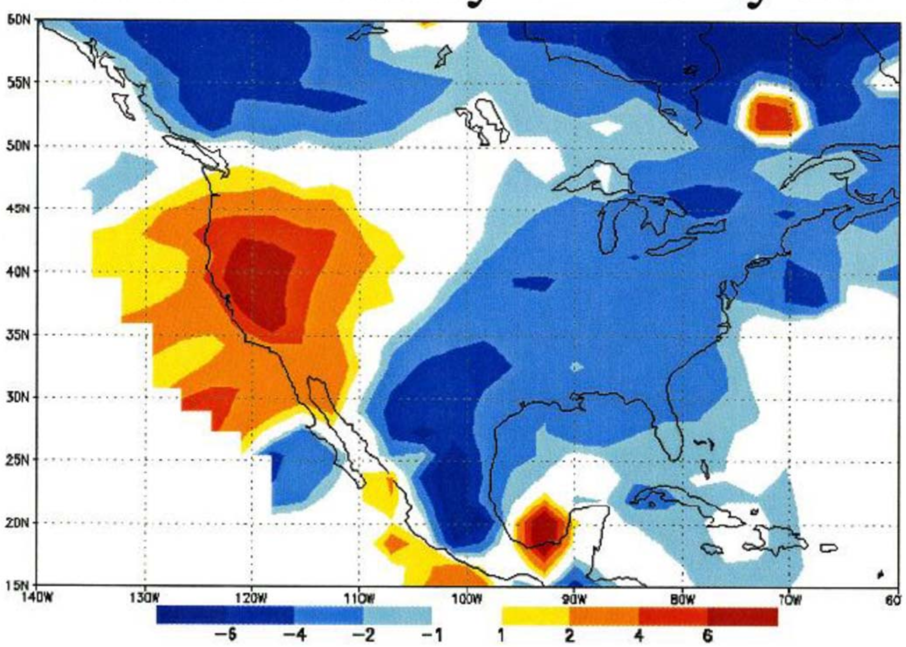


Differences

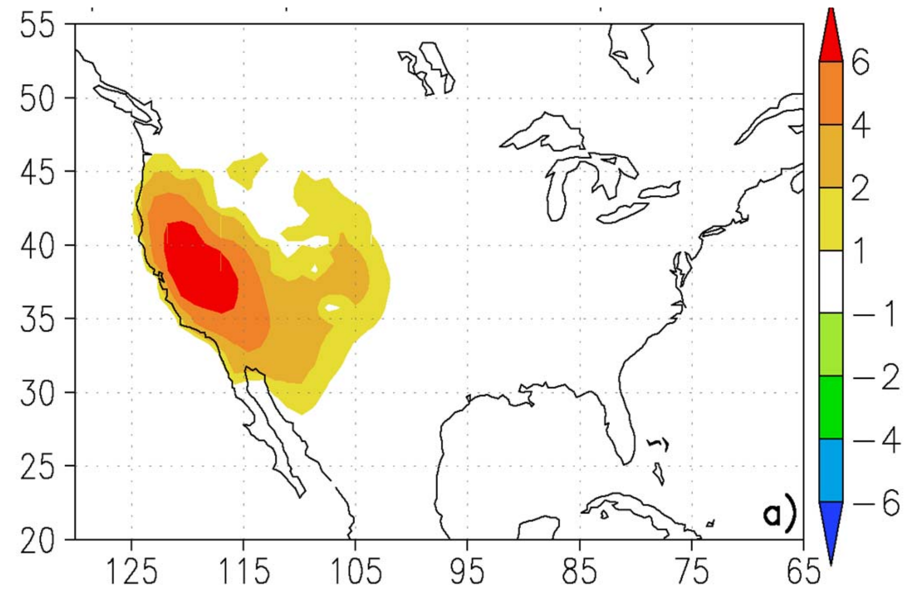


The GCM and the RCM were integrated for two months from May 1-10 initial, 1998 through June 30, 1998, with two different initial SUBT conditions over the Western U.S : one from May 1998 (a cold winter as control) and another from May 1992 (a warm winter as anomaly)

OBS sfc T May 92 – May 98



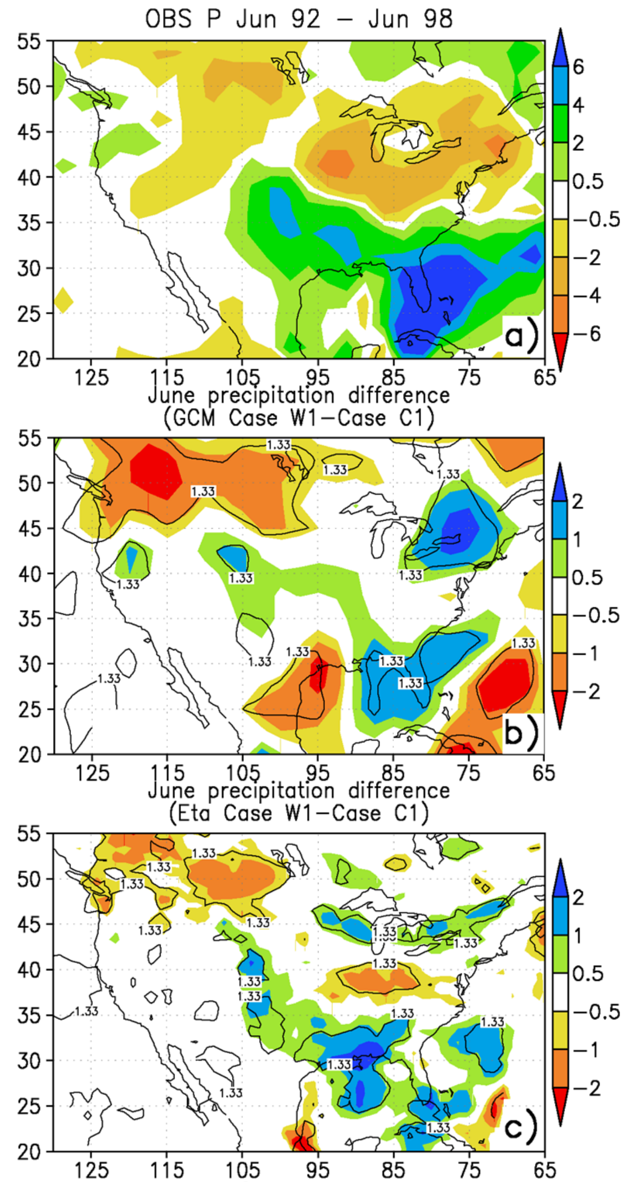
Imposed Subsurface temperature (SUBT) anomalies **at the 1st time step**



Observed June Precipitation difference btw 1992 and 1998

NCEP GCM-simulated June Precipitation difference btw warm and cold SUBTs

Eta RCM-downscaled June Precipitation difference btw warm and cold SUBTs



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The impact of spring subsurface soil temperature anomaly in the western U.S. on North American summer precipitation: A case study using regional climate model downscaling

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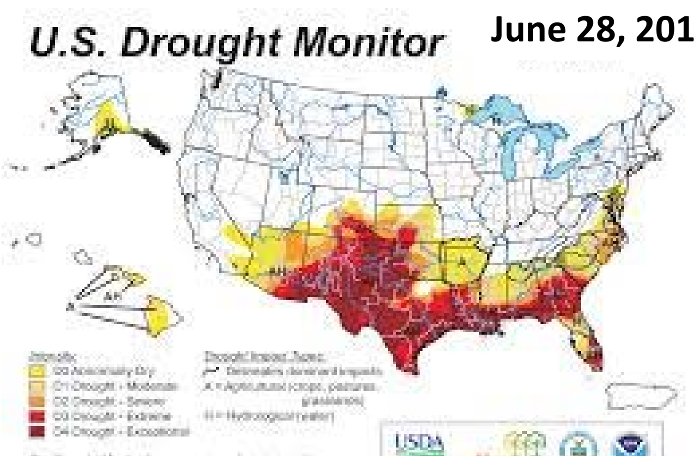
Received 27 February 2012; revised 24 April 2012; accepted 25 April 2012; published 2 June 2012.

[1] This study explores the impact of spring subsurface soil temperature (SUBT) anomaly in the western U.S. on North American summer precipitation, mainly southeastern U.S., and possible mechanisms using a regional climate Eta model and a general circulation model (GCM). The GCM produces the lateral boundary condition (LBC) for the Eta model. Two initial SUBT conditions (one cold and another warm) on May 1st were assigned for the GCM runs and the corresponding Eta runs. The results suggest that antecedent May 1st warm initial SUBT in the western U.S. contributes positive June precipitation over the southern U.S. and less precipitation to the north, consistent with the observed anomalies between a year with a warm spring and a year with a cold spring in the western U.S. The anomalous cyclone induced by the surface heating due to SUBT anomaly propagated eastward through Rossby waves in westerly mean flow. In addition, the steering flow also contributed to the dissipation of perturbation in the northeastern U.S. and its enhancement in southeastern U.S. However, these results were obtained only when the Eta model run was driven by the corresponding GCM run. When the same reanalysis data were applied for both (cold and warm initial SUBT) Eta runs' LBCs, the precipitation anomalies could not be properly produced, indicating the intimate dependence of the regional climate sensitivity downscaling on the imposed global climate forcing, especially when the impact was through wave propagation in the large-scale atmospheric flow.

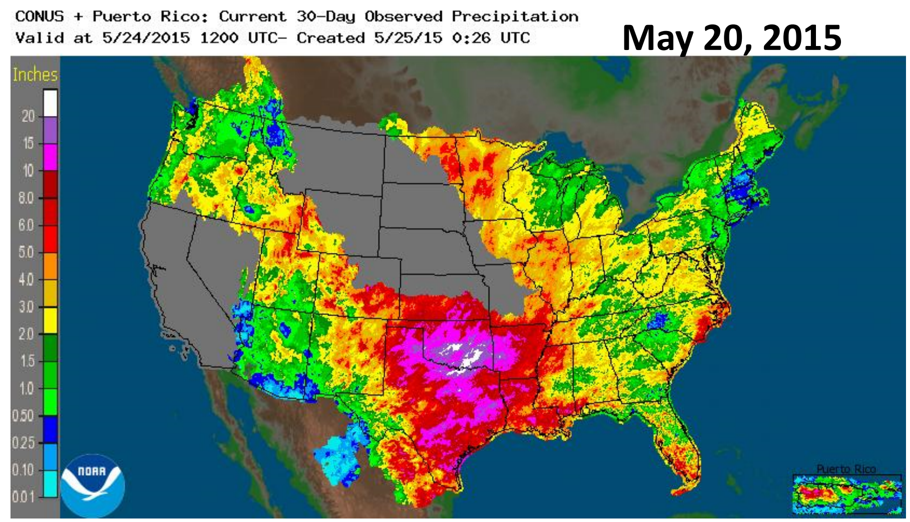
Citation: Xue, Y., R. Vasic, Z. Janjic, Y. M. Liu, and P. C. Chu (2012), The impact of spring subsurface soil temperature anomaly in the western U.S. on North American summer precipitation: A case study using regional climate model downscaling, *J. Geophys. Res.*, *117*, D11103, doi:10.1029/2012JD017692.

2). Further Analyses of Observational Data

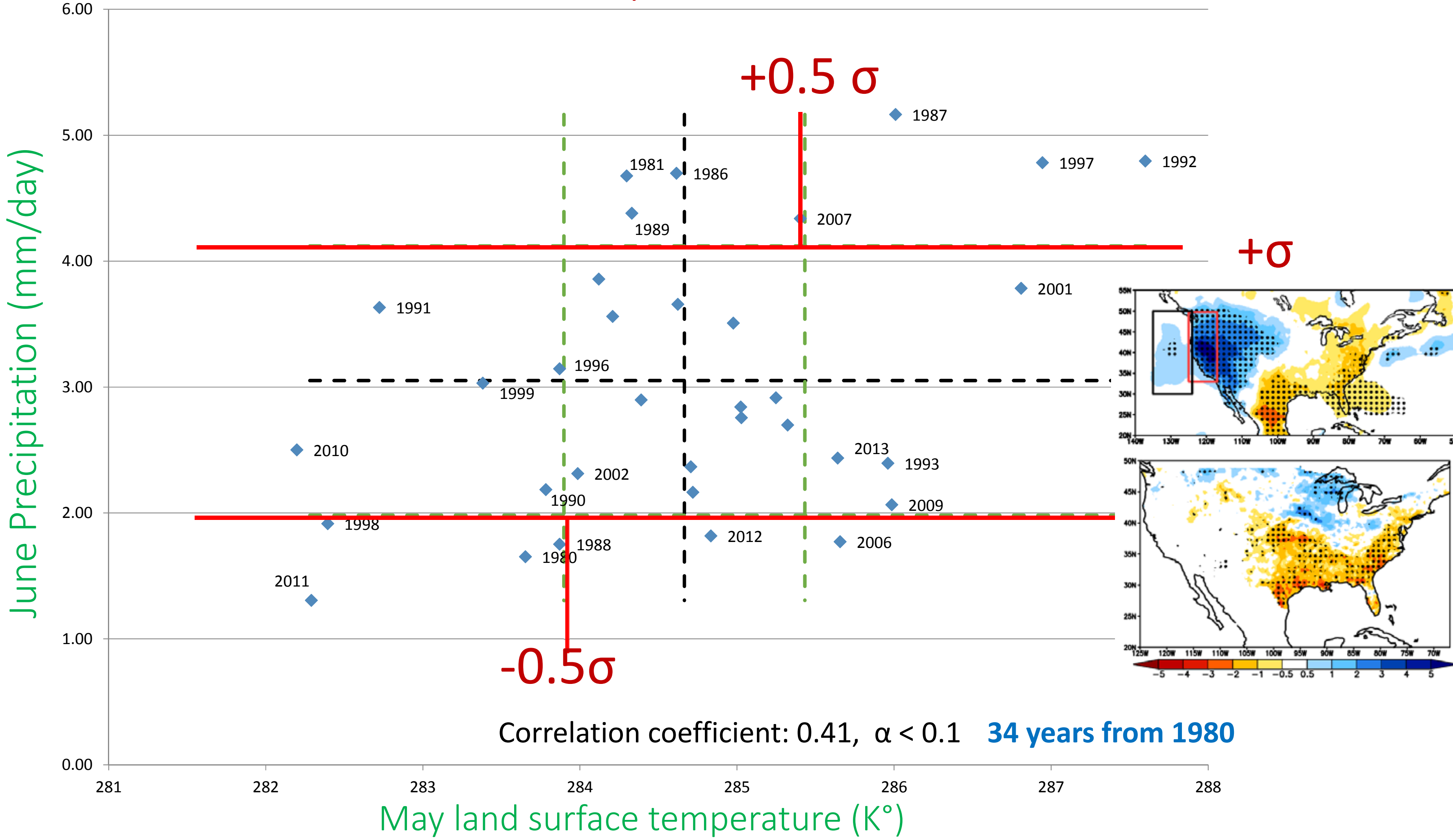
June 28, 2011



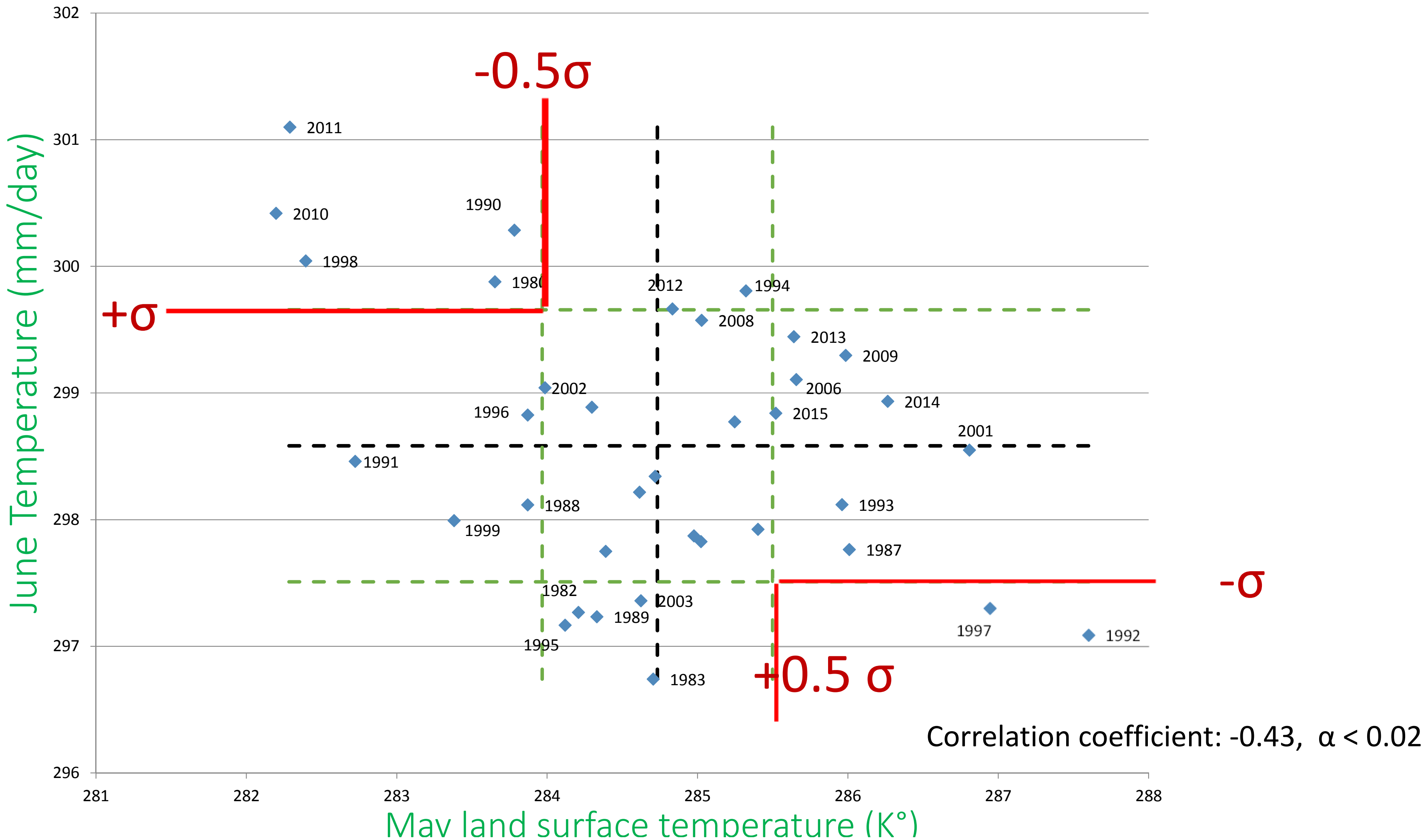
May 20, 2015



May land surface *temperature* (NWUS) vs June *Precipitation* (SGP)



May land surface *temperature* (NWUS) vs June *Temperature* (SGP)



3). North American Extreme Case Studies

3.1). 2011 Texas Drought Case

Environmental Research Letters

LETTER

Spring land temperature anomalies in northwestern US and the summer drought over Southern Plains and adjacent areas

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Keywords: land temperature, US drought and heat, regional climate model, southern great plains, sea surface temperature

Supplementary material for this article is available online

Abstract

Recurrent drought and associated heatwave episodes are important features of the US climate. Many studies have examined the connection between ocean surface temperature changes and conterminous US droughts. However, remote effects of large-scale land surface temperature variability, over shorter but still considerable distances, on US regional droughts have been largely ignored. The present study combines two types of evidence to address these effects: climate observations and model simulations.

Goal: *To understand whether this relationship is valid for the 2011 drought and heat case and how SST plays role in this drought.*

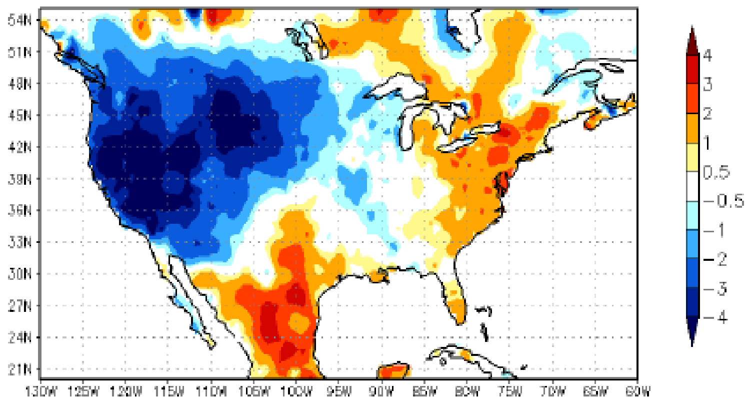
Experimental design:

The WRF-NMM/*SSiB* regional climate model (*RCM*)

The NCEP GSF coupled with the *SSiB* model

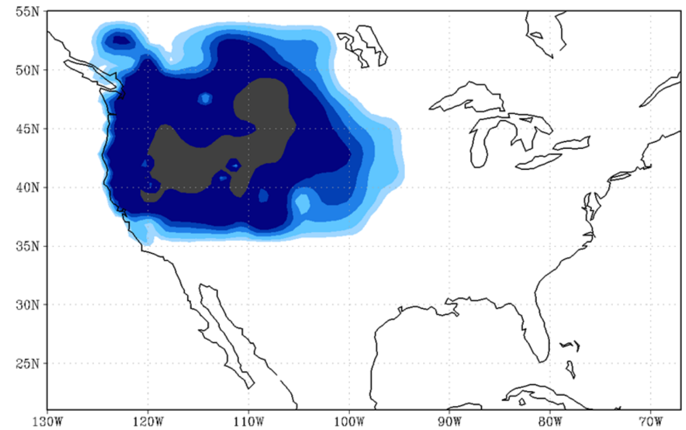
Case 1: Imposed initial subsurface temperature (SUBT) anomaly based on surface temperature differences between May 2011 and 9 warmest years

Observed

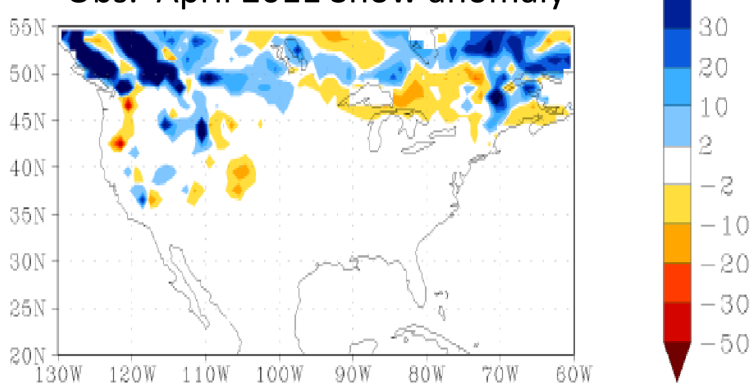


April 2011 snow water Equi. Anomaly

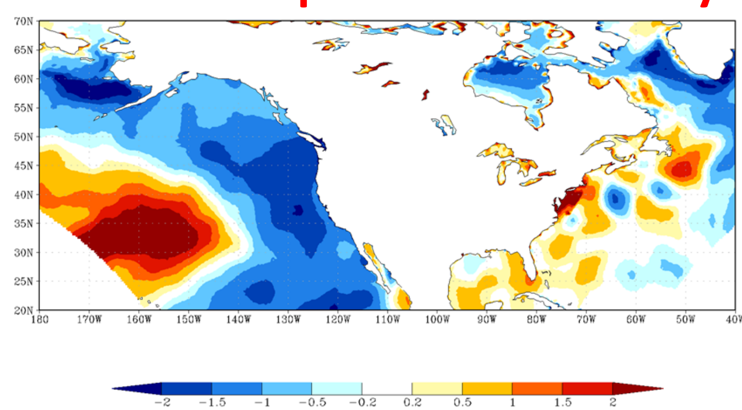
Case 1 Imposed Initial SUBT Condition at 1st step



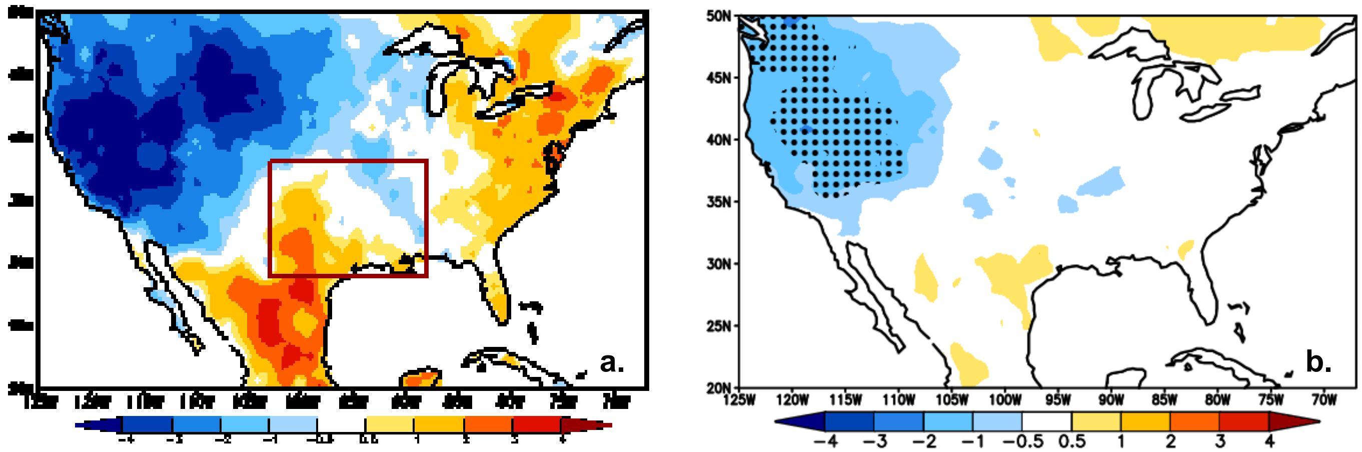
Obs. April 2011 Snow anomaly



Case 2 Imposed SST anomaly

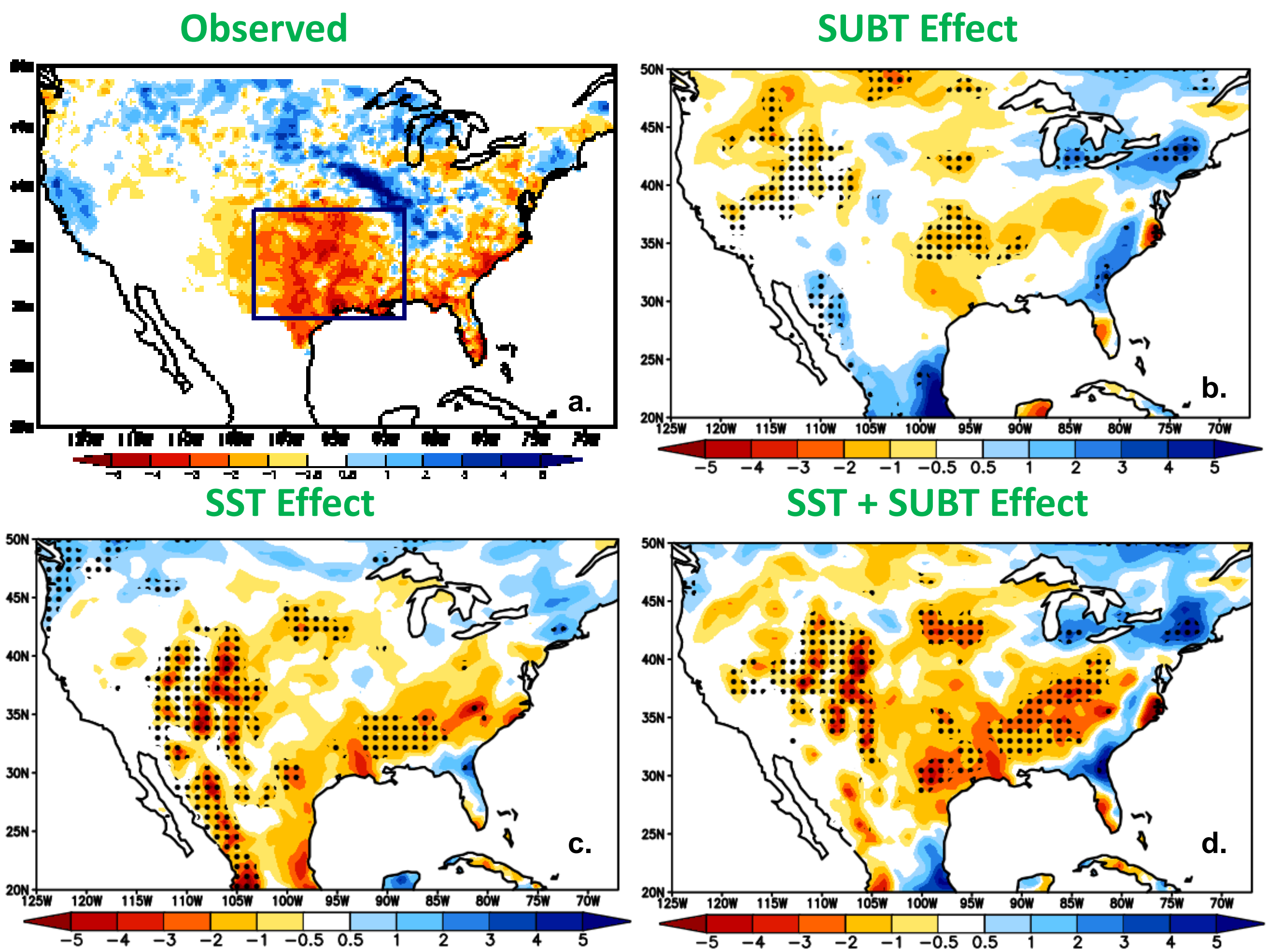


Observed/WRF simulated anomaly/difference of surface temperature (°K) for May. (**a.**) Observed; (**b.**) SUBT effect



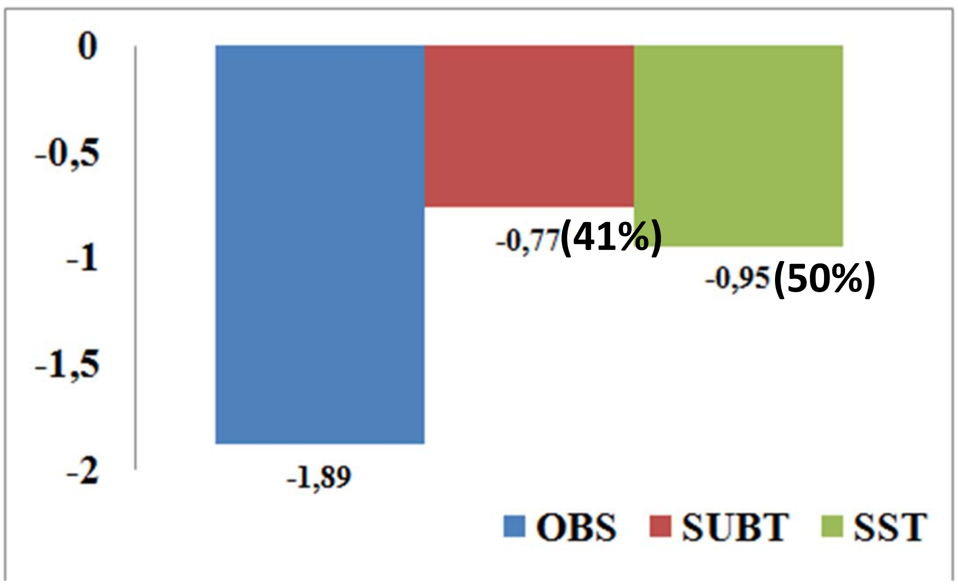
The dotted areas denote statistical significance at the α=0.01 level of t-test values.

Observed/WRF-NMM simulated anomaly/difference of June Precipitation (mm day^{-1})



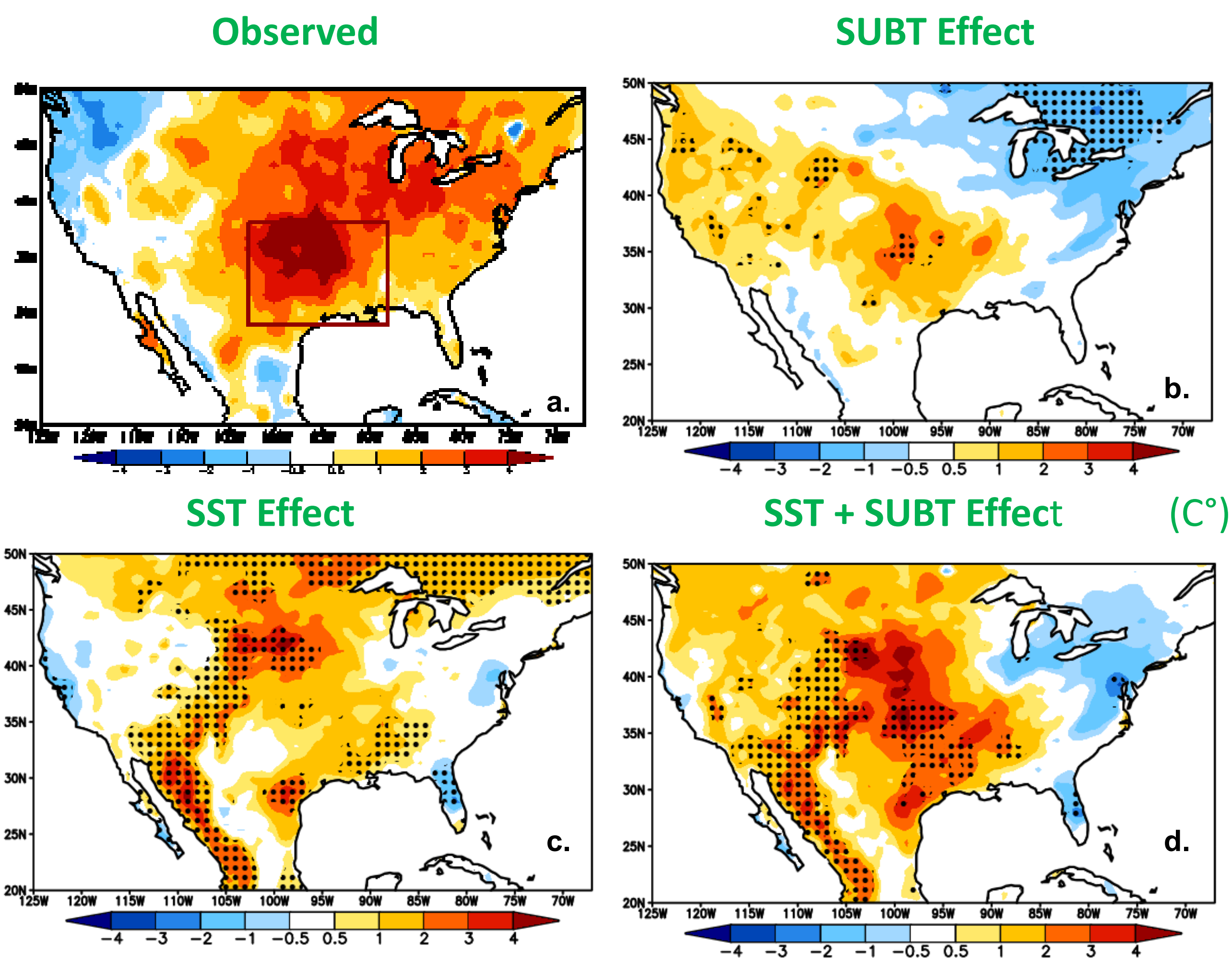
The dotted areas denote statistical significance at the α=0.01 level of t-test values.

Observed/WRF-Simulated June Precipitation anomaly/difference over Southern Great Planes

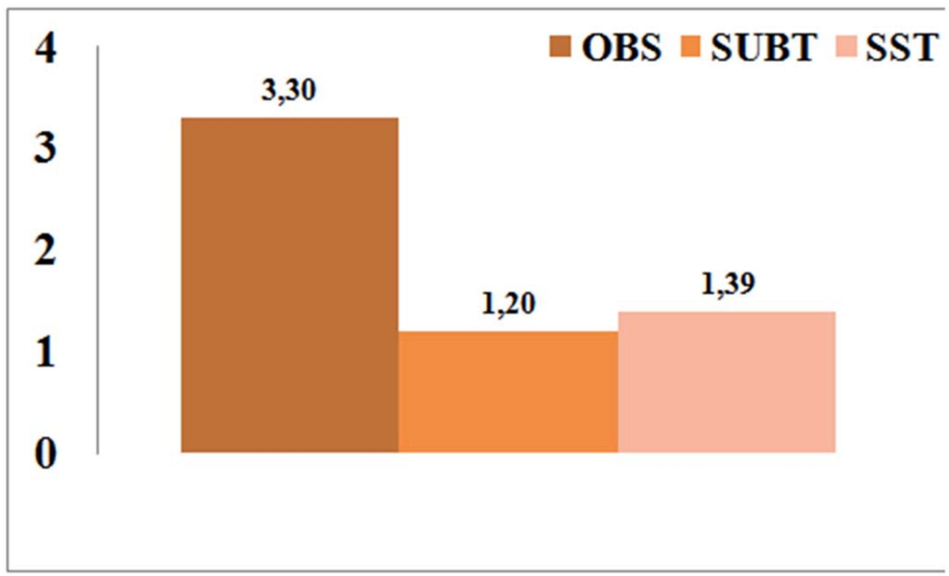


SUBT: Subsurface Temperature; SST: Sea Surface Temperature

Observed/WRF-NMM simulated anomaly/difference of June-July Temperature



Observed/WRF-Simulated June-July surface temperature anomaly/difference over Southern Great Planes



SUBT: Subsurface Temperature; SST: Sea Surface Temperature

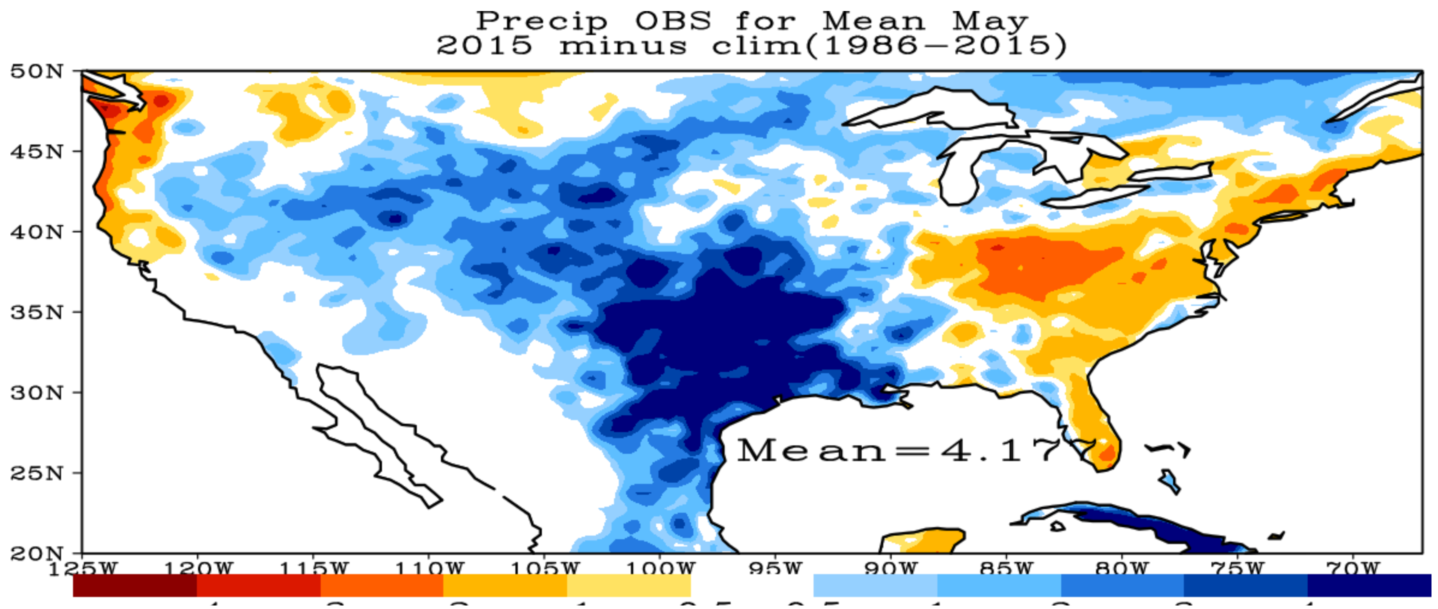
3.2). 2015 Texas Flood

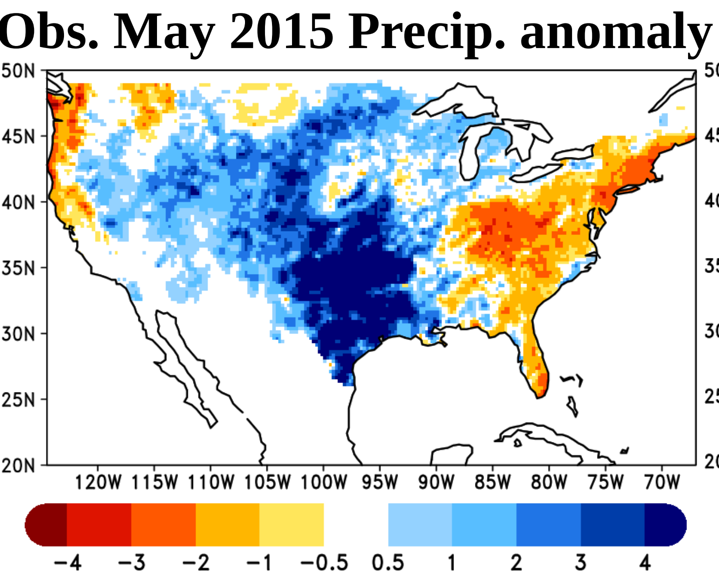
Goal: *To understand the cause of 2015 flood and possible mechanisms.*

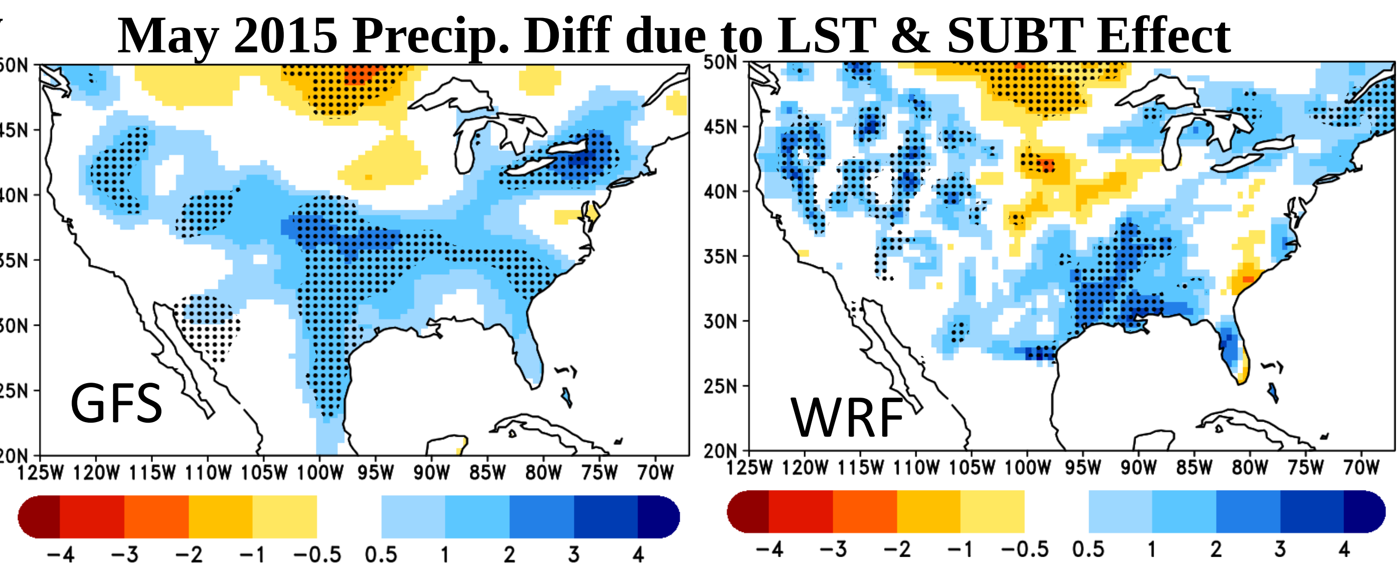
Experimental design:

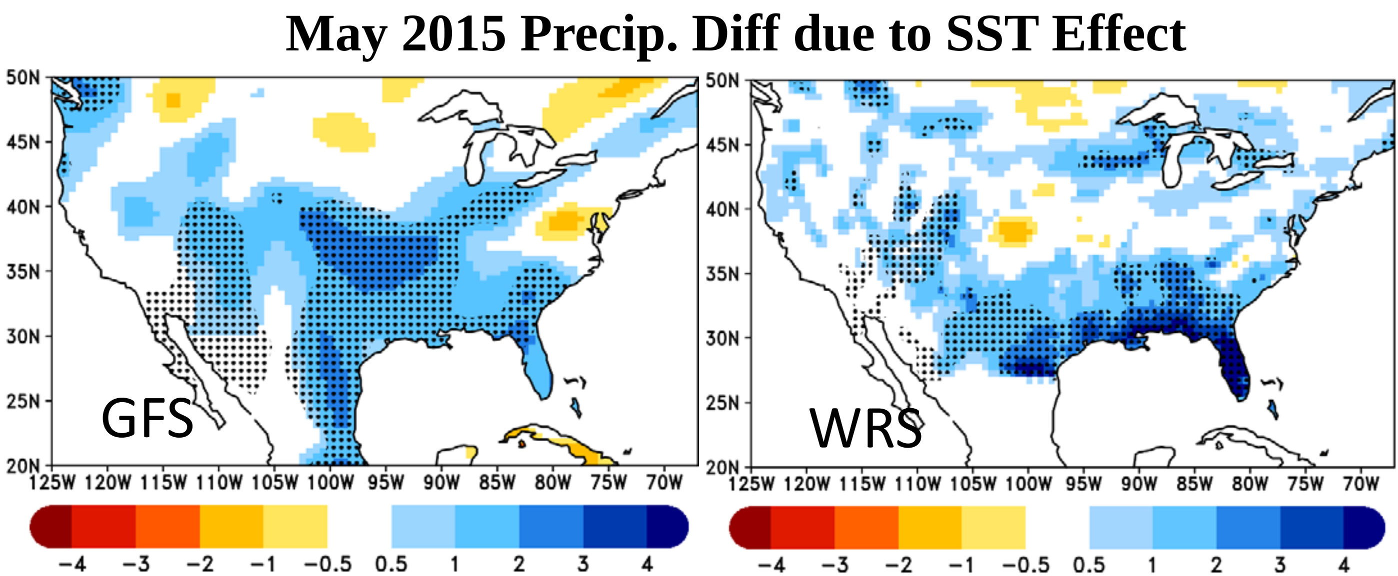
The WRF/*SSiB* regional climate model (*RCM*)

The NCEP GSF coupled with the *SSiB* model

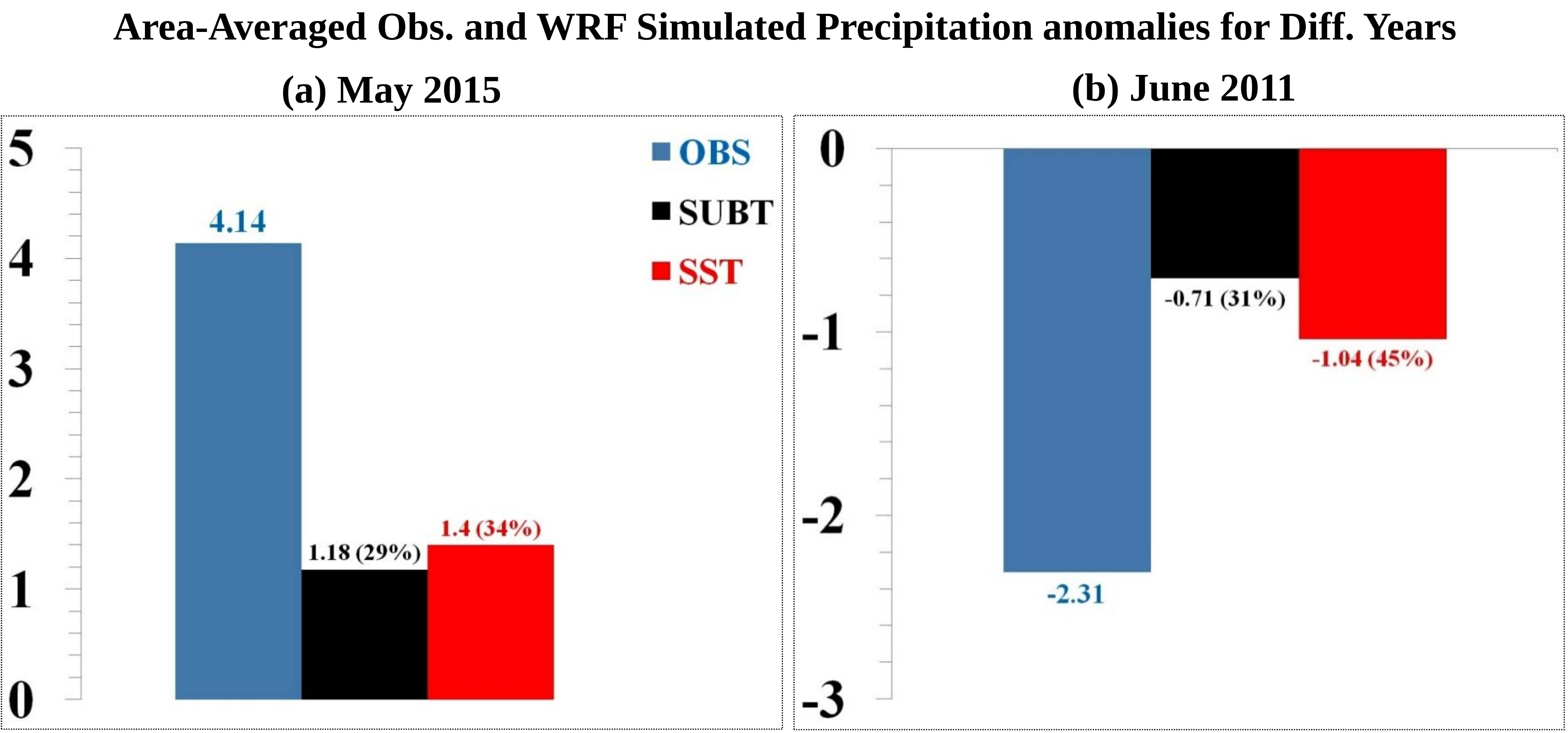








Observed and Simulated May 2015 Precipitation Anomalies over United States. **(a)** Observed May precipitation difference between 2015 and the benchmark; **(b)** NCEP-GCM-simulated May precipitation difference between Case 2015 and Case noSUBT_NA (i.e., LST and SUBT effects); **(c)** Same as **(b)** but for WRF; **(d)** NCEP-GCM-simulated May precipitation difference between Case 2015 and Case noSST_NA (i.e., SST effect); **(e)** same as **(d)** but for WRF. Units: mm day^{-1}. The dotted areas denote statistical significance at the α <0.1 level of t-test values.



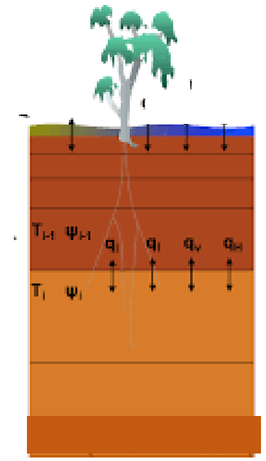
Observed and simulated precipitation anomalies over United States. (a) Area-averaged observed and WRF simulated (LST & SUBT and SST effects) May 2015 precipitation anomalies over SGP (88–103°W and 29–38 °N). **(b)** Area-averaged observed and WRF simulated (LST & SUBT and SST effects) June 2011 precipitation deficit over SGP. Units: Precipitation: mm day^{-1}.

5). Issues

Soil Model

Subsurface data over high elevation

Force Restore method for soil temperature



Energy balance at the ground surface

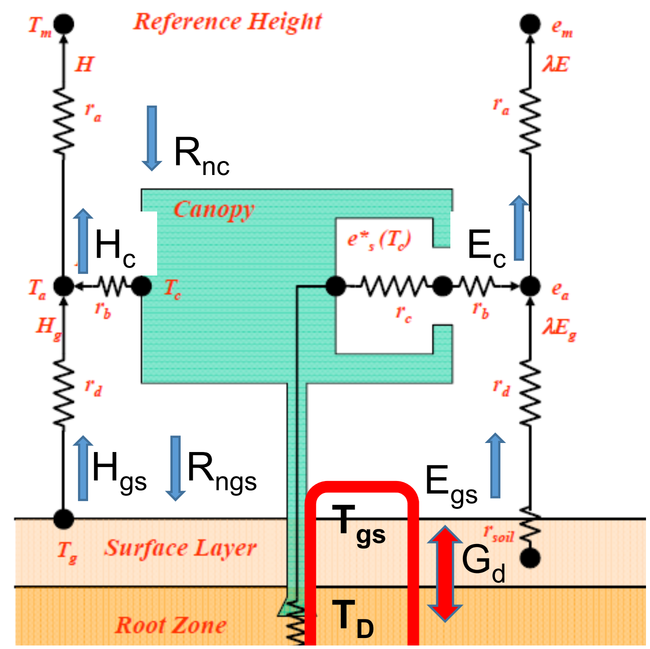
$$C_{gs}\frac{\partial T_{gs}}{\partial t}=2\sqrt{\pi}(R_{ngs}-H_{gs}-\lambda E_{gs})-\frac{2\pi C_{gs}}{\tau}(T_{gs}-T_{d})$$

Energy Balance term   Restore term G_D

Deep soil temperature equation:

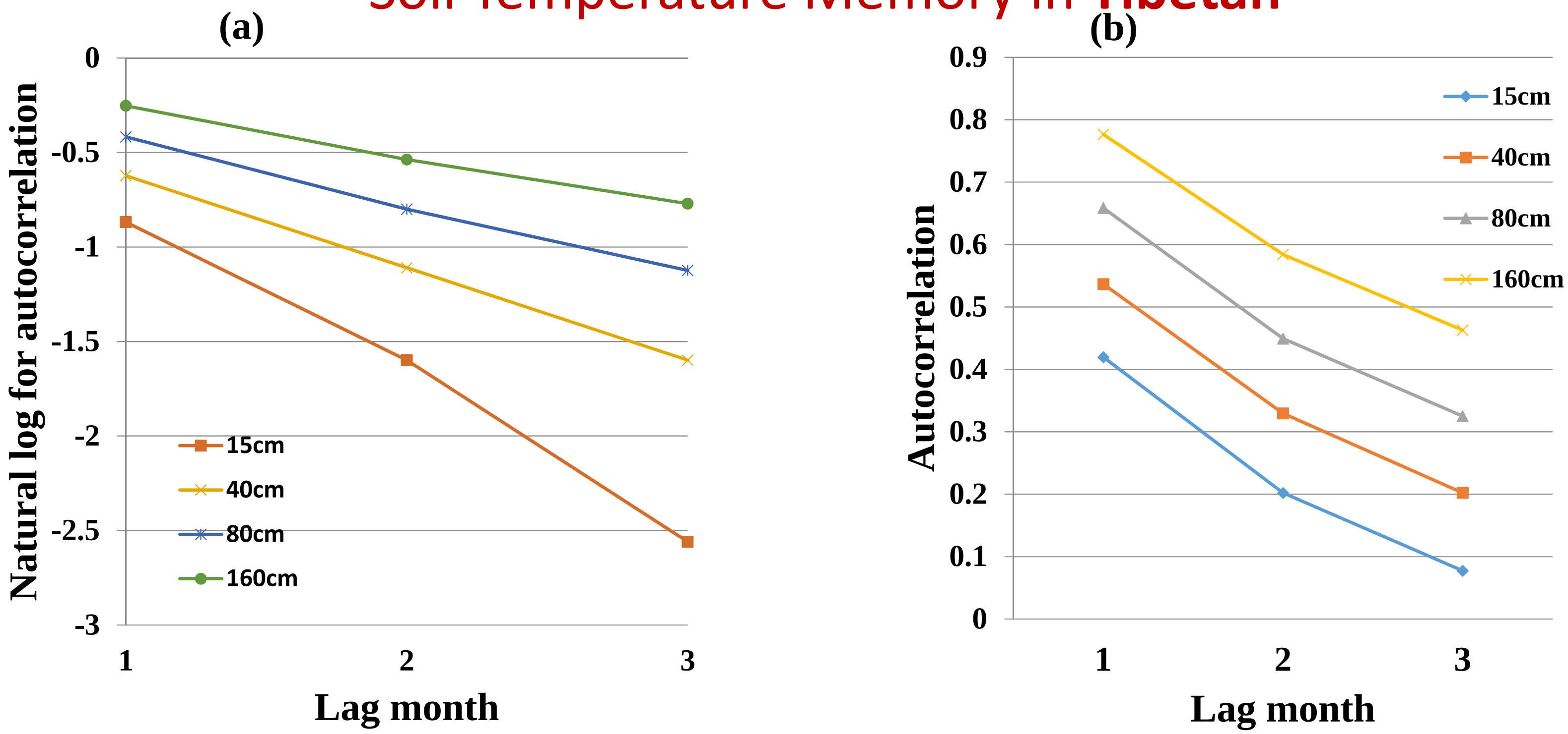
$$C_{d}\frac{\partial T_{d}}{\partial t}=G_{D}$$

where the τ is the period heating (1day), G_D is heat from the surface reservoir to the subsurface, C_{gs} and C_d take into account the depth of heat penetration for diurnal and annual cycle, respectively.



Bhumralkar, 1975; Blackkadar, 1976; DearDorff, 1978; Sellers et al. (1986); Dickinson (1988); Xue et al. (1996)

Soil Temperature Memory in **Tibetan**

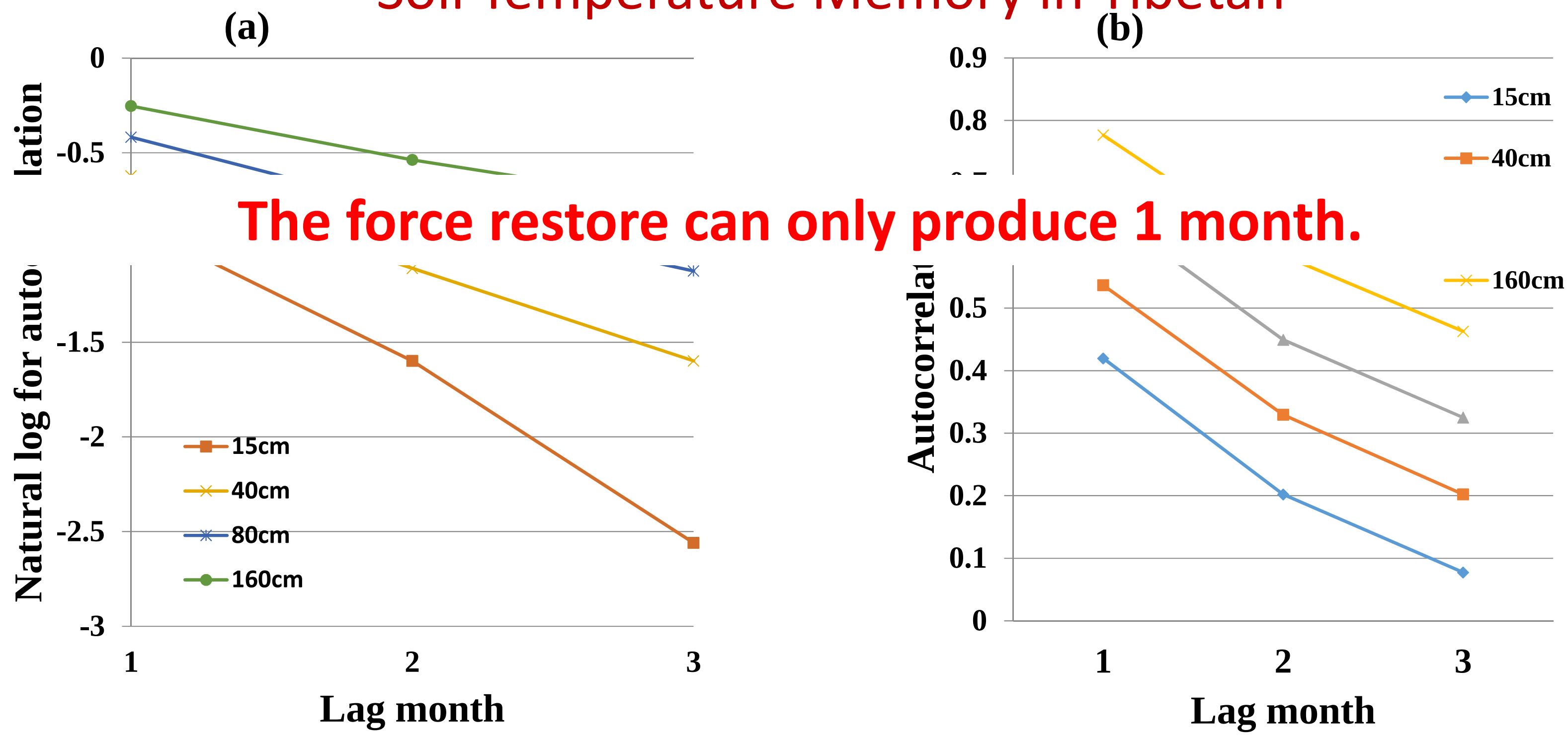


Relationship of (**a**) ln[autocorrelation of soil temperature] and (**b**) autocorrelation vs the time lag, for various thicknesses of soil layers. For convenience, the persistence, which is based on the slope of the lines on the left panel, is listed in the table. They are calculated based on the method described in Entin et al. (2001) and Hu and Feng (2004).

	Persistence
15cm	**1.18**
40cm	**2.05**
80cm	**2.83**
160cm	**3.86**

Soil Temperature Memory in Tibetan

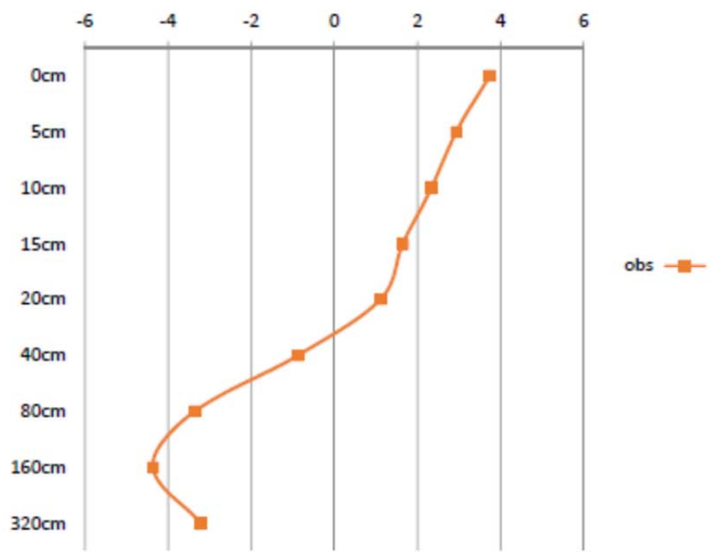
The force restore can only produce 1 month.



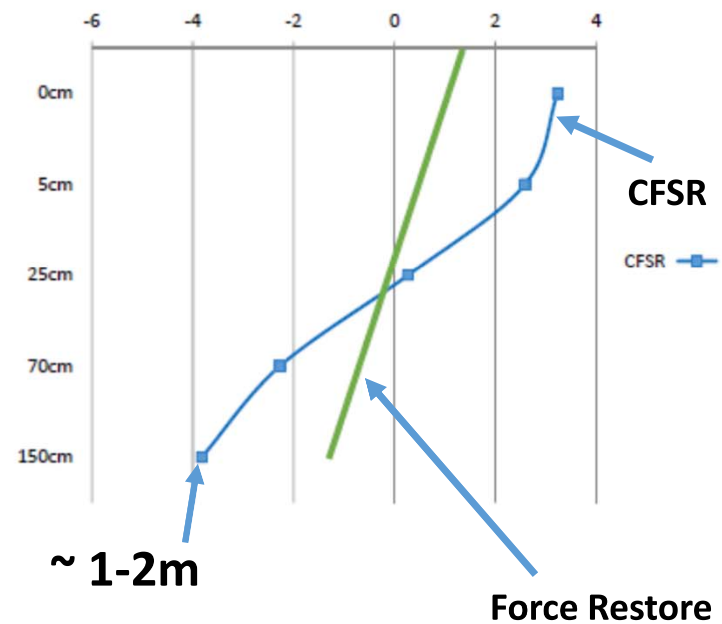
<u>FIG. S1</u>. Relationship of (**a**) ln[autocorrelation of soil temperature] and (**b**) autocorrelation vs the time lag, for various thicknesses of soil layers. For convenience, the persistence, which is based on the slope of the lines on the left panel, is listed in the table. They are calculated based on the method described in Entin et al. (2001) and Hu and Feng (2004).

	Persistence
15cm	**1.18**
40cm	**2.05**
80cm	**2.83**
160cm	**3.86**

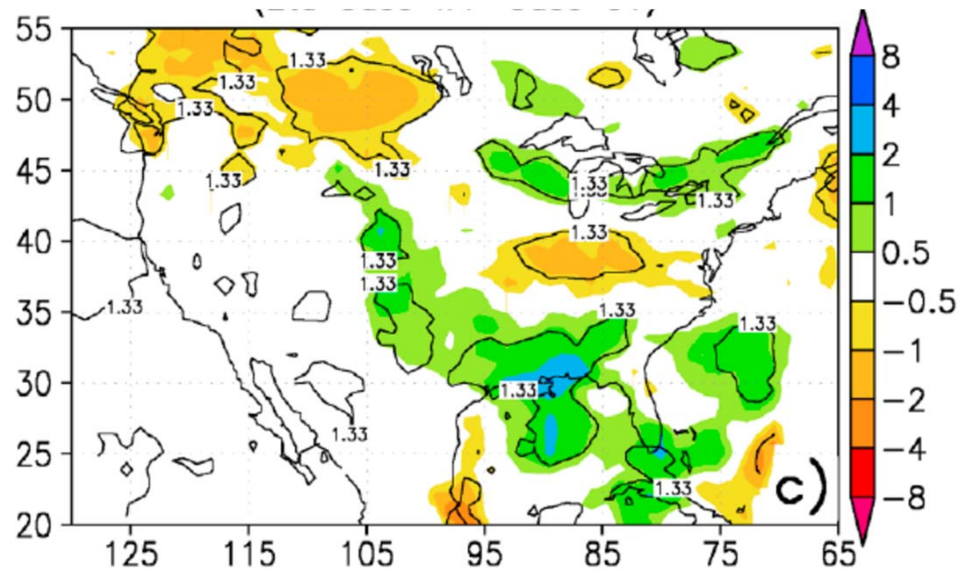
Observed Soil T Profile



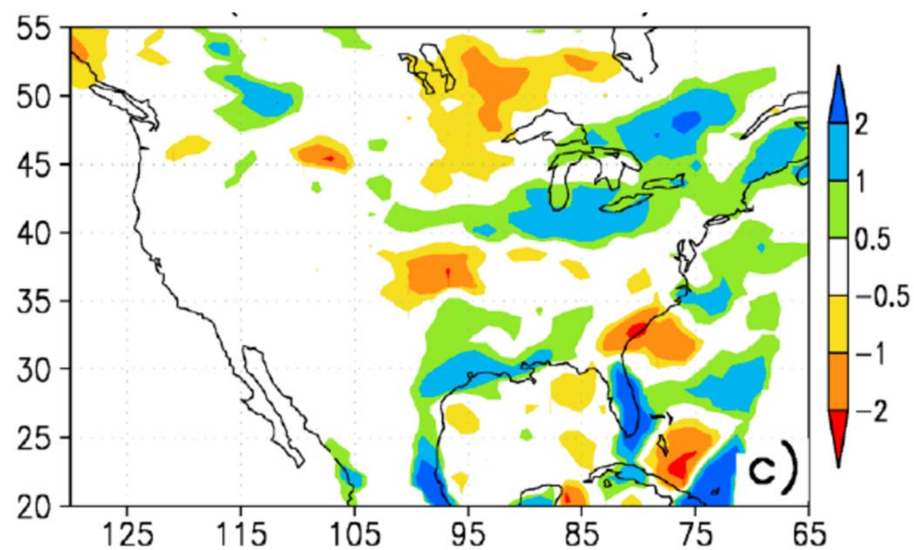
Reanalysis and Force Restore T Profile



May soil temperature Profile over the Tibetan Plateau



RCM Downscaling from GCM SUBT Effect

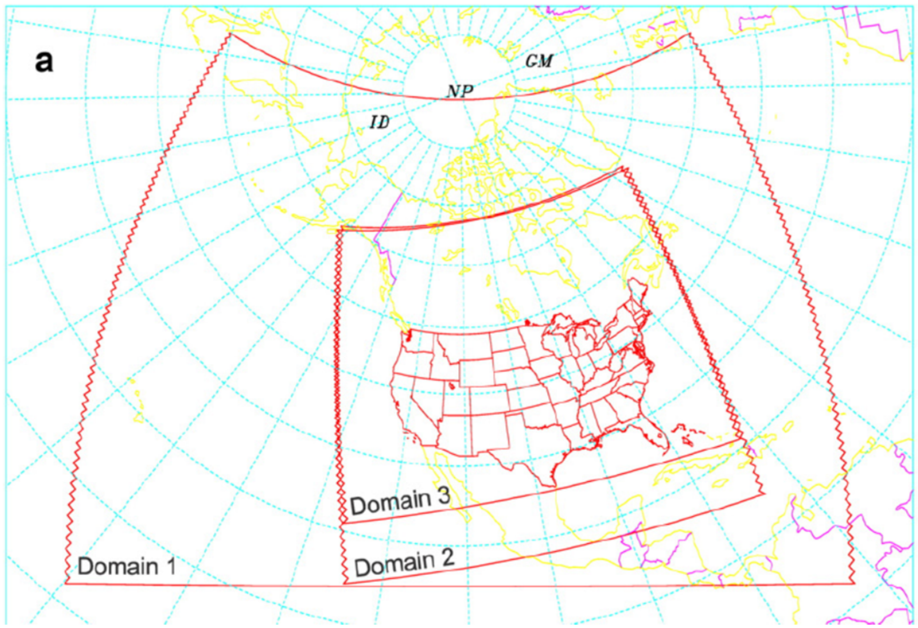


RCM Downscaling from **the same reanalysis lateral boundary condition**

Xue et al., 2012

The RCM is designed by its very nature to preserve the large scale features that imposed from the lateral boundary conditions (LBC) but to produce fine scales feature that are not exist in the LBC. Using the same LBC for both the control run and anomaly runs would hamper the development of the perturbation produced in the anomaly run because the imposed LBC tries to reinstall the climate in the control run.

Xue, Janjic, Dudhia, Ratko, De Sales, 2014. AR



Summary

1). SST effects on the drought/flood have been investigated for several decades but land surface temperature effect is largely ignored. The findings relating LST/SUBT anomalies to downstream extreme events can serve as a new approach – complementing SST and snow anomalies – in understanding and predicting high-impact phenomena in N. America and East Asian regions. Its effect is compatible to SST's and is the 1st order forcing in the drought.

2). The LST downstream effects in N. America are associated with a large-scale atmospheric stationary wave extending eastward from the LST anomaly region. The climate feature there favors a southward steering flow, helping the anomalous vorticity to extend to the south.

3). It is challenging to apply the SUBT effects for intraseasonal-seasonal prediction. The most important issue is to reproduce the observed LST anomaly over upstream mountain areas. Further model improvement and SUBT data collection are imperative.

4). This research is still in the incipient stage. More studies with different models and data sets, different approaches, and different cases and regions are necessary to understand its effects, mechanisms and initial LST anomaly causes, and make the LST/SUBT anomaly becomes a useful tool for addressing drought and flood prediction issues