The Tibetan Plateau-Rocky Mountains Circumglobal (TRC) Wave Train and S2S Precipitation Prediction Regionally and Globally: Results from the GEWEX/LS4P Project

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Q. Tang, D. Neelin, W. K.-M. Lau, LS4P Team.

The Weeks3-4/S2S Webinar July 1 2024

Impact of Initialized Land Temperature and Snowpack on Sub-Seasonal to Seasonal Prediction (LS4P)

Inception in the 2018 GEWEX Science Conference
Alberta, Canada, 6–11 May 2018

Co-Chairs: Yongkang Xue, Aaron Boones, Tandong Yao

GEWEX/LS4P Project Goals:

- ***What is the impact of the initialization of large-scale land surface temperature/subsurface temperature (LST/SUBT) in high mountains in climate models on the S2S prediction over different regions?***
- ***What is the relative role and uncertainties in these land processes versus in SST in S2S prediction?***

Xue et al., (2021, GMD)

Major LS4P Participants

21 ESM Groups;
9 RCM Groups;
7 Data Groups;
1 Data Base

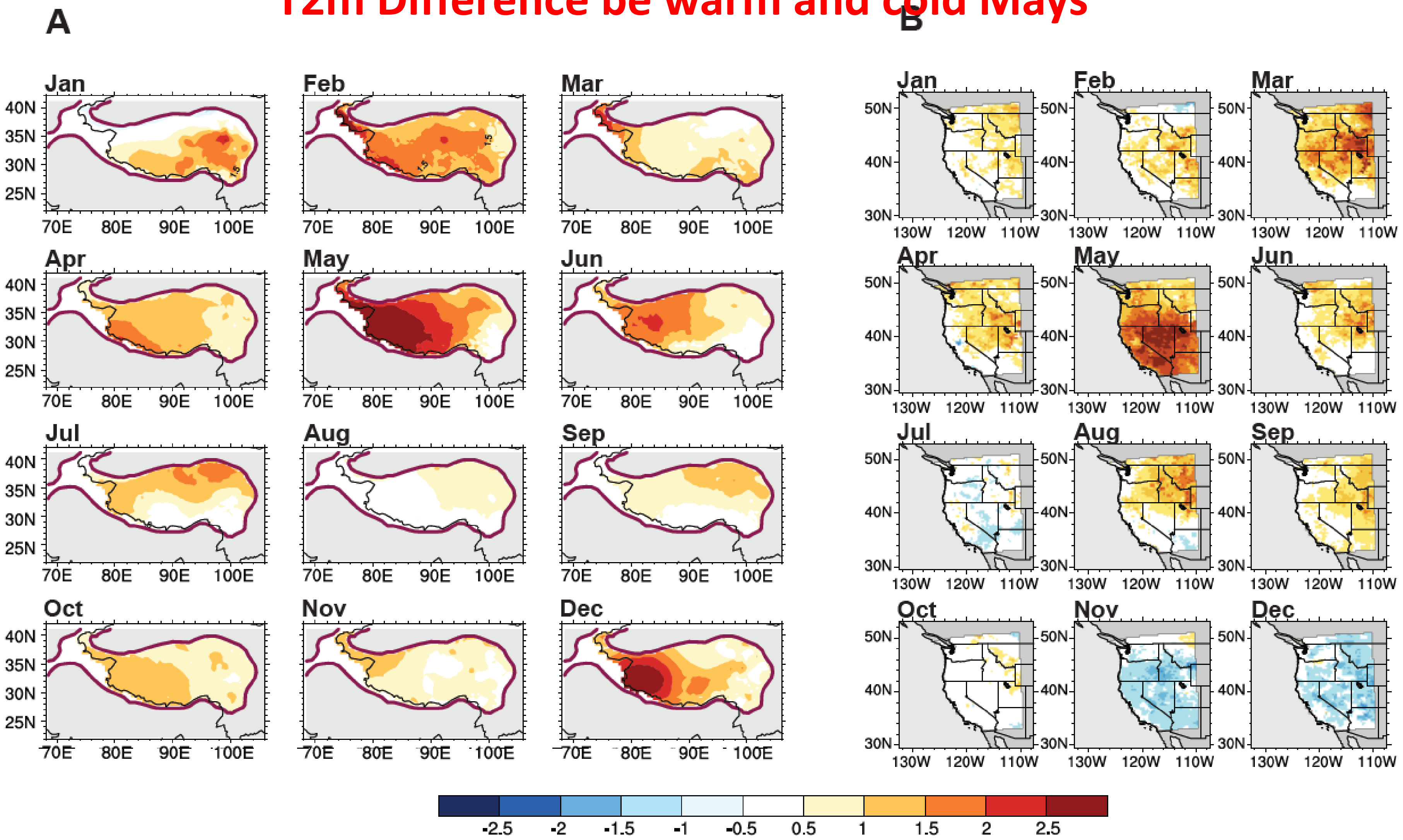
Five workshops (1998, 1999, 2022, 2023 AGU, 1999 Nanjing University)

WECS, Nepal

LS4P Website: http://ls4p.geog.ucla.edu

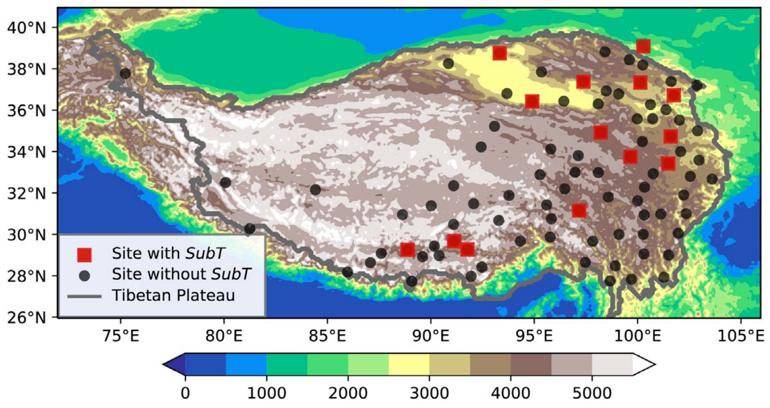
Observational Evidence

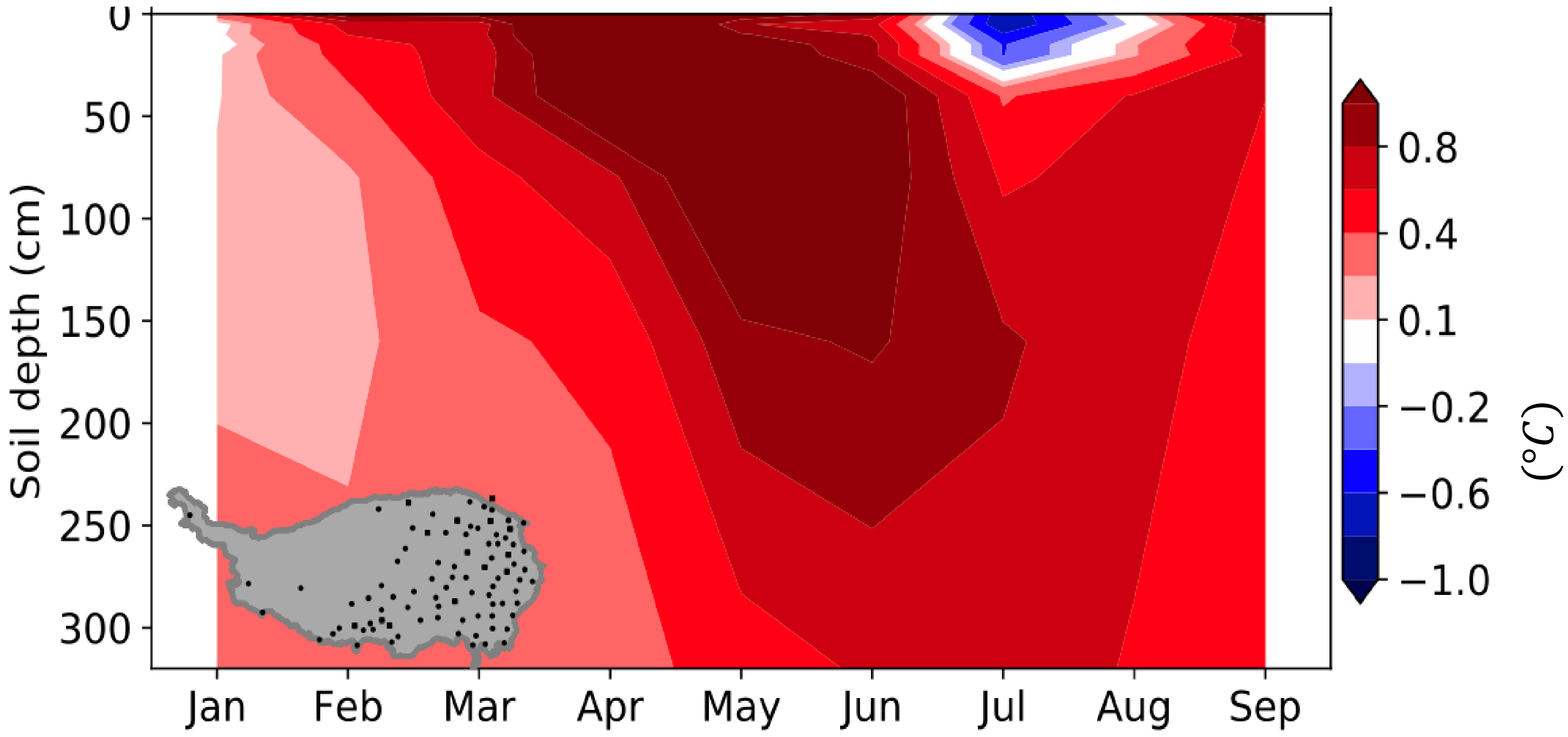
T2m Difference be warm and cold Mays



Observed monthly T2m difference between warm and cold years (°C). (a) over the TP based on CMA data; (b) over the western US (WUS) based on NARR data. Note: Years are selected based on TP and WUS May T2m anomalies, using a threshold of 0.5 standard deviation during the period 1981-2010. The years are applied for all months.

Observed difference of surface & subsurface temperature and snow *between year with warmest and coldest springs*

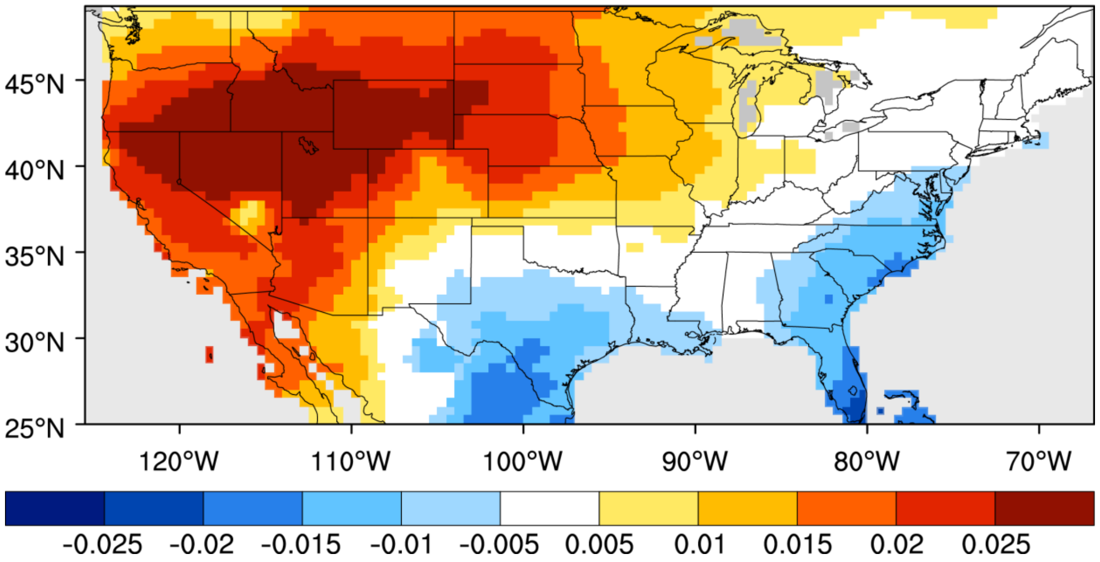




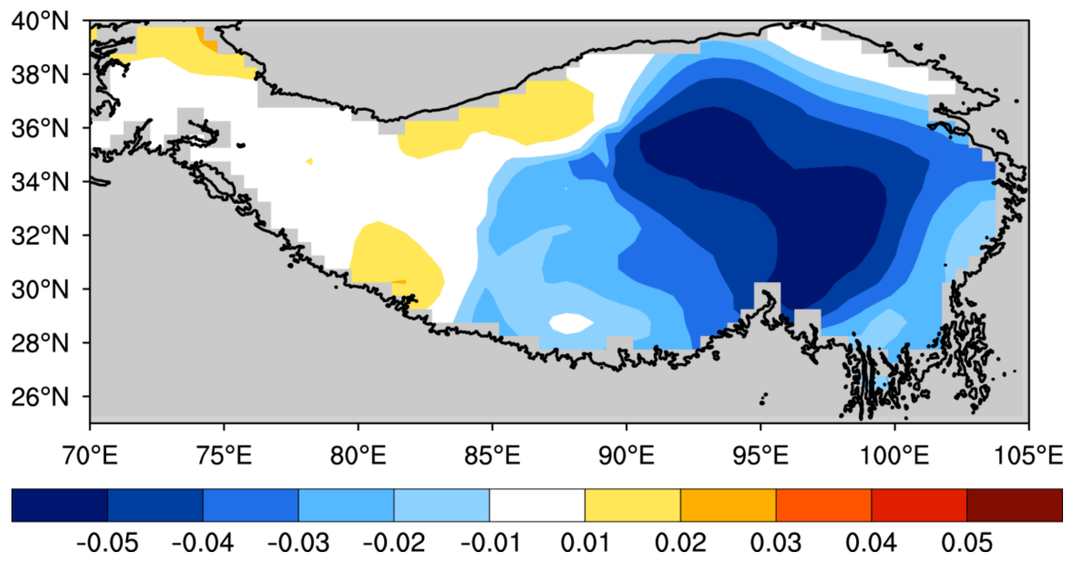
Liu et al., 2020, JGR

Cold: 1982, 1983, 1986, 1990, 2001
Warm: 1999, 2004, 2007, 2009, 2010, 2015

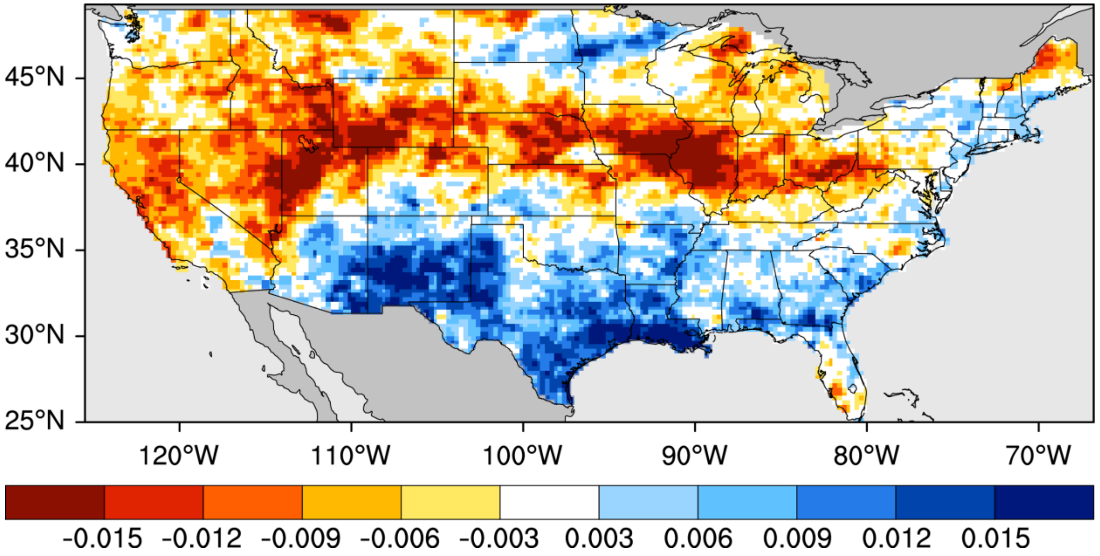
(a) First May 2-m temperature MCA Mode

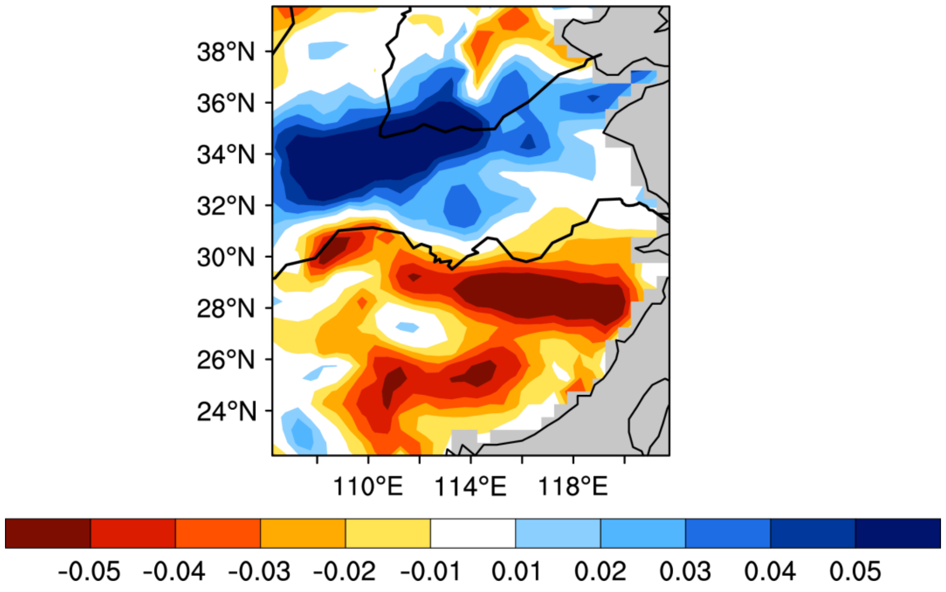


(a) First May 2-m temperature MCA Mode



(b) First June Precipitation MCA Mode

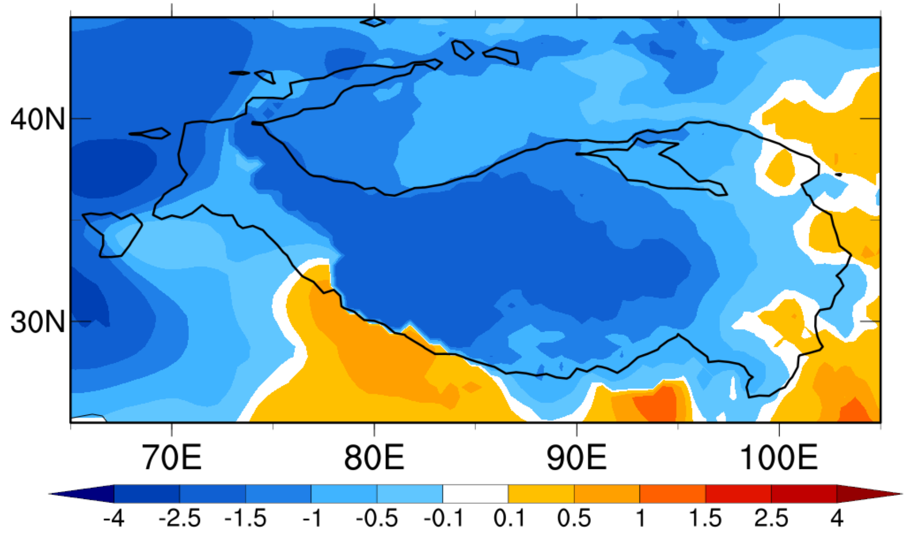


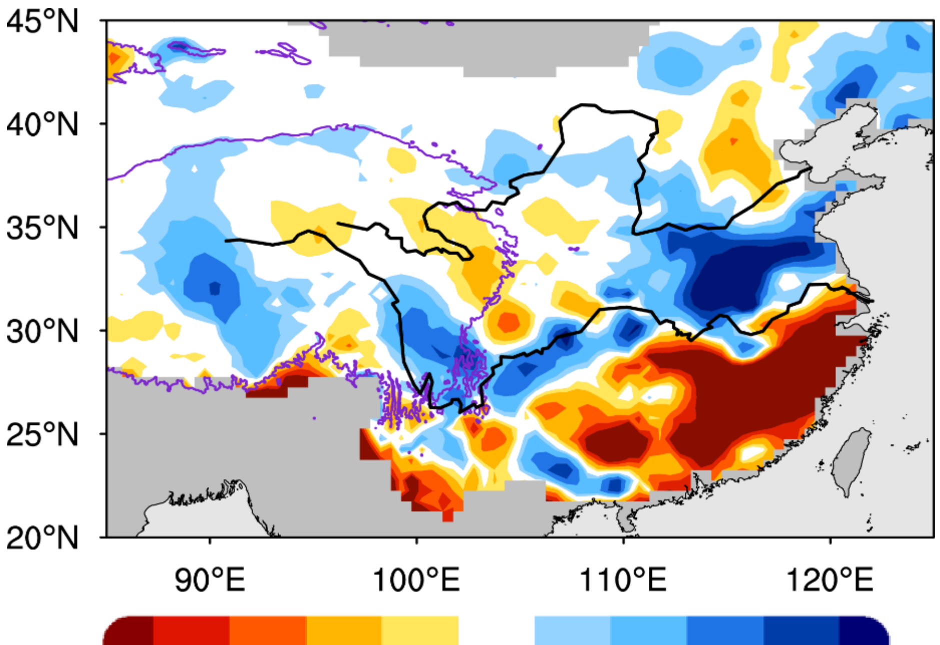


First MCA Mode (May 2-m Temperature vis June Precipitation)

MCA: Maximum Covariance Analysis (Xue et al., 2018)

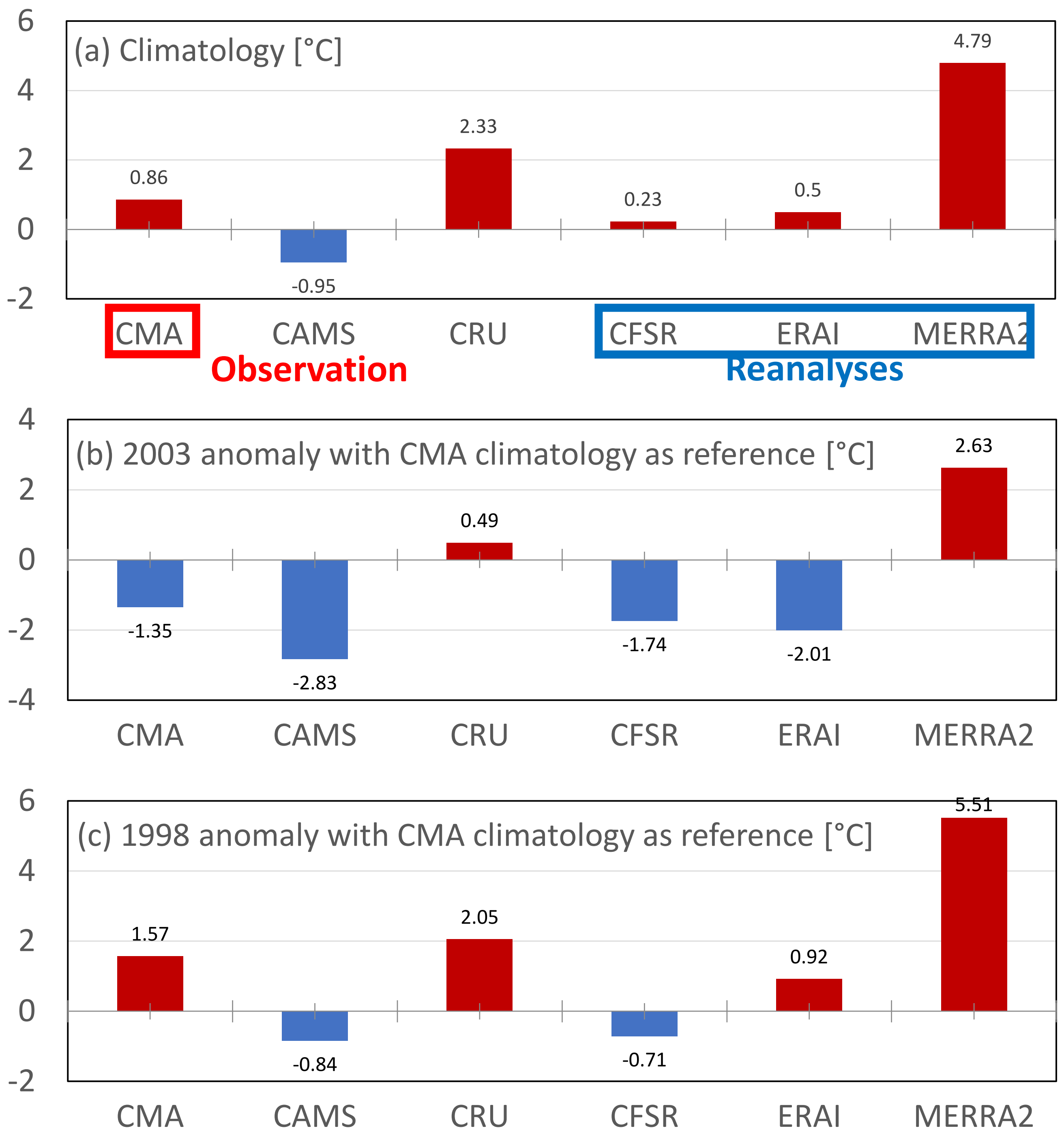
Phase I: Tibetan Plateau LST/SUBT Effect is the focus; June 2003 is the first case.

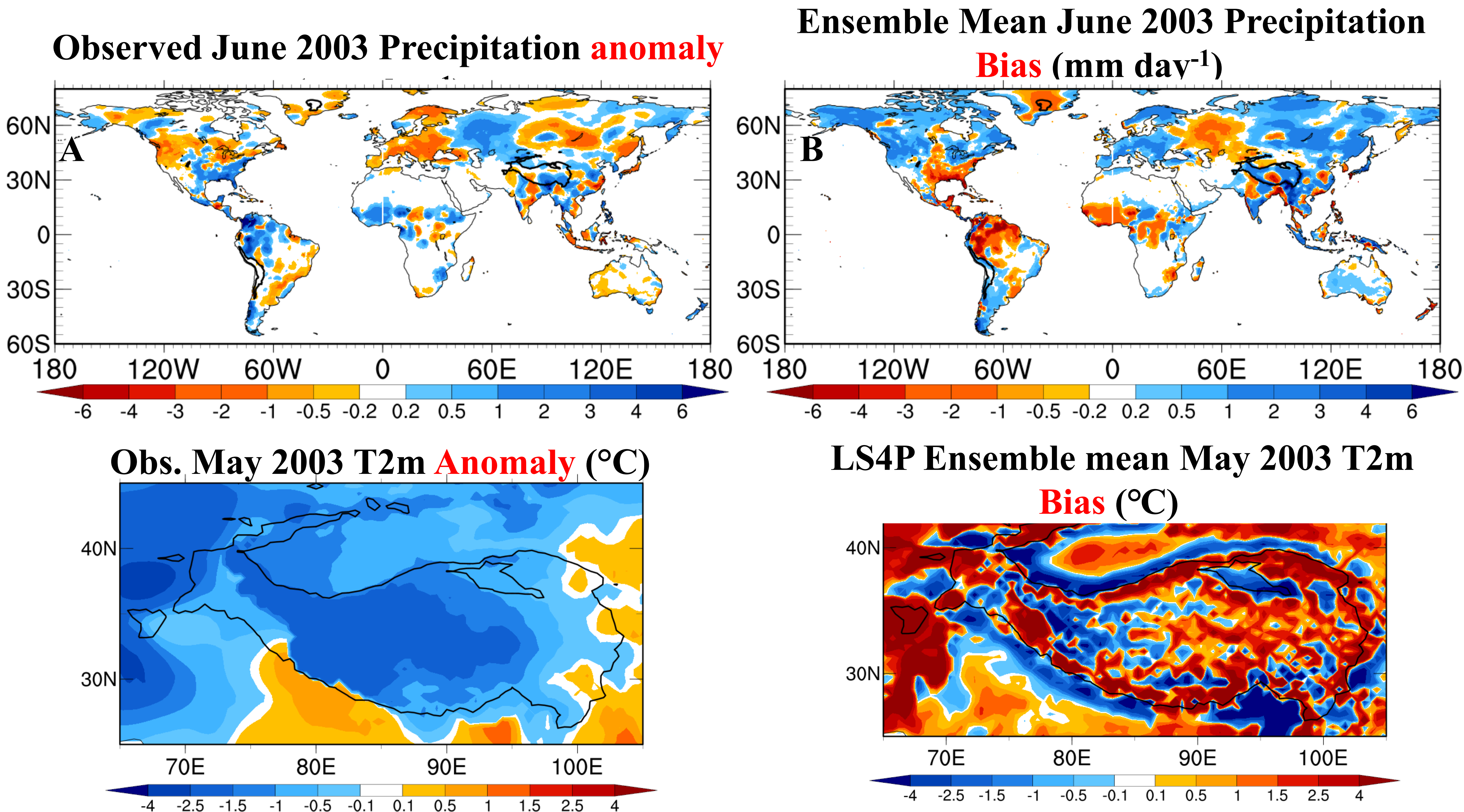




Xue et al., 2018, JGR

Observed 2 meter May temperature of Tibetan Plateau over 4000 m





Observed June 2003 Precipitation anomaly
A
Ensemble Mean June 2003 Precipitation
Bias (mm day-1)
B
60N
30N
0
30S
60S
180
120W
60W
0
60E
120E
180
-6 -4 -3 -2 -1 -0.5 -0.2 0.2 0.5 1 2 3 4 6
Obs. May 2003 T2m Anomaly (°C)
LS4P Ensemble mean May 2003 T2m
Bias (°C)
40N
30N
70E
80E
90E
100E
-4 -2.5 -1.5 -1 -0.5 -0.1 0.1 0.5 1 1.5 2.5 4

Development of Initialization Methodology

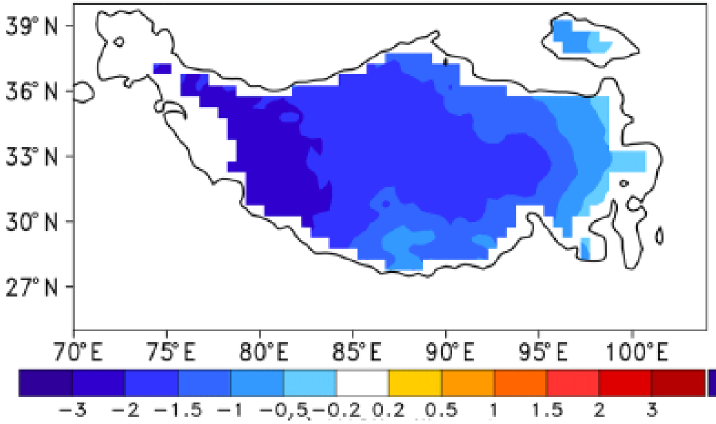
Principles Consideration: (1) Model bias; (2) Observed Anomalies; (3) Tuning parameter

Applying the mask, $\tilde{T}_0(i,j)$, will be defined as follows:

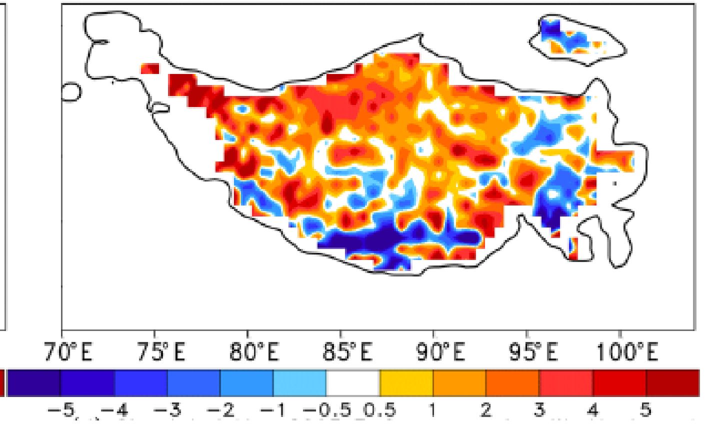
$$\tilde{T}_0(i,j) = T_0(i,j) + \Delta T_{\text{mask}}(i,j) = T_0(i,j) + \left[-n \times T_{\text{obs anomaly}}(i,j) - T_{\text{bias}}(i,j)\right],$$
$$\text{when } \bar{T}_{\text{obs anomaly}} \times \bar{T}_{\text{bias}} \geq 0, \quad (1a)$$

Xue et al. (2021, GMD)

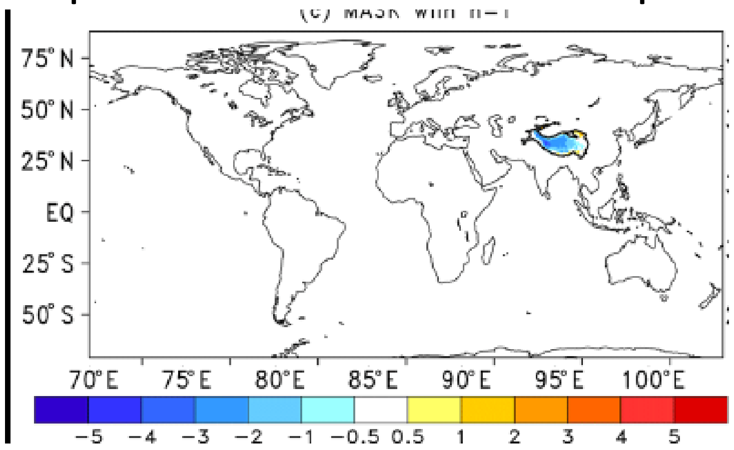
Observed May T2m Anomaly



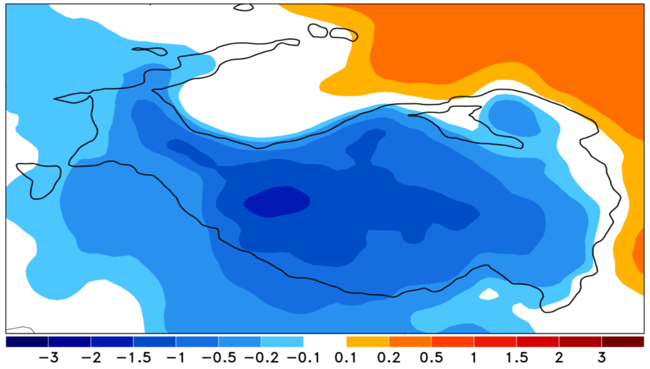
Simulated May T2m Bias



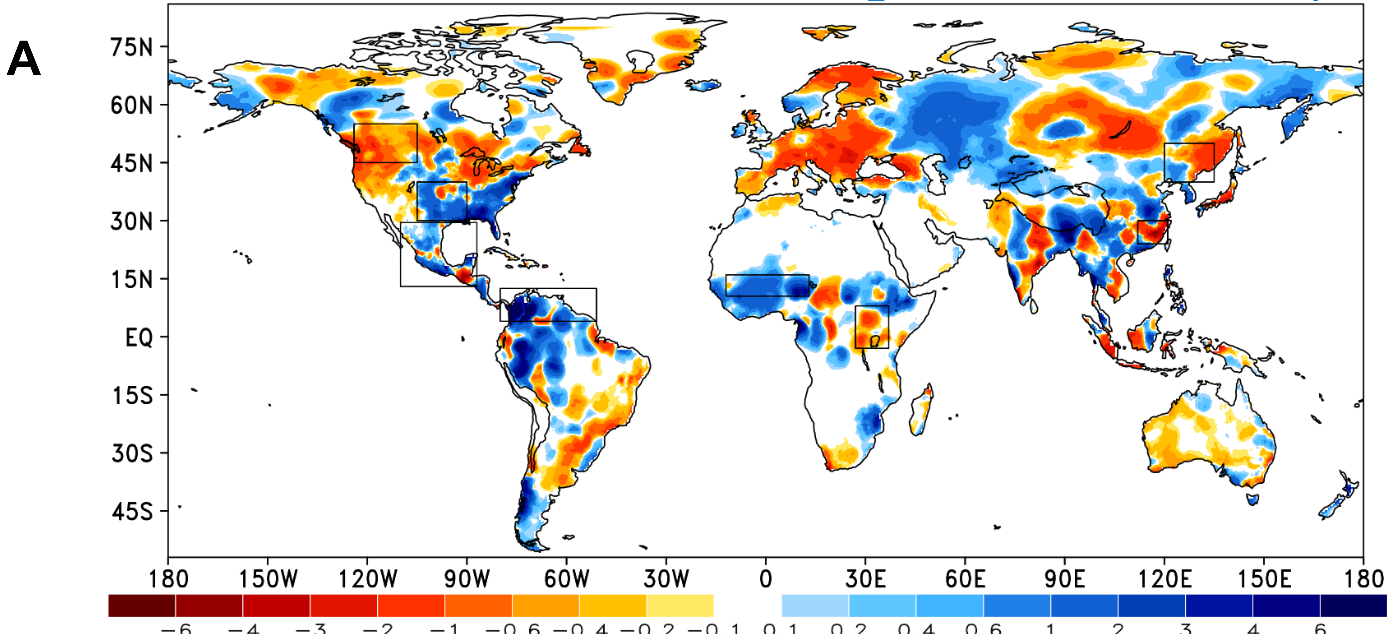
Imposed Mask at 1st time step



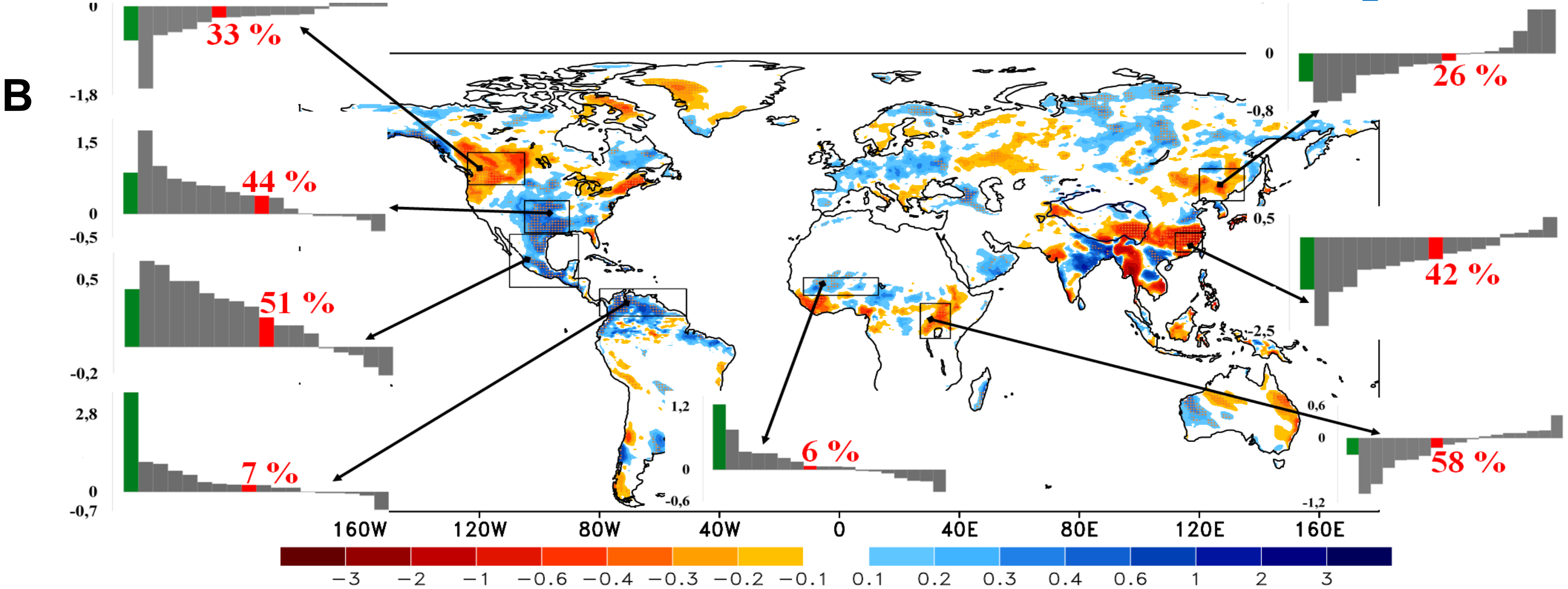
Simulated May T-2m difference after imposing mask for initial condition



Observed June 2003 Precipitation Anomaly

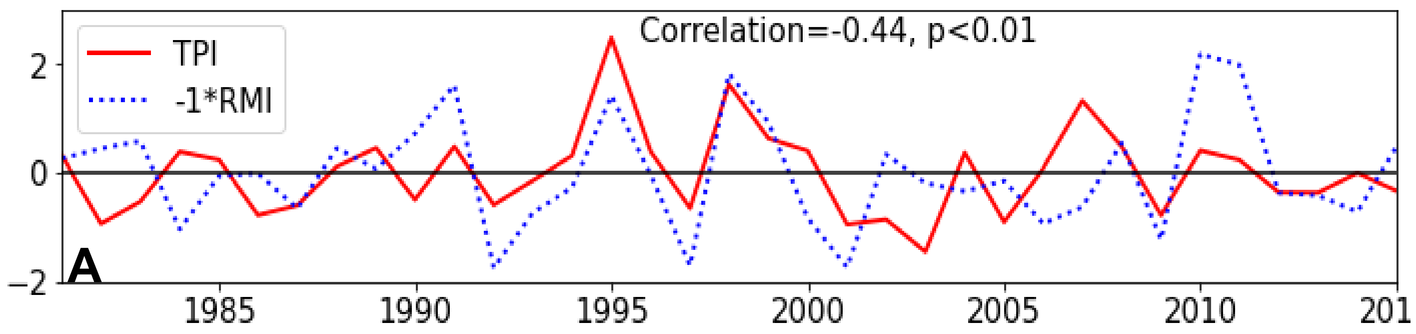


Simulated TP LST/SUBT effect on June 2003 Precipitation

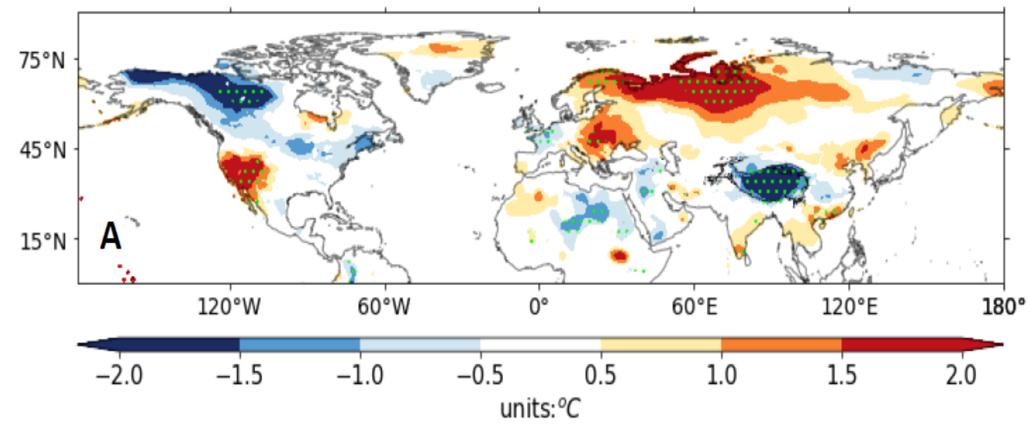


Identify 8 hotspot regions

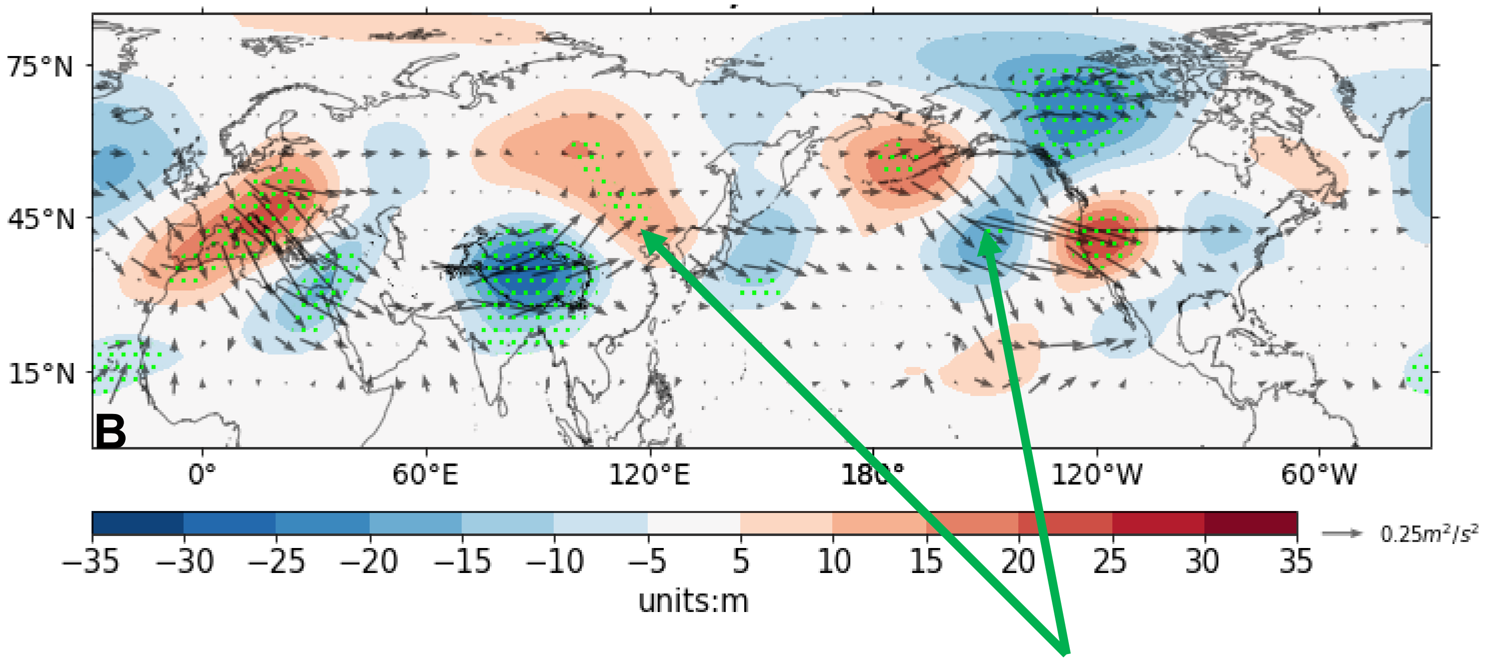
Observed May TPI and RMI time series from 1981-2015



Observed difference based on the five coldest and the five warmest Mays over the Tibetan Plateau



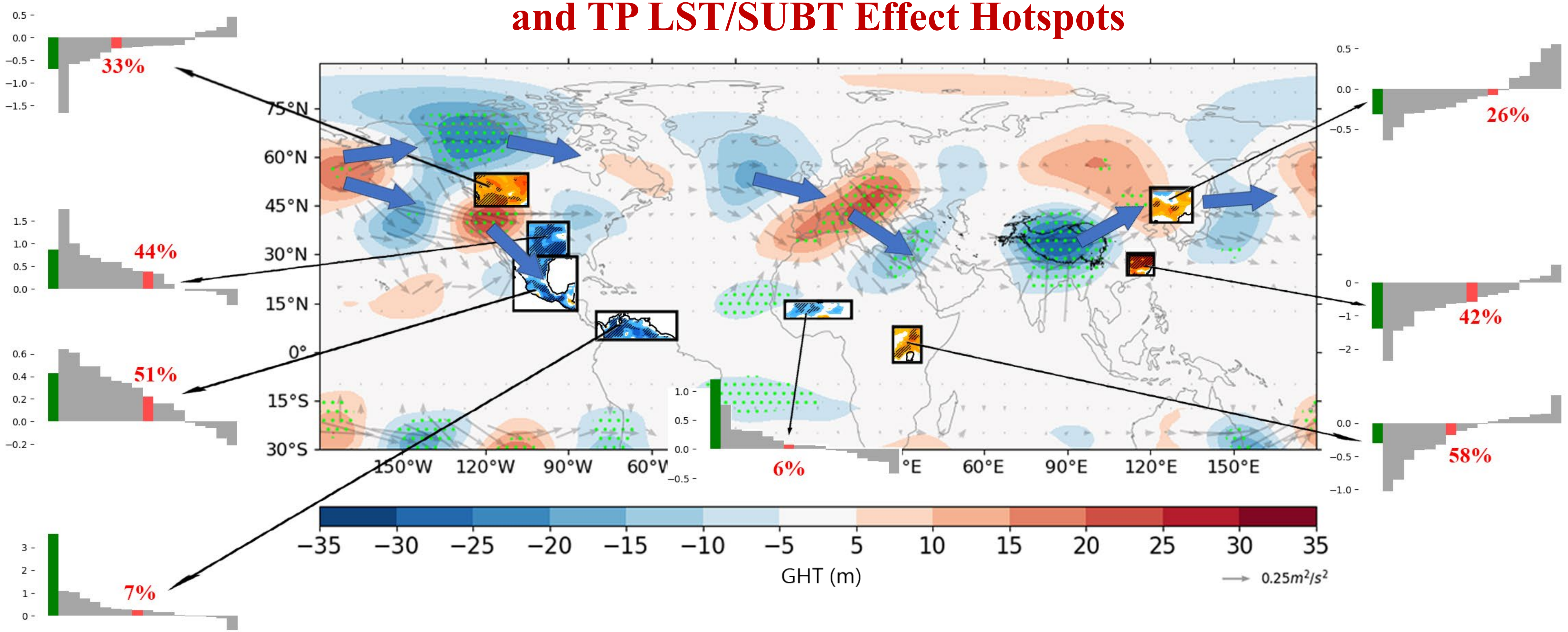
Observed Wave Train due to TP May T2m anomaly



Tibetan-Rocky Mountain Wave train

. Linkage between the TP and North America. (A) TPI and RMI time series. (b) Wave train. Notes: Fig. 4B is the regression of May 200-hPa geopotential height (m) of NCEP Reanalysis I from 1981-2015 onto (-1) * normalized May TPI and corresponding wave activity flux (WAF; m2/s2). Shadings denote the geopotential height, vectors denote the WAF.

Tibetan Plateau – Rocky Mountain Circumglobal Wave Train (TRC) and TP LST/SUBT Effect Hotspots

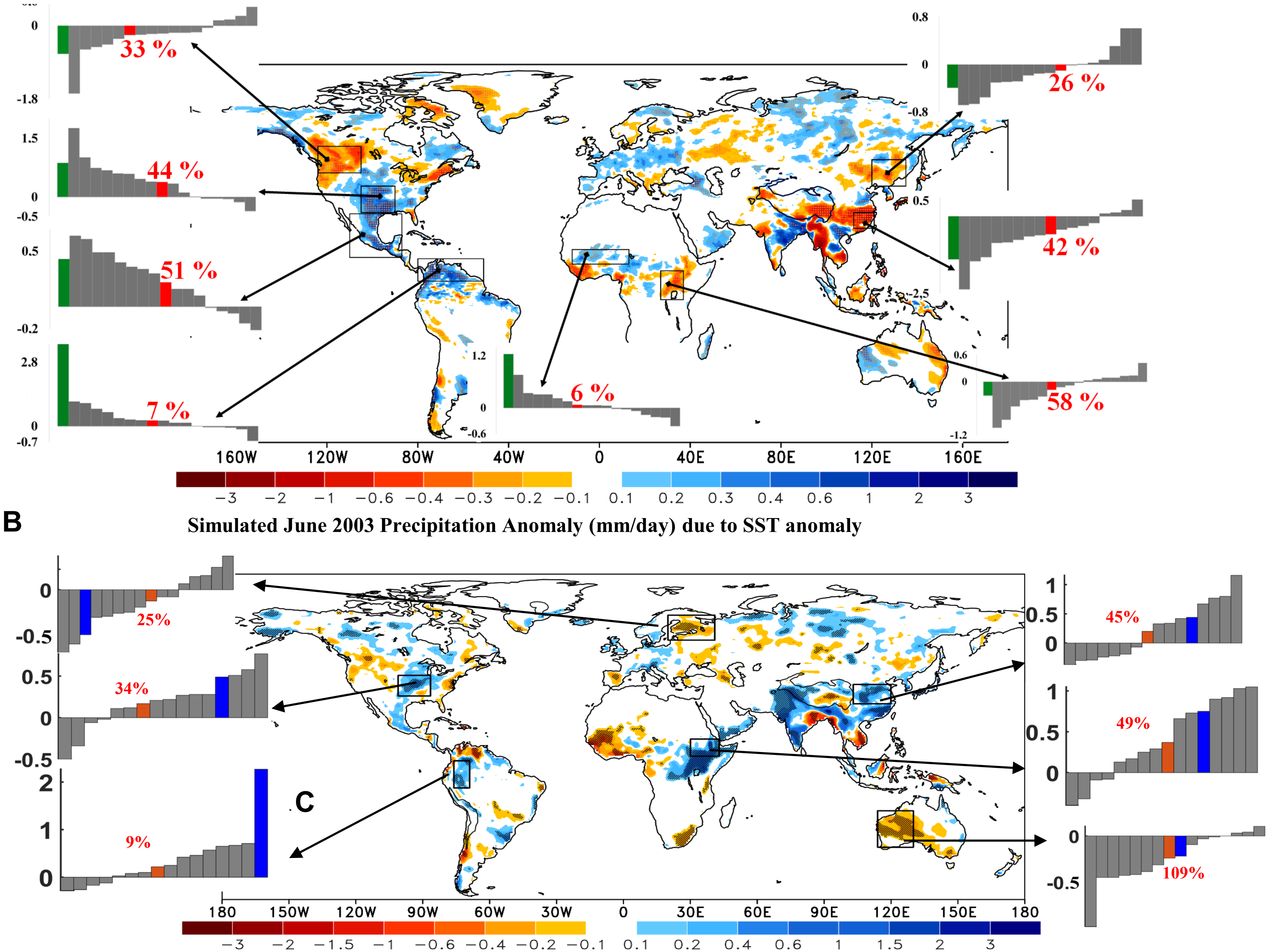


The schematic demonstrates the TRC global influence and possible hotspots. The color shadings within the boxes are snapshots of the LS4P multi-model--simulated June 2003 precipitation anomalies due to the effect of cold Tibetan Plateau land surface and subsurface temperature (LST/SUBT), and elsewhere the shaded areas show the observed 200-hPa geopotential height (GHT) anomalies due to the cold Tibetan Plateau temperature. The green bar corresponds to the observations and the red bar is the ensemble mean in each hot spot. Green dots represent a statistical significance at $p<0.1$. The light vectors are wave activity flux, and the heavy blue arrows indicate the TRC propagation. The figure is based on Xue et al. (BAMS, 2022, Climate Dynamics 2023).

Comparison of June 2003 Precipitation Anomaly due to LST/SUBT and SST Effect(mm/day)

TP LST/SUBT hot spots

Global SST hot spots



TRC Wave Train Effects

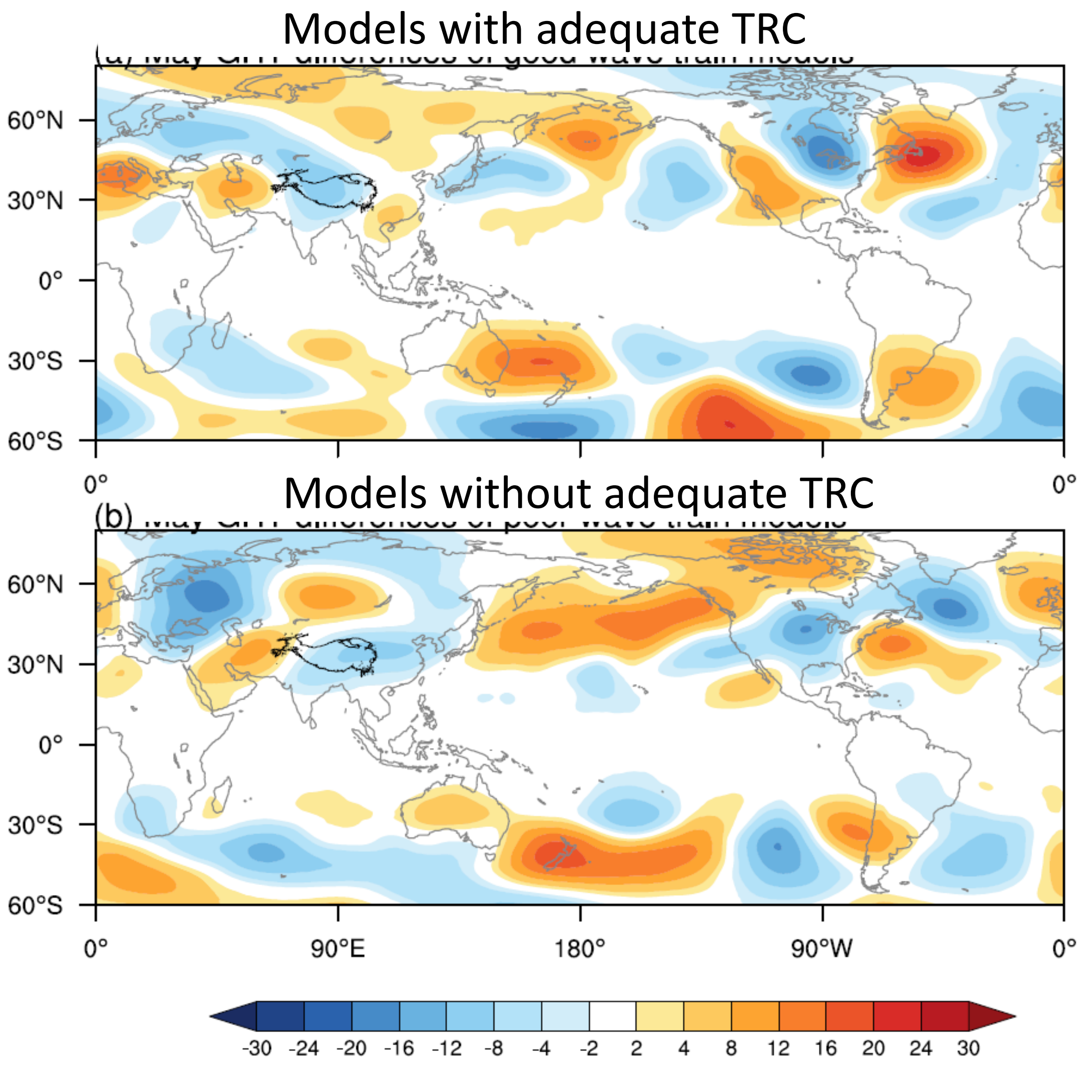
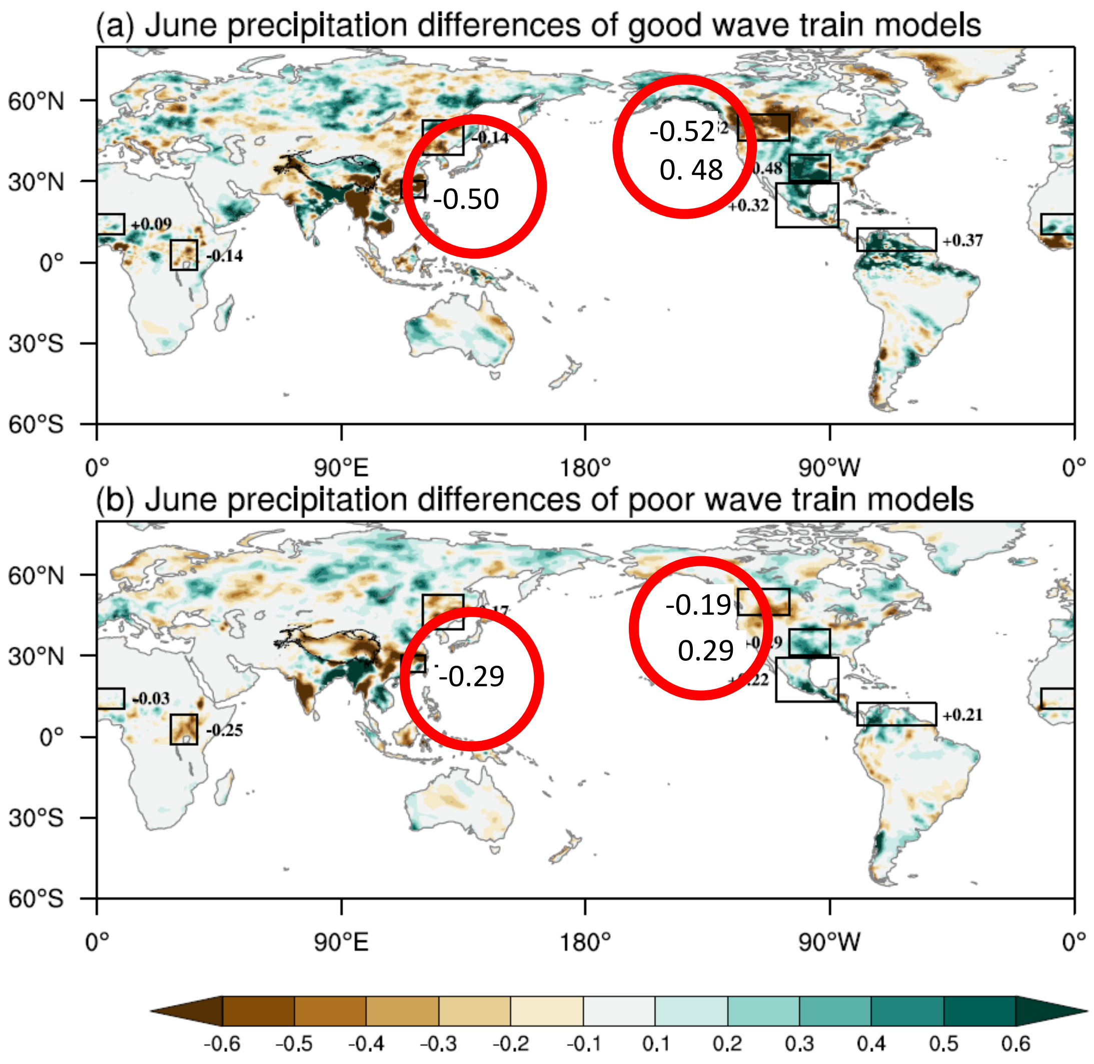
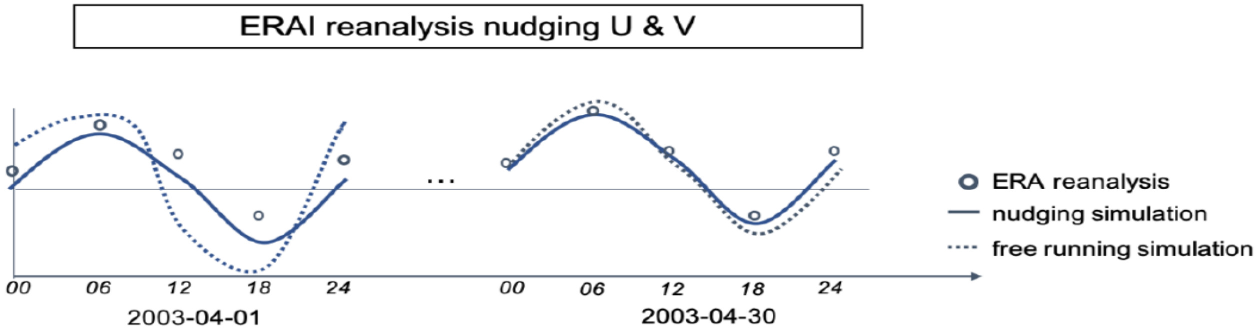


Figure 9. Ensemble mean of May geopotential height (m) differences due to the TP LST/SUBT effect (a) for the 5 models with best TRC wave train simulations and (b) for the 5 models with relatively poor TRC wave train simulations.



Zhang Y. et al., 2024, Climate Dynamics



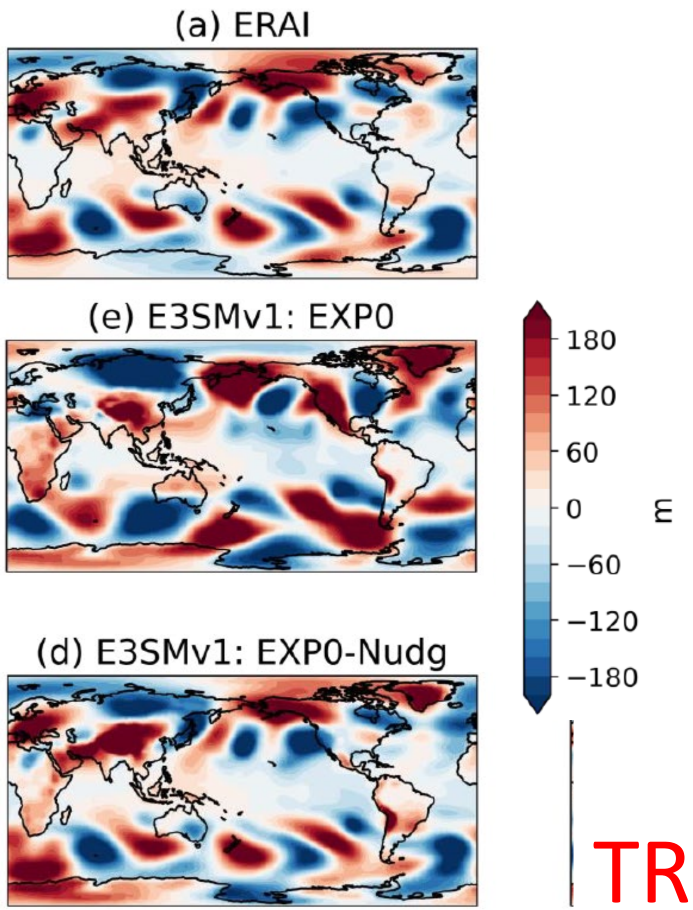
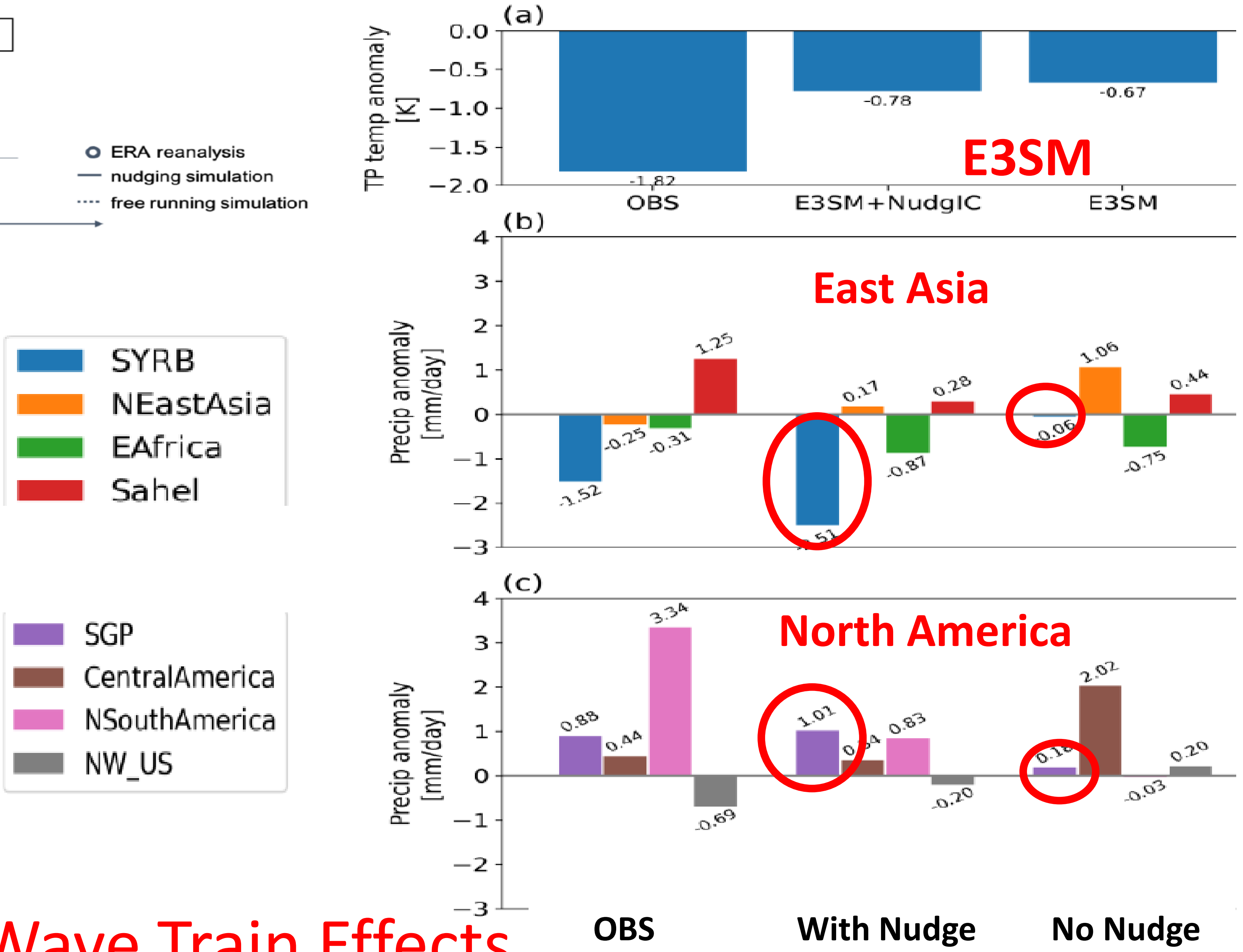


Figure 5. Non-zonal geopotential height at 200 hPa (m) from (a) ERAI, (b) CIESM EXP0-Nudg, (c) CIESM EXP0, (d) E3SMv1 EXP0-Nudg, and (e) E3SMv1 EXP0 on April 30th, 2003.



TRC Wave Train Effects

Qin Y, Q. Tang et al., Climate Dynamics 2023

Publications

Geosci. Model Dev., 14, 4465–4494, 2021
https://doi.org/10.5194/gmd-14-4465-2021

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2021

Impact of Initialized Land Surface Temperature and Snowpack on Subseasonal to Seasonal Prediction Project, Phase I (LS4P-I): organization and experimental design

Yongkang Xue[1], Tandong Yao[2], Aaron A. Boone[3], Ismaila Diallo[1], Ye Liu[1], Xubin Zeng[4], William K. M. Lau[5], Shiori Sugimoto[6], Qi Tang[7], Xiaoduo Pan[2], Peter J. van Oevelen[8], Daniel Klocke[9], Myung-Seo Koo[10], Tomonori Sato[11], Zhaohui Lin[12], Yuhei Takaya[13], Constantin Ardilouze[3], Stefano Materia[14], Subodh K. Saha[15], Retish Senan[16], Tetsu Nakamura[11], Hailan Wang[17], Jing Yang[18], Hongliang Zhang[19], Mei Zhao[20], Xin-Zhong Liang[5], J. David Neelin[1], Frederic Vitart[16], Xin Li[2], Ping Zhao[21], Chunxiang Shi[22], Weidong Guo[23], Jianping Tang[23], Miao Yu[24], Yun Qian[25], Samuel S. P. Shen[26], Yang Zhang[23], Kun Yang[27], Ruby Leung[25], Yuan Qiu[12], Daniele Peano[14], Xin Qi[18], Yanling Zhan[12], Michael A. Brunke[4], Sin Chan Chou[28], Michael Ek[29], Tianyi Fan[18,10], Hong Guan[30], Hai Lin[31], Shunlin Liang[32], Helin Wei[17], Shaocheng Xie[7], Haoran Xu[5], Weiping Li[33], Xueli Shi[33], Paulo Nobre[28], Yan Pan[23], Yi Qin[27,7], Jeff Dozier[34], Craig R. Ferguson[35], Gianpaolo Balsamo[16], Qing Bao[36], Jinming Feng[12], Jinkyu Hong[37], Songyou Hong[10], Huilin Huang[1], Duoying Ji[18], Zhenming Ji[38], Shichang Kang[39,40], Yanluan Lin[27], Weiguang Liu[41,24], Ryan Muncaster[31], Patricia de Rosnay[16], Hiroshi G. Takahashi[42], Guiling Wang[41],

BAMS
In Box

2022

Spring Land Temperature in Tibetan Plateau and Global-Scale Summer Precipitation

Initialization and Improved Prediction

Yongkang Xue, Ismaila Diallo, Aaron A. Boone, Tandong Yao, Yang Zhang, Xubin Zeng, J. David Neelin, William K. M. Lau, Yan Pan, Ye Liu, Xiaoduo Pan, Qi Tang, Peter J. van Oevelen, Tomonori Sato, Myung-Seo Koo, Stefano Materia, Chunxiang Shi, Jing Yang, Constantin Ardilouze, Zhaohui Lin, Xin Qi, Tetsu Nakamura, Subodh K. Saha, Retish Senan, Yuhei Takaya, Hailan Wang, Hongliang Zhang, Mei Zhao, Hara Prasad Nayak, Qiuyu Chen, Jinming Feng, Michael A. Brunke, Tianyi Fan, Songyou Hong, Paulo Nobre, Daniele Peano, Yi Qin, Frederic Vitart, Shaocheng Xie, Yanling Zhan, Daniel Klocke, Ruby Leung, Xin Li, Michael Ek, Weidong Guo, Gianpaolo Balsamo, Qing Bao, Sin Chan Chou, Patricia de Rosnay, Yanluan Lin, Yuejian Zhu, Yun Qian, Ping Zhao, Jianping Tang, Xin-Zhong Liang, Jinkyu Hong, Duoying Ji, Zhenming Ji, Yuan Qiu,

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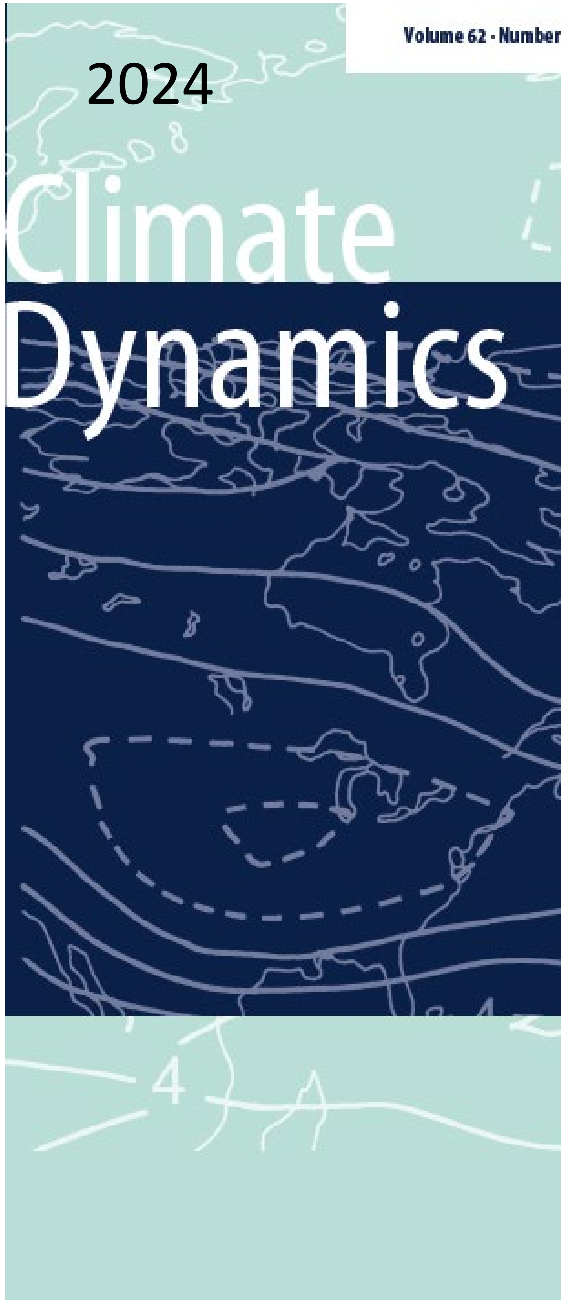
Special Issue: Subseasonal-to-Seasonal predictability of extreme precipitation and land forcing

Guest Editors: Yongkang Xue · William K-M Lau

2024



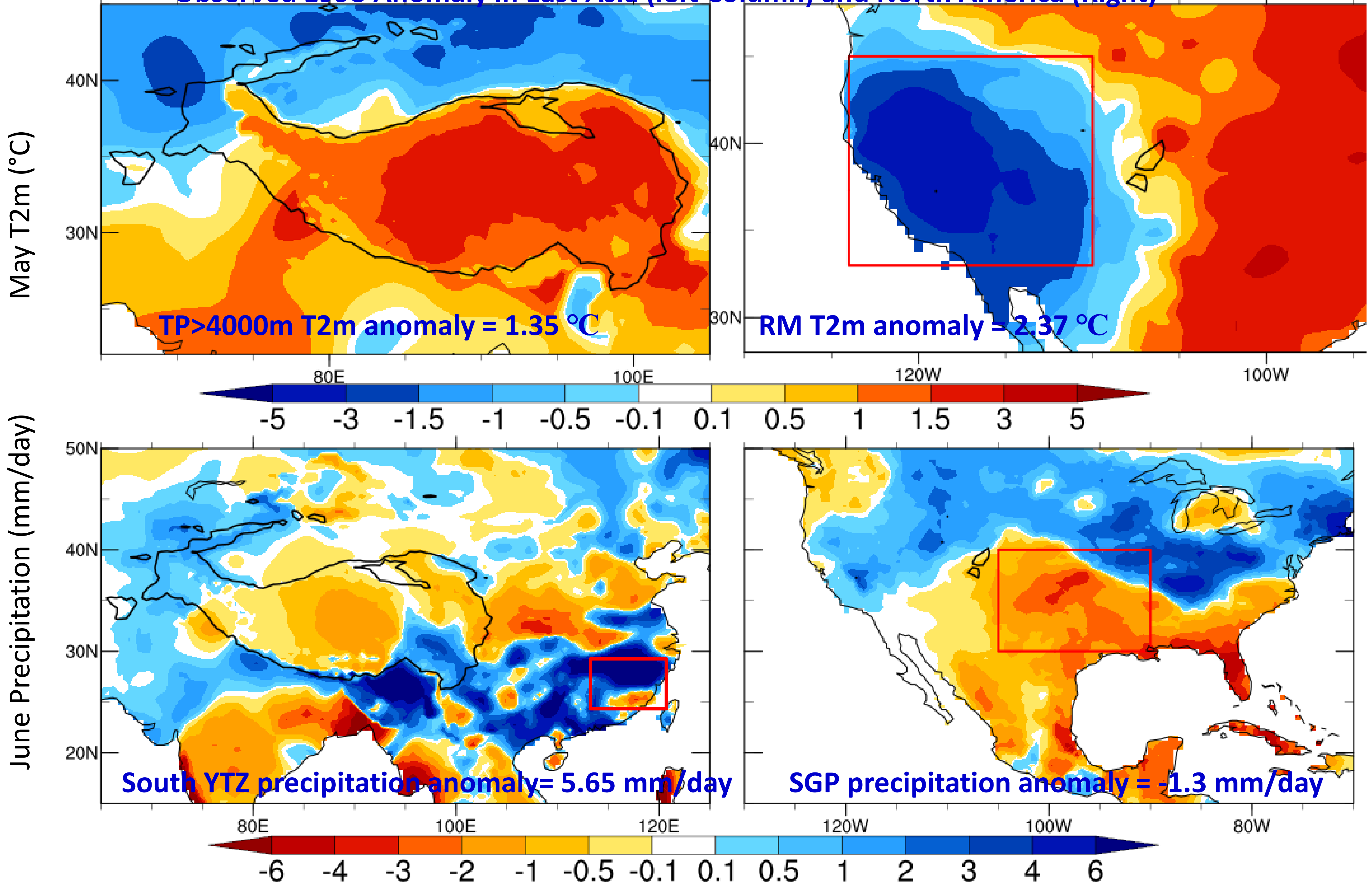
LS4P Phase II (May-August 1998)

Major Objevtives:

(1). Case study for 1998: Cold Rocky Mountains and Warm Tibetan Plateau in Spring and drought in Southern Great Plains and June flood in Yangtze River, respectively.

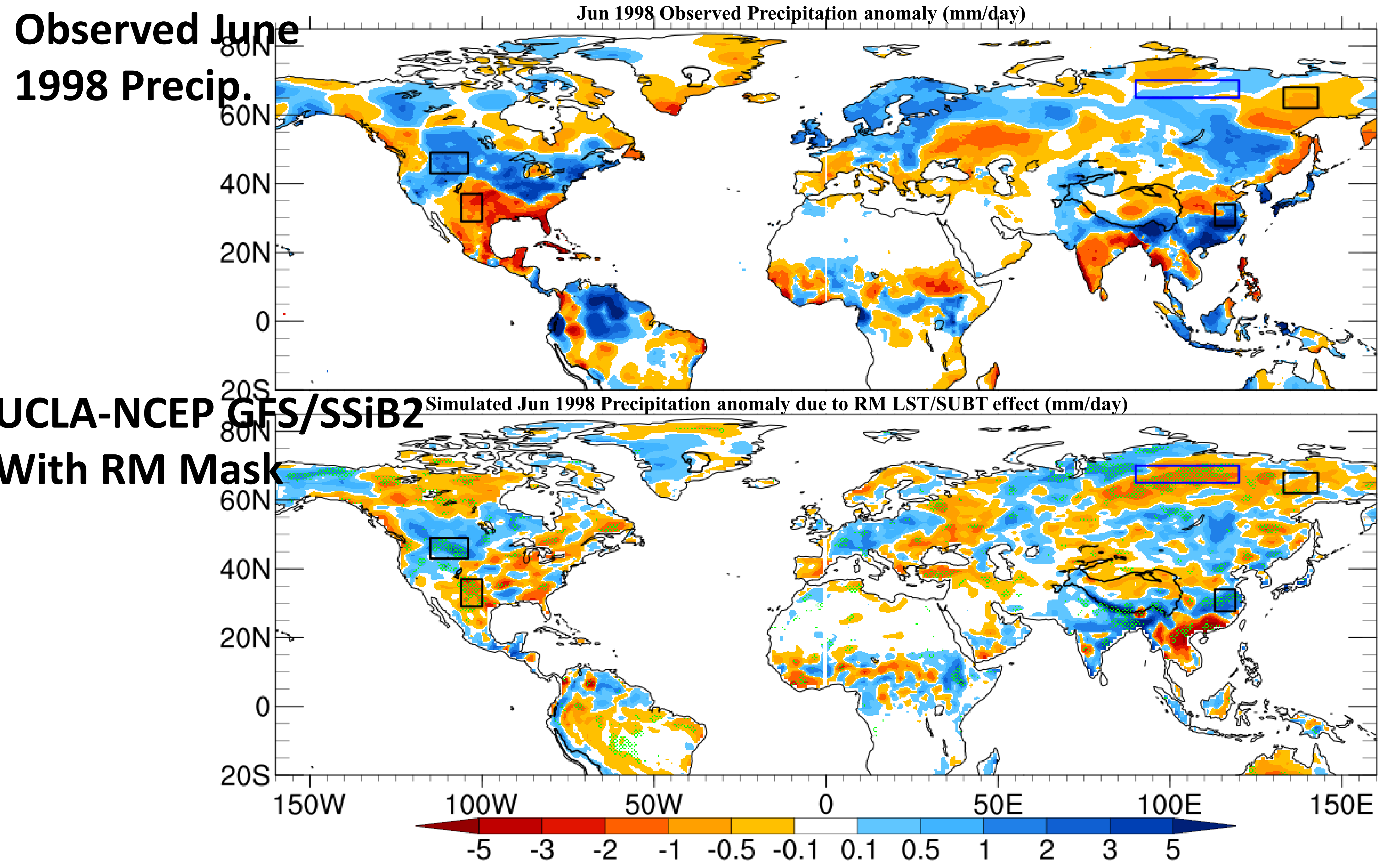
(2) The LS4P research on other years and seasons, such as late summer and winter.

Observed 1998 Anomaly in East Asia (left Column) and North America (Right)



EVMWF-IFS Sensitivity Statistics (Preliminary)

	May 1998 2m Temperature (°C)		June 1998 Precip mm/day
	Tibetan Plateau		S. Yangtze Basin
Obs. Anomaly	1.404		5.668
Bias in CONTROL	-3.314		-5.281
Sensitivity Experiments	Experiment minus CONTROL		
TP Δt n=1	0.618		0.672
TP Δt n=3	0.717		1.759



Observed June 1998 Precip.
Jun 1998 Observed Precipitation anomaly (mm/day)
UCLA-NCEP GFS/SSiB2 With RM Mask
Simulated Jun 1998 Precipitation anomaly due to RM LST/SUBT effect (mm/day)
80N
60N
40N
20N
0
20S
150W
100W
50W
0
50E
100E
150E
-5 -3 -2 -1 -0.5 -0.1 0.1 0.5 1 2 3 5

Observed and Simulated Jun 1998 precipitation anomaly (mm/day)
Over Yangtze River Basin and South Great Plains

	Obs anomaly	RM Cold LST/SUBT effect	TP Warm LST/SUBT effect	SST effect
Yangtze River Basin (26-31N;104-120 E)	3.26	1.11	1.44	1.04
South Great Plains (27-37N;107W-80W)	-1.45	-0.71	-0.61	-0.11

Note: The 1998 was a very strong El Niño Year. The SST has very strong impact in the tropical regions, such as Sahel, Central Africa, Amazon, and Central America at S2S scale (not listed in the table).

Summary

1). Observational data show a potential for the LST/SUBT to provide land memory at the S2S time scale, and a lag relationship between May T2m anomaly over the TP/RM and June precipitation anomaly downstream.

2). In ESM experiments, by properly producing observed May TP T2m anomaly, the S2S predictions over hot spot regions are improved. The consideration of the TP LST/SUBT effect has produced about 25%-50% of observed precipitation anomalies in most of 8 hotspot regions. For comparison, 6 regions with significant SST effects were identified in the 2003 case, explaining about 25-50% of precipitation anomalies over most of these regions.

3). The TP LST/SUBT influence is underscored by an observed out-of-phase oscillation between the TP and RM surface temperatures and a downstream TP-RM Circumglobal (TRC) wave train linking the TP to North America.

4). LS4P II focuses on TM effect and RM-TP Interactions. We welcome more groups to participate in.