Early summer surface air temperature variability over Pakistan and the role of El Niño–Southern Oscillation teleconnections

Irfan Ur Rashid

E-mail: irfanpmd@gmail.com

Co-Authors: M. Adnan Abid (ICTP), M. Almazroui (CECCR), F. Kucharski (ICTP), M. Hanif (PMD), S. Ali (GCISC), M. Ismail (CECCR)

Rashid et al. (2022), DOI: 10.1002/joc.7560

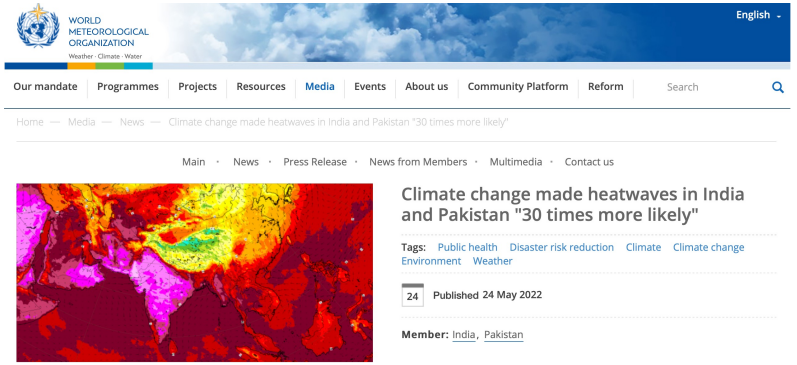
ICTP, 27 July 2022

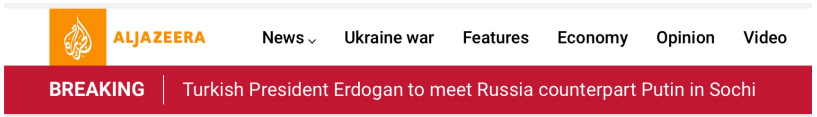
Outline

1. Motivation
2. Data and Methods
3. Temperature Variability over Pakistan
4. How ENSO affects Temperature Variability over Pakistan
5. AMIP Model Simulations and Idealized Experiment
6. Conclusion and Future Directions

Rashid et al. (2022), DOI: 10.1002/joc.7560

Motivation

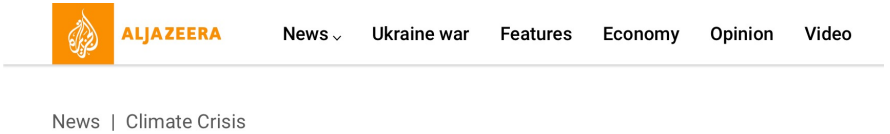




News | Climate Crisis

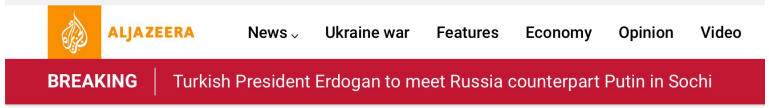
Pakistan city hits nearly 50C as blistering heatwave grips nation

Parts of the nation already scorched by temperatures of nearly 50Cs as officials warn of acute water shortages and a threat to health.



News | Climate Crisis

‘Perfect climate storm’: Pakistan reels from extreme heat



Asia / Pacific

ON THE GROUND

'World's hottest city' wilts under scorching Pakistan heatwaves

News | Climate Crisis

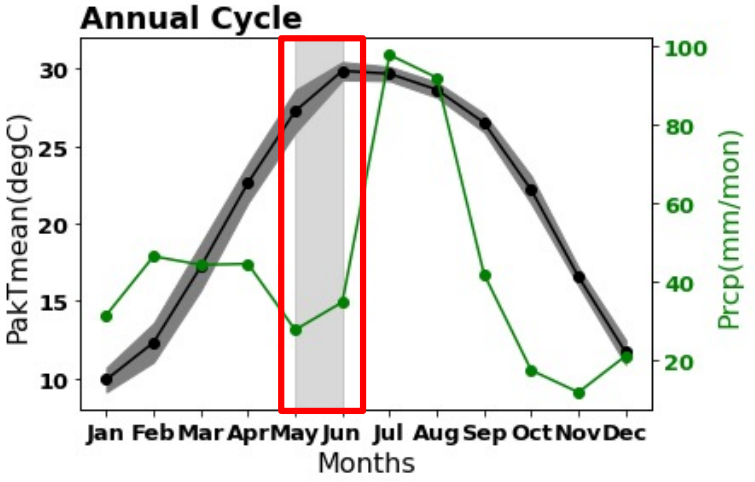
Pakistan city hits nearly 50C as blistering heatwave grips nation

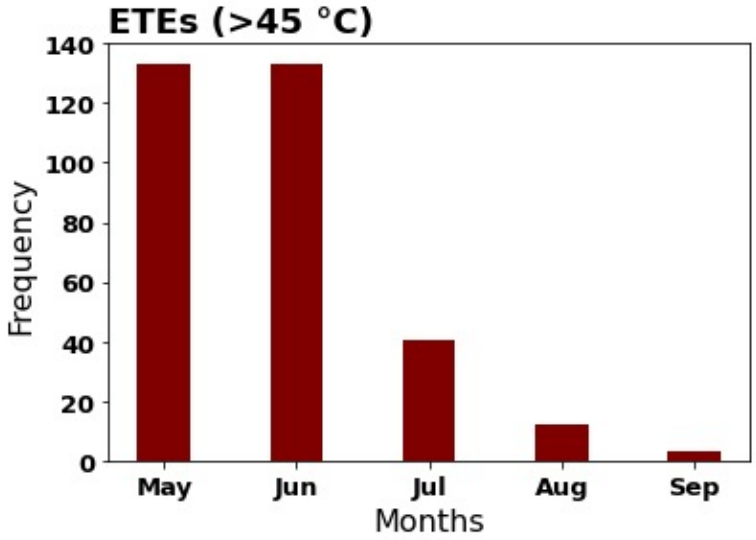
Parts of the nation already scorched by temperatures of nearly 50Cs as officials warn of acute water shortages and a threat to health.

Rashid et al. (2022), DOI: 10.1002/joc.7560

Motivation

- Pakistan is home of more than 220 million people, with an arid to semi-arid climate.
- Agriculture contributes about 24% to the Pakistan Gross Domestic Product (GDP), and about 43% of the labour are exposed to the extreme temperature conditions.
- The SAT over Pakistan peaks during early summer (pre-monsoon, May-Jun) season compared to the consequent monsoon season (July-September) over Pakistan.
- The early summer period is considered as dry and the hottest season over Pakistan, which may result in extreme temperature conditions.
- The region also experiences heatwaves during early summer season, but the underlying mechanism that modulates the temperature extremes are still unknown.

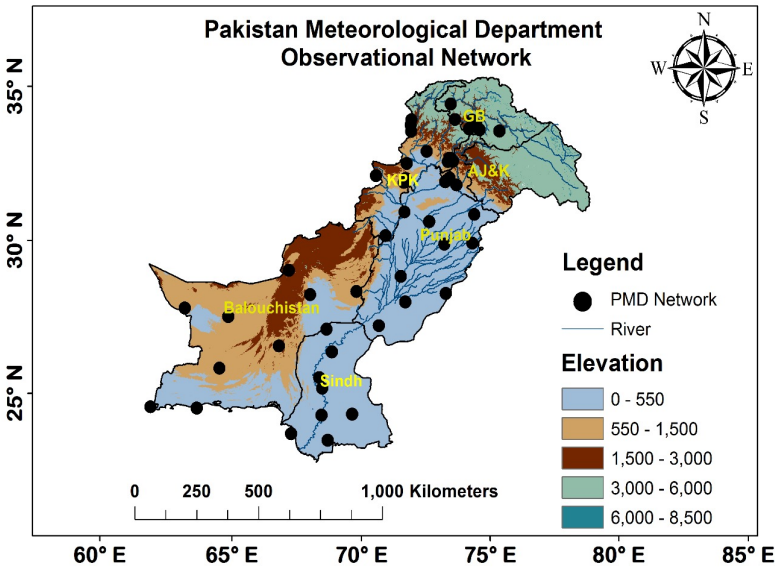




Rashid et al. (2022), DOI: 10.1002/joc.7560

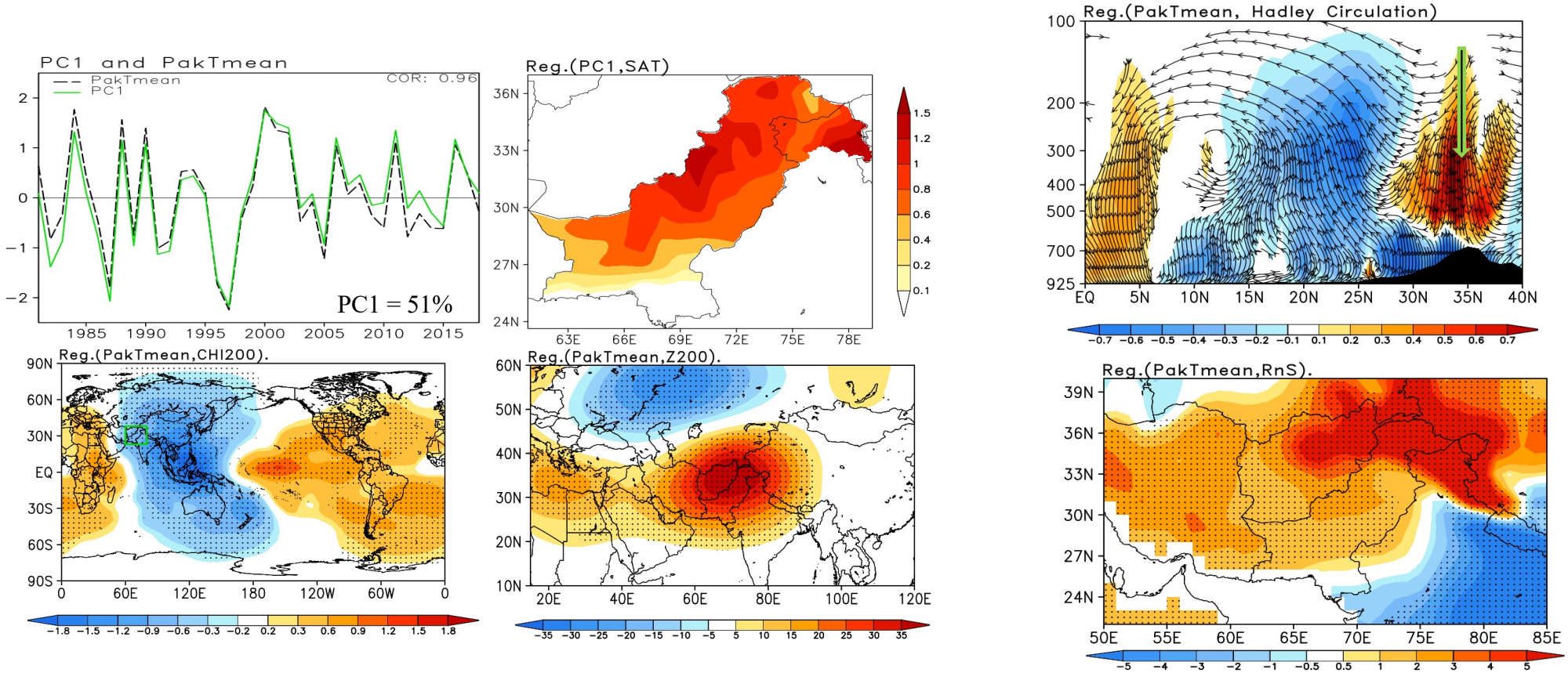
Data and Methods

- In situ mean surface air temperature (SAT) data for 49 PMD stations for the period 1981-2018.
- The country averaged SAT is used as temperature index, referred as PakTmean.
- Fifth generation European Re-Analysis (ERA5) data was used for the period 1981-2018.
- Saudi-KAU AGCM AMIP Simulation with T42 atmospheric resolution are used to analyze the SAT variability over Pakistan for the period 1871-2016 (Almazroui et al. 2017).
  - Total 10-ensemble member are simulated by forcing each member with observed monthly varying HadISST dataset.
- Idealized experiments are carried out by forcing the model with only MJ El Niño (La Niña) anomaly composites in the ENSO region and elsewhere the climatological SST.



Rashid et al. (2022), DOI: 10.1002/joc.7560

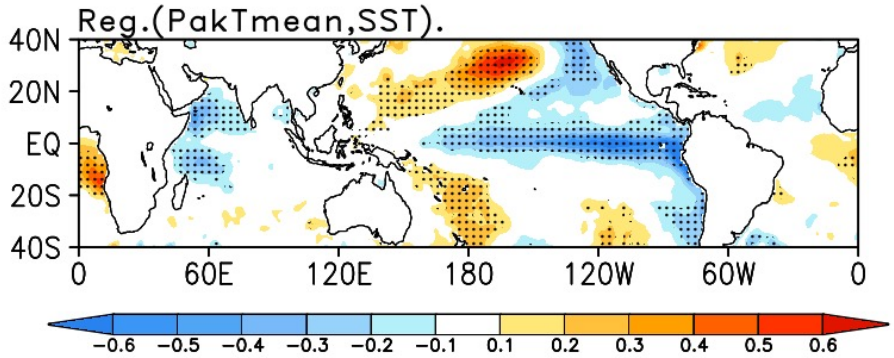
Temperature Variability over Pakistan

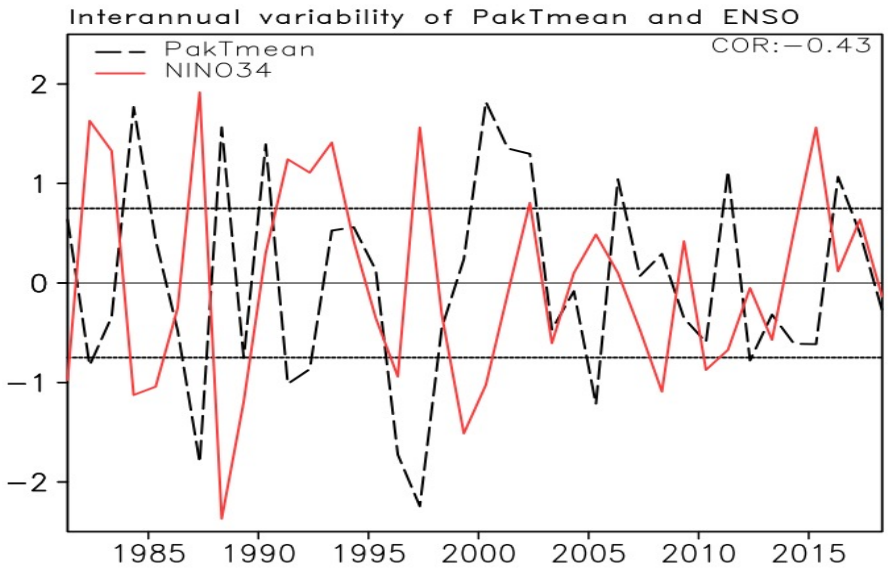


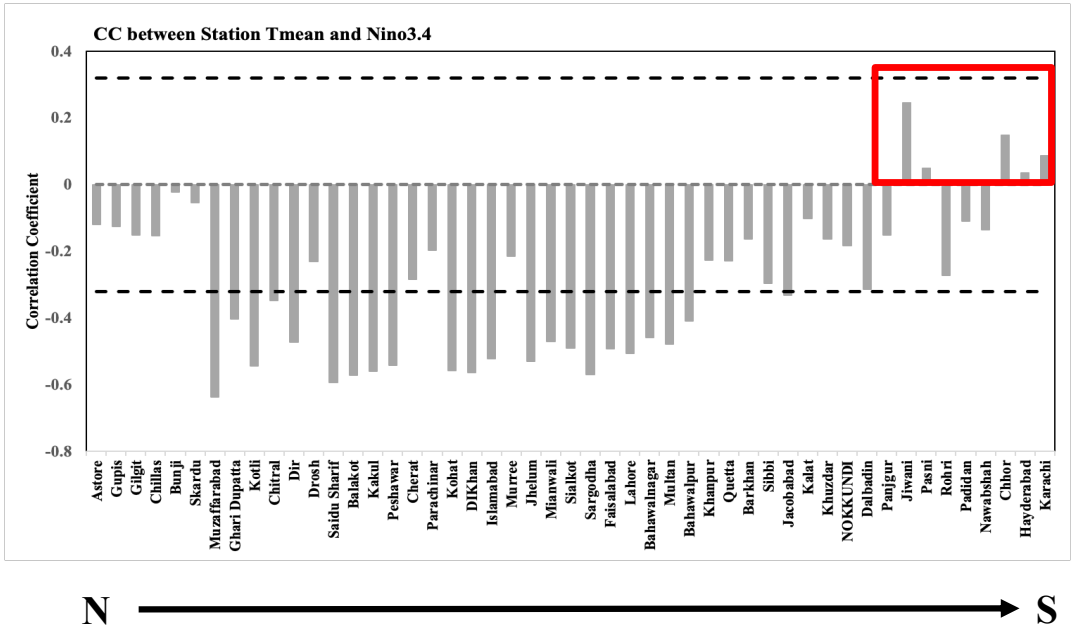
❑ The SAT variability over Pakistan during early summer season is mainly associated with upper-level positive geopotential height anomalies modulated through the strengthening of the walker and Hadley circulation.

Rashid et al. (2022), DOI: 10.1002/joc.7560

How ENSO affects Temperature Variability over Pakistan



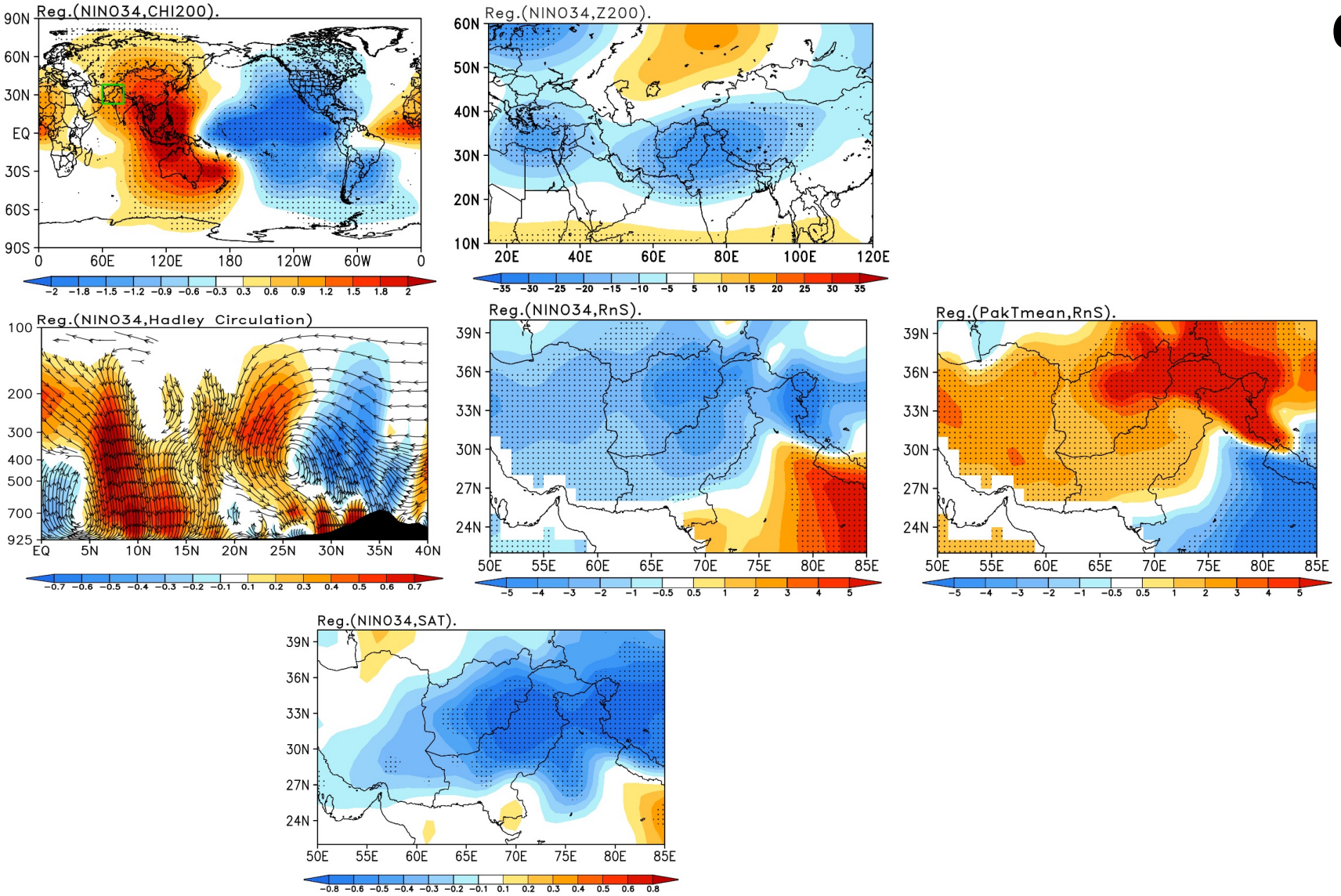




N → S

Rashid et al. (2022), DOI: 10.1002/joc.7560

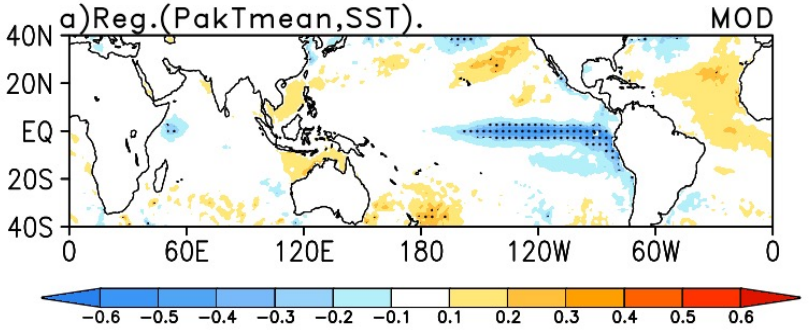
Cont……



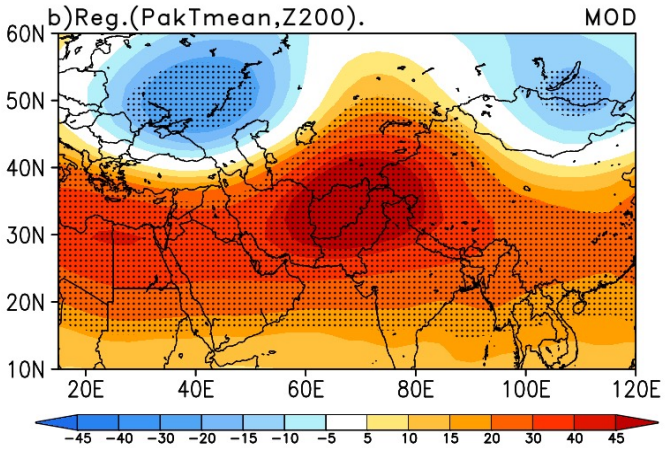
Rashid et al. (2022), DOI: 10.1002/joc.7560

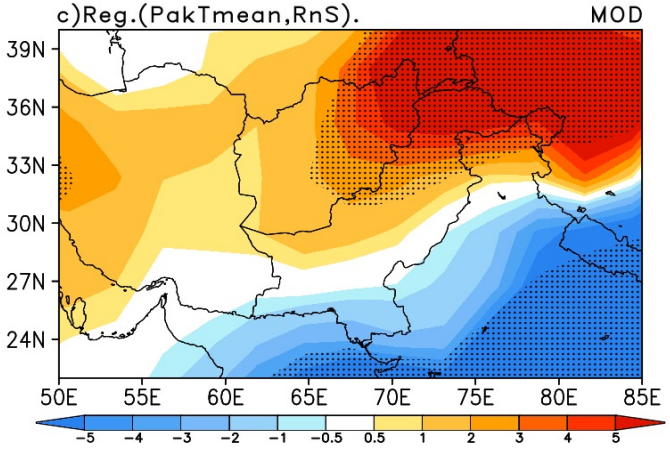
Saudi-KAU AGCM AMIP Simulations

- Saudi KAU AGCM AMIP Simulations for the period 1871-2016 and analyzed only for common period i.e., 1981-2016 with 10 ensemble members.



- Saudi-KAU model reproduced the observed pattern quite well.



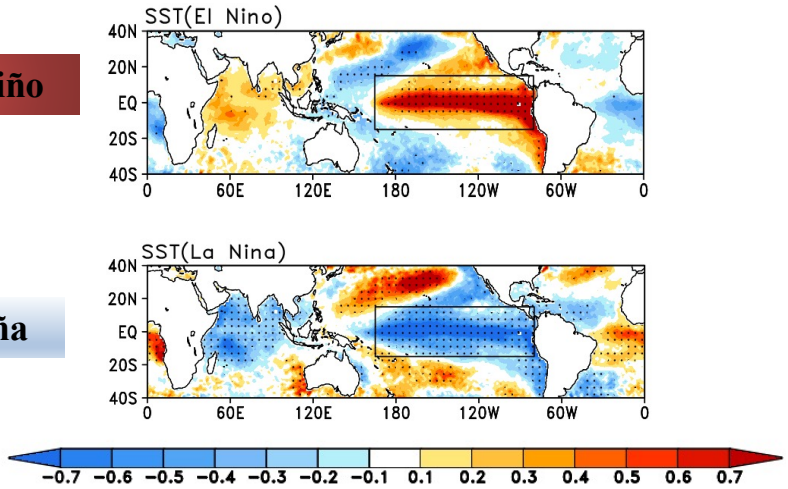


Rashid et al. (2022), DOI: 10.1002/joc.7560

Saudi-KAU AGCM Idealized Experiments

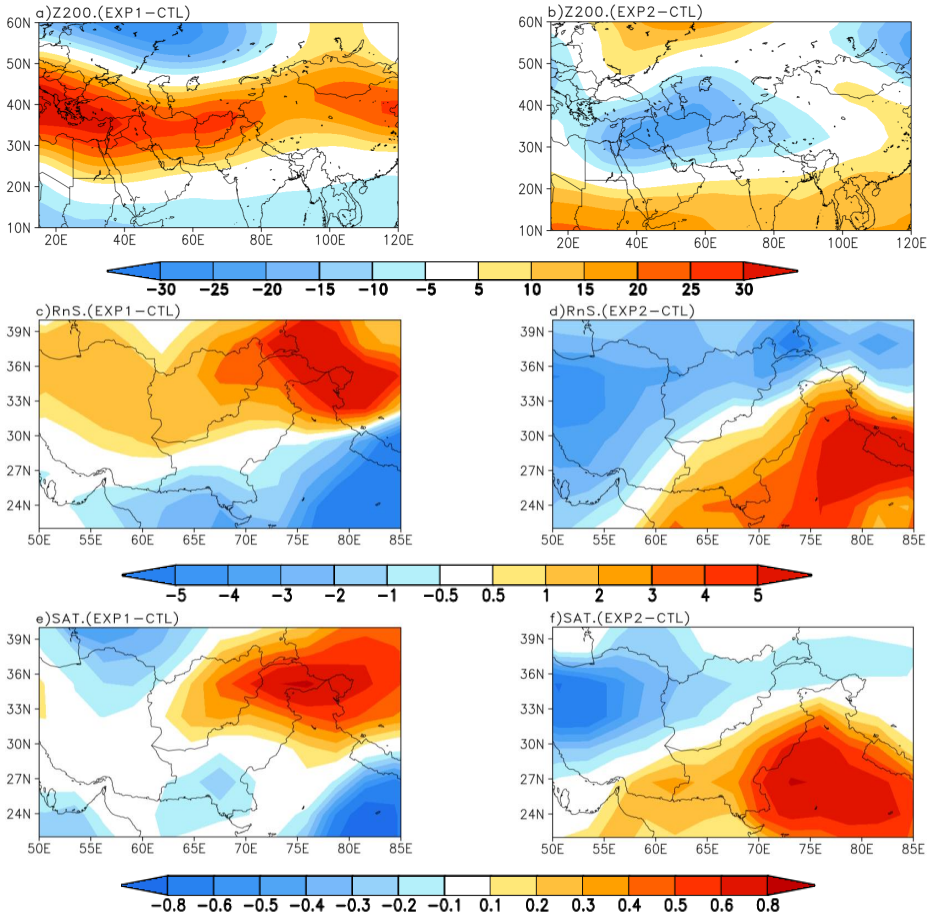
ExP: El Niño

ExP: La Niña



ExP: La Niña

ExP: El Niño



- Saudi-KAU AGCM Idealized experiments confirm that the upper-level positive geopotential height anomaly response leads to above normal SAT over the central and northern Pakistan during La Niña, while the opposite was noted for the El Niño experiment.

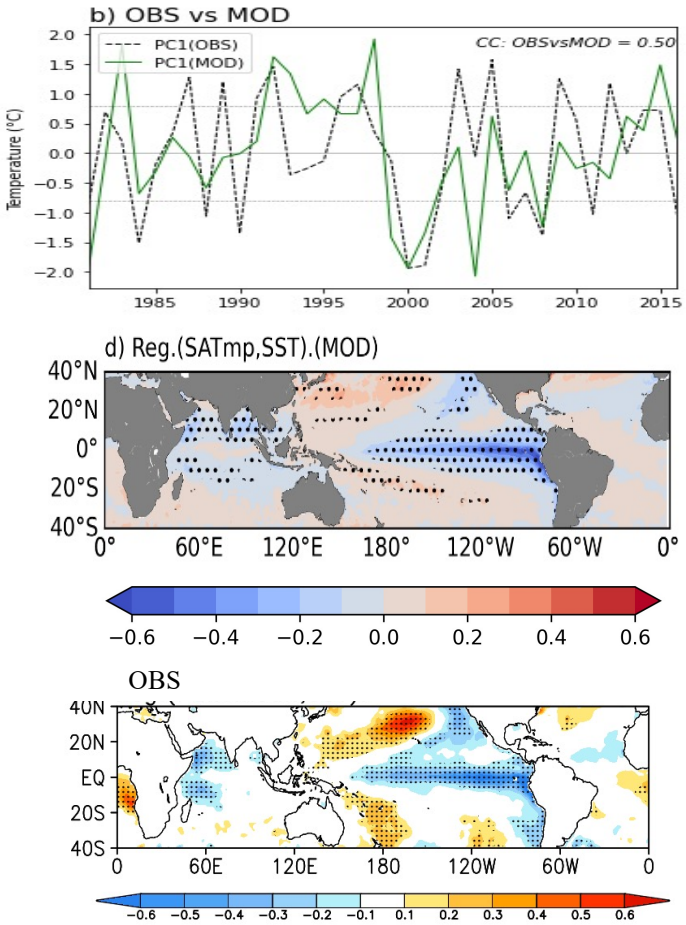
Rashid et al. (2022), DOI: 10.1002/joc.7560

Conclusion and Future Direction

- This study demonstrate that how ENSO is contributing to the regional temperature extremes.
- The cold ENSO phase favors the positive geopotential height anomalies due to the strengthening of the walker circulation that enhance the sinking motion and result in less cloudiness leading to the extreme higher surface temperature conditions over Pakistan, while the opposite happens in the warm ENSO phase.
- In future the predictability of the temperature extremes on sub-seasonal to seasonal time scale will be assessed using the dynamical prediction model datasets.
- Furthermore, this mechanism will be used to understand the warming over the region in the present and future climate using the Coupled Global Climate models.
- The individual extreme temperature events attribution.

Work in Progress

ECMWF SYS5 (1 month lead i.e., April ICs with 25 ensemble members)



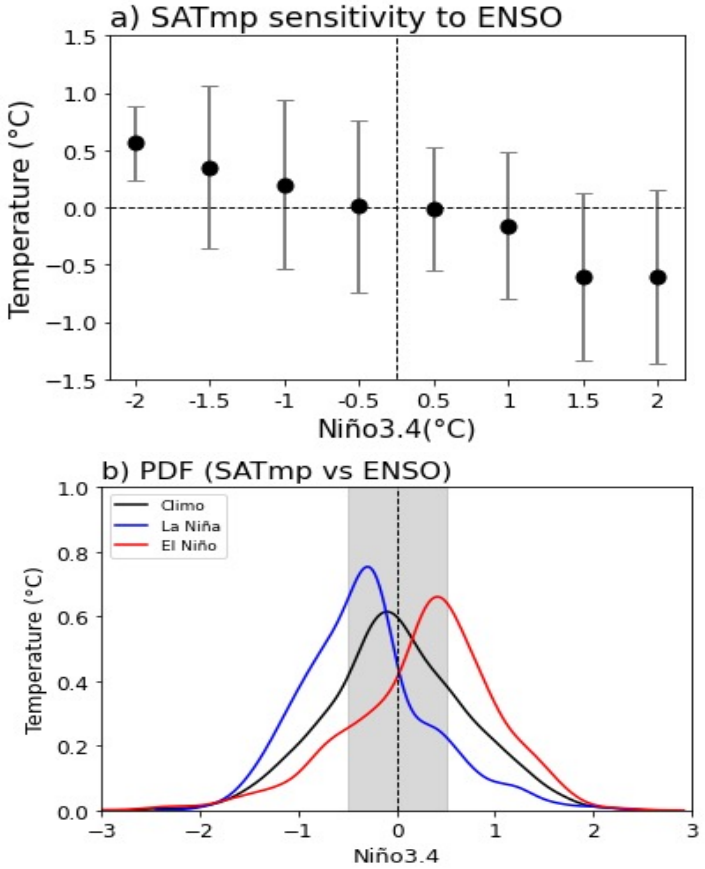
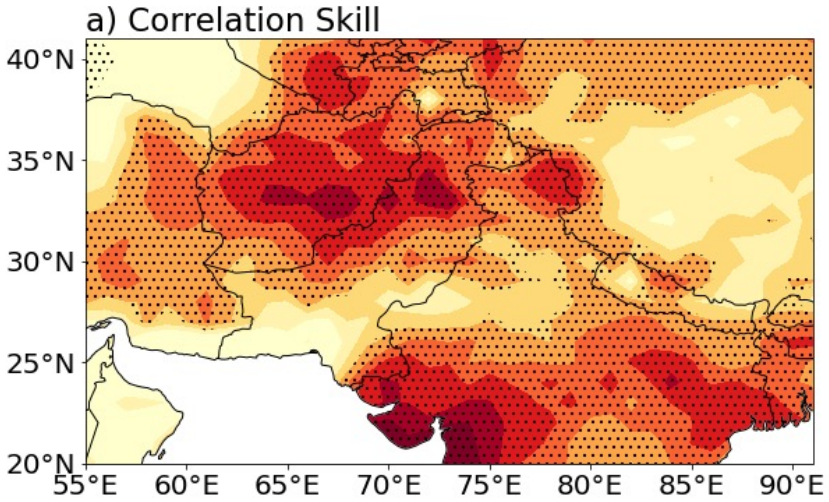
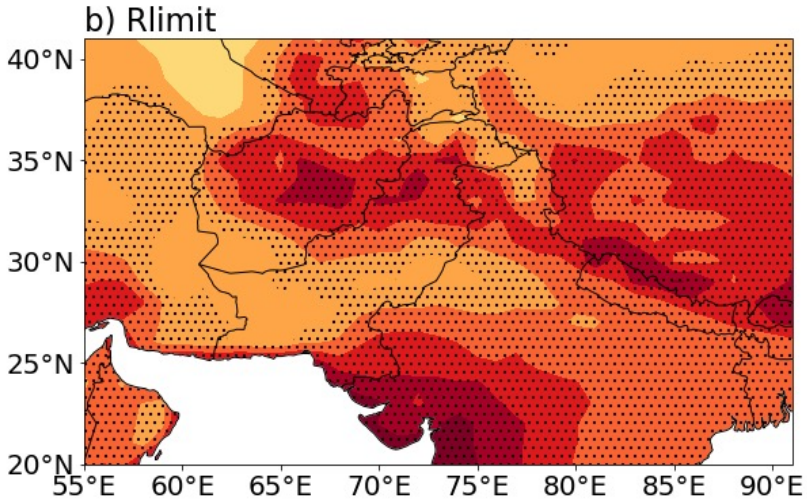


Fig: a) SAT ensemble mean anomalies (black closed circles) and spread (grey whisker) in each bin of Niño3.4 Index (x-axis) and **b)** Probability Distribution Function (PDF) of SAT anomalies for La Niña (blue), El Niño (red) events and their climatological pdf (black) based on 25x36 =900 sample size during early summer season for the period 1981-2016.

Predictability





Rashid et al. In Progress

Received: 8 December 2020 | Revised: 19 January 2022 | Accepted: 24 January 2022
DOI: 10.1002/joc.7560

RESEARCH ARTICLE

International Journal of Climatology RMetS

Early summer surface air temperature variability over Pakistan and the role of El Niño–Southern Oscillation teleconnections

Irfan Ur Rashid[1] | **Muhammad Adnan Abid**[2,3] | **Mansour Almazroui**[3,4] | **Fred Kucharski**[2,3] | **Muhammad Hanif**[1] | **Shaukat Ali**[5] | **Muhammad Ismail**[3]

[1]Climate Change Impact and Integration Cell (CIIC), Pakistan Meteorological Department, Islamabad, Pakistan

[2]Earth System Physics, The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy

[3]Centre of Excellence for Climate Change Research (CECCR)/Department of Meteorology, King Abdulaziz University, Jeddah, Saudi Arabia

[4]Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, UK

[5]Global Change Impact Studies Centre (GCISC), Islamabad, Pakistan

Correspondence
Irfan Ur Rashid, Climate Change Impact and Integration Cell (CIIC), Pakistan Meteorological Department (PMD), Islamabad, Pakistan.
Email: irfanpmd@gmail.com

Abstract

Early summer (May–June) is the season where the surface air temperature (SAT) variability is largest and may result in extreme temperature conditions over Pakistan. Therefore, we analysed the early summer interannual SAT variability over Pakistan for the period 1981–2018 using observational dataset and model simulations. We noted that upper-level anticyclonic circulation anomalies over Pakistan, which are associated with upper to the middle tropospheric descending motion, favour clear skies with an increase in net shortwave radiation that leads to extreme surface warming over the region. Moreover, the El Niño–Southern Oscillation (ENSO) based on Niño3.4 SST index is negatively associated with SAT anomalies over Pakistan. The cold ENSO phase favours the positive geopotential height anomalies due to the strengthening of the Walker circulation that enhance the sinking motion and result in less cloudiness leading to the extreme higher surface temperature conditions over Pakistan, while the opposite happens in the warm ENSO phase. Moreover, the Saudi-KAU Atmospheric Global Climate Model (AGCM) simulated large-scale patterns that are in good agreement with the observations. Sensitivity experiments with the AGCM confirm that cold SST anomalies in the ENSO region significantly favour above-normal SAT anomalies over Pakistan, while the opposite happens in the warm ENSO phase. These results are important to understand and potentially predict regional heatwaves over the South Asian region, particularly over Pakistan.

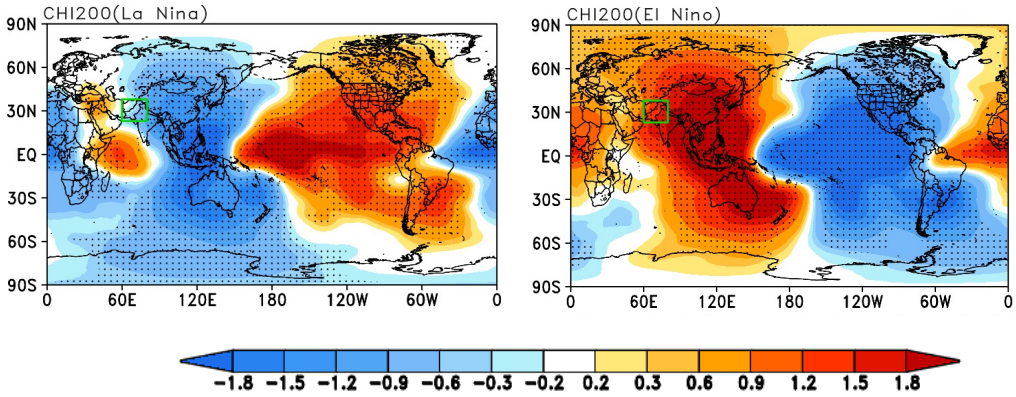
KEYWORDS
early summer, ENSO, Hadley circulation, Pakistan, surface air temperature, Walker circulation

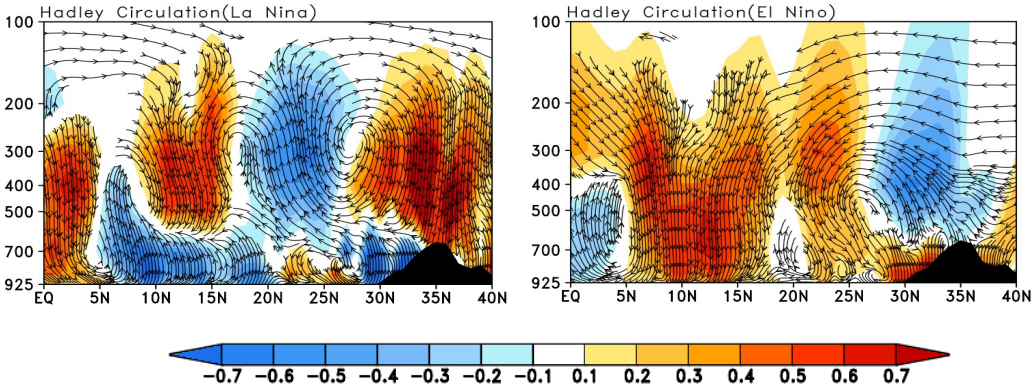
Thanks

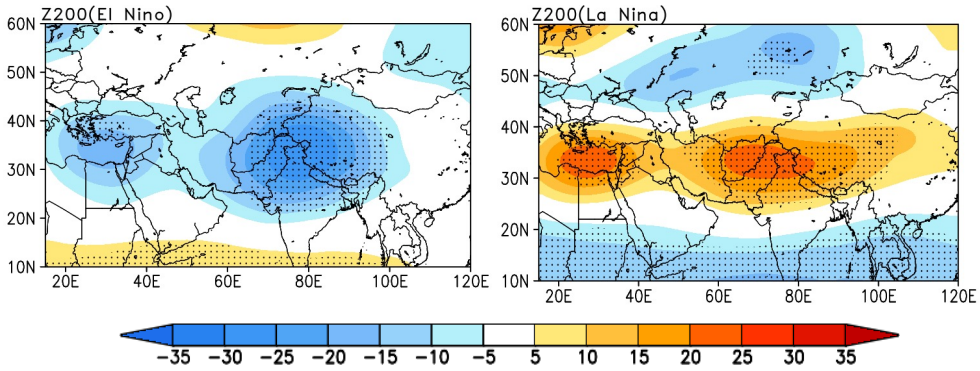
Rashid et al. (2022), Early summer Surface Air Temperature variability over Pakistan and the role of ENSO teleconnections, International Journal of Climatology, DOI: 10.1002/joc.7560

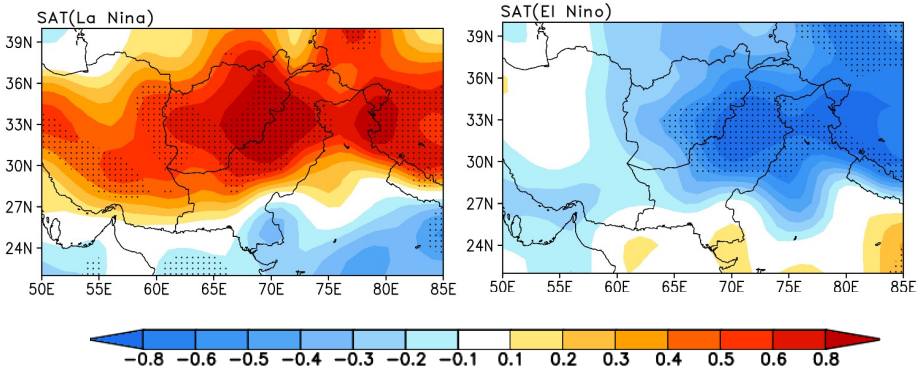
ENSO Composites:

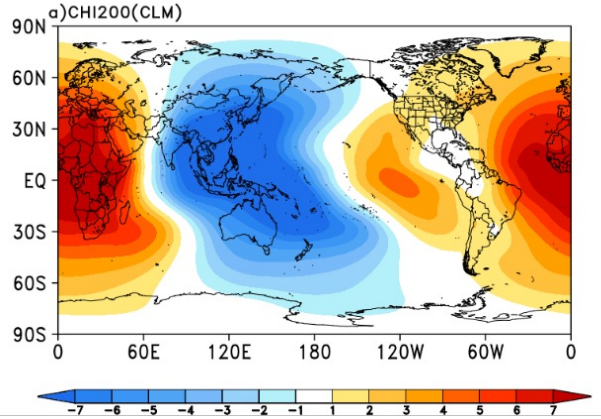
Cont..

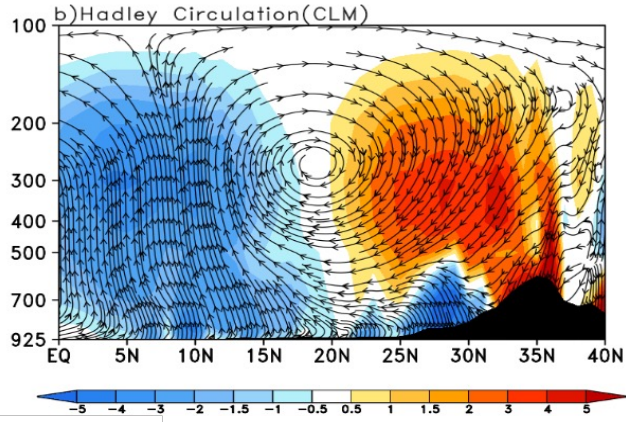


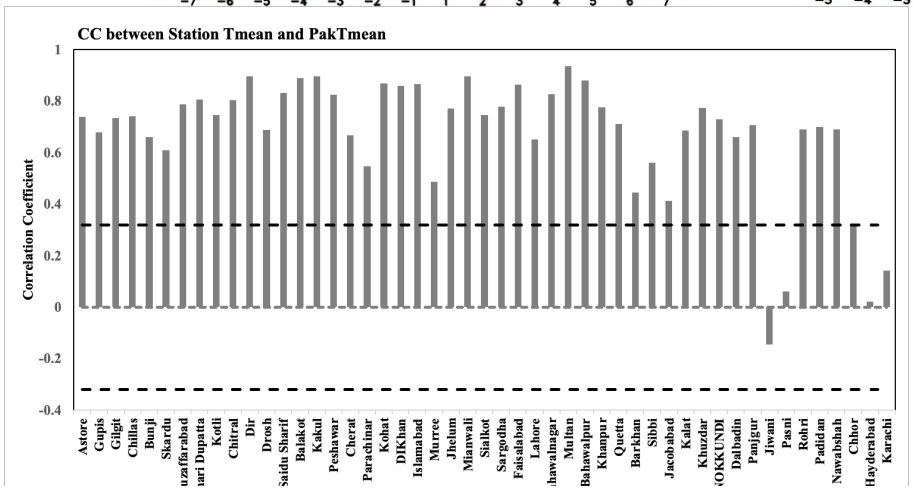




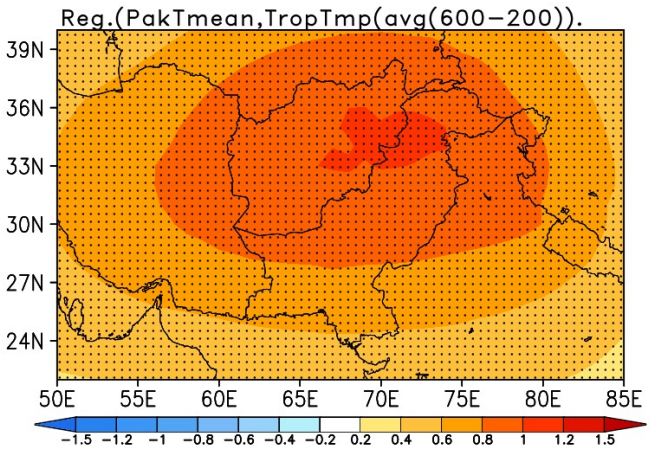


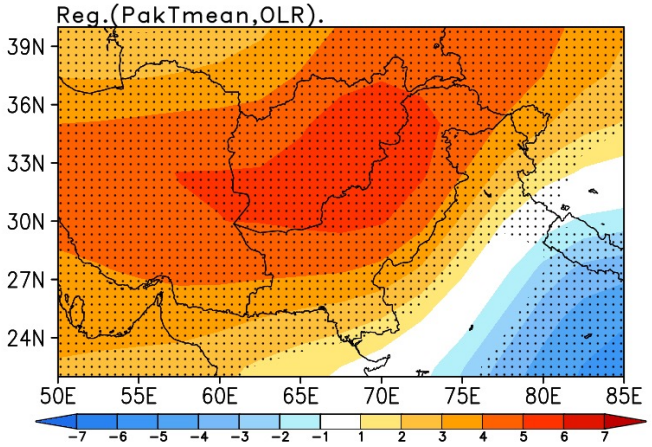

a)CHI200(CLM)
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−7 −6 −5 −4 −3 −2 −1 1 2 3 4 5 6 7


b)Hadley Circulation(CLM)
100
200
300
400
500
700
925
EQ
5N
10N
15N
20N
25N
30N
35N
40N
−5 −4 −3 −2 −1.5 −1 −0.5 0.5 1 1.5 2 3 4 5

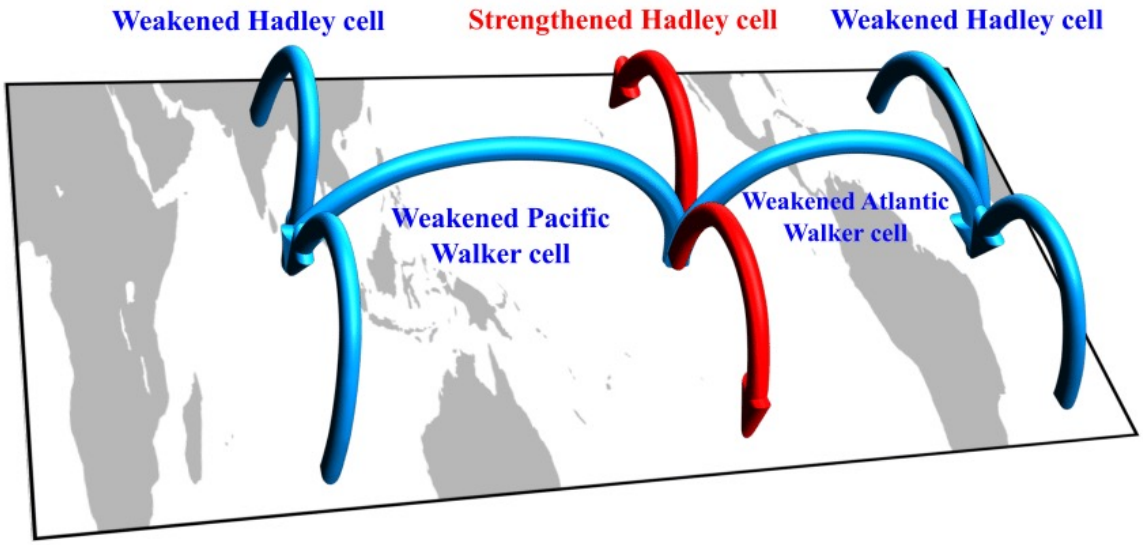

CC between Station Tmean and PakTmean
Correlation Coefficient
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Astore
Gupis
Gilgit
Chillas
Bunji
Skardu
uzaffarabad
uari Dupatta
Kotli
Chitral
Dir
Drosh
Saidu Sharif
Balakot
Kakul
Peshawar
Cherat
Parachinar
Kohat
DIKhan
Islamabad
Murree
Jhelum
Mianwali
Sialkot
Sargodha
Faisalabad
Lahore
hawalnagar
Multan
Bahawalpur
Khanpur
Quetta
Barkhan
Sibbi
Jacobabad
Kalat
Khuzdar
OKKUNDI
Dalbadin
Panjgur
Jiwani
Pasni
Rohri
Padidan
Nawabshah
Chhor
Hayderabad
Karachi

Cont……





- The upper-level height anomalies favour the sinking atmospheric motion, increasing the upper to mid tropospheric air temperature, restricting the middle and low-level cloud formation implying an increase in surface solar radiation.



Source: wang et. Al., 2019