Synchronization of the Recent East African Long Rains Decline and Northwestern Asian Warming

Samson Hagos

Earth Scientist

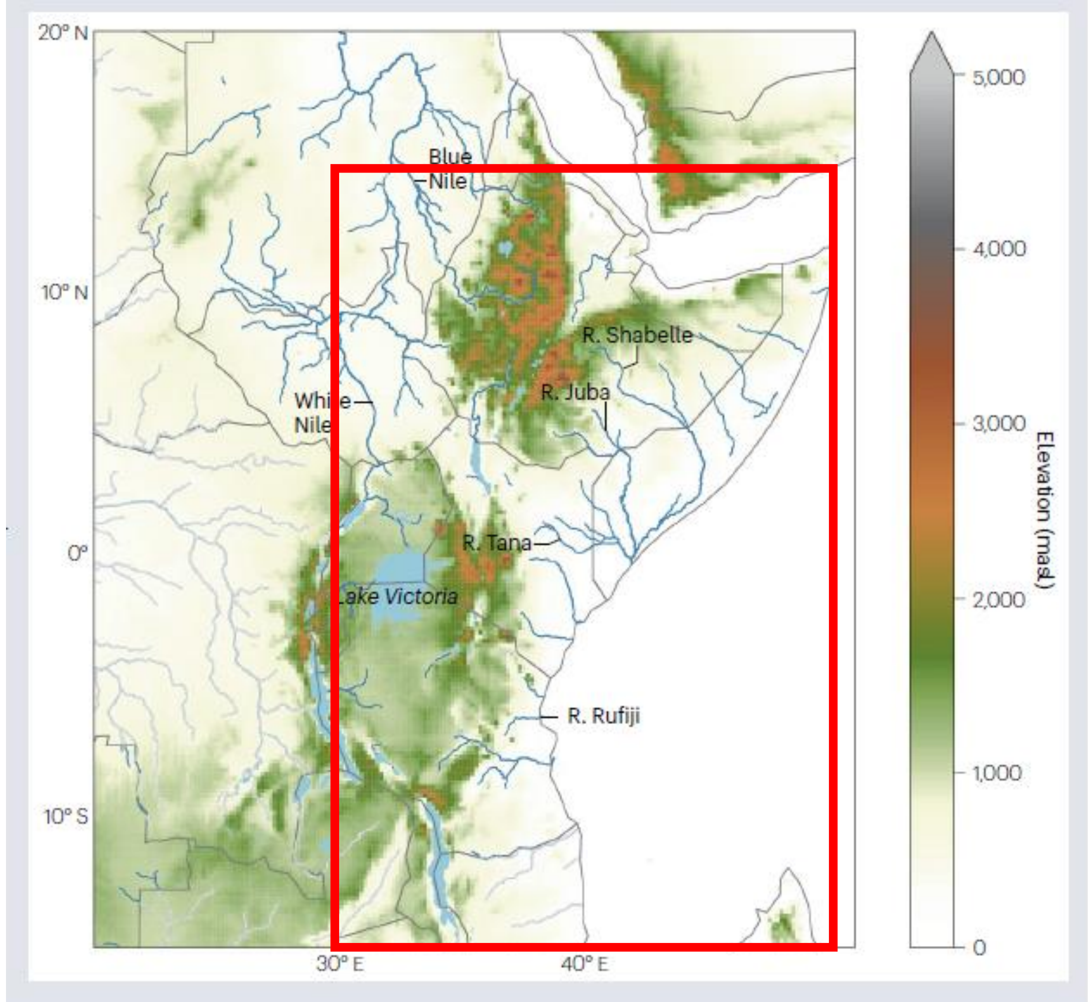
Pacific Northwest National Laboratory

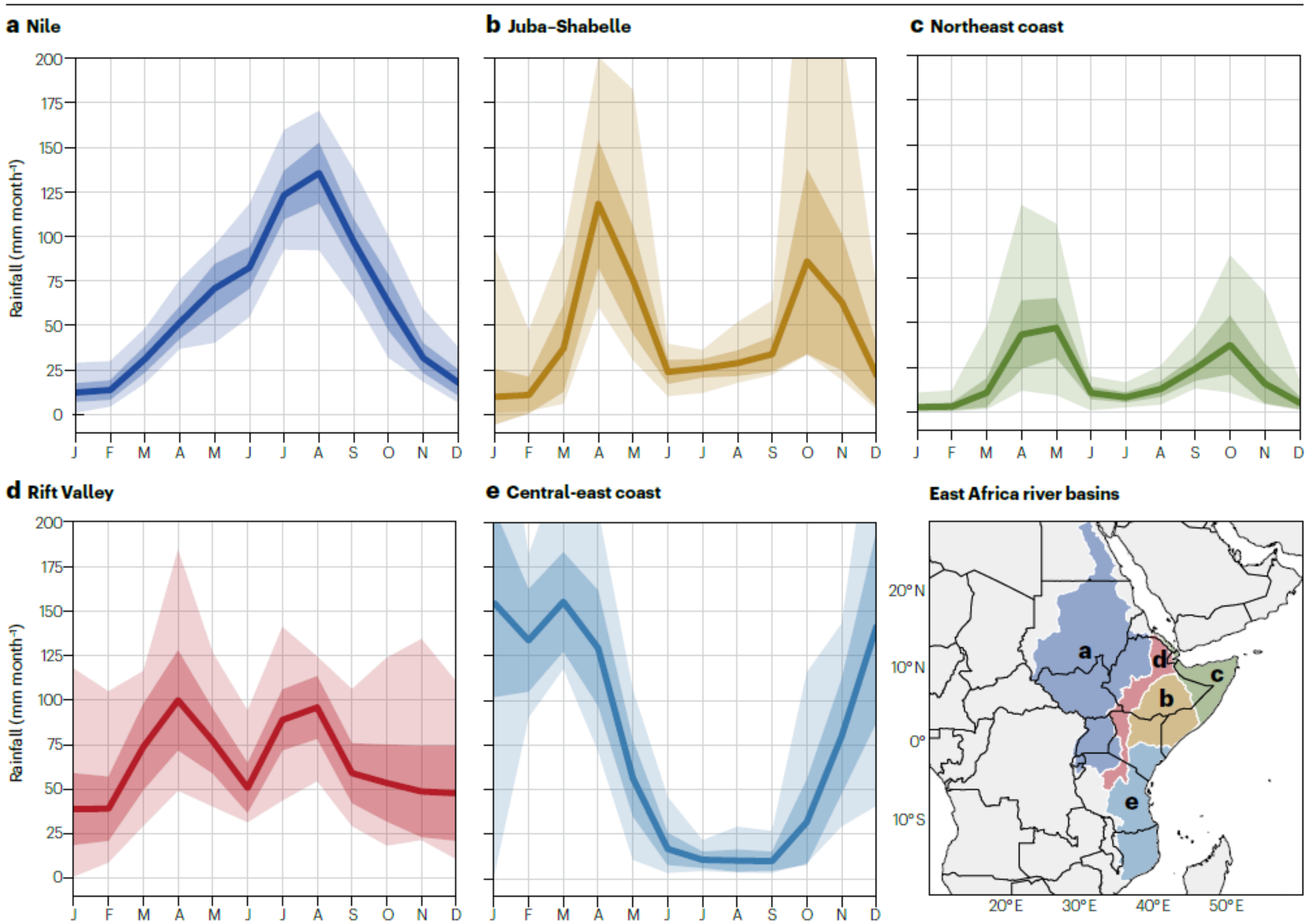
Richland WA USA

Contributors: *Po-Lun Ma, Sandro W. Lubis, Karthik Balaguru, Chuan-Chieh (Jay) Chang, Pengfei Shi, Oluwayemi Garuba, L. Ruby Leung*

PNNL is operated by Battelle for the U.S. Department of Energy

Introduction: The geography and climatology of East Africa





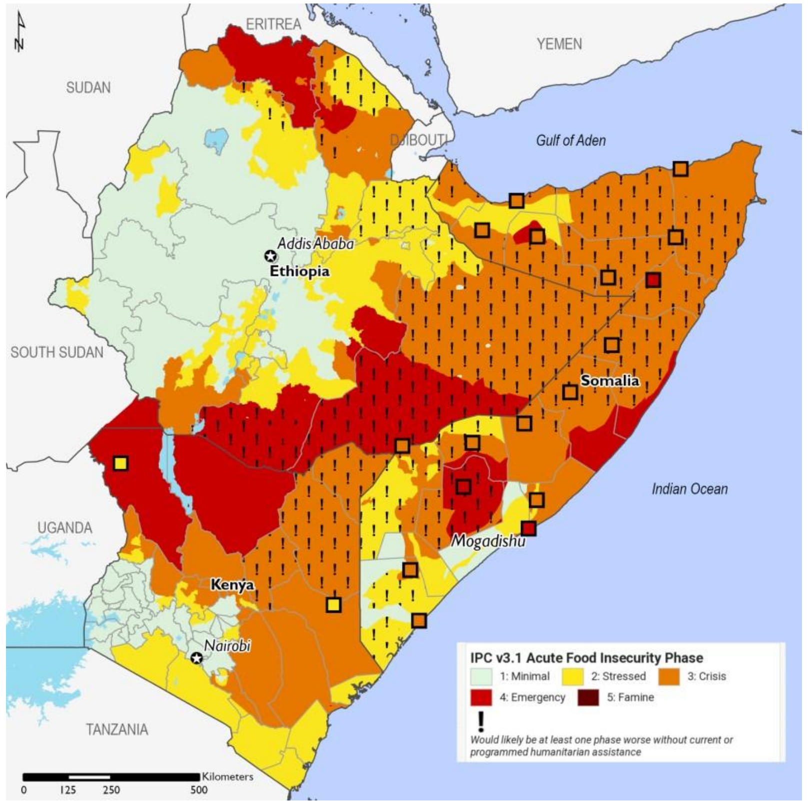
- East Africa is defined by its geographical diversity.
- While variable depending on latitude, the region is marked by two rainy seasons MAM and SON often referred to as "long rains" and "short rains" respectively.

Adapted from Palmer et al. (2022) Nature Reviews Earth and Environment

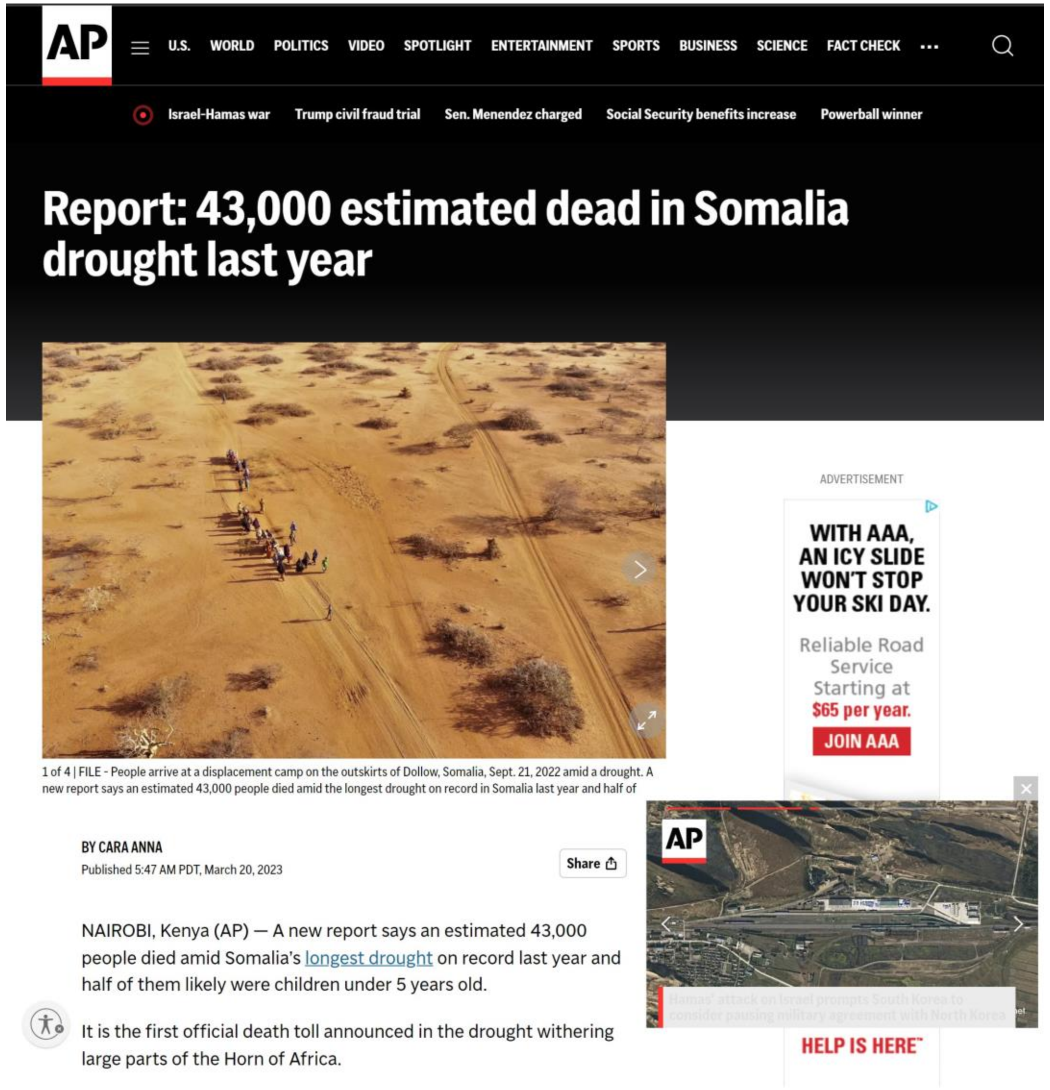
Introduction: Droughts

Droughts have a devastating impact on the lives and livelihoods of populations of the region.

2020–2023 Horn of Africa droughts



FEWS (Famine Early Warning System) map of the region between October 2022 to January 2023.



AP | U.S. WORLD POLITICS VIDEO SPOTLIGHT ENTERTAINMENT SPORTS BUSINESS SCIENCE FACT CHECK ...

Israel-Hamas war | Trump civil fraud trial | Sen. Menendez charged | Social Security benefits increase | Powerball winner

Report: 43,000 estimated dead in Somalia drought last year

1 of 4 | FILE - People arrive at a displacement camp on the outskirts of Dollow, Somalia, Sept. 21, 2022 amid a drought. A new report says an estimated 43,000 people died amid the longest drought on record in Somalia last year and half of

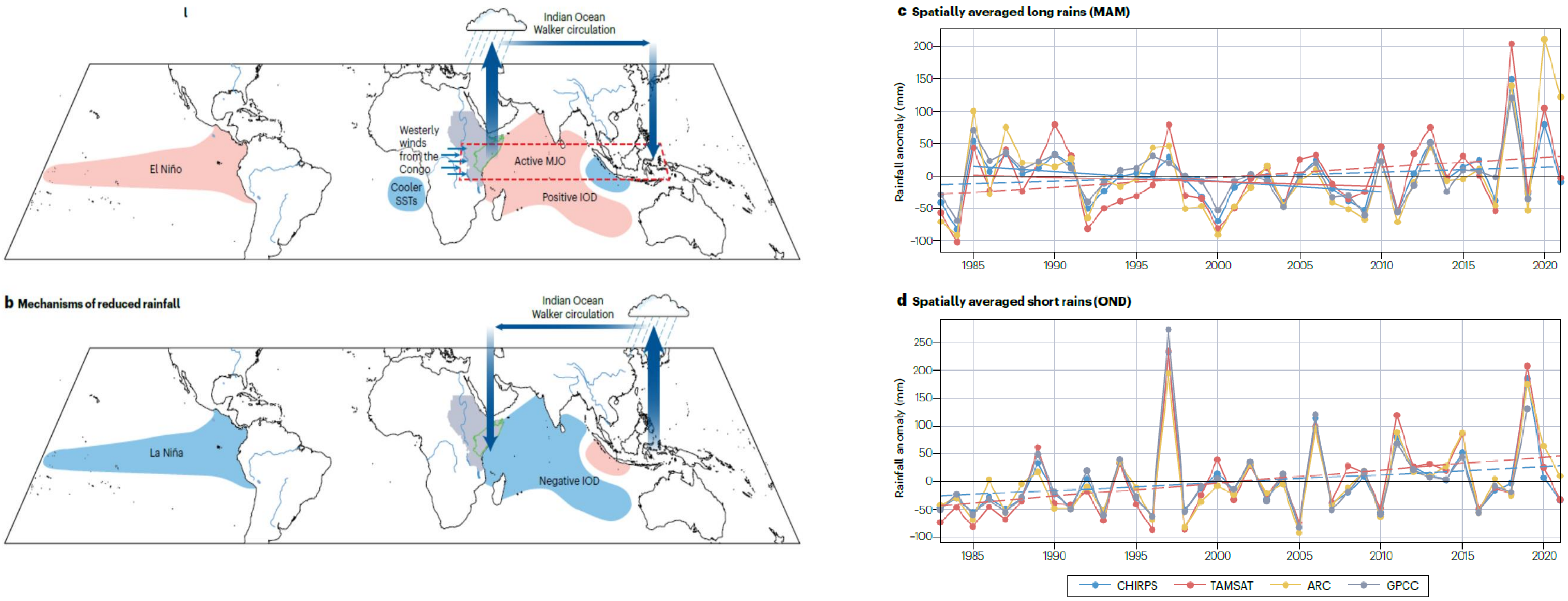
BY CARA ANNA
Published 5:47 AM PDT, March 20, 2023

Share

NAIROBI, Kenya (AP) — A new report says an estimated 43,000 people died amid Somalia's longest drought on record last year and half of them likely were children under 5 years old.

It is the first official death toll announced in the drought withering large parts of the Horn of Africa.

Introduction: Interannual and decadal variability and extremes

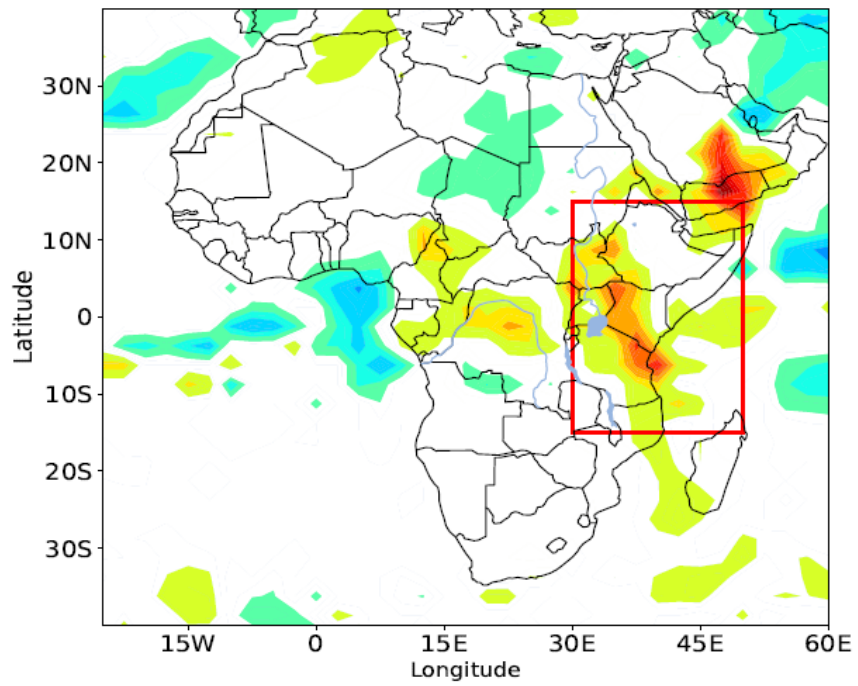


- In general the variability is related to the modulation of walker circulation by SSTs over the tropical oceans (ENSO, IOD and PDO).

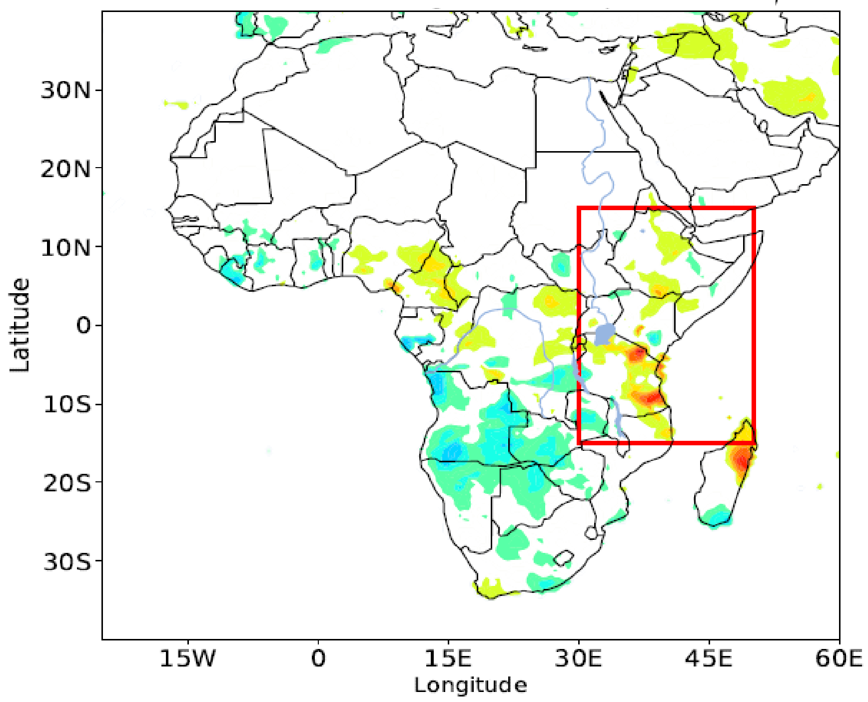
Adapted from Palmer et al. (2022) Nature Reviews Earth and Environment

A robust decline in “long rains” has been observed from 1980 to 2014

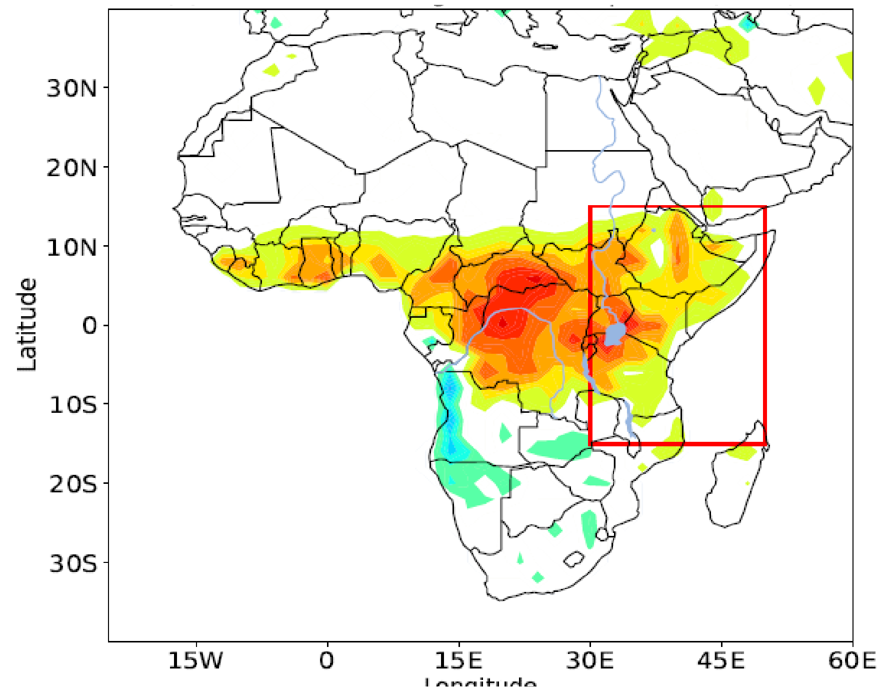
GPCP

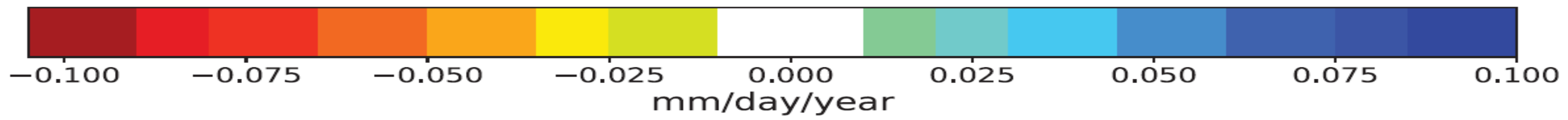


CRU

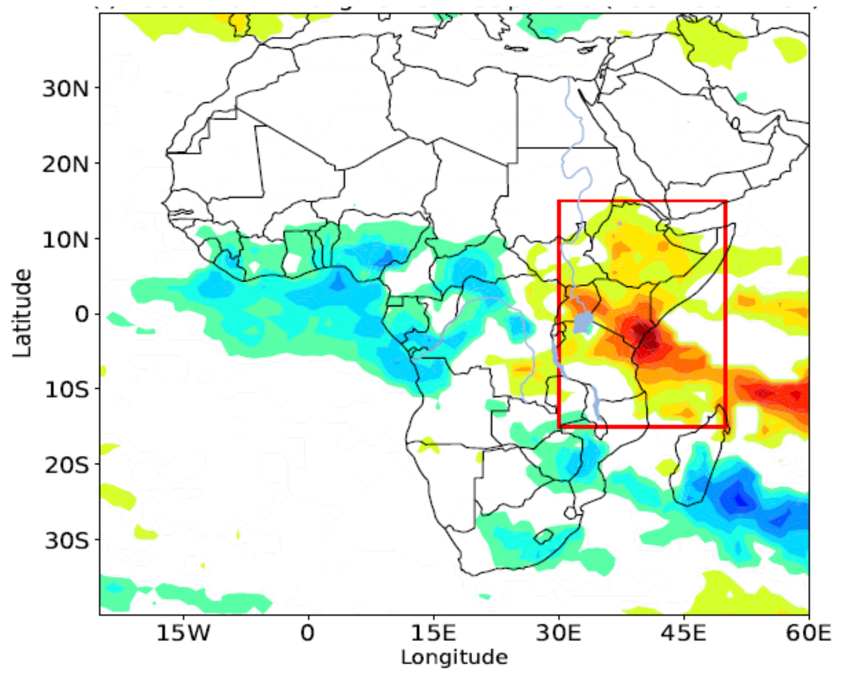


ERA5



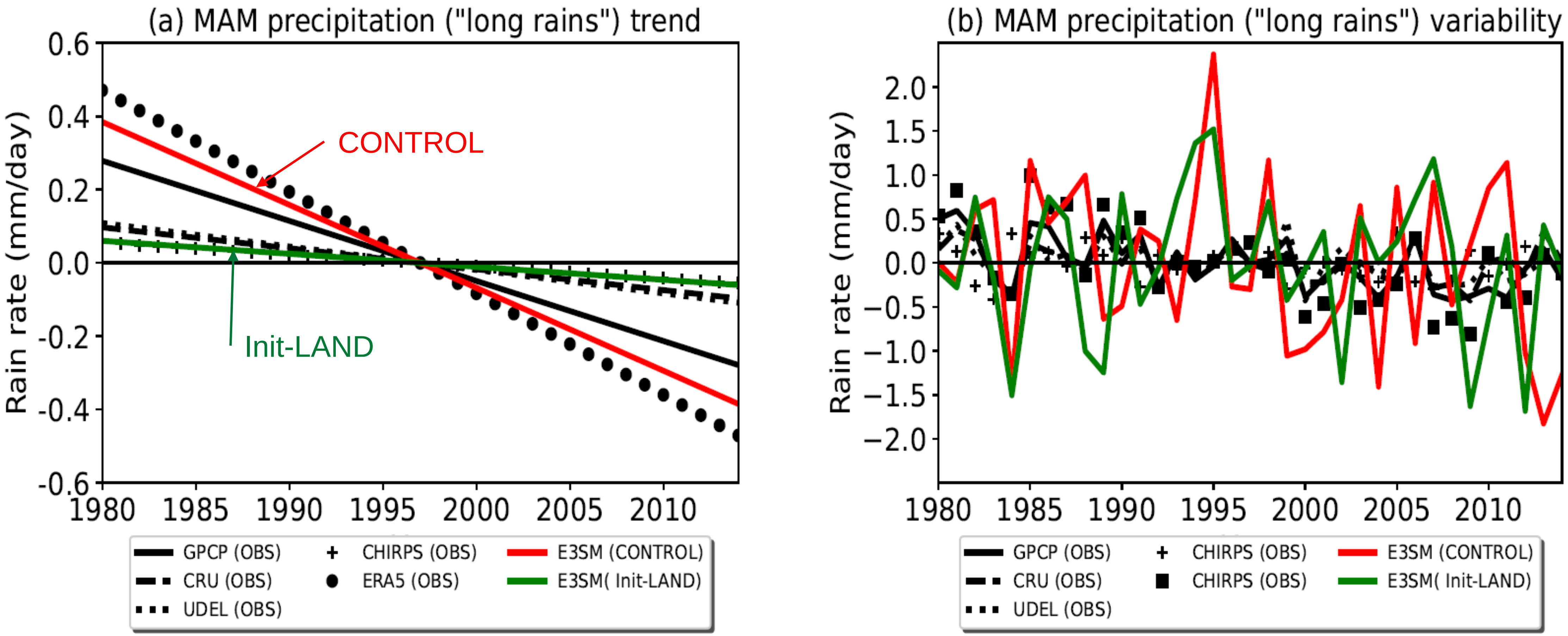


E3SM-V2 CONTROL simulation



- Multiple observational products confirm the long-term decline of East African March-April-May rainfall but there is some spread in the magnitude and areal extent.
- E3SM V2 Control simulation captures this trend.

Role of land surface feedback in the long-term decline and inter-annual variability of long rains



- The contrast between trend in CONTROL (red) and Init-LAND (green) indicates much of the decline involves land-surface feedbacks.
- The inter-annual variability is affected by the land-surface feedbacks.

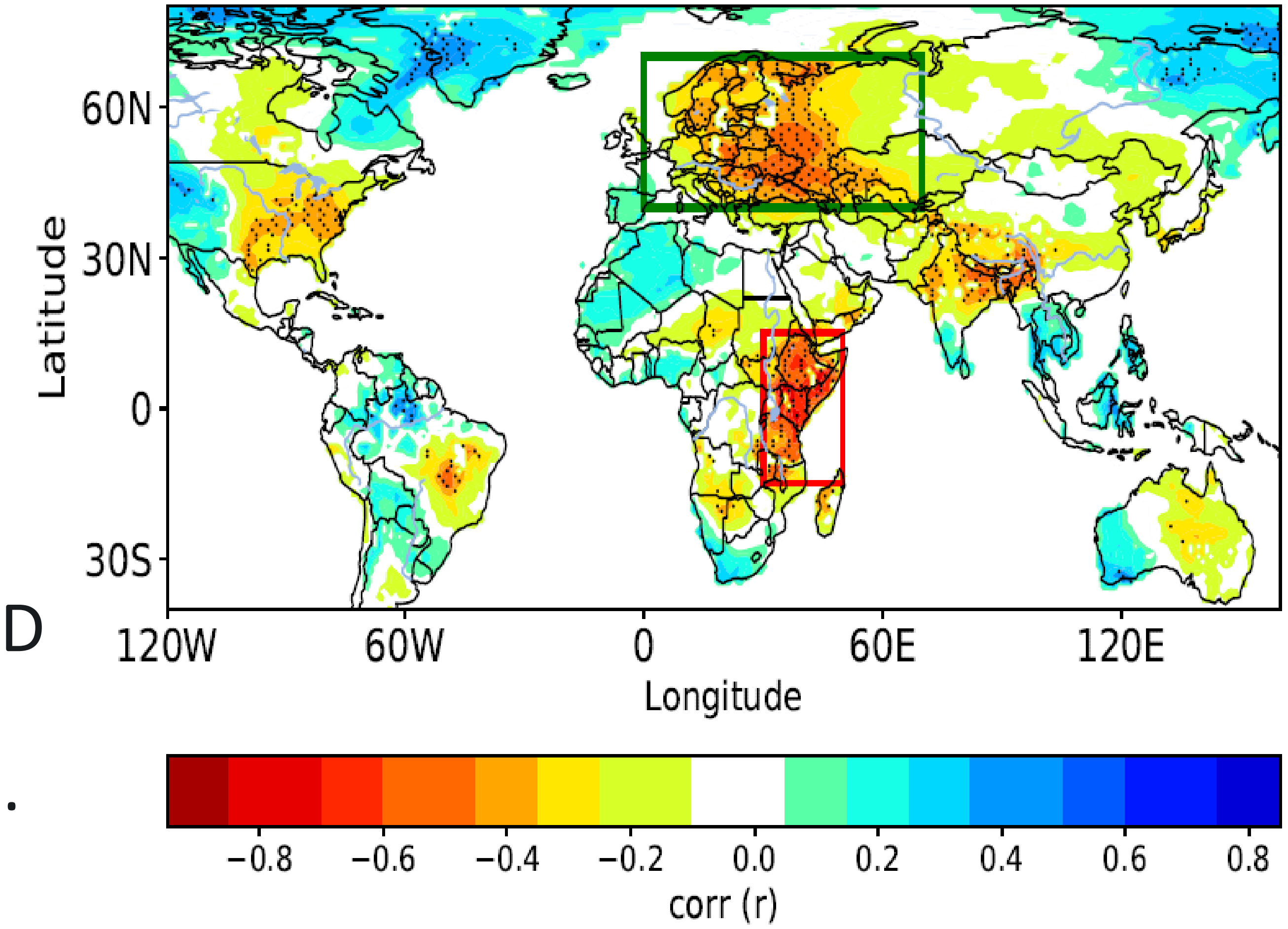
Remote impacts of land surface temperature

$$\Delta EA\_Precip = EA\_Precip_{control} - EA\_Precip_{init-LAND}$$

$$\Delta TSFC = TSFC_{control} - TSFC_{init-LAND}$$

- The difference in East African “long rains” precipitation between CONTROL and Init-LAND simulations is **strongly correlated with land surface temperature over northwestern Asia**.

Correlation between ΔEA_Precip and $\Delta TSFC$



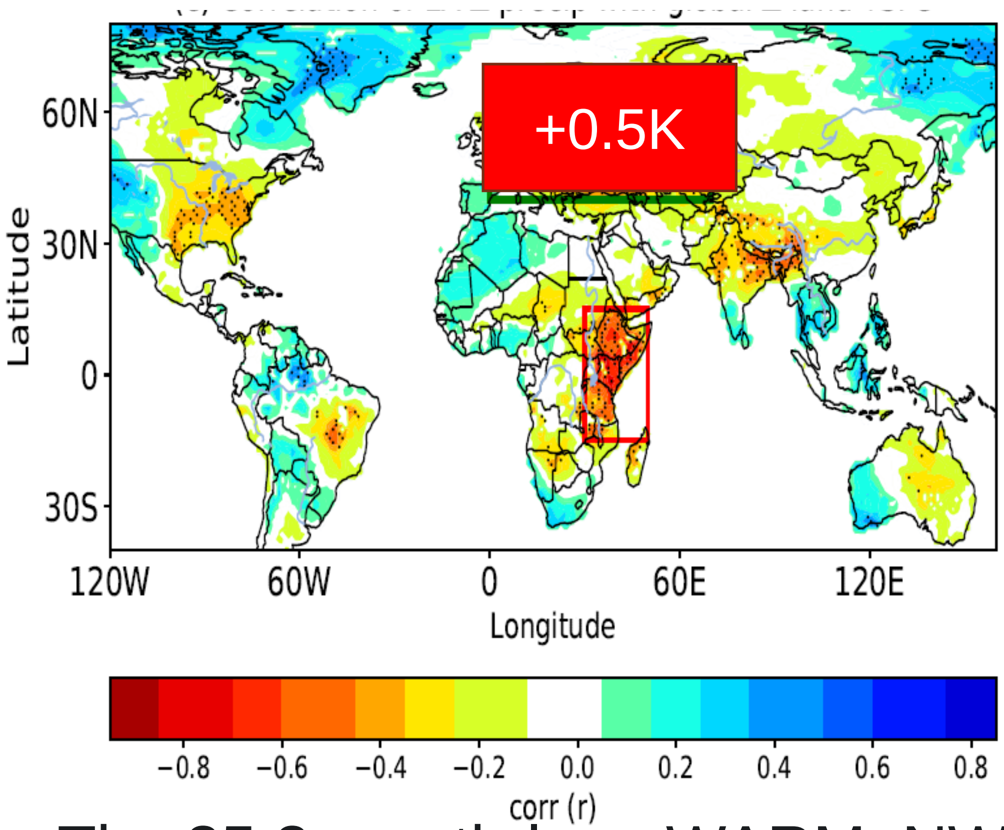
The dots mark correlations with statistical significance at 95 percentile.

Investigation of Causality

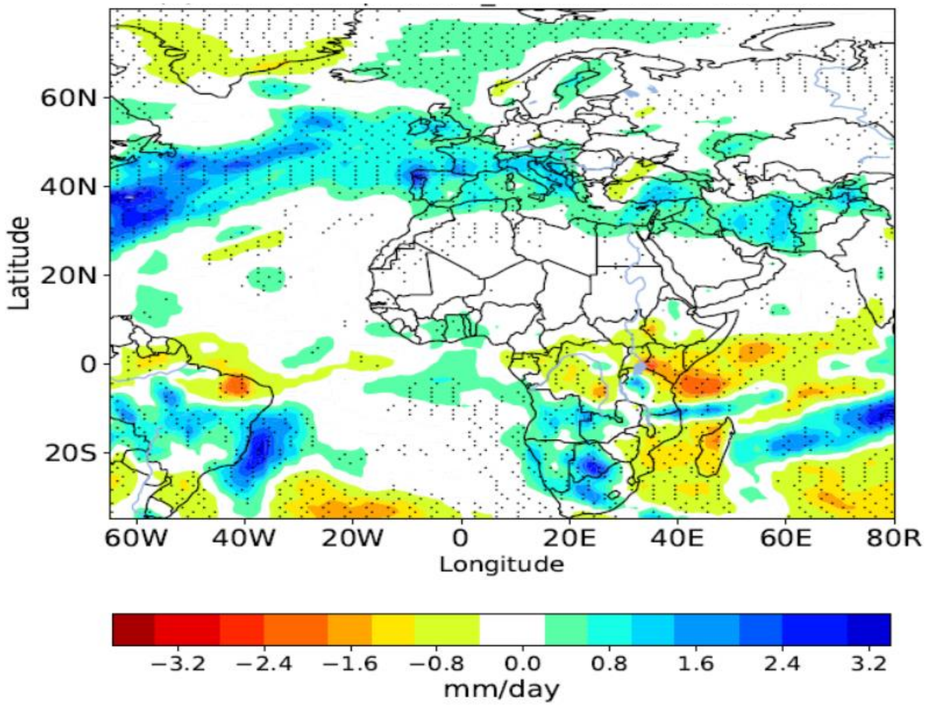
- How does the warming over northwest Asia affect East Africa long rains?

Idealized simulations

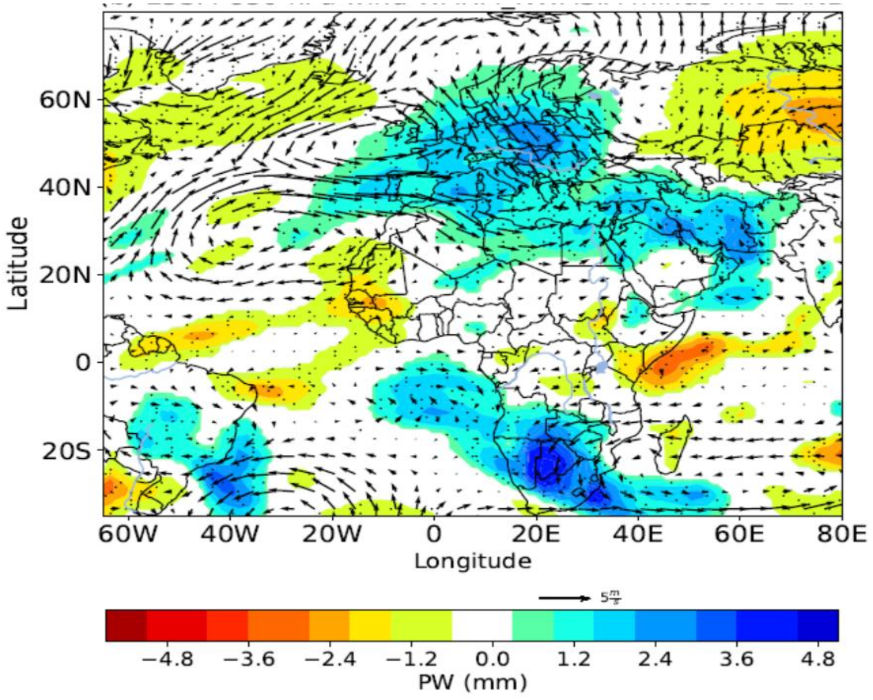
WARM_NWASIA ensemble of E3SM experiments



Impact on precipitation



Impact on PW and Circulation

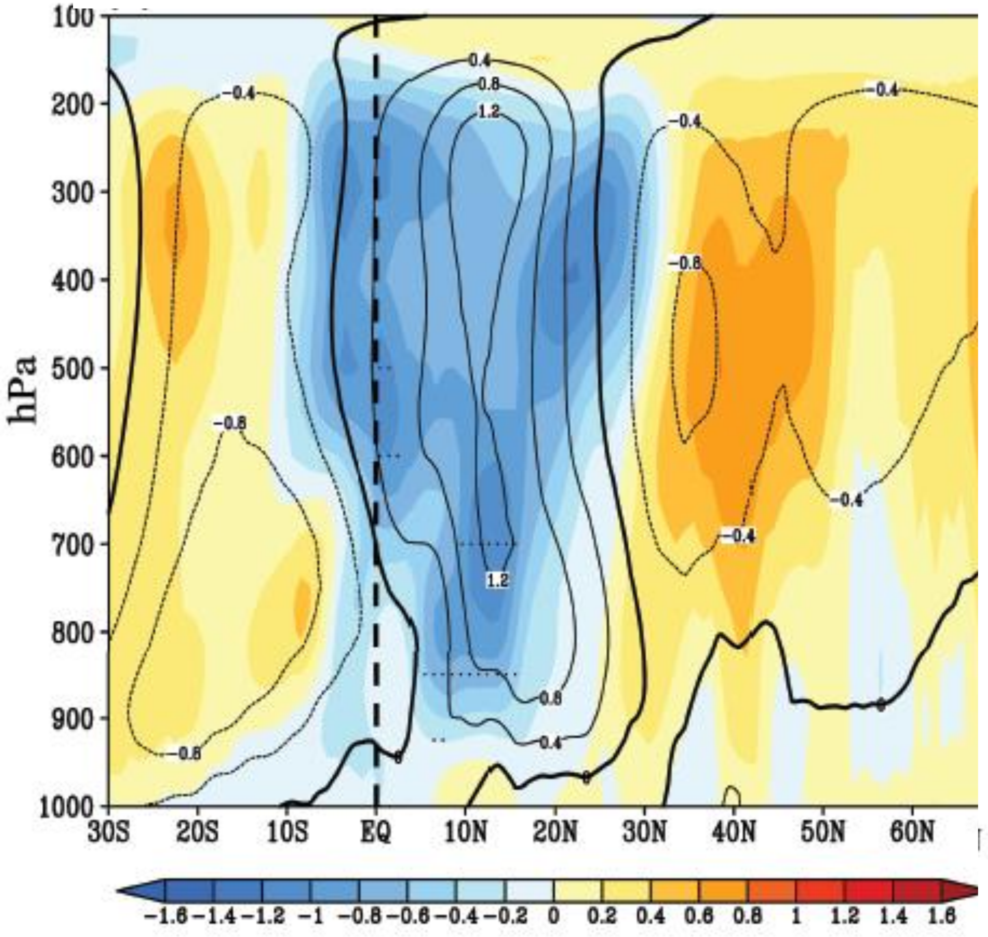


- The 35 3 month-long WARM_NWASIA experiments are initialized with a +0.5 K warming over northwestern Asia

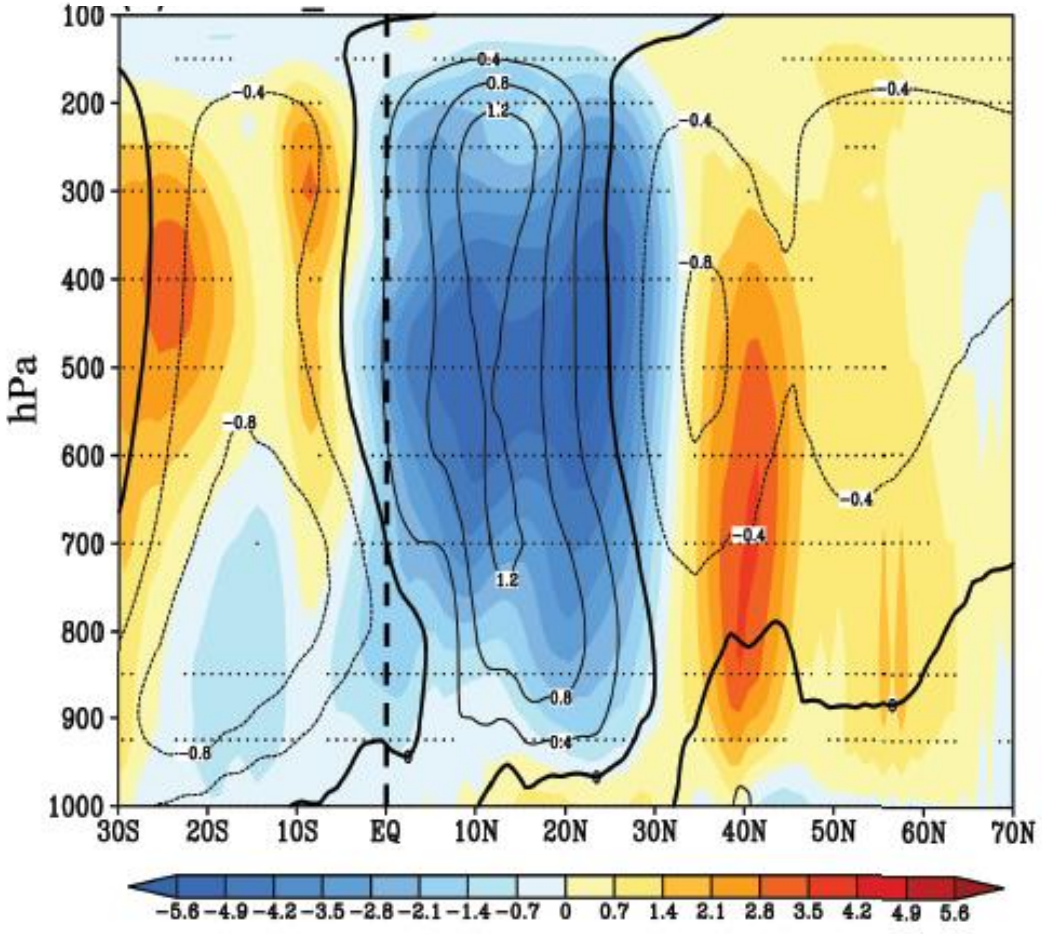
- Warming over northwestern Asia introduces dry conditions over Eastern Africa

Investigation of Causality Mechanism

Control minus Init-LAND



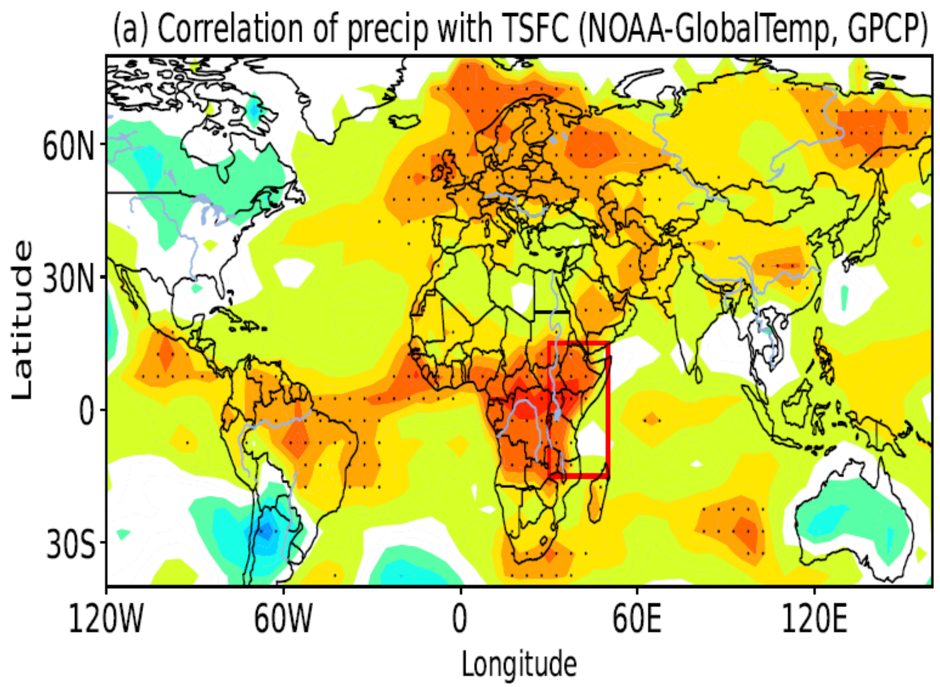
WARM_NWASIA minus Init-LAND

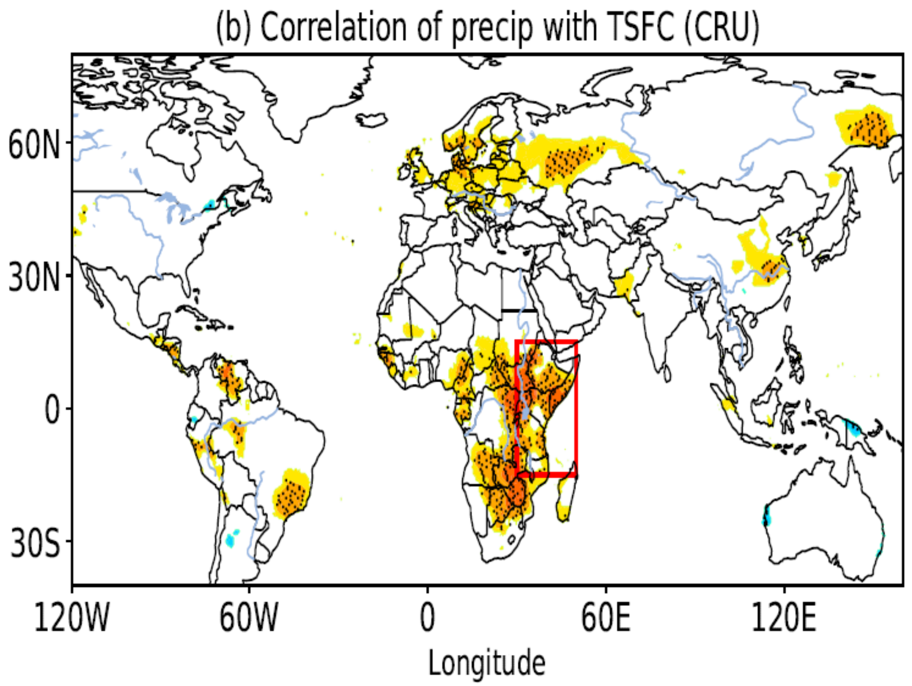


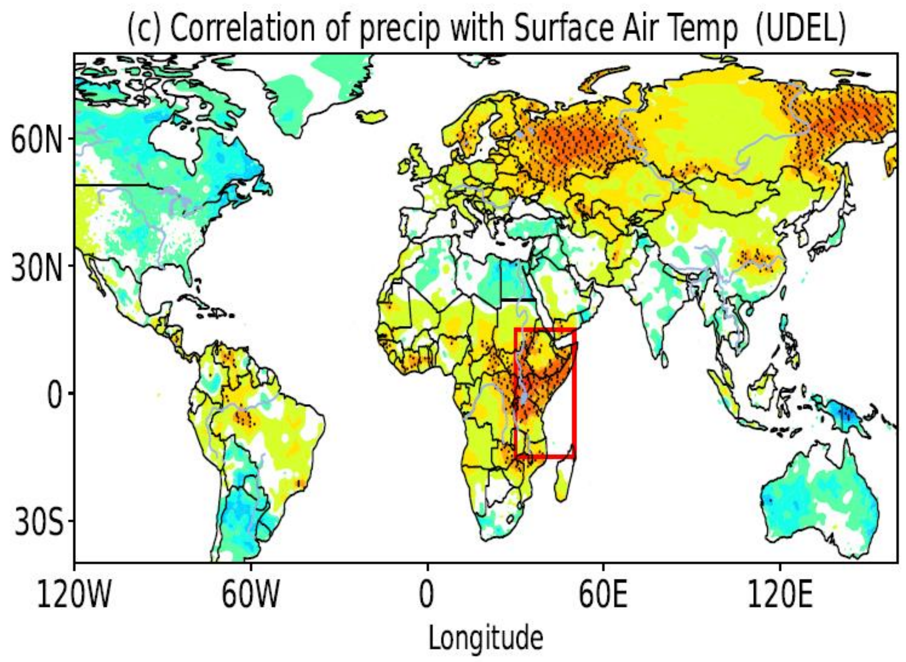
MAM seasonal-mean meridional stream function averaged over 30°E-50° E.

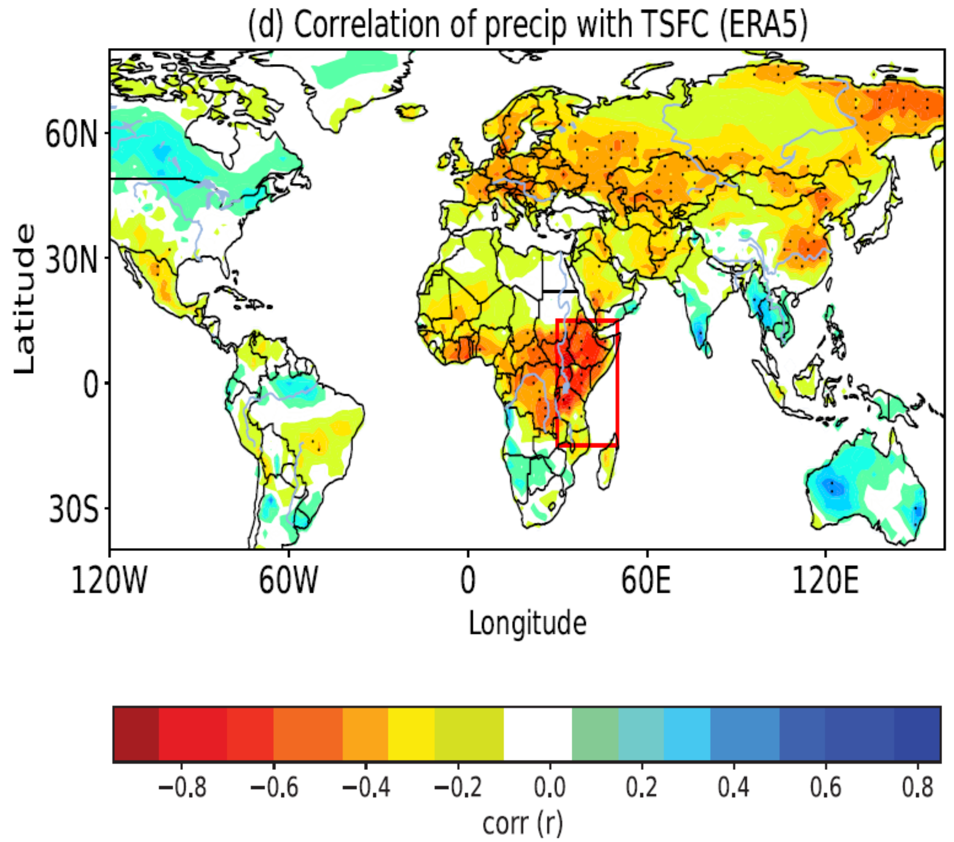
- Warming over northwestern Asia weakens the regional Hadley cell, introduces subsidence over eastern Africa.

Observational evidence of synchronization







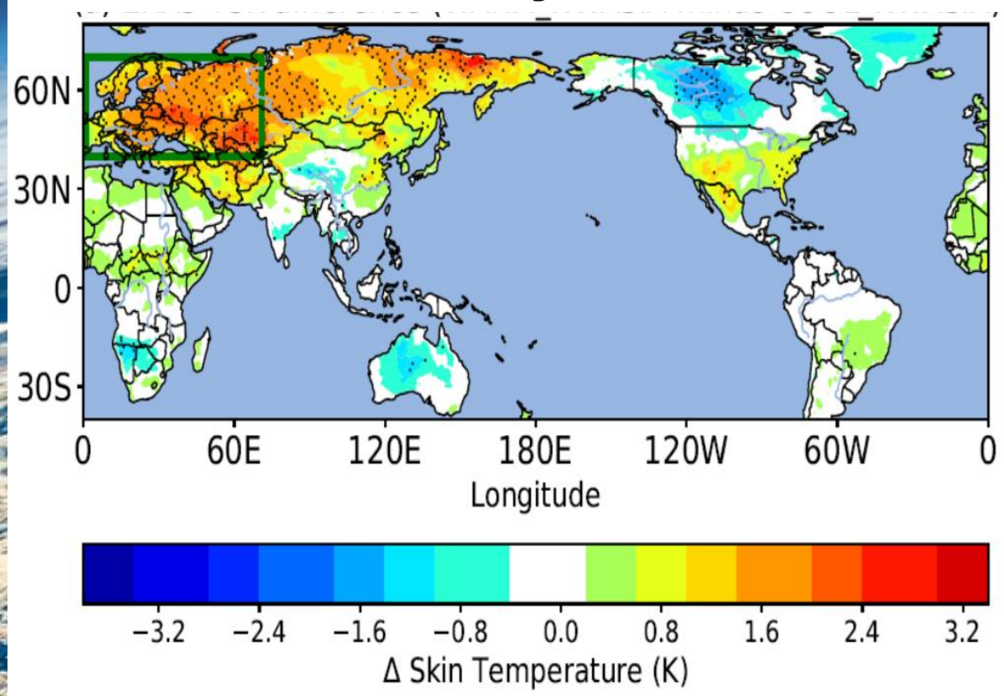


- Statistically significant correlation between observed MAM precipitation averaged over East Africa with observed MAM average land temperatures indicates a robust synchronization between Northwestern Asia land surface temperature and East African Long rains precipitation.

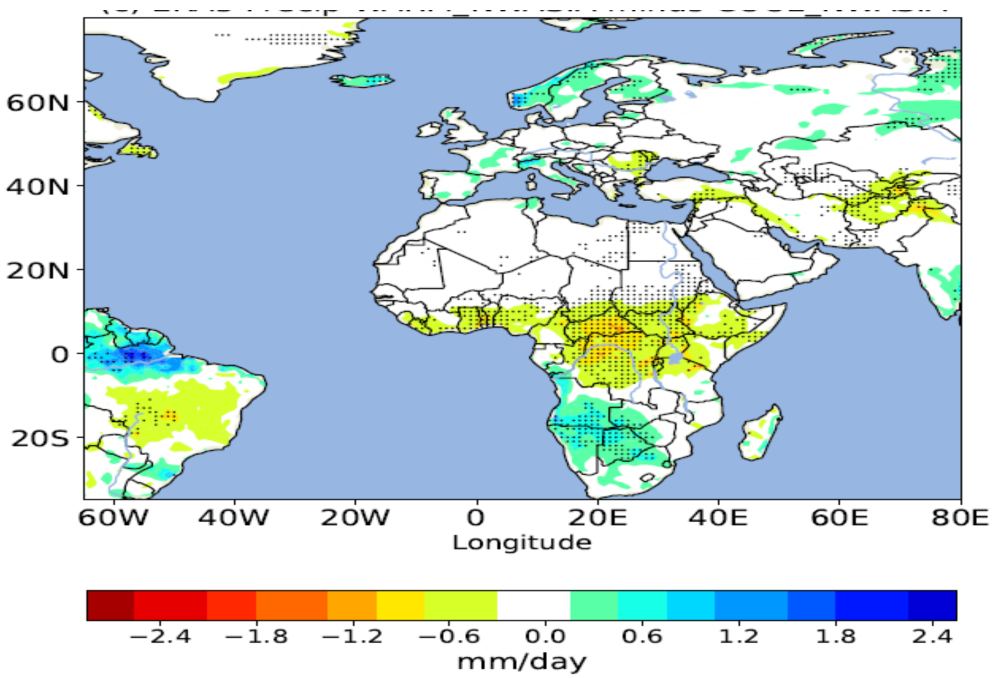
Investigation of Causality

- How does the warming over northwest Asia affect East Africa long rains?

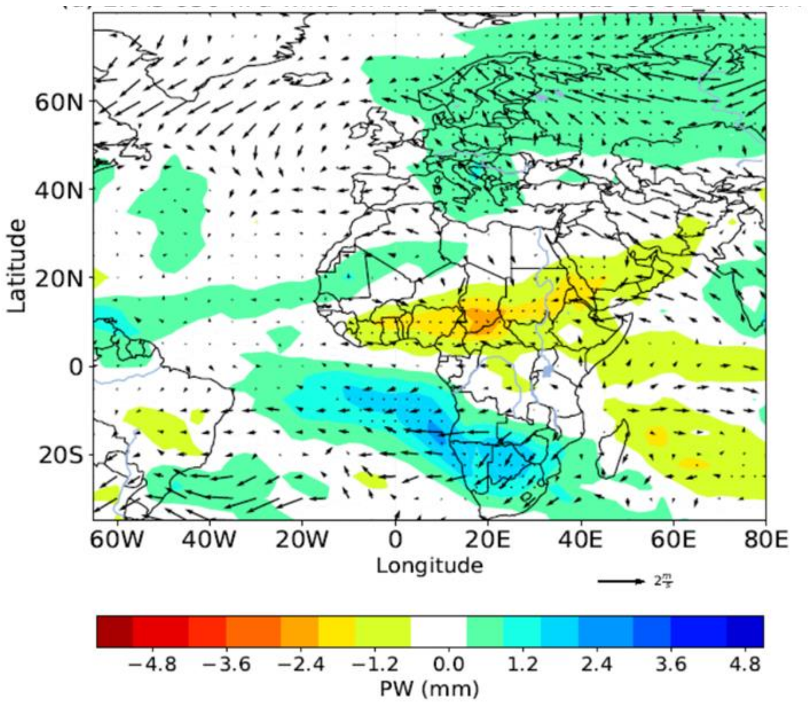
Differences in composites land surface temperature of WARM_NWASIA and COOL_NWASIA years in ERA5



Differences in precipitation

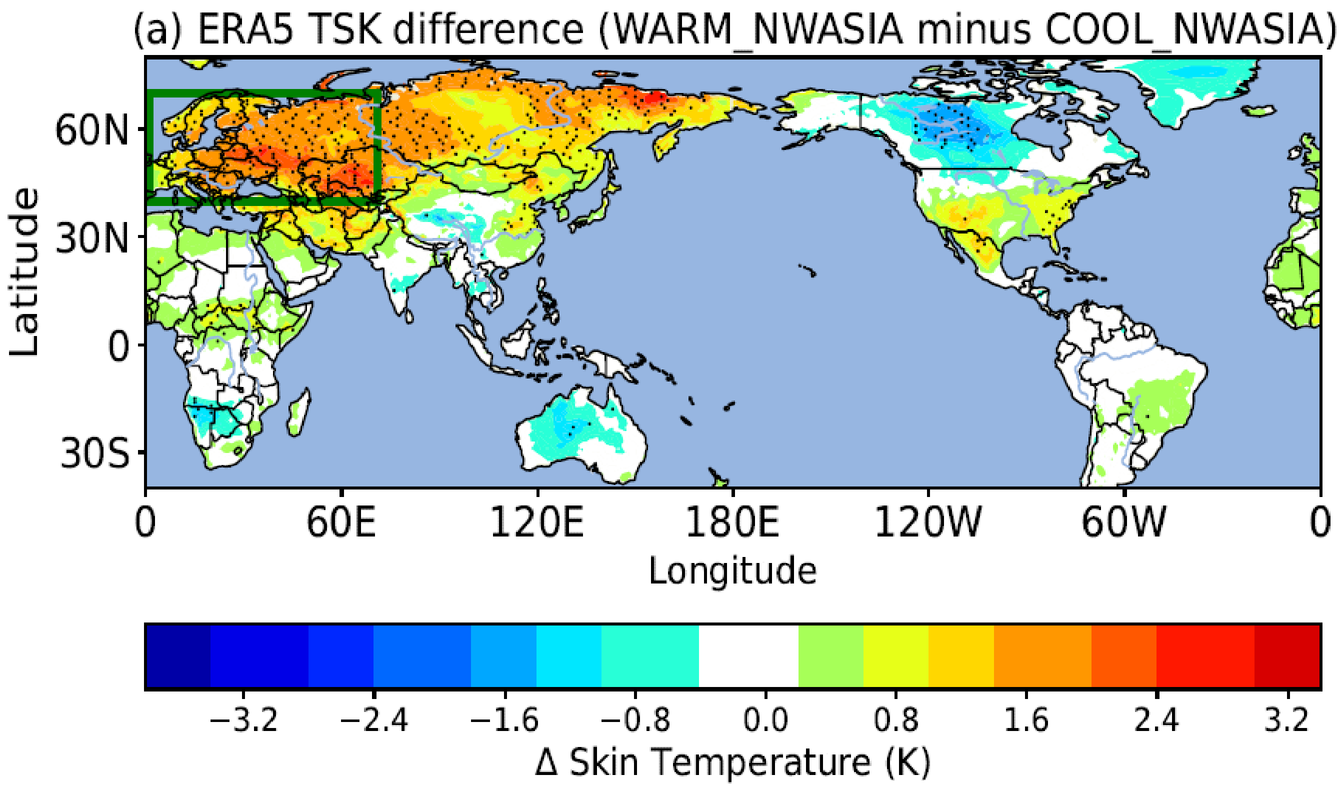


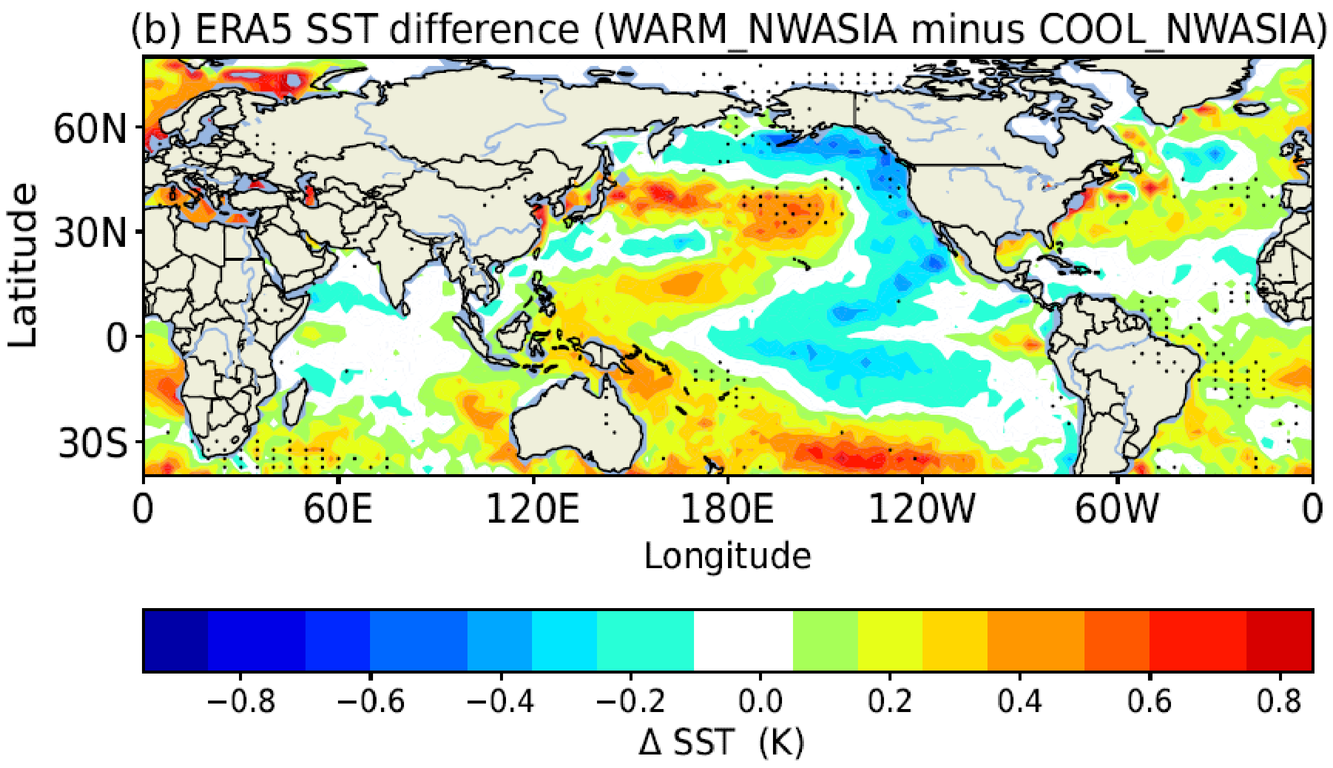
Differences in pw and circulation



Warming over Northwestern Asia is associated with dry conditions over Eastern Africa in ERA5 reanalysis as well

Relationship between the warming over land and SST patterns





- The average difference in SST between MAM WARM_NWASIA and COOL_NWASIA years from ERA5 reanalysis approximates the **cool phase of PDO** and to a lesser extent **La-Nina** conditions.
- This suggests these SST patterns may ultimately be the forcing for the precipitation deficit during East African “long rains” indirectly through warming of northwestern Asia.

Summary

- Much of previous research has been centered around the **impacts of SST variability**.
- We find a significant contribution of **warming in northwestern Asia** to the decadal decline in the East African long rains as well as to their inter-annual variability.
- While the role of cool phase of PDO and La-Nina are still important the direct impact of Pacific SSTs in the absence of **strong land surface feedback appears to be limited**.

Future work: Implications for the "East African climate Paradox"

- Is there a systematic relationship between projected changes in long rains by a global model and the ability of model to capture this impact from land surface feedback?

Pacific Northwest
NATIONAL LABORATORY

Thank you