COLUMBIA CLIMATE SCHOOL
LAMONT-DOHERTY EARTH OBSERVATORY

The seasonal cycles of the Horn of Africa rains

Kevin Schwarzwald
Columbia University, International Research Institute for Climate and Society (IRI), Lamont-Doherty Earth Observatory (LDEO)

based on work with Richard Seager, Lisa Goddard, Mingfang Ting, Kate Marvel, with additional thanks to Weston Anderson, Adam Sobel

3rd Summer School on Theory, Mechanisms and Hierarchical Modeling of Climate Dynamics: Tropical Oceans, ENSO and their teleconnections, ICTP, Trieste, Italy, July 29, 2022

COLUMBIA CLIMATE SCHOOL
LAMONT-DOHERTY EARTH OBS

The seas
Horn of A

(1966-2022)

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Columbia University, I (IRI), Lamont-Doherty Earth Observ

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IRI

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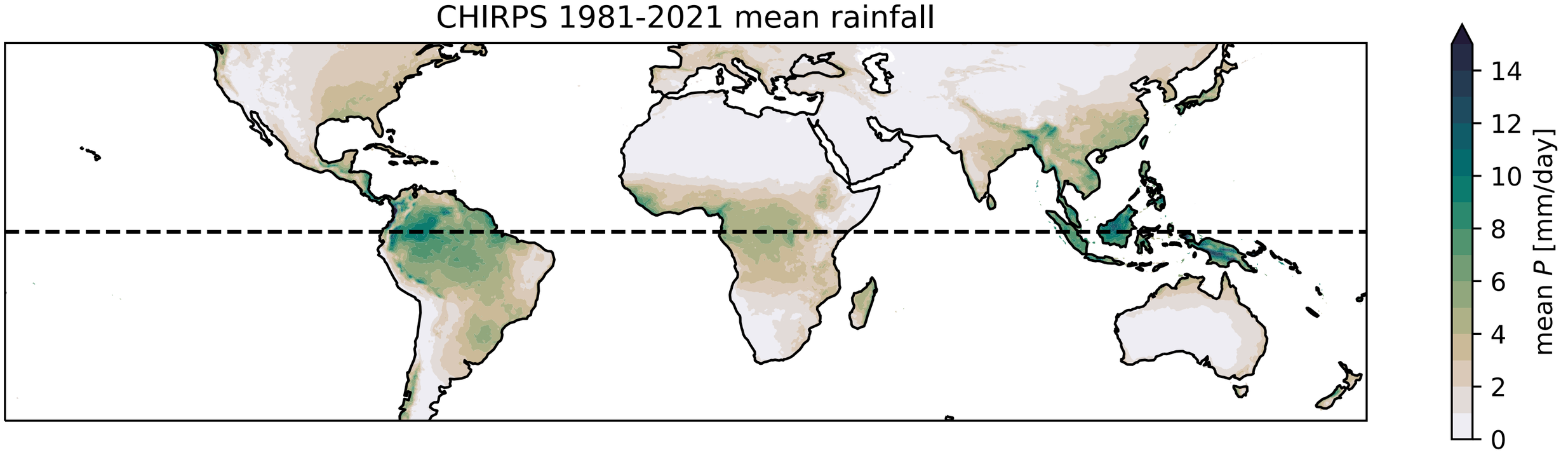
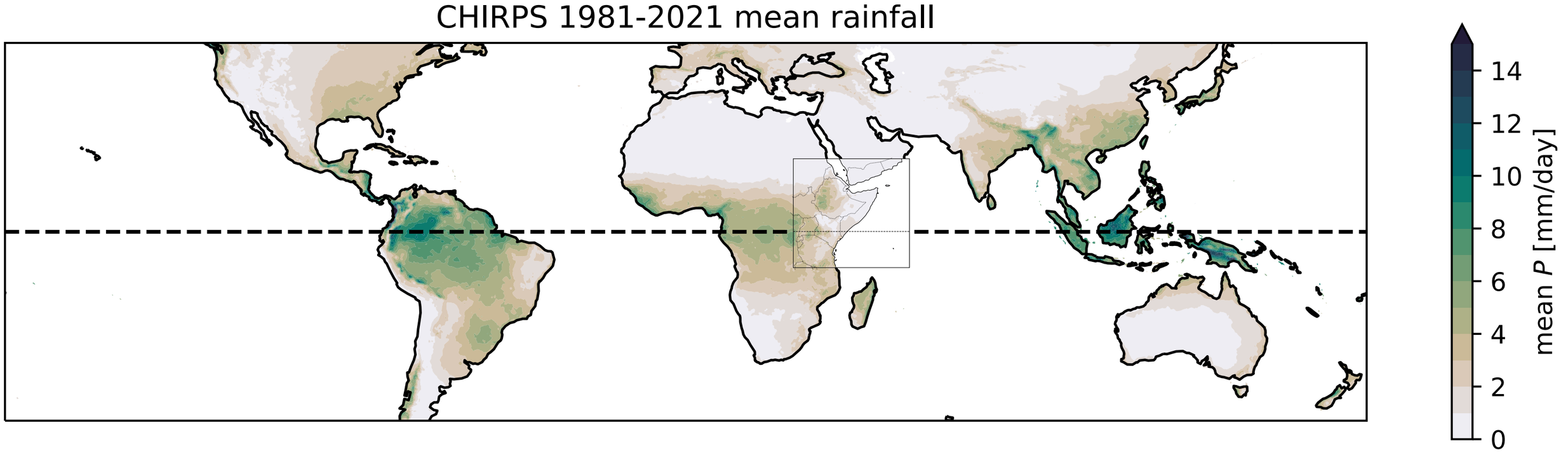

CHIRPS 1981-2021 mean rainfall
14
12
10
8
6
4
2
0
mean P [mm/day]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14
12
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6
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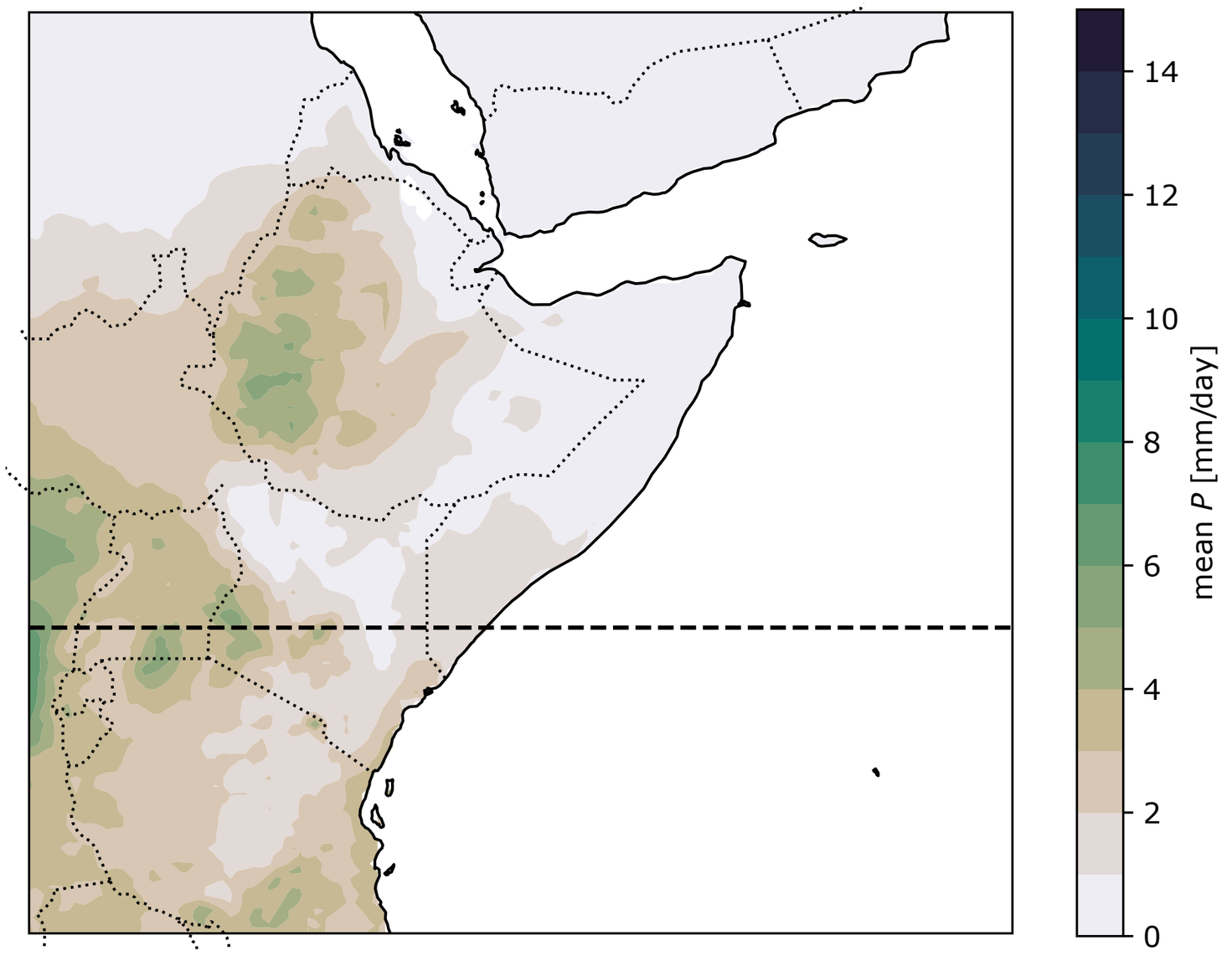
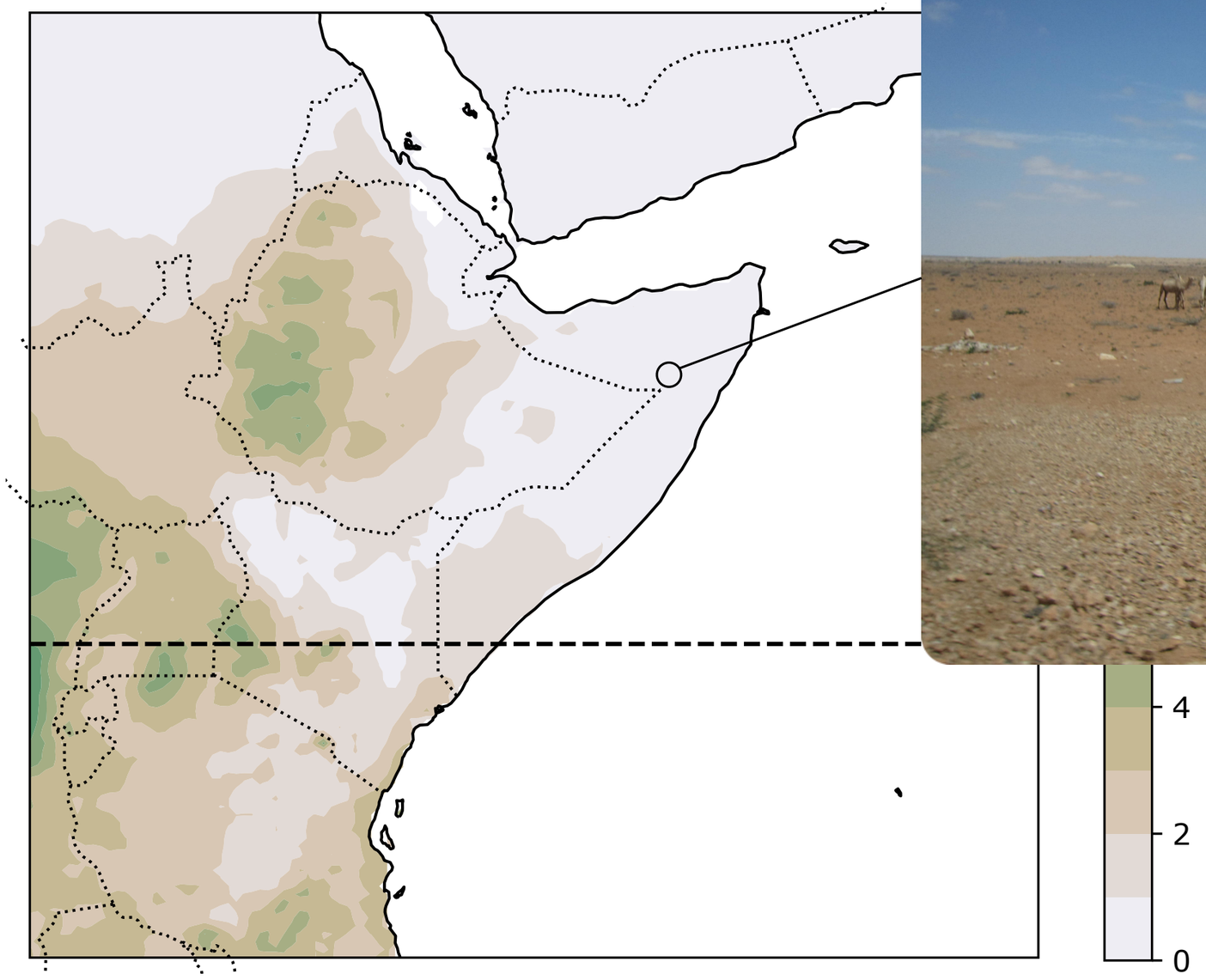
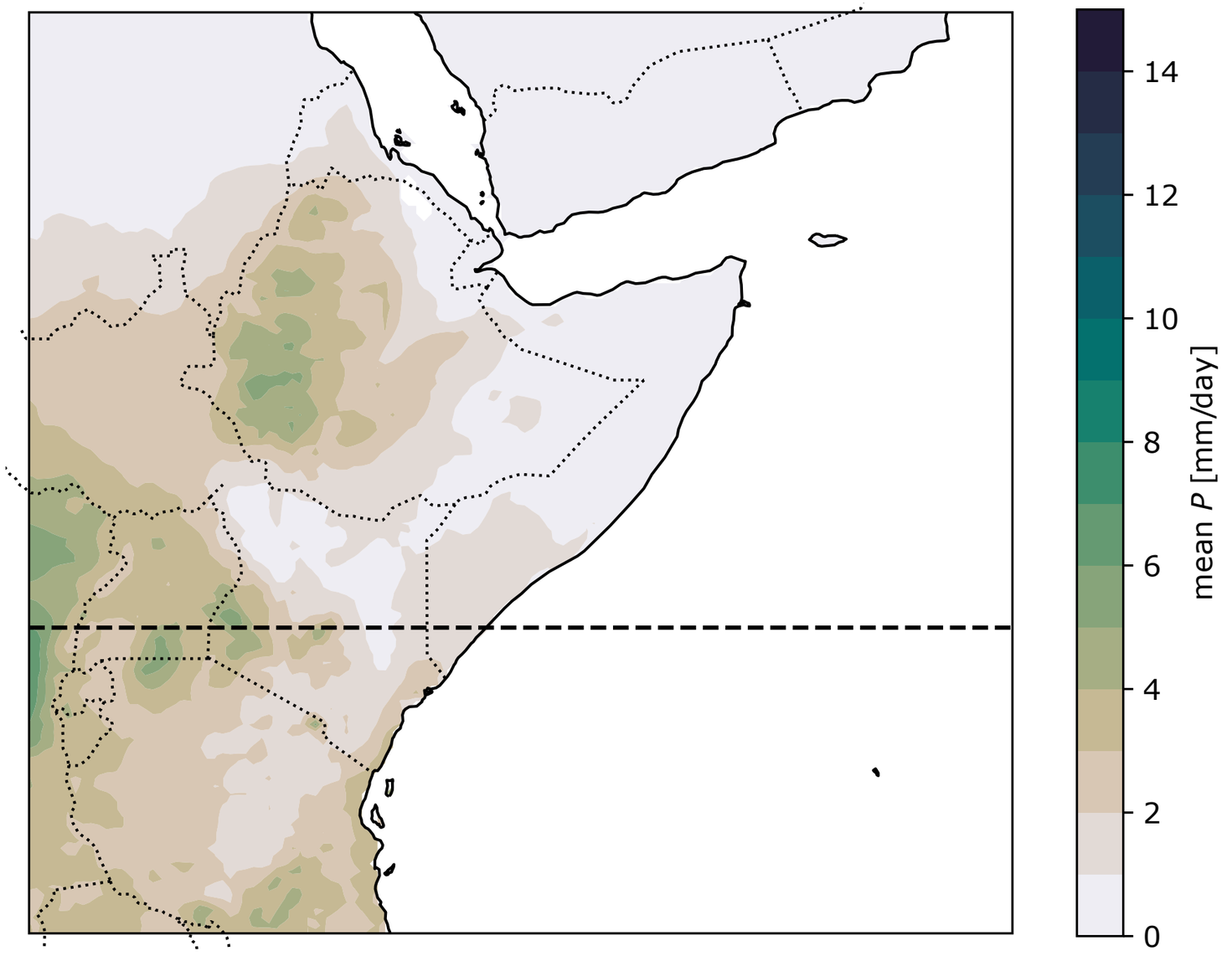
2
0
mean P [mm/day]


14
12
10
8
6
4
2
0
mean P [mm/day]

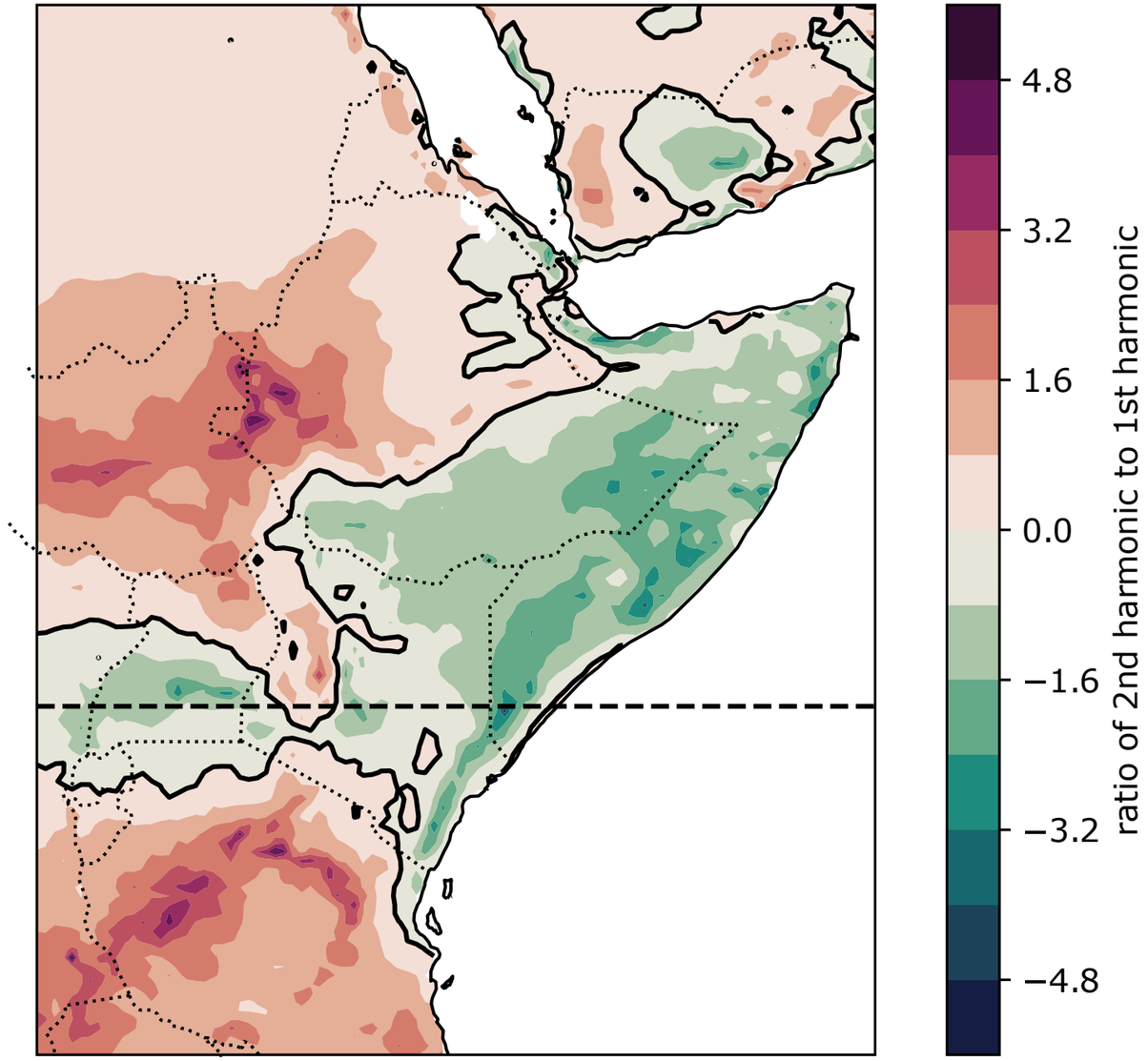


Current 4-season (soon to be 5?) drought due to the double (triple?)-dip La Niña

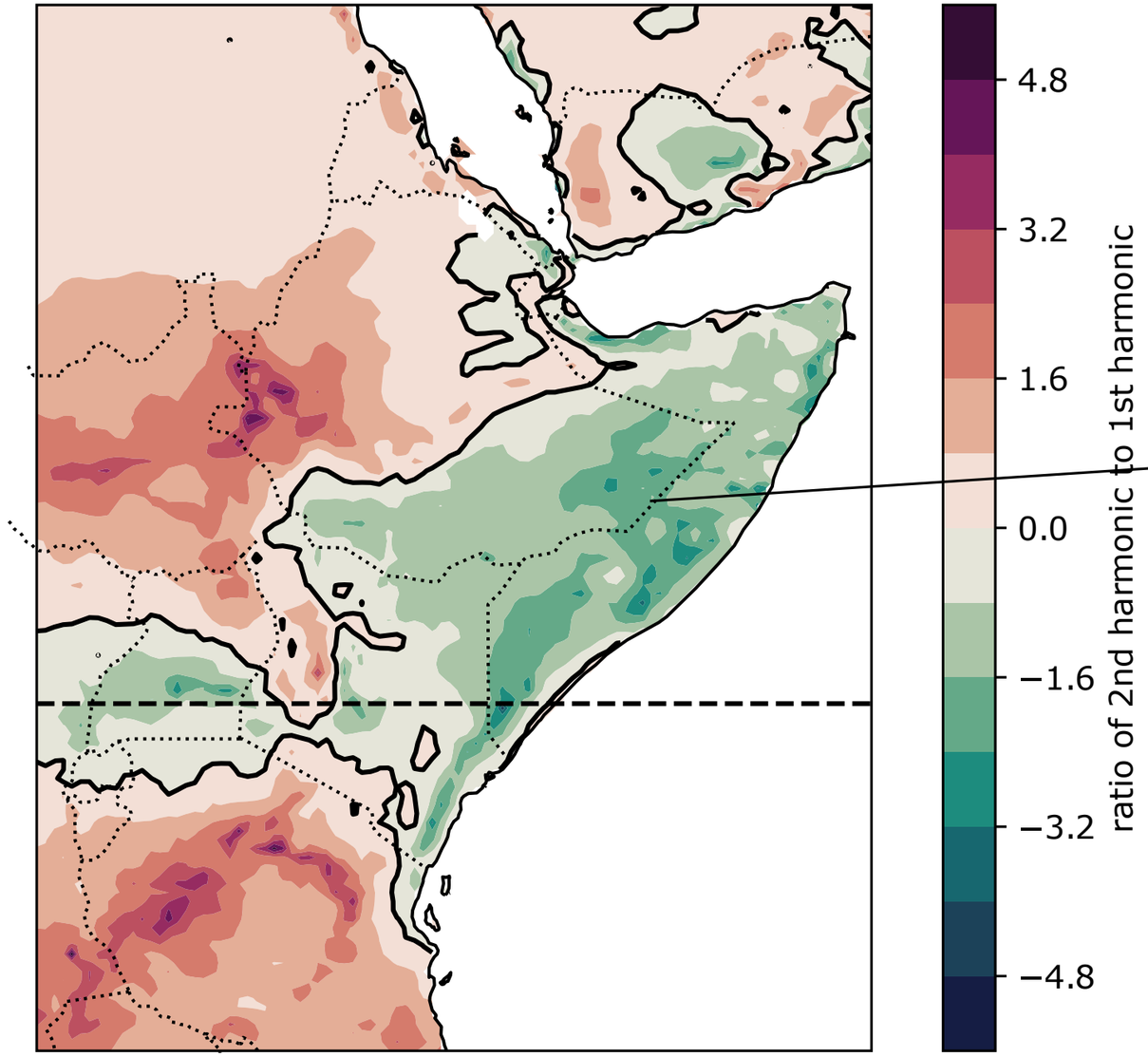
(Image: near Garowe, Puntland; IMO staff via Creative Commons)

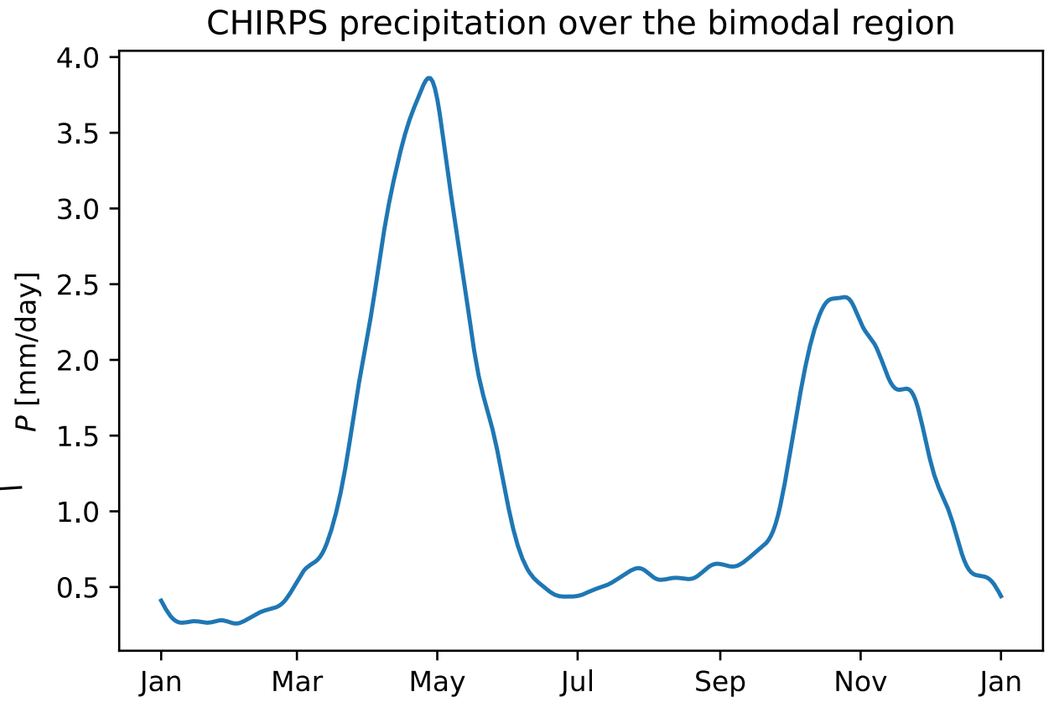

14
12
10
8
6
4
2
0
mean P [mm/day]

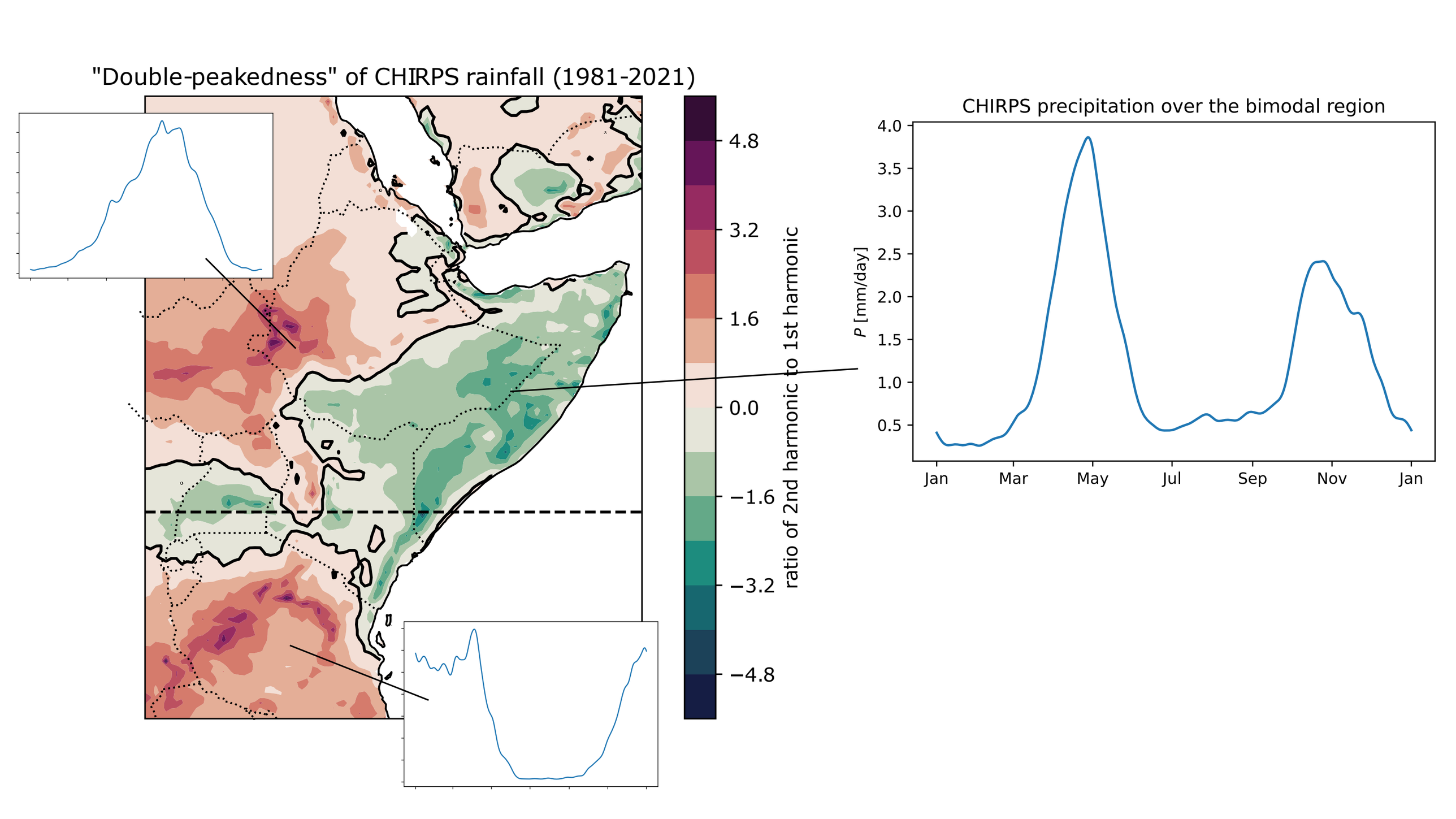
"Double-peakedness" of CHIRPS rainfall (1981-2021)



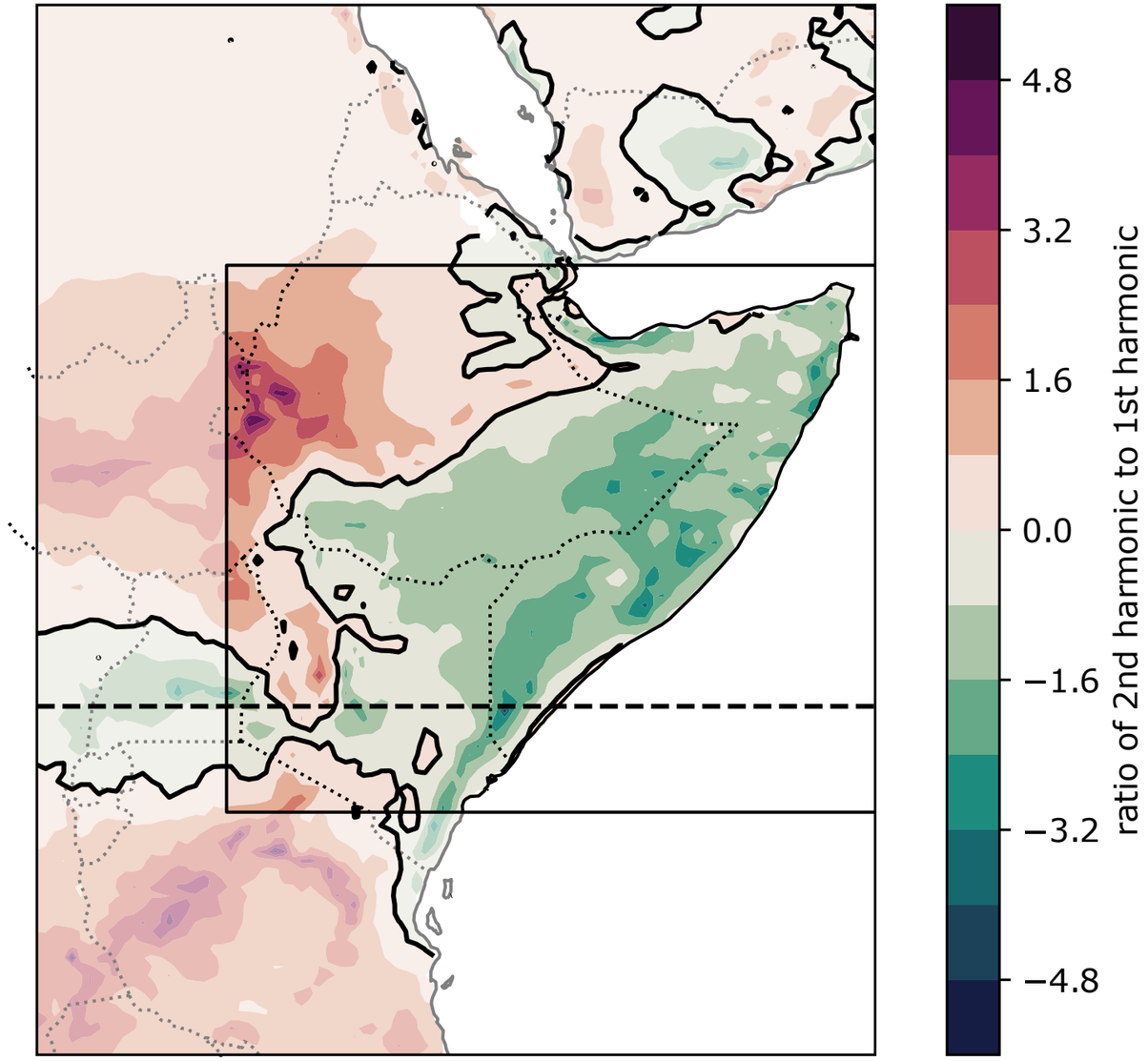
"Double-peakedness" of CHIRPS rainfall (1981-2021)

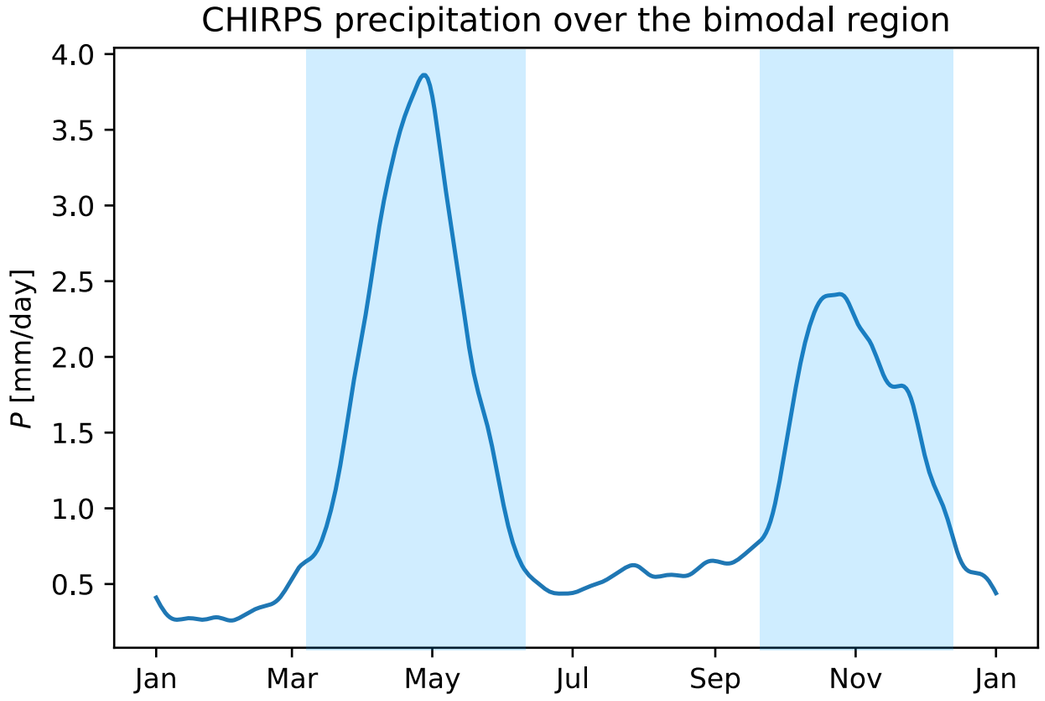





"Double-peakedness" of CHIRPS rainfall (1981-2021)
4.8
3.2
1.6
0.0
−1.6
−3.2
−4.8
ratio of 2nd harmonic to 1st harmonic
CHIRPS precipitation over the bimodal region
P [mm/day]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Jan
Mar
May
Jul
Sep
Nov
Jan

"Double-peakedness" of CHIRPS rainfall (1981-2021)

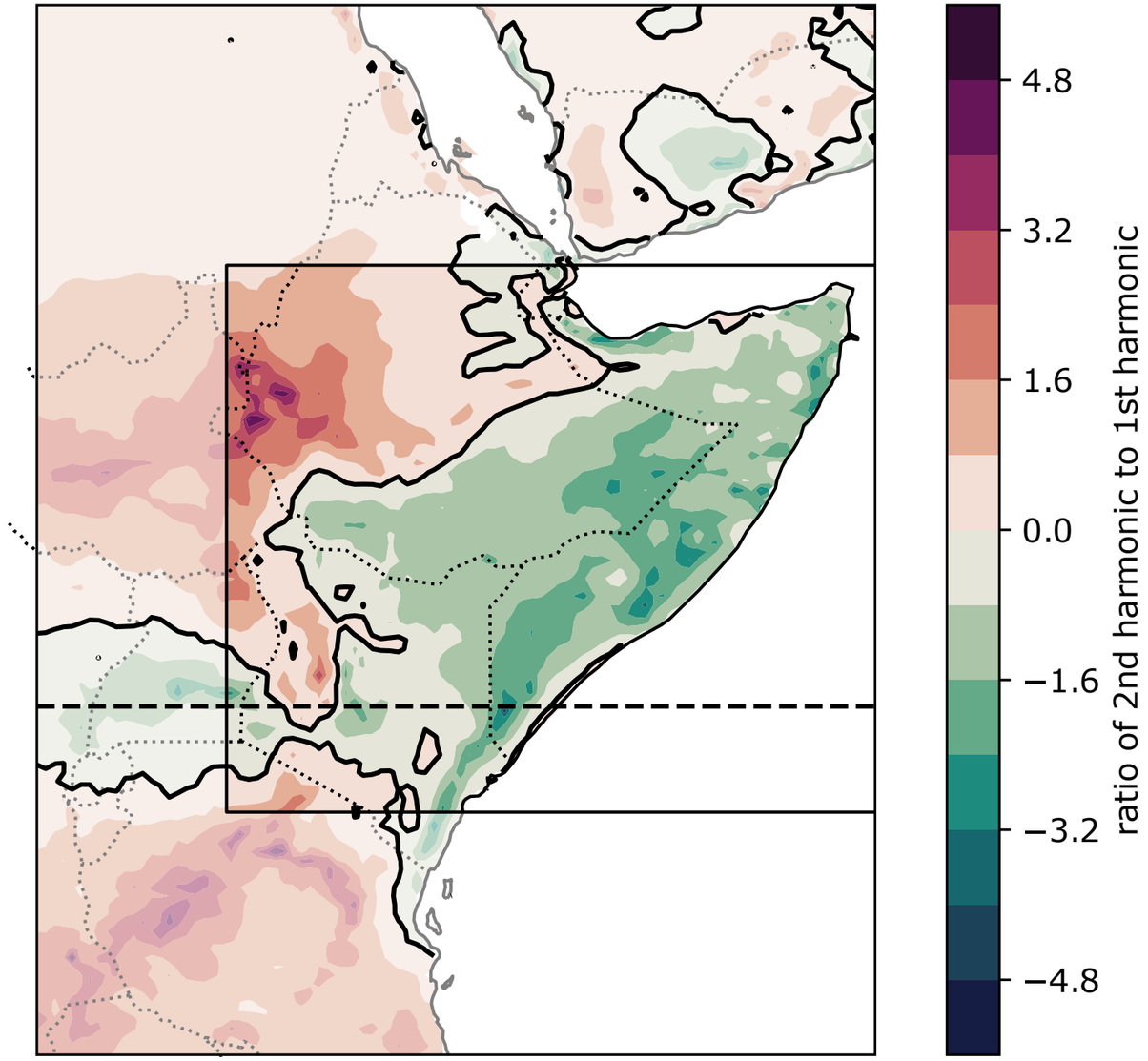


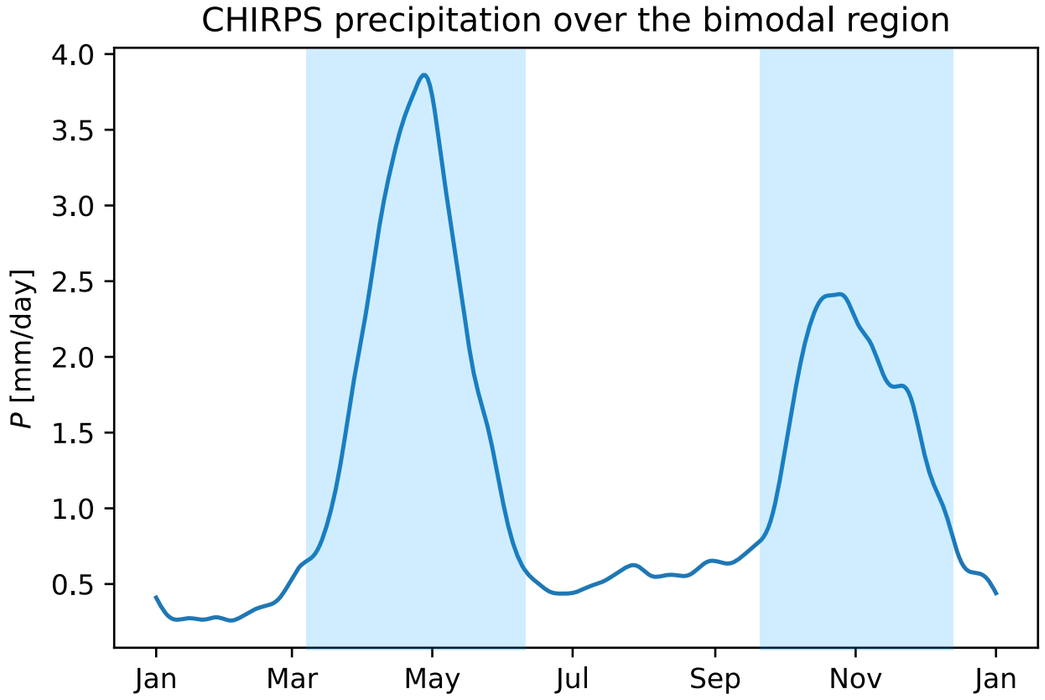


„Long“ rains
Gu (Somali)
Masika (Kiswahili)

„Short“ rains
Deyr (Somali)
Mvuli (Kiswahili)

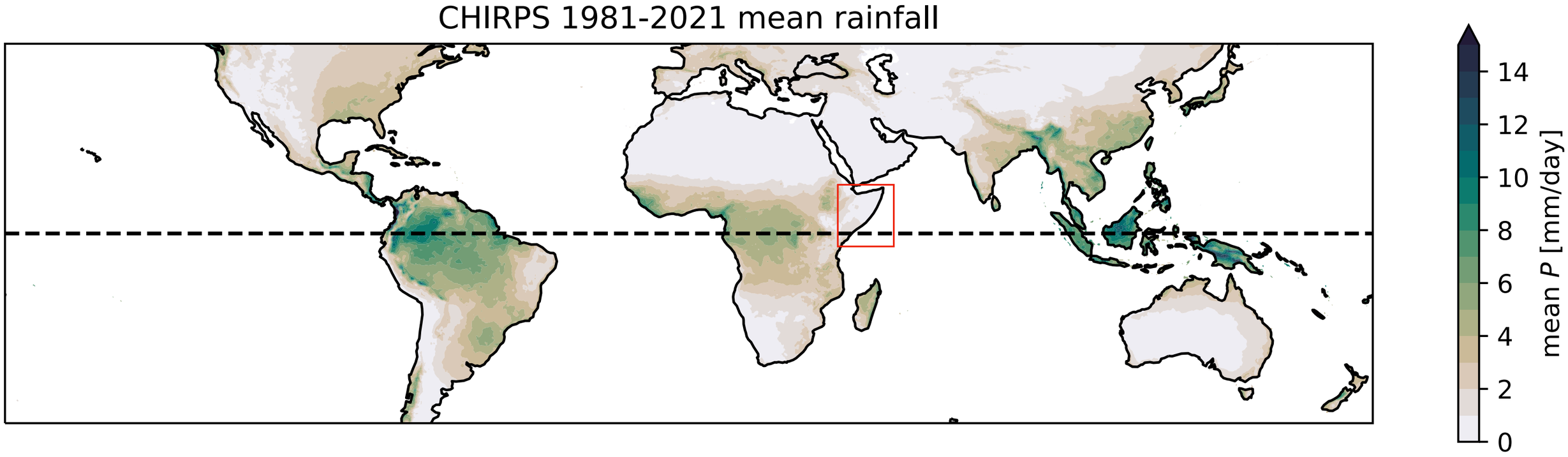
"Double-peakedness" of CHIRPS rainfall (1981-2021)



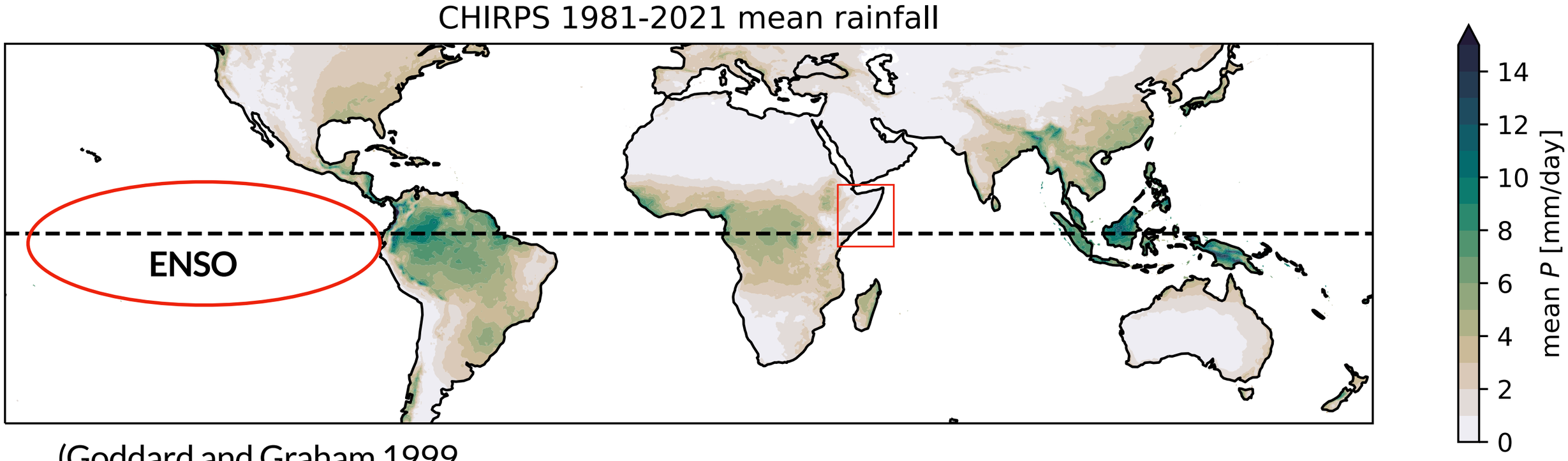


„Long“ rains	„Short“ rains
- Longer	- Shorter
- Wetter	- Drier
- Less variable	- More variable
- Fewer known teleconnections	- Connected to ENSO, IOD,...

The long and short rains have been connected to …

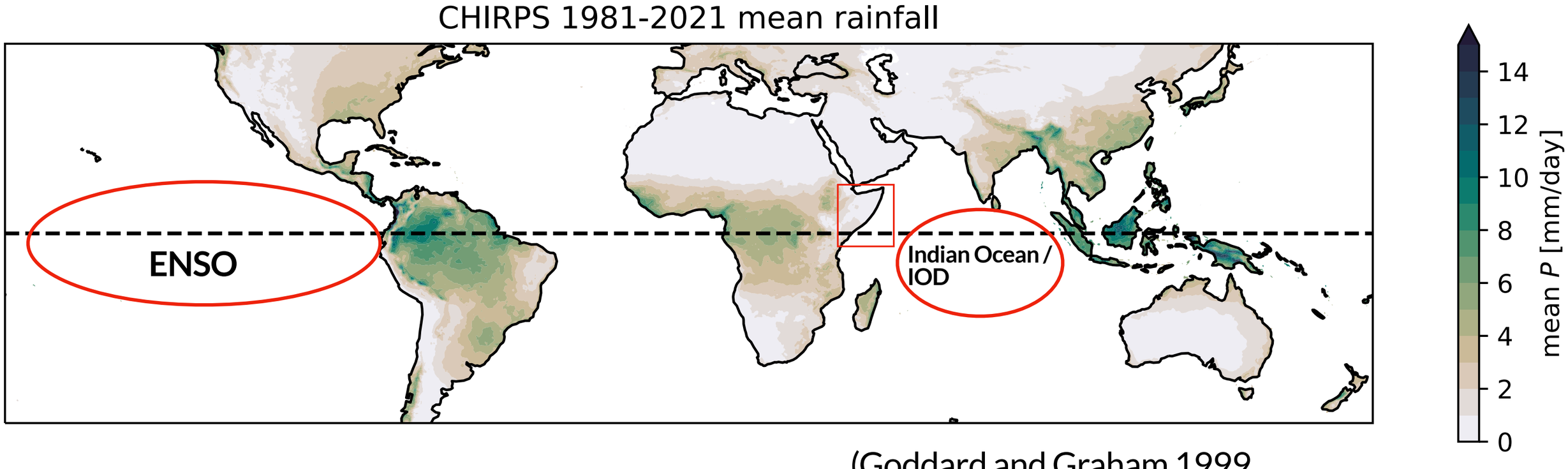


The long and short rains have been connected to …



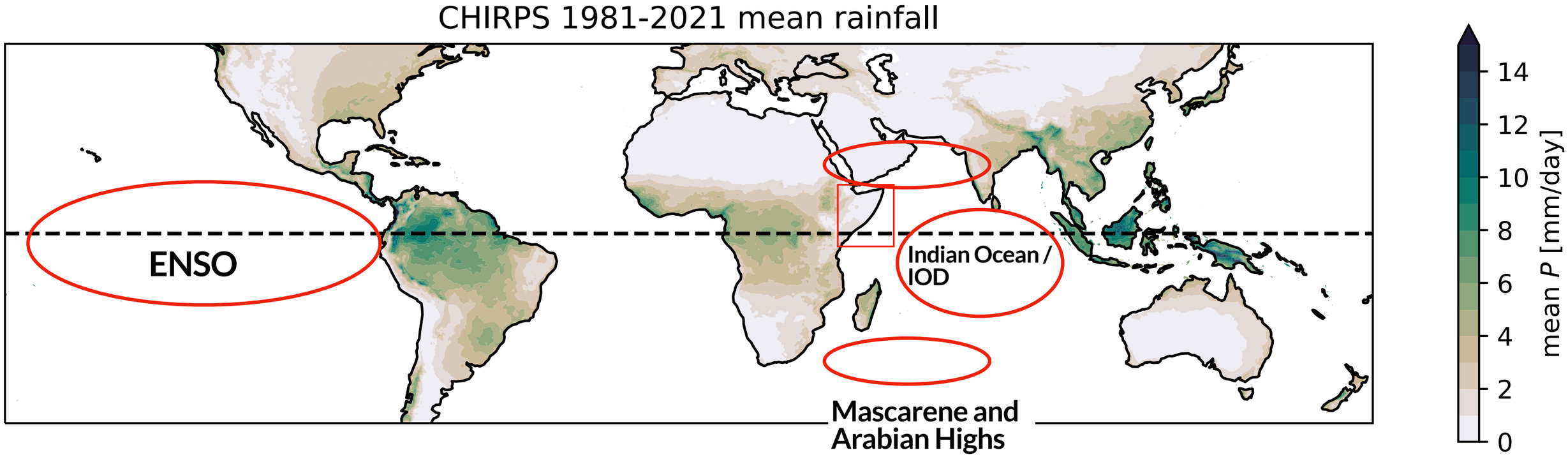
(Goddard and Graham 1999,
Nicholson et al. 2001,
etc. etc.)

The long and short rains have been connected to …



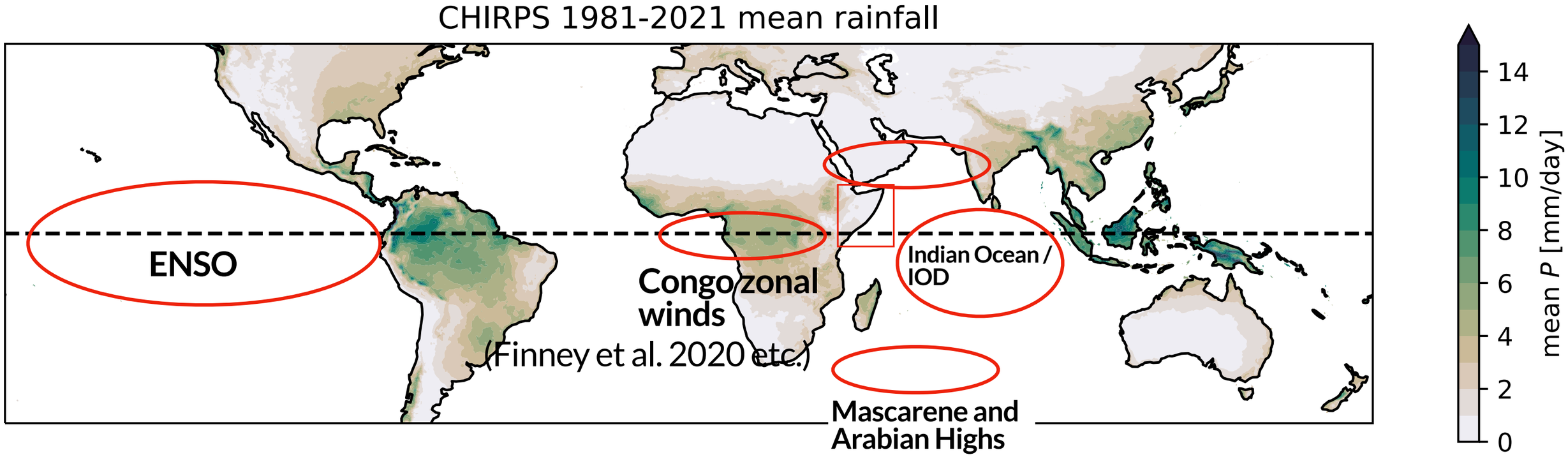
(Goddard and Graham 1999,
Liebmann et al. 2014,
Blau and Ha 2020, etc.)

The long and short rains have been connected to …



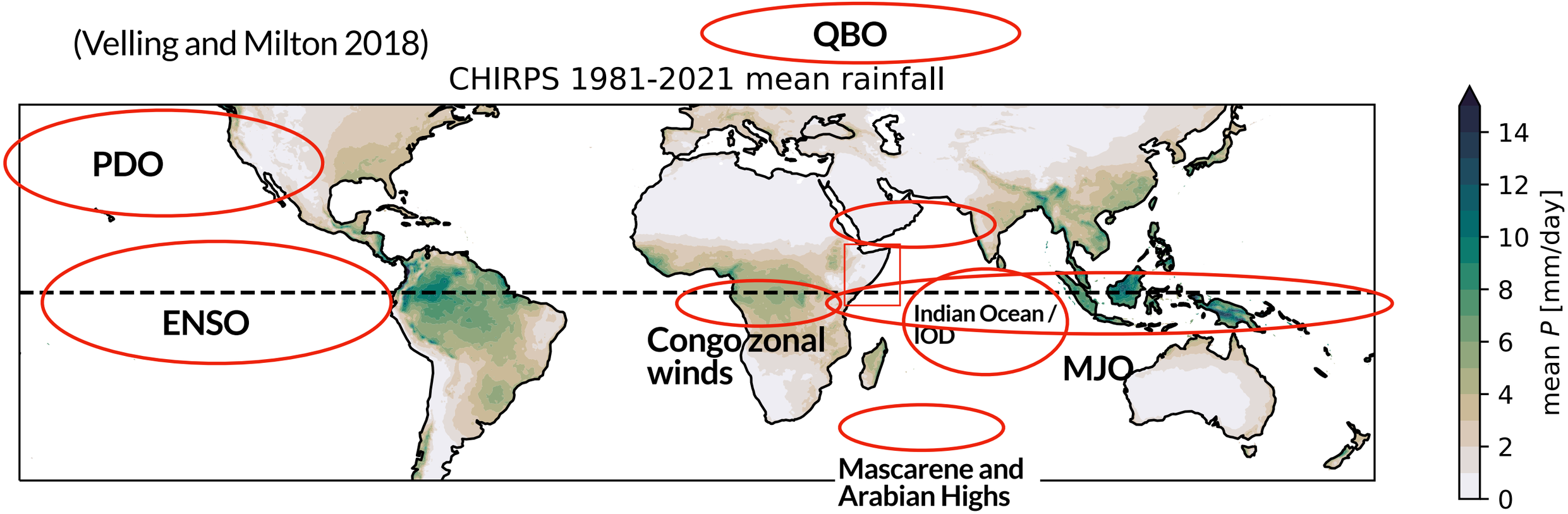
(Vizy and Cook 2020)

The long and short rains have been connected to …

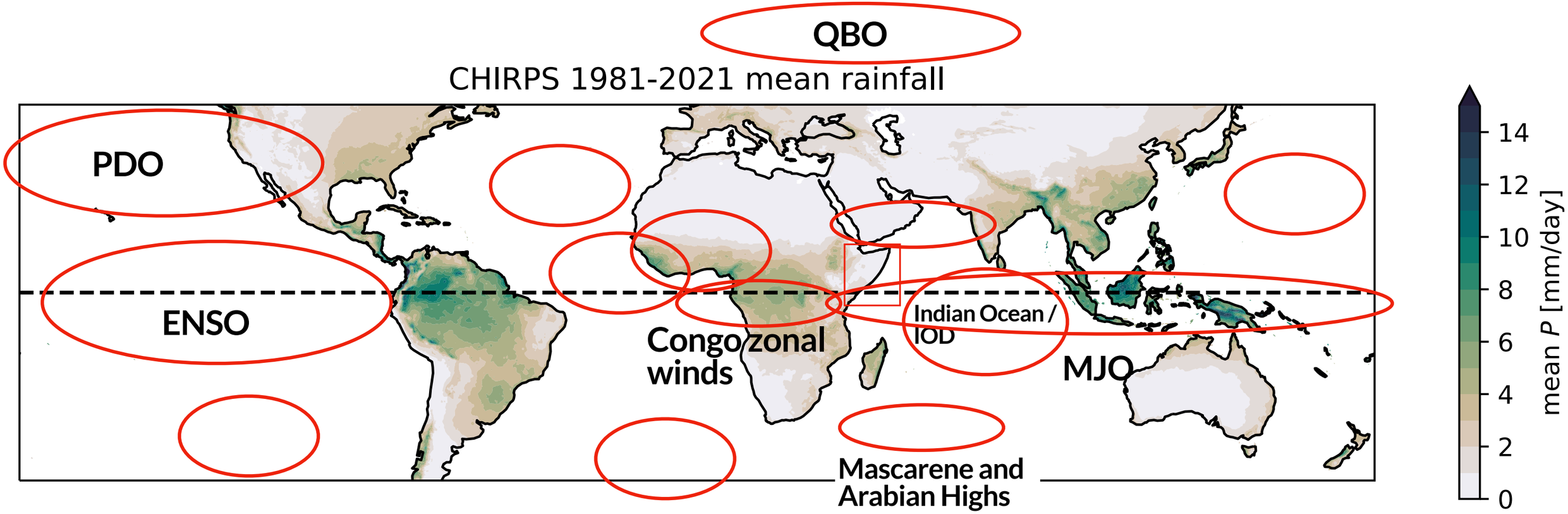


The long and short rains have been connected to …

(Velling and Milton 2018)



The long and short rains have been connected to …



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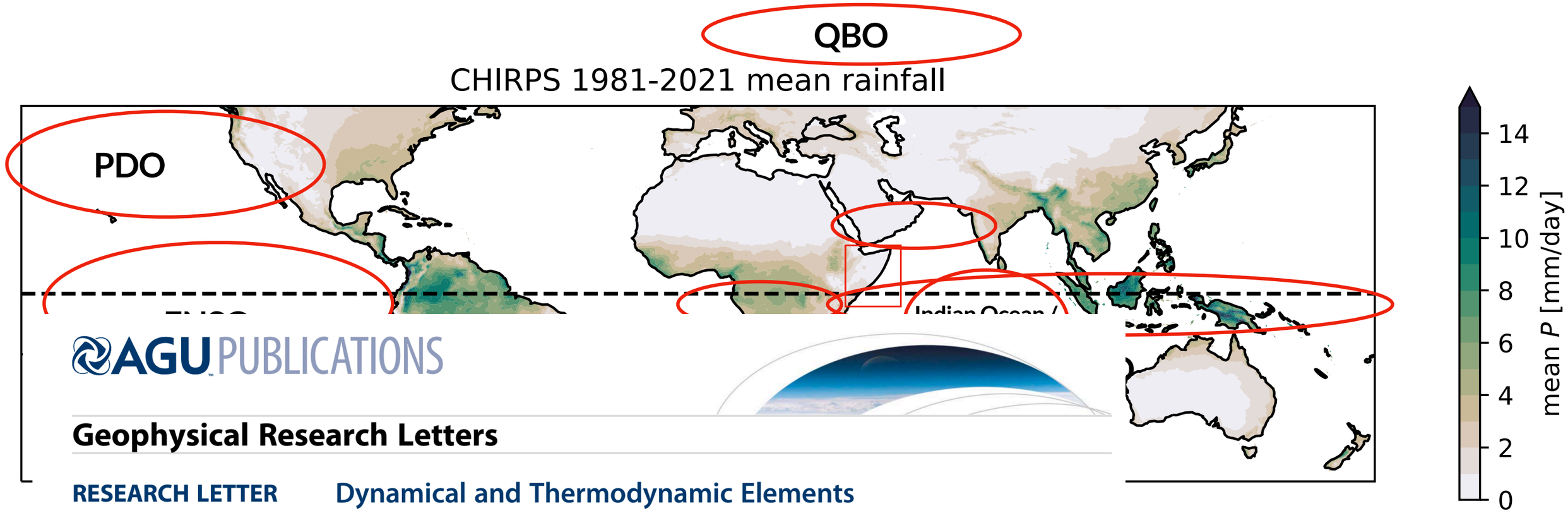


AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2017GL075486

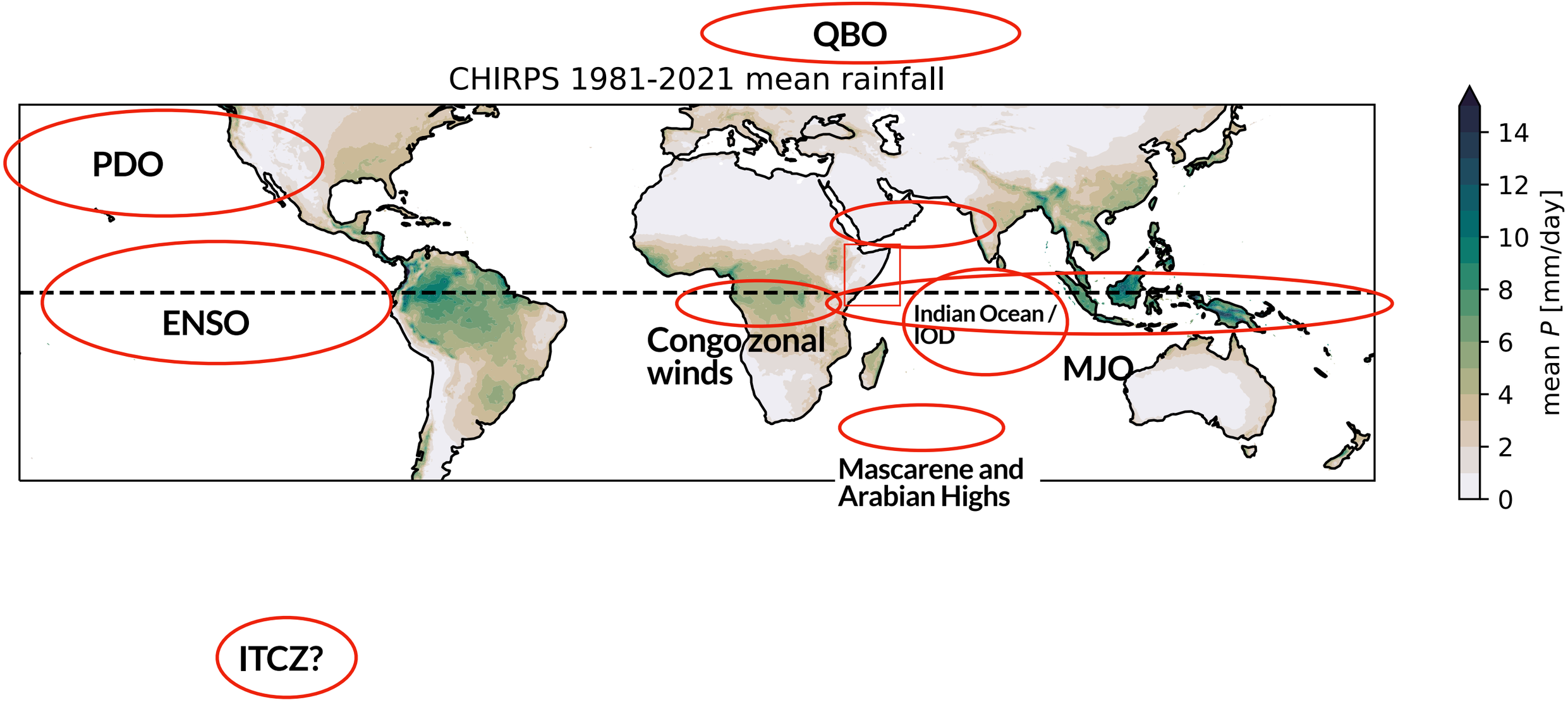
Key Points:
- Moisture budget decomposition indicates that CMIP5 end of 21st century projections for wetter conditions in equatorial East Africa are primarily due to a weakening of the zonal overturning circulation
- Uncertainties are associated with our

Dynamical and Thermodynamic Elements of Modeled Climate Change at the East African Margin of Convection

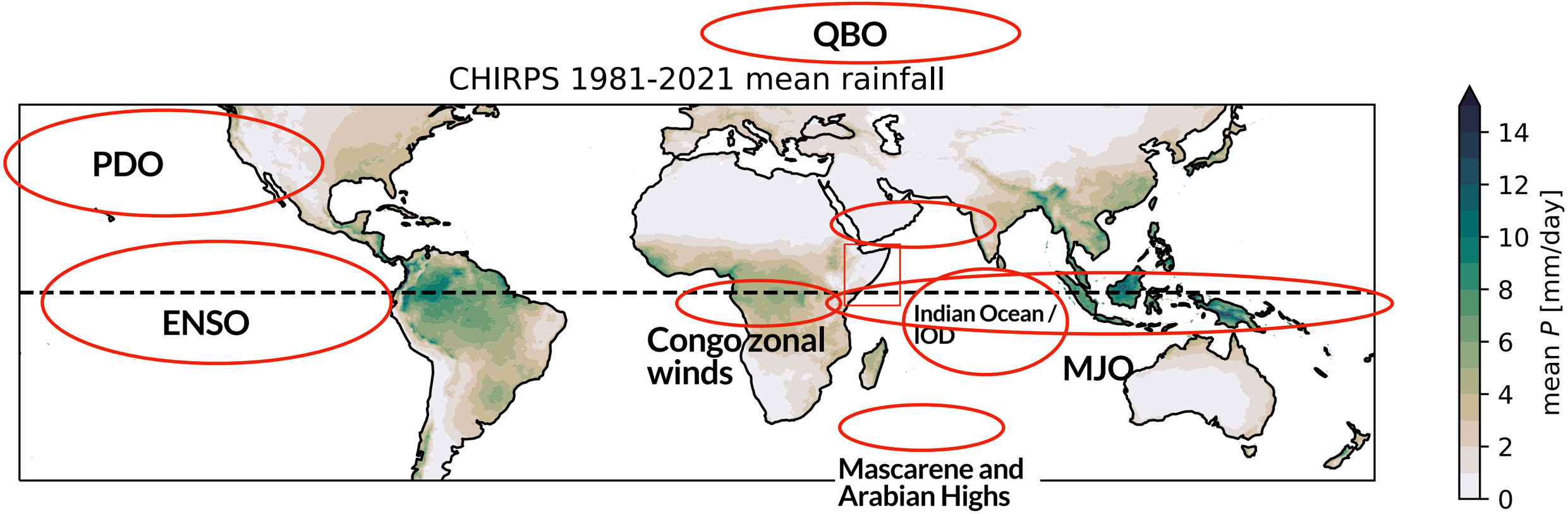
Alessandra Giannini[1], Bradfield Lyon[2], Richard Seager[3], and Nicolas Vigaud[1]

[1]International Research Institute for Climate and Society, The Earth Institute at Columbia University, Palisades, NY, USA, [2]Climate Change Institute and School of Earth and Climate Sciences, University of Maine, Orono, ME, USA, [3]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, USA

The long and short rains have been connected to …

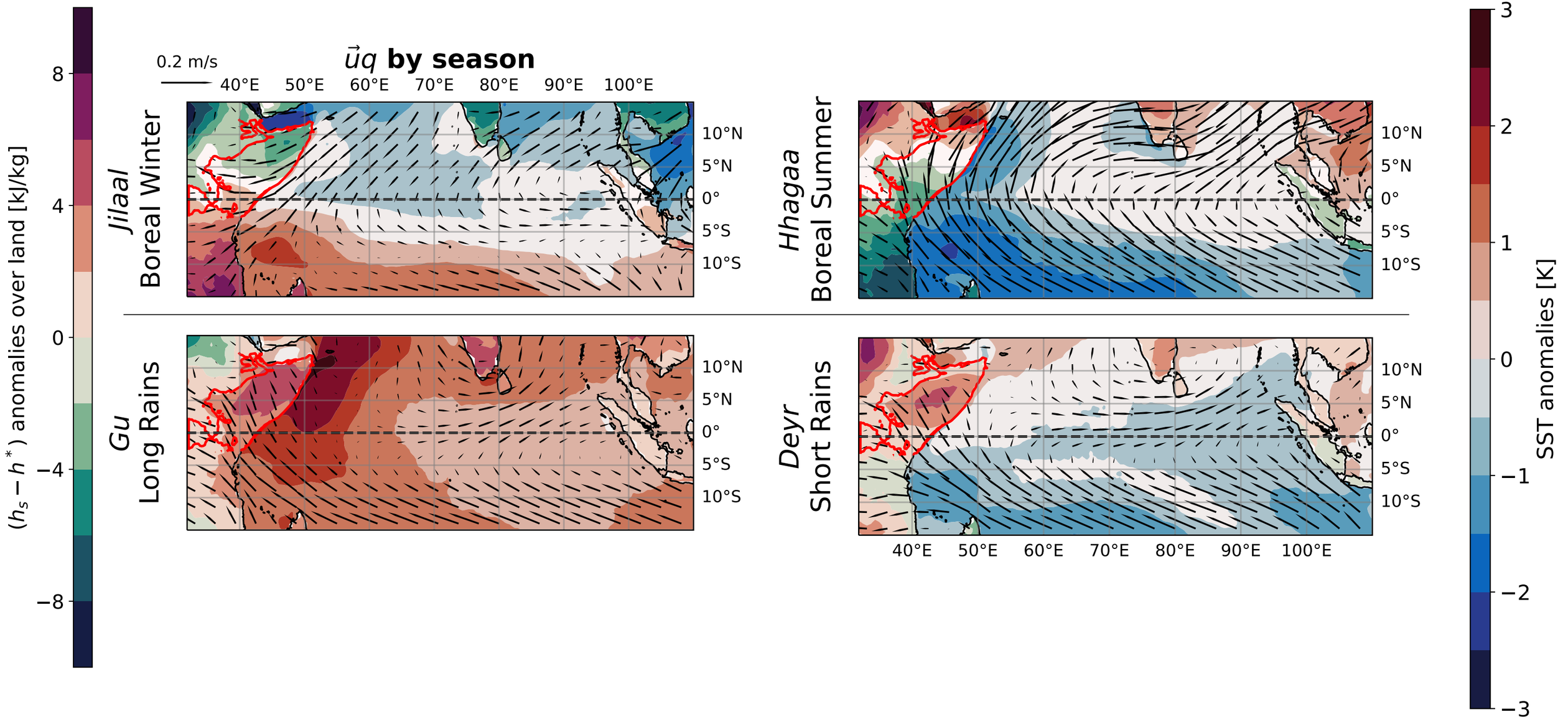


The long and short rains have been connected to …

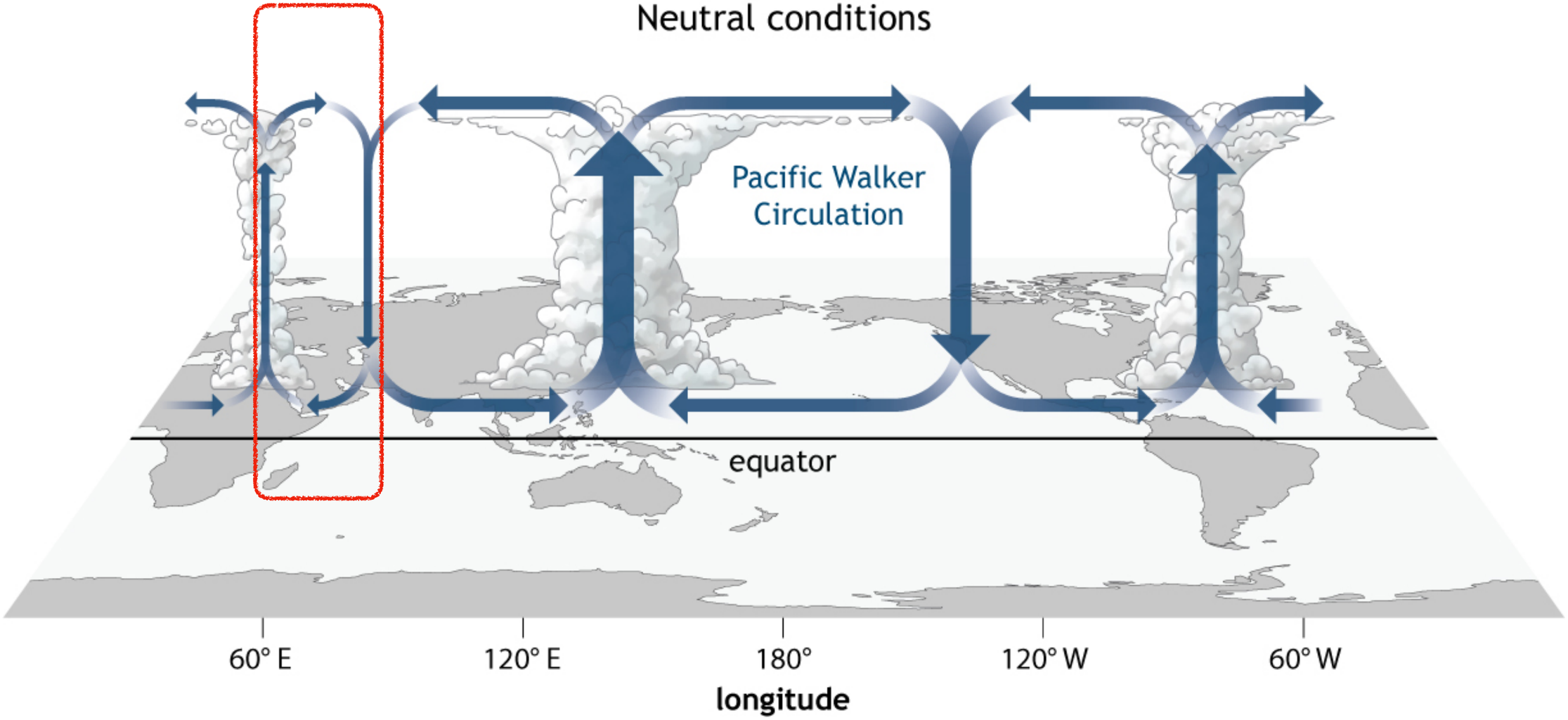


ITC[redacted]? (Nicholson 2018)

The long and short rains occur in the „shoulder" seasons, when the monsoonal winds switch directions



The GHA is affected by modulations in the Walker Circulation



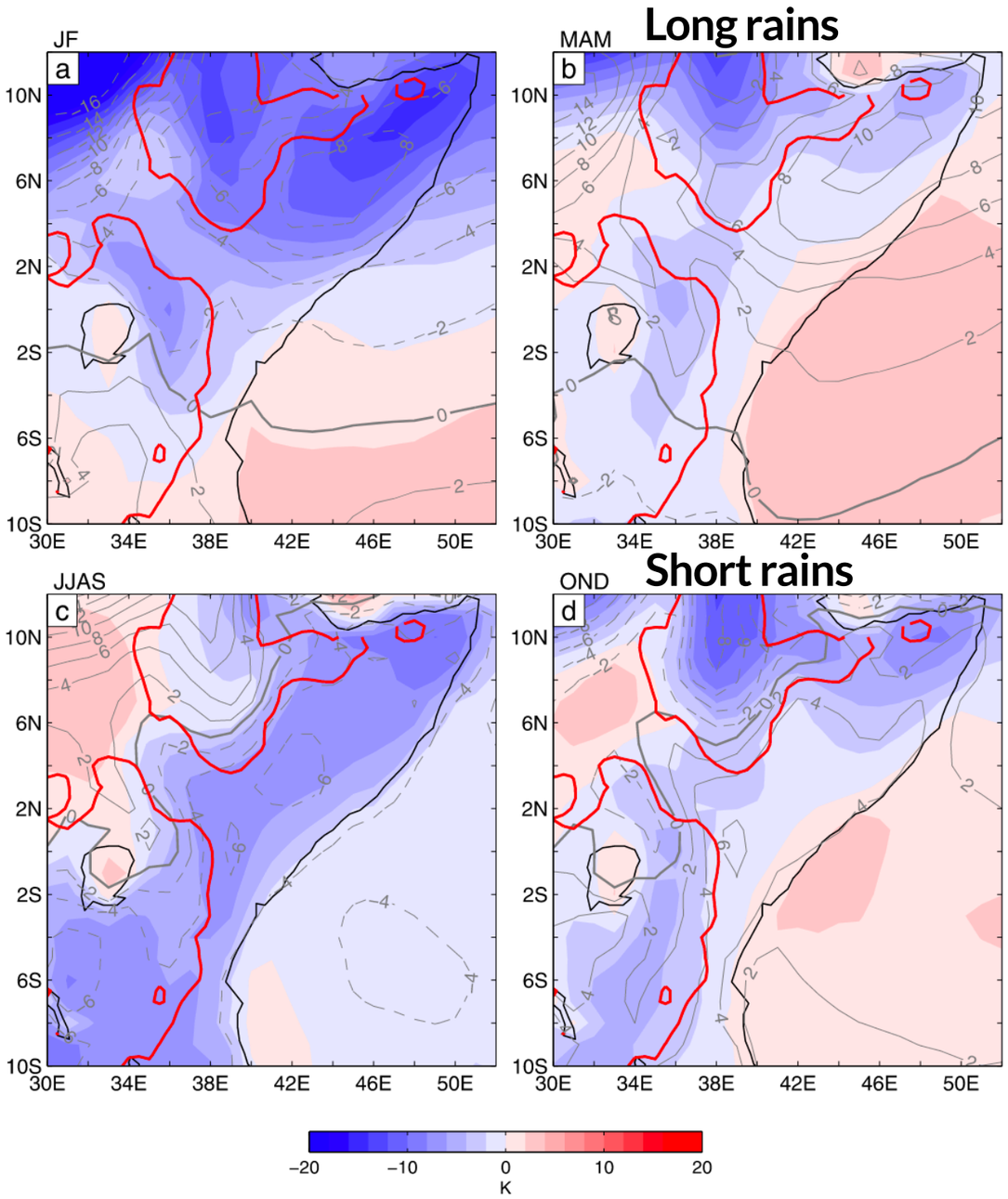


FIG. 7. Seasonal climatologies of the surface moist static energy (MSE) minus the saturated MSE at 700 hPa (colors) and their changes from the previous season (contours), both from ERA-Interim. The MSE is normalized by the heat capacity of the air at constant pressure so that it has the unit of kelvin. The thick red lines are the contours of the 1000-m topographical elevation.

How to disentangle all of these influences?

h_s - h^* as a metric of large-scale stability (e.g., Cook and Seager 2013)

$$\text{large-scale stability} \approx h_s - h^*$$

$$h_s = c_p T_s + g z_s + L_v q_s$$

$$h^* = c_p T + g z + L_v q^*$$

h_s - $h^* > 0$: a rising, saturated parcel will have positive thermal buoyancy at the level of h^*

(Need to pick h^* above the lifting condensation level)

Yang, Wenchang, Richard Seager, Mark A. Cane, and Bradfield Lyon. "The Annual Cycle of East African Precipitation." *Journal of Climate* 28, no. 6 (March 15, 2015): 2385–2404. https://doi.org/10.1175/JCLI-D-14-00484.1.

Limitations of monthly averages…

Sample short rain extents
(Average across GHA)

Sep. 29 - Nov. 12
Sep. 26 - Nov. 19
Sep. 29 - Nov. 13
Sep. 30 - Nov. 15
Oct. 5 - Nov. 13
Oct. 4 - Nov. 15
Oct. 7 - Nov. 14
Oct. 2 - Nov. 20
Sep. 30 - Nov. 16

vs.

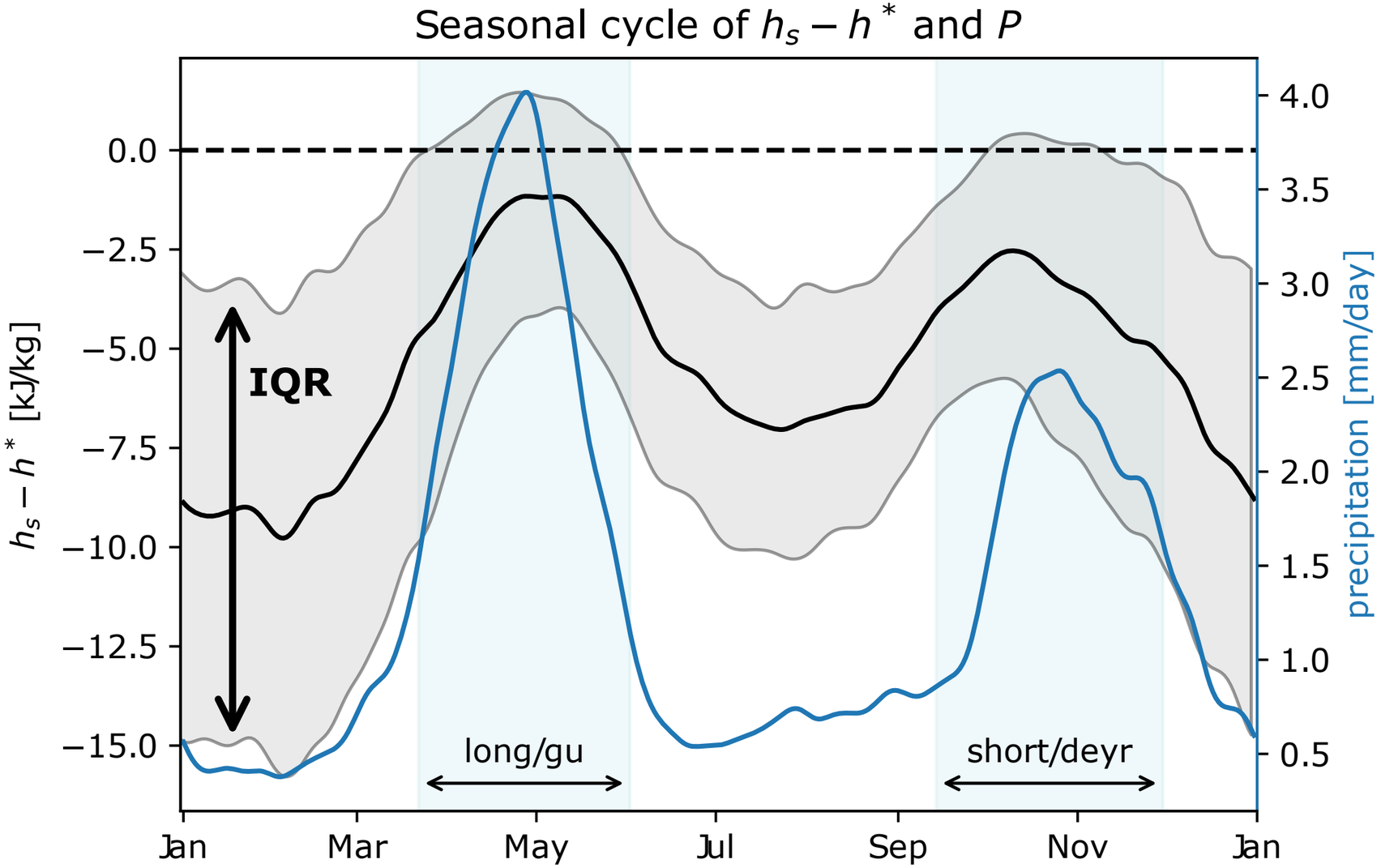
OND or SON
average

Especially since seasonal timing is modulated by the dynamics!

The long and short rains through a h_s - h^* framework

- Daily rainfall data (1981-2021) through CHIRPS *(Funk et al. 2014; validated over the Horn of Africa by Dinku et al. 2018, etc.)*
- Daily atmospheric reanalysis data (T, q, z, 1981-2021) from MERRA2 *(Bosilovich et al. 2015)*
- Onset and demise of rainy seasons using the method by *Dunning et al. 2018* based on inflection points in the cumulative precipitation anomaly
- Seasonal composites calculated as means between average GHA onset and demise for each year

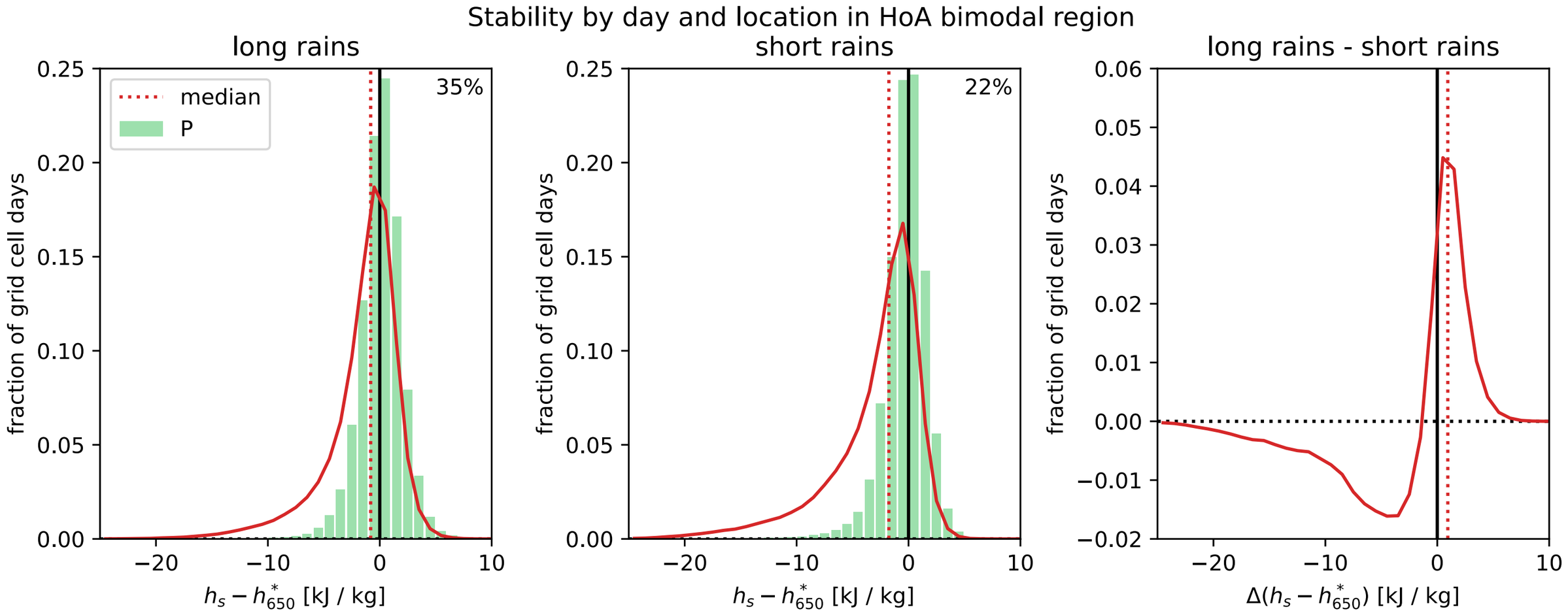
The rainfall climatology tracks the h_s - h^* climatology



Schwarzwald, Kevin, Richard Seager, and Mingfang Ting. „The seasonal cycles of the Horn of Africa rains.“ *In prep.*

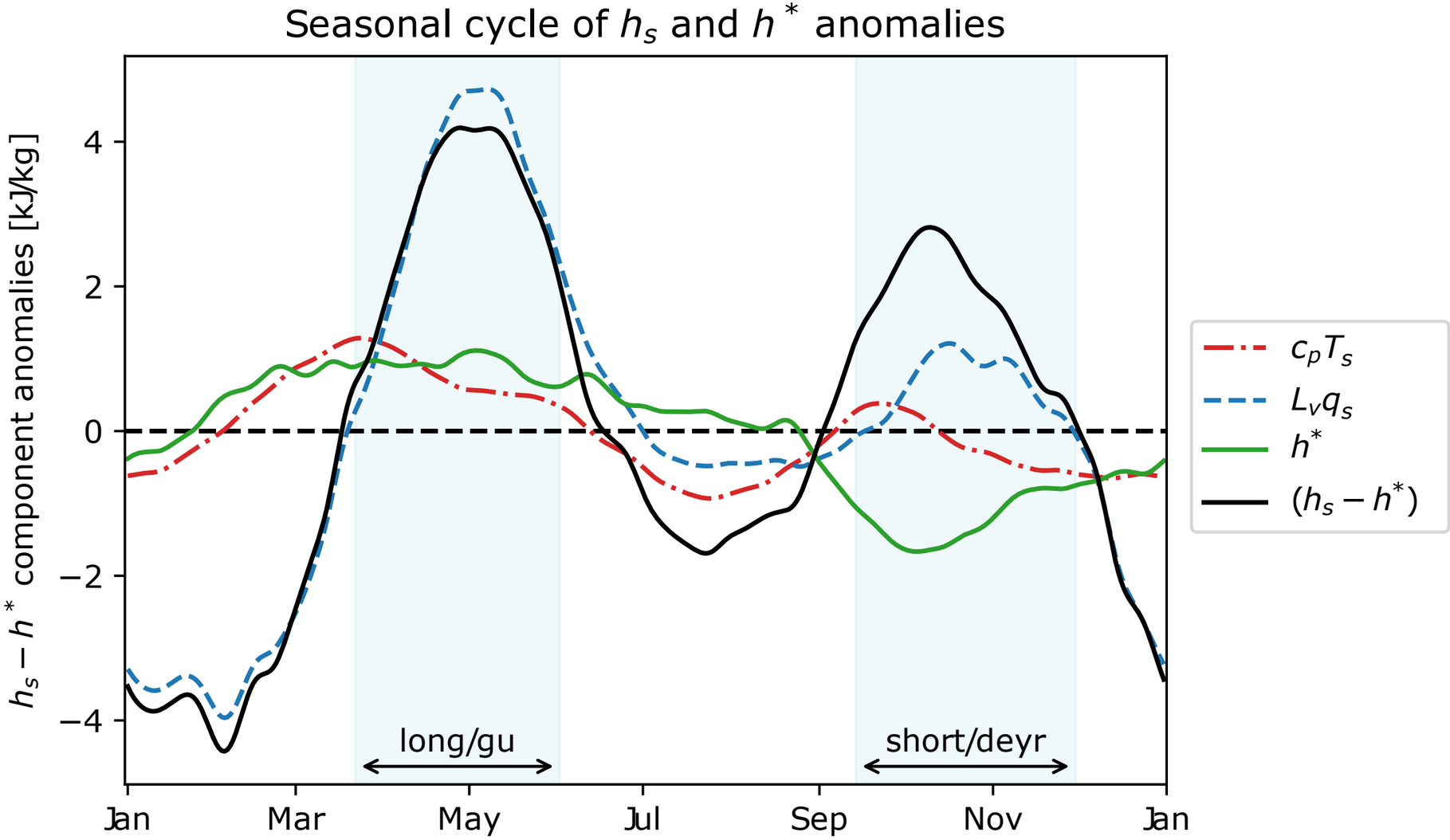
Rain falls on days with higher h_s - h^*

Schwarzwald, Kevin, Richard Seager, and Mingfang Ting. „The seasonal cycles of the Horn of Africa rains.“ *In prep.*



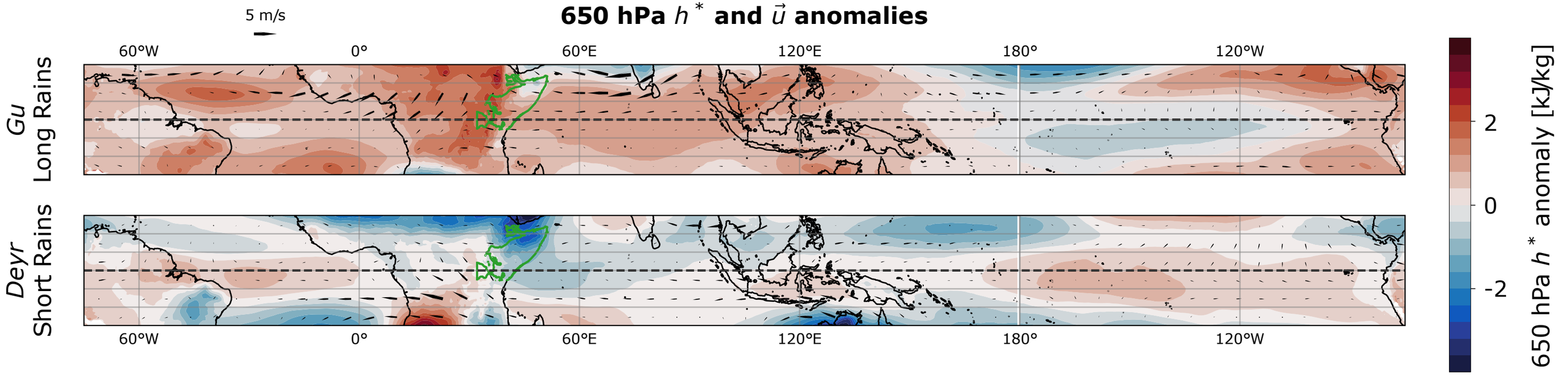
The components of h_s - h^* show three seasonal cycles:

1. T_s : double-peaked, phase-shifted from rainy seasons
2. q_s : double-peaked, w/ rainy seasons
3. h^* : single-peaked, w/ minimum during short rains



Schwarzwald, Kevin, Richard Seager, and Mingfang Ting. „The seasonal cycles of the Horn of Africa rains.“ *In prep.*

During the long rains, GHA h^* maximum associated with Atlantic - Indian Ocean basin wide maxima



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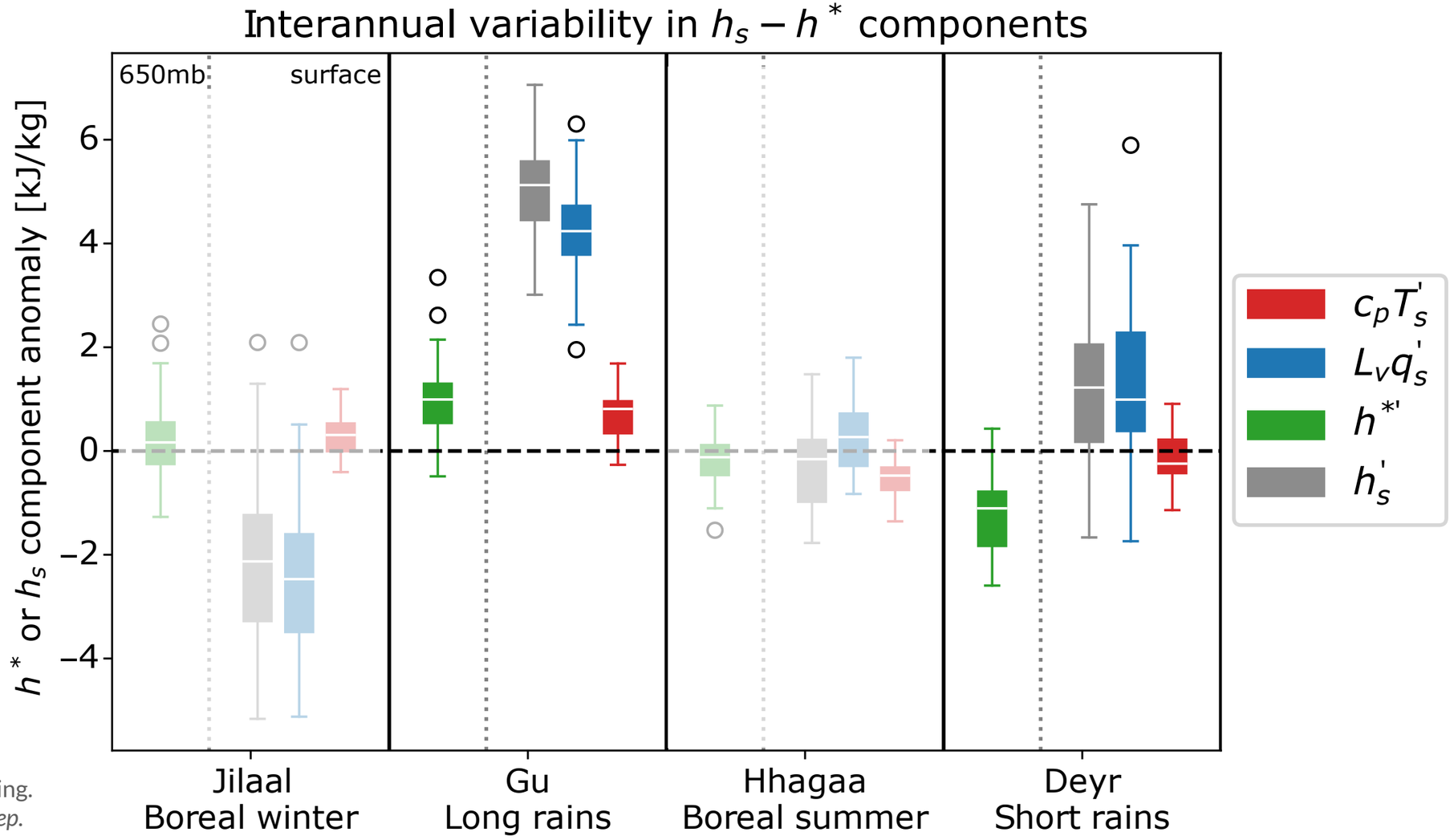
During the short rains, GHA h^* minimum more anomalous for its latitude…

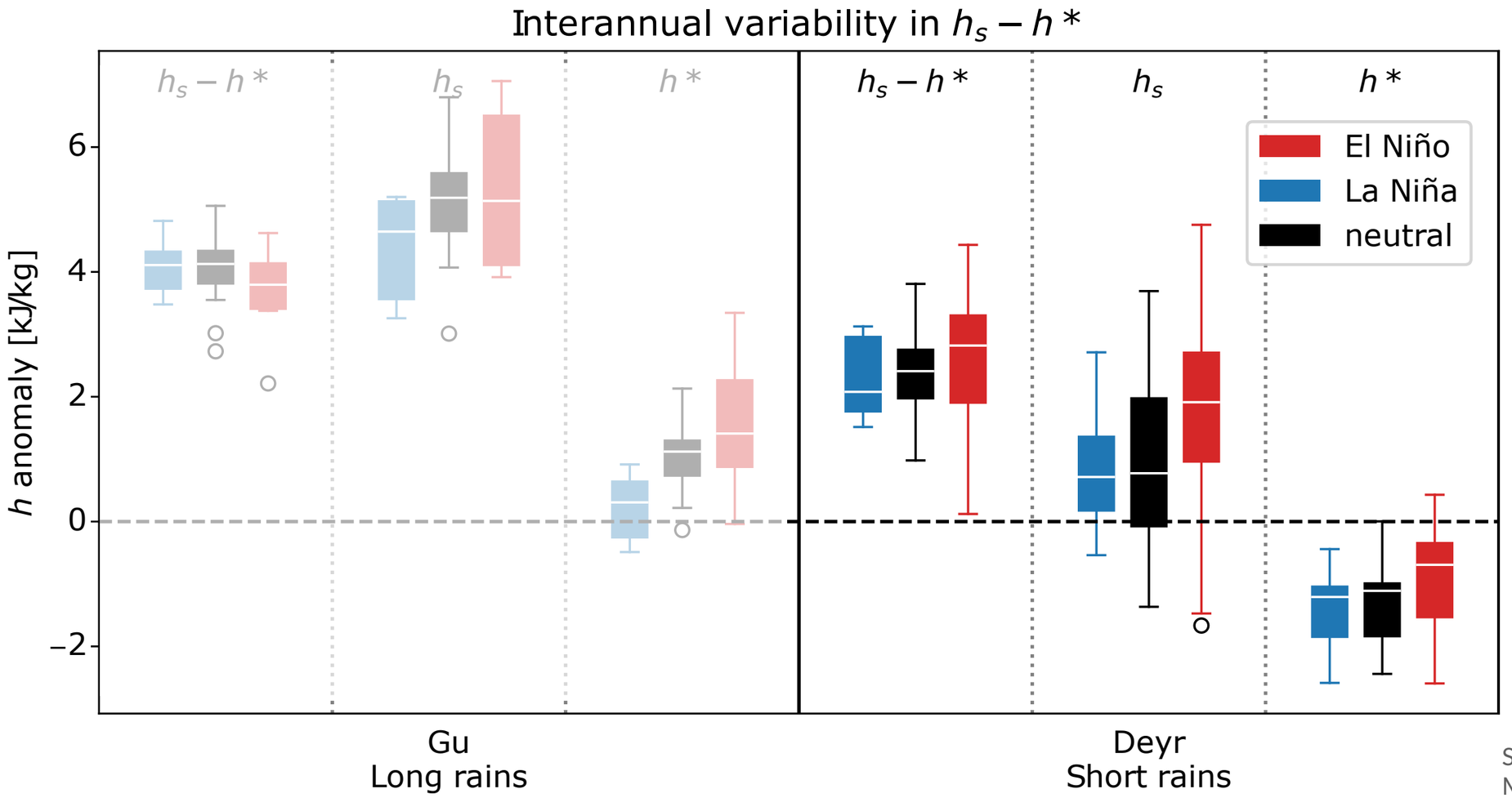
Can h_s - h^* improve our understanding of interannual variability in the GHA rains?

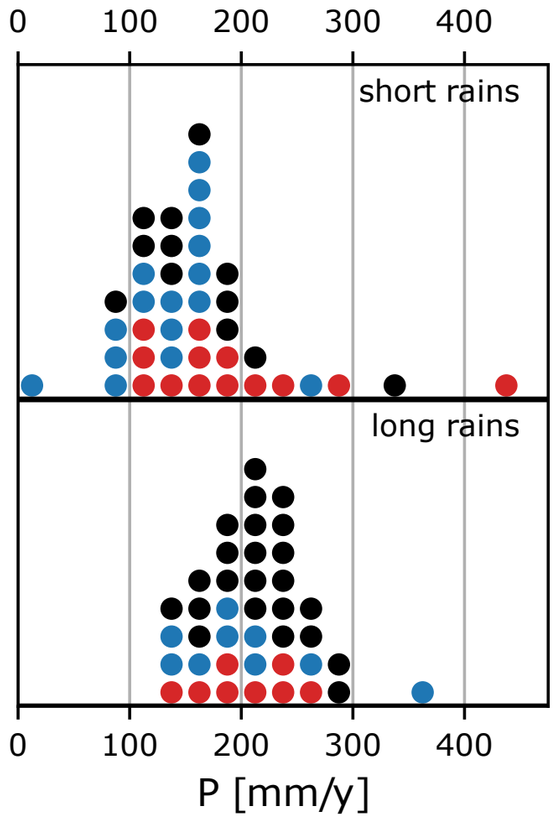
Interannual variability in h_s - h^* is largely driven by surface moisture, with a substantial influence of trop. T, particularly during the short rains



Schwarzwald, Kevin, Richard Seager, and Mingfang Ting. „The seasonal cycles of the Horn of Africa rains.“ *In prep.*

El Niño conditions associated with increased h^* in both rainy seasons and h_s during the short rains (IOD?); net impact on h_s - h^* is larger in short rains





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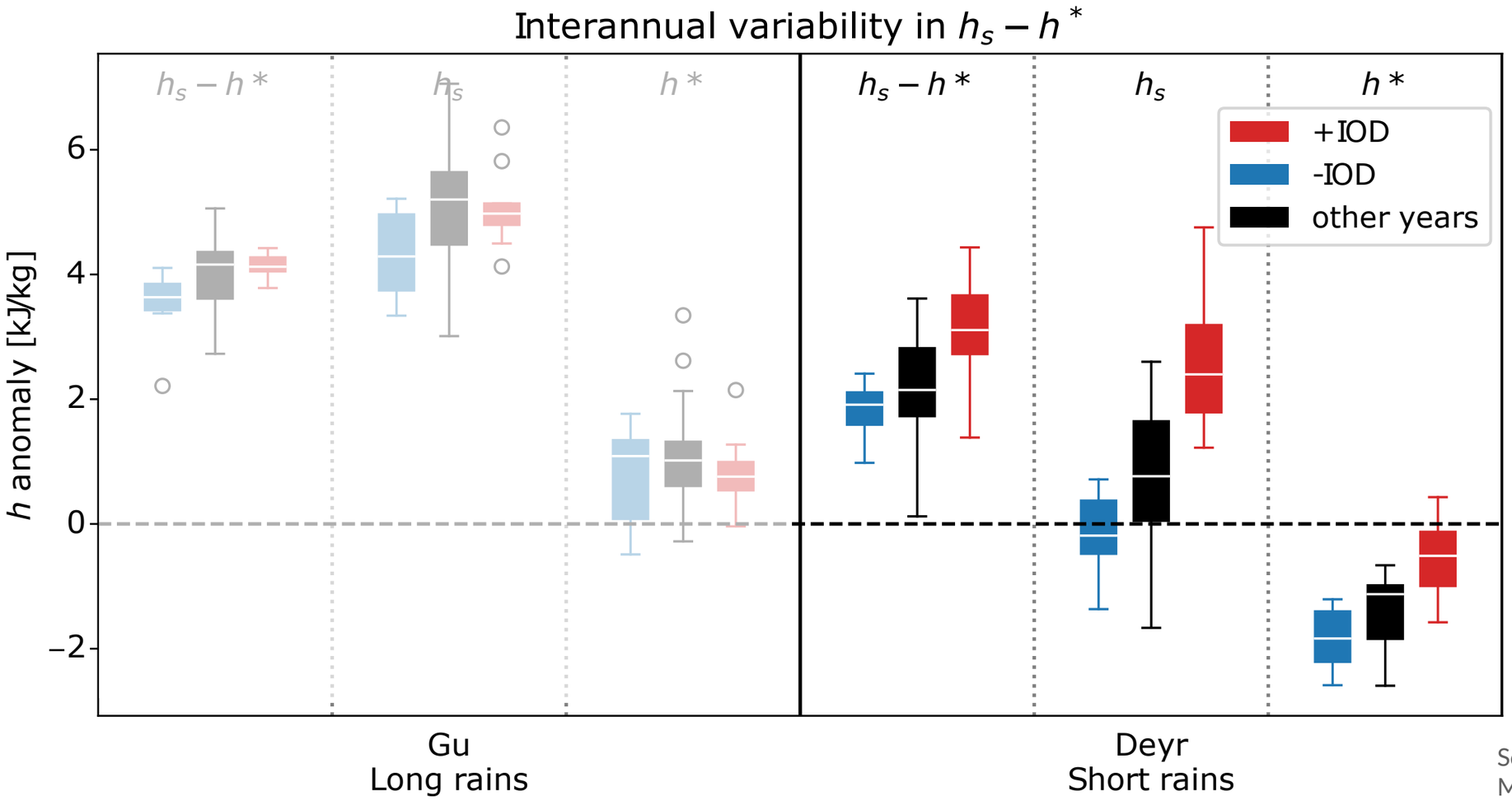
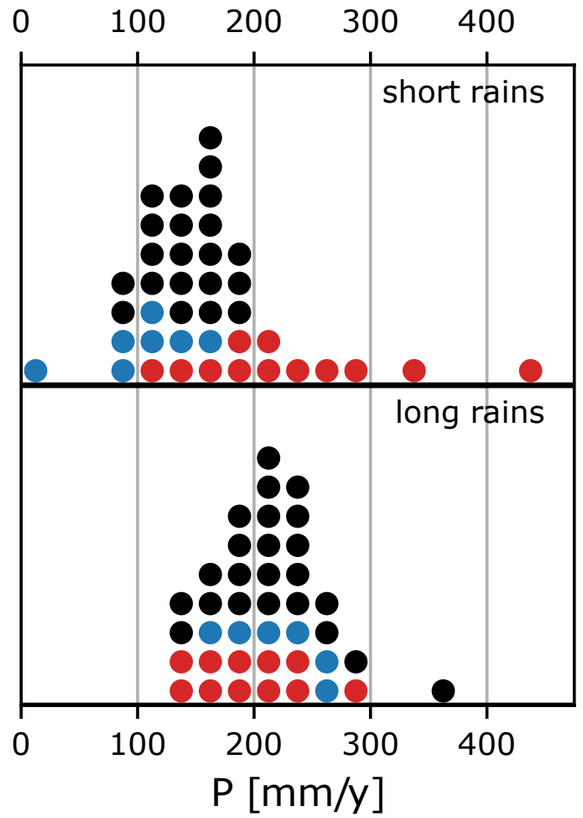
IOD associated with much stronger h_s anomalies (and therefore +h_s - h^* anomalies) during the short rains, in line with stronger correlation of +IOD (vs. ENSO) with rainfall



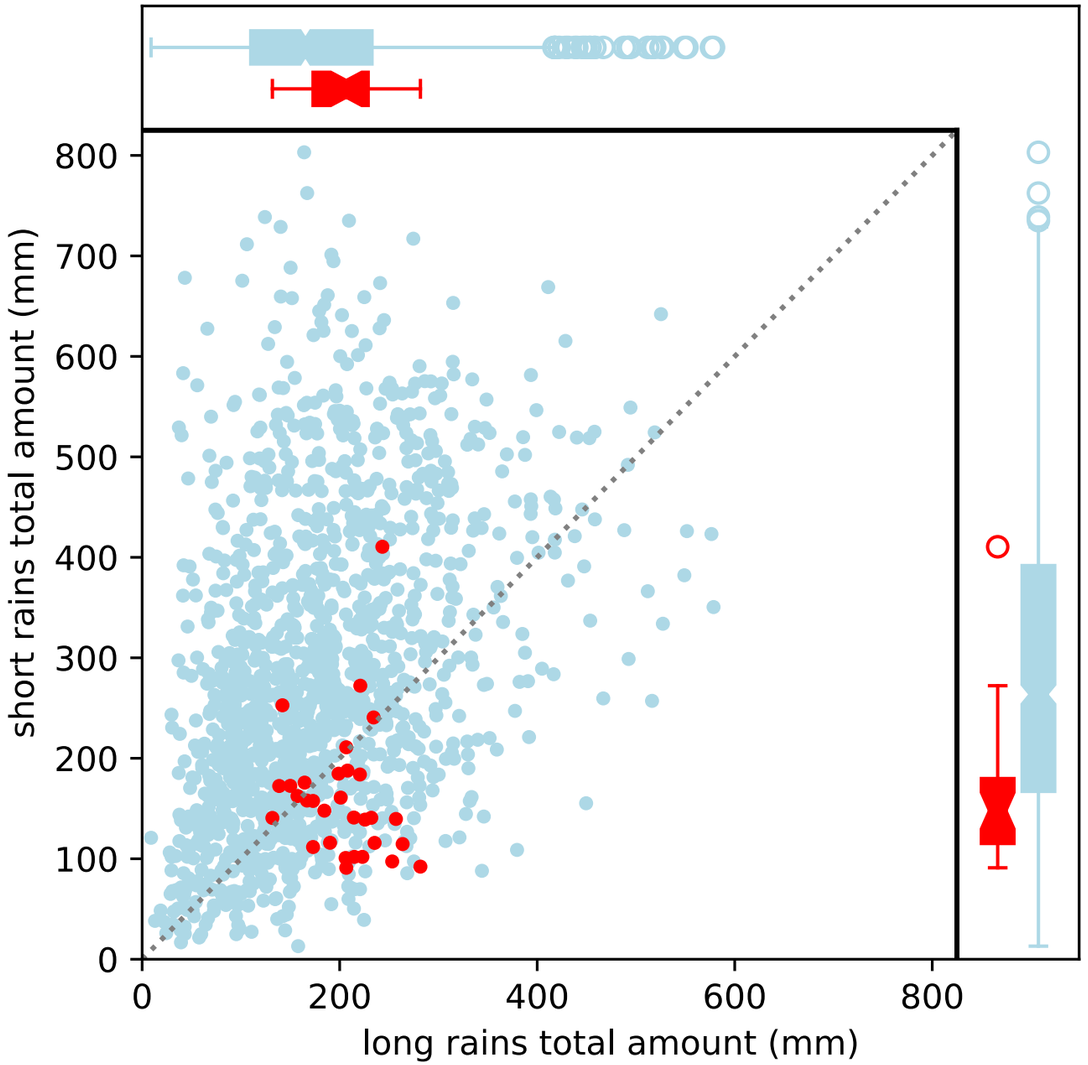


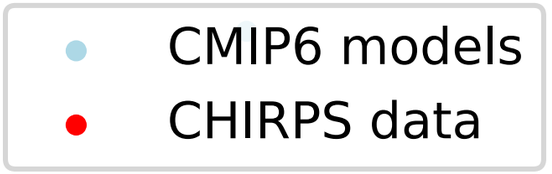
Schwarzwald, Kevin, Richard Seager, and Mingfang Ting. „The seasonal cycles of the Horn of Africa rains." *In prep.*

Using h_s – h^* as a diagnostic of GCM behavior…

Total rainfall by season

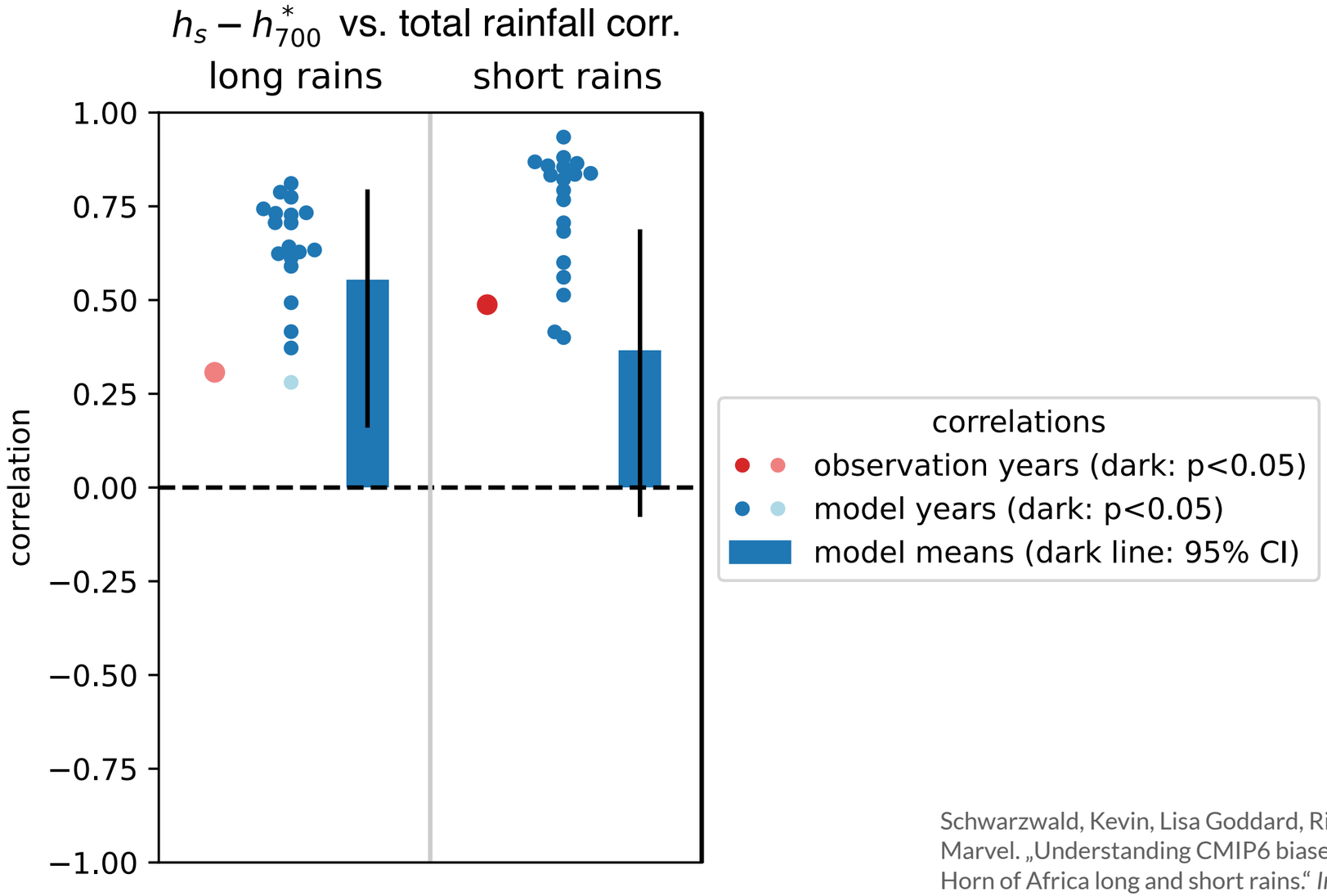
Short rains





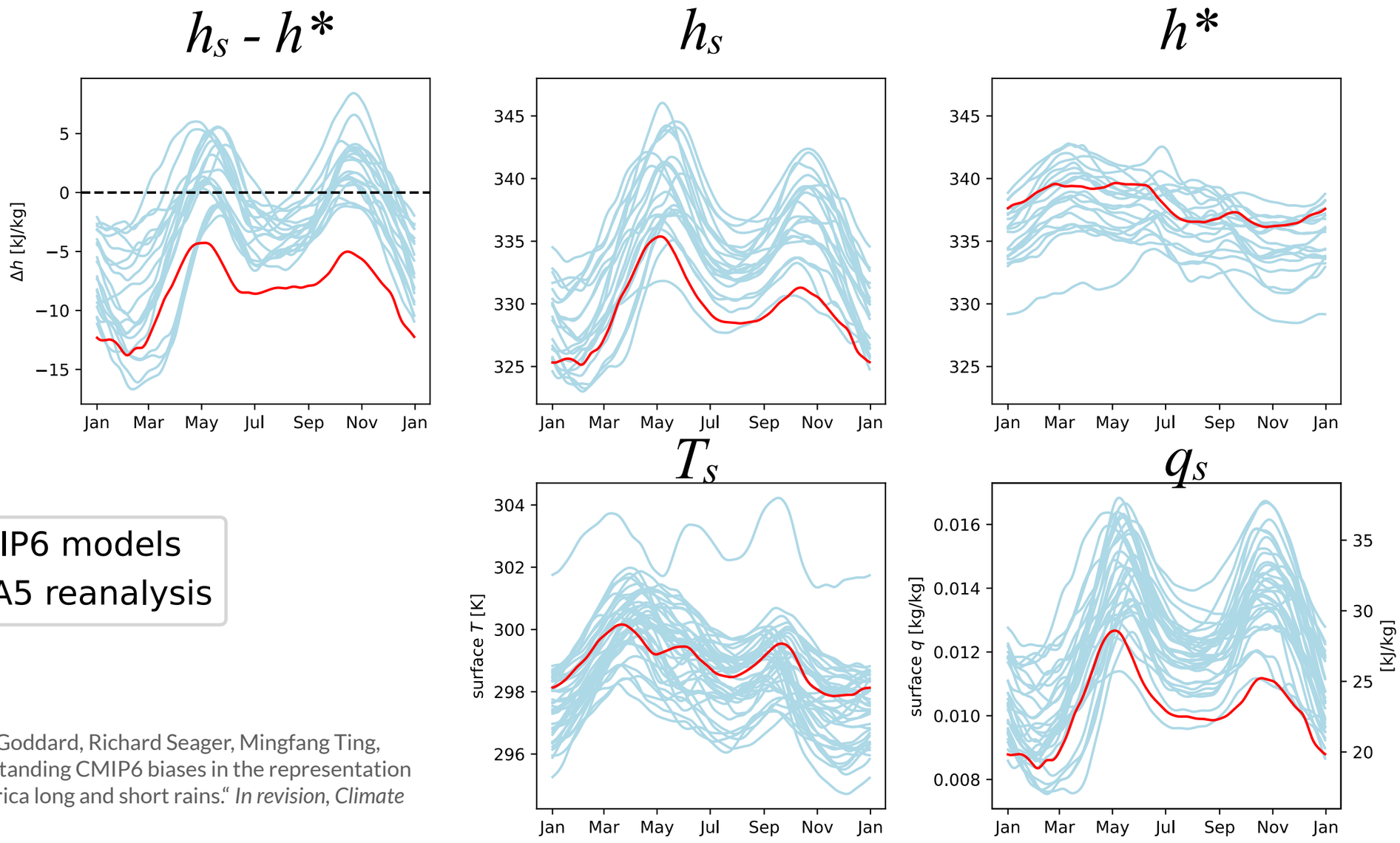
Long rains

Using h_s - h^* as a metric of GCM performance



Schwarzwald, Kevin, Lisa Goddard, Richard Seager, Mingfang Ting, and Kate Marvel. „Understanding CMIP6 biases in the representation of the Greater Horn of Africa long and short rains." *In revision, Climate Dynamics.*

Using h_s - h^* as a metric of GCM performance



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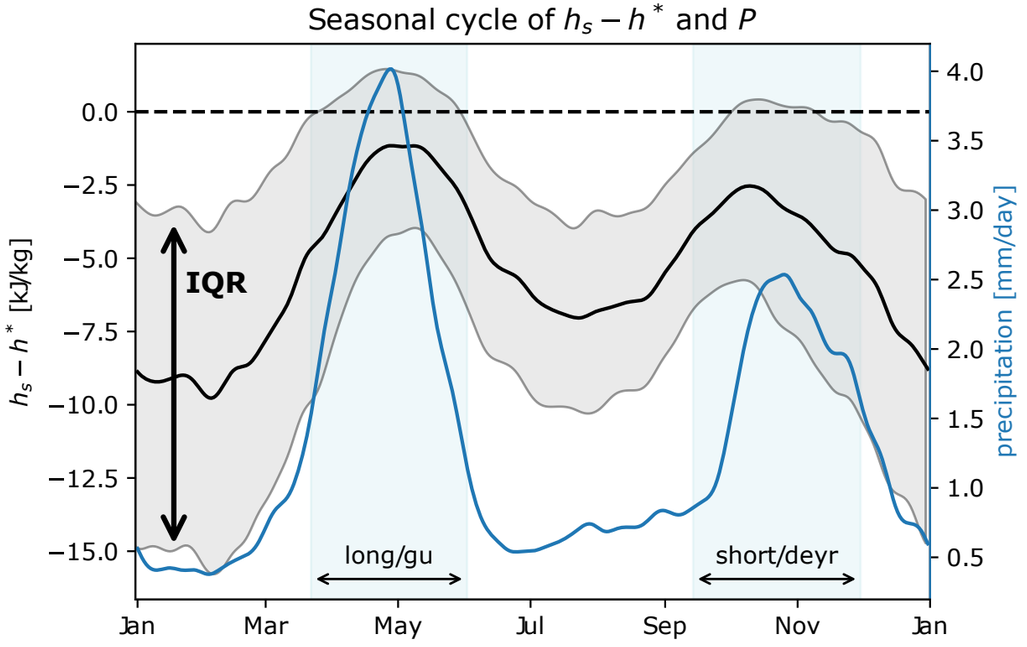
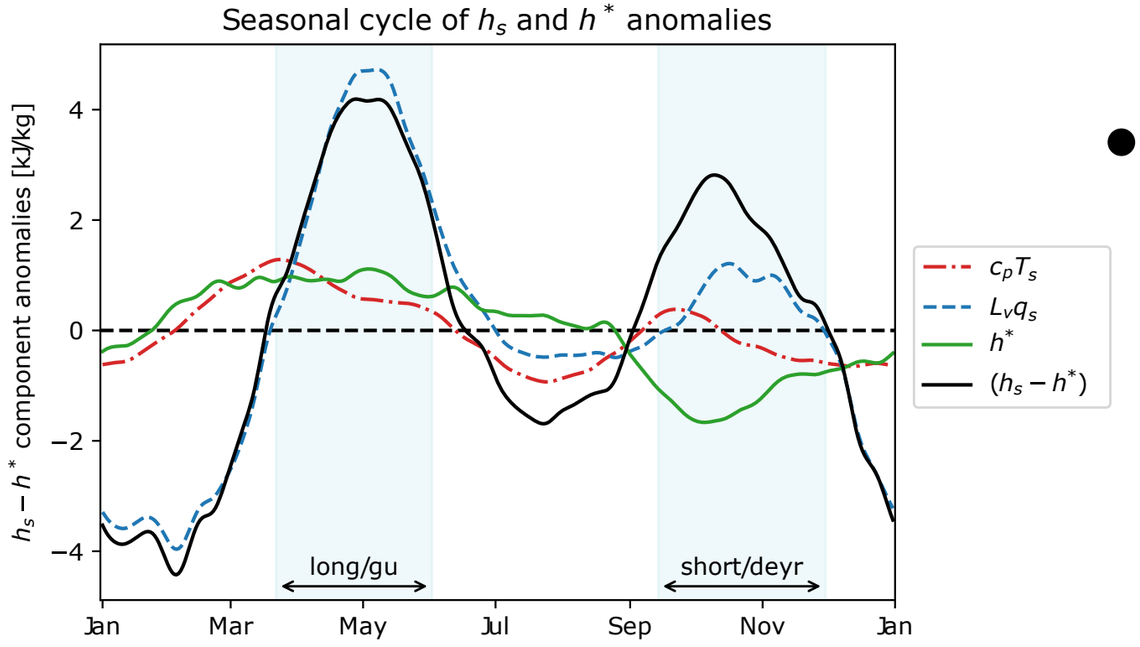




Conclusions

- h_s - h^* closely tracks the GHA rainfall climatology
- During the long rains, h_s - h^* anomalies are dominated by q_s
- During the short rains, h_s - h^* anomalies arise through both q_s and h^*, in line with greater interannual variability, teleconnections
- El Niño associated with increased h^* (tropospheric warming); q_s modulation by IOD needed to understand joint impact
- h_s - h^* can diagnose model errors…

NENSIC

New Era Network for Societally Integrated Climatology

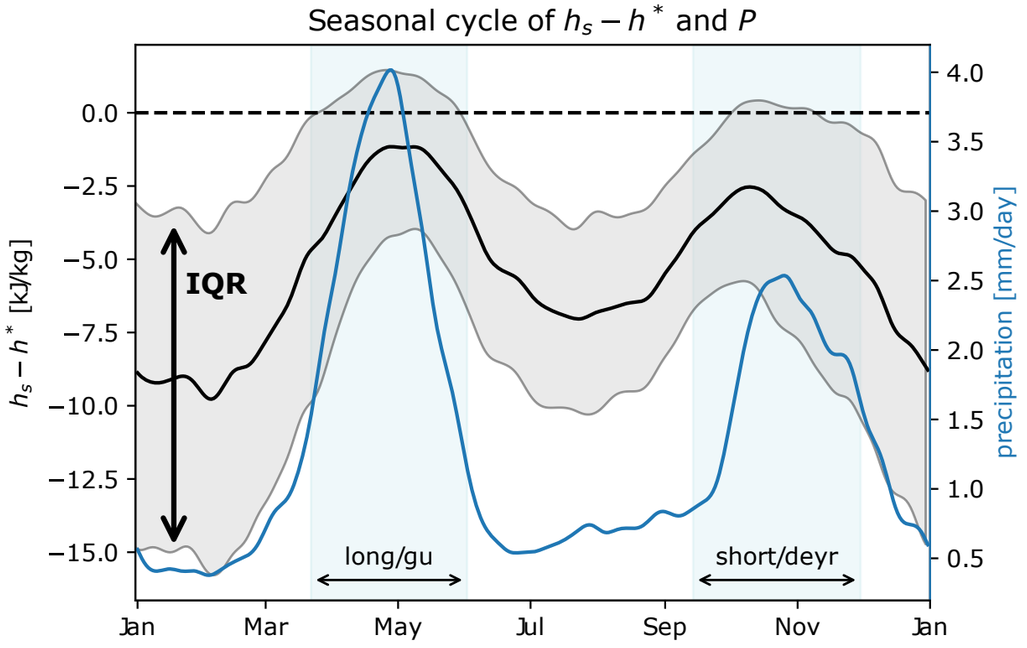
nensic.org

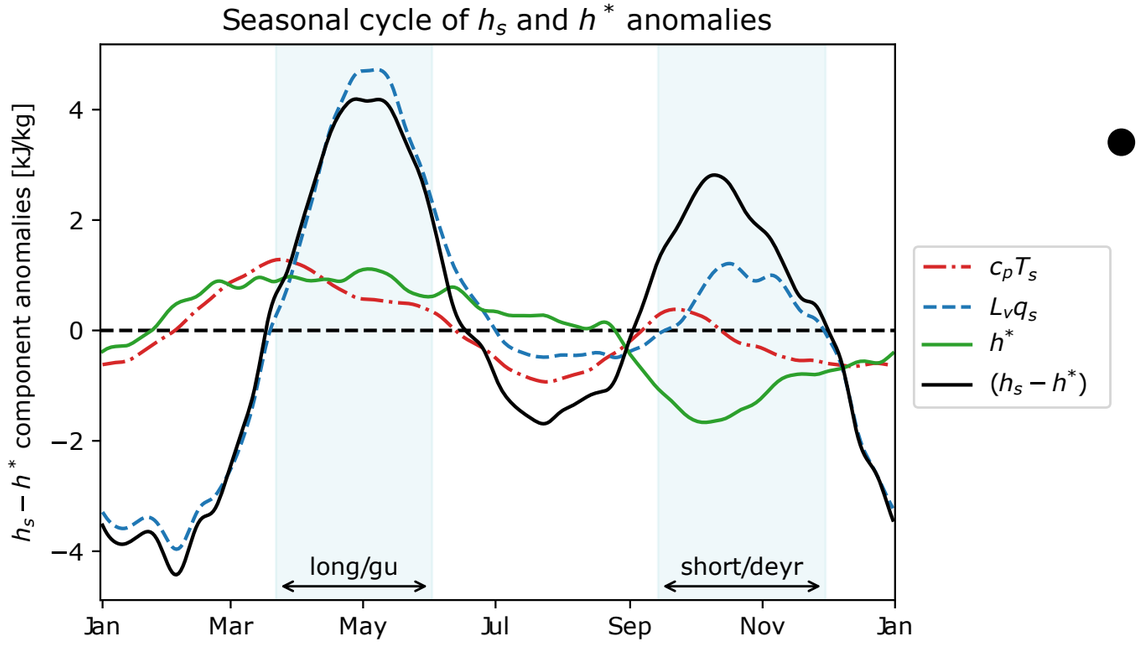
WE ARE

A network, a platform for collaboration and open dialogue, a series of events, open to any young researchers or professionals interested in climate and environmental issues, with a global reach.

WE AIM TO

- Build a network of young researchers and professionals active in the broader climate space across all disciplines and sectors
- Improve interdisciplinary communication by building informal connections between disciplines
- Provide a friendly, inclusive, and accessible venue for members to share their work and find collaborators





Conclusions

- h_s - h^* closely tracks the GHA rainfall climatology
- During the long rains, h_s - h^* anomalies are dominated by q_s
- During the short rains, h_s - h^* anomalies arise through both q_s and h^*, in line with greater interannual variability, teleconnections
- El Niño associated with increased h^* (tropospheric warming); q_s modulation by IOD needed to understand joint impact
- h_s - h^* can diagnose model errors…

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`xagg` **- raster data to polygons for python**

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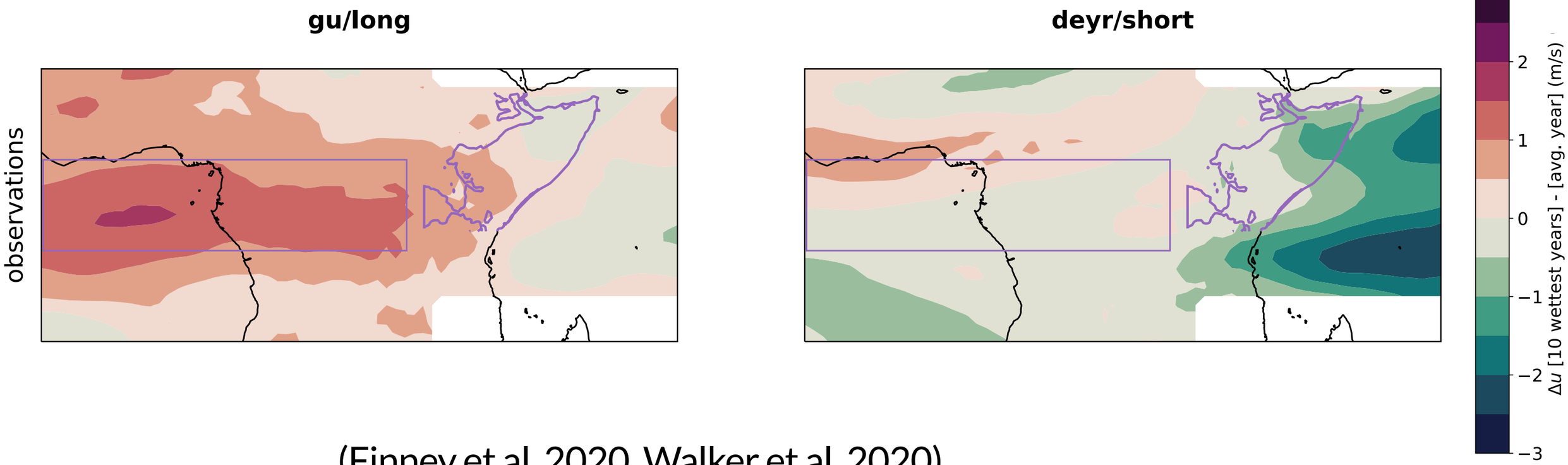
What are we missing with this h_s - h^* framework ?

Congo Basin equatorial westerlies at *700 hPa* connected with wet long rains



(Finney et al. 2020, Walker et al. 2020)

Only ~ T, z; ignores higher level moisture entrainment

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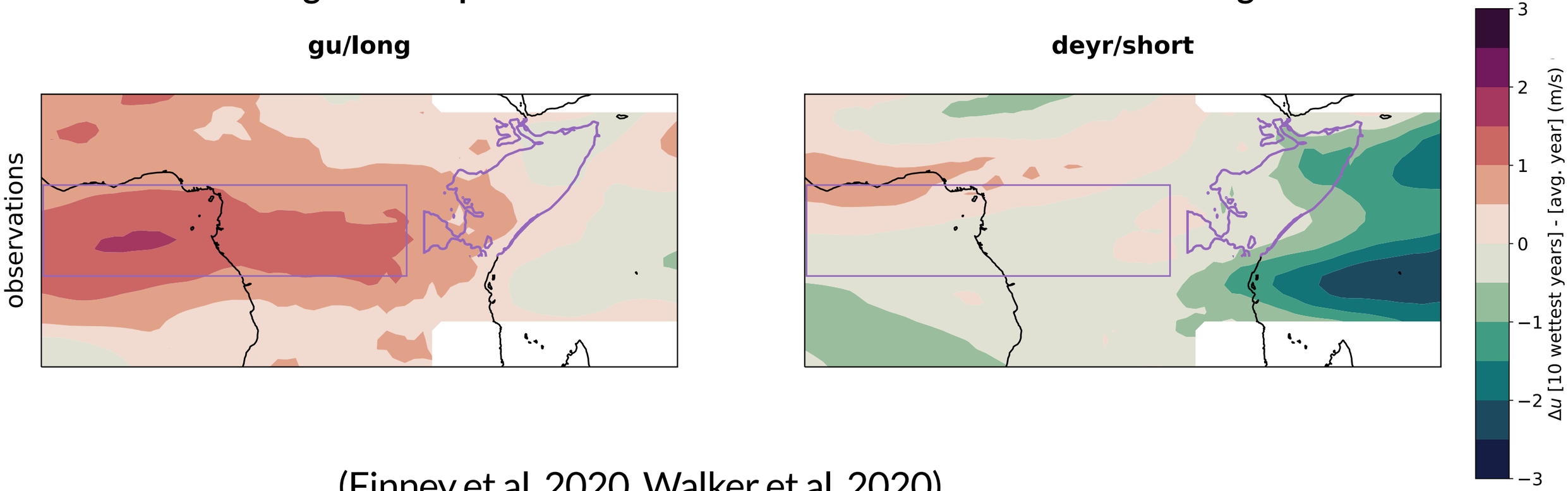

(Finney et al. 2020, Walker et al. 2020)