

The North American monsoon

Current scientific issues and perspectives for the future

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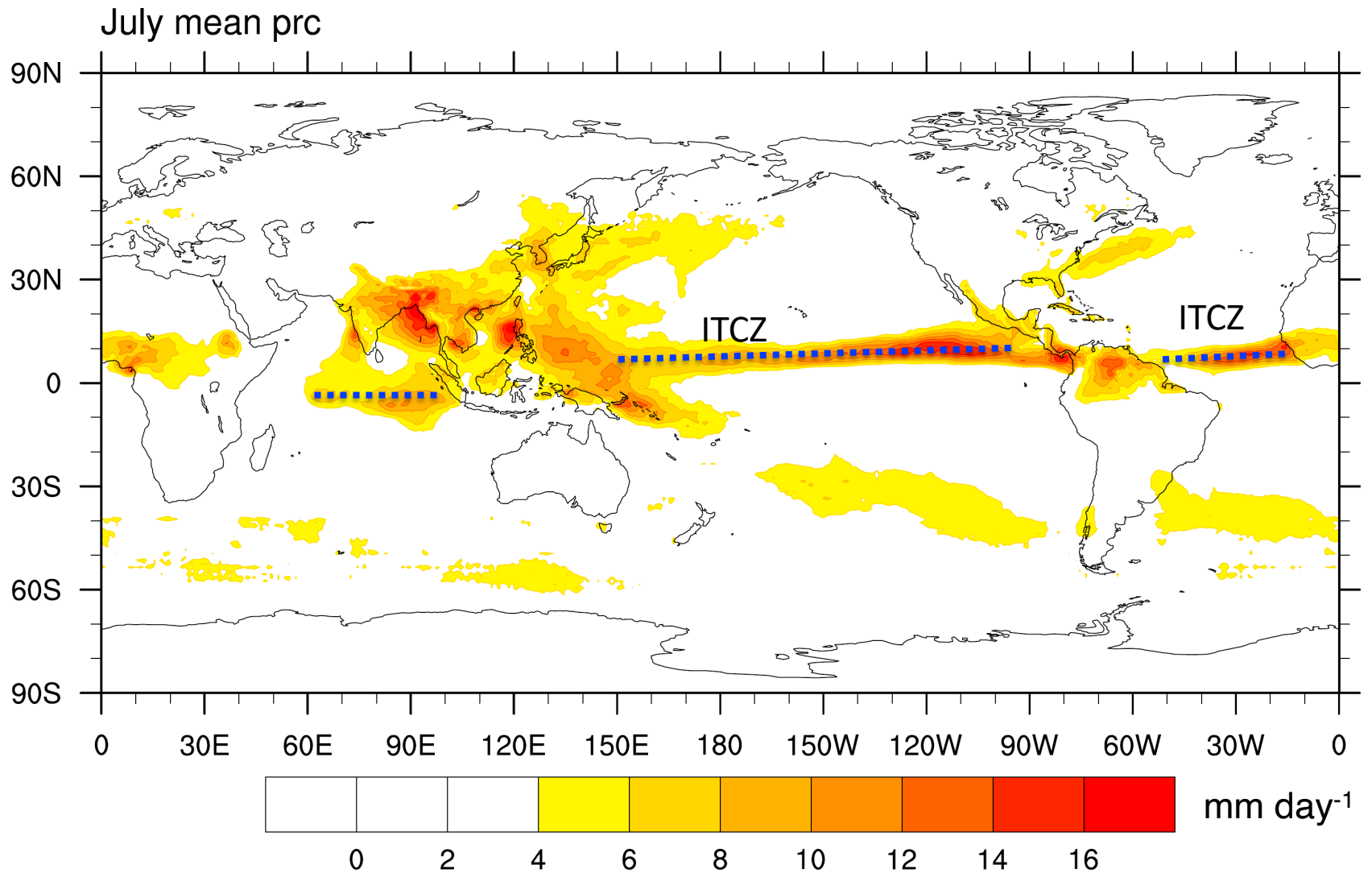
Department of Physics and Astronomy



Outline

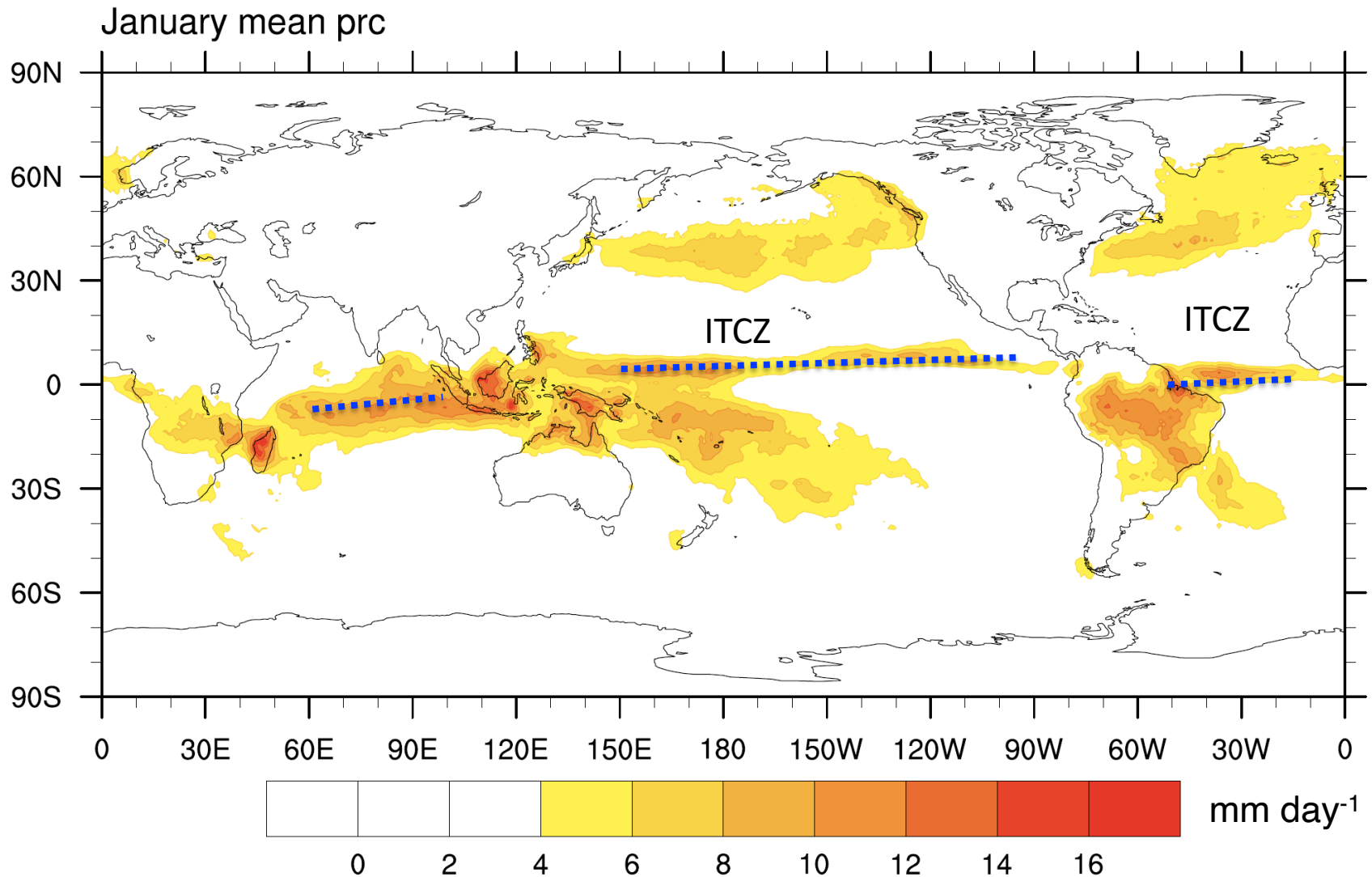
- The North American Monsoon (NAM)
- The NAM under global warming
- Challenges for the prediction of the NAM in a warmer climate

The global monsoon



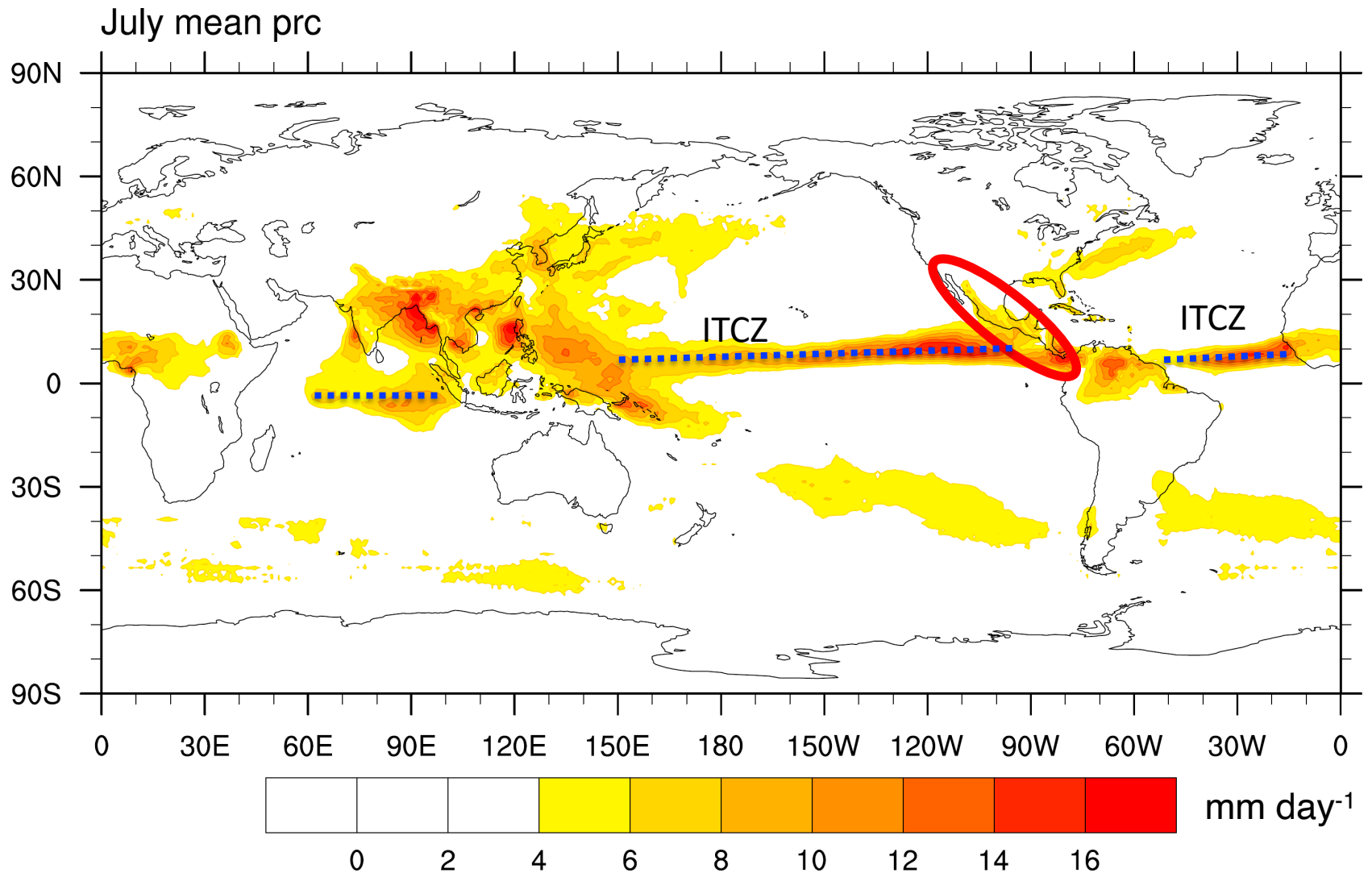
Data source: GPCP 1DD. Courtesy of S. Bordoni

The global monsoon



Data source: GPCP 1DD. Courtesy of S. Bordoni

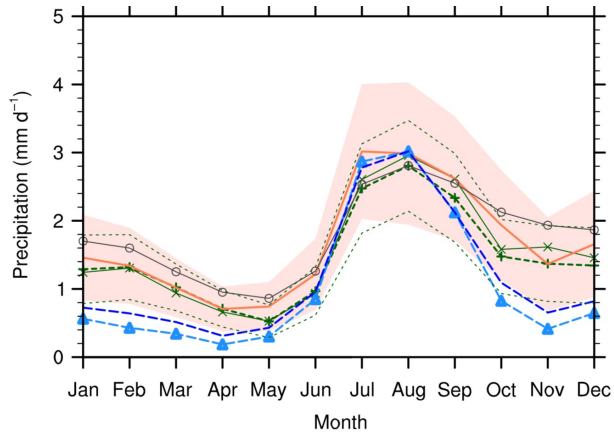
The global monsoon



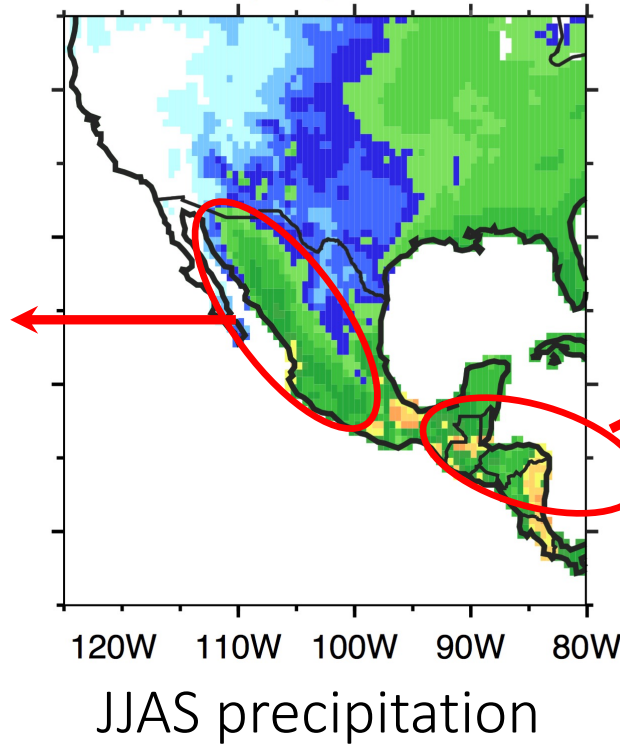
Data source: GPCP 1DD. Courtesy of S. Bordoni

Central American vs. NW Mexico

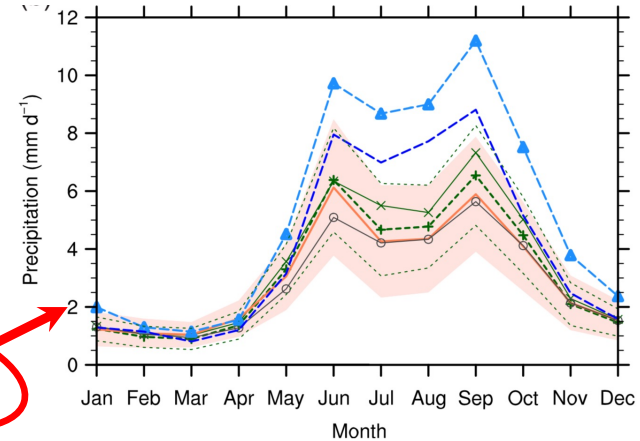
Monsoon “core” region,
unimodal regime



Observed precipitation--GPCP



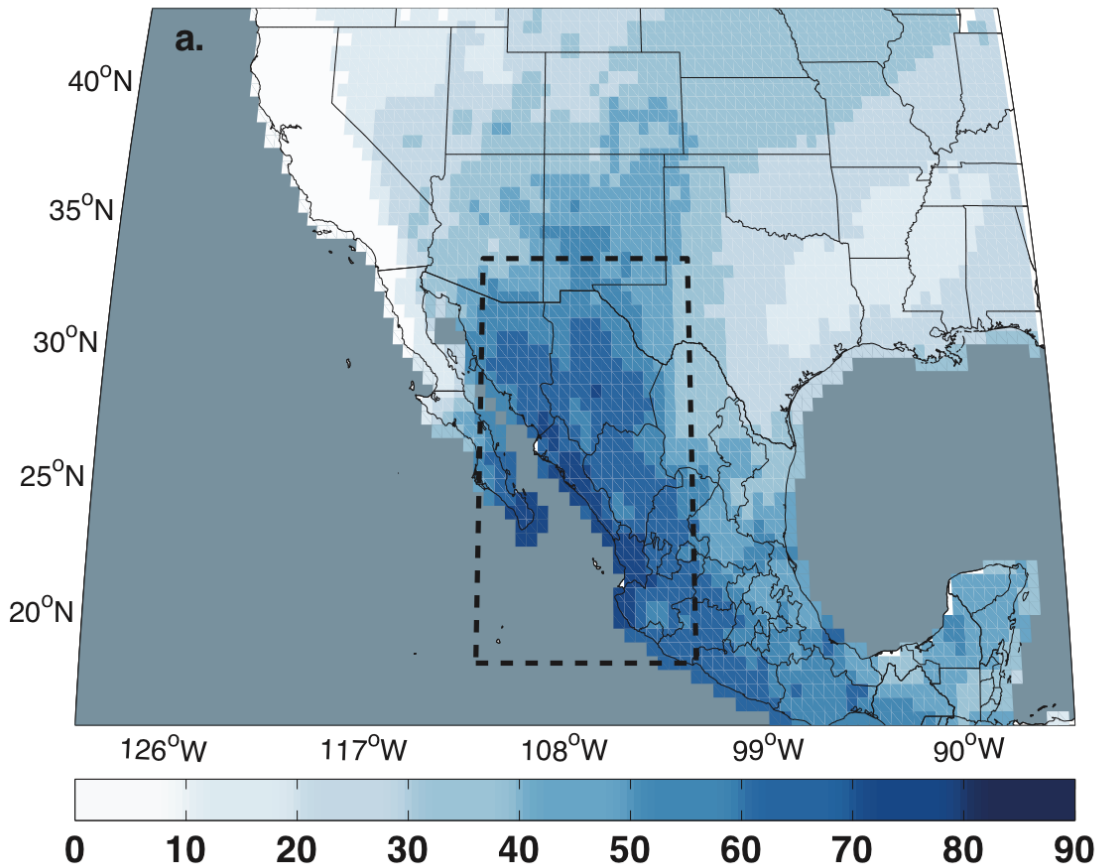
CA Midsummer droughts,
bimodal regime



The socio-economic importance of the NAM

70% of annual precipitation in NW Mexico, ~40-50 % of annual precipitation over SW US

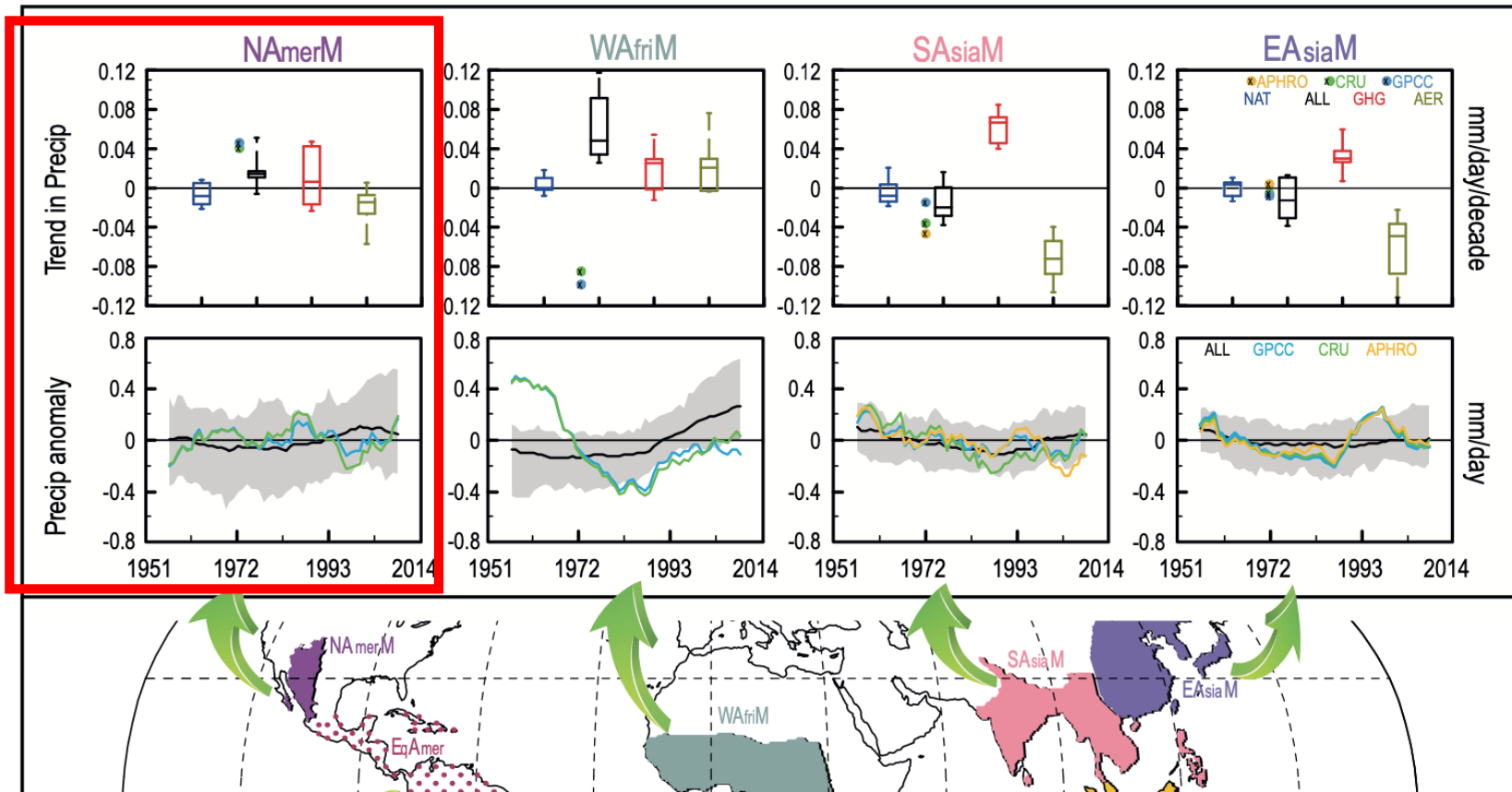
JAS Precipitation, % of Annual



- NW Mexico is primary region of irrigated grain farming
- SW USA states population is steadily growing (e.g., in AZ from 263,000 to over 7 million in 100 years) and so water used for domestic (5%) and agriculture (75%) purposes
- Extreme precipitation events

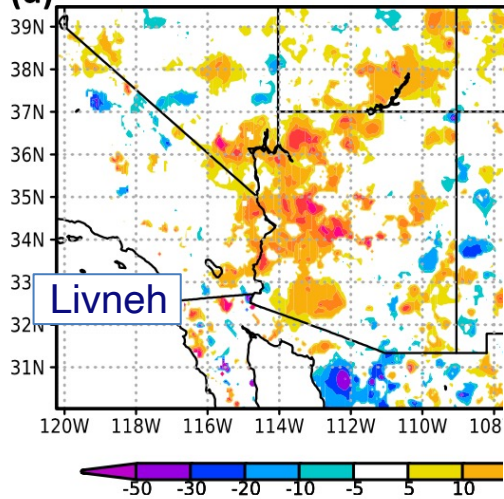
Current climate change and the NAM

Trend and change in precipitation (1951–2014) over monsoon regions



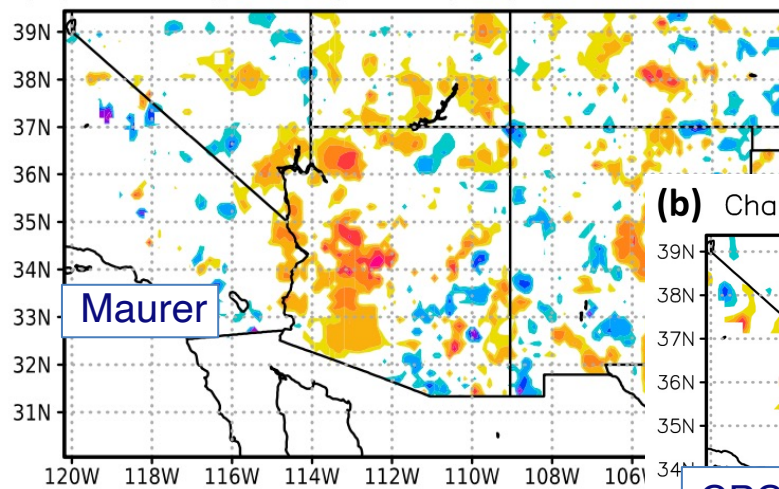
Observed NAM changes: extreme precipitation

(d) Changes in daily Livneh precipitation extremes

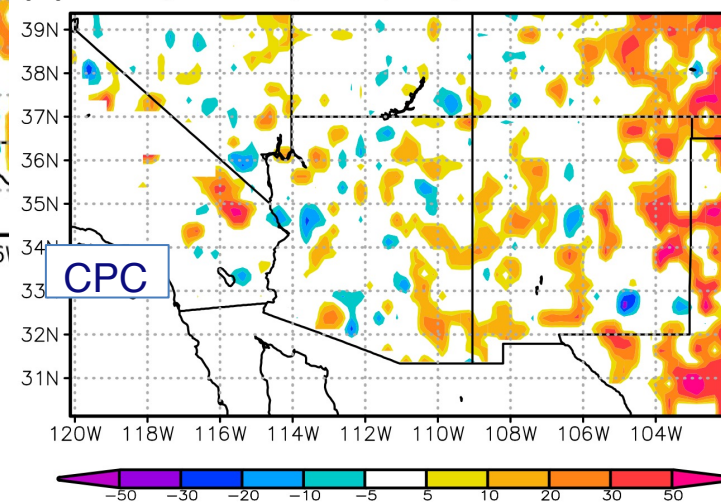


1980-2010 vs. 1950-1970

(b) Changes in daily Maurer precipitation extremes



(b) Changes in daily CPC precipitation extremes



mm/day

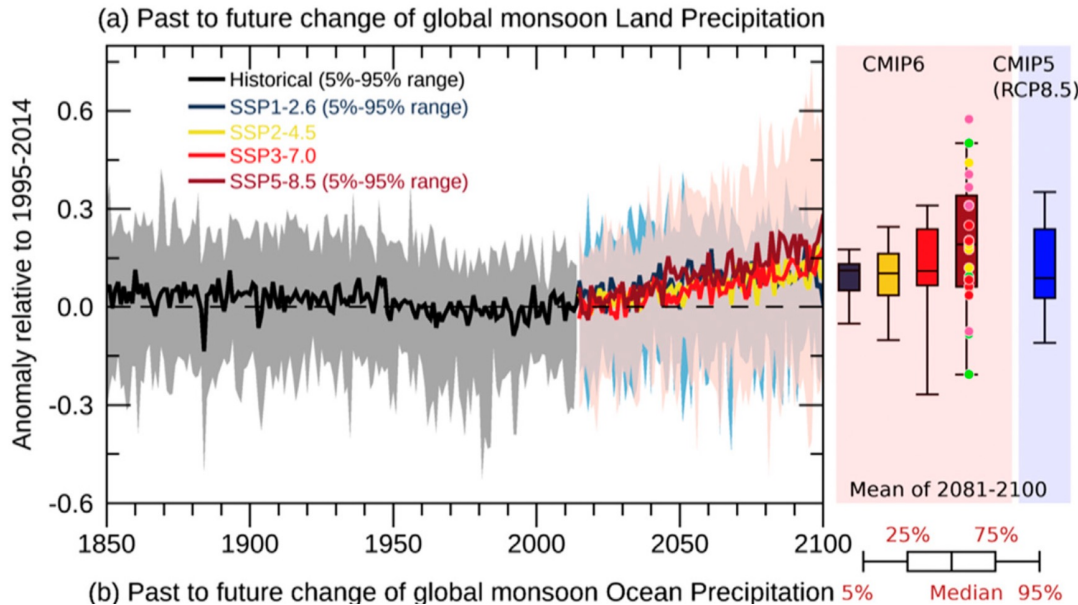
Luong et al., 2017, JAMC

Similarly also in Demaria et al. 2019, GRL

Current climate change and the NAM

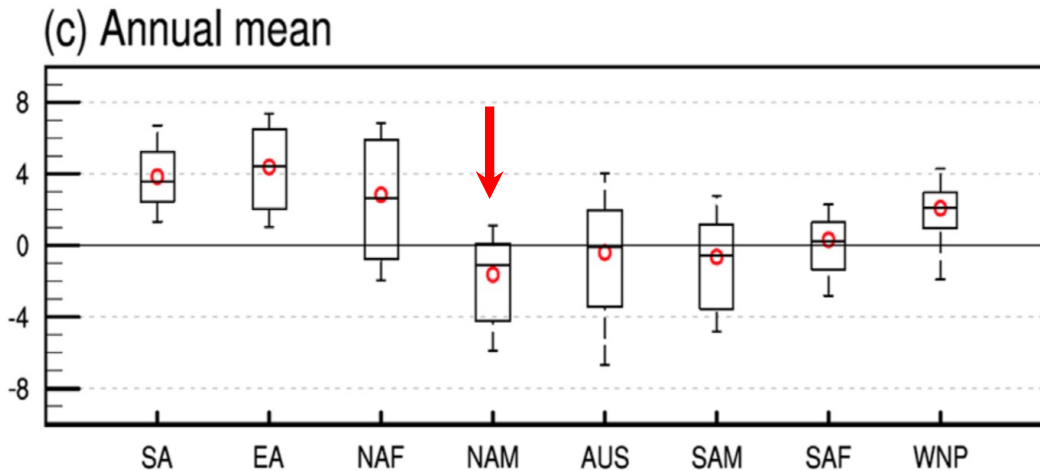
- Observations suggest small or no trends over SW US. Decadal –ve trend over CA but no certain attribution to anthropogenic global warming (Pascale et al., 2021)
- Very limited knowledge of what happens NW Mexico: very few studies suggest no significant changes in summertime precipitation
- Increase in the magnitude of extreme events in NAM and Central American rainfall under anthropogenic global warming (Aguilar et al. 2005; Luong et al. 2017).

What do climate projections suggest?



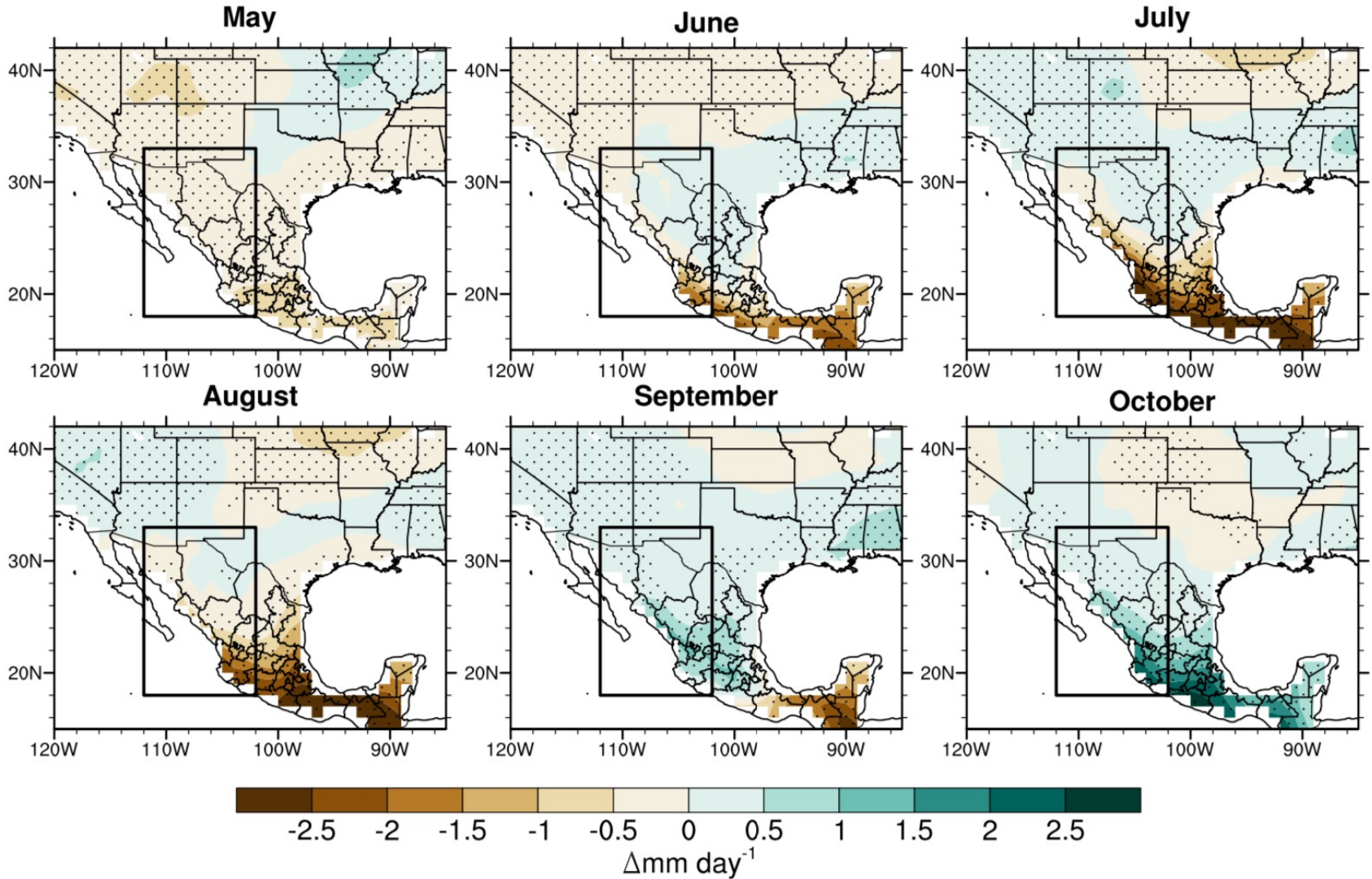
Models CMIP6 models indicates a larger increase in monsoon rainfall over land than over ocean

(b) Past to future change of global monsoon Ocean Precipitation



CMIP6 projection of the NAM

Δ Precip, CMIP6



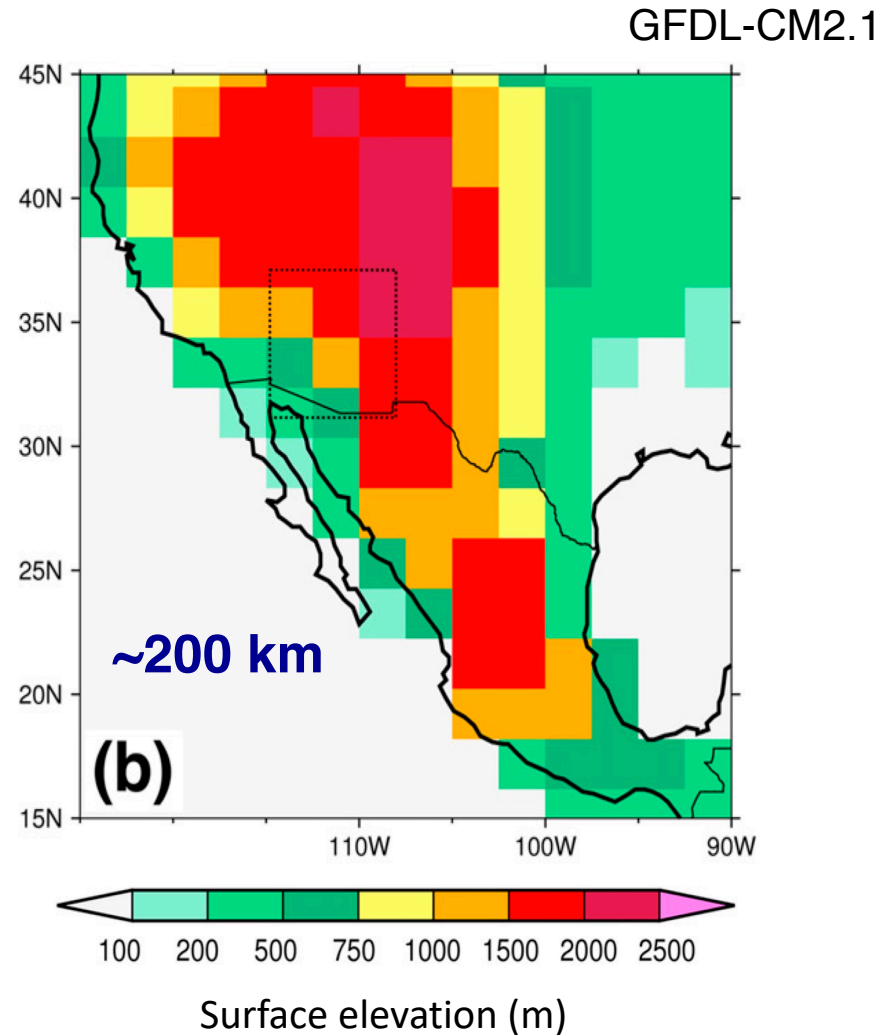
CMIP6 projection of the NAM

- GCMs suggest an early-to-late redistribution of the mean NAM precipitation with little overall reduction, and a more substantial reduction for Central American precipitation
- “There is low confidence in projections of changes in precipitation amounts for the North American monsoon (IPCC5)”
- “both paleoclimate evidence and observations indicate an intensification of the NAmM in a warmer climate (medium confidence)” (IPCC6)

Why such a low confidence in GCM projections?

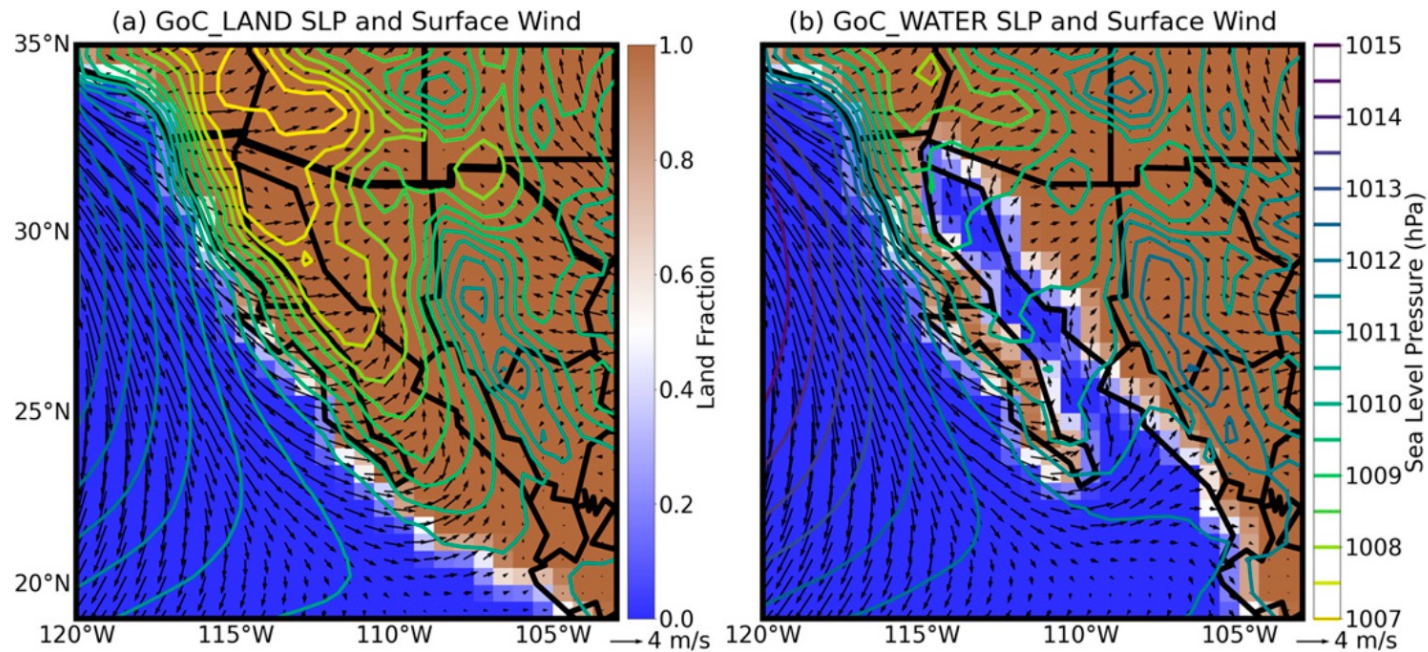
Where are the issues with the NAM?

- Coarse horizontal resolution



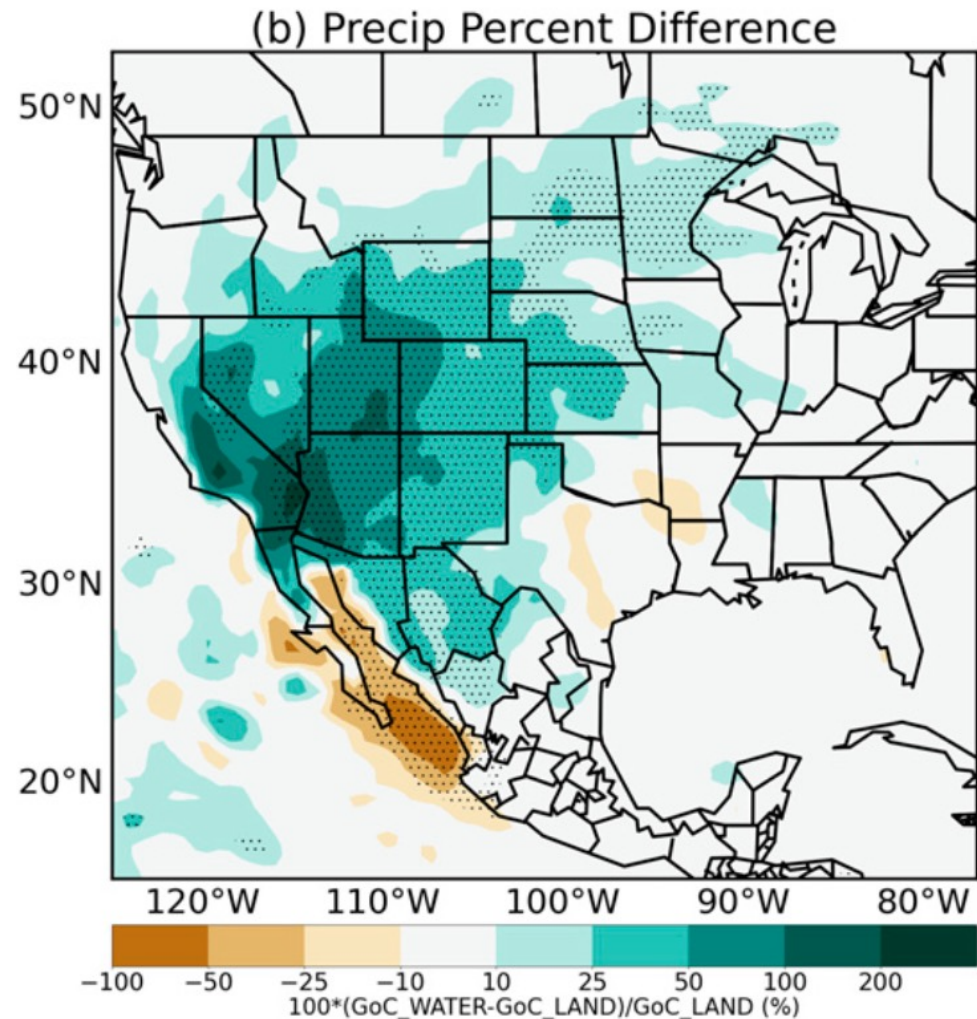
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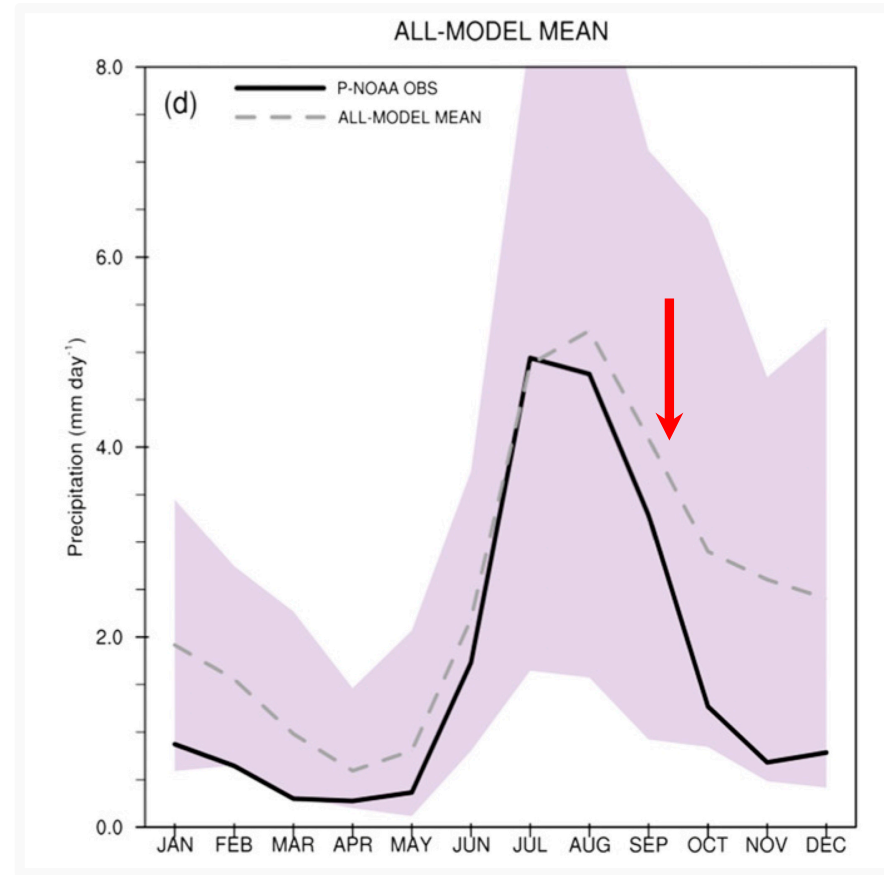
Where are the issues with the NAM?

- Coarse horizontal resolution



Where are the issues with the NAM?

- Coarse horizontal resolution
- SST biases → “retreat problem”

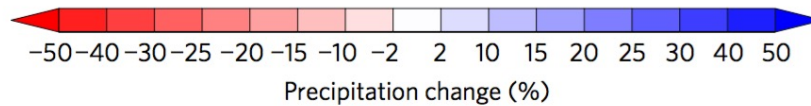
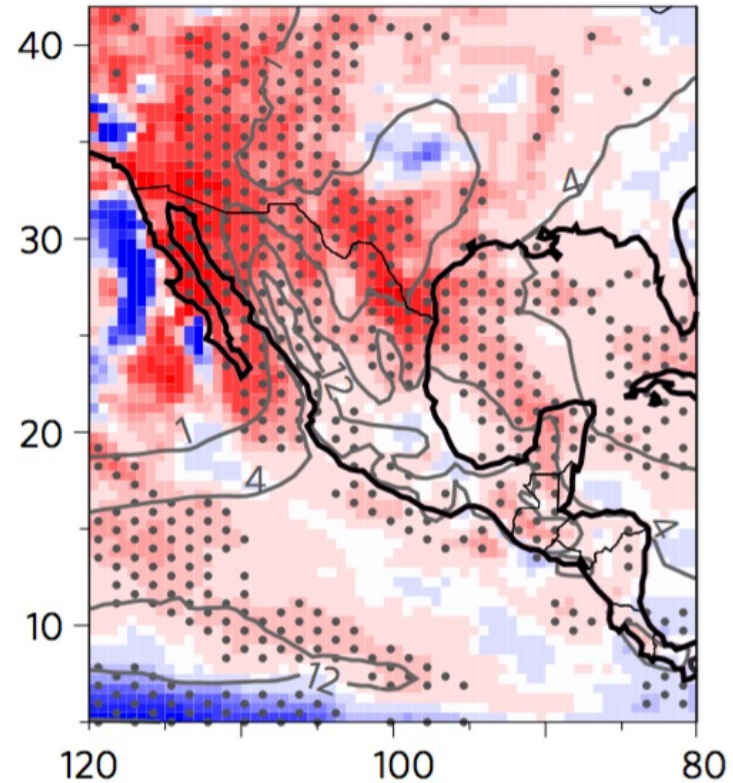
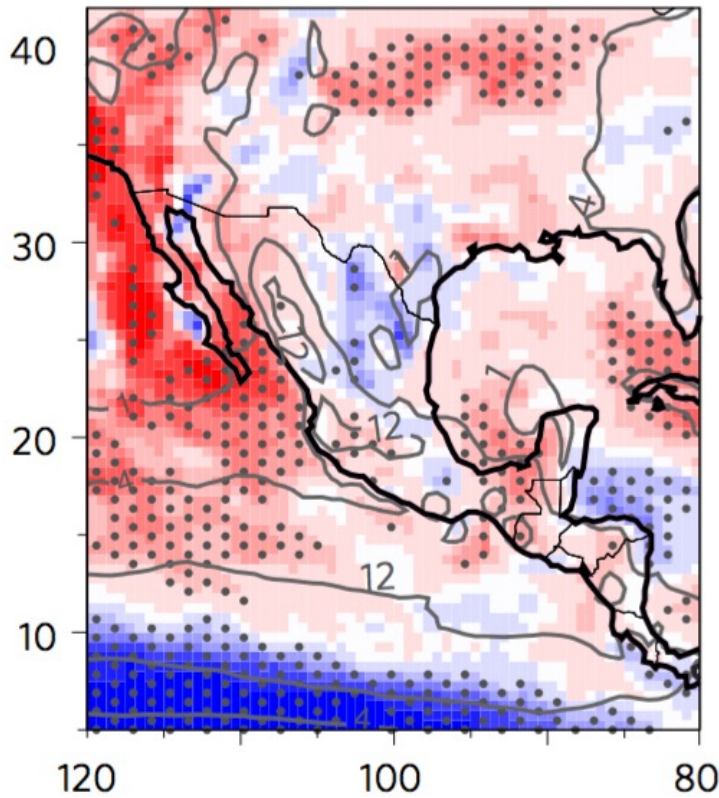


Sheffield et al. (2013), JCLIM
Also Ye & Wang, (2023), JCLIM

NAM response to 2xCO₂ sensitive to SST biases

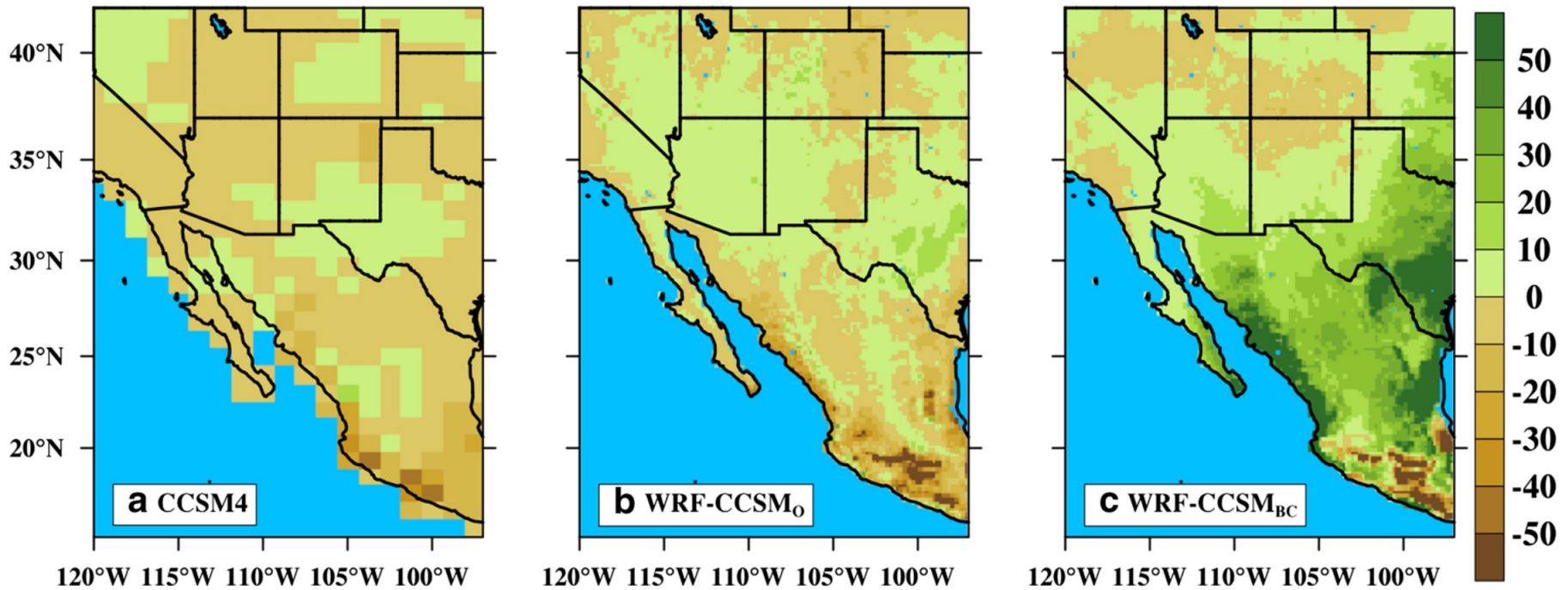
high-res. model (feat. SST biases)

high-res., flux-adjusted model (no SST biases)



Both local and remote biases may lead to large uncertainties...

JJAS Precipitation Change [mm month⁻¹]



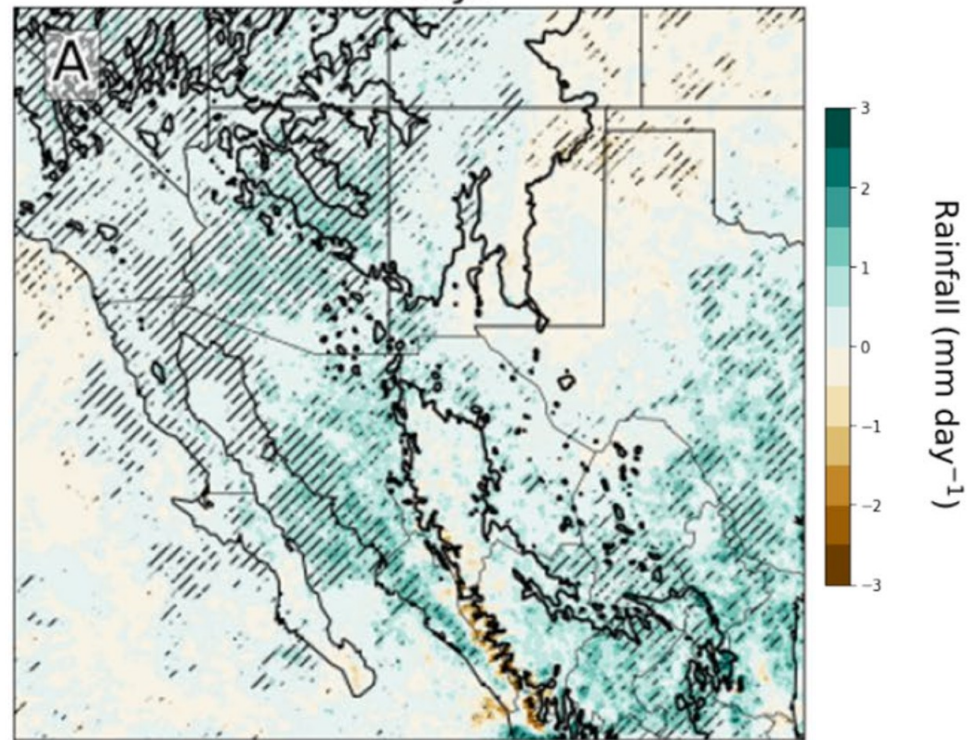
dyn. downscaling

removing SST biases+
dyn. downscaling

Where are the issues with the NAM?

Rainfall changes from a convection-permitting RCM

- Coarse horizontal resolution
- SST biases → “retreat problem”
- Parameterized convection cannot realistically capture NAM precipitation

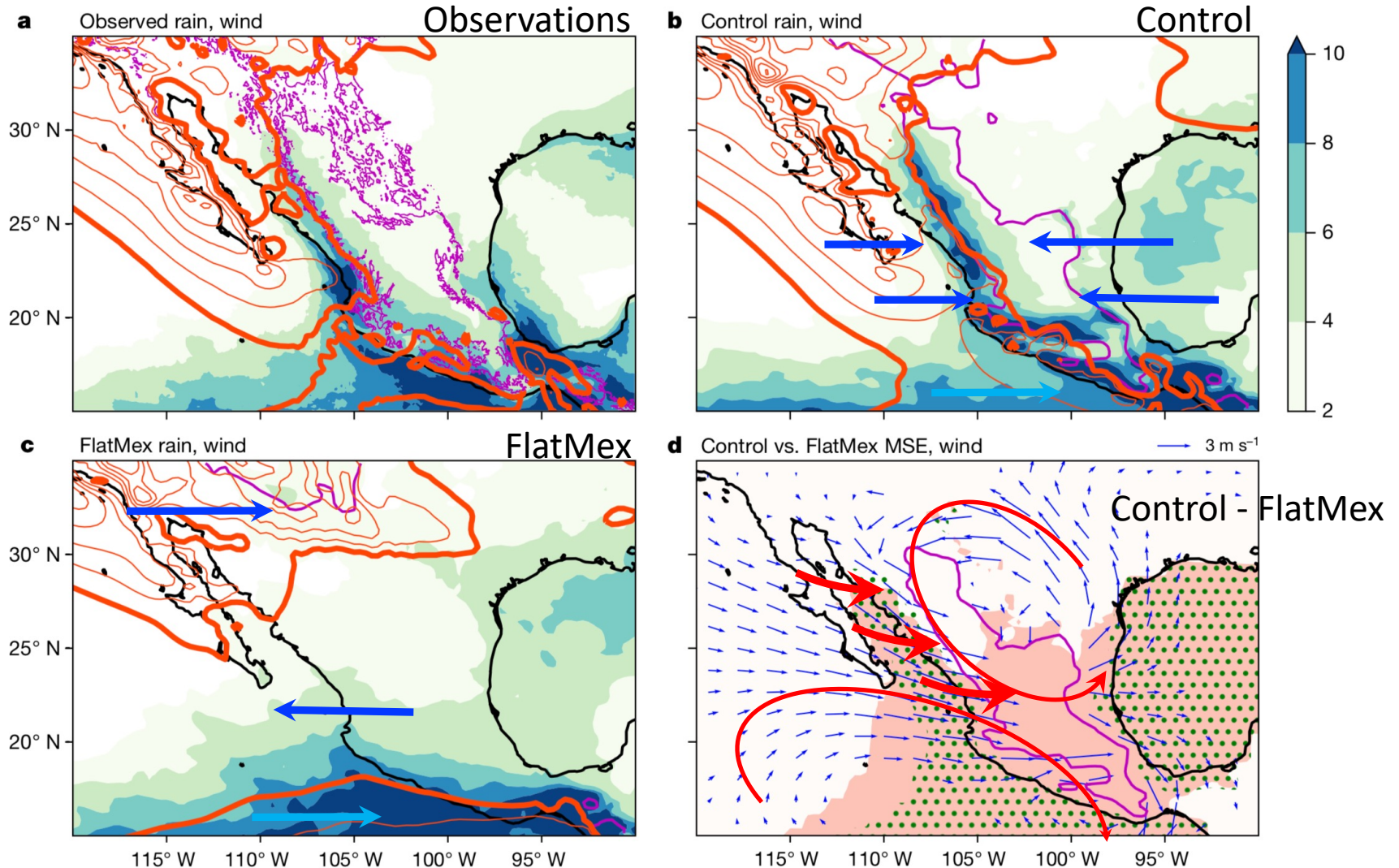


Warning: just 12 years long run....

Where are the issues with the NAM?

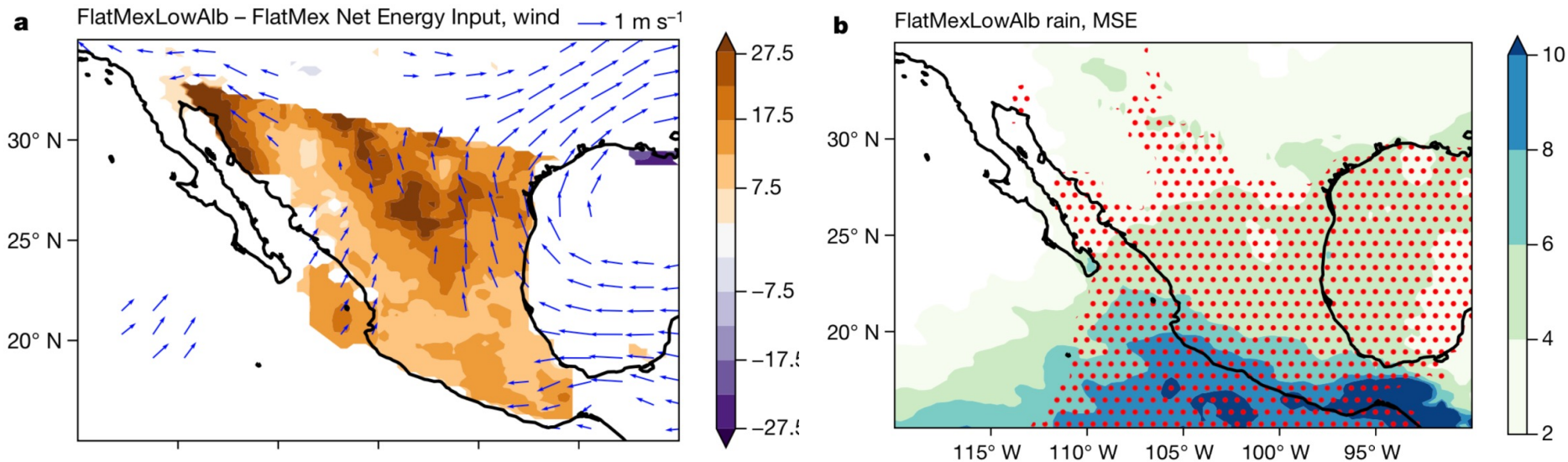
- Coarse horizontal resolution
- SST biases → “retreat problem”
- Parameterized convection cannot realistically capture NAM
- Do we fully understand the NAM?: the mechanisms that organize NAM precipitation around orography still debated

Orographically or thermally forced?



Response to a pure thermal forcing

FlatMexLowAlb - FlatMex



- The alternative hypothesis that the core NAM is primarily driven by thermal, rather than mechanical, orographic forcing tested using FlatMexLowAlb
- As expected for a thermally forced tropical monsoon, peak rainfall lies on the equatorial side of the high-MSE region

Summary

- Impacts of global warming still **modest**: small negative or null trends in the last decades in mean precipitation, increase of extreme rains
- **Low-to-medium confidence** in future projections:
 - SST biases in adjacent oceans;
 - Unresolved mechanisms (orography, Gulf of California, etc.)
 - Inadequacy of GCMs in representing convection
 - Uncomplete comprehension of the NAM basic mechanisms
- Increased resolution in GMCs and CPM likely to alleviate some of these issues
- More idealized studies to better understand the processes -> Devising new studies to evaluate the impact of global warming on mechanical and thermal forcing.

Thank you for your attention

