

1. Motivation and Goals

- The high-cloud radiative effect (HCRE) affects monsoons through atmospheric and surface pathways, but previous studies mainly focus on the atmospheric pathway.
- This study quantifies how HCRE modulates monsoon systems when ocean surface temperatures respond to atmospheric changes.

2. Hypothesis

- HCRE warms the troposphere, weakens monsoon precipitation, and shifts monsoon extent via changes in large-scale circulation.

3. Methods / Experimental Design

Model

- Atmospheric component of ICON-ESM
- External forcing (GHGs, aerosols, solar): CMIP6 protocol

Experimental Design

- Two ocean configurations:
 - Prescribed SST (pSST) using climatology from 1979-2008
 - Slab Ocean Model (SOM) with 50 m mixed layer
- Two cloud-radiative setups:
 - HC-on (CTRL): full cloud-radiative interactions
 - HC-off: high-level clouds radiatively transparent

	SST prescribed	Slab Ocean
HC - on	pSST _{CTRL}	SOM _{CTRL}
HC - off	pSST _{HC-off}	SOM _{HC-off}

Monsoon & High Cloud Definition

- Summer – winter precipitation difference > 2 mm day⁻¹
- Summer precipitation > 55% of annual total



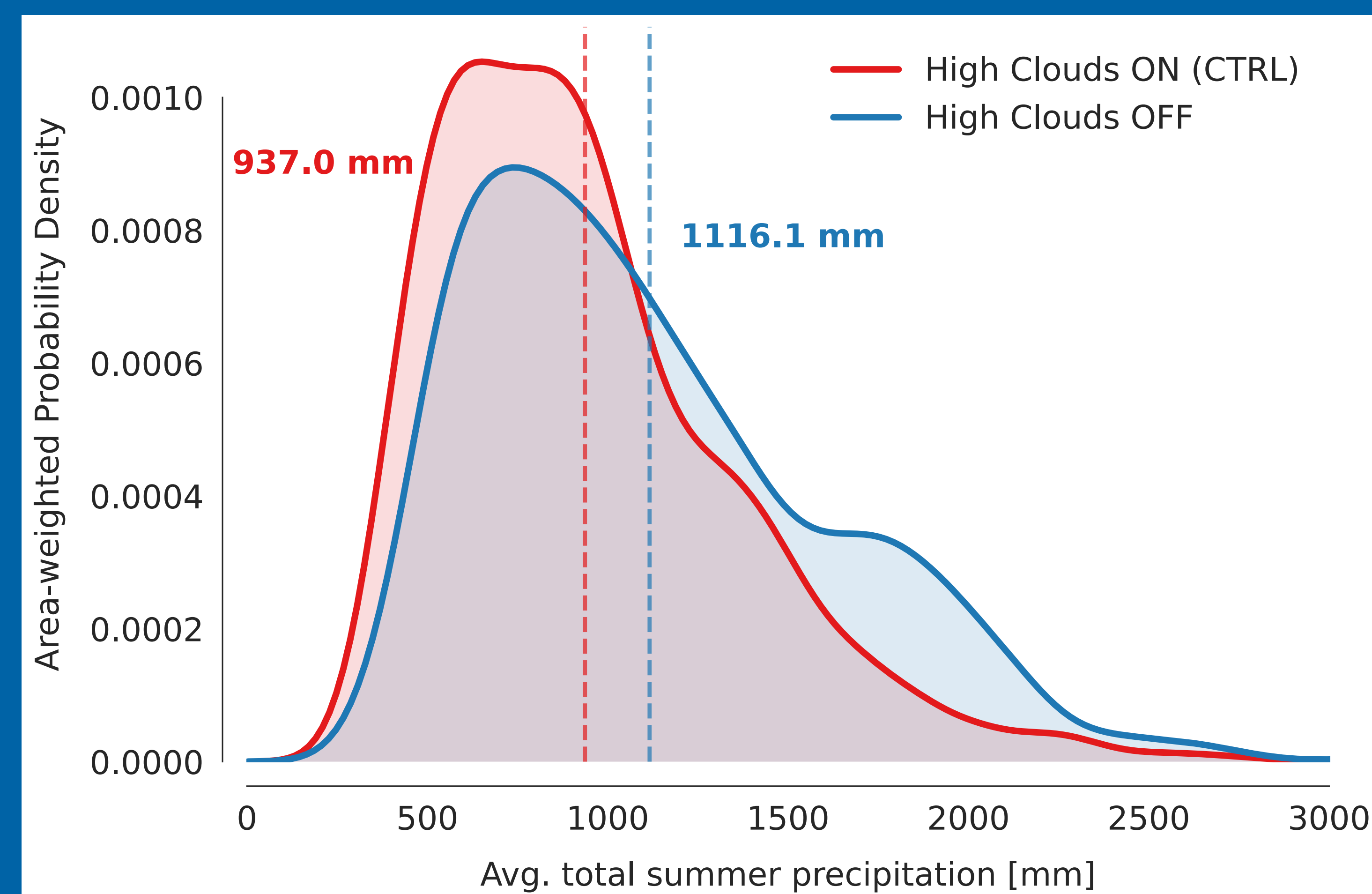
Impact of high-cloud radiative effects on monsoons

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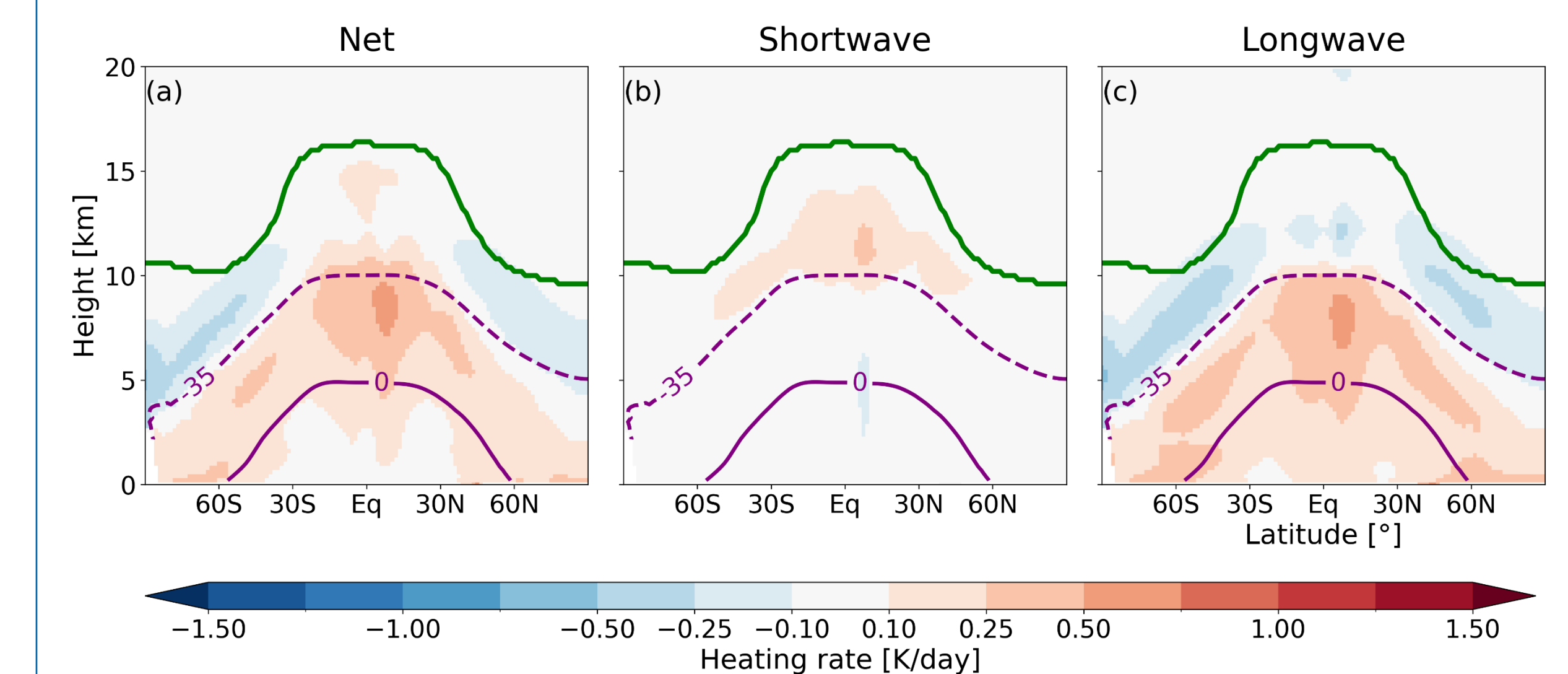
High-level clouds reduce mean and extreme monsoon precipitation



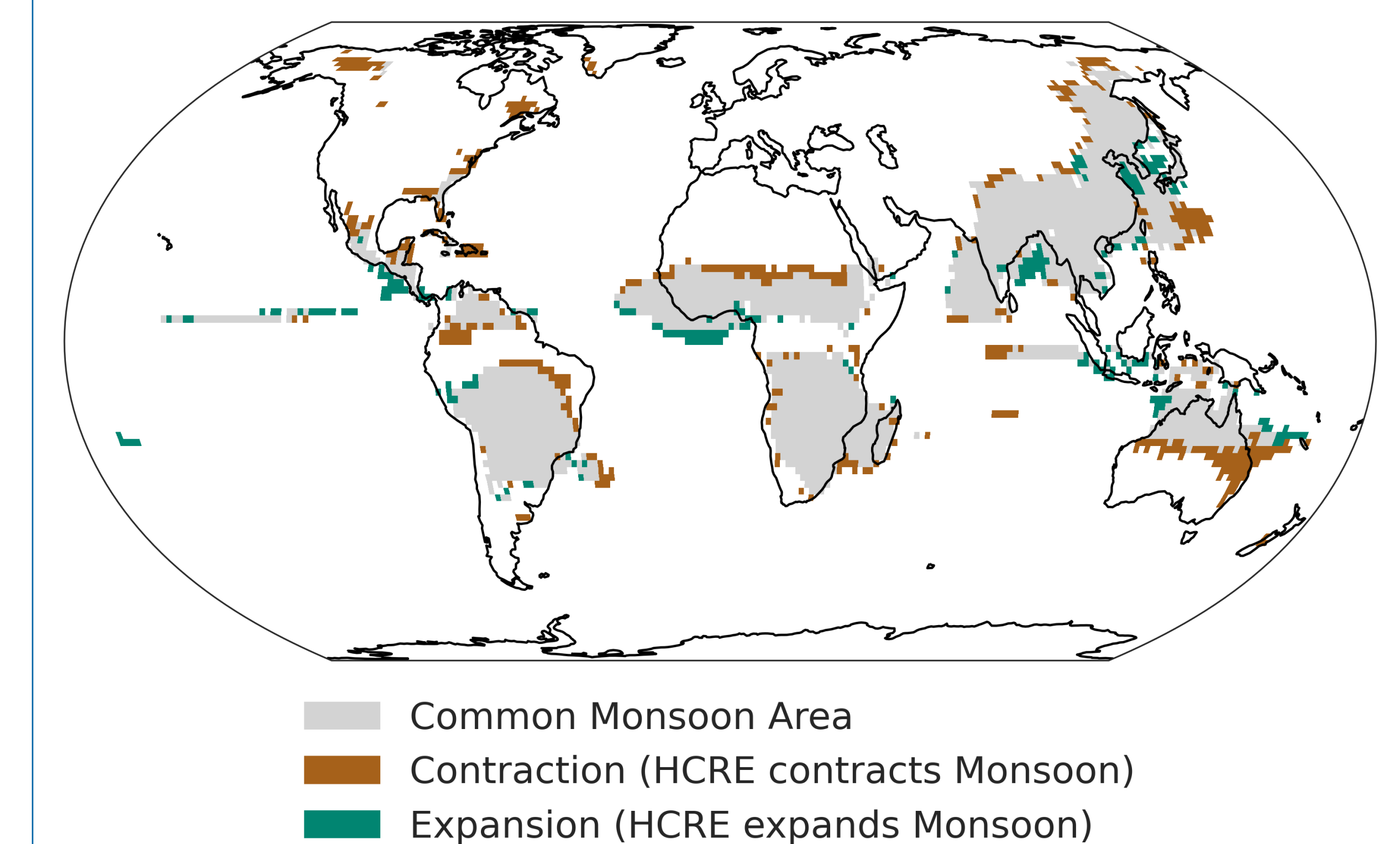
Area-weighted distribution of summer precipitation over the common monsoon domain

5. High Clouds Warm Troposphere & Modulate Monsoons

- High clouds radiatively heat the troposphere across all latitudes.
- Tropospheric radiative warming reduces the atmospheric need for latent heat release from condensation and explains the lower precipitation in HC-on simulations.
- In the upper troposphere at high altitudes, high clouds have a net cooling effect, increasing meridional temperature gradients.



- In prescribed SST simulations, HCRE leads to regional contraction and expansion of monsoon areas, with no uniform shift
- Precipitation changes are spatially heterogeneous



6. Summary & Outlook

- High clouds warm the troposphere and reduce latent heating, leading to lower mean and fewer extreme monsoon precipitation.
- Prescribed SST results show HCRE modulates monsoons; ongoing slab ocean simulations will quantify the role of the surface pathway

7. Preceding Work

- Haslehner et al. (2024), High-cloud radiative heating, JGR-A

