Intensification of tropical precipitation extremes from more organised convection

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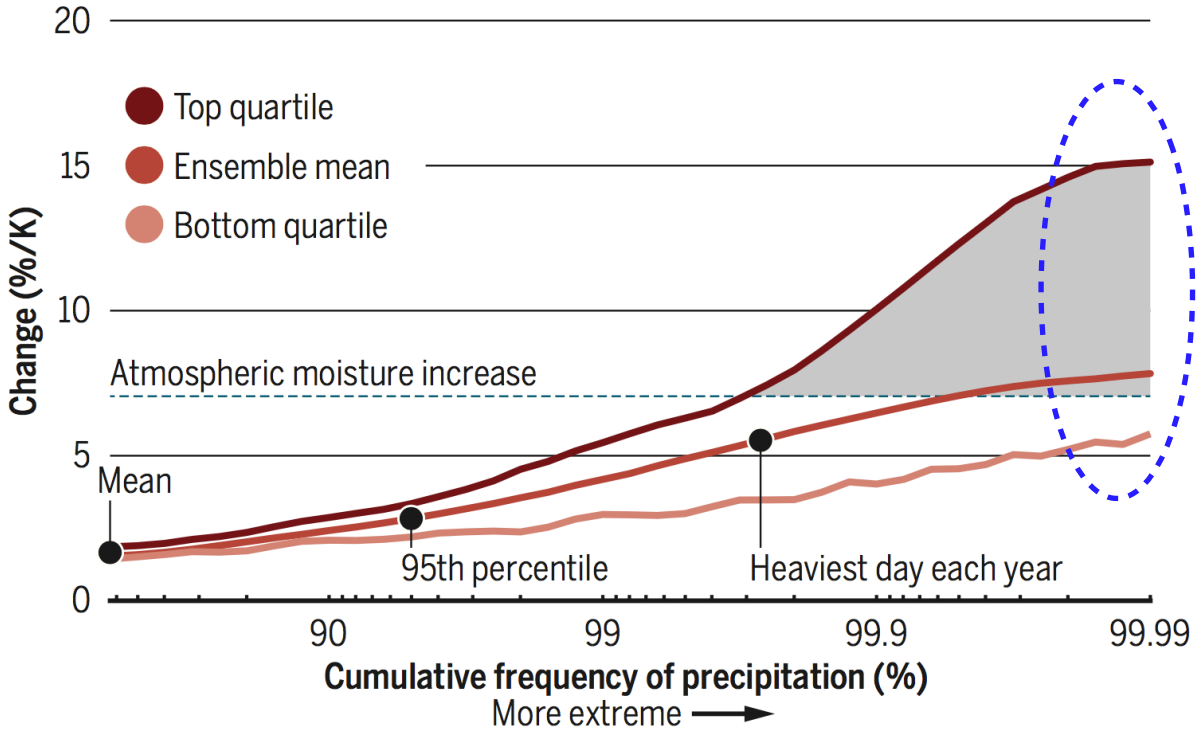
MAX-PLANCK-INSTITUT FÜR METEOROLOGIE

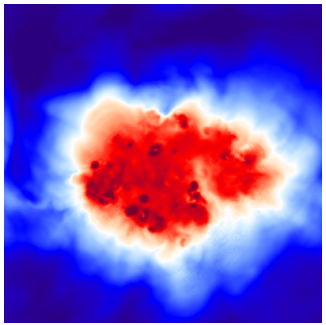
Large uncertainties in future changes in extreme precipitation



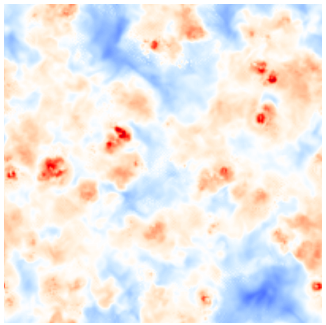
Pendergrass (2018)

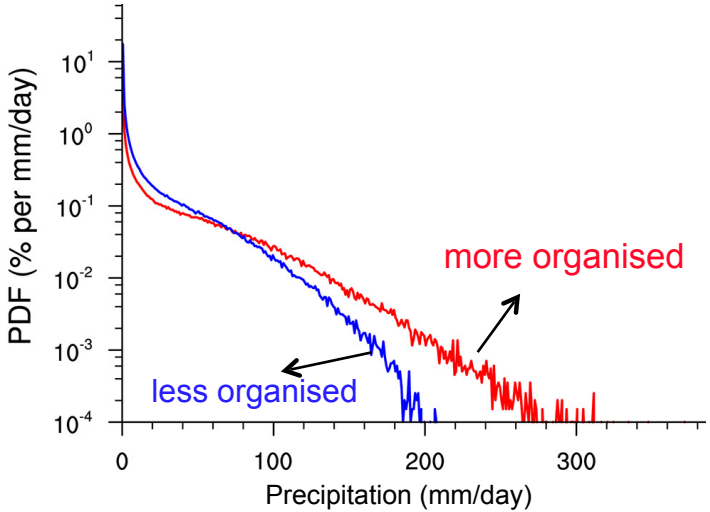
Dynamical contribution from changes in convective organisation

More organised



Less organised

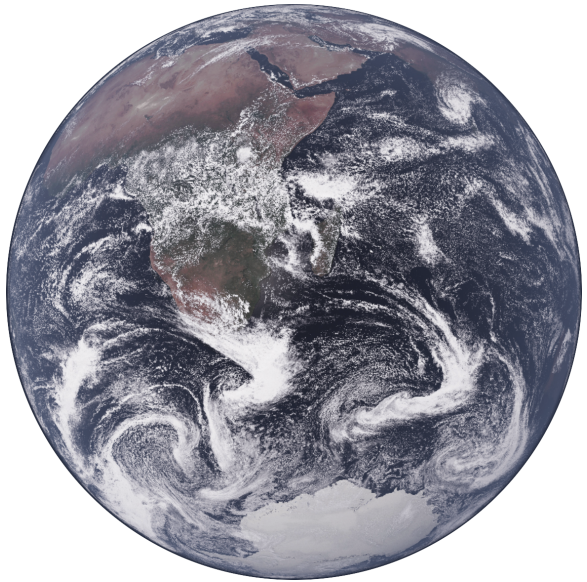




Bao & Sherwood (2019)

Global storm resolving models (GSRMs)

- High resolution (<5km), global domain
- Realistic conditions (forcing, with rotation)
- With large-scale circulation



ICON 1 km visualization (MPI-M&DKRZ)
Hohenegger et al. 2023

Questions:
Does the impact of convective organisation on precipitation extremes work beyond RCE?

Q1: Are precipitation extremes and convective organisation related in present-day climate?

Q2: Do changes in organisation explain changes in extremes with warming?

Simulations and data

Models: Experiment setup

- ICON model
- 5 km horizontal resolution over the global domain
- 90 vertical levels
- No deep and shallow convective parameterisation

Experiment	Time	SST?
$ICON_{A/O}$	Late Jan- Dec 2020	coupled
$ICON_{A,2020}$	Apr-Sep 2018-2020 (ERA5)	fixed
$ICON_{A,1850}$	Apr-Sep 1850 (piCon)	fixed
$ICON_{A,2070}$	Apr-Sep 2070 (SSP585)	fixed

Observations: IMERG

- 0.1˚ half-hourly satellite retrieves.

Monsoon 2.0

Daily precipitation extremes: P_{ext}

Precipitation extremes are defined as extreme percentiles, for example, P_{95} is 95th percentile of daily precipitation over the tropical domain (30N-30S)

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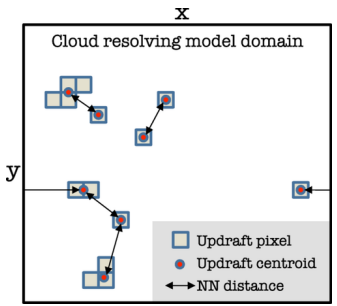
Measuring convective organisation

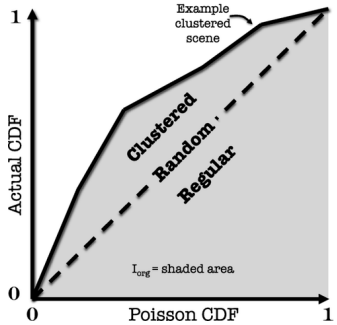
- I_{org}: clustering metric

Convective grids are identified as grid points with daily $P > P_{95}$ over the tropics (30N-30S)
Two convective grids belong to one convective cluster if they are connected.

- N: Number of convective clusters

- S: Average size of convective clusters (radius)

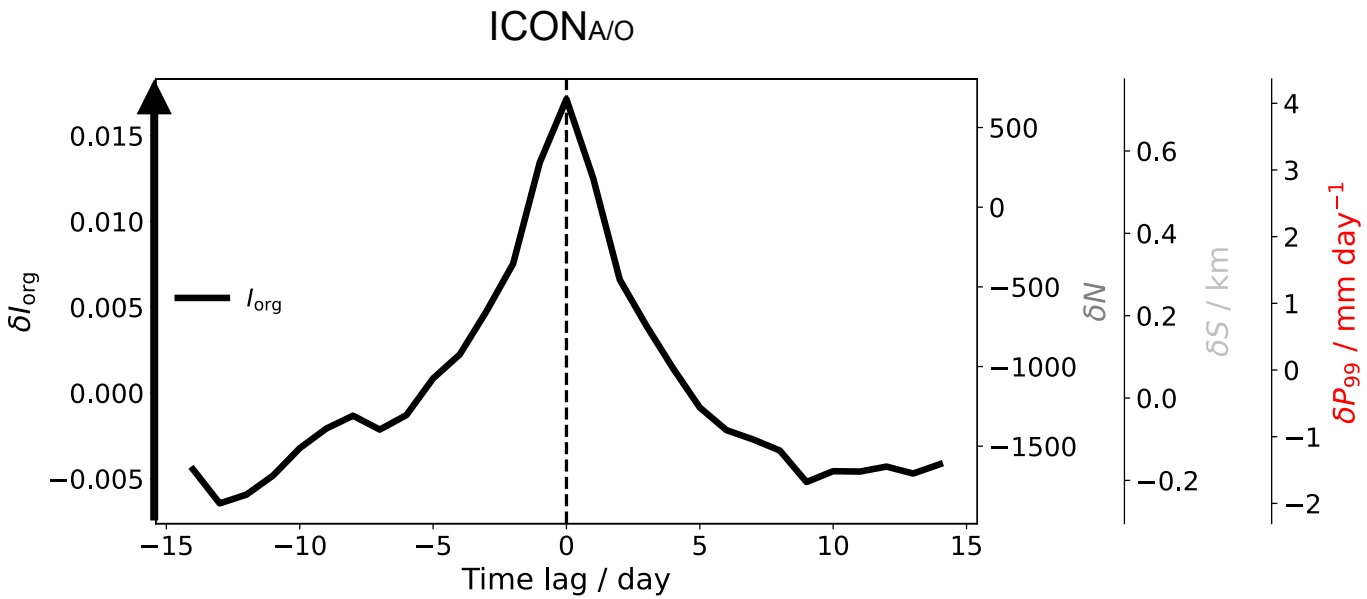




Tomkins & Semie (2017)

Q1: Are precipitation extremes and convective organisation related in present-day climate?

Time evolution of organisation and precipitation extremes during the composite peak organization events



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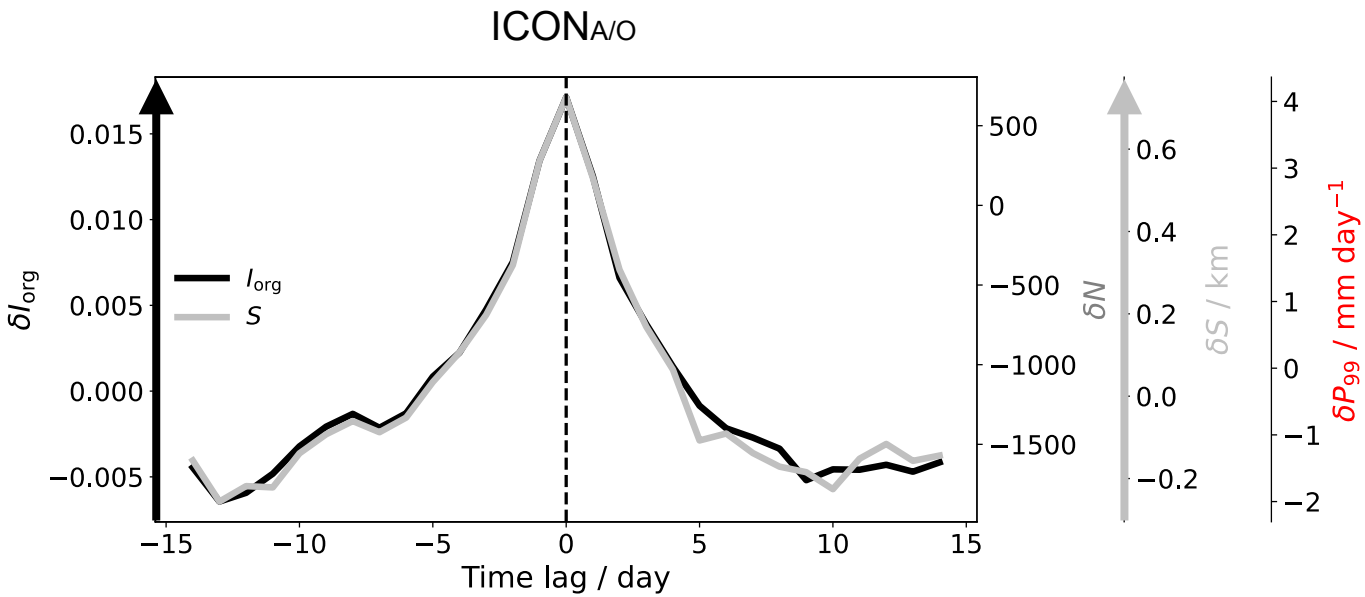

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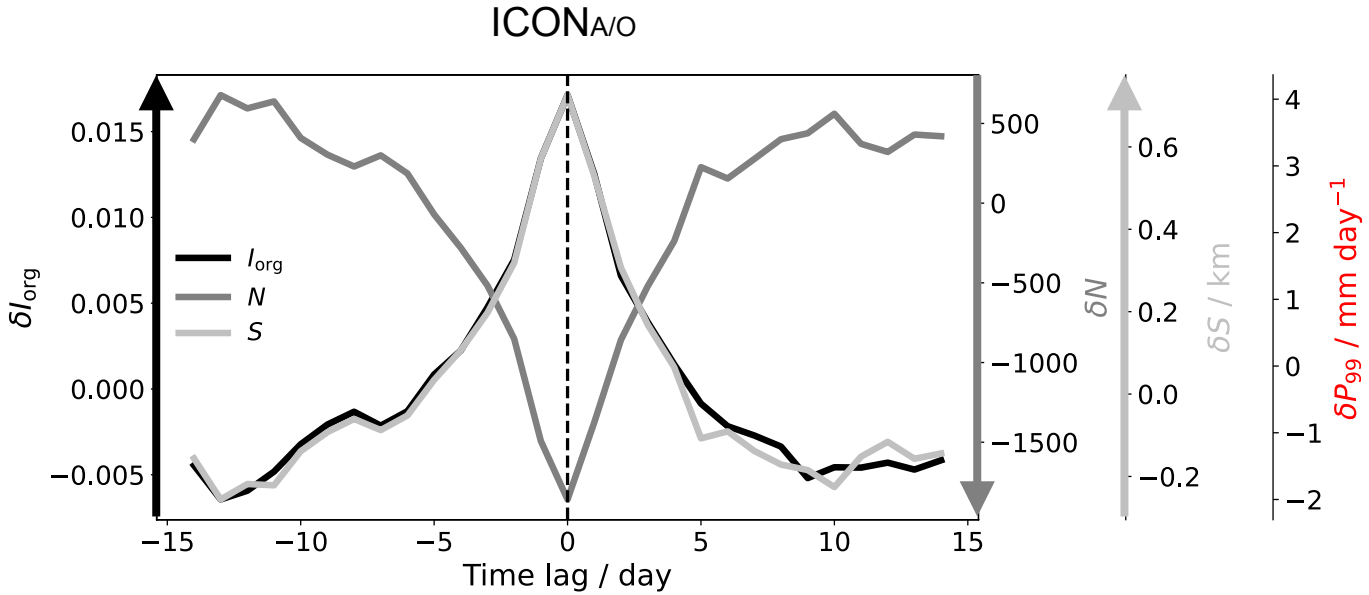

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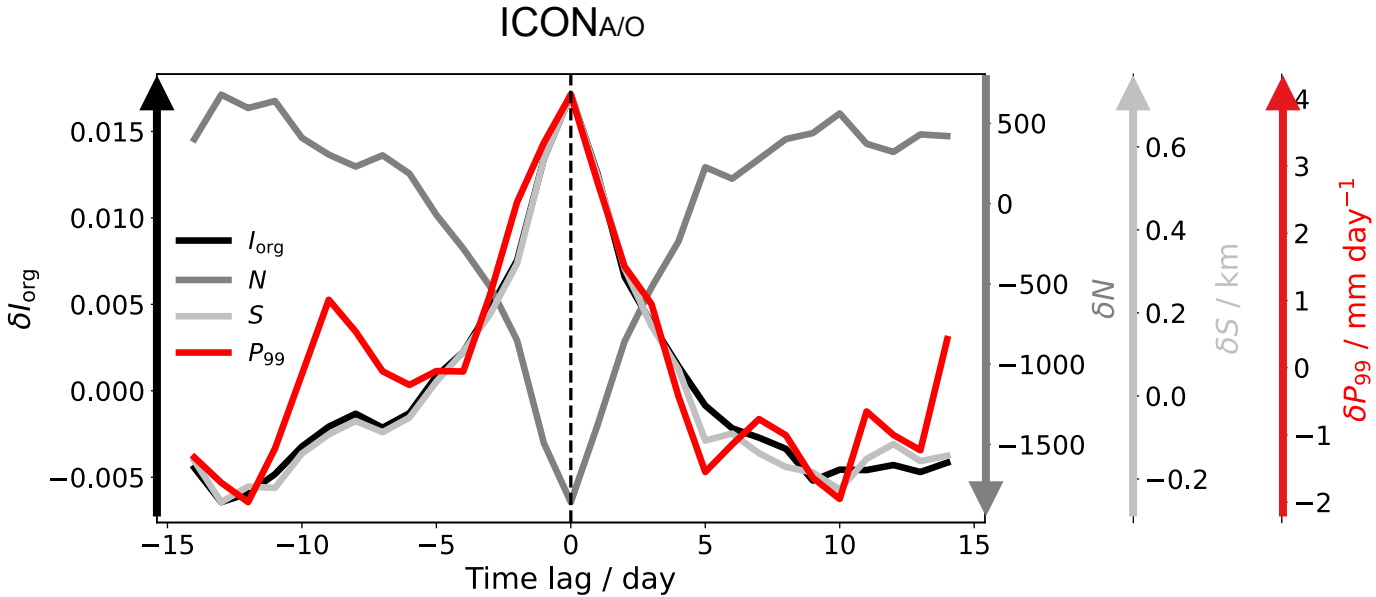
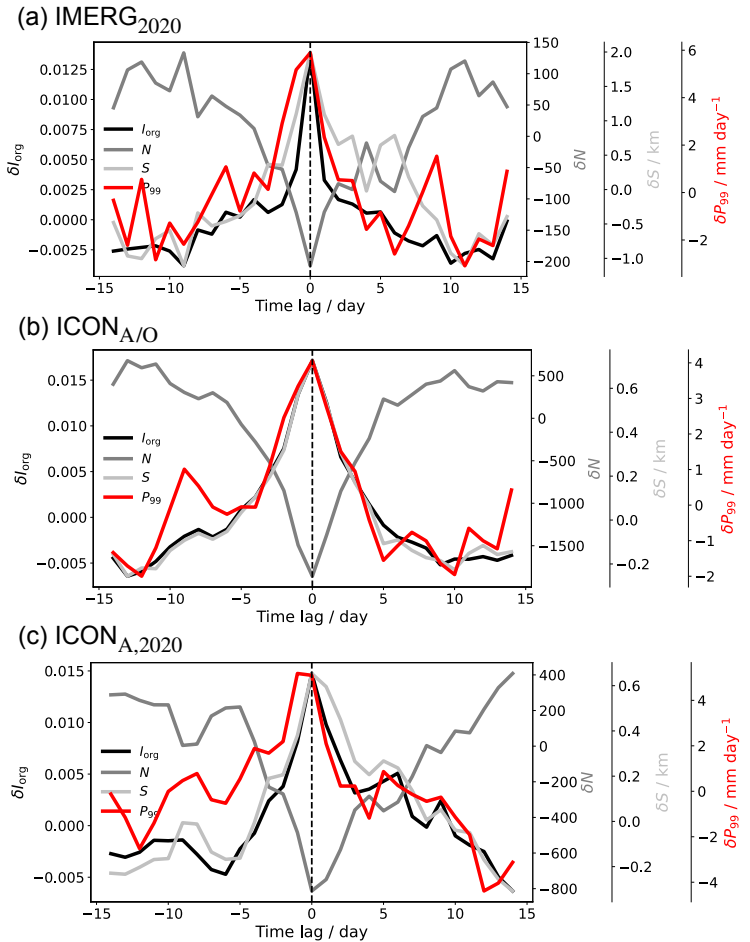


Time evolution of organisation and precipitation extremes during the composite peak organization events

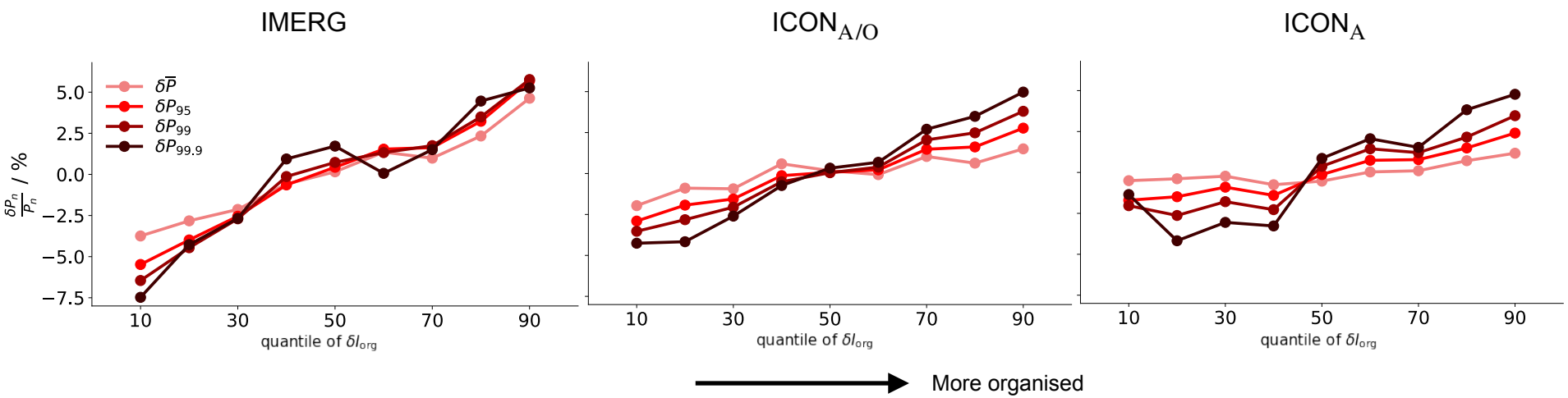
IMERG

$ICON_{A/O}$

$ICON_{A}$



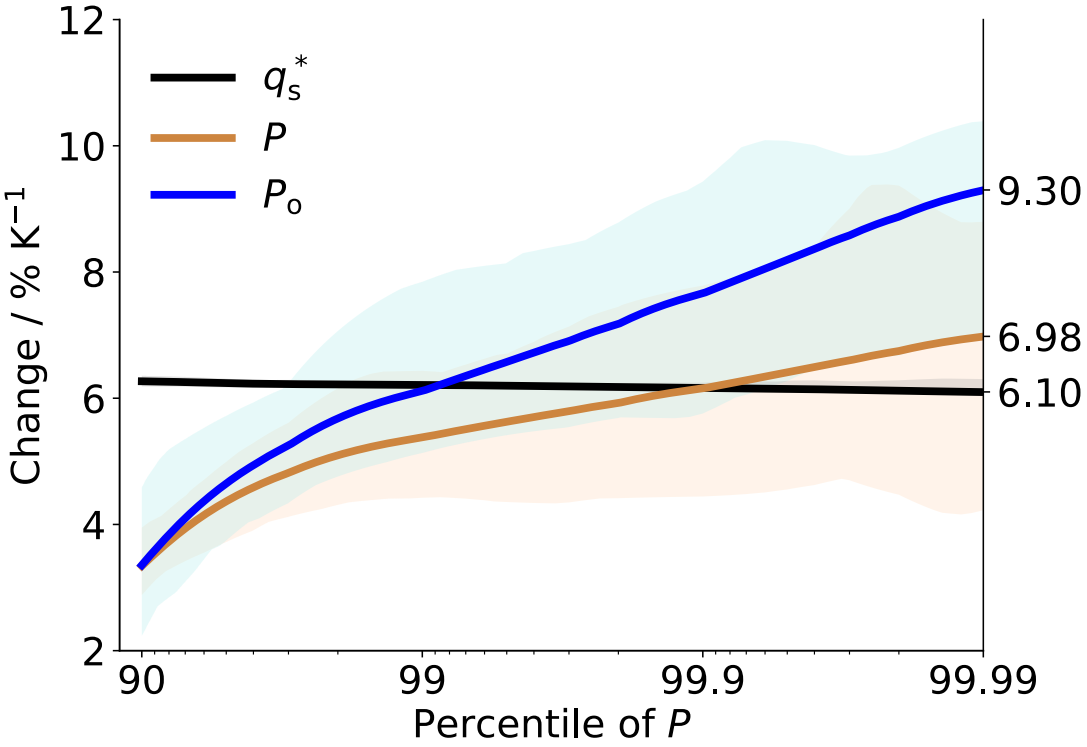
Precipitation amounts sorted by organization



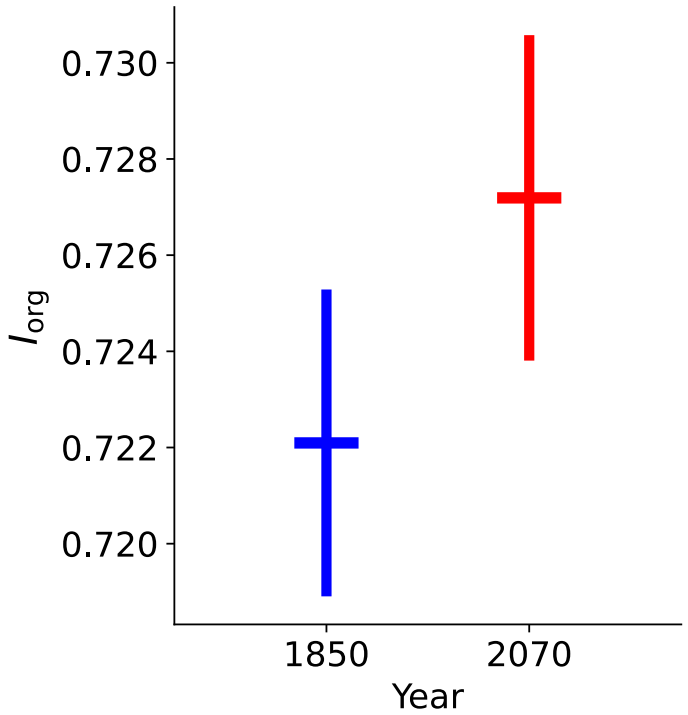
- With increased δI_{org}, δP_{ext} increases

Q2: Do changes in organisation explain changes in extremes with warming?

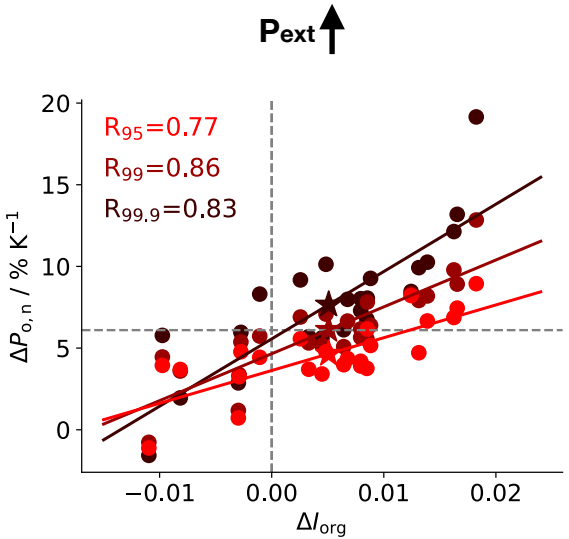
Change in daily precipitation extremes in 2070 relative to 1850 from ICON$_A$



The degree of organization increases with warming

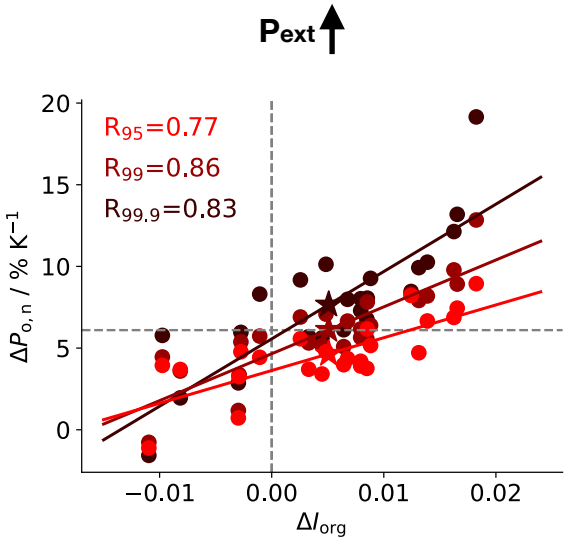


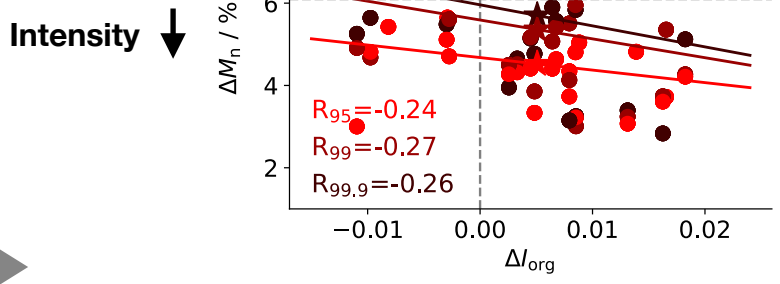
Future changes in I_{org} vs changes in P_{ext}

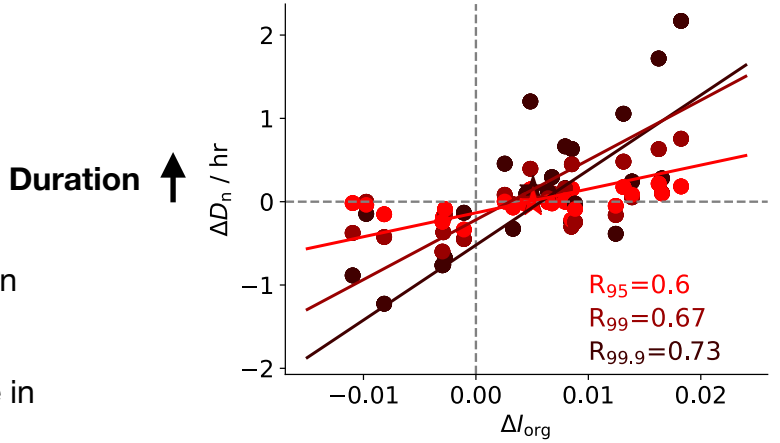


- Changes in convective organization are well correlated with changes in daily precipitation extremes.

Future changes in I_{org} vs changes in P_{ext}





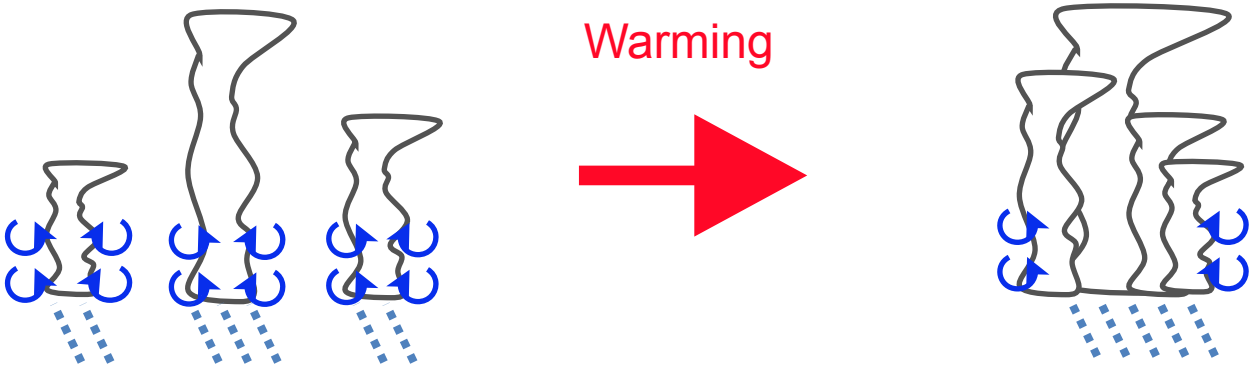


- Changes in convective organization are well correlated with changes in daily precipitation extremes.
- Increased duration rather than intensity is responsible for the increase in daily precipitation extremes with organization.

Mechanisms

Less organised

More organised



- Organised meso-scale circulation, duration —> dynamics (+)

Thermodynamics + Organisation >7%/K

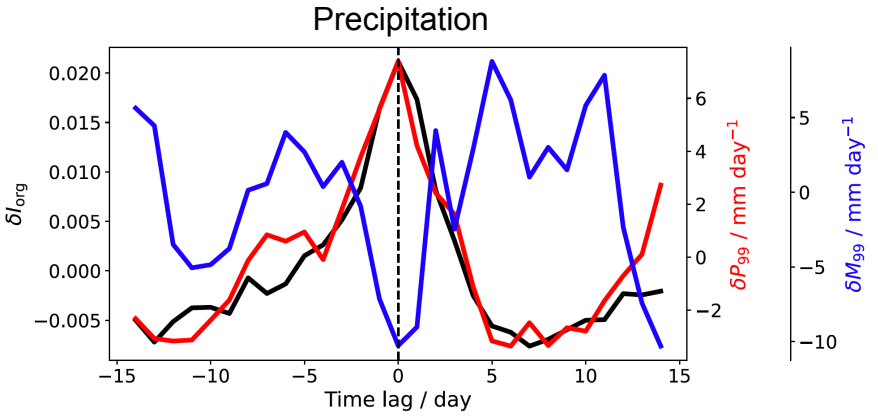
Summary

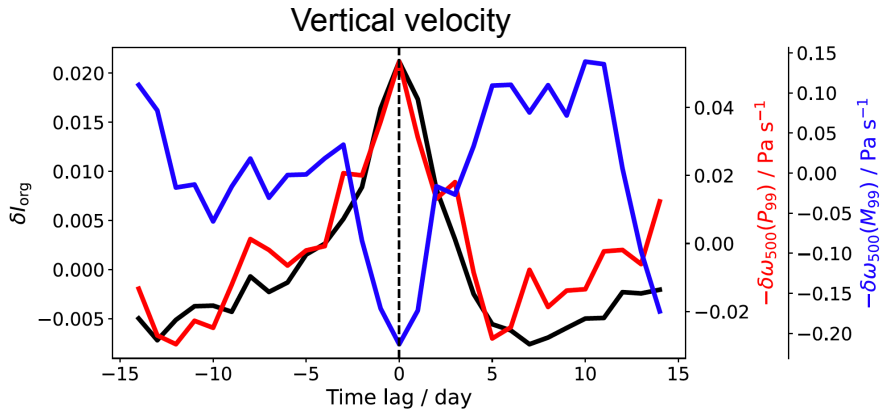
1. GSRMs show strong relationships between convective organisation and daily extreme precipitation. Observations broadly support the modeling results.

2. GSRMs predict that the degree of convective organisation tends to increase in a warmer climate, and this accompanies substantial increases in precipitation extremes, likely exceeding Clausius-Clapeyron for the strongest events.

Bao *et al.* (2024) Intensification of daily tropical precipitation extremes from more organized convection.*Sci. Adv.* **10**,eadj6801

Convective organization impacts the dynamics of precipitation extremes



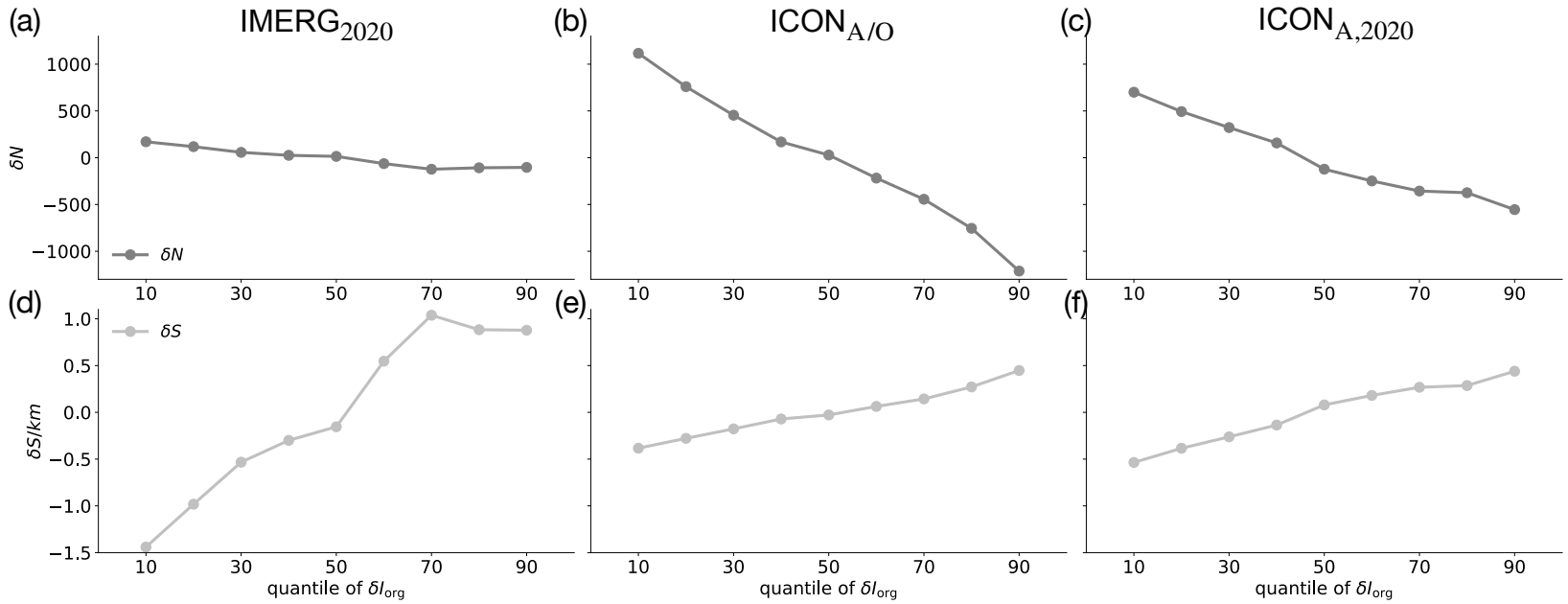


With increased organization,:

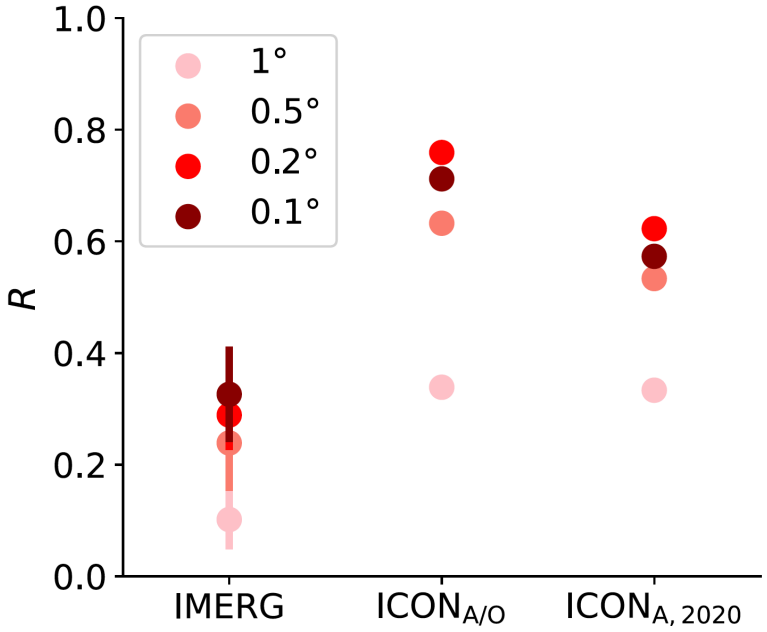
- Total daily extremes δP_{ext} increases
- Intensity δM_{ext} decreases

- Updrafts corresponding to total daily extremes $\delta\omega(P_{ext})$ increases
- Updrafts corresponding to the intensity $\delta\omega(M_{ext})$ decreases

Number/Size of convective clusters sorted by organization



R between I_{org} and P_{95}



- Correlations decrease when resolution is coarser