Intensification of precipitation extremes from more organised convection

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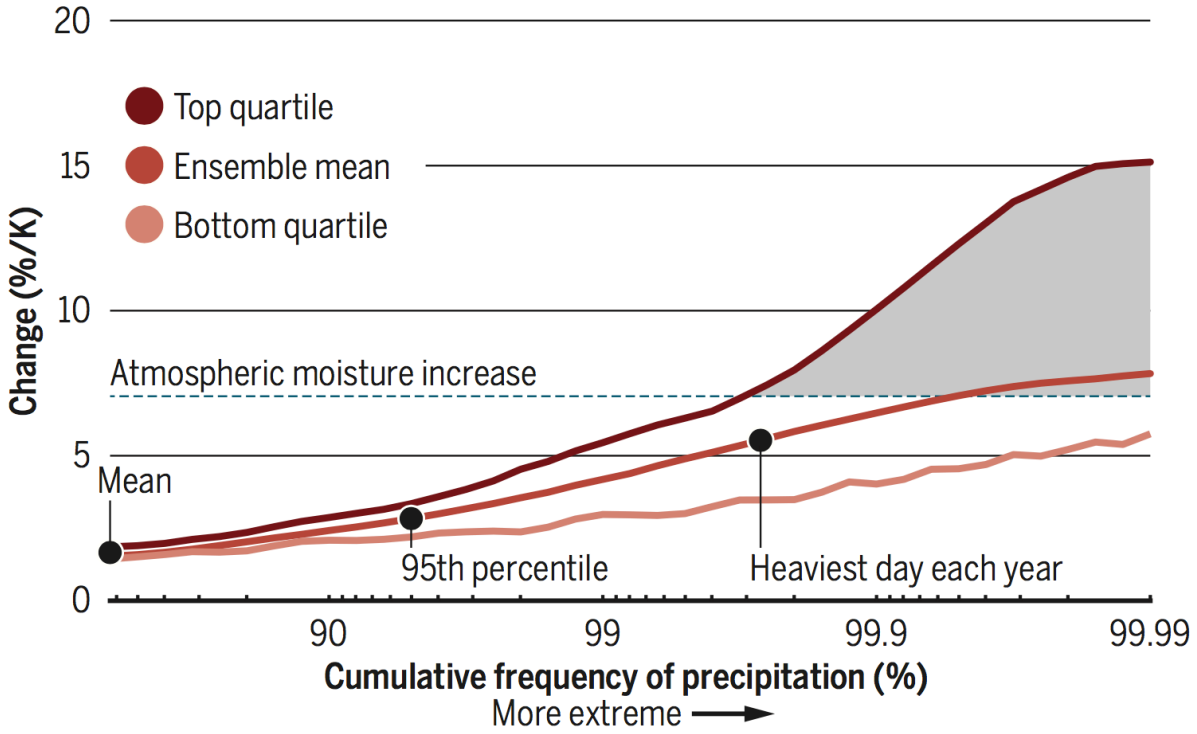
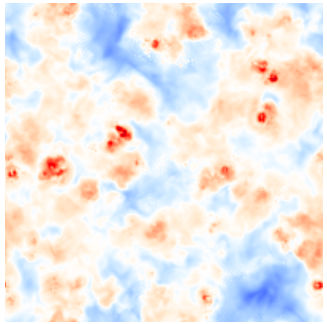
Extreme precipitation is complicated



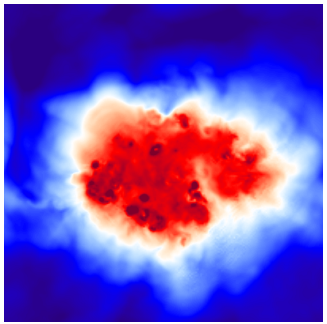
Pendergrass (2018)

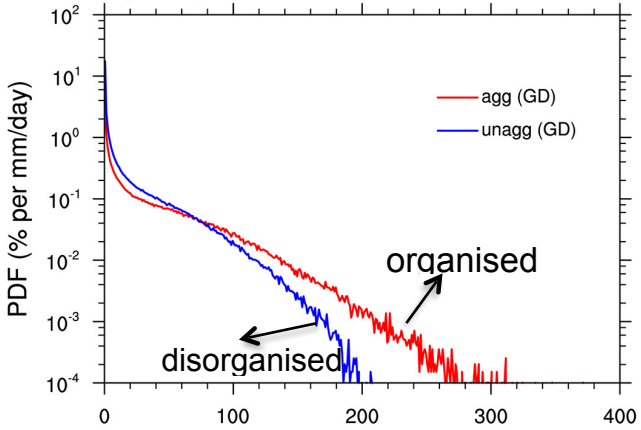
Dynamical contribution from changes in convective organisation

Disorganised



Organised





Bao&Sherwood (2019)

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

1. Does the impact of organisation exist in present-day climate?

2. 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
- Only radiation, microphysics and turbulence are parameterized.

Experiment	Time	SST?
ICON$_{A/O}$	Late Jan- Dec 2020	coupled
ICON$_{A,2020}$	Apr-Sep 2020	fixed
ICON$_{A,2070}$	Apr-Sep 2070 (RCP8.5)	fixed

Observations: IMERG

- 0.1˚ half-hourly satellite retrieves.

Monsoon 2.0

Hohenegger, C. et al. ICON-Sapphire: simulating the components of the Earth System and their interactions at kilometer and subkilometer scales, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2022-171, in review,

Daily precipitation extremes: P_{ext}

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

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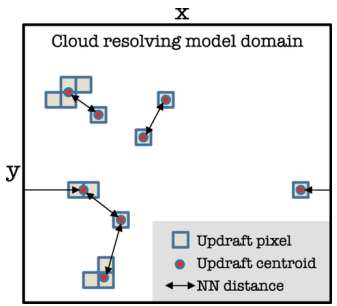
Measuring convective organisation

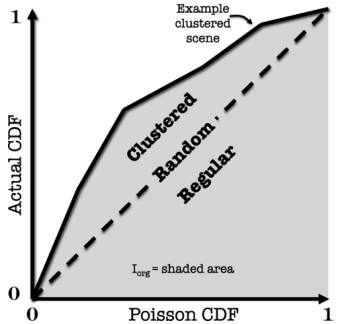
- I_{org}: clustering metric

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

- N: Number of convective objects

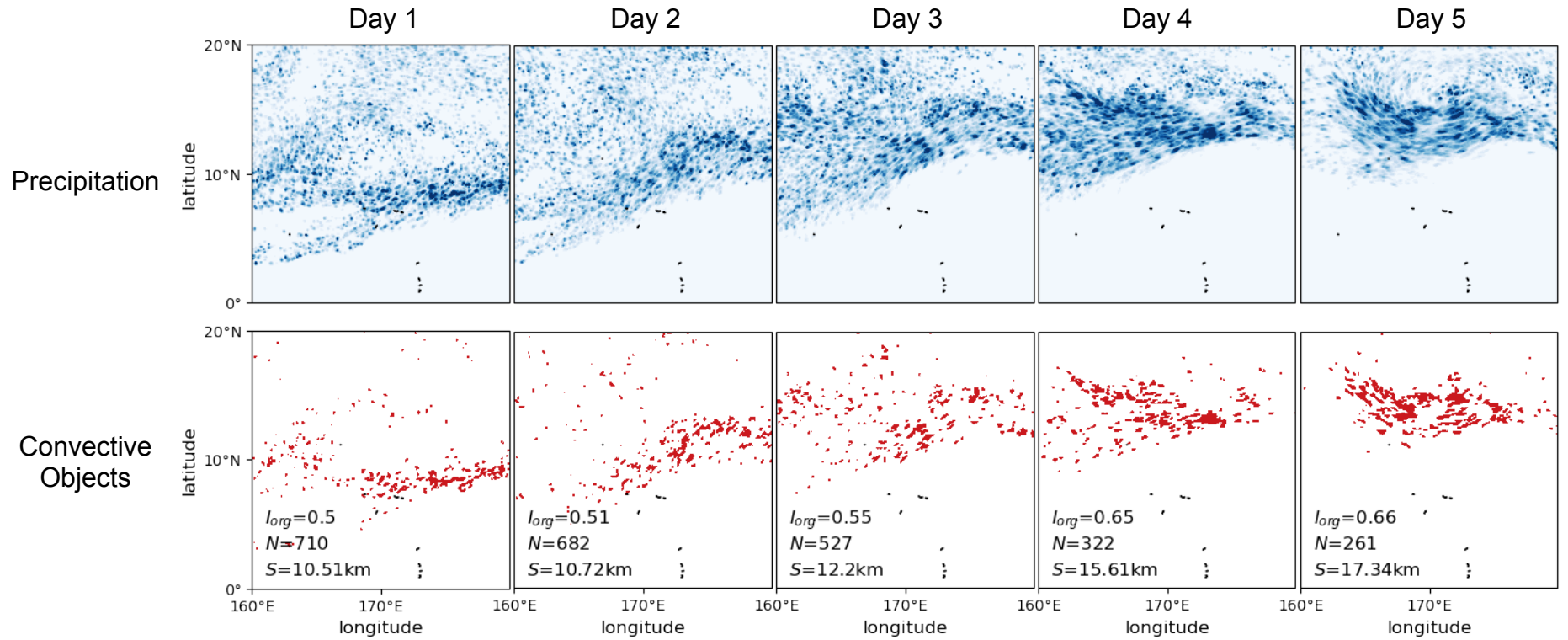
- S: Average size of convective objects (radius)



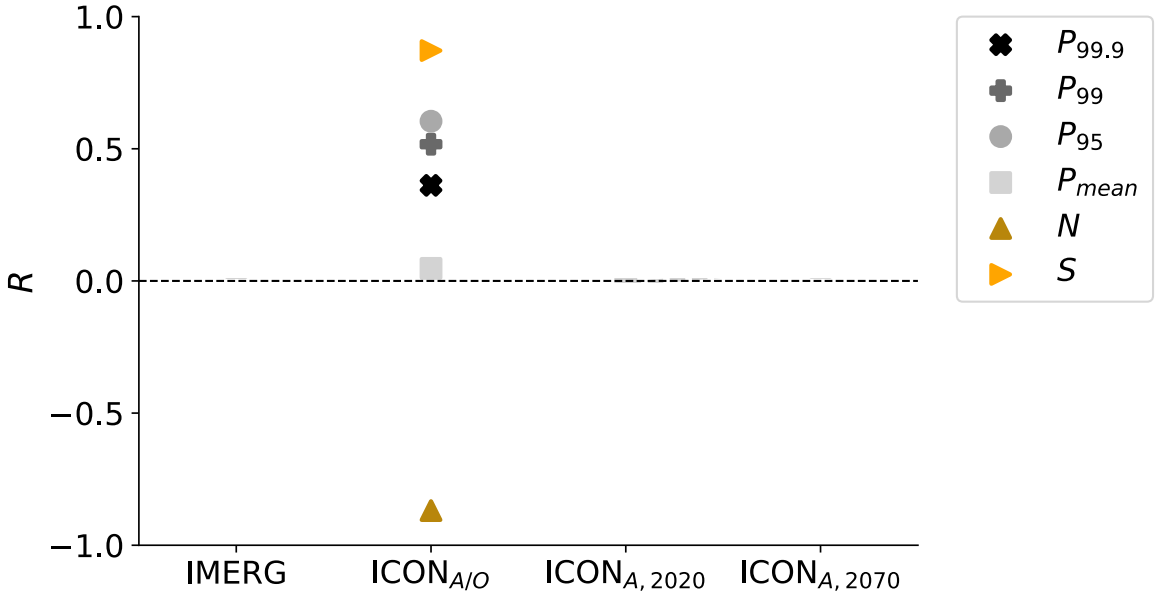


Tomkins&Semie (2017)

Snapshots of daily precipitation and convective objects from 5 consecutive days simulated by ICON$_{A/O}$



Daily precipitation extremes and convective organisation are related in present-day climate



- With increased I_{org}, P_{ext} increases, N decreases, but S increases.

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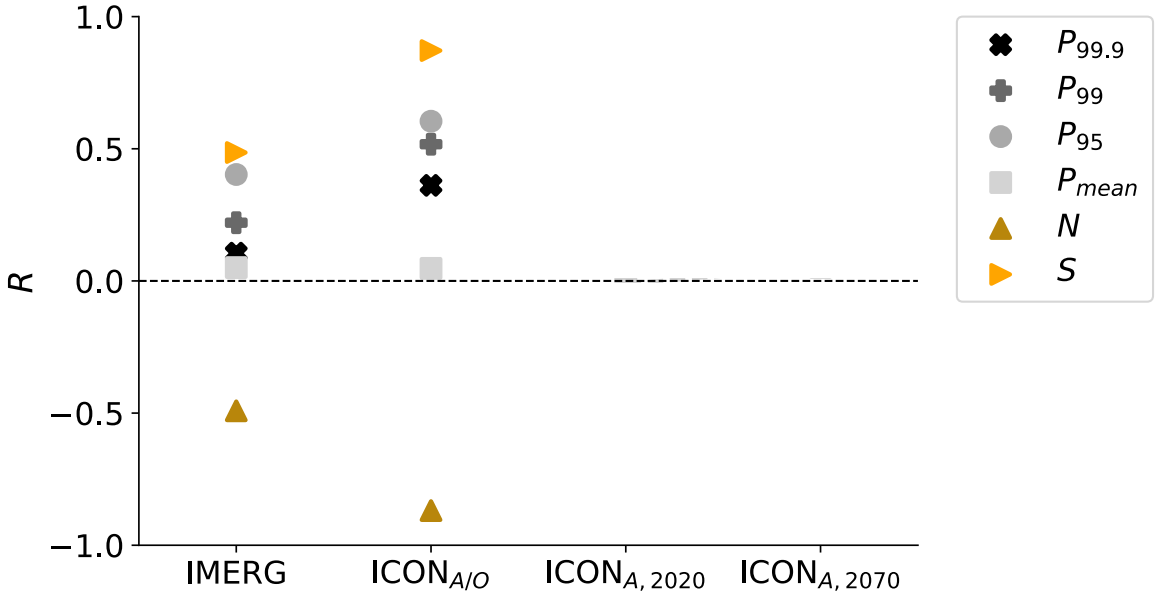

- With increased I_{org}, P_{ext} increases, N decreases, but S increases.
- IMERG broadly supports the modeling results, but with weaker correlations.

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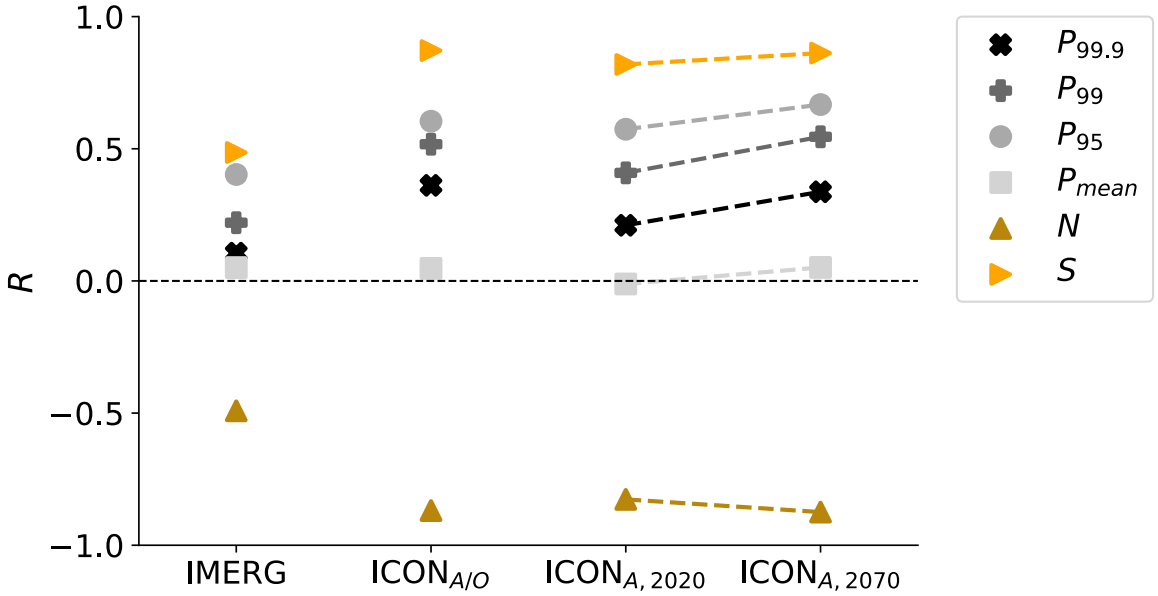
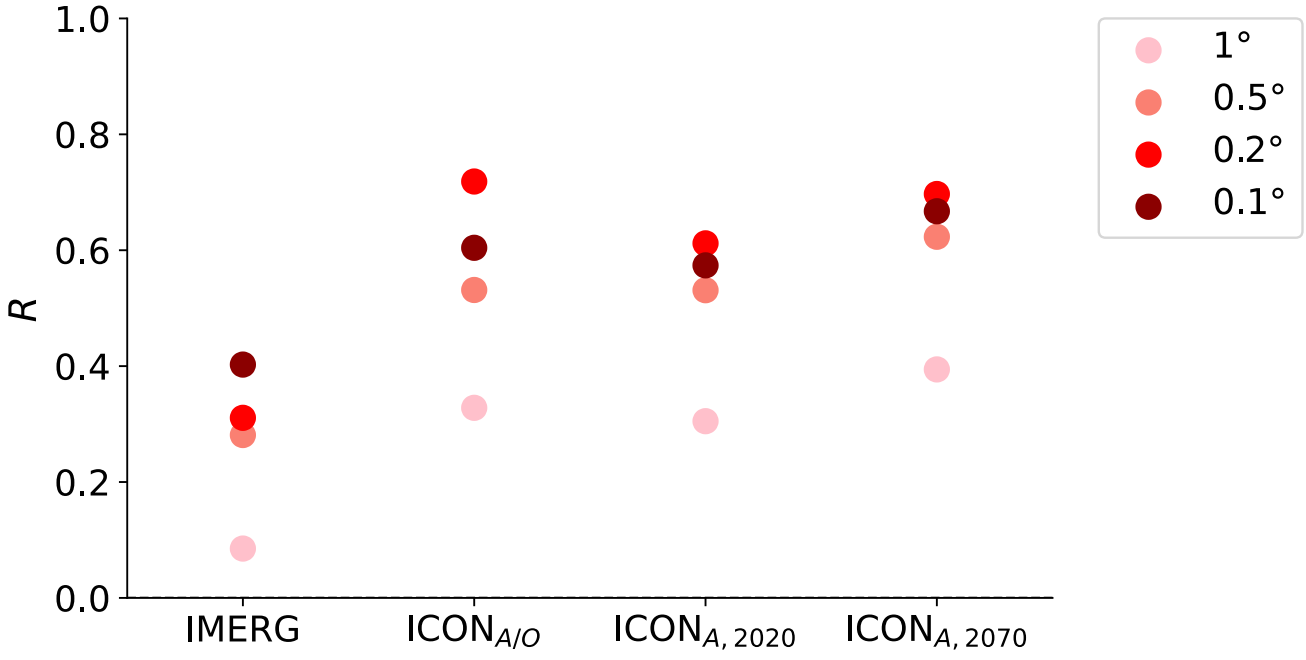
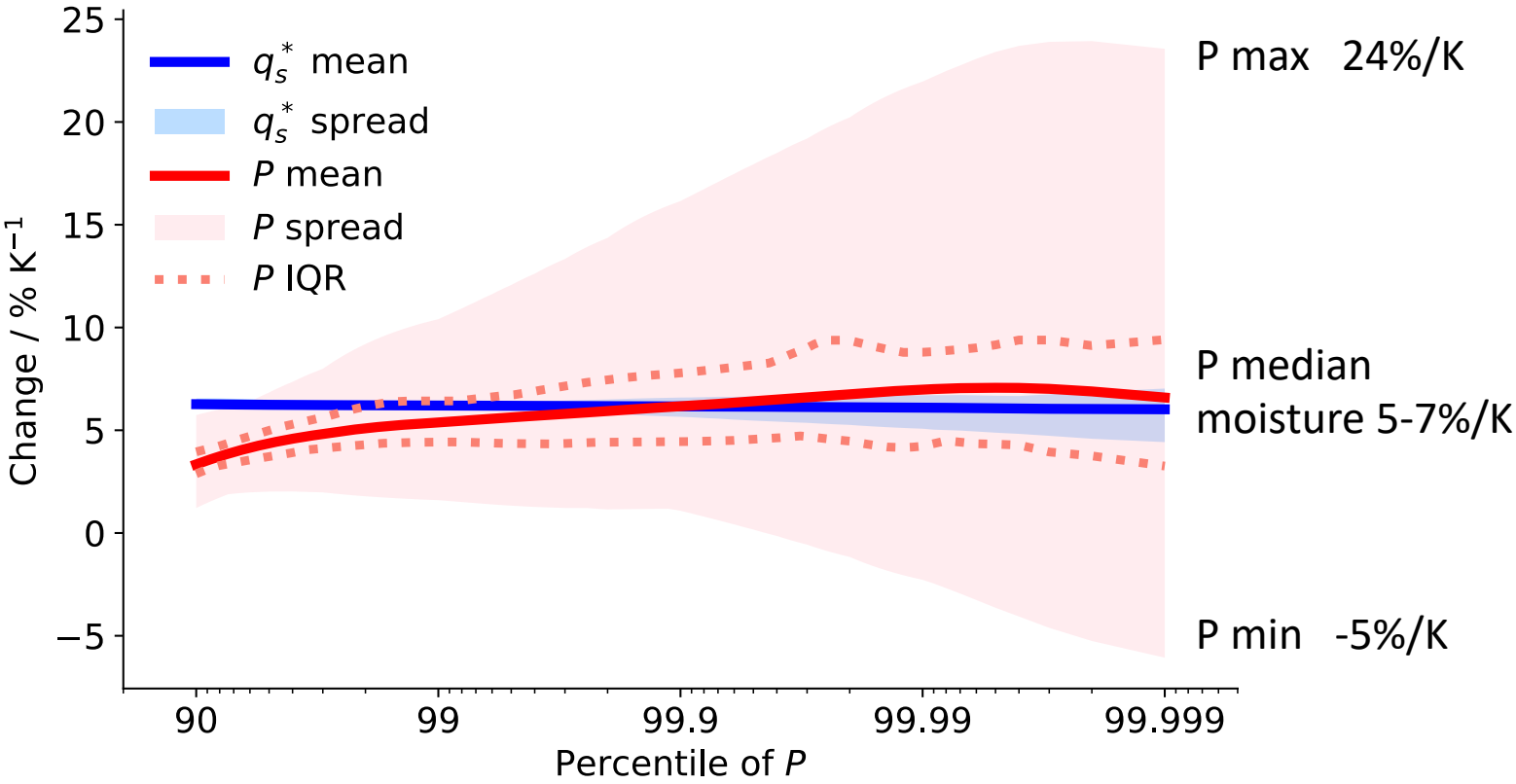


- With increased I_{org}, P_{ext} increases, N decreases, but S increases.
- IMERG broadly supports the modeling results, but with weaker correlations.
- The relationship between I_{org} and P_{ext} strengthens in a warmer climate.

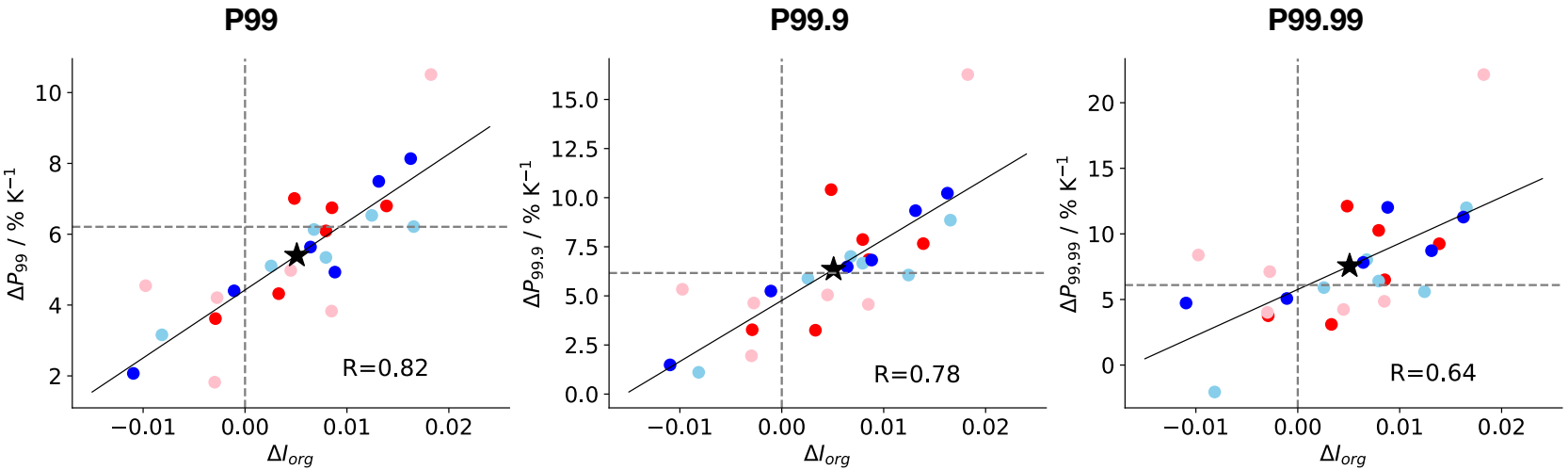
Correlation between I_{org} and P_{95}



Change in daily precipitation extremes in 2070 relative to 2020 from ICON$_A$



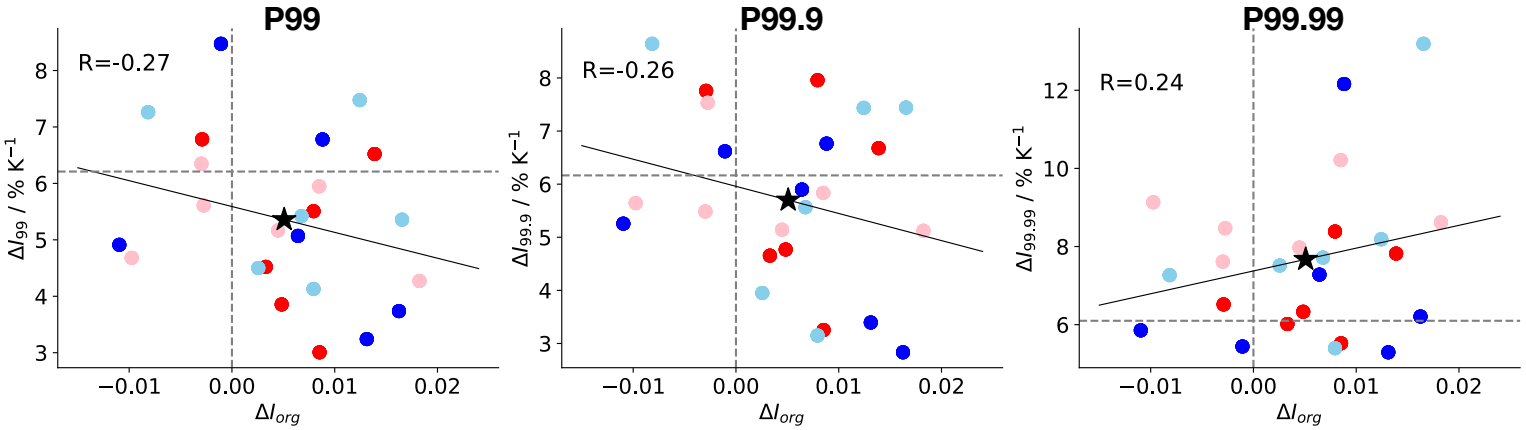
Scatter plots of future changes in I_{org} vs changes in P_{ext}



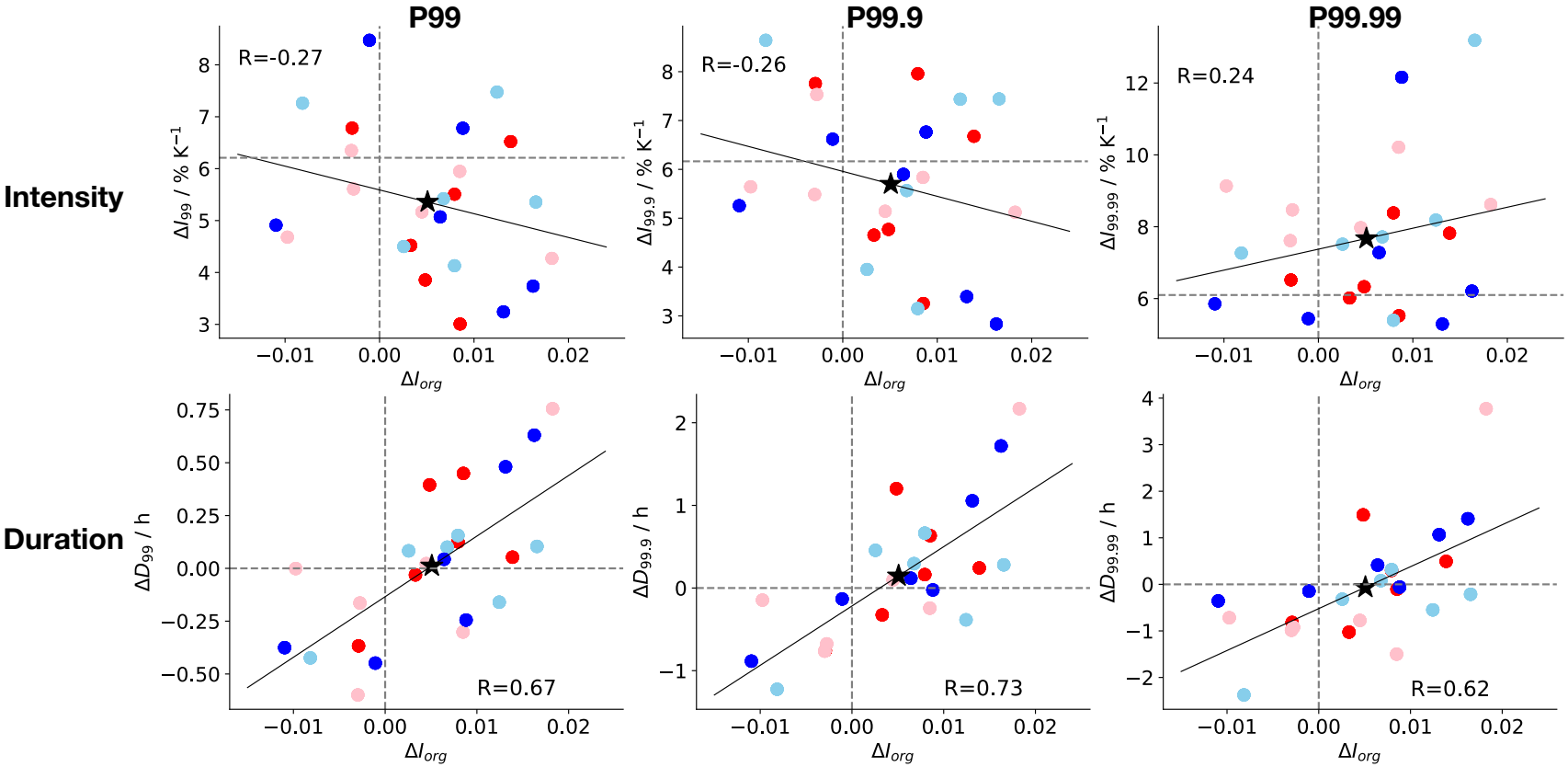
- Changes in convective organization explains changes in precipitation extremes.
- 17 out of 24 members show that the degree of organisation increases in a warmer climate.

Scatter plots of changes in I_{org} vs changes in precipitation intensity / duration

Intensity



Scatter plots of changes in I_{org} vs changes in precipitation intensity / duration



- It is mainly changes in duration that correlates with ΔI_{org}

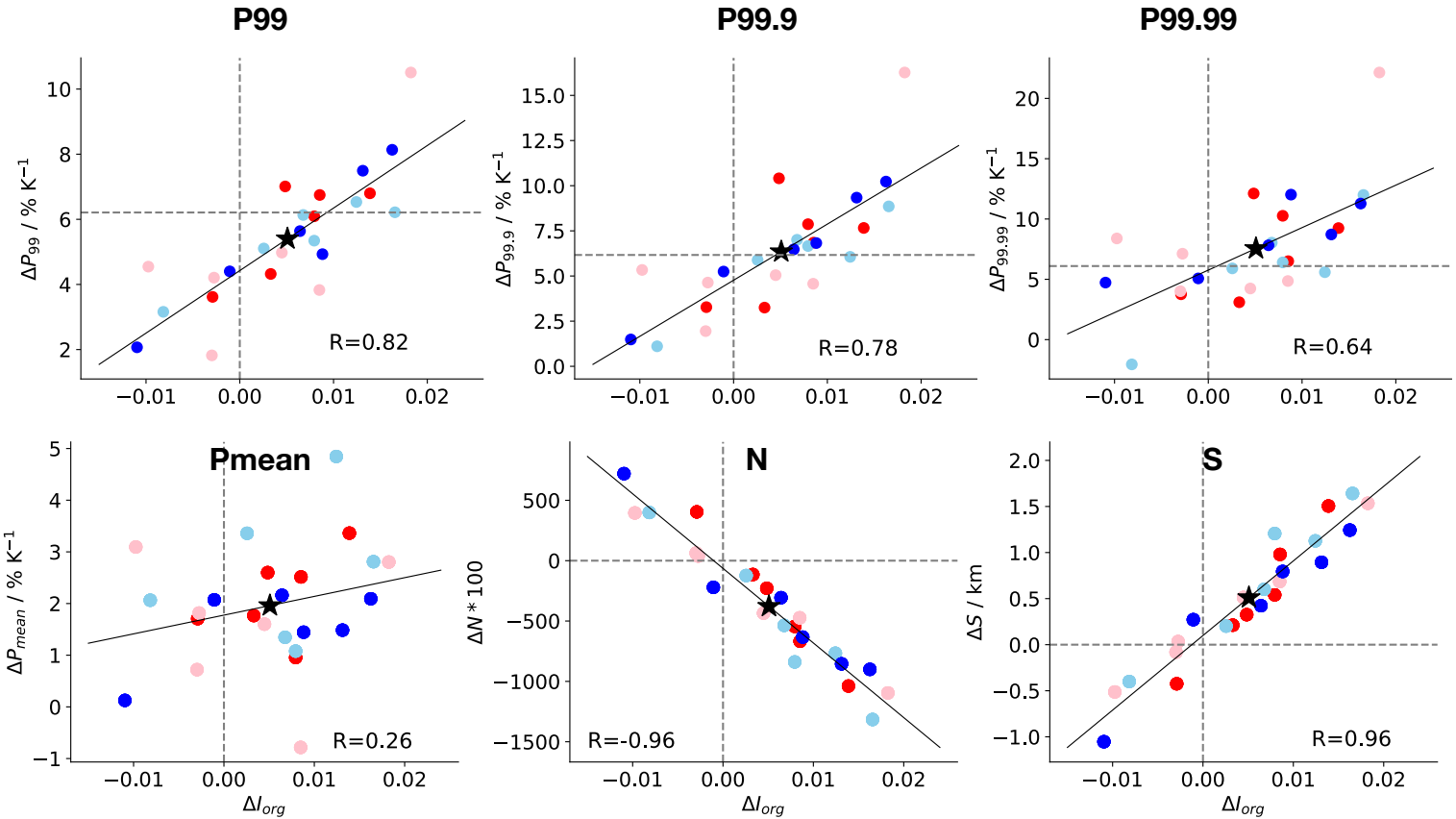
Summary

1. Storm-resolving simulations (both coupled and uncoupled) show strong relationships between convective organisation and daily extreme precipitation.

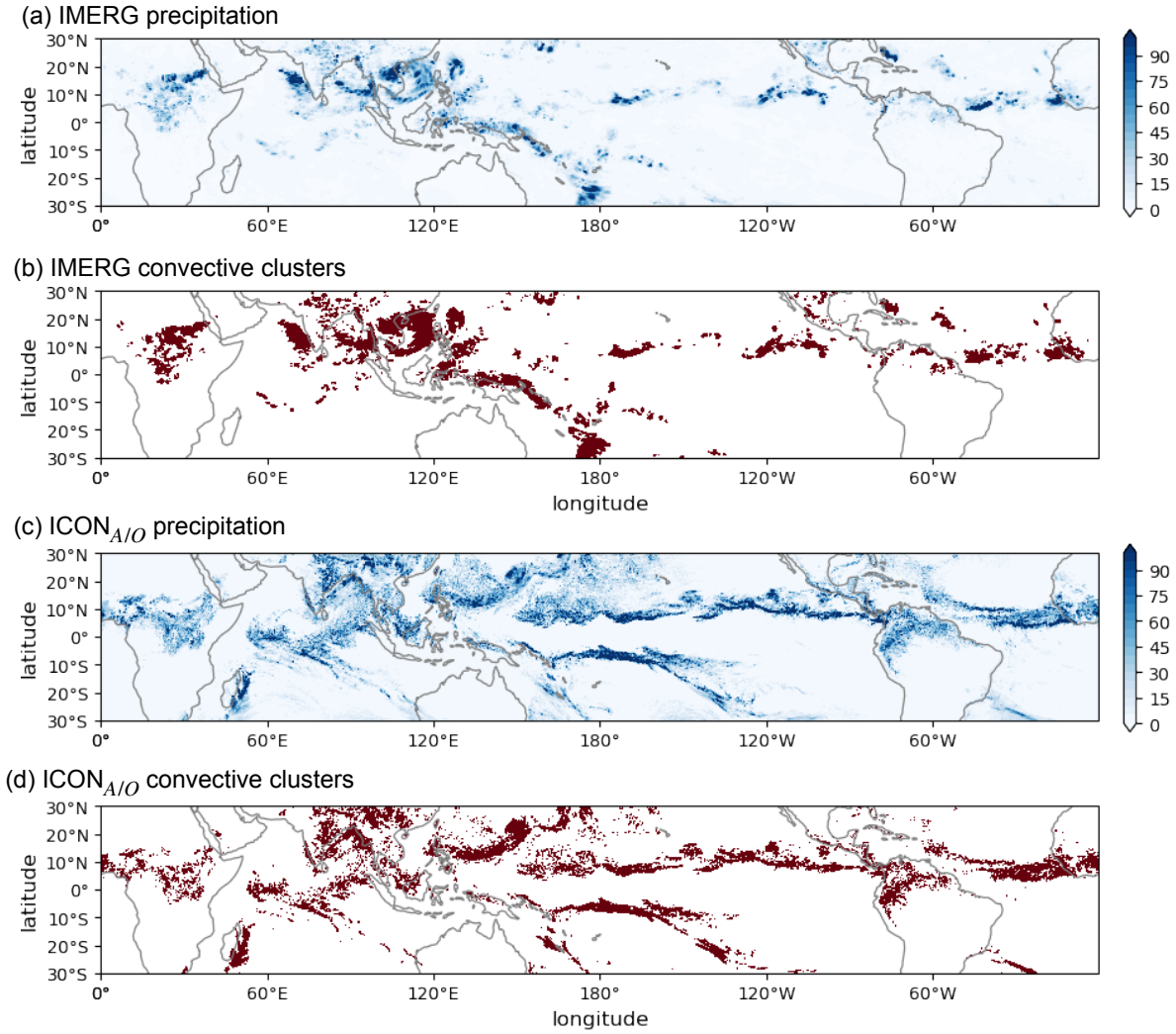
2. Observations broadly support the modeling results, but with weaker correlations.

3. The models 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.

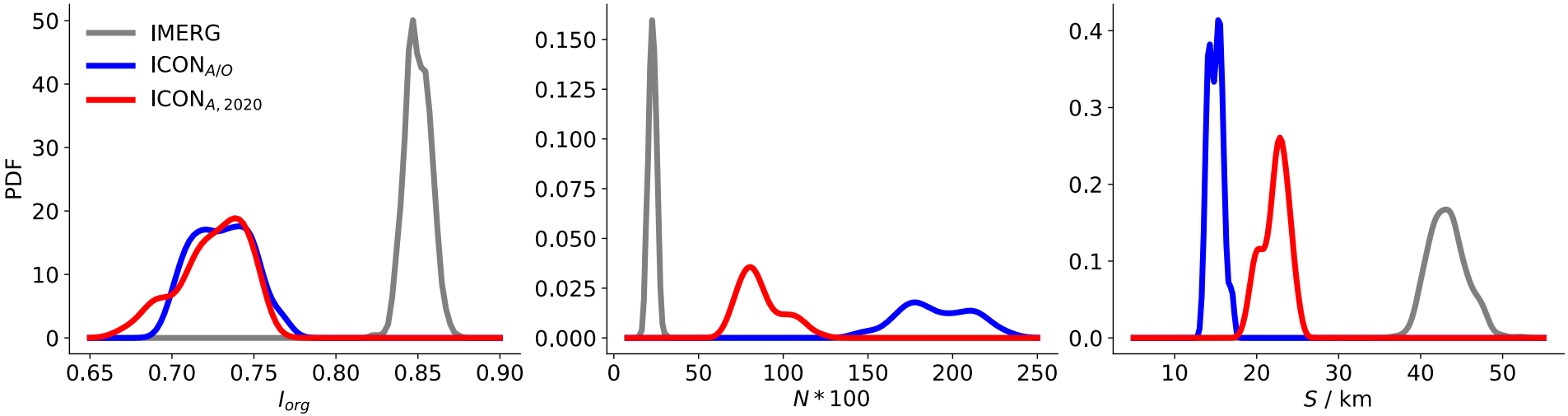
Scatter plots of changes in I_{org} vs changes in precipitation



- Changes in convective organization explains changes in precipitation extremes


(a) IMERG precipitation
(b) IMERG convective clusters
(c) ICON$_{A/O}$ precipitation
(d) ICON$_{A/O}$ convective clusters
latitude
longitude
30°N
20°N
10°N
0°
10°S
20°S
30°S
0°
60°E
120°E
180°
120°W
60°W
90
75
60
45
30
15
0

PDF of I_{org}, N and S



IMERG has much weaker correlations over the ocean areas