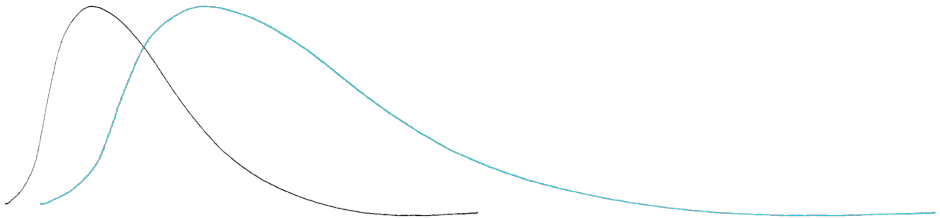
Massachusetts Institute of Technology

MIT CLIMATE GRAND CHALLENGES

The role of variability changes for future extreme precipitation

Can high resolution models reduce the uncertainty?



Iris de Vries,
Raffaele Ferrari, Paul O'Gorman

“Surprise events”

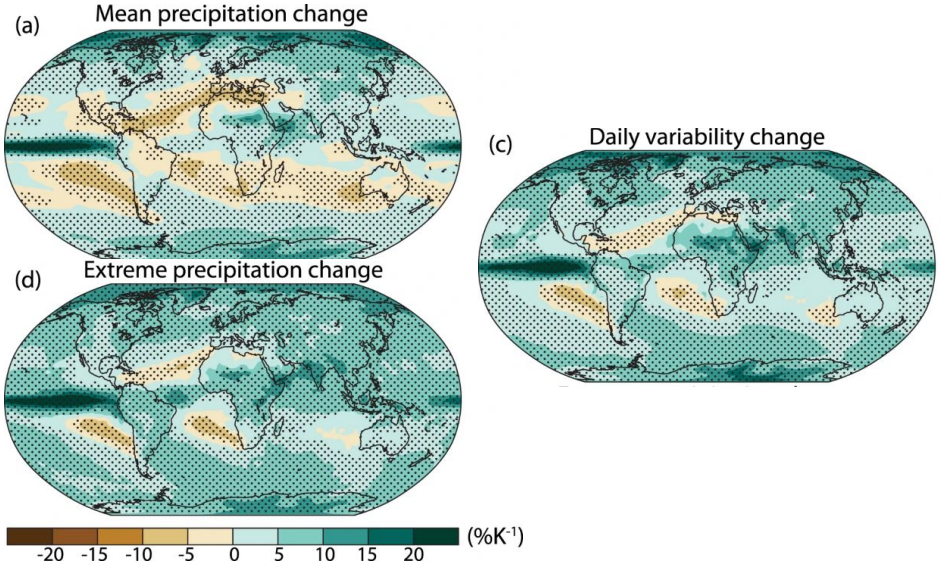
Germany, July 2021,
WMO

Pakistan, September 2022,
Al-Jazeera

Libya, September 2023,
BBC

Valencia, October 2024,
The Guardian

Extreme precipitation is especially “surprising”



Pendergrass et al. (2017)

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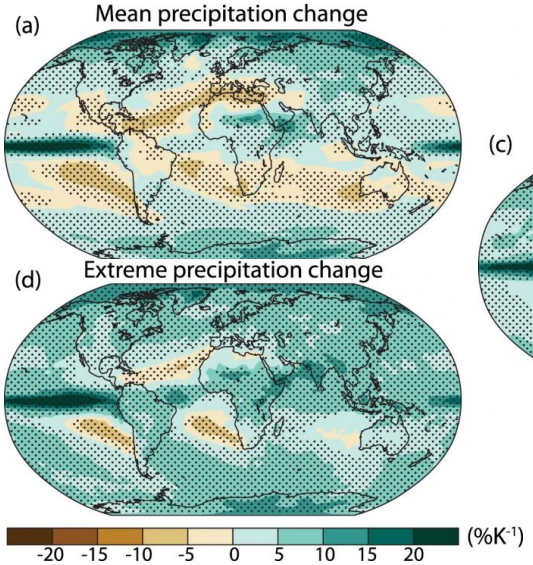

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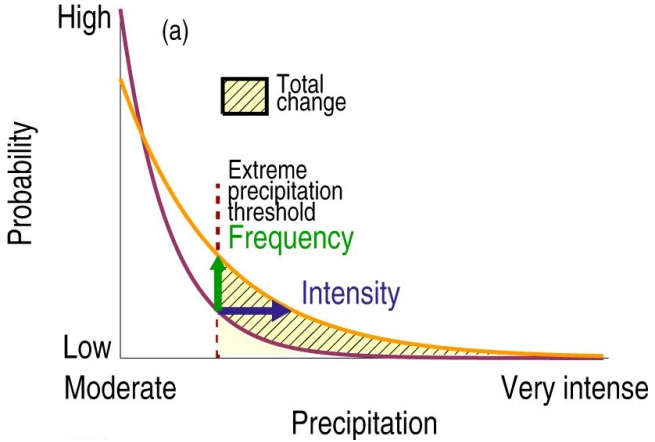

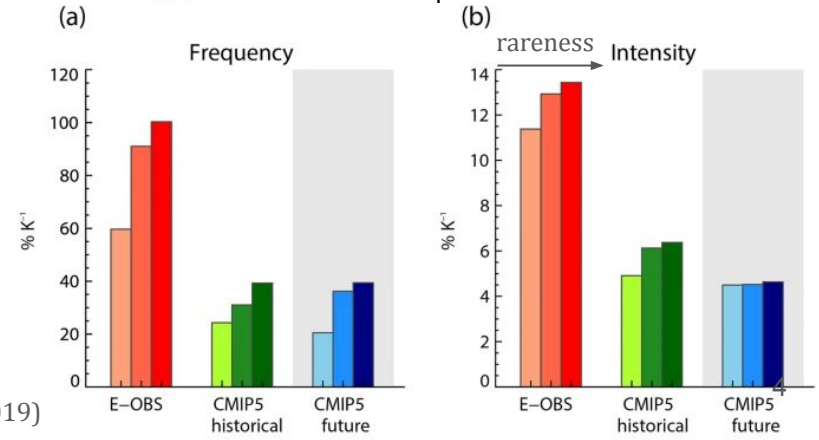

Myrhe et al. (2019)

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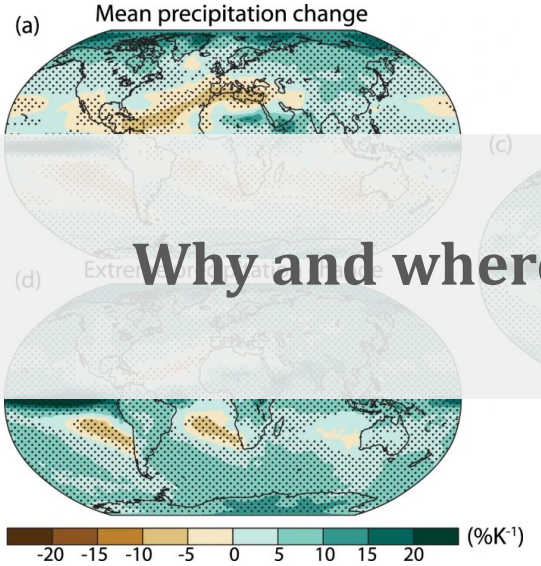

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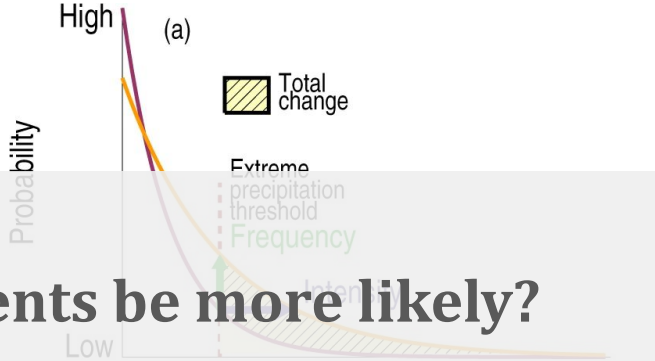
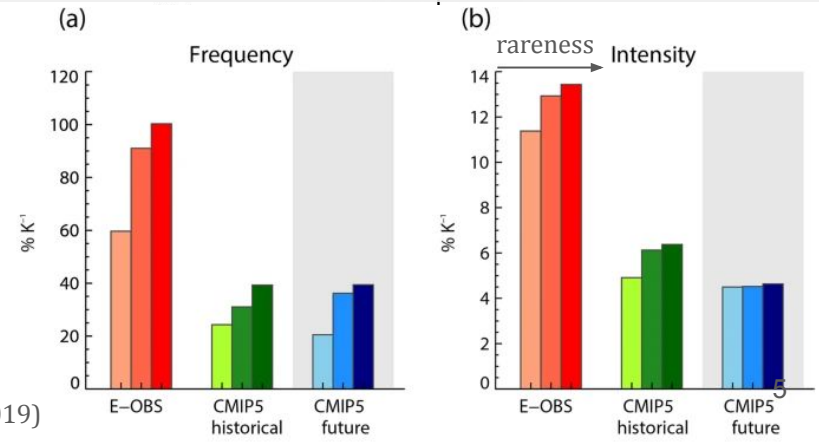


Why and where might surprise events be more likely?



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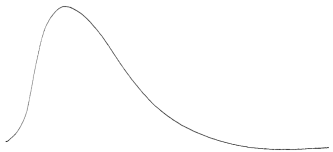
Extreme precipitation framework

Generalised extreme value distributions (GEV) : block maxima



GEV(μ, σ, ξ)
μ = location parameter ~ mean
σ = scale parameter ~ variability
ξ = shape parameter ~ skewness

Extreme precipitation framework

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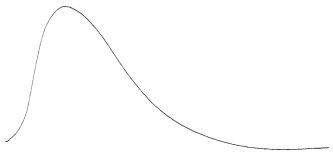

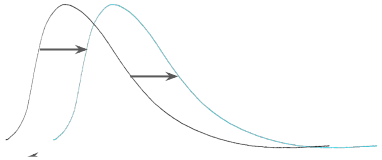

↑ Location parameter μ → shift

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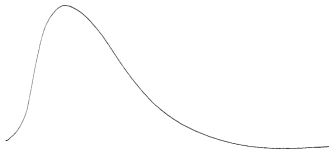

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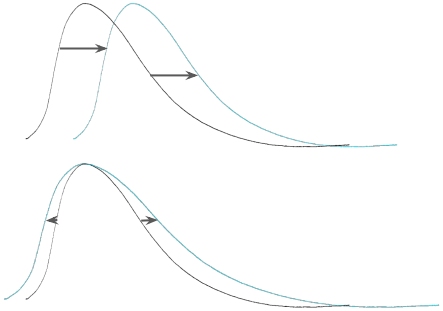

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↑ Scale parameter σ → widening

Extreme precipitation framework

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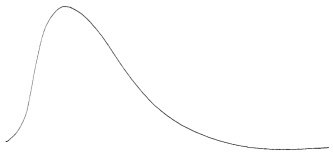

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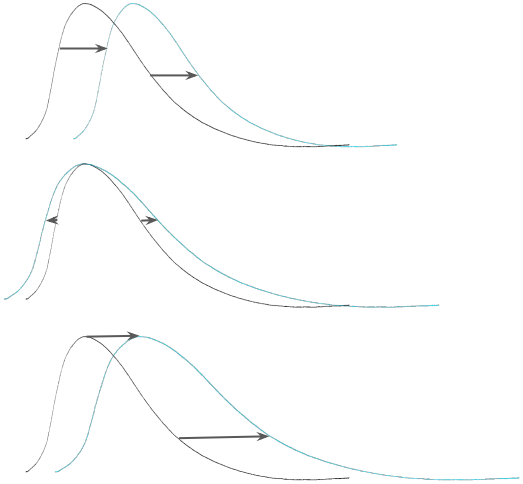
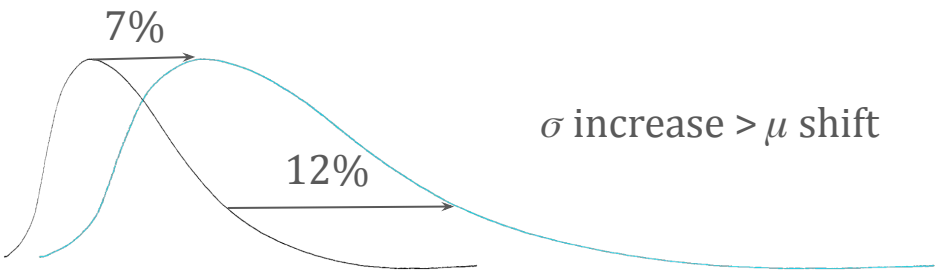


↑ Location parameter μ → shift

↑ Scale parameter σ → widening

↑ μ and σ → it's complicated

The key role of variability: RAINE



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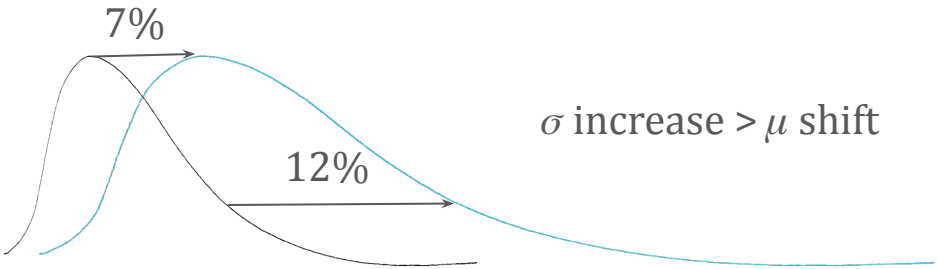

Rareness Amplified INtensification of Extremes (RAINE)

The RAINE effect

$$F(x) = e^{-t(x)}, \text{ with } t(x) = \left[1 + \xi\left(\frac{x-\mu}{\sigma}\right)\right]^{-\frac{1}{\xi}}$$

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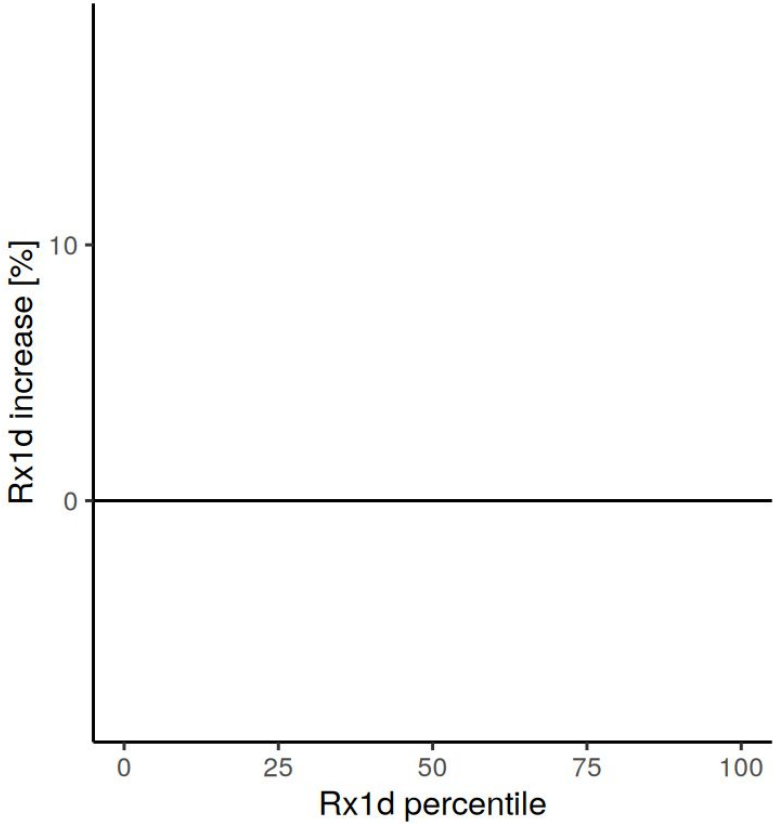

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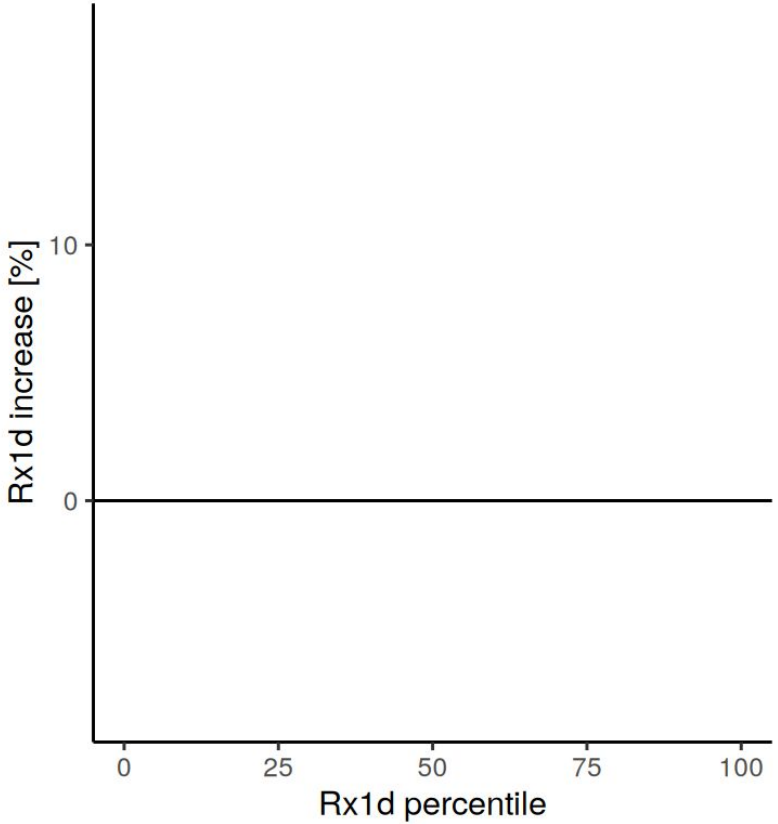

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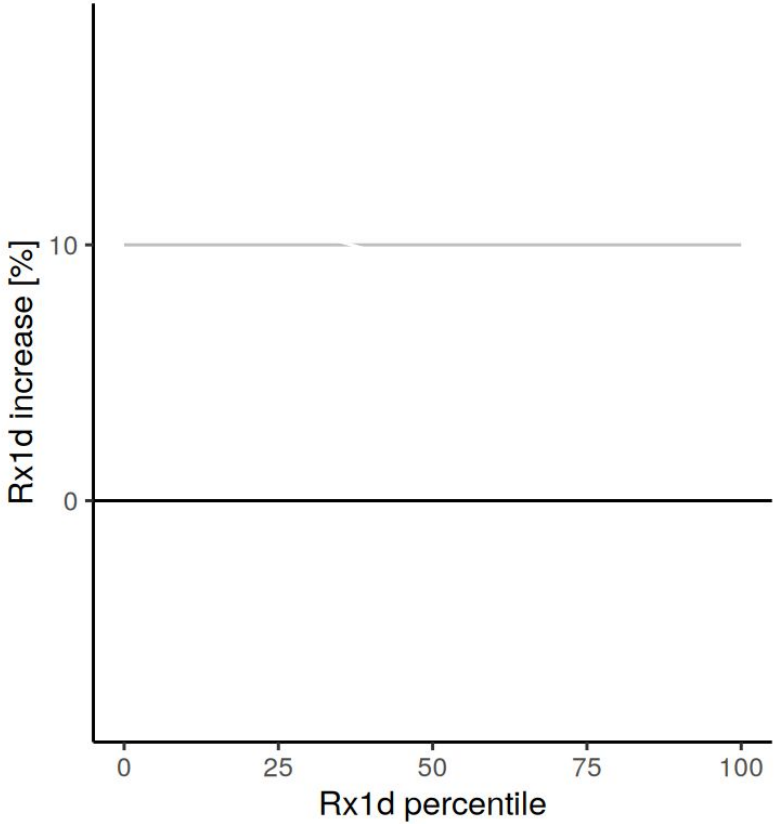

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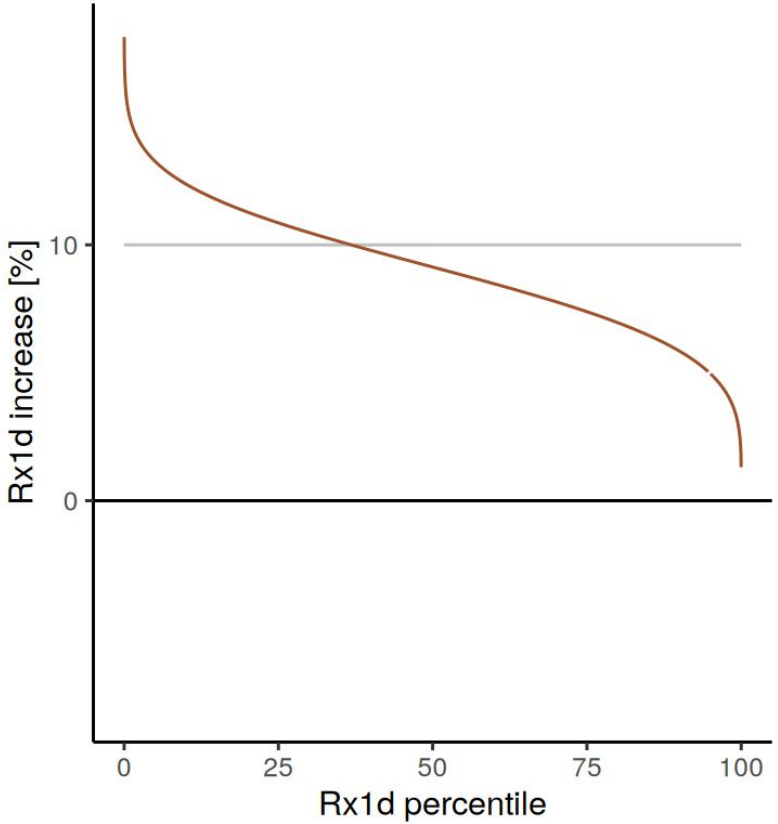

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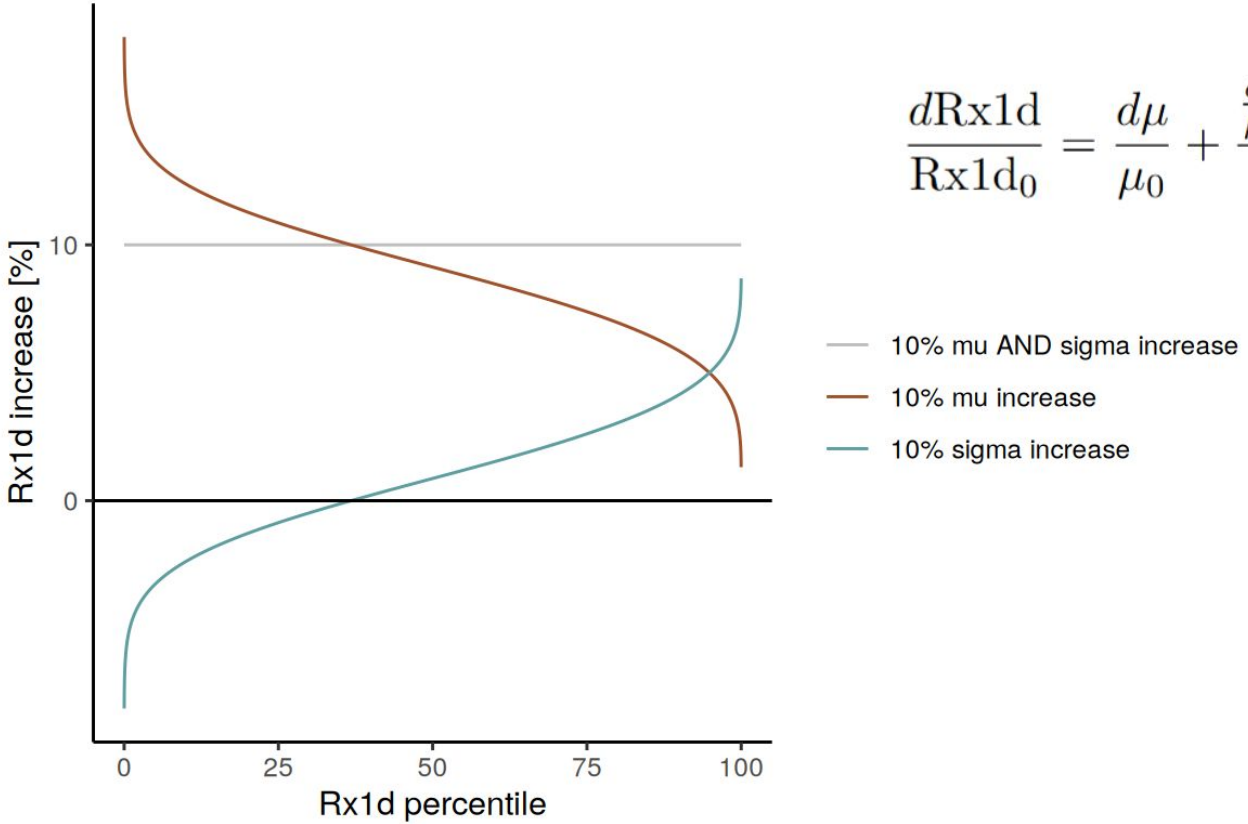
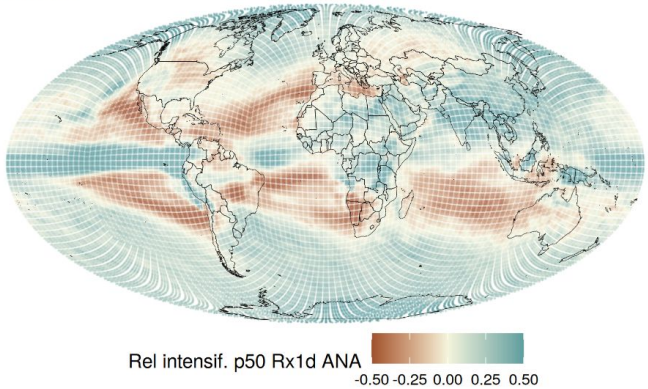


RAINEness in MESACLIP

- Seasonal Rx1d (MJJAS)
- Non-stationary GEVs (linear μ and σ covariates)
- 2006-2100 RCP8.5

RAINEness in MESACLIP

CESM-LR



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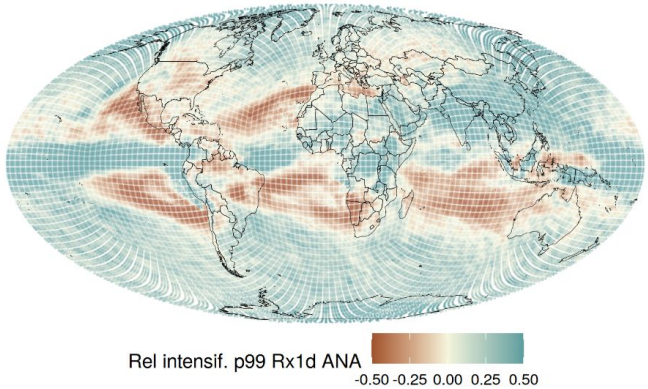
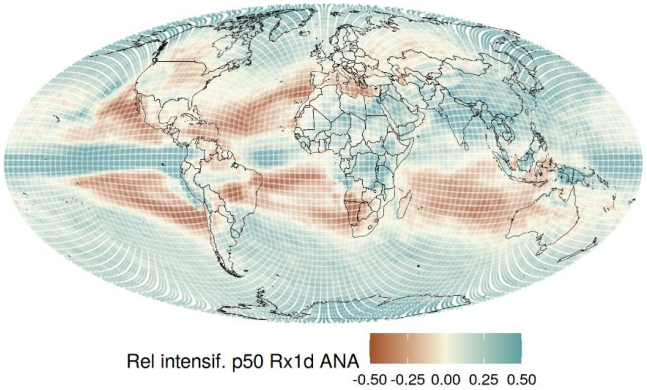
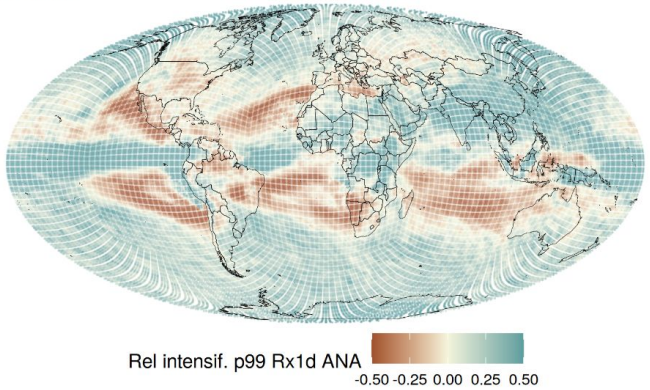


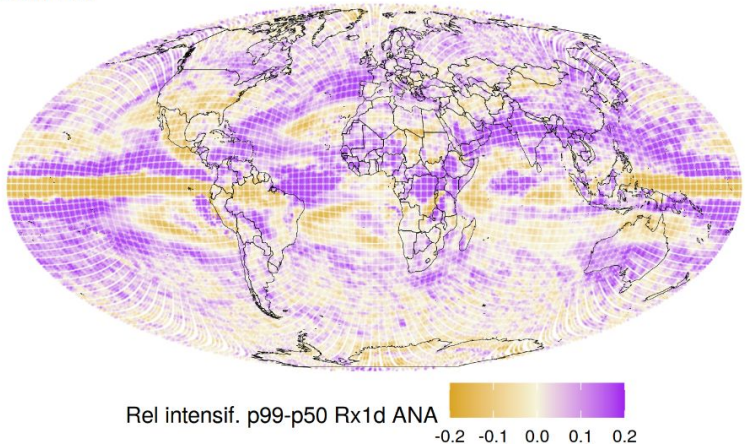
RAINEness in MESACLIP LR

CESM-LR



CESM-LR





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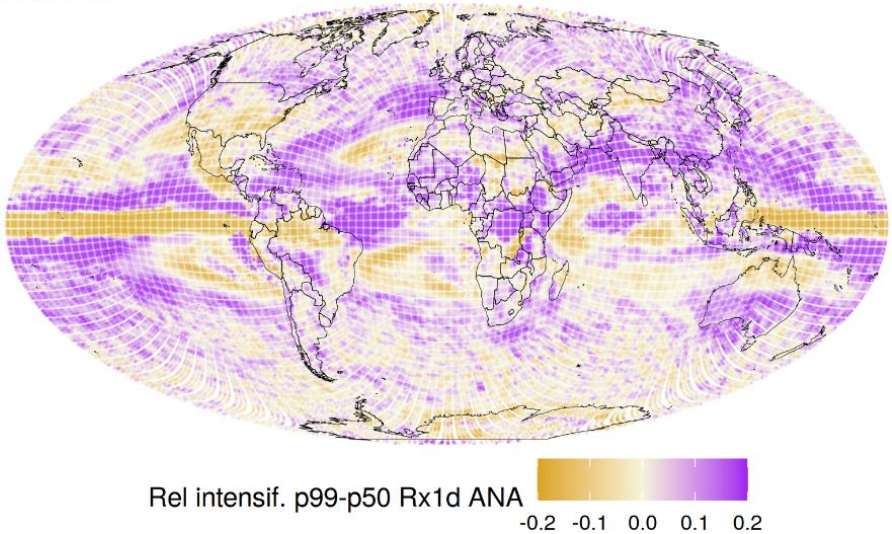

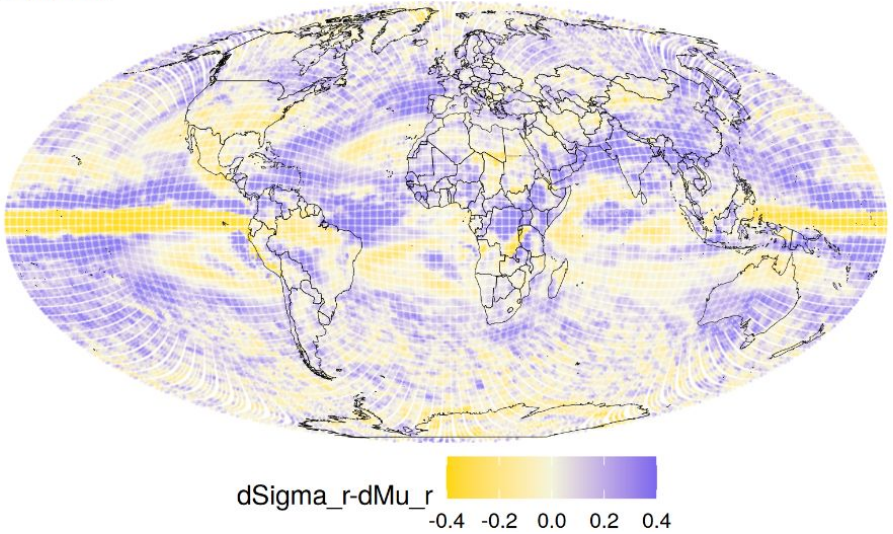

What explains the pattern?

- Thermodynamics, Clausius-Clapeyron → not skewed
- Dynamics
  - CAPE?
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  - Updraft?
  - Moisture convergence?
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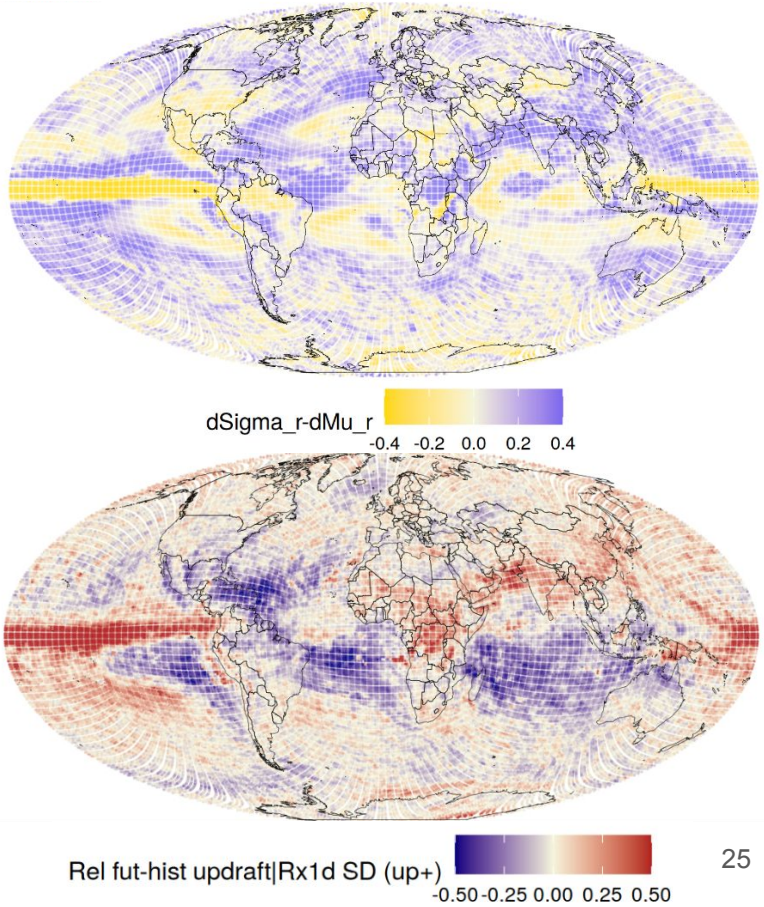

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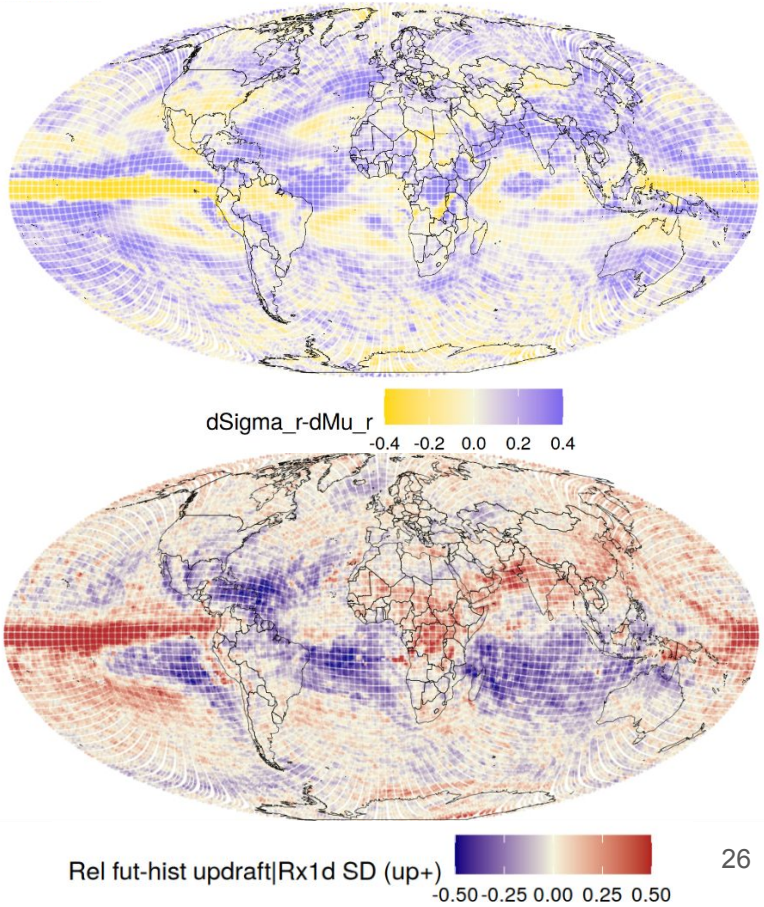
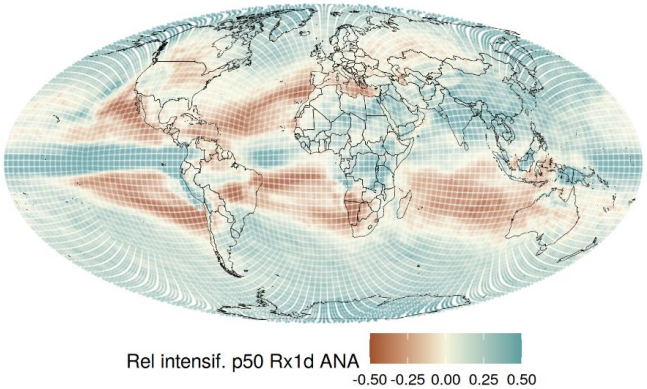
→ High resolution



RAINEness in MESACLIP HR

CESM-LR



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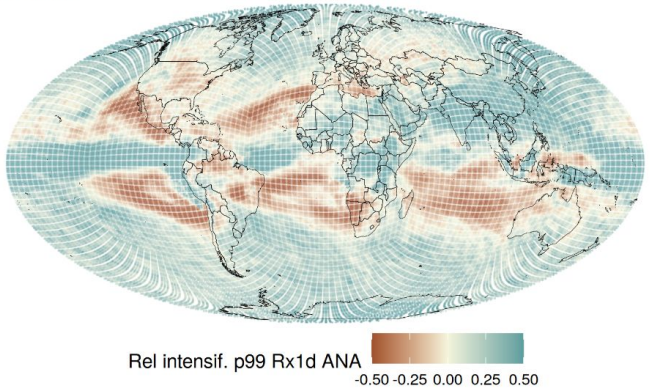

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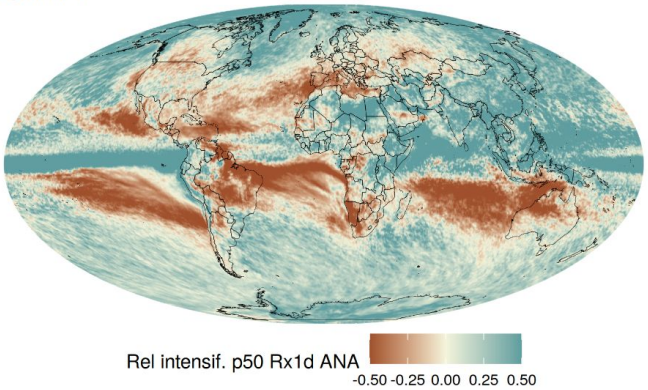

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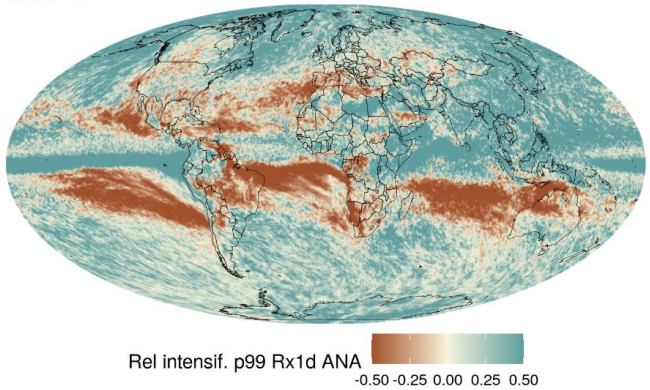
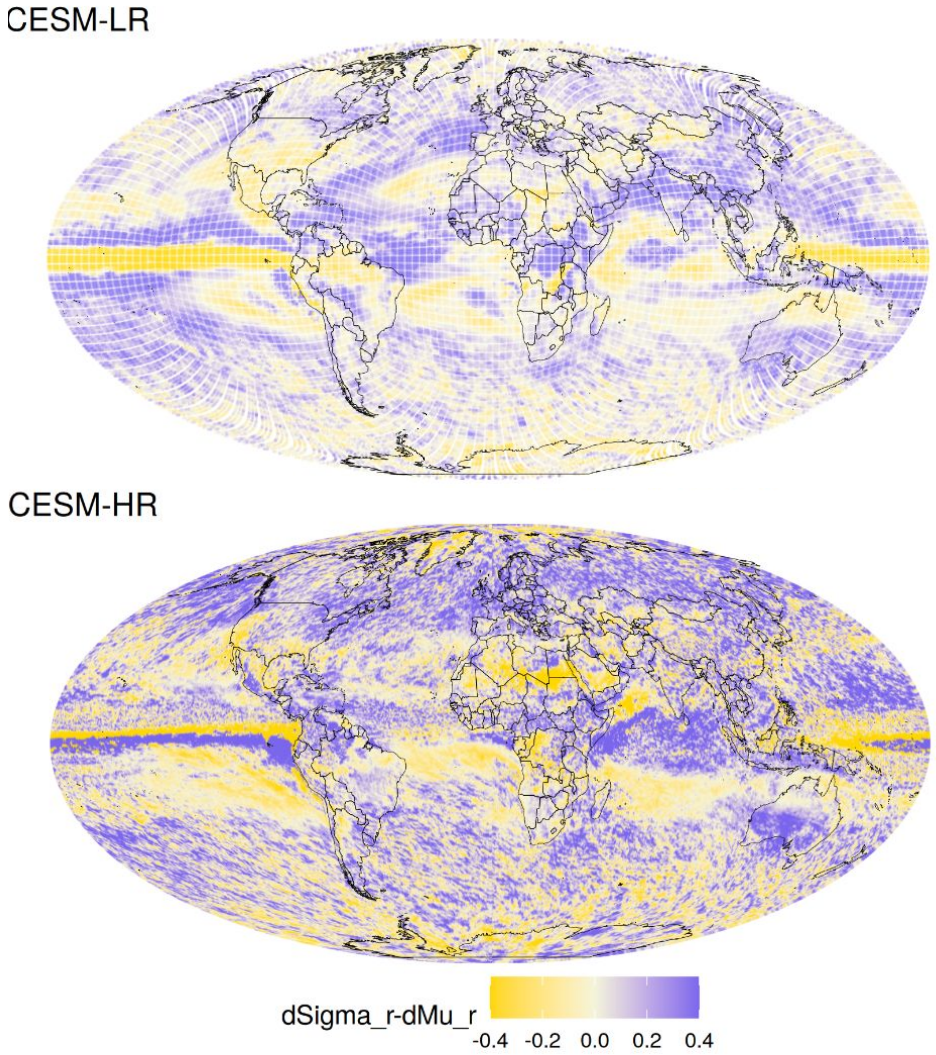


RAINEness in MESACLIP HR

- More localised features
- Stronger RAINE MJJAS NH
- Differences tropics
- Caveat: 3 members



RAINE conclusions & outlook

- Simple statistical diagnostic for potential extreme precipitation hotspot regions
- Key driver: increasing variability of extremes
- Yet to find predictors
- Goal: constrain models & observations