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How can we attribute extreme events

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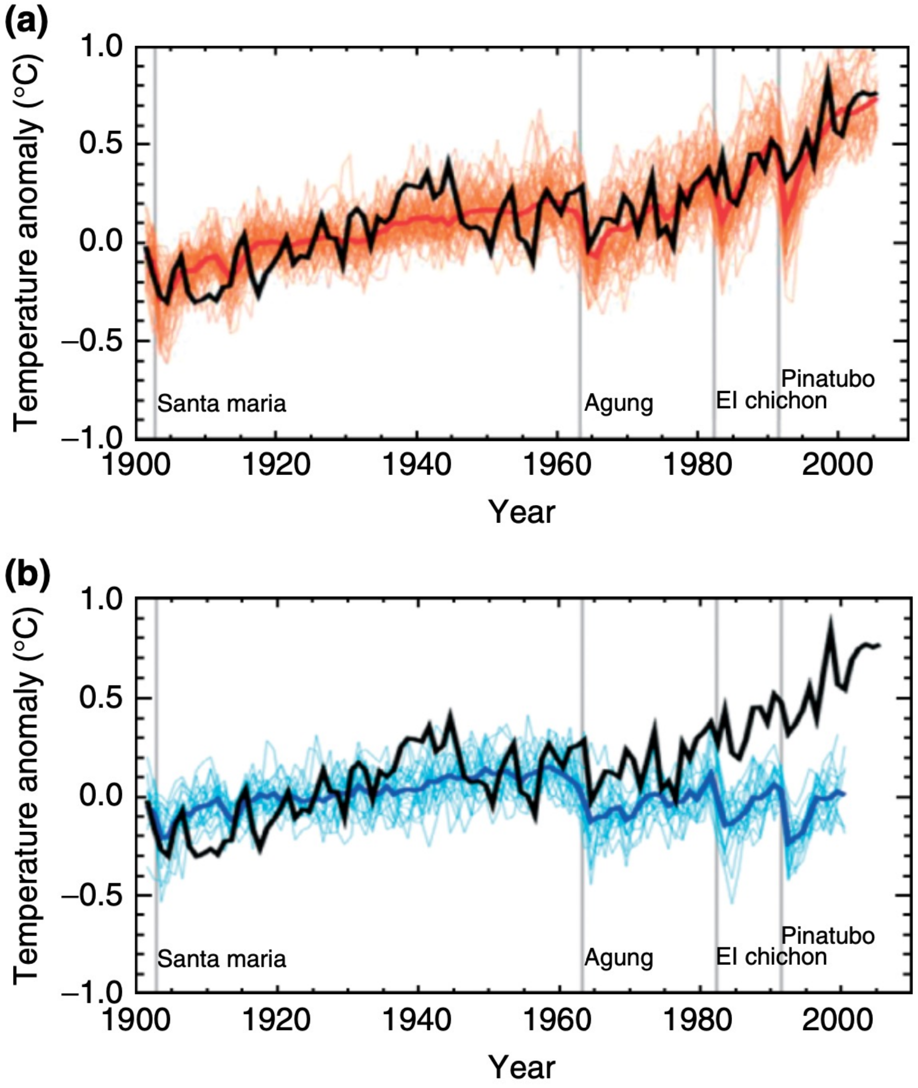
Detection and Attribution

What is detection and attribution analysis

- Detection and attribution seeks to determine whether climate is changing significantly, and if so, what has caused such changes (Stott et al. 2010).

Detectable and attributable changes



- **Detectable** observed change: highly unlikely to occur due to internal variability alone.
- **Attributable** change: the relative contribution of causal factors has been evaluated along with an assignment of statistical confidence (Knutson 2017).

◄ Figure: Global mean surface temperature anomalies compared with climate model simulations (Stott et al. 2010).

The purpose of attribution

- Identify the impacts of anthropogenic climate change that are already occurring (Eyring et al. 2021).
- Facilitate an understanding of the current risks of extreme events (Stott et al. 2010).
- Improve confidence in model predictions and point out areas where models are deficient and need improving (Stott et al. 2010).

Methodology

- Fingerprint-based methods, e.g., optimal fingerprinting.
- Non-fingerprint-based methods, e.g., Granger causality test, and direct comparison of time series and spatial patterns.
- Multistep attribution
- Extreme event attribution

Extreme Event Attribution

Probability(risk)-based attribution

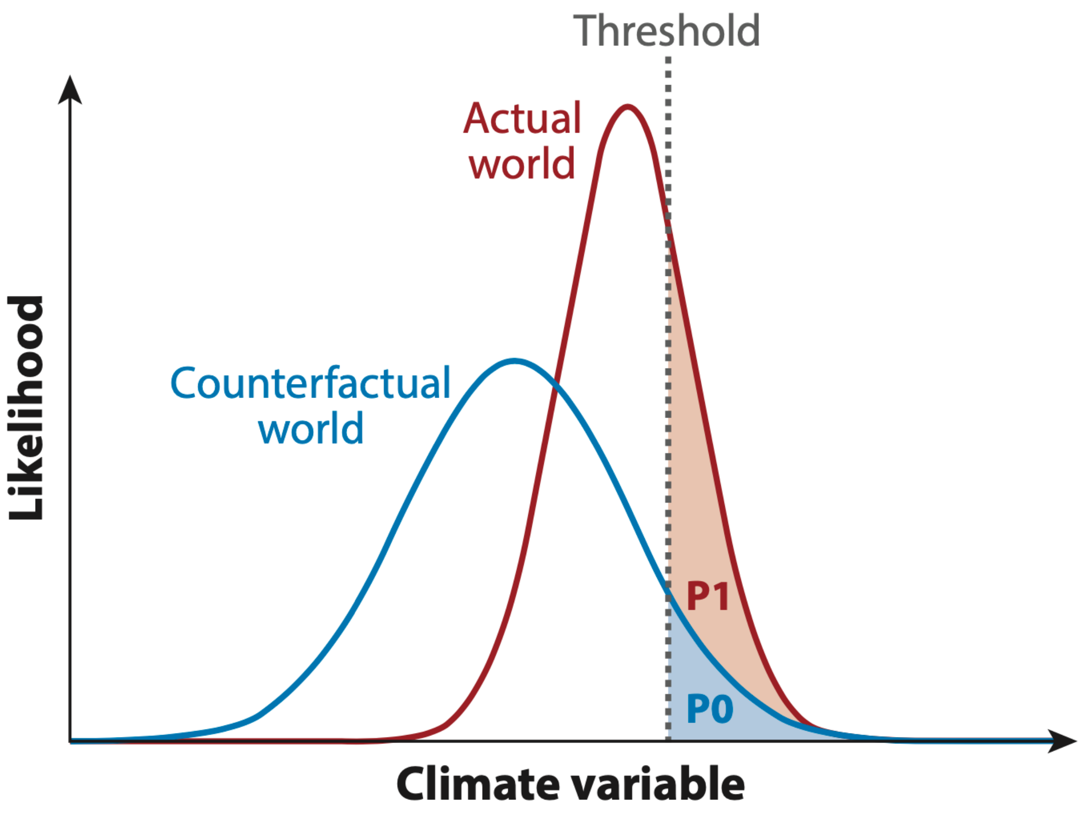


Figure: Schematic of the distribution of a climatic variable under different climate conditions (Otto 2017).

- To determine whether the frequency and/or magnitude of a class of extremes is changing due to anthropogenic climate change (Philip et al. 2020).
- Probability of extreme event in
  - Counterfactual world: P_0
  - Factual world: P_1
- Probability ratio = P_1/P_0.

Generalized extreme value (GEV) distribution

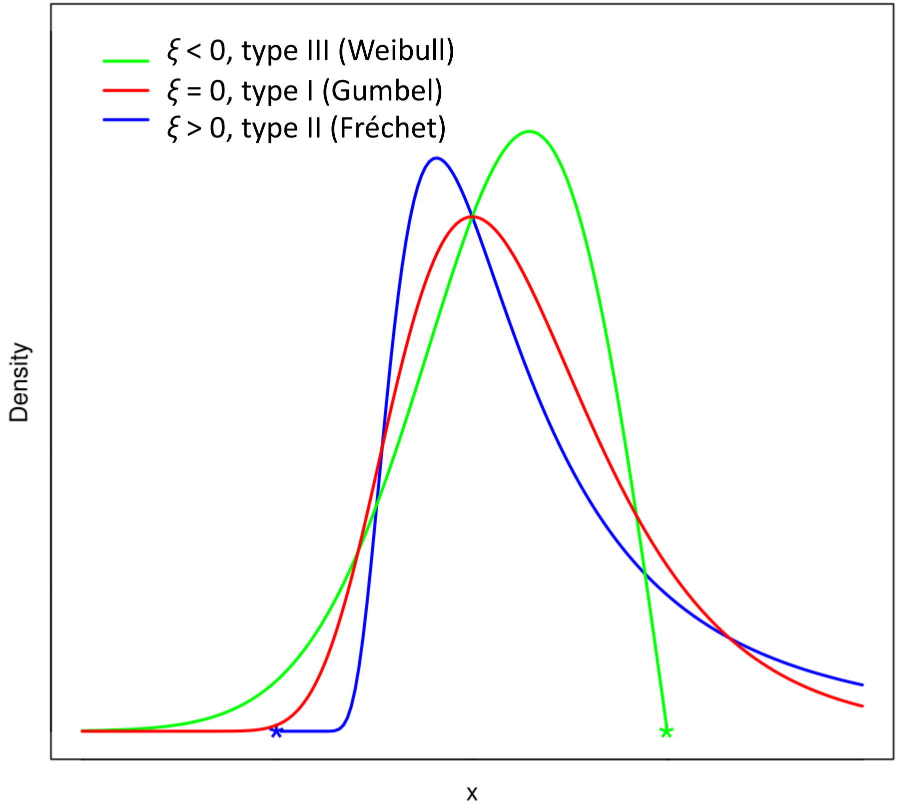


Figure: Generalized extreme value distribution with different shape parameter. (Figure from: https://en.wikipedia.org/wiki/Generalized_extreme_value_distribution)

- The GEV distribution describes the largest observation from a large sample (Coles, 2001, Philip et al. 2020).
- It can be formulated as

$$P(x) = \exp\left[-\left(1 + \xi \frac{x-\mu}{\sigma}\right)^{-1/\xi} \right]$$

- where x is the variable of interest, μ is the location parameter, σ is the scale parameter, and ξ is the shape parameter.

Representation of the counterfactual and factual world

- Empirical approach
  - Separating the period
  - Non-stationary GEV fit (Philip et al. 2020)
    - Shift fit: $\mu = \mu_0 + \alpha T'$, where α is the trend to be estimated, and T' is the global mean surface temperature.
    - Scale fit: $\mu = \mu_0 \exp(\alpha T'/\mu_0)$, and $\sigma = \sigma_0 \exp(\alpha T'/\mu_0)$
    - Shift and scale fit
- Climate model approach

Attribution of extremely rate events in the Mediterranean Region using high-resolution COREX ensemble

Background and objective

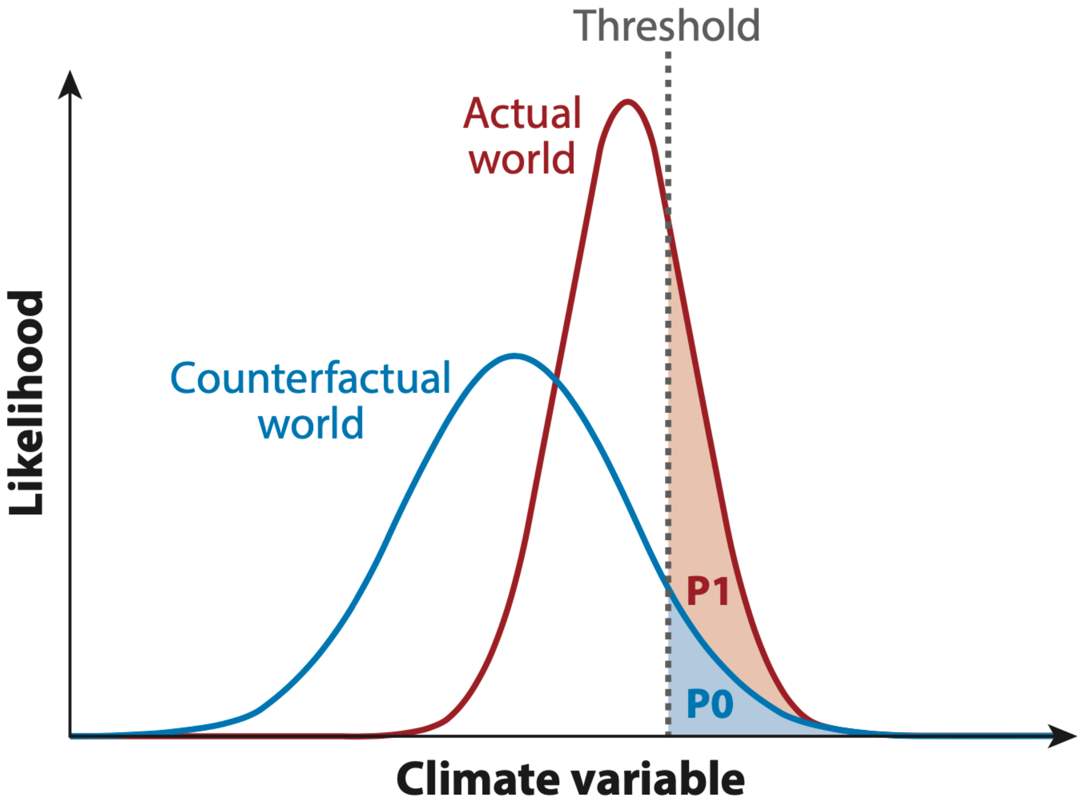


Figure: Schematic of the distribution of a climatic variable under different climate conditions (Otto 2017).

- For unprecedented extreme events, observational record may show a probability of occurrence close to 0.
- Such extremes might be captured by climate models.
- Objective: to explore the applicability of high-resolution climate model ensemble in extreme event attribution.

Data and methodology

- Data
  - Daily precipitation from the E-OBS gridded dataset.
  - Nine members of CORDEX EUR-11 ensemble that has the historical and RCP4.5 scenarios.
- Methodology
  - Quantile mapping for bias correcting the model-simulated daily precipitation.
  - Probability-based attribution on both observed and modeled data.

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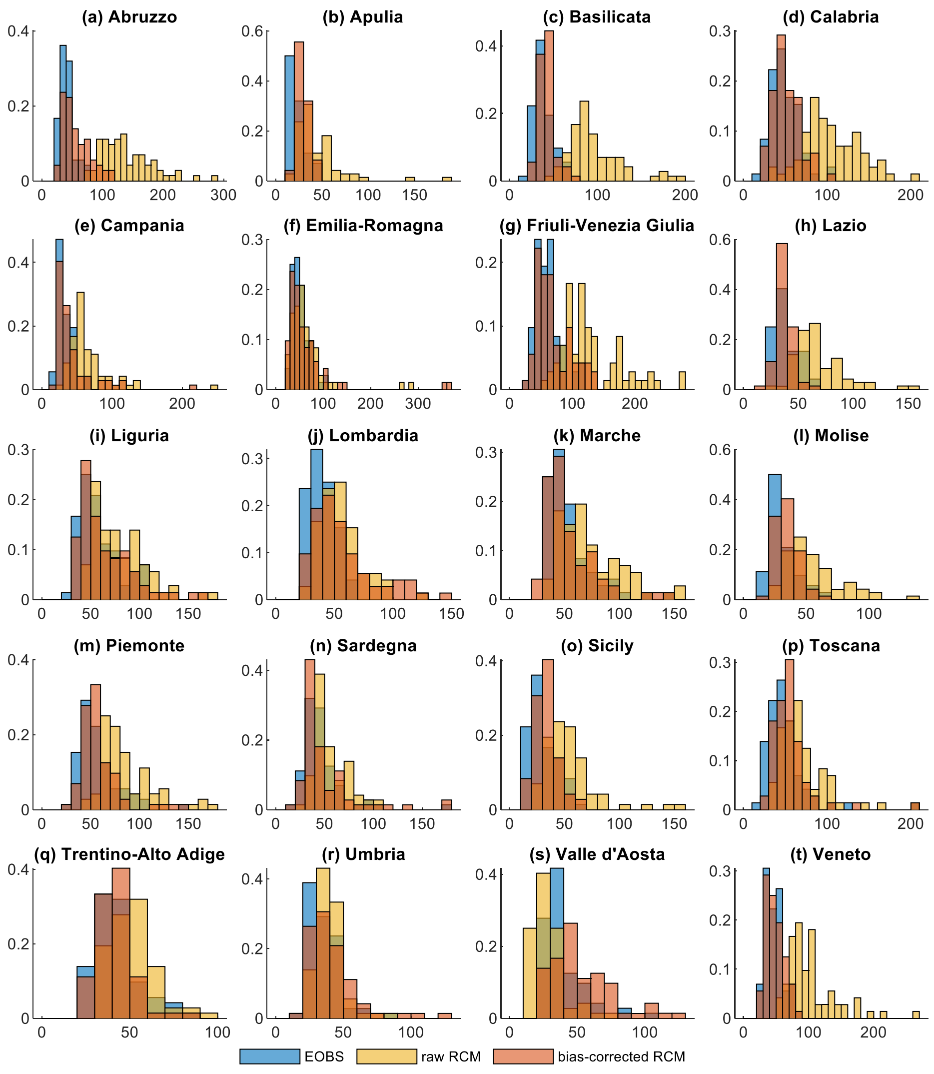
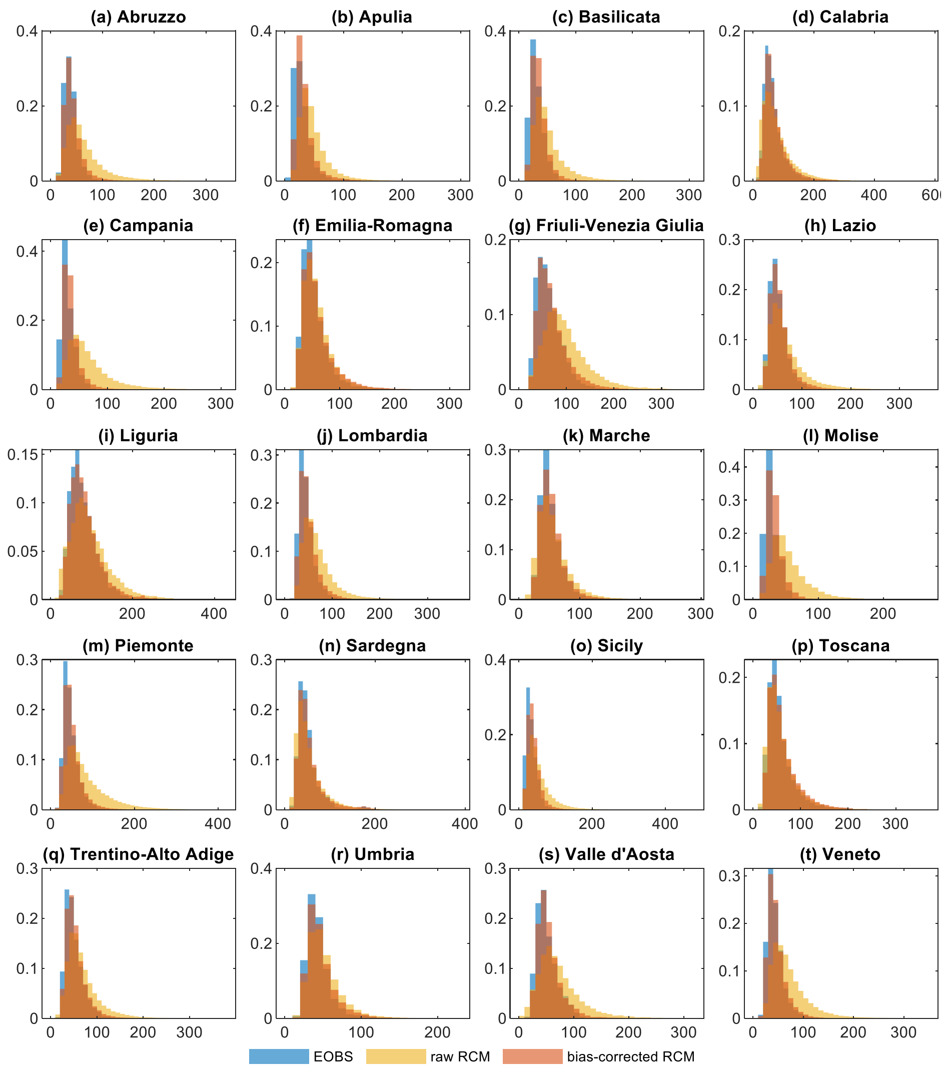
Bias correction

► Figure: Normalized histogram for annual maximum precipitation of the observation, raw RCM, and bias-corrected RCM; an example for a single grid in one RCM.

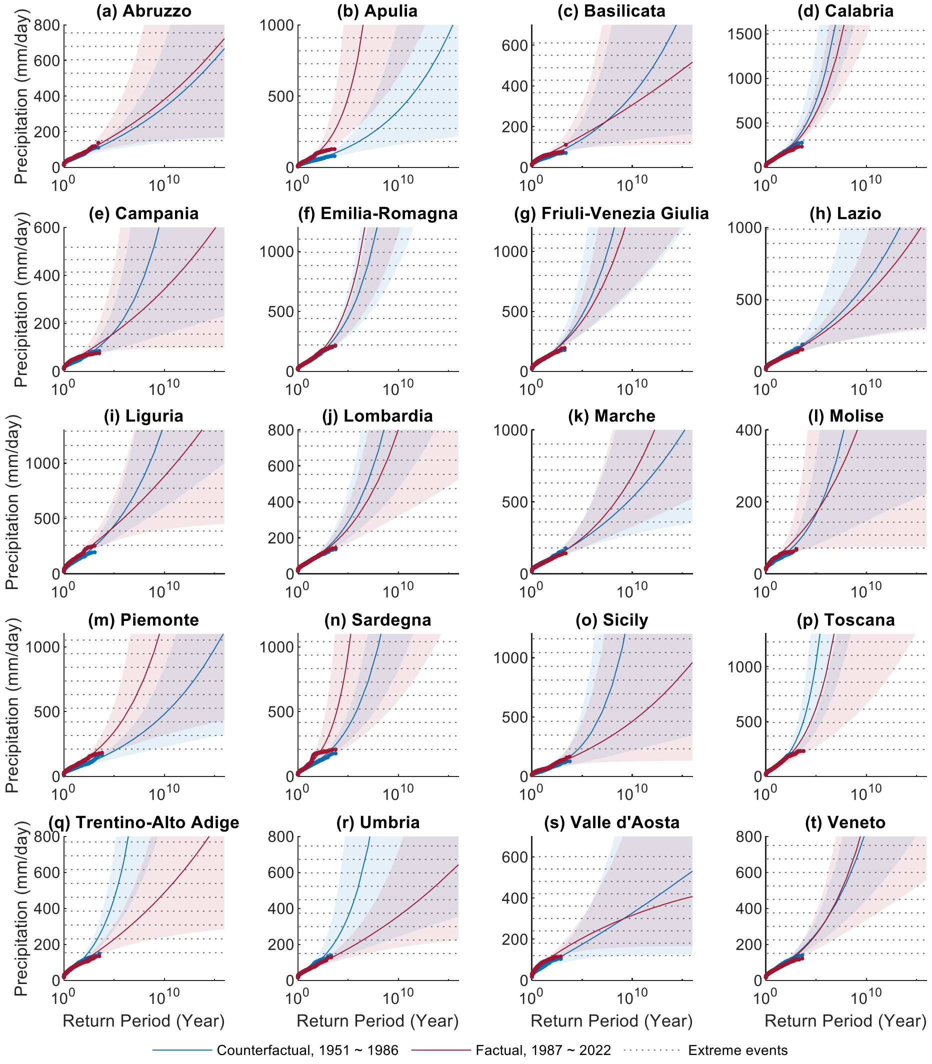




◄ Figure: Normalized histogram for annual maximum Precipitation. For each region, the grids and RCMs are pooled to produce the distribution.

Attribution based on E-OBS

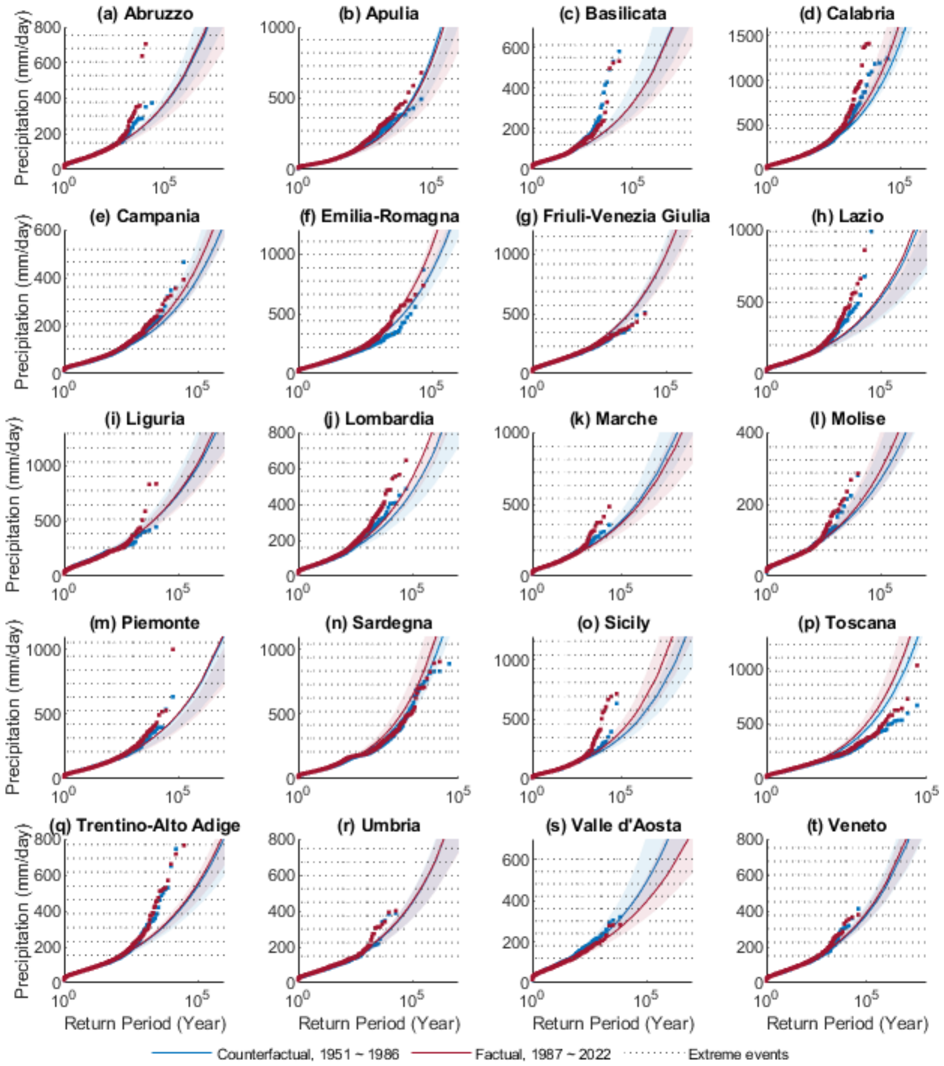
► Figure: Empirical and fitted GEV distribution for the historical period based on EOBS data.

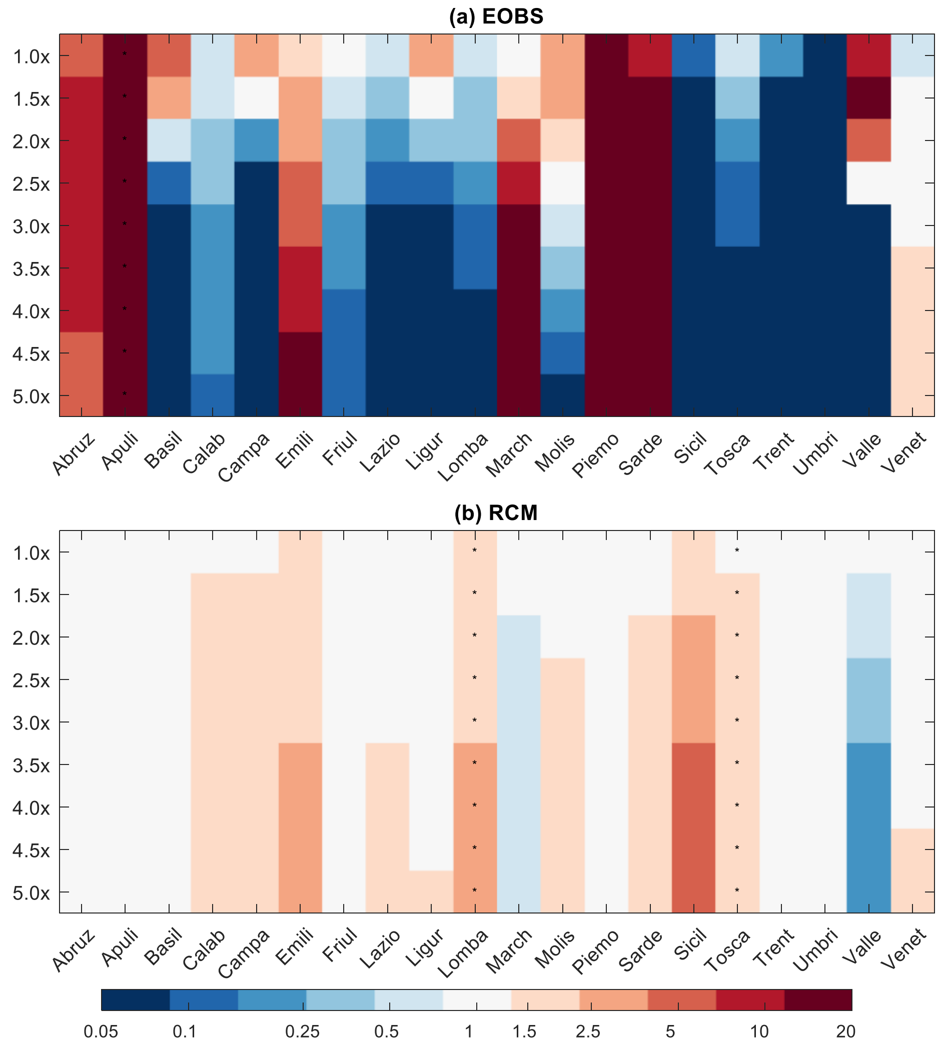


- The historical period is separated into two:
  - Counterfactual: 1951 to 1986
  - Factual 1987 to 2022
- Annual maximum precipitation of each period is used to fit the GEV distribution.
- Definition of extremely rare events:
  - Multiplying the historical maximum precipitation of E-OBS by coefficients from 1.0 to 5.0 in steps of 0.5.

Attribution based on CORDEX ensemble

► Figure: Empirical and fitted GEV distribution for the historical period based on bias-corrected CORDEX data.

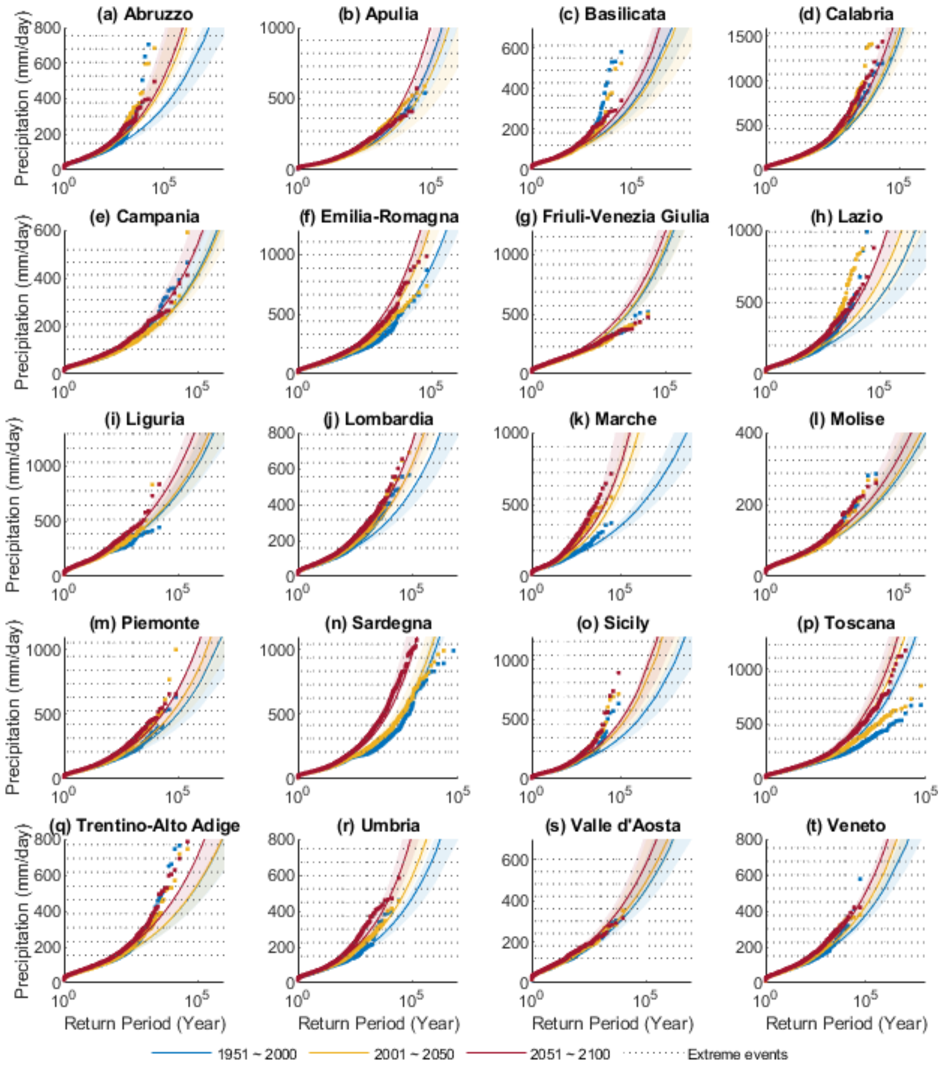


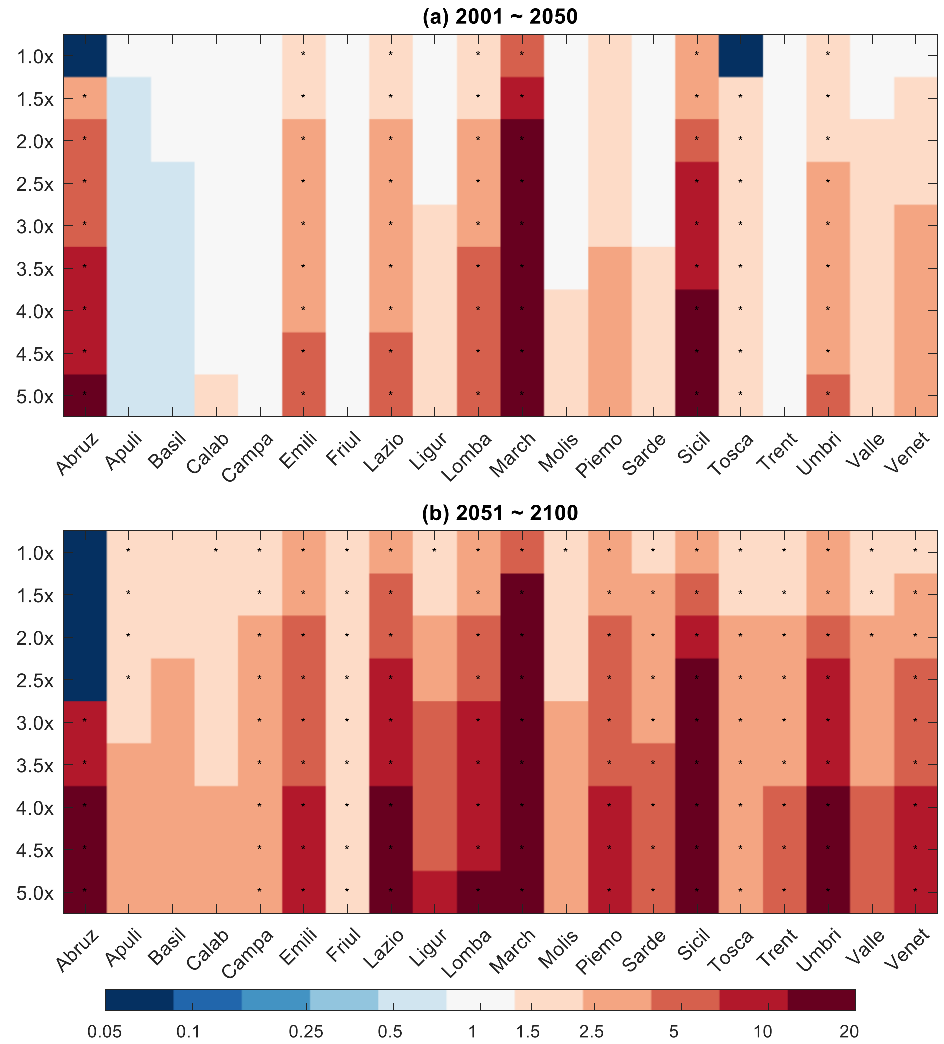


◄ Figure: Probability ratio over the historical period based on E-EOBS and CORDEX ensemble.

Projected future risk

► Figure: Empirical and fitted GEV distribution for the historical and future periods based on bias-corrected CORDEX data.





◄ Figure: Probability ratio for the two future periods.

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