Uncertainties in the projections of the extreme precipitation events over East Asia

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Introduction

- Incidence of precipitation extremes is increasing (IPCC, 2022)
- Intensification of heavy precipitation, typhoon landfalls and draughts is projected in future
- East Asia is especially vulnerable to climate change (high population density at coastlines + natural and topographic factors)
- Extreme precipitation-> lot of potential damage-> need for accurate and reliable climate projections

SOURCES OF UNCERTAINTY

INTERNAL VARIABILITY

Comes from the climate system's natural variability, and in models from different initializations

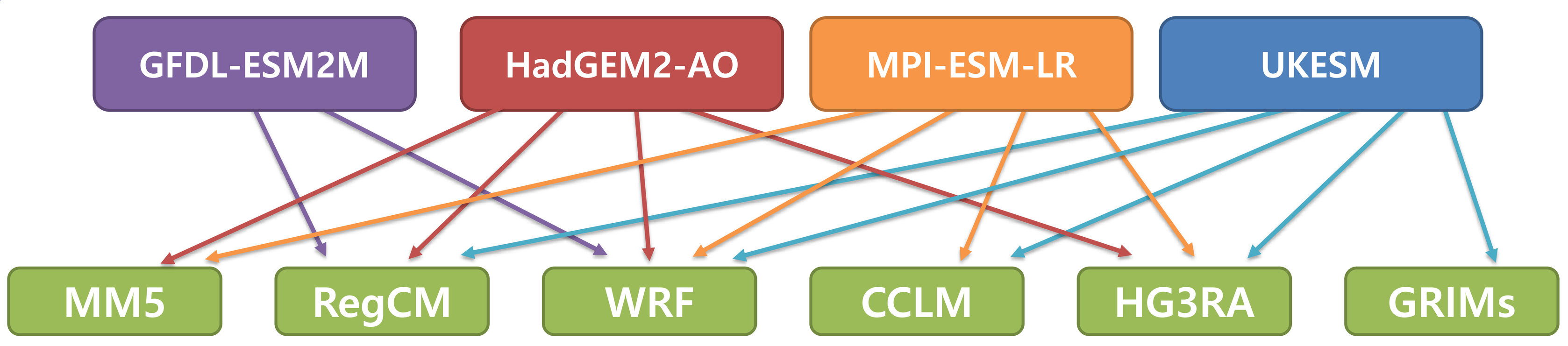
MODEL UNCERTAINTY

Model parametrizations, different settings, limited equations, resolution -> with same forcing, different models project different outcomes

SCENARIO UNCERTAINTY

Uncertainties in the development of societies and economies -> uncertainty in the future radiative forcing

Data & Methods



Graphic 1: CGCM (top row) and RCM (bottom row) models used in study. Arrows denote the combinations

- Historical - (1981-2005) ; RCP2.6 & SSP1-2.6 (low emissions) and RCP8.5 & SSP5-8.5 (high emissions) - (2014-2099)
- Domain analyzed: 100°-150°E, 20°-50°N (East Asia)

INDICES

- Average daily precipitation, SDII (simple daily precipitation intensity index), Rx1d (maximum one day precipitation), Rx5d (maximum cumulative 5-day precipitation)

BIAS CORRECTION

- Quantile Delta Mapping (Cannon et al., 2015)

SEPARATING UNCERTAINTIES

- Method described in Hawkins and Sutton (2009;2011) : projections are fit (using least squares) to the fourth order polynomial:

$$X_{m,s,t} = x_{m,s,t} + i_{m,s} + \varepsilon_{m,s,t}$$

- Internal variability is defined as residuals from the fits: $IV = \frac{1}{N_m}\sum_m var_{s,t}(\varepsilon_{m,s,t})$
- Model unc. is defined as multi-scenario mean of the variance of the fits

$$MU(t) = \frac{1}{N_s}\sum_s var_m(x_{m,s,t})$$

- Scenario unc. is variance of the multi-model means: $SU(t) = var_s\left(\frac{1}{N_m}\sum_m x_{m,s,t}\right)$

Model evaluation and future projections

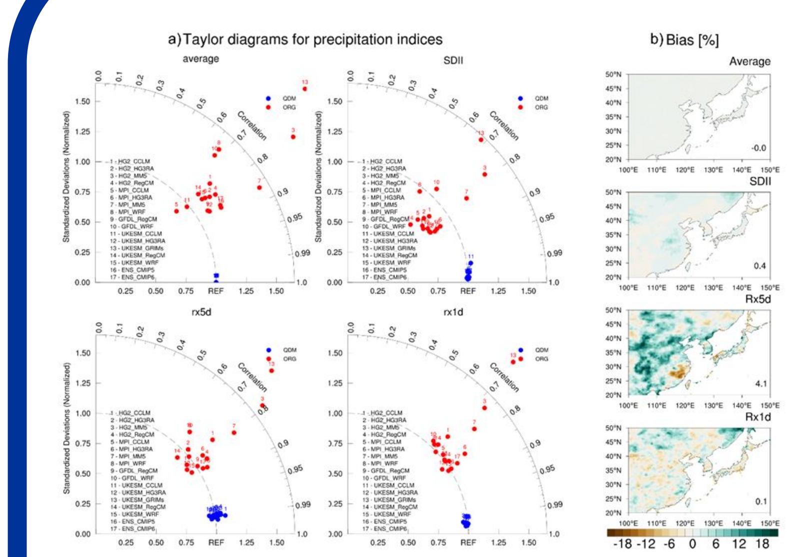


Figure 1. Taylor diagrams (a) and the average bias for historical period (b) for average precipitation, SDII, Rx5d and Rx1d. Red dots are before BC, blue dots after

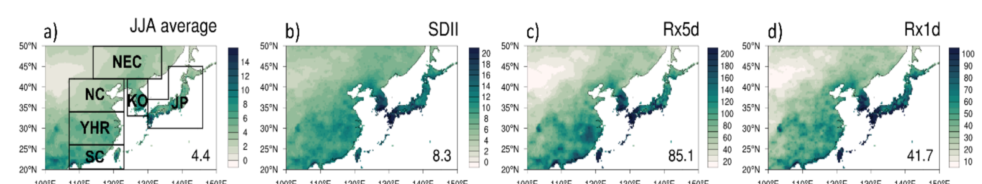


Figure 2. Spatial distribution of the observed boreal summer (JJA) meal daily precipitation, SDII, Rx5d and Rx1d. Domains: North-East China(NEC), North China (NC), Yangtze-Huaihe River Basin (YHR), South China (SC), Korea (KO) and Japan (JP)

MODEL EVALUATION

- Bias correction (BC) significantly improves the performance of the mode
- There is no remaining bias for average precipitation, but small bias remains for SDII, Rx1d and Rx5d -> good performance

FUTURE PROJECTIONS

- Mean precipitation - small changes
- SDII change - somewhat larger in the high emission scenarios
- Rx5d and Rx1d - larger increases, big contrast between low emission and hig emission scenarios, and the higher increase the more extreme the index is
- Rx1d is projected to increase over 50% by the end of the century, over 70% in some parts of the domain

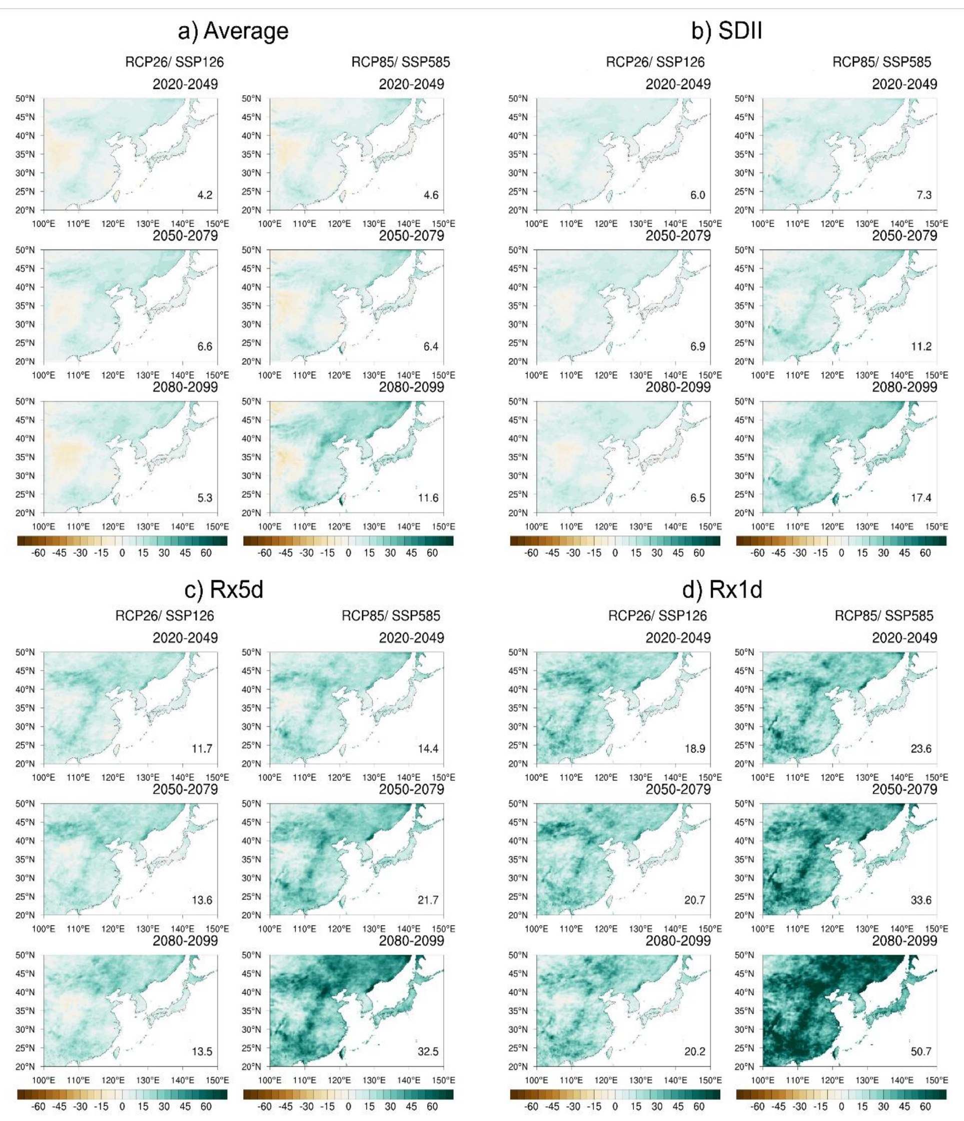


Figure 3. Future changes in the precipitation indices

Uncertainties in projections

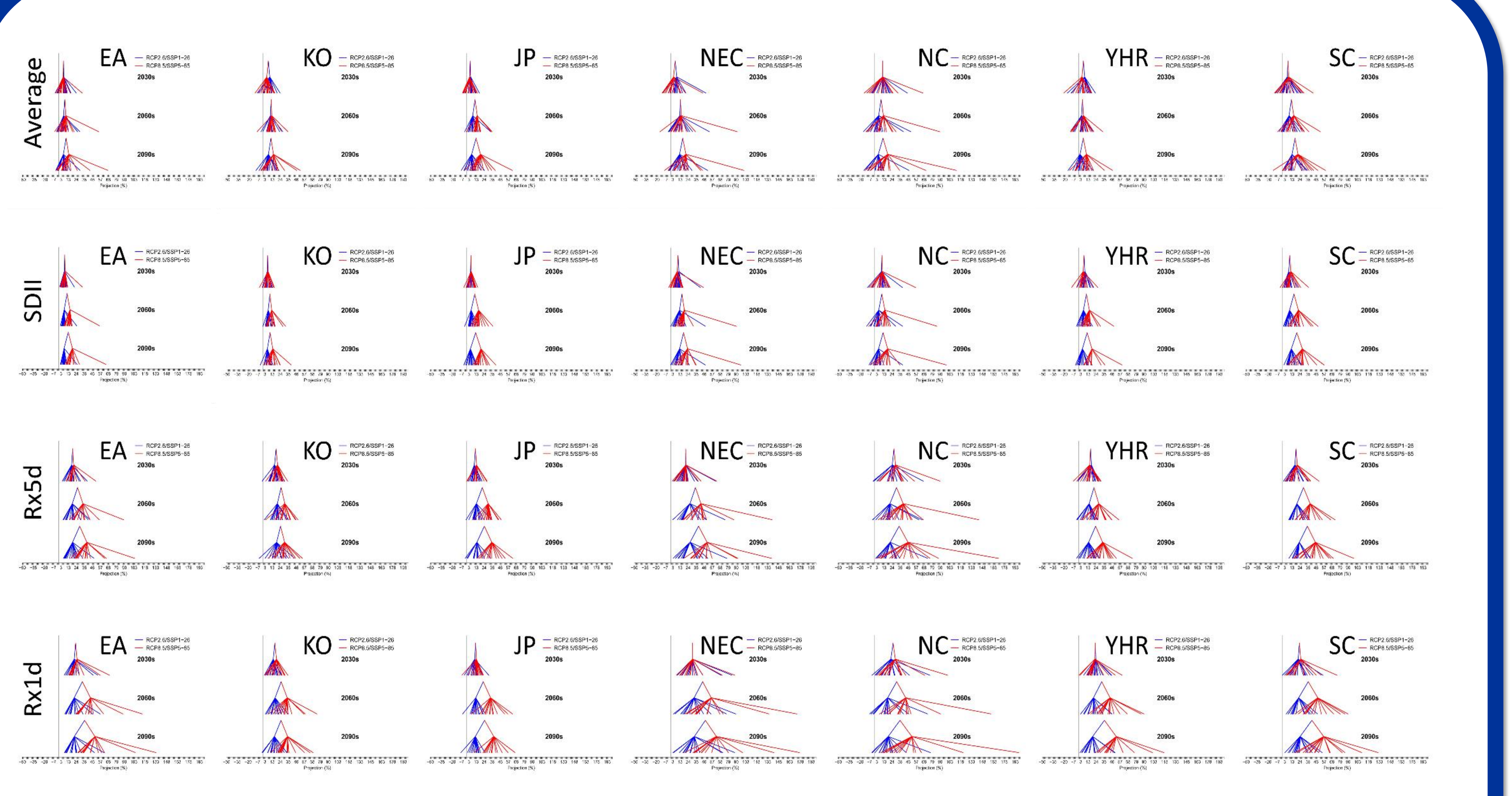


Figure 3: The cascade plots of the area-averaged predictions (in percent of change) for each domain (left-to-right: East Asia(EA), KO, JP, NEC, NC, YHR and SC), for the four indices (top-to-bottom average, SDII, Rx5d and Rx1d)

- TOP plot: 2030s, middle plot:2060s, bottom: 2090s ; top of each plot shows the scenario average, middle average of projections per scenario, and bottom each model prediction. RCP2.6/SSP1.-2.6 is marked in blue, and RCP8.5/SSP5-8.5 in red
- Rx1d and Rx5d have larger spread (more uncertainty) than average and SDII

- In the near future (top row), internal variability accounts for most of the uncertainty
- In the 2060s (mid row), the model uncertainty takes over as largest source of uncertainty, especially for average and SDII
- Scenario uncertainty is negligible for average and SDII all the way until the end of the century, but plays a role in Rx5d and Rx1d

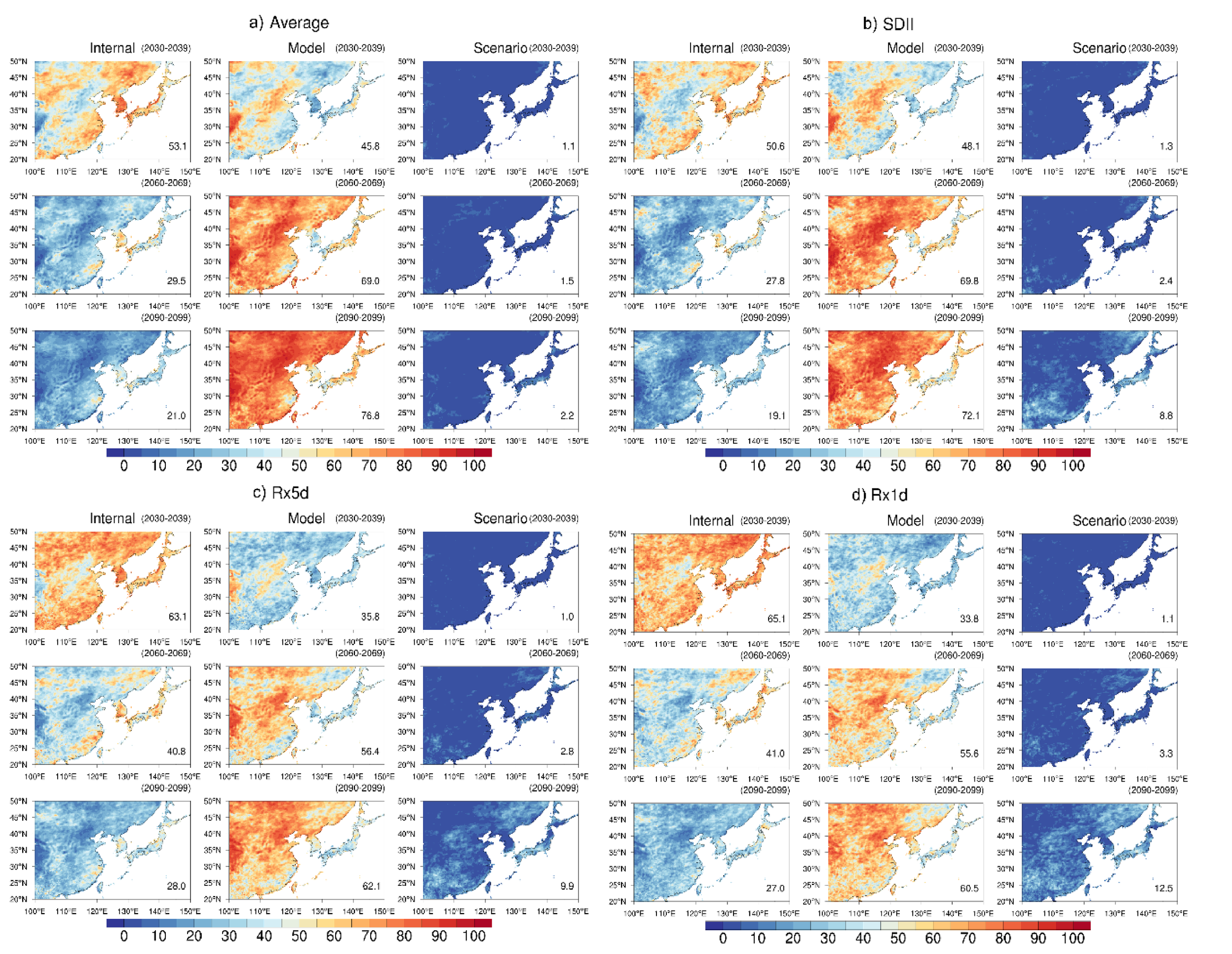


Figure 4: The contributions [%] of each part of the uncertainty for a) mean daily precipitation, b) SDII , c) Rx5d and d) Rx1d

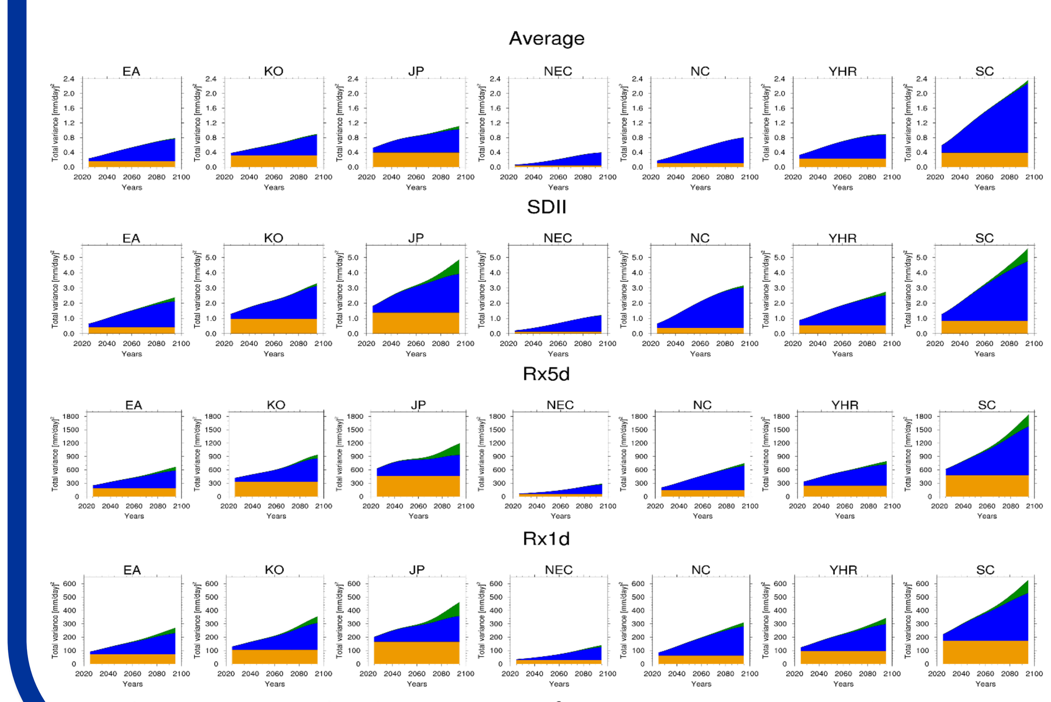


Figure 5: The total variance [mm/day]^2 averaged over each domain

- Total uncertainty is higher in wetter domains, and highest in SC, JP, KO
- The variance of the whole domain is smaller than each subdomain, except NEC
- SC,KO and JP (the wettest domains) have the highest internal uncertainty and scenario uncertainty by the end of the century for the extreme indices

Summary

- After bias correction, models simulate current climate well and are appropriate for assessment of future climate
- Internal variability is main component of uncertainty at the beginning of projections, but is around mid-century overtaken by model uncertainty for majority of the domain
- Model uncertainty is largest contributor for all indices at the end of century
- Scenario uncertainty is insignificant contributor in near future for all indices, but as time goes by, the more extreme the precipitation, the larger the influence of the scenario uncertainty
- Areas most vulnerable to scenario differences are KO (Korea), JP (Japan), SC (Southern China) and YHR (Yangtze-Huaihe river basin)

✓ **References and Sources:**

Juzbasic A., Park, C., Cha D.H., Ahn J.B., Chang E.C., Min S.K., 2023: Assessment of uncertainty factors in the future projections of precipitation extremes in East Asia using bias-corrected multi-RCMs (in preparation)

Cannon, A. J., Sobie, S. R., & Murdock, T. Q. (2015). Bias Correction of GCM Precipitation by Quantile Mapping: How Well Do Methods Preserve Changes in Quantiles and Extremes? Journal of Climate, 28(17)

Hawkins, E., & Sutton, R. (2009). The Potential to Narrow Uncertainty in Regional Climate Predictions. Bulletin of the American Meteorological Society, 90(8), 1095-1108

Hawkins, E., & Sutton, R. (2011). The potential to narrow uncertainty in projections of regional precipitation change. Climate Dynamics, 37(1-2), 407-418.

✓ **Acknowledgement**

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