A classification algorithm for selective dynamical downscaling of precipitation extremes

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BINGO – a better future under CLIMATE CHANGE
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1. Targeted downscaling - why and how?

Convection-permitting models (CPMs) add value, especially for extremes, to coarser resolution models (Prein et al., 2015) and provides invaluable fine-scale detail for hydrological modellers. Such simulations are however computationally expensive. **To reduce computational expense, we develop a classification algorithm for selective CPM-downscaling of days with increased risk of extreme precipitation.**

Based on observed rainfall (REGNIE, 24h), large-scale Z500 patterns (ERA-Interim) accompanying extremes are selected and clustered via the SANDRA method (Philipp et al., 2007) to create references. Circulation patterns from RCM simulations (EURO-CORDEX domain) are then compared to these reference extremal patterns to identify potential extreme days (**PEDs**). Similar days are chosen for CPM downscaling, subject to additional tests of local-scale meteorological predictors in the catchment region.

Here we present the results of our method for the Wupper catchment in Germany, one of the six catchments within the BINGO project. Evaluation is performed for both present and future (RCP8.5) climates. Our CPM is COSMO-CLM at 0.02° resoution.

2. Extremal Weather Patterns

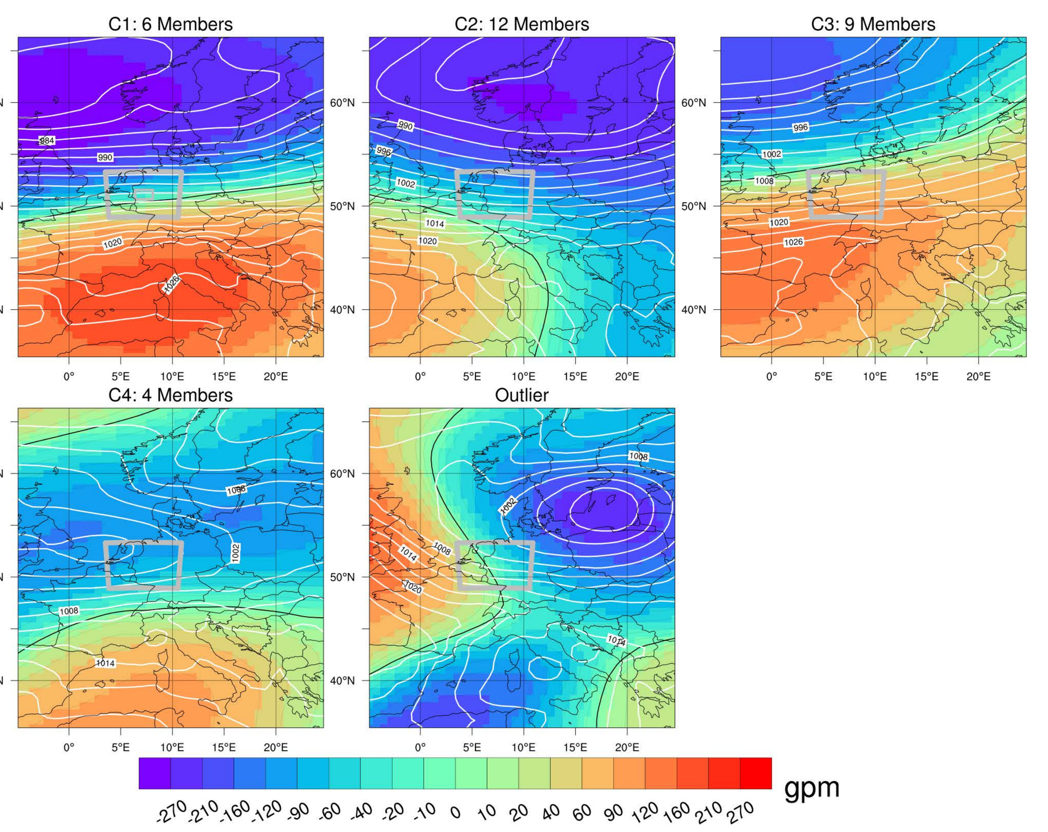

Figure 1. Wupper Extremal Patterns (DJF).

500 hPa geopotential height anomalies of DJF extremal patterns identified for the Wupper catchment.

The grey box centred on the catchment marks the extent of the 2.2-km downscaling domain, the centre of which is shown in Fig. 4.

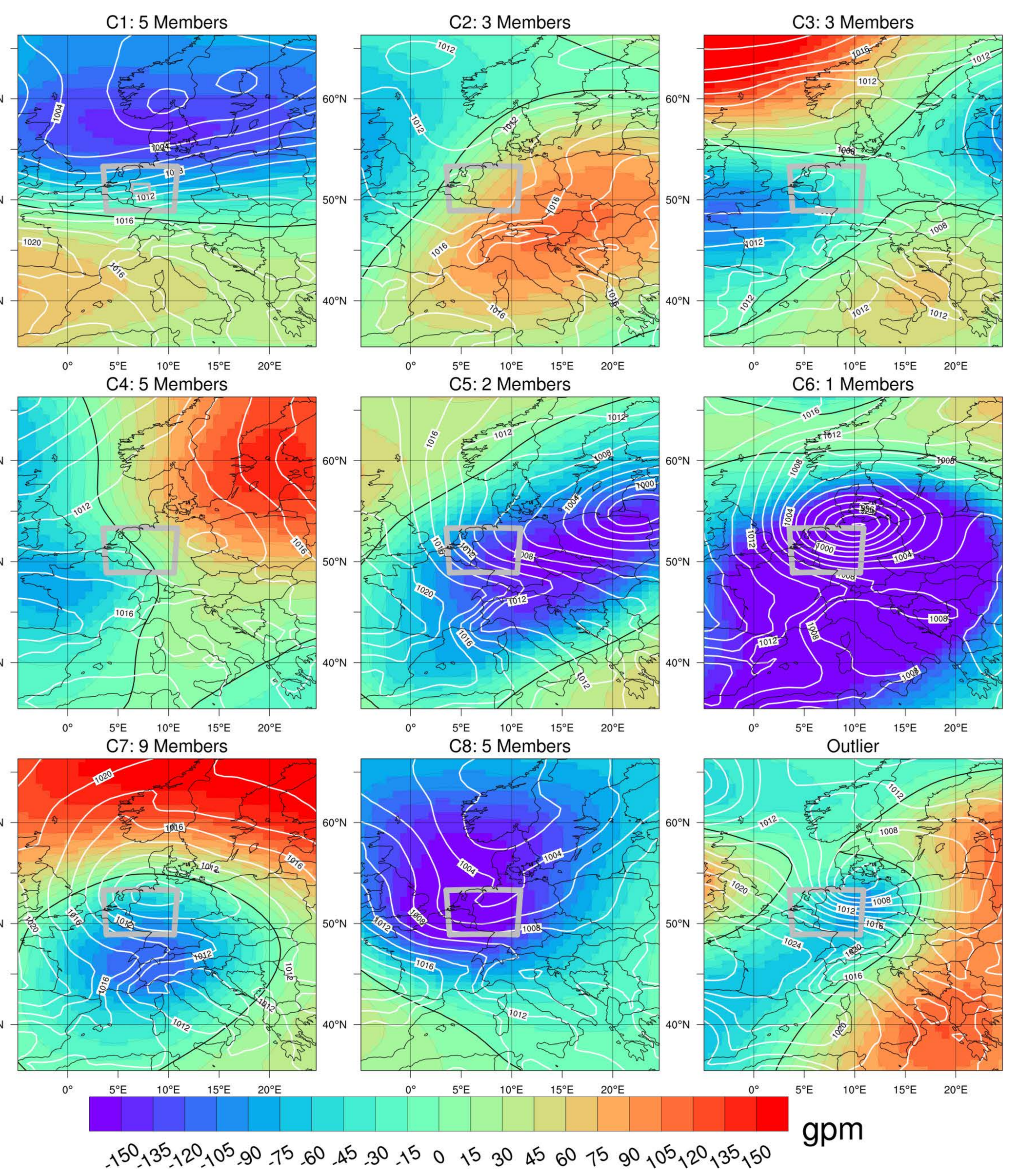

Figure 2. Wupper Extremal Patterns (JJA).

As in Fig. 1, except for JJA.

3. Classifying Potential Extreme Days (PEDs)

```
for j in (1, ..., K) do                                  # Extremal patterns 1 to K
    if (ρi,j ≥ ρjt) then                                 # Synoptic-scale tests
        if (RH700i ≥ RH700thresh) then                   # Local-scale tests
            if (DIV500i ≥ DIV500thresh .OR. CAPEi ≥ CAPEthresh) then
                if (Pi ≥ P95) then
                    DAYi classified as PED
                end if
            end if
        end if
    end if
end do
```

Figure 3. Classification Algorithm Schematic. Example for a single day ***i*** in summer. $\rho_{i,j}$ is the Pearson pattern correlation between day ***i*** and cluster ***j***, with ρ_{jt} the threshold for cluster ***j***. Local-scale predictors and thresholds are empirically chosen. DJF algorithm is the same, except without CAPE and with RH at 300 hPa.

4. Convection-permitting Downscaling

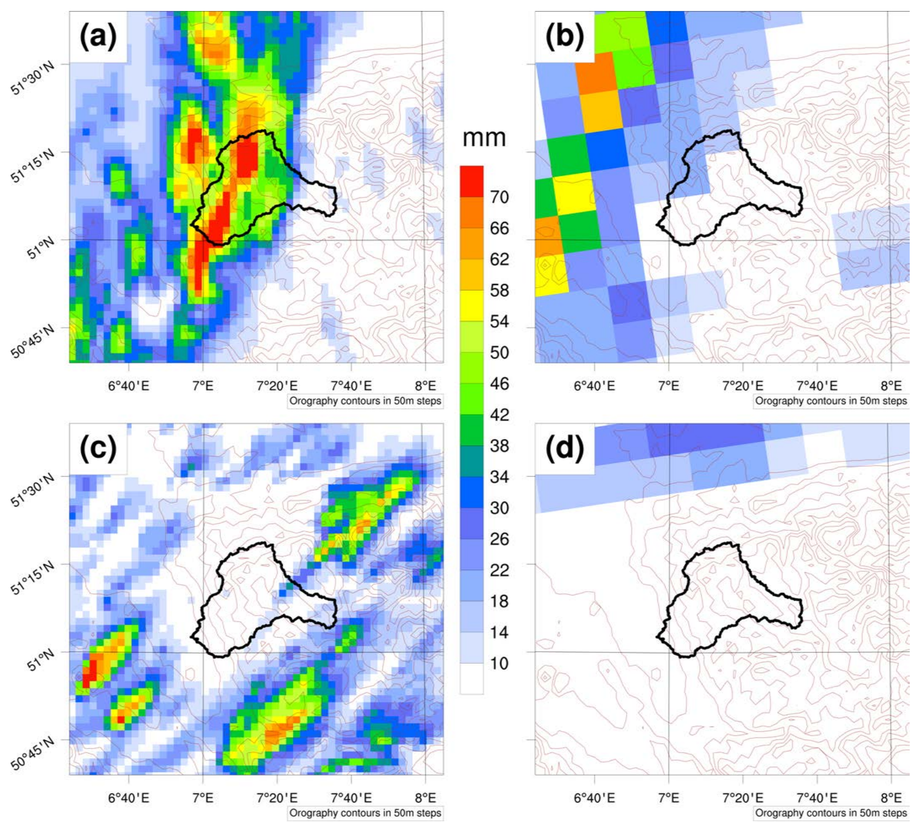

Figure 4. Illustrative modelled PEDs.

(a) Example summer PED downscaled to 0.02° and **(b)** the same day in the 0.11° model. In this example, the strongest precipitation directly strikes the catchment in the 0.02° CCLM despite missing the catchment in the parent 0.11° CCLM.

(c) Near-miss. Example summer PED with highly localised intense precipitation which falls outside the catchment in the 0.02° CCLM. **(d)** The corresponding day in the 0.11° CCLM.

5. Evaluation of present-climate PED Statistics → observed and modelled

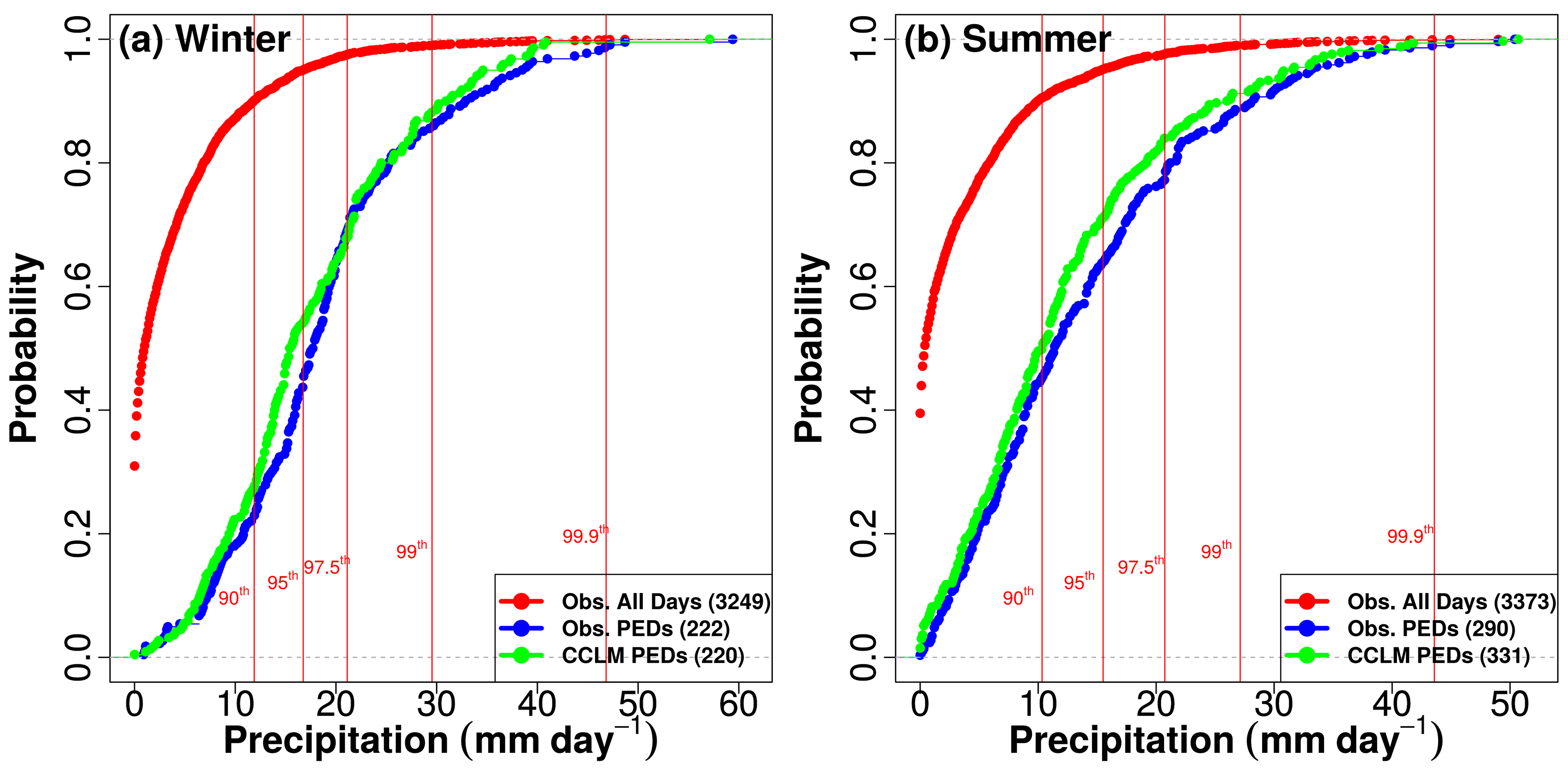

Figure 5. ECDFs of daily precipitation for all days (red, obs.), PEDs (blue, obs.), and CCLM PEDs (green, downscaled to 0.02°). **(a)** Winter 1980-2015, **(b)** summer 1979-2015. Values are area avgs. over the Wupper catchment. Red lines mark percentiles of the all-day distribution. Obs. PEDs are identified from reanalysis, CCLM PEDs from 0.11° EURO-CORDEX runs (ERA-Interim LBCs).

The classification algorithm reduces the number of days to simulate by over 90% and CCLM-02 well reproduces the observed PED statistics.

6. Testing with 0.02° continuous JJA simulations

We additionally test the method by using 0.02° JJA time-slice simulations, to see how many of the actually simulated 0.02° extremes were identified by the algorithm and compare performance across climates. The GCM is MPI-ESM-LR, which was downscaled to 0.11° as part of EURO-CORDEX. We look at historical (1970-1999) and future (2070-2099, RCP8.5) summers.

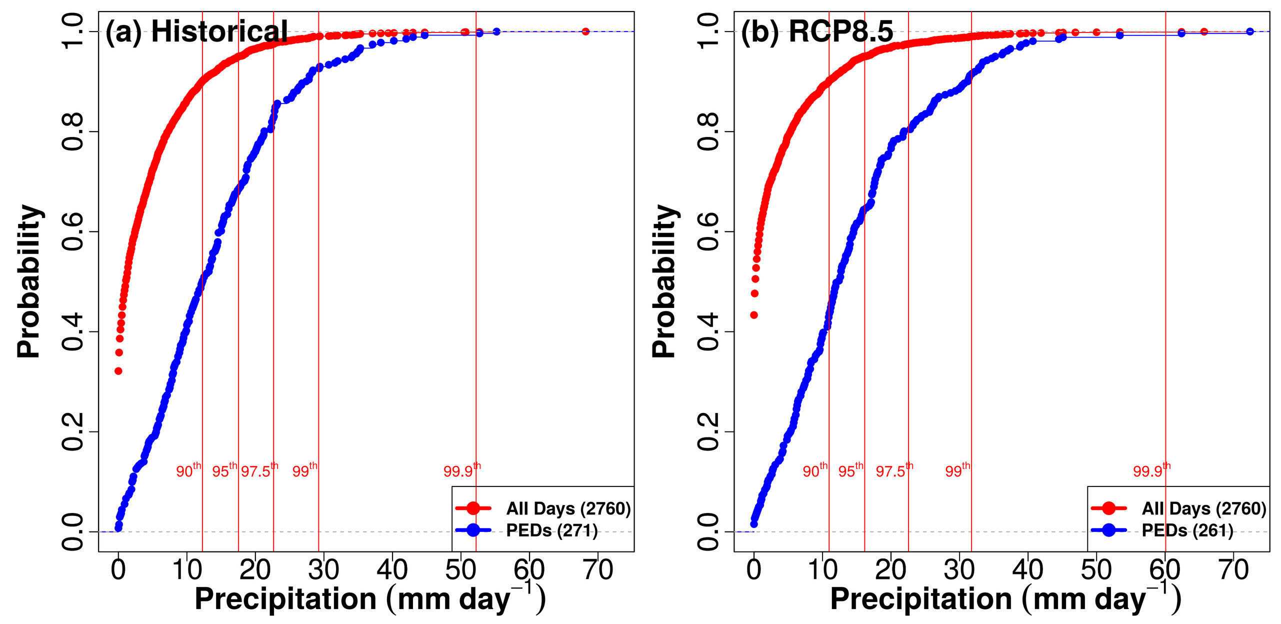

Figure 6. Historical & Future ECDFs (JJA). Values are area averages over the Wupper catchment from CCLM-02 for all days (red) and PEDs (blue). The PEDs again reduce the number of days to downscale by over 90%.

The identified PEDs contain at least 75% of the actual extremes (P > P_{99D}) and performance is consistent across climates.

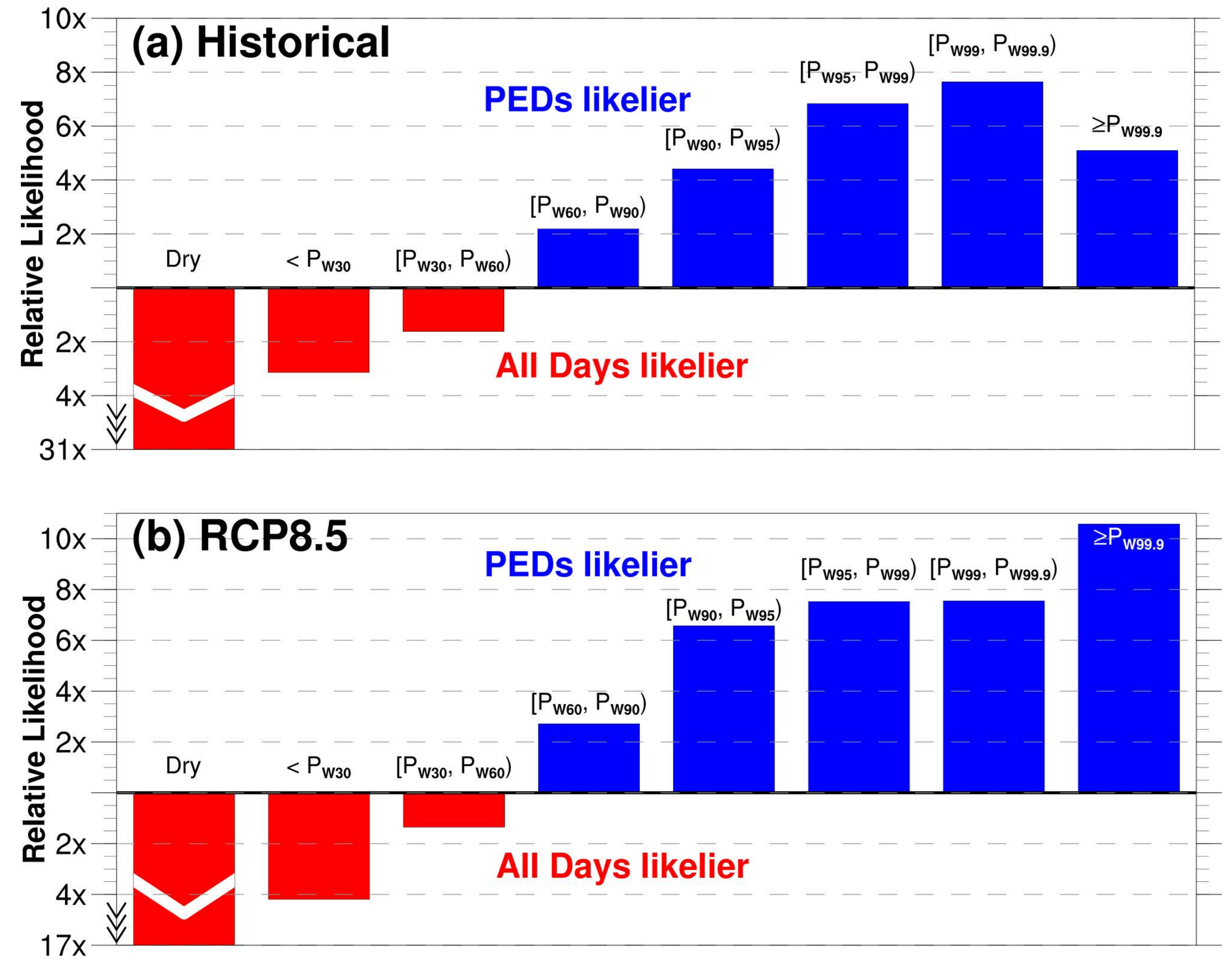

Figure 7.

Relative likelihoods of finding a precipitation day within a given intensity range between the PEDs (blue) and All Days (red).

(a) historical,
(b) RCP8.5 simulations.

As can be seen, **days with intense rainfall are far likelier amongst the PEDs.**

7. Summary and Conclusions

→ Algorithm (Fig. 3) **reduces number of days to downscale by >90%** (Fig. 5)

→ With skillful selection, **CPM well reproduces observed PED statistics** (Fig. 5)

→ Performance similar using different parent GCM (Fig. 6)

→ **Consistent across historical/future climates** (Figs. 6/7)

→ Applications include creating forcing data for hydrological models for stress testing, design situations, case-studies, etc.

→ Method however cannot be used for traditional projections, which instead require continuous downscaling

→ Full study can be read in HESSD

Acknowledgements and References

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