Bias-Correcting extreme value projections using GEV parameter estimation

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Context and aims

- Extremes that occur on daily timescales impact on many human and biophysical systems (Woodruff *et al.* 2006; Fischer and Shar, 2010);
- Models in the CMIP3 ensemble have been used for global and regional projections of extremes (Kharin *et al.*, 2007; Perkins *et al.*, 2009), however biases within the models may produce magnitudes of extremes which are not plausible at regional scales;
- Dynamical downscaling by RCMs while useful can be computationally expensive;
- Various statistical downscaling functions also exist, however most are designed using monthly data, and are based on quantile transfer functions (Panofsky & Brier, 1968; Crimp *et al.*, 2002; Li *et al.*, 2010);
- Percentile transfers are not always suitable, as they do not account for future changes in the distribution;
- This study attempts to design a transfer function correcting for model bias in the distribution of daily extremes, using estimated Generalized Extreme Value (GEV) parameters, and compares this with two quantile transfer functions (Panofsky & Brier, 1968; Li *et al.*, 2010).

Data

- REGION: Pacific region encompassing both land and ocean spanning 120E-210E, 25S-20N;
- OBSERVATIONS: ERA40 reanalysis used as dataset to "train" GCM against;
- MODEL: CSIRO Mk 3.5 GCM, 20c3m and A2 scenarios;
- TIME PERIODS: training: 1981-2000, projections: 2081-2100;
- VARIABLES: precipitation (Pr), maximum temperature (Tmax).

Methods

- GEV samples calculated per variable at each grid box for both scenarios and ERA40;
- GEV parameters (μ, σ, *K*) estimated per sample;
- Four methods used to correct 20th Century model sample:

Li *et al.* (2010) method 1 (Li_1; adapted from Panofsky and Brier, 1968):

$$x_{m-p.adjst} = F^{-1}_{o-c}(F_{m-c}(x_{m-p}))$$

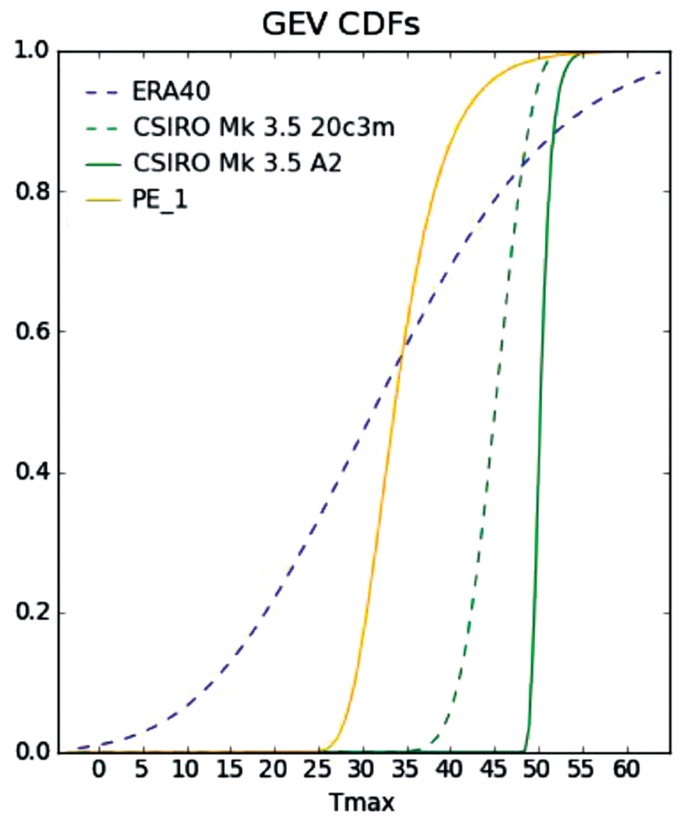
Li *et al.* (2010) method 2 (Li_2):

$$x_{m-p.adjst} = x_{m-p} + F^{-1}_{o-c}(F_{m-p}c(x_{m-p})) - F^{-1}_{m-c}(F_{m-p}(x_{m-p}))$$

Perkins and Erwin methods 1 and 2 (PE_1, PE_2; Figure 1):

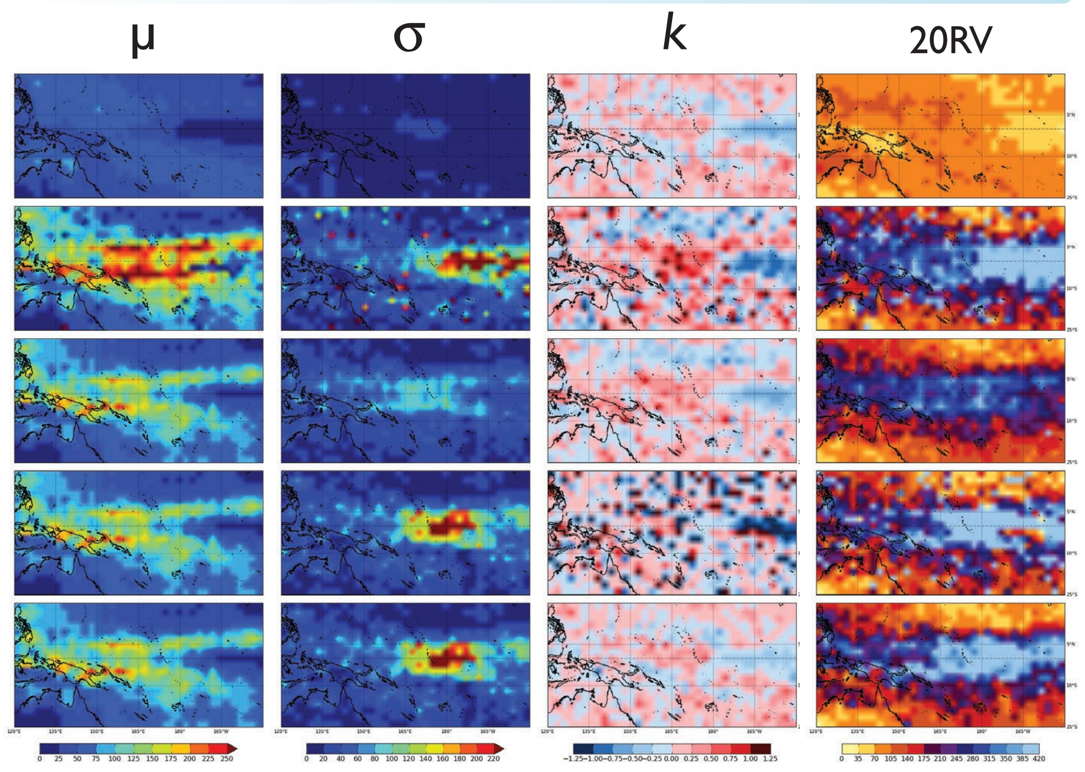
$$x_{m-p.adjst} = \mu_{scaled} + \sigma_{scaled}\left(\frac{1-(-ln(F_{m-p}(x_{m-p}))^{k_{scaled}}}{k_{scaled}}\right)$$

- Each transfer function fitted separately to A2 samples to correct for 20th century model biases;
- 20-year return value (20RV) projections calculated for each transformed and original model sample;
- Kolmogorov-Smirnov (KS) test employed to determine if each of the transformed A2 GEV samples are significantly different from the original GEV sample. Two-sample version used where H_0 means both samples are from the same distribution.



> Figure 1: Schematic showing how the PE method works. Distributional parameters (μ, σ, *K*) are calculated for each of the ERA40 (blue dash), CSIRO 20c3m (green dash) and CSIRO A2 (green solid) samples. The scaling factors for each of the parameters between ERA40 and CSIRO 20c3m is calculated via the third equation. The respective scaling factors are then fitted to the CSIRO A2 parameters, resulting in a new transformed set. These new parameters are used to create the yellow CDF and the underlying bias-corrected sample.

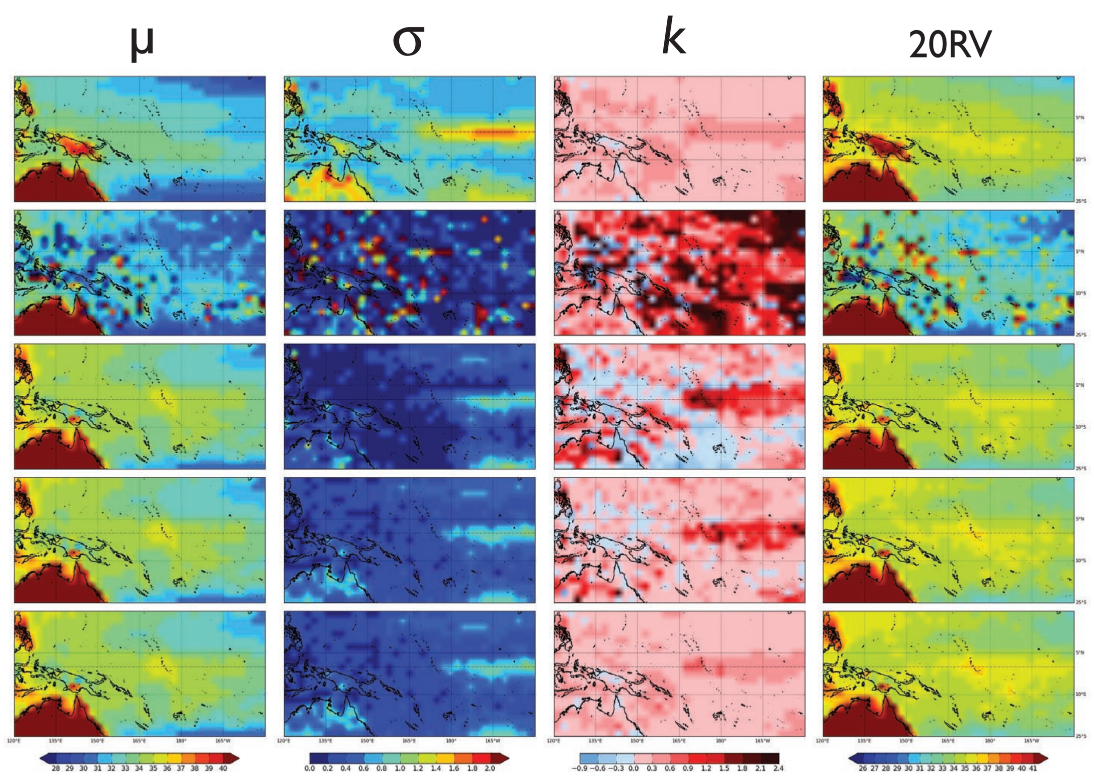
Results



> Figure 2: location, scale and shape parameters, and 20yr return values of Pr estimated for the original sample and each of the corrected samples for the A2 scenario, 2081-2100. All units (except *K*) are in mm day^{-1}.

Pr (Figure 2):

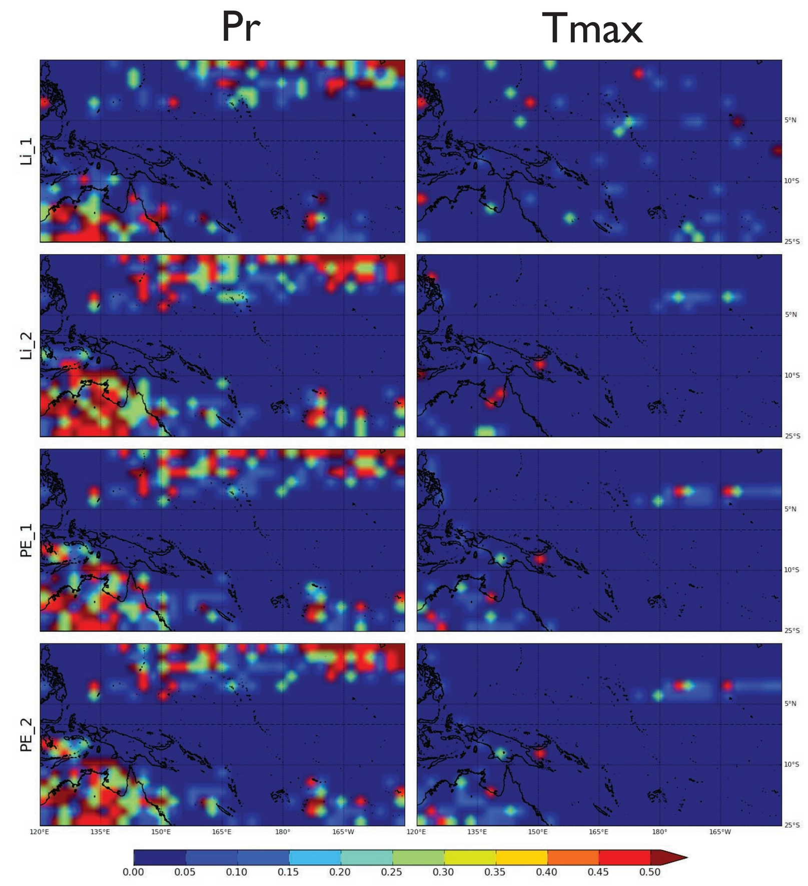
- μ in transformed samples show expected spatial characteristics (ITCZ, SPCZ); better positioning in Li_2 and PE methods;
- σ has spurious values in Li_1, Li_2 has less variance over Equator than PE methods;
- Spurious *K* values in PE_1 – original model *K* changes substantially through time. PE_2 is not biased by this change;
- 20RV projections are more intense in each transform → known model errors diminish;
- Most 20RV change seen in equatorial regions;
- Scattered spurious projections seen in PE_1 sample, but not in PE_2.



> Figure 3: Same as Figure 1 but for Tmax, units (except for *K*) in °C.

Tmax (Figure 3):

- μ anomalous in Li_1, similar in Li_2 and PE methods;
- σ reduced over whole region in Li_2 and PE methods, especially in cold tongue. PE methods show more variance in west of region;
- *K* different in all samples – anomalous in Li_1, largely +ve over cold tongue in Li_2 and PE_1, +ve over all of PE_2;
- Li_1 results in cooler and sometimes anomalous projections over whole region;
- All other transformed samples have similar projections – warmer than original sample, except over Papua New Guinea.



> Figure 4: KS test p-values for Pr and Tmax, where each transformed GEV A2 sample was compared to the original GEV A2 sample, taken directly from model output. P<0.05 was used to reject H_0.

KS Test (Figure 4):

- All corrected Pr samples had p-values <0.05 in centre of region, thus rejecting H_0. P-values >0.05 scattered in northern and southern areas, and over Australia;
- H_0 rejected for most of Tmax. Some p-values >0.05 in all transformed samples, mostly in northeast and some grid boxes over Australia.

Conclusions

- Assuming the 20th century distribution applies in the 21st century (Li_1) infers some spurious return values, and overall projections are too cold/wet;
- Incorporating future CDF (Li_2) helps to adjust for changes in higher moments, though does not look at them directly; PE methods take direct higher moment biases into account;
- Using PE_1 shows how much model *K* can change through time (especially in Pr), thus affecting corrected return value projections (*K* defines extent of tail, how 'extreme' the extremes are);
- PE methods highlight the importance of capturing distributional change through time, and will be refined with further research.

Future work

- Use r-largest GEV samples (Coles 2001) to determine sensitivity of transforms to sample size;
- Incorporating change in parameters through time;
- Perform PE methods for other CMIP3 (CMIP5) models and use transfer functions as an evaluation tool that focus on extremes;
- Also use PE methods for RCM model output over the Pacific region;
- Form a similar parameter transformation for other distributions.

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