MOS correction of GCM- and RCM-simulated daily precipitation

PLEIADES

VolkswagenStiftung

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GEOMAR

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Challenge

Extreme precipitation events constitute **major natural hazards**. Projections of long-term changes in extremes are **limited** by the spatial resolution and systematic errors of General Circulation Models (GCMs).

The international project **PLEIADES** aims to develop a statistical correction method based on **model output statistics** (MOS) for precipitation simulated in Regional Climate Models (RCMs) and GCMs.

MOS: a downscaling solution

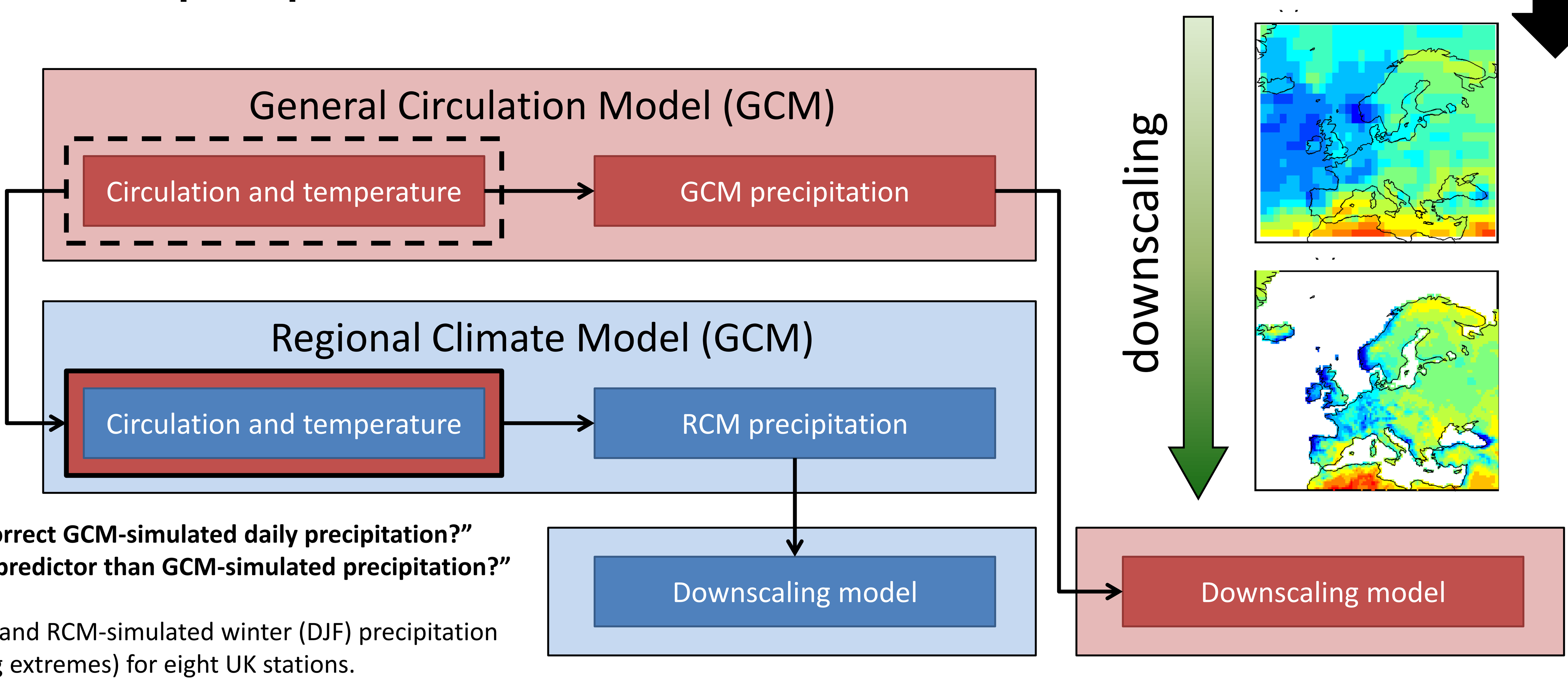
We propose a stochastic MOS correction method for simulated daily precipitation that also includes a downscaling step. GCM MOS models are fitted under simulations nudged to ERA-40 – this permits a comparison of simulated and observed sequences of precipitation events, an approach termed "event-wise" MOS.

Here, a 'mixture' model (Vrac and Naveau, 2007) is used to model the complete (extreme and non-extreme) precipitation distribution. This is combined with the vector generalised linear model (VGLM) developed by Maraun *et al*. (2010) and Maraun *et al*. (2011) in order to estimate precipitation based one or more 'predictors'.

MOS correction of GCM and RCM precipitation

RCMs are high-resolution dynamical models nested within a GCM (i.e. driven by the circulation and temperature fields) for a given area. RCM simulations are widely available in Europe and North America, but computational expense means a lack of coverage in regions such as Africa. Additionally, RCMs remain limited by systematic errors and biases.

Eden *et al*. (2012) (also Widmann *et al*., 2003) showed that a direct correction of monthly GCM precipitation is possible, with results favourable when compared to RCM output.



KEY QUESTIONS:

1. "to what extent can MOS be used to directly correct GCM-simulated daily precipitation?"

2. "is RCM-simulated precipitation a better MOS predictor than GCM-simulated precipitation?"

Here, we apply the VGLM mixture model to GCM- and RCM-simulated winter (DJF) precipitation in order to downscale daily precipitation (including extremes) for eight UK stations.

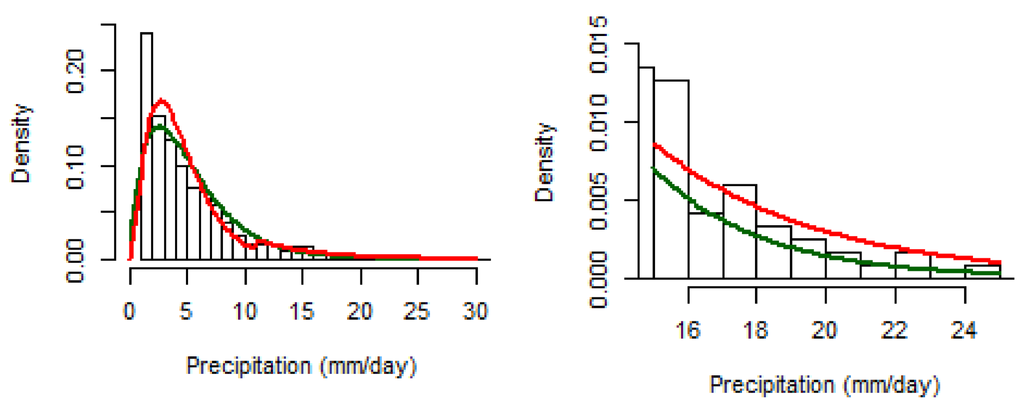
VGLM mixture model

The **mixture model** (Vrac and Naveau, 2007) combines **gamma** and **GPD** to provide a PDF for the whole distribution.

Mixture weights

$$G(r_i|\beta)=c_\beta\left[\left(1-w(r_i|m,\tau)\right)\Gamma(r_i|\gamma,\lambda)+w(r_i|m,\tau)\,GPD(r_i|\xi,\sigma,u=0)\right]$$

Gamma pdf　　GPD pdf



The VGLM allows each mixture model parameter to be modelled as a function of one or more predictors:

- Total precipitation (TP)
- Large-scale (frontal) precipitation (LP)
- Convective precipitation (CP)
- Non-local predictors (spatial mean and variance of the three precipitation variables).

GPD:

$$\sigma_i=\sigma_0+\beta_{11}x_{1i}+\ldots+\beta_{1n}x_{ni}$$
$$\xi_i=\xi_0$$

Gamma distribution:

$$\lambda_i=\lambda_0+\beta_{21}x_{1i}+\ldots+\beta_{2n}x_{ni}$$
$$\gamma_i=\gamma_0+\beta_{31}x_{1i}+\ldots+\beta_{3n}x_{ni}$$

Mixture weights:

$$m_i=m_0$$
$$\tau_i=\tau_0$$

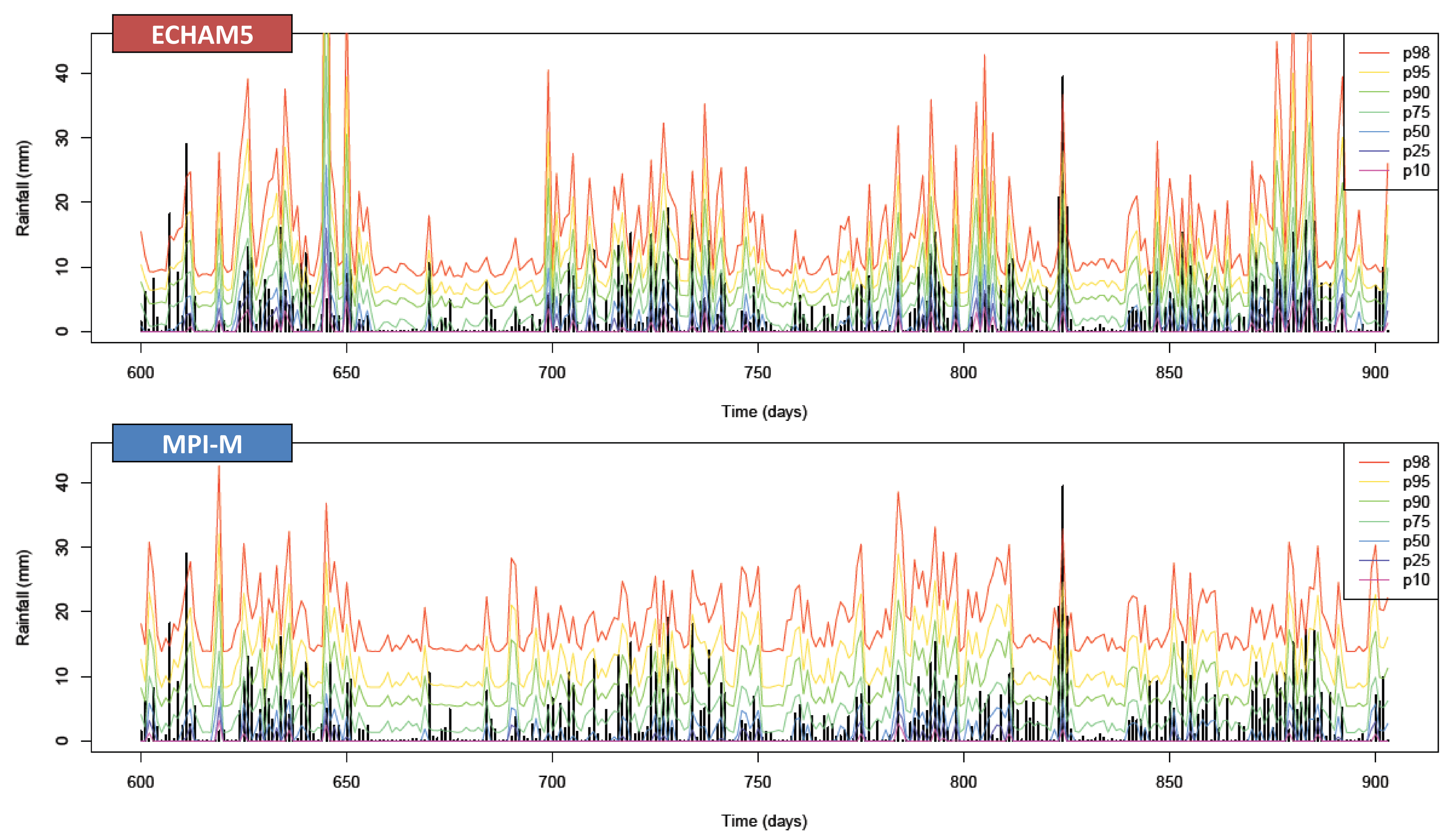
$\hat\sigma_0,\hat\xi_0,\hat\lambda_0,\hat\gamma_0,\hat m_0,\hat\tau_0,\hat\beta_{11},\ldots,\hat\beta_{3n}$ are estimated using maximum likelihood estimation (MLE).

Application to simulated precipitation

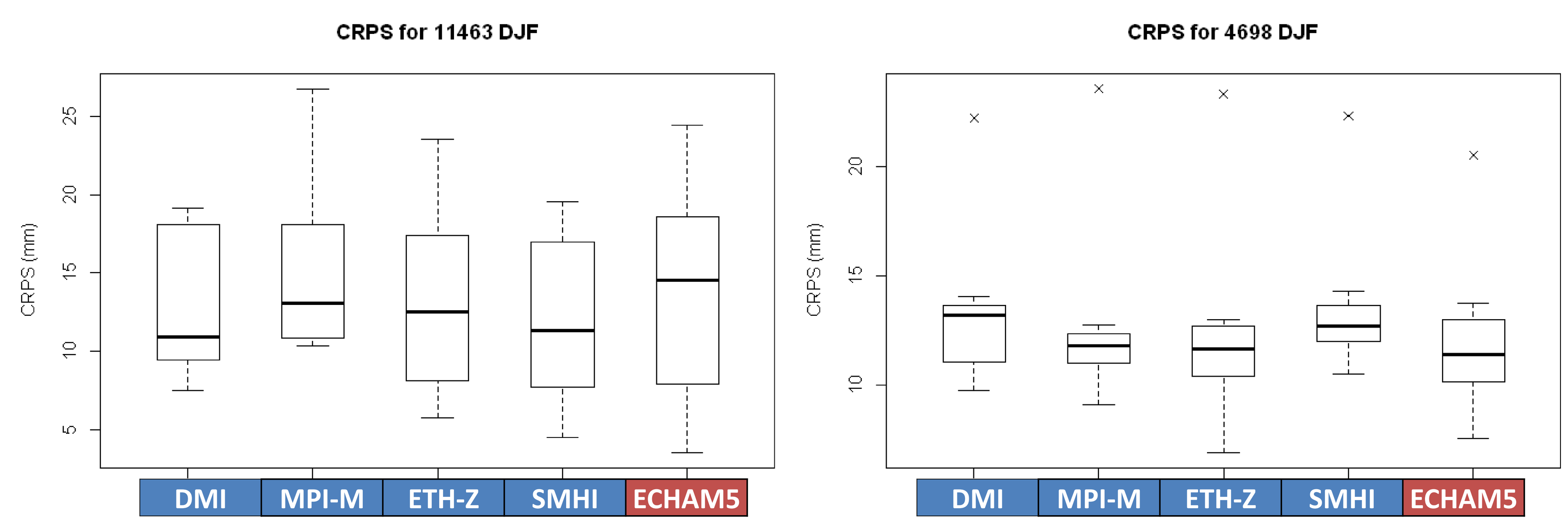
The VGLM mixture model was fitted to simulated winter (DJF) precipitation from several RCMs and one (ERA-40 nudged) GCM. The Akaike information criteria (AIC; shown below) are, in general, smaller for models fitted on GCM precipitation.

Station		RCM				GCM
		DMI	MPI-M	ETH-Z	SMHI	ECHAM5
Anglesey	11463	7008	7029	6998	6979	**6861**
Bude	1418	7041	6968	**6957**	7016	7016
Belfast	16374	6266	6265	6279	**6232**	6294
Blyth Bridge	274	6216	6243	6211	6226	**6187**
Sandringham House	4698	4958	4940	4937	4963	**4905**
Sheffield	525	**5865**	5896	5876	5886	6126
Oxford	606	4571	4575	4557	4576	**4533**
Dover	7031	5131	5124	5120	5124	**5092**

When applied to independent data for a validation period (1991-2000), an estimated pdf is produced for each daily simulated precipitation value. The VGLM mixture model is able to reproduce daily variability, although marked differences exist in the variance of the estimated quantiles (examples shown below).



To assess the performance of simulated precipitation as predictors for the extreme tail, the Continuous Rank Probability Score (CRPS), weighted for events above the 98[th] percentile, were calculated. In general, there is little difference shown in the performance of RCM and GCM precipitation across the set of stations used (examples shown below). CRPS calculated for the whole distribution is a necessary next step.



Summary and next steps

- Initial analysis suggests that GCM-simulated precipitation offers excellent potential as a predictor for local-scale daily precipitation as part of an event-wise MOS downscaling approach.
- The inclusion of the RCM step in downscaling process does not produce more informative output, particularly for extreme events.
- Considering the large-scale (frontal) and convective components of simulated precipitation as separate predictors may be a promising approach to extracting the maximum predictive information.

Selected references

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