MOS downscaling of extreme European precipitation

*Jonathan M. Eden[1], Martin Widmann[1], Geraldine Wong[2], Thomas Kent[1], Douglas Maraun[2] and Mathieu Vrac[3]

(1) School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, UK (j.m.eden@bham.ac.uk).
(2) Helmholtz Centre for Ocean Research Kiel (GEOMAR), Kiel, Germany.
(3) Laboratoire des Sciences du Climat et de l'Environnement, Gif-sur-Yvette, France

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 RCMs and GCMs.

MOS: a downscaling solution

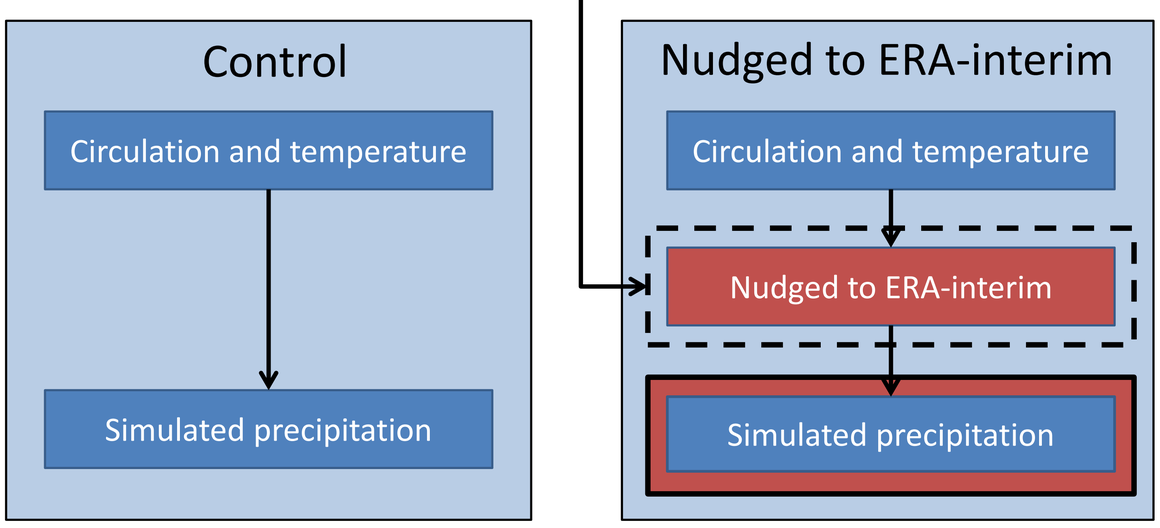
We propose a MOS correction method for GCM-simulated daily precipitation that also includes a downscaling step. MOS models are fitted under GCM simulations nudged to ERA-interim – this permits a comparison of simulated and observed sequences of precipitation events, an approach termed "event-wise" MOS.

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'.

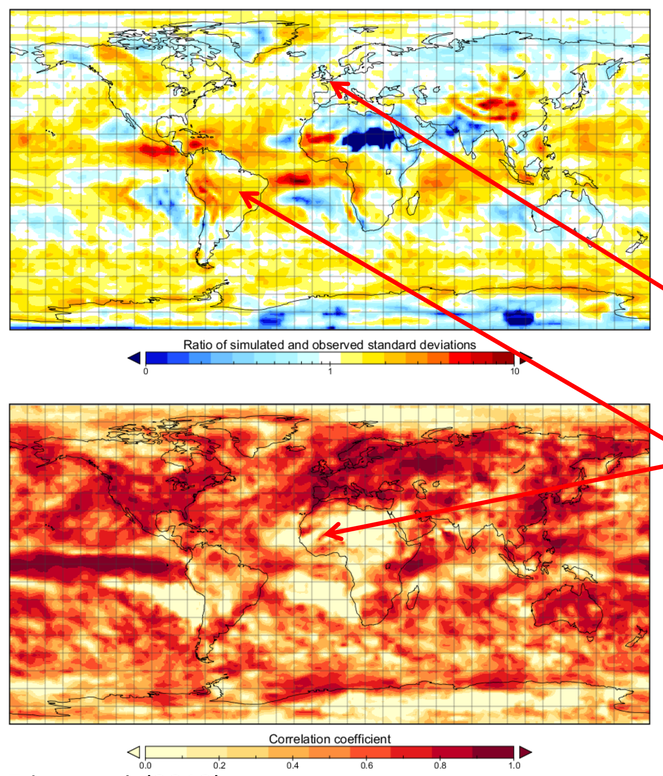
"Event-wise" MOS and nudged GCM simulation

KEY QUESTION: "how well does GCM-simulated precipitation perform given a realistic large-scale climatic state?"

Two simulations were conducted using ECHAM5: a free-running (control) simulation and a simulation in which circulation and temperature fields are **nudged** (forced) toward ERA-interim.



ECHAM5 (nudged) precipitation vs GPCC observations (DJF 1979-2010)



Eden *et al*. (2012)

The nudged simulation is forced into temporal phase with the observed record. Thus, it is possible to make an event-wise comparison of simulated and observed precipitation.

Main findings:

1. ECHAM5 performs well across much of the extra-tropics, particularly over Europe and North America.
2. Performance is poorer where rainfall is dominated by convective processes.
3. In regions where skill is high, GCM precipitation may offer potential as a predictor in an event-wise MOS downscaling approach (also Widmann *et al*., 2003).

Stationary mixture model

KEY QUESTION: "is the stationary mixture model a better fit for UK daily precipitation than a model based on a gamma distribution?"

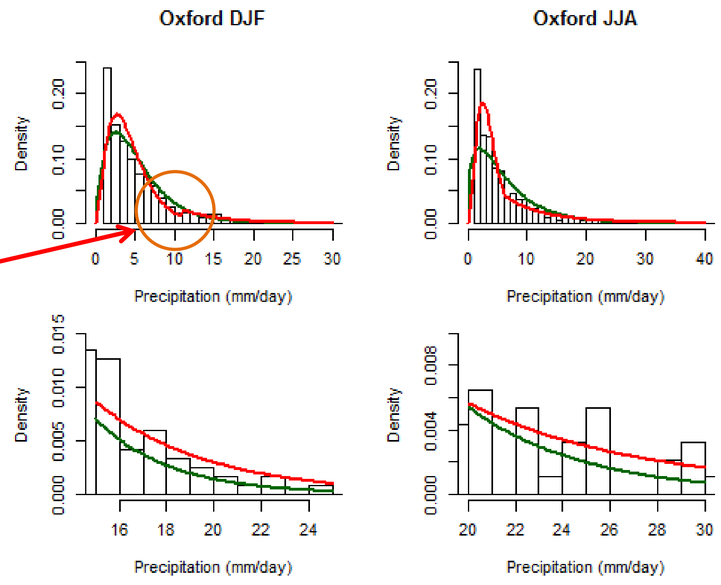
The **mixture model** Vrac and Naveau, 2007) combines **gamma** and **GPD** to provide a PDF for the whole distribution.

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

Mixture weights; Gamma pdf; GPD pdf

Main findings:

1. The **mixture model** is a better fit for observed precipitation at four UK stations (including Oxford; left), particularly across the extreme tail.
2. The 'kink' at the transition between gamma and GPD means some uncertainty remains about whether the weight parameters (*m* and *τ*) should be fixed or included in the estimation procedure.



Development of a VGLM downscaling model

KEY QUESTION: "how does GCM precipitation perform as a predictor for local-scale daily precipitation as part of a VGLM downscaling model?"

$$\sigma_i = \sigma_0 + \beta_{11}x_{1i} + \mathrm{L} + \beta_{1n}x_{ni}$$
$$\xi_i = \xi_0 \quad \text{(GPD)}$$
$$\lambda_i = \lambda_0 + \beta_{21}x_{1i} + \mathrm{L} + \beta_{2n}x_{ni}$$
$$\gamma_i = \gamma_0 + \beta_{31}x_{1i} + \mathrm{L} + \beta_{3n}x_{ni} \quad \text{(Gamma distribution)}$$
$$m_i = m_0 + \beta_{41}x_{1i} + \mathrm{L} + \beta_{4n}x_{ni}$$
$$\tau_i = \tau_0 + \beta_{51}x_{1i} + \mathrm{L} + \beta_{5n}x_{ni} \quad \text{(Mixture weights)}$$

$\hat{\sigma}_0, \hat{\xi}_0, \hat{\lambda}_0, \hat{\gamma}_0, \hat{m}_0, \hat{\tau}_0, \hat{\beta}_{11}, \mathrm{K}, \hat{\beta}_{5n}$ are estimated using maximum likelihood estimation (MLE).

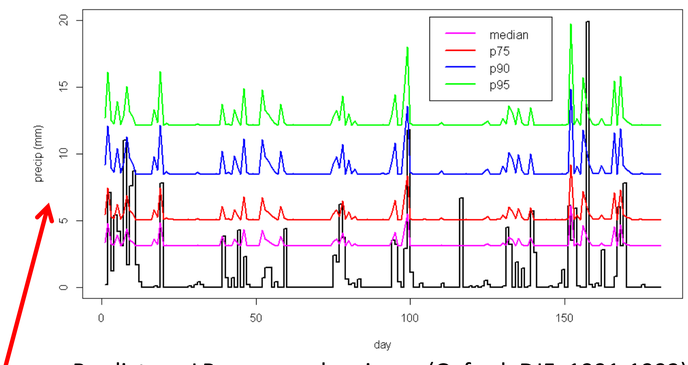
The VGLM allows each mixture model parameter to be modelled as a function of one or more predictors:

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

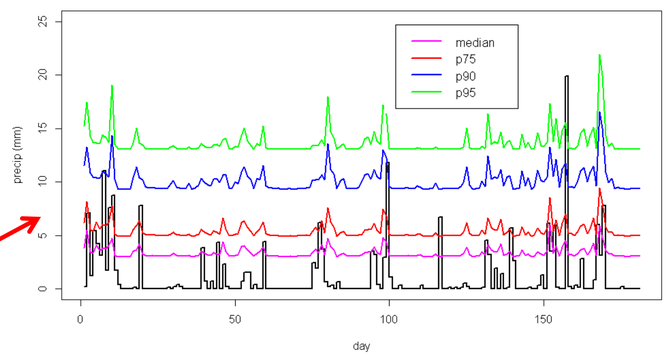
Main findings:

1. Cross-validation used to assess VGLM performance in reproducing local precipitation quantiles.
2. LP outperforms TP when used as sole predictor for winter precipitation.
3. Taking spatial means and variances as predictors offers potential to correct location biases.

Predictor: LP (Oxford; DJF; 1991-1992)



Predictors: LP mean and variance (Oxford; DJF; 1991-1992)



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.
- A mixture model VGLM, calibrated on simultaneous sequences of simulated and observed events, is able to reproduce realistic daily precipitation quantiles.
- Considering the large-scale (frontal) and convective components of GCM-simulated precipitation as separate predictors appears to be promising approach to extracting the maximum predictive information.

Next steps…

- A thorough comparison of will be made between mixture model VGLMs calibrated on GCM precipitation and those calibrated on output from numerous RCM products.
- Further work will involve VGLM application to a larger number of stations throughout the UK and other parts of Europe.

Selected references

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