Variability of extreme daily precipitation in the United Kingdom. Observed and simulated relationships with the synoptic scale atmospheric circulation.

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Douglas Maraun[1,2], Tim J. Osborn[2] and Henning W. Rust[3]

1. Introduction

Extreme precipitation is a major natural hazard in the United Kingdom. To assess likely future impacts of extreme precipitation on local scales it is important to understand changes in the intensity of extreme precipitation on decadal and multidecadal time scales. Ultimately, this also requires to (1) understand the natural variability of local precipitation extremes and the relationship to its large scale driving processes, and (2) how regional climate models reproduce variability and relationships respectively.
First, we investigate the relationship between synoptic scale airflow and local extreme daily precipitation, based on a set of 689 rain gauges across the UK.The relationships show pronounced spatial patterns related to the interaction between airflow, orography and the surrounding seas.
Second, we evaluate the representation of precipitation extremes and its relationship with large scale atmospheric flow in a set of 18 25km-resolution regional climate models (RCMs) used in the ENSEMBLES project. Common metrics to evaluate RCM simulated precipitation such as mean precipitation or numbers of wet days do not assess the representation of physical mechanisms causing precipitation events, i.e. the representation of potential drivers and the relationships between these drivers and precipitation. Yet this shortcoming might be crucial when different mechanisms affect precipitation, and when these mechanisms respond differently to climate change. Here, we apply the inferred relationships as metrics to evaluate the representation of physical relationships by comparing the spatial patterns of the observed relationships with the spatial patterns of the simulated relationships.

2. Data and Statistical Model

Observational: 1. **UKMO:** 5km gridded daily data from *Perry et al., 2009*, 1958-2005; averaged to 25km.
2. **EOBS:** 25km gridded daily data from *Haylock et al., 2008*, used are 1961-2000.

RCM data: 14 RCMs from the ENSEMBLES project, 25 km resolution, driven with ERA40 reanalysis, 1961-2000; available from ensemblesrt3.dmi.dk

Airflow: daily strength s_i, direction d_i and vorticity v_i, calculated from sea level pressure in the area 45N-65N, 20W-10E

Generalised extreme value distribution
We model the **monthly maxima of daily precipitation *z*** at month *i*, occurring at day t_i using the GEV (e.g. *Coles, 2001*).

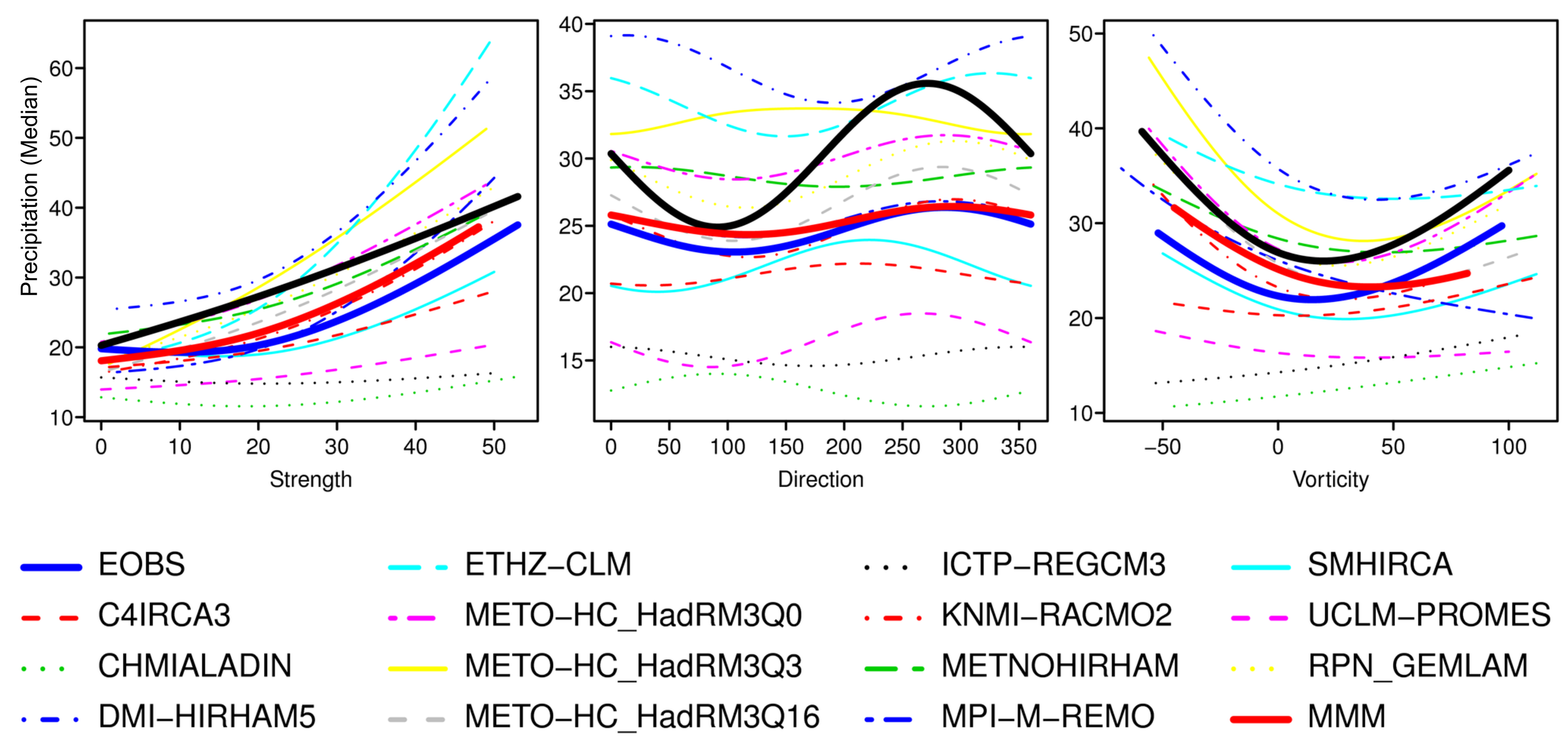
$$G(z;\mu,\sigma,\xi) = \exp\left\{-\left[1+\xi\left(\frac{z-\mu}{\sigma}\right)\right]^{-1/\xi}\right\}$$

μ location (position), σ scale (width), ξ shape (tail) parameter

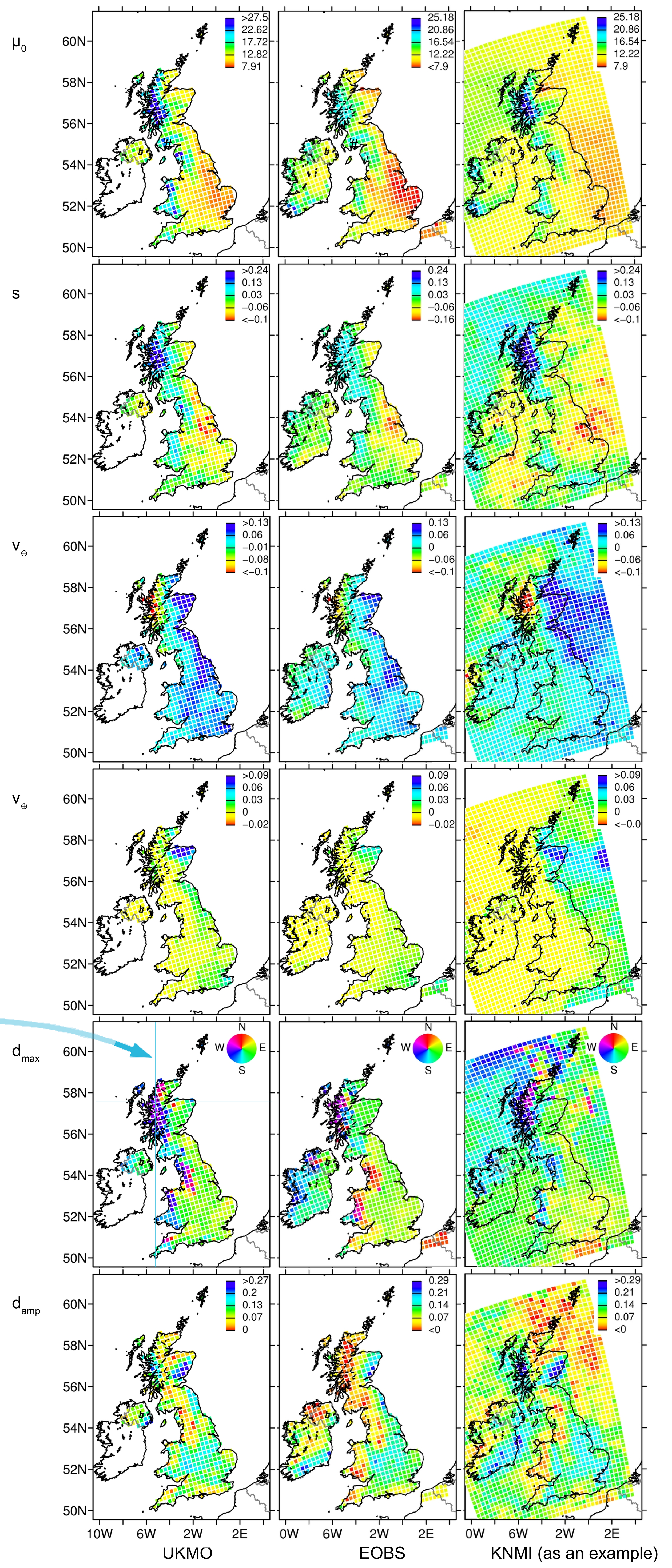
Vector generalised linear model (VGLM)
We model the influence of the airflow covariates on the GEV parameters using a VGLM (*Yee and Stephenson, 2007*).
The strength and vorticity influence ($f_s(s_i)$ and $f_v(v_i)$) is modelled as natural splines with 2 d.o.f., the influence of direction $f_d(d_i)$ as a phase shifted sine, as well as the annual cycle f_t.

$$\begin{aligned}\mu_i &= \mu_0 + f_{\mu,s}(s_i) + f_{\mu,v}(v_i) + f_{\mu,d}(d_i) + f_{\mu,t}(t_i)\\ \sigma_i &= \exp(\sigma_0 + f_{\sigma,s}(s_i) + f_{\sigma,v}(v_i) + f_{\sigma,d}(d_i) + f_{\sigma,t}(t_i))\\ \xi_i &= \xi_0\end{aligned}$$

3. Example Grid Box (West Scotland, 57°N, 5°W)

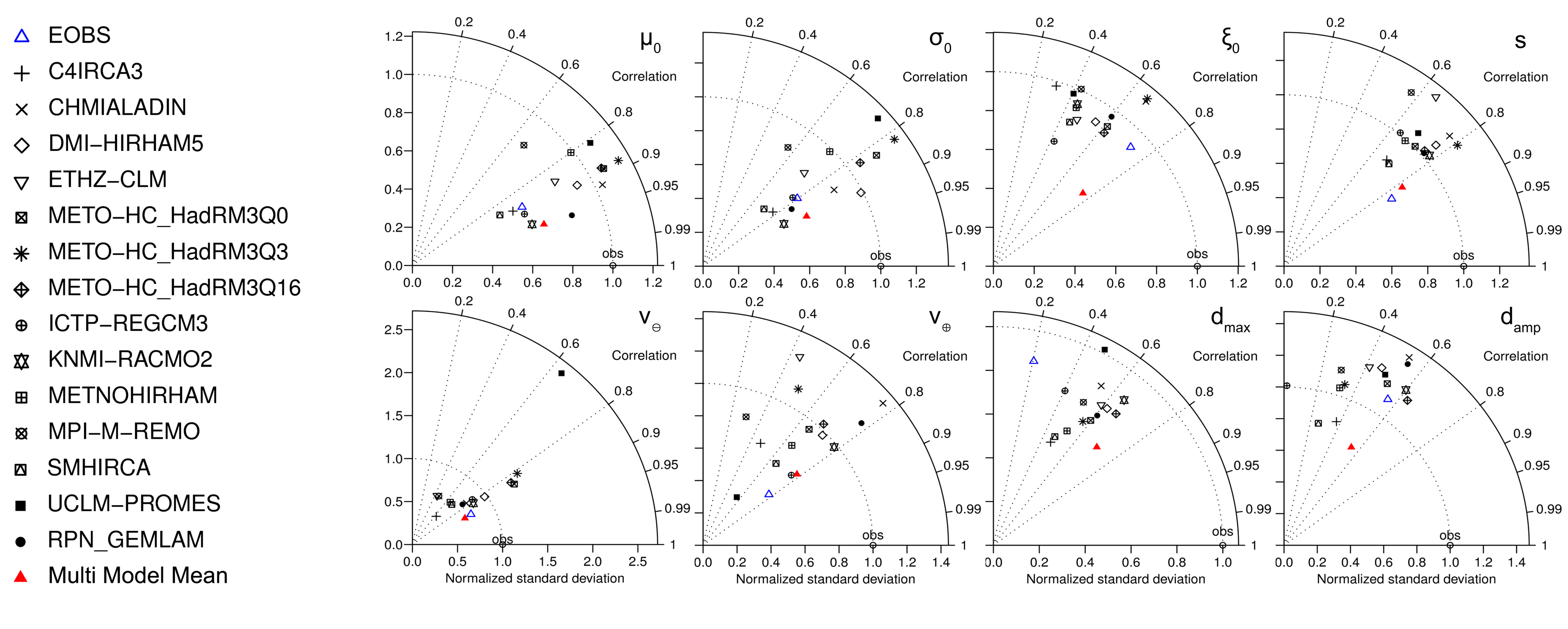


4. Spatial Relationships



μ_0: location; s: strength relationship; vorticity relationship $v_\ominus$: anticyclonic, $v_\oplus$: cyclonic; d_{max}: direction of maximum precipitation; d_{amp}: relative amplitude of direction dependence

5. Model Evaluation Relative to UKMO



6. Summary

1. Airflow exhibits a strong influence on UK daily precipitation extremes, with a spatial pattern related to the interplay between the prevailing westerlies, the surrounding seas and orography.
2. The selected ENSEMBLES 25 km resolution RCMs simulate the relationship between synoptic airflow and extreme precipitation reasonably well. However, the dependence on cyclonic vorticity and direction is considerably biased. These biases might affect regional projections of future precipitation extremes in the corresponding areas of the United Kingdom.

References:
S Coles. An Introduction to statistical modeling of extreme values. Springer, 2001
MR Haylock et al. A European daily high-resolution gridded data set of surface temperature and precipitation for 1950-2006. J. Geophys. Res., 113:20119, 2008
D Maraun, HW Rust and TJ Osborn. Synoptic airflow and UK daily precipitation extremes. Development and validation of a vector generalised model. Extremes, 13,133-153, 2010
D Maraun, TJ Osborn and HW Rust. The influence of synoptic airflow on UK daily precipitation extremes. Part I: observed spatio-temporal relationships. Clim. Dyn., 2010
M Perry, D Hollis and M Elms. THe Generation of Daily Gridded Datasets of Temperature and Rainfall for the UK. Climate Memorandum no 24, UK Met Office, 2009
TW Yee and AG Stephenson. Vector generalized linear and additive extreme value models. Extremes, 10:1-19, 2007

[1] Department of Geography, University of Giessen
Senckenbergstrasse 1, 35390 Giessen
douglas.maraun@geogr.uni-giessen.de

[2] Climatic Research Unit, School of Environmental Sciences
University of East Anglia, Norwich NR4 7TJ, United Kingdom
t.osborn@uea.ac.uk

[3] Laboratoire des Sciences du Climat et de l'Environnement
91191 Gif-sur-Yvette, France
henning.rust@lsce.ipsl.fr