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Use of very high resolution climate model data for hydrological modelling in southern Britain

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Introduction

Previous work driving hydrological models directly with data from regional climate models (RCMs) used data on an approximately 25x25km grid, which generally required some form of further downscaling before use by hydrological models. Recently, higher resolution data have become available from a NERC Changing Water Cycle project, CONVEX. As part of that project the Met Office Hadley Centre has run a very high resolution (1.5km) RCM, nested in a 12km RCM driven by ERA-Interim boundary conditions (1989-2008). They have also run baseline and future climate scenarios, nesting the RCMs in a global climate model. The 12km RCM runs cover Europe, while the 1.5km RCM runs only cover southern Britain.

Using these data, we aim to test the added-value of very high resolution climate model data for hydrological modelling of floods, and investigate the effect of climate model resolution on projections of changes in peak river flow under climate change. Here, we first discuss the calculation of potential evaporation (PE), which is a main input for our hydrological model alongside precipitation. We then show some initial flow results, comparing performance using the ERA driven RCM runs to that using observed inputs, and looking at differences in high flows simulated using the Baseline and Future RCM runs.

Method

Hydrological model

CLASSIC-GB - national gridded version of CLASSIC (Climate and LAnd-use Scenario Simulation In Catchments; Crooks and Naden 2007), which is a semi-distributed catchment-based model used extensively for modelling the potential impacts of climate change on river flows and flooding in relatively large catchments across Great Britain. Here, CLASSIC-GB is run with a 1km spatial resolution (aligned with the GB National Grid) and a 1-hour time-step.

Hydrological model inputs

The hydrological model needs inputs of precipitation and PE. Hourly total precipitation from the 12km RCM is downscaled to the required 1km spatial resolution using area-weighting and standard average annual rainfall patterns (Bell et al. 2007), while that from the 1.5km RCM is downscaled using area-weighting. PE is not available directly from the RCMs (see below). We also run the model with observed inputs, for comparison; daily 1km precipitation from CEH, and monthly 40km PE for short grass from the Met Office Rainfall and Evaporation Calculation System (MORECS, Hough et al. 1996). Each is equally divided according to the model time-step.

ERA-Interim driven RCM runs

PE estimation

PE for short grass is not available directly from the RCMs, so has been estimated from other meteorological variables using the commonly-applied Penman-Monteith formula (Monteith 1965). To estimate monthly PE, two different averaging methods were compared: a) Calculating daily PE from daily meteorological variables and then averaging and b) Calculating a monthly average of the meteorological variables and then calculating monthly PE. The two methods yield almost identical results so we chose to make daily PE and then the monthly average. Figure 1 shows a comparison of seasonal mean PE from the ERA-driven RCMs against observation-based PE (MORECS). We also compared two different formulations for calculating vapour pressure (used to estimate PE); one uses mean temperature (pe1) and the other uses max and min (pe2). Using 1990 as a test dataset, we compared pe1 and pe2 for three MORECS sites.

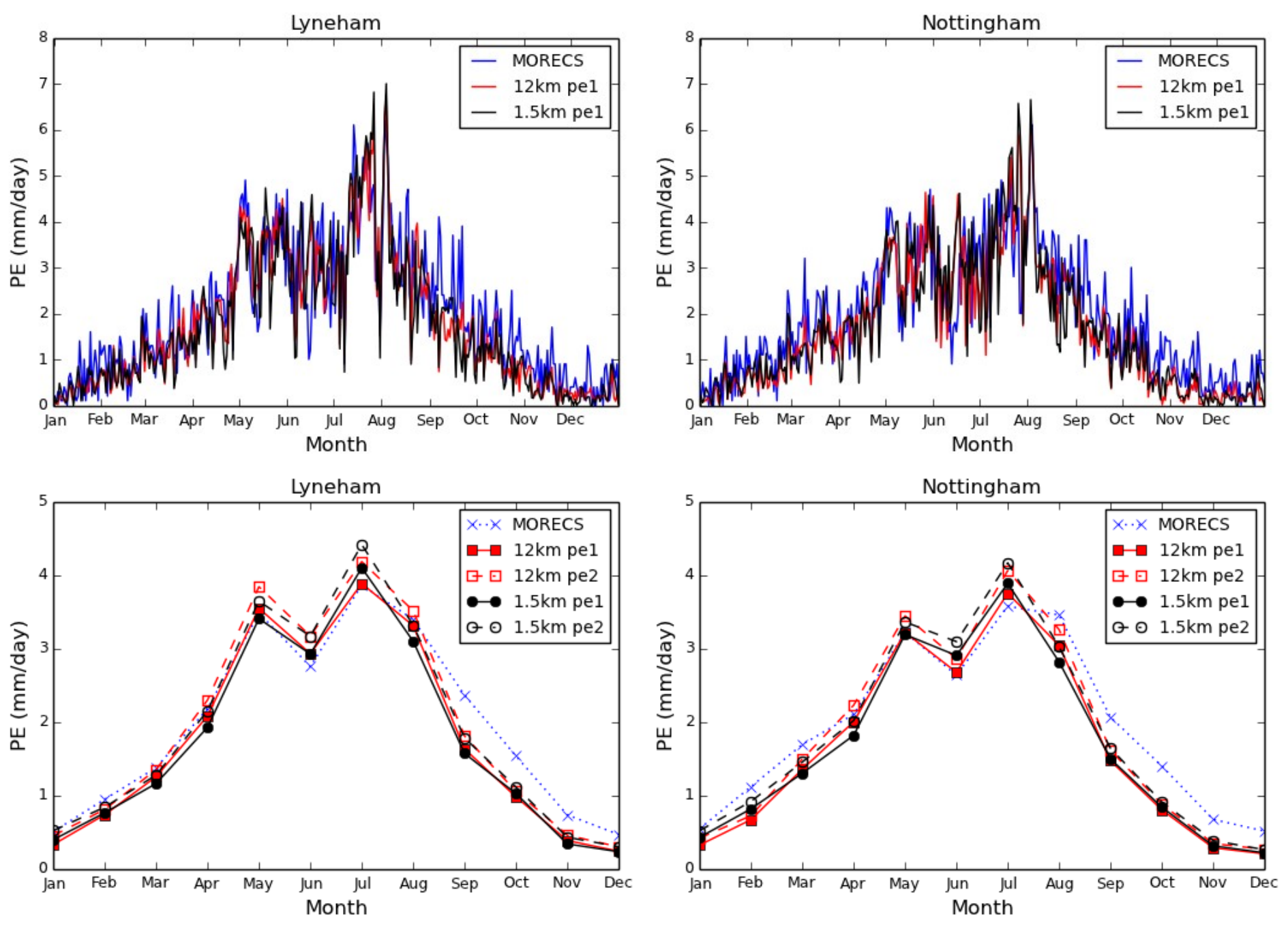

Figure 2: ***Comparison of daily and monthly MORECS PE and ERA driven RCM PE for 1990, for two MORECS sites.***

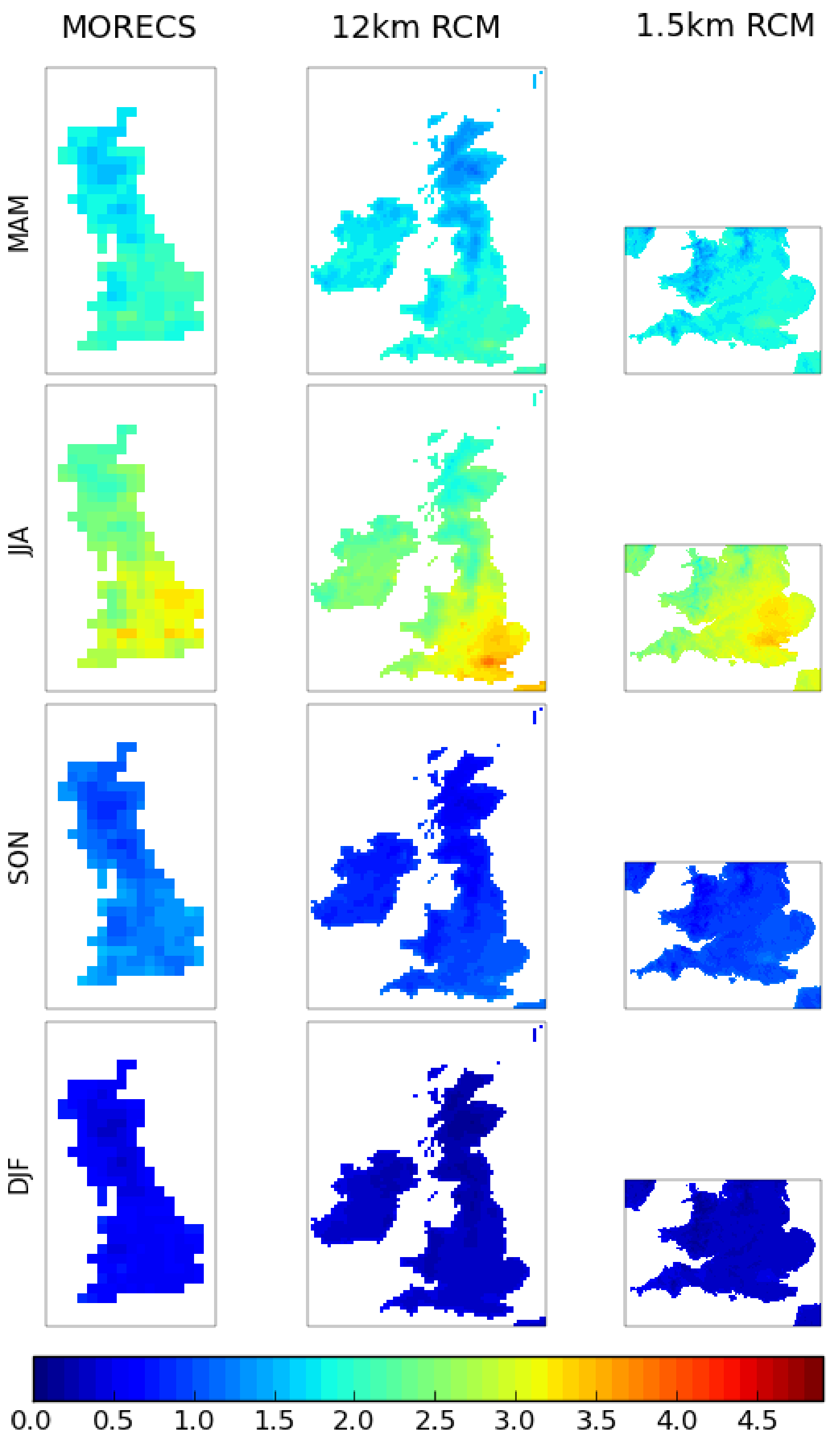

Figure 1: ***Comparison of seasonal average PE (mm/day) from MORECS and the 12km and 1.5km ERA driven RCMs, for 1990-2007.***

Figure 2 shows the comparison for Nottingham (Midlands) and Lyneham (Southern). We chose pe1 as it compares slightly better to MORECS PE. Figures 1 and 2 show that the 12km and 1.5km RCM PE values are very similar to each other and comparable to MORECS PE. Due to this similarity we have chosen to use the 12km PE as input to our hydrological model, so the only difference in results using the 12km and 1.5km RCM runs comes from the rainfall data.

Modelling results

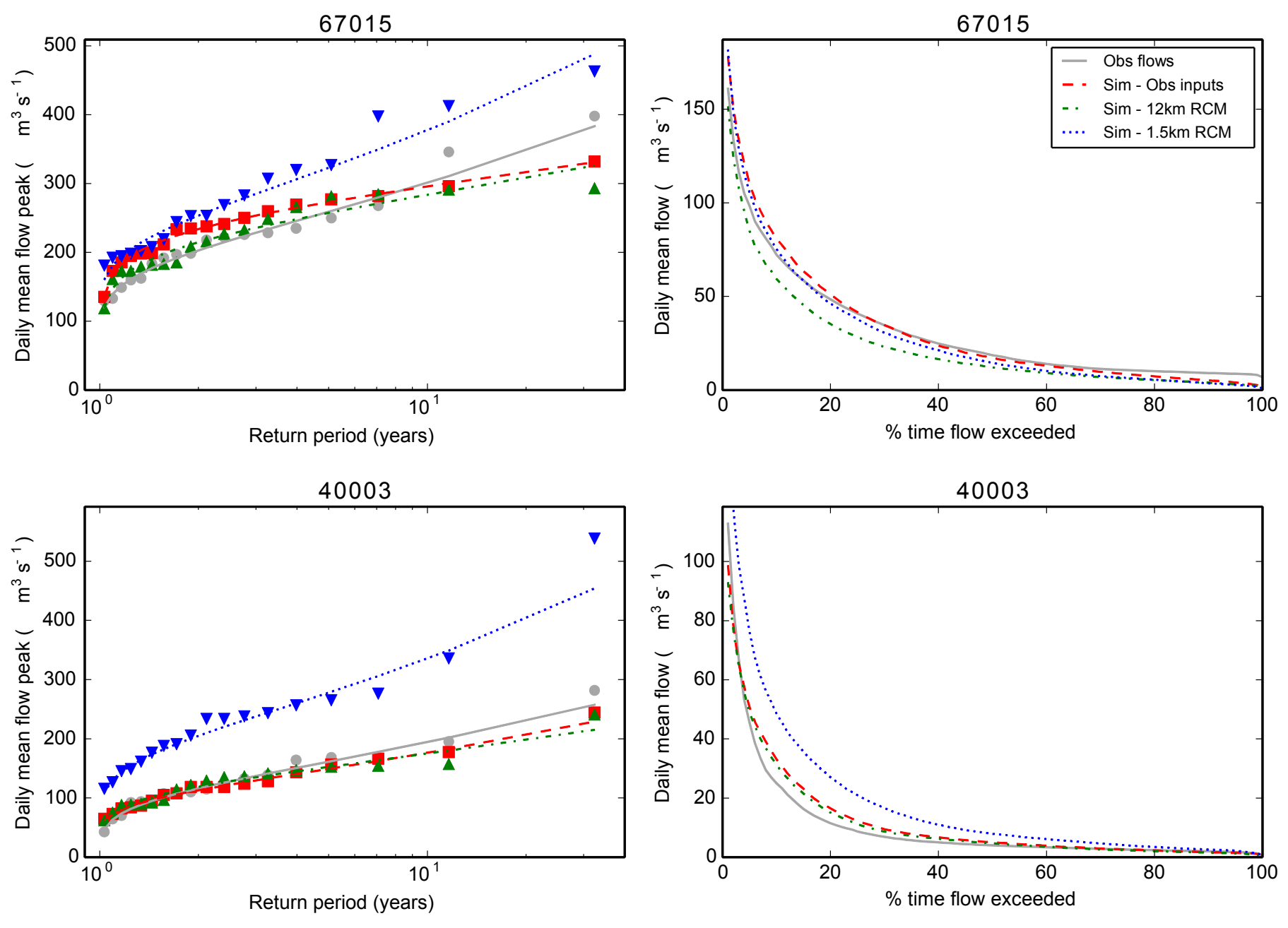

Figure 3: ***Flood frequency curves (left) and flow duration curves (right) for catchments 67015 (north Wales) and 40003 (south-east England).***

Initial results looking at simulation of daily mean river flows and flood peaks in 31 catchments using the ERA-driven RCM data show that performance for the 12km and 1.5km RCMs varies by catchment (Figures 3 and 4). For example, for 67015 the flow duration curve from the 1.5km RCM is better than from the 12km RCM, but the opposite is true for 40003.

Biases using the RCM inputs seem to be positive in eastern catchments and negative in western ones; a pattern not shown when using observed inputs. Also, biases using the 1.5km RCM are often greater than for the 12km RCM (Figure 4).

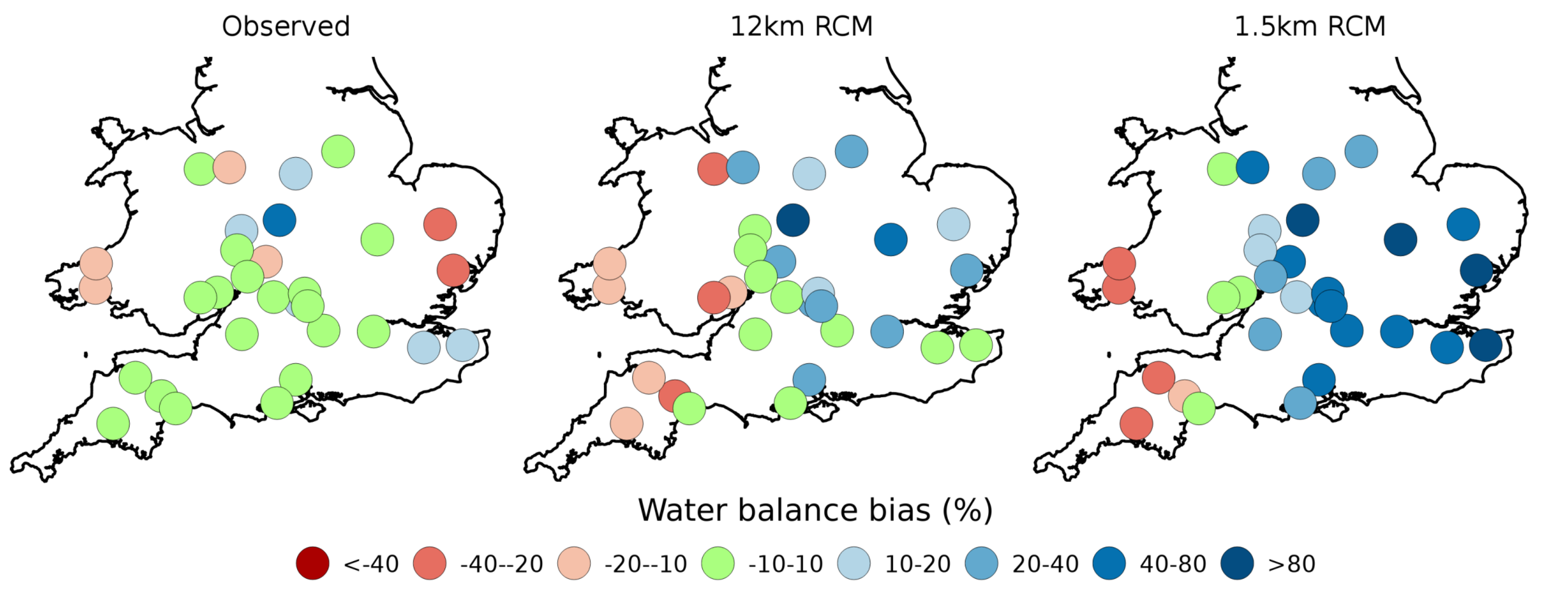

Figure 4: ***Bias in the modelled water balance using observed inputs and ERA driven RCM inputs.***

Baseline and Future RCM runs

PE estimation

PE can be affected not just by changes in meteorological inputs, but also by changes in the behaviour of vegetation. In particular, higher CO$_2$ concentrations lead to stomatal closure, and Bell et al.(2011) show that it is important to include the influence of changes in stomatal resistance, r$_c$, for projections of future PE. We therefore use data from the UKCP09 RCM ensemble to estimate monthly percentage changes in r$_c$ (valid for A1B emissions), and use pattern scaling (Mitchell, 2003) to transform these to changes valid for the RCP8.5 emissions used by the CONVEX runs. We then apply these r$_c$ changes to the MORECS r$_c$ values when estimating PE for the Future RCM runs. Figure 5 shows seasonal mean PE from the Baseline and Future RCM runs, and percentage changes between them. PE changes are lower than they would be had we not included changes in r$_c$, but very similar for the 12km and 1.5km RCMs.

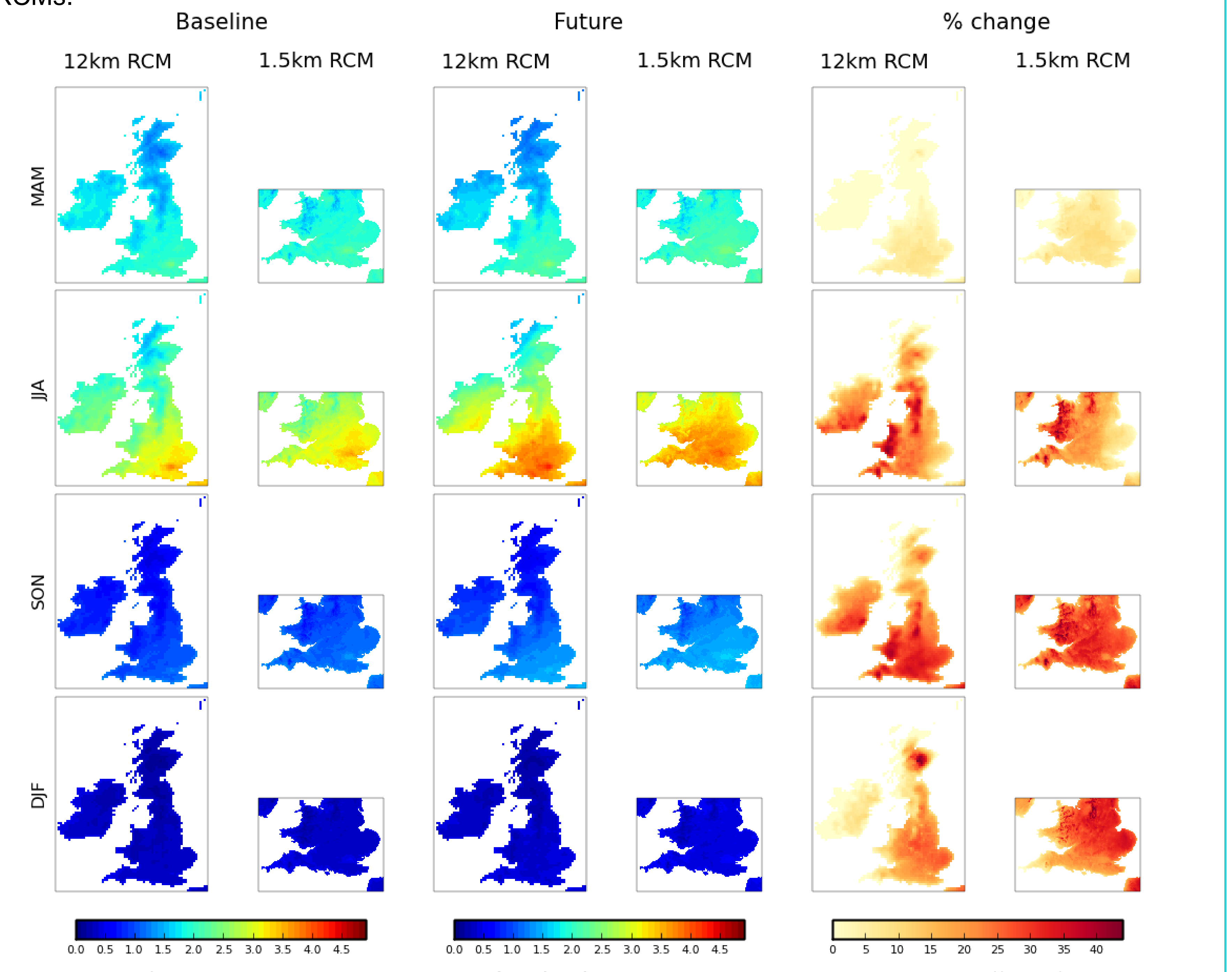

Figure 5: ***Changes in seasonal average PE (mm/day) under climate change, including the effect of changes in stomatal resistance. The averages are for 1997-2008 for the baseline RCM run and for 12 yrs in the 2100s for the Future RCM run.***

Modelling results

Initial results looking at simulated changes in flood peaks, using the 12km and 1.5km Baseline and Future RCM runs, show differences between projections at the two resolutions.

Figure 6 shows the projected percentage changes in10-year return period flood peaks. The 1.5km RCM shows larger increases in parts of Wales and north-west England than the 12km RCM, while the 12km RCM shows larger increases in parts of south-east England than the 1.5km RCM.

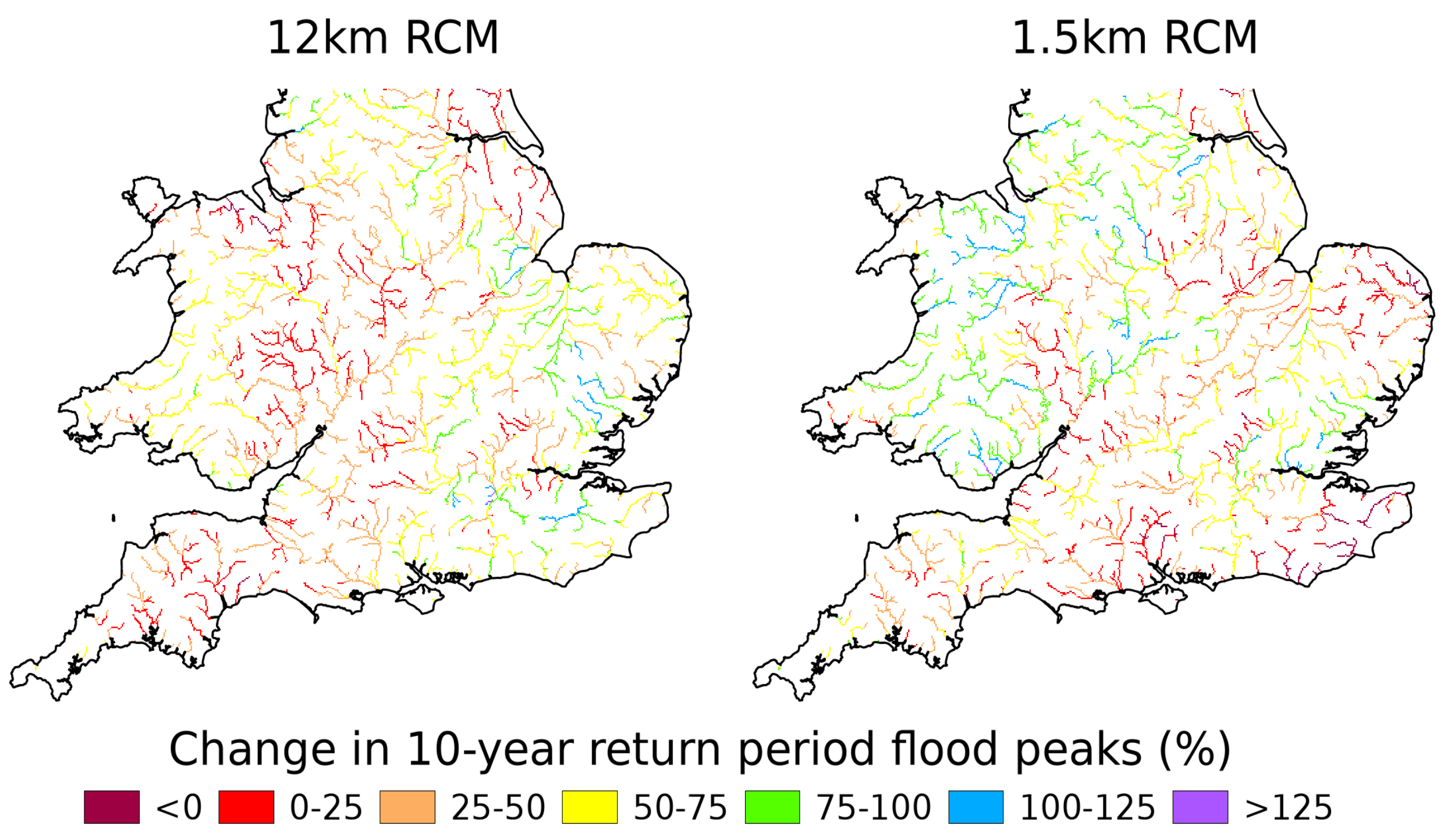

Figure 6: ***Percentage changes in 10-year return period flood peaks under climate change.***

Conclusions and further work

Initial model results illustrate:

* There are often larger biases in simulated flows using data from the 1.5km ERA driven RCM than from the 12km ERA driven RCM. Although hourly rainfall biases are lower in the 1.5km RCM (Kendon et al. 2012), daily rainfall biases are larger (Chan et al. 2013); this probably explains the problems when simulating flows in relatively large catchments with the 1.5km RCM data.

* Different projections of change in flood peaks are simulated by the 12km and 1.5km RCMs, for year 2100 under RCP8.5 emissions. This may be expected, as Kendon et al (2014) showed some differences in projections of rainfall changes between the 12km and 1.5km RCMs.

Further work will include:

* Simulation of river flows in smaller catchments, and simulation of pluvial flooding, which are both more likely to benefit from improvements in the representation of heavy rainfall events in the 1.5km RCM compared to the 12km RCM.

* Comparison of patterns of flood changes and rainfall changes, and seasonal analyses.

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