Improved representation of European precipitation in a 25-km atmospheric global circulation model

Reinhard Schiemann[1], Alexander J. Baker[1], Marie-Estelle Demory[1], Kevin Hodges[1], Stephanie J. Johnson[1,3], Matthew S. Mizielinski[2], Malcolm J. Roberts[2], Jane Strachan[1,2], Pier Luigi Vidale[1]

[1]National Centre for Atmospheric Science, University of Reading, UK. [2]Met Office Hadley Centre, UK. (3) ECMWF, Reading, UK.

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

NATURAL ENVIRONMENT RESEARCH COUNCIL

Joint Weather & Climate Research Programme

1. Introduction

It is important to assess how well global circulation models (GCMs) capture the probability distribution, and in particular extremes, of climate variables to determine, for example, how suitable they are for event attribution studies. Here, we

- assess the role of horizontal resolution in an atmospheric GCM (AGCM), whose resolution is increased from ~135 to ~25km, for the representation of European mean, and extreme 1-day precipitation over large European river basins.
- examine the reasons for the sensitivity of the simulated precipitation to model resolution.

2. Extreme value analysis

- Apply the Block Maxima method. Here, a block is comprised of 1-day precipitation values in a river basin throughout a season in one year.
- Fit a Generalised Extreme Value (GEV) distribution to the block maxima.
  - 3 parameters: location μ, scale σ and shape ξ
- Fig. 1 illustrates the effect of the location μ, scale σ and shape ξ parameters in a Gumbel diagram.

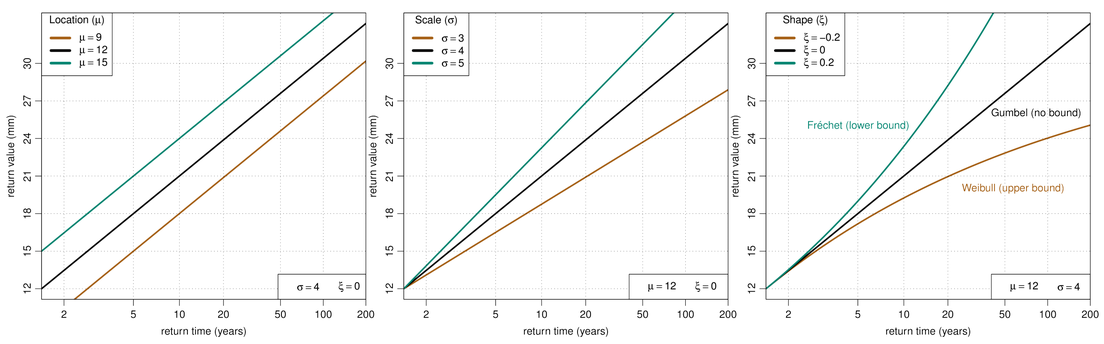
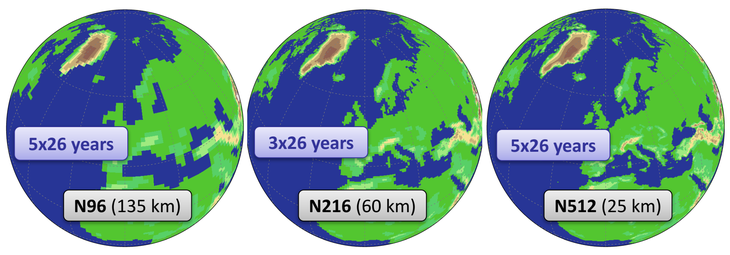


Fig. 1: Illustration of the GEV distribution in a Gumbel diagram. (a) Varying the location μ (μ = 9, 12, 15 mm) for constant scale σ and shape ξ, (b) varying the scale σ (σ = 3, 4, 5 mm) for constant location μ and shape ξ, (c) varying the shape ξ (ξ = -0.2, 0, 0.2) for constant location μ and scale σ.

3. AGCM and simulations, observations

HadGEM3-GA3

- Project UPSCALE (Mizielinski *et al*. 2014)
- 85 levels
- OSTIA SSTs
- Different resolutions, otherwise very similar



Observational reference: ENSEMBLES E-OBS daily gridded European precipitation (1950 – 2013).

4. Model evaluation: mean precipitation

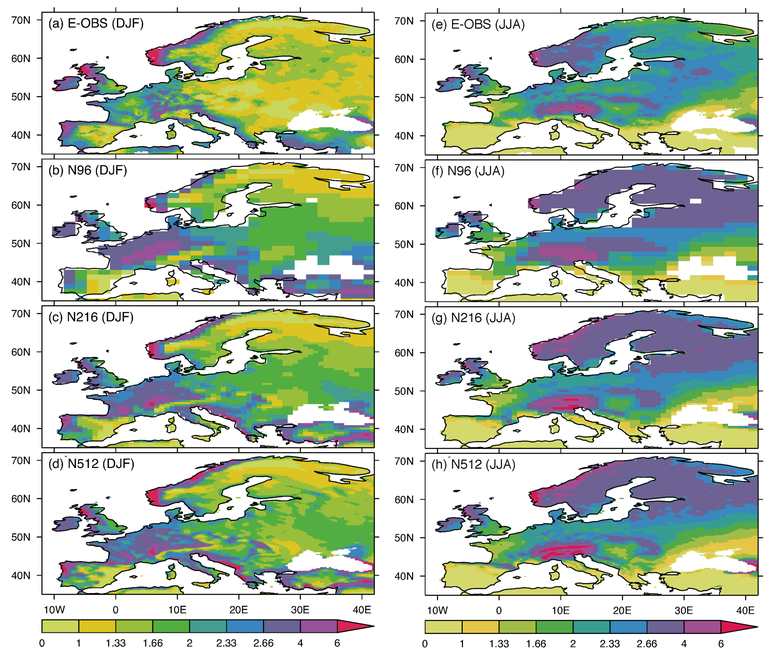


Fig. 2: Mean precipitation (mm day^{-1}) in E-OBS observations and in HadGEM3-GA3 at three different resolutions, for winter (left) and summer (right). The colour scale is nonlinear to capture mesoscale variations.

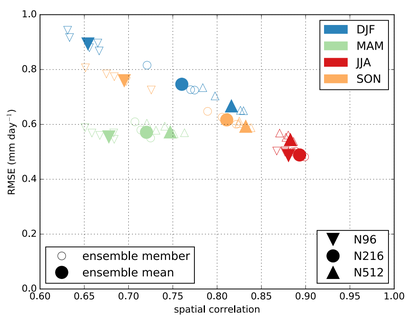


Fig. 3: Root mean square error and spatial correlation between HadGEM3-GA3 precipitation and E-OBS observations in Europe (-14-50E, 38-70N).

- overall wet bias in both DJF and JJA
- displaced response to the Alps at N96 in DJF
- very strong summer precipitation over the orography at N512 resolution
- significant improvement in representing mean precipitation, except during JJA (Fig. 3)

5. Model evaluation: extreme precipitation

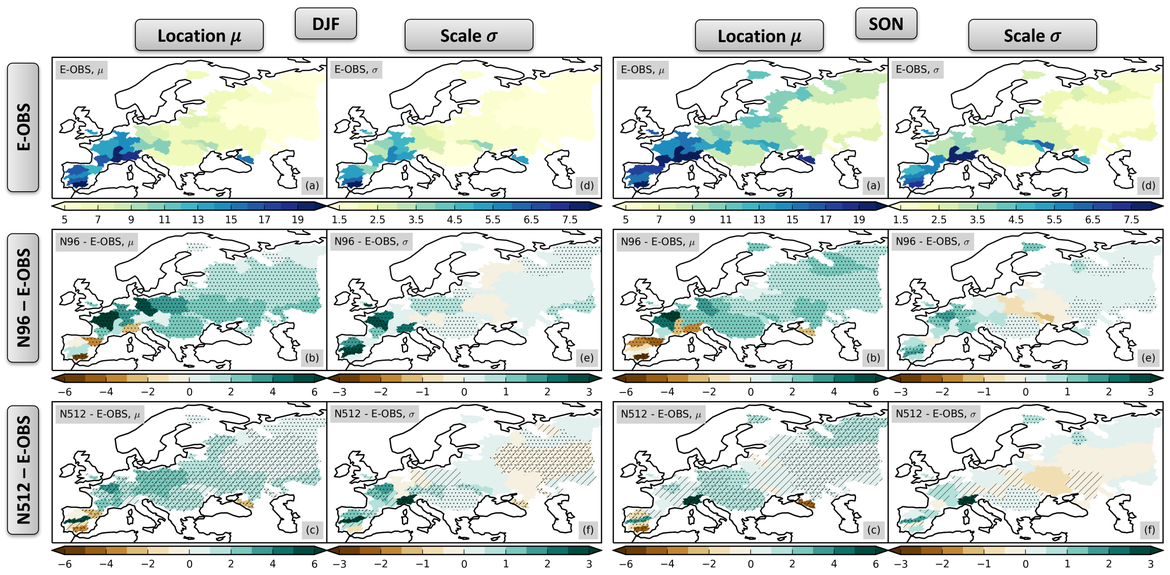


Fig. 4: Estimated GEV parameters for daily basin-average precipitation for DJF (left) and SON (right), (a-c) location parameter μ and (d-f) scale parameter σ, both in mm day^{-1}, and for (a,d) observations (E-OBS) and differences from E-OBS for (b,e) N96 and (c,f) N512 resolution. Stippling (hatching) shows statistically significant differences between the models and E-OBS (between N512 and N96).

Table 1:Numbers of basins with smallest bias in μ and σ. For example, the number 4 for μ in DJF at N96 resolution means that for 4 out of all 33 basins the bias in μ of the N96 model is smaller than that of the N216 and N512 models.

	μ			σ		
	N96	N216	N512	N96	N216	N512
DJF	4	**15**	14	11	8	**14**
MAM	12	6	**15**	**12**	11	10
JJA	**14**	10	9	**14**	10	9
SON	4	9	**20**	7	7	**19**
Σ	34	40	**58**	44	36	**52**

- clear improvement at higher resolution in simulating basin-mean extreme precipitation, in particular for basins in the North European Plains from the Loire in the west to the Vistula in the east, especially in SON, but also in DJF and MAM
- no improvement in JJA

6. Discussion of mechanisms

Is the North Atlantic stormtrack better represented at higher resolution, and does this cause the improved representation of European precipitation? This has been shown for a different model where resolution has been increased in a similar way (EC-EARTH version 2.3, van Haren et al. 2015, *J. Climate*).

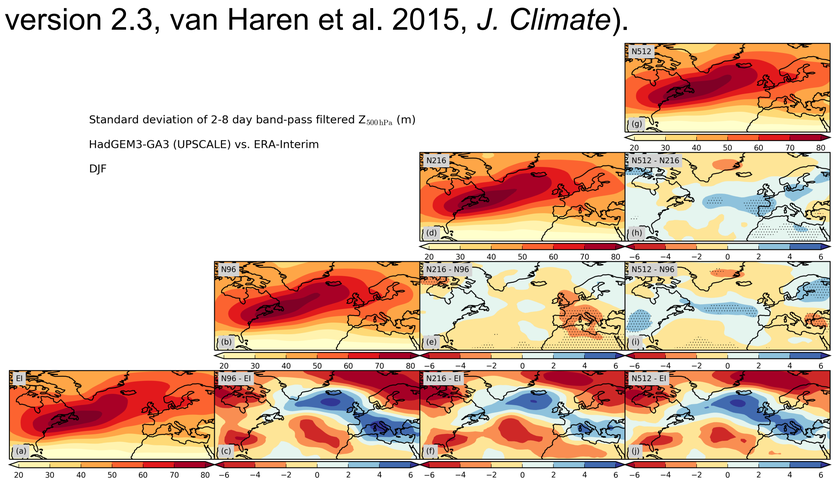


Fig. 5: Standard deviation of 2-8 day band-pass filtered geopotential height (m). (a) ERA-Interim reanalysis, (b,d,g) model at resolutions N96, N216, and N512, (c,f,j) model biases with respect to ERA-Interim, and (e,h,i) differences between model resolutions. Stippling shows statistically significant differences.

- different stormtrack response N96-N216 and N216-N512, whereas precipitation response is consistent with both resolution increases (Fig. 2)
- better representation of the stormtrack is not the (main) reason for improvement in simulated European precipitation

What about the orography?

- Much of the improvement seen in mean precipitation is due to the better representation of orography at the higher resolution as shown by a sensitivity experiment with a high-resolution atmosphere over coarsened orography (Fig. 6).
- This result extends to extreme precipitation in some areas, notably for the biases around the Alps at low (N96) resolution (not shown).

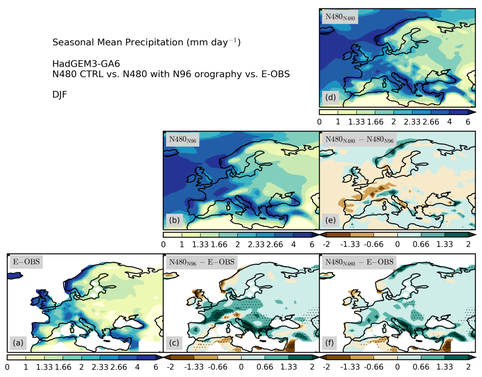


Fig. 6: DJF precipitation in mm day^{-1} in a control experiment at N480 resolution ($N480_{N480}$) and a sensitivity experiment with coarsened orography ($N480_{N96}$).

6. Conclusions and outlook

HadGEM3-GA3 simulates European mean, and daily extreme precipitation over large river basins more realistically as the resolution is increased from ~135 to ~25 km. In HadGEM3-GA3, this resolution sensitivity is more strongly associated with the better resolved orography in the higher-resolution model than has been shown in a previous study for a different model (EC-EARTH), for which resolution sensitivity in the North Atlantic stormtrack is more important. These results highlight the importance of multi-model studies into the role of resolution. Simulations currently carried out in CMIP6-HighResMIP, e.g. the PRIMAVERA project, will enable such multi-model studies.

hrcm.ceda.ac.uk

*contact: r.k.schiemann@reading.ac.uk