Mean and extreme precipitation over European river basins better simulated in a 25km AGCM

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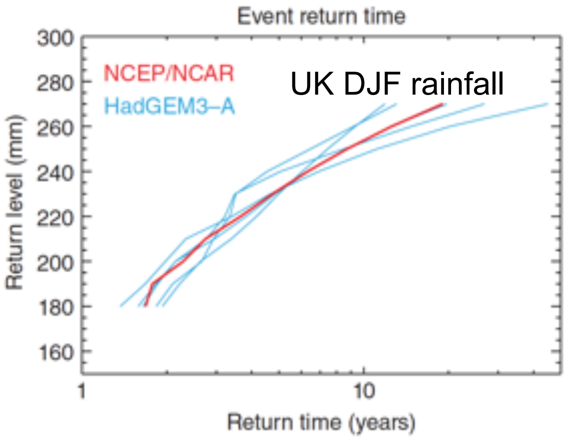
Introduction

- a few years back (IPCC AR3, Giorgi et al. 2001)
  - GCMs with several hundred kilometres grid spacing
  - RCMs for downscaling to *O*(50 km) over continents
- now
  - GCMs with 25 km grid spacing and smaller
  - downscaling to cloud-resolving scales *O*(1 km)
- continuous need for model evaluation
  - to assess if models are fit for purpose, e. g.,
    - for estimating climate risks
    - event attribution studies
  - for entire PDF of climate variables, and in particular extremes
  - ➢ extreme value analysis (parametric approach)
  - at relevant / reasonable scales
  - ➢ here: daily precipitation, European river basins > 50000 km^2
- reasons for resolution sensitivity in the model
  - ➢ North Atlantic storm track
  - ➢ orography



Stott et al. 2016

Model and simulations, observations

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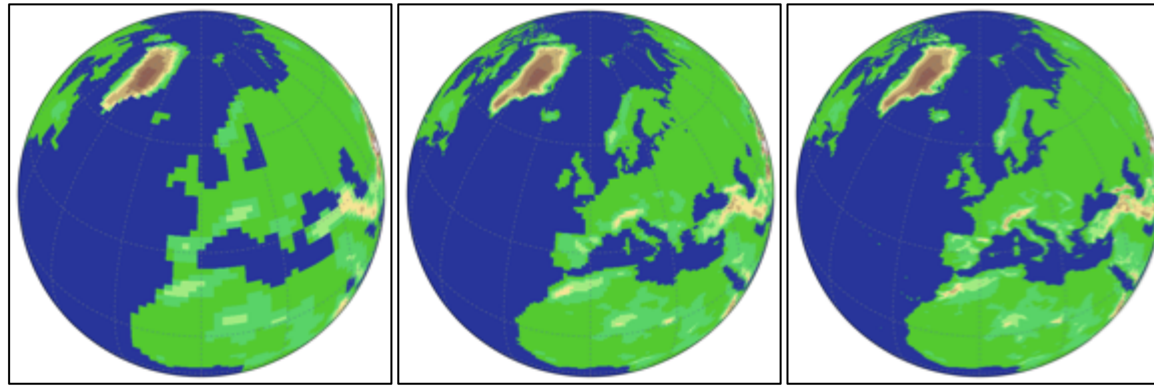
HadGEM3-GA3

- 85 levels
- top @ 85 km
- OSTIA SSTs (1985-2010)
- UPSCALE project (Mizielinski et al. 2014)

➢ UK High Resolution Global Climate Modelling Collaboration: hrcm.ceda.ac.uk



N96 (135 km)	**N216** (60 km)	**N512** (25 km)
low	medium	high resolution
5 x 26 years	**3** x 26 years	**5** x 26 years

E-OBS

- reference for model evaluation
- gridded daily gauge precipitation for Europe
- Haylock et al. 2008

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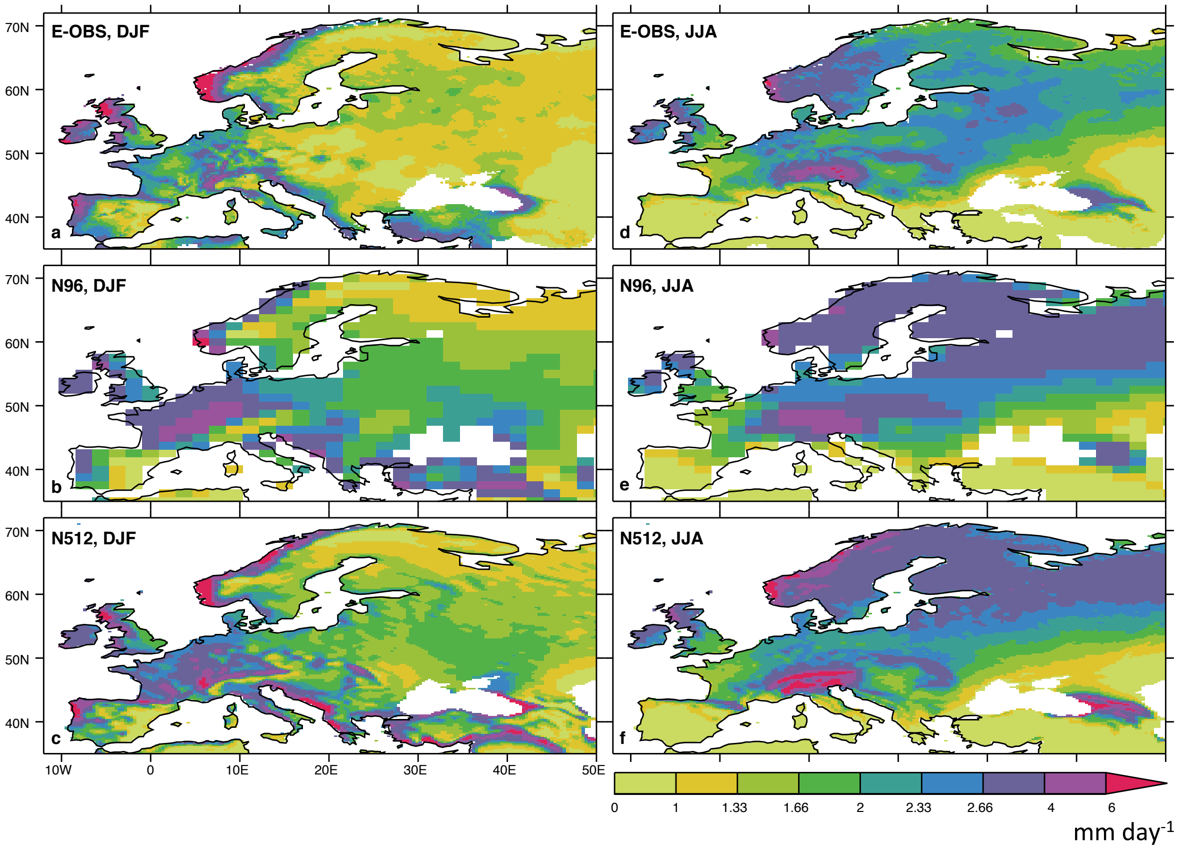
Mean precipitation



Seasonal mean precipitation

	DJF	MAM	JJA	SON
E-OBS	1.64	1.48	1.78	1.87
N96	2.09±0.05	2.17±0.05	2.15±0.03	2.05±0.03
N216	2.05±0.10	2.19±0.07	2.09±0.06	2.06±0.05
N512	2.08±0.05	2.22±0.01	2.06±0.02	2.03±0.06

mm day^{-1}

Mean precipitation

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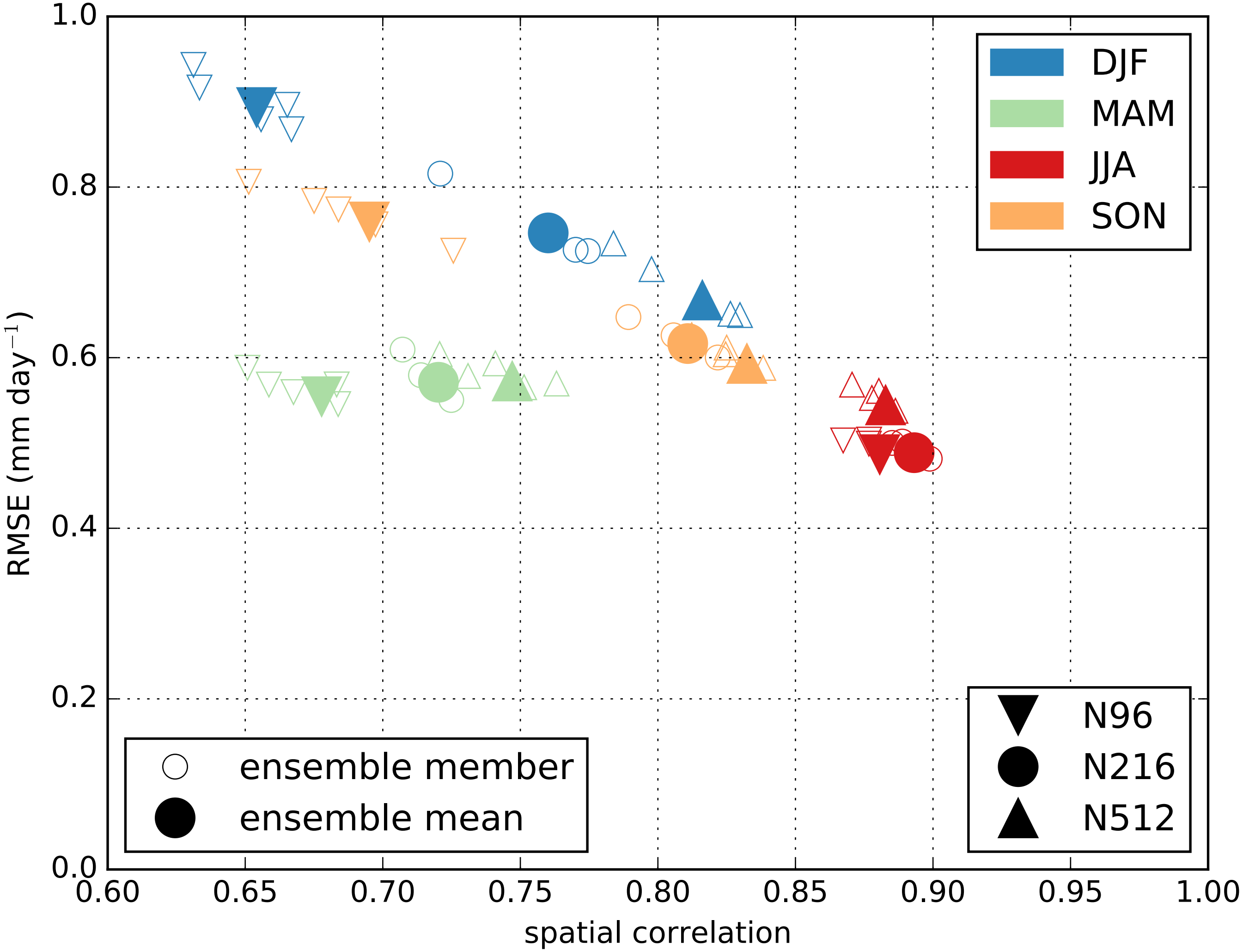

- clear improvement with resolution in SON, DJF, MAM
- small difference in JJA

Extreme value analysis: method

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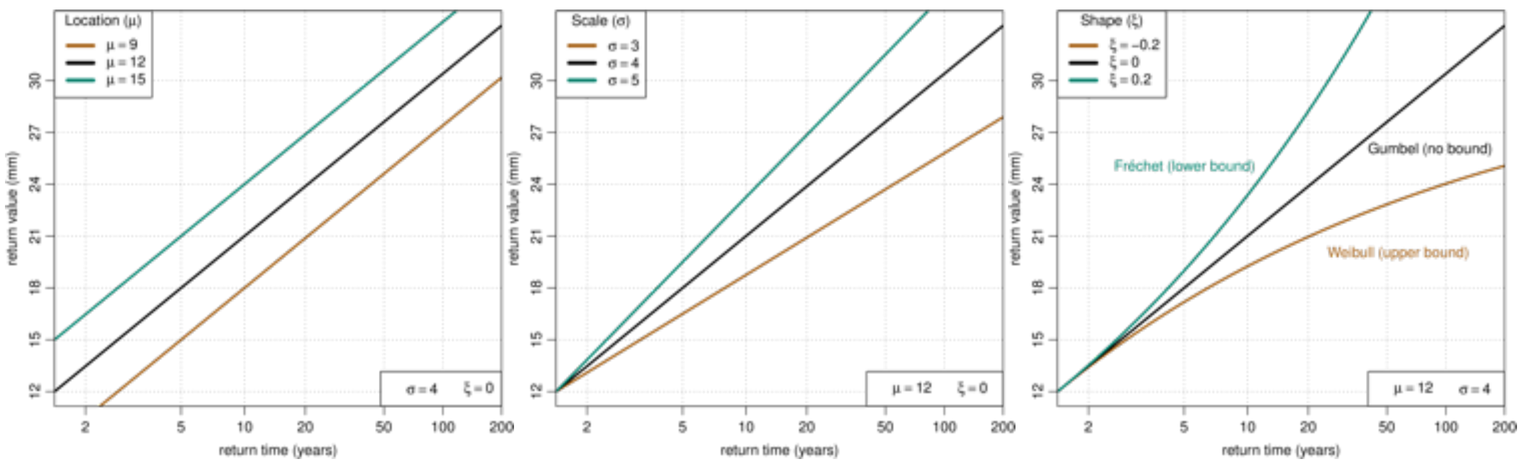
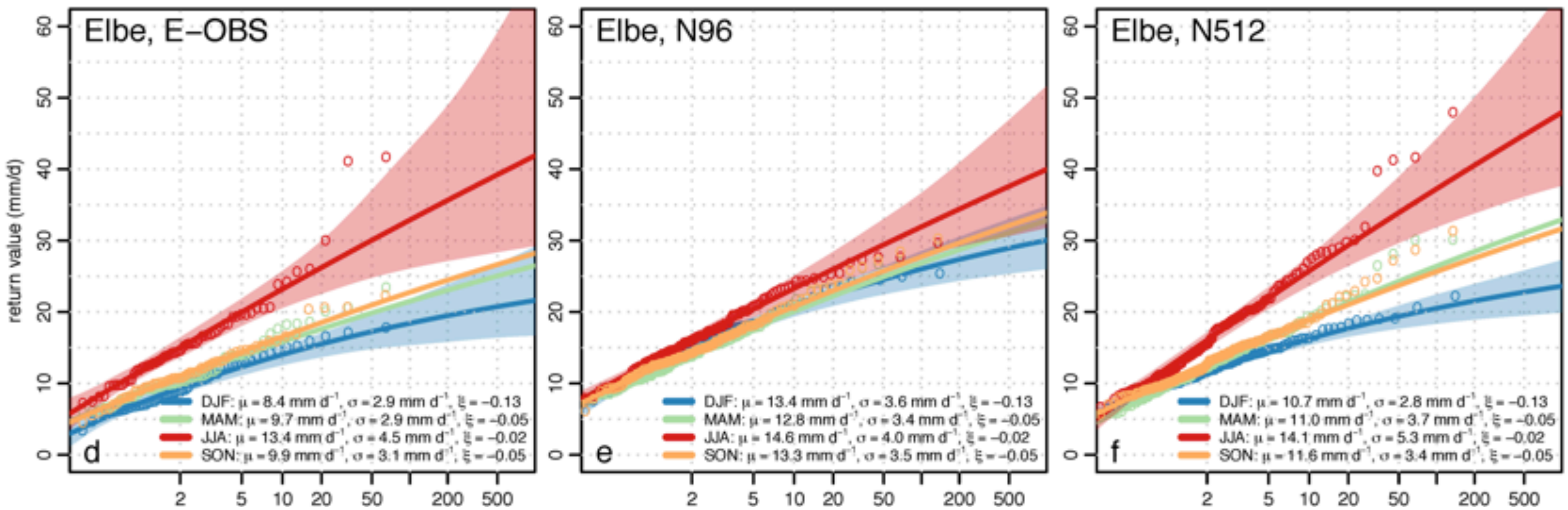
- apply the method of block maxima
  - block: 1-day precipitation values in a river basin throughout one season in one year
- fit a Generalised Extreme Value (GEV) distribution to the block maxima
  - 3 parameters: location μ, scale σ, shape ξ



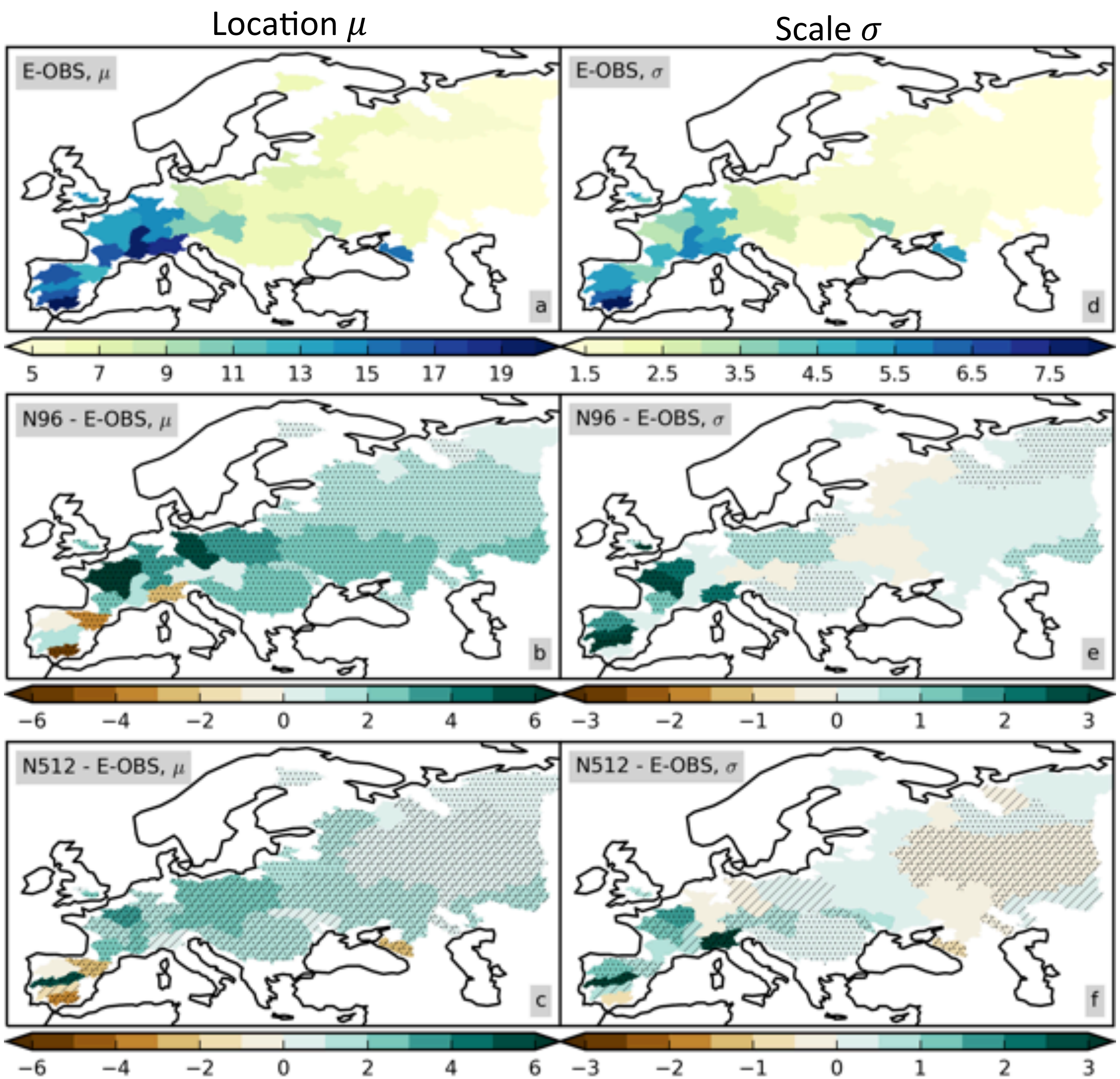
  - not all 3 parameters can be fitted robustly for each basin
    - ➢ fix ξ to the mean value across all basins, then fit μ and σ for each

Extreme value analysis: example

- river Elbe (central Europe)



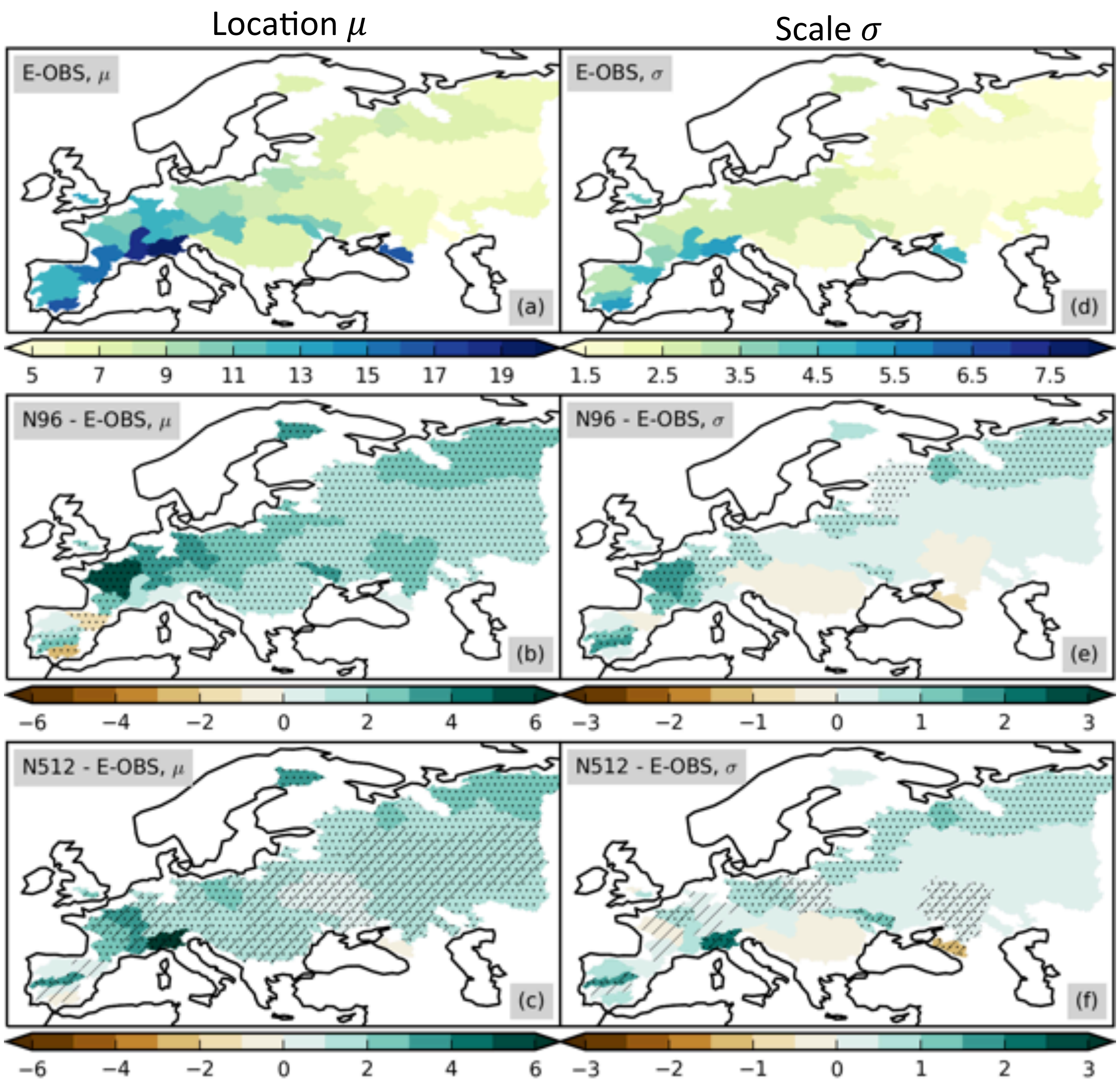
Extreme value analysis: DJF



(all mm per day)

- DJF: clear improvement in the location parameter μ, and some for shape parameter in northwest Europe

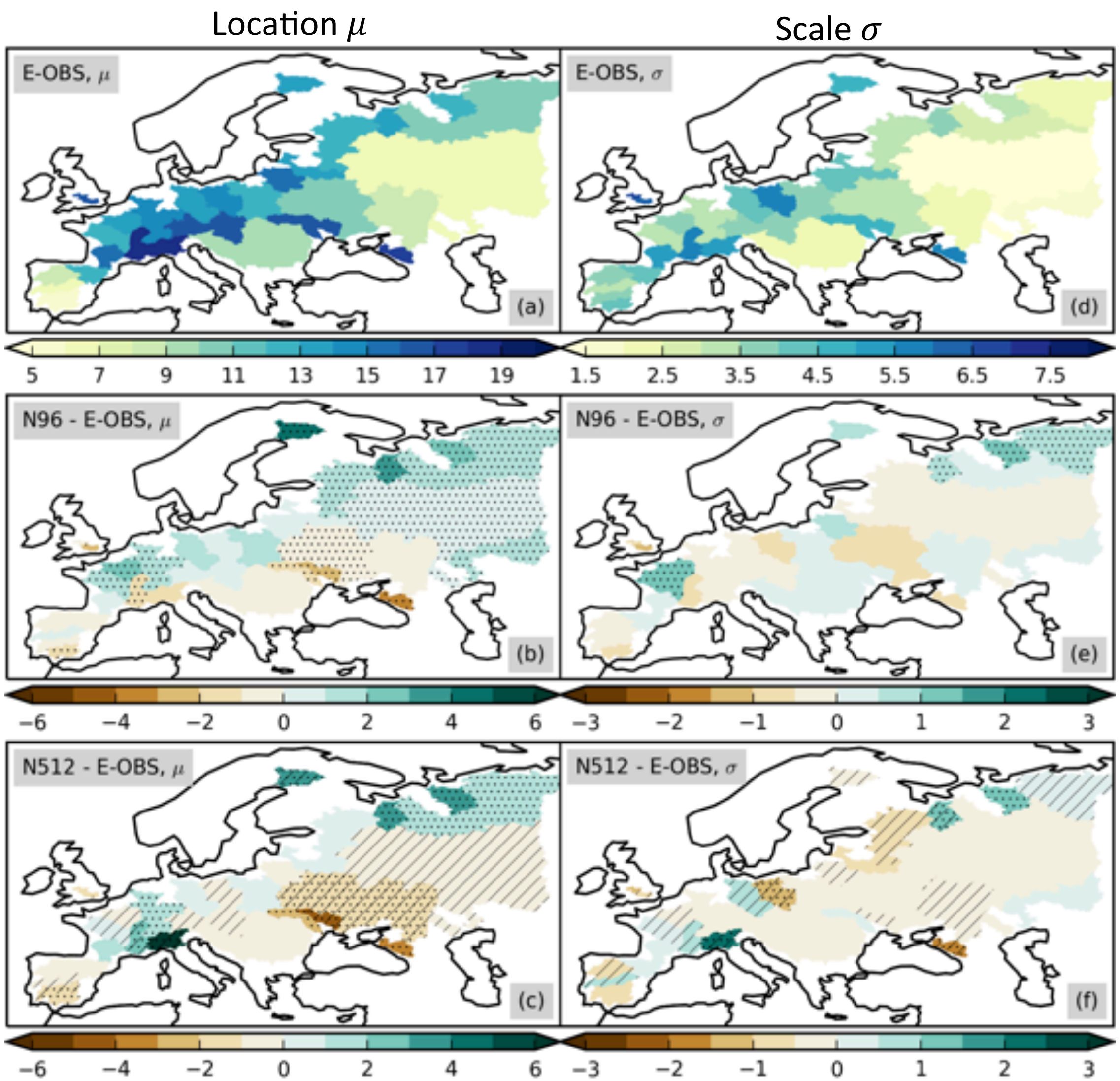
Extreme value analysis: MAM



(all mm per day)

- MAM

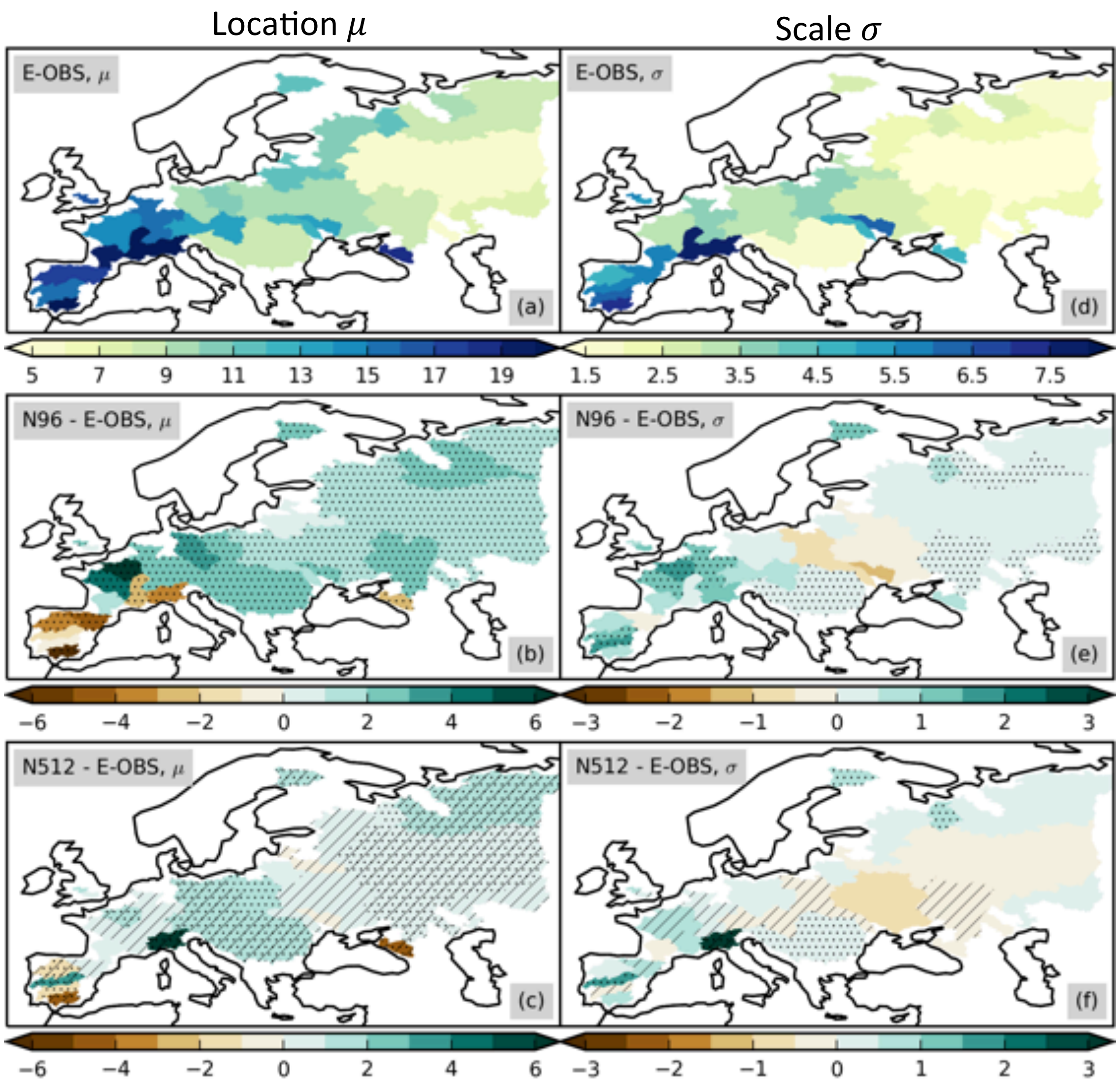
Extreme value analysis: JJA



(all mm per day)

- JJA: Similar performance at both resolutions

Extreme value analysis: SON



(all mm per day)

- SON: very clear improvement both for the location and scale parameters

Extreme value analysis: summary statistics

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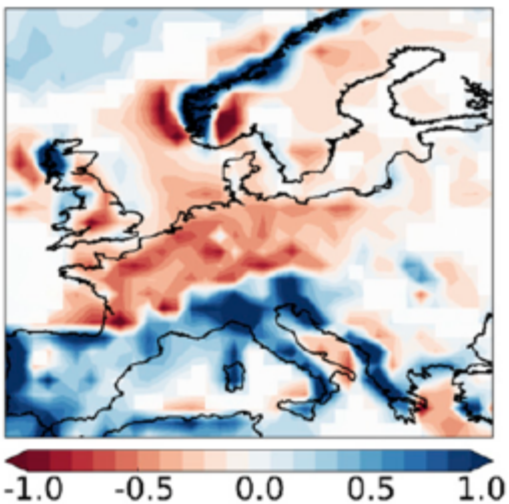
- 'absolute relative bias' (%)

$$\max\left(\frac{\theta_{\mathrm{model}}}{\theta_{\mathrm{obs}}}, \frac{\theta_{\mathrm{obs}}}{\theta_{\mathrm{model}}}\right) - 1 \quad \text{, where } \theta = \mu \text{ or } \sigma$$

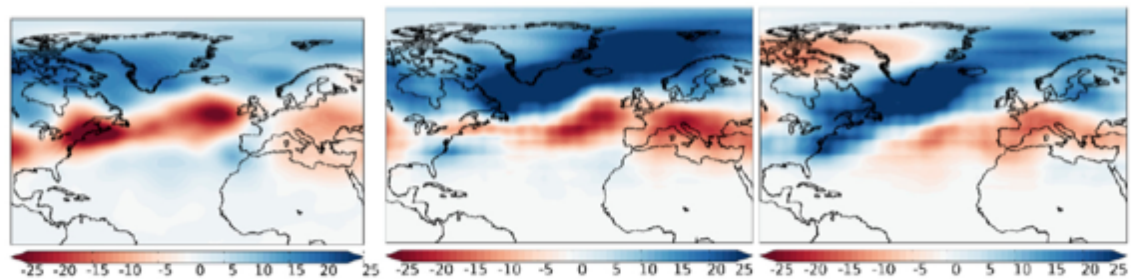
	μ			σ		
	N96	N216	N512	N96	N216	N512
DJF	22	16	**16**	17	16	**16**
MAM	25	21	**20**	19	**18**	19
JJA	**9**	10	10	**10**	14	12
SON	18	12	**8**	17	12	**8**

Storm track and resolution: previous results

- CMIP5: North Atlantic storm track improved in higher-resolution models (Zappa et al. 2013)
- EC-Earth @ 25km resolution (van Haren et al. 2015):



(c) T799 - T159 precip

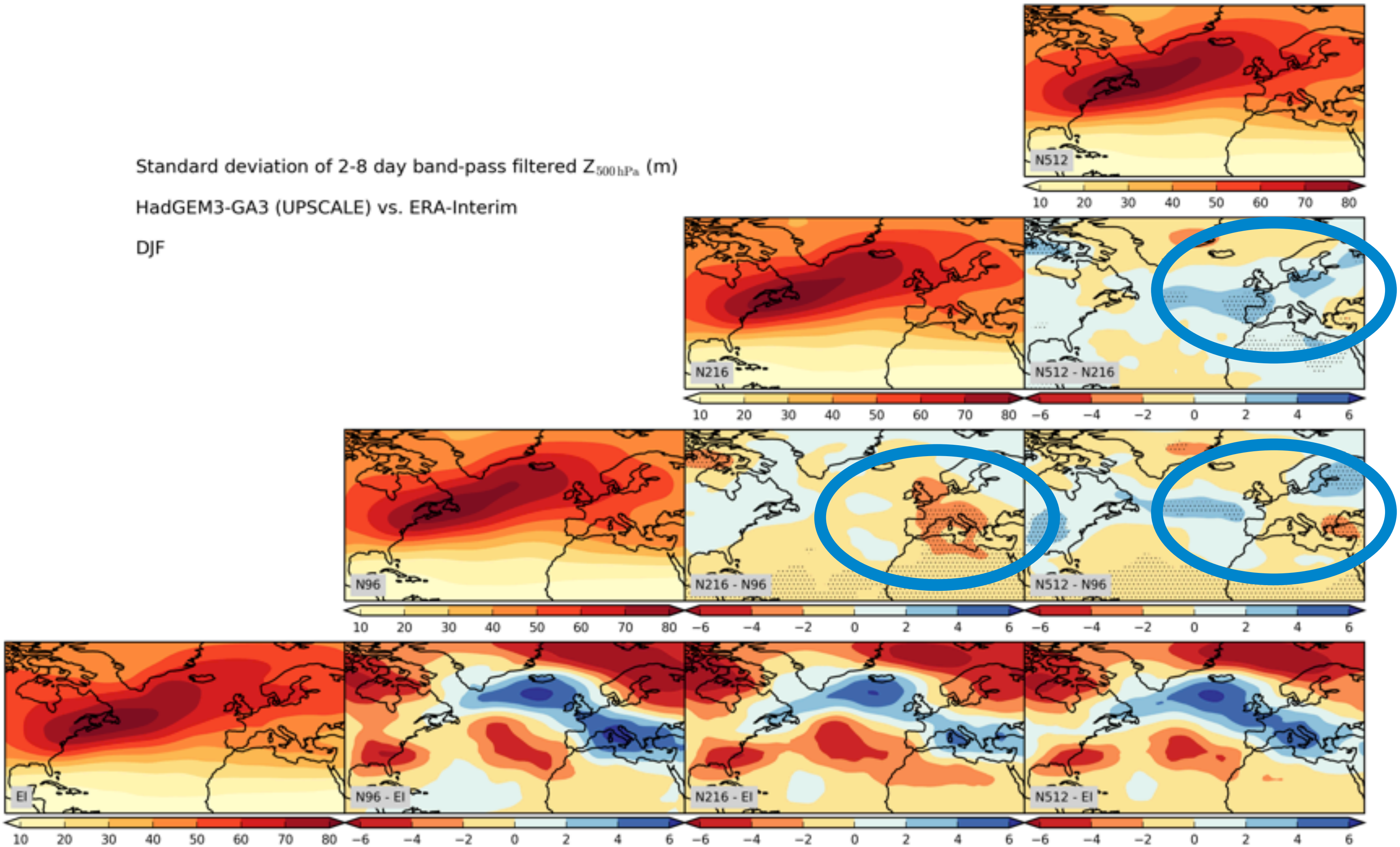


(d) T799 - T159 (e) ERAI - T159 (f) ERAI - T799

FIG. 9. Storm track calculated as the variance of 2–8-day bandpass filtered Z500 ($m^4 s^{-4}$).

➢ "Our findings show, assuming that sufficient temporal- and vertical-resolution data are saved to do a detailed moisture budget analysis, that our high-resolution AGCM has a better representation of the North Atlantic storm track and therefore precipitation."

Resolution sensitivity of the storm track (DJF)



- ➢ small resolution sensitivity over Europe (~5%)
- ➢ different sign for N96 − N216 and N216 − N512 (not so for precipitation − not shown)

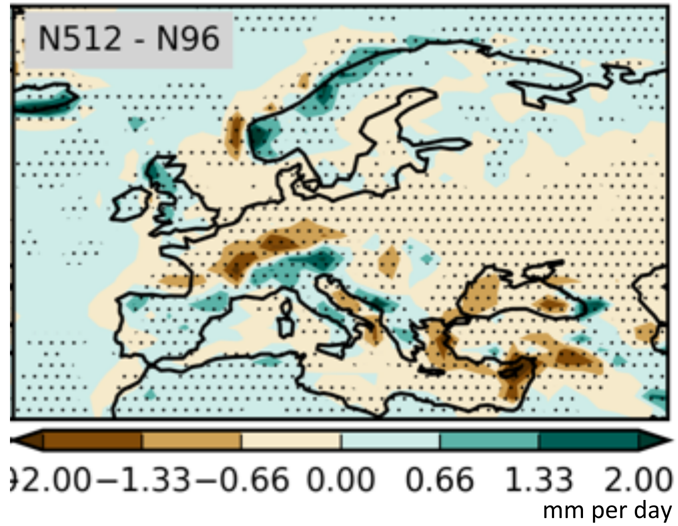
Orography sensitivity experiment

- take a high-resolution atmospheric model (HadGEM3-GA6 N480) and
- apply low-resolution (N96) orographic boundary conditions

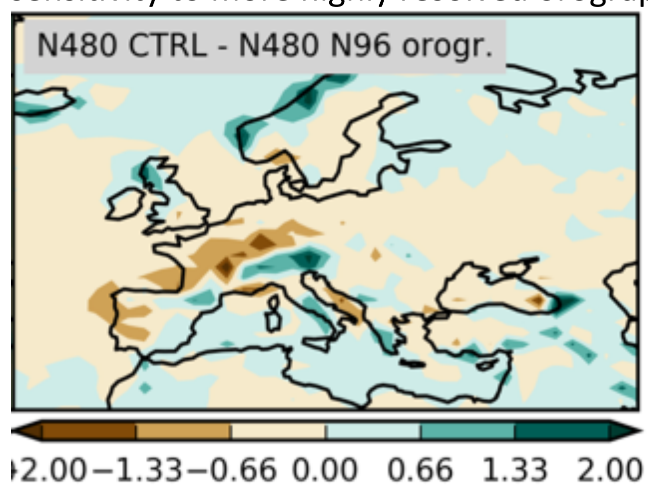
➢ sensitivity to the more highly resolved orography is similar, in geographical distribution and magnitude, to the total resolution sensitivity in many parts of Europe

➢ result for DJF extends to other seasons, and to extreme precipitation in northwest Europe (but not elsewhere) (not shown)

total sensitivity to resolution (DJF):



sensitivity to more highly resolved orography only (DJF):



Summary and conclusions

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Have evaluated mean and extreme precipitation in HadGEM3-GA3 simulations with a resolution increase from 135 to 25 km.

Schiemann et al. 2018, HESS-D,
DOI: 10.5194/hess-2017-732

Mean precipitation
- continent-mean precipitation greater than in E-OBS (20-50% depending on season)
- RMSE (continent-mean bias removed) between 0.5 and 1 mm day^{-1} (larger in DJF than in JJA)
- resolution sensitivity:
  - SON, DJF, MAM: improved at higher resolution (by about 25% RMSE)
  - JJA: small changes

Extreme precipitation (daily, over large European river basins)
- typical biases in GEV location and scale parameters around 20%
- much larger biases (>50%) for some basins
- resolution sensitivity:
  - DJF, MAM: GEV location parameter bias reduced (by about 30%)
  - SON: GEV location and scale parameter biases reduced (by more than 50%)
  - JJA: small changes

Drivers of resolution sensitivity in precipitation ("orography vs. North Atlantic storm track"):
- resolution sensitivity in the storm track plays a role, but is not the dominant factor
- better resolved orography at the higher resolution largely explains resolution sensitivity in many parts of Europe for mean precipitation, and in central/northwest Europe for extreme precipitation
- smaller role for storm track in HadGEM3-GA3 than in a previous study with EC-Earth @ 25km
  - ➢ potentially good news for downscaling (for km-scale cloud-resolving simulations) with HadGEM3
  - ➢ further model intercomparison needed (CMIP6-HighResMIP, PRIMAVERA)