Recent trends in extreme weather - A model study

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Summary

- Changes in precipitation are the largest for the most extreme events.
- Such events are not represented well in low-resolution models.
- We find that recent changes in total and extreme precipitation are better represented in higher-resolution models.

Introduction

Precipitation occurs on a wide range of scales, from short-lived, local, intense precipitation events to more persistent, large-scale, low intensity events. Coarse-resolution models (dx ~ 200 km) often fail to represent the most intense precipitation events, while higher-resolution models (dx ~ 50 km) often reproduce observed precipitation events much better (Fig. 1). Apart from coarser horizontal resolution, coarse-resolution models also suffer from excessive damping, longer time step, smoother orography, lower vorticity in cyclones etc.

While total precipitation has changed recently, the changes to the most intense precipitation events (e.g. 90th percentile) are generally larger than the changes to the median. If coarse-resolution models can not represent such events, they may not be able to represent recent changes in precipitation.

Data

We use observations of daily precipitation from the ENSEMBLES data set (Haylock et al., 2008) gridded onto a 0.5x0.5 degree grid covering most of Europe. We also use 12-hourly 12-hour forecasts of precipitation from ERA-Interim reanalysis, available at 0.7x0.7 resolution.

We simulate the periods 1982-1986 and 2012-2016 using time-slice experiments with the OpenIFS model (Carver et al. in prep.). For each year, we run a 14-month simulation from 1 January to 28 February the next year, discarding the first 2 months as spin-up. We run the simulations at spectral truncations T159 (dx ~ 125km), T255 (dx ~ 78km) and T511 (dx ~ 39km). The T159 and T511 configurations have 91 vertical levels, while T255 has 60 vertical levels. Daily SST and sea-ice concentrations (SIC) are taken from the NOAA SST dataset at 0.25° horizontal resolution.

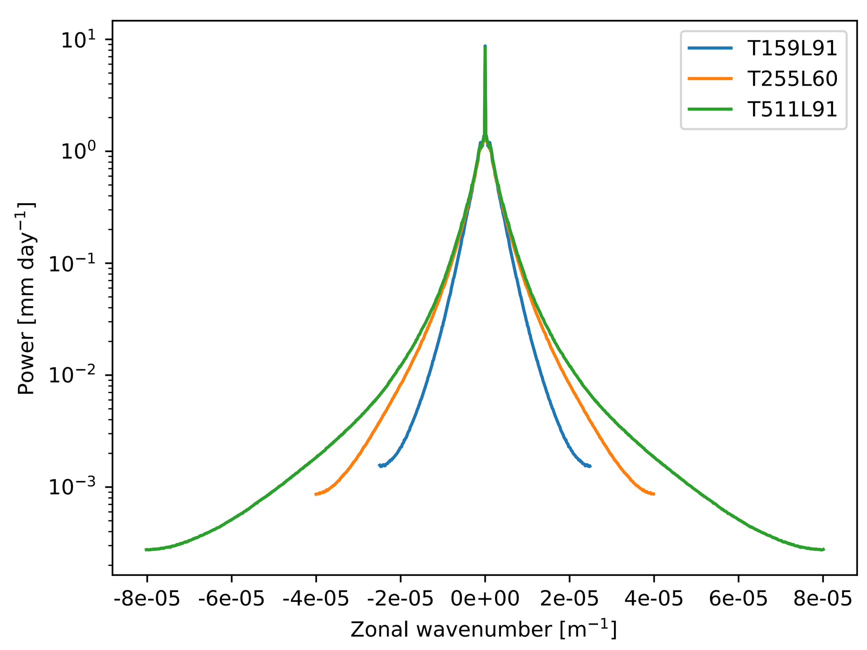

Fig 1. Spectral power of 6-hourly precipitation between 40°N-60°N averaged over first 200 days of simulation in 1982.

References

Carver et al.: The ECMWF OpenIFS numerical weather prediction model release cycle 40r1: description and use cases. in prep.

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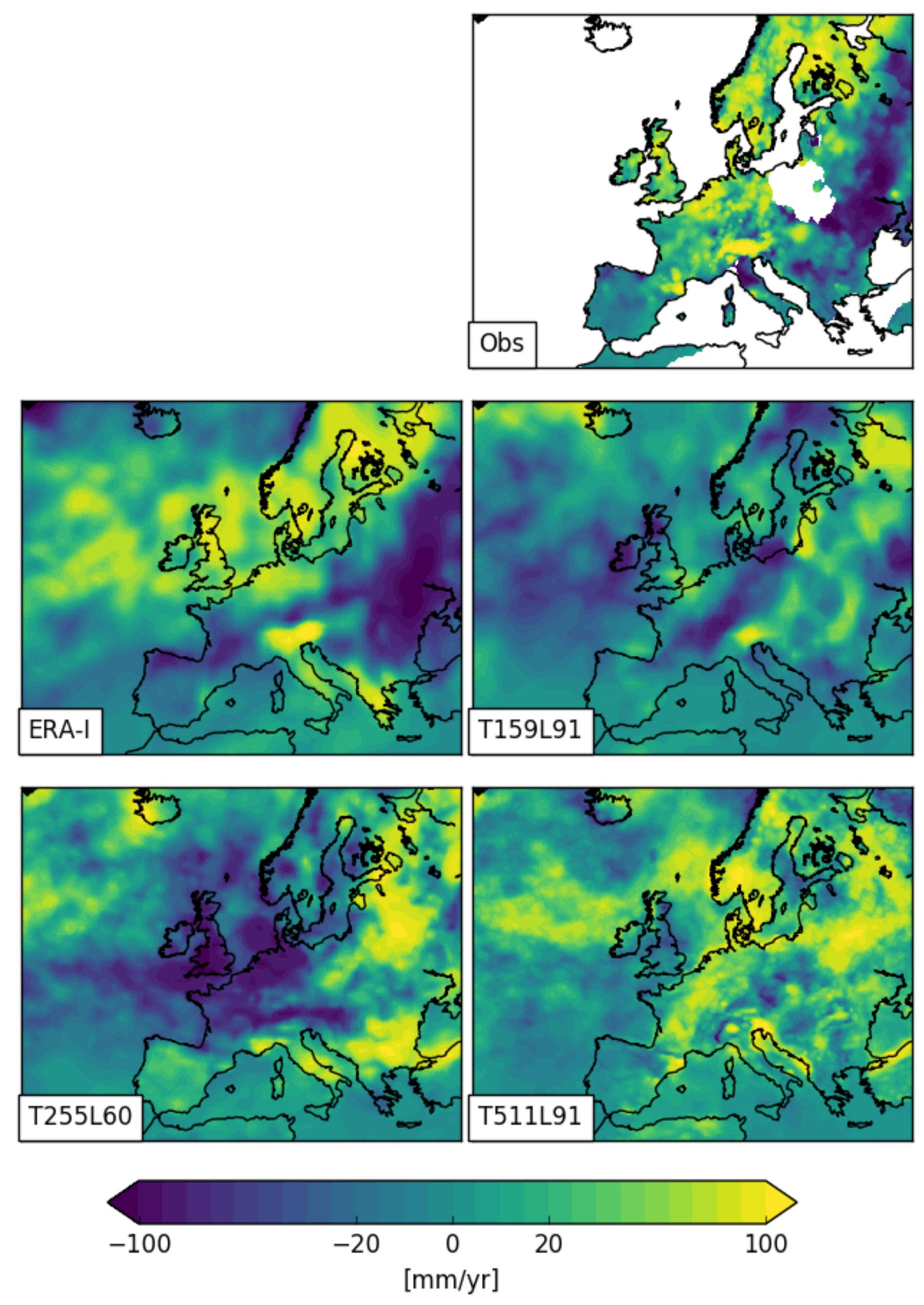

Fig 2. Change in total summer precipitation from 1982-1987 to 2012-2017. Colour scale is not linear.

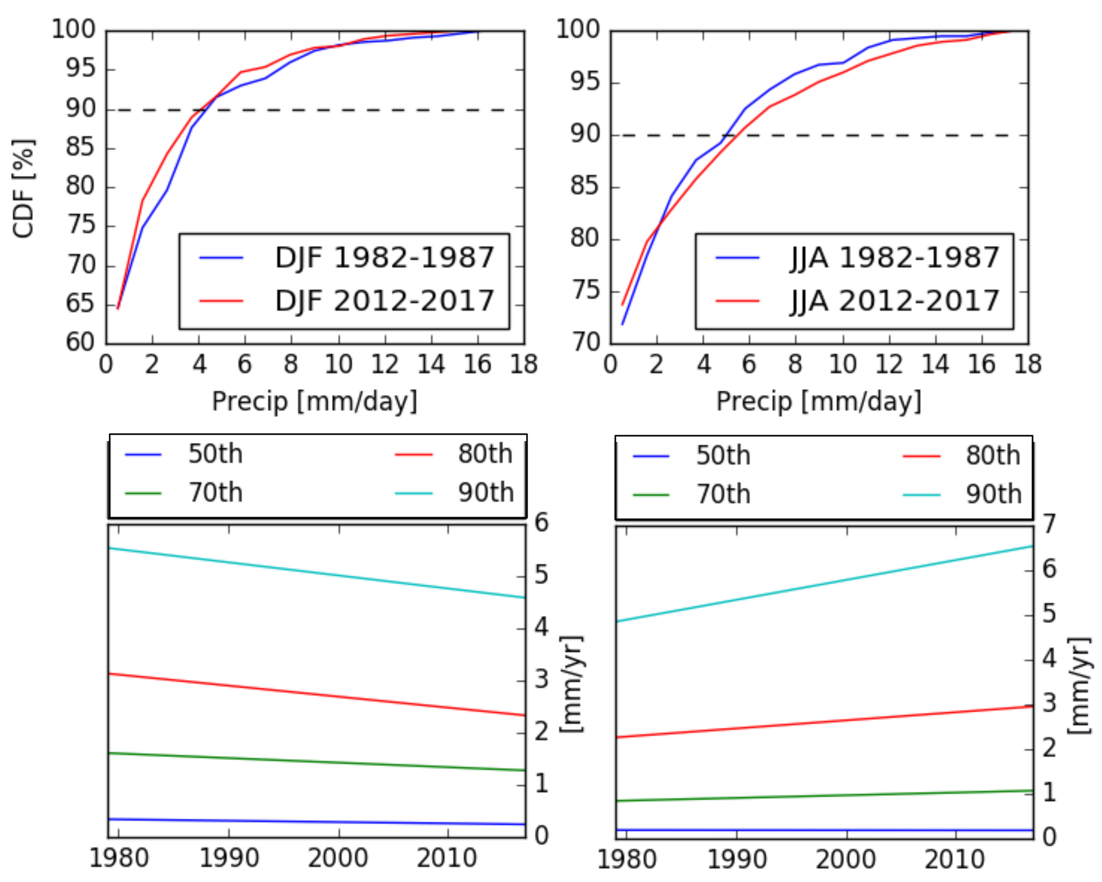

Fig 3. Top: Cumulative distribution of daily precipitation events over Paris. Lower: Linear trend in daily precipitation over Paris at different percentiles. Left: Winter. Right: Summer.

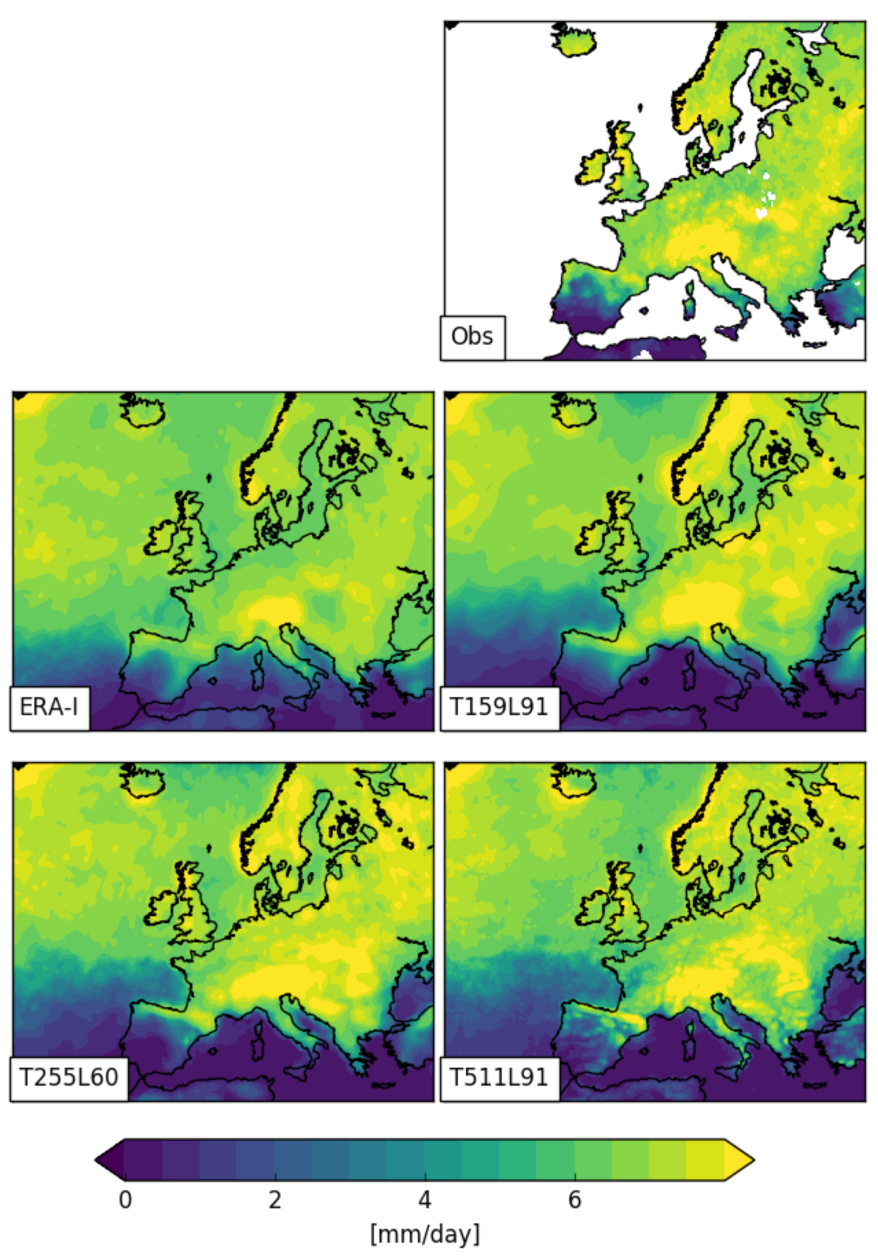

Fig 4. 95th percentile of daily summer precipitation events averaged over 1982-1987. Colour scale is not linear.

Results

Observed total precipitation has increased over much of Europe in both summer and winter (Fig. 2). Summer precipitation has increased significantly over the Benelux region and the Alps. This is not reproduced by free-running simulations at T159 and T255. At T511 resolution, the results agree much better with observations and ERA-Interim.

As an example, the total precipitation over Paris has increased in summer and decreased in winter. The changes are due to a narrowing and widening of the distributions of precipitation events in winter and summer respectively. Fitted linear trends are larger for higher percentiles, showing changes in width of distribution (Fig. 3).

Finer horizontal resolution increases the intensity of 95th percentile precipitation events and concentrates the events to mountainous regions (Fig. 4). Maximum precipitation over European continent increases with finer resolution and T511 is closer to observations than T159, T255 (Fig. 5). ERA-Interim underestimates extreme precipitation over the European continent, likely due to insufficient horizontal resolution.

The intensity of 95th percentile events in daily summer precipitation has increased over much of central Europe from 1982-1987 to 2012-2017. The overall pattern of the increase is represented in ERA-Interim, but magnitude is underestimated. Both T159 and T255 simulate large regions of decreased intensity in 95th percentile, while T511 reproduces observed changes much better (Fig. 6). The biases in T159 and T255 are present for lower percentiles and the median as well, suggesting it may arise from inadequate representation of the large-scale flow.

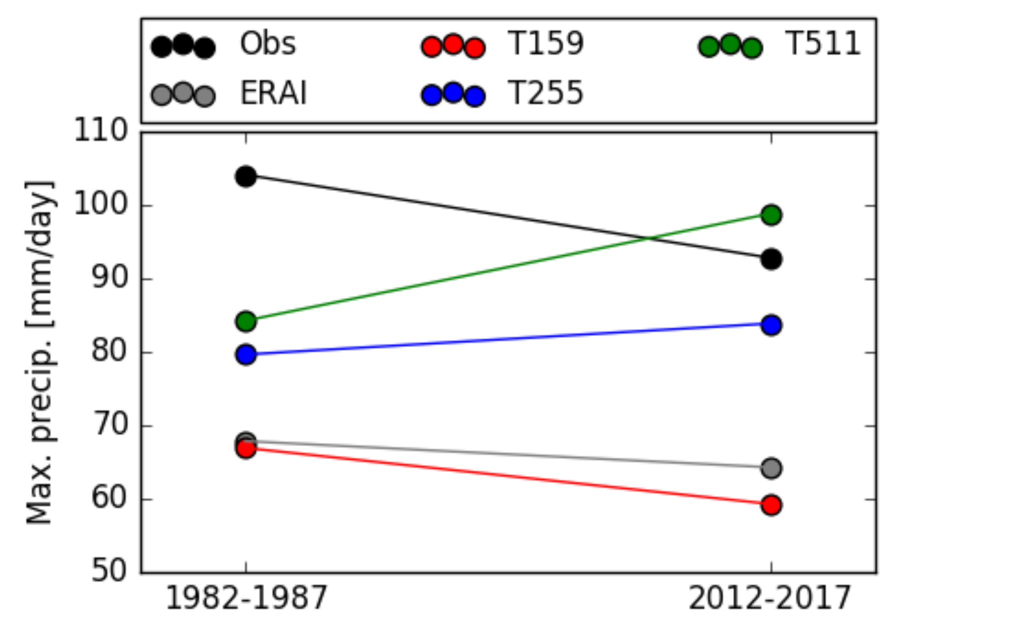

Fig 5. Maximum daily winter precipitation events on the European continent averaged over 1982-1987 and 2012-2017.

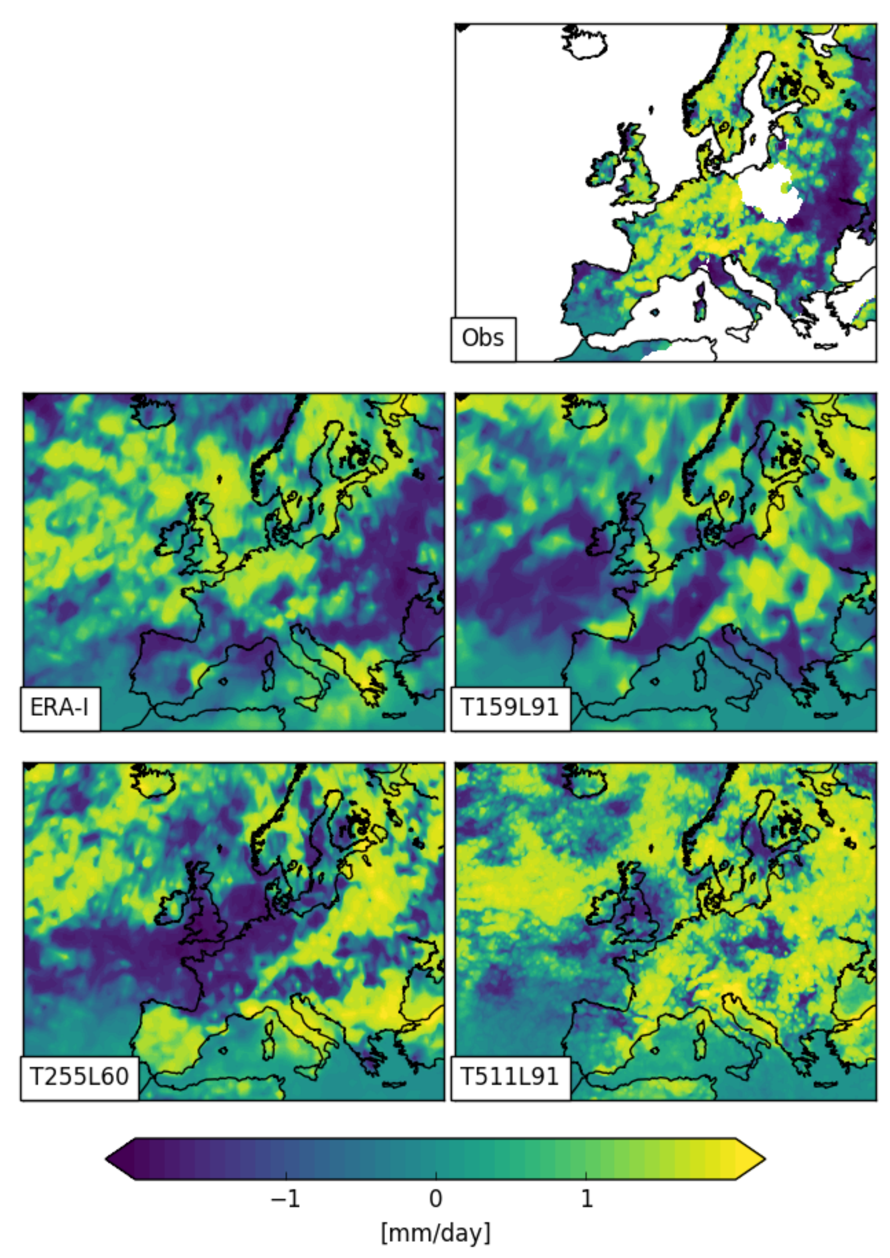

Fig 6. Change in 95th percentile of daily summer precipitation events from 1982-1987 to 2012-2017. Colour scale is not linear.