Climate change at convection-permitting scales

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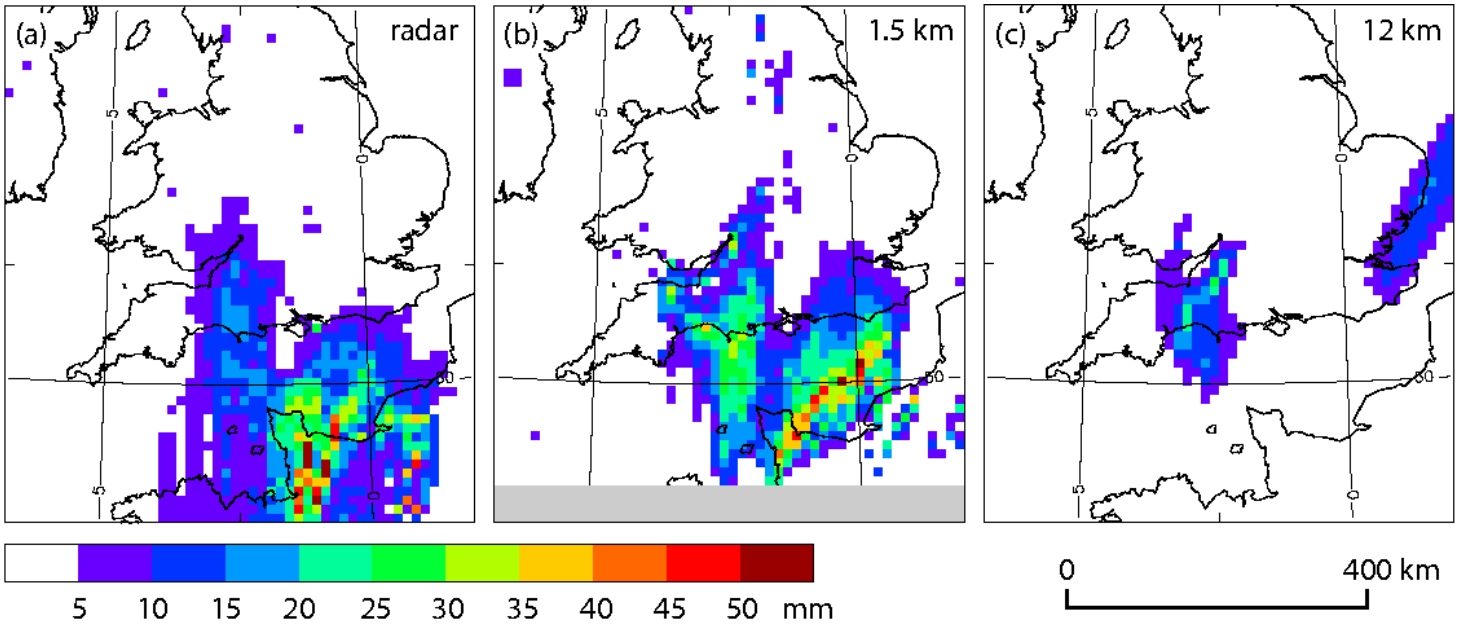
Introduction

- Heavy rainfall is increasing on daily timescales, but how changes will manifest on sub-daily timescales remains highly uncertain.
- Climate models rely on a convective parameterisation and are unable to reliably simulate sub-daily rainfall.
- Sub-daily observations are sparse, but in some regions hourly rainfall extremes are increasing faster than expected from temperature changes
- It is short duration convective extremes which are responsible for flash flooding events.

Benefits of high resolution for forecasting convective storms



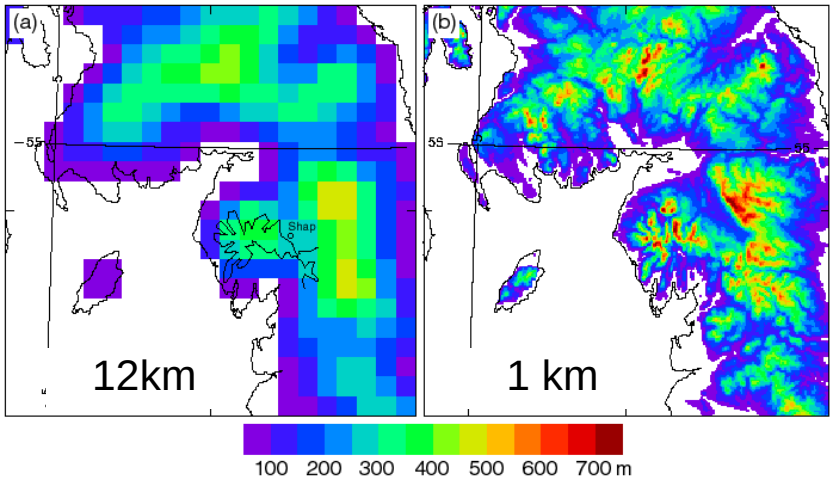
5-hour rainfall accumulations for (a) radar, (b) 1.5km forecast model, (c) 12km forecast model

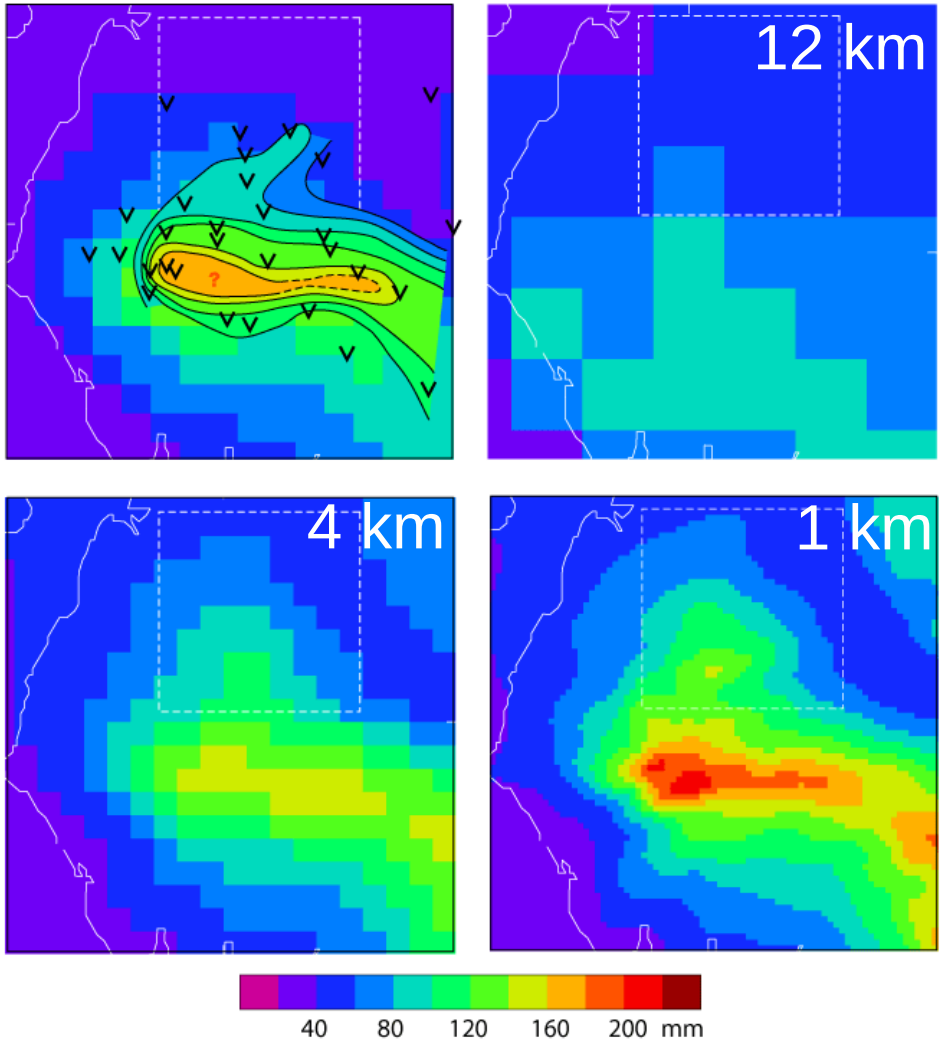
Case study: 27th July 2013; Courtesy: Nigel Roberts

Improved representation of orographic rain at kilometre-scale

Rain gauge observations and model forecasts

Model orography

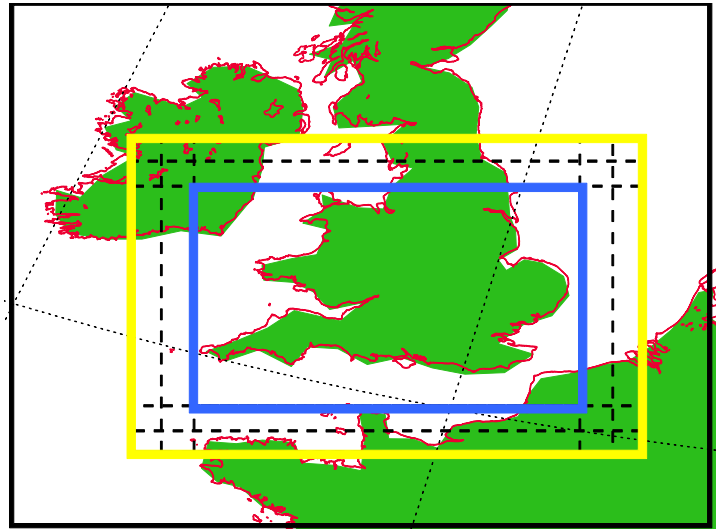




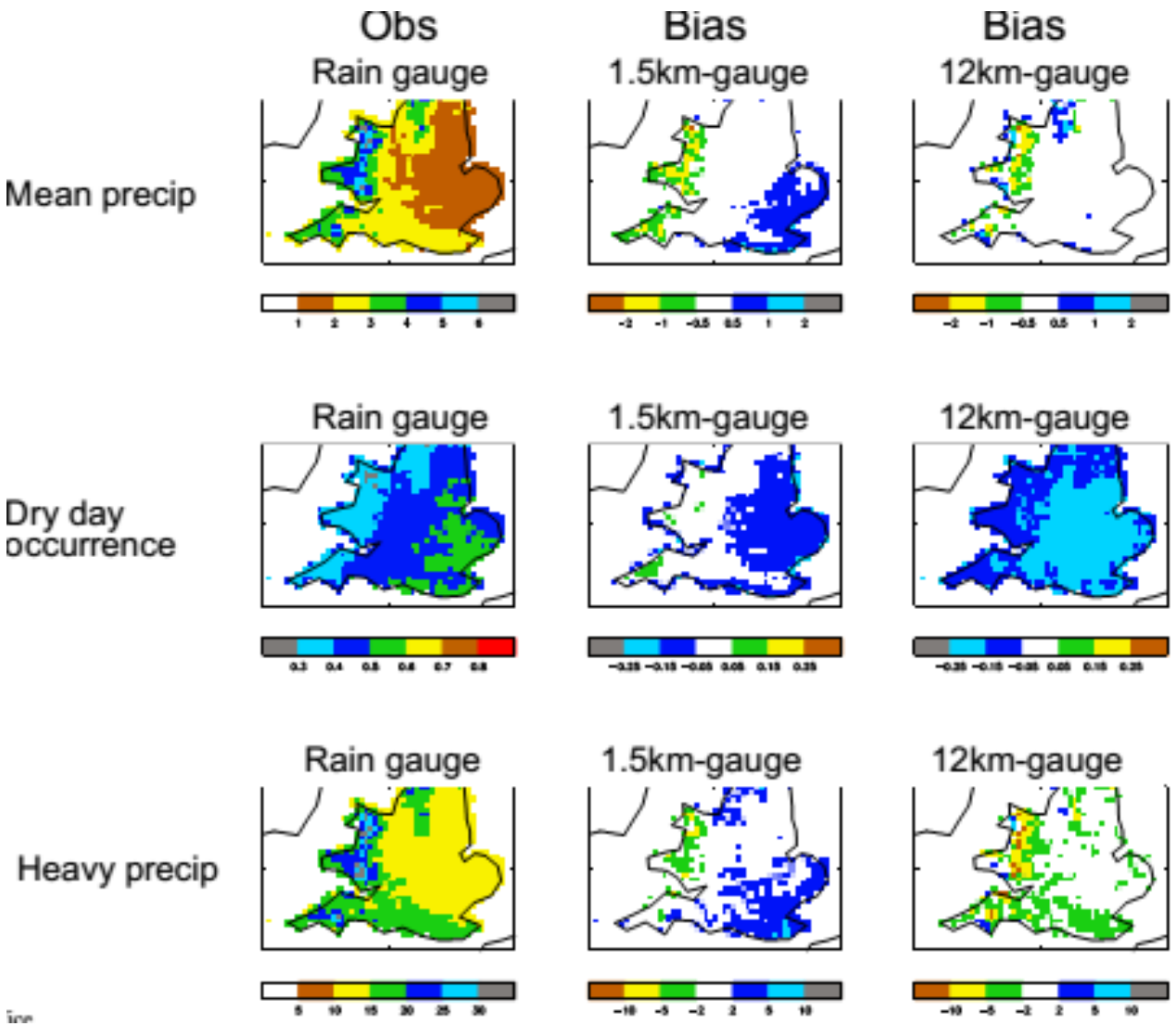
Case study: Carlisle flood, Jan 2005

First regional climate simulations at 1.5km resolution over UK

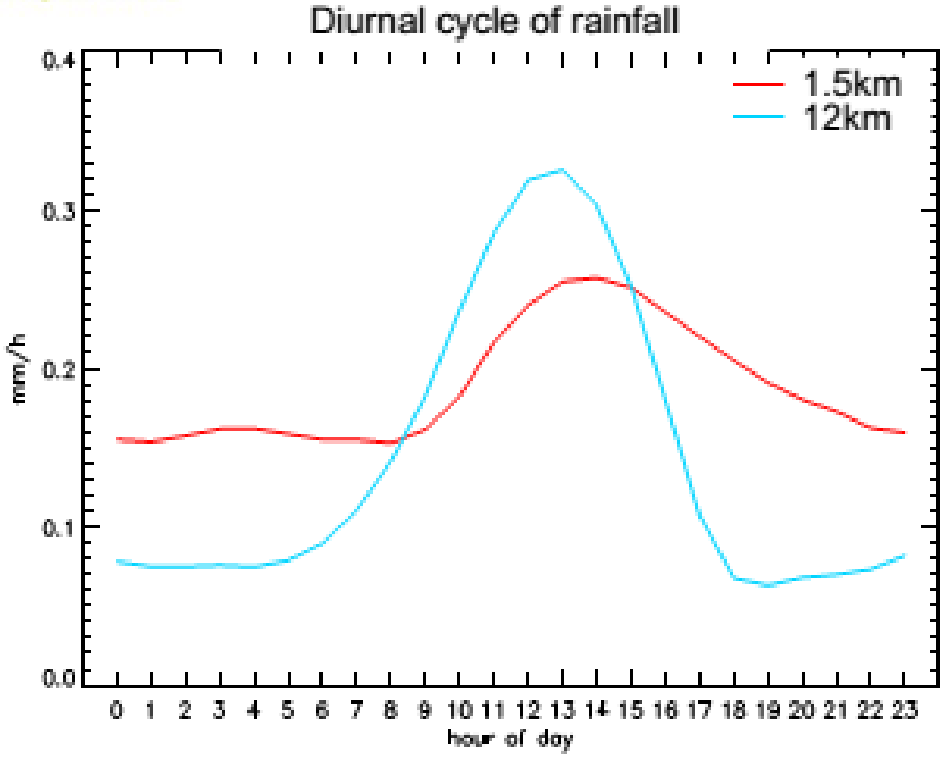
- First climate simulations at convection permitting scales run as part of CONVEX project.
- Span southern England and Wales at 1.5km resolution.
- Driven by 12km European RCM, which is in turn driven by ERA-interim or 60km GCM.
- Explicitly represents convection without need for parameterisation scheme.
- Runs completed to date:
  - Reanalysis driven run (1989-2008)
  - 13y control (1996-2009) and 13y future (~2100) climate change experiments



Daily precipitation (1990-2003)



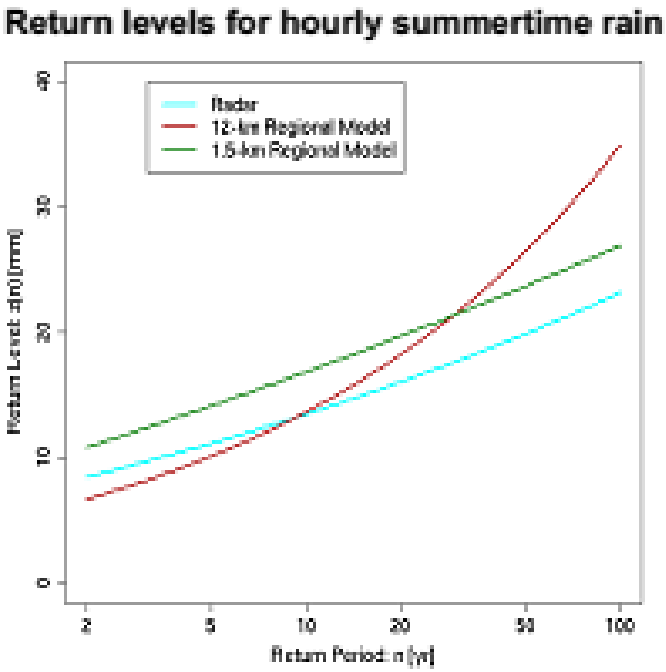
Hourly rainfall characteristics

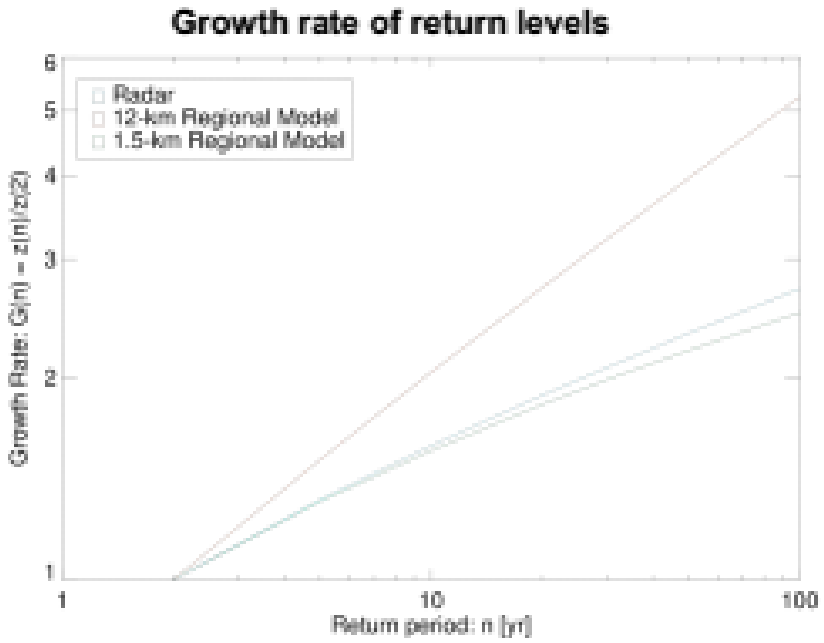


- Diurnal cycle of convection is much more realistic in 1.5km compared to 12km model
- Duration and extent of heavy rain is also much more realistic in 1.5km model

Kendon et al, 2012, J Climate

Extreme summer rainfall



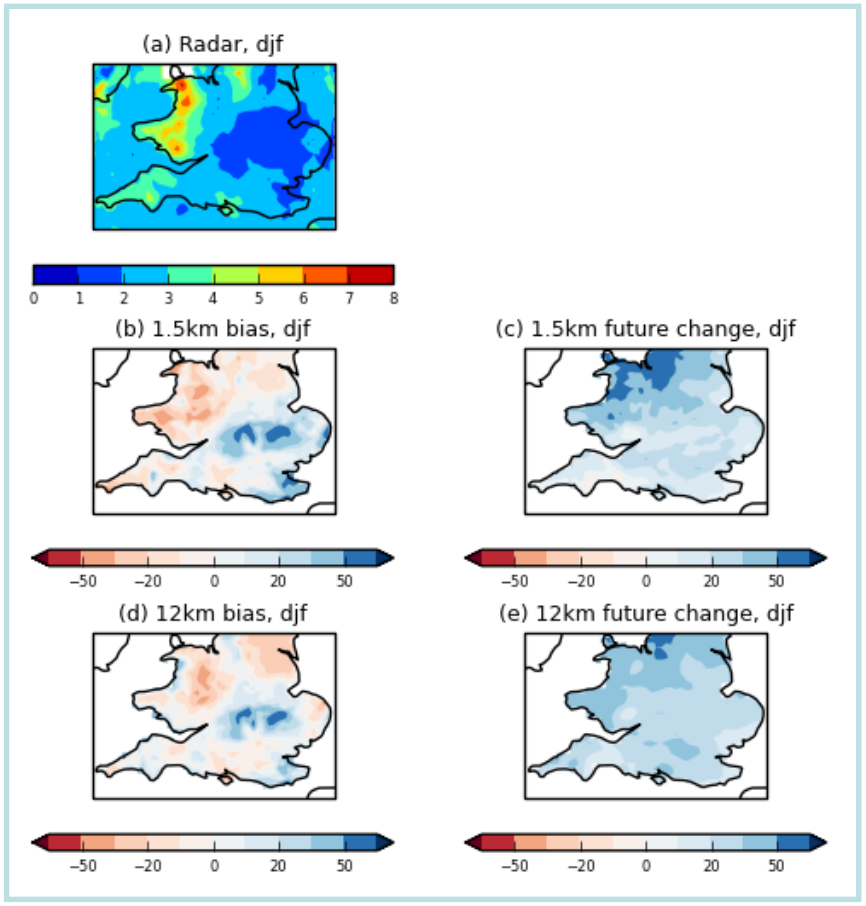


- In 12km RCM extremes increase too rapidly with return period – physically implausible high intensities are linked to grid point storms
- 1.5km RCM gives a much more realistic representation of the growth rate of extremes

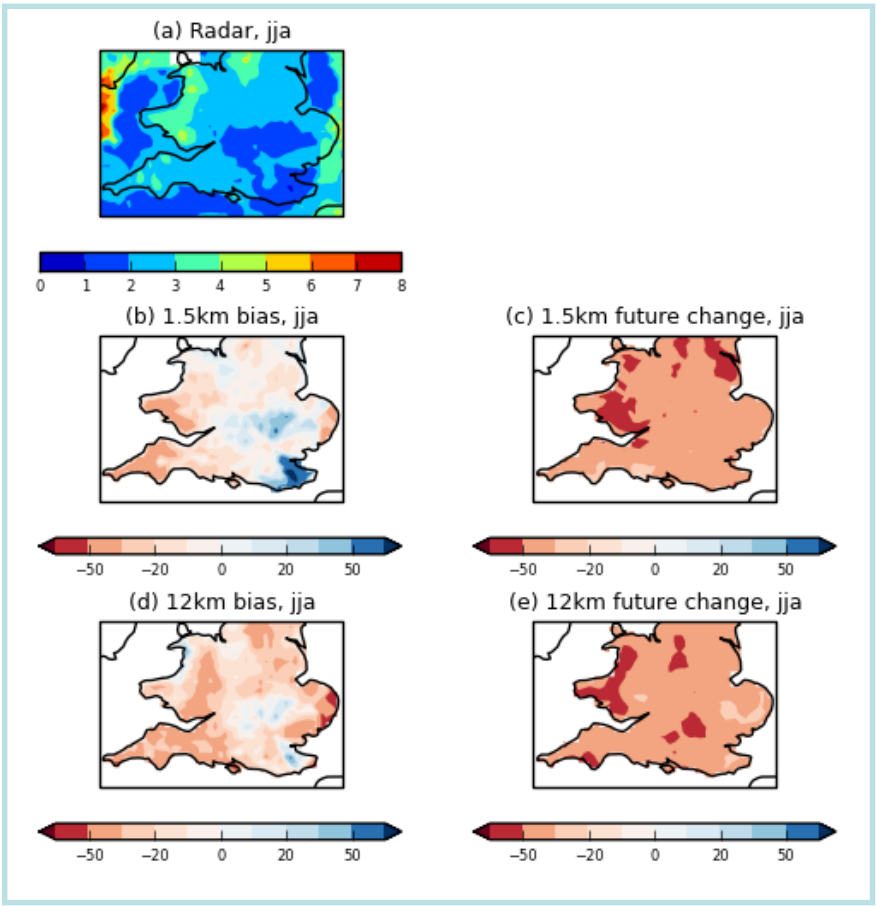
Chan et al, 2014, J.Climate

Future change in seasonal mean rainfall

Winter

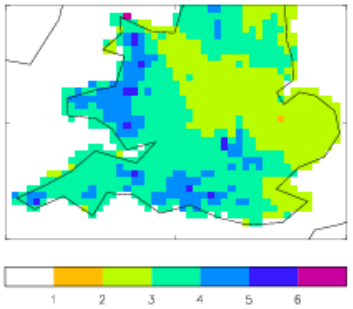


Summer

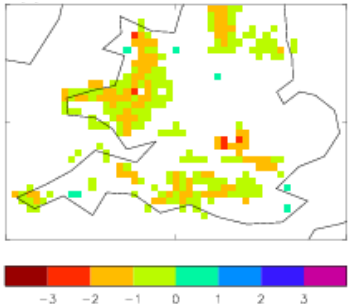


Future change in heavy rainfall at hourly timescale in winter

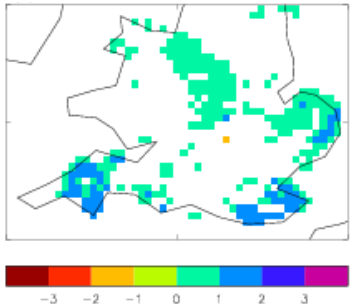
Observed heavy rain (radar)



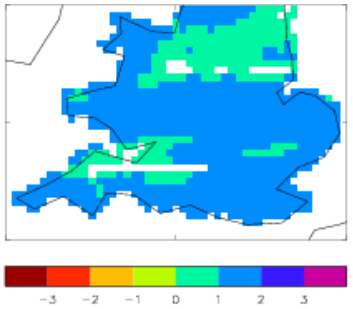
12km model - radar



1.5km model - radar



12km model future change



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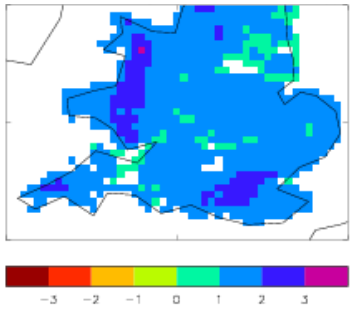
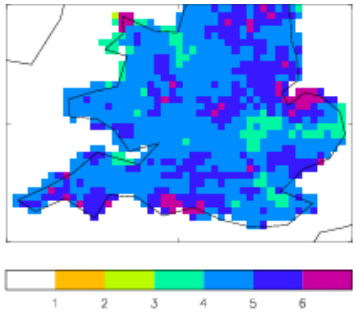


White = model biases and future changes not significant at the 1% level

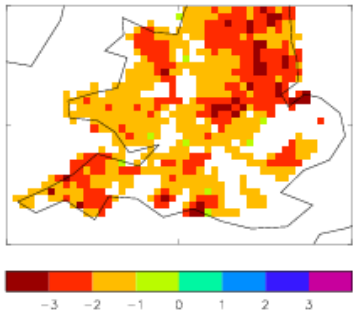
Kendon et al, 2014, Nature Clim. Change

Future change in heavy rainfall at hourly timescale in summer

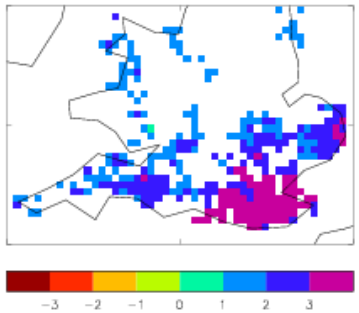
Observed heavy rain (radar)



12km model - radar



1.5km model - radar



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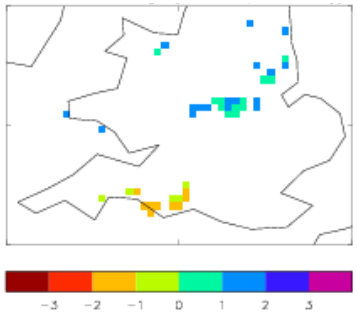
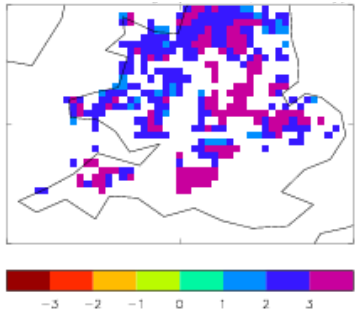


1.5km model future change



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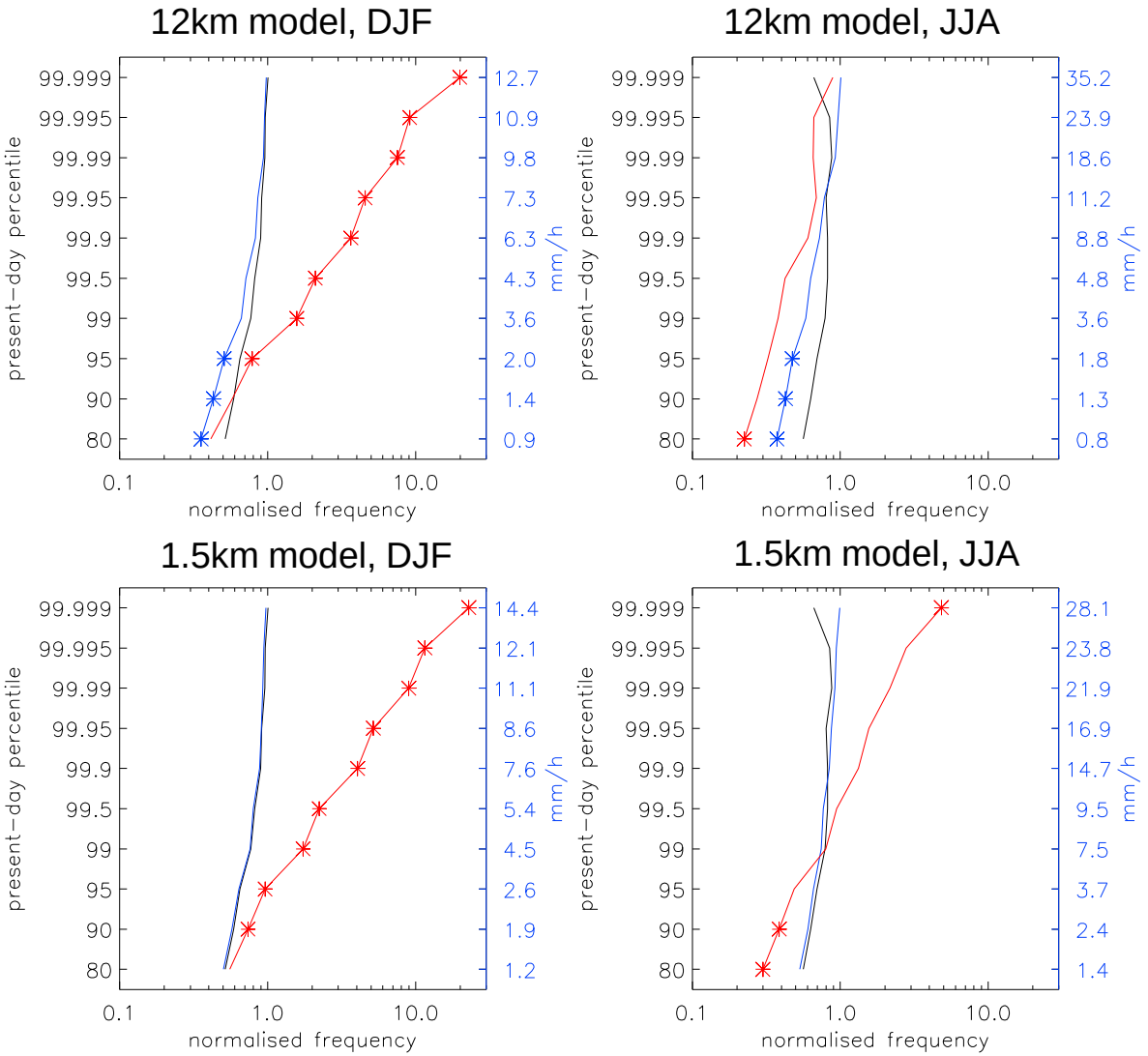
Kendon et al, 2014, Nature Clim. Change

Frequency of exceeding high thresholds



radar

present-day

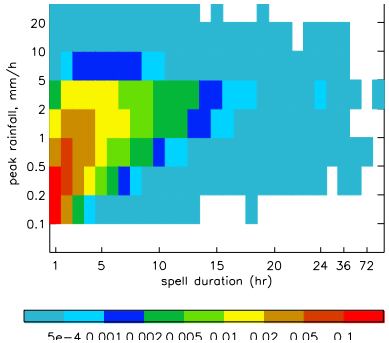
future

significant bias/change

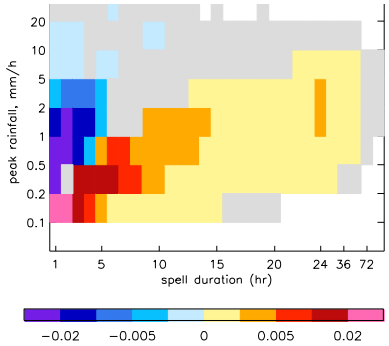
Kendon et al, 2014, Nature Clim. Change

Duration-intensity characteristics of rainfall for winter

Observed distribution (radar)



12km model - radar



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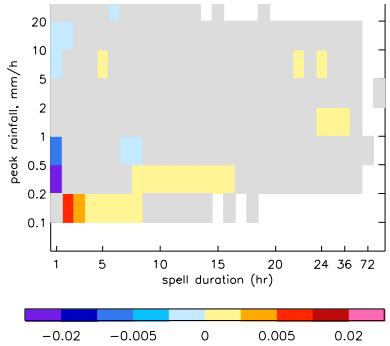
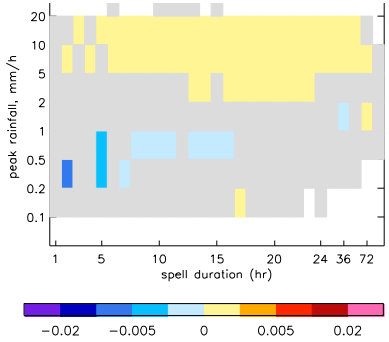
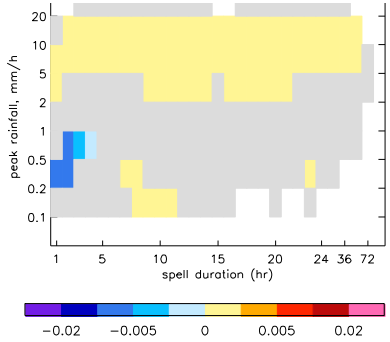


12km model future change



1.5km model future change



Grey = model biases and future changes not significant at the 1% level

Kendon et al, 2014, Nature Clim. Change

Duration-intensity characteristics of rainfall for summer

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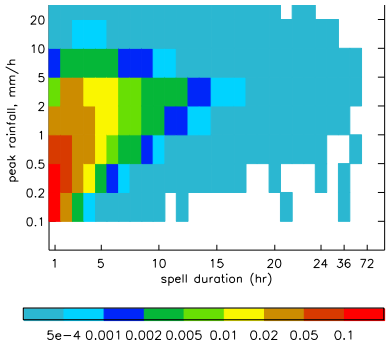
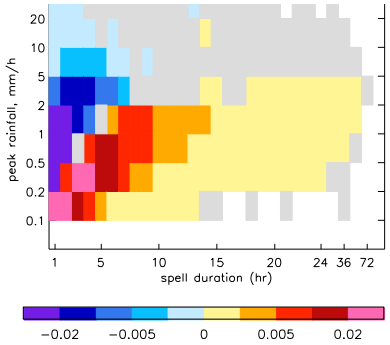
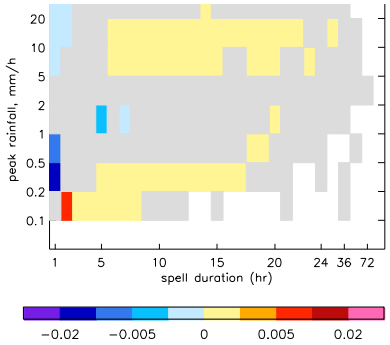


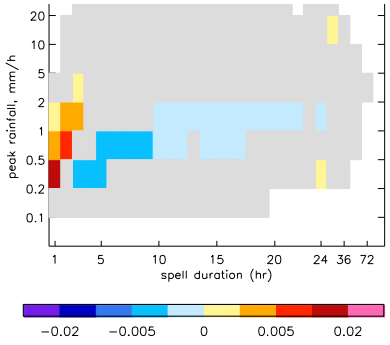
12km model - radar



1.5km model - radar



12km model future change



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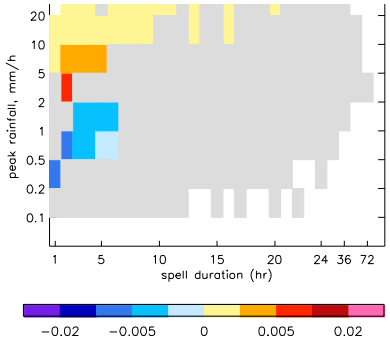

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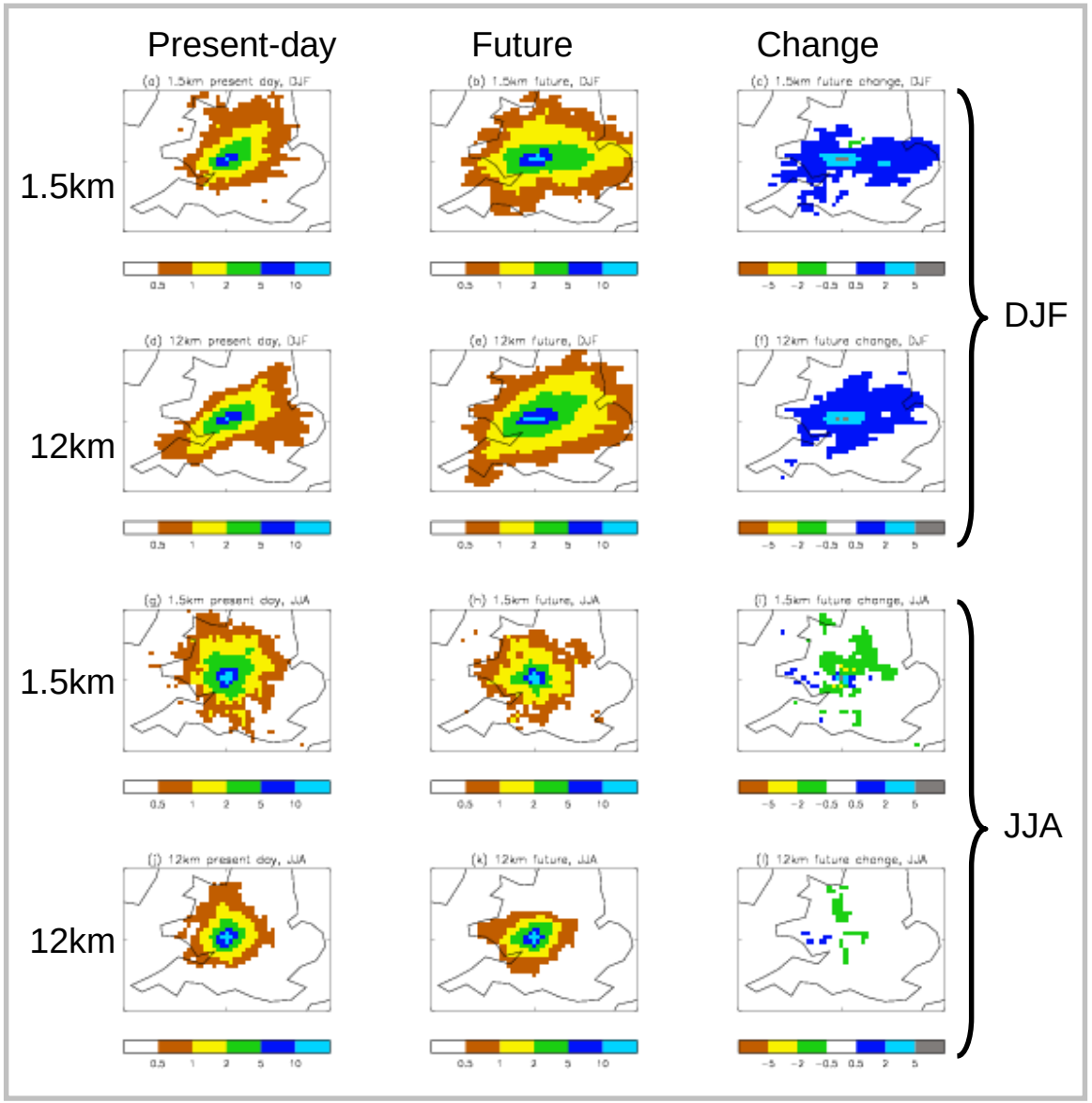
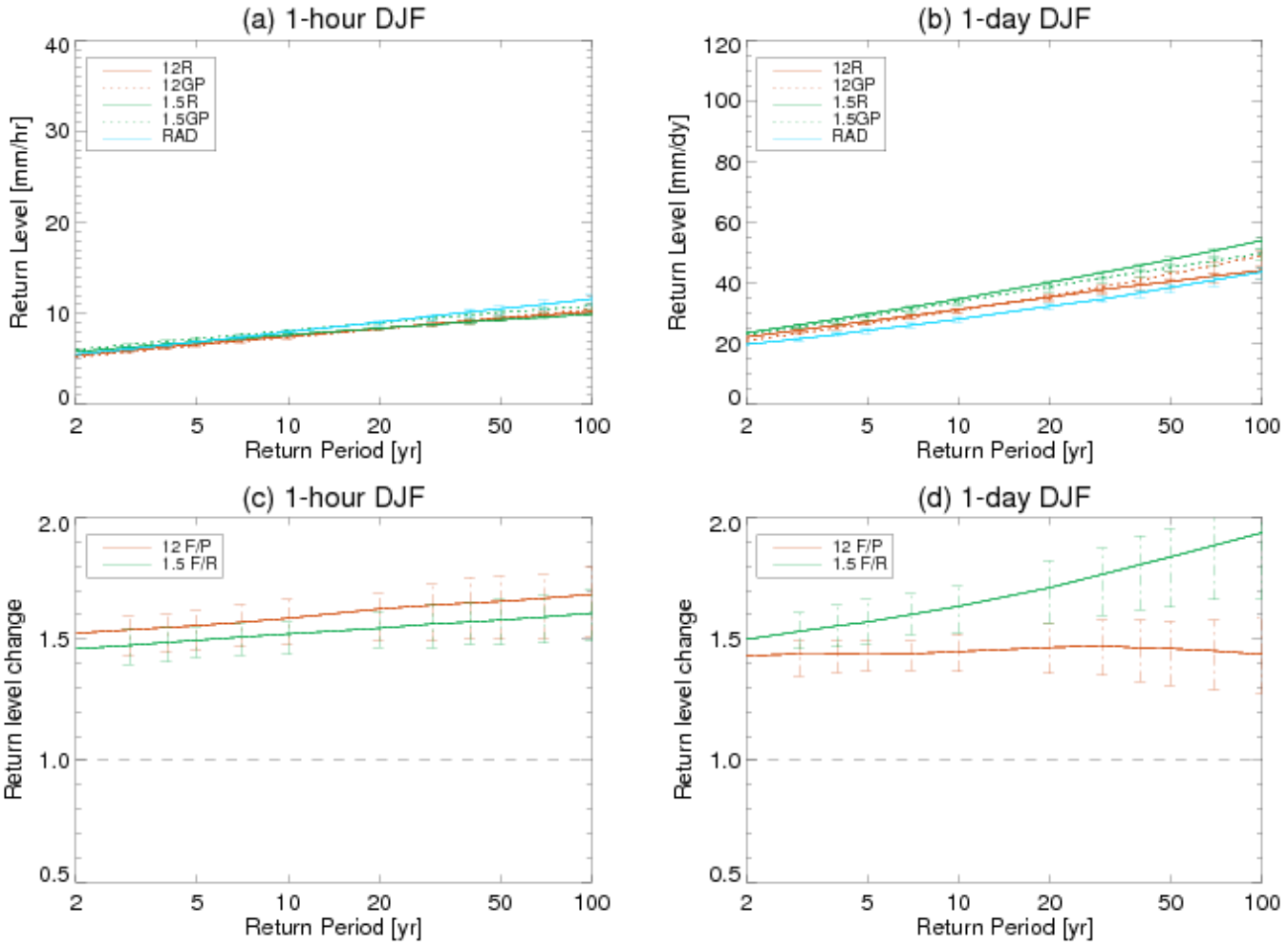
Kendon et al, 2014, Nature Clim. Change

Visualising ‘typical’ heavy events

- Why are there consistent changes in winter, but very different changes in summer?

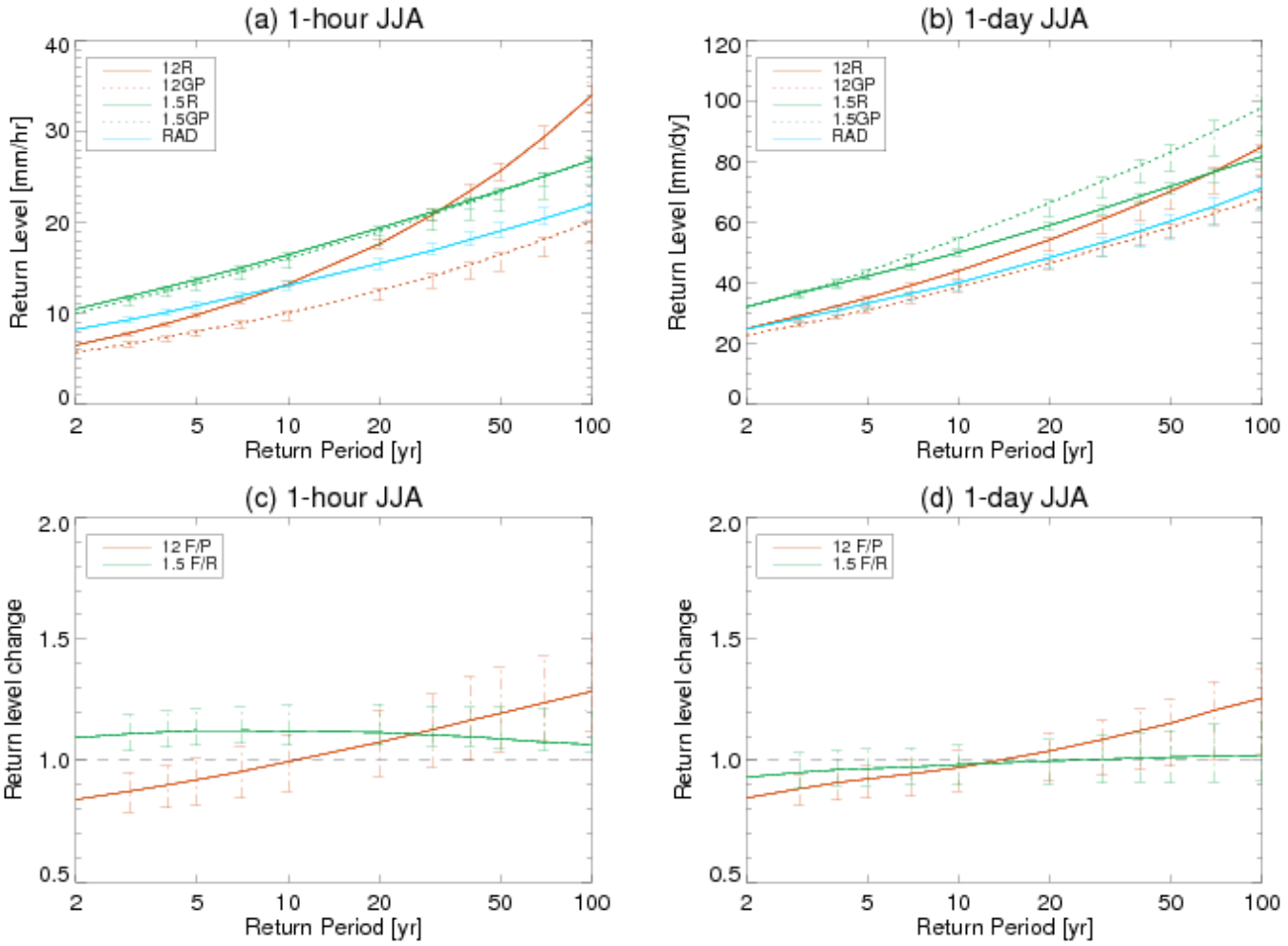


Change in extremes in winter



Chan et al, 2014, ERL

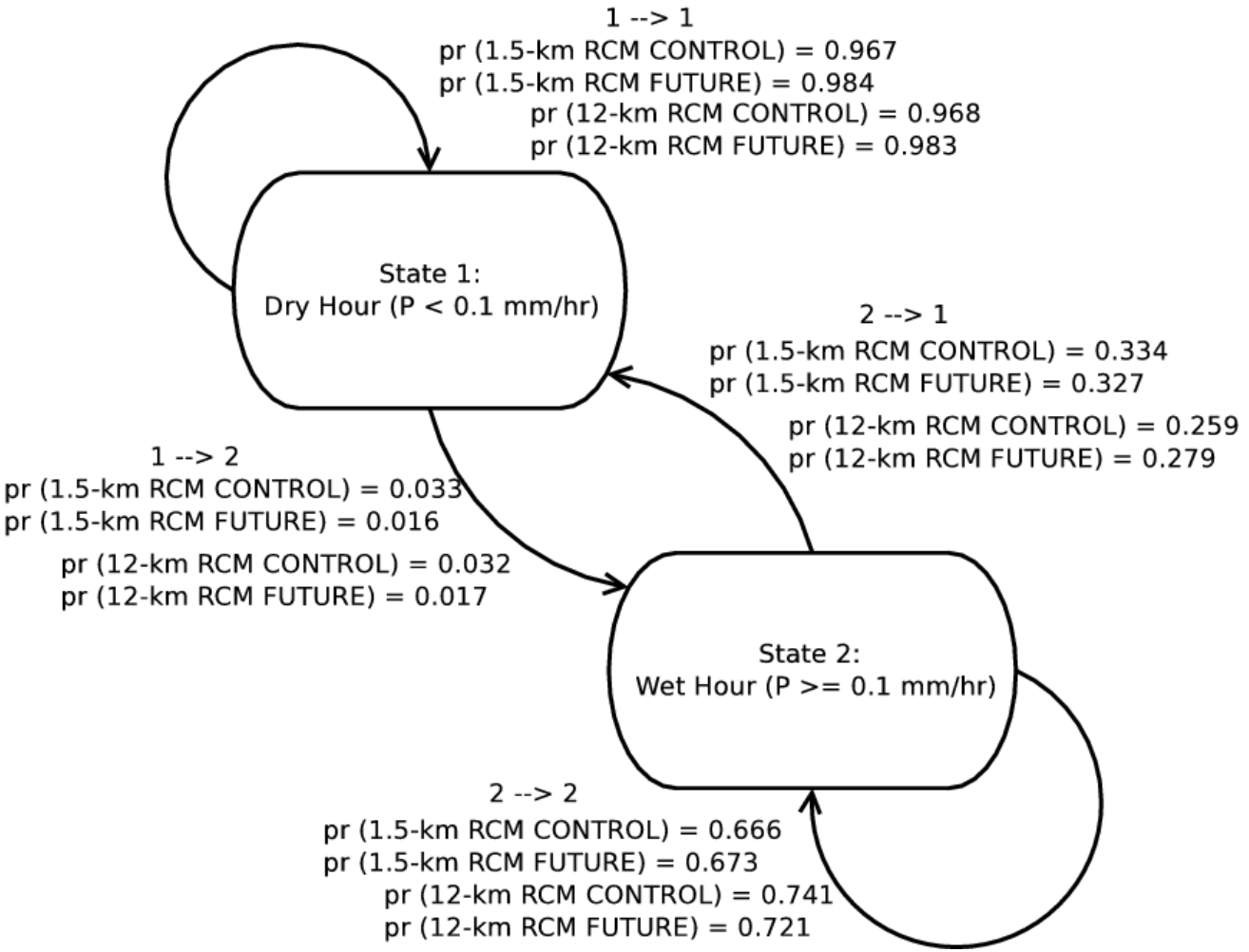
Changes in extremes in summer



Chan et al, 2014, ERL

More intense storms yet drier climate

Dry – wet state matrix for summer



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Conclusion

- Convection-permitting models simulate realistic hourly rainfall characteristics, unlike coarser RCMs, giving us confidence in their ability to project future changes
- Future projections of increases in UK winter rainfall are robust from coarser to higher resolution models.
- Convection-permitting model shows an intensification of hourly rainfall in summer not seen at coarser resolution
  - Significantly more events exceeding high thresholds (30mm/h) indicative of flash flooding
- Large decreases in rainfall occurrence in summer, driven by large-scale changes common to both 1.5km and 12km models
- Convection-permitting model captures present-day scaling between temperature and precipitation intensity, and indicates this cannot simply be extrapolated into the future
- Accurate representation of the local storm dynamics is essential for predicting changes to convective extremes

Current work exploiting 1.5km climate model