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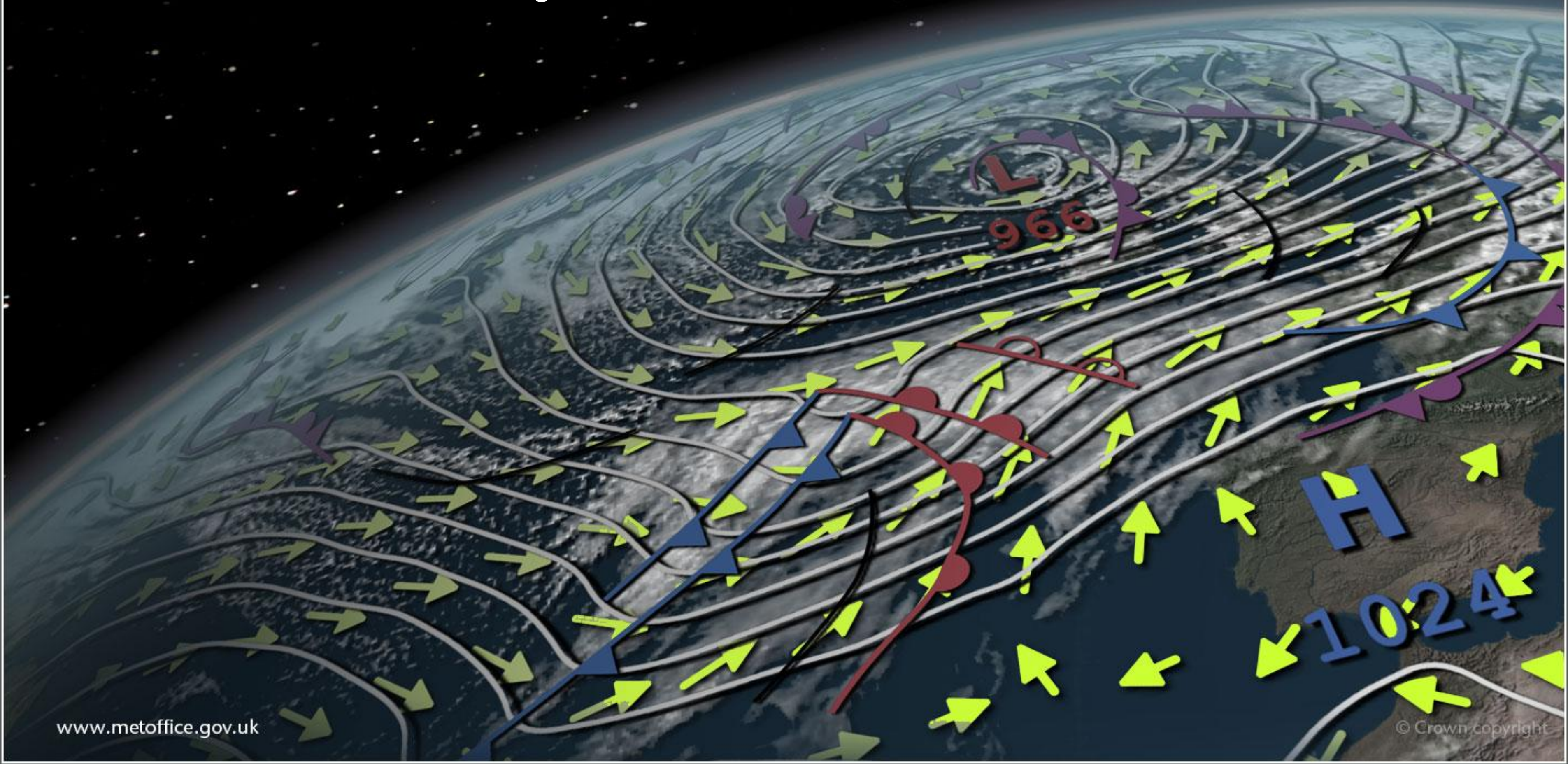
The changing character of rainfall at convection permitting scales

Lizzie Kendon

Thanks to: Nigel Roberts and Steven Chan



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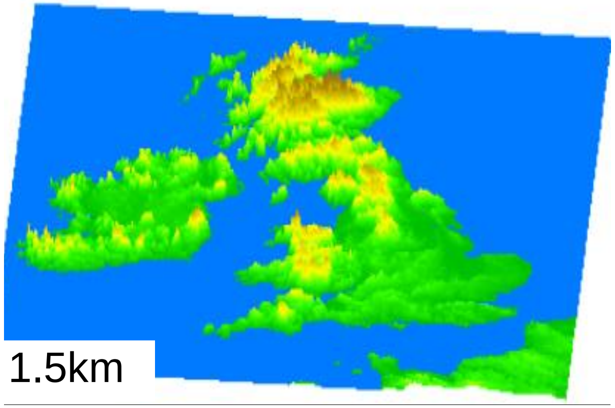
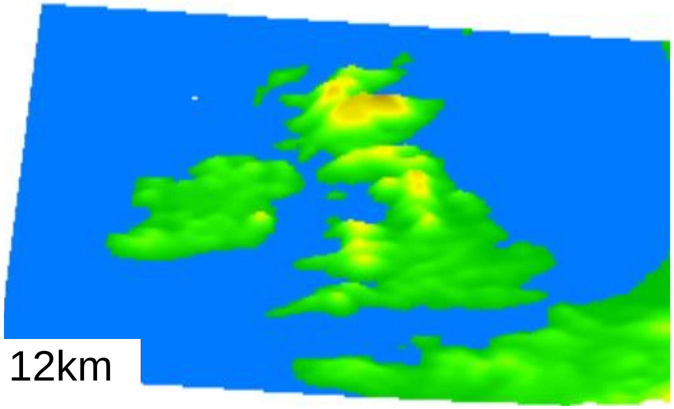
Benefits of high resolution in NWP

- Use of 'convection-permitting' models is now common practice in numerical weather prediction (NWP)
- Explicitly represented convection
  - ➢ Diurnal cycle, showers coming inland, organisation, convective outflows, back-building, realistic rates
- Better local topography
  - ➢ Sea breeze convergence, elevated heating, valley cooling, localised fog, orographic enhancement of rain, peninsular shower bands





Lean et al 2008, Roberts & Lean 2008, Weisman et al 2008, Schwartz et al 2009 & Weusthoff et al. 2010

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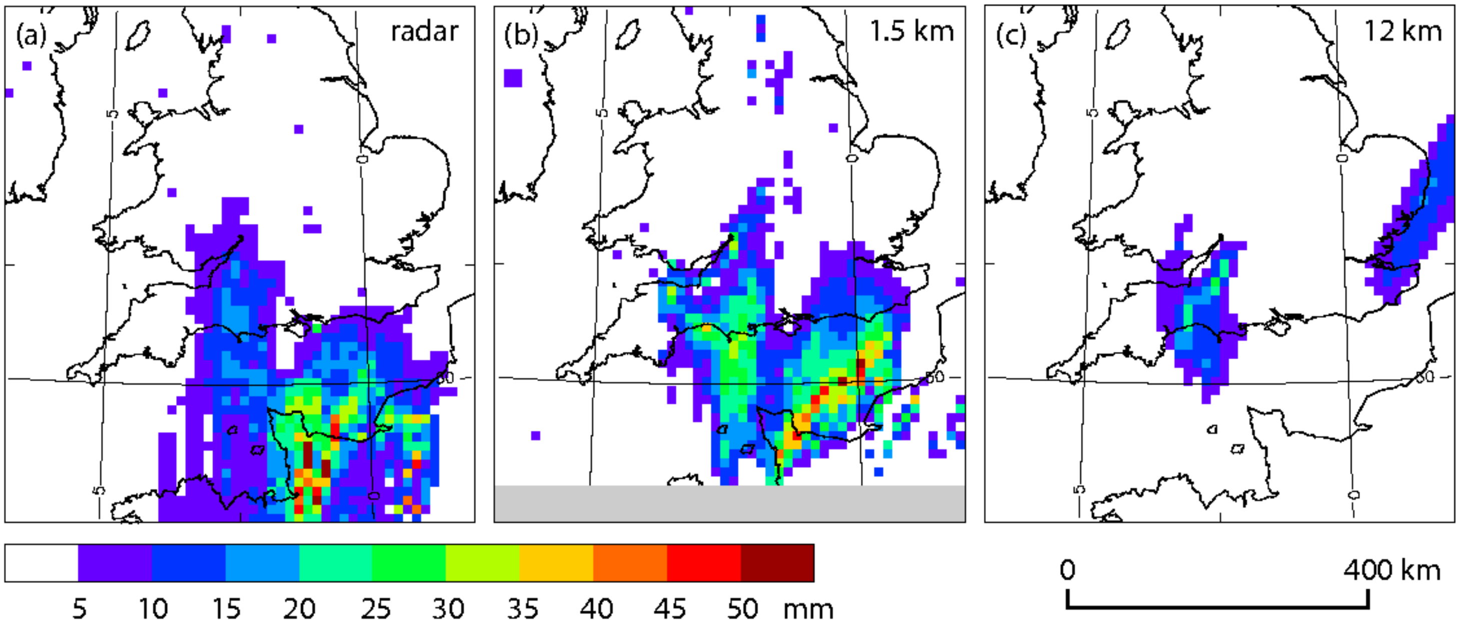
Improved representation of convective storms in 1.5km forecast model



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

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

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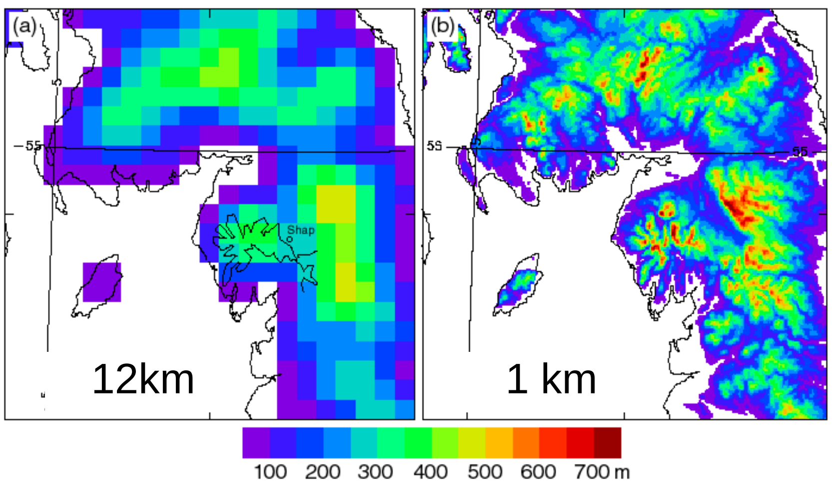
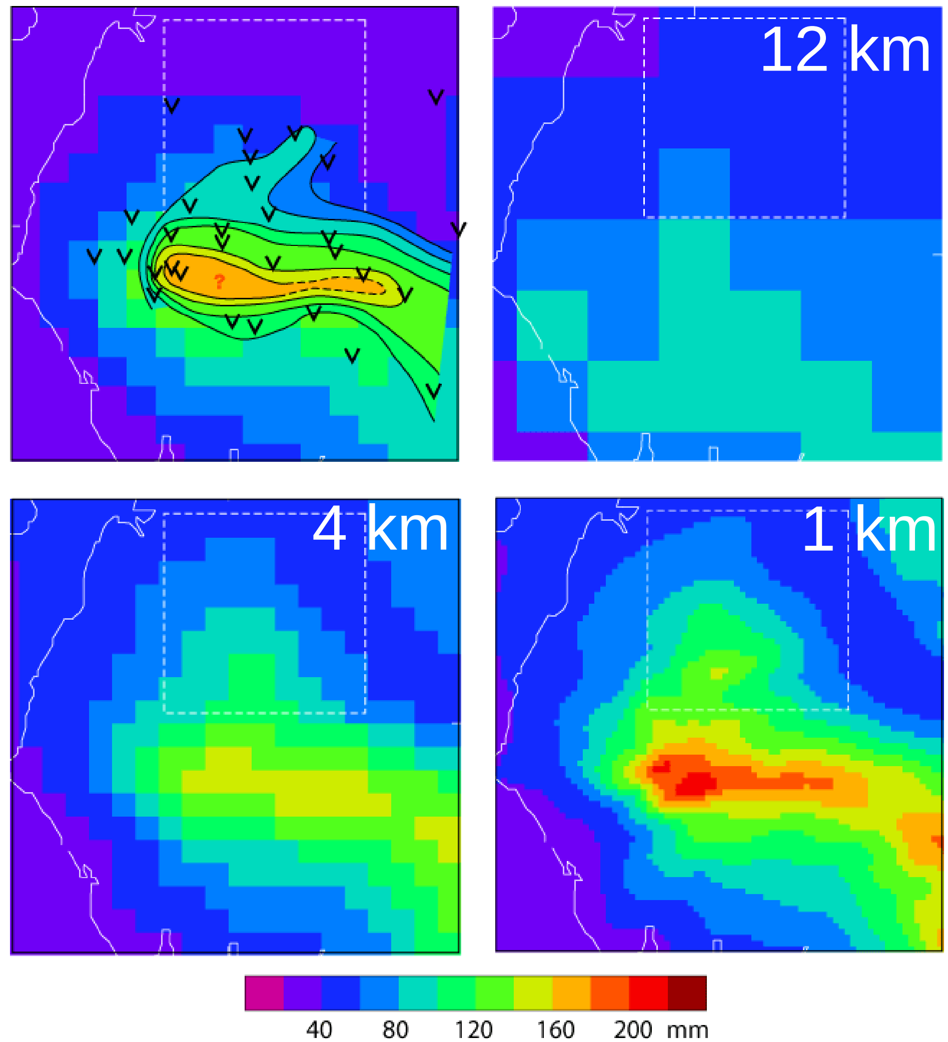
Improved representation of orographic rain at kilometre-scale

Model orography



Rain gauge observations and model forecasts



Case study: Carlisle flood, Jan 2005

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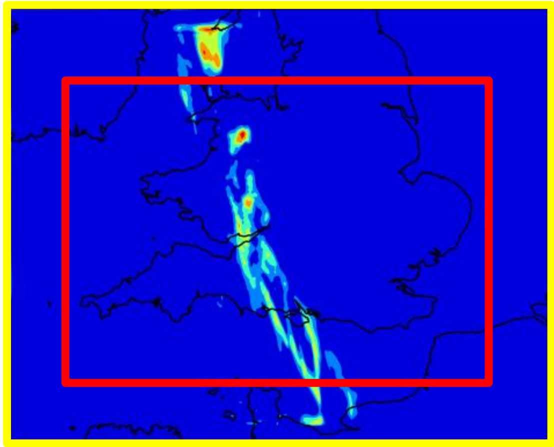
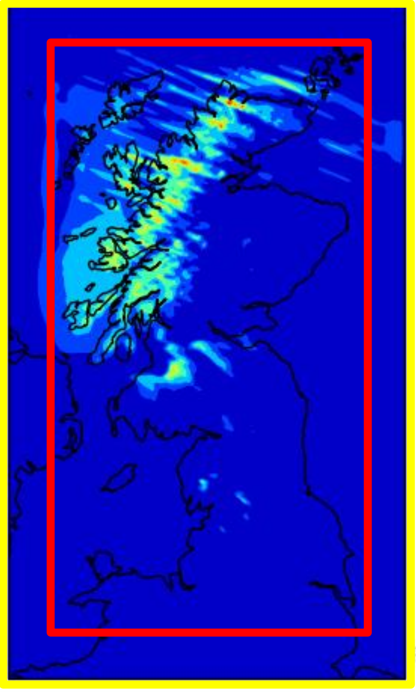
First regional climate simulations at 1.5km resolution over UK



1) First climate simulations at convection permitting scales run over *southern UK*, as part of CONVEX project.

- Driven by 12km European RCM, which is in turn driven by ERA-interim or 60km GCM.
- Runs completed:
  - Reanalysis driven run (1989-2008)
  - 13y control (1996-2009) and future (~2100) climate change experiments



2) Climate simulations, with identical set up, now complete for *northern UK*, as part of NUTCAT project

Daily precipitation (1990-2004)

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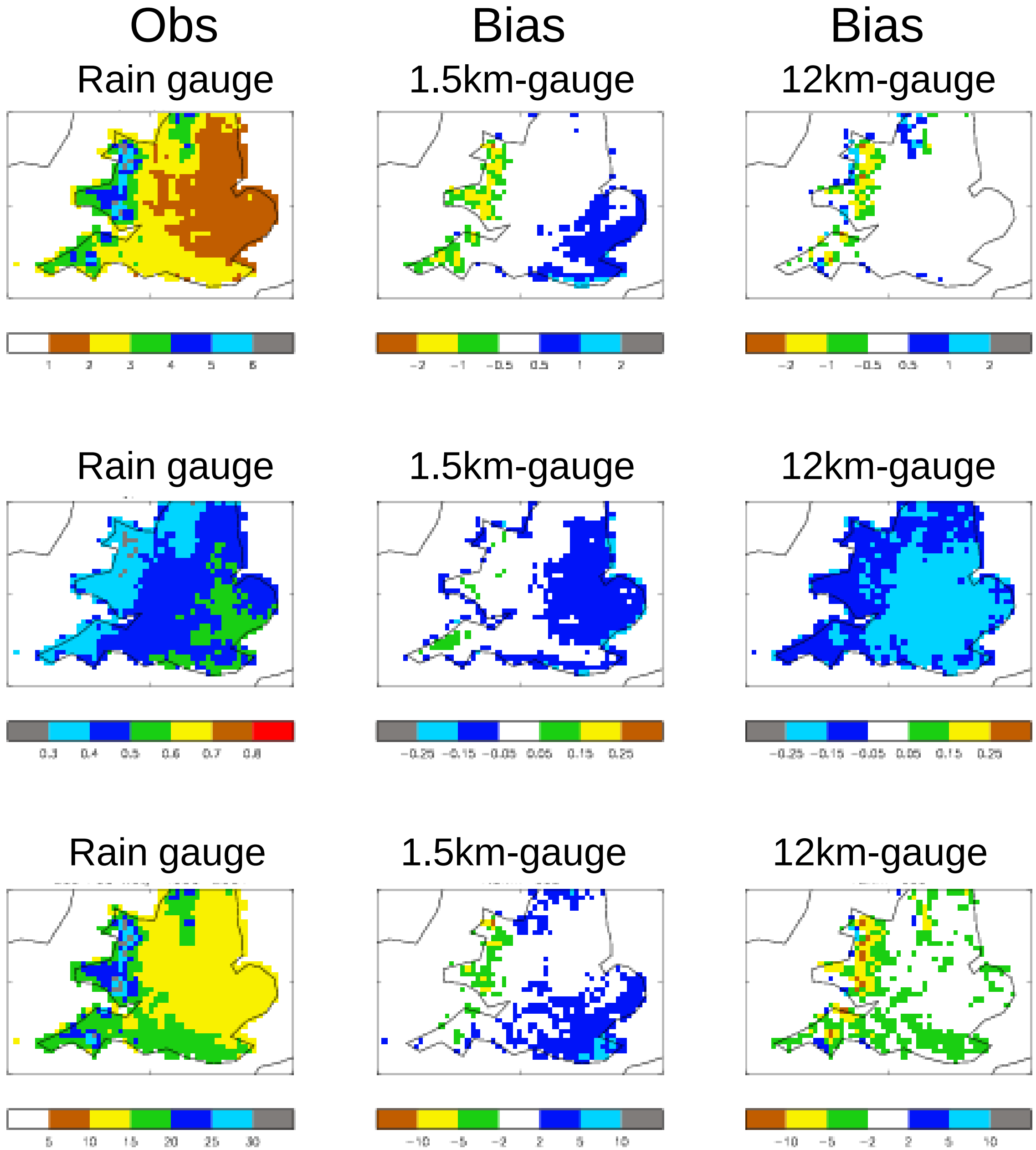

Mean precip

Dry day occurrence

Heavy precip

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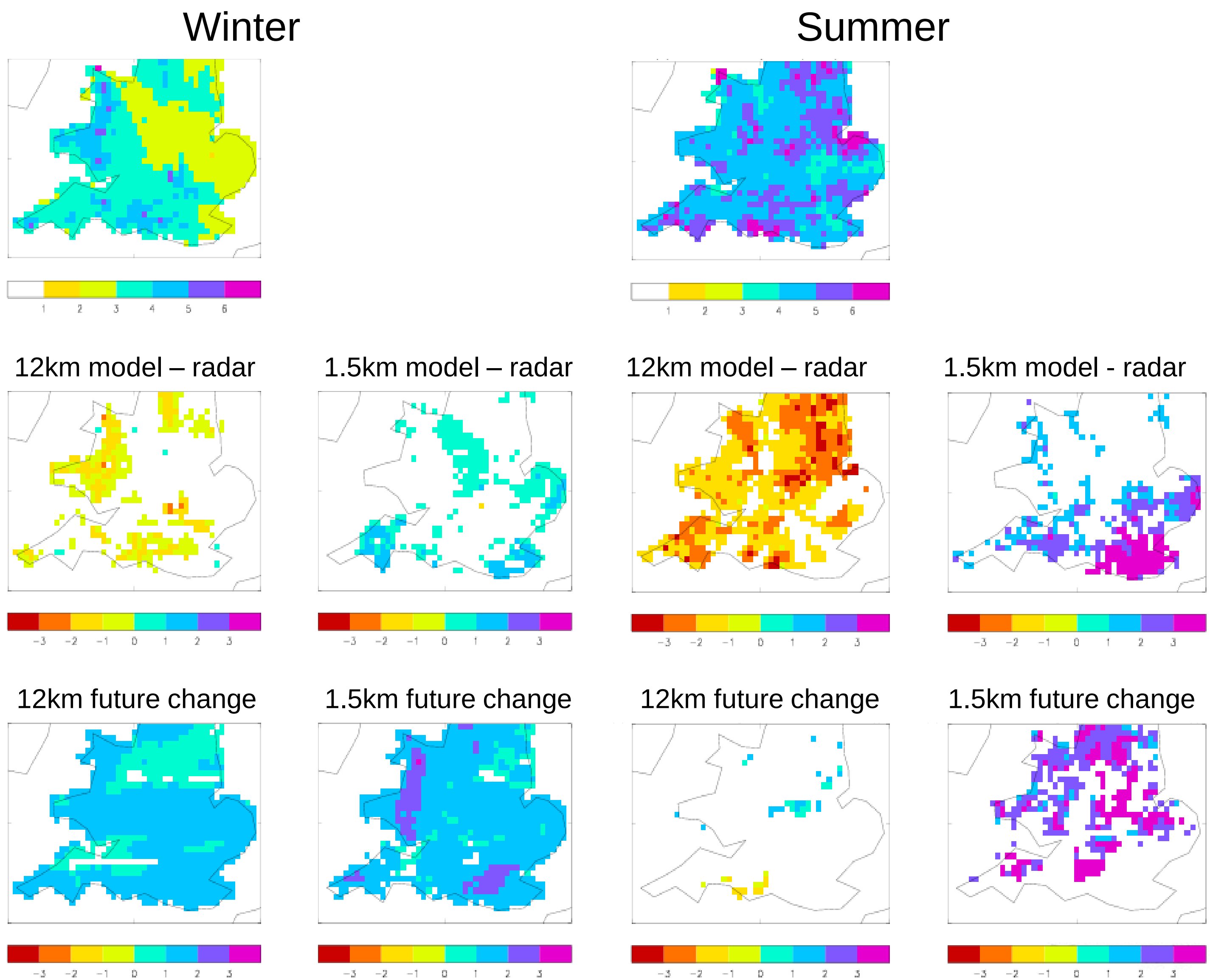
Future changes in heavy rainfall at hourly timescale

Observations

Model bias

Future change



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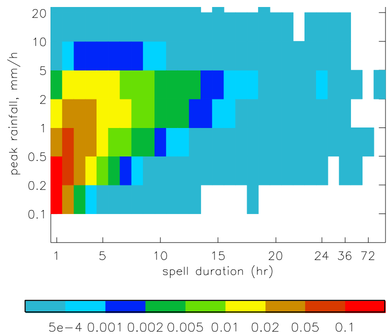
Duration-intensity characteristics of rainfall

Southern UK, Winter

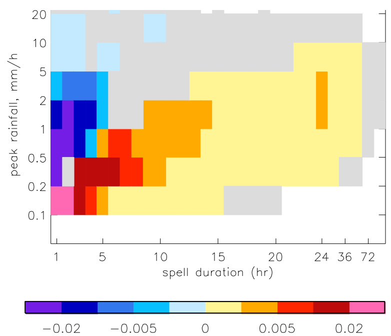
Observations

Observed distribution (radar)

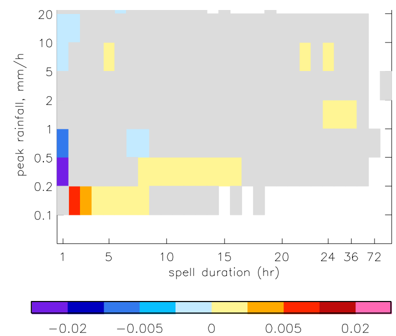


Model bias

12km model - radar

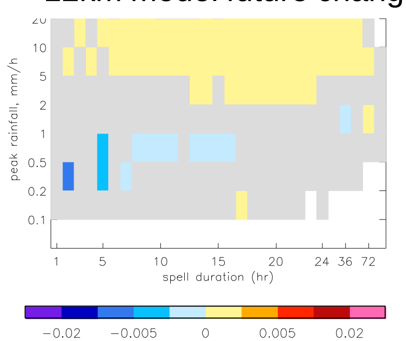


1.5km model - radar

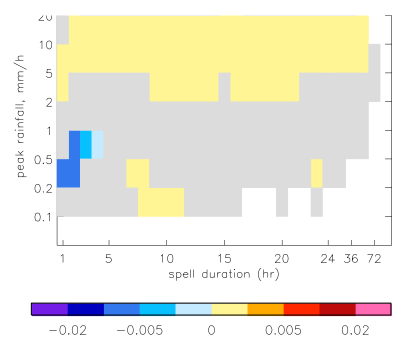


Future change

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

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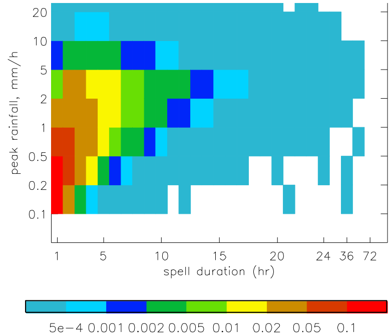
Duration-intensity characteristics of rainfall

Southern UK, Summer

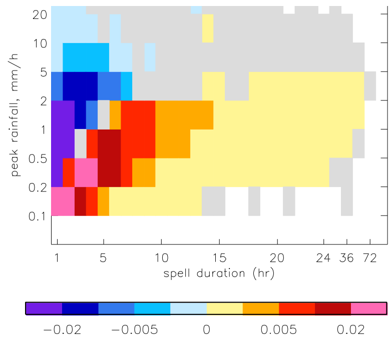
Observations

Observed distribution (radar)

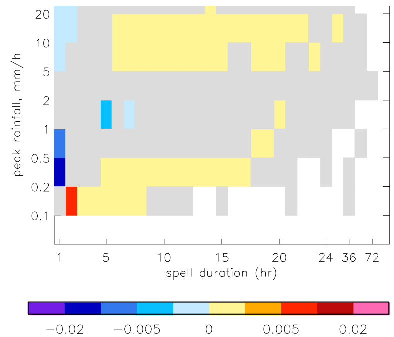


Model bias

12km model - radar

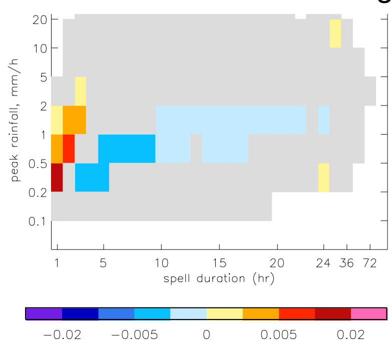


1.5km model - radar

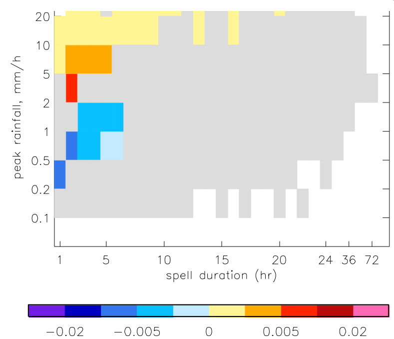


Future change

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

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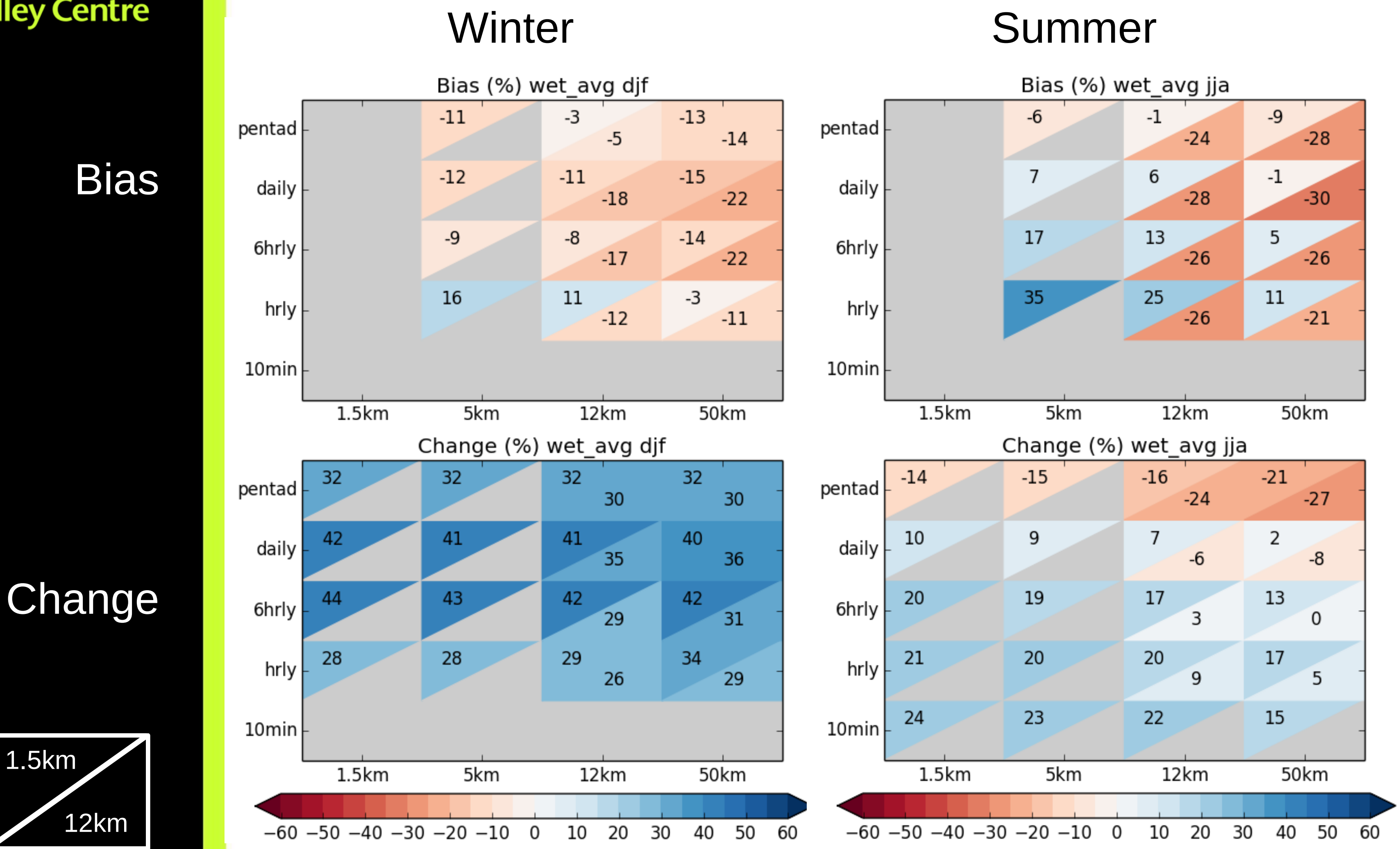
Changes in rainfall intensity across space and time scales



Bias (%) wet_avg djf	1.5km	5km	12km	50km
pentad		-11	-3 / -5	-13 / -14
daily		-12	-11 / -18	-15 / -22
6hrly		-9	-8 / -17	-14 / -22
hrly		16	11 / -12	-3 / -11
10min				

Bias (%) wet_avg jja	1.5km	5km	12km	50km
pentad		-6	-1 / -24	-9 / -28
daily		7	6 / -28	-1 / -30
6hrly		17	13 / -26	5 / -26
hrly		35	25 / -26	11 / -21
10min				

Change (%) wet_avg djf	1.5km	5km	12km	50km
pentad	32	32	32 / 30	32 / 30
daily	42	41	41 / 35	40 / 36
6hrly	44	43	42 / 29	42 / 31
hrly	28	28	29 / 26	34 / 29
10min				

Change (%) wet_avg jja	1.5km	5km	12km	50km
pentad	-14	-15	-16 / -24	-21 / -27
daily	10	9	7 / -6	2 / -8
6hrly	20	19	17 / 3	13 / 0
hrly	21	20	20 / 9	17 / 5
10min	24	23	22	15

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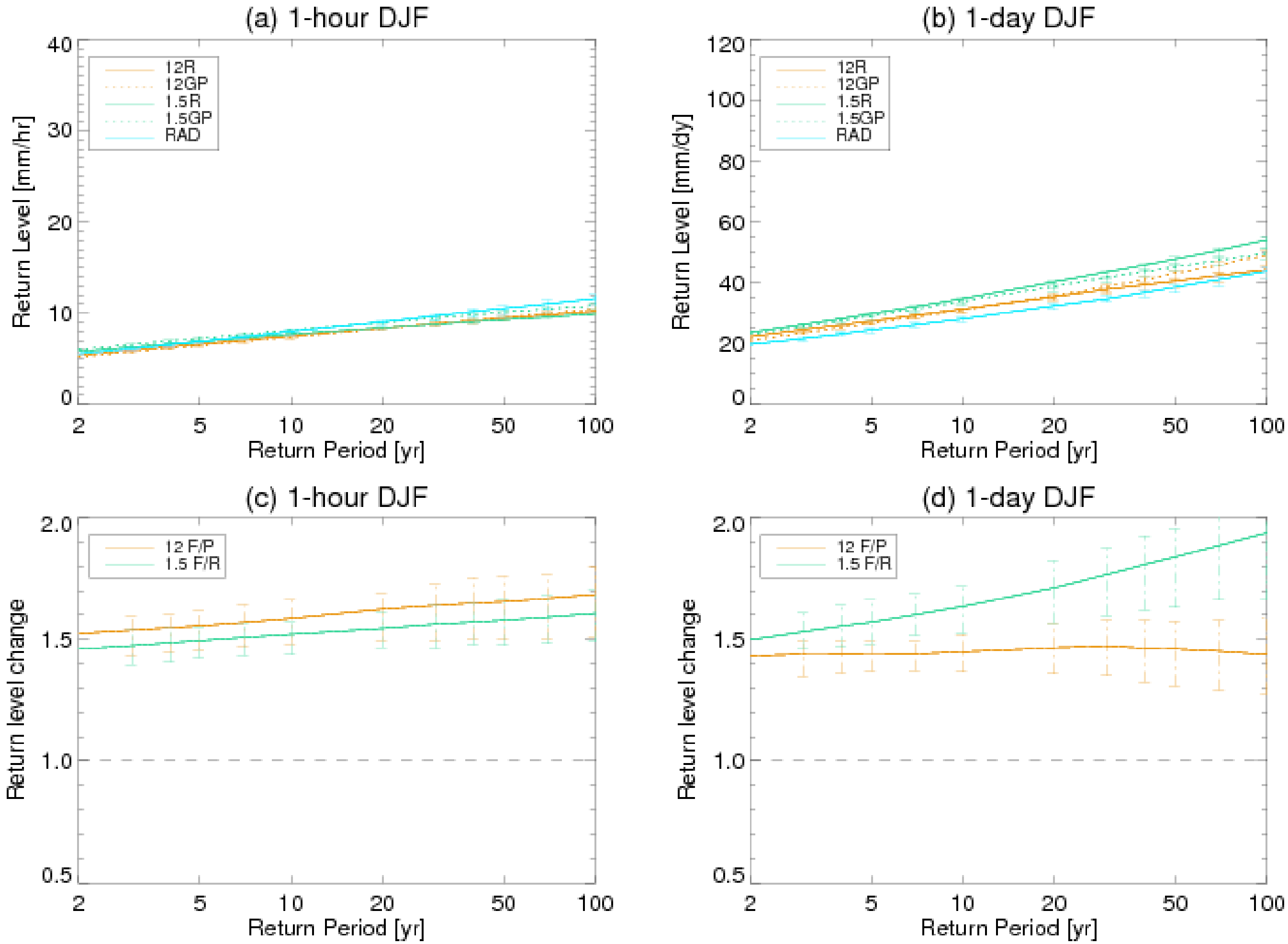
Change in extremes in winter



Chan et al, 2014, ERL

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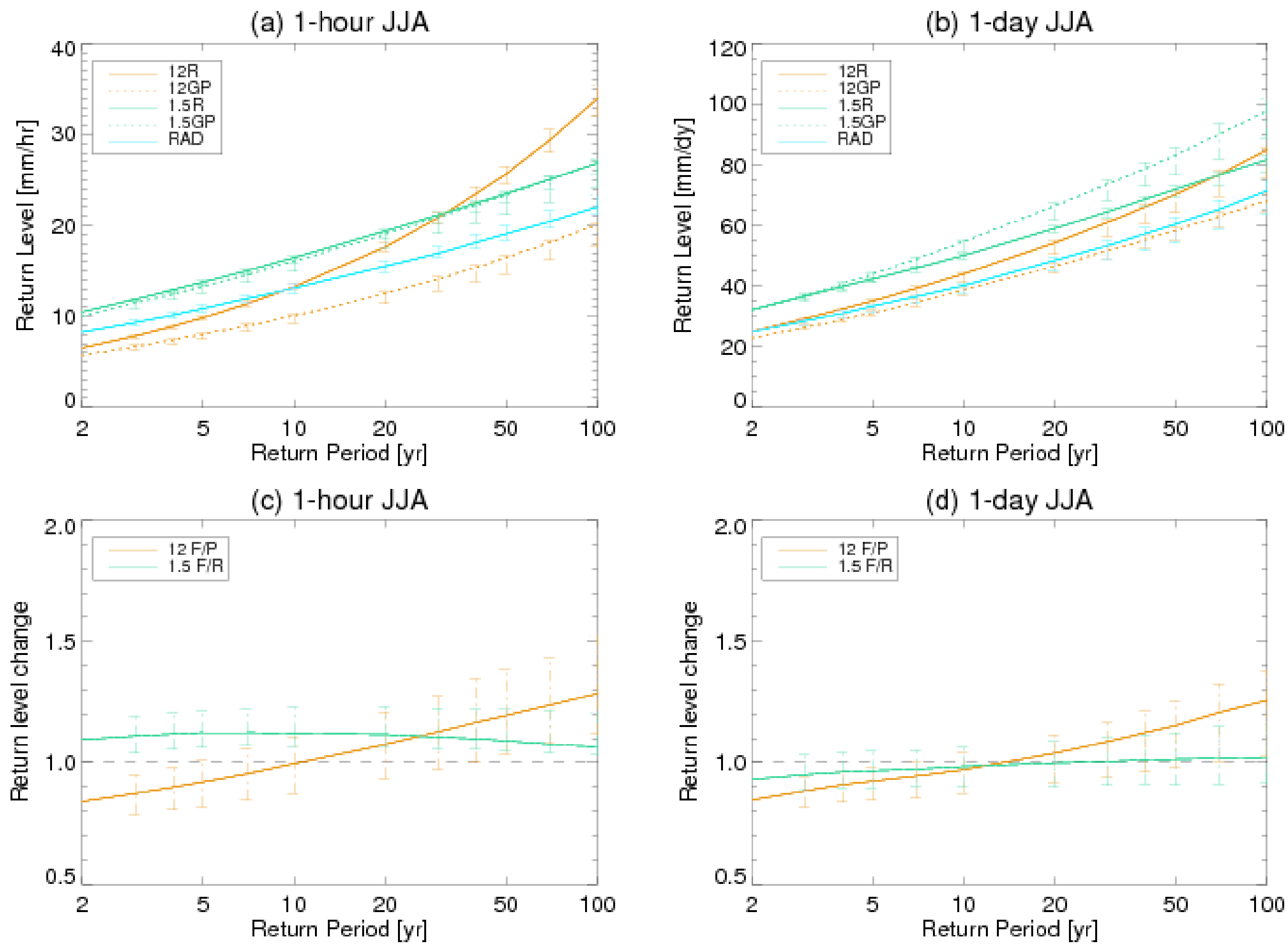
Change in extremes in summer



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Temperature-precipitation scaling

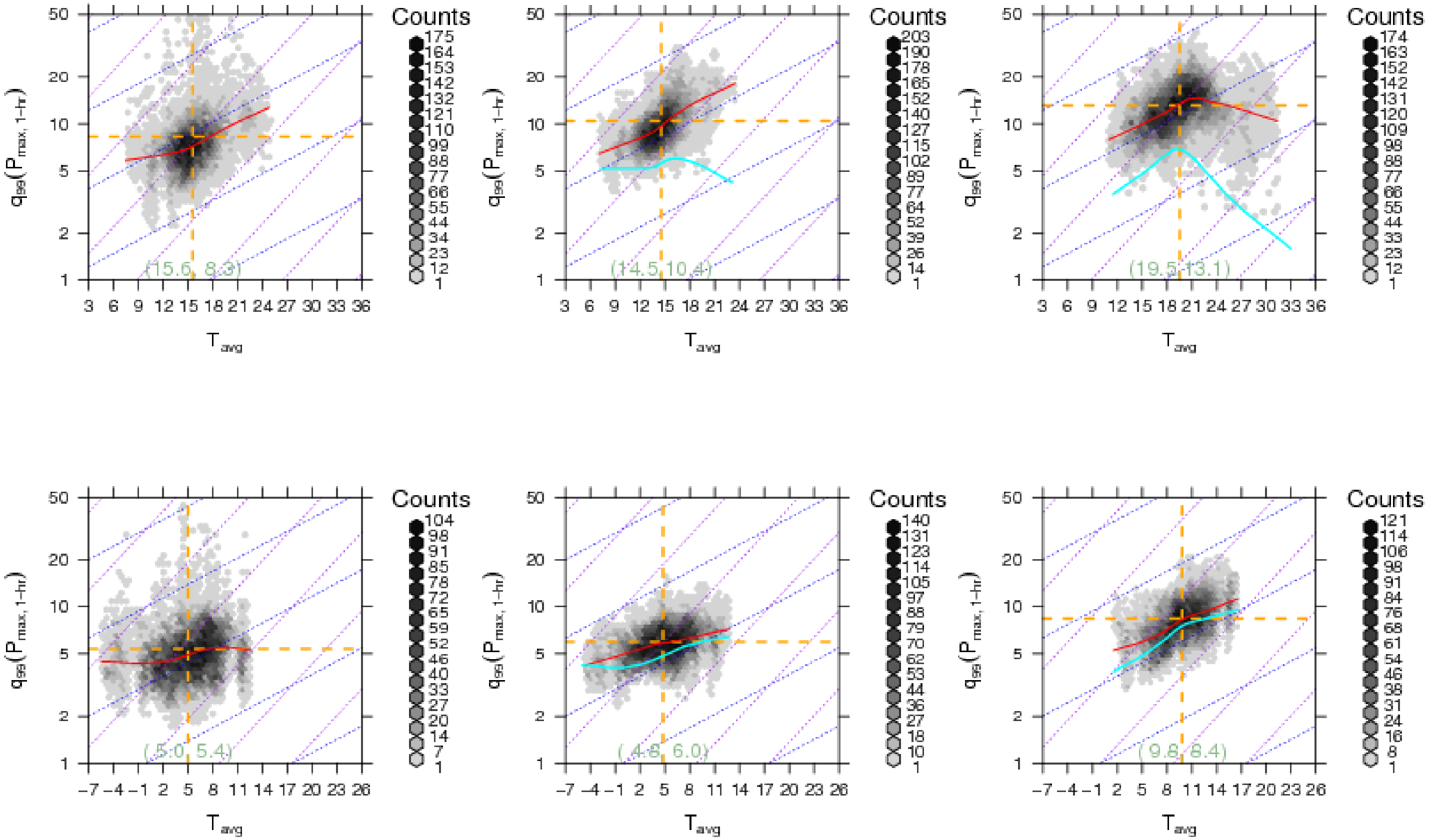
Obs

Present –day 1.5km (red)
12km (blue)

Future 1.5km (red)
12km (blue)

JJA

DJF



Chan et al, Nature Geosci., accepted

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Resolution dependence of UK projections

Changes which are robust from coarser to higher resolution RCM, driven by large-scale changes inherited from driving GCM	Changes for which representation of the local storm dynamics, or high resolution orography, is important
Decrease in summertime mean rainfall	Intensification of hourly rainfall in summer
Increase in wintertime mean rainfall	Changes in hourly and daily summertime extremes
Increase in heavy rainfall in winter	Changes in rainfall extremes over steep orography in winter
Large decrease in rainfall occurrence in summer	Changes in rainfall duration

❖Similar results found for 2.2km simulations over Alps using COSMO-CLM (*Ban et al, 2015, GRL*)

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Summary

- 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
- 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
- Similar results obtained for 2.2km COSMO-CLM over Alps compared to 1.5km MetUM over southern UK

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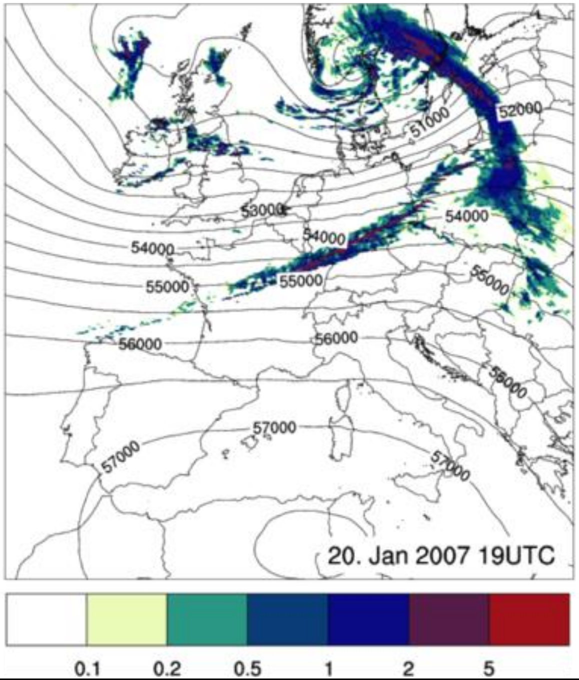
Future outlook

- Convection-permitting climate change simulations to date:
  - 1.5km UK (Kendon et al 2014); 2.2km Alps (Ban et al 2015), 2.8km SW Germany (Fosser et al submitted)
- How robust are changes in hourly rainfall extremes in convection-permitting models?
  - Need for coordinated modelling experiments to assess uncertainties (H2020 EURO-CORDEX)
  - 2.2km pan-European climate simulations
- UKCPnext
  - First probabilistic projections at km-scales

Pan-Europe 2.2km



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