UKCP09 in light of new CONVEX results

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The UK Climate Projections released in 2009 (UKCP09) provide state-of-the-art probabilistic climate projections at 25km resolution over the UK. They include projections of changes to seasonal mean temperature and precipitation, the warmest day of summer and the wettest day of winter and summer (Figure 1). Weather generator results from UKCP09 provide time series data at high spatial resolution (5km) but the climate change information in these is only at the 25km scale.

UKCP09 projections form the basis for assessing the likelihood of different outcomes, consistent with climate modelling capability and understanding at the time of release. As our modelling capability and understanding improves we expect these projections will change, and here we assess how new results from the CONVEX project contribute to this.

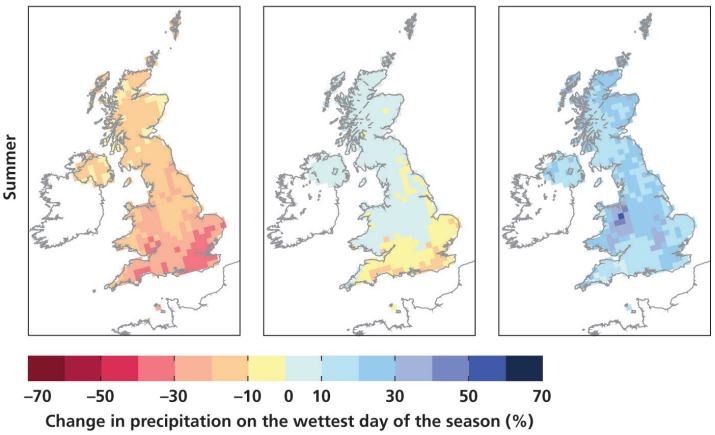

Figure 1. UKCP09 projected changes in the wettest day of summer (%) by 2080s under medium emissions scenario. Shown are changes at the 10% (left), 50% (middle) and 90% (right) probability levels corresponding to "very unlikely to be less than", "central estimate" and "very unlikely to be greater than".

As part of CONVEX, the Met Office Hadley Centre has carried out new climate change simulations at very high resolution (kilometre-scale grid spacing) for a region of the UK. This represents a major step forward in our modelling capability, and provides a first look at how convective storms may change in the future.

Only a single model integration for the present-day and a future climate scenario has been carried out with this high resolution model, due to computational cost – and so we are not able to provide probabilistic projections at kilometre-scales. However, the new results from CONVEX do allow us to explore the possibility of extending UK adaptation advice to consider aspects which are beyond the capabilities of the modelling underpinning UKCP09. Also, they allow us to begin identifying those aspects of coarser resolution model projections (e.g. from UKCP09) which are considered more robust, and conversely those which are notably different at higher resolution (Table 1).

Cars in flood on the Great North Road, Newcastle upon Tyne. Photo from the 28th June 2012 "Toon Monsoon" event in Newcastle upon Tyne, UK, where there was almost 50mm rainfall in 90 mins. ncjMedia Ltd - John Millard.

Changes which are likely to be robust from coarser to higher resolution models, driven by large-scale changes inherited from global climate models	**Changes for which representation of the local storm dynamics, or high resolution orography, is important**
=> Confidence in coarse resolution climate model projections	=> Need for very high resolution (km-scale) model for accurate projections
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	Increases in multi-hourly rainfall extremes over steep orography in winter
Large decrease in rainfall occurrence in summer	Changes in rainfall duration

Table 1: Summary of those aspects of UK rainfall change which are well represented in typical climate models, and those for which the CONVEX results show the need for new very high resolution modelling.

CONVEX results suggest that kilometre-scale models are needed to provide sufficiently reliable projections of future changes in the duration and intensity of summertime rainfall. The more detailed representation of the land surface relief (orography) used at high resolutions also appears to be beneficial for representing changes in heavy rainfall over mountains in winter. In addition to rainfall, there are other variables for which high resolution climate models may be needed to provide reliable future projections, but further research is required to establish if this is the case. For example, they could include urban temperature projections, severe wind gusts, fog and lightning. This has implications for a number of impact areas (Table 2).

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Impact area	UK climate projections currently available	New information from high resolution model
Flash flooding (important in urban areas and small, steep catchments)	Heavy rainfall is expected to increase in winter. Coarse resolution climate models are unable to provide reliable projections of future changes in short duration intense rainfall, important in summer.	First evidence that intense rainfall events, associated with severe flash flooding (30mm/h), could become several times more frequent by 2100. Increases in intensity of hourly rainfall extremes are seen in both winter and summer.
Renewable energy (wind energy)	Future changes in wind are uncertain. 12-25km resolution models with appropriate gust diagnostics can represent cyclonic storms and their associated winds, but not the most severe convective wind gusts.	Kilometre-scale models are needed to represent severe wind gusts, associated with convective squall lines.
Transport (flooding, visibility, strong winds and snow)	Heavy rainfall is expected to increase in winter, with an associated increase in large-scale flooding, but see above for flash flooding. 25km models suggest reduced fog in future in many regions and seasons, but with considerable uncertainty. Coarse resolution models should be sufficient for projecting changes in cyclonic storms and temperature-driven changes in snow.	See above for flash flooding. High resolution models are required to adequately represent local fog and severe wind gusts, which may be very disruptive to transport. High resolutions may be required for accurate snow projections over mountainous regions.
Urban heat	Urban areas are warmer than rural surroundings, and can increase heat stress especially into the evening and night. Coarse resolution models show increases in temperature extremes, but do not adequately describe the urban environment.	The km-scale model can better include cities, and hence allows us to examine future temperature projections in urban areas with greater confidence.
Electrical distribution (lightning)	25km models suggest increases in the number of lightning days in future, however there is considerable uncertainty regarding the accuracy of coarse model lightning diagnostics.	A new lightning diagnostic, developed for the Met Office km-scale model, has the potential for more accurate lightning predictions.

Table 2: Summary of future climate projections currently available for the UK and new information from CONVEX, for different impact areas.

In addition, within CONVEX a new hourly rainfall observational dataset has been developed and quality controlled for the UK at Newcastle University using data from the UK Met Office, the Environment Agency and the Scottish Environment Protection Agency, and there are plans to further develop this dataset into a km-scale gridded product. These observations have been compared to outputs from the high resolution climate model runs as well as being analysed themselves. Results suggest that in the short observational time series available, there are no significant trends in rainfall intensity for summer short-duration events. However, the intensity of summer storms are shown to be linked to temperature in an approximately Clausius-Clapeyron scaling (~6.5% increase in rainfall intensity for 1°C temperature rise), particularly under anticyclonic conditions.

Boscastle flood, 16 August 2014. This was due to several hours of torrential rain, which was well forecast by the 1km forecast model.

Incorporating CONVEX results into the UKCP09 Weather Generator

The improvements in both observational understanding of hourly rainfall statistics and the projections from km-scale models could be incorporated within the UKCP09 Weather Generator. The new observational results would allow us to improve the parameterization of the UKCP09 Weather Generator for hourly rainfall extremes and particularly improve the simulation of summer hourly rainfall extremes. Projected changes from the km-scale climate model runs could also be used to investigate the possibility of reconfiguring some of the hourly changes in intense rainfall, noting that additional km-scale simulations would be needed to provide information sufficiently robust to be included in any future operational release of the weather generator. This could potentially provide a mechanism of improving the representation of changing hourly rainfall intensities within UKCP09. This would not be an alternative to UKCPnext but instead sit alongside this as the Weather Generator is able to provide numerous stochastic runs which can be used to test system robustness and account for model bias.

UKCPnext

For UKCPnext there are plans to carry out higher resolution regional climate downscaling. This includes the possibility of using kilometre-scale models for the UK (such as those used for operational forecasting as shown in Figure 2) to provide advice on how local, sub-daily extreme rainfall events may change.

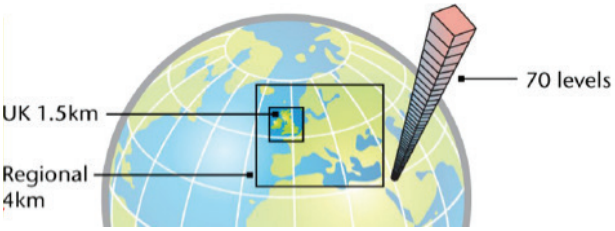

Figure 2: Model configuration used for operational weather forecasting at the UK Met Office