Natural Environment Research Council

UK CLIMATE RESILIENCE PROGRAMME

FUTURE-DRAINAGE: Ensemble climate change rainfall estimates for sustainable drainage

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Newcastle University · JBA consulting · Loughborough University · Met Office

Overview of FUTURE-DRAINAGE

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Aim:

- To provide revised rainfall uplifts for climate change in line with UKCP18, to assess the uncertainty in these rainfall uplifts and provide new guidance for urban drainage design and modelling surface water flooding in urban areas.

- Funded by NERC for 12 months (until Oct 2020)

Newcastle University | JBA consulting | Loughborough University | Met Office

Overview of FUTURE-DRAINAGE

Project Team:

- Newcastle University: Hayley Fowler, Steven Chan
- UK Met Office: Elizabeth Kendon
- JBA Consulting: Murray Dale, Rob Lamb
- Loughborough University: Qiuhua Liang, Xilin Xia, Xiaodong Ming, Huili Chen

Overview of FUTURE-DRAINAGE

<u>Objectives:</u>

- Assess regional pooling approaches for uplifts
- Revise existing uplifts based on high-resolution climate models from UKCP18 and other UKCP18 products
- Examine the impact of the revised uplifts on sewer flooding
- Compare the national RoFSW methodology to outputs from fully dynamic urban flood models using the revised uplifts to assess the level of detail needed for future urban predictions.
- Produce new guidance on methodologies for UK urban drainage design and urban flood risk assessment based on UKCP18.

Overview of FUTURE-DRAINAGE

Stakeholder Interactions:

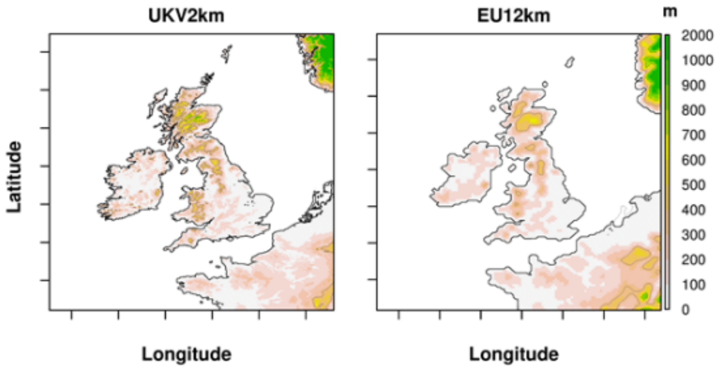
- Initial workshop to input stakeholder needs into design of outputs (September 2019).

- Final workshop to release new guidance and tools (TBD).

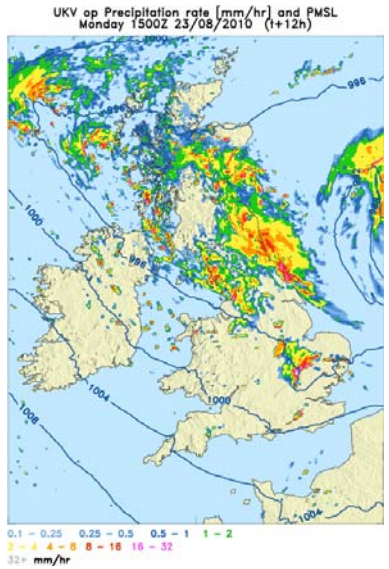
Proposed project outputs:

- Revised regional rainfall uplifts for two future time-slices (2021-2040, 2061-2080 relative to 1981-2000) for RCP8.5 for 1h, 3h, 6h, 12h, 24h for a number of return periods.
- Assessment of uncertainties in uplifts from climate projections and methodological construction.
- Recommendation on required revisions to RED-UP tool.
- Flood maps for 6 UK cities using best estimate and worst reasonable case uplifts, assessing uncertainties.
- Guidance on use of rainfall uplifts, managing uncertainties in the projections, using uplifts to generate urban flood risk projections, monitoring and uptake

What are the 2.2km UKCP Local projections?



New set of 12 climate projections using a model as detailed as that typically used for weather forecasts



Enabling us to explore

New estimates of changes in daily and hourly extremes
- Storms
- Summer downpours
- Severe wind gusts

Supports UK risk assessments

Hydrological impacts modelling e.g. flash floods

Climate change for cities e.g. urban extremes

First ensemble of climate projections at convection-permitting scale

What are the 2.2km UKCP Local projections?

The Local (2.2km) model better represents small scale behavior in the real atmosphere, such as convection.

Local (2.2km) better captures the influence of mountains, coastlines and urban areas, due to the high resolution.

Specification of urban areas is much more precise

Local (2.2km) describes the types and extremes of weather for your local area over coming decades.

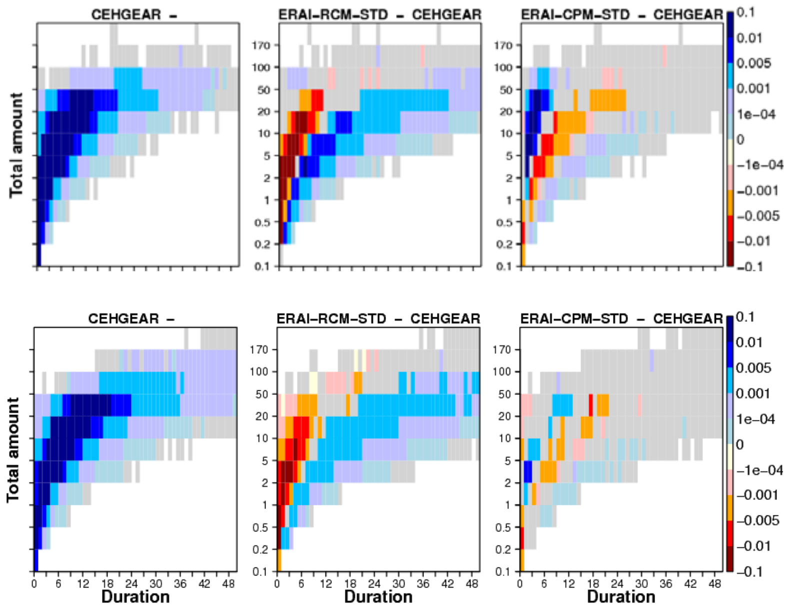
What are the 2.2km UKCP Local projections?

Met Office

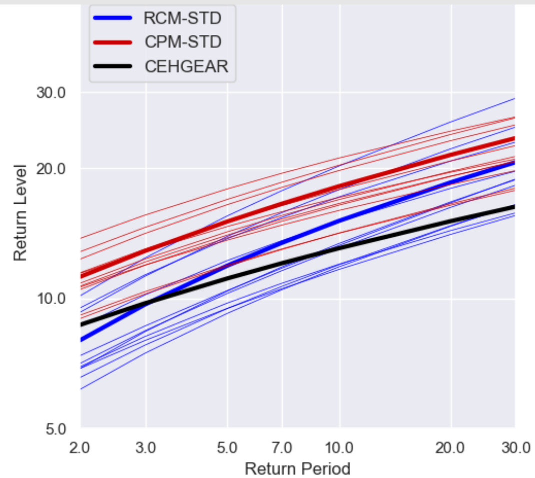
Local (2.2km) better simulates hourly rainfall, including extremes.

For the first time, it provides credible information for changes on hourly scales.

Amount-duration of (top) summer and (bottom) winter rainfall events



Extreme hourly precip over southern UK, JJA



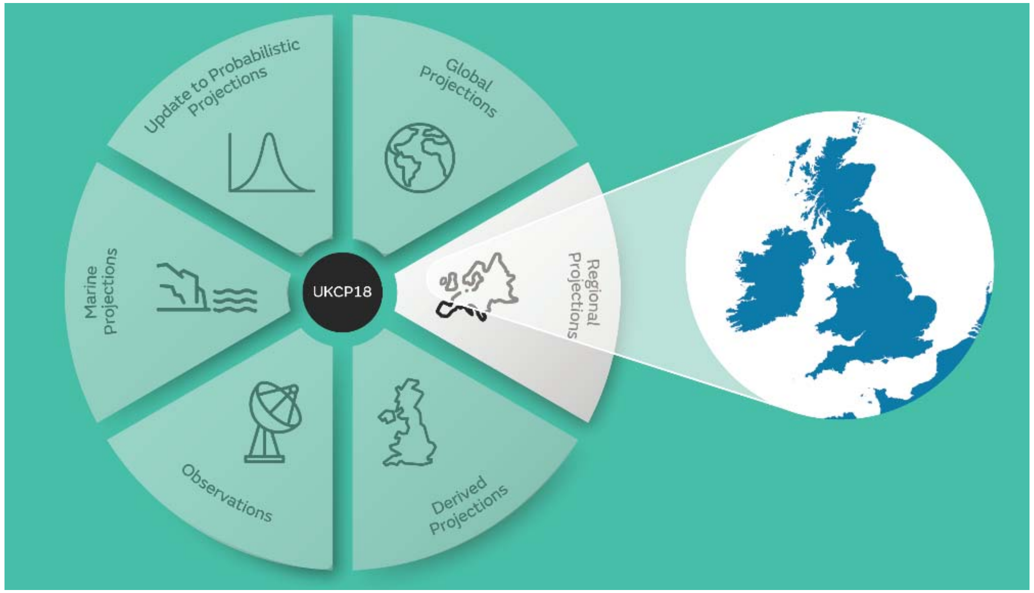
Local 2.2km overestimates hourly extremes, but gives better representation of the rate at which extremes increase with increasing return period ("growth-curve")

Local (2.2km) gives some improvements in how rainfall varies day-to-day and hour-to-hour.

Projecting the future using the Local (2.2km)

UKCP18 2.2km ensemble

- 2.2km resolution for UK
- 12 members driven by 12km Regional
- 1981-2000, 2021-40, 2061-80
- High emissions scenario RCP8.5
- GCMs/RCMs use physical parameter perturbation to obtain ensemble spread



The local (2.2km) results do not change the UKCP18 headline message of a "**greater chance of warmer wetter winters and hotter drier summers**" across the UK in future

Local 2.2km adds further capability to the UKCP18 suite of climate projections.

Challenges in estimating return levels from climate model data

UK CLIMATE RESILIENCE PROGRAMME

- **<u>Goal:</u>** To make meaningful estimates for extreme rainfall return levels and their future changes using the state-of-the-art climate model projections
- Kilometre-scale (“convection permitting”) model simulations like UKCP Local have good representation of precipitation extremes
- But pose challenges for traditional approaches in dealing with regional extreme estimates (e.g., regional frequency analysis; Hosking and Wallis 1997) as spatial-temporal correlation and spatial inhomogeneities difficult to account for

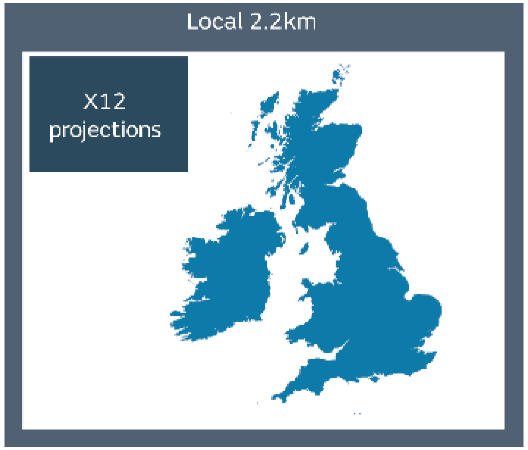
New spatial approach to estimate return levels

Estimation of extreme value distribution for all grid points (Youngman 2018)

- Works for multiple extreme value modelling approaches (annual maximum, peaks over threshold, and point process –chosen here)

- Use **Generalised Additive Model** (GAM) (Hastie and Tibshirani 1986) to spatially smooth the parameters and reduce noisiness, fitted to 2n largest events per year

- The x and y coordinate covariates are used to spatially smooth the extreme value parameters of the point process. The approach computes the estimates for all grid points together, considering that points around the same (x, y) should have similar parameters. In the past, we have estimated parameters at each (x, y) grid point separately, hence we produced more noisy estimates as the method ignored estimates from nearby grid points.

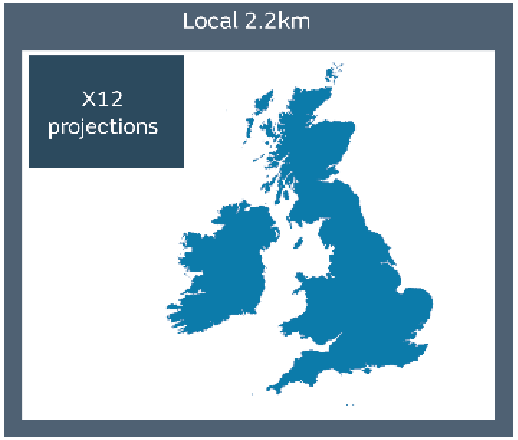


New spatial approach to estimate return levels

Estimation of extreme value distribution for all grid points (Youngman 2018)

- <u>Additional covariates add local information to the extreme parameters</u>:
  - We use **only one covariate**: mean climatological precipitation and hourly precipitation intensity for daily and hourly extremes respectively, and a single shape parameter is fixed for the UK
  - The model accounts for the way orography and coastlines affect precipitation dependent on wind direction (windward vs lee). The goal is to use the actual mean precipitation as a proxy (based on an approach used to model wind extremes in Youngman, 2018)

- Adjustments (Ribatet et al. 2012) are applied to account for temporal co-occurrence of extremes for the same month
- The Youngman (2018) method is applied to data for each ensemble member and time-slice separately

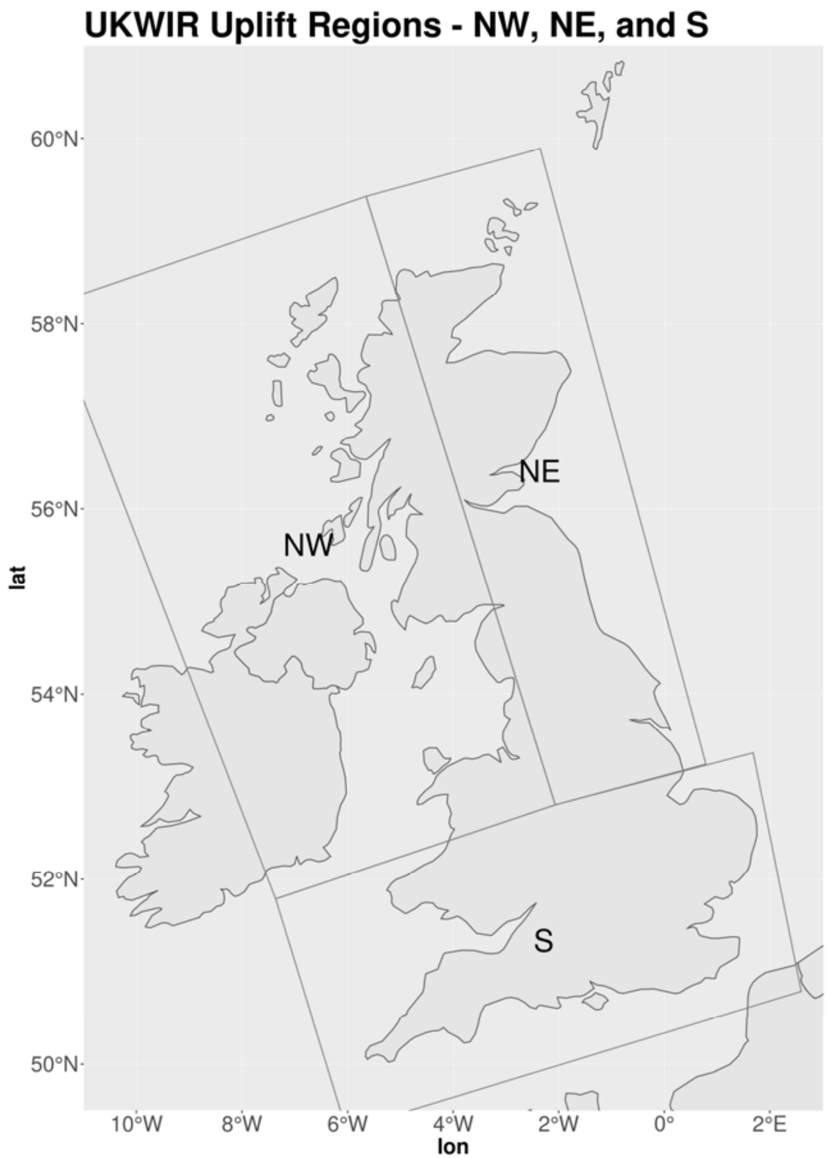


Combining ensemble spread information with uncertainty estimates of extreme value fitting

- **<u>Two uncertainties are attached to the return levels and uplift estimates:</u>**
  - Uncertainties of the extreme value model fit that are specific to a particular ensemble member for a particular time-slice (uncertainty of the fits themselves)
  - Uncertainties due to the climate model ensemble spread (due to model physics parameter variation)
- To combine both uncertainties, we statistically simulate the return levels and uplifts for each ensemble member separately. Afterwards we pool the simulated return levels and uplifts across the ensemble members to form a "super" uncertainty range from which we can estimate the confidence interval (Fosser et al., accepted).
- **Unexplored uncertainties include the uncertainty due to emission scenario** – the RCP8.5 scenario is a high-end emission scenario, so diagnosed uplifts can be seen as the relative high case.

The UKWIR Uplift Regions

- 3 uplift regions were identified as part of UKWIR study (Dale et al. 2017)
- They were based on uplifts of two single-ensemble 1.5km CPM simulations for northern and southern UK.
- We re-estimated the uplifts and their combined ensemble-fit uncertainty from the UKCP Local ensemble
- Note: rectangles are geometric approximations of the regions; Ireland and non-land grid points are excluded from the analysis



UKWIR Stage 1 & 2 – 2014-2017 used a 1.5km convection-permitting model

Uplifts for 30-yr event

		2030s	2050s	2080s
North West UK	Central Estimate	20%	35%	55%
	High Estimate	35%	65%	110%
North East UK	Central Estimate	10%	20%	35%
	High Estimate	30%	50%	85%
South UK	Central Estimate	10%	15%	25%
	High Estimate	20%	35%	65%

Note that High Estimate is from regional spatial variability in uplift values

But remember…

- UKWIR results were based on two CPM simulations split north and south for **~2100 RCP8.5**, but also driven by a different GCM configuration. UKCP Local is one domain with 12 CPM simulations.
- In the UKWIR report, 1h and 24h uplifts for the north (region NW and NE) are higher than the south.

UKCP18 2.2km ensemble

- 2.2km resolution for UK
- 12 members driven by 12km Regional
- 1981-2000, 2021-40, **2061-80**
- High emissions scenario RCP8.5
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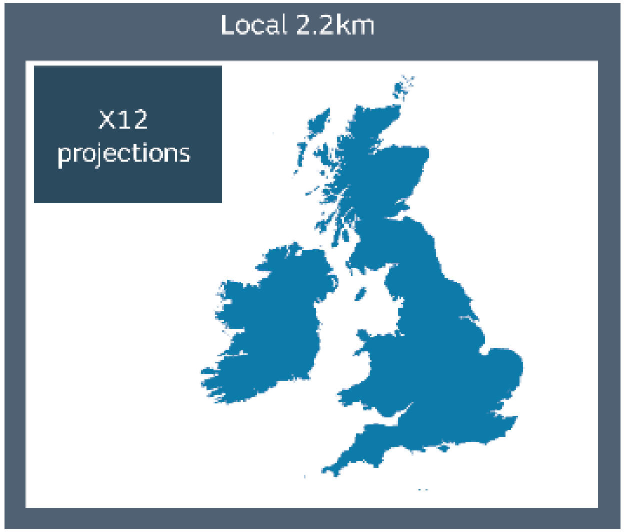


Preliminary Results UK Average Uplifts

Left column:

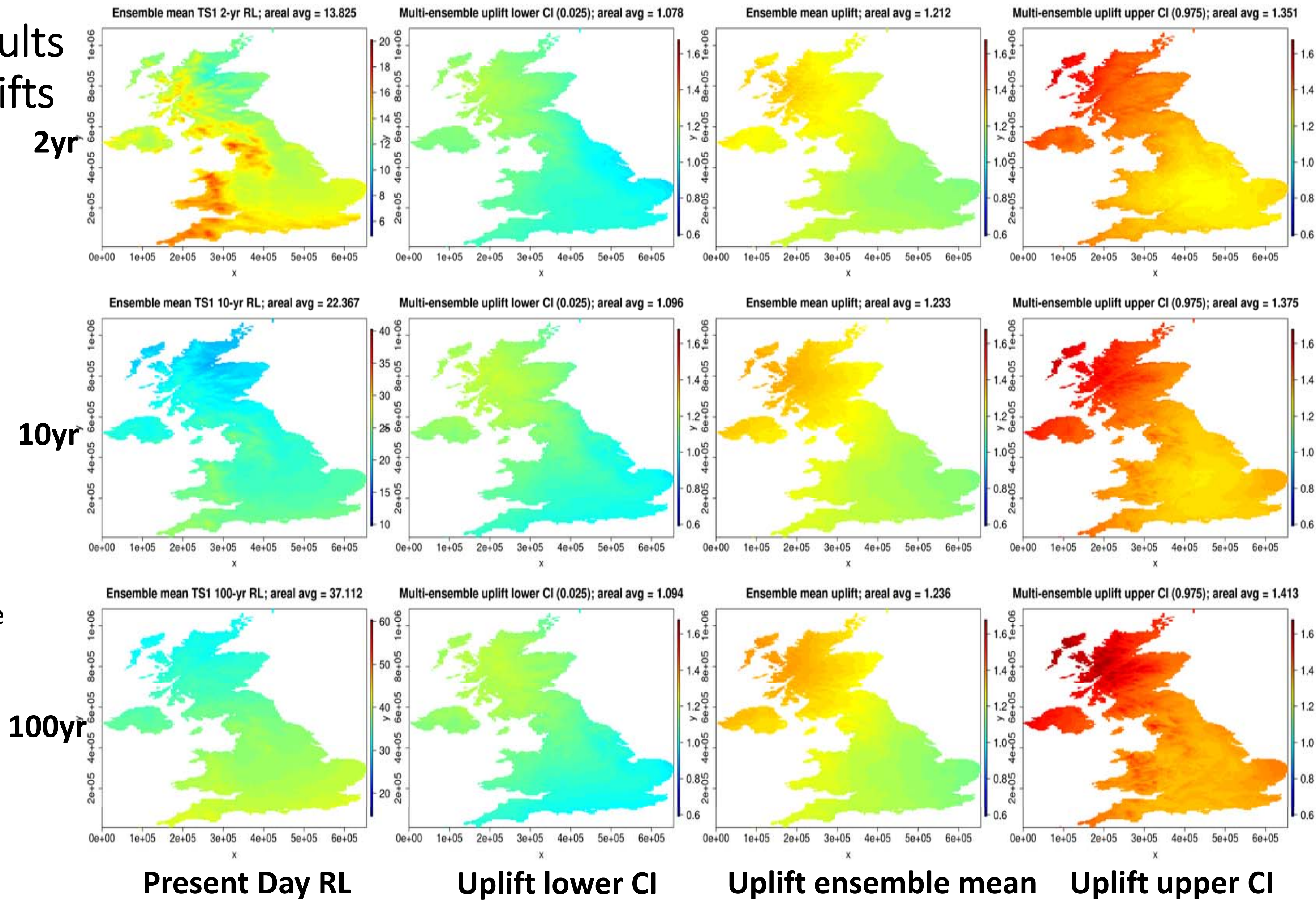
Return levels for ensemble mean 1981-2000

Right 3 columns: Uplifts for2061-80

Centre-left – 2.5 percentile (“lower bound”)

Centre-right – Ensemble mean uplift

Right – 97.5 percentile (“upper bound”) UK-average uplifts:

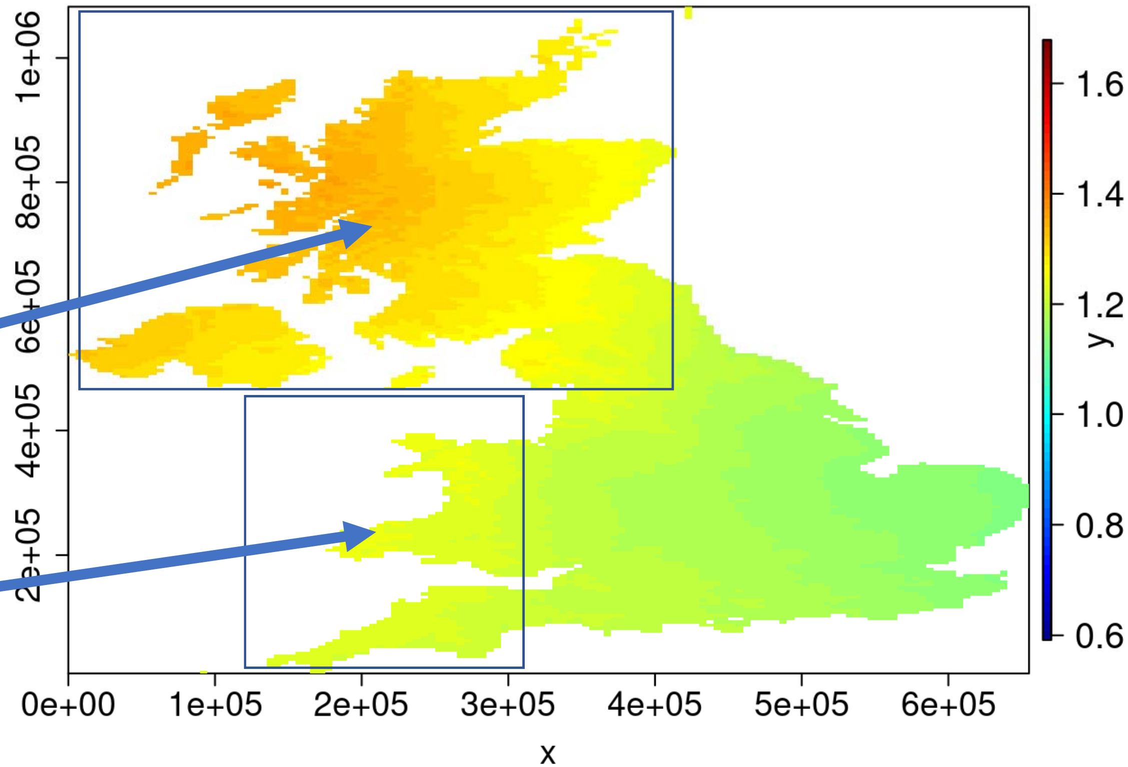


Regional Variation

- **<u>A northwest/southeast gradient with highest uplifts north</u>**
- **Average uplift across UK ~25%**

- Highest uplifts in Scotland and Northern Ireland

- Somewhat higher uplifts are noticeable for Wales and SW England
- Otherwise, most of England (including London) show lower uplifts



New uplifts based on UKCP Local

- **UKCP Local uplifts show similar north-south and east-west pattern to previous UKWIR work**
- UKWIR results were based on two CPM simulations split north and south, but also driven by a different GCM configuration. UKCP Local is one domain with 12 CPM simulations.
- **Work so far is for the 2061-2080 period and not directly comparable to UKWIR uplifts.**
- **UKCP Local produces similar central uplifts to those of UKWIR. This is NOT dependent on the new method.**
- We are using a different method to estimate confidence intervals which combines spatial and ensemble uncertainty thus the confidence intervals on the estimates are slightly smaller
- Uplifts not likely to be released until early 2021

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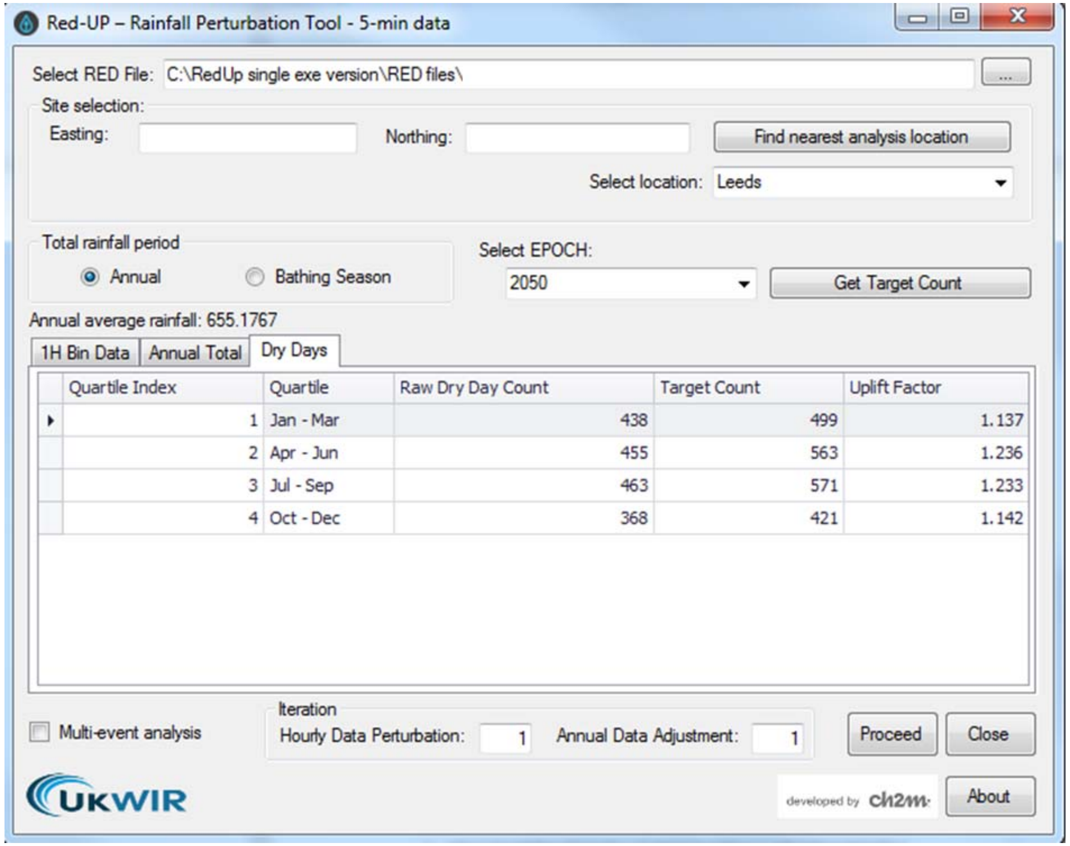
Water industry implications

Murray Dale, Technical Director, JBA Consulting

Adjustments to RED-UP

- RED-UP uses uplift factors from the Met Office model data processing
- Uplift factors vary by season
- Perturbations are different for different time horizons (Epochs)
- RED-UP also fits to future dry day estimates and future bathing season and non-bathing season estimates



Summary points

- New uplifts affect discrete event changes (sub-daily duration)
- Uplifts and other characteristics of future rainfall from UKCPLocal will affect the factors used in RED-UP to perturb rainfall time series
- Uplifts may vary regionally

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Current UK Guidance

Defra Guidance (2006)
Peak rainfall climate change allowances, applicable for England and Wales

Parameter	1990-2025	2025-2055	2055-2085	2085-2115
Peak rainfall intensity (preferably for small catchments	+5%	+10%	+20%	+30%

Environment Agency 2011 guidance (2011)
Change to extreme rainfall intensity compared to a 1961-90 baseline

Applies across all of England	Total potential change anticipated for 2020s	Total potential change anticipated for 2050s	Total potential change anticipated for 2080s
Upper end estimate	10%	20%	40%
Change factor	5%	10%	20%
Lower end estimate	0	5%	10%