Department for Environment Food & Rural Affairs | Department for Energy Security & Net Zero | Department for Science, Innovation, & Technology | Met Office Hadley Centre | Environment Agency

UKCP18 Factsheet: Using rainfall data from UKCP

Rainfall plays a significant role in supporting multiple ecosystem services and can cause significant societal and economic impacts on various timescales. Short, intense rainfall events can lead to pluvial or surface flooding. Prolonged periods of excessive rainfall can increase the risk of fluvial or river flooding. Long periods of low rainfall can result in drought conditions with implications for water supply, agriculture and food production.

Key rainfall characteristics include intensity, frequency and duration which are variable in both time and space. These features are represented by different types of data: absolute values (e.g. rainfall rate in mm/hr or total volume in mm), change relative to baseline (e.g.%); and presented in different forms: e.g., probability distributions, timeseries and maps at multiple scales.

What is the purpose of this guidance?

In 2022, users of UKCP identified the need for spatially explicit rainfall information as well as information for a range of return periods and durations, antecedent conditions, drought, sub-hourly time scales and for reservoir safety. Since the release of UKCP18 (Lowe et al, 2018) there has been a wealth of datasets and information developed covering these topics, that can be used for analysing rainfall and its impacts on society.

The purpose of this guidance document is to highlight what rainfall information currently exists within UKCP and what to consider when choosing a data product. It also provides information on other tools and datasets that have been developed within the field since the release of UKCP18 that are linked with UKCP data. The guidance focuses on datasets that are based on, and compliment UKCP, however it is not an exhaustive list of datasets that are available for analysing rainfall.

Who is this guidance for?

This guide is aimed at practitioners in industry, research, government or third sector organisations who have some level of existing knowledge in rainfall analysis.

Contents

1. Understanding recent and future changes in rainfall

The Met Office publishes a range of **UK maps and data** providing up to date information on current observations in rainfall, including climate summaries, UK climate extremes and averages, as well as actual and anomaly maps of observed rainfall.

The **State of the UK Climate**, is published annually by the Met Office and includes an up-to-date assessment of observed changes in rainfall.

There have been several reports and factsheets published on the projected changes in rainfall from UKCP:

- **UKCP Headline Findings** – summary of the most important information from UKCP and key messages for decision makers.
- **UKCP Precipitation Factsheet** – summary of key information from UKCP for precipitation metrics.
- **UKCP Local Update Report** and **UKCP Local Transient Projections report** - these reports describe the results from the 2.2km convection permitting model, which has led to new **research on extremes**.
- **UKCP Probabilistic Projections of Climate Extremes report** – describes projections of 20, 50, 100 year return levels of daily precipitation and 5-day accumulated precipitation.

Further scientific reports and guidance documents can be found on our **UKCP Science** and **How to use UKCP** web pages.

2. What rainfall products are available from UKCP and when should you use them?

The following reports and factsheets set out the different strands of data available from UKCP, when they should be used and their key caveats and limitations:

- **UKCP precipitation factsheet** – outlines the various UKCP rainfall products.
- **UKCP Guidance: How to use the land projections**

Table 1 summarises the different UKCP projections and some of their uses for rainfall applications. It is important that users consider the potential advantages of each UKCP product as well as the sensitivity of their applications to uncertainty in the UKCP outputs. It is recommended that any analysis using the global, regional, local, and derived projections is placed in the broader uncertainty context of the probabilistic projections.

The icons below are used in the table to summarise which products sample uncertainty from greenhouse gas emissions and model uncertainty, as well as the temporal resolution that is available for each product. The icons also summarise which rainfall applications the products should be used for. Further information on the different strands of uncertainty and spatial coherence can be found in section 2.1.

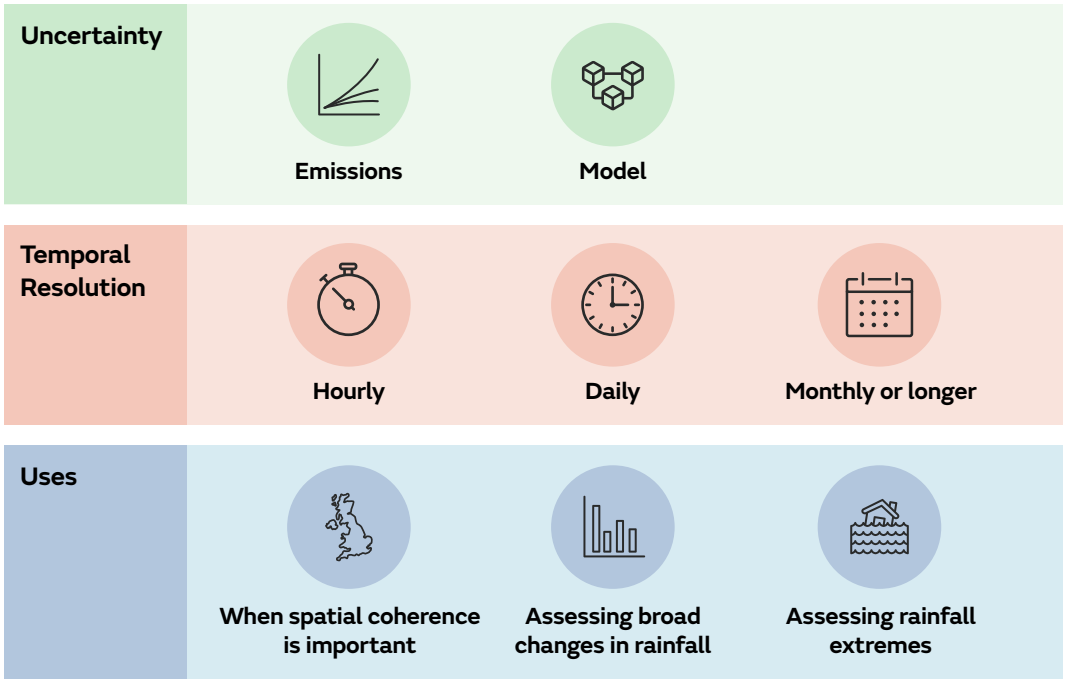

Table 1 UKCP projections and rainfall applications

UKCP Projections	Description	Which rainfall applications should it be used for?
Probabilistic (25km)	Combines a range of climate model data (both the Met Office's Hadley Centre model and international models from CMIP5), observations and advanced statistical methods to simulate a wide range of climate outcomes for five emission scenarios (RCP2.6,4.5,6.0,8.5 & SRESA1B). These projections sample the broadest sources of uncertainty in monthly precipitation data.	▪ For understanding broad changes in rainfall at monthly timescales or longer. ▪ To assess a broad range of future changes for rainfall across a range of emission scenarios. ▪ Assessing rainfall changes at a specific 25km grid square, not at multiple locations where spatial coherence is important.
Probabilistic Extremes (25km)	An extension of the probabilistic projections focused on extremes. Projections of 20-, 50- and 100-year return levels of daily precipitation (Rx1day) and 5-day accumulated precipitation (Rx5day), for five emission scenarios (RCP2.6,4.5,6.0,8.5 & SRESA1B).	▪ Assessing daily rainfall extremes. ▪ For analysis of extremes at specific 25km grid squares, for particular return periods, but not for analysis of joint risks at spatially distributed locations.
Global (60km)	A set of 28 climate simulated past, present and futures from both the Met Office's Hadley Centre model (15 members) and international models from CMIP5 (13 models) and therefore assess both model and parameter uncertainty. UKCP Global is available for a high emission scenario (RCP8.5). Data has been statistically derived for a low emissions scenario RCP2.6 – see UKCP Derived Projections in Table 2 for more details.	▪ Assessing rainfall and rainfall change at multiple locations where spatial coherence matters. ▪ Assessing daily rainfall. ▪ For large scale impact studies e.g. across the whole UK or globally where spatial detail is not important. ▪ Where the wider range of uncertainties (including CMIP5-13) are important. ▪ For linking the pattern of rainfall back to large-scale drivers, such as weather type and storm track characteristics. ▪ To add global and uncertainty context to UKCP Regional and Local rainfall projections.
Regional (12km)	A set of 12 high resolution projections from the Hadley Centre model, for a high emissions scenario (RCP8.5), spanning a narrower range of uncertainty compared to the global projections. UKCP Regional covers the UK and Europe at higher spatial detail and provides an improved representation of daily extremes.	▪ Where spatial scale is important over wider sampling of uncertainty. ▪ Assessing daily extremes in rainfall at catchment scales**. ▪ Assessing rainfall change at multiple locations where spatial coherence matters.
Local (2.2km)	A set of 12 very high-resolution projections downscaled from the regional projections over the UK for a high emissions scenario (RCP8.5). Spans a narrower range of uncertainty compared to the global projections. UKCP Local provides the most physically realistic projections of local rainfall extremes at hourly timescales. It can better resolve the influence of urban, mountainous, and coastal areas on the local climate.	▪ Assessing rainfall impacts at the local scale that requires enhanced spatial detail. ▪ Assessing extreme rainfall in summer. ▪ Assessing changes in mean rainfall in winter. ▪ Analysis of sub-daily data. ▪ Rainfall extremes in urban areas and areas with rapidly varying topography. ▪ Where convective rainfall events are of particular interest. ▪ Assessing rainfall change at multiple locations where spatial coherence matters

*Return levels of daily precipitation and 5-day accumulated precipitation.
**UKCP Local however is expected to provide more reliable projections than UKCP Regional especially where there is a convective element (which is the case in summer and for wintertime convective showers triggered over the sea and advected inland).
†Samples parameter uncertainty only.

2.1 Considerations when using UKCP for rainfall applications

Emissions Uncertainty: The pathway we take for the emission of greenhouse gases depends on demographic and socio-economic development over time as well as technological change and the implementation of policy commitments. A range of emissions scenarios can be used to sample this uncertainty. The UKCP Probabilistic projections provide the broadest overview using a range of emissions scenarios. The Global, Regional and Local projections only sample a high emissions scenario, RCP8.5. A selection of these projections are available at global warming levels (GWLs), which partly overcomes the availability of only RCP8.5. GWLs represent the increase in surface temperatures averaged over the globe expressed relative to the pre-industrial period (1850–1900). Using GWLs allows the assessment of changes in rainfall when global temperatures reach, 1.5°C, 2°C and 4°C. Several GWLs are assessed as we do not yet know which level will be reached as this depends on future greenhouse gas emissions choices and the sensitivity of the climate system.

Model Uncertainty: There are two types of model uncertainty – parameter uncertainty and structural uncertainty. Parameter uncertainty arises from the inability of climate models to resolve every process within the climate system, requiring the use of physical equations and parameters. In UKCP, parameter uncertainty is assessed within the Met Office's Hadley Centre model (GC3.05-PPE) by perturbing model parameters within expert-specified ranges to develop a range of simulations of the future climate, called the Perturbed Parameter Ensemble (PPE).

Uncertainty can arise from the structure of the climate model itself which influences how sensitive the model is to the emission forcings, as well as the spatial and seasonal patterns of change that are determined by changes in the regional processes or dynamics. This type of uncertainty can be assessed by using a range of climate models. The UKCP Probabilistic, Global products and Probabilistic Extremes products use both the Hadley Centre climate model (GC3.05-PPE) and models from CMIP5 (CMIP5-13). The Hadley Centre model has a higher climate sensitivity to greenhouse gases compared to other models. The UKCP Regional and Local currently only include downscaled versions of the Hadley Centre climate model and sample a narrower range of structural uncertainty, however they capture parameter uncertainty from the PPE. Figure 1 compares seasonal mean changes in precipitation (%) across all UKCP products for Scotland and England. Changes in summer precipitation in England show a considerable drying trend in the Local and Regional projections (following the driving GC3.05-PPE), whereas the CMIP5 simulations and the UKCP Probabilistic projections indicate more modest reductions or small increases in rainfall. It should be noted that additional UKCP Regional and Local simulations downscaling selected members from CMIP5 will be made available in 2024. These will provide wider uncertainty context for impacts studies.

The **EuroCORDEX-UK project**, funded through the UK Climate Resilience Programme, offers a facility to supplement the UKCP Regional projections with information from a broader range of high-resolution climate simulations from the EuroCORDEX downscaling experiment. The additional projections will provide a more comprehensive sampling of uncertainty in the high resolution UKCP projections.

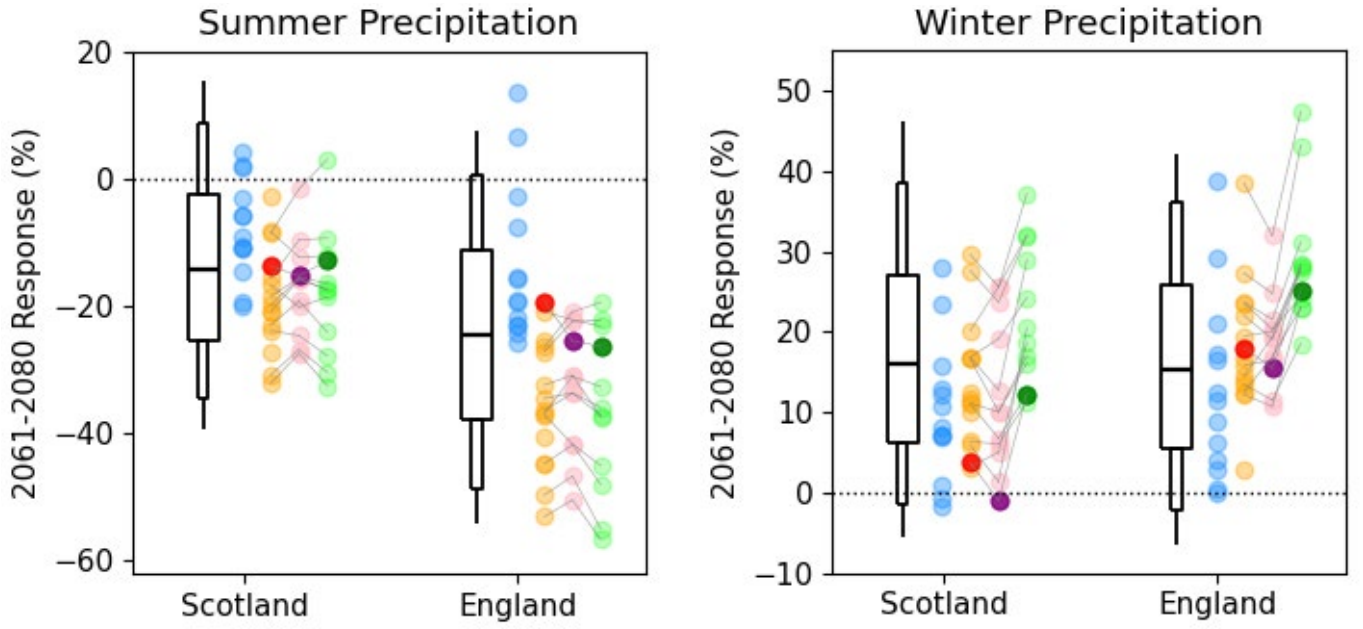

Figure 1 Comparison of seasonal mean changes in precipitation (%) across all UKCP products. Projected changes for 2061-2080 relative to 1981-2000 for summer and winter, under RCP8.5 emissions. The box and whiskers denote the 5, 10, 25, 50, 75, 90 and 95% probability levels of the UKCP probabilistic projections. Orange dots (with standard member (STD) in red) denote members of GC3.05-PPE and blue dots those of CMIP5-13, which together comprise the UKCP Global (60km) projections. Pink dots (with STD in purple) show the Regional (12km) projections and green dots (with STD in dark green) those of the Local (2.2km) projections.

Assessing rainfall extremes: UKCP Probabilistic Extremes, Regional (RCM) and Local (CPM) are the three UKCP products that can be used to assess extreme rainfall. The CPM gives a good representation of hourly precipitation extremes and how these increase with increasing return period over the southern UK (the observations typically lie within the 12-member ensemble spread, Figure 2). However, all models have biases compared to the real world, but they can still provide useful information. Over the northern regions, the CPM generally underestimates return levels, especially in winter (DJF) (Figure 2). In the RCM, the rate at which extremes increase with return period (the "growth curve") is too steep compared to observations. Consequently, the RCM tends to overestimate high return period events (particularly in summer (JJA) and autumn (SON), even though there may be good agreement with observations for modest return periods (Kendon et al., 2021)). In terms of seasonal maximum values of hourly precipitation across UK regions, or the number of events exceeding a high threshold such as 20mm/hr, UKCP Local is found to give much better agreement with observations compared to UKCP Regional (Kendon et al., 2023a, 2023b) There is evidence of some unphysical hourly rainfall values at local (<5km) scales in UKCP Local, but these are rare and much less common than in UKCP Regional where unphysically high rainfall values occur as a result of numerical instabilities in the model (so called 'grid point storms') (Kendon et al., 2023a). It is these grid point storms which lead to the overestimate of high return period events in UKCP Regional (Figure 2). The CPM captures the growth curve better. Further information can be found in the **UKCP18 Local report**.

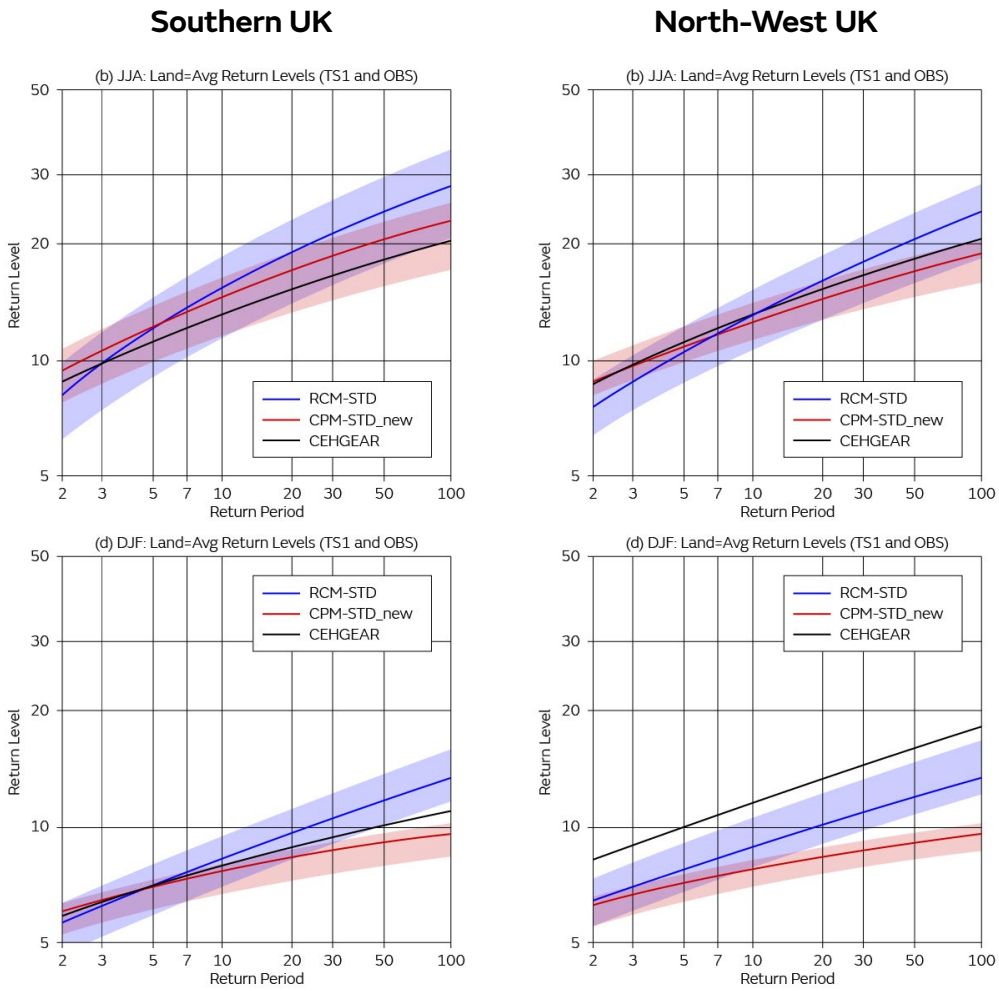

Figure 2 Southern and North-West UK average return level of hourly precipitation extremes from Kendon et al, 2021. Average return level of daily maximum hourly precipitation as a function of return period, for individual summer (JJA) and winter (DJF). Shown are the return levels (mm/h) for the CEHGEAR gauge observations (1990-2014, black); and the RCM (blue), and CPM_new (red) model ensembles (1981-2000). The standard member (STD, solid line) is shown, with the shaded region corresponding to the ensemble spread. The regional average values have been calculated using the regional frequency analysis method.

Spatial Coherence: Spatial coherence is important when analysing climate risks at different geographical locations at the same time and if there is physical connection between the climate characteristics at these locations, e.g., national assessments. UKCP Global, Regional and Local products are spatially coherent and can be used for assessing rainfall across a geographical area. Probabilistic projections are not spatially coherent and should only be used to assess rainfall change for a single area.

Table 2 provides more specific considerations in terms of caveats and limitations for each product.

Table 2 Caveats and Limitations of UKCP products for rainfall applications.

Product	Caveats & Limitations
UKCP Probabilistic	▪ Makes use of a range of global climate models which can show biases compared to observations. ▪ Does not explicitly represent smaller-scale processes such as atmospheric convection. ▪ Adopts approaches to emulating climate models, managing structural uncertainty, using a particular simple energy balance model and downscaling. Each stage of the method has many assumptions and relies on expert judgement. ▪ May not capture all possible future climate outcomes due to, for example, some potential influences on future climate that are not yet understood and may be absent or not reliably captured in the models. ▪ See the **UKCP Science Overview Report** for more details.
UKCP Probabilistic Extremes	▪ Cumulative frequency distributions are smoothed as well as clipped to remove extreme values that may be less physically plausible than those within the bulk of the probability distribution. Clipping is applied at 5th and 95th percentiles. ▪ While not a limitation, it is important to note that in summer, 1-day precipitation at 50-year return level remains close to the baseline while other UKCP products show a significant decrease in mean summer rainfall throughout 21st century e.g. the Probabilistic Projections in the south east of England (i.e. not extreme rainfall). This is because different processes contribute to extreme precipitation values compared to future seasonal mean precipitation. In summer, there is a shift to less frequent, more extreme rainfall and therefore the seasonal mean may decrease while daily extreme values may stay similar to the baseline or increase. ▪ See **UKCP Probabilistic Extremes report** and **factsheet** for more details.
UKCP Global	▪ Widespread wet bias in Europe and UK region in winter. Biases vary with season and location and are largest in winter and at high elevations. The observational datasets do suffer from rain gauge undercatch and this may contribute to part of this model-observational discrepancy, particularly over high terrain. ▪ Dry biases are more limited in extent. ▪ See section 3.4 in **UKCP Land Report** for more detail, including information on interannual variability bias and performance at global scale.
UKCP Regional	▪ Tends to be a broad scale wet bias in winter partly inherited from the global driving model but also due to the intensification of the hydrological cycle which is typical of regional models. ▪ In winter, the regional climate model (RCM) can be too wet in the south-east UK by more than 40%, whilst over the mountains in the north and west the RCM tends to be too dry. ▪ In summer the RCM is 20-50% wetter than observations in the north of the UK. ▪ The RCM should not be used to look at hourly precipitation variability and extremes due to unphysically high rainfall values as a result of numerical instabilities in the model. ▪ See **UKCP Land Report** for further details.
UKCP Local	▪ UKCP Local provides a better representation of how precipitation varies daily and hourly compared to UKCP Regional, resulting in reduced biases in seasonal mean precipitation in UKCP Local. ▪ UKCP Regional is unable to capture short intense downpours which are more realistically captured in UKCP Local, although they tend to be too heavy. ▪ UKCP Local has a wet bias in winter particularly over high terrain, leading to wet biases for mean and heavy daily precipitation. ▪ UKCP Local tends to overestimate heavy summer precipitation and hourly precipitation extremes, however this has been considerably improved (by about 20%) in the latest update to UKCP Local. ▪ See **UKCP Local Report** for further details.

3. Where can I find UKCP rainfall data?

There are several locations where you can download UKCP rainfall data:

- **UKCP Website** - provides headline findings and a key results spreadsheet.
- **UKCP User Interface (UI)** – download datasets, plot graphs and maps for the UK.
- **Met Office Climate Data Portal** – view and download climate data in a range of geospatial formats including shapefile, KML, GeoJSON, Geodatabase and csv formats
- **CEDA Data Catalogue** – download raw datasets of UKCP.

For further information see **UKCP Guidance: Data availability, access and formats**.

4. Which UKCP rainfall product should I use?

Many rainfall products and tools have been developed since the release of UKCP that can be categorised into primary, derived and impact data as explained below.

Primary Data

Information from raw observations or UKCP climate projections.

Derived Data

Information derived from primary data that is not a direct output from observational measurements or climate models. E.g., climate indicators, rainfall frequency information.

Impact Data

Outputs from impact models driven by primary or derived data sources. E.g., high and low flow datasets.

1. Use the decision tree below to identify datasets or tools that you may wish to use depending on your requirements for rainfall information. They have been colour coded depending on whether they are a source of primary, derived or impact data.
2. Find out further information and links to the dataset or tool in Table 3 as well as examples on their use.
3. Locate the dataset or tool in the diagram in Figure 3 to see how it relates to UKCP.

Do you need information to understand observed changes in rainfall or impacts?	Do you need high level messages, summary information, or a broad understanding of modelled changes in rainfall?	Do you need spatial rainfall information, graphs or maps specific to your region or local area?	Do you need data to assess extremes in rainfall or for input to flood models or drainage design?	Do you need outputs from hydrological models for e.g. water resources management?
Rain gauge data	**UKCP Headline Findings**	**Met Office Climate Data Portal***	**UKCP Local**	**eFLaG**
HadUK-Grid	**UKCP Key Results Spreadsheet**	**UK Climate Risk Indicators**	**FUTURE-DRAINAGE uplifts**	**MaRIUS-G2G**
CEH-GEAR	**City Packs**	**UKCP Regional & Local**	**RED-UP**	**Surface water and river flood maps**
National River Flow Archive	**UKCP Probabilistic & Global**	**EuroCORDEX-UK**	**CEH Rainfall frequency grids**	**FUTURE-FLOOD[1]**
	UKCP Derived Projections	**CHESS-SCAPE**	**Probabilistic Projections of Climate Extremes**	
			Climate change impacts on peak river flows	

* Tool provides both raw and derived data

[1] FUTURE-FLOOD is a NERC funded project which will provide new estimates of compound pluvial and fluvial flood hazard across the UK for 1980-2080, translated to policy-relevant global warming levels using UKCP Local. This data is not currently available, but work is in progress.

Table 3 provides a list of primary, derived and impact data and tools for rainfall available for the UK. The purpose of this table is not to recommend specific data products as this will be highly dependent on the use case, nor provide a comprehensive list of data products out there. We have only included free to access data and services. Other paid services are available from a number of purveyors but these are not listed here.

While the caveats and limitations of UKCP data has been covered earlier in this document, users should familiarise themselves with the caveats and limitations linked to the other non-Met Office datasets provided in the table. Links to internet sites maintained by others are provided solely as a convenience to you and not as an endorsement by the Met Office of the content on those third-party sites. More details of the Met Office links policy can be found on the **Met Office website**.

Table 3 Rainfall products related to UKCP and other relevant rainfall datasets.

Rainfall Data / Information	What is it? / Variables?	What rainfall data does it use?	Spatial resolution	Is it bias corrected[1]?	Format / How To Access?	What can you use it for? (Examples linked)
Primary Data						
Rain gauge data	Hourly and daily rainfall data from rainfall gauges.	Observations	Point locations	N/A	Met Office MIDAS-Open (1853-to present) SEPA Rainfall Data EA Rainfall Data Cyfoeth Naturoil Cymru Rainfall Data	Evaluating models, understanding current changes in rainfall, understanding spatial variability in rainfall. It is important to note that rain gauge data can be affected by measurement undercatch. Gauges may miss localised events. Biases in measurements can vary between season and location and are largest at high elevations[2].
HadUK-Grid	Gridded daily (1891-present) and monthly (1862-present) rainfall for the UK.	Observations	1km	N/A	UKCP User Interface (Absolute values, maps, plots/graphs, csv) Met Office Open Climate Data Portal (shapefiles) CEDA (NetCDF)	Understanding the spatial variability of long-term rainfall conditions, e.g. State of the UK Climate. For bias adjustment of model data. To support hydrological and drought monitoring, e.g. CEH Historic Droughts tools. Putting past extreme rainfall into the context of climate change. Evaluating models. Gridded datasets are estimates that have been interpolated from adjacent rain gauges. Higher errors exist in areas of sparser station coverage and complex terrain[3].
CEH-GEAR **CEH-GEAR1hr**	Gridded hourly, daily and monthly rainfall for GB & NI for 1890-2019 (CEH-GEAR), 1990-2016 (CEH-GEAR1hr)	Observations	1km	N/A	CEH Data Centre	As above but for sub-daily rainfall.

[1] Bias corrected data - All climate models exhibit systematic differences between model results and observations and you need to consider whether to modify the datasets to correct for these. This is called bias-correction and is a popular approach used by many researchers and climate data users. For further guidance see: **UKCP18 Guidence on Bias Correction**

[2] Kendon et al (2021) **Update to UKCP Local (2.2km) projections**.

[3] Perry, M. and Hollis, D. (2005), The generation of monthly gridded datasets for a range of climatic variables over the UK. Int. J. Climatol., 25: 1041-1054. **https://doi.org/10.1002/joc.1161**

Rainfall Data / Information	What is it? / Variables?	What rainfall data does it use?	Spatial resolution	Is it bias corrected[1]?	Format / How To Access?	What can you use it for? (Examples linked)
Primary Data (Continued)						
UKCP Probabilistic, Global, Regional & Local projections	Projections of sub-daily[4], daily, monthly, seasonal & annual precipitation rate (mm/day), precipitation rate anomalies (%). Data available between 1961-2100 depending on product.	UKCP	2.2km-60km	No	UKCP User Interface (Absolute values, maps, plots/graphs, csv) Met Office Open Climate Data Portal (shapefiles) CEDA (NetCDF)	Understand changes in rainfall patterns, extreme rainfall and associated impacts across the UK. E.g. water availability, assessing urban drainage resilience.
UKCP Key Results Spreadsheet	Headline messages on rainfall and figures from UKCP	UKCP Probabilistic	25km	No	Report, excel spreadsheet	Providing summary information on key climate variables.
City Packs	High-level, non-technical summaries of a city's future climate including rainfall. Available for ~20 cities across the UK	UKCP Probabilistic	25km	No	Factsheet	Informing climate change risk assessment, communication, and training tool.
Euro CORDEX-UK	All variables available from UKCP and derived information on dry spells, wet days, and percentile-based rainfall thresholds for 1981-2080 and a range of global warming levels.	CMIP5	12km	No	EuroCORDEX-UK plot explorer CEDA (NetCDF)	To supplement UKCP18 projections with a wider range of climate models to sample model uncertainty.
Derived Data						
CEH Rainfall frequency grids	Rainfall Depth-Duration-Frequency Grids for 1 & 3hr durations and 5-200year return periods derived from FEH rainfall depth-duration-frequency model.	Observations	Gridded 1km & catchment averages	N/A	Licenced through UKCEH (Arc/Info Grid Ascii)	Analysis of rainfall at different return periods. Input to hydrological or other impact models.
Impact relevant precipitation indicators	Sector specific information on future change in extreme rainfall, drought and flood indicators as well as average climate.	UKCP Global, Probabilistic, Regional	12km grid, Local Authority Areas, counties, districts, Local Resilience Forums, region, nation	Yes	Met Office Open Climate Data Portal UK Climate Risk Indicators Tool	Understand spatially explicit changes in rainfall, river runoff and drought indicators across the UK. E.g. Climate Change Impacts and Adaptations in the UK story map

[4] UKCP Local only

Rainfall Data / Information	What is it? / Variables?	What rainfall data does it use?	Spatial resolution	Is it bias corrected[1]?	Format / How To Access?	What can you use it for? (Examples linked)
Derived Data (Continued)						
Probabilistic Projections of Climate Extremes	Monthly, seasonal and annual mean changes in daily and 5-day accumulated precipitation for 20-, 50- and 100-year return periods	UKCP Probabilistic	25km, admin regions, river basins and countries	Yes	UKCP User Interface (Absolute values, maps, plots/graphs, csv) CEDA (NetCDF)	Analysis of extreme rainfall at different return periods.
UKCP Derived Projections	A set of climate futures for the UK at global warming levels of 2 °C and 4 °C. Data has also been statistically derived for a low emissions scenario RCP2.6.	UKCP Global	60km	No	UKCP User Interface (Absolute values, maps, plots/graphs, csv) CEDA (NetCDF)	Understanding broad changes in rainfall over the UK at different levels of global warming.
FUTURE-DRAINGE uplifts (Supersedes UKWIR 2017) See additional guidance below table.	Percentage uplifts for future change in UK rainfall for 1-24hour durations and 2-100year return periods, RCP8.5	UKCP Local	5km & catch-ments	No	CEDA EA Rainfall Allowances Tool SEPA Climate Change Allowances tool	Analysis of rainfall at different return periods for surface water flood modelling, drainage design, and considering risk to infrastructure. (Chan et al, 2023)
Climate change impacts on peak river flows **(UKCP case study)**	Percentage changes in peak river flows for 10, 20 and 50 year return period flood events.	CEH-GEAR, UKCP18 Probabilistic	1km & catch-ments	No	EA River Flow Allowances Tool SEPA Climate Change Allowances tool	Assessing changes to river flood risk in larger catchments at a regional level, for use in land use planning and flood protection scheme design.
RED-UP perturbed rainfall data	Time series perturbation tool that allows historic rainfall data to be perturbed to be representative of future high emissions (RCP8.5) climate.	UKCP Local (version 3 of RED-UP tool only)	Point locations	No	UKWIR	Informing Drainage and Wastewater Management Plans.
CHESS-SCAPE future climate data set	Daily mean precipitation flux and other climate variables for 1980-2080, RCP8.5	UKCP Regional	Down-scaled to 1km	Available with and without bias adjustment	CEDA (NetCDF)	Modelling climate change impacts in the UK, such as impacts on water quality in Scottish lakes, and drinking water.

Rainfall Data / Information	What is it? / Variables?	What rainfall data does it use?	Spatial resolution	Is it bias corrected[1]?	Format / How To Access?	What can you use it for? (Examples linked)
Impact Data						
National River Flow Archive	Daily and peak river flow data for the UK derived from the UK hydrometric gauging network.	Observations	Point locations	N/A	From NFRA website (.csv)	Fluvial flood analysis and drought analysis.
eFLaG	Nationally-consistent time-series of precipitation and PE projections as well as hydrological projections, for 1981-2080	UKCP Regional	1km grid and catchment average	Yes	CEH Data Centre (CSV or Shapefile) eFLaG Portal	Water resources and drought planning, hydrological and ground water modelling. High/low flows analysis. Water resources modelling.
MaRIUS-G2G	Event set of past and future drought conditions. Soil moisture, river flow and climate variables	Observations -CEH-GEAR and MORECS Regional model data – Met Office HadRM3P model	1km, 25km and catchment	Yes	CEH Data Centre (NetCDF) About Drought: Spatial Data Inventory Drought Data Hub	Water resources and drought planning.
Surface water and river flood maps	Maps showing areas at risk of flooding produced by the UK Environment Agencies. Maps for England show present day risk only. A subset of the maps produced for Scotland, Wales and Northern Ireland show the area projected to be at risk in future under a single climate scenario.	FEH DDF model, NRFA Peak Flow Dataset Climate projections dependent on currency of mapping.	5m	N/A	Viewer services: Environment Agency, Scottish Environmental Protection Agency, Natural Resources Wales, Rivers Agency GIS data downloads through data.gov.uk for England and Wales and Scotland	To assess the long term risk of flooding to particular locations.

5. How do these rainfall products relate to UKCP?

Figure 3 below indicates the underpinning data from UKCP that has been used to derive the datasets and tools from Table 3 that can be used in research and industry to assess rainfall.

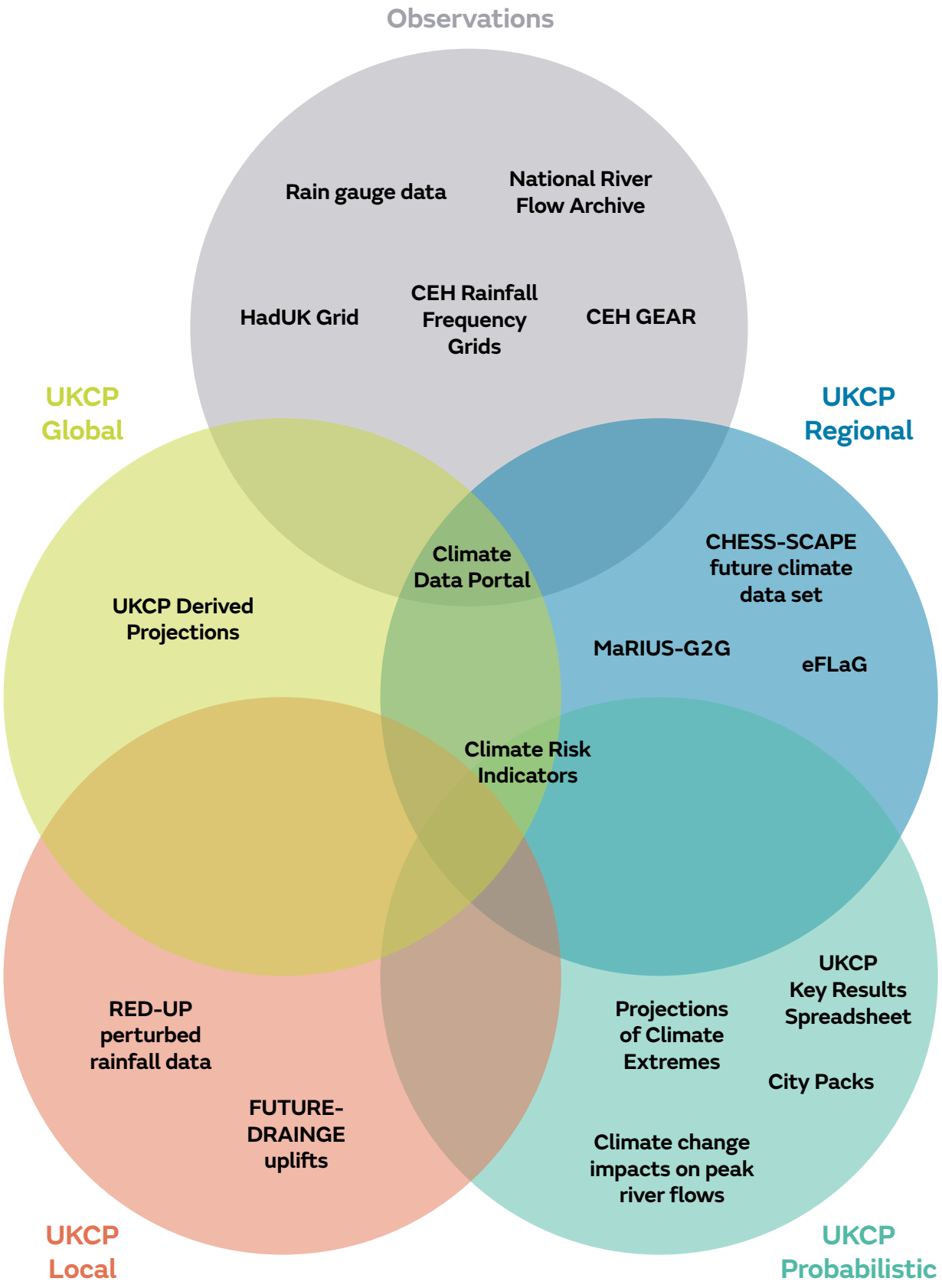

Figure 3 Linkages between rainfall based datasets and UKCP products.

6. Is sub-hourly information available in UKCP?

Observed sub-hourly rainfall records are limited in number especially for extreme rainfall events. This is because any rain-gauge network may not capture detailed rainfall patterns for these short durations due to the highly localised nature of these events. Sub-hourly rainfall observations are collected by the Met Office and available for looking at **UK rainfall records for short durations**.

Southern UK sub-hourly 10min rainfall from an older version of the Met Office's convection permitting model (an updated version of which is used for the UKCP Local projections) was examined for present and future climates (Chan et al., 2016). While a clear intensification of sub-hourly rainfall was detected, no evaluation of model performance at the sub-hourly timescale is possible due to a lack of sub-hourly rainfall observations. Furthermore, we cannot assume that the improvements in hourly rainfall from the use of convection permitting models extends to sub-hourly timescales without evaluation (Chan et al., 2016). We therefore have greater confidence in outputs at hourly timescales which are provided through UKCP Local.

7. Climate change allowances for flood risk assessment by regulatory bodies

The **Environment Agency (EA)** and **Scottish Environment Protection Agency (SEPA)** have subsequently updated their guidance on climate change allowances for peak rainfall intensity in flood risk assessment for England and Scotland using the new uplifts from FUTURE-DRAINAGE. Guidance in Wales and Northern Ireland has not yet been updated.

The uplifts have been developed against a baseline period of 1981-2000 and are appropriate to use with FEH13 depth-duration-frequency (DDF) data. Guidance[5] is provided by the FUTURE-DRAINAGE project on the use of uplifts with FEH22 and scaling back the uplifts based on the change in the baseline data period. Once such method could be linear interpolation to extrapolate changes to different baselines, using uplifts to earliest future period as indicative of the rate of change of extreme rainfall throughout the baseline period.

8. Is there information for probable maximum precipitation for reservoir safety?

Probable maximum precipitation is a method for characterising extreme rainfall and used for reservoir safety. An Environment Agency funded project has comprehensively reviewed methods for estimating the probable maximum precipitation (PMP) and probable maximum flood (PMF)[6]. It has also updated cataloging of observed extreme floods and rainstorms in the UK, finding several exceedances of current estimates of the probable maxima. From this project the EA are developing new methods and guidelines to understand risks posed to reservoirs from extreme flood events.

[5] **https://artefacts.ceda.ac.uk/badc_datadocs/future-drainage/FUTURE_DRAINAGE_Guidance_for_applying_rainfall_uplifts.pdf**

[6] **https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/improving-probable-maximum-precipitation-pmp-and-probable-maximum-flood-pmf-estimation-for-reservoir-safety**

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