Department for Environment Food & Rural Affairs

Department for Business, Energy & Industrial Strategy

Met Office Hadley Centre

Environment Agency

Probabilistic Projections of Climate Extremes

This factsheet provides summary information on what the Probabilistic Projections of Climate Extremes (PPCE) are, the key results and the situations where you may wish to use them. For a detailed description of the underpinning science, see UKCP Additional Land Products: Probabilistic Projections of Climate Extremes (Murphy et al, 2020).

1. What are the Probabilistic Projections of Climate Extremes?

The Probabilistic Projections of Climate Extremes provide information on 21st Century temperature and precipitation extremes across the UK. They use a similar methodology to the Probabilistic Projections published in 2018 (PP2018), augmented by use of extreme value theory to support projections of long return-period events.

The PP2018 provide estimates of monthly, seasonal and annual mean changes whereas the PPCE provide an estimate of extreme daily values.

Information is provided at 25km resolution for five emissions scenarios (RCP 2.6, 4.5, 6.0 and 8.5, and SRES A1B). See guidance on emissions scenarios in UKCP Guidance: Representative Concentration Pathways.

2. What data is available and where can I access them?

The Probabilistic Projections of Climate Extremes provide:

- Daily maximum temperature, daily precipitation and 5-day accumulated precipitation
- Five emissions scenarios: RCP 2.6, 4.5, 6.0 and 8.5, and SRES A1B
- 25km grid resolution over the UK using the Ordnance Survey's British National Grid
- Each meteorological season, i.e. winter (December-January-February), spring (March-April-May), summer (June-July-August) and autumn (September-October-November)
- Values representing the return level for extreme events at 20-, 50- and 100-year return periods
- Actual rather than anomalies (i.e. changes compared to a baseline period).

Unlike the PP2018, the following is not available

- Monthly or annual values or multi-year averages over 20/30-year time intervals. This is because there aren't sufficient data points to provide monthly data and the PPCE are highly dependent on season, making an annual value not only difficult to produce but also of limited utility.

- Country, administrative region and river basin region averages. This is because over a large region, average 100-year return levels are very variable and therefore not meaningful.

We have chosen to provide the data as cumulative distribution functions (cdfs) and probability distribution functions (pdfs), but not as a set of individual samples drawn from these distributions. This is because it would not be appropriate to interpret samples of return level in the same way as the UKCP Probabilistic Projections. The return levels data is an expression of future climatological properties, rather than outcomes that will necessarily occur in the year in question (see Murphy et al, 2020).

You can view and download the datasets from the UKCP User Interface. If you wish to download the whole dataset and are familiar with handling netCDF data, you can download the datasets from the CEDA Archive. Further information is available in UKCP Guidance on data availability, access and formats.

3. What can I do with them that I couldn't do before?

The PPCE allows you to assess changes in temperature and precipitation extremes across five emissions scenarios using an approach that gives a broad assessment of known modelling uncertainties. This is not available in any other UKCP product.

The data are expressed as a range of percentiles for values of a return level (e.g. the 20-year return level for daily maximum temperature). These percentiles represent the uncertainty range for the intensity of an event expected once within the given return period (e.g. 1 in 20 year). In other words, the probability of a variable exceeding the projected return level in a given year is $\frac{1}{\text{return period}}$.

For the nuclear industry, the guidance on the use of this information is clear where the period and percentiles are prescribed and that an adequately conservative emissions scenario is selected (ONR et al, 2019).

Where they're not prescribed, let's take an engineering example: you wish to design a drainage system to cope with a 1 in 20 year return period event and it has a design life of 50 years. The return period is usually recommended in engineering design codes. It could also be informed through a vulnerability analysis of your site which would determine the level of drainage that you wish to invest in. To check whether your drainage system is resilient to future climate change, the Probabilistic Projections of Climate Extremes (PPCE) provides return levels for the 1 in 20 year return period for 2070 for a number of emissions scenarios. You should then perform a sensitivity study and see how your risk profile changes with different emission scenarios and at different percentiles to understand what adaptation measures are required. For example, you could design to the 90th percentile of the 20 year return level in 2070 under the RCP 6.0 and see how likely the design threshold being exceeded would be under RCP 8.5 (i.e. take the 90th value within RCP 6.0 and see which percentile this corresponds to for RCP 8.5).

The PP2018 provided mean statistics for a number of climate variables (e.g. temperature, precipitation, surface pressure). The PPCE are produced using a technique (extreme value theory) based on Brown et al. (2014) where a dependence is assumed between probability distributions parameters and global mean surface temperatures.

You could potentially derive the metrics available in the PPCE from UKCP Global (60km), UKCP Regional (12km) and UKCP Local (2.2km) using the same method. However, the representations of uncertainties in comparison to the PPCE are more limited in these products and sample a narrower range of uncertainty.

In addition, the intensity of extremes can show a strong dependence on spatial scale, especially for precipitation metrics. Therefore, results expressed at the native grid scale of UKCP Global, Regional or Local will not be directly comparable to the 25km scale of the PPCE results.

The PPCE results were generated with a specific choice of extreme value methodology (Murphy et al., 2020). While it could potentially be applied to other UKCP products other methods using alternative statistical assumptions can be chosen. In this case, choice of technique would become another potential source of differences relative to the PPCE results.

4. What are the key results?

Under a high emissions scenario (RCP 8.5), median return levels for all variables in all seasons increase. As we saw in the Probabilistic Projections, the uncertainties grow during the 21st Century.

As stated above, the PP2018 provide estimates of monthly and seasonal mean changes in summer daily maximum temperature whereas the PPCE provide an estimate of extreme daily values. Figure 1 presents an example of how the values differ for the high emissions scenario, namely:

- The extreme values are always much higher than the means, as expected
- The uncertainty range for the 20-year return levels tend to be quite similar to those for the seasonal mean temperature
- Medians increases with rarity, because 1-in-100 year events are by construction higher than 1-in-20 or 1-in-50 year events
- Uncertainty ranges in return level also increase slightly with return period

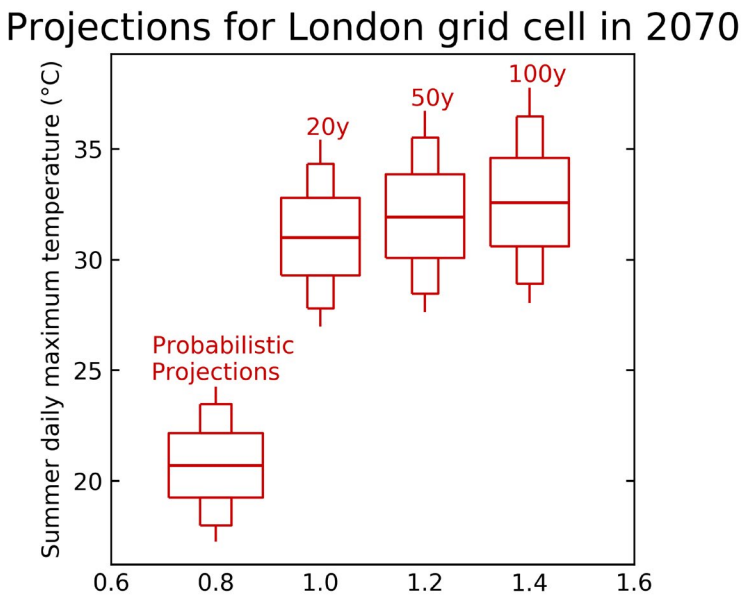

Figure 1 A comparison of summer daily maximum temperature for a London grid cell in the year 2070 for the Probabilistic Projections and Probabilistic Projections of Climate Extremes (PPCE) for a high emissions scenario (RCP 8.5). Boxes and whiskers denote the 5, 10, 25, 50, 75, 90 and 95th percentiles. The PPCE are annotated with the 20-, 50- and 100-year return periods. Probabilistic Projections boxplots are calculated by adding the anomalies to observed values from HadUK-Grid for 1980-2018 (Hollis et al, 2019).

5. How does it impact other UKCP documents and products?

The results from the Probabilistic Projections of Climate Extremes does not change any other UKCP product.

6. What else should I be aware of when using the data?

Clipping

As explained in a UKCP Technical Note (see https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-technical-note-clipping-and-baseline-guidance-on-land-strand-1-data-in-ukcp18.pdf) , the 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. The clipping is applied at the 5th and 95th percentiles and described in more detail in Murphy et al (2020).

Little change seen in median values of 1-day extreme precipitation

While other metrics show increases in future median (50th percentile) values through the 21st Century, you will find that the 1-day precipitation at the 50-year return level remains close to the baseline (see Figure 14 of Murphy et al, 2020). This contrasts with the Probabilistic Projections where the median for mean summer rainfall (i.e. not extreme) for southeast England shows a significant decrease through the 21st Century The difference is due to different processes contributing to 1-day extreme precipitation values compared to future seasonal mean precipitation values details of which are available in Murphy et al (2020).

Existing guidance

Before using the PPCE data, we recommend reading UKCP18 Guidance: Caveats and Limitations. We also recommend reading the science report on the PPCE (Murphy et al, 2020) where you can find examples of and explanations for the results that we see (section 3).

This document can be cited as:

Murphy JM, Brown S and Fung F (2020). UKCP Factsheet: Probabilistic Projections of Climate Extremes. Met Office, Exeter.

References

Brown SJ, Murphy JM, Sexton DMH, Harris GR (2014). Climate projections of future extreme events accounting for modelling uncertainties and historical simulation biases. Climate Dynamics. 43:2861-2705. https://doi.org/10.1007/s00382-014-2080-1

Hollis D, McCarthy M, Kendon M, Legg T and Simpson I, 2019. HadUK-Grid—A new UK dataset of gridded climate observations, Geoscience Data Journal, https://doi.org/10.1002/gdj3.78. OPEN ACCESS.

Murphy JM, Brown S and Harris G (2020). UKCP Additional Land Products: Probabilistic Projections of Climate Extremes, Met Office. Available at: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcpprobabilistic-extremes-report.pdf. OPEN ACCESS.

Office for Nuclear Regulation, Environment Agency and Natural Resources Wales, 2019. Use of UK Climate Projections 2018 (UKCP18) by GB Nuclear Industry, Position Statement, March 2019. Available at http://www.onr.org.uk/documents/2019/ukcp18-position-statement.pdf