Department for Environment Food & Rural Affairs | Department for Business, Energy & Industrial Strategy | Met Office Hadley Centre | Environment Agency

UKCP18 Guidance: How to use the CDF and PDF plots

What do PDFs and CDFs show?

Plots of probability distribution functions (PDFs) and cumulative distribution functions (CDFs) are a way of representing the UKCP18 probabilistic projections. The probabilistic projections assign a probability to climate change outcomes, recognising that (a) we cannot give a single answer and (b) giving a range of possible climate change outcomes is of limited use if we cannot identify the more or less likely outcomes. Plots of PDFs and CDFs are available from the UKCP18 User Interface for a chosen location, future time period and emissions scenario.

Within any given range of plausible climate changes, we cannot talk about the absolute probability of climate changing by some exact value — for example, a temperature rise of exactly 6.0ºC. Instead we talk about the probability[1] of climate change being less than or greater than a certain value, using the Cumulative Distribution Function (CDF). A change at the 50% probability level is as likely as not to be exceeded.

The CDF is useful for those who want to know the probability of climate change being less than some threshold where an impact of interest starts to occur. However, the CDF is not useful for understanding the relative probability of different specific outcomes.

The Probability Density Function (PDF) is an alternative representation of the same distribution, which is a useful visualisation of the relative likelihood of different climate outcomes.

How to use the PDFs and CDFs: examples

Figure 1 shows an example of a CDF created using the UKCP18 User Interface. The grey dotted line indicates that there is a 10% probability of a mean temperature change being less than about 0.7ºC in the winter in 2080-2099 with respect to 1981-2000. The blue dotted line indicates that there is a 90% probability of temperature change being less than about 3.5ºC.

[1] Probabilities in CDFs are conventionally taken to range between 0 and 1, although we refer to them here as percentages between 1 and 100

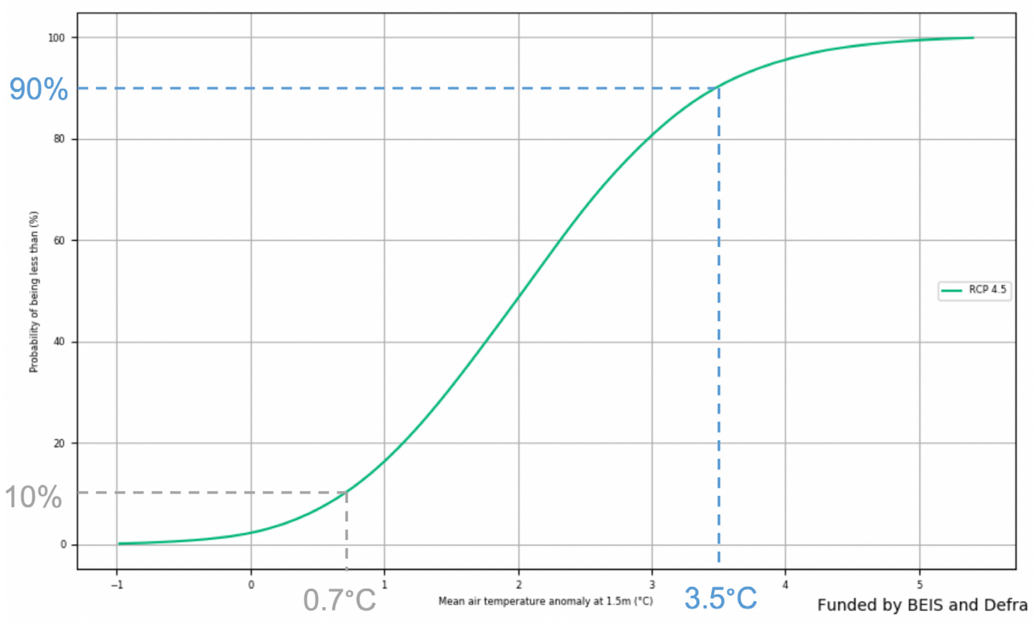

Figure 1 Example cumulative density function (CDF) of air temperature for 2080-2099 for a medium emissions scenario, RCP4.5, with respect to 1981-2000. Dotted lines indicate the 10% and 90% probability levels and associated temperature values. Created using UKCP18 User Interface.

These statements conventionally concern the probability of change being less than a given threshold, but of course we can turn them around to give the probability of exceeding that threshold. In that case, the CDF can be read as a 90% probability of temperature change exceeding about 0.7ºC and a 10% probability of temperature change exceeding about 3.5ºC in the winter in 2080-2099 with respect to 1981-2000.

The Probability Density Function shown in Figure 2 is an alternative representation of the same distribution. As probability is represented by the area under a PDF curve, the y-axis in Figure 2 is referred to as a probability density.

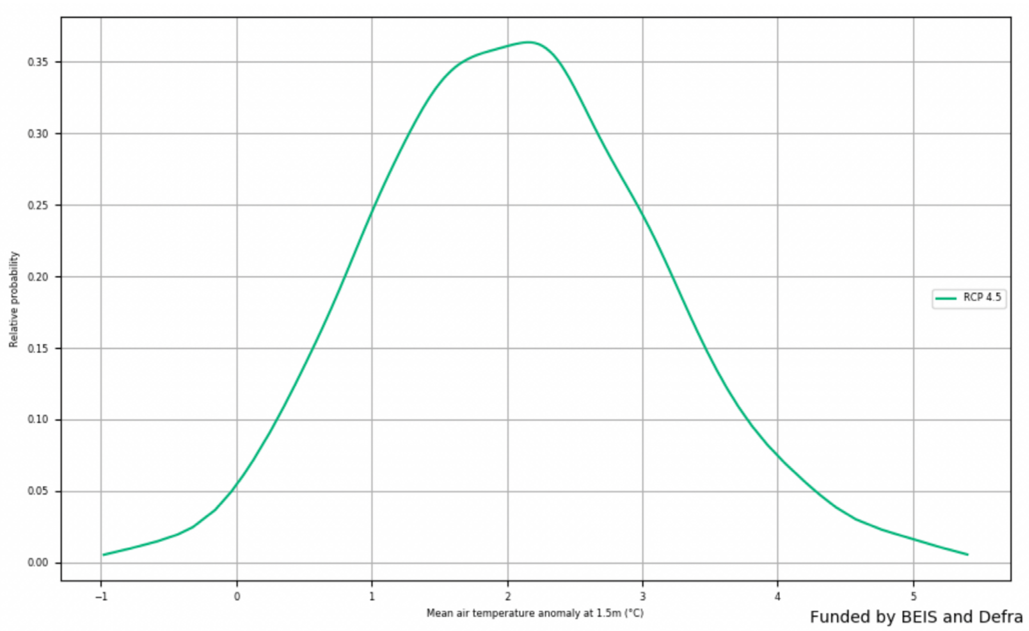

Figure 2 Probability density function (PDF) of mean winter air temperature for 2080-2099 for RCP4.5 with respect to 1981-2000.

For a given value of climate change, the CDF is the area under the PDF to the left of that value of climate change. As the CDF has a maximum value of 100%, the area under the PDF curve cannot be more than 100%.

What to be aware of when using PDFs and CDFs

As a PDF plot shows the relative probability associated with a specified amount of change, it is not recommended that they be used to explore the climate change associated with a certain probability level. You may find that, in practice, it is more informative to know the probability of a change being greater than or less than a specified value (for example, the probability associated with a specific temperature change). Similarly, you may need to ascertain the amount of change associated with a specified probability level (for example the 10% probability level, which changes are very unlikely to be less than). In both these cases, it would be more appropriate to use a CDF.

The PDF can be thought of more simply in relative terms by comparing the ratios of probability density for different outcomes. For instance, as the probability density at 1.0ºC is about 0.6 (per ºC) and the probability density 1.6ºC is about 0.2 (per ºC), then a temperature change of 1.0ºC is about 3 times more likely than one of 1.6ºC. Hence, for simplicity, PDF plots from the User Interface are all labelled relative probability rather than probability density (per ºC).

The distribution shown in Figure 2 is smooth and almost symmetrical; in practice the UKCP18 distributions will vary in shape, depending on how the effects of uncertain climate system processes combine to produce different projections for different variables, time periods and locations.

It is very important to understand what a probability means in the context of UKCP18. The interpretation of probability generally falls into two broad categories. The first type of probability relates to the expected frequency of occurrence of some outcome, over a large number of independent trials carried out under the same conditions: for example the chance of getting a 5 (or any other number) when rolling a dice is 1 in 6, that is, a probability of about 17%. This is not the meaning of the probabilities supplied in UKCP18, as there can only be one pathway of future climate.

In UKCP18, we use the second type of probability, called Bayesian, where probability is a measure of the degree to which a particular level of future climate change is consistent with the information used in the analysis, that is, the evidence. In UKCP18, this information comes from observations and outputs from a number of climate models, all with their associated uncertainties. The methodology that allows us to generate probabilities is based on large numbers (ensembles) of climate model simulations, but adjusted according to how well different simulations fit historical climate observations in order to make them relevant to the real world. The user can give more consideration to climate change outcomes that are more consistent with the evidence, as measured by the probabilities. Hence, Figure 1 does not say that the temperature rise will be less than 0.2ºC in 10% of future climates, because there will be only one future climate; rather it says that we are 10% certain (based on data, current understanding and chosen methodology) that the temperature rise will be less than 0.2ºC. One important consequence of the definition of probability used in UKCP18 is that the probabilistic projections are themselves uncertain, because they are dependent on the information used and how the methodology is formulated.

For more information on the uncertainty in the probabilistic projections please see the UKCP18 Science Overview (Lowe et al, 2018) and Land Projections Science Report (Murphy et al, 2018).

How can I access PDFs and CDFs?

Plots of PDFs and CDFs are in the UKCP18 Science Reports available at the UKCP18 website.

You can create your own PDF and CDF plots for UK on the UKCP18 User Interface. The full dataset is available from the CEDA Data Catalogue: note that this requires familiarity with handling large datasets.

References

Lowe JA, Bernie D, Bett PE, Bricheno L, Brown S, Calvert D, Clark RT, Eagle KE, Edwards T, Fosser G, Fung F, Gohar L, Good P, Gregory J, Harris GR, Howard T, Kaye N, Kendon EJ, Krijnen J, Maisey P, McDonald RE, McInnes RN, McSweeney CF, Mitchell JFB, Murphy JM, Palmer M, Roberts C, Rostron JW, Sexton DMH, Thornton HE, Tinker J, Tucker S, Yamazaki K, and Belcher S (2018). UKCP18 Science Overview report. Met Office.

Murphy JM, Harris GR, Sexton DMH, Kendon EJ, Bett PE, Clark RT, Eagle KE, Fosser G, Fung F, Lowe J, McDonald RE, McInnes RN, McSweeney CF, Mitchell JFB, Rostron JW, Thornton HE, Tucker S and Yamazaki K, 2018. UKCP18 Land Projections: Science Report. Met Office.