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

UKCP Factsheet: Global Warming Level information in UKCP

February 2025

Introduction

This factsheet summarises the information available from the UK Climate Projections (UKCP) suite of products on Global Warming Levels in February 2025. It accompanies the release of global warming level information for the UKCP Probabilistic Projections and UKCP Regional (12km) which are now available on the UKCP User Interface. This document describes what the datasets are, where they can be found, caveats and limitations as well as where to find further information.

Climate projections are produced as time-series that evolve over time as emissions of greenhouse gases lead to changing climate responses. Another way to use climate information is to focus on characterising how the climate may look at different levels of global warming rather than at different time periods under specific emissions scenarios.

For example, we could ask what the UK climate might be like if the world warms by 2 ºC above pre-industrial conditions. It is also one of the approaches taken in both the Intergovernmental Panel on Climate Change's Sixth Assessment Report as well as the Independent Assessment of UK Climate Risk (CCRA4).

Note that while this reframes the climate information, timings on when a level of global warming is reached are still retained- further information on this methodology is provided below.

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Version 1.0

1. What are Global Warming Levels?

Global Warming Levels (GWLs) represent climates that have reached a mean global temperature at specific levels above the pre-industrial period (defined here as 1850-1900). We can study the potential climate of the future world by looking at a range of Global Warming Levels.

This document describes the approach to select data from existing datasets that represent the climate at a particular GWL, which are available on the UKCP User Interface for the Probabilistic Projections and UKCP Regional. For the datasets described here, the timing of each GWL is based on a combination of observed global warming and estimations from global climate model simulations. We calculate the change in global mean surface air temperature compared to the pre-industrial and then smooth the year-to-year fluctuations (here we use a 20-year moving average). We then select a 20-year period where the global warming value of the 20-year mean is closest to the warming level in question. Figure 1 further illustrates how GWLs have been extracted.

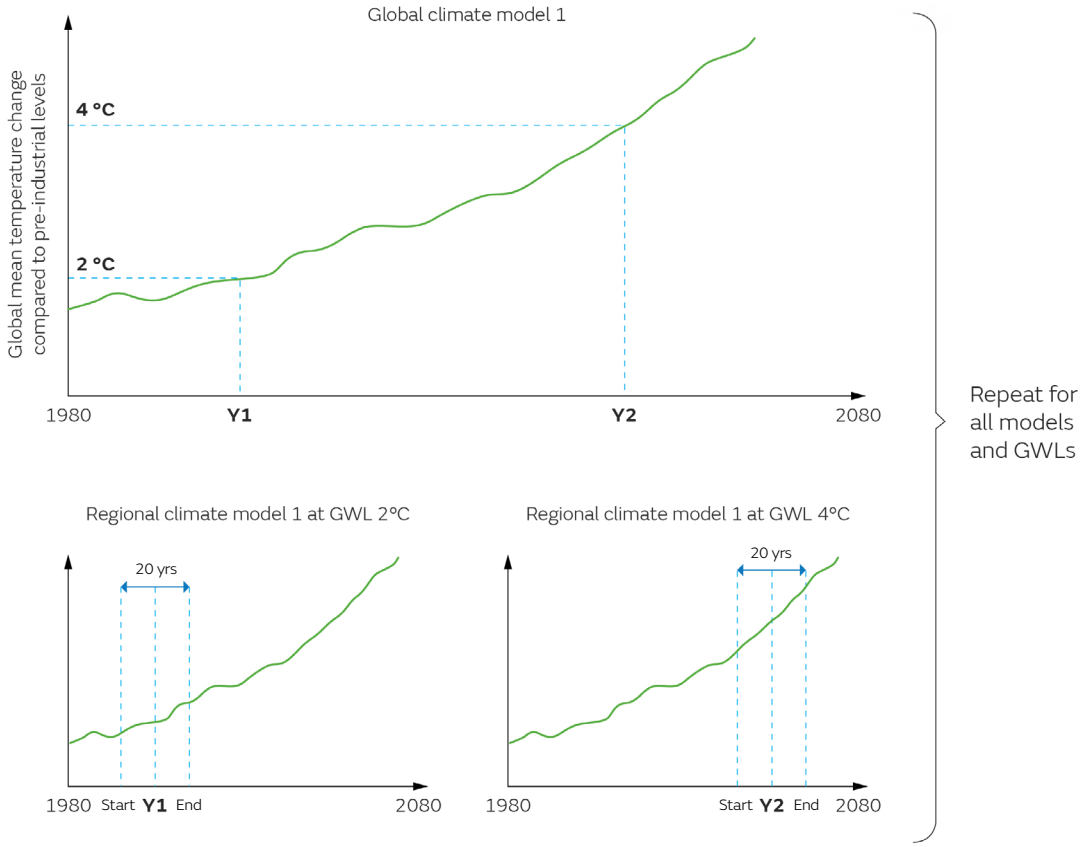

Figure 1 Illustration of how Global Warming Levels (GWLs) have been extracted. A smoothed timeseries (20-year moving average) of global mean temperature change from a global climate model (top) is used to determine the year (Y1 and Y2) in which the specified temperature change (or Global Warming Level) is reached (+2 °C and +4 °C) above the pre-industrial period (1850-1900). The 20 years that it represents is then extracted for the regional climate model (bottom): start and end years are provided in Table 1 for the members of UKCP Global (60km) which have been downscaled to create the UKCP Regional (12km) data. Note this figure is solely used to explain the general concept of GWLs and should not be used to determine real figures or data, and it is not to scale.

2. How are the periods for each Global Warming Level defined in the UK Climate Projections?

As described above, the GWLs are defined relative to the pre-industrial period (1850-1900). As UKCP climate data do not include results prior to 1900, additional steps are required to define the Global Warming Level. For UKCP datasets, global mean surface air temperature changes are first calculated relative to 1981-2000. The observed warming relative to 1850-1900 for the 1981-2000 reference period is then added from HadCRUT5 (Morice et al. 2021) (i.e. 0.59 °C).

The corresponding source of the global mean surface air temperatures for each of the UKCP datasets are as follows:

- To extract data from UKCP Regional and Local, the relevant 20-year period to represent a GWL is derived from the driving UKCP Global ensemble member, i.e. the global climate model that sets the boundary conditions for the simulation. See Table 1 for the resulting 20-year periods following the above approach. Note that the data are derived for a high emissions scenario (also known as RCP 8.5).

Member number	GWL1		GWL1.5		GWL2		GWL2.5		GWL3		GWL4	
	START	END	START	END	START	END	START	END	START	END	START	END
01	1995	2014	2008	2027	2018	2037	2029	2048	2037	2056	2052	2071
04	1994	2013	2005	2024	2015	2034	2025	2044	2034	2053	2048	2067
05	1996	2015	2008	2027	2020	2039	2031	2050	2040	2059	2055	2074
06	1994	2013	2007	2026	2017	2036	2027	2046	2036	2055	2052	2071
07	1994	2013	2006	2025	2019	2038	2030	2049	2038	2057	2052	2071
08	1995	2014	2007	2026	2020	2039	2031	2050	2041	2060	2058	2077
09	1992	2011	2003	2022	2016	2035	2025	2044	2032	2051	2045	2064
10	1995	2014	2009	2028	2020	2039	2030	2049	2038	2057	2055	2074
11	1993	2012	2006	2025	2017	2036	2027	2046	2036	2055	2052	2071
12	1998	2017	2012	2031	2023	2042	2033	2052	2042	2061	2055	2074
13	1993	2012	2005	2024	2017	2036	2027	2046	2037	2056	2052	2071
15	1993	2012	2007	2026	2020	2039	2032	2051	2041	2060	2056	2075
23	1997	2016	2012	2031	2028	2047	2036	2055	2044	2063	2064	2083
25	1993	2012	2009	2028	2024	2043	2035	2054	2043	2062	2060	2079
27	2008	2027	2027	2046	2038	2057	2049	2068	2060	2079	--*	--*
29	1999	2018	2017	2036	2031	2050	2044	2063	2056	2075	2075	2094

Table 1 Start and end years of the 20-year time slices for each pseudo-Global Warming Level (GWL, °C) for members of the UKCP Global (60km) model ensemble. The member numbers in the table correspond to the same member numbers in UKCP Regional (12km). Note that years are defined from December to November in order to capture complete seasons, hence the year 1981 represents 1 December 1980 to 30 November 1981. These start and end years can be used to extract and make your own GWL data sets. * Member 27 does not reach a GWL of 4°C by 2100. Please see appendix D of **UKCP18 Guidance on data availability**, access and formats for further information on member numbers.

- For the Probabilistic Projections, global mean temperature anomalies are obtained from the corresponding sample. Note this dataset includes 3,000 samples and are for four emissions scenarios (RCP 2.6, 4.5, 6.0 and 8.5).

3. Why is the GWL information for the Probabilistic Projections provided at different emissions scenarios and which one should be used?

When applying the method described in Section 2, the range of values for a variable obtained in the 20-year window is likely to be different for a low emissions scenario compared to a high emissions scenario. This is due to a variety of reasons including the steepness of the global mean temperature curve: as the curve for a high emissions scenario is much steeper as the world warms faster, the difference between the global mean temperature at the start and end of the 20-year window will be greater than a low emissions scenario. Also, it could be affected by the timing of the response of the local climate such as the land surface. We have therefore included GWL information for multiple emissions scenarios for the Probabilistic Projections.

While we do not provide advice on which emissions scenario to use, it is worth noting that RCP 2.6 represents a world that has a higher chance of meeting the Paris Agreement aims. RCP 4.5 and RCP 6.0 represent worlds that better reflect current policies and commitments to greenhouse gas emissions reductions. As UKCP Global, Regional and Local GWL data are derived from RCP 8.5 simulations, we have also included this emission scenario. Also see CCC (2024) on their selection of GWLs and their relationship with global emission trajectories.

4. What UKCP data are available and where can I find them?

There are three main channels for you to obtain information at GWLs:

- **UKCP User Interface** where you can find data for the UK only on the Ordnance Survey's British National Grid.
- **CEDA Archive** where you can find all climate model data.
- **Climate Data Portal** where you can find UKCP and UKCP-related data in GIS formats.

The available datasets for Global Warming Levels are summarised in Table 2.

You can also extract and make your own GWL datasets by using the start and end years given in Table 1 for different ensemble members. Only the Probabilistic Projections GWL data are on both the CEDA Archive and the UKCP User Interface. For example, you may wish to do this if you're analysing variables not currently available on the User Interface or from the datasets only available on the CEDA Archive on the model's native grid.

In 2018, the Derived Projections were also produced to provide information at GWLs as well as for a low emissions scenario (RCP 2.6) (Gohar et al, 2018). At the same spatial resolution as UKCP Global i.e. 60km. The method used a different approach to the one described above. Longer timeseries (50 years) of data that are representative of the GWL were produced rather than simply extracting 20 years directly from the original climate model data.

Data Product	GWLs (°C)	UKCP User Interface	CEDA Archive	Climate Data Portal
UKCP Probabilistic Projections	1, 1.5, 2, 2.5, 3, 4	✓	✓	
UKCP Global (60km)		✓		
UKCP Regional (12km)		✓		Precipitation, temperature, derived metrics (growing/ cooling/heating degree days, drought severity index, frost/icing/ summer/tropical days)
UKCP Local (2.2km)		✓ on 5km grid*		
UKCP18 Derived Projections	2, 4	✓	✓	

*Coming soon

Table 2 Location of UK Climate Projections datasets at Global Warming Levels

5. What additional datasets are there and how do they relate to UKCP?

Since 2018, several datasets have been produced that sometimes use different methodologies to provide information at GWLs. Analysis of the different methods shows that how the GWL is defined compared to the pre-industrial period has the greatest impact on which years are selected. These are summarised in Table 3. Note that the GWL calculation approach described in this factsheet is the same as that described in the CCRA4 Proposed Methodology (CCC, 2024).

Title	Method for identifying GWLs	Implications
UKCP Derived Projections Gohar et al (2018) Derived Projections Report	A 25-year period smoothing is used and observed warming (0.51 °C) is based on HadCRUTv4. 50 years of data is produced using a combination of time-shifting to produce time-mean climate changes and pattern scaling to extract time series of variability.	The smaller observed warming in HadCRUTv4 means the selection window is later than in our approach. Note that the additional processing means that variabilityz may not be physically consistent.
Future changes to high impact weather in the UK Hanlon et al (2021) Climate Data Portal	Similar to this document but a 21-year period is selected and observed warming (0.51 °C) based on HadCRUTv4.	HadCRUTv4 has a smaller observed warming than HadCRUTv5.. This means that the selection window is later than our approach.
Probabilistic UK climate projections conditioned on Global Warming Levels Steptoe & Murphy (2024)	Similar to this document but all emissions scenarios are used to define the cumulative distribution function of climate changes. The tolerance for the threshold that a GWL is exceeded is ±0.5 °C unlike in our method which is ±0.1 °C.	The use of ±0.5 °C and all emissions scenarios available means a larger sample is used to define the cumulative distribution function compared to our approach.
High impact scenarios for the UK Arnell et al (2021) https://uk-cri.org	A 30-year period is extracted where the global mean surface air temperature first exceeds the GWL.	The analysis also uses a "delta method" for bias correction, which excludes the climate model variability estimate.

Table 3 List of documents and products on Global Warming Levelsrelated to the UK Climate Projections.

6. What can I do with the datasets that I couldn't do before?

The datasets described in this document opens opportunities to explore impacts of different global warming futures for different UKCP data products compared to the Derived Projections published in 2018 (see Derived Projections factsheet). The GWL dataset for the Probabilistic Projections provides a larger range of outcomes. The GWL dataset for UKCP Regional/Local also provides higher spatial resolution meaning that the effects of coastlines and topography are better simulated by the climate model.

GWLs can be easier to understand and communicate as including emissions scenarios require additional explanation. It also allows for simpler comparisons across different models and lines of evidence, as it helps to reduce the influence of some uncertain factors (e.g. the large-scale sensitivity of climate models to increasing emissions). This can be helpful for analyses in which timescales are not overly important and for metrics that do not strongly depend on the pathway of forcing, or which do not have a strong memory effect. In the Independent Assessment of UK Climate Risk for the UK's Fourth Climate Change Risk Assessment (CCRA4), GWL framing is used alongside global emissions trajectories, enabling the use of UKCP18 datasets that are only available at one emissions scenario, see Table 1 of CCC (2024).

7. What are the limitations of the Global Warming Level approach?

The procedure described above to produce data to support analysis at GWLs is one of multiple approaches and there are limitations; indeed all current methods have them. Based on James et al (2017), our current approach:

- For the UKCP Regional and Local GWLs data which are based on only one emissions scenario it is assumed Assumed that the implications/impacts of each GWL will be the same regardless of the emissions pathway. For example, the local response at a GWL 3.0 °C reached by greenhouse gas emissions alone or with the addition of aerosol forcings and land use changes could be different.
- Assumes that local changes are primarily dependent on thermodynamics rather than dynamical changes.
- Does not capture any time lag in the response to anthropogenic forcing or changes due to emissions reductions.
- Requires selecting a time window which could be sensitive to multi-decadal natural variability such as localized aerosol forcing, i.e. changes may not be due to global temperature changes
- Means that each GWL will have a different ensemble size: this is because not all UKCP Global members reach a particular GWL.

Additionally, we use a 20-year period to define each GWL which is a balance of capturing natural variability whilst still being able to show differences between GWLs. Therefore, it does not describe the full range of natural variability. The 20-year periods defined by the GWLs (especially for lower values) overlap if you select 0.5 °C increments. This means that the same time series data could be used when comparing closely adjacent GWLs, i.e. differences between the GWLs may not be as easily detectable.

As sea-level rise is a slow process compared to the atmospheric warming, the GWL approach is unsuitable for providing sea-level information.

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

Before you start using the data, you should consult the following set of UKCP guidance materials:

- **How to use the UKCP18 land projections**
- **Caveats and limitations**
- **Data availability, access and formats**
- **Bias correction**

References

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