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: Downscaled CMIP5 Members

New ensemble members have been added to UKCP Regional (12km) and UKCP Local (2.2 km) bringing in wider information about future climates simulated by models developed in the international community via the 5th phase of the Coupled Model Intercomparison Project (CMIP5). These datasets complement the original 12-member UKCP Regional and UKCP Local products and support a more robust assessment of future climate changes at fine spatial scales. It brings these products more in line with UKCP Global (60 km), which already includes CMIP5 results, although still with less comprehensive sampling of uncertainty.

This factsheet summarises the key findings from the "Augmenting UKCP Local (2.2km) projections by down-scaling global models from CMIP5" report[1] and provides additional guidance on the datasets. If you are unfamiliar with UKCP Regional and Local, we advise that you familiarise yourself with existing reports and guidance[2,3].

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What is CMIP5 and why have we included it?

CMIP5 stands for the fifth phase of the Coupled Model Intercomparison Project where climate modelling centres across the world contributed results from a set of global climate model experiments. These results were used in the Intergovernmental Panel on Climate Change's fifth assessment report published in 2013. Thirteen of these climate model results, selected due to their performance against relevant metrics and for credible realisations of UK risks[4] (CMIP5-13) were incorporated in UKCP Global (60 km) alongside a 15-member perturbed physics ensemble (PPE-15) based on the Met Office global climate model (GCM), HadGEM3-GC3.05. We have shown notable differences between the future projections from the Met Office's model compared to other GCMs from CMIP5. For example, the Met Office model typically projects a greater future increase in temperature and decrease in precipitation in summer compared to the other CMIP5-13 GCMs[3].

[1] Short and Kendon (2024) available at https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp-cmip5-downscaling-report.pdf.

[2] See Kendon EJ et al (2021) Update to UKCP Local (2.2km) projections, Met Office Hadley Centre, Exeter, July 2021, www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/ukcp18_local_update_report_2021.pdf and Kendon EJ et al (2023) UKCP Local (2.2km) transient projections, Met Office Hadley Centre, Exeter, March 2023, www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp_local_report_2023.pdf.

[3] Murphy et al (2018) UKCP18 Land Projections: Science Report, Met Office Hadley Centre, Exeter, March 2019, www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Land-report.pdf

[4] See McSweeney CF, Murphy J, Sexton D, Rostron J, Yamazaki K, Harris G (2018). Selection of CMIP5 members to augment a perturbed–parameter ensemble of global realisations of 21st century climate for the UKCP18 scenarios. Hadley Centre Technical Note No. 102, Met Office, Exeter, UK, https://digital.nmla.metoffice.gov.uk/IO_28f93601-3178-4c48-8621-fb4388ec66a1

UKCP18 also includes climate projections at a finer scale: UKCP Regional (12 km) and UKCP Local (2.2 km). When these were published, only 12 PPE members were downscaled. As a result, they sample a narrower range of potential futures compared to UKCP Global. To address this, we have augmented UKCP Regional and Local by driving the regional and convection-permitting models respectively with four members of the CMIP5 GCM ensemble.

The augmented UKCP Regional and Local now supports a more robust assessment of future climate changes at finer spatial scales.

How were the CMIP5 models selected for downscaling?

The thirteen CMIP5 members from UKCP Global were sub-selected based on their ability to represent features of the climate important for the UK (such as circulation patterns, and temperature[4]) as well as a diversity in future changes, especially in summer. The four models chosen are ACCESS1-3, IPSL-CM5a-MR, MPI-ESM-LR and MRI-CGCM3. The global mean temperatures for these climate models warm less quickly than the original 12 PPE members.

Note that in UKCP Global, MPI-ESM-MR was used but the necessary driving data was not available at the time to allow the downscaling. We opted to use the MPI-ESM-LR model instead. The model performs very similarly to the MR version[4].

What is the impact of augmenting UKCP Regional and Local?

The result of including four members of the CMIP5 ensemble is an increase in the spread of the Regional and Local projections (see Figures 1 and 2). Future changes in precipitation and temperature in the CMIP5-driven regional models largely follow those in their parent GCMs, with differences between the responses of CMIP5 parent and nested models being comparable to those between members of the existing UKCP18 PPE.
We present these results using two approaches: Figure 1 shows the climate changes for RCP 8.5 between a future time period (2061-2080) and the baseline (1981-2000) aligned with existing UKCP18 documentation. Figure 2 shows the climate changes at a global warming level of +3 ºC compared to pre-industrial - a framing for future changes that is less dependent on emissions scenario and climate model sensitivity.

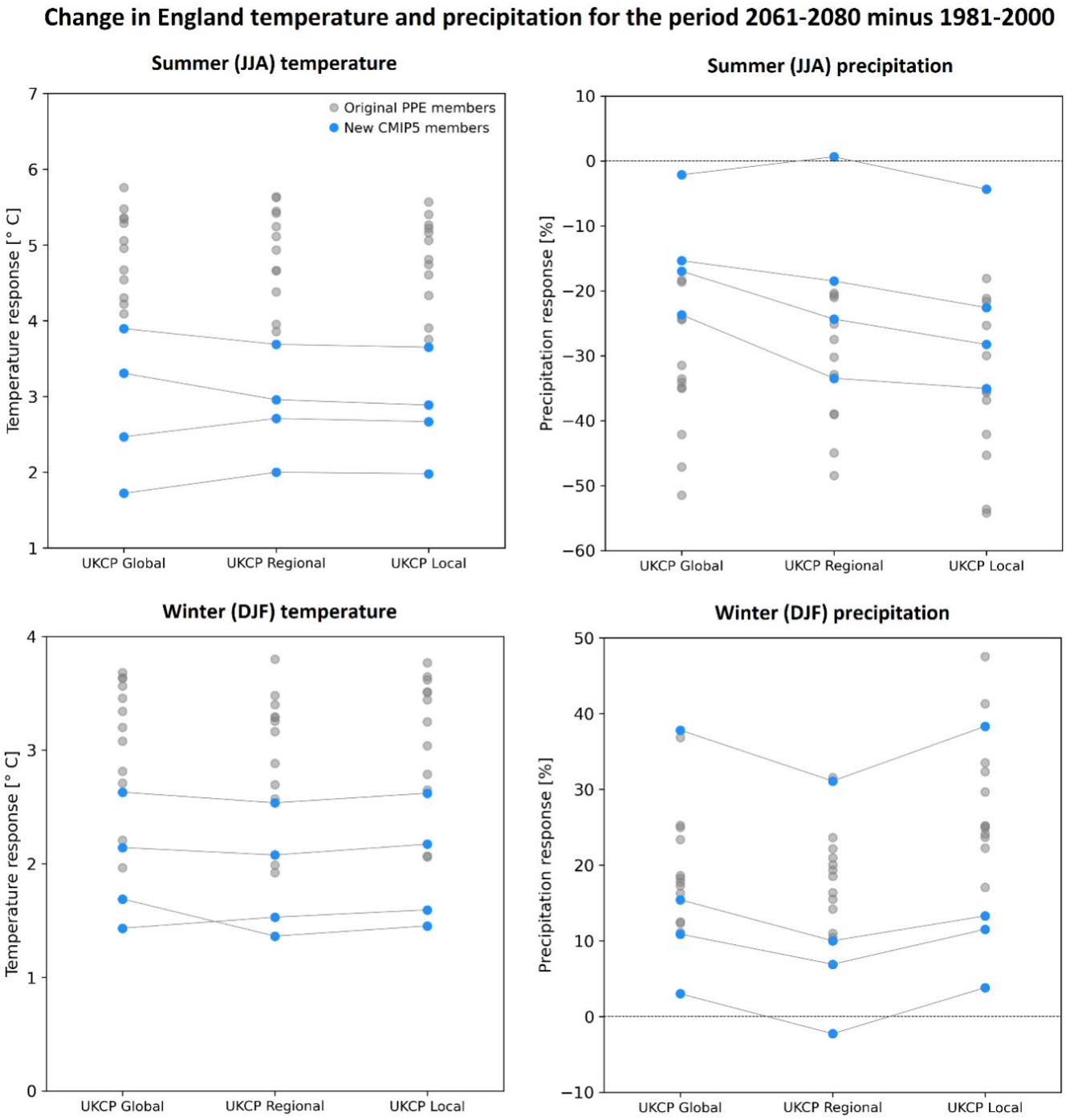

Figure 1 Plots showing the range of future summer changes in England: left-hand panels show changes for mean surface air temperature and right-hand panels precipitation for 2061-2080 compared to 1981-2000, with the top row showing changes in summer and the bottom row the changes in winter. Original PPE members and New CMIP5 members refer to the UKCP Global (60 km) PPE-15 and CMIP5-4 ensemble members respectively.

We also assessed the new simulations provided by the downscaled models driven by CMIP5 GCMs and they are mostly comparable to those in the existing UKCP Regional and Local simulations. Exceptions to this are for winter precipitation from the MRI-driven and summer precipitation from the MPI-driven CMIP5 downscaled models, for which issues with present-day performance mean projections are considered unreliable for these specific cases. More detailed comparisons and exceptions are presented in the science report[1].

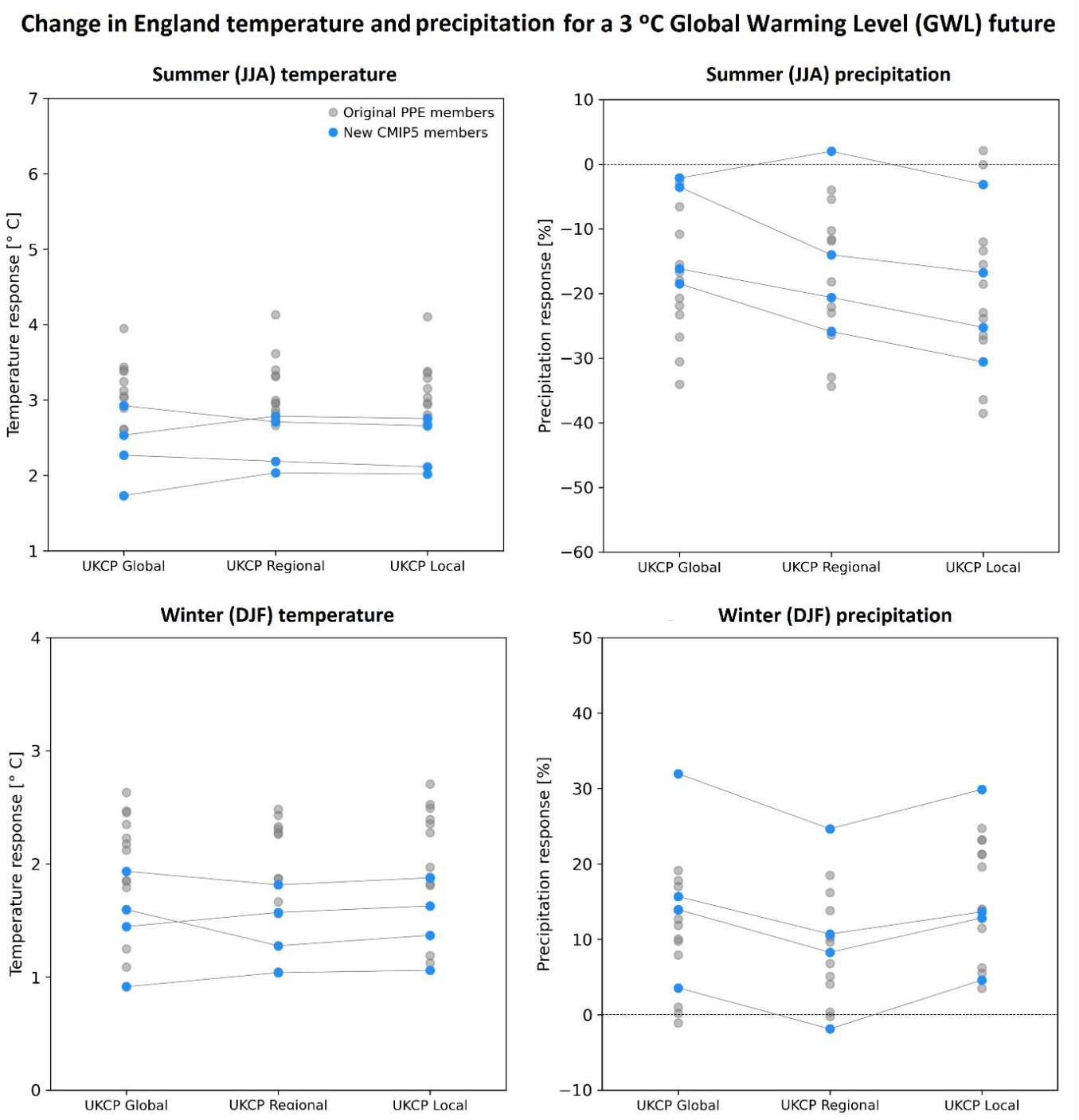

Figure 2 As Figure 1 but showing the changes in England summer (top row) and winter (bottom row) temperature (left hand side) and precipitation (right hand side) for the 3 °C Global Warming Level. This corresponds to the difference between a 21y future period, centred on the year when global mean surface temperature reaches 3 °C above pre-industrial, and the baseline (1980-2000) period.

Short and Kendon (2024)[1] compare downscaled changes for the UK at a given Global Warming Level (GWL). At a GWL of +3 °C compared to pre-industrial, in summer, some of the new members have a reduced temperature increase in the UK compared to the twelve original members. Some members have smaller changes in summer precipitation than the original members (the original members favour summer drying conditions, while some of the new members explore a future less affected by drying conditions).

There are also new outcomes for winter. At +3 ºC GWL, some of the new members indicate larger increases in winter mean precipitation and a more pronounced intensification of extremes than the original members, whilst some others indicate that overall decreases in winter rainfall could be plausible in Scotland (whereas almost all the original members indicated increased rainfall). Several of the new members indicate smaller wintertime temperature increases for the UK than the original members. Further differences are described in Short and Kendon (2024)[1].

Does this change the "Warmer wetter winters, hotter drier summers" headline message?

Although some members do project a drier winter or a wetter summer (Figures 1 & 2), the headline message from the UKCP18 simulations that we can expect a greater chance of warmer, wetter winters and hotter drier summers remains the same.

How does this impact existing analyses using UKCP Regional and Local?

Users working in a GWL-based framework

The CMIP5 simulations introduce modest differences in the projection ranges under a GWL framework. However, they do bring in scenarios in which the UK warms less quickly compared with the global average, particularly for summer temperatures. The range of regional precipitation changes is slightly larger when including them (see Figure 2).

Users working in a time-dependant framework

The CMIP5 simulations will have significant impact on the ensemble mean and median as well as the lower range. However, they do not affect the upper range of climate changes of average temperature and rainfall changes. The CMIP5 simulations warm less quickly resulting in moderate changes in the seasonal mean regional precipitation. This means the drying trend is less strong in summer and the wetting trend is less strong in winter (see Figure 1).

Are analyses based on the original UKCP Regional and Local still valid?

The Met Office model on which UKCP Regional and Local projections are based is known to have a relatively high climate sensitivity (or ECS). Although high climate sensitivities are regarded as less likely to be realised in the real world, they cannot currently be excluded based on available evidence. For this reason, we have advised UKCP users to use UKCP Regional and UKCP Local in the context of other UKCP products which draw from a wider range of models. The UKCP18 Probabilistic Projections combine information from multiple models, including a number of CMIP5 models, which have a wide range of ECS values. UKCP Global uses both the high climate sensitivity models from the Met Office in addition to a number of CMIP5 models with a wider spread of sensitivities. By including a new set of CMIP5-driven simulations in UKCP Regional and UKCP Local, we are making it easier for users to consider this wider range of climate sensitivities. Focussing on regional scale projections, a recent analysis by Swaminathan et al. (2024) has suggested that models with a

higher climate sensitivity do not necessarily have less plausible regional projections, based on an analysis of heavy rainfall, drought and wildfire conditions.

Climate model projections can be used in ways that are somewhat independent of climate sensitivity. One way is through the use of Global Warming Levels (GWLs), which present future climate changes at a specific level of global average temperature change (e.g. 2°C above pre-industrial values) and so are independent of timing or emissions pathways.

Analyses based on the existing UKCP-local and regional studies remain valid. However, because these new CMIP5-4 simulations introduce new plausible outcomes that are outside of the range of the existing runs, some users may wish to consider extending their work to bring in these new simulations.

What are the limitations?

Uncertainty range is still underestimated

While augmenting UKCP Regional and Local is shown above to increase the uncertainty range, the ensembles still underestimate uncertainties in future changes because:

- The number of alternative global climate models we have been able to downscale is small.
- As with the original datasets, uncertainty in the representation of physical processes within the climate model used for UKCP Local are not accounted for.
- Projections have been produced for a single emissions scenario (RCP 8.5) only.
- No information from other convection-permitting model simulations covering the UK has been included.

The most comprehensive uncertainty range in the UKCP18 dataset for land variables is from the Probabilistic Projections, although we recognise that they may not provide the necessary data required for all applications such as providing daily data across the UK that is spatially coherent. The EuroCORDEX-UK dataset and tools developed by UCL under the UK Climate Resilience programme[5] can also be used to explore wider uncertainties associated with using different GCM and RCM combinations in 12km simulations, but these do not include information at convection-permitting resolutions.

Only regridded 5 km data available for UKCP Local

It has been noted that there are instances of high rainfall at the raw 2.2km grid scale in UKCP Local (2.2 km) data (see Short et al, 2024) that have physically unrealistic spatial characteristics, manifesting as linear features aligned with the model grid. For this reason, data from the CMIP5-driven runs for UKCP Local are only available on a 5 km grid (using the Ordnance Survey National Grid reference system; OSGB), alongside the UKCP Regional data (also on an OSGB grid).

[5] https://www.ucl.ac.uk/statistics/research/eurocordex-uk

Where are the data?

You can find the augmented datasets on both the UKCP User Interface[6] and the CEDA Archive[7] and their availability is presented in Table 1.

On the UKCP User Interface, the data is available when you select "Land Projections: Regional (12 km)" or "Land Projections: Local (2.2 km)" from the left-hand menu. Both datasets are available on the Ordnance Survey's national grid (OSGB) for the UK at 12 km and 5 km spatial resolution for UKCP Regional and Local respectively for the time-period December 1980 to November 2080. The data are available for RCP 8.5 as well as global warming levels. Both the CMIP5 and original PPE datasets for both UKCP Regional and Local are available.

On the CEDA Archive, there is a more complete set of data available in NetCDF format. In addition to including the UK data available on the User Interface the data is also available on the 12 km whole North-Atlantic European domain for UKCP Regional.

Variable (short name)	UKCP User Interface		CEDA Archive	
	UKCP Regional	UKCP Local	UKCP Regional	UKCP Local
Cloud cover (clt) Relative humidity (hurs) Specific humidity (huss) Mean sea level pressure (psl) Net long wave radiation (rls) Net short wave radiation(rss) Snow (snw) Maximum temperature (tasmax) Minimum temperature (tasmin) Eastward wind (uas) Northward wind (vas) Snowfall+ (prsn)	Daily, monthly, seasonal, annual 12 km over UK only Countries, regions & rivers in UK	Daily, monthly, seasonal, annual 5 km over UK only Countries, regions & rivers in UK	Daily, monthly, seasonal, annual ~12 km over Europe, 12 km over UK Countries, regions & rivers in UK	Daily, monthly, seasonal, annual 5 km over UK only Countries, regions & rivers in UK
Precipitation (pr) Mean temperature (tas) Wind speed (sfcWind) Gusts (wsgmax10m)	As above	As above plus hourly	As above	As above plus hourly

Table 1 Details of variables available for UKCP Regional and UKCP Local from two web interfaces: UKCP User Interface and CEDA Archive. All data are available for a high emissions scenario (RCP 8.5) and at global warming levels (1.5, 2.0, 2.5, 3 and 4 °C). +prsn is only available for UKCP Local.

Please note, for both the User Interface and the CEDA Archive, the UKCP Regional data for all variables on the 30th November 2014 is missing from members 23 and 27. Reviewing a range of sources of data and comparing November 2014 to surrounding years we do not see any significant impacts from this missing data.

[6] https://ukclimateprojections-ui.metoffice.gov.uk

[7] https://catalogue.ceda.ac.uk

What data characteristics should you be aware of?

For users of UKCP Global data from the CEDA Archive, the ensemble members are identified by a number[8]. Note that to follow the existing naming convention, the MPI-ESM model used here, MPI-ESM-LR is labelled as member 29. See Table 2.

The PPE members of UKCP Regional and Local use a 360-day calendar, i.e. 12 months of 30 days. The CMIP5 members use different calendars, namely a Gregorian calendar model which has dates that are concomitant with the real world and a 365-day calendar which uses a real-world calendar but ignores the occurrence of the 29th February in leap years. See Table 2.

CMIP5 Member	Member number	Calendar used
ACCESS1-3	23	Gregorian
IPSL-CM5a-MR	25	365-day
MPI-ESM-LR	29	Gregorian
MRI-CGCM3	27	Gregorian

Table 2 Naming conventions and calendar systems used for each of the CMIP5 members

Reference

Swaminathan, R., Schewe, J., Walton, J. et al. (2024) Regional impacts poorly constrained by climate sensitivity. Earth's Future. 12. doi.org/10.1029/2024EF004901.

[8] See UKCP18 Guidance: Data availability, access and formats, www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance-data-availability-access-and-formats.pdf