Department for Environment Food & Rural Affairs

Department for Business, Energy & Industrial Strategy

Met Office Hadley Centre

Environment Agency

FAQ on UKCP Local (2.2km)

Update published in 2021

1 Who is this document for?

This document provides information for those who have used or are planning to use UKCP Local (2.2km) projections and is a companion document to the report "Update to UKCP Local (2.2km) projections".

On 22 July 2021, we released an update to the UKCP Local (2.2 km) projections, replacing the original dataset from September 2019. For many users and applications, we expect little impact on existing or planned analyses but there are a number of situations (described below) where you should repeat your analysis with the updated dataset.

This update does not affect any other UKCP product, i.e. the Probabilistic Projections, UKCP Global, UKCP Regional (12km), Derived Projections and Marine Projections.

2 What is UKCP Local (2.2 km) and why has it been updated?

UKCP Local (2.2km) is based on a 2.2km "convection-permitting" climate model that provides a step forward in our ability to simulate small scale behaviour seen in the real atmosphere, in particular atmospheric convection – a key process driving many of our extreme weather events. Due to the high spatial resolution, compared to more traditional climate models, it also better represents the influence of mountains, coastlines and cities (Kendon et al 2019).

The climate model used to generate UKCP Local, originally released in 2019, included an error in the computer code that determines how much of the solid precipitation falls as snow and how much as graupel (soft small ice pellets that form in convective clouds). In turn, this affects some other variables (e.g. the amount of lying snow, which leads to colder winter temperatures, and hourly precipitation extremes) and leads to differences that are significant[1]. This error has now been fixed and the simulation rerun.

We have also made improvements relating to the representation of the snowpack, as well as fixing some other minor code errors and releasing a lightning metric.

An in-depth analysis and description of the issue can be found in the Update to UKCP Local 2.2km projections report, Kendon et al (2021), available on the Guidance and Science Report section of the UKCP web pages.

[1] Differences are significant when they are greater than the standard deviation across the UKCP Local ensemble.

3 How does the Local (2.2km) update affect the headline findings?

The Local (2.2km) update does not change the UKCP18 headline message of a greater chance of warmer, wetter winters and hotter, drier summers across the UK in future (Murphy et al, 2018).

For 2061-80, under a high greenhouse gas emissions scenario (RCP8.5), the update suggests winters will be warmer by 3.3°C (2.0-3.5°C)[2] and wetter by 26% (15-40%)[2]; whilst summers will be hotter by 4.6°C (3.6-5.0°C)[2] and drier by 29% (17-47%)[2].

Changes to the headline finding statements related to the temperature of hot summer days, the frequency of hot spells and hourly precipitation extremes are as follows. Under a high emissions scenario by the 2070s:

- The temperature on hot summer days shows increases of 3.8 to 6.8°C compared to recent climate. In the original data, this range was 3.7 to 6.8°C.
- The frequency of hot spells over the Southern UK (two or more days over 30°C) increases to 4.1 occurrences per year, compared to 0.20 occurrences in recent climate. In the original data, these were 4.3 and 0.25 per year, respectively.
- Hourly rainfall associated with an extreme event that typically occurs once every two years increases by 29% (central estimate). In the original data, this increase was 25%.

4 How different are the updated data compared to the original?

The projected changes in the updated data are qualitatively the same as the original dataset for the following:

- UKCP Local largely reinforce the UKCP Regional (12km) results in terms of UK seasonal mean changes (note that consistency is generally increased compared to the original UKCP Local). One exception is for changes in winter precipitation where UKCP Local shows greater increases compared to the UKCP Regional.
- For applications focussing on extremes, or requiring information on fine spatial scales, UKCP Regional and UKCP Local are expected to be the primary source of information.
    - For heavy daily precipitation events, UKCP Local is more reliable especially in summer, due to the better representation of convection.
    - For hourly precipitation including extremes, you should only use the UKCP Local. However, the results are likely to underestimate the uncertainty range.
- We recommend that UKCP Local is used in combination with other UKCP products, rather than in isolation, in order to give the most complete picture of future climate.

However, the data values are different between the original and updated datasets. Details are provided in Table 5.1 of the Kendon et al (2021) (and reproduced in Appendix A).

[2] The range quoted corresponds to the UK-average of the 2nd lowest to 2nd highest responses across the 12-member updated ensemble.

In addition to changes in the quantitative values, there are changes in the qualitative statements around snow and lightning, with the latest update:

- For snow, UKCP Local differs from the UKCP Regional, likely due to the improved representation of wintertime convective showers and the better resolution of high terrain.
- The simulation of lightning is considerably improved and has now been made available.

5 What should I do if I've already used the original UKCP Local (2.2km)?

If your existing analysis or application requires the following variables from the original UKCP Local data, then there should be little effect, but the new UKCP Local data are preferred for all new applications:

- Summer temperature including extremes
- Summer mean precipitation
- Cloud

Note that for daily values, you should ideally use UKCP Local alongside the UKCP Global projections to give a more comprehensive uncertainty range.

However, if your existing analysis or application uses the following variables from the original UKCP Local, you should repeat your analysis using the updated dataset to quantify any impact on your particular application:

- Snow
- Cold winter temperatures
- Hourly precipitation extremes
- Surface winds over the ocean, some localised regions over Ireland and Scottish mountains

Also affected but to a lesser extent are winter precipitation and heavy daily precipitation events, for which present-day values are affected, but with future changes not significantly impacted by the rerun. If you choose not to repeat your analysis with these datasets, extra care should be taken in assessing the credibility of the results, including comparison with the updated data.

6 Which existing UKCP documents and datasets does the update affect?

The update only affects the UKCP Local datasets (available on the UKCP User Interface and the CEDA Archive). It does not affect any other dataset in the latest set of UK Climate Projections published since November 2018.

On the existing documentation that include UKCP Local results:

- **UKCP Local (2.2km) science report** (i.e. UKCP Convection-permitting model projections: Science report) - the figures and numbers quoted in the report have not been updated – please refer to the Update to UKCP Local 2.2km projections report (Kendon et al, 2021) for revisions to key figures and numbers.
- **UKCP Headline Findings** – The statements are not qualitatively different but the UKCP Local-based numbers have been updated.
- **Factsheet on Snow** – this has been updated.
- **Factsheet on UKCP Local (2.2km)** – this is not affected by the updated data. A summary of UKCP Local is also available in Kendon et al (2021).

All the above documents are available on the UKCP web page on Guidance and Science Reports. We have placed suitable warning messages and a link to this document and the Update to UKCP Local 2.2km projections report on the UKCP web pages.

On existing datasets:

- The CEDA Archive includes both the original and updated UKCP Local datasets. The original data will be available on the CEDA Archive until 21 July 2022, after which time only the updated data will be available. Links to this and the technical note are included in the data folders.
- The UKCP User Interface only includes the updated UKCP Local dataset as this is the preferred version for use. If you require the original dataset, please contact the UKCP Helpdesk. Warning messages are included in the data request forms.

7 When will FUTURE-DRAINAGE outputs be available?

The FUTURE-DRAINAGE project uses the updated UKCP Local projections and will provide revised rainfall uplifts and new guidance for UK urban drainage design and urban flood resilience. We are aware that many organisations are awaiting the results of this project. We have worked with the FUTURE-DRAINAGE team, who have contributed to the evaluation of the updated projections, allowing FUTURE-DRAINAGE outputs to be released at the same time as the UKCP Local update.

8 What does this mean for the Environment Agency's climate allowances?

The Environment Agency uses both climate projections and impacts research to create climate allowances for flooding in the following guidance:

- Flood risk assessments: climate change allowances - used by local authorities and developers to ensure development is resilient to climate change impacts.
- Adapting to climate change: advice to flood and coastal erosion risk management authorities - used by risk management authorities (RMAs) when applying for Flood and Coastal Erosion Risk Management (FCERM) Grant-in-Aid to build FCERM schemes.

The Environment Agency has already updated climate allowances for sea level rise in December 2019, using the UKCP18 marine projections, and in summer 2021 new climate allowances for fluvial flooding were published using the UKCP18 Probabilistic Projections.

The Environment Agency are likely to use UKCP Local, and in particular the results of FUTURE DRAINAGE, to inform updates to climate allowances for rainfall, used in assessments for surface water flooding and to inform drainage design. Any updates to climate allowances for rainfall are likely to published later in 2021 at the earliest.

9 Does the update change the relationship between UKCP products?

UKCP Local (2.2km) is one product from the suite of information in the latest UK Climate Projections. While the high spatial resolution allows more realistic representation of atmospheric processes, the dataset currently only provides data for three 20-year time slices, for one emissions scenario (RCP8.5) and one climate model (twelve variants of the Met Office Hadley Centre model are downscaled). If you wish to explore a larger range of outcomes, we advise using the probabilistic projections in the first instance and UKCP Global (60km) (see Figure A.1). If you wish to explore a continuous time series from 1981 to 2080, we advise using UKCP Regional (12km). However, we do typically find larger differences (or biases) when comparing UKCP Global and Regional with observations than for UKCP Local. Also, only UKCP Local provides reliable projections of changes in hourly rainfall including extremes, for which the updated dataset only should be used.

UKCP Local (2.2km) provides the most spatially detailed picture of future climate for most of the UK. However, due to the proximity of the Shetland Islands to the northern boundary of the model domain used for these projections, data produced for this location are not reliable and should not be used. For studies including the Shetland Islands, analysis could include:

- Use of other UKCP products, including the Regional (12km) projections,
- Consideration of alternative approaches, for example using Local (2.2km) projections for an analogous location,
- Use of convection-permitting model datasets from other experiments, such as that from the European Climate Prediction (EUCP) Project (see www.eucp-project.eu).

References

Kendon, E. J., et al (2019) UKCP Convection-permitting model projections: Science Report, Met Office Hadley Centre, Exeter. https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP-Convection-permitting-model-projections-report.pdf

Kendon, EJ, et al (2021) Update to UKCP Local 2.2km projections, Met Office. Available from https://www.metoffice.gov.uk/research/collaboration/ukcp/guidance-science-reports

Murphy, JM, et al (2018) UKCP18 Land Projections: Science Report, Met Office. Available from https://www.metoffice.gov.uk/research/collaboration/ukcp/guidance-science-reports

Appendix A

The following figures and tables are reproduced from the Technical note: Update to UKCP Local 2.2km projections.

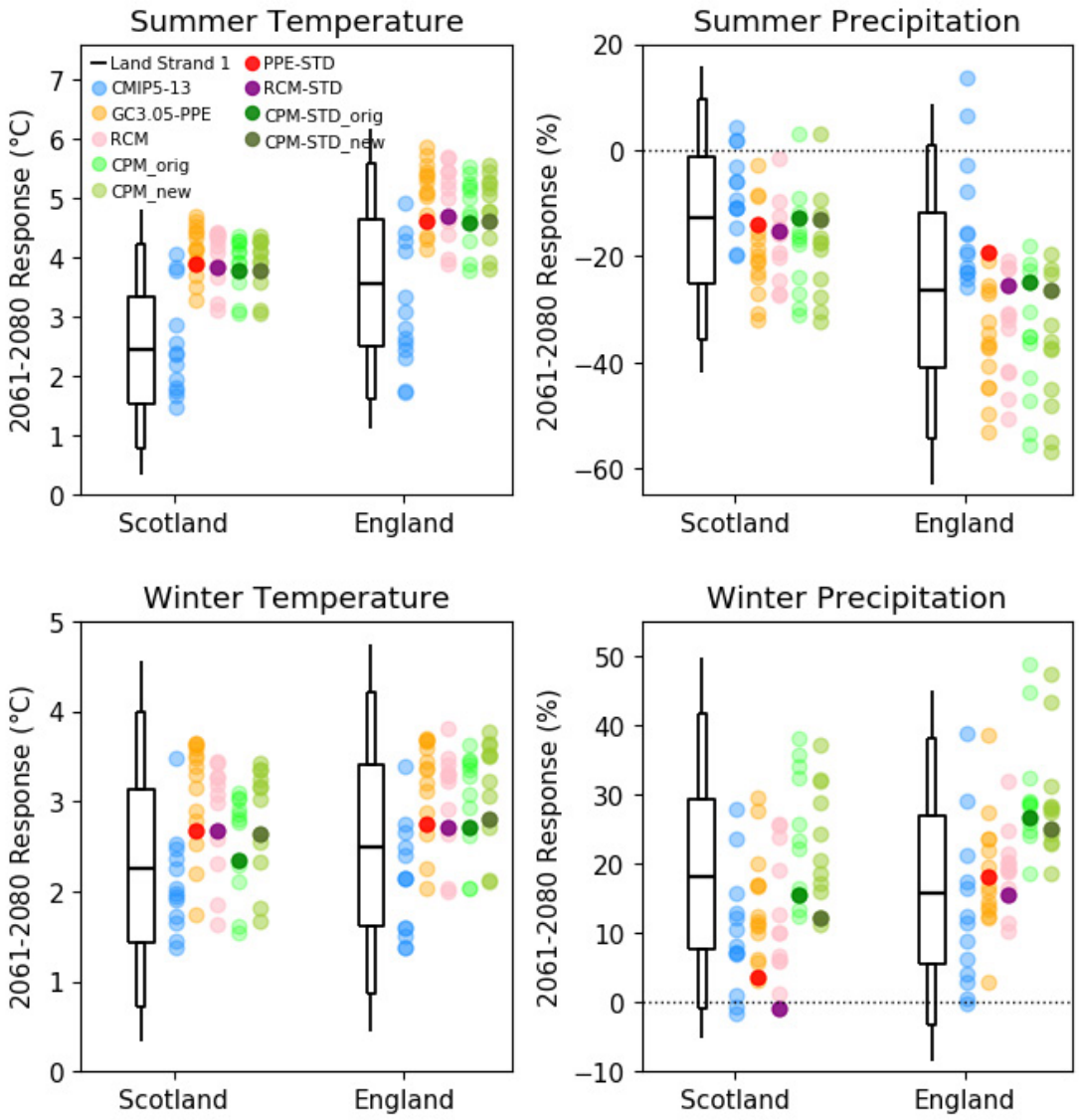

Figure A.1. Comparison of seasonal mean changes across UKCP18 products. Projected changes for 2061-2080 relative to 1981-2000 for Scotland and England in (top) JJA and (bottom) DJF, under RCP8.5 emissions. Results are shown for surface air temperature (left, °C) and precipitation (right, %). Box and whiskers denote the 5, 10, 25, 50, 75, 90 and 95% probability levels of the UKCP probabilistic projections (Strand 1). Orange dots (with STD in red) denote members of GC3.05-PPE and blue dots those of CMIP5-13, which together comprise the UKCP Global (60km) projections (Strand 2). 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 (with the original UKCP Local in fluoro-green and updated UKCP Local in olive-green, Strand 3). Reproduced from Figure 5.1 of Kendon et al (2021).

Impact metric (with some example impact areas)	Continue to use original UKCP Local (2.2km) projections?	Use of new UKCP 2.2km reruns alongside other UKCP18 products?
Snow (e.g. infrastructure inc. transport and energy, natural environment/habitat)	✘ Original UKCP 2.2km data underestimate snow and its future change	Some added value from 2.2km over mountains and due to better representation of winter convective showers. UKCP Global projections provide wider sampling of uncertainty.
Lightning (e.g. infrastructure inc. transport, communications and energy)	✘ Lightning data not released from original UKCP 2.2km	* Available from new 2.2km reruns only
Cold winter temperatures (e.g. infrastructure inc. transport and energy, health, natural environment/habitat)	✘ Original UKCP 2.2km data underestimate future increases in winter temperature (especially for cold winter days and cold spells over Scotland)	Some added value from 2.2km over mountains. UKCP Regional equally plausible. UKCP Global projections provide wider sampling of uncertainty.
Winter precipitation (e.g. winter flooding affecting multiple impact areas)	~ Original UKCP 2.2km data underestimate winter mean precipitation, but graupel code error has small impact on future changes. New 2.2km reruns should be preferred dataset for all new assessments.	~ Greater increases in UKCP 2.2km due to better representation of winter convective showers. Other UKCP18 products based on coarser models may underestimate "upper-end" responses.
Summer mean precipitation and soil moisture (e.g. water resources, drought affecting agriculture and natural ecosystems)	✔ Summer mean precipitation not significantly impacted by graupel code error, although new 2.2km reruns should be preferred dataset for all new assessments. ~ Soil moisture slightly higher in new 2.2km reruns.	UKCP 2.2km projections provide enhanced spatial detail and evidence of drier future soils than Regional 12km. Use alongside UKCP Probabilistic and Global projections due to wider sampling of uncertainty.
Hourly precipitation extremes (e.g. summer flash flooding affecting multiple impact areas)	✘ Original UKCP 2.2km data overestimate present-day return levels and underestimate future changes in hourly precipitation extremes.	* Use new 2.2km reruns only. Regional 12km projections considered unreliable.
Hot summer temperatures and heatwaves (e.g. transport, thermal building design and health)	✔ Results not significantly impacted by graupel code error, although new 2.2km reruns should be preferred dataset for all new assessments.	UKCP 2.2km projections provide more reliable local changes over cities and larger increases in hot spells over southern UK due to drier soils. Use alongside UKCP Regional and Global projections due to wider sampling of uncertainty.
Surface winds (e.g. infrastructure inc. transport, water, communications, energy, forestry/natural environment)	~ Original UKCP 2.2km data underestimate wind speeds mainly over the ocean. Significant impacts over land limited to localised regions over western Ireland and Scottish mountains. New 2.2km reruns should be preferred dataset for all new assessments.	Some added value from 2.2km expected over mountains and coastlines. UKCP Regional equally plausible. UKCP Global projections provide wider sampling of uncertainty.

Table 1. Summary of advice on use of new 2.2km reruns compared to original UKCP Local (2.2km) data and other UKCP18 products by impact sector. . Red ✘ means 'no', green ✔ 'yes', purple ~ 'use new 2.2km runs in preference to original 2.2km runs and be aware of caveats indicated for other UKCP products' and blue * 'use new 2.2km runs only'. Reproduced from Table 1 of Kendon et al (2021).

Phenomenon	1. Significant impact of code changes in rerun?	2. CPM_new improved present-day biases compared to RCM?	3. CPM_new different future changes compared to RCM?	4. Comment on reliability for projecting future change
Temperature				
Winter mean temperature	~ CPM_new colder in present-day, with slightly greater future increases.	~ Similar biases in CPM_new and RCM	~ Similar future increases	CPM_new and RCM projections equally plausible. CPM_new more reliable than CPM_orig especially over northern Scotland.
Summer mean temperature	No	~ CPM_new is warmer than RCM, but similar UK-mean biases	~ Similar future increases	CPM_new and RCM projections equally plausible.
Cold winter days	**Yes** – CPM_new significantly colder in present-day, with considerably larger future increases	**Yes – cold winter days in the north are too cold in the RCM, with reduced biases in CPM_new**	~ Similar future increases in temperature	CPM_new and RCM projections both plausible, although improved representation of topography in CPM may have influence on local projections over mountains. CPM_orig should not be used.
Hot summer days	No	~ Slightly reduced biases in CPM_new	~ Similar future increases	CPM_new and RCM projections equally plausible.
Cold spells over north UK	**Yes** – more cold spells in CPM_new in present-day, and larger future decreases in the frequency of cold spells	**No** – CPM_new has too many cold spells	~ Similar future decreases in frequency	CPM_new and RCM projections equally plausible. CPM_orig should not be used.
Hot spells over south UK	No	~ Slightly reduced biases in CPM_new	+ Larger future increases in frequency	CPM_new and RCM projections both plausible. Some improvement in biases in CPM_new possibly related to drier soils in CPM.

Phenomenon	1. Significant impact of code changes in rerun?	2. CPM_new improved present-day biases compared to RCM?	3. CPM_new different future changes compared to RCM?	4. Comment on reliability for projecting future change
Precipitation				
Winter mean precipitation	**Yes** – CPM_new significantly wetter over mountains in present-day. Little impact on future changes.	**Yes** – reduced biases in CPM_new	+ Substantially greater increase in CPM_new compared to RCM	CPM_new most reliable, with considerably reduced biases compared to RCM and better representation of wintertime convective showers
Summer mean precipitation	**No**	**Yes** – reduced biases in CPM_new	~ Slightly greater decrease in CPM_new compared to RCM	CPM_new most reliable, with considerably reduced biases compared to RCM and better representation of convection
Heavy daily precipitation events in winter	~ CPM_new wetter in present-day. Little impact on future changes.	**Yes** – considerably reduced biases in daily variability in CPM_new	~ Increases slightly greater in CPM_new compared to RCM	CPM_new most reliable, with considerably reduced biases compared to RCM and better representation of wintertime convective showers
Heavy daily precipitation events in summer	~ CPM_new has reduced summer precipitation intensity in present-day, and future decreases in heavy daily precipitation are slightly larger	**Yes** – considerably reduced biases in daily variability in CPM_new	+ Greater tendency for increase in summer precipitation intensity in CPM_new compared to RCM	CPM_new most reliable, with considerably reduced biases compared to RCM and better representation of convection.
Hourly precipitation variability (all seasons)	~ CPM_new has reduced precipitation intensity especially in summer in present-day, and tendency for slightly greater future increases in summer hourly precipitation intensity	**Yes** – considerably reduced biases in CPM_new	+ Significant increase in hourly precipitation occurance in winter in CPM_new not seen in the RCM + Greater increase in summer rainfall intensity in CPM_new	CPM_new most reliable, with considerably reduced biases compared to RCM and better representation of convective processes.
Hourly precipitation extremes (all seasons)	**Yes** – hourly extremes significantly reduced in CPM_new in present-day, and future increases are greater	**Yes** – CPM_new better represents the rate at which extremes increase with increasing rarity	- Similar increases in 2-year return level, but smaller increases for 10-year (and longer) return levels for some regions/seasons	Use CPM_new only. RCM projections of hourly precipitation extremes considered unreliable. CPM_orig should not be used.

Phenomenon	1. Significant impact of code changes in rerun?	2. CPM_new improved present-day biases compared to RCM?	3. CPM_new different future changes compared to RCM?	4. Comment on reliability for projecting future change
Other				
Soil moisture	~ Soil moisture slightly higher in CPM_new in present-day and future climate	**Yes** – soils are drier in CPM_new for most members	~ Similar decreases in soil moisture in summer, with soils remaining drier in CPM_new	CPM_new most plausible, due to improved present-day biases related to more realistic hourly and daily precipitation variability
Falling snow	**Yes** – less days of falling snow in CPM_new in present-day, and greater future decrease in falling snow	~ Similar UK biases, but more realistic snowfall over NW Scotland in CPM_new	- Smaller percentage decrease in falling snow in CPM_new	CPM_new most plausible due to improved representation of wintertime convective showers compared to RCM. CPM_orig should not be used.
Lying snow	**Yes** – more days of lying snow in CPM_new in present-day, and greater future decrease in lying snow in absolute terms	~ Similar biases, but more lying snow over high ground in Scotland	- Smaller percentage decrease in lying snow in CPM_new	CPM_new most plausible due to improved representation of wintertime convective showers and better representation of mountains over Scotland compared to RCM. CPM_orig should not be used.
Cloud	**No** – slightly more cloud in winter in CPM_new in present-day. Little impact on future changes	**Yes** – reduced cloud cover biases in winter, and reduced shortwave and longwave surface radiation biases in summer and winter in CPM_new	- Smaller decreases in cloud cover (or greater tendency for increases in winter) in CPM_new	CPM_new and RCM projections both plausible. Greater tendency for cloud increases in winter in CPM_new may reflect improved representation of wintertime convective showers.
Lightning	**Yes** – unrealistic features no longer seen in CPM_new	Lightning output not available for RCM	Lightning output not available for RCM	Use CPM_new only.
Surface winds	**Yes locally** – stronger winds in CPM_new in present-day over the ocean, western Ireland and the Cairngorms. Significant impacts on future changes confined to isolated regions.	Not possible to assess.	+ Greater future decreases in wind speed over south-east UK in winter and across UK in summer in CPM_new	CPM_new and RCM projections equally plausible, although added value of CPM over mountains. CPM_orig should not be used for projections over the Scottish mountains and over the sea to the NW of the UK.

Table A.2. Summary of present-day biases and future changes in the updated UKCP Local (CPM_new) compared to UKCP Regional (RCM), whether these have changed significantly from the original UKCP Local (CPM_orig), and the implications for the reliability of future projections. (1) Significant impact of rerun, with red indicating '**yes**', grey '**no**,' and purple '**~**' indicating impact but significance not assessed (differences are judged significant if they are greater than the standard deviation across the CPM ensemble); (2) Improved present-day biases in CPM_new compared to RCM, with green indicating '**yes**', red '**no**' and grey '~' similar biases; (3) Future changes in CPM_new compared to RCM, with orange '**+**' indicating greater and blue '**-**' smaller magnitude of change in CPM_new, and grey '~' similar changes; and (4) Comment on reliability of future projections.

Reproduced from Table 5.1 of Kendon et al (2021).