Department for Environment Food & Rural Affairs

Department for Business, Energy & Industrial Strategy

Met Office Hadley Centre

Environment Agency

UKCP18 Factsheet: Snow

Version 2.0, published 22 July 2021

This factsheet summarises the key information currently available on the UKCP18 projections over land for snow metrics. Read this before using any snow products as it describes the data availability, the key future climate changes (if any) that you should see and the caveats and limitations.

We recommend that you read the UKCP18 Science Overview (Lowe et al, 2018) to understand the different components of the projections. For a comprehensive description of the underpinning science, evaluation and results see the UKCP18 Land Projections Report (Murphy et al., 2018) and the UKCP18 Convection-permitting model projections report (Kendon et al., 2019a), updated in 2021 (Kendon et al 2021). Please note that this factsheet focuses on the regional and local projections which is part of a suite of land projections that consist of the following:

- **Probabilistic projections** - these combine climate model data, observations and advanced statistical methods to simulate a wide range of climate outcomes and advanced scenarios (RCP2.6†, RCP4.5, RCP6.0, RCP8.5 and SRESA1B).
- **Global (60km) projections** - a set of 28 climate futures at 60km grid resolution, showing how the 21st Century climate may evolve under the highest emission scenario, RCP8.5. They assess the uncertainty across different models from different modelling centres as well as the uncertainty in model parameters. It incorporates 15 members of the Met office Hadley Centre model, HadGEM3-GC3.05 (PPE -15), and 13 other climate models selected from the climate models that informed the Intergovernmental Panel on Climate Change's 5th Assessment report (CMIP5-13).
- **Regional (12km) projections** - a set of 12 high resolution projections at 12km (RCM-PPE) downscaled from the PPE-15 over the UK and Europe. They assess the uncertainty in the regional model parameters, as well as uncertainty in the large-scale conditions from the driving global model.
- **Local (2.2km) projections** – a set of 12 very high resolution projections at 2.2km (CPM-12) downscaled from the regional projections over the UK which assess different local conditions given the uncertainty in the driving information.
- **Derived projections** – a set of climate futures for the UK at 60km grid resolution for a low emissions scenario, RCP2.6 and a global warming level of 2 °C and 4 °C. These have been derived from the global projections using statistical techniques.

The Local projections were updated in July 2021, due to an error in the model code that affected snow (details in Kendon et al., 2021). This factsheet was updated at the same time, to reflect the new results for snow. Snowfall and lying snow projections are significantly different between the new and original UKCP Local results, due to fixing the error and the snowpack science improvements. For these variables, the original 2.2km projections are considered unreliable and should not be used.

† Note that the "RCPs" are not strictly emission scenarios but the term is used here for brevity - further information on emissions scenarios and RCPs can be found in UKCP18 Guidance: Representative Concentration Pathways.

Headline messages

- Widespread and substantial snow events have occurred in 2018, 2013, 2010 and 2009, but their number and severity have generally declined since the 1960s.
- For the period 2061-2080, under a high emissions scenario (RCP8.5), the Regional (12km) and Local (2.2km) projections show a decrease in both falling and lying snow across the UK relative to the 1981-2000 baseline. In general, the decreases in percentage terms are smaller in both falling and lying snow in mountainous regions (e.g. Scottish Highlands) than in low-lying regions (e.g. southern England).
- There are differences in estimates of future snow between the Regional (12km) and Local (2.2km) projections. Decreases in both falling and lying snow (over Scottish mountains) are larger in the regional projections compared to the local projections. We have greater confidence in the new Local (2.2km) projections compared to the Regional projections, since differences can be linked to the improved representation of wintertime convective showers and topography in the 2.2km model.
- The Updated Local 2.2km projections (released July 2021) have a much improved representation of snowfall and lying snow at the surface compared to the original Local 2.2km projections (released September 2019). In general this leads to greater consistency between the Local (2.2km) and Regional (12km) projections.

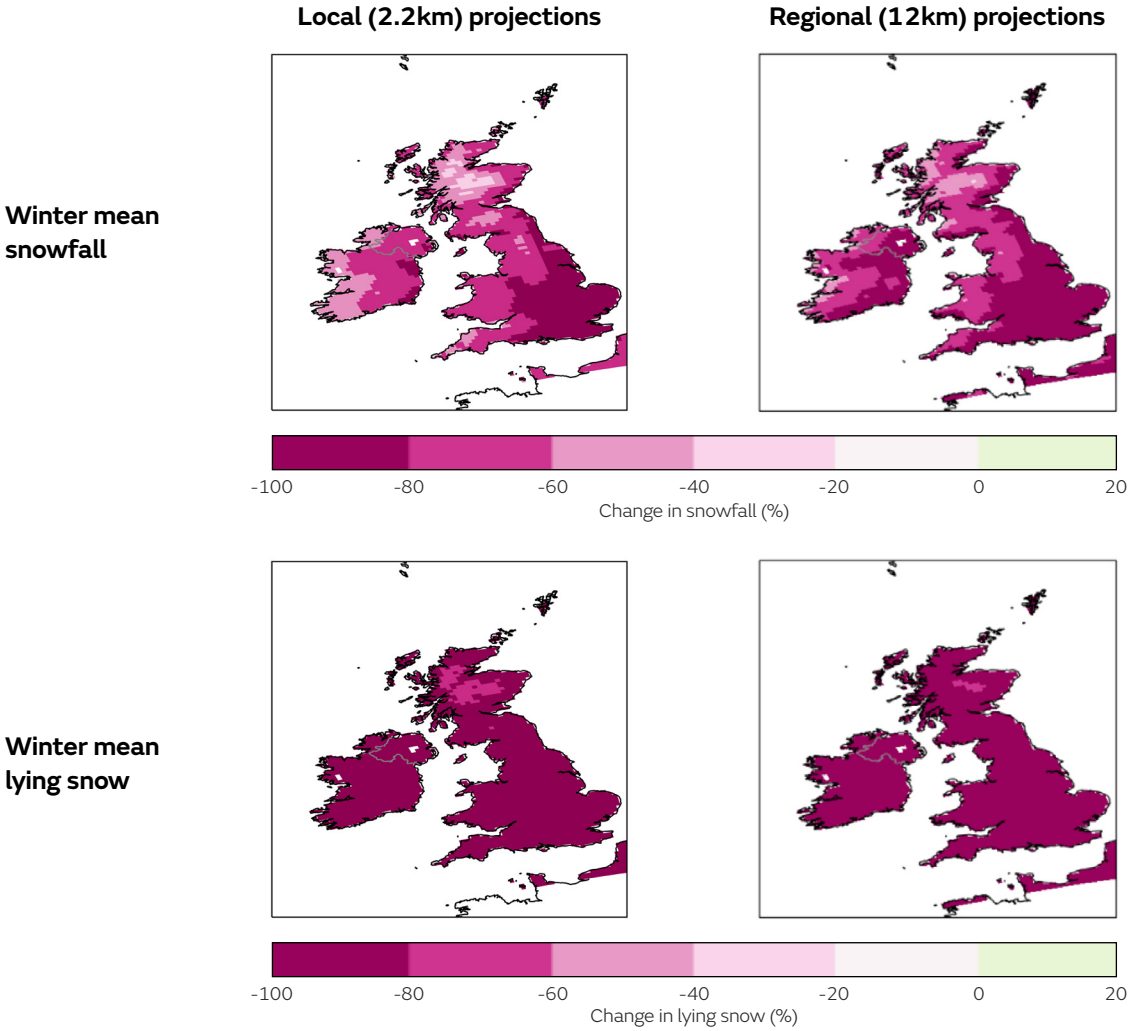

Figure 1 Future change in snow variables in winter for 2061-2080 compared to 1981-2000. Maps of future percentage change (%) in winter mean snowfall (top row) and winter mean lying snow (bottom row) averaged across the 12 members of the CPM-12 (left) and RCM-PPE (right).

What data are available and where can you find them?

	Observations	Regional (12km) projections	Local (2.2km) projections
Snow variables	Days of falling snow per month† Days of lying snow per month†	Snowfall amount (mm/day) Lying snow amount (mm/day)	Snowfall amount (mm/day) Lying snow amount (mm/day)
Geographical extent	UK	UK Europe	UK
Spatial resolution	5km	12km	2.2km
Temporal resolution	Daily Monthly	Daily Monthly Seasonal Annual	Daily Monthly Seasonal Annual
Period of data	1961-2017	1980-2080	1980-2000 2020-2040 2060-2080
Emissions scenarios	n/a	RCP8.5*	RCP8.5*

Table 1 Summary of available snow variables for UKCP18. Snow variables are not available for the probabilistic, derived and global projections.

† Based on observation network.

* Further information on emissions scenarios can be found in UKCP18 Guidance: Representative Concentration Pathways.

You can access the data and visualisations via the UKCP18 User Interface. All other simulations and other datasets are available via the Centre for Environmental Data Analysis (CEDA) Data Catalogue (http://catalogue.ceda.ac.uk) but note that this requires the technical skill to analyse large datasets.

Observed snow variables have not been updated as part of UKCP18. However, the data can be downloaded at the CEDA Data Catalogue. Further details can be found on the UKCP09 observed gridded datasets web page.

How do the results compare to observations?

We have compared the RCM (Regional Climate Model) and CPM (Convection-Permitting Model) to observations to assess how well the models simulate snow in the past (1981-2000). Figure 2 suggests that the RCM and CPM overestimate the number of days of lying and falling snow – these metrics were also used to evaluate the previous generation of UK Climate Projections (UKCP09) and described in the UKCP09 technical note on snow (Brown et al, 2010). For the number of days with falling snow, the new CPM data show better agreement with observations and with the RCM, than the original CPM data. Both overestimate similarly for the number of days with lying snow. However, this overestimation could relate to the choice of threshold for converting snow fall flux (snowfall) or snow amount (lying snow) to days of falling/lying snow. This choice is subjective, and higher thresholds could easily be justified that would give improved model agreement with observations. However, the climate models do capture the downward trend in lying snow through time (not shown).

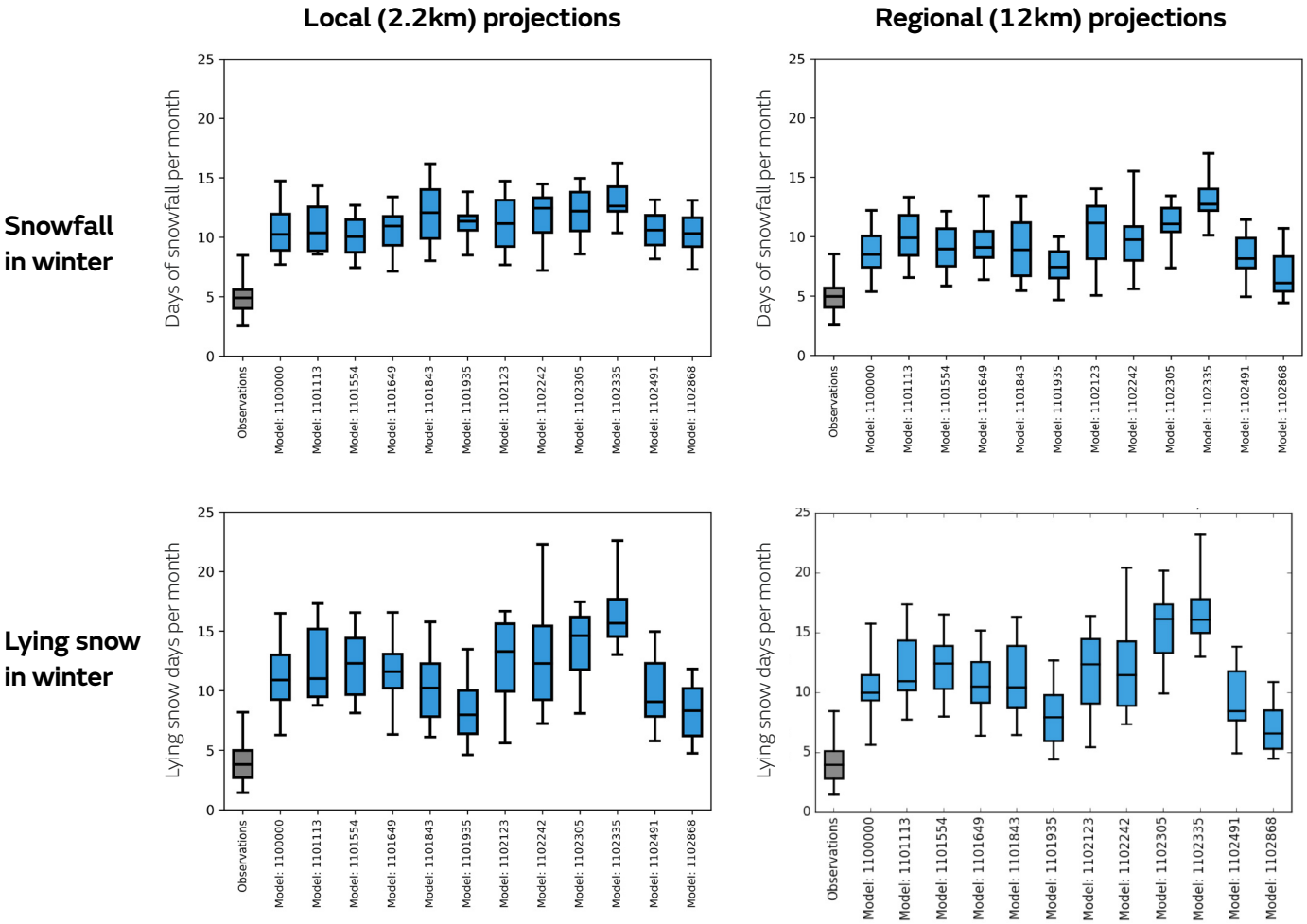

Figure 2 Comparison of observed and simulated winter UK-average snow variables for 1981-2000 where rectangular boxes indicate the range of results at 25th, 50th and 75th percentiles and whiskers show 5th and 95th percentiles. Plots show observations in grey from the National Climate Information Centre (NCIC) and climate model results in blue. The panels on the left of Figure 2 are the results from 12 convection-permitting models. On the right are the corresponding results from regional climate models. Top row panels show number of days of snowfall per month in winter, defined by snowfall flux being greater than 0.02 mm/day. Bottom row panels show number of days of lying snow in winter, defined by snow amount being greater than 0.02 mm.

We also have results where the RCM and CPM are driven by a reanalysis dataset, ERA-Interim. Reanalysis datasets combine information from multiple sources of observations and simulate the observed atmosphere. Using this reanalysis dataset to drive regional climate models allows day-to-day direct comparisons with observations, rather than using mean statistics. However, we would still not expect the exact timing and positioning of weather systems in the models to match the observations. The results show that:

- Both models represent the spatial variability well across the UK in winter (i.e. greater snowfall in northern and highland areas).
- The winter-to-winter temporal variability in falling snow is better represented in the RCM.
- The winter-to-winter temporal variability in lying snow is better represented in the CPM.

The differences between the RCM and CPM are mainly due to the differences in the way the models simulate snowfall and the improved representation of topography in the CPM (see Kendon et al, 2019a, Section 3.5 for further details). In the updated Local 2.2km projections (released July 2021), there is a much improved representation of snowfall and lying snow at the surface compared to the original Local 2.2km projections (released September 2019). In general this leads to greater consistency between the CPM and RCM.

The updated Local (2.2km) model produces more snowfall over the Scottish mountains and less in the vicinity of the northwest coastline of Scotland compared to the RCM. There is also more lying snow over high ground in Scotland in the CPM. These differences are likely explained by the higher resolution of the CPM leading to a better representation of mountains, and the ability of the CPM to better represent the movement of convective showers inland. Therefore, the Local (2.2km) projections provide the best information available on snow in the UKCP suite of products, due to the better representation of topography and wintertime convective showers.

What do you need to be aware of?

This factsheet details the biases in the data, though direct comparison with observations is difficult. Users should be aware that both the Regional (12km) and Local (2.2km) projections underestimate uncertainties, as they only downscale versions of the Met Office Hadley Centre model.

Although the local projections can provide information on small-scale weather events in the future, they should not be confused with an operational weather forecast, which provides information on weather that is likely to be experienced in the next few days. Instead the local projections provide a set of plausible projections of climate change for the UK, if we follow a high emission scenario (i.e. RCP8.5). In particular, they provide information on the local effects of changes in the types of weather that may be experienced in the future.

The local projections sample a narrower range of potential future outcomes than the full set of global projections. In particular, the regional climate models only downscale 12 members of the PPE-15 (and are in turn downscaled using the CPM) and none of the CMIP5-13. If you would like to explore other potential futures, consider using the EURO-CORDEX multi-model regional climate model simulations (see www.euro-cordex.net).

Unlike the regional projections, global and probabilistic projections, the local projections do not sample the uncertainties in which the climate model represents climate processes (i.e. parameter uncertainties). So, the local projections generally provide a narrower range of future outcomes than the regional projections, although there are exceptions (e.g. for winter rainfall – see Kendon et al (2021)).

While high-resolution downscaling adds value to climate projections provided by their driving models, the regional and convection-permitting models do not, in general, correct large-scale biases inherited from global simulations.

Whilst the UKCP18 projections represent the latest scientific understanding and the results have been peer reviewed by independent experts, keep in mind the caveats and limitations of the projections. Although our understanding and ability to simulate the climate is advancing all the time, our models are not able to represent all of the features seen in the present day real climate. This means that when including the climate projections in your decision-making, consider how best to factor the capabilities and limitations of UKCP18. This should be informed by a thorough understanding of the consequences of different climate outcomes – perhaps including those beyond the ranges of uncertainty presented in UKCP18.

Find out about the caveats and limitations in UKCP18 Guidance: Caveats and Limitations as well as UKCP18 Factsheet: UKCP Local (2.2km) Projections, available from the factsheets page.

Where can you find more information?

For further information on UKCP18:

- Find out more about observed snow in the State of the UK Climate Report (Kendon et al, 2019b)
- Download the snow data from the UKCP18 User Interface and the CEDA Data Catalogue
- Find out more on the underpinning science in the UKCP18 Convection-Permitting Model Projections: Science Report (Kendon et al, 2019a) and Updated Local (2.2km) Projections report (Kendon et al 2021).
- Further information and guidance is available at the UK Climate Projections website.

This document is citable as Pirret JSR, Fung, F, Kendon E, Lowe J (2021). UKCP18 Factsheet: Snow. Met Office Hadley Centre, Exeter

References

Brown S, Boorman P and Murphy J (2010). Interpretation and use of future snow projections from the 11-member Met Office Regional Climate Model ensemble, Met Office. Available at: https://webarchive.nationalarchives.gov.uk/20181204111057/http://ukclimateprojections-ukcp09.metoffice.gov.uk/media.jsp?mediaid=87949&filetype=pdf OPEN ACCESS.

Kendon E, Short C, Pope J, Chan S, Wilkinson J, Tucker S, Bett P, Harris G and Murphy J (2021). UKCP Local Projections Update: Technical Note. Available from: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/guidance-science-reports

Kendon E, Fosser G, Murphy J, Chan S, Clark R, Harris G, Lock A, Lowe J, Martin G, Pirret J, Roberts N, Sanderson M and Tucker S (2019a). UKCP Convection-permitting model projections: Science report, Met Office. Available at: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/UKCP-Convection-permitting-model-projections-report.pdf. OPEN ACCESS.

Kendon M, McCarthy M, Jevrejeva S, Matthews A, Legg T (2019b) State of the UK Climate 2018, International Journal of Climatology, http://rmets.onlinelibrary.wiley.com/toc/10970088/2019/39/S1. OPEN ACCESS

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. Available at https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Overview-report.pdf. OPEN ACCESS.

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. Available at: https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Land-report.pdf