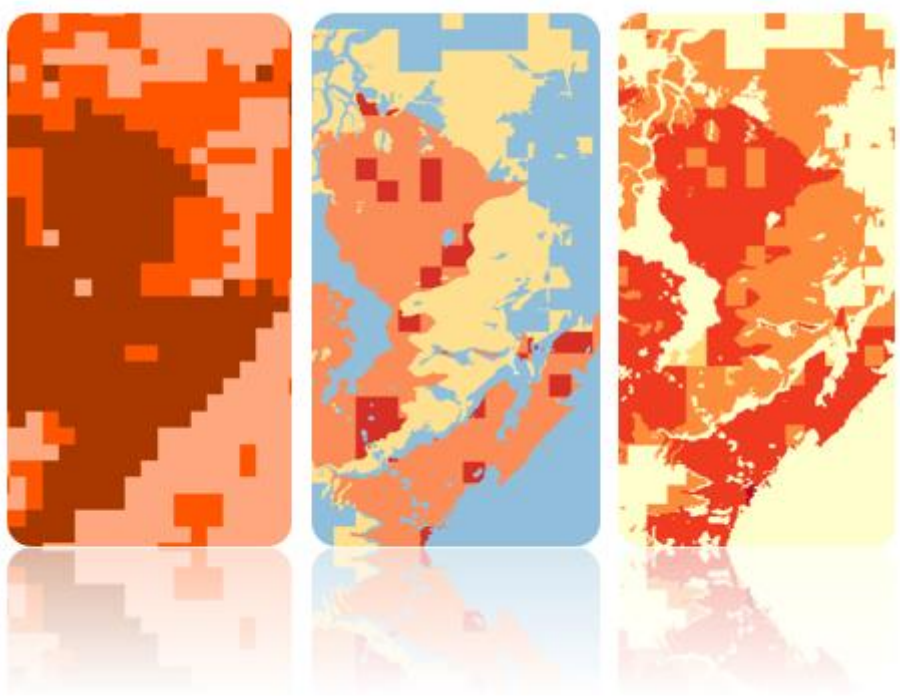
British Geological Survey

User Guide for the British Geological Survey GeoClimateUKCP18: Clay Shrink-Swell dataset

GeoAnalytics & Modelling Programme

Open Report OR/20/013



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User Guide for the British Geological Survey GeoClimateUKCP18: Clay Shrink-Swell dataset

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BRITISH GEOLOGICAL SURVEY

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Summary

This report is the guide for users of the British Geological Survey (BGS) GeoClimateUKCP18 dataset. GeoClimateUKCP18 is the second BGS GeoClimate product. The first, GeoClimateUKCP09, applies the UK Climate Projections released in 2009, called UKCP09. GeoClimateUKCP18 utilises the latest UKCP18 climate projections, released 2018-2019.

The GeoClimate methodology utilises the highest resolution climate projection data. UKCP18 provides climate projections at the highest resolution for different time windows to those provided by UKCP09. Therefore, GeoClimateUKCP09 and GeoClimateUKCP18 projections are not for the same time windows. Details of these time windows are provided later in this document.

GeoClimateUKCP18 is hereafter referred to as GeoClimate, within this User Guide.

GeoClimate provides information on the potential for clay shrink-swell to occur at a given location, during a given future time period, based on a combination of geological, hydrological and climate projection data.

Acknowledgements

A number of BGS colleagues have contributed to the project. This assistance has been received at all stages of the study. Many thanks to the reviewers of this document: Chris Williams, Katy Lee and Andy Barkwith. In addition to the collection and processing of data, a number of BGS colleagues have freely given their advice, and provided local knowledge.

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1 Introduction

The purpose of GeoClimateUKCP18 Clay Shrink-Swell is to provide information on the projected future change in susceptibility of clay shrink–swell across Great Britain due to climate change. It considers the changing climate and the associated changes in near-surface ground water content, as well as the static variables of geology and geotechnical values. In this guide, GeoClimateUKCP18 Clay Shrink-Swell is hereafter referred to as GeoClimate.

Two versions of the GeoClimate clay shrink-swell dataset are available: GeoClimate Open which is a freely available overview dataset and GeoClimate Premium which is a licenced (paid-for) higher resolution and more detailed dataset. GeoClimate Open is designed as an overview for national use and GeoClimate Premium data is designed to provide input data into regional – local risk and mitigation assessments.

Both GeoClimate Open and Premium datasets comprise a suite of datasets for specified time periods and identify areas of potential change in clay shrink-swell susceptibility as a result of the impacts of climate change.

The GeoClimate datasets, and accompanying documentation, provide information for users on the ***natural*** characteristics and properties of shrink-swell prone geological units for the assessment of climate change impacts in Great Britain. GeoClimate looks specifically at the geological factors that influence shrink-swell subsidence and the climatic effects/interactions. It does not consider any human or artificial factors.

2 About the GeoClimate Datasets

2.1 GEOLOGY AND CLIMATE CHANGE

Across the UK, clay-rich geological deposits, such as the London Clay Formation, are susceptible to volume change due to changes in water content. The susceptibility to this shrinking and swelling varies, dependant on the clay mineralogy and lithology. Changes in annual rainfall and temperature patterns are increasing the likelihood of this volume change occurring (Harrison et al., 2012). These changes can lead to ground movement that damages houses, near surface infrastructure, and other light structures. This damage often results in insurance claims due to subsidence (Crilly, 2001).

With the overarching controlling factor of water content being the input from rainfall, and loss due to evapotranspiration, specific sites can also be affected by local factors such as trees and other vegetation removing water from the ground, as well as human induced factors such as surface sealing in which rain water enters drains rather than the ground (Jones, 2002, 2004).

2.2 LICENSED & OPEN DATA PACKAGES

The GeoClimate data product is provided as two options, either Open data (under an Open Government Licence) or more detailed licensed Premium version. The data content of each package is as follows:

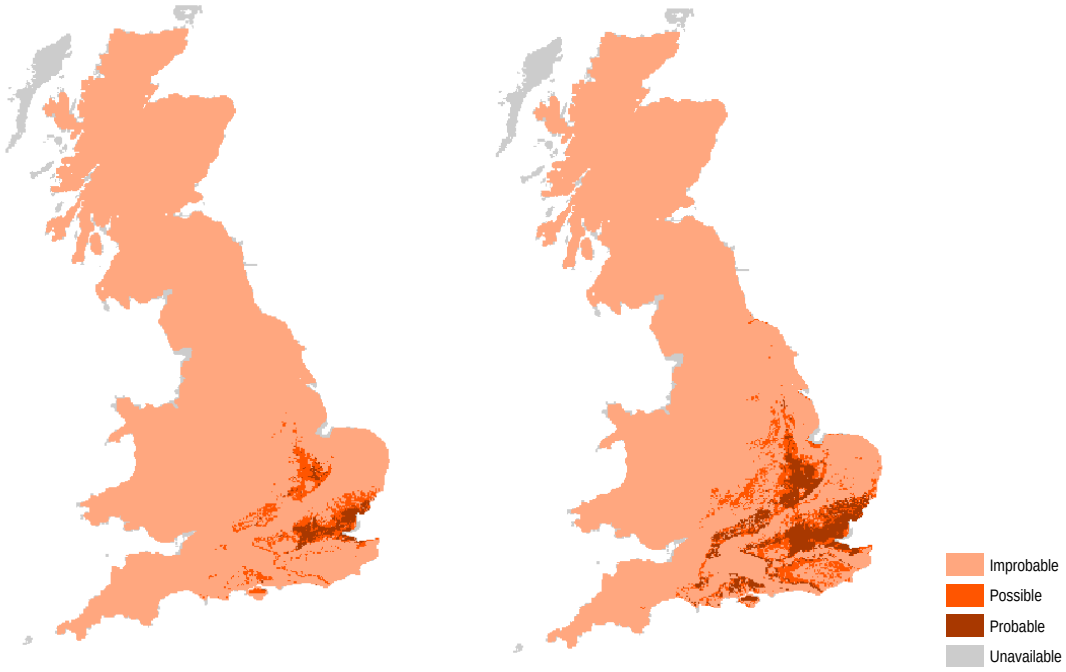
2.2.1 GeoClimate Open

This is a 1:4000,000 scale product, consisting of 2 km grid squares, and is freely available on the BGS GeoIndex. The outputs are shown for time period envelopes, centred on 2030 and 2070, with 1 average dataset provided for each time period.

The dataset is based on the median average outcome for the Representative Concentration Pathway (RCP) 8.5, a comparatively high greenhouse gas emissions scenario (Van Vuuren, 2011), combined with the most susceptible GeoSure value (worst case) within the grid cell. There are no additional statistics provided.

GeoClimate Open is provided for two 11-year windows:

- Centred on 2030 (11 year window 2025 to 2035)
- Centred on 2070 (11 year window 2065 to 2075)



a) b)

Figure 1 GB overview of GeoClimate Open datasets for (a) 2030 and (b) 2070

2.2.2 GeoClimate Premium

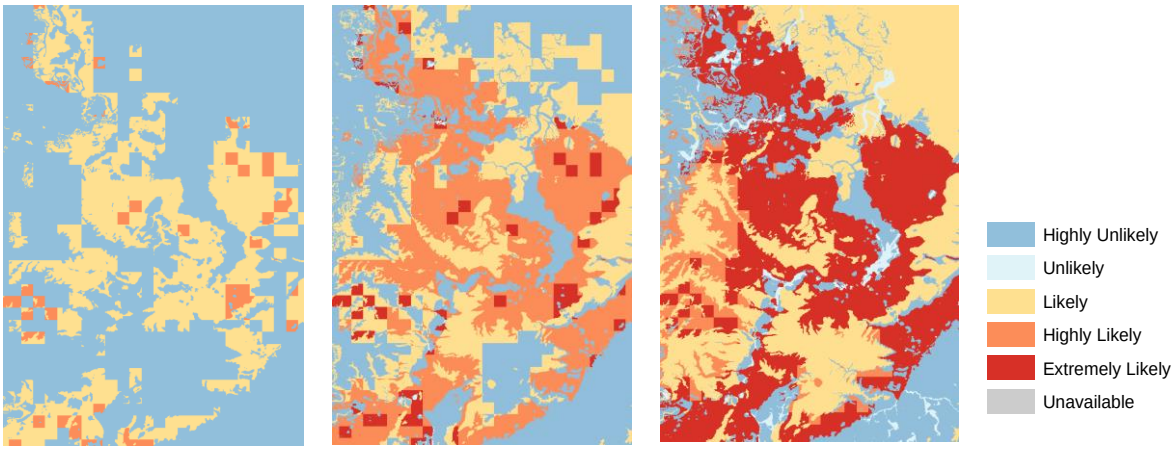
GeoClimate Premium provides projections at the highest resolution possible, taking into consideration the input datasets. It is based on the best resolution datasets

available at national scale and coverage; the 1:50,000 BGS geological data and 1:4000,000 UKCP18 climate projection data. The UKCP18 climate projection data produces the 2 km pixels, as seen in Figure 2, which contrast with the finer resolution provided by the BGS geological linework.

GeoClimate Premium is provided as area polygons, for 2 time period envelopes, centred on 2030 and 2070, and based on the RCP8.5 emissions scenarios, with the 10th and 90th percentile (wetter and drier) statistics provided. An example of the variation shown between the average, wetter and drier scenarios, is provided in Figure 2.

GeoClimate Premium is provided for two 11-year windows:

- Centred on 2030 (11 year window 2025 to 2035)
- Centred on 2070 (11 year window 2065 to 2075)



a) GeoClimate Premium: wetter b) GeoClimate Premium: average c) GeoClimate Premium: drier

Figure 2 GeoClimate premium 2070 data showing the likelihood that foundations will be affected by wetter (a), average (b) and drier (c) conditions.

To enable a comparison of GeoClimate Open and Premium, Table 1 provides details related to dataset resolution and precision.

Table 1 GeoClimate Open and Premium comparison

	GeoClimate Open	GeoClimate Premium
Susceptibility categorisation	3 categories	5 categories
Scale	1:4000,000	Quasi-1:50,000
Coverage	Great Britain	Great Britain

UKCP18 Emissions scenario	Highest emissions scenario (RCP8.5)	Highest emissions scenario (RCP8.5)
Temporal projections (11 year windows)	2030s, 2070s	2030s, 2070s
Projections provided	Median average	Median average, wetter, drier
Number of individual layers supplied	2	6
Format	Vector polygon, supplied as ESRI shp.	Vector polygons, supplied as ESRI shp.

2.3 BACKGROUND

Shrink-swell is recognised as the costliest geohazard across Great Britain. For example, due to the hot dry summer of 2018, more than 10,000 households made claims worth a total of £64 million to deal with the impact of subsidence between July and September, according to the Association of British Insurers (ABI) (Insurance Times, 2018). This was the highest level of subsidence insurance claims since the heatwaves of 2006 and 2003 (Which, 2018). Over an average year, insurers would usually expect to pay out approximately £75 million to rectify the impact of subsidence on homes (Guardian, 2018).

The BGS GeoSure Shrink-swell dataset considers the physical properties of the geology to provide a susceptibility rating for potential ground movement. It does not, however, account for changes in climate, and parameters that will affect soil water content.

GeoClimate clay shrink-swell has been developed to enable the climate variables to be considered, alongside the geotechnical properties of the ground immediately below and around the foundations, and provide a longer term, modelled analysis for resilience assessments. It is essentially a national hazard susceptibility map, showing change in susceptibility with time, due to changes in climate. This methodology has been developed by engineering geologists, hydrogeologists, geophysicists and information developers at the British Geological Survey, following stakeholder engagement, and is presented as a series of GIS data layers.

UKCP18 uses cutting-edge climate science to provide updated observations and climate change projections up to 2100. These include projections of rainfall, temperature and sea level rise throughout the 21st Century. UKCP18 builds upon UKCP09 (Murphy et al., 2009) utilised in GeoClimateUKCP09, to provide the most up-to-date assessment of how the climate of the UK may change over the 21st century (Murphy et al., 2018).

GeoClimateUKCP18 utilises the UKCP18 Convection Permitting Model climate projections for the UK at 2.2 km local resolution. These are at a spatial resolution on par with operational weather forecast models. These were produced using the Met Office HadGEM3-GC3 model and are better-able to represent small scale atmospheric processes, than regional climate models which run on a coarser resolution. They were selected for use as they allow the modelling of these important

small scale climatic processes that lead to the weather we experience within the UK, due to this higher level of spatial detail. For example, summertime rainfall intensity and duration, short duration rainfall extremes and flash flooding. The UKCP local (2.2 km) projections are provided for one emissions scenario, Representative Concentration Pathway, RCP8.5, the high greenhouse gas emissions scenario.

2.4 WHO MIGHT REQUIRE THIS DATA?

Natural ground stability hazards, such as clay shrink-swell may lead to financial loss for anyone involved in the ownership or management of property. These hazards could increase in likelihood and propensity when considering the impacts of a changing climate. These impacts could relate to increased insurance premiums, depressed house prices and, in some cases, engineering works to stabilise land or property.

The identification of areas of potential increased risk of clay shrink–swell susceptibility from climate change will be of use to all those required to plan for longer-term resilience into the 21st Century. This includes planners, developers, construction companies, and utility companies, consulting engineers, builders, loss adjusters, the insurance industry, architects and surveyors. These hazards may also impact on anyone involved in infrastructure networks (road or rail) or utility companies.

The key benefit of GeoClimate is that it provides a ‘hot spot’ map of susceptible areas, which can inform mitigation strategies (and therefore save time associated with fewer manual site visits), prioritise works and aid risk reduction. The product might be used to inform future requirements for changes in the design of foundations so buildings are not affected by the increased hazard. The cost of such prevention may be very low, and is often many times lower than the repair bill following ground movement. Where GeoClimateUKCP18 can be integrated within the workflows of our intended user base it can support prioritisation of remedial action, or help define buildings at most risk, thereby reducing subsidence events and potentially saving the costs of rebuild and disruption.

3 GeoClimate product development summary

GeoClimate combines current GB clay shrink-swell hazard susceptibility, GB groundwater modelling, and climate change projections to project future clay shrink-swell hazard susceptibility. The methodology considers 12 UKCP18 climate realisations, which results in 12 daily soil moisture projections. These are sorted from wettest to driest at every location, and the 10th and 90th percentile calculations of these provide the wetter and drier projections. These ‘extreme’ projections convey the variation and uncertainty within the scenario modelling and allow the user to consider the best- and worst-case scenario for shrink-swell susceptibility according to their needs.

3.1 INPUT DATASETS

The datasets utilised and combined to create GeoClimate are:

1. **CEH Hydrology of Soil Types** (HOST) (Boorman et al., 1995).

   https://www.ceh.ac.uk/services/hydrology-soil-types-1km-grid

   - A soil class value sampled at daily intervals at 1 km

2. **UKCP18 2.2 km gridded CPM climate ensemble**

   https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/download-data

   - Representative Concentration Pathway (RCP) 8.5 (Met Office Hadley Centre, 2018)

3. **BGS Hydrogeology 1: 625,000** GIS polygon data.

   https://www.bgs.ac.uk/products/hydrogeology/maps.html

   - To determine run-off coefficient values

4. **NEXTMap®** Britain elevation data

   - Digital Terrain Model licensed from INTERMAP®
   - Built using Interferometric Synthetic Radar (InSAR) data
   - 5 m resolution

5. **BGS GeoSure shrink-swell** dataset

   https://www.bgs.ac.uk/products/geosure/shrink_swell.html (Lee & Diaz Doce, 2018)

   - The potential for shrink–swell to be a hazard, assessed using 1:50,000 scale digital maps of superficial and bedrock deposits.

6. **OS Open Map** – Local (coastline) https://www.ordnancesurvey.co.uk/business-government/products/open-map-local

   - 1:10,000 scale

3.2 MODELS UTILISED

The BGS Groundwater Zooming Object Oriented Distributed Recharge (ZOODRM) distributed recharge model (Mansour et al., 2018) was used to generate gridded daily soil moisture deficit (SMD) values for UK, based on inputted climate variables and ground data.

4 GeoClimate Open: Technical Information

Note: These data are intended to be used as a national overview and are not suitable for local assessments. The data is derived from the GeoClimate Premium dataset by taking the 'worst-case' susceptibility classification for each grid cell. Users should therefore be aware that this score does not necessarily apply to the whole of a 2 km cell but that the cell does include some proportion of the worst-case rating.

4.1 OUTPUTS

The GeoClimate Open data layers have been provided as 2 datasets, 1 for each given time period and identify a GB-wide distribution for increased susceptibility to clay shrinkage, related to subsidence, for the 21st century. The data are provided on a 2 km grid.

GeoClimate Open provides 1 layer for each time period:

- Average (50th percentile of days above threshold)

4.2 TEMPORAL SCALE

For the GeoClimate Open suite of layers, a susceptibility score is provided for the following 11-year time periods:

- 2030s (2025 to 2035)
- 2070s (2065 to 2075)

4.3 ATTRIBUTES

The GeoClimate Open datasets contain the fields summarised in Table 2 below.

Table 2 GeoClimate Open fields and descriptions

Field Name	Field Description
CLASS	Classification of hazard using values:- Improbable, Possible, Probable, Unavailable
LEGEND	Description of the potential for the hazard to change (see Table 3)
VERSION	Dataset name and version number

The GeoClimate Open susceptibility legend descriptions include the class values described in table 2, plus an 'unavailable' category (Table 3).

Table 3 GeoClimate Open colours, classes and susceptibility text

Class	Associated susceptibility text (legend text)
Improbable	It is improbable that climate change will affect clay shrink-swell susceptibility and change the likelihood of ground movement, which causes subsidence.
Possible	It is possible that climate change will affect clay shrink-swell susceptibility and change the likelihood of ground movement, which causes subsidence.
Probable	It is probable that climate change will affect clay shrink-swell susceptibility and change the likelihood of ground movement, which causes subsidence.
Unavailable	Input datasets unavailable.

Note 'Unavailable' classification: It is not possible to generate output grids for islands **remote** to mainland UK, due to groundwater modelling limitations. Therefore, GeoClimate values for the Scottish Islands (including Orkney and Shetland Isles) are categorised as 'Input datasets unavailable'.

Similarly, some areas of the coastal zone are not classified due to the incomplete extent of the input datasets.

Example Score Interpretation: The GeoClimate Open rating for the area of interest is Probable (Brown) in the 2070 projection. This shows that it is probable that the likelihood of clay shrink-swell occurring in this area, causing subsidence in low-rise buildings, will increase due to changes in climate, by 2070.

For all GeoClimate Open results, the rating provided is the highest GeoClimate value within the selected 2 km pixel. For a more precise rating, please consult the GeoClimate Premium product (Section 3).

5 GeoClimate Premium: Technical Information

Note

GeoClimate Premium provides projections at the highest resolution possible, taking into consideration the methodology and input datasets. It is based on the best and most appropriate resolution datasets available at national scale and coverage; the 1:50 000 BGS geological data and 2.2 km UKCP18 climate projection data. The 2 km pixels seen in GeoClimate Premium, which contrast with the finer resolution provided by the BGS geological linework, originate from the climate projections and the output grid generated by the ZOODRM groundwater model.

In comparison to GeoClimate Open, which is a simplified pixelated dataset, finer scale evaluations are possible due to the higher resolution geological linework, the wetter and drier scenario datasets and increased GeoClimate classifications,

however the scale of climate projections should be considered when carrying out detailed local-scale assessments.

5.1 OUTPUTS

The GeoClimate Premium data layers have been provided as a series of temporal datasets for a given time period and identify a GB-wide distribution for increased susceptibility to clay shrinkage, related to subsidence, for the 21st century.

GeoClimate Premium provides 3 layers for each time period:

- Average (50th percentile of days above threshold)
- Wetter (10th percentile of days above threshold)
- Drier (90th percentile of days above threshold)

5.2 TEMPORAL SCALE

These 3 data layers are provided for the following 11-year time periods:

- 2030 (2025 to 2035)
- 2070 (2065 to 2075)

5.3 ATTRIBUTES

The GeoClimate Premium datasets contain the fields summarised in Table 4 below.

Table 4 GeoClimate Premium fields and descriptions

Field Name	Field Description
CLASS	Classification of hazard using values: - Highly Unlikely, Unlikely, Likely, Highly Likely, Extremely Likely
LEGEND	Description of hazard (Table 5)
VERSION	Dataset name and version number

The GeoClimate Premium susceptibility class descriptions include the following 5 categories, plus an ‘unavailable’ category (Table 5).

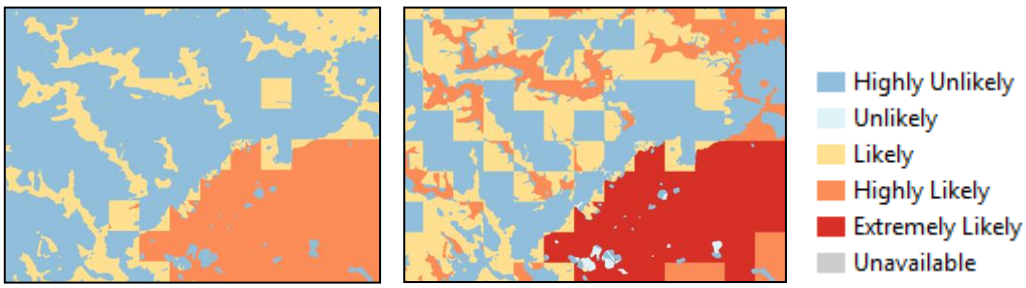
The classifications do not equate to a percentage likelihood of occurrence as the classes combine a range of soil moisture deficits and propensities to change volume, and therefore cannot be categorised in this way. They are qualitative subjective expert assessments based on quantitative results.

Table 5 GeoClimate Premium colours, classes and susceptibility text

Colour	Class	Associated susceptibility text (legend text)
Blue	Highly unlikely	It is highly unlikely that foundations will be affected by increased clay shrink-swell due to climate change.
Light Blue	Unlikely	It is unlikely that foundations will be affected by increased clay shrink-swell due to climate change.
Yellow	Likely	It is likely that foundations will be affected by increased clay shrink-swell due to climate change.
Orange	Highly likely	It is highly likely that foundations will be affected by increased clay shrink-swell due to climate change.
Red	Extremely likely	It is extremely likely that foundations will be affected by increased clay shrink-swell due to climate change.
Grey	Unavailable	Input datasets unavailable.

Note: It is not possible for ZOODRM to generate output grids for islands **remote** to mainland UK, due to groundwater modelling limitations. Therefore, GeoClimate values for the Scottish Islands (including Orkney and Shetland Isles) are categorised as 'Input datasets unavailable'.

Similarly, areas of the coastal zone are not classified due to the incomplete extent of the input datasets.



a) GeoClimate Premium 2030 b) GeoClimate Premium 2070

Figure 3 GeoClimate (a) 2030 and (b) 2070 median average datasets example

Figure 3 provides an example of change in clay shrink-swell susceptibility between the 2030 average and 2070 average datasets.

6 GeoClimate Premium: Difference map

An additional set of GeoClimate Premium datasets are provided, which show the differences between a modelled baseline and the modelled forecasts.

Modelled outputs for the time period 1985-1995 were generated using the same methodology as for all GeoClimate datasets. The differences in classification from the 1985-1995 GeoClimate score (baseline) were calculated for each time period, to provide a value for difference-in-classification.

6.1 ATTRIBUTES

The GeoClimate Premium: Difference datasets contain the fields summarised in

Table 6 below.

Table 6 GeoClimate Premium: Difference fields and descriptions

Field Name	Field Description
DIFFERENCE	Number of classification changes (-1 to +4)
LEGEND	Description of the changes (see Table 7)
BASE_CLASS	Classification of the baseline value: - Highly Unlikely, Unlikely, Likely, Highly Likely, Extremely Likely in the baseline dataset (1985-1995)
LEGEND	Description of hazard (Table 5)
VERSION	Dataset name and version number

Table 7 describes this classification of the GeoClimate Premium Difference maps.

Table 7 GeoClimate Premium difference map, colours, values and text

Colour identifier (RGB)	Change in classification	Difference from 1985-1995 susceptibility text
194,230,153	**-1**	Decrease of 1 classification
255,255,204	**0**	No change in classification
254,217,118	**1**	Increase of 1 classification
253,141,60	**2**	Increase of 2 classifications
240,59,32	**3**	Increase of 3 classifications
189,0,38	**4**	Increase of 4 classifications
189,189,189	**-999**	Unavailable

Figure 4 provides an example of the GeoClimate Premium Difference map.

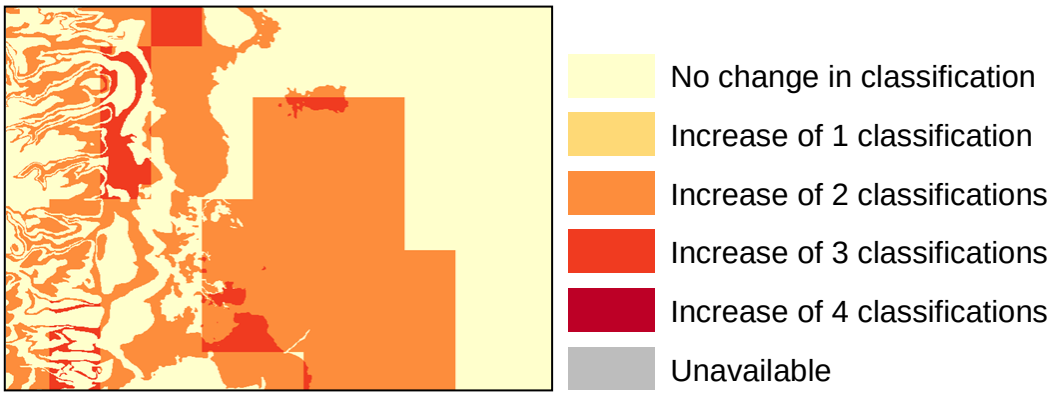


Figure 4 GeoClimate Premium Difference example area, from the 2070 average dataset

7 Frequently Asked Questions

What is the relationship between GeoSure and GeoClimate?

The GeoSure Shrink–Swell rating does not change for a geological deposit. However, the projected changes in climate vary across Great Britain, and therefore the GeoSure shrink-swell rating letter is combined with a number that represents the 'dry days' projected for that area, to provide a GeoClimate rating.

Whereas GeoSure Shrink-swell considers only the physical properties of the geology, GeoClimate considers how these physical properties may be affected in the future as a consequence of projected changes in climate according to UKCP18. Where users are interested in "current climatic conditions", we provide a baseline dataset (based on the time period (1985-1995) which should be referred to.

How do GeoClimate Open and Premium compare?

For a visual comparison of the 2 datasets, Figure 5 demonstrates the difference of GeoClimate Premium and Open, for an area in the south east of Great Britain.

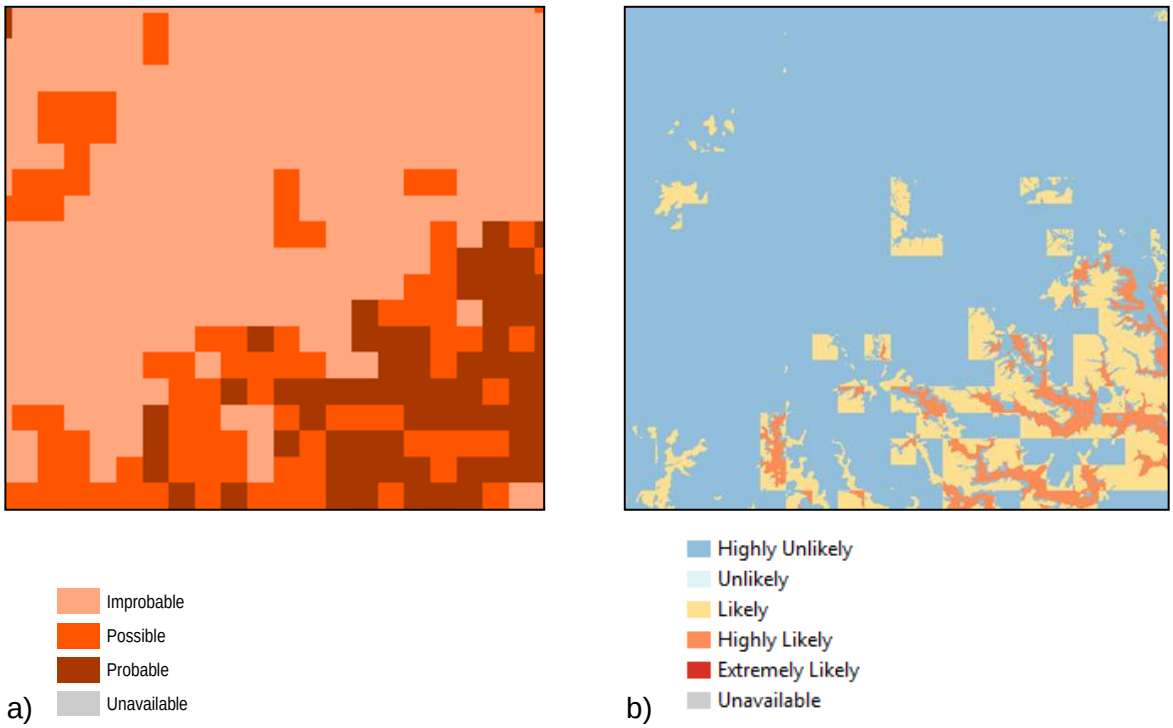


Figure 5 GeoClimate a) Open and b) Premium comparison for an example 40 km^2 area in south east GB

Figure 6 illustrates a 2 km^2 area which demonstrates the increased resolution provided by GeoClimate Premium in comparison to GeoClimate Open.

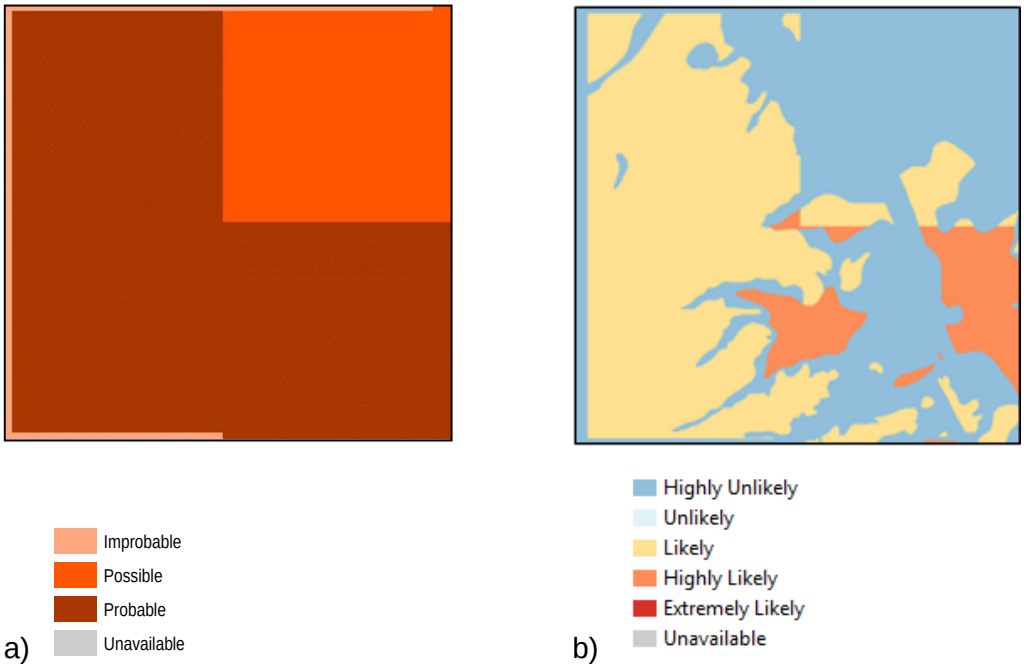


Figure 6 Comparison in data resolution of GeoClimate a) Open and b) Premium for an example 2 km^2 area in central GB

Which Climate projections are used in GeoClimateUKCP18?

GeoClimateUKCP18 utilises the UKCP18 Convection Permitting Model climate projections for the UK at 2.2 km resolution. These were produced using the Met Office HadGEM3-GC3 model and are better-able to represent small scale atmospheric processes (e.g. large convective storms) than regional climate models run on a coarser resolution. The projections consist of a 12-member ensemble, forced with the highest greenhouse gas concentration and emissions pathway (RCP8.5).

How does GeoClimateUKCP18 compare to GeoClimateUKCP09?

GeoClimateUKCP09 was based on the UKCP09 medium emissions scenario. GeoClimateUKCP18 utilises the updated UKCP climate scenarios, UKCP18, using the 2.2 km local projections (Murphy et al., 2018) to ensure the resolution provided in GeoClimateUKCP09 is maintained. These UKCP18 higher resolution projections were provided for only one scenario, RCP8.5. Although RCPs are not strictly the same as emissions scenarios, RCP8.5 should be considered to be comparable to the high emissions scenario.

The UKCP18 clearly outlined that general climate change trends over land for the 21st Century were broadly consistent with UKCP09 projections; both showing increased chance of milder, wetter winters and hotter, drier summers.

Therefore, GeoClimateUKCP09 and GeoClimateUKCP18 vary due to advancements in climate modelling between UKCP09 and UKCP18, and the use of a higher emissions scenarios in GeoClimateUKCP18.

For further details of UKCP18 compared to UKCP09, please see the Met Office official document:

https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance-ukcp18-for-ukcp09-users.pdf

Why does the susceptibility change over time?

Changes in susceptibility are driven by both the mineralogical and lithological characteristics of the geology, and climate. Some areas of the country will never experience clay shrink-swell due to the underlying geology, and these areas remain ‘improbable’ in every time period. In other areas, the underlying geology contains clay minerals that can shrink and swell due to the presence of water, but are not yet experiencing fluctuations large enough to trigger visible volume change and ground movement.

Is GeoClimate Open enough for my needs?

BGS GeoClimate Open projects that it is improbable that many areas will experience increased susceptibility to clay shrink-swell by the 2030s. As the climate continues to change, more geological formations containing shrink-swell susceptible clay minerals will experience larger fluctuations in water content. This will lead to the area projected to experience rising susceptibility increasing in size.

If it is consistently improbable that your area of interest will experience changes in clay shrink-swell susceptibility, then GeoClimate Open provides all the information you require to consider the impact of climate change on clay shrink-swell. You should however consult BGS GeoSure shrink-swell to identify the existing susceptibility.

If it is probable that the area of interest will experience changes in clay shrink-swell susceptibility, GeoClimate Premium will provide further, more detailed and higher resolution information, such as larger scale polygons rather than the small-scale grid, more future time periods, maximum and minimum projections and increased categories of susceptibility.

How are the GeoClimate Premium average, wetter and drier scenarios calculated?

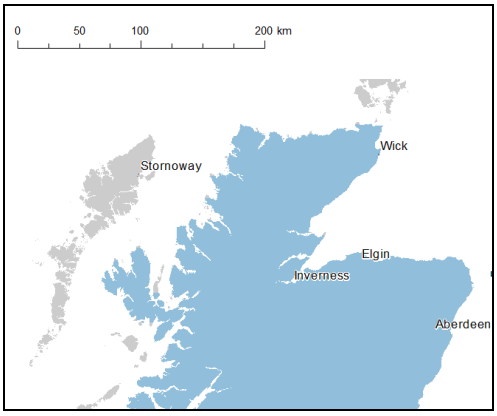
The GeoClimate methodology provides 12 values for each grid square, originating from the use of a 12-member perturbed parameter ensemble of global climate simulations. The 10th percentile has been utilised to represent the wetter conditions, the 50th percentile represents median average conditions and the 90th percentile represents drier conditions.

See Figure 2 which demonstrates the variation in the average, wetter and drier output datasets for 2070.

What does the data unavailable category represent?

The reason for the ‘unavailable’ category arises from 2 different sources. Firstly, all the input datasets required are not available for the Scottish Islands (including Orkney and Shetland Isles). Therefore, results for these areas are categorised as ‘Input datasets unavailable’.

Secondly, during the data processing, extremely high outlying values of soil moisture deficit were observed. Those events were associated with the coastline and originate with the UKCP18 climate scenarios data. To account for this, any grid point with extremely high soil moisture deficit values was removed and replaced with a null value. It is therefore not possible to provide a GeoClimate score and the cell is recorded as ‘unavailable’.

a) 

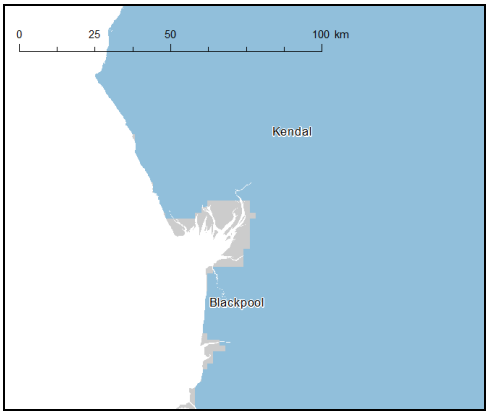
b) 

Figure 7 GeoClimate Premium of a) the Outer Hebrides and b) Morecambe Bay, demonstrating the two origins of data unavailable areas (grey).

Why does GeoClimate Premium appear to be pixelated, when it is derived from the 1:50,000 geology polygons?

The gridded nature of areas of GeoClimate Premium is due to the resolution of the soil moisture deficit data generated using the BGS groundwater model (ZOODRM). This provides an output grid with a resolution of 2km. Therefore, when combined with the geological 1:50,000 polygon dataset, in areas where the soil moisture deficits values lead to a varying GeoClimate Premium classification, across areas of consistent volume change potential, the grid is clearly visible.

8 Considerations

- The GeoClimate Premium dataset has been developed at a quasi- 1:50,000 scale and must not be used at coarser scales. GeoClimate Premium provides projections at the highest resolution possible, considering the methodology and input datasets. It is based on the best and most appropriate resolution datasets available at national scale and coverage. The 2.2 km scale of climate projections should be considered when carrying out detailed local-scale assessments.
- The GeoClimate Open dataset has been developed at 1:4000,000 scale and must not be used at larger scales.
- GeoClimate is concerned with potential ground stability related to ***natural*** shrink–swell geological conditions only.
- GeoClimate is based on, and limited to, an interpretation of the records in the possession of The British Geological Survey at the time the dataset was created.
- Our range of GeoClimate Products are developed using climate scenario data obtained from 3rd parties, so, although BGS strives to make it as accurate as possible, we can offer no warranty as regards fitness for purpose or accuracy. Furthermore the Products information provided is the result of modelled outputs and provided as best available, scientifically modelled data only.
- An indication of natural ground movement due to shrink–swell does not necessarily mean that a location will be affected by ground movement or subsidence. Such an assessment can only be made by inspection of the area by a qualified professional.
- GeoClimate does not identify the cost of a hazard being realised and, therefore, does not consider risk. GeoClimate examines the conditions that leave an area exposed to a hazard and the change in potential for this hazard to worsen due to climatic change.
- A high hazard does not necessarily translate to a high risk. For example, if a particular location has a relatively high ground stability hazard, but the properties are designed to withstand the hazard, with foundations that take the effects of climate change into consideration, they will not be at risk due to this geohazard.
- The level of potential hazard does not mean that damaging ground movement is going to happen but is an indication of causative factors that may occur and how severe they are thought to be.
- The text provided in the GeoClimate clay shrink-swell dataset are designed to provide a general indication of the meaning of the various GeoClimate clay shrink-swell dataset levels. If the data are to be used for advising specific sectors of end users in detail, e.g. home-buying, property insurance, site development and construction, then the BGS can provide additional end user guidance and attribution details for the data. To find more about this, please contact our Business Solutions department through the Central Enquiries Desk using the contact details at the start of this document.

9 Licensing Information

9.1 GEOCLIMATE OPEN

GeoClimate Open is made available under the Open Government Licence subject to the following acknowledgement accompanying the reproduced BGS materials: "Contains British Geological Survey materials ©UKRI 2020".

The Open Government Licence is a simple and straightforward licence that allows anyone - businesses, individuals, charities and community groups - to re-use public sector information without having to pay or obtain permission.

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The British Geological Survey does not sell its digital mapping data to external parties. Instead, BGS grants external parties a licence to use this data, subject to certain standard terms and conditions. In general, a licence fee will be payable based on the type of data, the number of users, and the duration (years) of a licence.

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In general terms, a BGS digital data licensee **will** be permitted to:

- make internal use of the dataset(s)
- allow a specified number of internal users to access/use the data (the number of users will be agreed with the licensee and specified in the licence document) for the purposes of their day-to-day internal activities
- reproduce extracts from the data up to A3 for use in external analogue (paper/hard copy) or non-query able electronic (e.g. secured .pdf) format: to meet a public task duty; fulfil a statutory requirement; and/or as part of academic or other non-commercial research

But **will not** be permitted to:

- provide a bureau service for others or incorporate the data in the generation of products or services for commercial purposes
- sell, assign, sublicense, rent, lend or otherwise transfer (any part of) the dataset(s) or the licence
- place (any part of) the dataset(s) on the Internet

The BGS is committed to ensuring that all the digital data it holds which is released to external parties under licence has been through a robust internal approval process, to ensure that geoscientific standards and corporate quality assurance standards are maintained. This approval process is intended to ensure that all data released: (i) is quality assured; (ii) meets agreed BGS data management standards; (iii) is not in breach of any 3rd party intellectual property rights, or other contractual issues (such as confidentiality issues), that would mean that release of the data is not appropriate.

When the BGS digital datasets are revised any upgrades will be automatically supplied to the licensee, at no additional cost. Geological map datasets are revised on a periodic rather than on an annual basis, licensees will therefore not automatically receive a new dataset each year unless changes have been made to the data.

These are general comments for guidance only. A licensee of BGS's digital data is provided with full details of the basis on which individual BGS datasets licensed to them are supplied.

If you have any doubts about whether your proposed use of the BGS data will be covered by a BGS digital licence, the BGS Intellectual Property Rights (IPR) section will be happy to discuss this with you and can be contacted through the following email address: iprdigital@bgs.ac.uk BGS IPR will usually be able to provide reassurance that the licence will cover individual user requirements and/or to include additional 'special conditions' in the licence documentation, addressing specific requirements within BGS's permitted usage.

9.3 CONTACT INFORMATION

For all data and licensing enquiries please contact:

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Glossary

Clay shrink-swell	Shrink–swell occurs as a result of changes in the moisture content of clay-rich soils. This is reflected in a change in volume of the ground through shrinking or swelling. Swelling pressures can cause heaving, or lifting, of structures whilst shrinkage can cause differential settlement.
Hazard	A potentially damaging event or phenomenon.
Risk	The impact of the hazard on people, property or capital. The GeoClimate dataset does not identify the cost of a hazard being realised, and therefore does not consider risk. It only examines the conditions that leave an area exposed to the hazard. It is therefore a hazard dataset.
Subsidence	Subsidence is a lowering or collapse of the ground. It can be triggered by a change in drainage patterns, heavy rain, by water abstraction or man-made disturbance. Subsidence has the potential to cause engineering problems such as damage to foundations, buildings and infrastructure.
UKCP18	UKCP18 uses cutting-edge climate science to provide updated observations and climate change projections out to 2100 in the UK and globally. The project builds upon UKCP09 to provide the most up-to-date assessment of how the climate of the UK may change over the 21st century.
ZOODRM	Zooming Object Oriented Distributed Recharge model

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