ORDNANCE SURVEY

UK SPACE AGENCY PROJECT

PROVIDING HEAT DATA TO END USERS FOR RESILIENCE AND ADAPTATION PLANNING

Ordnance Survey

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Version History

Version	Date	Description	Authors
1.2	17/03/2022	Report	Donna Lyndsay (Ordnance Survey), John Remedios (National Centre for Earth Observation)

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Executive summary

Project objective

Space4Climate support the UK's world-leading climate community to deliver, sustain and make use of climate information from space, enabling it to be integrated in a variety of climate services for global economic and societal benefit. This project supports the Space4Climate working group mission in creating climate services and actionable sights from space.

Space4Climate identified a growing need for evidence to support adaptation planning for heat events but believed that take up and awareness of existing Earth observation products in the UK was limited. This project was designed to determine the level of awareness and understanding of the data available, and to understand any barriers to the use of the data.

The spatial heat profiles in the data provided by National Centre for Earth Observation identify areas of greatest risk from high temperatures. The key mission was to understand how to turn these space derived heat data observations into insights for the end user to use with their existing systems. The aim is to support the provision of satellite data insights to those developing planning policy, and resilience and adaptation plans

Discovery work

During the discovery process, 300 people were interviewed directly about the data. In addition, there were 447 unique sessions on the website and 348 unique visitors. This discovery work was in the form of direct interviews, workshops, and feedback forms.

This work suggests there is a clear need and desire to use space-based climate insights to support sustainability challenges. A considerable proportion (88%) of those interviewed could see real value of the data in their work. However, 85% were not aware of the heat data or had any form of access to it, suggesting a degree of market failure in reaching the userbase.

Most respondents wanted to obtain the data through Application Programme Interfaces (39%) or as bulk download (39%).

Barriers to use were unfamiliar formats, inability to visualise and use the data in standard tools and inability to combine the data with user geospatial data holdings to make the insights useable.

Some use cases identified by end users were:

- Understanding the heat profiles of building and surface materials to targeting grants and investments for greening (e.g. tree planting schemes, parks, green roofs) and blueing strategies (e.g. increasing water features to cool an area, such as fountains or new access to water features).

- Use the data to identify schools and colleges of greatest heat risk. Once the estate-wide heat risks are understood, prioritise, alongside the other climate change risks of flood and water scarcity, to develop solutions which are nature-based solutions, wherever possible.

- Use the data to support the heatwave plan for the UK for targeting resources and creating impactful communication plans. At times of excessive heat, could it be used to focus resources to those most at need and help predict where NHS might get increased Accident & Emergency (A&E) attendances.

- The data could be used in the Office for National Statistics 5-year project assessing the link between health and environment – what conditions impact or improve health and how this impacts the country as a whole

- The data could be used by local authority planners to remotely check if planning conditions around heat have been met.

Recommendations

In the discovery sessions we uncovered the need and desire to use space-based climate data within the Public Sector user base, but technical barriers, lack of metadata and the skills needed to access the data are preventing use and limiting uptake. The use cases (section 5) describe in detail how the data could help inform the end users' needs, if the data was made more accessible.

Recommendation 1

To reduce the technical barriers identified in the discovery section 3 and in the use cases in section 5, and in the technical report (appendix 1) we recommend the Government provide access to open climate data in formats that public sector bodies can gain insights from, to address their climate challenges. This access should also allow the large-scale take-up of space derived products by innovators and companies enabling them to create new products and services to support climate and ecological emergency facing the UK.

To support this, the data provided by the National Centre for Earth Observation (or any iteration of Earth observation climate data) needs to support the UK National Data Strategy's FAIR (Findable, Accessible, Interoperable and Reusable) principles to make it useable for a wide variety of end users. It must be discoverable and accessible in simple, plain language and ideally with supporting contextual topographic information, i.e. a map base, for a range of users including non-experts. The project proves it can answer the core needs for users in the UK, therefore there is potential for it to be scaled up for provision nationally through the Public Sector Geospatial Agreement. Key recommendations are:

1. Simple, clear, non-expert descriptions are needed to make the data findable.
2. Clear metadata and data description documentation should be provided so users can determine data provenance and whether the data meets user requirements.
3. The data should be provided in easy-to-use industry standard formats, not just netCDF. Most end users wanted formats they are familiar with, such as TIFF, which can be easily viewed or interpreted in GIS software. Other key aspects for the data include:
    a. A requirement for embedded metadata to support and easily identify each product.
    b. By providing the data as a GeoTIFF, separate latitude and longitude bands will not be needed, reducing file sizes.
    c. Any naming format needs to be consistent and intuitive and capable of supporting a UK scale dataset.
4. UK customers should also have the data provided in British National Grid to enable direct linking with their other geospatial information sets.
5. Retain an Open Data approach under the Open Geospatial Licence terms so users can understand what terms apply to the data and the correct copyright statements. Additionally, ensure the licence is linked to the supply of the data.

Recommendation 2

To support the use cases and customer needs identified (sections 4 and 5), the data also needs to be capable of supporting historical time series analysis. This functionality was highlighted as a requirement

by partners as well as public sector bodies. To monitor future heat waves in the UK there is also a need to deliver climate quality heat data at appropriate resolutions in near-real time. In line with FAIR principles, it must be provided with robust metadata, be supplied in a consistent manner, and have information on the confidence of the measurements and appropriate use of the data.

Recommendation 3

End users equally preferred bulk download (39%) or access via Application programme Interfaces (39%). Bulk download can be provided by NCEO but an appropriate route for supply is via existing via Application programme Interfaces (API) routes such as the Ordnance Survey OS Data Hub APIs (or other API providers) which is commonly used by PSGA members and licensed partners to access Ordnance Survey products. We also recommend a clearly defined refresh plan or a notification subscription system so users can return to bulk download new data when notified. To enable UK community uptake, users should be able to access British National Grid positioned GIS ready data accessed via the OS Data Hub for immediate use.

Recommendation 4

The Office for National Statistics (ONS) recommend a lookup between the Unique Property Reference Number and the raster value for each band to support statistical analysis in a way non-geographical analysts could easily use. The Ordnance Survey could potentially provide this lookup table with support from the Geospatial Commission. The ONS also recommended summary statistics from the heat data for Census geographies. This would make the data more accessible and significantly increase the use of heat data in most applications, including heath metrics.

Recommendation 5

Operationalise the provision of UK wide heat data (including historical time series) in a form that meets FAIR principles. This should be provided in accessible data formats with an assured longevity and consistency of supply. Data could then be provided out to the PSGA customer base via Application Programme Interfaces, such as the OS Data Hub, to over 5000 end users, or through new value-added services created by the community.

Costs of supply should be considered against the tangible financial benefits of evidence-based targeting of interventions. Several end users outlined potential uses for identifying areas that could support tree planting schemes across rural and urban landscapes. Analysis across 11 UK city regions estimated the benefits of urban blueing and greening for these regions alone was £274 million in a single year, through avoided productivity losses and reduced cooling costs[1]. It was felt that targeted, data driven approach could maintain and increase this benefit in line with new urban developments and climate change.

Heat-related fatalities in England are projected[2] by the Climate Change Committee to increase with climate change. These fatalities have high economic costs, estimated in this study as a range from £323 million to £9.9 billion per year by the 2050s.

Recommendation 6

This project has indicated a lack of awareness in the data products available from the Earth observation community to support end user needs. Therefore, we recommend a focused training course or programme for PSGA users. This could support wider uptake of Earth observation data and services.

[1] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/ecosystemaccountsforurbanareas

[2] https://www.theccc.org.uk/wp-content/uploads/2019/07/Outcomes-Heat-preventable-deaths-case-study.pdf

Glossary

API Application Programming Interface

CCRA Climate Change Risk Assessment.

EO Earth observation

Geo6: Partner bodies of the Geospatial Commission (The British Geological Survey, The Coal Authority, HM Land Registry, Ordnance Survey, UK Hydrographic Office, The Valuation Office Agency).

GIS Geographical Information System

DEFRA Department for Environment Food & Rural Affairs

DfE Department for Education

DI Discomfort Index

DLUHC Department of Levelling Up, Housing and Communities

IPCC The Intergovernmental Panel on Climate Change

LSOA Lower Layer Super Output Areas for reporting of small area statistics

LST Land Surface Temperature

NCEO National Centre for Earth Observation

NetCDF Network Common Data Format

NDVI Normalised Difference Vegetation Index

MSOA Middle Layer Super Output Areas for reporting of small area statistics

MUGA Multi Use Games Area

ONS Office for National Statistics

OS Ordnance Survey- Great Britain's National Mapping Service

PHE Public Heath England

PSGA Public Sector Geospatial Agreement

QGIS A free open source Geographical Information System

TIFF Tag Image File Format

UHI Urban Heat Index

UKSA UK Space Agency

1. Project Background

1.1 The need

The Climate Change Committee reported in June 2021 that adaptation to heat should be one of the highest UK adaptation priorities in the next two years for the UK.[3]

The core needs identified were around risks to human health, wellbeing and productivity from increased exposure to heat in homes and other buildings.

The latest UK Climate Projections suggest that a hot summer like 2018 is likely to occur every other year by 2050, by which time, in the absence of additional adaptation, the number of heat-related deaths could more than triple from today's level from around 2,000 per year to around 7,000.

According to a study published last year from Rutgers University in the US, as many as 1.2 billion people around the world could face heat stress conditions by 2100 if current levels of global warming continue.

1.2 The Project Mission

Chaired by the UK Space Agency, Space4Climate support the UK's world-leading climate community to deliver, sustain and make use of climate information from space, enabling it to be integrated "as standard" in a variety of climate services for global economic and societal benefit. This project supports the Space4Climate working group mission in creating climate services and actionable sights from space.

The project identified the need for heat data in the Climate Change Committee recommendation for adaptation planning for heat events. The project is designed to create an understanding of urban heat profiles and identify areas of greatest risk to those developing planning policy and resilience and adaptation plans.

The key mission was to explore how to provide data and insights that are easily accessible by the end user. The outcomes of this project will help inform how we mobilise other Earth observation data insights to meet this requirement.

Heat data created by the National Centre for Earth Observation's (NCEO) Leicester University team estimates how heat affects urban areas and how that is likely to impact on people, i.e. what is the risk and what are the statistical consequences.

The information is derived from NCEO's unique land surface temperature algorithm applied to data from thermal infra-red sensors in space, a particular UK capability. NCEO heat data products are developed in a framework tied to climate quality data thus giving assurance and quantitative assessment. This will help inform strategic planning decisions and health response to heat emergencies (e.g. major cities in the UK) by indicating extremes and areas of highest risk to human health.

The heat data was provided as Open Data under open licence terms.

This project will publish this report and its insights to the international community.

[3] (Independent Assessment of UK Climate Risk Advice to Government for the UK's third Climate Change Risk Assessment (CCRA3) https://www.ukclimaterisk.org/

1.3 Why Now?

Many UK councils and local authorities have declared a climate emergency[4] but struggle to obtain the data to help them and their communities understand the climate impacts.

While there are multiple platforms available, it still requires expertise to provide the data in a format end users can engage with. From a user perspective, there is no current easy-to-use interface for this data consistent with other UK spatial products. This project provides insight into potential ways to achieve this for the Public Sector Geospatial Agreement (PSGA) customer base.

The data has been tested with the OS PSGA customer base to determine whether it supports their needs for responding to the climate emergency and with the aim of creating resilient communities. Ordnance Survey already supports over 5,000 public sector bodies and 6,000 business in accessing geospatial data and there have been over six billion API requests through the OS Data Hub since its launch in July 2020. By linking the heat data to OS data, through familiar systems, PSGA customers should be able to access the insights they need. If successful, the scale-up in usage would be transformational and could galvanise climate-resilient data-based services for local authority net-zero planning.

We also assessed whether the delivery of climate data will deliver climate insights through statistical analytics. Therefore, data was provided to, amongst others, the Office for National Statistics (ONS) to assess whether it could help support for Sustainable Development Goal 11 (Sustainable Cities and Communities).

1.4 Partners and Roles

1. National Centre for Earth Observation (NCEO) – data creation and supply

   NCEO undertook the data processing and provision of the data to OS. Heat data products were supplied at 30m spatial resolution (resampled from 100 metre input data) and were derived from long-term, operational space assets thus future-proofing the supply of raw measurements.

   The information was derived using NCEO's unique land surface temperature Optimal Estimation algorithm, a unique UK capability. The algorithms were applied to the LANDSAT 8 Collection 2, Level 1 dataset (this dataset re-grids the thermal infra-red 100 metre data to 30 metres to be consistent with the visible wavelength channels), obtained from the United States Geological Survey (USGS). A refresh plan and mode of future data supply has been designed based on feedback from customer surveys and interviews through OS discovery work.

   The heat data created by NCEO's Leicester University team provides indications of how heat affects urban areas and the potential impact this could have on people and was made available for the following cities – Glasgow, Liverpool, Leicester, Cardiff, Plymouth - so spatial variability could be assessed. Data for Lusaka in Zambia was also provided as an international sample for testing with our Zambian contacts. All data was made available under Open Data licence terms.

2. Ordnance Survey (OS)- customer discovery and requirements and trials.

   OS's role was customer discovery, requirements gathering and onward provision of data from NCEO to potential end users. We worked with the NCEO to provide correct interpretations of the data and help build materials to inform use cases from our customer base. OS also worked with ONS to

[4] Climate emergency declarations in the United Kingdom - Wikipedia

see if the data could support statistical needs, for reporting to SDG11 and with international partners to see if outputs met their needs for resilience planning.

1.5 Outcomes

The key outcome is the findings and insights held in this report. It aims to provide an understanding of how the public sector could access and use climate data to meet adaptation, resilience, and delivery to the Sustainability Development Goals.

What does success look like?

PGSA members understand how to access and use the data to help plan and inform citizens about heat impacts. ONS understand how to access, use, and onward provide the data to meet their core needs. NCEO and the Earth observation community, through Space4Climate, tailor datasets to meet customer need and meet the technical requirements of customer facing, assured delivery.

In summary, this report provides an understanding in how to place climate data into the hands of those who need it to create real impact.

2. OS technical discovery

The project discovered several processing steps that would be needed to enable widespread adoption – these have been described in three categories – pre-project, project and post-project. These stages are reported in full in appendix 1.

In summary, the NCEO supplied the initial pre-project data in Network Common Data Format (netCDF). This is a common format for sharing array structured scientific data. While netCDF files can typically be opened in most Geographic Information Systems (GIS), Ordnance Survey encountered problems rendering the data. Ordnance Survey therefore took the decision to convert the data into a more familiar Tag Image File Format (TIFF) and also supply this to the end users to enable a comparison of the two formats by customers.

The information contained in the data consisted of

- Latitude (LAT)
- Discomfort Index (DI) – a measure of the heat that a person experiences
- Normalised Difference Vegetation Index (NDVI) – a measure of vegetation health
- Longitude (LON)
- Land Surface Temperature in Kelvin (LST) - a surface 'skin' measurement of temperature
- Land Surface Temperature in Centigrade (LST_degC) - a surface 'skin' measurement of temperature
- Urban Heat Index (UHI) – a measure highlighting the difference in the ability of an environment to absorb and hold heat

During this early technical phase, the following key points were identified:

- A requirement for embedded metadata to easily identify each product, including a defined Coordinate Reference System useful for the customer. In the UK this would be British National Grid (BNG) which would align the data with Ordnance Survey data.
- The naming format needs to be consistent and intuitive.

Once processed, the data was provided to the Ordnance Survey rapid prototyping team to set up external access to the data, ready for end user discovery.

3. The customer discovery

3.1 Research design

The core aim of the project was to collect qualitative research to understand the interest and barriers to adoption for this data by a mixture of PSGA customers, alongside a mix of OS licensed partners. The research was broken down into face-to-face discovery meeting sessions and workshops. A webpage with an online questionnaire and download link was created to enable as many contacts as possible to access and feed into the discovery. The webpage was specifically sent out to the Scottish Government (the Geographic Information Science & Analysis Team (GI-SAT), Data, Statistics and Digital Identity Division), OS commercial Partners, PSGA members, the Office for National Statistics, Welsh government, The Royal Town Planning Institute, Rural Payments Agency, and the Geo6 - with an invitation to circulate to other interested parties.

After reviewing the questionnaire feedback, a selection of contacts was approached for one-to-one interviews to help additionally inform the discovery and insights on usability, barriers and use cases. The project was also promoted via LinkedIn, however the most significant take up was after direct contact via email. Two workshops were held with the Greater London Authority to explore the data and get feedback from 50 planners and local Authority personnel. A demonstrator was created for Zambia for International discovery. This was due for presentation to the Zambian President in February 22 but has since been delayed due to Covid.

Anonymised feedback and survey summary is provided in appendix 2 and 3. Key common areas and insights are provided in the results section. Those quoted in the report gave explicit permission to be named and quoted. All other contacts and personal details have been destroyed unless explicit interest in continued contact has been provided.

Once the data was provided by NCEO and processed, with their advice, into a format that was usable by OS, a number of example use cases and indices were created through a series of sprints by the OS Rapid Prototyping Team (a group consisting of Product manager, Scrum master and data scientists). This process was to provide context, stimulate thought, ideas and understanding of how the heat data could be linked with other more familiar spatial datasets to provide insights. Using Plymouth as the case study area, OS showcased how the heat data could be used for identifying population and infrastructure at risk of overheating, the relationship of hot areas to greenspace, and how the data can be used to monitor change. This served to provide a good understanding of the potential use of the data to those who had never seen or heard of the data product before.

3.2 Heat Data Case Studies

Heat Vulnerability Index

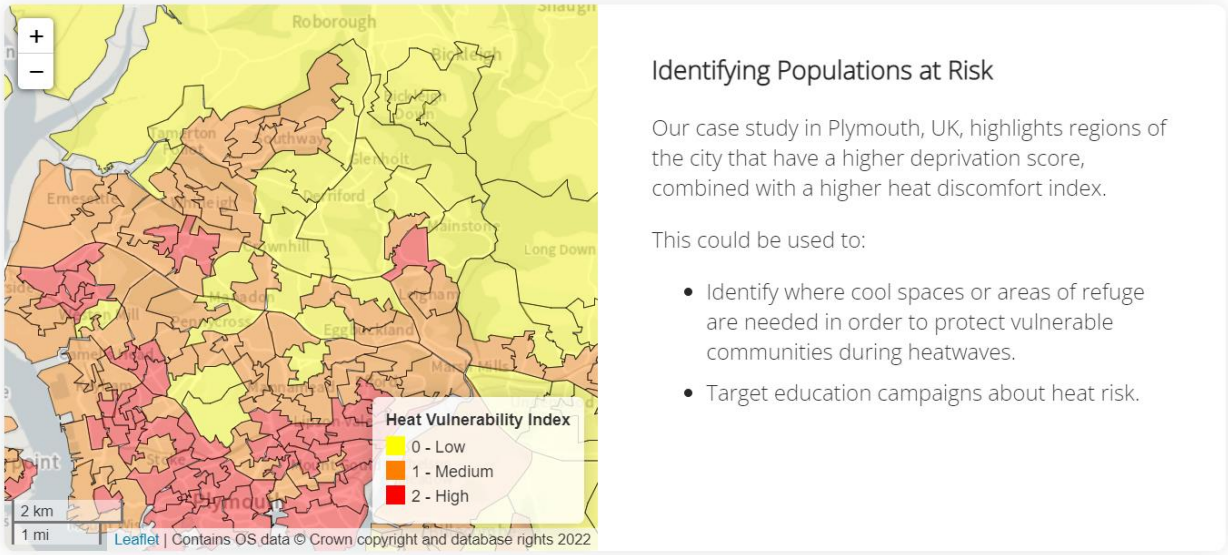


Figure 1 Populations at Risk

Our Heat Vulnerability Index highlights regions within an urban extent that could be particularly vulnerable during a heat event. Regions are considered vulnerable if they have a deprived population and a high local temperature due to the urban heat island effect. Lower Layer Super Output Areas (LSOA) were selected as the unit for the index. These are part of the Census geographic hierarchy designed to improve the reporting of small area statistics in England and Wales.

The index was calculated by combining the index of multiple deprivations per LSOA with the median discomfort index, which is determined by sampling NCEO's discomfort index layer for each of the same LSOAs. The raster sampling was done using a zonal statistics tool in the GIS package QGIS.

To output the heat vulnerability index as a category (high, medium, low risk), a median threshold was applied to the deprivation and discomfort scores. If an LSOA had an above-median deprivation and discomfort index, then it was classified as high risk. Conversely, if an LSOA had a below-median deprivation and discomfort index then it was classified as low risk. Any other combinations were classified as medium risk.

Infrastructure at Risk

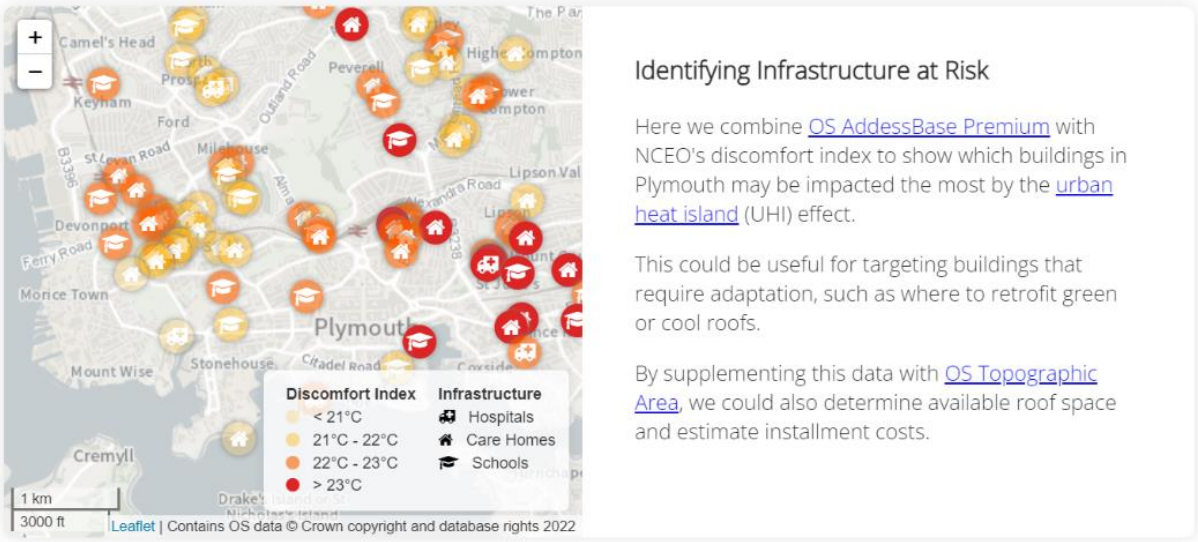


Figure 2 Infrastructure at risk

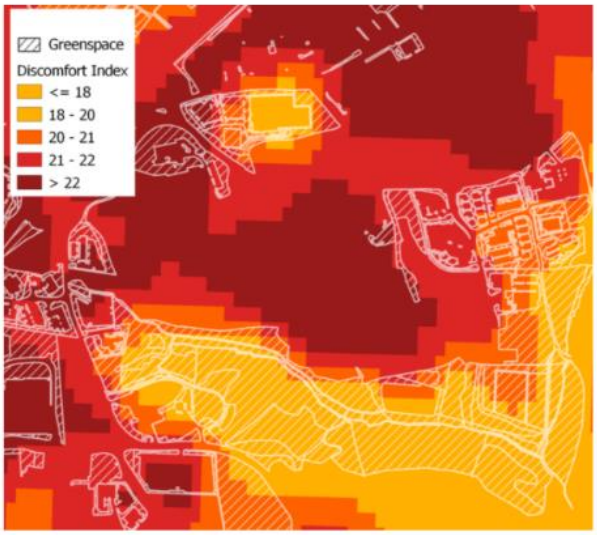
Our infrastructure risk data set identifies specific sites that could be vulnerable during a heat event – in particular, we have studied schools, hospitals, and care homes.

Sites that are considered vulnerable are those that are located within a region that experiences high localised temperatures due to the urban heat island effect.

The data set was created by finding the locations of potentially vulnerable sites in the AddressBase® Premium product by querying for specific classification codes – and then sampling NCEO's discomfort index layer at each coordinate point. The raster sampling was done using a point sampling tool in QGIS.

When plotted according to discomfort index, clusters of schools, hospitals and care homes begin to emerge that are particularly vulnerable.

Greenspace



Visualising Greenspace

Greenspaces with trees alleviate the UHI effect. In this illustration, we have combined NCEO's discomfort index with OS Greenspace to understand the relationship between greenspaces and discomfort. This could be used to:

- Inform decisions about where to plant trees in order to most efficiently reduce discomfort.
- Monitor tree planting projects over time to ensure that these programs are working as intended.

Figure 3 Visualising greenspace

To visualise areas of greenspace and how they corelate to cooler urban areas, we overlaid the OS Greenspace layer onto NCEOs discomfort index layer. This allows us to analyse trends between greenspace areas and localised temperature variations, as well as identify regions where greening strategies might be used for maximum effect.

4. Results

There is a genuine appetite and desire to access the insights that Earth observation data can provide to support the implementation and monitoring of policies and interventions related to climate change and adaptation. Some engagement metrics are:

- In total 300 people were interviewed about the data directly. There were 447 unique sessions on the website and 348 unique visitors.
- Only 15% were currently using the data.
- 88% saw the value of using the data in their work, with 12% not seeing any value of the data for their work.
- In terms of access, 39% wanted to access the data as bulk download, 39% wanted to access the data through an Application Programming Interface (API) and 15% via a web interface, although undefined as to whether this is as a map web interface.

Common user feedback on the data was:

- They struggled to open netCDF and multilayer GeoTiff.
- They found it difficult to extract layers they needed and to colour code them.
- All end users were used to dealing with vector data but only 15% had used Earth observation data.
- Many who struggled with the format only found the data useful when overlaid on a basemap.
- All users would like the data combined with geospatial data to give context.
- The data would only have widespread adoption if it was free at the point of use, primarily due to budget constraints.
- Most end users required it to be supplied in a non-technical way.
- All users need metadata and documentation to understand exactly what they are looking at.
- Temporal slices of statistics including minimums, maximums, averages, durations, need to be included so that trends can be identified.
- Where index information has been created e.g., Urban Heat Island or Discomfort Index, further information should be provided to better understand its potential use and any associated thresholds e.g., in the case of the discomfort index, at what levels cause health concerns etc.

4.1 Sectoral Specific Reponses

Local Authorities

The Public Sector currently struggle with accessing traditional geospatial insights to drive decisions, often using geospatial data only as a traditional map base rather than for digital geo insights. They now must

understand climate challenges and resilience, particularly since many have now declared climate emergencies.

Awareness of Earth observation data was present but knowledge on how to access and use it is very limited within the public sector. Knowledge of the heat data and its availability was extremely limited.

This Heat data project has now inspired several potential applications; from understanding the heat profiles of building and surface materials to targeting grants and investments for greening (e.g. tree planting schemes, parks, green roofs) and blueing strategies (e.g. increasing water features to cool an area, such as fountains or new access to water features).

Areas of interest highlighted by end users to explore are listed below.

- Understanding the applications of thermal data in urban areas has been a key ask from the Scottish Government to help inform resilience strategies.

- Several visitors outlined potential uses for identifying areas that could support tree planting schemes (including cooling water/rivers for fish) across rural and urban landscapes. Analysis across 11 UK city regions estimated the benefits of urban blueing and greening was £274 million in a single year for these regions alone, through avoided productivity losses and reduced cooling costs[5]. It was felt that targeted approach could maintain and increase this benefit in line with new urban developments and climate change.

- Planning authorities want to be able to monitor policy impact and interventions and surface material impacts.

- The heat data can be useful in informing the monitoring of progress of climate action plans, and potentially in planning for assessing occupation.

- Local authorities articulated the benefit of the data being open and free to use, which naturally makes it financially accessible. The challenges and costs are in format conversion and the interpretation of the data. They also highlighted the value of being able to freely show the data to citizens to help support behavioural change and policy implementation through visualisation of the data in a way that the public can easily understand (e.g. a thematic map view), and respond to.

- They specified new requirements that should drive adoption. For example, the Department of Levelling Up, Housing and Communities (DLUHC) have introduced a new requirement on overheating into the Building Regulations[6] to ensure that new residential buildings are built for a warming climate. The new requirement prioritises addressing overheating through passive measures including reducing solar gains and sufficient removal of heat.

- There was a suggestion that higher resolution heat data could be used in future to identify when a building is occupied post construction for taxation purposes.

[5] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/ecosystemaccountsforurbanareas

[6] Overheating: Approved Document O - GOV.UK (www.gov.uk)

Government bodies

Several Government bodies were keen to engage including Department for Education (DfE), Defra, Natural England, National Health Service (NHS) and the British Geological Survey. UK Hydrographic Office expressed an interest in heat distribution around ports.

Areas highlighted where the end users wanted to explore the data use were:

- To look at river and stream temperatures to identify the effects of trees on temperatures, (particularly on water temperatures) and enable the targeting of new areas for tree planting.
- To understand how the Heat Data could be used within DfE's Sustainability & Climate Change strategy[7] launched at COP26 (the United Nations Climate Change Conference held in Glasgow November 2021).
- To understand how the data can be used to support the heatwave plan for the UK for targeting resources and creating impactful communication plans.
- At times of excessive heat, could it be used to focus resources to those most at need and help predict where NHS might get increased Accident & Emergency (A&E) attendances.

Initial thoughts on use within the Office for National Statistics (ONS) was around supporting data needs for Sustainable Development Goal (SDG) 11. Discussions with the SDG team indicated mature data usage for SDG reporting and that heat data was not a necessary addition or that it provided any additional value. However, it was felt that ONS's data combined with this heat data could assist with the Heatwave plan for England. It was also felt it may be applicable in several projects around Natural Capital and the Data Science Campus' mobility work. ONS are currently assessing the data and seeing what could be done to inform statistics for the Heatwave plan.

Small and Medium Enterprises (SME's), consultants, corporates, third sector

SME's were keen to explore the potential for supporting the Sustainable Development Goals. They want to see how it could be provided to the private sector to foster innovation through the use of Open Data products and to respond to user needs for new services. Corporates felt the data would need to provide an indication of change over time (observed and forecast), rather than a single snapshot in time, to meet the various climate change scenarios knowns as Representative Concentration Pathways[8] (a greenhouse gas concentration trajectory adopted by the Intergovernmental Panel on Climate Change) published in UK Climate Change Projections[9]. It was felt that this could lead to not just new, innovative products and services around climate but also energy usage and NetZero transformation strategies.

From a planning consultancy perspective, the data was seen as useful baseline data for further environmental impact assessment and modelling work.

[7] Sustainability & Climate Change: A draft strategy for the education & children's services systems (publishing.service.gov.uk)

[8] https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance---representative-concentration-pathways.pdf

[9] https://www.metoffice.gov.uk/research/approach/collaboration/ukcp

For third sectors (at a high level), the data was of possible interest in tackling biodiversity loss and climate change. For example, could it be used to target land management techniques to mitigate for the effects of excess heat?

Office for National Statistics (ONS) feedback

The feedback below was provided by the Geospatial Analysis and Capability division within ONS for this report.

Raster data is very rarely used at ONS and there are few people with the skills to effectively use it (mainly the Geospatial and Geography teams who are proficient GIS users). ONS offer desktop GIS across the organisation, but its use is limited and those who do use it tend to be doing simple vector operations. Most of ONS' analysts/statisticians are working with either R or Python within ONS' big data platform. All the data ONS holds is stored securely on this platform, and it is not possible to extract raw data, only aggregated data which has passed disclosure control checks. The architecture behind the platform has not been built with spatial data in mind so it would not be possible to ingest the heat data in its current format. This would significantly limit the use of the heat data across ONS, meaning we could not bring the heat data together with our other datasets without losing a lot of spatial resolution.

ONS suggest that to make the data more usable to analysts it would be better to be able to link the values within the rasters to objects or geographies that are more commonly used. For example, providing a lookup between UPRNs (Unique Property Reference Number) and the raster value for each band would be suitable format for ingest to our data platform and would be the type of data that non-geographical analysts could easily use. Many of the statistics produced by ONS, and used by others, are provided for areas – if ONS could produce a range of suitable summary statistics from the heat data for these areas then again, this data could easily be combined with ONS' existing products. ONS suggest these be created over a range of geographies, particularly for the Census geographies (output area, Lower Layer Super Output Areas (LSOA), Middle Layer Super Output Areas (MSOA)) and local authorities. While we appreciate that this method would reduce the spatial detail provided by the raster data, it would significantly increase the usability of the heat data which would otherwise likely be discarded as too complex to use in most applications at ONS.

Regarding the data, ONS would require a greater detail in the data's metadata and more information about the underlying methodology before being able to confidently use this data in any setting, and particularly so to produce official statistics. In particular:

- *In terms of a methodology, ONS would ideally like one aimed at an educated but non-specialist user which would allow them to understand the steps taken to reach the final product, and to allow the user to assess and understand the suitability of the data for their application and to understand any caveats with it.*

- *For each band, ONS would want details of how the various indices and measures have been calculated to assess suitability of this data for specific use cases.*

- *For national statistics production ONS are required to provide detailed information on the source of the underlying data which would allow the analysis to be completed by another user who has access to the data. For satellite data this would mean ONS require a suitable identification (ID) code for the tiles used in the underlying mosaic. It may be worth investigating this more if ONS is to use satellite data for national statistics.*

- *ONS predominantly work in British National Grid so would need to do some reprojection for analysis There are several use cases for this data across ONS. Here are some of the current use cases:*

- *A 5-year project assessing the link between health and environment – what conditions impact or improve health and how this impacts the country as a whole.*

- *Assessment of various measures of natural capital and potentially the impact of climate change on these resources.*

- *The Data Science Campus are interested to see if they could meaningfully integrate this data into their current work on mobility (both internally and internationally).*

- *ONS geography teams as an additional variable when considering the development of our products around the built environment (for example, rural urban classification etc).*

5. Specific Customer Use cases

5.1 Use case 1: Supporting the heatwave plan for the England.

Testing Organisation NHS Devon Clinical Commissioning Group

Problem Statement: Heat risk is hard to communicate. Can the heat data be used to support planning and messaging for the Heatwave plan?

The UK heatwave plan designed to protect health from heat-related harm. It sets out what should happen before and during periods of severe heat in England. It describes what preparations both individuals and organisations can make to reduce health risks. It includes specific measures to protect at-risk groups which include older people, the very young and people with pre-existing medical conditions as well as those whose health, housing or economic circumstances put them at greater risk of harm from very hot weather. The plan is also intended to mobilise individuals and communities to help to protect their neighbours, friends, relatives, and themselves against avoidable health problems during spells of very hot weather.

Relevant documents are:

Heat-health Alert service - Met Office[10]
Heatwave Plan for England (publishing.service.gov.uk)[11]

Data suitability: David Lewis, Senior Information Specialist, Strategic Intelligence, NHS Devon Clinical Commissioning Group downloaded the NCEO data with the heatwave response in mind. He found the data more usable as a TIFF output overlain with OS map data. The Earth observation data files alone did not provide enough context or metadata to enable David to glean any insights from. Once supplied with the TIFF and OS map data he could immediately identify hotspots of potential concern. He commented:

"It's good to be able to see the geographical areas below to allow you to instantly see where the 'hot-spots' are. You might then like to focus NHS services and support to those areas directly."

[10] Heat-health Alert service - Met Office
[11] Heatwave Plan for England (publishing.service.gov.uk)

Figure 4 Exeter Land Surface Temperature

Figure 5 Hospital showing heat island effect

Outcomes: David and his Director also believed that the data might be useful for long term planning, and that they could do more detailed work on risk around temperature as part of wider demand modelling, whether that be heat related illness or cold. The 16 days revisit time wasn't seen as a barrier if the hotspots had a consistency to them. They also felt that with additional work it could be used to support a communications piece of work. For example, what are the associated outcomes, what measures can people take etc.

The heatwave plan for England outlines the communication cascade and how many stakeholders are involved. Being able to visualise the data in map form is a very powerful and immediate mechanism for communication of invisible risks. The data will now be explored by the Head of Forecasting.

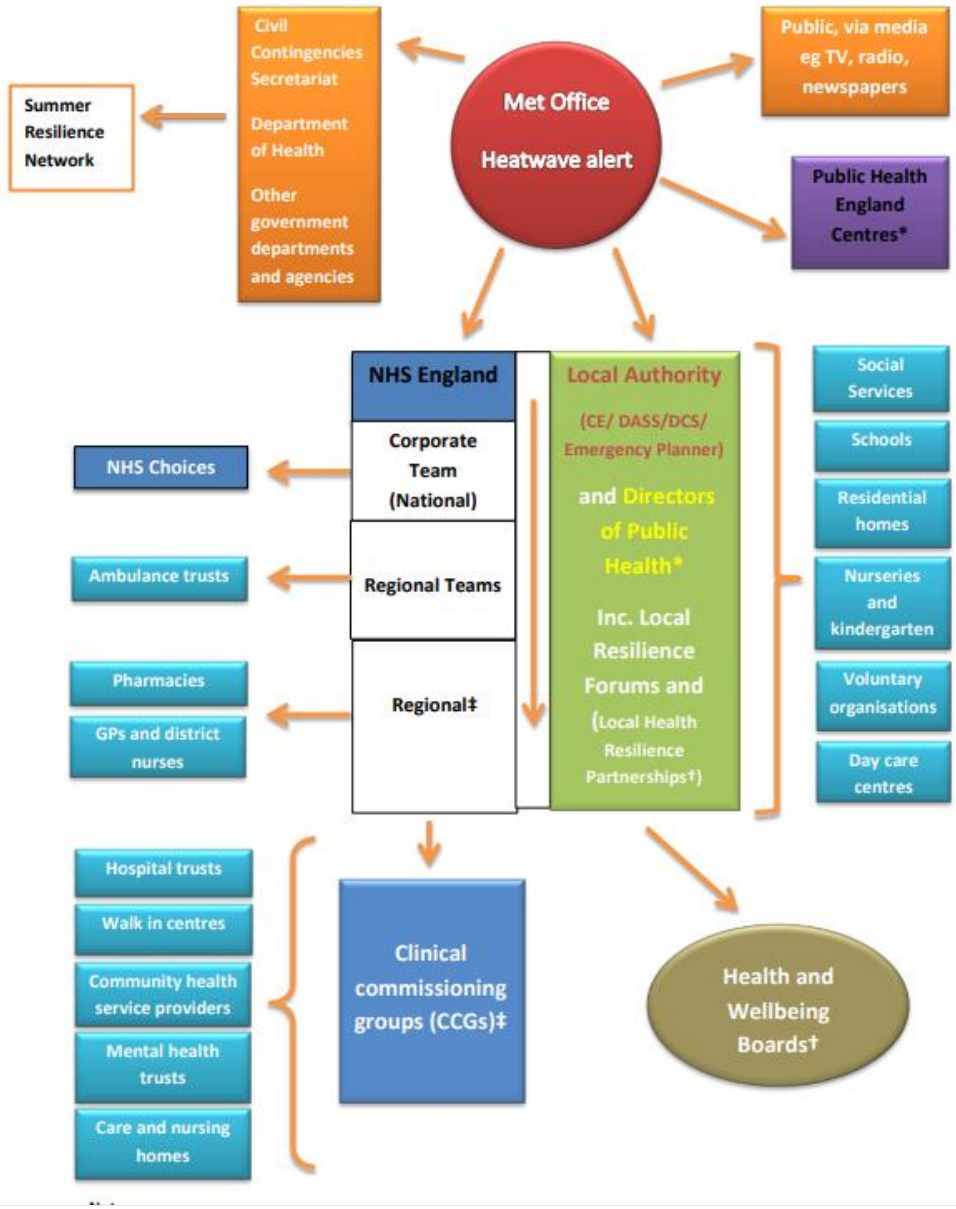


Figure 6 Typical cascade of heatwave alerts from the English Heatwave plan

5.2 Use case 2: Planning and building regulations

Testing organisation and personnel: The Greater London Authority planners.

Problem statement: It is difficult to remotely check if planning conditions around heat have been met. Can the data be used to support remote monitoring of adherence to planning conditions?

The planners highlighted the Department of Levelling Up, Housing and Communities (DLUHC) new overheating management requirement in the Building Regulations[12]. This is to ensure that new residential buildings are built for a warming climate. The new requirement prioritises overheating through passive measures including reducing solar gains and sufficient removal of heat. Statutory guidance has been produced to accompany the new requirement. Whilst the planners can set conditions in planning approval, they have no way to assess whether these conditions have been adhered to, particularly in areas such as heat.

Data suitability: They felt the data could give them a good understanding of adherence and the impact of new surface materials in the heat profile of an area. For example, some industrial buildings clearly increased land surface temperature through their surface reflectance. It was felt this could help inform planning policy and urban design though an evidential base. It was also felt that the data could be used to help other polices such as insulation (targeting of grants) and greening and blueing infrastructure policies.

The Green infrastructure focus map trial[13] website funded by the Mayor of London is available and uses Urban Heat Island data, however very few were aware of the data or its use.

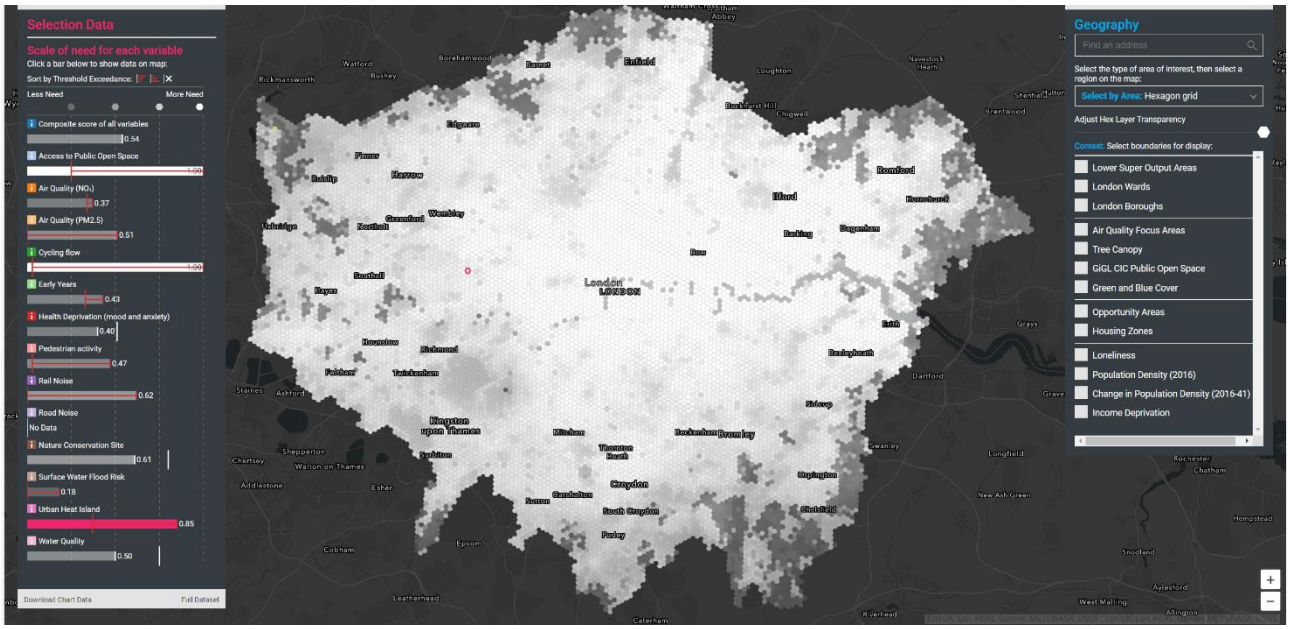


Figure 7 London Greenspace infrastructure website trial, Mayor of London

Outcome: When the heat data is combined with geospatial data, it changes how people respond to and want to use it. We believe this is because it removes it from an abstract context to something they can understand, relate to and reference. The image below (Figure 8) shows the Urban Heat Island data overlaid on top of a land use map derived from OS MasterMap® Topography Layer. This image illustrates the influence of industrial units on the evolution of urban heat islands. Consequently, there were discussions around the potential of these data for monitoring sustainable development schemes.

It was also noted that the Climate Change Committee in the UK Climate Change Risk Assessment 2022[14] identified risks to human health, wellbeing and productivity from increased exposure to heat in

[12] https://www.gov.uk/government/publications/overheating-approved-document-o

[13] https://data.london.gov.uk/dataset/green-infrastructure-focus-map

[14] UK Climate Change Risk Assesment 2022 (publishing.service.gov.uk)

homes and other buildings. This was identified as one of the eight priority areas for action in the next two years and that it could be addressed through building regulations and strategies and planning reform.

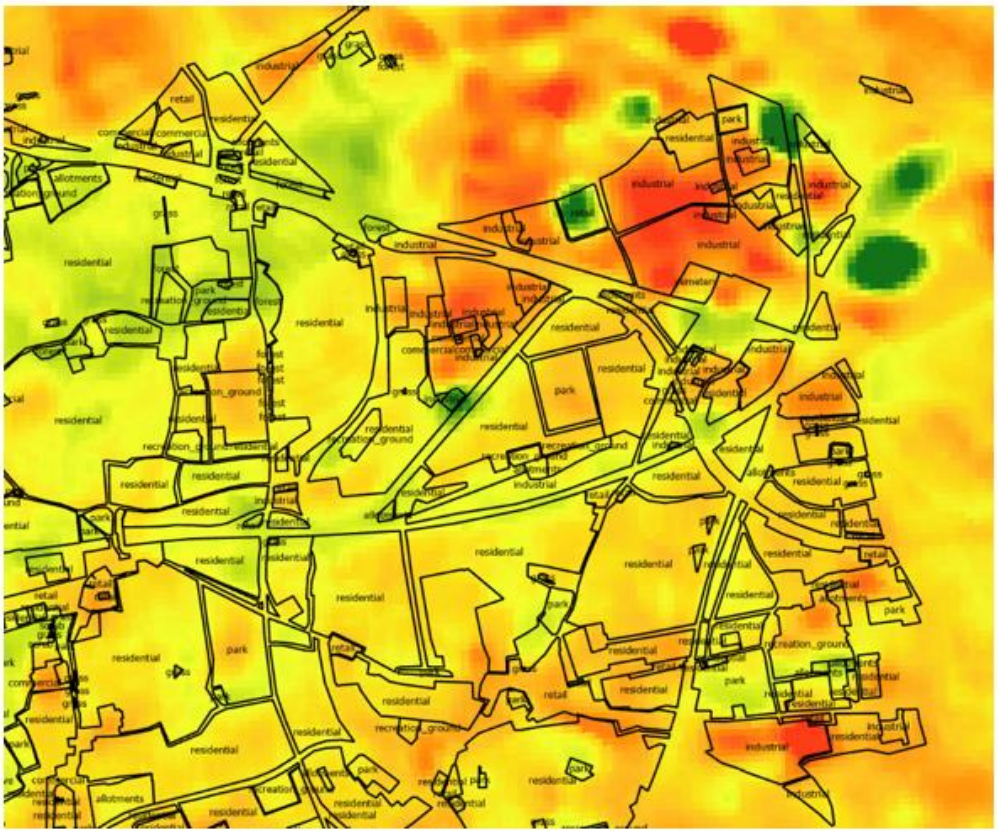


Figure 8 Urban Heat Islands highlighted using OS derived land use polygons

5.3 Use case 3 – School Resilience planning - Department for Education

Testing organisation: The Department for Education.

Problem Statement: The Department for Education (DfE) is taking urgent action to co-ordinate activity to respond and adapt to the effects of climate change. It needs to use data to identify schools and colleges of greatest heat risk.

In spring 2021, the Department for Education established a Sustainability and Climate Change Unit (SCCU) to drive this co-ordination and, through engagement, research, data analysis and sustainability expertise, to identify where we can make the greatest impact. As part of this, DfE's Sustainability & Climate Change strategy[15] was launched at COP26 by the Secretary of State[16]

Actions within the strategy, regarding the Education Estate include: We will deliver urgent and ambitious action to understand the risk to and adapt our education estates to cope with climate change. Investment will be made in measures to adapt to the three highest priority risk areas identified in the

[15] Sustainability & Climate Change: A draft strategy for the education & children's services systems (publishing.service.gov.uk)

[16] https://www.gov.uk/government/news/education-secretary-puts-climate-change-at-the-heart-of-education--2

Climate Change Committee Independent Assessment of UK Climate Risk 8: increased heat risk, flood risk and water scarcity.

Data suitability:

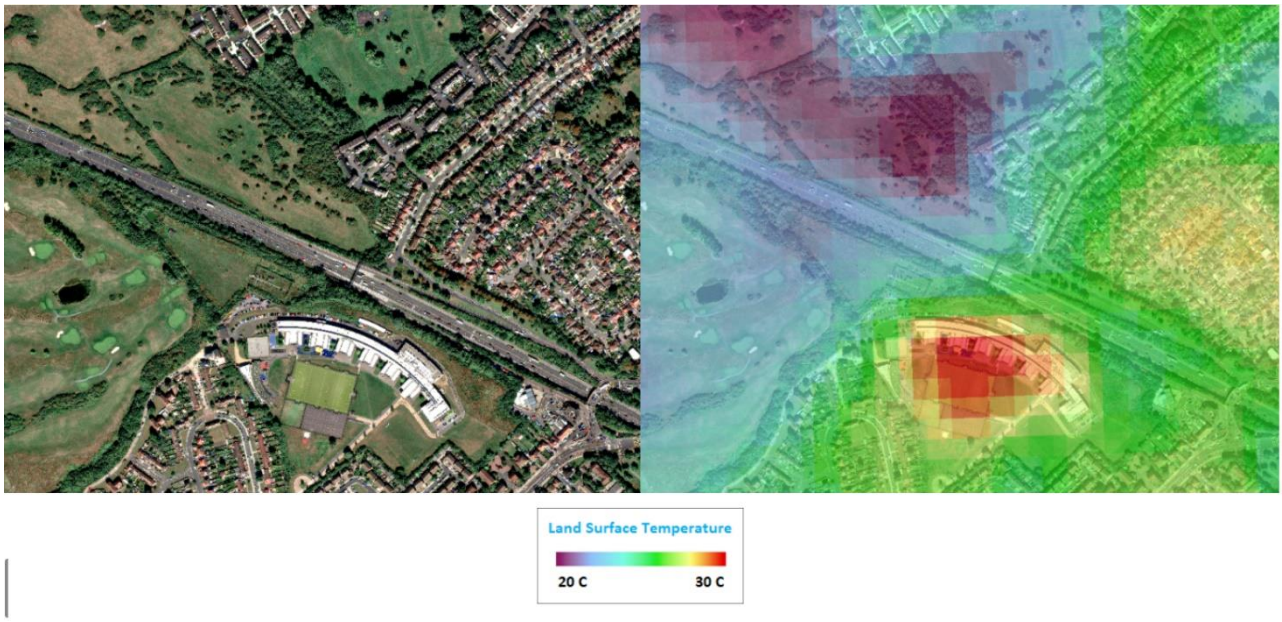


Figure 9 Land surface temperature effect from a Multi-Use Games Area (MUGA) at a school site, the effect is only visible in the heat data.

The figure above demonstrates the value in contextualising the data, in this case by overlaying it on top of high-resolution imagery. This example shows the impact of urbanisation on land surface temperature, with developed land showing as warmer than undeveloped land. It is also interesting to note the region of high Land Surface Temperature over the pitch in the centre of the image. It is only when we combine the data with OS MasterMap® data that the pitch is identified as a manmade surface, illustrating how artificial pitches get significantly warmer than traditional grass pitches. The combination enabled the end user to have an immediate response to the heat profile of the Multi Games Use Area in front of a school. This map, and GIS data was provided to enable the DfE to assess whether this data can help support the insight need for climate risk 8.

Outcomes: The Technical Standards division recognises the Ordnance Survey Heat Data Project has the potential to contribute to understanding the heat risk across the English school and colleges estate. In development of actions within the strategy, the Heat Data Project shall be included in discussion with SCCU and could help to address how to:

- Use the data to identify schools and colleges of greatest heat risk
- Once the estate-wide heat risks are understood, prioritise, alongside the other climate change risks of flood and water scarcity, to develop solutions which are nature-based solutions, wherever possible.

5.4 Use case 4: Lusaka, Zambia case study

Testing organisation: Zambia Ministry of Local Government and International Growth Centre and Commonwealth Association of Architects.

Problem statement: Can the Heat data for Lusaka be used to help inform policy decisions around the city and informal settlements?

70% of the Urban Population in Lusaka live in unstructured informal settlements. Expansion that outpaces a governments' capacity to plan for it, leads to challenges including sanitation issues, poor quality and unsafe housing, gaps in service provision including clean water, and a lack of social mobility. These factors associated with urban poverty can lead to a stagnant urban economy.

There are significant financial benefits to addressing the challenges of urbanisation before informal settlements become large and unmanageable, which is why cities are increasingly the focus of government policy e.g. retrofitting infrastructure after a settlement has emerged is up to three times more expensive [17] than installation alongside housing construction. Well planned infrastructure also increases land value and encourages private investment.

We explored the use of Heat data in Lusaka to test how it could help inform policy decisions around the city and informal settlements. Access to heat maps enable identification of those urban areas that are most vulnerable/threatened by rising temperatures. Heat islands with excessive temperatures can negatively affect quality of life and health outcomes. Understanding where these regions occur, would allow for an informed approach to combat these effects.

Data suitability: This heat map of Lusaka shows a clear differential between the high temperatures emitted within commercial/industrial parts of the city and the low temperatures experienced within well-vegetated, and affluent residential areas. By linking this data at a property level, it enables analysis of human comfort index over time and what mitigation effects can be put in place e.g. building material, vegetation, cost effective/green energy demands for air conditioning etc and helps support future, heat resilient urban development.

Outcomes: Surface temperature is an additional variable that could be used by an Artificial Intelligence tool to help identify different land uses. Using analytics, we can also classify buildings through their associated temperatures.

Covid delayed the meeting with the Zambian President, so these examples are to be discussed with the Zambian government this year and responses reported back to the UK Space Agency outside of the timelines of this project.

[17] Land policy is needed to coordinate investment and settlement. The private sector cannot do this alone. - IGC (theigc.org)

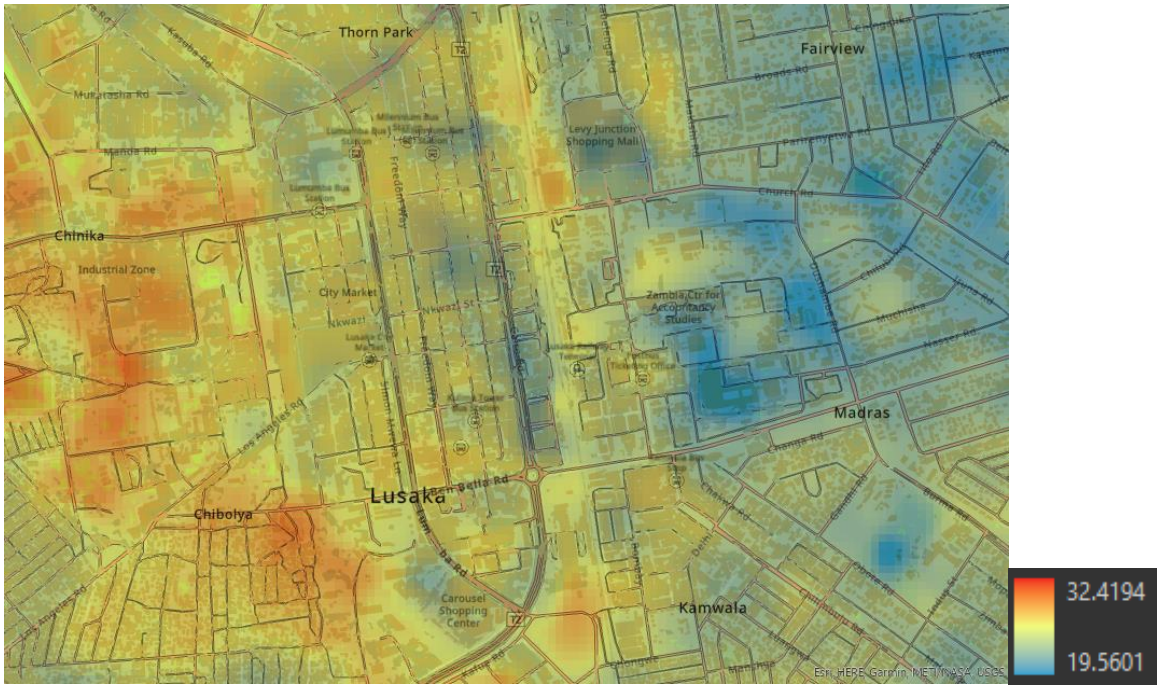


Figure 10This heat map of Lusaka shows a clear differential between the high temperatures emitted within commercial/industrial parts of the city and the low temperatures within well-vegetated, and affluent residential areas

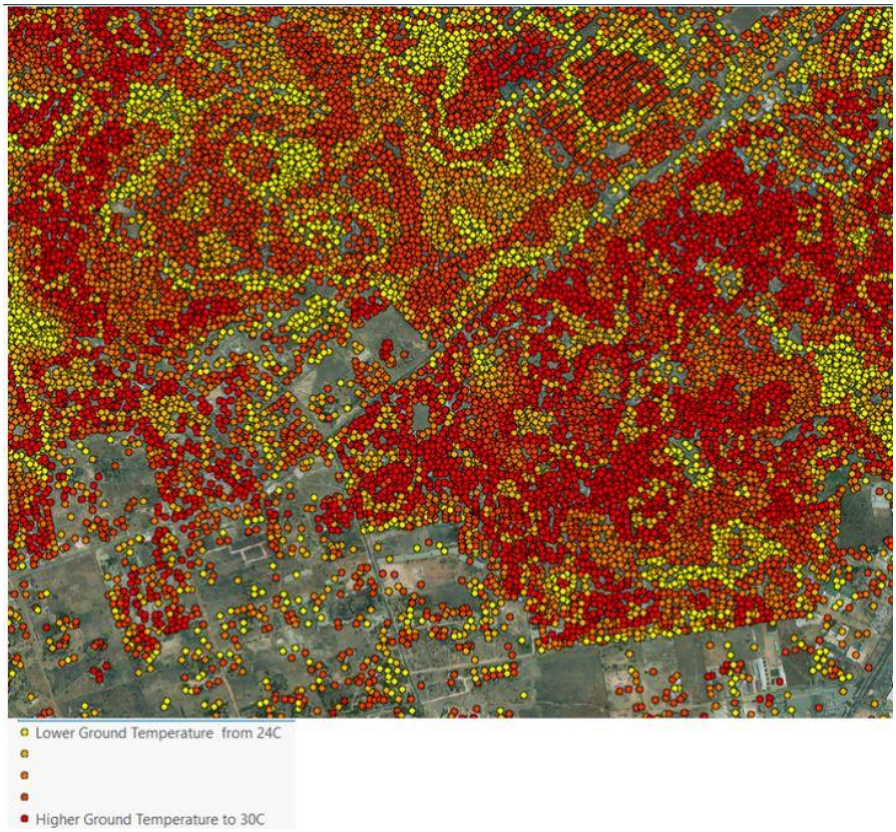


Figure 11 Buildings in Lusaka classified by their associated temperatures.

6. Recommendations

6.1 Data Access and FAIR

Many Public Sector Geospatial Agreement customers were not aware of the data and its discoverability by non-expert users is limited. Typically, it is only accessible to those with deep technical knowledge that informs how to convert the data into a format they can use.

Therefore, we recommend the data provided by the NCEO, or any iteration of Earth observation climate data, needs to support the UK National Data Strategy's FAIR (Findable, Accessible, Interoperable and Reusable) principles to make it useable for a wide variety of end users.

In addition, future data supply should include detailed metadata and descriptive documentation.

Recommendation 1. To reduce the technical barriers identified in the discovery section 2.4 and use cases in section 6 we recommend the UK Space Agency and partners provide access to open climate data in formats that public sector bodies can gain insights from, to address their climate challenges. This access should also allow the large-scale take-up of space derived products by innovators and companies enabling them to create new products and services to support climate and ecological emergency facing the UK.

To support this, the data provided by the National Centre for Earth Observation (or any iteration of Earth observation climate data) needs to support the UK National Data Strategy's FAIR (Findable, Accessible, Interoperable and Reusable) principles to make it useable for a wide variety of end users. It must be discoverable and accessible in simple, plain language and ideally with supporting contextual topographic information, i.e. a map base, for a range of users including non-experts. If the project proves it can answer the core needs for users in the UK, there is potential for it to be scaled up for provision nationally through the Public Sector Geospatial Agreement. Key recommendations are:

1. Simple, clear, non-expert descriptions are needed to make the data findable.
2. Clear metadata and data description documentation should be provided so users can determine data provenance and whether the data meets user requirements.
3. The data should be provided in easy-to-use industry standard formats, not just netCDF. Most end users wanted formats they are familiar with, such as TIFF, which can be easily viewed or interpreted in GIS software. Other key aspects for the data include:
    a. A requirement for embedded metadata to support and easily identify each product.
    b. By providing the data as a GeoTIFF, separate latitude and longitude bands will not be needed, reducing file sizes.
    c. Any naming format needs to be consistent and intuitive and capable of supporting a UK scale dataset.
4. UK customers should also have the data provided in British National Grid to enable direct linking with their other geospatial information sets.
5. Retain an Open Data approach under the Open Geospatial Licence terms so users can understand what terms apply to the data and the correct copyright statements. Additionally, ensure the licence is linked to the supply of the data.

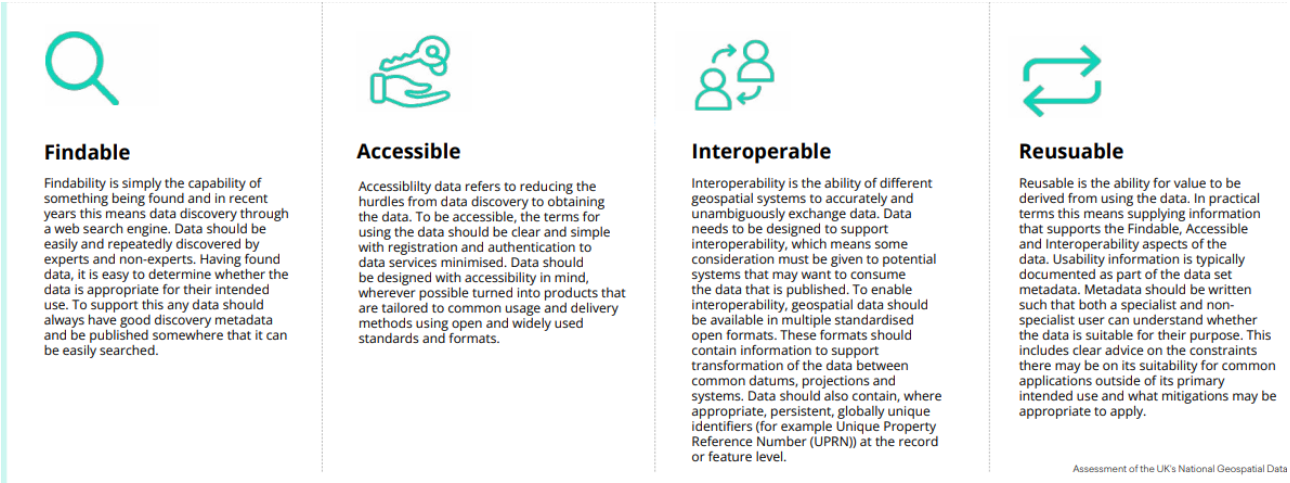


Figure 12 FAIR principles

Recommendation 2. To support use cases identified and customer need, the data also needs to be able to support historical time series analysis. This was highlighted as a need by corporates as well as public sector bodies. Without this the data is not climate data but rather snapshots in time. Data also needs to capture extreme events over the time series. To monitor future heat waves in the UK there is also a need to deliver climate quality heat data at appropriate resolutions in near-real time. Future access would benefit from long term time series of these climate quality data with UK coverage. The capability to capture past and future extreme events would provide key information to support climate resilience.

As in FAIR, it must be provided with good metadata, enable consistent supply, and have information on the confidence of the measurements and appropriate use of the data.

6.2 Access

Application Programming Interfaces (APIs) were seen as a preferred route for data access. If the NCEO is unable to support APIs it is recommended that an appropriate route for supply could be via existing APIs, such as the Ordnance Survey DataHub API (or other API providers) which is commonly used by PSGA members and licensed partners to access Ordnance Survey products.

UKSA should also support work on an Earth observation data supply framework to improve the pipeline and standards (Open Geospatial Consortium compliant[18]), including the metadata data format.

Future access would benefit from long term time series of these climate quality data with UK coverage. The capability to capture past and future extreme events would provide key information to support climate resilience.

We also recommend a clearly defined refresh plan so that users know when to access the data or a notification subscription system so users can return to bulk download new data when notified. An innovative approach is needed to ensure potential users and customers have a mechanism to provide accessibly beyond the academic/research fields. Currently potential end users cannot access this data in the

[18] https://www.ogc.org/

formats they can easily use. For example, PSGA and UK private sector users, including the developer community, want British National Grid positioned GIS ready data accessed via the OS Data Hub for immediate use. The heat data could be supplied as processed vector data files which contain the insights they want, or raster files pre-processed for PSGA customer use, with appropriate metadata. At the far end of the scale, even PDF outputs of locations of heat data with map data on request were deemed useful.

Recommendation 3. It is recommended, an appropriate route for supply is via existing API routes such as Ordnance Survey OS DataHub APIs (or other API providers) which is commonly used by PSGA members and licensed partners to access Ordnance Survey products. We also recommend a clearly defined refresh plan so that users know when to access the data or a notification subscription system so users can return to bulk download new data when notified.

To enable UK community uptake, users should be able to access British National Grid positioned GIS ready data accessed via the OS Data Hub for immediate use.

The Office for National Statistics provided some clear recommendations for widening the usability of the data for statistical analysis:

- Providing a lookup between UPRN (Unique Property Reference Number) and the raster value for each band would be the type of data those non-geographical analysts could easily use.

- The production of suitable summary statistics from the heat data for Census geographies (output area, lower layer super output areas (LSOA) and middle layer super output areas (MSOA)) and local authorities. This would significantly increase the usability of the heat data which would otherwise likely be discarded as too complex to use in most applications and make the data more accessible to the Citizen.

What was clear from the research was that the value of the data was limited to those who knew how to handle complex datasets however, real insights and understanding for the 86% who didn't currently use the data, was apparent when the Earth observation data was combined with a map. This enabled immediate interpretation by the end user and an understating of the value the insights could bring. The value of the data was limited to those who knew how to handle complex datasets and tools

Any provision for the heat data to flow to PSGA customers must also supply robust metadata, user guides and "how to's" to create maps and insights.

We would also recommend greater public access to the data so citizens can see what is happening on their street. This could also increase public engagement by supporting Local Authorities in their publications online and offline.

Recommendation 4. The Office for National Statistics recommend a lookup between the Unique Property Reference Number and the raster value for each band to support statistical analysis in a way non-geographical analysts could easily use. Ordnance Survey could potentially provide this lookup table with support from the Geospatial Commission. The Office for National Statistics also recommended summary statistics from the heat data for Census geographies. This would make the data more accessible and significantly increase the use of heat data in most applications, including heath metrics.

6.3 Costs

To meet the customer needs and operationalise the provision of UK wide heat data in a form that meets FAIR principles, historical time series and in more accessible data formats we need to ensure longevity and consistency of supply. To operationalise for the UK, the following activity will need to be undertaken:

1. Automating the scheme to cover all UK cities
2. Improved cloud detection and flagging
3. Quality assurance assessment
4. Updating the metadata to include methodology and estimate of uncertainty
5. Scheme for geo-referencing of land surface temperature data to location identifiers.
6. Testing of near real-time system

Costs of supply should be considered against the tangible financial benefits of evidence-based targeting of

Recommendation 5. Operationalise the provision of UK wide heat data in a form that meets FAIR principles, historical time series and in more accessible data formats to ensure longevity and consistency of supply. Data could then be provided out the PSGA customer base via Application Programme Interfaces such as the OS Data Hub, to over 5000 end users, or through new value-added services created by the community.

interventions. For example, several end users outlined potential uses for identifying areas that could support tree planting schemes (including cooling water/rivers for fish) to supporting tree planting schemes across rural and urban landscapes. Analysis across 11 UK city regions estimated the benefits of urban blueing and greening was £274 million in a single year for these regions alone, through avoided productivity losses and reduced cooling costs[19]. It was felt that targeted, data driven approach could maintain and increase this benefit in line with new urban developments and climate change.

Heat-related fatalities in England are projected[20] by the Climate Change Committee to increase with climate change. These fatalities have high economic costs, estimated in this study as a range from £323 million to £9.9 billion per year by the 2050s. They also state the likelihood of a major unprecedented heatwave event in the next decade is considered high.

6.4 Training and awareness specifically for PSGA users.

The Dynamic Purchasing Marketplace is a new way to provide access to the market to all procurements run by Crown Commercial Service using a Dynamic Purchasing System. Buyers can access framework

[19] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/ecosystemaccountsforurbanareas

[20] https://www.theccc.org.uk/wp-content/uploads/2019/07/Outcomes-Heat-preventable-deaths-case-study.pdf

agreements that meet common purchasing requirements across government. A focused training course for PSGA users could support wider uptake of Earth observation data as the Dynamic Purchasing System supports Earth observation and geospatial data acquisition for the public sector. Without a good understanding of the usability, application and use cases, the uptake of Earth observation insights will still be restricted to those with the prior knowledge of Earth observation data, which, if our sample is representative, indicates a limited uptake and impact.

It would be valuable for end users to see a variety of worked up use cases so they can see how it relates to their own work. If data is not made available in industry standard formats, then informal recorded workshops could provide low-cost training.

ESRI[21] have expressed a desire to make NCEO datasets available via the ESRI system and as web resources, so users are not so reliant on specialist Geographical Information System software. Resources like services in the ESRI Living Atlas or presenting the content in an accessible way via Web Apps, Application Programme Interfaces and StoryMaps. This could be a good way to inform end users as to use cases and application.

Recommendation 6. This project has indicated a lack of awareness in the data products available from the Earth Observation community. Therefore, we recommend a focused training course or programme for PSGA users. This could support wider uptake of Earth observation data and services.

[21] https://www.esri.com/en-us/about/about-esri/overview

7. Concluding remarks

This project has uncovered the need and desire to use space-based climate data within the Public Sector, however technical barriers and the skills needed to access the data are preventing use. We recommend the UK Space Agency and partners look to create a platform (or use one that currently exists and can be adapted) that provides access to open climate data in formats that enable public sector bodies to gain insights to address their climate challenges. It should also enable the large scale to take up of space derived products by companies, under open licensing terms, to create new products and services to support climate and ecological emergency. The FAIR principles, including metadata that is easy for non-expert users to interpret, should also be applied.

This investment would have significant impact in the uptake and mobilisation of the use of space-based climate data products and insights across the UK to support resilience against heat events.

8. Appendix 1 Technical report

8.1 Pre-project data

The pre-project period refers to initial investigations of the data as it would be typically provided by the NCEO.

Data format

The NCEO supplied the initial pre-project data in Network Common Data Format (netCDF). This is a common format for sharing array structured scientific data. The arrays are stacked in a 3D structure. In the case of the data supplied by NCEO, each flat 2D array represented the data arranged in a latitude and longitude grid with the third dimension being the different products supplied (Figure 1).

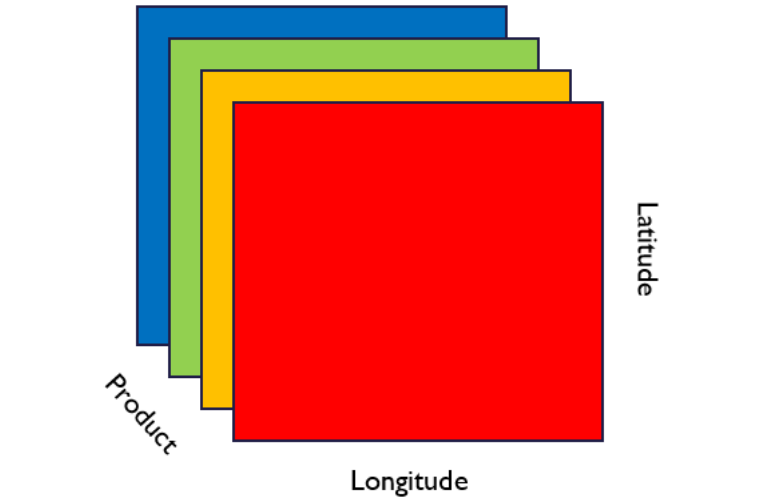


Figure 13 Basic netCDF data structure

The products contained in the netCDF files initially provided by the NCEO were:

Latitude (LAT)
Discomfort Index (DI) – a measure of the heat that a person experiences
Normalised Difference Vegetation Index (NDVI) – a measure of vegetation health
Longitude (LON)
Land Surface Temperature in Kelvin (LST) - a surface 'skin' measurement of temperature
Land Surface Temperature in Centigrade (LST_degC) - a surface 'skin' measurement of temperature
Urban Heat Index (UHI) – a measure highlighting the difference in the ability of an environment to absorb and hold heat

While netCDF files can typically be opened in most Geographic Information Systems (GIS), we encountered problems rendering the data. We therefore took the decision to convert the data into a

more familiar Tag Image File Format (TIFF). To do this, the array data were flattened and read into a Geopandas data frame as point data. The Geocube Python library was then used to rasterise the point data, which was then written to a TIFF file. When passing the data to Geocube, the desired coordinate system and resolution are given as inputs and thus the resulting TIFF contains the necessary meta data required for viewing in geospatial software. In an initial exploration of the data, we also noted issues with data values at the edge of the images. Where 'no data' values had not been set correctly, abnormally high values of temperature were recorded which required addressing before the data could be used.

8.2 Project data

One of the aims of this project is to ensure that these data can be supplied in a format that can be easily interrogated by a user, regardless of experience.

Data format

Based on the initial pre-project exploration of the data, NCEO subsequently ensured that areas with no data had no data values correctly assigned, removing the anomalously high temperatures recorded in the pre-project data. They also provided the project data as both netCDF and TIFF.

The TIFFs contained 7 bands, at 30 metre pixel resolution, with each band representing the corresponding product in the netCDF files:

Table 1 TIFF bands

Band	Product
1	Latitude
2	DI
3	NDVI
4	Longitude
5	LST (K)
6	LST (°C)
7	UHI

The data were originally supplied in the WGS84 co-ordinate reference system (CRS). To align the data with Ordnance Survey data, which is supplied in the British National Grid (BNG), some level of transformation may be required, unless using a GIS that can do this automatically. For this project the data were left in the CRS as supplied by NCEO. To view the data, each individual band needed to be visualised as a separate product. Identifying the contents of each band in the TIFF required cross referencing with a separately supplied band index.

Key points identified at this stage include:

- A requirement for embedded metadata to easily identify each product, including a defined Coordinate Reference System for the customer.
- If the data are provided as a GeoTIFF, the latitude and longitude bands will not be needed.
- The naming convention needs to be consistent and intuitive.

8.3 Post project

To support the widescale adoption of heat data (and future climate products) by the PSGA customer base, OS has identified the following:

- The provider of the data should be responsible for data governance and archiving, and for providing confidence and provenance assurance for the data.

- Users are likely to need national coverage. OS will need to work with NCEO to identify how GB coverage can be achieved (in addition to specific Areas of Interest) including the possibility of utilising data from multiple satellite sensors.

- OS would need to develop a way for customers to interact and clip out data if they are to onward supply the data (possibly via a Data Cube).

- There is a need for more comprehensive metadata and product documentation.

- Evidence suggests that single layer TIFFs for each product are more suitable for users.

- There is real value in long term time series of these data. Without this it's not climate data but rather snapshots in time. Data also needs to capture extreme events over the time series. Such a system may need to incorporate multiple sensors and, in the long-term, would need further research on scaling.

- To monitor future heat waves in the UK there is a need to deliver climate quality heat data at appropriate resolutions in near-real time.

- OS and users need to better understand how each metric is created. Critical to understanding these data is the need to provide contextual geospatial data.

Additional recommendations for widening the usability of the data for statistical analysis are:

- Providing the ability to link UPRN (Unique property Reference Number) to a raster value for each product would be the type of data that non-geographical analysts could easily use.

- Many of the statistics produced by the Office for National Statistics (ONS), and used by others, are provided for geographic areas. ONS suggest the creation of summary statics from the heat data created over a range of geographies (particularly for the Census geographies - output area, lower layer super output areas (LSOA) and middle layer super output areas (MSOA)) and for local authorities. This would significantly increase the usability of the heat data which would be discarded as too complex for use in most applications at ONS.

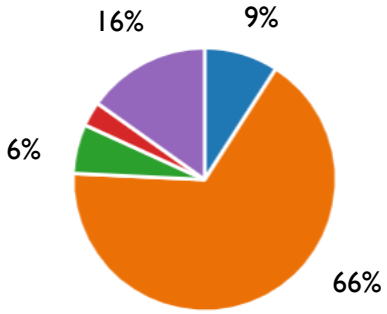
9. Appendix 2: Statistics

Total – 348 (includes interviewed and online)

6. Sector:

More Details

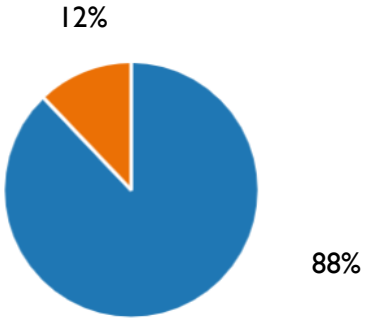
- OS Partner
- Public Sector
- Education
- Research
- Other



8. Do you think this data will be useful for your work?

More Details Insights

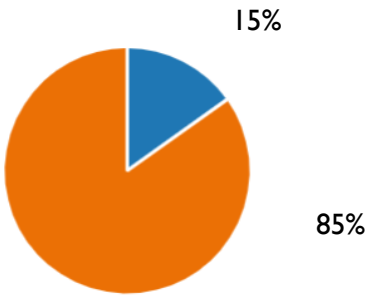
- Yes
- No



11. Do you currently use any of this type of data?

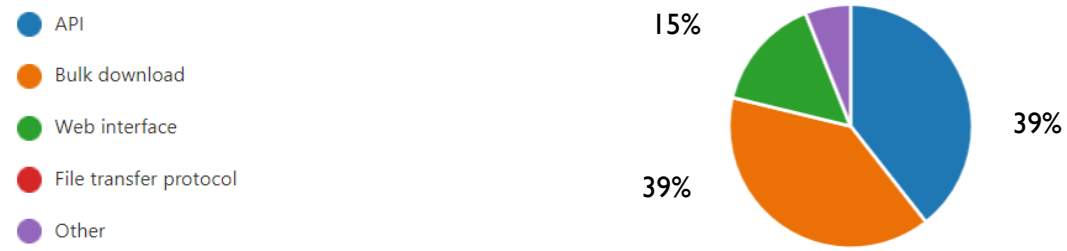
More Details

- Yes
- No



13. How would you like to access this data in the future?

More Details



10. Appendix 3 Customer voice, Anonymised feedback examples

Why you think this data would be useful to your work?

"Assessing the potential impact of heat on geological hazard"

"I'd be looking to tie it in with either management for nature, or looking at encouraging people to benefit from nature"

"Our users are researchers and teachers that would find research utility and pedagogic value"

"Understanding impact of climate change, planning adaptation, identification of communities most at risk from heat and when combined with other data allow more in depth analysis."

"Given the recent increase in extreme heat events reference data is required in ordered to understand the potential distribution of risk to people, buildings and infrastructure"

"Heat data would be a very valuable dataset for town planning and urban design."

"This could help inform the planting of trees"

"To look at river and stream temperatures. To look at the effects of trees on temperatures, particularly on water temperatures."

"1) Looking at tree planting impact and let us know where we are planting trees is the correct location. 2) Help with monitoring change in data over the years"

"We can target action to where there can be effective adaptation or mitigation measures e.g. change in land management, introducing trees or water feature to reduce urban heat island effect"

"Managing heat in the Urban environ has impact/opportunities for ground heat dissipation and heat management"

"pollution mapping team may find useful"

"The bands mentioned (2, 3 & 7) have little interest to me : 2 and 3 are mostly focused on more densely populated environments; band 7 is available from existing sources. I am interested in what the other bands offer."

"Heat data will help in understanding areas that will heat up more and need to be targeted for building resilience."

"To help us respond to the climate crisis across many different service areas of the council"

"At times of excessive heat it can focus resources to those most at need and help predict where we might A&E or Emergency attendances from"

"This data will help to identify at risk areas of the city to heat stress, becoming increasingly important with projected climate forecasts. It will also help to identify priority areas for interventions and possibly provide information on progress."

"From a Local Authority's point of view, the heat data can be useful in informing the monitoring of progress regarding the climate action plan, and potentially in planning for assessing occupation. From a planning consultancy perspective, this data would be useful as baseline data for further environmental impact assessment and modelling work."

"We are piloting street scene interventions to assess their impact on among other things the urban heat island effects."

"We have said yes in the context of our customer base……Many are starting to focus on the impacts of Climate change on their business and the customers/citizens they are responsible for."

"I have not seen the data because it is not in a format that we can use or distribute to any of the stakeholders throughout society (that's all 68 million of us) to which this data is imperative. I <u>really</u> hope we can speak about making data accessible, understandable and usable and in a format that builds knowledge and trust…"

"The data can be used to inform policy and local development projects organised by the County Council. The wider authorities can also benefit from the data, and it will be useful to inform unitary frameworks from 2023."

What are the problems you think this data could potentially help you solve?

"At a high level, tackling biodiversity loss and climate change. Can we use it to enhance people's perception of the natural world? I'd like to overlay the data with our areas of conservation interest - if there are overlaps, we'll need to consider how to manage the land to mitigate for the effects of excess heat"

"Many applications - energy efficiency; SGDs etc"

"Allow us to get a much better understanding of who and where heat risk is most significant so we can work with partners to plan and mitigate."

"Help us better understanding urban micro-climate and user behaviour."

"Optimise where we target tree planting"

"Make safer/more comfortable spaces to live. Ensure the land management measures being proposed will be resilient to future change."

"Identifying opportunities for GSHP (air cooling) and issues with infrastructure heat management"

"It could help us better identify where to plant trees in order to keep rivers cool for fish populations. However this will depend on the resolution of the data. We are primarily focussed on rivers less than 10m wide as these benefit most from tree shading and cooling."

"Where to locate tree planting"

"I am interested in whether the data could be used to determine / test our understanding of the presence of thermal refugia across and within landscapes"

"Heat forecast could be useful for identifying drought conditions or other heat-related stress-inducing conditions for livestock and crops and hence farmers."

"Help with work with NHS"

"If there's a correlation between where people live and if heat effects their interaction with NHS services. How often if the data updated? Should it be daily to be really useful?"

"Heat data will help in understanding areas that will heat up more and need to be targeted for building resilience."

"No GIS programme, nor do the majority of stakeholders in the UK to which this is relevant/imperative!"

"Questions around public health and how we manage the impacts of climate change, planning for biodiversity and natural capital gain, how urban planning policy could mitigate the climate crisis and many other areas."

"Areas within the City that are most vulnerable to heat stress/overheating, to enable targeted interventions; assess the effectiveness of interventions such as vegetation planting, SuDS etc."

"This data could potentially help fill in the gap regarding gaining reasonable understanding of activities within development post construction, during its occupation."

"Monitoring the impact of intervention and identifying cool routes."

"Unsure at the moment - but can possibly see whether an area a development is being constructed will be impacted by heatwaves"

"- Identifying vulnerable populations

- planning future building design at discrete individual buildings perspective, but also for a services base e.g. cool spaces, where people can do to escape the Heat.

- greenspace planning

- identifying habitats at risk (wildlife and ecosystems)

- identifying monuments and buildings at risk"

"We are piloting street scene interventions to assess their impact on among other things the urban heat island effects."

"I have downloaded the UK's Climate Risk Assessment and incorporated it into our grid for addressing the Objectives eluded to within the UN SDG 13 Climate."

"Mitigating the urban heat island effect and inform the Council which areas in [the County] may be most impacted by heat waves, which could inform retrofitting policies and future funding. The data could also add to the knowledge base around the positive impact of street trees and other urban vegetation on localised temperature and their mitigating role against heat. Additionally, this data could inform an approach to road surface and roof surface colouring in order to mitigate the localised heating effect."

11. Appendix 4. Extracts from the Heatwave Plan

Figure 3.1: Commissioners of health and social care (all settings) and local authority Directors of Public Health

Level 0	Level 1	Level 2	Level 3	Level 4
Long-term planning All year See accompanying document 'Making the Case' for more detail	**Heatwave and summer preparedness programme** 1 June to 15 September	**Heatwave is forecast – alert and readiness** 60% risk of heatwave in the next 2 to 3 days	**Heatwave action** Temperature reached in one or more Met Office National Severe Weather Warning Service regions	**Major incident – emergency response** Central Government will declare a Level 4 alert in the event of severe or prolonged heatwave affecting sectors other than health
Working with partner agencies, incorporate into JSNA's/HWS's long term plans to prepare for, and mitigate, the impact of heatwaves, including: • how to identify and improve the resilience of those individuals and communities most at risk • ensuring that a local, joined-up programme is in place covering: • housing (inc loft and wall insulation and other plans to reduce internal energy use and heat production) • environmental action: (eg increase trees and green spaces; external shading; reflective paint; water features) • other infrastructure changes (eg porous pavements) • engaging the community and voluntary sector to support development of local community emergency plans • making progress on relevant Public Health Outcomes Framework indicators	• work with partner agencies, providers and businesses to coordinate heatwave plans, ensuring vulnerable and marginalised groups are appropriately supported • work with partners and staff on risk reduction awareness (eg key public health messages – box 1), using a variety of methods to maximise dissemination • ensure care homes and hospitals are aware of the heatwave plan and are engaged in preparing for heatwaves • continue to engage the community and voluntary sector to support communities to help those most at risk • ensure other institutional establishments (eg prisons, schools) are aware of heatwave guidance • ensure organisers of large events take account of possible heat risks	• communicate public media messages – especially to 'hard to reach' vulnerable groups • communicate alerts to staff and make sure that they are aware of heatwave plans • implement business continuity • increase advice to health and social care workers working in community, care homes and hospitals	• media alerts about keeping cool • support organisations to reduce unnecessary travel • review safety of public events • mobilise community and voluntary support	**National emergency** Continue actions as per Level 3 unless advised to the contrary **Central government will declare a Level 4 alert in the event of severe or prolonged heatwave affecting sectors other than health and if requiring coordinated multi-agency**
High-risk groups **Community**: over 75, female, living on own and isolated, severe physical or mental illness; urban areas, south-facing top flat; alcohol and/or drug dependency, homeless, babies and young children, multiple medications and over-exertion **Care home or hospital**: over 75, female, frail, severe physical or mental illness; multiple medications; babies and young children (hospitals).				
*Because Level 2 is based on a prediction, there may be jumps between levels. Following Level 3, wait until temperatures cool to Level 1 before stopping Level 3 actions. ** Level 4: A decision to issue a Level 4 alert at national level will be taken in light of a cross-government assessment of the weather conditions, co-ordinated by the Civil Contingencies Secretariat				

Figure 3.2: Providers – health and social care staff in all settings (community, hospitals and care homes)

Level 0	Level 1	Level 2	Level 3	Level 4
Long-term planning All year See accompanying document 'Making the Case' for more detail	**Heatwave and summer preparedness programme** 1 June to 15 September	**Heatwave is forecast – alert and readiness** 60% risk of heatwave in the next 2 to 3 days	**Heatwave action** Temperature reached in one or more Met Office National Severe Weather Warning Service regions	**Major incident – emergency response** Central government will declare a Level 4 alert in the event of severe or prolonged heatwave affecting sectors other than health
Professional staff (all settings): • develop systems to identify and improve resilience of high-risk individuals • request an HHSRS assessment from EH for clients at particular risk • encourage cycling/walking where possible to reduce heat levels and poor air quality in urban areas **Care homes and hospitals:** • work with commissioners to develop longer term plans to prepare for heatwaves • make environmental improvements to provide a safe environment for clients in the event of a heatwave • prepare business continuity plans to cover the event of a heatwave (eg storage of medicines, computer resilience, etc) • work with partners and staff to raise awareness of the impacts of severe heat and on risk reduction awareness (key public health messages – box 1)	**Professional staff (all settings):** • identify high-risk individuals on your caseload and raise awareness of heat illnesses and their prevention among clients and carers (see key public health messages – box 1) • include risk in care records and consider whether changes might be necessary to care plans in the event of a heatwave (eg initiating daily visits by formal or informal care givers for those living alone) **Care homes and hospitals:** • ensure business continuity plans are in place and implement as required; ensure appropriate contact details are provided to LA/NHS emergency planning officers to facilitate transfer of emergency information • identify or create cool rooms/areas (able to be maintained below 26°C) • install thermometers where vulnerable individuals spend substantial time	**Professional staff (all settings):** • check high-risk people have visitor/ phone call arrangements in place • reconfirm key public health messages to clients • check client's room temperature if visiting **Care homes and hospitals:** • check indoor temperatures are recorded regularly during the hottest periods for all areas where patients reside • ensure cool areas are below 26°C • review and prioritise high-risk people • ensure sufficient cold water and ice • consider weighing clients regularly to identify dehydration and rescheduling physio to cooler hours • communicate alerts to staff and make sure that they are aware of heatwave plans • ensure sufficient staffing • implement business continuity	**Professional staff (all settings):** • visit/phone high-risk people • reconfirm key public health messages to clients • advise carers to contact GP if concerns re health **Care homes and hospitals:** • activate plans to maintain business continuity – including a possible surge in demand • check indoor temperatures are recorded regularly during the hottest periods for all areas where patients reside • ensure staff can help and advise clients including access to cool rooms, close monitoring of vulnerable individuals, reducing internal temperatures through shading, turning off unnecessary lights/equipment, cooling building at night, ensuring discharge planning takes home temperatures and support into account	**National emergency** Continue actions as per Level 3 unless advised to the contrary **Central government will declare a Level 4 alert in the event of severe or prolonged heatwave affecting sectors other than health and if requiring coordinated multi-agency response**
High-risk groups **Community**: Over 75, female, living on own and isolated, severe physical or mental illness; urban areas, south-facing top flat; alcohol and/or drug dependency, homeless, babies and young children, multiple medications and over-exertion **Care home or hospital**: over 75, female, frail, severe physical or mental illness; multiple medications; babies and young children (hospitals).				
*Because Level 2 is based on a prediction, there may be jumps between levels. Following Level 3, wait until temperatures cool to Level 1 before stopping Level 3 actions. ** Level 4: A decision to issue a Level 4 alert at national level will be taken in light of a cross-government assessment of the weather conditions, co-ordinated by the Civil Contingencies Secretariat				

Figure 3.3: Community and voluntary sector and individuals

Level 0	Level 1	Level 2	Level 3	Level 4
Long-term planning All year See accompanying document 'Making the Case' for more detail	**Heatwave and summer preparedness programme** 1 June to 15 September	**Heatwave is forecast – alert and readiness** 60% risk of heatwave in the next 2 to 3 days	**Heatwave action** Temperature reached in one or more Met Office National Severe Weather Warning Service regions	**Major incident – emergency response** Central government will declare a Level 4 alert in the event of severe or prolonged heatwave affecting sectors other than health
Community groups: • develop a community emergency plan to identify and support vulnerable neighbours in event of a heatwave • assess the impact a heatwave might have on the provision and use of usual community venues • support those at-risk to make sure they are receiving the benefits they are entitled to **Individuals:** • make environmental improvements inside and outside the house which reduce internal energy and heat • install loft and wall insulation • identify cool areas in the house to use in the event of a heatwave • of on medications, ensure that these can be stored at safe levels in a heatwave	**Community groups:** • further develop community emergency plan • support the provision of good information about health risks especially with those vulnerable groups and individuals (see key public health messages – box 1) **Individuals:** • find good information about health risks and key public health messages to stay healthy during spells of severe heat (see key public health messages box 1) • look out for vulnerable neighbours	**Community groups:** • keep an eye on people you know to be at risk • stay tuned into the weather forecast and keep stocked with food and medications • check ambient room temperatures **Individuals** • stay tuned into the weather forecast • check ambient room temperatures – especially those rooms where disabled or high risk individuals spend most of their time • keep an eye on people you know to be at risk – ensure they have access to plenty of cool liquids • look out for vulnerable neighbours	**Community groups:** • activate community emergency plan • check those you know are at risk **Individuals** • follow key public health messages • check those you know are at risk	**National emergency** Continue actions as per Level 3 unless advised to the contrary **Central government will declare a Level 4 alert in the event of severe or prolonged heatwave affecting sectors other than health and if requiring coordinated multi-agency response**
High-risk groups **Community**: Over 75, female, living on own and isolated, severe physical or mental illness; urban areas, south-facing top flat; alcohol and/or drug dependency, homeless, babies and young children, multiple medications and over-exertion **Care home or hospital**: over 75, female, frail, severe physical or mental illness; multiple medications; babies and young children (hospitals).				
*Because Level 2 is based on a prediction, there may be jumps between levels. Following Level 3, wait until temperatures cool to Level 1 before stopping Level 3 actions. ** Level 4: A decision to issue a Level 4 alert at national level will be taken in light of a cross-government assessment of the weather conditions, co-ordinated by the Civil Contingencies Secretariat				

Figure 3.4: National Level: NHS England, PHE, DHSC, Met Office, Other Government Departments

Level 0	Level 1	Level 2	Level 3	Level 4
Long-term planning All year	**Heatwave and summer preparedness programme** 1 June to 15 September	**Heatwave is forecast – alert and readiness** 60% risk of heatwave in the next 2 to 3 days	**Heatwave action** Temperature reached in one or more Met Office National Severe Weather Warning Service regions	**Major incident – emergency response** Central government will declare a Level 4 alert in the event of severe or prolonged heatwave affecting sectors other than health
• the Cabinet Office will take the lead on coordinating and working across government to prepare for severe heatwave and other associated extreme climate events - individual government departments will work with their partners on such preparations • national implementation of the National Adaptation Programme will continue, improving protection from severe weather events • DHSC, PHE and NHS England will look to improve monitoring and analysis of heat-related illness and deaths and evaluate the heatwave plan • PHE and NHS England will issue general advice to the public and professionals and work closely with the NHS, OGDs and other national organisations that produce advice on staying healthy and ensuring service continuity during periods of prolonged severe heatwaves	• preparations are the overall responsibility of PHE in collaboration with the Met Office, NHS England, DHSC and local bodies • PHE and NHS England will make advice available to the public and professionals • NHS England will ensure national guidance is cascaded to local services, and identify organisations most vulnerable to heatwaves • heat-health watch alerts will be sent by the Met Office to the agreed list of organisations and Category 1 responders as noted in Figure 2.4 – PHE and NHS England will cascade the alerts to sub-national units within their organisations • DHSC will liaise with CO and OGDs to ensure agreed responses are mobilised as required –MHCLG will share info with LRFs • PHE will routinely monitor syndromic and mortality surveillance	• a Level 2 alert will be sent by the Met Office to the agreed list of organisations and Category 1 responders as noted in Figure 2.4 • central government departments, which should then cascade the information through their own stakeholder networks and front-line communication systems • DHSC will ensure OGDs, particularly MHCLG RED are aware of the change in alert level and brief ministers as appropriate • PHE will make advice available to the public and professionals in affected regions via NHS Choices, NHS England, DHSC (GovNet), and Met Office websites • NHS England will hold health services to account for taking appropriate actions to prepare for a heatwave • PHE will continue to monitor syndromic and mortality surveillance	• as per Level 2 arrangements • Met Office will continue to monitor and forecast temperatures in each area, including the likely duration of the period of the heatwave, the likely temperatures to be expected and the probability of other regions exceeding the Level 3 threshold • NHS England will muster mutual aid when requested by local services • PHE will continue to monitor syndromic and mortality surveillance and produce a weekly report for inclusion within a weekly PHE heatwave output	Level 4 alert issued at national level in light of cross-Government assessment of the weather conditions, coordinated by the CCS based in the CO. Implementation of national emergency response arrangements by central government. Response likely to involve: • national government departments • executive agencies • public sector, including health sector • voluntary sector PHE will continue to monitor syndromic and mortality surveillance and produce a weekly report for inclusion within a daily PHE heatwave output
High-risk groups **Community**: Over 75, female, living on own and isolated, severe physical or mental illness; urban areas, south-facing top flat; alcohol and/or drug dependency, homeless, babies and young children, multiple medications and over-exertion **Care home or hospital**: over 75, female, frail, severe physical or mental illness; multiple medications; babies and young children (hospitals).				
*Because Level 2 is based on a prediction, there may be jumps between levels. Following Level 3, wait until temperatures cool to Level 1 before stopping Level 3 actions. ** Level 4: A decision to issue a Level 4 alert at national level will be taken in light of a cross-government assessment of the weather conditions, co-ordinated by the Civil Contingencies Secretariat				

12. Contributors

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