Insights into Modelling Wildfires in the UK

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Wildfire Risks in the UK

The Role of Climate Change

- Climate change is driving an unprecedented increase in wildfire risks in the UK. Research shows that the number of days conducive to wildfires in the south of England could rise from 20 to 111 by the 2080s.

- Rising temperatures lead to drier conditions, making the UK's green landscapes more susceptible to igniting. The country's average temperature has increased by approximately 1˚C since the late 19th century, significantly altering precipitation patterns and drying out vegetation.
- Historically confined to late March to September, the UK's fire season has now expanded, with wildfires recorded as early as February and as late as December, challenging the conventional understanding and preparedness for these events.

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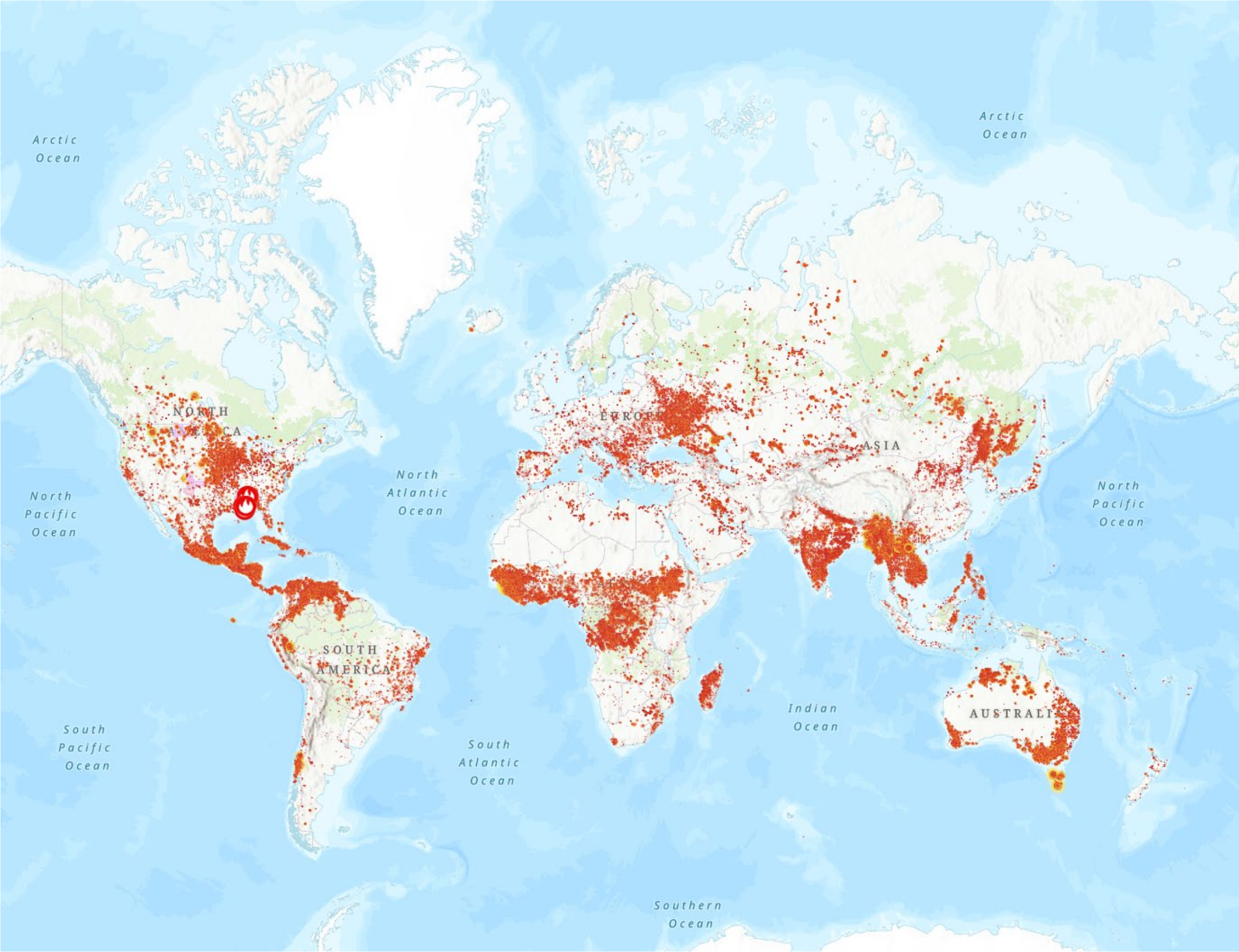
IMAGE CREDIT: BBC News

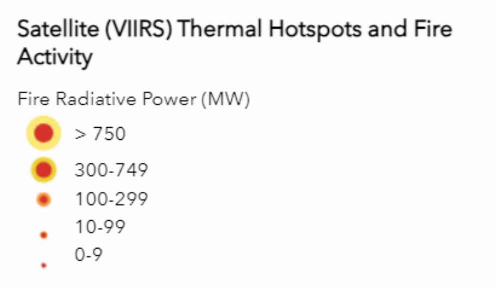
Global Significance

Quick background



Fire Season and Increased Frequency

- "Recent trends have seen the UK's wildfire 'season' to extend significantly. For instance, in 2018, wildfires occurred outside the traditional season, demonstrating that the threat is no longer seasonal but year-round."
- This is part of a global pattern where areas like the western United States, Australia, and the Amazon experiencing more frequent and intense wildfires, highlighting the urgent need for a coordinated global response to climate change and wildfire management.



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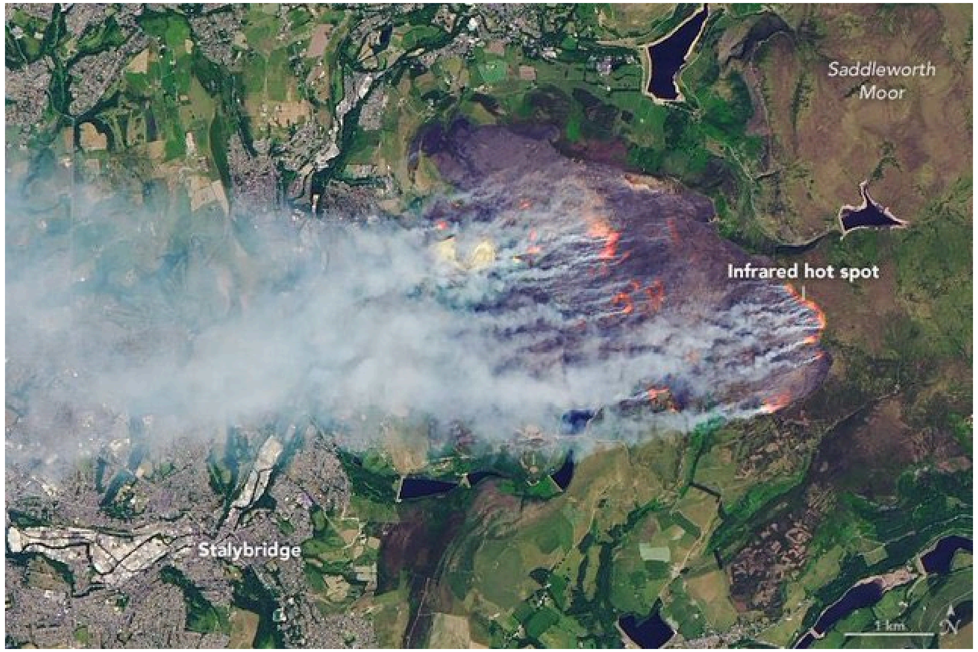

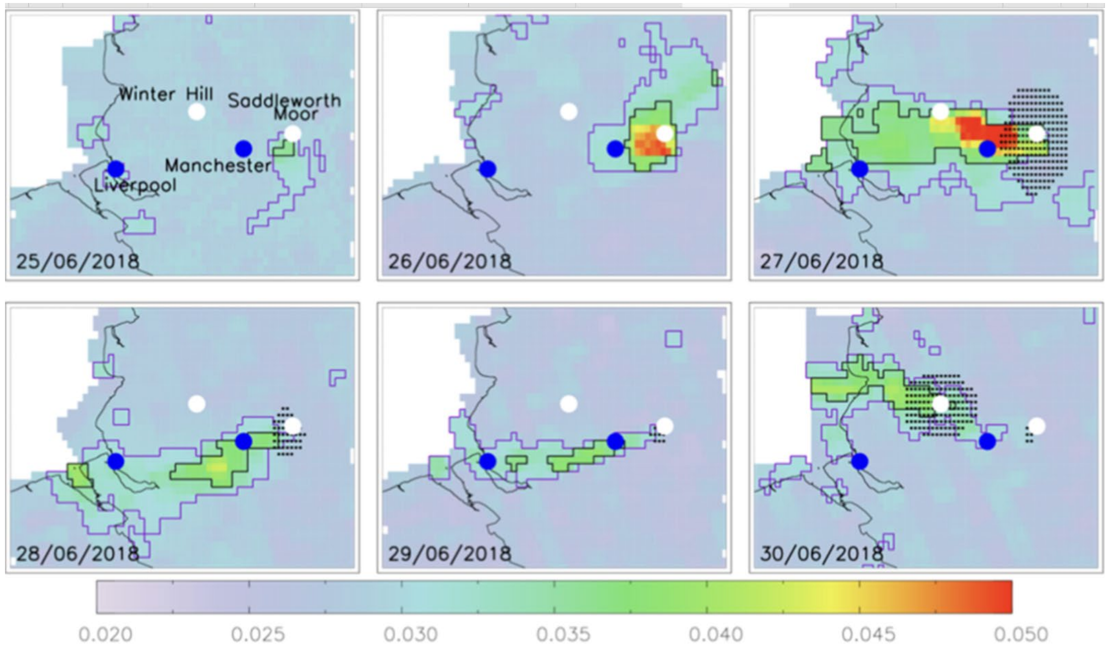

UK Wildfires

Saddleworth Moor Wildfire

- "The Saddleworth Moor wildfire in June 2018 serves as a stark example of the evolving wildfire threat in the UK. This wildfire, one of the worst in recent UK history, lasted for about three weeks and covered an area of over 18 square kilometres (km^2)."
- This event had a significant impact on air quality, with monitoring stations recording high levels of particulate matter (PM_{10} and $PM_{2.5}$). Such pollutants have deep respiratory penetration and are a major concern for human health.
- Satellite imagery and ground-based air quality monitoring stations played a crucial role in tracking the spread of smoke and assessing environmental impact, demonstrating the critical need for advanced monitoring technologies in managing wildfire incidents.
- (Graham et al., 2020)

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Key Goals for the Study

1. Calculate the Energy Mass Balance (EMB) of the readily accessible fuel in Hamsterley Forest, consider different types of fuel present and their associated combustion characteristics and properties.

2. Utilise AERMOD's Plume Dispersion Modelling software. Predict the dispersion of the gases and fumes generated by the fire using gaussian plume models under different meteorological scenarios.

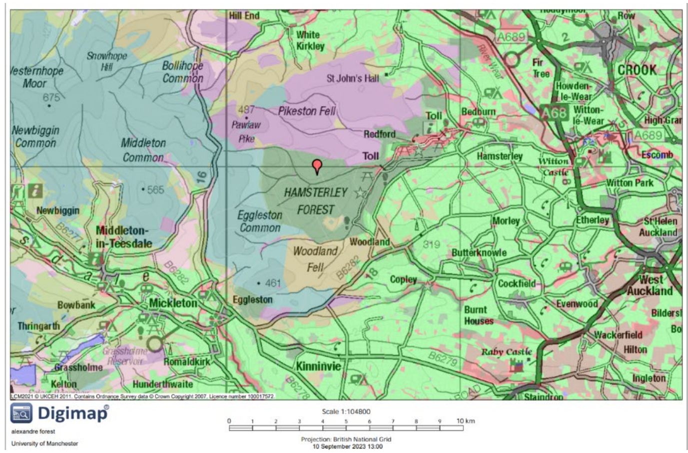
3. Analyse and assess the impacts of the plume dispersion on local air quality (focusing on human health). Explore the potential strategies needed to mitigate and minimise the adverse effects on the environment and human health.

Why Hamsterley?

Location

- Hamsterley Forest is located forest in County Durham and owned and managed by Forestry England. It is the largest forest in County Durham and covers more than 5,000 hectares. The forest has a rich diversity of mature woodland, with Scots Pines that are aged around 70 years, but it does have a variety of younger plantation, plus great trees possibly planted in the 19th century by the Surtees family.

- Being located between Weardale and Teesdale, and lying close to the Pennines, the whole area opens endless possibilities for visitors to explore the great outdoors of Durham. The forest has become more commercial over the past 5 years and Forestry England is assessing future projects to further develop the area and provide up to 100 sensitive cabins and associated amenities.

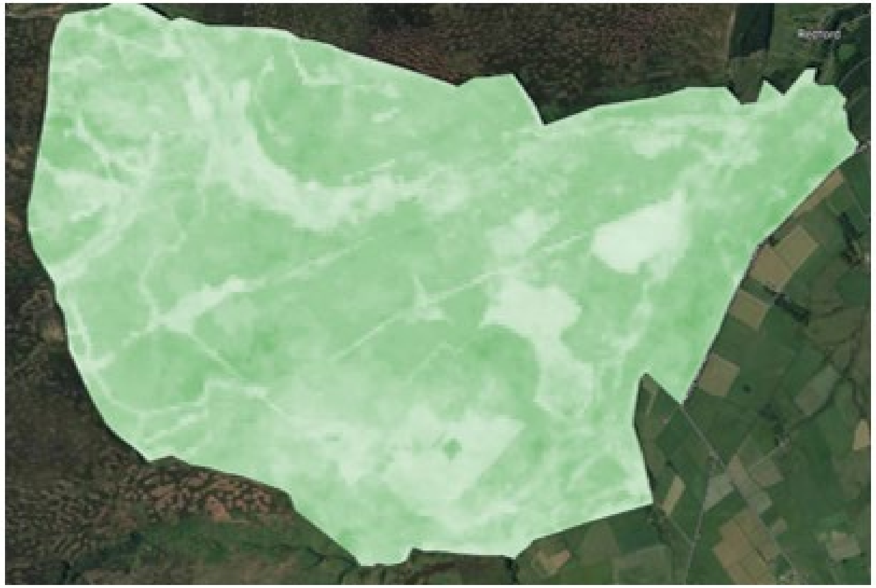


Forest Health

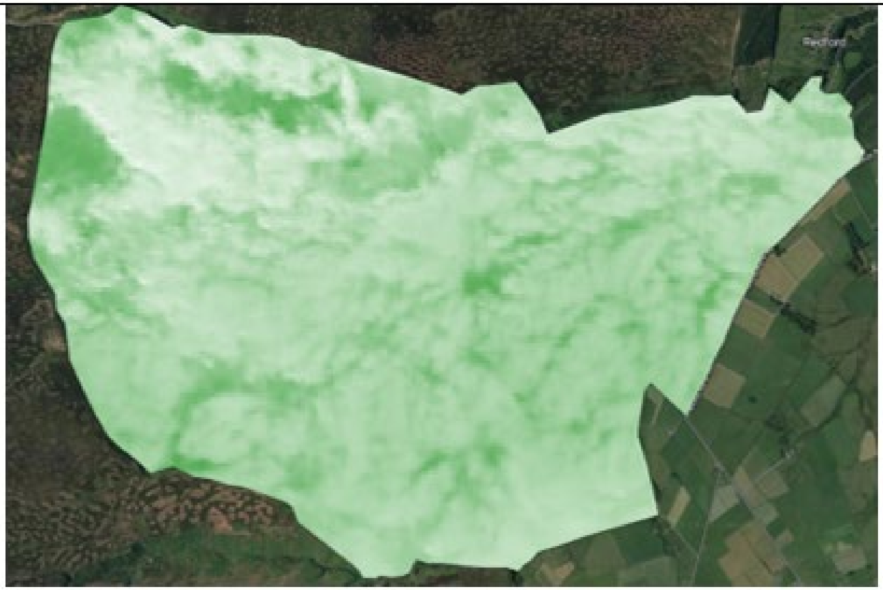
MODIS | Landsat Series

Created using Google Earth Engine

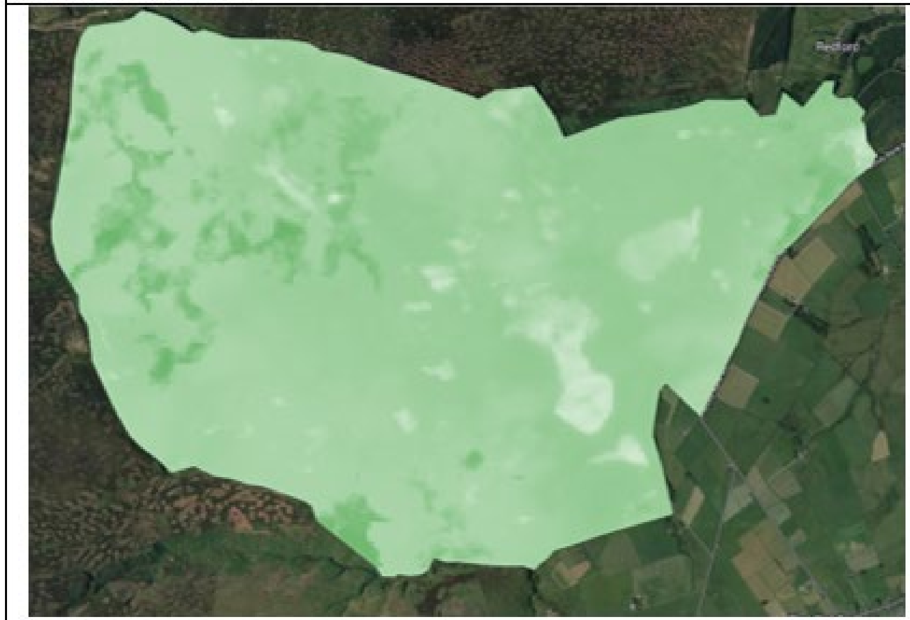
- Red Wavelengths
- Near-Infrared (NIR)
- NDVI and EVI data



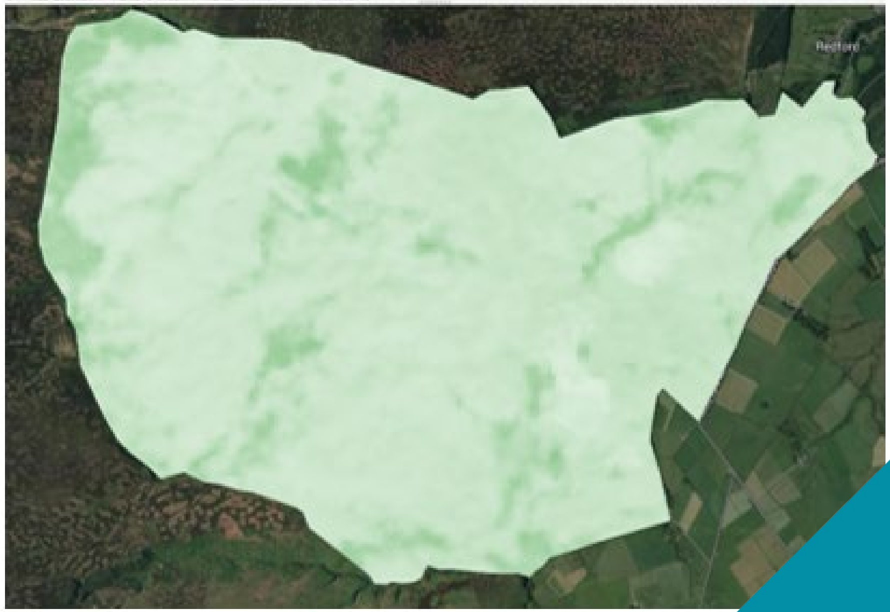
Annual 2019



July 2019



August 2019



September 2019

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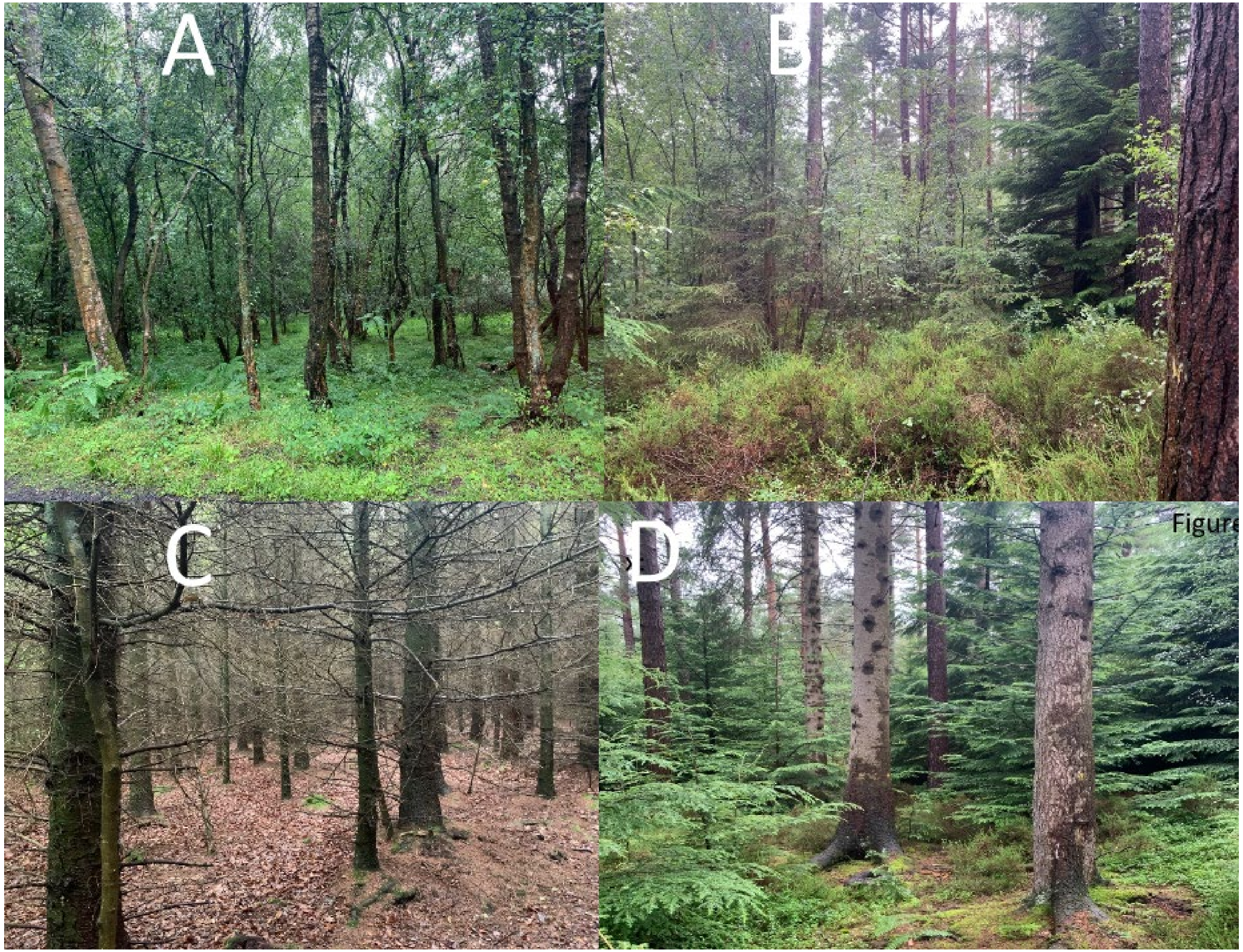
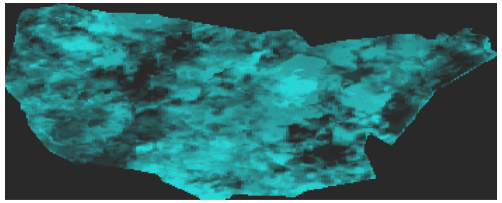
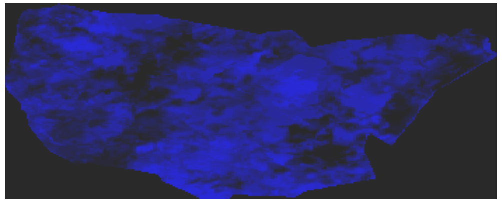


Field Research

- AGB = a x (DBH)b (Chave et al., 2014)
- Using “a” and “b” as constants specific to the calorific values of individual tree species, tree allometry can be used to validate the AGB value using the DBH (easiest measured value) measurements from the forest plot.
- ‘a’, the "allometric coefficient" and it represents a scaling factor that adjusts the magnitude of the biomass estimates.
- ‘b’ represents the "allometric exponent" and it determines the rate at which biomass changes as DBH changes.

Calculated Biomass





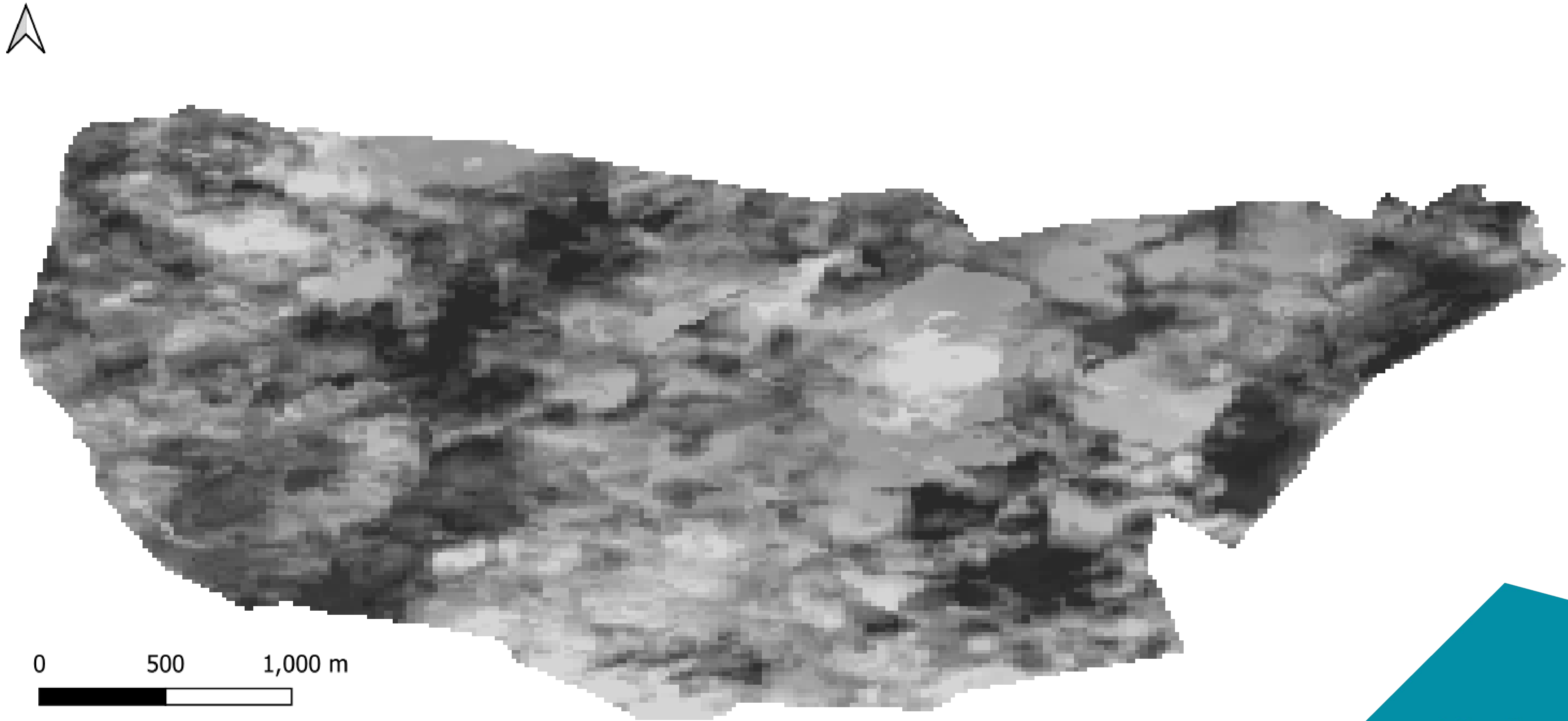


IMAGE CREDIT:

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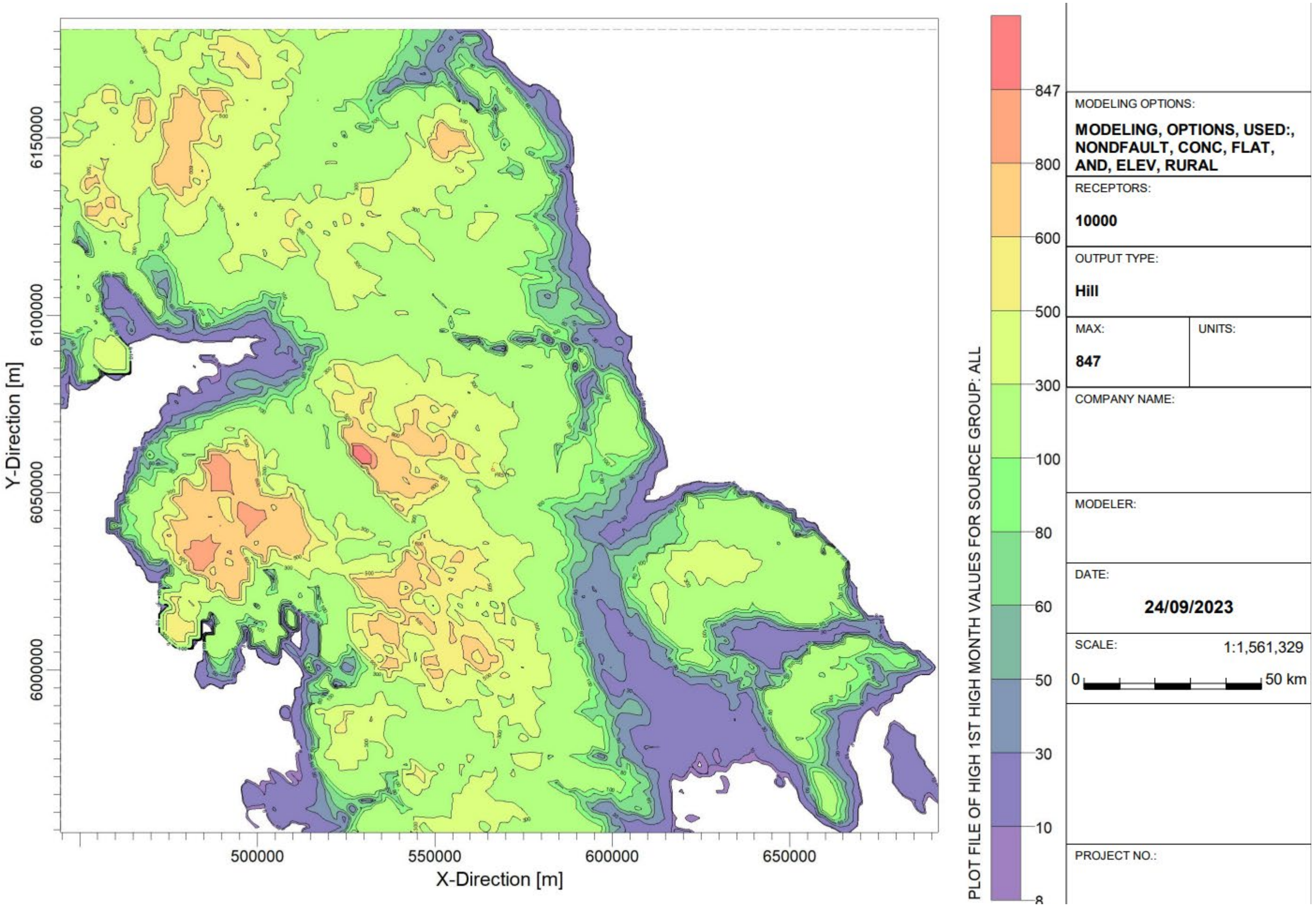
Terrain Modelling Using DEMs



- AERMAP, which is part of the AERMOD modelling system, is responsible for processing terrain data, including digital elevation models (DEMs).
- AERMAP has a built-in capability to handle the terrain data required for AERMOD dispersion modelling.
- AERMAP can process elevation data from various sources, including user-provided elevation files and the U.S. Geological Survey's (USGS) National Elevation Dataset (NED).

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Accessible Fuel

- Using these values, we can calculate the energy contained in each component of the biomass. For example, the total energy in the oak component of the biomass would be:

- (20 MJ/kg) x (0.3) x (4,960,462 kg) = 29.7 MJ / 3e12

Tree Specie	Calorific Value (MJ/Kg)
English Oak (Quercus robur)	20.0
Scots Pine (Pinus sylvestris)	19.5
Silver Birch (Betula pendula)	20.5
European Beech (Fagus sylvatica)	21.5
Ash (Fraxinus excelsior)	20.5
Sitka Spruce (Picea sitchensis)	19.5
Rowan (Sorbus aucuparia)	20.0

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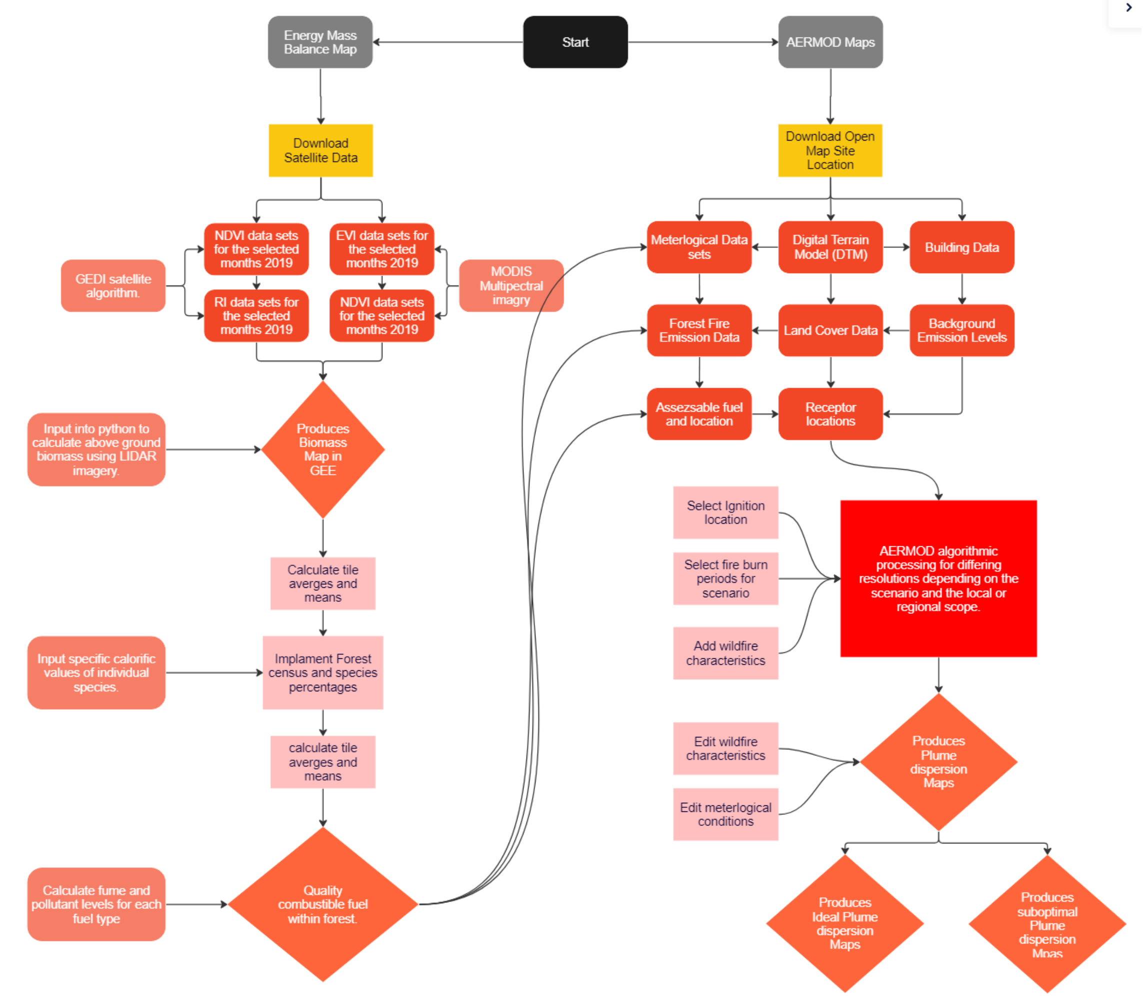
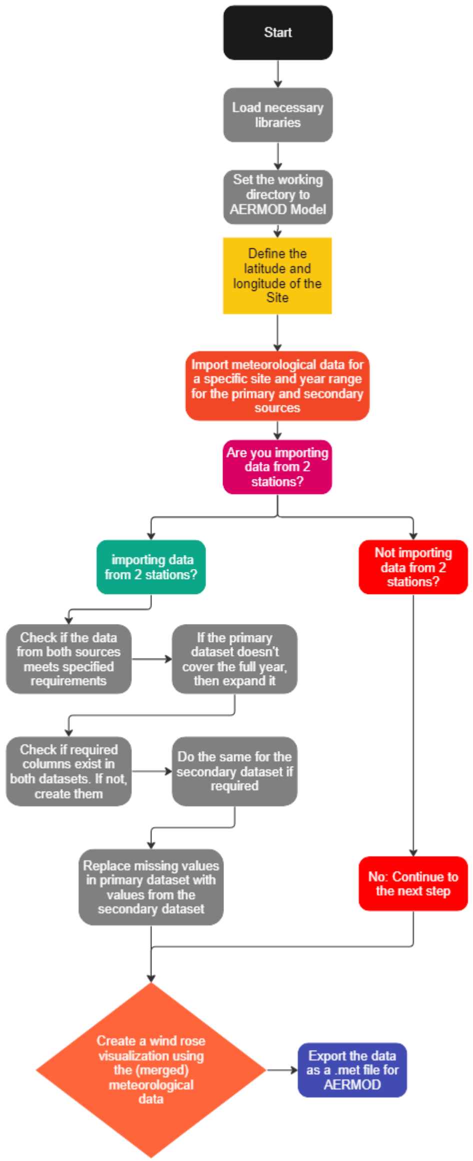
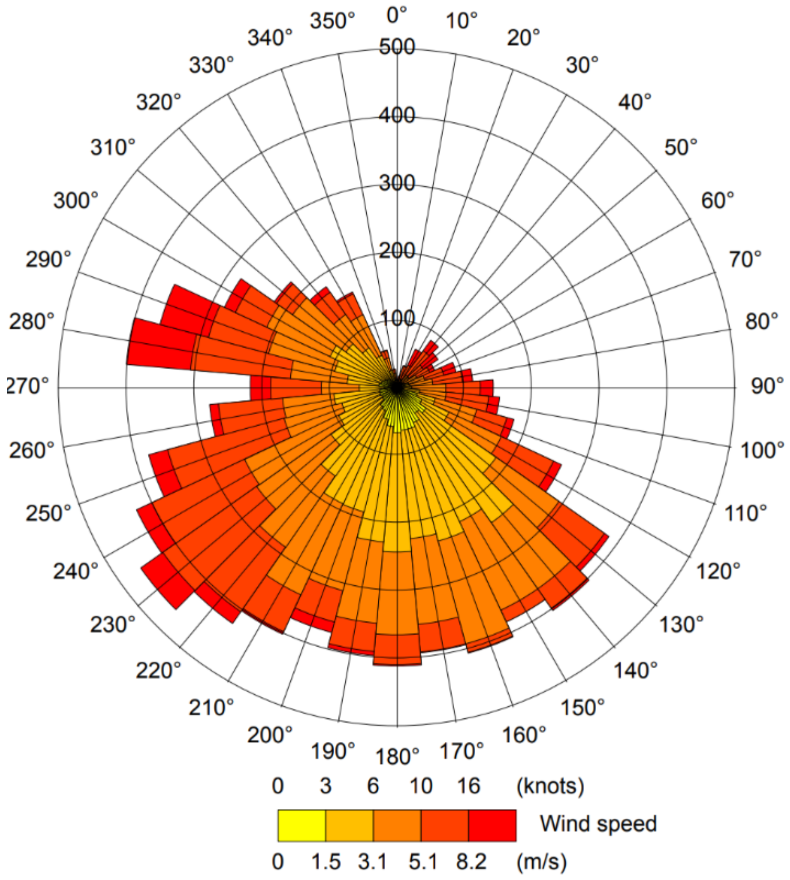
Compiling Data







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Theoretical Dispersion Modelling using AERMOD

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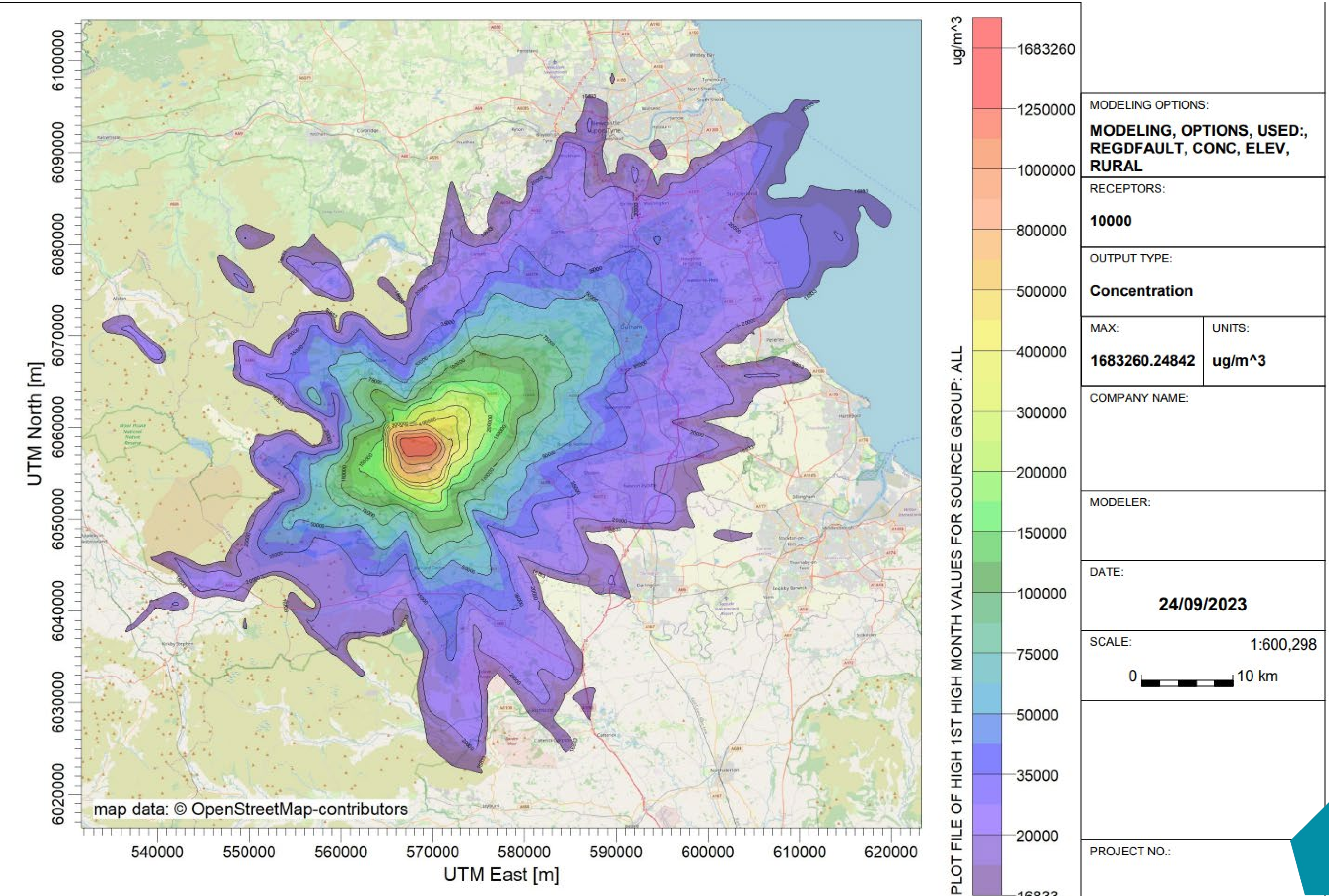

NO_2

Main 1-hour NO_2 Concentration Map

Wildfire based pollutants when breathed in have immediate and severe health consequences even in short-term inhalation periods.

Long term exposures of NO_2. are associated with multiple health effects, predominately raspatory and cardiovascular problems (Simons & Wood, 2003)

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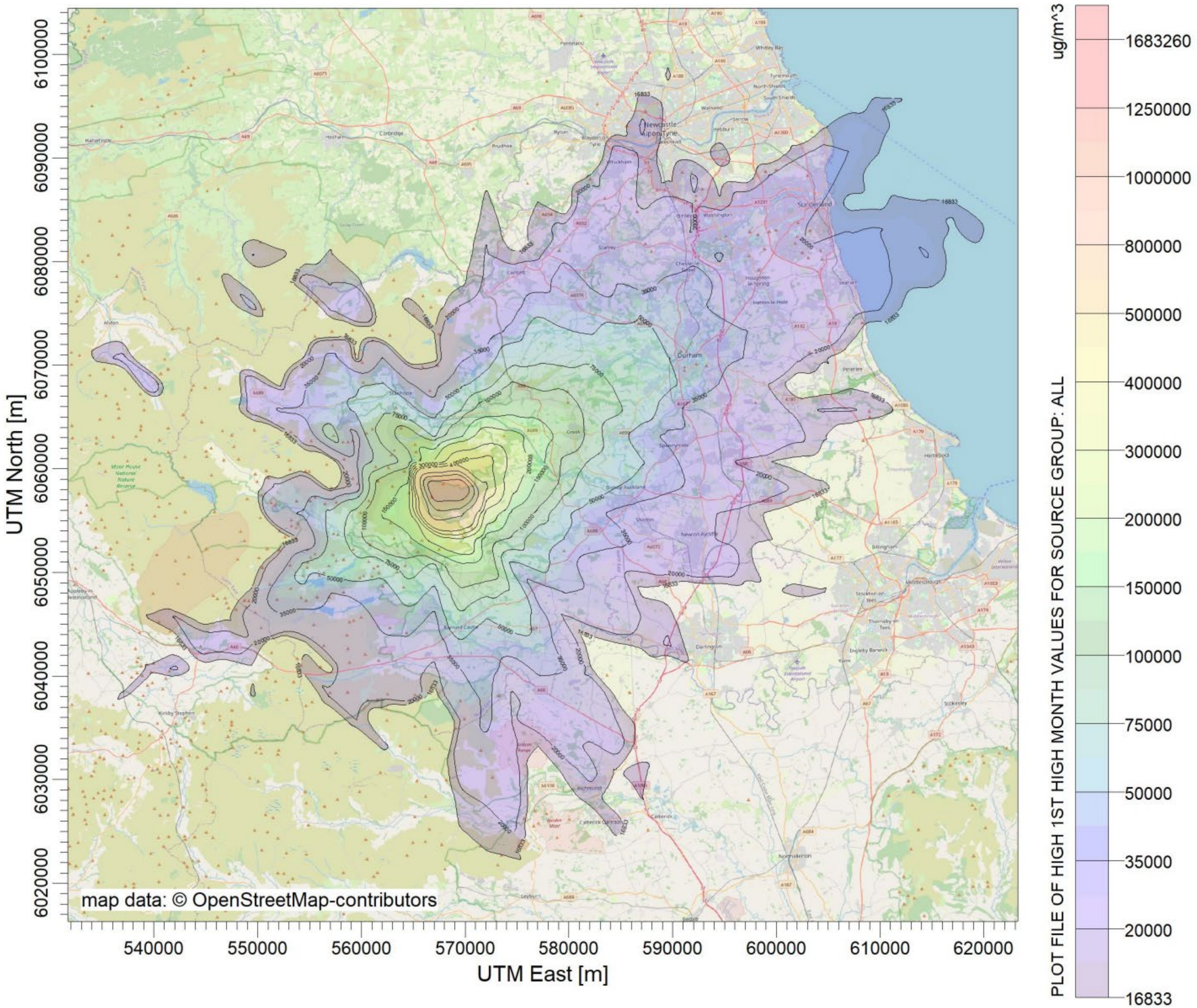
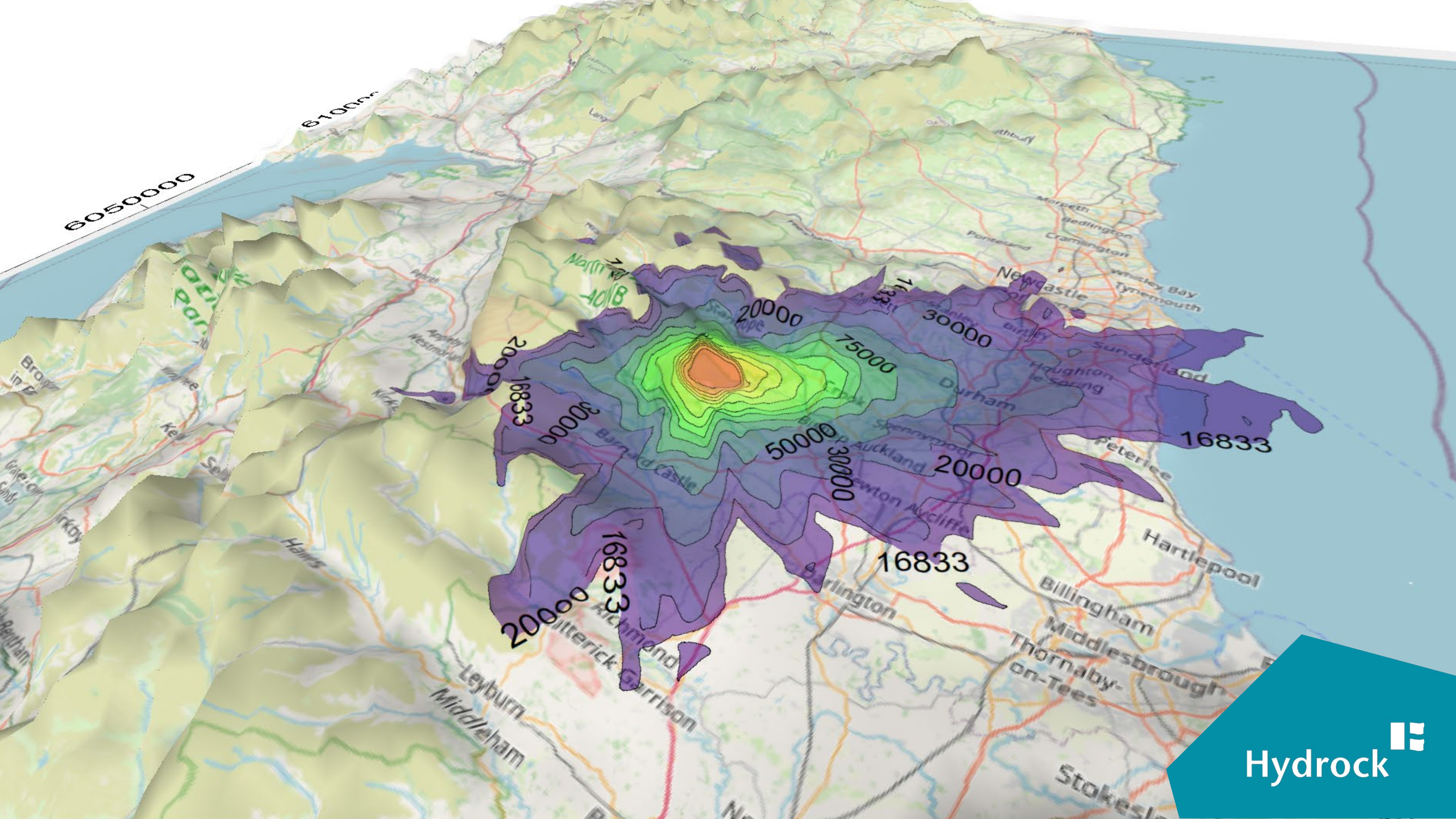


NO_2

- Exposure to pollutants can cause chest constriction and coughing, especially in those with asthma or lung damage from smoking. A 10 µg/m³ rise in pollutants may lower asthmatic lung function by up to 2% (McConnell et al., 2002), significantly impacting affected communities.

- Chronic Respiratory Diseases develop rapidly as a result of exposure to deteriorated air quality. For every annual increase of 10 µg/m³, an 15% increase in asthma symptom days in children is expected (Gauderman et al., 2004).


6050000
20000
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16833
Newcastle
Tynemouth
Whitley Bay
Cramlington
Bedlington
Morpeth
Sunderland
Houghton-le-Spring
Durham
Spennymoor
Bishop Auckland
Barnard Castle
Newton Aycliffe
Peterlee
Hartlepool
Darlington
Billingham
Middlesbrough
Thornaby-on-Tees
Richmond
Catterick Garrison
Leyburn
Middleham
Hawes

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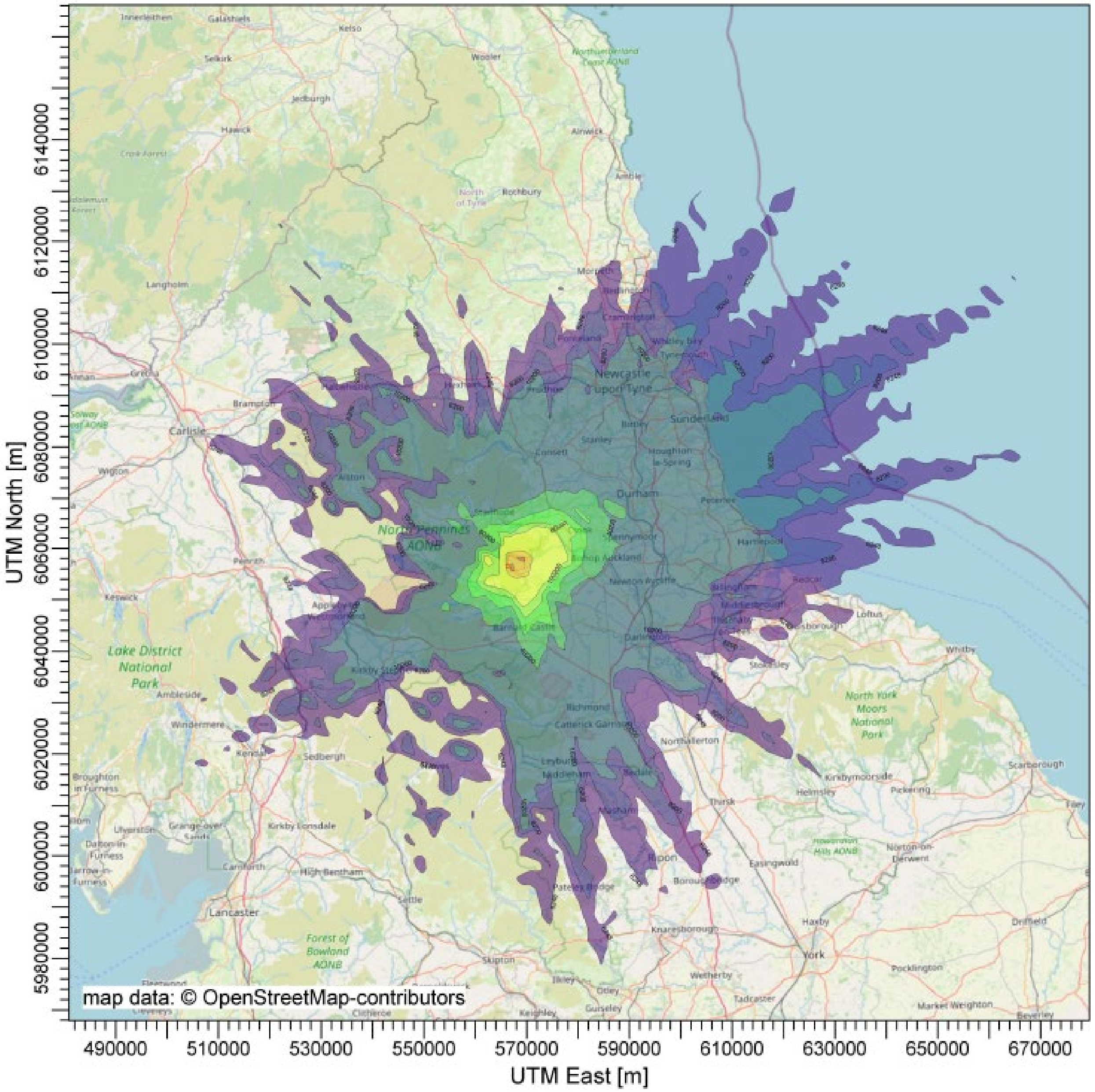
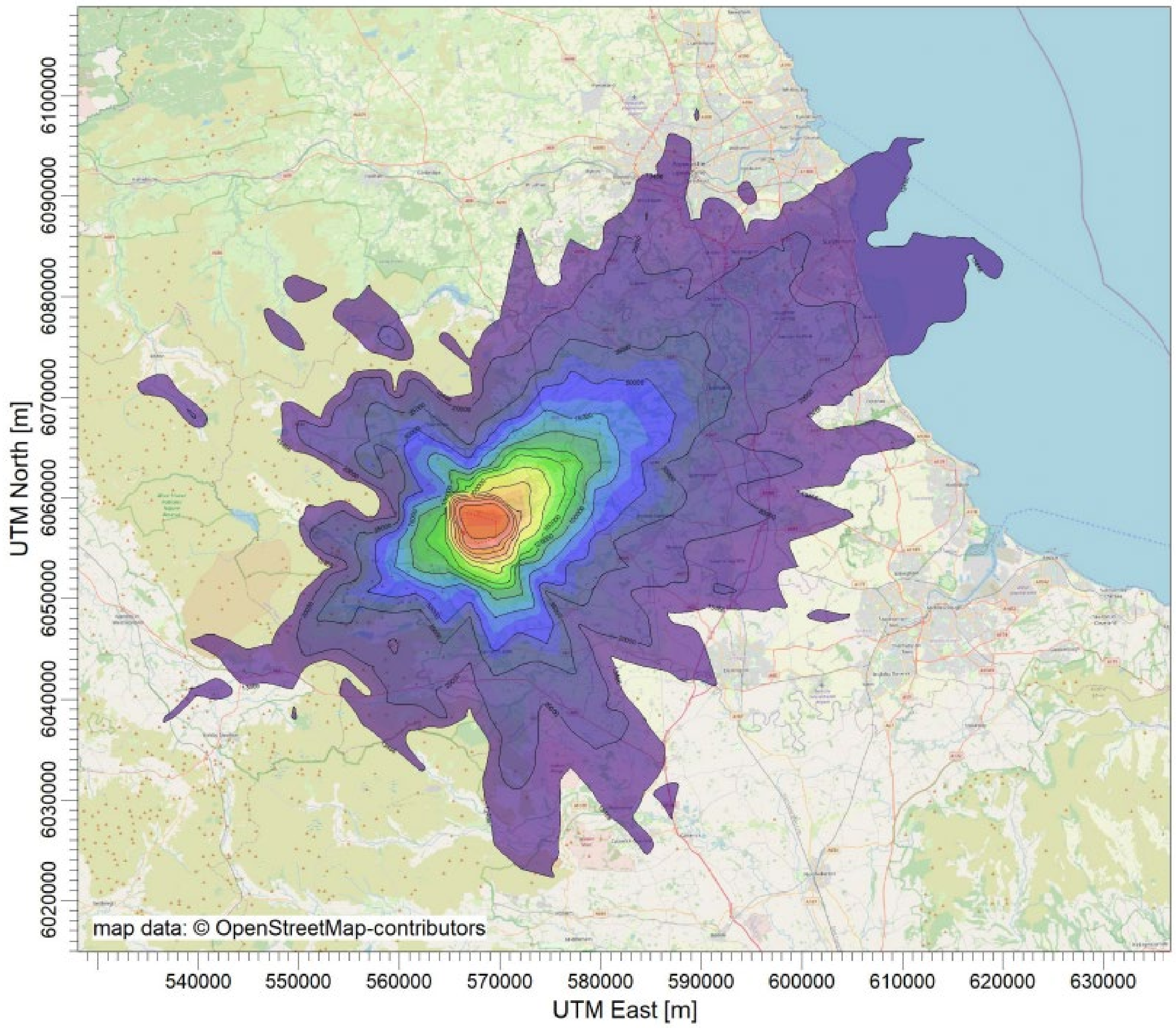


Main PM2.5 1-Hour Concentration

- Topographical layering is incompatible within a model larger than 5km long, it had to be removed.
- This causes a larger, unrealistic, spread with lower reliability and higher uncertainty. The map PM2.5 suggests a direct correlation with NO2. and SO_2 isopleths.
- However, these pollutants are molecularly heavier (SO2 and NO2 are 64 and 56 grams per mole respectively) and drop off much faster than nitrogen. Therefore, receptors further away are at lower risk than those in proximity to the fire meaning that there is likely an inverse exponential correlation between the two.



Controlled Burn Strategy

- To reduce the impact of wildfires, strategies can be put in place through monitoring and preplanning. A common and effective management strategy is the implementation of controlled burns and forest thinning. By the removing of the most assessable fuel through the removal of trees and dry foliage, the effects of the fire are reduced.
- This has been implemented in the model by reducing the total fuel 20% unevenly distributed in attempt to simulate this procedure (Habeck, 1996 and Stephens et al., 2009).

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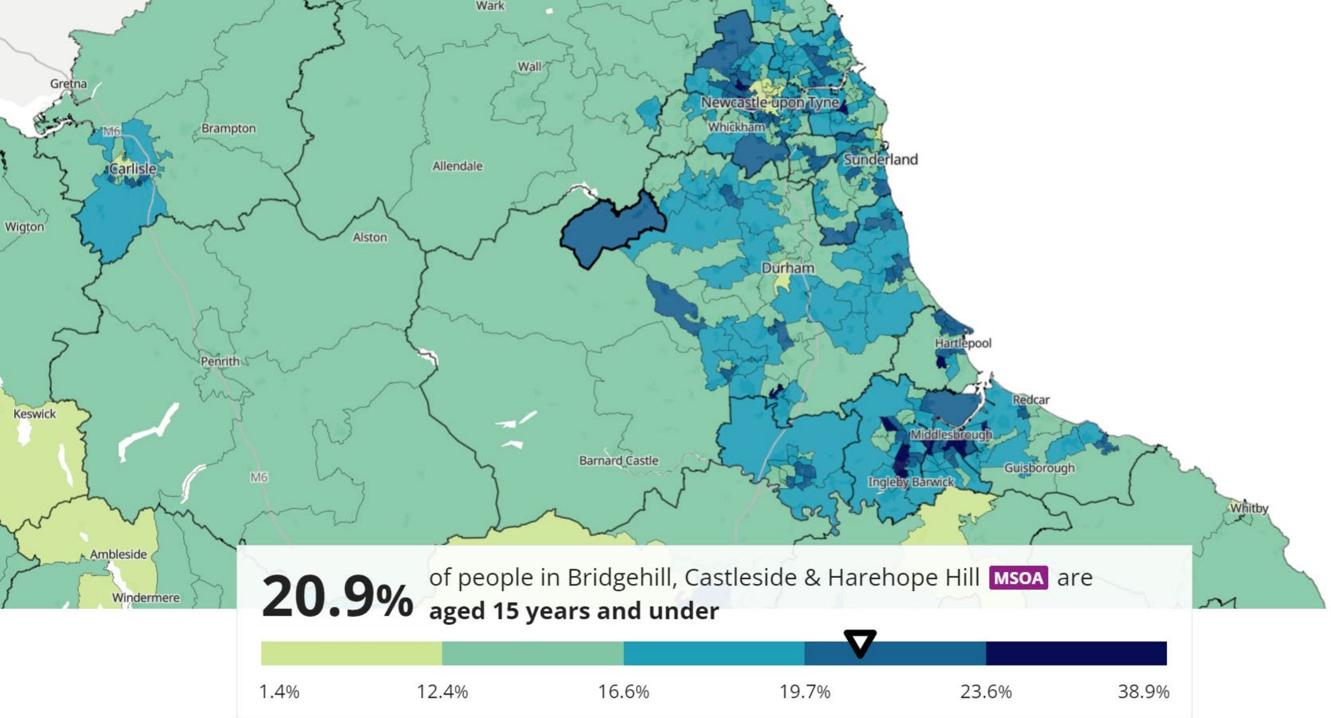

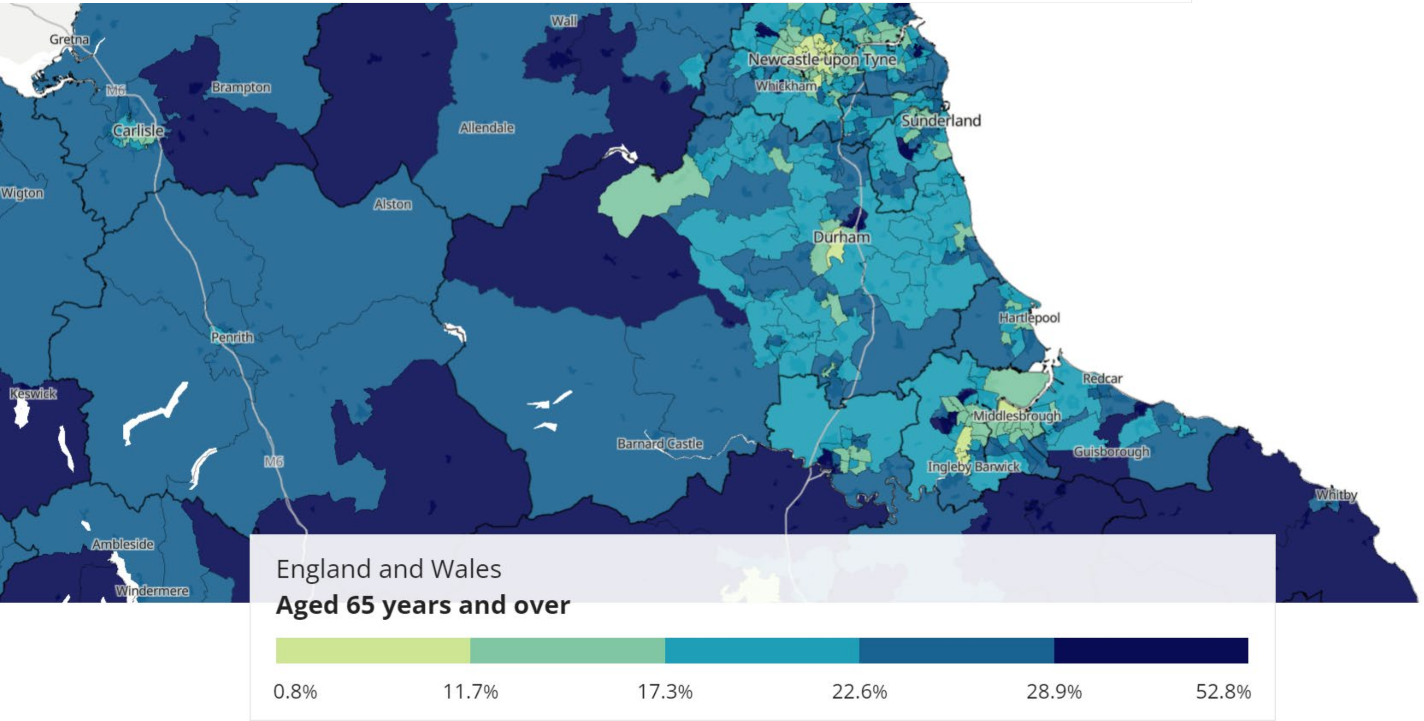

Data from Office of national statistics 2021 Census.

Thank you

Any questions?

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