Identifying National Sea Level Change and Vulnerable Infrastructure in Liverpool

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Rationale

England and the UK are facing challenges due to rising sea levels. As someone not from England, I wanted to learn more about how these coastal cities could be impacted by rising sea levels and potential flooding. Sea level rise is a global concern, but its effects on local areas can differ, due to regional variations in ocean currents, tidal patterns, and land subsidence. I was curious about prominent coastal cities such as Southampton, Newcastle, and Portsmouth, which have major roles in the country's economy, history, and infrastructure. Between 1901 and 2018, the global mean sea level has risen about 20 cm [4]. The rate of sea level rise is also increasing. From 1901-1971, the rate of sea level rise was about 1.3 mm/year. From 2006-2018, the rate of sea level rise has jumped to about 3.7 mm/year [4]. By mapping these changes, we can provide critical insights into the spatial variability of sea level rise and identify areas most at risk of flooding, erosion, and loss of habitat in England. As of 2020, the population of coastal towns in England and Wales sat at around 5.3 million residents [3], many of them in densely populated urban areas. Coastal flooding is becoming more common due to rising sea levels, and has already impacted England, such as the 2013-14 winter storms, where several hundred homes were flooded on the east coast of England. On top of that, in southern England, around 50,000 homes lost power. Many rail services were cancelled due to both coastal and river flooding from these storms [2]. Even cities that are slightly inland, such as London, have experienced flood events; even if a city is not considered coastal, the impacts of sea level rise have a far reach. As projections estimate the change in sea level to continue to rise to be between 0.27 and 1.12 meters by the end of the century [1] extreme flooding events will continue to occur. By mapping historical and current sea levels changes and integrating this data with elevation and land use information, this project aims to identify areas in England most vulnerable to future flooding events. This information can help stakeholders, such as planners, environmentalists, and policymakers, form a clear picture of what is at stake. This project seeks to provide a comprehensive visualization of sea level change around England and its implications for urban areas at a low elevation. It also has a specific focus on Liverpool and its infrastructure, where the sea level seems to be most on the rise.

Cartography

General Cartography

The map is divided into two panels, each serving distinct but complementary purposes. The left panel provides a national-level overview of sea level change across England, while the right panel zooms in on the Liverpool region, illustrating specific areas and infrastructure at risk. It employs a consistent projection, ensuring spatial accuracy between the two panels. Labels are placed to avoid crowding and maintain readability, while map elements, such as scale bars and north arrows, are placed to reduce interference with the map.

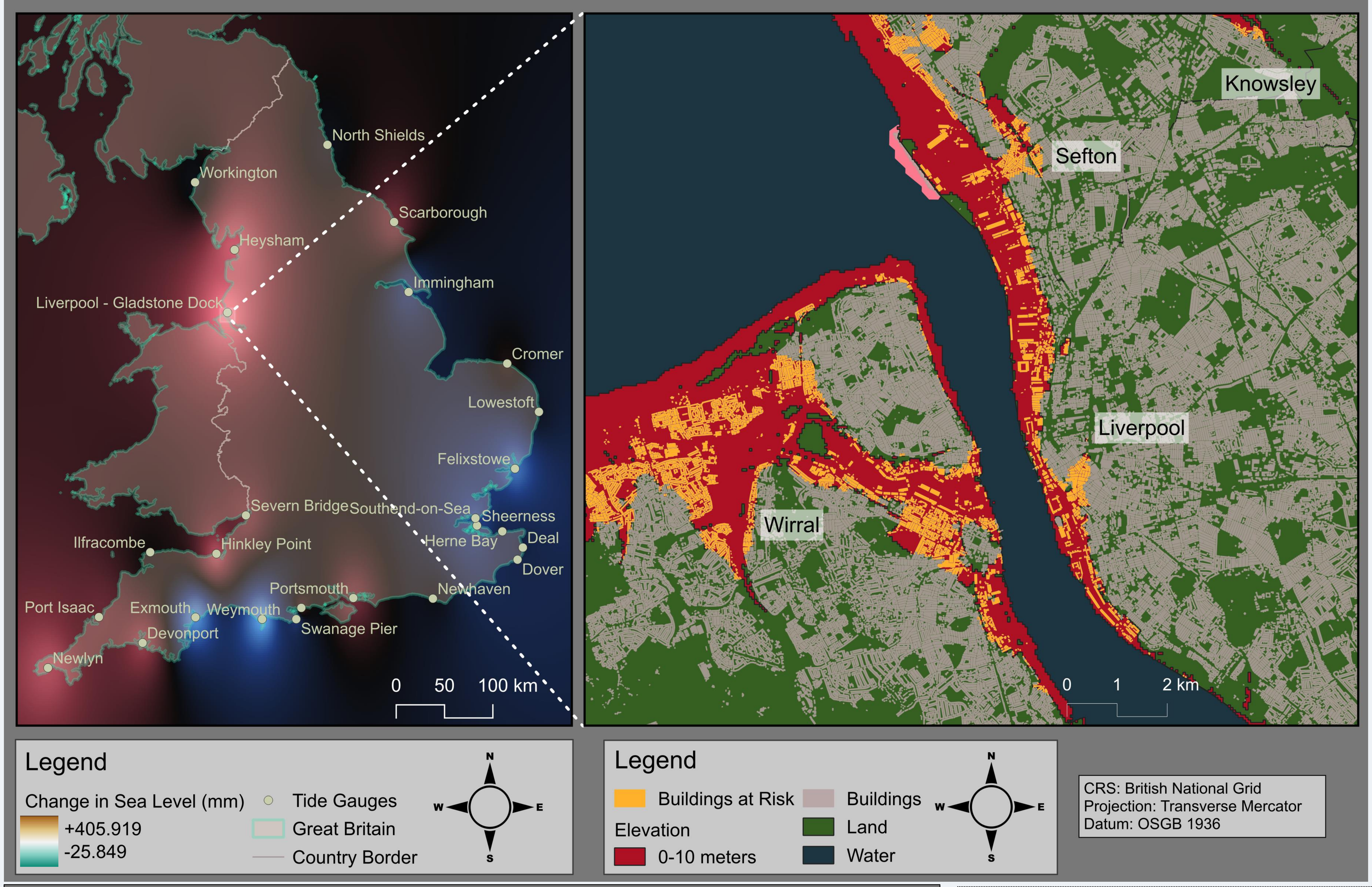
National-Level Map Design (Left Panel)

The national map uses a gradient color scheme to visualize sea level change intensity, with cooler blues indicating areas of smaller or negative change, and with warmer reds highlighting regions experiencing significant increases in sea level. The color choice is meant to convey risk, as warm colors are intuitively associated with danger. The labels of tide gauges near key coastal cities are placed best as possible to avoid overlapping with the gradient symbology, but due to the extent, some labels are missing. The white dashed line emphasizes the specific transect shown in detail on the right panel, creating a visual connection between the two scales. The dark background is meant to enhance the visibility of the gradient symbology while also providing a clear contrast for the tide gauges. The inclusion of a distance scale at the bottom reinforces the spatial context, ensuring users can gauge the geographic extent of sea level change across England.

Local-Level Map Design (Right Panel)

The Liverpool-extent map focuses on areas vulnerable to flooding, incorporating building polygons, elevation data, and administrative areas. Flood risk zones are represented in red; those areas denote zones within the 0–10-meter elevation range. Buildings within those zones are shaded in yellow. The use of warmer red and yellow colors is also meant to emphasize danger, as those areas are most susceptible to flooding. Land and natural spaces are represented in green, contrasting sharply with the flood zones to enhance readability. Towns/cities are labeled to provide the user with additional spatial context and to show the flood prone regions in those respective towns. The fine resolution of the right panel ensures that individual buildings are discernible. This allows stakeholders, such as urban planners or policymakers, to assess specific infrastructure at risk. A detailed scale bar aids in interpreting the spatial dimensions of the local map, making it suitable for granular analysis.

Sea Level Change in England (2000-2023)



Data Description

Tide Guage data

This data was sourced from The Permanent Service for Mean Sea Level (PSMSL), which provides long-term tide gauge records. This dataset is a critical source for assessing sea level changes over time and offers historical sea level data from decades ago. It is globally recognized as a benchmark for sea level studies [5], and it has a standardized method of data collection. However, the coverage is point-based, meaning it only provides data at specific coastal locations that I selected. Interpolating this data to create a continuous sea level surface introduces uncertainty, especially in regions with sparse tide gauge coverage, as interpolation assumes uniformity in trends that may not exist. I also chose to use the metric sea level data as opposed to the monthly or annual mean sea level data, meaning the sea level measurements could contain outliers due to the time the measurements were taken.

Elevation Raster

The elevation raster for the local-level map was obtained from the OS Terrain 50 dataset, which is a high-resolution, accurate dataset that provides a 50-meter grid of elevation values across the UK. I chose this as it would be suitable for identifying areas vulnerable to flooding. It is separated into different tiles, making it easier to work with than one entire UK raster. The Ordnance Survey ensures consistent quality, as well as national coverage [6]. While the resolution of the dataset is sufficient for regional analysis, it might miss some fine-scale elevation details in densely populated areas, such as Liverpool, which may affect the accuracy of flood risk modeling. This data is also static, an updated version is published every July, but due to constant urban development or erosion, the flood risk assessment could not be entirely accurate.

Buildings, Land, Borders

The buildings, land, and borders data were sourced from the OS Open Zoomstack geopackage, which offers comprehensive vector data across the UK. It is a versatile dataset for urban and regional analysis. Due to this dataset containing vector data for the entirety of the UK, while also being updated biannually, it may miss some small or newly constructed buildings. At smaller scales, it generalizes features, as the geopackage would be far too large without generalization, so accuracy will be reduced when looking at specific areas in the UK.

Water

Natural Earth provides global-scale datasets for natural features, such as oceans and continents. This dataset is useful for its broad coverage and simplicity, but its resolution can be coarse due to the scale of the files. No analysis was done with this layer, it was used only to represent the River Mersey and Liverpool Bay in the local-level map.

While the data sources are generally fit for purpose, there are limitations in resolution, accuracy, and temporal relevance. The combination of these datasets allows for a comprehensive analysis, but users should be aware of potential uncertainties, especially when interpreting results at smaller spatial scales. Integration with local datasets would be useful to improve accuracy.

Methodology

Data Collection and Preparation

The analysis began by gathering essential datasets, including a Great Britain shapefile, historic and current sea level data. The sea level data, originally in .txt format, was converted to .csv for compatibility with QGIS. Each .csv file, representing a point along England's coastline, was geocoded using latitude and longitude coordinates.

Calculating Sea Level Change

The individual point layers were then merged into a single layer, and to determine sea level change, a new column (change) was added to each attribute table, calculating, via the Field Calculator tool, the difference between the earliest year (usually 2000) and the most recent year (usually 2023). Investigation of this new column showed Heysham and Liverpool had the largest increase, at 364 and 406 mm, respectively. Using the Inverse Distance Weighted (IDW) Interpolation tool, a raster was created to visualize spatial patterns of sea level change across England's coastline.

Flood Risk Assessment

Focusing on Liverpool, elevation raster files were imported and merged. The Raster Calculator tool was used to query areas with elevations between 0 and 10 meters, highlighting zones most susceptible to potential flooding. These areas were then converted from raster to vector format using the Raster to Vector tool. To distinguish areas of interest, the vector layer's symbology was set based on an attribute value of 1, corresponding to regions matching the elevation filter criteria. Finally, an intersection analysis was conducted between the building polygons from and the vectorized elevation layer. This step identified 14,249 buildings located within the vulnerable 0–10-meter elevation range in Liverpool and surrounding areas.

Word count: 1575

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