The UK needs an open data portal dedicated to coastal flood and erosion hazard risk and resilience

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Abstract – In the UK, coastal flooding and erosion are two of the primary climate-related hazards to communities, businesses, and infrastructure. To better address the ramifications of those hazards, now and into the future, the UK needs to transform its scattered, fragmented coastal data resources into a systematic, integrated, quality-controlled, openly accessible data portal. Such a portal would support analyses of coastal risk and resilience by hosting, in addition to data layers for coastal flooding and erosion, a diverse array of spatial datasets for building footprints, infrastructure networks, land use, population, and various socio-economic measures and indicators derived from survey and census data. Rather than prescribe user engagement, the portal would facilitate novel combinations of spatial data layers in order to yield scientifically, societally, and economically beneficial insights into UK coastal systems.

Keywords

open data, geomatics, geospatial information systems

1. A clear and present need

This team of authors – who collectively have many decades of professional experience working with coastal and marine science issues in the UK – recently attempted to produce a national-scale, quantitative, analytical map of risk from coastal flood and erosion hazard in England using existing open-access datasets. We found that this could not be done to our collective satisfaction – nor to the satisfaction of nearly forty well-informed stakeholders at a national workshop that we hosted. Difficulties stemmed from the availability, accessibility, and quality of the necessary datasets: gaps in the spatial data that precluded a national synthesis; proprietary and thus inaccessible data sets; inconsistent levels of spatial and temporal resolution; incompatible analytical methodologies between related datasets; and information that had simply never been gathered.

Analyses of risk and resilience to coastal hazard like the kind we attempted matter because, in the UK, flooding and coastal change are leading climate-related hazards to communities, businesses, and infrastructure (CCC, 2018). Managing the impacts of flooding and coastal change carries a heavy financial burden (Penning-Rowsell, 2015; Uberoi and Priestley, 2017; EA, 2018). Reports to UK Government on flood risk (Uberoi and Priestley, 2017) highlight the need for more maintenance spending on flood protection, efficiency savings to offset costs of new defences, and "value for money" analysis of local flood protection. The UK Department for Environment, Food & Rural Affairs (Defra) recently announced a project titled "Updating guidance on shoreline management plans: UK Coastal Database", motivated by the fact that "to date there is no record of the total loss of homes, land or infrastructure on the coast", and there exists no clear, systematic way to estimate what future losses might occur under different climate scenarios (Defra, 2020). The UK Environment Agency has a statutory duty, per the Flood and Water Management Act of 2010, to develop and deliver a National Flood and Coastal Erosion Risk Management Strategy for England, which is being revised (EA, 2020a). In November, 2020, the Environment Agency and Defra announced a £200 million Flood and Coastal Resilience Innovation Programme in England, which will fund competitively selected projects to run into 2027 (EA/Defra, 2020).

Our national analysis confirmed that England lacks the comprehensive, quality-controlled, compatible, and collated open-access datasets of coastal hazard, exposure, and defences required to assess spatial patterns of risk and resilience (**Box 1**). Analysis of those patterns support data-driven, forward-looking decisions for sustainable management of current and future coastal systems. We emphasise open-access. There are proprietary databases and data products maintained by the insurance industry, engineering consultancies, and private geospatial companies. There are also relevant datasets maintained by government agencies but not necessarily publicly available. In some cases, awareness of certain datasets (and their provenance) depends on the institutional knowledge of a handful of individuals nearing retirement. Many datasets that are available lack the completion and standardisation needed to systematically assess coastal risk or resilience (**Box 2**). We found potentially relatable datasets that were not standardised or coordinated scattered across a fragmented network of organisations with responsibility for coastal protection and defences infrastructure. Some datasets exist for one nation of the UK (e.g., England or Scotland) but not the others, forcing certain comparisons to end abruptly at political rather than geographical boundaries. There are also plentiful "raw" data sources available – historical maps, ortho-rectified aerial imagery, lidar, bathymetry, and more – that are not yet processed into standardised data products (e.g., benchmarked shoreline position) ready for data users.

This is not a plea for more data – the Big Data revolution and rapid expansion of remote-sensing capabilities are already ensuring that more data are coming. Rather, this is a call for quality-assured, openly accessible data, which is a catalyst not only for innovation in analytical and fundamental scientific insight, but also for the delivery of coastal risk and resilience strategy and planning. The UK has an opportunity to take better care of the diverse coastal spatial datasets it already has developed, and to build the data-management infrastructure for new generations of spatial data products – including those from remote-sensing technologies that are yet to be operationalised. An open-data portal dedicated to the component systems from which coastal flood and erosion risk emerge – spatial and temporal datasets that represent not only characteristics of the coastal hazards themselves, but also the assets and populations exposed to coastal hazard and how vulnerable they are to impacts – needs to be regarded as an achievable and essential national resource and priority.

2. Examples of issues encountered with spatial datasets in England

The spatial scale of our attempt to evaluate coastal flooding and erosion hazard risk was effectively set by the most complete spatial coverage of coastal defences that we could source. A dataset of English coastal defences, both engineered and natural, is available through the Channel Coastal Observatory (CCO, 2020b), and is based on the 1997 Coastal Protection Survey of England and aerial photography. Aside from extending only to England, the dataset is valuable but incomplete: for example, the dataset only includes open coastline and does not follow the interior coastline of any estuaries, despite the presence of defences there; no beach nourishment works are included; nor does the dataset include records of defence installation, maintenance, functional condition, or repairs. (There is a national statutory requirement to maintain a registry of inland flood defences, but not coastal defences.) Despite the ubiquity of beach-nourishment projects around the country, the UK lacks any comprehensive record of their application, cost, volume, or spatial extent. The review of European beach-nourishment practices by Hanson et al. (2002) is nearly two decades old, and unlike the US dataset maintained by the Program for the Study of Developed Shorelines (PSDS, 2020), its underlying dataset is not publicly available.

Given the extent to which readily erodible shorelines in England and the wider UK are constrained by coastal-defence infrastructure, information on hard and soft defences, and their management, is vital. In addition to the Coastal Protection Survey of England from 1997, there is the National Flood and Coastal Defence Database, now included within the Environment Agency's new Asset Information Management System, but this only includes assets under the auspices of the Environment Agency in England, omitting defences under other jurisdictions. The National Receptors Dataset likewise provides some information on assets and property at risk, but access is limited by a restricted licence (EA, 2020b). The problem extends to other UK nations. Reporting for Scotland's recent comprehensive national assessment of coastal change

(Dynamic Coast, 2020) notes that data availability for coastal defences around the Scottish coast is "nationally patchy and has not yet been assimilated into a single and standardised dataset" (Fitton et al., 2017).

To address coastal-erosion hazard at a spatial scale that matched the coastal defences dataset for England, we ultimately used a Landsat-derived global dataset of shoreline-change trends (Luijendijk et al., 2018) because it was the only resource that offered complete, standardised coverage of shoreline change at a spatial scale greater than sub-national regions. England-wide data ostensibly exist from the FutureCoast project (FutureCoast, 2002), but these are not in a readily accessible format and are approaching two decades of dormancy. The Environment Agency National Coastal Erosion Risk Map (EA, 2020c) comprises binned projections of future change based on past erosion rates, and thus as a data product is some steps removed from the data that underpin it.

To capture broad categories of flood likelihoods on coastal floodplains in the presence of current flood defences, we used the Environment Agency "Risk of Flooding by Rivers and Sea" dataset (EA, 2020b). However, because that dataset does not include specific information about flooding source (i.e., river or sea), we overlayed the "Flood Map for Planning (Rivers and Sea)" (EA, 2020d) to define areas of coastal floodplain susceptible to flooding from coastal, tidal and/or fluvial events. Notably, the polygons that comprise these two datasets – "Risk of Flooding by Rivers and Sea" and "Flood Map for Planning (Rivers and Sea)" – differ in their spatial extents because the former considers the influence of extant flood defences and the latter does not.

These examples illustrate just some of the data-assimilation issues we encountered – even having limited our analysis to England.

3. The data-management legacy of Shoreline Management Plans

Much of the impetus for a data-driven understanding of national coastal flood and erosion risk, is to gain an integrated vantage of regional Shoreline Management Plans (SMPs). Shoreline Management Plans are non-statutory, large-scale, long-term strategic plans that aim at reducing the impacts of coastal flooding and erosion on population, infrastructures, and natural environments (Cooper et al., 2002). The first generation of SMPs were developed in the 1990s – with contributions from a few of the authors here – and segmented the coastline of England and Wales into 11 littoral cells and 46 sub-cells according to general patterns of alongshore sediment transport (Motyka and Brampton, 1993; Cooper et al., 2002; Leafe et al., 1998; Nicholls et al., 2013). The process of establishing the SMPs prompted recommendations for an improved evidence base of coastal change, which ultimately led to the creation of the National Network of Coastal Monitoring Programmes of England (CCO, 2020a). Revised between 2006–2011, 22 SMPs, subdivided into nearly 2000 Policy Units, presently cover the coastline of England and Wales. Shoreline Management Plans have also been applied to reaches of Scotland's coast (Dynamic Coast, 2020).

Data compilation and analysis for previous rounds of coastal assessments in England and Wales, particularly in the late 1990s, were outsourced to consultants, but those datasets were largely lost or remain proprietary information, rather than being made publicly available. Different SMPs employed different consultants, introducing methodological disparities and differences in quality control (Potts, 1999). Regional studies have used different methods of shoreline-change analysis, for example, without standardizing to a common data framework, complicating the essential process of stitching regional datasets into a freely accessible, searchable national inventory. The recent Infrastructure UK review (EA, 2014) recognised the need for better asset data, to be supported by the Creating Asset Management Capacity (CAMC) programme, including improved records for defences, such as berm-crest levels and standard-of-protection. Five years later, recognition of that need has not yet translated into accessible, publicly available data products or a platform for them – though user communities of coastal data remain hopeful.

For now, separate databases for different jurisdictions, the lack of integrated datasets from local to national scales, inconsistent data protocols, and the patchiness of public availability present significant hurdles to any transparent and open-source analysis of UK coastal flood and erosion risk. Availability of baseline coastal data has been highlighted by the UK Geospatial Commission as a national spatial data infrastructure need (Geospatial Commission, 2019). Further work is planned through the UK Hydrographic Office (UKHO) to support the greater understanding of the British coastline via the Coastal Zone Mapping Project (UKHO, 2020). This initiative is currently specifying best-practice and collating an understanding of needs and auditing current data "so that integration, discoverability and access to this data can be improved" (UKHO, 2020). In addition, the UKHO has developed an automated mapping of the present coastline from Sentinel 2 satellite data, which will provide an updated framework for coastal mapping and be openly accessible. National agencies and regional groups are developing their own platforms of standardised, openly accessible coastal and coastal-change data, such as the Regional Flood and Coastal Committees (RFCC) Decision Support Tool, which provides web-based applications for the East Anglia RFCC region (RFCC, 2020), and the data resources from the National

Coastal Change Assessment in Scotland (Dynamic Coast, 2020), which were created as an evidence base for strategic management (Hansom et al., 2017).

4. From risk to resilience – a portal imagined

Using open and accessible datasets with common standards to develop a more holistic, multi-dimensional perspective of coastal risk can reinforce policy instruments of coastal management in a world where sea-level rise and climate change are recognised as a growing threat to livelihoods and lives. Beyond risk, there is growing interest in measuring and enhancing resilience to coastal hazards (Rosati et al., 2015; Masselink and Lazarus, 2019; Townend et al., 2020). If risk represents systemic exposure to disruption by a hazard, then resilience extends to how a system anticipates and recovers from disruption. While there are a set of established metrics for risk, metrics for resilience are still taking shape (Masselink and Lazarus, 2019). The data portal proposed here will greatly facilitate the development of such metrics, which are multi-dimensional, requiring stakeholder valuation and multi-criteria analysis (e.g., Townend et al., 2020).

In the UK, some coastal data acquisition, processing, and analysis is undertaken and archived by the Channel Coastal Observatory and the British Geological Survey. The Environment Agency – and its equivalents in the devolved national administrations – also maintains their own geomatics teams, in charge of surveying, remote sensing, and data analysis. Independent research teams funded by national research councils also generate new coastal geospatial datasets, including repeated high-resolution imagery, topographic and bathymetric scans, and surveys of coastal ecological biodiversity. Where public money is spent on data-generating projects via national funding bodies, an open framework for data management and public provision could ensure national standards across datasets, rapidly integrate new datasets into the national catalogue, generate simple but valuable products from these data (e.g., shorelines from orthophotos and structure-from-motion terrains).

To integrate these and other coastal data sources, both archival and new, the Channel Coastal Observatory is an obvious host – although quality control, standardization, and geospatial analysis (e.g., systematic shoreline delineation) are resource-intensive activities. But to support analyses of coastal risk and potentially coastal resilience – not just coastal hazard – any such portal will need to integrate a wide array of spatial datasets for building footprints, infrastructure networks, land use, heritage sites, ecosystem services, population, and various socio-economic measures and indicators derived from survey and census data. The portal could ensure that different datasets could be readily and reliably integrated to facilitate novel analyses of spatial relationships of interest to a given user.

One example of new, value-added data resources that such a portal could provide would be layers of housing footprints, infrastructure, transportation networks, and coastal defences digitized from detailed (1:2500) historical maps, of which the UK has a rich catalogue. Such a resource would enable quantitative assessments of how patterns of coastal risk have evolved in space and time. These patterns could be linked to datasets derived from census data, such as indices of social disadvantage at the coast (UK Parliament HL, 2019), and to historic hazard events, such as data archived by SurgeWatch (Haigh et al., 2017). The data portal could also include repeated empirical and modelled assessments of natural defences – beaches, tidal wetlands – that may be impacted by human activities, given that changes in the states and behaviours of those natural systems can affect, and be affected by, engineered interventions. By including coastal physical topography, management units such as mapped floodplains, and administrative units such as post codes and local authorities, users would be free to define the coastal zone according to their specific focus – by some fixed shoreline, or a threshold elevation, or official delineation – and pursue anything from local case studies to regional comparisons to a national assessment. Moreover, users could select from different data levels (e.g., raw imagery, post-processed/simplified layers, value-added analytics), spatial scales, and temporal series, depending on their analytical needs.

5. Realising a resource

One existing model of a standardized, searchable, freely accessible platform for coastal datasets – national-scale coverage of sea-level rise impacts and short- and long-term shoreline change, along with hurricane strikes and geomorphic forecasts of storm-driven change – is the USGS Coastal Change Hazards Portal (USGS, 2020a), which is further reinforced by the USGS EarthExplorer (USGS, 2020b). Others examples include coastal portals for Scotland (Dynamic Coast, 2020), Belgium (Flanders Marine Institute, 2020), and the Netherlands (Rijkswaterstaat, 2020). The European Topic Centre on Inland, Coastal and Marine waters, an international consortium working with the European Environment Agency, has likewise highlighted a vision for the assimilation of coastal datasets (ETC-ICM, 2020). Our concept of an open data portal aligns with and encourages the ambitions articulated in a recent strategy document by the Environment Agency for a revamped National Flood Risk Assessment tool that would use an open-data framework to provide "a single picture of flood and coastal risk" (EA, 2020a).

An open data portal for risk and resilience to coastal flood and erosion hazard for risk should not prescribe user engagement: any number of outcomes could emerge from novel combinations of spatial datasets, facilitated by robust data management, from unanticipated scientific insights into UK coastal systems to better support of ongoing monitoring and assessment initiatives. The portal for which we advocate would not only comprise a public good unto itself, but also enable societal and economic benefits of innovation and discovery from analysis of those data (Zhu et al. 2019; Nagaraj et al., 2020; Tassa, 2020) – precisely because they are openly accessible.

Acknowledgements

The authors gratefully acknowledge support from the Strategic Priorities Fund UK Climate Resilience Programme through UK Research & Innovation award NE/S016651/1, and a Southampton Marine and Maritime Institute (SMMI) Doctoral Studentship to S.A.

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Box 1 – Defining coastal risk

There are many ways to map risk from geohazards, but most combine probabilistic representations of physical *hazard*, *exposure* of assets or people, and/or *vulnerability*.

Natural coastal phenomena such as storm-driven flooding and erosion are *hazards* when they threaten damage to human communities or environmental resources that people value (Lavell et al., 2012). *Exposure* may refer to people, infrastructure, and socioeconomic and environmental assets that are subject to potential damage or loss in the event of a hazard occurrence. *Vulnerability* attempts to characterise ways in which exposed people and assets may be adversely affected by a hazard, especially where hazard impacts may have differential effects across a demographic mosaic (Cutter and Emrich, 2006; Lavell et al., 2012; Leuttich et al., 2014).

Natural coastal systems, such as beaches and marshes, can buffer some of the flood and storm impacts on exposed populations and assets, but their protective capacities – which also have limits – are often compromised by development pressures. As a result, on many developed coastlines around the world, engineered hazard protection plays an important role: infrastructure like "hard" seawalls or "soft" beach nourishment can buffer exposed populations and assets from all but very large-magnitude hazard events. Flood defences are built to a design standard of, for example, a 1:100 year flood event (0.01 likelihood of occurring each year). Seawalls might have an expected lifespan on the order of a century, whereas beach nourishment requires sustained, cyclical renourishment every few years.

Hazard protection alters the probabilistic distribution of hazard events (Werner and McNamara, 2007) and may also encourage additional development behind it – an unintended feedback variously termed "the levee effect" or the "safe-development paradox" (Burby, 2006; DiBaldassarre et al., 2015, 2018; Armstrong et al., 2016; Armstrong and Lazarus, 2019; Tobin, 1995; White, 1945). Spatial connectivity may add further complexity, if the failure of defences in one location results in damage at another, as can occur in many low-lying floodplains (Wang et al., 2019).

Quantifying coastal risk in some coastal regions, such as estuaries or large bays, may be especially challenging because flood hazard can arise from oceanographic (storm surges plus tides and/or waves), fluvial (increased river discharge) and/or pluvial (direct surface runoff) sources. Most existing flood risk assessments consider these main drivers of flooding separately, despite their intrinsic correlation. Depending on local geographic characteristics (which influence lag times between flooding drivers), "compound flood events" can result in disproportionately extreme impacts (Wahl et al., 2018; Zscheischler et al., 2018). Compound events remain underexamined and excluded from disaster-management plans – an omission that fundamentally and seriously biases existing flood risk assessments.

Box 2 – Completion and standardisation of dataset attributes

Geospatial coastal datasets tend to be structured and managed differently by different local authorities and other agencies, making the collation and integration of data at the UK-wide scale a challenging process. A basic dataset attribute that would aid integration is spatial coverage and spatial registration to a common basal reference. At present, coastal datasets do not necessarily include include both the open coast and estuaries, for example. (Users can always exclude what they do not want, but they cannot include data that do not exist.) For datasets that track (or could track) changes over time, versions and metadata that are not recorded consistently – that is, according to a standardised protocol – ultimately hinder efforts to investigate evolving, spatially correlated relationships among hazard, exposure, and vulnerability.

We suggest that key coastal data to support UK coastal assessments might include:

- coastal physical characteristics, morphology and physiography and material
- coastal erosion / accretion datasets – geospatial data and attribute data by erosion and accretion mechanism, reclamation
- coastal defence data, record of defences over time, by type, condition, and maintenance actions, defended area
- natural defence types, structure, standards, and condition
- event records, by type (e.g., landslip, erosion, flooding), severity, and impact
- coastal setback actions /managed realignment / natural breaches, locations, extent and mechanisms
- assets / infrastructure defended, including buried infrastructure
- records of losses, by actions and costs incurred in response to erosion and flood
- monitoring types, responsibilities, and costs
- historic properties / development histories, by type
- location of planning policies for protection vs development, land cover, habitat, and land-use histories
- coastal community structure and historic records of demographic change and disadvantage (sensitivity and adaptive capacity)