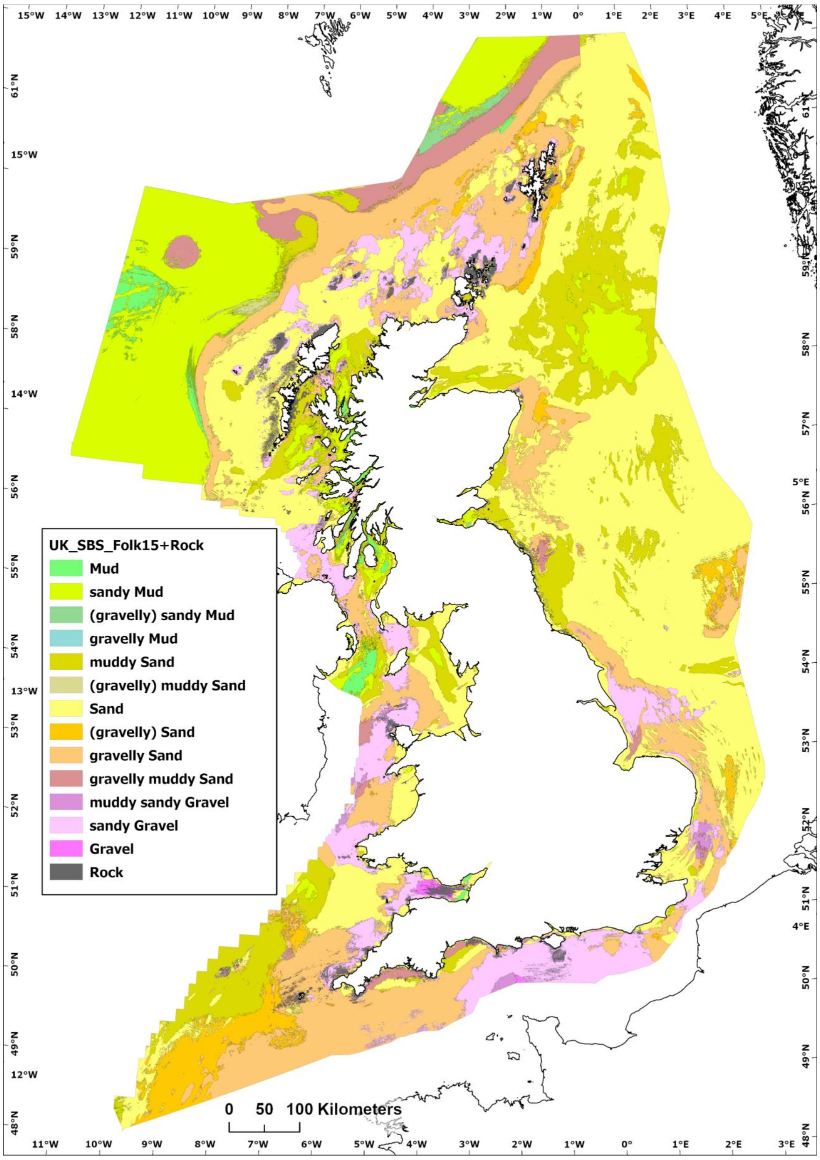
User Guide for Predictive Seabed Sediments - UK (v1)

Marine Geoscience programme

Open report OR/25/040



BRITISH GEOLOGICAL SURVEY

MARINE GEOSCIENCE PROGRAMME

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User Guide for Predictive Seabed Sediments - UK (v1)

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Map

Predictive Seabed Sediments - UK (v1)

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Predictive classified (Folk15+Rock) SBS map.

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FOREWORD

The British Geological Survey (BGS) is a world-leading geological survey, focusing on public-good science for government, and research to understand earth and environmental processes. We are the UK's premier provider of objective and authoritative geoscientific data, information, and knowledge to help society to:

- use its natural resources responsibly
- manage environmental change
- be resilient to environmental hazards

We provide expert services and impartial advice in all areas of geoscience. As a public sector organisation, we are responsible for advising the UK Government on all aspects of geoscience as well as providing impartial geological advice to industry, academia and the public. Our client base is drawn from the public and private sectors both in the UK and internationally. The BGS is a component body of the Natural Environment Research Council (NERC), part of UK Research and Innovation (UKRI).

DATA PRODUCTS

The BGS produces a wide range of data products that align to government policy and stakeholder needs. These include baseline geological data, engineering properties and geohazards datasets. These products are developed using in-house scientific and digital expertise, and are based on the outputs of our research programmes and substantial national data holdings.

Our products are supported by stakeholder focus groups, identification of gaps in current knowledge and policy assessments. They help to improve understanding and communication of the impact of geo-environmental properties and hazards in Great Britain, thereby improving society's resilience and enabling people, businesses, and the government to make better-informed decisions.

SEABED SEDIMENTS

This User Guide describes newly developed predictive maps of seabed sediment (SBS) composition across the UK Continental Shelf (UKCS). These maps provide an update and alternative to currently available national-scale SBS maps that BGS has produced since the late 1970s (https://www.bgs.ac.uk/datasets/marine-sediments-250k/). Characterising the distribution of seabed sediments is important for numerous applications, including: habitat mapping and marine ecosystem science, marine aggregate and minerals, offshore infrastructure siting/monitoring, defence and shipping, and coastal and marine management. In 2024 the Joint Nature Conservation Committee (JNCC) approached BGS, and ultimately provided co-funding (via Defra's Natural Capital and Ecosystem Assessment (MNCEA) programme) for BGS to update the national-scale SBS mapping, with the agreement that resulting digital map products will be publicly accessible by BGS via the Open Government Licence (OGL).

ACKNOWLEDGEMENTS

This work was supported by the British Geological Survey via NERC national capability, together with co-funding from Defra's Natural Capital and Ecosystem Assessment (MNCEA) programme. We thank Helen Lillis, Ashley Elliot, and Elly Hill of JNCC for supporting and reviewing this work. Henry Holbrook of BGS is thanked for preparation of the digital products, and Cefas are thanked for providing access to OneBenthic data resources.

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SUMMARY - PREDICTIVE UK SEABED SEDIMENT (SBS) MAPPING

The national-scale Predictive Seabed Sediments (UK) dataset comprises four digital map products, including one classified SBS map, as well as maps of the predicted proportions of %gravel, %sand, and %mud. This User Guide describes the production of these maps which characterise the distribution of SBS composition across the UK Continental Shelf (UKCS). The maps are generated using a machine learning algorithm known as a Distributional Random Forest (DRF). The input data consists of more than 38,000 legacy measurements of the proportion of mud, sand and gravel from locations across the study area which were collated from various sources, as well as exhaustive maps of various covariates that are likely to be related to the spatial distribution of seabed sediments.

The predicted UK SBS map outputs were reviewed via a qualitative assessment (QA) protocol (e.g. contrasting with existing maps, and local examples higher-resolution data and mapping), and following methodological improvements based on this feedback, updated SBS map products were prepared. The results of statistical validation of the map outputs are presented in this report. Several measures of uncertainty are also presented together with the predicted SBS maps.

These maps are presented at a national-scale, with a spatial resolution of approximately 110m, covering the UKCS (*slightly modified UKCS area based on data availability*). The input data and model outputs are listed below.

Input data:

- Sediment sample compilation:
  - %Mud, %Sand, %Gravel (various sources, listed in the Appendix)
- Model covariates
  - Bathymetry data (EMODnet)
  - Bathymetric derivatives:
    - Slope
    - Maximum Curvature
    - Relative Topographic Position at four spatial scales
  - Hydrodynamics (EMODnet):
    - Kinetic energy – waves
    - Kinetic energy – currents
  - Distance from Coast

Predicted UK SBS map products:

- Classified SBS map (most likely class) (vector format):
  - Folk15 (also including Rock layer)
- Expected proportion of sediment (raster format) (0-100%):
  - %Mud
  - %Sand
  - %Gravel

The map citation, metadata and overview can be found here:
British Geological Survey, 2025. User Guide for Predictive Seabed Sediments UK v1. British Geological Survey. OR/25/040. https://doi.org/10.5285/5a74b5aa-ebe2-4079-a870-7f6c34e6ac3d

The information provided in this User Guide is intended to provide a quick-start guide to using and understanding this BGS digital product.

INTRODUCTION

PREVIOUS NATIONAL-SCALE SEABED SEDIMENT MAP PRODUCTS

The newly developed Predictive UK Seabed Sediment (SBS) map products presented here provide an update and alternative to previously released national-scale SBS products ('Seabed Sediments 250K' - https://www.bgs.ac.uk/datasets/marine-sediments-250k/), also known as DigSBS-250k. The SBS 250K map was first produced in 1977 and updated over multiple iterations, most recently in 2011 (BGS, 2011). This mapping built on the systematic programme of geological and geophysical surveying that BGS conducted across the UK Continental Shelf (UKCS) from the 1970s-1990s (Fannin, 1989). Interpreted sediment boundaries were based on manual delineation using available sediment samples, and increasingly high-quality and high-resolution seabed data that became available through the years (e.g. side-scan sonar, multibeam bathymetry & backscatter). The incorporated national-scale 250k SBS mapping therefore included largely qualitative interpretations undertaken by multiple mapping geoscientists over several generations, using data of variable quality and vintage.

In recent years there has been significant progress in developing more quantitative methods for mapping the distribution of SBS (e.g. Diesing et al., 2014; Misiuk et al., 2018), much of which has been driven within the benthic habitat mapping community (e.g. GeoHab). Approaches that incorporate, or are fully based upon, quantitative methods have several advantages: i) Reproducible, particularly for producing map updates when new data and/or methodological improvements become available, ii) reduce interpretation bias (e.g. potentially by multiple interpreters), iii) provide measures of uncertainty. For these reasons BGS has developed this new suite of map products to meet diverse user needs (e.g. habitat mapping and marine ecosystem science, marine aggregate and minerals, offshore infrastructure siting/monitoring, defence and shipping, and coastal and marine management).

PREVIOUS QUANTITATIVE APPROACHES TO MAPPING SEABED SEDIMENT COMPOSITION WITHIN THE EUROPEAN CONTINENTAL SHELF

The proportions of mud, sand and gravel within seabed sediment samples are compositional data. This means that these proportions must sum to 1 at every location. If the three proportions are modelled and mapped independently then generally this constraint will not be satisfied. Instead, the three proportions must be transformed to two correlated variables that are modelled and mapped across the study region. Upon back-transformation, the predicted mud, sand and gravel can be obtained. Lark et al. (2012) predicted the proportions of sand, gravel and mud across the UKCS by utilising the additive log-ratio (ALR) transform within a geostatistical approach. Their bivariate model (known as the co-kriging model) accommodated a correlation between the two transformed variables although the strength of the correlation was, perhaps unrealistically, required to be constant across the study area. They later extended their geostatistical approach to include linear relationships between the transformed variables and covariate data (Lark et al., 2015). Wilson et al. (2018) used a hybrid approach to map seabed sediment variables including the proportions of mud, sand and gravel. Interpolation was used to produce maps in regions of high data density whereas random forests were used to model the proportions in areas of low data density. In using this approach, the authors assumed that the same relationship between the sediment composition and the covariate data applied across the study region.

The Centre for Environment, Fisheries and Aquaculture Science (CEFAS; Mitchell et al., 2019) and The Geological Survey of the Netherlands (TNO-GDN, 2023) have recently used machine learning to produce large-scale maps of seabed sediment composition within the north-west European continental shelf. The TNO-GDN maps use classification random forests to directly classify the sediment according to the Folk15, Folk7 and Folk5 systems. They do not produce maps of the proportion of mud, gravel and sand, presumably because of challenges in ensuring that the expected values of these quantities are consistent with observed classes. These challenges arise because in regions consisting of quite distinct seabed sediment types, there is a tendency for the average of the gravel, sand and mud proportions to be predicted although samples with this composition might not be observed. In addition to various physical covariates, TNO-GDN include the coordinates and rotated versions of the coordinates within their random forests to account for any spatial pattern that is not explained by the physical covariates. The use of the coordinates as covariates can lead to sharp jumps in the predicted composition at certain longitude or latitude values and a banding effect is seen in the predicted maps. Such banding artefacts are minimized by also including rotated versions of the coordinates as covariates.

CEFAS (Mitchell et al., 2019) calibrated random forests for the ALR-transformed mud, sand and gravel proportions. They then back-transformed to produce maps of the expected proportions of each component and determine the Folk15, Folk5 and EUNIS level 3 classes which correspond to these expected proportions. Mitchell et al. (2019) provides thorough validation statistics for their predictions and classifications. These provide a means by which we can gauge the reliability of our maps although it should be noted that they are not directly comparable since our dataset and study area are not identical.

DATA AND METHODOLOGY

METHODOLOGY - A PREDICTIVE MODEL OF SEABED SEDIMENT COMPOSITION

This report describes the production of maps of seabed sediment composition across the UKCS. The maps are generated using a machine learning algorithm known as a Distributional Random Forest (DRF; Ćevid, et al., 2022). The input data consists of more than 38,000 legacy measurements of the proportion of mud, sand and gravel from locations across the study area which were collated from various sources, as well as exhaustive maps of various covariates that are likely to be related to the seabed sediment composition. The outputs are maps of:

- the expected proportion of gravel
- the expected proportion of sand
- the expected proportion of mud
- the most likely Folk15 class

A MACHINE LEARNING APPROACH TO THE SPATIAL PREDICTION OF SEABED SEDIMENT COMPOSITION

The seabed composition layers described in this report were produced using a DRF, as implemented in the Python DRF package (Michel et al., 2021). In common with previous large scale seabed mapping exercises, the ALR transform was applied to legacy observations of the proportions of gravel, sand and mud. Sediment observations collected before 1990 were removed from the dataset if a post-1990 sample had been collected within 0.04 degrees longitude/latitude. Where multiple observations had been collected from the same location only the most recent was included in the model. Observations collected from locations where any of the covariates had unrealistic values were also removed as were any samples where the sum of gravel, sand and mud was not 100%. A bivariate DRF was then calibrated to these transformed data and 22 layers of covariate data (12 covariates corresponding to 0, 15, 30, 45, 60, 75 degree rotations of latitude or longitude and 10 physical covariates described in Section 2.6). The calibrated DRF was then used to predict the expected mud, sand and gravel proportions and to determine the most likely classifications on regular rasters with spacing 0.001 degrees longitude or latitude across the UKCS. These rasters were converted to shapefiles.

The 38,207 legacy sediment samples were randomly divided into calibration (80%), validation (10%) and testing (10%) datasets. The testing data were used to experiment with different hyperparameter values for the DRF. The proportion of correctly classified test samples and the average root mean squared errors on predicting gravel, sand and mud were used as criteria to select the optimal value of these parameters. The final model was evaluated by predicting each of the output layers at the location of the validation data and determining the proportion of locations where the predicted classifications agree with the observed classes and the errors in predicting the mud, sand and gravel proportions.

This workflow tackles several of the challenges of mapping seabed sediment compositions and classifications. In particular:

- The use of a random forest algorithm permits complex (nonlinear and spatially varying) relationships between the covariate data and the legacy observations;
- The partial removal of pre-1990 data (keeping samples where no more recent sample had been collected nearby) managed the trade-off between the unreliability of old samples and the gaps that appear in the observation map if they are all removed;
- Unexplained spatially-correlated components of variation are represented by including longitude and latitude amongst the covariates and banding artefacts are minimised by also including rotated versions of these covariates;
- The use of the ALR transform ensures that the mud, sand and gravel components sum to 100%;
- The multivariate DRF accounts for the correlations between the two ALR transform components;
- The proportions of sand, gravel and mud and the probability of class memberships are consistent since they are all inferred from the same model.

The workflow differs from that adopted by TNO-GDN (2023) in that classification maps are inferred from predicted gravel, sand and mud maps rather than by a direct classification of the classes of each sample. It differs from the CEFAS (Mitchell et al., 2019) workflow (i) in the manner in which the classifications are derived from the gravel, sand and mud predictions and (ii) in using a bivariate random forest model rather than two univariate models.

From a probabilistic perspective, the classification maps are consistent with the expected mud, sand and gravel layers. However, it should be noted that at a particular location, the mapped mud, sand and gravel percentages might not correspond to the most likely class in a particular scheme. This is because the classification accounts for uncertainty in the mud, sand and gravel predictions.

SEDIMENT CLASSES

Model class predictions have been prepared according to the BGS modified Folk sediment classification scheme (Folk, 1954; BGS, 2011), which can be converted into several simplified variations (e.g. Long, 2006; Kaskela et al., (2019) (Fig. 1 and Table 1).

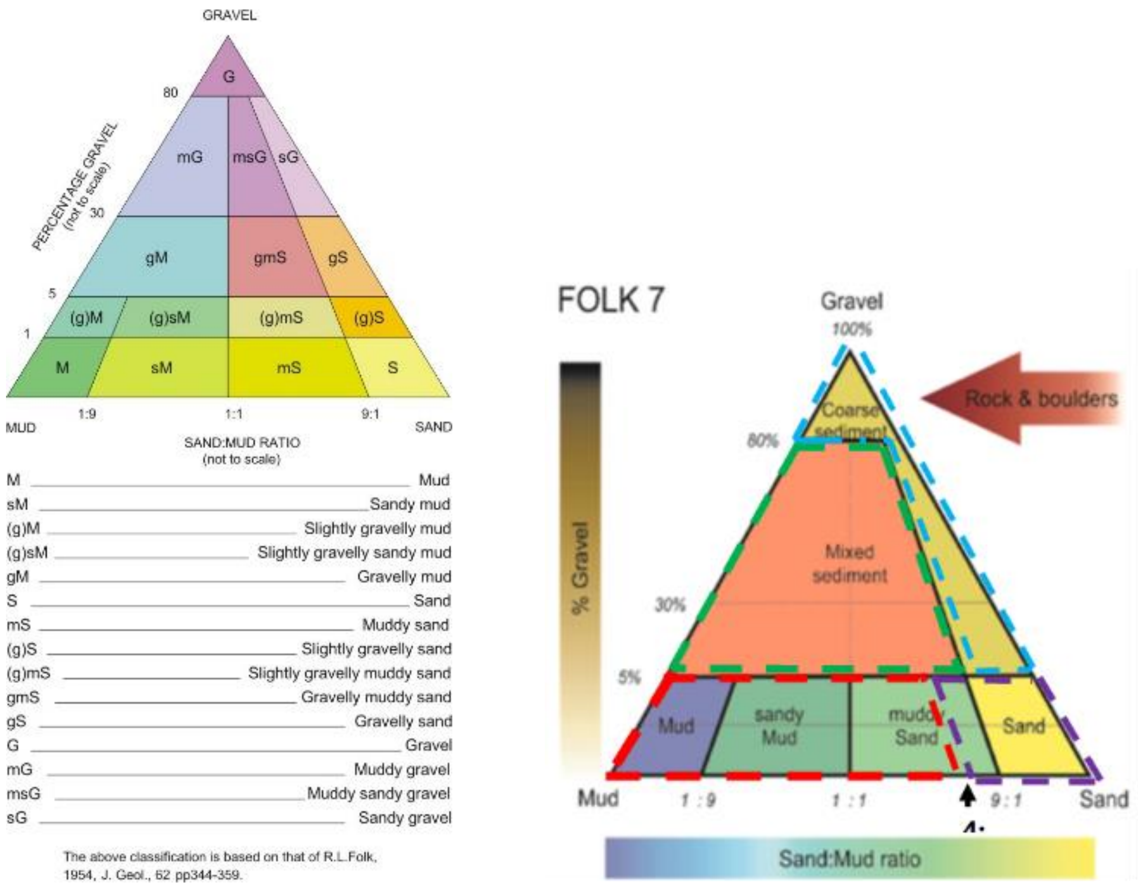

Figure 1. Left inset) BGS Modified Folk classification (Folk15) (Fig. 9); Right inset) Simplified Folk7 classification as well as modified sediment Sand:Mud ratio (i.e. 4:1) applied within the Hybrid class (Table 1). Modified from Kaskela et al., 2019. Only the Folk15 classification (+ rock) map is released here as a digital product (Fig. 9). The Hybrid classification map is shown for illustration purposes only (Fig.10).

Table 1: Common simplified/aggregated Folk sediment class variations:

Folk 7 class	**Marine Habitat Classification level 3 class**	**Hybrid/most granular class (Fig. 11)**	**Definition**
Rock	Rock	Rock	(spliced in from the previous rock mapping project)
Coarse sediment	Coarse sediment	Coarse sediment	
Mixed sediment	Mixed sediment	Mixed sediment	
Mud	Mud and sandy mud	Fine mud	As in Folk 7
Sandy mud		Sandy mud	As in Folk 7
Muddy sand		(Muddy) Muddy sand	Between 1:1 and 4:1 sand:mud
	Sand and muddy sand	(Sandy) Muddy sand	Between 4:1 and 9:1 sand:mud
Sand		Clean sand	As in Folk 7

ROCK AT SEABED

The distribution of rock (presented in Folk15 and Hybrid classified maps) is not an output from the predictive SBS model but instead taken from a previous JNCC-Cefas-BGS mapping initiative to produce national-scale layer of rock at seabed (Diesing et al., 2015; Downie et al., 2016; Brown et al., 2017), and compiled into a single layer within JNCC (2019). Within the classified Folk15 and Hybrid maps, where present, this rock layer replaces the model predicted sediment class. Where rock is present, it is denominated by R and ROCK.

QUALITATIVE QA PROCESS

A qualitative geological QA process was undertaken to 'sense check' the model SBS outputs, and contrast and compare against existing national, regional, and local-scale maps. Observations on the model outputs were captured as both site-specific feedback (e.g. classification bias/error resulting from duplicate samples – issue addressed), as well as thematic feedback. (e.g. apparent linear artifacts in several locations). This feedback was then used to adjust and improve model parameters.

The new predicted SBS maps were compared/contrasted (within a GIS environment) with the following existing maps:

- Local-scale (e.g. based on high-resolution bathymetry/backscatter):
    - BGS Seabed Geology mapping (https://www.bgs.ac.uk/datasets/bgs-seabed-geology/) (e.g. Bristol Channel, Offshore Yorkshire);
    - rMCZ mapping - https://hub.jncc.gov.uk/assets/eb19497a-5b36-480d-8b46-23b8318e007a;
    - Previous BGS predictive mapping (Farnes MCZ) (Lark et al., 2015);
- National-scale:
    - BGS Sediment Sediments 250k (https://www.bgs.ac.uk/datasets/marine-sediments-250k/);
    - Previous BGS predictive mapping (based on samples only) (Lark et al., 2012);
    - Cefas predictive mapping (Mitchell et al., 2019);
    - Sediment mapping to support sedimentary Carbon assessment (Smeaton et al., 2021.

Importantly, the maps were also directly/visually compared (within a GIS environment) with the sample database as well as the EMODnet bathymetry, and high-resolution multibeam bathymetry in a number of locales to investigate the relative fit with observed seabed geomorphology (e.g. large sediment banks (which may or may not have sediment samples) associated with sand-rich sediment).

MODEL INPUT DATA

SAMPLE DATA COMPILATION

A list of the input particle size analysis (PSA) datasets is presented within the Appendix. The data were obtained from various online sources, data providers and data compilations including BGS Seabed Samples, OneBenthic (Cefas), ICES, Marine Recorder, INFOMAR, JNCC Survey data and others. Existing data compilations such as OneBenthic were particularly useful. The distribution of PSA sediment samples used is shown in Figure 2.

Some datasets contained %Mud, %Sand, %Gravel, whereas some contained grainsize fractions which were combined. The data were reformatted where necessary and compiled together into a single file containing Longitude, Latitude, %Mud, %Sand, %Gravel for each sample. Additional metadata were also extracted and included where available (SurveyID, SurveyName, SampleID, SampleAlias, Owner, Equipment, Date, Access).

Distribution of sample data is variable (Fig. 2), particularly for more recent (post-1990) data with more accurate positions. Some recently collected data were either not yet available, not received in time or were restricted so were not included in this compilation. There are several geographic gaps in coverage, such as the northerwestern area beyond the continental shelf break, the far northern area and southwest Celtic Sea area. There is also a notable, and surprising sample gap off part of the Dorset coast within the English Channel. Some recent data, such as data from the Poseidon project which were not yet available at the time of this project may help partially fill some gaps.

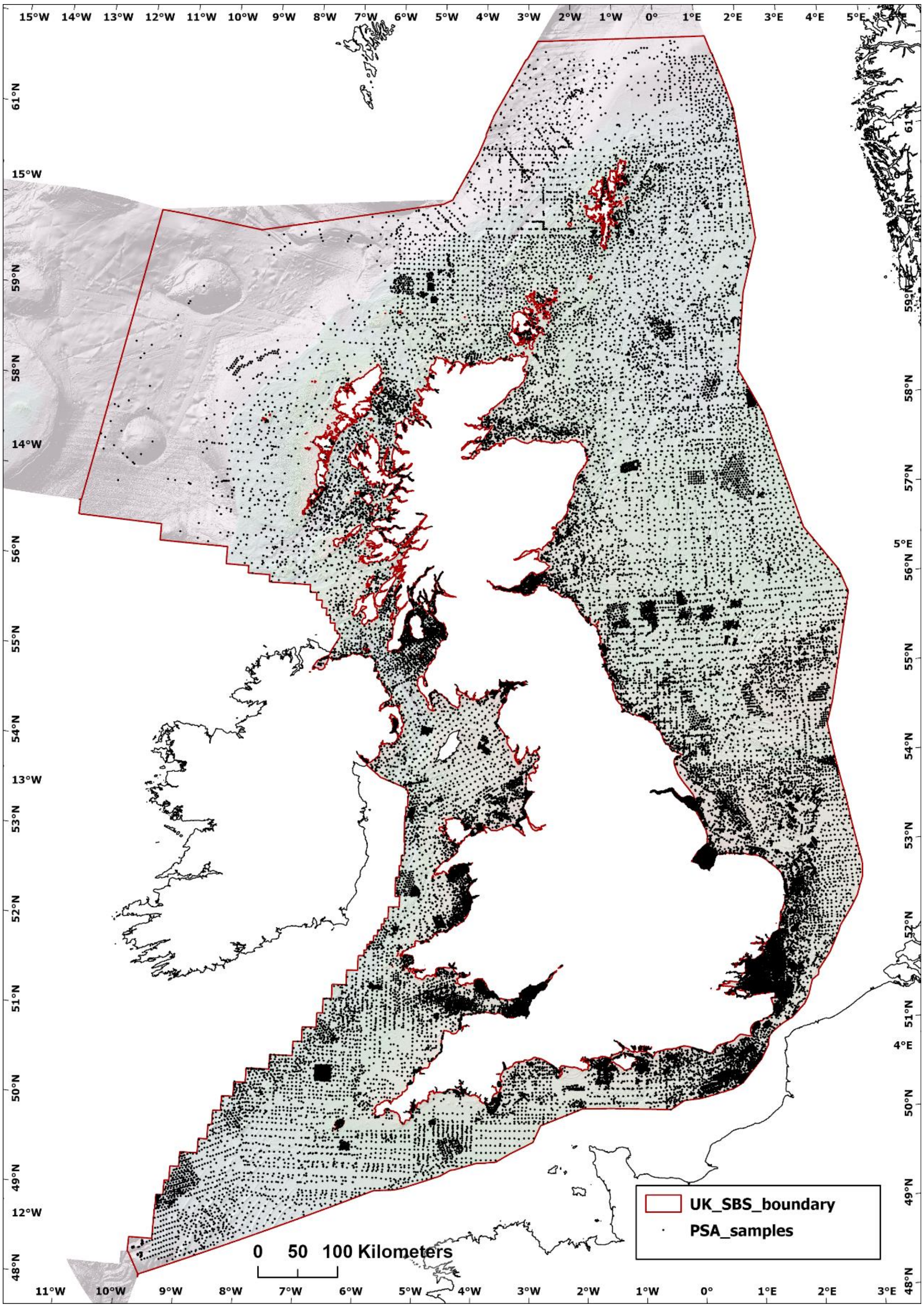

Figure 2. Distribution of PSA sediment samples used within this study. Figure contains EMODnet bathymetry © European Union, available under CC BY 4.0.

The data included in the input data compilation were generally openly available with a few exceptions. A small portion of the data in the BGS Seabed Samples dataset with a variety of data owners are currently restricted. Work is currently ongoing though a data approval process to release these data via the BGS GeoIndex Offshore. The compiled % gravel/sand/mud data file which is a useful resource could then be published as a standalone dataset. Further work would be required to incorporate the full PSA data into the BGS database/GeoIndex.

Some data were initially considered, but not used because they did not contain required data such %gravel/sand/mud or positions. For example, sample data from the Maritime and Coastguard Agency (MCA) led UK Civil Hydrography Programme (CHP) contain visual descriptions of sediment only rather than quantitative data.

Around 10000 CHP seabed samples are stored at the BGS Core Store. Grab samples are routinely collected on an approximately 5 km grid within the CHP survey areas with at least one sample being taken in each major textural area identified, giving the most numerous, and widely distributed seabed sediment samples around the UKCS. However, these samples are currently under-utilised. Undertaking systematic particle size analyses on these samples (and future samples) is recommended as this would be help fill gaps in data coverage for input into future versions of the Seabed Sediment map as well as providing significant value to other UK marine activities/stakeholders.

Improving data flows could also improve the data distribution for future compilations. There were some overlaps of samples between various datasets. The contents between compilations such BGS and Cefas OneBenthic could be cross-checked. Data flows could be clarified and refined to increase the efficiency of compiling data. While it is possible in some cases to request access to restricted data from the data owners, particularly for industry data, this can be time-consuming. Open release of PSA data without long delays would also help make data flows more efficient.

MODEL COVARIATES

All model covariates have full coverage, and are spatially continuous across the UKCS area. Covariate figures are presented within the Appendix (Figs. 13-21).

BATHYMETRY DATA (EMODNET)

Bathymetry data (depth to seabed) represents a fundamental dataset, and the EMODnet Bathymetry compilation represents the best available bathymetric surface with coverage across the entire UKCS (Fig. 3) (EMODnet, 2022). The EMODnet bathymetry is provided in geographic coordinates with a spatial resolution of 1/16 x 1/16 arc minutes (~110m).

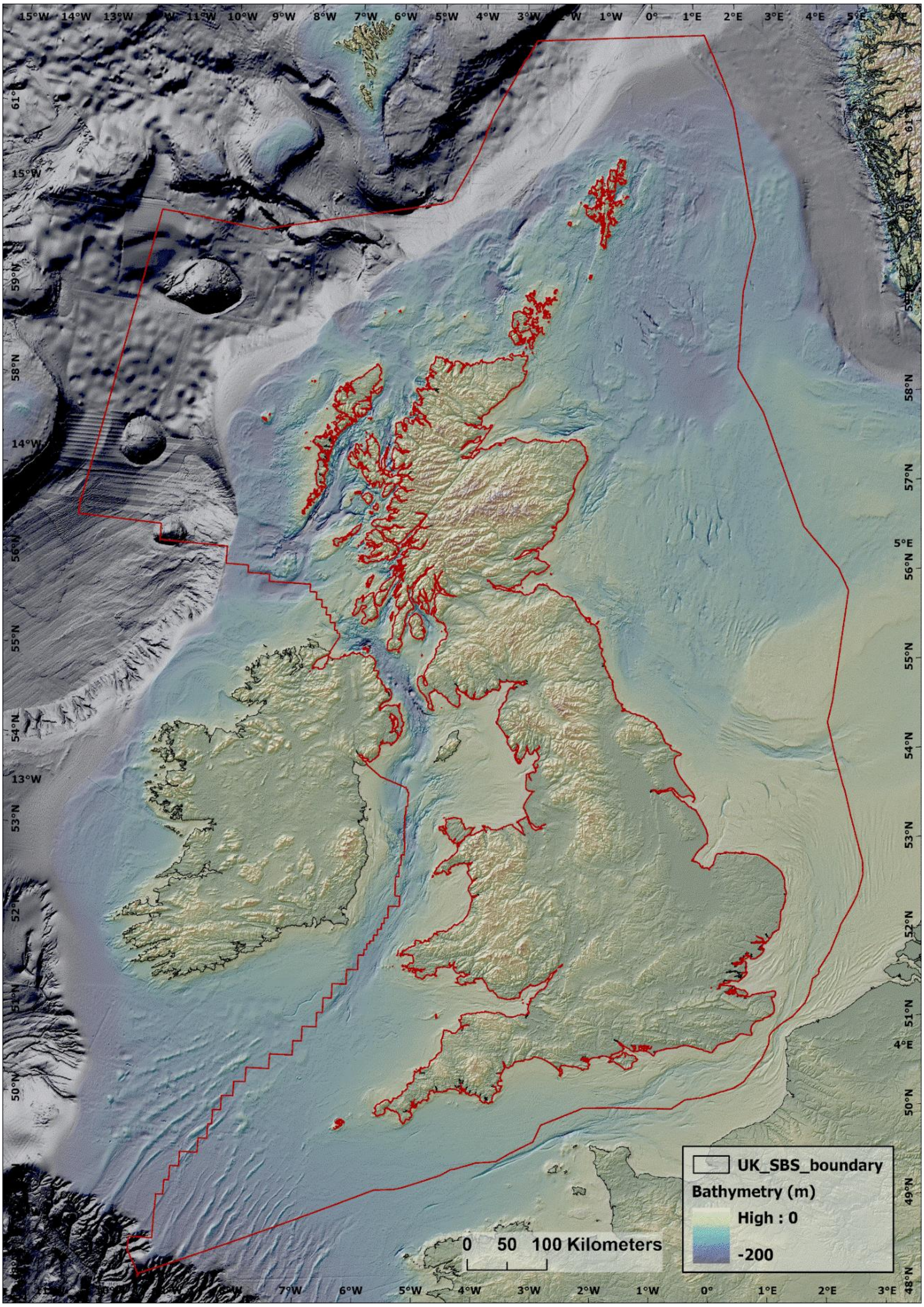

Figure 3. Regional Bathymetry data shown with the modified UKCS boundary used within this project. EMODnet Bathymetry. Figure contains EMODnet bathymetry © European Union, available under CC BY 4.0.

BATHYMETRIC DERIVATIVES:

The bathymetric derivatives are all derived from the EMODnet bathymetry, and shown within the Appendix.

SLOPE
Bathymetric slope (degrees) was calculated within ESRI ArcGIS Pro using the Planar method.

MAXIMUM CURVATURE
Maximum Curvature was calculated within Whitebox Geospatial software (Lindsay, 2016), where the highest value of curvature is expressed at a given point of the topographic surface. Curvature values are dimensionless, and positive values correspond to ridge positions while negative values indicate closed topography (e.g., depression or channel).

RELATIVE TOPOGRAPHIC POSITION (RTP)
RTP measures the relative highs and lows of a topographic (in this case bathymetric) surface within a specified local neighbourhood. RTP was calculated at four spatial scales (5cell - 550m; 21cell - 2310m; 89cell - 9790m; 377cell - 41,470m), within Whitebox Geospatial software (Lindsay, 2016). Values are bound between -1 and 1, corresponding to negative and positive morphology respectively.

HYDRODYNAMICS
Hydrodynamic layers were sourced from the EMODnet product catalogue, and were both originally prepared to support the EUSeaMap project (https://emodnet.ec.europa.eu/geoviewer/)

KINETIC ENERGY AT SEABED DUE TO WAVES
The kinetic energy due to wave action at the seabed has been expressed here as $KE = \frac{1}{2} mUwp^2$, where Uwp is the peak value of water particle velocity on the seabed during the passage of the wave. A high resolution (~300m) bespoke wave model based on the DHI Spectral Wave model was used to augment the coastal areas where the ProWAM model resolution was inadequate. Energy layers were built using data from National Oceanographic Centre (NOC) wave (ProWAM at a resolution of 12.5km) and current models (the CS20, CS3 and NEA models at resolutions of 1.8km, 10km and 35km respectively).

EMODnet dataset identifier: ke_waves_atlantic

(https://emodnet.ec.europa.eu/geonetwork/srv/api/records/2a2659c4-ce1b-4feb-81cf-a2bcbc362a3f)

KINETIC ENERGY AT SEABED DUE TO CURRENTS
90th percentile Kinetic Energy due to currents at the seabed in the Atlantic Sea, expressed in: N / m^2. Created for the EMODnet Seabed Habitats broad-scale habitat map. North Sea and Celtic Seas (year 2001): a composite created by ABPmer of NOC POLCOMS CS20 (1.8km resolution); NOC POLCOMS CS3 (10km (2007) and NOC POLCOMS North East Atlantic.

EMODnet dataset identifier: ke_currents_atlantic
(https://emodnet.ec.europa.eu/geonetwork/static/api/records/d72bfeca-ceb5-4faa-b7b0-e95db8c6310b)

DISTANCE FROM COAST
The Distance to the nearest coast covariate was developed by NASA's Ocean Biology Processing Group. The global dataset was clipped to the UKCS, and is available at 0.04 degree grid increment (NASA, 2009).

AREA POLYGON – MODIFIED UKCS
While the project aimed to have full UKCS coverage, i.e., infilling the entire official UKCS area (which extends beyond the geological continental shelf), sample data scarcity beyond the shelf break required that we limit the area to ensure model validity, as well as minor variations along the coast.

An initial UKCS polygon based on UKHO boundaries was provided by JNCC, then clipped in three areas to exclude areas with low sample density: 1) far NW (e.g. Rockall Basin and Hatton Bank), 2) far SW (beyond Celtic Sea shelf break), and 3) very far North (part of Norwegian Channel). Coastline sourced from Marine Regions available under CC BY 4.0.

Offshore from the UK coast, the project UKCS polygon was further modified according to the following principles (in order of priority): 1) the UKCS polygon extends to the coast where all model covariates are present (i.e., overlapping), and 2) the UKCS polygon extends to 500m distance from the coast.

A buffer of 1km beyond the final project UKCS polygon was given to all model covariates to avoid any potential boundary artifacts within the modelling, and clipped to the project UKCS polygon for submission.

RESULTS

The new BGS Predictive Seabed Sediments UK (v1) provide digital maps of seabed sediment (SBS) composition across the UK Continental Shelf (UKCS). These sediments are those that are present at seabed, the interface between the geological substrate below, and the water column above. The physical properties and grain size (or composition) of these sediments depends on a variety of factors, including: the nature of the underlying geology (e.g. glacial vs. unconsolidated marine deposits), the hydrodynamic environment, terrigenous sediment input (e.g. fluvial), biogeochemical processes operating at the seabed, and the physiography and geomorphology of the seabed environment (e.g. Pantin, 1991; Reynaud and Dalrymple, 2012; Gao and Collins, 2014; Amaro et al., 2016; Caruso et al., 2022). Seabed sediments are commonly unconsolidated, and as such are potentially transitory and mobile over variable timescales (e.g. tidal, seasonal, storm cycles).

This section describes the implementation and results of the newly developed predictive mapping approach, as well as a qualitative assessment of the predictive SBS maps. The primary classified map is the predicted Folk SBS map (15 sediment classes + rock), emulating past BGS SBS map products (Fig. 9). Percentage sediment maps (%mud/sand/gravel) are also delivered (Figs. 6-8), and these maps often show greater detail and nuance with regards to sediment distribution and associated processes. We also present (for illustration only) a simplified 'Hybrid', classified Folk map (Fig. 10) as this is commonly used within marine ecosystem studies, and this also demonstrates how the predictive approach can easily generate variable classified outputs. We reiterate here that the rock distribution within the classified maps is not a product of the predictive sediment modelling, but rather is taken from a previous rock mapping exercise (Section 2.4; JNCC, 2019).

IMPLEMENTATION OF THE DRF ALGORITHM

The DRF hyperparameter experiments revealed that the minimum number of observations in a node was the parameter which primarily controlled prediction accuracy. The most accurate predictions occurred when this was set to two and the DRF contained more than 500 trees. The final model was fitted with a minimum of two observations per node and 1000 trees.

The importance of each of the covariates within the DRF was assessed by randomly permuting the values of that covariate and then quantifying the increase in mean squared error of predictions. This process indicates (Fig. 4) that kinetic energy at seabed due to currents ('KE_current') is the most important covariate. Kinetic energy at seabed due to waves ('KE_wave'), latitude ('Lat'), bathymetry ('Bathy'), distance from coast ('Coast_dist') and relative topographic position over 377 cells ('RTP_377') are also important covariates to a similar degree. None of the other physical covariates impact the predictions (with the available sample data) beyond the level of the various rotations of longitude and latitude. It is possible that with higher sediment sample density, finer-scale covariates may offer improved predictive power (e.g. RTP_21 and RTP_89). The importance however of the kinetic energy covariates is clear, highlighting that hydrodynamic layer selection will be a key consideration for future model improvements.

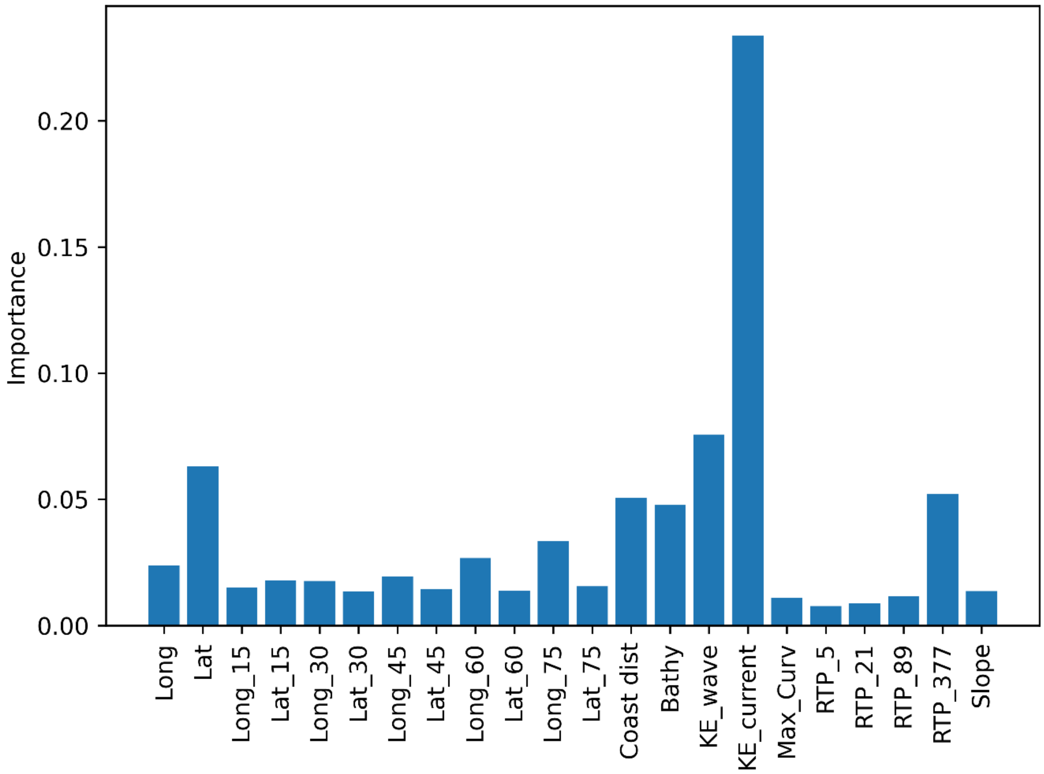

Figure 4. Importance of the different covariates in the SBS machine learning model.

Clear positive correlations are evident between the predicted and observed values of the ALR transformed variables at the sites of the test data (Fig. 5). The proportions of variance explained for each variable are 0.56 and 0.71. On average, these values are slightly less than the proportions of 0.63 and 0.68 explained by the model of Mitchell et al. (2019).

The Confusion table (Table 2) indicates the proportion of observations in the test data that are correctly classified according to the Folk15 scheme. The overall accuracy is defined as the proportion of observations that are correctly classified. The producer's accuracy for a particular class is the proportion of observations of that class which are correctly classified. The user's accuracy for a class is the proportion of predictions of that class that match the corresponding observed values. The overall accuracies for the Folk15 and Hybrid schemes is 57% and 69% respectively. In common with the results of Mitchell et al. (2019), this accuracy is likely to be inflated due to the spatial clustering of observations where detailed seabed sediment surveys have been conducted. Mitchell et al. (2019) recorded slightly larger accuracy of 59%, but this improvement are likely to have been the result of them removing all pre-1990 observations from the data set leading to a proportionally more clustered dataset. Indeed, when our model was re-fitted without any pre-1990 data, a marginally larger accuracy than that of Mitchell et al. (2019) was obtained.

For all classification schemes it is evident that the producer's accuracies are larger for the most abundant classes. The most abundant class, 'Sand', has a producer's accuracy of 84% whereas only four other classes have producer's accuracy greater than 50%. This is an indication that the proportion of the most abundant classes are being over-estimated by the model and conversely the proportions of the least abundant classes are being under-estimated. For instance, 1045 of the validation samples were observed to be 'Sand' according to the Folk15 scheme whereas 1470 'Sand' samples were predicted. Conversely, 23 'gravelly mud Sand' samples were observed but only 11 were predicted. The same issue is evident to a larger degree in the results of Mitchell et al. (2019). In their Folk 15 classification, only the 'Sand' class had producer's accuracy greater than 50%.

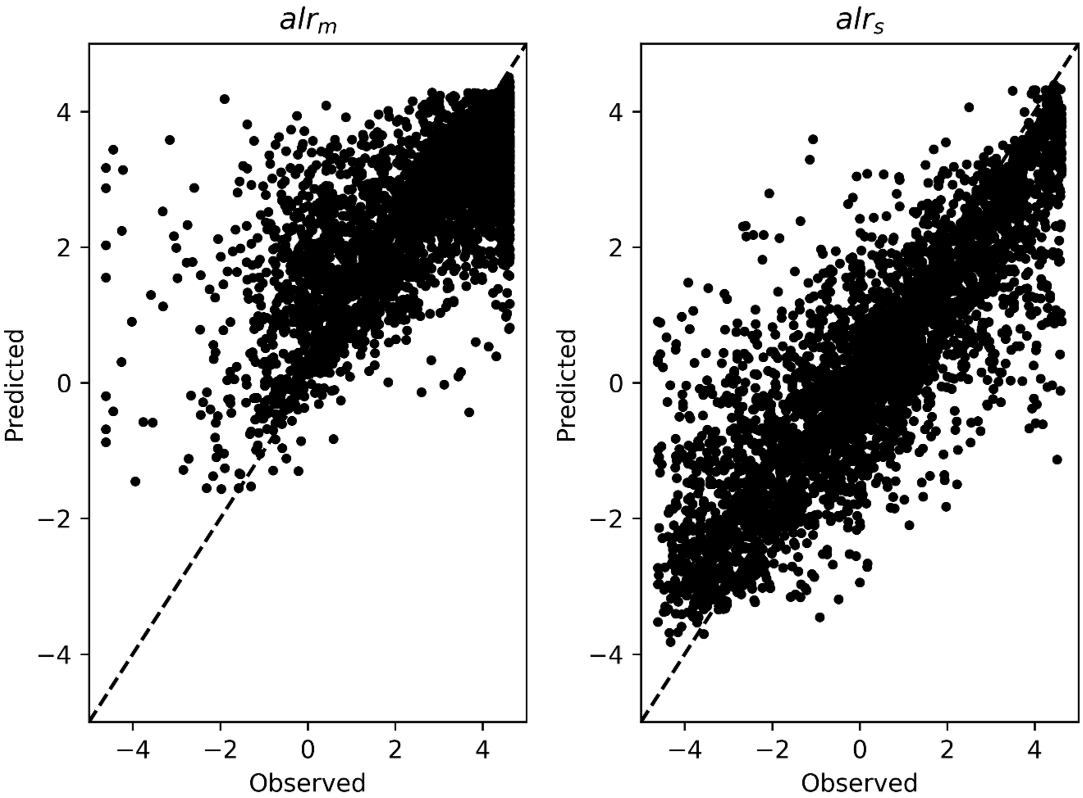

Figure 5. Comparison of observed and predicted ALR transformed sediment composition values for the test data.

Table 2. Confusion table for Folk15 classification. Abbreviations for confusion table: ‘M’ Mud; ‘sM’ sandy Mud; ‘mS’ muddy Sand; ‘S’ Sand; ‘(g)M’ (gravelly) Mud; ‘(g)sM’ (gravelly) sandy Mud; ‘(g)mS’ (gravelly) muddy Sand; ‘(g)S’ (gravelly) Sand; ‘gM’ gravelly Mud; ‘gmS’ gravelly muddy Sand; ‘gS’ gravelly Sand, ‘mG’ muddy Gravel, ‘msG’ muddy sandy Gravel, ‘sG’ sandy Gravel, ‘G’ gravel; ‘fM’ fine Mud; ‘(m)mS’ (muddy) muddy Sand; ‘(s)mS’ (sandy) muddy Sand; ‘clean S’ clean Sand; ‘M & sM’ Mud and sandy Mud; ‘S & mS’.

		Observed																
		M	sM	mS	S	(g)M	(g)sM	(g)mS	(g)S	gM	gmS	gS	mG	msG	sG	G	Sum	User's acc
Predicted	M	30	4	1	1	1	1	1	0	0	1	2	2	0	3	1	48	62
	sM	23	133	22	4	0	9	5	1	4	5	0	1	1	1	0	209	63
	mS	3	37	331	53	0	3	49	13	3	17	8	0	10	3	1	531	62
	S	4	27	112	883	0	3	18	161	1	37	115	0	22	67	20	1470	60
	(g)M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	(g)sM	1	3	0	0	0	2	2	0	2	1	0	0	0	0	0	11	18
	(g)mS	0	0	0	1	0	0	13	1	0	3	1	0	0	0	0	19	68
	(g)S	0	0	3	30	0	0	4	89	0	8	25	0	3	2	0	164	54
	gM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	gmS	0	0	3	5	0	1	7	9	5	65	14	0	17	1	0	127	51
	gS	3	3	2	50	0	3	8	111	3	31	336	3	18	138	6	715	46
	mG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	msG	0	0	0	1	0	0	2	0	2	6	2	0	26	5	2	46	56
	sG	0	0	0	15	0	1	1	18	3	12	76	1	26	257	31	441	58
	G	1	0	0	2	0	0	0	0	0	0	3	0	3	9	14	32	43
	Sum	65	207	474	1045	1	23	110	403	23	186	582	7	126	486	75	3813	
	Prod acc	46	64	69	84	0	8	11	22	0	34	57	0	20	52	18		57

Table 3. Confusion table for the Hybrid classification. Number of correctly classified validation samples are highlighted in grey. Abbreviations for confusion table given in Table 2.

		Observed								
		fM	sM	(m)mS	(s)mS	mixed	clean S	coarse	Sum	User acc. %
Predicted	fM	26	3	2	0	3	0	4	38	54
	sM	30	158	33	5	20	5	3	254	62
	(m)mS	1	25	191	48	13	20	6	304	63
	(s)mS	0	0	17	57	5	9	0	88	65
	mixed	1	3	9	10	125	17	24	189	66
	clean S	4	30	80	118	73	1224	229	1758	70
	coarse	4	11	7	7	103	173	877	1182	74
	Sum	66	230	339	245	342	1448	1143	3813	Overall
	Prod. Acc %	39	69	56	23	37	85	77		69

PREDICTIVE SBS MAP OUTPUTS

Below we present several key map outputs, including the percentage sediment (proportions of gravel/sand/mud) (Figs. 6-8), as well as the classified Folk15+rock, and Hybrid SBS maps (Figs. 9-10).

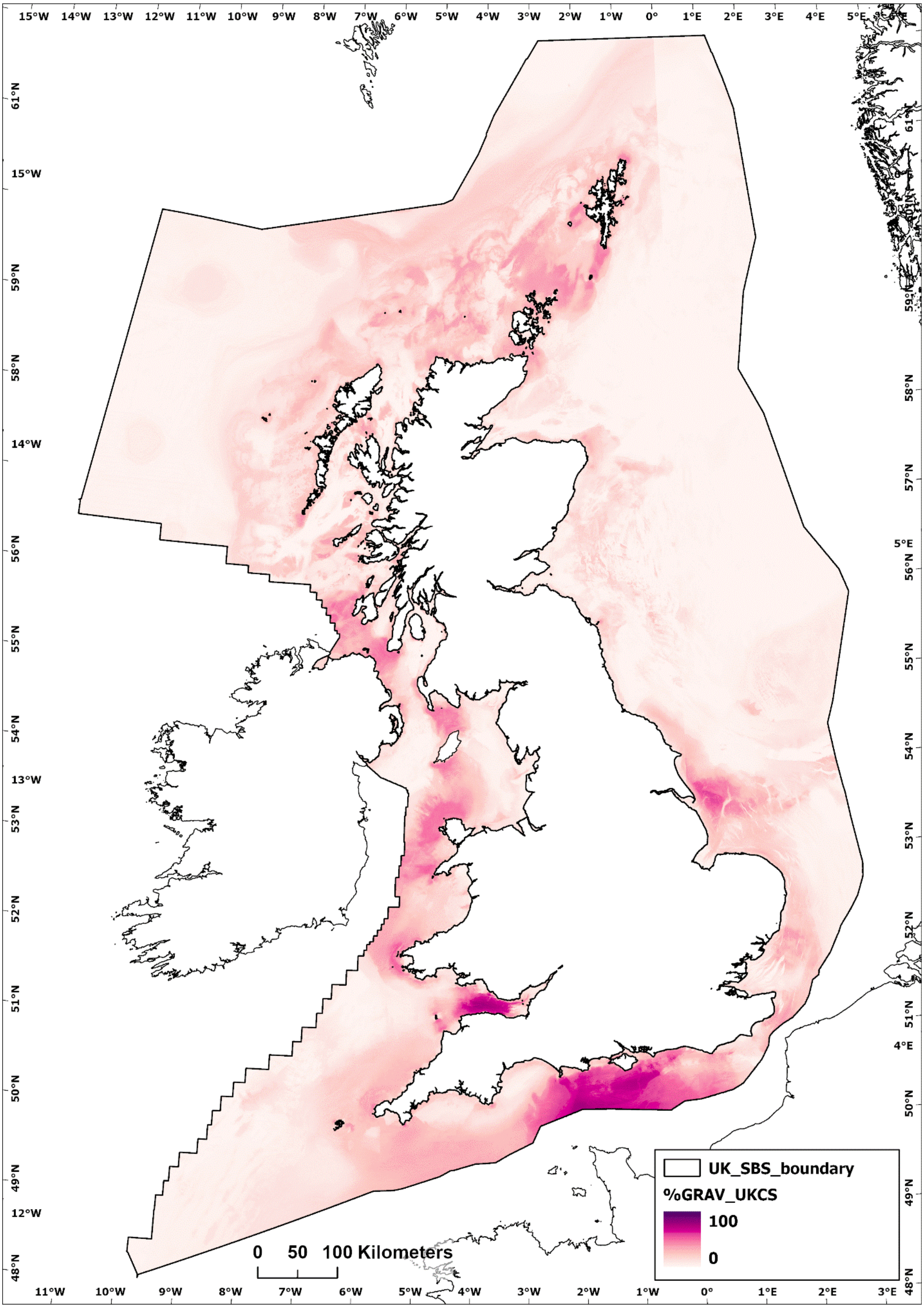

Figure 6. Predictive SBS map product: The expected proportion of gravel.

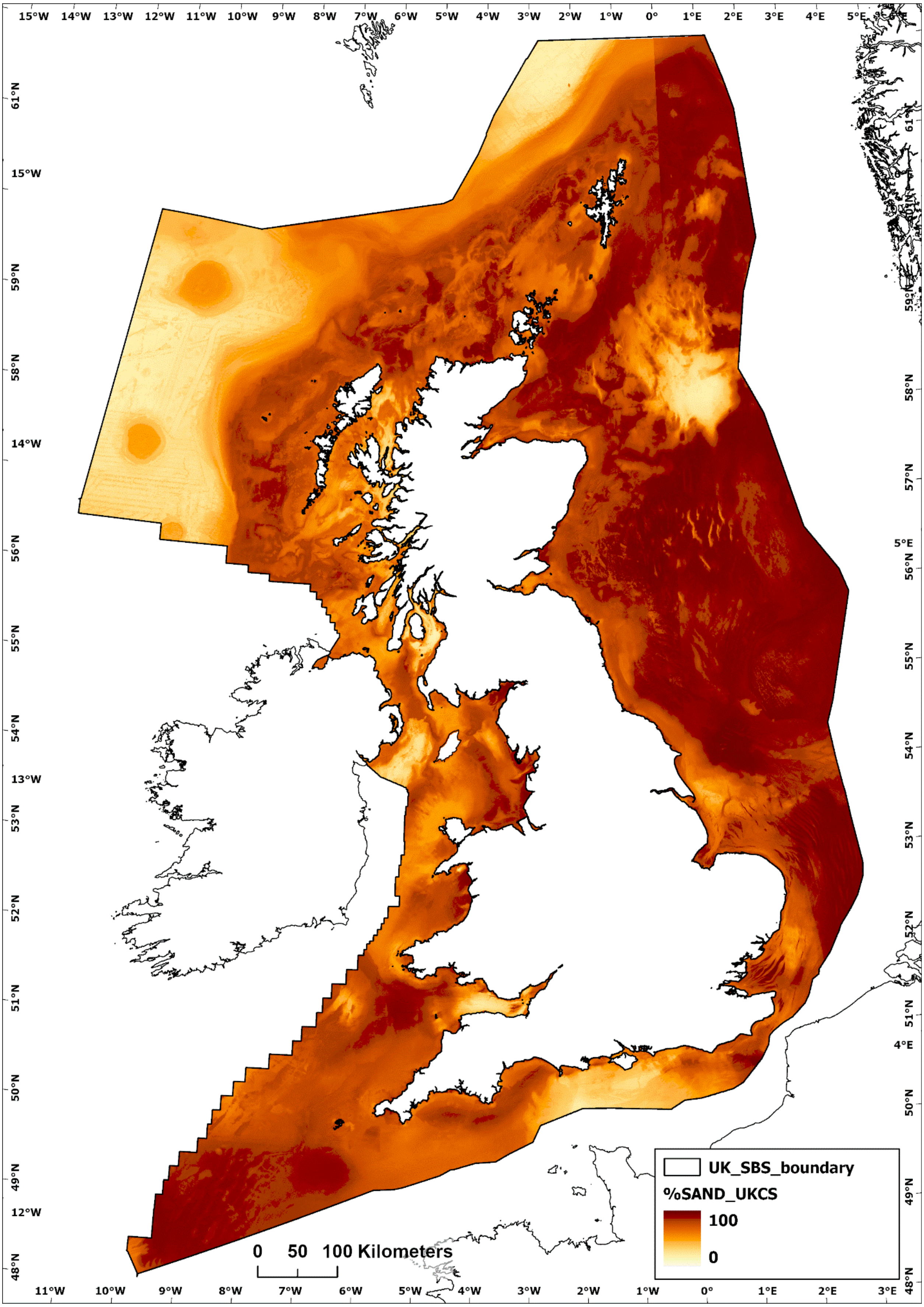

Figure 7. Predictive SBS map product: The expected proportion of sand.

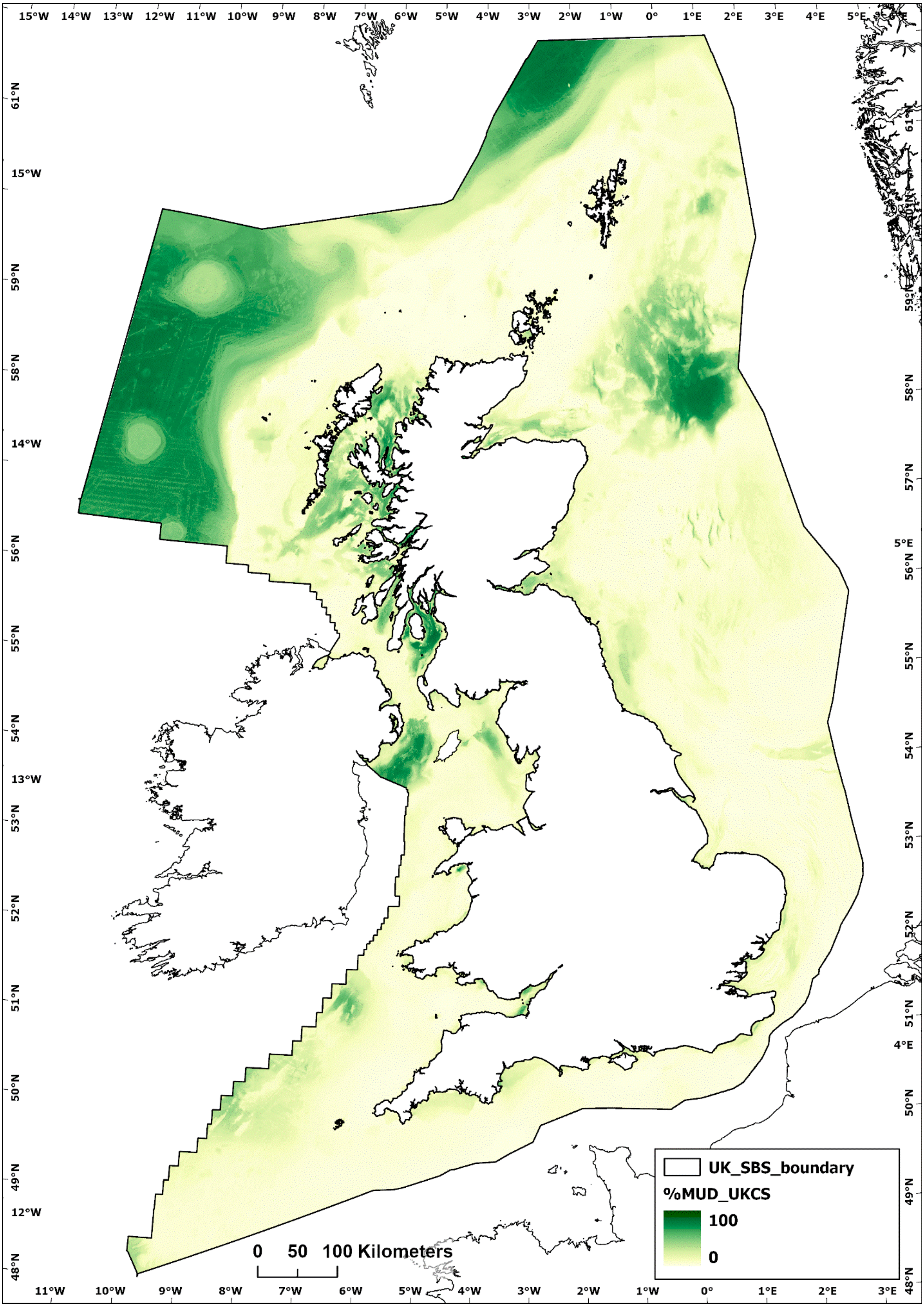

Figure 8. Predictive SBS map product: The expected proportion of mud.

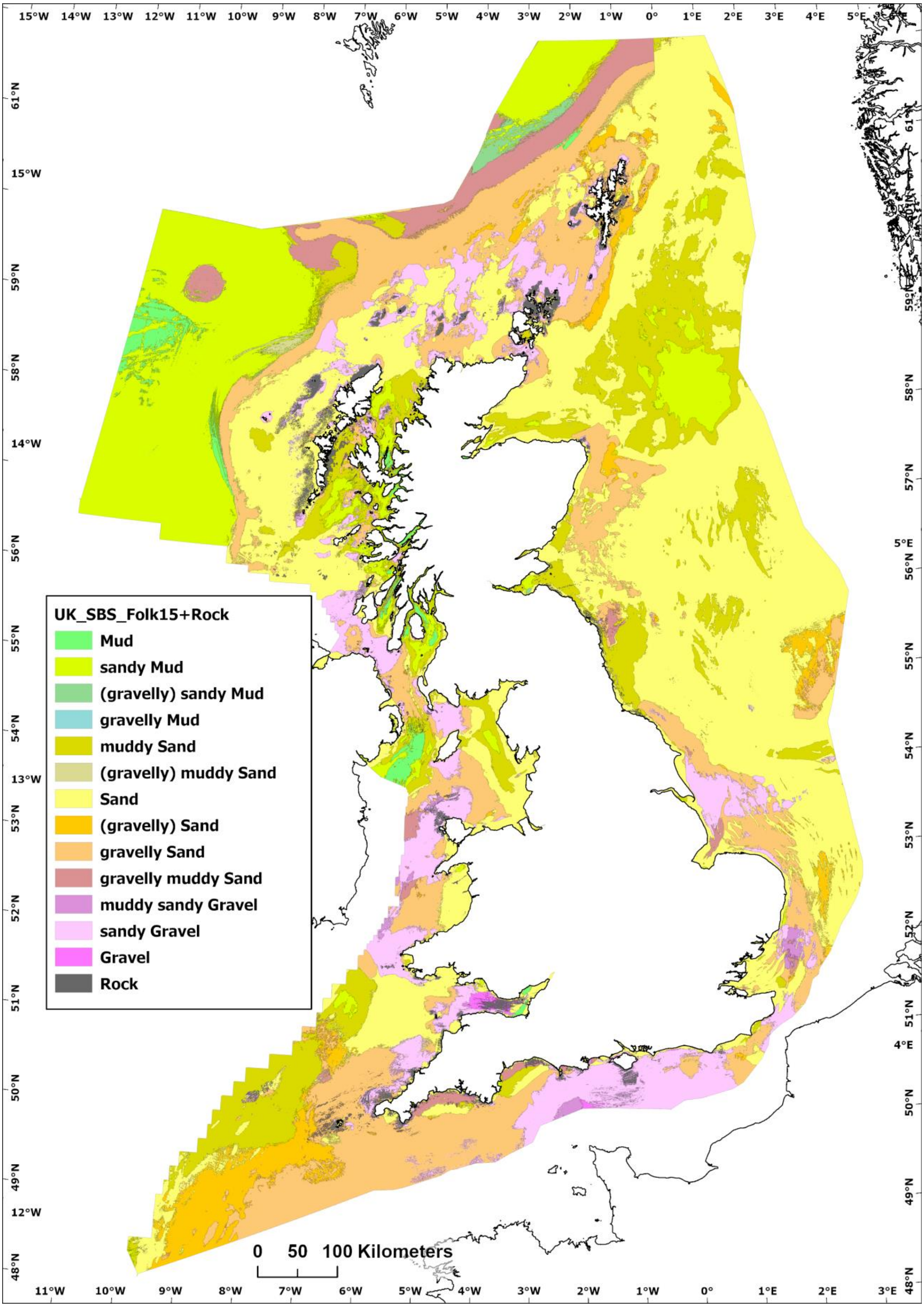

Figure 9. Predictive SBS map product: Mostly likely sediment class according to Folk15 classification + rock.

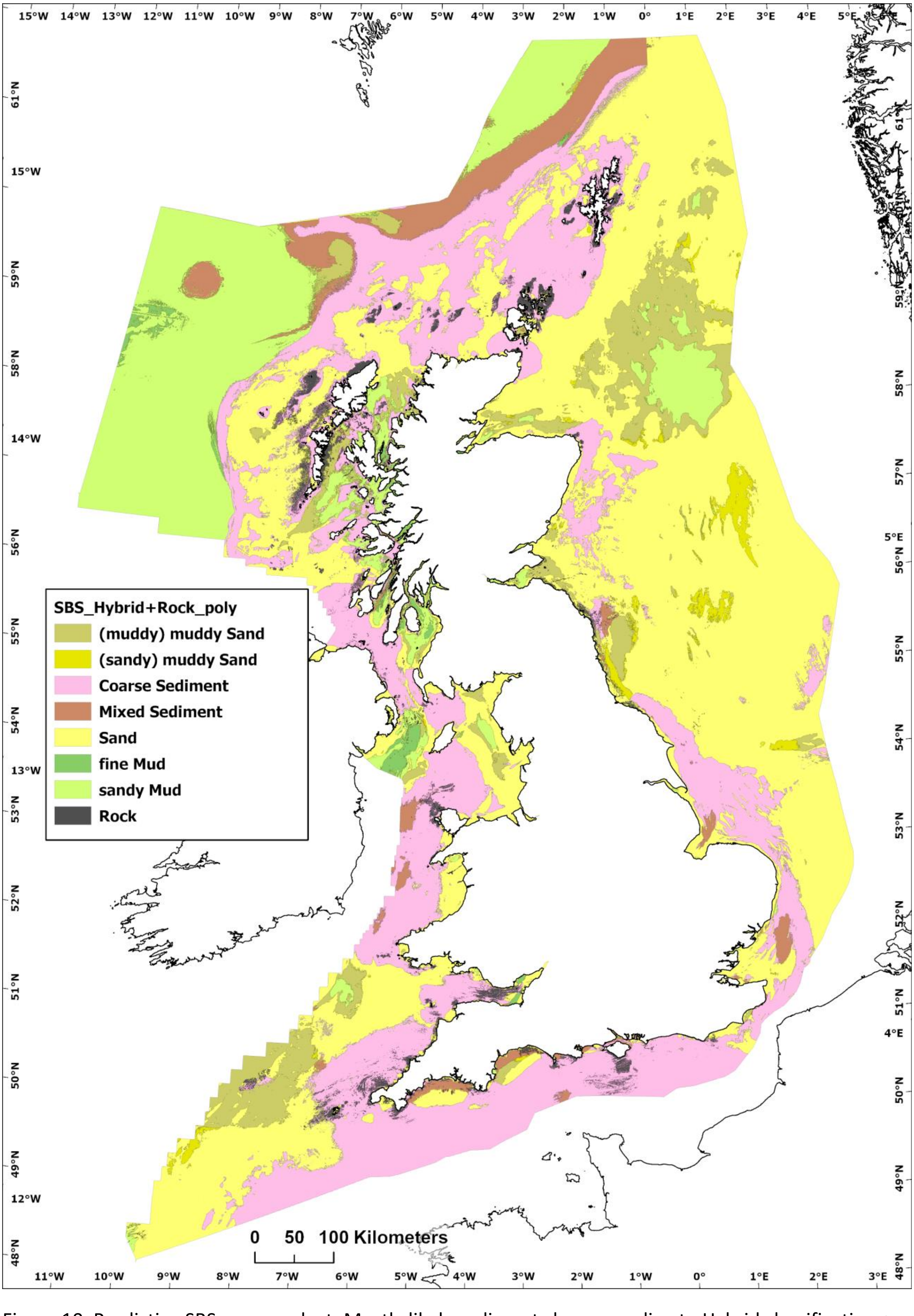

Figure 10. Predictive SBS map product: Mostly likely sediment class according to Hybrid classification + rock Included for illustration purposes only, i.e. not released as BGS product.

QUALITATIVE GEOLOGICAL ASSESSMENT

Overall, we are impressed with the overall apparent accuracy of the model, consistency across the UKCS, as well as the detail the new predicted SBS maps manage to capture. The percentage sediment maps (%mud/sand/gravel) in particular show great complexity, which in almost all circumstances that we've checked appears to correlate with local (e.g. seabed geomorphology), as well as regional phenomena (e.g. hydrodynamic energy and sediment sample distribution). For example, the model will predict (accurately in our interpretation) that large banks (e.g. sediment banner banks) are associated with sand-rich sediment, even when no samples are present, and the geometry of the predictions (%sediment and classified maps) is concordant with the geometry of the geomorphological feature.

We also note that the new predicted SBS maps compare favourably in comparison to previous predictive SBS mapping efforts (e.g. Lark et al., 2012; Mitchel et al., 2019; Smeaton et al., 2021). The new maps build and improve on previous predictions by producing a clearer association with seabed geomorphological features at multiple scales, and are not affected by apparent 'bullseye' gridding artefacts (i.e. concentric pattern around sample points) observed in some previous efforts.

There are several linear artifacts (e.g., outer Bristol Channel) in the model which we will aim to redress within future versions. In some largely flat areas, e.g., on Dogger Bank, but particularly within the deep Rockall Basin (where there is also low sample density), apparent ship track artifacts are also preserved within the final map outputs.

CONCLUSIONS AND FUTURE WORK

The quantitative predictive mapping (DRF) approach has led to predictions and classifications of seabed sediment composition of a similar degree of accuracy to those of Mitchell et al. (2019). In the classifications of Mitchell et al. (2019), the proportions of the most abundant classes were over-predicted. A similar problem is evident in our classifications but to a lesser extent.

The qualitative geological QA demonstrated that the new predictive SBS maps show excellent detail that correlates well with seabed features (and interpreted sediment associations), and the apparent accuracy appears high and consistent across the UKCS. Future work will hopefully incorporate multibeam echosounder bathymetry and backscatter data (where available over extensive areas) to provide further detail and accuracy of the SBS map predictions.

There are a number of issues in the production of these maps that merit further investigation. The primary one of these is the clustered nature of the available sediment composition observations. The problem of clustered data when using random forests to predict maps has been recognised as an issue (Wadoux et al., 2020) but no general solution has been accepted. Selective down-sampling of the clusters might lead to improved predictions. The tests of hyperparameters could be expanded as the impact of removing non-important covariates from the model could be explored.

Further work could enhance the input particle size analysis input data for future versions by incorporating additional datasets, securing permissions for restricted data and releasing data where possible. It would also be beneficial to add data to the BGS database/GeoIndex, cross-check contents between compilations such BGS and Cefas OneBenthic and ensure efficient data flows. Additionally, undertaking and including analyses from Civil Hydrography Programme samples would further enrich future versions.

TECHNICAL INFORMATION

SCALE

This Predictive Seabed Sediments (UK)dataset is produced for use at a national-scale scale, with a spatial resolution of approximately 110m covering the UKCS (*slightly modified UKCS area based on data availability*) (Section 2.6.3)

COVERAGE

The BGS Predictive Seabed Sediments (UK) map covers an area of approximately 646,578.16 km^2 (Figures 3,11).

Figure 11 - Coverage of BGS Predictive Seabed Sediments (UK) shown in dark blue. Background image from World Ocean Base dataset compiled by Esri, Garmin, GEBCO, NOAA NGDC, and others (Ocean Basemap).

ATTRIBUTE DESCRIPTION

Each geological theme (map layer) in BGS Predictive Seabed Sediments (UK) a series of attribute fields. Attribution is specific to the layers, for example, bedrock objects are attributed with lithostratigraphy, chronostratigraphy or lithodemic class, whereas the *Structural Geology* layer with features such as fractures is not. Table 4 describes the attribute fields in each layer. Note the following abbreviations are used as attribute values: N/A - Not applicable and N/D - Not defined.

Table 4 - Names and their descriptions of the attribute table fields of the polygonal features of the BGS Predictive Seabed Sediments (UK) (v.1) dataset.

Field name	Description
FOLK_S	Folk classification symbol text
FOLK_CLASS	Folk classification of sediment
LEX_RCS	The two-part code, LEX & RCS, used to label the geological units in BGS Geology data: e.g. PNG-MDST
LEX_RCS_D	Description of the two-part code above giving the name and the lithology of the unit: e.g. Penarth Group-Mudstone
LEX	Lexicon (or LEX) code. First part of the LEX_RCS label. Up to 5 characters (mostly letters). An abbreviation of the rock unit or deposit as listed in the BGS Lexicon of Named Rock Units: e.g. LI
LEX_D	Description of the Lexicon code above giving the name of the unit: e.g. LIAS GROUP is the full name of the unit coded as LI
RCS	The RCS code (or an abbreviation for the string of RCS codes given in full in RCS_X)
RCS_D	Description of the RCS code(s) above giving the lithology of the unit: e.g. MUDSTONE and LIMESTONE
MAX_TIME_D	Maximum or oldest age of the unit, to the most accurate time (or geochronological) division possible: e.g. ALBIAN
MIN_TIME_D	Minimum or youngest age of unit, to the most accurate time (or geochronological) division possible: e.g. APTIAN
BGSREF	BGS reference colour for the polygon based on the LEX_ROCK code pair. The default printing colour defined as a 3-digit number:
DATASET	Official name of the dataset
VERSION	Version of the digital data. The version number is changed when a new dataset is released following major changes

DATA FORMAT

The BGS Predictive Seabed Sediments (UK) data are in both raster and vector formats and comprise four geospatial data layers: Three layers of predicted proportions of sediment, %gravel, %sand, %mud respectively (raster format) (0-100%); Classified SBS map, Folk15 + rock (most likely class) (vector format).

Vector map is released in ESRI shapefile format, and the rasters are provided in Tiff format Other vector formats are available on request. More specialised formats may be available but may incur additional processing costs. Please email BGS Enquiries (enquiries@bgs.ac.uk) to request further information.

DATASET HISTORY

The BGS Predictive Seabed Sediments (UK) digital map was created in 2025. This is the first release of the dataset.

DISPLAYING THE DATA

It is recommended that the classified Folk15+rock SBS layer is displayed based on the "FOLK_CLASS" field in the attribute table (Table 5). The "FOLK_CLASS" field provides the classified sediments predicted at the location. The percentage sediment layers are displayed using monochrome colour gradients.

Table 5 – Colour symbology intended for the *Classified SBS* layer based on field "FOLK_CLASS".

FOLK_CLASS	RED	GREEN	BLUE	HEX	LOOKS LIKE
(gravelly) muddy Sand	224	224	148	#E0E094	
(gravelly) Sand	255	201	0	#FFC900	
(gravelly) sandy Mud	148	224	148	#94E094	
Gravel	255	117	255	#FF75FF	
gravelly Mud	148	224	224	#94E0E0	
gravelly muddy Sand	224	148	148	#E09494	
gravelly Sand	255	201	117	#FFC975	
Mud	117	255	117	#75FF75	
muddy Sand	224	224	0	#E0E000	
muddy sandy Gravel	224	148	224	#E094E0	
Rock	130	130	130	#828282	
Sand	255	255	117	#FFFF75	
sandy Gravel	255	201	255	#FFC9FF	
sandy Mud	224	255	0	#E0FF00	

TABLE 6 - COLOUR SYMBOLOGY INTENDED FOR THE PREDICTED %SAND LAYER.

Data Classification	RED	GREEN	BLUE	HEX	LOOKS LIKE
0.00	255	255	229	#FFFFE5	
12.50	255	247	188	#FFF7BC	
25.00	254	227	145	#FEE391	
27.50	254	196	79	#FEC44F	

50.00	254	153	41	#FE9929	
62.50	236	112	20	#EC7014	
75.00	204	76	2	#CC4C02	
87.50	153	52	4	#993404	
100.00	102	37	6	#662506	

TABLE 7 COLOUR SYMBOLOGY INTENDED FOR THE PREDICTED %MUD LAYER.

Data Classification	RED	GREEN	BLUE	HEX	LOOKS LIKE
0.00	255	255	226	#FFFFE2	
25.00	183	222	149	#B7DE95	
50.00	65	174	87	#41AE57	
75.00	29	123	54	#1D7B36	
100.00	0	80	0	#005000	

TABLE 8 - COLOUR SYMBOLOGY INTENDED FOR THE PREDICTED %GRAVEL LAYER.

Data Classification	RED	GREEN	BLUE	HEX	LOOKS LIKE
0.00	255	247	243	#FFF7F3	
12.50	253	224	221	#FDE0DD	
25.00	252	197	192	#FCC5C0	
27.50	250	159	181	#FA9FB5	
50.00	247	104	161	#F768A1	
62.50	221	52	151	#DD3497	
75.00	174	1	126	#AE017E	
87.50	122	1	119	#7A0177	
100.00	73	0	106	#49006A	

LIMITATIONS

DATA CONTENT

The BGS Predictive Seabed Sediments (UK) portrays the distribution of seabed sediment composition across the UK Continental Shelf (UKCS) The mapping, description and classification of seabed sediments are based upon the predictions, evidence, and interpretations available at the time.

SCALE

The digital map is produced for use at a national-scale scale, with a spatial resolution of approximately 110m covering the UKCS (*slightly modified UKCS area based on data availability*). This digital map is generalised and the map outputs should be used only as a guide to the geology at a local level, not as a site-specific geological plan based on detailed site investigations.

ACCURACY/UNCERTAINTY

There are a range of issues that variably effect the accuracy and uncertainty of the map products including:

- The sediment sample data were acquired from multiple surveys, with different equipment, and significantly, at different times. The potential transitory nature of seabed sediments indicates sediment composition may (and is likely to) change over time. There is therefore inherent uncertainty in combining these sample datasets of variable age together within the model;
- The sediment sample data were not acquired for the purpose of building a national-scale SBS map but are a compilation of datasets collected for different purposes. Therefore, there is potential for particular sediment types to be over-represented in the data used to train the DRF and therefore potential bias in the resultant predictions;
- Inaccuracies in the covariate data could be propagated into the model, introducing spurious predictions;
- Selection of covariate data impacts the model predictions, and therefore non-optimal selection of covariates may impact the quality and accuracy of the predictive outputs. Future updates to the method will involve optimising the model covariates as well as increasing the sample database.
- Regions with reduced sample density are likely to have greater uncertainty.

DISCLAIMER

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APPENDIX

MODEL COVARIATES

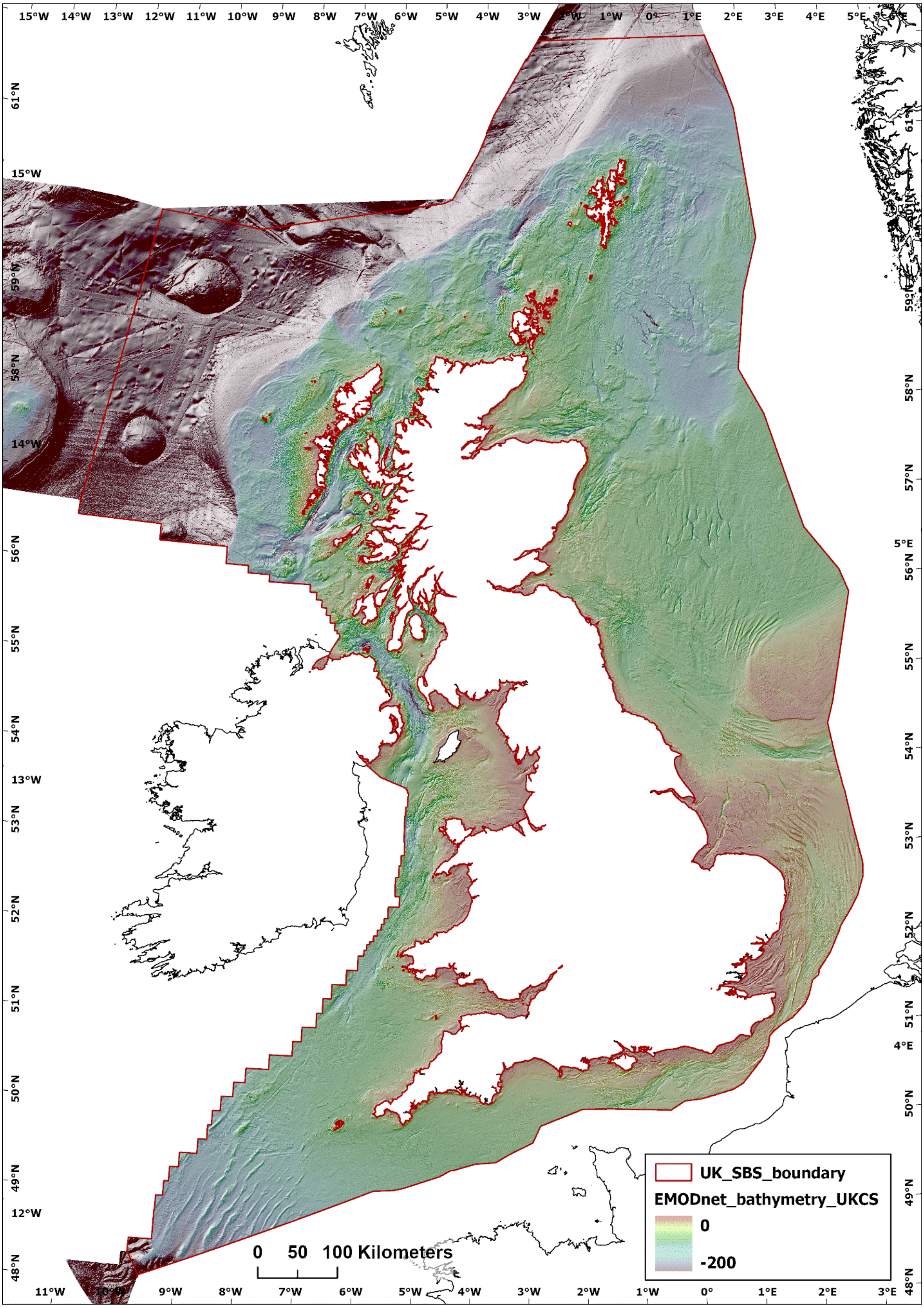

FIGURE 12. BATHYMETRY DATA (WATER DEPTH IN METRES – LOWEST ASTRONOMICAL TIDE (LAT)) (EMODNET, 2022).

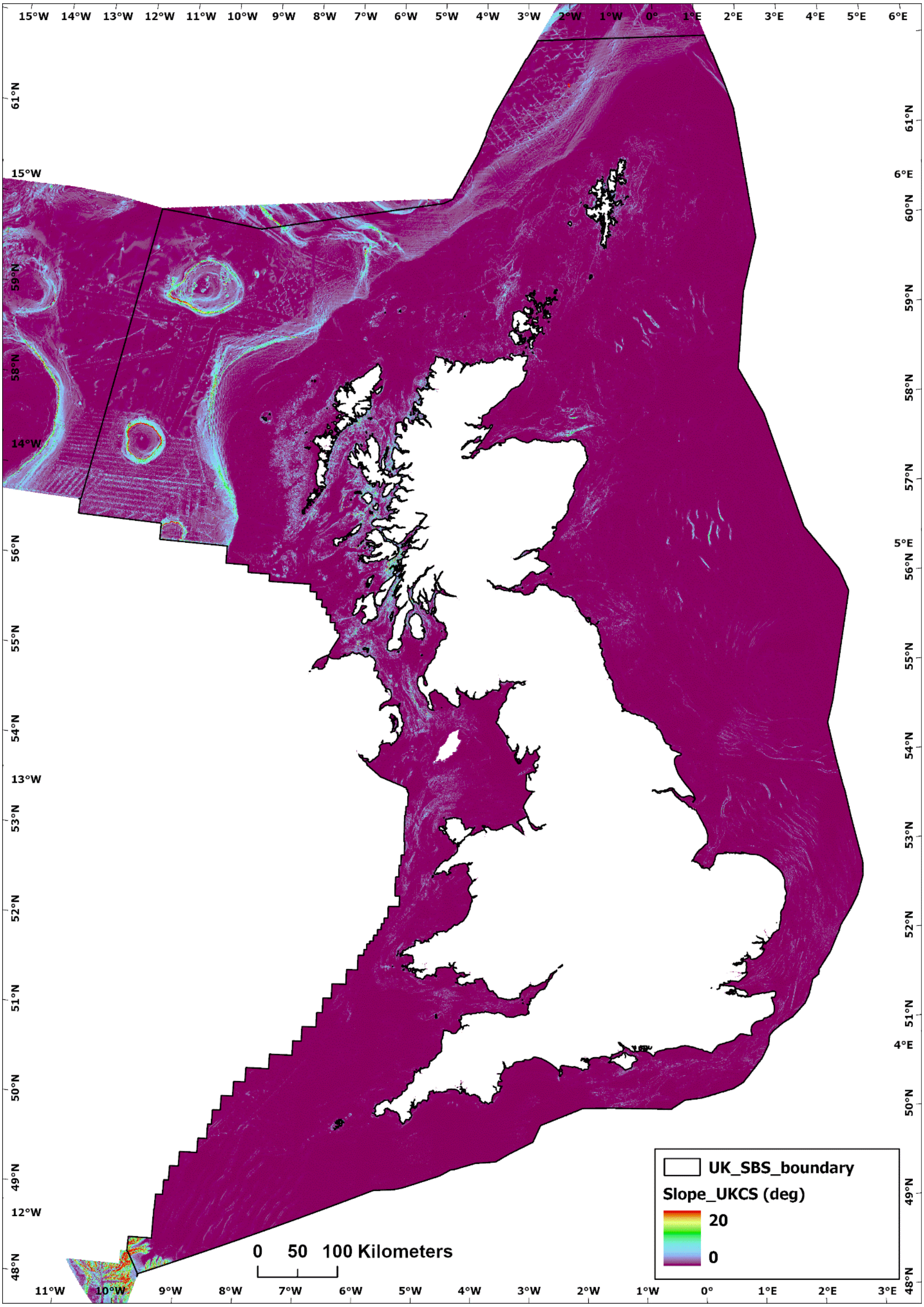

FIGURE 13. BATHYMETRIC SLOPE, BASED ON EMODNET BATHYMETRY (EMODNET, 2022).

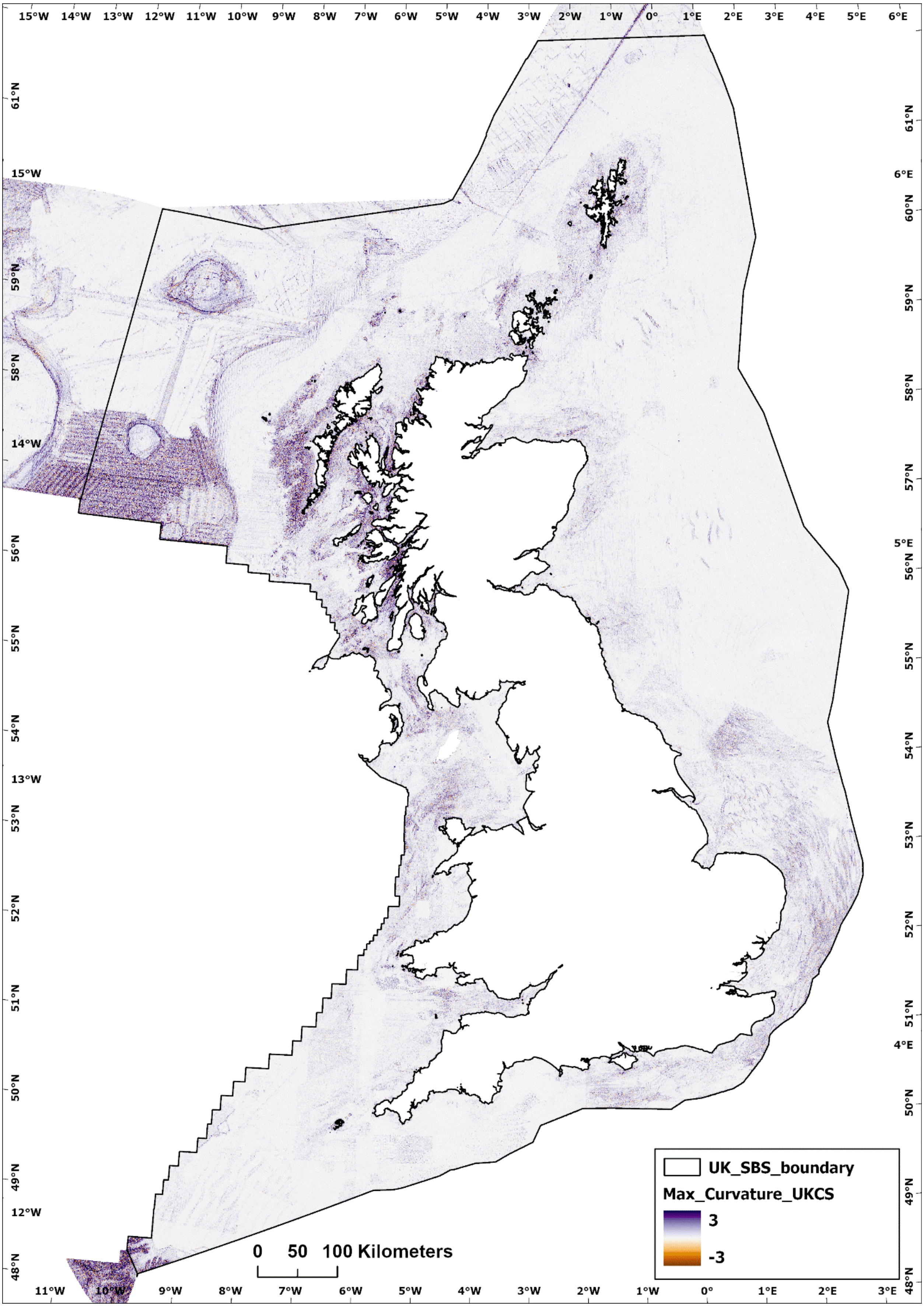

FIGURE 14. MAXIMUM CURVATURE, BASED ON EMODNET BATHYMETRY (EMODNET, 2022).

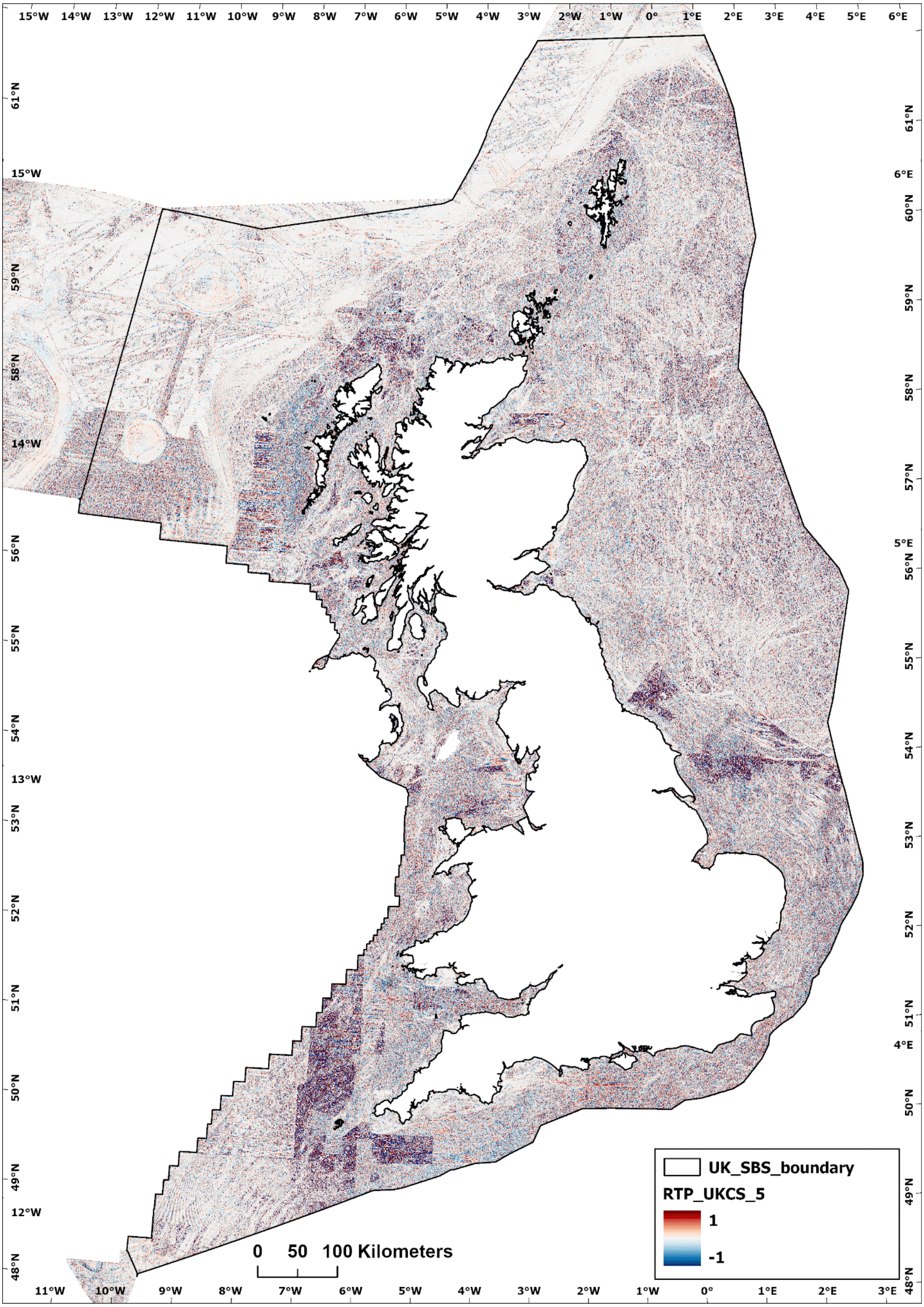

FIGURE 15. RELATIVE TOPOGRAPHIC POSITION (RTP) WITH 5CELL NEIGHBOURHOOD, BASED ON EMODNET BATHYMETRY (EMODNET, 2022).

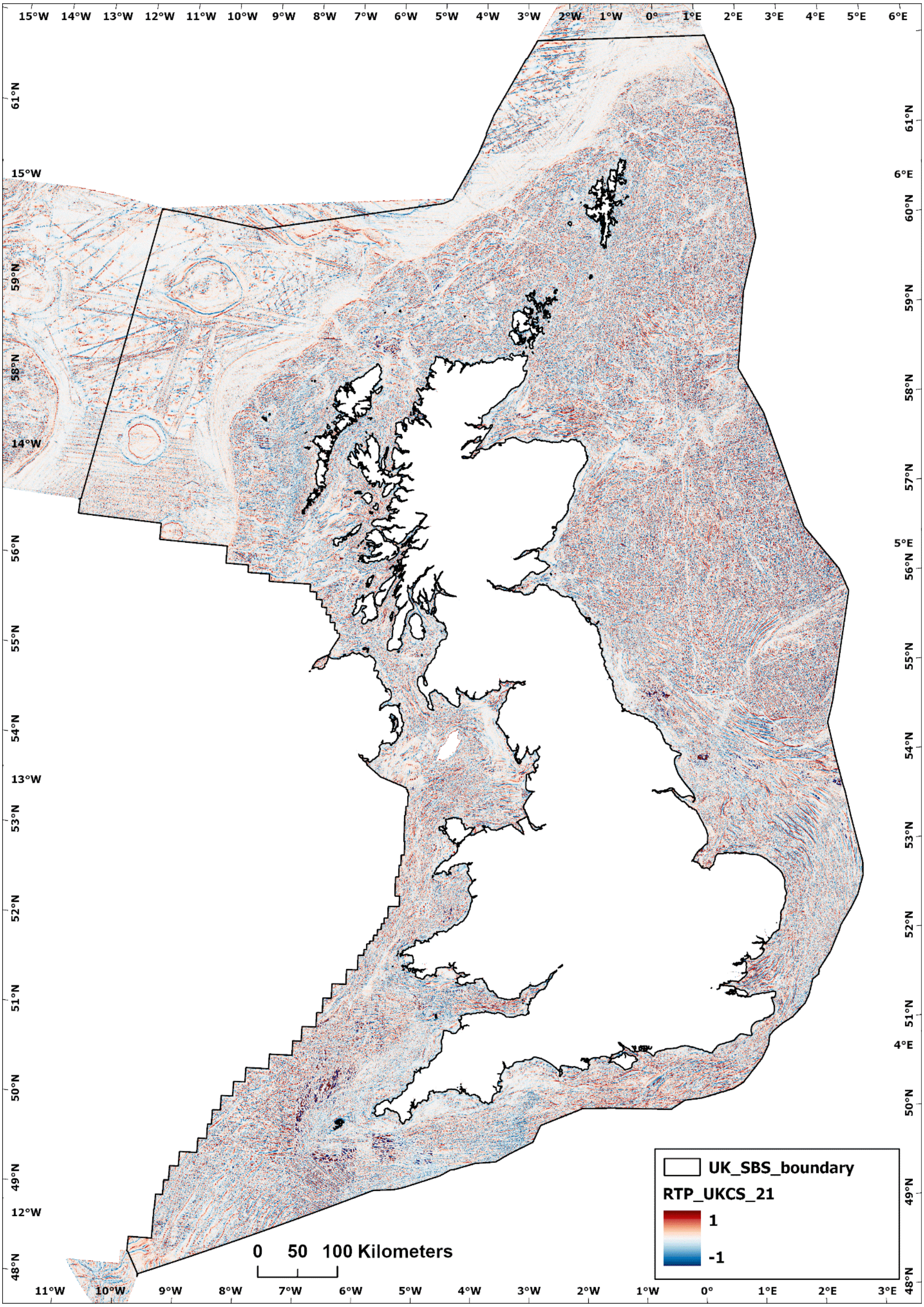

FIGURE 16. RELATIVE TOPOGRAPHIC POSITION (RTP) WITH 21CELL NEIGHBOURHOOD, BASED ON EMODNET BATHYMETRY (EMODNET, 2022).

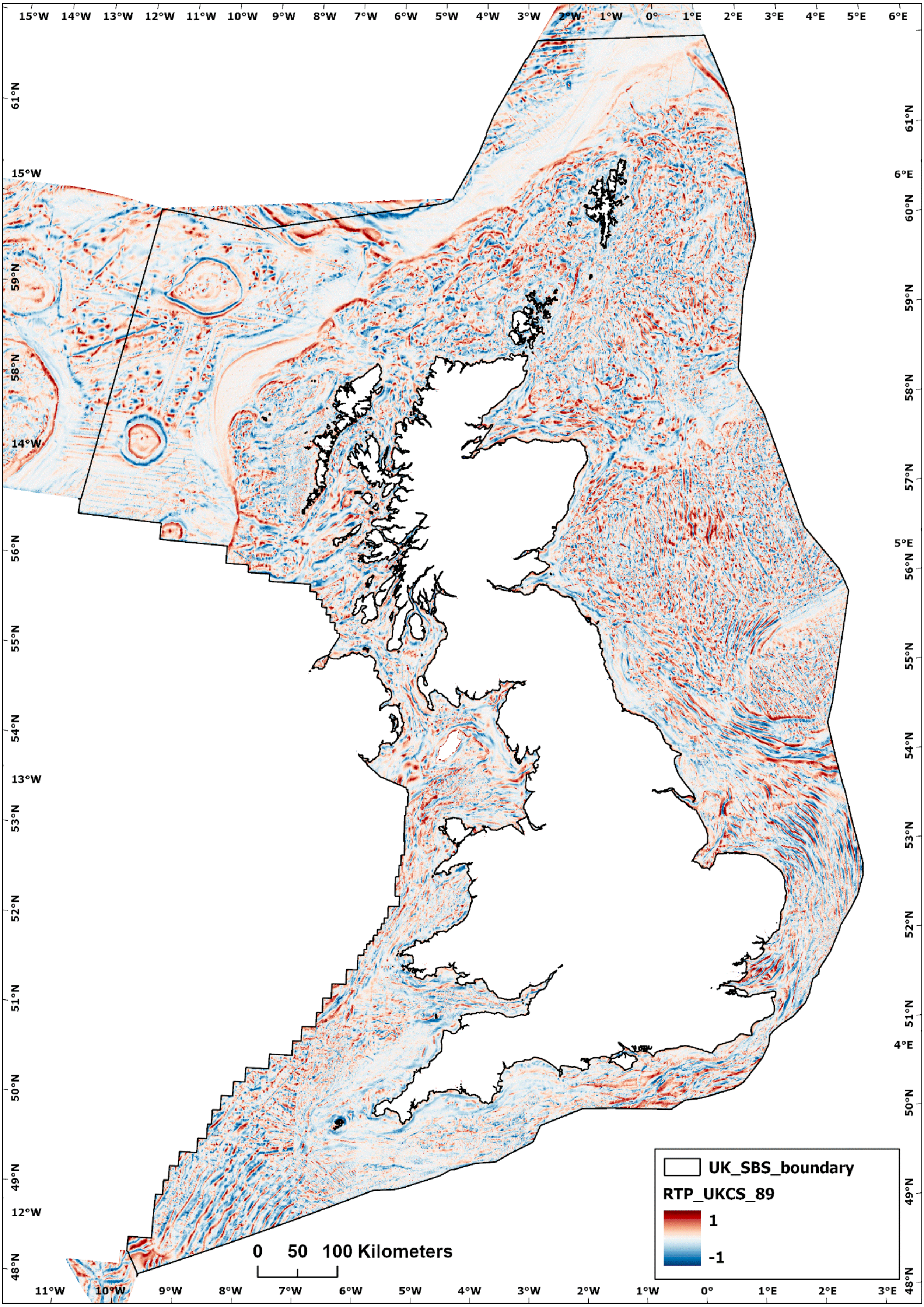

FIGURE 17. RELATIVE TOPOGRAPHIC POSITION (RTP) WITH 89CELL NEIGHBOURHOOD, BASED ON EMODNET BATHYMETRY (EMODNET, 2022).

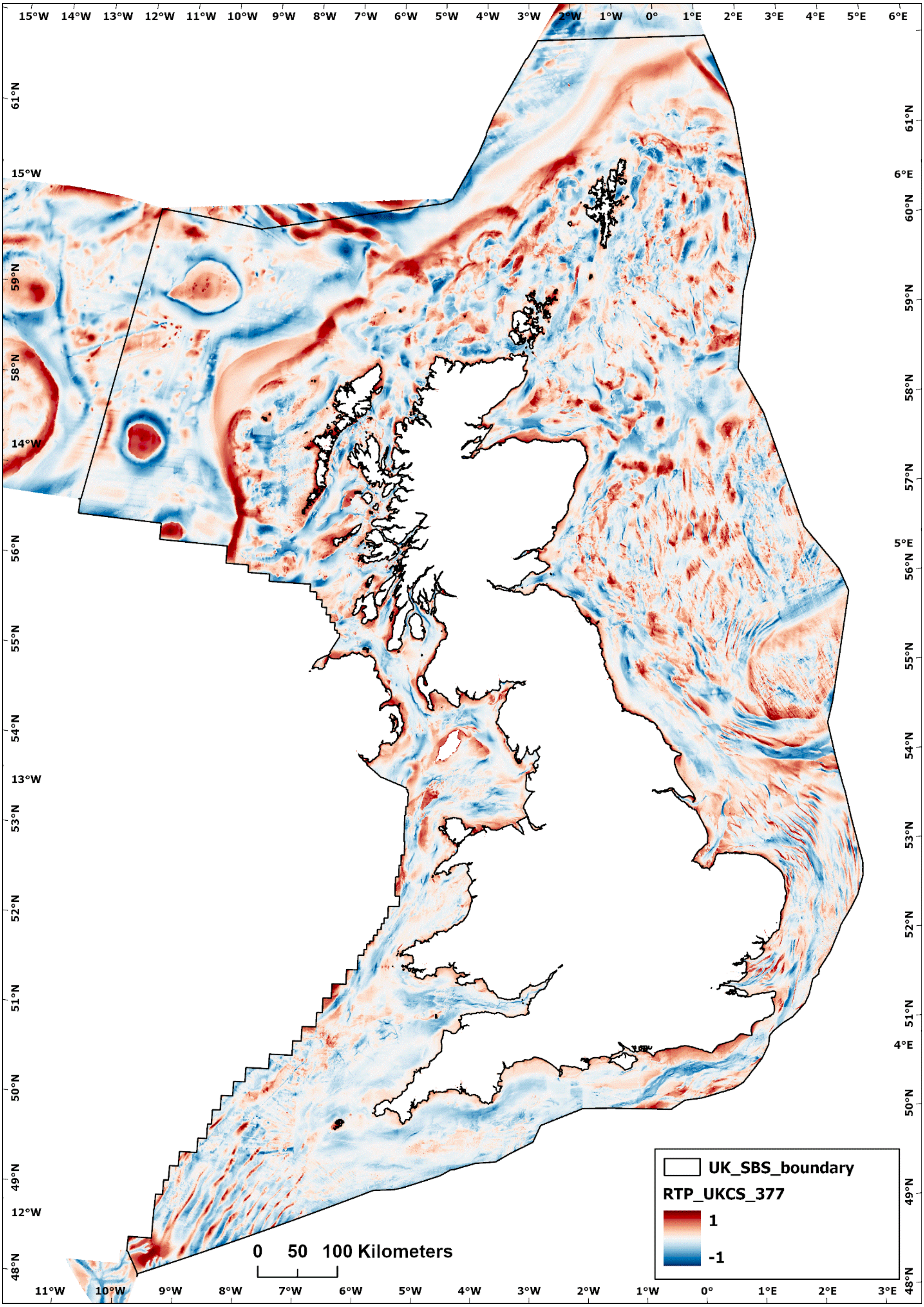

FIGURE 18. RELATIVE TOPOGRAPHIC POSITION (RTP) WITH 377CELL NEIGHBOURHOOD, BASED ON EMODNET BATHYMETRY (EMODNET, 2022).

HYDRODYNAMIC LAYERS

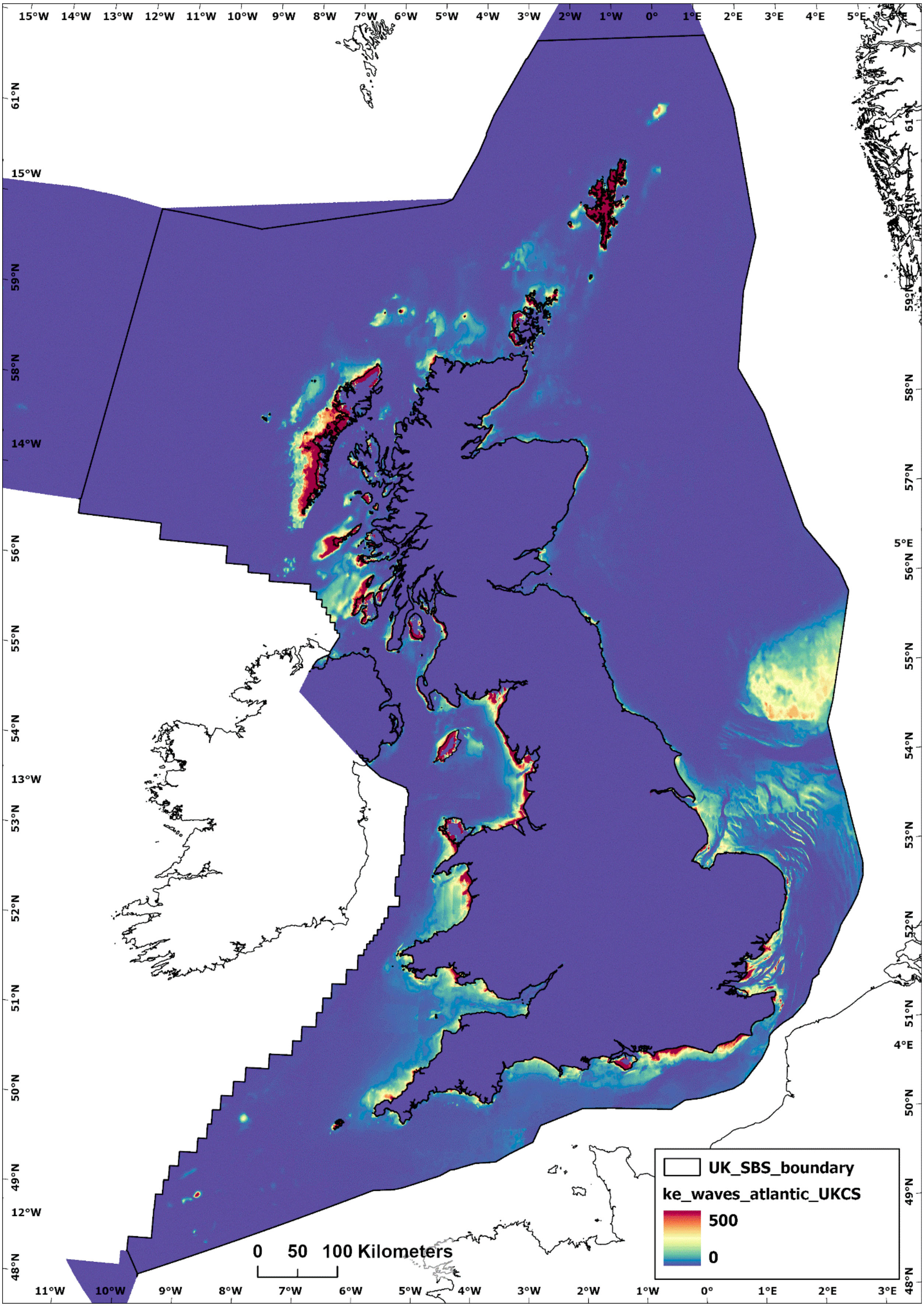

FIGURE 19. KINETIC ENERGY AT SEABED DUE TO WAVES (EMODNET).

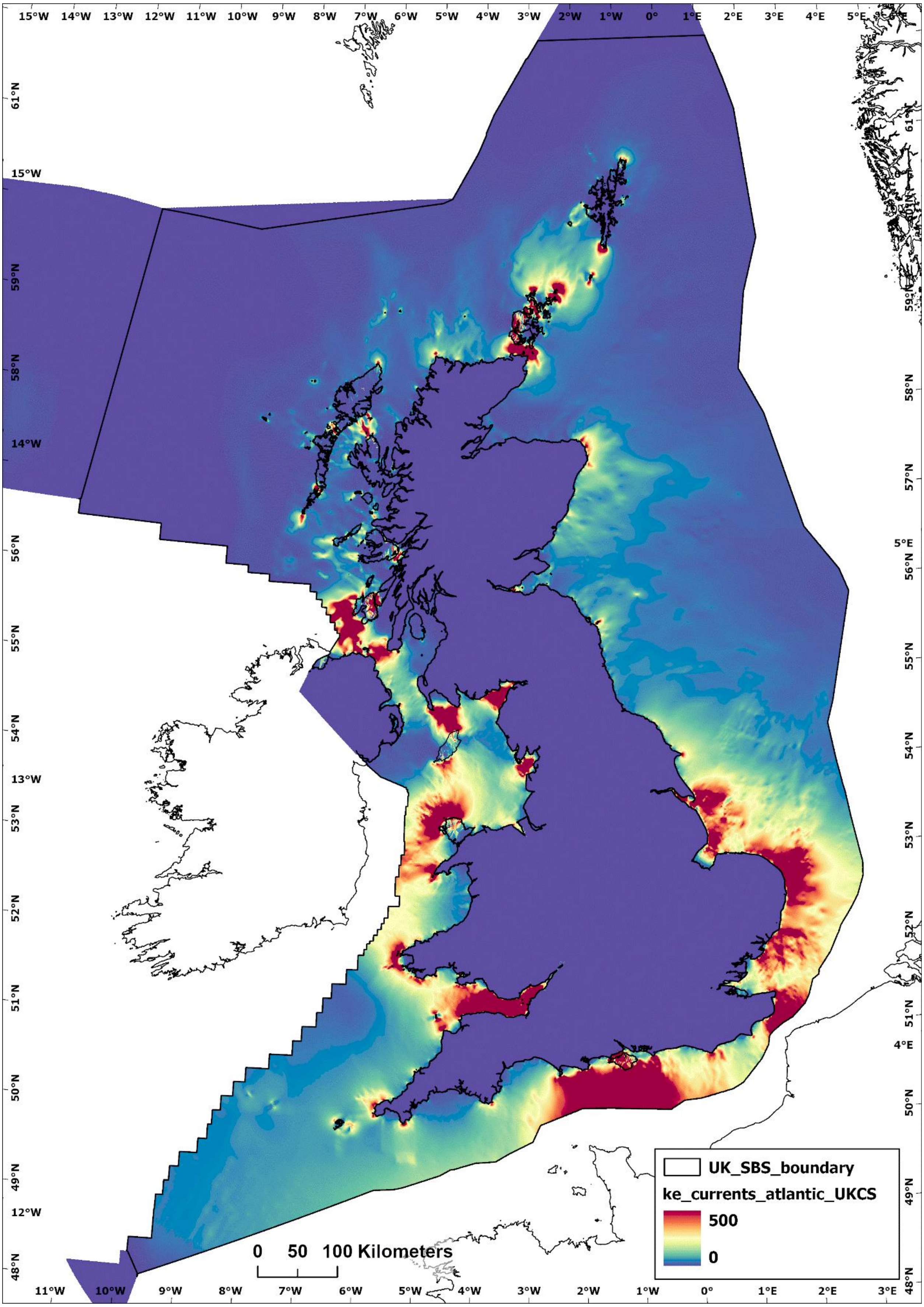

FIGURE 20. KINETIC ENERGY AT SEABED DUE TO CURRENTS (EMODNET).

DISTANCE TO COAST

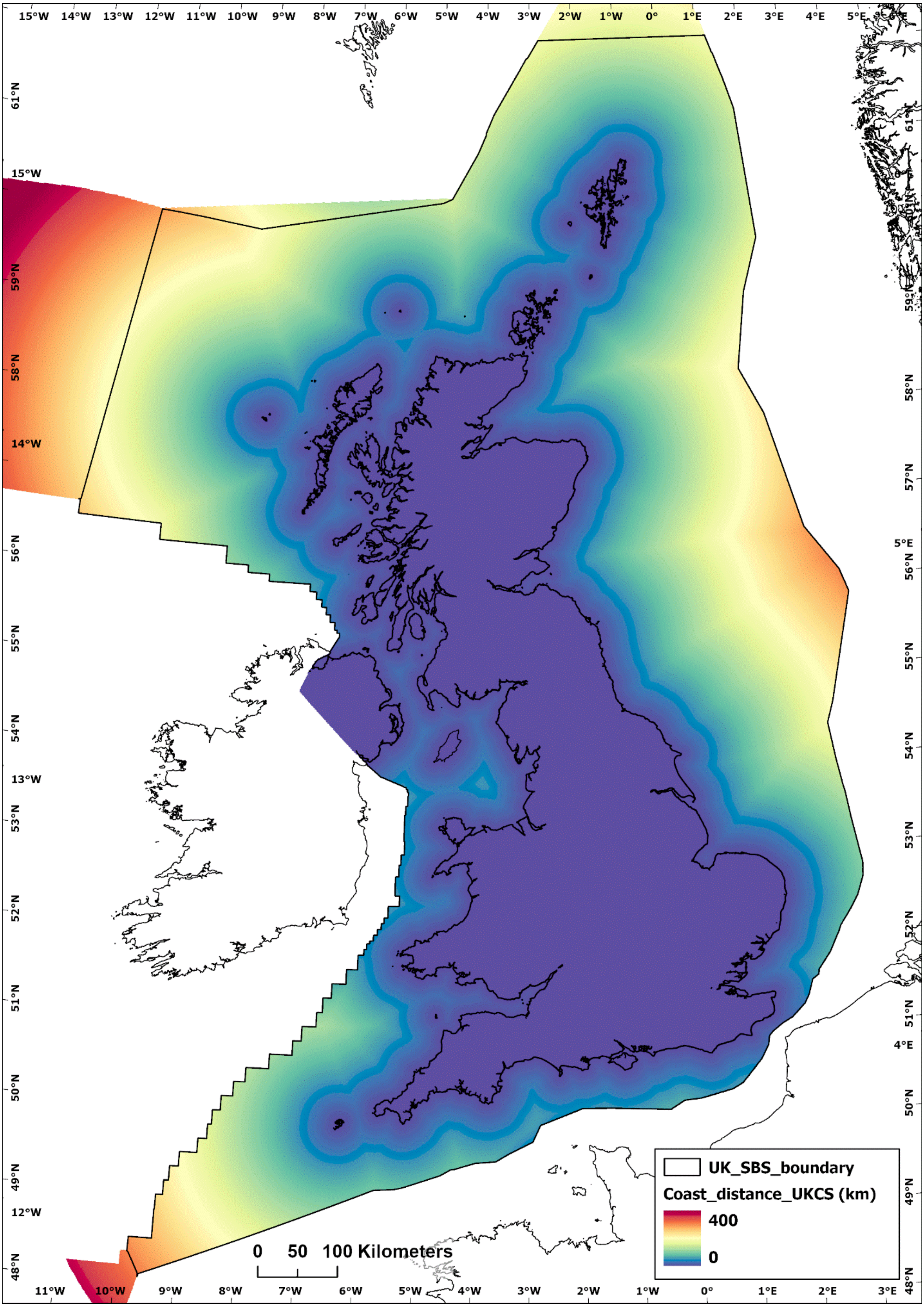

Figure 21. Distance to the nearest coast (NASA, 2009).

DATASET SOURCES

Dataset title	Dataset owner / compiler	Data citation	Access constraints
BGS Seabed Samples	British Geological Survey	Data derived from BGS Seabed Sample data layers, available https://mapapps2.bgs.ac.uk/geoindex_offshore/home.html extracted from internal database on 28/08/2024. "Contains British Geological Survey materials ©UKRI [2024]". Other data providers as contained within the database.	Mostly Open Government Licence v3.0, some restricted
OneBenthic	Centre for Environment, Fisheries and Aquaculture Science (Cefas)	Data derived from Cefas OneBethic, available from https://rconnect.cefas.co.uk/onebenthic_dataextractiongrabcore/ downloaded on 3/7/2024	Open
Cefas Experimental Fishing Impact	Centre for Environment, Fisheries and Aquaculture Science (Cefas)	RV Cefas Endeavour Staff & Cefas Sediment Laboratory Staff (2019). Fladen experimental fishing impact recovery data - Particle size analysis. Cefas, UK. V1. doi: https://doi.org/10.14466/CefasDataHub.84	Open Government Licence v3.0
Marine Recorder v20220124	Joint Nature Conservation Committee (JNCC)	Data derived from UK Marine Recorder (Public) snapshot (v20220124), available from https://hub.jncc.gov.uk/assets/b9934e31-39b6-41f9-9364-d1e93db68307 received from JNCC on 28/6/2024. Data licenses, access and use limitations as described per survey as contained within the database.	Open Government Licence v3.0
ICES Contaminants and biological effects of contaminants in sediment	ICES	Data derived from ICES Contaminants and biological effects of contaminants in sediment, available from https://dome.ices.dk/views/ContaminantsSediment.aspx downloaded on 18/07/2024. Data providers are acknowledged as contained within the database.	Open
JNCC survey data	Joint Nature Conservation Committee (JNCC)	Data derived from Joint Nature Conservation Committee (JNCC) survey data received from JNCC on 31/07/2024	Open Government Licence v3.0
INFOMAR Seabed Sediment Samples Irish Waters	INFOMAR	Data derived from INFOMAR Seabed Sediment Samples Irish Waters, available from https://experience.arcgis.com/experience/3f2815ec89e745d2b65630429d06385c/page/Page-1/?views=Download-Vector-Datasets#data_s=id%3AdataSource_37-Marine_Download_Seabed_Survey_Vector_Data_IE_Waters_WGS84_1010%3A4 downloaded on 23/07/2024	Open
Scottish Government survey data	Scottish Government Marine Directorate	Data derived from Scottish Government Marine Directorate survey data received from Scottish Government Marine Directorate on 9/9/2024	Open Government Licence v3.0
Shelf Sea Biogeochemistry	Centre for Environment, Fisheries and Aquaculture Science (Cefas) / University of Southampton	Silburn B.E.; Sivyer D.B.; Kroeger S.; Parker R.; Mason C.; Nelson P.; Bolam S.G.; Thompson C.(2017). Shelf Sea Biogeochemistry sediment characterisation. British Oceanographic Data Centre - Natural Environment Research Council, UK. https://doi.org/10.5285/47110529-757c-40b5-e053-6c86abc0eddc	Open Government Licence v3.0
Marine Environment Monitoring and Assessment National database (MERMAN)	MERMAN	These data are a snapshot of the data held within MERMAN obtained on the (13*/08/2024*). The data were supplied by the British Oceanographic Data Centre on behalf of the Clean Safe Seas Evidence Group. Data were collected by the Agri-Food and Biosciences Institute, Centre for Environment, Fisheries and Aquaculture Science, Department of Agriculture, Environment and Rural Affairs, Environment Agency, Food Standards Scotland, Marine Scotland Science, Natural Resource Wales and Scottish Environment Protection Agency. The data were funded by Agri-Food Biosciences institute, Department of Agriculture, Environment and Rural Affairs, Department for Environment, Food and Rural Affairs and Scottish Government. These data contain public sector information licensed under the Open Government Licence v3.0.	Open Government Licence v3.0
2023 Characterizing seabed sediments at contrasting offshore renewable energy sites	Bangor University	Amjadian P, Neill SP and Martí Barclay V (2023) Characterizing seabed sediments at contrasting offshore renewable energy sites. Front. Mar. Sci. 10:1156486. https://doi.org/10.3389/fmars.2023.1156486	Creative Commons Attribution License (CC BY)

Abundance and biomass of benthic infauna from mud grabs in the Irish sea as part of a mud habitat project from 2014-2015	Agri-Food and Biosciences Institute (AFBI)	(2019): Abundance and biomass of benthic infauna from mud grabs in the Irish sea as part of a mud habitat project from 2014-2015. Marine Biological Association. (Dataset). https://doi.org/10.17031/cclqtr	Creative Commons Attribution License (CC BY)
2003 Royal Haskoning Ltd Fal Estuary marine ecological grab and core survey	Royal Haskoning	(Royal Haskoning (UK Head Office)) (2023): 2003 Royal Haskoning Ltd Fal Estuary marine ecological grab and core survey. The Archive for Marine Species and Habitats Data (DASSH). (Dataset). https://doi.org/10.17031/64b9039539533	Open
2016 Eastern Inshore Fisheries and Conservation Authority (EIFCA) The Wash Comparative Mapping study	Eastern Inshore Fisheries and Conservation Authority (EIFCA)	(Eastern Inshore Fisheries and Conservation Authority (EIFCA)) (2018): 2016 Eastern Inshore Fisheries and Conservation Authority (EIFCA) The Wash Comparative Mapping study. DASSH. (Dataset). https://doi.org/10.17031/1835	Open
2016 Eastern Inshore Fisheries and Conservation Authority (EIFCA) The Wash Comparative Mapping study (Day 2)	Eastern Inshore Fisheries and Conservation Authority (EIFCA)	(Eastern Inshore Fisheries and Conservation Authority (EIFCA)) (2018): 2016 Eastern Inshore Fisheries and Conservation Authority (EIFCA) The Wash Comparative Mapping study (Day 2). DASSH. (Dataset). https://doi.org/10.17031/1836	Open
2007 Natural England (NE) Lundy. Sedimentary biotope mapping	Natural England	2007 Natural England (NE) Lundy. Sedimentary biotope mapping. DASSH. (Dataset)	Open Government Licence v3.0
2000 English Nature (NE) and Plymouth Marine Laboratory (PML). Survey of infaunal organisms on Isles of Scilly Special Area of Conservation (SAC) intertidal sandflats.	Natural England	2000 English Nature (NE) and Plymouth Marine Laboratory (PML). Survey of infaunal organisms on Isles of Scilly Special Area of Conservation (SAC) intertidal sandflats. DASSH. (Dataset)	Open Government Licence v3.0
Scottish Environment Protection Agency coastal waters around fish farms 2021/2022	Scottish Environment Protection Agency	Data derived from Scottish Environment Protection Agency (SEPA) survey data received from SEPA on 2/10/2024	Open Government Licence v3.0

FREQUENTLY ASKED QUESTIONS

Q: WHAT DOES THIS MAP SHOW?

A: The BGS Predictive_Seabed_Sediments_UK_v1 includes digital maps of seabed sediment (SBS) composition across the UK Continental Shelf (UKCS). These released BGS maps include one classified SBS map (Folk sediment class; vector), and three percentage-sediment maps (rasters) giving the proportions of gravel, sand, and mud.

Q: What are the different colours on the map for?

A: The different colours are to show the different seabed sediment compositional classes, as listed in the BGS Lexicon of Named Rock Units.

Q: HOW ACCURATE IS THIS MAP?

A: This Predictive Seabed Sediments (UK) dataset is produced for use at a national-scale scale, with a spatial resolution of approximately 110m covering the UK Continental Shelf (UKCS). The maps are developed using predictive mapping approaches, employing a suite input data that relate to the distribution of seabed sediments. Users should be aware that while this is modelled map output based on consistent criteria, the underlying data include their own underlying variations and uncertainties, so users of the resultant geological maps should be aware of these uncertainties as well as model limitations. Further details about the accuracy of this dataset are provided in the 'Limitations' section of this report.

Q: HOW OFTEN WILL THIS MAP BE UPDATED?

A: As more data become available, and/or model improvement can be made.

Q: WHERE CAN I GET DIGITAL DATA?

A: This digital map is made publicly accessible by BGS via Open Government Licence (OGL), subject to certain standard terms and conditions. Currently the data are available via the BGS Offshore Geoindex.

Q: IN WHAT FORMATS CAN THESE DATA BE PROVIDED?

A: This is available in a range of GIS formats, including ArcGIS (.shp). More specialised formats may be available but may incur additional processing costs. Please email BGS Enquiries (enquiries@bgs.ac.uk) to request further information.

Q: I DON'T HAVE A GIS. CAN I STILL VIEW THE DATA?

A: Yes! Our Offshore Map Viewer is a good place to start. It is an online data and GIS service that covers a very wide range of marine geoscience research.

Q: Can I use this map as part of a commercial application?

A: Yes, as this product is provided via Open Government License (OGL) v3.0. For further queries regarding the licencing terms of our products, please contact digitaldata@bgs.ac.uk.

Q: I THINK THE GEOLOGY MAP MIGHT BE WRONG. WHAT CAN I DO?

A: We make every effort to ensure that our mapping reflects our best understanding. Sometimes our map products need to be revised as new evidence (such as new data) are obtained and simple errors sometimes get through our quality assurance procedures. We are currently working on a web service to improve notifications of errors that have been found and corrected; we hope to make this available soon. If you think you have spotted a problem with our datasets please let us know.

GLOSSARY

Jargon	Explanation
ArcGIS	Geographic Information System (GIS) software for working with maps and geographic information maintained by the Environmental Systems Research Institute (ESRI).
Attribute	Named property of an entity. Descriptive information about features or elements of a database. For a database feature like census tract, attributes might include many demographic facts including total population, average income, and age. In statistical parlance, an attribute is a variable, whereas the database feature represents an observation of the variable.
Bathymetry	The measurement of the water depth in oceans, seas, or lakes over an area of seabed. In other words, bathymetry is the underwater equivalent to topography.
Bedrock	The main mass of rocks forming the earth, laid down prior to 2.588 million years ago. Present everywhere, whether exposed at the surface in rocky outcrops or concealed beneath superficial deposits, artificial ground or water. Formerly called solid.
Epoch	Geological unit of time during which a rock series is deposited. It is a subdivision of a geological period.
ESRI	Environmental Systems Research Institute (ESRI) is an international supplier of Geographic Information System (GIS) software, web GIS and geodatabase management applications.
Geophysical data	Data that has been acquired by recording and analysing measurements of the Earth's physical properties, such as electrical, gravity, magnetic, radioactivity and seismic properties.
Geospatial data	Data that has a geographical component to it. This means that the records in a dataset have locational information directly linked to them, such as geographic data in the form of coordinates, address, city, or postcode.
Lexicon	Vocabulary defining rock names, the BGS Lexicon of Named Rock Units database provides BGS definitions of terms that appear on our maps and in our publications. https://www.bgs.ac.uk/lexicon/home.html
Lithological units	A rock identifiable by its general characteristics of appearance colour, texture and composition defined by the distinctive and dominant, easily mapped and recognizable petrographical or lithological features that characterize it.
Lithology	Rocks maybe defined in terms of their general characteristics of appearance: colour, texture and composition. Some lithologies may require a microscopical or chemical analysis for the latter to be fully determined.

Polygon	Polygons are a representation of areas. A polygon is defined as a closed line or perimeter completely enclosing a contiguous space and is made up of one or more links.
Scale	The relation between the dimensions of features on a map and the geographic objects they represent on the Earth, commonly expressed as a fraction or a ratio. A map scale of 1/100,000 or 1:100,000 means that one unit of measure on the map equals 100,000 on the earth.
Sedimentary	Rocks that originated from the broken up, or dissolved and re-precipitated, particles of other rocks. Examples include claystone, mudstone, siltstone, shale, sandstone, limestone and conglomerate. Sedimentary rocks cover more than two-thirds of the Earth's surface. They are formed from the weathering and erosion products of rock material, which have been transported (usually by water or wind), redeposited and later lithified.
Sediments	Mud, sand, gravel, boulders, bioclastic material (shells, plants), and other matter carried and deposited by water, wind, or ice.
Shapefile	The shapefile format is a geospatial vector data format for geographic information system software. It is developed and regulated by ESRI as a mostly open specification for data interoperability among ESRI and other GIS software products.
Vector	A representation of the spatial extent of geographic features using geometric elements (such as point, curve, and surface) in a coordinate space.

REFERENCES

Amaro, T., Huvenne, V.A.I., Allcock, A.L., Aslam, T., Davies, J.S., Danovaro, R., De Stigter, H.C., Duineveld, G.C.A., Gambi, C., Gooday, A.J. and Gunton, L.M., 2016. The Whittard Canyon–A case study of submarine canyon processes. Progress in Oceanography, 146, pp.38-57.

BGS, 2011. User Guide for the British Geological Survey DiGSBS250K Dataset. British Geological Survey Internal Report, IR/11/026.

Brown, L.S., Green, S.L., Stewart, H.A., Diesing, M., Downie, A.L., Cooper, R. and Lillis, H., 2017. Semi-automated mapping of rock in the Irish Sea. Minches, Western Scotland and Scottish Continental Shelf, p.33.

Caruso, S., Maselli, V., Rea, B. and Spagnolo, M., 2022. Deep-water sedimentation processes on a glaciated margin: The Foula Wedge trough mouth fan, West of Shetland. Marine Geology, 446, p.106769.

Ćevid D., Michel L., Näf J., Bühlmann P., Meinshausen N., 2022. Distributional random forests: Heterogeneity adjustment and multivariate distributional regression J. Mach. Learn. Res., 23, 1-79.

Diesing, M., Green, S.L., Stephens, D., Lark, R.M., Stewart, H.A. and Dove, D., 2014. Mapping seabed sediments: Comparison of manual, geostatistical, object-based image analysis and machine learning approaches. Continental Shelf Research, 84, pp.107-119.

Diesing, M., Green, S.L., Stephens, D., Cooper, R. and Mellett, C.L., 2015. Semi-automated mapping of rock in the English Channel and Celtic Sea. Joint Nature Conservation Committee.

Downie, A., 2016. Semi-automated mapping of rock in the North Sea. Joint Nature Conservation Committee.

EMODnet Digital Bathymetry (DTM 2022). EMODnet Bathymetry Consortium. https://doi.org/10.12770/ff3aff8a-cff1-44a3-a2c8-1910bf109f85.

Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary-rock nomenclature. The Journal of Geology, 62(4), pp.344-359.

Gao, S. and Collins, M.B., 2014. Holocene sedimentary systems on continental shelves. Marine Geology, 352, pp.268-294.

JNCC, 2019. Prediction of outcrops or subcrops of rock in UK shelf seabed (public). https://www.data.gov.uk/dataset/fee92896-76a9-4718-a576-cd0d42224751/prediction-of-outcrops-or-subcrops-of-rock-in-uk-shelf-seabed-public. https://doi.org/10.25603/840424.1.0.0

Kaskela, A.M., Kotilainen, A.T., Alanen, U., Cooper, R., Green, S., Guinan, J., van Heteren, S., Kihlman, S., Van Lancker, V., Stevenson, A. and EMODnet Geology Partners, 2019. Picking up the pieces—harmonising and collating seabed substrate data for European maritime areas. Geosciences, 9(2), p.84.

Lark, R.M., Dove, D., Green, S.L., Richardson, A.E., Stewart, H. and Stevenson, A., 2012. Spatial prediction of seabed sediment texture classes by cokriging from a legacy database of point observations. Sedimentary Geology, 281, pp.35-49.

Lark, R.M., Marchant, B.P., Dove, D., Green, S.L., Stewart, H. and Diesing, M., 2015. Combining observations with acoustic swath bathymetry and backscatter to map seabed sediment texture classes: The empirical best linear unbiased predictor. Sedimentary Geology, 328, pp.17-32.

Lindsay, J.B., 2016. Whitebox GAT: A case study in geomorphometric analysis. Computers & Geosciences, 95, pp.75-84.

Long, D., 2006. BGS Detailed Explanation of Seabed Sediment Modified Folk Classification; British Geological Survey, Nottingham, UK.

Michel L., Ćevid D., 2021. Drf: Distributional random forests. URL: https://CRAN.R-project.org/package=drf, R package version 1.1.0

Misiuk, B., Lecours, V. and Bell, T., 2018. A multiscale approach to mapping seabed sediments. PLoS One, 13(2), p.e0193647.

Mitchell, P.J., Aldridge, J. and Diesing, M., 2019. Legacy data: How decades of seabed sampling can produce robust predictions and versatile products. Geosciences, 9(4), p.182.

NASA, 2009. Distance to the nearest coast. https://oceancolor.gsfc.nasa.gov/resources/docs/distfromcoast/.

Pantin, H. M., 1991. The sea-bed sediments around the United Kingdom: their bathymetric and physical environment, grain size, mineral composition and associated bedforms. British Geological Survey Research Report, SB/90/1. 47pp.

Reynaud, J.Y. and Dalrymple, R.W., 2012. Shallow-marine tidal deposits. Principles of tidal sedimentology, pp.335-369.

Smeaton, C., Hunt, C.A., Turrell, W.R. and Austin, W.E., 2021. Marine sedimentary carbon stocks of the United Kingdom's exclusive economic zone. *Frontiers in Earth Science*, *9*, p.593324.

TNO-GDN, 2023. Seabed-sediment map. TNO - Geological Survey of the Netherlands, www.dinoloket.nl/en/subsurface-models; visited on 2025-02-07.

Wadoux, M.J.-C., Minasny, B., McBratney, A.B., 2020. Machine learning for digital soil mapping: Applications, challenges and suggested solutions, Earth-Science Reviews, 2010, 103359.

Wilson, R.J., Speirs, D.C., Sabatino, A. and Heath, M.R., 2018. A synthetic map of the north-west European Shelf sedimentary environment for applications in marine science. Earth System Science Data, 10(1), pp.109-130.