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GSEU'S POSITIONING ON MARINE GEOLOGICAL INFORMATION IN LIGHT OF OFFSHORE WINDFARMS AND COASTAL VULNERABILITY TO ENVIRONMENTAL AND CLIMATE CHANGE

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Executive Summary

The European Commission has designated offshore windfarm development and assessment of coastal vulnerability to environmental and climate change as focal points for a European Geological Service. Together, Europe's Geological Survey Organisations (GSOs) are well-positioned to take up this role and to support the multifunctional use of pan-European marine space. Both offshore wind and coastal vulnerability are rapidly growing markets for GSOs. Although our geological information and knowledge are widely considered to be crucial elements in time- and cost-efficient development of offshore windfarms and in accurate assessment of coastal vulnerability, they have been underused. Key reasons are that they are neither fully FAIR (findable, accessible, interoperable and reusable) nor fit-for-purpose.

This report, the first deliverable of GSEU WP5, sets the stage for strengthening the position of European GSOs as a provider of services addressing two key societal issues in Europe. It summarises the current roles and activities of the different GSOs and outlines a plan to improve their position. Individually and jointly, GSOs need to learn from each other how to fulfil various statutory, commercial, scientific, collaborative, and strategic tasks and roles. Demonstrating the added value of GSOs' marine output is best done by incorporating joint, harmonised products in EMODnet, the European Marine Observation and Data network, and by creating a strong link with Copernicus services. Improvements to the jointly developed European Geological Data Infrastructure EGDI will turn it from a regular portal into a decision-support instrument, creating easily adoptable and harmonised pan-European marine products that will reduce risk while saving time and cost.

Abbreviations	
2.5D	Functionality to show stacked layers
AL	Albania
BE	Belgium
CMEMS	Copernicus Marine Service
CY	Cyprus
D	Deliverable
DK	Denmark
EC	European Commission
EE	Estonia
EGDI	European Geological Data Infrastructure
EGMS	European Ground Motion Service (Copernicus)
EMODnet	European Marine Observation and Data network
ES	Spain
ES-C	Catalonia, Spain
EU	European Union
FAIR	Findability, Accessibility, Interoperability, Reusability
FI	Finland
FO	Faroe Islands
FR	France
GR	Greece
GSEU	Geological Service for Europe
GSO	Geological Survey Organisation
H2020	Horizon 2020

HR	Croatia
IE	Ireland
INSPIRE	Infrastructure for Spatial Information in the European Community
IS	Iceland
IT	Italy
LT	Lithuania
LV	Latvia
MT	Malta
NGO	Non-Governmental Organisation
NL	The Netherlands
NO	Norway
PL	Poland
PT	Portugal
SE	Sweden
SI	Slovenia
SLR	Sea-Level Rise
SRIA	Strategic Research and Innovation Agenda
T	Task
UA	Ukraine
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WP	Work Package

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1. Introduction

The European Commission, and especially the Directorates General responsible for some of Europe's main climate and sustainability policies, have identified offshore windfarm development (hereafter offshore wind) and assessment of coastal vulnerability to environmental and climate change (hereafter coastal vulnerability) as key focal points for a European Geological Service. The associated call, HORIZON-CL5-2021-D3-01-16: Support to the activities of the European Geological Services, states that there is "a need to collate and integrate geological and climate-related information and data to assess and map coastal vulnerability, and to optimise siting of offshore windfarms (as well as associated infrastructure)". Together, Europe's Geological Survey Organisations are well-positioned to do this successfully and to support the multifunctional use of pan-European marine space. A dedicated work package (WP5: Coastal vulnerability assessment & optimised offshore windfarm siting) sets the stage for improved evidence-based decision-making and long-term sustainable management related to two of Europe's most pressing marine geological issues. It will use comprehensive inventories of harmonised data and information, and exchange knowledge and tools within GSOs. The GSOs participating in WP5 aspire to promote the societal importance of geology, thus strengthening the position of individual GSOs and the Geological Service for Europe as contributors to decision-making considering future climate change and sea-level rise.

WP5 is strongly linked to EU policy. Geology and Europe's aim to be the first climate-neutral continent, captured in the Green Deal, go well together. Marine geological data, information and services optimise knowledge-based pan-European decision-making, while offshore wind, generates unprecedented amounts of new survey data and information. GSOs in countries active in offshore wind can map the seabed and its shallow subsurface (substrate up to about 100 m) much better than before. These GSOs can increasingly predict where wind turbines can be supported, and power cables can be trenched. The Strategy on Adaptation to Climate Change, another key component of Europe's common policy, requires GSO expertise on coastal behaviour and geohazards, bringing spatial heterogeneity of subsurface properties into focus. Increasing cooperation between the Marine Geology Expert Group and the Earth Observation and Geohazards Expert Group of EuroGeoSurveys, a not-for-profit organisation representing the Geological Surveys of Europe, has shown at a pan-European scale that areas with specific sets of geological conditions are more susceptible to effects of climate change than others. At the same time, however, it is impossible to predict precisely when and where the potential capability of geohazards to cause damage or loss will turn into actual events such as landslides. The concept of awareness mapping, adopted by several GSOs, identifies areas requiring extra attention from competent authorities (through research, monitoring or prevention measures) without suggesting that there is imminent or long-term risk. By contributing to the Green Deal and the Strategy on Adaptation to Climate Change, GSEU intends to strengthen the links between GSO knowledge and EU policy, supporting choices that help both the EU and its individual member states.

Offshore wind is one of the fastest growing marine markets for GSOs. Driven by the Green Deal, the expansion of renewable energy has been accelerating. A growing number of European countries are increasingly looking at offshore sites to alleviate pressures on terrestrial land use and to reduce associated societal opposition to windfarm development as an important element in the energy transition. Also, winds are more consistent at sea and tend to blow more at night in some places, thus complementing production of solar energy during the daytime. Successful rollout of offshore wind requires preparatory, construction-related, and maintenance activities. In this interdisciplinary work, the fields of geology, engineering, ecology, physics, meteorology, archaeology and spatial management meet. Although geology is widely considered to be a crucial element in time- and cost-efficient development of offshore windfarms, it has been underused (Fig. 1). Key reasons are the fragmented nature and limited visibility of geological data, particularly from the subsurface of the seabed, and the difficulty that end users experience when using geological data products that are typically not made specifically for this purpose. Commonly, it is not intuitively clear to these users how geological properties are best translated into decision-supporting attributes. In short, GSO data and data products are neither FAIR nor tailor-made.

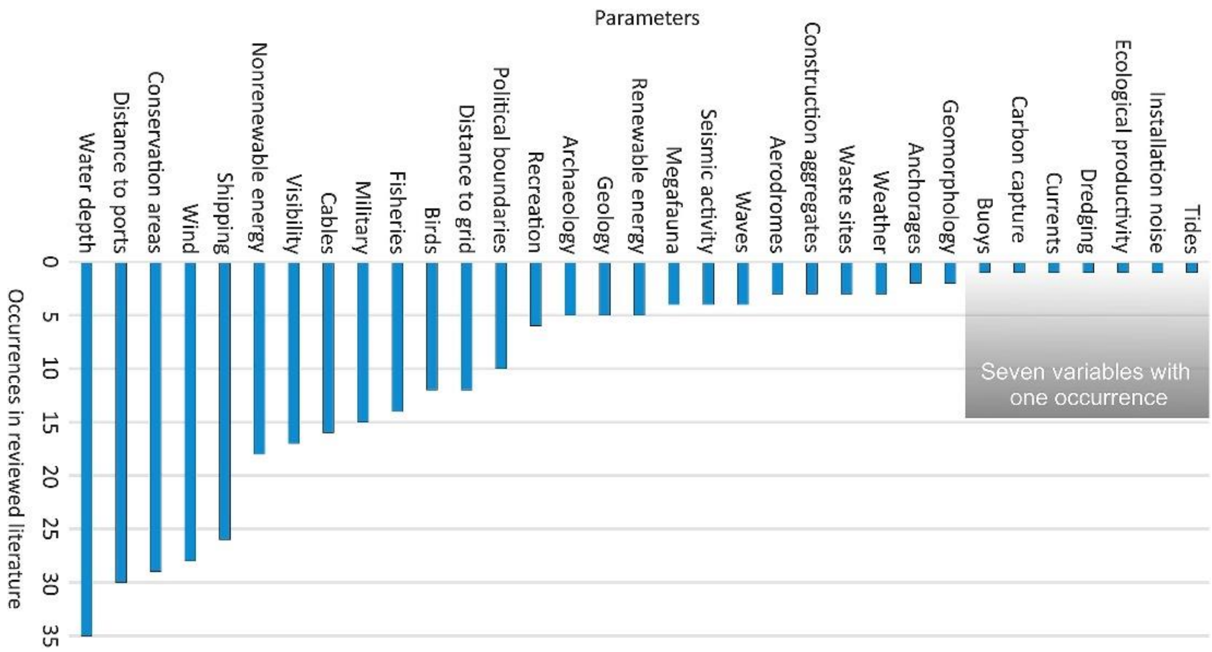

Figure 1. Parameters considered in 49 peer-reviewed GIS studies for offshore wind (Peters et al., 2020). Only 10% of these studies addressed geology.

The role of European GSOs in coastal-vulnerability assessments is also modest, despite two geological parameters (landform and relative resistance to erosion) being key elements of standard analyses and indices (Gornitz et al., 1994). Consequently, geological contributors to coastal vulnerability (particularly erosion, land subsidence, eutrophication, and pollution) have mainly been considered in a descriptive capacity, not in an explanatory or predictive way. In addition, only morphological, grain-size and process-related geological parameters have been considered. Information on the subsurface, with its stratification, fracturing, differential erodibility, and influence on subsidence, is still rarely used.

The importance of geology in pan-European coastal-vulnerability maps with predictive value can best be demonstrated when GSOs work together on data products that are easily incorporated in multidisciplinary platforms, particularly EMODnet, the European Marine Observation and Data network, or harvested from Copernicus services. The Copernicus Marine Service and the European Ground Motion Service are especially relevant. Such an embedded approach enables geologists to incorporate physical process data produced by the wider research community (EMODnet Physics, EMODnet Bathymetry), as well as remote-sensing data providing the pan-European coverage lacking in field studies. In addition, joint portals and cross-disciplinary cooperation make it more likely that geological output is easily accessible, adoptable, and even adaptable by non-expert users. Like in wind, cooperation ensures that geological data and information are both FAIR and tailor-made. Exchange between GSEU's geology portal for land and sea (EGDI) and the interdisciplinary EMODnet Central Portal (linking geology to bathymetry, physics, chemistry, biology, seabed habitats and human activities) must be facilitated.

This T5.3 report, the first deliverable (D5.5) of GSEU WP5, sets the stage for strengthening the position of European GSOs as a provider of services tackling the two important societal issues of offshore wind and coastal vulnerability to a range of environmental and climate-related factors, especially SLR. It summarises the current roles and activities of the different GSOs and outlines a plan to improve their individual and joint positions, partly through ongoing work in the other WP5 tasks (T5.1 on coastal vulnerability and climate change, T5.2 on offshore windfarm siting, and T5.4 on cross-thematic alignment). An update of D5.5, due February 2026, will contain a full roadmap for collective data services and data management (D5.6) that establishes GSEU as a key service centre for marine geological information.

2. Positioning of GSOs

The pan-European underuse of geological data, information, and knowledge, despite their value for offshore wind, is best illustrated by strongly differing positions of GSOs. Some are key players, while others have been limited to the sidelines. For some GSOs, offshore wind is either not yet on the national agenda or not yet implemented. Even where offshore wind is being rolled out, the underuse of GSO resources and expertise inhibits acceleration of time- and cost-efficient windfarm development in Europe's marine waters.

Like offshore wind, the positions of GSOs in the coastal-vulnerability domain vary strongly, a reflection of diverse responsibilities, differing national research landscapes, and differences in funding resources. For many GSOs, a clear legal framework is lacking. While short-term geological processes driven by tides, waves and wind are well-captured in models used by engineers, coastal-zone managers and policy makers, longer-term processes (providing degrees of freedom that can be implemented as boundary conditions to constrain shorter-term models) and lithological heterogeneity in the subsurface are frequently overlooked. Learning from each other, transferring knowledge and skills, and working on joint acquisition would better position GSEU to provide marine and coastal substrate attributes such as cohesiveness, erodibility, permeability, and susceptibility to compaction, especially in the long term.

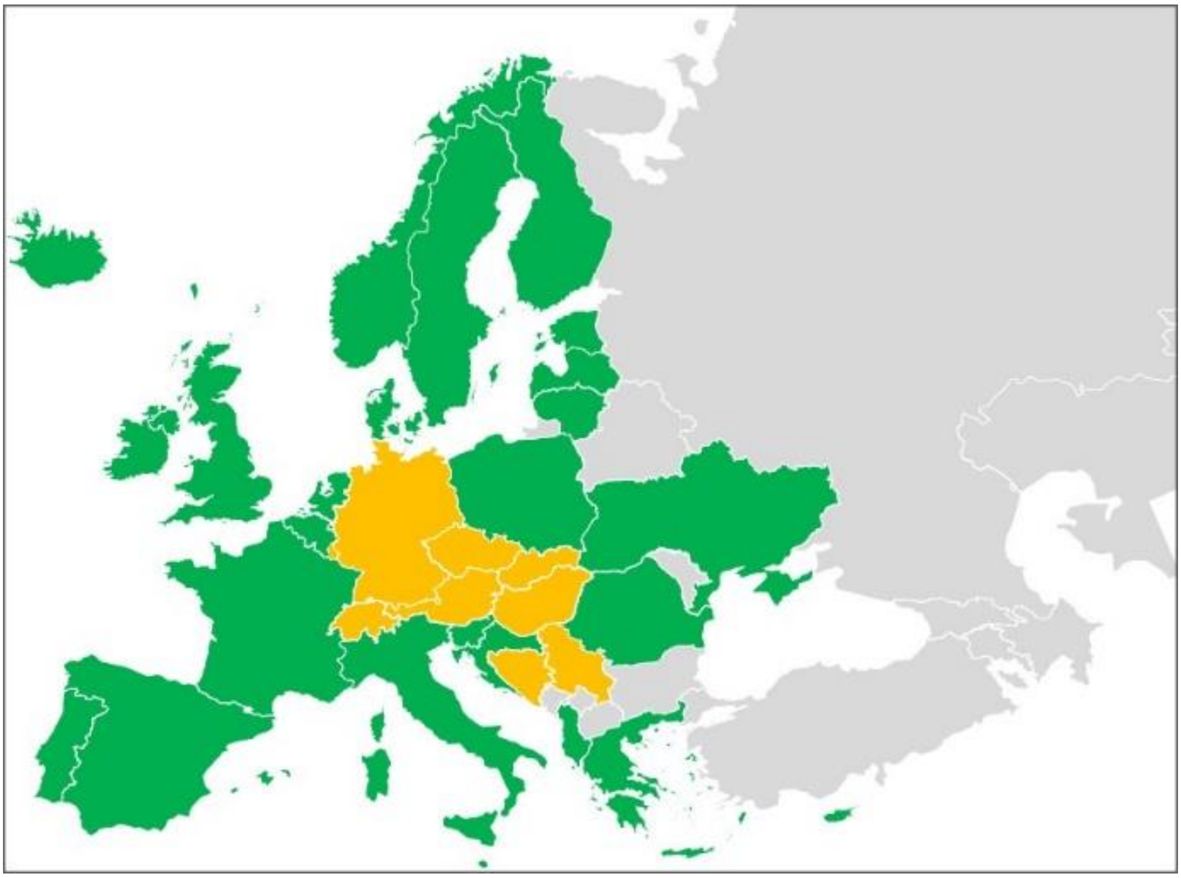

Figure 2. Countries represented in GSEU T5.3 (green), countries represented in GSEU but not in T5.3 (orange), and countries not represented in GSEU (grey).

To this end, the GSOs involved in GSEU WP5 (Fig. 2) filled out a questionnaire about their respective positions in the fields of offshore wind and coastal vulnerability. Information was provided by Sokol Marku (AGS, Albania); Vera Van Lancker (RBINS, Belgium); Ozren Hasan (HGI, Croatia); Nicholas Papadimitriou (GSD, Cyprus); Jørgen Overgaard Leth and Verner Brandbyge Ernstsen (GEUS, Denmark); Sten Suuroja (EGT, Estonia); Bartal Højgaard (Jarðfeingi, Faroe Islands); Aarno Kotilainen (GTK, Finland); Fabien Paquet and Aurélie Maspataud (BRGM, France); Eleftheria Poyiadji, Irene Zananiri and Dimitrios Galanakis (HSGME, Greece); Anett Blischke (ISOR, Iceland); Eoin Mac Craith and Xavier Monteys (GSI, Ireland); Andrea Fiorentino (ISPRA, Italy); Māra Brūne (LVGMC, Latvia); Vytautas Minkevičius (LGT, Lithuania); Charles Galea (MFE-CSD, Malta); Sytze van Heteren (TNO, Netherlands); Nicole Jeanne Baeten (NGU, Norway); Grzegorz Uścinowicz (PGI, Poland); Pedro Brito (IPMA, Portugal); Marian Munteanu (IGR, Romania), Ana Novak (GeoZS, Slovenia); Teresa Medialdea Cela (IGME, Spain); Jordi Pinyol Guamis (ICGC, Spain); Sarah Josefsson (SGU, Sweden); Stella Shekhunova (IGS, Ukraine) and Nicola Dakin (BGS, United Kingdom). Many of them were assisted by colleagues.

The results of this questionnaire are summarised below, addressing statutory, commercial, scientific, cooperative, and strategic tasks and roles that the different GSOs have at the national level. The lists and tables with answers highlight both commonalities and differences. They will be used to decide which themes are most suitable and relevant for pan-European cooperation and for improvement of GSOs' positions.

2.1. Statutory and Long-Term Programme-Related Tasks of GSOs with Reference to Offshore Wind and Coastal Vulnerability

Currently, only the Irish GSO has a statutory task defined specifically for offshore wind. The GSOs in Albania and the United Kingdom have an explicit, but broadly defined, task to facilitate the energy transition. All other partners in this field act either under generic statutory obligations or in the absence of governance by national law.

The main (formal and informal) statutory tasks concerning the seabed and its subsurface with relevance to offshore windfarm siting and coastal vulnerability include:

- collection of geological data and information, including systematic seabed and coastal mapping (AL, BE, CY, DK, EE, ES, ES-C, FI, FO, FR, GR, HR, IE, IS, IT, LT, LV, MT, NO, PL, PT, SE, SI, UA, UK)
- storage and administration (metadata) of geological data in open- or limited-access repositories, safeguarding confidential data (BE, CY, DK, EE, ES, ES-C, FI, FO, FR, GR, HR, IE, IS, IT, LT, LV, MT, NL, NO, PL, PT, SE, SI, UA, UK)
- impartial dissemination (including teaching) of existing geological information and knowledge to society (BE, CY, DK, EE, ES, ES-C, FI, FO, FR, GR, HR, IE, IS, IT, LV, NL, NO, PL, PT, SE, SI, UA, UK)
- data analysis and geological characterisation, including modelling (BE, CY, DK, EE, ES, ES-C, FI, FO, FR, HR, IE, IS, IT, LT, LV, NL, NO, PL, PT, SE, SI, UA, UK)
- protection and sustainability of marine environment and heritage (BE, CY, DK, EE, ES, FI, FR, IE, IS, PL, PT)
- geohazard assessment and awareness (CY, DK, ES-C, FR, NL, NO, PL, PT, SE, UK)

- business and decision support, including advisory consulting (DK, EE, FI, FO, FR, IE, IS, NL, UK)
- territorial management with legislation, policy, regulation and licensing (AL, BE, CY, GR, MT, PT, SE)
- coordination of joint/third-party impact assessments (BE, FR, IT).

Additional (formal and informal) statutory tasks concerning the coastal zone and its subsurface with relevance to coastal vulnerability are:

- coastal monitoring and research in relation to climate change (AL, BE, EE, ES-C, FR, HR, IE, IT, LV, PL, PT, SE, UK)
- coordination and quality control of governmental advice on adaptation to, and mitigation of, the negative effects of SLR, including early warning (ES-C, FO, FR, LV, PL, SE, UK).

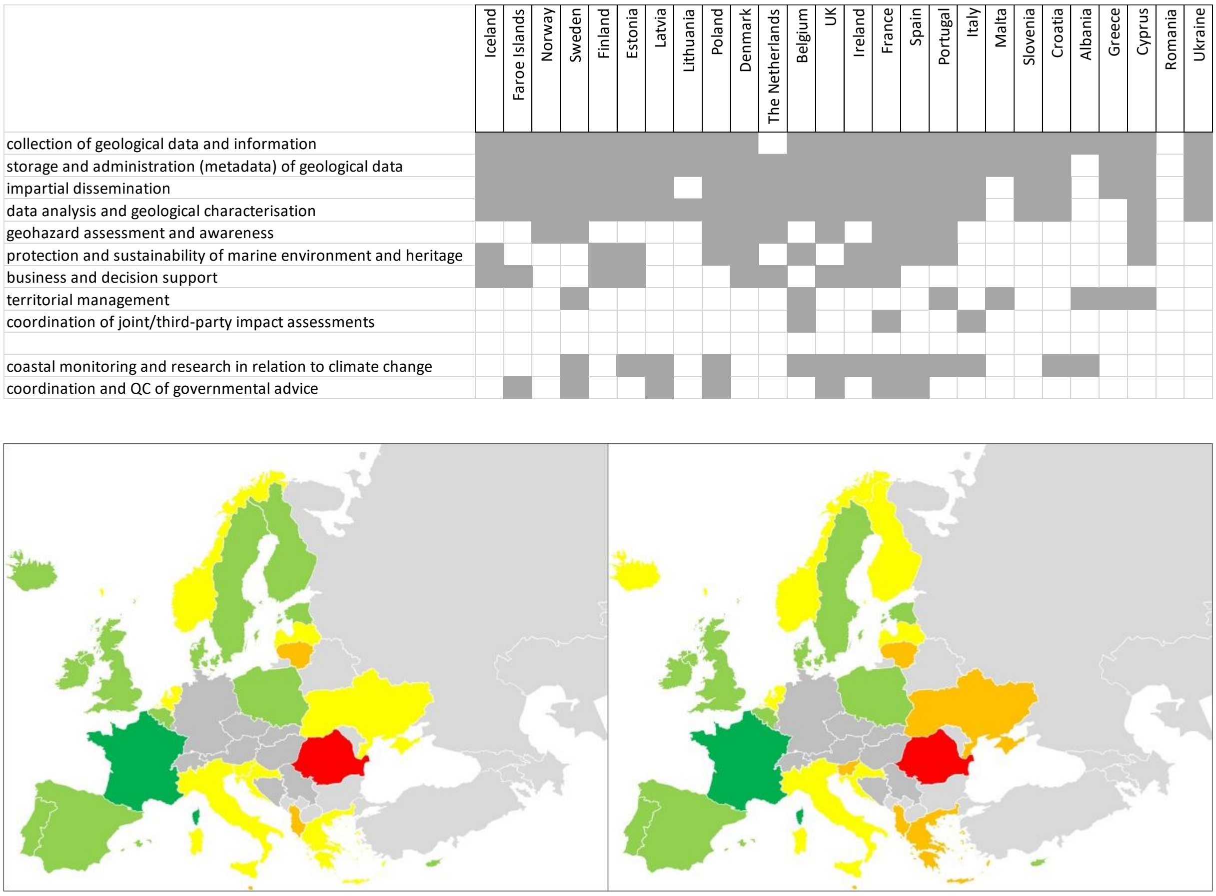

Figure 3. Variety of statutory and long-term programme-related tasks carried out by GSOs in support of or preparation for offshore wind (left) and coastal vulnerability (right). The colours indicate the percentage of listed tasks in which a GSO has been active: red is 0-20%, orange is 20-40%, yellow is 40-60%, light green is 60-80% and dark green is 80-100%. Although this assessment of activity is indicative only, it shows regional patterns of frontrunners (GSOs that will mainly share expertise) and followers (GSOs that will mainly gain expertise). Overall, offshore wind and coastal vulnerability are represented well, especially in western Europe.

Typically, a range of general-purpose geological activities and data products serve governments, industry, NGOs and the general public. Most maps are not tailor-made for offshore wind or coastal vulnerability, limiting their usefulness, but other data and information resources are highly relevant. They will facilitate the access of GSOs not yet involved in these two issues (Fig. 3). GSOs that are part of larger, multidisciplinary research institutes are more likely to be involved in environmental assessments.

2.2. Short-Term Project-Related Activities of GSOs Considering Offshore Wind and Coastal Vulnerability

Multiple GSOs are active commercially in offshore wind, coastal vulnerability, or both, providing expert advice and/or conducting field research for public as well as private clients. Their roles entail:

- desk studies and incidental expert advice (CY, DK, EE, FI, FR, GR, HR, IE, IS, LV, NL, PL, PT, SI, UA, UK)
- free or paid data supply (AL, DK, ES, FI, FR, GR, IE, IS, MT, NL, NO, SE, UK)
- dedicated field research (BE, DK, EE, ES, ES-C, FI, FO, FR, PL, PT, UK)
- facilitation, supervision, and evaluation of third-party investigations (ES, ES-C, FR, IE, LT).

Roles specific to offshore wind are:

- modelling of the subsurface and other elements of the natural system (DK, ES-C, FI, NL, UK)
- licensing (CY, MT).

Roles specific to coastal vulnerability are:

- geohazard assessment and flood mapping (ES, ES-C, FO, FR, IE, NO, SI, UK)
- development of information and decision-support systems (BE, ES-C, FR, IE, NL, UK)
- coastal zone management and strategy (ES-C, FR, IS, UK).

	Iceland	Faroe Islands	Norway	Sweden	Finland	Estonia	Latvia	Lithuania	Poland	Denmark	The Netherlands	Belgium	UK	Ireland	France	Spain	Portugal	Italy	Malta	Slovenia	Croatia	Albania	Greece	Cyprus	Romania	Ukraine
desk studies and incidental expert advice	■				■	■	■		■	■	■		■	■	■		■			■	■		■	■		■
free or paid data supply	■		■	■	■					■	■		■	■	■	■			■			■	■			
dedicated field research		■			■	■			■	■		■	■		■	■	■									
facilitation, supervision and evaluation								■						■	■	■										
modelling of the subsurface					■					■	■		■			■										
licensing																			■					■		
geohazard assessment and flood mapping		■	■										■	■	■	■				■						
development of information and decision-support systems											■	■	■	■	■	■										
coastal zone management and strategy	■													■	■	■										

This project-related work (Fig. 4), addressing specific end-user questions, is done for dedicated national agencies (AL, BE, CY, DK, FO, GR, IE, IS, LT, LV, MT, NL, PL, PT, RO, SI, UA, UK), regional and local governments (AL, DK, ES, ES-C, FI, GR, IE, IS, NO, SI), private companies (EE, FI, FO, FR, IS, LV, UK) and NGOs. For most GSOs, the offshore wind market is growing (DK, EE, ES-C, FI, FO, IE, IS, MT, NL, PL, PT, UK). The coastal-vulnerability market is stable (NL) to growing (DK, EE, ES-C, FO, FR, IE, PL) and rarely shrinking (PT). Some GSOs (GR, PT) are making preliminary inquiries to establish themselves in the commercial market of offshore wind or coastal vulnerability. For a few GSOs (IE, IT, SE), commercial activities are either not permitted or allowed only when private actors are incapable of performing a particular activity, to avoid unfair competition and disturbance of the market.

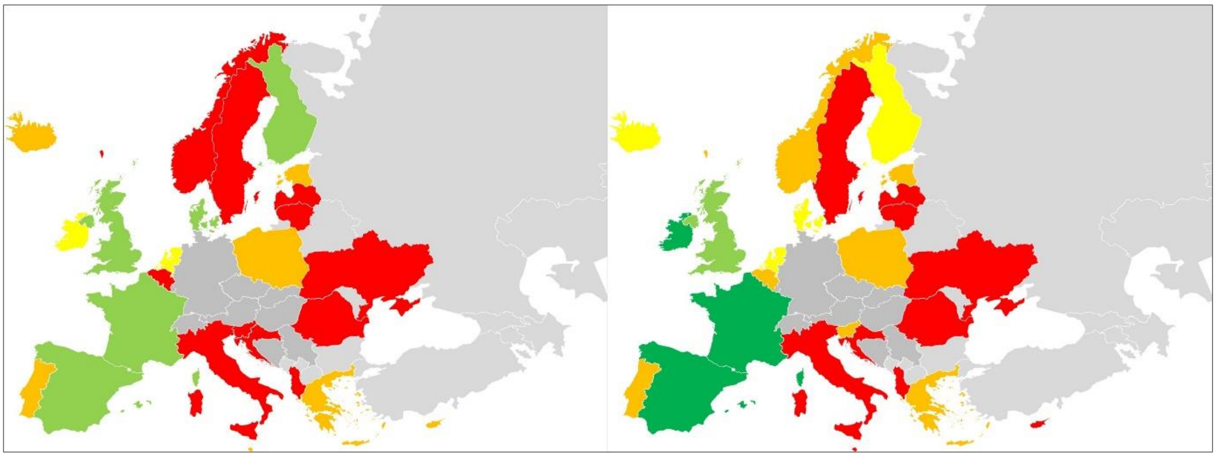

Figure 4. Variety of short-term project-related tasks carried out by GSOs for offshore wind (left) and coastal vulnerability (right). Compared to statutory and programme-related tasks, GSO involvement is more limited.

2.3. Increasing Knowledge Base of GSOs through Activities for Offshore Wind and Coastal Vulnerability

Through both programme- and project-related work on or relevant to offshore wind and coastal vulnerability, GSOs attain more knowledge on substrate-related processes and parameters influencing various risks and costs associated with natural geological change and human activities. During the past decade, GSOs have learned much more about the seabed and its subsurface than would have been possible without all data and information collected for offshore wind, either by the GSOs or by third parties. In particular, progress has been made on:

- seabed properties and stratigraphic successions (BE, CY, DK, EE, ES-C, FI, FR, GR, HR, IE, IS, MT, NL, NO, PL, PT, SE, SI, UA, UK)
- geotechnical and geohazard heterogeneity (CY, DK, ES-C, FI, GR, IE, MT, NL, UK)
- environmental (status and impact) and geochemical characterisation (BE, EE, FI, UA, UK)
- geology relevant to marine spatial planning and optimal use of other resources (BE, DK, IE, SE)
- methodological development and uncertainty assessment (DK, GR, NL)
- machine-learning in subsurface characterisation (DK, NL, UK).

Related to coastal vulnerability, most progress has been made on:

- geological and subsurface influence on landslides/erosion and subsidence (BE, CY, DK, ES-C, FI, FO, FR, IE, IS, IT, MT, NL, NO, SE, SI, UA, UK)
- understanding (climate-related) coastal behaviour (including flooding) from coastal-zone monitoring and surveying (CY, DK, EE, ES-C, FR, IE, IS, LT, LV, MT, PL, PT, SE, SI, UK)
- coastal zone development in relation to sea-level change (DK, EE, FI, FR, IE, IS, IT, LV, SE)
- impact prediction and hotspot identification (AL, CY, FR, IE, IS, MT, SI, UK)
- mitigation and (urban) adaptation measures, including sand extraction and nourishment (BE, CY, DK, FR, IT, NL, PT, SE)
- geological and subsurface influence on vulnerability (resilience/recovery) (CY, ES, FR, IE, UK)
- understanding zones of mixed sediment (DK, FR, SE)
- using Copernicus and other satellite data to assess recent coastal change (FR, IE, UK)
- past storm-surge levels (FR, NL).

	Iceland	Faroe Islands	Norway	Sweden	Finland	Estonia	Latvia	Lithuania	Poland	Denmark	The Netherlands	Belgium	UK	Ireland	France	Spain	Portugal	Italy	Malta	Slovenia	Croatia	Albania	Greece	Cyprus	Romania	Ukraine
seabed properties and stratigraphic successions	X		X	X	X	X			X	X	X	X	X	X	X	X	X		X	X	X		X	X		X
geotechnical and geohazard heterogeneity					X					X	X		X	X		X			X				X	X		
environmental and geochemical characterisation					X	X						X	X													X
geology relevant to marine spatial planning				X						X		X		X												
methodological development and uncertainty assessment										X	X												X			
machine-learning in subsurface characterisation										X	X		X													
geological and subsurface influence on risk	X	X	X	X	X					X	X	X	X	X	X	X		X	X	X				X		X
understanding coastal behaviour from monitoring and surveying	X			X		X	X	X	X	X			X	X	X	X	X		X	X				X		
coastal zone development in relation to sea-level change	X			X	X	X	X			X				X	X			X								
impact prediction and hotspot identification	X												X	X	X				X	X		X		X		
mitigation and adaptation measures				X						X	X	X			X		X	X						X		
geological and subsurface influence on vulnerability													X	X	X	X								X		
understanding zones of mixed sediment				X						X					X											
using Copernicus and other satellite data													X	X	X											
past storm-surge levels											X				X											

This progress has been reported in journal articles, conference papers, reports, map explanations and presentations (see lists at the end of this report). Sharing reports and presentations between GSOs has been suboptimal, and even journal articles are not actively exchanged beyond GSOs from the same regional sea.

Knowledge on seabed properties and stratigraphic successions is well-represented at most GSOs, closely followed by understanding of substrate structure and composition on coastal processes. These are also some of the first topics addressed in T5.1 and T5.2. However, many of the identified tasks, roles and topics are a focal point of just a few GSOs (Fig. 5). This is where cooperation will lead to the fastest progress. Uncertainty assessment, machine learning and subsurface influence on vulnerability are important themes to address.

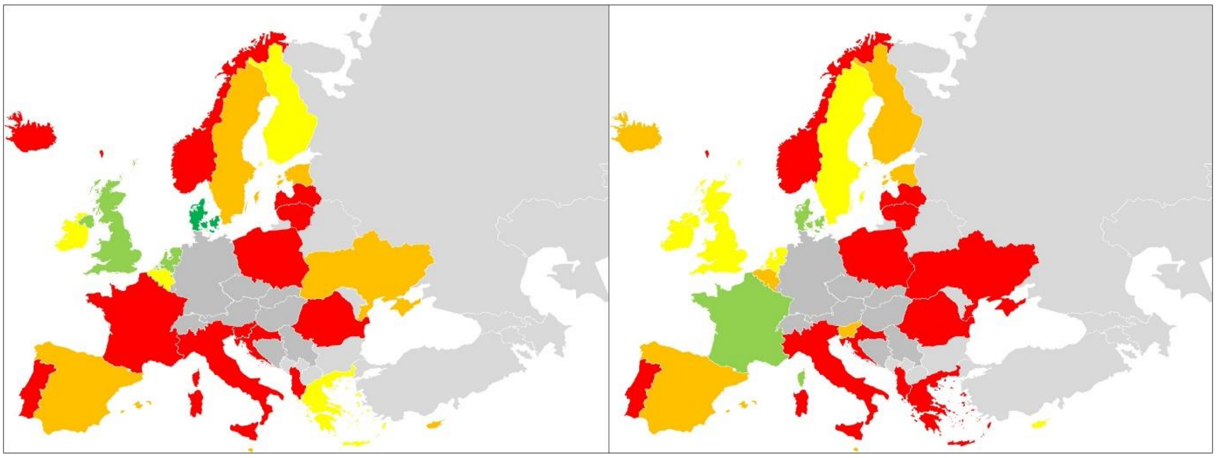

Figure 5. Knowledge dissemination of GSOs directly addressing offshore wind (left) and coastal vulnerability (right). With a few exceptions, it has been too limited to generate enough visibility and have sufficient impact. The lead partners for T5.1 (FR; coastal vulnerability and climate change) and T5.2 (UK; offshore windfarm siting) are well-chosen.

2.4. Cooperation of GSOs in Offshore Wind and Coastal Vulnerability

Further improvement of our individual and collective positions as geological service providers requires increased cooperation. Key partners have been international organisations like UNESCO (CY) and the EC (ES, FI), dedicated national agencies (AL, BE, CY, DK, EE, ES, FI, FO, FR, GR, HR, IS, LT, LV, MT, NL, NO, PL, PT, SE, UA, UK), regional governmental agencies (BE, DK, ES, ES-C, FR, GR, IT, SE, UK), municipalities (FO, FR, IT, GR, SE), private companies (BE, CY), universities and other research institutes (BE, DK, EE, FR, IS, NO, SI), as well as other GSOs.

Alignment and cooperation on both offshore wind and coastal vulnerability mainly concerns:

- sustainable development and environmental protection, including evaluation of environmental status (European Directives) (AL, BE, CY, DK, EE, ES, ES-C, FR, GR, HR, IE, IS, MT, PT, SE, UA, UK)
- spatial planning and integrated management (BE, CY, DK, EE, ES, FR, IE, IT, MT, PL, PT, SE, UK)

- policy and strategy, legislation, and custodian tasks (BE, CY, DK, EE, ES, ES-C, IE, IS, MT, PT, UA, UK)
- business and governmental support, project coordination, and tender/proposal management (BE, CY, DK, EE, FI, FR, IE, MT, NL, SE).

Alignment and cooperation specific to offshore wind concerns:

- energy-transition policy and climate-change roadmaps (IE, MT, SE, UA)
- joint/third-party governmental support (BE, DK, NL)
- power grids (infrastructure) and power plants (SE).

Alignment and cooperation specific to coastal vulnerability concerns:

- coastal zone management, including coastal safety (population, built environment), coordination of adaptation and mitigation, tourism (AL, ES, FI, FO, FR, GR, IS, LT, MT, NL, NO, PT, SE, SI)
- joint applied research (hydro- and morphodynamic modelling, surveying, and monitoring) (DK, FO, FR, HR, IE, NL, NO, PL)
- raising awareness (FR, IE, NO, SE)
- promoting and funding research (FR, IE, SE)
- making climate-change roadmaps (ES-C, FR).

	Iceland	Faroe Islands	Norway	Sweden	Finland	Estonia	Latvia	Lithuania	Poland	Denmark	The Netherlands	Belgium	UK	Ireland	France	Spain	Portugal	Italy	Malta	Slovenia	Croatia	Albania	Greece	Cyprus	Romania	Ukraine
sustainable development and environmental protection	■			■		■				■		■	■	■	■	■	■		■		■	■	■	■		■
spatial planning and integrated management				■		■			■	■		■	■	■	■	■	■	■	■					■		
policy and strategy, legislation, and custodian tasks	■					■				■		■	■	■		■	■		■					■		■
business and governmental support				■	■	■				■	■	■		■	■				■					■		
energy-transition policy and climate-change roadmaps				■										■					■							■
joint/third-party governmental support										■	■	■														
power grids and power plants				■																						
coastal zone management	■	■	■	■	■			■			■				■	■	■		■	■		■	■			
joint applied research		■	■						■	■	■			■	■						■					
raising awareness			■	■										■	■											
promoting and funding research				■										■	■											
making climate-change roadmaps															■	■										

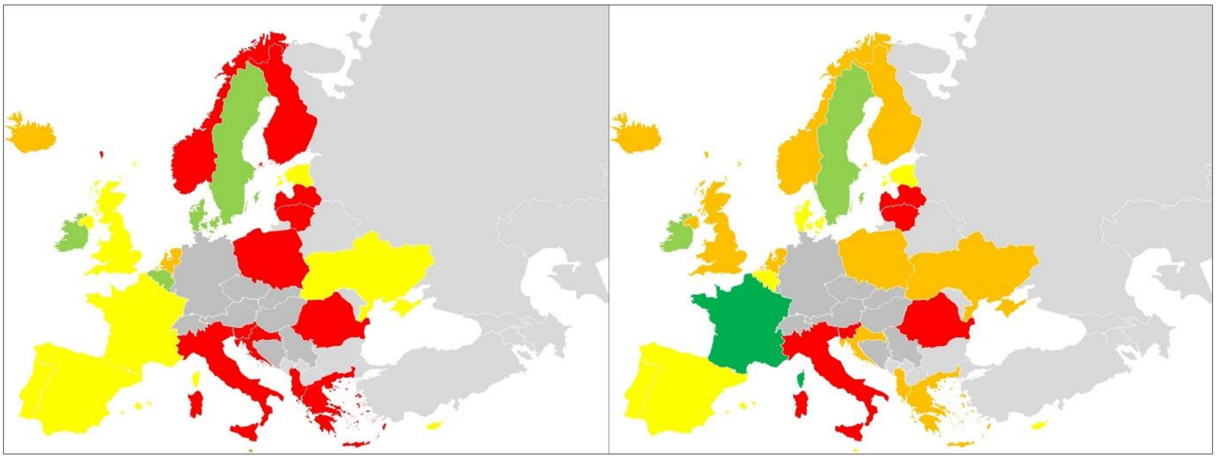

Figure 6. Cooperation of GSOs in offshore wind (left) and coastal vulnerability (right). Existing networks are stronger for coastal vulnerability than for offshore wind, but only few GSOs are fully embedded in interdisciplinary groups.

The position of GSOs within interdisciplinary networks addressing offshore wind or coastal variability should be improved (Fig. 6). Even crucial topics like spatial planning and integrated management have only been addressed properly across the two themes by a few of the GSOs (Fig. 7). As these are linked to policy and strategy, GSEU must ensure that geology can be more easily incorporated into decision-making. National and European roadmaps addressing climate change and the energy transition need to get stronger and include plans to create easily adoptable geological input.

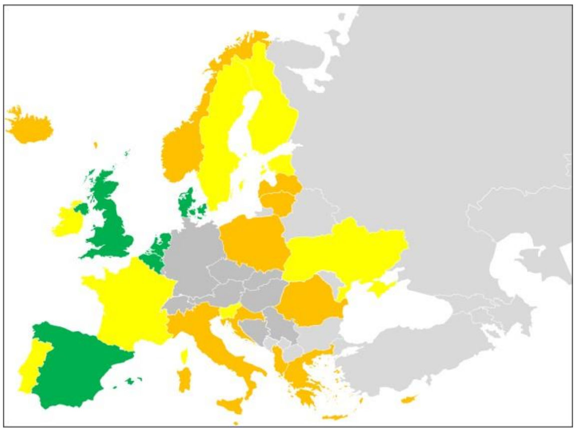

Figure 7. Direct involvement of GSOs in decision-support and spatial planning related to offshore wind or coastal vulnerability. The development of adoptable geological decision-support modules is still in its infancy.

2.5. Strategies to Strengthen the Position of GSOs in Offshore Wind and Coastal Vulnerability

GSOs have varying positions in the fields of offshore wind and coastal vulnerability, from total or relative outsiders to key players. These differences in position are reflected in the strategies they use. To become more relevant, GSOs have been working on or implementing differing strategies aimed at societal challenges and questions at a national level. A few GSOs have no strategy yet on offshore wind or coastal vulnerability. Joint, pan-European progress requires exchange and optimisation of strategies as part of GSEU. Past cost-benefit analyses have shown that geological mapping and data collection generate an excellent return on investment (Van der Meulen et al., 2013; Hill et al., 2020; Verbruggen et al., 2020). The main general strategic steps identified thus far are:

- building collaborative networks and professional partnerships with:
    - governmental agencies (BE, CY, DK, ES, FI, FR, HR, IE, IS, MT, NL, NO, SE, UK)
    - multidisciplinary national expert groups (BE, DK, FO, FR, IE, IS, NL, PT, SE, UK)
    - other GSOs and research institutes (BE, DK, FI, FR, IE, NL, NO, PT, RO, UK)
    - developers (EE, IE, PT)
- creation of data/knowledge base and identification of knowledge gaps (AL, BE, DK, FI, FR, GR, IE, LV, NL, PL, PT, SI, UK)
- active stakeholder engagement from a geological perspective (AL, DK, ES-C, IE, IS, IT, NL, UA, UK)
- methodological development:
    - protocols and guidelines (DK, EE, FI, FR, IT, NL, PL, UA)
    - decision-support system (BE, IE, NL, PT, UK)
- increasing business development and project-acquisition efforts (GR, IS, IT, NL).

Strategies specific to offshore wind are:

- investment in generic pre-development seabed mapping (AL, BE, DK, GR, IE, NO, PL, SE, SI, UK)
- dedicated database development with improved data availability and harmonisation (BE, DK, FR, IE, MT, PT, UK)
- embedding geology in large-scale marine spatial planning (site suitability) (BE, DK, EE, IE, SE, SI)
- collection and storage of physical samples (BE, DK, FR, IE, NL, UK)
- development of modelling capacity (surficial processes and subsurface structure) (BE, FI, NL, UA)
- acquisition of equipment and software (DK, HR, IE, PT)
- investment in high-resolution development-related seabed mapping (DK, IE, UK)
- promotion of initial investment (Greenfield approach) (IS).

Strategies specific to coastal vulnerability are:

- investment in high-resolution coastal mapping and monitoring, especially at vulnerable hotspots and in the white ribbon (AL, DK, EE, ES, FI, FO, FR, IE, LT, NO, PT, UA, UK)
- focussing on land-sea interaction (CY, DK, FR, GR, IE, MT, SE).

	Iceland	Faroe Islands	Norway	Sweden	Finland	Estonia	Latvia	Lithuania	Poland	Denmark	The Netherlands	Belgium	UK	Ireland	France	Spain	Portugal	Italy	Malta	Slovenia	Croatia	Albania	Greece	Cyprus	Romania	Ukraine
partnerships with governmental agencies	■		■	■	■					■	■	■	■	■	■	■			■		■			■		
partnerships with national expert groups	■	■		■						■	■	■	■	■	■		■									
partnerships with GSOs and research institutes			■		■					■	■	■	■	■	■		■								■	
partnerships with developers						■								■			■									
creation of knowledge base and identification of knowledge gaps					■		■		■	■	■	■	■	■	■		■			■		■	■			
active stakeholder engagement from a geological perspective	■									■	■		■	■		■		■				■				■
development of protocols and guidelines					■	■			■	■	■				■			■								■
development of decision-support system											■	■	■	■			■									
increasing business development and project-acquisition efforts	■										■							■					■			
investment in generic pre-development seabed mapping			■	■					■	■		■	■	■						■		■	■			
dedicated database development										■		■	■	■	■		■		■							
embedding geology in large-scale marine spatial planning				■		■				■		■		■						■						
collation and storage of physical samples										■	■	■	■	■	■											
development of modelling capacity					■						■	■														■
acquisition of equipment and software										■				■			■				■					
investment in high-resolution seabed mapping										■			■	■												
promotion of initial investment (Greenfield approach)	■																									
investment in high-resolution coastal mapping and monitoring		■	■		■	■		■		■			■	■	■	■	■					■				■
focussing on land-sea interaction				■						■				■	■				■				■	■		

Three things can be noticed. First, most strategies are employed by only a few GSOs (Fig. 8). Secondly, the number of GSOs working together on offshore wind and coastal vulnerability is small. Now that two platforms are in place to meet and work together, EMODnet Geology and GSEU, this cooperation among GSOs must be intensified. Together, GSOs can build a strong professional partnership with a better knowledge base, effective lobbying, state-of-the-art vessels and equipment, top-level mapping and modelling capabilities, an easily adoptable set of tools, and a better chance to contribute to marine spatial planning at all scales. GSOs need use cases to demonstrate what goes wrong when geology is not properly incorporated into decision-making, and to show their capability to save cost and reduce risk. Finally, strategies of some GSOs are regular ongoing activities for others. Clearly, less experienced GSOs can quickly profit from more experienced GSOs.

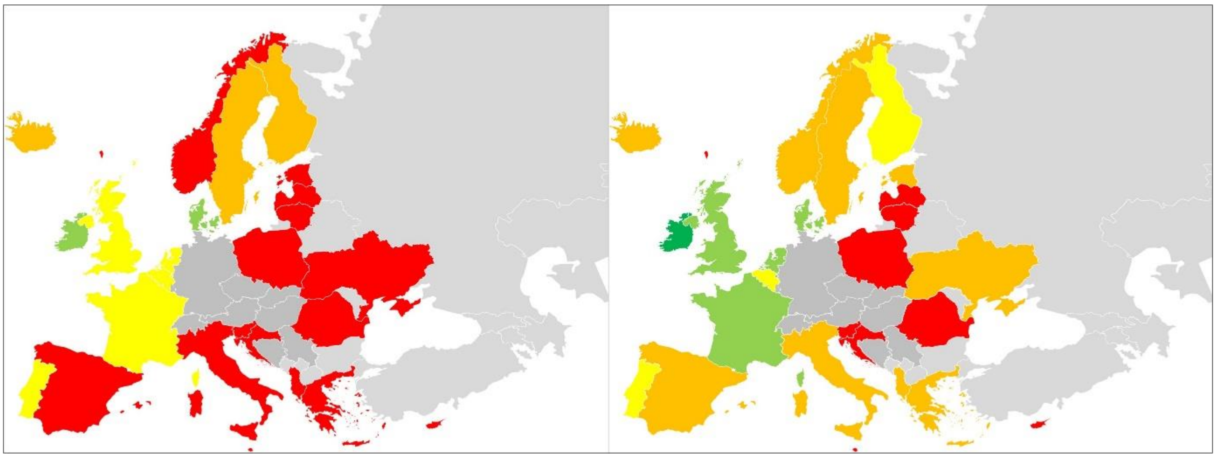

Figure 8. Effort level of GSOs in developing or improving strategies for offshore wind (left) and coastal vulnerability (right). There is a clear need to elaborate on these important marine geological topics in the GSEU SRIA.

3. From Individual GSOs to a GSEU: Joint Service and Business Case

There are clear opportunities to improve the overall position of GSOs within the fields of offshore wind and coastal vulnerability. At the moment, though, there are still several barriers for GSOs to get more involved nationally. Some of the main issues hampering their involvement in these domains are:

- tasks (primarily) assigned to other national agencies, with or without direct geological knowledge
- tasks left to market, preventing market disturbance by non-commercial entities
- tenders prescribing geological studies in combination with highly specialistic foundation-related geotechnical analyses
- lack of experience in topic concerned
- difficulty joining or forming consortia with all required expertise and a fair distribution of funds
- lack of visibility
- poor adoptability and adaptability of geological data products:
    - format,
    - generic rather than applied (tailor-made).

Three experiences (from the anonymised GSO A, GSO B and GSO C) related to offshore wind demonstrate on the one hand how these barriers prevent GSOs to contribute their unique data, information, and knowledge, and on the other hand that there are opportunities when things go wrong in the development phase.

GSO A is active in a country where offshore wind is still in its infancy. All requirements, standards and protocols for pre-development desk and field studies still need to be documented. GSO A involves other GSOs in this preparatory work, ensuring a complete and highly detailed recommendation on geological needs and importance. After the recommendations are adopted, the governmental funding is not arranged per discipline but for several disciplines together. GSO A is forced to compete with ecologists and environmental scientists in subdividing a single grant. Lesson: at an early stage, GSOs need to establish a financially separate position in an interdisciplinary research context.

GSO B is invited by its government to submit a bid to create a ground model for a windfarm zone that has been selected for further development. A large dataset of surficial (side-scan-sonar and multibeam data) and subsurface (boreholes, CPTs and seismic-reflection profiles) information is available for combination with existing knowledge that is best represented by GSO B. After submitting a proposal, the evaluation committee concludes that GSO B has no relevant experience in offshore wind. Despite knowing more about the physical seabed and subsurface than its competitors, the bid is disqualified. Lesson: GSOs need to form consortia so that both regional geological expertise and generic experience in offshore wind are represented (Fig. 9).

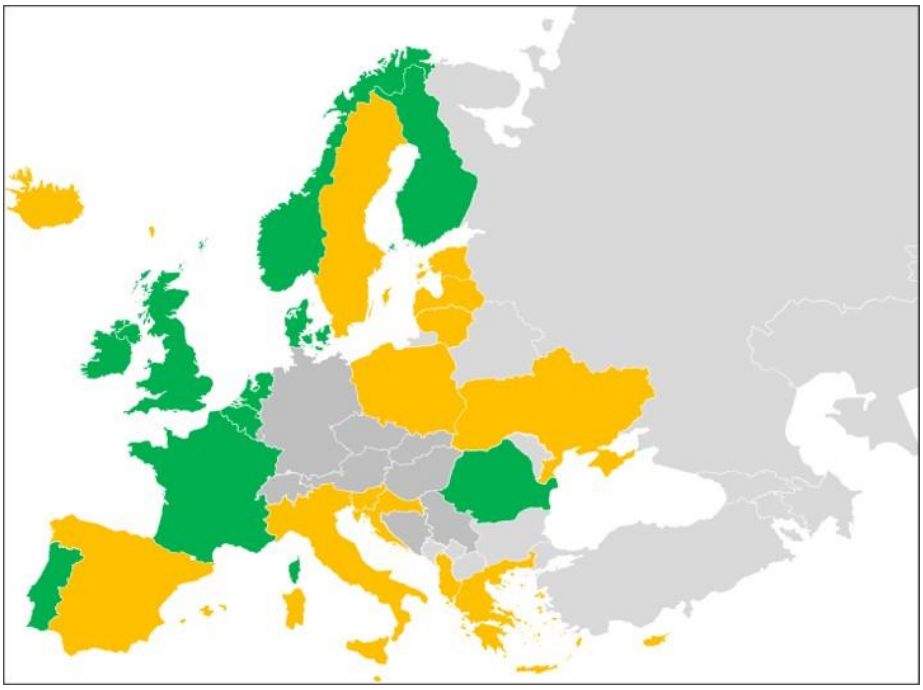

Figure 9. Cooperation between GSOs to share expertise related to offshore wind and coastal vulnerability. This cooperation is mostly bilateral and typically not project related. GSEU will broaden these existing networks, building on EMODnet's ongoing joint work concerning other geological themes. A sea-basin approach will be a major first step.

GSO C is active in a country where offshore wind has matured. Different windfarms are operational or under construction. Aside from some incidental expert advice, its involvement has been limited. At some point after pre-development was completed, detailed field surveys show that a geohazard causes complications. Both government and industry turn to GSO C, known as the national authority on subsurface structure and composition. GSO C maps and explains the geohazard, predicting its spatial heterogeneity and defining mitigation measures. By demonstrating its added value (small cost, large benefit), GSO C demonstrates that a national authority on seabed and subsurface should not be overlooked. Lesson: fully engage with government and industry, emphasising the need for knowledge of GSOs even when not consulted commercially or when acting in a subsidiary role.

These experiences demonstrate the need to provide better knowledge, products, and service than competitors, and to show the capability to do so. Obviously, a less experienced GSO should learn from more experienced GSOs. Even the most experienced GSOs, however, can still improve within a fertile GSEU network that enables work in different marine environmental settings. Three steps, relevant to offshore wind and coastal vulnerability, need to be taken:

- jointly developing state-of-the-art standards and protocols
- documenting and sharing lessons learned (positives and negatives)
- using EGDI to share knowledge and show the added value of joint, pan-European data products.

4. Upgrading the EGDI Platform

For more than a decade, the EGDI portal has been the engine delivering geological data and information to EMODnet. It has proven its value as a useful instrument and platform, but visualisation and other use by non-geologists especially has also shown that there is room for improvement. Although many of the current shortcomings are associated with the generic nature of most marine geological data products (they are not fit-for-purpose), some are specific to limitations of the controlled vocabularies that have been used, or with functionality of the EGDI portal itself.

Building on EMODnet's foundation of marine data and information, WP5 of GSEU will develop prototypes for a new set of products that can be applied directly by end users in offshore wind and coastal vulnerability. Through EGDI, it will be possible to connect this new generation of marine products to terrestrial geology. This connection is needed to explain and predict features and processes taking place at the land-sea boundary. By feeding the WP5 data products back into EMODnet, they can also be used in the interdisciplinary context that is needed for informed decision-making in the marine realm.

Fifteen years of cooperation in EMODnet Geology has shown that harmonisation to common terms defined under Europe's INSPIRE Directive improves the uniformity of pan-European marine maps made by GSOs. It has also demonstrated several deficiencies of the current INSPIRE standards for geological attributes. Some of these standards complicate the present and required INSPIRE-compliant classification process because they do not have enough granularity – degree of subdivision – for key seabed characteristics. Others miss the complete relational structure of terms that is needed to create data products able to address pan-European to regional scales.

A fully relational classification of mapped features makes it easier to simplify maps and legends as the scale increases (Fig. 10). Maps currently shown are not scalable onscreen, meaning that each data product can be viewed by users at any zoom level. GSOs need to start thinking about linking maps to specific zoom ranges to improve clarity and increase flexibility for end users and stakeholders. The scale at which a map or other dataset can be used must be intuitively clear. By using the highest level of hierarchy for pan-European maps and lower levels of hierarchy for regional maps marked by less variability, the number of legend units shown is optimised to ensure legibility. Working with dynamic legends, for which EGDI has developed a prototype, is especially important in geology.

To promote adoptability, vectorised data (shapefiles) should be delivered together with rasterised data. One of the main challenges will be setting up a layer module allowing users to analyse subsurface landscapes in lateral as well as vertical space. Vertically stacked layer sequences are rarely a layer cake of horizontal units with uniform thickness. Recently developed 2.5D functionality within EGDI will become a key element of decision-support modules that can be incorporated into interdisciplinary policy instruments.

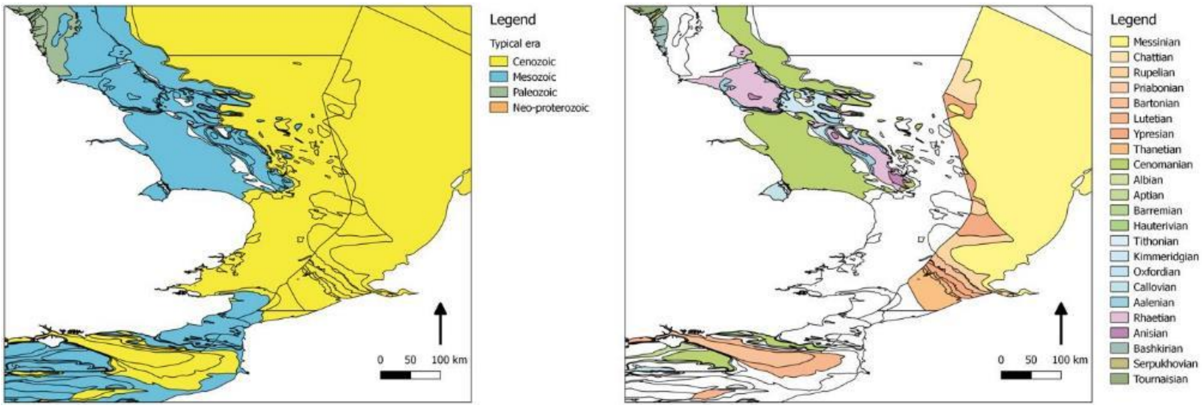

Figure 10. Full-coverage overview (left) versus partial-coverage detailed (right) maps show the added value of both, depending on the intended scale of application. The full-coverage product enables transnational to pan-European analysis, the partial-coverage products highlight data gaps and can be used for local to national spatial evaluation.

Other WP5 components in EGDI will include:

- yellow pages for GSOs, GSO departments, and GSO personnel (who is who in offshore wind and coastal vulnerability)
- standards and protocols
- use cases and lessons learned.

5. Conclusions and Recommendations

Up until now, data, information, and knowledge of GSOs has not been used to its fullest potential in questions related to two of Europe's most urgent marine issues: offshore wind and coastal vulnerability. To change this, geological data and information must become both FAIR and tailor-made. By working together in GSEU on data products that are easily incorporated in multidisciplinary platforms, especially EMODnet in its role to support the EU's integrated maritime policy, GSOs have an opportunity to become more relevant to the broader community.

The results of the GSEU T5.3 inventory give rise to the following recommendations to make this happen:

- integrate and optimise two platforms: EMODnet Geology (ensuring thematic interdisciplinarity in the analysis of marine basins) and EGDI (connecting the geology of land and sea)
- strengthen the GSO network, following parallel sea-basin and pan-European approaches and making sure that there is enough to be gained for frontrunners and followers alike
- strengthen interdisciplinary networks that offer the chance to work on spatial planning as well as integrated marine and coastal management
- publish on offshore wind and coastal vulnerability for better visibility and more impact
- accelerate the development and use of new standards, protocols an tools such as machine learning to create and update increasingly flexible output quickly and frequently.

6. References

Peters, J. L., Remmers, T., Wheeler, A. J., Murphy, J., & Cummins, V. (2020). A systematic review and meta-analysis of GIS use to reveal trends in offshore wind energy research and offer insights on best practices. Renewable and Sustainable Energy Reviews, 128, 109916.

Gornitz, V. M., Daniels, R. C., White, T. W., & Birdwell, K. R. (1994). The development of a coastal risk assessment database: vulnerability to sea-level rise in the US Southeast. Journal of Coastal Research, SI 12, 327-338.

Hill, P. R., Lebel, D., Hitzman, M., Smelror, M., & Thorleifson, H. (2020). The changing role of geological surveys: introduction. Geological Society of London Special Publication, 499, doi: 10.1144/SP499-2020-19.

Van der Meulen, M. J., Doornenbal, J. C., Gunnink, J. L., Stafleu, J., Schokker, J., Vernes, R. W., Van Geer, F. C., Van Gessel, S. F., Van Heteren, S., Van Leeuwen, R. J. W., Bakker, M. A. J., Boogaard, P. J. F., Busschers, F. S., Griffioen, J., Gruijters, S. H. L. L., Kiden, P., Schroot, B. M., Simmelink, H. J., Van Berkel, W. O., Van der Krogt, R. A. A., Westerhoff, W. E., & Van Daalen, T. M. (2013). 3D geology in a 2D country: perspectives for geological surveying in the Netherlands. Netherlands Journal of Geosciences, 92(4), 217-241, doi: 10.1017/S0016774600000184.

Verbruggen, K., Braiden, A. K., Lee, M., Scanlon, R., Cullen, S., & Finlay, S. (2020). Relevant and flexible geosurveys? How Geological Survey Ireland is adapting. Geological Society of London Special Publication, 499, doi: 10.1144/SP499-2019-150.

7. GSO Literature & Portals Related to Offshore Wind

Bitinas, A., Žaromskis, R., Gulbinskas, S., Damušyte, A., Žilinskas, G., & Jarmalavičius, D. (2005). The results of integrated investigations of the Lithuanian coast of the Baltic Sea: geology, geomorphology, dynamics and human impact. Geological Quarterly, 49.

Carpentier, S., Peuchen, J., Paap, B., Boullenger, B., Meijninger, B., Vandeweijer, V., ... & Van Erp, F. (2021, March). Generating synthetic CPTs from marine seismic reflection data using a neural network approach. In Second EAGE workshop on machine learning (Vol. 2021, No. 1, pp. 1-3). European Association of Geoscientists & Engineers.

Cartelle, V., Barlow, N. L., Hodgson, D. M., Busschers, F. S., Cohen, K. M., Meijninger, B. M., & van Kesteren, W. P. (2021). Sedimentary architecture and landforms of the late Saalian (MIS 6) ice sheet margin offshore of the Netherlands. Earth Surface Dynamics, 9(6), 1399-1421.

Cotterill, C. J., Phillips, E., James, L., Forsberg, C. F., Tjelta, T. I., Carter, G., & Dove, D. (2017). The evolution of the Dogger Bank, North Sea: A complex history of terrestrial, glacial and marine environmental change. Quaternary Science Reviews, 171, 136-153.

Degraer, S., Brabant, R., Rumes, B., & Vigin, L. (2018). Environmental impacts of offshore wind farms in the Belgian part of the North Sea: Learning from the past to optimise future monitoring programmes. Scientific Reports Series: Memoirs on the Marine Environment.Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management Section. 239 pp.

Degraer, S., Brabant, R., Rumes, B. & Vigin, L. (eds). (2023). Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Progressive Insights in Changing Species Distribution Patterns Informing Marine Management. Memoirs on the Marine Environment. Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management Section, 115 pp.

Degraer, S., Vanaverbeke, J., Arboleda, C. E., Baeye, M., Brabant, R., Depestele, J., Gill, A. B., Hajivalie, F., Herman, L., Hostens, K., Hutchison, Z., Kapasakali, D. Kerckhof, F., Kint, L., Lopez Lopez, L., Luyten, P., Montereale Gavazzi, G., Ong Ee, Z., Paoletti, S., Reis, S., Rolleberg, N., Rumes, B., Sigray, P., Stewart, B., Stienen, E., Troch, P., Van Colen, C., Van den Eynde, D., Vanermen, N., Van Hoey, G., Van Lancker, V., Wu, M., & Zupan, M. (2023). Executive Summary, pp. 15-26. In: Degraer et al. (eds.) (2023). EDEN 2000. Exploring options for a nature-proof development of offshore wind farms inside a Natura 2000 area. Memoirs on the Marine Environment. Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management Section.

Emelyanov, V. A., Mitropolsky, A. Y., Nasedkin, E. I., & Pasinkov, A. A. (2004). Geoecology of the Black Sea shelf of Ukraine, Akademperiodika, Kiev, 296 pp.

Gavin & Doherty Geosolutions (2021). A review of the Irish offshore renewable energy (ORE) sector's data and information requirements in the context of the INFOMAR seabed mapping programme. https://www.geoscience.ie/review-of-irish-offshore-renewable-energy-sectors-data-information-requirements-gdg/.

Guinan, J., McKeon, C., O'Keeffe, E., Monteys, X., Sacchetti, F., Coughlan, M., & Nic Aonghusa, C. (2021). INFOMAR data supports offshore energy development and marine spatial planning in the Irish offshore via the EMODnet Geology portal. Quarterly Journal of Engineering Geology and Hydrogeology, 54(1), qjegh2020-033.

Hademenos, V., Stafleu, J., Missiaen, T., Kint, L., & Van Lancker, V. R. (2019). 3D subsurface characterisation of the Belgian Continental Shelf: a new voxel modelling approach. Netherlands Journal of Geosciences, 98, e1.

Iceland's Government Council (2023). Wind energy: options and feasibility. Working Group on Wind Energy, Ministry of the Environment, Energy and Climate, ISBN 978-9935-9705-4-1, April 2023, p. 89.

Iceland's Government Council (2023). Offshore wind energy: working group report. Working Group on Wind Energy, Ministry of the Environment, Energy and Climate, ISBN 978-9935-9705-8-9, April 2023, p. 107, annexes 1-10.

Illmatic Energy (2020). A review of the Irish offshore renewable energy (ORE) sector's data and information requirements in the context of the INFOMAR seabed mapping programme. www.infomar.ie/sites/default/files/pdfs/Illmatic energy infomar ore review report.pdf.

Kint, L., Hademenos, V., De Mol, R., Stafleu, J., van Heteren, S., & Van Lancker, V. (2021). Uncertainty assessment applied to marine subsurface datasets. Quarterly Journal of Engineering Geology and Hydrogeology, 54(1), qjegh2020-028.

Larsen, B., & Leth, J. O. (2001). Geologisk kortlægning af Vestkysten. Regionalgeologisk tolkning og en samlet vurdering af aflejringsforholdene i området mellem Nymindegab og Horns Rev (Geological mapping of the West Coast. Regional geological interpretation and an overall assessment of the depositional conditions in the area between Nymindegab and Horns Rev). Volume 1(2): Tekstbind. Udført for Kystdirektoratet i 2000 og 2001. GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2001 No. 96 https://doi.org/10.22008/gpub/18363

Larsen, B., Leth, J. O., Konradi, P., & Czakó, T. (2001). Geologisk kortlægning af Vestkysten. Regionalgeologisk tolkning og en samlet vurdering af aflejringsforholdene i området mellem Nymindegab og Horns Rev (Geological mapping of the West Coast. Regional geological interpretation and an overall assessment of the depositional conditions in the area between Nymindegab and Horns Rev). Volume 2(2): Databind: Udført for Kystdirektoratet i 2000 og 2001. GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2001 No. 96 https://doi.org/10.22008/gpub/18364.

Le Bot, S., Van Lancker, V., Deleu, S., De Batist, M., Henriet, J. P., & Haegeman, W. (2005). Geological characteristics and geotechnical properties of Eocene and Quaternary deposits on the Belgian continental shelf: synthesis in the context of offshore wind farming. Netherlands Journal of Geosciences, 84(2), 147-160.

Montereale Gavazzi, G., Degraer, S., & Van Lancker, V. (2023). Chapter 1. Predictive modelling of seafloor surficial gravel distribution within the Princess Elisabeth offshore wind farm zone (Belgium), pp. 27-63. In: Degraer et al. (eds.) (2023). EDEN 2000. Exploring options for a nature-proof development of offshore wind farms inside a Natura 2000 area. Memoirs on the Marine Environment. Brussels: Royal

Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management Section.

Monteys, X., Guinan, J., Green, S., Gafeira, J., Dove, D., Baeten, N. J., & Thorsnes, T. (2017, December). National Seabed Mapping Programmes Collaborate to Advance Marine Geomorphological Mapping in Adjoining European Seas. In AGU Fall Meeting Abstracts (Vol. 2017, pp. OS41A-1374).

Nanson, R., Arosio, R., Gafeira, J., McNeil, M., Dove, D., Bjarnadóttir, L., ... & Nichol, S. (2023). A two-part seabed geomorphology classification scheme. Part 2: Geomorphology classification framework and glossary-Version 1.0. Published 14th April 2023. DOI: 10.5281/zenodo.7804019.

Novak, A., Šmuc, A., Poglajen, S., & Vrabec, M. (2020). Linking the high-resolution acoustic and sedimentary facies of a transgressed Late Quaternary alluvial plain (Gulf of Trieste, northern Adriatic). Marine Geology, 419, 106061.

Nyberg, J., Zillén-Snowball, L., & Strömstedt, E. (2022). Spatial characterization of seabed environmental conditions and geotechnical properties for the development of marine renewable energy in Sweden. Quarterly Journal of Engineering Geology and Hydrogeology, 55(4), qjegh2021-091.

O'Toole, R., Judge, M., Sacchetti, F., Furey, T., Mac Craith, E., Sheehan, K., ... & Monteys, X. (2022). Mapping Ireland's coastal, shelf and deep-water environments using illustrative case studies to highlight the impact of seabed mapping on the generation of blue knowledge.

Phillips, E., Cotterill, C., Johnson, K., Crombie, K., James, L., Carr, S., & Ruiter, A. (2018). Large-scale glacitectonic deformation in response to active ice sheet retreat across Dogger Bank (southern central North Sea) during the Last Glacial Maximum. Quaternary Science Reviews, 179, 24-47.

Phillips, E., Johnson, K., Ellen, R., Plenderleith, G., Dove, D., Carter, G., ... & Cotterill, C. (2022). Glacitectonic evidence of ice sheet interaction and retreat across the western part of Dogger Bank (North Sea) during the Last Glaciation. Proceedings of the Geologists' Association, 133(1), 87-111.

Prampolini, M., Coratza, P., Rossi, S., Parenti, C., Galea, C., Caruana, A., & Soldati, M. (2021). Geomorphology of the seafloor north east of the Maltese Islands, Central Mediterranean. Journal of Maps, 17(2), 465-475.

Ronchi, L., Fontana, A., Novak, A., Correggiari, A., & Poglajen, S. (2023). Late-Quaternary Evolution of the Semi-Confined Alluvial Megafan of Isonzo River (Northern Adriatic): Where the Fluvial System of the Southern Alps Meets the Karst. Geosciences, 13(5), 135.

Saresma, M., Virtasalo, J., Li, Z. -S., Mohapatra, D., & Solowski, W. (2023). Geotechnical properties determination of soft coastal sediments by FF-CPT in the northern Gulf of Finland. In: Baltic Sea Science Congress 2023, 21-25, August 2023, Helsinki, Finland. The science we need for the Baltic Sea we want. Book of abstracts. 121.

Shniukov E. F., Melnyk V. Y., & Ynozemtsev Yu. Y. (eds) (1985). Heolohyia shelfa USSR: Lytolohyia (Geology of UkrSSR shelf: Lithology). Kyev: Nauk. dumka, 190 pp.

Shniukov E. F., Melnyk V. Y., & Ynozemtsev Yu. Y. (eds) (1987). Heolohyia shelfa USSR: Tectonica (Geology of UkrSSR shelf: Tectonics). Kyev: Nauk. dumka, 178 pp.

Trobec, A., Busetti, M., Zgur, F., Baradello, L., Babich, A., Cova, A., ... & Vrabec, M. (2018). Thickness of marine Holocene sediment in the Gulf of Trieste (northern Adriatic Sea). Earth System Science Data, 10(2), 1077-1092.

Tuuling, I., Suuroja, S., Veski, A., & Liira, M. (2021). Ülevaade meregeoloogilisest andmestikust meretuuleparkide planeerimiseks (An overview of marine geological data for offshore wind farm planning). Eesti Geoloogiateenistuse Teadusnõukogu otsusega 21-7, 59 pp.

Van Hulle, F., Le Bot, S., Cabooter, Y., Soens, J., Van Lancker, V., Deleu, S., Henriet, J. P., Palmers, G., Dewilde, L., Driesen, J., Van Roy, P., & Belmans, R. (2004). Optimal offshore wind energy developments in Belgium. SPSDII Scientific Support Plan for a Sustainable Development Policy. Part I Sustainable Production and Consumption Patterns. Energy. Brussel (B), Belgian Science Policy (D/2004/1191/17), 153 pp.

Van den Eynde, D., Baeye, M., & Van Lancker, V. (2023). Chapter 8. Effect of wind farms on the siltation of gravel beds, pp. 173-216. In: Degraer et al. (eds.) (2023). EDEN 2000. Exploring options for a nature-proof development of offshore wind farms inside a Natura 2000 area. Memoirs on the Marine Environment. Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management Section.

Van Lancker, V., Francken, F., Kint, L., Terseleer, N., Van den Eynde, D., De Mol, L., ... & van Heteren, S. (2017). Building a 4D voxel-based decision support system for a sustainable management of marine geological resources. In Oceanographic and Marine Cross-Domain Data Management for Sustainable Development (pp. 224-252). IGI Global.

Van Lancker, V, Francken, F, Kapel, M, Kint, L, Terseleer, N, Van den Eynde, D, Hademenos, V, Missiaen, T, De Mol, R, De Tré, G, Appleton, R, van Heteren, S, van Maanen, P. P., Stafleu, J, Stam, J, Degrendele, K, & Roche, M. (2018). Transnational and integrated long-term marine exploitation strategies (TILES). Final Report. Brussels: Belgian Science Policy 2018 – 82 p. (BRAIN-be - Belgian Research Action through Interdisciplinary Networks) (incl. data portal; voxel models; decision-support tool).

Portals:
https://geologia.pgi.gov.pl/arcgis/apps/MapSeries/index.html?appid=8d14826a895641e2be10385ef3005b3c

https://north-sea-energy.eu/en/energy-atlas/

https://www.infomar.ie/maps/interactive-maps/data-and-sub-bottom-profiler-viewer

https://odnature.naturalsciences.be/mumm/en/windfarms/

8. GSO Literature & Portals Related to Coastal Vulnerability

Adell, A., Nunes De Brito Junior, A., Almström, B., Goodfellow, B., Bokhari Irminger , S., Hallin, C., & Nyberg, J. (2021). Open-access portal with hindcast wave data for Skåne and Halland. Vatten: tidskrift för vattenvård /Journal of Water Management and research, 77(2), 81-90. https://www.tidskriftenvatten.se/wpcontent/uploads/2021/06/VATTEN_21_2_81-90.pdf.

Anderson, A., Vilumaa, K., Tonisson, H., Kont, A., Ratas, U., & Suuroja, S. (2014). Geomorphology of coastal formations on present and ancient sandy coasts. Journal of Coastal Research, (70), 90-95.

Antonioli, F., Anzidei, M., Amorosi, A., Presti, V. L., Mastronuzzi, G., Deiana, G., ... & Vecchio, A. (2017). Sea-level rise and potential drowning of the Italian coastal plains: Flooding risk scenarios for 2100. Quaternary Science Reviews, 158, 29-43.

Baeteman, C. (2005). How subsoil morphology and erodibility influence the origin and pattern of late Holocene tidal channels: case studies from the Belgian coastal lowlands. Quaternary Science Reviews, 24(18-19), 2146-2162.

Bakker, M. A., van Heteren, S., Vonhögen, L. M., van der Spek, A. J., & Van der Valk, B. (2012). Recent coastal dune development: effects of sand nourishments. Journal of Coastal Research, 28(3), 587-601.

Bertels, L., Houthuys, R., Deronde, B., Janssens, R., Verfaillie, E., & Van Lancker, V. (2012). Integration of optical and acoustic remote sensing data over the backshore–foreshore–nearshore continuum: a case study in Ostend (Belgium). Journal of Coastal Research, 28(6), 1426-1436.

Bøe, R., Rise, L., Blikra, L. H., Longva, O., & Eide, A. (2003). Holocene mass-movement processes in Trondheimsfjorden, Central Norway. Norsk Geologisk Tidsskrift, 83(1), 3-22.

Bøe, R., Longva, O., Lepland, A., Blikra, L. H., Sønstegaard, E., Haflidason, H., ... & Lien, R. (2004). Postglacial mass movements and their causes in fjords and lakes in western Norway. Norwegian Journal of Geology/Norsk Geologisk Forening, 84(1).

Böhme, M., Oppikofer, T., Longva, O., Jaboyedoff, M., Hermanns, R. L., & Derron, M. H. (2015). Analyses of past and present rock slope instabilities in a fjord valley: Implications for hazard estimations. Geomorphology, 248, 464-474.

Candela, T., & Koster, K. (2022). The many faces of anthropogenic subsidence. Science, 376(6600), 1381-1382.

Declercq, P. Y., Gérard, P., Pirard, E., Walstra, J., & Devleeschouwer, X. (2021). Long-term subsidence monitoring of the Alluvial plain of the Scheldt river in Antwerp (Belgium) using radar interferometry. Remote Sensing, 13(6), 1160.

Deronde, B., Houthuys, R., Henriet, J. P., & Lancker, V. V. (2008). Monitoring of the sediment dynamics along a sandy shoreline by means of airborne hyperspectral remote sensing and LIDAR: a case study in Belgium. Earth Surface Processes and Landforms: The Journal of the British Geomorphological Research Group, 33(2), 280-294.

Ernstsen, V. B., Andersen, M. S., Al-Hamdani, Z., Leth, J. O., Sørensen, C., Steinbacher, F., Larsen, L. R., & Kroon, A. (2016). Grøn laser forbinder land og vand (Green laser connects land and water). Geoviden - Geologi og Geografi, 2016(2), 12-14. https://www.geoviden.dk/wp-content/uploads/2020/11/geoviden-2-2016.pdf.

Furlani, S., Devoto, S., Biolchi, S., & Cucchi, F. (2011). Factors triggering sea cliff instability along the Slovenian coasts. Journal of Coastal Research, (61), 387-393.

Gulbinskas, S., Mileriene, R., & Zaromskis, R. (2009). Coastal management measures in Lithuanian Baltic coast (South Eastern Baltic). In Coastal Engineering 2008: (In 5 Volumes) (pp. 4042-4052).

Harff, J., Furmańczyk, K., & Von Storch, H. (Eds.). (2017). Coastline changes of the Baltic Sea from South to East: past and future projection (Vol. 19). Springer.

Hasan, O., Miko, S., Brunović, D., Papatheodorou, G., Christodolou, D., Ilijanić, N., & Geraga, M. (2020). Geomorphology of Canyon Outlets in Zrmanja River Estuary and Its Effect on the Holocene Flooding of Semi-enclosed Basins (the Novigrad and Karin Seas, Eastern Adriatic). Water, 12(10), 2807.

Hasan, O., Smrkulj, N., Miko, S., Brunović, D., Ilijanić, N., & Šparica Miko, M. (2023). Integrated Reconstruction of Late Quaternary Geomorphology and Sediment Dynamics of Prokljan Lake and Krka River Estuary, Croatia. Remote Sensing, 15(10), 2588.

Højgaard, B., & Mortensen, L. (2013). Kanning av havbrýning eystan fyri Nólsoyarbygd (Coastal erosion survey east of Nólsoy village). Jarðfeingi report 2013-03.

Iadanza, C., Trigila, A., Vittori, E., & Serva, L. (2009). Landslides in coastal areas of Italy. Geological Society, London, Special Publications, 322(1), 121-141.

Idier, D., Paris, F., Le Cozannet, G., Boulahya, F., & Dumas F. (2017). Sea-level rise impacts on the tides of the European Shelf. Continental Shelf Research 137, 56–71. https://doi.org/10.1016/j.csr.2017.01.007.

Klein, J., Jarva, J., Frank-Kamenetsky, D., & Bogatyrev, I. (2013). Integrated geological risk mapping: a qualitative methodology applied in St. Petersburg, Russia. Environmental earth sciences, 70, 1629-1645.

Kolega, N. (2006). Slovenian coast sea floods risk. Acta geographica Slovenica, 46(2), 143-167.

Korbar, T., Markušić, S., Hasan, O., Fuček, L., Brunović, D., Belić, N., ... & Kastelic, V. (2020). Active Tectonics in the Kvarner Region (External Dinarides, Croatia)—An Alternative Approach Based on Focused Geological Mapping, 3D Seismological, and Shallow Seismic Imaging Data. Frontiers in Earth Science, 8, 582797.

Kotilainen, A. T., & Kaskela, A. M. (2017). Comparison of airborne LiDAR and shipboard acoustic data in complex shallow water environments: Filling in the white ribbon zone. Marine Geology, 385, 250-259.

L'Heureux, J. S., Longva, O., Hansen, L., & Vanneste, M. (2014). The 1930 landslide in Orkdalsfjorden: morphology and failure mechanism. In Submarine Mass Movements and Their Consequences: 6th International Symposium (pp. 239-247). Springer International Publishing.

Le Cozannet, G., Garcin, M., Bulteau, T., Mirgon, C., Yates, M. L., Méndez, M., Baills, A., Idie, D., & Oliveros, C. (2013). An AHP-derived method for mapping the physical vulnerability of coastal areas at regional scales, Natural Hazards and Earth System Sciences, 13, 1209–1227, https://doi.org/10.5194/nhess-13-1209-2013, 2013.

Le Cozannet, G, Nicholls, R. J., Hinkel, J, Sweet, W. V., McInnes, K. L., Van de Wal, R. S. W., Slangen, A. B. A., Lowe, J. A., & White, K. D. (2017). Sea level change and coastal climate services: the way forward. Journal of Marine Science and Engineering. 2017; 5(4):49. https://doi.org/10.3390/jmse5040049.

Le Cozannet, G., Bulteau, T., Castelle, B., Ranasinghe, R., Woppelmann, G., Rohmer, J., Bernon, N., Idier, D., Louisor, J., & Salas-y-Melia, D. (2019). Quantifying uncertainties of sandy shoreline change projections as sea level rises, Scientific Reports, 9, 42, https://doi.org/10.1038/s41598-018-37017-4.

Louisor, J., Brivois, O., Mouillon, P., Maspataud, A., Belz, P., & Laloue J. -M. (2022). Coastal flood modeling to explore adaptive coastal management scenarios and land-use changes under sea level rise. Frontiers in Marine Science, 9, 710086. doi: 10.3389/fmars.2022.710086.

Luetzenburg, G., Svennevig, K., Bjørk, A. A., Keiding, M., & Kroon, A. (2022). A national landslide inventory for Denmark. Earth System Science Data, 14(7), 3157-3165.

Mateos, R. M., Sarro, R., Díez-Herrero, A., Reyes-Carmona, C., López-Vinielles, J., Ezquerro, P., ... & Monserrat, O. (2023). Assessment of the Socio-Economic Impacts of Extreme Weather Events on the Coast of Southwest Europe during the Period 2009–2020. Applied Sciences, 13(4), 2640.

Mil-Homens, M., Brito, P., Magalhães, V., Rosa, M., Neres, M., Silva, M., ... & Terrinha, P. (2022). Integrated geophysical and sedimentological datasets for assessment of offshore borrow areas: the CHIMERA project (western Portuguese Coast). In Asch, K. et al. (eds.), From Continental Shelf to Slope: Mapping the Oceanic Realm. Geological Society, London, Special Publications, 505, https://doi.org/10.1144/SP505-2019-100.

Mortensen, L. (2023). Riva í bakkanum uppi yvir Rivtanga í Nólsoy og meting av vanda fyri omanlopi (Fracture in the cliff at Rivtanga, Nólsoy, and rockfall hazard and risk assessment). Jarðfeingi report 2023-04.

Nirgi, T., Rosentau, A., Habicht, H. L., Hang, T., Jonuks, T., Jõeleht, A., ... & Tõnisson, H. (2020). Holocene relative shore-level changes and Stone Age palaeogeography of the Pärnu Bay area, eastern Baltic Sea. The Holocene, 30(1), 37-52.

Nordh, D., Goodfellow, B., Hollander, J., & Danielsson, P. (2022). A review of environmental aspects of beach nourishment. Literature Study, Swedish geotechnical institute, SGI, Linköping, 2022-09-22, 72 pp.

Nørgaard-Pedersen, N. (2021). Screening af potentielle sandindvindingsområder i Reservationsområde 1, Nordsøen, for Kystdirektoratet. Rådgivning og bistand vedrørende indhentning af fremtidige råstofindvindingstilladelser i forbindelse med kystdirektoratets fællesaftaler (Screening of potential sand-extraction areas in Reservation Area 1, North Sea, for the Danish Coastal Authority. Advice and assistance regarding obtaining future raw-material extraction licenses in connection with the Coastal Directorate's joint agreements). GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2020 No. 10 https://doi.org/10.22008/gpub/34507.

Nørgaard-Pedersen, N. (2021). Screening af potentielle sandindvindingsområder ved Lønstrup for Kystdirektoratet. Rådgivning og bistand vedrørende indenting af fremtidige råstofindvindingstilladelser i forbindelse med kystdirektoratets fællesaftaler (Screening of potential sand-extraction areas at Lønstrup for the Danish Coastal Authority. Advice and assistance regarding obtaining future raw-material extraction licenses in connection with the Coastal Directorate's joint agreements). GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2020 No. 8 https://doi.org/10.22008/gpub/3450

Nørgaard-Pedersen, N., Bennike, O., & Rödel, L.-G. (2021). Efterforskning og kortlægning af sandressourcer i Nordsøen for Kystdirektoratet - Lønstrup fase 1a (Exploration and mapping of sand resources in the North Sea for the Danish Coastal Authority - Lønstrup phase 1a). GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2021 No. 9 https://doi.org/10.22008/gpub/34569.

Nørgaard-Pedersen, N., Bennike, O., & Rödel, L.-G. (2021). Efterforskning og kortlægning af sandressourcer i Nordsøen for Kystdirektoratet - Lønstrup fase 1b (Exploration and mapping of sand resources in the North Sea for the Danish Coastal Authority - Lønstrup phase 1b). GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2021 No. 8 https://doi.org/10.22008/gpub/34568.

Nørgaard-Pedersen, N., Bennike, O., & Rödel, L. G. (2023). Efterforskning og kortlægning af sandressourcer i Nordsøen for Kystdirektoratet - Lodbjerg A og B (Exploration and mapping of sand resources in the North Sea for the Danish Coastal Authority - Lodbjerg A and B). GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2021 No. 16 https://doi.org/10.22008/gpub/34576.

Nørgaard-Pedersen, N., & Sørensen, P. (2016). Kystfodring - et eksempel på genbrug i naturen (Coastal nourishment - an example of recycling in nature). Geoviden - Geologi og Geografi, 2016(2), 18-19. https://www.geoviden.dk/wp-content/uploads/2020/11/geoviden-2-2016.pdf.

Nørgaard-Pedersen, N., Winther, L. H., & Rödel, L.-G. (2021). Efterforskning og kortlægning af resterende sandressourcer i bygherreområde 562-AE Thyborøn, Nordsøen for Kystdirektoratet (xploration and mapping of remaining sand resources in client area 562-AE Thyborøn, North Sea for the Danish Coastal Authority). GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2021 No. 23 https://doi.org/10.22008/gpub/34583.

Nørgaard-Pedersen, N., Winther, L. H., & Rödel, L.-G. (2021). Efterforskning og kortlægning af resterende sandressourcer i bygherreområde 562-PA Thyborøn, Nordsøen for Kystdirektoratet (Exploration and mapping of remaining sand resources in client area 562-PA Thyborøn, North Sea for the Danish Coastal Authority). GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2021 No. 22 https://doi.org/10.22008/gpub/34582.

Nørgaard-Pedersen, N., Winther, L. H., & Rödel, L. G. (2021). Efterforskning og kortlægning af resterende sandressourcer i bygherreområde 578-AA Husby Klit, Nordsøen for Kystdirektoratet. Rev. 12/01/2022 (Exploration and mapping of remaining sand resources in client area 578-AA Husby Klit, North Sea for the Danish Coastal Authority). GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2021 No. 21 https://doi.org/10.22008/gpub/34581.

Nørgaard-Pedersen, N., Winther, L. H., & Rödel, L. G. (2023). Efterforskning og kortlægning af resterende sandressourcer i bygherreområde 562-AD Ferring, Nordsøen for Kystdirektoratet (Exploration and mapping of remaining sand resources in client area 562-AD Ferring, North Sea for the Danish Coastal Authority). GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2021 No. 24 https://doi.org/10.22008/gpub/34584.

Nørgaard-Pedersen, N., & Witt, N. H. (2021). Screening af potentielle sandindvindingsområder indre Horns Rev for Kystdirektoratet. Rådgivning og bistand vedrørende indhentning af fremtidige råstofindvindingstilladelser i forbindelse med kystdirektoratets fællesaftaler (Screening of potential sand-extraction areas within Horns Rev for the Danish Coastal Authority. Advice and assistance regarding obtaining future raw-material extraction licenses in connection with the Coastal Directorate's joint agreements.). GEUS. Danmarks og Grønlands Geologiske Undersøgelse Rapport Vol. 2020 No. 9 https://doi.org/10.22008/gpub/34506.

Nyberg, J., Goodfellow, B., Ising, J., & Hedenström, A. (2020). Kustnära sedimentdynamik. SGU-rapport 2020, 4.

Orviku, K., Tõnisson, H., Kont, A., Suuroja, S., & Anderson, A. (2013). Retreat rate of cliffs and scarps with different geological properties in various locations along the Estonian coast. Journal of Coastal Research, (65), 552-557.

Payo, A. (2023). Innovative Representation of the Coastal Topo-Bathymetry and Subsurface for Flooding and Erosion Risk Reduction. Journal of Marine Science and Engineering, 11(10), 1933.

Pinto, C., Pires, B., Penacho, N., Silveira, T., Mil-Homens, M., Terrinha, P., ... & Magalhães, V. (2019, June). Caracterização de Manchas de Empréstimo Para Alimentação Artificial de Praias—Projeto CHIMERA (Characterisation of borrowing locations for artificial beach nourishment: Project CHIMERA). In Proceedings of the 5a Conferência Sobre Morfodinâmica Estuarina e Costeira, Lisboa, Portugal (pp. 24-26).

Pinyol Guamis, J., & González, M. (2021). El Sistema de Información Dinámica del Litoral (SIDL): una herramienta para la gestión de los riesgos costeros en Cataluña (The Dynamic Coastal Information System (SIDL): a tool for managing coastal risks in Catalonia). Geotemas (Madrid), (18), 492.

Robinet, R., Castelle, B., Idier, D., Harley, M. D., & Splinter, K. D. (2020). Controls of local geology and cross-shore/longshore processes on embayed beach shoreline variability, Marine Geology, 422, 2020, 106118, ISSN 0025-3227, https://doi.org/10.1016/j.margeo.2020.106118.

Rohmer, J., Manceau, J., Guyonnet, D., & Boulahya F. (2018). HYRISK: Hybrid methods for addressing uncertainty in RISK assessments, EarthArXiv, https://doi.org/10.31223/osf.io/j67cy.

Sánchez Artús, X., Gracia Garcia, V., Espino Infantes, M., Sierra Pedrico, J. P., Pinyol Guamis, J., & Sánchez-Arcilla Conejo, A. (2023). Present and future flooding and erosion along the NW Spanish Mediterranean Coast. Frontiers in marine science, 10.

Savastano, S., Gomes da Silva, P., Sánchez, J. M., Tort, A. G., Payo, A., Pattle, M. E., ... & Monteys, X. (2024). Assessment of Shoreline Change from SAR Satellite Imagery in Three Tidally Controlled Coastal Environments. Journal of Marine Science and Engineering, 12(1), 163. https://doi.org/10.3390/jmse12010163.

Šegina, E., Komac, B., & Zorn, M. (2012). Influencing factors the rockwall retreat of flysch cliffs on the Slovenian coast. Acta geographica Slovenica, 52(2), 303-334.

Smiraglia, D., Cavalli, A., Giuliani, C., & Assennato, F. (2023). The Increasing Coastal Urbanization in the Mediterranean Environment: The State of the Art in Italy. Land, 12(5), 1017.

Speybroeck, J., Bonte, D., Courtens, W., Gheskiere, T., Grootaert, P., Maelfait, J. P., ... & Degraer, S. (2006). Beach nourishment: an ecologically sound coastal defence alternative? A review. Aquatic conservation: Marine and Freshwater ecosystems, 16(4), 419-435.

Stafleu, J., Maljers, D., Gunnink, J. L., Menkovic, A., & Busschers, F. S. (2011). 3D modelling of the shallow subsurface of Zeeland, the Netherlands. Netherlands Journal of Geosciences, 90(4), 293-310.

Svennevig, K., Koch, J., Keiding, M., & Luetzenburg, G. (2023). Assessing the impact of climate change to landslides using public data, a case study from Vejle, Denmark. Natural Hazards and Earth System Sciences Discussions, 2023, 1-26.

Svennevig, K., Luetzenburg, G., Keiding, M. K., & Pedersen, S. A. S. (2020). Preliminary landslide mapping in Denmark indicates an underestimated geohazard. Geus Bulletin, 44, 5302.

Terrinha, P., Medialdea, T., Batista, L., Somoza, L., Magalhães, V., González, F. J., ... & Ribeiro, C. (2022). Integrated thematic geological mapping of the Atlantic Margin of Iberia. In Asch, K. et al. (eds.), From Continental Shelf to Slope: Mapping the Oceanic Realm. Geological Society, London, Special Publications, 505, https://doi.org/10.1144/SP505-2019-90.

Thiéblemont, R., Le Cozannet, G., Toimil, A., Meyssignac, B., & Losada I. J. (2019). Likely and high-end impacts of regional sea-level rise on the shoreline change of European sandy coasts under a high greenhouse gas emissions scenario, Water, 11, 2607, https://doi.org/10.3390/w11122607.

Thiéblemont, R., Le Cozannet R., Rohmer J., Toimil A., Alvarez-Cuesta M., & Losada, I. J. (2021). Deep uncertainties in shoreline change projections: an extra-probabilistic approach applied to sandy beaches. Natural Hazards and Earth System Sciences, 21 (7), 2257-2276. 10.5194/nhess-21-2257-2021.

Uścinowicz, G., Szarafin, T., Pączek, U., Lidzbarski, M., & Tarnawska, E. (2021). Geohazard assessment of the coastal zone: the case of the southern Baltic Sea. Geological Quarterly, 65(1).

Van Lancker, V., Deronde, B., De Vos, K., Fettweis, M., Houthuys, R., Martens, C., & Mathys, M. (2015). Chapter 6. Kust en zee (Coast and sea), pp 1-70. In: Borremans et al. (eds.). Geologie van Vlaanderen (Geology of Flanders). Genootschap van Gentse Geologen. Academia Press.

Virtasalo, J., Österholm, P., Kotilainen, A., & Åström, M. (2022, May). Enrichment of trace metals from acid sulphate soils in sediments of the Kvarken Archipelago, eastern Gulf of Bothnia, Baltic Sea. In EGU General Assembly Conference Abstracts (pp. EGU22-8632).

Virtasalo, J. J., Österholm, P., & Asmala, E. (2023). Estuarine flocculation dynamics of organic carbon and metals from boreal acid sulfate soils. Biogeosciences, 20(14), 2883-2901.

Portals:

https://visors.icgc.cat/inundacio-permanent/#10.49/40.6902/0.7005

https://visors.icgc.cat/subsidencia-projectes/#/0419

https://riskcoast.acentoweb.com/en/portada?set_language=

https://gitlab.brgm.fr/users/sign_in (account needed)

https://sealevelrise.brgm.fr/sea-level-scenarios/#map=0/2/0.000000/0.000000/ar5scenario_allmodels_RCP26/2024/greendyn_m,greensmb_m,antdyn_m,antsmb_m,glac_m,gia_m,ocn_m,grw_m&map=1/2/0.000000/0.000000/greendyn_m,greensmb_m,antdyn_m,antsmb_m,glac_m,ocn_m,grw_m,gia_m/5,10,16,-5,18,32,5,1&map=2/2/0.000000/0.000000/low/low-end-SLR-projections-RCP26/proj_median&map=3/2/0.000000/0.000000/srocc-slr-85/2024/slr_md&tab=ar5

https://eng.geus.dk/products-services-facilities/data-and-maps

https://kyst.dk/klimatilpasning/vaerktoejer/kystatlas

https://kms.maps.arcgis.com/apps/webappviewer/index.html?id=8669133b3f4842b7a9a19fb24b08ffd5

9. Appendix I – Task 5.3 Partners

	Partner Name	Acronym	Country
2	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	TNO	Netherlands
3	Sherbimi Gjeologjik Shqiptar	AGS	Albania
5	Bureau de Recherches Géologiques et Minières	BRGM	France
6	Ministry for Finance and Employment	MFE-CSD	Malta
7	Hrvatski Geološki Institut	HGI-CGS	Croatia
8	Institut Royal des Sciences Naturelles de Belgique	RBINS-GSB	Belgium
9	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	PGI-NRI	Poland
10	Institut Cartogràfic i Geològic de Catalunya	ICGC	Spain
12	Department of Environment, Climate and Communications - Geological Survey Ireland	GSI	Ireland
13	Agencia Estatal Consejo Superior de Investigaciones Cientificas	CSIC-IGME	Spain
15	Geološki zavod Slovenije	GeoZS	Slovenia
17	Istituto Superiore per la Protezione e la Ricerca Ambientale	ISPRA	Italy
20	Institute of Geological Sciences National Academy of Sciences of Ukraine	IGS	Ukraine
23	Geologian Tutkimuskeskus	GTK	Finland
25	Ministry of Agriculture, Rural Development and Environment of Cyprus	GSD	Cyprus
26	Norges Geologiske Undersøkelse	NGU	Norway
27	Latvijas Vides, ģeoloģijas un meteoroloģijas centrs SIA	LVGMC	Latvia
28	Sveriges Geologiska Undersökning	SGU	Sweden
29	Geological Survey of Denmark and Greenland	GEUS	Denmark
30	Institutul Geologic al României	IGR	Romania

33	Elliniki Archi Geologikon kai Metalleftikon Erevnon	HSGME	Greece
35	Lietuvos Geologijos Tarnyba prie Aplinkos Ministerijos	LGT	Lithuania
38	Eesti Geoloogiateenistus	EGT	Estonia
40	Íslenskar Orkurannsóknir	ISOR	Iceland
41	Instituto Português do Mar e da Atmosfera	IPMA	Portugal
42	Jarðfeingi	Jardfeingi	Faroe Islands
48	United Kingdom Research and Innovation - British Geological Survey	UKRI-BGS	UK