GeoNetZero Centre for Doctoral Training (CDT): Geoscience and its Role in the Low Carbon Energy Transition

(2022 start)

Project Title:
Assessing Seabed Integrity under Increased Pressures from Offshore Windfarm Developments

Host institution: University of Dundee

Supervisor 1: Prof Sue Dawson

Supervisor 2: Dr Alan Cuthbertson

External supervisory support: Marine Scotland Science (MSS, Dr Rory O'Hara Murray) and British Geological Survey (BGS, Mr Gareth Carter)

Project description (250 words max.):

The seabed around the UK continental shelf (UKCS) is highly complex and heterogenous in both composition and structure over a wide range of spatial scales, from macro- and mesoscale features (e.g. continental margins, stable/unstable slopes, sandbanks, gravel bars, Fig. 1) to micro-scale properties (e.g. sediment type, composition, shape and size). Subsurface geological features (e.g. buried channels, bedrock) underpin this complexity and spatial heterogeneity, and influence the decision making process in terms of the suitability of marine seabeds to support the provision of offshore wind farm developments and other marine renewable energy infrastructure.

An overarching project aim will be to develop detailed spatial maps of near-bed hydrodynamics and bed shear stresses at wind farm development sites on the UKCS, utilising the Scottish Shelf Model (SSM), in partnership with MSS. New predictive sediment transport tools will be used to inform the assessment of seabed stability and sediment mobility across different spatial and temporal scales. In this context, SSM has never been used before for offshore sediment transport or morphodynamic simulations. These SSM simulations will also be informed by newly-defined regional 'GeoLayers' of seabed surface properties and subsurface geological features, to be developed in collaboration with BGS. This will be augmented by approaches to current licence holders for access to site-specific survey data to help develop higher-resolution, site-specific Geolayers at current and future offshore developments. The ultimate goal of the SSM simulations and Geolayers development is to inform a new, integrated methodology for the assessment of seabed integrity, identifying regions most susceptible to instability and sediment mobilisation in the context of current and future offshore development plans.

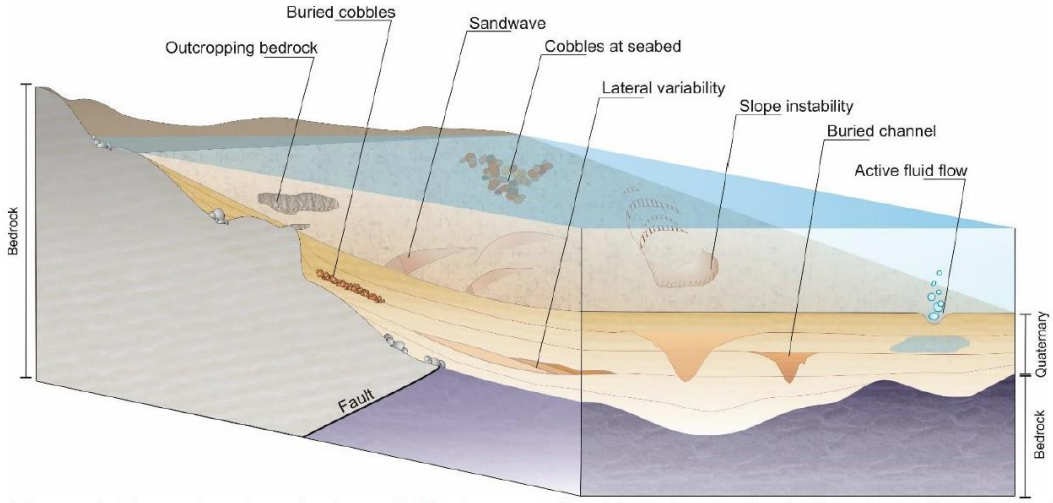

Figure 1: Example of seabed spatial heterogeneity driven by geological factors, directly and indirectly influencing spatial planning for offshore infrastructure

Stated link to the overarching theme of the CDT i.e. The Role of Geoscience in the Energy Transition and the challenge to meet the net zero emission targets (NOTE: In order to qualify for

NEO Energy CDT funding, there must be an explicit link to the Energy Transition with a clear application to the UK's Continental Shelf (UKCS). For projects supported by 100% matched funding from your University, links to the broader Energy Transition remit are sufficient):

The proposed project fits well with the overarching theme of the CDT, as it focuses on a specific challenge requiring to be addressed to meet the net zero emission targets: namely, mitigation of environmental impacts and potential compromises to seabed integrity that could arise from continued expansion of offshore wind farms developments and other marine renewable infrastructure on the UKCS under current and future climatology conditions. As such, the proposed project falls under the following sub-headings:

- Geological evaluation of wind farm sites;
- Environmental Impacts and Dependencies resulting from continued exploration and/or the deployment of low carbon technologies.

Details of mapping/fieldwork locations/data to be used by the project and confirmation of access to key data being secured (please attach map as an appendix if relevant):

The initial part of the project (Year 1) will involve data-mining and analysis of existing outputs from the wider-domain, regional SSM. This will utilise existing hydrodynamic datasets from the recently-completed MSS 25-year (1993-2017) physical reanalysis of SSM[1], as well as the 1-year present day (1962-2011)[2,3] and future 2050 (2038-2062) climatology simulations[4,5]. These are available through the MSS website (https://marine.gov.scot/information/wider-domain-scottish-shelf-model) and will be analysed with the support of MSS (Dr Rory O'Hara Murray). This initial study will also collate and assess existing Geolayers (provided by BGS) of the physical character of the seabed (e.g. seafloor slope gradient, mobile bedforms) and shallow subsurface environment (e.g. quaternary engineering geology). When combined with the developed near-bed hydrodynamic property maps (from SSM outputs), these Geolayers can provide a regional scale framework for assessing seabed integrity and vulnerability, by identifying regions most susceptible to instability, sediment mobilisation and morphodynamic change under both present day/future climate change hydrodynamic scenarios.

Further into the project (Year 2 onwards), the project will focus on developing and running new SSM simulations for a chosen case study site (e.g. Moray Firth, Fig. 2) or sites, where there are significant ongoing developments within the offshore wind farm sector. Specific input datasets for the Moray Firth, including the sub-model domain SSM (Fig. 2b), with localised cell resolutions down to 10 m around seafloor bathymetric features of interest or development (Fig. 2c), are again available from the MSS website. Site specific survey data will also be sought from current offshore developers and licence holders to provide equivalent Geolayer information on surface/subsurface seabed geology in and around these development sites, at a much higher-resolution than is currently available from regional-scale BGS Geolayers. This data will be integrated into the sub-model SSM simulations to investigate local-to-regional scale seabed impacts from altered near-bed hydrodynamics around individual wind farm sites and identify how individual offshore developments influence the specific vulnerability of affected seabed regions. This is an entirely novel application of the SSM as it has not previously been used for assessing marine sediment dynamics or seabed morphodynamics. These multi-scale scenario runs will also consider knock-on effects from the assessment of seabed sediment mobility (i.e. identification of sites where erosion/deposition is enhanced) to predict changes to coastal and continental slope stability, as well as potential detrimental impacts on protected marine sites (SPAs, SACs) for the 25 year SMM reanalysis, and 1-day present day and future 2050 climatologies. Current baseline hydrodynamic simulations will be verified by ADCP field measurement datasets, made available by Marine Scotland Science, especially around or near existing development sites (e.g. offshore wind-farms), to provide confidence in the hydrodynamic

model predictions. Appropriate field datasets on sediment transport and morphodynamic evolution around offshore wind farms will be sought for the verification of the SSM scenario runs at current and planned development sites.

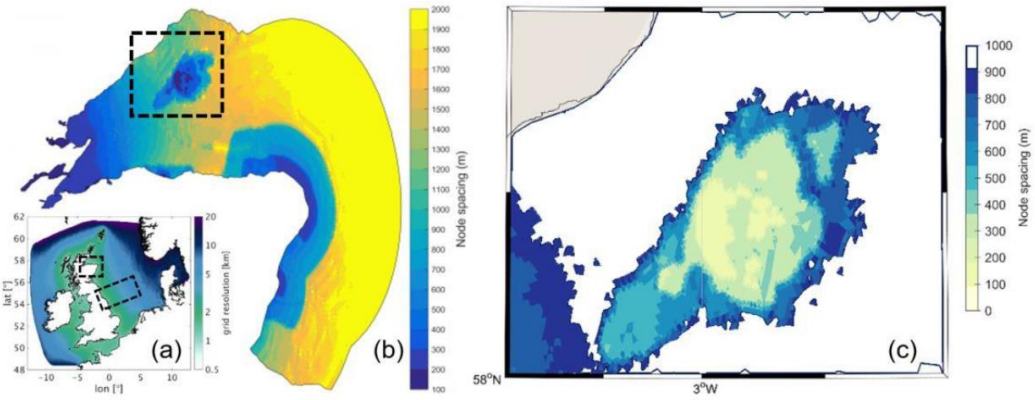

Figure 2: (a) Wider-domain Scottish Shelf model (SSM) showing locations of case study sites; (b) Moray Firth sub-region model domain[19]; (c) enhanced cell/node resolution around Smith Bank, Outer Moray Firth.

References:

1 http://marine.gov.scot/information/scottish-shelf-waters-reanalysis-service.
2 De Dominicis M, O'Hara Murray R, Wolf J & Gallego A. 2018. The Scottish Shelf Model 1990 – 2014 climatology version 2.01. doi: 10.7489/12037-1. (Data source).
3 De Dominicis M, O'Hara Murray R & Wolf J. 2017. Multi-scale ocean response to a large tidal stream turbine array. Renewable Energy, 114, 1160-1179.
4 De Dominicis M, O'Hara Murray R, Wolf J & Gallego A. 2019. The Scottish Shelf Model 2038 – 2062 future climatology 2.02. doi: 10.7489/12231-1. (Data source).
5 De Dominicis M, Wolf J, & O'Hara Murray, R. 2018. Comparative effects of climate change and tidal stream energy extraction in a shelf sea. Journal of Geophysical Research: Oceans, 123, 5041–5067. https://doi.org/10.1029/2018JC013832.

Outline of planned work schedule for the 4-year research period:

Year 1 – Data-mining and analysis of existing regional-scale SSM outputs to produce near-bed hydrodynamics maps (e.g. bed shear velocities) and link with available BGS GeoLayers of surface sedimentology and subsurface geology to provide a rationale for the spatial assessment of seabed vulnerability and integrity.

Year 2 – Development of sub-model domain SSM scenario runs at the case study site (i.e. Moray Firth) to identify changes to hydrodynamics and seabed sediment dynamics arising from existing operational offshore wind farm developments.

Year 3 – Conduct future scenario model runs with the SSM sub-model domain for Moray Firth to assess seabed vulnerabilities from future offshore developments in the context of future near-term climate change scenarios.

Year 4 – Combine findings from Years 1 – 3 above to develop a high-level assessment methodology for seabed integrity, identifying seabed regions most susceptible to sediment mobility from current and future marine development pressures and seabed operations and near-term climate change scenarios.

Any Additional Research Costs (NOTE: Each CDT studentship includes an individual Research Training and Support Grant (RTSG) budget of £20k for the full 4-year study period)

Purchase of a high-performance workstation (£10k). Travel and subsistence costs for trips to/from Aberdeen (Marine Scotland Science) and Edinburgh (British Geological Survey) to support collaboration with external partners (see below).

Supervisory arrangements and involvement of external partners (NOTE: Please indicate the area(s) of expertise covered by each supervisor. External collaboration is encouraged, but if proposed partner is not currently providing support to the CDT, please outline the extent of the partner's involvement with the project.)

Dr Rory O'Hara Murray (Marine Scotland Science, Aberdeen): support in analysing existing datasets from Scottish Shelf Model simulations, generation of near-bed hydrodynamic mapping, and running case-study scenario model runs with sub-domain SSM for the Moray Firth. (Support in-kind offered for access to HPC cluster facilities at MSS).

Mr Gareth Carter (British Geological Survey, Edinburgh): support in utilising existing GeoLayers of properties and characteristics of surface seabed sedimentology and subsurface geology on UKCS to develop, along with near-bed hydrodynamic mapping, a framework for seabed integrity.

Likely graduate career routes:

- Numerical modeller in coastal/marine environments
- Surface/subsurface sedimentologists/geologist in the marine renewables sector
- Continued research within relevant academic areas (e.g. geohazard risk assessments for offshore, submarine and seafloor infrastructure).