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Potential environmental impact of tidal energy extraction in the Pentland Firth at large spatial scales: results of a biogeochemical model

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Abstract. A model study was carried out of the potential large-scale (> 100 km) effects of marine renewable tidal energy generation in the Pentland Firth, using the 3-D hydrodynamics–biogeochemistry model GETM-ERSEM-BFM. A realistic 800 MW scenario and a high-impact scenario with massive expansion of tidal energy extraction to 8 GW scenario were considered. The realistic 800 MW scenario suggested minor effects on the tides, and undetectable effects on the biogeochemistry. The massive-expansion 8 GW scenario suggested effects would be observed over hundreds of kilometres away with changes of up to 10 % in tidal and ecosystem variables, in particular in a broad area in the vicinity of the Wash. There, waters became less turbid, and primary production increased with associated increases in faunal ecosystem variables. Moreover, a one-off increase in carbon storage in the sea bed was detected. Although these first results suggest positive environmental effects, further investigation is recommended of (i) the residual circulation in the vicinity of the Pentland Firth and effects on larval dispersal using a higher-resolution model and (ii) ecosystem effects with (future) state-of-the-art models if energy extraction substantially beyond 1 GW is planned.

1 Introduction

1.1 Background

Techniques to generate marine renewable energy are maturing, with wind turbines currently being installed in their hundreds to thousands, and first commercial models of tidal energy generators are becoming available, with wave-energy generators not far behind and macro-algae farming at the field-testing research stage. Energy in the atmospheric and marine environment is a resource that is not replenished immediately and at a local scale by solar or orbital sources, and is subject to physical conservation laws. Hence, extracting energy for human use leaves less energy remaining in the system, at least for some distance downstream of the extraction area. As a result, if applied in large farms with hundreds of devices, marine renewable energy extraction has the potential to noticeably alter the local and regional hydrography, and through that influence the marine ecosystem. Potential effects on the physical marine environment include changes in tidal currents, residual circulation, wave climate, bed-shear stress and associated transport of materials, turbulence, turbidity, water temperature, salinity and stratification, and noise levels. Knock-on effects on the biological marine environment could include changes in nutrient and plankton transport (including larval stages), changes in primary production, changes in food availability and feeding and migration behaviour, and resulting changes in species composition and distribution. All of these potential effects, including many others, have been identified in a series of review studies