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Potential changes in the circulation pattern in the Celtic Sea due to tidal energy generation

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It is common sense that extraction of ocean kinetic energy in large quantities may change circulation patterns in coastal seas thus influencing both the general state of the environment and the extractable energy resource. This paper assesses the backward effect on the ocean currents by a hypothetical array of tidal turbines installed in the shallow sea. As the industrial size tidal farms on the shelf have not been built yet, and no statistical data are available, the only way of predicting their impact on circulation is reliant on physically based deterministic modelling. In this study, a 3D ocean circulation model POLCOMS is used to estimate (i) the actual values of extractable kinetic energy at different levels of rated power capacity of the farm, and (ii) alterations to the pattern of residual currents and pathways of passive tracers. As water flow is influenced both by tidal and non-tidal currents, the model takes into account wind-driven and density-driven currents generated by meteorological forcing as well as astronomical tides. Numerical modelling has been carried out for a hypothetical tidal farm located in the Celtic Sea north of Cornwall, an area known for its high level of tidal energy. It is shown that in contrast to common belief a linear drag is a better representation of interaction of the flow with an in-stream tidal farm, not the quadratic frictional law. Modelling results clearly indicate that extracted power does not grow linearly with the increase in the rated capacity of the farm. For the case studies covered in this paper, a 100-fold increase in rated generation capacity of the farm results only in 7-fold increase in extracted power. In case of a high power farm, kinetic energy of currents is altered significantly as far as 10-20 kilometres away from the farm. At high levels of extracted energy the currents tend to avoid flowing through the farm, an effect which is not captured with 1D models. Residual currents are altered as far as a hundred kilometres. The paper analyses simulated dispersion of passive drifters drouged at 22.5 m and launched at different distances from the tidal farm. It is shown that the changes in the dispersion patterns are highly sensitive to the location relative to the farm and to the costline. Some of the passive drifters experience significant variations in the end-to-start distance due to energy extraction ranging from 13% to 238% while others are practically unaffected. This pilot study shows that the area-wide effects have to be taken into account when designing the tidal farm to minimise the negative effects on the environment and enhance the positive ones. This work was partly supported by EU FP7 MyOcean project.