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Can tidal energy farms create temperature fronts in the coastal ocean?

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Although an industrial scale tidal farm comprising a large set of submerged turbines has not been built yet, tidal power is considered to be one of potential sources of renewable energy in the future. For example, India plans to install a 50MW tidal farm in the Gulf of Kutch which could be further expanded to deliver more than 200MW. As tidal stream generators extract kinetic energy from the ocean currents, they change the circulation pattern and hence affect the marine environment. Recent research has shown (Shapiro, 2011, Neill et al., 2009) that a tidal farm can modify currents and sediment transport outside the farm as far as up to a hundred kilometres.

This paper studies the potential effect of a tidal farm on the temperature structure in a shallow sea using a 3D ocean model POLCOMS which was modified to include effects of kinetic energy extraction as detailed in (Shapiro, 2011). The model is set up in the Celtic Sea known for its high levels of tidal energy. The model is driven by 15 tidal constituents and the meteo forcing. Effects of tidal farms of varying sizes and power capacities (from 50 MW to 1500MW) have been studied during summer months. The simulated farms are placed in various locations north of the Cornish coast. It has been shown that even smaller farms can modify temperature distribution as far as a few tens of kilometres from the farm, and sometimes generate localised temperature fronts. This effect is particularly strong during the month of June when the fronts penetrate from surface to the seabed. The fronts are more pronounced during the spring tides, however they are still seen during the neaps. As the seasonal thermocline strengthens towards the end of summer, the fronts are mostly seen in the upper ocean layer, with warmer waters in the area of the farm and cooler waters outside the farm.

The physical mechanism of front generation is linked to abrupt changes in the current patterns due to energy extraction from the ocean. The currents inside the farm become weaker, whilst the currents outside the farm (at a scale comparable to the baroclinic Rossby radius) become stronger. Such stronger currents enhance the mixing of the water column outside the farm, and weaker currents inside the farm reduce turbulent mixing and facilitate formation of a stronger thermocline. The overall effect is generally similar to the formation of fronts between tidally mixed and stratified areas of a shallow sea (Simpson and Hunter, 1974). Effect of geometrically smaller farms is less pronounced as the water particles travel in and out the affected zone during the tidal cycle (over the length of the tidal excursion) and hence are influenced by the above mechanism only during a proportion of the tidal cycle. Reduced vertical mixing within the area of the farm and positive heat balance explains higher temperatures at the surface. In the beginning of summer when thermal stratification is relatively week, the thermocline is significantly altered and the fronts propagate to a greater depth. Development of a stronger thermocline towards the end of summer inhibits the effect of mixing and the fluctuations of the depth of the upper mixed layer due to energy extraction are suppressed .

References.

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