Marine Radar Derived Current Vector Mapping at a Planned Commercial Tidal Stream Turbine Array in the Pentland Firth

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Abstract

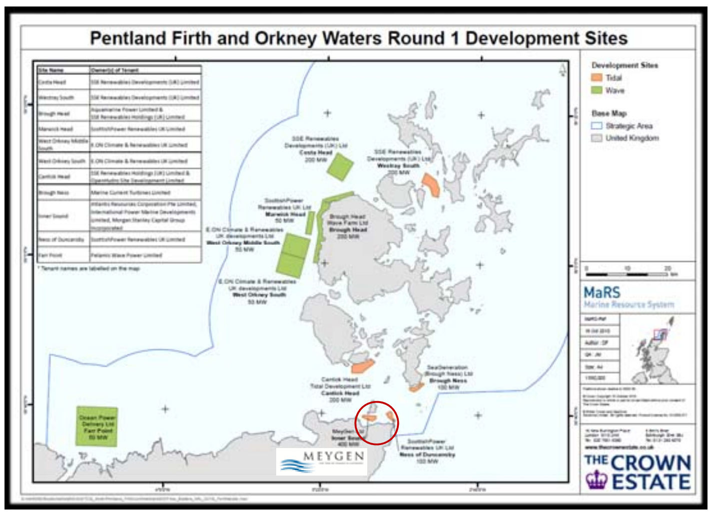
The first small grid-connected arrays of tidal stream turbines are expected to be deployed in UK waters over the next few years, with MeyGen beginning installation operations in late 2014, and planning electricity generation by 2016.

Understanding the high spatial and temporal variability of currents exhibited at such sites is of critical importance in determining turbine locations in terms of optimising predicted energy generation and device longevity.

A marine radar was deployed on a remote clifftop overlooking a 4.8km radius area of the Inner Sound of Stroma in the Pentland Firth, Scotland, for 3 months during spring 2013. The area viewed by the radar includes the Crown Estate lease areas for Meygen Ltd (Inner Sound of Stroma) and Scottish Power Renewables (Ness of Duncansby). Data were post processed to extract current vector maps based on determining the Doppler shift of sea surface waves by the tidal current.

This same analysis is now running operationally at the European Marine Energy Centre (EMEC) Fall of Warness Tidal Test Site producing current vector maps when there is sufficent sea clutter present.

See: ***noc.ac.uk/projects/flowbec*** & click on the marine radar viewer link



Method

Wave patterns are evident in radar backscatter from the sea surface – known as sea clutter. A sequence of these sea clutter images is recorded using a WaMoS radar digitiser. A data window of 640m x 640m is passed through a 3D FFT to yield a 3D frequency-wavenumber spectrum, and a secondary algorithm is used to more precisely define the low wavenumber (long wavelength) waves that the FFT resolves poorly (Bell & Osler, 2011).

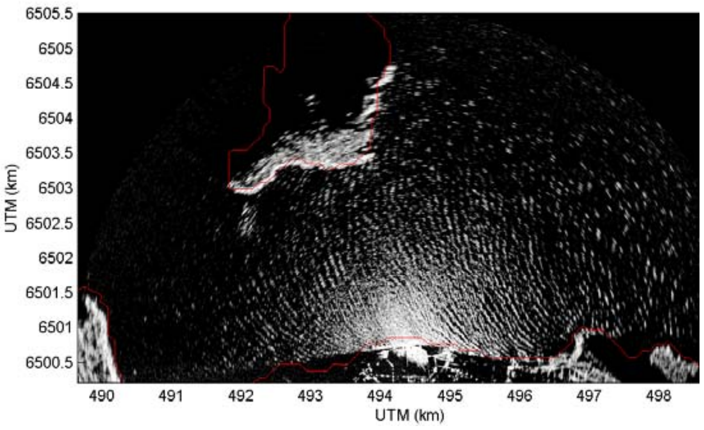
The location of the wave energy in this 3D spectrum is a function of the water depth, the wave frequencies present and the current.

The combination of current vector and water depth that best explain the observed wave behaviour through linear wave theory are then fitted to the spectrum, and the analysis window translated across the study area to build up the water depth and current vector maps.

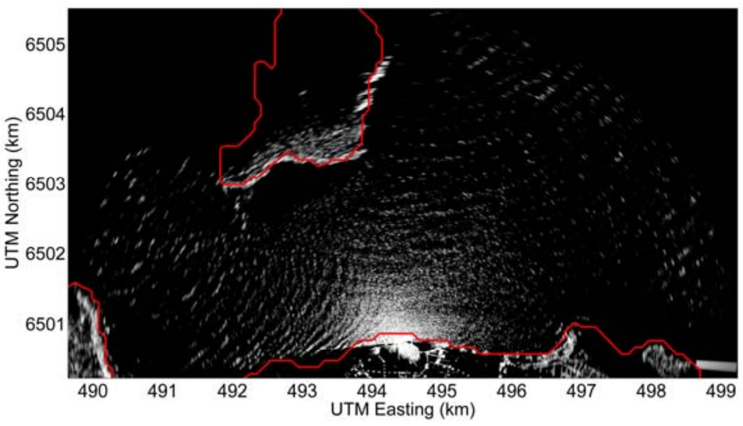
The analysis is only able to derive a current when there is sufficient sea clutter for the wave patterns to be identified by the FFT. The range over which sea clutter is visible is related to the wave height, so the best data are obtained in higher sea states, while calmer weather yields low data returns.

Bell, Paul; Osler, John. 2011. Mapping bathymetry using X-band marine radar data recorded from a moving vessel. Ocean Dynamics, 61 (12). 2141-2156. DOI: 10.1007/s10236-011-0478-4

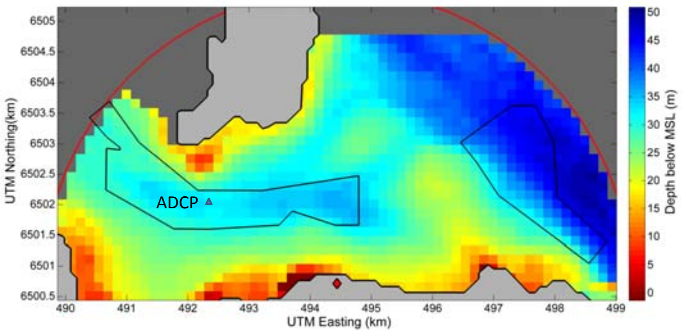
Marine X-band Radar



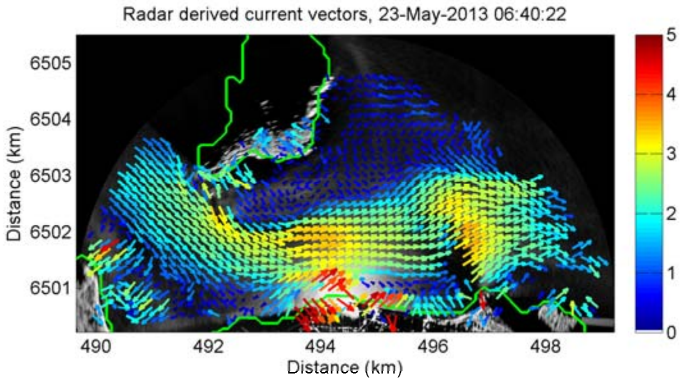
Radar image snapshot of waves (sea clutter) – Easterly waves.



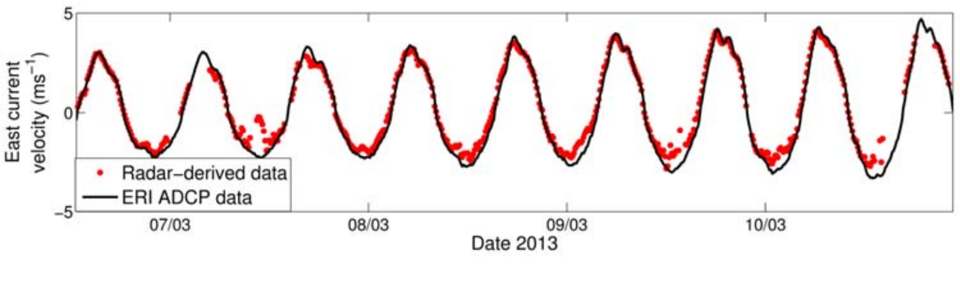
Radar image snapshot of waves (sea clutter) – Westerly waves.

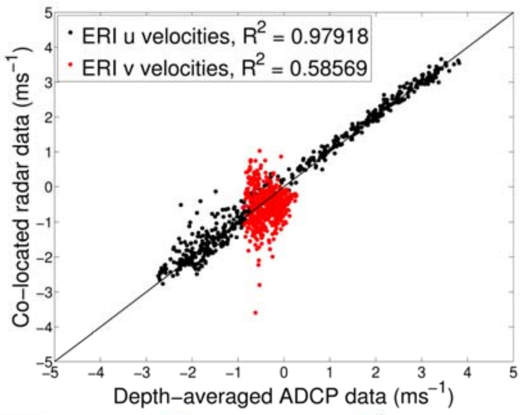


Radar derived water depth map (MeyGen & Scottish Power Renewables Leases in black)



Current vector map representing 5 minute average





Validation of radar derived currents against Acoustic Doppler Current Meter (ADCP).

ADCP data courtesy of ERI Thurso.

Summary

The ability to collect time series of current vector maps using a shore based system will add value to in-situ measurements by enabling validation of model outputs at a large number of points across a site of interest and placing the in-situ measurements into a broader context, reducing risk and increasing confidence in resource assessments and turbine placement decisions.

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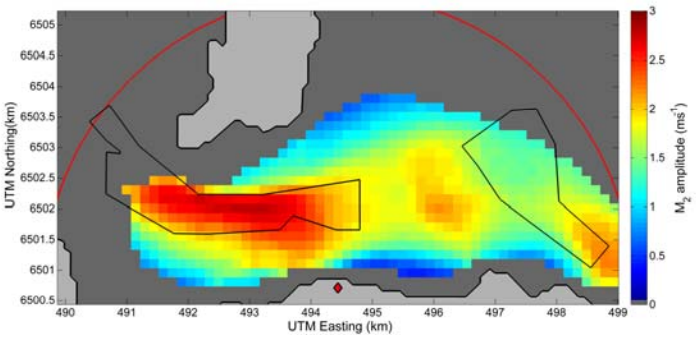
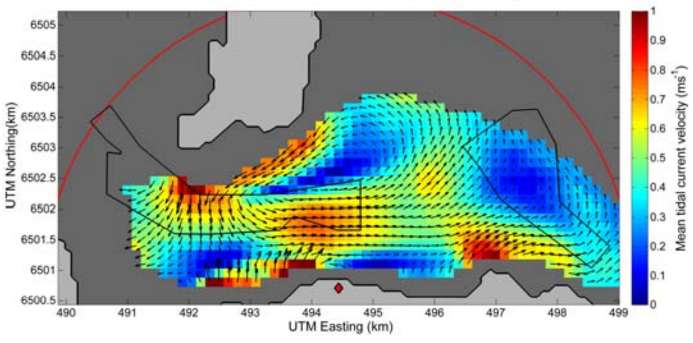
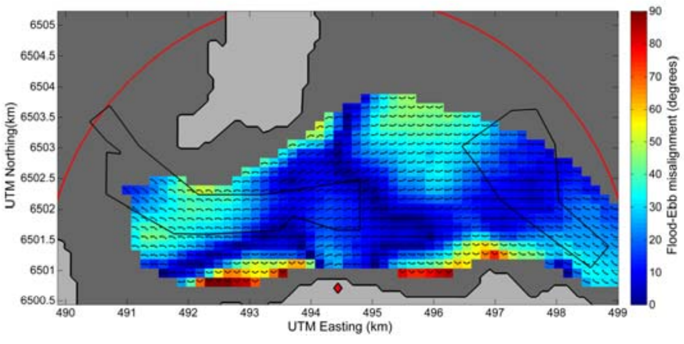


Tidal harmonic analysis allows identification of the main tidal components. The magnitude of the principle lunar tidal component M_2 is shown here. (maximum of ~3m/s)



Strong mean flows of up to 1m/s associated with headland eddies are evident – places the ADCP point measurements into a much wider context.



Differences in the alignment between the ebb and flood currents can be up to 50° in regions of strongest flow. This can reduce turbine efficiency if the turbine alignment is fixed.