Measuring Wave Modulation by a Large Offshore Wind Farm

David Christie

Bangor University, School of Ocean Sciences

19th Jan 2022

PRIFYSGOL
BANGOR
UNIVERSITY

Motivation

Offshore wind turbines scatter incoming waves, causing reflection and diffraction of waves in their immediate vicinity. This can affect

- sediment transport and coastal processes,
- structural loading,
- the available wave resource for hybrid wind-wave developments.

What effect do large, regular wind turbine arrays have on the wave climate?

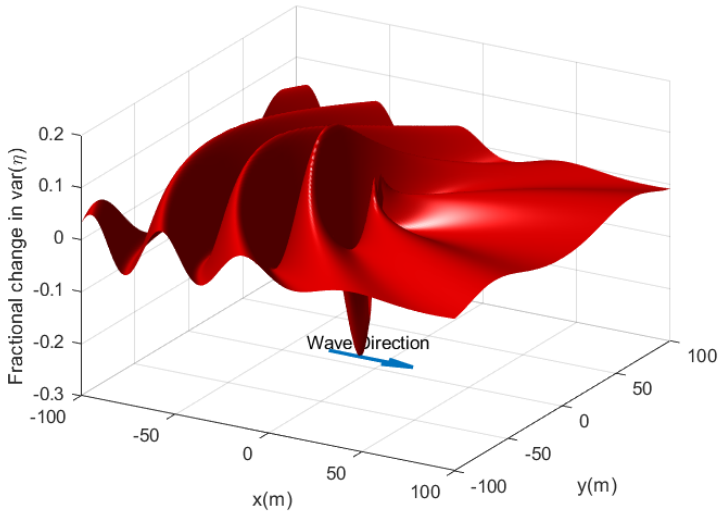
- Significance and spatial extent of wave modulation
- Dependence on wavelength, location, and turbine separation and configuration
- Trapping, resonance, selective absorption

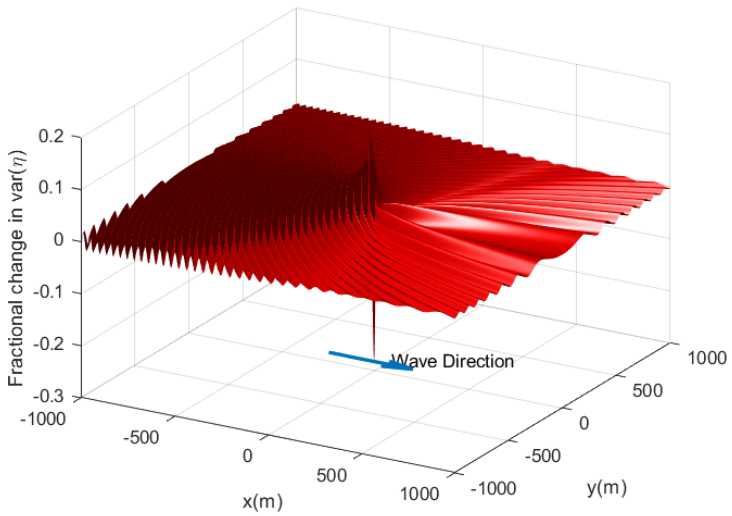
Use Gwynt y Môr (and neighbours) as a case study.

PRIFYSGOL BANGOR UNIVERSITY

The Problem

Wave Scattering by Arrays of Vertical Cylinders





- Scattered waves from by a single monopile turbine can be calculated analytically
- Multiple turbines are more challenging due to array interactions
- Coupled problem: incident waves at each monopile also scattered by neighbours
- Existing treatments restricted to ≤ 6 scatterers
- Gwynt y Môr had 160 turbines!

PRIFYSGOL BANGOR UNIVERSITY

Original Approach

- Simplified calculation: Superpose single-turbine solutions, neglecting array effects.
- Hypothesis: this is sufficient for typical turbine sizes and spacings
- Test this with field measurements
- Purchase RBR Solo D—wave16 Logger (and sundries) for wave measurements
- Summer campaign of multiple deployments around the perimeter of Gwynt y Môr
- Combine with existing in-situ wave buoy data to test spatial variation

PRIFYSGOL BANGOR UNIVERSITY

Developments

Challenges:

- Delayed start to the project: award in May, but unable to purchase anything until late August
- Sensor delivered in October so multiple deployments not possible
- Initial modelling: difficult to separate wave modulation by turbines from bathymetry-induced variation

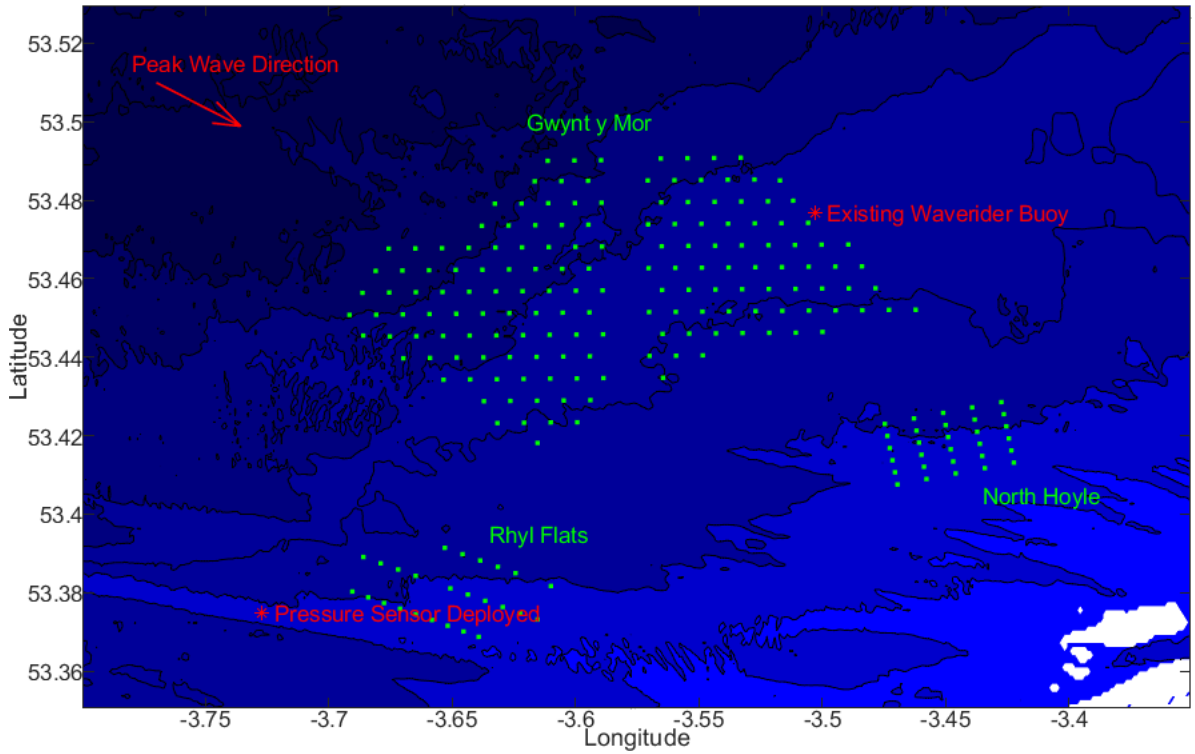
Opportunities:

- Wider literature review during hiatus
- A numerical code (solves the Helmholtz equation with Neumann boundary conditions at multiple cylindrical scatterers and a radiation condition) was recently developed for electromagnetic and acoustic applications ("MieSolver")
- This can be directly applied to water waves in arrays of cylindrical monopiles!

PRIFYSGOL
BANGOR
UNIVERSITY

New Approach

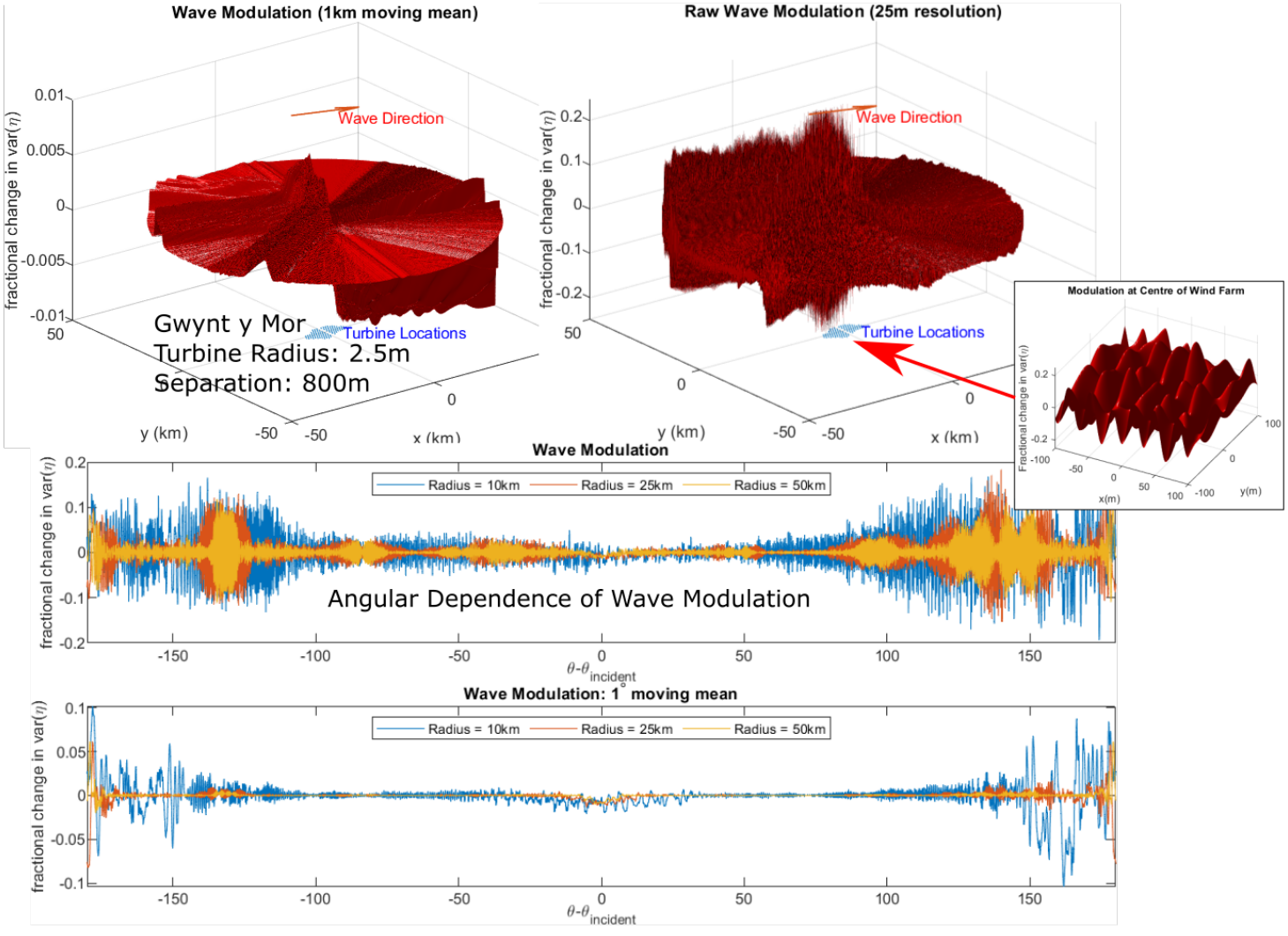
- Use new numerical solver to improve numerical treatment of wave scattering around wind farms, including array effects.
- Use existing buoy for incoming wave data in Gwynt y Môr model.
- Pressure sensor deployed 11/11/21, near Rhyl Flats wind farm.
- Use full winter's wave data for new Rhyl Flats model.
- Data also used for wave statistics, nearshore model validation, student projects.



PRIFYSGOL BANGOR UNIVERSITY

Sample Results

Spectral Peak (measured by Gwynt y Môr buoy): $\lambda = 60$m



PRIFYSGOL BANGOR UNIVERSITY

Observations

- The numerical solver can readily be applied to large offshore wind array scattering calculations.
- By contrast, previous treatments were limited to < 6 turbines.
- Modulation varies on wavelength scale (and very sensitive to direction and wavelength)
- Averaged results show small systematic effects of turbines (order 1%): increase downwave, decrease upwave but persist over long distances.
- Analysis was for relatively small (5m diameter) monopiles.
- Trend is towards increasing turbine diameter, approaching 8m-10m - effect may become more significant (also for wider gravity-based structures).

Next steps

- This is underway, and more results will be presented at OSM22.
- The sample calculation was for monochromatic waves at peak period/direction.
- Full directional spectrum can be readily calculated by superposing solutions for each wavelength and direction.
- This is underway, and more results will be presented at OSM22.
- On recovery of sensor, can repeat analysis for Rhyl Flats.
- Effect of increasing radius can be investigated.

Thank you for your attention

The project acknowledges the support of the Supergen ORE Early Career Research Fund and the Smart Efficient Energy Centre at Bangor University, part-funded by the European Regional Development Fund, administered by the Welsh Government.
References: [1] `https://doi.org/10.1590/2318-0331.252020190140`; [2] `https://doi.org/10.1145/3381537`

PRIFYSGOL BANGOR UNIVERSITY