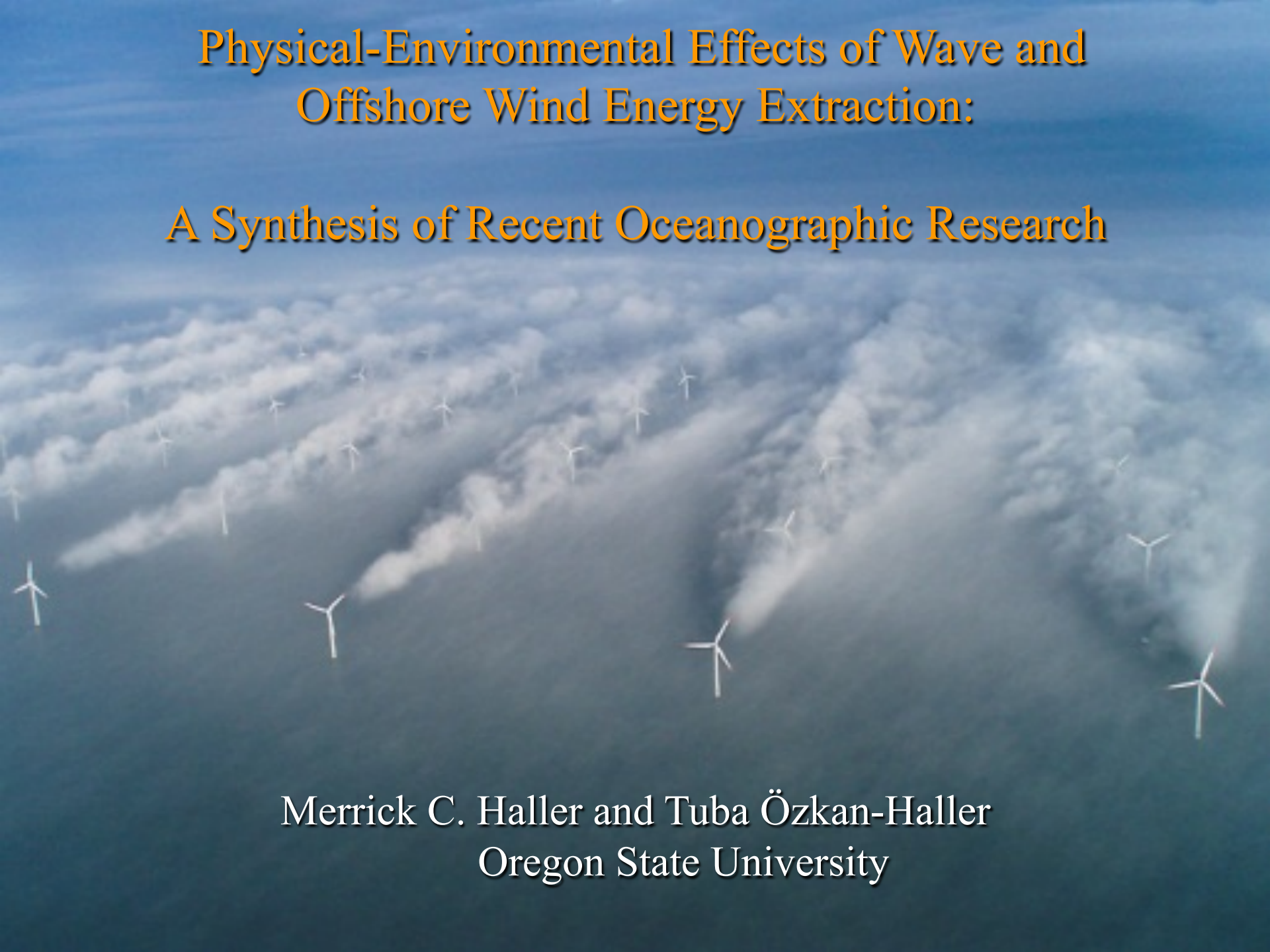
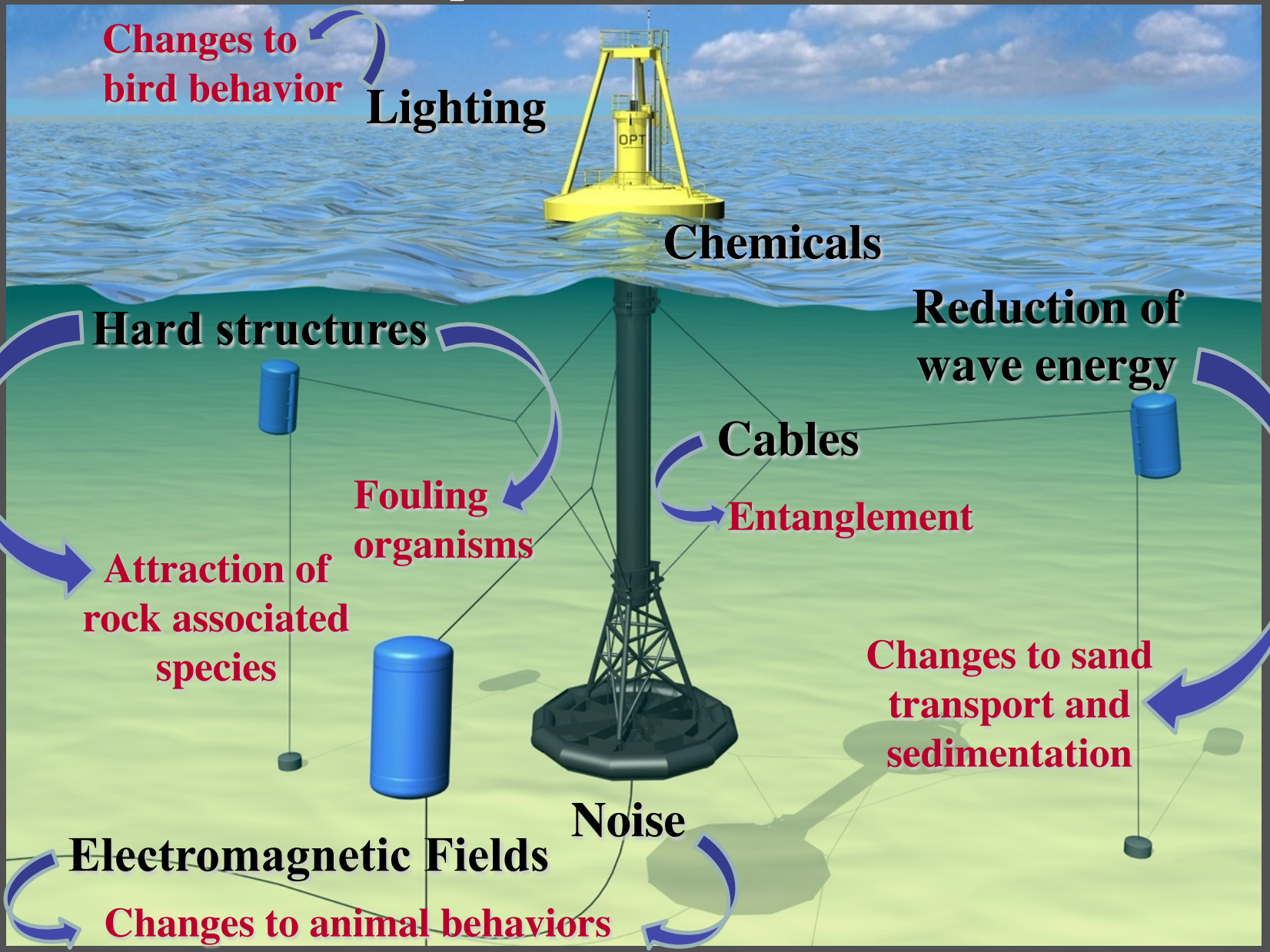


Physical-Environmental Effects of Wave and Offshore Wind Energy Extraction:

A Synthesis of Recent Oceanographic Research

Merrick C. Haller and Tuba Özkan-Haller
Oregon State University

Potential Impacts of Marine Renewables



Physical Effects of Marine Renewables

- Wave energy converters / offshore wind
- near-field / far-field
- waves & winds
- coastal circulation & sediment transport

How does the system work?

- Inputs: resource characterization
- Device performance – there is a diversity of technologies
- Array interactions – aggregate near-field effects
- Area of influence: propagation to the far-field (modeling)
- Far-field impacts (e.g. winds/waves-currents-transport)
- Challenge: ***we are data poor***

Resource characterization – offshore wind

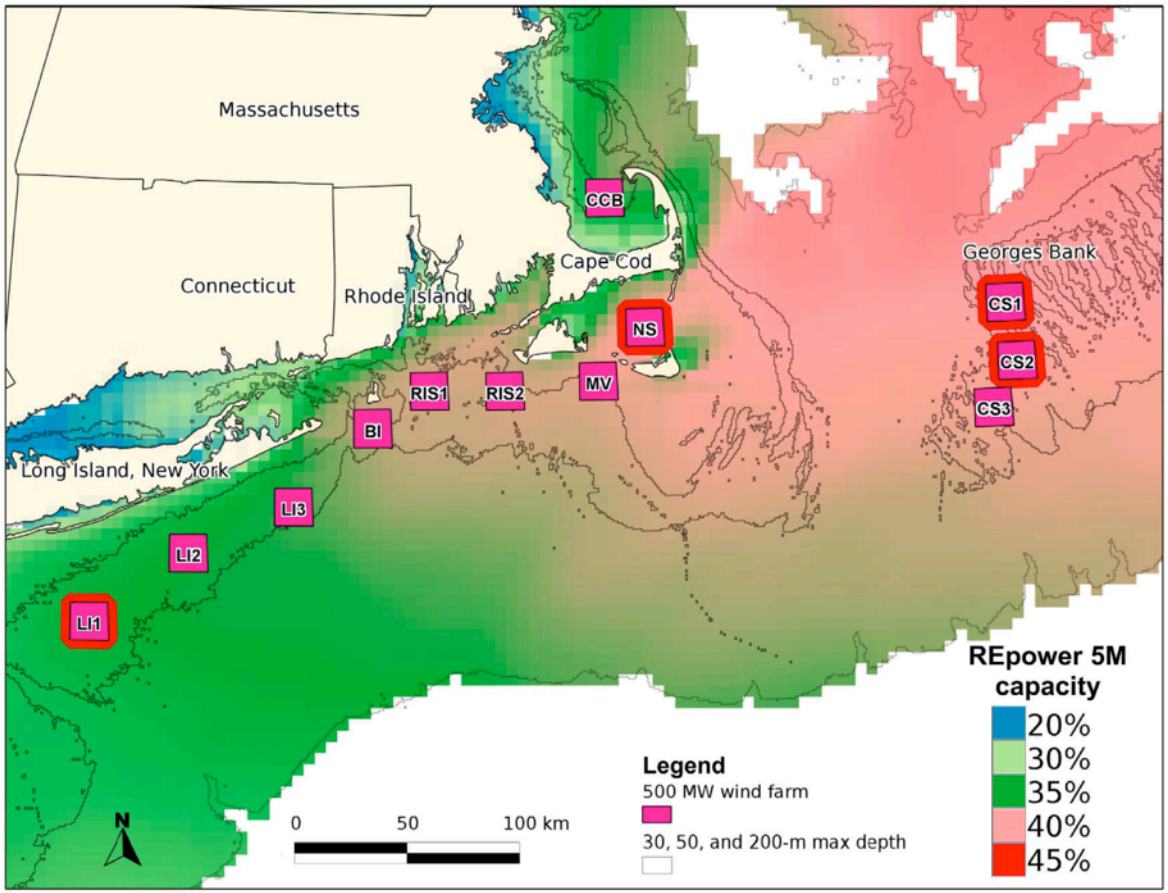
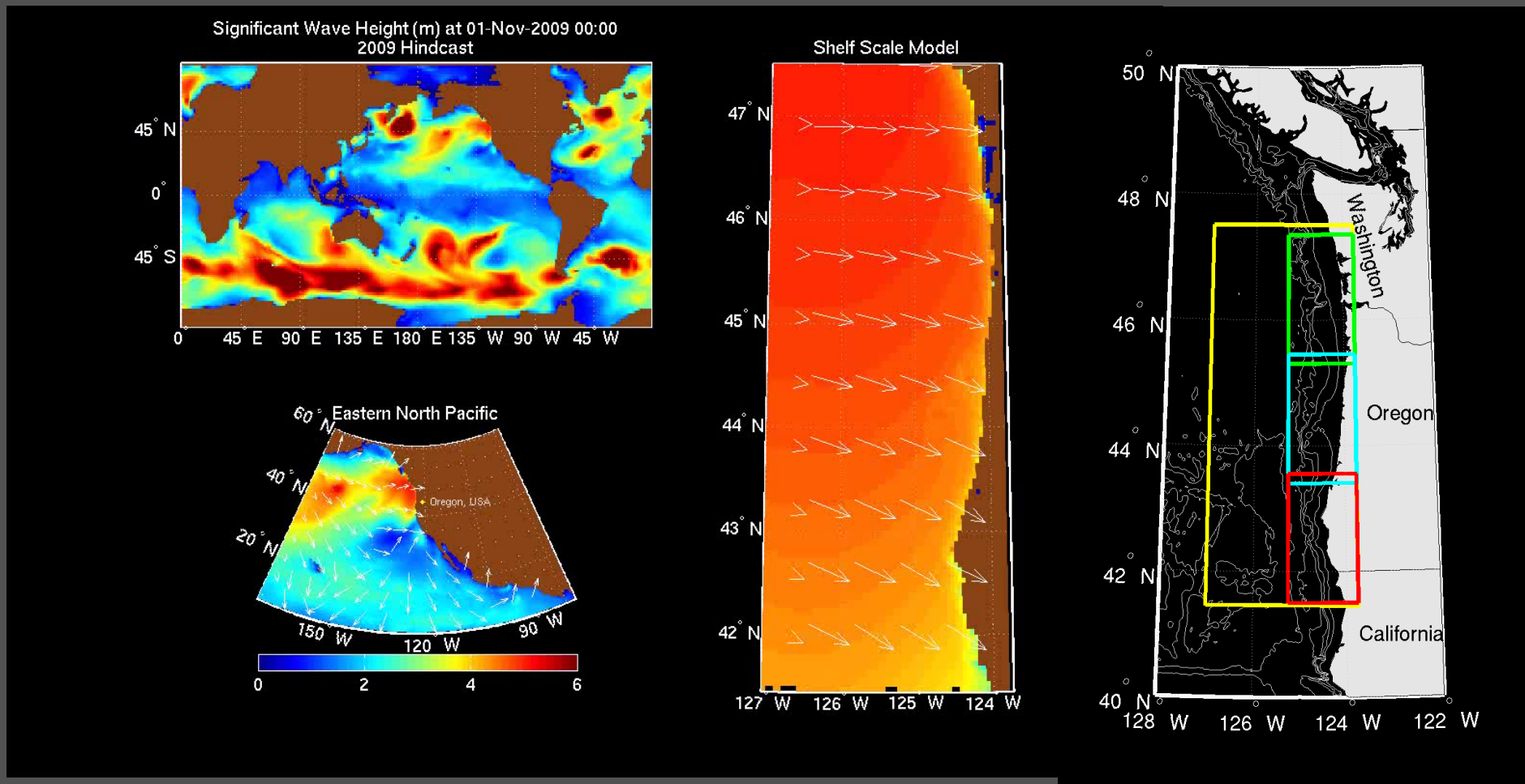


Figure 1. The 2006–2010, 90-m mean summer peak-time (08:00–21:00 EST) capacity factor (gross) based on a REpower 5M, 5.0-MW turbine. Twelve, 500-MW wind farms located in the highest capacity factor US East Coast summer peak-time wind resource and in waters ≤50-m depth are also shown. The four red-highlighted wind farms were selected for the ideal grid (*LI*1, *NS*, *CS*1, *and CS*2).

(Dvorak et al., *Geophys. Res. Lett.*, 2012)

Resource characterization – waves

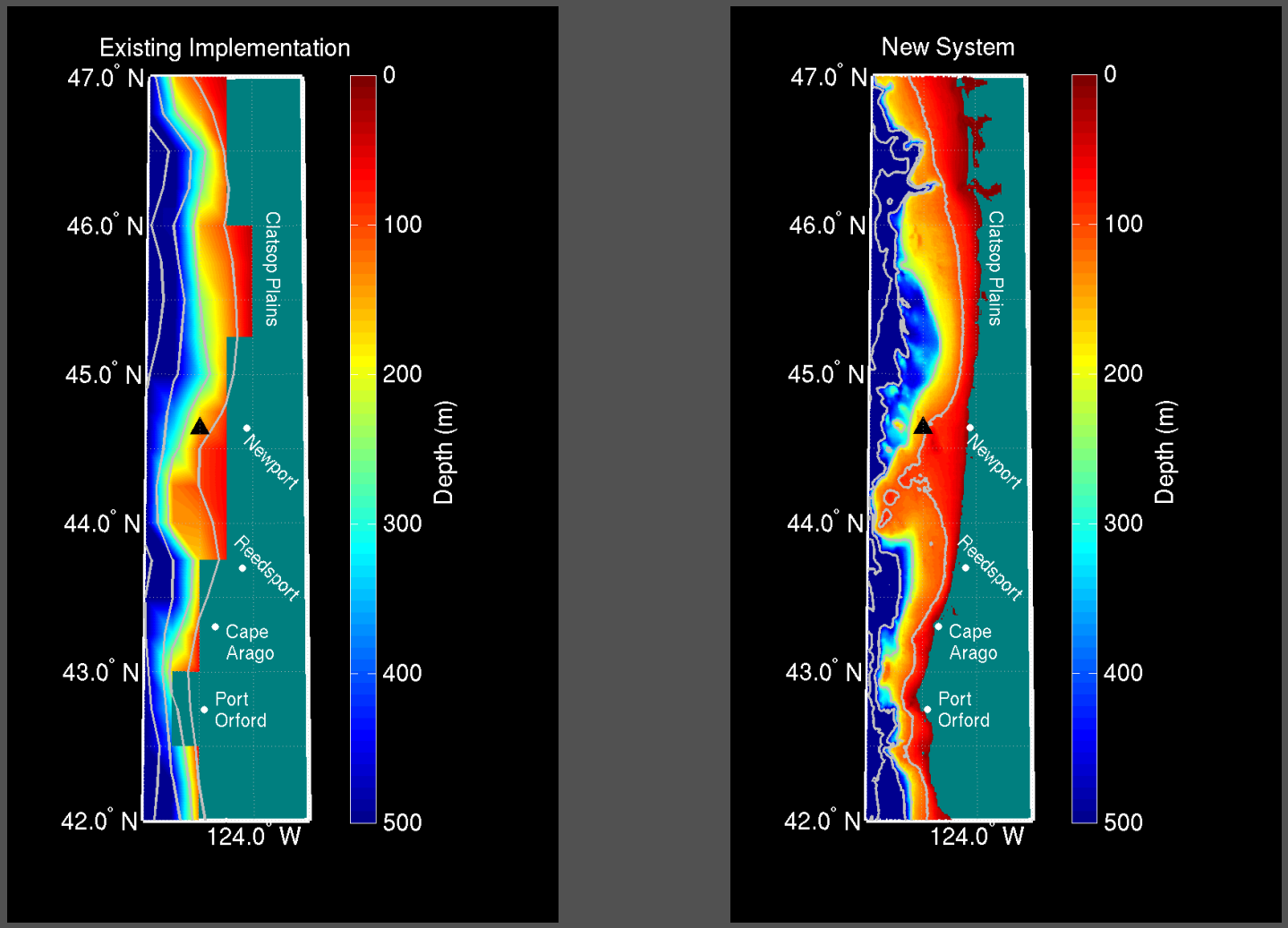


(Garcia et al., *Weather and Forecasting.*, in press)

Need hindcasts and forecasts

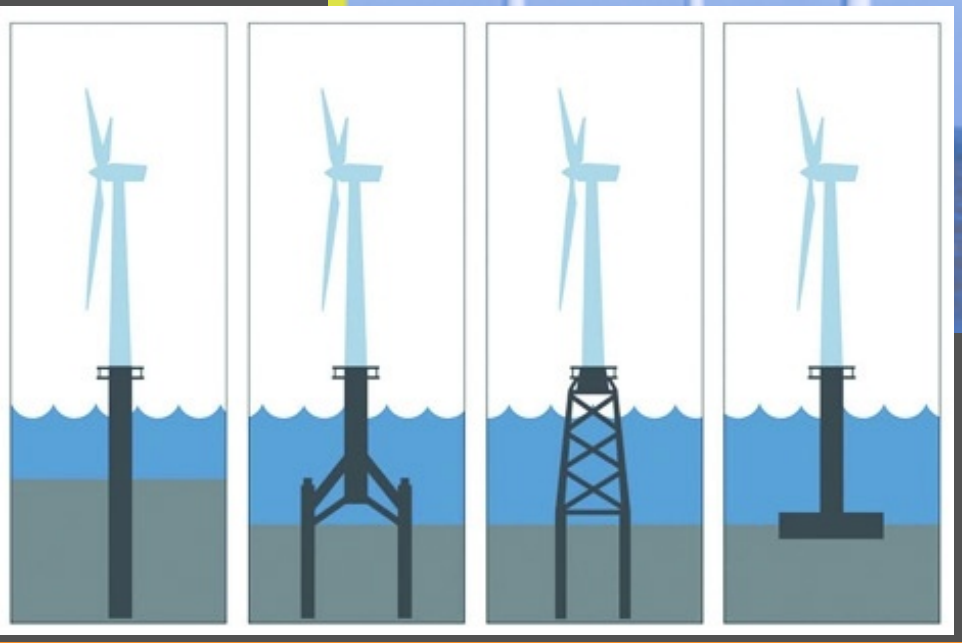
Resource characterization – waves

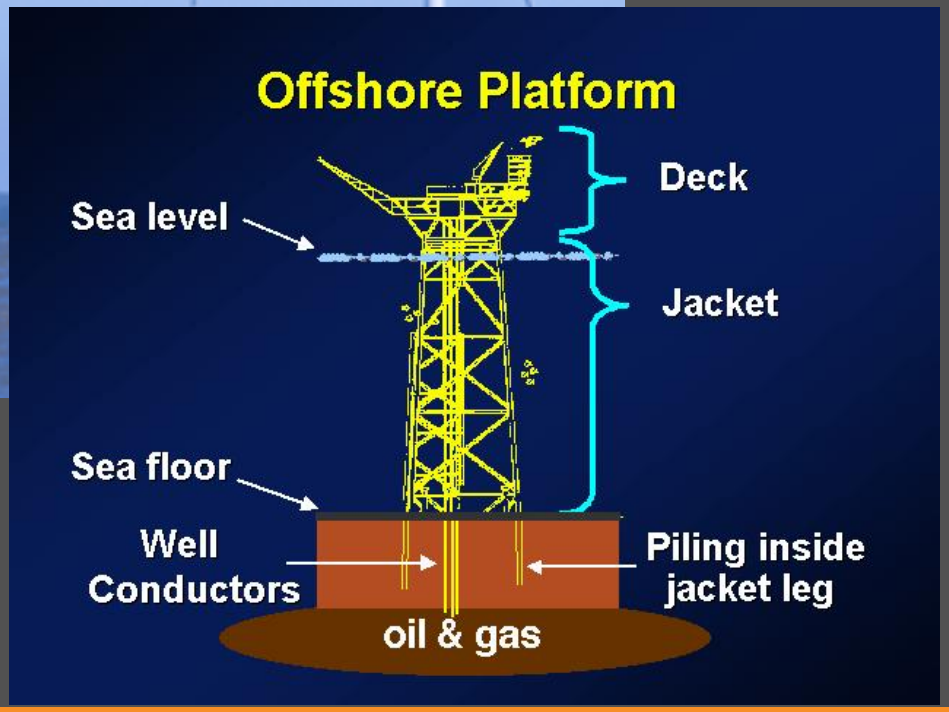
Need characterization at high resolution



(Garcia et al., *Weather and Forecasting.*, in press)

Physical effects: waves and winds





Physical effects: waves

plethora of devices

Physical effects: waves (near-field)

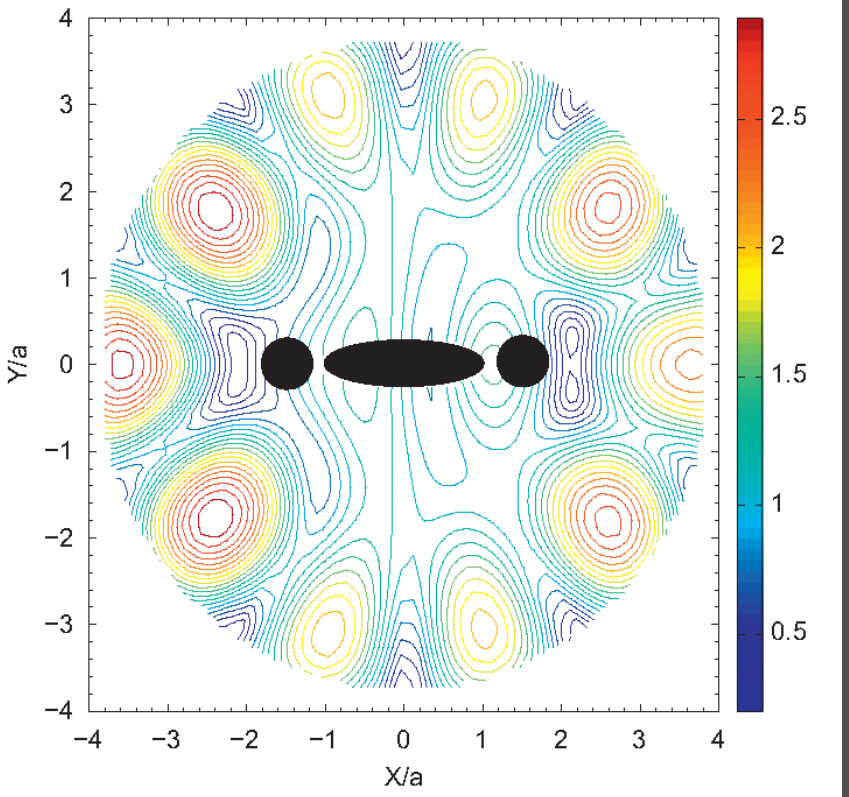


Fig. 21. Maximum free surface amplitudes ($|\eta/H/2|$) due to the interaction of an incident plane wave ($\gamma=0°$, $k_0a=2$) with the group of three cylinders of the 3rd configuration (Fig. 4).

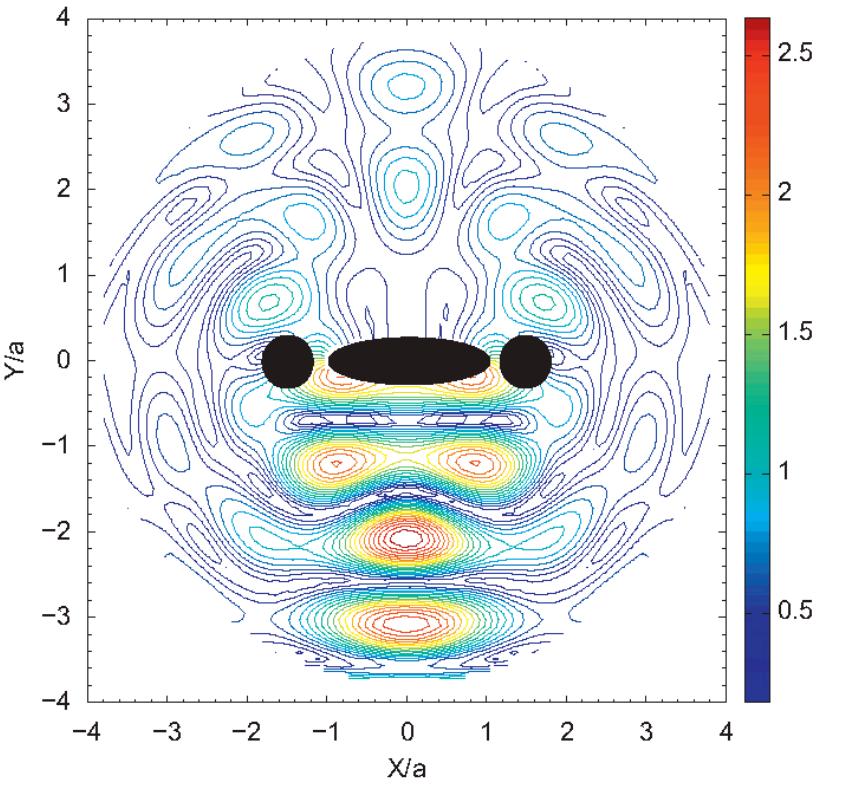


Fig. 24. Maximum free surface amplitudes ($|\eta/H/2|$) due to the interaction of an incident plane wave ($\gamma=90°$, $k_0a=3.5$) with the group of three cylinders of the 3rd configuration (Fig. 4).

(from Chatjigeorgiou, *Ocean Eng.*, 2011)

WEC/wave interaction

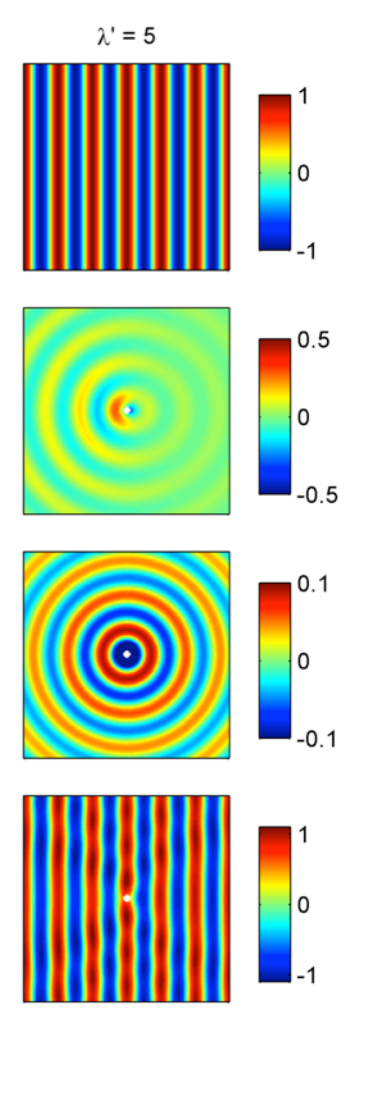
Surface elevation

Incident

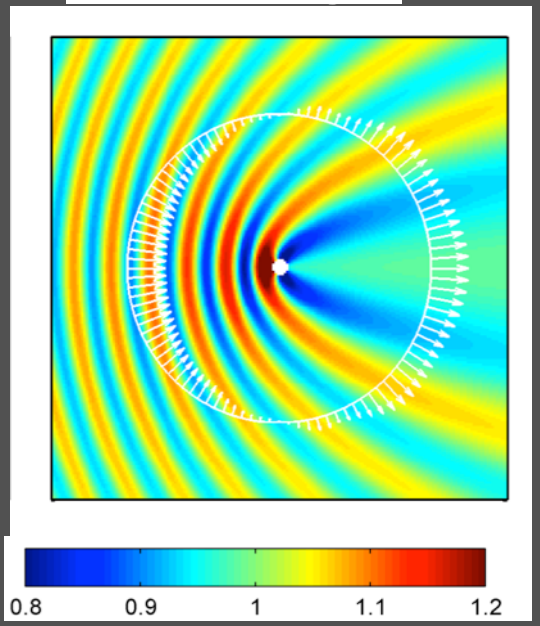
Diffracted

Radiated
(due to WEC motion)

Total



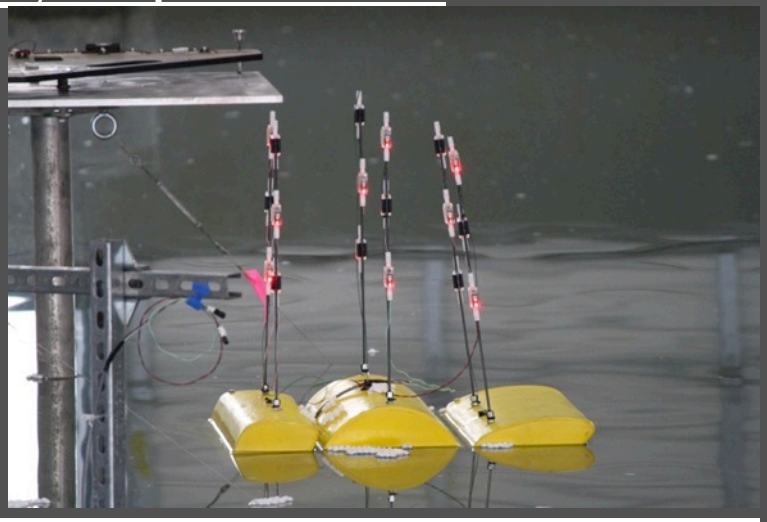
Wave Height

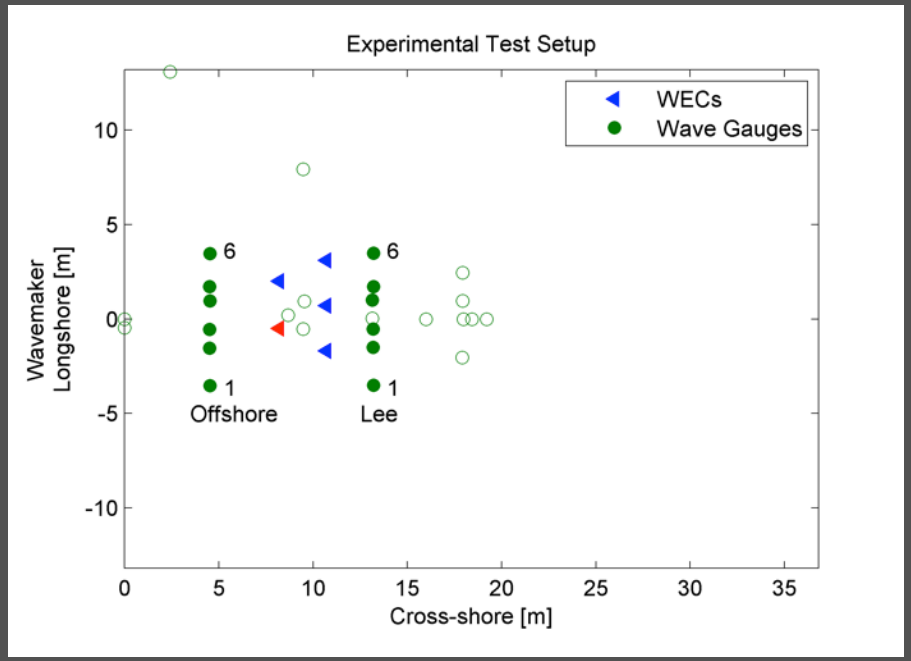


WAMIT simulations

Physical effects: WEC-Array experiments

OSU Hinsdale Lab





(Haller et al., *EWTEC, 2011*)

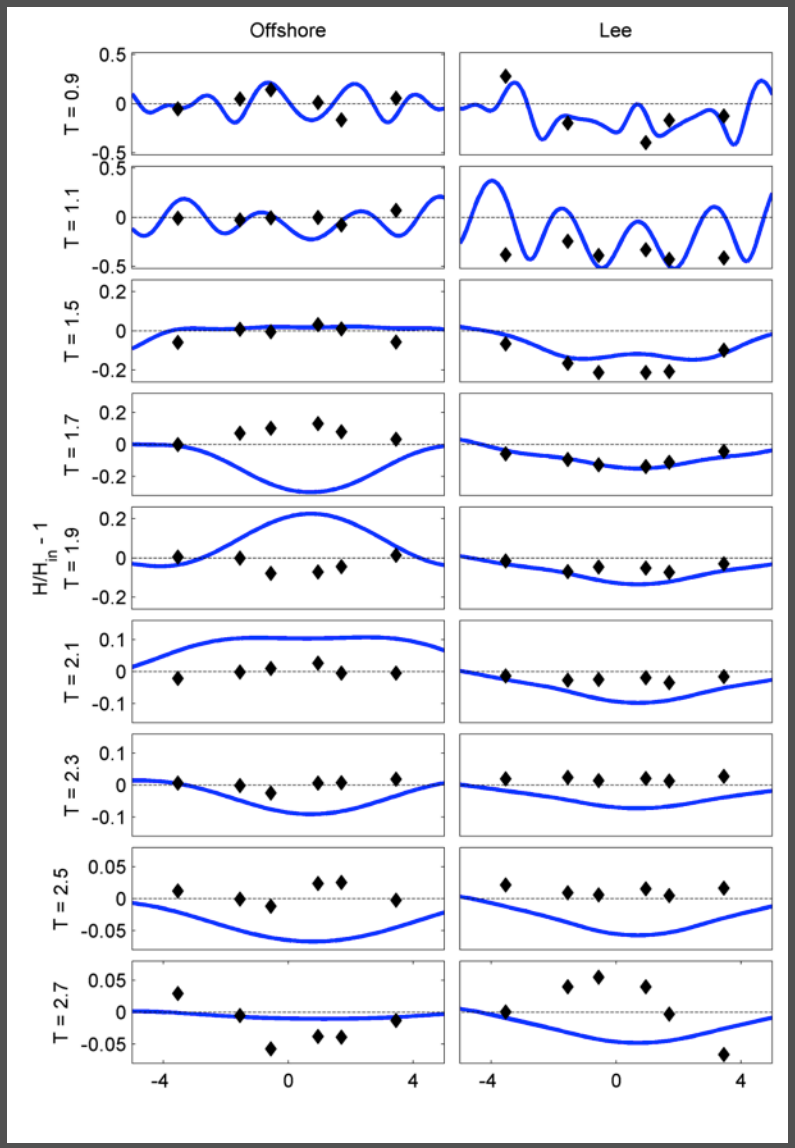
Monochromatic waves

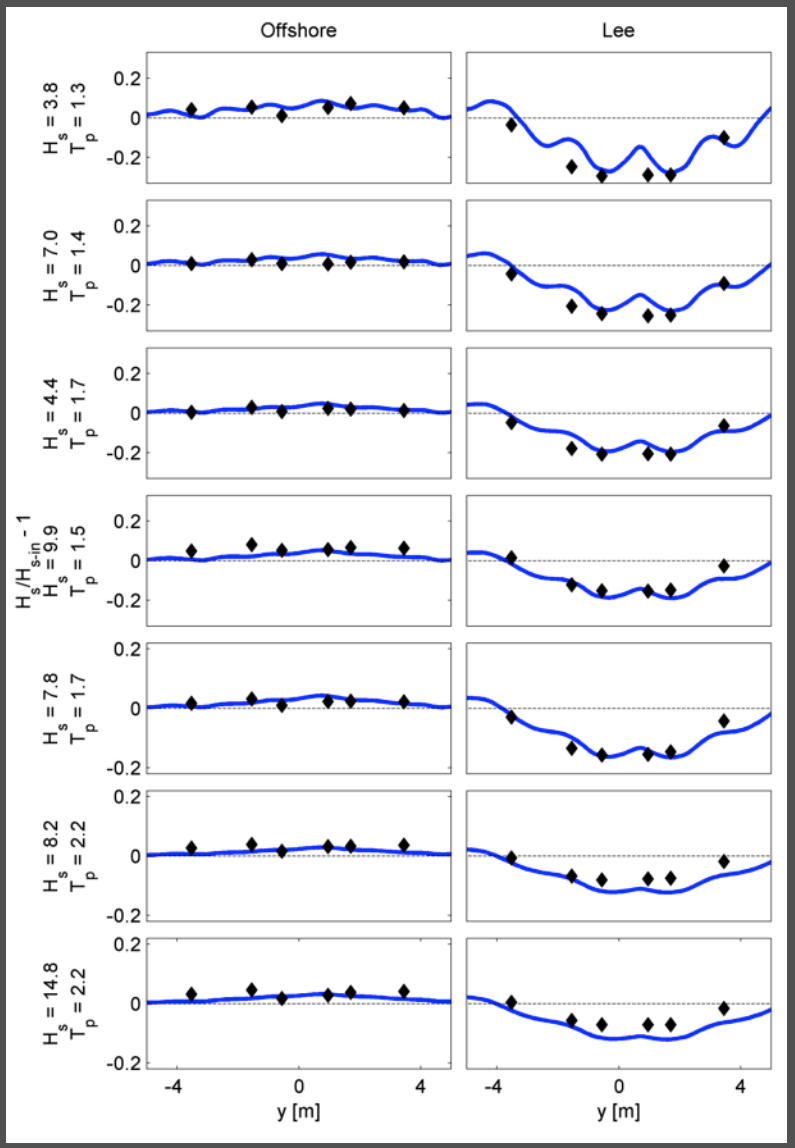
Offshore Lee

Real seas

Offshore Lee

T increasing

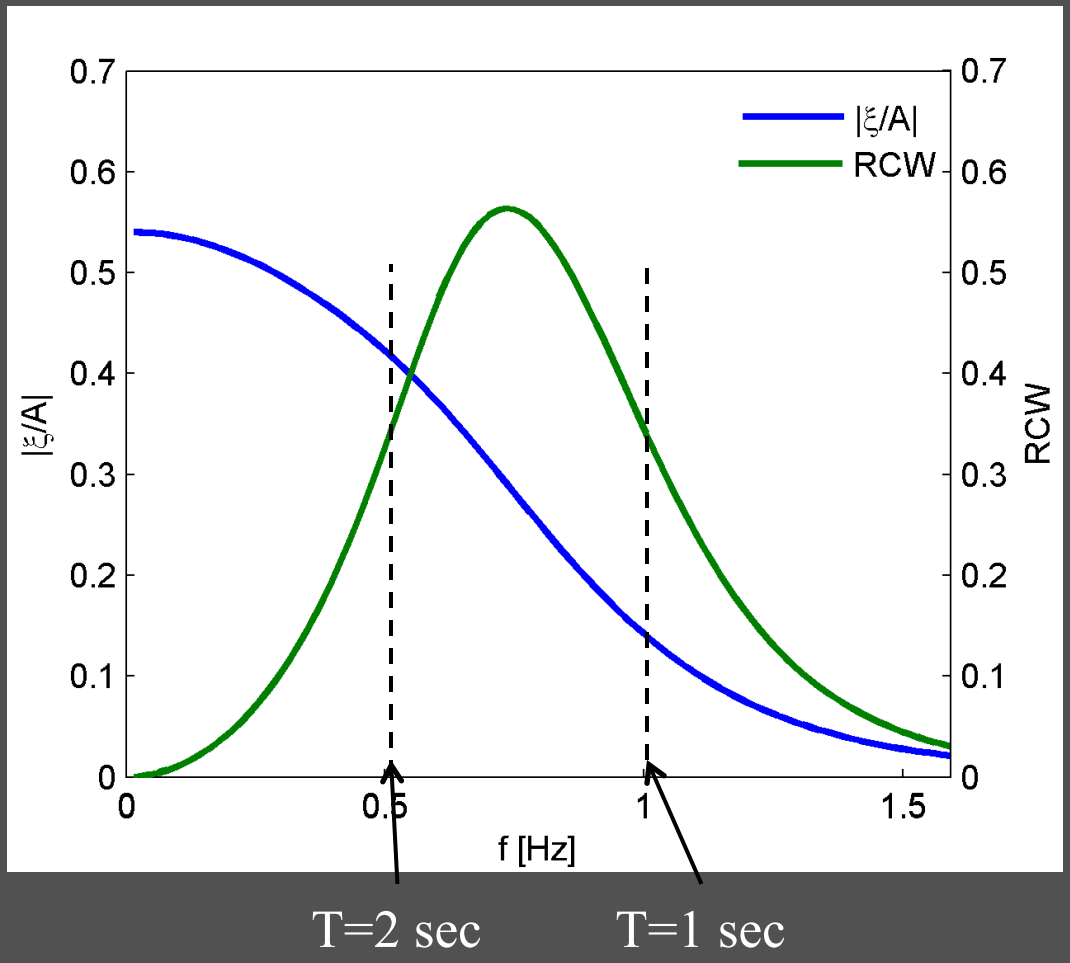




(McNatt, M.S. Thesis, 2012)

Oregon State University

Near-Field WEC Effects – two cases

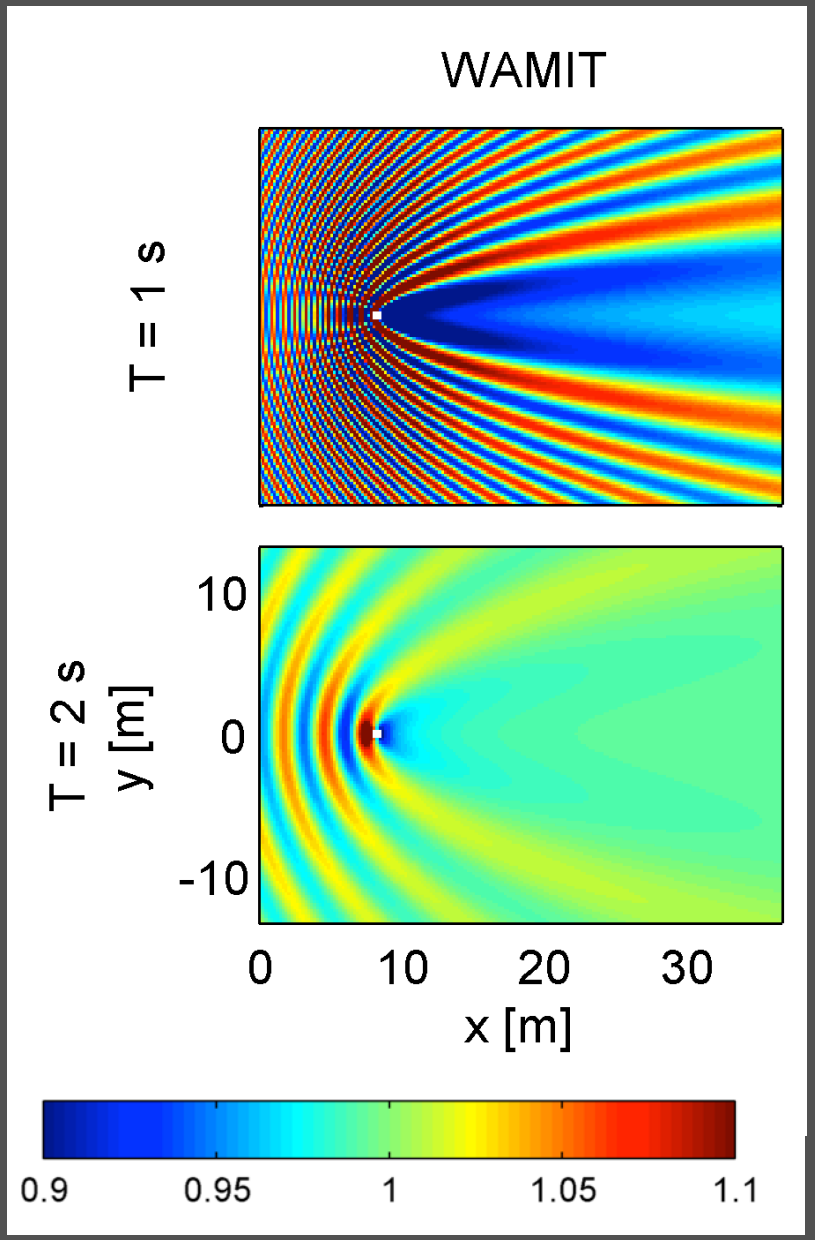


One device – two waves

- similar extracted power
- different WEC response

T=1sec – diffraction/radiation
T=2sec – absorption

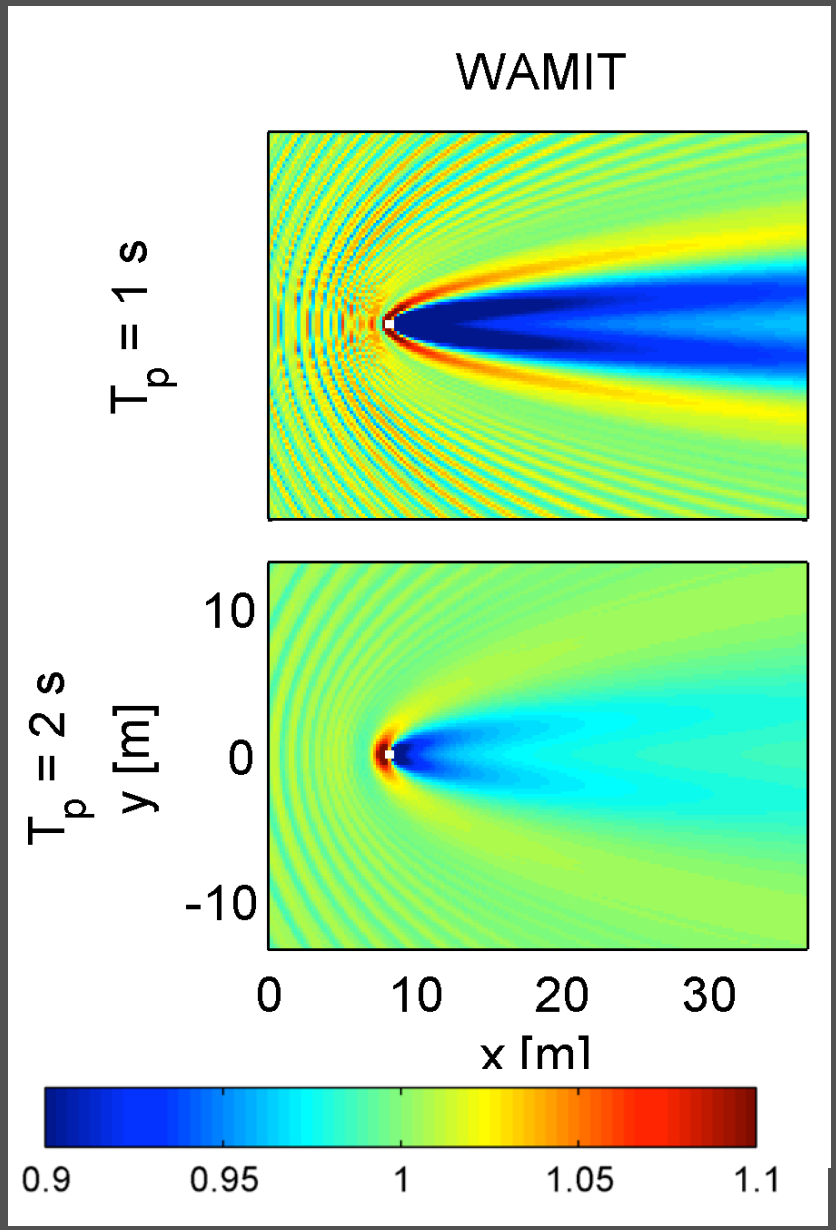
Near-Field WEC Effects – Monochromatic waves



diffraction/radiation

absorption

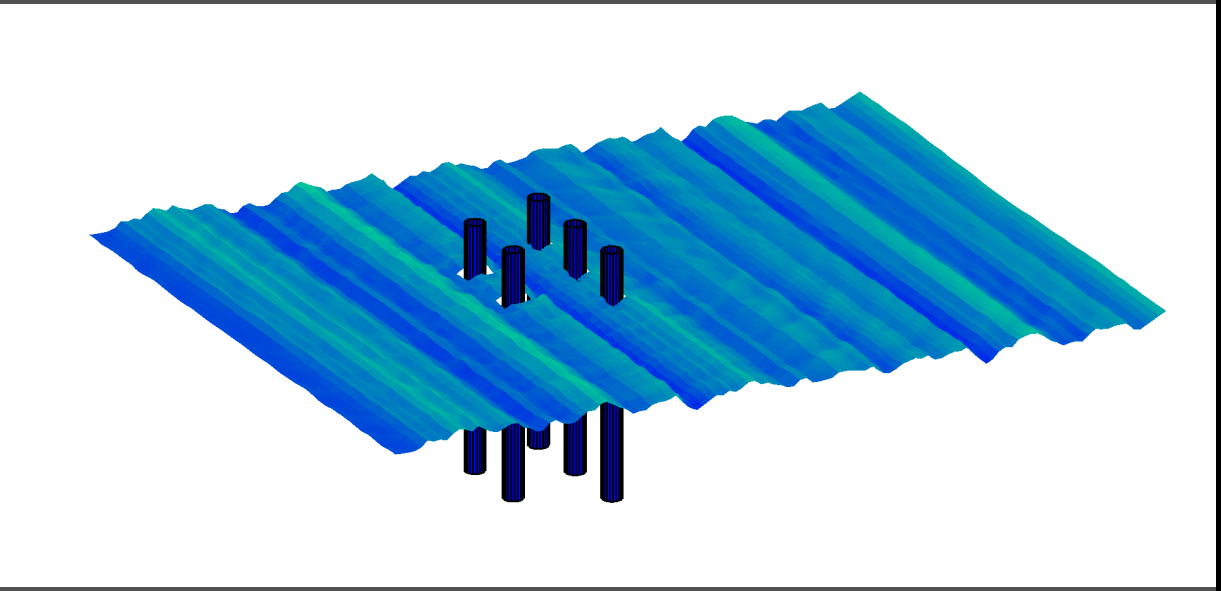
Near-Field WEC Effects – Random waves

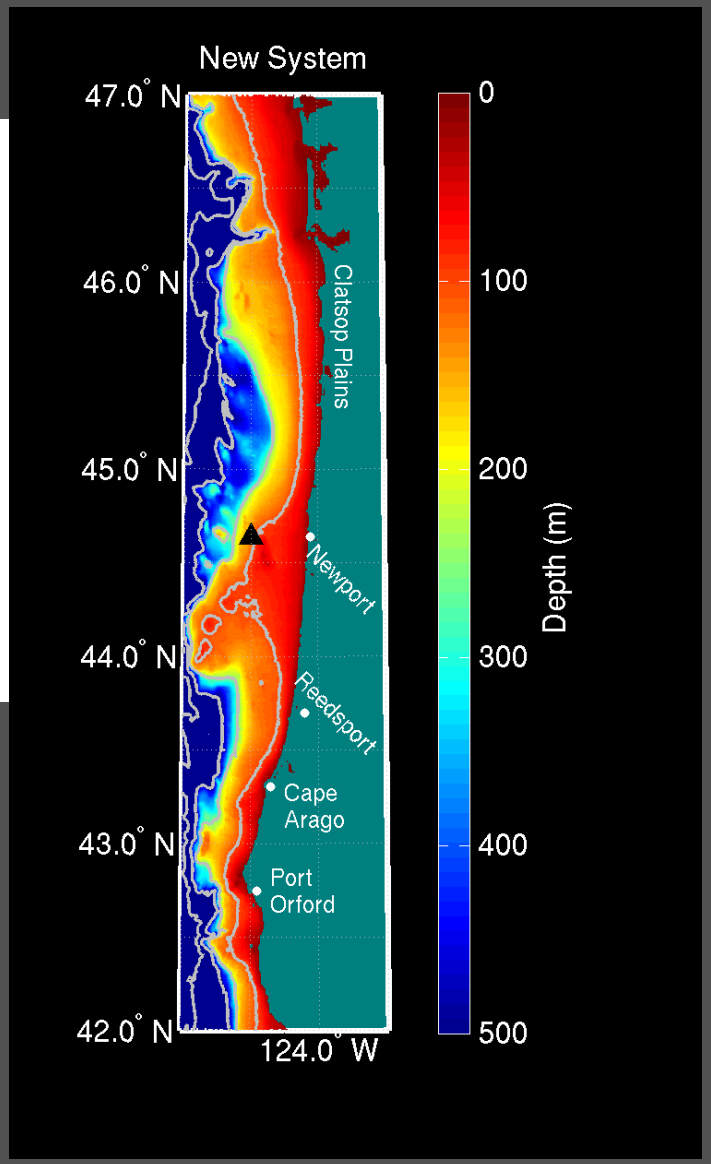


diffraction/radiation

absorption

Physical effects: waves (far-field)





Physical effects: waves (far-field)

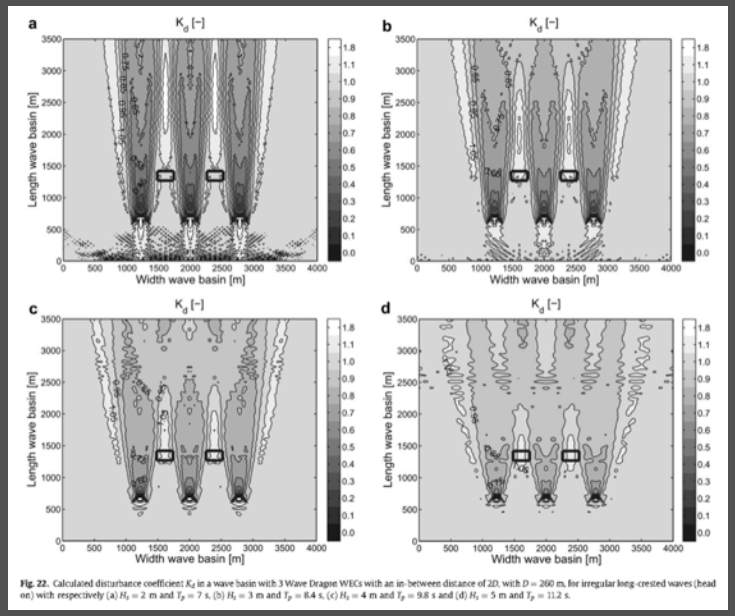
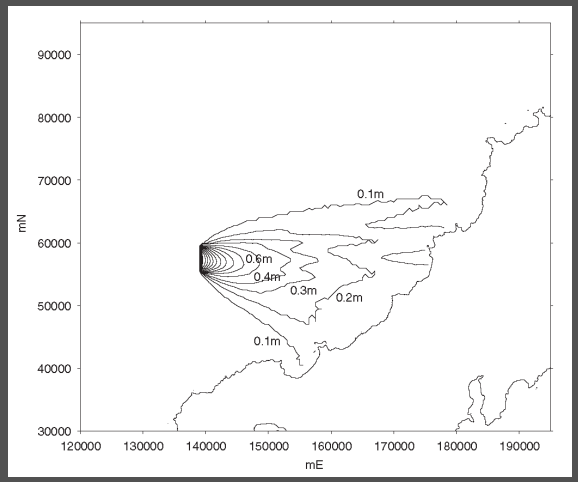
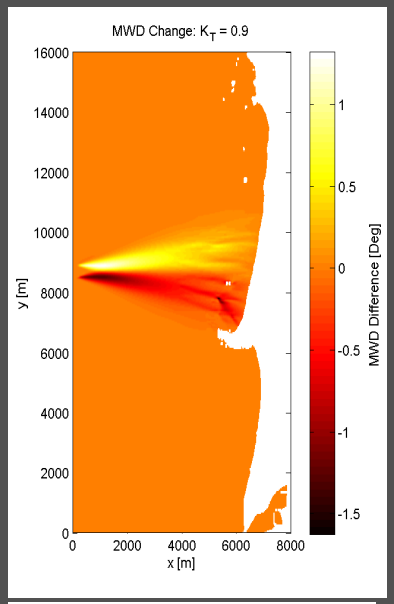


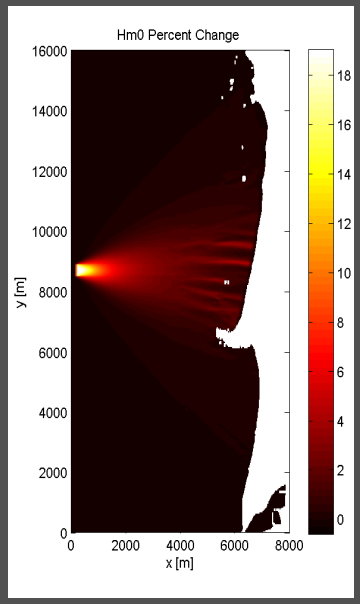
Fig. 22. Calculated disturbance coefficient K_d in a wave basin with 3 Wave Dragon WECs with an in-between distance of 2D, with $D = 260$ m, for irregular long-crested waves (head on) with respectively (a) $H_s = 2$ m and $T_p = 7$ s, (b) $H_s = 3$ m and $T_p = 8.4$ s, (c) $H_s = 4$ m and $T_p = 9.8$ s and (d) $H_s = 5$ m and $T_p = 11.2$ s.

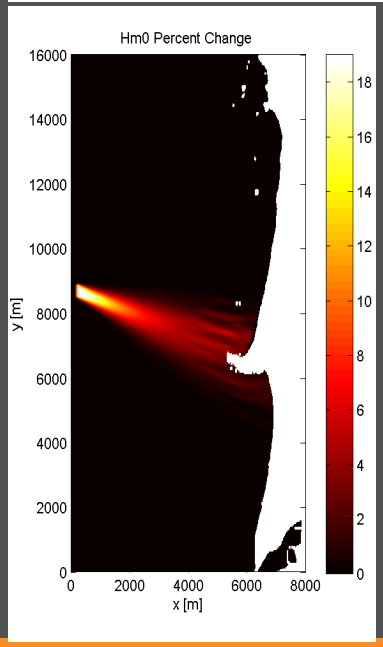
(Beels et al., *Renewable Energy*, 2010)

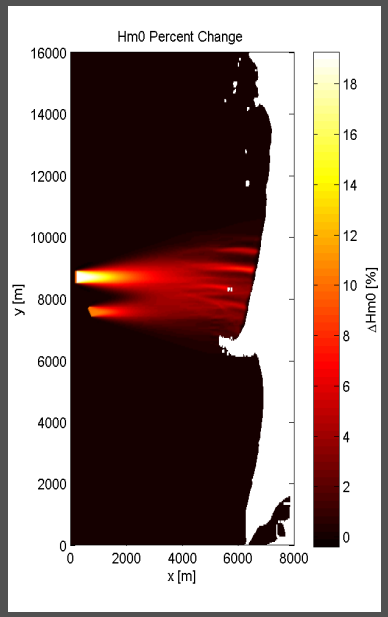


(Millar et al., *Ocean Eng.*, 2010)

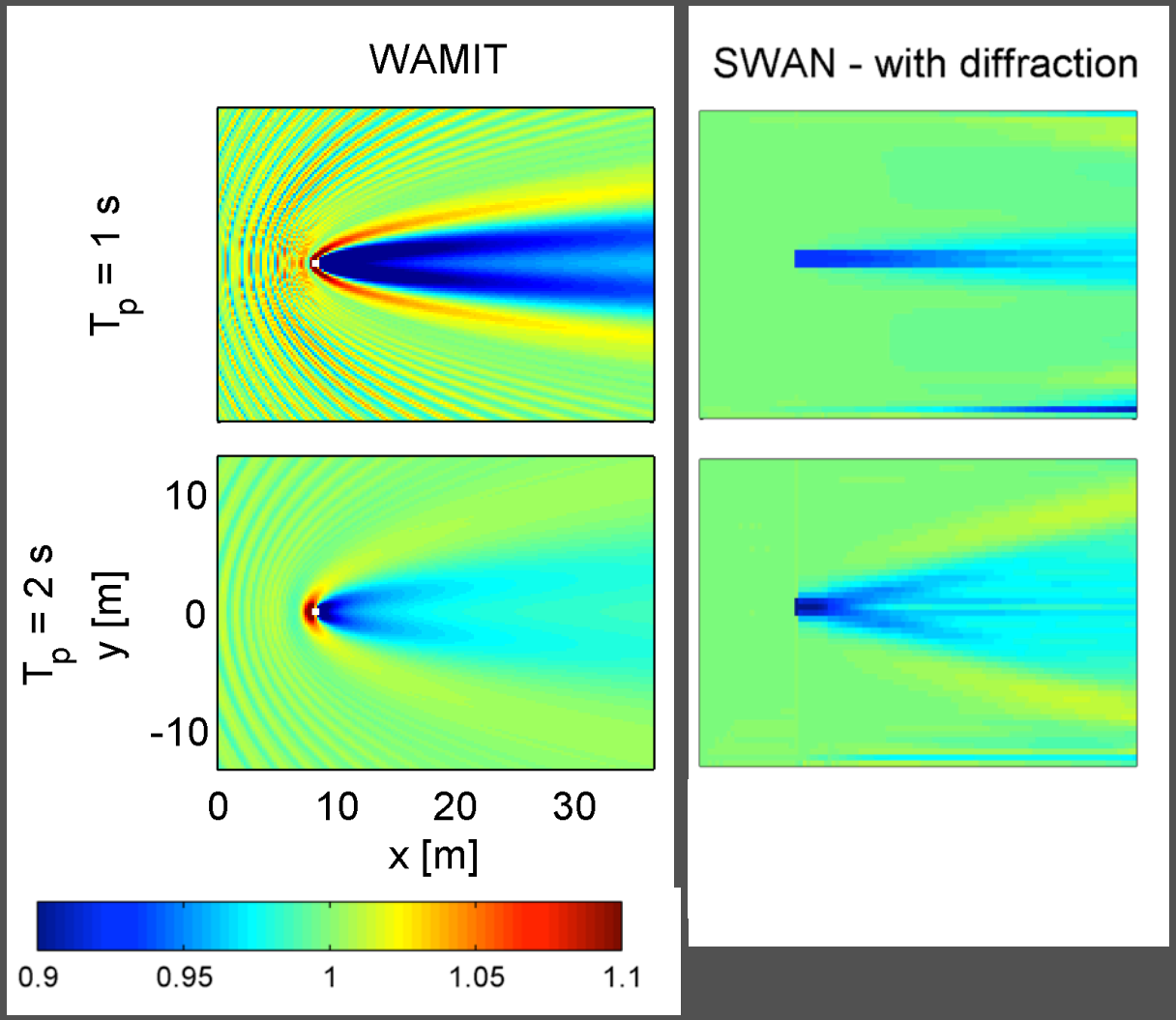




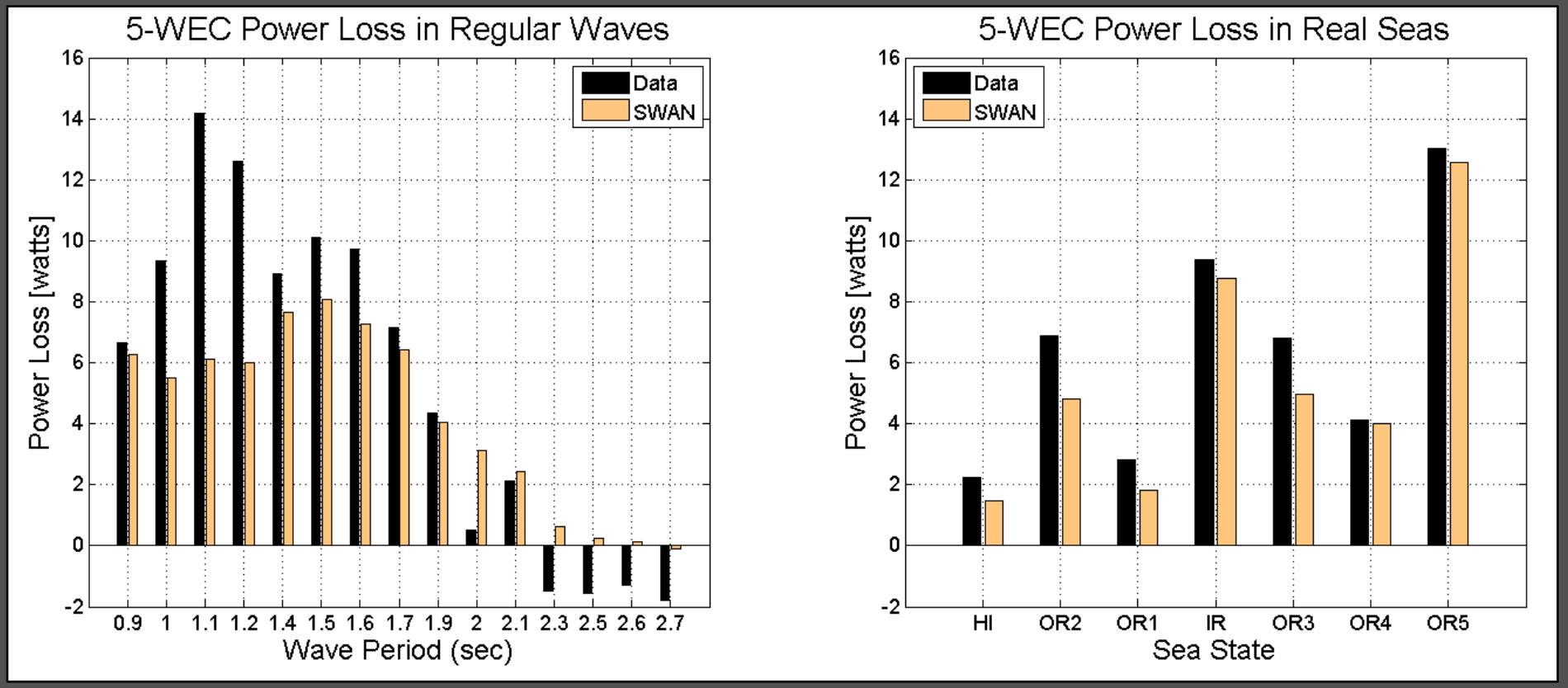




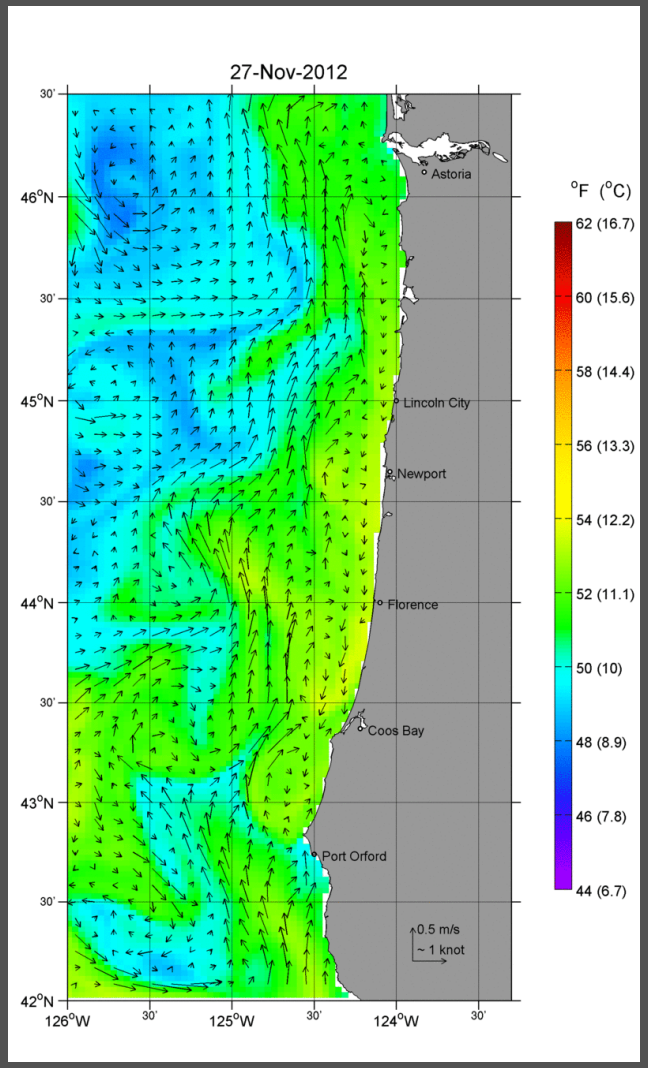
Area model verification (SWAN)



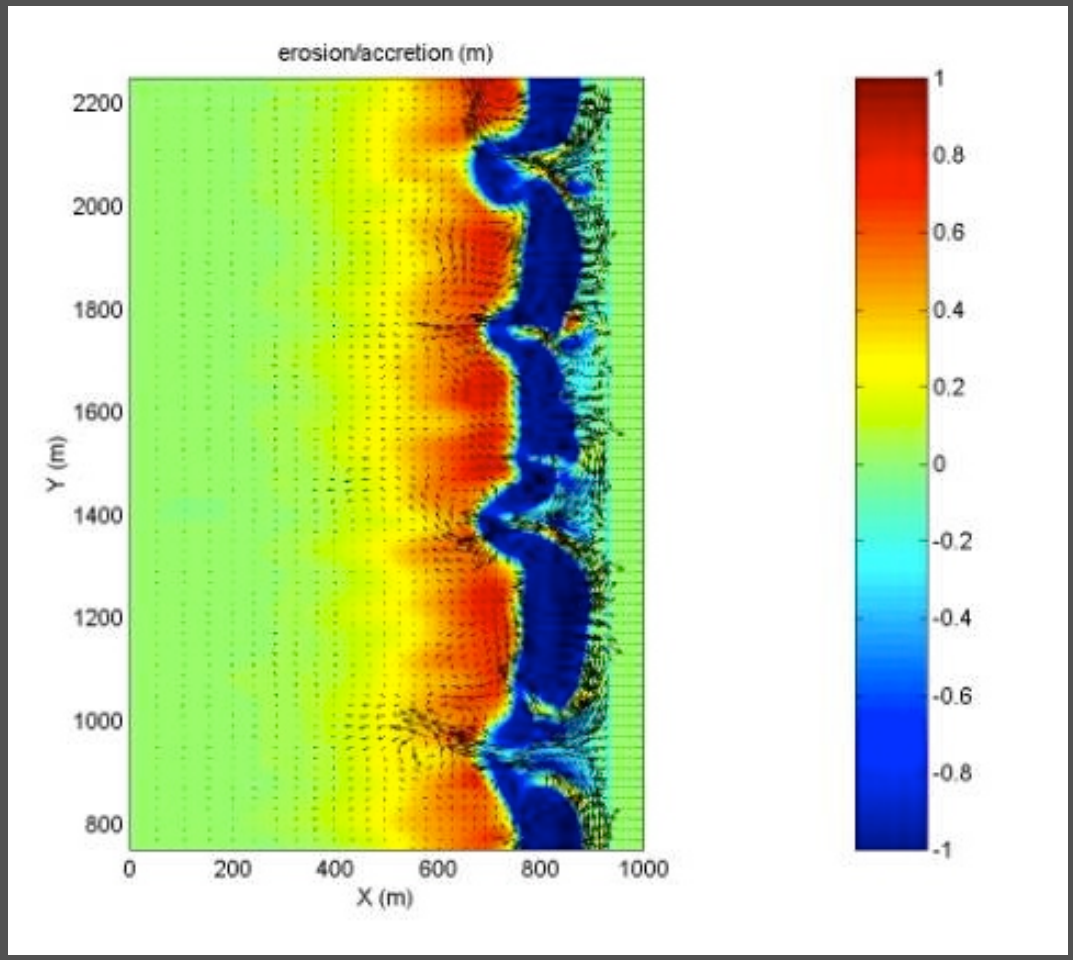
Model/data comparison: wave energy deficit



Physical effects: coastal circulation

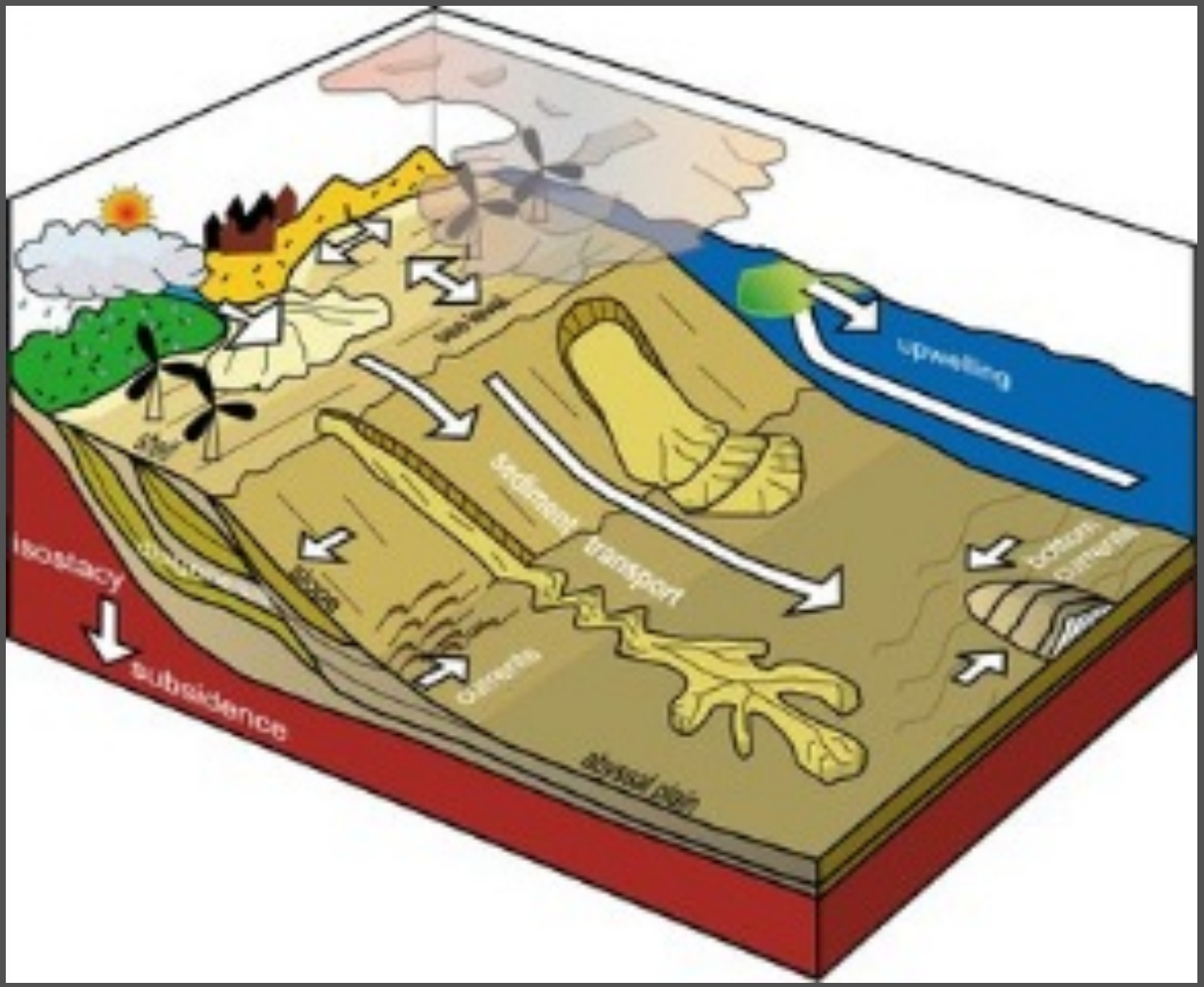


Oregon coastal current forecast (OrCOOS)



Rip current circulation

Physical effects: sediment transport



Physical effects: arrays

HyWind floating turbine

Summary on Physical Effects of Marine Renewables

- WECS / offshore wind
- Physical system: resource – energy extraction – local / far-field effects

- Assessible / Understood
  - resource characterization, devices in isolation, wind arrays

- Uncertainties
  - aggregate array effects, field data
  - far-field impacts on currents and sediment transport