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# Waves, Wave Energy And the West Coast of Canada

West Coast Wave Initiative (WCWI)

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WCWI

WEST COAST WAVE INITIATIVE



# Waves and Wave Energy – What / How / Where / When



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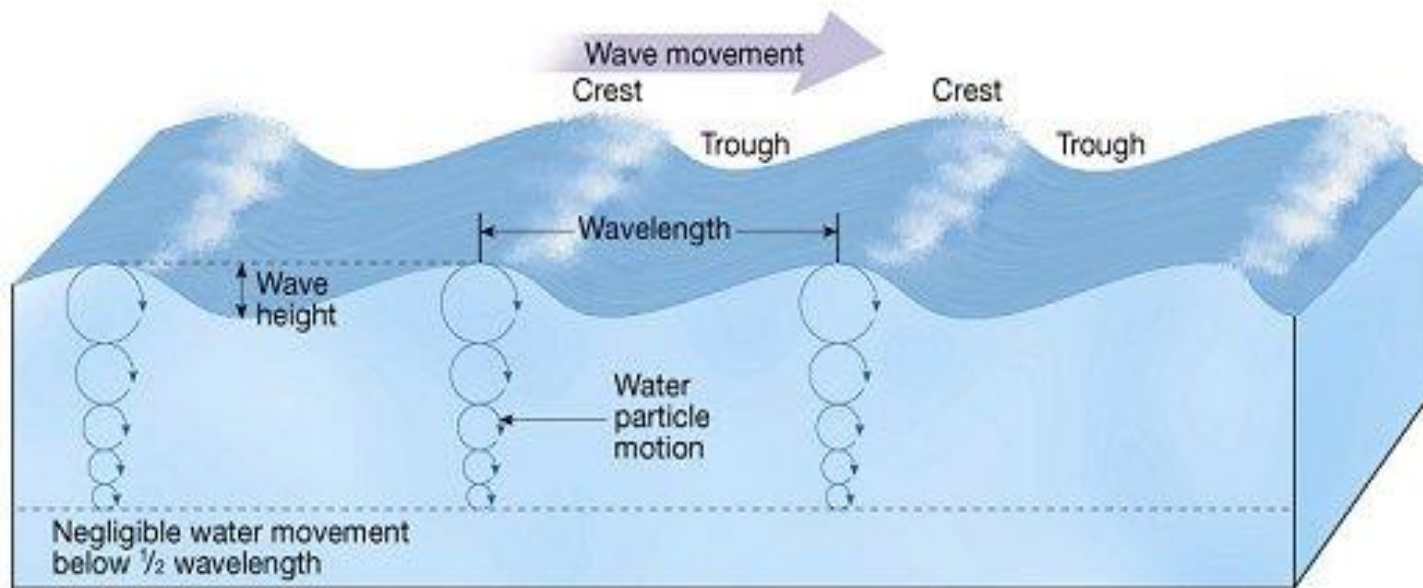
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# Wave Parameters and Terms

## Wave Basics:

- Wave Crest
- Wave Trough
- Wave Height (Vertical distance from wave trough to crest - m)
- Wavelength (Distance from one crest to the next crest - m)
- Wave Period (Time from one crest to the next crest - sec)



# Wave Creation – How ?

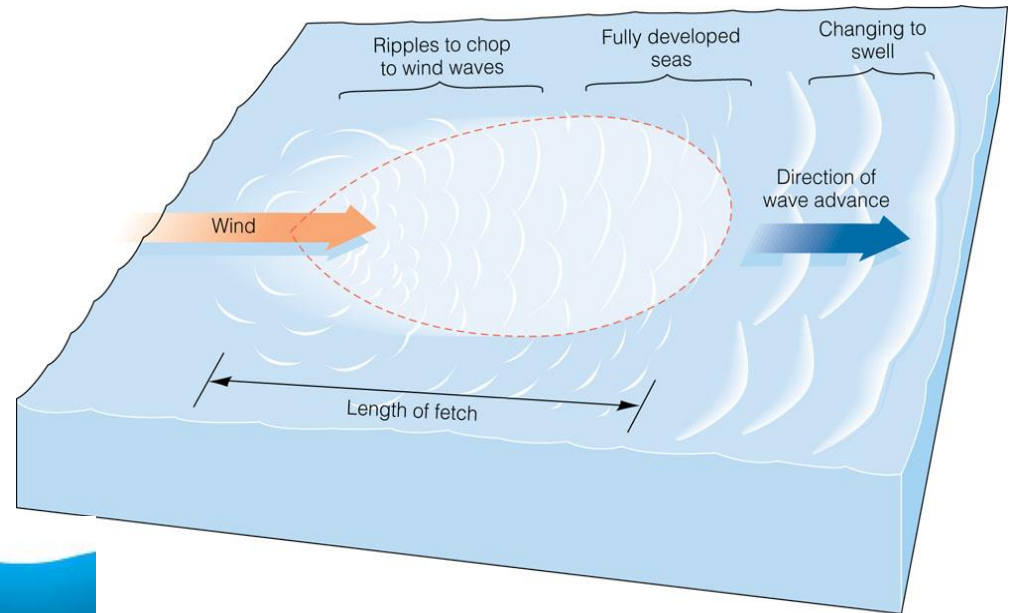
## Wave Creation:

- Wind Speed
- Fetch (distance)
- Time

Ripples > Chop

Chop > Wind Waves

Wind Waves > **Swell**



WIND 15 KNOTS = WAVES 1.5 METRES = LENGTH 25 METRES

WIND 25 KNOTS = WAVES 3 METRES = LENGTH 32 METRES

WIND 40 KNOTS = WAVES 5 METRES = LENGTH 55 METRES

Example:

Fetch: 50 NM (90 km)

Time: 6 Hours

Wind Speed...



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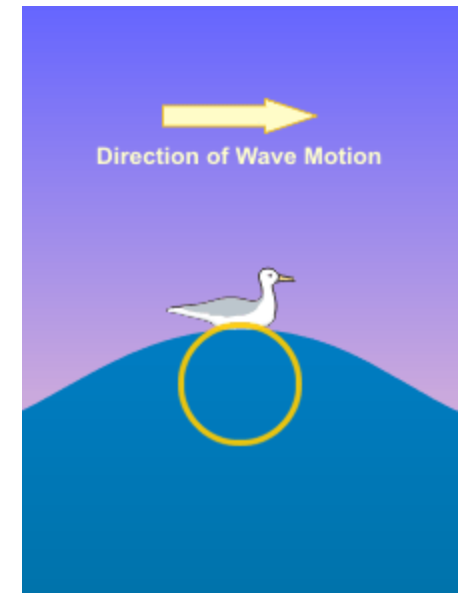
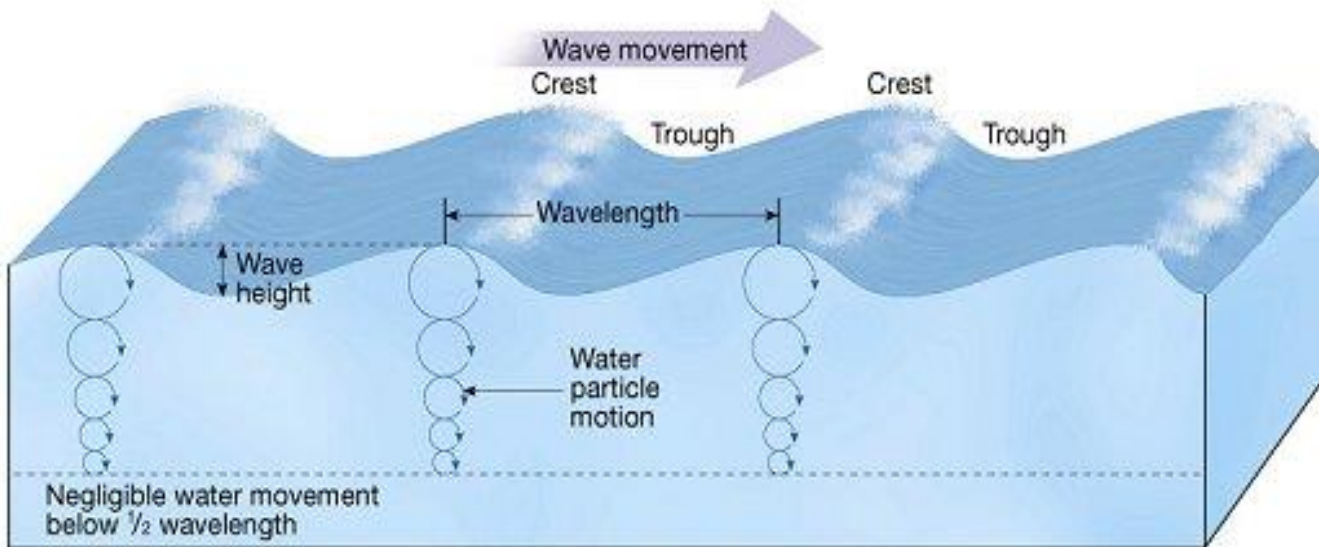
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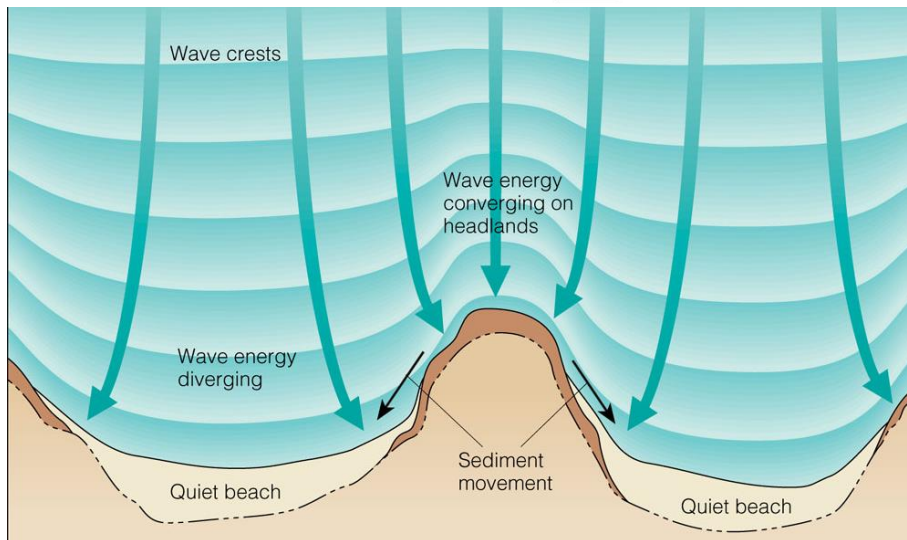
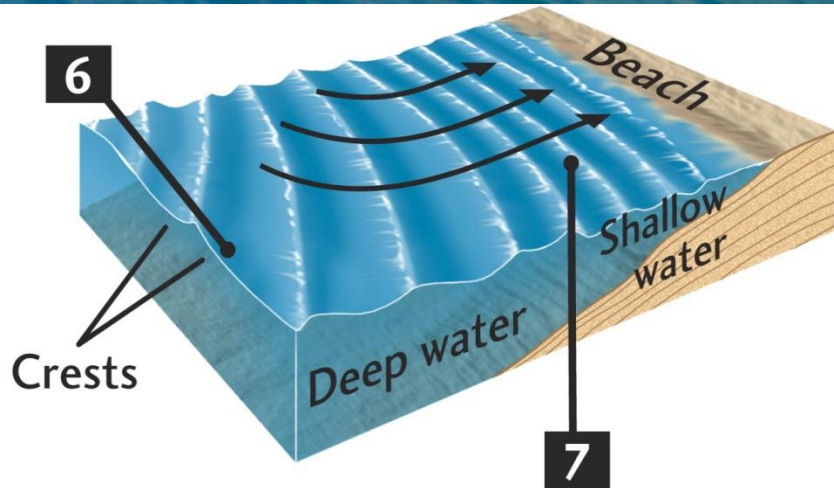
# Basic Wave Equations

## Wave Equations:

- Wavelength ( $L$ ) = Wave Speed ( $C$ ) \* Wave Period ( $T$ )
- Deep Water:
  - Wave speed:  $C \sim 1.5 T$  ( 10 sec wave = 15 m/s)
  - Wavelength:  $L \sim 1.5 T^2$  ( 10 sec wave = 150 m)
- Waves "feel" the bottom at a depth of  $d \sim 0.5L$



# Effects of Shallow Water on Waves



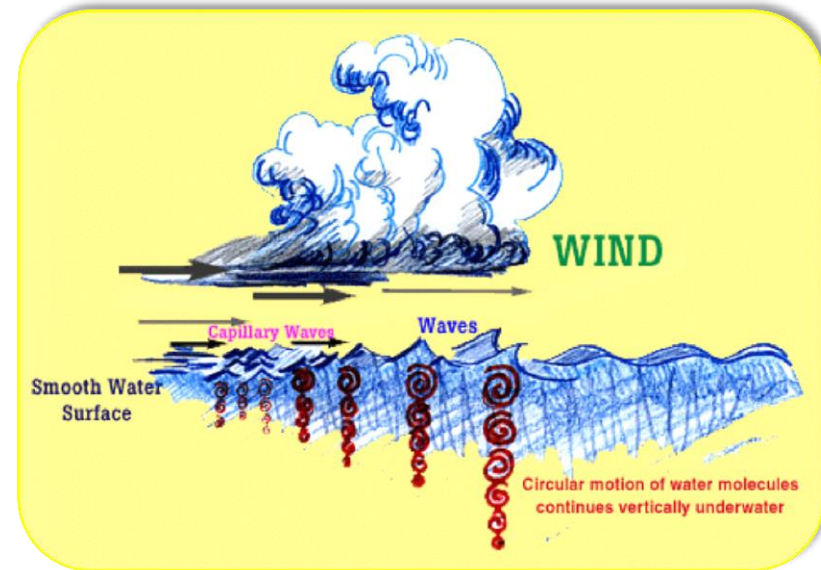
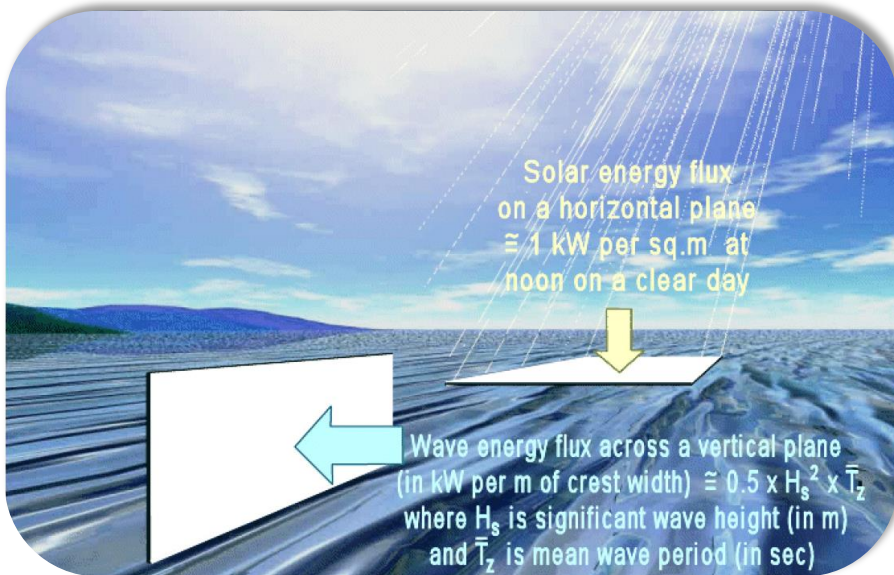
- Shallow Water:
  - Wave period is constant
  - Wave speed:  $C = \sqrt{gh}$
- Therefore, waves in shallow water move slower.
- Result: Waves bend towards the shallow areas.
- Area's where waves converge result in larger waves.
- Period remains constant.



# What is Wave Energy? Solar Energy ?

## Wave Energy

- Wave energy is sometimes described as a concentration of solar energy.
- Differential Heating  $\Rightarrow$  Winds  $\Rightarrow$  Swell
- Potential Energy + Kinetic Energy

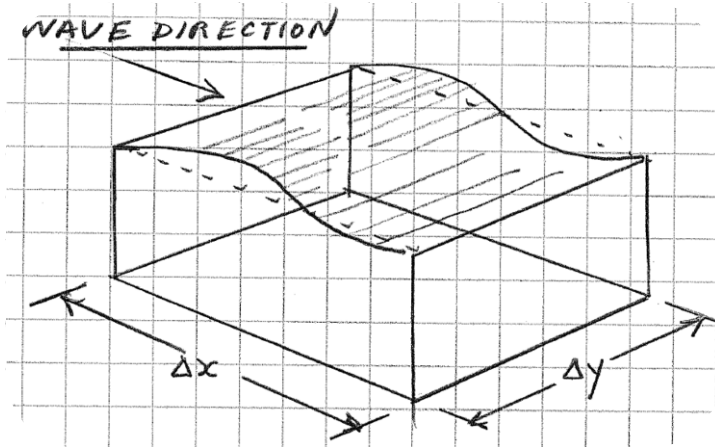


- Wave energy converters work with long period water waves (*swell*).
- The magnitude of the power transport in ocean waves has inspired a variety of WEC concepts





# Power in Waves (Wave energy transport)



$$\frac{E_{tot}}{\Delta x \Delta y} = \frac{1}{8} \rho g H^2$$

$$c_g = \frac{\Delta x}{\Delta t} = \frac{g}{4\pi} T$$

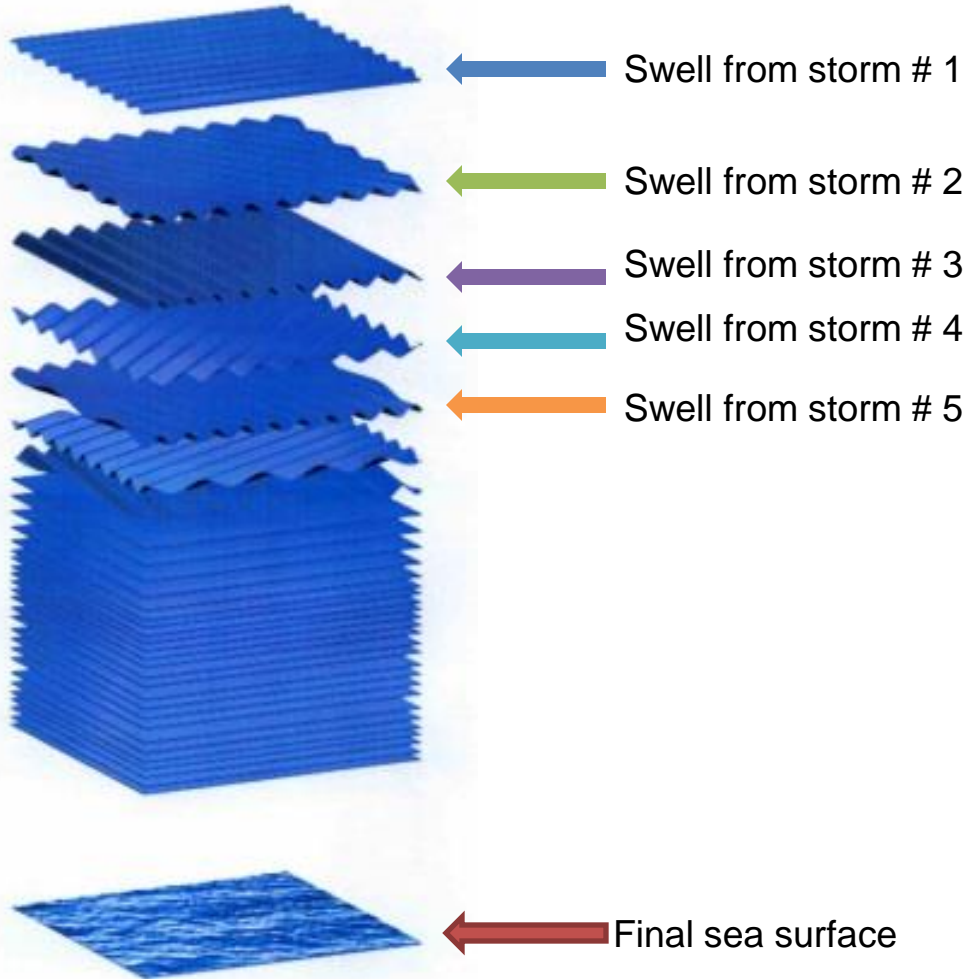
$$J \equiv \frac{P_{tot}}{\Delta y} = \frac{E_{tot}}{\Delta t \Delta y} = \frac{\Delta x}{\Delta t} \frac{E_{tot}}{\Delta x \Delta y} = c_g \frac{E_{tot}}{\Delta x \Delta y}$$

$$J = c_g \frac{1}{8} \rho g H^2 = \left( \frac{g}{4\pi} T \right) \frac{1}{8} \rho g H^2$$

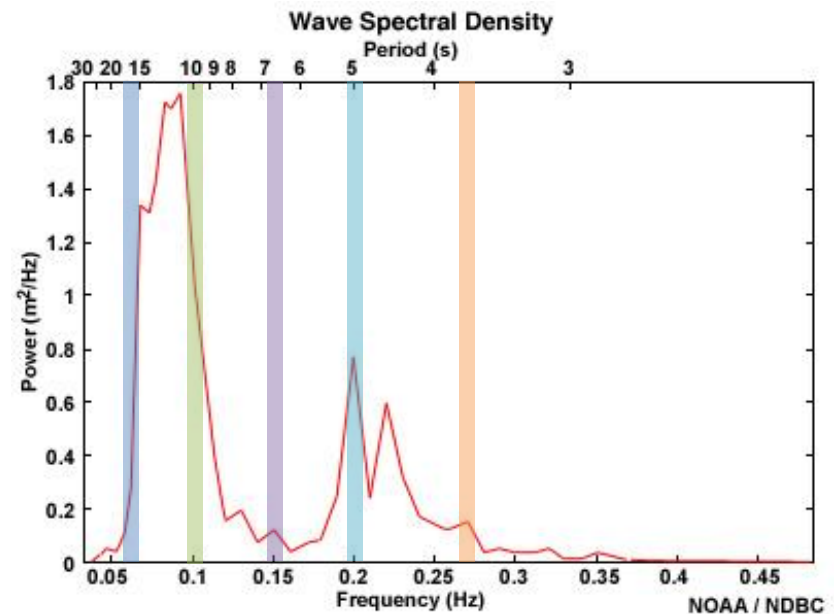
$$J = \frac{1}{32\pi} \rho g^2 H^2 T \quad \frac{\text{Watts}}{\text{meter}}$$



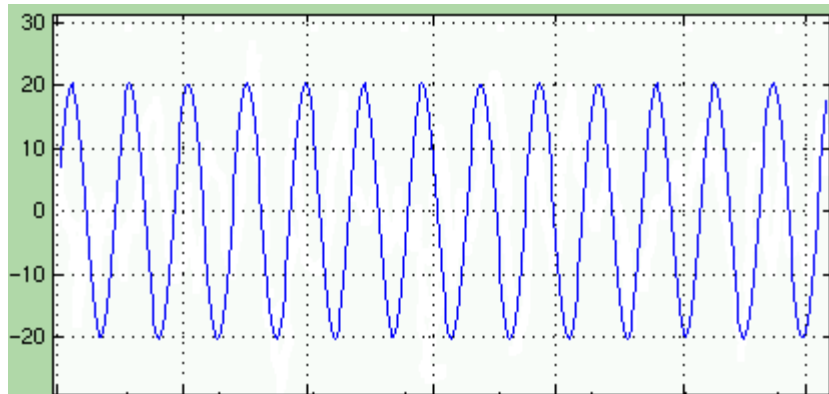
# Irregular Waves and Wave Spectrums



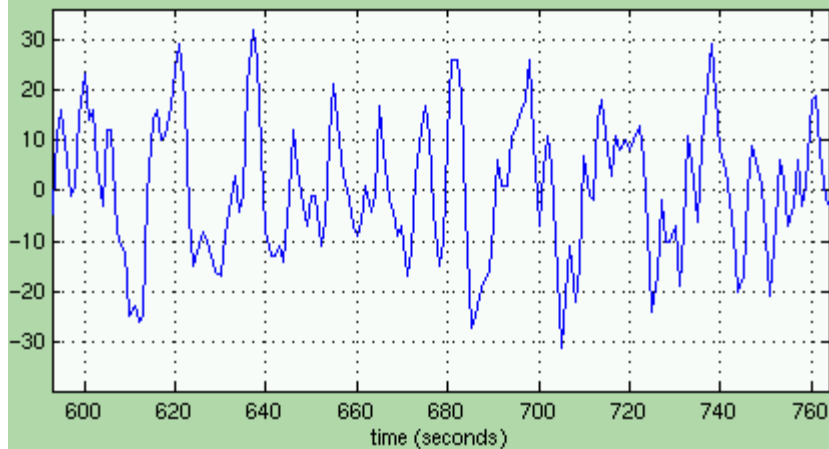
## Wave Spectrum



# Regular vs. Irregular Waves



$$J = \frac{1}{32\pi} \rho g^2 H^2 T \quad \frac{\text{Watts}}{\text{meter}}$$



$$J \approx \frac{1}{64\pi} \rho g^2 H_s^2 T_p \quad \frac{\text{Watts}}{\text{meter}}$$

Relates to the wave spectrum



# Global Wave Energy Map

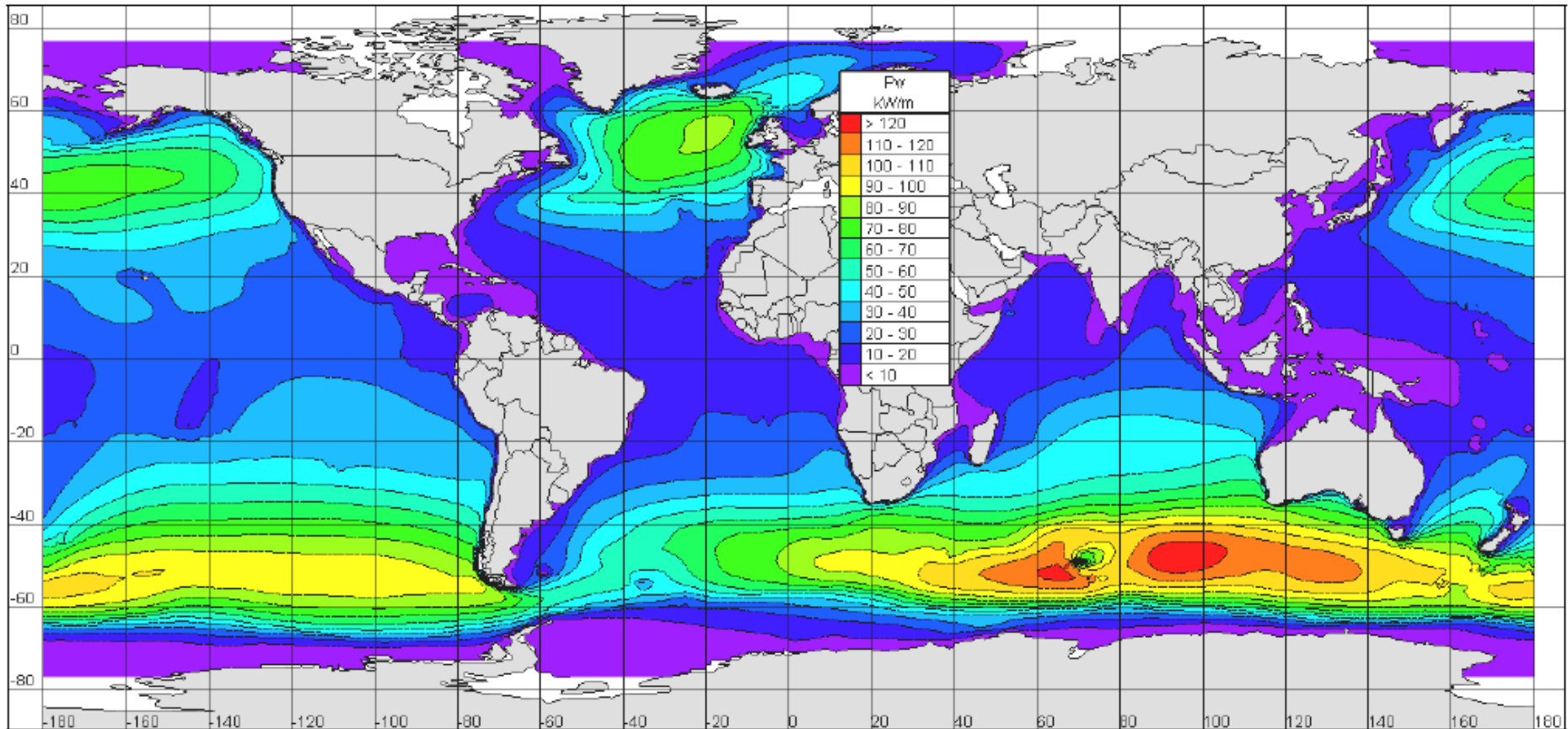
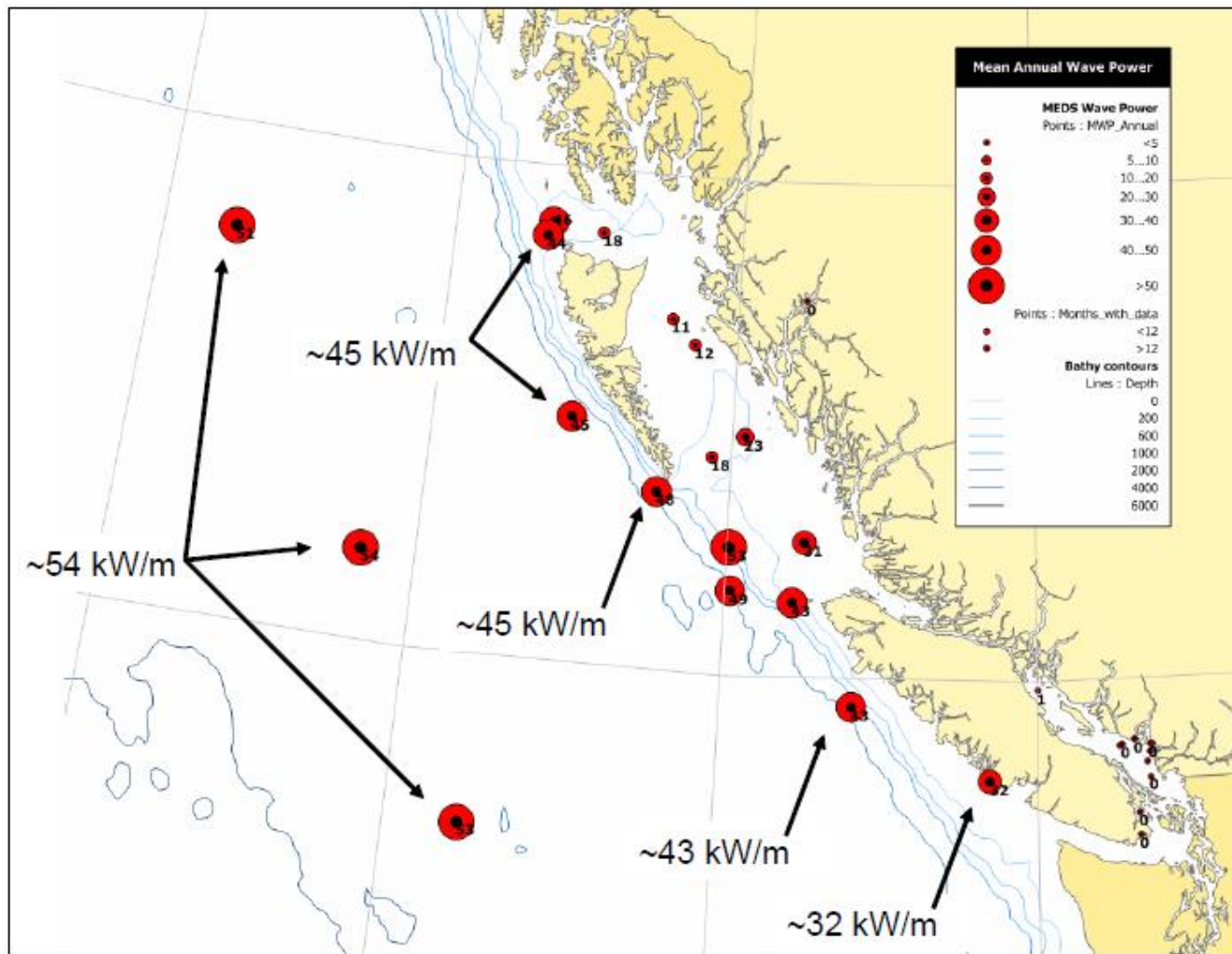


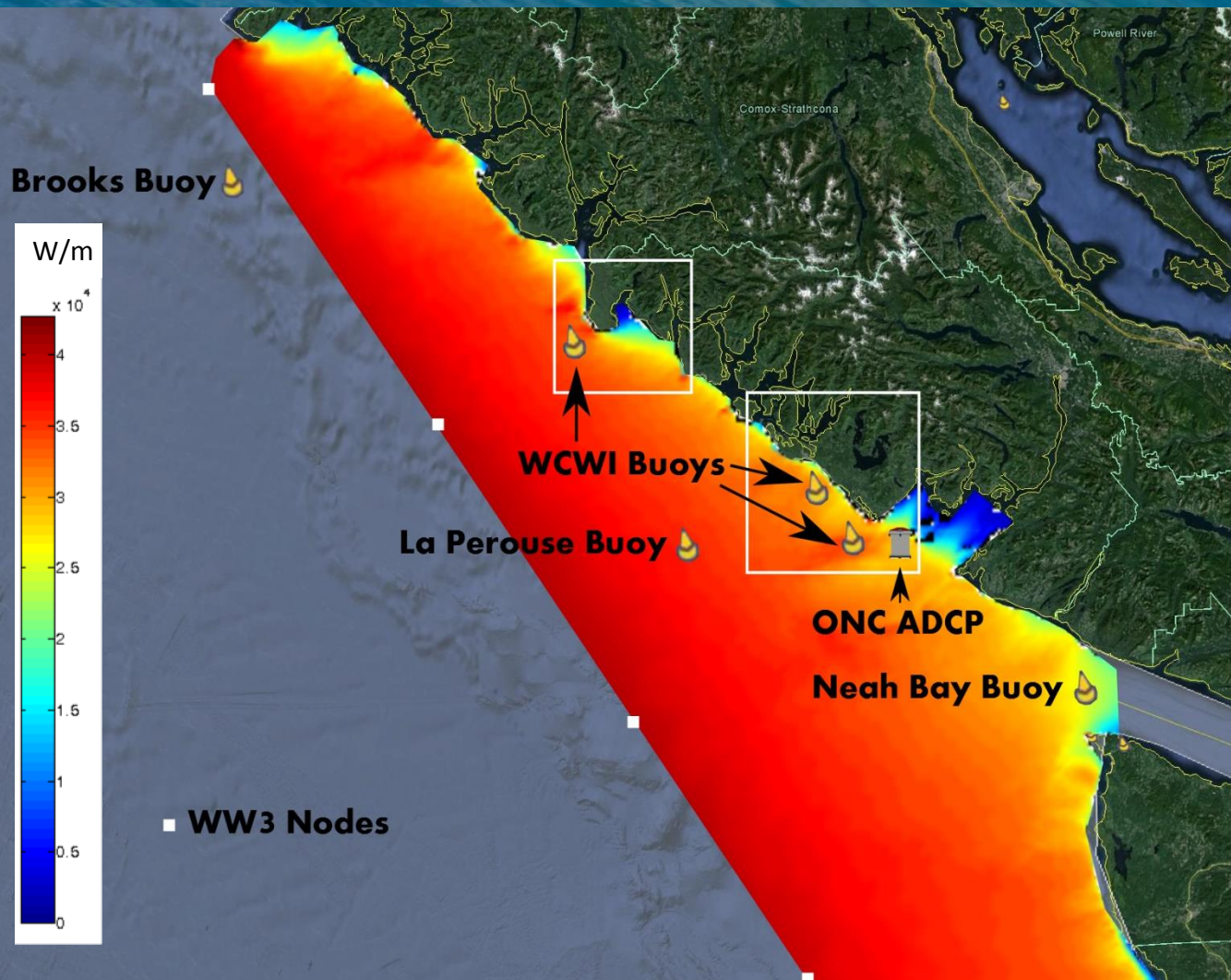
Figure 4. Global distribution of annual mean wave power.



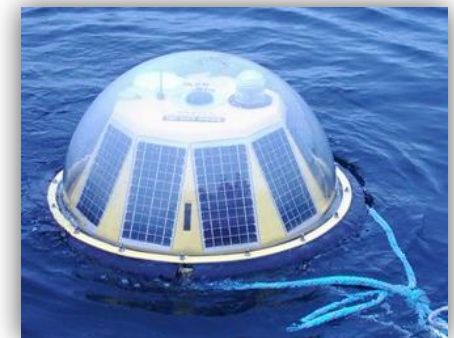
# What we knew before WCWI...



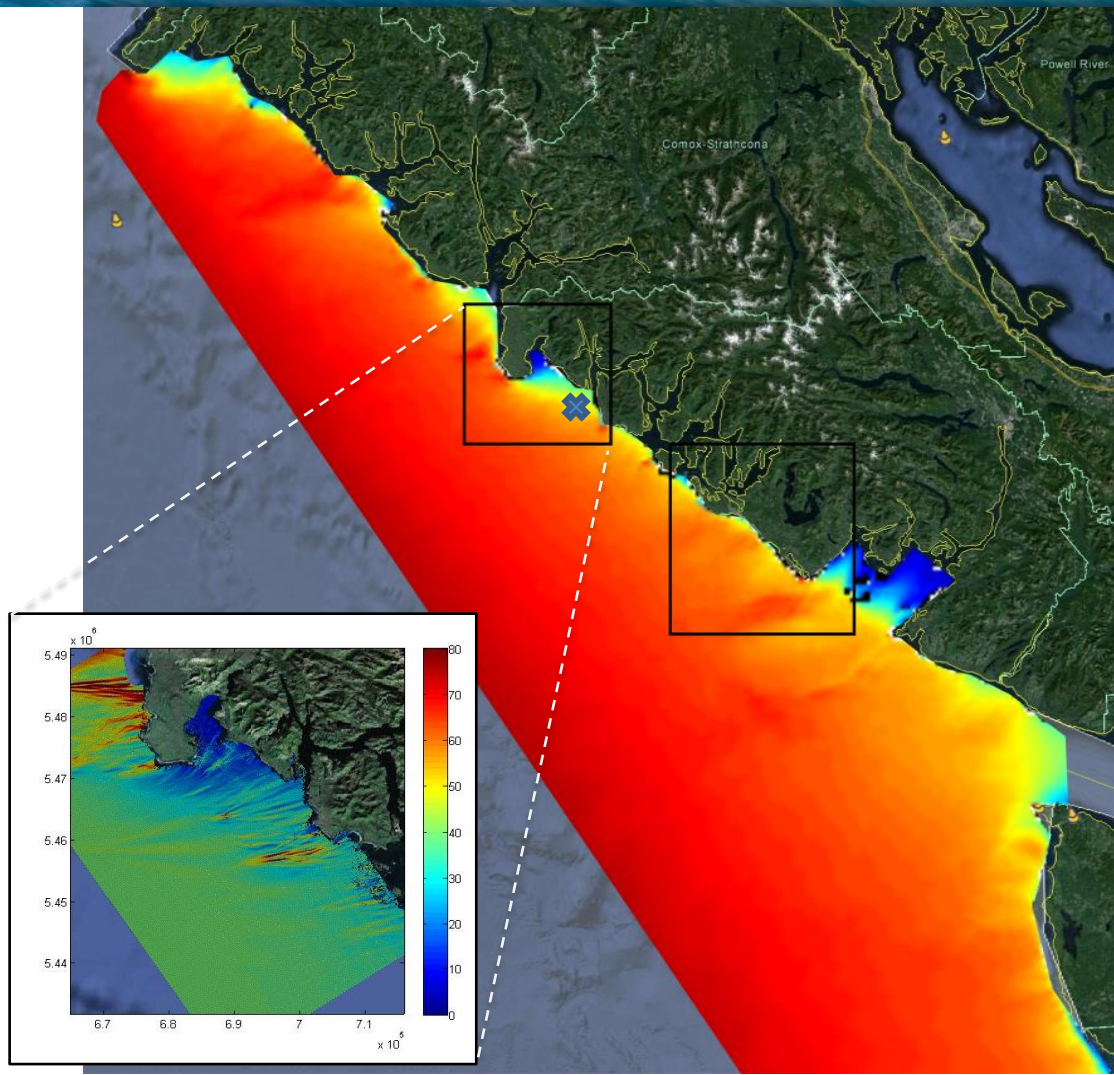
# West Coast SWAN Wave Model



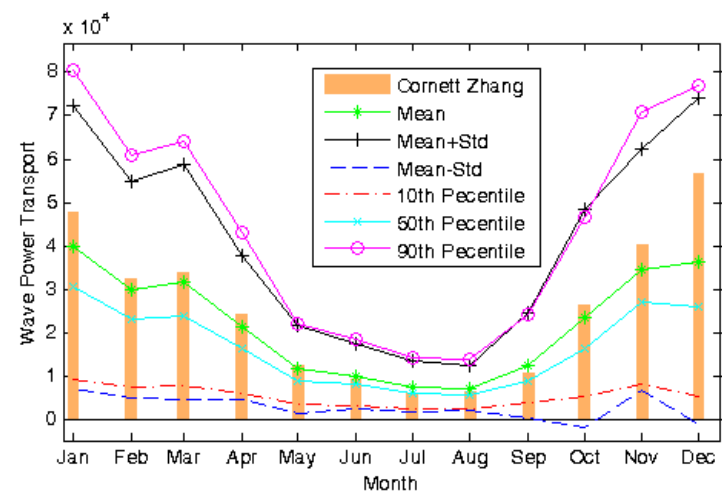
## Wave Measurement Buoys



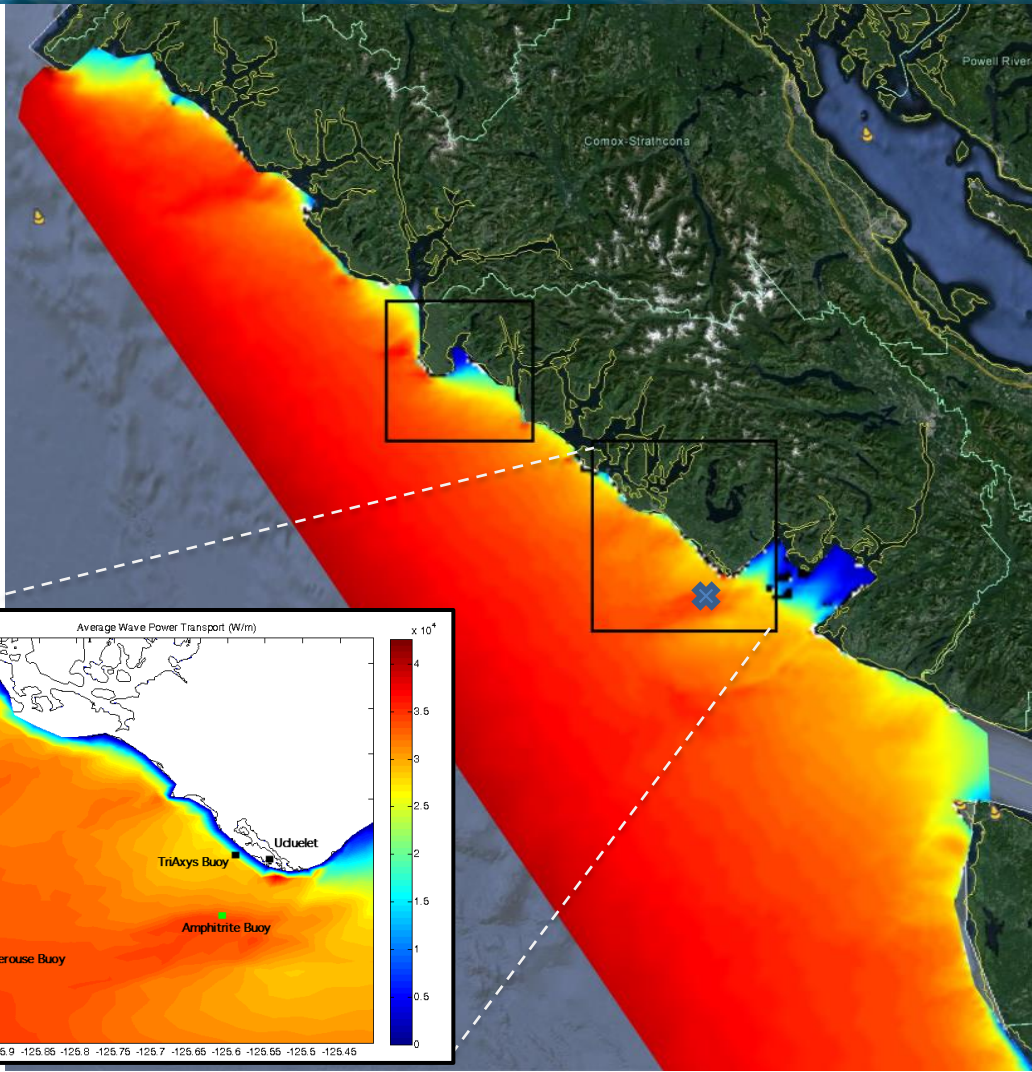
# Hot Springs Cove – North of Tofino



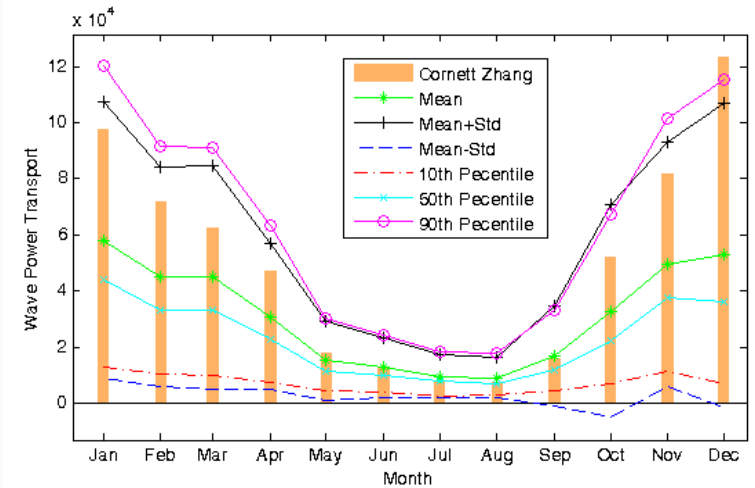
	Energy Transport (kW/m)	Wave Height (m)	Energy Period (sec)	Wave Direction (degrees)
<b>Winter</b>				
Mean Value	34.1	2.38	9.77	240
Mean 10 <sup>th</sup> %	8.4	3.56	11.9	215
Mean 90 <sup>th</sup> %	69	1.36	7.69	255
<b>Summer</b>				
Mean Value	10.1	1.35	9.4	238
Mean 10 <sup>th</sup> %	19.8	1.93	12.7	215
Mean 90 <sup>th</sup> %	3.5	0.91	6.71	257



# Gross Wave Resource Assessment - Ucluelet

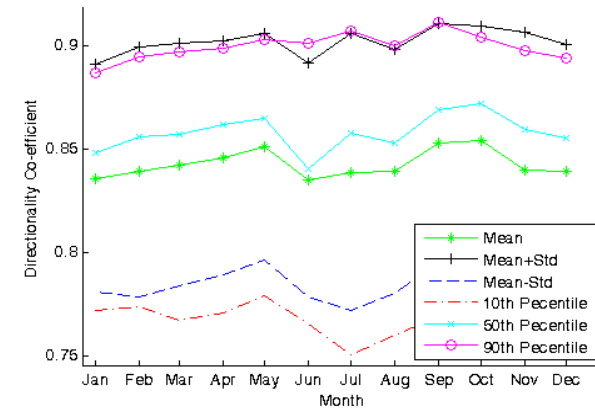
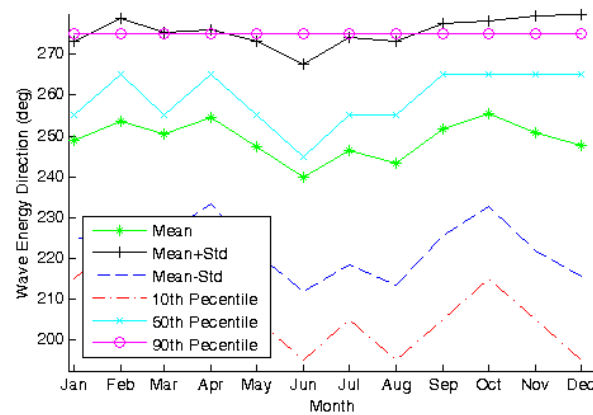
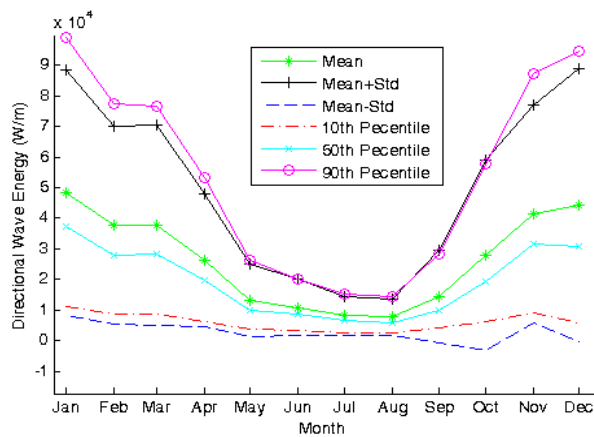
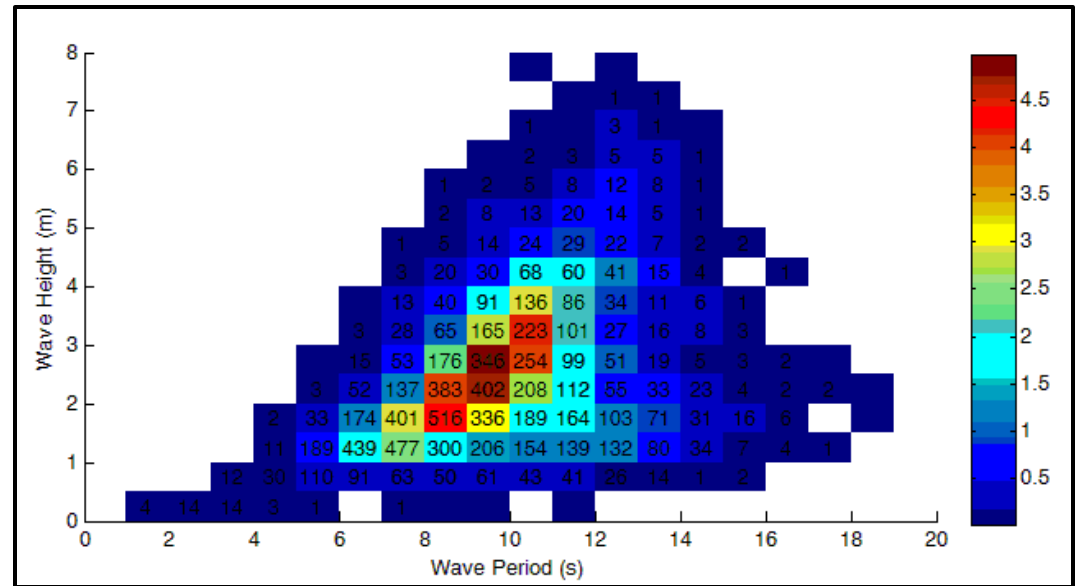
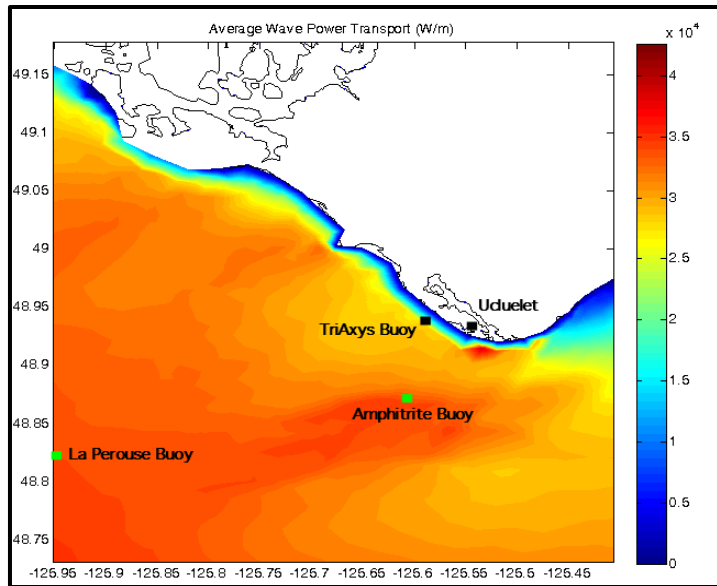


	Energy Transport (kW/m)	Wave Height (m)	Energy Period (sec)	Wave Direction (degrees)
<b>Winter</b>				
Mean Value	41.9	2.70	9.84	250
Mean 10 <sup>th</sup> %	8.70	1.50	7.56	215
Mean 90 <sup>th</sup> %	87.0	4.07	12.1	275
<b>Summer</b>				
Mean Value	10.8	1.51	8.78	246
Mean 10 <sup>th</sup> %	2.10	0.98	6.21	201
Mean 90 <sup>th</sup> %	28.0	2.14	12.1	275





# Gross Wave Resource Assessment - Ucluelet



# West Coast Wave Initiative at the University of Victoria

Ok, we now understand waves BUT how do we make electrical power from waves ?

Many different ways...



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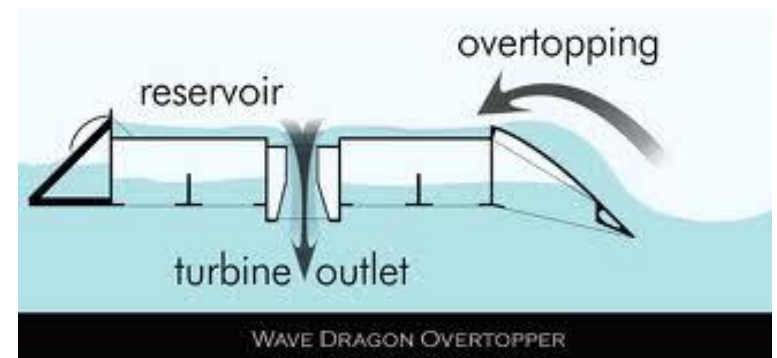
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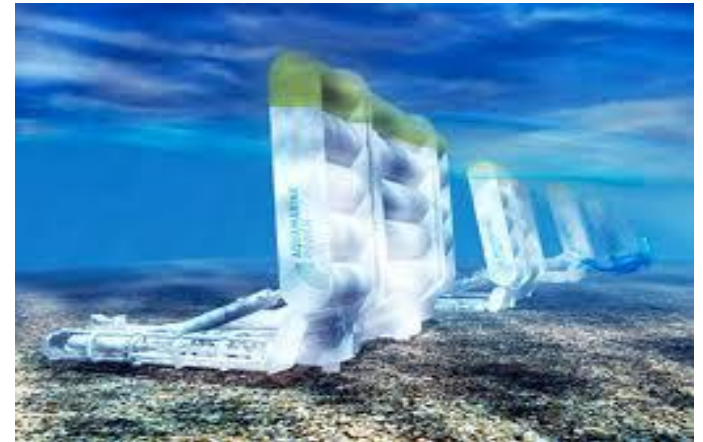
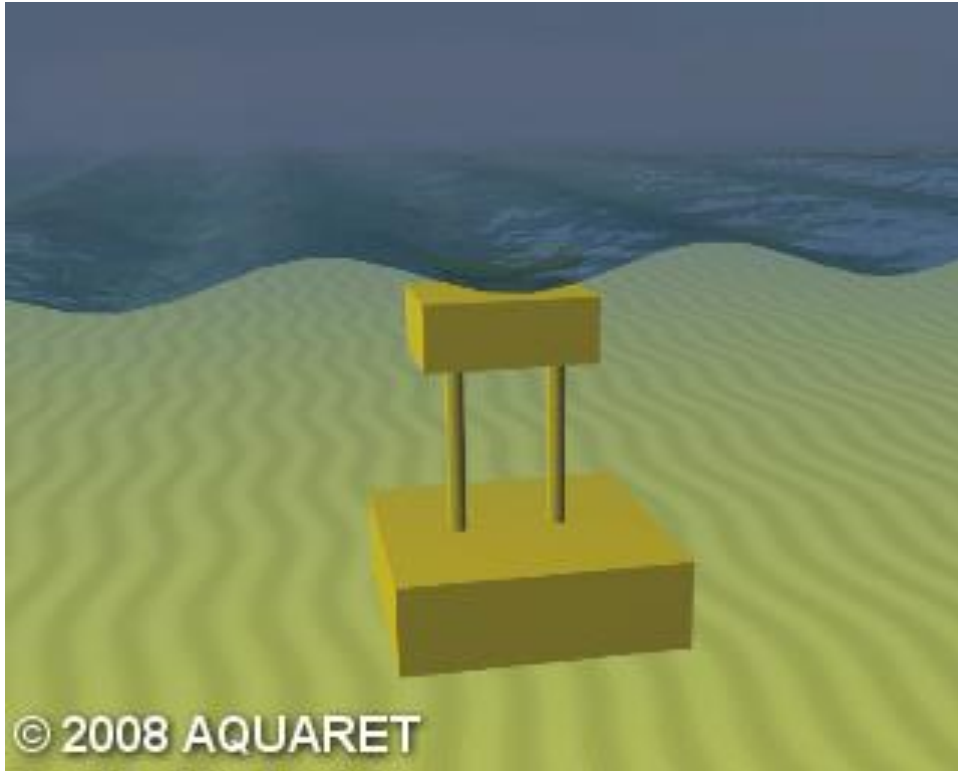
# Wave Energy Converters: Oscillating Water Column



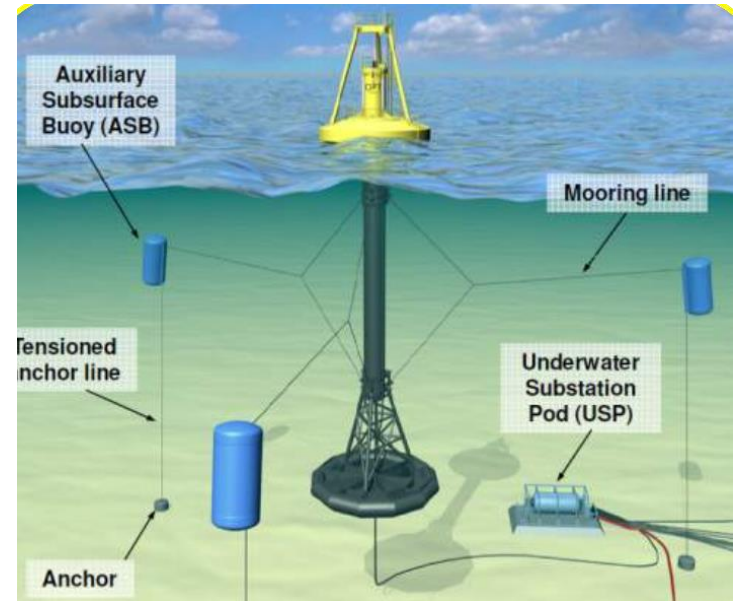
# Wave Energy Converters: Overtopping Device



# Wave Energy Converters: Shallow Submerged Device



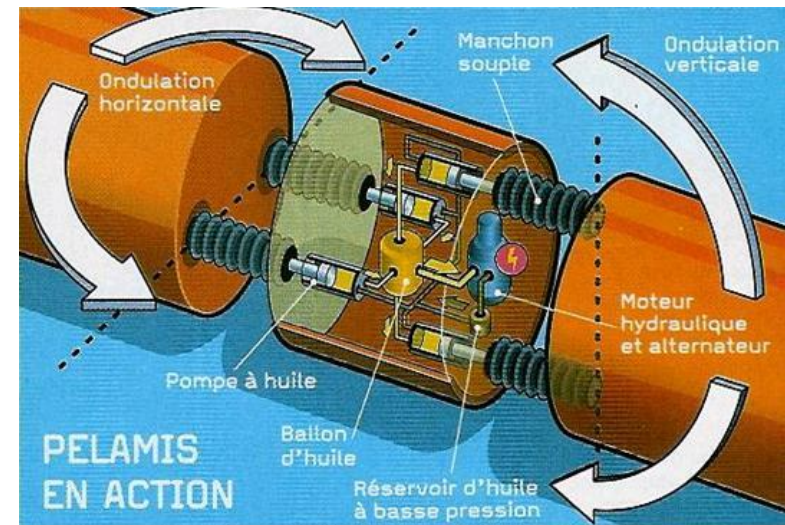
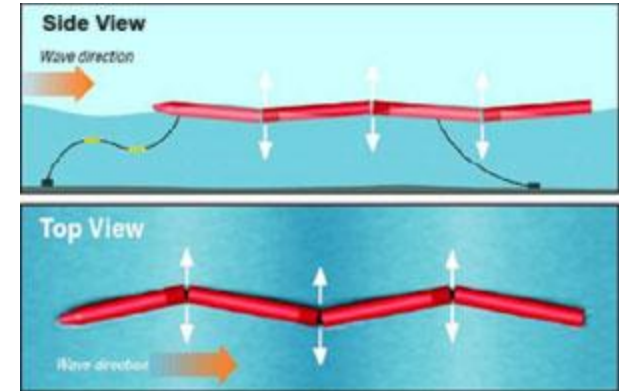
# Wave Energy Converters: Point Absorber



# Wave Energy Converters: Platform Devices



# Wave Energy Converters: Attenuators

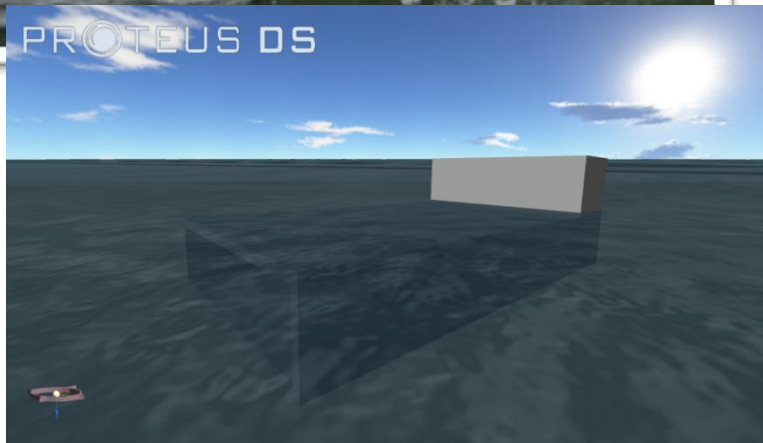




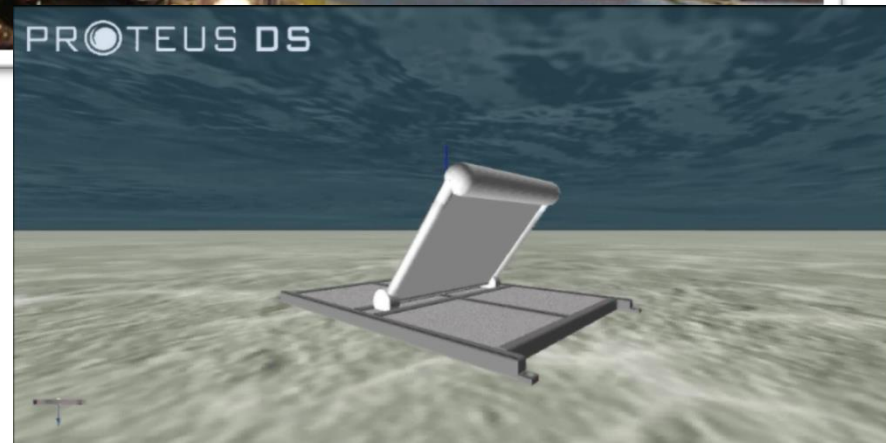
# West Coast Wave Initiative – Partner technologies



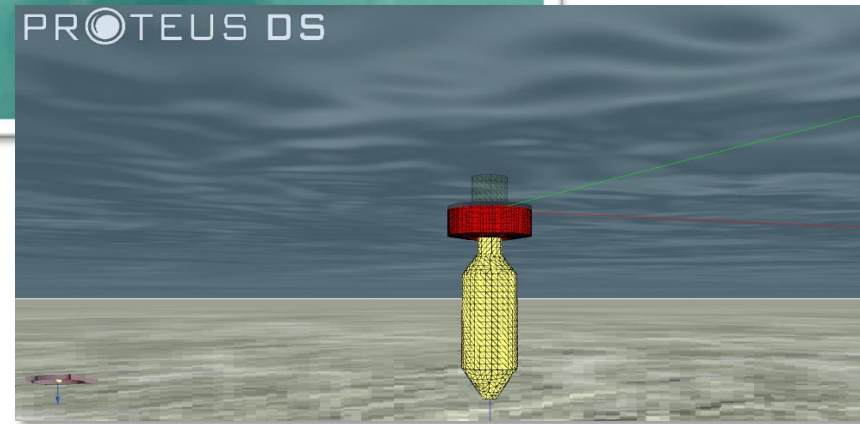
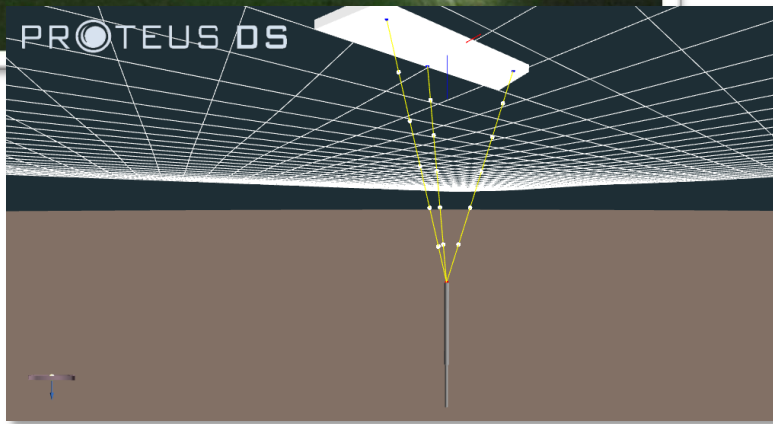
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PROTEUS DS

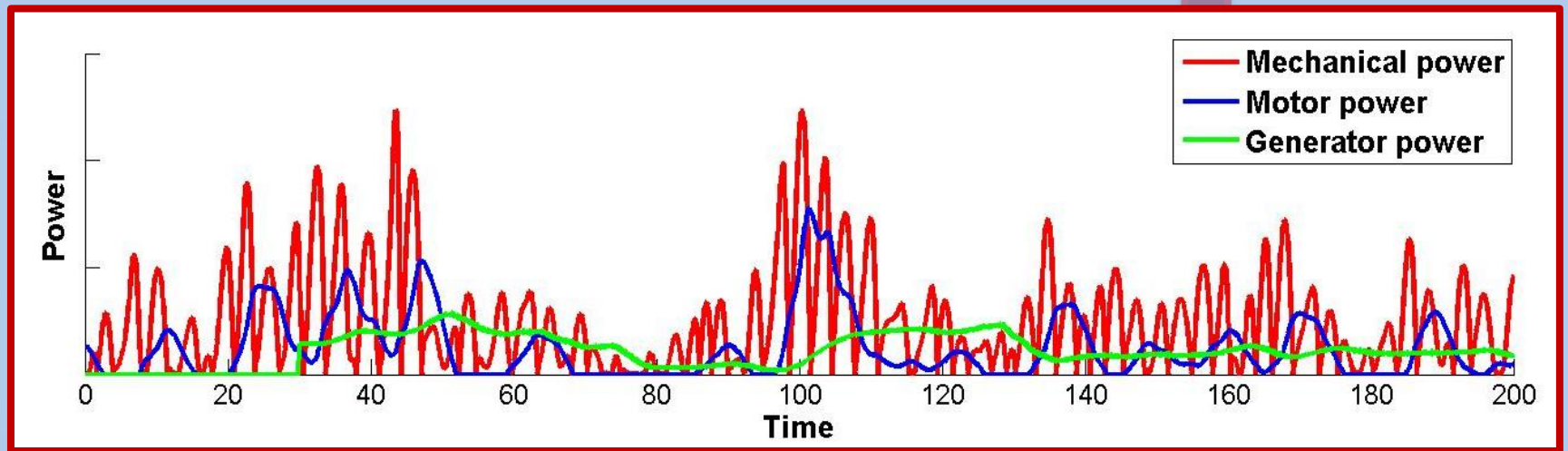
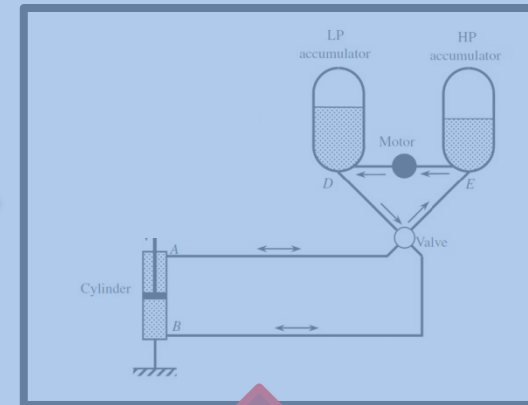
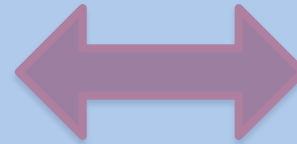
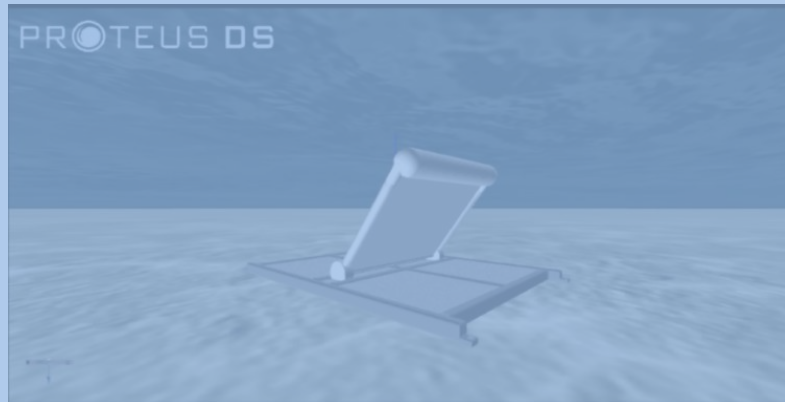


# West Coast Wave Initiative – partner technologies



# Technology Simulations – power take off dynamics

Wave energy | Motivation & objectives | People | Gross resource | **Net resource** | Usable resource

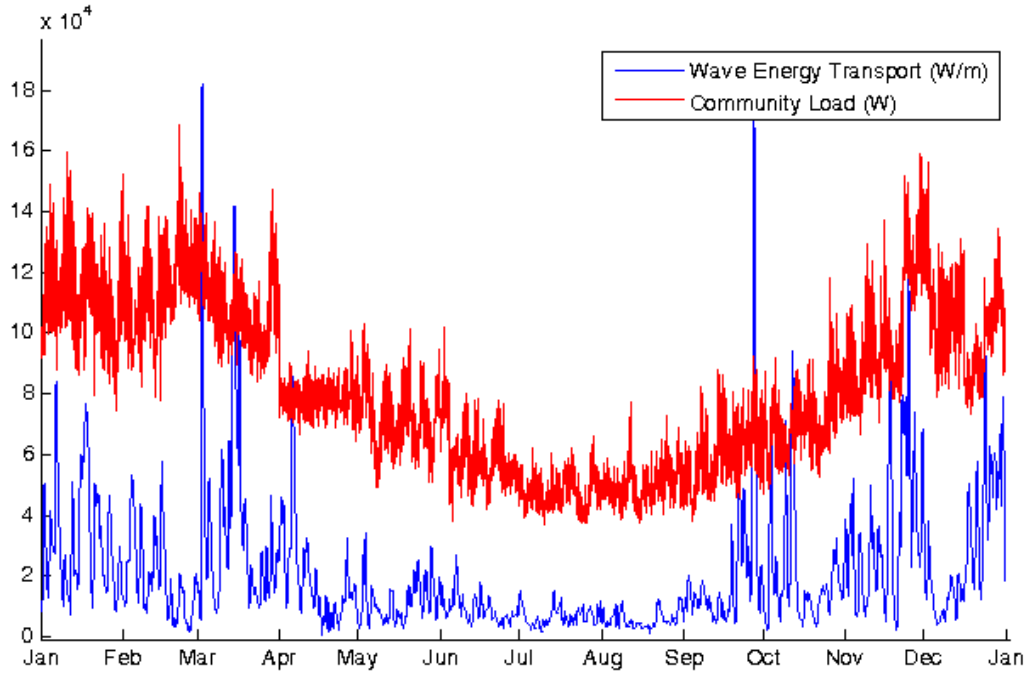


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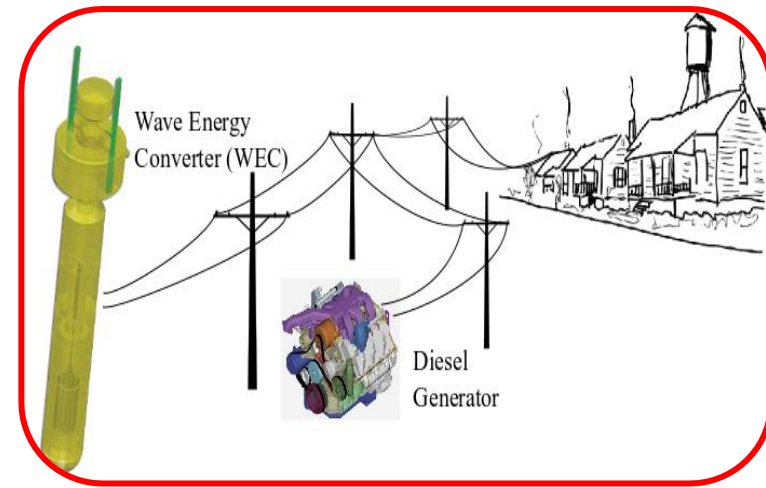
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# Kilowatt Scale Integration: Hot Springs Cove

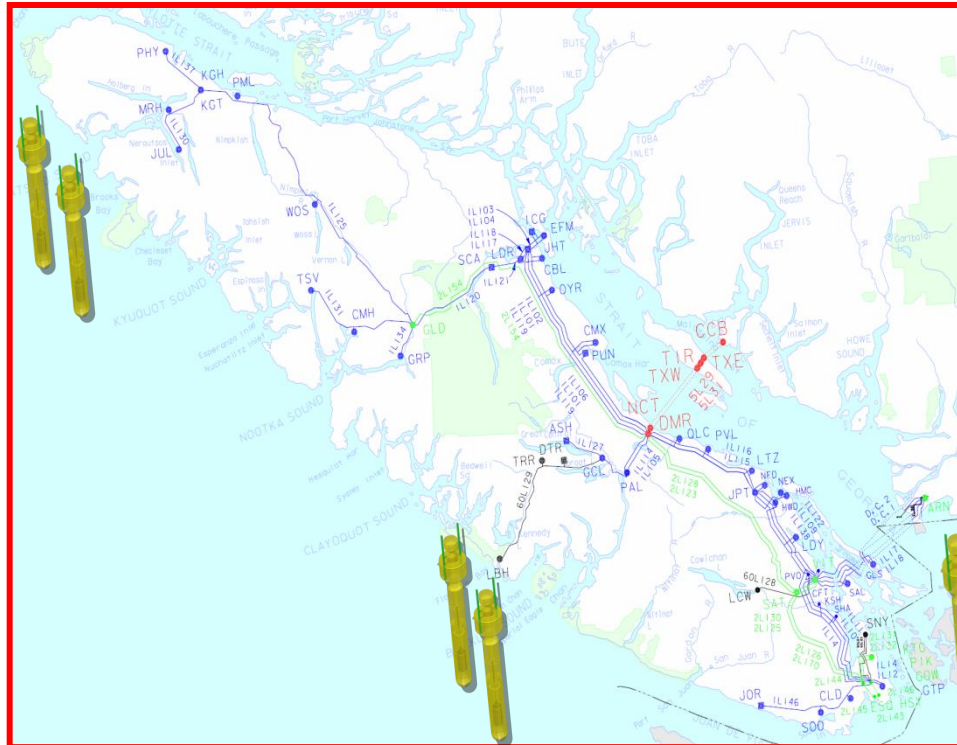


KW

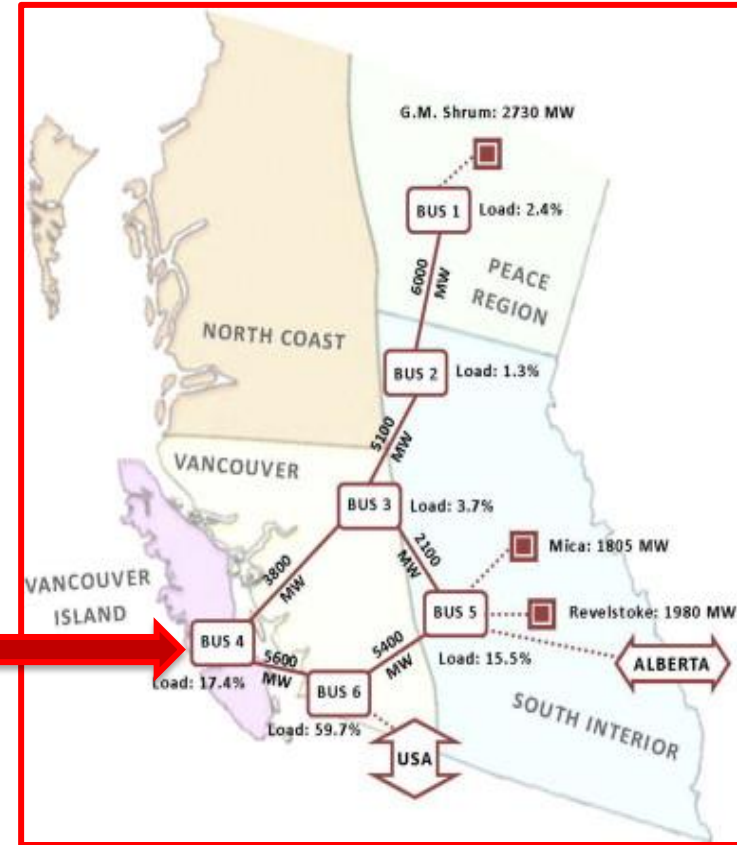


# Next Step: Megawatt and Gigawatt Scale Integration

MW



GW





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