

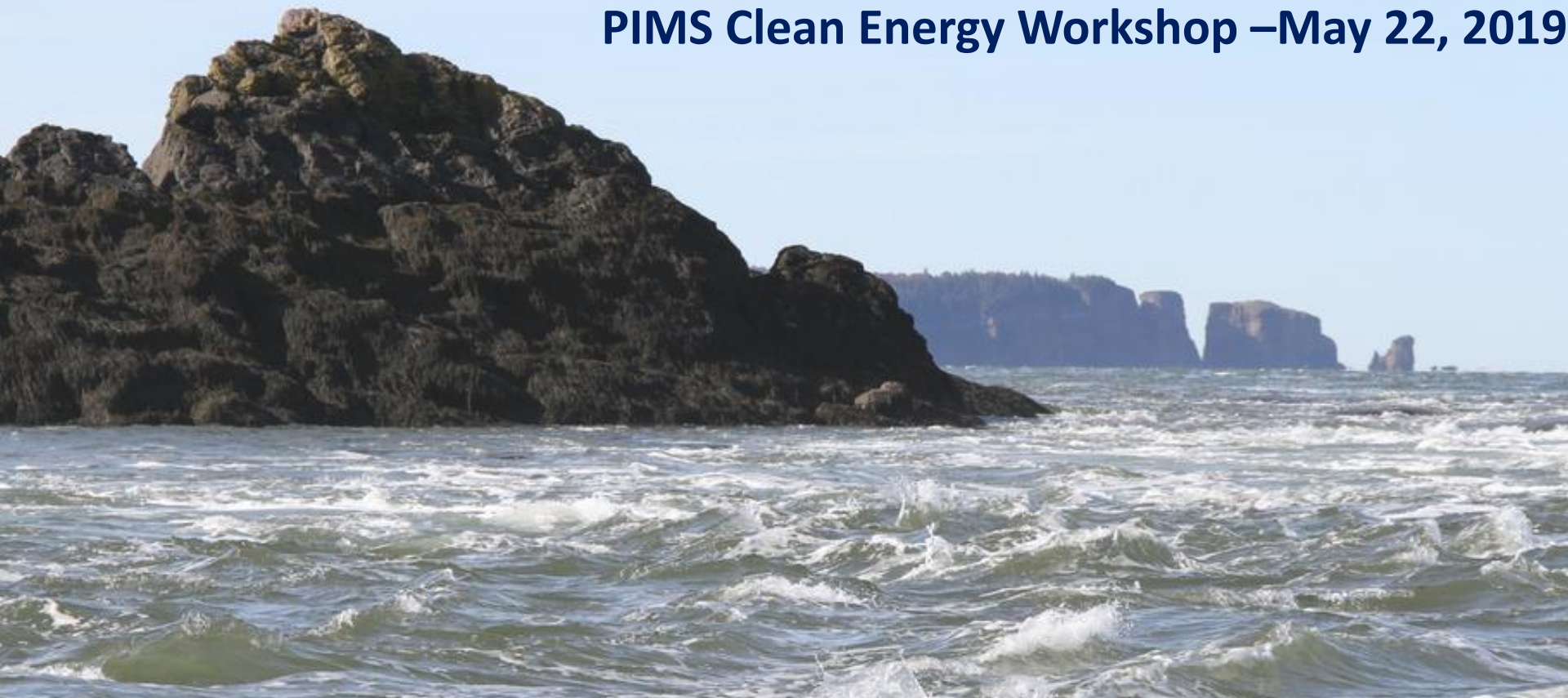


Introduction to Water Energy

Richard Karsten

Acadia Tidal Energy Institute

PIMS Clean Energy Workshop –May 22, 2019



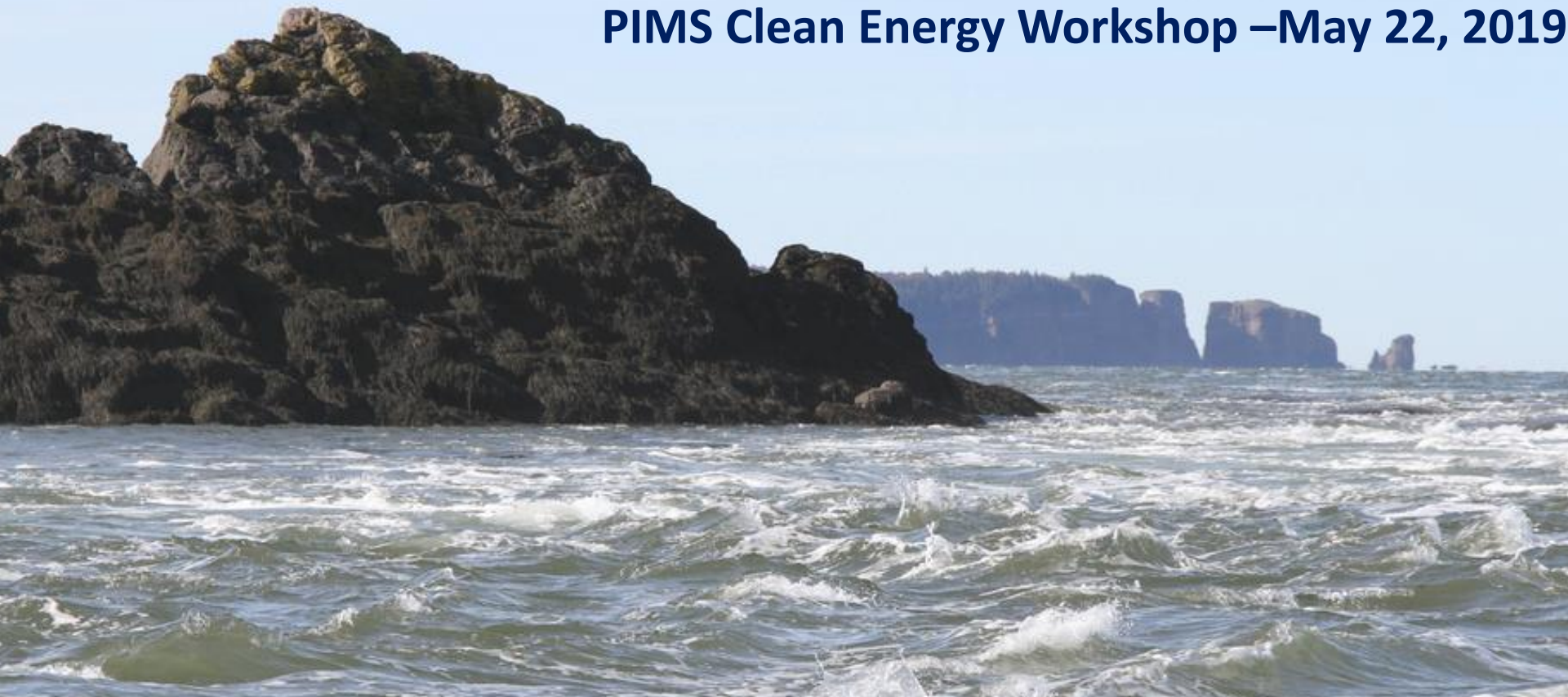


Introduction to Marine Renewable Energy

Richard Karsten

Acadia Tidal Energy Institute

PIMS Clean Energy Workshop –May 22, 2019





Marine Renewable Energy Session

- **Introduction: Richard Karsten**
- **First Part: Understanding the Ocean**
 - Turbulence measurements: Justine McMillan
 - Wake characterization: Joel Culina
- **Discussion**
- **Second Part: Designing MKE Devices**
 - Turbine technologies: Guy Dumas
 - Flapping dynamics: Rajeev Jaiman
- **Third Part: Wave Energy**
 - Wave energy modelling: Anthony Truelove
- **Discussion**

Andritz Hydro Hammerfest turbine at MeyGen



Introduction to Marine Renewable Energy

Outline

- What is Marine Renewable Energy
- What is the resource?
- Some challenges and
some mathematics
- Conclusions: Some Headlines

MCT in Strangford Lough





What is Marine Renewable Energy

- Energy from currents ... Marine Kinetic Energy
 - Tidal Currents



Minas Passage, Bay of Fundy

OpenHydro Deployment, 2017





What is Marine Renewable Energy

- Energy from currents ... Marine Kinetic Energy
 - Tidal Currents



Mavi Innovations Mi1 floating turbine deployed at Blind Channel, British Columbia.

<https://marinerenewables.ca/>



What is Marine Renewable Energy

- Energy from currents ... Marine Kinetic Energy
 - Tidal Currents
 - Rivers Currents



Ocean Renewable Power Company
Alaska

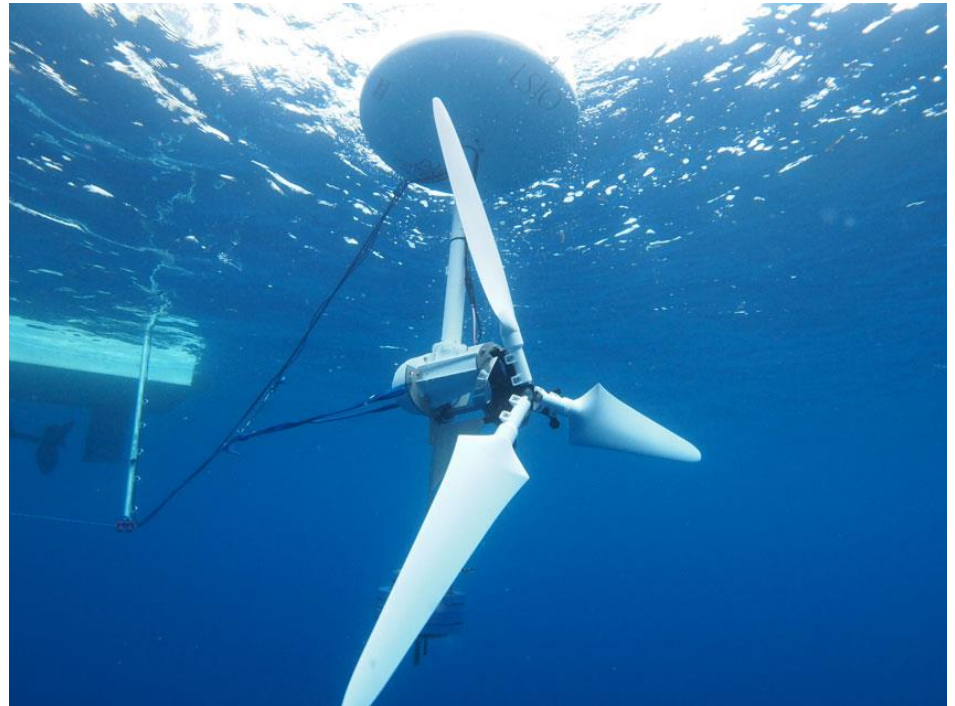


New Energy Corp.



What is Marine Renewable Energy

- Energy from currents ... Marine Kinetic Energy
 - Tidal Currents
 - Rivers Currents
 - Ocean Currents



Okinawa Institute of Science and Technology Graduate University
<https://www.oist.jp/news-center/photos/ocean-current-turbine-towing-experiment>



What is Marine Renewable Energy

- Energy from Waves





What is Marine Renewable Energy

Others, that are not being discussed ...

- Tidal Barrages
- Ocean Thermal Energy Conversion (OTEC)
- Sea Water Air Conditioning (SWAC) projects
- Salinity Gradient

Other water energy:

- Offshore Wind
- Hydroelectricity
- Run of River





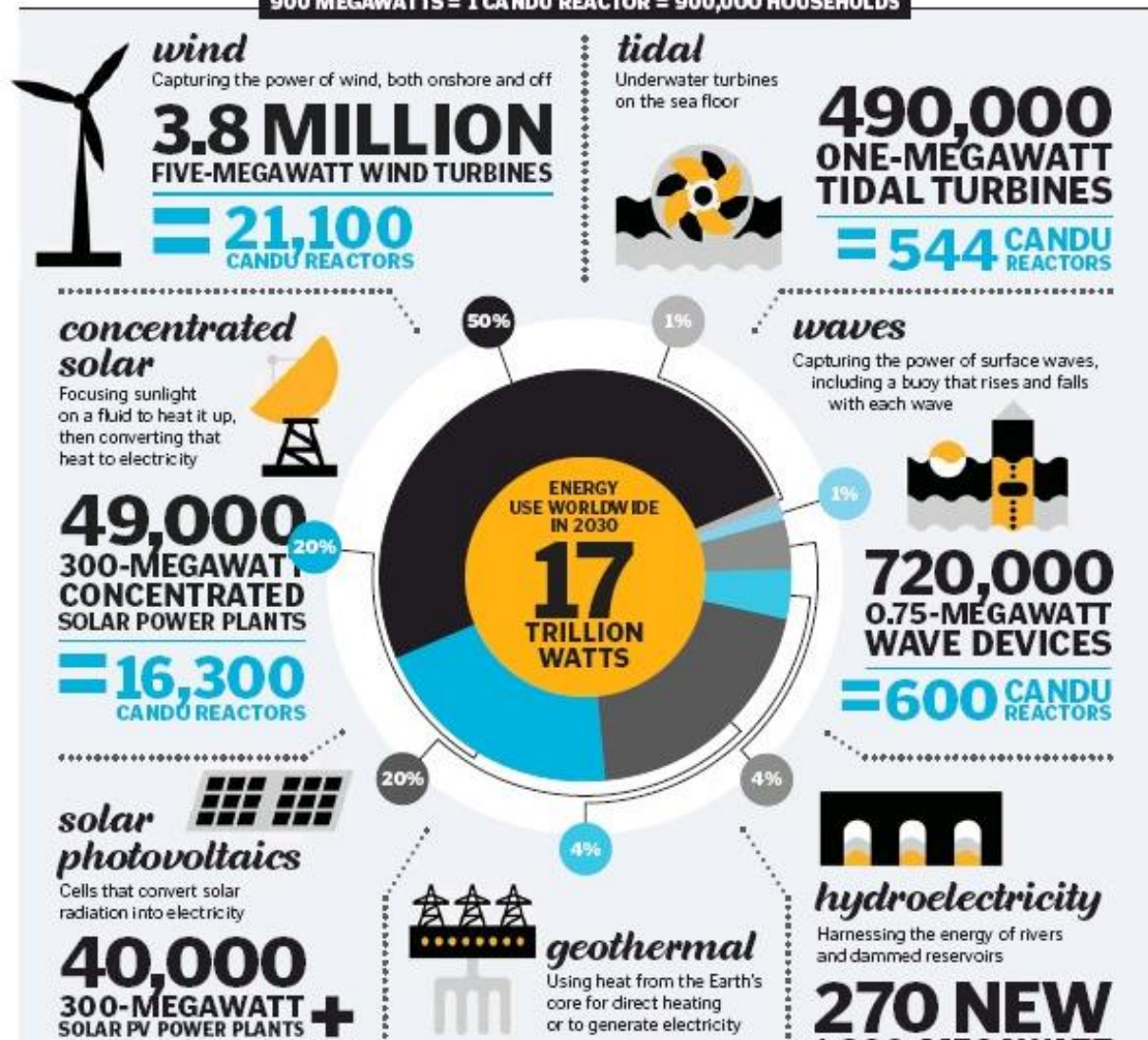
A fully renewable world

Globe and Mail Report on Business

900 MEGAWATTS = 1 CANDU REACTOR = 900,000 HOUSEHOLDS

Tidal energy:
490,000 turbines
1% of Total
(10-20 turbines)

Wave Energy:
720,000 devices
1% of Total
(30-50 devices)





What is the resource? Tidal

High Potential Areas for Tidal Resources

Canada: British Columbia, the Bay of Fundy and the St. Lawrence seaway are some of the world's best tidal current resources and are close to significant electricity demand

UK: ~18TWh/yr of technically extractable tidal current resource. 40% of it is concentrated in the far north of Scotland (Pentland Firth and Orkney Islands)

India: The Gulf of Kutch and the Gulf of Khambhat in the State of Gujarat both have significant tidal power resource >250MW

Korea: In the south, around Mokpo, the tidal currents are amongst the fastest in the world. According to KORDI, the Korean resource for tidal current power is 500MW

US: Alaska, Washington, California and Maine have good power density. Clear process for gaining exclusivity over particular sites

Chile: At least 500MW potentially available

France: Strong tides around the Channel Islands

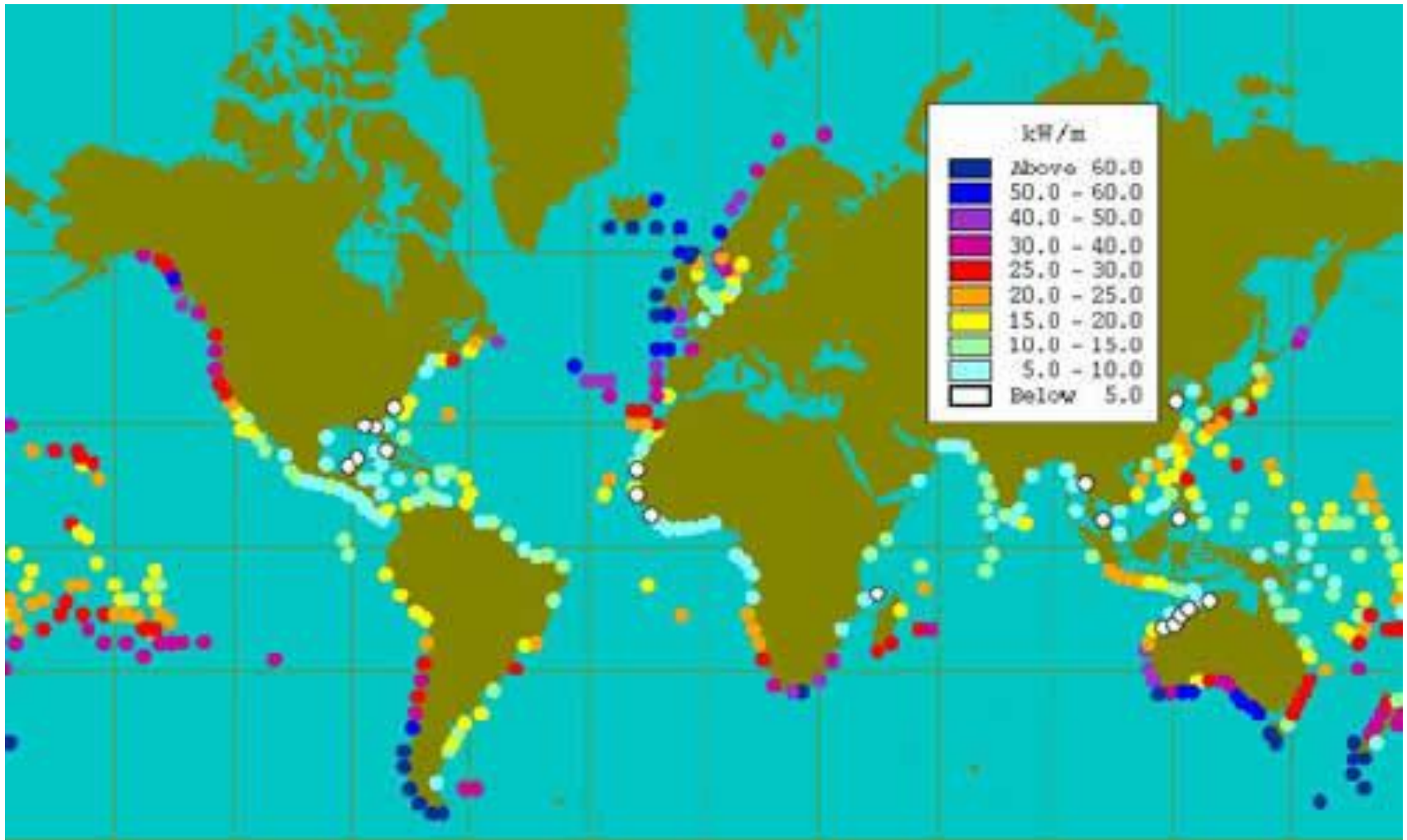
Japan: Excellent resources between the islands

China: has enormous tidal current resources as well as river resources. Best large tidal sites found in Shanghai and Zhejiang province region

Australia: King Sound in the North West has some of the highest tides in the world (~10m).



What is the resource? Wave





Marine Renewable Energy: Challenges

- Difficult Ocean Environment
- Intermittent Power Production
- Environmental Impacts
- Device Design: capacity vs durability vs cost
- Financial Viability

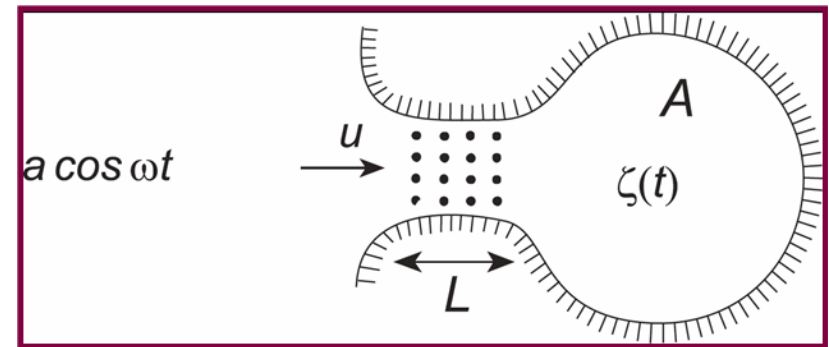
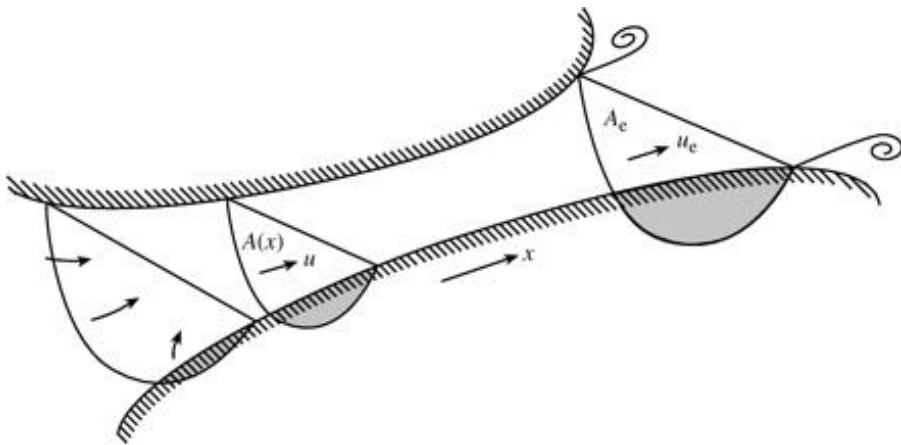


Wello Penguin



Calculating the resource

- Mathematical Models: Garrett and Cummins (2005)



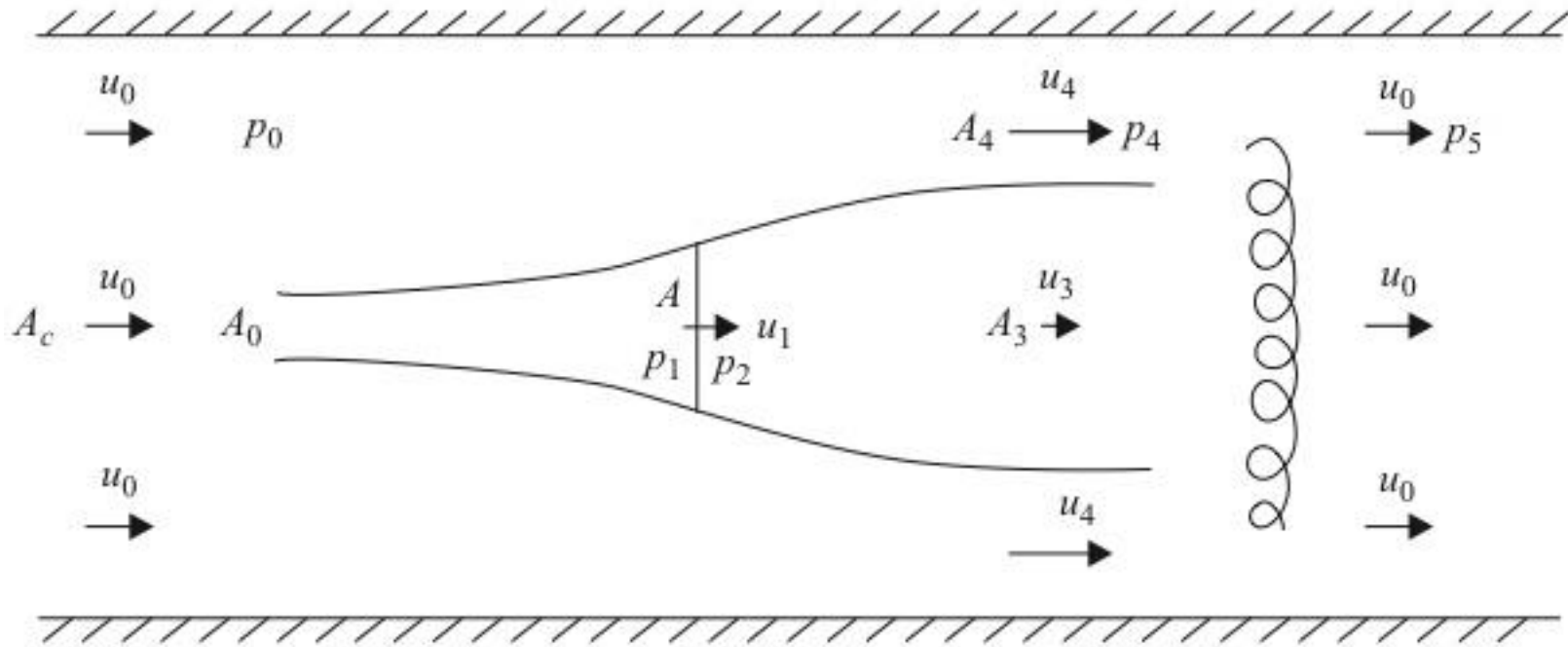
Simply physics and calculus $\Rightarrow P_{max} = \frac{1}{4} \rho g a Q$

(Direct analogy of Maximum Power Law of electric circuits)



Calculating the resource

- Mathematical Models: Garrett and Cummins (2007)



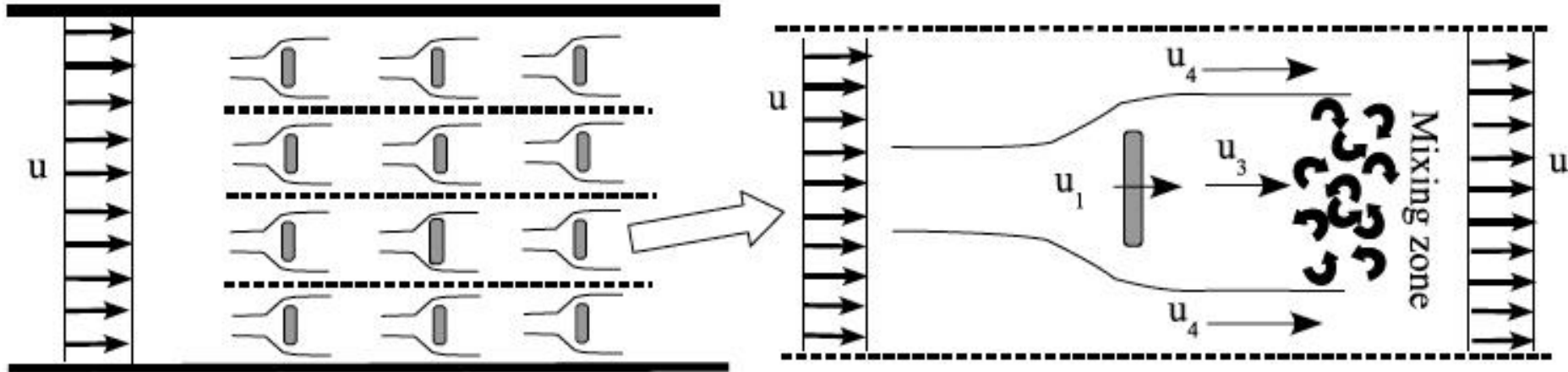
Conservation Laws \Rightarrow Algebraic Equations

(extension of Betz Law, Linear Momentum Actuator Disc Theory)



Calculating the resource

- Mathematical Models: Vennell (2012)

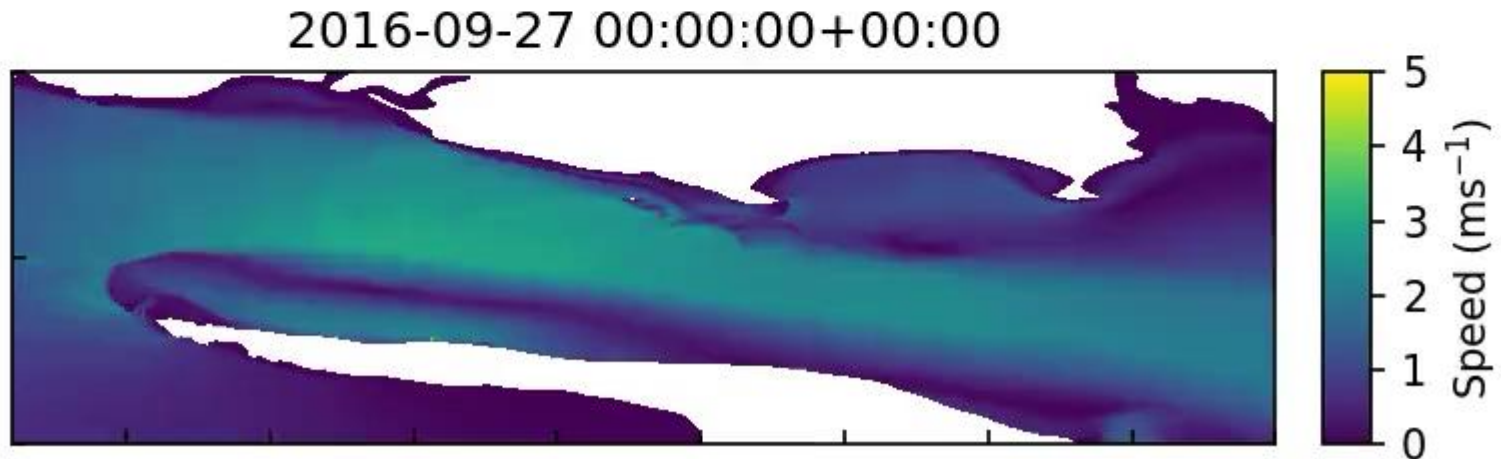


Combine models together



Calculating the resource

- Numerical Models: Simulate the tidal currents

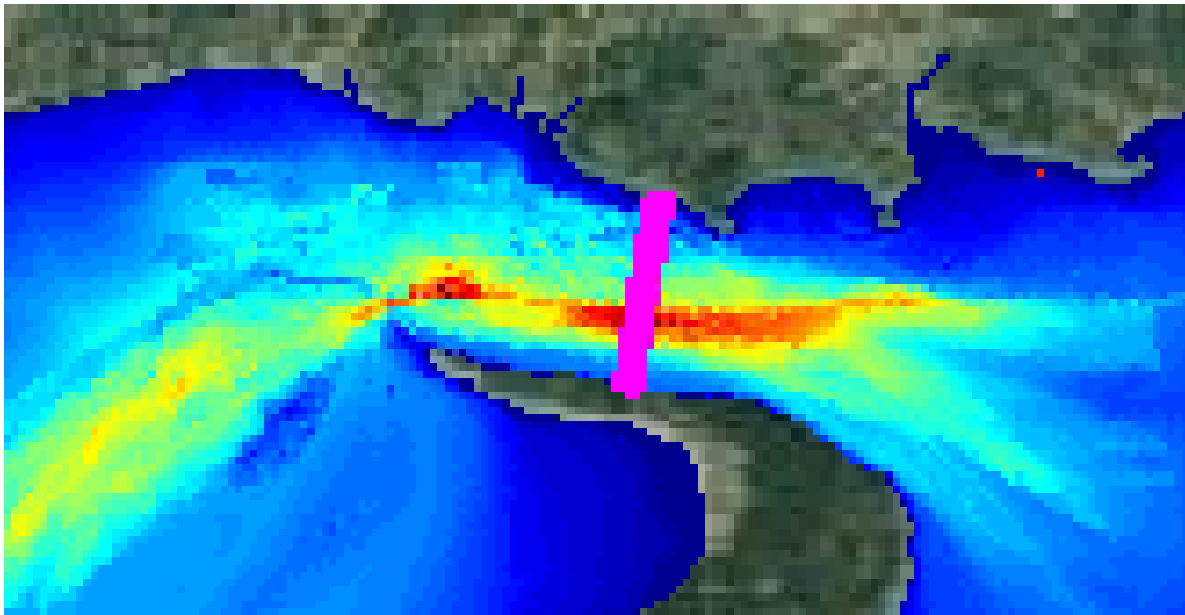


Mathematically: Making appropriate approximations in modelling both the ocean and the extraction of energy



Calculating the resource

- Numerical Models: Simulate Extracting Energy

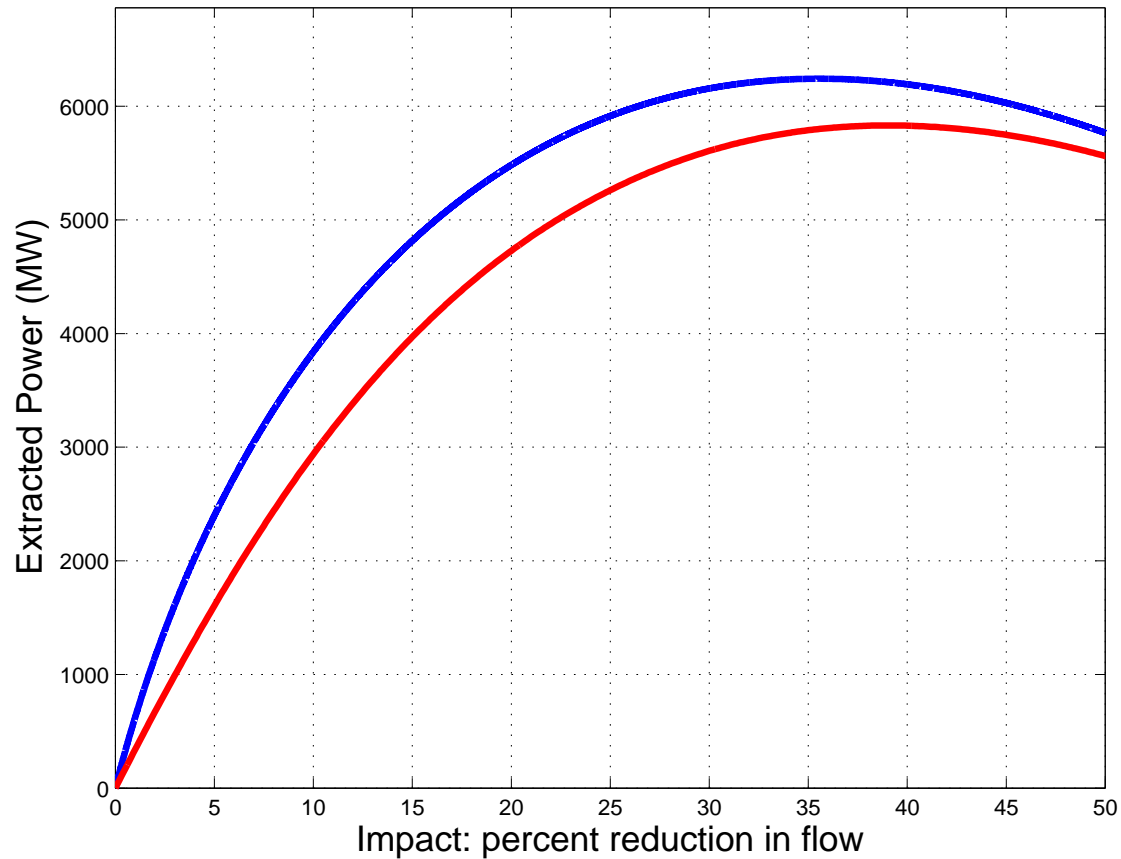


Mathematically: Making appropriate approximations in modelling both the ocean and the extraction of energy



Calculating the resource

- Mathematical Models: Models and theory agree



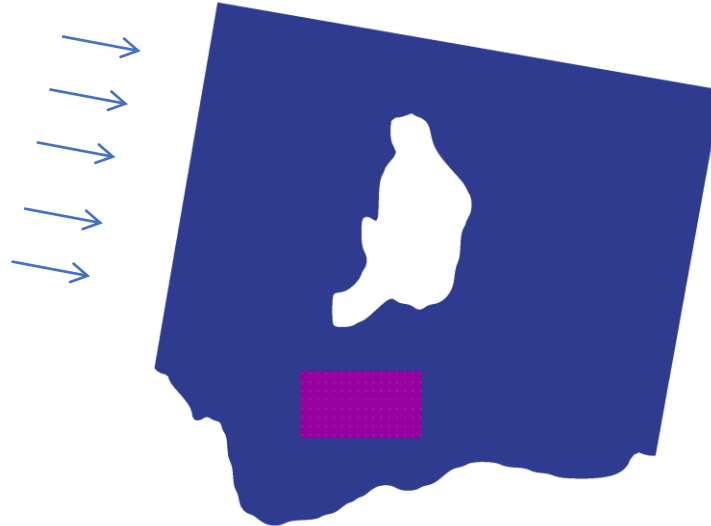


Optimization: Turbine Farm Design

Optimize the location of turbines in a farm: MeyGen



Map



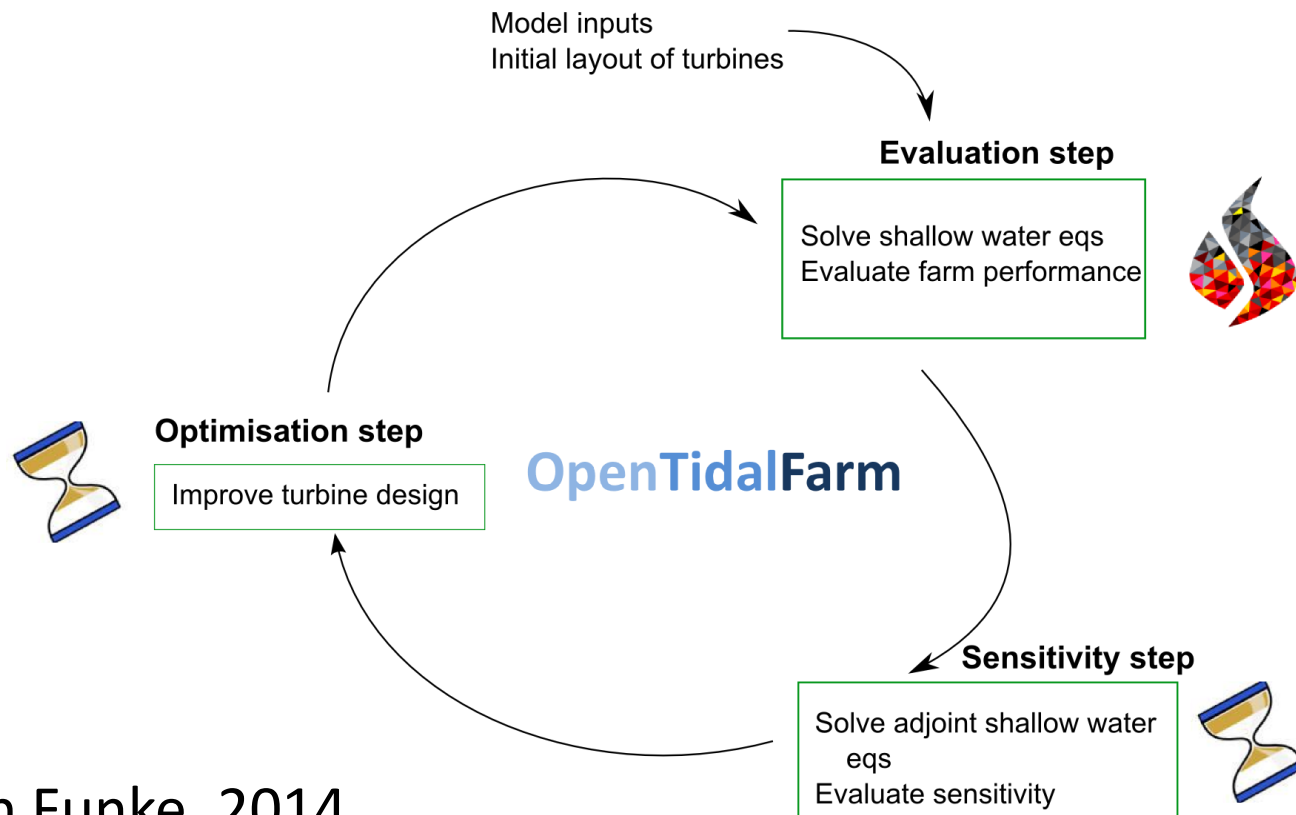
Domain and farm area

Simon Funke, 2014



Optimization: Turbine Farm Design

Optimize the location of turbines in a farm

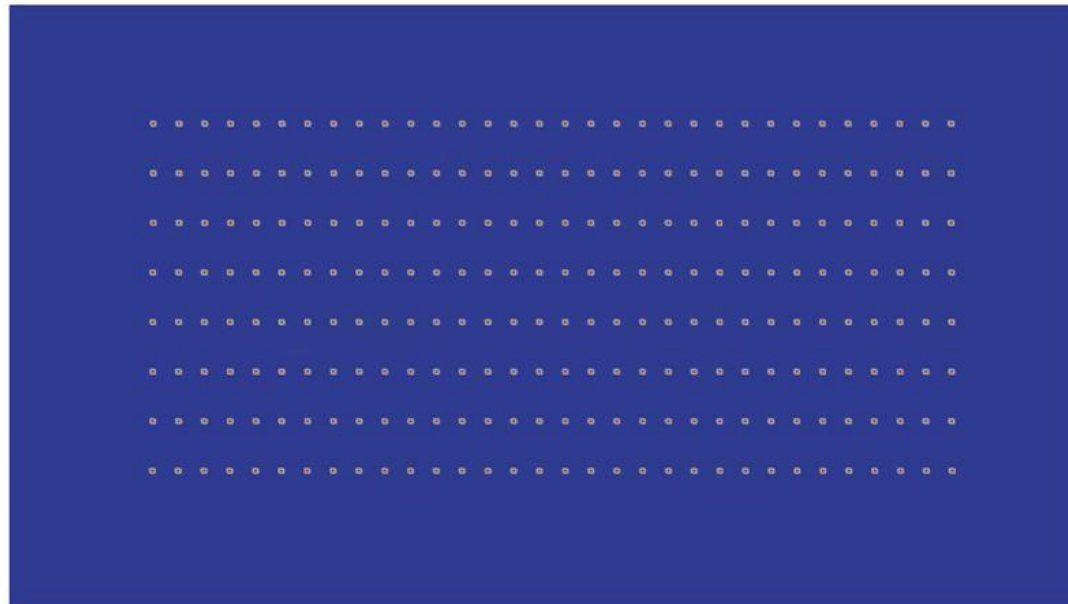


Simon Funke, 2014

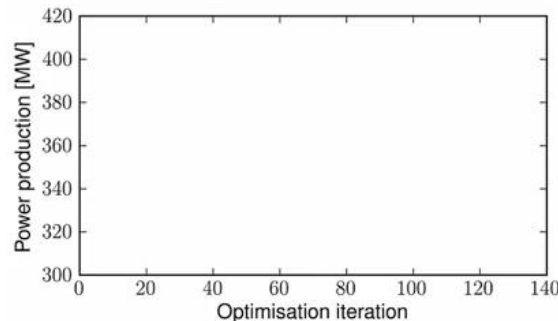


Optimization: Turbine Farm Design

Optimize the location of turbines in a farm



Simon Funke, 2014

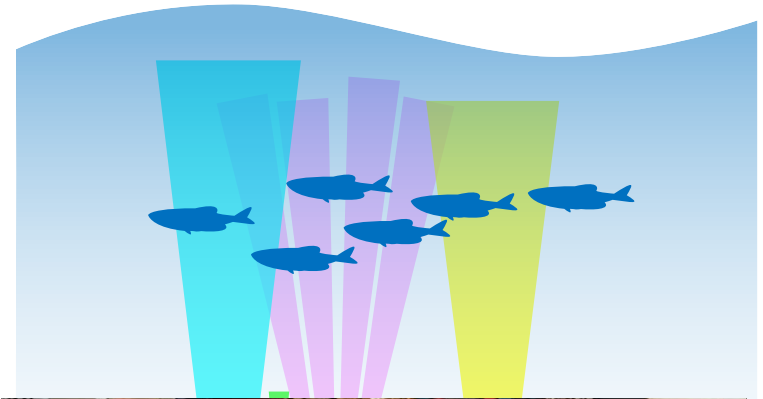




Observing Marine Life

Haley Viehman, Acadia / FORCE

Gemini Imaging Sonar

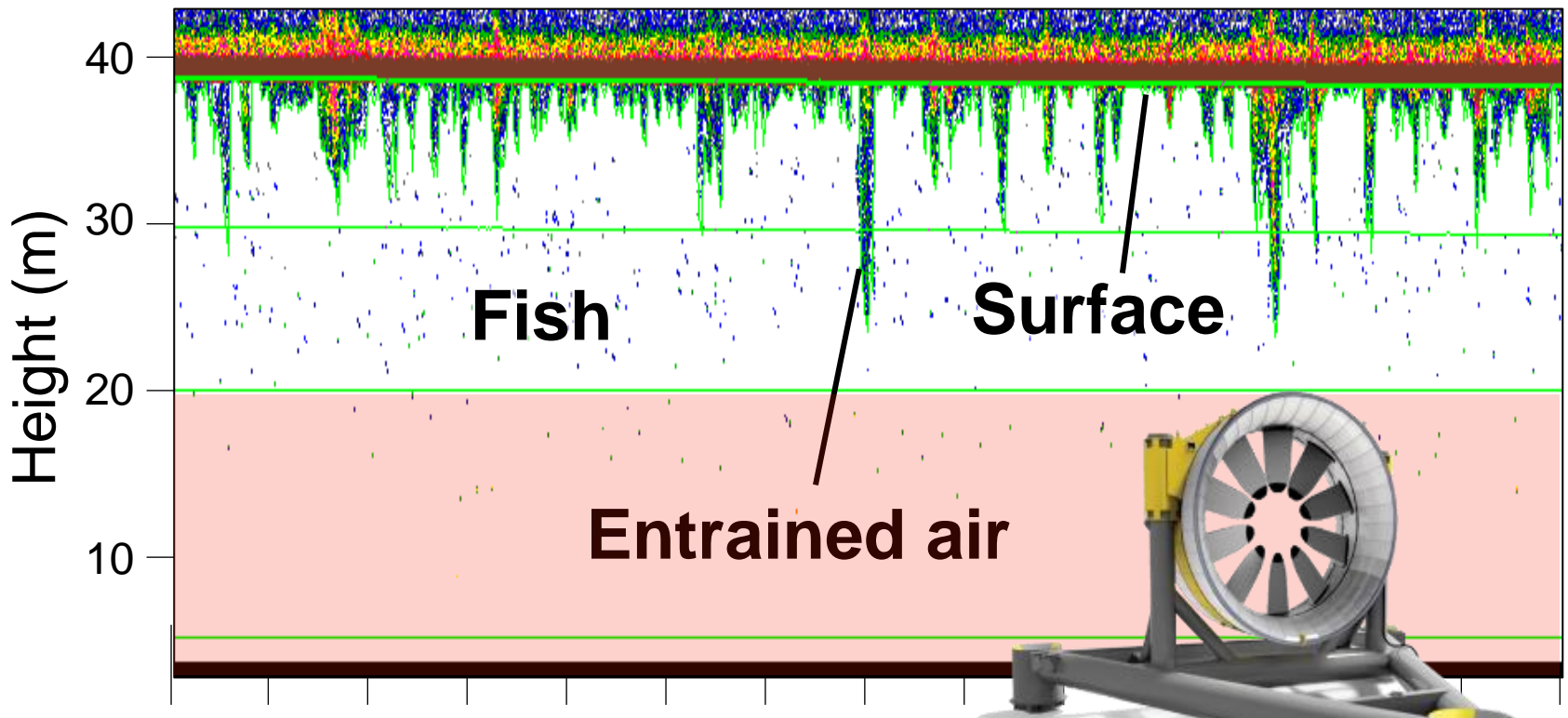




Observing Marine Life

Haley Viehman, Acadia / FORCE

Volume Backscatter with Depth and Time



Mathematics: Signal processing, Machine Learning



Modelling Marine Life Interactions

Fish around OpenHydro test turbine





Modelling Marine Life Interactions

- Individual Behaviour Models (IBMs)

A minimal model of predator–swarm interactions
Yuxin Chen and Theodore Kolokolnikov

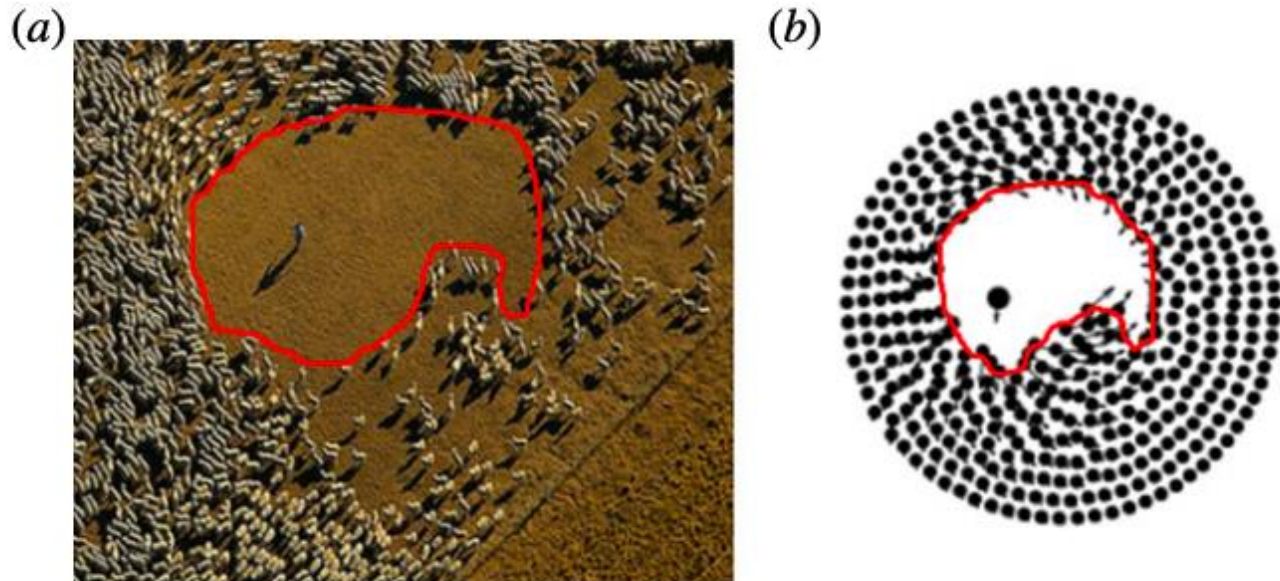


Figure 4. (a) The empty region surrounding the shepherd from figure 1a is shown with a curve. (b) Similar region observed in simulations of (1.1) and (1.2). (Online version in colour.)



Modelling Marine Life Interactions

Simulating Harbour
Porpoise Habitat Use in
a 3D Tidal Environment

Thomas Lake, Ian
Masters, T. Nick Croft
Swansea University



(i) Wider start distribution, responding to food, depth and noise



Conclusions: Challenges

- Headlines from last year:

New attempt to harness Bay of Fundy tidal power



Cape Sharp Tidal installing new turbine in Minas Passage

CBC News · Posted: Jul 20, 2018 2:39 PM AT | Last Updated: July 20, 2018





Conclusions: Challenges

- Headlines from last year:

Naval Energies exits tidal energy, OpenHydro seeks liquidation

July 27 (Renewables Now) - Just a day after successfully deploying an in-stream tidal turbine in Canadian waters, Naval Energies has decided to cease all investments in tidal turbines as it has determined that the market for this technology is closing.

The French marine renewables specialist announced its decision today, saying that it plans to focus on



OpenHydro Open Centre Turbine at EMEC



Conclusions: progress

Headlines from last week:



Atlantis and GE to Build World's Largest Tidal Turbine

<https://marineenergy.biz/2019/05/19/highlights-of-the-week-19/>



Conclusions: progress

Headlines from last week:



Nova Gets New €5 Mln Tidal Energy Project

<https://marineenergy.biz/2019/05/19/highlights-of-the-week-19/>



Conclusions: progress

Headlines from last week:



OPT Achieves Power Generation Milestone in Adriatic Sea

<https://marineenergy.biz/2019/05/19/highlights-of-the-week-19/>



Questions ?



SME Plat-I