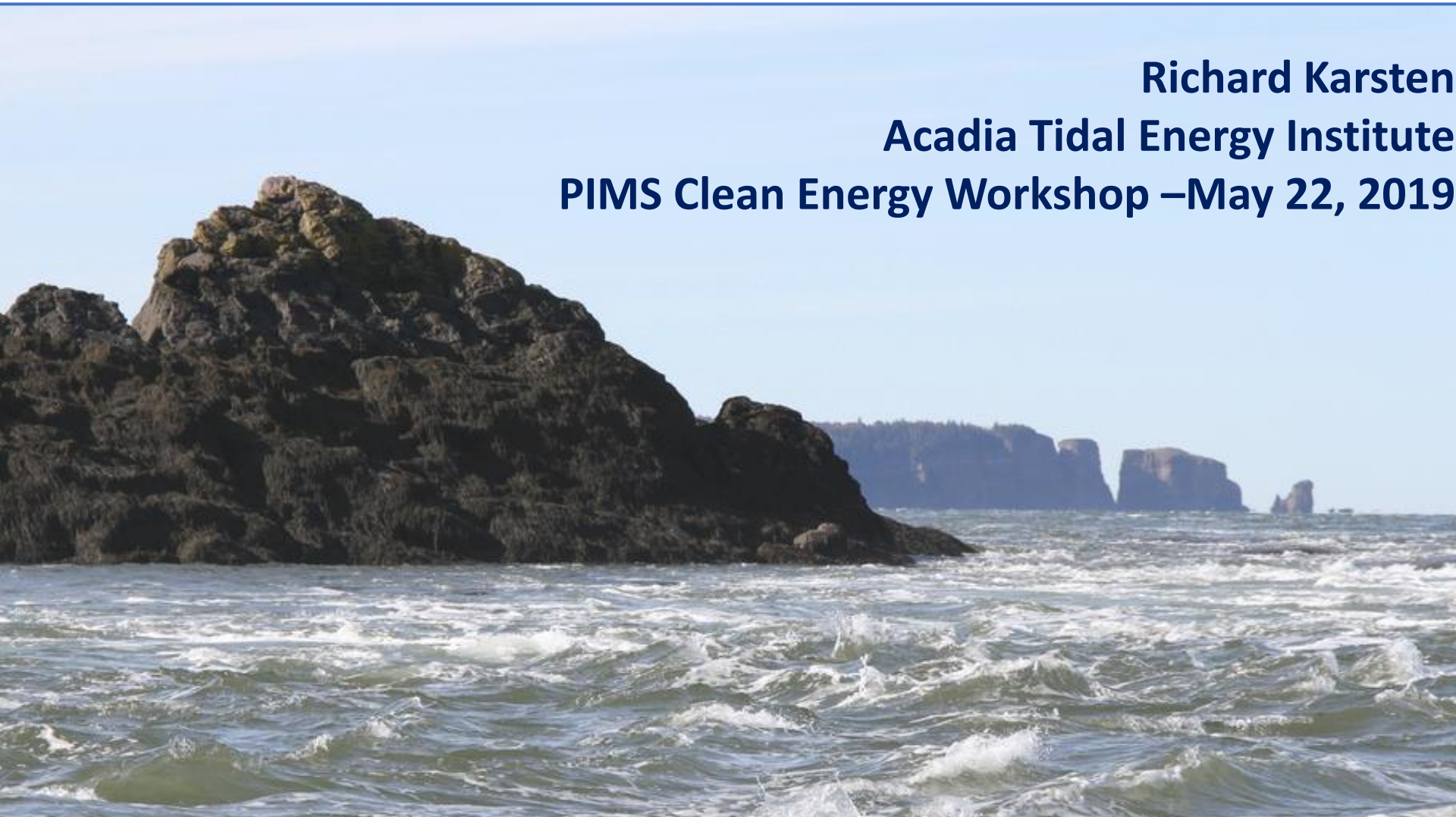
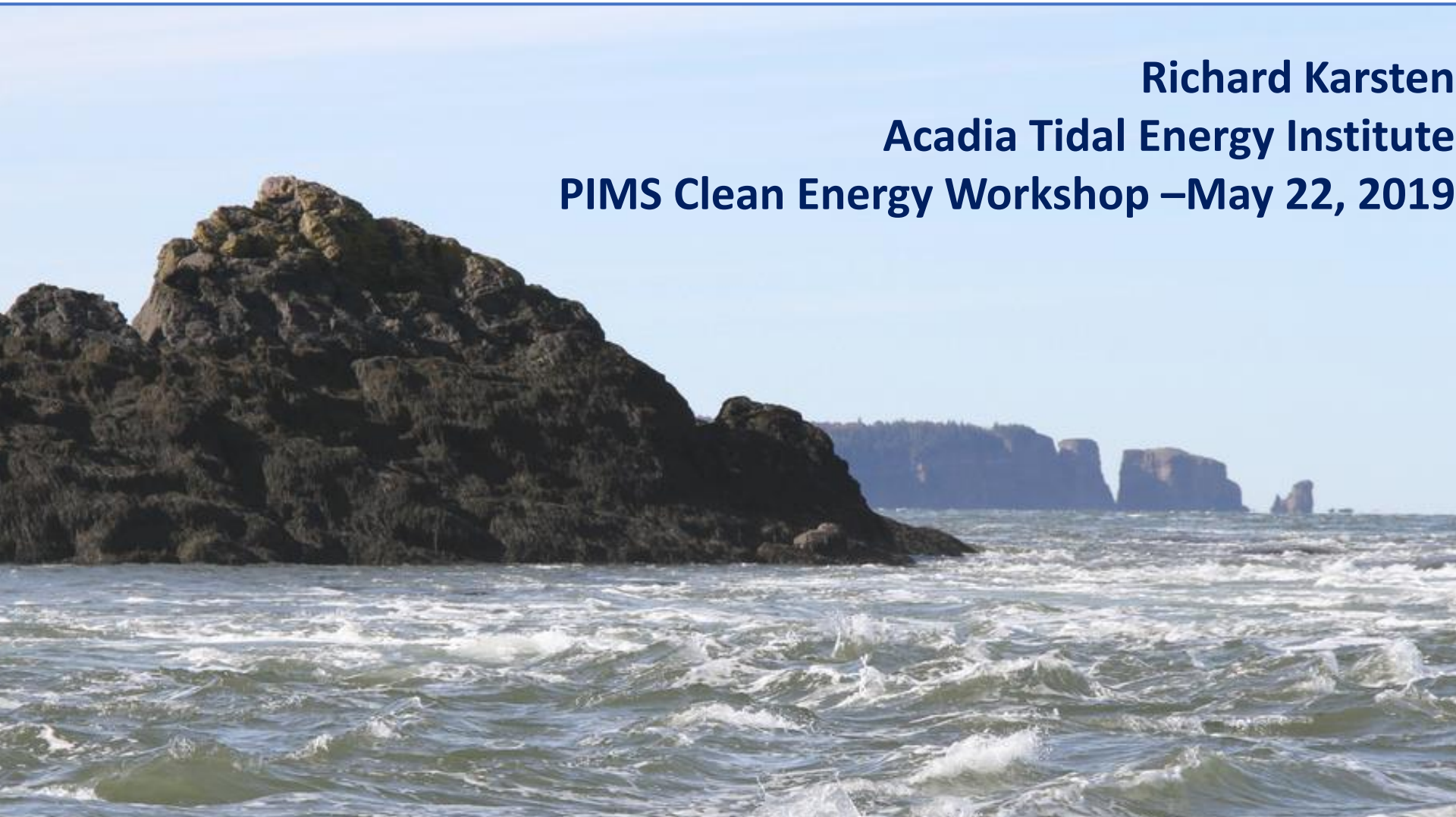
Introduction to Water Energy



Richard Karsten
Acadia Tidal Energy Institute
PIMS Clean Energy Workshop –May 22, 2019

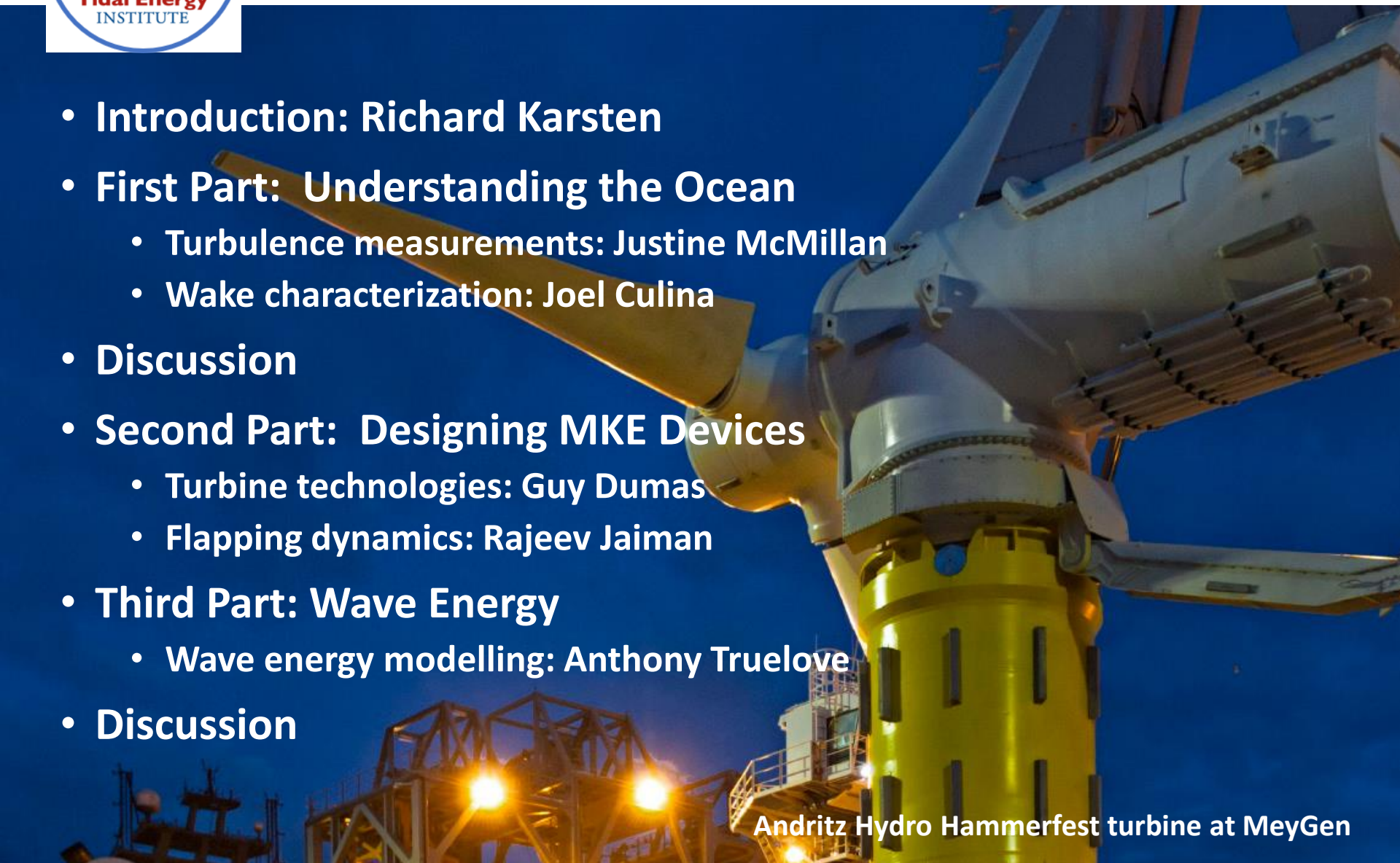
Introduction to Marine Renewable Energy



Richard Karsten
Acadia Tidal Energy Institute
PIMS Clean Energy Workshop –May 22, 2019

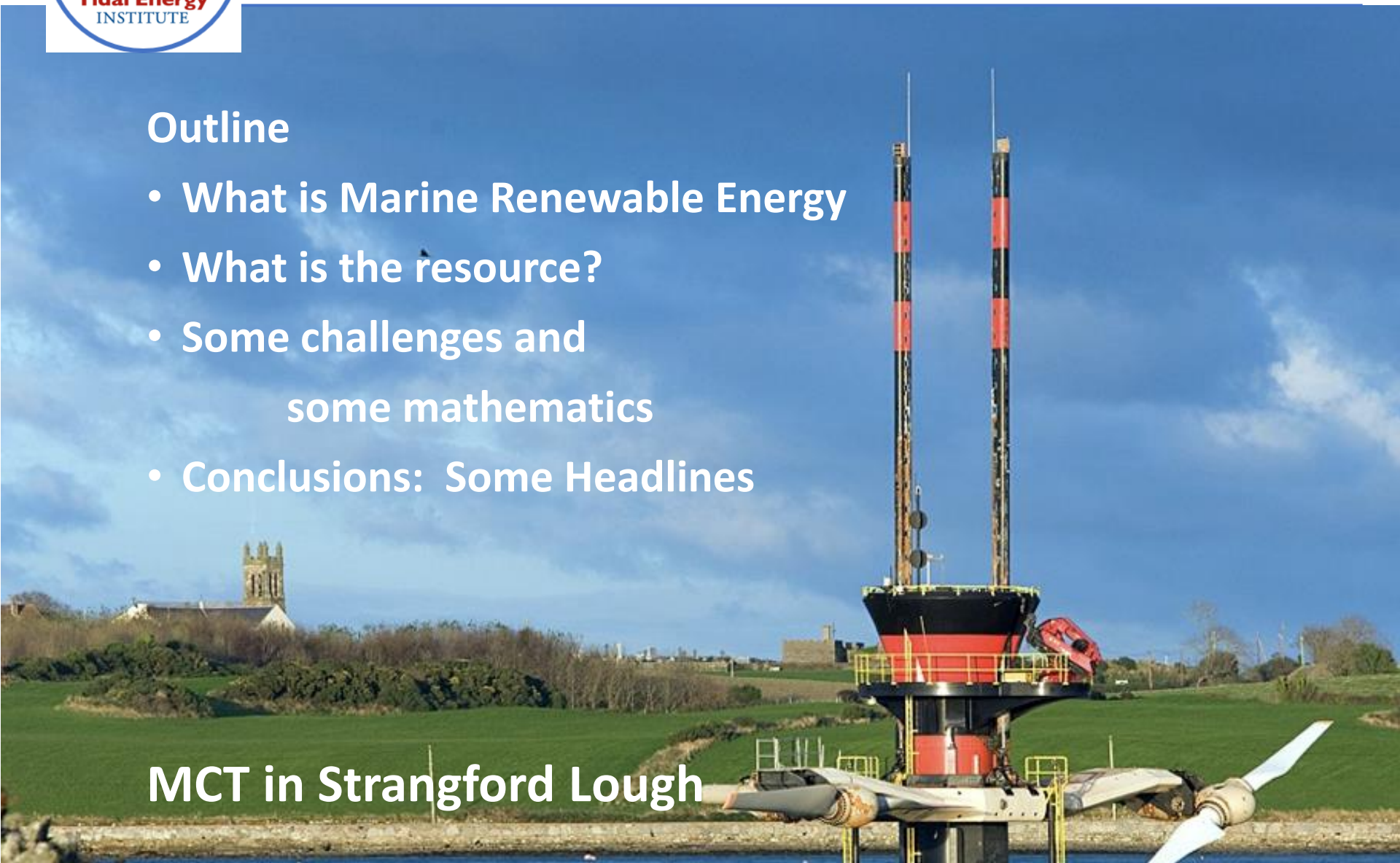
Marine Renewable Energy Session

- **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

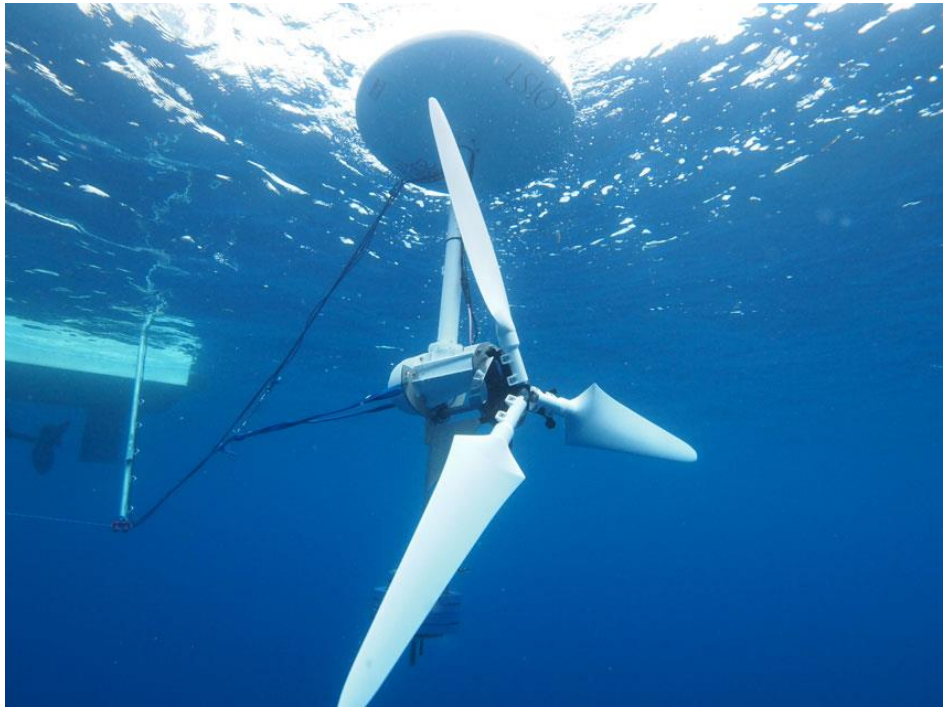
- Energy from currents … Marine Kinetic Energy
  - Tidal Currents
  - Rivers Currents

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:

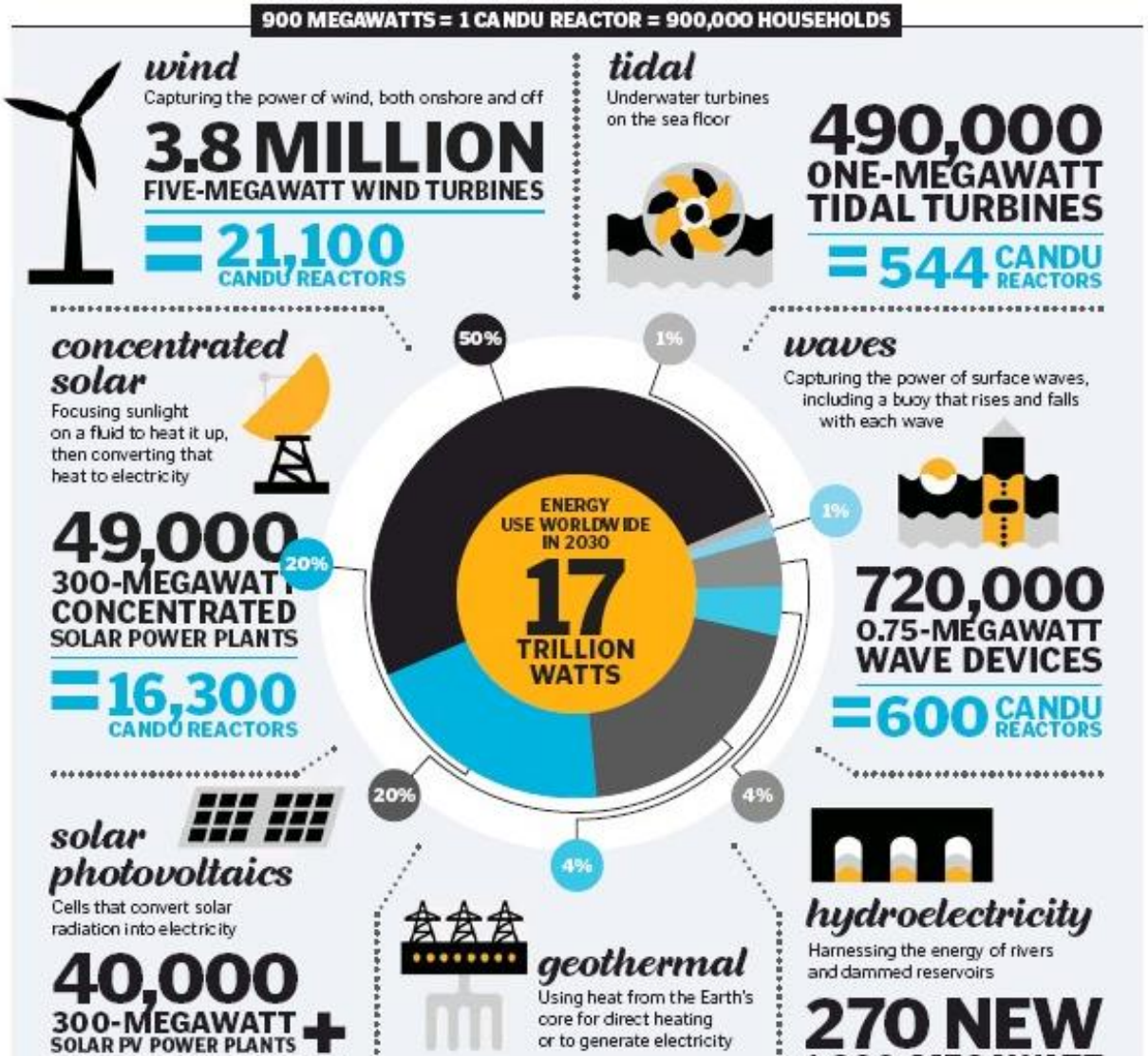
- Offshore Wind
- Hydroelectricity
- Run of River

A fully renewable world

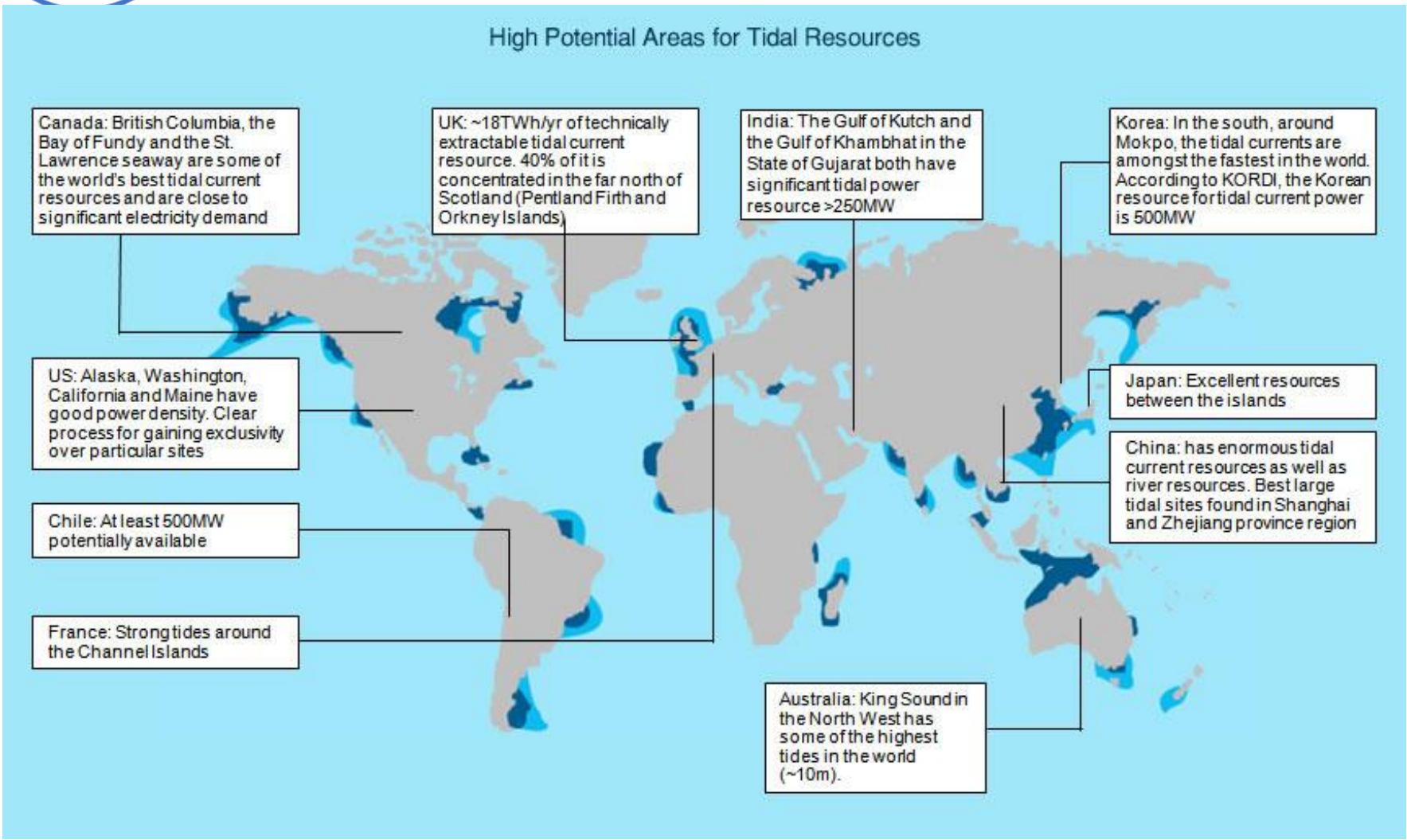
Tidal energy:
490,000 turbines
1% of Total
(10-20 turbines)

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

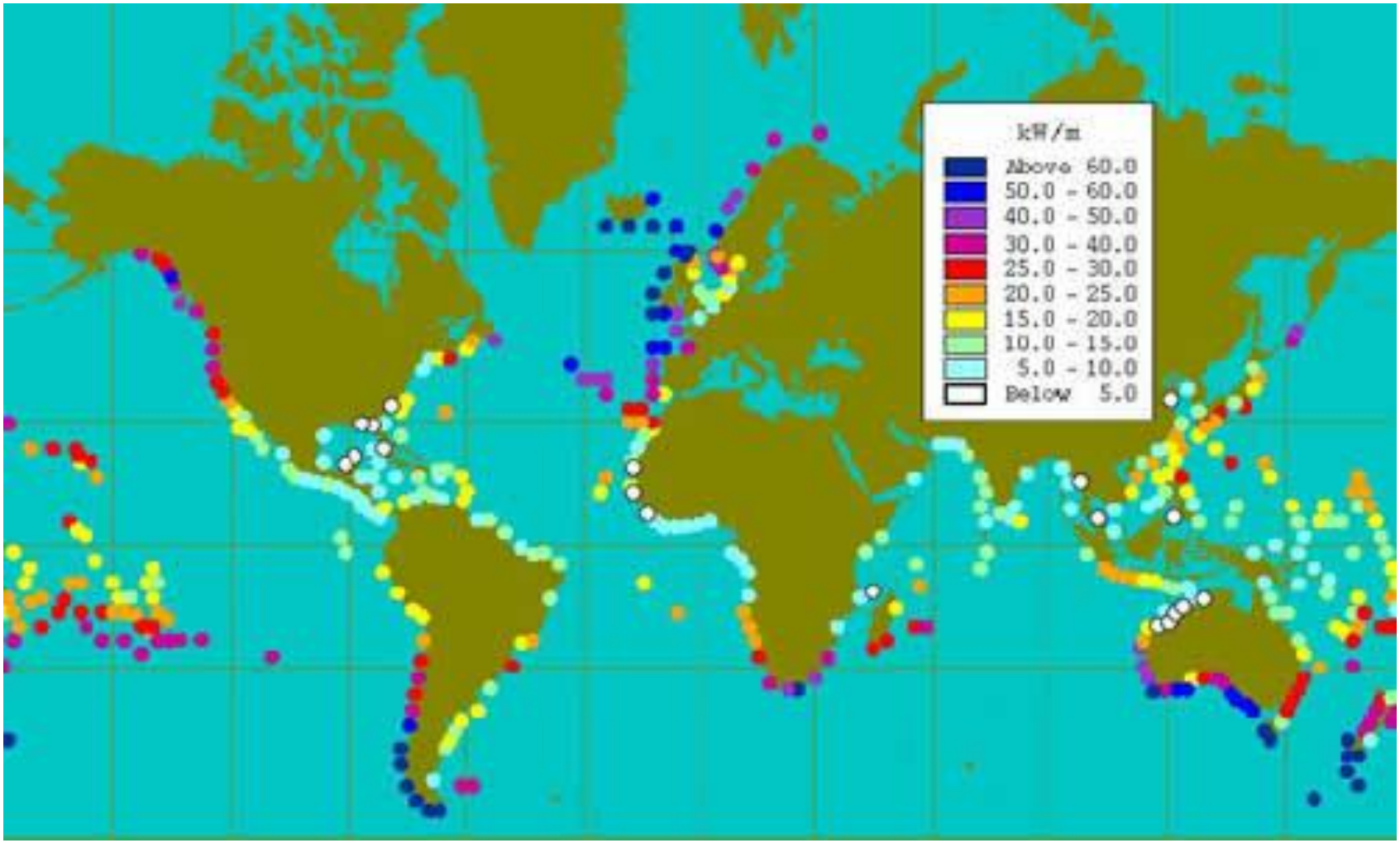
Globe and Mail Report on Business



What is the resource? Tidal



What is the resource? Wave

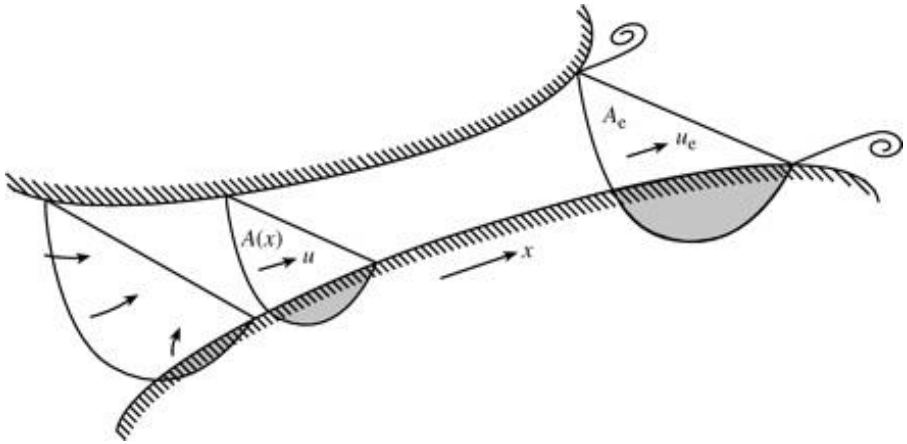


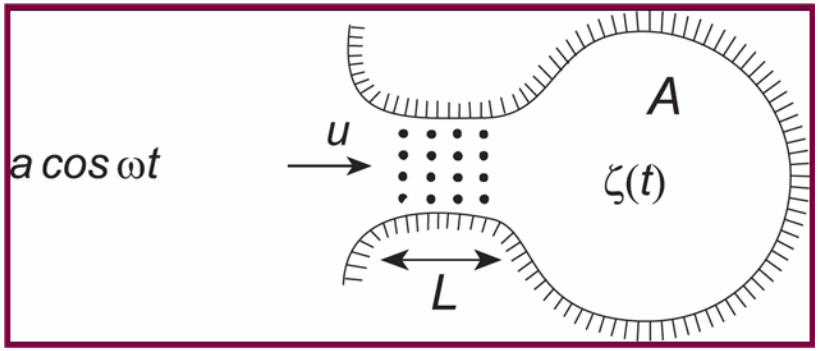
Marine Renewable Energy: Challenges

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

Calculating the resource

- Mathematical Models: Garrett and Cummins (2005)



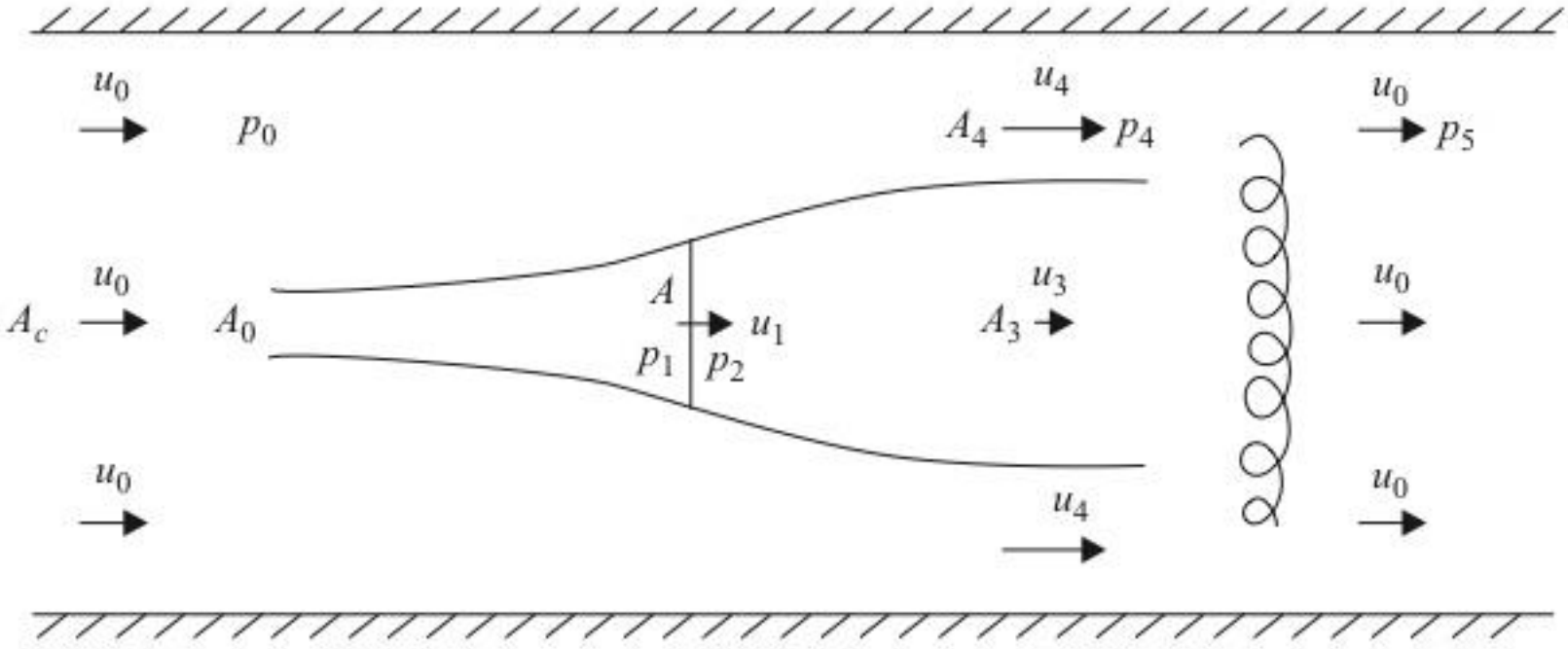


Simply physics and calculus => $P_{max} = \frac{1}{4}\rho g a Q$

(Direct analogy of Maximum Power Law of electric circuits)

Calculating the resource

- Mathematical Models: Garrett and Cummins (2007)

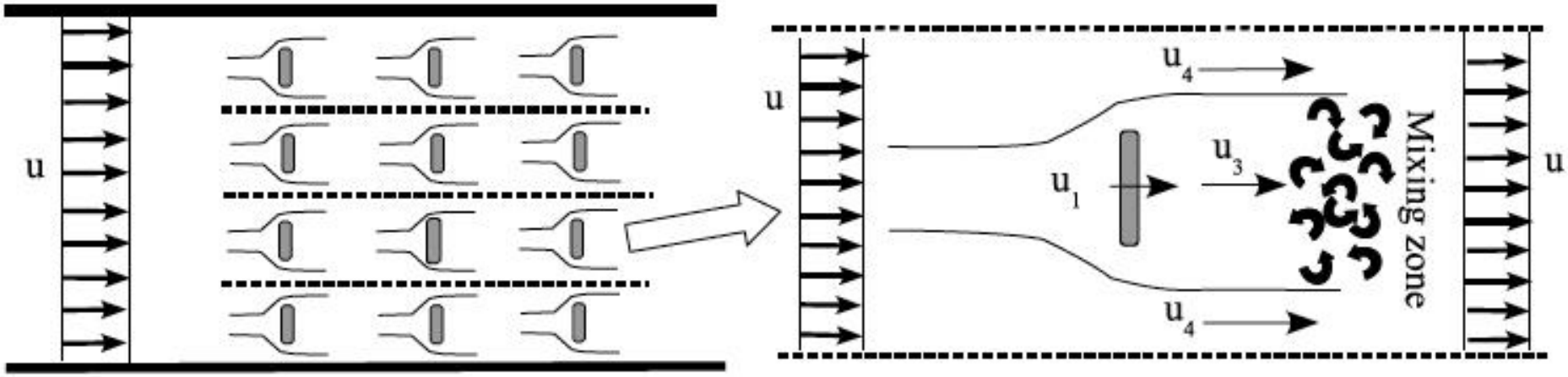


Conservation Laws => Algebraic Equations

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

Calculating the resource

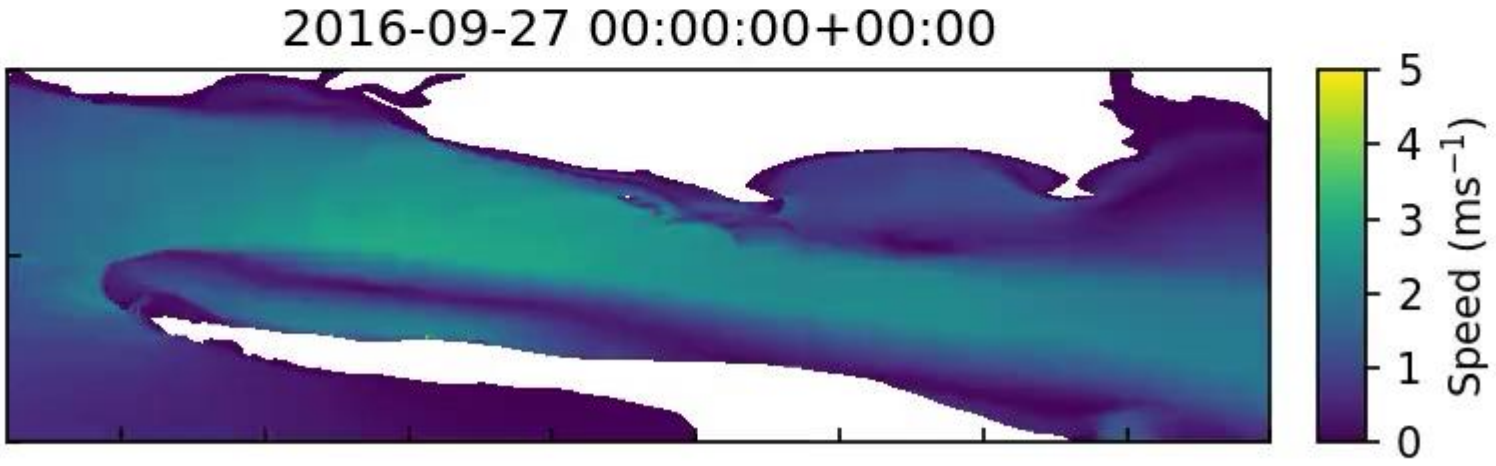
- Mathematical Models: Vennell (2012)



Combine models together

Calculating the resource

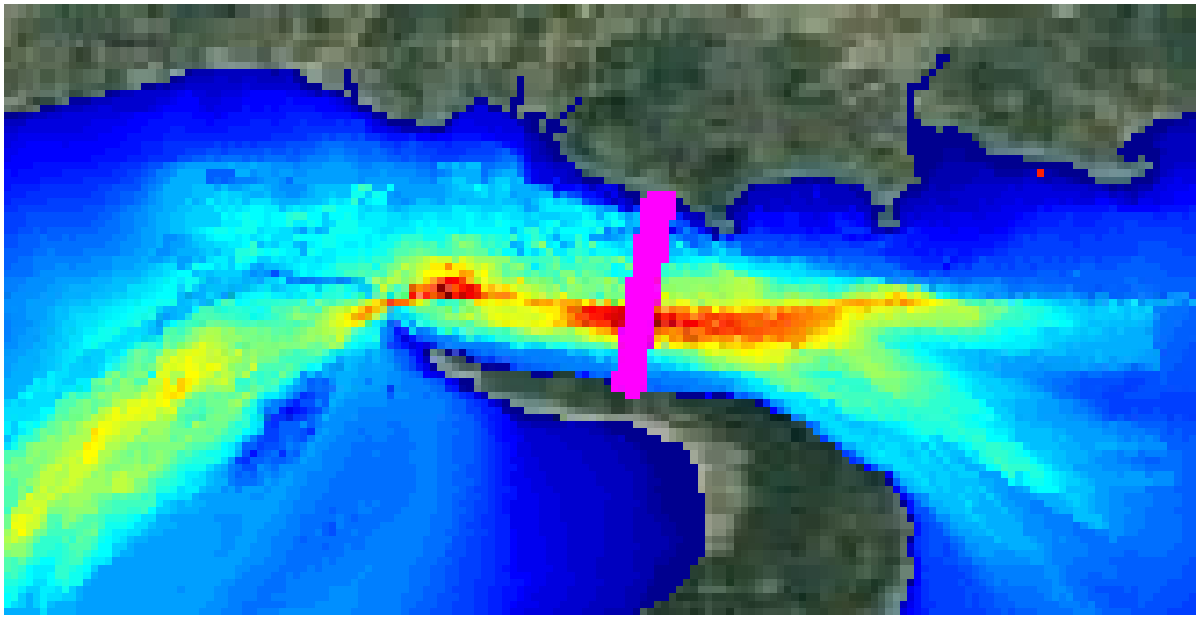
- Numerical Models: Simulate the tidal currents



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

Calculating the resource

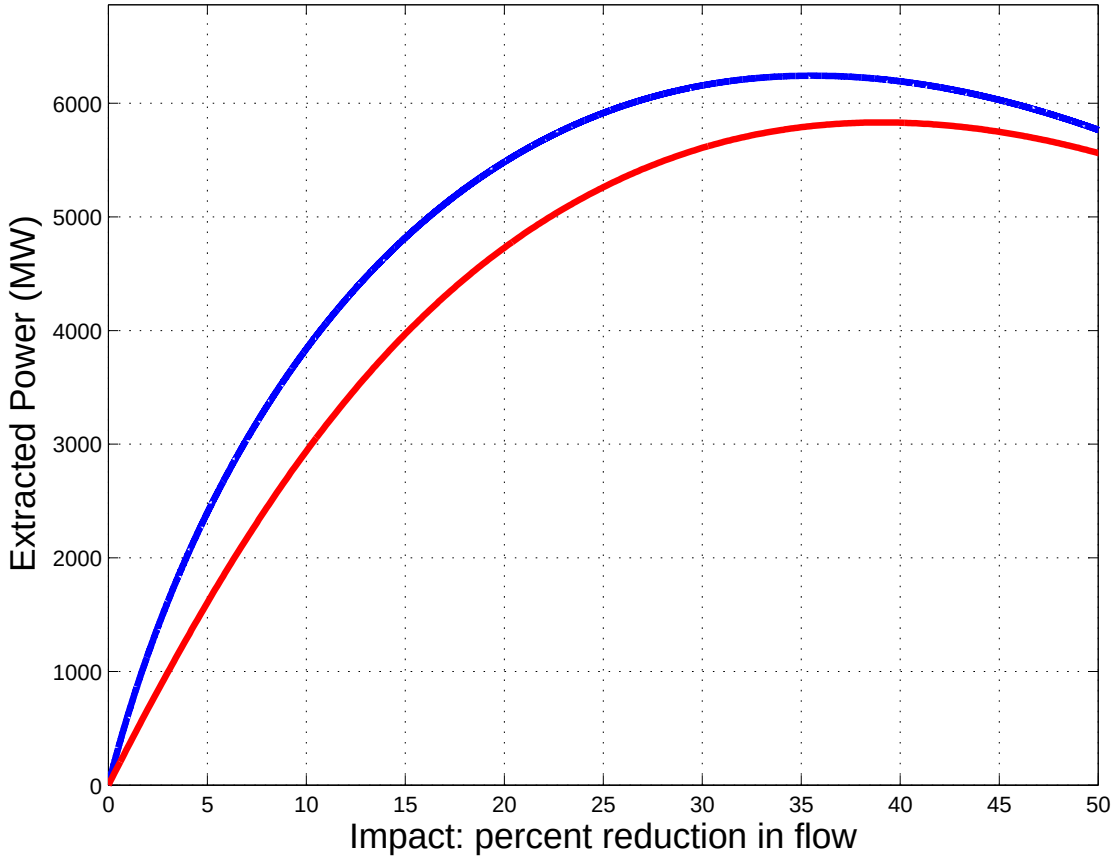
- Numerical Models: Simulate Extracting Energy



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

Calculating the resource

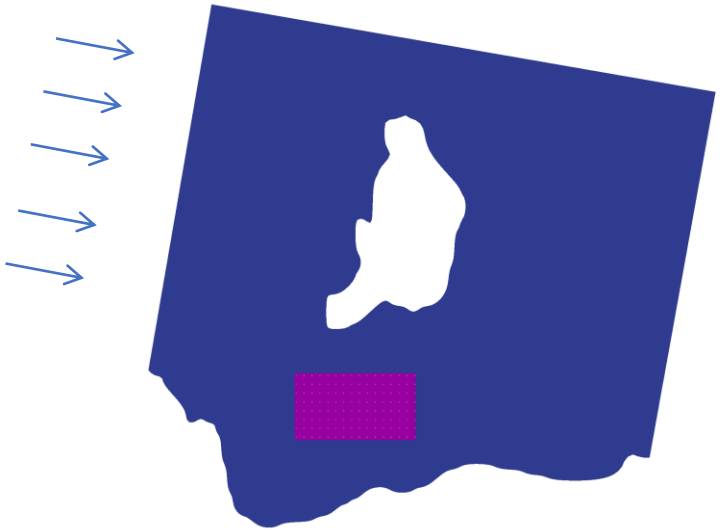
- Mathematical Models: Models and theory agree



Optimization: Turbine Farm Design

Optimize the location of turbines in a farm: MeyGen

Map

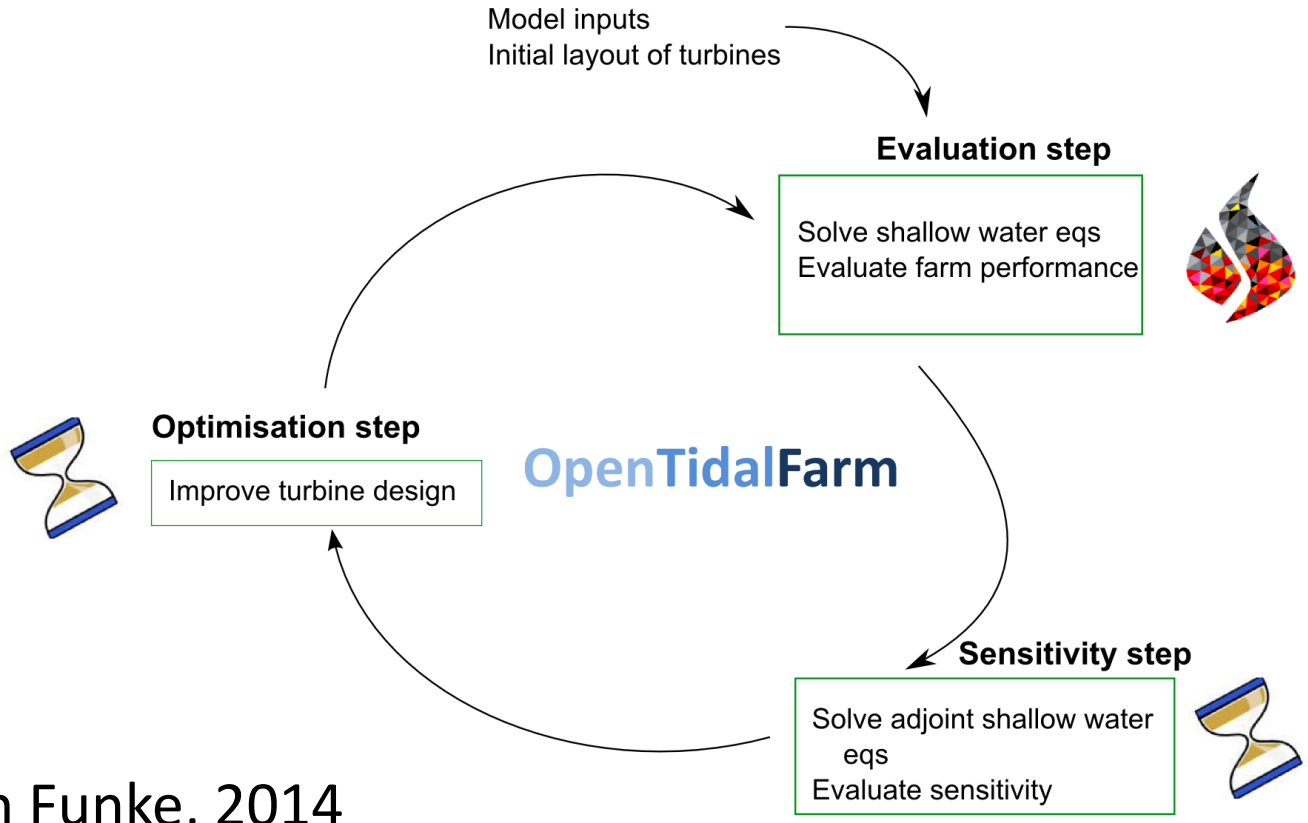


Domain and farm area

Simon Funke, 2014

Optimization: Turbine Farm Design

Optimize the location of turbines in a farm



Simon Funke, 2014

Optimization: Turbine Farm Design

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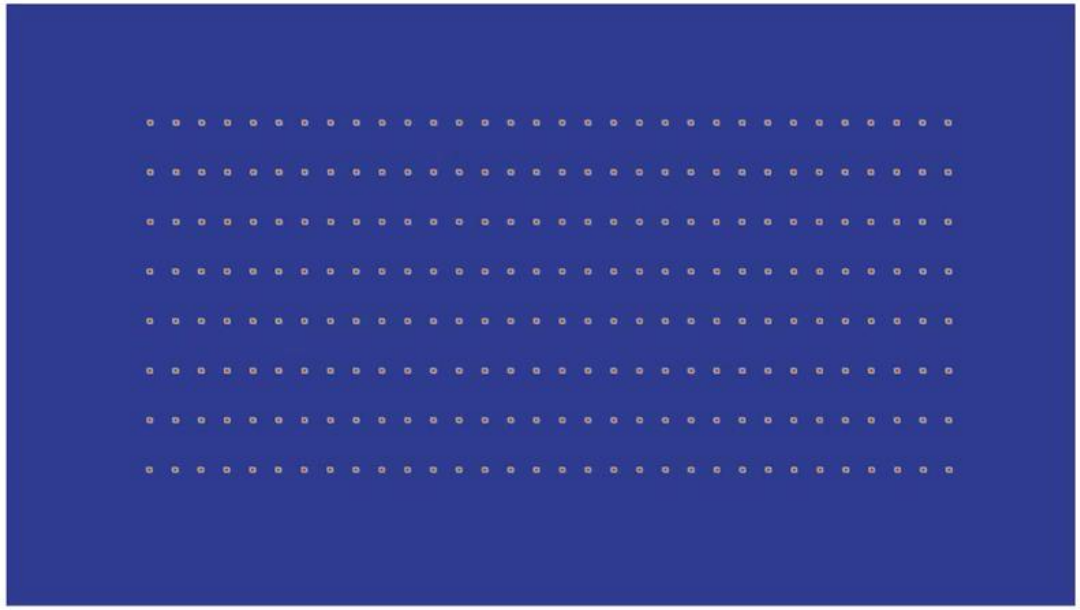
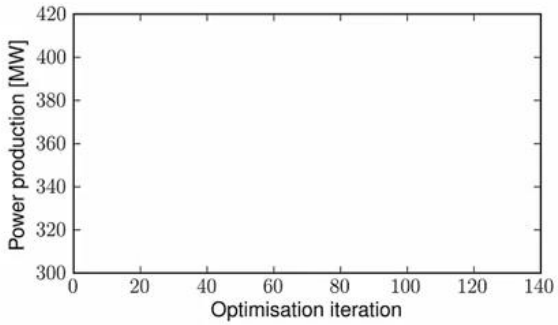


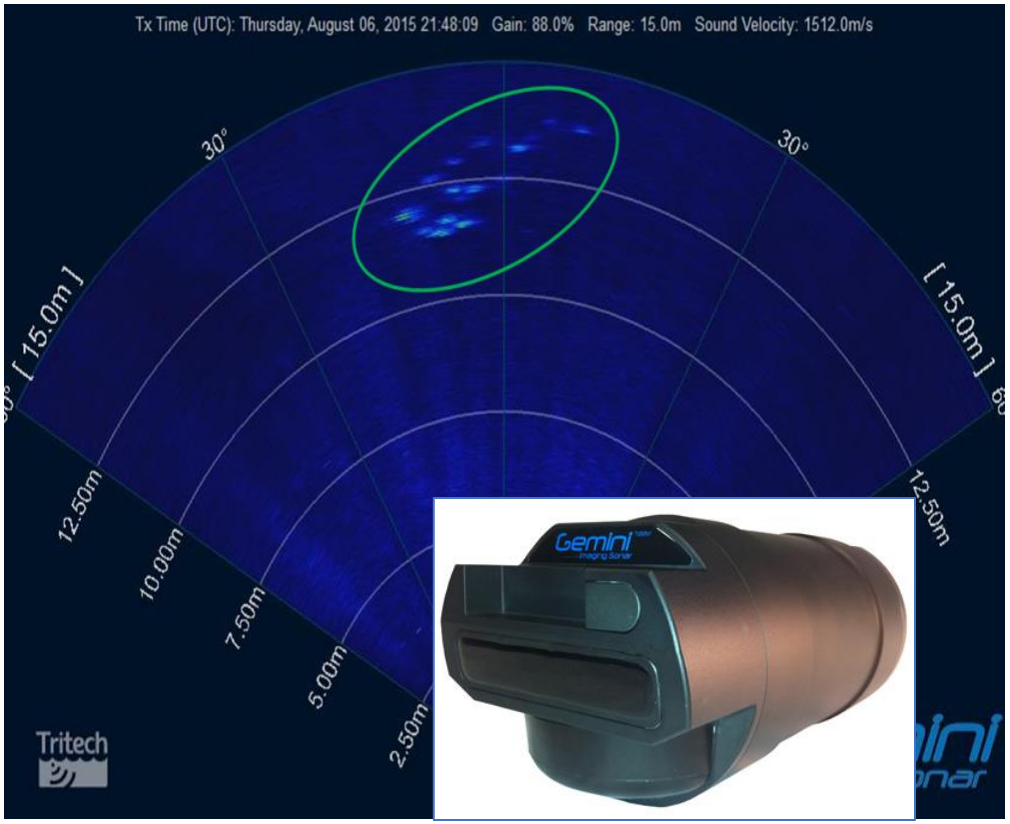
Simon Funke, 2014

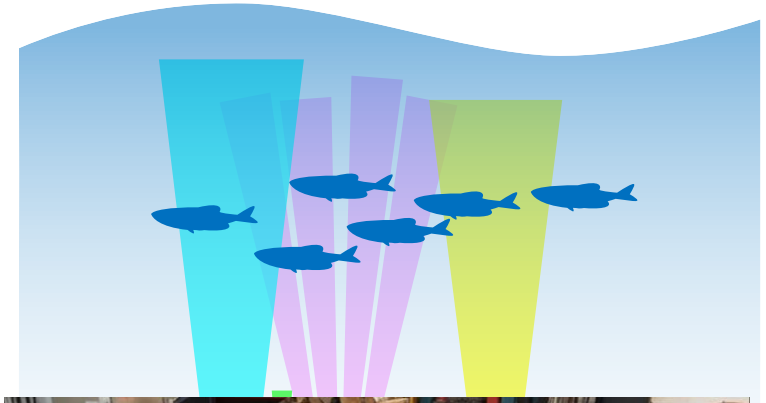


Observing Marine Life

Haley Viehman, Acadia / FORCE

Gemini Imaging Sonar

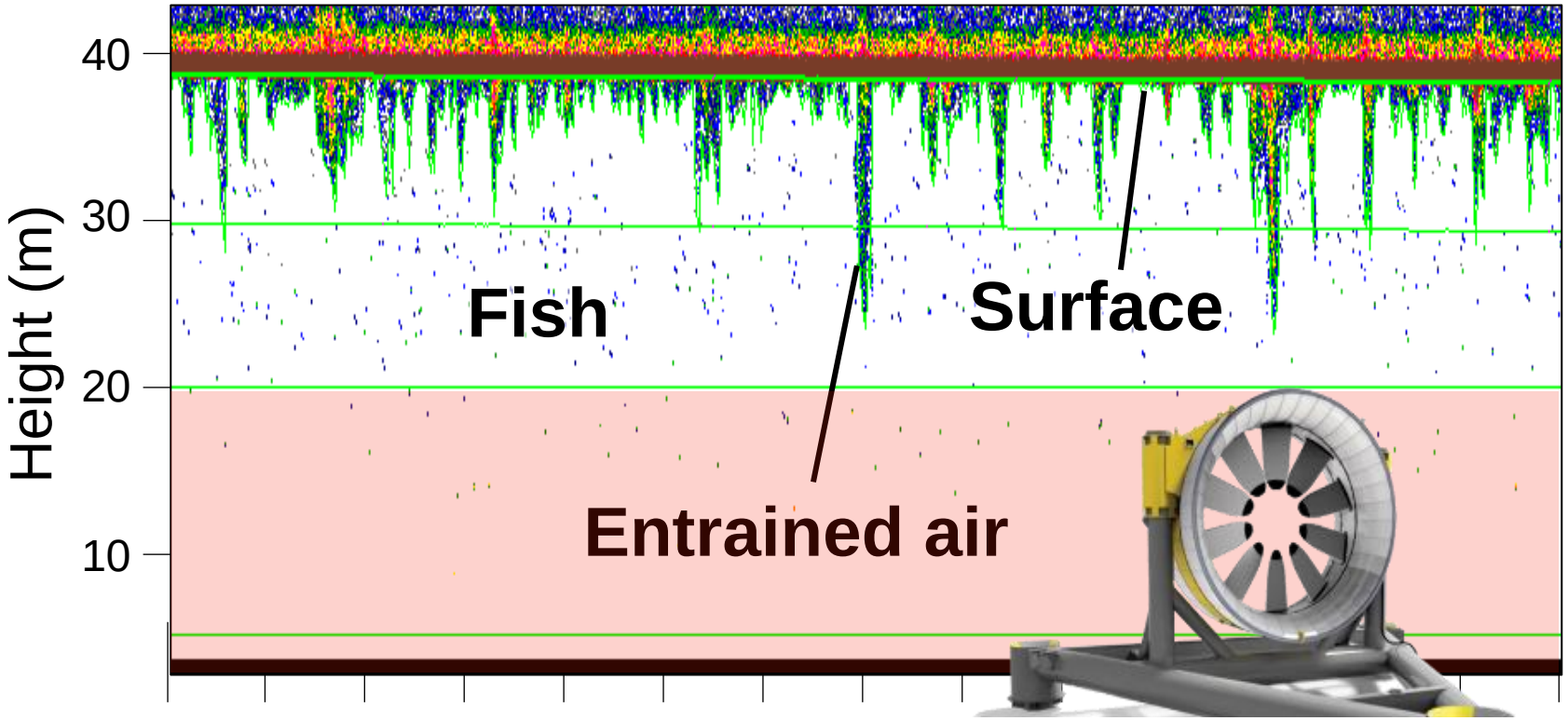




Observing Marine Life

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

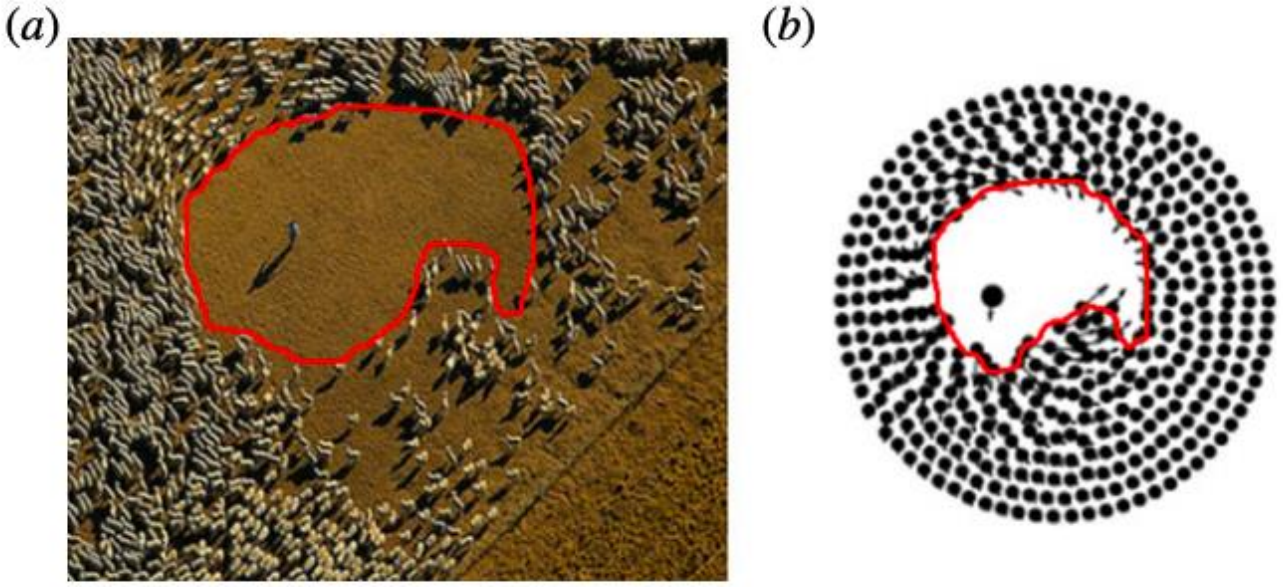


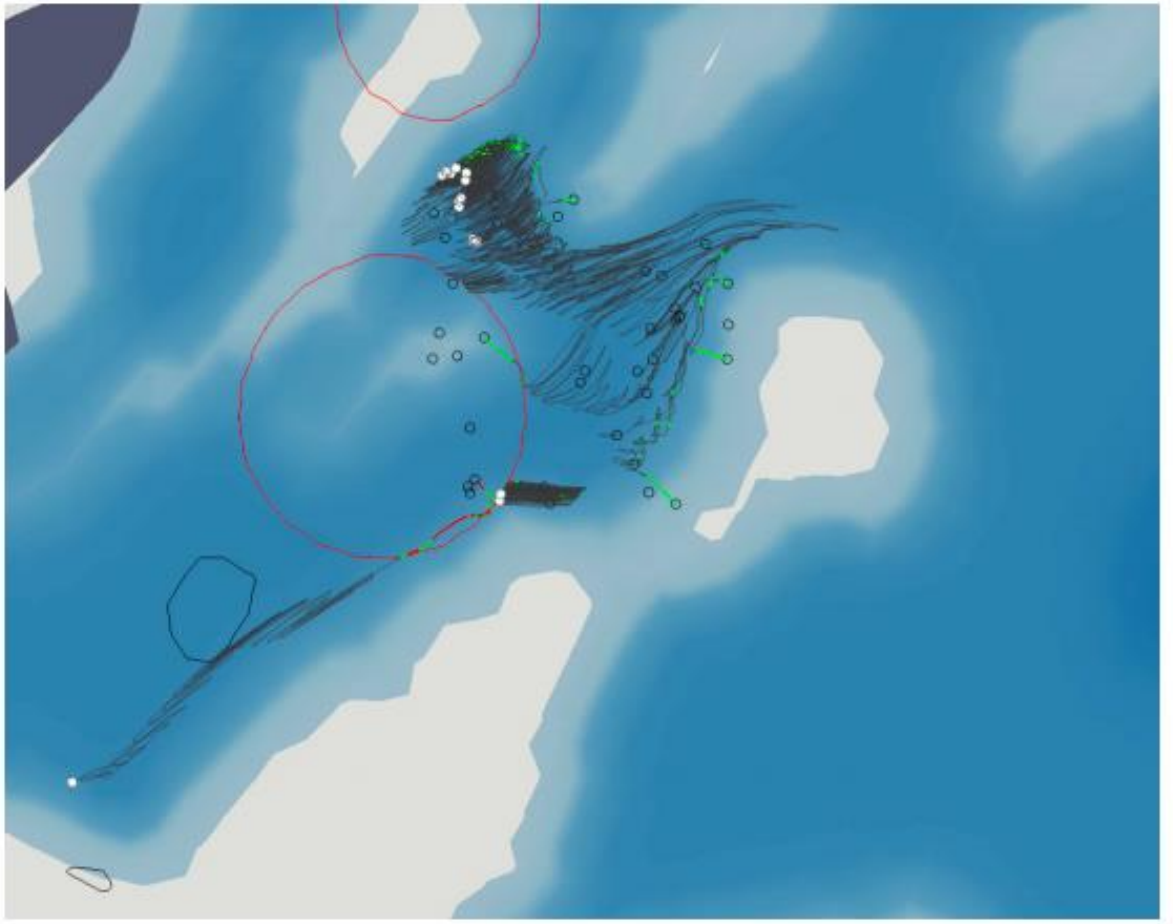
Figure 4. (*a*) The empty region surrounding the shepherd from figure 1*a* is shown with a curve. (*b*) Similar region observed in simulations of (1.1) and (1.2). (Online version in colour.)

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

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 ?