Harnessing the power of the ocean currents

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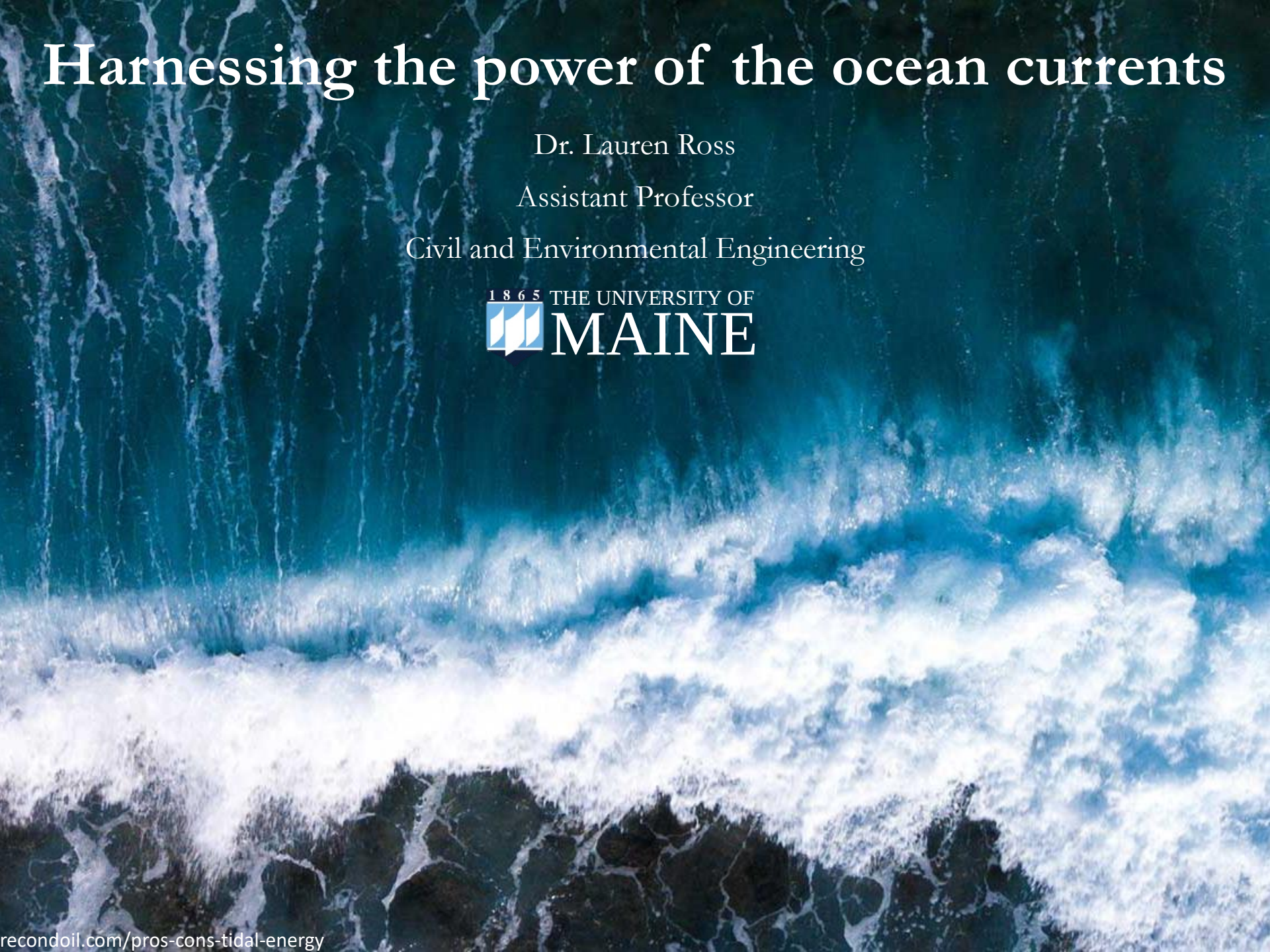
Civil and Environmental Engineering

1865 THE UNIVERSITY OF MAINE



recondoil.com/pros-cons-tidal-energy

Marine Renewable Energy

Wave & Wind Energy – Received the most attention

Wind Energy

Photo by Ethan Andrews

Ocean & Tidal Currents

https://wavetidalinfo.weebly.com

Why Tidal Energy? Tidal power is reliable!

→ Know how much electricity will be generated at given time

Water denser than air (~800x)

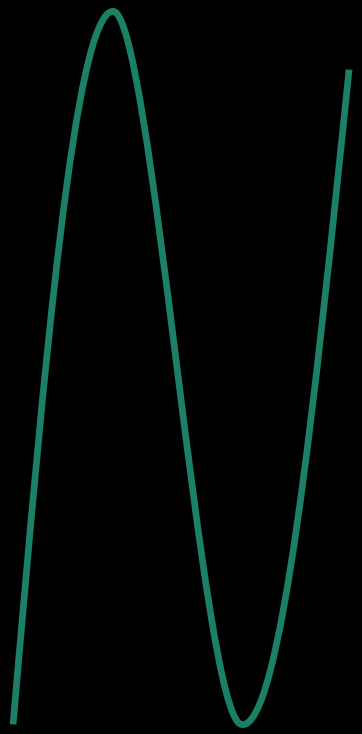
→ Tidal flow of a few m/s ≈ 450 km/h (300 mph) wind.

→ Tidal turbines smaller than wind turbines.

Tides: gravitational pull of moon and sun with the rotation of the earth

Tides – Minas Passage, Nova Scotia
Max tidal range 15m (50 ft)

Thomas Hill Standpipe



Adapted from: Chris Brackley/Canadian Geographic

Tides – Minas Passage, Nova Scotia
Max tidal range 15m (50 ft)

Thomas Hill Standpipe

<u>The Tides</u>:

- 160 billion tons of water each tide in Bay of Fundy
- 14 billion tons through Minas Passage
- Flow 2-5 m/s (18 km/h)

<u>Power Potential</u>:

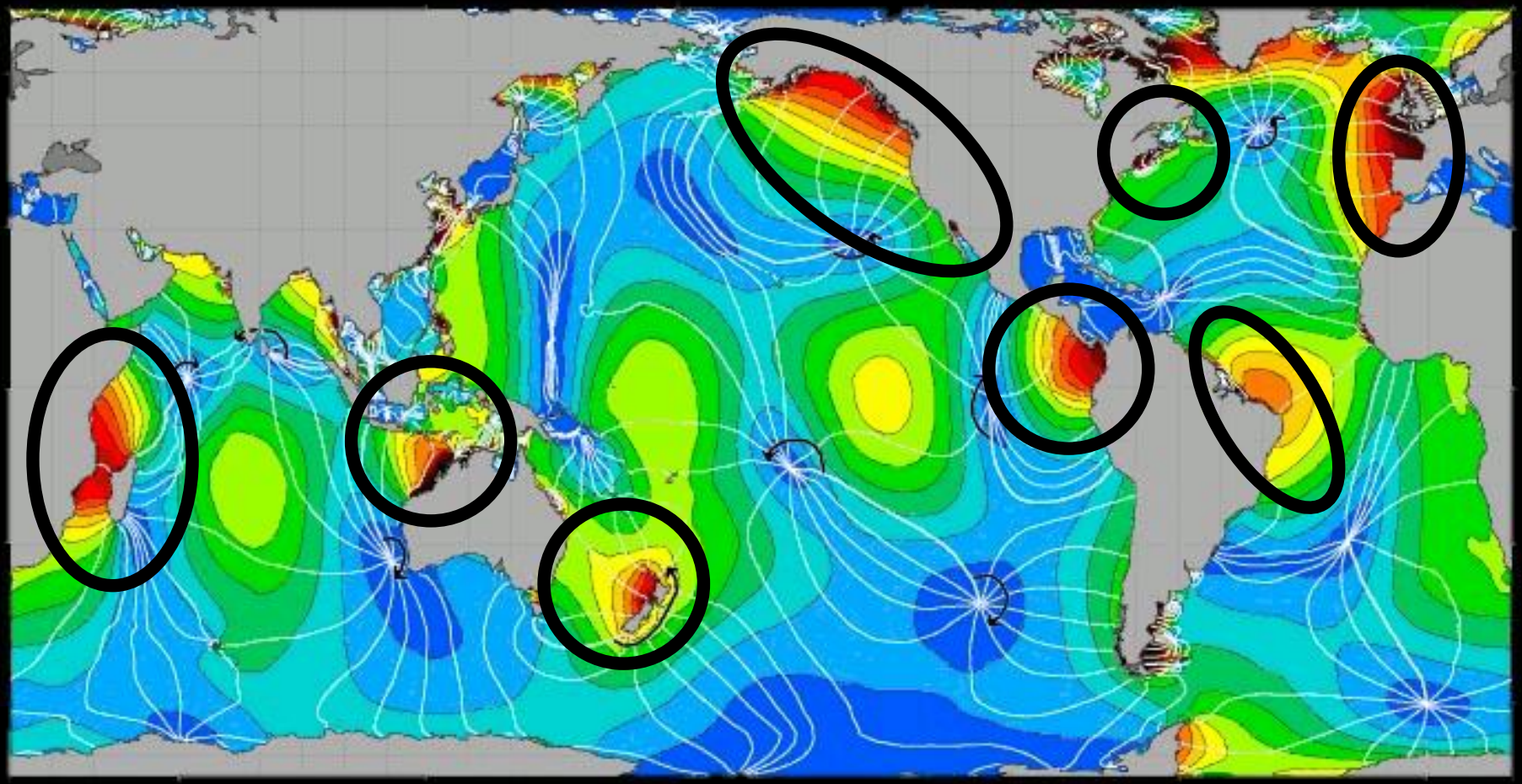
- **50,000 MW** – Estimated energy in Bay of Fundy
- **6,000-8,000 MW** – Estimated energy in Minas Passage
- **300 MW** – Nova Scotia's goal for power generation in Minas Passage
  → **270,000 HOMES! (only 1% of total potential!)**

Tyana Awada/Canadian Geographic

Tides around the world

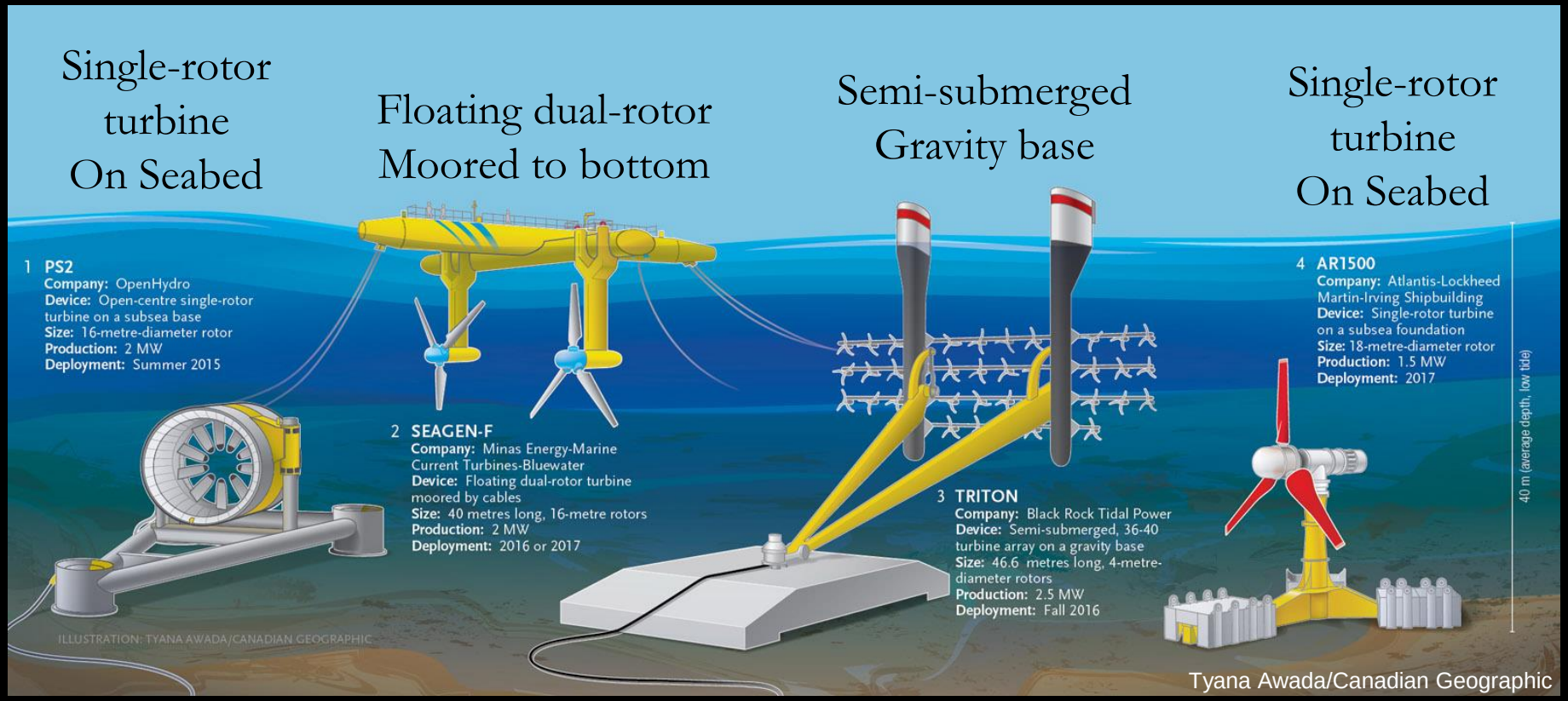
Red – Large Tides

Blue – Small Tides



Adapted from: R. Ray, TOPEX/Poseidon: Revealing Hidden Tidal Energy GSFC, NASA.

How electricity is generated
Four prototypes in Minas Passage

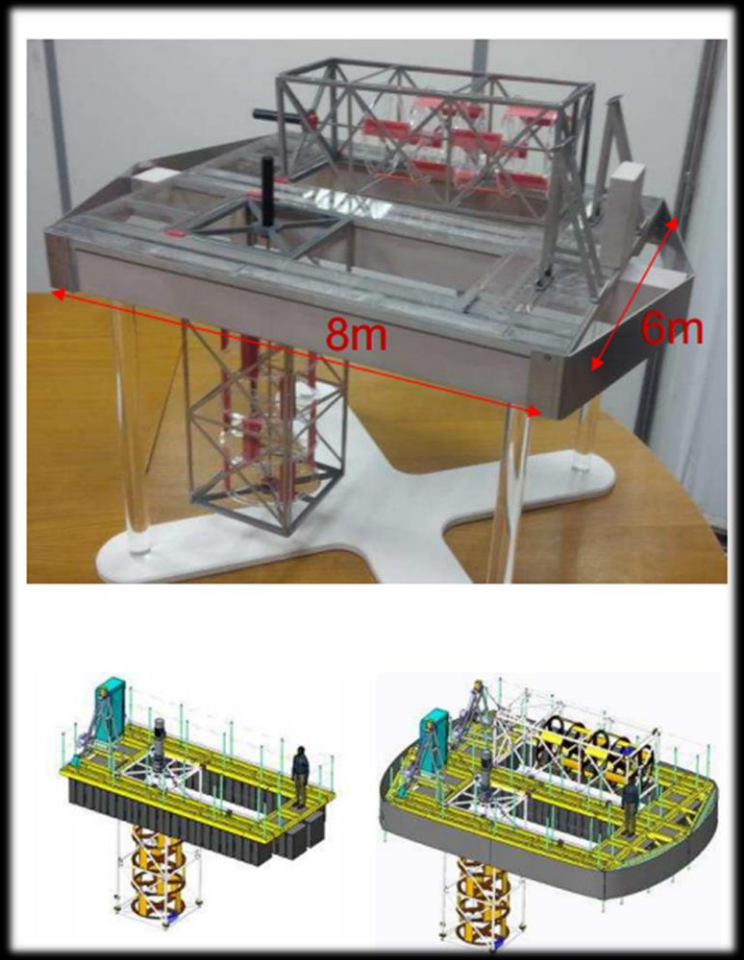


Tyana Awada/Canadian Geographic

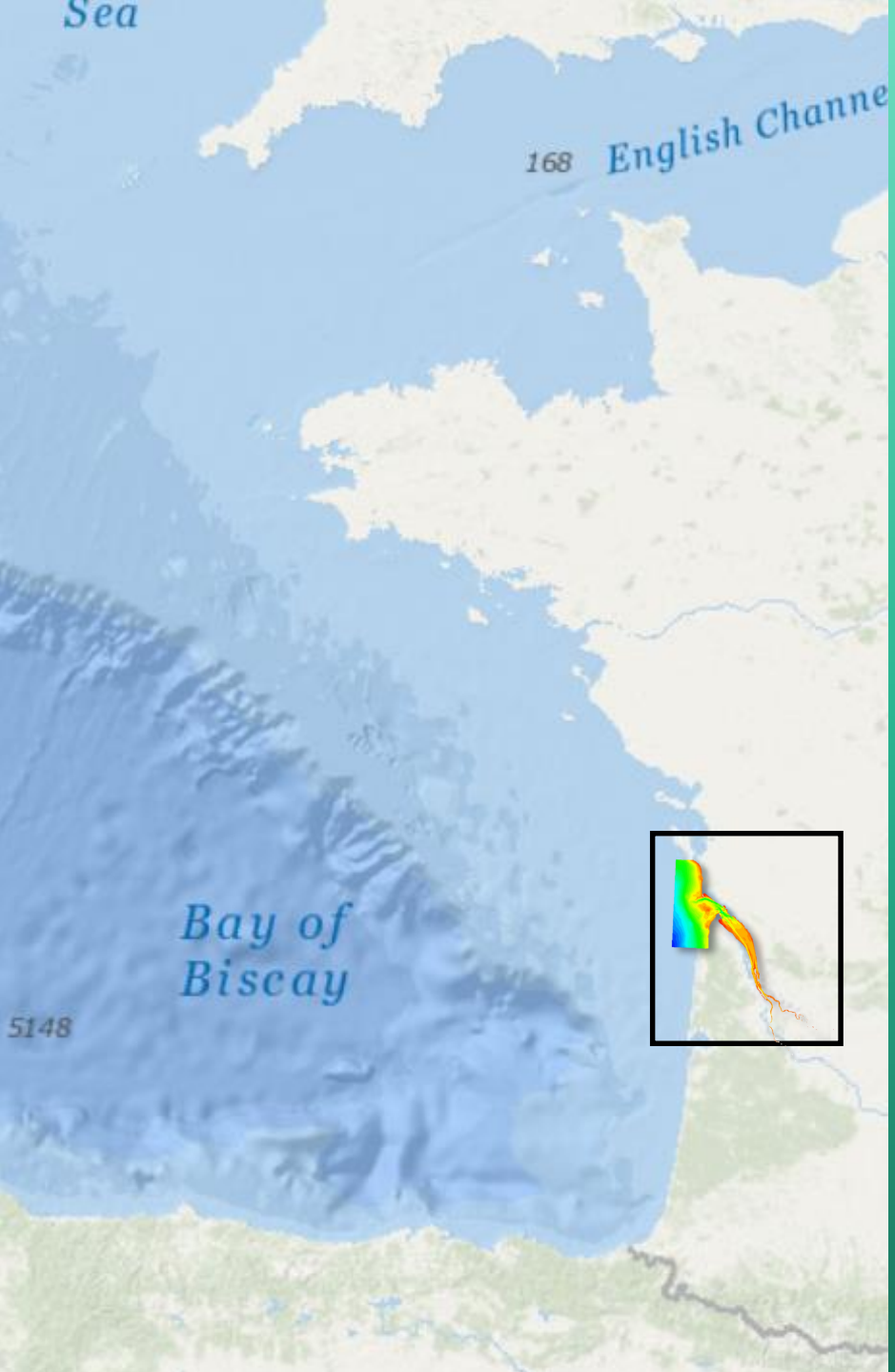
What type of turbine?

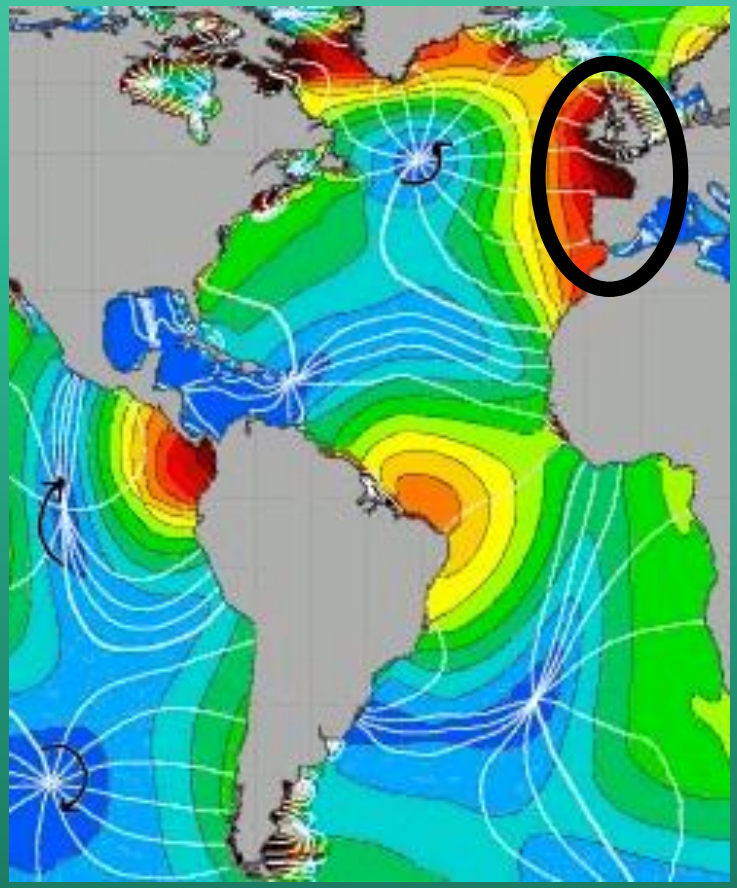
- Estuary
- Floating platform – moored to seabed

Parameter	value
$Platform\ Width$	6 m
$Platform\ Length$	8 m
$Draft$	0.3 m



Southwest Coast of France

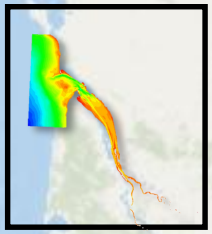




Goals:

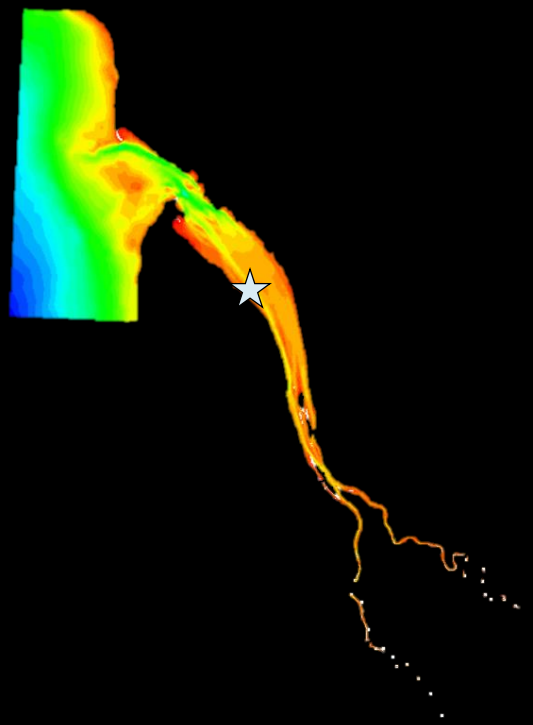
1. Determine the energy potential in the Gironde

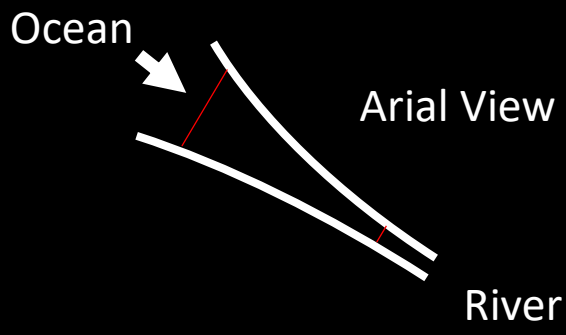
2. Examine how implementing turbines will affect the environmental conditions of the estuary
   - → Water levels
   - → Currents
   - → Sediment transport

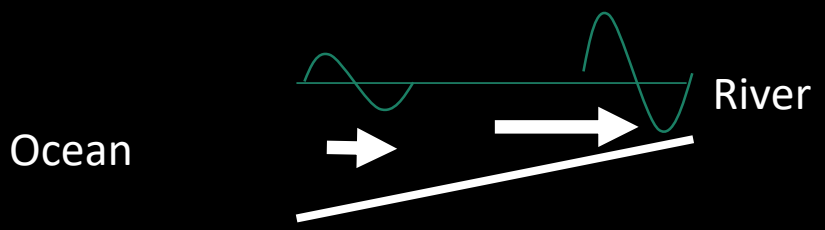


Why the Gironde is Unique

- In an area of large tidal range, but also:
  - Coastline convergence – **STRONG tidal currents**







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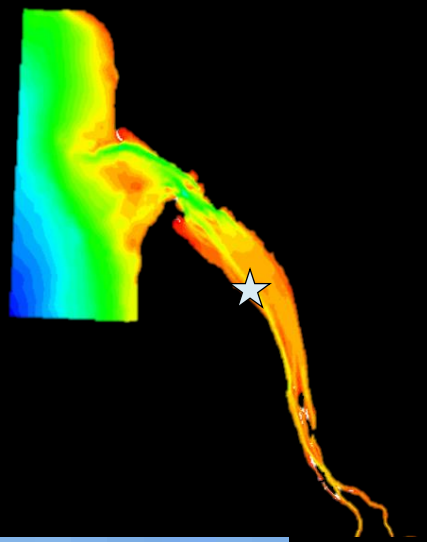
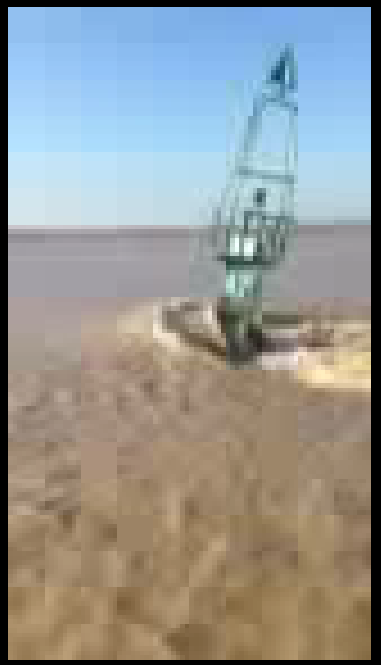


Tidal Bore, France
http://www.theinertia.com/



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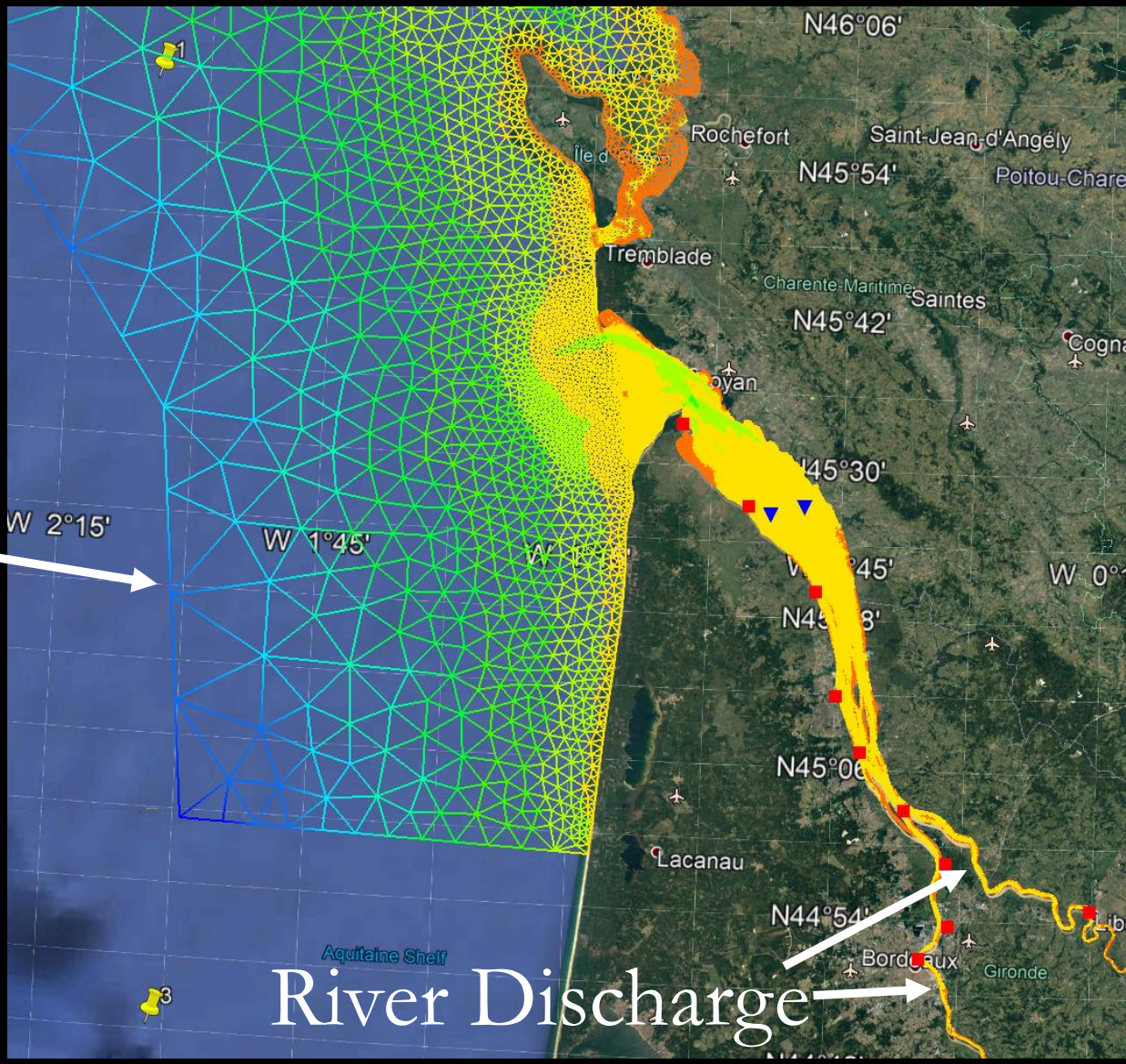
Steps:

1. Develop numerical model to simulate currents in the Gironde
   - Validate model
2. Determine optimal location for turbine placement
   - Energy potential
   - Feasibility
3. Determine optimal orientation of turbines
4. Analyze affects on environment.

Model

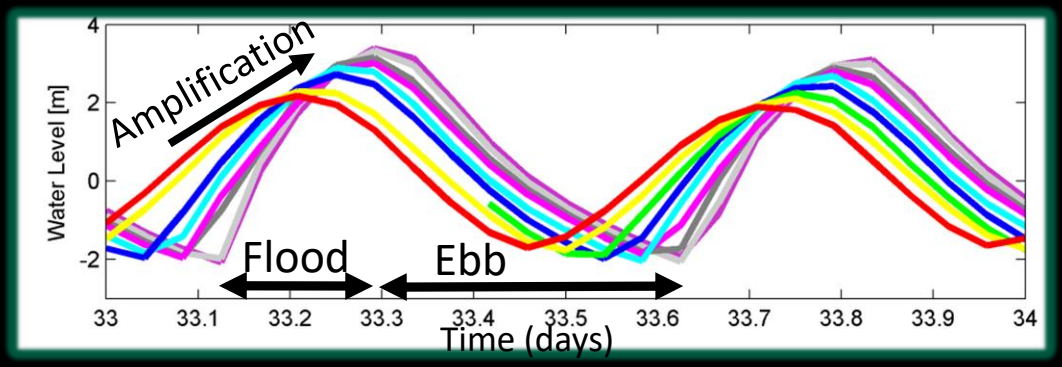
2 km to 20 m mesh size

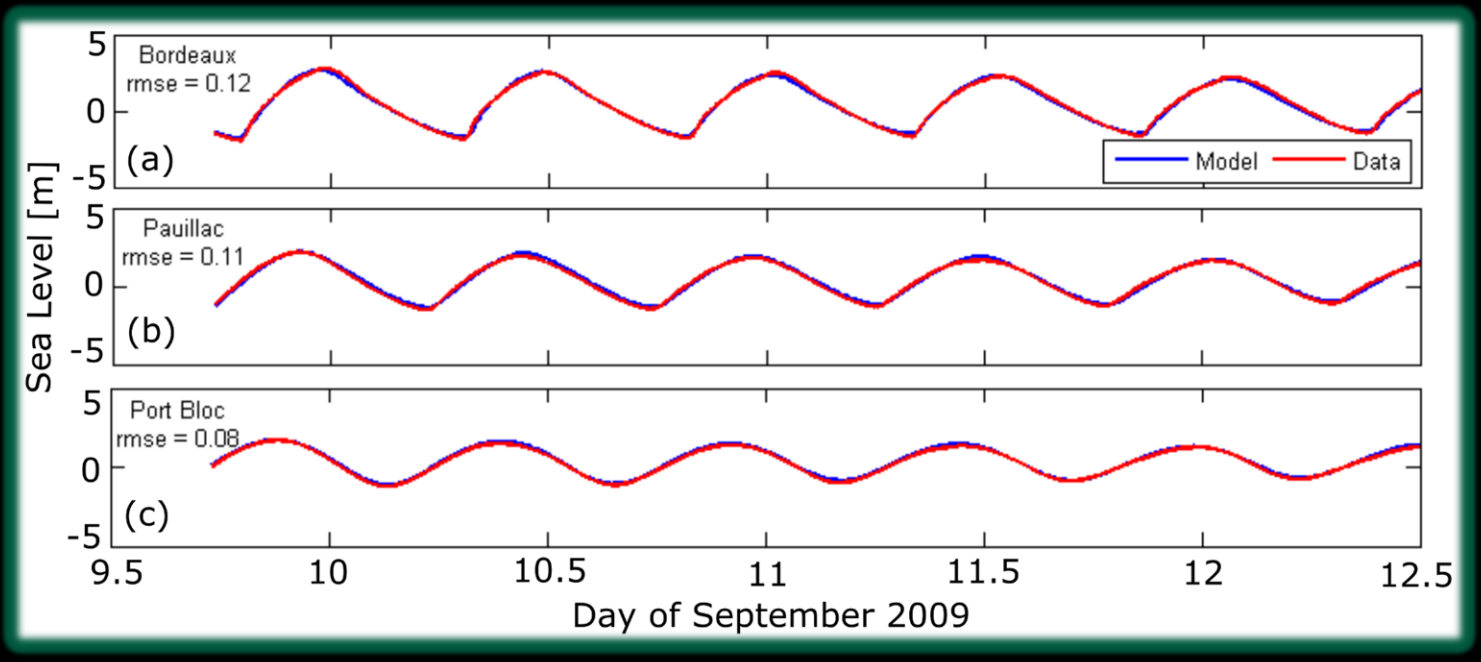
Forced by Tide



Tidal Validation

9 tide stations

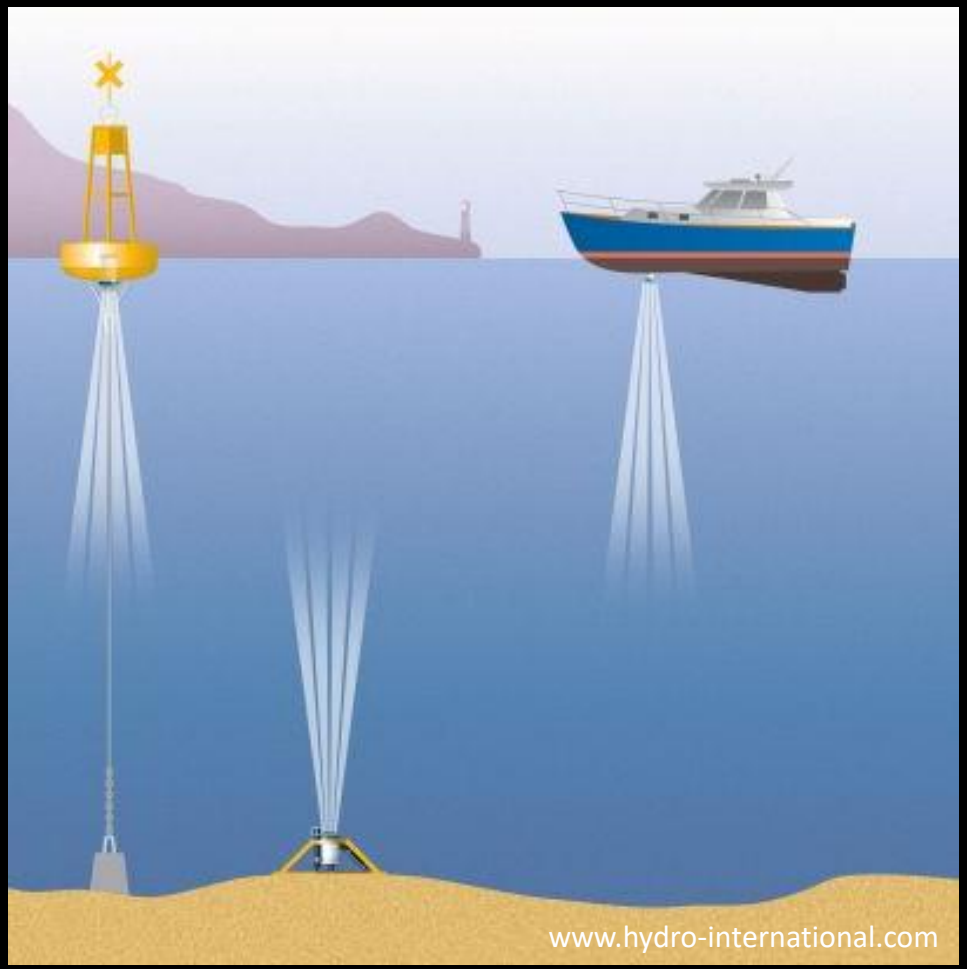




Velocity Validation

Acoustic Doppler Current Profiler (ADCP)

www.teledynemarine.com



www.hydro-international.com

Velocity Validation

1. ADCP on mooring device

2. Put in water with huge winch

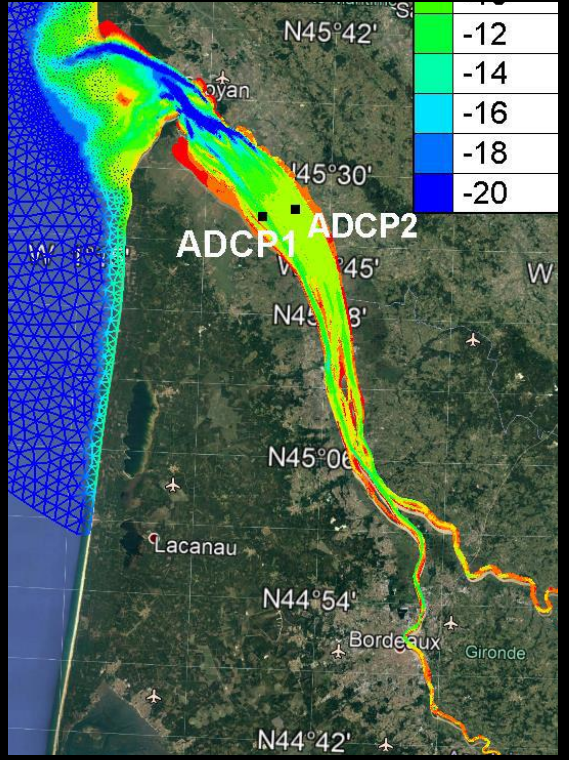
4. Drop huge anchors to make sure it stays put for 6 months

3. Let out rope attached to mooring in flood and ebb tide directions

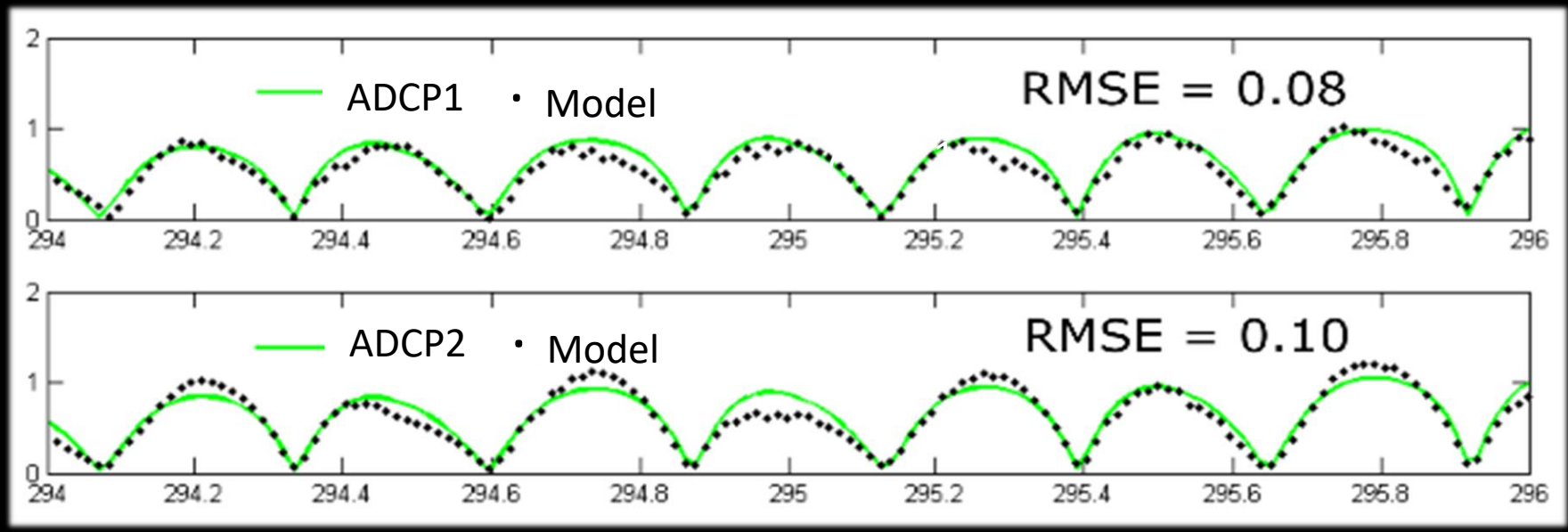
5. Hope it is still there 6 months later…

Velocity Validation

Compare model results with data



After all that work we get…



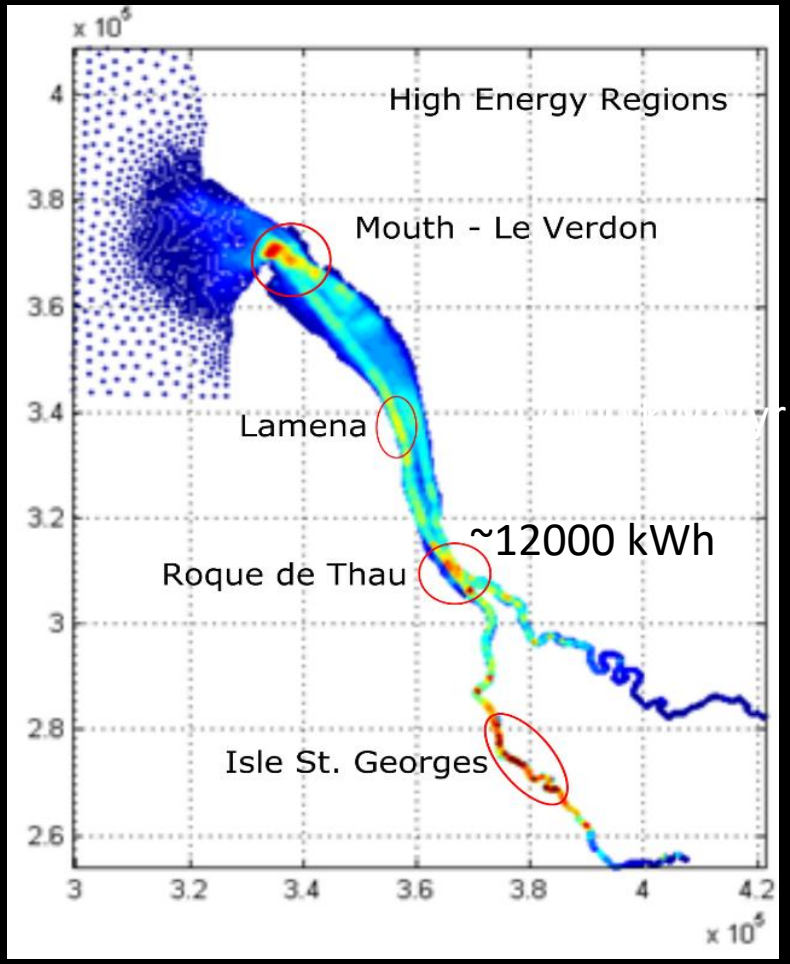
What is the best location for the turbines?

- Identify locations with highest energy potential

$$E = \sum_{t=T_0}^{t=T_f} \frac{1}{2}\rho U(t)^3 \Delta t \ [\mathrm{kWh\ m^{-2}\ yr^{-1}}]$$

  - Le Verdon
  - Lamena
  - Roque de Thau
  - Isle St. Georges
- To consider:
  - Environmental feasibility for the turbines
  - Obstruction of navigation channel
  - Proximity to an electric grid

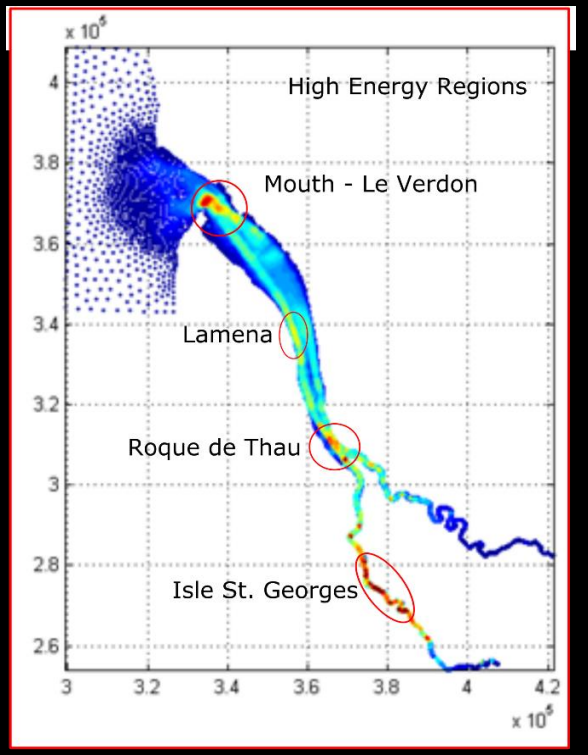
Kinetic energy power density



What is the best location for the turbines?

Turbines generate electricity ONLY when currents exceed this velocity!

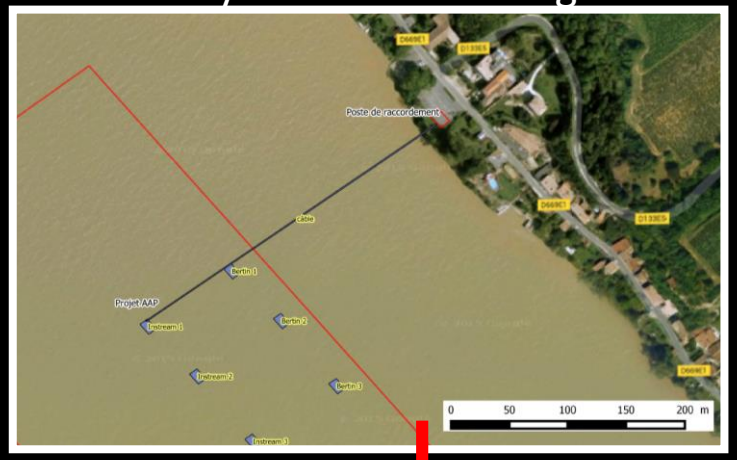
Place	% time vel >1.4 m/s (surface)
Roque de Thau	27.6%
Lamena	17.5%
~~*Isle St. Georges*~~	~~35.5%~~
~~*Le Verdon*~~	~~NOT considered due to **environmental conditions**~~

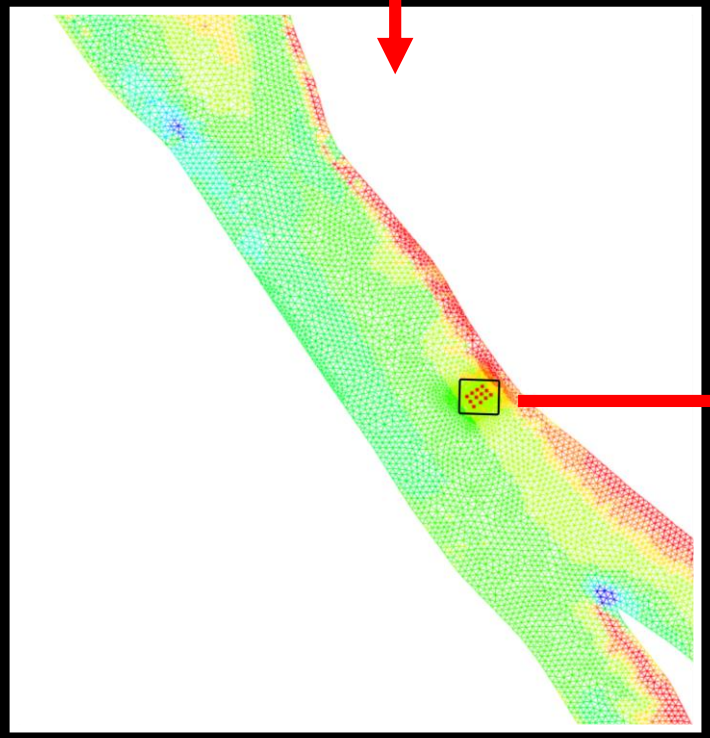


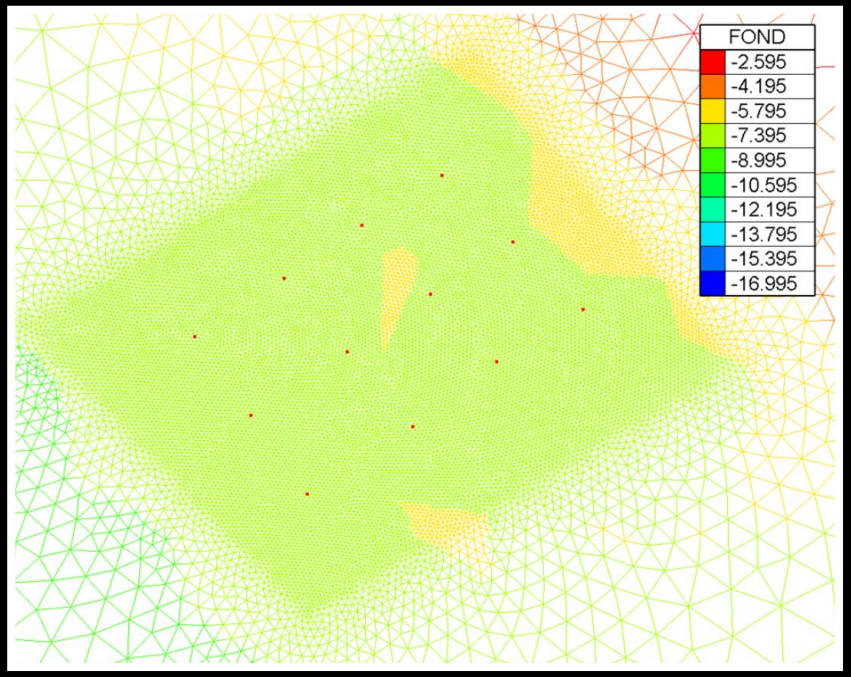
Conclusion: The turbines will be deployed at **Roque de Thau!!**

Where to put the turbines in the model?

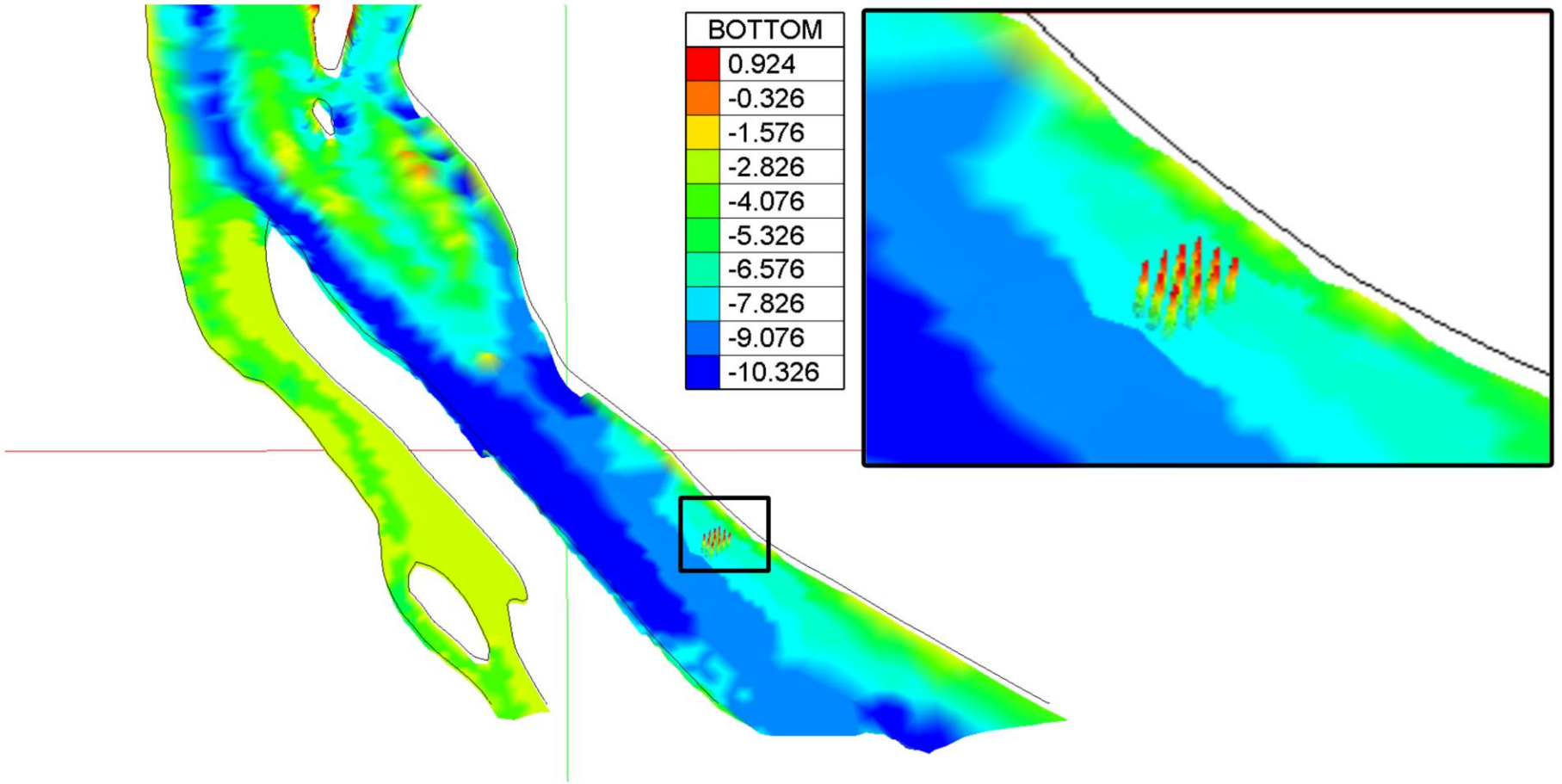
Provided by Bertin Technologies



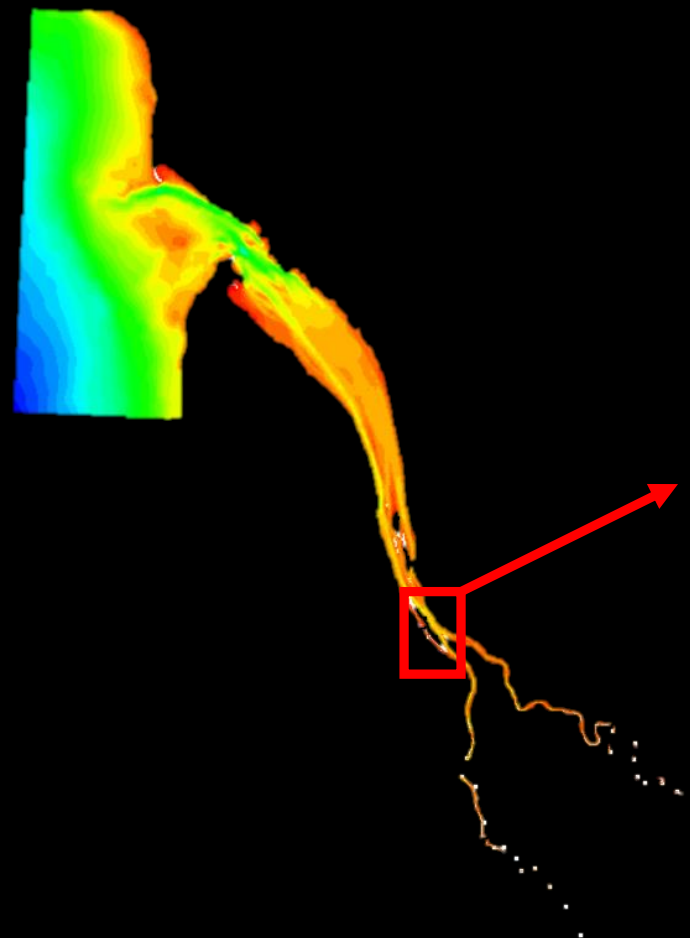


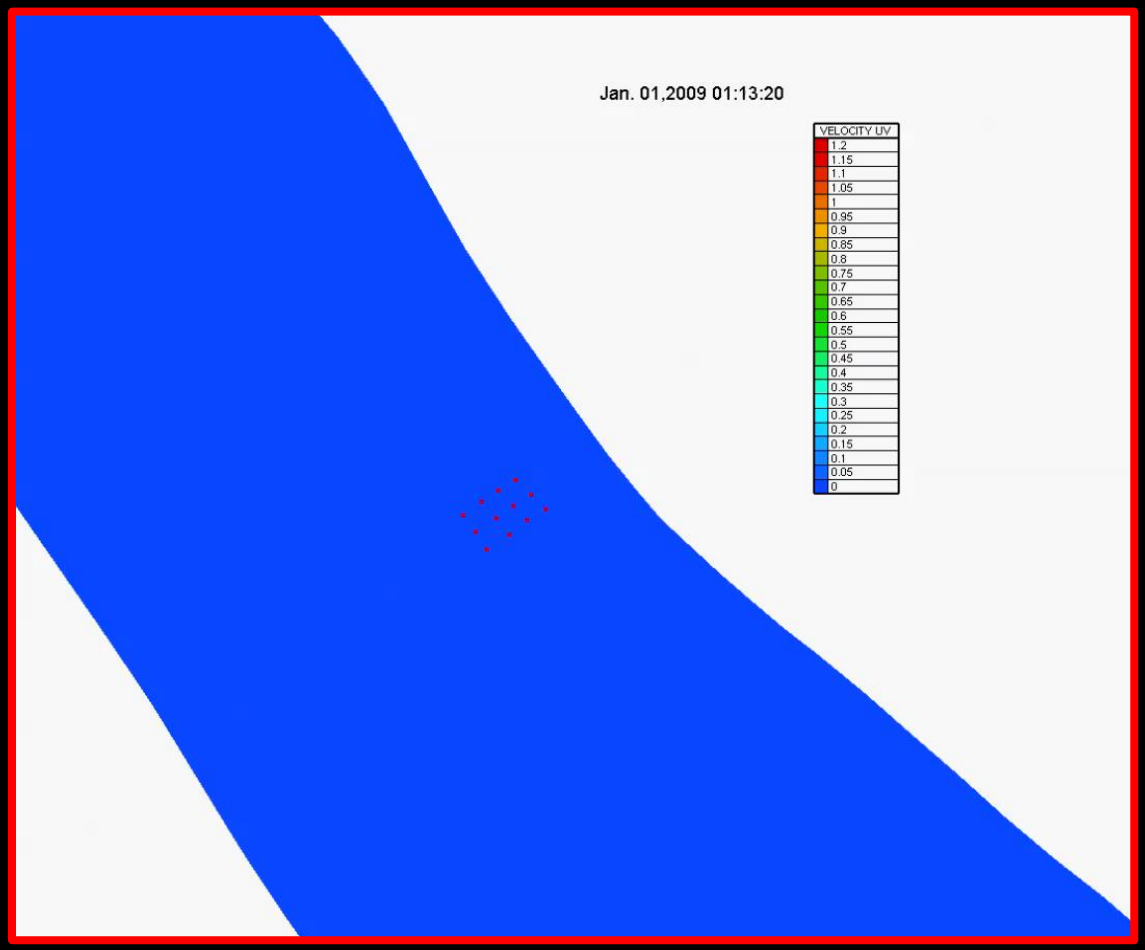


Implementation of the turbines in 3D.



Impact of the tidal turbines on the currents [m/s]





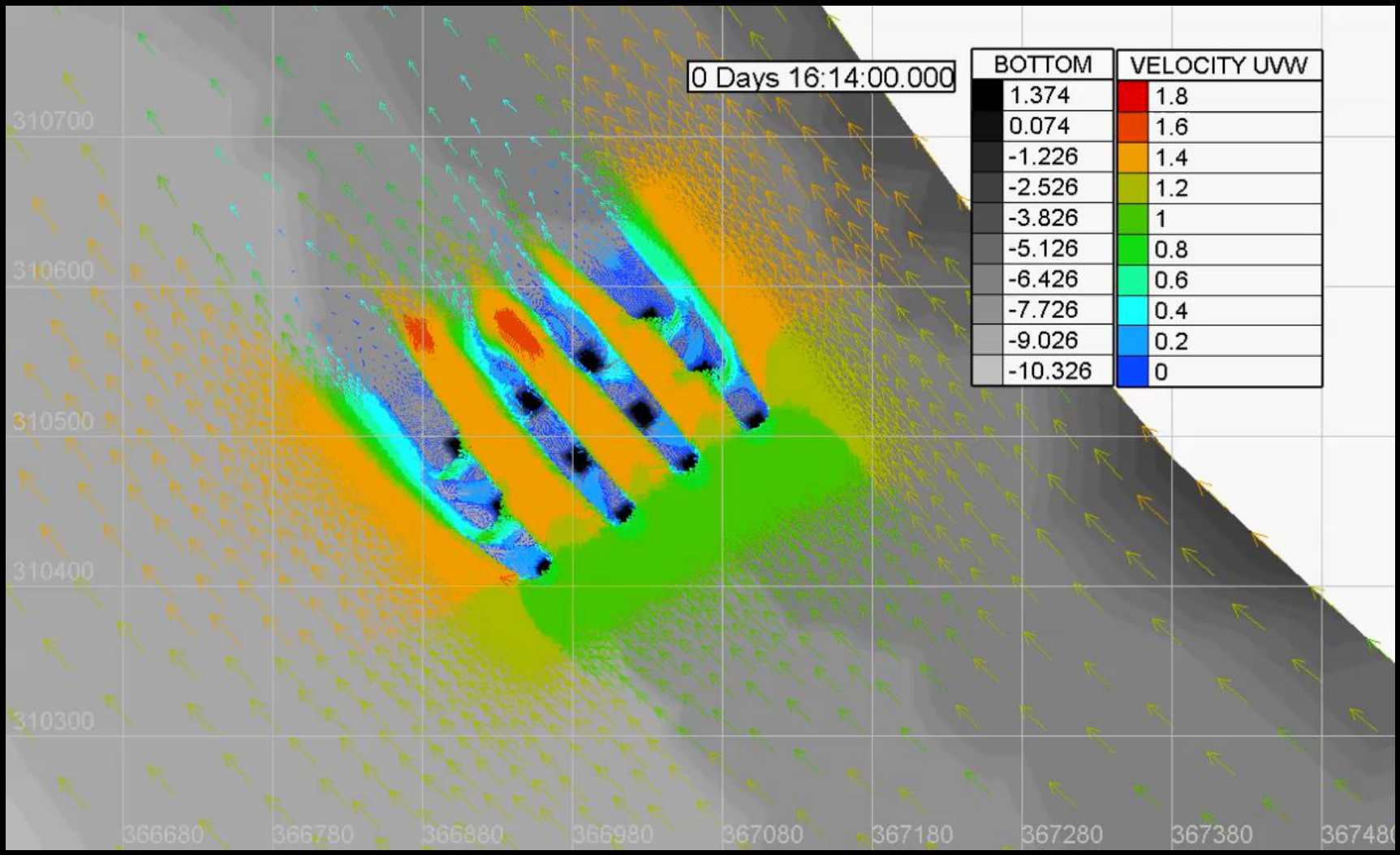
Strategic placement of turbines in a tidal estuary:

→ Reduce wake effects within the tidal array

→ Maximum energy captured from the system as a whole.

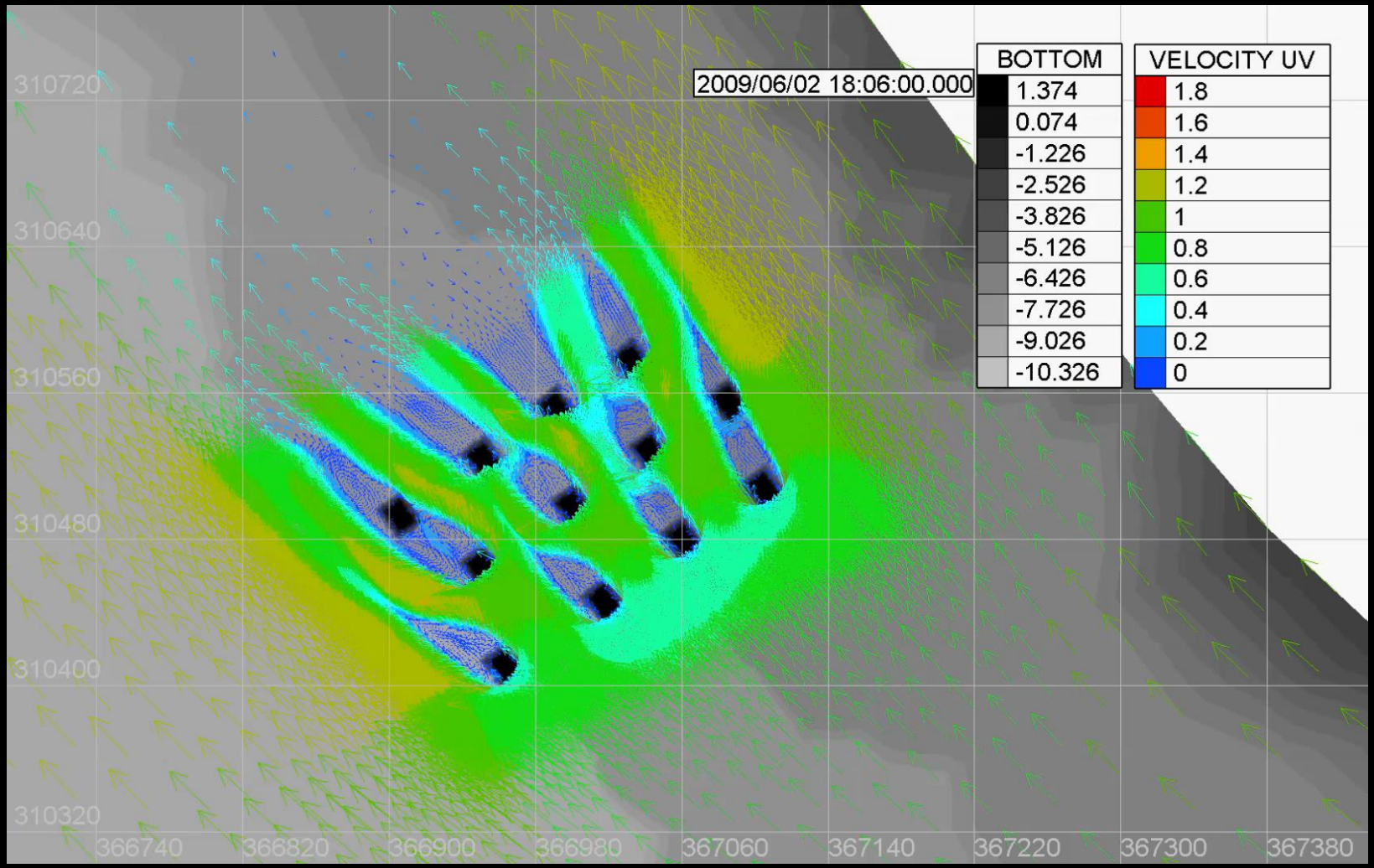
Turbines Inline Orientation

→ Wake affects, decrease energy extraction



Turbines Staggered Orientation

→ More energy potential, more environmental change

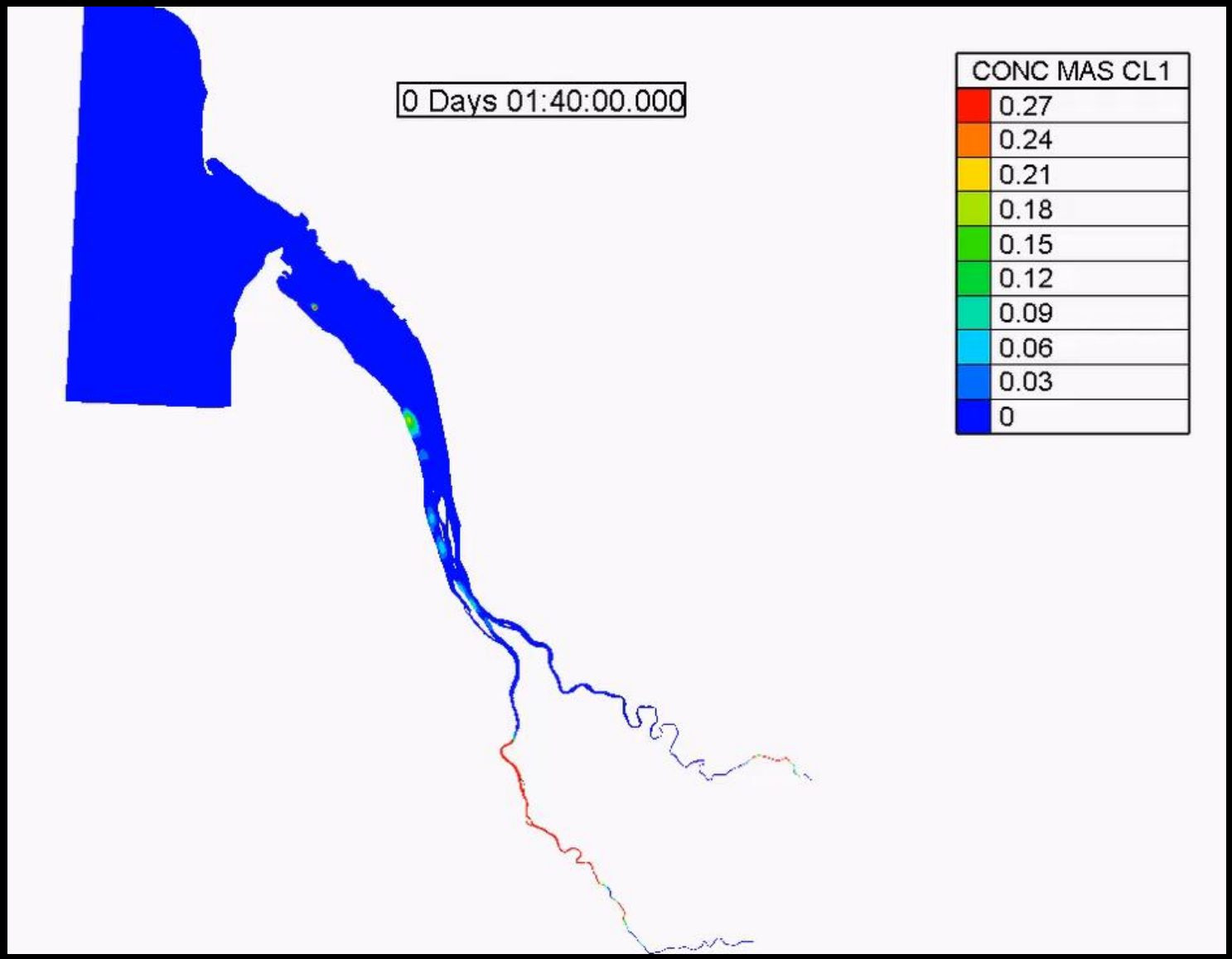


Considerations

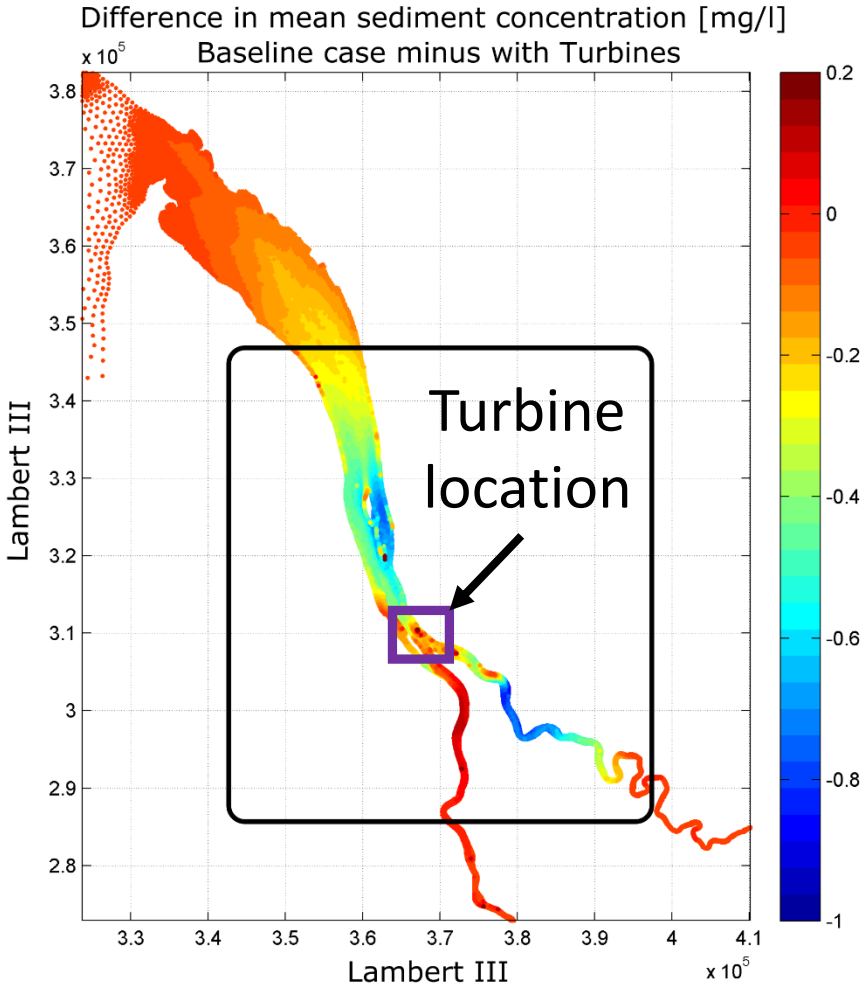
- Effect of turbines on currents
  - → change natural flow structure in the estuary, which will affect:
    - Sediments
  - → this estuary has a lot of mud!
  - → development of new morphological features
    - → we don't want any new underwater mountains created by the turbines
    - → Dredge 24/7/365

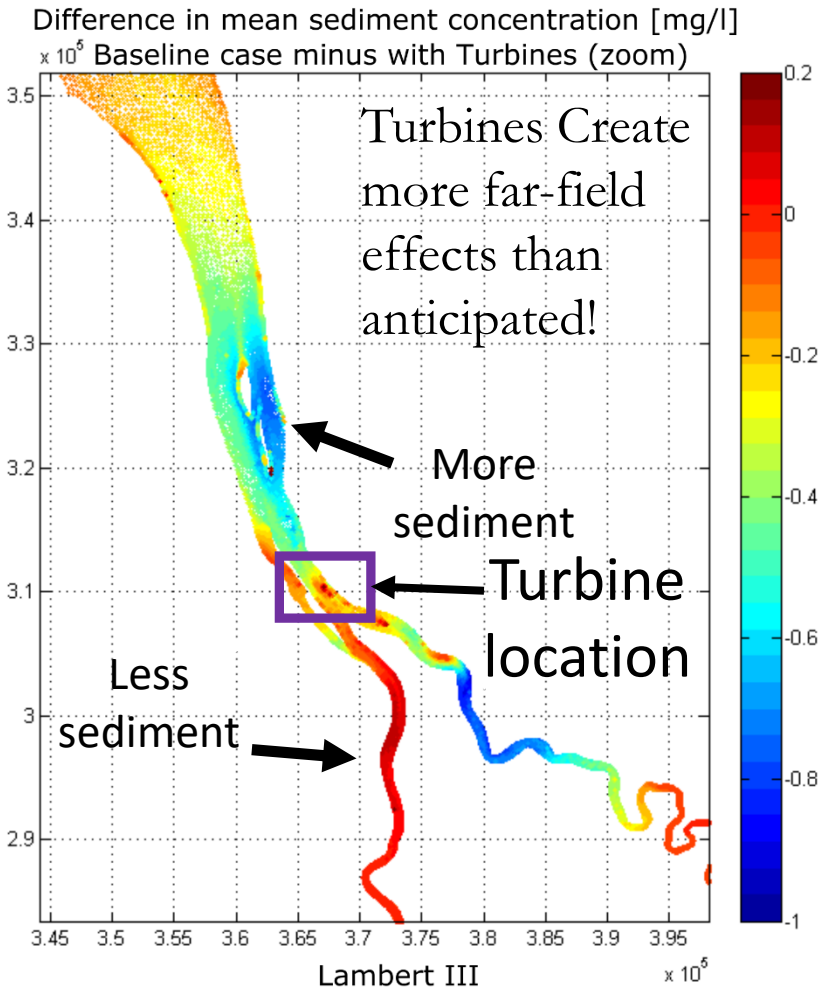
Impact on Suspended Sediment Concentration (SSC)

Start with 4,000,000 tons of sediment near the rivers to initiate



Impact of turbines on sediments in the estuary [mg/l]
Difference in sediment concentration with and without turbines





What we know:

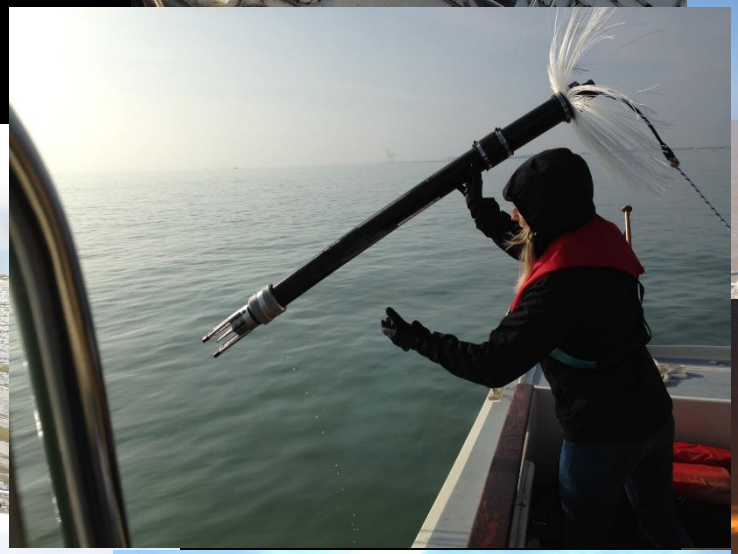
→ Climate change is an imminent threat!
  → Must turn toward more sustainable energy solutions!

→ Tidal turbines are a reliable and efficient means of generating electricity in coastal locations. With potential locally!

→ We need to better understand how implementing the turbines will affect the natural environment.

→ More prototype designs need to be developed, tested and modeled.
  → ASCC at UMaine

Acknowledgements:
Sohaib Alahmed &



Thank you!!!