A Circulation Model for the Discovery Islands, Canada: The First Step in Assessing Tidal Energy Potential and Impacts

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IOS

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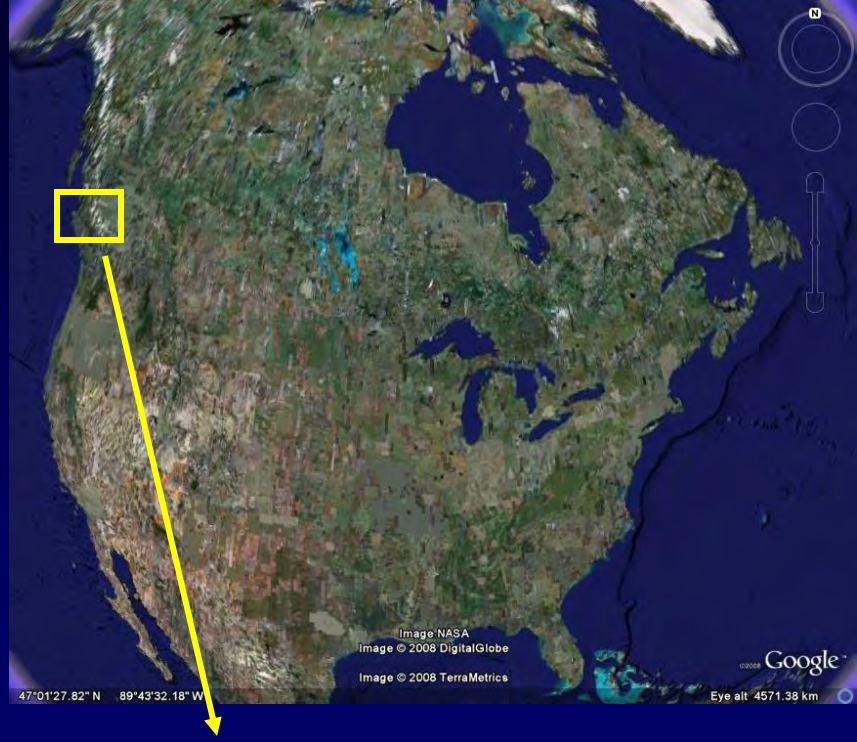
Outline

- Background
  - Region of interest
  - Previous tidal power estimates
- New model details
- Preliminary model evaluations
  - Simulation for April 1-28, 2010
- Energy flux & tidal dissipation estimates
- Summary & future work

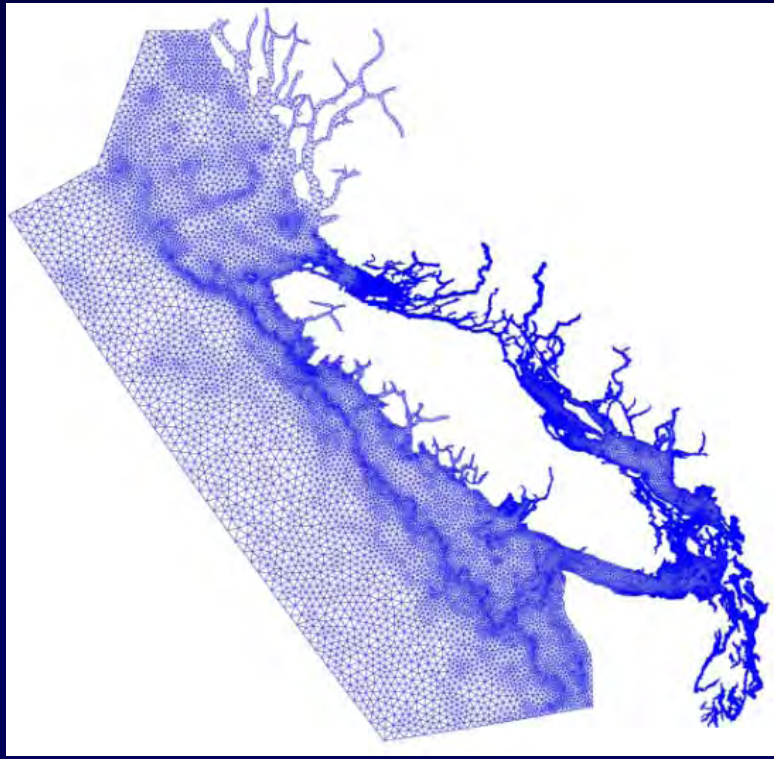
Background

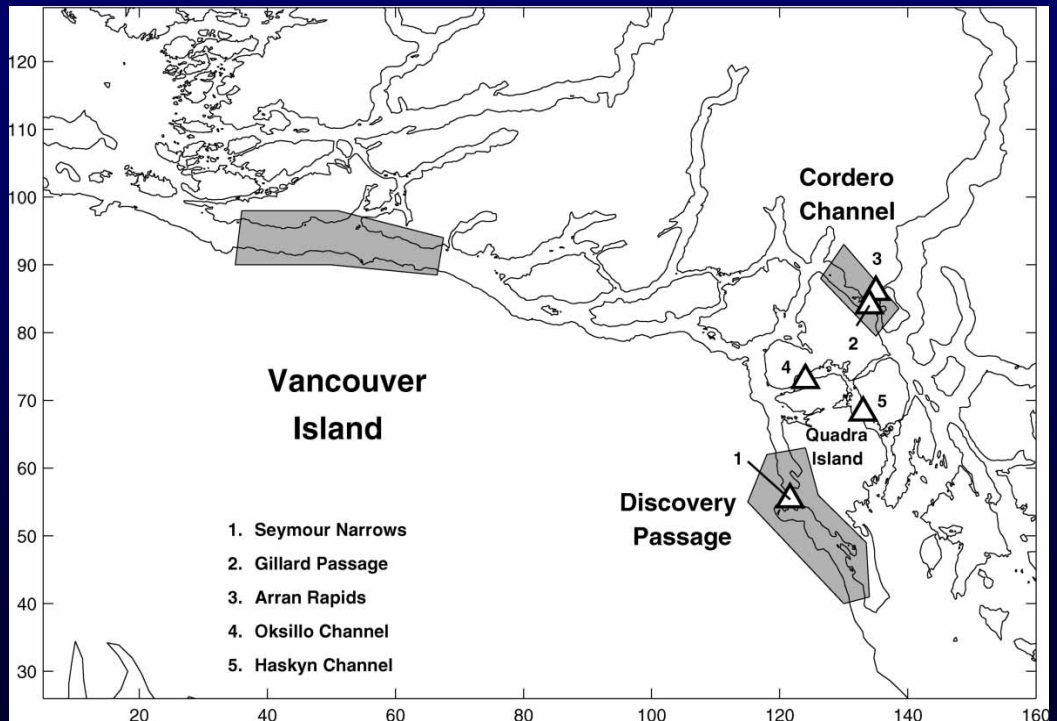
- Discovery Islands region has some of the strongest tidal currents in the world
  - M_2, S_2, N_2 elevation phases in Johnstone & Georgia Straits differ by ≈ 8 hr



Sutherland et al (2007)

- *Estimated extractable power from turbine farms in 3 regions*
- *compared Garrett & Cummins (2005) theoretical values vs estimates using 2D tidal model encircling Vancouver Island*





Sutherland et al (2007)

- At maximum power extraction, volume transport drops to 58% of natural
- In multi-channel system, placing turbines in only one channel will partially divert flow
- Far-field effects of power extraction:
  - M_2 degenerate amphidrome off Victoria shifts eastward
  - in Strait of Georgia, elevations decrease by approx 5%, currents change by 1-2 cm/s

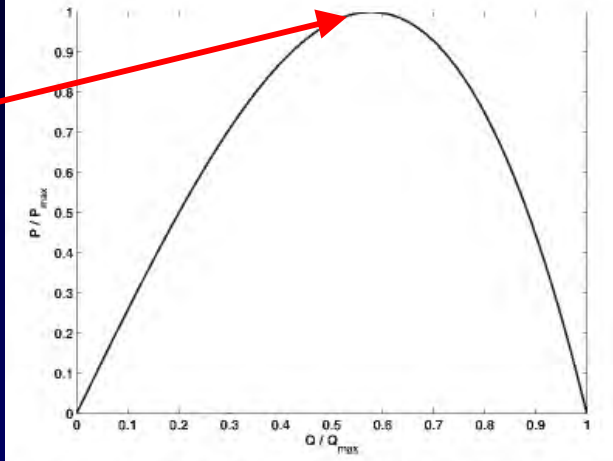


Fig. 2 The variation in the extractable power as a function of the reduced volume flux due to the presence of turbines for the situation in which there is a quasi-steady force balance in the natural state between pressure head and friction [1]. The volume flux is expressed as a fraction of the peak volume flux in the natural state and the power as a fraction of the maximum that can be extracted

Table 1 Results from simulating turbines in certain regions of Johnstone Strait

Location	Theoretical dissipation (MW)	Modelled dissipation (MW)	Percent vol. flux at max dissipation
Discovery Passage w/ Cordero closed	826	886	58
Johnstone Strait	1320	1335	58
Discovery Passage	573*	401	57
Cordero Channel	598*	277	58

Asterisks denote power estimates for channels where the water can be diverted and equation (1) is no longer valid.

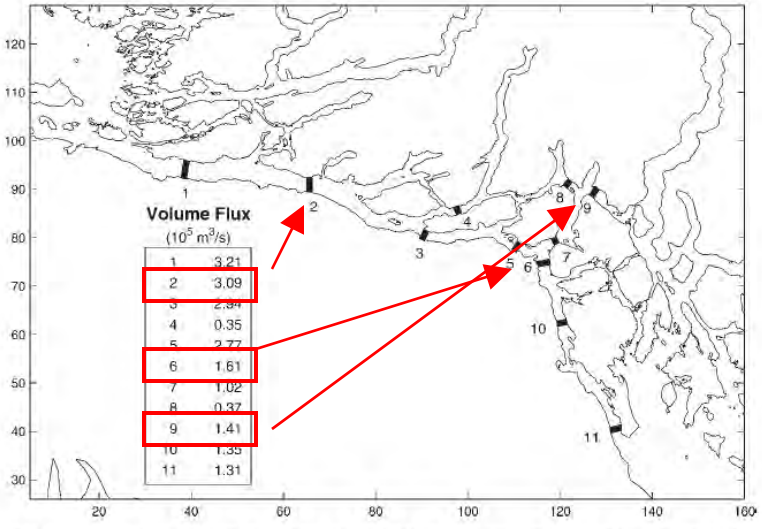
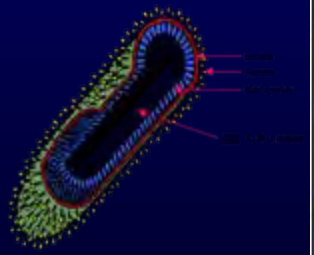


Fig. 6 Volume flux through Johnstone Strait with no channels blocked. The axes give the horizontal distances in kilometres

Discovery Islands Model

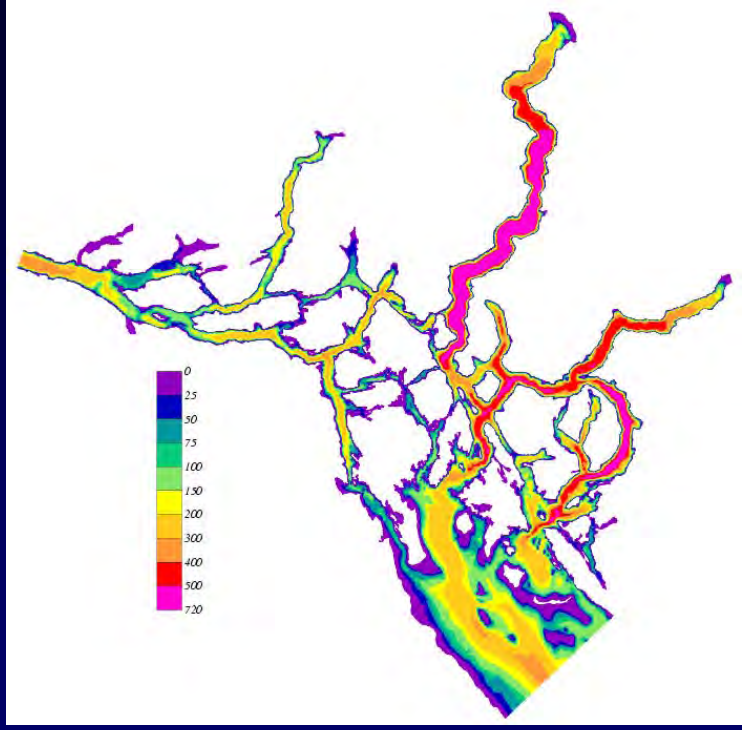
- Objective: Develop coupled biological-physical models to help salmon farms address
  - dispersion of sea lice to wild salmon
  - IHN virus transport from one farm to others

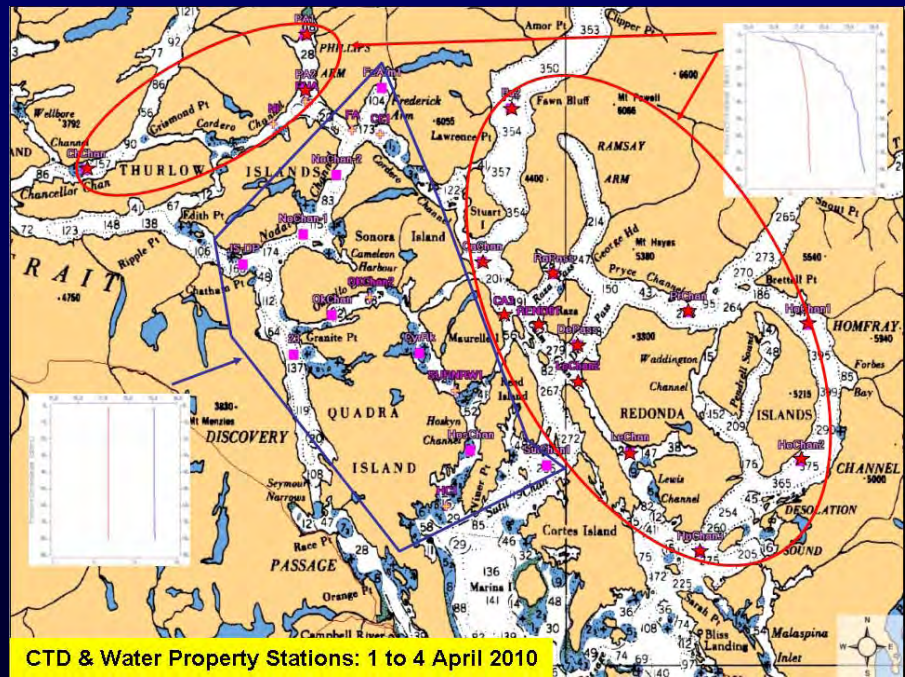
- Physical model must be 3D and include non-tidal forcings
  - Can also be used to study tidal power issues



Model Challenges

- Strong tidal currents
- Deep fiords with seasonal river discharges
  - Strong stratification
- Strong mixing among the islands





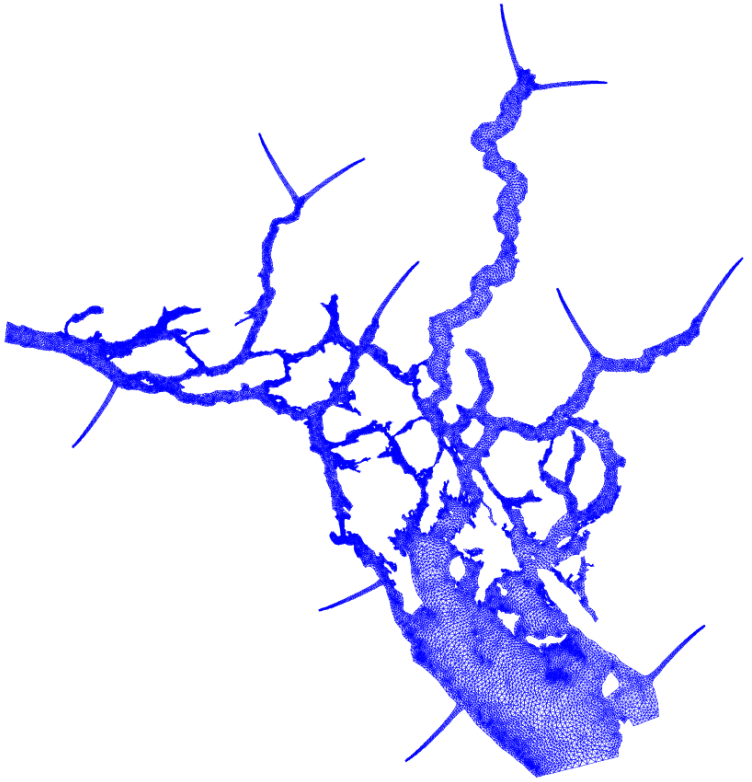
Grid

Horizontal:

- 37596 nodes, 68467 triangles
- Resolution from 1.7km to 90m
- 11 rivers

Vertical:

- 20 unequally-spaced sigma coordinates



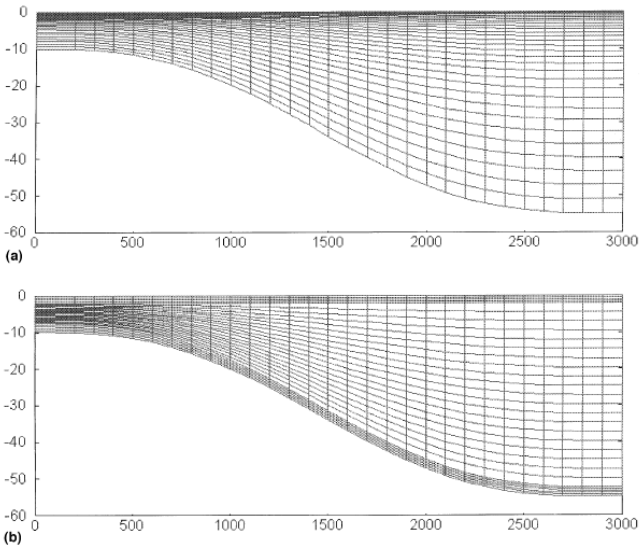
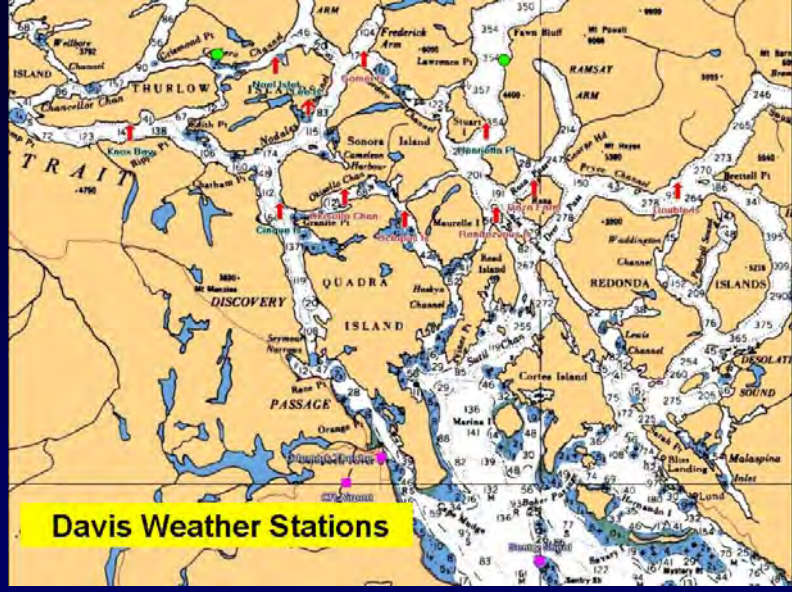


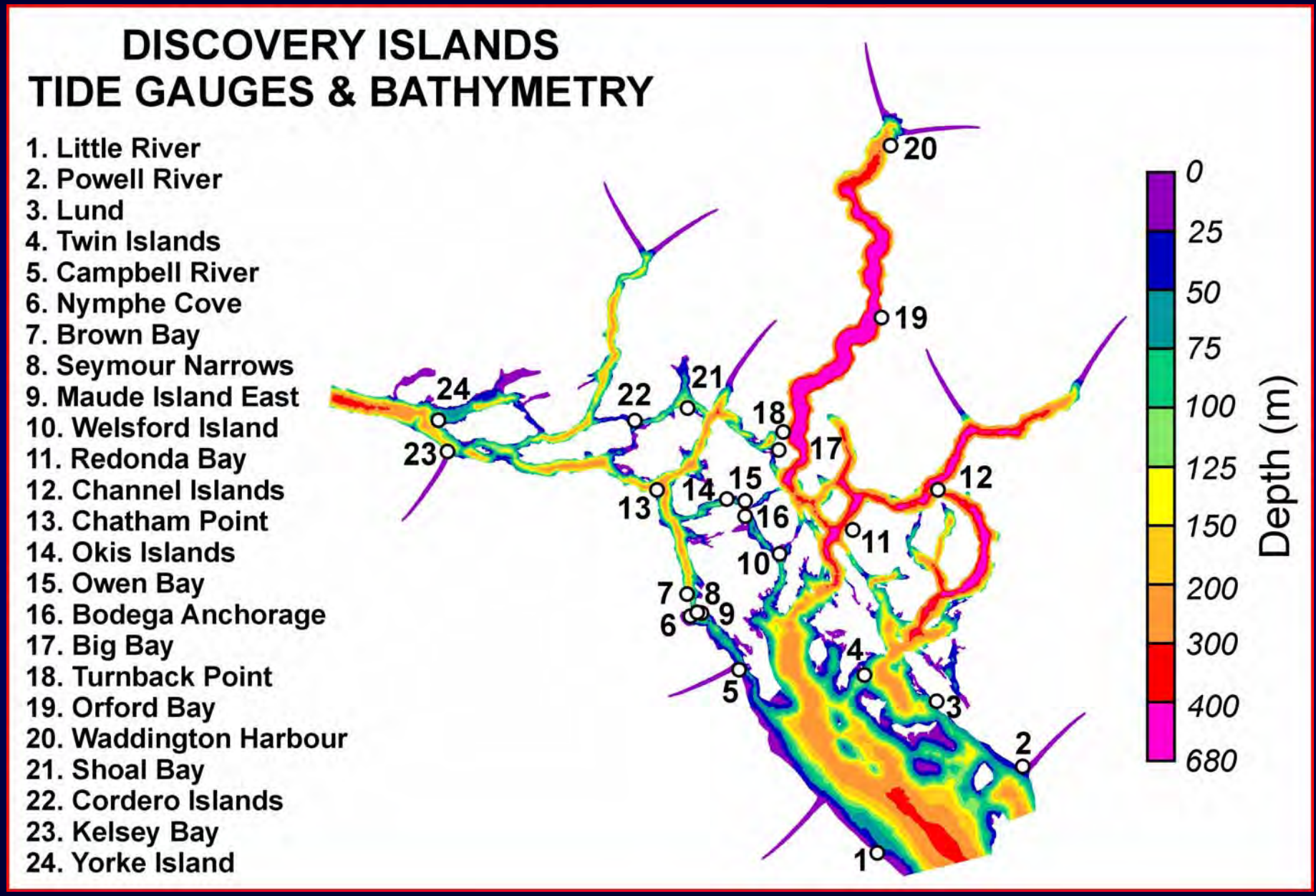
Fig. 1. Examples of the non-equidistant sigma co-ordinate grid with: (a) high resolution near the surface and (b) the constant layer transformation with co-ordinates parallel to the bottom and surface.

Model Details

- FVCOM (version 2.7.1)
  - 3D baroclinic, hydrostatic
  - q-ε turbulent mixing
  - M_2, S_2, N_2, K_1, O_1 tides
  - Atmospheric forcing from weather stations
  - Initial 3D temperature & salinity fields from CTD surveys
  - Radiation/nudging bcs
  - April 1-28, 2010 hindcast on 64 Intel processors took approx 38hr

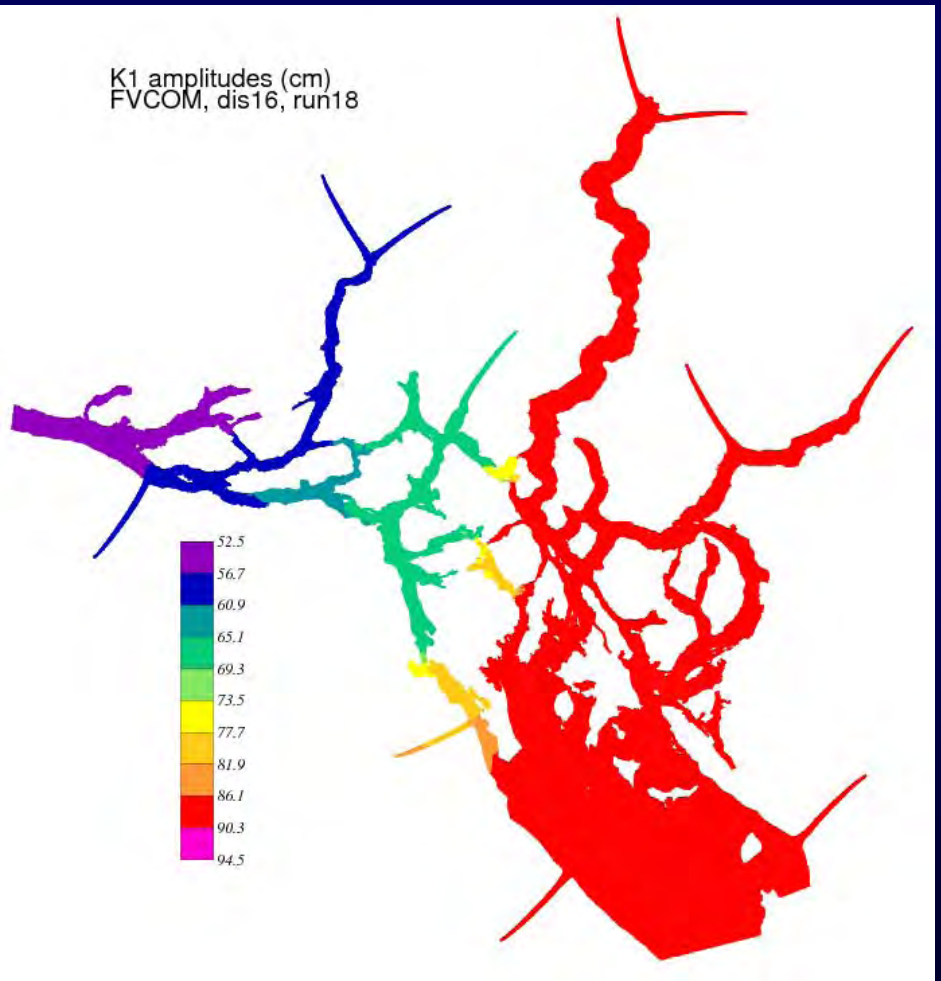


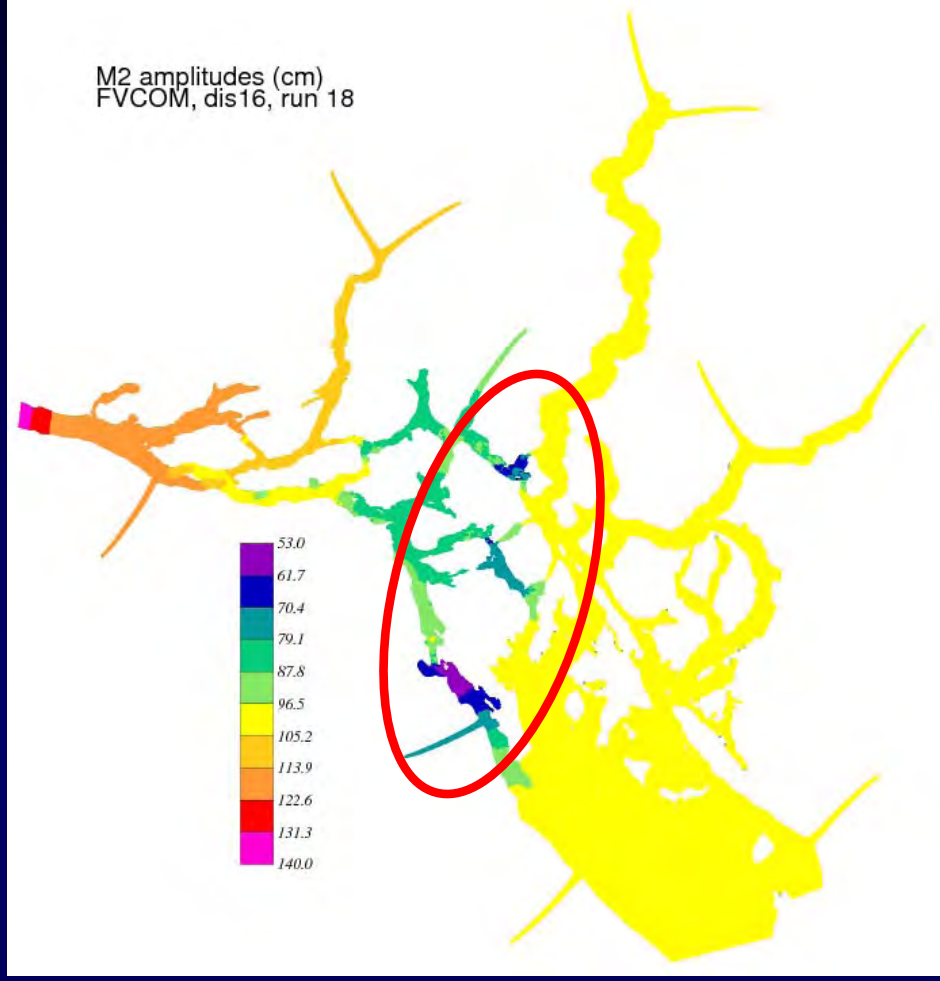
Model Tidal Evaluations



- *24 tide gauges with historical time series longer than 169 days*

Preliminary M_2 & K_1 Elevation Amplitude Evaluations

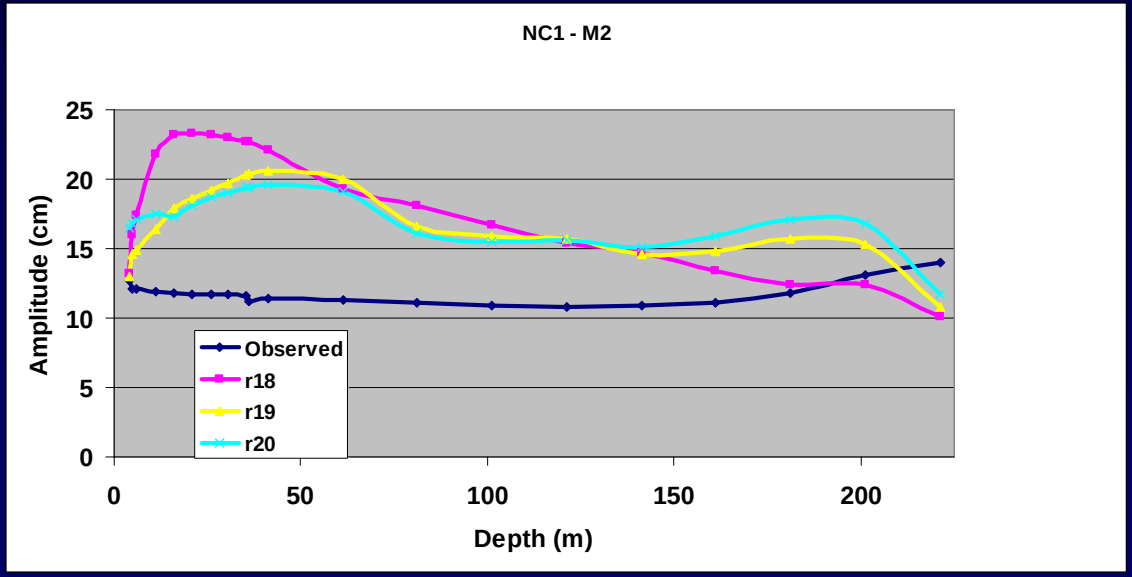


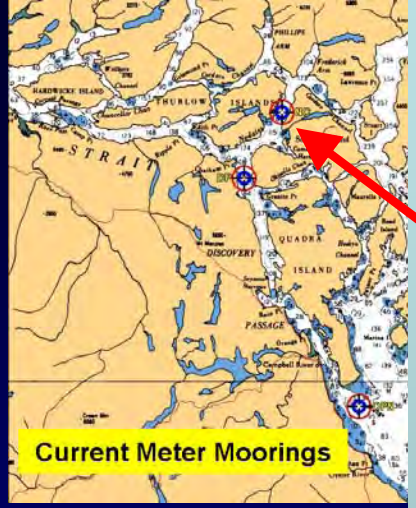


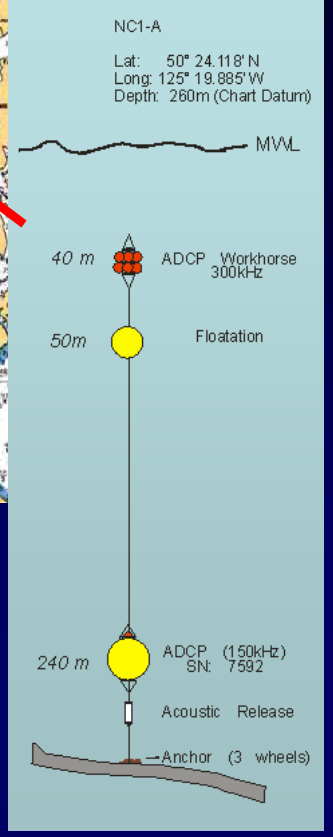
Average amp/phase errors vs 24 tide gauge locations

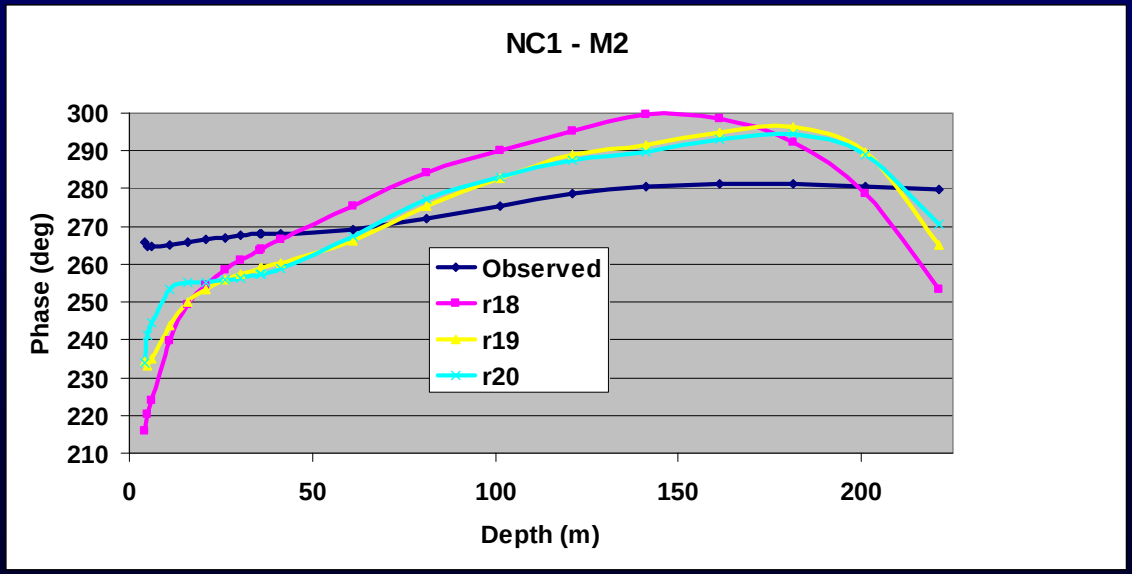
- *distance in complex space*
- *M_2: 4.0 cm*
- *K_1: 3.0 cm*

Preliminary M_2 Current Speed & Phase Evaluations



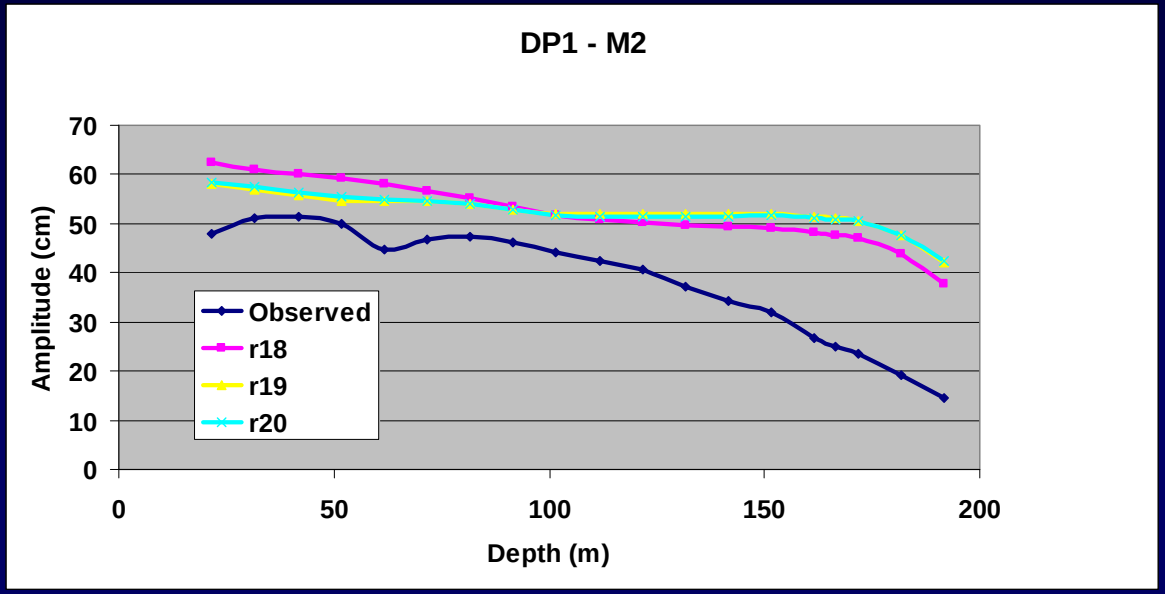


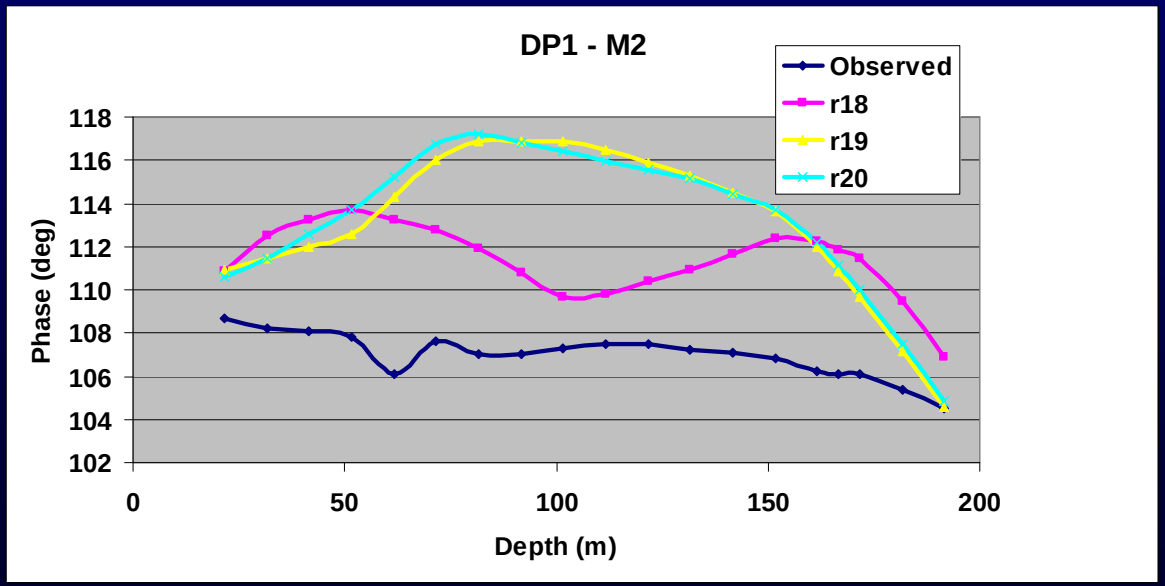


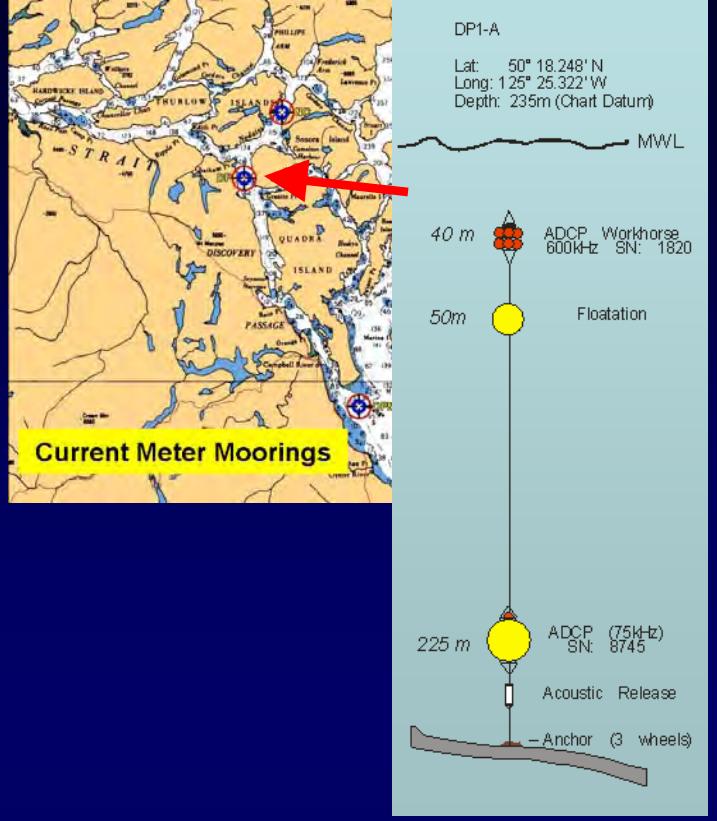


- Model speeds are too large
- Phases (timings) are too soon near-surface & too late at depth (30° ≈ 1 hour)
- Suggests we don't have vertical mixing/dissipation right

Preliminary M_2 Current Speed & Phase Evaluations

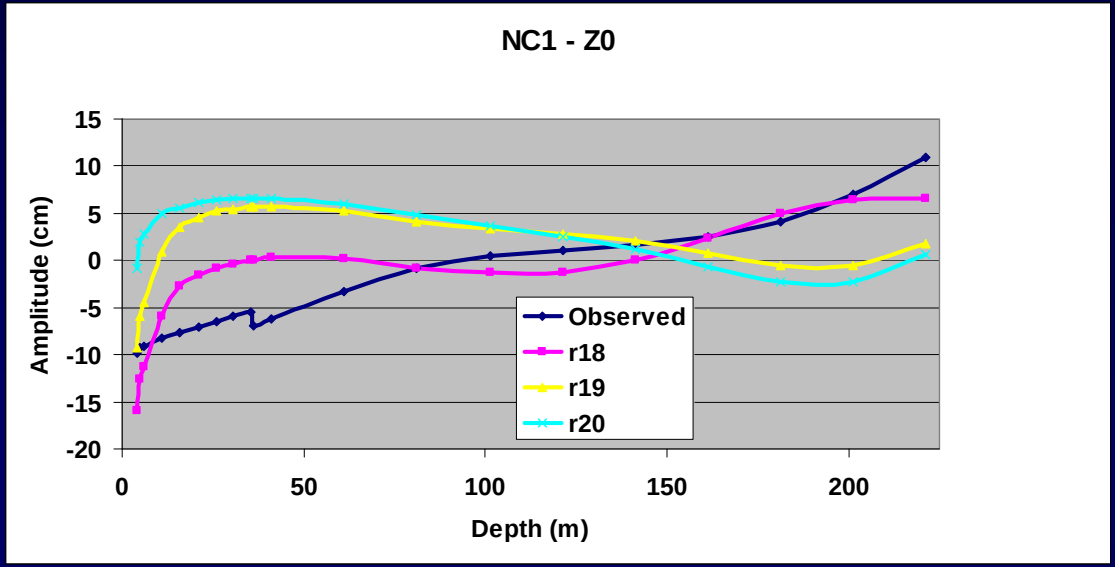


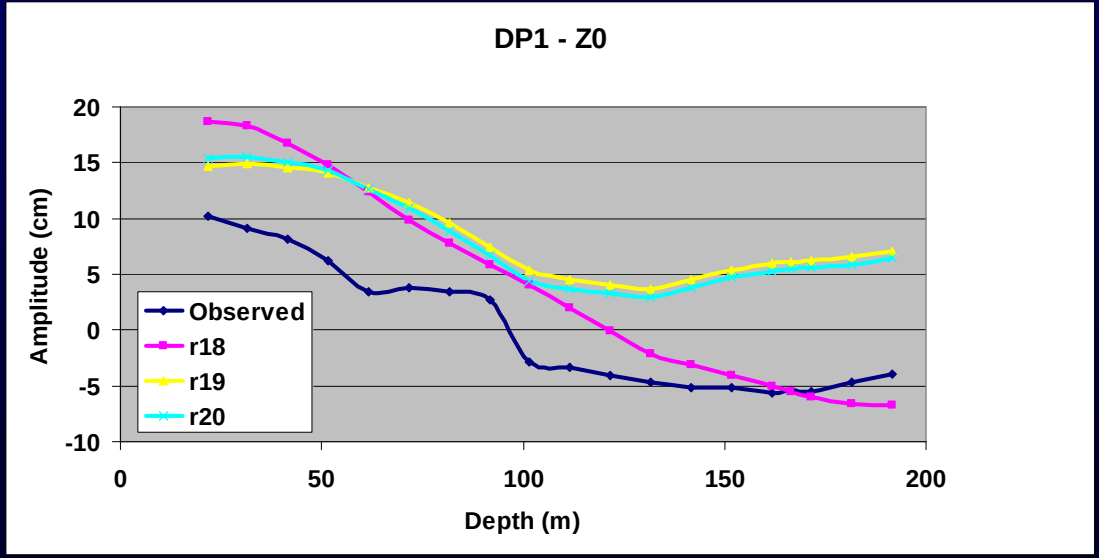


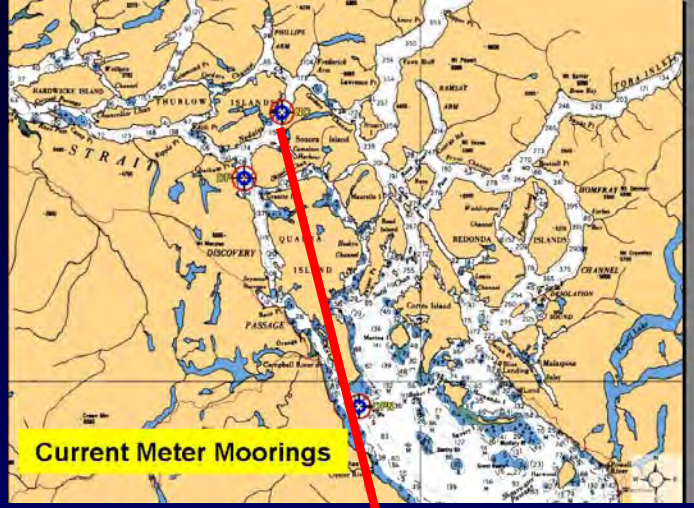


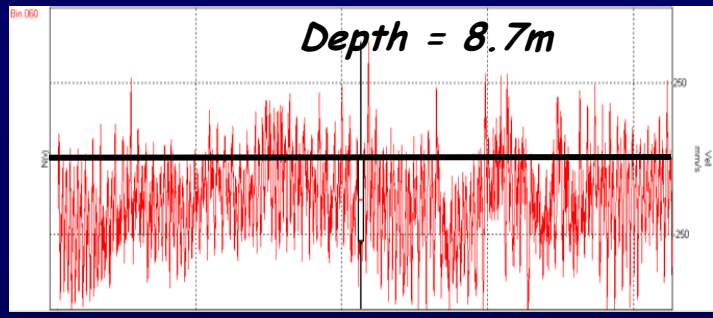
- *Model speeds are too large*
- *Phases are too late at all depths*
- *Again, suggests problem with mixing/dissipation*

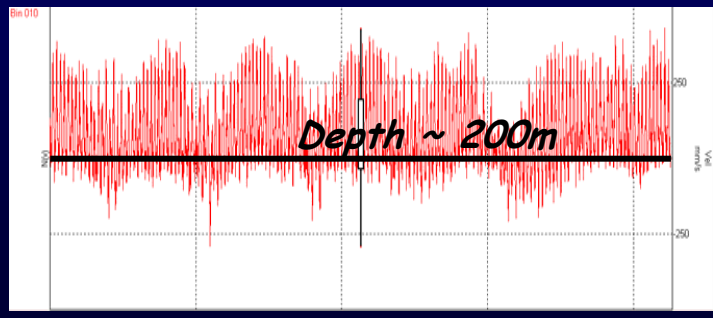
Preliminary Mean Current Evaluation





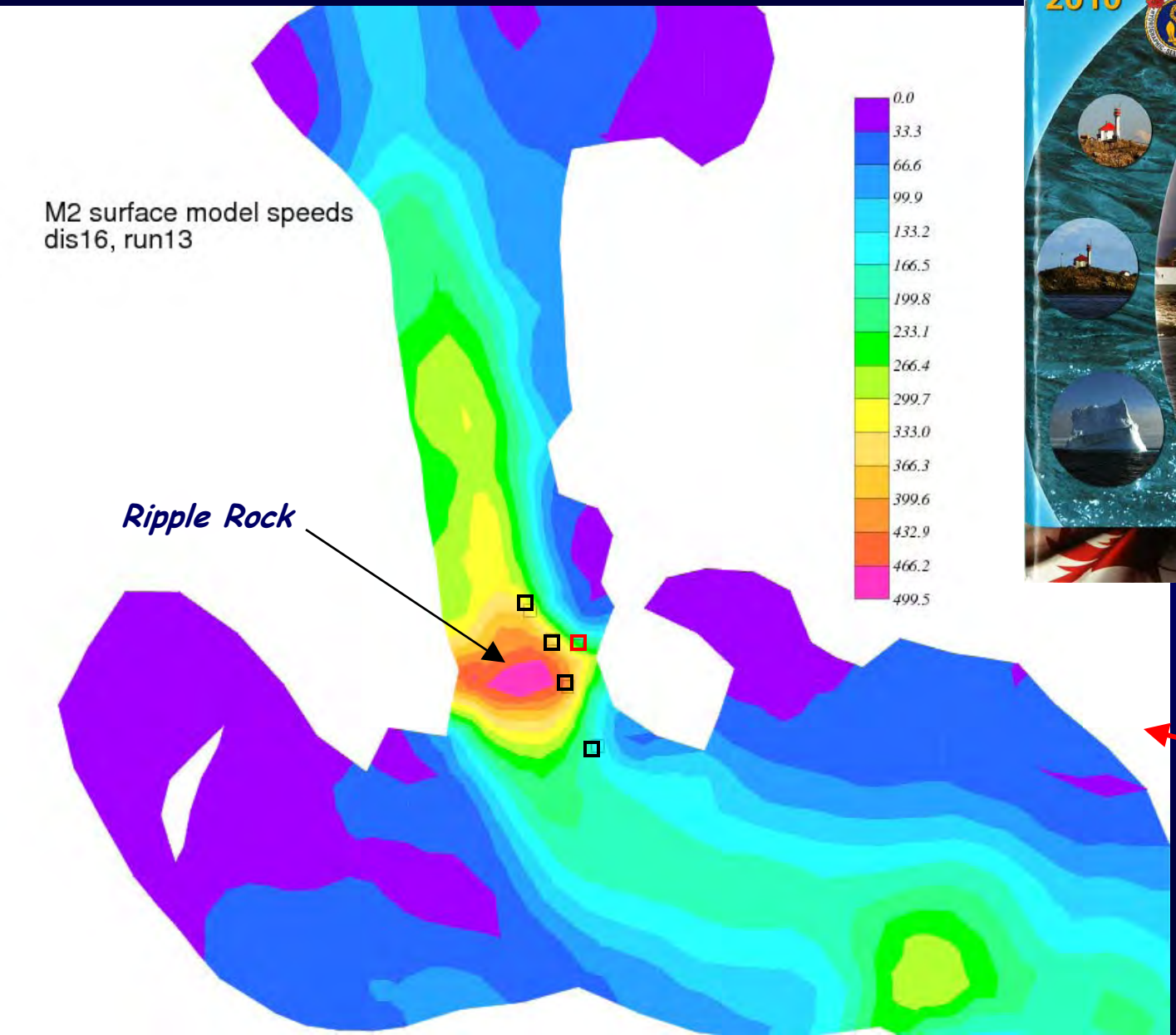


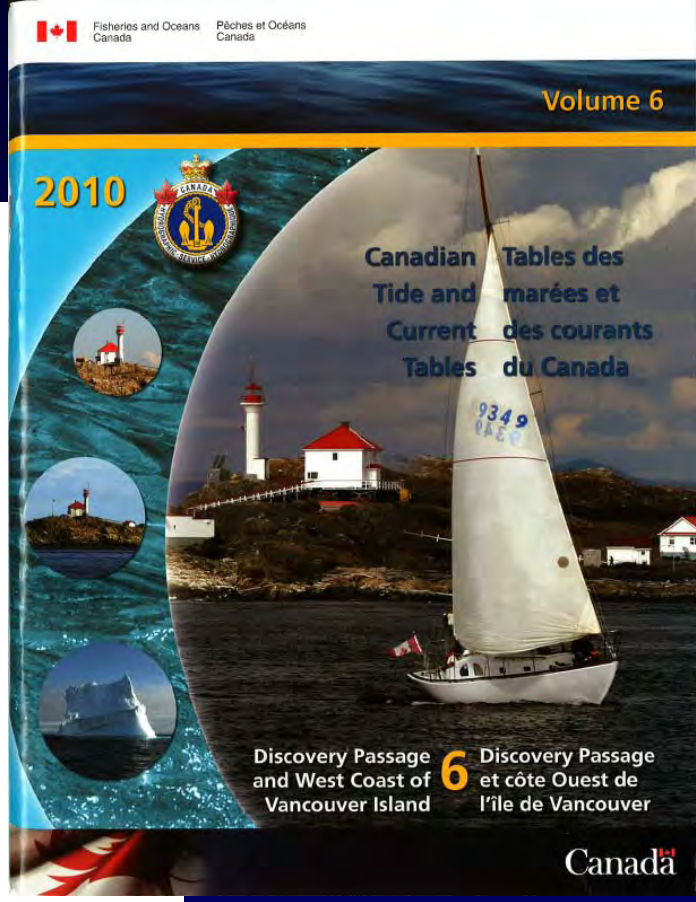


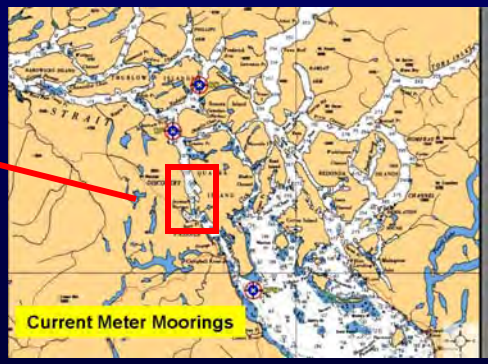


positive is to NE

Model Currents Evaluation vs Tide Table Observations







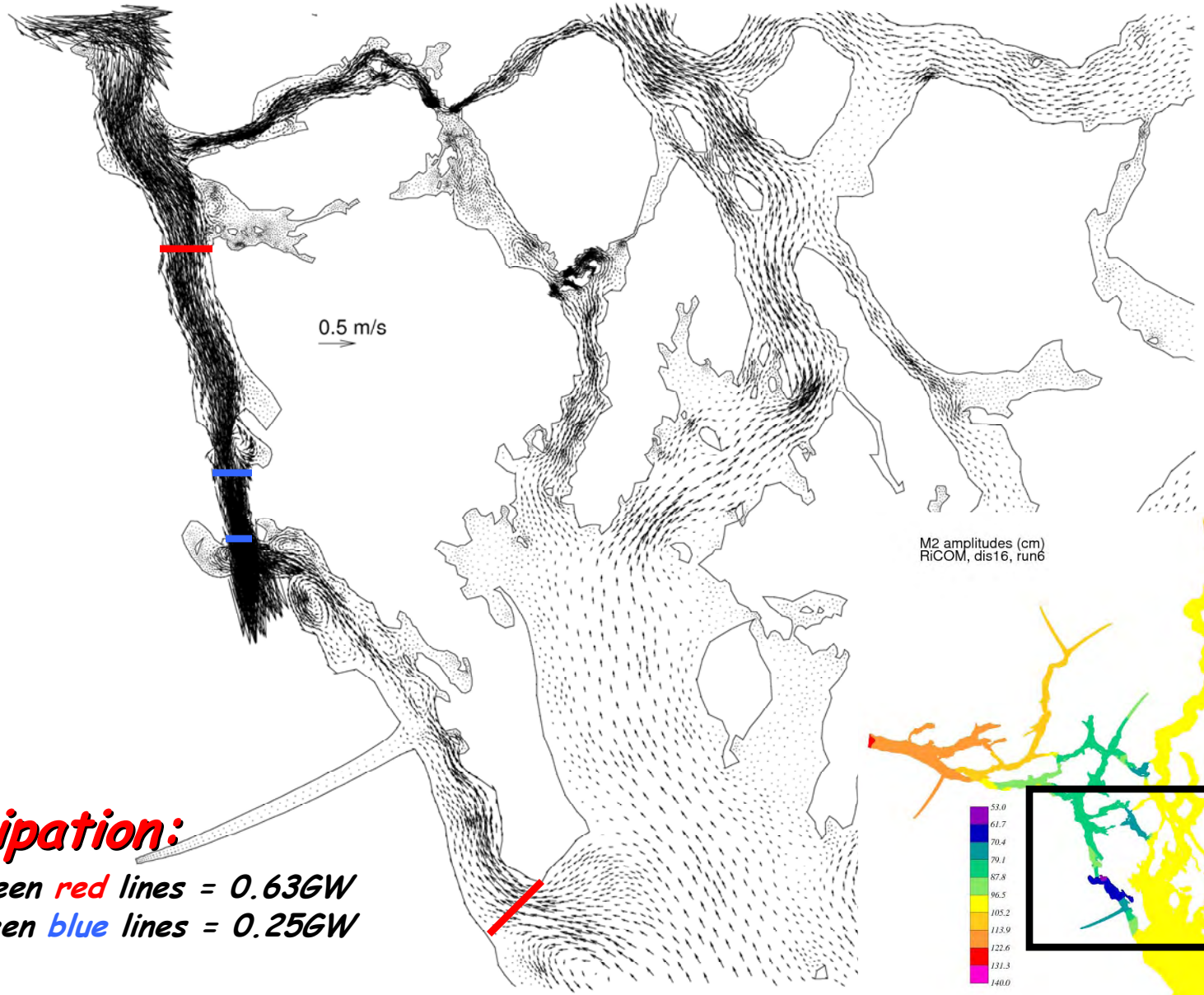
Seymour Narrows

FVCOM M_2 Surface Current Evaluation

site	Model speed	Model phase	Observed speed	Observed phase
Arran Rapids	373.2	264.4	456.4	266.7
Beazley Passage	335.5	91.4	369.4	85.4
Gillard Passage	154.0	88.0	355.8	91.2
Hole-in-the-Wall	380.8	267.1	373.3	269.0
Seymour Narrows	374.8	110.8	466.1	112.9
Ripple Rock	491.9	115.6	???	

- Pretty good except at Gillard (?)
- Observed currents need to be re-analysed
- Current locations used in Tide Tables need more accuracy

M_2 Energy Flux & Dissipation



Dissipation:

- between red lines = 0.63GW
- between blue lines = 0.25GW

Summary & Feasibility

- Despite the challenging region, FVCOM is reasonably accurate for tidal elevations
  - But need to understand & fix current inaccuracies vs depth
- Feasibility needs to consider environmental impacts (e.g., salmon migration), transportation (e.g., cruise ship & barge traffic in Discovery Passage), access to power grid, etc
  - Proto-type installation now being studied by ASL Environmental Sciences in Canoe Pass off Discovery Channel

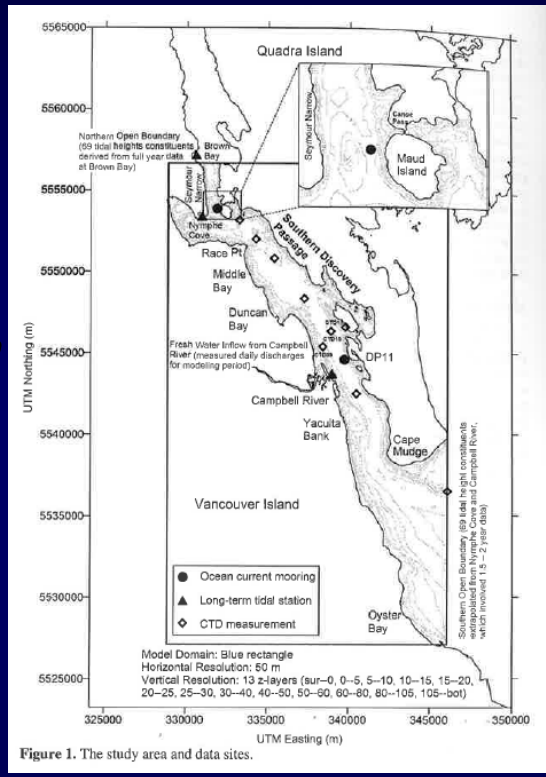


Figure 1. The study area and data sites.

Jiang & Fissel (2010)

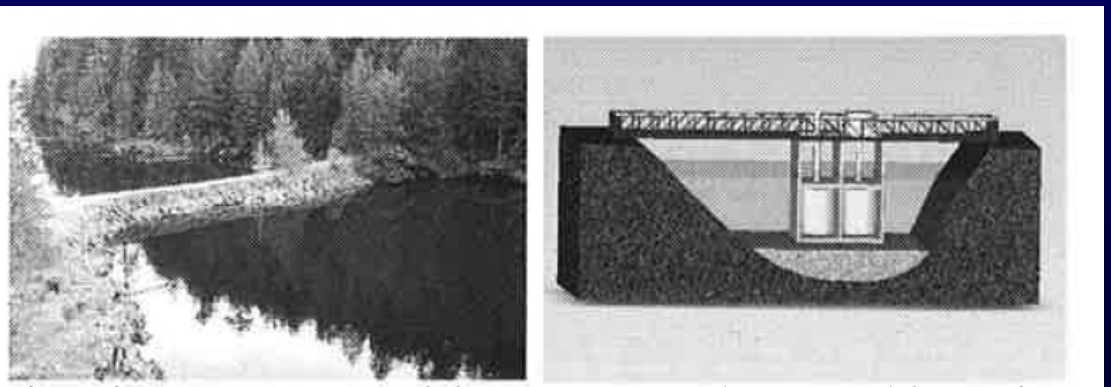
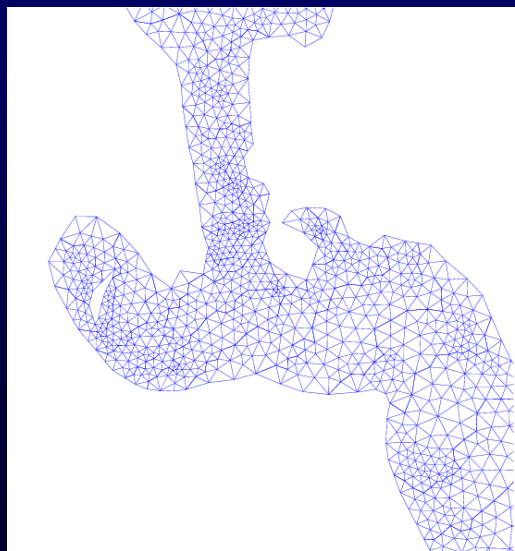


Figure 6. Photo (left) showing existing rock dam and depicted graph (right) showing replacement of the dam with two underwater turbines.

Future Work

- **Model simulations:**
  - Incorporate winds & heat flux
  - Improve current accuracy
  - Evaluate model temperature & salinity time series vs observations
  - Implement newer/faster version of FVCOM
  - Move to higher resolution grid

- **Re-analyse near-surface historical current measurements**



- **Repeat Sutherland et al. (2007) turbine experiments**


Thanks for your Interest