Uncertainties in Modelling Water-borne Disease Transmission among Salmon Farms in the Discovery Islands, British Columbia

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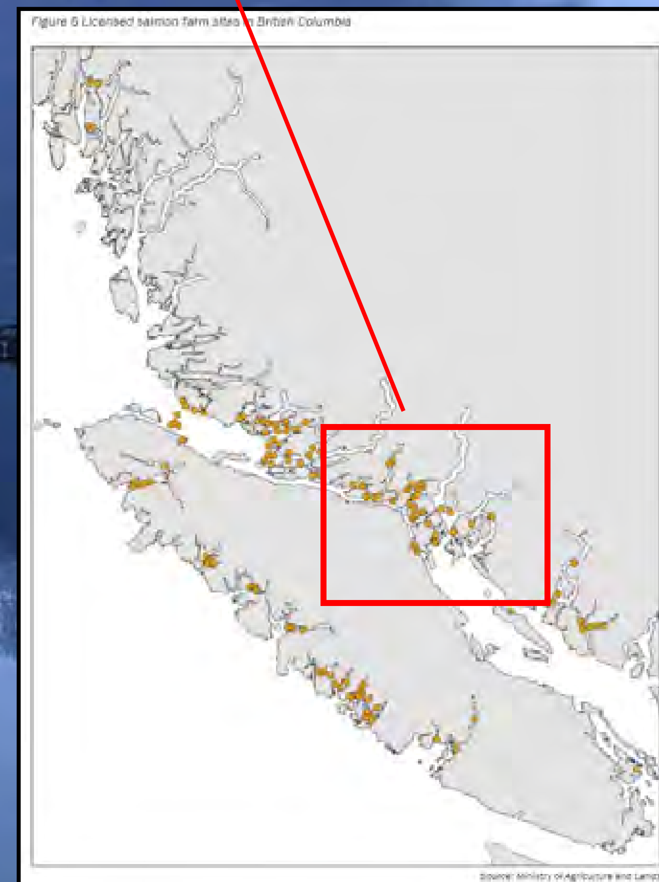
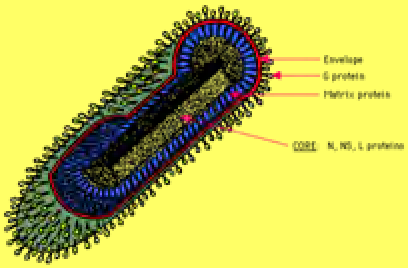
Outline

- Background & motivation
- Circulation model
- Biological model
- Uncertainties
- Summary & future work



Infectious Hematopoietic Necrosis Virus (IHNV)

- *Infects a variety of salmon and trout species along the northeast Pacific*



- *BC farmed Atlantic salmon infections:*
  - *1992-97: 14 netpen sites near Campbell River*
  - *2001: 26 sites, spread from Campbell River*
  - *2002: 10 sites on west coast of Vancouver Island*
- *High costs- culling entire farms*

What was learned?

- Transmission spread rapidly
- Infected farms had an identical virus type

  → farm to farm transmission

  - Anthropogenic (poor bio-security)
  - Waterborne (needs more study)

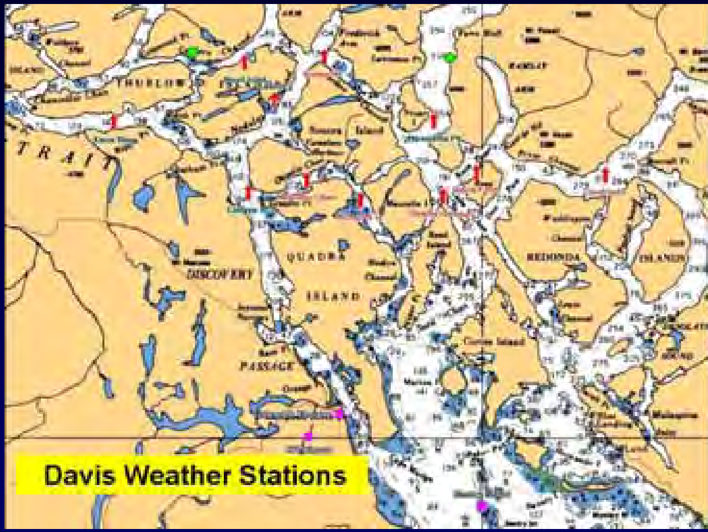
Model Components

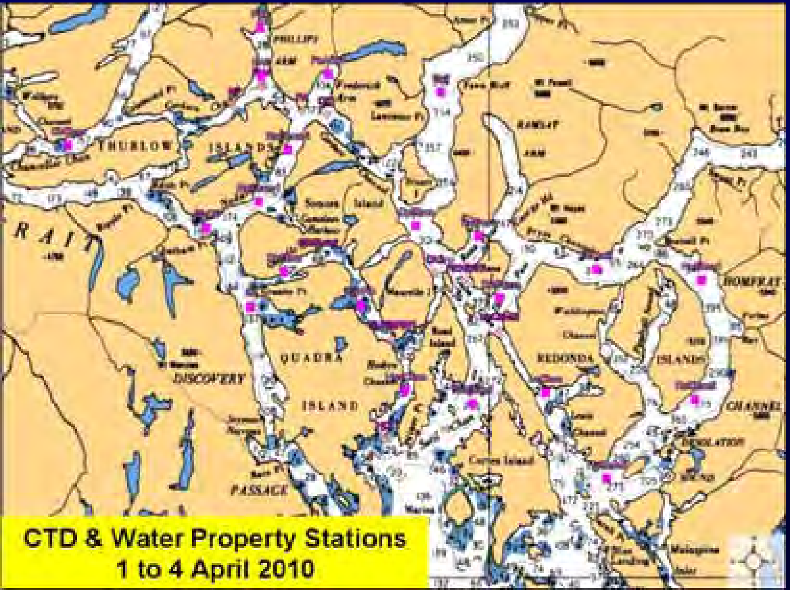
1. **Circulation model:**
   - FVCOM
     - Finite Volume Coastal Ocean Model
   - Requires observational data to initialize, force, & evaluate

2. **Coupled biological model:**
   - Takes FVCOM output + UV radiation observations to disperse & kill IHN viruses originating on salmon farms
     - Standard "particle" tracking
   - Requires lab experiment results to specify model parameters & relationships
     - Shedding rates, minimum infective dosages, virus stability, …

Field Observations

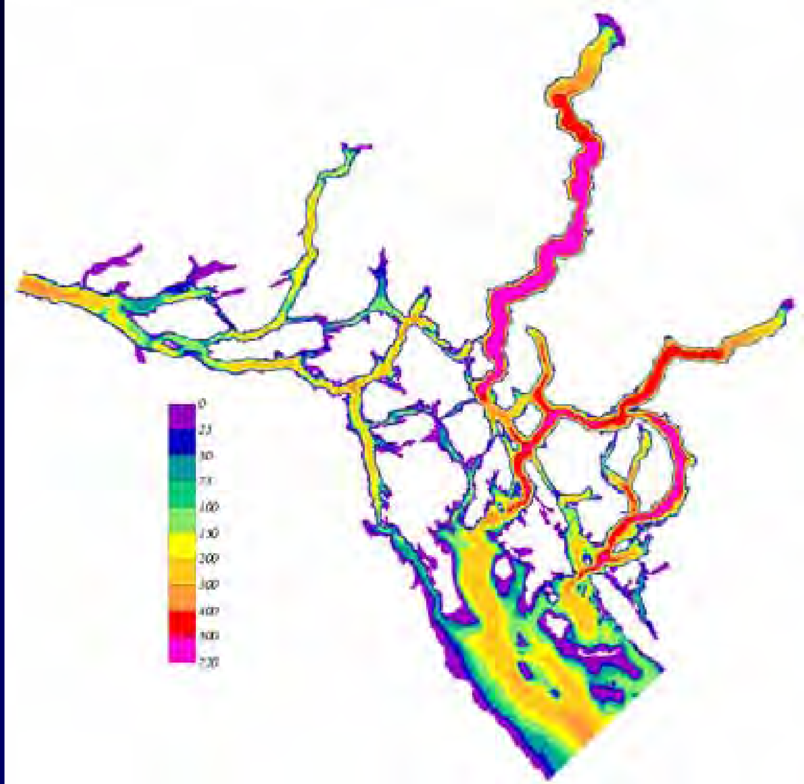
- ***Weather stations:***
  - ***12 deployed: Oct 2009 to Feb 2010***
  - ***Measure winds, UV radiation, heat flux components***
- ***Water property surveys:***
  - ***Temperature & salinity profiles***
- ***Current Meter Moorings:***
  - ***3 deployed in Oct 2009***





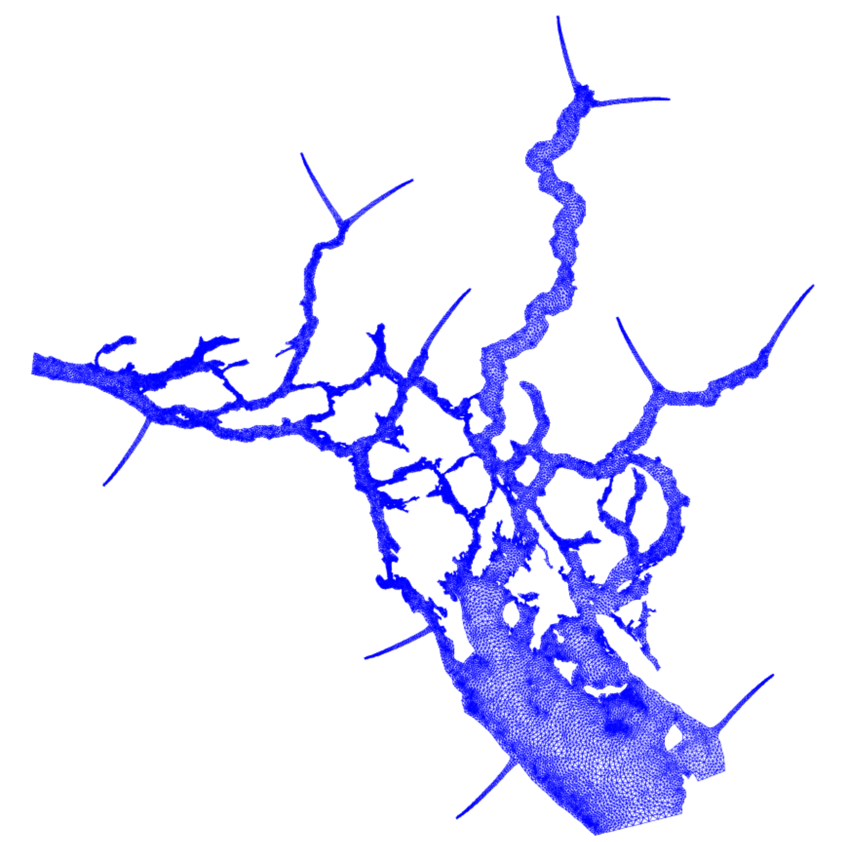
Regional Challenges

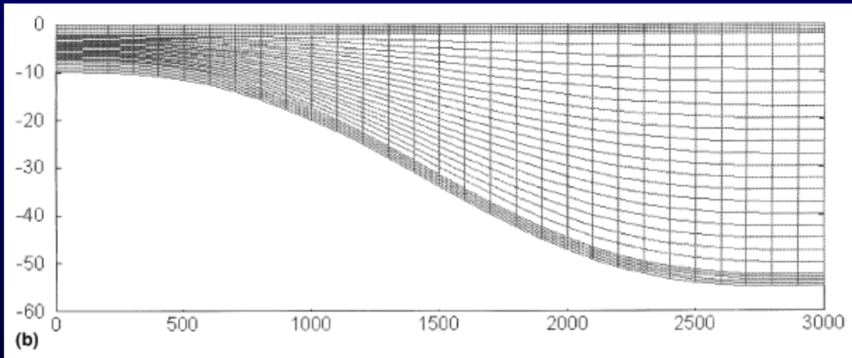
- Deep fiords with seasonal river discharges
  - Strong stratification
  - Potential baroclinic pressure gradient problems in FVCOM
- strong mixing in island channels
  - Some of the strongest tidal currents in the world



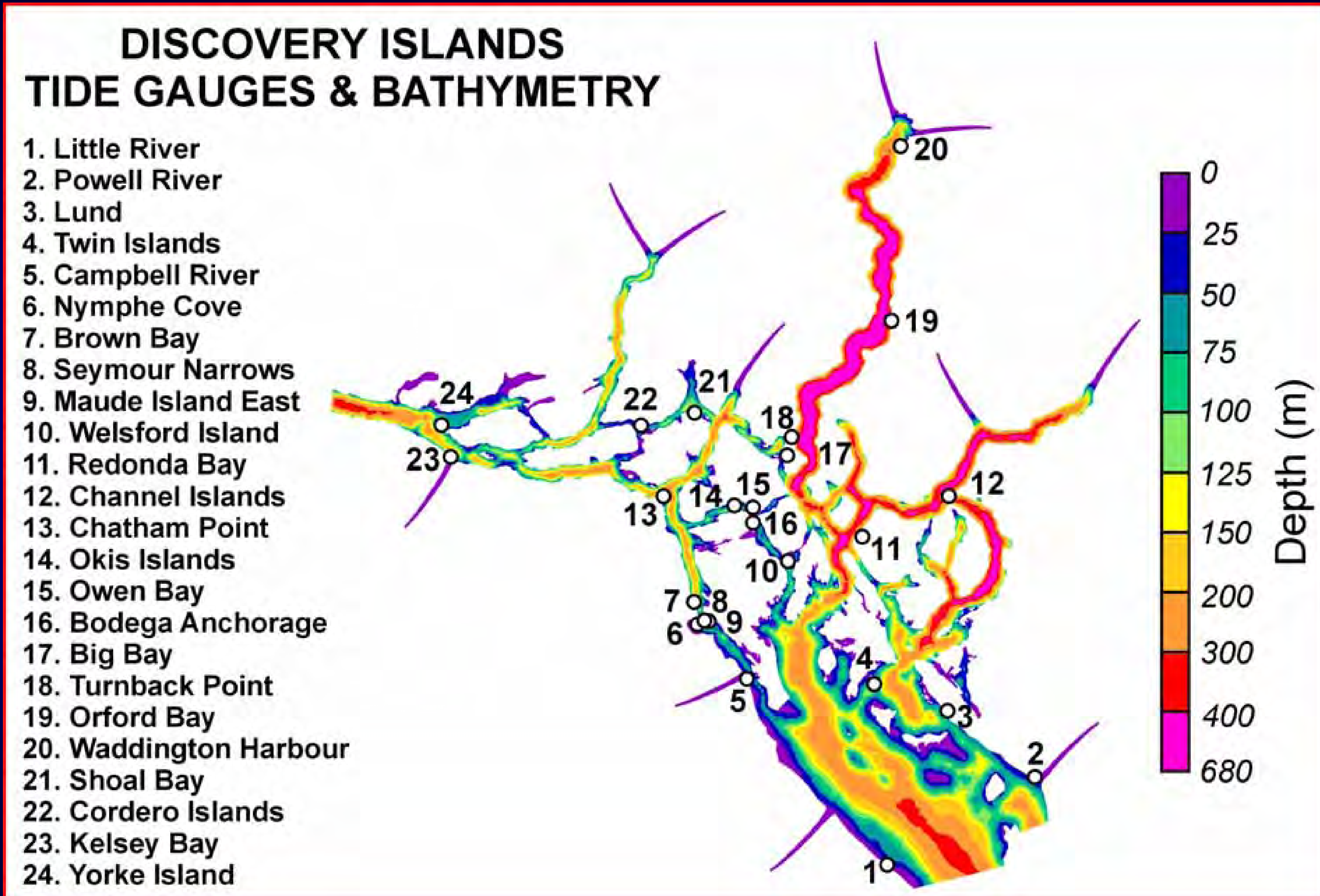
Model Overview

- Simulation for April 1-28, 2010
  - Tides, river discharge & weather station data for forcing
  - April 1-4 CTD observations blended with climatology to initialize TS fields
  - Current meter & tide gauge observations to evaluate accuracy
- Horizontal grid:
  - 37596 nodes, 68467 triangles
  - Resolution from 1.7km to 90m
  - 11 rivers
- Vertical grid:
  - 20 unequally-spaced sigma coordinates



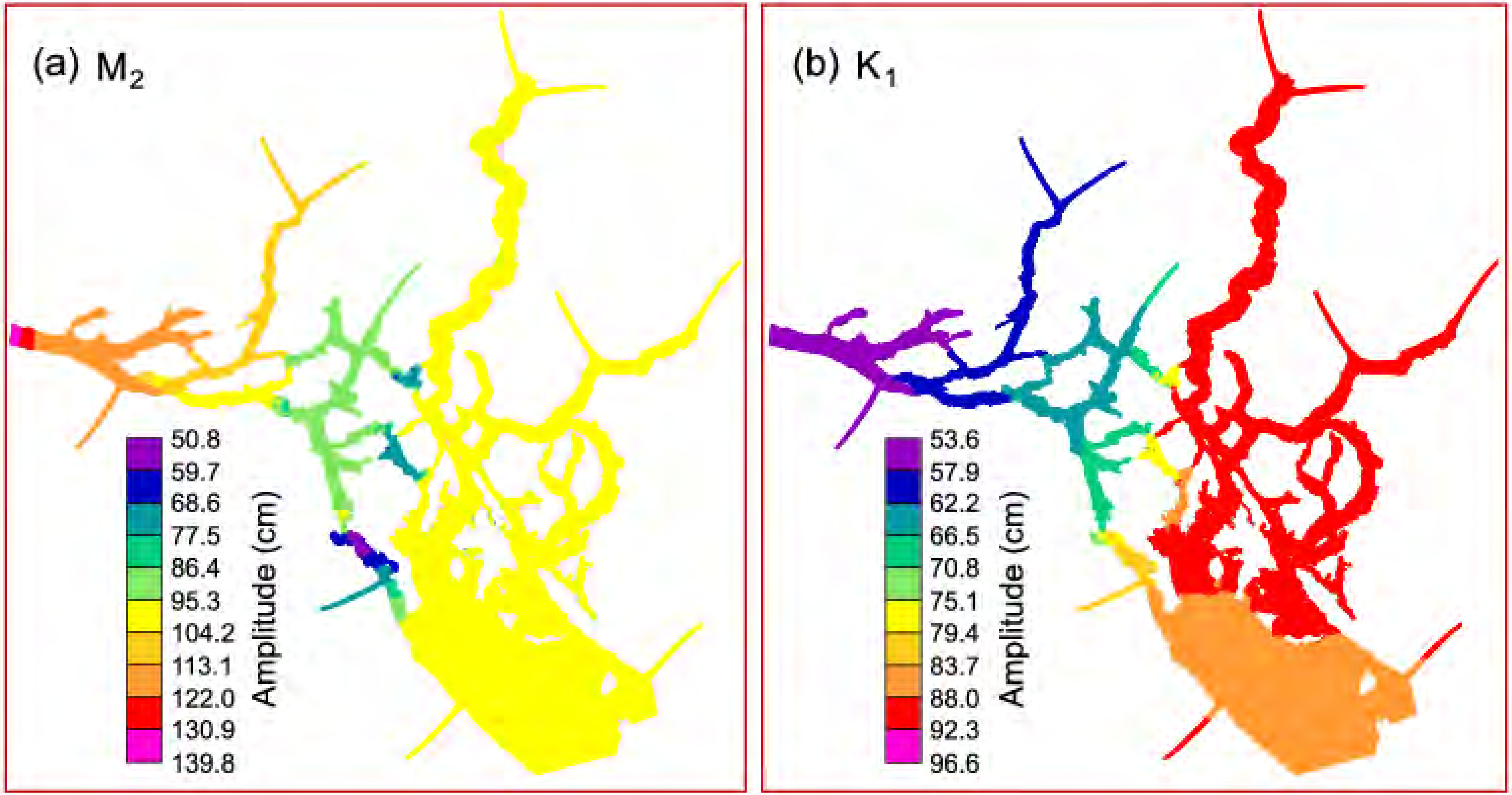


Model Evaluations: sea level



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

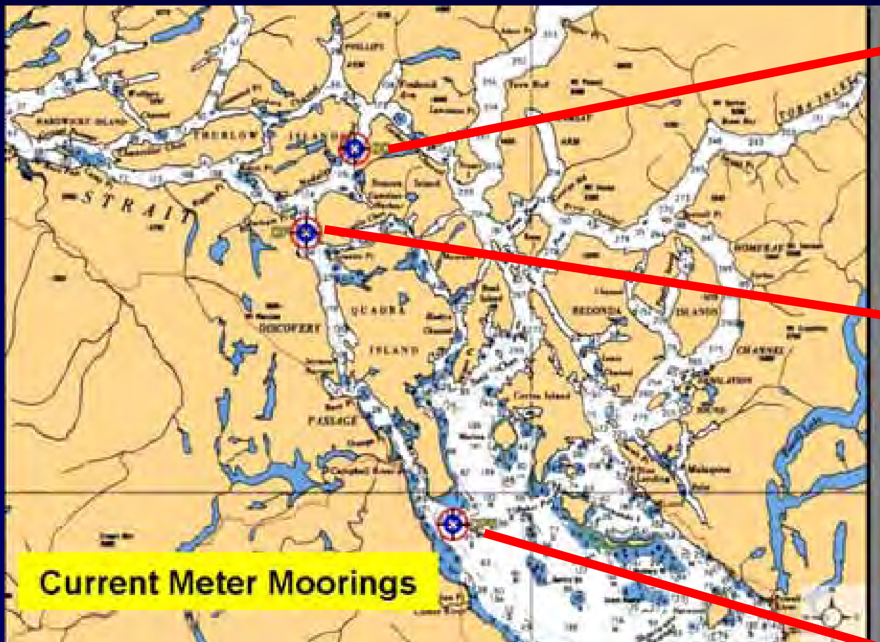
M_2 & K_1 Tidal Elevation Evaluations

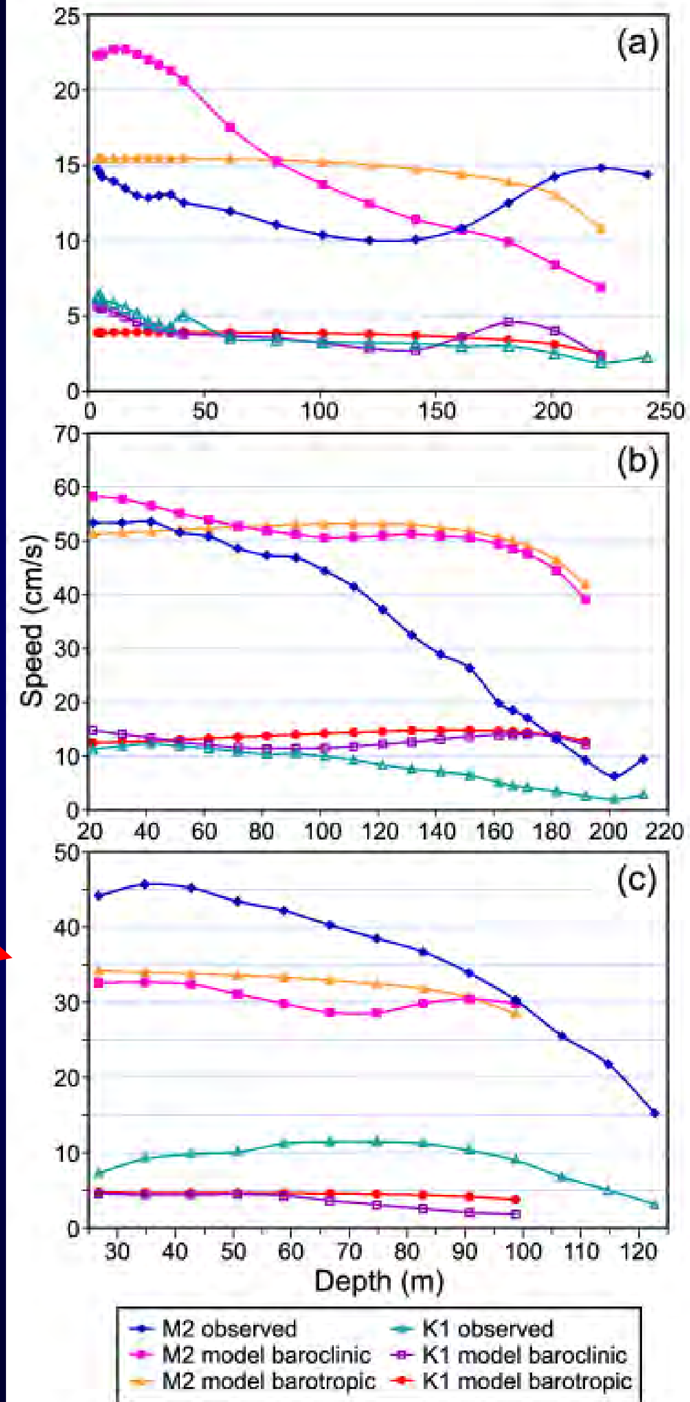


Average amplitude/phase errors vs 24 tide gauge locations

- *distance in complex space*
- *M_2: 3.9 cm*
- *K_1: 3.2 cm*

M_2 & K_1 Tidal Current Evaluations vs Depth





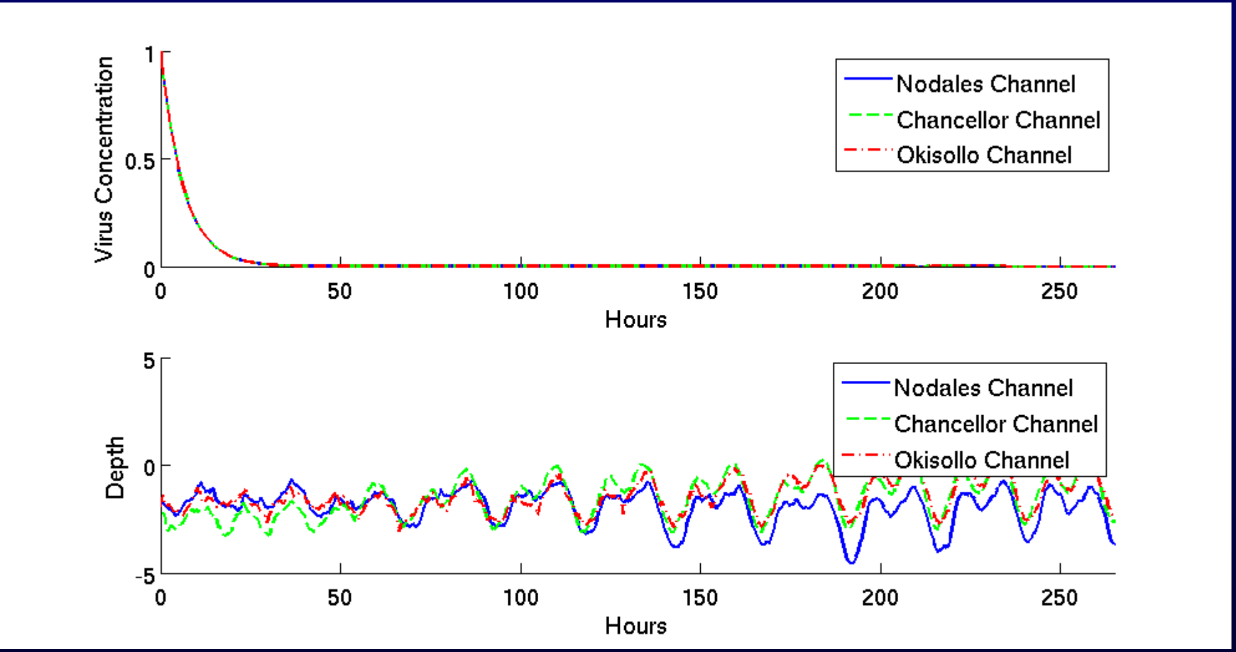
- K_1 model speeds generally OK
- M_2 not as good
  - Surface values good at Discovery but deteriorate with depth
  - off Cape Mudge, too weak
  - in Nodales, too strong

IHN Virus Biological Model

IHN virus mortality function of T, S, UV radiation

$$V(t) = V(t-1) * \exp(-a * U(t)_0 * \exp(-kz) - b)$$

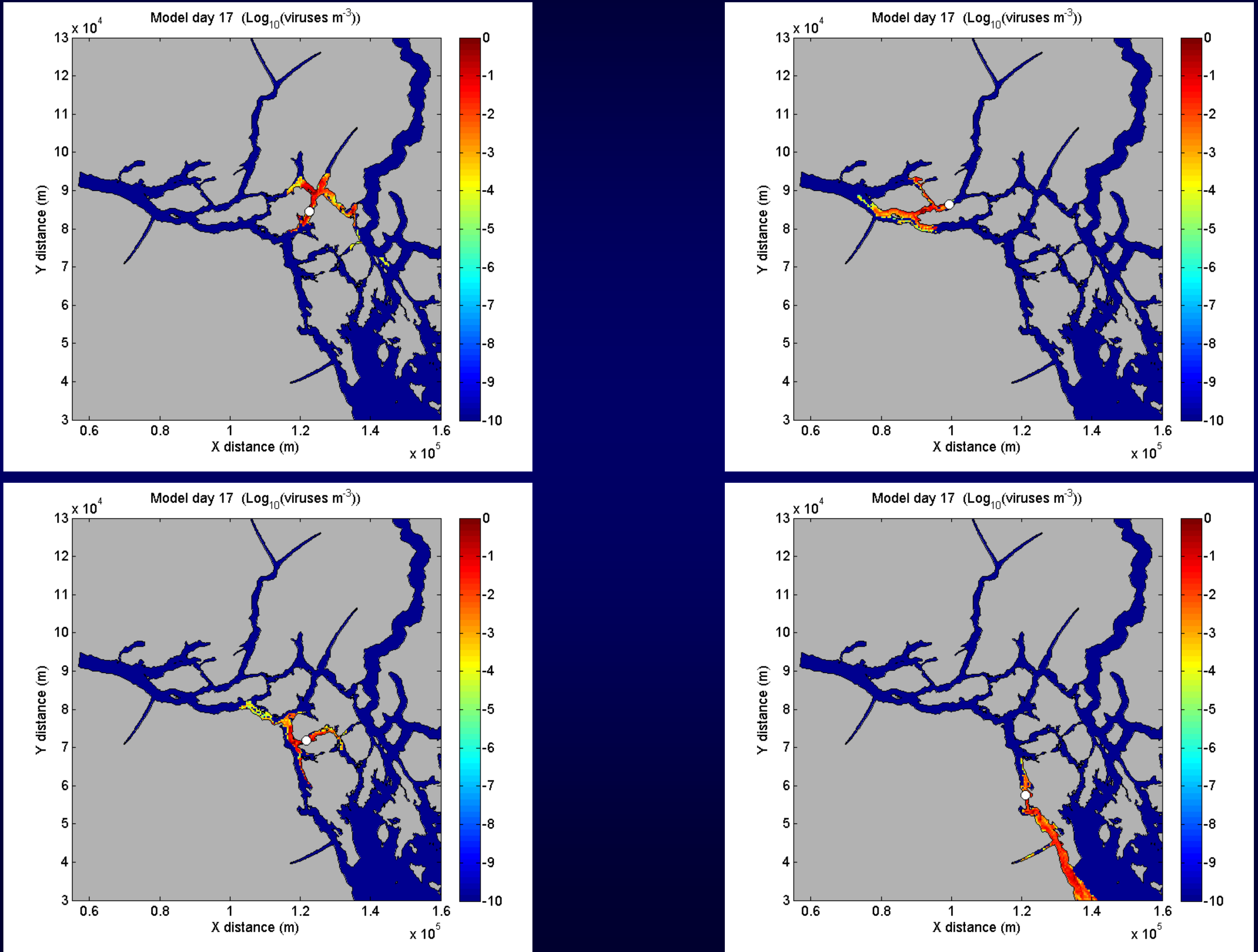
V(t) is the virus concentration, U(t) is the UV radiation value at sea surface, z is the depth, a, k and b are constant values determined from lab experiments



Time series of virus concentration and average depth for 3 farm releases

Preliminary Near-Surface Concentrations

(100,000 virus particles released per hour over 19 days & in top 2m, tracked for 5 days)



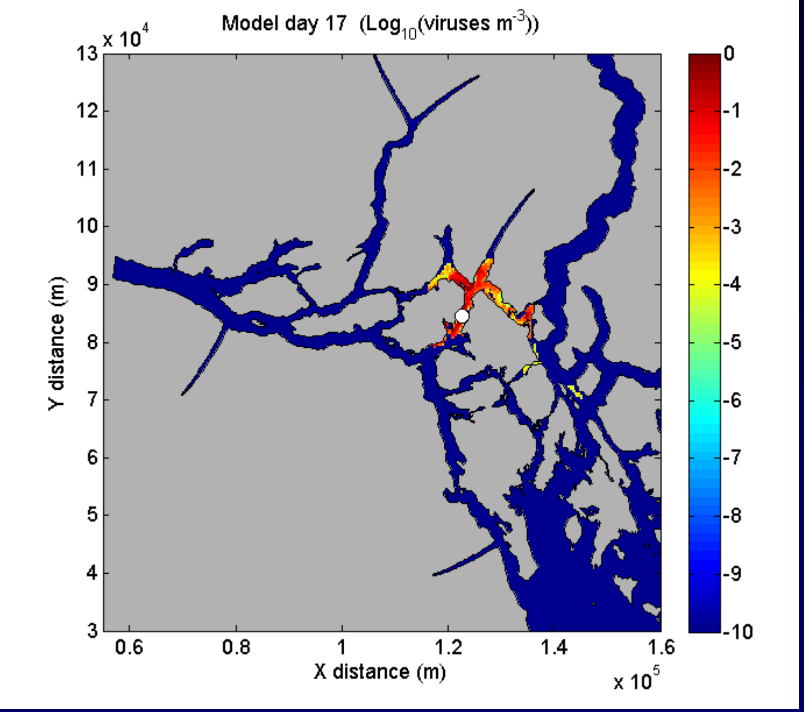
Will nearby farms be infected?

- *Model viral releases need to be scaled by the shedding rates*
  - *Lab work estimated 6 $\times 10^{10}$ viral particles per hour*
  - *Scale-up present concentrations (max 1 virus/m^3) by 6×10^5*

- *Model concentration fields need to be interpreted in terms of minimum infectious dose*
  - *Lab min dose is*

    10 PFU/ml = 10^7 virus/m^3

  - ➢ *Nearby farms may not be infected (under present assumptions)*



Model Uncertainties

- **Biological model**
  - ***Extension of lab-based parameters & relationships to open ocean***
    - ***Shedding rates; minimum infective dosages; virus stability with UV, T, S; …***
  - ***Neglect of other important factors (e.g., bacterial content)?***

- **Physical model**
  - ***accuracy of model fields (u,v,w,T,S)***
  - ***Sufficient range of model simulations (over different forcing conditions)***

Reducing Uncertainties

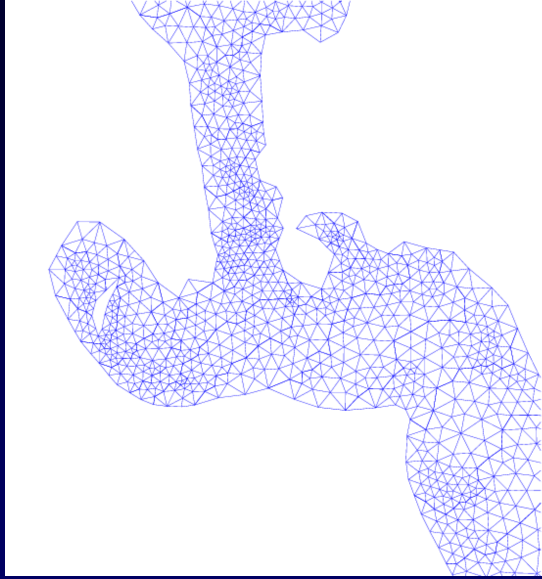
- **Biological model**
  - **Field observations (where feasible) & more lab experiments**
  - **An actual disease outbreak to provide data**

- **Physical model**
  - **More observations to evaluate model accuracy**
  - **Improvements in model forcing fields, resolution, physical processes, …**

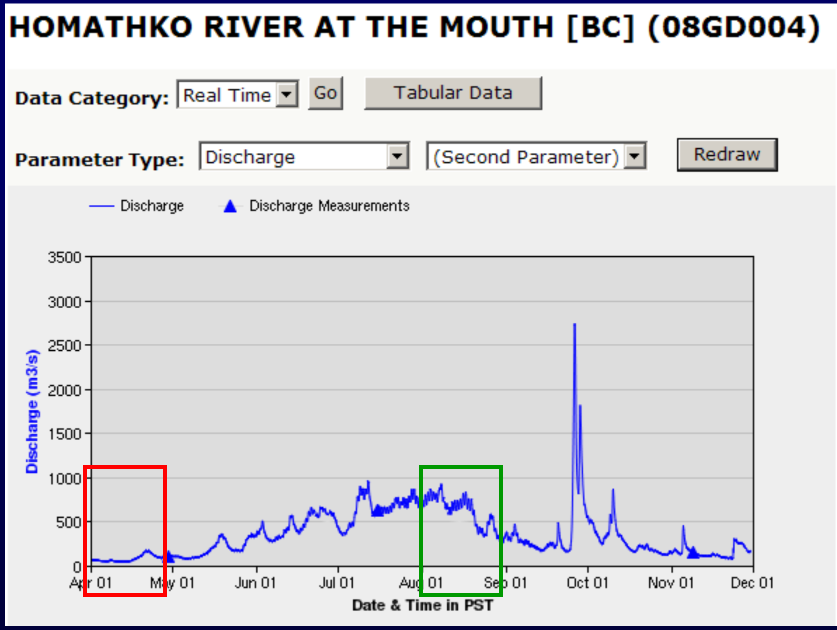
Summary

- Preliminary circulation & IHN virus water-borne transmission models have been developed for the Discovery Islands
- Preliminary near-surface results suggest nearby farms may not reach minimum infective doses, but more study needed
- Many uncertainties
  - Some can be reduced

Future Work



- **Model details:**
  - Move to higher resolution grid
    - Better coastline & depths
  - Implement newer/faster(?) version of FVCOM



- **Model simulations**
  - Virus releases below 2m
  - include other mortality dependencies (e.g., T,S)
  - Later in summer with more freshwater