MEOPAR

MARINE ENVIRONMENTAL OBSERVATION
PREDICTION & RESPONSE NETWORK

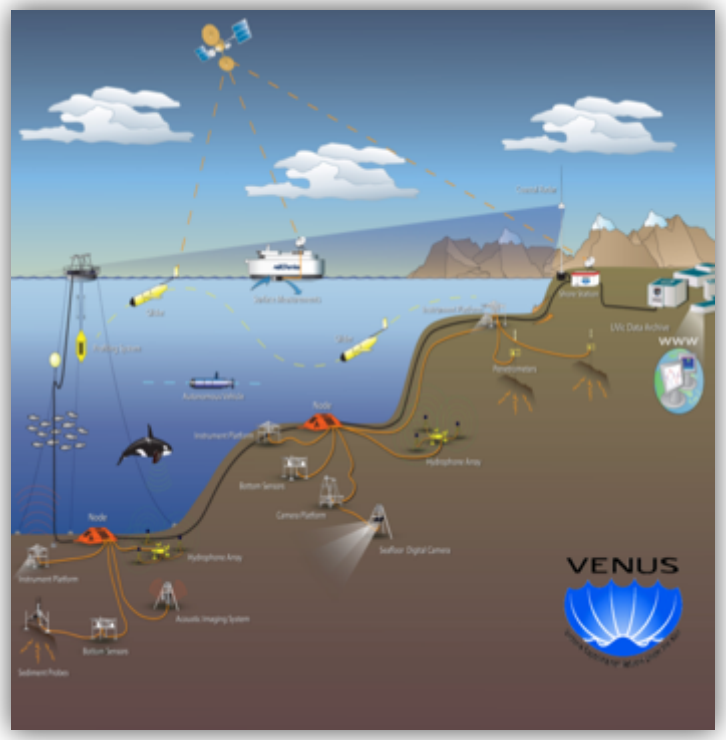
A Relocatable Coupled Atmosphere-Ocean Prediction System

By: Hal Ritchie and IP1.1 Project Team
Dalhousie University & Environment Canada

MEETING THE CHALLENGES OF OUR CHANGING OCEAN

Main Goals

- Build and test coupled atmosphere-ocean forecast system that can be set-up within hours of a marine emergency, anywhere in Canadian waters
- Provide short-term forecasts (hours to days) of physical properties of atmosphere and ocean to guide response to a marine emergency
- Develop ability to assimilate data (e.g., observations from altimeters, gliders) and downscale predictions from larger scale models
- Develop modules for offline prediction of movement and dispersion of plumes of hazardous materials
- Develop mechanisms for rapid appraisal of socio-economic values and risks, including community based approaches.



Models and Field Tests

Atmospheric Model: The operational Environment Canada Global Environmental Multi-scale (GEM) weather forecast model.

Ocean Model: Shelf version of the NEMO (Nucleus for European Modelling of the Ocean) ocean forecast system. Start from system already implemented by the Canadian Operational Network of Coupled Environmental PredicTion Systems (CONCEPTS) for Gulf of St. Lawrence.

Strait of Georgia (SoG, years 1 to 4): In situ ocean observations from VENUS (e.g., surface current fields from CODAR, temperature and salinity from moorings, gliders, and instrumented ferries), and a drifter experiment. Ocean model to be forced by winds from high resolution forecast model developed for the west coast.

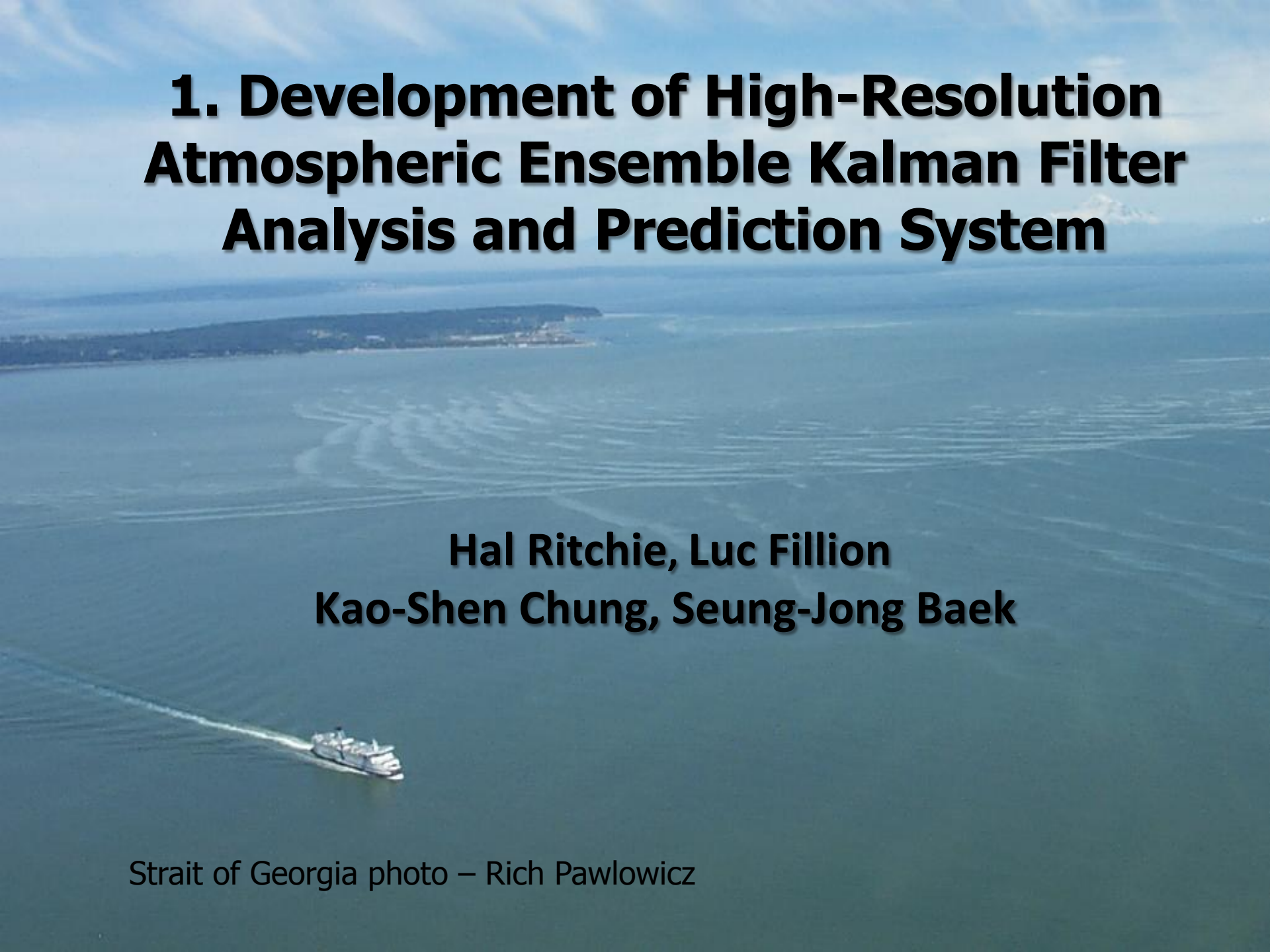
Scotian Shelf (SS, years 4 to 5): In situ ocean data collected by OTN (Ocean Tracking Network), supplemented by specially designed field program led by Observation Core, including small scale tracer release experiment.

Main Activities and Personnel

Activity	Network Investigator	HQP
1. Develop a relocatable capability for the coupled GEM-NEMO system	Ritchie (EC, Dal), Fillion (EC, McGill)	J-P Auclair, F. Chegini, K-S Chung, S-J Baek
2. Develop and test ocean data assimilation (ODA) schemes	Thompson (Dal)	V. Korabel, A. Katavouta
3. Develop tracer prediction modules	Niu (Dal), Thompson (Dal)	E. Rogers
4. Develop relocatable tide and storm surge model to provide boundary conditions for NEMO	Brunet / Bernier (EC, McGill), Thompson (Dal)	T. Kodaira, F. Woslyng
5. Prepare and diagnose ocean observations and data sets	Pawlowicz (UBC)	M. Halverson
6. Develop mechanisms for rapid appraisal of socio-economic values & impacts	Charles (SMU)	B. Paterson In the Observation Core

1. Development of High-Resolution Atmospheric Ensemble Kalman Filter Analysis and Prediction System

Hal Ritchie, Luc Fillion
Kao-Shen Chung, Seung-Jong Baek



Strait of Georgia photo – Rich Pawlowicz

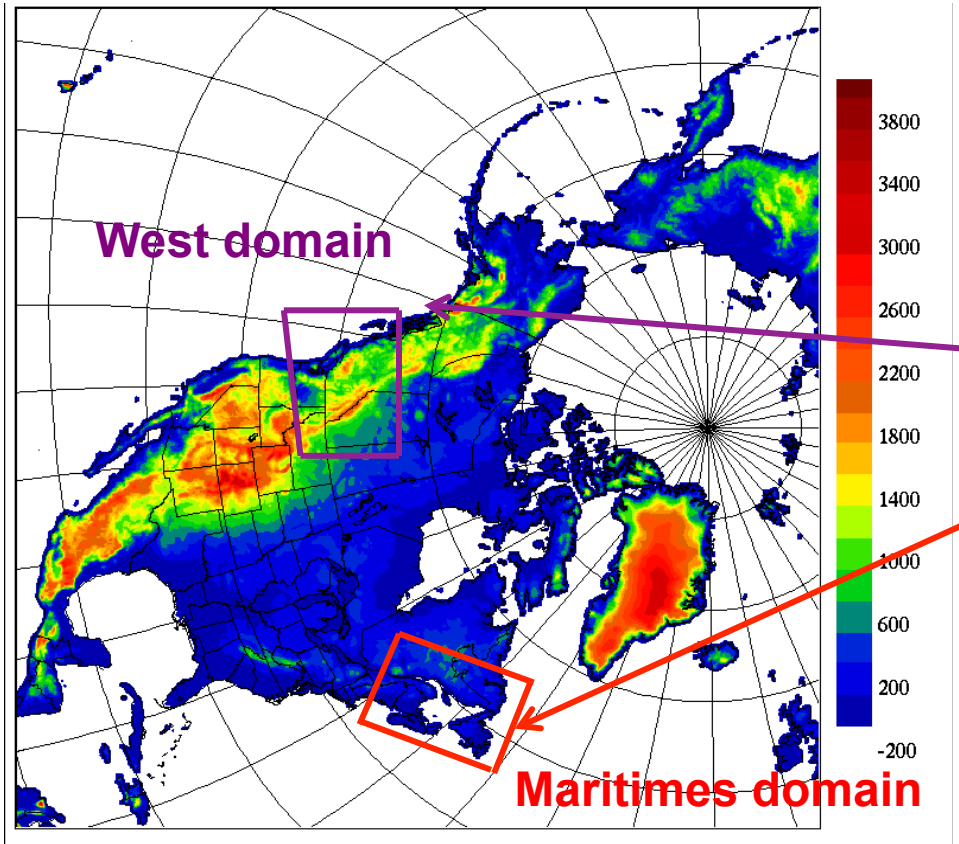
Current setup of HREnKF_2.5km

Maestro: 1.3.1-rc2
GEM_4.5.0-rc2
Conventional data assimilation

0000 1200 0000 0300 UTC

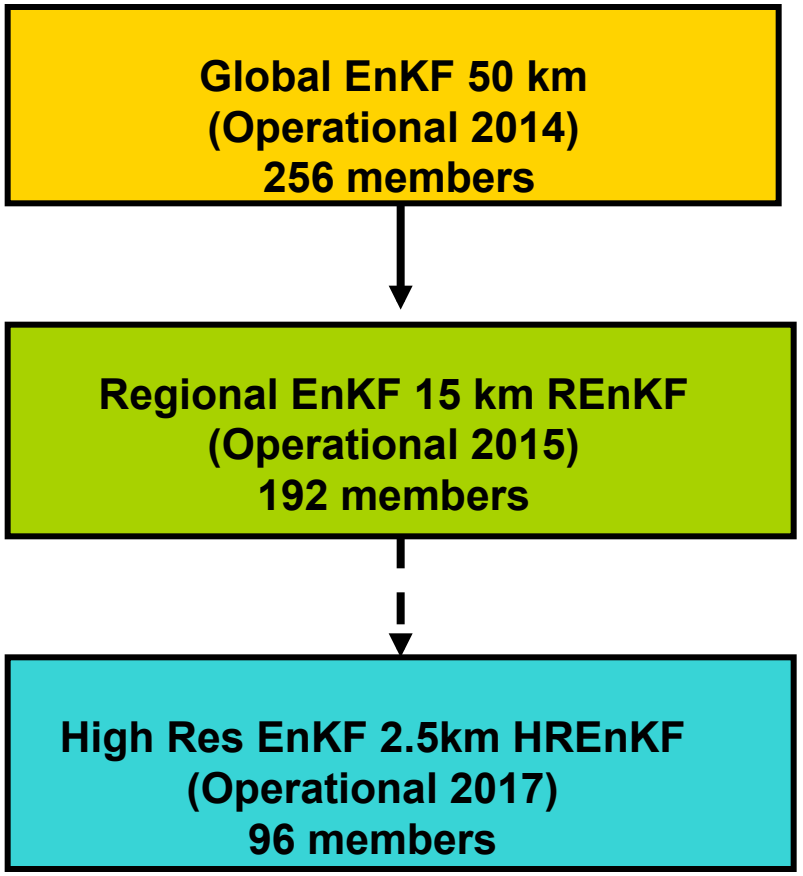
REnKF_15km 1-day cycling

Hr_driver 12-hour
LBCs (15-min) 3df format



HREnKF_2.5km
(1-H cycling)

Flow chart for ensemble of IC/BC for MEOPAR HREnKF



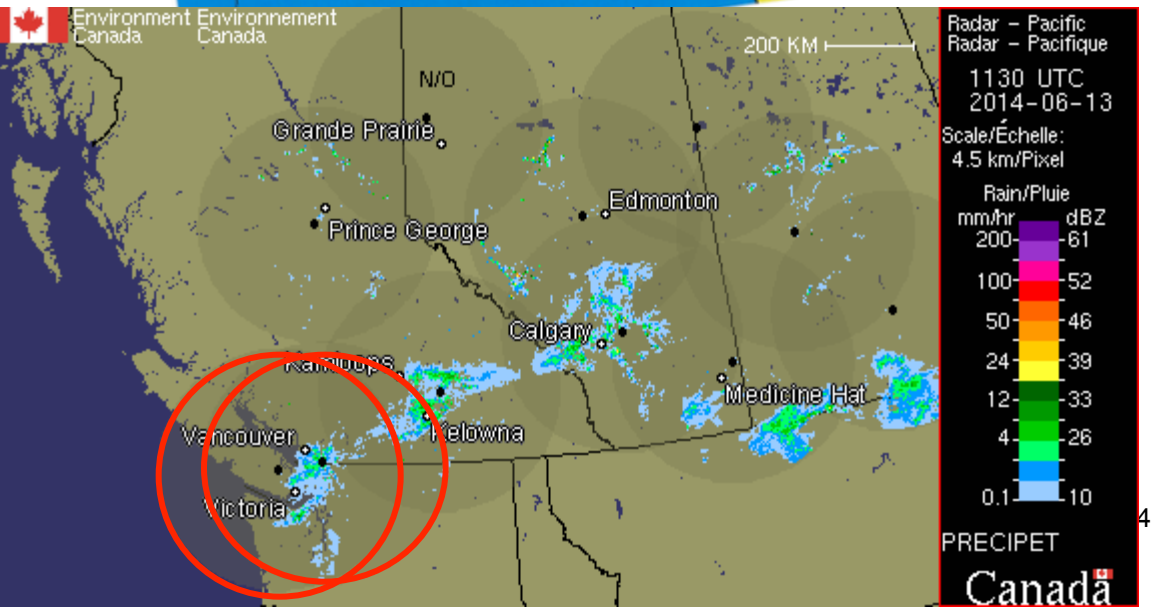
To obtain ensemble members

Better mesoscale systems

MEOPAR project

Verification of numerical weather prediction

Surface stations over the domain

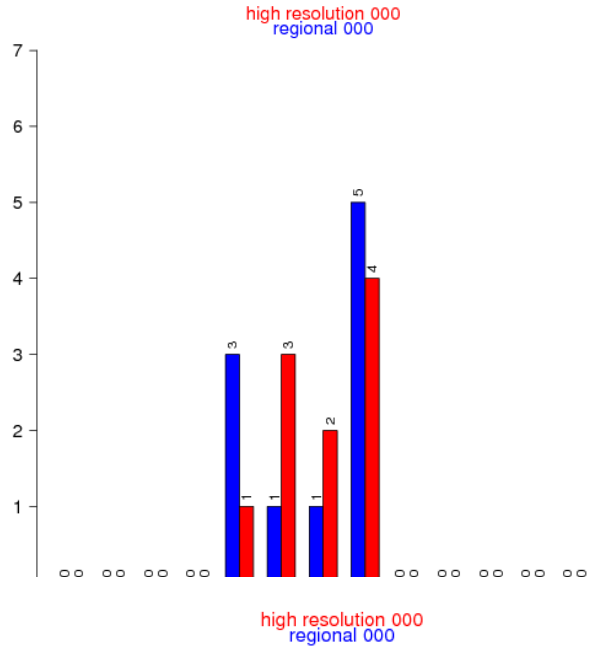


Two radar sites

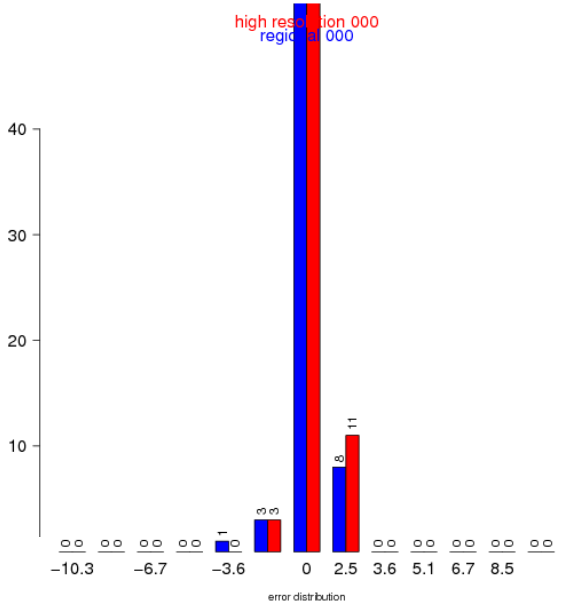
1. Aldergrove (near Vancouver)

2. Victoria

wind direction

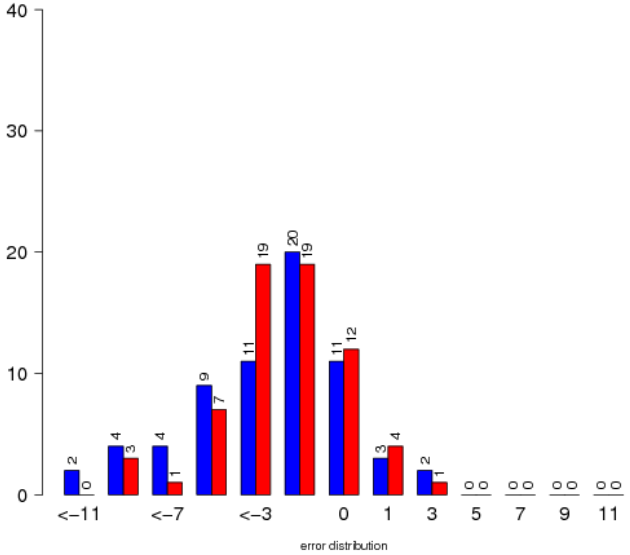


wind speed

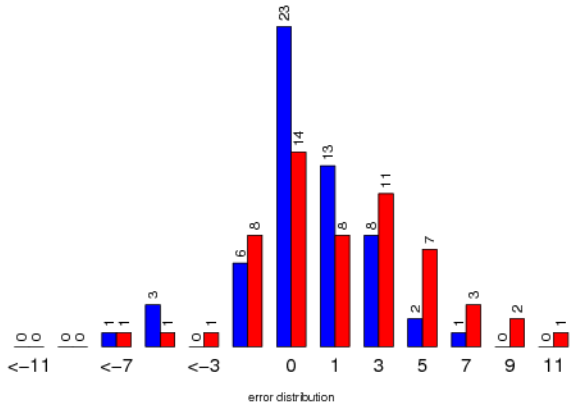


0000 UTC (12-h)

Temperature

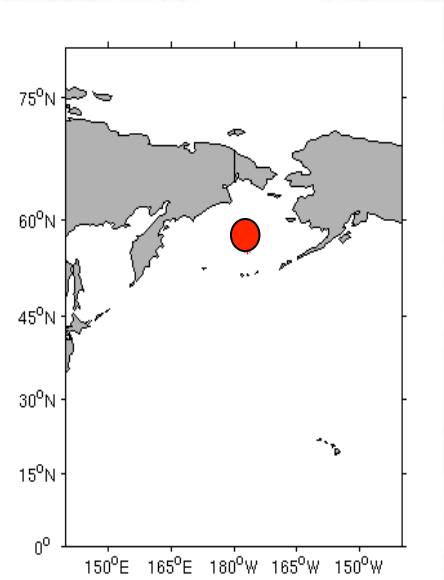


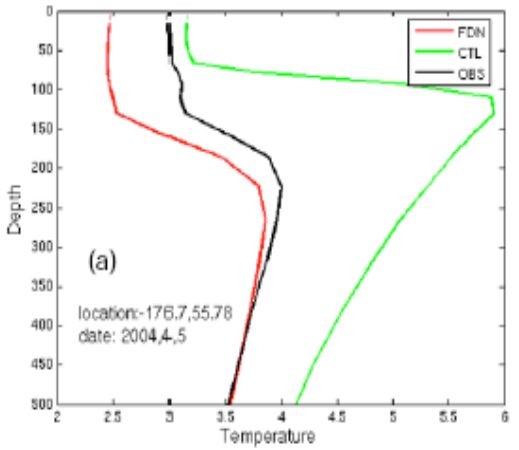
Humidity (Td)

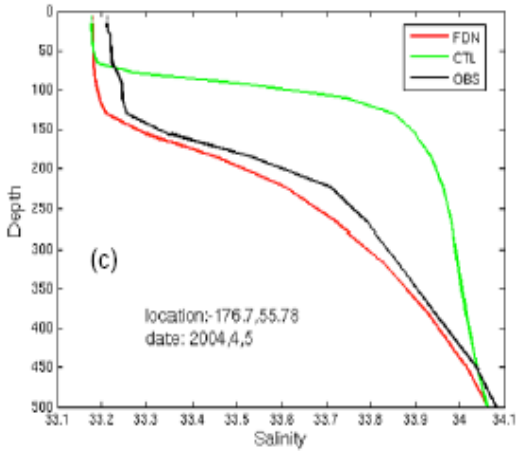


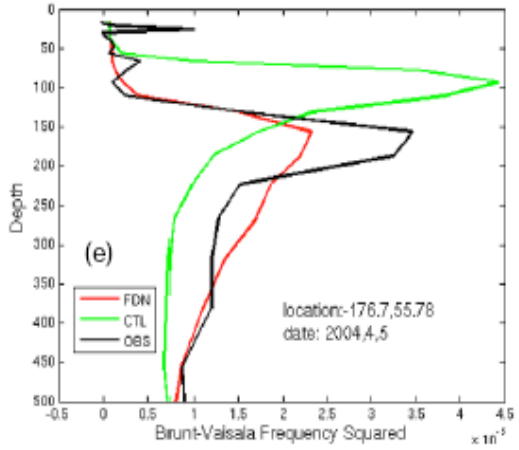
Reducing bias by frequency dependent nudging: facilitating ODA in relocatable models

Comparison of observed and simulated vertical profiles of temperature and salinity







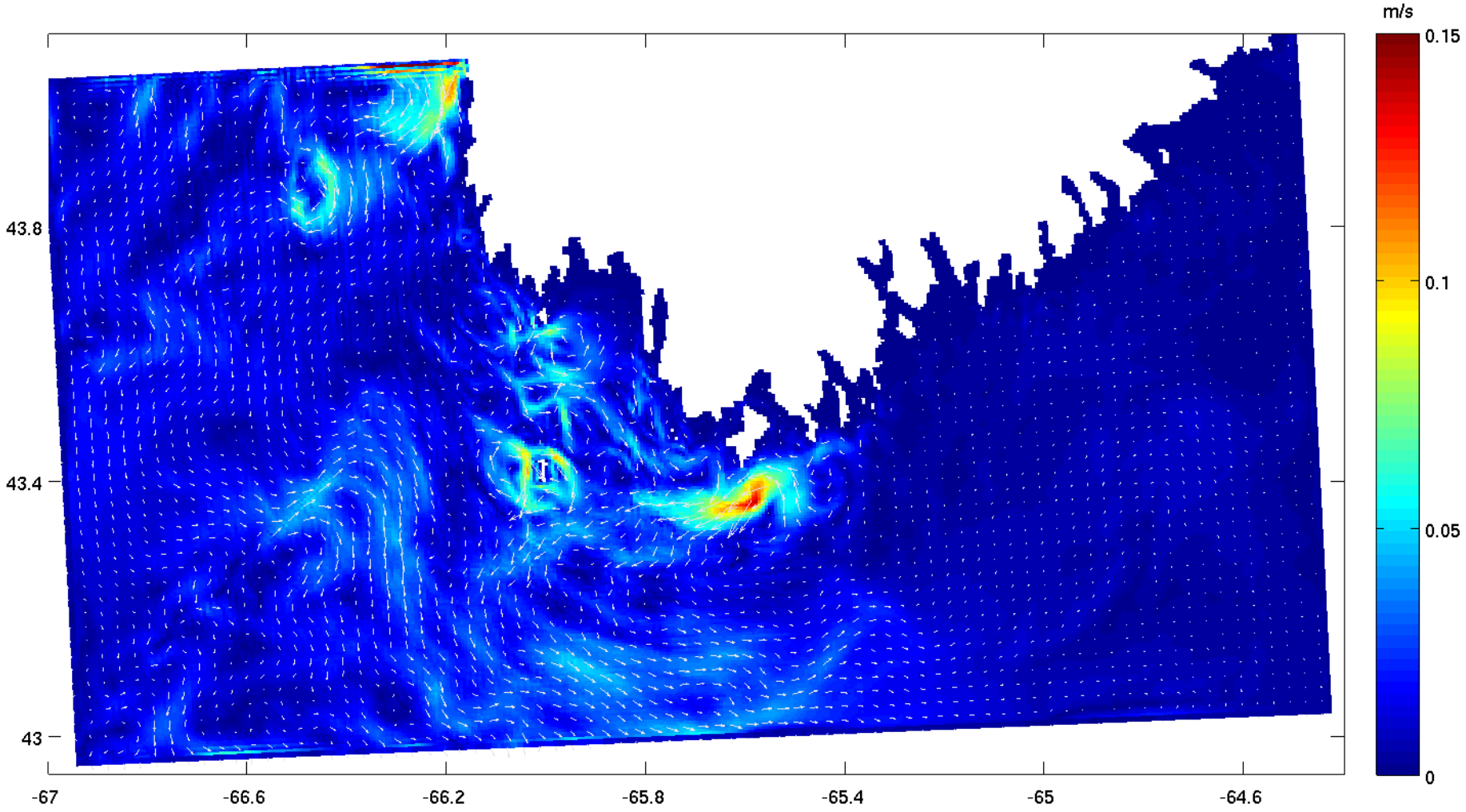


Reducing Drift and Bias of a Global Ocean Models by Frequency Dependent Nudging to Observed Seasonal Climatology, He, Thompson, Ritchie, Dupont and Lu, Atmosphere-Ocean, June 2014.

First demonstration of relocatability:
High resolution model of circulation off southwest Nova Scotia

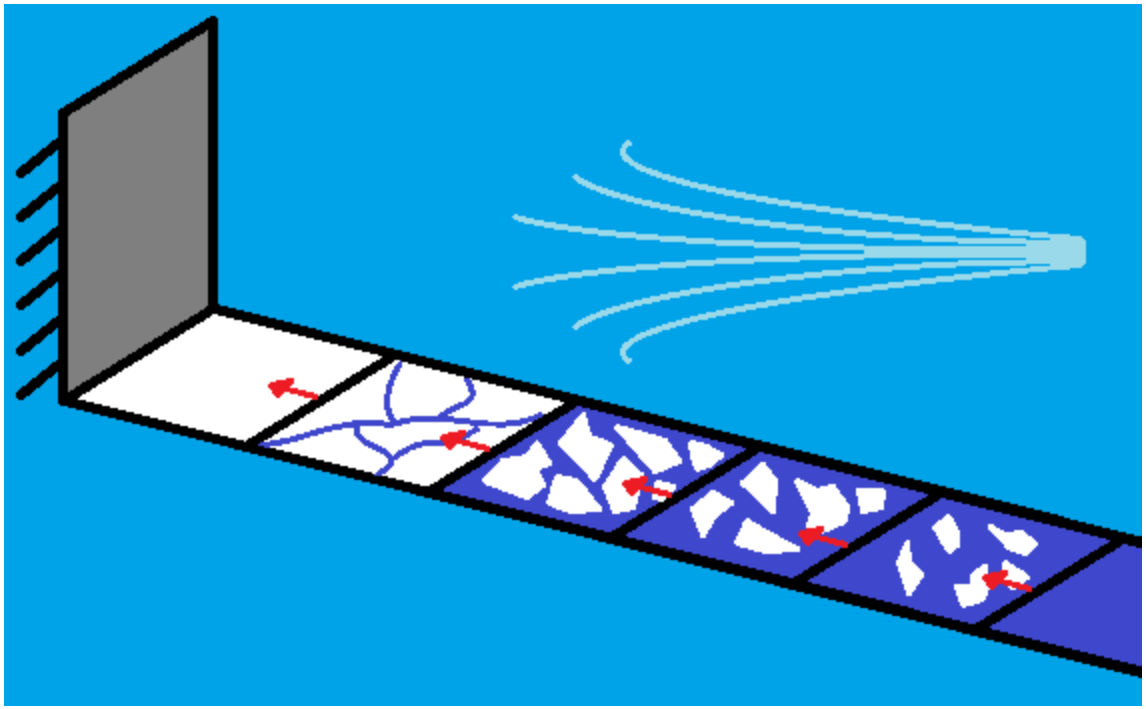
Chegini, Lu, Thompson, Ritchie

Depth Averaged tidal residual currents



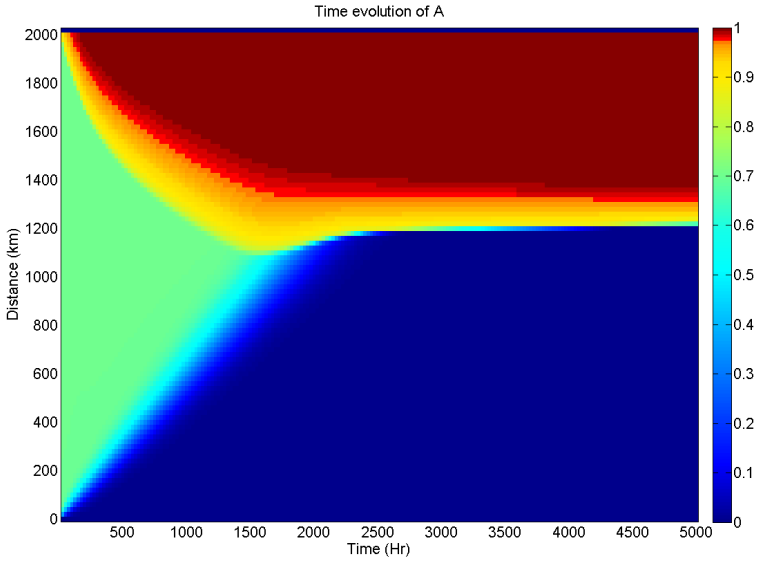
Improving sea ice model numerics

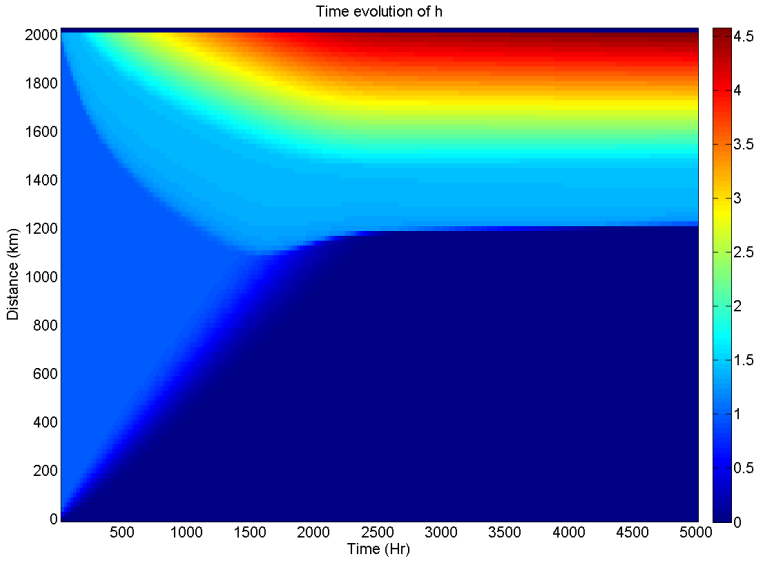
Jean-Pierre Auclair, Hal Ritchie, Jean-François Lemieux

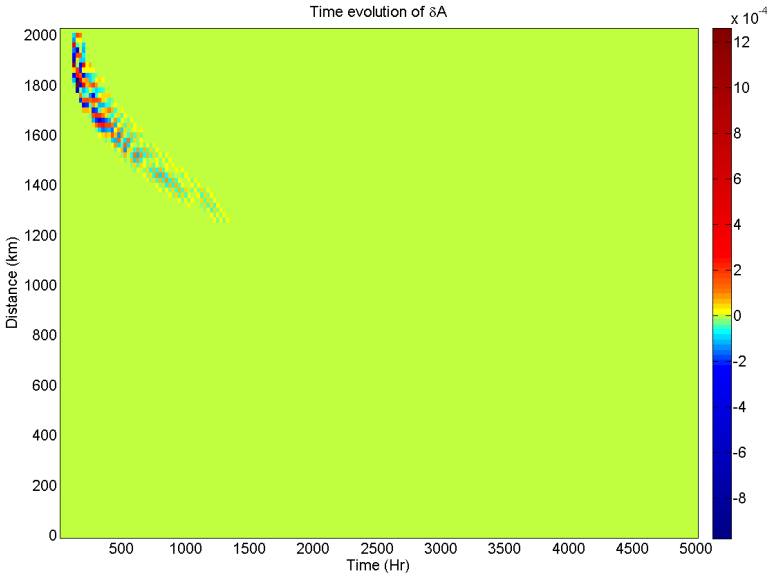


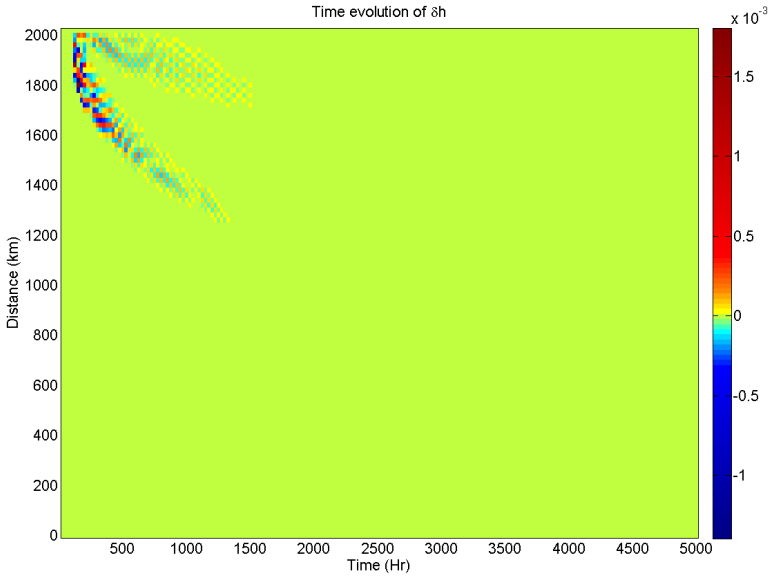
Fluxes through leads in sea ice are crucial for atmosphere-ocean coupling, and present solvers have problems, especially at high resolution.

1D Experiment: Exact Jacobian method converges faster, will be more accurate and efficient than Jacobian-free









2. Ocean Downscaling and Data Assimilation

Keith Thompson

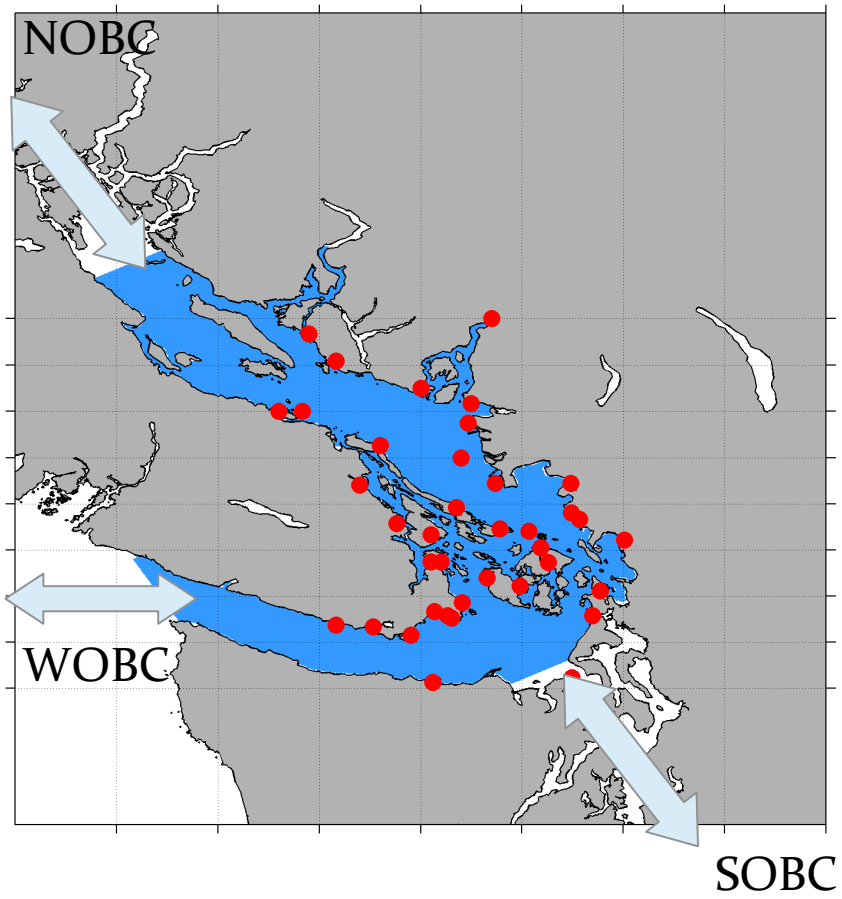
Vasily Korabel (Research Associate)
Anna Katavouta (Graduate Student)

Develop methods to downscale coarser-scale model predictions, and assimilate local observations into the relocatable ocean model. Goal is to improve initial conditions, and thus model forecasts.

Initially develop and test schemes in the data rich Strait of Georgia, then focus on the Scotian Shelf.

Provide a couple of examples: assimilating tidal information and ocean downscaling on the Scotian Shelf.

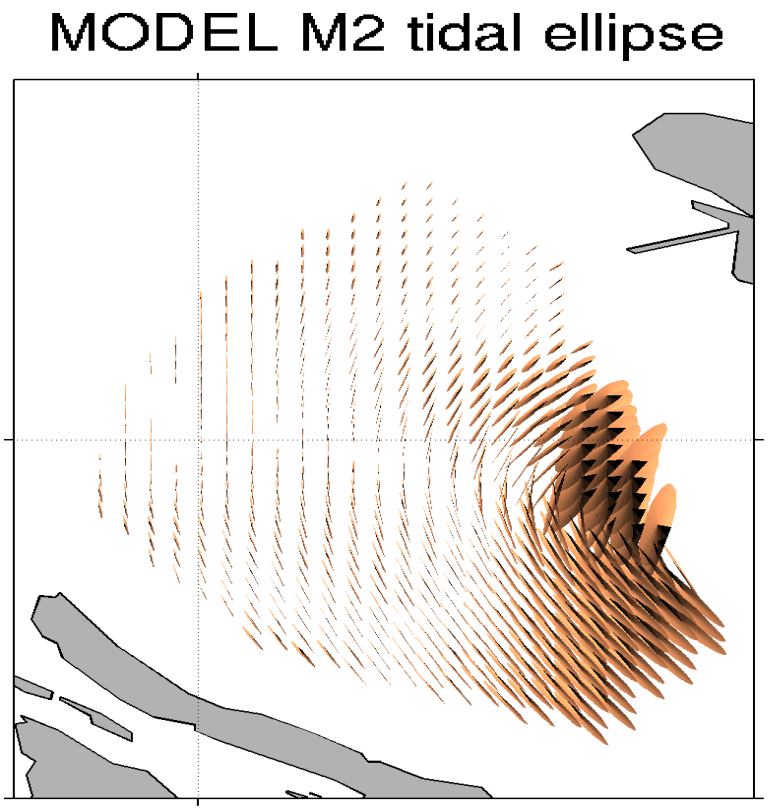
Rapid Assimilation of Tides in the Strait of Georgia

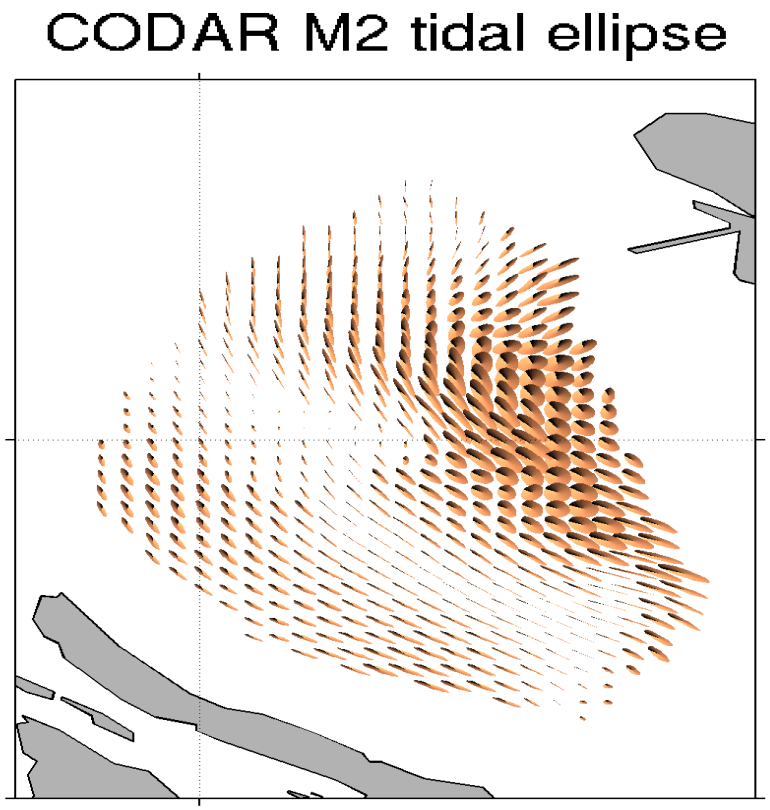


- Blue shows model domain. Red dots show tide gauges providing data for validation and assimilation.
- Model is forced by observed tides at open boundaries.
- Eight constituents from webtide: (K1,K2,M2,N2,O1,P1,Q1,S2).

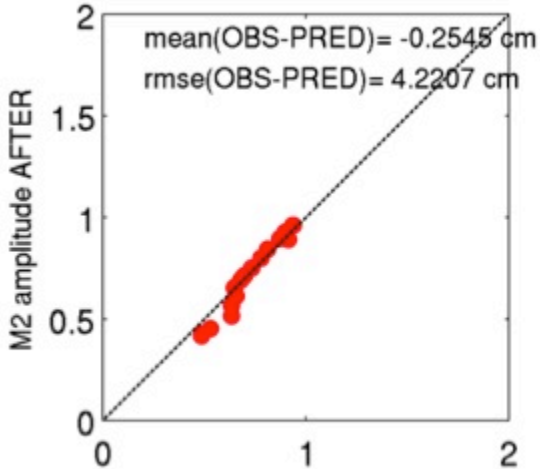
Performance of Barotropic Model With No Assimilation: Surface Currents

Currents observed by the VENUS CODAR system in the Strait of Georgia.

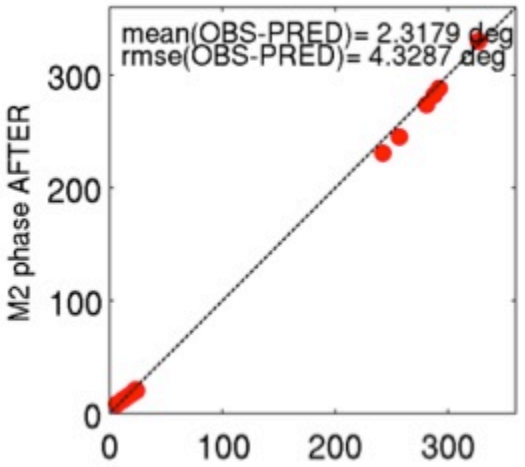




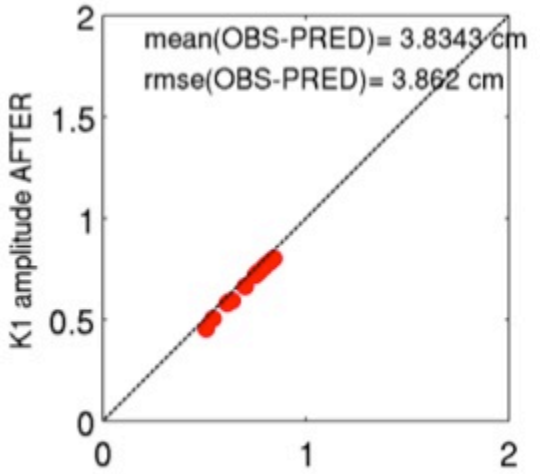
Performance of Model With Rapid Assimilation of Coastal Sea Level



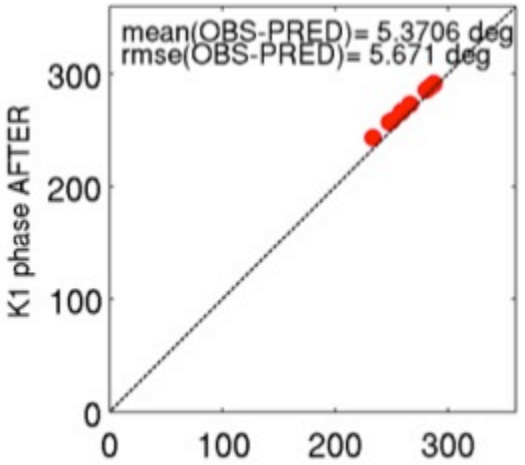
M2 amplitude observed



M2 phase observed

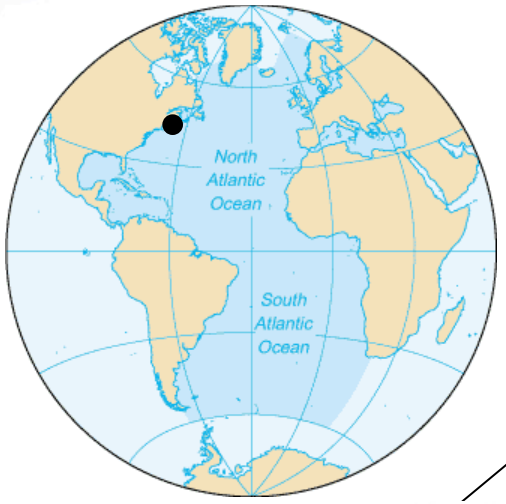


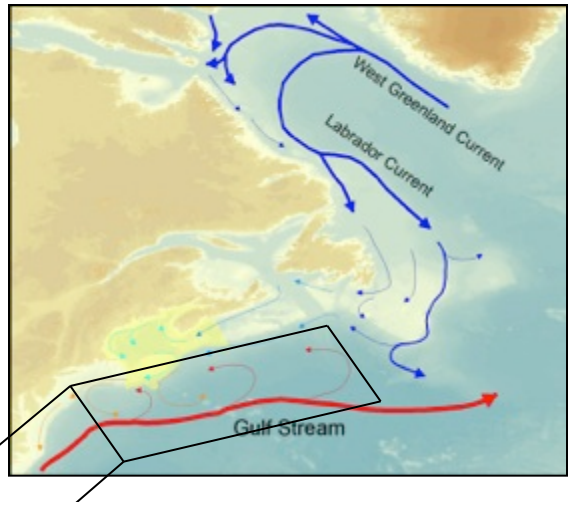
K1 amplitude observed

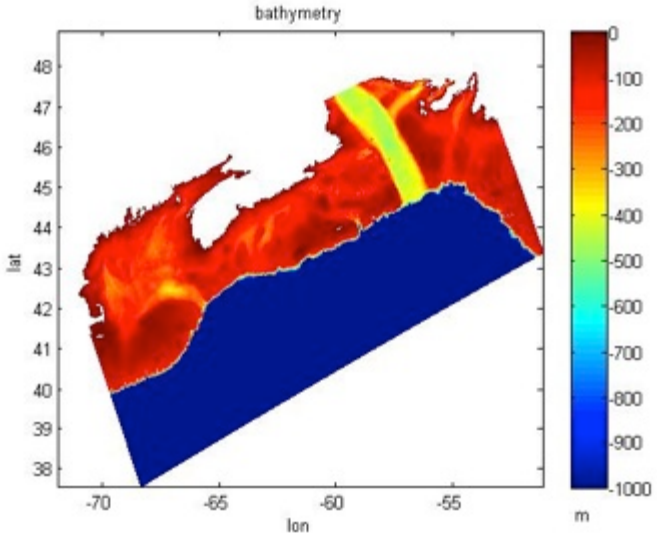


K1 phase observed

Downscaling on the Scotian Shelf







- Developing new ways of ocean downscaling
- Based on fact that local detail can be recovered from history of the large scale
- Initial and open boundary conditions from global HYCOM (1/12°)
- Downscaling using NEMO 3.1 with 1/36° and 52 vertical levels
- Tides (M2,S2,N2,K1,O2) from LEGOS

3. Tracer Module Development (Niu, Rogers)

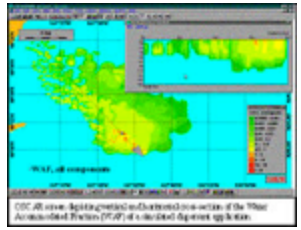
- **The main objective is to develop tracer prediction modules for the *relocatable coupled atmosphere-ocean prediction system*.**
- **This includes the development of modules for the forward- and backward-tracking of**
  - **the drift of common search and rescue (SAR) objects, and**
  - **hazardous material (HAZMAT) materials (including marine oil and/or chemical spills) and objects.**



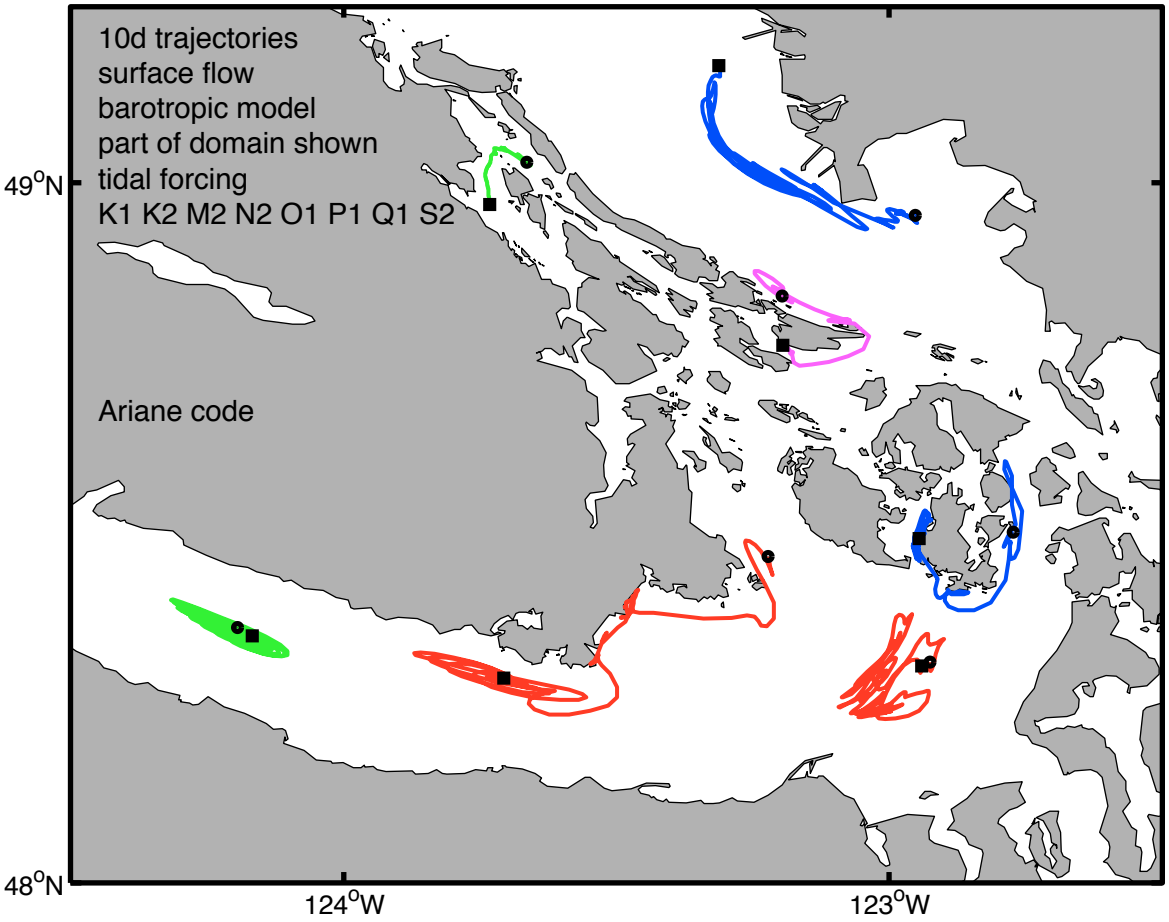

Milestones (Tracer Model Development)

- Milestones & Accomplishments (**Completed** and **In Progress**)
  - **Setup and evaluation of Ariane & Leeway models (SAR);**
  - **Development of Backtracking algorithms using Ariane & Leeway (SAR);**
  - **Setup OSCAR model for oil & chemical spills (Application: Saint John, NB);**
  - **Development of backtracking algorithms using OSCAR (oil & chemical spills);**
  - **Integration of OSCAR with Strait of Georgia model to design tracer release experiments.**

- Milestones & Goals for the Coming Year
  - **Further development of SAR backtracking algorithms and conduct case studies;**
  - **Further development of oil & chemical backtracking algorithms and conduct case studies;**
  - **Development of a stand-alone oil & chemical spill model (with backtracking capability) for technology transfer to interested users.**

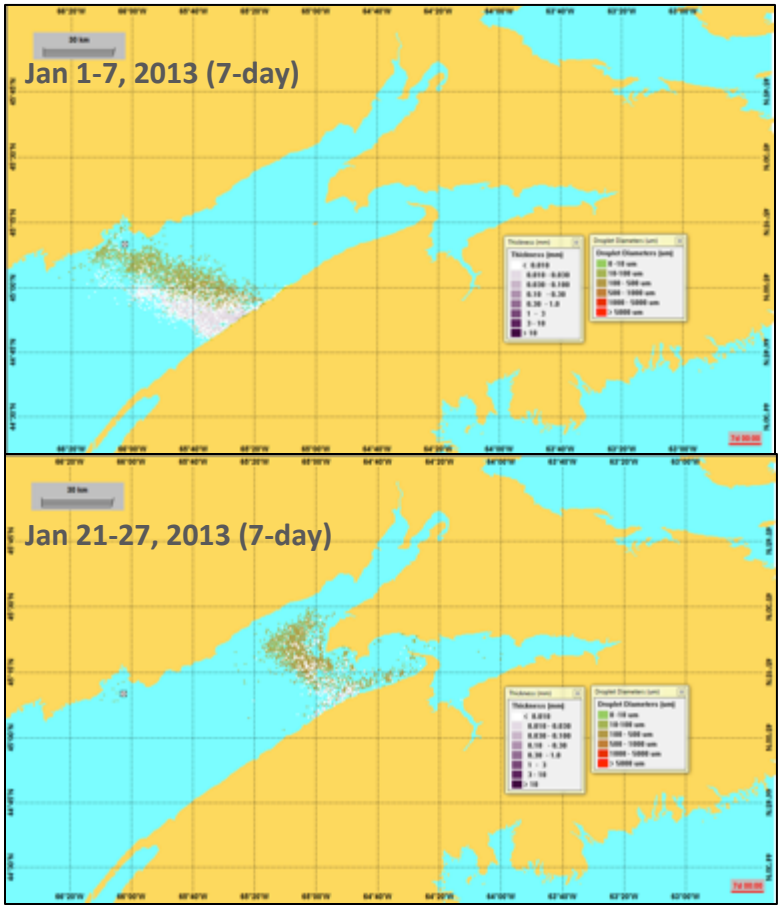


Particle Trajectories in the Strait of Georgia



Example: Modeling of Oil Spill in Saint John Harbour

Two Single Model Run



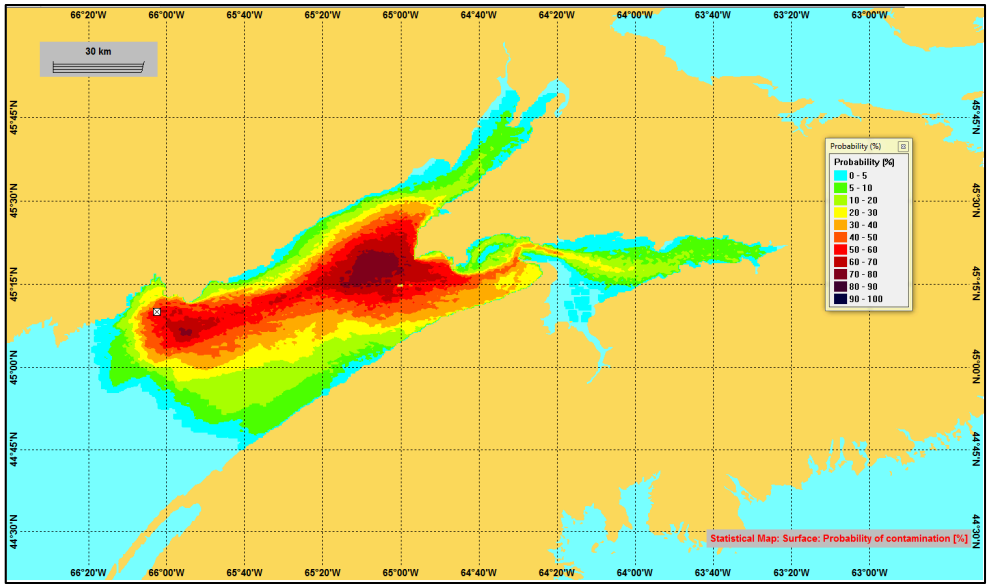
Surface & Subsurface oil

Stochastic Model Run

1. Jan 1-7, 2013
2. Jan 2-8, 2013

… …

20. Jan 23-29, 2013



Probability of Surface Contamination

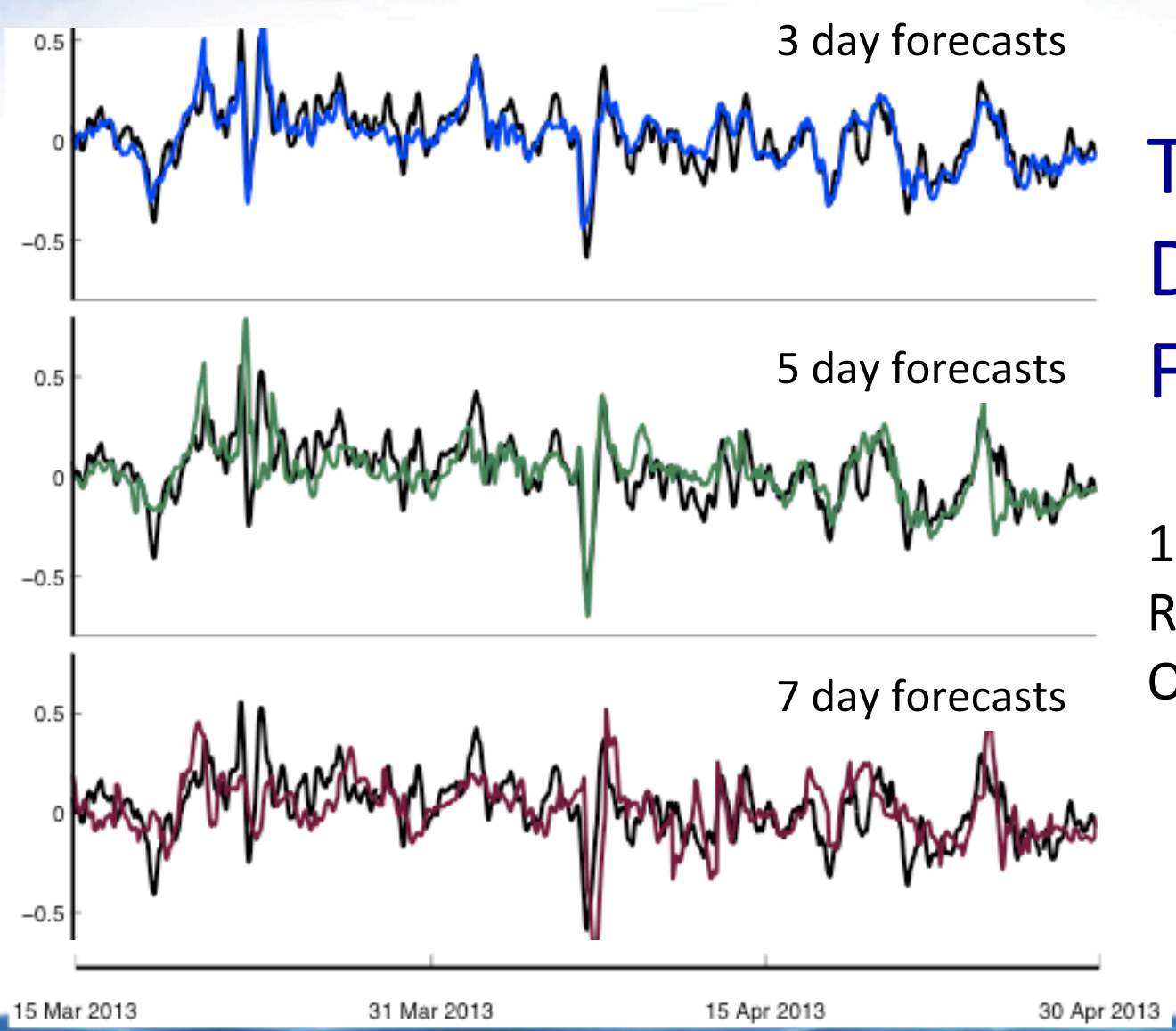
4. Storm Surge Forecasting

CoLeads: Natacha Bernier, Keith Thompson

Tsubasa Kodaira (Post Doctoral Fellow)
Fred Woslyng (Technical support)

Develop a tide and storm surge forecast system that can provide open boundary conditions for the relocatable ocean model.

The initial system is being developed for the east coast and is built on Dalcoast (resolution of 1/30°) . We are developing a global forecast system and also exploring the value of ensemble forecasts.



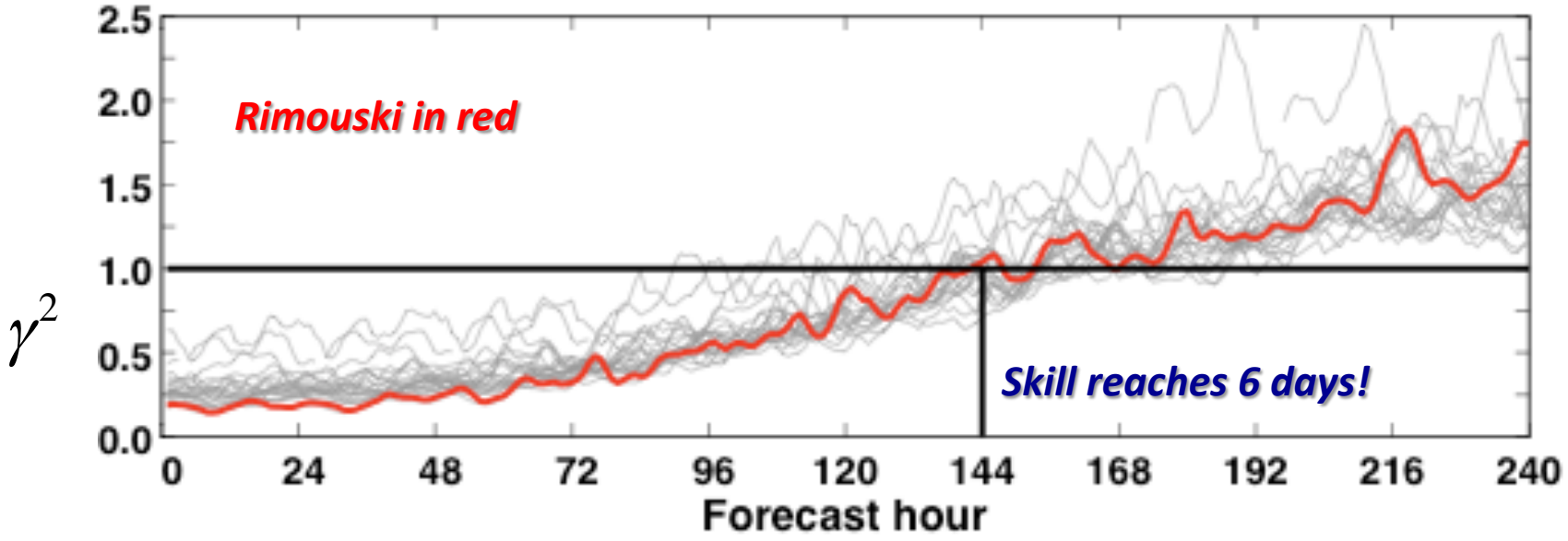
Typical Deterministic Forecasts

15 Mar-30 Apr 2013
Rimouski
Observations in black

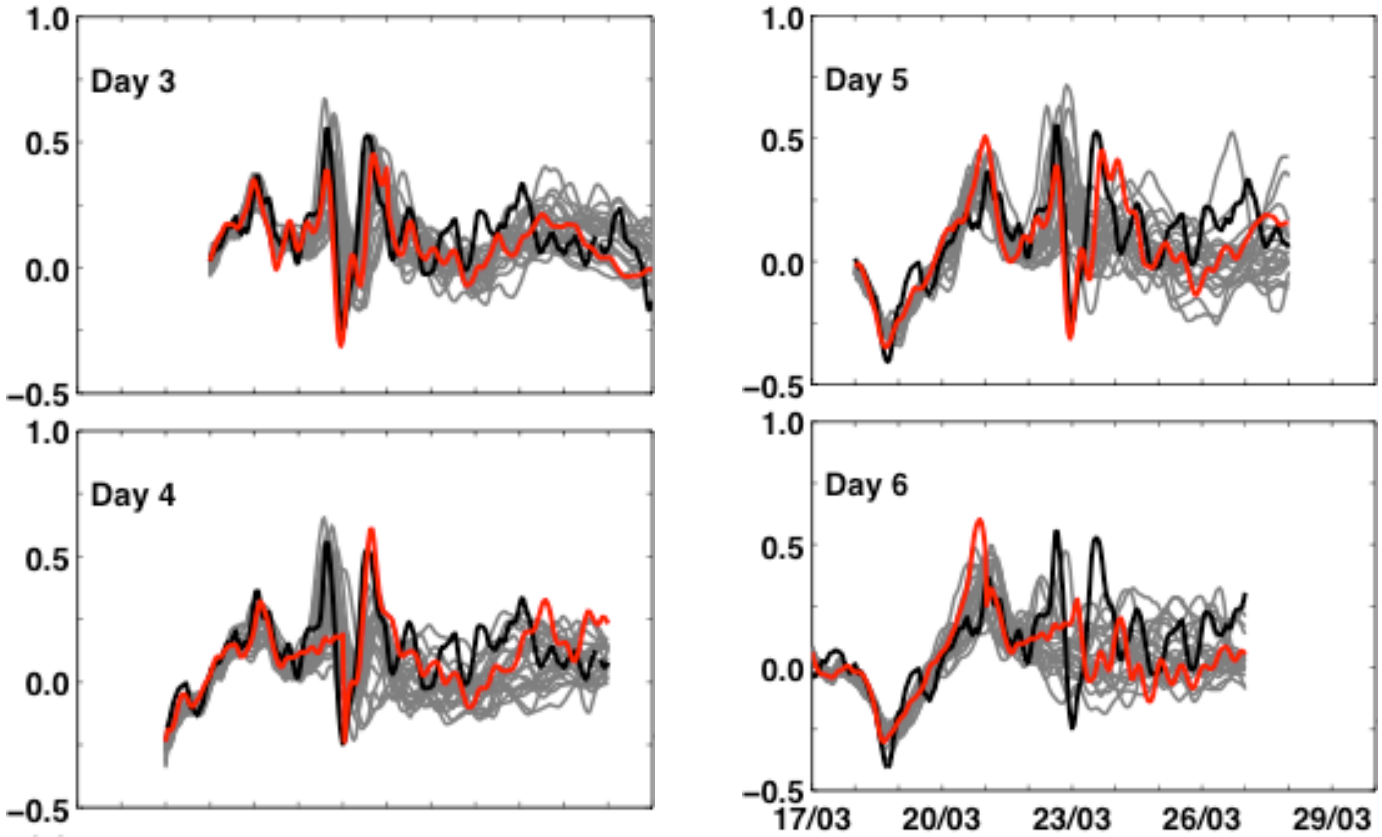
How Good are the Deterministic Forecasts?

For each of 22 east coast tide gauges, and data from March 2013 to March 2014, calculate

$$\gamma^2 = \frac{\mathrm{var}(\eta_{obs} - \eta_{\mathrm{mod}})}{\mathrm{var}(\eta_{obs})} = \frac{error}{obs}$$



Generation of Ensemble Surge Forecasts



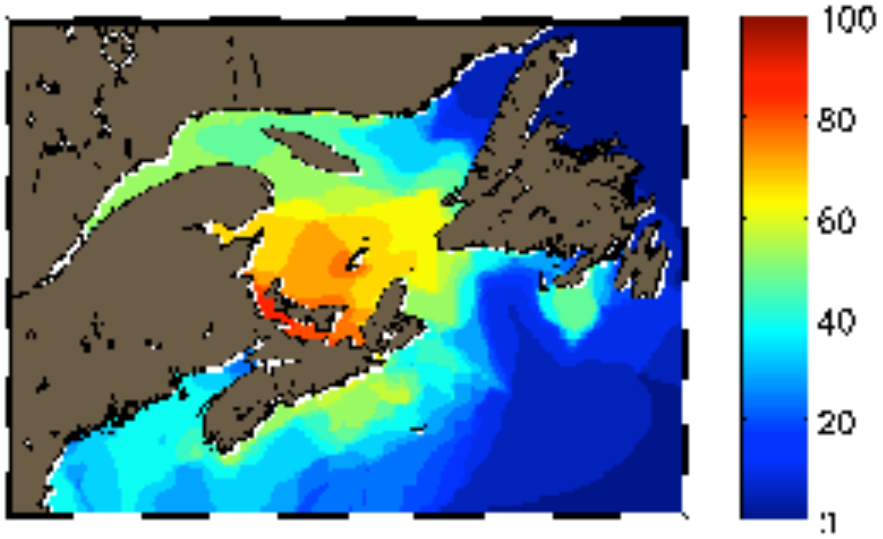
Rimouski
March 2013

Observed
Deterministic
Ensemble

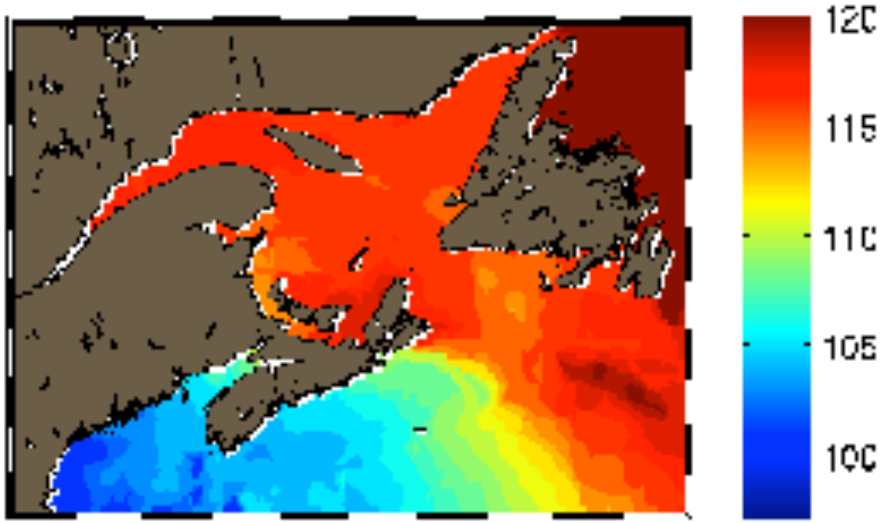
Visualizing Ensemble Surge Forecasts

5d forecast for 22 March, 2013 (based on ensemble of size 21):

Prob(surge will exceed 0.4m)



Median time of surge (h)



5. The relocatable model – field observations

Rich Pawlowicz, Mark Halverson
Dept. of Earth, Ocean, and Atmospheric Sciences,
University of British Columbia

Project Purpose:

- Evaluate different data sources for accuracy and reliability w.r.t. real ocean parameters (primarily CODAR)
- Provide data for model assimilation/evaluation (QA/QC, instrument issues)
- Determine the essential aspects of Strait of Georgia forcing and response (aka the science)

Research Progress

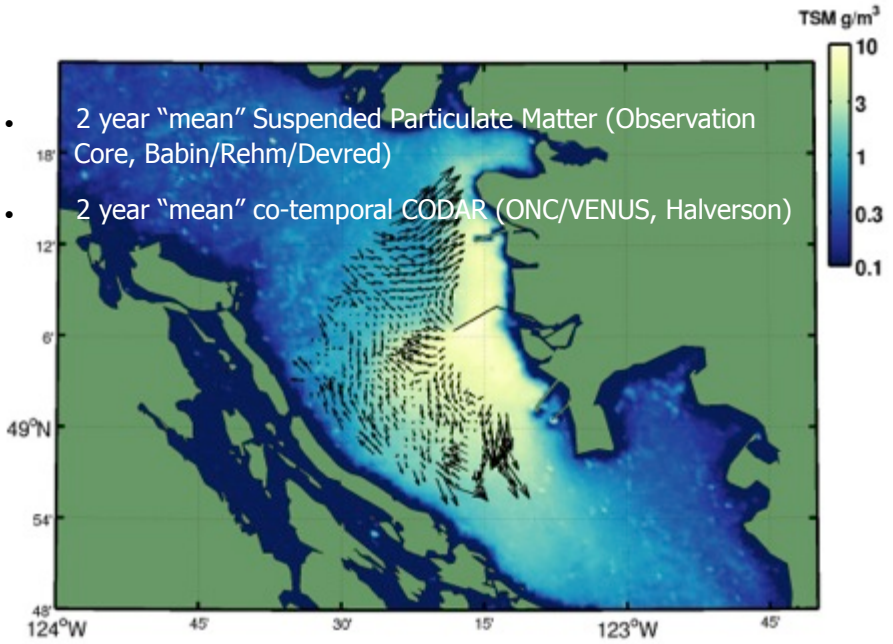
Milestones to date

- Compiled list of available observations and wrote report “A Strait of Georgia Primer”; proposed scenarios for model evaluation.
- Acquired/evaluated multi-year CODAR dataset (w/ ONC – Ocean Networks Canada)
- Acquired/corrected/evaluated moored ADCP dataset (w/ONC)
- Acquired/corrected vessel-mounted ADCP datasets (w/ ONC, Metro Vancouver)
- Acquired/evaluated satellite SPM dataset (w/Devred+Rehm)
- Acquired/investigated EC wind datasets for SoG
- MH visited U. Dalhousie (w/ Thompson et al.), attended CODAR workshop.

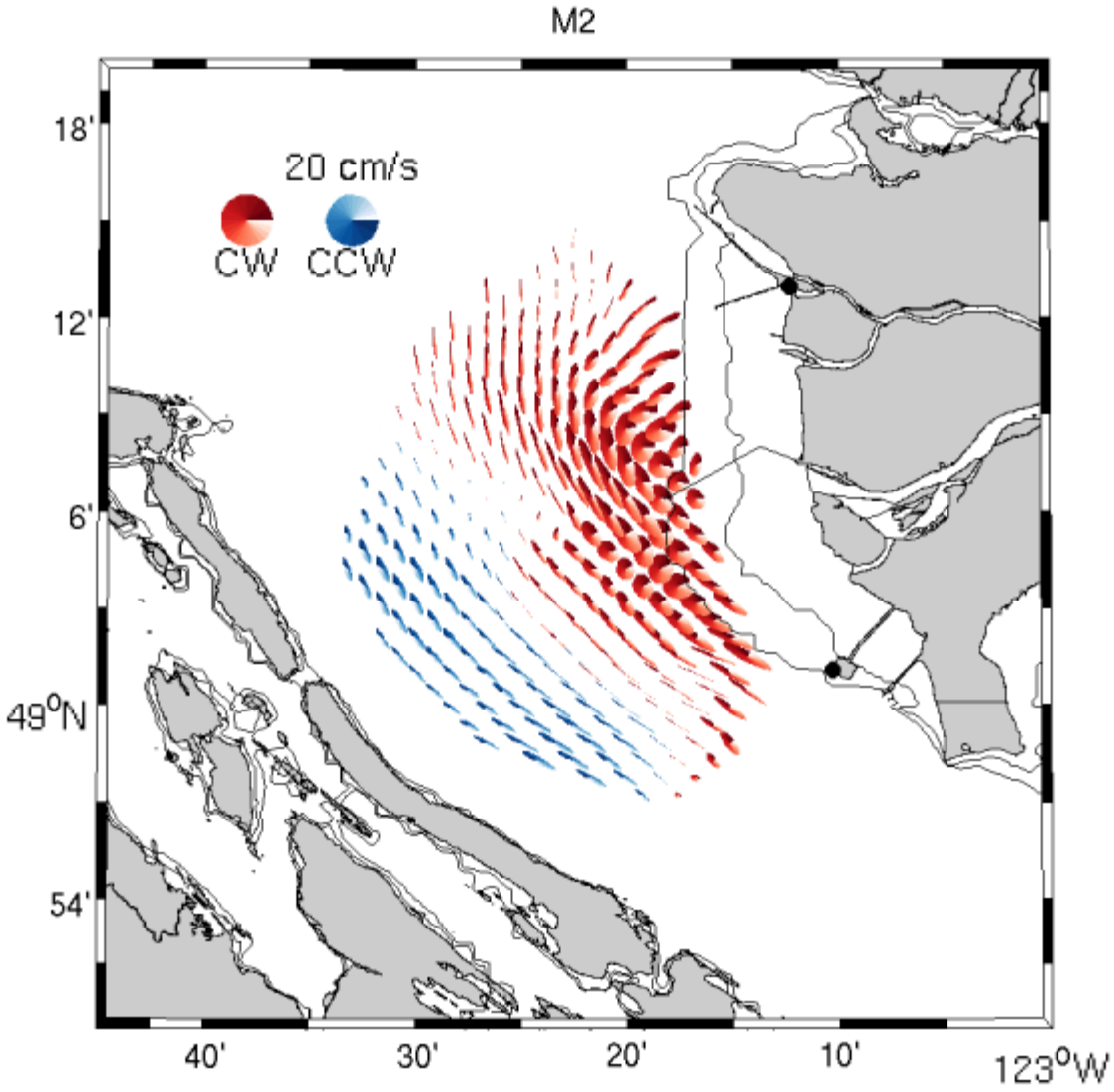
Upcoming milestones

- Complete first ms on CODAR (MH)
- Carry out Strait of Georgia drifter experiment with IP1.1 and IP1.2 (MH, Denman, ONC + the whole party)
- First tests of models (advise/assist Allen, Thompson)

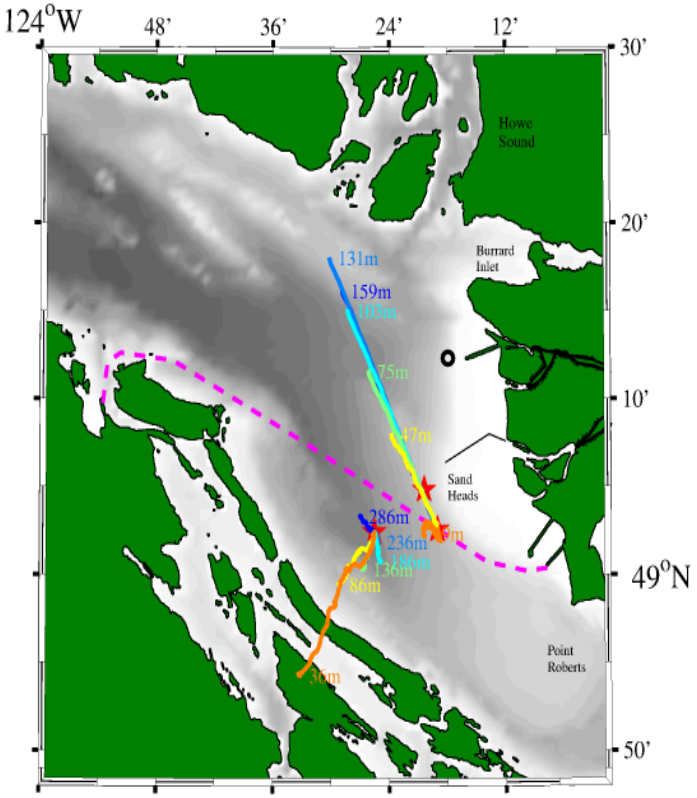
- 2 year “mean” Suspended Particulate Matter (Observation Core, Babin/Rehm/Devred)
- 2 year “mean” co-temporal CODAR (ONC/VENUS, Halverson)



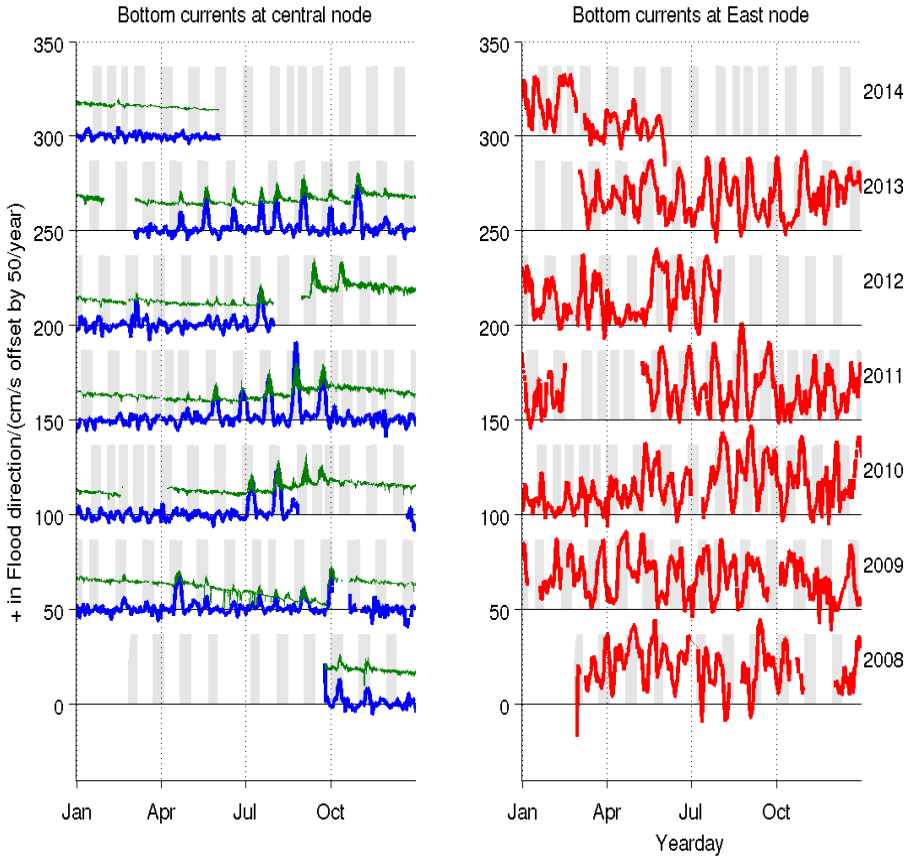
(1) CODAR: Example of M2 tidal ellipses, shallow run-up



(2) Moored ADCP (ONC/VENUS node), 6-year average currents

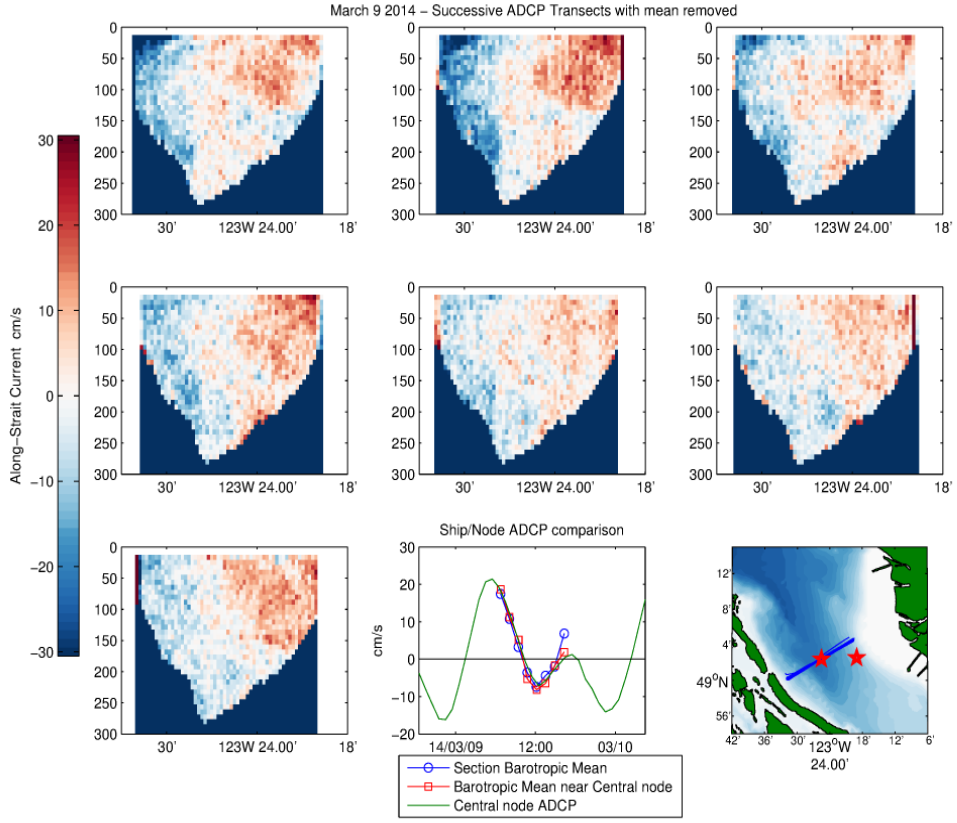


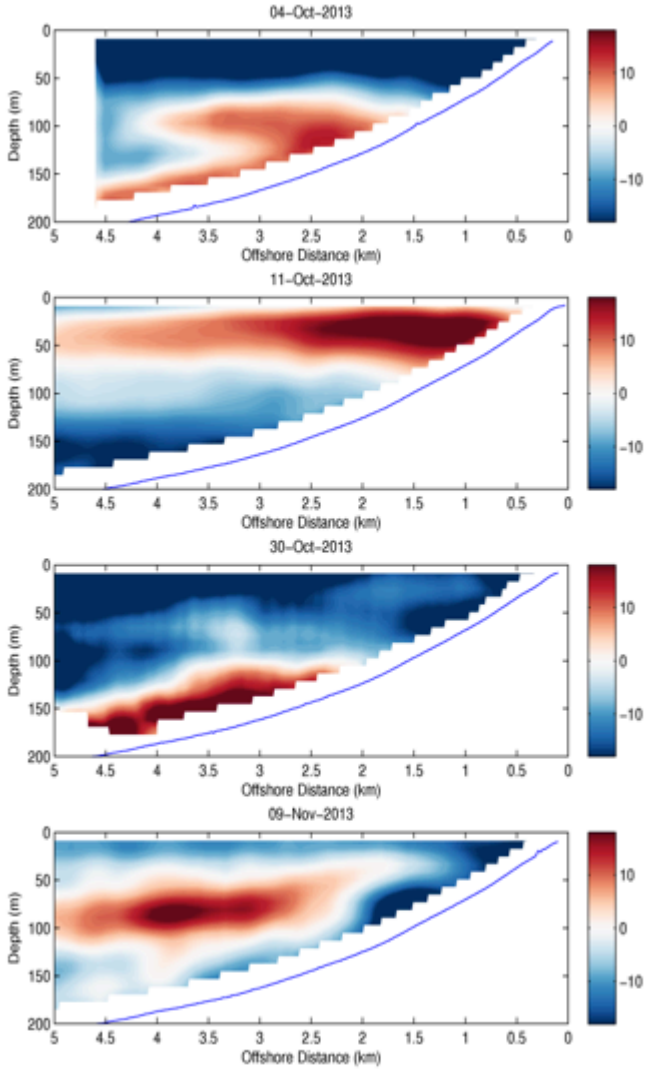
Distance to hodograph tips shows "mean 2–day displacement"



(3) Vessel-mounted ADCP (currents)

- Cross-boundary transects (UBC Kraken)
- Cross-Strait transects (CCGV Tully)





Summary / Plans

Overall research is on track, and in some cases extended.

Main milestones and goals for years 4 and 5:

- Complete testing and demonstrating systems in SoG and the SS
- Development of data/information products for receptor groups
- Publication of results
- Knowledge / technology transfer to CONCEPTS

An important lesson learned is the value of collaboration

- Within MEOPAR: IP1.2, Prediction and Observation Cores
- Outside MEOPAR: CONCEPTS

Questions?

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