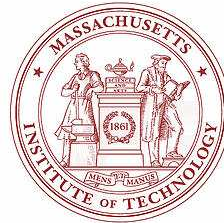


PN07 Environmental and Acoustical Modeling, Predictions and Adaptive Sampling

Pierre Lermusiaux, Pat Haley, Wayne Leslie, Oleg Logutov, Jinshan Xu, H. Hornick

Mechanical Engineering, MIT



http://modelseas.mit.edu/Sea_exercises/PLUSNet07

-
- ❖ **Summary of Main Accomplishments**
 - ❖ **Ocean Data and Dabob Processes**
 - ❖ **Physical Ocean Modeling and Multi-asset Data Assimilation**
 - ❖ **Coupled Physical-Acoustical Modeling and Predictions**
 - ❖ **Tides/internal tides: processes, modeling and predictions**
 - ❖ **Issues and Conclusions**



MIT Modeling Accomplishments

- Issued 10 sets of real-time nowcasts and forecasts of temp., salinity, velocity and acoustic TL at 3 frequencies and 3 source depths
 - Assimilated ship and glider data
 - Forecasts forced by our own high-resolution barotropic tides and by NOGAPS atmospheric flux predictions
 - Coupled Ocean-Acoustic Models: Free-surface HOPS and C-Snap
- Data analyzed and quality controlled daily
- Web: http://modelseas.mit.edu/Sea_exercises/PLUSNet07 for daily distribution of plots and all model data files

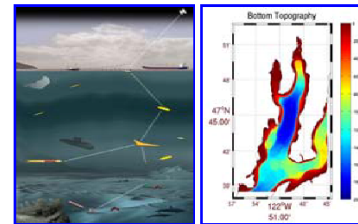
PO Results:

- Dabob Bay closer to a Fjord than open-ocean, which was challenging but interesting for us: No shelf, salinity drives density
- Found (and forecasted) that internal tides and atmospheric forcing are important for cross-bay currents, sub-surface cold layer dynamics and deep cold layer.

PN07: Persistent Littoral Undersea Surveillance Network 2007 Exercise - Dabob Bay - MODELSEAS Home Page

P.F.J. Lermusiaux, P.J. Haley, Jr.,
 W.G. Leslie, O. Logutov, J. Xu,
 A. Agarwal, L. Burton, H. Hornick, M. Ueckermann
 H. Schmidt

Massachusetts Institute of Technology
Center for Ocean Engineering
Mechanical Engineering
 Cambridge, Massachusetts

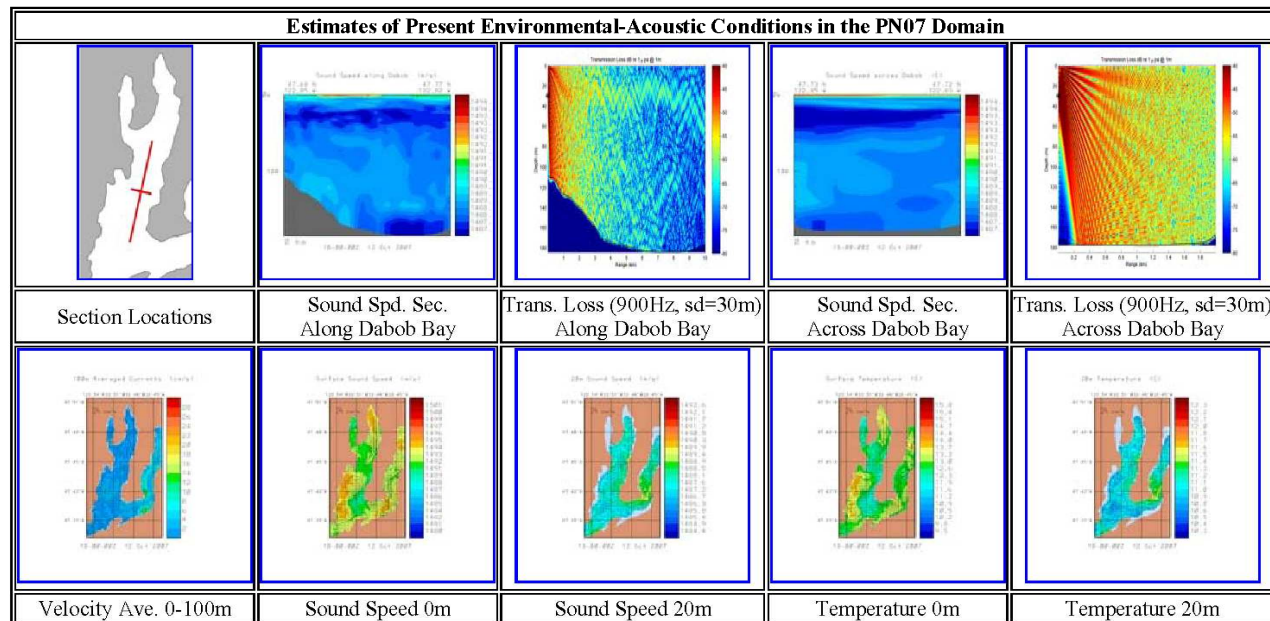


- [Real-Time PN07 Exercise \(Analyses, Forecasts\)](#)
- [Background information and historical data](#)
- [Asset Deployment](#)
- [Additional PLUSNet Links](#)
- [Some References and Presentations](#)
- [Additional links of interest](#)

MIT PN07 Team Leaders

H. Schmidt, A. Baggeroer, J. Curcio, J. Leonard, P. Lermusiaux and D. Rus

PN07 Real-time Exercise



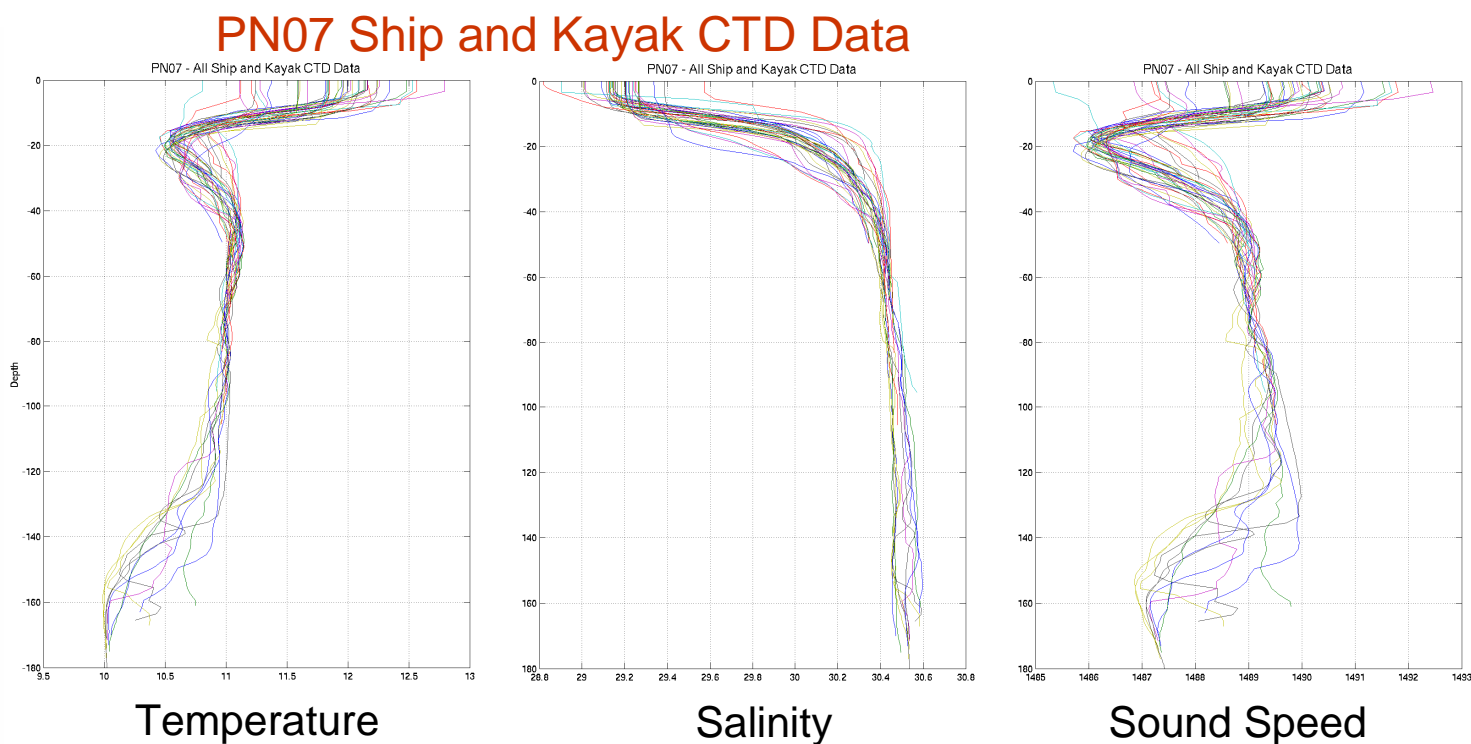
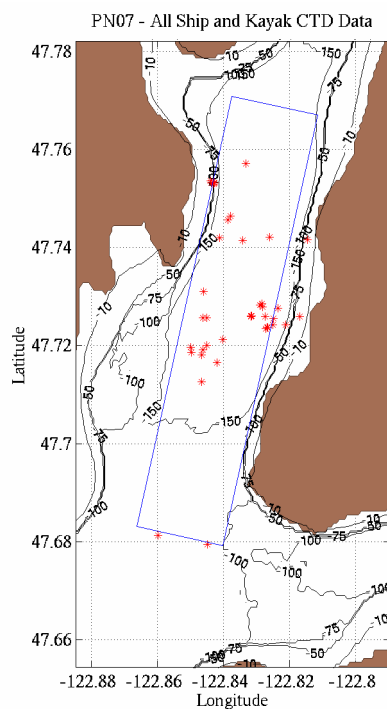
PN07 in situ observations:

Thanks to all for your CTD data!

- 43 profiles from ship and kayak CTDs
- Over 3000 profiles from UW-APL SeaGliders
- Data requires inter-calibration on daily basis
- AUV data being processed

Simple Inferences from Data

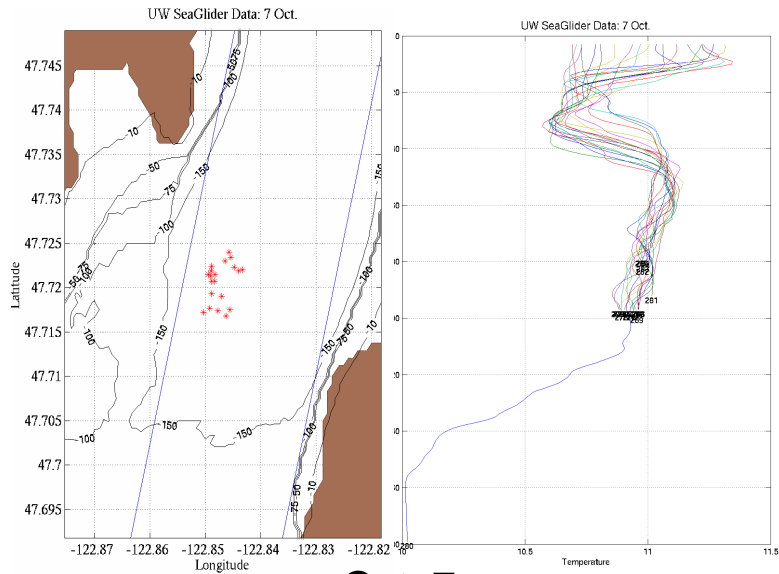
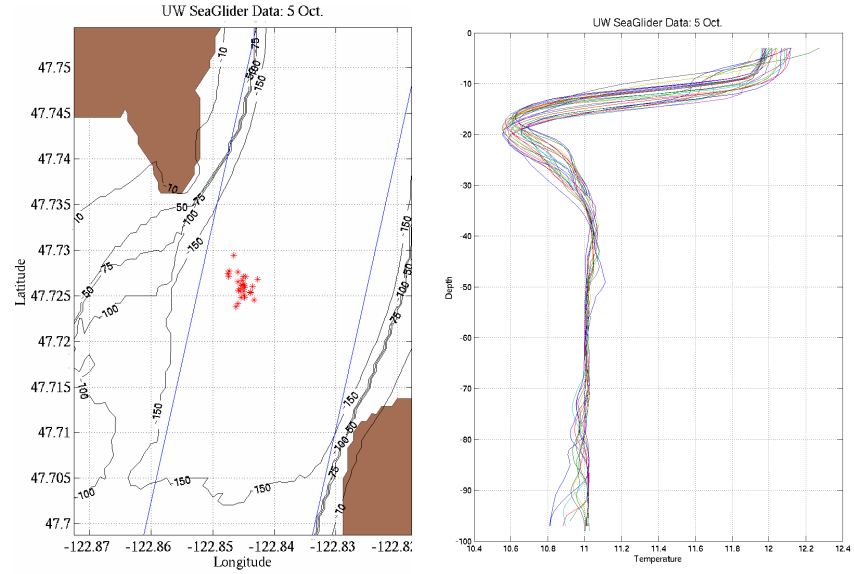
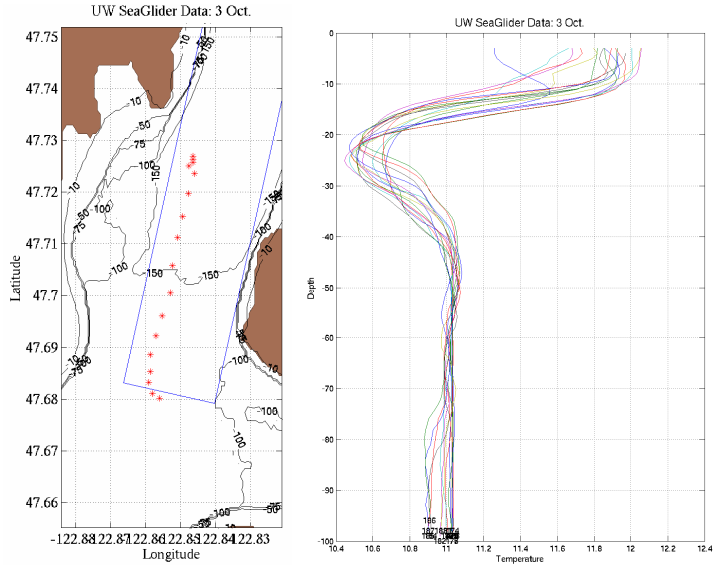
- Salinity drives density
- Temperature behaves almost as a passive tracer (“slides” with wind forcing): 4 layers
 - summer surface thermocline, cold sub-surface (20m), intermediate, cold bottom



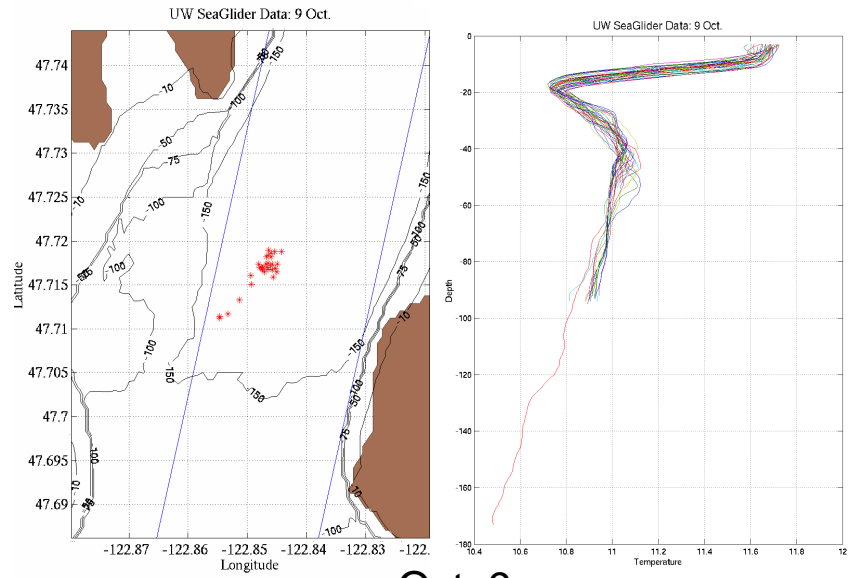
UW-APL SeaGlider 116 Data

Oct. 3

Oct. 5



Oct. 7

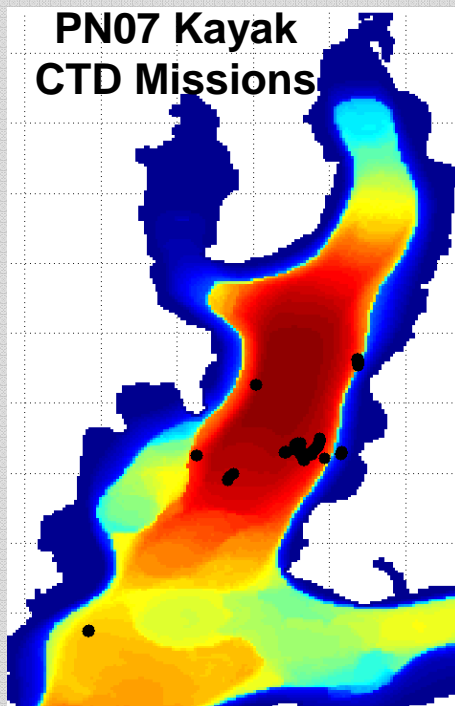


Oct. 9

Adaptive Planning of Kayak Missions

Four A-priori Formulated Goals:

- sample specific model-driven estimates: higher uncertainty/variability areas
- cross-calibration and cross-validation of instruments (ship CTDs, gliders)
- sample Hood Canal - Dabob Bay interactions and tidally-driven features
- measure wind-driven modes of variability

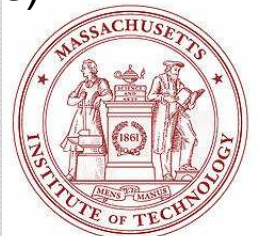


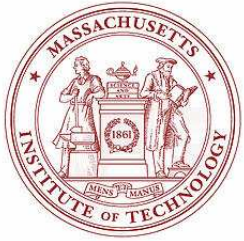
Successful Missions:

- examined the internal wave activity in Dabob
- collected data for glider/ship CTD cross-calibration
- sampled modes of upper layer variability
- sampled upper layer response to wind events

Unaccomplished (logistical difficulties) :

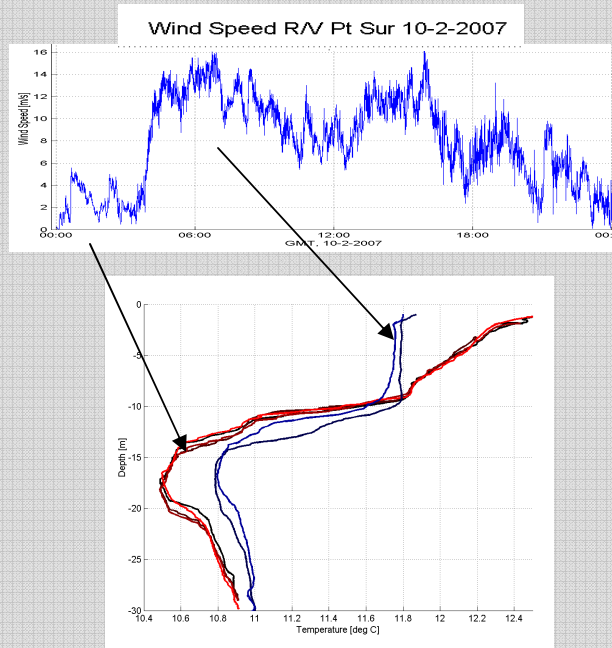
- sampling of tidal effects



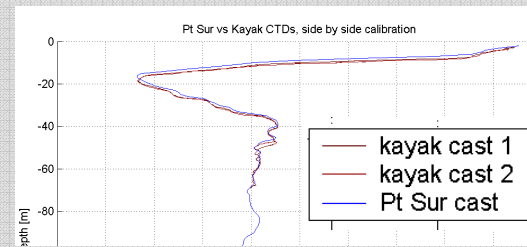


Examples of Kayak Missions

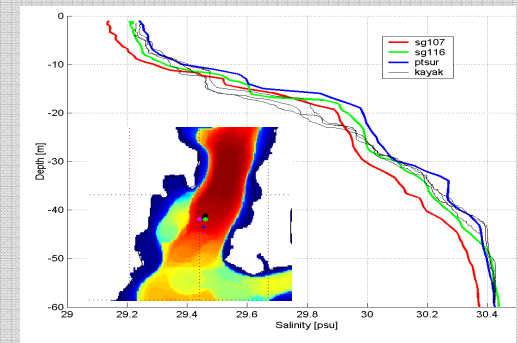
■ response to a wind event



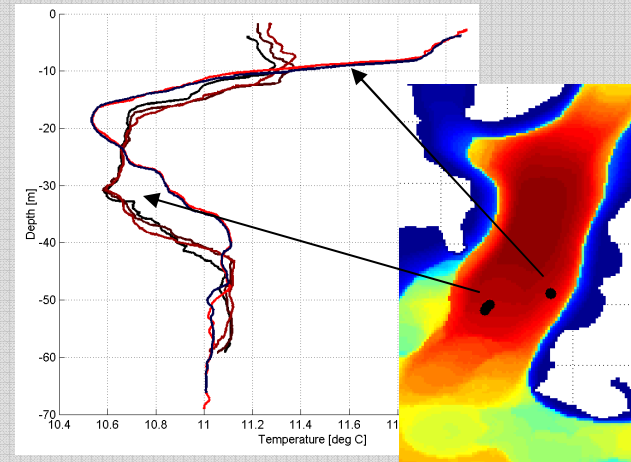
■ kayak CTD calibration using Pt Sur

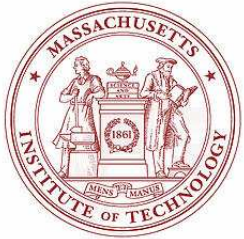


■ Glider calibration using kayak CTD (Oct 7, 20GMT)



■ Upper layer spatial structure



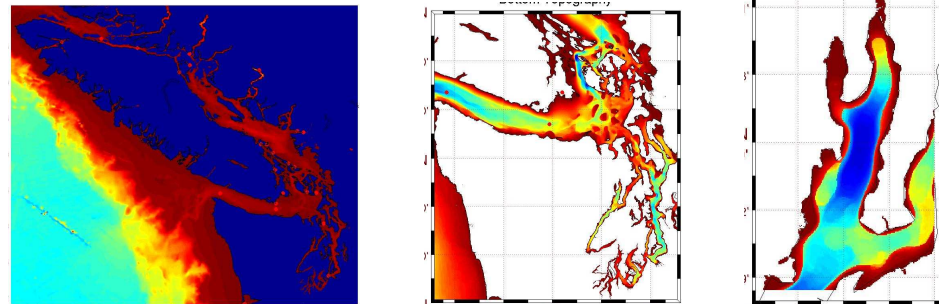


Tides and Tidal Modeling

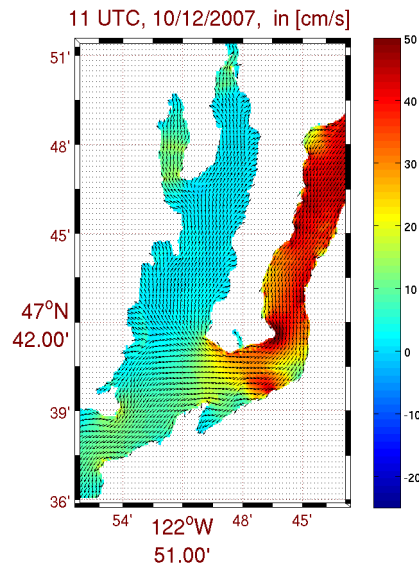
Hourly tidal estimates for the entire duration of PN07 have been provided at: http://modelseas.mit.edu/Sea_exercises/PLUSNet07

■ tidal estimates were obtained from generalized-inverse solution of the shallow water equations, in nested multi-scale domains over high resolution bathymetry

■ tide gauges were assimilated to correct for errors in open boundary conditions of the three nested domains

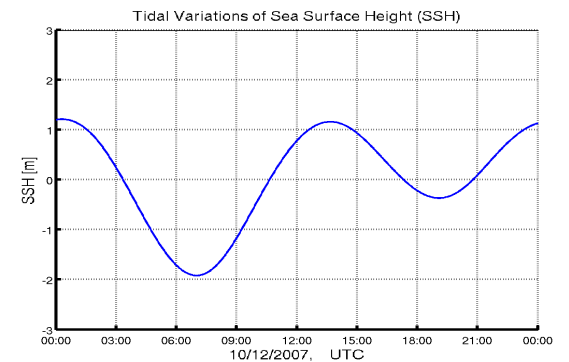
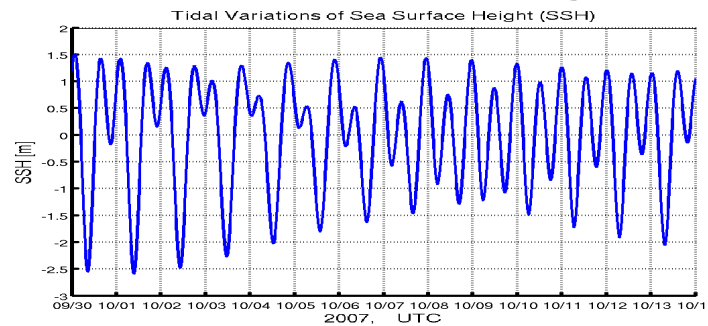


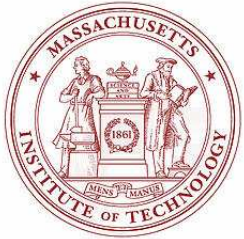
Tidal Currents [cm/s]



3 nested domains were utilized

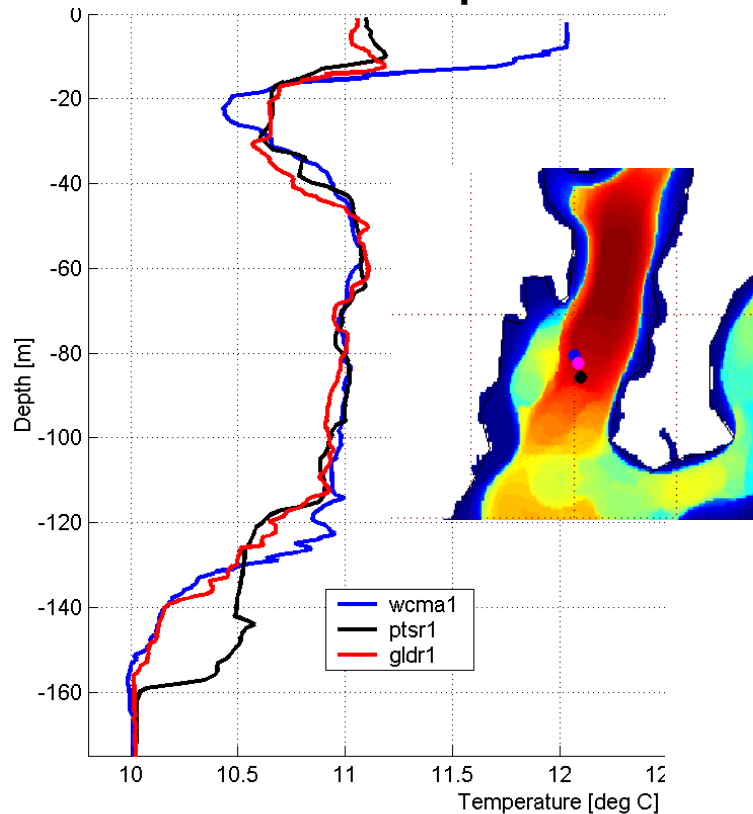
Tidal Sea Surface Height [m]





Internal Tides and Deep Layer Variability

CTD T example



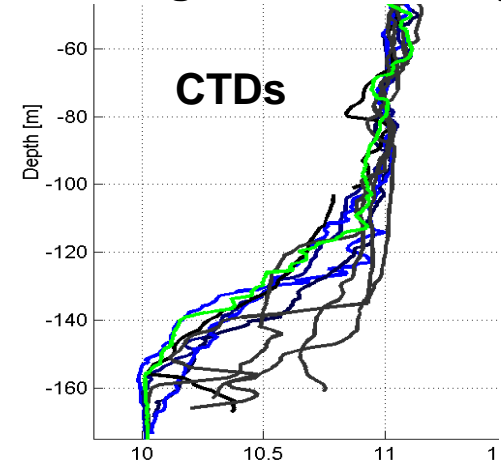
note wave-like patterns in 120-160 m layer

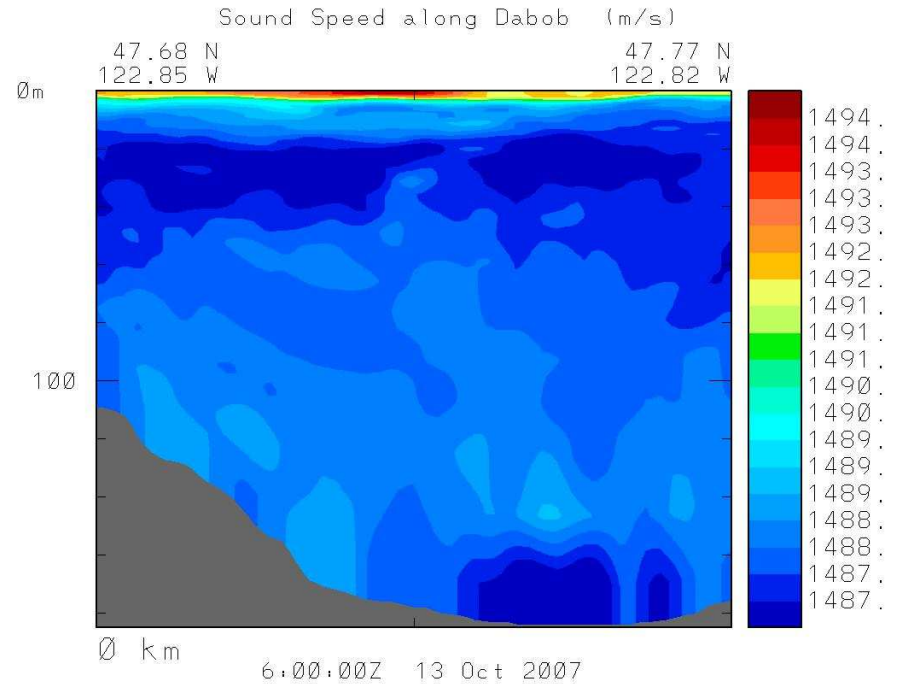
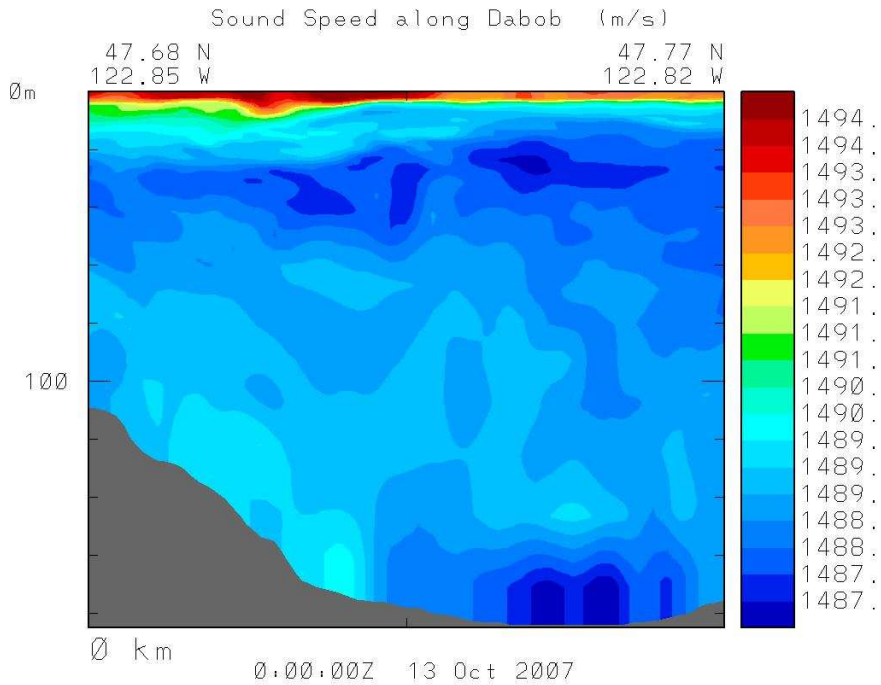
Data revealed greater than anticipated variability in deep layer

- occasional deeper glider dives were requested
- current hypothesis: internal tides
- we will combine collected data with model simulations to conclusively determine the source of deep layer variability and properties
- model parameters will be tuned to properly capture the process

unprecedented data set collected for describing/ understanding deep layer variability

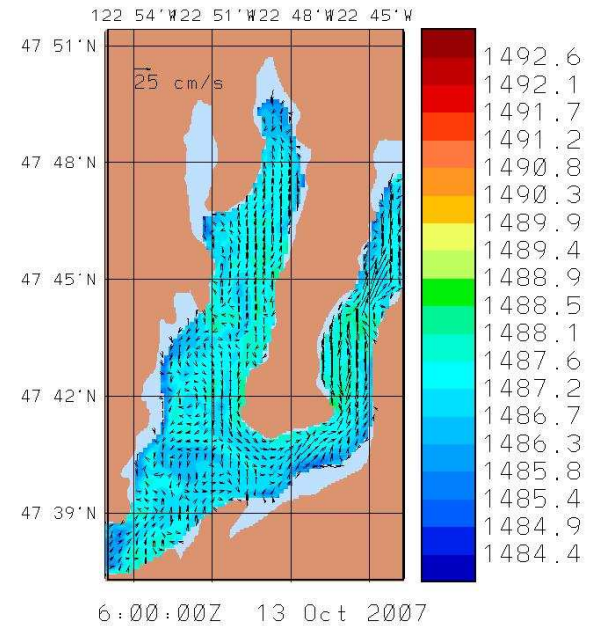
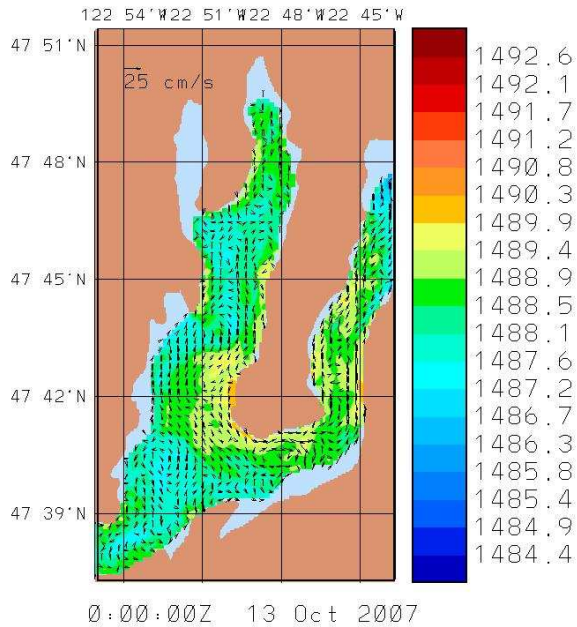
range of T variability





20m Sound Speed (m/s)

20m Sound Speed (m/s)

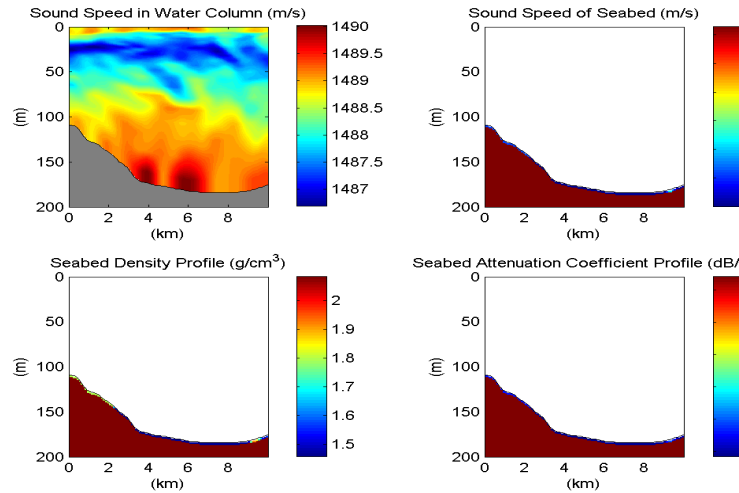


**Should you want
To go back to Dabob
Tonight, here are
Our predictions,
Oct 13, 00Z and 06Z**

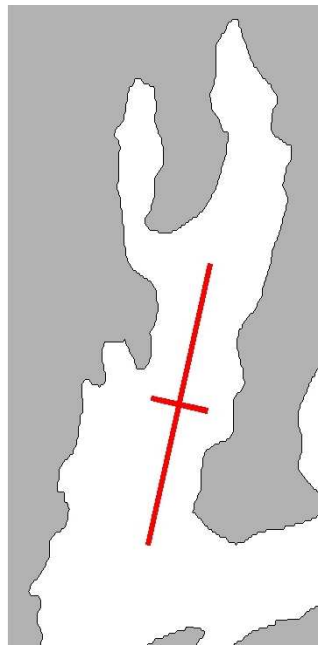
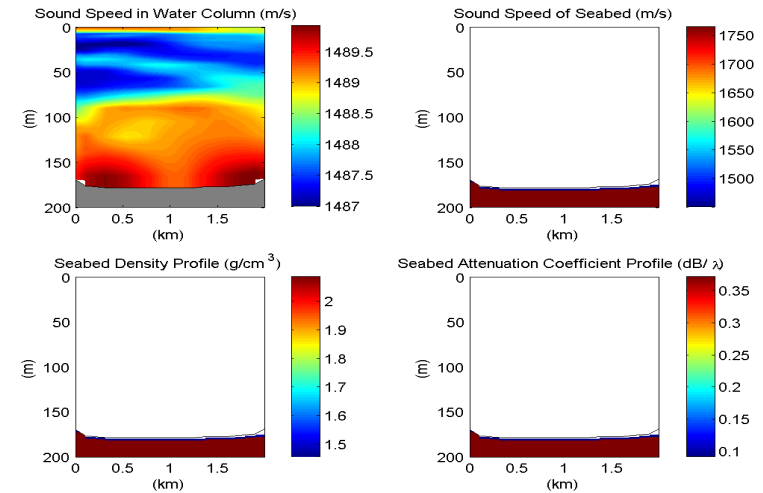
**Ps: note effects of
tides/internal tides**

Dabob Bay Geoacoustic Model and Acoustic TL Predictions

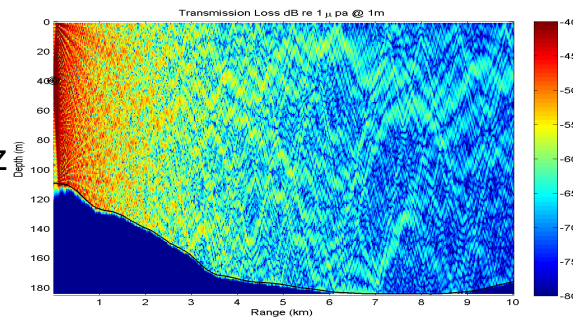
Along Dabob Bay



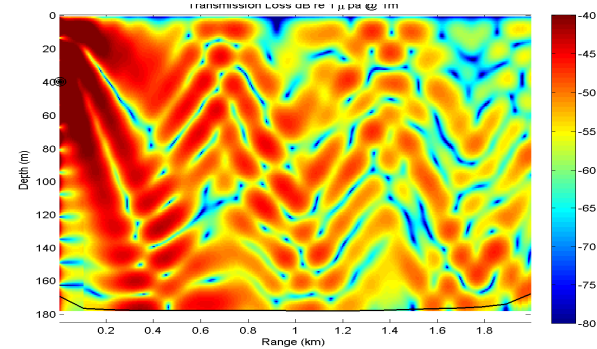
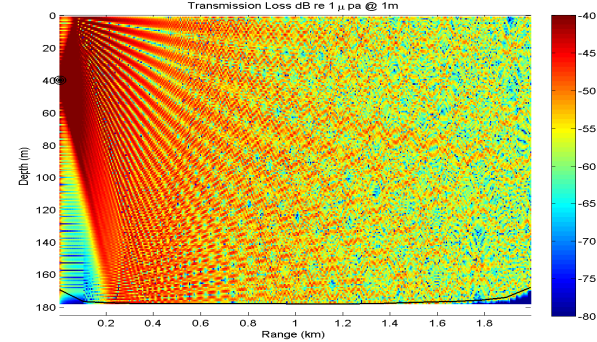
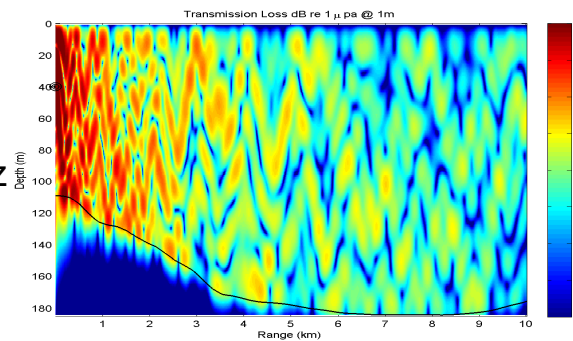
Across Dabob Bay



900 Hz



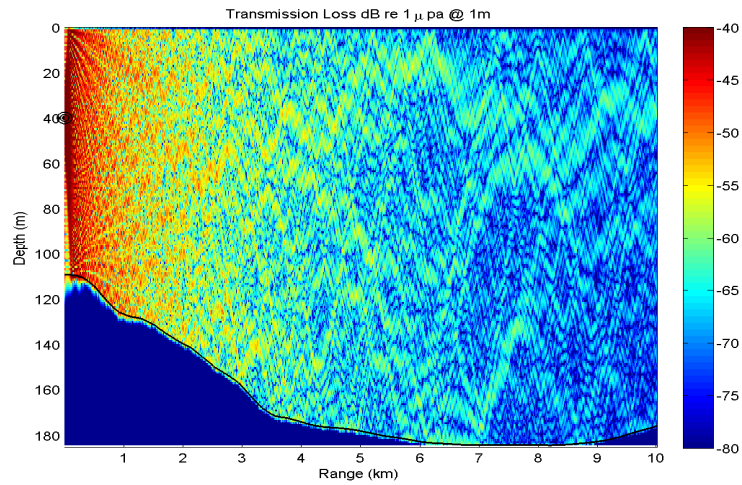
100 Hz



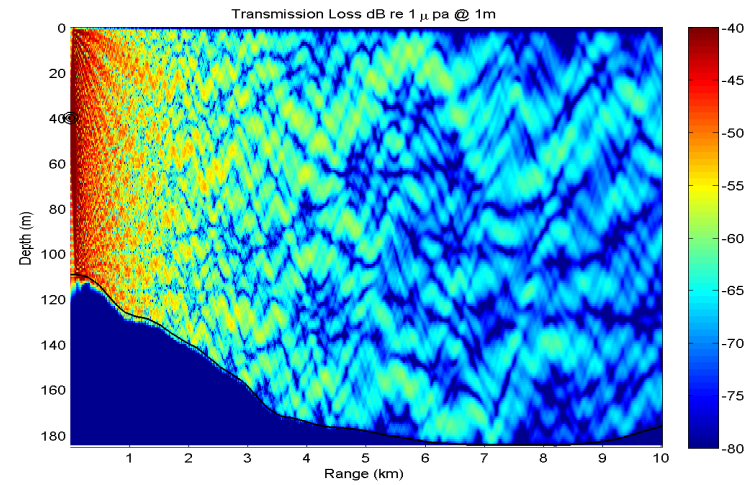
Two Geo-acoustic Models used in real-time

HFEVA Range-Dependent Model (Left), Silt-Clay Range-Independent (Right)

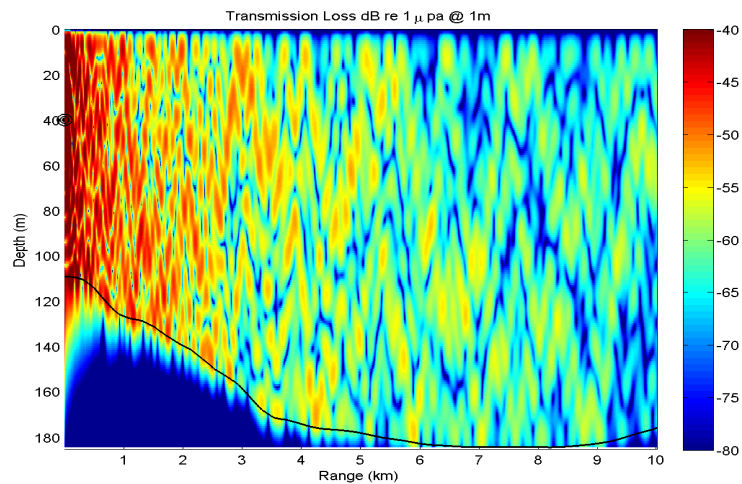
900 Hz, src_depth 40 m



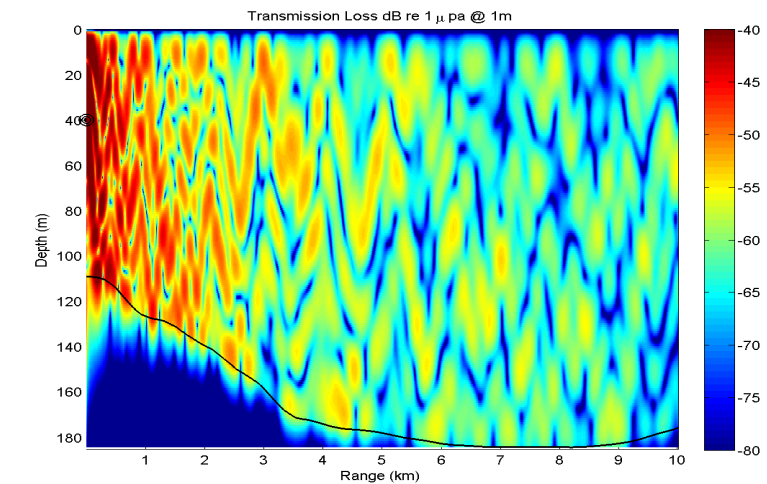
900 Hz, src_depth 40 m



100 Hz, src_depth 40 m

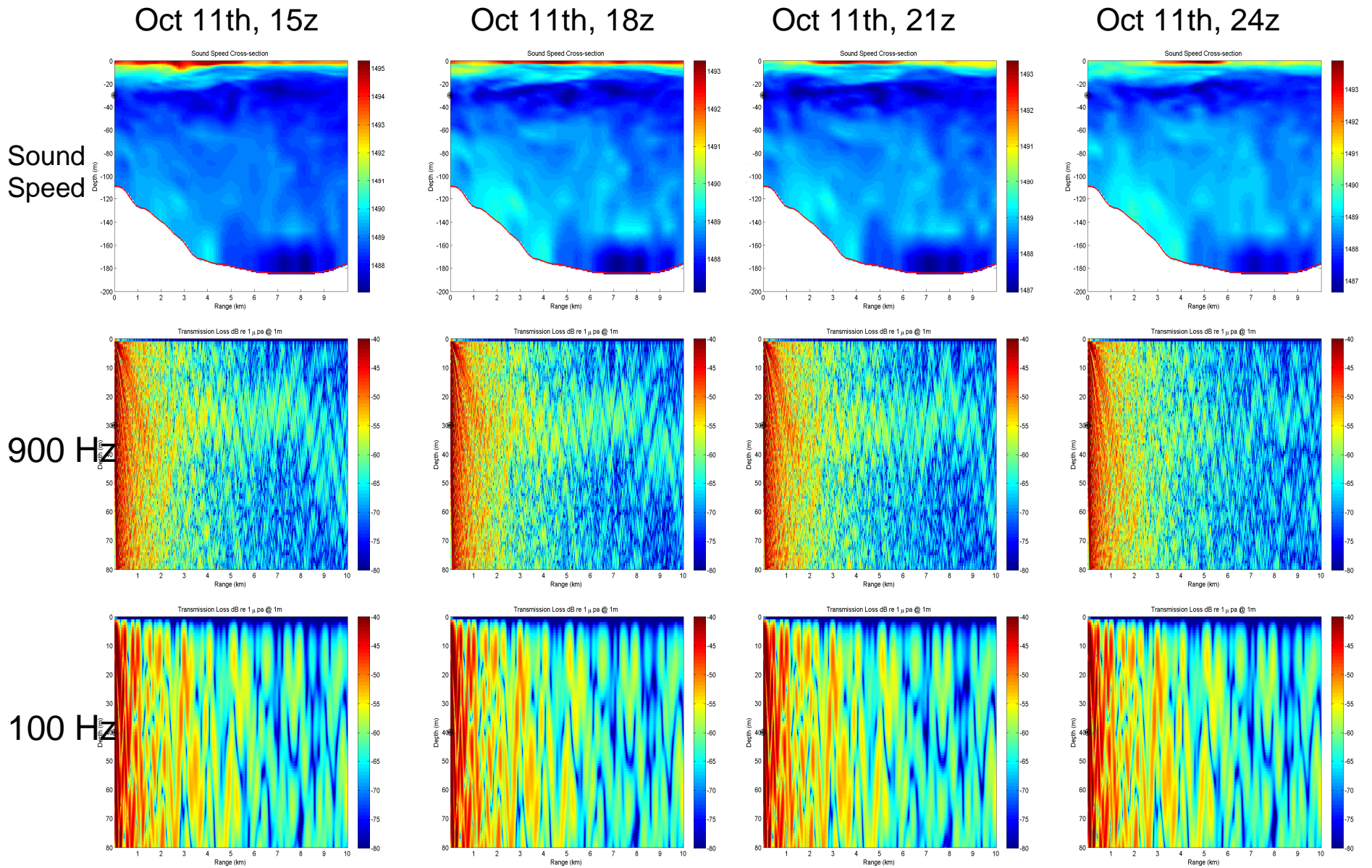


100 Hz, src_depth 40 m



PS: Thanks to Katherine, Mike et al. from HLS, and to NAVOCEANO

Tidal Effects on Acoustic TL Estimations and Predictions



Here source is at 30 m depth (leads to larger tidal effects on the acoustics than at 40m)

MIT Modeling Accomplishments

PO Results

- Dabob Bay closer to a Fjord than open-ocean!, which was challenging for modeling but interesting for us:
 - No shelf, pycnocline hits steep topography right away and so sigma levels
- Found (and forecasted) that internal tides and atmospheric forcing are important for cross-bay currents, sub-surface cold layer dynamics and deep cold layer

Acoustic Results

- Seabed bottom properties found critical factor to estimate TL, especially for higher frequency
- Water column fluctuations (we showed tidal effects, but atmospheric forcing also matters) also found important for TL
- We are researching quantities that would quantify the TL variations over the 10 days.

Extra slides

Snapshot Time-Series of the Estimated Ocean State (every 6 hours)										
T 0m	T 20m	T 50m	C 0m	C 20m	C 50m	Vel. 0m	Vel. 20m	Vel. 50m	0-100m Ave. Vel.	Wind Stress

Vertical Sections			
T. along Dabob Bay	T. across Dabob Bay	C. along Dabob Bay	C. across Dabob Bay

Transmission Loss Estimates (at 06Z and 18Z)						
5 Oct.	6 Oct.	7 Oct.	8 Oct.	9 Oct.	10 Oct.	11 Oct.

- The ocean predictions are obtained using the Harvard Ocean Prediction System and its free-surface primitive-equation model and data assimilation schemes. These predictions are combined with a range-dependent seabed model (courtesy of NAVOCEANO and Mike Porter and his HLS team) to estimate the environmental fields used for acoustic predictions. The acoustic model utilized is the Coupled SACLANTCEN normal mode propagation loss model (C-SNAP). It is a range-dependent one-way coupled modes model with impedance matching to account for energy conservation.
- [Files Containing our Data-driven Model Estimates and Predictions](#)
 - [ASCII formatted files for NAFCON](#)
- Barotropic tidal predictions for PN07 in Dabob Bay
 - [Calculation of Barotropic Tides](#)
 - [Sea Surface Height](#)
 - [Tidal Current](#) at 3 hour intervals
 - [Tidal Current](#) at hourly intervals

As these results show, we expect barotropic tidal currents to be stronger on Sep 30-Oct 01 and weaker around Oct 09, 2007. Tidal variability is the largest in the Hood Canal. The center portion of Dabob Bay is a shadow zone for tides (weak barotropic tides).

Archived Issued Products								
3 Oct.	4 Oct.	5 Oct.	6 Oct.	7 Oct.	8 Oct.	9 Oct.	10 Oct.	11 Oct.

[Return to top of document](#)

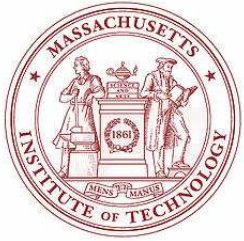
MIT-developed background information and historical data

- [Historical Data near Dabob Bay](#)
- [Background information on Dabob Bay](#)
- [Tidal Height predictions for PN07 in Dabob Bay](#) from XTide program
- [Historical Data near Nanoose](#)
- [Strait of Georgia References](#)

[Return to top of document](#)

Asset Deployment

- Operational area layout [\[PNG\]](#) [\[PPT\]](#)
- [Important information for research vessels](#) Rev. 27 Aug. [\[PDF\]](#)



Sampling with Kayaks

■ Data Flow:

- CTD data transmitted directly to modelseas.mit.edu via wi-fi
- kayak controlled from modelseas.mit.edu via wi-fi

■ Advantages:

- in theory, kayak can be controlled directly by ocean model
- more flexibility to craft missions for specific processes or model uncertainties
- kayak can capture small scale structure (internal waves, cross-front)

■ Encountered Limitations :

- logistical constraints (limits on times/places of kayak launches)
- weather (flexibility of choosing sampling locations exists only in good weather)
- battery constraints (in practice, only a few full CTD casts possible before battery change required)
- hardware issues (winch, reliability, etc)