Applications for Mapping Spilled Oil in Arctic Waters

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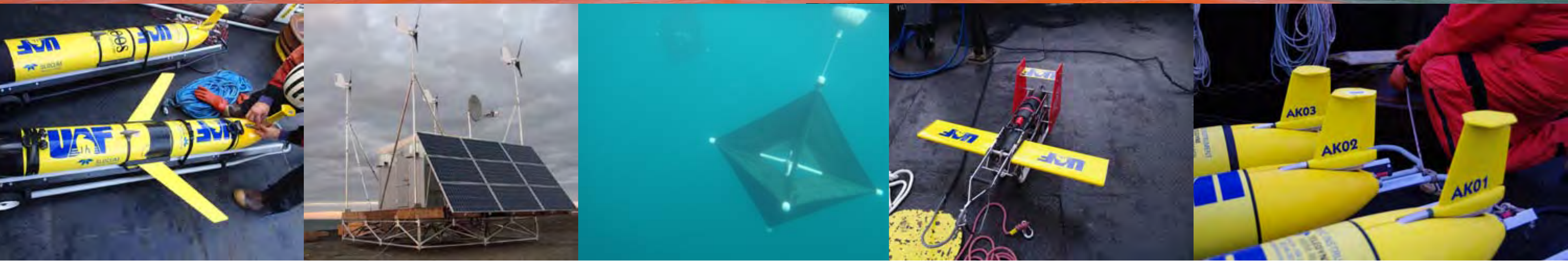

Arctic Oil Spill Symposium, Fairbanks, March 6th, 2014

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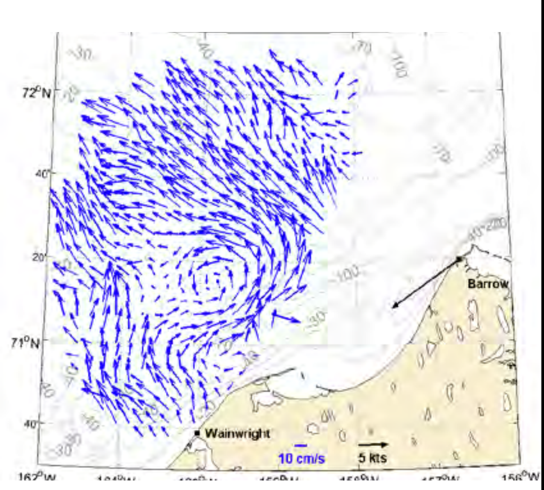
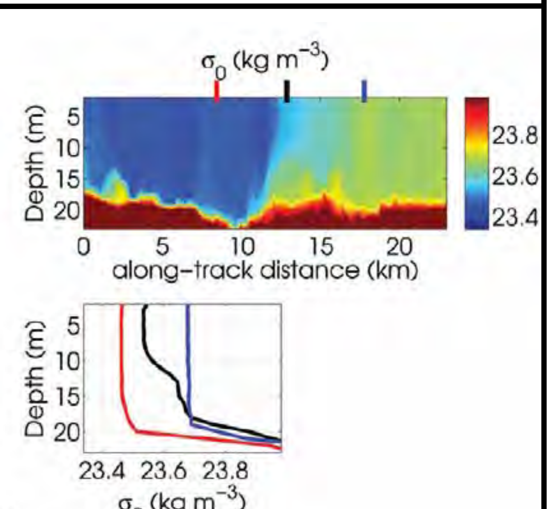
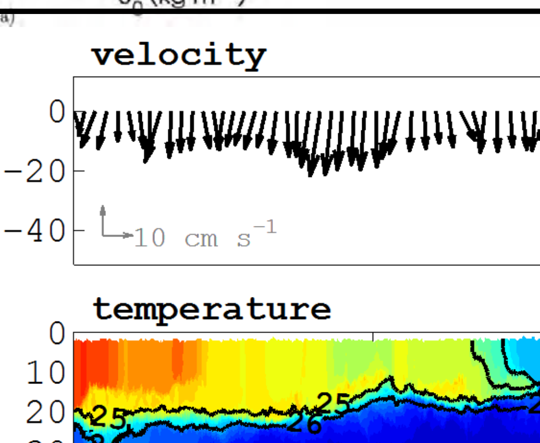
UAF physical oceanography group have operated sub-surface moorings, High-Frequency Radars (HFRs) & Remote Power Modules, AUV gliders, towed vehicles and satellite-tracked drifters since 2009. Most of the data is transmitted in *real time* via satellite. Constitutes one of the largest observing efforts in the Arctic to date.

This talk focuses on observational assets and technology and their application for oil spill monitoring.







High Frequency Radar (HFR)

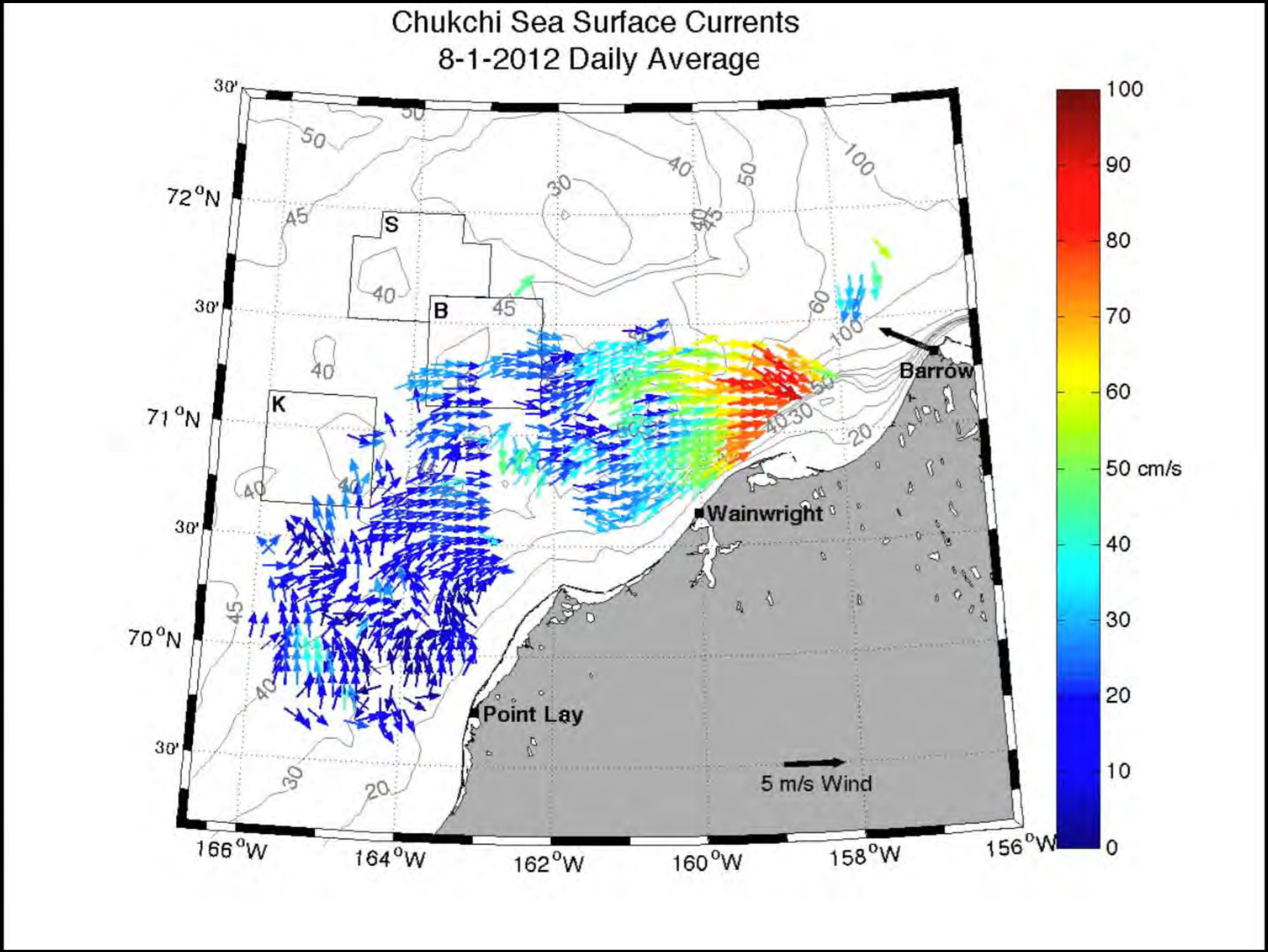
Land-based radars producing hourly 2-D current vectors over 150 km offshore at 6-km horizontal resolution.

Operate 5 units 2009-2013 in remote Arctic Alaskan regions (Barrow, Wainwright, Point Lay, Cape Simpson) from June to October, and since 2013 at Cape Simpson.

Remote Power Module (RPM)

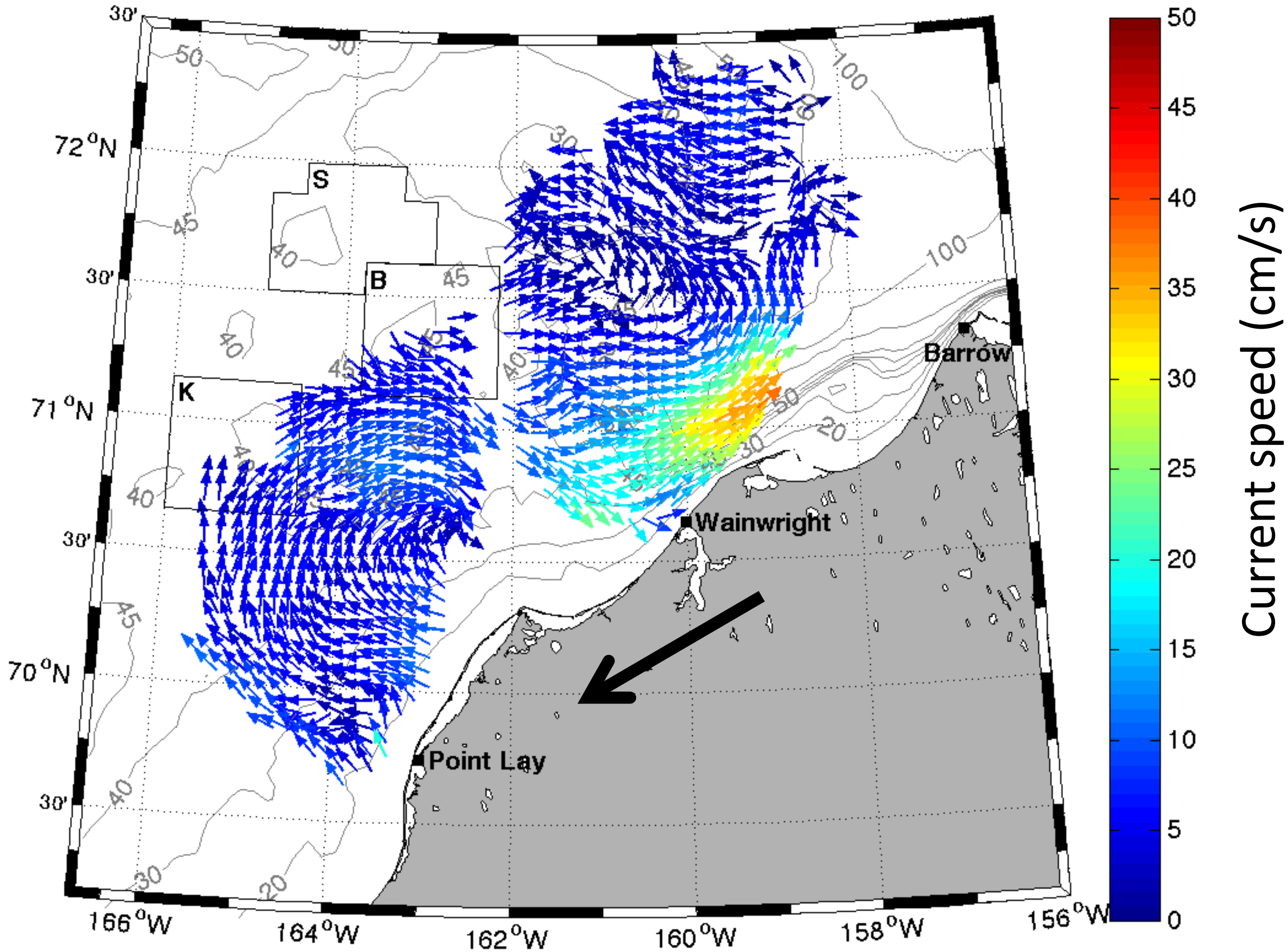
Fully-automated, renewable (solar and wind) hybrid power station provide power to HF radars. Designed to operate in Arctic and sub-Arctic maritime environments. Enables freedom to position HFR's where needed without grid power.

Animation of HFR daily-average surface current maps

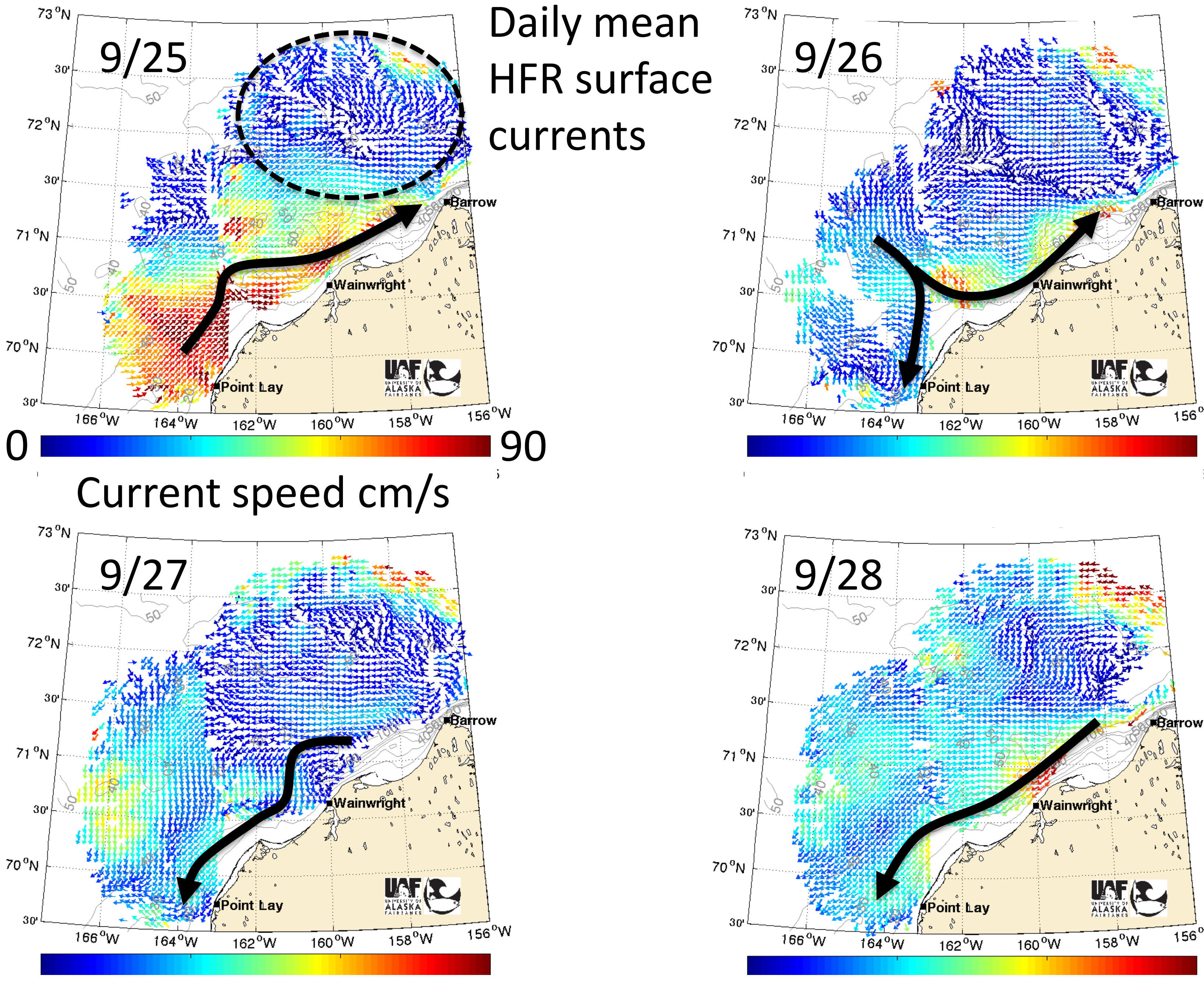


Time period: 08/01 to 10/31, 2012. Wind vector from Barrow airport.

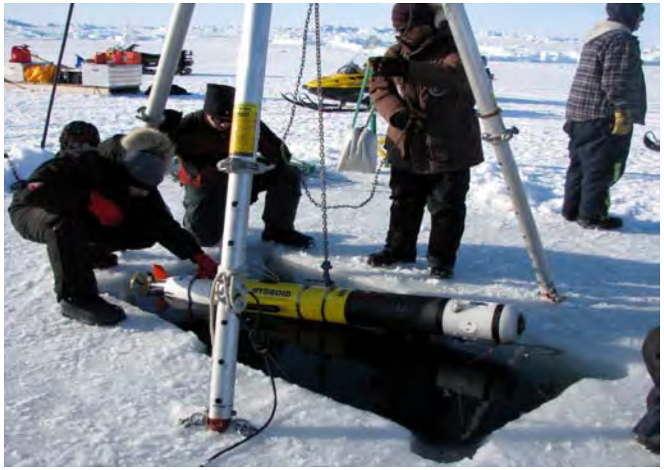
Mean HFR surface current field for NE winds < 6 m/s

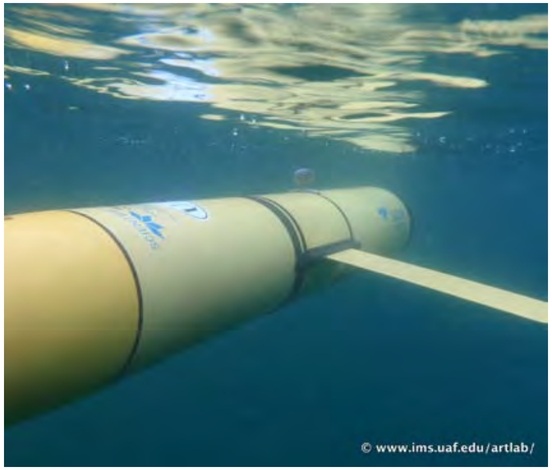


Mean surface currents oppose the NE winds for wind speeds < 6 m/s. Sustained and higher winds reverses the flow


Daily mean
HFR surface
currents
9/25
9/26
9/27
9/28
Barrow
Wainwright
Point Lay
73 °N
72 °N
71 °N
70 °N
30'
166 °W
164 °W
162 °W
160 °W
158 °W
156 °W
0
90
Current speed cm/s

Autonomous Underwater Vehicles (AUVs)





Left: Deploying the REMUS AUV through coastal sea ice offshore of Barrow, Alaska. Photo: Al Plueddemann **Middle:** Webb Slocum glider nearing the surface in Auke Bay, Alaska, 2010 . Photo: S. Danielson **Right:** The Exocetus Costal Glider being field tested during extremely stratified conditions in Resurrection Bay, Seward, Alaska, 2012. Photo: P. Winsor

☑ Gliders can sample an area for up to 4 months autonomously.

☑ The Coastal Glider can handle extremely stratified locations.

☑ Real-time data via Iridium, which enables adaptive sampling – important!

☒ Development need for long-term autonomous sampling under ice – we can't do this right now…

☒ Most commercial gliders can't operate well in Arctic conditions…

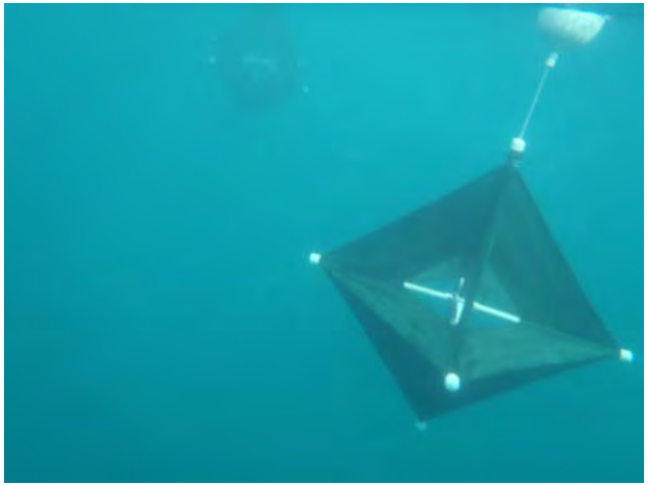
Above: Webb Slocum G2 glider after a 2.5 month mission

Above: Deploying gliders of the 32’ vessel “Tukpuk”, Wainwright, Alaska

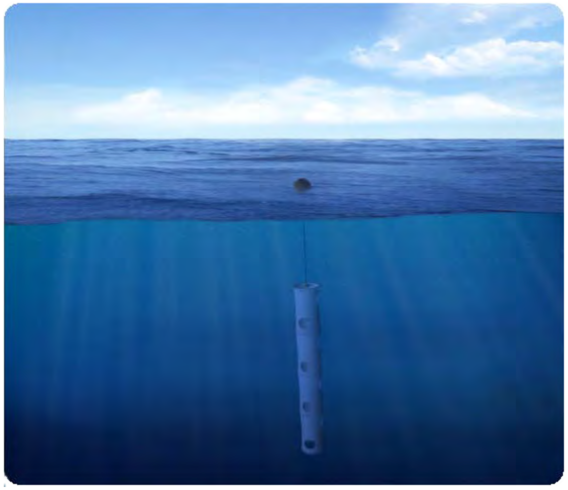
AUV operations 2009-2013 using 3 Webb Slocum gliders performing > 12000 km of track length, collecting >30,000 CTD profiles. All units equipped with Wetlabs three-channel “Eco Pucks” for sampling hydrocarbon/CDOM and chlorophyll, and some with SUNA optical nitrate sensors. Essentially biochemical-physical autonomous labs.

Longest single mission duration 2.5 months using lithium batteries. Small 30’ fast local landing vessel for deployments and recoveries. --> Sea-ice melt water lenses, strong coastal jets and “annoying biology” can be challenging…

Satellite-tracked ice-strengthened drifters: In order to define the circulation, temperature and salinity structure in a large fjord system on the west coast of Greenland, we have deployed several ice-strengthened drifters equipped with Seabird microCAT CTDs, where drifters measure salinity at 0, 7, and 15 m depth.



Microstar SST-Iridium surface drifter

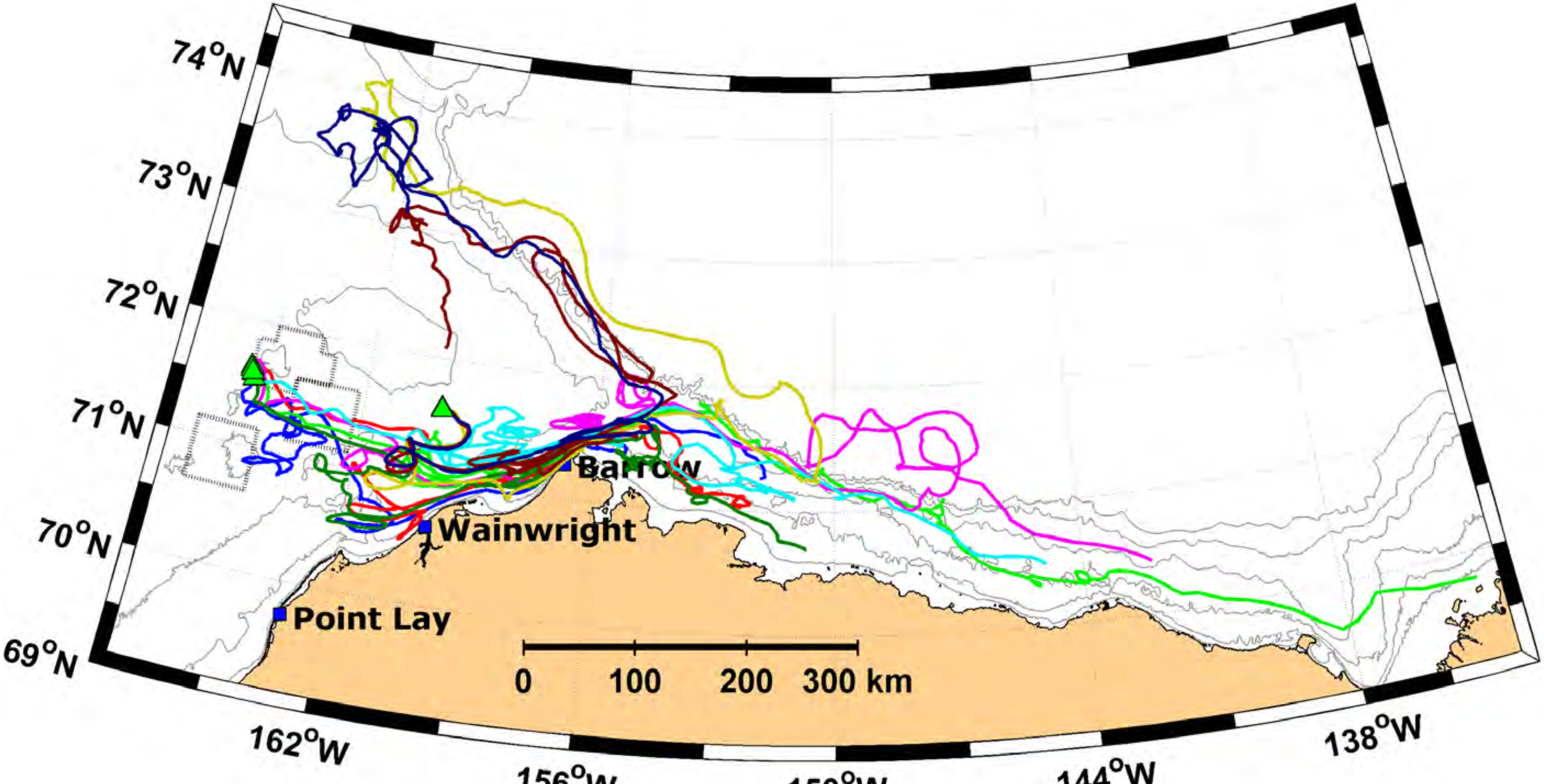


20-m drogued CTD-chain-Iridium drifter

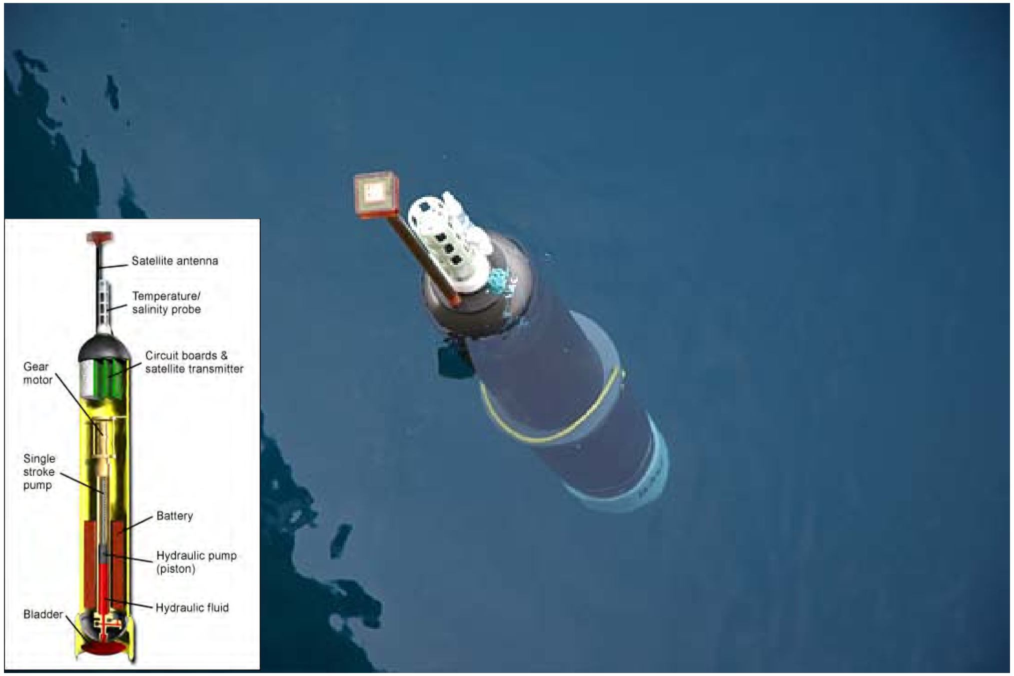
Ice-strengthened drifter deployed through sea ice in the inner Nuuk fjord system, southwestern Greenland, 2014.

Photo: Kunuk Lennert

Example of drifter tracks
Chukchi and Beaufort Seas - 2011 data



Polar Profiling Floats - Winsor (UAF) & Owens (WHOI)

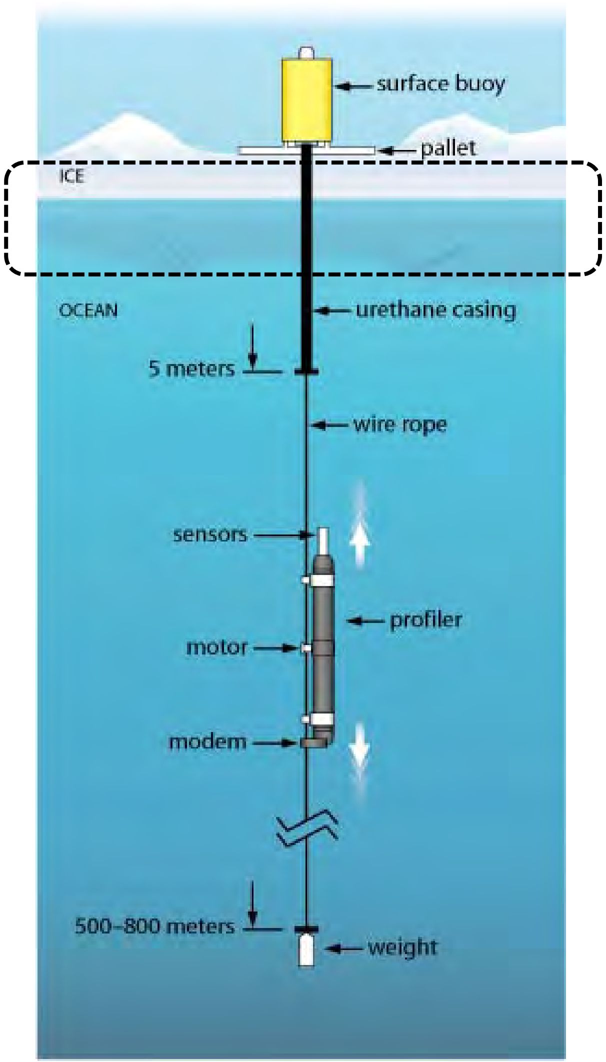


Luc Rainville, on the Swedish icebreaker Oden in August 2005, prepares to test an experimental float designed for under-ice operations in the Arctic. (Photo by P. Winsor)

- Uses Iridium for 2 way communications, and GPS for positioning. Can also use subsurface acoustic tracking for positioning.
- Drifts at a programmable depth up to ~ 2000 m, and goes to its maximum depth to make CTD profile. It also obtains GPS fixes at the start and end of the surface phase.
- Sensors including Temperature, Salinity, Pressure, and Dissolved Oxygen (all from SBE).
- Ice detection algorithm uses conductivity with Iridium satellite to detect open water. If no link established, it submerges to 50 m, waits 2 hours and surfaces again. Will try 50 times and then go on to next profile.
- With dissolved oxygen sensor, nominal lifetime is 4-5 years with profiles every 10 days.

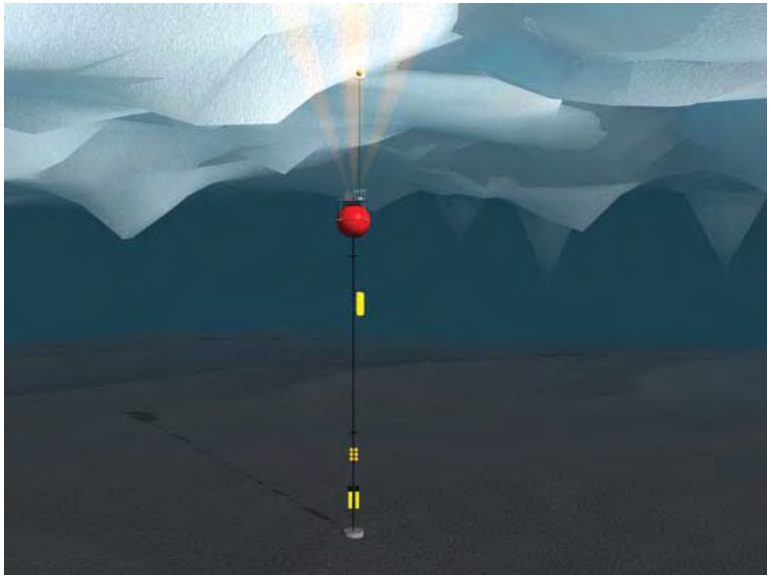
Profiling moorings and buoys

Ice-tethered profiler (WHOI – Toole)



www.whoi.edu/itp

Arctic winch mooring (WHOI – Pickart)



Sub-surface MMP moorings (UAF – Simmons)

Acrobat Towed Vehicle

-real-time data feed through faired, small diameter Kevlar cable

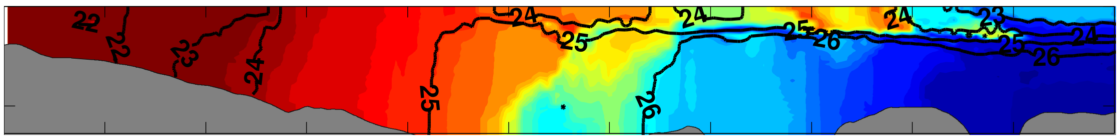
-large data bandwidth via Ethernet

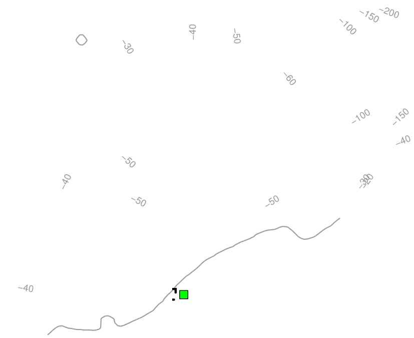
-small and easy to operate and deploy/recover from small vessels even Zodiac

-6 knot tow speed generates high-resolution data over large areas

-we instrumented the Acrobat with a 16 Hz Seabird FastCat CTD and 8 Hz Wetlabs Eco Puck

55-km Acrobat cross section across the mouth of Barrow Canyon

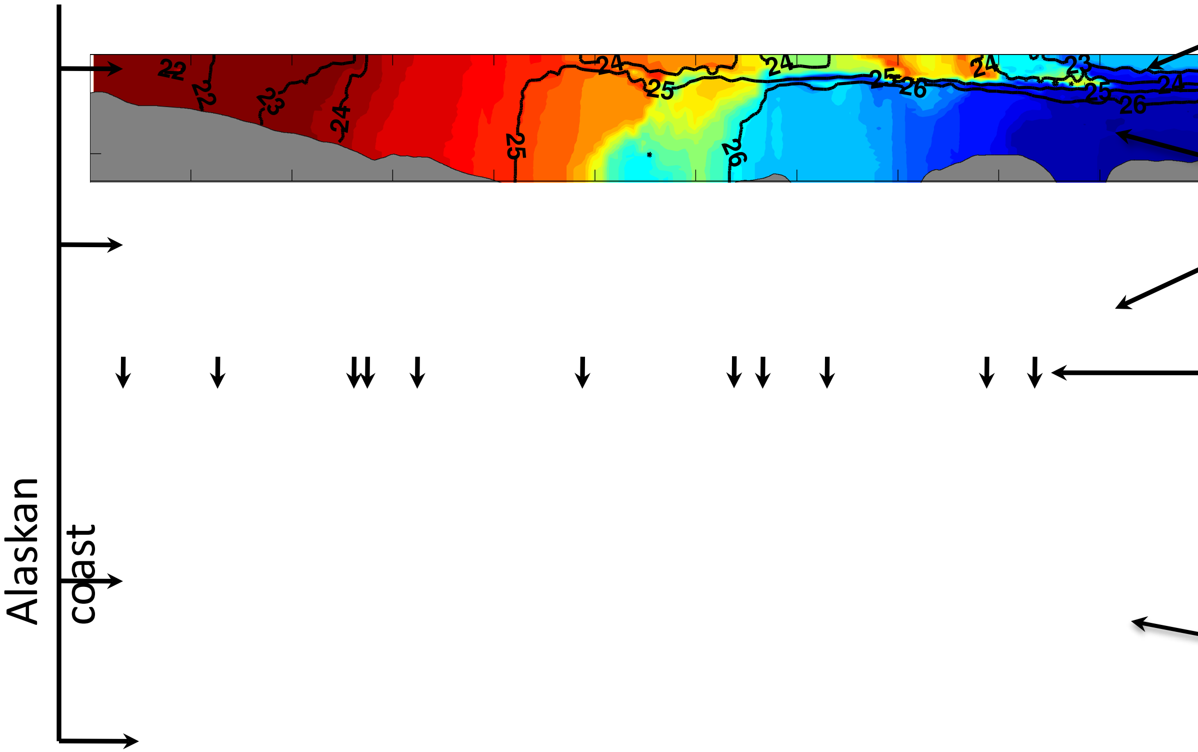




Alaskan coast

This section consists of over 125 vertical profiles from the Acrobat vehicle sampled over a 5-hour period

Nearshore domain <15 m depth, rarely sampled.



Cold and fresh surface layer from ice melt

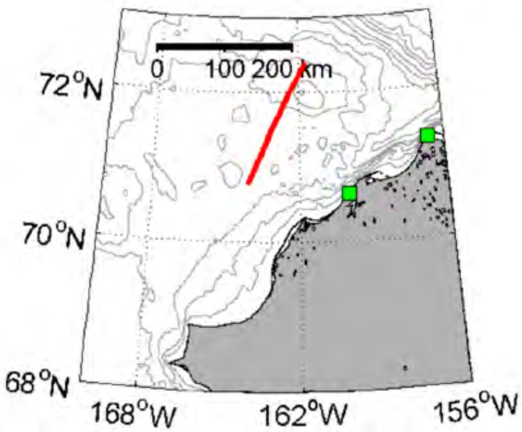
Winter water or “cold pool”

Multiple horizontal density fronts

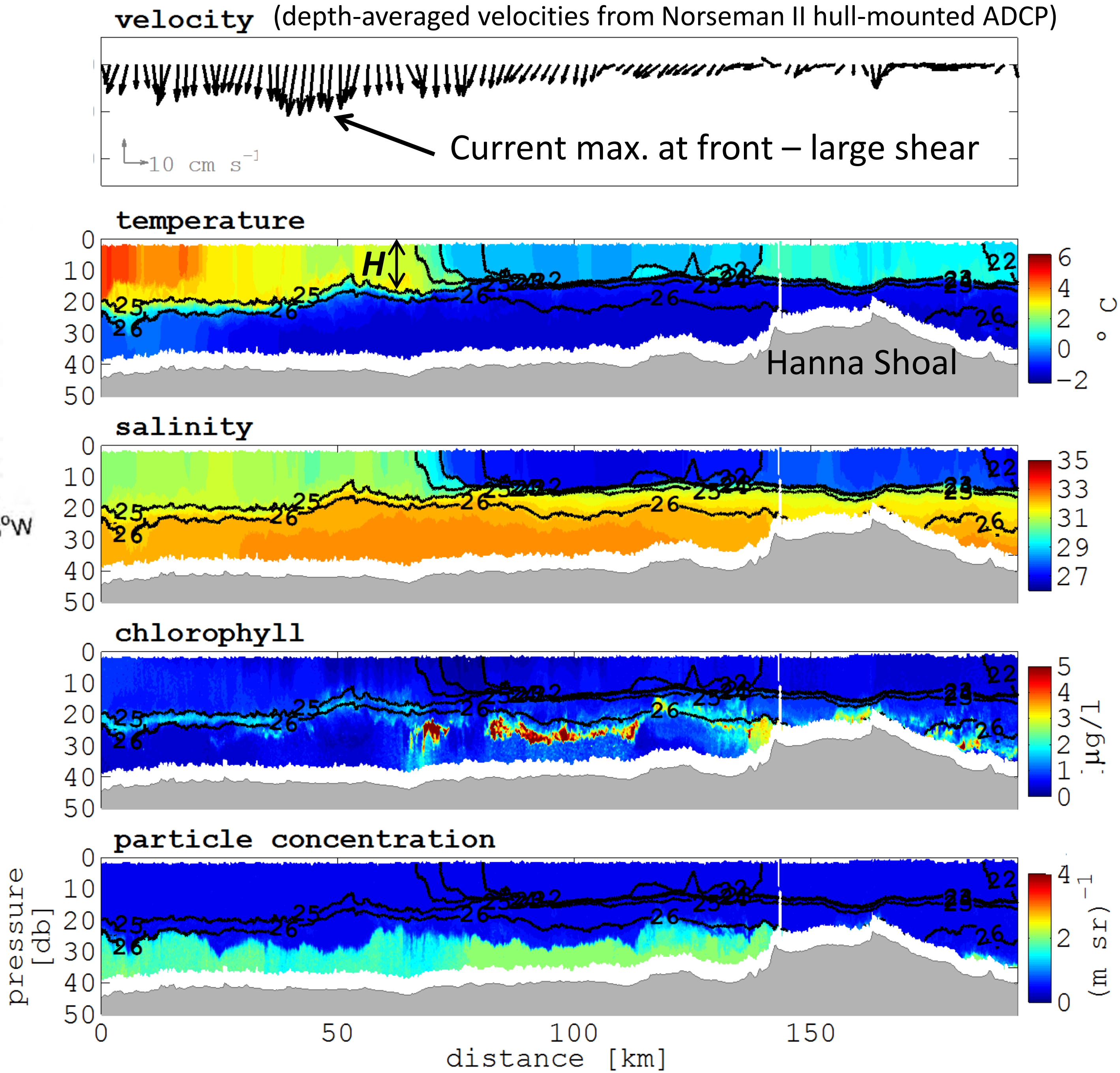
Patchy chl max. associated with top of cold pool and “downdraft” at front

Strong flow with large re-suspended sediment concentrations

Preliminary data
Sept. 16, 2013

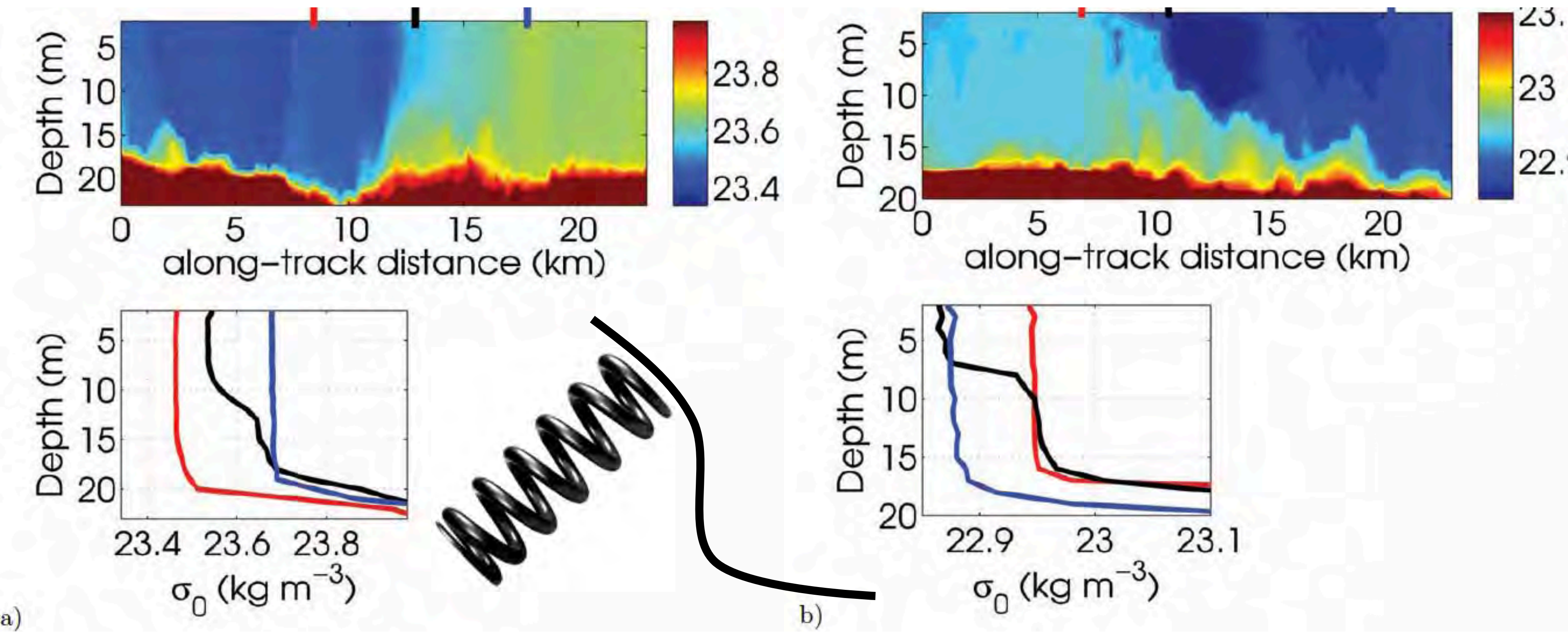


200-km physical-biooptical section (14-hrs) using the towed Acrobat and hull-mounted ADCP



$L_R = NH/f$ (based on the density difference $\Delta\rho_H$ across the surface layer of depth H). Here L_R = 1.4 ± 0.4 km.

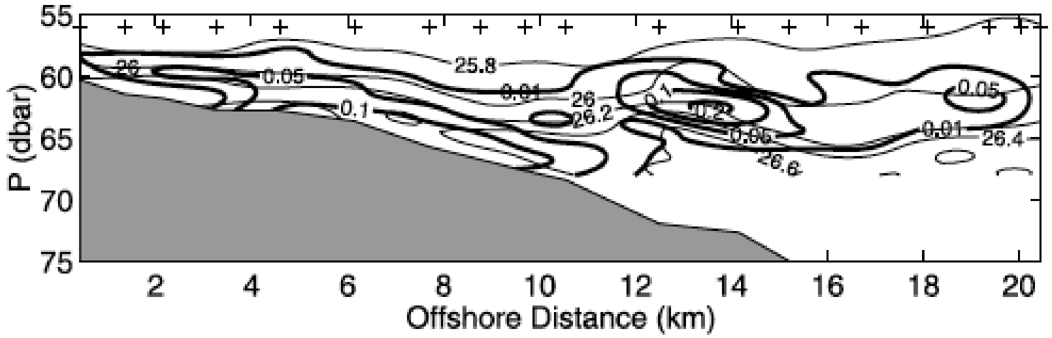
Gliders & towed vehicles enable us to observe fronts & submesoscale features



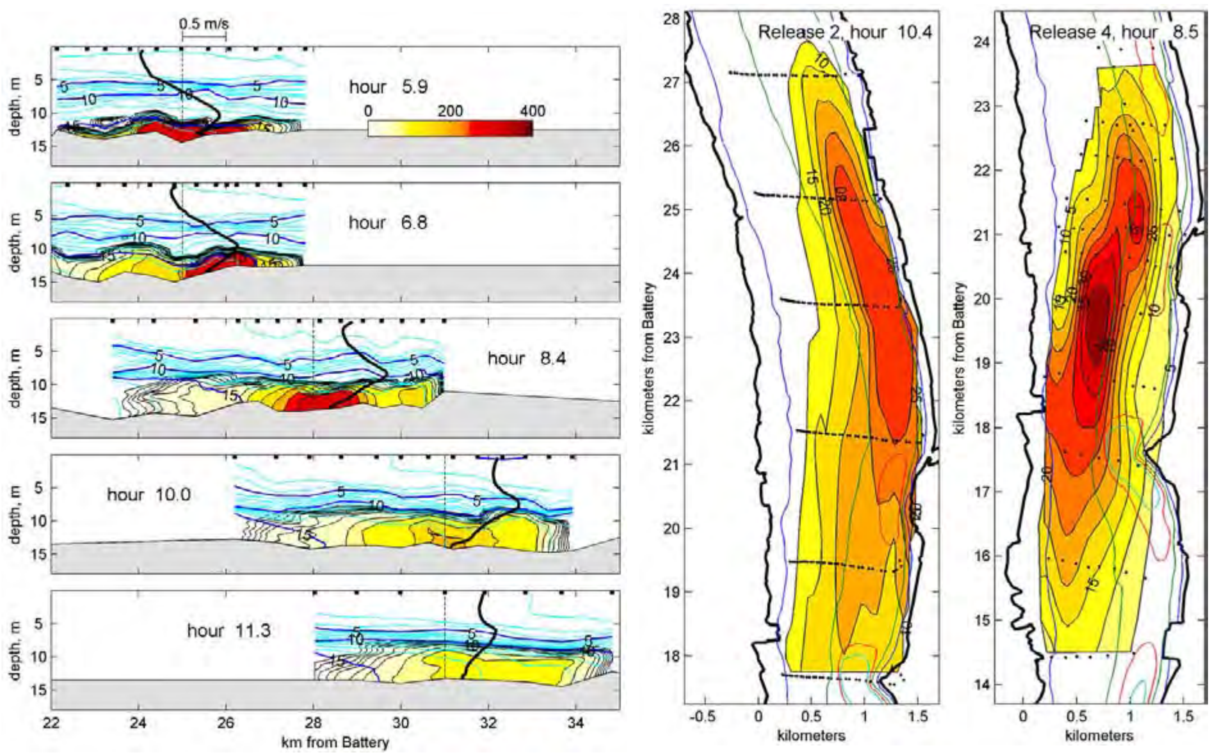
Top: depth-distance glider sections of potential density (kg m^{-3}) anomaly (referenced to 0 dbar) with locations of the potential density profiles (bottom panels) marked. Profiles are centered at the front (black) and on either side of the front (red and blue). From Timmermans and Winsor (2012).

The high spatial resolution of glider and towed vehicle observations enable us to analyze the structure on lateral scales on the order of ~1 km. These submesoscale processes are important for changing the upper-ocean structure on a time scale of ~ days.

Small- and large-scale dye release experiments



Ledwell et al. (2004)



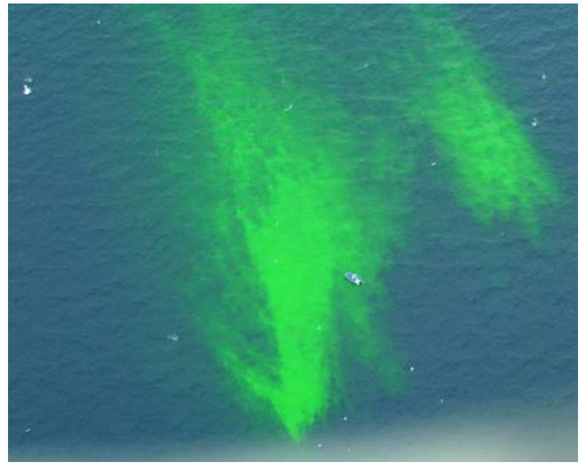
Geyer et al. (2008)

Rhodamine WT and fluorescein dyes can be injected into layers of interest and traced inexpensively over time and space.

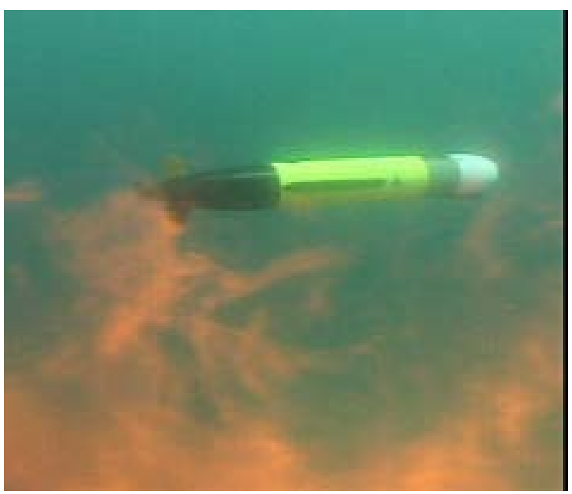
May be an excellent tool for the lower/upper halocline, step structures, eddies, upper- ocean-to-ice interface studies

Combine microstucture and fluorometer profiling

We can now combine microstructure and fluorometer profiling from fixed and towed instruments and drifters/buoys with autonomous adaptive sampling using AUVs



SIO 2005 – dye dispersion experiment using CTD, drifters and fluorometer



Arrieta et al. (2003) – rhodamine mapping with REMUS AUV

ARCTREX – Arctic Tracer Release Experiment

Applications for Mapping Spilled Oil in Arctic Waters

NSL BOEM AK 12-03ba

PI: Dr. P. Winsor, UAF.
Co-PIs: Robert Chant, Rutgers and Harper Simmons, UAF.

ARCTREX Method: Dye release & mapping

We propose to use purposeful injections of a fluorescent dye as a tracer. We propose to conduct a minimum of one dye injection in the summer of 2014 in the upper mixed layer. If conditions and time allows we will conduct a second release in the bottom layer. Similar dye experiments will be performed in 2015.

To prepare for the dye injection we first conduct hydrographic surveys of the study area to define the 3-D structure of the density field and flow field using a towed vehicle, AUV gliders, shipboard systems and drifters, and also measure the turbulent characteristic using a microstructure instrument.

Dye will be injected by pumping 50 kg of Rhodamine-WT in a 20% water solution through a hose attached to a CTD suspended from the ship. The dye solution is mixed with propanol to achieve the anticipated *in situ* density. Use of this mixture together with the rapid 1000 to 1 dilution as the dye solution is injected through a diffusing nozzle, has precluded any subsequent anomalous density driven flow in past experiments.

Within 2 hours of injection, surveys of the dye patch will begin using the through-flow system, towed Acrobat, drifters, and gliders. We will attempt to map the plume/patch in 3D over time and relay this information to Arctic ERMA

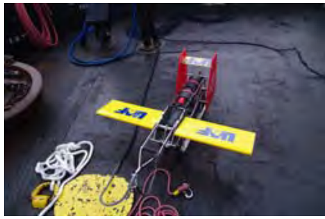
Surface dye injection (and drifter) in Hudson River Plume, Mid Atlantic Bight

Bob Chant, Rutgers

ARCTREX Observational Assets

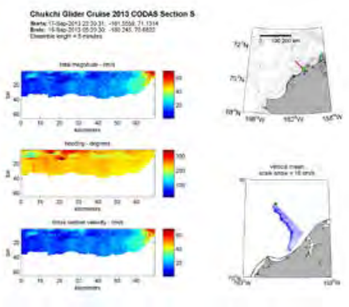
Acrobat towed vehicle

- fast CTD, Eco Puck (3-channel optics), and Rhodamine fluorometer
- towed at ~6 knots, <1 m vertical and ~200-300 m horizontal resolution



Norseman II

- underway thermosalinograph w/ ducted in-line Rhodamine fluorometer
- hull-mounted ADCP, water column currents in 1-2 m bins



VMP 250 microstructure profiler

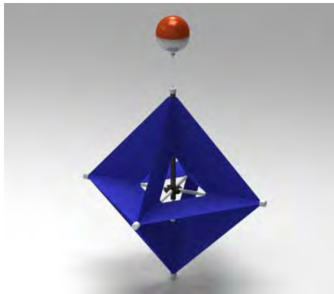
- samples high-resolution O(cm) vertical shear, and microT and S (512 Hz)
- also equipped with Rhodamine fluorometer and CTD

AUV Slocum gliders

- autonomous real-time full-depth data sampling using CTD and Eco Pucks
- we are consider equipping with Rhodamine fluorometer too

Microstar surface drifters

- two-way satellite communication
- provides surface ocean drift through GPS and SST, reprogrammable

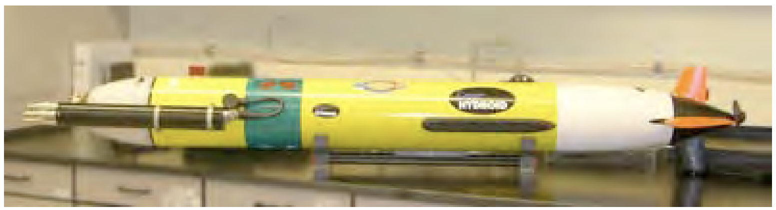


Microstructure measurements in ice covered waters

RMS5500 Deep-sea Turbulence Profiler – central Makarov Basin, 2005. Photo: P. Winsor

Rockland Microrider turbulence package

Designed for AUVs, towed vehicles, profiling platforms etc



Features:

Internal Data Recording
1000 m pressure rating (6000 m option available)
Up to five turbulence sensors
2x SPM-38-1 microstructure turbulence shear probes
2x FP07-38-1 microstructure fast thermistors
1x SBE7-38 microstructure conductivity sensor*
1x High resolution pressure sensor;
2x high-accuracy accelerometers,
1x tilt sensor;
Support for Seabird SBE-3F / SBE-4C WOCE accuracy temperature and conductivity sensor*;

Autonomous very-near-surface sampling of the ocean-atmosphere interface

Photo: Ben Allsup, Teledyne Webb

Applications for Mapping Spilled Oil in Arctic Waters

The proposed project is designed around existing observational assets and real time data display system (glider data, satellite-tracked drifter data, towed vehicle, HFR). We intend to collaborate with NOAA's Environmental Response Management Application ERMA (Arctic ERMA) and BSEE, with the goal being real time data ingestion of our data into their response system. Critical for proper response actions to an oil spill is real time data from the field and forward model integration for predicting the plume evolution in time.

ERMA is a web-based GIS tool that assists both emergency responders and environmental resource managers in dealing with incidents that may harm the environment. ERMA integrates and synthesizes data—some of which happens in real time—into a single interactive map, providing a quick visualization of the situation and improving communication and coordination among responders and environmental stakeholders.

We will evaluate the effectiveness of the entire suite of instruments and techniques described above to track the released dye under diverse environmental conditions. Ideally, the initial work outline here will lead to an evaluation of the ERMA system and oil spill trajectory models such as the General NOAA Operational Modeling Environment (GNOME) and their capability to hindcast the movement and dispersion of the released dye.

Environmental Response Management Application (ERMA®)

Functions

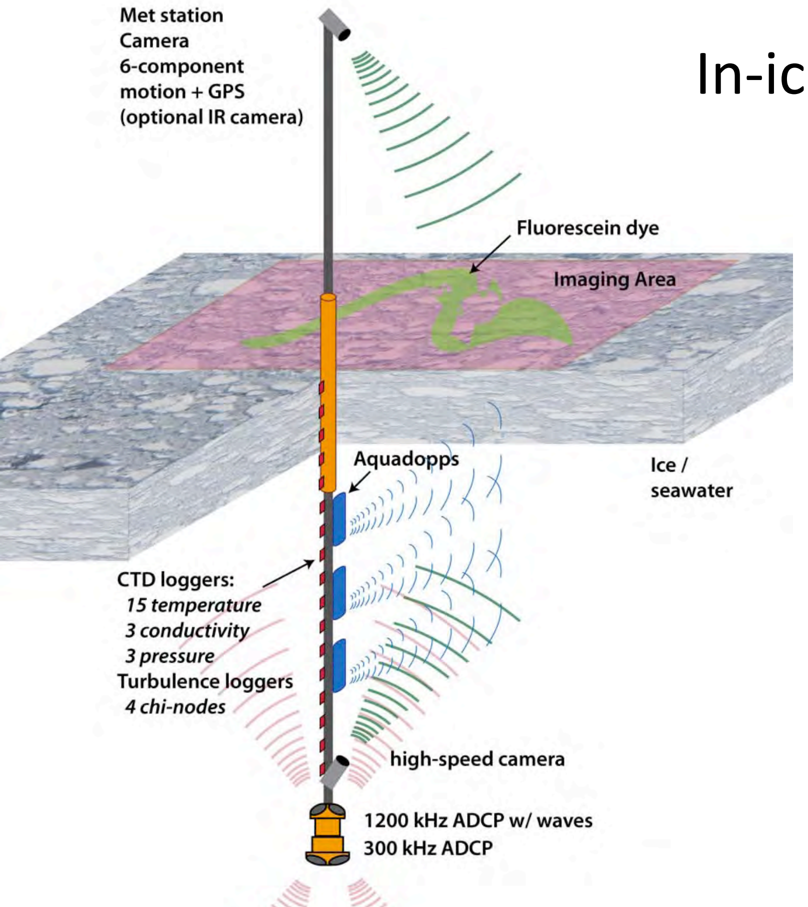
- Web-based mapping tool
- Analyze and visualize environmental information
- Prepare for, respond to, assess impacts from hazardous incidents or conditions
- Increases communication, coordination, and efficiency

Website (launched for public use July 31, 2012)

- https://www.erma.unh.edu/arctic

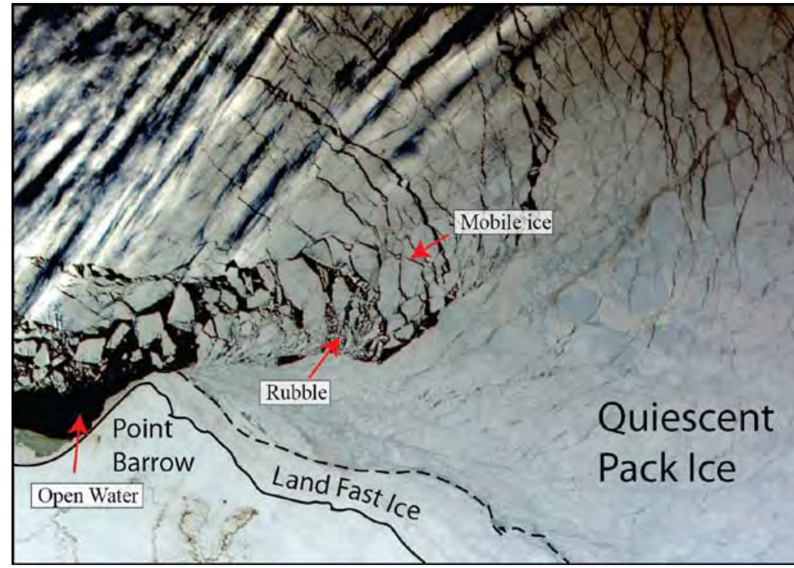
Thank you ☺

In-ice dye-turbulence measurements

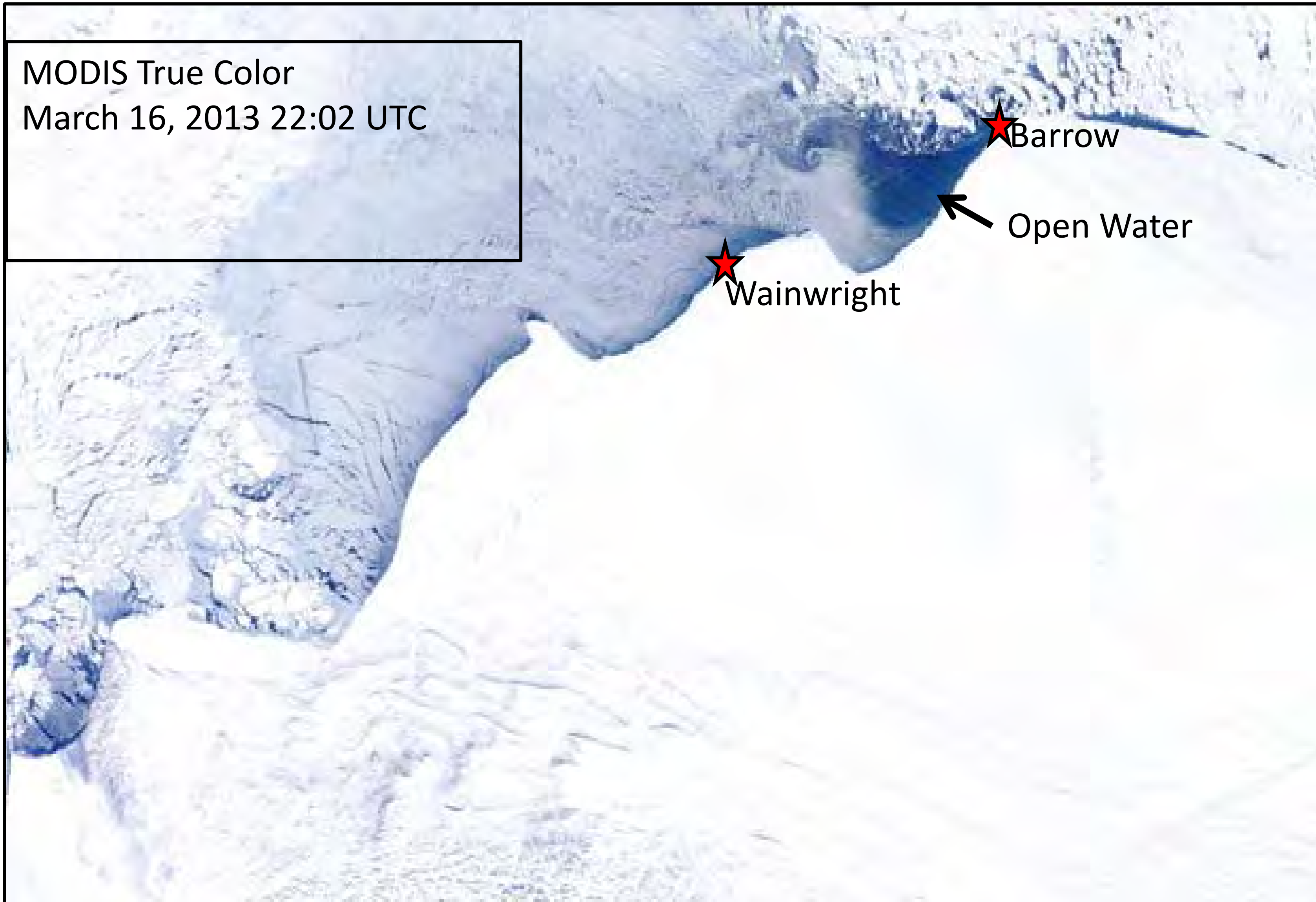


Sketch of the ITMAST turbulence buoy instrumented with cameras to monitor dye dispersion, a 3D motion package to monitor orientation and x-y-z acceleration of the package and Aquadopp current meters that will directly measure the turbulent flow field at sub-centimeter spatial resolutions.

Simmons, Hutchings, Winsor, Nash and Shroyer in prep.

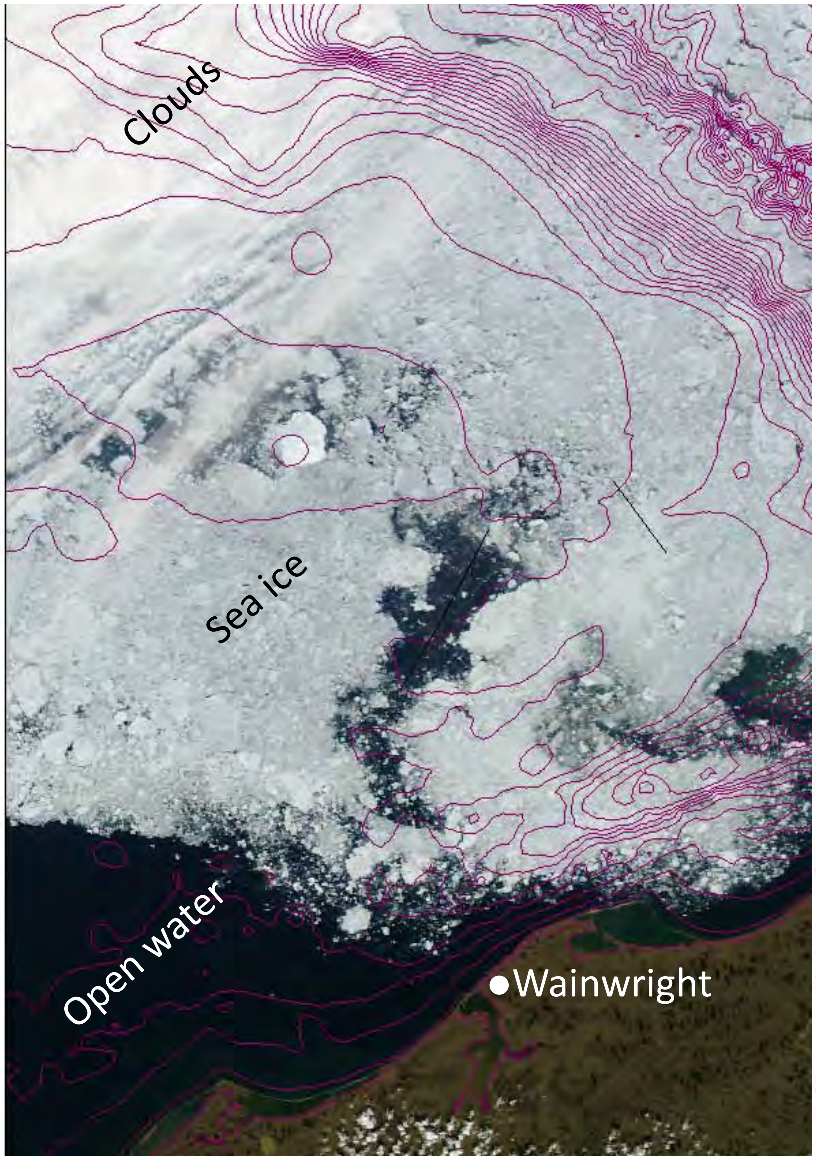


MODIS image of ice-conditions off Barrow, Alaska illustrating a range of spring ice regimes accessible from Barrow. The four ice regimes that we hope to sample are illustrated as well as the location of the Barrow Ice Radar. Inset shows the recovery of a buoy in brash ice


MODIS True Color
March 16, 2013 22:02 UTC
Barrow
Open Water
Wainwright

2012 – an anomalous ice year in the Chukchi Sea

MODIS satellite image – July 11, 2012



Huge multi-year ice floe observed from the Norseman II, south of Hanna Shoal, August 25, 2012. Photo: P. Winsor