Measuring Ocean Dispersion and Tracking Oil in Arctic Waters
or
How to utilize autonomous technology to map the faith of oil in water

P. Winsor¹, H. Simmons¹, H. Statscewich¹, Seth Danileson¹, Kate Hedstrom¹
R. Chant², E. Hunter²

¹Autonomous Remote Technology (ART) lab, Institute of Marine Science, College of Fisheries and Ocean Sciences, University of Alaska Fairbanks.
²Department of Marine and Coastal Sciences, Rutgers University.
Critical for proper response to an oil spill is **real time data** from the field and models for predicting the evolution over time and space.

→ Example of observational and model capabilities
→ How to measure dispersion and its importance
→ Small-scale physical oceanographic processes

**Case study:**
**ARCTREX: Applications for Mapping Spilled Oil in Arctic Waters**

- 2014-2015 dye releases in the Northeastern Chukchi Sea
- **Test available observational technology**, capability to map a dye plume in time and space, simulating an oil spill, and provide real time data to response agencies.
Technology for observing and monitoring the ocean environment in *real time* at small spatial scales and long temporal scales

**HF Radar:** Real-time surface current and ocean environment mapping in two-dimensions. Enables real-time currents for science, monitoring oil spill response, search and rescue, and Arctic domain awareness (ship tracking). UAF has developed unique high-latitude experience and remote operational capability. **Hank Statscewich – next talk!**

**Autonomous Underwater Vehicles (AUVs):** enable real-time ocean data, adaptive sampling, including e.g. real-time passive acoustic monitoring, detection and identification. Can operate dormant, or actively for ~4 months. Arctic domain awareness application with continuous presence at high latitudes.
HF Radar:
Land-based 5 MHz long-range network

6-km grid covering 80,000 km²
Monitor the Chukchi-Hanna Shoal ecosystem year-round from the vantage of multiple disciplines, across multiple trophic levels, and with high temporal resolution.

- Relate timing and magnitude of fluctuations of nutrient and carbonate chemistry, particles, phytoplankton, zooplankton, fish and marine mammals to variations in each other and the currents, waves, wind, light, and ice.
- Provide reference observations for evaluating and improving regional and global-scale biogeochemical, ice-ocean circulation, ecosystem, stock-assessment, and oil spill response models.
Numerical Model Development & Applications
Hydrological – Ice – Oil – Ocean Circulation Modeling

Recent Improvements
- Wetting & Drying: better tides
- Coastal river discharges: FW & heat
- Multiple ice model options
- Nested ice-ocean models
- Landfast ice parameterization

Pan-Arctic
ROMS Modeled

Observed

Seth Danielson and Kate Hedstrom, UAF
Ice detection buoy: A Real-time Sensor System for Detecting Freeze-up on Arctic Shelves

→ Provides real-time data on the vertical temperature and salinity structure of the ocean so that agency permitting agencies, and stakeholders, including the oil and gas industry and subsistence users, will know when offshore sea ice formation begins.

→ Data can be used to evaluate and refine NOAA and NWS sea ice forecast models (both existing models and those under development), which depend upon accurately predicting the seasonal evolution of the thermohaline structure of the ocean.

→ Useful in guiding remote sensing algorithms for frazil ice detection, a notoriously difficult process for remote sensing platforms.

→ Provides a new technology platform for real-time enabled year-round Arctic observations.
2017 Real-time Ice Detection Buoy data

- Wind Speed
- Temperature
- Salinity

Depth (m)

August September October
ARCTREX: Applications for Mapping Spilled Oil in Arctic Waters

Rhodamine dye releases in 2014 & 2015
“Typical conditions”: 55-km cross section at the mouth of Barrow Canyon

MW: ice melt water, cool, dilute, $T \approx 0^\circ C$, $S \approx 26$

BSW: Bering Sea water, warmer and saltier, $T \approx 5^\circ C$, $S \approx 30$

WW: winter water formed by ice formation, near-freezing, saline
ARCTREX Method: Dye release & mapping
Purposeful injections of a fluorescent dye as a tracer in the summer of 2014 (A second release was performed in 2015)
Dye Injection

Instabilities and filaments

Surface drifter

Rhodamine WT dye
Injection 1: Surface mixed layer

- ~45 kg of dye injected into a well mixed surface layer over a stratified pycnocline.
- Surveyed over the course of 3 days with 23 realizations of the dye ("patch").
- NW winds 7-8 m/s.

- Dye patch stayed in the surface mixed layer.
- Surface mixed layer grew by ~5 m. Dye thickness increased with the increasing surface mixed layer.

Injection 2: Subduction

- ~45 kg of dye into a weakly stratified environment.
- Surveyed over the course of ~1 day, 11 realizations of the dye ("patch").
- NW or W winds at 10 m/s.

- Dye patch subducted under a fresher body of water to the north of the injection site.
- Initial horizontal dispersion is large compared to Injection 1.
- Upon subduction, mixing into the dense water below and the fresher water above.

[Map of Injection 1 - Mixed Layer and Injection 2 - Subduction with labels: Hannah Shoal, Barrow, Wainwright, Kliondike]
Injection 1: Mixed layer

Injection 2: Subduction

Subduction: Dye disappears from the surface

Implication: Not visible from air or by satellites
Injection 2: Subduction — Dye injected *inshore* of front

Note: Water inshore was *saltier*, cooler and denser

i.e. *reverse* of expected configuration
The dye subducted at the front, strained, sheared, and the front advected northward with some vertical mixing and horizontal dispersion.
Patch dispersion (horizontal mixing)

- **INJ1**
  - Dispersion over km vs km plot with circles indicating the patch dispersion.
- **INJ2**
  - Similar plot to INJ1, showing different dispersion patterns.

**Graphs**:
- **Patch area (km²)** vs **hours since injection**
  - **Inj 1**: 1.31 m²/s
  - **Inj 2**: 4.05 m²/s

The graphs illustrate the dispersion patterns and rates of injection for both INJ1 and INJ2, with INJ2 showing significantly higher dispersion rates compared to INJ1.
Summary

→ We have developed, deployed and operated real-time capable HFR, AUV gliders and moorings for the last 10 years in polar regions (Arctic, Greenland and Antarctica). Only group that operates HFR and gliders consistently in polar regions.

→ Full ecosystem sensor systems + pan-arctic modeling

→ Real-time oceanographic systems enable response agencies and coastguard with updated, best-available information, including supporting logistics and safe response approaches.

→ Next: i) through-ice real-time ocean currents, ii) rapid-deployable remote power modules, iii) nearshore UAV-ASV air-ocean coupled autonomous operations
Thank you 😊
Dr. Peter Winsor, CFOS, UAF: pwinso@alaska.edu