

STUDY TITLE: Arctic Tracer Release Experiment (ARCTREX) -- Applications for Mapping Spilled Oil in Arctic Waters.

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BRIEF ABSTRACT: Oil exploration and increased shipping traffic in Arctic waters significantly elevate the risk of oil spills. The Arctic Tracer Release Experiment (ARCTREX) was designed to test the ability of available observational technology to sample a simulated oil spill in the Chukchi Sea and to transmit data to a shore-based, online emergency management application. During the ice-free seasons of 2014 and 2015, three releases of Rhodamine-WT dye were performed. During the field campaigns, data were transmitted to a version of NOAA's Environmental Response Management Application (ERMA 2015) that is configured for the Arctic region, improving communication and coordination among responders and environmental stakeholders during future events. The diversity of environments and the extremely rough weather experienced during the field experiments allowed us to fully evaluate the performance of the instruments; the TSG and the towed undulating Acrobat vehicle are capable of tracking dye over time in great detail while being able to operate in stormy seas with significant wave heights approaching three meters. Dye was distributed throughout the surface mixed layer and, in one case, was subducted below the surface layer, requiring instruments capable of sustained subsurface measurements.

BACKGROUND: Oil exploration and increased shipping through Arctic waters bring with them the increased possibility of oil spills. Previous oil spills in other areas have demonstrated the utility of real-time data in modeling and directing the oil spill response, and it was an open question whether the challenges created by the Chukchi Sea's unique characteristics such as sea ice and extreme weather would allow the collection of this critical data. This study lays the groundwork for answering this question by using simulated oil spills to assess this capability in the Chukchi Sea.

OBJECTIVES: The project had five specific research objectives: 1. Conduct field tests of the dispersal and tracking of nontoxic Rhodamine dye off the Chukchi coast, 2. Develop, test, and deploy instrumentation for Autonomous Underwater Vehicles (AUV) and other instrumentation that can be customized for use in the Arctic to detect the spatial and temporal locations of surface and subsurface spills. 3. Track the dispersed dye plume by incorporating input from the AUVs, towed CTDs, and other real-time data collection sensors in the Chukchi Sea (e.g., surface currents from HF Radar, towed CTDs, drifters, real-time WRF high-resolution wind fields, data from meteorological buoys and other offshore instruments) to assess the fate and transport of the dye plume, 4. Evaluate the effectiveness of the suite of instruments to track the released dye under diverse environmental conditions, and 5. Calculate parameters that quantify small-scale transport processes based on measurable oceanographic and meteorological data.

METHODS: The main purpose of the ARCTREX experiment was to map the evolution of a dye plume over time and space in order to simulate an oil spill event and to provide real-time data to the Arctic ERMA system. To do this, we conducted purposeful injections of a fluorescent dye, Rhodamine-WT, as a passive ocean tracer. We conducted two successful dye injections in September 2014 and another in September 2015, all in the upper mixed layer. A deep-water release was attempted in 2015 but was not successful

RESULTS: Dye is dispersed at an average rate of $\sim 7.7 \text{ m}^2 \text{ s}^{-1}$, and local ocean dynamics (particularly wind mixing and horizontal density gradients) have a profound impact on the fate of the dye, laterally and vertically, on time scales as short as a couple of hours. The diversity of environments and the extremely rough weather experienced during the field experiments allowed us to fully evaluate the performance of the instruments; the TSG and the towed undulating Acrobat vehicle are capable of tracking dye over time in great detail while being able to operate in stormy seas with significant wave heights approaching three meters. Dye was distributed throughout the surface mixed layer and, in one case, was subducted below the surface layer, requiring instruments capable of sustained subsurface measurements.

CONCLUSIONS: Our results show that it is feasible to track a passive dye in detail using the technologies mentioned above. The effort requires high-end knowledge of operating instruments and ships and becomes significantly more difficult if there is no surface expression of the dye, such as the subducting dye in release #2 in 2014. In this case, for instance, simulating dispersed oil that has sunk down into the water column and mapping the detailed three-dimensional evolution of the plume in time and space becomes challenging. We also successfully transmitted data to NOAA's Arctic ERMA and UAF's web pages in near real time, proving that this capacity does exist in the Chukchi Sea with available technology. The results from the three dye releases show that dye patches are advected and strained horizontally over the full depth of the mixed layer. Dye injection #2 in 2014 also showed that in addition to horizontal dispersion, fronts in the Chukchi Sea can significantly alter the fate of dye (and likely

dispersed oil), and can generate conditions that make tracking the dye significantly more difficult.

STUDY PRODUCT(S):

Winsor, P., H. L. Simmons, R. Chant, 2017. Arctic Tracer Release Experiment (ARCTREX): Applications for Mapping Spilled Oil in Arctic Waters, Final Report to Bureau of Ocean Energy Management, M13AC00008, OCS Study BOEM 2017- 062, University of Alaska Fairbanks, Fairbanks, AK, 79 pp.

MAP SHOWING AREA OF STUDY (Figures 7 and 18 of report OCS Study BOEM 2017-062):

