ASL Environmental Sciences
#1-6703 Rajpur Place
Victoria, British Columbia
V8M 1Z5 Canada

Acoustic Detection of Subsurface Oil

David Lemon and Todd Mudge

11 December 2018

Introduction

Marine sensitivities to hydrocarbon pollutants pose serious impediments to offshore hydrocarbon production-related activities. Consequent efforts to strengthen spill and leakage prevention capabilities require clean-up and mitigation commitments which, in turn, create needs for in situ detection and characterization of water column oil and gas content. Detection of subsurface oil by fluorometry or spectrometry is limited to the location of the instrument itself and is not suitable for monitoring larger areas. Longer range detection is possible using underwater acoustics, however unambiguous target identification is difficult using acoustics alone. Autonomous underwater vehicles (UAV) or ship-towed bodies are a means of combining the long-range detection capabilities of acoustics, with the identification ability of point sensors.

Instrumentation

The AZFP is a multiple-frequency, calibrated scientific echosounder, with low power consumption, making it well-suited to operation on autonomous vehicles for extended periods of time. An AZFP unit can have up to 4 frequency channels; lower frequencies have longer detection ranges, while higher frequencies provide finer resolution and stronger returns from small targets. The available frequencies and other characteristics of the AZFP are summarized in table 1.

Table 1. AZFP frequency characteristics.

AZFP Specifications					
f (kHz)	SL (dB)	Receiver Dynamic Range (dB)	Minimum Detectable S_v @ 50m (dB)	Nominal Full - 3dB beamwidth (°)	Maximum Sidelobe (dB)
38	208	90	-101	12	-15
67.5	205	87	-95	10	-15
125	210	89	-98	8	-18
200	210	88	-91	8	-20
455	210	80	-71	7	-20
769	210	80	-48	7	-22
1250	211	80	n/a	7	-16
2000	212	75	n/a	7	-19

Vehicles

AUVs can be motorized vehicles or gliders, which use only buoyancy changes for mobility. Gliders are the lowest cost but present the most challenges for integrating instruments because of their limited on-board power. AZFPs have been successfully integrated into Teledyne-Webb Slocum gliders. Figures 1 and 2 show examples of the installation and deployment in those gliders. AZFPs have also been deployed in towed bodies, (e.g. Botwing, as shown in Figure 3).

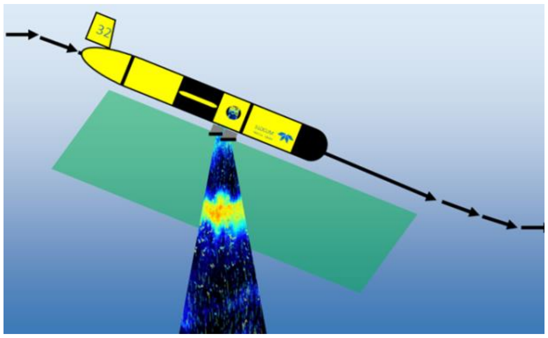

Figure 1. Schematic of glider with AZFP.

Figure 2. AZFP transducers mounted on a glider.

Figure 3. Launching an AZFP-equipped towed body.

Subsurface Oil Detection

A recent experiment in a large test tank using an AZFP with 4 high-frequency channels (455, 769, 1250 and 2000 kHz) has shown that subsurface oil is detectable with those acoustic frequencies. The figure below (Figure 4) shows the signal received from oil injected into the tank. The injection begins at the point labelled 1, and stopped at 2, after which the oil can be seen rising through the water.

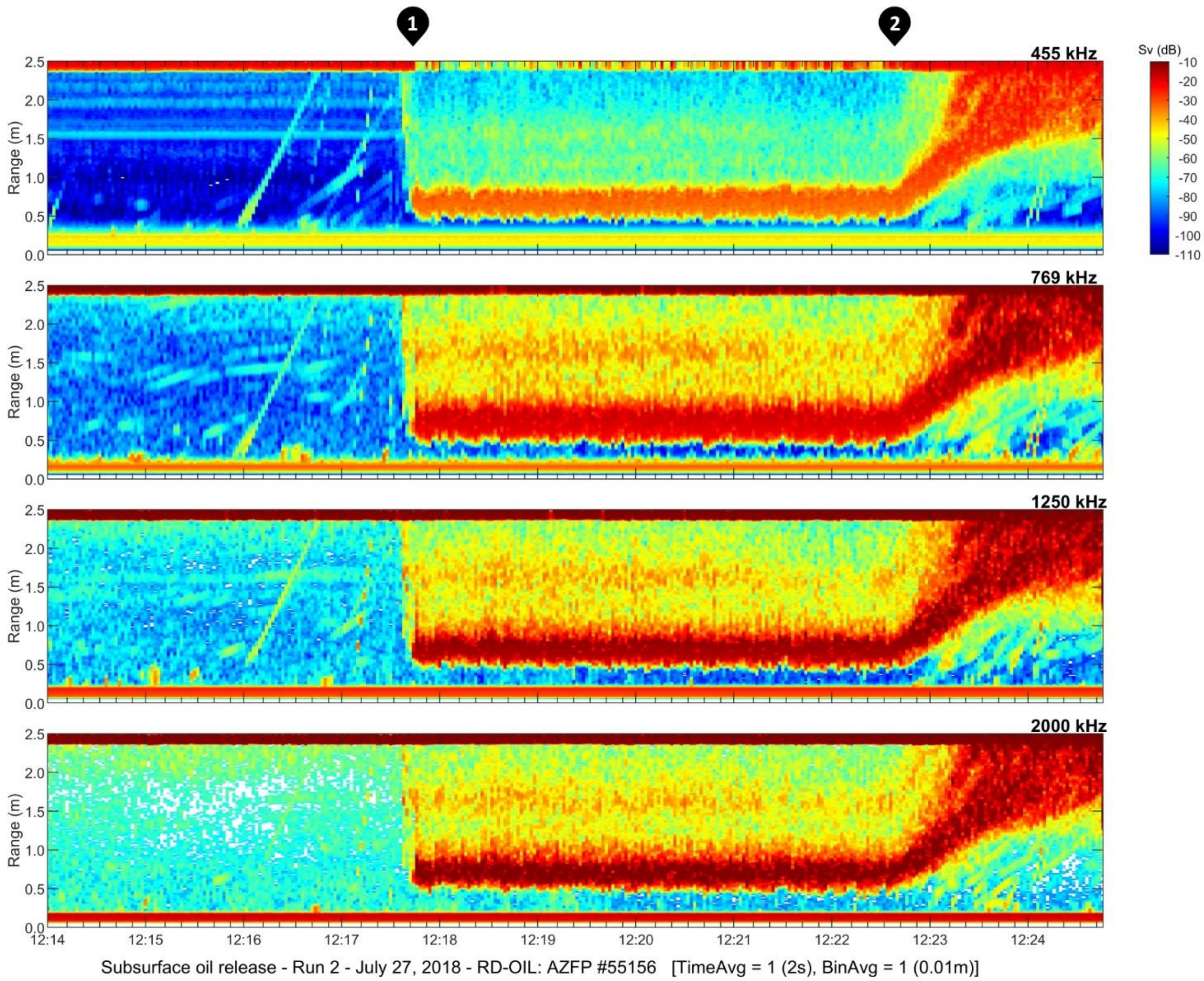

Figure 4. Oil injection event as recorded by the four frequencies of the AZFP.

The data show that oil in the water can be detected acoustically for all four frequencies used (455, 769, 1250 and 2000 kHz). The largest absolute backscatter signals are at the highest frequencies which suggests that the emulsified oil droplets in the test were primarily small and on the order of a 100 µm. This is perhaps a result of the turbulence of the jet used to inject the oil (Li and Garrett 1998). The Signal-to-Noise Ratios are ~55, ~60, ~65, and ~65 dB for frequencies 455, 769, 1250 and 2000 kHz. This suggests that lower frequencies might also be effective in detecting oil in water, particularly if the droplets are larger.

While acoustic backscatter alone will have difficulty to unambiguously determine the presence of oil, it can identify areas in the water column with anomalously high acoustic backscatter that are 10s to 100s of meters away from the echosounder. These areas of anomalous high backscatter can be identified in real-time by expert users or potentially by automated tools such as AI and machine learning. Once anomalous long-range acoustic signals are detected, an AUV or towed body can be tasked to fly through the area with short range sensors, such as fluorometers, and confirm the presence or absence of oil. Acoustics could concurrently detect the vertical and horizontal extent of the subsurface oil plume as the point sensors fly through the plume.