Proceedings of the 25th International Conference on
Port and Ocean Engineering under Arctic Conditions
June 9-13, 2019, Delft, The Netherlands

Trends in Seismic Data Acquisition in Areas with Surface Ice

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ABSTRACT

The Arctic has great significance in relation to the exploration and exploitation of its huge petroleum resources. Seismic surveys are the key part of petroleum exploration. Reflected sound waves are used to produce a 3D subsurface geological model, which helps to take a decision on drilling location for potential hydrocarbon resources. Seismic surveys are very complex operations, and growing energy demand pushes exploration activities into highly challenging environments, for example areas covered with surface ice, which necessitate exceptionally sophisticated approaches. We have carried out state-of-the-art studies on the use of unmanned aerial systems and autonomous underwater vehicles during seismic data acquisition procedures in such environments. Our conclusion is that both of these techniques are highly relevant for all stages of seismic operations offshore. We have also studied the possible effects on marine life from the sound waves, which are introduced during these surveys. We have found that great caution must be exercised in whale's habitat; and recommend further studies on the direct effects.

KEY WORDS: Seismic data acquisition; Surface ice; Marine mammals; Unmanned aerial systems; Autonomous underwater vehicles.

INTRODUCTION

Reflection seismology procedures are normally used to evaluate the properties of the earth′s subsurface, using seismic waves reflected off geological features (Indiveri and Gomes 2014, Abreu et al. 2016). Seismic surveys represent a fundamental part of offshore exploration, creating imagery of subsurface rock formations that facilitate the location and evaluation of oil & gas reservoirs (Indiveri and Gomes 2014). Other uses of these surveys include assessments of the seabed for offshore construction, installations of renewable energy infrastructure, academic studies of the geology, and civil engineering projects in shallow coastal zones.

Surface ice has a severe effect on sound waves, and alterations caused by the ice generate inaccurate subsurface images. Seismic data acquisition in ice conditions (Figure 1) requires a reconsideration of the whole workflow of the conventional process i.e., movement of streamers under the ice in water for offshore exploration (Rypdal et al. 2012, Tomashin and Gorbachev 2013).

Figure 1: Seismic acquisition offshore a) normal sea conditions b) in areas with surface ice

The most recent United States Geological Survey study of yet to find (YTF) hydrocarbons assesses that nearly 25% of the world's undiscovered hydrocarbon resources are to be found in the Arctic (Rice 2012). In view of growing world demand for oil & gas, the unexploited reserves of the Arctic are becoming of great interest. Barriers to the acquisition of marine seismic data in the Arctic are extreme weather conditions (Tomashin and Gorbachev 2013) and the extreme environmental sensitivity of these regions (Rice 2012, Rice et al. 2013). Furthermore, harsh operating conditions, including limited or no daylight, extreme cold temperatures and unpredictable and varying ice concentrations and coverage (Naylor 2013, Rice et al. 2013) shorten the time window for conventional seismic operations, create extreme risks to in-water acquisition equipment and introduce unwanted noise into the data.

MULTI VESSEL SEISMIC OPERATIONS

One of the solutions to the issue of surface ice occurring offshore is the deployment of dual ice-class seismic vessel operations. To support the seismic vessel, an icebreaker will be required to create a path in the ice to ensure safe passage and to provide support for operational safety. Multi-vessel seismic operations necessitate integrated navigation. The challenges for this system are the integration of a number of inputs from the ice-management system (Rypdal et al. 2012), for example, radar and satellite images, tracking specific ice features, multiday forecasting as well as seismic vessel track prediction (Rice et al. 2013).

UNMANNED AERIAL SYSTEMS AND SEISMIC OPERATIONS

Unmanned aerial systems (UAS), also referred to as drones, seem to be one of the fastest emerging technological developments (Hall 2018) and are modernizing the way in which raw data can be acquired (Stewart et al. 2016). These systems are progressively being adopted by the oil & gas industry for monitoring and inspection operations (Gagon 2016).

There is a huge potential for using UAS in geophysical and survey operations (Barnard 2008) in general, and these systems can offer a great advantage in hostile environments, for example in areas with surface ice. Drones can be used to collect data from wireless seismic recording systems during onshore operations. BP in Alaska has deployed UAS at its Prudhoe Bay site, where floods, ice breakups and ice floes continuously change the topography, making other methods difficult, costly and time-consuming. This technology is also helping the exploration teams in Azerbaijan to generate economical 3D models of onshore outcrops (BP 2014). At present, the leading application for this technology is within pipeline surveillance (Cunningham 2015), the monitoring of flaring on platforms, offshore facility monitoring and inspection, and response to oil spills (Chevron 2015). ConocoPhillips surveyed sections of the Chukchi Sea with a drone named ScanEagle (Hester 2018). The prospective use of drones within the geophysical sector of the oil & gas industry, in the areas of land and marine seismic operations and magnetic surveys, has evolved in recent times.

UAS Integration within Onshore Seismic Acquisition

UAS could potentially be deployed during all stages of an onshore seismic acquisition project, from the pre-operation to the post-operation stage. Their present-day principal application is within pre-operations, where they are being used for the reconnaissance of study areas (Lopez and Caldwell 2017) to detect hazards and possible access routes for the survey team (King 2017). Due to the lower operational cost of UAS, in comparison to manned aircraft, repeated surveys can be carried out over the same area to identify changes that occur over time, for example, the depletion of an oil reserve and leakage from pipelines (Barnard 2008).

Drones flying above wireless seismic (Crice 2011) recording systems during onshore data acquisition operations, in areas with surface ice, could retrieve and transfer data rapidly for analysis. Due to recent technological advancements, a seismic drone (Stewart et al. 2016, Sudarshan et al. 2016) has been developed with attached geophone, which is capable of flying along a survey line, recording the signals from the energy source (Sudarshan et al. 2016). This type of seismic drone, upgraded for operations in hostile and harsh environments like the Arctic, could offer huge potential. UAS integration offers the possibility of improved, efficient and safe operations, as well as reduced social and environmental impacts (Smith 2016, Lopez and Caldwell 2017), with lower accompanying costs.

During the exploration of oil & gas, seismic data acquisition is primarily associated with various Health Safety Security and Environmental (HSSE) risks, for example, exposure to remote and hazardous areas, and can generally be a lengthy process, due to the presence of surface ice, challenging access routes and the large area of study. These associated risks could safely be dealt with by applying UAS for planning, hazard identification, and mapping and data acquisition procedures. Current progress in the application of UAS technology in land seismic operations is yet to be commercially deployed but results from initial experiments show a considerable advancement in raw seismic data acquisition. The drones are capable of flying to the site of interest, landing using GPS, recording echoes and vibrations, storing the data within their system and returning to the base (Lopez and Caldwell 2017).

UAS Integration within Marine Seismic Acquisition

The prospect for UAS involvement in marine seismic operations is also vast. Most offshore seismic data in the world is gathered using large towed streamer arrays (scale of kilometers) (Indiveri and Gomes 2014). The towed streamer vessels cannot stop moving, if they come across surface ice, without loss of equipment. Therefore, repairs must be carried out while towing. Marine seismic operations can often have associated HSSE risks, due to remote and unpredictable weather and sea conditions.

Using the combination of a camera and a thermal imaging-equipped UAS above the study area can furthermore allow for an initial biological and environmental assessment. Breeding grounds, migrating marine species, areas of active animal activity and potential fishing grounds can be identified, and plans can be made to successively avoid these, to ensure an insignificant effect from operational activities (King 2017).

AUTONOMOUS UNDERWATER VEHICLES AND OFFSHORE SEISMIC OPERATIONS

In the conventional operation of a marine geophysical survey, one or more acoustic sources (air guns), towed by a vessel, emit signals, which enter the seafloor, reflect off geological features and travel back to several acoustic receivers (hydrophones) positioned on streamers towed from the same vessel. In this scenario, the air guns and hydrophones are coupled, and the geometry of the hydrophones is fixed. Typically, both the air -guns and the streamers are towed very close to the sea surface by a support vessel. From an operational prospective, these surveys may come across several challenges in harsh operating conditions, for example in the presence of ice. These surveys can be simplified, with the vessel only towing the air -guns, while the extended streamer arrays are exchanged for shorter ones, which are towed from autonomous underwater vehicles (AUVs).

A great opportunity lies in employing AUVs or marine robots to carry out seismic acquisition offshore in areas with surface ice, (Figure 2) (WiMUST 2018). This technology has already been tested under the EU project WiMUST (Widely scalable Mobile Underwater Sonar Technology). A system of cooperating AUVs has been employed to simplify seismic surveying. This method can offer significant advantages over streamer towing operations in offshore areas with surface ice.

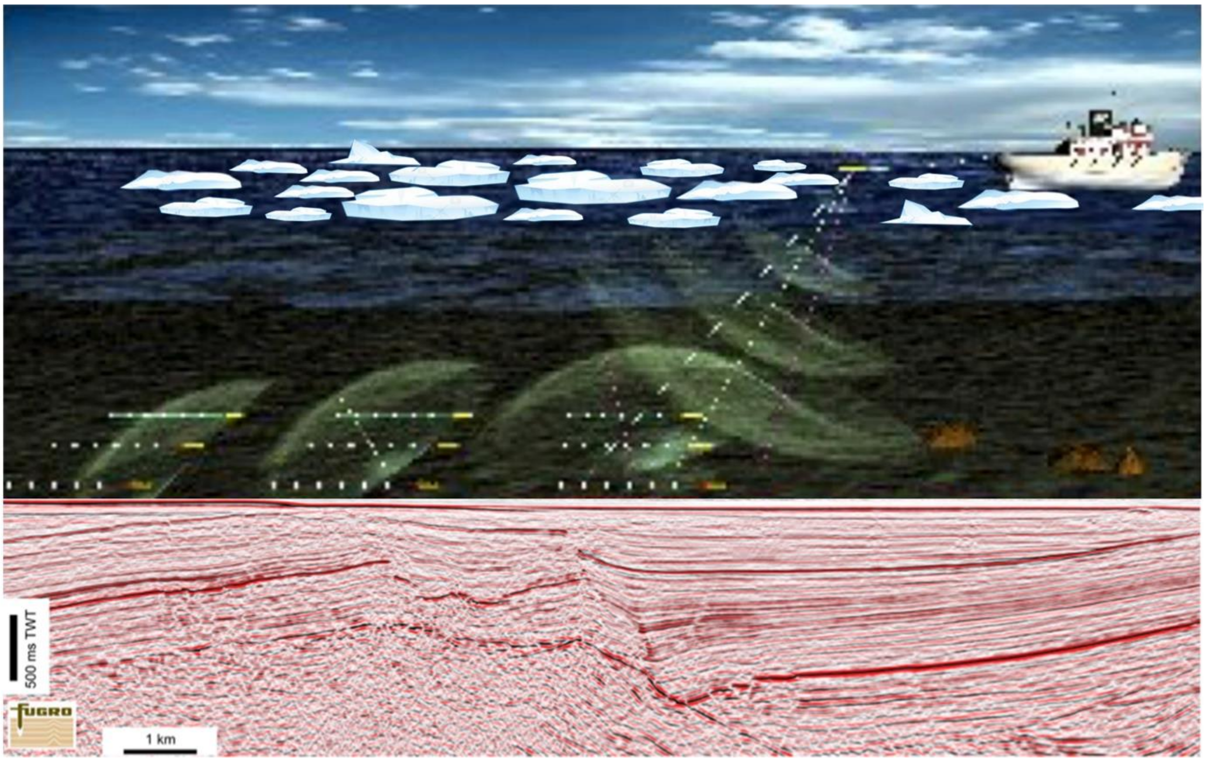

Figure 2 AUV employment in seismic acquisition offshore in areas with surface ice

The suggested system comprises a small fleet of AUVs that carry hydrophones to acquire subsurface-profiling acoustic data. The improvement in the existing geophysical seismic surveys by cutting the cable (Indiveri and Gomes 2014), disconnecting the acoustic source from the receivers (hydrophones) and using marine robots to acquire seismic data instead of conventional streamers can open new horizons in the exploration of challenging environments like the Arctic. Instead of using a complex kilometer-scale spread streamer array, a state-of-the-art concept of employing short streamers of small aperture, towed by autonomous underwater vehicles (Abreu et al. 2016), which work together in a cooperative formation, can make the acquisition process practical in harsh and difficult ice-infested environments offshore. The AUVs are equipped with hydrophone streamers of small aperture and act as sensing and communication nodes of a reconfigurable mobile acoustic network. The whole system acts as a distributed sensor array capable of recording data, obtained by illuminating the seabed and the sub-bottom with strong acoustic waves from a source installed on- board a support vessel.

OFFSHORE SEISMIC OPERATIONS AND MARINE MAMMAL ACTIVITY

There are a number of natural sources of sound within marine environments, i.e., wind, rain, waves and marine mammal vocalizations. These sources contribute to a relatively high level of ambient sounds. Baleen whales (including humpback and blue) use sounds to communicate in the ocean, and the call of a blue whale can travel for hundreds of miles.

Seals are found in all oceans of the world. Ice seal species in the Arctic and Antarctica have had little exposure to man-made sound. Dolphins themselves generate sound both to communicate and to map their marine environment through natural sonar.

Sound waves introduced during seismic operations emit a sound that lasts less than 0.1 second and is normally repeated every 10 to 15 seconds as the seismic vessel moves along a data acquisition line. Industry experience from offshore seismic surveys around the world, along with international scientific research, suggests that there is a low likelihood of biologically significant harm to marine life from these surveys. For decades to come, the oil & gas and geophysical industries will carry out seismic imaging to explore and develop the petroleum resources needed to meet global energy demands. With the help of proper planning and mitigation measures, seismic surveys could be executed safely and without significant impact on marine life in general and marine mammal populations in particular (MMOA 2018). Drones can be a potential substitute to manned aerial flights for marine mammal activity monitoring, in order to lower the safety risks, for both humans and marine life, involved in flights over remote areas of the Arctic Ocean. UAS can be used to monitor and track marine mammals in the areas of seismic operations; these are non-obtrusive and efficient systems for acquiring the required data, while decreasing the need for individuals to access the local marine flora and fauna.

CONCLUSIONS

This paper discussed the techniques that can be employed at different stages of seismic data acquisition operations in areas with surface ice, both onshore and offshore. The paper has presented the idea of using unmanned aerial systems (drones) and autonomous underwater vehicles during these procedures. The huge potential of drones in the geophysical sector has been explained, particularly during seismic procedures in the presence of surface ice, both onshore and offshore, in all stages: from pre-operation to post operation. A recent suggested idea of employing autonomous underwater vehicles for offshore seismic operations in normal sea conditions has the prospect of being deployed in the ice-infested waters of the Arctic. The paper recommends that detailed studies need to be carried out to find the effect of sounds, which are introduced during these surveys, on marine life in Arctic waters.

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