



The law of the sea and current practices of marine scientific research in the Arctic

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ABSTRACT

The rapid changes in both climate and human activity occurring in the Arctic Ocean demands improved knowledge about this region. Combined with eased accessibility due to reduced sea ice cover and new technologies, this has led to increased research activity in the region. These circumstances put pressure on the applicable legal framework, i.e. the United Nations Convention on the Law of the Sea. Therefore, a conversation is needed between legal and marine scientists to promote the alignment between the legal framework and current practices of marine scientific research in the Arctic. This article showcases three current practices of marine scientific research in the Arctic, which are subsequently analysed in light of the existing legal framework, highlighting the legal questions arising from the use of these three technologies. The three technologies analysed here are seabed structures off Svalbard, floating ice-tethered observatories deployed across the marine Arctic, and remote sensing activities paired with in situ measurements.

1. Introduction

The environmental impacts of climate change are making the Arctic Ocean a place of increasing economic and environmental importance. The warming of the Arctic is at a rate almost twice the global average [1], and the rapid retreat of sea ice makes the ocean more accessible for both resource exploitation and shipping. This, in turn, stresses the Arctic Ocean ecosystems [2]. Due to these reasons, marine scientific research is of particular interest in the Arctic Ocean. However, the lack of infrastructure, the remoteness of the area and the challenging climate, makes data acquisition challenging and often requires novelty in the research methods chosen.

Marine scientific research is internationally regulated by the 1982 United Nations Convention on the Law of the Sea (UNCLOS). Coined the “constitution for the oceans,” [3], the UNCLOS sets out States’ rights and obligations in the world’s oceans. However, the UNCLOS was negotiated at a time in which neither the increased accessibility to the Arctic Ocean, nor some of the novel research technologies we see today, were a reality. In addition, scholars have identified legal gaps and/or uncertainties with respect to the regulation of marine scientific research by the

UNCLOS, including the lack of clarity of certain terms, and the consent regime [4–10].

Increased scientific activity and demand on knowledge in an incrementally more ice-free Arctic Ocean requires a conversation between legal and marine scientists in order to promote alignment between the provisions enshrined in the UNCLOS and contemporary practice of marine scientific research. Researchers from the disciplines of law, physics, biology, and oceanography have therefore gathered in the frame of the Arctic Ocean Technology and Law of the Sea (ATLAR) project at UiT The Arctic University of Norway to build an interdisciplinary awareness of the current practices of marine scientific research and the legal framework that aims to regulate this activity in the Arctic Ocean.

This article introduces three methods for data acquisition and marine scientific research in the Arctic: ocean monitoring using seabed structures, floating ice-tethered observatories, and satellite remote sensing. The aim is to answer the following questions: What legal issues arise from analysing these current practices of marine scientific research in light of the legal framework, and to what extent do some of the current practices of marine scientific research in the Arctic challenge this

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framework? Working with and responding to these questions will contribute to a broader discussion on whether the international legal framework adequately regulates current practices of marine scientific research. Additionally, this work can provide a basis from which marine scientists working in the Arctic Ocean can design their future research projects to fit well within the UNCLOS, as well as pinpoint challenges within the current regulatory regime.

The following sections will introduce the UNCLOS (section 2) and the three examples of marine scientific research (section 3). Section 4 analyses these in light of the legal framework, and offers a discussion regarding the challenges to the UNCLOS and legal issues derived therefrom. Some concluding remarks are presented in section 5.

2. The legal framework

The UNCLOS is the general international legal framework for all maritime affairs and usages of the oceans, including marine scientific research. Unlike Antarctica – land surrounded by ocean, the marine Arctic is an ocean surrounded by land. The 1982 UNCLOS therefore applies to the marine Arctic, as confirmed by the five littoral Arctic coastal States [11]. The UNCLOS has been in force since November 1994, and is legally binding on its 168 States parties [12].

The objective of the UNCLOS is to create “a legal order for the seas and oceans which will facilitate international communication, and will promote the peaceful uses of the seas and oceans, the equitable and efficient utilization of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment” (Preamble). In other words, the UNCLOS regulates, at least to some extent, “almost every possible activity on, in, under, and over the sea” [13].

To do this, the UNCLOS divides the world’s oceans and their seabed into different maritime zones, where States have more sovereignty and/or sovereign rights closer to the land. Starting from the coast, a coastal State has a territorial sea comprising of the seabed and water column up to 12 nautical miles (Articles 2; 3). It may declare an exclusive economic zone (EEZ) covering the water column and seabed to some extent, up to 200 nautical miles (Articles 56; 57). Furthermore, it has a continental shelf comprising the seabed up to 200 nautical miles or to the outer edge of the continental margin when that extends beyond 200 nautical miles (Article 76). The abovementioned maritime zones are zones in which coastal States have sovereignty or sovereign rights and jurisdiction for the purpose of resource management, marine environmental protection, and marine scientific research. Beyond these zones, the high seas (the water column beyond the limits of the EEZ and/or the territorial sea) and the Area (the seabed beyond the limits of the continental shelf) are considered areas beyond national jurisdiction (Articles 86; 1(1)(1)). The UNCLOS prescribes certain rules and regulations specific to these different maritime zones. In addition, the UNCLOS also includes general sections that take a more thematic approach, such as those parts dealing with the protection and preservation of the marine environment (Part XII) and marine scientific research (Part XIII).

Part XIII of the UNCLOS sets out rules and provisions regarding marine scientific research (Articles 238–265). It provides for the promotion and facilitation of marine scientific research (Article 239). The UNCLOS does not define marine scientific research, but it does provide general principles for the conduct of marine scientific research (Article 240) and a regime to obtain the consent of the coastal State. In the territorial sea (up to 12 nautical miles from the coast), research may only be conducted with the express consent of the coastal State (Article 245). Marine scientific research in the EEZ and the continental shelf also requires the consent of the coastal state, but Article 246 provides that the coastal State should normally grant its consent “for marine scientific research projects by other States or competent international organizations” except in a few specific circumstances. If a coastal State does not respond to a request for consent within four months, it may be considered as “implied consent” (Article 252). In the Area and on the high seas,

all States have the right to conduct marine scientific research (Articles 256; 257).

3. Current practices of marine scientific research in the Arctic

Data from the Arctic Ocean can be obtained from different domains: from the seabed, by using seabed structures or moorings; from the sea surface, either using floating devices or ships; or from the atmosphere, by using satellites, planes or drones. There are also technologies that operate throughout the entire water column, such as remotely operated vehicles and autonomous underwater vehicles. The current article focuses on seabed structures (3.1), floating ice-tethered observatories (3.2), and satellite remote sensing (3.3).

The reasons for choosing these three technologies are twofold. First of all, the three technologies are examples of how data from the Arctic Ocean can be obtained from the three different domains (from the seabed, from the sea surface, and from the atmosphere). Secondly, these three specific technologies are used by three of the authors of this article in their own research, thereby providing valuable insights to answer the research questions set out in this article. Although similar research technologies may be used throughout the world – and in fact they are¹ – autonomous research technologies such as the ones described here are more attractive to the Arctic’s unique environmental challenges.

3.1. Seabed structures

One way to obtain data from the ocean is to deploy structures equipped with scientific instruments on the seabed, often referred to as ocean observatories. An advantage of this approach is the possibility to acquire continuous time-series from a specific location without having to be present with a ship. This is particularly useful in the Arctic Ocean, where ship access is mostly limited to ice and storm-free conditions and therefore limits data acquisition to summertime. Stationary ocean observatories are therefore a convenient way to investigate temporal variability and obtain measurements across the whole year from the Arctic Ocean. Seabed observatories have previously been used on several occasions in the Arctic Ocean, for example the MASOX observatory [16].

The K-Lander ocean observatory (see Fig. 1) developed by Kongsberg Maritime and the Norwegian Centre of Excellence CAGE (Center for Arctic Gas Hydrate, Environment and Climate [17]) is an example of a seabed structure used for data acquisition in the Arctic Ocean. CAGE is a research centre that investigates gas hydrates in the Arctic with the aim to understand how methane release from the seabed can affect the environment. In particular, the two K-Landers are used to investigate the seepage of methane gas from the seabed offshore West Spitsbergen and in the Barents Sea. Being a very potent greenhouse gas, the release of methane to the Arctic Ocean could potentially have consequences for the global climate if the methane gas reaches the atmosphere [18]. The K-Landers make it possible to monitor the methane seep sites throughout the whole annual cycle and therefore improve the existing knowledge on methane release from the seabed in the Arctic, which has mainly been based on summer observations up until now.

The K-Lander observatory consists of a metal frame 3.6 metres wide and 1.6 metres high (Fig. 1). Scientific instruments and batteries are mounted inside the metal frame. The K-Lander is specifically designed to be trawl proof, having tilted sidewalls such that fishing equipment will ideally slide over the observatory without damaging it.

The instruments mounted on the K-lander typically measure ocean current velocity and direction, temperature, salinity, pressure, carbon dioxide, methane, and oxygen. All data is stored locally and are

¹ See for example the broad-scale global array of floats measuring temperature and/or salinity, otherwise known as Argo [14], or the GasQuant lander on the seabed [15].

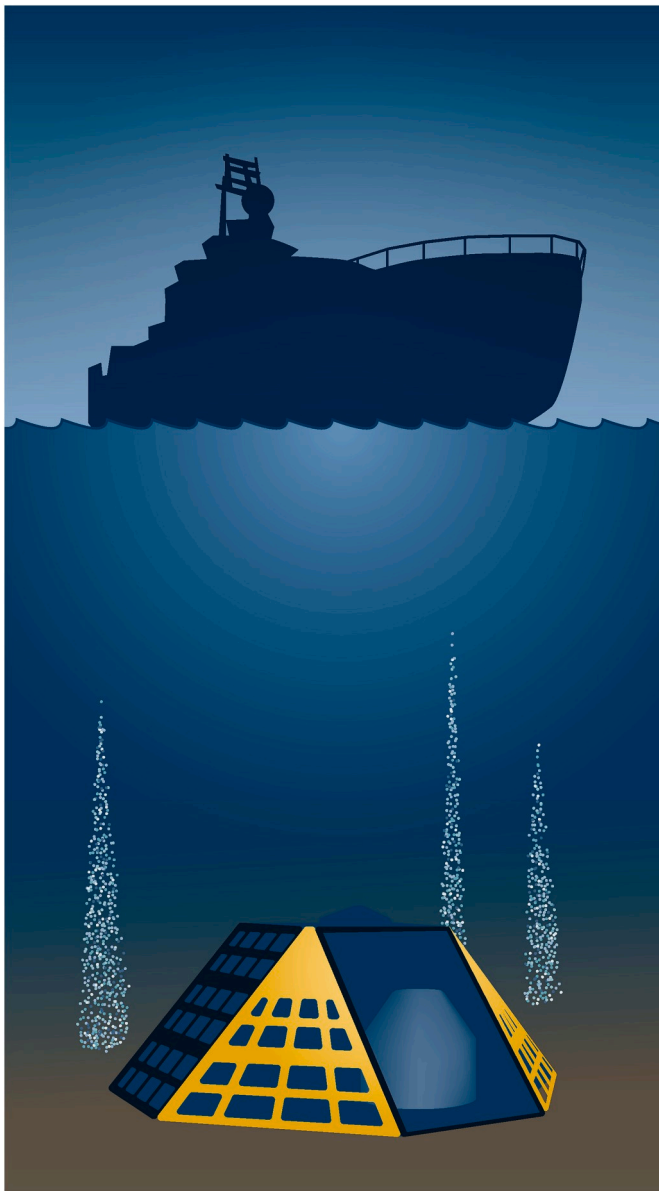


Fig. 1. The K-Lander ocean observatory seen on the seafloor as an example of a seabed structure. The white plumes represent gas seepages.

retrieved along with the equipment. So far, the K-Landers have been deployed and retrieved twice along the West Spitsbergen continental margin and in the Barents Sea.

3.2. Floating ice-tethered observatories

Another method for gathering data in ice-covered waters is the use of floating ice-tethered observatories. An ice-tethered observatory can be described as a buoy equipped with different sensors to perform measurements in the ice and/or the underlying water column. The term 'ice-tethered' refers to the deployment of the observatory, which is done by drilling a hole in the ice and lowering the observatory into the underlying water column until the sensors reach the targeted depth (Fig. 2). Ice-tethered observatories have previously been deployed as part of other research projects, such as the Ice, Atmosphere, Arctic Ocean



Fig. 2. An example of an ice-tethered observatory. This example is of the bio-acoustic observatory.

Observing System (IAOOS) [19–21].²

This article looks at the observatories that will be set out by the ArcticABC project (Arctic Ocean ecosystems: applied technology, biological interactions and consequences in an era of abrupt climate change) [23]. This international project, funded and led by Norwegian institutions, aims to create more knowledge about the long-term physical and biological processes in the Arctic Ocean, and how these processes influence its ecosystems.

In order to meet this objective, five types of ice-tethered observatories are being developed, each of them aiming at collecting different types of data: Type 1 measures the ice thickness and temperature; Type 2 measures the salinity and light in the ice and underlying water column; Type 3 performs bio-acoustic measurements, providing information on

² Berge et al. provide an overview of how the floating ice-tethered observatories described here compare to other ice-tethered platforms [22].

where fish and other organisms are located (Fig. 2); Type 4 measures light in a high spectral resolution; and type 5 monitors the weather. Together, these five types of observatory form a so-called 'cluster'. Several of these clusters will be deployed at strategic locations in the Arctic Ocean, where they will be fixed in sea ice. The majority of clusters will be deployed in 'drift ice', which by definition drift with the wind and currents across the Arctic Ocean. All observatories will operate autonomously, transmitting their GPS-position and battery status regularly via the Iridium satellite network. Some observatories also send data via the satellite network, whilst others store them locally.

3.3. Remote sensing

A third way to obtain data from the Arctic Ocean is by using remote sensing technologies. Satellite remote sensing is a technology where sensors mounted on satellites are used to acquire information from an object or phenomenon on Earth [24–26]. The data obtained is then often used for the purpose of improving natural resource management and the protection of the environment [27]. A significant part of the Arctic

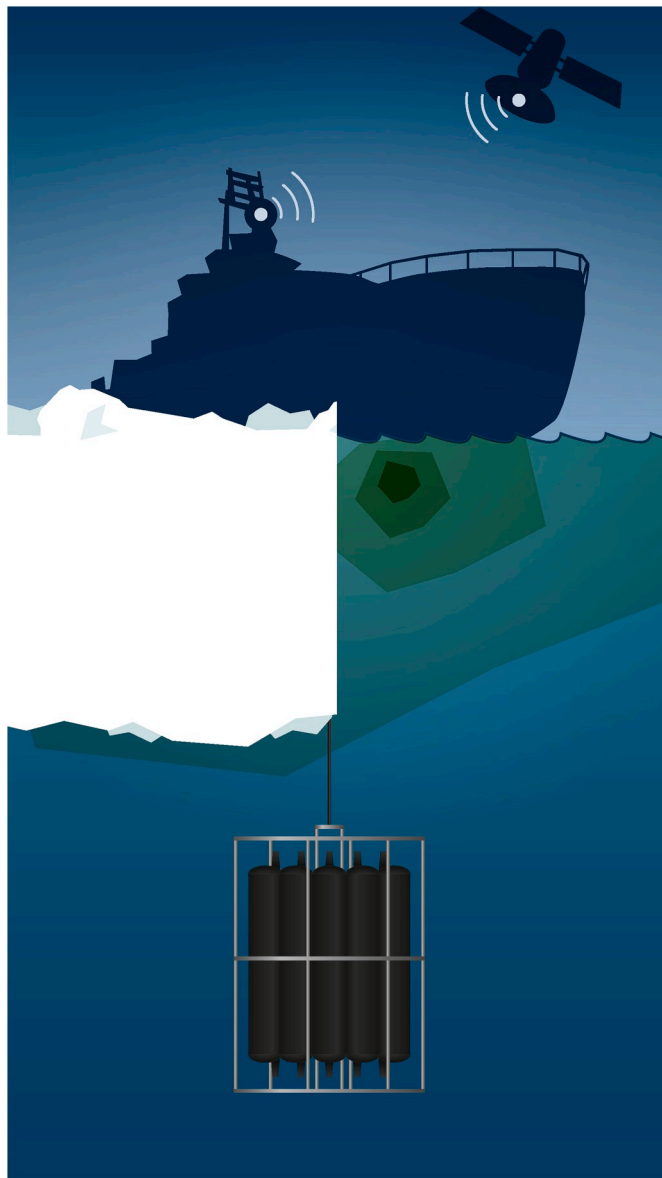


Fig. 3. In-situ measurement of Chl-a in the Marginal Ice Zone (MIZ) coordinated with overpass of satellite, as an example of remote sensing.

Ocean is ice-covered throughout the year [28–31]. Therefore, using remote sensing technologies to monitor the Arctic Ocean is highly beneficial as it allows data acquisition from difficultly accessible areas.

The remote sensing technology referred to in this article uses satellite data from optical sensors matched with simultaneous measurements obtained from water samples. This data is used for monitoring the occurrence and distribution of primary production in the Marginal Ice Zone (MIZ) across the Arctic by estimating the concentration of Chlorophyll-a (Chl-a). The MIZ can be defined as “the transition area from open water to continuous sea ice” [32] and is a hotspot for primary producers, such as algae and phytoplankton [33]. These form the basis of food webs [34], and thus, knowledge about primary production in the marine Arctic can contribute to understand changes in Arctic ecosystems [33,35]. Algae and phytoplankton are photosynthetic organisms and require light to live and grow, for which the Chl-a molecule is required. Thus, estimating the abundance of Chl-a in the water column is a method of monitoring the occurrence and distribution of primary producers [36]. Chl-a concentration in the water column can be measured in situ by using its light absorption characteristics [37].

To estimate Chl-a content by using satellite remote sensing, one needs to relate the data acquired by optical sensors onboard satellites to the *in-situ* measurements [38]. These *in-situ* measurements are typically carried out through the use of research vessels [38], equipped to take water samples (Fig. 3). These samples are then analysed in a laboratory to retrieve the Chl-a content.

4. Analysis

As iterated above, the purpose of this article is to analyse the abovementioned technologies in light of the 1982 UNCLOS, see what legal issues arise and how these technologies might challenge the legal framework. This section will discuss three characteristics of the research technologies presented above and the issues that arise from them.

The first of these characteristics is the geographical location of the marine scientific research conducted (section 4.1). All three research technologies have the Arctic Ocean as their geographical scope. However, they operate in different geographical locations and under different jurisdictions, which might pose a challenge. The second characteristic concerns the methods and means used for the research (section 4.2). The three research technologies employ various methods and means, infrastructure and equipment. These are subject to some specific regulations in the UNCLOS, which might be challenged by the research projects. The third and final characteristic is the potential risks to the marine environment (section 4.3). The UNCLOS provides obligations to protect and preserve the marine environment, and this section will look at to what extent these research technologies are consistent with these obligations.

Some of the legal issues described below arise with respect to specific terms used in the UNCLOS. In this respect, it is important to emphasize that, within international law, treaties are interpreted in accordance with the rules of treaty interpretation provided for in the Vienna Convention on the Law of Treaties [39]. This means that any treaty, including the UNCLOS, shall be interpreted “in accordance with the ordinary meaning” of the terms “in their context” and in light of the “object and purpose” of the treaty (Article 31). If these rules still leave the meaning unclear or leads to a “manifestly absurd or unreasonable” result, recourse may be had to the preparatory works of the treaty (Article 32).

4.1. Geographical scope

The three different technologies, although all researching the Arctic Ocean, have different geographical domains. The seabed structure is fixed on the continental shelf offshore Svalbard, the floating ice-tethered observatories have a more dynamic geographical scope, and the remote sensing technology covers a very large area.

4.1.1. Seabed structure

The seabed structure offshore Svalbard is positioned on the seabed of Norway's territorial sea, within 12 nautical miles off the coast. According to the UNCLOS, a coastal State has full sovereignty in the territorial sea (Article 2(2)). The location of the structure is therefore subject to Norwegian domestic law. In case a foreign State would like to conduct scientific research in the territorial sea of Norway, it would need to ask for its consent to do so. The current research technology is operated by a Norwegian university (as opposed to a foreign actor), and so the geographical location would not raise any legal questions relating to the international law of the sea.

However, sovereignty over Svalbard and its waters remains a controversial issue [40,41]. The archipelago is regulated by a special regime, namely the 1920 Spitsbergen Treaty [42]. This treaty, preceding the 1982 UNCLOS, established Norwegian sovereignty over the archipelago, subject to the stipulations in the treaty (Article 1). One of the stipulations in the treaty is the principle of non-discrimination, granting the around 40 Contracting Parties equal access to the land territory and its territorial waters (Articles 2, 3). These territorial waters are now interpreted to at least include the territorial sea up to 12 nautical miles, and Norway declared a territorial sea off Svalbard in 2004 [43], making the principle of non-discrimination applicable to the *location* of the seabed structure. The question now remains whether the principle of non-discrimination also applies to the research *activity*.

The Spitsbergen Treaty provides that all contracting parties have "equal liberty of access and entry for any reason or object whatever to the waters, fjords and ports" of the territory of Svalbard (Article 3). It is unclear whether 'waters' in this regard refers to the rivers and lakes on Svalbard, or whether this also includes the territorial waters, and thus the territorial sea. Nevertheless, contracting parties are subject to the same conditions of equality "to the exercise and practice of all maritime [...] enterprises both on land and in the territorial waters" (Article 3). Research activities are not mentioned specifically, but they could be considered a 'maritime enterprise'. It is worthy to note Article 5 of the Spitsbergen Treaty, which, in 1920, stipulated that new conventions should be concluded "laying down the conditions under which scientific investigations may be conducted in the said territories." This suggests that scientific research is included in the non-discriminatory rights of the contracting parties to the Spitsbergen Treaty, but it also suggests that said research could be subject to various conditions. No such convention has ever been concluded – thus no such conditions have been imposed – and so it remains unclear what this provision means today. This may either mean that marine scientific research is subject to full Norwegian sovereignty [44], as is maintained by Norway [45], or, alternatively, it may imply that contracting parties to the 1920 Spitsbergen Treaty have an extended right to conduct marine scientific research in territorial waters off Svalbard (if scientific research is indeed to be considered a non-discriminatory right of all contracting parties to the Spitsbergen Treaty), compared to the rights they have under the 1982 UNCLOS (according to which they would require Norway's consent to conduct scientific research in Norway's territorial sea). The current research technology is operated by a Norwegian actor, but if a foreign actor were to be involved, these are valid legal issues.

4.1.2. Floating ice-tethered observatories

The floating ice-tethered observatories have a very dynamic geographical scope, as the majority of the observatory clusters will drift with the sea ice. Some of the observatory clusters will be deployed in 'fast ice' (sea ice connected to land), thus staying at the same location, whilst most of the clusters will be deployed in 'drift ice' (sea ice moved by winds and currents), and may thus drift across jurisdictional boundaries. As of December 2019, one cluster has been deployed in the Canadian Arctic, in fast ice close to a small settlement called Qikiqtarjuaq. Two more clusters were deployed in the fast ice of the Van Mijenfjord in Svalbard and in the Arctic Ocean north of Svalbard. Another cluster is planned to be deployed at the Russian drift ice station

located close to the North Pole in the Arctic Ocean pack ice. As the project progresses it is likely that more clusters will be set out in the Arctic Ocean.

Deployment of these floating ice-tethered observatories will thus take place both in areas within national jurisdiction and beyond national jurisdiction. Furthermore, the majority of the clusters will drift along with the sea ice, and as the drift-track is difficult to predict, they may enter the waters of any of the five Arctic coastal States (Canada, USA, Russia, Norway and Denmark in respect of Greenland). According to the UNCLOS, Norway, hosting the institution undertaking the research activity, would thus need consent from all other Arctic coastal states to execute this project. As explained above, coastal States should in "normal circumstances" (Article 246(3)) grant their consent for research projects, but an exception to this rule is if the research project involves "the construction, operation or use of artificial islands, installations and structures" (Article 246(5)(c)) referred to elsewhere in the UNCLOS (Article 60). There is no agreement on the precise meaning of these terms [46,47]. However, Soons claims the reference to "installations and structures" in Article 246(5)(c) refers to "stationary (fixed and anchored floating) installations" only, thus excluding free-floating buoys for example [48]. Others, too, have concluded that floats and gliders should be considered "equipment", rather than "installations and structures" [49,50]. The distinguishing factor seems to be the size and permanency of the feature [26,49,50]. As observed by another scholar, the legal status of any floating research device ultimately depends on the type of data collected [6]. It may cautiously be concluded that the floating ice-tethered observatories described here are not "installations and structures" for the purposes of Article 246(5)(c), and thus, coastal States could not withhold consent for this reason alone. However, with the rise of new technologies, the lack of a definition of installations, structures, and equipment in the UNCLOS may provide unclarity with respect to the discretion to withhold consent. Irrespective of the classification of the ice-tethered observatory, having to obtain consent from all Arctic coastal States would be a tedious procedure, and scientists have already observed that there are accessibility problems in the Arctic [51].

Not only would Norway need consent from all the concerned coastal States, it is also under an obligation to provide accurate information about the research project. According to the UNCLOS, the researching State should provide a full description of the "nature and objectives" of the research project, the "precise geographical areas in which the project is to be conducted" and the "expected date of [...] deployment of the equipment and its removal, as appropriate" (Article 248). This information needs to be communicated to the coastal State at least 6 months before the research project commences (Article 248). For the floating ice-tethered observatories described above, this is problematic. These rules do not seem to "fit the needs of deployment and use of profiling floats and gliders" such as the ice-tethered observatories discussed here [49]. A precise geographical area will be hard to determine. Although general drift patterns of Arctic sea ice are known, the prediction of future geographical locations of a floating cluster is difficult. The inability to provide accurate information may decrease the likelihood of obtaining consent from coastal States: coastal States may withhold consent when the research project contains inaccurate information according to Article 248 regarding the "nature and objectives" of the project (Article 246(5)(d)). This justification to withhold consent does not seem to extend to inaccurate information regarding the precise geographical location or the expected date of deployment [47,52]. A coastal State can therefore not withhold consent if the information concerning the precise geographical location is inaccurate, although it can postpone giving consent according to Article 252 of the UNCLOS.

With the likelihood that we will see more of these international projects involving autonomous observatories, the consent regime established in the 1982 UNCLOS may be problematic. As one author observed, the UNCLOS "is based on the premise that it is possible to differentiate between science that is conducted in the various maritime zones" [5]. This premise does not hold up for floating ice-tethered

observatories. Projects such as these will have difficulty fulfilling the requirements of the consent regime, including the duty to provide accurate information. Although failure to provide such information is not a ground to refuse consent, it can delay the research project considerably. The legal question which thus arises from this analysis is how to implement the consent regime and obligations when such information, due to the nature of technology, is unavailable, and when the nature of the technology leads to such a dynamic geographical location. In addition, the lack of clarity surrounding the definition of 'installations and structures' will have to be addressed in order to effectively regulate these autonomous observatories.

4.1.3. Remote sensing

The geographical scope of the optical remote sensing technology is much larger than the other two technologies previously discussed. The research conducted with the help of this technology aims to estimate Chl-a in the MIZ. To do this, one needs to relate the measurements from satellites to measurements conducted at location by research vessels [38]. This research thus consists of both data acquisition from space as well as from the water column. The object of study is the ocean, but as a large part of this research does not take place on the sea, is this research then covered by Part XIII of the UNCLOS, or is there perhaps another legal regime (more) applicable?

According to some authors, Part XIII of the UNCLOS does not include scientific research undertaken from "outside of the surface, water column, subsoil or seabed in the marine environment," such as remote sensing and other *ex situ* techniques [53]. The drafting history of the UNCLOS confirms this, as a proposal by developing countries to explicitly include satellites in the marine scientific regime was rejected [24,54]. The consent regime established in Article 246 is applicable to marine scientific research projects conducted *in* the exclusive economic zone. Although the airspace is considered to be included in this zone [48], it is unlikely that outer space is part of this zone too. Thus aircraft may be subject to the regime in Part XIII of the UNCLOS [10,48], but it is unlikely that the same applies to satellites.

However, an alternative interpretation exists. The provisions of Part XIII themselves do not include any specific requirement that the research activity shall take place in, on, or below the water column. In fact, the UNCLOS departed in this regard from the 1958 Convention on the Continental Shelf [55], which implied that the marine scientific research concerning the continental shelf must be "undertaken there" (Article 5). Although this specific geographical requirement has not been included in the 1982 UNCLOS and one could thus argue that this geographical requirement does not exist anymore, many provisions in Part XIII do refer to marine scientific research *in* the EEZ or *on* the continental shelf, implying that the research activity must be undertaken there. Whether remote sensing is thus included in the regime of marine scientific research of the UNCLOS remains unclear.

At the same time, scientific research conducted by using remote sensing may be governed by the principle of the freedom of outer space, according to the Outer Space Treaty [24], [56]. Principle IV of The Principles Relating to Remote Sensing of the Earth from Space confirms that the freedom of scientific investigation in outer space applies to remote sensing of the Earth [27].

If the Outer Space regime is the main applicable regime, there is no requirement of consent to conduct marine scientific research through remote sensing. However, if the UNCLOS was to be the applicable regime, a researching State would need to obtain consent from the coastal State to conduct remote sensing activities in that State's maritime zones. The other provisions of Part XIII would then be applicable to the remote sensing activities too. This issue remains unclear, although it is more likely that the freedom of outer space is the main principle here [26].

Although remote sensing activities are presumably not covered by the UNCLOS, the accompanying *in-situ* data collection, done by ships, is. The *in-situ* data collection must adhere to Part XIII of the UNCLOS, which

is made difficult because the MIZ is a moving area. These two activities, in order to conduct meaningful research, are inextricably linked. The legal question which thus arises is to what extent Part XIII applies to remote sensing, and how the potential application of that regime interacts with other legal regimes applicable, such as the Outer Space regime.

4.2. Research methods and means

This section will discuss the methods and means used by the three research technologies in light of the legal framework. Two legal issues arising therefrom are identified here: the duty to use appropriate scientific methods and means, and the duty to retrieve the equipment after the research has been conducted.

4.2.1. 'Appropriate methods and means'

The UNCLOS prescribes that marine scientific research shall be conducted "with appropriate scientific methods and means" (Article 240 (b)). Considering that this treaty was negotiated in the seventies, it is uncertain what would qualify as 'appropriate' at the time, what would qualify as 'appropriate' today, and whether this could be interpreted to include modern technologies such as floating ice-tethered observatories. Gorina-Ysern has observed that many States have either directly cited this provision, or otherwise paraphrased it in their national legislation [9].

The ordinary meaning of the term 'appropriate' thus remains unclear. The object and purpose, however, may provide some explanation. According to Soons, the intention of this requirement was to prohibit the use of methods and means which "are unnecessarily and unreasonably damaging to the marine environment or to other uses of the sea" [48]. However, this is actually already covered by subparagraphs (c) and (d) of the same provision. This would mean that 'appropriate' would have to refer to something else, as it would otherwise be an empty term. Another interpretation suggests that 'appropriate' requires some recognition of the methods and means used [47]. However, the wording used here, differs from the wording used in Article 204 for example, which refers to "*recognised* scientific methods".

The negotiating history may also provide clarification. Based on an earlier draft of this provision, "appropriate methods and means" seems to refer to vessels, aircraft, devices, equipment or installations [54]. However, because an explicit reference to these examples did not make it to the final result of the negotiations, it could open the door to a broad interpretation, potentially including new technologies such as floating ice-tethered observatories and satellites. Furthermore, 'appropriate' should be interpreted in an evolutionary way [57], implying that it requires methods and means to be 'appropriate' to the place, the purpose of the research, and time of its use. A researching State thus has some discretion on how to interpret this term.

Any potential confusion concerning the term 'appropriate' could have been remedied with a clear definition of marine scientific research. However, there is no such definition in the UNCLOS, which some authors have identified as a legal gap [49,50]. During the negotiations of UNCLOS, several definitions were proposed, but States could not agree. Eventually, no definition was included in the text because the States agreed that the meaning of the term would become clear through the provisions of Part XIII [48]. It appears that the five Arctic coastal States have implemented the provisions of Part XIII differently, and that there is no uniform definition of marine scientific research across the Arctic [10,51]. The absence of such a uniform definition could mean that there is a possibility to include future research technologies or other technological developments [47].

The legal issue here is whether technologies developed after the seventies are still covered by the legal regime and are considered 'appropriate' methods and means. Due to the harsh climate in the Arctic, researchers often need to develop and apply novel technologies such as floating ice-tethered observatories or remote sensing to obtain data.

Although these technologies might not have satisfied the ‘appropriateness’ criteria of the seventies, they may be considered appropriate in today’s understanding of the term. Many of the terms in the UNCLOS, after all, are considered “inherently evolutionary” [57], and the term ‘appropriate’, is arguably one of them.

4.2.2. Retrieval of research equipment

Article 249 imposes a duty to retrieve the research equipment when deployed in the EEZ or on the continental shelf. Once the research is completed, researching States need to ensure that “unless otherwise agreed,” the scientific research installations or equipment is removed (Article 249(1)(g)). This provision might be problematic for current practices of marine scientific research. Both the seabed structure and the floating ice-tethered observatories anticipate a potential risk for the loss of some research equipment.

The seabed structure (K-Lander) is retrieved after a one-year deployment via an acoustic release system: an acoustic signal is sent to a transponder to trigger the release of a buoy connected to the observatory with a rope, which can be hoisted along with the whole structure onto the ship once it reaches the sea-surface. In case of an unlikely transponder or release mechanism failure, or if the K-lander is tipped over by bottom trawler doors, the retrieval of the seabed structure requires a remotely operated underwater vehicle to hook the structure to a ship-mounted winch. In addition to the legal obligation, the cost of the structure and the value of the collected data would justify such an alternative recovery operation.

The retrieval priority for the floating ice-tethered observatories depends on how the observatories store the data. As described above, five observatories form a cluster. Of this cluster, three observatories are ‘online data observatories’, meaning that they send their data via the satellite network. Two of these observatories are ‘local data storage observatories’, which means that they must be retrieved in order to obtain the data. These observatories will be located from the latest received GPS-coordinates and retrieved with a ship. In contrast, the ‘online data observatories’ will only be retrieved if they are in the same area as one of the ‘local data storage observatories’ and easily accessible.

Two of the research technologies analysed in this article might leave some parts of their equipment in the ocean. The duty to retrieve the research equipment is not absolute (Article 249(1)(g)); the researching State could agree with the coastal State to leave the equipment in the ocean. One author has commented that the UNCLOS “leaves it essentially to the coastal State to decide whether or not research installations must be removed” [26]. According to another author, sometimes it might be “unreasonable” to require researching States to fully comply with this obligation, especially when equipment is lost and cannot be found after “reasonable efforts” have been made to locate said equipment, or when equipment can only be retrieved at a high cost whilst the equipment is likely not to harm the marine environment [48]. These exceptions may be applicable to the research technologies analysed here. Furthermore, the obligation to retrieve research equipment does not explicitly apply to research equipment in the Area³ or in the high seas. However, this duty may still arise following from the obligation not to interfere with other uses of the ocean and/or the obligation to protect the marine environment in Article 240. Although the requirement to retrieve research equipment from the EEZ or the continental shelf should not be regarded as a condition to be met to obtain consent, in some situations this has been the case [47]. The legal question arising from the three technologies in light of the duty to retrieve the research equipment is to what extent this duty is an absolute duty, and to what extent a researching State may exercise discretion, either because of ‘agreement’, or because retrieving the equipment may do more harm than leaving the equipment in the ocean.

³ Although see Article 143(1) which provides that marine scientific research activities in the Area shall be carried out “in accordance with Part XIII”.

4.3. Potential risks to the marine environment

A final legal challenge potentially arising from the current practices of marine scientific research is the risks these technologies pose to the marine environment, and how these can be regulated. The UNCLOS provides a general obligation to protect and preserve the marine environment (Article 192). Article 240(d) confirms that this obligation also extends to the conduct of marine scientific research: the research has to be conducted in compliance with this obligation. Furthermore, a coastal State may withhold its consent if a research project in its EEZ or on its continental shelf “introduces harmful substances into the marine environment” (Article 246(5)). Previously, research activities have been noted to have significant effects on the marine environment, especially activities such as periodic underwater release of acoustic signals, the seeding of iron, the experimental mining of ferromanganese nodules, the catch of whales, and the catch of Southern blue fin tuna [58,59]. This section will analyse to what extent the research technologies described in this article threaten the fulfilment of that obligation and the legal questions arising therefrom.

The environmental risks of using the seabed structure are limited, and relate to the batteries used. These batteries are disposable lithium batteries (Li-SOC I2), and a failure of these batteries could result in leakage of toxic waste, endangering the surrounding marine environment. However, the incentives to make these batteries as safe as possible are strong, and a potential environmental impact is relatively small. After use, the batteries from the seabed structure are sent to a certified recycling facility for disposal.

The deployment of floating ice-tethered observatories in a remote area such as the Arctic Ocean is a complex undertaking. The main environmental risk is that observatories could be left behind and consequently end up as marine litter in the Arctic Ocean. This risk is highest for the ‘online data observatories’ as these have a lower priority for retrieval. Harmful material like batteries and electronics would be introduced into the marine environment. Another potential risk is that marine mammals get entangled. The observatories have ropes that are equipped with different types of sensors that hang in the water. However, this risk is expected to be limited since the ropes are hanging vertically in the water and in general do not exceed a length of approximately 10 metres.

Satellite remote sensing does not pose any risks to the marine environment, although the *in-situ* measurements can have the same impacts on the marine environment as shipping, including accidental oil spills, noise emissions, and problems with hazardous waste or ballast water release.⁴ However, these potential adverse environmental effects are not specific to marine scientific research activities as they concern all ships at sea.

To fully understand threats to the marine environment and to develop effective environmental protection strategies, we need advances in scientific knowledge, obtained through marine scientific research. At the same time, we might not fully comprehend the environmental impacts of the activity, and marine scientific research may thus be hampered due to environmental protection measures restricting the activity. This has been deemed the paradox of marine scientific research [61]. Obligations concerning the protection and preservation of the marine environment may “stifle the conduct of [marine scientific research] by limiting access and creating overly onerous administrative requirements” [59,62]. There is thus a challenge to reconcile the two, and find the balance between conducting marine scientific research, and the protection and preservation of the marine environment.

⁴ Although ships are currently the most common method for obtaining the *in-situ* measurements, new methods, such as autonomous sea gliders, are appearing as alternative methods for collecting *in-situ* measurements, which may have different environmental impacts [60].

5. Concluding remarks

The climate of the Arctic is changing more rapidly than that of other regions in the world, and the swift loss of sea ice makes the area more accessible. The changing climate and increased human activity can have tremendous effects on the marine Arctic ecosystems. Marine scientific research in the Arctic is crucial, both to map the potential footprint of human activity in the region as well as predicting changes in the global climate, and is essential to valuable policy-making.

Although the Arctic Ocean is opening up, the challenges for conducting marine scientific research remain. Seasonal sea ice cover, the polar night, remoteness, and harsh weather all contribute to a demanding research environment. These difficult conditions coupled with the urgent need for knowledge, results in increased activity and employment of new and innovative technologies to overcome these challenges.

This article has shown to what three different research technologies may challenge the adequacy of the applicable legal framework in the Arctic and what legal questions arise from the use of those technologies. Although some of the issues described in this article may be common to all marine scientific research practices, they are especially apparent in the context of these specific research technologies deployed in the Arctic Ocean. To summarize, the geographical location of the ice-tethered observatories and the satellite remote sensing challenge the existing requirement to obtain consent from coastal States to conduct marine scientific research due to the dynamic and remote location of the research equipment. The novelty of the methods and means used may challenge the principle of 'appropriateness' and of the duty to retrieve research equipment. Finally, the seabed structure and the ice-tethered observatories may pose relatively small risks to the marine environment - which is the case for all *in-situ* data acquisition in the Arctic Ocean - requiring an adequate way to find a balance between the right to conduct marine scientific research and the duty to protect and preserve the marine environment. For all of these examples, the legal question is how to give effect to the legal obligations enshrined in UNCLOS, without hampering the meaningful research conducted by these three technologies. To seek an interpretation of UNCLOS which promotes research on the marine environment aligns well with the preamble of UNCLOS, where it is explicitly stated that it should "promote the [...] study, protection and preservation of the marine environment".

Amendment procedures of the UNCLOS are tedious and unlikely due to the principle of consensus (see Article 312). However, through evolutionary interpretation, the meaning of the law of the sea can adapt to new circumstances. In addition, other treaties may influence the interpretation of the law of the sea [57], such as the Agreement on Enhancing International Arctic Scientific Cooperation [63] that entered into force in May 2018. According to this treaty, the Arctic States must facilitate access to research areas for each other (Article 6(1)),⁵ and must facilitate the processing of research applications consistent with the UNCLOS (Article 6(2)). This may mean that consent to conduct marine scientific research in the marine Arctic could be more easily obtained.

The UNCLOS, despite being faced by the abovementioned challenges, is still the applicable legal framework, and may continue to provide a solid foundation for the regulation of marine scientific research in the Arctic. Nonetheless, a first requirement in order to avoid non-alignment between the legal framework and research activity is to establish and maintain a conversation on how to conduct research, as well as develop a modern interpretation of the applicable legal framework that accommodates the current practices of marine scientific research in the Arctic Ocean.

⁵ However, this requirement is subject to international law, which means that coastal States still have the discretion to withhold consent according to the UNCLOS.

Author contributions

Woker, Schartmüller and Dølven carried out the major part of the work for this article. Schartmüller and Dølven contributed and wrote most of the content for the technological aspects of the paper. Blix contributed content for the section on remote sensing. Woker contributed the legal knowledge and, with the help of Schartmüller and Dølven conducted the analysis. All authors contributed to the preparation of the manuscript.

Declaration of competing interest

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