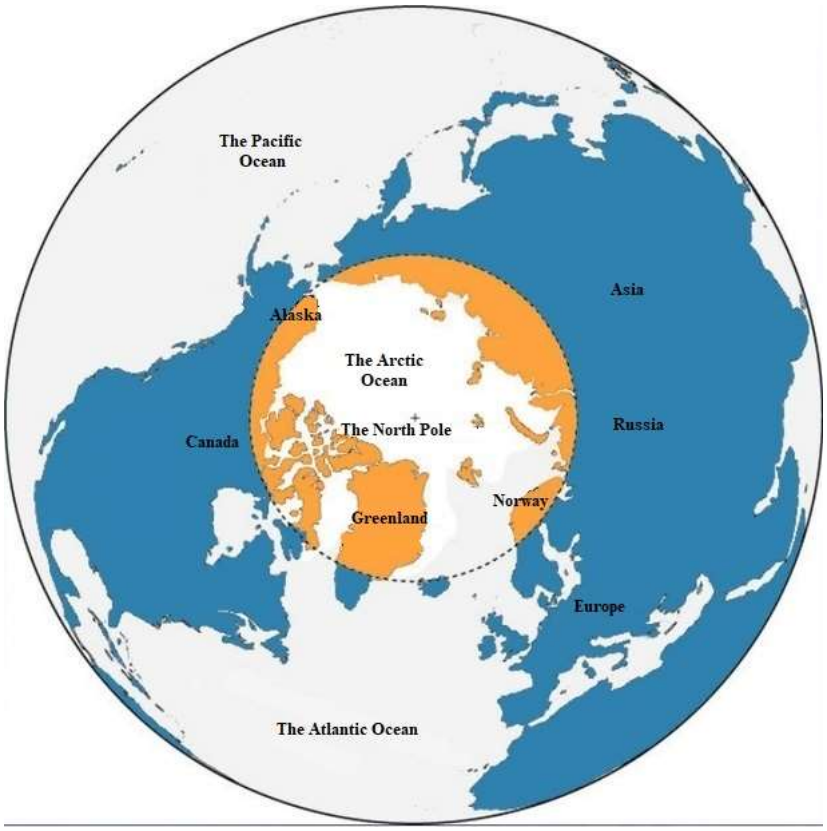
Ocean-Bottom Seismographs based on molecular-electronic sensors: deployment in the Arctic



The Arctic

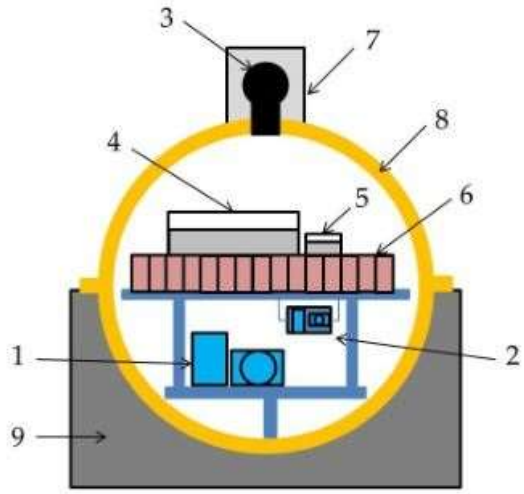
Value and Objective

The Arctic is of particular interest due to its prospects in terms of hydrocarbon extraction, development of marine transport routes, building engineering constructions and military bases. Thus, various seismic activities of the region require detailed studies by instrumental methods.

An objective of a seismic hazard assessment is highly essential and one of difficult problems of seismology. To assess seismic hazards in the Arctic seas ocean-bottom seismographs of several modifications and systems based on them were tested for the first time.

Molecular-electronic sensor CME-4111 (120 sec – 50 Hz) in a special housing

Molecular-electronic sensor CME-4311 (60 sec – 50 Hz) in a special housing



1. CME-4311 sensor
2. SV-10 short-period sensor
3. 5007m hydrophone 4. URS-S recorder
5. Digital compass module
6. Batteries unit
7. Protective half-cover for hydrophone
8. Duralumin sphere
9. Concrete ballast

Solution

To find a solution, there were used the first results of several pilot deployments of the ocean-bottom seismographs (OBS) developed by Shirshov Institute of Oceanology of the Russian Academy of Sciences (IO RAS) and Ilyinskiy A.D., a sole proprietor, in the Laptev sea in 2018 – 2020.

The OBS are equipped with two types of broadband molecular-electronic sensors: CME-4111 (120 sec) and CME-4311 (60 sec). These sensors were made by R-sensors, Dolgoprudny, Moscow region, Russia. Molecular-electronic sensing elements have a high conversion factor – it can register the smallest motion exposures such as natural seismic Earth signals over the noise of accompanying electronics of the sensor.

The bandwidths of the sensors involved in the study are 0.0083 (120 sec) to 50 Hz for CME-4111 and 0.0167 (60 sec) to 50 Hz for CME-4311. The noise performance of the both seismometers is almost identical.

The both seismometers optionally have the same type and size, light stainless-steel case and are pin-to-pin compatible.

A design of the **ocean-bottom seismograph** is presented at the picture on the left.

The OBS developed by IO RAS is suitable for a wide range of tasks, including seismological monitoring, active and passive seismics, and high-resolution seismoacoustic research.

The OBS is equipped with two 3-component sensors and a hydrophone.

The 3-component broadband sensor CME-4311 of 0.0167 (60 sec) – 50 Hz is based on the molecular-electronic technology.

The 3-component short-period sensor is based on SV-10 and SH-10 classic electromechanical geophones of 10 – 200 Hz (analogy of GS-20DX).

The 5007m hydrophone of 0.04 – 2500 Hz was also developed by IO RAS, Moscow, Russia.

An external view of the **OBS** is presented at the picture on the left.

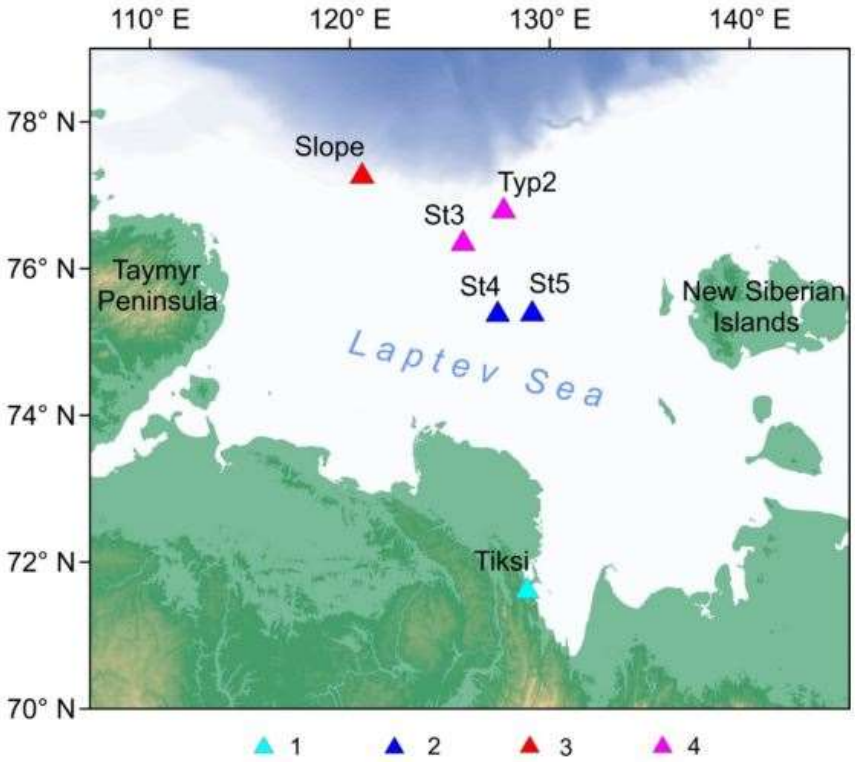
Deployment, results, conclusions

The Laptev sea is one of the most interesting regions for complex scientific research. It is the most seismically active water area among the Russian Arctic seas.

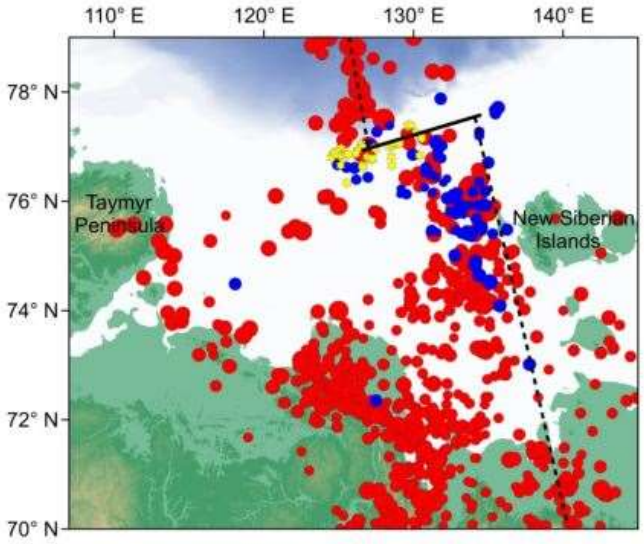
Since 2018, under the program of seismological research there have been a few scientific cruises to the Laptev Sea organized by The Pacific Oceanological Institute, Vladivostok, and by IO RAS. The goal of the expeditions was to determine seismic and seismotectonic characteristics of the region by registering local microearthquakes, remote teleseismic events and ambient seismic noise on the shelf and the continental slope of the Laptev Sea.

In addition, new data on seismicity and present tectonics of the region are extremely necessary for a detailed seismic hazard assessment.

During the time of expeditions, the OBS were deployed for 1 year on the shelf and on the continental slope of the Laptev sea – that is a technical goal of the seismological works program. By now, the records of two 1-year campaigns have been obtained. The picture below shows the **long-term deployment sites** for the AMK-73 cruises (2018) and the AMK-78 (2019) expeditions.



1. TIKSI permanent broadband seismic station included into GSN
2. OBS on the inner shelf deployed by the AMK-73 expedition
3. OBS on the slope deployed by the AMK-73 expedition
4. OBS on the outer shelf deployed by the AMK-78 expedition

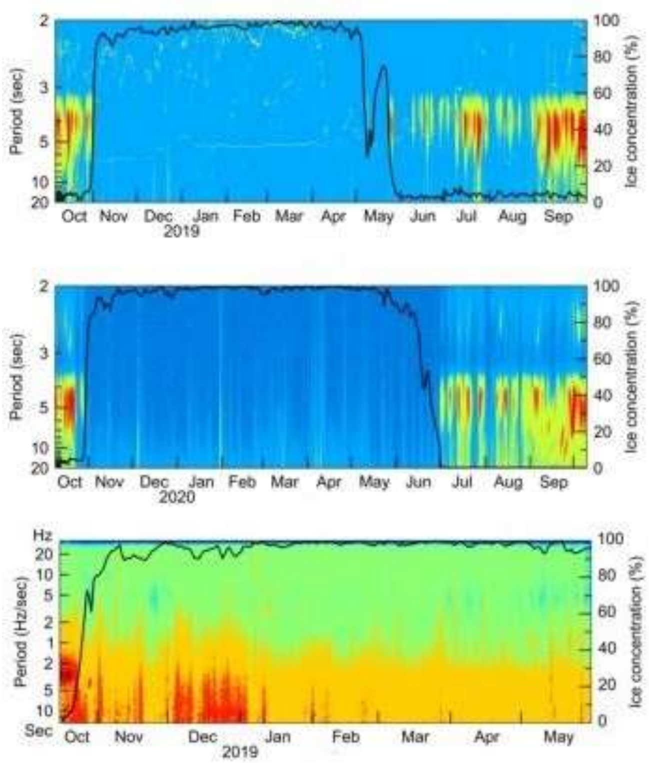


Earthquake epicenters in the Laptev Sea:
***red** – joint regional catalog by ISC*
***blue** – most clearly recorded by the OBS*
***yellow** – methane seeps on the outer shelf*
***dotted line** – supposed boundary between the Eurasian and North American tectonic plates*
***solid line** – supposed transcurrent fault*

Results

Several modifications of the OBS developed by IO RAS and Ilyinskiy A.D. depend on the permissible depths and frequency range. The OBS records obtained during the time of pilot installations in the Laptev sea were used to demonstrate the applicability of the OBS for seismic hazard assessment in the Arctic.

Two field campaigns of 2018–2019 and 2019–2020 resulted in high-quality seismic records. Standard alkaline batteries allow for 3–5 months of recording. Lithium batteries allow for 7–8 months of recording. It turned out that the OBS recording capabilities on the Arctic shelf and the upper slope are highly dependent on the level of ambient seismic noise which, in turn, is influenced by the wind waves. Thus, it is recommended conduct the OBS recording on the Arctic shelf in ice-covered time periods. For this, it is necessary to deploy the OBS in September-October and dismantle in June.



Spectrograms
of the ambient seismic noise

Conclusions

The main characteristics of the broadband **molecular-electronic sensors** such as permissible installation angles, operation temperature ranges, sensitivity and dynamic ranges appeared suitable for obtaining records under the Arctic conditions to solve the seismological problems.

In addition to fundamental research, an engineering direction is also essential. Studying peculiarities of the sea soils influence and water columns on the propagating seismic waves will be useful in the future construction of an oil&gas infrastructure in the promising Arctic region.

The described OBS demonstrated efficiency in solving a wide range of seismological problems and will be actively used in further Arctic expeditions.

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