

Ocean observatories for Earth system sciences in the key region **Atlantic-Arctic Ocean**

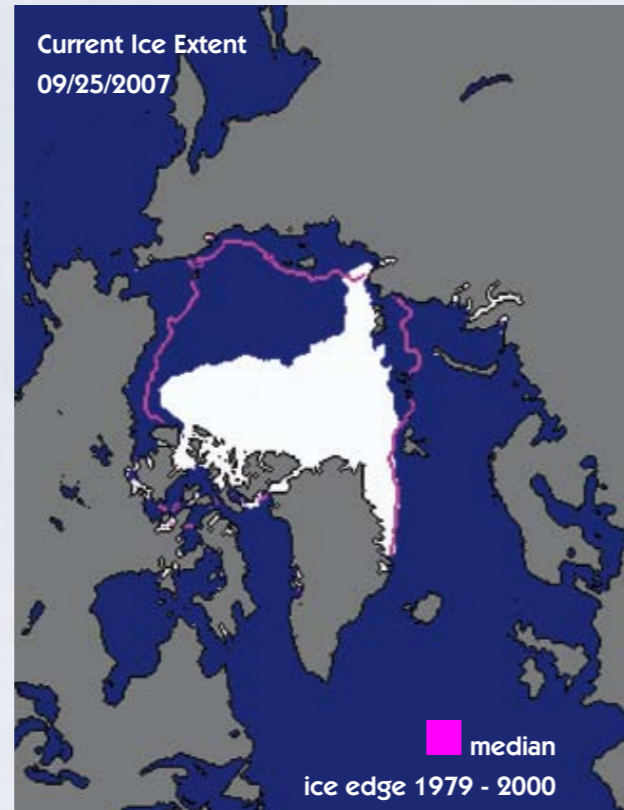


KDM

Konsortium Deutsche Meeresforschung

Ocean observatories in the key region Atlantic-Arctic Ocean: A vision

This brochure offers a vision for an integrated network of ocean observatories in the North Atlantic/Arctic Ocean region. There is an enormous need by society for ocean observation in this key region of the Earth system under rapid change with consequences for our climate, for the coastal regions and for the sustainable use and protection of marine ecosystems. With this initiative, the German marine research community aims to contribute knowledge and infrastructure for a better understanding of change in the polar region, and for a better planning of societal responses. It is a main goal of the German Marine Research Consortium (KDM) to realize this vision within this decade, in close cooperation with our European partners and other international collaborators.



National Snow and Ice Data Center, Boulder, CO

Objectives

- Observation and prediction of change in the key region North Atlantic-Arctic Ocean
- Improved methods for research and visualization of the ocean environment
- Holistic ecosystem research and impact studies through high-resolution observations in space and time
- Contribution to sustainable, environmentally friendly offshore exploration and underwater technologies

Underwater technologies and data services

Interactive ocean sciences

Understanding the causes and effects of rapid change in the North Atlantic-Arctic Ocean region is a major scientific challenge. Ocean observatories are an essential requirement for earth system sciences, due to a growing need for direct observation, high temporal resolution, interactive measurements and experimental analyses. Broadband networks with deep-sea cables can provide energy supply and interactive data transfer. Experiments and observations in all water depths can be controlled from land. Beyond basic research, this opens new possibilities for maritime technology and industry, for example for the development and testing of new underwater interventions under realistic conditions. In the past decade, the German Ministry for Education and Research (BMBF) as well as the European Commission have supported feasibility studies and international scientific networks for the development of long-term ocean observatories and now it is time for their implementation. This brochure describes the needs, future perspectives and vision for ocean observation of the German marine research community. It proposes a multidisciplinary network of submarine observatories to monitor critical changes in the key region Atlantic-Arctic Ocean, by addressing cutting edge problems in the fields of biology, geology, geochemistry, oceanography and the climate sciences.

Technical challenges

- Reliable operation of underwater platforms for construction and maintenance of subsea infrastructure
- Improvement of the long-term performance of instruments and sensors
- Development of efficient procedures to prevent corrosion and fouling
- Remote operation of installed systems
- Interactive access to all instrument functions
- Introduction of inter-operability through use of appropriate standards
- Real-time transfer of high quality data to international open-access data bases

Perspectives

- Integration of new methods from the areas of robotics, nanotechnology and marine genomics
- Expertise in innovative and cutting-edge underwater techniques
- Real-time observations of oceanic processes
- Seamless integration of research data into the international Earth Observation Network GEO

The changing Arctic Ocean

external forces and internal effects

The warming of the Arctic atmosphere has proceeded twice as fast as the global mean during the past decades. Models predict that this trend will continue. The interaction between the Atlantic and the Arctic causes oceanic change, influencing the formation of sea ice beyond the seasonal variation. The atmosphere exerts a similar long-range effect from lower latitudes into the Arctic region. Together, both contributions regulate and modulate the climatic conditions in the Arctic, the enormous freshwater fluxes from land as well as the element cycles in the ocean. Observations of local variations must therefore be coupled to information about the global climate system. In the ocean, long-term time series are not yet available with the necessary spatial resolution or data quality, and decadal fluctuations make it difficult to identify trends on climatic time scales. Such analyses enabled by long-term ocean observatories are a precondition for understanding the consequences of climate change for the Atlantic-Arctic region.



Scientific objectives

- Understanding of the coupling between atmospheric and oceanic fluctuations, regionally and over the entire North Atlantic-Arctic Ocean.
- Assessing at high temporal resolution change in water mass properties and exchange between key areas such as Denmark Strait, Labrador Sea, Fram Strait, Laptev Sea.
- Determining the change in Arctic ocean circulation and its interaction with increasing fresh water content and decreasing sea ice cover
- Relating Arctic change to global processes

Technical visions

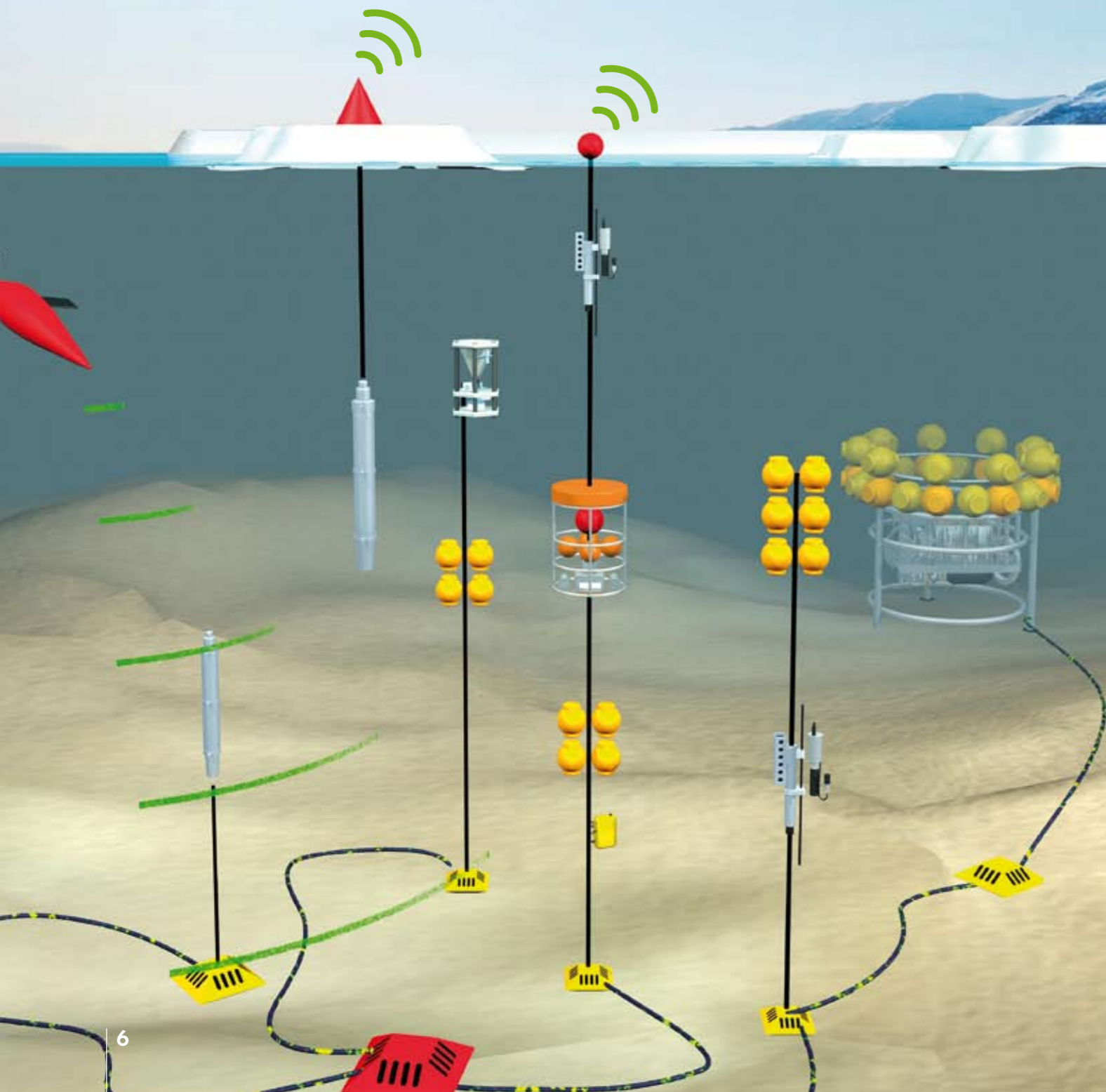
To achieve these objectives a network of autonomous observation platforms needs to be developed and implemented across the North Atlantic and the Arctic. The already existing HAFOS (Hybrid Arctic Float Observing System) determines inflow conditions and internal changes through the combined deployment of autonomous measurement systems at fixed positions (moorings), in free drift (ice tethered platforms, floats) and on defined routes. The individual components need further cross-linkage with regard to communication systems. This can be realized by means of satellite connections, acoustical methods and/or data transmitters in the form of gliders or other autonomous underwater vehicles (AUVs). Autonomous systems in the water column must be able to connect to underwater „docking stations“ in order to assure long-term energy supply and data transmission.

Furthermore, ice-breaking research vessels are needed for the maintenance of the autonomous modules and to determine parameters, which cannot be measured by sensors. The in situ measurements complete the Arctic-wide determination of oceanic change over long time scales, with good spatial coverage through satellite remote sensing. A better coverage with in situ observation systems in the Arctic is critical, but presents a particular challenge due to ice coverage.



Biogeochemistry of the Arctic Ocean

Climate change in the North Atlantic and Arctic will affect marine element cycles of the Arctic Ocean. The acidification of the ocean caused by the continuous uptake of anthropogenic CO_2 from the atmosphere changes the chemical milieu, particularly in the Arctic Ocean. Together with concurrent changes in the physical environment, this can cause diverse and unforeseen feedback effects. Marine ecosystems not only react to changes in the surrounding physical, chemical and biological conditions but can also affect these, e.g. by changes in elemental cycles. These complex interactions between biogeochemical cycles and the physical and biological system of the Arctic Ocean demand an innovative and well-linked observational approach.



Scientific objectives

- What influence does the shrinking ice coverage have on the gas exchange (CO_2 , O_2 , N_2O) between the atmosphere and the Arctic Ocean?
- How will biogeochemical cycles in the Arctic Ocean be influenced by changes in marine ecosystems such as warming and acidification?
- To what degree can the dynamics of carbon, oxygen and nutrients in the surface ocean allow conclusions about the physical and biological forcing factors?

Technical visions

The observational strategy for the suggested research work is based on two different approaches:

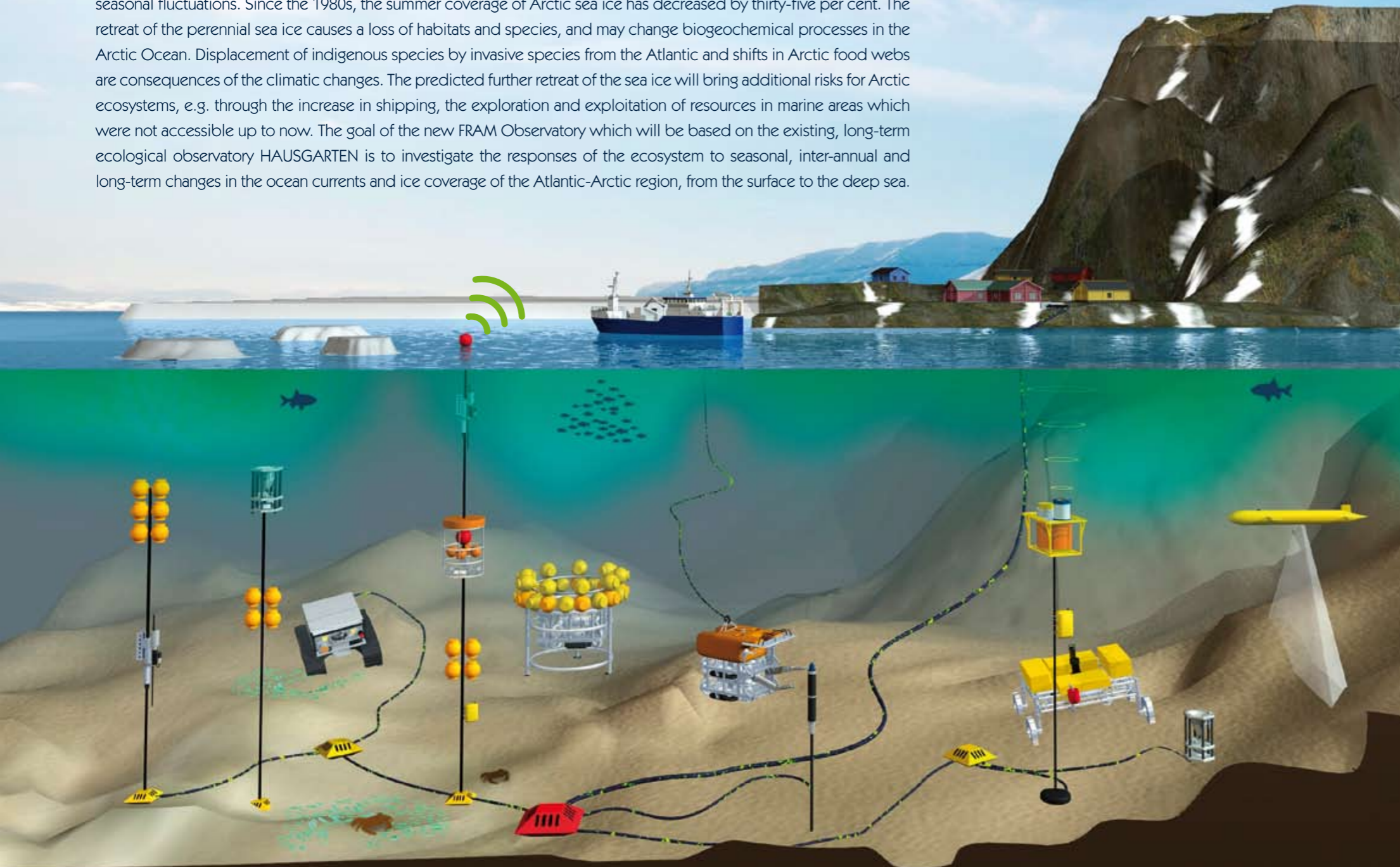
(I) The existing long-term observatory HAUSGARTEN is to be extended by adding a near-surface observational component for autonomous measurements. For high-resolution investigations of surface gradients, biogeochemical sensors (e.g. temperature, salinity, CO_2 , O_2 , total gas pressure, chlorophyll, and nitrate) will be integrated to profile between a few hundred meters depth and the ocean surface by anchored winch systems. This new functionality plays an important role in the German contribution to the international „Integrated Carbon Observing System“ (ICOS). The studies of the Atlantic-Arctic Gateway place research in the Fram Strait into a larger Atlantic context and are complemented by Voluntary Ship Observations (VOS) and other Observatories (e.g. Cap Verde Ocean Observatory - CVOO).

(II) The second approach utilizes the „Hybrid Arctic Float Observing System“ (HAFOS), in which drifting (floats, ice-tethered platforms) and other mobile platforms (gliders) are instrumented for measurements of key biogeochemical parameters (CO_2 , O_2 , total gas pressure, chlorophyll, nitrate). The combination of approaches (I) and (II) permit year-round observations in both ice-covered and ice-free regions, the identification of trends and of the internal variability of the biogeochemical system.



Arctic marine ecosystems under rapid change

The Arctic Ocean is covered with sea ice all year round, but the extent and thickness of the ice are subject to strong seasonal fluctuations. Since the 1980s, the summer coverage of Arctic sea ice has decreased by thirty-five per cent. The retreat of the perennial sea ice causes a loss of habitats and species, and may change biogeochemical processes in the Arctic Ocean. Displacement of indigenous species by invasive species from the Atlantic and shifts in Arctic food webs are consequences of the climatic changes. The predicted further retreat of the sea ice will bring additional risks for Arctic ecosystems, e.g. through the increase in shipping, the exploration and exploitation of resources in marine areas which were not accessible up to now. The goal of the new FRAM Observatory which will be based on the existing, long-term ecological observatory HAUSGARTEN is to investigate the responses of the ecosystem to seasonal, inter-annual and long-term changes in the ocean currents and ice coverage of the Atlantic-Arctic region, from the surface to the deep sea.



Scientific objectives

- What are the consequences of sea ice retreat for the ecosystems of the Northern Hemisphere, including the deep Arctic?
- What are the climate effects of change on element cycles in the Atlantic and Arctic Oceans?
- Are there pelagic and benthic indicator species for change in the marine environment?
- Are there critical threshold values in temperature, acidity, sea ice coverage and contamination, to cause a massive change in Arctic biotopes when exceeded?

Technical visions

The FRAM Observatory "Frontiers in Arctic marine Monitoring" builds upon the long-term ecological research observatory HAUSGARTEN in the Fram Strait. This area is influenced both by the East Greenland and the West Spitsbergen Currents. The observatory consists of 17 stations along an East-West transect (water depths from 1000 – 5500 m) and a latitudinal transect along the 2500 m depth line almost to 80°N, from the ice-free to the ice-covered zone. FRAM will consist of modular instruments and is planned to connect to the Norwegian underwater cable network. The technical visions include benthic crawlers - which collect sediment samples and transmit videos – modern sediment traps, different optical, hydrographical and acoustical measurement arrays as well as ecological experimental test fields and infrastructure.



Methane from the seabed

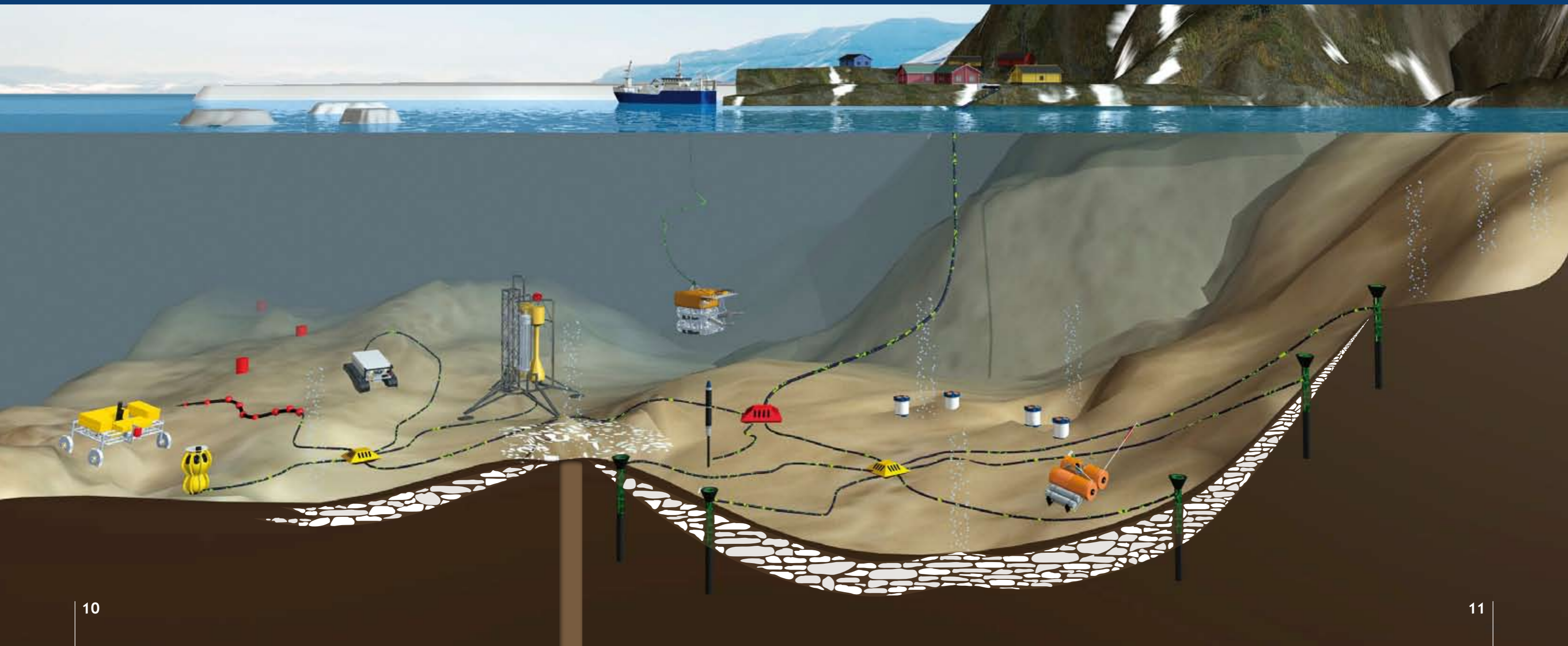
Large amounts of carbon are stored in the form of methane hydrates in the Arctic continental margins. Composed of methane and water, hydrates are only stable under high pressures and low temperatures. Because of ocean warming it is feared that a fraction of these hydrates might dissociate, releasing methane gas. Depending on the strength of the fluxes, the emitted methane could be utilized by microorganisms, or enter the atmosphere as highly effective greenhouse gas. Since methane hydrates act to stabilize the seabed, their dissociation could also lead to underwater slides. In the Fram Strait west of Spitsbergen first evidence was obtained that the process of hydrate decomposition has already started, as substantial gas leakage was observed at the upper continental slope. In order to determine the relationship between the distribution and dissociation of methane hydrates, changes in the ocean hydrography and other parameters, it is necessary to observe these complex systems continuously and on a long-term basis. Through interdisciplinary research enabled by sub-sea infrastructure and drill hole observatories (CORKS - Circulation Obviation Retrofit Kits), predictions can be made regarding the future development of methane hydrate dissociation and the consequences to be expected for benthic ecosystems, slope stability and atmospheric feedback mechanisms.

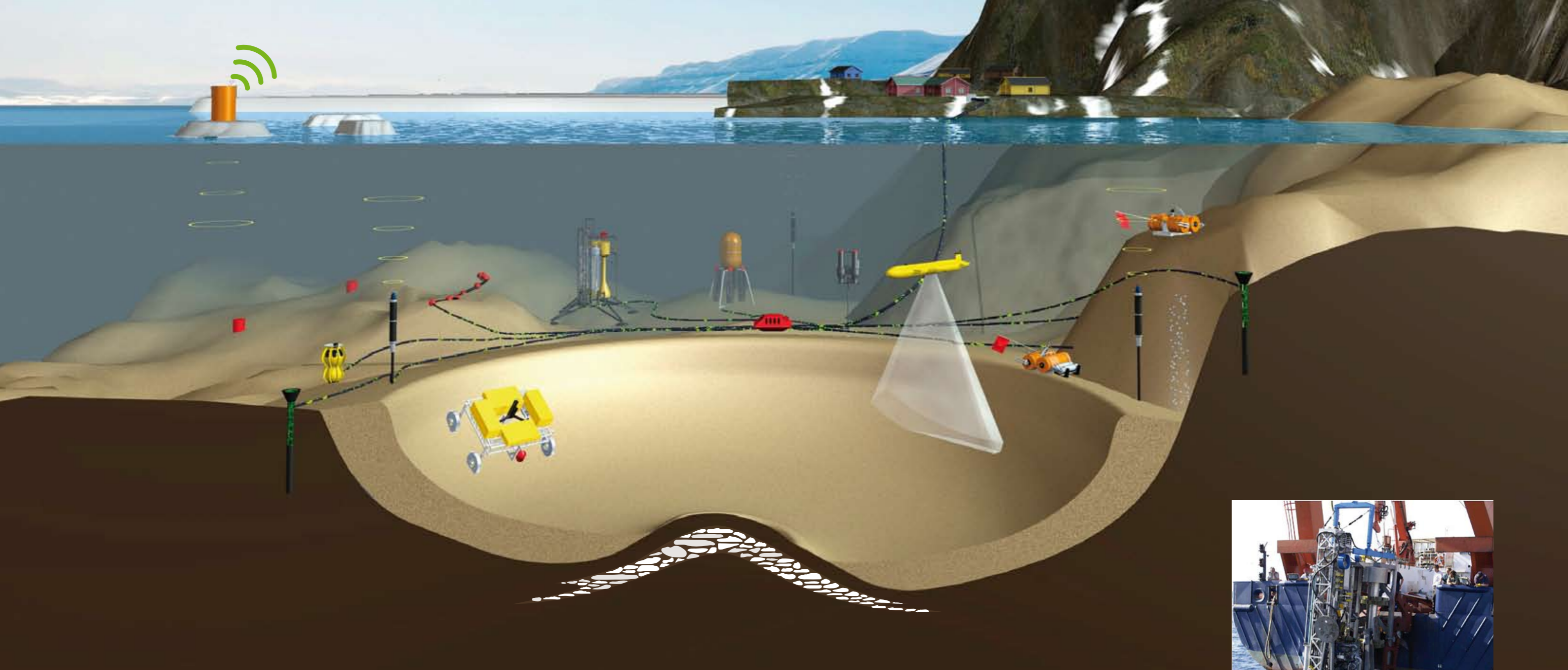
Scientific objectives

- Is methane hydrate dissociation proceeding and at what rate?
- How does the additional methane input affect the Arctic ecosystem?
- Does methane from hydrate dissociation get into the atmosphere and does this process affect the climate?
- Can sediment slides be triggered and what are the ecological and economical consequences?

Technical visions

Numerous gas leakages have been observed on the continental margin of Spitsbergen at the upper border of the methane hydrate stability zone. Here, a permanent observatory should be installed in addition to autonomous modular systems. The cable connection to the FRAM Observatory and the planned Norwegian deep-sea cable network would allow for continuous hydrographic data acquisition as well as the operation of hydro-acoustic bubble detector systems, seismometers and various geophysical and chemical sensors (methane, pH). Drill hole observatories (CORKS) should be implemented to detect changes in the shallow seabed down to a depth of 200 m.





Geodynamics and geohazards

Earthquakes and submarine sediment slides pose a great threat to populated coastal regions. Although there is a general understanding of the processes during an earthquake or a slide, observations of phenomena causing them are lacking. Only through long-term observations can these be identified, and their use for predictions be assessed. Land observatories have shown that earthquake prediction is difficult. In contrast, we see great potential for submarine observatories installed on potentially unstable slopes, in order to monitor their stability. A systematic monitoring of critical parameters (e.g. pore pressure, micro-seismicity and slope gradient) would be the first step in developing an efficient warning system for submarine slides. The continental margins of the North Atlantic and the Arctic Oceans must be observed, because dissociating gas hydrates caused by global warming could have a large influence on slope stability. Furthermore, since the last glacial maximum, the entire continental plate of Scandinavia is under relaxation and abundant micro-earthquakes have been recorded.

Scientific objectives

- How stable are the Arctic slopes? Will they be destabilized by internal changes in physical parameters (e.g. pore pressure) or by short-term external triggers?
- How do the geological controls and their indicators (pore pressure, slope gradient, fluid fluxes, and temperature) change over time?
- Does global warming have an influence on slope stability? Which processes trigger slope slides?
- Can we identify precursor phenomena (e.g. increase in pore pressure, creeping) for slope instability, which could be used for the development of efficient warning systems?

Technical visions

Much of the required sensor technology is already available, but needs to be modified for long-term operation on ocean observatories. The pore pressure is the primary parameter for the stability of slopes. In order to monitor critical layers over long periods of time, pore pressure sensors can be installed in drill holes. For this, existing sensors and drill hole instruments must be minimized in order to collect data efficiently with regard to time and cost. The drill hole measurements should be combined with a number of measurements at the seabed (e.g. slope gradient, bottom temperature and pressure). Modular observatories allow for flexible operation.

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