Ocean and marine ecosystems

<u>State-of-the-art and challenges</u>: The knowledge of physical and biological processes in the Arctic Ocean is limited, because the ice cover severely hampers observations, both in the upper layers and deep waters. There is a severe lack of *in situ* multidisciplinary, in particular biogeochemical data for the Arctic Ocean and significant patterns of the Arctic ecosystem are not currently well monitored. It is a pronounced technological and logistical challenge to improve the ocean component of iAOS.

Multidisciplinary *in situ* data in the Arctic Ocean are still collected mainly during icebreakers expeditions, aircraft surveys, or from manned drifting platforms. However, these activities are irregular in time, very expensive, biased to the summer season, and hence poorly suited for providing regular long-term monitoring data. Moorings have been deployed at key locations in the gateways and rims of the Arctic Ocean (Beszczynska-Möller et al., 2011; NABOS, http://research.iarc.uaf.edu/NABOS2/), but they mainly deliver physical parameters from fixed depths in delayed mode. Biogeochemical and profiling sensors for moored applications are still very limited, resulting in insufficient multi-disciplinary data. Only in the Fram Strait, the key region for Arctic-Atlantic exchanges, the multi-disciplinary observatory (Hausgarten/FRAM) has been implemented for long-term ecosystem monitoring (Soltwedel et al., 2005).

In the last decade, the Ice-Tethered Profilers (ITPs) significantly increased the number of high-quality upper-ocean observations available from the central Arctic (Toole et al., 2011). ITPs offer a platform that can carry a cluster of instruments with real time capability and recently the prototype bio-optical sensor suite was developed for ITPs for ecosystem monitoring (Laney et al., 2015). However, the ITP network is still sparse and covers only a limited ice-covered part of the Arctic Ocean. The Argo programme of oceanographic floats is the main ocean observing system for the global ocean (Riser et al., 2016) but Argo floats relay on surface access, therefore are not suitable for ice-covered Arctic regions. Only recently have the ice-capable RAFOS floats have been implemented (Klatt et al., 2007). Gliders have proven to be efficient for the upper ocean measurements in many parts of the world but as ARGO floats they need open water for data offload and positioning. Gliders and floats operating in ice-covered regions have to rely on underwater geo-positioning systems (GPS). Regional acoustic networks for acoustic thermometry, underwater GPS, and passive acoustic (Mikhalevsky et al. 2015) have been used in Fram Strait (UNDER-ICE project, H. Sagen), and in the Beaufort Sea (CANAPE project, P. Worcester). Gliders have been successfully operated under sea-ice in the Davis Strait (Lee et al., 2013) and were tested in Fram Strait (EU ACOBAR project). However, the under-ice navigation of gliders is still in the development stage and European gliders have not yet been proved in the Arctic environment.

The knowledge of the ecosystems of the more southerly parts of the Arctic, especially the Barents Sea (Sakshaug et al. 2009, Jakobsen and Ozhigin 2011), is at least the same level as for most temperate seas. In the Barents Sea there has been coordinated (Soviet) Russian and Norwegian biological research surveys for decades, some time series go back more than 100 years. The surveys have traditionally targeted fish species of high commercial value (cod, herring, capelin), but over the last decade one has developed also far broader cruises targeting ecosystem understanding. Advanced ecological and environmental reporting and management system is used for the Barents Sea to support sustainable exploitation of marine resources.

Most of the biological sampling, especially sub-surface, is still done from research vessels, the long distance from ports to the high Arctic ads to the costs and feasibility. Even baseline information regarding physical, chemical and biological conditions is generally lacking in the Arctic Ocean (Anon., 2011). Similar to physical observations, the main restriction to developing good Arctic biological observation systems is the ice cover. Consequently, there are large knowledge gaps concerning the presence, abundance and distribution of planktonic organisms, fish species, marine mammals and benthic organisms in the Arctic. Furthermore, very little is known about the production capacity at species level, hence also in an ecosystem context (Anon, 2011). The lack of understanding of how the ecosystem responds to the changes in the Arctic physical environment is a challenge (e.g. Wassmann, 2011).

<u>Expected progress beyond state-of-the-art:</u>

- Develop (or adapt to Arctic conditions) biogeochemical sensors and systems for measurements on moorings, bottom-installed systems and Ferryboxes.
- Implement multidisciplinary moored observatories with a full suite of biogeochemical measurements in the Arctic boundary current and across the shelf-deep ocean gradient to extent the existing network of moored arrays around the Arctic Ocean (NABOS in the Eurasian and Makarov Basin, ArcticNet in the Western Arctic).
- Upgrade the coastal ecosystem monitoring in the Baffin Bay, Disko Bay and Young Sound regions to a multi-disciplinary approach.
- Extend the ITP network in the Eurasian sector of the Arctic Ocean in collaboration with US, Chinese, Korean and Japanese programmes.
- Extend the global network of glider endurance lines with regularly repeated glider surveys in the ice-free areas in Fram Strait and the Nansen Basin.
- Provide baseline characteristics of the sound scape in the Arctic for future environmental assessments by passive acoustic data. Provide acoustic thermometry data to validate and constrain ice-ocean models.
- Advance ecological and environmental understanding by merging and synthesizing iAOS data through ecosystem modelling at the regional (Barents Sea) and local (areas off Greenland) scales
- Collect and make available biological and physical data from different platforms and databases.
- Validate the ecosystem models by means of physical and biological observations from the iAOS
- Generate higher-level, ecosystem specific model products towards targeting management and harvesting of living marine resources while protection of the Arctic environment (Arctic Council 2015)
- Adapt existing ecological and environmental reporting and management systems for use in the Arctic
- Demonstrate the usefulness of data integration through a sustained and optimized observing system to Norwegian and Greenland fisheries and environmental authorities.