INTAROS synthesis of gap analysis of the existing Arctic observing systems

Michael Tjernström (MISU), Roberta Pirazzini (FMI), Stein Sandven (NERSC) Hanne Sagen (NERSC), Torill Hamre (NERSC), Carsten Ludwigsen (DTU), Agnieszka Beszczynska-Möller (IOPAN), David Gustafsson (SMHI), Georg Heygster (UB), Mikael Sejr (AU), Andreas Ahlstrøm (GEUS), Francisco Navarro (UPM), Mathias Goeckede (MPG), Donatella Zona (USFD), Erik Buch (EUROGOOS), Mathilde Sorensen (UiB), Thomas Soltwedel (AWI), Finn Danielsen (NORDECO)

This document is the executive summary of the INTAROS deliverable that synthesizes a substantial assessment activity of Arctic observations within INTAROS and provides higher-level recommendations for future improvements of the Arctic observing system.

A comprehensive assessment of a substantial subset of Arctic observing systems, data collections and satellite products across scientific disciplines was carried out in INTAROS, also including data repositories and a brief scientific gap analysis. The assessments cover a multitude of aspects such as sustainability, including funding, technical maturity and data handling for the entire chain from observation to users, including metadata procedures and availability to data. The gap analysis includes both technical aspects, such as spatial and temporal cover and resolution or accuracy, and a smaller set of scientific gap analyses where models and observations were used synergistically. Community based environment monitoring programs were surveyed and assessed separately; they do not form part of the present assessment.

The assessed observing systems were first ranked according to general sustainability and other aspects, were analyzed subsequently. While the range of sustainability is large, it was found that high scores on all other aspects, such as for data handling and technical maturity, are more likely for systems with high sustainability. Moreover, many systems with high sustainability, as well as advanced systems for data handling and availability in place, resulted from national commitments to international monitoring or infrastructure programs, several of which are not necessarily particular to the Arctic.

For observations over Arctic land, the quality of some existing systems would benefit from being enhanced by new instruments or improved methods. Adequate observing of snow properties is problematic due to the high spatial variability of snow. While this also applies to hydrological observations, this situation is improving because of large overarching international projects. Observations of aerosols and some trace gases are also lacking in some specific regions. For the Arctic Ocean, there is a lack of in-situ observing capacity across all disciplines, which necessarily has to be based on or supported by ships (research vessels and/or icebreakers). For the ocean, under-ice observing is limited by lack of communication systems for data transfer in near-real time. This is for instance the case for Argos floats, gliders, moorings and sea-floor networks. In the atmosphere, icebreaker-based summertime science expeditions provide the only reliable information on atmospheric vertical structure. While scientific expeditions likely provide the highest quality observations available for the Arctic Ocean region, the scores for almost all other aspects including sustainability and data handling in general, and atmospheric observations in particular, are among the lowest.

Satellite observations provide the only possibility for a sufficient areal and temporal cover and resolution, due to the convergence of polar satellite orbital tracks on the poles. However, the nature of the method excludes observations below the ocean surface. Satellite products also typically score high on data handling aspects, although some products lack uncertainty and/or quality information. While retrieved temperature, and to a lesser extent, humidity at levels in the atmosphere is generally adequate for monitoring, satellite profiling of the atmosphere suffers from significant and seasonally varying biases. Passive satellite sensing of clouds is also problematic; while some bulk products, such as cloud fraction, are useful during the sunlit season, more precise information, such as liquid water path, has high uncertainty as indicated by comparing different retrievals from the same set of sensors. In the dark season, when visible radiation channels vanish, most cloud products from satellite observations are very unreliable. For sea-ice observations, extensive assessment have been done in other studies (e.g. Polar View, 2016).

Traditionally, observation network assessments build on the network concept with a "comprehensive" level including all observations, a "baseline" level of an agreed subset of sustained observations, and a "reference" level, with observations adhering to specific calibrations and traceability criteria. Examples from atmospheric observations are the "comprehensive" global GCOS radiosounding network, the "baseline" GUAN (GCOS Upper Air Network) and "reference" GRUAN (GCOS Reference Upper Air Network) networks. With the lack of in-situ observations especially from the Arctic Ocean and the logistical difficulties to deploy new stations, this concept does not work well in the Arctic.

In summary, we recommend that:

- *advancement in Arctic observing should be done in international global or regional programs with well-established routines and procedures, rather than to invest in new Arctic-specific programs*
- *investments in new instruments and techniques be done at already established sites, to benefit interdisciplinary studies and optimize infrastructure costs*
- *more observations be based on ships of opportunity and that a subset of ocean, sea-ice and atmosphere observations always be made on all research expeditions, regardless of their scientific aim*
- *the funding structures for science expeditions is reviewed to maintain, and preferably increase, the number of expeditions and to safeguard funding for appropriate data handling and storage*
- *observing-network concept for the Arctic Ocean is revised, so that coupled reanalyses represent the "comprehensive level", satellite observations complemented with available in-situ data is the "baseline level", while scientific expeditions is the "reference level". This requires substantial improvements in reanalysis, better numerical models and data assimilation, better satellite observations and improved data handling and accessibility for scientific expeditions.*

References:
Polar View (2016). Polaris: Next Generation Observing Systems for the Polar Regions. D2.1 Gaps and Impact Analysis Report, ESA, 180 pp.