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6	IOPAN		**29**	U Helsinki	
7	DTU		**30**	GFZ	
8	AU		**31**	ARMINES	
9	GEUS		**32**	IGPAN	
10	FMI	***0,5***	**33**	U SLASKI	
11	UNIS		**34**	BSC	
12	NORDECO		**35**	DNV GL	
13	SMHI		**36**	RIHMI-WDC	
14	USFD		**37**	NIERSC	
15	NUIM	***12***	**38**	WHOI	
16	IFREMER		**39**	SIO	
17	MPG		**40**	UAF	
18	EUROGOOS		**41**	U Laval	
19	EUROCEAN		**42**	ONC	
20	UPM		**43**	NMEFC	
21	UB		**44**	RADI	
22	UHAM		**45**	KOPRI	
23	NORCE		**46**	NIPR	
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DISSEMINATION LEVEL		
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CI	Classified, information as referred to in Commission Decision 2001/844/EC	

EXECUTIVE SUMMARY

The INTAROS project aims to improve access to and the quality of environmental measurements across the Arctic in a multi-disciplinary manner. One key aspect of this work is documentation and collation of information about status of existing observing systems. This work has been undertaken as part of Work Package 2: Exploitation of existing observing systems. The main effort has been to collect important metadata about each of the observing systems by many of the project partners as well as third parties using a standardised set of questionnaires. Questions asked included, but were not limited to, reflections on observing system management. The replies to the questions provide valuable indicators of the observing system maturity following approaches undertaken in the H2020 GAIA-CLIM project [Thorne et al., 2017].

The results of the questionnaires were presented in deliverables D2.1, D2.4 and D2.7, which provided detailed qualitative descriptors of each observing system, divided into atmospheric, ocean and terrestrial domains, without any overall synthesis. The present report aims to undertake such an assessment of in-situ observing system maturity across the domains. It first selects 40 observing systems following reconciliation of cross-thematic systems and removal of those systems that did not provide adequate information. It then takes a series of cross-sections through those observing systems contributed by WP2 to elucidate strengths and weaknesses of the selected systems relative to state-of-the-art practices.

In the context of the system of systems architecture espoused by the Global Climate Observing System, the selected in-situ networks were assessed according to the three-tier maturity classification: (1) reference, (2) baseline and (3) comprehensive observation system, which was used in the H2020 GAIA-CLIM project. This GCOS system recognises that a system-of-systems approach an appropriate mix all three types represents the optimal solution. The assessment showed that the vast majority of the observing systems were operating at baseline and comprehensive levels across all domains, but only two systems attain reference level, which requires the application of metrological and management best practices in all aspects. Additional reference quality measurements would be highly desirable to complement existing capabilities, and several observing systems that may in future attain reference quality status are identified.

It is clear that observing system maturity is intrinsically linked to the sustainability of support, both financial and expertise. Those observing systems that have sustainable support have better documentation, metadata, data management and uncertainty characterisation. Further work is required to ensure more sustainable support for Arctic observing programs in order to make observations more useable and widely available, in agreement with the FAIR principles [www.datafairport.org].

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1. Introduction

The rapid on-going changes in the Arctic present an urgent need to better observe, characterize and quantify processes and changes in a broad suite of oceanic, atmospheric, terrestrial and cryospheric components. Understanding and responding to these changes requires coordinated efforts by the global scientific community. The European Commission's Horizon 2020 program has funded several projects dedicated to the evaluation and consolidation of the observing capacities in the Arctic. These have been focussed on the assessment of different aspects such as, but not limited to: satellite sea ice and terrestrial cryosphere observations, biogeochemical observations including pollutants, existing infrastructures, and global (including the Arctic) in situ atmospheric observations (QA4ECV, GAIA-CLIM). Many of these activities are being continued and further developed under the present H2020 INTAROS project (2016-2021). Starting from the results and heritage of these antecedent projects, INTAROS aims to develop and promote an efficient integrated Arctic Observation System by extending, improving and unifying existing and evolving systems in the different regions of the Arctic and across the atmosphere, ocean and terrestrial domains.

The INTAROS project includes many partners who are either data producers or data providers (or both) for the ocean, the biosphere, the cryosphere, the atmosphere and the land surface. The data, which are acquired from many different platforms (research vessels, moorings, permanent stations, aircrafts, satellites etc), are of different processing levels and time spans, and are stored in a broad range of repositories (institutional, national or international). The first step undertaken by INTAROS toward the collation of selected data into an integrated Arctic Observing System was the assessment of strengths, weaknesses, and gaps of the existing observing systems with respect to various societal requirements. This assessment was based on the responses provided by INTAROS partners through an online survey (https://intaros.nersc.no/content/survey-existing-observing-systems-public-version). The survey was composed of three questionnaires, the first two addressed the in situ observations: one specifically addressed the sustainability, data management, and temporal/spatial coverage of the *in situ* observing systems, and the other addressed the characteristics of the data collections belonging to the observing systems, such as data uncertainty, resolution, metadata and documentation. The third questionnaire was relevant to the satellite products and also addressed all aspects covered by the other two questionnaires. Herein we restrict further consideration to solely the Arctic domain in-situ observing systems and their data collections using the results of the first two questionnaires.

In INTAROS, an in-situ observing system is defined to consist of a data collection component and a data management component. The data collection component is comprised of one or more sensors either belonging to a common fixed platform (which can be a single unit or a collection of units forming a network) or installed on a temporary moving platform. The assessment was separately done for the different domains and reported in the previous deliverables D2.1 (ocean and sea ice), D2.4 (atmosphere), and D2.7 (land and terrestrial cryosphere). For aspects around questionnaire design, recruitment of respondees, gaps in responses etc. these precursor deliverables together with D2.10 which accompanies the present deliverable should be referred to. The objective of this report is to provide a more holistic evaluation of the maturity of the surveyed in situ observing systems across all domains, on the basis of the maturity scores given by partners in the survey. The results detailed herein inform about the strengths and weaknesses of the Arctic data production and maintenance chain, evidencing areas where improvement would be especially beneficial. This report is complementary to the companion report D2.10 on the "Synthesis of gap analysis and exploitation of the existing Arctic observing systems". In D2.10, only a synthesis of the discussion on maturity scores is reported, and a general evaluation of the in situ and satellite-based data and observing infrastructures is done, to highlight their main gaps with respect to various societal needs and to provide recommendations on how to fill those gaps.

The remainder of this report is structured as follows:

- Section 2 outlines the methodology of maturity assessment applied and its heritage
- Section 3 provides a brief overview of the observing systems assessed and criteria for their selection / aggregation
- Section 4 summarises results for in-situ observing systems and their data collections
- Section 5 concludes by highlighting a number of key findings and future steps

2. Measurement system maturity assessment approach and limitations

The concept of assessing the maturity of climate records was first formally proposed by Bates and Privette [2012]. Their premise was that there exist process aspects such as documentation, metadata, data availability etc. which are (quasi-)objectively measurable and where higher quality attainment portend quality indicators around the value of the product to end-users. For example, better documented products will *a priori* be more accessible and useable than those for which documentation either does not exist or is inadequate.

Maturity assessment approaches have subsequently been further developed by several parties, arising a variety of presently employed processes to assess maturity [Peng, 2018]. Amongst these, the FP7 CORE-CLIMAX project developed a framework with the objective to provide guidance for producing and validating Essential Climate Variable data products with focus on quality control, accuracy and traceability of data. This maturity assessment evaluated the level of data description and documentation, software readiness, public data delivery and usage. It was successfully applied to a broad range of different types of datasets – satellite products, in situ observation-based products and reanalyses and across a number of domains. The approach was further developed under the Horizon 2020 GAIA-CLIM project to consider observational capabilities (as opposed to climate data records) and applied to the evaluation of the maturity level of global in situ atmospheric networks [Thorne et al., 2017]. The CORE-CLIMAX and GAIA-CLIM approaches share many commonalities but differ in important respects reflecting the fundamental distinctions between observing systems and derived data products.

The aim of the present deliverable within the INTAROS project is to apply a version of this pre-existing GAIA-CLIM observing system maturity assessment methodology to a broad variety of observation systems providing observations in the Arctic oceanic, atmospheric, and terrestrial domains. As noted in Thorne et al., 2017 and the GAIA-CLIM deliverable the maturity assessment criteria are designed to be flexible and should apply across thematic domains and be equally applicable to fixed and mobile observing systems. It is up to the assessors to agree *a priori* on the criteria to include and which aspects to weight most heavily in coming to a decision as to maturity of candidate observing systems. Furthermore, it is important to present and retain all assessed information as different aspects of the system maturity will be of greater or lesser import to given potential applications and thus to overly aggregate the information is to diminish utility.

Within INTAROS the pre-selection of what to assess was *de facto* undertaken as part of the questionnaire design, and led to the inclusion of 5 of the 7 overarching assessment categories proposed under GAIA-CLIM. The assessed categories are: 1) metadata, 2) documentation, 3) uncertainties characteristics, 4) data management, and 5) observing system sustainability. Such an approach permits the construction of a system maturity matrix (SMM) and an evaluation of the system capabilities both within each category and overall. The categories and sub-categories are presented in figure 2.1. The responses in each subcategory are ranked between 1 and 6 (sometimes 6 is not used), with the score reflecting the maturity of each aspect and higher values indicating greater maturity. The guidance provided for in situ and airborne observations questionnaire responders is summarised in ANNEX 1 and consists of modified guidance from GAIA-CLIM tailored appropriately to the challenges and specificities of observing in the Arctic domain.

Data management	Sustainability	Uncertainty	Metadata	Documentation
Storage	Scientific and expert support	Traceability	Standards	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to records		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

Figure 2.1. Assessed categories and subcategories and System Maturity Matrix structure for in situ observing systems, modified via category selection from that employed within GAIA-CLIM.

The Global Climate Observing System has advocated a tiered concept of comprehensive (CMP), baseline (BSL) and reference (REF) networks of observing systems, each of which meets a different subset of the needs for climate data [GCOS, 2015]. The concept was further developed via the maturity matrix under the GAIA-CLIM H2020 project [Thorne et al., 2017], and has been integrated into the WMO Integrated Observing System design principles [WMO, 2018]. This tiered concept underpins the present assessment. The tiers are characterised as follows:

- Reference observing systems provide metrologically traceable observations, with quantified uncertainty at a limited number of locations or for a limited number of observing platforms, for which traceability has been attained [GAIA-CLIM, D1.3].
- Baseline observing systems produce long-term records that are capable of characterising regional, hemispheric and global-scale features. They lack the absolute traceability of the reference observing systems.
- Comprehensive observing systems aim to characterise local and regional features with high spatio-temporal resolution.

The main characteristics of each maturity class are presented in figure 2.2. The rationale is that these distinct tiers, when integrated, act to support each other to constitute an integrated observing capability at the lowest possible overall cost [Seidel et al., 2009, Thorne et al., 2017, 2018] (Figure 2.3). That is to say that the optimal observing system configuration would consist of an appropriate mix of all three types of observations recognising not only that each is useful for distinct purposes, but that their value is maximised when they can be used in an integrated manner. Each assessment strand is assigned a score based upon the (quasi-)objective assessment criteria laid out in Thorne et al., 2017 and the GAIA-CLIM deliverable, with scores of 1-2 equating to comprehensive expectations; 3-4 baseline expectations; and 5-6 reference expectations.

REFERENCE	BASELINE	COMPREHENSIVE
-Measurements are fully traceable; - Standards are implemented on all steps; - Uncertainty budget is qualified and refers to each data point; - Full metadata allows a reprocessing; - Network management is sustainable.	-Periodical assessment of instruments and uncertainties; - Uncertainties are evaluated through an instrumental performance or literature; - Metadata and documentation trace all changes in protocols; - Observations have long-term commitment.	-Only initial documentation is available; - Uncertainty quantification is based on instrument or expert knowledge; - Long-term operation is not required.

Figure 2.2. The main characteristics of the reference, baseline and comprehensive observational systems.

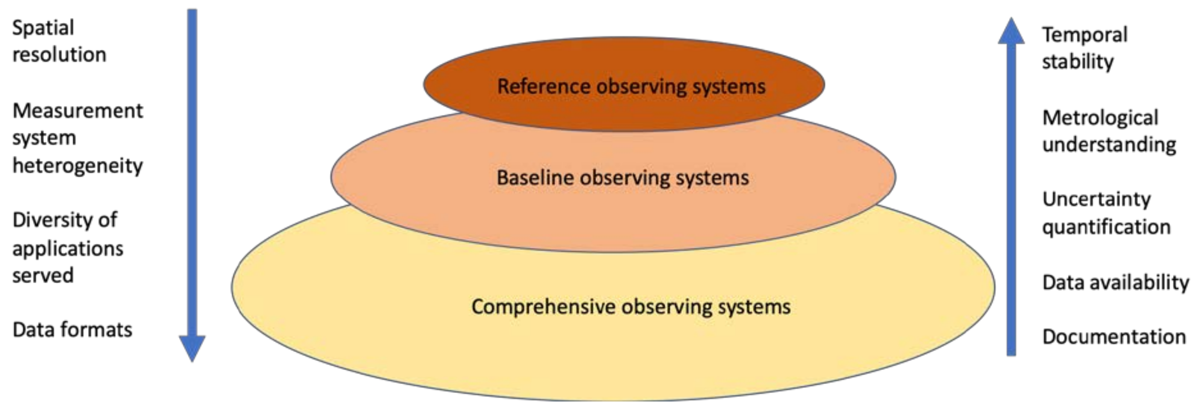

Figure 2.3. GCOS suggested structure of the observational systems based on maturity classification formalised by the H2020 GAIA-CLIM project. For each ECV ***all tiers*** *should be present if the observing system as a whole is to work effectively. Figure modified from Thorne et al., 2018.*

For the present analysis, for a given observing system there were potentially multiple responses for the metadata, documentation and uncertainty quantification categories which were collated at the data collection level via Questionnaire B, whereas there was only ever one response for the remaining categories collected via Questionnaire A. In such cases, the lowest score from the available responses was retained in a given category for the observing system aggregated scores. This assures equivalence of assessment and a conservative overall assessment. All such aggregated cases are analysed separately in Section 4.4. In reality there is a heterogeneity in the comprehensiveness of responses received. Even where multiple data collection surveys were returned these need not necessarily cover all data collections under the purview of the observing system. The retention of the lowest score in the observing system component of the assessment is deemed the most equitable solution given this heterogeneity.

To alleviate the risk of penalising an individual system for one or two low scores, the final maturity class assignment for a given observing system permits a small number of scores below the threshold. For example, a system is referred to as baseline class if the number of lower scores (scores 1 and 2) does not exceed 4.

To identify systems close to transition to a higher capability assignment, where with relatively little effort a substantial increment in capabilities may be achievable, two additional transitional classes named comprehensive-baseline and baseline-reference are used herein. If, for a given observing system, the number of scores in the next category is equal to or exceeds the number of assigned tier scores but not by a sufficient margin to make the full step up, the system is placed into such a transitional class. Strictly speaking, however, the systems in such transitional groups belong to the corresponding lower maturity class. The introduction of these transitional classes should be considered as an aid for identification of those systems with a good opportunity for maturity upgrade after rectifying identified weaknesses.

The challenges of assuring a robust assessment of the maturity level assignment based upon the single snapshot online survey and SMM tool have to be accounted for. Potential uncertainties can arise due to: inadequacies in the guidance; incomplete knowledge of the observing system assessors; and ambiguity in performance of the observing systems, amongst others. This issue has been well recognised in precursor projects. Within the GAIA-CLIM project a redundancy exercise involving five networks was performed [Thorne et al., 2017]. In this exercise several networks were assessed independently by several suitably qualified individuals to ascertain the degree of ambiguity in the final assessment. This exercise showed reasonable overall consistency in independently assigned maturity scores (+/-1). In several cases, however, the uncertainties within one sub-category were much larger. Nevertheless, they did not affect the attribution of maturity class for the network overall when an approach that allows for a number of categories falling below the threshold such as that applied here is used.

The robustness of the overall assessment of pan-Arctic observing system maturity is also related to how holistic it is in terms of considering the totality of available observing systems. While INTAROS partners have experience in a huge range of Arctic observing systems it is also true that not all known Arctic observing systems were covered by the questionnaire process. There are necessary assumptions required about the representativeness of the returned surveys to the state of the art in Arctic observing system programs and all facets of their management. Given the broad range of observing systems surveyed this is a reasonable assumption, but clearly it cannot be absolutely guaranteed that remaining observing systems challenges and strengths are in-line with those identified herein.

3. Summary of in-situ observing systems assessed

A detailed description of the individual data collections and observing systems assessed within INTAROS can be found in deliverables 2.1, 2.4 and 2.7 and is not repeated here. Annex 2 to the present deliverable includes brief information covering aspects of temporal and spatial coverage, data centre and observed variables as well as individual observing system scoresheets. As an intention of INTAROS is to inform iAOS (integrated Arctic Observation System) by extending, improving and unifying existing and evolving programs, the primary assessment of the present-day maturity was made at the level of observational systems.

To achieve this assessment required the aggregation and reconciliation of the results presented in prior deliverables. The following steps were undertaken:

1. Assembling the data collections belonging to one observing system (independently of observing platforms / domains) or to one observing program (e.g. in the case of the FRAM program run by the Alfred Wegener Institute) and consider responses for each such aggregation as a single observing system.

2. Removal of those observing systems that did not provide complete information about the state of their data collections (i.e. did not complete both questionnaires). Information was available on only two criteria (sustainability and data management) in the prior deliverables. These systems were excluded from the present analysis to avoid unwarranted heterogeneity in assessment.

These reconciliation activities led to a reduction in total observing system count from 56 considered in precursor reports to 40. It also led to the creation of a new cross-thematic category of observing systems that monitor across two or more domains and which, due to the nature of prior deliverables, were effectively redundantly described two or more times.

Assessed systems as well as their short names used in the present deliverable are presented in the table 3.1 and in Annex 2. The observing systems are highly heterogeneous in terms of their objectives, design and data acquisition platforms. They range from fixed-point observations (terrestrial stations, mooring platforms, etc), through observations from moving platforms (research/commercial vessels, aircrafts or gliders). They provide measurements of oceanic, atmospheric, terrestrial and cryospheric parameters in many parts of the Arctic. Temporal coverage varies significantly: from short campaigns to continuous long-term records of over 200 years, from high frequency repeat observations (hours or minutes) all year round to seasonal and “occasional” repeat measurements. The information about the systems is provided either by the data producers or by the data providers. Observing systems can be thematic or focused (confined to a specific theme or discipline) or cross-thematic. The latter observe various parameters in different domains and unified either by common objectives and programs (ex.: Greenland Ecosystem Survey) or observing infrastructure (ex.: IMR Research Vessel).

Table 3.1 Main portfolio of assessed observing systems separated by observing domain and their abbreviation

	Name of Observing system	Short name
OCEAN AND SEA ICE	A-TWAIN	A-TWAIN
	A-TWAIN Poland (Polish contribution to the A-TWAIN moored array)	A-TWAIN PL
	Long-term large-scale monitoring program AREX	AREX
	ArgoPoland	ArgoPoland
	European Gliding observatories	EGO gliders
	FRontiers in Arctic marine Monitoring	FRAM
	Fram Strait Multipurpose Acoustic System	Fram MAS
	Global Sea Level Observing System - Greenland	GLOSS-Greenland
	IMR Barents Sea Opening mooring array	IMR BSOMA
	IMR fixed hydrographic sections	IMR FHS
	IMR Fixed hydrographic (near coastal) station network	IMR FHScoast
	IMR SI_Arctic vessel mounted ADCP system	IMR SI
	NorArgo	NorArgo
	R/V Håkon Mosby	R/V HåkonMosby
ATMOSPHERE	AC-AHC2 stable water isotope measurement stations	AC-AHC2
	Aerosol, Clouds and Trace Gases Research Infrastructure	ACTRIS
	Atmospheric ship-based field campaigns ASCOS, ACSE, N-ICE2015, Polarstern cruises.	Atmospheric ship-based campaigns
	Global Atmosphere Watch - Aerosols	GAW-Aerosols
	Global Climate Observing System (GCOS) Reference Upper Air Network	GRUAN
	Radiosounding network in the Arctic (AMAP and IGRA)	RNA
	Regional GAW – Aerosol	Regional GAW
	WMO Global Observing System meteorological holdings	GOS met
LAND AND TERRESTIAL CRYOSPHERE	Arctic-HYCOS	Arctic-HYCOS
	Fluxnet	Fluxnet
	Glacier Thickness Database	GlaThiDa
	GLISN network Greenland	GLISN
	GNET - GPS networks	GNET
	Norwegian National Seismic Network	NNSN
	Randolph Glacier Inventory	RGI
	World Glacier Monitoring Service-Fluctuations of Glaciers Database	FoG
MULTI-DISCIPLINARY	Airborne observations of surface-atmosphere fluxes	AIRMETH
	Greenland Ecosystem Monitoring program	GEMP
	Hornsund Station	Hornsund
	IMR Barents Sea Winter Survey	IMR BSWS
	IMR-PINRO Ecosystem Survey	IMR-PINRO ES
	NIVA Barents Sea Ferry Box	NIVA BSFB
	Pan-Eurasian Experiment	PEEX
	Program for Monitoring of the Greenland Ice Sheet	PROMICE
	Sodankylä station	Sodankylä
	Tower network for atmospheric trace gas mixing-ratio monitoring	Gas-Mix TN

Observing systems vary enormously in their heritage across all domains (figure 3.1). Across all domains, and also in the cross-domain category there are a few long-term (50-year+) observing systems and then a large number of shorter-term programs that have generally been instigated in the latter part of the twentieth Century or even in the earliest years of the present Century. This proliferation of recent additions may simply reflect a desire to snapshot currently in existence capabilities and not portend a sustained increase in our ability to collectively monitor changes in the Arctic environment. Efforts to better snapshot ceased capabilities may be valuable in future.

Oceanic observing systems overall have the shortest lifetime. However, the survey excluded the ICOADS collection of ship observations [Freeman et al., 2017] and early whaling logs which would both constitute records starting the 18th or 19th Centuries. For assessed systems, the two IMR observing programs start in the early-to-mid nineteenth Century. Most remaining assessed observing systems are much more recent and contain a large number of seasonal campaign based programs. The atmospheric observing systems include the Global Observing System surface and radiosonde observing systems which while long-lived as entities have changed substantively in coverage through time. There are then, again, a large number of more recent additions. Several terrestrial domain observing programs extend back to the late nineteenth / early 20th Century period. There are fewer recent additions than for remaining domains. Finally, the cross-thematic observing systems tend to be more recent additions with only one extending back prior to the middle of the twentieth Century.

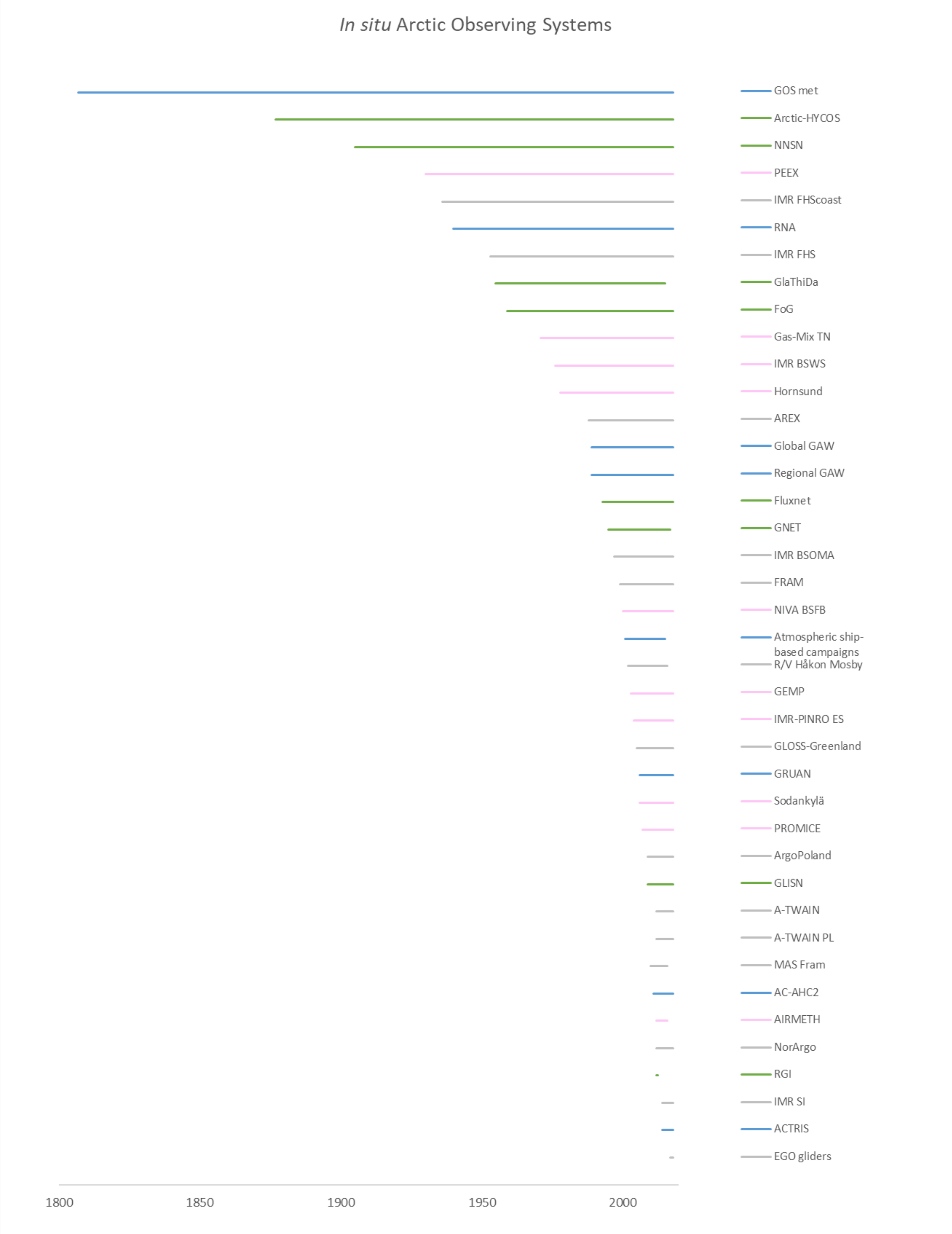

Figure 3.1. Temporal duration of ocean (grey), atmospheric (blue), terrestrial (green) and multi-disciplinary (pink) in-situ observing systems being assessed. Short-names are given in Table 3.1.

4. Maturity assessment of observing systems of the INTAROS collection

4.1 Over-arching assessment across all observing systems

An overall summary is given in Table 4.1. The majority of the assessed observing systems (72%) belong to the comprehensive class of observations systems having low scores in a substantial number of the assessment strands being evaluated (final column in Table 4.1). There are nine baseline observing systems making up a further 23% of the total systems assessed. There are only two reference level observing systems; one each in the atmospheric and terrestrial domains respectively. Recall that our classification assigning procedure is based on conservative criteria in cases where multiple data collections were associated with a single observing system (Section 2). Table 4.2 presents a summary of observing systems' maturity by domain.

All baseline-assessed systems have several low scores of 1 and 2 indicative of comprehensive status operations in some aspects of their operation. They should plan an amelioration in these subcategories. Availability of user feedback mechanisms, validation reports and provision of robust data version control procedures are the most frequent shortcomings identified in these observing systems. They constitute documentation aspects, which highlight post-processing issues and should be feasible to address both without undue delay and at relatively low cost. If amelioration is not feasible in the near future, all 7 observing systems classified as baseline should strictly speaking be considered as transitional from comprehensive to baseline.

Equally, several observing systems from the transitional comprehensive-baseline class (e.g. FRAM, PROMICE land program etc) could be upgraded relatively easily, as they have sustainable scientific and funding supports and have already advanced key practices in the uncertainty category. These systems should be encouraged to review their practices in the near future with a view to being promoted to full baseline network status. The efforts would generally have to include revision of uncertainty aspects as well as significant work on aspects of documentation (measurement methodology/standards, validation activities and series user guidance). In addition, the user feedback collection is reported to be a common weakness for the majority of these transitional observing systems. A decision on feasibility of a network maturity upgrade is dependent upon what aspects require attention. For instance, without sustainable expert and funding support, the evolution of a network to higher level on a sustained basis will be challenging. On the other hand knowledge of its maturity may encourage investment decisions to instigate longer-term support.

Table 4.1. Maturity scores of in situ observing systems (grey colour - oceanic systems; blue colour - atmospheric systems; green colour - terrestrial systems; pink colour - multi-disciplinary systems in left hand column). For observing systems with multiple data collection responses the lowest scores have been used in the metadata, documentation and uncertainties categories (see Section 2). Darker colours in the maturity assessment columns denote more mature systems.

	METADATA			DOCUMENTATION			UNCERTAINTIES						DATA MANAGEMENT						SUSTAINABILITY			
Name of Observing system	Standards	Collection Level	File Level	Description	Validation Report	Series User Guidance	Traceability	Comparability	Standards	Validation	Quantification	Quality Management	Storage	Access	User feedback	Updated to record	Version control	Preservation	Expert support	Funding support	Site representativeness	MATURITY CLASS
*A-TWAIN	1	2	4	1	2	2	2	2	na	na	2	3	2	6	1	2	2	4	5	3	na	CMP
*A-TWAIN PL	3	3	3	3	3	2	3	2	na	na	3	4	3	5	2	2	2	2	4	3	na	CMP-BSL
*AREX	4	3	3	3	2	2	4	3	na	na	4	2	6	5	2	3	2	3	4	4	na	CMP
ArgoPoland	4	3	4	2	3	2	5	4	na	na	2	4	6	6	1	3	4	4	4	3	na	BSL
EGO gliders	5	4	5	2	2	2	2	4	na	na	2	4	6	5	3	3	3	4	3	4	na	CMP-BSL
*FRAM	5	2	3	1	1	1	6	6	2	1	2	1	6	5	2	4	4	4	6	5	na	CMP-BSL
IMR BSOMA	1	2	3	2	2	2	2	1	2	2	2	3	4	3	2	2	1	4	5	4	na	CMP
IMR FHS	3	3	3	2	2	3	2	2	na	na	2	2	4	5	2	4	1	4	5	5	na	CMP-BSL
IMR FHScoast	3	2	3	4	1	2	2	2	na	na	1	1	4	4	2	na	1	4	4	5	na	CMP
IMR SI	na	2	2	3	2	4	2	2	na	na	2	2	2	3	2	3	1	3	4	3	na	CMP
GLOSS-Greenland	3	1	na	1	2	2	2	2	1	1	1	5	4	3	2	2	2	3	3	3	3	CMP
R/V Håkon Mosby	4	3	4	na	na	na	na	na	na	na	na	na	3	4	2	3	2	3	5	5	na	na
*Fram MAS	1	2	3	1	1	1	1	1	2	1	1	1	2	2	1	2	2	3	3	2	na	CMP
NorArgo	1	3	4	3	2	3	2	2	na	na	3	3	6	6	5	4	na	5	6	3	na	BSL
AC-AHC2	na	na	na	2	2	1	2	2	2	1	2	1	2	2	2	2	2	3	1	1	1	CMP
*RNA	3	3	4	1	2	2	5	2	na	na	3	5	6	5	1	6	3	5	3	5	na	CMP-BSL
*GAW	4	2	2	3	2	2	2	2	na	na	2	1	6	5	2	2	2	5	5	5	4	CMP
*Regional GAW	4	3	2	3	2	2	2	2	na	na	2	1	6	5	2	2	2	5	5	5	4	CMP
*ACTRIS	4	5	5	4	2	3	5	5	na	na	5	5	6	5	5	5	2	5	6	6	4	BSL
GRUAN	5	5	5	6	5	6	6	5	6	6	6	5	6	6	5	5	5	5	5	6	5	REF
GOS met	1	5	4	1	2	3	2	2	3	1	1	4	6	6	5	4	4	5	3	5	1	CMP-BSL
*Atmospheric ship-based campaigns	1	2	2	1	1	1	1	1	1	1	1	1	2	3	2	2	2	4	1	1	na	CMP
Fluxnet	1	3	3	3	3	3	2	2	3	2	2	2	4	3	1	3	3	4	1	2	3	CMP-BSL
*World Glacier Monitoring Service-Fluctuations of Glaciers Database	5	3	3	3	2	3	na	na	3	3	3	3	6	6	3	3	5	5	5	6	3	BSL
Glacier Thickness Database	4	3	3	3	2	3	na	na	3	3	3	3	6	6	3	3	5	5	5	6	3	BSL
GLISN network Greenland	6	6	6	6	6	6	5	5	6	3	3	6	6	6	3	3	3	6	6	3	6	BSL-REF
*Norwegian National Seismic Network	6	6	5	6	4	5	6	6	na	na	6	5	6	6	2	1	1	5	6	6	5	BSL-REF
GNET - GPS networks	5	5	5	6	5	5	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	REF
Randolph Glacier Inventory	4	3	3	3	2	3	na	na	3	3	3	3	6	6	6	3	5	5	5	6	3	BSL
Arctic-HYCOS	5	2	5	1	1	2	4	3	na	na	2	4	5	5	1	4	4	4	5	5	5	CMP-BSL
*Greenland Ecosystem Monitoring program	1	2	1	1	1	1	1	1	1	1	1	1	2	4	2	2	2	3	5	6	na	CMP
IMR Barents Sea Winter Survey	1	2	2	1	1	1	1	1	1	1	1	1	3	3	1	2	1	3	1	6	na	CMP
*IMR-PINRO Ecosystem Survey	1	2	2	1	1	1	2	2	1	1	1	1	2	3	2	2	1	4	1	6	na	CMP
*NIVA Barents Sea FerryBox	3	3	3	3	2	4	1	3	na	na	2	3	1	3	2	2	2	3	6	4	na	CMP-BSL
Pan-Eurasian Experiment	4	3	3	2	2	2	2	2	1	1	2	1	2	2	2	2	2	4	3	5	3	CMP
*Sodankylä station	1	3	3	1	2	2	2	2	na	na	2	1	2	5	2	4	2	3	6	6	4	CMP
*Airborne observations of surface-atmosphere fluxes	1	2	4	1	1	1	2	3	1	2	2	2	2	2	2	na	2	4	4	4	5	CMP
*PROMICE automatic weather station network	1	3	5	4	1	3	1	1	1	2	2	3	5	6	2	6	5	5	6	6	4	CMP-BSL
*Hornsund Station	5	3	3	2	1	2	1	1	2	1	1	1	4	3	2	2	2	4	4	5	3	CMP
Tower network for atmospheric trace gas mixing-ratio monitoring	4	4	3	3	3	3	6	6	6	6	6	5	2	2	2	3	4	4	3	3	3	BSL

* - Observing systems provided evaluation for multiple data collections. See for details Section 4.4.

Table 4.2. Distribution of observing systems by maturity classes following the synthesis presented in Table 4.1.

Class	Total	Oceanic	Atmospheric	Terrestrial	Multi-disciplinary
Comprehensive	**18**	**7**	**3**	**0**	**8**
Comprehensive-Baseline	**11**	**4**	**4**	**2**	**1**
Baseline	**7**	**2**	**1**	**4**	**0**
Baseline-Reference	**1**	**0**	**0**	**1**	**0**
Reference	**2**	**0**	**1**	**1**	**0**

4.2 Assessment of observing systems by individual assessment strands

4.2.1 Sustainability

Sustainability of the observing systems is evaluated via three criteria: availability of expert support, funding stability, and site representativeness (the latter assessed for fixed observational assets only). Sustainability was assessed in Questionnaire A and so there is only one set of responses per observing system. Considering the maturity class for the first two subcategories for which almost all observing systems were assessed, 55% of the responses indicate the highest level of achievable maturity, e.g. sustained continuous operational funding and scientific expert support including development capacities (Figure 4.1). A further 34% of the answers refer to baseline level scores of 3 or 4 in these categories, meaning that these observing systems have established measurement infrastructures, protocols and expert support, but they have been funded on "project-to-project" basis without guaranteed long-term continuity. The balance of observing systems, an alarmingly large number, have very real immediate risk of funding continuity.

The project-to-project or uncertain funding support for almost half of the surveyed observing systems significantly handicaps the continuity in data management and in sustained development of instrument characterisation and resulting quantification of data uncertainties, and can introduce a gap in the observational series. Sustained support is necessary to ensure a sustainable constellation of Arctic observational capabilities from in-situ measurements moving forwards.

Site representativeness is only applicable to observing systems with fixed observational assets and so answers are available only for a subset of primarily atmospheric and terrestrial observing systems. Representativeness is key if oftentimes sparse observations are going to be used to infer broader implications of Arctic change. The preponderance of scores at baseline capability suggests that improvements to representativeness of the observing systems may be possible in some cases.

Equally, it may reflect real trade-offs between logistic constraints, costs, land rights and other aspects which all play a role in siting considerations.

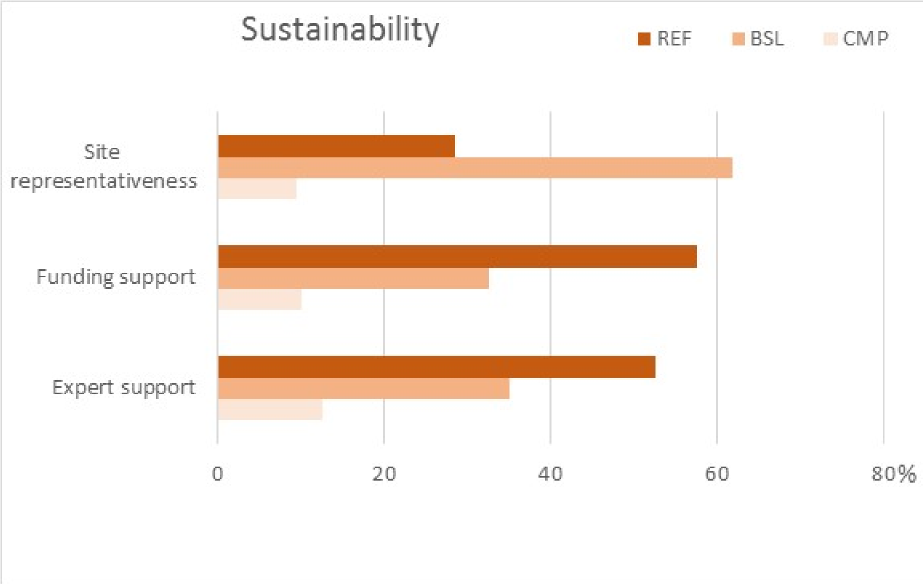

Figure 4.1. Percentage distribution of the answers by maturity class in the sustainability category. Note that site representativeness answers were only provided for fixed observational assets. The scores are divided into: Ref (5-6), BSL (3-4) and CMP (1-2) and correspond to the collated responses shown in Table 4.1. It is the collated scores in Table 4.1 that determine the ultimate designation of each contributing observing system assessed.

4.2.2 Data Management

Evaluation of the maturity of the data management practices is based on five criteria: storage, access and preservation practices, frequency of data updates, control of version of data products, software or documents, as well as collection and consideration of user feedback (Figure 4.2). Data management was assessed via Questionnaire A and so there is only one set of responses per observing system.

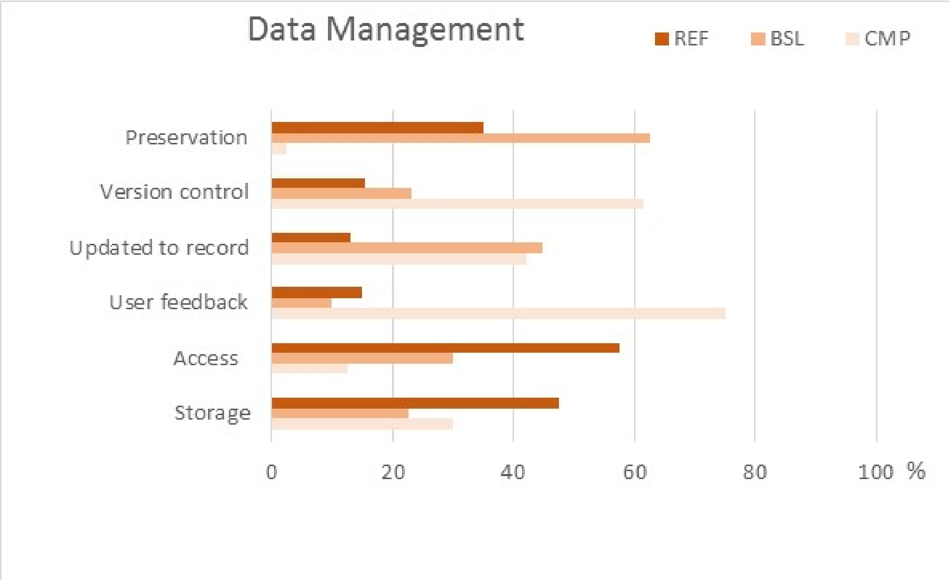

Figure 4.2. Distribution of the answers by maturity class in the data management category. See Figure 4.1 for further details of interpretation.

Twenty one (53 %) of the submitted observing systems have adopted the highest maturity level state-of-the-art practices for both data storage and data access. They provide unrestricted access and store data in nationally and internationally recognised repositories. While most observing systems also apply the same advanced management practices to archived raw data/versions/metadata necessary to understand and reprocess data, some prefer to preserve the archives for raw data at the local institutional level. This leaves the fundamental data holdings prone to a potential single point of failure and efforts should be made to ameliorate this as it is these fundamental data rather than derived products that have the longest-term value. Work within INTAROS under WP5 may be able to contribute to improving this issue for some of these observing systems where the coordinating body is able to muster resources to provide access to the system's raw data.

Version control has generally not been considered as an important issue in data management practices by most of the observing systems being assessed. Only six observing systems have established full version control protocols, considering all aspects necessary for users to be able to appropriately cite and retrieve particular versions of the holdings. Nine more systems perform some form of version control at an institutional level. Seven systems did not develop version control of data collections at all. Some of these may simply be because there has only ever been one version and thus denoting versions has never been required, but experience suggests there will be collections that have incremented versions but have not documented this. In the remaining 17 observing systems, representing 44% of the total, the version control is made by data collectors themselves without any formalised process. Version control is key to allow strict replicability and a strict version control is preferable. Version control is a low cost and low overhead activity that could be formalised quickly.

The frequency of the record updates is strongly related to the observing system objectives and design. In the Arctic context many of the observations are periodic campaign data given the harsh nature of the observing environment. For such systems there is a cap to the score attainable in this category as higher scores allude to operational data receipt, which is not applicable. Regular updates are expected by nature only from systems established for operational purposes and in place on a continuous basis. Those systems (with the highest 5 and 6 scores in corresponding subcategory) arise almost exclusively among atmospheric and terrestrial observational systems that are generally undertaken at fixed locations. Two of them (PROMICE and RNA) update the data in near-real time. Four systems have more delay, which still corresponds to operational requirements. About 66% of systems update the data irregularly (many of these are campaign based observing systems) and one system indicated an absence of data updates (presumably because it is a static record). If data are to be used in decision support it is often, but not always, vital to provide data in a timely manner.

The collection and consideration of the user feedback is the weakest part of the data management plans for the majority of observing systems included in the INTAROS survey. Only six observing systems (15%) have established high maturity level feedback mechanisms with routine analyses and assessment of the results of the feedback. Four more systems collect such feedback systematically but have no formal process as to how to process and respond to such feedback. All remaining systems (about 74%) receive any user feedback at best on an *ad hoc* basis with no formal mechanisms in place. The user feedback is important to developers and measurement providers as it permits improving the quality and accessibility of the data.

4.2.3 Uncertainty characterisation

Robust uncertainty characterisation is essential if data is to be used appropriately. All measurements are imperfect, and in challenging environments such as the Arctic this is amplified. It is critical to understand and quantify this uncertainty to ensure appropriate usage of the observations. The internationally accepted nomenclature and practices for uncertainty characterisation have been established and described in the Guide to Uncertainties in Measurements [JGCM, 2017]. In the INTAROS survey the maturity of the systems in regard to uncertainty characterisation has been evaluated through six subcategories: measurement traceability, measurement comparability (both applied only to an initial measurement), product/data series standards consideration and product validation (both applied to data derived from initial measurements), uncertainties quantification and routine quality monitoring. These were assessed at the data collection level via Questionnaire B so for several observing systems multiple assessments were undertaken. In general, the systems consistently reporting the highest scores in these strands of uncertainty category have also adopted advanced practices in many other categories (data management, metadata or documentation). This is unsurprising because full quantification of uncertainty requires documentation and understanding of all facets of the measurement series and such well-resourced observing systems will in general take care of all facets of data management.

Complete measurement traceability, characterised by established regular calibration and quantification of data processing chains, required for reference quality measurements, was reported only by 5 observing systems (figure 4.3). Three other observing systems make inter-comparison with primary or secondary measurement standards regularly, but have not yet quantified the uncertainty arising from all processing steps. Seven systems have not considered calibration at all for certain data collections, and the remaining 24 (or 61%) of systems make the comparison to standards irregularly. The vast majority of systems thus attain only comprehensive measurement standards in regard to attaining measurement traceability.

Comparability refers to the ability to strictly compare as equivalent two or more separate measurements arising as contributions to a given observing system. Differences between instruments measuring nominally the same measurand should be regularly quantified. The situation regarding comparability is very similar to that described for traceability with relatively few reference and baseline quality systems and most being comprehensive. Overall, a few more systems attain baseline status or higher in this category than in traceability.

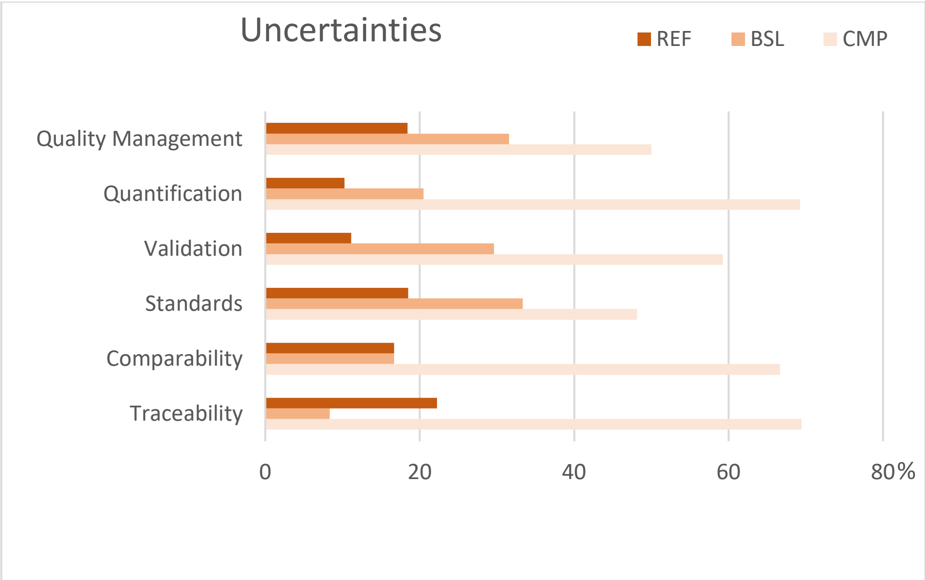

Figure 4.3. Distribution of the answers by maturity class in uncertainties category. See Figure 4.1 for further details of interpretation.

The status of independent verification of derived data products is evaluated via the standards and validation subcategories. Only three of the 26 systems providing derived products make inter-comparison of the data regularly and have participated in international inter-comparison campaigns, steps required to attain the highest maturity level. Eight other systems validated their products for limited locations and/or for limited time. Eleven observing systems did not consider aspects around validation, although five of them have at least defined or even implemented standardised uncertainty nomenclature.

Among those observing systems with the highest maturity levels for traceability and comparability of their measurements, only four attain the reference level of uncertainties quantification with all identified systematic effects removed from the data. Eight more systems provide comprehensive information on uncertainties, but for half of them these uncertainties lack absolute traceability, corresponding to baseline maturity requirements. Nine systems do not quantify the errors and a further 43% account the uncertainties inadequately from a metrological viewpoint, only grossly attempting to quantify issues arising from systematic or random effects. Thus, the vast majority of observing systems attain only comprehensive measurements status for the quantification of measurement uncertainty.

Implementation of a routine quality monitoring procedure is undertaken by 42% of the surveyed observing systems. Seven (or 19%) of these implement the routine at all production levels, consistent with reference network practices. Twelve others (or 33%) have defined or already partly implemented such routines, consistent with baseline operations. However, many observing systems still do not permanently monitor the quality of the provided data and thus attain only comprehensive status in this respect. Routine quality monitoring is key in identifying data issues early and thus rectifying issues quickly. To realise the value of any measurement program it is highly advisable to instigate and maintain routine quality monitoring such as to minimise the periods with erroneous data receipt.

Overall, the uncertainty maturity is a challenge across the board for very many of the observing systems assessed with a clear majority evaluated as meeting only comprehensive category performance in all aspects. Given that no measurements are perfect this lack of attention to rigorous quantification, verification and presentation of uncertainty estimates is a clear challenge to observing systems in the Arctic domain that requires attention if we are to properly quantify and understand environmental changes in the region.

4.2.4. Metadata

Metadata is a key element of data collections facilitating data discovery and data interpretation many years hence. Metadata has been assessed at the data collection level so several assessments may have been performed per observing system. Metadata should follow one or more recognised standards to ensure maximum usefulness. At the moment no universal standard for earth observational data exists, although substantive efforts towards standardisation of metadata have recently been made by WMO during implementation of Integrated Global Observing System (WIGOS). This standard is documented in WIGOS Metadata Standard manual (2017). It is one emerging class of metadata schemas compatible with the ISO-19115 standard. An overview of the content and structure of the WIGOS standard metadata structure is presented in figure 4.4. It includes attributes applied to entire data series (processing methods, ownership, contacts) and to measurements themselves (time, location, units, ambient conditions etc). The first type of metadata corresponds to the collection level strand in the INTAROS survey, while the second refers to the file level strand.

Figure 4.4. Standard WIGOS metadata content [WIGOS, 2017].

Almost all observing systems provide metadata on both collection and file level (Figure 4.5). More than 66% of INTAROS surveyed observing systems have at a minimum identified a metadata standard to employ. Several observing systems have already implemented them to the highest maturity level (29 % for data files and 19 % for data collections). Many systems (> 50%) provide a description or metadata with details considered to be enough for data understanding and usage, according these systems a baseline level of metadata management. Availability of metadata of only incipient level allowing very basic but incomplete information to be discovered was reported by 33 % and by 18 % of systems (for data collections and for data file level respectively).

Metadata is an area where for relatively small effort substantive increases in network maturity could accrue for a large number of observing systems considered by INTAROS. These metadata can assure accessibility and usability of the data collections in the long-term and their retention in a standardised manner should be strongly encouraged.

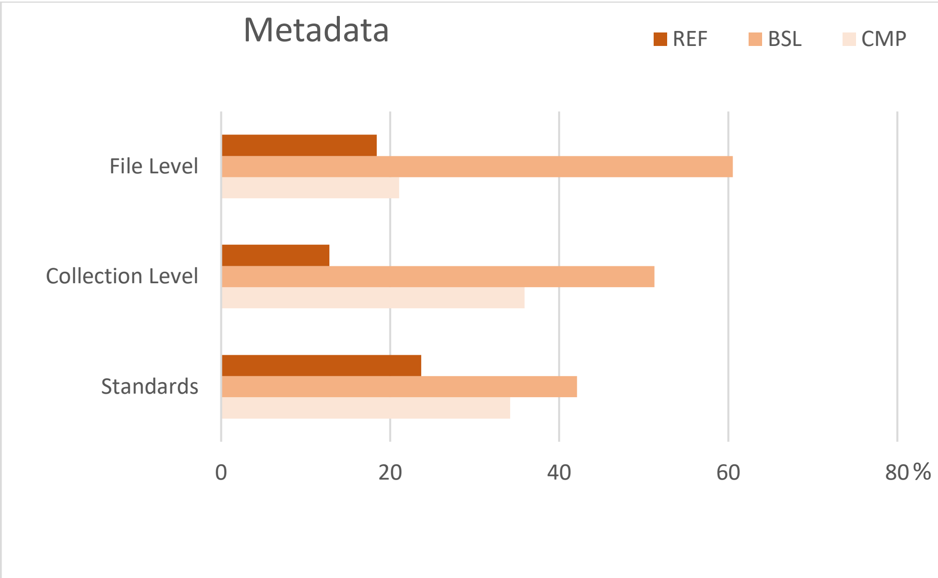

Figure 4.5. Distribution of the answers by maturity class in metadata category. See Figure 4.1 for further details of interpretation.

4.2.5. Documentation

Documentation accompanies the data collections and, if the observing system is to attain state-of-the-art should cover at least three aspects: i) a formal description of measurement methodology; ii) a formal validation report; and iii) formal measurement series user guidance. Only three observing systems were assessed to have attained the highest maturity level of documentation for all data collections amongst all three subcategories (including formal periodical update of the documentation and its publication, Figure 4.6). Several observing systems also reported on the existence of journal publications describing the physical/methodological basis of measurements, raw data processing etc. (4 observing systems) or results of validation activities (1 system) for all data collections covered by the assessment. Thirteen assessed observing systems either do not provide reports or limit the description/validation reports to only selected data collections. More than half of the observing systems do not provide sufficient documentation to allow for robust understanding and usage of the data and thus fall into the comprehensive network capability category.

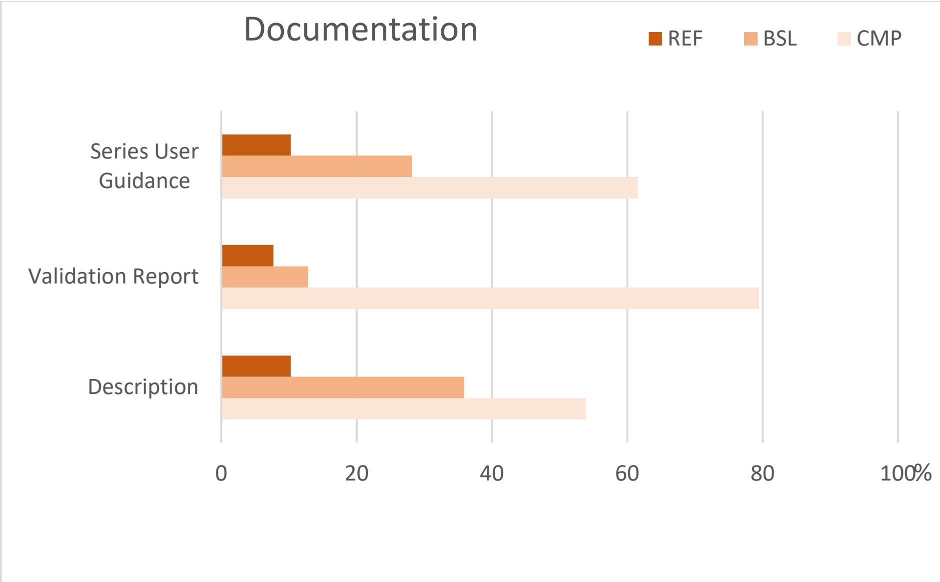

Figure 4.6. Distribution of the answers by maturity class in documentation category. See Figure 4.1 for further details of interpretation.

4.3 Synthesis of observing system strengths / weaknesses by domain.

Another informative way to look at the results rather than by maturity assessment strand is by scanning across each domain. This elucidates strengths, weaknesses and challenges that pervade each domain and others that are peculiar to a specific domain. This may, in turn, point to community-wide issues and practical steps, which can lead to improvements in future. It may also help identify areas where best practices could be shared between these diverse observational domains and communities, which is a key aspiration of the INTAROS project. The results are summarised in Figure 4.7 and analysed per domain as follows:

Terrestrial observing systems. The strongest attribute of the terrestrial systems is their high sustainability. More than half of the terrestrial observing systems included in the assessment belong to national operational systems or are a part of long-term national research programs with corresponding long-term funding and expert support. This solid long-term basis appears to have allowed many of the terrestrial observing systems to make significant progress in all other categories, and especially so in data management. Many of them have already implemented advanced practices in uncertainties characterisation. They have also recognised the importance of metadata collection and preservation. Only two terrestrial observing systems indicated initial (comprehensive) level in metadata strands, with all remaining systems attaining baseline or reference quality. In common with all other domains, the documentation production is the weakest aspect. The present assessment identified among terrestrial observing systems, one reference-level system, the Greenland GPS Network, which provides the observations on glacier and ice sheets mass change and land uplift. The Greenland Ice Sheet Monitoring Network observing earthquakes is a second potential candidate reference quality observing system as it operates already in 70% of assessed categories at a reference level.

Figure 4.7 Comparison of maturity level in main 5 categories by assessed domain

Atmospheric observing systems. The atmospheric observing systems are overall less sustainable than the terrestrial observing systems. They exhibit a high degree of intra-domain heterogeneity in maturity across most categories implying something close to a tiered systems approach already exists. This perhaps reflects that the concept of tiered networks as articulated by GCOS has been most developed in the atmospheric domain and that many atmospheric observing systems are under the management of national meteorological services. Uncertainty characterisation has a number of reference quality observing systems, virtually none at baseline level and then a large number of poorly quantified and understood observing systems. Several atmospheric systems have paid significant attention to uncertainty handling protocols as well as on elaboration of documentation and high-level metadata. Among assessed atmospheric observational systems, one operating on the reference maturity level was identified. It is global GRUAN network observing the state of the upper atmosphere of the Arctic at three high latitude stations.

Ocean and sea ice observing systems. Oceanic systems are assessed to be the least sustainable domain with relatively few oceanic Arctic observing systems being long-term sustainable. The oceanic domain has strong practices in data storage and access. Conversely, they are weak on data preservation and metadata aspects which calls into question long-term accessibility and usability. Uncertainty characterisation and documentation for most oceanic systems are only assessed to be at a comprehensive maturity level. Among oceanic systems three (AREX, ArgoPoland and NorArgo) operate on an overall maturity level very close to the baseline. Four others (A-TWAIN Poland, EGO Gliders, IMR FHS and NIVA BSFB) could evolve in future to the baseline maturity level as they are already assessed in 50 % of strands on this level. None of the assessed ocean and sea ice observing systems got sufficiently high scores to be categorized as reference systems. It is clear that there exist substantive opportunities to improve this situation through targeted investment in future. Particular focus is required upon the uncertainty quantification if true metrological reference quality measurements are to be procured in future for this domain.

Cross-thematic observing systems. A handful of the cross-thematic observing systems consist of truly equal efforts being made to observe across two or more domains. In general, however, for the cross-thematic systems the atmospheric programs are of secondary importance being measurements made to support the analysis of the oceanic / terrestrial domain that are of primary interest. As noted in the next section this often drags down the overall scores for the three categories which were responded to per data collection (metadata, documentation and uncertainties) as the lowest score was used when assessing cross-observing system performance (Section 2). In the metadata and uncertainties categories these observing systems are commensurately comparably weak for cross-thematic observing systems. On the other hand, cross-thematic observing systems have high sustainability – second only to terrestrial observing systems. Documentation is also relatively strong in these cross-thematic observing systems. Cross-thematic observing systems bring the benefit of simultaneously assessing across multiple parameters of interest and are commensurate with the supersites concept underlying reference quality observations and the INTAROS supersites ambition.

Overall, it is clear that many aspects of maturity follow from the provision of a long-term sustainable support for observing systems. Those domains with the strongest scores in the sustainability category tend to score more strongly in remaining categories. The ocean domain, unsurprisingly, is overall the least mature owing to the nature of the domain which places significant additional challenges on all aspects of long-term observations.

4.4. Assessment of data collections for individual observing systems

As noted in Section 1, for many, but not all, observing systems multiple responses were given for the data collections questionnaire. For these observing systems a more forensic analysis is possible for those three categories covered by that questionnaire: metadata, documentation and uncertainties. It is important to stress that there is substantial heterogeneity in how responses have been provided. Most observing systems will consist of very many data collections yet there is substantial heterogeneity in how these have been reported, reflecting the challenges in the questionnaire collection. Despite clear instructions and follow-ups by the WP leaders to all observing system respondees there remains heterogeneity. Some observing systems provided simply a single response either because only a single data collection was available (e.g. GRUAN consisted at the time of a single data product) or seen as relevant to INTAROS, or because the assessor deemed the answers for a single data collection to be sufficient. Even where multiple responses were provided, generally not all variables observed by the system were assessed.

Full details of the data collection level responses are included in the report cards for those observing systems where multiple responses were provided within Annex 2. The responses fall into two distinct categories. There are cases where the maturity scores given to the data collections belonging to the same system were rather homogeneous, reflecting a common overall treatment and management of the data (Table 4.4.1 provides an example). Then there were cases where the scores were highly heterogeneous, demonstrating the different applications, management, or technical complexity of the instruments that compose the observing system. Such score heterogeneity tends as a result to be greater in the uncertainty characterisation categories than metadata and documentation categories (Table 4.4.2 provides an example). It is clear that for some observing systems there are primary target measurement systems to which great attention is paid, supported by ancillary measurement systems of lower priority and maturity.

Table 4.4.1 individual data collection scores for the main A-TWAIN array of moored buoys. The score assigned to the observing system as a whole is in the top row and individual scores are given in each of the subsequent rows on a per data collection level.

Name	METADATA			DOCUMENTATION			UNCERTAINTIES					
	Standards	Collection Level	File Level	Description	Validation Report	Series User Guidance	Traceability	Comparability	Standards	Validation	Quantification	Quality Management
***A-TWAIN**	1	2	4	1	2	2	2	2	na	na	2	3
Hydrography (Seabird microcat SBE37)												
Hydrography (Seabird Microcat SBE37, Seabird Seacat SBE16)	1	2	4	1	2	2	2	2			2	3
Current (RDI Workhorse ADCP, 150kHz)	1	2	4	1	2	2	2	2			2	3
Current (RDI Workhorse ADCP, 300kHz)	1	2	4	1	2	2	2	2			2	3
Current (Nortek Continental ADCP)	1	2	4	1	2	2	2	2			2	3
hydrography, September 2012 and September 2013 (CTD SBE 911plus)	1	3	4	2								
hydrography and current, Sep 2012 - Sep 2013 (RDI 300 kHz Sentinel ADCP, SBE37 microcatm RDI 300 kHz Sentinel ADCP)	1		4									

Table 4.4.2 As Table 4.4.1 but for the multi-thematic PROMICE observing system. The assessed data collections are grouped by domain: the uppermost 6 rows belong to the atmosphere and the lowermost raw belong to the cryosphere. The coloured rows summarize the scores in the respective domains. Note the marked heterogeneity in scores for the uncertainty characterisation category.@

Name	METADATA			DOCUMENTATION			UNCERTAINTIES					
	Standards	Collection Level	File Level	Description	Validation Report	Series User Guidance	Traceability	Comparability	Standards	Validation	Quantification	Quality Management
***PROMICE automatic weather station network_A_T**	1	3	5	4	1	3	1	1	1	na	2	3
PROMICE Air temperature 2m	1	3	5	4	1	3	1	1			2	3
PROMICE Wind speed and direction 2m	1	3	5	4	1	3	1	3	1		2	3
PROMICE air pressure	1	3	5	4	1	3	1	3	1		2	3
PROMICE Shortwave radiation budget	1	3	5	4	1	3	5	6			2	3
PROMICE Longwave radiation budget	1	3	5	4		3	5	6	1		2	3
PROMICE Relative humidity	1	3	5	4	1	3	1	3	1		2	3
***PROMICE automatic weather station network_A_T**	1	3	5	4	4	3	6	6	1	2	2	4
PROMICE ice surface ablation	1	3	5	4	4	3	6	6	1	2	2	4

5. Summary of maturity assessment of INTAROS observational systems.

We have herein undertaken a synthesis and assessment of Arctic observing system maturity for INTAROS. The assessment has built upon the deliverables D2.1, D2.4 and D2.7 by considering in-depth the maturity of those 39 observing systems that provided complete information following merger of multi-thematic systems which had been considered across 2 or more of the precursor deliverables. This exercise has included:

- An assessment undertaken at the observing system aggregate level (Section 4.1)
- An assessment of each category at the observing system granuality (Section 4.2)
- Per observing domain assessment, including cross-thematic observing systems (Section 4.3)
- Assessment across data collections for observing systems that returned surveys for multiple contributory data collections (Section 4.4)

The assessment has considered five broad areas of observing system maturity: sustainability, metadata, documentation, data management and understanding / quantification of uncertainty. Within each category objectively assessable aspects have been considered to arise a final assessment (Section 2).

The tiered system-of-systems approach should be the aim for all domains of the Arctic observing system, consistent with the principles of GCOS and WIGOS. Presently, in all domains and in cross-thematic observing systems there exist a range of comprehensive and baseline quality observing systems. There is, however, currently an overall paucity of observing systems operating at the highest, reference quality, level within the Arctic. Reference quality measurements can in principle be attained from fixed or mobile platforms, and need not be continuous (e.g. campaign based programs should qualify). But, presently, only two systems have been assessed as attaining truly reference quality whereby a clear majority of the assessed activity is truly at the state-of-the-art level.

The single strongest message arising from this assessment is that what is key if we wish to instigate and / or maintain high maturity observing systems is sustainability of support. There is a clear and unambiguous correlation between maturity in this category and in all remaining categories. Observing systems with high sustainability do better on average in all remaining categories. Without sustained funding and expert support it is difficult to attain and then maintain high maturity in remaining aspects. Much of our in-situ Arctic domain observing capacity is currently funded either on a piecemeal basis or project-to-project and steps should be undertaken to address this where possible to assure sustainability. Otherwise, such episodic / uncertain funding generally inhibits efforts to curate, document and serve key data and metadata in a coherent and sustained fashion. Researchers are, rightly, concerned with publishing results and securing the next tranche of funding support.

If funders do not provide long-term programmatic support and stress the importance of metadata, uncertainty quantification, documentation and data provision aspects the current situation fundamentally shall not change. Sustained infrastructure support that both enables, but also directs, time to be spent on such post-processing activities is a clear priority. These activities increase the intrinsic value of the data, making them more useable by a larger segment of users and for a longer time into the future through increasing discoverability, accessibility and understanding.

Overall, data management is amongst the strongest performance aspects for existing observing systems assessed, although for very many systems there is still substantial room for improvement. The strongest aspects are data preservation and data access practices. A common weakness is establishing a mechanism for the collection of and acting upon user feedback. The work under WP5 of INTAROS, which this current activity feeds into may improve the data management situation, but this can only be assured if the WP5 activity is able to be self-sustaining post-project cessation.

Uncertainty characterisation is sufficient only for a handful of observing systems. The routine monitoring of data quality and the validation of data (their comparability) are the strongest aspects. Traceability to SI or community accepted standards and uncertainty quantification, in general, are much less well developed. Without a robust uncertainty estimate the value of any given observation is substantively diminished. There is no such thing as a perfect measurement. A well understood measurement, with robust uncertainty quantification is the next best thing. While undoubtedly the Arctic is an extreme environment and absolute traceability a challenging proposition it should be strived to obtain such measurements more broadly than has been the case hitherto. Not all measurements need attain such goals, but a sufficient subset should to enable us to anchor other observations against.

Metadata is a significant challenge across the vast majority of the assessed observing systems. The metadata are generally more advanced on the file level, while their elaboration on collection level (which includes attributes that apply across the whole of a measurement series) is lower. Metadata retention is key if data are to be used decades or centuries hence, long after those who undertook the measurements have retired. Without adequate attention being paid to metadata collection and retention the value of observations can quickly atrophy. Metadata collection and retention is a low overhead activity but suffers from low prioritisation in many measurement programs owing to the nature of the funding or the need for data immediacy. As a community we can do better in future with regards to metadata policy and provision.

Documentation is the worst overall current area of performance across observing networks as a whole. Where documentation is undertaken, systems clearly prefer to produce at first a formal description of the physical and methodological basis. Documentation, like metadata, enables users in both the present and the future to use the data appropriately.

The terrestrial observational systems are overall the most advanced in all five assessed categories. Atmospheric observing systems come next, with relatively little difference in several categories. Lower sustainability puts the oceanic systems in last place. Terrestrial and atmospheric programs benefit from being able to be carried out from fixed locales in cases when they can easily and repeatedly be inspected and serviced. In many cases, the observing stations in the Arctic are not easily accessible and the cost of operating the observing systems is high. Ocean observations are either vector measurements moving with surface or sub-surface currents or require significant effort to reach and service on a regular basis. Maintaining multi-decadal records in such an environment is a challenging proposition and will generally require greater funding. For multi-thematic observing systems, the domain specific subsets oftentimes aligned with the within domain tendencies leading to differences that were more marked between than within observing domains.

Different domains have particular strengths and weaknesses suggesting that community accepted norms and best practices differ distinctly. Given the aim for integrated observations, INTAROS can have a clear role potentially in identifying best practices and promoting their dissemination across all domains during the remainder of the project's lifetime.

Those observing systems that returned assessments for multiple data collections highlight that in many cases there is internal heterogeneity in all aspects, but in particular uncertainty characterisation, that can be substantial. A handful of observing systems returned assessments for one or more original and reprocessed data collections. The reprocessed collections scored consistently higher maturity assessments. This highlights that retrospective reprocessing and documentation can increase the latent value of observations already collected and efforts to do so, where it is possible, should be encouraged.

As an assessment tool, the System Maturity matrix (SMM) has demonstrated a substantive benefit for actors of the Arctic observational systems in the context of INTAROS. Its further extension for a larger scientific and operational community has been recommended by INTAROS expert reviewing board. An elaboration and large advertising of a short guide based on SMM tool questions/answers would be helpful for all researchers running established observations in the Arctic. A brief (but not full) overview of a broad range of international observational systems acting in the Arctic that were not considered by INTAROS but could be involved in further assessment campaigns is given in D2.10. The success of the SMM assessment has initiated further development. An interactive tool allowing a visualisation of the summary of responses in the form of maturity matrix and a displaying of the evolution of the network maturity is already an ongoing action undertaken in the framework of the new ArcticMap project funded by the Norwegian Directorate for Environment and Climate (2018-2021). Such tool needs to be further developed and maintained to provide updated information about the increasing amount of data that will be generated in the coming years.

Aknowledgments

The authors are grateful to Hajo Eicken for his valuable and thorough review of this report. The key review comments and the author's answers are appended at the end of the report. Although time limitations made it impossible to address all the comments in depth in this revised deliverable, Hajo Eicken suggestions will be further addressed in the publications that will follow.

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ANNEX1. Questionnaires' structure, suggested answers and scores attributed to each answer.

METADATA	DOCUMENTATION	UNCERTAINTIES	DATA	SUSTANABILITY
Standards: It is considered to be good practice to follow recognized metadata standards. Unless and until an ISO standard is developed and applied the assessors' judgement will be required as to the appropriateness of the standards being adhered to.	**Formal description of scientific methodology** refers to a description of the physical and methodological basis of the measurements, network status (if applicable), processing of the raw data and dissemination.	**Data traceability** is the property of a measurement whereby it can be related to stated references (national or international standards), through an unbroken chain of comparisons and processing all having stated uncertainties. Not relevant to data products	**Data storage**	**Scientific and expert support:** The degree of scientific and technical expertise that underpins the measurement program.
1. No standard considered	1. Limited scientific description of methodology available from data collector, instrument manufacturer, or PI	1. None	1. Data are not stored in any institutional repository, but in a personal repository.	1. None (No scientific or technical support is available)
2.N/A	2. Comprehensive scientific description available from data collector, instrument manufacturer, or PI	2. Comparison to independent stable measurement or local secondary standard undertaken irregularly	2. Data are stored in an institutional/departmental repository	2. Minimal scientific support required to sustain the program is available, sufficient to maintain the measurement program at present state, but not in case of major failure or breakdown of the observing system
3. Metadata standards identified and/or defined and partially but not yet systematically applied	3. As in (2) + Journal paper on measurement methodology published	3. As in (2) + independent measurement / local secondary standard is itself regularly calibrated against a recognized primary standard	3. Data are stored in distributed repositories (institutional and not)	3. Technical expertise is available to support operation of the observing system
4. As in (3) + standards systematically applied at file level and collection level.	4. As in (3) + Comprehensive scientific description available from Data Provider	4. As in (3) + processing steps in the chain of traceability are documented but not yet fully quantified	4. Data are stored in a National repository according to legal constraints on their location	4. As in (3) + at least two technical experts to secure the measurement program operation
5. As in (4) + metadata standard compliance systematically checked by the data provider	5. As in (4) + Comprehensive scientific description maintained by Data Provider	5. As in (4) + traceability in the processing chain partly established	5. Data are stored in National data repositories without legal constraints on their location	5. N/A
6. As in (4) + extended metadata that could be useful but is not considered mandatory is also retained.	6. As in (e) + Journal papers on measurement series/product updates published	6. As in (5) + traceability in the processing chain fully established	6. Data are stored in International data repositories	6. As in (4) + research and development to ensure that the observing system is based on state of the art technology
Collection level metadata includes attributes that apply across the whole of a measurement series, such as processing methods (e.g., same algorithm versions), general space and time extents, creator and custodian, references, processing history, etc.	**Formal validation report** contains details on the validation activities that have been done to assess the fidelity/reliability of the data collection.	**Data comparability** evaluates the extent to which the data collection has been validated to provide realistic uncertainty estimates and stable operations through in the-field comparisons.	**Data access:** Level of open distribution of data, documentation, and any software to process the data. The highest scores in this category can only be attained for data provided free of charge without restrictions on use and reuse.	**Funding support:** The long-term financial support that underpins the measurement program.
1. None	1. None	1. None	1. Unknown	1. None (No dedicated funding support is evident for the measurement program)
2. Limited	2. Informal validation work undertaken	2. Validation using external comparator measurements done only periodically and these comparator measurements lack traceability	2. Data is available request to trusted users or through supervision by originator	2. Project based funding support available
3. Sufficient to use and understand the data independent of external assistance.	3. Instrument has participated in certified intercomparison campaign and results available in gray literature	3. As in (2) + Validation is done sufficiently regularly to ascertain gross systematic drift effects	3. Data is available on automated request through originator	3. As in (2) + expectation of follow on founding
4. As in (3) + enhanced discovery metadata	4. Report on intercomparison to other instruments, etc.; Journal paper or product validation published	4. As in (3) + (Inter)comparison against corresponding measurements in large-scale instrument intercomparison campaigns	4. Data and documentation are available on supervised request through originator	4. As in (3) + not dependent upon a single investigator or funding line
5. As in (4) + complete discovery metadata meets appropriate (at the time of assessment) international standards	5. As in (4) + Sustained validation undertaken via redundant periodic measurements	5. As in (4) + compared regularly to at least one measurement that has traceability as in (5) or (6)	5. Data and documentation are available on automated request through originator	5. Sustained infrastructure support available to finance continued operations for as far as can be envisaged given national and international funding vagaries
6. As in (5) + regularly updated	6. As in (5) + Journal papers describing more comprehensive validation, e.g. error covariance, validation of quantitative uncertainty estimates published	6. As in (5) + compared periodically to additional measurements including some with mature traceability	6. As (5) + source data, code and metadata available upon request or automated without any restrictions	6. As in (5) + support for active research and development of instrumentation or applied analysis of the observations
File level metadata includes such elements as time of observation, location, measurement units, measurement specific metadata such as ground check data, measurement batch number, ambient conditions at time of observation etc.	**Formal measurement series or product user guidance** contains details necessary for measurement users to discover and use the data in an appropriate manner.	**Standards** is only applied **to derived data products** resulted from summarized measurements or are composed of integrated measurements (ex.: climatological time series). To support a claim of traceability, the provider must document the measurement process or system used to establish the claim and provide a description of the chain of comparisons that were used to establish a connection to a particular stated reference.	**User feedback:** Level of established mechanisms to receive, analyse and ingest user feedback.	**Site representativeness (for terrestrial stations):**
1. None	1. None	1. None	1. None	1. Unknown
2. N/A	2. Sufficient information on the data collection available to allow user to ascertain minimum set of information required for appropriate use	2. Standard uncertainty nomenclature is identified or defined	2. Ad hoc feedback (which may be acted upon)	2. N/A
3. Limited	3. Comprehensive documentation on how the measurement is made or the product derived available from data collector or instrument manufacturer or PI, including basic data characteristics description	3. As in (2) + Standard uncertainty nomenclature is applied	3. Programmatic feedback (systematic collection of user feedback related to the measurements and dissemination of lessons learnt)	3. The site only represents the immediate surrounding environment
4. Sufficient to use and understand the data independent of external assistance.	4. As in (3) + including documentation of manufacturer independent characterization and validation	4. As in (3) + Procedures to establish SI traceability are defined	4. As in (3) + consideration of published analyses	4. The site is representative of a broader region around the immediate location
5. As in (4) + Limited location (station, grid point, etc.) level metadata along with unique measurement set metadata (coordinate bounds) are provided.	5. As in (4) + regularly updated by data provider with instrument / method of measurement/processing updates and/or new validation results	5. As in (4) + SI traceability partly established.	5. Established feedback mechanism and international data quality assessment results are considered	5. As in (4) + the site environment is likely to be unchanged for decades
6. As in (5) + Complete location (station, grid point, etc.) level and measurement specific metadata.	6. As in (5) + measurement description and examples of usage available in peer-reviewed literature	6. As in (5) + SI traceability established	6. As in (5) + Established feedback mechanism and international data quality assessment results are considered in continuous data provisions	6. As in (5) + the long-term site representativeness is guaranteed, e.g. due to protected area.

METADATA	DOCUMENTATION	UNCERTAINTIES	DATA	SUSTANABILITY
		Validation is relevant **for derived data products**. It evaluates the extent to which the product has been validated to provide uncertainty estimates.	**Updates to record:** Level of systems in place to update data records when new observations or insights become available.	
		1. None	1. None (No update is made to the measurement series or data products after initial release)	
		2. Validation against external reference data done for limited locations and times	2. Irregularly following accrual of a number of new measurements scientific exchange and progress or new insights	
		3. Validation using external reference data done for global and temporal representative locations and times	3. N/A	
		4. As in (3) + intercomparison against corresponding data records	4. Regularly updated with new observations and utilizing input from established feedback mechanism	
		5. As in (4) + data provider participated in one international data quality assessment	5. Regularly operationally by stable data provider as dictated by availability of new input data or new innovations	
		6. As in (4) + data provider participated in multiple international data assessments and incorporated feedbacks into the product development cycle	6. As in (5) + initial version of measurement series or data products shared in near real time.	
		Uncertainty quantification evaluates the extent to which uncertainties have been fully quantified and their ease of use.	**Version control:** Level of measure taken to trace back the different versions of algorithms, software, format, input and ancillary data, and documentation used to generate the data record	
		1. None	1. None	
		2. Limited information on uncertainty arising from systematic and random effects in the measurement	2. Versioning by data collector	
		3. Comprehensive information on uncertainty arising from systematic and random effects in the measurement	3. N/A	
		4. As in (3) + quantitative estimates of uncertainty provided within the measurement products characterizing more or less uncertain data points	4. Version control institutionalized and procedure documented	
		5. As in (4) + systematic effects removed and uncertainty estimates are partially traceable	5. Fully established version control considering all aspects	
		6. As in (5) + comprehensive validation of the quantitative uncertainty estimates	6. As in (5) + all versions retained and accessible upon request	
		Routine quality monitoring is the monitoring of data quality while processing the data.	**Long term data preservation:** Level of Long Term Data Preservation according to ESA-guidelines (http://earth.esa.int/gscb/ltdp/).	
		1. None	1. None	
		2. N/A	2. Local archive retained by measurement collector	
		3. Methods for routine quality monitoring defined	3. N/A	
		4. As in (3) + Routine monitoring partially implemented	4. Each version archived at an institutional level on at least two media	
		5. As in (4) + Monitoring fully implemented at all production levels	5. Data, raw data and metadata is archived at a recognized data repository, national archive, or international repository.	
		6. As in (5) + Routine monitoring in place with results fed back to other accessible information, e.g. metadata or documentation	6. As in (5) + all versions of measurement series, metadata, software etc. retained, indexed and accessible upon request.	

N/A – not defined or not applied.

ANNEX 2. MATURITY ASSESSMENT SUMMARIES of the OBSERVING SYSTEMS.

The cards for multi-disciplinary Observing Systems are split up one per observing domain.

Assessments for the metadata, documentation and uncertainty characterisation categories are specific to the assessed data collections outlined in Deliverables 2.1, 2.4 and 2.7. These may or may not be indicative of broader observing system performance in these areas as outlined in Section 4.4. For these observing systems the data collection summaries for the three categories are shown as supplemental information to the main report summary.

For global observing systems the assessment pertains only to the sub-component operating within the Arctic domain and may, or may not, be indicative of broader performance characteristics bearing in mind the specific and unique challenges involved in Arctic observations.

Where the data collection assessments are known to apply to only a subset of the parameters monitored by the observing system this is highlighted by **this style** to denote that subset that are applicable.

List of the observing systems that provided assessment of one or more data collections.

Observing system	Short name
Ocean and sea ice	
A-TWAIN	A-TWAIN
A-TWAIN Poland (Polish contribution to the A-TWAIN moored array)	A-TWAIN PL
Long-term large-scale monitoring program (AREX)	AREX
ArgoPoland	ArgoPoland
EGO gliders (European Gliding obervatories)	EGO gliders
FRontiers in Arctic marine Monitoring (FRAM)	FRAM
Fram Strait Multipurpose Acoustic System	Fram MAS
Global Sea Level Observing System - Greenland	GLOSS-Greenland
IMR Barents Sea Opening mooring array	IMR BSOMA
IMR fixed hydrographic sections	IMR FHS
IMR Fixed hydrographic (near coastal) station network	IMR FHScoast
IMR SI_Arctic vessel mounted ADCP system	IMR SI
NorArgo	NorArgo
RV Hakon Mosby	RV Hakon Mosby
Atmosphere	
AC-AHC2 stable water isotope measurement stations	AC-AHC2
Aerosol, Clouds and Trace Gases Research Infrastructure	ACTRIS
Atmospheric ship-based campaigns ASCOS, ACSE, N-ICE2015, Sea State 2015, and Polarstern cruises	Atmospheric ship-based campaigns
Global Atmosphere Watch - Aerosols	GAW- Aerosols
Global Climate Observing System (GCOS) Reference Upper Air Network	GRUAN
Radiosounding network in the Arctic (AMAP and IGRA)	RNA
WMO Integrated Global Observing System - Surface meteorological holdings	GOS-surface met
Land and terrestrial cryosphere	
Arctic-HYCOS	Arctic-HYCOS
Fluxnet	Fluxnet
Glacier Thickness Database	GlaThiDa
GLISN network Greenland	GLISN
GNET - GPS networks	GNET

Norwegian National Seismic Network	NNSN
Randolph Glacier Inventory	RGI
World Glacier Monitoring Service-Fluctuations of Glaciers Database	FoG
Multi-disciplinary observing systems	
Airborne observations of surface-atmosphere fluxes	AIRMETH GFZ
Greenland Ecosystem Monitoring program	GEMP
Hornsund Station	Hornsund
IMR Barents Sea Winter Survey	IMR BSWS
IMR-PINRO Ecosystem Survey	IMR-PINRO
NIVA Barents Sea FerryBox	NIVA BSFB
Pan-Eurasian Experiment (PEEX)	PEEX
Program for Monitoring of the Greenland Ice Sheet (PROMICE)	PROMICE
Sodankylä station	Sodankylä
Tower network for atmospheric trace gas mixing-ratio monitoring	Gas-Mix TN

OCEANIC OBSERVING SYSTEMS

A-TWAIN
A-TWAIN mooring array north of Svalbard

Mooring array from the shelf across the continental slope north of Svalbard. Main aim: long-term monitoring of the Atlantic Water inflow to the Arctic Ocean for climate research.

Institution performing the assessment:
Institute of Marine Research, Norway

Geographical area:
81-82° N, 31° E

Time:
2012-ongoing

Data owners:
Norwegian Polar Institute and Institute of Marine Research.
URL: data.npolar.no

ECV/parameters:
Subsurface temperature, **Subsurface salinity**, **Subsurface current** Seas surface height, Oxigen

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
Hydrography (Seabird microcat SBE37)												
Hydrography (Seabird Microcat SBE37, Seabird Seacat SBE16)	2	2			2	3	1	2	4	1	2	2
Current (RDI Workhorse ADCP, 150kHz)	2	2			2	3	1	2	4	1	2	2
Current (RDI Workhorse ADCP, 300kHz)	2	2			2	3	1	2	4	1	2	2
Current (Nortek Continental ADCP)	2	2			2	3	1	2	4	1	2	2
hydrography, September 2012 and September 2013 (CTD SBE 911plus)							1	3	4	2		
hydrography and current, Sep 2012 - Sep 2013 (RDI 300 kHz Sentinel ADCP, SBE37 microcatm RDI 300 kHz Sentinel ADCP)							1		4			

Key strengths:

File level metadata; Data access and preservation; routine quality management; access to scientific and expert support

Key challenges:

Instigation of metadata standards and application at the collection level; all aspects of documentation; uncertainty characterisation and quantification; instigation of user feedback. Funding support could be strengthened and may ameliorate all of the above.

A-TWAIN Poland

A-TWAIN Poland (Polish contribution to the A-TWAIN moored array)

Polish contribution to the mooring array from the shelf across the continental slope north of Svalbard. Main aim: long-term monitoring of the Atlantic Water inflow to the Arctic Ocean for climate research. In some years, the IOPAN extends the mooring upstream at 18 or 22°E to monitor Atlantic water transformation along the northern Svalbard slope.

Institution performing the assessment:
The Institute of Oceanology of the Polish Academy of Sciences, IOPAN

Geographical area:
81-82°N, 22-32°E

Time:
2012-ongoing

Data owners:
Institute of Oceanology PAS, Sopot, Poland
URL: data are available on request

ECV/parameters:
Subsurface temperature, **Subsurface salinity**, **Subsurface current**, Sea State, Sea Ice, Oxigen

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
A-TWAIN Poland 2012-2013 Ocean temperature	4	4				4	3	3	3	3	3	2
A-TWAIN Poland 2012-2013 Ocean salinity	4	4			3	4	3	3	3	3	3	2
A-TWAIN Poland 2013-2015 Ocean temperature	4	4			3	4	3	3	3	3	3	2
A-TWAIN Poland 2013-2015 Ocean salinity	4	2			3	4	3	3	3	3	3	2
A-TWAIN Poland 2015-2017 Ocean temperature	4	2			3	4	3	3	3	3	3	2
A-TWAIN Poland 2015-2017 Ocean salinity	4	2			3	4	3	3	3	3	3	2
A-TWAIN Poland 2015-2017 Ocean current	3	3			4	4	3	3	3	4	4	2

Key strengths:

Routine data quality management; data access; traceability; and access to scientific and expert support.

Key challenges:

Lack of comparability; lack of long-term data preservation, version control, updates and a user feedback mechanism. Differentiation in comparability between earlier (higher scores) and more recent (lower scores) data collections.

AREX

AREX: Long-term large-scale multidisciplinary Arctic monitoring program

AREX is focused on multidisciplinary observations in physical oceanography, air-ocean interactions, ocean biogeochemistry and ecology to study the long-term changes of abiotic and biotic Arctic environment. Summer large-scale field measurements have been carried out in the Nordic Seas and European Arctic from board of the IOPAN research vessel Oceania

Institution performing the assessment:
The Institute of Oceanology of the Polish Academy of Sciences, IOPAN

Geographical area:
70-81°N; 0-22°E (eastern Nordic Seas and Fram Strait)

Time:
1988-ongoing

Data owners:
Institute of Oceanology PAS, Sopot, Poland
URL: http://www.iopan.gda.pl/hydrodynamics/po/cruises.html

ECV/parameters:
Subsurface temperature, **Subsurface salinity**, **Subsurface current**, **Oxigen**

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
AREX salinity	4	5			4	4	4	3	3	4	4	2
AREX ocean dissolved oxygen	4	5			4	3		3	3	3	4	2
AREX ocean currents from LADCP	4	3	3		4	2		3	3	3	2	2
AREX ocean currents from VMADCP	4	3			4	4	4	3	3	3	2	2

Key strengths:

Metadata standards; traceability and uncertainty quantification; comparability for some but not all data collections; data storage and access; observing system sustainability

Key challenges:

Documentation is relatively low maturity; there is room to improve routine data quality management for several data collections; there is a lack of version control, and a user feedback mechanism

ArgoPoland

ArgoPoland - deployments of Argo floats in the Nordic Seas

Polish Argo floats are deployed in the subpolar North Atlantic to trace Atlantic water pathways and monitor transformation of Atlantic inflow during its northward transition towards the Arctic Ocean.

Institution performing the assessment:

The Institute of Oceanology of the Polish Academy of Sciences, IOPAN

Geographical area:

73-80°N, 0-20°E (the eastern Norwegian and Greenland seas and eastern Fram Strait)

Time:

2009-ongoing

Data owners:

Institute of Oceanology PAS, Sopot, Poland

URL: http://www.ifremer.fr/co-argoFloats/

ECV/parameters:

Subsurface temperature, Subsurface salinity, Subsurface current, Oxigen

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:

Traceability of measurements; data storage and access

Key challenges:

Documentation of data collections; uncertainty quantification; user feedback mechanism and updates to the record; long term funding support.

EGO-Glider
EGO "Everyone's Gliding Observatories" platform

EGO "Everyone's Gliding Observatories" platform is promoted as a tool to share Arctic glider data. Glider deployments have been carried out in 2017 and 2018. Monitoring of the glider missions, real time transmission of the data and glider piloting can be achieved through the EGO system.

Institution performing the assessment:
CNRS/LOCEAN

Geographical area:
Fram Strait

Time:
2017-2018

Data owners:
CNRS/LOCEAN
URL: http://www.coriolis.eu.org/

ECV/parameters:
Subsurface temperature, Subsurface salinity, Subsurface current, Sea surface temperature, Seas surface salinity, Suspended particulate matter, Ocean colour

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:

Metadata standards and file level detail; comparability and routine quality management; data storage, access and preservation; funding support

Key challenges:

All aspects of documentation of one or more assessed data collections; traceability and uncertainty quantification; updates to record, version control and user feedback protocols.

FRAM

FRontiers in Arctic marine Monitoring

The FRAM observing system is an infrastructure initiative of the German Helmholz Association (HGF), allowing synchronous observations in the water column and at the seafloor. It comprises already existing long-term observatories HAUSGARTEN and ‘79°N Oceanographic Mooring Array’ as well as Fram Strait mooring array between Svalbard and Greenland.

Institution performing the assessment:
Alfred Wegener Institute - Helmholtz Centre for Polar and Marine Research

Geographical area:
Fram Strait 78 - 80.1 degrees latitude and -5.5 and 11.1 longitude

Time:
1999-ongoing

Data owners:
Alfred Wegener Institute - Helmholtz Centre for Polar and Marine Research
URL: https://www.awi.de/en/expedition/observatories/ocean-fram.html

ECV/parameters:
Subsurface temperature, **Subsurface salinity**, Subsurface current, Sea State, Sea Ice, Ocean Sound, **Oxygen**, Mineral nutrients, Mineral carbon, Dissolved organic carbon, Ocean Colour, **phytoplankton, zooplankton, sediment biochemical parameters**

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
Unified Database for Arctic and Subarctic Hydrography			3	4	2	5		3	3	3	6	1
Biogenic particle flux y from mooring sediment traps	6	6			2	4	5	5	5	3	6	2
Inorganic nutrients measured water samples since 1997	6	6			2	4	5	5	5	2	2	2
High resolution sea-bed photographs and footage from repeated long term surveys	6	6			2	4	5	5	5	3	6	2
Ship borne CTD surveys of temperature and salinity			3	2	3	5	5	3	3	3	4	6
Ship borne CTD surveys of oxygen and chlorophyll			3	2	2	3	5	3	3	1	2	2
Biogeochemical parameters from deep-sea sediments, long-term AWI-HAUSGARTEN	6	6			2	5		5	5	6	6	6
Physical Oceanography Mooring-Data Fram Strait Mooring Array			3	4	2	3	5	3	3	2	4	2
Benthic oxygen fluxes in the Arctic Fram Strait	6	6			2	4		5	5	3	2	3
AWI Polarstern VM ADCP measurements			2	1	3	1	5	2	2	2	1	2

Key strengths:

Metadata standards and, for many data collections, collection and file level inclusion; documentation for a subset of data collections; data traceability and comparability; data storage and access; observing system sustainability

Key challenges:

All aspects of data collection documentation for some collections; uncertainty quantification and routine quality management for several data collections; user feedback.

Fram MAS
Fram Strait Multipurpose Acoustic System

A network of fixed mooring systems with acoustic transceivers in the Arctic Ocean will provide an underwater geo-positioning system for all users in direct analogy with GPS positioning. It has been implemented in a sequence of year-long research experiments (ACROBAR, UNDER-ICE, DAMOCLES) in the Fram Strait and in the Beaufort Sea.

Institution performing the assessment:
NERSC

Geographical area:
Fram Strait, 78-80 N, -4W - 8E.

Time:
2008-2009, 2010-2012,2014-2016

Data owners:
NERSC
URL: https://archive.norstore.no/pages/public/datasetDetail.jsf?id=10.11582/2017.00012

ECV/parameters:
Acoustic travel time, Ambient noise, Depth-range-averaged ocean temperature

Maturity assessment matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
ACOBAR:XBT measurements and derived values - Fram Strait-2010-2012					6	1		3	3	2		
ACOBAR-2010-2012-Depth-Range-Averaged-Ocean-Temperature			2	2	2	2		3	3	3	2	2
ACOBAR-2010-2012-ambient-noise			2	1	2	1		3	3	3	2	2
ACOBAR-2010-2012-acoustic traveltimes			2	1	2	2		2	3	3	2	3
DAMOCLES-2008-2009-traveltime	4	3	2	2	5	4	3	3	3	2	2	2
DAMOCLES-2008-2009-Depth-Range-Averaged-Ocean-Temperature			2	2	2	2	3	3	3	3	2	2
DAMOCLES-2008-2009-ambient noise	1	1	2	1	2	1	3	3	3	2	1	2
DAMOCLES-2008-2009-acoustic-traveltime			2	2	2	2	3	2	3	2	2	2
UNDER-ICE-2014-2016-ambient noise			2	2	2	2	3	3	3	1	2	2
UNDER-ICE-2014-2016-acoustic-travel time			2	1	2	2	3	3	3	1	2	
UNDER-ICE-2014-2016-ambient noise			2	1	1	1	3	2	3	3	2	1

Key strengths:

File level metadata; data preservation and provision of scientific and expert support

Key challenges:

Metadata standards; documentation; uncertainty characterisation; data storage, access, user feedback, updates and version control; provision of sustainable funding support.

GLOSS-Greenland

Global Sea Level Observing System - Greenland

Network provides daily and high-frequency (5 minutes) measurements of relative sea level, including gps measurement corrected for atmospheric pressure. Network consists of 4 stations located around Greenland.

Institution performing the assessment:
Technical University of Denmark

Geographical area:
4 gauges around Greenland

Time:
2005 ongoing

Data owners:
Technical University of Denmark

URL: http://www.ioc-sealevelmonitoring.org

ECV/parameters:
Sea surface height

Maturity Assessment Matrix:

Observing system		**Data collections**		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	**2**	**3**	**4**	**5**	**6**	Not applicable or no data provided

Key strengths:

Routine quality management; data storage

Key challenges:

Metadata; documentation; uncertainty quantification; user feedback, data updates and version control; all aspects of observing system sustainability.

IMR-BSOMA

IMR Barents Sea Opening Mooring Array

Fixed moorings along a section across the western Barents Sea. 5 mooring locations to cover the main inflow from the southwest. The data are mainly used for climate and environmental monitoring and research, including process-oriented research.

Institution performing the assessment:
Institute of Marine Research, Norway

Geographical area:
71.5-73.5 N, 19.32-19.77 E.

Time:
1997-ongoing

Data owners:
Norwegian Marine Data Centre
URL: contact for data randi.ingvaldsen@imr.no

ECV/parameters:
Sea surface temperature, **Subsurface temperature**, **Sea surface salinity**, **Subsurface salinity**, **Subsurface current**, **Subsurface current**, Mineral carbon, Dissolved organic carbon

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:

File level metadata; routine quality management; data storage, access and preservation; observing system sustainability

Key challenges:

Metadata standards and collection level characterisation; all aspects of documentation; uncertainty characterisation; updates to record, version control and user feedback protocols.

IMR FHS

IMR fixed hydrographic sections

The survey is set up to monitor across northwardly flowing currents. It is used for oceanographic and climate monitoring and research as well as for monitoring of important fish stocks. Hydrographic sections are a compromise between observing at a few positions with high frequency, and undertaking a spatially broader coverage with many measurement points with low frequency.

Institution performing the assessment:
Institute of Marine Research, Norway

Geographical area:
6 sections in area 68.4-81.2N, -15-37.3E..

Time:
1953-ongoing (some observations exists since 1929)

Data owners:
Norwegian Marine Data Centre
URL: contact for data post@hi.no

ECV/parameters:
Sea surface temperature, **Subsurface temperature**, **Sea surface salinity**, **Subsurface salinity**, Oxigen, Mineral nutrients, Dissolved organic carbon, phytoplankton, zooplankton

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:
Metadata; data storage, access, updates and preservation; observing system sustainability.

Key challenges:
Documentation aspects for at least some assessed data collections; uncertainty characterisation; user feedback mechanisms and version control.

IMR FHScoast

IMR Fixed hydrographic (near coastal) station network

Long-ongoing (1936-) network of single hydrographic stations at strategic places by the Norwegian coast. Used for oceanographic and climate monitoring and research. Used indirectly for monitoring of important fish stocks and fisheries management. Set up to monitor northwards flowing currents.

Institution performing the assessment:
Institute of Marine Research, Norway

Geographical area:
3 stations : 71.13 N, 24.016E, 68.367 N 13.633E, 68.116 N, 14.533 E.

Time:
1936-ongoing

Data owners:
Norwegian Marine Data Centre
URL: contact for data post@hi.no

ECV/parameters:
Sea surface temperature, **Subsurface temperature**, **Sea surface salinity**, **Subsurface salinity**, Oxigen, Mineral nutrients, Dissolved organic carbon

Maturity Assessment Matrix

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:
Formal description of the measurement methodologies; data storage access and preservation; observing system sustainability.

Key challenges:
Provision of validation reports; uncertainty characterisation; user feedback and version control protocols.

IMR_SI

IMR SI_Arctic vessel mounted ADCP system

The observation network is part of the SI Arctic /Arctic ecosystem survey and funded by SI Arctic, which is a Strategic Institute program awarded to IMR by the Ministry of Fisheries through the Research Council of Norway for January 1 2014- December 31 2018 (5 years).

Institution performing the assessment:
Institute of Marine Research, Norway

Geographical area:
77.5-82.5N, 3-25E

Time:
2014-2018

Data owners:
Norwegian Marine Data Centre

URL: contact for data post@hi.no

ECV/parameters:
Surface current, **Subsurface current**

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	**2**	**3**	**4**	**5**	**6**	Not applicable or no data provided

Key strengths:
Provision of most aspects of required documentation; availability of scientific and expert support.

Key challenges:
Metadata provision; uncertainty characterisation; most aspects of data management, but in particular version control; sustainability of funding

NorArgo

The NorArgo network is applied for climate and environmental monitoring and research, process-oriented research and applied research supporting operational services. The main goal is to monitor: the ocean climate variability, the water mass transformation, the physical and biological variability of the upper ocean, the deep currents, using the drift of the floats. (8 physical and biogeochemical parameters are measured.

Institution performing the assessment:
Institute of Marine Research, Norway

Geographical area:
60° -80° N, 10° -15°E

Time:
2012-ongoing

Data owners:
Institute of Marine Research
URL: ftp://ftp.ifremer.fr/ifremer/argo.

ECV/parameters:
Sea surface temperature, **Subsurface temperature**, **Sea surface salinity**, **Subsurface salinity**, **Surface current**, **Subsurface current**, Oxigen, Mineral nutrients, Ocean Colour

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:
File level metadata; data management; aspects of documentation; uncertainty quantification and routine quality management; provision of scientific and expert support.

Key challenges:
Metadata standards; traceability and comparability; sustainable funding support

ATMOSPHERIC OBSERVING SYSTEMS

AC-AHC2

AC-AHC2 stable water isotope measurement stations

Within the project AC-AHC2 (Atmospheric circulation and Arctic hydrological cycle changes), data between Network stations (including Bergen) and the continuous stable isotope measurements on board of R/V Polarstern are shared.

Institution performing the assessment:
University of Bergen

Geographical area:
Svalbard, Bergen, Greenland, Iceland, Siberia, Polarstern, Ships of opportunity, Aircraft campaign Iceland

Time:
2011-ongoing

Data owners:
CNRS-LSCE, UiB, AWI, others
URL: contact for data Valérie Masson-Delmotte valerie.masson@lsce.ipsl.fr

ECV/parameters:
Water vapor isotopes $H_2{}^{16}O$,HDO, $H_2{}^{18}O$

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:

Provision of scientific and expert support; site representativeness

Key challenges:

Documentation; data management. Note that incompleteness of responses provided inhibits a comprehensive assessment for this observing system.

ACTRIS

Aerosol, Clouds and Trace gases InfraStructure

The European Research Infrastructure ACTRIS has two long-term stations in the AMAP region (Ny Ålesund & Pallas-Sodankylä) providing cloud profile information at a very high temporal and vertical resolution.

Institution performing the assessment:
Finnish Meteorological Institute

Geographical area:
Ny Ålesund station and Pallas-Sodankylä station

Time:
2014 - ongoing

Data owners:
European Union
http://actris.nilu.no

ECV/parameters:
Cloud boundaries, Cloud fraction, Cloud liquid water content, Cloud ice water content, Liquid water path , **Aerosols**

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	**2**	**3**	**4**	**5**	**6**	Not applicable or no data provided

One data collection (aerosol number size distribution) was assessed twice, before its ingestion in the ACTRIS database and after its upgrade to comply with the standards required by the ACTRIS database (see table below). The scores reported in the maturity assessment matrix of the ACTRIS observing system correspond to the status of the data included in the database.

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
aerosol number size distribution	2	2			2	1	4	3	2	3	2	2
Hydrometeor classification upgraded	5	5				2	5	5	5	2		

Key strengths:

Metadata; uncertainty characterisation; data management; observing system sustainability

Key challenges:

Documentation; use of standards; version control of the data provision

Atmospheric ship-based campaigns

Atmospheric ship-based campaigns ASCOS, ACSE, N-ICE2015, Sea State 2015, and Polarstern cruises

Extensive surface-based remote-sensing instrumentation of cloud properties was deployed during ASCOS, ACSE and N-ICE2015 experiments aiming scientific understanding of the Central Arctic climate processes, boundary-layer processes & clouds.

Institution performing the assessment:
Department of Meteorology of Stockholm University (MISU)

Geographical area:
77.9-87.5N, -11.06-9.57 E., 71.4-85.15N, -179.2-25.79 E..

Time:
August - September 2008, July-October 2014, winter 2015

Data owners:
Department of Meteorology of Stockholm University

URL: www.ascos.se; http://bolin.su.se/data/

ECV/parameters:
tropospheric Tair, relative humidity, **wind speed/direction**, **sensible/latent heat**, **momentum fluxes**, **surface net long/shortwave radiation**, cloud mask, **cloud liquid water path**, **cloud IWC**

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	**2**	**3**	**4**	**5**	**6**	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
Near surface sensible heat flux			1	2	1	1	1	2	3	1	2	1
Near surface latent heat flux			1	2	1	1	1	2	3	1	2	1
Near surface momentum flux			1	1	1	1	1	2	3	1	2	1
Net surface longwave radiation	2	2			1	1	1	2	3	1	2	1
Net surface shortwave radiation	1	1			1	1	1	2	3	1	2	1
Downwelling surface longwave radiation	2	2			1	1	1	2	3	1	2	1
Downwelling surface shortwave radiation	1	1			1	1	1	2	3	1	2	1
Cloud base and cloud top boundaries; cloud fraction			1	2	2	2	1	2	3	1	1	1
Cloud liquid water path	5	2			4	5	4	3	4	3	2	2
UPPER-AIR: Temperature	2	2			2	1		2	2	1	2	1
UPPER-AIR: Water vapor	2	2			2	1		2	2	1	2	1
UPPER-AIR: Wind speed and direction	2	2			2	1		2	2	1	2	1
Cloud ice water content			1	1	2	1	3	2	3	3	2	2

Key strengths:

Data access and preservation

Key challenges:

Metadata for most data collections; documentation; uncertainty characterisation for all data collections considered except cloud liquid water path; lack of sustainability

GAW-Aerosols

Global Atmospheric Watch (GAW) – Aerosols

Long-term surface-based atmospheric composition measurements program. The basis of GAW are the surface-based observations of global and regional contributing stations.

Institution performing the assessment:
Finnish Meteorological Institute

Geographical area:
>60 terrestrial pan-Arctic stations

Time:
1989 – ongoing

Data owners:
WMO
URL: https://public.wmo.int/en/programmes/global-atmosphere-watch-programme

ECV/parameters:
Surface and Upper: Tair, Wind speed and direction, Water vapour; Pressure, Precipitation, Surface radiation budget, CO_2, CH_4, other greenhouse gases, **Total column ozone**, **Aerosols**, Cloud properties

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	**2**	**3**	**4**	**5**	**6**	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
Aerosol number concentration	2	2			2	1	4	2	3	3	2	2
Aerosol light absorption coefficient	2	2			2	1	4	3	2	3	2	2
Aerosol light absorption coefficient upgraded	2	3			5	3	4	4	3	4	4	3
Aerosol light scattering coefficient	2	2			2	1	4	3	2	3	2	2
Aerosol particle number size distribution	2	2			2	1	4	2	3	3	4	2
Total column ozone	2	4	3	4	2	3	4	3	3			

Key strengths:

Metadata standards; data storage, access and preservation; observing system sustainability and site representativeness

Key challenges:

Metadata provision; documentation; uncertainty characterisation for most data collections assessed, in particular routine quality management; user feedback, version control and updates

GRUAN

Global Climate Observing System (CGOS) Reference Upper Air Network

The GRUAN consists of a global collection of stations undertaking high quality, metrologically traceable measurements of the atmospheric column. Presently, data streams are limited to the Vaisala RS-92 radiosonde product.

Institution performing the assessment:
Maynooth University

Geographical area:
Pallas-Sodankylä, Barrow, Ny-Alesund stations

Time:
2007/2009/2006- ongoing

Data owners:
DWD, GRUAN WG

www.gruan.org

ECV/parameters:
Upper Tair, **Upper- Wind speed and direction**, **Upper-Water vapour**

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strength:

The network is of the highest Reference maturity level in all sub-categories.

Key challenges:

None

RNA

Radiosounding network in the Arctic (AMAP and IGRA)

The global radiosonde network was established for operational weather service purposes. The radiosounding data collection included in this assessment is the Integrated Global Radiosonde Archive (IGRA), administered by the National Center for Environmental Information (NCEI).

Institution:
Finnish Meteorological Institute

Geographical area:
~70 terrestrial pan-Arctic stations

Time:
varying setup starting from 1940-1950 – ongoing

Data owners:
National Meteorological Surveys

URL: https://public.wmo.int/en/programmes/global-observing-system

ECV/parameters:
Upper Tair, Upper Wind speed and direction, Upper Water vapour

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
Integrated Global Radiosonde Archive (IGRA) (Soundings from Canada, United States, Greenland, Faroe Islands, Norway, and Finland)	5	4			3	5	3	3	4	1	3	2
Integrated Global Radiosonde Archive (IGRA) (Soundings from Russia))	5	2			3	5	3	3	4	1	2	2

Key strengths:

Data storage, access, updates version control and preservation; observing system sustainability

Key challenges:

Metadata; documentation; uncertainty characterisation; and user feedback

GOS-surface met

WMO Global Observing System - Surface meteorological holdings

The observing system includes collated global, regional and national level surface-based meteorological holdings.

Institution performing the assessment:

Maynooth University

Geographical area:
~ 3000 stations

Time:
1807- ongoing

Data owners:
Maynooth University, NOAA NCEI, UK Met Office, UK STFC (on behalf of Copernicus)

URL: contact for data Peter Thorne, peter.thorne@mu.ie

ECV/parameters:
Surface temperature, **Surface humidity**, **Precipitation**, **Snow cover**, **Surface pressure**, **Surface winds**, Various ancillary

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:

Collection level metadata; data management; sustainable funding support

Key challenges:

Metadata standards; knowledge of measurement methodologies; uncertainty characterisation; site representativeness.

TERRESTRIAL OBSERVING SYSTEMS

Fluxnet
Monitoring of greenhouse gas fluxes

The network monitors the greenhouse gas fluxes in the Arctic. Two separate observational platforms are considered, i.e. the network of eddy-covariance (EC) flux sites in high northern latitudes, and the tall tower observations of atmospheric greenhouse gas mixing ratios.

Institution performing the assessment:
The University of Sheffield, Max-Planck-Institute for Biogeochemistry

Geographical area:
129 stations in pan-Arctic domain

Time:
different setup started from 1993 - ongoing

Data owners:
Multiple institutions
URL: http://ameriflux.lbl.gov/, https://fluxnet.ornl.gov/

ECV/parameters:
CO_2, CH_4, other greenhouse gases, Snow depth, Soil temperature

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:

Metadata provision; documentation; data storage and preservation

Key challenges:

FoG

World Glacier Monitoring Service-Fluctuations of Glaciers Database

The World Glacier Monitoring Service (WGMS) collects standardized observations on changes in mass, volume, area and length of glaciers with time (glacier fluctuations), as well as statistical information on the distribution of perennial surface ice in space (glacier inventories). It covers glaciers worldwide, but the spatial information collected here has been restricted to the glacier regions within the AMAP area..

Institution performing the assessment:
Universidad Politécnica de Madrid (Dept. of Mathematics Applied to ICT)

Geographical area:
pan-Arctic

Time:
1959-ongoing

Data owners:
World Glacier Monitoring System
URL: http://wgms.ch/fogbrowser/

ECV/parameters:
Glaciers Area, elevation change, **mass change**

Lack of metadata standards; uncertainty characterisation; user feedback; lack of observing system sustainability

Maturity Assessment Matrix:

Observing system		**Data collections**		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	**2**	**3**	**4**	**5**	**6**	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
Glacier-wide surface mass balance (winter, summer, annual)			3	3	3	na	5	3	3	3	2	3
Point surface mass balance (winter, summer, annual)			3	3	3	na	5	3	3	3	2	3
Point snow density (winter, summer, annual)			3	3	3	na		3	3	3	2	3

Key strengths:

Metadata standards; data management; observing system sustainability

Key challenges:

Documentation; uncertainty characterisation

GlaThiDa

Glacier Thickness Database (GlaThiDa)

The World Glacier Monitoring Service (WGMS) collects standardized observations on glacier ice-thickness data. It covers glaciers worldwide, but the spatial information collected here has been restricted to the glacier regions within the AMAP area.

Institution performing the assessment:
Universidad Politécnica de Madrid (Dept. of Mathematics Applied to ICT)

Geographical area:
pan-Arctic

Time:
1955-2015

Data owners:
World Glacier Monitoring System
URL: http://www.gtn-g.org/data_catalogue_glathida/

ECV/parameters:
Glaciers thickness

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:

Data management; observing system sustainability

Key challenges:

Documentation, in particular a formal validation report; uncertainty characterisation; user feedback; site representativeness

GLISN

Greenland Ice Sheet Monitoring Network

The GLISN network has established a real-time sensor array of 33 stations to enhance and upgrade the performance of the scarce existing Greenland seismic infrastructure for detecting, locating, and characterizing glacial earthquakes and other cryo-seismic phenomena, and contribute to our understanding of Ice Sheet dynamics.

Institution performing the assessment:
GEUS

Geographical area:
19 points within 61.2-81.6 N, 29.2-57.2 W

Time:
2009-ongoing

Data owners:
GEUS, IRIS, GEOFON
URL: glisn.info

ECV/parameters:
Earthquakes

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strength:

Metadata; documentation; routine quality monitoring; data storage, access and preservation; provision of science and expert support; site representativeness

Key challenges:

Validation and uncertainty quantification; user feedback, updates and version control; lack of long-term funding support

NNSN
Norwegian National Seismic Network

Real-time Broadband network of seismographs. Spatial coverage varies and is limited to land areas in the Arctic. From 1992, all stations, except NORSAR arrays, were formally assembled in the national network. The Norwegian oil industry has supported the operation of seismic stations at UiB since 1984.

Institution performing the assessment:
University of Bergen

Geographical area:
~50 points in Norway, Svalbard and adjacent ocean areas

Time:
1905-ongoing

Data owners:
University of Bergen
URL: skjelv.no

ECV/parameters:
Earthquakes

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
Seismograms	6	6			6	6	6	6	5	6	4	5
Earthquake catalog (event time, location, depth, magnitude, etc)			6	4	6	5	6	6	5	6	4	5

Key strengths:

Formal description of measurement methodology; uncertainty characterisation; data management; observing system sustainability

Key challenges:

User feedback

GNET

The Greenland GPS Network

GNET is constructed to measure the impact of climate cycles and climate change on ice mass balance in the world's second largest ice sheet. The primary objective of GNET is to "weigh" the Greenland ice sheet by measuring the earth's instantaneous elastic response to contemporary changes in ice mass.

Institution performing the assessment:
Technical University of Denmark

Geographical area:
~60 points around the Greenland

Time:
1995-2017

Data owners:
Technical University of Denmark
URL: for data contact Shfaqat Abbas Khan, abbas@space.dtu.dk

ECV/parameters:
Glacier and Ice sheets mass change, Land uplift

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths:

The network performance fully corresponds to highest Reference maturity level.

Key challenges:

None

Arctic-HYCOS

Hydrological Arctic observing system

The Arctic-HYCOS is an observation system under implementation by the National hydrological services in Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden and US, in collaboration with The Global Runoff Data Centre and the WMO. Arctic-HYCOS is intended to serve as a component of the World Hydrological Cycle Observing System network, providing river discharge data.

Institution performing the assessment:
Swedish Meteorological and Hydrological Institute

Geographical area:
pan-Arctic, 427 gauge stations

Time:
1877-ongoing

Data owners:
GRDC
URL:
http://www.bafg.de/GRDC/EN/04_spcldtbss/41_ARDB/arcticHycos.html?nn=201698

ECV/parameters:
river discharge

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strength:

Metadata standards and file level provision; data storage and access; observing system sustainability

Key challenges: Documentation; uncertainty quantification; user feedback

RGI

Randolph Glacier Inventory (RGI)

The RGI is a global inventory of glacier outlines. It is supplemental to the Global Land Ice Measurements from Space initiative (GLIMS). Future updates are planned to the RGI and the GLIMS Glacier Database in parallel during a transition period. All these data are incorporated into the GLIMS Glacier Database.

Institution performing the assessment:
Universidad Politécnica de Madrid (Dept. of Mathematics Applied to ICT)

Geographical area:
pan-Arctic

Time:
2012

Data owners:
NSIDC
URL: http://www.nsidc.org/RGI

ECV/parameters:
Glaciers Area, elevation change, glacier outlines, glacier topography

Maturity Assessment Matrix:

Observing system		**Data collections**		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	**2**	**3**	**4**	**5**	**6**	Not applicable or no data provided

Key strengths: Data management; observing system sustainability

Key challenges:

Metadata provision; documentation; uncertainty characterisation; site representativeness

MULTI-DISCIPLINARY OBSERVING SYSTEMS

AIRMETH

Airborne Measurements of Methane Fluxes

AIRMETH is airborne Methane Fluxes flight campaigns in the Mackenzie Delta, North Slope of Alaska and Lena river delta. Three campaigns took place during the growing seasons and in spring (Lena delta). The campaigns consisted of horizontal tracks at ~40 m – 80 m above ground for greenhouse gas flux and vertical profile flights within and beyond the atmospheric boundary layer

Institution performing the assessment:
Helmholtz Centre Potsdam German Research Centre for Geosciences

Geographical area:
Mackenzie Delta, North Slope of Alaska and Lena river delta

Time:
2012-2014, 2016

Data owners:
Helmholtz Centre Potsdam German Research Centre for Geosciences
URL: contact for data torsten.sachs@gfz-potsdam.de

ECV/parameters:
Greenhouse gas and heat fluxes (CH_4, CO_2, latent and sensible heat), **Greenhouse gas concentrations** (CH_4, CO_2, H_2O), **air temperature**, **air pressure**

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
vertical_profiles_Polar 5	2	3			2	4	3	2	4	1	2	2
vertical_profiles_Helipod	2	3			2	4	3	2	4	2	2	2
turbulent_fluxes_Polar5	2	3			4	4	3	2	4	3	2	2
flux_maps_Polar5			1	2	4	2	1	2	4	3	1	1

Key strengths:

Observing system sustainability and site representativeness; file level metadata

Key challenges:

Data management; Uncertainty handling; documentation

GEMP: Greenland Ecosystem Monitoring Programme

The GEM programme is conducted at three sites in Greenland. It consists of five sub-programmes GlacioBasis, ClimateBasis, BioBasis, MarineBasis and GeoBasis. The programme is designed to quantify climate change and ecosystem responses in Greenland. For this report only the marine programme in East Greenland was assessed. This sub-programme for physical ocean data program consists of a fixed mooring combined with a repeated CTD transect every year in August.

Institution performing the assessment:
Aarhus University

Geographical area:
Coastal waters East Greenland (74 N 21 W) and West Greenland (64 N; 51 W and 69 N; 53 W).

Time:
2003- ongoing.

Data owners:
Aarhus University
URL: http://data.g-e-m.dk/

ECV/parameters:
Sea surface temperature, **Sub surface temperature**, **Sea surface salinity**, **Subsurface salinity**, **Inorganic nutrients**, **total alkalinity and total inorganic carbon**, **zoo- and phytoplankton composition**, **Sea ice cover**, **sea ice and snow thickness.**

The full GEM programme measures several 100's of variables and a full list cannot be presented here.

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
marinebasis	3	2			2	1	1	2	1	1	2	2
inorganic nutrients	5	4			2	1	1	2	3	1	1	1
total alkalinity and total inorganic carbon	3	3			1	1	1	2	3	1	1	1
plankton composition	1	1	1	1	1	1	1	2	3	1	1	1
Temperature	1	2			1	1	1	2	3	1	1	2
salinity	1	2			1	1	1	2	3	1	1	2
inorganic nutrietns (N, P and Si)	2	1			2	1	1	2	3	1	1	2
phytoplankton, zooplankton	1	1	1	1	1	1	1	2	3	1	1	2
Primary production	1	1	1		1	1	1	2	3	1	1	1
sea ice cover	1	1	1		1	1	1	2	3	1	1	2
Sea ice and show thickness	1	1			1	1	1	2	3	1	1	1

Key strengths:

Observing system sustainability; data access and preservation, ecosystem focus

Key challenges:

Metadata, documentation and uncertainty handling.

Hornsund

Meteorological and cryospherical measurements at the Polish Polar Station Hornsund, Svalbard (WIGOS 01003)

Polish Polar Station Hornsund (WMO 01003) is located on the northern shore of Hornsundfjord on Wedel Jarlsberg Land in SW Spitsbergen. It conducts year-round observations and measurements. Meteorological data in the form of SYNOP are sent every hour to WMO database.

Institution performing the assessment:
Institute of Geophysics Polish Academy of Sciences

Geographical area:
77°00′N 15°33′E

Time:
1982 - ongoing

Data owners:
Institute of Geophysics Polish Academy of Sciences
URL: hornsund.igf.edu.pl

ECV/parameters:
Tair, **wind speed and direction**, **Water vapour**, **Air Pressure**, **Precipitation**, **cloud cover and type**, **radiation budget, snow depth**, **spatial snow cover**, **Snow Water Equivalent**, **Frontal position of tidewater glaciers**

Maturity Assessment Matrix:

Observing system		**Data collections**		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	**2**	**3**	**4**	**5**	**6**	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
Long term PPS_Hornsund_Precipitation	1	1	2	2	2	1	5	3	4	3	1	2
Long term PPS_Hornsund_Water vapor	3	3	3	3	2	2	5	3	3	2	2	2
Long term PPS_Hornsund_Wind speed and direction	3	3	3	3	2	2	5		3	2	2	2
Long term PPS_Hornsund_Air Pressure	3	3	3	3	2	2	5	3		2	2	2
Long term PPS_Hornsund_Total radiation	1	3		3	2	2	5	3	3	2	2	2
Long term PPS_Hornsund_Cloud cover, cloud type	1	1	2	1	1	2	5	3	3	2	2	2
Long term PPS_Hornsund_Air temperature	3	3	3	3	2	2	5	3	3	3	2	2
Long term PPS_Hornsund_The meteorological station 01003_manual obs.	1	2					5	6	5	2		2
Snow depth, SWE, spatial extent (21 points)	1	1	3	2	2	1	5	3	3	3	2	2
Front positions of tidewater glaciers in Hornsund (S Svalbard)	2	3			2	2		1	1	3	2	2
Snow cover - Hornsund glaciers	2	3			2	2		1	1	3	2	2

Key strengths:

Observing system sustainability and metadata

Key challenges:

Documentation; uncertainty characterisation; user feedback, record updates and version control

IMR BSWS

IMR Barents Sea Winter Survey

The survey is based upon in-situ measurements from scientific vessels. It provides a range of interdisciplinary observations and makes these available mainly towards advice to fisheries management and various applied research projects. It is less broad than Barents Sea Ecosystem Survey and more focused on the main commercially harvested fish stocks.

Institution performing the assessment:
Institute of Marine Research, Norway

Geographical area:
68-80 N, 7-56 E..

Time:
1976-ongoing

Data owners:
Norwegian Marine Data Centre
URL: contact for data post@hi.no

ECV/parameters:
Sea surface temperature, sea subsurface temperature, Sea surface salinity, Sea subsurface salinity, Sea surface current, Sea subsurface current, mineral nutrients, mineral carbon, dissolved organic carbon, particulate phosphorous, zooplankton, Fish characteristics, Air temperature, wind speed and direction.

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Missing info on the different data collections

Key strength:
Data storage, access and preservation; long-term sustainable funding support
Key challenges:
Metadata standards; all aspects of documentation and uncertainty characterisation; version control and provision of sustained scientific and expert support.

IMR-PINRO

IMR-PINRO Ecosystem Survey

The survey is based upon in-situ measurements from 3 scientific vessels. It provides a broad range of interdisciplinary observations and makes these available towards advice to fisheries management and various applied and more basic research projects.

Institution performing the assessment:
Institute of Marine Research, Norway – Polar Institute of Fishery and Oceanography, Russia

Geographical area:
68-82 N, 5-60 E.

Time:
2004-ongoing

Data owners:
Norwegian Marine Data Centre

URL: contact for data post@imr.no, elena.eriksen@imr.no

ECV/parameters:
Seas surface temperature, **Seas subsurface temperature**, **Seas surface salinity**, **Sea subsurface salinity** Surface current, Subsurface current, mineral nutrient, Mineral carbon, Dissolved organic carbon, zooplankton, **fish characteristics**, benthos, mammals, Tair, wind speed and direction, sea surface pressure

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
IMR-PINRO Ecosystem Survey Hydrography	2	2	3		2	2	4	3	4	2	2	3
IMR-PINRO Ecosystem Survey Nutrients	2	2	2	2	2	2	3	2	4	2	2	3
IMR-PINRO Ecosystem Survey Fish	2	2	1	1	2	1	1	2	4	1	2	2

Key strengths:

Data storage, access and preservation; long-term funding support

Key challenges:

Metadata standards for fish survey data collection; all aspects of documentation and uncertainty characterisation for all data collections assessed; version control; availability of sustainable scientific and expert support

NIVA BSFB

NIVA Barents Sea Ferry Box

The Barents Sea Ferry Box system is a suite of sensors installed on a ship of opportunity, the M/S Norbjørn, that makes ~ 30 roundtrip voyages between Tromsø (Norway) and Longyearbyen (Svalbard) every year. Some voyages make stops at Bear Island and Ny Ålesund (Svalbard).

Institution performing the assessment:
Norwegian Institute for Water Research

Geographical area:
sections between 69.67-78.92, 11.91-19.11 E

Time:
2008 ongoing

Data owners:
Norwegian Institute for Water Research
URL: https://www.niva.no/en/water-data-on-the-web/ferrybox-ships-of-opportunity

ECV/parameters:
SbT, **SbS**, **O_2**, **pCO_2**, **pH**, **OceanColour, Wind speed and direction**, **Hyperspectral radiance/irradiance**

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
NIVA FerryBox_sea surface salinity	6	3			2	5	4	3	3	4	2	6
NIVA FerryBox_sea surface temperature	6	3			2	5	4	3	3	4	2	6
NIVA FerryBox_chlorophyll a fluorescence	6	3			3	5	4	3	3	4	2	
NIVA FerryBox_turbidity	5	3			2	5	4	3	3	4	2	6
NIVA FerryBox_dissolved oxygen	2	3			2	5	4	3	3	4	2	6
NIVA FerryBox_sea surface pH	5	3			2	3	4	3	3	3	2	6
NIVA FerryBox_sea surface pCO2	5	3			2	3	4	3	3	4	2	4
NIVA FerryBox_radiance/irradiance	6	3			2	6	3	3	4	4	5	6
NIVA FerryBox_wind speed/direction (true)	1	3		2		6	3	3	4	4	2	6

Key strengths:

Observing system sustainability; traceability and quality management for many data collections, measurement series user guidance;

Key challenges:

Comparability and uncertainty quantification; data storage, user feedback, updates and version control.

PEEX

PEEX (Pan-Eurasian Experiment)

PEEX initiated in 2012, is an international, multidisciplinary, multiscale program. PEEX is aimed to establish an *in situ* observation network, which would cover environments from the Arctic coastal regions, tundra to boreal forests, from pristine to urban megacities.

Institution:
University of Helsinki

Geographical area:
11 stations along Russian Subarctic and Arctic region

Time:
different setup starting from 1930 - ongoing

Data owners:
University of Helsinki, Earth Cryosphere Institute SB-RAS, University of Eastern Finland
URL: https://peexdata.atm.helsinki.fi

ECV/parameters:
Air temperature, **Air humidity**, **Precipitation**, **Wind speed and direction**, **Soil Temperature**, **Ground temperature (bore hole)**

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
Air temperature	2	2	1	1	2	1	3	3	3	2	2	2
Relative humidity, wind direction and speed, precipitation	2	2	1	1	2	1	3	3	3	2	2	2
Temperature profiles of the soil/peat layers, and soil/peat temperature profile down to the bed rock (bore hole)	2	2	1	1	2	1	3	3	3	2	2	2

Key strengths:

Sustainable funding support; metadata standards; data preservation.

Key challenges:

Data management and provision to users; documentation; uncertainty characterisation.

PROMICE

Programme for Monitoring of the Greenland Ice Sheet

PROMICE is operated by the GEUS in collaboration with the DTU Space and the *Greenland Survey* (Asiaq). The PROMICE station network currently consists of 22 automatic weather stations (AWS), of which 19 are on the ice sheet proper.

Institution performing the assessment:
Geological Survey of Denmark and Greenland

Geographical area:
Eight melt regions of the Greenland ice sheet

Time:
2007-ongoing

Data owners:
Geological Survey of Denmark and Greenland

URL: www.promice.dk.

ECV/parameters:
Tair, **Relative humidity**, **Wind speed and direction**, **Short/Longwave budget**, **Pressure**, Surface elevation change, **ice surface ablation**, ice velocity, mass balance, grounding line location, ice shelf thickness, topography

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
PROMICE Air temperature 2m	1	1			2	3	1	3	5	4	1	3
PROMICE Wind speed and direction 2m	1	3	1		2	3	1	3	5	4	1	3
PROMICE air pressure	1	3	1		2	3	1	3	5	4	1	3
PROMICE Shortwave radiation budget	5	6			2	3	1	3	5	4	1	3
PROMICE Longwave radiation budget	5	6	1		2	3	1	3	5	4		3
PROMICE Relative humidity	1	3	1		2	3	1	3	5	4	1	3
PROMICE ice surface ablation	6	6	1	2	2	4	1	3	5	4	4	3

Key strength:

File level metadata provision; formal description of measurement methodology; traceability and comparability for radiation measurements; data management and provision; long-term observing system sustainability and site representativeness

Key challenges:

Lack of metadata standards; no validation report; uncertainty characterisation for non-radiation data collections; provision of a user feedback mechanism

Sodankylä

Meteorological and cryospheric observations at the Sodankylä station, Finland.

At the FMI Sodankylä station is automatic meteorological station located in two sites: forest site and bog site. It provides precipitation, air temperature and snow depth measurements with 10–min frequency.

Institution performing the assessment:
Finnish Meteorological Institute

Geographical area:
Pallas-Sodankylä station (67.36663N 26.62901E)

Time:
2006(forest)/2010 (bog) - ongoing

Data owners:
Finnish Meteorological institute

http://litdb.fmi.fi/luo0015_data.php

ECV/parameters:
Tair, **Precipitation**, **Snow Depth, Snow depth**, **Snow water equivalent**, **Soil temperature**, S**oil dielectric constant**

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

DATA COLLECTIONS	UNCERTAINTY HANDLING						METADATA			DOCUMENTATION		
	Traceability	Comparability	Standards	Validation	Uncertainty quantification	Routine quality management	Standard	Collection level	File level	Description of meas. method.	Validation report	User guidance
AWS_precipitation	5	6			3	4	1	3	4	1	2	2
AWS_air temperature	5	6			6	4	1	3	4	1	2	2
snow depth station_Air temperature	3	3			2	2	1	3	4	2	2	2
Soil frost/snow stations_Soil temperature	2	3			3	2	1	3	3	3	2	3
Snow depth stations_snow depth	5	5			6	2	1	3	3	2	2	2
Snow scale SWE_snow water equivalent	2	3			3	1	1	3	3	2	4	2
Manual SYNOP observations_snow depth	2	3			3	2	1	3	3	1	2	2
AWS_Snow depth	3	3				4	1	3	3	1	2	2
Soil frost/snow stations_soil dielectric constant	2	2			2	2	1	3	3	3	2	3
Soil frost/snow stations_snow temperature	2	2			2	2	1	3	3	3	2	3

Key strengths:

Data access; observing system sustainability, uncertainty quantification for most of atmospheric observations

Key challenges:

Metadata standards; documentation; uncertainty quantification for most of snow observations; data storage, user feedback and version control.

Gas-Mix TN

Tower network for atmospheric trace gas mixing-ratio monitoring

This network monitors greenhouse gas fluxes in the Arctic. Two separate observational platforms are considered, i.e. the network of eddy-covariance (EC) flux sites in high northern latitudes, and the tall tower observations of atmospheric greenhouse gas mixing ratios.

Institution performing the assessment:
Max-Planck-Institute for Biogeochemistry

Geographical area:
~ 16 stations in pan-Arctic region

Time:
different setup starting from 1971- ongoing

Data owners:
Site specific owners
URL: numerous sites i.e. https://oao.exeter.ac.uk/?page_id=9

ECV/parameters:
Air temperature, Humidity, Wind, CO2, CH4, other greenhouse gases, Snow cover

Maturity Assessment Matrix:

Observing system		Data collections		
Data management	**Sustainability**	**Uncertainty handling**	**Metadata**	**Documentation**
Storage	Scientific and expert support	Traceability	Standard	Formal description of measurement methodology
Access	Funding support	Comparability	Collection level	Formal validation report
User feedback	Site representativeness	Standards	File level	Formal measurement series user guidance
Updates to record		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

1	2	3	4	5	6	Not applicable or no data provided

Key strengths: Metadata standards and provision at the collection level; uncertainty characterisation; version control and data preservation

Key challenges:

Documentation; data storage, access and user feedback; observing system sustainability

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