Exploitation of the existing Arctic observing systems under the INTAROS project – WP2

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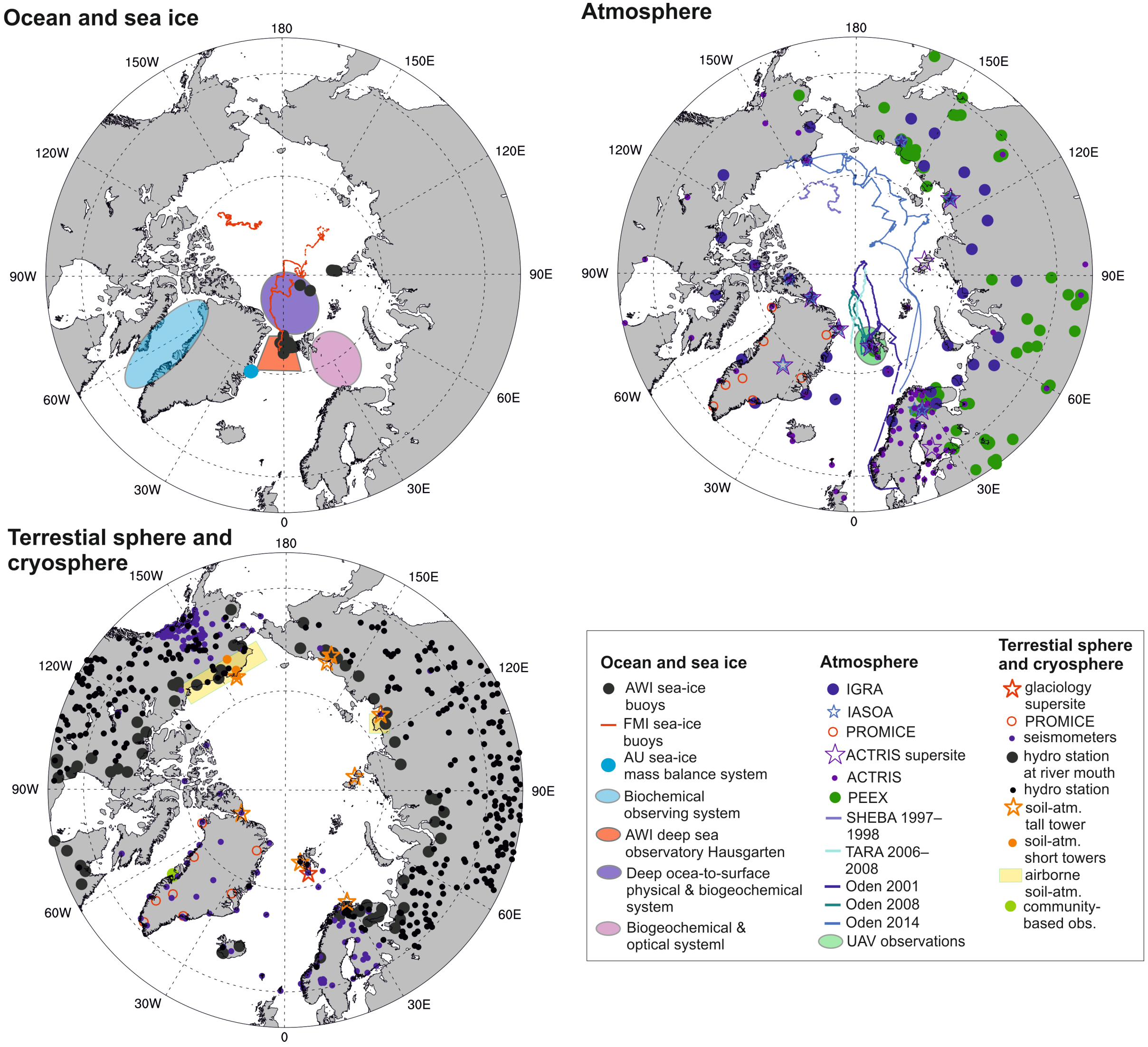
Overall objective of WP2



Assess, exploit, and standardize the existing Arctic observing systems

26 EU partners

Specific objectives of WP2

Task 1. Analyze strengths, weaknesses, and gaps of the existing observation networks and databases.

Task 2. Exploit selected datasets in order to increase the quality and number of data products

Task 3. Enhance standardization of data and metadata to ensure that best practices are followed, and integrate sparse in situ data into established networks, preparing their delivery to the iAOS

Task 4. Synthesis and recommendations.

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Task 4. Synthesis and recommendations.

Definitions: IN SITU OBSERVIG SYSTEM

It consists of a data collection component (infrastructure) and a data management component (e-infrastructure).

The data collection component is comprised of multiple sensors either belonging to a common platform (such as tower, mooring, glider, buoy), which can be a single unity or a collection of units forming a network, or installed on a temporary platform (ship, aircraft, UAV, ocean/sea ice/land station).

The data management component includes hardware and software for data repository(s), the data processing, data discovery and visualization services. The management can be centralized in a single institution or distributed among several national institutions, which, in many cases, have agreed on common standards for the data and metadata formats, documentation and management.

Atmospheric observing systems: several of them are international networks, that follow standardized data managements.

Marine observing systems: are more diversified and fragmented, providing more types of data with various degree of standardization. They are usually identified on the basis of the utilized platforms (moorings, floats, gliders,…),

Definitions: IN SITU DATA COLLECTION

It is defined as "a collection of data, or measurement series, that have common characteristics in terms of quality, resolution, and coverage".

In most cases, the instrumentation used to collect the data determines the characteristics of the collection. The instruments applied to collect the data range from manual tools to fully automatized sensors. Hence, a data collection generally includes all the variables measured with a single instrument. In situ data collections also include derived data products which result from processing of individual measurements or composition of multiple measurements. In situ data collections can be surface-, subsurface-, and air-borne.

Different kind of in situ data collections:

1) data from established in situ networks, having regional (or Pan-Arctic) spatial coverage and variable temporal coverage,

2) data from single stations, having local areal coverage and variable temporal coverage,

3) data from field campaigns (land-, ship-, aircraft-, UAV-based measurements), with limited temporal coverage and from point to regional spatial coverage.

Method: Survey

Creation of **3 QUESTIONNAIRES**, to collect the info needed **TO ASSESS**:

A. The Arctic existing in situ observing systems
B. The Arctic in situ data collections: existing and exploited
C. The Arctic satellite products: existing and exploited

The questionnaires were web-based, open to all partners and collaborators through the INTAROS internal web page

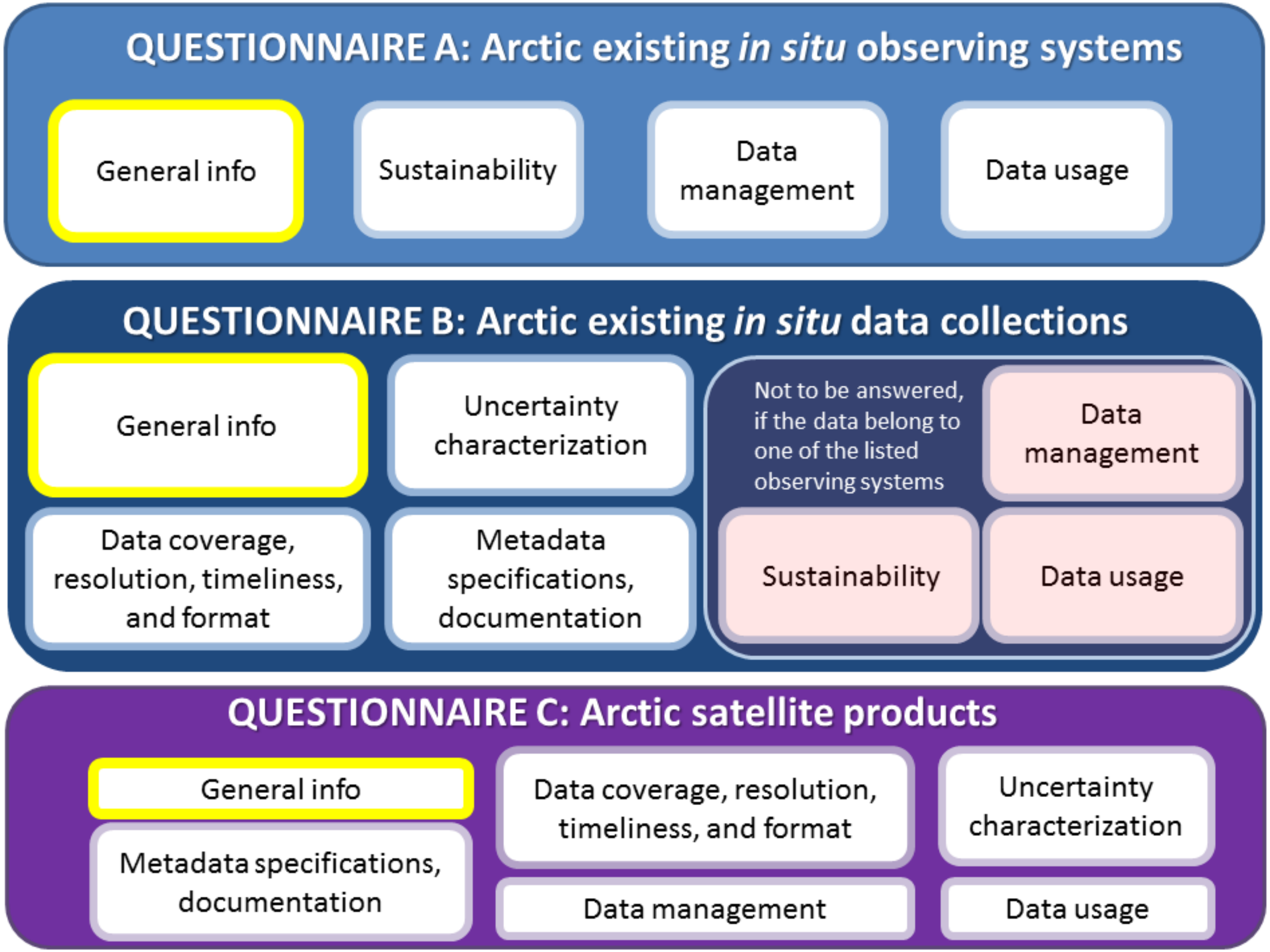
Foundation of the survey

This survey in large part builds upon similar efforts to assess:

- ☐ **climate data record maturity** (under the FP7 CORE-CLIMAX project, FP7 CORE-CLIMAX project. See CORE-CLIMAX Climate Data Record Assessment. Instruction Manual, CC/EUM/MAN/13/002, EUMETSAT, 2013),
- ☐ **measurement series maturity** (under the H2020 GAIA-CLIM project. See Thorne et al., Making better sense of the mosaic of environmental measurement networks: a system-of-systems approach and quantitative assessment, Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2017-29, in review, 2017),
- ☐ **data management maturity** of the Polar observing systems (under the H2020 EU-PolarNet project. See Deliverable No. 3.1 - Survey of the existing Polar Research data systems and infrastructures, including their architectures, standard/good practice baselines, policies and scopes, 2016),

However, it addresses different data and domains, namely **Arctic in situ and satellite based observations from the ocean, atmospheric, terrestrial, and cryo- spheres.**

Content of the survey



QUESTIONNAIRE A: Arctic existing *in situ* observing systems

- General info
- Sustainability
- Data management
- Data usage

QUESTIONNAIRE B: Arctic existing *in situ* data collections

- General info
- Uncertainty characterization
- Data coverage, resolution, timeliness, and format
- Metadata specifications, documentation

Not to be answered, if the data belong to one of the listed observing systems

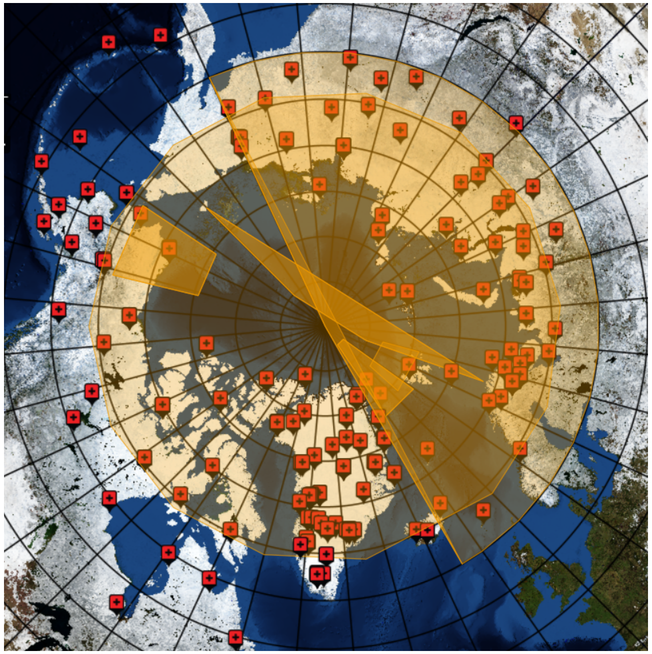
- Data management
- Sustainability
- Data usage

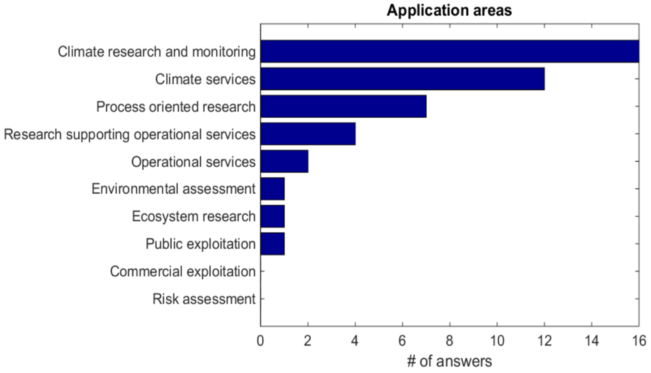
QUESTIONNAIRE C: Arctic satellite products

- General info
- Metadata specifications, documentation
- Data coverage, resolution, timeliness, and format
- Data management
- Uncertainty characterization
- Data usage

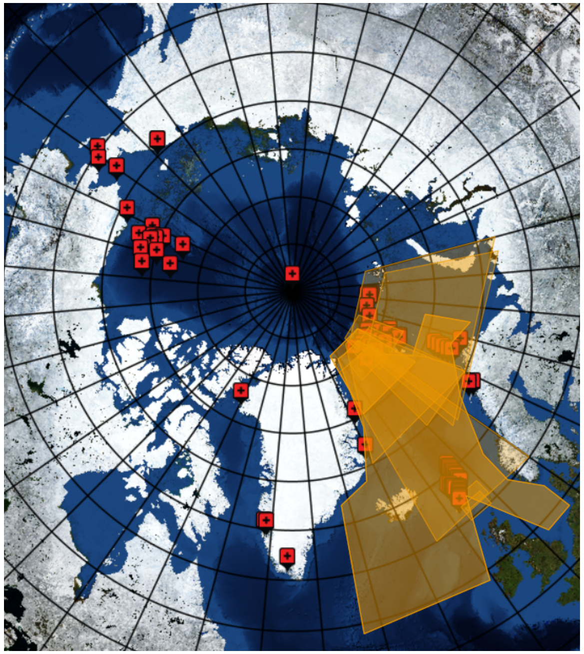
Overview of surveyed data:

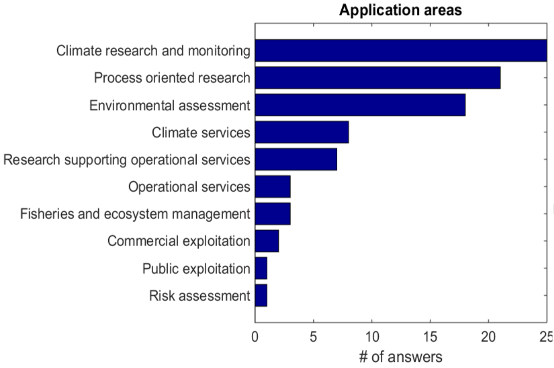
Atmosphere



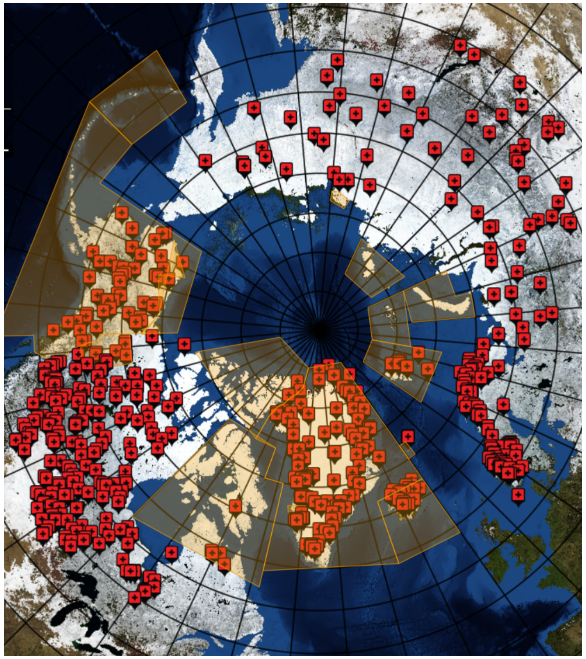


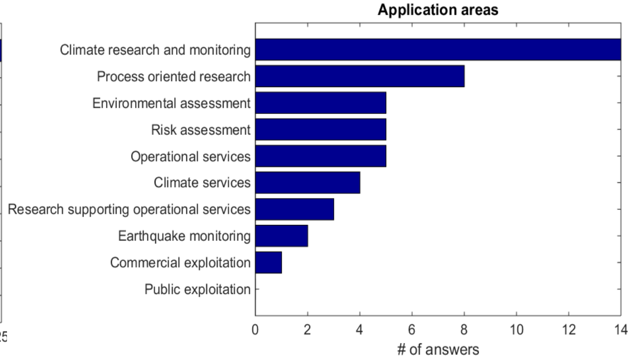
Ocean and sea ice



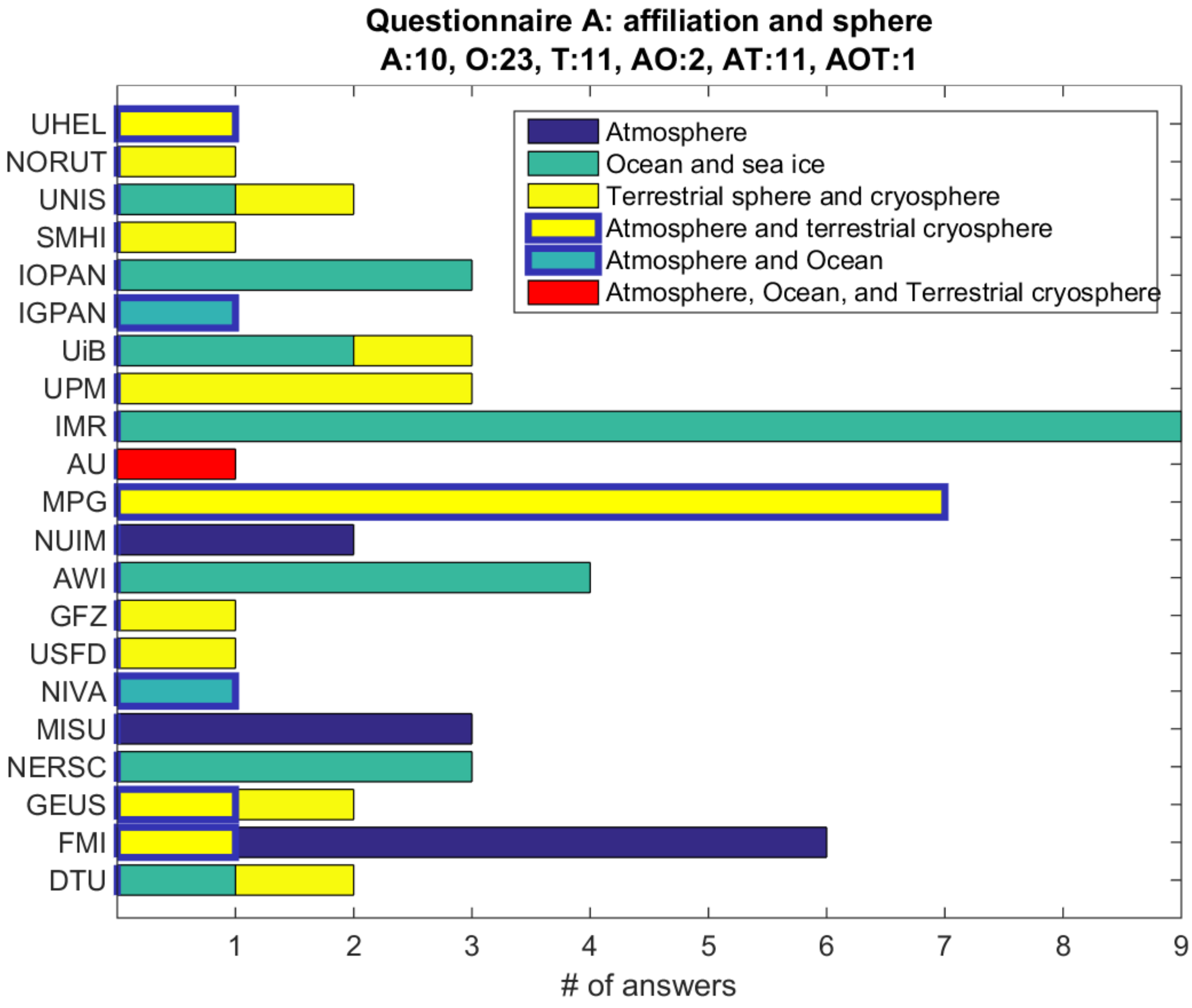


Land and terrestrial cryosphere

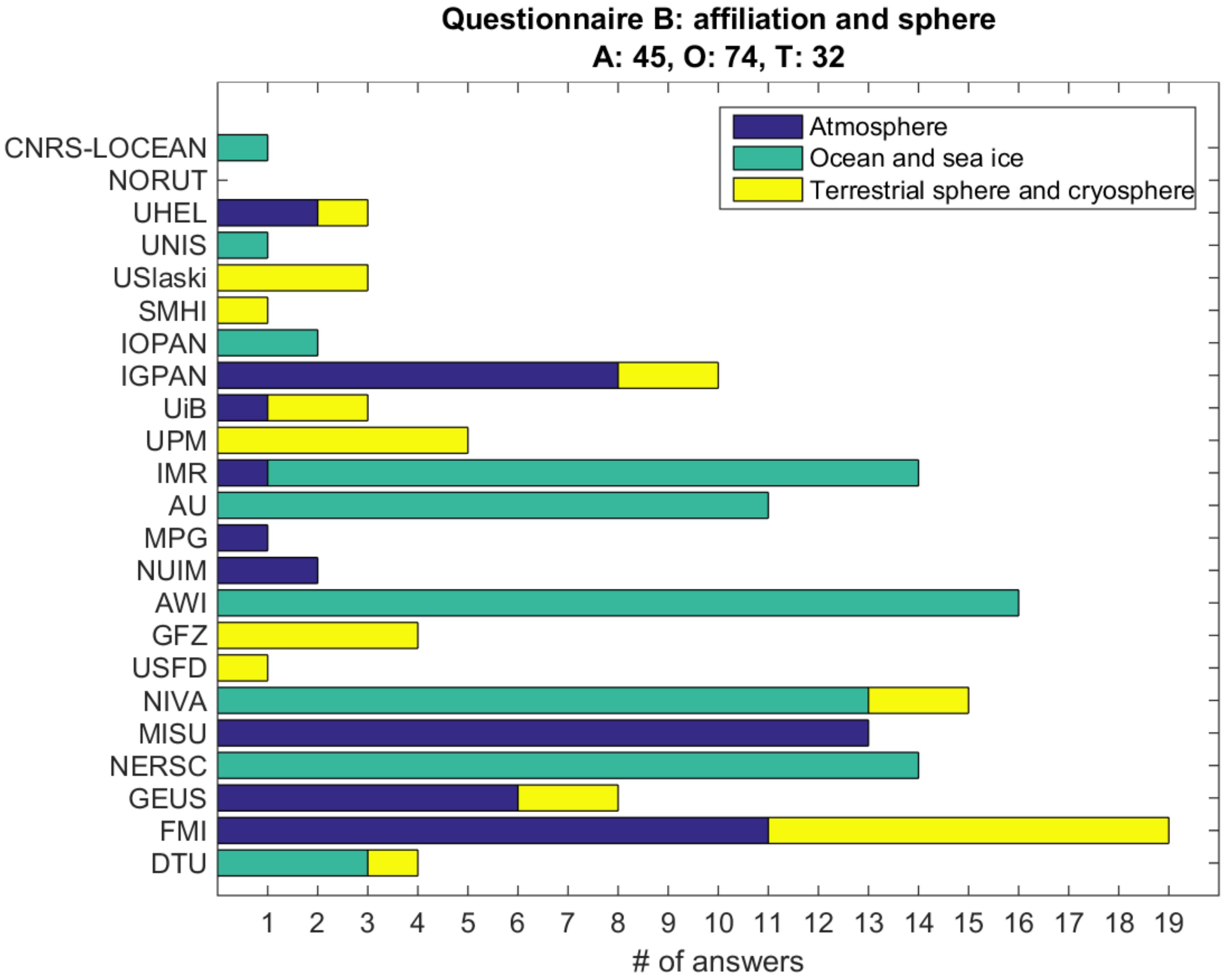




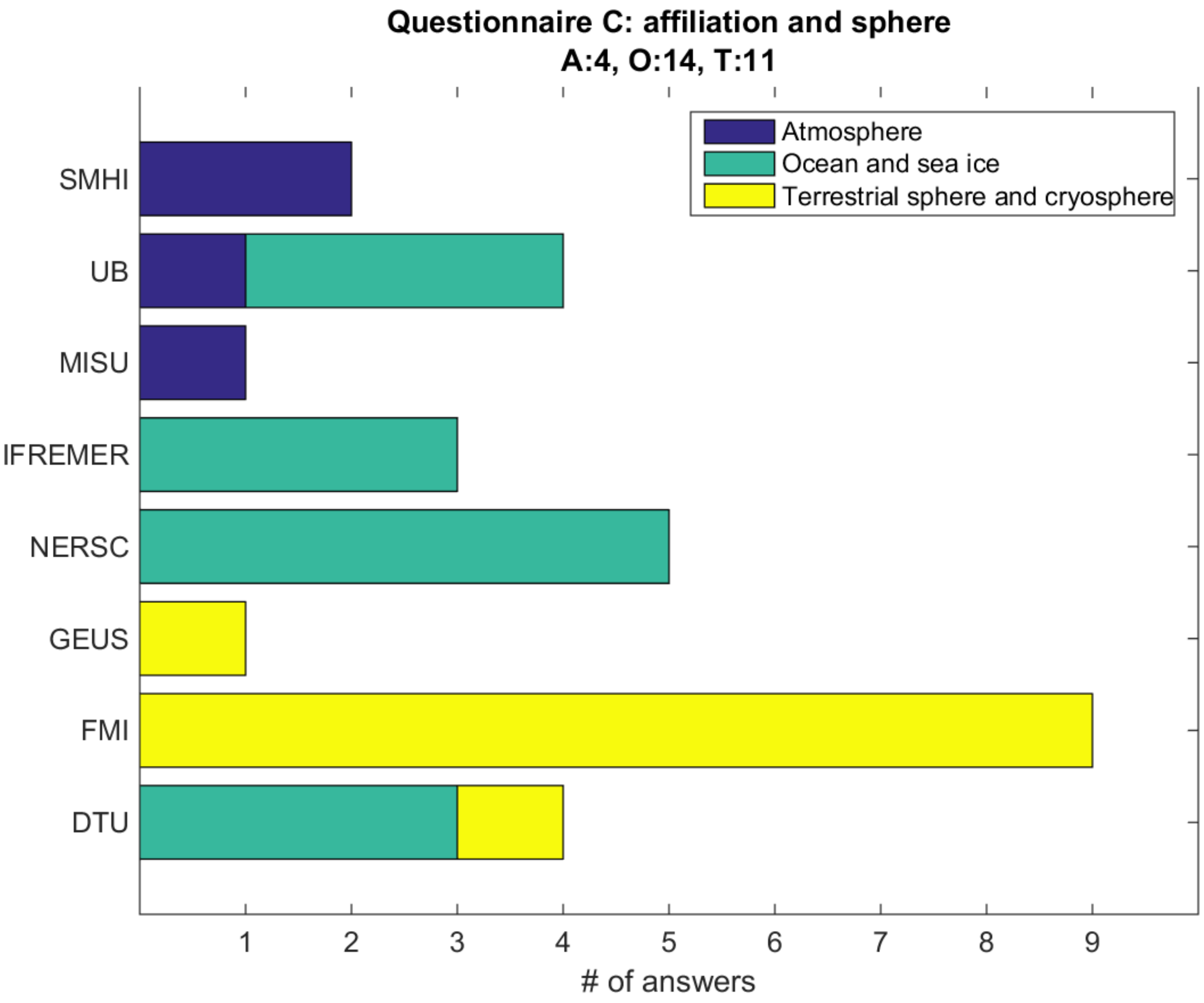
Survey overview. QA: 58 answers



Survey overview. QB: 149 answers



Survey overview. QC: 29 answers



Gap analysis: Data Specification vs Data Requirements

Requirements:

- For **in situ observing systems**, definition of requirements are stated for the spatial and temporal coverage of the systems and are discussed with respect to the scientific and/or monitoring purposes of the systems.
- For **satellite products and in situ data collections**, requirements are defined for data characteristics such as uncertainty and spatio-temporal coverage and resolution. They are taken from the WMO OSCAR database (https://www.wmo-sat.info/oscar/requirements). If OSCAR requirements are inapplicable (because not suitable for non-gridded data, or not tailored to the Arctic domain, or other reasons e.g. just missing), other requirements are described.
- For the sustainability of the observing systems, their data management, data uncertainty, metadata specifications and data documentations, the maturity gaps were defined with respect to the uppermost maturity level 6, in a scale from 1 to 6.

Results: Sustainability and data management

Atmosphere

SUSTAINABILITY

Observing system	Scientific and expert support	Funding support	Site representativeness (for land-based stations)
AC-AHC2 stable wa			
IMR-PINRO Ecosys			
IMR Barents Sea Wi			
Arctic Summer Clou			
Arctic Clouds during			
Norwegian Young S			
Sea State 2015 in situ			
Polarstern in situ fie			
Greenland Ecosyste			
PROMICE Automat			
Greenland Climate			
Radiosounding netw			
Global & regional G			
ICOS			
ACTRIS			
FMI Sodankylä (AW			
GRUAN			
Surface meteorological holdings (GOS)	3	5	1
Tower network for atmospheric trace gas mixing-ratio monitoring	3	3	3
NIVA Barents Sea FerryBox	6	4	
PEEX (Pan-Eurasian EXperiment)	3	5	3
Airborne observations of surface-atmosphere fluxes	4	4	5
Polish Polar Station Hornsund (WIGOS 01003)	4	5	3

DATA MANAGEMENT

Observing system	Data storage	Data access	User feedback	Updates to record	Version control	Long term data preservation
AC-AHC2 stable water isotope measurement stations	2	2	2	2	2	3
						4
						4
						4
						4
						4
						4
						4
						4
						5
						3
						5
						5
						5
						5
						4
GRUAN						5
Surface meteorological holdings (GOS)	6	6	5	4	4	5
Tower network for atmospheric trace gas mixing-ratio monitoring	2 - 4	2	2	3	4	4
NIVA Barents Sea FerryBox	4	3	2	2	2	4
PEEX (Pan-Eurasian EXperiment)	2	2	2	2	2	4
Airborne observations of surface-atmosphere fluxes	2	2	2		2	4
Polish Polar Station Hornsund (WIGOS 01003)	4	3	2	2	2	4

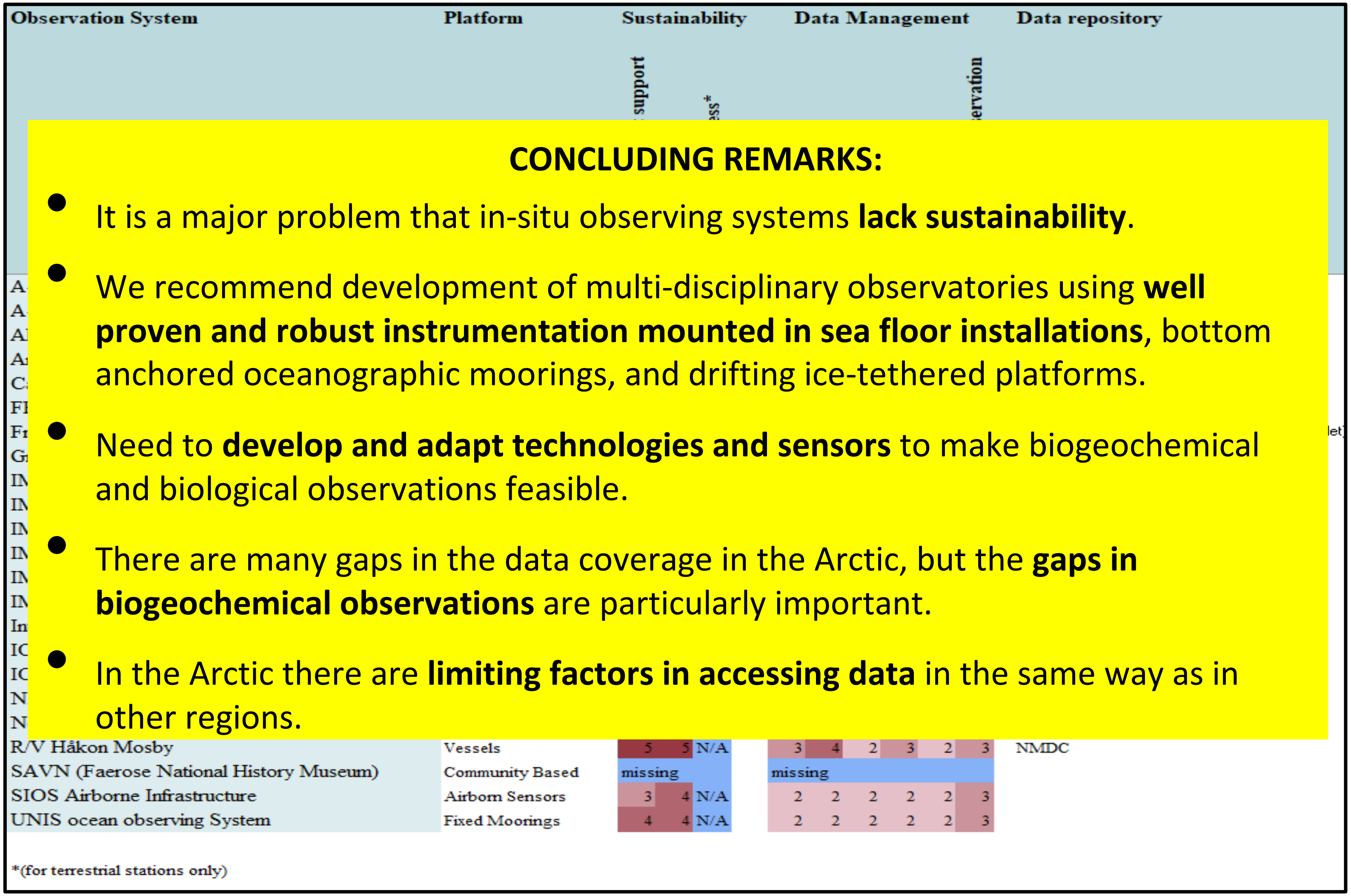
CONCLUDING REMARKS

- There is a severe lack of all types of atmospheric observations over the Arctic Ocean. **Solution:** airborne dropsondes networks or satellite sensors: → development of retrieval methods for satellite atmospheric products should **target the special requirements that pertains to the Arctic**.

- Satellite retrievals rely on a priori information obtained trough models **Solution to improve them**: process studies → **more research-grade observations** (**icebreaker-based field campaigns**).

Results: Sustainability and data management

Ocean and sea ice



Observation System	Platform	Sustainability			Data Management						Data repository
R/V Håkon Mosby	Vessels	5	5	N/A	3	4	2	3	2	3	NMDC
SAVN (Faerose National History Museum)	Community Based	missing			missing						
SIOS Airborne Infrastructure	Airborn Sensors	3	4	N/A	2	2	2	2	2	3	
UNIS ocean observing System	Fixed Moorings	4	4	N/A	2	2	2	2	2	3	

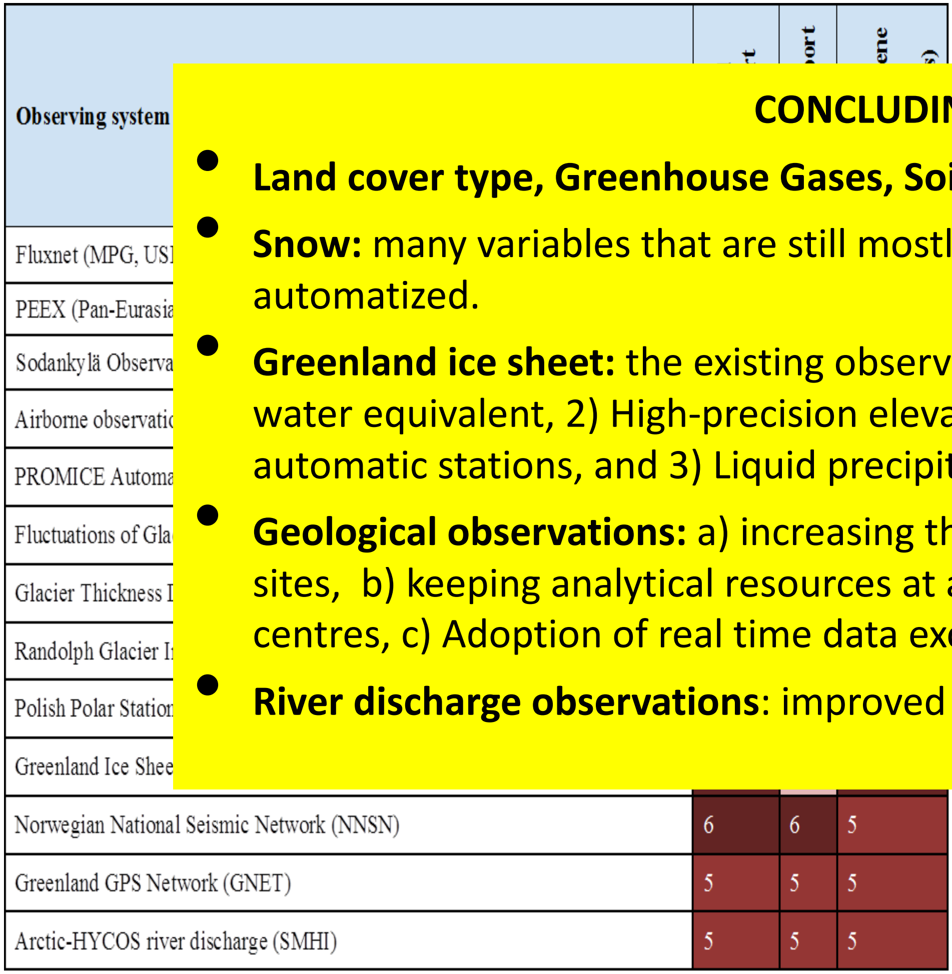
*(for terrestrial stations only)

CONCLUDING REMARKS:

- It is a major problem that in-situ observing systems **lack sustainability**.
- We recommend development of multi-disciplinary observatories using **well proven and robust instrumentation mounted in sea floor installations**, bottom anchored oceanographic moorings, and drifting ice-tethered platforms.
- Need to **develop and adapt technologies and sensors** to make biogeochemical and biological observations feasible.
- There are many gaps in the data coverage in the Arctic, but the **gaps in biogeochemical observations** are particularly important.
- In the Arctic there are **limiting factors in accessing data** in the same way as in other regions.

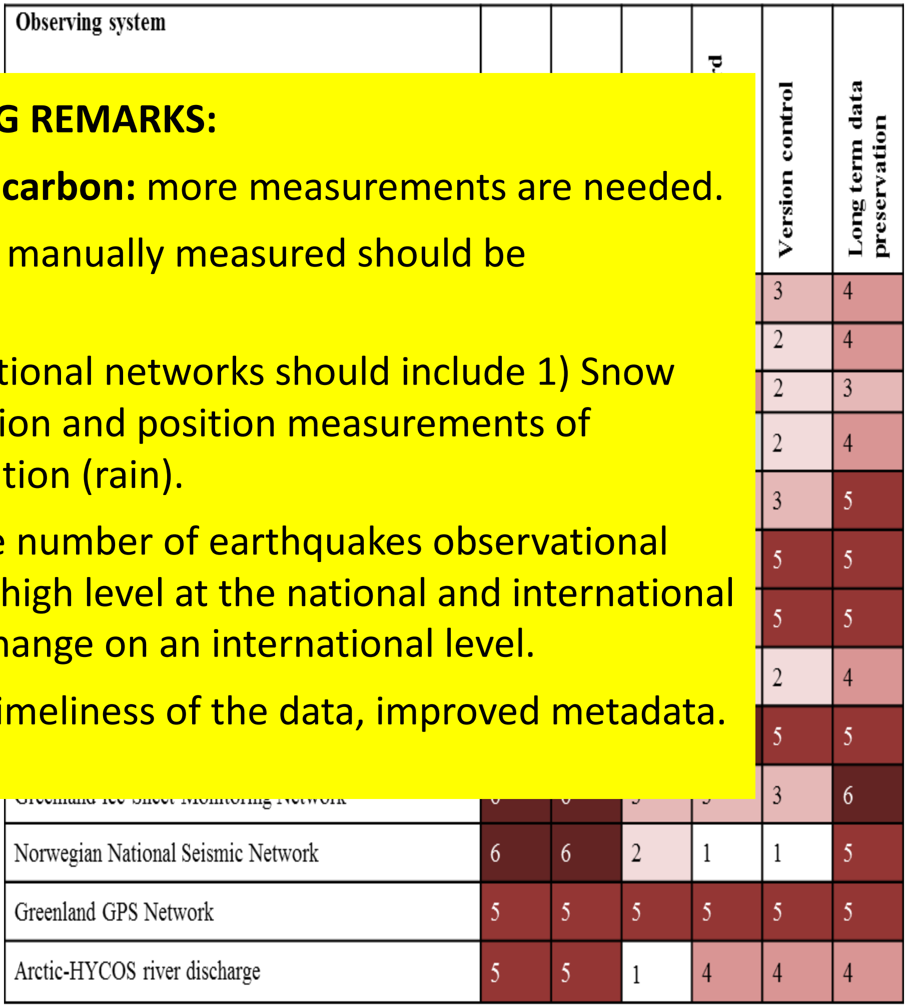
Land and terrestrial cryosphere

SUSTAINABILITY



Observing system	t	ort	ene s)
Fluxnet (MPG, USI			
PEEX (Pan-Eurasia			
Sodankylä Observa			
Airborne observatio			
PROMICE Automa			
Fluctuations of Gla			
Glacier Thickness I			
Randolph Glacier I			
Polish Polar Station			
Greenland Ice Shee			
Norwegian National Seismic Network (NNSN)	6	6	5
Greenland GPS Network (GNET)	5	5	5
Arctic-HYCOS river discharge (SMHI)	5	5	5

DATA MANAGEMENT



Observing system				d	Version control	Long term data preservation
					3	4
					2	4
					2	3
					2	4
					3	5
					5	5
					5	5
					2	4
					5	5
					3	6
Norwegian National Seismic Network	6	6	2	1	1	5
Greenland GPS Network	5	5	5	5	5	5
Arctic-HYCOS river discharge	5	5	1	4	4	4

CONCLUDING REMARKS:

- **Land cover type, Greenhouse Gases, Soil carbon:** more measurements are needed.
- **Snow:** many variables that are still mostly manually measured should be automatized.
- **Greenland ice sheet:** the existing observational networks should include 1) Snow water equivalent, 2) High-precision elevation and position measurements of automatic stations, and 3) Liquid precipitation (rain).
- **Geological observations:** a) increasing the number of earthquakes observational sites, b) keeping analytical resources at a high level at the national and international centres, c) Adoption of real time data exchange on an international level.
- **River discharge observations**: improved timeliness of the data, improved metadata.

WP2 Deliverables

☐ Reports on present observing capacities and gaps **(Task 2.1)** **(31 May 2018)**

D2.1 **Ocean and sea ice**

D2.4 **Atmosphere**

D2.7 **Terrestrial sphere and cryosphere**

☐ Reports on exploitation of existing data **(Task 2.2)** **(31 May 2018)**

D2.2 **Ocean and sea ice**

D2.5 **Atmosphere**

D2.8 **Terrestrial sphere and cryosphere**

☐ Observational gaps revealed by model sensitivity to observations **(Task 2.1)**

D2.12 **Ocean and sea ice (UHAM), Atmosphere (FMI), Terrestrial sphere (MPG)** **(30 November 2018)**

☐ Catalogue of data products and services **(Task 2.3)** **(30 November 2018)**

(Sparse data that trough INTAROS are made accessible via well served data repositories)

D2.2 **Ocean and sea ice**

D2.5 **Atmosphere**

D2.8 **Terrestrial sphere and cryosphere**

Expansion of the assessment

PLAN:

- Inclusion of the Arctic data and observing systems that were not addressed in the firsts reports
- The responses to the survey shall be automatically stored in a web based database, openly accessible, were the results of the assessment are shown through simple plots/tables.
- Whenever new responses are received, the assessment should be updated

This tool will enable the demonstration of the benefits (in terms of gap closure) of the enhancements and expansions of the observing systems.

Resources: **ArcticMap** project funded by the Norwegian Directorate for Environment and Climate

Impacts so far:

- Same methodology applied to scientific and community based programs (**WP2 and WP4**): first time!
- **ARICE** project adopted the survey to monitor the observing systems based on research vessels
- **AOS and INTAROS** had a coordinated effort to evaluate the observational needs In the Arctic
- **AGU**: dedicated session WP2 session with AOS contributors
- **EGU**: dedicated WP2-WP3 session
- **SAON and AMAP**: they support the continuation work in WP2
- **Ministries** (from Denmark and Norway) have given positive feedback to the WP2 assessment

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Thank you for your attention

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Sustainability scores

Scientific and expert support: The degree of scientific and technical expertise that underpins the measurement program.

1. None (No scientific or technical support is available)
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. Technical expertise is available to support operation of the observing system
4. As in (3) + at least two technical experts to secure the measurement program operation
5. *N/A*
6. As in (4) + research and development to ensure that the observing system is based on state of the art technology

Funding support: The long-term financial support that underpins the measurement program.

1. None (No dedicated funding support is evident for the measurement program)
2. Project based funding support available
3. As in (2) + expectation of follow on founding
4. As in (3) + not dependent upon a single investigator or funding line
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) + support for active research and development of instrumentation or applied analysis of the observations

Site representativeness (for terrestrial stations):

1. Unknown
2. *N/A*
3. The site only represents the immediate surrounding environment
4. The site is representative of a broader region around the immediate location
5. As in (4) + the site environment is likely to be unchanged for decades
6. As in (5) + the long-term site representativeness is guaranteed, e.g. due to protected area.

Data management scores

Data storage:

1. Data are not stored in any institutional repository, but in a personal repository.
2. Data are stored in an institutional/departmental repository
3. Data are stored in distributed repositories (institutional and not)
4. Data are stored in a National repository according to legal constraints on their location
5. Data are stored in National data repositories without legal constraints on their location
6. Data are stored in International data repositories

Data access: Level of open distribution of data, documentation of data, and any software to process the data from raw measurement to geophysical variables needed by the users. The highest scores in this category can only be attained for data provided free of charge without restrictions on use and reuse.

1. Unknown
2. Data is available request to trusted users or through supervision by originator
3. Data is available on automated request through originator
4. Data and documentation are available on supervised request through originator
5. Data and documentation are available on automated request through originator
6. As (5) + source data, code and metadata available upon request or automated without any restrictions

User feedback: Level of established mechanisms to receive, analyse and ingest user feedback.

1. None
2. Ad hoc feedback (which may be acted upon)
3. Programmatic feedback (systematic collection of user feedback related to the measurements and dissemination of lessons learnt)
4. As in (3) + consideration of published analyses
5. Established feedback mechanism and international data quality assessment results are considered
6. As in (5) + Established feedback mechanism and international data quality assessment results are considered in continuous data provisions

Data management scores

Updates to record: Level of systems in place to update data records when new observations or insights become available.

1. None (No update is made to the measurement series or data products after initial release)
2. Irregularly following accrual of a number of new measurements scientific exchange and progress or new insights
3. *N/A*
4. Regularly updated with new observations and utilizing input from established feedback mechanism
5. Regularly operationally by stable data provider as dictated by availability of new input data or new innovations
6. As in (5) + initial version of measurement series or data products shared in near real time.

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 under consideration.

1. None
2. Versioning by data collector
3. N/A
4. Version control institutionalized and procedure documented
5. Fully established version control considering all aspects
6. As in (5) + all versions retained and accessible upon request

Long term data preservation: Level of Long Term Data Preservation according to ESA-guidelines (http://earth.esa.int/gscb/ltdp/).

1. None
2. Local archive retained by measurement collector
3. *N/A*
4. Each version archived at an institutional level on at least two media
5. Data, raw data and metadata is archived at a recognized data repository, national archive, or international repository.
6. As in (5) + all versions of measurement series, metadata, software etc. retained, indexed and accessible upon request.

Recommendations

Atmosphere:

- Many surface-based observation systems that exist but were designed for other purposes also carry out atmospheric observations → through INTAROS these data can become available to the atmospheric scientific and operational community.
- There is a severe lack of all types of atmospheric observations over the Arctic Ocean, in particular observations of the vertical structure of the atmosphere are lacking. A real solution to this problem probably have to rely on either **airborne dropsondes networks or satellite sensors**. → development of retrieval methods for satellite atmospheric products should **target the special requirements that pertains to the Arctic**, where the cloudiness is high, absolute moisture relatively low and the atmospheric boundary layer is very shallow.
- Satellite retrievals rely on a priori information obtained trough models (either operational models or reanalysis) → Improvement has to be based on process studies → there has to be **more research-grade observations**, that usually only comes from short **icebreaker-based field campaigns**.

Recommendations

Ocean and sea ice:

- It is a major problem that in-situ observing systems lack sustainability. Especially, the ocean under the ice has no long-term funded and operational observing system.
- We recommend development of multi-disciplinary observatories using well proven and robust instrumentation mounted in sea floor installations, bottom anchored oceanographic moorings, and drifting ice-tethered platforms.
- There is still a need to develop and adapt technologies and sensors to make biogeochemical and biological observations feasible.
- There are many gaps in the data coverage in the Arctic, but the gaps in biogeochemical observations (oxygen, nutrients, Chl-a, Carbon/pH) are particularly important.
- In the Arctic there are limiting factors in accessing data in the same way as in other regions.

Recommendations

Land and terrestrial cryosphere:

- **Land cover:** a more specific set of cover types for the Arctic is needed. In particular, shrubs, mosses and water tolerant grasses/sedges need to be included.
- **Greenhouse Gases:** more measurements are needed in autumn/winter, in the discontinuous (or melting) permafrost zone, and in Siberia. Also, the GHG fluxes measurements need to be linked to simultaneous soil water status measurements and vegetation type/wetland type.
- **Soil carbon:** is the largest store of terrestrial carbon, but there are only very sparse measurements of it.
- **Snow:** variables such as snow depth, snow water equivalent, and snow grain size are still mostly manually measured, but time series across the snow season would be needed. Snow albedo measurements would be needed in much more sites.
- **Greenland ice sheet:** To improve our estimates of the current and future contribution of the Greenland ice sheet to sea level rise, the existing observational networks should include 1) Snow water equivalent, 2) High-precision elevation and position measurements of automatic stations, and 3) Liquid precipitation (rain).
- **Geological observations:** a) increasing the number of earthquakes observational sites, especially offshore, b) keeping analytical resources at a high level at the national and international centres, c) Adoption of real time data exchange on an international level among the nations and researchers that conduct seismological monitoring in the Arctic region.
- **River discharge observations**: improved timeliness of the data, improved metadata including uncertainty characterization and supporting documentation.

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WP2 Deliverables

❑ Catalogue of data products and services (Task 2.3) (30 November 2018)

(Sparse data that trough INTAROS are made accessible via well served data repositories)

D2.2 Ocean and sea ice

D2.5 Atmosphere

D2.8 Terrestrial sphere and cryosphere

❑ Report on synthesis and recommendation from WP2 (Task 2.4) (31 May 2019)

D2.10 All spheres

❑ Report on the maturity scores of existing observing systems (Task 2.4) (31 May 2019)

D2.11 All spheres

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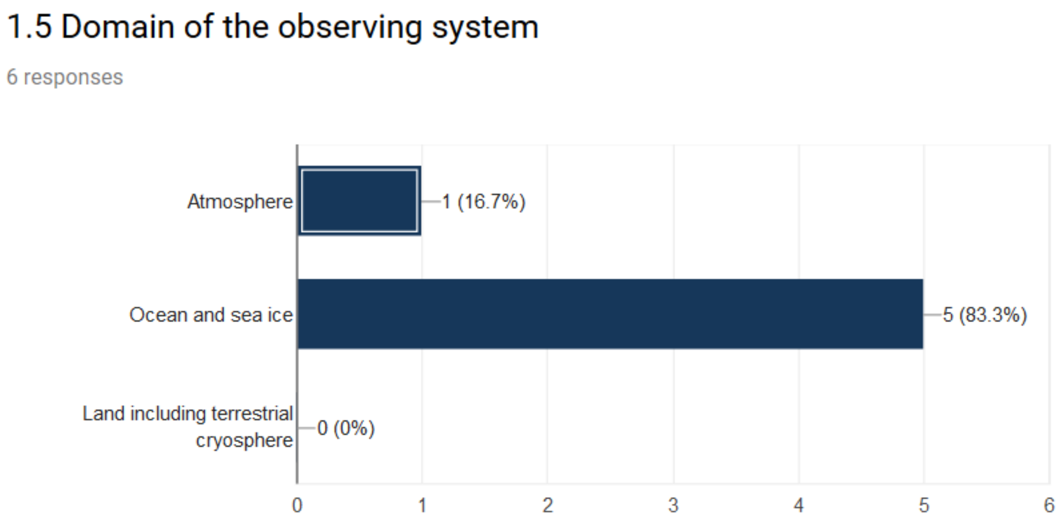
Questionnaire A open to external collaborators on 16 April 2018

Accessible at: https://intaros.nersc.no/node/651


1.5 Domain of the observing system

6 responses

Ocean and sea ice:

Beaufort Gyre Observing System (BGOS) – Woods Hole Oceanographic Institution (USA)
Faroe Shelf – Faroe Marine Research Institute (Faroe Islands)
GSR-exchanges (Fixed moorings) – Faroe Marine Research Institute (Faroe Islands)
GSR-exchanges (Repeated sections) – Faroe Marine Research Institute (Faroe Islands)
WHOI ITP Program - Woods Hole Oceanographic Institution (USA)

Atmosphere:

Thule High Arctic Atmospheric Observatory - INGV & ENEA (Italy)