INTAROS synthesis of gap analysis of the existing Arctic observing systems

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Survey

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

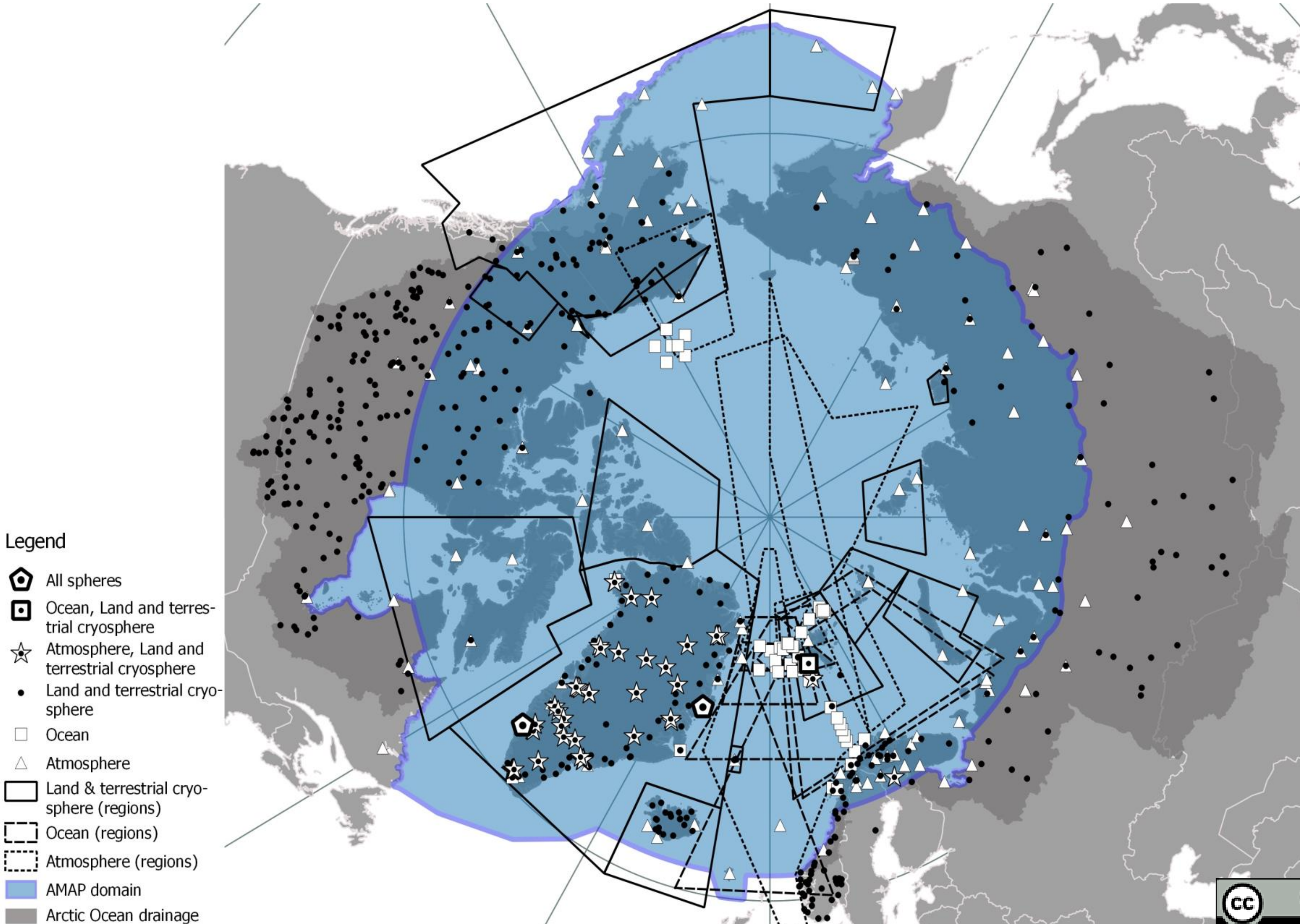
QUESTIONNAIRE C: Arctic satellite products

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

MODEL SENSITIVITY STUDIES

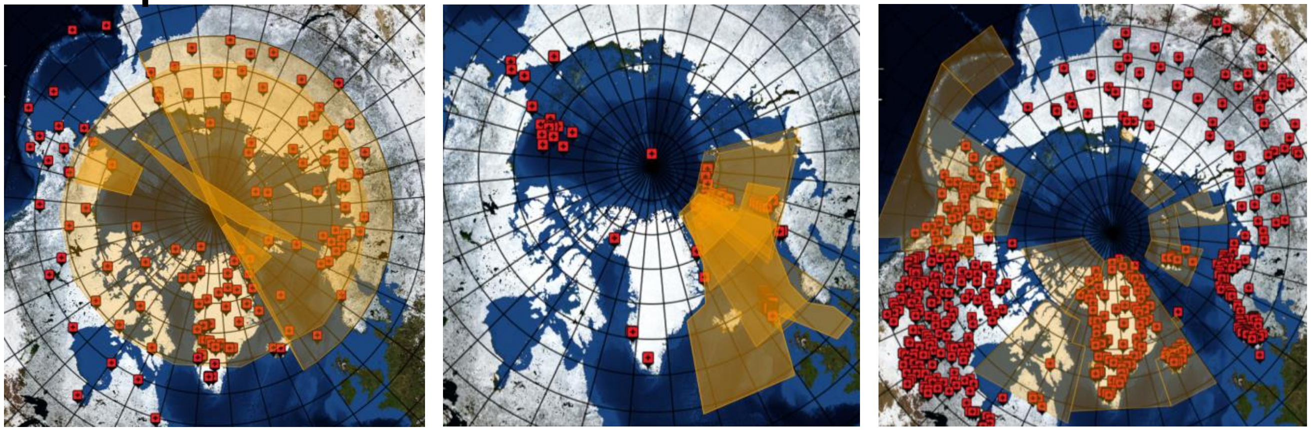
ATMOSPHERE: ECMWF model sensitivity to radiosounding observations
OCEAN MIT GCM sensitivity to SSH and salinity
LAND inverted modeling of ‘field of view’ for GHG tower network.

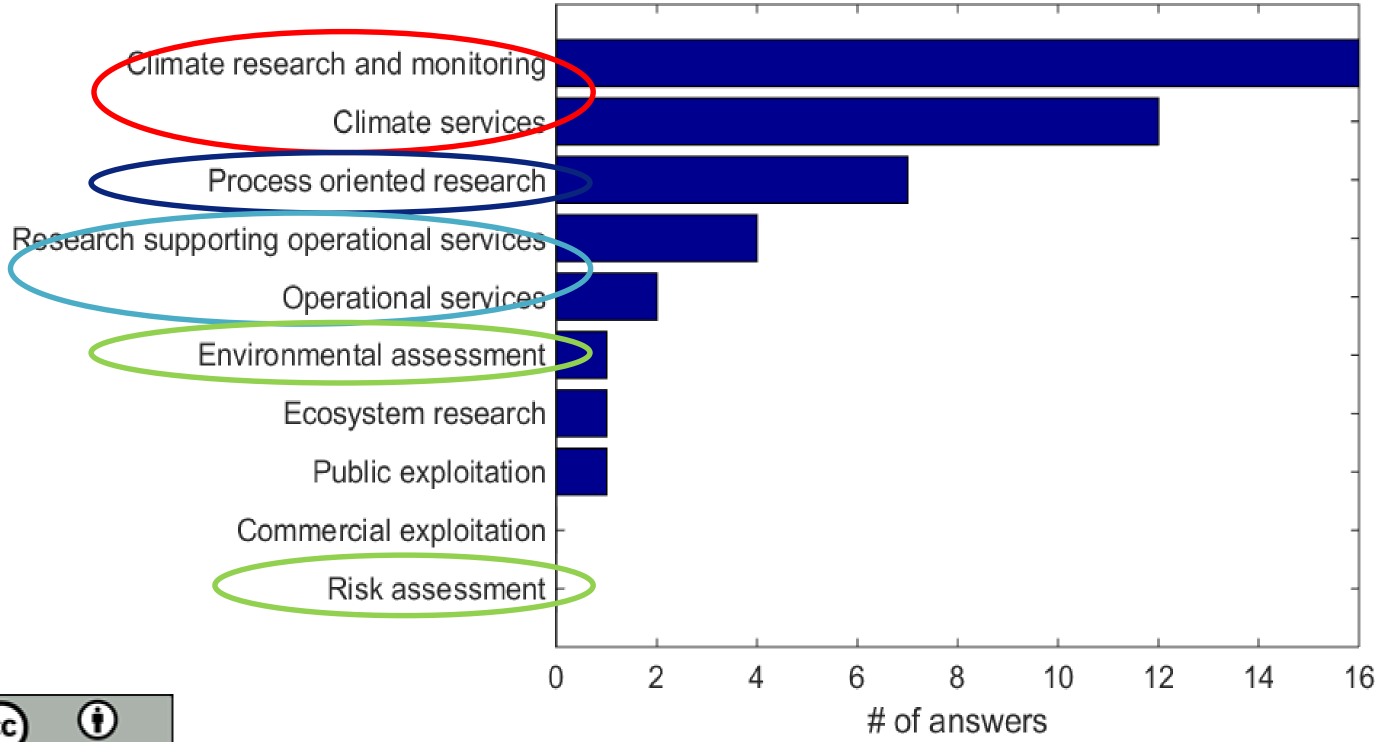
Synthesis


Legend
All spheres
Ocean, Land and terrestrial cryosphere
Atmosphere, Land and terrestrial cryosphere
Land and terrestrial cryosphere
Ocean
Atmosphere
Land & terrestrial cryosphere (regions)
Ocean (regions)
Atmosphere (regions)
AMAP domain
Arctic Ocean drainage

ATMOSPHERE:
Overview of surveyed data

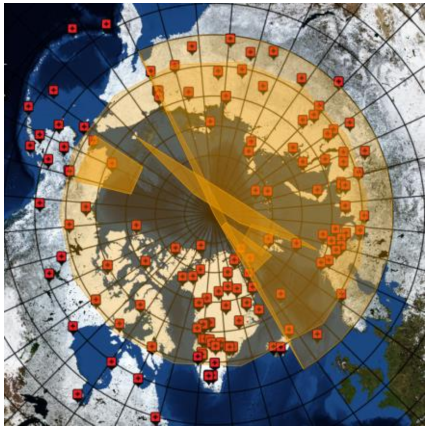
Atmosphere

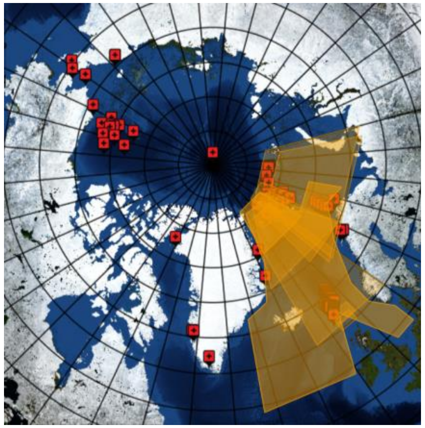


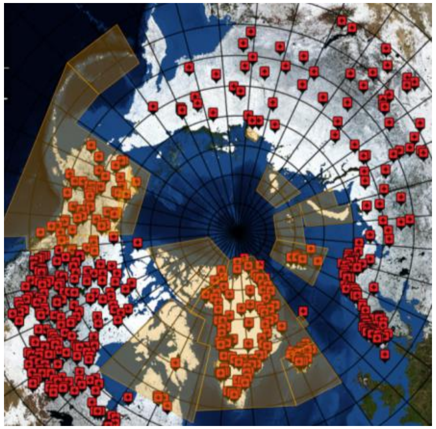


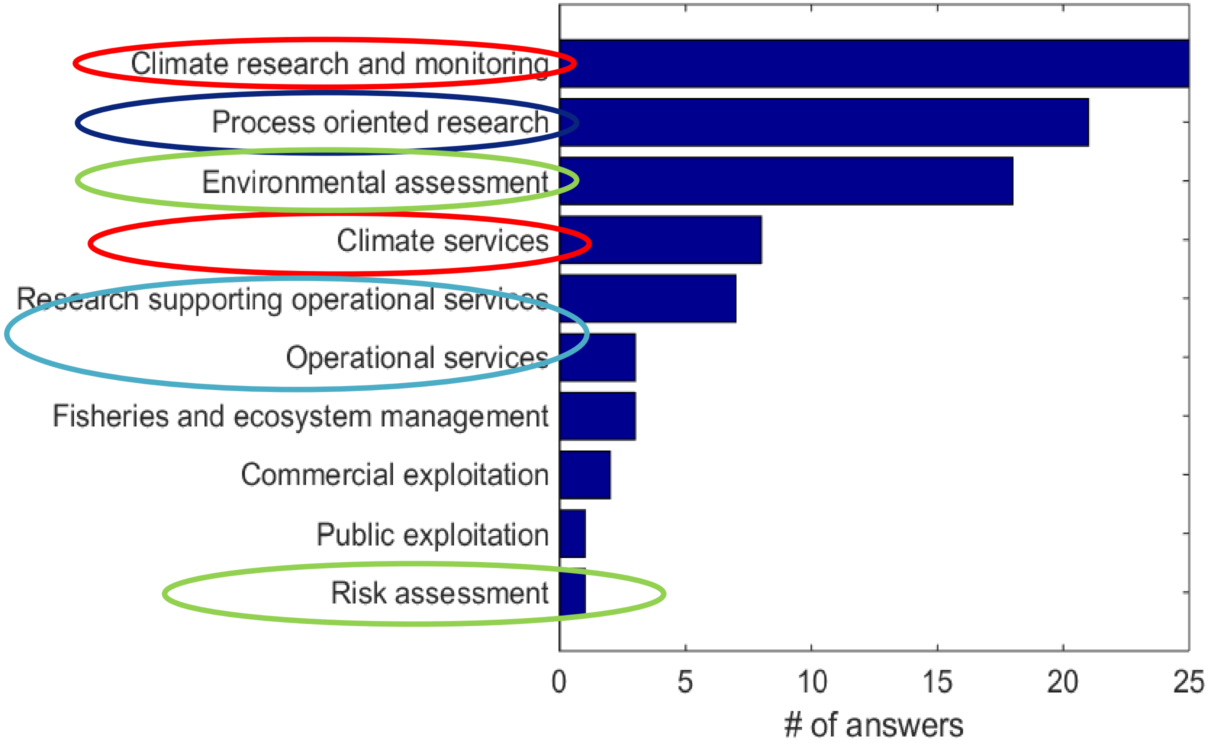
OCEAN and SEA ICE: Overview of surveyed data

Ocean & Sea Ice



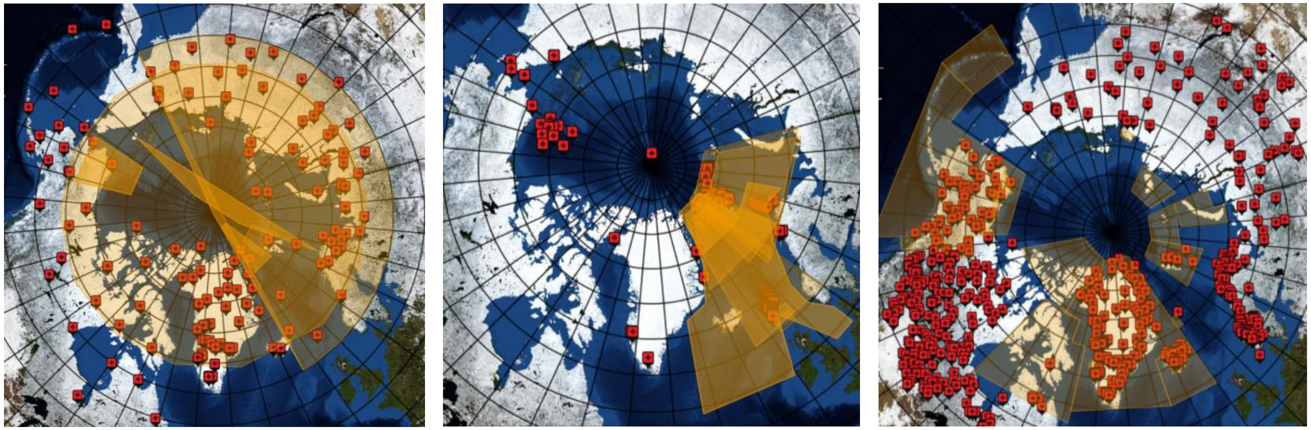


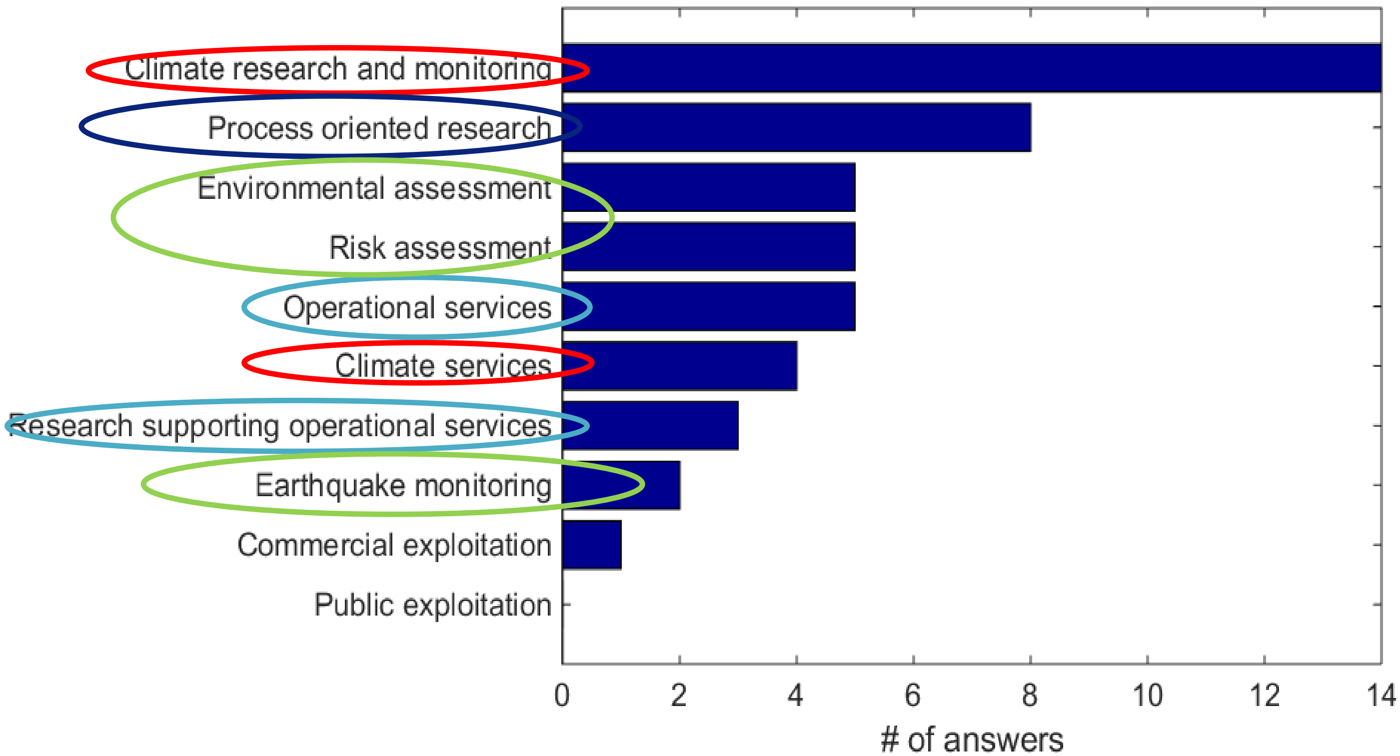




LAND and TERRESTRIAL CRYOSPHERE: Overview of surveyed data

Land and terrestrial cryosphere





Identified gaps

Marine environment

Atmosphere: Observational gaps are in almost everything, especially in the vertical structure of atmosphere and of clouds; satellite retrievals, especially of clouds and profiling, are inadequate

Ocean & sea ice: Main gaps are in the vertical structure under ice, biogeochemical and biological observations, long-term moorings, sea-ice thickness and snow on the ice

Terrestrial environment

Atmosphere: There is need of increased data quality in some parts of the Arctic; long-term process (e.g. "super site") observations of clouds and aerosols, especially in Russian Arctic where trace gas and trace-gas fluxes also have gaps

Land & cryosphere: Main gaps are in: scarcity of number/type of snow, glacier & ice sheet mass balance observations; availability of near-real-time observations; lack of characterization of satellite products

Maturity scores

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

Data management	Sustainability	Uncertainty	Metadata	Documentation
Storage	Scientific and expert support	Traceability	Standards	Description of methodology
Access	Funding	Comparability	Collection level	Validation report
User feedback	Site representa-tiveness	Standards	File level	User guidance
Updates		Validation		
Version control		Uncertainty quantification		
Data preservation		Routine quality management		

INTAROS Maturity scores

	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

Synthesis of Maturity: terrestrial environment

INTAROS

Maturity summary of the Arctic terrestrial *in-situ* observing systems, by domain: atmosphere, land and terrestrial cryosphere and **multidisciplinary**. Shades of red correspond to the maturity scores

Observing systems	Sustainability	Data management	Uncertainty handling	Metadata handling	Documentation
GRUAN, ACTRIS, ICOS, GNET-GPS Network, GLISN, NNSN, Arctic-HYCOS	High	High	High or medium-high	High	High
Global/regional GAW, PROMICE, GlaThiDa, WGMS-FoG, RGI	High	High or medium-high	Low	Medium-high	Medium
Radiosoundings network, GOS Surface synoptic measurements, Sodankylä supersite	High	Medium-high	Medium-high	Medium	Low
Radiosounding network, GEM	High	Medium-high	Low	Low	Low
Hornsund supersite	Medium	Medium	Low	Medium	Low
GC-Net	Medium	Medium	No information	No information	No information
Tower network for atmospheric trace gas mixing-ratio monitoring	Medium	Low	High	Medium	Medium
'luxnet, PEEX, Airborne observations of urface-atmosphere fluxes	ow-Medium	Low-Medium	Low	Medium	Low

Synthesis of Maturity:
marine environment

Maturity summary of the Arctic marine *in-situ* observing systems, by domain: ocean and sea ice in blue, atmosphere in orange, and **multidisciplinary systems in black**. The shades of red correspond to the maturity scores.

Observing systems	Sustainability	Data management	Uncertainty handling	Metadata handling	Documentation
FRAM	High	Medium	Low-medium	Medium-high	Low-medium
IMR PINRO Ecosystem Survey & Barents Sea Winter Survey, Greenland Ecosystem Monitoring Programme	High	Low-medium	Low	Low	Low
NorArgo	Medium	High	Low-Medium	Medium	Medium
IOPAN Long-term Monitoring in Svalbard Fjords	Medium	High	Not assessed	Not assessed	Not assessed
Argo Poland	Medium	Medium-High	Medium-high	Medium	Low-Medium
A-TWAIN / A-TWAIN Poland	Medium	Medium-High	Low	Low-medium	Low
NIVA Barents Sea FerryBox	Medium	Low-medium	Medium-high	Medium	High
IOC Tide Gauges in Greenland, AREX	Medium	Low-Medium	Low	Low	Low
International Arctic Buoy Programme	Medium	Low-Medium	Not assessed	Not assessed	Not assessed
Atmospheric field experiment (ASCOS, ACSE, N-ICE), Polarstern soundings	Low	Low-medium	Low-medium	Low-medium	Medium
Fram Strait Multipurpose Acoustic System	Low	Low	Low	Low-Medium	Low

Synthesis and recommendations (1)

CONCLUSIONS:

- High sustainability is a proxy for high scores across the board and such systems result from national, regional or global infrastructures often not specific to the Arctic $\Rightarrow$

  Integrate Arctic observing in existing national/regional/global program rather than inventing new Arctic specific systems

- Scientific campaigns/expeditions provide the highest quality observations, but are deficient in almost all other aspects, especially on data management $\Rightarrow$

  Revisit funding models for this activity and increase coordination between operational and scientific organizations

- Satellites provides the only data with sufficient spatial and temporal cover, but quality is sometimes lacking $\Rightarrow$

  Invest in better satellite retrievals and improved models and data assimilation

Synthesis and recommendations (2)

CONCLUSIONS:

- Arctic Ocean:
  A lack of in-situ observing capacity across all disciplines. Almost nothing in the atmosphere; subsurface installations robust but few but and deliver data in delayed mode ⇒

  Paradigm shift in system design where field experiments correspond to the reference system, satellites to baseline and reanalysis replaces the comprehensive level

- Arctic land:
  Quality is a larger problem than coverage ⇒

  Upgrade and complement existing stations, rather than expanding new networks; deploy new technology at existing stations