Assessment and Exploitation of the existing Arctic observing systems under the INTAROS project

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Abstract

The identification of "The Business Case for a pan-Arctic Observing System", main goal of the Arctic Observing Summit 2018, requires a thorough evaluation of the present observing system. In the framework of the H2020 project Integrated Arctic Observation System (INTAROS), the existing Arctic observing systems and selected in situ and satellite data products are assessed, exploited, and standardized to enable their delivery to a multidisciplinary, integrated Arctic Observing System (iAOS) through established databases. This assessment and exploitation is carried out in the INTAROS Working Package 2 (WP2) and it addressed observations of the ocean, atmosphere, cryosphere and land including physical, chemical, and biological parameters.

Strengths, weaknesses, gaps in spatial/temporal coverage, missing monitoring parameters, sustainability, and data management of the existing in situ observation networks are analyzed. Moreover, coverage, resolution, timeliness, uncertainty, format, and metadata of selected in situ and satellite data collections are assessed with respect to the requirements needed for applications within weather prediction and sea ice services, hazard risk assessment and prevention, climate, environmental protection. The quality and the processing of selected datasets are improved to meet the highest standards set by the European and international organizations. New products resulting from the exploitation of available data are provided, and sparse data are made accessible through the existing repositories.

The main result is the enhanced quality, quantity, accessibility and documentation of existing Arctic observations, which are then ready to be ingested into the iAOS. The assessment will provide a reasoned basis for future observational funding calls, investment planning, and improvements of the observing system.

1. Method applied to perform the assessment

The assessment and gap analysis of the present Arctic observing system are performed through 4 steps: 1) a survey on the characteristics of the existing and recently exploited (via INTAROS) in-situ and satellite-based observations of the ocean, atmosphere, terrestrial sphere and cryosphere, 2) an evaluation of the requirements of the addressed data for various applications, 3) a gap analysis of various aspects of the data, obtained through the comparison between the surveyed data characteristics and the identified requirements and through Observing System Simulation Experiments (OSSE), and 4) an assessment of the system maturity.

1. The web-based survey was undertaken via three questionnaires (Fig 1), and built upon similar efforts to assess climate data record maturity (EUMETSAT, 2014), measurement series maturity (Thorne et al. 2015; 2017), data management maturity of the Polar observing systems (EU-PolarNet, 2016), and polar satellite

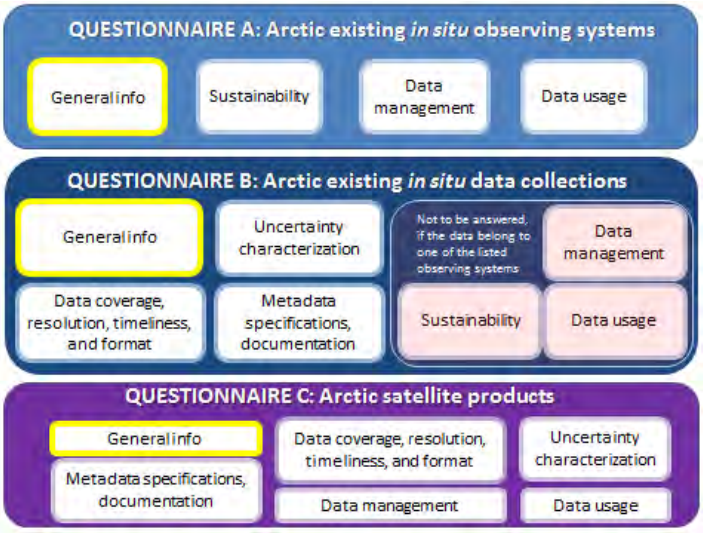

Figure 1. *Schematic illustration of the topics addressed in the three questionnaires*

products (Polar View, 2016). The survey was designed to collect homogeneous and consistent information about in-situ and satellite observations across the bio, geo, and chemical spheres.

2. The requirements are defined with respect to data applications: climate, operational services, environmental protection, geo-hazard forecast, research development. When applicable, the requirements listed in the WMO OSCAR database (https://www.wmo-sat.info/oscar/requirements) for the in-situ and satellite-based data collections were used. When the OSCAR requirements were inapplicable, other requirements were described, following the general indications provided by the INTAROS Initial Requirement Report.

3. The gaps of the existing Arctic observing system were identified on the basis of the comparison between the data characteristics obtained through the survey and the identified requirements. Moreover, OSSE experiments performed using ocean, land and atmospheric models will reveal observational gaps from the perspective of operational and climate monitoring applications.

4. A synthesis and assessment of the observing system maturity across the Arctic and across domains will be performed on the basis of the information collected through the survey, following the methodology developed in previous EU projects (EUMETSAT, 2014; Thorne et al. 2015; 2017) and discussions with GCOS and WMO.

2. Next step and applications

Only INTAROS partners contributed to the fist assessment and gap analysis and to the maturity assessment report. However, an updated assessment will include also the information on the existing observing systems provided by collaborators outside the INTAROS project through the Questionnaire A, which is openly accessible from the INTAROS web page (www.intaros.eu). The described assessment and exploitation effort carried out in the INTAROS WP2 well integrates into the framework of the International Arctic Observations Assessment developed by the IDA Science and Technology Policy Institute (STPI) and the Sustaining Arctic Observing Networks (SAON) (IDA STPI and SAON, 2017). The aim of the framework is to assess the societal benefits derived from Arctic Observations. The INTAROS work is an essential contribution of the Phase 1 of the framework, which aim to the identification of the observational inputs that are or can be used to develop key products and services for the society. As such, *the INTAROS work will provide a reasoned basis for future observational funding calls, investment planning, and improvements of the observing system.*

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A Cold Regions Information Service Approach for Societal Benefits

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1. GEO Cold Regions Initiative

Earth's Cold Regions, covering the Arctic, Antarctic, high-latitude oceans, Himalaya-Third Pole, and mountain cold areas, are experiencing the fastest rate of climate, ecological and environmental change, which severely affect the entire Earth System. These changes have impacts on more than one hundred countries and on the people living therein, and they also influence many aspects of society and economic development in all parts of the world.

Aiming to implement the vision of the intergovernmental Group on Earth Observations (GEO) to address the global environmental change, and its resulting impacts and challenges, the Cold Regions Initiative (GEOCRI) was established to broaden and share Earth observations. GEOCRI will develop a user-driven approach for Cold Regions information services to strengthen synergies and foster collaboration at a global scale, providing coordinated information services across a range of stakeholders to facilitate well-informed decisions and support sustainable development.

2. Information Service Approach

GEOCRI is taking an **Information Service Approach** to cover the eight **Societal Benefit Areas** identified by GEO: Biodiversity and Ecosystem Sustainability, Disaster Resilience, Energy and Mineral Resources Management, Food Security and Sustainable Agriculture, Infrastructure and Transportation Management, Public Health Surveillance, Sustainable Urban Development, Water Resources Management and support the global policy. This will ultimately lead to a decision policy supporting the UN Sustainable Development Goals (SDGs) , the Paris Agreement and Sendai Framework for Disaster Risk Reduction.

A Big Earth data-product-information-SBA-Global Policies procedure, the Data Value Chain, provides a data- and knowledge-based value-added chain for an information services mechanism (Fig. 1). The GEOSS system and its portal, also connected to a database federation will provide the necessary information basis. Data federation will be organized in strict cooperation with other initiatives, in particular those developed by IASC, WMO and SAON through the Arctic Data Committee (ADC), to take into account the complex and disperse panorama of in polar data repositories/organizations/portals. Also starting from information background, essential cold regions variables will be identified through the domain experts corresponding to the SBAs. Together with them a higher system of indicators will be identified/discussed to directly support the modelling system on the SBAs and global policies.

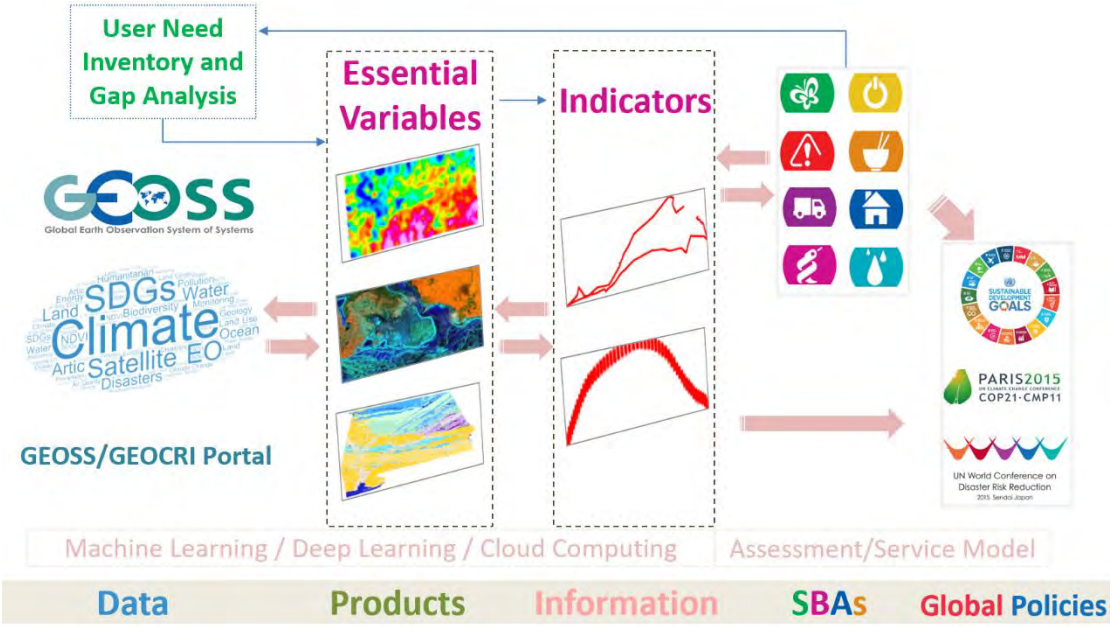

Fig.1 Data Value Chain : an Cold Regions Information Service Approach for Societal Benefits

The Data Value Chain incorporates the entire information services process. It integrates the data providers and data users, transforming data driven information and knowledge in algorithm, including the emerging Big Earth Data, Deep Learning techniques, tools and products for decision makers. Combination of open access satellite data, in-situ observations and modelling prediction is fundamental for this chain and should/will be largely explored in order to identify all potentialities for societal benefits areas.

3. Implementation Developments

The GEOCRI initiative includes infrastructure networking, a data federation system, essential variable identification, and best practices for the selected SBA priorities covering the cold regions. The **Implementation** Plan of GEOCRI is grouped into five tasks: Infrastructures, Monitoring Network and Data, In-situ and Remote Sensing Integration, User Engagement and Capacity Building, and Management and Monitoring. A co-lead group was established to envision and implement this aim.

Recent key developments and synergy activities for implementing this information approach in GEOCRI include, but are not limited to:

- The infrastructure task works on strengthening the collaboration between infrastructure networks and operators by sharing of best practices, for example, to leverage improved research infrastructure accessibility beyond the Arctic to other cold regions. The focus is on helping to identify the gaps and potential overlap in Earth observing capacity, and on the integration and interoperability of in-situ and remotely sensed Earth observations in cold regions across the environmental, ecological and societal domains. This component is working with the different international communities relevant to the Earth's cold regions, especially the Committee on Observations and Networks (CON) for Sustaining Arctic Observing Networks (SAON), and etc.
- Building on broader data sharing principles, GEOCRI is working in partnership with international and national organizations to achieve substantial progress in making cold regions research and monitoring datasets discoverable and available to the broadest range of users. Progress is being made through and leverage the GEOSS data infrastructure and its community portal function. Recently, GEOCRI has partnered with the Arctic Data Committee of the International Arctic Science Committee (IASC) and the SAON program and other polar region organizations to work towards a federated search network that will further increase our ability to find important, high quality data.
- The Essential Cold Region Variables (ECRVs) currently developed in GEOCRI and in collaboration with several other actors, like international and national Arctic and cryosphere science bodies, are the key to bridge the Earth observations infrastructure, data and societal benefits. The ECRVs will include a set of identified variables related not only to purely climate and environment, but also to the societal and economic development over the Earth's cold regions. These essential variables, once in place, can help to estimate how and to what extent the Earth Observations support the global policy, like UN Sustainable Development Goals (UN SDGs), and the Paris agreement through GEO's well-established international cooperation.
- The indicators/variables and users/stakeholders can be connected through the user needs and knowledge gap analysis actions. These will be used by GEOCRI to show where future research investments would have to focus to gain a more complete understanding of cold regions, especially Arctic systems. A combination of interviews and a standardized survey are used to develop a database that will numerically demonstrate the key research needs, user needs of Canada's Arctic population are being researched in a comprehensive study that will feed into GEOCRI. Available information from recently completed synthesis reports (i.e. Arctic Biodiversity Assessment, Arctic Climate Impact Assessment) is reviewed and key knowledge gaps are identified by Polar Knowledge Canada.

Improved understanding and collaboration across the Earth's Cold Regions, together with data sharing and its federation mechanism, efficient information flow, better-integrated observing capacity, will help to assist timely and effective decision-making to reach societal benefits and support sustainable development in these regions and beyond.

What happens in the cold regions affects the entire Earth System and humankind across the globe. The GEOCRI's international observation science collaboration and understanding of the Earth's Cold Regions, and information service provide an endeavour for a better society.

Merged Observatory Data Files (MODFs) from an Arctic Atmospheric Observing Network: Developed to support the Year of Polar Prediction (YOPP) - A success story in progress for the AOS Operating Systems and Networks Subtheme

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The International Arctic Systems for Observing the Atmosphere (Uttal et al., 2016, Vihma, et al., 2016, and www.IASOA.org) is consortium of scientists that work with the measurements made at observatories that encircle the Arctic Ocean. Arguably, IASOA ca be considered the most substantive, already existent component of a pan-Arctic Observing system for atmospheric and related surface and snow-ice observations for Arctic terrestrial regions. The consortium has a long history of partnership initiated during the International Polar Year (IPY) and over the last decade, the focus has been on developing cross-network inventories, filling observing gaps, providing data access, developing standardized observing practices compiling climatologies of individual components of the Arctic system, and supporting science working groups with research outcomes. As IASOA enters it second decade, the challenge is to not only maintain and expand high-quality, long-term, observing programs and science, but also to develop products and protocols that will allow full usage of the observational datasets.

Data discovery and access has been a topic since the inception of IASOA and data stewardship efforts have included promoting submission of data to global archives and developing the framework for an IASOA data portal (https://www.esrl.noaa.gov/psd/iasoa/dataataglance). The limitation of the first approach is that individual global network archives such as BSRN (http://bsrn.awi.de/) or ebas (http://ebas.nilu.no/) are developed for a narrow range of instrument specific variables; the limitation of the second approach is that the portal is dependent on target repositories voluntarily complying with metadata standards that allow data harvesting.

IASOA is currently taking a new approach to data usability by developing standardized Merged Observatory Data Files (MODFs) to support the verification and modeling plans of the Year of Polar Prediction (YOPP, Jung et al., 2016). This short statement is submitted to the AOS Operating Systems and Networks Subtheme and describe "Use of data and information derived from observing systems". The MODFs which are being developed in collaboration with the YOPP modeling and verification teams will have the following properties:

- There will be one MODF per observatory per defined period (not a continuous product).
- The MODFs will not be real-time
- MODFs will be consistent with YOPP model output files and will internally match time and interval conventions, levels and units and externally match output formats (TBD)
- Surface meteorological variables will be acquired consistently for all stations from NOAA/NCEI
- Each variable will processed consistently for all observatory, typically with a single individual/team responsible for processing assigned variables for all observatory MODFs rather than establishing processing format/procedure/requirement protocols and relying on processed contributions from individual researchers

- IASOA working group specialists will determine most usable and representative MODF values for the many variables (e.g. turbulent fluxes) that have multiple measurement and derivation techniques
- The YOPP atmosphere-surface variable inventory will be expanded to include green-house gases and atmospheric constituents
- Missing data flagging protocols will be developed to accommodate the fact different observatories have different permutations of instruments and measurement capabilities, data may be embargoed, data exists but has failed QC, resources may not be available for processing etc.
- Uncertainty estimates will be included with units information
- The initial MODFs will be for the YOPP 2018 special observing periods (Feb-Mar and June-July-Aug).
- Each observatory and SOP specific MODF will have an individual doi.
- Each MODF will internally and externally attribute all contributing parties
- The MODFs generated specifically for YOPP will be hosted by ACTRIS (https://www.actris.eu/) as well as by IASOA (www.iasoa.org)
- Policies will be develop to accommodate and document the situation when individual MODF variables constitute either duplicate or alternative products that are generated from the same original raw data but served through other archives

This short statement is submitted to the AOS Operating Systems and Networks Subtheme and contributes to the discussion on "Use of data and information derived from observing systems". These unique dataset multi-variate observatory measurements will not only enable detailed process-based analysis investigations for YOPP when paired with the high frequency, site specific model outputs, but it will also produce prototype canonical data files that will substantially increase the usability and accessibility of information across the IASOA network for other research objectives as well as public and commercial applications. The MODF product described thus furthers a business case for an integrated Arctic Observing system.

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