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Toward a Pan-Arctic Observing System: Analysis of Current Observational Gaps and Issues

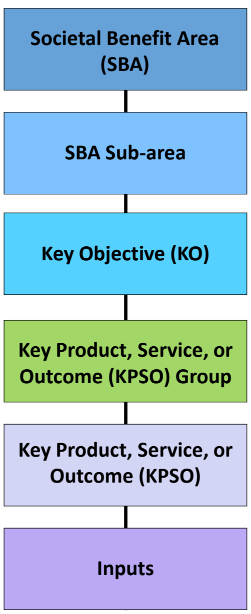
While many countries currently observe the Arctic's physical, biological, and human systems, gaps in observational coverage remain. In order to address these gaps globally and systematically, it is necessary to first understand what observations currently being used, by whom, and for what purposes. The 2017 *International Arctic Observations Assessment Framework* presents a common structure for understanding the purposes to which Arctic observations are applied.[1] The *Framework* was developed by an international group of Arctic subject matter experts (SMEs) and serves as a benchmark that can be used by nations to assess their own reliance on Earth observations on the achievement of Arctic objectives. It presents 12 Arctic societal benefit areas (SBA), 41 SBA sub-areas, and 163 key objectives to which Arctic observations contribute. This statement lays out a method to identify the observational gaps that would need to be addressed in order to achieve systematic observational coverage in the Arctic, also known as a Pan-Arctic Observing System.

In order to determine observational gaps, three pieces of information are needed: (1) objectives that articulate why Earth observations in the Arctic are needed, (2) information about how different observations contribute to each objective, and (3) information about how well these objectives are currently being achieved. By examining the extent to which each objective is met, it will be possible to determine when additional observations are needed to fully meet the objective. The *Framework* provides the first piece of information (the objectives), and because each objective was developed by an international group of SMEs with the intention of being broadly applicable across national boundaries, they are well-suited for an international gap analysis. An objective may not be achieved due to a lack of observations, issues with existing observations, or issues associated with the production, management, or dissemination of observations or derived products. Identifying which of these issues should be addressed is the key to improving the ability to meet Arctic objectives and provide societal benefits.

Given the set of Arctic objectives, the next steps are to gather the additional two pieces of information identified above: information about the contribution of observations to achieving each objective and how well each objective is currently being met. We discuss how a method used by the United States to assess the federal reliance on Earth observation assets can be adapted to gather this information. The United States Government conducts Earth Observation Assessments (EOAs) to understand the impact of individual Earth observation systems, sensors, networks, surveys, datasets, and sampling programs on meeting its key civil objectives. The process relies on a value tree analysis, which defines the ways that

[1] IDA Science and Technology Policy Institute and Sustaining Arctic Observing Networks. 2017. International Arctic Observations Assessment Framework. IDA Science and Technology Policy Institute, Washington, DC, U.S.A., and Sustaining Arctic Observing Networks, Oslo, Norway, 73 pp.

Earth observations are used to achieve societal benefits, identifies specific products and services that are currently used to meet the objectives, and then evaluates the contribution of individual Earth observations to developing that product or service. The value tree used in the EOA consists of six levels (Figure 1). Societal Benefit Areas (SBAs), which form the top level, are environmental, economic, and social domains in which public services and research provide societal benefit. SBA sub-areas are natural thematic subdivisions within each SBA. Key objectives (KOs) are activities that support national goals and can be clearly linked to Earth-observing systems, data, or products. Key products, services, and research outcomes (KPSOs) are the data, information, and analytical products or research findings that directly support progress toward meeting KOs. The inputs are the Earth observations needed to produce KPSOs. KPSOs that belong to the same category or class of information products or research area are organized into KPSO groups.



Societal Benefit Area (SBA): Environmental, economic, and social domains in which public services and research provide societal benefit.

SBA Sub-area: The major thematic component within an SBA; natural subdivision of the parent SBA

Key Objective (KO): An activity within a sub-area that is clearly supported by and can be linked to Earth-observing systems, data, and products

Key Product, Service, or Outcome (KPSO) Group: A group of KPSOs that belong to the same category or class of information products or research area

Key Product, Service, or Outcome (KPSO): A primary or important information product, service, or outcome required to make progress toward or meet a KO

Inputs: The data, information, and Earth-observing systems needed to produce KPSOs

Figure 1. EOA 2016 Value Tree Levels

The *Framework* establishes the top three levels of an international Arctic value tree. Nations and institutions can assess the extent to which these objectives are being achieved within their own context by determining the KPSO groups, KPSOs, and inputs that are used to achieve these objectives. Once this is accomplished, national or institutional experts can determine the extent to which the objectives are being achieved currently, and if any shortcomings are due to the insufficient production or provision of KPSOs or issues with underlying observation inputs (such as geographic coverage, spatial resolution, temporal frequency, etc.) or due to another limiting process such as data management. If multiple nations and institutions complete this process, the results can be shared and experts from each can collectively decide whether there is a gap in global or regional observational coverage or if there are other deficiencies that need to be addressed. This effort could be used to inform international, national, and institutional policies to address these gaps, maintain the continuity of observations, or share observational data and information products.

In order to reach the stage where collective inter-comparison among nations and institutions is possible, it is necessary for these groups to rigorously develop the bottom levels of the value tree (KPSO groups to inputs). Developing the KPSO Group and KPSO levels of the value tree allows for preliminary inter-comparison to understand if there are products or services that currently exist for each objective. Doing further elicitations with the SMEs that produce each identified KPSO will allow for a full tracing from an individual product to the observations relied upon to develop it. As an example of how a country or institution might build out further levels of the value tree using the Arctic *Framework*, one of the objectives within the "Weather Effects on Economic Productivity" sub-area of the "Weather and Climate SBA" is "Provide sector-specific weather predictions for economic productivity." Each nation or institution could determine KPSO groups (perhaps one KPSO group per relevant sector, such as fishing, transportation, energy production, tourism, etc.) and the constituent KPSOs representing sector-specific weather predictions. An example of a KPSO Group could be "Weather predictions for transportation," and example KPSO could include the "Special Marine Warning: Anchorage" produced by the U.S. National Weather Service or the "Weather forecast for shipping" produced by the Finish Meteorological Institute.

In the case of the EOA process, once the list of KPSOs is generated, elicitations with SMEs who produce the KPSO are conducted to generate a list of inputs needed. In the case of the sector-specific forecasts, SMEs would be asked about the inputs needed to produce each forecast. The list of inputs would likely include satellite observations, airborne meteorological observations, radar network information, and coastal buoy array data, among others, as well as modeled output. Because the output of a model may rely on additional observational inputs, to capture the full range of inputs contributing to the forecast, additional elicitations would need to be conducted with the SMEs that manage the identified models to generate a list of the inputs they rely on. Once each input to the forecast is traced down to all the observational inputs, the final list should be complete. At each elicitation step, information on the SME's satisfaction with each of the underlying observational inputs should be collected based on a standardized scale (the scale that the U.S. uses in its EOA process is displayed below). This should be repeated for each KPSO. Together these two pieces, the list of inputs and satisfaction, provide information about the reliance on individual observational inputs as well as any issues with those observations in the context of KPSO production.

Performance / Satisfaction Scale		
100	Ideal	Meets all requirements and exceeds some
90	Fully Satisfied	Meets all requirements
80	Good	Meets all major requirements with minor limitations
70		
60	Fair	Meets most major requirements, with significant limitations
50		
40	Poor	Fails to meet many major requirements, but provides some value
30		
20	Very Poor	Fails to meet most major requirements, but provides minor value
10		
1	No Capability	Provides no value

Figure 2. Standardized Satisfaction Scale

To determine whether additional observations are needed to meet the objectives (as opposed to addressing issues with existing observations or KPSO provision), additional information should be gathered from experts with scientific, operational, and policy expertise who are able to address the application of KPSOs to the objective(s) in question. These experts should be asked to determine: (1) the extent to which the set of KPSOs listed, as a whole, are sufficient for achieving the objective, and (2) the adequacy of individual KPSO for meeting the objective. These experts should answer the following questions:

- Do KPSOs exist that help meet the objective in question?
- If not, is this due to a lack of observations or inadequacies in the production, management, or dissemination of existing observations?
- If not, is this due to the inadequacy of the KPSO(s) in meeting the objective?

This information, in tandem with the standardized KPSO SME satisfaction information can provide a robust understanding of observational gaps, as well inadequacies associated with existing KPSOs or their underlying observations.

By developing the value tree through each key objective, KPSO Group, and KPSO down to the underlying Earth observation inputs, and determining satisfaction and adequacy, it will be possible to identify where additional observations, modifications to existing observations, as well as improvements to products and services, are needed. These analyses can be combined across national and institutional boundaries to identify how the global Arctic community can work together to strengthen the existing Arctic observing network and collaboratively address gaps, continuity issues, and emerging challenges.