A strategy for prioritization within SIOS

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SIOS is conceived as a regional response to the Earth System Science (ESS) challenges posed by the Amsterdam Declaration[1] on Global Change. SIOS is intended to develop and implement methods for how observational networks in the Arctic are to be construed in order to address these issues in realms approaching the continental scale. The rationale for this document is to:

a) Provide guidelines for how to proceed with merging the initial bottom-up gap analysis process with the overarching goals of SIOS.
b) Remind the scientists and funding organizations that SIOS must not lose its Earth System Science focus and become an uncoordinated sum of infrastructure that happens to be fundable.
c) Provide a strategy for the continued development of SIOS which should lead to a strategic roadmap in future.

ESS background

Earth System Science is in itself a colossal task that has led to the inception of the Earth System Science Partnership (ESSP; www.essp.org). The ESSP community has recently published a strategy document[2]. The abstract reads:

The Earth System Science Partnership (ESSP) was established in 2001 by four global environmental change (GEC) research programmes: DIVERSITAS, IGBP, IHDP and WCRP. ESSP facilitates the study of the Earth's environment as an integrated system in order to understand how and why it is changing, and to explore the implications of these changes for global and regional sustainability. Joint research projects on carbon dynamics, food, water and health have been established. As a result of an independent review, the ESSP developed a new strategy that will provide an internationally coordinated and holistic approach to Earth system science. The approach integrates natural and social sciences from regional to the global scale. The mainstay of the ESSP is to identify and define Earth system science challenges, enable integrative research to address these challenges, and build scientific capacity. The GEC research community also faces an increasing challenge to present research results in more accessible and informative ways to stakeholders, especially to policy-makers. In response, the ESSP is developing new services that include knowledge products, Earth system science fora, a synthesis journal and interdisciplinary collaborative research. Coping with GEC is an

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[1] Moore B, Underdal A, Lemke P, Loreau M: The Amsterdam declaration on global change. In: In Challenges of a Changing Earth: Proceedings of the Global Change Open Science Conference. Amsterdam, The Netherlands, 10–13 July 2001. Edited by Steffen W, Jäger J, Carson D, Bradshaw C. Challenges of a Changing Earth: Proceedings of the Global Change Open Science Conference. Amsterdam, The Netherlands, 10–13 July 2001 Springer-Verlag; 2001:207-208. GBP Global Change Series.

[2] Leemans, R., Asrar, G., Canadell, J.G., Ingram, J., Larigauderie, A., Mooney, H., Nobre, C., Patwardhan, A., Rice, M., Schmidt, F., Seitzinger, S., Virji, H., Vörösmarthy, C. and Young, O.: 2009, 'Developing a common strategy for integrative global change research and outreach: the Earth System Science Partnership (ESSP)', Current Opinion in Environmental Sustainability 1, 4-13.

enormous challenge and one the world must respond to successfully. Our common goal is, therefore, to develop the essential knowledge base needed to respond effectively and quickly to the great challenge of GEC.

There is thus general consensus within ICSU and other overarching scientific bodies that Earth System Science should at this time be focused on GEC related topics.

The ESSP represents a concerted effort by DIVERSITAS, IGBP, IHDP and WCRP to establish a partnership that:

(1) enables the community to identify and carry out research on scientific problems of high social and policy significance in a unified and integrative manner;
(2) initiates and supports capacity building;
(3) provides a high-level platform for effective engagement with stakeholders and the policy community; and,
(4) facilitates efforts to ensure the continued vitality of the scientific enterprise

A case for ESS in Svalbard

Implicit in the ESS concept is that we are studying a closed system. The Earth is not a closed system but is influenced by external variability (both with respect to energy, mass exchange and influence of gravitational fields from coincidental heavenly bodies). Furthermore, the internal characteristics of Earth are also changing (e.g. number of radioactive nuclei remaining in Earth declines with time altering the amount of energy available for volcanism and continental drift). These influences shape the Earth System on all time scales. Of particular note is that energy exchange has externally forced variability (e.g. solar radiation) that influences the Earth system on decadal and shorter time-scales.

ESS is by definition a global study so applying system analysis studies on the regional scale has some severe deficiencies. These need to be acknowledged and considered when prioritizing efforts. For example, many entities can pass through a region without modifying or being modified within the region yet they may still play important roles for the Earth system and/or for the region. Some of the entities observed changing in a region can have drivers outside that region causing this change. Changes in an entity at some location can also be due to redistribution within the region or between regions without it necessarily being important for the Earth system. Sometimes natural barriers define a region making it meaningful to study the realm thus delineated as a closed system for certain entities. In regional work there will always be complications for the system analysis because there are more often than not other relevant entities that can pass the same barrier unobstructed.

Some Svalbard specific examples to illustrate the above: ocean currents transport large amounts of heat past Svalbard yet the ocean-atmosphere exchange in the Svalbard area is probably small when discussing the overall Arctic heat balance though it certainly influences the local climate. There is anecdotal evidence that polar bears are increasing in numbers around Svalbard, despite increases in concentrations of toxic chemicals entering the food chain and (presumably) adverse effects through changes in climate, but the fact that hunting was banned in 1973 is probably still the dominating factor influencing the regional polar bear population. Anecdotes regarding increased numbers of bear sightings on the west coast can be related to redistribution of bears as their fear of human contact has waned. For the reindeer Svalbard can be considered as essentially a natural enclosure. The grazing is modified by goose droppings that are both direct food for reindeer and fertilizer for the grass but the goose population is, nevertheless, mainly increasing because of changes in management and habitat in their wintering grounds.

Despite these challenges to the ESS approach in general and the Svalbard-specific examples provided it is, nevertheless, considered appropriate to develop an ESS observational platform on the archipelago.

For example it is frequently suggested that the polar systems have lower complexity than other regions; from this follows that deconvolving the Arctic system may be a more tractable problem than tackling other regions. Simultaneously the Arctic is a region of special interest for GEC both for its climate sensitivity and its fragile ecosystems.

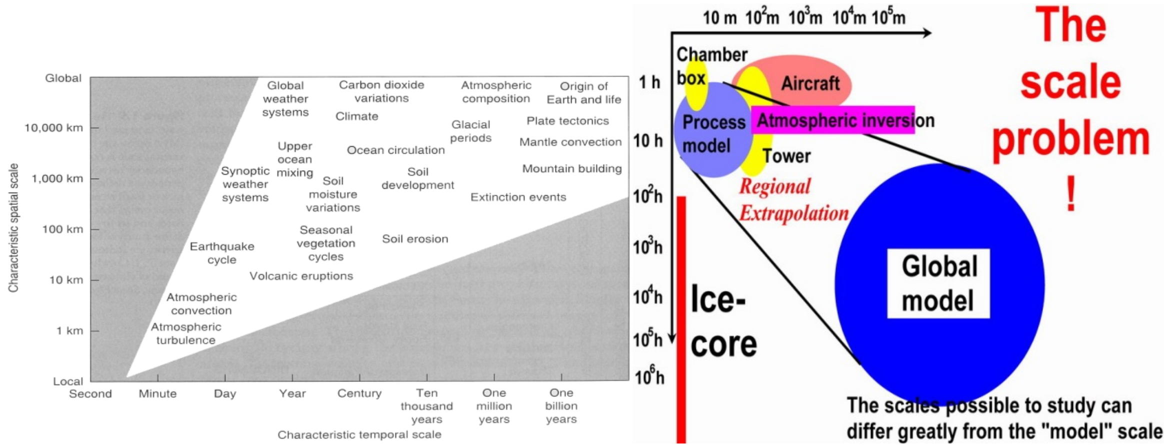
In a general sense it is tempting to conjecture that the larger the region or the stronger the boundaries (physical or otherwise) the more of the variations observed will originate from processes and phenomena within the region and the less will the boundary transfers be dominating the variations. Presently studies are to a large extent limited to point measurements or single fjords or glaciers in Svalbard; SIOS will aim to address more effective regional coverage with the goal of providing a better foundation for a regional system understanding.

Svalbard is a region within the Arctic that provides physical barriers for at least some of the entities and processes that are particularly relevant for a system understanding. This makes it possible to formulate studies where one utilizes the boundaries to separate internal transformations within the region and external factors. Svalbard is also a region with relatively substantial data coverage already as well as infrastructure and access capacity. It, thus, singles itself out as a region of choice to develop the ESS approach. Such an endeavor will provide increased understanding of the region and will significantly advance ESS methods.

The core measurement program of SIOS will provide a high level of interlinked systematic observations that are guaranteed to be available over time. This will further enhance Svalbard as an experimental environment where it will be attractive to perform basic and applied research.

Overall design considerations

The challenge for SIOS is to establish an infrastructure and measurement program on Svalbard that provides an environment that energizes ESS science. How can we design an observational network that is sensitive enough and dense enough to pinpoint the cause of change? We need to consider scales in our regional network design.



The left panel is an assessment of processes in the real world; the right is a simple analysis of some of the measurement techniques we are utilizing to study these processes. A current gap in SIOS is that of scrutinizing the gaps of knowledge in this type of context. Within the SIOS gap analysis there are only brief discussions and considerations regarding the number of measurements required to quantify the entities for Svalbard as a whole. The figures also clearly support the conclusion that a regional study like SIOS has limitations in an ESS endeavor.

What further complicates the situation is that the Earth System and in particular the regional Arctic System are in a process of rapid (and possibly accelerating) change beyond the boundaries of the realms investigated with current Earth System Models, e.g., changes between ice ages and interglacials. The Arctic System may enter a phase where processes considered up to then as irrelevant for the time horizons included in a system study may accelerate so much that they become relevant; one cannot then any longer simply extrapolate the system description applied in the model. This would severely hamper the ambition to identify an adequate set of parameters to cover the important aspects of Arctic change. A strategy[3, 4] to meet this challenge would seem to be a moderate oversampling in terms of the number of parameters, combined with regular reviews of the continuing relevance of these parameters for the system.

It is clear that for most parameters of interest in the ESS regime there is a clear under-sampling in both the temporal and spatial domains. This is true globally as well as in the Svalbard (and polar generally) environment. Philosophically, any basic research can be relevant for our pursuit of elucidating GEC but an argument is made here for a prioritization strategy to make most efficient headway on the issues society needs addressed at the present time. All measurements are potentially useful for the unknown questions of the future; for example, a mundane observational record that is not displaying any “exciting” change (or publications) can become incredibly important if some unpredicted change occurs in the system. The ozone hole story is a case in point. We don’t know what questions society will be asking in the future because we simply don’t know what the long term effects of something that we do or release may be. We don’t know what the future society

3 Lindenmayer, D. B. and G. E. Likens, 2009, Adaptive monitoring: a new paradigm for long-term research and monitoring, Trends in Ecology and Evolution Vol.24, No.9.

4 Nichols, J. D. and B. K. Williams, 2006, Monitoring for conservation, Trends in Ecology and Evolution Vol.21, No.12.

may be sensitive to other than (possibly) entities that influence our bodies or basic resources (e.g. food).

If we had exact data for everything everywhere we would not need models. If we had perfect models we would not need data. Neither of the two will happen anytime soon. An important issue for SIOS is to consciously meld model development and sampling/monitoring strategies such that we acquire the most rapid and cost effective development of both to maximize the amount of understanding from the available information. Inevitably, data will be limited in time and space and the gaps between can only be "filled" through models. Conceptually, data should be acquired in time and space realms where model data entail our only knowledge (e.g. testing/verifying models) and models should be utilized to point to areas where our present knowledge (as depicted in the model) suggest that there is large (poorly predictable) variability and also to point to areas where further measurements are superfluous.

When exploring entities with unknown variability and for which we have little understanding of the mechanisms controlling their variability we must begin with acquiring data. The temporal and spatial resolution that is useful to pursue in a monitoring effort can be (partially) explored with high resolution studies in a period and/or area of choice. Such studies can lead to conclusions regarding meaningful sampling strategies (to the extent that the high resolution study has captured the scales of variability). There are many limitations but this can provide a better strategy than starting with single stations at whatever temporal scale happen to be possible. There is a strong case for performing high resolution studies to determine representativity of the anticipated data before investing in long time series and monitoring.

A strategy for SIOS

SIOS must be designed around topics related to GEC in such a manner that we can:

1) Detect change
2) Attribute change
3) Describe the effects of the change
4) Understand and communicate what will be required to mitigate, adapt to and/or reverse change

Some overarching (pragmatic) considerations:

i. "Environmental" in GEC involves the entire system but building a complete ESS observational program should focus towards the interface between atmosphere and Earths' surface and the processes there where many existing programs are already active. There remain fundamental (energy- and mass- exchange) weaknesses (and uncertainties) for the interface descriptions in ESS models.
ii. "Change" in GEC is for all practical purposes (management and mitigation) considered on century or shorter time-scales.
iii. ESFRI (and thus SIOS) commitments have a decadal perspective.

If one accepts these points there are consequences regarding themes of observation and the spatial and temporal scales involved. The points influence what should be considered as part of the monitoring/observation activity and what are considered add-on experiments. It also has bearing on where the core of activity should be and what phenomena and processes the observational system regard as "external" forcing to the regional ESS effort. This still leaves outstanding the issue as to what strategy SIOS should adopt to handle/quantify these boundary conditions in space and time.

Activities to be prioritized are measurements that other data series need for their interpretation and measurements that will plausibly see change on decadal time-scales. Priority should also be given to conducting systematic representativity analysis of the measurements programs through an intimate interaction with the modeling communities. Solitary measurements that need no one else and are not used by anyone else should not be considered as core SIOS activities. Obviously such measurements have profound value as basic research and can suddenly become immensely important when a "surprise" occurs but in the infancy of SIOS the issues relevant to the questions posed at the present time must be prioritized.

The SIOS Knowledge Center should be a place where the accrued knowledge is being compiled in a way that ensures we are making the correct choices at each crossroad where future prioritization and directions need to be crafted. The Knowledge Center should also provide a venue that enables research, informs society and builds capacity as suggested by Leemans et al. (footnote 2). An important capacity building activity should be that of encouraging development of new observational techniques for environmental monitoring in frigid and sensitive areas. The comprehensive knowledge of the Svalbard system and observations harbored within the Knowledge Center combined with the general accessibility of Svalbard should facilitate rapid development of new high technology observation schemes. The Knowledge Center should provide an intellectual environment where sampling strategies and observational practices are developed at the intersections between stringent scientific evaluations, pure statistical considerations, what is technically possible, what is economically possible, and the specific issues of doing long term measurements in Svalbard. The Knowledge Center can then be an international melting pot for developing the science of how to conduct long term environmental monitoring in a manner that efficiently benefits society.

To the extent that SIOS shall function as a logistics provider for “experimental” measurement a criterion of prioritization could be for experiments that perform studies that require utilization of data from the core measurement program for their interpretive work.

Svalbard is to be one of the best managed wilderness areas of the world; 65% of the land areas and 87% of the marine areas within the 12 nm line are protected as nature reserves or national parks. There are provisions allowing science to be performed in the protected areas but under compliance to a number of regulations. There is at the same time compelling need for data from these regions. There is a grand challenge in developing techniques that produce the data necessary for ESS work with minimal environmental footprints. SIOS must stimulate innovation in techniques and accelerate their use in the Arctic.

Based on these considerations it is tempting to define specific criteria to apply to the prioritization of SIOS infrastructure investments. This note highlights that there are many considerations to take into account. The most important being the fundability of a specific infrastructure as this may in practice be defined from national priorities essentially independent of any SIOS project considerations. It is also clear that SIOS will evolve during the course of its existence and so care is necessary to not overly “hard wire” the infrastructure at the outset. Rather SIOS should evolve and grow in a responsive manner over time, that reflects developing opportunities and priorities, whilst holding to the core ESS values; SIOS must be innovative, dynamic and, counter intuitively, conservative at the same time.

Guidelines for prioritization

Scientific guiding themes:

- State variables of importance for GEC diagnostics.
- Energy and mass exchange.
- Combined effects of human perturbations.
- Effects of GEC on organisms, populations, and ecosystems.
- Measurements that will plausibly detect change on decadal time-scales.
- Systematic representativity analysis of the measurements programs through an intimate interaction with the modeling communities.
- Solitary measurements should not be considered as core SIOS activities.
- Innovation in monitoring techniques, methods and sampling strategies.

Other guiding themes:

- SIOS infrastructure must contribute to the filling of gaps, spatial or temporal, as well as providing added value information in achieving increased insight to governing processes.
- The investments shall contribute to the overarching ESS approach of SIOS.
- SIOS infrastructure providers should envisage decadal scale operational commitment to ensure the benefits of a unique reliable core data set for SIOS partners.
- There must be a clear added value to other parts of the SIOS project.
- Investments should be consistent with national prioritizations.
- Investments in singular infrastructure and research projects not providing essential parts of the above shall not be included in SIOS.
- New measurements of unconfirmed value can be associated with SIOS activities as they may have future importance, but should not be included in the core set of SIOS measurements.