Sustainable seamless monitoring in the Arctic

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Research monitoring of the Arctic environment has been carried out as two elements, remote sensing including the satellite and in situ observation. However, in situ field observations are hampered by the harsh environment of the Arctic, resulting in a sparseness of observing stations and large data gaps. Although recent progress in satellite monitoring has generated new information, there are still many factors that need to be observed in situ (e.g., ground truth measurement for microwave bands, snow density and temperature, soil moisture in surface soil). Accurate monitoring of the Arctic environment requires continuous, high density measurements that may only be achieved through international cooperation.

For convenience, the monitoring fields are divided into the ocean, cryosphere, atmosphere and land, followed by the priority long-term monitoring method. For the ocean, the monitoring of sea ice change in extent and thickness, marine ecosystem and material cycle throughout the year using an icebreaker and satellites are needed. In the cryosphere, determining the mass balance and related various quantities of the Greenland ice sheet and the mountain glaciers in the Arctic, the monitoring of coastal erosion, thermokarst associated with thawing, and management of boreholes to measure permafrost temperature in the permafrost region are essential. In the atmosphere, long-term precise measurement and understanding of the spatial variation of atmospheric minor constituents involved in changes of the climate, cloud and precipitation are important. For the monitoring over land, development and maintenance of comprehensive observing stations (super site) for the monitoring of vegetation change, terrestrial ecosystems and meteorological and hydrological elements, including heat, water and carbon fluxes at land surface are needed. The monitoring of all of the above elements will require both in situ observations and remote sensing.

For the monitoring of the above described elements, various organizations, systems, and facilities are required:

Research vessels

Japan does not possess an ice breaking research vessel, which could be operated in the Arctic Ocean. Japanese Arctic researchers are obliged to use foreign vessels for their research operations, and as a result developing a sound observation plan is challenging and the operations are limited. A new research ice breaker is a way to overcome this situation. The new vessel would allow us to immensely improve our observation ability

of the Arctic Ocean. The equipment particularly needed includes: a moon pool, multi-purpose winch, automatic launcher for radio sonde, ROV (remotely operated vehicle), chemical-biological-geological laboratory (including cold rooms), long-time navigation capable and multi-sensor equipped AUV (autonomous underwater vehicle), sampling capable ROVF, long and large diameter piston corer, multi-beam bathymeter for ocean bottom survey, sub-bottom profiler for strata probing.

Satellite

It is necessary to improve the observation of sea ice distribution by using a micro-wave radiometer installed on satellite, which would double the present spatial resolution of AMSR2 (89GHz and 3～5km). An integrated observation system of Synthetic Aperture Radar (SAR) and Laser/Radar altimeter is also very effective for detecting the mass change of ice sheet/glacier, sea ice and snow cover. It also needs to develop a gravity measuring satellite, such like GRACE.

Japan now has plans to launch GCOM-C1/SGLI, which would cancel the dependency to US visible sensors in monitoring of the terrestrial and marine ecosystem.

Aircraft

Aircrafts are important platforms of observations between satellite and ground measurement. Especially it is needed to provide a platform for the electromagnetic induction probe (EM) in measuring the sea ice thickness and for direct measurement of atmospheric compositions and cloud particles. In the past, a commercial aircraft has been used for such Arctic observations, but it is effective to develop and possess an airplane with a new technology instruments. On the other hand, the usage of un-manned aircraft may also be a possibility.

Research and observation base in the Arctic

As a non-Arctic state, Japanese Arctic scientists need to have base stations in the Arctic. These stations must be long-term comprehensive measurement sites. The research goals, the measurement methods and their data are shared by the scientists of the host country under bi-lateral cooperation protocols. The priority of the measurements goes to the collection of various environmental parameters. Such a base is also important for early career scientists, especially those learning the operational skills in the harsh environment in the Arctic. There is also a need for an institute to maintain and manage the research base in the Arctic in cooperation with Arctic states, including the necessary domestic arrangements.

Data archive

The data archive system must be user friendly and flexible to differently formatted data. A Data Center is needed, where data rescue, digitization of data, and identification of dataset using DOI system can be operated. Cooperation with an international data center is essential to collect and use the various databases.

Instruments (Atmosphere, Upper-Atmosphere, Cryosphere, Land and Ocean)

There is a great need for instruments. One example is the development of a large radar network with EISCAT-3D, MU radar at Shigaraki, Japan, Equatorial Atmospheric radar in Indonesia, etc. for the distributed monitoring of the upper-atmosphere. Other examples are a high-resolution stable isotope analyzer for aerosols and gases, and a high resolution ice-core melt analyzer in the area of glaciology. For the terrestrial vegetation, a Hyper Spectral Camera, which will reveal the

composition of the tree, is necessary. Development of an observation platform, such as ROV and AUV, is also important to be able to observe the sea ice from below.

Numerical model

In addition to hardware, such as massive calculation resources and large storage, there is a need to secure human resources to develop models and run the hardware. Furthermore, a system which will enable research technicians to prepare data and develop source codes is needed.

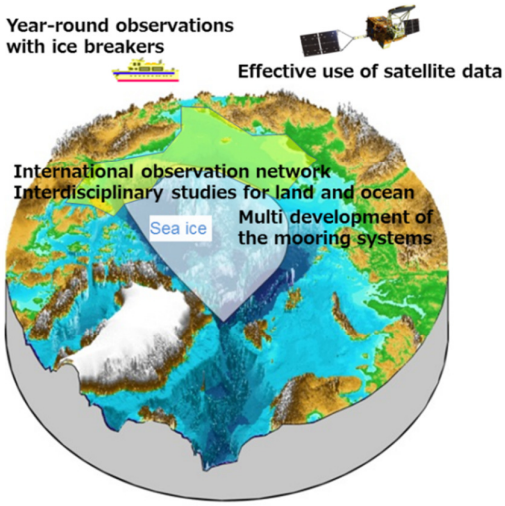

Figure 1: Elements necessary for the monitoring of marine ecology in the future (conceptual diagram). (References to the figure should be made in the body of the text)

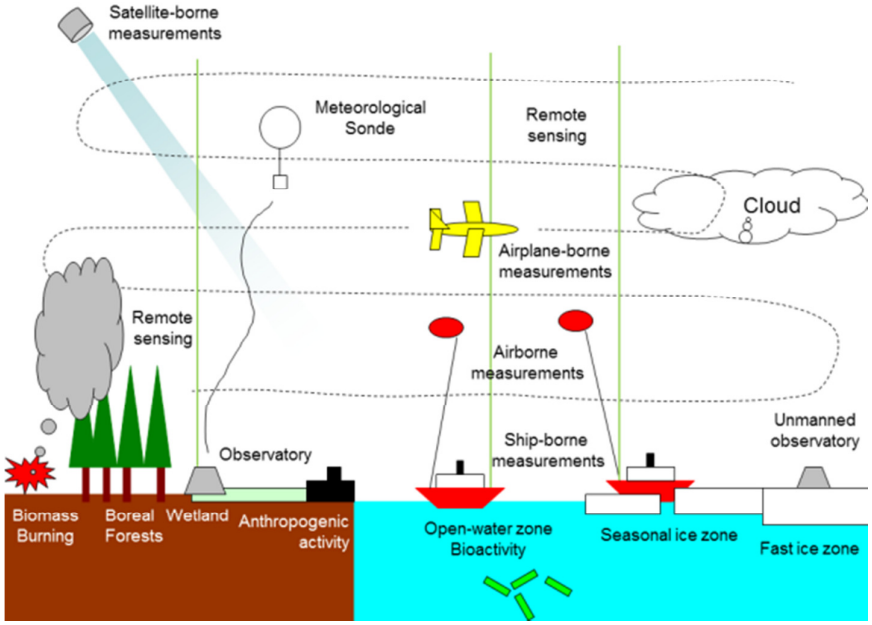

Figure 2: Elements necessary for the monitoring of atmospheric minor constituents in the future (conceptual diagram). [Theme A] (References to the figure should be made in the body of the text)