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Deliverable 6.2.

Recommendations for automatic environmental data collection of ice going vessels

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1. Abstract

In the Arctic Ocean, more environmental observations are needed. One way to fill the lack of observations is to engage commercial vessels to participate in environmental data collection. Nowadays, this type of work is coordinated by JCOMM as the Voluntary Observing Ships (VOS) Scheme. The VOS Scheme focuses on marine meteorological and oceanographic data and currently does not cover the Arctic Ocean. Our goal is to extend VOS type of work to the Arctic Ocean and increase the number of observations of sea ice and snow cover. This will be done by establishing the ARICE Ships of Opportunity (SOP) Programme. In all the steps towards the SOP Programme, the key thing is to ensure the high quality of the data. For this, the guidelines of the VOS Scheme will be used as a basis.

In this document we determine the environmental variables that should be (automatically) observed on board the participating vessels in the Arctic. These recommendations are based on Deliverable 6.1, which presented the state of the art in data collection on board vessels navigating in the Arctic Ocean. As Deliverable 6.1 showed, automatic measurements are currently very rare. The needed technology for systematic autonomous observations exists only for few meteorological (temperature, wind speed and direction and relative humidity) and oceanic variables (temperature and salinity of surface layer). Therefore, this document discusses also visual observation of some other variables that are found important.

Technological developments needed for enhanced automatic data collection in the Arctic will be discussed in next steps towards the ARICE SOP Programme. This will be done in a close co-operation between the research community and the private sector operators and reported in forthcoming deliverables.

2. Introduction

In the changing climate, the Arctic Ocean is a region of especially high interest. The Arctic region undergoes globally the strongest warming and the changes in the Arctic sea ice cover are substantial. A good understanding of the changing Arctic requires comprehensive monitoring but in the Arctic Ocean the collection of environmental observations has been and is very limited due to difficult access. Thus, there is a need for more data. Enhanced data coverage would benefit both the science community and the Arctic marine industry which has an increasing interest in Arctic Ocean as shrinking sea ice cover is making a previously nearly inaccessible region attractive for various types of operations. A deep understanding of the numerous processes connected to changes in the Arctic climate, sea ice and ocean is needed for better forecasting models and improved risk assessment and is thus a key to improved safety and sustainability of all the Arctic operations.

One way to fill the lack of environmental data can be a co-operation with private sector operators. The idea of engaging commercial vessels to participate in the environmental data collection is not new. International collaboration in recruiting ships for taking and transmitting meteorological observations was developed already nearly 150 years ago. Since 1994, this work has been called the Voluntary Observing Ships (VOS) Scheme, first running as a programme of Maritime Safety

Committee, and since 1999 under the coordination of the WMO/IOC Joint Technical Committee for Oceanography and Marine Meteorology (JCOMM). There are also other smaller programmes where the data collection is limited to some particular region or in certain type of measurements (e.g. FerryBox work).

The World Ocean Council (WOC) has initiated the SMART Ocean-SMART Industries (SO-SI) program to engage the broad range of ocean industries in hosting or deploying instrumentation. The WOC SO-SI program works to accelerate and scale up the number and location of vessels and platforms involved in data collection, providing a business organization to build on and support existing schemes, such as VOS. The Arctic is a geographic priority for the WOC SO-SI program overall, and via the ARICE project specifically.

The VOS Scheme focuses on marine meteorological and oceanographic data and currently does not cover the Arctic Ocean. The ARICE goal can be considered as extending VOS type of work to the Arctic Ocean and increase the number of observations of sea ice and snow cover. WMO and JCOMM have detailed guidelines for data collection in the VOS Scheme (reference 2) as well as generally for marine observations (references 1 and 3). These requirements, for the relevant parts, should be met also in the ARICE Ship of Opportunity Program (SOP) and other data collection. In the VOS scheme, many visual observations are included. However, the general direction in environmental monitoring is towards automatic instruments and real-time data transmission. In our work, a goal is in an improvement of automatic data collection, taking into account the special challenges of the Arctic Ocean. This requires new technological solutions due to harsh conditions of the Arctic Ocean and due to general lack of automatic measurement devises in the sea ice and snow observations. In ARICE, the topic of technological developments will be discussed in workshops with both industry and science representatives, and further developed in Deliverable 6.5.

This document is based on Deliverable 6.1, in which we presented the results of the survey collecting information of the state of the art in data collection on board vessels navigating in the Arctic Ocean. In this document, we feed the results of the survey into recommendations of environmental variables that all the vessels operating in the Arctic should record. Ideally, this data collection is automated and continuous. However, automatic measurements are currently very rare and limited to basic meteorological and oceanic variables which support the navigation. Therefore, this document also discusses visual observation of some other variables that are found important. In the short term, the systematic and standardized collection of those visual observations is seen as the best option as the needed technology for automatic measurements does not exist yet. However, in the long run, automatic instruments are the optimal solution in order to collect data comprehensively and systematically.

The aim of this document is to determine the environmental variables that should be (automatically) observed on board the participating vessels in the Arctic. Some of these observations are important for operational use mainly while others belong to the group of essential climate variables defined by WMO. However, determining the desired data is just a small part of the entire process towards establishing the SOP program. The key thing is to ensure the good quality and usability of the data. Questions that need to be carefully considered are include:

- What are the requirements of the ships/industry partners participating in data collection?

- Do we want to focus on the frequently used routes only, or do we want any available observations? Should we define priority areas of interest?
- How do we undertake the process of recruiting ships? Is it done by national research institutes, ARICE or some other party, like the WOC SMART Ocean-SMART Industries program?
- Who invests in instruments? Who is responsible for deployment, calibration and maintenance of instruments and for the training of the ship crew?
- Who is responsible for the data quality control and for ensuring the data is properly stored and shared?

The guidelines of VOS scheme (*reference 2*) serve as a good basis when discussing these questions and setting the principles of ARICE SOP program.

3. Shipborne environmental data collection in the Arctic

In this chapter, data collection of meteorological, oceanic, and sea ice and snow variables are discussed separately. In addition to these environmental observations, key ship data needs to be recorded in standardized manner. At this point, we do not go much into the details regarding instruments and deployments although some aspects are pointed out. Those will be discussed more during the next steps towards the establishing the ARICE SOP program, and they will be described in the forthcoming deliverables. Also, the needs for new technological solutions will be a topic of workshops and deliverables 6.3 and 6.5. However, we highlight here that all the measurement practices in the ARICE SOP program should follow the guidelines of WMO and VOS scheme (*references 1 to 3)*.

The aim cannot only be enhanced environmental data collection in the Arctic but also needs to include the ensuring the good quality of the data. This applies to all the steps from recruiting of the ships to the instrument installations and maintenance, data collection and to the post processing and storing of the data. Moving ships are not easy platforms for achieving accurate measurements. Movement and vibration of the ship bring special challenges for the durability of the instruments and the accuracy of measurements, as well as for the instrument deployment location and technique. Ships have superstructures and masts causing distortion of the flow as well as several sources of heat, moisture and particles, which need to be taken into account when planning the deployment sites of the instruments. Every vessel has its own structural design and thus the optimal placement of instruments is vessel dependent. For many meteorological and oceanic measurements, the VOS scheme guidelines provide a good list of aspects that need to be considered in deployment design, and those requirements and recommendations should be followed also in ARICE SOP program. For SOP program, we need to determine whose responsibility it is to control and carefully document how the measurement sites are determined and designed on board each vessel.

In order to make the data useful, all the included variables need to be defined unambiguously. Many variables have very universal definitions, while some others have various definitions or

interpretations. A good example of the latter ones is the sea surface temperature (SST) which can refer to temperature of sea surface skin of few millimeters or to the mean temperature of the mixed layer of several meters thickness. For each variable, also the measurement frequency needs to be determined, taking into account the use of the data. In the VOS scheme, majority of the observations are taken with an interval of 6, 12 or 24 hours.

3.1 Meteorological observations

Based on the Deliverable 6.1, we recommend that all the vessels record automatic observations of:

- Air temperature
- Air pressure
- Wind speed and direction
- Relative humidity/dew point

These are the variables that currently are observed on board nearly all the vessels navigating in the Arctic Ocean, although primarily for navigational purposes. These measurements are conducted in an automatic manner, showing that the needed technology exists and is widely in use. All the observations currently made do not meet the quality criteria of instrument, deployment, calibration and maintenance determined for the marine observations in the VOS scheme. However, these issues can be solved with existing technologies and thus high quality data of these variables can be widely recorded in an automatic manner.

Wind measurements are particularly challenging, as pointed out in the WMO marine observations guide as well. It is very difficult to obtain a good exposure due to superstructures, masts, etc. When the observations are made from moving ship, the true wind needs to be calculated from the recorded relative wind and ship speed and course, which brings a considerable source of error. The good exposure of the instrument often requires the measurement height to clearly differ from the standard measurement height of 10 m and the correction to equivalent 10 m surface wind is needed. Thus, the metadata, as well as ship data, are particularly important for the wind observations.

As Deliverable 6.1 showed, automatic and continuous measurements of greenhouse gases are already possible, but this is currently underway onboard some research vessels only. As the technology exists but is not widely spread yet, it is not yet realistic to include these measurements in the recommendations for all the vessels. However, this is likely to change in the future.

3.2 Oceanic observations

Based on the Deliverable 6.1, we recommend continuous, automatic observations of:

- Sea surface temperature (SST)
- Sea surface salinity (SSS)

Both the definition and the measurement methods of these oceanic variables are less universal and standardized than those of the basic meteorological observations. Different definitions and methods

are discussed in WMO's Guide to Meteorological Instruments and Methods of Observations /Part II, Chapter 4. It is said that the measured temperature and salinity should be the values of the sea surface representative of conditions in the near-surface mixing layer underlying the ocean skin. Also, the guide highlights the importance of good quality of SST measurements as its difference with air temperature is needed to determine several important characteristics of the lower layers of air masses, e.g. the stratification.

The technology for automatic and continuous measurements of several physical, chemical and biological water quality variables exists. These measurements are conducted using through flow systems (e.g. FerryBox), but currently these measurement systems do not work in ice covered waters. However, these water quality observations from the Arctic Ocean would have a high value. Therefore, when navigating in ice free waters in the Arctic region, the use of FerryBox system is recommended. This is possible for ships in any type of operations in the Arctic since entering the ice pack does not cause damage to the FerryBox system. The FerryBox system typically measures temperature, salinity, turbidity, oxygen saturation, pH, chlorophyll a fluorescence and nutrients. The FerryBox data collection is guided and coordinated by EuroGOOS (http://eurogoos.eu/ferrybox-task-team/). A possibility to extend FerryBox data collection into the ice-covered waters would need new technological solutions. As these data would have a very high value, this topic will be brought up in the forthcoming technology-oriented work in ARICE.

3.3 Sea ice and snow observations

Currently, very few automatic instruments for sea ice and snow observations exist. This was clearly shown by Deliverable 6.1 as well, where only one research vessel reported any automatic sea ice measurement (ice load on the hull). However, several visual observations of sea ice conditions are done in all the vessels as they are needed for safe navigation. Therefore, the crews of the ships in the Arctic are experienced in making visual sea ice observations and the systematic and standardized collection of those observations is currently the best way to enhance the shipborne sea ice and snow data collection. Also, in the discussions on technological developments, a high priority needs to be given to sea ice measurements as we are currently lacking instruments for automatic observations.

A work towards a standardized collection of visual shipborne sea ice and snow observations in the Arctic has been running for several years under the project IceWatch. IceWatch coordinates the collection and archiving of the observations and provides a software which observers use for reporting the sea ice conditions. Also, IceWatch provides a detailed manual for making the observations. So far, IceWatch has been mainly used by research vessels during their Arctic expeditions but the programme welcomes any observers.

The automatic weather station systems sometimes used in VOS Scheme allow a manual input of visual observations. Those are one option for collection of sea ice observations. However, for the best findability and usability of the data, it would be ideal to have all the visual sea ice observations in one archive. Thus, we recommend that all the ships navigating in the Arctic feed their visual sea ice observations in the IceWatch.

The recommended visual sea ice observations include:

- Location of ice edge
- Sea ice concentration
- Sea ice types (new ice, first year ice, multiyear ice, deformed ice)
- Sea ice thickness
- Floe size
- Ice bergs

In the future, visual observation will hopefully be replaced by automatic instruments. This would eliminate the impact of observer dependent interpretation of the conditions and allow continuous measurements. For some variables (like sea ice thickness) automatic recording could be achieved by developing existing instruments to be reliably working as autonomous shipborne deployment while automatic observation of some other variables (like floe size) would need more innovative approach. For instance, electromagnetic devices for measuring total thickness of sea ice and snow exist and those can be deployed on the bow or side of the ship. So far these installations have been used only on short term campaigns, but potentially these type of measurements could be in operational use soon.

3.4 Ship data

The minimum ship data that needs to be recorded simultaneously as environmental observations are the position, course and speed of the ship. These can be taken from the ship's own navigation system (like gyro compass) or computed using satellite navigation system (usually GPS).

Electronic log books for VOS Scheme are recommended by JCOMM (http://sot.jcommops.org/vos/resources.html#ops03) and those should be used in ARICE SOP Programme as well.

4. Conclusions

This document presents the recommendations for shipborne environmental observations in the Arctic to be conducted onboard both the research vessels and ships of private operators. This idea of recruiting commercial vessels in data collection is not new but extends the VOS Scheme type of work to the Arctic Ocean. The Arctic Ocean is the region where more observations are highly needed but ice cover and harsh conditions make many areas difficult to reach and also bring special challenges for instrumentations. The overall goal is for key meteorological, oceanic and sea ice/snow observations to be recorded automatically and continuously. At freezing temperatures this is an ambitious goal and requires still technological developments of several measurement methods. Currently, the needed technology for systematic autonomous observations exists only for few meteorological (temperature, wind speed and direction and relative humidity) and oceanic variables (temperature and salinity of surface layer).

Technological developments needed for enhanced automatic data collection in the Arctic will be discussed in next steps towards the ARICE Ship and Platforms of Opportunity Programme. This will be

done in a close co-operation between the research community and the private sector operators. The work will start with workshops where the priorities and goals of both sides are presented, and then continue towards determining the fields where the technological developments are seen especially beneficiary. As the Deliverable 6.1 showed, automatic instruments for recording sea ice and snow observations are currently completely lacking and both further development of existing technologies and new innovative approaches are needed. Also, the developments of the existing FerryBox through flow system to work in the ice-covered waters would provide the possibility to collect significant amounts of important oceanic data of several physical, chemical and biological variables. But, as mentioned earlier, the focus of the technological development related work is to be determined in the forthcoming workshops.

When recruiting commercial vessels in data collection, a key thing is to ensure the good quality of the data. For this, the guidelines of the VOS Scheme provide excellent basis, and for all the relevant parts, those requirements and recommendations should be fulfilled also in data collection within ARICE. A moving ship with several superstructures and sources of heat, moisture and particles is a very challenging platform for environmental observations. Also, the optimal deployment location of the instruments is vessel dependent. This makes the metadata highly important. For recruiting commercial vessels, the responsibilities of ensuring the data quality needs to clearly clarified. This applies to all the steps from the recruiting process to the deployment, calibration and maintenance of the instruments, training of the ship crew, quality control of the data as well as ensuring that the data is archived and shared in proper manner.

References:

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