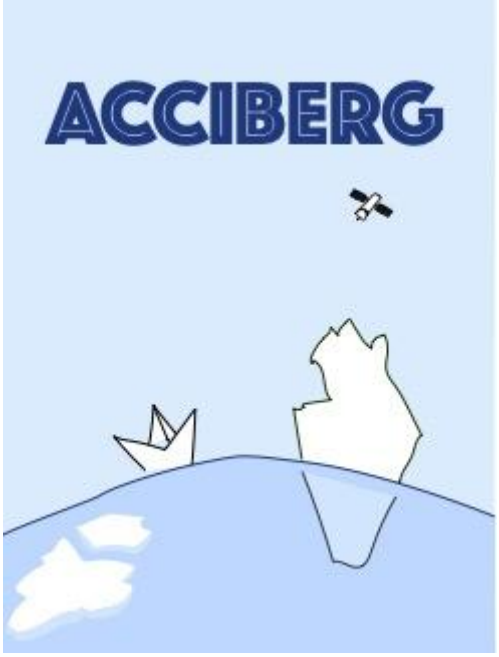

Arctic Cross-Copernicus forecast products for sea ice and iceBERGs

Deliverable 4.1

Safety Protocols for Citizen Science Demonstrations

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101081568.

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1. Scope

The main objective of ACCIBERG is to improve the quality of Arctic forecasts across Copernicus Marine and Climate Change services and develop a new iceberg forecasting service making optimal use of Copernicus satellite data, services, and infrastructures in support of maritime safety in the Arctic.

The new iceberg forecasts will be automated and validated by project members and stakeholders, and will benefit a wide range of user groups navigating in the Arctic, from fisheries to cruise tourism and marine surveillance. ACCIBERG will provide prototype products ready to be implemented in the Copernicus services and accessible from a single entry point: its inherent cloud computing solution.

To assist with developing and quantifying the effect of improvements to monitoring and forecasting, in situ or ground truth observations of icebergs are required. As the polar regions are data sparse, ACCIBERG will draw on the opportunities for iceberg observations from scientific and civilian maritime activities. To ensure that this is done in a safe way, we present here some protocols for shipboard and drone observations that should be adhered to when performing data collection.

2. Iceberg Observations

The Canadian Ice Service publication "*MANICE: Manual of Standard Procedures for Observing and Reporting Ice Conditions*" (Canadian Ice Service, 2005) provides an overview of the ways of acquiring visual iceberg observations from the surface, and from the air. The method of reporting is the same for both, and the standard terminology used is described here.

The principal objective of surface observations is to identify and report all the icebergs that are present within the area covered. The observer should set his/her observing limits to the extent that he/she can be certain that all icebergs have been reported with a high degree of confidence.

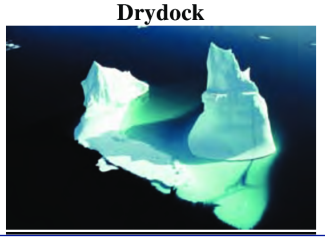
With aerial iceberg observations. reporting should be whenever possible given that the observer typically will have no control over the flight track or conditions. Visibility should be 15 nautical miles (~28 km) and the optimal altitude for visible observations is approximately 1500 feet (~450 meters).

The standard sizes and shapes of icebergs are shown in Table 1 and Table 2.

Table 1: Standard sizes of icebergs [Source: MANICE, 2005]

Iceberg Size	Height above sea surface (meters)	Length (meters)	Weight (Megatons)
Growler 	less than 1 m	less than 5 m	0.001
Bergy Bit 	1 m to less than 5 m	5 m to less than 15 m	0.01
Small Berg 	5 m to 15 m	15 m to 60 m	0.1
Medium Berg 	16 m to 45 m	61 m to 120 m	2.0
Large Berg 	46 m to 75 m	121 m to 200 m	10.0
Very Large Berg 	Greater than 75 m	Greater than 200 m	Greater than 10.0

Table 2: Typical iceberg shapes [Source: MANICE, 2005]

Shape	Average height to draft ratio	Shape	Average height to draft ratio
Tabular 	1:5	**Wedge** 	1:5
Non-Tabular 	1:5	**Drydock** 	1:1
Domed 	1:4	**Blocky** 	1:5
Pinnacle 	1:2		

These definitions are derived from the WMO standard *Sea-Ice Nomenclature* (WMO, 2014)

In Canadian waters iceberg reports are encoding according to the standards described in MANICE Chapter 4 and developed by the Meteorological Service of Canada and International Ice Patrol. Within ACCIBERG, we aim to follow these standards as much as possible to ensure compatibility and interoperability.

The following information should be recorded:

- Platform type: Whether it is an airplane, helicopter, icebreaker (research vessel) including helicopter, other ship (including yachts and cruise ships), or shore station.
- Observer: Professional or citizen scientist.
- Observation basics: The date and time UTC, observing longitude/latitude coordinate, and altitude (for aircraft).
- Environmental conditions: Visibility, sea ice, swell height and direction.

- Observation type: Individual or cluster of icebergs.
- Iceberg position: Either a longitude/latitude coordinate if observed from radar, or estimate of the distance and direction from the observing position.
- Numbers, sizes and shapes of icebergs: Size and shape using standard iceberg reporting terminology.
- Confidence level/Method of observation: Whether the report is based on radar information, or visual estimate.

A **report sheet template** is provided in Section 7a, and can be downloaded as a PDF at https://bit.ly/Iceberg_Report.

3. Safety Protocols for Shipboard Observations

The largest proportion of the iceberg is invisible, below sea level. This is subject to melting which alters the underwater shape, and therefore changes the centre of mass of the iceberg resulting in instability. The change to a stable orientation can be quite sudden, resulting in the iceberg rolling over.

Rolling icebergs can generate large waves, and underwater portions can suddenly surface, in the near vicinity. In addition, large tabular icebergs can also suddenly calve large pieces, with similar results.

Icebergs can look stable for days or weeks but they can roll, break apart or collapse without any warning or visible signs of instability. The invisible ice foot of an iceberg can be big and quickly come to the surface during a roll. There are no official rules for a safe distance to an iceberg. As a rule of thumb no one should be closer than 5 times the height of an iceberg at any time. As an example the distance to a 25m high iceberg should be no less than 125m.

If a GPS-tracker is to be deployed, this should always be done remotely, preferably by an unmanned aircraft. See the next section on Safety Protocols for Drone Operations.

The primary safety protocol is to observe remotely, from a distance. The distance will depend on the size of the iceberg, and the size of the vessel. For ACCIBERG, the interest is in the location of the iceberg, its approximate size and shape, and its drift if observable. All of these can be achieved without going close to, or onto, the iceberg.

This is also the recommendation of the Governor of Svalbard in their Safety in Svalbard pubøication (Sysselmesteren, 2019):

> *Small ice bergs formed by calving from the glaciers are also common in the fjords. Ice bergs only hold 1/9 of their mass above water and can be very unstable. Ice bergs breaking or flipping over can cause waves, putting small boats close by at risk. It may be tempting to get close to glacier fronts that plummet into the fjord. This is dangerous however, as the glaciers calve and serious damage can be caused by falling ice or tidal waves. You should therefore keep at a distance of several hundred meters from all glacier fronts.*
>
> *Glaciers can calve on land and calving can also occur in the winter, causing large cracks and tidal waves in the ice.*

The Association of Arctic Expedition Cruise Operators (AECO) has similar recommendations in its Operations Guidelines (AECO, 2022):

> ***Glacier Fronts***
>
> *Glaciers fronts may calve, causing flood waves and/or flying bits of ice. Keep your distance!*

The recommended minimum distance to glaciers in the Arctic is no less than 200 meters. For high activity glaciers such as glaciers fed directly from the Greenland Inland Ice Cap a distance of 400 meters is recommended.

At some glacier fronts, even this may be too close, especially in narrow fjords, shallow fjords and fjords with high cliffs. Show extra caution and always increase the distance to the glacier fronts if the glacier calves in shallow water or on land – use good judgement.

- *All glaciers may calve, even if the probability of a glacier calving may differ. E.g. the probability of the Bråsvell glacier calving is much smaller than the Monaco glacier, but the Bråsvell glacier may still calve.*
- *All zodiacs must keep an appropriate distance (including a buffer zone) away in order to handle a possible calving.*
- *Avoid being trapped by islands or in brash ice close to the glacier front in case a calving occurs.*
- *Factors that might affect the probability of a calving:*
    - *Glacier front height*
    - *Water depth in front of the glacier*
    - *Gradient of the glacier*
    - *The speed of the glacier front*
    - *Degree of fracturing in the glacier front*
    - *Sea and current dynamics under the glacier front*
    - *Fjord width, sea depth and topography as high cliffs*

Icebergs

- *Potentially unstable: all icebergs can suddenly flip over, causing flood waves. Keep your distance! Icebergs are continuously under the influence of waves, tides, currents and temperature, and therefore potentially unstable. Remember that 90% of the berg is under water.*
- *Sudden flipping might cause huge waves, or parts of the iceberg might come to the surface at unexpected places.*
- *Never approach an iceberg too closely.*
- *Details: see Glacier fronts.*

For ACCIBERG, shipboard observations of icebergs can be satisfactorily conducted at a safe distance by visual observation. Additional measurements can be carried out using radar or drones, if available.

A **safety summary sheet** has been prepared and is available in Section 7b, and online at https://bit.ly/Iceberg_Safety_Sheet

4. Safety Protocols for Drone Observations

The use of unmanned aircraft, also known as drones, Unmanned Aerial Vehicles (UAVs), or Remotely Piloted Aircraft Systems (RPAS), opens up the possibility for additional perspectives on observing icebergs. Systems are increasingly affordable, and more likely to be available from expedition cruise vessels.

The first protocol to observe is not for safety, but **is to ascertain that the necessary permissions have been obtained to fly** the drone. That includes from the master of the vessel that is being used as a launch platform, or from the expedition leader or shore station manager if on land. Some areas of the polar regions may have additional requirements, especially around airports where there are typically strict no-fly zones.

For example, on Svalbard there are no-fly zones for 5 km around Longyearbyen and Ny-Ålesund airports, with Ny-Ålesund having an additional restriction of radio silence within 20 km (which therefore limits drones to only fully autonomous systems without communications transmissions) (Sysselmesteren, 2023). All users of drones heavier than 250 g must also register with the Norwegian Civil Aviation Authority.

A comprehensive manual on all aspects of drone operations can be found in the *Arctic Science RPAS Operator's Handbook* (AMAP, 2015).

In terms of safety, the key requirements are:

- Ensure that the drone operates away from personnel, and other aircraft activity.
- Avoid damage to other infrastructure such as the vessel, or shore-based buildings or installations.
- Do not disturb wildlife.
- Ensure that the payload, particularly additional equipment such as GPS-trackers, are within the capabilities of the drone.
- Operate well within the range and endurance of the drone, leave sufficient reserves for unplanned incidents.
- Have a recovery plan in case the drone ditches in the sea, or crash-lands.

The International Cooperative Engagement Program for Polar Research (ICE-PPR) project conducted a successful deployment of GPS trackers onto icebergs in the summer of 2021, in the waters west of Greenland (Naval News, 2021). This found that having multiple drones helped the deployment by providing additional viewpoints to determine the best drop location for the payload.

5. Discussion and conclusions

We have summarised here some key requirements for safely observing icebergs both from ships and from drones. These are expected to be useful both for scientific observers and citizen scientists in acquiring iceberg observations for ACCIBERG.

6. References

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7. Information Summary Sheets

a. Iceberg Reporting Sheet

A PDF-version of this reporting sheet for printing can be downloaded at https://bit.ly/Iceberg_Report

Arctic Cross-Copernicus forecast products for sea ice and iceBERGs

Iceberg Report Sheet

PLATFORM TYPE (tick one) ☐Icebreaker (research vessel) including helicopter
☐Other ship (including yachts and cruise ships) ☐Shore Station ☐Airplane ☐Helicopter

OBSERVER (tick one) ☐Professional Scientist ☐Citizen Scientist

NAME	

OBSERVATION BASICS

Date (YYYY-MM-DD):		Time UTC (HH:MM):	
Latitude (DD°MM.MMM'H):		Longitude (DDD°MM.MMM'H):	
Altitude Units (tick one):	☐ meters ☐ feet	Altitude:	

ENVIRONMENTAL CONDITIONS

Visibility:		Sea Ice:		Swell Direction:		Swell Height:	

OBSERVATION TYPE (tick one): ☐Individual iceberg ☐Cluster of Icebergs

ICEBERG POSITION

PRECISE	Latitude (DD°MM.MMM'H):		Longitude (DDD°MM.MMM'H):	

OR

ESTIMATE	Distance (km/miles):		Direction (degrees):	

NUMBERS, SIZES AND SHAPES OF ICEBERGS

Total number of icebergs:					Radius of cluster (km/miles):					
ICEBERG NUMBERS	Tabular	Non-Tabular	Domed	Pinnacled	Wedged	Drydock	Blocky	Ice Island	Not Specified	Undetermined (Radar Target)
Growler										
Bergy Bit										
Small										
Medium										
Large										
Very Large										
Not Specified										
Radar Target										

CONFIDENCE LEVEL / METHOD OF OBSERVATION (tick one in each box)

Position: ☐Radar position, with visual confirmation ☐Visual only	Iceberg Size: ☐Measured ☐Estimated

Other Notes:	

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101081568.

Arctic Cross-Copernicus forecast products for sea ice and iceBERGs

Iceberg Report Sheet

ICEBERG SIZES

Name	Height above sea surface (meters/feet)	Length (meters/feet)	Name	Height above sea surface (meters/feet)	Length (meters/feet)
Growler	< 1 m < 3 ft	< 5 m < 16 ft	Medium Berg	16 to 45 m 51 to 150 ft	61 to 122 m 201 to 400 ft
Bergy Bit	1 to 4 m 3 to 13 ft	5 to 14 m 15 to 46 ft	Large Berg	46 to 75 m 151 to 240 ft	123 to 204 m 401 to 670 ft
Small Berg	5 to 15 m 14 to 50 ft	15 to 60 m 47 to 200 ft	Very Large Berg	> 75 m > 240 ft	> 204 m > 670 ft

ICEBERG SHAPES

Shape	Average height to draft ratio	Shape	Average height to draft ratio
Tabular 	1:5	Wedge 	1:5
Non-Tabular 	1:5	Drydock 	1:1
Domed 	1:4	Blocky 	1:5
Pinnacle 	1:2	Ice Island 	1:11

Graphics are used from "*MANICE: Manual of Standard Procedures for Observing and Reporting Ice Conditions*" (Canadian Ice Service, 2005), apart from Ice Island, from NSIDC.

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b) Iceberg safety infographic

A PDF-version of this infographic for printing can be downloaded at
https://bit.ly/Iceberg_Safety_Sheet