

Amundsen Science: an integrated management approach to optimize the use of Canada's most versatile observing system at sea

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Introduction

The field acquisition of marine samples and data in the Arctic is highly demanding in terms of financial and logistical resources. Although such enterprise is associated with high costs and a large carbon footprint, there is a crucial need to obtain these data in the context of a changing Arctic system that requires synoptic information for evidence-based decision-making.

Amundsen Science is the not-for-profit organization responsible for the management of the scientific mandate of the Canadian research icebreaker CCGS *Amundsen*. It facilitates access to the icebreaker and its state-of-the-art pool of scientific equipment for multidisciplinary research up to 140 days a year, accommodating the needs of researchers operating in both Arctic coastal and marine environments. Since its science refit in 2003, the vessel spent more than 2,500 days at sea, welcoming more than 1,900 researchers and students and producing over 400 datasets.

Through its integrated operational approach, Amundsen Science is dedicated to optimizing the use of the vessel and increase data usage by the Canadian and international research community. Strategies implemented before, during and after the expeditions by the organization demonstrate that the presence of a neutral entity at the interface between the Canadian Coast Guard and the user base yield greater research outcomes and collaborations than if researchers would be left alone in the course of the development of their at-sea research program.

Expedition planning

The planning of an Arctic expedition aboard the CCGS *Amundsen* begins with the submission of ship-time applications by research programs. Then, the User Advisory Committee, composed of arm's length experts from diverse scientific fields, evaluates the various applications and considers the geographical scope of the proposed programs, their feasibility, and the adequacy between methods and the scientific objectives. While the management team of Amundsen Science is there to support the implementation of the scientific expedition on the CCGS *Amundsen*, it is truly the community of users who drive the direction and decision-making of the organization. Once approved, the integrated cruise plan developed for a given season is shared widely. Logistical constraints are further addressed through various planning meetings, including through a user workshop held in person every year in Quebec City. User programs benefit from Amundsen Science's expertise and experience in the planning of scientific expeditions, with a team of managers and coordinators developing scenarios for the expedition plan at the early stage, ensuring the procurement of applicable research permits, and coordinating with the Canadian Coast Guard for the implementation and actual execution of the field campaign.

One of the key strategies to optimize the *Amundsen's* observing capacities is to work towards increasing synergies and collaborations between user programs sharing similar objectives and target regions to make an optimal use of berths, ship-time, equipment and technical resources. This approach led to increased cooperation between academia and public sectors, data sharing and improved training opportunities for early career scientists and students. Ultimately, users become also ambassadors of the facility since the most important success criterion for Amundsen Science is their satisfaction and the achievement of their scientific objectives.

State-of-the-art equipment

The CCGS *Amundsen's* central pool of equipment is composed of oceanographic profilers, hull-mounted sonars, meteorological sensors and robotic instrumentation. In addition to the 65 scientific systems, the ship's pool of equipment include 22 onboard and portable laboratories that can accommodate the needs of physical, chemical, and biological oceanographers, paleoceanographers, geologists, atmospheric researchers and remote-sensing specialists. Amundsen Science also manages coring equipment, moorings buoys and sensors, and part of the fish and zooplankton nets. This pool of equipment is maintained yearlong by a team of highly skilled technicians and engineers to ensure proper maintenance, calibration, and overturn when applicable. The team also guarantees a presence on the vessel at all times during the scientific expeditions to provide efficient troubleshooting, rapid repairs and to maintain the central systems as the ship sails. Over the last field seasons, these efforts have led to the near-continuous operation of all our underway systems and to an equipment efficiency rate of 97% in average. Users of the facility also drive the development of the central equipment pool by providing feedback and suggestions to Amundsen Science for the consideration of equipment upgrades and procurement.

The main scientific instruments include a sub-work class Remotely Operated Vehicle (ROV) and two oceanographic profilers: a CTD-Rosette, and a Moving Vessel Profiler (MVP, see Fig 1). The ROV allows for minimal disturbance benthic surveys and collects high-resolution imagery. The pool of robotic instrument also includes an Autonomous Underwater Vehicle (AUV), a smaller ROV, and a drone. Coring equipment, atmospheric sensors, hull-mounted echo sounders and an underway thermosalinograph are also part of the equipment available for science programs onboard.

Data management and sharing

Data collected by the central pool of equipment, including with the underway hull-mounted and atmospheric systems, are processed through predetermined quality assurance and quality control standards. Amundsen Science adheres to the principles of data findability, accessibility, interoperability, and reusability (Wilkinson et al., 2016) and is committed to provide an open access to the data collected during the expeditions. The team of data curators and managers is continuously improving the data standardization and workflow by developing new tools and software and by keeping up with best practices in terms of data processing and archiving.

The organization is dedicated to increase data usage by disseminating datasets in open format and by getting involved in polar data management initiatives and projects on a national scale (e.g.: Canadian Consortium for Arctic Data Interoperability – [CCADI](#)). Additional initiatives are developed within and outside the organization to highlight the large pool of datasets. Recently, Ratsimbazafy et al. (2023) presented the data acquisition, the processing methods and an overview of the data collected during the 2021 expedition aboard the CCGS *Amundsen*, as the ship traveled over 30 000 km during a 122-day mission across the Canadian Arctic Ocean. Amundsen Science also leads numerous outreach activities and supports the dissemination of research findings resulting from the annual expeditions. Such initiatives are crucial to increase the benefits of the CCGS *Amundsen*'s observing systems and to improve the outcomes of the expeditions.

Reference

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