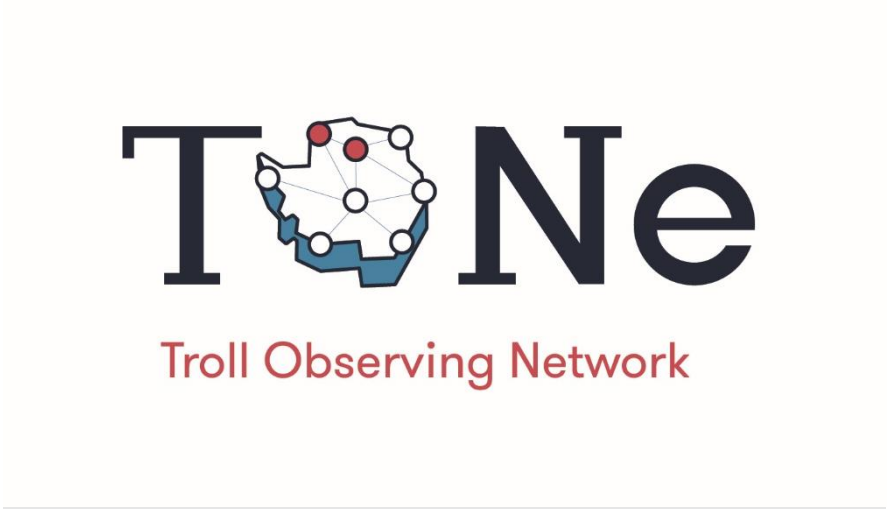

Annual report
Year 1: March 2022-March 2023

Troll Observing Network (TONe) infrastructure

Troll Observing Network partner consortium

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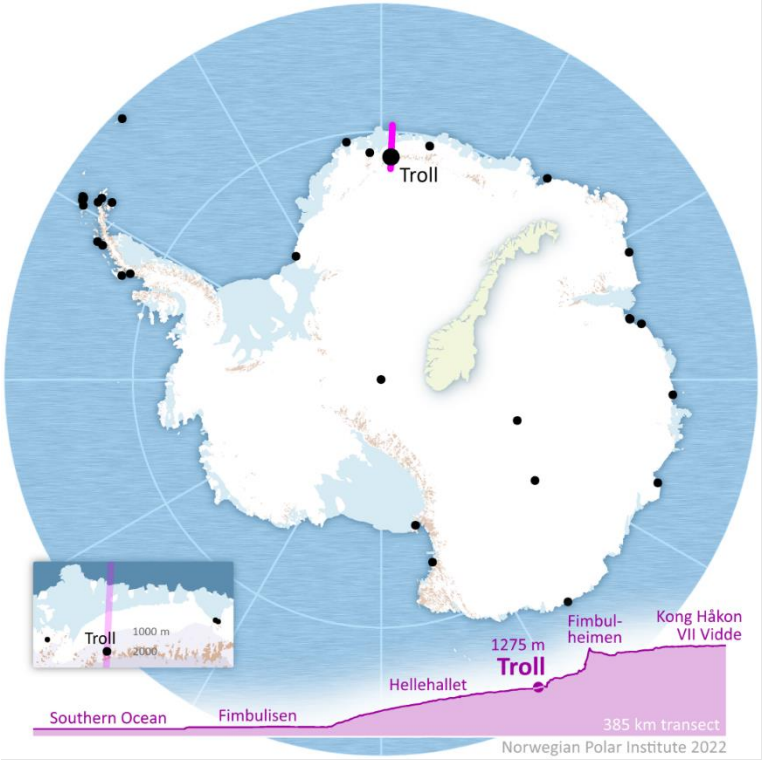
1. Introduction

In December 2021, the Norwegian Antarctic research community with NPI in front received the greatest Christmas present from the Research Council of Norway: The national infrastructure Troll Observing Network (TONe) was one of the 22 infrastructures that received funds from the Research Council of Norway's call on FORSKNINGSINFRATRUKTUR AV NASJONAL VIKTIGHET.

Antarctica and the surrounding Southern Ocean are key drivers of Earth's oceanic and atmospheric systems. Our entire planet is interconnected with, and greatly influenced by, processes originating in the far south. We will not be able to fully understand how the Earth system works without comprehensive and up-to-date knowledge of the physical, biological, chemical and geological processes taking place there. An extensive observation and data gathering effort is required across the entire Antarctic continent and its surrounding ocean to gain the necessary knowledge needed.

The Troll Observing Network (TONe) is a comprehensive infrastructure network that aims to contribute significantly to this goal. It is centered at the Norwegian Antarctic research station Troll and focused on the Dronning Maud Land (DML) region, a region of Antarctica with relatively little observational data available. The initiative is spearheaded by the Norwegian Polar Institute (NPI), in collaboration with an additional five Norwegian and three international partners (NILU, NORSAR, NORCE, University of Oslo. University of Begen, BAS, University of Leeds and Washington State University).

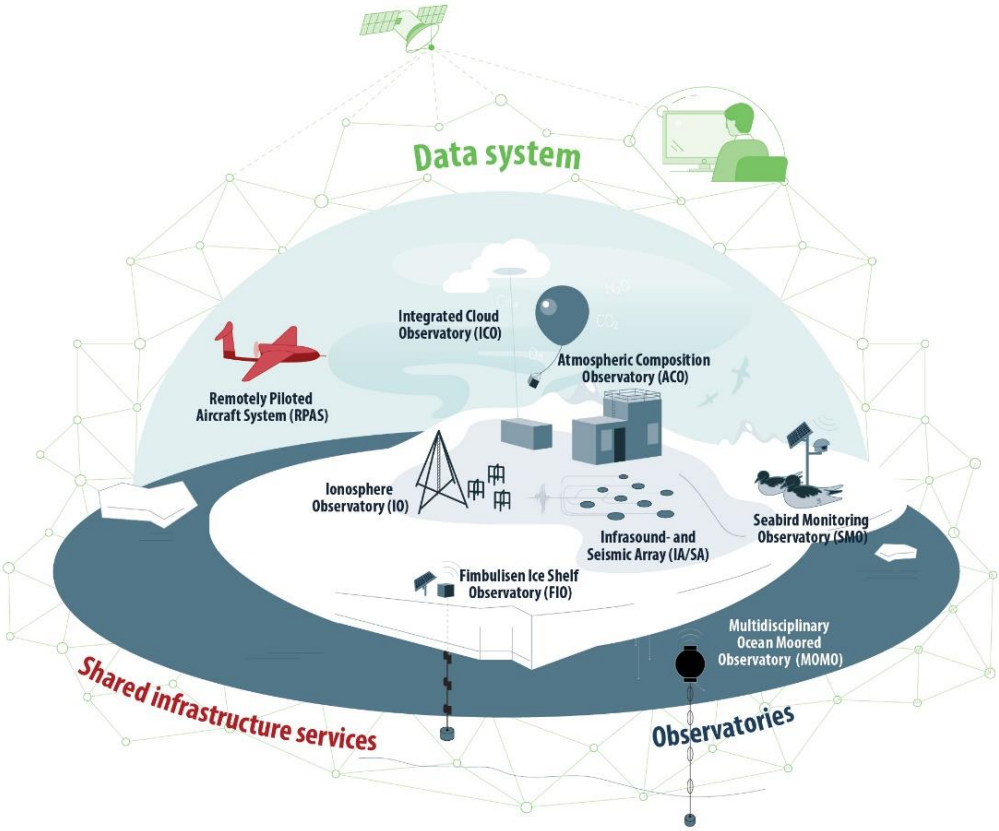


Troll Observing Network provides long-term measurements within all compartments of the Earth System in a data poor region in data-poor Antarctica. Troll Research Station is located at a unique spot among other Antarctic stations by being at the continental slope, far from the coast and not at the inland plateau.

TONe includes eight distinct observatories that will provide data that will greatly improve our understanding of:

- key global processes relevant to climate and sea-level change (an ocean observation system in open ocean and one under the Fimbul Ice Shelf)
- atmosphere dynamics (a cloud observatory and an air composition observatory)
- solid earth structure and cryosphere dynamics (a seismic observatory)
- space weather dynamics (an infrasound and an ionosphere observatories)
- the effects of global changes on marine ecosystems (a seabird observatory)

TONe also includes a drone service that will collect data over large parts of DML. Finally, TONe will ensure wide and free access to data from the observatories and drone service to the entire national and international research community, in the interests of serving society globally.



TONe consists of three parts: The eight observatories, the shard drone infrastructure service and the data management system.

This is a report for the first year of TONe, covering activities from March 2022 to March 2023.

2. TONe activities in year 1

The first part of the first year of Troll Observing Network (TONe) focused on establishing the project administration and setting up the agreements. After the first Antarctic summer season (2022/23), TONe was fully in motion and three observatories were already established.

The first quarter of 2022 was spent in project negotiations with the Research Council of Norway (RCN). The original TONe proposal, submitted in 2020, asked for a total of NOK 197 MILL. After having completed negotiations with RCN in which cuts were required, TONe was granted a total of NOK 157 MILL (18% cut from the original budget). The TONe consortium had already agreed that the observatories would have the highest priorities if cuts deemed necessary, which for TONe implied that four of the five shared services had to be taken out. In addition, the cut implied that some instruments could not be included in some of the observatories as originally planned.

The project official start was 1st March 2022. In the first week of May we had the official kick-off for TONe and the first annual meeting in Tromsø. The kick-off was a good opportunity to also introduce the new infrastructure project in its entirety to the partner consortiums' leaders and the Ministry of Climate and the Environment.

The first Annual Meeting 5th-6th May was the first opportunity for the entire project group to meet in person. Several issues were on the agenda:

- project management and budgeting routines
- general and detailed dialogs with the NPI Operation and logistical department (OLA) - Antarctic section responsible for managing and operating Troll Research Station
- introductory dialog about the TONe data management system
- information regarding regulations related to the protection of the environment and safety in Antarctica, and the process to notify the activities.

The TONe consortium also started the initial discussions about the TONe communication strategy.

Later in May it was known that RCN had to reconsider its entire budgetary system, and the partner consortium had to enter into a dialog with the RCN on how TONe possibly could be implemented with a delay in the financing plan and which consequences this would have on the project progress. The dialogue was very constructive, and in the last week of June we received the project agreements without any changes to the funding scheme. In September the partner agreement was signed by all parties, and NPI could finally accept and sign the overall agreement with RCN.

Due to the above-mentioned uncertainties in funding and the delay with the agreements, some of the partners in TONe did not start the tender and purchasing processes until after the agreements were in place, which led to delays for some of the work packages compared to the original plan. We were therefore forced to apply to RCN to be able to shift some of the funds ahead in time. RCN approved the requested changes without any questions.

The partner consortium was also concerned about uncertainties associated with a general high increase in all costs compared to when the proposal was submitted in 2020. For the purchases in the first year, we have managed to stay within budget, but larger investments will take place in 2023-24 and it remains to be seen how the general price increase will affect the different TONe work-packages in the future.

From the TONe kick-off meeting in Tromsø 5th May 2022. Photo: E. V. Jenssen, NPI.

NPI employed an engineer at the OLA – Technical support section, that will follow up the TONe project from the technical side. He will work with the TONe project leader and co-leader in the management of the project, and as a coordinator on the technical side between OLA-Antarctic section and the partners. The engineer started 1st December 2022, and after two intensive weeks in Tromsø he departed to Antarctica and Troll Research Station for a month to get an overview of and insight into how the station is operated and managed. He also conducted a field survey regarding the placement of the different observatories to be located at Troll and how best to plan for the next years regarding the construction phase.

Sec. 3 details the activities within each work package, but summarized the TONe consortium reached some very definite milestones at the end of the first year:

- Setting up the camera systems and weather stations in the Seabird Monitoring Observatory. With this, the observatory has been established with automatic instruments. During the coming Antarctic summer seasons, the results from the automatic data collection will be compared to the traditional methods.
- Establishing the three instruments in Atmospheric Composition Observatory. With this, the observatory has been established.
- Setting up some of the instruments of Multipisiplinary Ocean Moored Observatory. The last sensors and instruments will be established in the 2024/25 season.
- Establishing a proof-of-concept for TONe data server.
- Shipment of equipment for Fimbulisen Ice Shelf Observatory to Troll. The equipment will be used for setting up the observatory in the 2023/24 Antarctic summer.
- Site survey to Troll by NORSAR for the Seismic- and Infrasound Array and by UiO for the Ionospheric Observatory.

Despite the uncertainties and delays, and the challenging situation with a general high price growth, the first year of TONe has to be characterized as a successful year.

3. Summary of work and progress for the observatories, shared services and data system

3.1 Ionospheric Observatory

The University of Oslo's Ionospheric Observatory (IO) for studying the upper atmosphere will be extended by adding a digital ionosonde (digisonde) to the existing infrastructure. The digisonde will measure vertical profiles of electron densities, plasma and flow velocities in the ionosphere.

During the Antarctic summer 2022/23 a field survey for the location of the sender and receiver antennas, masts and radio hut was carried out. The tender and purchasing processes started in early 2023.

3.2 Atmosphere Composition Observatory

The Atmosphere Composition Observatory is an expansion of NILUs ongoing atmosphere monitoring at Trolhaugen with new instruments to complement the ongoing monitoring of UV, total ozone, aerosols, pollutants, climate/greenhouse gases and other trace gases. TONe brings in three new instrument setups, and in this first year of TONe, the instruments have been purchased, calibrated, shipped to Troll and installed at Trollhaugen.

- A CO_2, CH_4, CO monitor from Picarro. This was installed already in December 2021 and data from the first year is available. The data are being quality assured in accordance with the ICOS standard and will be reported to the EBAS database infrastructure.
- An aerosol particle sizer (APS) which allows for measuring aerosol in different size fractions. This instrument was purchased in august 2022 and was shipped down to Antarctica in December. The instrument was installed at the site during the visit of NILU scientist in February 2023.
- An instrument (an ESA/NASA PANDORA spectrometer) for vertical column observations of different trace gases (O_3, NO_2, SO_2 and formaldehyde) important for satellite validation was purchased in August 2022. The instrument was built and tested in the US, then shipped to NILU where it was checked and repacked and sent with the flight down to Troll in January 2023. It was also installed at the site in February 2023.

Pandora instrument at Trollhaugen. Photo: NILU

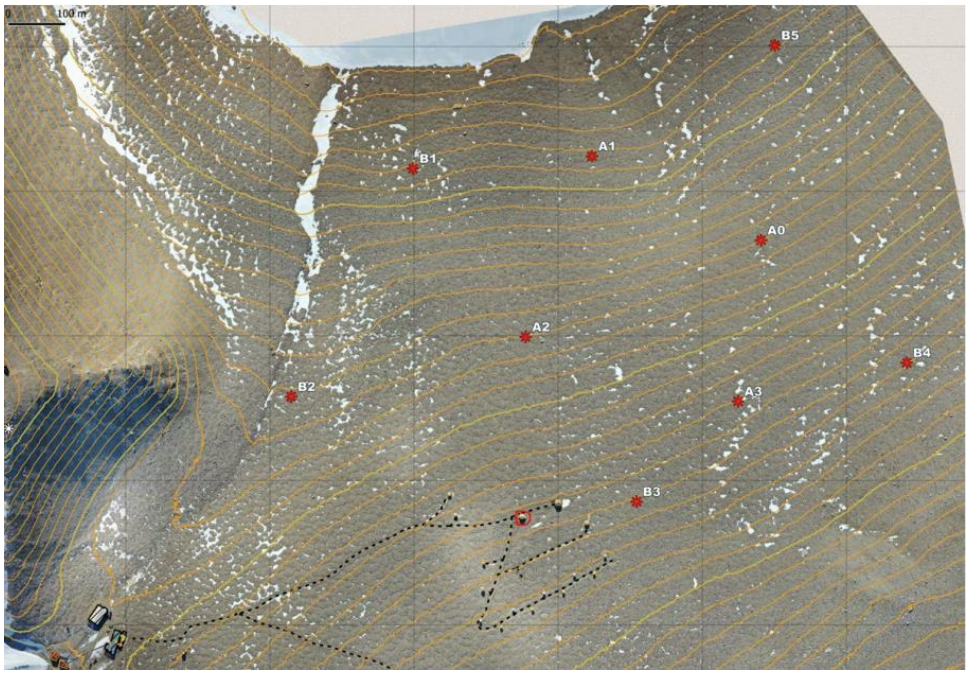
3.3 Integrated Cloud Observatory

The Integrated Cloud Observatory (ICO) is a brand-new activity for the NPI at Troll. It consists of new passive and active remote sensing instruments for measuring temperature and humidity profiles and cloud and aerosol characteristics and will look at the coupling between clouds and aerosols and their role in the surface energy balance.

The ICO is in the early preparatory stage, getting tender documents ready for the purchases of the main instruments. In addition, we are planning for the exact location and method of installation of the three containers. The main start-up of activities in the ICO will happen in year two of TONe.

3.4 Seismic Array and Infrasound Array

The new Seismic Array (SA) that will be installed at Troll as part of TONe will be one of the globally important high-quality seismic observatories. Currently NORSAR has a single seismic station running at Troll, but the new array will be able to measure more parameters of the observed seismic waves and lower the threshold for seismic signals significantly.



Planned array configurations for the SA/IA.

The new Infrasound Array (IA) will be co-located with the seismic array. The IA will use infrasound waves to allow characterization of upper stratosphere, mesosphere and lower thermosphere dynamics, and quantification of vertical coupling between these layers.

After the TONe kick-off meeting in May 2022, NORSAR concentrated on preparing the tender documents for the purchase of the seismic sensors and the digitizers to be used. The tender documents had been sent out to a list of known instrument vendors in Canada, Switzerland, UK and USA before the summer holiday season 2022 with a deadline to answer until the end of August 2022.

The vendors answered with bids within the deadline and NORSAR started the evaluation process. In parallel it became clear that NORSAR could travel to Troll already in November 2022 for a site survey for the SA /IA. Due to this opportunity, the final decisions about the purchase of seismic sensors and digitizers were postponed to after the site survey at Troll.

A detailed report about the very successful site survey at Troll is in preparation and will be finalized as Project Deliverable in summer 2023.

After the site survey, final decisions about the purchase of 10 seismic sensors and 10 digitizers were made, a detailed purchase protocol was prepared, and the instruments were then ordered from vendors in US and Canada in December 2022.

3.5 Fimbulisen Ice-shelf Observatory

The core of the NPI and UiB Fimbulisen Ice-shelf Observatory (FIO) consists of instruments that will be deployed by means of hot-water-drilling to monitor oceanographic conditions under the ice shelf, together with instrumentation on top of the ice shelf to monitor its surface and basal mass balance.

The observatory which consists of two sites in the central and northern Jutulstraumen area, will be established during a major tractor-based field campaign in the 2023/24 Antarctic summer season.

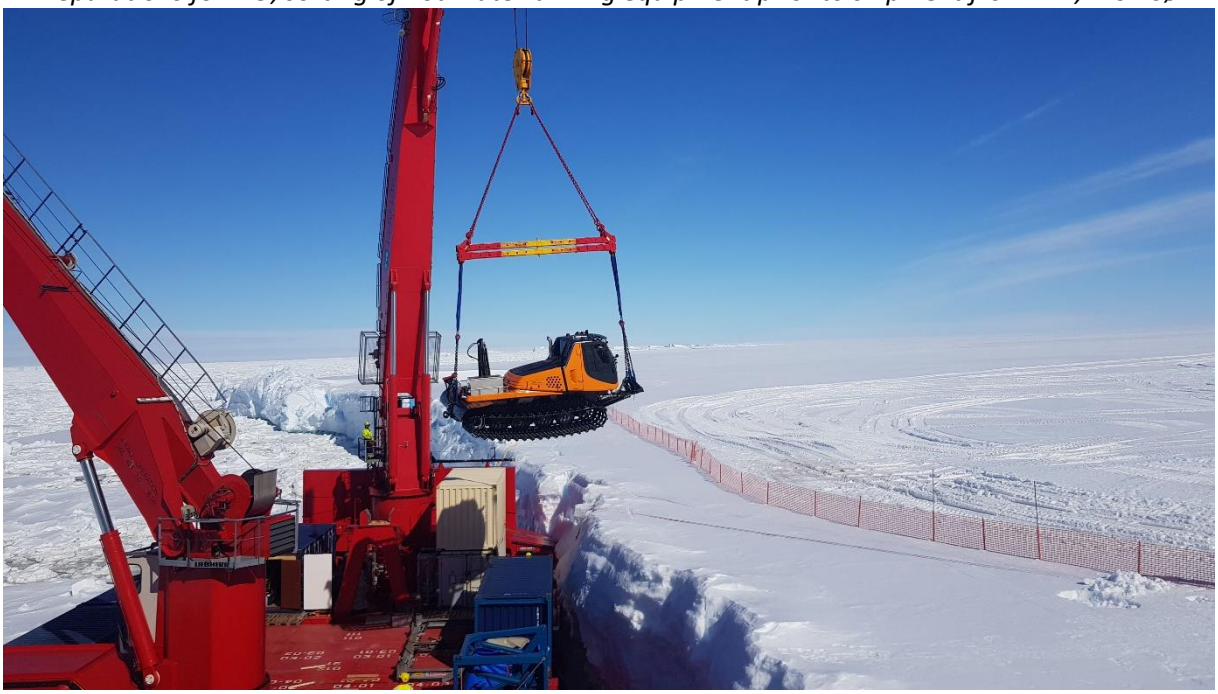
The observatory is derived from the legacy of three existing ice shelf cavity moorings that were established in 2009/10 (NPI RCN funded Fimbul-top-to-bottom project). Those instruments are still partially operative, and in early 2022 three additional years of data were retrieved by an air-supported service campaign. The data are currently being analysed and published within the RCN iMELT project.

Most of the remaining activities in 2022 were associated with preparing the hot-water-drill facility (which will be provided by BAS), detailed planning and procurement of scientific instrumentation, and planning and preparing the logistics for the 2023/24 field campaign. The field campaign involves the deployment of approximately 10 tons of science equipment and 11 people for 50 days in deep-field conditions on the ice shelf.

Thanks to swift budget allocations after initial delays of the project start-up, procurements were completed in time to be shipped southbound with the 2022/23 Troll station supply cruise. The bulk part of the equipment is currently winterized at Troll and further campaign preparations are in route for realization of the establishment of the observatory as planned.

The planned establishment of FIO within TONe has attracted additional partners. They will contribute with deployment of (a) a novel oxygen isotope sensor from CNRS Grenoble (France) to quantify glacial melt water content as part of the OCEAN:ICE Horizon Europe project (https://ocean-ice.eu/); as well as (b) the deployment of the Icefin underwater robot (https://schmidt.astro.cornell.edu/) from Cornell University (USA) for detailed explorations of the cavity geometry and ice-ocean interaction processes, in addition to (c) various parameters that will be observed during the deployment through the open borehole. Results from FIO will also play a vital role for the newly RCN funded Centre of excellence for ice, Cryosphere, Carbon and Climate (iC3).

Preparations for FIO, sorting of hot-water-drilling equipment prior to shipment from NPI, Tromsø.



FIO preparations, unloading of the tractor vehicle (Everest) at the loading bay at the ice shelf in Dronning Maud Land. This vehicle will support the field campaign in 2023/24.

3.6 Multidisciplinary Ocean Moored Observatory

The NPI and UiB's Multidisciplinary Ocean Moored Observatory (MOMO) consists of three oceanographic moorings that are located at the Antarctic continental margin outside Dronning Maud Land to monitor oceanographic, biogeochemical and biological parameters along in the Antarctic Slope Front and seasonal sea ice zone.

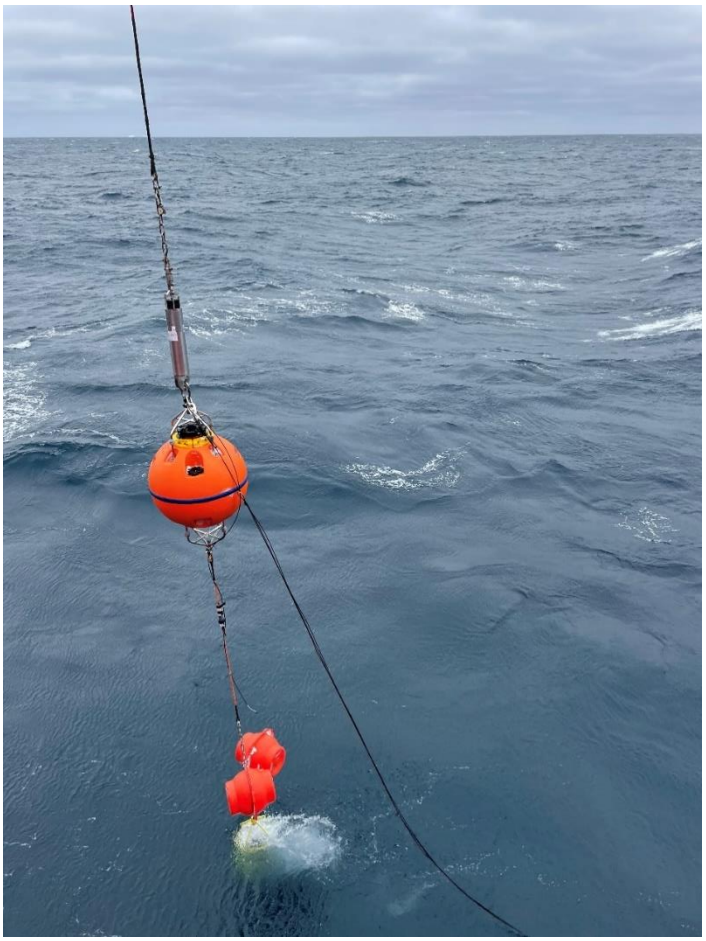
After detailed planning and procurement of instrumentation, the first deployment of the MOMO moorings was completed as part of the NPI-TrollTransect 2023/24 cruise that conducts scientific work from the Troll Research Station supply vessel.

During this cruise, data was retrieved from two existing moorings that were initiated during the R/V Kronprins Haakon cruise in 2019 and serviced for the first time during the TrollTransect cruise in 2020/21. These moorings have now been extended with additional instrumentation, and a third mooring has now been deployed. Based on experiences from two mooring-turnover cruises, final adjustments to the MOMO configuration are now being made and long-term instrumentation will be procured, such that the observatory will be fully operational from its next service that is planned in 2024/25.

Water samples and profiling data along an expanded north-south transect are routinely collected during the TrollTransect cruises. Linking the MOMO mooring locations to this north-south transect provides the spatial context for the mooring time series.

The efforts around establishing MOMO have spun-off additional funds within the OCEAN:ICE Horizon Europe project (https://ocean-ice.eu/) that integrates MOMO within an international distributed moored observatory network along the Antarctic continental slope in the Atlantic sector of the Southern Ocean. The establishment of MOMO has also been showcasing for a framework to observe, understand and project ecosystem response to environmental change in the East Antarctic Southern Ocean (Gutt et al. 2022, https://doi.org/10.5194/bg-19-5313-2022). Data from MOMO in combination with auxillary data from the TrollTransect cruises will also play a vital role for iC3 and the RCN funded I-CRYME project.

TrollTransect 2022/23 MOMO deployment, instrument preparations on deck. Photo: NPI



TrollTransect 2022/23 MOMO deployment, instruments entering the sea. Photo: NPI.

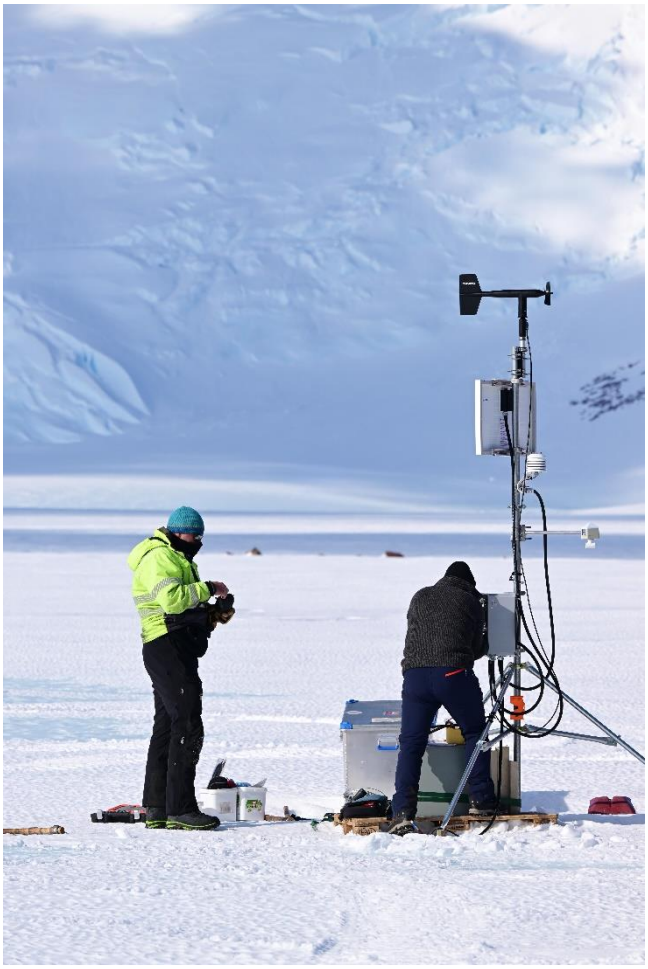
3.7 Seabird Monitoring Observatory

The NPI's Seabird Monitoring Observatory (SMO) will provide key information on seabird distribution, status and trends, and will allow a continuation, and expansion of the ongoing wildlife monitoring activities NPI have been preforming in DML for decades.

The SMO is mostly based on the use of time-lapse cameras. Nine cameras have been purchased in 2022 and were installed at the Jutulsessen and Svarthamaren colonies in Nov/Dec 2022. Five of these cameras are high-resolution ones using both external batteries and solar panels as sources of energy. These cameras are expected to work all year round and provide information on the density of breeding birds and their timing of breeding. The other cameras are regular trail cameras that should provide information on bird breeding success (chick survival).

Additionally, a weather station has been deployed ca. 1 km from Tor station (Svarthamaren area). Data from this station will be used to better understand the relationship between weather conditions and seabird life-history. Data from this weather station are sent daily via satellite to DataGarisson, and will feed into Norwegian Polar Data Centre.

Camera system in Jutulsessen. Photo: NPI



Weather station for the seabird monitoring observatory in the Svarthamaren area. Photo: NPI

3.8 Remotely Piloted Aircraft System

The NORCE and NPI's Remotely Piloted Aircraft System (RPAS) service will be a brand-new service available for researchers and operated from Troll. This service consists of two new fixed-wing long-range RPA with large payload capacity with data collection capability horizontally and vertically to cover large parts of DML. Sensor packages include VHF radar for bedrock and grounding line mapping, GHz radar for snow precipitation mapping, aerial cameras for, e.g., seabird, marine mammal and sea-ice mapping, sensors for meteorological, cloud and aerosol profile measurements and hyperspectral sensors for measurements of chlorophyll and primary production. The RPA service will complement and strengthen data collection from the TONe observatories.

The time since fall 2022 has been used for dialogue and tender process with the deliverer for the GHz radar, University Kansas.

3.9 Data management system

The first phase of the TONe data management system is to specify, procure and install the on-site data infrastructure at Troll Research Station. Core specifications for the server installation and plans for the physical installation at Troll were developed during 2022. Following this, the first one of several data servers was procured in the autumn and shipped to Troll ahead of the Antarctic summer for installation. This single server is intended as a proof of concept, and a test programme will be carried out before orders are placed for the remaining servers and data storage units.

The test server was connected and operational in mid-December. Software installation, network configuration and testing, and testing of remote operations from Tromsø were well underway by the end of the year.

The TONe engineer has produced documentation for the existing IKT-infrastructure at Troll, and the dialogue with Norwegian Environment Agency IKT-department regards how to include new observatories to the existing IKT-infrastructure, and how to ensure high information security protection have been initiated. All networks will be surveilled by Norwegian National Security Authoritys (NSM) VDI (Warning system for digital infrastructure).

The next phase of the data management system work package will be to develop the data pipeline to Norway and the TONe data portal. This phase is to commence in 2023.

4. Outreach

Communication about TONe to the general public and to the research community are important parts of establishing TONe. Due to the importance and also feedback we received from the reviewers during the project evaluation process, we decided to make a communication strategy for TONe.

The first step towards such a communication strategy were an initial dialogue regarding TONe communication and ideas for outreach during the TONe annual meeting in May 2022.

A draft communication strategy was prepared by the TONe project management in collaboration with the NPI communication department. In December 2022 it was presented to the work package leaders and communication specialists at the partner institutions. The communication plan detailed the main message, TONe communication goals, target groups and stakeholders, what we need to communicate (including phases in our communication work), channels for communication, success

factors and roles and responsibilities. The draft plan was updated and adjusted based on feedback received, and the TONe communication strategy was finalized in Feb 2023.


TONe
Troll Observing Network

Kommunikasjonsstrategi

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TONe Communication Strategy was finalized in Feb 2023.

During the first year of TONe the following communication mechanisms have been established and produced:

- A webpage for TONe at https://www.npolar.no/en/tone/. This webpage exists both in Norwegian and English. Later in the project the dedicated TONe web portal will be established to ensure and provide access to all information about the infrastructure and its capabilities, the shared services, access policy, data management policy, terms of conditions and more.
- Other information material like pamphlets, posters, etc to be used to communicate TONe both to the research community and to stakeholders.
- TONe has set up its own Twitter social media channel: @TrollObservingNetwork, and uses the hashtag #TrollObservingNetwork. This account will be used to communicate with the international research community (user group). The partner institutions' own social media channels on Facebook, Instragram, Twitter will be used to communicate TONe to the general public.

Appendix 1 details the TONe communication activities for the first year.

Appendix 1: TONe Communication and Outreach Activities Year 1

TONe has been presented at the following scientific conferences/workshops:

- Det fjerde norske Antarktisseminaret (May 2022, Tromsø)
- SCAR Action Group RINGs workshop (June 2022, Malangen, Norway)
- SCAR Open Science Conference (Aug 2022, online)
- Forum for Research into Ice Shelf Processess (FRISP) (Sept 2022, Cambridge)

TONe has been presented for the general public and stakeholders:

- Open popular science seminar at Fram Centre (May 2022, Tromsø)
- Seminar for the section Ocean and Polar under Ministry of Climate and Environment (Oct 2022, Oslo)
- At the Climate Change Conference (COP 27). TONe ambassador Sebastien Moreau, NPI (Nov 2022, Sharm el-Sheikh, Egypt)

TONe was in the news/popular science publications:

- Geoforskning.no: https://geoforskning.no/ruster-opp-i-antarktis/ (Jan 2022)
- NORCE webpage: https://www.norceresearch.no/aktuelt/droner-pa-troll (June 2022)
- NRK: https://www.nrk.no/urix/nytt-overvakingssystem_-kamera-skal-vise-korleis-fuglane-har-det-i-antarktis-1.16211669 (Dec 2022)
- Titan.no: Travel blog: Part 1: https://titan.uio.no/blogg/2022/physicist-antarctica; Part 2: https://titan.uio.no/blogg/2022/settling-tor-station; Part 3: https://titan.uio.no/blogg/2022/life-field-station; Part 4: https://titan.uio.no/blogg-blogg/2022/heading-back-home (Dec 2022)