



Annual report

Year 2: March 2023-March 2024

Troll Observing Network infrastructure project



Troll Observing Network

Troll Observing Network partner consortium

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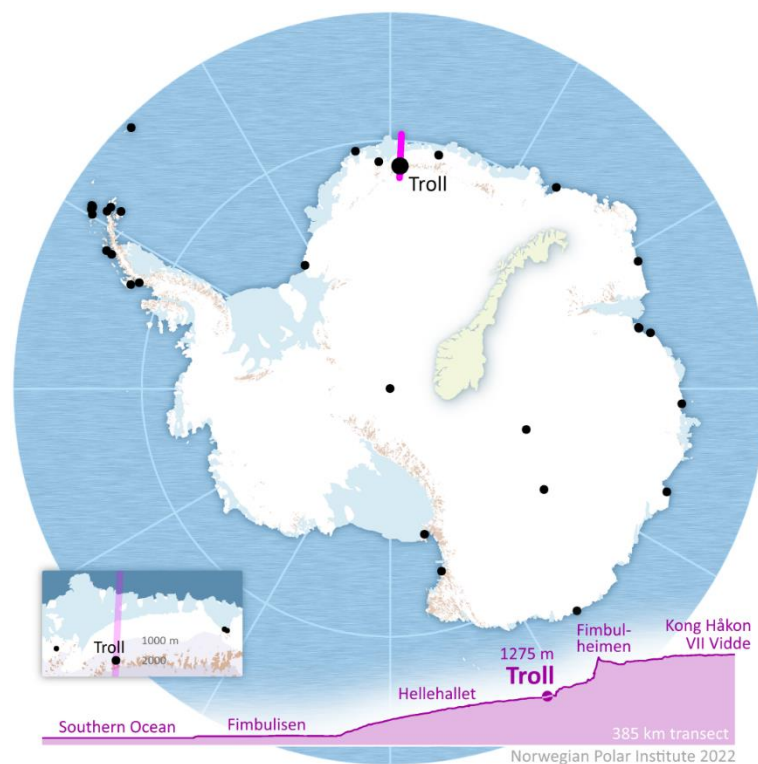
Photo frontpage by Tore Hattermann, Norwegian Polar Institute

Table of content

1. Introduction	3
2. Activities in 2023-24 (TONE year 2)	4
3. Summary of work and progress for the observatories, RPAS service and data management system	5
3.1 Ionospheric Observatory	5
3.2 Atmosphere Composition Observatory.....	6
3.3 Integrated Cloud Observatory	7
3.4 Seismic Array and Infrasound Array	8
3.5 Fimbulisen Ice-shelf Observatory	9
3.6 Multidisciplinary Ocean Moored Observatory	11
3.7 Seabird Monitoring Observatory	12
3.8 Remotely Piloted Aircraft System.....	12
3.9 Data management system.....	13
4. Outreach	14
4.1 TONE Communication and Outreach Activities Year 2	15
5. References	16
5.1 Publications	16
5.2 Datasets.....	16

1. Introduction

The TONE consortium just completed its second year of implementing the Troll Observing Network (TONE). TONE is a comprehensive infrastructure network centered around Troll Research Station and focus on the Dronning Maud Land (DML) region, a region of Antarctica with relatively little observational data available, thus contributing to the observation and data gathering effort required to gain new and necessary knowledge for Antarctica and the Southern Ocean.

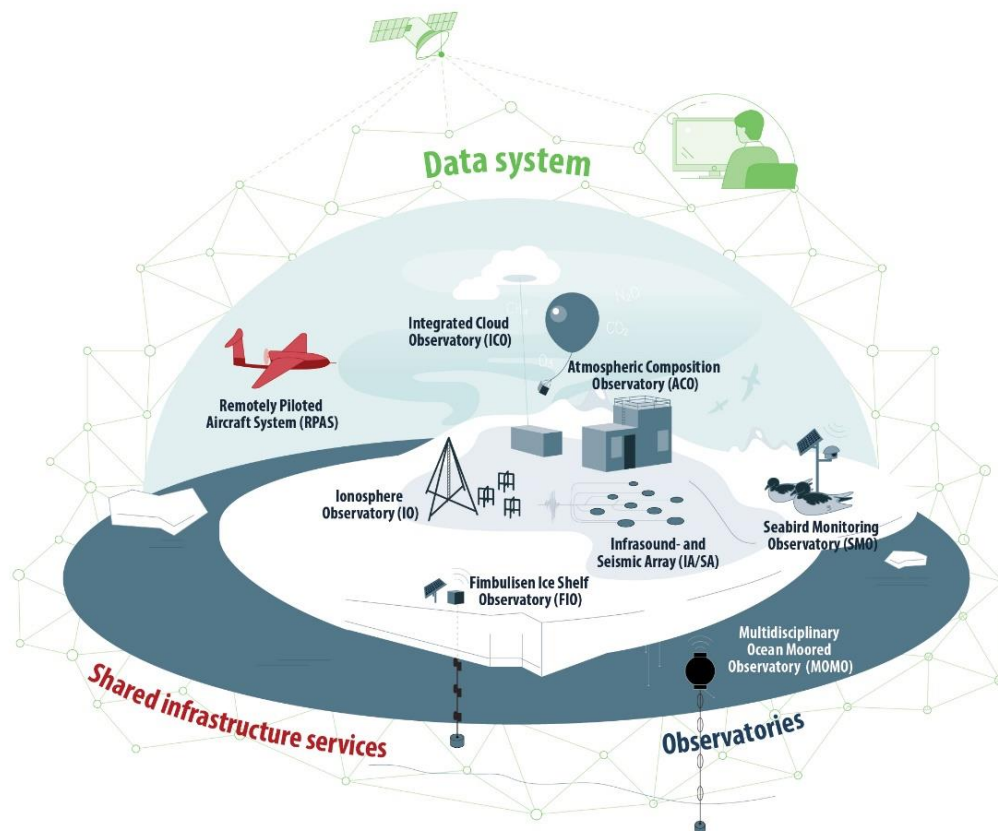


Troll Observing Network provides long-term measurements within all compartments of the Earth System in a data poor region in data-poor Antarctica. Troll Research Station is at a unique location among other Antarctic stations by being at the continental slope, far from the coast and not at the inland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

This is a report for the second year of TONE, covering activities from March 2023 to February 2024.

2. Activities in 2023-24 (TONE year 2)

The TONE consortium reached several very definite milestones during its second year:

- The Fimbulisen Ice-shelf Observatory was established through a fifty-days deep-field operation where hot water drilling was used to install two moorings at two locations at Fimbulisen. At one location the ice-shelf was 200m thick and at one 400m thick. The instrumentation attached to these moorings will continue the long time series established at Fimbulisen in 2009.
- Ground construction work at Troll was started to prepare for the installation of the Integrated Cloud Observatory's four containers next year.
- Data validation and adjustments of the systems are ongoing both for the Atmospheric Composition Observatory and the Seabird Monitoring Observatory.

Details on the work in the work packages can be found in Section 3.

3. Summary of work and progress for the observatories, RPAS service and data management system

3.1 Ionospheric Observatory

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

In 2023 the ionosonde was procured and manufactured. It was shipped with the annual supply vessel to Troll Research Station, where it arrived safe and sound in February 2024. The equipment will be stored over the winter to be ready for installation in the season of 2024/25.

The system purchased is the Lowell Digisonde DPS4D, which is the state-of-the-art digital ionosonde. The system has been operated worldwide, and it has also been deployed in Arctic and Antarctic conditions. We encountered one challenge with the standard system and its mast related to the heavy wind strengths at Troll Research Station. The system was not designed to withstand gale force winds. Thus, after discussions with the manufacturers the system was redesigned, and a new subcontractor for the mast had to be identified. In short, the mast for the sender antenna had to be shortened, and a new mast that can comply with the wind specifications was procured by the producer from a different subcontractor. The new mast is designed specifically for Troll Research Station and the heavy wind.

Shipping to Troll Research Station is not a straightforward task. For IO in particular it had to be carried out in three separate transports:

- 1) The heavy hardware, i.e. the receiving antennas, cables etc., were sent from the US to Tromsø in October/November 2023, and then sent by ship from Tromsø to Antarctica in December. The ship reached the ice shelf in January, where it was transported with belt-wagons to Troll Research Station, where it reached its final destination in February 2024.
- 2) The custom-made sender antenna mast was sent from Sweden to Denmark (Aalborg), where it was loaded on the same ship travelling from Tromsø to Antarctica.
- 3) Two crates with electronics and other delicate parts were sent from the US to Oslo in January 2024, and sent directly to Troll Research Station by air in mid-January 2024.

In February the principal investigator for IO visited Troll Research Station, and inspected all parts of the ionosonde and secured it for winter storage. Electronics and computers were stored in a warm container, while the structural parts were stored in the cold containers. Details on the ground construction work was discussed and the plan revised taking into account the current state of the TONe project and work carried out within other work packages, to ensure deployment and installation of the IO system in the Australian summer of 2024/2025.

Work to integrate the existing ionospheric observatory infrastructure into the TONe data management system was also started.



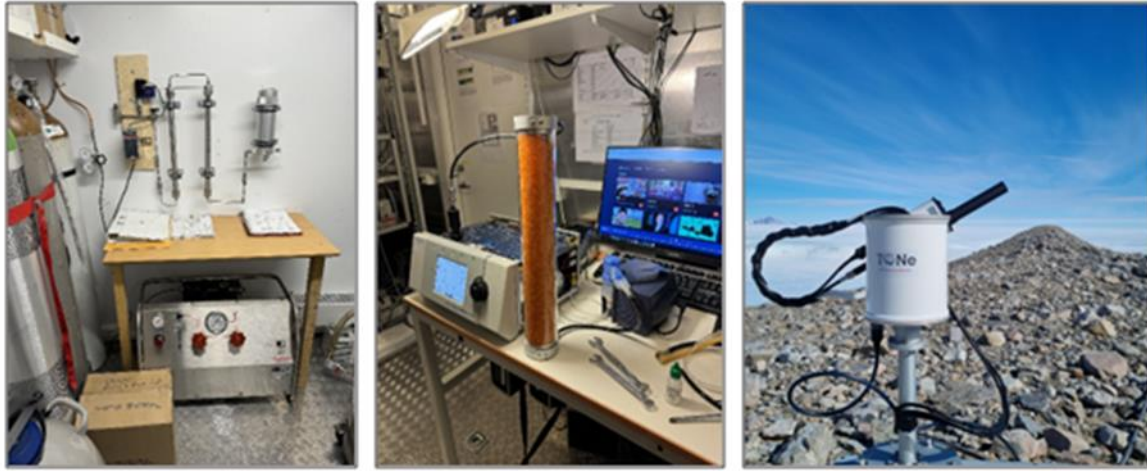
The 18-meter mast for the Ionospheric Observatory's digisonde, aboard the Silver Arctic (left), departed for the south and safely arrived in Antarctica, positioned on the ice outside Troll Research Station (right). Photos: Stig Flått (NPI, left) and Wojciech Miloch (UiO, right).

3.2 Atmosphere Composition Observatory

The Atmosphere Composition Observatory (ACO) is an expansion of NILU's ongoing atmosphere monitoring at Trollhaugen with new instruments to complement the ongoing monitoring of UV, total ozone, aerosols, pollutants, climate/greenhouse gases and other trace gases. The three instruments, which are part of the TONE project have all been installed and are in operation at the atmospheric observatory at Trollhaugen:

- The CO₂, CH₄, CO monitor from Picarro was installed already in December 2021, and data are available from these first years. This last year the focus has been on ensuring high quality data following the guidelines and using the standard from the ICOS infrastructure and streamlining the dataflow, including near real time data service to the EBAS database infrastructure. A high-pressure compressor system was installed as part of the calibration set-up (Figure 1 left). Some work is remaining for next season before the system is operational.
- The aerosol particle sizer (APS) which measures aerosols in different size fractions was installed in the beginning of 2023. The main work this last year has been on maintenance, quality assurance and to establish reporting routines to EBAS following the guidelines in ACTRIS (Figure 1 middle).
- The PANDORA spectrometer measuring vertical total column of different trace gases (O₃, NO₂, SO₂ and formaldehyde) was installed in January 2023 (Figure 1 right). NILU personnel have been participating in training both at NASA Goddard in the US and the calibration center in Innsbruck, Austria during the last year. This instrument is part of the Pandonia Global Network (PGN), and ESA-NASA initiative to ensure systematic processing and dissemination of the data especially targeted for satellite validation of atmospheric trace gases (i.e., for Sentinel-5P, and the upcoming Sentinel-4 and Sentinel-5 missions). The data will be openly available later in 2024 when there has been a full year of measurements and the baseline for proper calibration is established.

During the NILU annual maintenance trip to Troll Research Station in January-February 2024, NPI personnel were trained to ensure that the instruments are running in accordance with the standard operation procedures during the winter period.



Left: High pressure compression system for flask filling, middle: Calibration set-up for the APS and right: The Pandora instrument installed at the ACO. All photos: 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, cloud and aerosol characteristics and winds; it also introduces a weather balloon program at Troll for validating remote sensing results and improving atmospheric monitoring and operational forecasting. The observatory will be used to look at the variability in and the coupling between clouds, aerosols, atmospheric dynamics and atmospheric radiation, with an aim to understand their role in the local, regional and global climate.

During the 2023/24 austral summer season, ground was broken at Troll for the ICO, northeast of the weather station, at the edge of the undisturbed clean-air sector. The exact location was moved about 200 m farther from the main station building, in response to plans for the new Troll Research Station. By the end of the summer, all necessary steel structural beams were fixed in the rock. These are ready to act as the support points for the four instrument containers that will be installed next season, along with the platform and railings surrounding them. Digging and installation of cable ducts was also completed, so electrical and network lines are ready to be installed.

During the year, instrument and system specifications were prepared and dialogues continued with a variety of possible suppliers. A bidding process was completed for providing the automated weather-balloon launching system and a hydrogen generation system. The latter was not planned in the proposal phase, but it will make operations significantly more practical and less expensive by eliminating the need to purchase, ship and handle large, heavy racks of compressed helium. Geopolitical considerations connected to the war in Ukraine have left our preferred radar provider unable to deliver, but after discussions with other providers, we have decided on providers for the radar, lidar and microwave radiometer. Despite the changes under way, we are on track to make the initial acquisitions and construction within our budget.

During the end of this second-year purchases are being finalised. The radiosonde (weather balloon) system is a Robotsonde manufactured by MeteoModem in France, along with a hydrogen generation

system from MeteoModem and Sagim in France. The radar is a FMCW-35 Ka-band scanning cloud radar manufactured by Radiometer Physics GmbH (RPG) in Germany. A HATPRO-LT microwave radiometer is also being purchased from RPG, and a CL61 depolarisation lidar is being purchased from Vaisala.



*Ongoing groundwork for ICO showing the poles for the ICO containers.
Photo: Simen Rykkje, Norwegian Polar Institute*

3.4 Seismic Array and Infrasonic Array

The new Seismic Array (SA) located at solid ground in the Troll area 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. The seismic array will be co-located with the new Infrasonic Array (IA) to measure the middle atmospheric dynamics

This second year was dominated by finalizing all technical solutions of the planned new seismic and infrasonic arrays. The main working steps were:

- Finalizing the order to purchase 9 Kinometrics borehole STS-5, 1 Nanometrics borehole Trillium 360 and 10 Quanterra Q330HRS digitizers.
- Deciding on the bidding results and then purchase of the 10 infrasonic sensors.
- Purchase of the infrasonic-noise-reduction system and 6 km cable.
- Testing of all equipment at NORSAR's test facility Stendammen (Hedmark) and at NORSAR main office.
- Developing solutions for all additional components like power supply, data communication, array center, borehole casings and boxes to host digitizers, electronics and the infrasonic sensor at the 9 array sites.
- Secure packing of all array equipment in a container for shipping to Troll.

This work was finalized as planned and the container with all material to build the arrays reached Troll in January 2024.

Towards the end of 2023 it became clear that the location of the array met some unforeseen complications. Related to pre-planning of a new Troll Research Station, it became evident that the

station will be run also on renewable energy, and that a windmill park and a field of solar panels will be established near the station. It is known that in particular windmills produce seismic noise, which reduces the capabilities of seismic stations and arrays even at larger distances. In the case of Troll, simulations were made that made it evident that a negative impact on the seismic array in the planned location can be expected. NORSAR had the opportunity to take part in the NPI organized study tour to Troll Research Station in January 2024, and was able to investigate alternative array locations at larger distance from the planned windmill installations. The conclusion of this tour was that there exist other alternative locations for the array. The discussion on location is still on-going.



The NORSAR team at Kjeller is delighted after successfully packing the container with equipment and instruments for the seismic- and infrasound array, which is now headed south with the Silver Arctic. Photo: NORSAR.

3.5 Fimbulisen Ice-shelf Observatory

The core of the NPI and UiB Fimbulisen Ice-shelf Observatory (FIO) consists of instruments 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 consists of two sites in the central and northern Jutulstraumen area.

An extensive and successful 50-days long field campaign was carried out during the 2023/24 Austral season to replace the current outdated and outlived instruments deployed at Fimbulisen during the last International Polar Year in 2009. The set-up is a combination of state-of-the-art and cutting-edge under ice shelf ocean instrumentation deployed under the northern, 200 m thick, and central, 400 m thick, part of Fimbulisen. A hot water drill was used to drill the holes needed to deploy the instrumentation under the ice shelf. FIO also includes the establishment of co-located autonomous

surface and basal mass balance and ice shelf motion (snow accumulation, dynamics, tides, strain) measurements.

The suite of autonomous oceanographic sensors together with surface instrumentation provide insight into the ice shelf mass balance, and continued monitoring of ocean properties below the ice shelf cavity that started in 2010. Complemented by the array of multidisciplinary oceanographic moorings in MOMO in front of the ice shelf, these observatories provide unique insights into the coastal marine environment in the Atlantic sector of East Antarctica, its relevance for marine ecosystems, the ice sheet mass balance and sea level, and linkages to large-scale climate dynamics.

An open and international collaborative approach was imperative for the successful implementation of the FIO observatory. While the NPI provided the heavy deep field logistic support to realize the 1500 km overland traverse to the drill sites, including field safety and domestics, British Antarctic Survey contributed with the hot-water drill and expertise that roots in decade-long fruitful science collaborations. In addition, collaboration partners from US (Cornell University) complemented borehole instrumentation with under-ice robotics (Icefin) to gather detailed observations of the under-ice shelf geometry and hydrography in the ice-ocean boundary region. In combination, the collectively obtained datasets will contribute significantly to developing new formulations of basal melting for global-scale climate models that will ultimately reduce uncertainty in future sea level rise, in addition to the continuation of a unique time series of the ocean climate at the East Antarctic coastal environment.



The TONe-Fimbulisen field team after successful deployment of the ice shelf observatory in January 2024. Photo: Julien Witwicky, Université Grenoble Alpes.

Such an extensive long deep field expedition requires extensive field preparations; in this case it started in spring 2022 with purchases of instruments and equipment and in fall 2022 the heavy equipment was shipped to Troll. Throughout 2023, detailed campaign preparations took place,

including formalization of the collaboration with the new partners. Prior to the deployment, a week-long field course was held in Tromsø. Such detailed preparation and field course where the 11 participants got to know each other in more depth beforehand, was crucial for the successful and efficient teamwork on the ice.

Time series from the old moorings have been analysed as part of the iMelt project (Lauber et al. 2023a, Lauber et al. 2023b, Lauber et al. 2024, Lindbäck et al. 2023) and datasets published (see reference list).



A bird's eye view on the hot-water-drilling field camp on Fimbulisen. Photo: Harvey Goodwin, NPI.

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 the deployment of new sensors and service of the observatory in January 2023, and also based on experiences from two mooring-turnover cruises, final adjustments to the MOMO configuration were planned, and the last instruments for the observatory has been procured during 2023.

The first time series from the observatory have, together with the old data from Fimbulisen, been analyzed as part of the iMelt project (Lauber et al. 2023) and data has been published (see reference list). As part of this work, new data processing and archiving procedures have been developed.

A new service is being prepared for the Australian summer 2024/25, after which the instrumentation shall be complete and fully operational.

3.7 Seabird Monitoring Observatory

The NPI's Seabird Monitoring Observatory (SMO) will provide key information on seabird population trends and will allow a continuation and expansion of the ongoing wildlife monitoring activities NPI has been performing in DML for decades. The observatory consists of automatic time-lapse camera systems installed already in the Australian summer 2022/2023 at two of the largest bird colonies in DML (Svarthamaren and Jutulsessen). A meteorological station has also been installed at Svarthamaren to record continuously local weather conditions.

During the last year, new time-lapse cameras have been acquired from a new manufacturer Hideaway (UK) as the previous one from US stopped producing such systems. Three of these cameras have been tested in Tromsø, and were installed at Svarthamaren in the austral summer season 2023/24. The first cameras installed in 2022/23 have all been checked in 2023/24 and their data downloaded. Some adjustments were needed for most cameras. In particular, two cameras at Jutulsessen had moved during a winter storm and needed reinforcement; the solar panel of another one at Svarthamaren broke and needed replacement and one camera at Svarthamaren did not work for unknown reasons. Most of the issues encountered in the first year have now been fixed. The camera systems will be checked again in 2024/25.

Also, the winter storm that moved some of the cameras, also damaged the weather station installed at Svarthamaren. Some sensors needed replacements and the station was moved to another, more sheltered location, closer to the bird colony. All sensors are now working properly and transmitting weather data daily.



The camera systems in Jutulsessen after the upgrade in summer 2023/24. Photos: Sebastien Descamps, NPI.

3.8 Remotely Piloted Aircraft System

The NORCE and NPI's Remotely Piloted Aircraft System (RPAS) service consists of fixed-wing long-range RPA with data collection capability horizontally and vertically to cover large parts of DML. The service will be available for researchers to use. The aircraft payload includes sensor packages to support the other observatories and large initiatives; For example, for FIO: VHF radar for bedrock and

grounding line mapping and GHz radar for snow precipitation mapping; for SMO: aerial cameras for mapping of colonies; for ICO: sensors for meteorological, cloud and aerosol profile measurements, for MOMO: hyperspectral sensors for measurements of chlorophyll and primary production and aerial cameras for sea-ice cover mapping.

During the last year the foci have been on acquiring an aircraft platform that complete the operational requirements that the user groups and observatories has specified as well as the payload the need to be integrated into the aircraft.

NORCE have visited three potential manufacturers that responded on the Request for Information call and fulfilled the minimum requirements. The final selection will be completed after a procurement process with international bids.

University of Kansas Center for Research, Inc. (CReSIS) joined the TONe consortium in January 2024. Their contribution will be to provide the radars systems that will be integrated into the aircraft. NORCE was also part of the study tour to Troll Research Station in January 2024. This site trip was also very useful in the sense it was used to plan for the operational setup at Troll.

Detailed planning for the shelter setup has also been developed and this plan will be finalized when the final decision on aircraft model has been made.

3.9 Data management system

The TONe data management system will comprise a local data storage and processing facility at Troll Research Station, permanent data storage and management at the partner data centres in Norway, and a common gateway and search interface for all TONe data. The TONe data management system will ensure long-term preservation and a unified access point for all TONe data.

During 2023 the work has been focussed on the establishment of the facility at Troll. The functional requirements of all the observatories have been mapped and a detailed specification document developed. The remaining three (of four) data servers with data storage units have been acquired. Due to emerging needs for a comprehensive upgrade of the existing ICT infrastructure at Troll Research Station a decision was taken to put the TONe server installation on hold until the next austral summer. Instead, the TONe servers will be configured and tested in Tromsø during 2024 and shipped to Troll for installation later this year.

As a part of establishing the new TONe data we have installed USB to ethernet and serial to ethernet on the existing University of Oslo installation at Sofietoppen. We were successful in making two of three instruments available over ethernet, this is preparation for establishing existing machines and instruments as virtual machines at the TONe data solution.

Meanwhile, the development work on the TONe data portal has started, with a metadata pipeline from the TONe data centres through NorDataNet.

A data transfer link by satellite has been established for FIO, whereby data are being continuously transferred to Tromsø in near real-time.

NPI have done a larger network upgrade at Troll together with SIKT. We are modernising all the network equipment and changing our network support from Norwegian Environment Agency (Mdir) ICT to SIKT. Sikt – Norwegian Agency for Shared Services in Education and Research is a public administrative body under the Ministry of Education and Research and is responsible for IT deliveries

to education and science in Norway. This change will provide better support for science, since Mdir IKT only provide general office support.

This upgrade will make sure that we are ready to implement the new science infrastructure at Troll.

As a part of this upgrade, NILU was moved out of the NPI network solution, and have its own open internet connection from KSAT (Kongsberg Satellite Services), which operates a ground station at Troll and have a well-developed ICT infrastructure on site.

4. Outreach

Outreach of TONe, both to the scientific community and the public is an important part of the project activities both for the project management and the partners. The TONe communication strategy established during the first year on TONe ensures that the various communication activities have a shared focus. During the development of the communication strategy, four main target groups were identified. Although the overarching message from TONe is the same, these groups should be targeted slightly different:

1. Target group 1: Other researchers and the research communities
NPI and the TONe partner group would like to mobilize the Norwegian research communities for increased research activity in Antarctica, aiming both at the Norwegian research groups that do not already have activities in Antarctica, but which are involved in fields with a potential for Antarctic work, and also at the international research community to increased collaboration. We also aim at attracting researchers who do not necessarily need to travel to Antarctica themselves, but who can utilize the TONe data in new ways. In particular, we would like to focus on the recruitment of younger researchers to Antarctic research.
2. Target group 2: Decision makers, Norwegian ministries and The Research Council.
This second target group is important for various reasons, including ensuring sufficient research funding to utilize the TONe infrastructure as well as the Troll Research Station.
3. Target group 3: The general public.
The general public is a diverse target group, which includes everyone who, for various reasons (education, personal involvement, etc.) is interested in information about climate and environmental changes in Antarctica or has a general interest in what is going on in Antarctica. It is important for us to show how the Norwegian research community contribute to increased knowledge about Antarctica, both on how it interacts with the global systems, but also for the management of Antarctica itself.
4. Target group 4: Management of research institutions, both Norwegian and foreign, including other nations' Antarctic programs.
This target group ensures Norway keeps it high standing in the various international Antarctic organizations as the Antarctic Treaty and the Committee for Environmental Protection.

The TONe webpage at <https://www.npolar.no/en/ton/> is our main information body, and the page includes detailed information on each observatory, the service and the data system.

A TONe information poster was made and has been distributed to various locations at Troll Research Station and at the partner locations.

The partner institutions' social media channels on Facebook, Instagram, and X are used to communicate TONe to the general public. TONe has its own social media channel on X @TrollObservingNetwork that is sporadically used.

During the second year of operation the TONe communication activities have been broad. The complete list is found below.

4.1 TONe Communication and Outreach Activities Year 2

Information about TONe in general and the individual observatories has been communicated widely the last year. Specifically, TONe has been presented at the following scientific conferences/workshops:

- Presentation on TONe-SA at the 83rd annual meeting for the German Geophysical Society in Bremen, Germany in March 2023
- Poster on TONe at annual internal Bjerknes Centre Getaway in Bergen, Norway in June 2023.
- Poster on TONe-MOMO and TONe-FIO at the Forum For Research Into Ice Shelf Processes (FRISP) in Stalheim, Norway in June 2023
- Poster about the Troll transect cruise at the Annual COMNAP meeting in Hobart, Australia in June 2023
- Poster on TONe at the General Assembly International Union of Geodesy and Geophysics (IUGG) in Berlin, Germany in July 2023. DOI: 10.57757/IUGG23-2802
- Presentation on TONe-RPAS service at the International Society for Atmospheric Research using Remotely-piloted Aircraft (ISARRA) in Bergen, Norway, in August 2023
- Presentation on the TONe marine observatories at SOOS Symposium 2023 - Southern Ocean in a Changing World in Hobart Australia in August 2023
- Talk and poster on the Norwegian contribution to the Pandora Global Network at the 2nd Pandora Global Network community meeting, Baltimore, US, October 2023. The Pandora instrument is part of TONe-ACO.
- Presentation on TONe-DATA at the International Data Week 2023 and at the annual meeting in SCAR Standing Committee on Antarctic Data Management (SCADM), both in Salzburg, Austria in October 2023
- Presentation about the TONe-FIO campaign for the Polar Network at the University of Bergen, in March 2024.

TONe was also in the media, both in terms of by popular science articles written by members of the consortium, but also in the news media:

- Article on TONe-SMO on the Norwegian Polar Institute web: Stormfullt fugleliv by E. V. Jenssen; <https://www.npolar.no/nyhet/stormfullt-fugleliv/>. March 2023.
- Article on TONe-FIO on Norwegian Polar Institute web: Fimbulisen i Antarktis smelter fra undersida by T. L. Sviggum Helgerud; <https://www.npolar.no/nyhet/fimbulisen-smelter-under/>. December 2023
- Interview in SR Radio Halland P4 with Elin Dareljus on TONe-FIO field work <https://sverigesradio.se/avsnitt/2280703> (1h10), December 2023
- Article on TONe-SMO in Forskning.no and Norwegian Polar Institute web: En bølge av intense snø-stormer får skylden for hekke-svikten hos sjøfugl i Antarktis, E. V. Jenssen, <https://forskning.no/antarktis-fugler-klima/en-bolge-av-intense-snostormer-far-skylden-for-hekkesvikten-hos-sjofugl-i-antarktis/2178113>. April 2023
- News article on previous FIO data in NRK: <https://www.nrk.no/urix/varmare-vatn-smeltar-is-fra-undersida-i-antarktis-1.16566213>. Sept. 2023.
- Interview on University of Bergen Bjerknes Center webpage: To måneder i Antarktis - intervju med Elin Dareljus: [To måneder i Antarktis - intervju med Elin Dareljus \(uib.no\)](https://www.uib.no/nyhet/to-maaneder-i-antarktis-intervju-med-elin-dareljus). Feb. 2024.

- Popular science article in Fram Forum: Troll Observing Network – status and progress in 2023, Njåstad and Pedersen, <https://framforum.com/2024/03/05/troll-observing-network-status-and-progress-in-2023/>. March 2024

In addition, TONE was presented for stakeholders:

- TONE was presented to leaders and rectors at main Norwegian research institutions at a study tour to Troll Research Station in January 2024

5. References

5.1 Publications

Lindbäck K., Darelius E., Moholdt G., Vaňková I., Hattermann T., Lauber J. & de Steur L. 2023. Basal melting and oceanic observations beneath Fimbulisen, East Antarctica. Unreviewed preprint. *ESS Open Archive*, 27 December, doi: 10.22541/essoar.170365303.33631810/v1.

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Lauber, J., Hattermann, T., de Steur, L., Darelius, E., Auger, M., Nøst, O. A. and Moholdt, G. 2023b. Warming beneath an East Antarctic ice shelf due to increased subpolar westerlies and reduced sea ice. *Nature Geoscience*, 16, 877–885. <https://doi.org/10.1038/s41561-023-01273-5>

5.2 Datasets

Daily averages of physical oceanography and current meter data from sub-ice-shelf moorings M1, M2 and M3 at Fimbulisen, East Antarctica since 2009: <https://doi.org/10.21334/npolar.2023.4a6c36f5>

Basal melt derived from a phase-sensitive radar (ApRES) at Fimbulisen, East Antarctica: <https://doi.org/10.21334/npolar.2023.1bbf3c47>

Hydrography and current meter data from two ocean moorings off the coast of Dronning Maud Land 2019-2021: <https://doi.org/10.21334/npolar.2023.45d176be>



Troll Observing Network

Annual report. Year 2: March 2023-March 2024
Troll Observing Network infrastructure project