Research ship of opportunity – Le Commandant Charcot to the North Pole

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Abstract. This article will present the data collection from the Norwegian scientists' research project on board Le Commandant Charcots North Pole expedition in August-September 2023, with a scope within Global Navigation Satellite Systems (GNSS), Low Earth Orbit (LEO) Communication Satellites and Ice Buoys. Operational testing in the artic environment is of particular interest, due to its high latitude, remoteness, increased traffic and a need for operational data on the availability and reliability of satellite services in the High North.

Introduction

A research ship of opportunity is a vessel which scientists are allowed to embark on certain missions in order to conduct data collection. Ponant's cruise vessel, Le Commandant Charcot (LCC), conducted four trips to the North Pole in 2023, and on the final trip from 26th August to 11th September, six scientists from Italy and Norway were embarked the ship to conduct data collection along the ships passage. The ship departed from Longyearbyen in Svalbard with course for the North Pole. After visiting the North Pole, the ship would visit Svalbard again, before continuing the passage to Greenland and finally arriving Reykjavik on the 11th September.

Equipment setup

The equipment taken on board the Le Commandant Charcot consisted of three parts:

1. GNSS logging equipment:
    a. from Septentrio with two antennas,
    b. a Portable Pilot Unit,
    c. a Galileo High Accuracy User Terminal.
2. Satellite communication logging equipment:
    a. Starlink antenna.
    b. Computer logging with Prometheus and Starlink logging software (WiFi connection)
3. Ice buoy to deploy on ice:
    a. ICEX buoy from Norwegian Defence Research Establishment (FFI).

When using a research ship of opportunity, especially with regards to antenna mounting, it is difficult to find an ideal spot with free line of sight. On board the Le Commandant Charcot the best place was identified to be on at the overboard platforms on deck ten (Figure 1), where the main and auxiliary antenna were mounted together with the Starlink antenna.

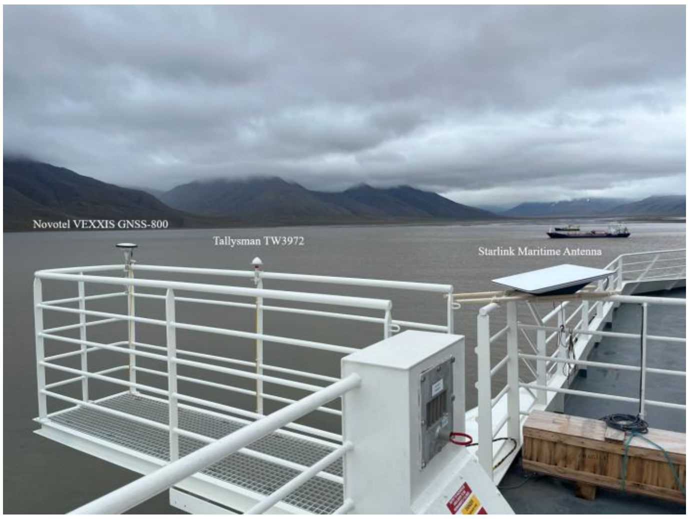

Figure 1 GNSS antenna mounting on overboard platform on deck ten of the vessel.

GNSS logging equipment
The set up of the GNSS equipment was conducted as shown in Figure 2. The equipment consisted of a main antenna of the type of Novotel VEXXIS GNSS-800, and an auxiliary antenna of the type of Tallysman TW3972, with a baseline between the antennas of 1,41 metres. The signal from the main antenna is splitted with a GNSS networking splitter, and further connected to a Septentrio PolaRx5, a Galileo High Accuracy User Terminal (standalone) and a Septentrio AsteRx SB i3. The Septentrio AsteRx SB i3 have both the main and auxiliary unit connected (dual antenna setup), in order to conduct attitude measurements. The data collection from AsteRx SB i3 and PolaRx5 is further presented and stored on two computers. Once a day a back-up procedure is conducted, in order to store all data.

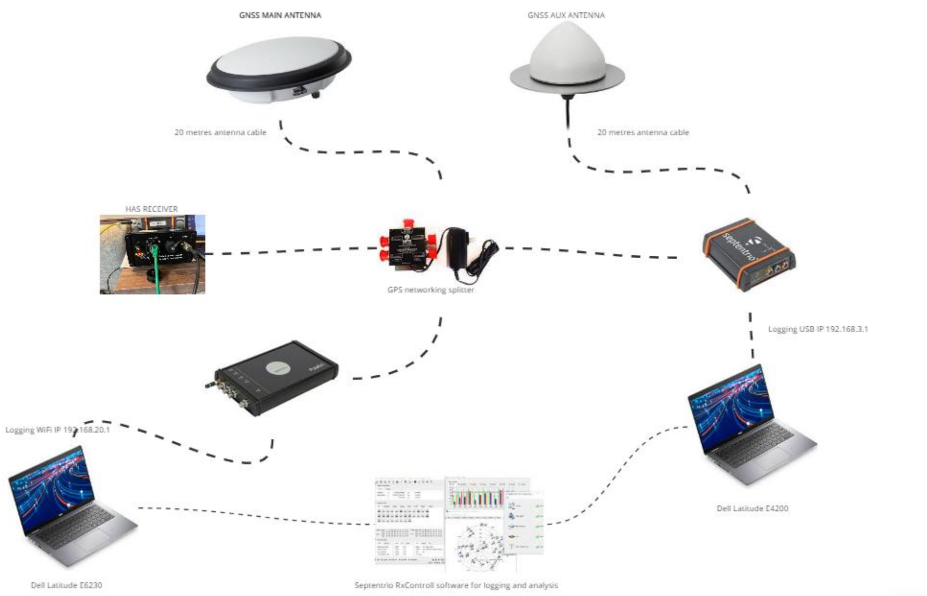

Figure 2 GNSS equipment setup

Satellite communication equipment setup - Starlink

Starlink is a broadband internet satellite constellation which orbits the earth in low earth orbit (LEO), approximately 550 km above ground[1]. It offers a low latency alternative to competitive internet satellite providers, which have moves in an earth orbit at about 35,786. In contrast to traditional satellite internet services, Starlink offers internet which supports streaming, online gaming, and video calls. This means that the system can be used for administrative ship purposes, crew welfare purposes, Search and Rescue (SAR) communication purposes, medical help purposes, amongst several other aspects.

A research purpose of the trip was to test the performance and the connectivity of Starlink in polar waters, and thus an independent Starlink High Performance kit was installed on board *Le Commandant Charcot*. The High-Performance Kit is tailored for high-speed connectivity up to 220 Mbps download speed and 20 Mbps upload speed, serving internet both in maritime and remote areas[2].

The Starlink High-Performance Kit consists of a Starlink Dish (which is the kits antenna and shown on the right in Figure 1), a Starlink Power Unit and a Starlink Wi-Fi router, as well as proprietary Starlink cables. The Starlink dish was mounted on the starboard overboard platform on deck ten, as shown in Figure 1. The Starlink maritime antenna[3] is working to around –30 °C, which makes it suitable for polar waters. The antenna also has a built-in snow melting function and can melt 75 mm of snow per hour.

There is no difference in setting up a Starlink High-Performance kit versus a normal Starlink kit, except that the High-Performance Kit is made for stationary installation on the vessel. The dish has no moving parts, as the Residential antenna has.

[1] https://www.starlink.com/technology
[2] https://www.starlink.com/legal/documents/DOC-1400-28829-70
[3] Specification and configuration: https://support.starlink.com/topic?category=10

Figure 3 Starlink coverage https://www.starlink.com/map 06.09.2023

As shown in Figure 3, there are coverage for high latitudes, including the Svalbard region. At the time of writing (06/09/2023), Greenland service date is unknown according to Starlink websites. However, after departing Svalbard and after visiting the North Pole, the passage plan for *Le Commandant Charcot* was to visit Greenland, before disembarking in Iceland. During the time LCC was in Greenlandic areas, connectivity of Starlink was good on the north-eastern coast of Greenland (Ittoqqortoormiit area). At 8th of September at 1230LT in the port of Ittoqqortoormiit, connectivity was 260 mbps download and 22mbps upload with a latency of 50ms.

The Starlink antenna was setup on deck ten on an overboard platform, as shown in Figure 1. The overboard platform was on the starboard side of the ship, and the ships infrastructure provides shadow for the antenna. This is shown in the Starlink application in Figure 4.

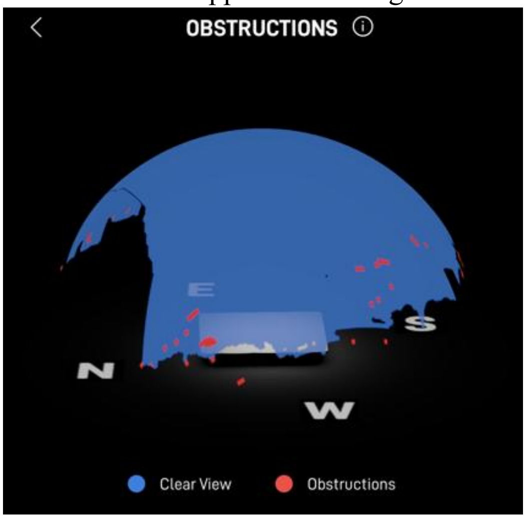

Figure 4 Starlink antenna blockage figure from the Starlink application (screen dump – Starlink App)

Portable Pilot Unit sensor equipment setup

A Portable Pilot Unit (PPU) is a support system for maritime pilots who board ships to offer a safe pilotage (under the pilotage act) into an area or harbour. Due to several different navigations systems and sensor setups, and issues relating to the usability and reliability of such systems, there has become a marked for PPUs. PPUs are divided into four components: sensors, display, software and charts, as shown in Figure 5.

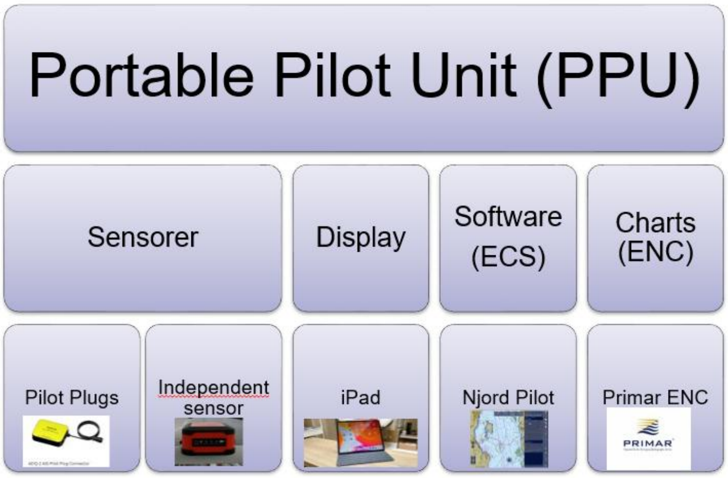

Figure 5 Portable Pilot Unit and its components

On board the LCC the PPU sensors were mounted on the ninth deck, and the PPU Displays with software and chart were logging continuously with Wi-Fi connection to the high-end PPU independent sensors during the voyage. This was conducted in order to test the PPU sensors in artic conditions and in addition gain experience in the use of the high-end sensors in order to further improve the next generation sensors which are developed in an innovation partnership with the Norwegian Coastal Administration Pilot Service[4].

Drifting buoy for under-ice oceanographic measurements[5]

Norwegian Defence Research Establishment (FFI) has adapted an original «CMR ICEX» type weather buoy (Norce, Norway) for long-term oceanographic data collection in the Arctic. The buoy is designed to sustain up to two years of operation in ice. The instrumentation includes a string of 10 small-size oceanographic data loggers (Star-Oddi), for measurement of ocean temperature and salinity in the upper 100 m of the under-ice water column. The motivation is to collect measurements of the under-ice Arctic water column, to complement other measurements where sampling of the upper water column is traditionally sparser. The instrument is equipped with a GPS-Iridium modem that allows for tracking of the buoy. Data is to be retrieved after buoy recovery The buoy was place on the ice at 86º16`N in the Nansen Basin.

[4] https://innovativeanskaffelser.no/innovation-partnership-support-tool-for-the-norwegian-pilot-service/
[5] Text and plots courtesy of FFI (www.ffi.no)

Figure 6 ICEX buoy deployed on ice with the LCC in the background.

Key figures of the buoy are:

Dimension: height 90 cm, diameter 60 cm, weight in air: 50 kg
Endurance: up to 48 months
Temperature: to -40° C
Sensors: Star-Oddi DST CTD

The buoy is expected to drift westward within the ice pack, then out into open ocean in the Fram Strait. The plot in Figure 8 (left) shows an example of simulated buoy drift for various deployment latitudes along 30° E, based on historic ice drift data from 2021/22. The plot in Figure 8 (right) shows the trajectory of the buoy as of January 4, 2024, based on GPS data received from the buoy.

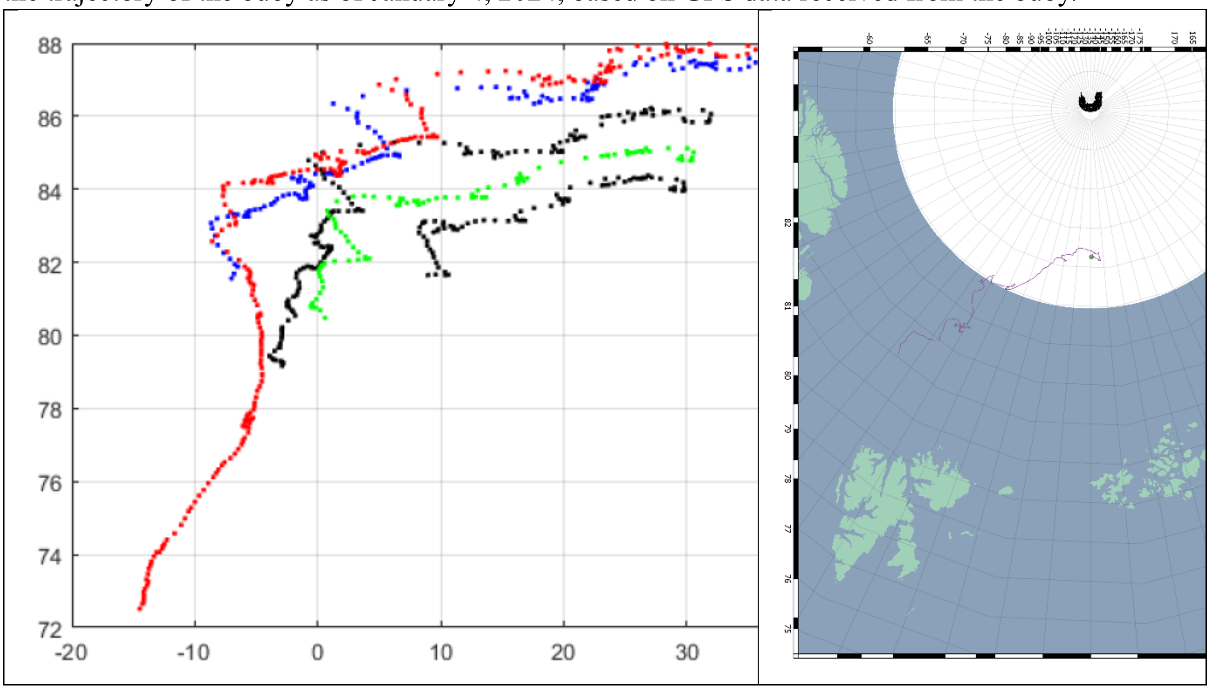

Figure 7 (Left) Simulated plot of the drift of the buoy, based on ice drift data from 2021/22 and for various deployment latitudes along 30° E. (Right) Actual buoy trajectory as of January 4, 2024, based on GPS data received from the buoy.

Ice Navigation

The conduct of Ice Navigation is developing, and the crew on board the LCC holds extensive and up-to-date knowledge of how ice navigation in polar regions is conducted. Information regarding the use of ice navigation radar, ice navigation tools such as IcySea[6] and other support tools (e.g., ArticInfo[7] and NAIS[8]) for assessing the best ship route through ice was gathered. Video recordings of ice navigation was conducted and can be used in ice navigation curriculums.

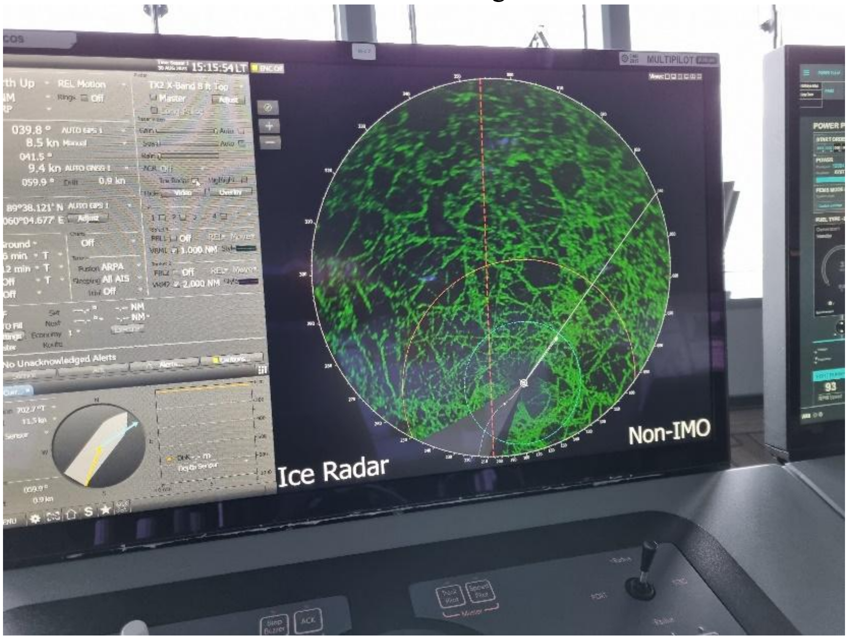

Figure 8 Ice Radar onboard LCC

The manoeuvrability of the LCC with its 34 MW propulsion power with two azipods makes the vessel highly manoeuvrable in ice conditions, and it is the world's strongest non-nuclear ice breaker with a Polar Class 2 certification (PC2). On the 30th August 2023 at 18:36 local time the LCC reached the North Pole and made an impressive manoeuvre to reach the exact 90°N (Figure 9).

[6] https://driftnoise.com/icysea/

[7] https://www.barentswatch.no/arcticinfo/

[8] https://nais.kystverket.no/

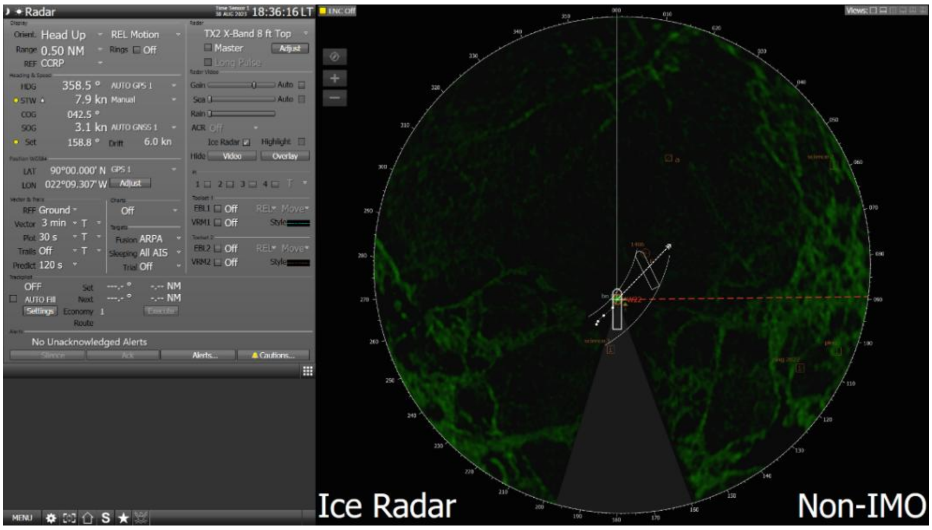

Figure 9 Screen dump from the LCC radar screen at the exact 90N LAT.

GNSS Data collection

The data was collected on hard disk drives on laptops on board the vessel, and there were two independent setups of GNSS logging and satellite communications logging.

GNSS logging were conducted with Septentrio RxTools[9]. In accordance with the setup of the equipment in Figure 2, logging data from a single antenna and a dual antenna setup was recorded on two separate computers. Once a day, tropospheric information (temperature, air pressure and humidity) was updated into the Septentrio SBi3 administration software. Back-up procedures was conducted once a day, and data will be further analysed with the logging files from the receiver with SBF analysing tool. It is a wide range of different parameters that can be analysed in SBF analyser. Some examples are sky plots with the number of satellites and the different constellations at the North Pole (Figure 10), which shows twelve GPS satellites, ten GLONASS satellites, eleven Galileo satellites, twelve Beidou satellites and two QZSS satellites (and no SBAS satellites due to the latitude).

[9] https://www.septentrio.com/en/products/gps-gnss-receiver-software/rxtools

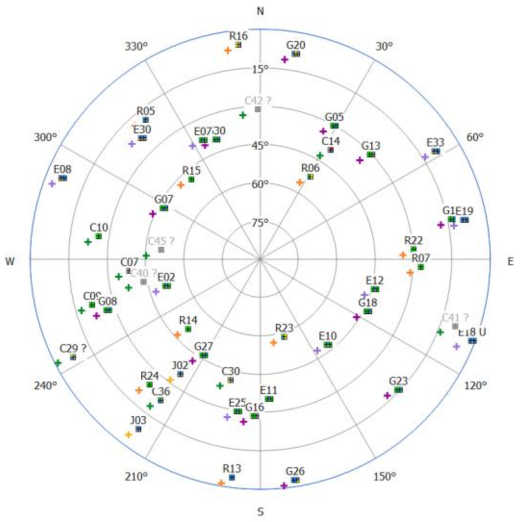

Figure 10 Sky Plot from the 30th August when LCC reached the North Pole

The number of space vehicles (SVs) in sight (above horizon) and in track are shown in number of satellites time plots (Figure 11).

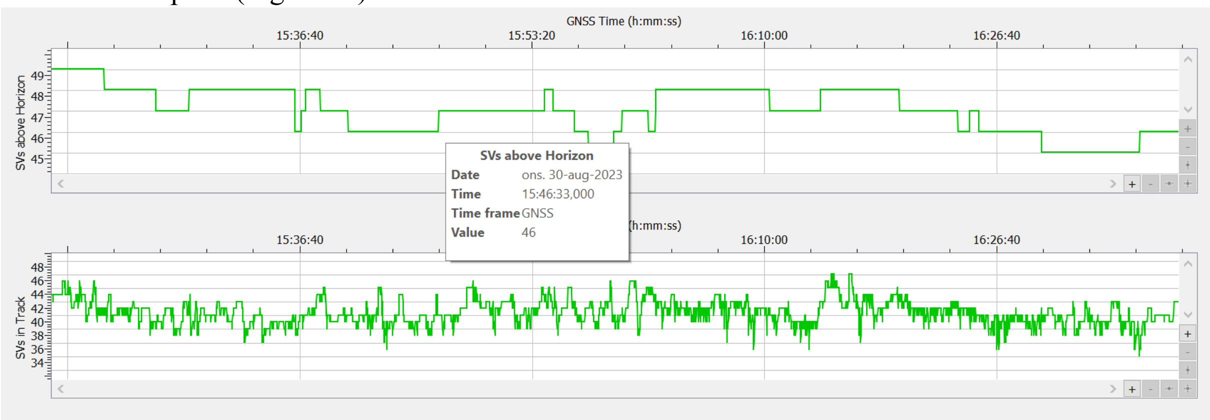

Figure 11 Number of satellites time plots

Along with other plots such as Dilution of Precision (DOP) shown in Figure 12, carrier to noise time plots, heading, pitch, roll (HPR) time plots, Total electron content time plot and multipath time plot just to mention some of the plots available in the analysing tool (SBF Analyzer).

Figure 12 Dilution of Precision Time Plot

“Galileo HAS it”

During the passage, data was collected with a Galileo High Accuracy User Terminal (Figure 13). The data is collected in collaboration with the Norwegian Space Agency (NOSA) and the European Union Agency for the Space Programme (EUSPA).

Figure 13 Galileo High Accuracy User Terminal

Galileo High Accuracy Service (HAS) provides precise corrections for satellite orbit, clock and signal biases. The Galileo HAS corrections are distributed via Galileo satellites, E6-B signal (1278.75

MHz) and the Internet. With Galileo HAS the user can achieve accuracy in the range of 20 centimetres free of charge using Precise Point Positioning (PPP), almost everywhere in the world[10].

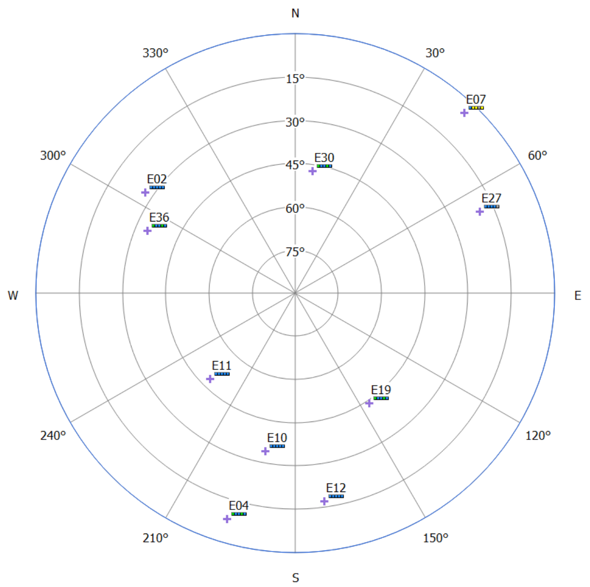

Figure 14 Sky Plot Galileo satellites at the North Pole 30th August 2023

The purpose of this experiment is to determine the performance of Galileo HAS in dynamic applications under challenging conditions.

Satellite communication data collection

Satellite communication logging was conducted by using software available on GitHub[11], which is an online code hosting platform where it is possible to download software for projects. Dan Wilcocks created a project in 2021 and provided a non-Starlink logging software which utilizes Prometheus software for collecting metrics in the Starlink systems, and Grafana (Figure 15) for visualisation purposes.

A separate computer was set up in the ships cabin, which was installed with Ubuntu (a Linux operating system), Prometheus and Grafana. The NTNU IT-department set-up the computer to be logging continuously, whenever the computer was powered on. Grafana provided an interface, as shown in Figure 15. Here is the metrics of download speed (purple graph, Mbps – Megabit per second), upload speed (yellow graph, Mbps), latency (blue graph, ms (milli seconds), and signal-to-noise ratio (SNR, red graph, measured in percent) displayed. Latency gives an indication of how fast a signal goes from the computer to the internet and back, and the SNR provides information about if there is any obstructions or loss of connection to the Starlink satellites. The software was set up to constantly log latency and SNR/loss of signal, and to test download and upload speed every hour.

[10] https://www.euspa.europa.eu/european-space/galileo/services/galileo-high-accuracy-service-has
[11] https://github.com/danopstech/starlink

Figure 15 Grafana interface

As shown for a longer period of time in the Figure 16 and Figure 17 below, there was varying, but stable and reliable connection when sailing from Longyearbyen to the North Pole.

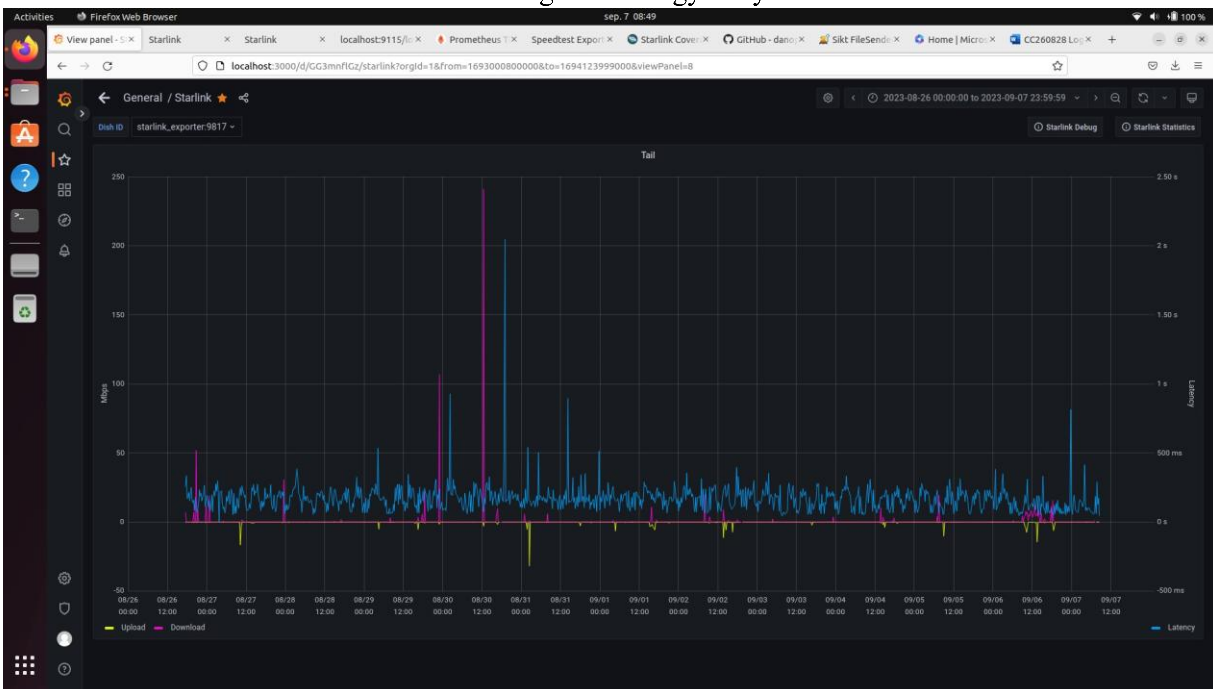

Figure 16 Download speed (purple), upload speed (yellow) and latency (blue).

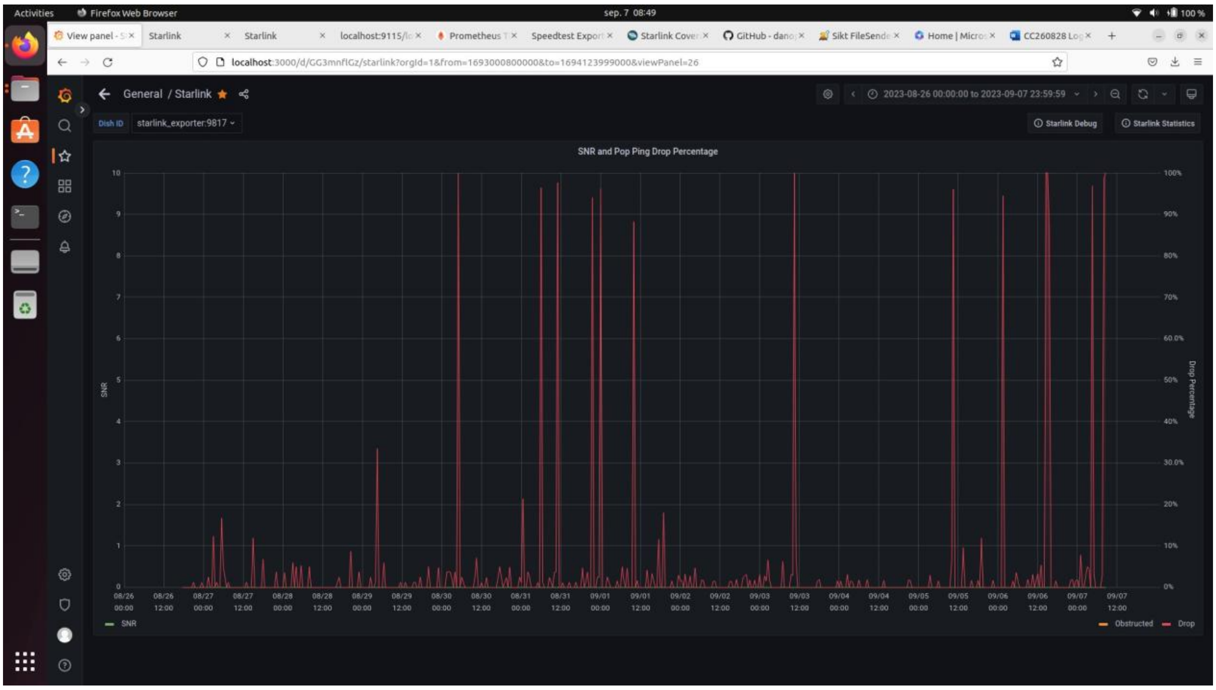

Figure 17 - SNR and loss of signal

Considering the connectivity on the North Pole itself, it was good reception, with between 100 ms to 240 ms latency, approximately 177 Mbps download speed and upload speed of approximately 37 Mbps (Figure 18).

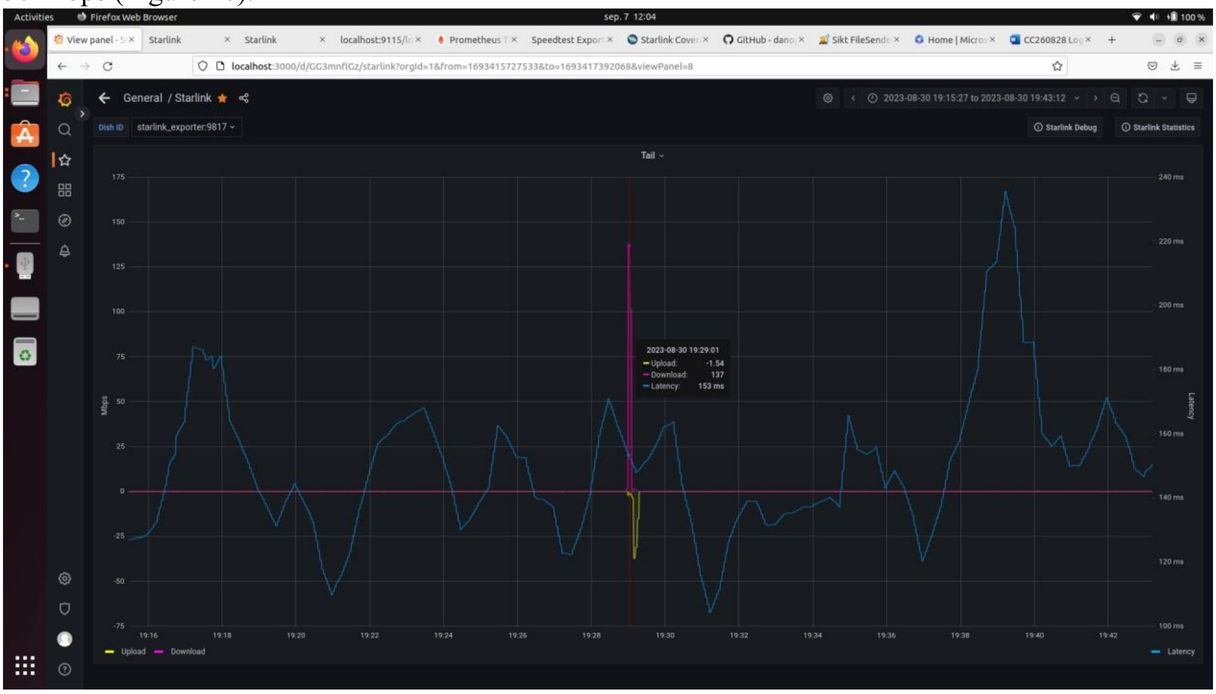

Figure 18 Starlink upload, download and latency at the North Pole.

Summary

There is an increasing interest in navigation in the artic region, and knowledge about how the satellites operate and function in the area are important to gain a better understanding of the challenges and opportunities in the artic region. Until the 10th September 2023, 170 ships have visited the North Pole. *Le Commandant Charcot* has visited the North Pole nine times since 2021. The LCC thus provide a good opportunity for researchers to collect data onboard a research ship of opportunity. In the period from 26th August 2023 to 9th September 2023, GNSS data and satellite communications data was collected for further analysis onboard the *Le Commandant Charcot*, and all data collected for GNSS, and satellite communication purpose can be shared upon request to one of the authors of this article.

The authors would like to acknowledge the crew, captain Patrick Marchesseau and science officer Mr. Daniel Cron of the *Le Commandant Charcot*.