St3TART
FRM for Sentinel-3 Land Altimetry

Sentinel-3 Topography mission Assessment through Reference Techniques (St3TART)

TD-12 - DESIR FRM Campaign log

	Function	Name	Signature	Date
Prepared by	St3TART Project Team & DESIR Project Team i-TechDrone	Sara FLEURY (LEGOS) and Laurent COGNET (i-TechDrone)		18/04/2023
Approved by	Project manager	Elodie DA SILVA		03/04/2023
Authorized by	Deputy CEO	Mahmoud EL HAJJ		03/04/2023
Accepted by	ESA Technical Project Manager	Pierre FEMENIAS		

NOVELTIS
153 rue du Lac – 31670 Labège – France
Ph: +33 (0)562 88 11 11 – Fax: +33 (0)562 88 11 12 – E-mail : noveltis@noveltis.fr

Distribution list

INTERNAL	EXTERNAL	
Name	**Name**	**Company / Organisation**
NOVELTIS Documentation	Mr. Pierre FÉMÉNIAS	ESA
Mr. Richard BRU	Mr. Jérôme BOUFFARD	ESA
Mr. Mahmoud EL HAJJ	Mr. Philippe GORYL	ESA
St3TART Project team	Ms Filomena CATAPANO	RHEA for ESA

Document status

Sentinel-3 Topography mission Assessment through Reference Techniques (St3TART) Deliverable Name			
Issue	**Revision**	**Date**	**Reason for the revision**
1	0	03/04/2023	Initial version
1	1	18/04/2023	Revised according to Final ESA review

Modification status				
Issue	Rev	Status *	Modified pages	Reason for the modification
1	1	D		Annex A last page has been deleted

* *I = Inserted* *D = Deleted* *M = Modified*

Acronyms

The acronyms used in this document are defined in [RD5].

Reference documents

N°	Reference	Title
[RD1]	ESA-EOPG-CSCOP-SOW-29, Issue 1 Rev. 4 – 28/10/2020	Statement of Work - Sentinel-3 Topography mission Assessment through Reference Techniques (St3TART)
[RD2]	NOV-FE-0899-PR-002	Technical Proposal
[RD3]	NOV-FE-0899-PR-004	Implementation Proposal
[RD4]	ESA Contract No. 4000135181/21/I-DT	ESA Contract – Copernicus ground segment Sentinel-3 Topography mission Assessment through Reference Techniques (St3TART)
[RD5]	NOV-FE-0899-NT-040	Acronyms list

Table of contents

1. Introduction

1.1 Purpose and scope

This document is the FRM Campaign Log for the "Sentinel-3 Topography mission Assessment through Reference Techniques (St3TART)" project, [RD1].

It is provided, as deliverable TD-12, as a summary following the DESIR campaign, which took place in Arctic in July 2022.

1.2 Overview of this document

In addition to this Introduction chapter, this FRM campaign log document includes the following chapters:

- General considerations
- Campaign means
- Campaign log
- First analysis of data collected
- Campaign synthesis

2. General considerations

2.1. Genesis and motivations of the DESIR project

The first analyses developed in the context of the St3TART project have allowed us to identify a technique that would significantly increase the reference measurements on the ice pack. It is to exploit the tremendous development of drones. Indeed, drones could be deployed from polar stations or icebreakers, thus increasing the spatio-temporal coverage of ice pack observations.

However, the deployment of UAVs in polar regions raises many difficulties. The main ones concern the management of the cold, the problems of precise localization far from any GNSS reference base, the servoing in a disturbed magnetic field near the poles, the control of take-off and landing operations from a moving support, and more generally the availability of height measurement sensors adapted to the ice pack and compact enough to be embarked.

A demonstration experiment was set up at the beginning of the project in conjunction with the CryoVex campaign in March 2022 off Upernavik. This campaign made it possible to carry out measurements on the ice pack using the VorteX.io sensor carried by a DJI M300 drone from the company i-TechDrone. The results of this campaign are presented in the TD-13.2 Final Campaigns report.

After the start of the St3TART project, a new opportunity opened to us to make measurements from an icebreaker. It was the call for tender of the H2020 ARICE consortium issued at the end of 2021 to embark on the Commandant Charcot between Svalbard and the North Pole in July 2022. As such opportunities are extremely rare, we took the initiative to put together a file which was accepted in February 2022.

The St3TART consortium has agreed to cover part of the costs, mainly related to the needs of a professional drone that can carry the sensors and its pilot for two weeks. The travel and stay on the Commandant Charcot will be paid by Ponant Science.

Thus, the DESIR project "Drone Experiment for Sea Ice Retrieval" has been integrated to the St3TART project in June 2022.

The purpose of this document is to present the progress of this mission and to draw the main conclusions concerning the feasibility of deploying a drone from an icebreaker and the types of measurements that can be made.

2.2. General Regulatory Points

Drone flights are subject to strict rules, but to date they remain specific to the country hosting the flight. Drone flights in Svalbard are regulated by local law due to a draconian policy of preservation of natural areas. Our flights were essentially planned over international waters, but as a precaution we requested permission to fly from the Norwegian authorities through the diplomatic services of the CNRS (leila.chabane@diplomatie.gouv.fr). This authorization, delivered for the duration of our stay, is provided in Annex A.

Drone flights in the Polar Circle are not governed by any particular regulation, as they are above international waters. However, the activities in this region are subject to AECO guidelines. This implies environment respect, particularly for travel on the ice pack and therefore for the deployment of drones.

Finally, the usage of a drone from a ship requires the authorization of the captain. This was given with rules specific to the safety of the ship and its passengers defined jointly by the captain, the helicopter pilot and the drone pilot: landing and take-off from flight desk, no flight at the same time as the helicopter on board.

During the first test flights, a smaller drone, managed by another scientific team, crashed on a wall of the boat. Analysis of the incident revealed that DJI's GPS-assisted landing mode is not compatible with the boat's movements. Thus, we also asked the captain to stop the ship during all drone operations and to secure the flight deck to prevent the unexpected passage of onlookers (as it is the case for helicopter’s flights), which was granted.

3. Campaign means

3.1. Equipment

3.1.1. Main equipment

The material that we brought on board the Commandant Charcot is essentially composed of a DJI M300 drone with 8 batteries with a stabilized pod and a BS60 battery charging station and a set of sensors to evaluate.

Figure 3.1: Drone M300 equipped with the DJI Zenmuse P1 camera

The main sensor we wanted to evaluate was the VorteX.io lidar that had already been deployed for the mission to Upernavik in March 2022 (see NOV-FE-0899-NT-070). Unfortunately, this sensor was unavailable at the last moment due to a conflict with other priority measurement missions in the United States and could not be replaced in time due to electronic component shortages.

In order to be able to carry out the essential of the mission, this sensor was replaced at the last minute by the following set of sensors:

- 1 YellowScan Mapper+ 3D lidar with camera which was graciously lent to us by YellowScan https://www.yellowscan-lidar.com/fr/products/mapper-plus/ (estimated cost: 60 000€),
- a high-precision DJI Zenmuse P1 camera lent by i-TechDrone (estimated cost: 800€),
- a box made by i-TechDrone integrating 4 models of drone altimeters:
    - 1 ultrasonic rangefinder I2CXL MaxSonar,
    - 1 laser rangefinder Lightware SF11,
    - 1 radar rangefinder NFA15,
    - 1 TeraRanger EVO40 sonar rangefinder.

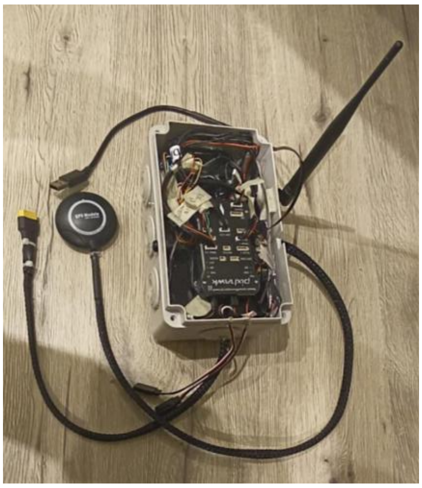

Figure 3.2: the 3 main sensors, from left to right: the 3D lidar YellowScan scanner, the Zenmuse P1 DJI camera and the box including the IMU and 4 altimeters from i-TechDrone.

Drone	Lidar	Camera
DJI Matrice M300 RTK	**YellowScan Mapper+**	**DJI Zenmuse P1**
MTOW 9kg		3 axis stabilized gimbal
Max payload 2.7kg	Point rate 240,000 /s. Repetitive scan pattern. Wave length 905nm / 35W	Photo sensor 45MP 8192x5460
Max range 4.5 km (radio limitation)	FOV Horizontal ±35° Vertical ±2.2°	Video sensor 4K 3840 x 2160
Wind limitation 23 m/s 82 km/h – 42 kt NO CHARGE	1.1 kg drone powered 1.3 kg batt incl. Sony camera 20.1 MP	
Max speed 23 m/s Operational max speed 15 m/s		
with 3 axis stabilized Gimbal to stabilise the instruments		

Table 1: main characteristics of the drone and the sensors

3.1.2. Auxiliary equipment

The ice-breaker Commandant Charcot is a 150m cruising ship but it has been designed to be also able to make scientific studies of the polar regions. Ponant offers 5-6 permanent places for scientists and the boat has 3 laboratories (wet, dry, and computers) reserved for them (see Figure 2).

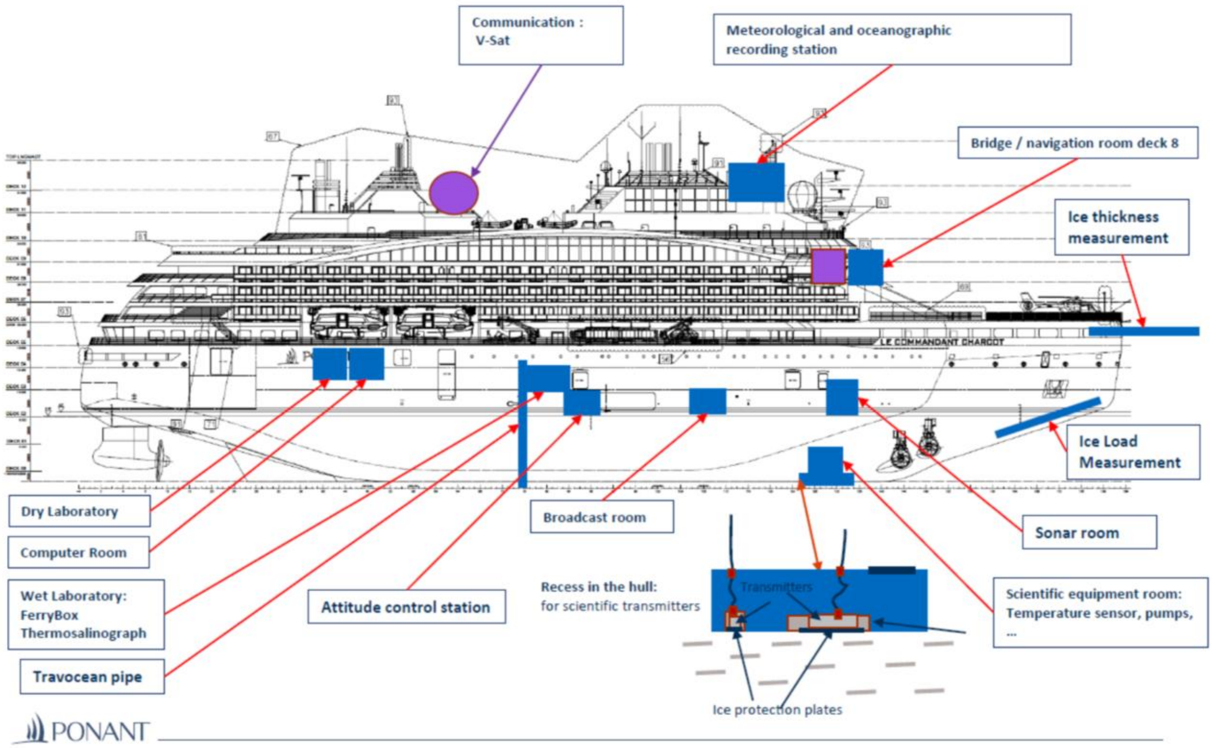

Figure 3.3: Science equipment on board Commandant Charcot

It also has many scientific types of equipment, including, for our part, a Sea Ice Measurement Sensor (SIMS) that is permanently suspended at the front of the boat when it is in the ice pack to measure the thickness of the ice. The SIMS, initially designed by Christian Haas (AWI), already equips several icebreakers. It is composed of electromagnetic sensor and a range finder and it provides the ice thickness in real time to the ship's command bridge. These data are also recorded and they will be used to be compared to our drone measurements.

Figure 3.4: Sea Ice Measurement Sensor (SIMS) that is suspended at the front of the boat when it is in the ice pack to measure the thickness of the ice.

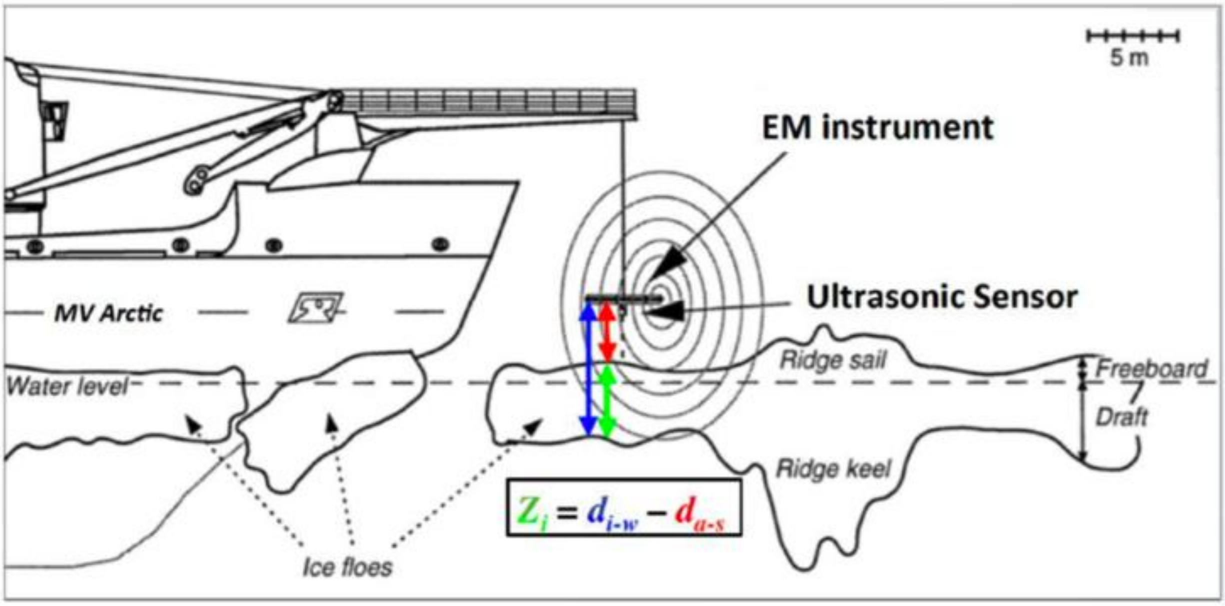

Figure 3.5: Principle of operation of the SIMS

We also had the necessary equipment to make holes in the ice pack and collect ice core. We have thus measured the characteristics of the ice pack at each stopover, and in particular the thickness of ice and snow and the temperature and salinity of the ice (Figure 5).

Figure 3.6: Ice coring and measurements of the main characteristics of the ice.

3.2. Human resources

On the occasion of the Arice call for tender we asked for and obtained 2 places on board the Commandant Charcot, one for Sara Fleury, the scientist in charge of the DESIR project, and one for Laurent Cognet, professional pilot of the i-TechDrone company.

4 other scientists were also present following this same call for ARICE projects: Dr Franz Vonbock a German at Hamburg University of Technology specialist of the structure of icebreakers, Dr Marcel Nicolaus a collaborator of Christian Haas specialist of the physics of the ice pack, Dr Nils Haentjens a French biologist at Maine University (US) and Christophe Perron, a Canadian PhD at Laval University studying the relations between the solar radiation through the ice pack and the planktonic development. Marcel Nicolaus also came with a drone to measure the albedo using a simple camera.

The Ponant Company had assigned us a person, Dr Daphné Buiron, in charge of helping us with the setting up and the realization of the measurements and to make the link with the captain of the ship to coordinate the navigation and the scientific measurements.

4. Campaign log

A daily log of our activities during the campaign is provided in section 4.2. In this section we focus on the flights and measurements that we were able to achieve.

4.1. Summary of the measurement opportunities

The expedition on the Commandant Charcot took place from the 8th to the 23rd of July, that is to say over 15 days of navigation between Longyearbyen and the North Pole. The North Pole was reached on July 13 and we turned back on July 14. As this was the first attempt of this icebreaker to reach the North Pole in July and with passengers, the captain did not want to stop before reaching the Pole to make sure to reach this goal on time.

Nevertheless, in order to be able to make first measurements without stopping the ship, the scientific team was dropped on the ice pack by helicopter in front of the ship's trajectory on July 11. We were recovered by the same airway 4 hours later. Before this expedition on the ice pack, we realized first test flights from the helideck.

All other measurement sessions were carried out during organized stopovers for passengers or during limited stops of the boat on request of the scientific team.

In particular, long stopovers were planned at the North Pole on July 13 and 14, but unfortunately the wind was too strong to make measurements. So, we have essentially done ice sampling. We were able to make our first very demonstrative flights over sea ice on July 15th just below 88°N (ie, in CryoSat-2 and IceSat-2 coverage) and on July 16th.

The day after, July 17th, the weather was too bad and July 18th we were already back to ice free Svalbard's waters. We then have decided to try the drone measurements over glaciers and growlers with the P1 camera, which was done on July 19th and on July 21st.

All these measures and attempted measures are summarized in the table below.

Stop Dates	Conditions	# flights	Sensor	lon	lat	time
11 July	Helicopter drop on sea ice	3 (tests)	P1			
13-14 July	North Pole, too windy	0				
15 July	Sea Ice	1	YS	55°13'41"	87°43'20"	12h00
16 July	2 flights over sea ice	2	YS	55°57'20"	85°32'55''	10h55
				55°59'26''	85°33'06''	11h48
17 July	bad weather, no visibility	0				
18 July	Svalbard coasts, animals, no flights	0				
19 July	small glacier from beach	3	P1	20.681	79.563	10h01
21 July	glacier front and growlers	4	P1	15.929	77.100	09h56

Table 2: Summary of the main measurement opportunities.

We can already retain the two following points:

1. The climatic conditions in the Arctic are very constraining and that is why it is important to have a sufficiently long period of time to have chances to meet good conditions. A drone permanently available on an icebreaker or a polar station can answer this constraint.

2. As we will see later, despite these difficulties we were able to collect 4 nice datasets, 2 with the YellowScan lidar scanner on the ice pack and 2 with the P1 camera on glaciers.

4.2. Daily log of the campaign

July 07:

- Travel to Paris.

July 08:

- Flight from Paris to Longyearbyen.
- Presentation of the boat.
- Evacuation exercise at the end of the day.
- AECO briefing.
- Charging of the batteries.
- Mapper+ assembly (switch of the type of drone power supply in battery position, verification of the lever arm, mounting of the mono-support with YellowScan dampers).
- Problem of recognition of the 2 micro-SD cards provided for the Mapper+.
- Tests of the UBlox GPS receiver in the sensor box: 31 visible satellites and correct 3D positions.

July 09:

- Teraranger / PX4 configuration tuning.
- SF11 integration in Ardupilot.
- Mandatory conference to present the cruise and the AECO charter (respect of the Arctic environment).
- Briefing with the ship's captain to explain our needs and know the restrictions.

Figure 4.1: July 10th: The drone pilot finalizing and testing the electronic box of the altimeters. Unfortunately, a wave got the better of the USB connector and we will not be able to test this box.

July 10th:

- Position N82
- Integration of Maxbotix sensor in the box with Ardupilot.
- No internet connection all day.
- Trying to format the micro-SD cards of the Mapper+ in Fat32 (see official documentation) but Windows 10 does not offer it (NTFS or ex-FAT). Try to download a formatting software on internet without success. Sent an email to YellowScan to find a solution, the email is not sent.

- Micro-USB connector out of order on the PIX4 following a movement of the boat. The onboard electronics technician managed to repair it partially but the connector remains very fragile. The telemetry module of the PIX4 does not work anymore. Reconfiguration of the telemetry module which works again.

Figure 4.2: July 11th: first test from the helideck

July 11th:

- MAPPER+ micro-SD card formatted in FAT32 following the successful download of a free software on the internet (4 hours of interrupted and resumed connections for 300Kb).
- Tried to control the Vortex nacelle with the PIX4. The reactions are much too nervous and oscillating vibratory phenomena can lead to the destruction of the servocontrols of the nacelle, the adjustment of the PID on the PIX4 is very complicated in the absence of downloadable documentation on the internet. The envisaged solution consists in removing the support on dampers to limit the effects of overcompensation and to stick the PIX4 directly on the platform of the box with double face tape.
- Reorganization of the wiring in the sensor box.
- Helicopter safety briefing (entry, exit and survival equipment).
- DJI account inaccessible on cell phone via the DJI Pilot application. Impossible to launch the application and therefore to fly in programmed mode with the Mavic.
- Test flights of the M300 from the Heli Deck of the boat:
    - The boat is stopped during water lifts from the dock.
    - Take off of the M300 without load without problem. Distance to 120m from the boat, height 54m and return for landing with manoeuvrability tests on the 3 axes.
    - Very violent sideways escape at 5 meters from the deck at a height of 3 meters during 0.5 seconds. Difficult to determine the origin of this behaviour (wind gust, eddy along the bridge, radio interference, weak GPS reception, magnetic interference, ...). Crossing recovered by countering in the opposite lateral direction to avoid a collision with the edge of the Heli Deck.
    - The boat starts moving again without warning (it was agreed with the bridge that we would be warned). The movement of the boat is detected by the IMU of the M300 just before the cut of the engines which try to counter while the drone is posed. Placing the drone on the deck with a foot to avoid a rollover. The German scientist who was flying his Mavic 3 cannot catch up with the relative movements and his drone hits the bulkhead at the back of the deck at full speed. The nacelle was separated from the drone, the

left front proximity sensor was destroyed (the drone will fly again after having repaired the nacelle and the absence of the proximity sensor did not prevent the following flights).

Figure 4.3: July 11th: First measurement tests from the ice pack.

- Heli transport on the ice pack for first flights with P1 for photogrammetry tests. The single mount is equipped with the Mapper+ dampers clamped. All proximity sensors are disconnected to avoid false alarms due to snowflakes.
    - 1st flight: As soon as the P1 takes off, it vibrates a lot which leads to an immediate landing for examination and alert messages on the Smart Controller (see video). Very strong sudden lateral movement during the descent (identical to the one encountered on the first flight of the morning on the boat). Tendency to roll over after landing countered with the controls. The P1 assembly is checked as well as the dampers.
    - 2nd flight: Same behaviour of the P1. Sudden strong loss of altitude (~3 meters) during the descent. Immediate landing. Again, a tendency to roll over after landing is checked with the controls. The dampers are cut, the P1 is dismantled and reassembled.
    - 3rd flight: The P1 performs normally but the vibration messages persist. The M300 is hovered at a height of 20 meters to avoid the gusts of wind on the ground. Attempts to program the desired mapping:
        - GSD is not specified and the height is arbitrarily set at 30m, i.e. a GSD of 0.38.
        - Speed not specified but it is decided to set it to 4m/s.
        - The NADIR is not requested in the documentation provided by Sara Fleury (written after Phantom 4 flights). The P1 must be tilted by 25° from the vertical (i.e. 65° from to the vertical (i.e. 65° to the RHF) and in the RLF axis of the UAV.
        - The photo interval is not specified and is arbitrarily fixed at 1 second.
        - Plotting on the Smart Controller seems to be impossible (problem analysed on back). Several attempts are unsuccessful. A manual flight following the approximate contour of the area is performed by marking POIs at each corner of the area. The mapping from these POI is correctly done but the loading to the drone does not work.
        - During all flights, the position of the radio control (yellow circle) and that of the drone (blue arrow) do not appear on the map.

    - If there is no background map and no zoom indication, the map is centered in the middle of the screen using the position centering icon. The radio control position icon is always invisible.
    - Tracing in waypoint mode according to a route estimated at 150 (resulting from the observation of the heading during the 1st flight) over a distance of about 300 meters then 90° right then straight on route at 330.
  - Problem of initialization of the PX4 (barometer driver): a factory reset is probably the best solution but before it is necessary to download locally the firmware to reinstall on the PX4.
  - The images of the P1 are sharp and well exposed with the semi-automatic settings. Contrast is good and details are usable. It may be necessary to lower the flight height to 20 meters or less to get even more detailed images of the ice pack structure.

July 12:

- Two researchers, including Sara Fleury, are positive to COVID. They are placed in isolation in the cabin. The others are tested negative.
- Backup of the logs of the M300 for the flights of July 11.
- Multiple attempts to trace the mapping zones on the Smart Controller to succeed in understanding why it does not work. The programming tests via Google Earth or Global Mapper do not work in the polar zones.
- Sara Fleury proposes to create a program in Python to calculate the coordinates of the trajectory points in order to program the flight point by point in waypoint mode. Development in progress.
- Preparation of the next day's Mapper flight.

Figure 4.4: July 13th: First sea ice sampling

July 13:

- New programming tests via the Smart Controller. From the moment we are north of N85°, the points and zones are represented at the top of the screen.
- It is impossible to draw a zone straddling the pole!
- Collaborative work during 3 hours on the ice pack in support of scientific experiments (albedo measurements, coring, measurement of luminosity under ice). Deployment and storage of equipment.
- USB PX4 plug out of order again. The micro-connector is definitively broken without possibility to change it. The on-board electronics engineer tries to solder the wires of a USB cable sacrificed for the occasion. After several attempts, we manage to find a wire path that allows soldering on the micro-switches. The whole thing is glued inside the PX4 box. The connection with the PC is done via the USB cable in place.

Figure 4.5: Take off from the helideck for sea ice measurements with the 3D lidar scanner.

July 14th:

- Disembarkation on the ice floe from the boat for the scientists and the passengers. The weather is still not favourable for the flights with a wind 28G46 (average wind 28kt with gusts to 46kt). The communication team of the boat asks if the drone can take pictures of the passengers' activities. Request refused because it would be necessary to remove the Mapper which is mounted, to change the dampers and to install the P1, without counting the risks of crash before the end of the mission.
- Participation in the activities of the scientists in the morning. The rest of the day is dedicated to the tidying up of the working space. Wiring of the NRA15 radar according to the plan provided. The tests of correct operation and the adjustment will be carried out only once the PX4 is operational again.
- Discussion with the German scientist who tries albedo measurements with the camera of his Mavic 3. There could be a track of development in this field. In the same way, he drags on the ice an interferometer in a sledge. Perhaps the use of the BRGM model in Arctic conditions should be investigated.

Figure 4.6: Measurements over sea ice and lead from the bridge

July 15:

- Sailing south with a drone flight planned from the ship in the early morning. The weather is not favourable with an average wind of 24kt and gusts to 44kt. The drone and helicopter flights are cancelled for the morning.
- LIDAR flight in the afternoon:
  - Wind250/21G34.
  - Temperature-2°C
  - QFE1002
  - Flight height 20m. The bridge being at 23m above the ice pack, the real height will be 33m.will be 33m.
  - Triggering set at 1 second.
  - Programmed flight impossible so manual GPS flight on a 248/068 axis facing the wind at the beginning of the mission. Ground speed between 1.5 and 3.8 m/s.
  - Strong inclination of the rotor on the wind (~10°)
  - Flight shortened after 19mn30 because of the increasing wind. Strong wind alarms throughout the mission.
  - Very tricky landing because of numerous wind gusts and a lot of vortices. Arrival and landing in the axis of the wind.
- Cloud Station analysis:
  - The boat drifted from 135m in 498 seconds and the wind was also too strong.
  - Some growlers moved under the effect of the wind. Their displacement is visible on the restitution and is consistent with the drift of the ice pack and the ship.
  - The 24Ghz laser penetrates under water or loose ice/snow by at least 3.3m since the bottom of some ponds appears as a second track.
  - Many spurious points up to 5m below the drone. The origin is unknown and cannot be linked to the landing gear... It is possible to filter them by changing the parameters in Cloud Station.

Figure 4.7: Typical scene

16 July:

- Vol1 Mapper:
    - Wind 210/3G5.
    - Temperature 0°C.
    - QFE999
    - Flight height 7.5m
    - Problem of connection TB60T9Right side. The locking system is loose. Tighten and check for proper operation.
    - Manual GPS flight on a 360/180 axis with 090 transects.
    - 3 roll escapes in mid-flight. The gusts over the ice pack are more than on the helipad.
    - Only a piece of the trajectory is recorded on the LIDAR and no photo is recorded. After rereading the Mapper manual, it is necessary to climb to an altitude higher than the one indicated in the configuration file (USB key) to trigger the automatic focus and allow the camera to take pictures... This height cannot be less than 20m.
    - Landing without problem.
- Vol2 Mapper:
    - Wind 040/9G15.
    - Temperature -3°C.
    - QFE996.
    - Flight height 7.5m.
    - Climb to 20m after take-off to cause calibration and start-up of the camera. Pre-mission alignment figures performed at 20m then descent to 7.5m.
    - Visibility and ceiling deteriorate very quickly. Sara FLEURY asks to fly on starboard over the nearest pond (~1.5km).
    - Loss of visibility on the aircraft at 900m.
    - Helicopter landing with a wind perpendicular to the boat, which increases the intensity of the vortices.
    - LIDAR recordings are correct but no photos are recorded.
- Vol3 Mapper:
    - Wind 2G12.
    - Temperature -0.8°C, set point -0.7°C.
    - QFE996.
    - Flight height 10m (small safety margin due to bad weather conditions. Arbitrary choice more psychological than anything else...).
    - Visibility estimated at 300m, ceiling estimated at 60m. Strong increase in humidity to 87%.

- Manual GPS flight in FPV mode to a level 2km to the rear.
- Followed by manual mapping (heading/timing).
- Mission aborted as soon as snowflakes appear on the FPV camera at 2.4km from the boat. Batteries 53%.
- Return to the boat using the radiated position indicated on the Smart Controller with a safety margin (sighting of the estimated front of the boat and stop if no visual at 50m).
- Initial return to 20m with a strong headwind (23m/s recommended). Climb to 40 to try to find a lighter wind then descend to 0m (~13m ice pack). The wind is half as strong. The FPV camera is covered with fog which makes it difficult to find the boat. The visual of the boat via FPV acquired at 260m (black shape without details). Climbing to 20m for final approach. Final visual on the drone at 30m, about 20m in front of the boat.
- Posed facing the wind.
- Instantaneous stop of the two rear engines as soon as the shutdown is requested. After examination, the stators are covered with melt ice (see Picture below).

Figure 4.8: stators covered with melt ice

- LIDAR data are well recorded but no photo.

- Flight4 Mapper: cancelled due to bad weather.
- Flight5 Mapper: cancelled due to bad weather.
- Mapper disassembly and P1 assembly.

Figure 4.9: July 16th Measurements of sea ice characteristics using different sensors, including drone, SIMS and drills.

July 17:
- o Unfavourable weather: less than 300m visibility, humidity 87%, temperature -1.2°C, dew point -0.7°C.
- o Work on Cloud Station.

Figure 4.10: July 17th on the way back at 83°23.4’ N 038°40.2’E the ice is already covered with melt pounds and disperses.

July 18:

- Arrival in Svalbard waters.
- Favourable weather: humidity 94%, temperature +0.9°C, dew point 0°C, wind 16G19.

July 19:
- Disembarkation in Zodiac with the drone for a P1 flight from the beach on an ice tongue.
- 3 P1 flights:
    - Wind20G21.
    - Temperature+1.7°C, low point0.7°C. o Wind20G21.
    - Humidity93%.
    - QFE1012.
    - Clear sky.
    - Programmed flight GPS.
    - 1 NADIR and 2 crossed 45°.

Figure 4.11: Measurements of a small glacier with the camera P1 from the beach

July 20th:
- Favourable weather: humidity 91%, temperature +1.2°C, dew point 0°C, wind 5G8.
- The boat is heading south without stopping.
- Anchorage in the north-east of Svalbard.
- The presence of animals spotted on the banks leads to the prohibition of flights by the naturalist of the boat despite the authorization delivered by the governor of Svalbard!

Figure 4.12: Measurements of the front of a large glacier with the P1 camera from the bridge

July 21st:

- Anchoring in a bay facing three glaciers. The most eastern one is not interesting for Sara Fleury. The one in the North has an interesting configuration but the presence of walruses forbids the flight.
- Without internet connection, it is not possible to locate the glacier precisely on the Smart Controller. The estimated distance from the boat is about 1.5km and the height of the ice front is estimated at 50m.

July 22 & 23:

- Packing of the equipment
- Return to Longyearbyen then Paris.

July 24th:

- Return to Toulouse or Pau

5. First analysis of data collected

5.1. Data collected with the 3D lidar scanner over sea ice

We have been able to accomplish 3 flights with the YellowScan over sea ice of about 20 minutes each on July 15th and 16th. We present the data that we obtained during these 3 flights and the first conclusions that we can draw from it. These data are presented in the form of 3D point clouds geolocated via the GPS of the drone.

The figure below shows a short sequence of measurements with on the left the 3D point cloud obtained, and on the right an image of the scene taken by the UAV controller. We can already appreciate the precision of the rendering and the resolution, knowing that the freeboard of the small floes at the edge of the large plate is about 10cm and that the ridges which border the large plate are about 50cm.

We also see that there is little backscatter from the water, certainly due to the specular character of this surface and the angles of the lidar shots. However, this is not limiting because the height of the floes above the water is quite noticeable and measurable.

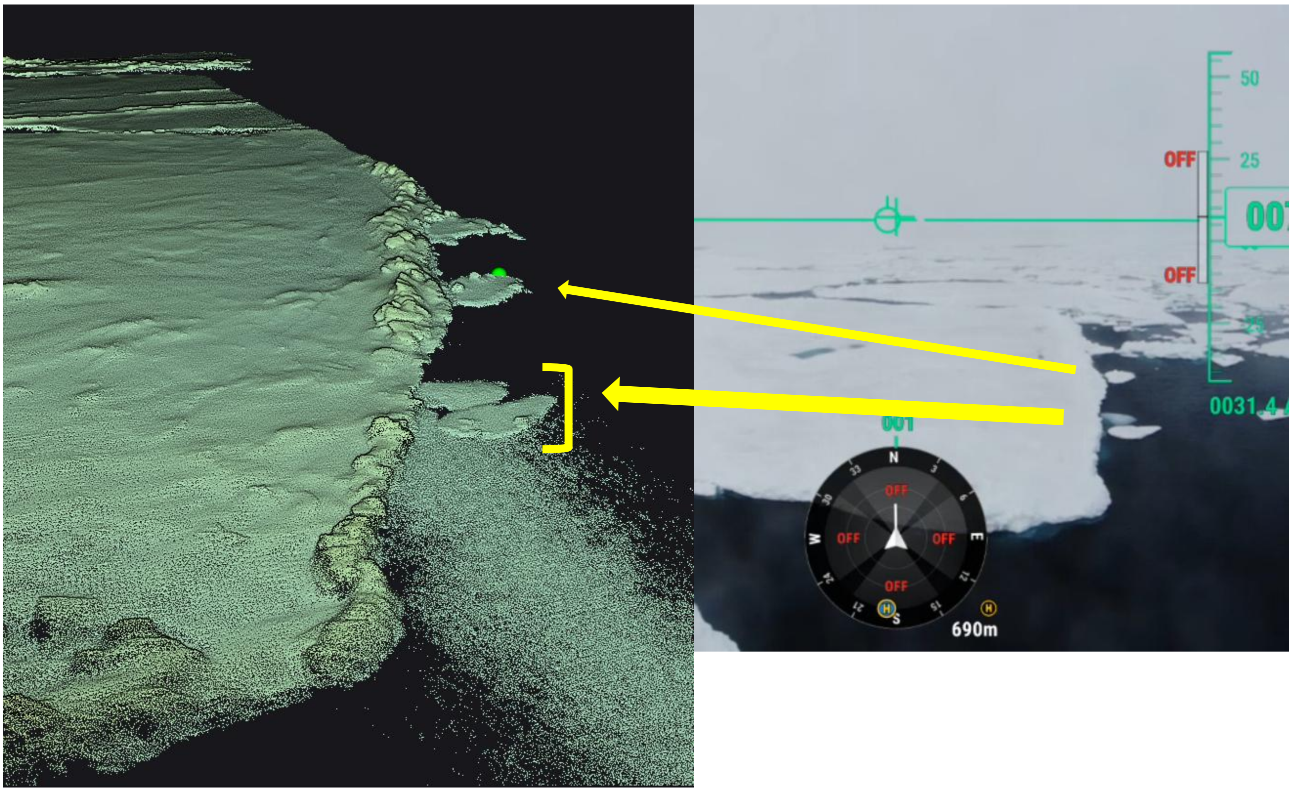

Figure 5.1: On the left: a 3D cloud of points obtained with YellowScan over sea ice. On the right: the corresponding image from the drone controller. We can clearly appreciate the quality and the precision of the 3D model relatively to the visual scene. The smaller floes have a freeboard of about 10cm and the ridges on the border of the big plate are of about 45cm height. We perceive some leads which cross the big plate of ice in back stage.

The following figure shows a similar scene but with a different visualization of the 3D reconstruction: the top image shows the trajectory of the drone from above between a floe 1 and a floe 2 through a lead, and the bottom image shows a cross-section of this trajectory in the 3D model. The 3D model allows to measure quite precisely a freeboard at point 2 of 49cm. The drone was flighing at 20m above sea level with a speed of 4 m/s.

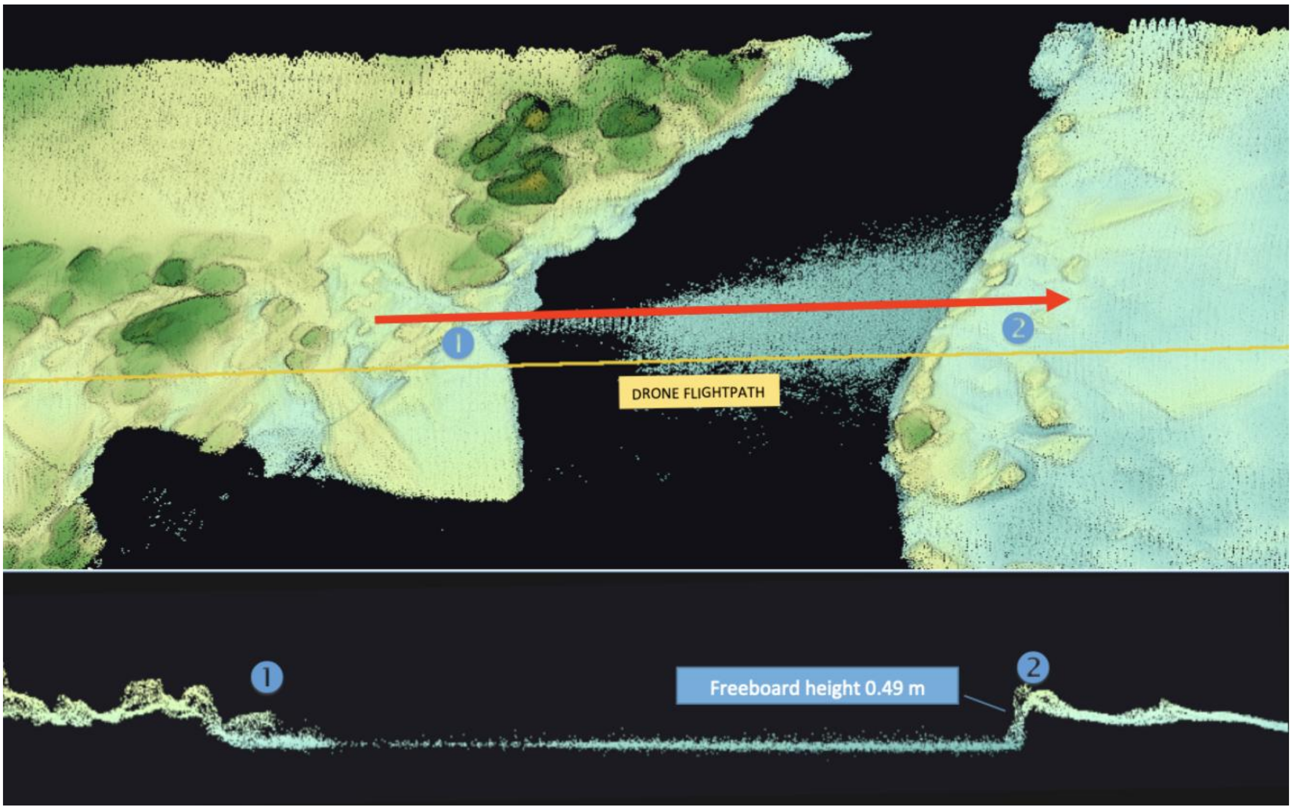

Figure 5.2: a cross section over a lead between two floes. The 3D model allows to measure quite precisely a freeboard at point 2 of 49cm. The drone was flighting at 20m above sea level with a speed of 4 m/s.

The two previous examples were based on a single trajectory of the drone. The following figure 5.3 illustrates the case of a succession of trajectories, during the same flight over the ice pack, with an overlap of the scene from one trajectory to the other. Aggregation of geolocated and dated 3D points in a single model allows observing and even measuring the drift of the ice pack, estimated here at 0.5km/h.

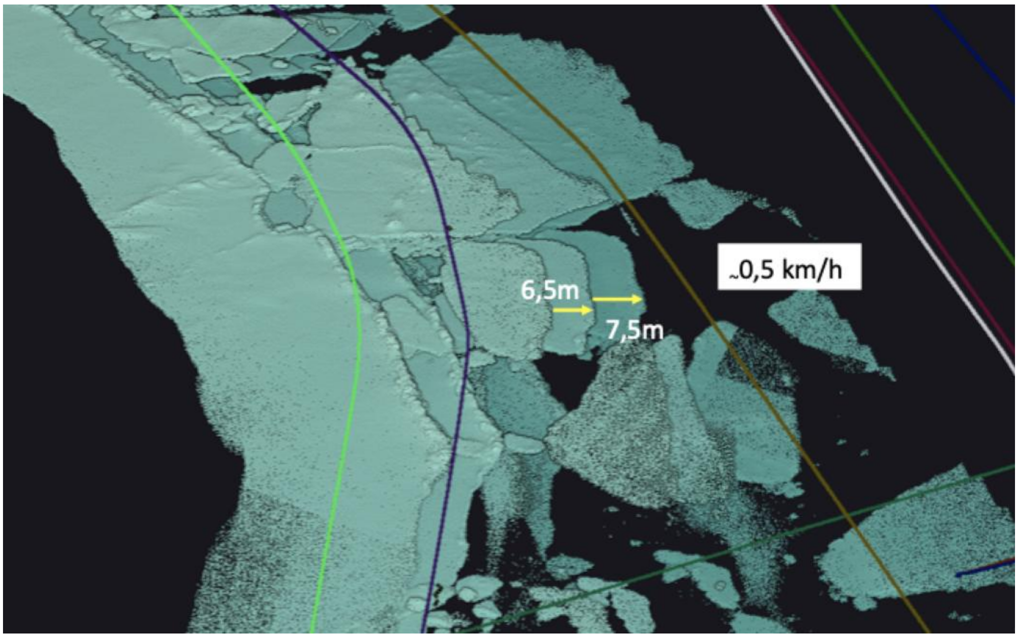

Figure 5.3: Ice drift observation from successive drone paths. Aggregation of geolocated and dated 3D points in a single model allows observing and even measuring the drift of the ice pack, estimated here at 0.5km/h.

Figure 5.3 illustrates the interest of the aggregation of measurements on successive trajectories in the same 3D model, for example to measure the drift of the ice pack. However, it hides a difficulty illustrated by the more complex scene of the following Figure 5.4.

In this 3D model, the 20 minutes of data have been aggregated. The bottom image corresponds to the red cut in the top scene. In this cut we see a significant difference of 1.71m between two heights of the same floe. This difference comes from the low quality of the drone positioning from the GPS. It is in fact a common quality of the height precision for a GPS but it raises important difficulties for the aggregation of data in a common scene.

This low height precision does not prevent to measure the freeboard *locally* as illustrated by Figure 5.2 but it prevents to estimate the freeboard few kilometres away from a lead. This raises a real problem because the freeboard at the edge of the ice is not representative of the freeboard of a large plate.

The usual technic to improve GPS positioning consists in using a static reference GNSS station to apply the well-known differential-GPS approach. But such an approach is not applicable over a drifting ship among a drifting ice. However, it exists GNSS post-processing technics such as the PPP-AR solution that allows improving the positioning down to few centimetres. We discuss about this possible improvement in Section 6.2.

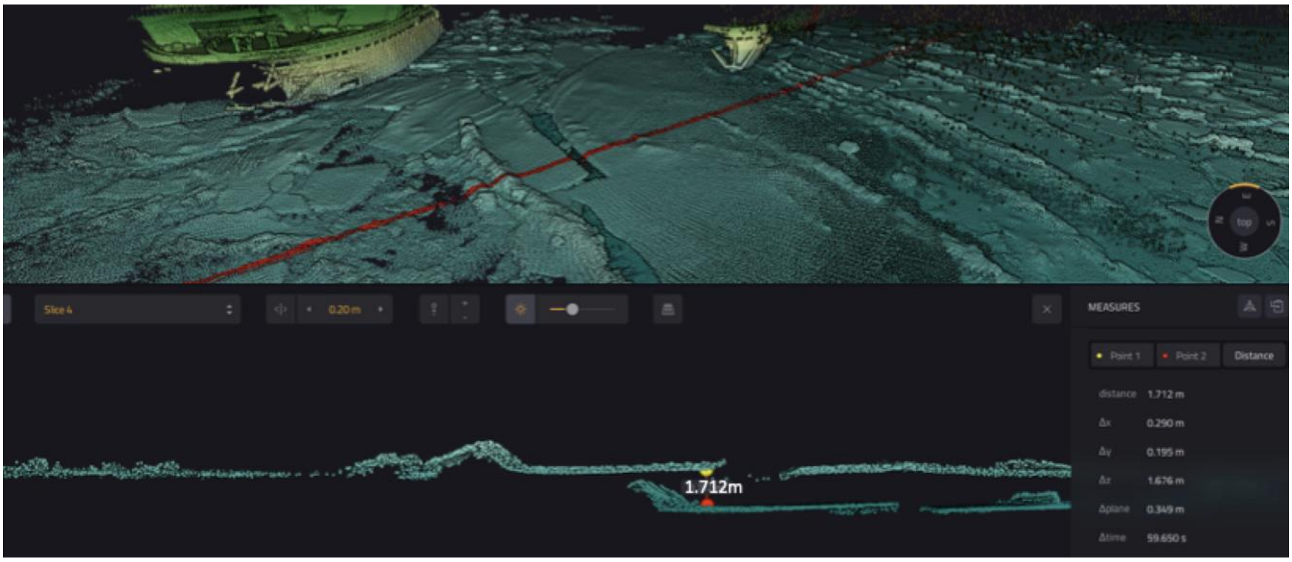

Figure 5.4: the bottom image corresponds to the red cut of the top image. We can observe an important height difference of 1.71m between two measurements of the same floe. This difference is due to the insufficient precision of the altitude of the drone. This problem could probably be solved using the PPP-AR GNSS post-processing.

The last example illustrated in Figure 5.5 shows a complex scene, including many trajectories. On the top left we can observe the ship that has been modelled during the calibration phase that follows the drone take-off. The successive trajectories are then illustrated with different colours. The last path is the dark blue trajectory coming from the right of the image and ending on the ship for the landing. We can observe the important drift of the boat on its port side (i.e., towards the right of the image).

We also observe that the drift of the ice pack follows a circular trajectory that differs from that of the boat. This is probably due to a combination of the boat's thrust when it arrived on site and the general drift of the pack ice.

This type of measurement makes it possible to observe rather complex phenomena, but it also illustrates the complexities involved in the reconstruction of such a scene.

The YellowScan company thought they could, with their experience, reconstitute the 3D scene of the ice pack and correct the GPS positions of the drone in the same movement. But their usual studies concern static scenes and they had to recognize that their software was not adapted. In fact, not only the scene is dynamic, but it is also deformed in its movement. A 3D reconstruction of the ice pack therefore seems difficult to achieve.

However, the objective here is to find the freeboard of the ice. We have already shown that this is directly measurable at the lead/ice transitions along each track. And this will also be measurable at a distance from the leads, provided that the drone can be positioned at a height with an accuracy of a few centimetres.

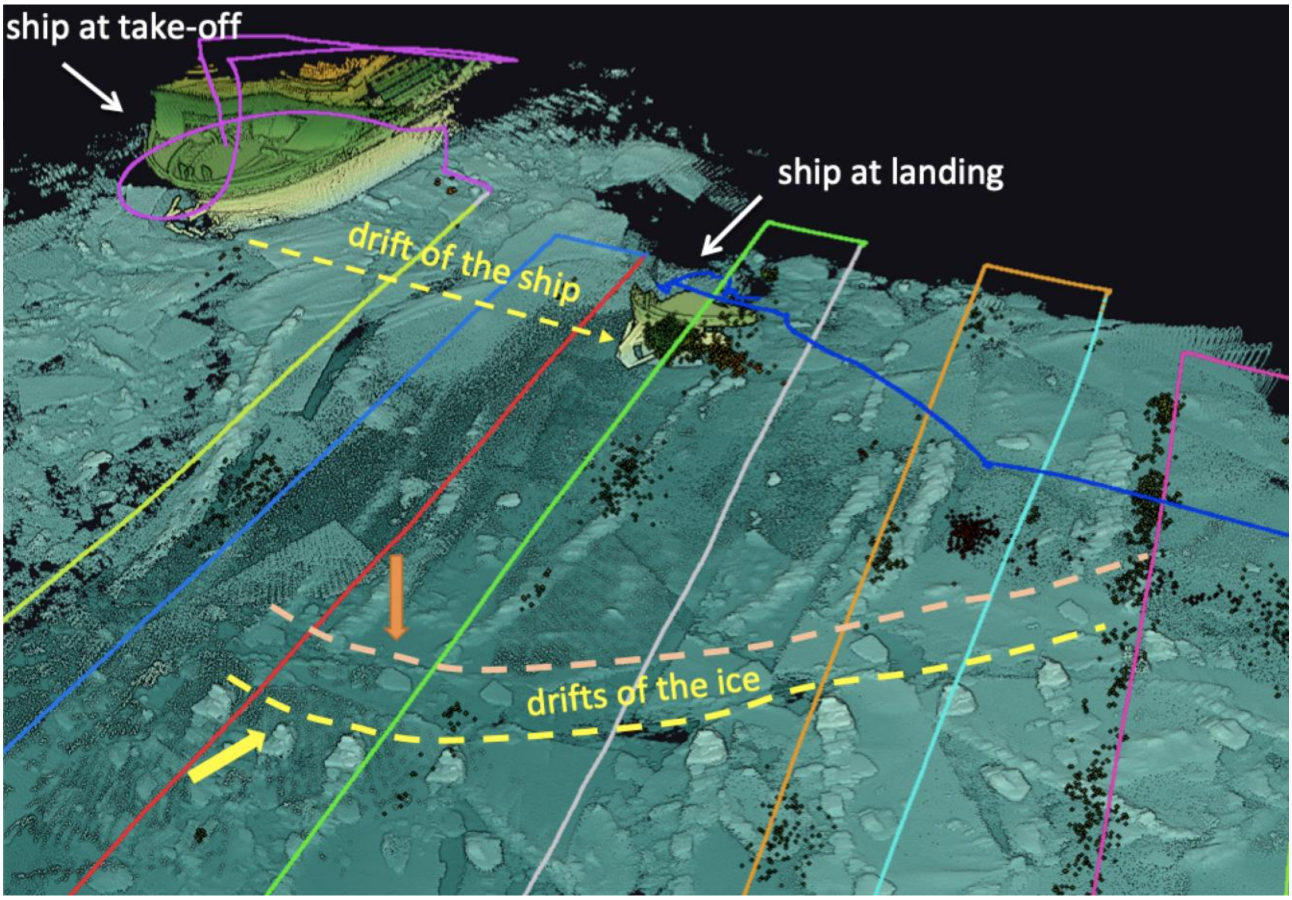

Figure 5.5: Complex scene that aggregates all the measurements of the successive paths of the drone within a same 3D model. We can observe the transversal drift of the ship to the right and the drift of the ice following a large arc.

5.2. Data collected with the P1 camera over glaciers

In this section we will show results of 3D reconstructions obtained by photogrammetry using the P1 camera. We are going to be less extensive because the 3D models concern glaciers (and also growlers), and not the ice pack, the main object of this study. However, this is interesting for two reasons: on the one hand, it could work at least partially on old ice floes, and therefore rough, which unfortunately we did not have the opportunity to test; and on the other hand, it shows that polar drones can be used for different types of applications and so be of interest to other fields of application.

The first example below shows the modelling of a 23m long growler (Figure 5.6) and the second a glacier front of about 600m long and 50m high (Figure 5.7).

The resolutions obtained are impressive with very precise representations of fractures, snow plates and melt pools.

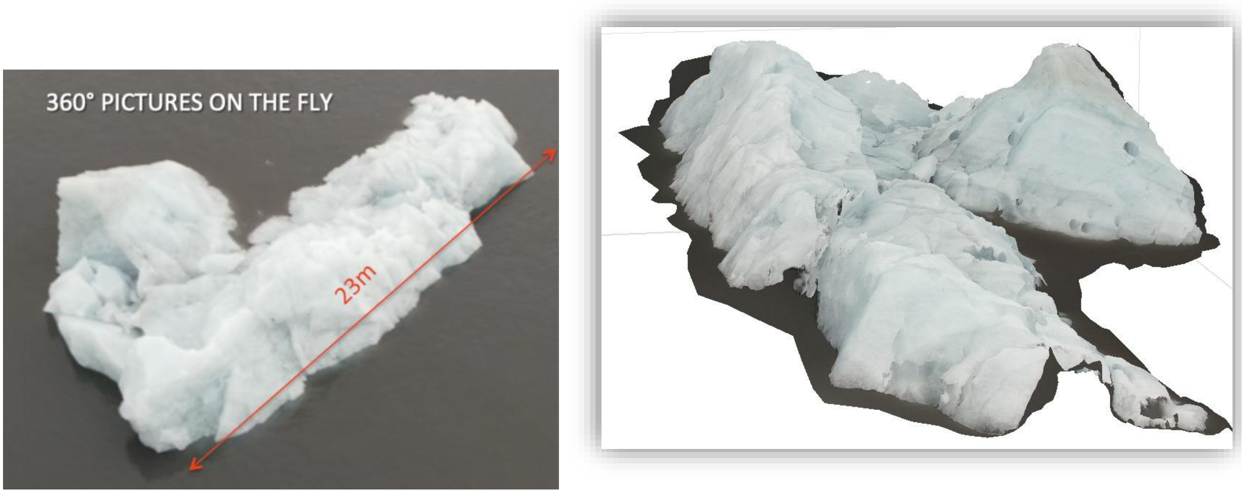

Figure 5.6: Photo of a 23m long growler on the left and its model obtained by photogrammetry on the right.

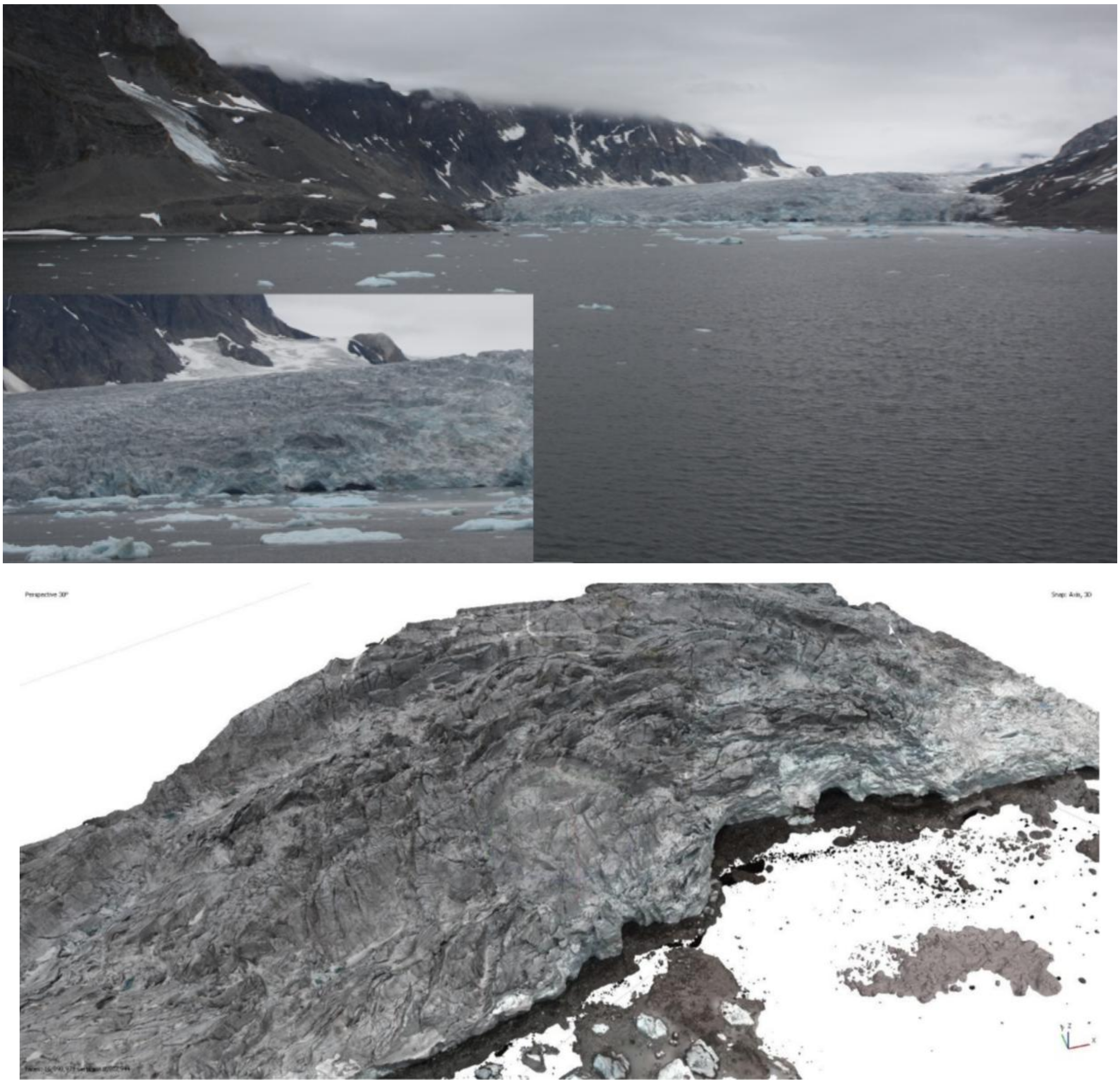

Figure 5.7: At the top, an overall photo of the glacier front, with a zoom on caves, and at the bottom, the 3D model produced by photogrammetry from the images acquired by the P1 camera.

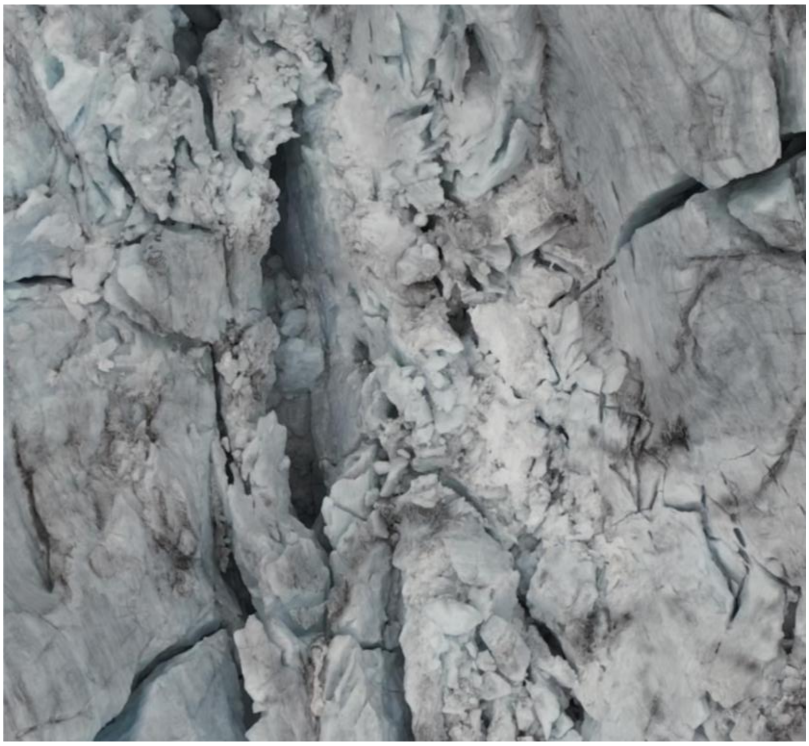

Figure 5.8: some zooms within the 3D model. We can observe fractures, snow plates and melt pools.

6. Campaign synthesis

6.1. Main results

The DESIR project had two main objectives:

- to demonstrate the feasibility of using lidar to measure sea ice freeboard, and
- to identify the difficulties of deploying a drone from an icebreaker.

Concerning the first point, the first analyses presented in this report already illustrate the high quality of the laser measurement over sea ice and its ability to measure freeboard. From this viewpoint we can confirm that the demonstration of the feasibility has been achieved.

However, it is clear that this experiment could not have been fully achieved without the support of a professional drone pilot. The equipment that has been used for this demonstrator is also too expensive to consider a large deployment of drones on each icebreaker or polar station. But the objective of this mission was also to identify the possible hard points and to analyse the possible workarounds. These points are developed in the following two subsections and none of these difficulties seem insurmountable.

Even if it does not directly concern the ice pack, we were also able to use the same drone to make DEMs of glaciers from the shore but also from the boat, with a camera, a relatively inexpensive sensor. The reconstruction of the DEM could be done with standard computer tools without encountering particular difficulties. Another team made albedo measurements of the ice pack, still from the boat. This illustrates the fact that a drone embarked on a boat can be used for different types of scientific measurements.

6.2. Difficulties and workarounds

We list here all the problems we encountered during this mission. They represent different levels of difficulty, but all of them must be taken into consideration in order to prepare future missions.

6.2.1. Commercial (DJI) interface not compatible with high latitudes

The control interface of the DJI drones is limited to 80°N and the projection used is a classical Mercator, which is not adapted to high latitudes. Whatever the model used, attention should be paid to these possible limitations and a dedicated interface with polar projection supported shall be asked.

6.2.2. Electronic and magnetic interferences

Electronic interference is a known problem for drone users. This interference can potentially disrupt the drone's radio control, video stream, internal drone control electronics or on-board sensors. Possible interfering elements come from the ship's electronics (mainly radars) or from the polar station. We were particularly warned of this risk but we did not notice any particular problem.

Another potential problem concerns the magnetic compass which is an element at the heart of the UAV servo system. We know for example that a drone crashed near the French station of Dumont d'Urville in Antarctica probably because of this problem (contact for more information: Laurent Arnaud from University of Grenoble-Alpes). In 2020, the South Magnetic Pole was at 64.07°S, 135.88°E which is at about 300km off the DDU station (see Figure 6.1 below). We did not perceive any particular problem concerning the magnetic compass of the drone during our journey between Svalbard and the North Pole. On the other hand, problems could occur near the North Magnetic Pole which was at 86.05°N 164.04°E in 2020, at about 400km from the North Geographical Pole (where we couldn't fly because of the weather) and diametrically opposed to our trajectory.

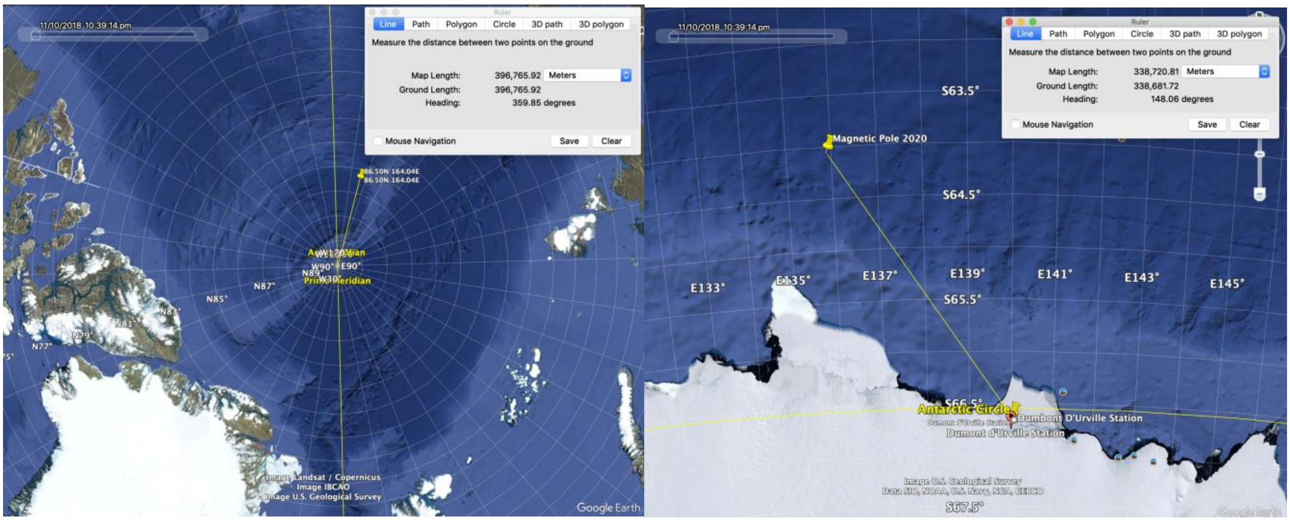

Figure 6.1 Position of the North and South Magnetic Poles in 2020.

6.2.3. Impacts of weather (wind, temperature, humidity)

The main concerns were the impact of low temperatures on the batteries and flight range. But the temperatures encountered were relatively mild. Moreover, the fact of deploying the drone from a boat allows to keep the batteries warm until the last moment. So that did not pose any particular problem.

The wind force and/or the lack of visibility frequently prevented us from flying. These limitations due to bad weather are frequent in the polar regions. They impact almost all measurement methods. If drones are less resistant to bad weather than planes or helicopters, they are easier to deploy, which allows us to take advantage of every meteorological opportunity. Thus, a drone permanently available on a boat or in a polar station could exploit every flight opportunity.

However, conventional drones, with 4 or 8 blades (like the one we used), have an intrinsically limited autonomy (20 to 30 minutes). To increase the coverage of the measurements on favourable occasions, it could be interesting to consider the use of fixed-wing UAVs, which have a much greater autonomy (1 to 2 hours) and are less sensitive to wind. However, the conditions of deployment from a navy or a polar station would require the use of VTOL UAVs (vertical take-off and landing). These are fixed-wing UAVs equipped with additional propellers that are only used for the take-off and landing phases. They are still relatively expensive (up to 100k€), but with their growing popularity prices are rapidly decreasing.

6.2.4. Take-off and landing from a ship

We were afraid that there would be problems of interference of transmissions (command or video) or attitude sensors of the drone with the electronics of the boat, but this did not happen.

Although we could operate the drone from a large space (the heliport in the front deck of the boat, see photo), the landing phases proved to be particularly perilous with both drone models.

The first symptoms were a feeling of loss of control of the drone's trajectory during the manoeuvres on the deck. During the first landing the small Mavic drone, operated by the colleagues, suddenly flew into the super-structure of the ship that dominates the foredeck and crashed into it.

In fact, the ship had resumed its course without being noticed and it is therefore the ship that came crashing down on the drone stabilized on the GPS in (x,y) during the descent phase.

Afterwards we took care to coordinate with the captain so that the ship was stopped during the take-off and landing phases.

Nevertheless, a boat stopped in the middle of the sea always drifts a little and when the drone touches the deck, slaved to the GPS, it tends to tip over.

Eventually, to make the drone more easily manipulated by a non-expert, or even to automate the landing, it could be interesting to have a servo-control relative to the position of the operator's remote control or relative to a visual target placed on the deck, two modes that already exist on other drone systems.

6.2.5. Model building of drifting ice

At first sight one could imagine being able to reconstruct a 3D model of the ice pack on the whole scene overflown by the drone. This consists in fitting the new measurements on portions of scenes already observed when there is overlap. This computer operation of merging point clouds is a technique that is now relatively classical and integrated in many commercial or free software for the reconstruction of 3D models. The operation allows in the same time to correct the positions of the drone relatively to the object and to get rid of the inaccuracies of the drone location.

But this technique is based on the assumption that the 3D object is itself static (a building, a statue, etc.). It can probably be extended to the case of a moving object, but only if it is undeformable (this brings us back to the problem of the uncertainty of the relative position of the drone/object). Unfortunately, not only does the ice pack moves, but it also deforms, and this can be significant as shown in figure 5.5. It is clearly impossible to model a deforming object statically.

It might be possible to design an algorithm that would perform a registration restricted to the vertical axis, the one we are mainly concerned with to reconstruct the height of the ice above the water.

However, we don't really need to reconstitute a 3D model of the ice pack. What is important here is to be able to measure the height of the ice relatively to the water along the path of the drone.

For this purpose, two complementary means must be implemented: a recalibration of the height of the drone relative to the water at the vertical of the leads combined with a precise location of the altitude of the drone. The accuracy of the altitude of the drone will condition the possibility of measuring the height of the floe towards its centre, at a distance from its edge.

In fact, we meet the conditions necessary to make altimetric measurements of the ice pack, whether by drone, aircraft or satellite.

6.2.6. Precise localisation of the drone

It is not necessary to have a precise location of the UAV to measure the freeboard at the edge of the ice since the UAV can simultaneously observe the water and the ice floe in the same scene as shown in Figure 5.2.

However, unless this ice is freshly broken, the ice edge is not representative of the freeboard of the entire ice floe. Indeed, the edges of the ice floes frequently present almost zero freeboard due to erosion phenomena, or on the contrary, an elevation (ridges) of several tens of centimetres due to a collision with other floes. These two cases are also clearly visible on the same figure 5.2.

It is therefore absolutely necessary to be able to measure the height of the floe towards the inside of the floe, far from the edge, and therefore without direct reference to the water level. For that, we need a centimetric precision on the altitude of the drone.

On the other hand, figure 5.4 shows a drift of nearly 1.7m between 2 consecutive tracks of the UAV. Only a few tens of seconds separate these 2 tracks.

This case is probably extreme because we have used the GPS integrated into the YellowScan sensor, which, as we explained earlier, only plays a secondary role, the drone being relocated during the point cloud merging operation that produce the static 3D models.

Nevertheless, achieving a few centimetres of precision in height is not trivial. This result can be obtained thanks to techniques such as differential GPS: a fixed GPS station near the manoeuvring area allows to record the instabilities of the GPS and to correct them by a posteriori processing. Unfortunately, it is not possible to install a fixed station in the open sea: both the ship and the ice pack are constantly drifting with winds and currents.

However, new and extremely innovative post-processing techniques have been developed by the GRGR group within its GINS processing chain (https://grgs.obs-mip.fr/recherche/logiciels/gins/). GINS integrates different methods such as PPP (Precise Point Positioning) or NRTK of GNSS data post-processing that allow to obtain an accuracy of a few centimetres without having a reference base.

To perform these post-processing techniques, it is essential to be able to use the raw GPS measurement files, called RINEX files. The majority of the GPS do not allow recording these files. For example, neither the DJI drones nor the YellowScan sensor can access these files. It will therefore be necessary to ensure in the future that these GPS files can be recorded. It also appears that a reference GNSS station on the ship can be operated by these methods, despite the ship's drift.

On the other hand, the VorteX.io lidar records these RINEX files. We will therefore use the measurements made in March 2022 at Uppernavick to test these new GNSS processing approaches. We will be able to evaluate/validate the results as a fixed GPS reference base was installed during these measurements made close to the shore.

6.2.7. Lidar measurements over water

The freeboard is by definition the height of the floes relative to the height of the water. The water level measured in the leads defines the reference level. It is therefore necessary to have a maximum of measurements on this surface, and if possible, at the beginning and end of the path of the drone. Unfortunately, due to the high specularity of the water, few laser measurements are returned to the sensor. This phenomenon can be clearly observed on Figures 5.1 and 5.2 where seawater is mainly black (no measurements) apart relatively few points at the vertical of the drone trajectory.

The probability of recovering measurements depends of course on the type of sensor (energy, frequency/focus of the laser and dimensions of the receiver), but for a given sensor, it mainly depends on the height of the sensor above the water. This height is always significantly lower than the maximum distance recommended by the manufacturer to measure land surfaces. Preliminary tests are therefore necessary to ensure that sufficient measurements will be collected above the leads.

6.3. Short term Perspectives

6.3.1. Freeboard computation from lidar cloud points

The first step of the data analysis will consist in extracting freeboard measurements from the 3D cloud points obtained with the YellowScan sensor. As GPS position is not reliable enough, we will implement a technique similar to the one used in spatial altimetry. It will be a matter of successively:

- extract the points in the vertical direction of the drone,
- identify among them the measurements on the water and the measurements on the floes,
- interpolate the water level under the floes
- measure the heights on the floes relative to the water reference, i.e. the freeboard.

The detailed methodology and results will be presented in the TD-13.2 report.

6.3.2. Validation against alternative data

Validation / Comparison against:

- the SIMS sensor of the ship
- field samplings of the ice
- satellite altimeters CS2/IS2 (if available for July)

This will be done before the end of the project and presented in the TD-13.2 report.

6.3.3. Precise GNSS positioning

We have started the studies with GRGS and results are expected within few months. They will probably not be over before the end of this project but a summary of the progresses will be provided in the TD-13.2 report.

6.4. Roadmap for polar drones FRM

The considerable development of UAVs brings new possibilities for measurements in hard-to-reach areas and in particular in the polar regions. They represent an intermediary between the delicate and very punctual measurements on the ground and the expensive and complex airborne measurements (see Figure 6.2). However, it should be noted that both field measurements and airborne measurements are still necessary, the former allowing to validate all the others and the latter offering wider coverage and scales that are close to those of satellites.

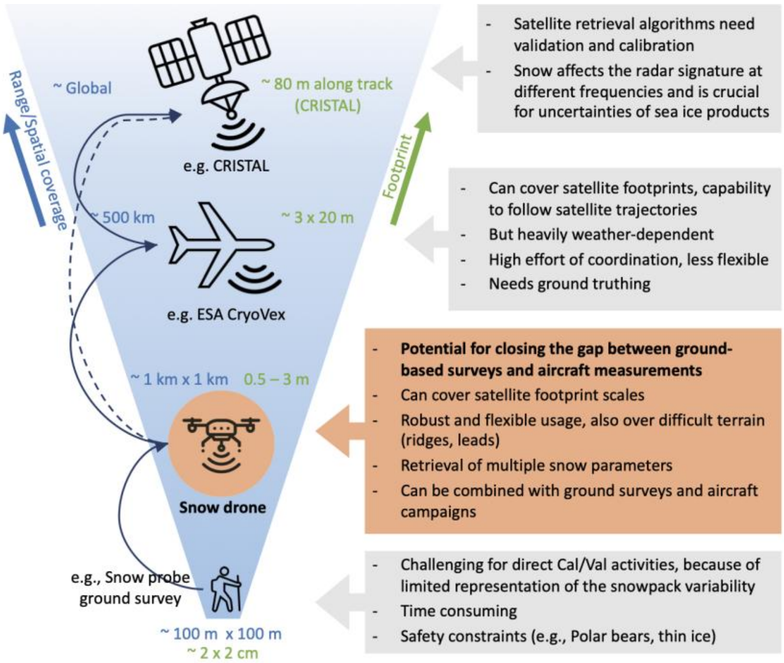

Figure 6.2: Drone measurements can fill the gap between wide-ranging but infrequent airborne measurements due to complexity and cost large and precise but very sparse field measurements (illustration from Robert Ricker, NORCE).

The drones deployed in each station and on each icebreaker could make it possible to take advantage of every favourable meteorological opportunity to carry out measurements, including during the polar night, without risk for the operators. This would considerably increase the spatial and temporal coverage of measurements in the Arctic and Antarctic basins.

To achieve this objective, a number of technical difficulties remain to be solved in order to adapt UAVs to polar measurements. These have been listed as exhaustively as possible in section 6.2 and it seems to be nothing insurmountable. It is also important to underline that other scientific teams in the framework of national or international projects are already using drones for their measurements. Concerning the ice pack, we can point out the project of the NORCE team of the University of Tromso (contact: Robert Ricker) which was able to make extremely precise measurements of the snow depth on the ice pack thanks to a drone equipped with a snow radar (Figure 6.3).

The role of large agencies, such as ESA, would be to set up large-scale projects to increase the synergy between these projects and to allow this technique to reach sufficient maturity to be deployed on a larger scale and at a lower cost.

Beyond the technical problems already mentioned, it is necessary to ensure that these solutions are sufficiently automated to allow their deployment by technicians on ships and polar stations. UAVs could also be used for many scientific or operational applications, such as measuring albedo, surface temperature, tracking glacier fronts or annual species, or searching for routes through the ice pack. It would therefore be interesting to design systems that can accommodate different types of sensors (camera, radar, lidar, etc.).

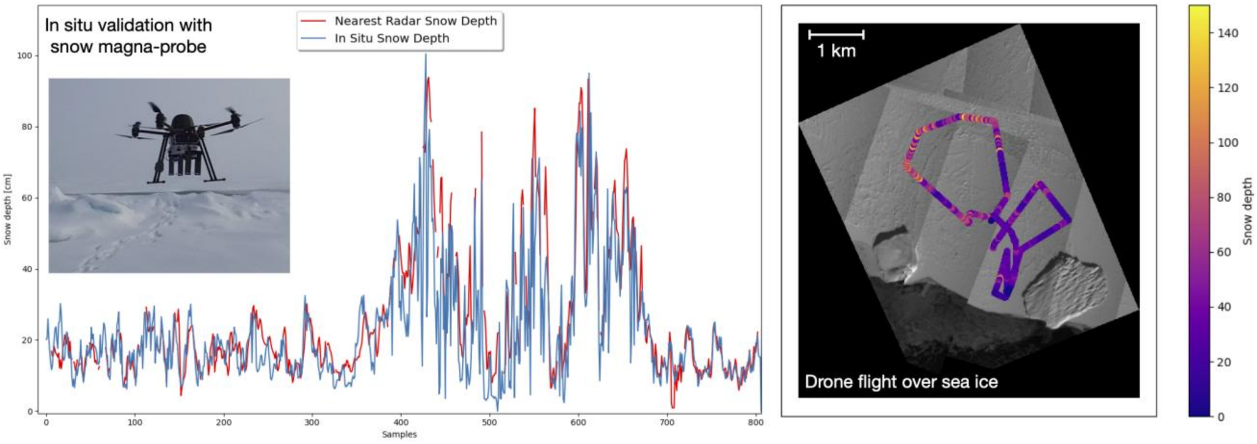

Figure 6.3: Snow depth measurements by NORCE using drone-born snow radar over sea ice. The trajectory shown on the right image was of about 10km length. The along track measurements in red were validated with in-situ snow depth measurements in blue using snow magna-prob. Illustration provided by Robert Ricker from NORCE.

Annex A - FLY PERMISSION FROM NORWEGIAN AUTHORITIES

DIRECTORATE OF FISHERIES

Embassy of the French Republic

Division: Development Section
Inquiries to: Agny Laukeland Bygnes
Telephone: +47 97432086
Our reference: 22/5736
Your reference:
Date: 16.06.2022

RV Le Commandant Charcot. Consent to conduct marine scientific research in the period 08.07.2022-23.07.2022

The Directorate of Fisheries, MSR Office refers to the Embassy's application dated 13th April 2022 concerning the planned research cruise. The Directorate of Fisheries hereby informs the Embassy that Norwegian authorities have granted consent in accordance with regulations laid down by Royal Decree of 30th March 2001 No. 360.

The marine scientific research is to be conducted by France

with the research vessel "Le Commandant Charcot", call sign FMNB,
during the period from 8th to 23rd July 2022
in the Norwegian Territorial Waters of Svalbard
and in the Fisheries Protection Zone around Svalbard.

The purpose of this cruise is to demonstrate the possibility to measure the thickness of the sea ice and of the snow using a drone equipped with a lidar and a camera.

Please be informed that utilisation of this consent is regarded as an acceptance of conditions given by authority of § 11 in the Royal Decree of 30th March 2001 No. 360. The consent granted is subject to compliance with the following conditions:

Final results and conclusions (§ 11 litra b) second alternative) from the planned cruise should be made available to the Directorate of Fisheries *within six - 6 - months* after the completion of the cruise.
If final results cannot be presented within six months, a preliminary report (§ 11 litra b) first alternative) should be made available pending the research state's final scientific results and conclusions. The report(s) is(are) to be presented to us as a data file, preferably in PDF format, or in RTF/MS Word or ASCII formats. The report(s) are to be sent to us on our e-mail address:

info@fiskeridir.no

Results and conclusions should be marked "13.04.2022, 08.07.2022-23.07.2022, Jnr. 22/5736".

DIRECTORATE OF FISHERIES Postal address: Postboks 185, 5804 Bergen, NORWAY | Telephone: +47 55 23 80 00
Organization number: 971 203 420 | E-mail address: postmottak@fiskeridir.no | Internet: www.fiskeridir.no

According to the application, a drone will be used from a boat to measure the sea ice thickness. The Norwegian Civil Aviation Authority (CAA Norway) states that the applicant must submit an application regarding drone flying in the specific category. Please see the attached statement from the CAA Norway for further information, or contact the CAA Norway directly.

Reference is made to the attached document from the Governor of Svalbard regarding "Information about research cruises around Svalbard". The Governor of Svalbard takes this opportunity to inform the scientist in charge that large proportions of Svalbard and the waters around Svalbard are protected areas, please see the map. If the research cruise is planning any activity within a protected area, the project leader must be familiar with the reguations for the spesific protected area and apply the Governor for permission if needed to conduct the planned research activities. Please note that use of acoustic equipment and seismic is not permitted in protected areas. For further information please contact the Governor of Svalbard.

It is requested that a copy of these documents shall be kept on board the research vessel.

Yours sincerely

Trond Ottemo
Head of Section

Agny Laukeland Bygnes
Senior Advisor

This letter is approved for electronic submission and does not need a handwritten signature.

List of recipients:
Embassy of the French Republic

Copy to:
Forsvarets Operative Hovedkvarter Postboks 800 2617 LILLEHAMMER

Our reference: 22/5736
Page: 2/3

Foh	Postmottak		
Havforskningsinstituttet	Postboks 1870 Nordnes	5817	BERGEN
Kystvakten			
Kystvakten	Postboks 295	8401	SORTLAND
Luftfartstilsynet			
UD Seksjon for traktat og havrett			

Attachments:

RV LE Commandant Charcot - Høring av søknad om forskningstokt i perioden 08.07.2022-23.07.2022 - Bruk av drone under forskningstoktet

Standard answer research cruises 2022