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SURVEY REPORT – KV "SVALBARD" 16-26 MARCH 2014

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Summary

The aim of the KV "Svalbard" survey was to test two UAVs (Unmanned Aerial Vehicles) to perform aerial photographic surveys of harp and hooded seal whelping patches on the drift ice in the West Ice area in the Greenland Sea. Digital cameras and a thermal infrared (IR) camera were used. We aimed to explore various survey altitudes and camera settings to obtain an optimal altitude and camera set up for photographing seal pups. Simultaneous use of digital and IR cameras enable us to explore combinations of those to detect and classify seals. Experience obtained from using the UAVs and the quality of the images taken, are promising. Both harp and hooded seals, including pups, were easily identified on the images taken at a flight altitude of 300 m. Also preliminary results from the IR camera are promising. It is, however, necessary to improve the range of the largest UAV and the methods for landing the aircraft on ice floes. Also some technical improvements on both aircrafts and operational equipment should be performed.

Introduction

The use of traditional photo aircrafts to assess seal populations in remote areas, such as the "West Ice" in the Greenland Sea, is expensive and have also become more difficult to operate during recent years. The aircrafts used by the aerial photo companies use petrol (Avgas 100LL), which has become difficult to obtain. Before the most recent seal assessment in the West Ice (in 2012, see Øigård et al. 2014a,b), fuel barrels had to be transported by truck from Norway to Denmark, and then by ship to Constable Point airport in East Greenland the autumn before the aerial photo surveys were carried out. Also, the airport on the Jan Mayen Island has been closed down for such activity, which make the aerial operations more risky due to lack of potential airports for landing under rapid changing weather conditions or technical problems. There are presently only two available airports – Constable Point and Akureyri in Island. On this background, the Institute of Marine Research (IMR) is seeking alternative (and cheaper) options to conduct aerial photo surveys of harp and hooded seals in the West Ice.

Aim of the survey

With funding from the Norwegian Research Council, IMR conducted a research survey with KV "Svalbard" to the West Ice during 16 to 26 March 2014. The aim of the survey was to test UAVs (Unmanned Aerial Vehicles) – Cryowing Mk.1 (CW1) and Cryowing Micro (CWM) – operated by the Northern Research Institute (Norut), to perform aerial photographic surveys of harp and hooded seal whelping patches on the drift ice. We aimed to explore various operational challenges such as operating the airframes under extreme cold and windy conditions, landing the smaller Micro Cryowing on KV Svalbard's helicopter platform, and landing the larger Mk.1 on ice floes.

Digital cameras were used, and we aimed to explore various survey altitudes and camera settings to obtain an optimal altitude and camera set up for photographing seal pups. Also, the CW1 was instrumented with thermal infrared (IR) camera, which enabled us to explore combinations of both cameras to detect and classify seals.

We aimed to cover a sub-area of a whelping patch with overlapping photos along and between parallel transect lines. The photos will be analysed using traditional visual inspection and modelled using a mosaic method, which will provide the total number of seal pups in the covered area. Then we will estimate the number of pups in the area using random sampling and traditional aerial strip transect methods in order to explore how various spacing between transects and between photos along the transect affect on the results.

The digital and IR images will be used to develop automatic analysing approaches, also by combining these images.

Reconnaissance

The distribution and configuration of the drifting pack-ice during the operation is shown in Fig. 1. As observed in 2007 (Øigård et al. 2010) and 2012 (Øigård et al. 2014a, b), the ice cover was close to the East Greenland coast also in 2014. Whelping seals (concentrations as well as scattered seals) were searched for in areas historically used by harp and hooded seals in the Greenland Sea. The reconnaissance part of the operation was adapted to the actual ice-configuration during the study period, cruising with the ship along the ice edge, to some extent also into the more packed drift ice, and observing with binoculars from the wheelhouse. The study period had been chosen to fit the expected pupping dates of the two species (mid to late March, see Rasmussen 1960; Øritsland 1964; Øritsland and Øien 1995; ICES 1998; Haug et al. 2006, Salberg et al. 2008; Øigård et al. 2010, 2014a, b).

KV “Svalbard” met the ice edge at 72º15’N/17º16’W on 18 March. On 19 March, a small patch of breeding hooded seals was observed in position 72º10’N/17º00’W – some experiments were conducted using the CWM in this patch. The general ice drift moved both the ice and the ship southwest-wards – on the 20 March (06:50 hours) the observed position was 72º03’N/17º18’W. From this position reconnaissance was continued northwards, and a harp seal breeding patch was found at 72º14’N/16º53’W. Strong winds (25–40 knots) made it impossible to operate the UAVs on 20 and 21 March, whereas in the early morning on 22 March the wind speed had dropped to 10–15 knots and operations using the CW1 could be continued. At this point the ship and the harp seal breeding patch had drifted southwest-wards to around the position 71º45’N/18º05’W.

KV “Svalbard” had to leave the ice during the night on 22 March.

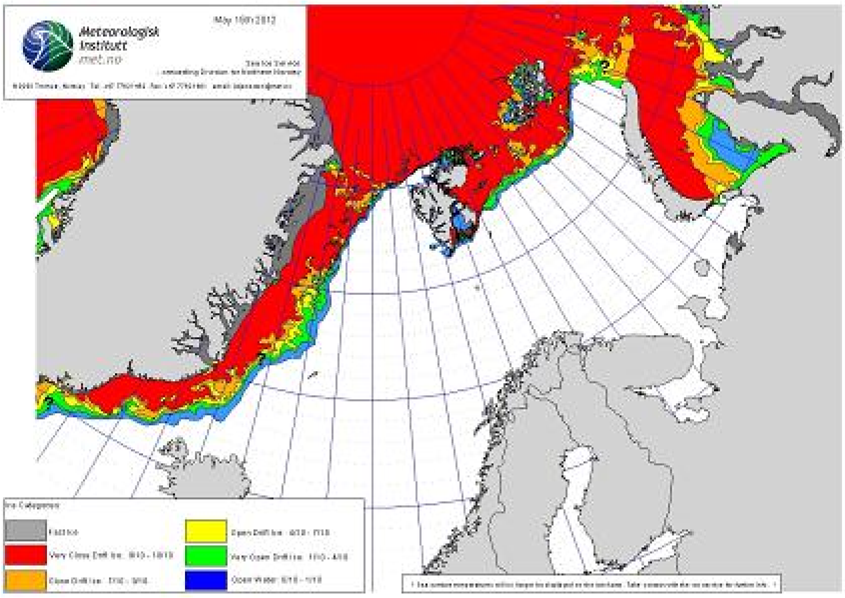

Figure 1. Drift ice distribution in the Greenland Sea on18 March 2014.

Ship and flight permits

IMR applied to the coastal states Denmark/Greenland for permit to operate KV "Svalbard" in the Greenland Sea outside the 12 nm boarder. Permission was given on 4 March. Norut applied for flight permits from both the Danish Civil Aviation Authority (CAA) and the Icelandic CAA for operating unmanned aircraft beyond visual line of sight. The area that was applied for was between 71º–74 º N and 10 º–20 º W and up to 3000ft. KV "Svalbard" aircraft radar was used to detect any conflicting air traffic that could enter the operations area. This made the application process easier because there was no need to create a temporary danger area for the operation. "Danger Area" is an airspace classification that could be established and activated by the CAA, it is published and warns other airspace users from using the area when it is activated. It is usually a minimum of 3 months needed for establishing such an area. Norut obtained permits from both the Danish and Icelandic CAAs (south of 73ºN is covered by the Reykjavik Flight Information Region (FIR) and north of 73ºN by the Søndre Strømfjord (FIR)). The Reykjavik Air Traffic Control (ATC) coordinated the NOTAM issue on behalf of both FIRs and for each operation a flight plan was called in to the affected FIR and when each operation was completed the ATC was notified again. Since all flights were south of 73 ºN all communication was with the Reykjavik ATC.

Airframes used

CW1 (Cryowing Mk1)

The CW1 airframe is produced by ET-Air S.R.O in Slovakia. Final assembly was done by Norut. The main airframe structure is fiberglass composite made using CNC (Computer Numerical Control) routed molds. The propulsion is a Zenoah G62, a 62cc two-stroke petrol engine, running on 95 octane petrol with a 2% oil mixture. The plane is equipped with Iridium modem and beyond radio line of sight range is only limited by fuel amount and battery capacity for powering avionics and payload. Up to 3 hours operation is possible in good weather. High wind and cold weather will reduce range. The aircraft is launched by pneumatic launcher from the ship deck, and needs adequate ice surface to land on.

Figure 2. Kjell-Sture Johansen is landing CW1 on a small ice floe. Photo: S. Solbø, Norut

CWM (Cryowing Micro)

The CWM airframe is produced by Skywalker Ltd. Final assembly was done by Norut. The main airframe structure is EPO, (Expanded PolyOlefin) a type of crash resistant foam which is carbon fiber reinforced. The propulsion system is electric and maximum airtime between charge/change of battery is 40 min. This aircraft is only equipped with line of sight 433 MHz radio modems and can therefore only be used for within a 10–20 km radius (range depend on antennas used for tracking and radionoise in the area). The aircraft is launched from the ship deck with a bungee catapult launcher. If the deck is large enough (like on the helicopter deck of KV Svalbard), it is possible to land the aircraft on the deck, or into a net mounted on the deck.

Figure 3. Take-off CWM from the KV "Svalbard" Helicopter deck, 19. March 2014. Foto: D. Stødle, Norut

Figure 4. Left: CWM in flight. Right: CW1 ready for takeoff. Photos: M. Poltermann

Operational Limitations

Possibilities and challenges in general associated with operating unmanned aircrafts in the Arctic for scientific data collection are described in Storvold et al. (2013).

CW1 (Cryowing Mk1)

The CW1 can be safely operated in wind speeds up to 15 m/s. During the survey in the West Ice we experienced wind that was above the safe limit, and we had to wait for acceptable conditions. Another problem is the need for pre-heating of the engine before it can be started in low temperatures. The low temperature is also affecting the useful capacity of the onboard batteries. Another limiting factor to consider when using the CW1 is the need for adequate landing areas. It is preferable with an ice sheet that is more than 80x20m for a safe landing.

Table 1. Technical specifications of CW1 and CWM.

	Cryowing mk. 1	**Cryowing Micro**
Weight	30 kg Maximum take of weight incl. fuel and instruments.	3.5 kg Maximum take of weight incl. batteries and instruments.
Wingspan	3.80 m	2.10 m
Engine	Two-stroke 62 cc, 6,Hp, weight 1.8kg	Electric
Fuel	Petrol/oil mixture (50:1)	Lithium Polymer Battery
Navigation	GPS	GPS
Operation		
Ground Equipment	PC with modem+RC control for manual take-off and landing	PC with modem+RC control for manual take-off and landing
Flight	Autonomous, but under ground control, catapult launch, belly landing.	Autonomous, but under ground control, hand launch, belly landing.
Air to ground communication	Radio during take-off/landing and UHF radio, GSM and Iridium satellite modem during flight	RC Radio during take-off/landing and UHF radio payload control and autopilot navigation
UAS		
Cruise speed	105 km/h	70 km/h
Range/endurance	400-500 km, based on current fuel tank capacity (6 ltr) and engine	70-100 km, 1 hour
Max altitude	4000 m.a.s.l.	4000 m.a.s.l.
Payload capacity	Approx. 12 kg included full fuel load (6 Liters), 150W available power from onboard PSU	Approx. 1 kg but weight affects range and endurance.
Basic instrumentation	3-axis IMU, GPS, PC104 w/250 GB SSD	

CWM (Cryowing Micro)

The CWM has a max wind speed limitation of 12 m/s. High winds and cold weather will have a large impact on range and flight endurance. The CWM is equipped with open source autopilot and this can sometimes be problematic due to firmware updates of unknown quality and cheap hardware. The bungee catapult launcher does not work when temperatures are below -5 ^{o} Celsius. This year's survey also showed a need for spare parts and an updated packing list should be made.

Payload Configuration

CWM Payload

The CWM was instrumented with a Canon EOS-M, a 18 MPix mirrorless SLR camera with a 22 mm, F1.8 lens, with the Magic Lantern hack firmware 2.3 installed to allow for interval shooting. In addition a Canon GPS and compass was attached to the camera, tagging images with correct time and position. A 320x240 pixel Tau-P uncooled bolometer manufactured by FLIR inc. with analog video out was captured with an onboard video grabber, time stamped and saved on an SD card. The camera had 9Hz video. Flight track and aircraft altitude were taken from the autopilot log based on the autopilots IMU (Inertial Measurement Unit) and GPS sensors. The Canon camera took one picture every two seconds and flight speed was about 18 m/s. With a flight altitude of 300 m the footprint is about 300 m wide.

CW1Payload

The CW1 was instrumented with a 16 bit, 640x480 pixel ICI-7460 uncooled bolometer IR camera from Infrared Cameras Inc, and a Nikon D5100 16MPix SLR Camera with a 35mm lens. Metadata on aircraft attitude (orientation) and position were collected using an Xsens MTI-G IMU at 100 Hz and a Holux GPS. The IR camera was programmed to take one image per second, while the Nikon camera was programmed to take one image every 2 seconds (maximum speed). The sensors were controlled by the onboard Linux PC and data collected were stored on a solid state. With a flight altitude of 300 m, which was used on March 22, the footprint is about 180 m wide.

Data processing

Every image is coupled with position info from the onboard GPS receiver and attitude from the IMS sensor. For the CW1 this is achieved through a common timestamp in the onboard computer, whereas on the CWM the camera has its own GPS receiver and the position and attitude information is retrieved from the autopilot log. This information is utilized together with the intrinsic camera parameters to compute the geographic position for each pixel in the image. This process is known as direct georeferencing. However, due to inaccuracy in the IMU attitude measurements and misalignment between camera and the IMU, the absolute position in direct geo-referencing usually has an error in the scale of 10–40 m, depending on flight altitude.

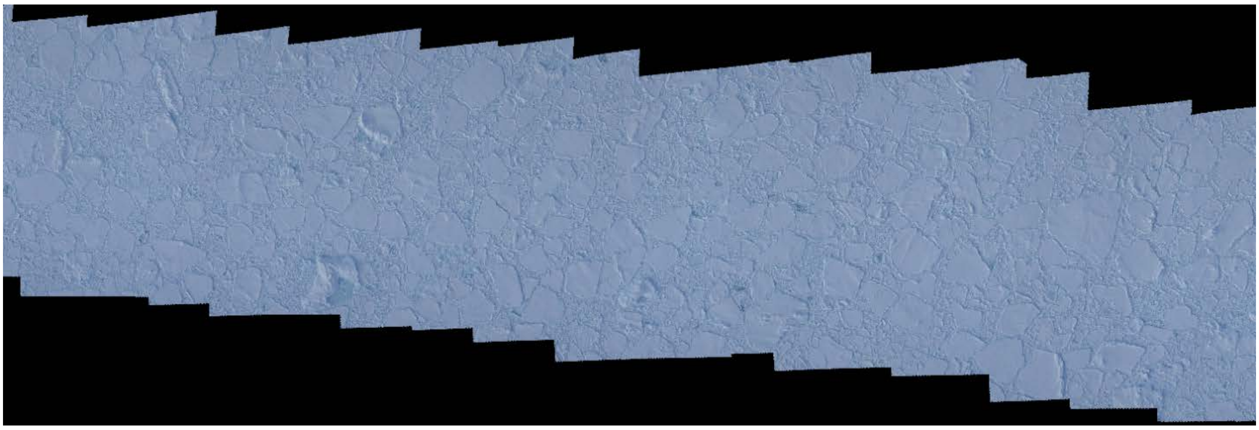

Figure 5. Sample of mosaic covering 1 km based on a single transect of images taken at an altitude of 300 m from CW1 on 22 March.

To generate a mosaic (Figs 5 and 6) for each flight transect, the corresponding images are stitched together in a process that aligns unique key-points in overlapping images. The commercial software package Agisoft PhotoScan is utilized to perform this task. This mosaic image is geo-referenced and can be imported into GIS software (Solbø and Storvold 2013; Stødle et al. 2013).

Figure 6. Mosaic from CWM flight on the 19 March. As the flight was mainly flown in manual mode due to airspeed sensor issues no structured grid was flown. The mosaic is based on 300 images from a 15 minutes flight.

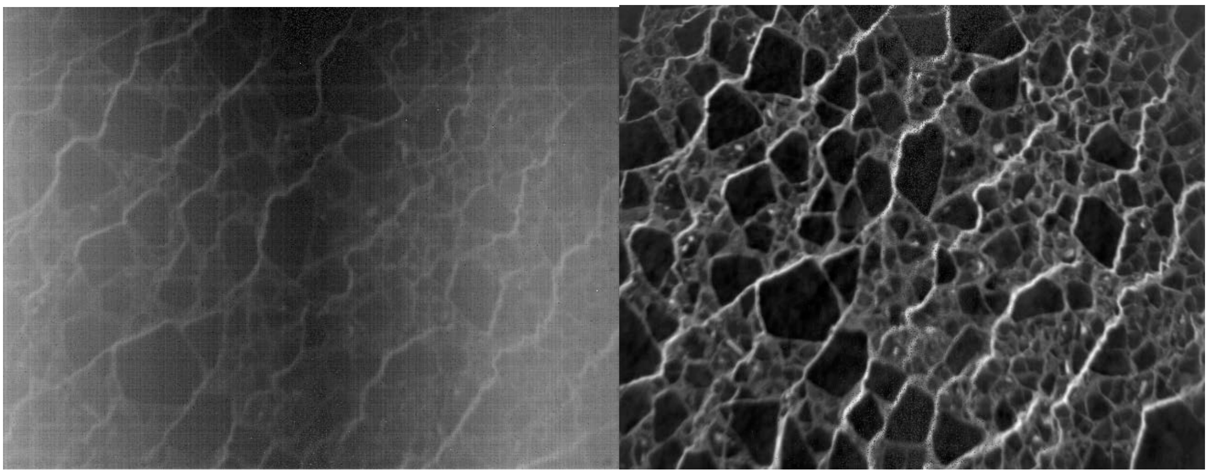

Figure 7. Left: Raw image from the ICI camera taken from the CW1 on 22 March.
Right: ICI image with corrected calibration applied.

The images from ICI IR camera are degraded by a bias, which might occur from an improper calibration of the camera. We estimate this bias by using the average of the 25 previous and 25 future image acquisitions.

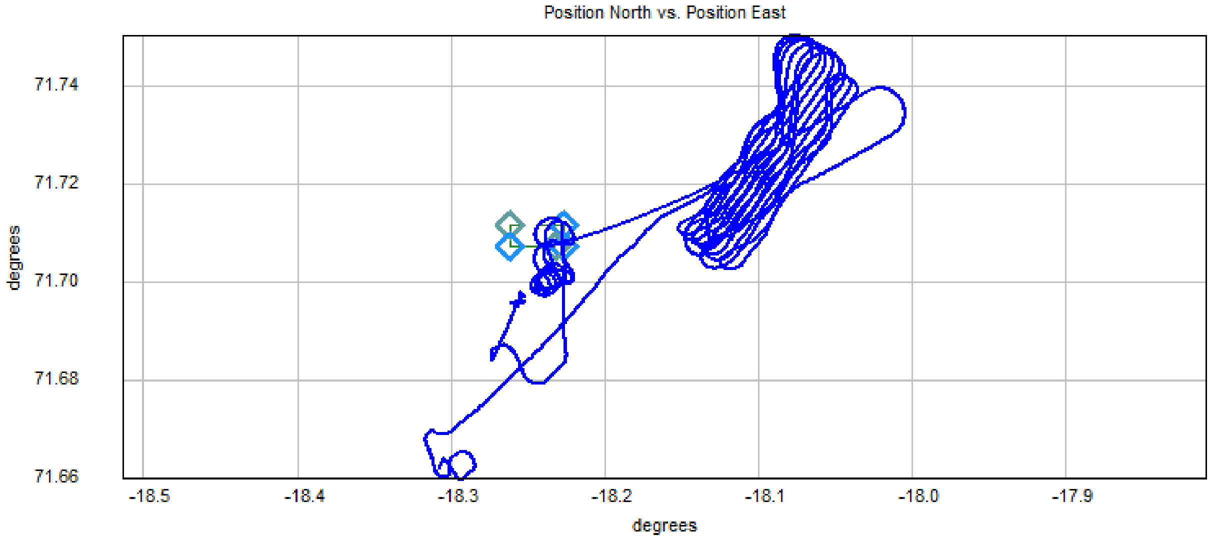

Figure 8. Flight track of the CW1 flight on 22 March.

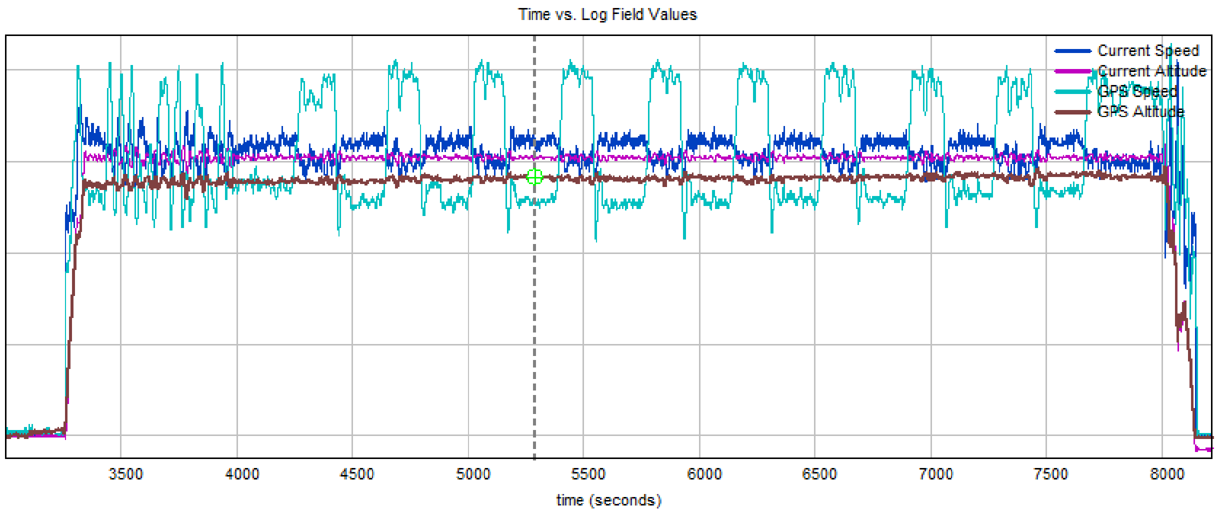

Figure 9. Altitude, airspeed and groundspeed from autopilot airpressure and GPS sensors. From the CW1 flight on 22 March.

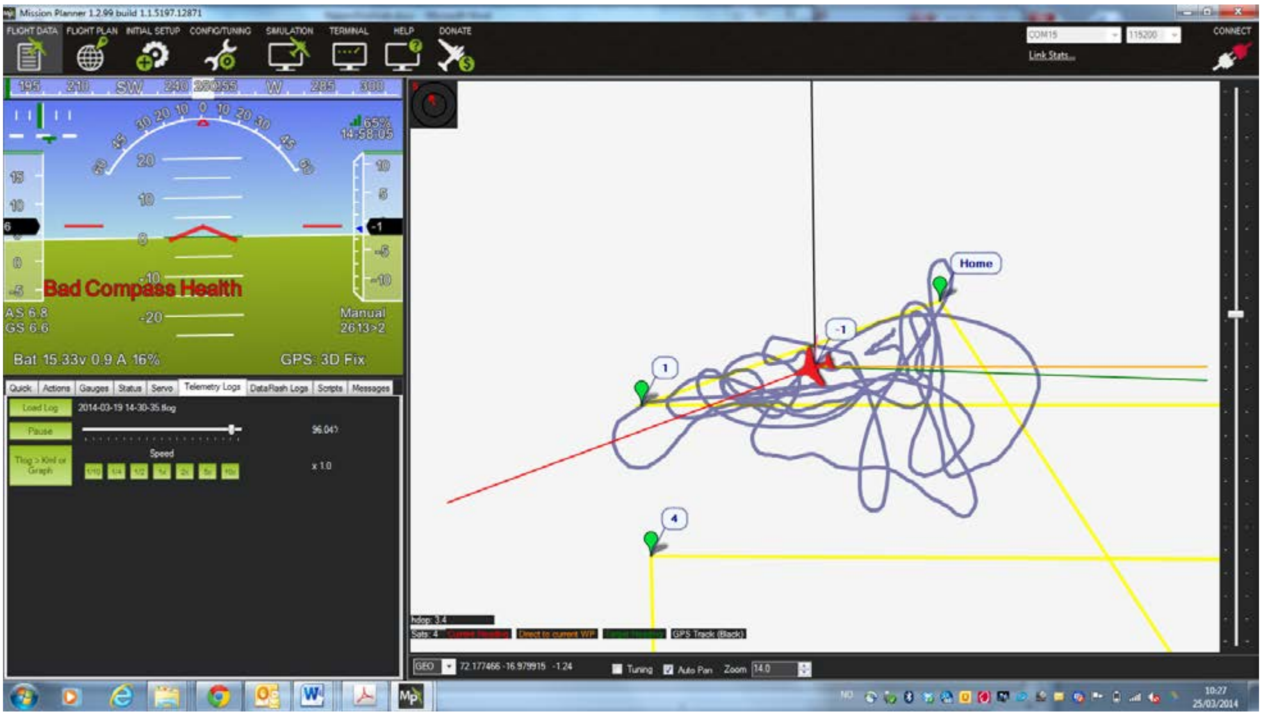

Figure 10. Flight track of the CWM on 19 March.

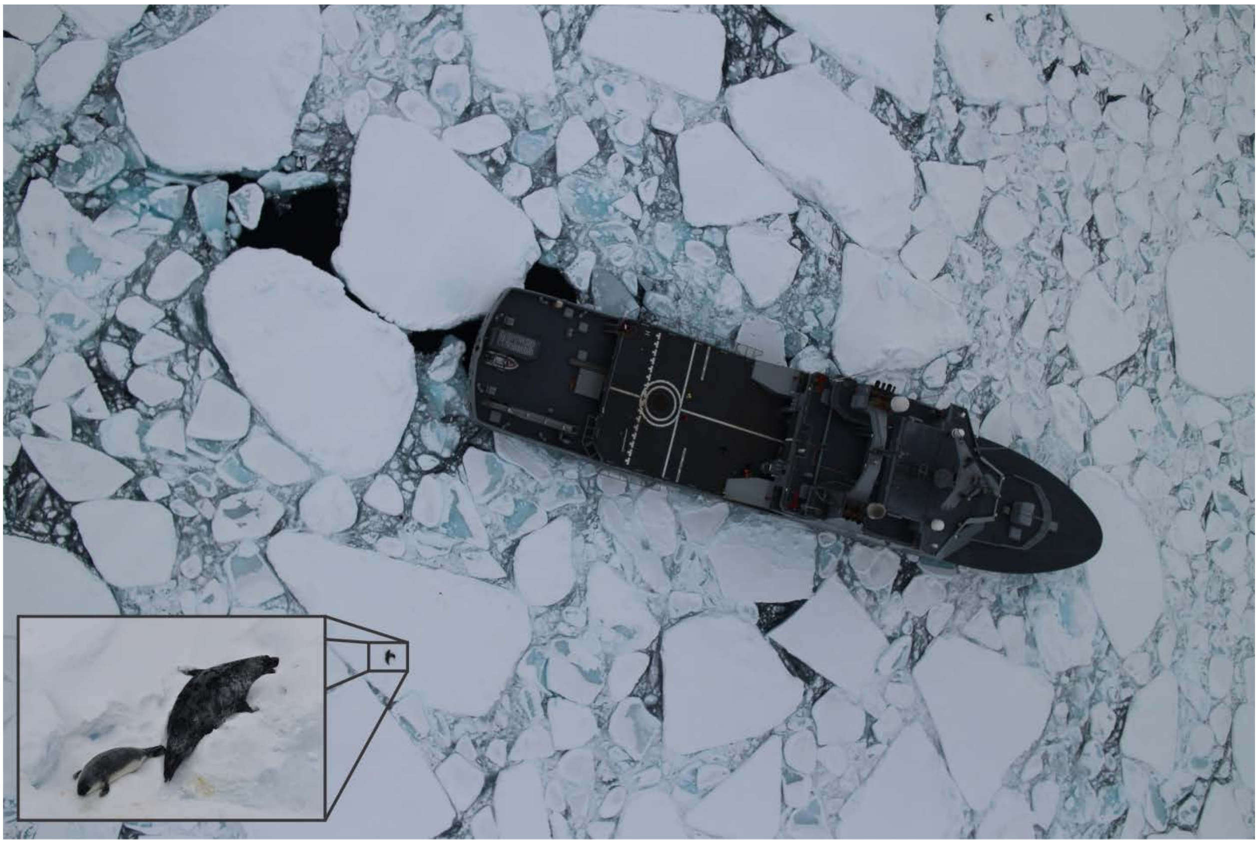

Figure 11. Image from CWMs Canon EOS-M camera on 19 March. A picture of hooded seals, taken from the ship, is added in the corner. Photo: Norut and K.-S. Johansen.

Figure 12. Kjell-Sture Johansen is performing a manual landing of the CWM on the KV “Svalbard” helicopter deck on 19 March. Photo: S. Solbø, Norut.

Results, discussion and improvements

We only had four days available in the survey area in March 2014, including 2 days with weather conditions unsuitable for UAV operations. We need to spend more time in the survey area to be able to perform more testing. Probably a three weeks survey will be optimal. However, results and experience obtained from the UAV flights and the quality of images taken from the digital cameras (Figs. 5, 6, 11 & 13) are promising. Both harp and hooded seals, including pups, are relatively easily identified on the images, particularly when using Photoshop. Also preliminary results from the IR camera (Fig. 7) are promising. It is, however, necessary to improve the range of the CW1 aircraft and the methods for landing the aircraft on the ice floes. In full scale harp and hooded seal assessment surveys to the West Ice an ice going vessel with helicopter is used. The helicopter could be used to find larger ice floes suitable for landing the CW1, and to transport the UAV-pilot to the ice floe. Also, the helicopter could be used to transport the UAV back to the ship after landing on the ice.

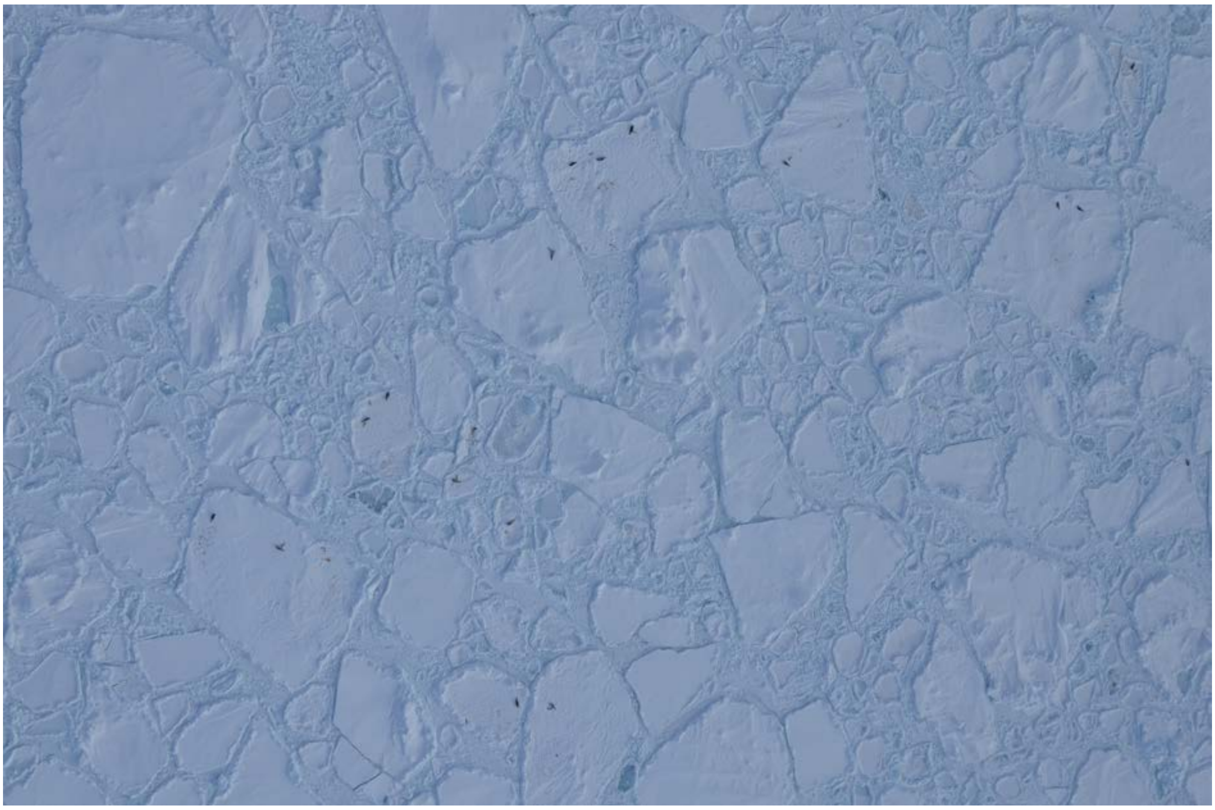

Figure 13. Image from CW1's Nikon D5100 Camera with a 35mm lens at 300 m altitude taken on 22 March.

We also wanted to cover a larger sub-area of a seal whelping patch with overlapping photos along and between parallel transect lines to make a mosaic, which will provide the total number of seals in the covered area. Then it will be possible to estimate the number of pups in that area using random sampling and traditional aerial strip transect methods in order to explore how various spacing between transects and between photos along the transect affect on the results. Due to lack of time and difficult weather conditions we were not able to perform a survey large enough to explore various sampling methods during this survey.

CW1

Next year's Cryowing Mk1 should be equipped with a bigger fuel tank and a generator to increase the range. A small net for stopping the aircraft during landing on the ice should be considered. The onboard battery solution should also be tested in a cold chamber, to set a safe limit on the battery voltage level. A heater system for the aircraft engine prior to start up is needed and we should consider using engine excess heat for keeping payload warmer. An unmanned helicopter for spotting suitable landing areas (larger ice floes) should also be considered. If next year`s survey will be performed from a ship without aircraft early warning radar, the application for a temporary danger area must be written at an early stage to ensure safe BVLOS (Beyond Visual Line of Sight) operation.

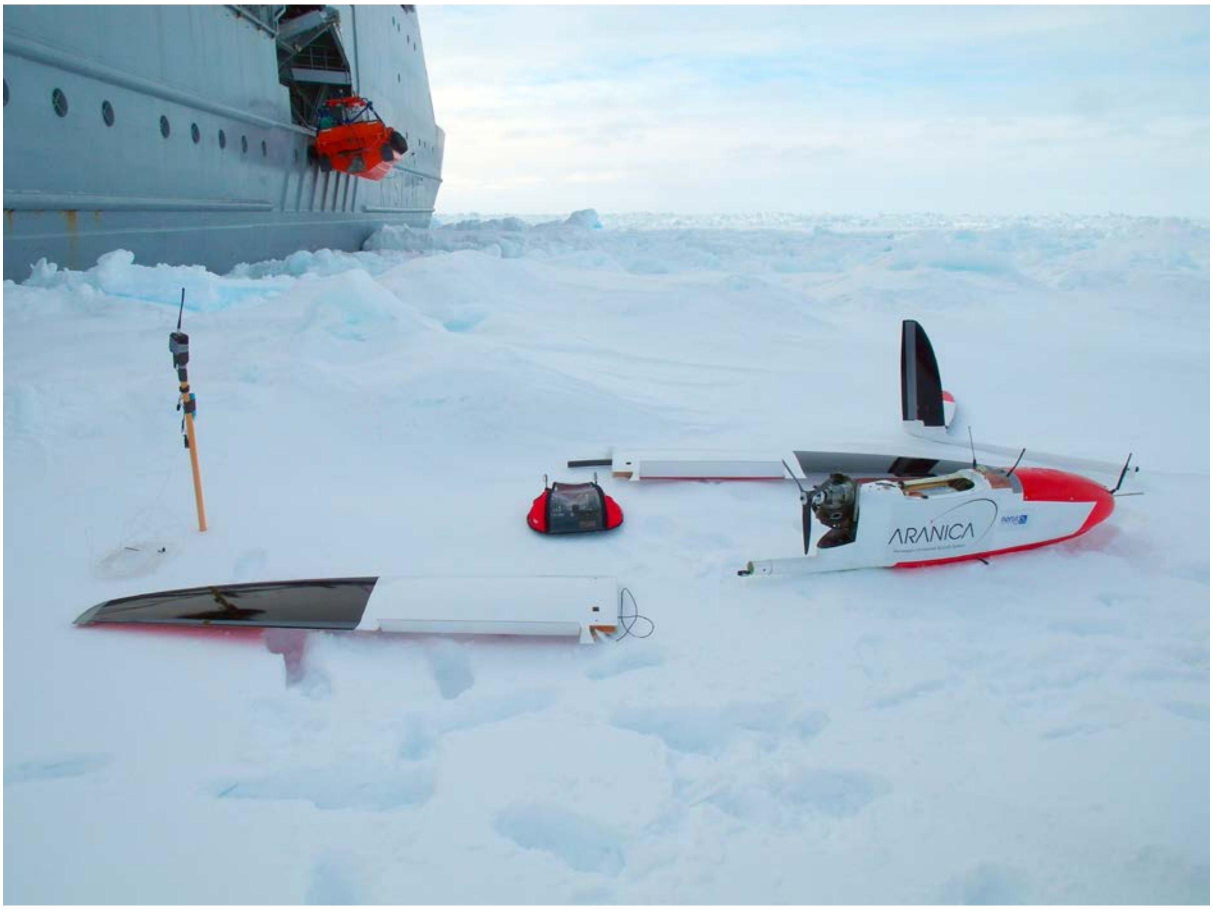

Figure 14. CW1 disassembled and ready to be packed in a container and picked up by the ship. Photo: M. Poltermann

CWM

Some work needs to be done on this airframe to increase its performance envelope. Also the payload system needs further testing. The bungee catapult needs to be redesigned both to ensure the operators safety, and to ensure its performance in cold weather. One solution would be to adapt the pneumatic launcher (used for CW1) to also be able to launch the CWM.

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