

Remote Sensing in the Arctic with Unmanned Aircraft: Helping Scientists to Achieve Their Goals

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Abstract – With the rapid changes occurring in the Arctic, scientists are looking for new tools to fill data gaps and assist with their understanding of Arctic climate processes. While satellites and manned aircraft have been the primary platforms for remote sensing, data gaps still exist. Unmanned aircraft have potential to help fill those gaps because of a variety of unique capabilities including long endurance. The primary challenge to flying unmanned aircraft in the Arctic is gaining access to the airspace. Based on the recommendations put forth by the Arctic scientists, the Arctic Council created a UAS Expert Group under the Arctic Monitoring and Assessment Program to help address these challenges. This paper will discuss how unmanned aircraft can assist scientists with obtaining data in Arctic, what the challenges are, and how the UAS Expert Group is helping.

Keywords: Unmanned, UAS, Environment, Arctic, Remote sensing, Climate change

1. INTRODUCTION

The Arctic is a critically important environment with a strong influence on global climate and a significant source of oceanic primary production. The effects of climate change are more pronounced in the Arctic than other latitudes and as a result, the Arctic is undergoing very rapid change. Sea ice thickness and coverage are diminishing faster than originally predicted (S.V. Nghiem et al 2007; J. Stroeve et al, 2007). Permafrost is thawing, and the resulting change in soil permeability is causing the surface waters to redistribute on the tundra (J.C. Rowland et al, 2010). Coastal erosion is rapidly increasing because of a rise in summertime sea surface temperatures, longer periods of open water and a decreased sea ice extent which gives waves more fetch to build energy and size (B. M. Jones et al, 2009). Because of the rapid changes, scientists are scrambling to understand the many climate processes and mechanisms of the Arctic.

Unfortunately, monitoring the Arctic is extremely difficult, both from satellites and from ground-based stations. Manned flights across the Arctic supply some critical data but are limited by weather conditions and often are not able to safely fly below the cloud deck, which can be as low as a few hundred. There are many satellites in polar orbits that provide excellent coverage of the Arctic, but unfortunately many of the instruments are unable to “see” through clouds that are present across the Arctic much of the year. Because of long endurance, low altitude flight, and lack of humans on board, UAS offer new solutions to taking measurements across the vast Arctic that could not easily be made

in any other manner. The measurements can fill in knowledge voids about weather, sea ice, ocean currents, pollution, marine mammals, and fish. Scientists across the Arctic are embracing this technology to be able to address questions that were previously could not be addressed.

Use of UAS for environmental research in the Arctic began when in 1999 researchers at the U. of Colorado were funded by the National Science Foundation to deploy Aerosondes from Barrow, Alaska over a period of five years (J. Curry, 2004). The number science missions using UAS in the Arctic has since gradually increased over the past decade. In 2010 Arctic UAS missions were performed in the United States, Norway, Greenland and Russia by at least five different operators of scientific UAS. In many ways the Arctic has become the proving grounds for civilian use of UAS. Scientifically, UAS are supplying data that would be difficult, impossible, risky or expensive to gather in any other manner. In addition to the great scientific value of the operations, the operations themselves contribute to gathering experience both for operators and regulators on how to perform safe operations and air space handling in an area where manned aviation is minimally impacted and the risk for life and property can be kept within acceptable industry standard.

Gaining access to the airspace required to fly UAS in the areas of interest continues to be a major hurdle to their full utilization as an Arctic observing platform. The lack of regulations specifically for UAS as well as the low priority given to UAS by Civil Aviation Authorities (CAAs) has made it difficult to conduct operations even in remote regions like the Arctic. These barriers are not insignificant and require much work to overcome.

In 2008, scientists from the different Arctic countries came together and unanimously agreed that UAS are a key tool to understanding the climate change occurring in the Arctic and its impact on the environment. As a result of their recommendations to the Arctic Council, a UAS Expert Group was formed to help the scientists studying the Arctic environment to utilize UAS more readily for their research. This paper will provide an overview of the Arctic Monitoring and Assessment Program (AMAP) UAS Expert Group and how it is promoting UAS usage for Arctic environmental research and monitoring by helping to break down the existing barriers will be discussed.

2. AMAP UAS EXPERT GROUP OVERVIEW

As a working group under the Arctic Council, the Arctic Monitoring Assessment Program (AMAP) has been an active advocate for gathering critical Arctic data. AMAP first addressed the issue of using unmanned aircraft in Spring of 2008 at a meeting of scientists where the significant data gaps that are

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present in Arctic studies, and the potential that UAS have to help fill those gaps were discussed. While the group strongly recommended the benefits of UAS, they acknowledged that the technology is not without challenges and understanding those challenges is necessary to realizing their potential as an environmental monitoring tool. One of the most significant challenges is getting access to the airspace in order to fly missions. At the 2008 meeting, it was decided that the potential of UAS far outweighed the challenges, airspace access is the greatest of these challenges, and that the issue should be raised to the Arctic Council level. Before accepting recommendations, however, it was requested that a meeting with the civil aviation authorities be held to determine the feasibility of improving access for UAS flights to conduct environmental monitoring. A second meeting was held in Oslo in the Fall of 2008 at which several CAAs, as well as Arctic scientists and UAS operators, met to discuss how access to the airspace over the Arctic for UAS flights could be improved more quickly yet without sacrificing safety. The CAAs present determined that they would be able to work with the science community to grant better access. Based on these discussions, it was recommended to the Arctic Council that a formal expert group be established under AMAP to assist with working the issues related to airspace. The Arctic Council met in April of 2009 and accepted the recommendations put forth, and the UAS Expert Group was established (SAO, 2009)

The UAS Expert Group is currently co-led by NASA (United States) and Norut (Norway). Representatives from each of the eight Arctic countries make up the group and include civil aviation authorities, individuals from research institutes and universities who have experience flying UAS, and scientists who are interested in flying UAS for environmental monitoring.

The AMAP UAS Expert Group has been focused on assisting the international Arctic scientific community with understanding the challenges associated to flying UAS with particular focus on airspace access. While there is significant interest in flying UAS for environmental monitoring, how to get the airspace access required in order to safely yet successfully conduct a mission is a mystery for many would be UAS users within the science community. Access varies from country to country across the Arctic, which adds to the challenge of understanding what steps are necessary. The Expert Group is working with Civil Aviation Authorities (CAAs) from each of the countries to understand what are current policies regarding access and what possible options exist to expand access safely to allow for greater environmental monitoring.

Understanding what operations have occurred, or are planned, and how airspace access was granted for those missions is one step the Expert Group is taking to assist scientists. Sharing this type of information is helpful to understanding how much activity is ongoing in the different countries and can be used to promote science cooperation among the organizations involved. It also serves to inform CAAs of how much activity there really is to help push for higher priority and more resources for UAS.

Several Missions in Norway, Greenland, the US and Russia have taken place in the past 2 years. The fact that these operations are occurring indicates that some access to airspace is achievable. Highlights of two missions that were successful despite air space restrictions will be given in Section 3.

3. RECENT UAS OPERATIONS IN THE ARCTIC

As examples of the types of UAS operations that have flown in the Arctic, two specific missions are highlighted next.

3.1 Ny-Ålesund, Norway

In 2009 and 2010 the Norut Cryowing UAS (Figure 1) was operated from Ny-Ålesund, Svalbard and Summit Camp on the Greenland Icecap.



Figure 1. The Norut Cryowing UAS is prepared for launch at the Ny-Ålesund airport May 2009 (<http://uas.norut.no>).

The project, called Variability of Albedo Using Unmanned Aircraft, was funded by the Norwegian Research Council, and led by the Norwegian Institute for Air Research in partnership with the Norwegian Polar Institute and Norut (<http://transport.nilu.no/projects/vauuav>). The project was focused on measuring the variation of snow albedo with the primary goal of investigating whether deposition of transported black carbon from either industrial emissions or forest fires could be detected at lower latitudes by using hyper spectral airborne instruments. Another goal was to detect and characterize the spectral albedo variation through the melting season on arctic snowfields, glaciers, and sea-ice. The upper panel of Figure 2 shows the spectral reflectance the lower panel the incoming and reflected irradiance. Figure 3 shows an image of the spectrometer footprint for the data shown in Figure 2.

In order to fly from Ny Alesund, an application was made to the Norwegian CAA that included a safety case describing how the mission would be conducted, what the risks were to other aircraft in the airspace and people on the ground, and how those risks would be mitigated. The permit obtained required the operation to notify air traffic control (ATC) in Longyearbyen prior to each flight and after flight termination. Flights were not performed over the no-fly zone above town. A Notice to Airmen (NoTAM) was issued covering the entire deployment establishing a danger area containing all planned flight paths. An almost identical approach was used at Greenland where a danger area was also established and a NoTAM issued for the whole operations period (12 weeks). ATC in Kangerlussuaq was notified right before and after each flight. All local operators were directly informed about the operation prior to start of operations in May.

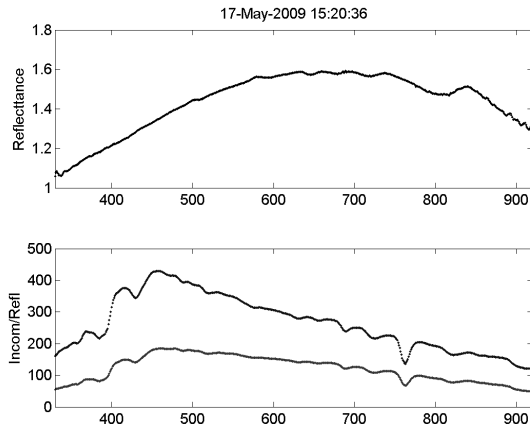


Figure 2. The upper panel shows directly measured spectral reflectance vs. wavelength. The lower panel shows incoming and reflected irradiance vs. wavelength in nanometers [mW/(m²nm)]. (Courtesy of Norut)

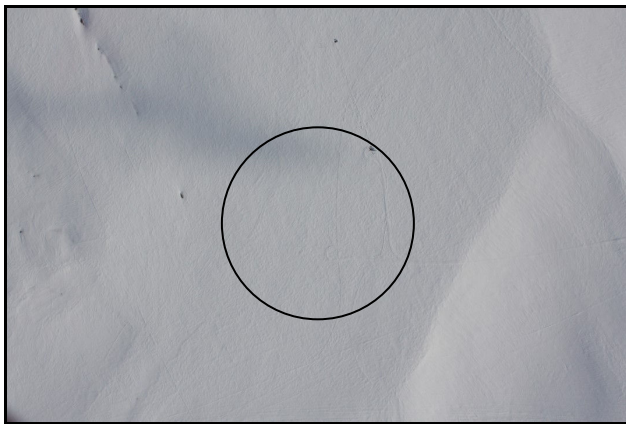


Figure 3. Aerial photo with indication of spectrometer footprint. Just visible within footprint is a ground validation station where both spectral reflectance and snow pit measurements were performed. Snow samples were also collected and filtered for black carbon concentrations. (Courtesy of Norut)

3.2 Bering Sea, USA

In 2009, NOAA, together with U. Colorado and U. Alaska, flew a Scan Eagle off of the NOAA vessel, MacArthur II, pictured in Figure 4. The purpose of the mission was to identify ice seals from the UAS and identify the ice types that were supporting those seals, pictured in Figure 5. The mission resulted in ten flights that gathered over 27,000 images. Flights ranged in altitude from 300 to 1000 feet and were up to eight hours in duration. All flights occurred successfully with no loss of aircraft.

Seal experts, using specialized software developed specifically for the mission, analyzed the resulting images. Over sixty seals were identified in the images. In addition, the ice was analyzed for ice

size, shape and concentration. Figure 6 gives an example of the images analyzed.



Figure 4. The Scan Eagle is shown here coming in for a landing on the MacArthur II ship after a successful flight over the Bering Sea. (Courtesy of NOAA)



Figure 5. Ribbon seals are one of the species of seals whose habitat is threatened by the diminishing sea ice. The 2009 mission in the Bering Sea demonstrated the usefulness of unmanned aircraft to record images of seals on Arctic ice. (Courtesy of NOAA)

An added benefit of using this technology as opposed to manned aircraft is that the small, relatively quiet vehicle did not seem to disturb the seals as much as a manned vehicle. The ability to analyze the images after the flight also proved a benefit over manned flights because care could be taken to assure proper identification of seals and, in some cases, seal species.

To access to the airspace required, a certificate of authorization was obtained from the Federal Aviation Administration, the CAA in the US. The application and approvals required took several months to obtain, and restricted the aircraft to fly within five miles of the ship. This signified one of the few non-emergency cases when permission was allowed beyond line of sight; permission was granted because an extensive safety analysis was done to assure minimum safety risks would be incurred in that area. While the potential for carrying out aerial surveys was demonstrated with these flights, the mission was unable to carry out a full survey of seals in the area because of the limited area covered.

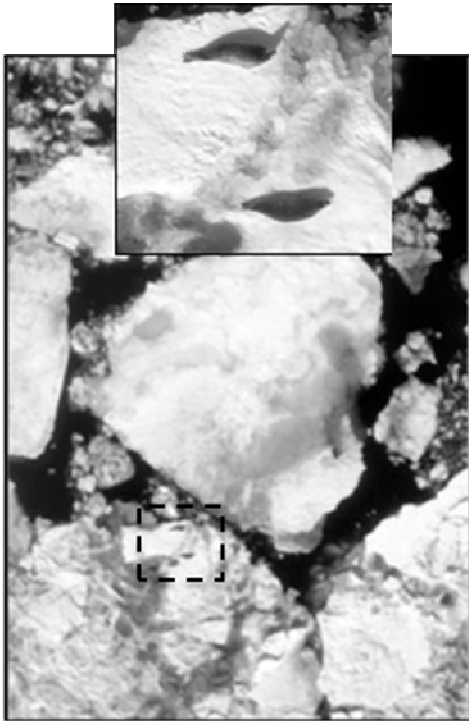


Figure 6. The image in was analyzed to identify seals over the Bering Sea. A close-up of the two seals found within the larger image (box).

4. UAS EXPERT GROUP FUTURE WORK

Understanding the current state of how airspace access is achieved and making the information available to the science community is one step the Expert Group has taken over the past year. Providing a viable safety case is major component of many of the applications required to gain approval for accessing airspace. However, many potential users of UAS are not aware of what such a safety case looks like. As a result, the UAS Expert Group is developing a guideline for safety case development to provide to the science community as another tool to assist with their efforts. Mission planning, points of contact for the CAAs and UAS experts, and best practices are all being compiled as well.

The information gathered and documented will be a significant step towards helping the science community to understand how to access airspace and fly UAS for Arctic research. However, to truly improve the access and help to identify and break down barriers, the UAS Expert Group will begin conducting and supporting science UAS missions across the Arctic. These missions will have viable science goals that contribute to the data needs about the Arctic and encourage collaboration between scientists from all across the Arctic. The goal of these missions will include educating CAAs and scientists alike on UAS operations and demonstrating how airspace access is achieved. Each operation completed will also contribute to build experience and statistics needed to improve and expand future operations. By conducting several smaller operations at various locations

across the Arctic, the airspace will be tested in all of the Arctic countries, including crossing airspace borders. Ultimately, these activities will culminate into a full Pan-Arctic campaign, where multiple UAS will be operating at the same time across the Arctic.

5. SUMMARY

The significant potential of UAS for use as a in situ and remote sensing platform has been identified by many scientists as a way to fill data gaps in the already existing sensor network. The need for such measurements is particularly critical in the Arctic where other technologies cannot meet the current monitoring needs. The challenges to fly safely and to accessing the airspace for remote sensing missions are significant, however, and will require additional effort in order to achieve scientific goals. As daunting as they seem, these challenges are not completely insurmountable, however, and a systematic, safety conscious approach will assist with overcoming the hurdles. By engaging with the CAAs from each of the countries, documenting access methods, and exercising these methods through demonstrations, the AMAP UAS Expert Group is taking steps to improve access to Arctic airspace more rapidly and safely.

6. REFERENCES

- B. M. Jones, C. D. Arp, M. T. Jorgenson, K. M. Hinkel, J. A. Schmutz, and P. L. Flint (2009), "Increase in the rate and uniformity of coastline erosion in Arctic Alaska", *Geophys. Res. Lett.*, 36, L03503, doi:10.1029/2008GL036205.
- J.C. Rowland, C. E. Jones, G. Altmann, R. Bryan, B. T. Crosby, G. L. Geernaert, L. D. Hinzman, D. L. Kane, D. M. Lawrence, A. Mancino, P. Marsh, J. P. McNamara, V. E. Romanovsky, H. Toniolo, B. J. Travis, E. Trochim, C. J. Wilson (2010), "Arctic Landscapes in Transition: Responses to Thawing Permafrost", *Eos Trans. AGU*, 91(26), 229, doi:10.1029/2010EO260001.
- J. Curry, J. Maslanik, G. Holland, and J. Pinto, "Applications of Aerosonde in the arctic," *Bull. of the Amer. Met. Soc.*, vol 23, pp 1855-1861, Dec 2004.
- J. Stroeve, M. M. Holland, W. Meier, T. Scambos, and M. Serreze (2007), "Arctic sea ice decline: Faster than forecast", *Geophys. Res. Lett.*, 34, L09501, doi:10.1029/2007GL029703.
- SAO (2009): "Senior Arctic Officials Report to Ministers", Tromso, Norway (<http://arctic-council.org/filearchive/FINAL%20SAO%20Report%20to%20Ministers%20April%202009.pdf>)
- S. V. Nghiem, I. G. Rigor, D. K. Perovich, P. Clemente-Colon, J. W. Weatherly, and G. Neumann (2007), "Rapid reduction of Arctic perennial sea ice", *Geophys. Res. Lett.*, 34, L19504, doi:10.1029/2007GL031138.