Evaluation of Routine Atmospheric Scientific Measurements using Unmanned Systems (ERASMUS)

Gijs de Boer[1,2], Brian Argrow[1], Dale Lawrence[1], Scott Palo[1], Geoff Bland[3], Jack Elston[1], James Maslanik[1]

(1) University of Colorado Boulder

(2) NOAA – National Oceanic and Atmospheric Administration – U.S. Department of Commerce

(3) NASA

Introduction

In this project, we propose to construct, instrument and operate multiple Unmanned Aircraft Systems (UAS) to make measurements at the US Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program's Oliktok Point, Alaska field site. The aircraft that we propose to build include two types of "micro" class UAS, and are described below. These aircraft will carry basic instrumentation to measure atmospheric temperature, humidity, wind, and pressure. Additionally, the larger (Pilatus) aircraft will carry instrumentation to measure cloud properties such as liquid water content, droplet size, and droplet number. The second Pilatus will carry instrumentation to measure aerosol number concentration and atmospheric radiation.

The proposed measurement campaign itself will serve two main purposes. First, it will support the collection of a detailed set of atmospheric measurements designed to compliment those concurrently obtained by the third ARM Mobile Facility (AMF3). This set of measurements will provide researchers with a focused case-study period for future observational and modeling studies pertaining to Arctic atmospheric processes. Measurements will be geared toward improved understanding of Arctic moisture, aerosol and radiation budgets.

The second purpose served by ERASMUS is to evaluate the potential for future routine atmospheric measurements using UAS at Oliktok Point. DOE's ability to activate restricted airspace at Oliktok Point makes it a valuable resource for UAS-based measurements, and we will provide feedback on the reality of making routine atmospheric measurements using these platforms. Information on environmental constraints, site-induced operational limitations and general operational strategies will be provided. This information should be helpful in the planning and execution of future UAS-based measurement campaigns at Oliktok Point.

Objectives

Science Questions:

- How do profiles of temperature and moisture evolve during clear to cloudy transitions?
- How do aerosol properties vary with height at high latitude locations?
- What role do moisture inversions play in the lifecycle of Arctic mixed-phase clouds and how does their structure evolve in space and time?
- How well do current remote-sensing retrievals perform in the Arctic environment?
- What is the spatial variability of heat and moisture fluxes from the surface over ice and land surfaces?

Operational Questions:

- What is the influence of environmental conditions on routine UAS operations at Oliktok Point?
- How many people are required to effectively carry out routine flights at Oliktok Point?
- What logistical obstacles exist at Oliktok Point that can hinder the routine use of UAS at the Oliktok Point facility?

The DataHawk UAS

Description

The DataHawk UAS was designed at the University of Colorado's Research and Engineering Center for Unmanned Vehicles (RECUV). This compact aircraft has a wingspan of 1 meter, weighs approximately 700 g, and can carry roughly 80 g worth of instrumentation. Current capabilities allow for roughly one hour of flight time (dependent upon flight track, environmental conditions) and allow the aircraft to operate in autonomous mode. Typical airspeeds are roughly 10-15 m s^{-1}, and the aircraft can fly missions up to 3 km without baloon assisted launch, and up to 10 km using a baloon for launch. The current ground station configuration has been tested to effectively communicate with the aircraft with a range of up to 3 km (horizontal) and 10 km (vertical). Combined with its low cost (~$1000 including parts and labor), this aircraft becomes a very attractive option for lower atmospheric science missions. Four identical DataHawk aircraft will be built for ERASMUS.

Photographs of the DataHawk in action in Colorado. The aircraft can be launched using a portable bungee launcher (left) or by hand (center). The right-hand image gives a good impression of the scale of the aircraft.

Aircraft	Instrument	Measurement	Notes
Datahawk	Custom Coldwire Probe	Temperature	80 Hz
Datahawk	Honeywell HIH4021	Humidity	8 Hz
Datahawk	Custom Multihole probe	3-D wind	8 Hz
Datahawk	Omega OS136	IR Surface Temperature	8 Hz

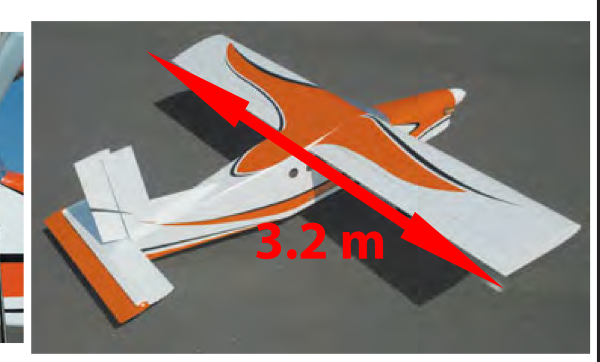
Main Measurement Targets for ERASMUS:

- Frequent (hourly) profiles of T, RH and winds over both land and sea ice surfaces (DataHawks)
- Horizontal variability of T, RH, and winds (Datahawks, HL1, HL2)
- Horizontral variability of (bulk) surface sensible/latent fluxes (DataHawks)
- Above-cloud environment/moisture inversions (DataHawks, HL1)
- Sub-cloud T and RH, along with spatial variability of these quantities (DataHawks, HL1)
- In-cloud liquid properties, including liquid water content, droplet size, droplet number and effective diameter (HL1)
- Profiles of aerosol number (HL2)
- Profiles of broadband SW and LW radiation (HL2)
- Spatial variability of broadband SW and LW radiation (HL2)

The HL (Heavy Lift) UAS

Description

Initial plans included the use of a modified Pilatus Porter from ICARE Sailplanes and Electrics (pictures below). This aircraft is a scale model of the Pilatus PC-6, an aircraft well known for its STOL (Short Take-off and Landing) performance. This aircraft has a 3.2 m wingspan, 2.5 m length and a flying weight of around 30 lb. It can carry roughly 10 lb of instrument payload, allowing for deployment of more exotic instrumentation, and features a relatively large internal storage space. Unfortunately, ICARE recently alerted us to the fact that the Pilatus has been discontinued and is no longer available for purchase. At this point, we are looking into a number of alternative aircraft with comparable performance. Despite the airframe uncertainty, we still expect that these aircraft will carry the instrumentation outlined in the table below. In addition, they will carry video cameras to provide information on surrounding conditions and icing. Two HL UAS will be built for ERASMUS.



Photographs of the Pilatus aircraft. The left- and right-hand images provide insight into the scale and layout of the aircraft. The center image provides a better look at the space available for instruments inside the payload bay (dimensions of bay: 20"x9.5"x12").

Aircraft	Instrument	Measurement	Notes
HL1	DMT Cloud Droplet Probe (CDP)	Hydrometeor size and number, LWC, Effective Diameter, mean Volume Diameter	ARM-Owned Modified Strut
HL1	Vaisala RS-92	Temperature	
HL1	Vaisala RS-92	Humidity	
HL2	Kipp & Zonen CNR4	Up- and downwelling LW and SW broadband radiation	.3-2.8 mm (SW)
HL2	HalTech HPC300	3-Channel aerosol concentration	>300 nm
HL2	Vaisala RS-92	Temperature	
HL2	Vaisala RS-92	Humidity	

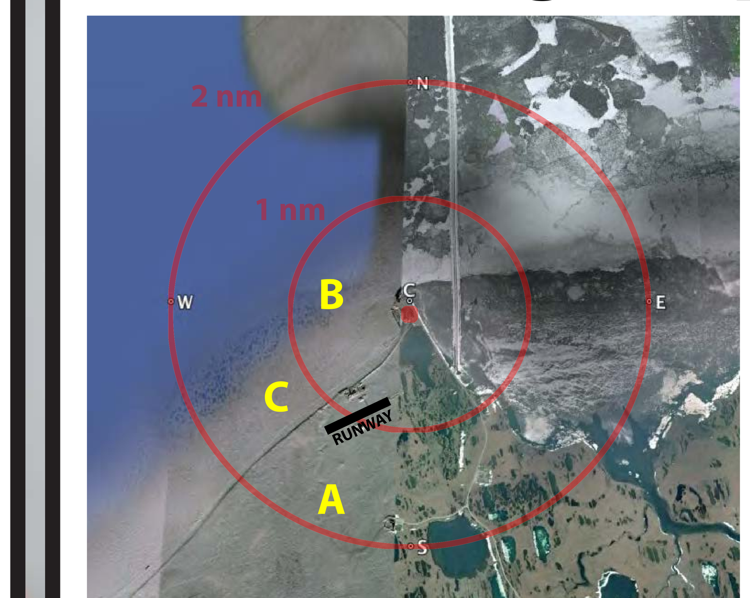
Acknowledgments

This research is supported by the US Department of Energy's (DOE) Atmospheric System Research (ASR) and Atmospheric Radiation Measurement (ARM) Programs.

ASR Atmospheric System Research

ARM Climate Research Facility

Planned Flight Operations



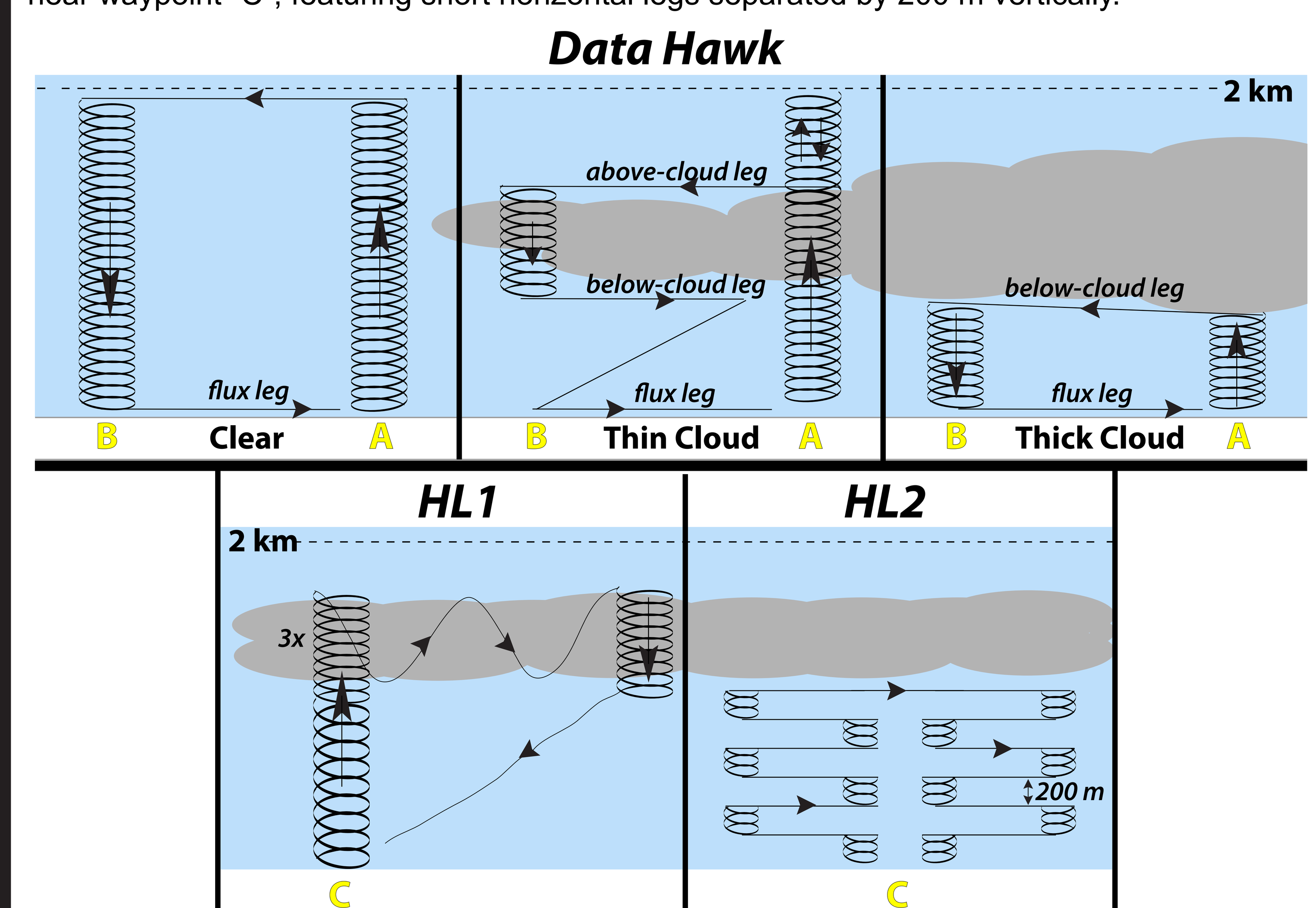
A satellite view of Oliktok Point (left) with waypoints (yellow), the restricted airspace (outer red circle), and the location of the runway (black line) overlaid. The righthand image shows the hanger space at Oliktok.

DataHawk Operations:

- Flights operating once per hour for 12 hours per day (700-1900 local time) for most of the 2-week campaign
- Two 24-hour demonstration periods which will feature continuous hourly sampling throughout the day/night.
- In clear conditions, flights will involve a spiral ascent at waypoint "A" on the map above up to 2 km altitude, a horizontal leg at 2km to waypoint "B" (approximately 2 nm away), a spiral descent to 10 m altitude, and a low-altitude leg back to waypoint "A" to measure surface fluxes.
- Under thin cloud conditions, the vertical spiral to 2 km will be followed by a descent to cloud top, a horizontal leg along cloud top between "A" and "B", a spiral descent through the cloud over "B", a below-cloud leg, a slow descent to "B" and a flux leg at low altitude.
- Under thick cloud conditions where the threat of icing is significant, the ascending spiral at "A" will be limited to the space between the surface and cloud base, and will be followed by a sub-cloud leg to "B", a spiral descent over "B" and a low-altitude flux leg.

HL UAS Operations:

- HL UAS will only be operated under conditions of special interest.
- HL1, which carries the CDP, will execute flights that go to waypoint "C", complete a spiral ascent into the cloud followed by several ascending and descending spirals through the cloud layer. If conditions permit, this will be followed by a porpoising flight pattern to capture spatial variability.
- HL2, which carries radiation and aerosol instrumentation, will complete a stairstep pattern near waypoint "C", featuring short horizontal legs separated by 200 m vertically.



Flight tracks for both aircraft types under a variety of atmospheric states. The yellow letters correspond to waypoint locations on the satellite map above.