ERASMUS: Campaign Summary and Highlights

Gijs de Boer[1,2], Dale Lawrence[1], Scott Palo[1], Brian Argrow[1], Gabe LoDolce[1], Nathan Curry[1], Will Finamore[1], Doug Weibel[1], Tevis Nichols[1], Phillip D'Amore[1], Ru-Shan Gao[2], Hagen Telg[1,2], Beat Schmid[3], Chuck Long[1,2], Mark Ivey[4], Al Bendure[4], Geoff Bland[5], Steven Borenstein[1], Jim Maslanik[1], Jack Elston[6], Terry Hock[7], Holger Vömel[7]

(1) University of Colorado Boulder (2) NOAA (3) Pacific Northwest National Laboratory (4) Sandia National Laboratories (5) NASA (6) BlackSwift Technologies (7) NCAR National Center for Atmospheric Research

Introduction

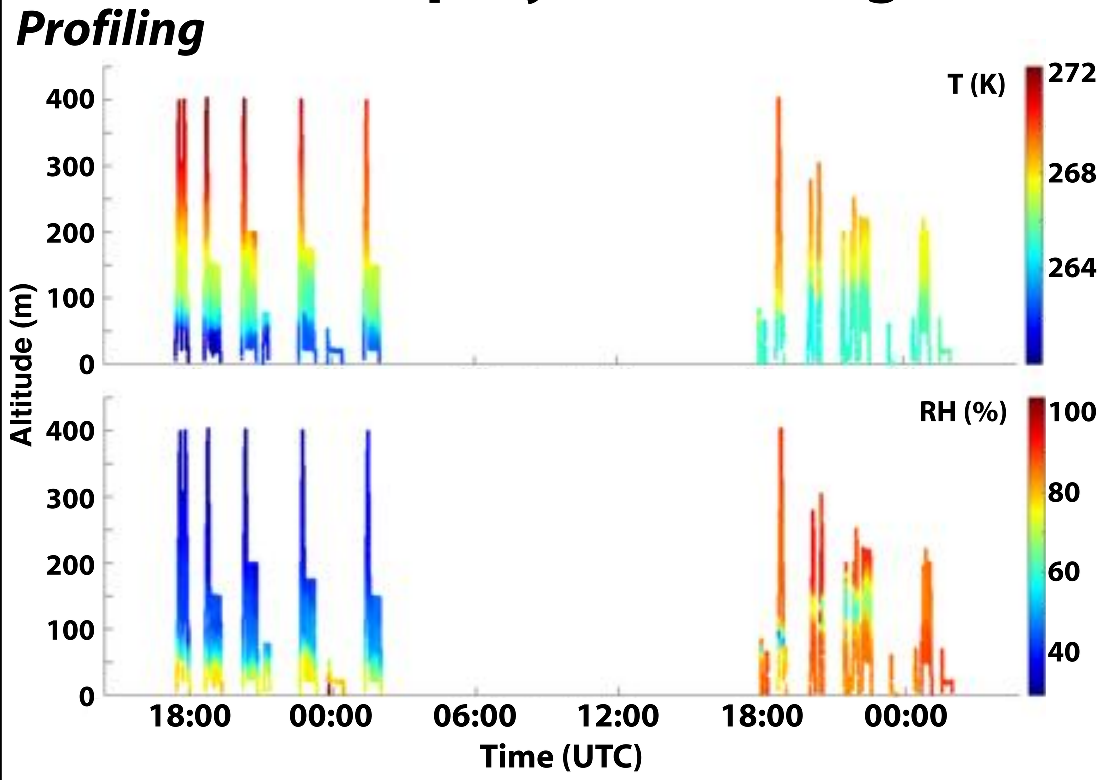
This poster presents information on unmanned-aircraft deployments to Oliktok Point, Alaska as part of the Evaluation of Routine Atmospheric Sounding Measurements using Unmanned Systems (ERASMUS) campaign.

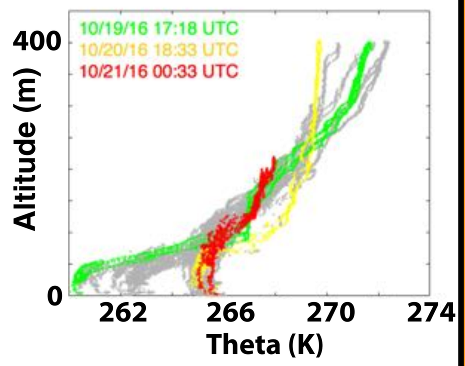
This includes an overview of the August, 2015 and October, 2016 deployments of the CU DataHawk2 aircraft. Over these two campaigns, data was collected on lower atmospheric thermodynamic structure, near-surface atmospheric fluxes, and surface temperature.

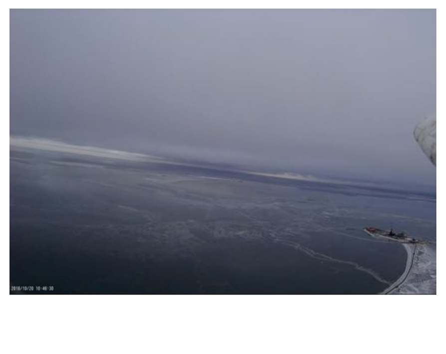
Additionally, we provide an overview on the CU Pilatus flights completed in April, 2016. The Pilatus was configured to fly with aerosol, radiation, and thermodynamic sensors. This aircraft was flown in three configurations: 1) Aerosol+thermodynamics, which includes the Printed Optical Particle Spectrometer (POPS) and NCAR-developed dropsonde sensors; 2) Aerosol+thermodynamics+broadband longwave, which includes everything in 1) in addition to up- and downward-looking Kipp and Zonen CGR4s, and 3) Aerosol+thermodynamics+broadband shortwave, which includes everything in 1) along with three Delta-T SPN-1 pyranometers and a high-accuracy IMU for attitude correction. Finally, we provide a summary of lessons learned from these flight campaigns, a summary of flights and weather conditions faced, ongoing evaluation of these data sets and their use in model evaluation, and a general summary of the ERASMUS effort.

DataHawk Deployments (Aug. 2015, Oct. 2016)

Profiling

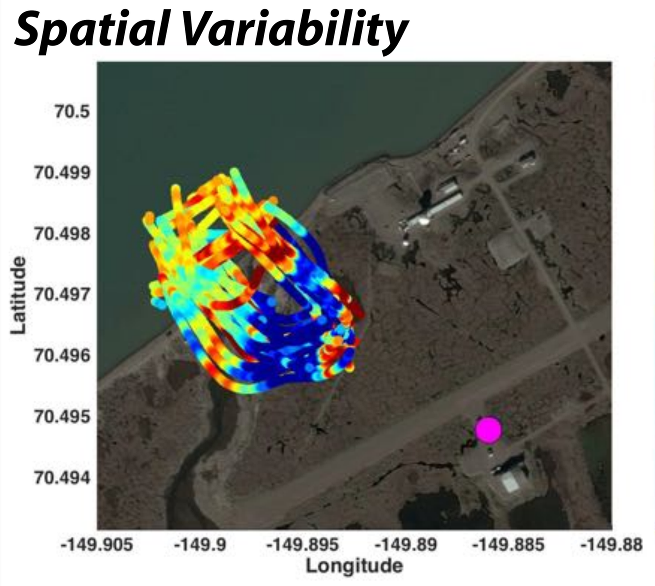


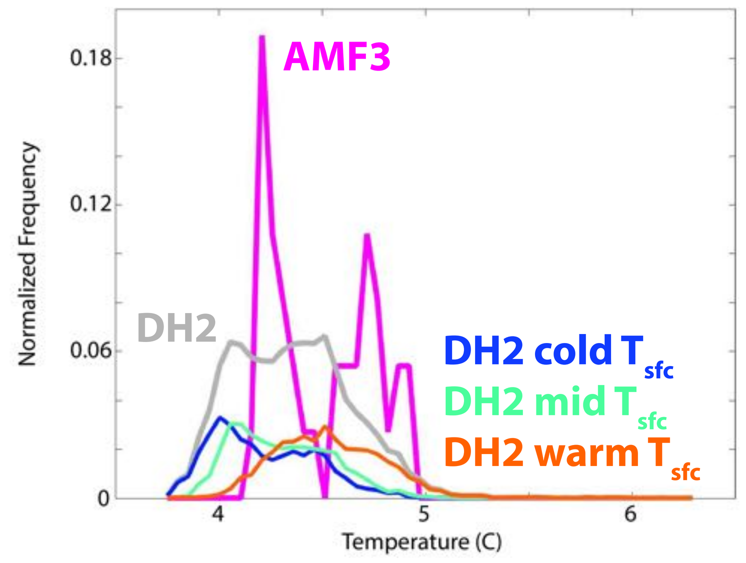




Temperature and relative humidity profiles from 10/2016. Note the stable boundary layer and its evolution over time under a transition from clear to cloudy conditions.

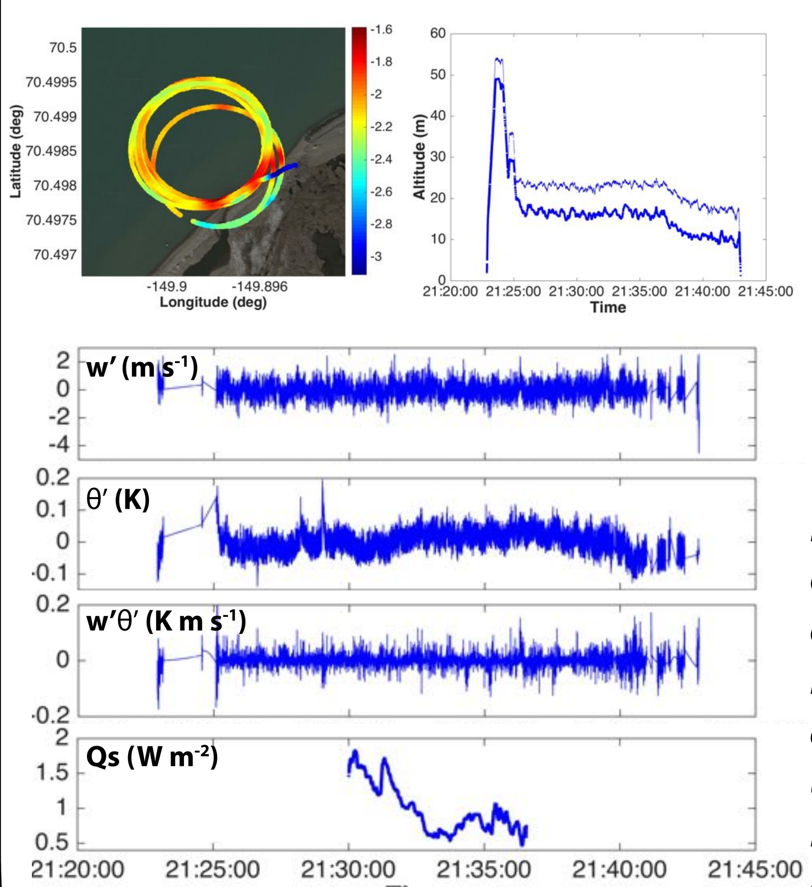
Spatial Variability

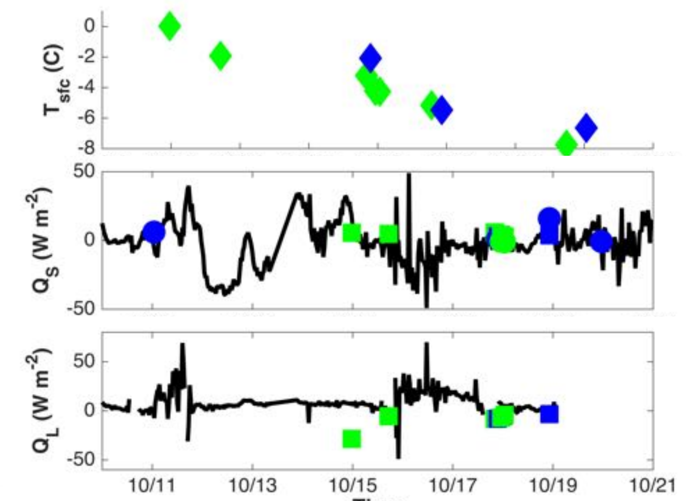




Left: Surface temperature measured during low-altitude flight. Tundra is slightly colder than water around it (ponds, river, ocean). Right: Near-surface air temperature distributions.

Turbulent Fluxes





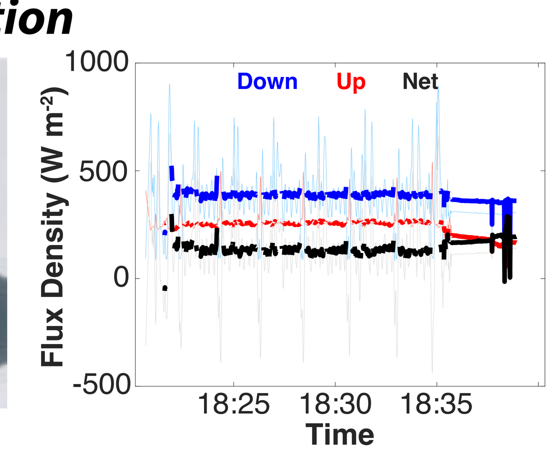
Left: An example flight targeting estimation of turbulent surface fluxes in the near-shore environment from 10/2016. Right: Comparison between Datahawk-derived sensible and latent heat fluxes and those measured by the Eddy-Covariance system at Oliktok Point from 10/2016. Both over-water (blue) and over-land (Green) flights are shown.

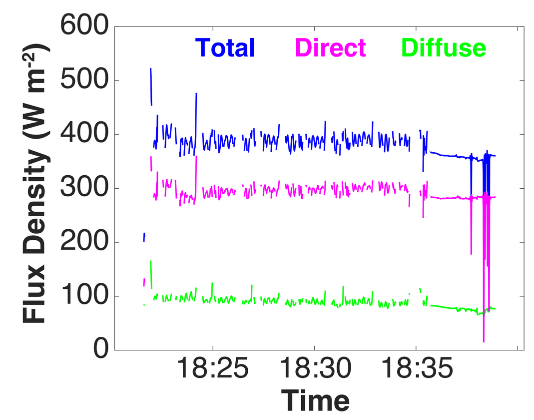
Platforms and Measurement Objectives

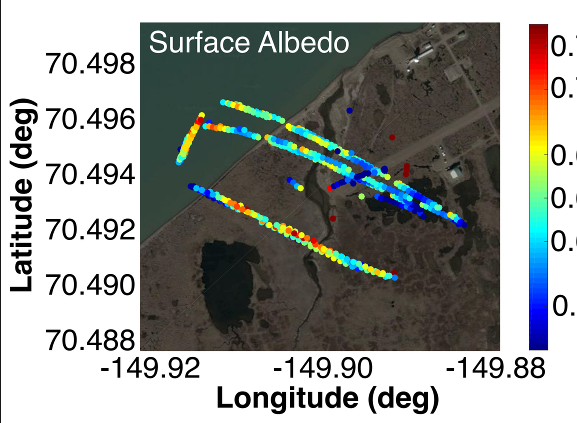
Aircraft	*Wingspan*	*Weight (empty)*	*Endurance*	*Measurement Capabilities*
CU DataHawk2	1 m	<1 kg	75 min	Temperature (fast from coldwire sensor + slow), humidity, wind estimate from local wind and aircraft state, pressure, IR surface and sky temperature, aircraft state
CU Pilatus	3.2 m	16 kg	25 min	Temperature (slow), humidity, pressure, aerosol size distribution (Gao et al., 2015), up/downwelling broadband shortwave irradiance (albedo), up/downwelling broadband longwave irradiance, aircraft state, auto-pilot-derived wind estimates

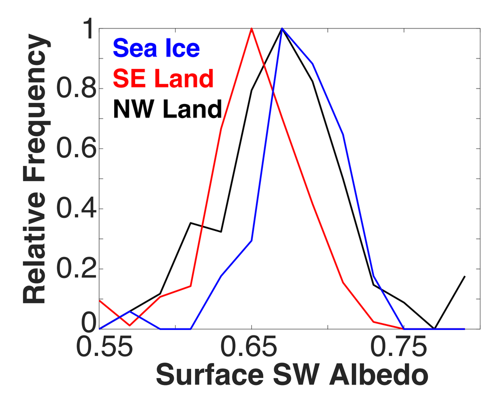
Pilatus Deployment (Apr. 2016)

Broadband Radiation

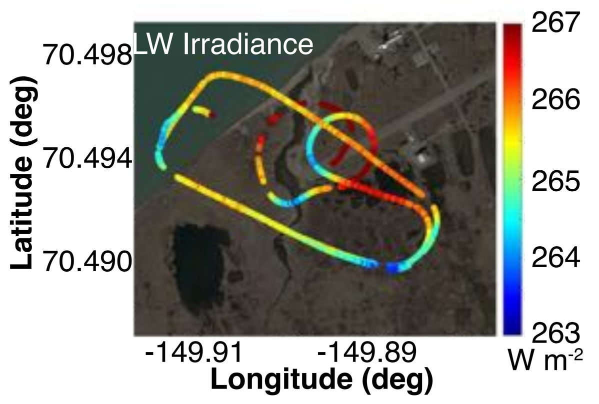






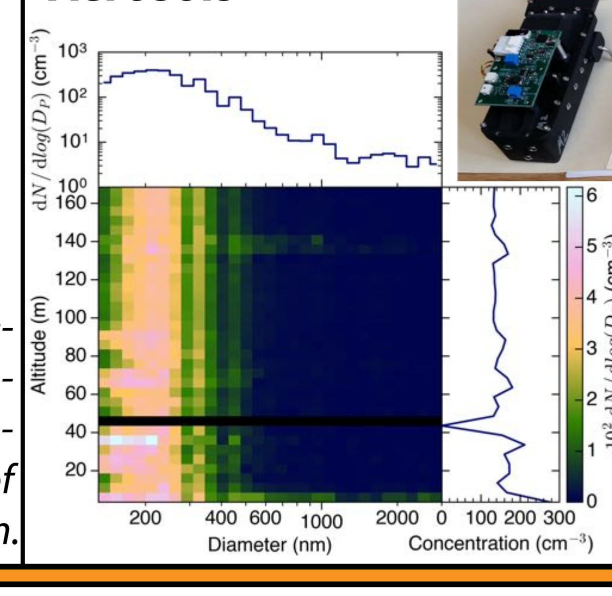


Delta-T SPN-1 pyranometers were deployed to measure broadband SW radiation and estimate surface albedo. Downwelling measurements were corrected using the technique from Long et al. 2009.



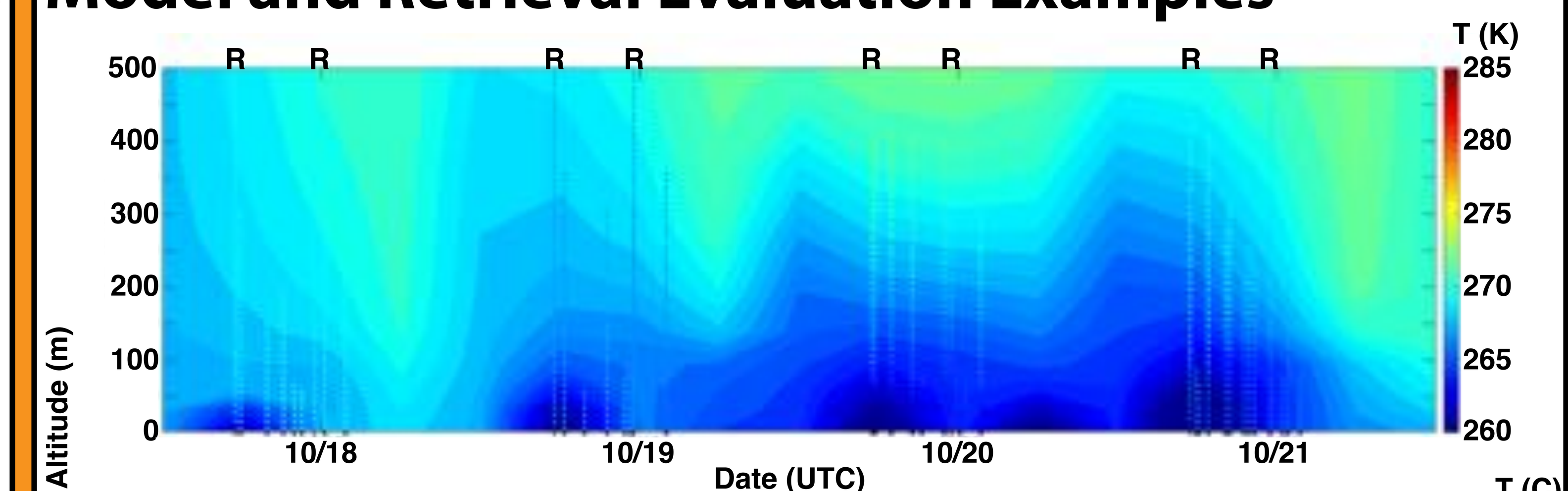
Kipp and Zonen CGR-4s were deployed to measure up- and downwelling LW irradiance. These sensors were found to have too slow of a response time for this application.

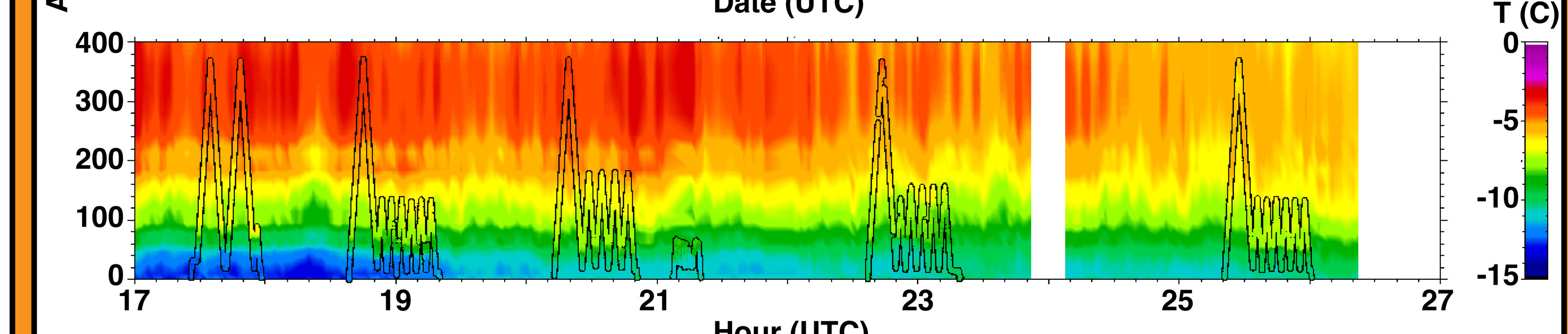
Aerosols



The Printed Optical Particle Spectrometer (POPS) was deployed on Pilatus to obtain profiles of aerosol size distribution.

Model and Retrieval Evaluation Examples

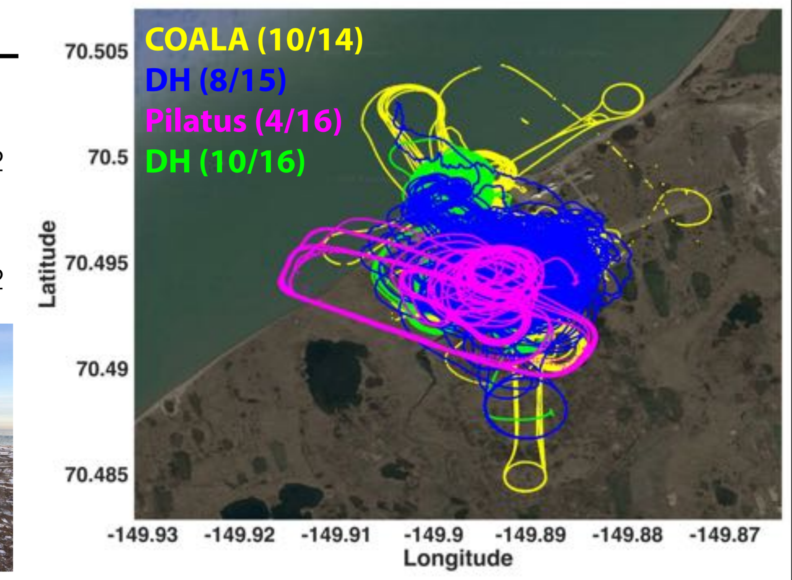




Temperature structure during October 2016 at Oliktok Point, as simulated by the Regional Arctic System Model (RASM) being used by NOAA PSD for sea ice forecasting. Dots represent DataHawk measurements and radiosonde measurements (denoted by "R"). The bottom figure shows DataHawk measurements plotted over the AERIoe retrieval of temperature.

Summary of Dates and Flights

Campaign	*Dates*	*Aircraft*
COALA	7-19 October, 2014	DataHawk
ERASMUS1	2-16 August, 2015	DataHawk2
ERASMUS2	2-16 April, 2016	Pilatus
ERASMUS3	10-22 October, 2016	DataHawk2

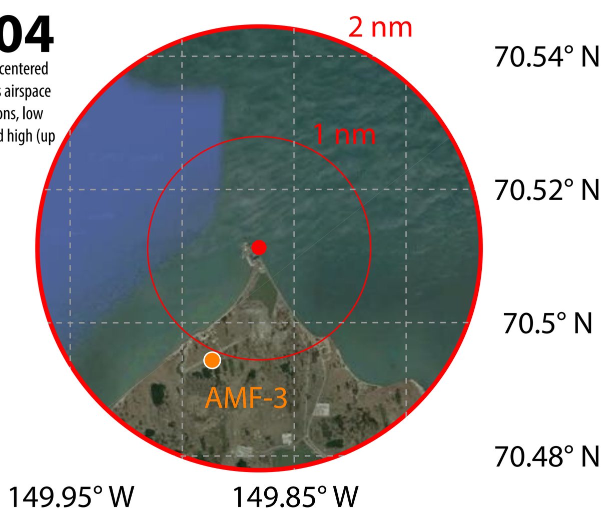


Details on the dates and flight patterns executed during each ERASMUS deployment. The photographs demonstrate some of the conditions faced by the flight crews.

Information on Airspace at Oliktok Point

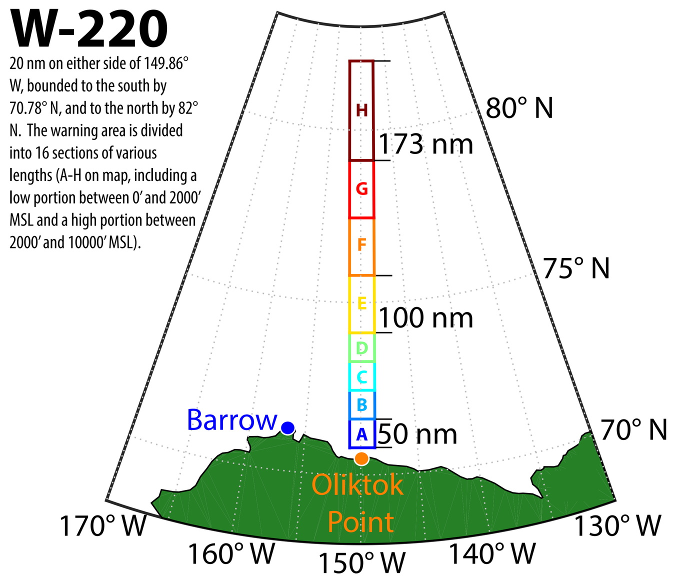
R-2204

4 nm diameter circle centered on Oliktok Point. This airspace is split into two sections, low (up to 1500' MSL) and high (up to 7000' MSL).



W-220

20 nm on either side of 149.86° W, bounded to the south by 70.78° N, and to the north by 82° N. The warning area is divided into 16 sections of various lengths (A-H on map, including a low portion between 0' and 2000' MSL and a high portion between 2000' and 10000' MSL).



Two areas of controlled airspace exist at Oliktok Point, including restricted area R-2204 and warning area W-220. ERASMUS was conducted entirely within R-2204.

Summary and Outlook

- Two different unmanned aircraft systems (CU DataHawk and CU Pilatus) were deployed to Oliktok Point, Alaska (OLI) over the course of three deployments to make measurements of the lower atmosphere and surface.

- OLI was found to be a challenging operating environment for unmanned aircraft. This was the result of two major issues: 1) Electromagnetic Interference resulting from the US Air Force Dew Line radar station, which impacted aircraft control systems and instrumentation; and 2) The weather conditions presented by the Arctic, which included a historically anomolous wind event (April 2016), cold temperatures, icing conditions, and low clouds and fog. While the weather conditions were not surprising, it is nearly impossible to prepare for them without experiencing them firsthand. The radar interference is a less well-understood issue that will likely impact systems operating at OLI in one way or another and its potential influence should be carefully weighed by operators.

- Despite the challenges, a substantial data was collected over a variety of seasons and meteorological regimes. We are beginning to analyze the datasets collected in order to improve our measurement capabilities and conduct scientific evaluation of surface fluxes, temperature structure, surface albedo and more.

- Knowledge gained through these deployments continues to be integrated into the ARM infrastructure through close collaboration with the ARM Aerial Facility (AAF) and the Tethered balloon team. Work conducted to improve the ability of the DataHawks to handle the radar interference has been integrated into the ARM-owned DataHawks

References

de Boer, G., M. D. Ivey, B. Schmid, S. McFarlane, and R. Petty (2016a), Unmanned platforms monitor the Arctic atmosphere, *EOS*, **97**, doi:10.1029/2016EO046441. Published on 22 February 2016.

de Boer, G., S. E. Palo, B. Argrow, G. LoDolce, J. Mack, R.-S. Gao, H. Telg, C. Trussel, J. Fromm, C. N. Long, G. Bland, J. Maslanik, B. Schmid, and T. Hock (2016b), The Pilatus Unmanned Aircraft System for Lower Atmospheric Research. *Atmos. Meas. Tech.*, **9**, 1845-1857.

Long, C.N., A. Bucholtz, H. JHonsson, B. Schmid, A. Vogelmann and J. Wood (2009): A method for correcting for tilt from horizontal in downwelling shortwave irradiance measurements on moving platforms, *Open. Atmos. Sci. J.*, **4**, 78-87.

Acknowledgements

This work was supported by the US DOE Atmospheric Systems Research (ASR) and Atmospheric Radiation Measurement (ARM) Programs. Additional support was provided by the National Center for Atmospheric Research (NCAR), the University of Colorado and the National Oceanographic and Atmospheric Administration (NOAA). All campaign data are publically available via the ARM data portal.