The Use of Small Unmanned Aircraft to Study High Latitude Boundary Layers

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The ERASMUS Campaign

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- Additional support from a wide variety of organizations, including NOAA Chemical Sciences Division (CSD), the National Center for Atmospheric Research (NCAR) and the Cooperative Institute for Research in Environmental Sciences (CIRES)
Deployment Location

Barrow 265 km Oliktok Point

Point Hope

Brooks Range

AMF-3

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).

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de Boer et al., 2016a
The DataHawk 2

DataHawk2

Description:
1 m wingspan
~800 g total weight
~$850 vehicle parts cost
15-20 m s\(^{-1}\) typical airspeed
75 min flight duration (level)
~70 km range (level)
~4 km max altitude (powered)

Measurement Capabilities
- Temperature
- Relative Humidity
- Pressure
- 3D wind vector estimate
- IR Surface Temperature
- Location
Atmospheric Profiling

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Turbulent Fluxes

Sensible Heat Flux

\[ H_s = \rho_a c_{pa} \overline{w'T'} = -\rho_a c_{pa} u_* T_s \]

\[ H_s = \rho_a c_{pa} C_h S (T_s - \theta) \]

Considerations:
- If interested in surface heat fluxes, are we operating in the surface layer?
- What is the response time of sensors used, and what sort of response time is required given the fact that we are sampling from a moving platform?
- How well can we estimate wind speed in both the horizontal and vertical components?
- What is the level of spatial heterogeneity of the surface and can we characterize this adequately?
Turbulent Fluxes: Eddy Covariance

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Turbulent Fluxes: Bulk

\[ H_s = \rho_a c_{na} C_h S(T_s - \theta) \]
Turbulent Fluxes: Bulk

\[ H_s = \rho_a c_{pa} C_h S (T_s - \theta) \]
Aerosols and Radiation

Long et al., 2009  de Boer et al., 2016b

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Aerosols and Radiation

[Graph showing flux density over time with labels for Down, Up, and Net]

[Map showing latitude and longitude with color scale for W m\(^{-2}\)]

Long et al., 2009
de Boer et al., 2016b

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Aerosols and Radiation

Gao et al., 2016
Summary

- We are using a variety of unmanned aircraft to understand Arctic boundary layers processes.

- We have operated the small, lightweight DataHawk 2 UAS in Alaska to evaluate thermodynamic structure and heat and moisture fluxes.

- We are interested in observing both turbulent surface fluxes as well as fluxes at layer interfaces (e.g. between surface layer and cloud-driven mixed layer).

- We have additionally operated the larger Pilatus UAS to obtain information on lower atmospheric aerosol particles and radiation.

- Various agencies (e.g. DOE, NOAA, NASA) are actively pursuing development of unmanned aircraft capabilities for community use.
Acknowledgments and References

Funding/Support:

References:

CU Pilatus

Delta-T SPN-1 (Broadband Shortwave)
- 0.4-2.700 μm
- < 200 ms response time
- 140 mm x 100 mm, 940 g
- Pilatus will fly with three SPN-1s — up and down unshielded, and upward looking with shielding pattern to separate between direct and diffuse radiation for aircraft attitude correction (See Long et al., 2009 for details on the correction)

Kipp and Zonen CGR4 (Broadband Longwave)
- 4.5-42 μm
- 18 s response time (95%)
- 79 mm x 72.5 mm, 600 g
- 180 degree FOV
- Pilatus will fly with two CGR4s — up and down looking

Printed Optical Particle Spectrometer (POPS)
- Developed by Ru-Shan Gao and colleagues (NOAA ESRL Chemical Sciences Division, Gao et al., 2016)
- Provides aerosol size distributions for particles between 140-3000 nm
- Inlet and tubing to be heated in order to provide dry size distributions and prevent icing
- Approximately 1 kg total weight, including battery (~800 g total), requires ~3 W of power
- Approximate dimensions: 15x10x7.6 cm (spectrometer), 13x10x2.5 (electronics)
- Weather balloon deployable