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Boundary-layer measurements and surface fluxes in the Canadian Arctic at Eureka observatory

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The NOAA Arctic Atmospheric Observatory Program

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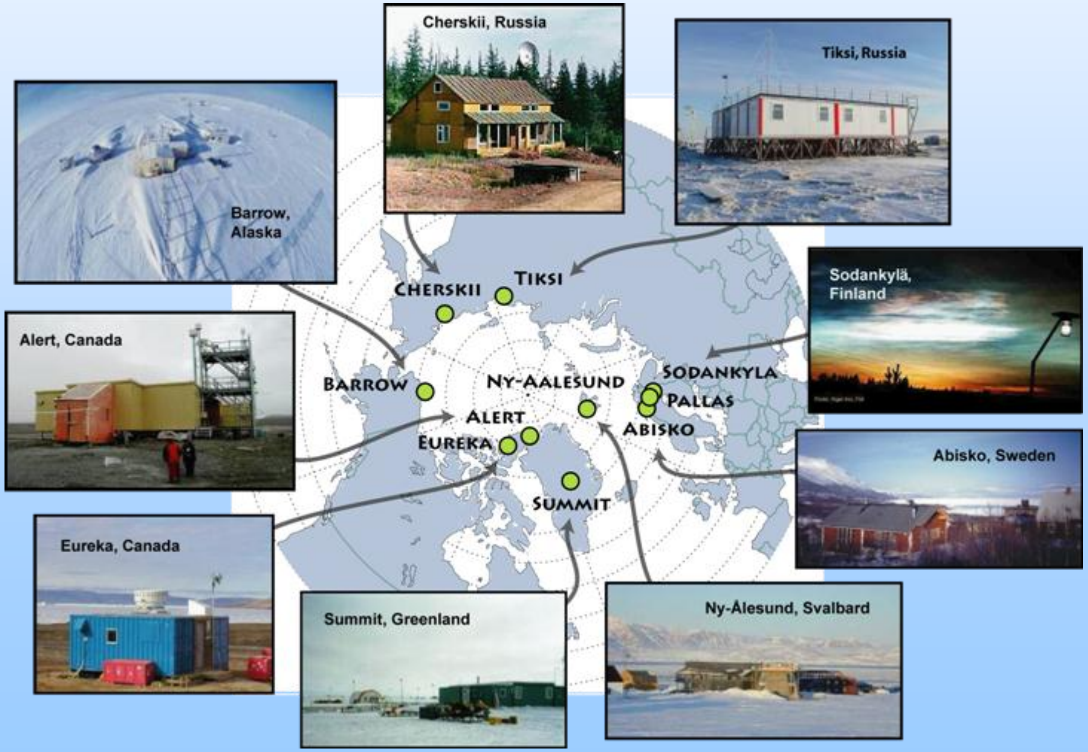
The interagency Study of Environmental Arctic Change (SEARCH) program has been conceived as a broad, interdisciplinary, multiscale program with a core aim of understanding the recent and ongoing, decadal, pan-Arctic complex of interrelated changes in the Arctic. These changes include, among other things, a decline in sea level atmospheric pressure, an increase in surface air temperature, cyclonic ocean circulation, and a decrease in sea ice cover. NOAA is one of eight federal agencies participating in the implementation of SEARCH. The primary observation sites are Alert and Eureka, Canada; Barrow, USA; Tiksi, Russia; Ny-Ålesund, Norway; and Summit, Greenland.



Eureka observatory, Canada

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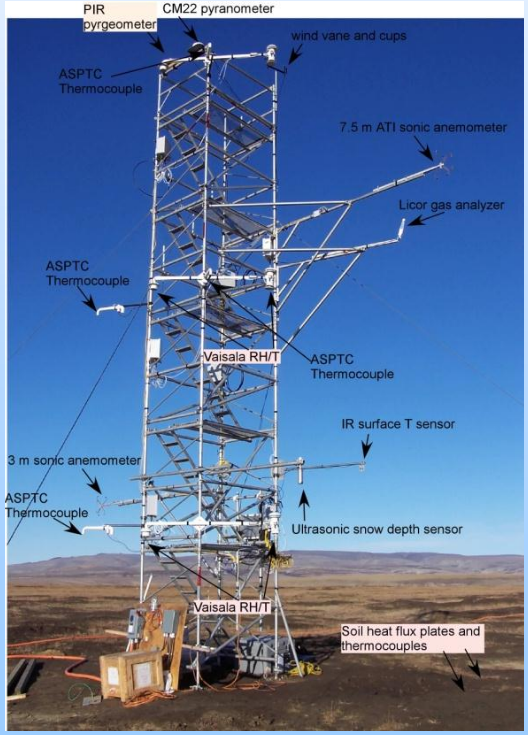
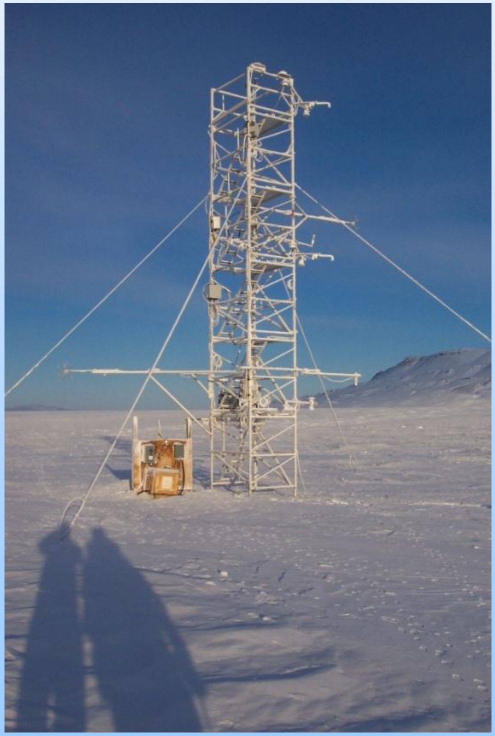
Eureka site (80.0 N, 85.9 W) is a long-term research observatory near the coast of the Arctic Ocean (Canadian territory of Nunavut). Eureka was established in 1947 as part of Arctic weather stations network and currently has been identified for enhanced instrumentation to monitor the changing Arctic climate. Beginning in 2004, remote sensors and in-situ instrumentation were installed at Eureka in framework of the SEARCH Program. Turbulent fluxes and mean meteorological data are continuously measured and reported hourly at various levels on a 10-m flux tower. Sonic anemometers are located at 3 and 8 m heights while high-speed Licor 7500 infrared gas analyzer (H_2O and CO_2) at 7.5 m height. Turbulent fluxes are based on the eddy-covariance technique. The thermal profile is measured by several slow T/RH sensors and differential temperature pairs at 2, 5 and 10 m heights. Surface characteristics are measured by thermal soil probes, an infrared surface temperature sensor, and a sonic snow-depth sensor.





Eureka (summer)

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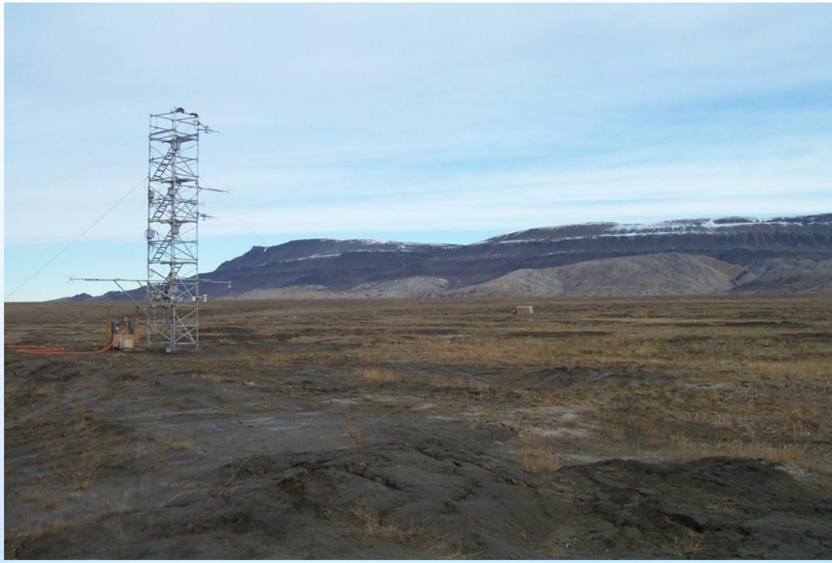

Eureka (winter)

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Seasonal Cycle of Radiative Fluxes at Eureka
2009 - 2010

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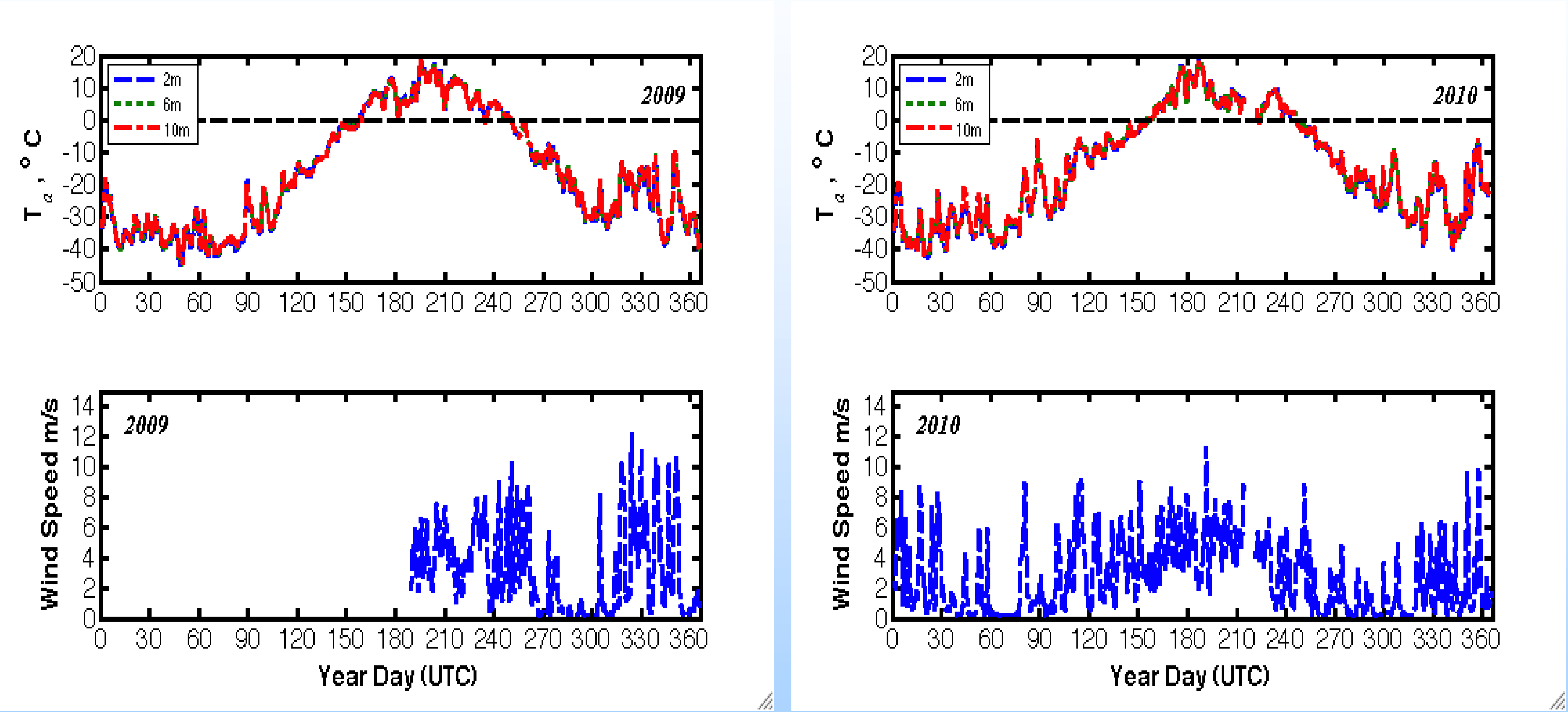

Annual cycles of daily averaged air temperature, measured at 2, 6, 10 m at the Eureka Flux Tower by Type-E Thermocouple/Campbell ASPTC-L and wind speed, measured at 10.5 m by RM Young Sentry anemometer.

Typical Surface-Layer Turbulence Spectra and Cospectra
(wind speed and sonic temperature)

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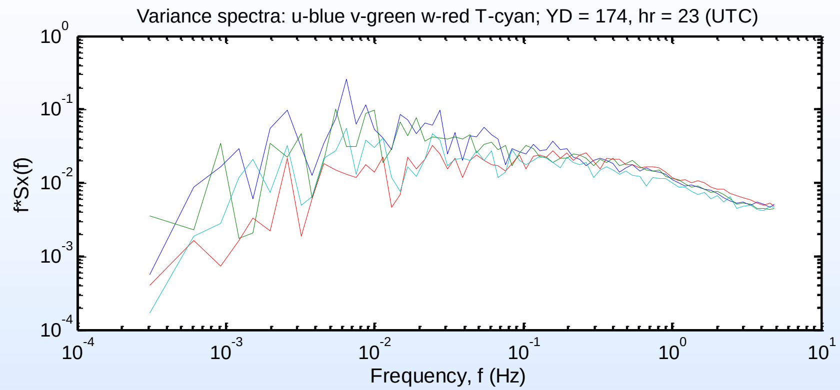

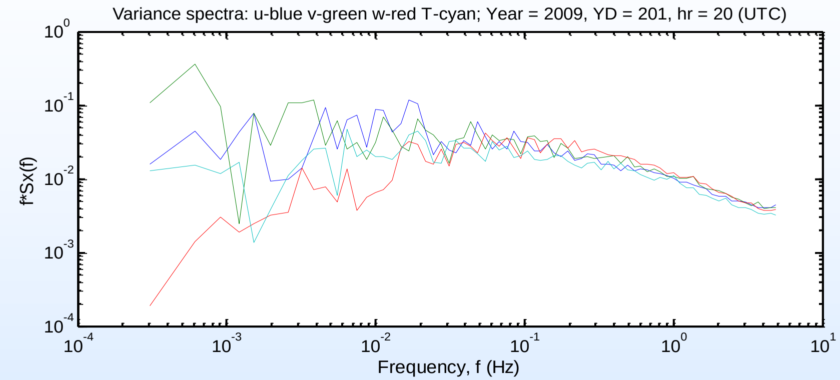

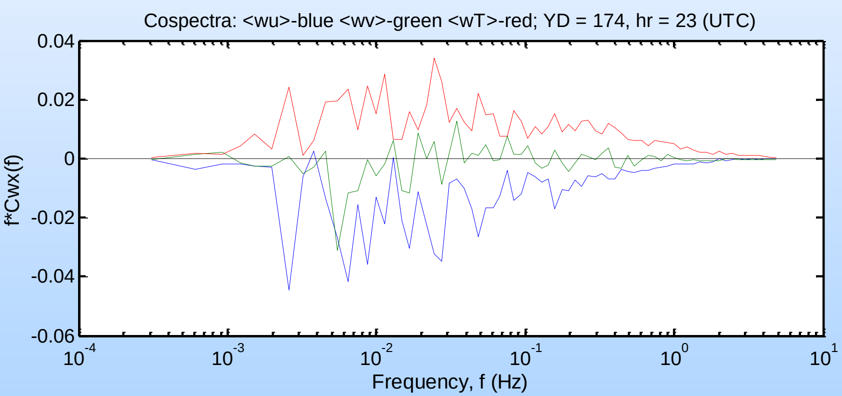

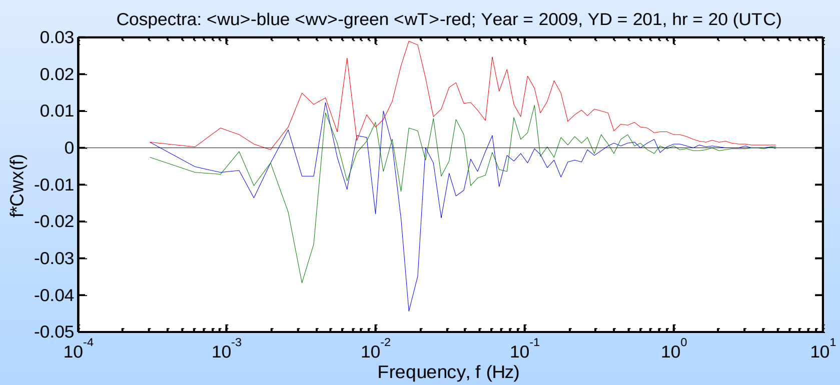

Typical raw spectra of the longitudinal, lateral, and vertical wind components and the sonic temperature (upper panel) and cospectra of the downwind and crosswind spectra and cospectra of the sonic temperature flux (bottom panel) measured at 8m during June 24, 2008, 23:00 UTC. Results show that the turbulent spectral curves have a wide inertial subrange, which obeys the Kolmogorov power law with slope close to −2/3 at high frequencies.

Typical raw spectra of the longitudinal, lateral, and vertical wind components and the sonic temperature (upper panel) and cospectra of the downwind and crosswind spectra and cospectra of the sonic temperature flux (bottom panel) measured at 3m during July 20, 2009, 20:00 UTC. Results show that the turbulent spectral curves have a wide inertial subrange, which obeys the Kolmogorov power law with slope close to −2/3 at high frequencies.

Water Vapor and Carbon Dioxide Flux Cospectra (Licor-7500)

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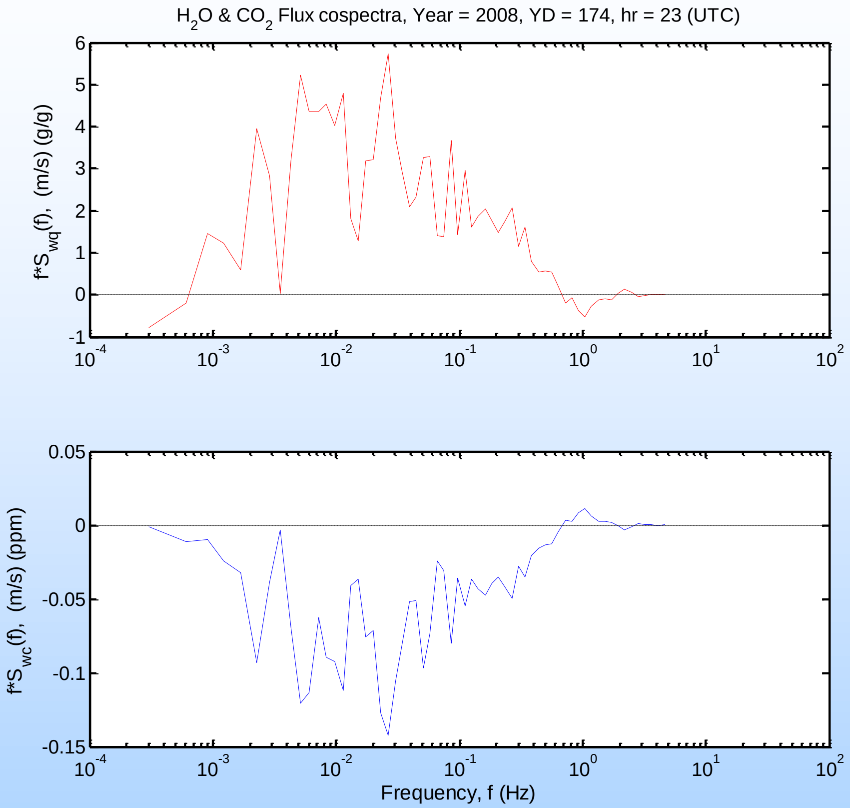

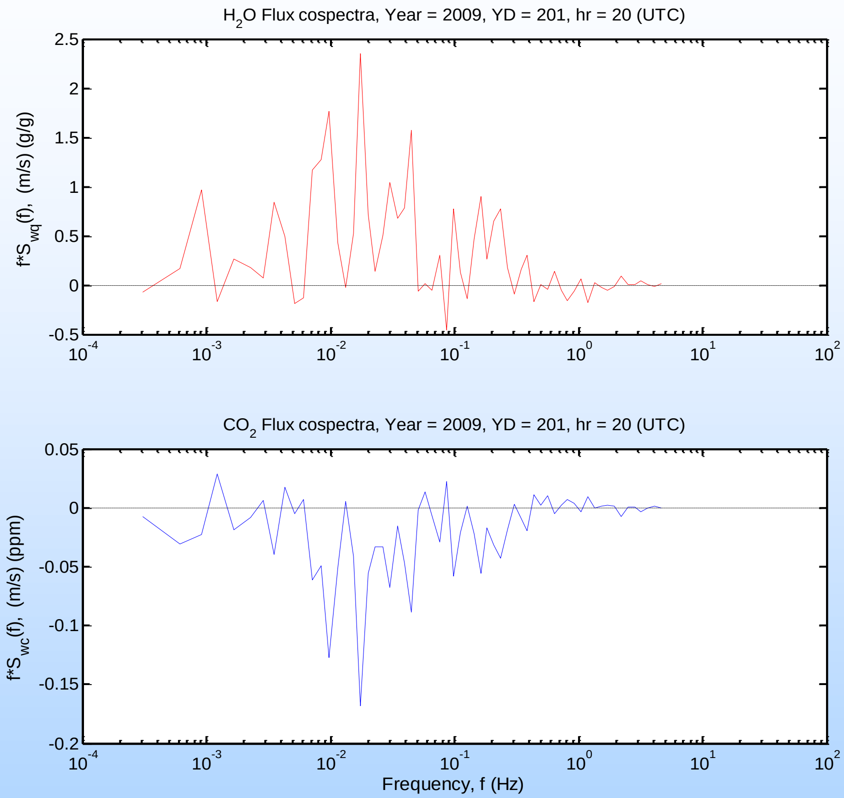

Typical raw cospectra of the H_2O (upper panel) and CO_2 (bottom panel) fluxes measured during June 24, 2008, 23:00 UTC (U = 4.32 m/s, T_a = 12.9 ºC, U_* = 0.28 m/s, H_s = 101.21 W/m^2). Turbulent fluxes are based on one-hour averaging and they were derived through frequency integration of the appropriate cospectra. H_2O flux is upward and CO_2 flux is downward.

Typical raw cospectra of the H_2O (upper panel) and CO_2 (bottom panel) fluxes measured during July 20, 2009, 20:00 UTC (U = 3.24 m/s, T_a = 18.7 ºC, U_* = 0.23 m/s, H_s = 102.21 W/m^2). Turbulent fluxes are based on one-hour averaging and they were derived through frequency integration of the appropriate cospectra. H_2O flux is upward and CO_2 flux is downward.

2008 Time Series of the Turbulent Fluxes

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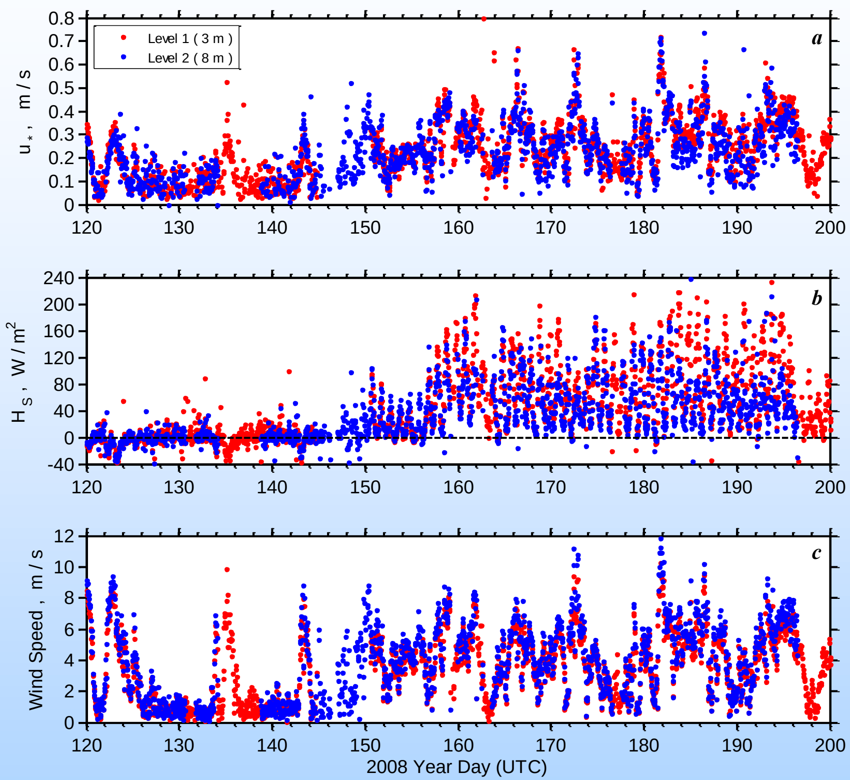

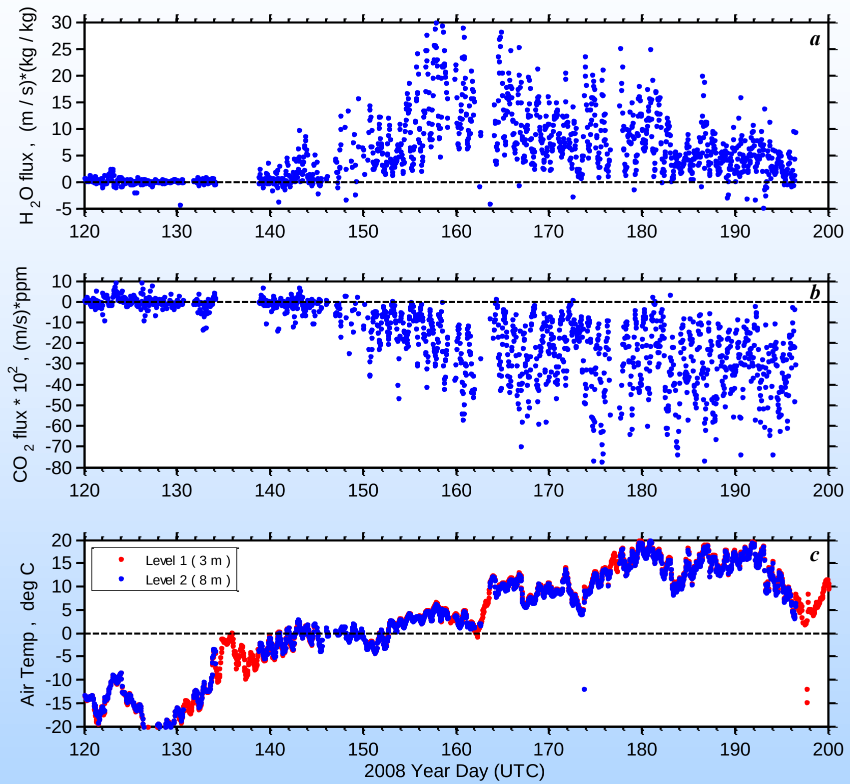

Time series of the hourly averaged (*a*) friction velocity, (*b*) sensible heat flux (H_s), and (*c*) wind speed for the Eureka site obtained during May-July 2008 (YD 120-200). Measurements were made by sonic anemometers located at 3 and 8 m above the surface. Positive values of H_s correspond to the unstable (convective) conditions and vice versa. Hourly averages of the sensible heat flux show large diurnal variations during summer.

Time series of the hourly averaged fluxes of (*a*) H_2O, (*b*) CO_2, and (*c*) air temperature for the Eureka site obtained during May-July 2008 (YD 120-200). Measurements were made by sonic anemometers and Licor-7500. Negative signs mean downward fluxes and vice versa. Hourly averages of the fluxes and air temperature show large diurnal variations during summer.

2009 Time Series of the Turbulent Fluxes

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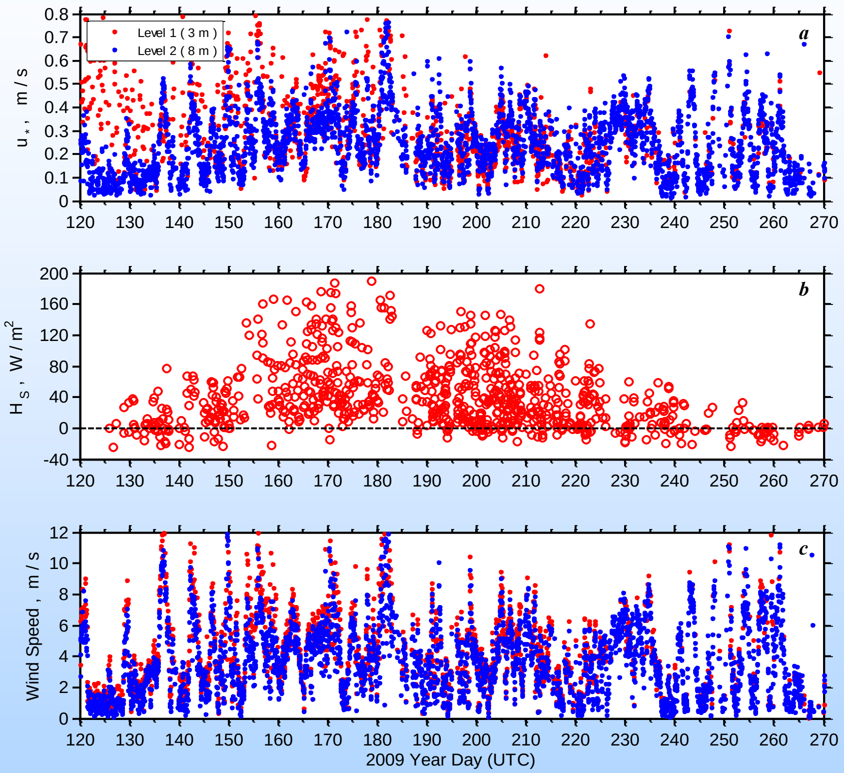

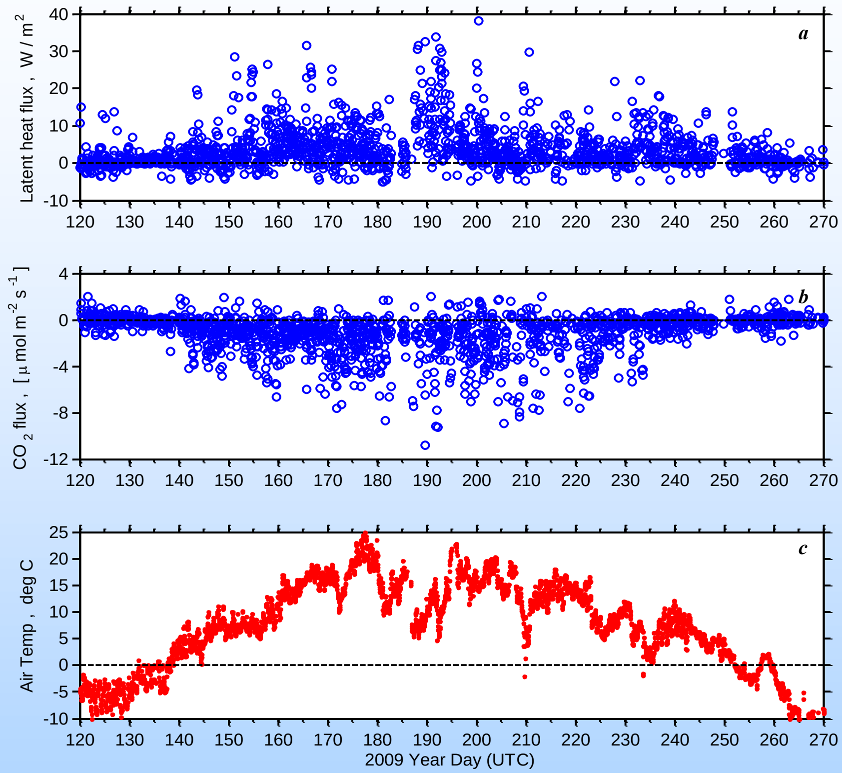

Time series of the hourly averaged (*a*) friction velocity, (*b*) sensible heat flux (H_s), and (*c*) wind speed for the Eureka site obtained during May-September 2009 (YD 120-270). Measurements were made by sonic anemometers located at 3 and 8 m above the surface. Positive values of H_s correspond to the unstable (convective) conditions and vice versa. Hourly averages of the sensible heat flux show large diurnal variations during summer.

Time series of the hourly averaged fluxes of (*a*) H_2O, (*b*) CO_2, and (*c*) air temperature for the Eureka site obtained during May-September 2009 (YD 120-270). Measurements were made by sonic anemometers and Licor-7500. Negative signs mean downward fluxes and vice versa. Hourly averages of the fluxes and air temperature show large diurnal variations during summer.

2010 Time Series of the Turbulent Fluxes

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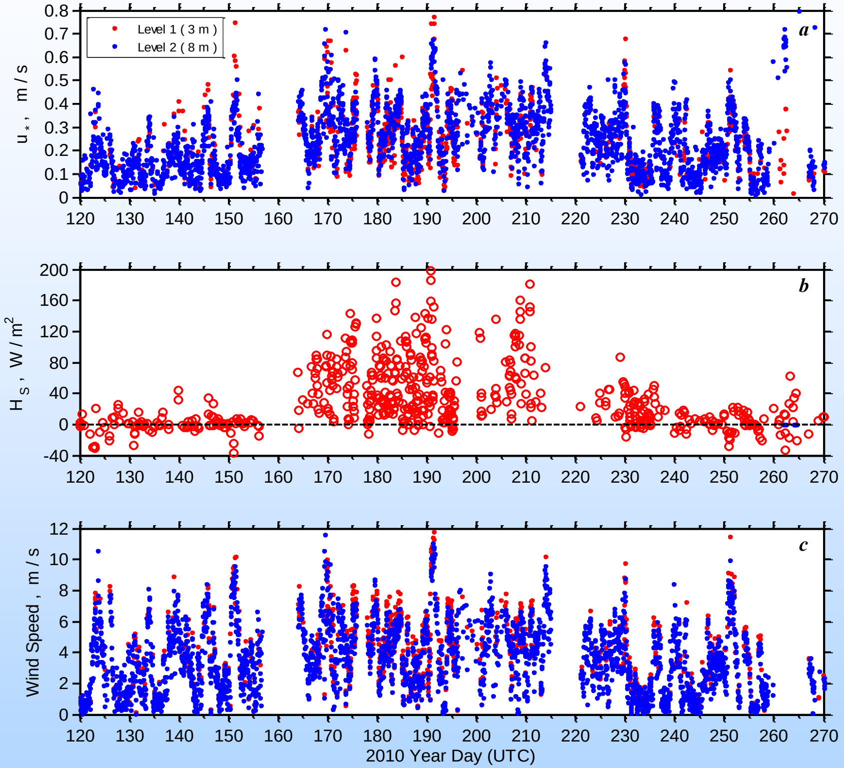
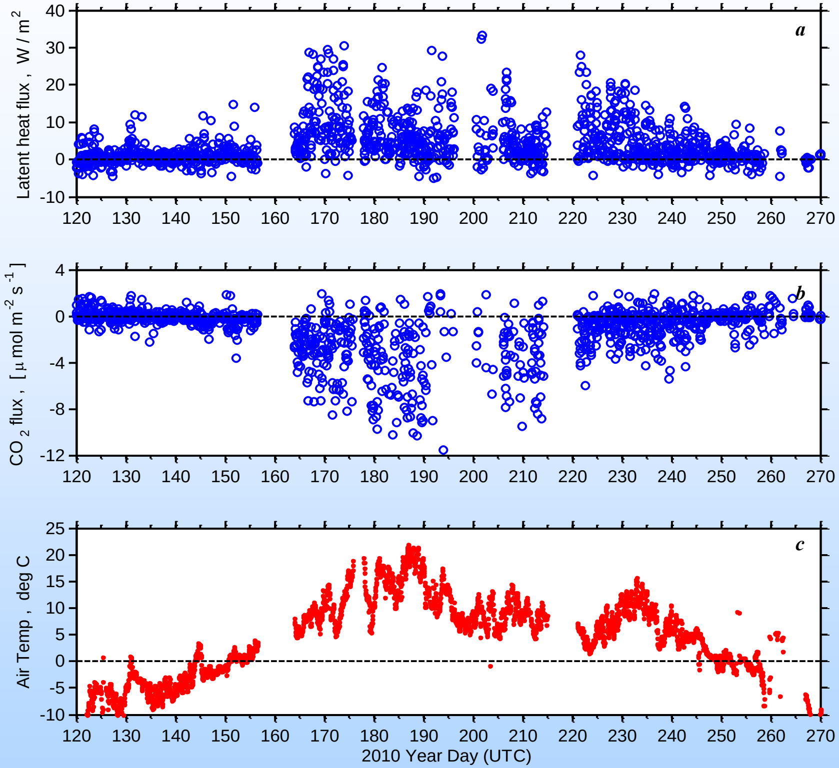


Time series of the hourly averaged (*a*) friction velocity, (*b*) sensible heat flux (H_s), and (*c*) wind speed for the Eureka site obtained during May-September 2010 (YD 120-270). Measurements were made by sonic anemometers located at 3 and 8 m above the surface. Positive values of H_s correspond to the unstable (convective) conditions and vice versa. Hourly averages of the sensible heat flux show large diurnal variations during summer.



Time series of the hourly averaged fluxes of (*a*) H_2O, (*b*) CO_2, and (*c*) air temperature for the Eureka site obtained during May-September 2010 (YD 120-270). Measurements were made by sonic anemometers and Licor-7500. Negative signs mean downward fluxes and vice versa. Hourly averages of the fluxes and air temperature show large diurnal variations during summer.

Seasonal Cycle of Radiative Fluxes at Eureka
2009 - 2010

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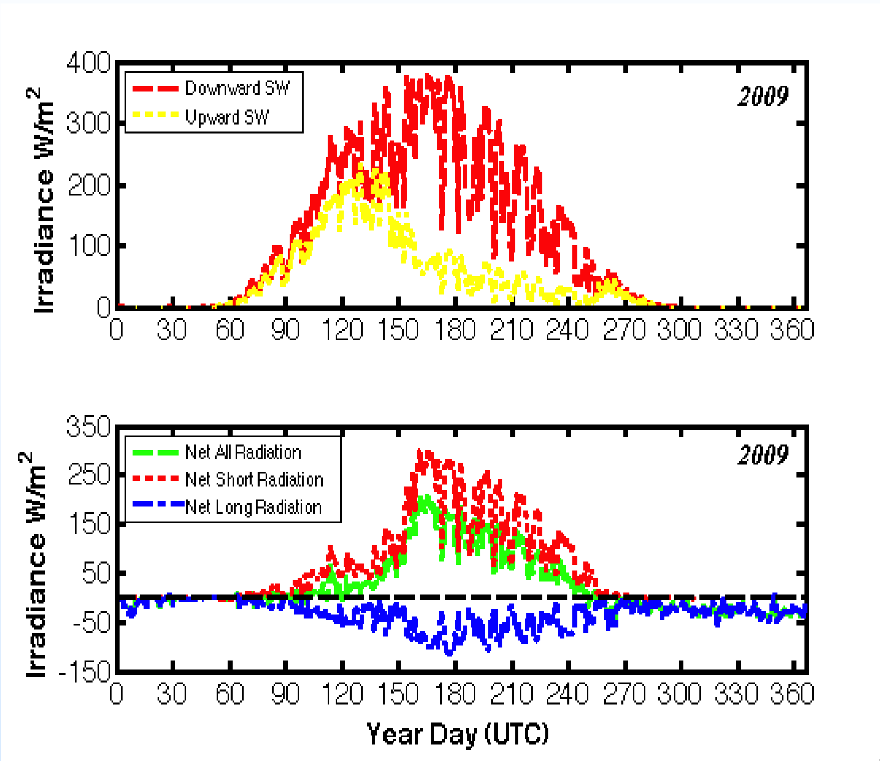

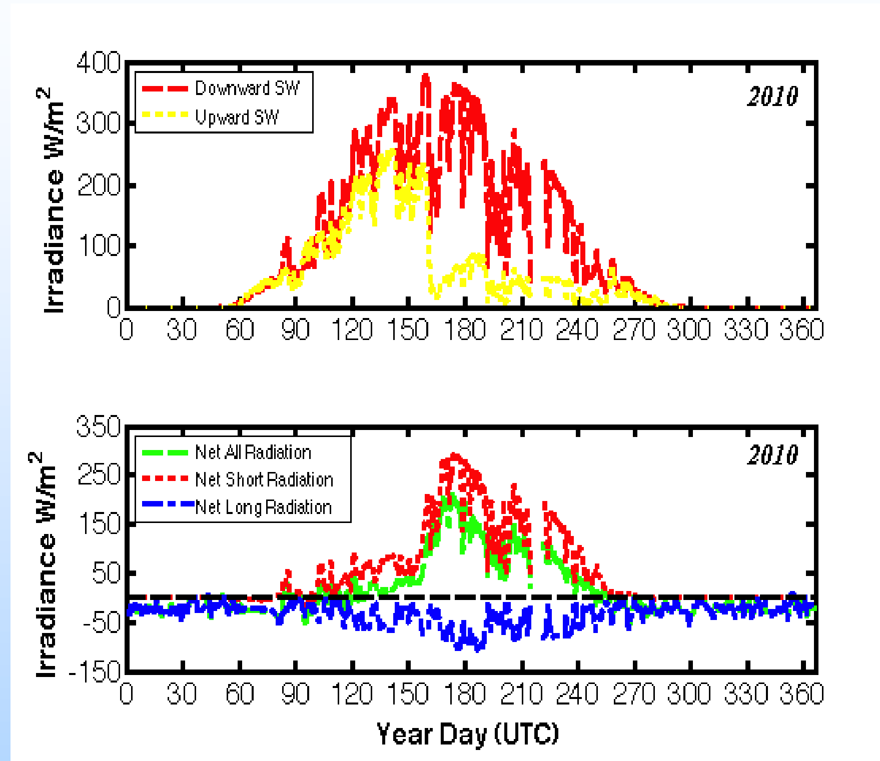

Annual cycles of the daily averaged short-wave radiation (Kipp&Zonen CM22) and the net radiative energy, measured at the Eureka Flux Tower during 2009 (left) and 2010 (right). Long-wave radiation component was measured by Eppley PIR.

Albedo, Soil Heat Flux, Snow Depth and Active Layer Temperatures (2009 – 2010)

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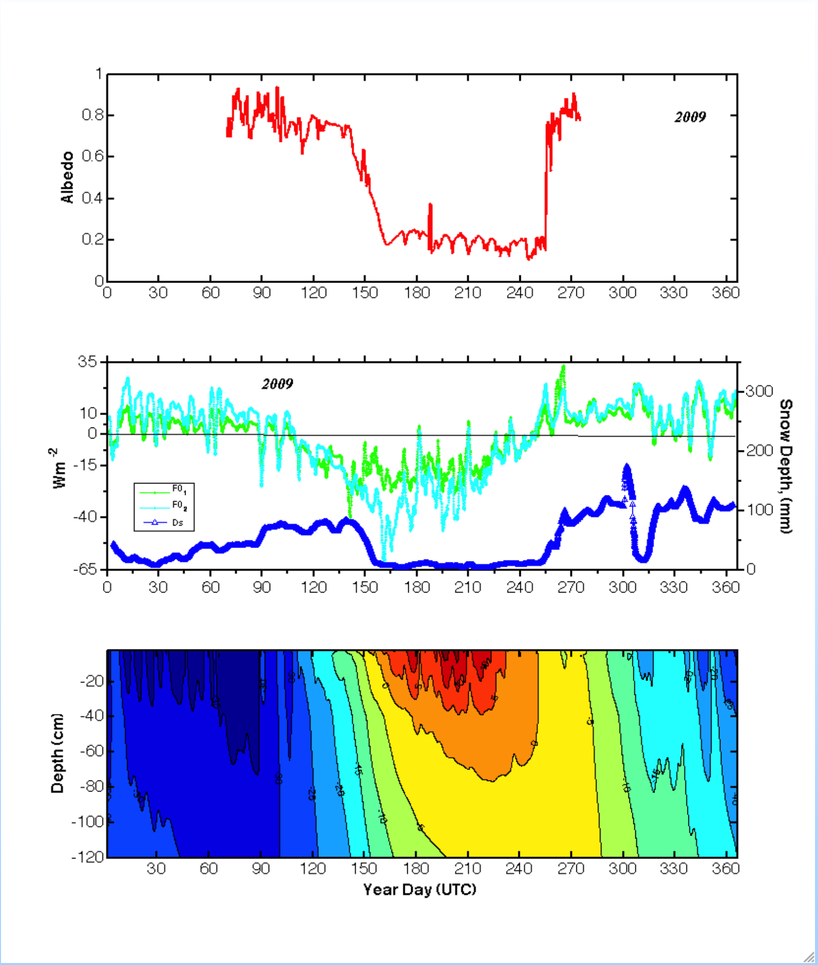

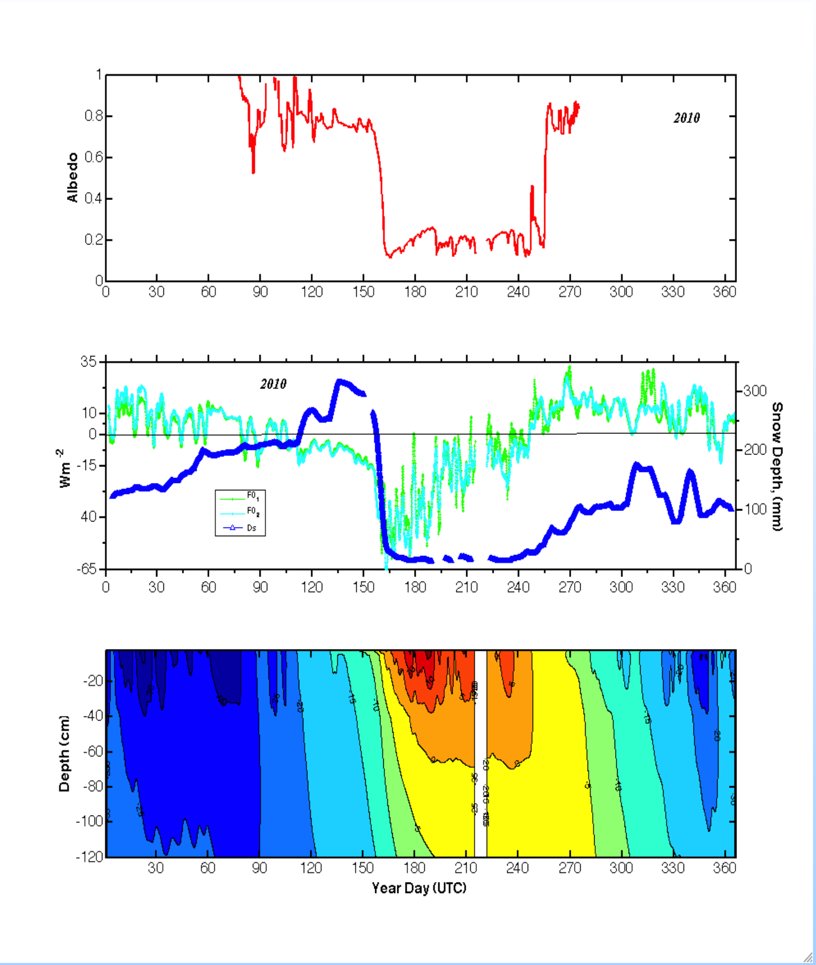

Annual cycles of daily averaged albedo (SWU/SWD); snow depth (5 days averages) (sonic ranging sensor) and daily averaged soil heat flux, plate 1 (placed in the grass area) and plate 2 (placed in raised mud). Contour plot of the daily averaged near surface soil and active layer temperatures, measured at the 11 levels (2, 5, 10, 15, 20, 25, 30, 45, 70, 95, 120 cm) below the surface (PRT sensor PT100/MRC soil probe).

Conclusions

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• This study analyzes and discusses turbulent fluxes including carbon dioxide flux data collected in Canadian Arctic at Eureka observatory (80.0 N, 85.9 W) during 2007-2010;

• The data show that the turbulent fluxes increase rapidly upon air temperatures rise above freezing during spring melt and eventually reach a summer maximum. According to our data, strong upward sensible and latent (water vapor) heat fluxes observed during summer months. This indicates unstable (convective) conditions on average. This study shows that the sensible heat flux, water vapor, and carbon dioxide fluxes exhibited clear diurnal cycles in Arctic summer. This behavior of the sensible heat flux is similar to the diurnal variations in mid-latitudes in summer.;

• It was found that on average the turbulent flux of carbon dioxide was mostly negative (uptake by the surface) in summer, i.e. the Eureka site was a net sink for atmospheric CO_2 during the growing seasons. During late summer and early autumn all turbulent fluxes rapidly decreases in magnitude when the air temperature decreases and falls below freezing;

• It is also found that in a summer period observed temporal variability of the carbon dioxide flux was generally in anti-phase with water vapor flux (downward CO_2 flux and upward H_2O flux);

• However the data show that sensible heat flux, water vapor and carbon dioxide fluxes were small and mostly irregular in the cold seasons while the ground remained completely covered with snow.

Questions?

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