Annual Cycles of Radiative Energy Fluxes in Eureka, Canada

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The Surface Energy Budget Equations

The thermodynamic exchange of heat and energy between the Arctic atmosphere and the surface is characterized by a set of equations composed of multiple terms that quantify the complex processes involved. The individual terms can be measured directly by using combinations of standard meteorological sensors . This has led to the installation of a number of micrometeorological (flux) towers in the Arctic region. The individual terms which represent the processing presented in this poster are highlighted in yellow below.

Surface Energy Budget (SEB)

1. Atmospheric energy flux at the surface (snow, ice, or soil), F_{atm}

$$F_{atm} = Q_{si} - Q_{so} + Q_{li} - Q_{lo} - H_s - H_l = SW_{net} + LW_{net} - H_{turb}$$

where Q_{si}, Q_{so}, Q_{li}, and Q_{lo} - incoming/outgoing shortwave/longwave radiative fluxes
H_s, H_l - turbulent sensible/ latent heat fluxes (COARE scheme with SHEBA z_0 for snow)

2. Energy flux needed to remove (heat and melt) fallen snow, F_{sm}

$$F_{sm} = [(L_f) + (C_{ps}\,\Delta T/\Delta t)]\,)(\rho_s)(D_s)$$
$$= [(3.34 \times 10^5\ \mathrm{J\,kg^{-1}}) + (2106\ \mathrm{J\,K^{-1}kg^{-1}})(30\ \mathrm{K}\ (6\ \mathrm{mos})^{-1})](0.25 \times 10^3\ \mathrm{kg\,m^{-3}})(0.57\ \mathrm{m})$$
$$= 2.1\ \mathrm{W\,m^{-2}}$$

where D_s - snow depth; ρ_s - snow density (250 kg m^{-3}); L_f - latent heat of fusion; $\Delta T/\Delta t$ - rate of change of snow temperature (30 K/(6 mos)); C_{ps} specific heat of snow

3. Energy flux into our out of soil, F_0

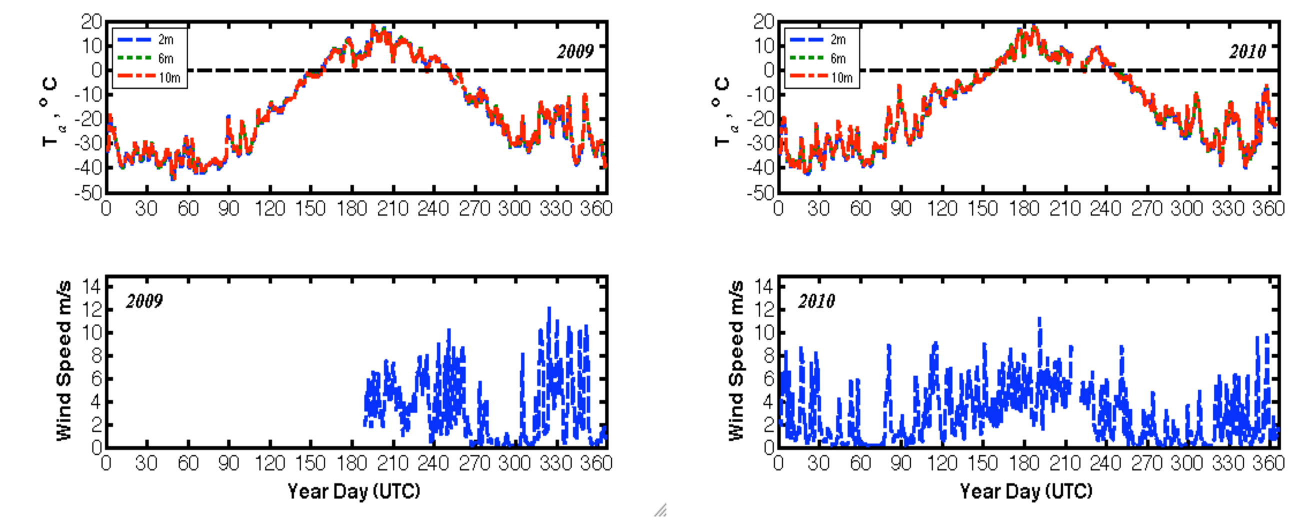
$$F_0 = F_{10} + C_{psl}\frac{\Delta \overline{T}}{\Delta t}\Delta z = -k_{sl}\left(\frac{T_{05}^{n} - T_{15}^{n}}{z_{05} - z_{15}}\right) - C_{psl}\left(\frac{T_{10}^{n+1} - T_{10}^{n-1} + T_{05}^{n+1} - T_{05}^{n-1} + T_{sfc}^{n+1} - T_{sfc}^{n-1}}{3(t_{n+1} - t_{n-1})}\right)(z_{10} - z_{sfc})$$

k_{sl} = soil thermal conductivity = 3.0 W m^{-1} K^{-1}
C_{psl} = soil heat capacity = 2.0 x 10^7 J m^{-3} K^{-1}(frozen; 2.6 x 10^7 for unfrozen)
k_{sl}/C_{psl} = thermal diffusivity = 1.5 x 10^{-7} m^2 s^{-1}
n = time index (hourly)

The Development Network of Arctic Micrometeorological (Flux) Towers

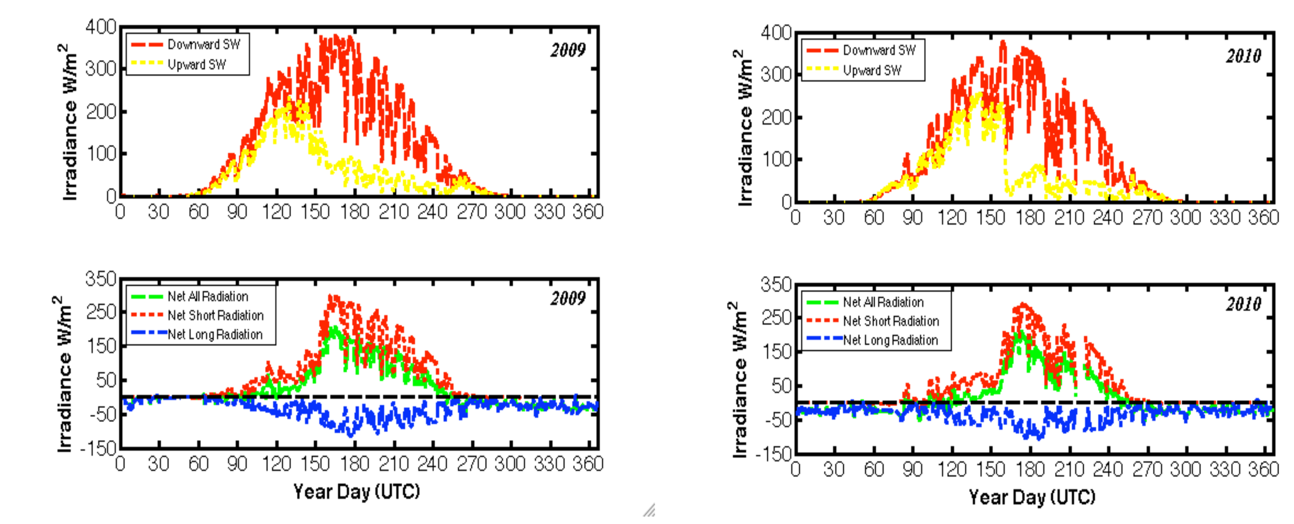
In this poster preliminary results are presented that describe the annual variability of Arctic radiation terms of the SEB. Two complete years of radiation data have been processed for 2009 and 2010. Snow depth, the onset of spring melt, the fall onset of snow accumulation and the surface albedo are interpreted in the context of the radiation terms. Eureka is located on Ellesmere Island in Nunavut, the northernmost and newest of Canada's three territories. At 80°N. It is just one of the tower installations that are springing up in the Arctic region and the research community focuses on the importance of these interface measurements. A Pan-Arctic understanding will be facilitated by the eventual analysis that will take a network approach to interpretation of SEB processes and resulting parameterizations.

Meteorological Measurements



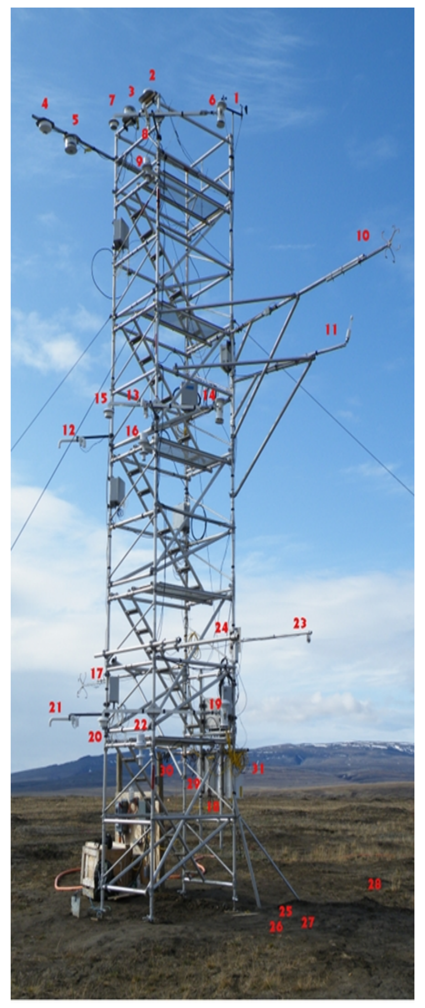
Annual cycles of daily averaged air temperature, measured at 2, 6, 10 m at the Eureka Flux Tower by Type-E Thermocouple/Campbell ASPTC-L and wind speed, measured at 10.5 m by RM Young Sentry anemometer

SW Radiation and Net Radiative Energy



Annual cycles of daily averaged SW radiation (Kipp&Zonen CM22) and calculated net radiative energy, measured at the Eureka Flux. LW radiation component was measured by Eppley PIR

The Instrumentation for Measuring the Surface Energy Budget (SEB)

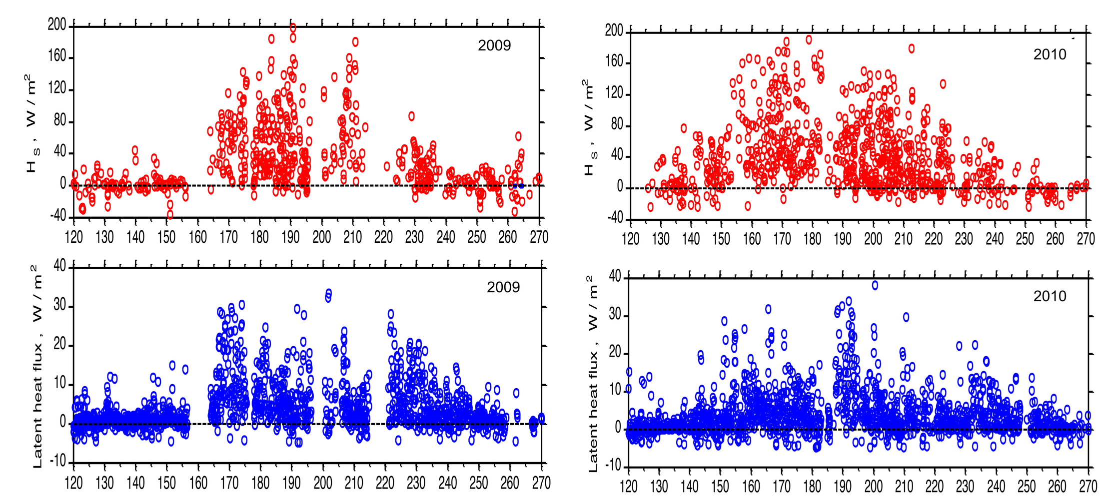


	10.5 Meter
1	R.M. Young sentry anemometer
2	Kipp & Zonen radiometer
3	Eppley radiometer
4	Kipp & Zonen radiometer
5	Eppley radiometer
	10 Meter
6	Vaisala temp
7	Vaisala RH
8	Thermocouple
9	RTD
	8 Meter
10	ATI Sonic anemometer
11	Licor open cell gas sampler
	6 Meter
12	Thermocouple
13	Thermocouple
14	Vaisala temp
15	Vaisala RH
16	RTD
	3 Meter
17	ATI Sonic anemometer

	2 Meter
18	pressure gauge
19	Vaisala temp
20	Vaisala RH
21	Thermocouple
22	RTD
	Ground
23	Apogee IR sensor
24	Campbell snow depth gauge
	- .2 meter
25	Heat flux plate 1
26	Heat flux plate 2
27	Thermocouple set of 4
	-1.2 meter
28	MRC soil probe
	other
29	Campbell Data Logger CR10-X
	Campbell battery voltage
	Campbell internal temp
	Campbell reference thermistor
	Licor control box temp
30	Service switch
31	UPS

To measure the SEB, standard, commercially available instrumentation is mounted on towers (10.5 m in Eureka) including sonic and cup anemometers, thermometers, humidity sensors, pyranometers, pyrogeometers, snow depth sensors, soil temperature probes, and surface heat flux plates. In Eureka, a total of 28 meteorological instruments are installed at 2m, 3m, 6m, 8m, 10m and 10.5.

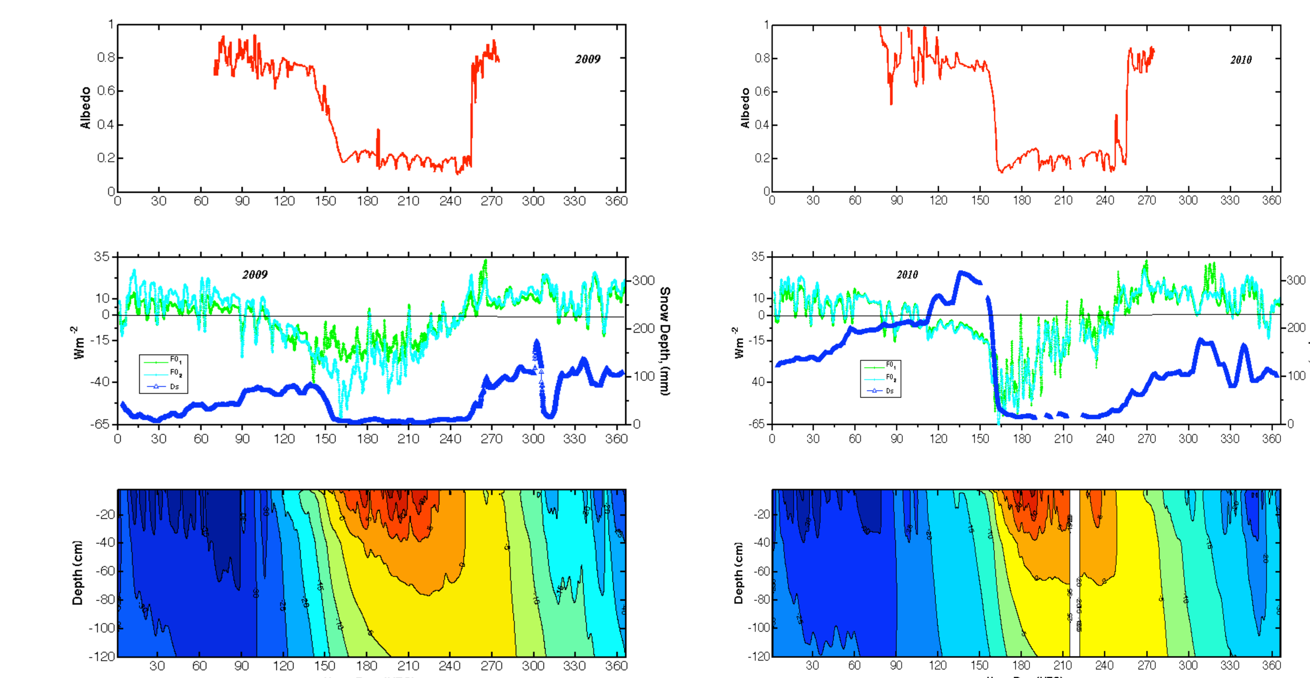
Turbulent Fluxes



May-September time series of the hourly averaged sensible heat flux (H_s), and latent heat flux (H_l). Measurements were made by sonic anemometers located at 3 and 8 m, and Licor-7500 at 8m.

Next Steps: All the terms of the SEB equation are measured directly, and the next steps will be to combine the individual terms to determine if equation closure can be achieved. Although similar studies have been completed for a year at an Arctic Ocean ice station (SHEBA) and for two years at a land station (Alert), the Eureka data will provide a unique opportunity for such detailed analysis at an Arctic station with the complex terrain and biological diversity, including local flora and fauna.

Albedo, Soil Heat Flux, Snow Depth and Active Layer Temperatures



Annual cycles of daily averaged albedo (SWU/SWD).
Snow depth (5 days averages) (Sonic ranging sensor/CSC#SR50A-L30) 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)