Agenda for today

- Motivatation: Future Ice Sheet States, Pattyn et al. 2018
- The glacier surface energy balance
  - An energy balance case study
- Detailed look at katabatic winds
- Detailed look at
- Detailed look at the melt-elevation feedback

Turbulent sensible and latent heat fluxes

- Warm air flowing over ice adds sensible heat to the surface.
- Dry air flowing over ice removes moisture and therefore latent heat.
- Both of these processes occur through mixing in a *turbulent boundary layer.*

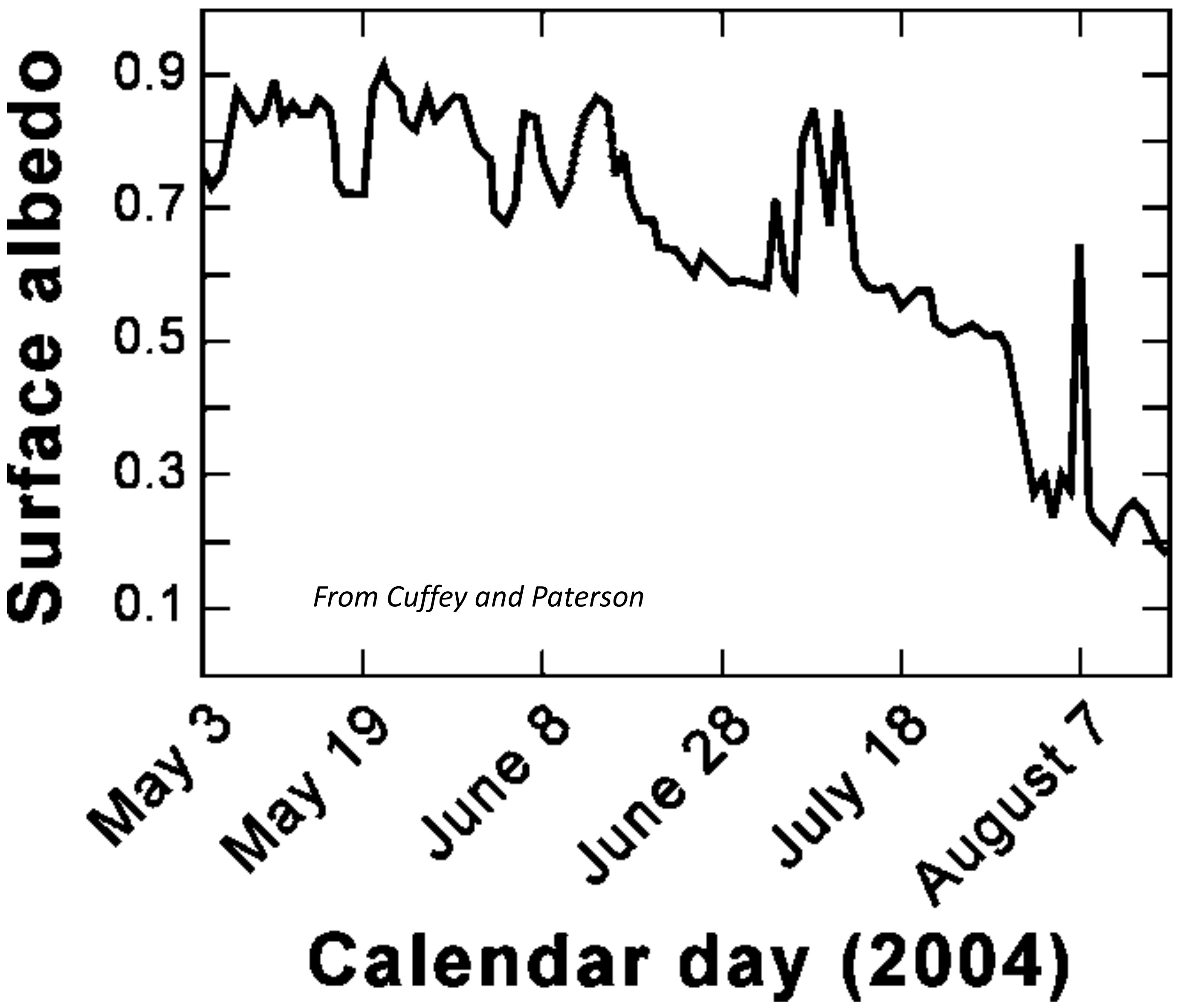
$$E_H = \rho_a c_a C_{\mathrm{H}}\, u\, [T_a - T_s]$$

$$E_E = \rho_a L_{v/s} C_{\mathrm{E}}\, u\, [q_a - q_s]$$

- C_E and C_H are *bulk exchange parameters*, u is the velocity, q is the moisture content, T is temperature, rho is density, c is the specific heat, and L is the latent heat.

Haig Glacier, Alberta, Canada, 50.7 N

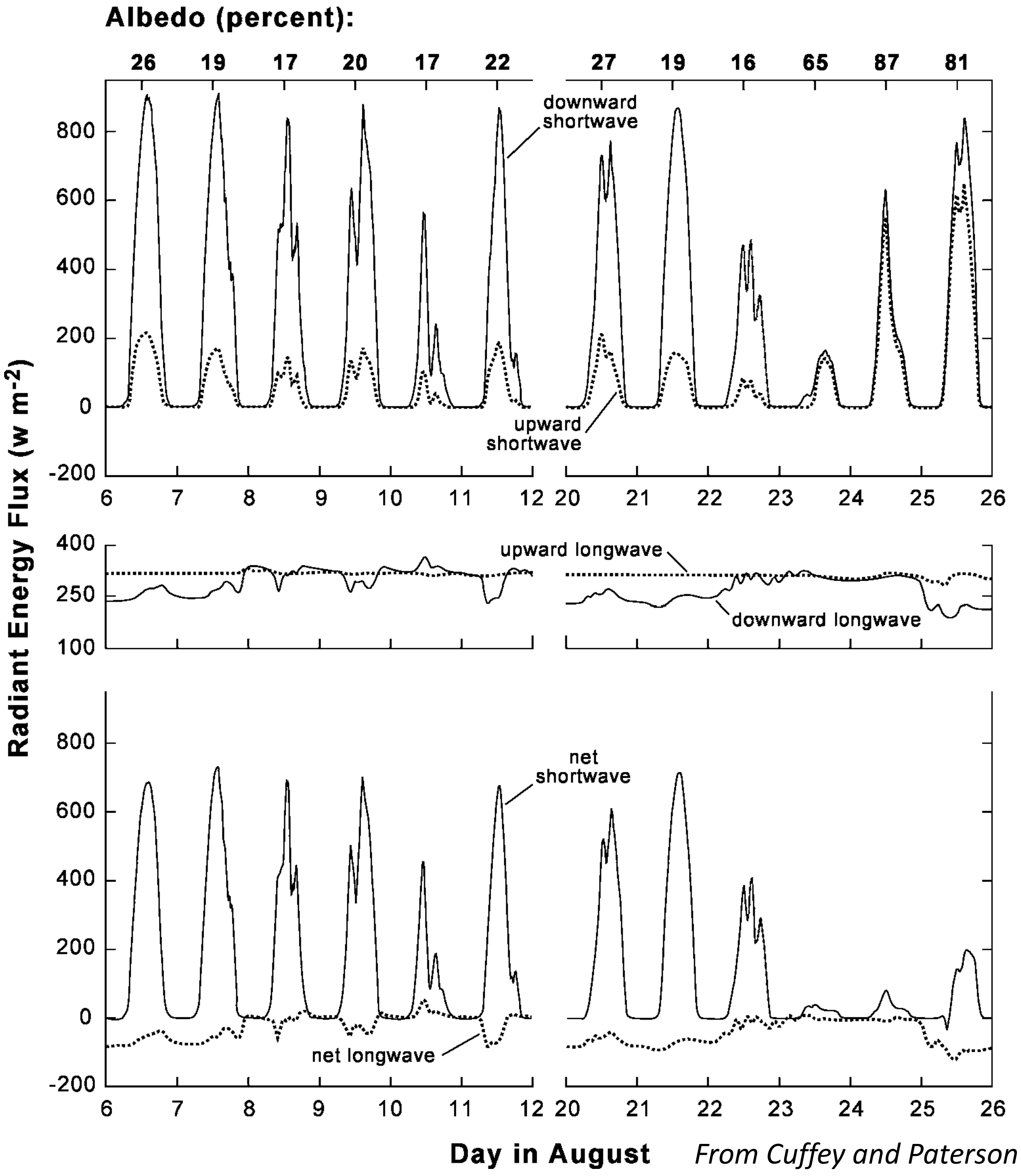
https://backcountryskiingcanada.com/



Surface albedo
0.9
0.7
0.5
0.3
0.1
From Cuffey and Paterson
May 3
May 19
June 8
June 28
July 18
August 7
Calendar day (2004)

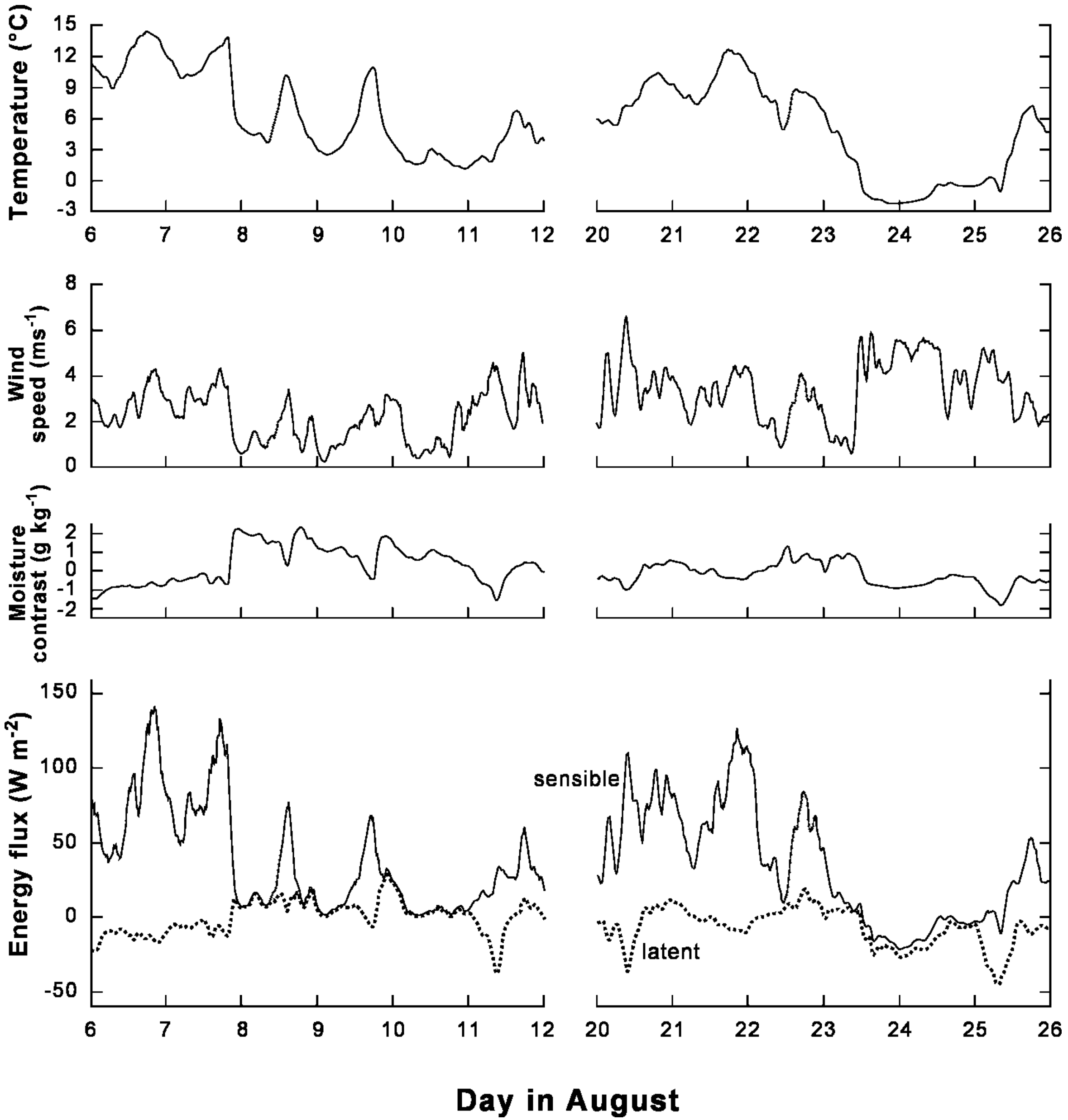
Field example: Radiant Fluxes

1. *Where is the biggest snowfall event? How can you tell? What is the total effect on the energy budget?*
2. *Why is there anticorrelation between net shortwave and net longwave?*
3. Where on the glacier was this site located?
4. *Why do both records start during sunny periods?*



From Cuffey and Paterson

Field Example: Turbulent Fluxes



From Cuffey and Paterson

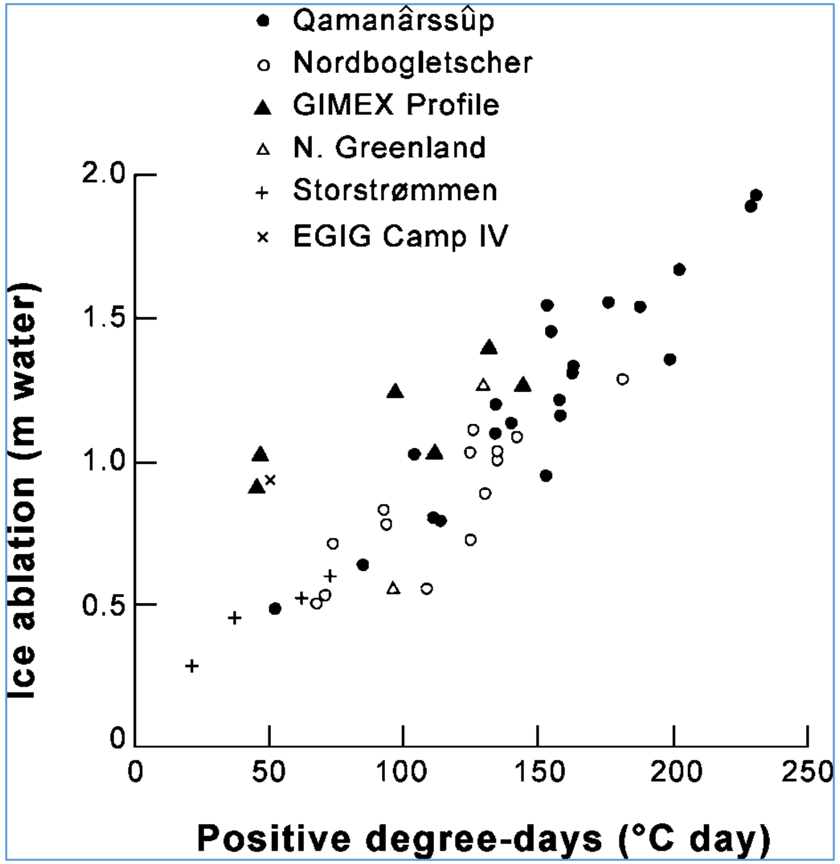
Modeling melting

Melting occurs when the glacier surface is

1. At the melting point, and
2. Has a positive net energy budget, $E > 0$

The resulting melt rate is, $\dot{m} = \dfrac{E}{\rho L_f}$

In practice, a “positive degree day” model is most commonly used.



From Cuffey and Paterson

Energy Regimes: The coldest climates

- Surface temperatures are well below freezing -> A positive energy balance results in *heating* rather than *melting.*

1. *Why does the sensible heat flux change sign seasonally?*
2. *What contributes to the radiative energy in the different seasons?*
3. *Why does the latent heat flux increase in the winter?*

Site	Elevation	Season	E_R	E_H	E_E
Vostok	3400 m	Summer	32	−25	−2
		Winter	−17	15	0
Mizuho	2230 m	Summer	20	−7	−8
		Winter	−38	37	0
Maudheim	37 m	Summer	9	6	†
		Winter	−22	13	†

† Not measured.   *From Cuffey and Paterson*