Referee comments on Use of a thermal imager for snow pit temperatures *by Shea, Jamieson, & Birkeland*

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Strengths

I like the paper. The study of snow would benefit greatly from a mechanism to rapidly measure temperature profiles at very fine depth resolution. The paper makes the case for this need. The interpretation of the results (Section 8) is particularly pertinent.

Major weakness

The problematic feature of the paper is the misinterpretation of the relationship between temperature and flux emitted from the surface in the wavelengths the camera senses. In Section 7.1, the discussion following equation (2) asserts, "To obtain temperature from watts, one uses the Stefan-Boltzmann law." However, the FLIR B300 measures infrared radiation from 7.5 to 13 μm. The Stefan-Boltzmann equation is the integral of the Planck equation over wavelengths 0 to ∞. At temperatures from –30 to 0°C (243-273°K), blackbody emitted radiation from 7.5-13 μm is 26.7%-31.9% of the Stefan-Boltzmann emission. Moreover, the relationship in this temperature and wavelength range is proportional to $T^{5.5}$ instead of T^4.

Probably, these errors do not affect the interpretation of temperature gradients, but it would be a shame for *The Cryosphere* to propagate the misunderstanding. The question is, how best to translate the output from the camera to actual absolute temperatures? The website of the FLIR B300 says the "Measurement mode" is "Delta T." The paper would benefit from a more precise description of what the camera says it measures, and how we convert those data into temperature. Let T be the snow surface temperature, ε_λ the spectral emissivity of snow, and $\beta(\lambda, T)$ the Planck equation. Then the radiation per steradian emitted from the surface is

$$W_{obj} = \int_{\lambda_1}^{\lambda_2} \varepsilon_\lambda \beta\,(\lambda, T) d\lambda$$

Depending on what the camera actually measures, it is possible to simplify the analysis. For example, can we ignore the change in snow's emissivity over the wavelength range and just use a constant value?

Other comments

Section 3.1 Line 15. This definition of a *temperature gradient* is inconsistent with the paragraph above, with general usage, and with usage throughout the paper. I think they mean "the difference in temperature between two points, divided by the distance between them, as an absolute value."

Sections 4, 6, 6.1. The emphasis to work quickly is entirely correct. The thermal IR emissions from the surface come from 1-2 mm from the surface, and the surface can rapidly equilibrate with the energy from the surroundings (air, body of the worker, etc). In this case, especially for deep pits, perhaps we should photograph as we excavate, whereas our usual practice with dial stem thermometers is to dig the pit, then measure temperature and density profiles.

Section 6, point #2. Theoretically, why is it important to have a smooth pit wall? Near nadir, emissivity is not very sensitive to view angle (Dozier and Warren, 1982). Similarly, do you need to have the camera pointed nearly orthogonally to the surface?

Section 7.2. Are these differences about what one would expect from theory?

Section 8.1.3. Equation (5) appears to be the saturation vapor pressure over water, not ice. Bohren & Albrecht (1998) use a slightly more complicated form:

$$\text{water: } \ln\frac{e_w}{e_0} = 6808\left(\frac{1}{T_0} - \frac{1}{T}\right) - 5.09\ln\frac{T}{T_0}$$

$$\text{ice: } \ln\frac{e_i}{e_0} = 6293\left(\frac{1}{T_0} - \frac{1}{T}\right) - 0.555\ln\frac{T}{T_0}$$

where $e_0 = 611\text{Pa}$ and $T_0 = 273.15°\text{K}$.

References

Bohren, C. F., and Albrecht, B. A.: Atmospheric Thermodynamics, Oxford University Press, 402 pp., 1998.

Dozier, J., and Warren, S. G.: Effect of viewing angle on the infrared brightness temperature of snow, Water Resour. Res., 18, 1424-1434, 10.1029/WR018i005p01424, 1982.