LABORATORY EXPERIMENTS OF HEAT AND MOISTURE FLUXES THROUGH SUPRAGLACIAL DEBRIS

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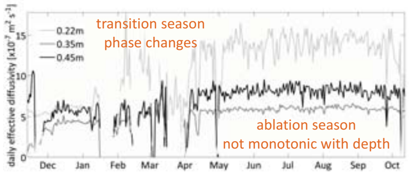
FWF Der Wissenschaftsfonds. IMGI

Why do we want to know about moisture content and flux in supraglacial debris?

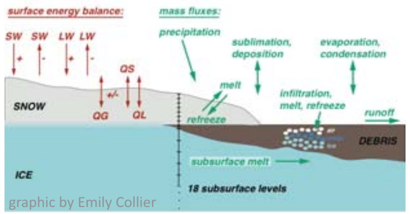
Debris over melting ice at Belvedere Glacier, Italy, 2003.

(1) Moisture content and its phase changes the thermal properties of the debris, which in turn affects the amount of melt energy delivered to ice beneath:

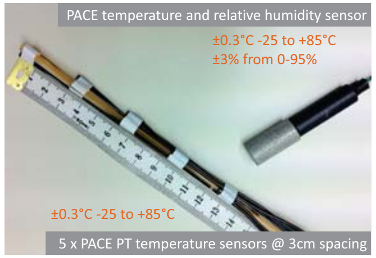


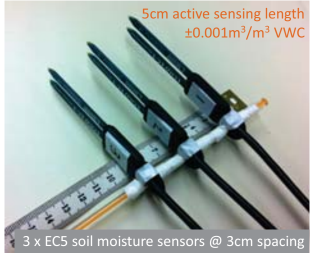
Effective thermal diffusivity measured at 3 depths in supraglacial debris on the Ngozumpa Glacier, Nepal, 2001-2002 shows large variability with season associated with moisture changes. Nicholson & Benn, ESPL, 2013.

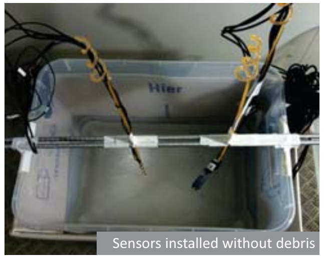
(2) Coupled atmosphere-land surface models require some information on moisture exchange between the debris-covered glacier surface and the atmosphere:

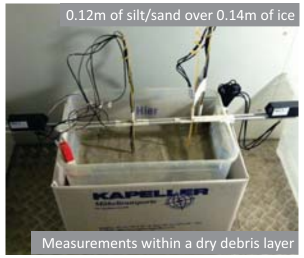


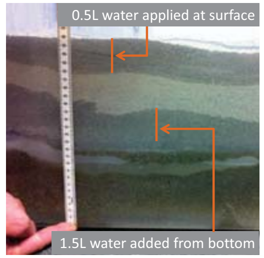
Probably cannot assume debris is dry and therefore switch off surface - atmosphere moisture flux for regional modelling where much of the glacier surfaces are debris covered. Collier et al., TC, 2013; TCD 2014.





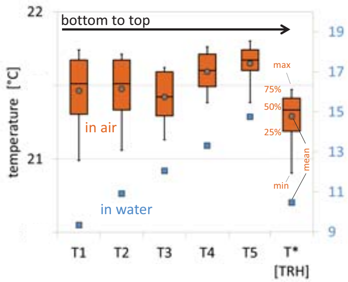




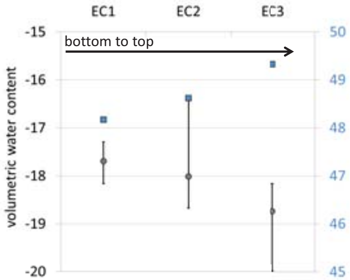


How do the sensors perform?

Logged data for 30 minutes in (1) air, and (2) undisturbed water overlying ice, to assess the stability of the readings.



Temperature sensors are stable to <1°C in air and <0.05°C in stratified water. All sensors are within 0.5°C of each other in air. The T/RH sensor T* readings were taken at the same level as T5 in air and the same level as T1 in water.

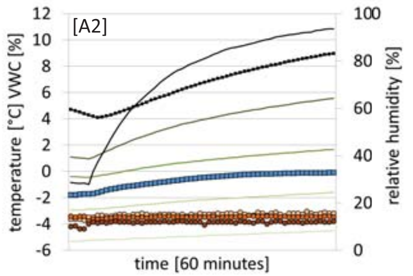


Soil moisture sensors were calibrated for mineral soils. In the end member conditions of air and water the sensors record lower values than the expected ones of -13.5% and 60% VWC resepctively. The readings in water are are perfectly stable.

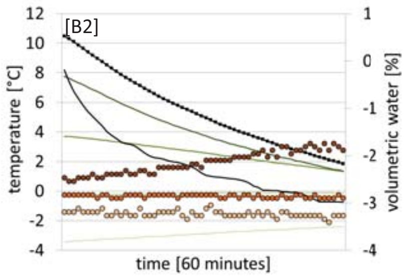
What experiments did we do, and what were the results?

[A] dry debris:	[1] 60 minutes @ -12°C [2] 60 minutes @ 20°C
[B] wetted from top with 0.5L:	[1] 60 minutes @ 20°C [2] 60 minutes at @ -12°C
[C] wetted from bottom with 1.5L:	[1] 60 minutes @ 20°C
[D] saturated with 3.5L more water:	[1] 21 hours @ -12°C [2] 90 hours melt out @ 20°C

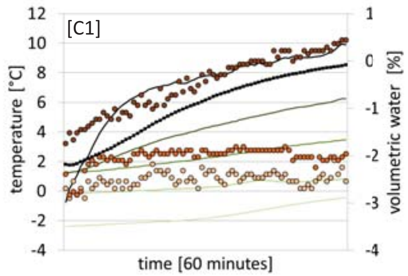
TEMPERATURES [°C]	LEVEL	MOISTURE [VWC|RH %]
T1	at ice	
T2	3cm above ice	EC1
T3	6cm above ice	EC2
T4	9cm above ice	EC3
T* T5	at surface	RH*



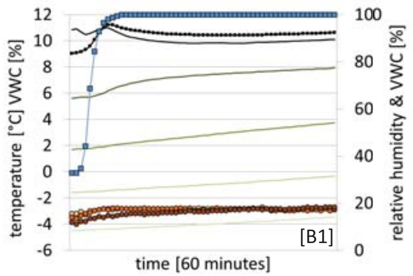
[A2] Volumetric water content (VWC) <0 suggests sensors should be calibrated for debris instead of standard mineral soil. VWC is insensitive to the gradually rising temperatures.



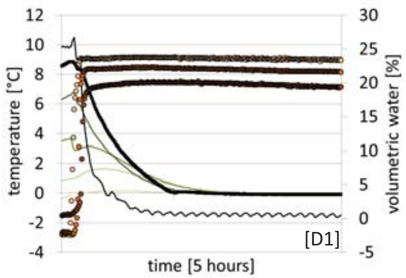
[B2] VWC at the uppermost sensor continues to rise as temperatures fall in response to the ambient -12°C. All VWC remains <0%. The combined temperature/humidity sensor cools more slowly than the surface thermistor.



[C1] VWC at lower 2 sensors shows a step increase after 1.5L of water was added at the base of the debris layer. At the upper sensor VWC continues to rise 3 hours after surface application of water and becomes positive.



[B1] VWC rises only slightly in the hour after 0.5L of water was sprayed on the surface, but the combined temperature/relative humidity sensor rapidly reaches and remains at 100% humidity. Surface temperatures peak shortly after the addition of water. The subsurface warms slowly as the experiment adjusts to room temperature.



[D1] VWC rises sharply at all EC sensors as the debris cover is saturated, and all vlaues are positive and increase with depth. Debris temperatures all drop to 0°C, except the surface thermistor appears to be partly exposed as it fluctuates with the freezer temperature control.

What can we conclude from this study?

- €25 thermistors are robust enough for wet freeze-thaw cycles
- Soil moisture sensors response slowly to small amounts of added moisture, but rapidly to flooding
- Soil moisture sensors need to be calibrated for a loose debris cover in order to derive accurate volumetric water content estimates.
- Atmospheric relative humidity sensors respond rapidly to wetting, so can indicate start of wetting event, but give poor data on drying rates.