Geliflution of soil on the Antarctic Peninsula

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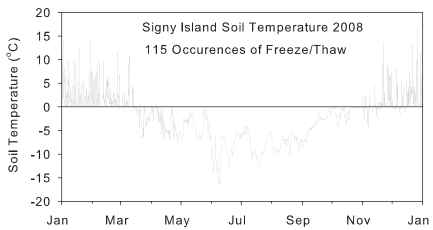
Freeze-thaw and climate change will impact Antarctic soils

- Gelifluction is the large drop in the mechanical stability of soil that occurs at the onset of freezing and thawing.
- With climate change predictions for the Antarctic Peninsula, cycles of freezing and thawing will likely increase, resulting in greater impacts from gelifluction.
- Soils will also be thawed for longer periods of time so risk of liquefaction increased.
- Fluctuations in mechanical stability will increase risk of slope movements, damage from wildlife trampling and disruption of microscale habitat for soil organisms.

Figure 1: Soil temperature of Signy Island samples



Gelifluction survey of Antarctic soils

Figure 2: Map showing sampling locations

- Surface soil (0-5 cm) was collected from Signy, Greenwich, Wiencke, and Livingston Islands, as well as from the northern tip of the Antarctic Peninsula – Alectoria.
- Part of a more widespread geographical study of soil response to climate change.

Measuring gelifluction

- Parallel plate rheometer fitted with a Peltier temperature controller used.
- Small soil samples needed in-line with conservation concerns.
- Freeze-thaw to measure gelifluction followed by stress-recovery to measure thixotropy.

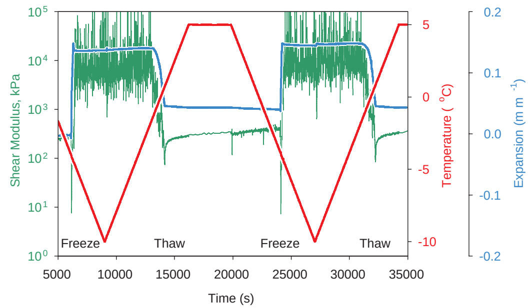


Figure 3: An oscillating 10 Pa shear stress was applied to sieved samples equilibrated to -0.5 kPa water potential. Freezing and thawing was controlled with a peltier temperature controller, with temperature ramps consisting of 5ºC to -10ºC over 2 hours, followed by -10ºC to 5ºC over two hours, and finally at constant 5ºC for 1 hour. Two cycles were applied with the analysis presented for the second cycle only.

Gelifluction and thixotropy of various Antarctic soils

Site	Shear modulus kPa	Gelifluction - % initial shear modulus		Freeze expansion m m^{-1}	Thixotropy - % initial shear modulus			Water Content g $100g^{-1}$
		Pre-freeze minimum	Thaw minimum		Stressed	Recovery 0.1 hour	Recovery 2 hours	
Alectoria	199.9^{a}	17.2^{ab}	15.7^{ab}	0.114^{a}	4.77^{a}	27.9^{a}	55.4^{ab}	31.8
Grenwich Island	42.70^{a}	38.9^{ab}	25.5^{bc}	0.092^{ab}	5.39^{a}	13.0^{a}	65.1^{ab}	44.8
Livingston Island 1	117.3^{a}	52.6^{b}	26.3^{bc}	0.066^{b}	3.74^{a}	20.0^{a}	33.3^{a}	30.5
Livingston Island 2	271.8^{a}	21.7^{ab}	33.9^{c}	0.062^{b}	4.97^{a}	65.2^{b}	81.5^{b}	33.7
Signy Island	202.9^{a}	32.3^{ab}	24.5^{abc}	0.125^{a}	4.08^{a}	19.1^{a}	31.4^{a}	33.2
Wiencke Island	336.2^{a}	21.5^{a}	9.7^{a}	0.083^{b}	4.34^{a}	24.9^{a}	34.2^{a}	45.1
L.S.D.	399.4	30.3	15.6	0.034	4.14	27.9	44.3	---
P	n.s.	n.s.	n.s.	<0.01	n.s.	<0.05	n.s.	---

Table 1: Different superscript letters in each column indicate significance difference (P<0.05, n=6).

- Onset of freezing or thawing causes a major drop in shear modulus.
- Even greater drop in shear modulus caused by liquefaction under an oscillating stress.
- Whereas some soils were thixotropic after liquefaction, others recovered poorly.

Implications and Conclusions

- Both freeze-thaw and the length of thawed periods will increase for Antarctic soils.
- Gelifluction and liquefaction were both shown to cause a massive reduction in mechanical stability.
- Soils are highly susceptible to repetitive damage from trampling by humans and wildlife
- Greater risk of landslides at large-scale.
- Ice crystal formation and thawing will alter pore microstructure, with implications to microbial habitat and carbon mineralisation in these soils.

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