Permafrustration

Why are we worried about this situation?

C. Albrechtsen, A. D. Davies, I. Hagen, K. Krennmayr & B. Lodhia

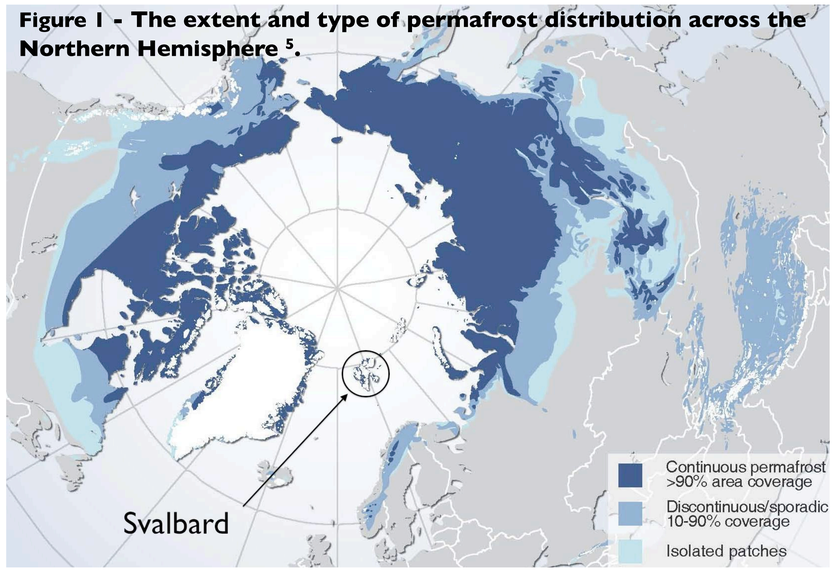
University of Vienna, University of Cambridge, University of Oslo, University of Copenhagen, Oxford University

Contact: ad575@cam.ac.uk

Introduction

- Permafrost is ground that remains at/below 0 °C for at least two consecutive years [1].
- The active layer lies above the permafrost; it is frozen in winter but thaws in summer [2].
- In the Northern Hemisphere, 23% of the exposed land area is covered by permafrost [3].
- Permafrost regions can be divided into three zones [4]:
  1. Continuous permafrost (underlying 90-100 % of the landscape)
  2. Discontinuous permafrost (50-90 %)
  3. Sporadic permafrost (0-50 %)
- Permafrost thickness can vary from less than a metre to more than 1500 metres [4].
- The distribution of it is closely related to the topography of the land, such as slope gradient, orientation, vegetation patters and snow cover.
- It is an important part of the cryosphere and is a key indicator of climate change.
- Warming climate will cause an increase in the active layer thickness and permafrost temperatures.

Figure 1 - The extent and type of permafrost distribution across the Northern Hemisphere [5].

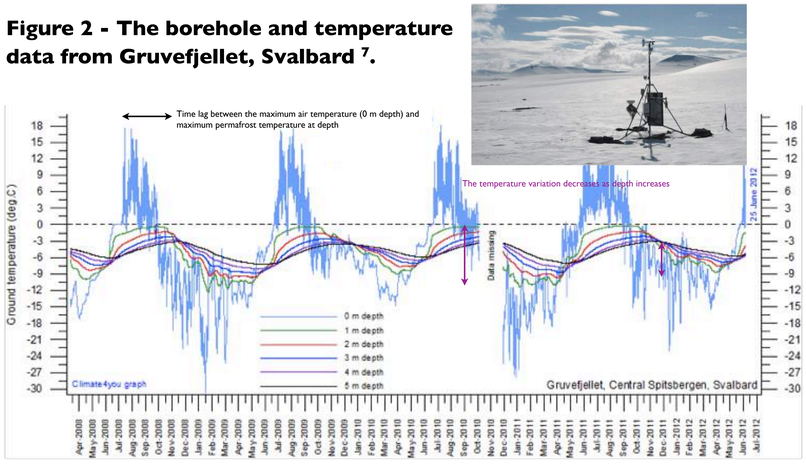


Svalbard's Permafrost

- Continuous permafrost covers the archipelago but is not generally present beneath glaciers.
- Permafrost area covers 25 000 km^2 - largest area in Europe outside Russia [6].
- Thickness ranges from 100 m in the valleys and coast to 500 m in the mountainous regions [7] (Figure 1).
- The ocean is a heat source so coastal permafrost is shallow.
- Accumulated snow and glacier ice insulates the ground resulting in shallow or absent permafrost.

- Svalbard is located near the northernmost branch of the North Atlantic current and it is the southern limit of polar pack ice.
- This makes the permafrost very sensitive to small variations in these phenomena [6].
- In Svalbard the permafrost is only a few degrees below freezing temperature and so any warming would have a significant affect on thawing [8].
- Studies to improve knowledge about permafrost distribution and its thermal state were begun during the fourth International Polar Year [8].
- The Circumpolar Active Layer Monitoring (CALM) network was begun - has 160 sites in the polar and subpolar regions with 14 participating countries.
- This resulted in twelve new shallow boreholes being drilled in Svalbard [8] (Figure 2)
- Studies from these boreholes suggest that the active layer thickness has increased from 74 cm to 100 cm from 1999-2009 [8].

Figure 2 - The borehole and temperature data from Gruvefjellet, Svalbard [7].



Structural Importance of the Permafrost

Damage to buildings and roads:

- A slight increase in ground temperature can create instability; damaging roads, bridges, harbours, power lines and pipelines.
- Thawing permafrost is currently the greatest geotechnical challenge facing engineers in arctic regions [9].
- Tourism, construction, and industrial activities take place near the shoreline, which is especially vulnerable to thawing since the permafrost is shallower.

Land and rockslides:

- Changing climate in the mountain permafrost zone is likely to lead to a significant increase in both scale and frequency of slope failures.

Carbon pool and the ecosystem

- The permafrost is the biggest storage for $C0_2$ - twice as large as the atmospheric carbon pool [9].
- Thawing permafrost exposes more carbon to the microbes and will therefore influence the terrestrial ecosystem
- Due to increased $C0_2$ plants will increase their productivity. However, these plant growth rates can not compensate for the carbon release.
- The species composition will change as the active layer alters, with changes in nutrients and soil conditions.

Methane Clathrate Release

- Methane clathrates consist of methane molecules trapped in cages of ice molecules.
- At the right pressure and temperature, methane gets trapped in clathrates close to the surface of permafrost.
- The sudden release of methane may lead to catastrophic climate change
- Methane release would produce a positive feedback mechanism, further enhancing methane release by causing permafrost thawing.
- Large and sharp negative δ13C excursions are characteristic of sudden methane release
- A sudden release of methane into the atmosphere is believed to have contributed to the Permo-Triassic Mass Extinction at 252 Ma.
- This caused changes in global oceanic circulation, an average global temperature rise of 6˚C and a mass extinction of 96% of all species [10].

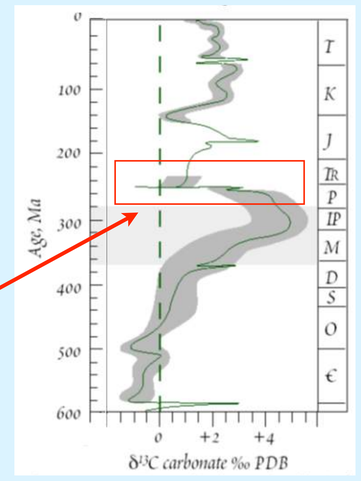


Figure 3 - δ13C values through Palaeozoic time [10].

Conclusions

- Dangerous consequences will result from continued global warming.
- Areas covered by permafrost, such as Svalbard, where the permafrost is marginally stable will be devastated by rapid changes to ecosystems and landscapes.
- Effects of a melting permafrost will be reverberated globally, as we are quickly approaching the tipping point of a runaway greenhouse affect.

Acknowledgements

We would like to thank Ólafur Ingólfsson and all the lectures at the IPY Field School 2012 for all their help and support.

References:

[1] Waller, R., Murton, J. et. al. 2012: *Glacier–permafrost interactions: Processes, products and glaciological implications*, Sedimentary Geology, 255: 1-28. ; [2] Burn, C. R. 1998: *The active layer: two contrasting definitions*, Permafrost Periglac. Process., 9: 411–416. ; [3] H. Juliussen, H. H. Christiansen, G. S. Strand, et. al 2010: *NORPERM, the Norwegian Permafrost Database - a TSP NORWAY IPY legacy*, Earth Syst. Sci. Data, 2, 235-246. ; [4] International Permafrost association - http://ipa.arcticportal.org/resources/what-is-permafrost.html (accessed 11/7/12) ; [5] UArctic Atlas - http://uarctic.org/AtlasMapLayer.aspx?m=643&amid=7149 (accessed 11/7/12) ; [6] Humlum, O., Instanes, A. and Sollid, J. L. 2003: *Permafrost in Svalbard: a review of research history, climatic background and engineering challenges*, Polar Research, 22: 191-215. ; [7] Humlum, O. 2012: *Permafrost* - http://www.climate4you.com/PermafrostMain.htm (accessed 11/7/12) ; [8] Christiansen, H. H., Etzelmüller, B., Isaksen, et. al. 2010: *The thermal state of permafrost in the nordic area during the international polar year 2007–2009*, Permafrost Periglac. Process., 21: 156-181. ; [9] Schuur, E., Bockheim, J. et. al. 2008: *Vulnerability of Permafrost Carbon to Climate Change: Implications for the Global Carbon Cycle*, BioScience, 58: 701-714. ; [10] Baud, A., Magaritz, M. & Holser, W. 1989: *Permian-Triassic of the Tethys: Carbon isotope studies*, Geologische Rundschau, 78: 649-677. BioScience September 2008 :Vol. 58, Issue 8 (Sep 2008), pg(s) 701-714 ; [10] Baud, A., Magaritz, M. & Holser, W. 1989: *Permian-Triassic of the Tethys: Carbon isotope studies*, Geologische Rundschau, 78: 649-677.