Note

Active layer monitoring in two Greenlandic permafrost areas: Zackenberg and Disko Island

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Abstract

Active layer monitoring in Greenland was started in 1996 and 1997, and forms part of the Circumpolar Active Layer Monitoring (CALM) Network of the International Permafrost Association (IPA). The results of the first years of this monitoring of thaw progression and maximum active layer thickness in two Greenlandic permafrost areas are presented. Two sites are in the continuous permafrost zone at Zackenberg in NE Greenland (74 °N), and one at Disko Island in W Greenland (69 °N), at the border between discontinuous and continuous permafrost.

The data collected at Zackenberg demonstrate interannual variation in the timing of thaw progression in the monitoring grid holding a seasonal snowpatch, while there is less variation in the horizontal grid without a snowpatch. The maximum active layer thickness for the two Zackenberg grids is more or less consistent for the first three years with averages from 58 to 66 cm in mid and late August. At Disko the active layer reached 71 cm in mid August 1998. Spatially the distribution of the maximum, annual active layer thickness within the grids is concordant.

Keywords

Active layer monitoring, permafrost, Greenland, Zackenberg, Disko Island.

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The active layer is the surface layer of ground which is subject to winter freezing and summer thawing in areas underlain by permafrost (Muller, 1947). This makes the active layer thickness mainly climatically controlled. The active layer is critical to the ecology and hydrology of permafrost terrain, providing a rooting zone for plants and acting as a seasonal aquifer for near-surface ground water (Burn, 1998). Likewise it enables the exchange of trace gasses such as carbon dioxide and methane, heat and moisture between the atmosphere and the soil in arctic areas.

Changes in the active layer thickness and timing of thaw progression are likely consequences of climate change. Therefore annual measurements of the active layer thickness, as performed in the Circumpolar Active Layer Monitoring (CALM) network, provide documentation for interannual fluctuations, and register the environmental impact of global climate change in permafrost areas (Nelson & Brown, 1996). Also active layer monitoring represents an important basis for verifying active layer modelling.

In Greenland monitoring of permafrost borehole temperatures and mapping of permafrost are sparse. However, in areas of intensive monitoring and research of the physical environment, such as at Zackenberg, where Zackenberg Ecological Research Operations (ZERO) (Meltofte, 1996) has operated since 1995, and on Disko Island at the Arctic Station in Qeqertarsuaq, where meteorological data has been collected since 1990 (Nielsen et al., 1996), participation in the CALM network is now initiated.

Circumpolar active layer monitoring, CALM

The CALM network currently consists of 69 research sites in the Northern Hemisphere (Figure 1) operated by researchers in 10 different countries. Seasonal thaw data has been collected since 1991 using a standard measuring protocol in the CALM grids. The network consists of permanently marked measuring grids, mainly in fine-grained soils in the Arctic. CALM grids generally measures 100 x 100 m or 1000 x 1000 m. The traditional method of soil thaw measurement is pushing a narrow-diameter metal probe into the soil to the point of refusal (Nelson & Oultcalt, 1982). In some grids also soil temperature and moisture content are logged within the active layer.

Currently, all CALM data are quality controlled by the individual researchers who established the grids and control data collection. Data are then reported to the Department of Geography at University of Cincinnati, where a group of researchers has a 5-year U.S. National Science Foundation grant for running CALM, including making the data available on the CALM web site: http://www.geography.uc.edu/~kenhinke/CALM.

The first two Greenlandic CALM sites, ZEROCALM1 and ZEROCALM2 were established in 1996 in Zackenberg, NE Greenland (Christiansen, 1997). In 1997 a third

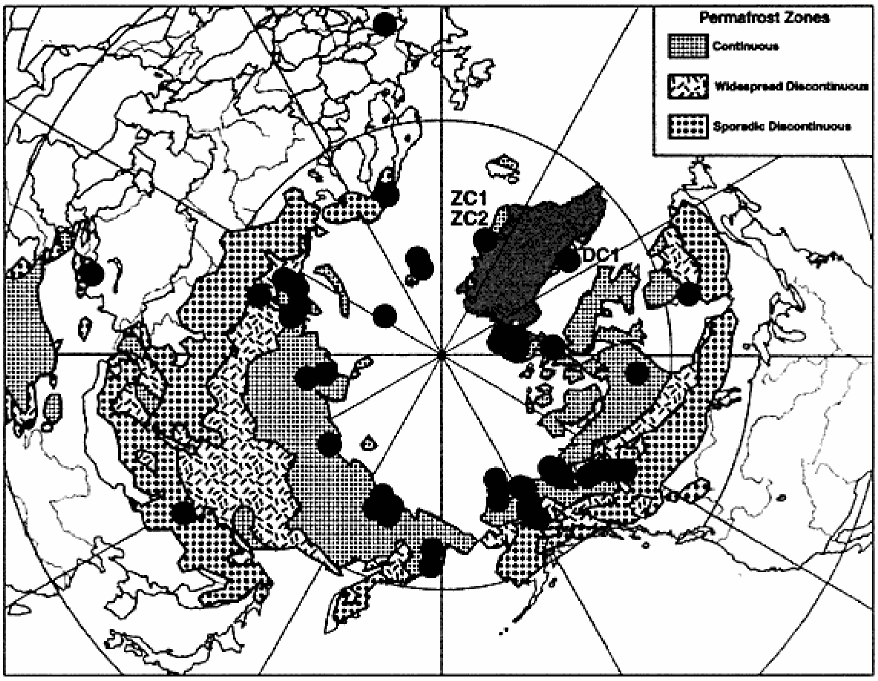

Figure 1: The Circumpolar Active Layer Monitoring (CALM) network sites. Based on map by Anna Klene and Nikolai Shiklomanow, University of Delaware, in Nelson & Brown (1996). ZC1 and ZC2 are the ZEROCALM1 and ZEROCALM2 grids at Zackenberg, NE Greenland. DC1 is the DISKOCALM1 grid at Disko Island, W Greenland.

CALM site, DISKOCALM1 was established near Qeqertarsuaq at Disko Island, central W Greenland.

CALM in Zackenberg, NE Greenland

Both ZEROCALM monitoring grids are located in the centre of the Zackenberg Valley at 74°28'N, 20°30'W. The long-term terrestrial monitoring commitment of the GeoBasis programme of ZERO (Christiansen & Humlum, 1996) ensures the annual late summer measurements of both grids (Christiansen, 1997), and makes it an important cooperating partner in the annual collection of CALM seasonal thaw progression data from both grids.

The ZEROCALM1 (ZC1) grid is located on a slightly SW sloping (0 - 2°) marine abraded plain, at 36-37 m a.s.l. The grid system measures 100 x 100 m. With a grid size of 10 x 10 m, there are 121 measuring points. Texturally, the grid is mainly sandy with some gravel. There is continuous vegetation dominated by *Cassiope tetragona*, but also with *Salix*, *Vaccinium*, mosses and lichens. Immediately south of ZC1, the ZERO meteorological station is located, and here soil temperatures are collected at 10 levels from the terrain surface through the active layer into the top permafrost, at a maximum depth of 150 cm. Air temperature, precipitation, wind speed, wind direction and other meteorological parameters are also logged at this station (Christiansen & Humlum, 1996). In the southern part of ZC1 a snow depth sensor was installed in 1997, continuously logging the winter snow depth (Rasch, 1998). Likewise in 1997 a permanent, double vehicle track was made crossing through the ZC1 grid.

The ZEROCALM2 (ZC2) monitoring grid is placed from 11-22 m a.s.l. and measures 120 x 150 m, also with a 10 x 10 m grid size, which gives 208 measuring points. It covers a seasonal snowpatch on a south-facing slope, maximally 15° inclined, surrounded by more level areas in the northern and southern parts. This grid is located in the Zackenberg Delta, and it includes two fluvial terraces. Texturally, the grid consists of both sand and silt-clay dominated sediments. The grid has an almost complete vegetation cover. There is a distinctive vegetation zonation controlled mainly by the snow cover duration in the snowpatch area, such as described by Christiansen (1996, 1998). In the areas outside the snowpatch *Dryas* dominate on the dry, coarse-grained upper fluvial level, whereas grasses and mosses dominate in the fine-grained, water-soaked fen area downslope the snowpatch. Some metres south of the grid there is a GeoBasis soil temperature monitoring profile, logging the temperature in 4 levels from the terrain surface, through the active layer down to 60 cm in the top permafrost.

CALM at Disko Island, W Greenland

At 69°16'N, 53°30'W about 2 km NE of the village Qeqertarsuaq/Godhavn on Disko Island the third Greenlandic CALM grid, called DISKOCALM1 (DC1), was established in 1997 on top of a broad-crested E-W extending moraine ridge, Pjeturssons Moræne, at about 125 m a.s.l. This grid measures 90 x 90 m, with 100 measuring points. Morphologically the grid slopes slightly (maximally 3°) towards the north in the northern end, slightly (maximally 3°) towards the south in the southern end, and is almost horizontal in the middle part. This reflects the moraine ridge top location. Vegetation, primarily mosses and *Salix*, covers about 80 % of the grid surface. The sediment is till, with some boulders. In the centre of the grid a soil temperature monitoring profile was installed in 1997, logging the temperature at 3 levels from the terrain surface down to 74 cm. In this grid it has only been possible to measure thaw thickness annually in the late summer.

Results

All measured maximum active layer thickness for the Greenlandic CALM grids are presented in Table 1, together with dates of the measurements and standard deviation.

The ZC1 grid results can be compared with the soil temperature data of the ZERO meteorological station, close to ZC1. These data show the maximum active layer depth to be about 92 cm in 1996 at 7 September, and about 92 cm in 1997 at 1 September. The relatively large difference between the measured maximum thaw depth in ZC1 and at the temperature profile close by, can be due to difference in texture, but since both ZC1 and the meteorological station are located on the same landform, this does not seem to be the main cause. It is, however, possible that the installation of the soil temperature sensors in a vertical tube in the soil may enable local downward water penetration in the profile, which might locally increase the active layer thickness. Soil temperature data from the GeoBasis profile immediately south of ZC2 has failed for the sensors closest to the permafrost top in both 1997 and 1998, so there is no other information on maximum active layer thickness from there.

Grid	*1996*	*1997*	*1998*
ZC1	*60 cm (16 Aug.)* *SD: 5 cm*	*62 cm (21 Aug.)* *SD: 5 cm*	*66 cm (31 Aug.)* *SD: 5 cm*
ZC2	*61 cm (16 Aug.)* *SD: 8 cm*	*58 cm (21 Aug.)* *SD: 10 cm*	*60 cm (31 Aug.)* *SD: 9 cm*
DC1	-	*57 cm (15 Jul.)* *SD: 14 cm*	*71 cm (19 Aug.)* *SD: 12 cm*

***Table 1:** Maximum active layer depths at the Greenlandic CALM grids from 1996 to 1998. SD = Standard deviation. ZC1 = ZEROCALM1, ZC2 = ZEROCALM2 and DC1 = DISKOCALM1. Numbers are averages of all grid points in each grid.*

The first three years of observation in both ZEROCALM grids show similarly shaped thaw progression curves, indicating a spatially almost equal thaw development in each grid (Figure 2). However, there was a temporal delay in the ZC2 grid thawing between 1996 and the following two years of 18-23 days for most of the mid summer period. This was not seen in ZC1. The main reason for this difference was an extended snow cover duration particularly downwind of the seasonal snowpatch in ZC2 in 1997 and 1998 compared to 1996. The increased snowpatch size is caused mainly by increased winter wind speed in the later two years, in combination with a more equal distribution of the snow precipitation during these winters. These informations are based on data from the ZERO meteorological station.

About 2 km away from the DISKOCALM1 grid the maximum active layer thickness is generally found in early September to be 170-195 cm at 20 m a.s.l. This is based on soil temperature data in sand and gravel sediments at the permanent meteorological station at the Arctic Station in Qeqertarsuaq (Humlum et al., 1999, Humlum, 1998). Presumably, the exposed location of the DC1 grid on top of the moraine ridge enables a reduced active layer thickness, suitable for the CALM probing technique. No thaw progression data have so far been obtained from this grid. Soil temperature monitoring in the DC1 grid partly failed in the first year, so there is no information on the maximum late summer thaw this way.

Perspective

Obviously, it would be relevant with more CALM grids in selected areas of Greenland, such as in North Greenland, e.g. at the manned stations. This would give a regional overview of the thermal state and thickness of the active layer, and thus the permafrost conditions. Permafrost

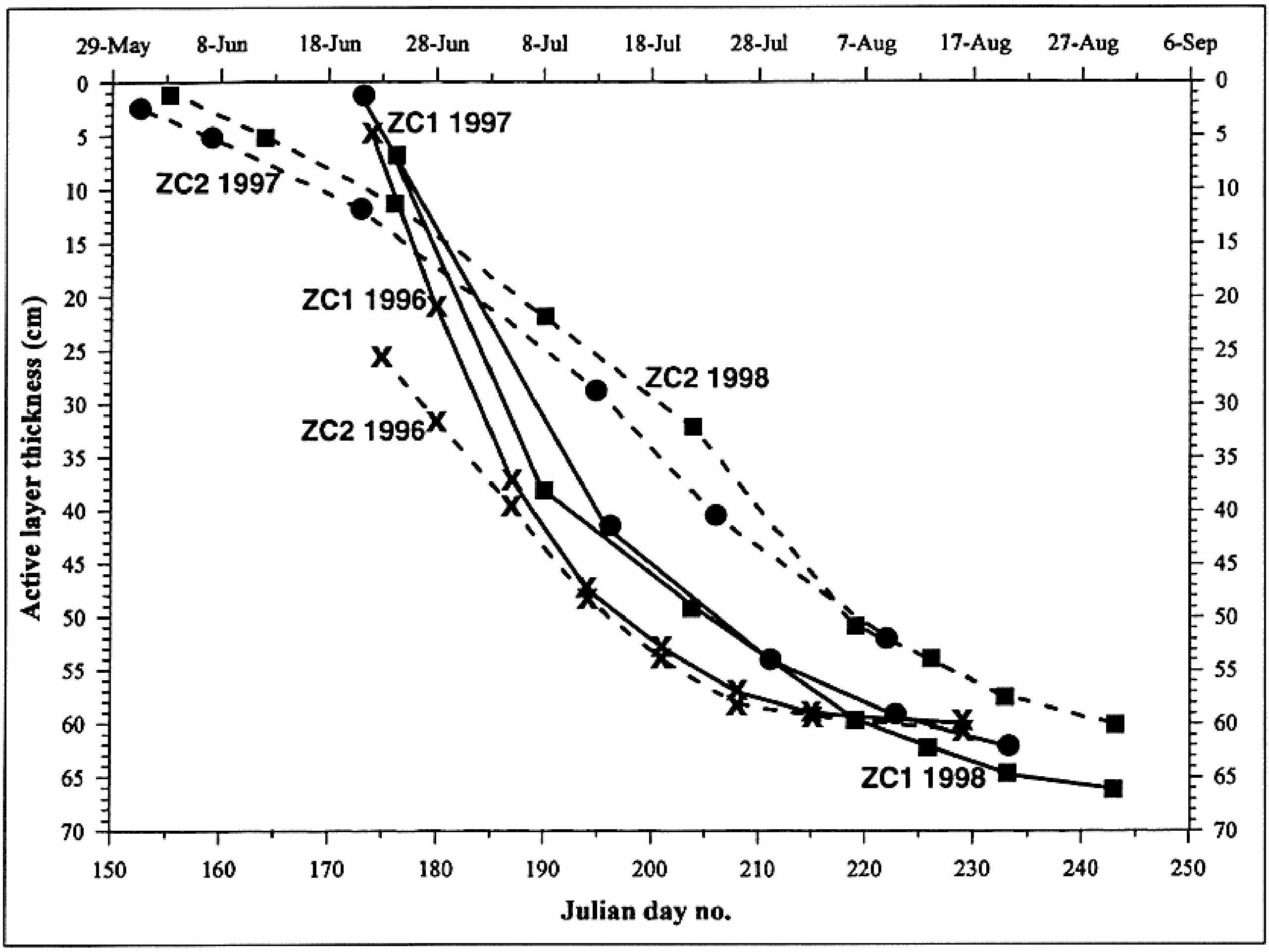

Figure 2: Average active layer thaw progression in the ZEROCALM1 grid (solid lines) and in the ZEROCALM2 grid (dashed lines) for the 1996-1998 summers, calculated from probing of 121 grid points in ZC1 and of 208 grid points in ZC2. Crosses, circles and squares represent respectively the timing of the 1996, 1997 and 1998 measurements.

monitoring should also be carried out in the discontinuous and sporadic permafrost areas of particularly SW Greenland, where climatic changes might have the largest socio-economic effects, by causing permafrost growth if the present climatic cooling in this area continues. Likewise if warming occurs, permafrost might disappear in certain areas, also affecting society by increased slope instability as is presently occurring in the European Alps (Haeberli & Beniston, 1998).

Snow fence manipulation is now also initiated at Zackenberg to study the effect of a prolonged snow cover duration on active layer thaw progression and associated physical processes (Jakobsen et al., 1999). This in combination with the presented active layer monitoring of natural conditions will allow a better understanding of how changes in key physical climatic change parameters such as snow precipitation and wind can affect the permafrost environment.

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GeoBasis programme of ZERO. Thanks to Claus Nordstrøm and Ole Humlum, both from the Institute of Geography, University of Copenhagen, who respectively measured the ZEROCALM grids medio August 1996, and the DISKOCALM1 grid medio August 1998.

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