Active Layer Monitoring: Geological Survey of Canada

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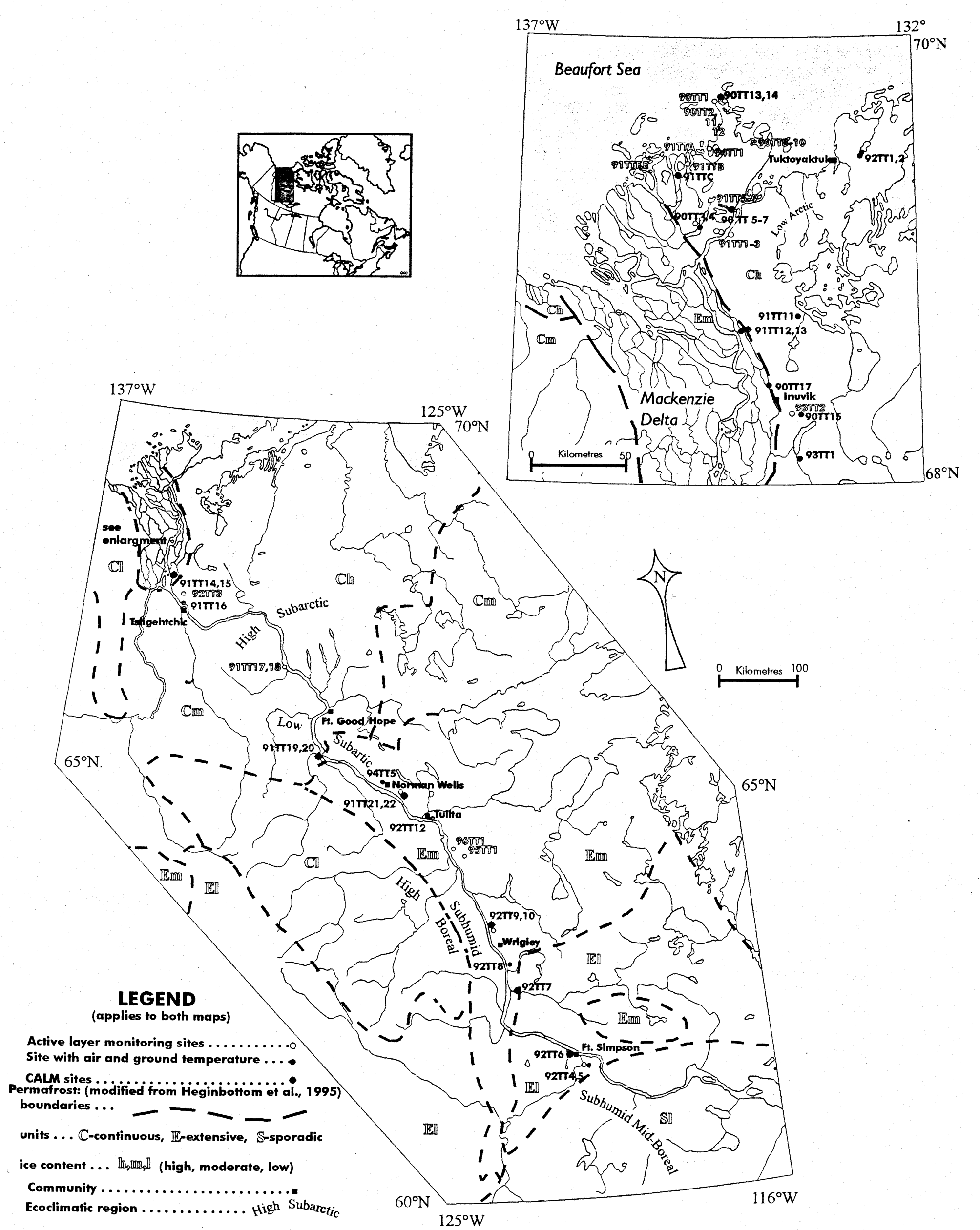
Geological Survey of Canada

GSC is monitoring the active layer at just under 60 undisturbed sites established in the Mackenzie Valley between 1990 and 1992.

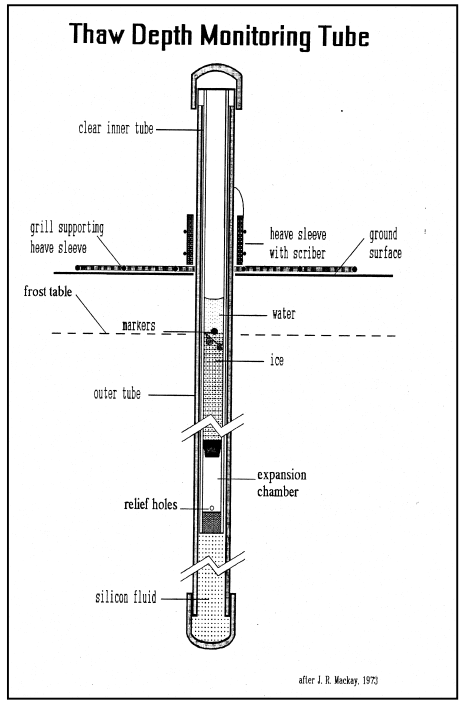
Site Map:



- The transect crosses several permafrost, and ecoclimatic boundaries as well as about 7 degrees of MAAT
- Sites are often clustered in groups of two or more thaw tubes with different settings
- Red sites are supported by complimentary air and ground temperature instrumentation
- 10 sites have been chosen as IPA CALM stations with the record published on the web
- The concept is of a very accessible, inexpensive, robust auto-recording instrumentation allowing collection of a large number of measurements during a single annual survey. If a pattern is seen at many, widespread situations it is probably of regional significance and strong enough to overcome local factors.

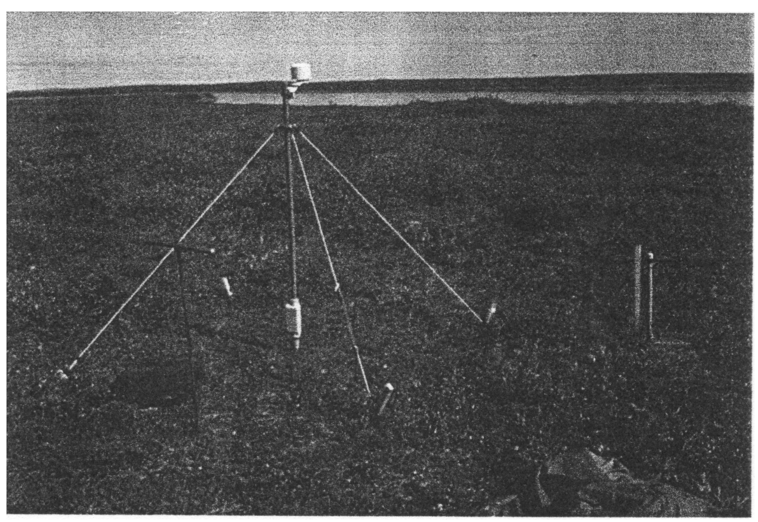
Frost Tubes:

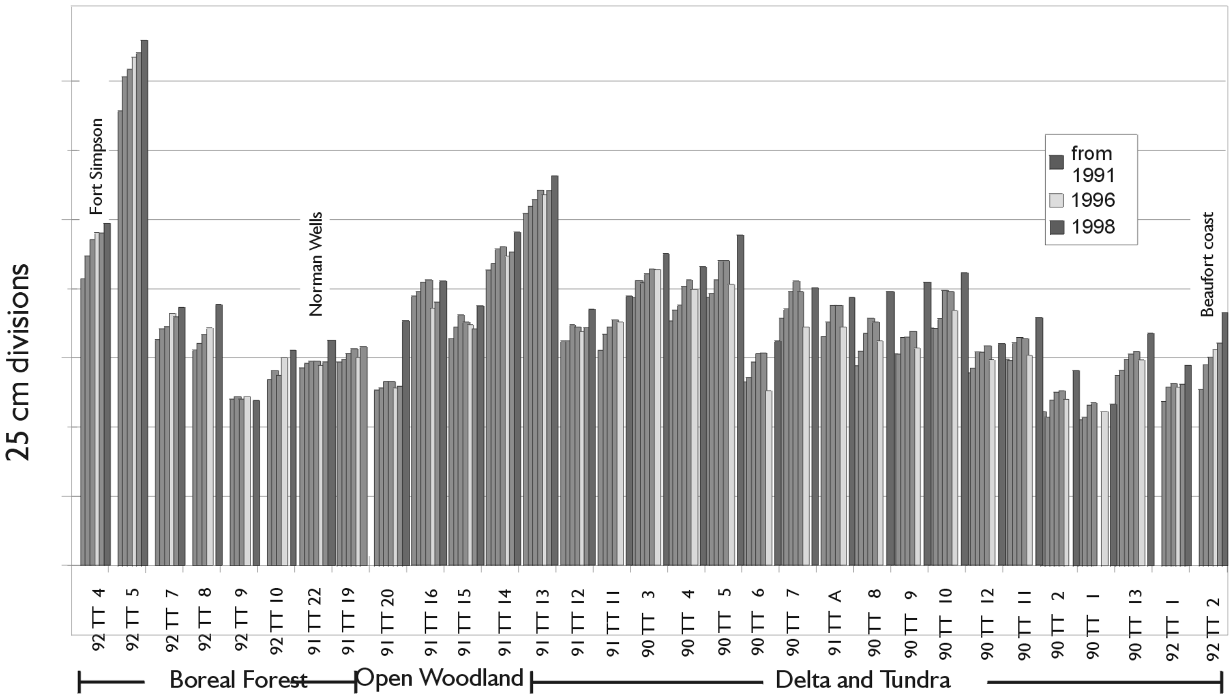
- Thaw (or frost) tubes are the primary device for measuring active layer in our system. These consist of a stable access tube anchored in permafrost, containing a clear plastic water and ice filled observation tube in which colour-coded markers record maximum thaw. A scriber records heave and subsidence on the painted access tube surface.
- An annual survey during the thaw season measures the previous season's thaw penetration from a stable reference, independent of the moving ground surface. Current ground surface relative to the reference and subsidence since previous visit allows calculation of the last year's active layer thickness, assuming concurrence with maximum subsidence.
- Other observations and measurements such as probing, moisture content, maximum heave, etc. are made to provide supporting information and to check the performance of the tube.



Mast

- As shown on the map, complimentary temperature records are gathered at many monitoring sites. Air temperatures and ground surface temperatures are recorded using miniature data loggers at six hour intervals. This data is retrieved and loggers replaced during the annual survey.





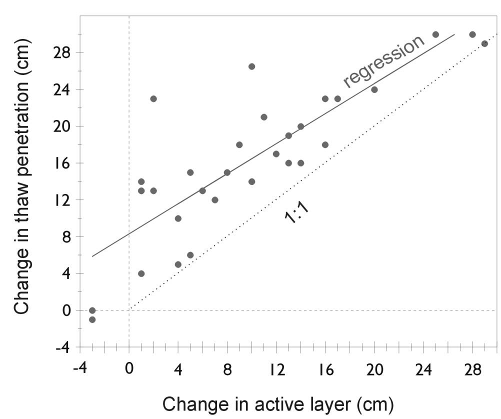
Year-to-year variation of maximum thaw penetration, measured from a stable reference point independent of the surface, at selected sites.

Annual Thaw Penetration:

- We now have from a 6 to 8 year record of annual thaw throughout the Valley and Delta. This chart presents corrected thaw penetration rather than active layer to facilitate comparison between sites.
- Thaw penetration has steadily increased during the period at most sites.
- North of Norman Wells, thaw in 1996 (the yellow bar) was substantially less than the previous year. 1996 was cooler than normal by as much as 2° during July and August and the response of thaw tubes builds confidence in the method.
- 1998 was an anomalously warm year Canada wide and particularly in the Mackenzie Valley. The red bar, representing 1998 thaw shows in most cases maximum thaw for the period, often by an unusually large increase.

Active Layer vs Thaw Penetration:

- The reason thaw penetration, measured from a reference independent of the ground surface, rather than active layer thickness is used to compare site to site is illustrated by the scatter. There is correlation between changes in active layer and thaw penetration over the period of record, still, considerable scatter exists due to variable thaw settlement. Ground ice content and soil character at each site as well as thaw penetration will effect active layer thickness,

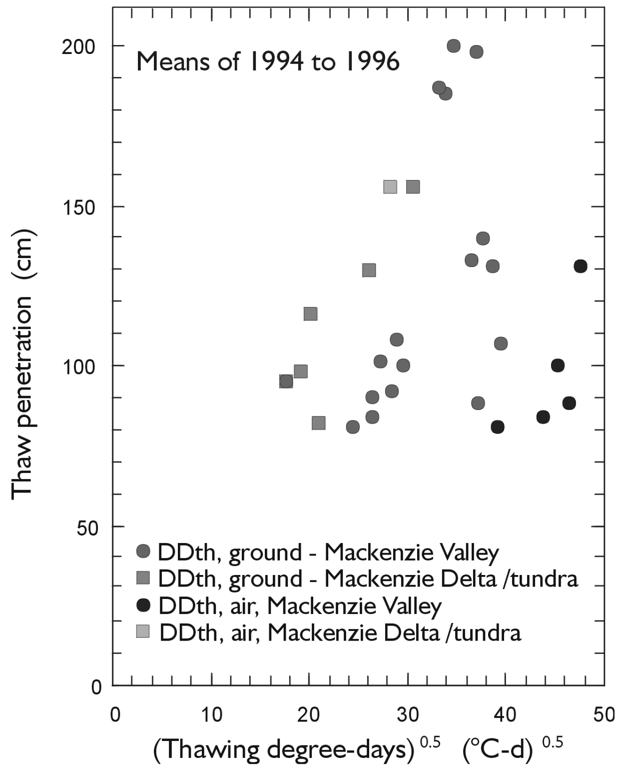


Change in thaw penetration versus change in active layer thickness, since installation. Illustrates the variable lag of active layer increase behind an increasing thaw penetration, measured from a reference point independent illustrating just one aspect of the complexity of active layer development.

- Changes in thaw penetration are often much greater than changes in active layer thickness pointing out that during at least an initial period of increasing thaw penetration, it may be difficult to estimate the rate or even to detect change simply by probing for thaw depth relative to ground surface.

Thaw Penetrtion vs DegreeDays:

- From the air and ground temperature records at several active layer monitoring sites it is possible to calculate thawing degree days and compare this index to thaw penetration as an intuitively important factor.
- Considerable variation of thaw penetration occurs over equivalent thawing degree days due to site factors such as snow cover, vegetation, insulating organic material, etc.
- The shift in Valley DDs compared to Delta/tundra DDs is not consistantly accompanied by greater thaw penetration, suggesting that more thermal energy is required to produce thaw penetration in the Boreal zone. Here is another indication of the complexity of the response of active layer to changing external thermal conditions.



Variability:

- Several of the stations are designated CALM sites and we have supplemented thaw tubes with 100 meter probing grids. This produces complimentary information on the local variability of active layer and how tube values compare.
- A common feature of the active layer is considerable lateral variability over short distances. This is evident in the grid ranges (yellow).
- A thaw tube calculation of active layer is a point value and may or may not represent the general situation in the immediate area, (green). Tubes where installed before the grid measurements mapped the distribution of active layer thickness around the site.
- Only two seasons of grid probing are available but the mean active layers from the grids are very similar year to year (blue). This is a feature of active layer that is also evident over longer periods in calculations from several thaw tubes at grid sites and elsewhere.

Variability of thaw depth around thaw tube sites

GRID	DATE	THAW TUBE	GRID MEAN	MAX	MIN	σ
North Hd.	Aug. 1998	65 cm.	52.5 cm.	84 cm.	37 cm.	8.2 cm.
	Aug. 1999	64 cm.	52.4 cm.	86 cm.	34 cm.	9.1 cm.
Taglu	July 1998	111 cm.	98 cm.	>132 cm.	67 cm.	17.8 cm.
	Aug. 1999	98 cm.	101 cm.	>132 cm.	72 cm.	14.5 cm.
Lousy Pt.	Aug. 1998	89 cm.	64 cm.	107 cm.	26 cm.	15.6 cm.
	Aug. 1999		61.9 cm.	100 cm.	8 cm.	15.7 cm.
Reindeer	June 1998	44 cm.	21.8 cm.	48 cm.	10 cm.	7.0 cm.
	Aug, 1998	73 cm.	47.6 cm.	74 cm.	24 cm.	11.1 cm.
	July 1999	61 cm.	34.3 cm.	62 cm.	17 cm.	11.0 cm.
Rengleng	June 1998	68 cm.	47.7 cm.	74 cm.	24 cm.	9.4 cm.
	Aug. 1998	116 cm.	82.3 cm.	116 cm.	54 cm.	14.2 cm.
	Aug. 1999		77.9 cm.	107 cm.	47 cm.	12.5 cm.
Francis Ck.	July 1998	54 cm.	37.3 cm.	79 cm.	21 cm.	11.6 cm.
	Sept. 1998	67 cm.	50.1 cm.	116 cm.	33 cm.	13.3 cm.
	Aug. 1999	49 cm.	48.6 cm.	100 cm.	30 cm.	14.0 cm.
Martin R.	Aug. 1999	76 cm.	69.9 cm.	>120 cm.	40 cm.	16.8 cm.

Closing Points:

- Some measure of thaw penetration independent of a fluctuating ground surface can contribute to early detection and quantification of near surface ground response to annual thaw.
- The process of thaw penetration and consequent active layer development is complex, depending on local factors as well as regional atmospheric forces.
- Perhaps the data produced by the monitoring effort can be used to select appropriate sites for modelling active layer processes and contribute to model training leading to a better understanding of the complicated process of active layer development?