Relation of Active Layer Depth to Vegetation on the Central Yamal Peninsula, Russia

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Introduction

The purpose of this study was to obtain ground observations in support of remote sensing data. The normalized difference vegetation index (NDVI) and leaf area index (LAI) were measured within a Circumarctic Active Layer Monitoring (CALM) program grid and compared to active layer depth (ALD) measurements. Additional data on active layer properties (soil texture and moisture content), surface features (spot-medallions, hummocks, polygonal pattern and windblown hollows), vegetation complexes, organic mat thickness, and shrub height were analyzed.

The study area is located on the central Yamal Peninsula in the watershed of the Se-Yakha and Mordy-Ykha Rivers. A CALM grid was placed on the top and slope of a highly dissected alluvial-lacustrine-marine plain, affected by landslides with sandy to clayey soils.

Active surface aeolian and landslide processes common in the study area produce vast areas of bare ground. The rate of revegetation and plant succession at such sites related to climate fluctuations was examined through repeated descriptions of vegetation coverage and species in 1993 and 2007.

Previous studies have shown that the main controls of the active layer dynamics are the types of surficial deposits, moisture content in the fall, thickness of organic cover, and air temperature in summer. In general, maximum ALD (1–1.2 m) is found in sands on bare surfaces or with sparse vegetation and low moisture content (up to 20%). Minimum ALD (50–60 cm) is found in peat or clay deposits covered by thick moss and with moisture contents more than 40%.

Methods

The active layer was monitored using a metal probe according to the procedure accepted by the CALM program (Brown et al. 2001) within a grid 100 x 100 m in 10 m increments. Ground and vegetation characteristics were recorded at each grid node. NDVI was measured using a portable ASD PSII spectroradiometer, and LAI was estimated using a LICOR-2000 plant canopy analyzer. NDVI is essentially an index of green, photosynthesizing vegetation, as it strongly depends on the absorption of red light. LAI (as estimated by the LICOR-2000) is the total area of aboveground plant tissue divided by the ground area that is covered by the extent of the plant canopy. Both NDVI and LAI are highly, positively correlated with the mass of aboveground vegetation, and this is true for Low Arctic tundra vegetation (Riedel et al. 2005).

A database was compiled that included ALD, NDVI, LAI, organic mat thickness, shrub height, dominant plant species, and cover of each plant community. The spatial distribution of various parameters was analyzed on a map compiled by interpolation of numerical data between grid-nodes using Surfer software, and field mapping of descriptive data (map not shown).

Active layer measurements in 2007 were accompanied by vegetation descriptions and measurements at each grid-node (121 points and their vicinities were characterized in the database). The data were sorted into three categories of ALD, the averages of all the parameters were calculated, and relations between these averages were analyzed within each category.

Results and Discussion

In general, for the entire CALM grid, the higher the vegetation indices and parameters the lower the ALD (Fig. 1). This result is within the generally accepted effect of vegetation insulation on ground temperatures and ALD (Melnikov et al. 2004).

Analysis of dominant plant species supports the idea that vegetation acts as an insulating mat. Of all the plant groups, moss showed the highest negative correlation with ALD, while lichens and shrubs were more favorable for thawing (or deep thaw was favorable for lichen and shrub growth) (Fig. 2).

Eight vegetation units (Table 1) were recognized within the grid. "Moist grass-sedge-dwarf shrub lichen-moss and green moss hummocky tundra" (#5, Table 1) is most widespread. Partly bare surfaces (#1, 2, 3, and 8, Table 1) are also common, though no bare nodes occurred on the windblown sands, due to recent vegetation recovery.

When the CALM grid was established in 1993, five bare surface grid-nodes occurred in windblown hollows (Leibman 1998). Revegetation of windblown sands started after

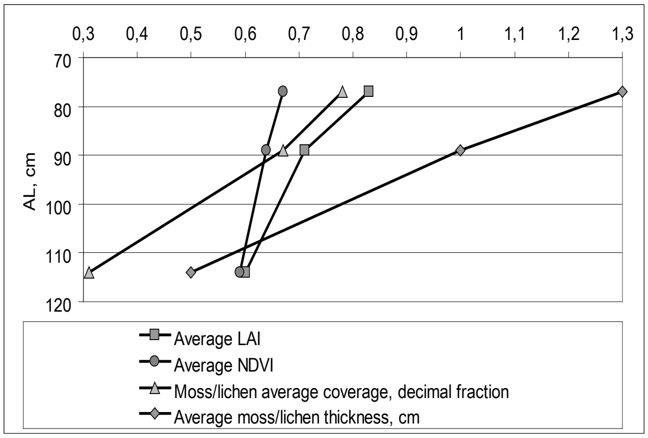

Figure 1. Relation between the active layer depth and average vegetation indices at a CALM grid, research polygon Vaskiny Dachi.

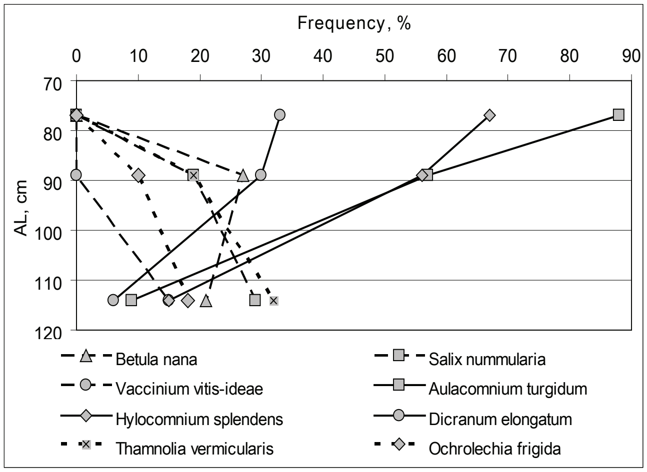

Figure 2. Relation between the active layer depth and frequency of dominant plant species at a CALM grid, research polygon Vaskiny Dachi.

Table 1. Legend for vegetation map of the CALM grid Vaskiny Dachi.

##	Vegetation complex (% bare surface)	Number of grid-nodes
1	Dry blowout sands	0
2	Dry grass-prostrate dwarf shrub-green moss-lichen tundra with spot-medallions (40–60%)	24
3	Dry grass-prostrate dwarf shrub-green moss and green moss-lichen tundra with spot-medallions (10–30%)	12
4	Moist grass-dwarf shrub lichen-moss and green moss tundra	4
5	Moist grass-sedge-dwarf shrub lichen-moss and green moss hummocky tundra	61
6	Moist grass-sedge-low shrub moss tundra	6
7	Wet willow-cotton grass cover	9
8	Moist willow-sedge-grass cover (30–50%)	5

considerable warming in 2000, so the observed revegetation resulted from eight years of change. Shear surfaces of two landslides within the CALM grid were exposed during the landslide event in 1989. Twelve grid nodes became bare surfaces following these events. A survey in 2007 showed that seven grid nodes were entirely revegetated (100% coverage by willow-cotton grass complex, #7, Table 1), and five grid-nodes were partly revegetated (up to 50% coverage by willow-sedge-grass complex, (#8, Table 1) in 18 years.

Conclusion

The active layer depth is negatively related to both LAI and NDVI. This is potentially helpful for mapping active layer depths, using remotely sensed vegetation indices and products. Organic matter coverage and thickness are also negatively related to active layer depth; this is especially true for moss cover. Contrary to the moss species, there is an ordinal relation between ALD and lichen/shrub species.

Temporal patterns of vegetation dynamics on bare surfaces after 10–18 years of revegetation result in the formation of dwarf shrub-lichen cover on dry sandy tops and gentle slopes, willow-cotton grass cover on wet landslide shear surface sites, and willow-sedge-grass cover on moist sites.

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References

Brown, J., Hinkel, K.M. & Nelson, F.E. 2001. The Circumpolar Active Layer Monitoring (CALM) program: Research designs and initial results. *Polar Geography* 24: 165-258.

Melnikov, E.S., Leibman, M.O., Moskalenko, N.G. & Vasiliev, A.A. 2004. Active layer monitoring in West Siberia. *Polar Geography* 28(4): 267-285.

Leibman, M.O. 1998. Active layer depth measurements in marine saline clayey deposits of Yamal Peninsula, Russia: procedure and interpretation of results. *Proceedings of the 7th Intl. Conference on Permafrost, Yellowknife, Canada, June 23–27, 1998*: 635-639.

Riedel, S.M., Epstein, H.E & Walker, D.A. 2005. Biotic controls over spectral indices of arctic tundra vegetation. *Intl. Journal of Remote Sensing* 26: 2391-2405.