COMPARISON OF WINTER COVER COMPONENTS FOR A SUBARCTIC LAKE AND PEATLANDS

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Introduction
In Canada, 25% or more of the land surface in the boreal and subarctic regions consist of peatlands (Koltai and Pollett, 1983). Though peatlands have been extensively studied, little research has been devoted to the winter conditions (e.g. snow and ice cover), which can exist for more than six months a year. This paper will discuss the winter cover components of peatlands and compare them to a similar type found on an adjacent lake. The lake was used as a reference, since its winter cover components have been well documented (e.g. Adams, 1981).

During the winter of 1984-85, a study of a lake and two peatlands was undertaken to note similarities and differences in their winter cover components. The study was conducted at Lac Knob, Arles fen and Capricorn fen in the subarctic region near Schefferville, Quebec. Although the mediums differ (e.g. the lake being free circulating water and the peatland consisting of a water-saturated organic soil), there were similarities in their type, growth decay and pattern of winter cover components. Snow, white and black ice (lake cover components) occurred on both (Fig.1), with peatlands having the additional winter cover component of seasonally frozen peat (i.e. terrestrial frost), underlain by a dehydrated layer of peat.

Snowcover
A snowcover can develop on lakes after the formation of ice. Depending on the weather conditions, the snowcover can be easily transported off and on the smooth ice sheet by winds. The general snow pattern, which exists after a storm and for the remainder of the winter, is characterized by an increase in snow depth at the margins, especially on the lee and downwind locations. On the other hand, exposed areas (e.g. the centre) exhibit a thin, highly compact snowpack (Adams et al., in press). This pattern is called a mature snow cover pattern.

Once the peatlands have commenced to freeze (either ice or terrestrial frost), the evolution of snowcover is similar to that of a lake. So is the subsequent mature snowcover pattern. The difference between lakes and peatlands is the sequence of development of the cover pattern. A lake surface is smooth, while the peatland has a varied microtopography caused by pools, hummocks, and vegetation locations. At the beginning of the winter, the exposed areas of peatlands usually have a greater snow depth than the margin because of sedges and shrubs retaining the snow. Once the depressions are "filled-in", the snowcover develops in a pattern similar to that of a lake.

The rough microtopography and vegetation of the peatland also affects the physical properties of the snowcover (Brown and Williams, 1972). The peatlands have a greater snow depth and water equivalent, due to vegetation retaining the snow, but has a lower snow density when compared to a lake.

White ice
There are several types of white ice development on a lake (Adams, 1981). A common form of white ice results from the slushing event. This occurs on an ice sheet following a heavy snowfall, which forces it below the hydrostatic water level.
The increased pressure on the ice sheet cracks it, and water upwells into the snowcover and refreezes. The white ice affects the lake ice sheet by restricting the black ice growth. Its formation and subsequent existence reduces thermal gradient from the atmosphere to the freezing front of the black ice (Adams, 1976).

The role of white ice development on peatlands is less important. It exhibits a limited growth and spatial variation in the ice cover. All types of white ice can occur, and generally there are two main growth periods. The first period is at the beginning of the ice sheet growth with snow melting and slushing occurring. The second period is during the spring melt with meltwater (snow, ice and terrestrial runoff) freezing on the existing ice sheet. As the percentage of winter cover which is white ice is small, its alteration of the temperature gradient would not greatly affect the freezing peat.

Black ice
Black ice makes up the greatest proportion of total ice on lakes. It is the first type of ice to form, and develops steadily throughout the winter. The growth can be affected by the snow and white ice cover since they act as an insulating layer. This also affects the thermal gradient from the black ice, thereby limiting its growth.

Peatlands also exhibit black ice, which forms in wet depressions (e.g., ponds/wet flarks). In ponds, the black ice develops downward to the peat medium. For wet flarks, the pooled water will freeze initially as black ice. The ice sheet on the wet flarks (usually less than 10 cm), is often partially or wholly converted to white ice during the winter through melting and subsequent refreezing events (Kingsbury, in prep.). The limited amount of black ice is not greatly affected by the snowcover. Usually the wet depressions are not deep (<1 m). The formation of black ice in this case, is only slowed by snow and not restricted. Likewise, white ice on black ice does not seem to significantly affect the growth of black ice.

Terrestrial frost
Depending on lake characteristics (i.e., depth, surface area), sediments below a frozen waterbody may be frozen. This is most apparent in shallow ponds, though it can occur along the margins of lakes.

Terrestrial frost in peatlands comprises the greatest ice cover component. The frost penetration starts in the upper layers of the peat, where it is saturated with water and less compressed. Initially, freezing is restricted to the water within the peat medium, forming a homogeneous pore ice. The surface layer freezes more slowly than the lake ice. This is due to the thermal properties of the peat and the snowcover (Moore, unpublished manuscript).

With a permanent snowcover, ice lenses are formed by segregation within the peat, beneath the freezing front. Under a shallow temperature gradient caused by the snowcover, water migrates to the freezing front and forms an ice lens. In the peat, the water migration forms a dehydrated layer under the freezing front (Juusela, 1967) and beneath the ice lens. The dehydrated peat depth (fig. 2) was also increased by a water table lowering during the winter (Kingsbury, in prep.) The dehydrated layer persists until it is resaturated with water during the spring melt (see Fig. 2). Snowcover on peatlands inhibits the depth of frost penetration (Eurola, 1975). Based on a mature snowcover on subarctic peatlands, increased snowcover results in a decreased movement of the freezing front downward into the peat (Fig. 3).

Growth rates
The monthly averaged ice or frost growth rates for both lake and peatlands followed the same pattern, i.e., rapid growth at the beginning of freeze-up, followed by a slower, but steady growth rate for the duration of winter. As noted in Figure 4, the depth of ice or frost growth is different for each medium. The lake ice at its monthly averaged peak ice conditions (P.I.C.) is 122.6 cm for April, whereas the peat for its monthly averaged P.I.C. is 60.3 cm for May. The shallower depth at which the peatlands reach P.I.C. affects its averaged growth rate being 0.32 cm/day whereas for the lake, it is doubled at 0.66 cm/day. The time to reach P.I.C. is longer for the peatlands.
as compared to the lake, resulting from the thermal conductivity of a frozen organic soil (i.e. peat) being 1.20 W m$^{-1}$ K$^{-1}$ (Goodrich, 1992) compared to ice at 2.22 W m$^{-1}$ K$^{-1}$ (Clark, 1966).

Decay rates
During the decay period, both lakes and peatlands had a similar decay pattern, i.e. a slow initial melt, followed by a steady increase in melt rate until the ice or frost cover was completely melted (Fig. 5). Also, both mediums exhibited surface and subsurface melt of their ice cover (Figs. 2 and 6). Though the pattern is generally the same, there are differences between the lake and peatlands in their ice or frost cover decay. It takes about the same time period to melt the ice cover for both, though the frost depth of a peatland is half as much as the lake. In fact, the average melt rate is twice as fast for the lake (1.51 cm/day) compared to the peatlands (0.76 cm/day). This can be attributed to the thermal properties of the peat. Comparing Figures 2 and 6, the time taken for complete melting of the ice cover in the peatland is longer than the lake. This is associated with the thermal properties of the peat making for a longer freeze-up time period and a slower melt process.

Conclusions
Both similarities and differences were noted between a subarctic lake and the winter cover components of peatlands. The snowcover illustrated the same mature snowcover pattern (i.e. snowcover depth increase at margins, decrease for exposed areas) on both the lake and peatlands. There were differences in the physical properties of the snow, with the peatlands snowcover having an increased depth and water equivalent but a decrease in its density. Both lake and peatland freeze-up was affected by the snowcover, with increased snow depth restricting ice or frost growth.

For both frost and ice cover, two types (white and black ice) were noted on both the lake and peatlands. However, the peatland ice cover largely composed of terrestrial frost (i.e. seasonally frozen peat) with a dehydrated layer beneath it. The peatland's ice cover growth and decay rates (0.32 cm/day; 0.76 cm/day) were slower than the lake's (0.66 cm/day; 1.51 cm/day) due to the thermal properties of the peat. Both mediums also illustrated surface and subsurface melt, during their ice or frost cover decay.

Acknowledgments
Research was carried out at the McGill Subarctic Research Station in Schefferville, Quebec, with funding provided by D.I.N.A. travel grant and N.S.E.R.C. I would like to thank D.R. Barr and the staff of M.S.E.R.S. for their aid in the field, Dr. R.K. Wright, D.T. Desrochers for their comments on written manuscript, and Mary Vanover for the typing of it.

References

Figure 1. Winter cover components for subarctic lakes and peatlands.

Figure 2. 1984-85 winter cover component profile for Capricorn fen, based on a wet flask site.

Figure 3. Relationship between snow depth and frost depth in subarctic peatlands, based on a "mature" snow cover.
Figure 4. Monthly averaged depth of ice freeze for a subarctic lake (---) and peatlands (---) for the winter of 1984-85.

Figure 5. Monthly averaged ice depth melt of a subarctic lake (---) and peatlands (---) for the spring of 1985.

Figure 6. 1984-85 winter cover component profile for Lac Knob.