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Determining Depth and Ice Thickness of Shallow Subarctic Lakes and Ponds using Spaceborne Optical and SAR Data

C.R. DUGUAY[1] AND P.M. LAFLEUR[2]

EXTENDED ABSTRACT

Shallow lakes and ponds are conspicuous features in northern Canada, Alaska, and eastern Siberia. During summer they play a significant role in the regional energy and water balance, and their importance in the global methane budget is now recognised (Kling *et al.* 1992; Michmerhuizen *et al.* 1996). There is also recent evidence that conductive heat losses from ice-covered lakes on the Alaskan North Slope, for example, make a significant contribution to the regional energy budget during winter (Jeffries *et al.* 1999). As well, it has been shown that the thickness and duration of ice cover on lakes are sensitive indicators of regional climate variability (Hall *et al.* 1994; Doran *et al.* 1996; Livingstone 1997). Limnologically, these variables have a wide-ranging influence on many physical and chemical properties of the aquatic ecosystem that directly or indirectly affect the biota, for example through changes in the length of the growing season, wind-induced mixing, gas transfer and underwater light availability (Vincent *et al.* 1998). Identifying those lakes that freeze or do not freeze to their bed each winter is also of interest in permafrost research. For example, Burn (1990) showed that frost heave can be observed within the zone of a lake where the lake is frozen to the bed, resulting in a modification of the lake level. Alternatively, lakes that do not freeze to the bottom can develop deeply thawed zones (taliks) due to the thermal effect of the year-round presence of a water body. A good knowledge of depth, ice cover duration, and ice thickness of subarctic and arctic lakes is also important as these variables determine the value of the lakes as sources of fresh water for settlements and industrial development (Sellmann *et al.*, 1975; Jeffries *et al.*, 1996).

A method to determine depth and ice thickness of shallow lakes and ponds using Landsat Thematic Mapper (TM) and ERS-1 SAR data was developed. A summer time Landsat TM image was used to map lake bathymetry and multi-date ERS-1 images acquired during winter were utilised to determine when and which lakes freeze to the bottom during winter. The two remotely sensed derived products were then combined to estimate ice thickness from lakes and ponds on a monthly basis. The method was developed and tested successfully in a subarctic tundra-forest landscape in the Hudson Bay Lowland near Churchill, Manitoba, Canada. Lake depth estimates derived from Landsat TM Band 2 compared well with measurements obtained in the field (root-mean-square error (RMSE) = 15 cm). Maximum ice thickness estimates were also within the range of those typically measured during winter in this study area (tundra and forest-tundra zones ≅ 1.85 m; open forest zone ≅ 1.25 m). Variations in ice thickness within and between the three ecological zones are explained by differences in lake morphometry (e.g., depth and area) and snow cover depth. Results from this study indicate that the method is particularly well suited for estimating depth and ice thickness of shallow oligotrophic and ultra-oligotrophic lakes that are widespread in many regions above treeline. However, the results also suggest that the Landsat-based method will require further testing and improvement if one wishes to map bathymetry for lakes in which large nutrient concentrations or amounts of suspended sediments are found.

Key words: Shallow lakes, bathymetry, icc thickness, ERS-1 SAR, Landsat TM.

[1] Laboratoire de télédétection et de modélisation des environnements froids (LTMEF), Département de géographie et Centre d'études nordiques, Université Laval, Sainte-Foy, Québec G1K 7P4, Canada
[2] Department of Geography, Trent University, Peterborough, Ontario K9J 7B8, Canad

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