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Ice Pile-Up on Shores in Northwestern Lake Ontario during Winter 1990
Crêtes glacielles sur les rivages du nord-est du lac Ontario au cours de l'hiver de 1990

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Résumé de l'article

Deux cas d*empilement de glaces se sont produits autour de petites îles du nord-est du lac Ontario pendant l'hiver de 1990: le premier, inhabituel, le 24 janvier, et le deuxième, à la débâcle, le 17 mars. Dans les deux cas, l'empilement s'est produit pendant des périodes plus chaudes. L'amincissement et l'affaiblissement de la glace ont alors été tels que des vents modérés ont pu transporter une partie des glaces vers le large. Peu de temps après, les vents du large ramenaient les glaces vers le rivage où elles se sont empilées dans les eaux peu profondes autour des îles pour former des crêtes. Dans les deux cas, l'empilement dépassait 104m3 en volume, mais était de petite étendue et a eu très peu de conséquences sur la morphologie littorale.

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Notes

ICE PILE-UP ON SHORES IN NORTHWESTERN LAKE ONTARIO DURING WINTER 1990

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ABSTRACT Two wind-driven ice pile-up events occurred at small islands in northwestern Lake Ontario in winter 1990, the first, an unusual, mid-winter event on 24 January and the second on 17 March at breakup. Both occurred during periods of warm weather which weakened and thinned the ice sheet so that moderate winds were able to drive part of the ice cover offshore. Soon after, onshore winds drove the ice back where it piled in shallow water along the islands. In both cases the volume of ice pile-up exceeded 10^4 m^3, but was very limited in extent and had little geomorphic effect on the coasts.

RÉSUMÉ *Crêtes glacielles sur les rivages du nord-est du lac Ontario au cours de l'hiver de 1990.* Deux cas d'empilement de glaces se sont produits autour de petites îles du nord-est du lac Ontario pendant l'hiver de 1990: le premier, inhabituel, le 24 janvier, et le deuxième, à la débâcle, le 17 mars. Dans les deux cas, l'empilement s'est produit pendant des périodes plus chaudes. L'amincissement et l'affaiblissement de la glace ont alors été tels que des vents modérés ont pu transporter une partie des glaces vers le large. Peu de temps après, les vents du large ramenaient les glaces vers le rivage où elles se sont empilées dans les eaux peu profondes autour des îles pour former des crêtes. Dans les deux cas, l'empilement dépassait $10^4 m^3$ en volume, mais était de petite étendue et a eu très peu de conséquences sur la morphologie littorale.

INTRODUCTION

Ice formation on northeastern Lake Ontario normally begins in protected bays in early December and proceeds to the exposed shores by January (Bolsenga, 1988). By late February ice reaches maximum extent, but covers only the eastern portion of the lake before decaying and breaking up by late March or early April (Assel *et al.*, 1983). Thermal expansion and the development of ice ridges occur almost every winter (Metge, 1977), although they have little or no geomorphic effect on coasts. Wind-driven ice push is more irregular both in timing and location. It normally occurs at breakup and only if suitable wind conditions coincide with partial melting and weakening of the ice sheet. Our observations since 1976 show only one ice-piling event at breakup in the Kingston area (Gilbert and Glew, 1986) before the winter of 1989-90. This note describes an unusual mid-winter event and an event at breakup in 1990, both at small islands near Kingston (Fig. 1).

MID WINTER ICE PILE-UP

Mean monthly temperatures at Kingston Airport (Fig. 1) were 1.7°C and 8.9°C below normal in November and December 1989 respectively (Atmospheric Environment Service, 1989), causing ice to form at Kingston on 14 December (Fig. 2), about 3 weeks before normal. Several periods of above freezing temperatures beginning in late December melted the insulating snow cover, allowing the ice to continue to grow in the cold periods between (Fig. 2). On 17 and 18 January temperatures reached 7.5°C and 7.0°C respectively accompanied by 15.8 mm of rain. This, combined with moderate south to southwest winds and waves from the open water of Lake Ontario, thinned and weakened the ice sheet. On 20 January the wind backed from southwest to northeast where it blew steadily during 21 January (A in Fig. 3). Despite the cold temperature of that day, the ice had been sufficiently weakened to move offshore in the gap between Amherst and Simcoe islands (Fig. 1). In the relatively warm temperatures of the 22nd and 23rd (Fig. 3), new ice was not able to form in the open water created by this ice movement.

The ice pile-up occurred between 22 and 24 January only at Salmon Island (Fig. 1). The event was not observed directly but may be inferred from meteorological conditions. Given that it was located only at the south and east sides of the island, it is unlikely that the southwest winds of 22 and 23 January (B in Fig. 3) were responsible. Amherst Island offers significant protection from this direction. However, by afternoon on the 23rd, southeast winds had developed, strengthening and veering to south by morning of the 24th with a maximum mean hourly speed of 50 km/h (C in Fig. 3). Onshore ice movement probably occurred at this time, although it may have continued during warm conditions and southerly winds through the 25th.

Unsafe ice conditions prevented visiting the site until 21 March, several days after breakup. The ice pile is mapped on Figure 1 as it was observed then, although melting in the intervening two months may have altered the ice and obscured some details.

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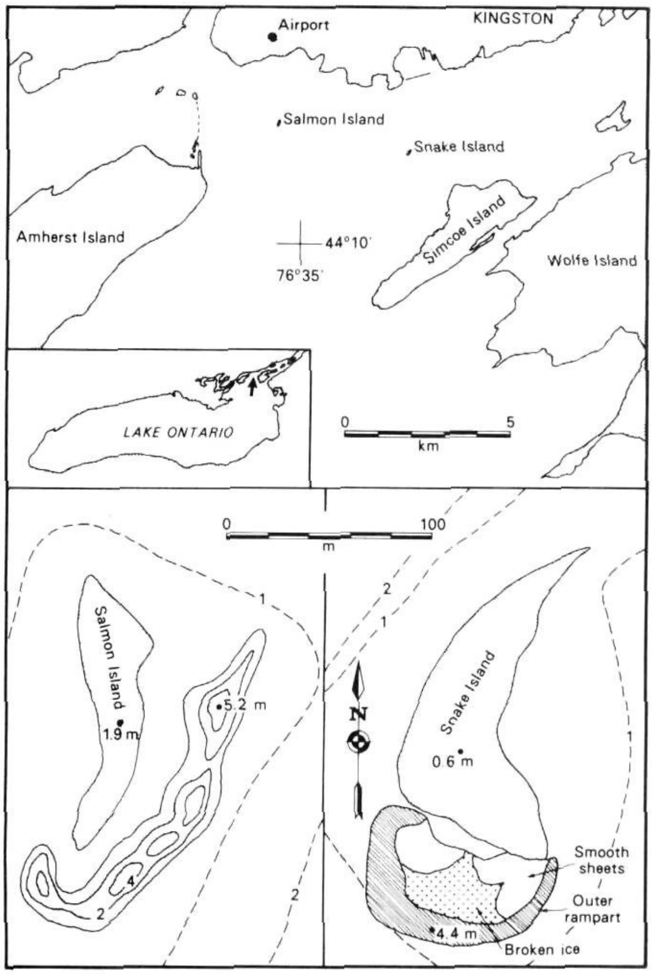

FIGURE 1. Area of eastern Lake Ontario studied showing the location of Salmon and Snake islands (above) and the ice piling sketched in the field (below). Contours at 2 m intervals were determined by chain and Abney level survey and isobaths at the time of ice piling were estimated from Canadian Hydrographic Service field sheet 8078.

Carte de localisation de la partie est du lac Ontario où se trouvent les îles Salmon et Snake (haut) et schéma des crêtes glacielles (bas). Courbes établies à 2 m d'intervalle et isobathes estimées au moment des empilements de glace à partir du feuillet n° 8078 du Service hydrographique du Canada.

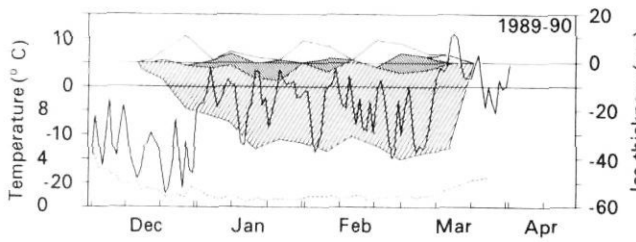

FIGURE 2. Growth of ice on Lake Ontario at Kingston in 1989-90. Black and white ice are shown by cross hatching, slush by stipple, and snow unshaded. Mean daily air temperatures were recorded at Kingston Airport (solid line: scale -25 to 15°C) and mean daily water temperature by the Public Utilities Commission at Kingston (dashed line: scale 0 to 8°C).

Développement de la glace sur le lac Ontario, près de Kingston, en 1989-90. Les hachures représentent la glace noire et la glace blanche, le pointillé, la neige mouillée, et la surface claire, la neige. Les températures journalières moyennes de l'air ont été enregistrées à l'aéroport de Kingston (ligne pleine: entre -25 et 15°C) et les températures journalières moyennes de l'eau (ligne tiretée: entre 0 et 8°C) par la Public Utilities Commission de Kingston.

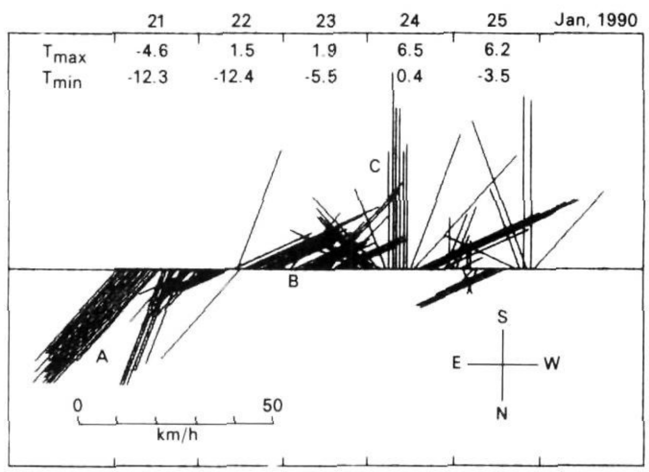

FIGURE 3. Mean hourly wind, and maximum and minimum temperatures at Kingston airport (Fig. 1) 21-25 January 1990. Orientation is as Figure 1. A, B, and C refer to discussion in text (source: Atmospheric Environment Service, 1990).

Directions moyennes des vents aux heures et températures maximales et minimales à l'aéroport de Kingston (fig. 1), du 21 au 25 janvier 1990. Même orientation que sur la figure 1. A, B et C sont expliqués dans le texte (source: Atmospheric Environment Service, 1990).

Salmon Island is formed from a cover of about 2 m of gravel on a submerged limestone platform extending from Amherst Island. The ice pile occurred in less than 1 m of water (Fig. 1) but did not actually reach the island itself. It formed a ridge of about 1.1 × 10^4 m^3 consisting of mounds (Fig. 4) one of which was over 5 m high. There was no evidence that sediment was transported by the ice, and no sediments were visible on its surface (compare Gilbert and Glew, 1986), although much of the limestone platform at the outside edge of the ice mass was swept free of stones. Whether this was due to the action of the ice or to waves during previous open water periods is unknown. Overall, the ice appears to have had little effect on the island or the lake bottom nearby.

ICE PILE-UP AT BREAKUP

Air temperature remained 1 to 5°C above normal through January, February and March 1990 at Kingston (Atmospheric Environment Service, 1990). Nevertheless, the ice grew to a maximum thickness of 0.44 m at the study site on 28 February. It remained nearly this thick until 11 March, when warm weather began to melt it rapidly (Fig. 2). Winds until 16 March were light and variable and air temperatures high (Fig. 5). During the night of 15-16 March moderate northeast winds (A in Fig. 5) blew part of the decayed ice sheet offshore, although ice near shore along the Kingston waterfront remained in place.

FIGURE 4. View looking south of the ice piling at Salmon Island, 21 March 1990. The island appears at far right.

Crêtes glacielles de Salmon Island vues vers le sud, le 21 mars 1990. L'île apparaît à l'extrême droite.

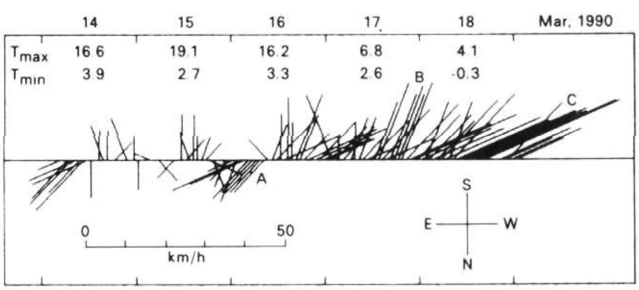

FIGURE 5. Mean hourly wind, and maximum and minimum temperatures at Kingston airport (Fig. 1), 14-18 March 1990. Orientation is as Figure 1. A, B, and C refer to discussion in text (source: Atmospheric Environment Service, 1990).

Directions moyennes des vents aux heures et températures maximales et minimales à l'aéroport de Kingston (fig. 1), du 14 au 18 mars 1990. Même orientation que sur la figure 1. A, B et C sont expliqués dans le texte (source: Atmospheric Environment Service, 1990).

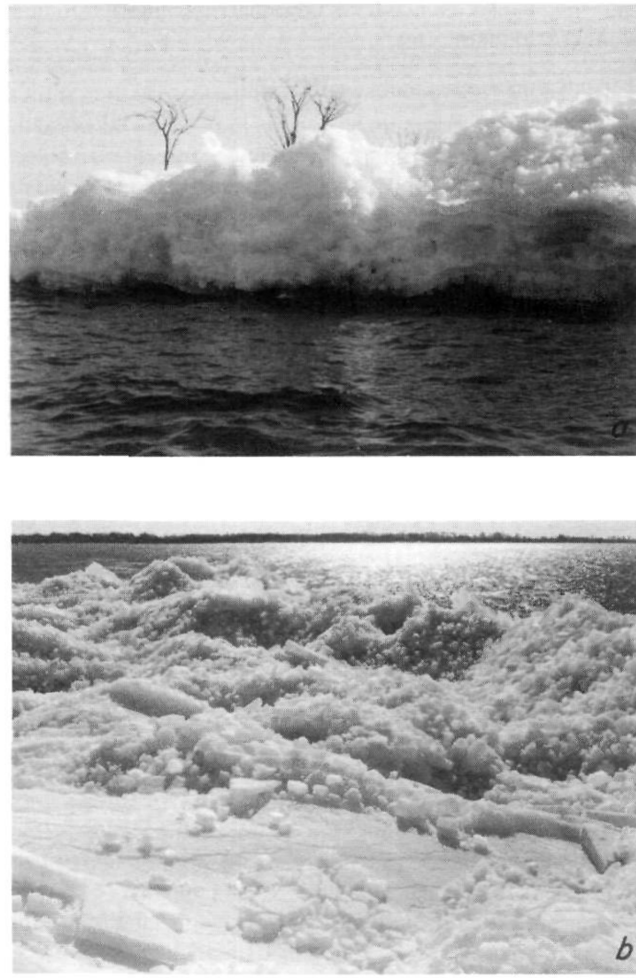

FIGURE 6. Views of ice piling at Snake Island, 21 March 1990 (a) looking northeast at the wave-eroded cliff, (b) looking southeast from the northwestern end of the rampart.

Crêtes glacielles à Snake Island, le 21 mars 1990 (a) vues vers le nord-est (b) vues vers le sud-est, à partir du nord-ouest.

The exact time of ice pile-up at Snake Island on 17 March was not observed, but it is inferred that it occurred during moderate south southwest winds (maximum mean hourly speed 20 km/h) during the afternoon (B in Fig. 5). When the site was visited on 21 March, strong winds (C in Fig. 5) had already eroded part of the southwest edge of the ice pile, exposing the internal structure (Fig. 6a).

Snake Island is similar to Salmon Island except that bedrock emerges above normal water level and the veneer of gravel is patchy and thinner than on Salmon Island. The ice pile-up occurred in water less than 1 m deep (except at the outside edge) and the inner edge of the pile just reached the shore. The candled ice sheet of average thickness 0.16 m was sufficiently flexible to deform and override sheets below while remaining relatively intact (Fig. 6a, b), a process also described by Gilbert and Glew (1986). At least 15 of these sheets can be seen in the exposed section (Fig. 6a) and probably at least 6 more occurred below the water level here. Only in the terminal stages when the ice built to more than about 2 m above the water level did it break into a jumbled mass of small, candled blocks which finally formed a rampart at the outer edge. The total volume, including the portion subsequently eroded by waves, was about 1.4×10^4 m^3.

As at Salmon Island, sediment was not pushed at the leading edge and no sediment was carried to the top of the ice mass or exposed in the wave-cut section (Fig. 6a, b). However, unlike the ice at Salmon Island which had refrozen into a relatively solid mass and which was still in place at the end of March, the ice at Snake Island did not freeze, and in the moderate winds (south to west 20-27 km/h) that continued until 26 March, it was rapidly eroded. By 25 March most of the ice was gone.

CONCLUSIONS

Wind-driven ice pile-up events in the inter-island area of eastern Lake Ontario near Kingston occur irregularly. In each case reported here and by Gilbert and Glew (1986), they required a combination of offshore winds followed by onshore winds associated with antecedent weakening of the ice cover.

Thus, mid-winter ice pile-up is probably much more rare than pile-up at breakup.

The limited observations reported here indicate that mid-winter pile-up persists much longer than those at breakup because (1) the ice sheet is stronger and less candled, (2) there is less open water formed subsequently in which waves may develop to erode the ice pile, and (3) persistent cold conditions that refreeze the ice pile into a solid mass are more likely to follow a mid-winter event.

Only moderate winds are required to produce ice pile-up when conditions are appropriate. In the examples reported here, mean hourly wind speeds did not exceed 50 km/h (mid-winter event) and 20 km/h (breakup event). Other reported values are similar (28 km/h: Gilbert and Glew, 1986; 19-24 km/h: Tsang, 1974).

Individual ice-push events in the Kingston area are limited to small areas. The mid-winter event on Salmon Island was observed nowhere else. The event at breakup on Snake Island also occurred to a lesser extent on Simcoe Island to the south but nowhere else, although breakup in the channel north of Amherst Island about a week later produced small ice pilings along those shores unrelated to the Snake Island event.

The ice piling is impressive, but as reported by Boyd (1980) from Lake St. Clair, the geomorphic effect of those events that have been observed on the shores in northeastern Lake Ontario is minor and significantly less than the effect of waves and currents during open water. No unique landforms are created (compare Gilbert, 1990); little alternation of the coast occurs, and what does is quickly obliterated by subsequent wave action.

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