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Abstract

Ground ice information is critical for infrastructure development planning and management in areas with permafrost. The Slave geological province is a mineral rich region spanning the Northwest Territories (NT) and Nunavut (NU). A proposed transportation system would connect NU to the national highway and rail system in NT, and to a deep-water port on the Arctic Ocean. Ground ice conditions have been characterized in some geomorphic settings, but overall, there is limited knowledge on ground ice abundance and distribution along the proposed route. This report provides geospatial files of modelled ground ice abundance across a broad portion of the Slave Geological Province encompassing the proposed infrastructure corridor, presented in O'Neill et al. (2024). The modelling is based on the routines used to produce the Ground ice map of Canada (GIMC), modified to incorporate more detailed, 1:125 000 scale surficial geology mapping. This report provides a brief description of the modelling routines and the spatial data layers for three modelled ground ice types (relict, segregated, and wedge), and for the combined abundance. Furthermore, a tool to generalize and summarize raster ground ice model outputs for use in broader-scale applications is described and demonstrated using the Slave Geological Province model outputs as an example. The tool allows specification of an output pixel size, and for each output pixel compiles the number of underlying smaller pixels in each abundance class and stores summary values in the output attribute table. This allows a scaling relation between modelling based on 1:125 000 scale surficial geology and lower resolution mapping that accounts for sub-grid spatial heterogeneity.

Introduction

This Open File accompanies O'Neill et al. (2024) and provides the geospatial files of model outputs from that manuscript. This ground ice mapping may be useful for reconnaissance-level planning to guide more detailed field investigations of ground ice in the Slave Geological Province around the proposed transportation corridor from Northwest Territories to Grays Bay, Nunavut.

This Open File includes the following folders/files:

1) GBYK_relict	*Modelled relict ice abundance geotiff*
2) GBYK_segregated	*Modelled segregated ice abundance geotiff*
3) GBYK_wedge	*Modelled wedge ice geotiff*
4) GBYK_abundance	*Modelled combined ice abundance geotiff*
5) gi_scaler.atbx	*ArcGIS Pro toolbox, require ArcGIS Pro 2.9 or more recent*

Study area

The study area spans northward from Great Slave Lake near Yellowknife, NT, to the coast of Coronation Gulf, NU (Figure 1). The region represents Canadian Shield terrain with varying surficial geology and was shaped by Late Wisconsin glaciation. The topography is gently undulating to moderately rugged, with numerous bedrock outcrops (Dredge et al., 1999). Till deposits and bedrock dominate the surficial geology. Tills are stony diamicton; those derived from granitic and gneissic rocks have a sandy matrix, while those sourced from sedimentary and metasedimentary rocks include an appreciable silt-clay fraction (Dredge et al., 1999). Glacial Lake McConnell deposited fine-grained lacustrine sediments in the Great Slave Lowlands prior to its recession (Wolfe et al., 2014).

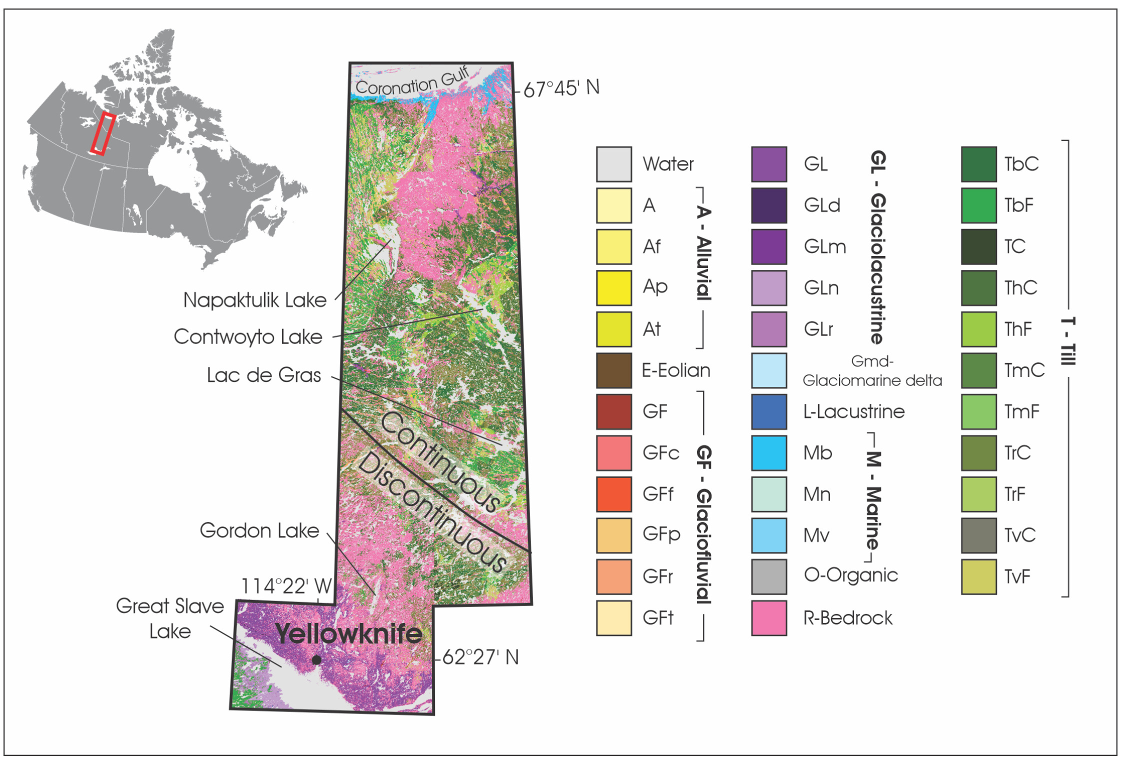

Figure 1. Study region and surficial material units on the compiled map sheets. The delineation between discontinuous and continuous permafrost zones is marked.

Near the Coronation Gulf Coast, emergence of the landscape following deglaciation left fine-grained marine deposits up to elevations of about 200 m asl (Dredge et al., 1999). Deglaciation near the coast commenced from about 10 500 BP to 9 600 BP, whereas near Aylmer Lake, south of Contwoyto Lake, deglaciation and vegetation establishment occurred by about 8 500 BP (Dredge et al., 1999).

The climate at Yellowknife is cold and continental with a mean annual air temperature (MAAT; 1981-2010) of -4.3 °C, and at Kugluktuk, about 120 km west of the north end of the study area, -10.3 °C (Environment and Climate Change Canada, 2022). Vegetation across this climate gradient transitions from boreal forest near Yellowknife to grassland-lichen-moss tundra in the north (Latifovic, 2019). Permafrost is discontinuous near Yellowknife and occurs in peatlands and areas with ice-rich, unconsolidated sediments; annual mean ground temperatures are -1.4 to 0 °C (Morse et al., 2016). Mean annual ground temperatures near Lac de Gras are about -6 °C, and -5 to -7 °C on the coastal plain east of Coronation Gulf (Wolfe et al., 2017).

Methods

Ground ice modelling

Details on the modelling approach and data processing are presented in O'Neill et al. (2024), and so are only briefly summarized here. Eleven 1:125 000 scale surficial geology maps were used for this regional-scale ground ice modelling (Geological Survey of Canada, 2017a, 2017b, 2016a, 2016b, 2015, 2014a, 2014b; Kerr, 2018, 2014; Olthof et al., 2014; Stevens et al., 2017). Till units were classified into fine- and coarse-grained dominated textures based on underlying bedrock geology as for the Ground ice map of Canada (Dredge et al., 1999; O'Neill et al., 2019). Major townsites (e.g., Yellowknife) or existing highway routes mapped as anthropogenic deposits were excluded from the modelling. Multiple bedrock types were combined into a single bedrock unit type. Surficial units that appeared on the GIMC retained their model parameter values. Units that were not represented at the national scale were assigned parameters based on a review of surficial geology-ground ice associations informed by the map unit legends and observations from prior investigations (e.g., Dredge et al., 1999; Kerr et al., 1996; Subedi et al., 2020; Wolfe, 1998; Wolfe et al., 2017). Vector shapefiles for surficial geology maps were rasterized with a pixel size of 250 m, whereas pixels were 1000 m on the GIMC. The pixel size was chosen to preserve small surficial geology polygons and detail around complex shorelines of small lakes. However, underlying surficial map units are commonly larger and map units from the other model data layers are highly generalized. The modelled abundance in an individual pixel thus represents the average condition of the broader mapping unit. A combined ground ice abundance output layer was produced from the relict, segregated, and wedge ice layers following the method used for the GIMC (O'Neill et al., 2022).

ArcGIS scaling tool

The generalization of surficial geology polygons used in the GIMC introduces significant inaccuracies in the national-scale modelled ground ice (O'Neill et al., 2024; Subedi et al., 2020; Wolfe et al., 2021). Therefore, a GIS tool GI-Scaler (Ground ice scaler), named after the GeoScaler tool for geology polygons developed by Smirnoff et al. (2012) was developed to aid in generalizing ground ice outputs from detailed mapping for use in smaller-scale applications and products. The tool employs Block Statistics in ArcGIS Pro (https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/block-statistics.htm) to simplify modelled ground ice abundance within "blocks" while maintaining information on sub-block heterogeneity in ground ice conditions. The input block size is customizable – we provide an example using 1000 m in this report, such that each block includes 16 pixels (4x4) from the regional-scale modelling with 250 m pixels. Near the edges of the map, there may be less pixels as the block footprint extends beyond the study area extent. Water has a value of 1000 on the input raster; the tool is specified to ignore this value when calculating the statistics for ice abundance in each block (min, max, mode, mean, median; Figure 2). Input requirements are provided in the metadata of the toolkit .atbx file. The output raster includes an attribute table with the following columns:

Value: list representing unique cell conditions in the raster

Count: total number of pixels represented by each unique cell condition

Min: the minimum abundance value in the block (none = 0, negligible = 1, low = 2, medium = 3, high = 4, very high = 5)

Max: the maximum abundance value in the block

Mode: the mode abundance value in the block

Mean: the mean abundance value in the block

Median: the median abundance value in the block. When the number of valid cell values in the block is odd, the median value is calculated by ranking the values and selecting the middle value. If the number of values in a block is even, the values are ranked and from the two middle values, the lower one is selected

px_0: the number of pixels in the block with value 0 (none)
px_1: the number of pixels in the block with value 1 (negligible)
px_2: the number of pixels in the block with value 2 (low)
px_3: the number of pixels in the block with value 3 (medium)
px_4: the number of pixels in the block with value 4 (high)
px_5: the number of pixels in the block with value 5 (very high)
px_1000: the number of pixels of water in the block
px_count: the total number of pixels in the block

	OID	Value	Count	min______	max______	mode______	mean______	median___	px_0______	px_1______	px_2______	px_3______	px_4______	px_5______	px_1000__	px_count
68	67	68	3248	0	2	0	1	0	8	0	8	0	0	0	0	16
69	68	69	3520	0	2	0	0	0	12	0	4	0	0	0	0	16
70	69	70	912	0	3	0	0	0	9	0	0	3	0	0	4	16
71	70	71	3600	2	2	2	2	2	0	0	4	0	0	0	12	16
72	71	72	16	2	2	2	2	2	0	0	1	0	0	0	10	11
73	72	73	864	0	2	0	0	0	5	0	3	0	0	0	8	16
74	73	74	1360	0	3	3	2	3	4	0	0	11	0	0	1	16
75	74	75	1040	0	3	3	1	3	5	0	0	8	0	0	3	16

Figure 2. Attribute table from the GI-Scaler tool output showing the fields defined above.

Model outputs

Images of the data files associated with this regional-scale modelling (Figures 3-5), and an example of a map generalized using the GI-Scaler tool (Figure 6) are presented below. Discussion of the regional-scale outputs, limitations, and comparison with the GIMC are presented in O'Neill et al. (2024).

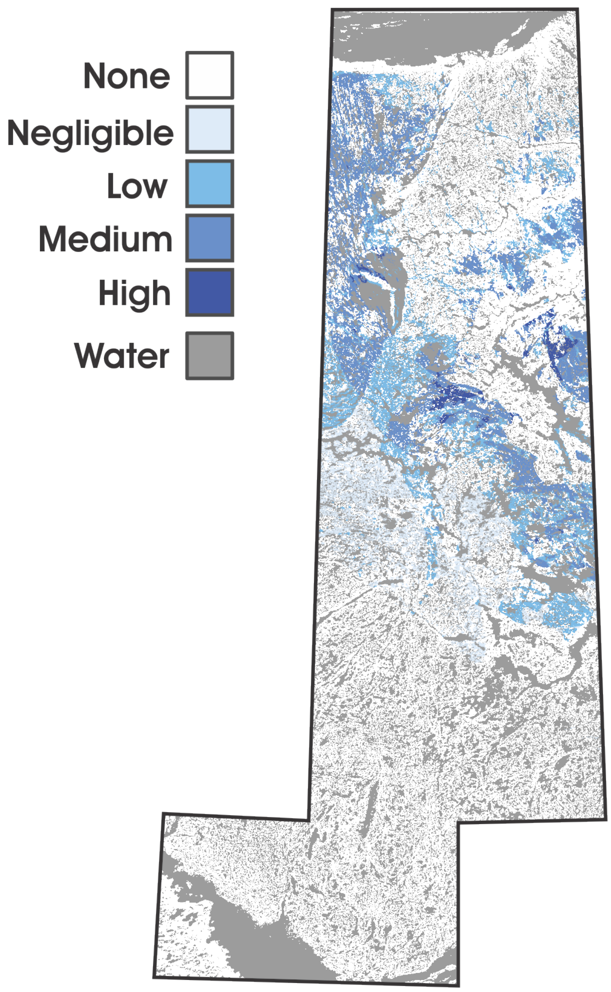

Figure 3. Modelled regional-scale relict (buried glacial) ice abundance based on 1:125 000 scale surficial geology compilation.

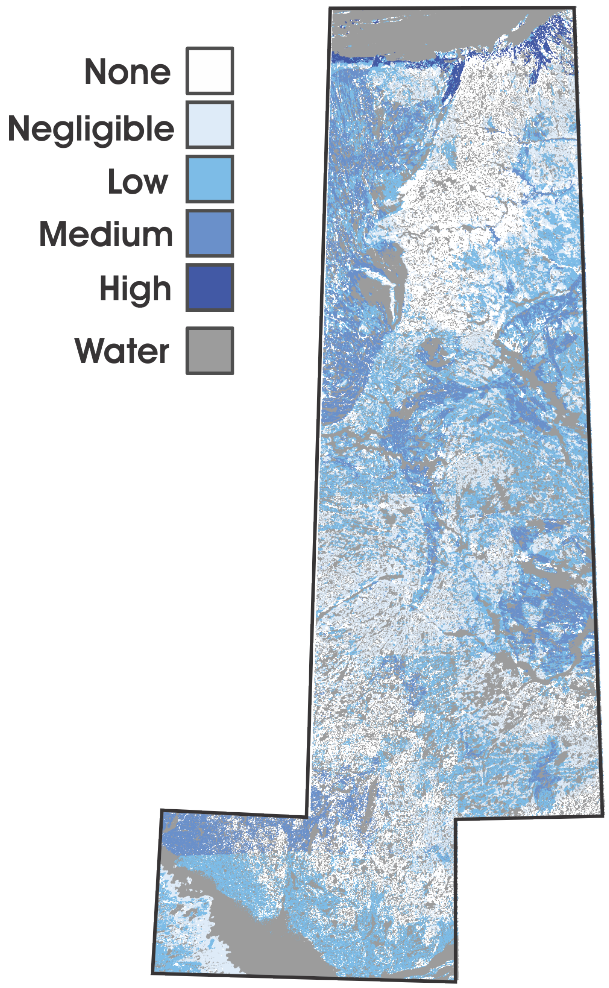

Figure 4. Modelled regional-scale segregated ice abundance based on 1:125 000 scale surficial geology compilation.

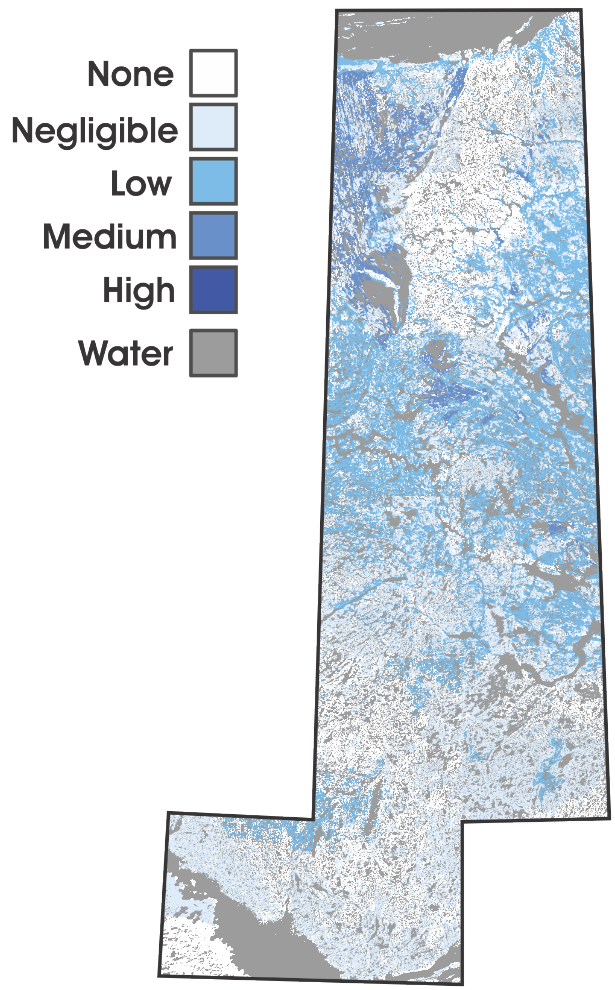

Figure 5. Modelled regional-scale wedge ice abundance based on 1:125 000 scale surficial geology compilation.

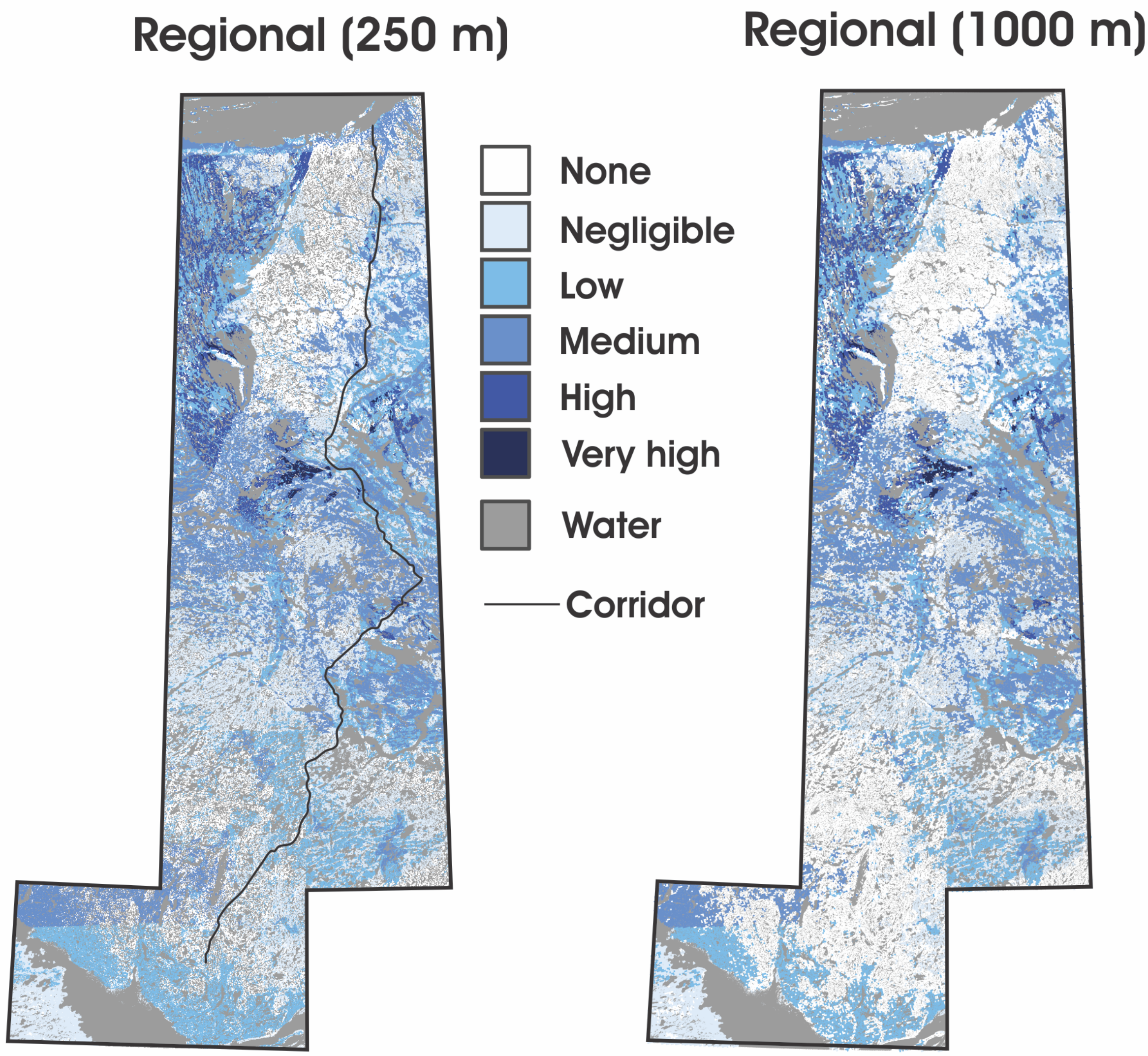

Figure 6. Combined ice abundance model output with 250 m pixels (left) compared to the output generalized using the GI-Scaler tool (right) with 1000 m pixels, with pixels coloured based on the median value of underlying 250 m pixels. The proposed transportation corridor is indicated.

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