Abstract

This map shows the spatial distribution of the relative ground surface displacement between the major terrain units during one summer in the area of Pangnirtung. The ground displacement was derived using interferometric synthetic aperture radar (InSAR) data for the summer of 2011. Stable ground represents locations where either no vertical change was calculated or where displacement was within the expected range of error (± 0.5 cm). Very low, low, moderate, and high downward displacement represents surface lowering on the order of 0.5 to 2, 2 to 4.5, 4.5 to 8.5, and 8.5 to 10 cm, respectively. Upward displacement represents a surface rise of 0.5 to 3 cm. Areas of no data result from a loss of interferometric coherence. These are typically water and other relatively smooth surfaces from which there is no radar return, or where there has been significant ground surface disturbance and the radar returns cannot be correlated. The InSAR results correspond well with the expected displacement associated with the characteristics of the major terrain units. The displacement reflects seasonal settlement caused by thawing of ice in the active layer or in the near-surface permafrost.

Résumé

Cette carte montre la distribution spatiale et relative, entre les différentes unités de terrain, des déplacements à la surface du sol au cours d'un été pour la région de Pangnirtung. Le déplacement à la surface du sol a été obtenu en utilisant les données de l'interférométrie radar à ouverture synthétique (InSAR) de l'été 2011. Un sol stable représente une zone où il n'y a pas de changement verticale dans le déplacement de la surface ou là où le déplacement est compris à l'intérieur de la marge d'erreur (± 0,5 cm). Des déplacements vers le bas très faibles, faibles, modérés et élevés représentent des diminutions de la surface d'élévation de l'ordre de 0,5 à 2, 2 à 4,5, 4,5 à 8,5 et 8,5 à 10 cm respectivement. Un déplacement vers le haut représente l'augmentation de la surface d'élévation de 0,5 à 3 cm. Les zones sans données sont le résultat d'une perte de cohérence interférométrique. Ces zones sont typiquement les étendues d'eau et les surfaces relativement lisses à partir desquelles il n'y a pas de réflexion radar ainsi que les zones où la perturbation de la surface du sol est importante. Dans ce cas, la réflexion radar ne peut être corrélée. Une bonne corrélation existe entre les données InSAR et les déplacements qui sont susceptibles de survenir selon la connaissance des caractéristiques des principales unités de terrain. Le déplacement est causé par le basement au dégel du mollisol ou du pergélisol riche en glace près de la surface.

National Topographic System reference

Cover illustration:
The beautiful landscape surrounding the hamlet of Pangnirtung, Photograph by A.-S. Carbonneau. 2011-013

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CANADIAN GEOSCIENCE MAP 67

(preliminary version)

SEASONAL SURFACE DISPLACEMENT DERIVED FROM INSAR

PANGNIRTUNG

Nunavut

1:5 000

SOIL MOISTURE

Soil moisture may affect the penetration depth of a radar wave and hence the InSAR measurements (Nolan and Fatland, 2003). A radar wave may penetrate dry soils, reflecting off the dry/wet interface; this can result in the displacement signal representing the movement of the moisture front rather than surface displacement. To account for the influence of soil moisture, volumetric moisture content was measured at several sites on May 31, 2010 and on August 4 and 5, 2011 (Table 1). Although different years, these values provide a qualitative sense of how volumetric water content progresses over a summer season. For wet soils, i.e. volumetric water contents above 30%, fluctuations in water content do not affect the penetration depth (Nolan and Fatland, 2003). Results show that most of the measured moisture contents of the spring snowmelt season and half of the late summer moisture contents were high enough to preclude penetration of the radar wave. For values less than 30%, some penetration is theoretically possible, however, according to the modelled example of Rabus et al. (2010) it is highly probable that any penetration will fall within our estimated margin of error for the InSAR measurement (± 0.5 cm). Therefore, soil moisture changes do not appear to be a significant factor influencing the interpretation of these InSAR results.

CORRELATION WITH SURFICIAL GEOLOGY

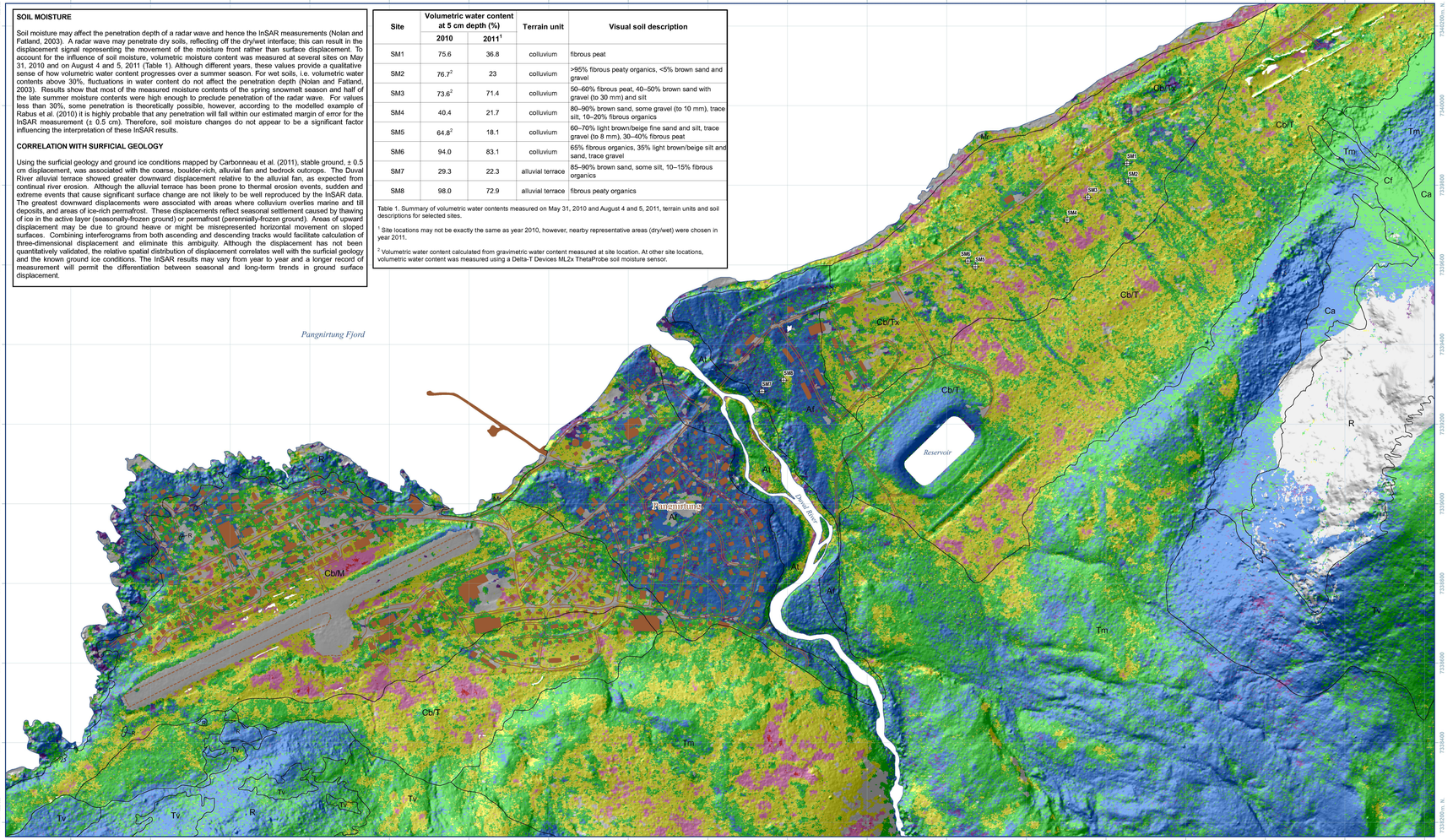
Using the surficial geology and ground ice conditions mapped by Carbonneau et al. (2011), stable ground, ± 0.5 cm displacement, was associated with the coarse, boulder-rich, alluvial fan and bedrock outcrops. The Duval River alluvial terrace showed greater downward displacement relative to the alluvial fan, as expected from continual river erosion. Although the alluvial terrace has been prone to thermal erosion events, sudden and extreme events that cause significant surface change are not likely to be well reproduced by the InSAR data. The greatest downward displacements were associated with areas where colluvium overlies marine and till deposits, and areas of ice-rich permafrost. These displacements reflect seasonal settlement caused by thawing of ice in the active layer (seasonally-frozen ground) or permafrost (perennially-frozen ground). Areas of upward displacement may be due to ground heave or might be misrepresented horizontal movement on sloped surfaces. Combining interferograms from both ascending and descending tracks would facilitate calculation of three-dimensional displacement and eliminate this ambiguity. Although the displacement has not been quantitatively validated, the relative spatial distribution of displacement correlates well with the surficial geology and the known ground ice conditions. The InSAR results may vary from year to year and a longer record of measurement will permit the differentiation between seasonal and long-term trends in ground surface displacement.

Site	Volumetric water content at 5 cm depth (%)		Terrain unit	Visual soil description
	2010	2011[1]		
SM1	75.6	36.8	colluvium	fibrous peat
SM2	76.7[2]	23	colluvium	>95% fibrous peaty organics, <5% brown sand and gravel
SM3	73.6[2]	71.4	colluvium	50–60% fibrous peat, 40–50% brown sand with gravel (to 30 mm) and silt
SM4	40.4	21.7	colluvium	80–90% brown sand, some gravel (to 10 mm), trace silt, 10–20% fibrous organics
SM5	64.8[2]	18.1	colluvium	60–70% light brown/beige fine sand and silt, trace gravel (to 8 mm), 30–40% fibrous peat
SM6	94.0	83.1	colluvium	65% fibrous organics, 35% light brown/beige silt and sand, trace gravel
SM7	29.3	22.3	alluvial terrace	85–90% brown sand, some silt, 10–15% fibrous organics
SM8	98.0	72.9	alluvial terrace	fibrous peaty organics

Table 1. Summary of volumetric water contents measured on May 31, 2010 and August 4 and 5, 2011, terrain units and soil descriptions for selected sites.

[1] Site locations may not be exactly the same as year 2010, however, nearby representative areas (dry/wet) were chosen in year 2011.

[2] Volumetric water content calculated from gravimetric water content measured at site location. At other site locations, volumetric water content was measured using a Delta-T Devices ML2x ThetaProbe soil moisture sensor.



Relative surface displacement

- Upward displacement (+0.5 to 3 cm)
- Stable (+0.5 to -0.5 cm)
- Very low downward displacement (-0.5 to -2 cm)
- Low downward displacement (-2 to -4.5 cm)
- Moderate downward displacement (-4.5 to -8.5 cm)
- High downward displacement (-8.5 to -10 cm)
- Loss of InSAR coherence.

Af — Geological contacts and label unit, for definition of the geological units below, see Canadian Geoscience Map 65 (Carbonneau et al., 2012).

Af	Fan sediments
At	Alluvial terraces
Ca	Talus
Cb/Mn	Colluvial blanket (Cb) over littoral to nearshore sediments (Mn)
Cb/T	Colluvial blanket (Cb) over reworked till (Tx)
Cb/Tx	Colluvial blanket (Cb) over till (T)
Cf	Bouldery debris flow
Mr	Beach sediments
R	Bedrock
Tm	Lateral moraine
Tv	Till veneer
Site	Soil moisture measurement

DISCLAIMER

Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources ("Canada"), Université Laval, and the hamlet of Pangnirtung do not warrant or guarantee the accuracy or completeness of the information ("Data") on this map and do not assume any responsibility or liability with respect to any damage or loss arising from the use or interpretation of the Data.

The Data on this map are intended to convey regional trends and should be used as a guide only. The Data should not be used for design or construction at any specific location, nor are the Data to be used as a replacement for the types of site-specific geotechnical investigations.

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Preliminary CANADIAN GEOSCIENCE MAP 67 Preliminary Preliminary Preliminary

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InSAR data by N. Short, 2011

Geology by A.-S. Carbonneau and M. Allard

Cartography (surficial geology) by A.-S. Carbonneau, P. Gosselin, and R. Boivin

Map projection Universal Transverse Mercator, zone 20. North America Datum 1983

Infrastructure and base data provided through the Digital Mapping Data Base, property of the Government of Nunavut.

Ground Control Points provided by Université Laval.

Seasonal ground displacement was derived for Pangnirtung using interferometric synthetic aperture radar (InSAR) data from the summer of 2011. RADARSAT-2 Spotlight scenes on an ascending orbit were acquired on June 12, July 6, July 30, August 23, and September 16. The data were interferometrically stacked and the three months of summer vertical displacement calculated according to the methodology outlined in Short et al. (2011). Each displacement measurement represents an area of approximately 1.5 x 1.5 m on the ground.

CANADIAN GEOSCIENCE MAP 67

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Nunavut

1:5 000

100 0 100 200 300 400 m

Shaded relief image prepared by A.-S. Carbonneau and derived from digital elevation model created from 50 cm WorldView-2 stereo satellite images acquired July 10, 2010. 1m DEM created using a proprietary stereo image matching process by PhotoSat Information Ltd.
Illumination: azimuth 315°, altitude 45°, vertical factor 1x

Proximity of the North Magnetic Pole causes the magnetic compass to be erratic in this area.
Magnetic declination 2012: 33°20'W, decreasing 29.2' annually.

The Geological Survey of Canada welcomes corrections or additional information from users.

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