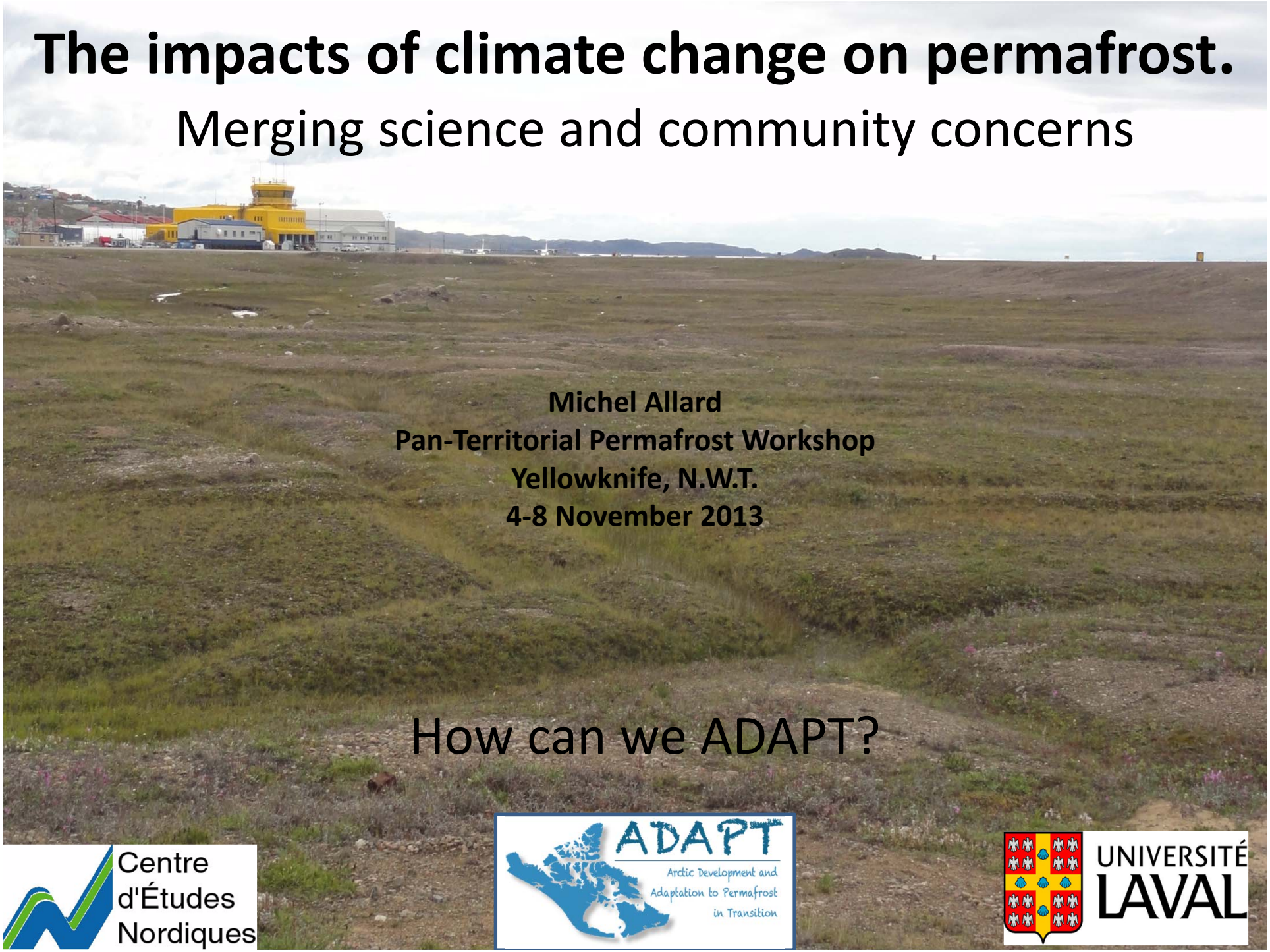
The impacts of climate change on permafrost.

Merging science and community concerns



Michel Allard

Pan-Territorial Permafrost Workshop
Yellowknife, N.W.T.
4-8 November 2013

How can we ADAPT?

Centre d'Études Nordiques

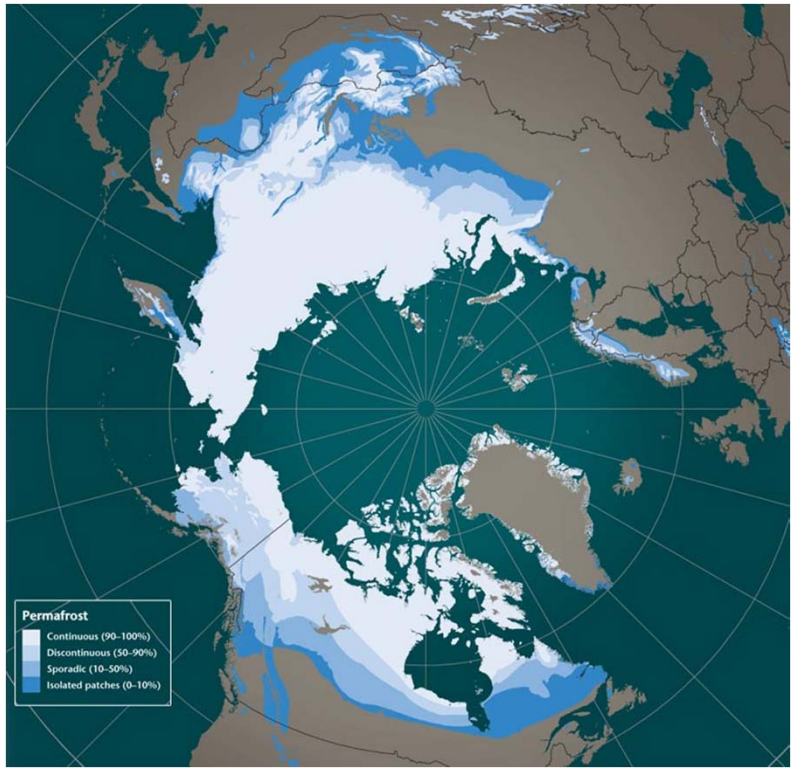
ADAPT
Arctic Development and Adaptation to Permafrost in Transition

UNIVERSITÉ LAVAL

Contents

- Definitions
- Temperature regime 101
- Thawing of permafrost: causes
- Geology and ground ice
- Permafrost in communities
  - Salluit, Nunavik
  - Technical example of community mapping (Puvirnituq)

Permafrost



ROCK OR SOIL THAT REMAINS BELOW 0^0C FOR LONG PERIODS OF TIME.

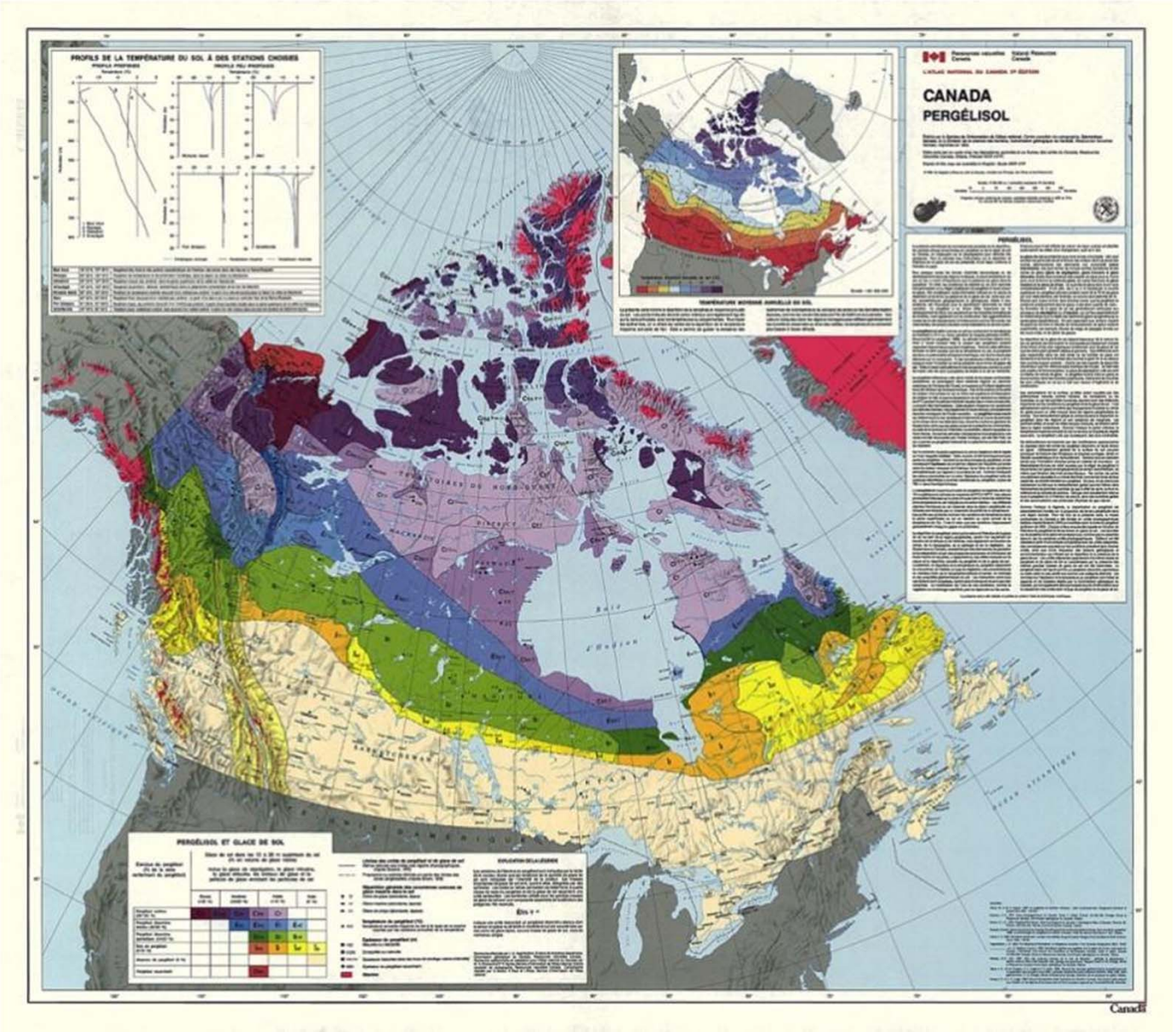
CONTAINS VARIOUS FORMS OF ICE THAT CAN BE ASSOCIATED WITH ITS FORMATION, PAST CLIMATE CHANGES, GROUND WATER MIGRATION, EROSION AND SEDIMENTATION.

SUPPORTS ECOSYSTEMS

SUPPORTS MAN-MADE INFRASTRUCTURES

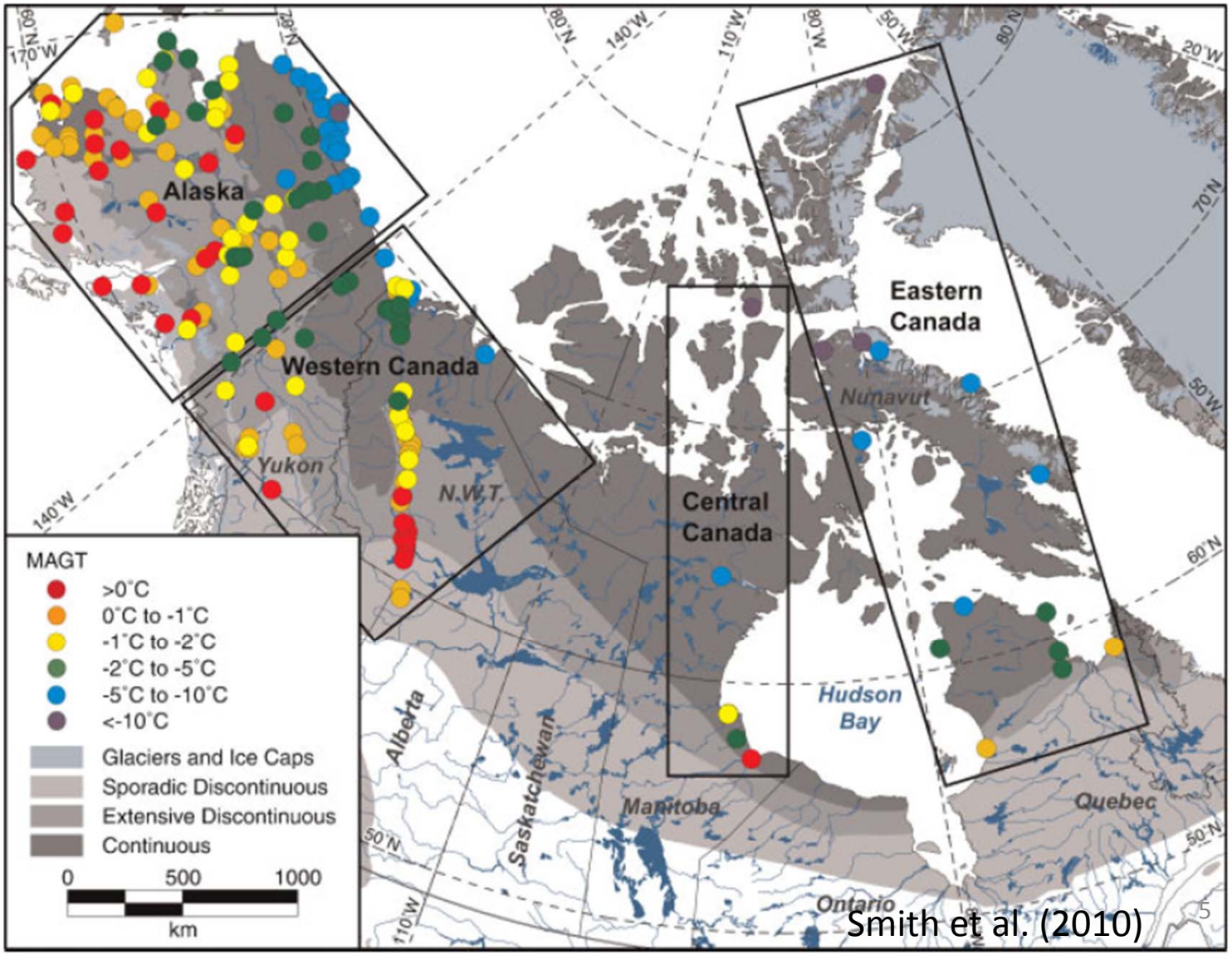
KNOWLEDGE OF PERMAFROST PROPERTIES SUCH AS GRAIN SIZE, ICE CONTENTS, INTERNAL ICE STRUCTURE (CRYOSTRUCTURE) AND MICRO-SCALE COMPOSITION (CRYOTEXTURE) IS ESSENTIAL FOR FUNDAMENTAL UNDERSTANDING OF LAND PROCESSES AND FOR ENGINEERING APPLICATIONS

Canada: a permafrost country



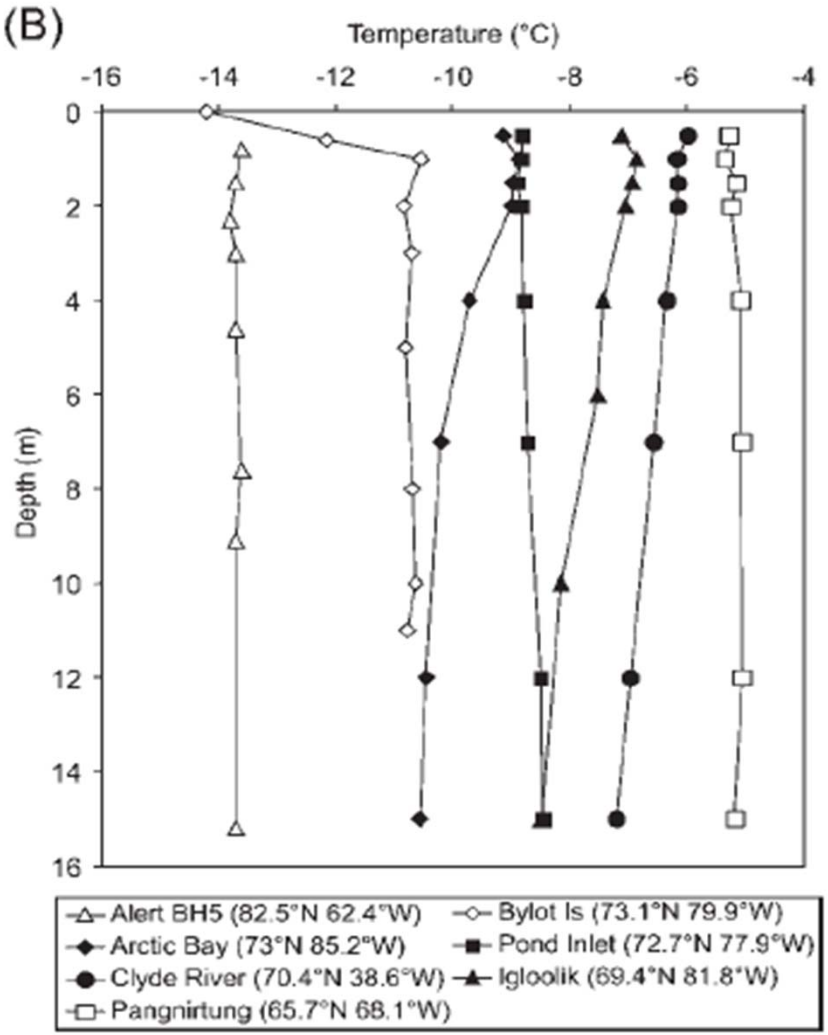
Atlas of Canada: Permafrost (http://atlas.nrcan.gc.ca)

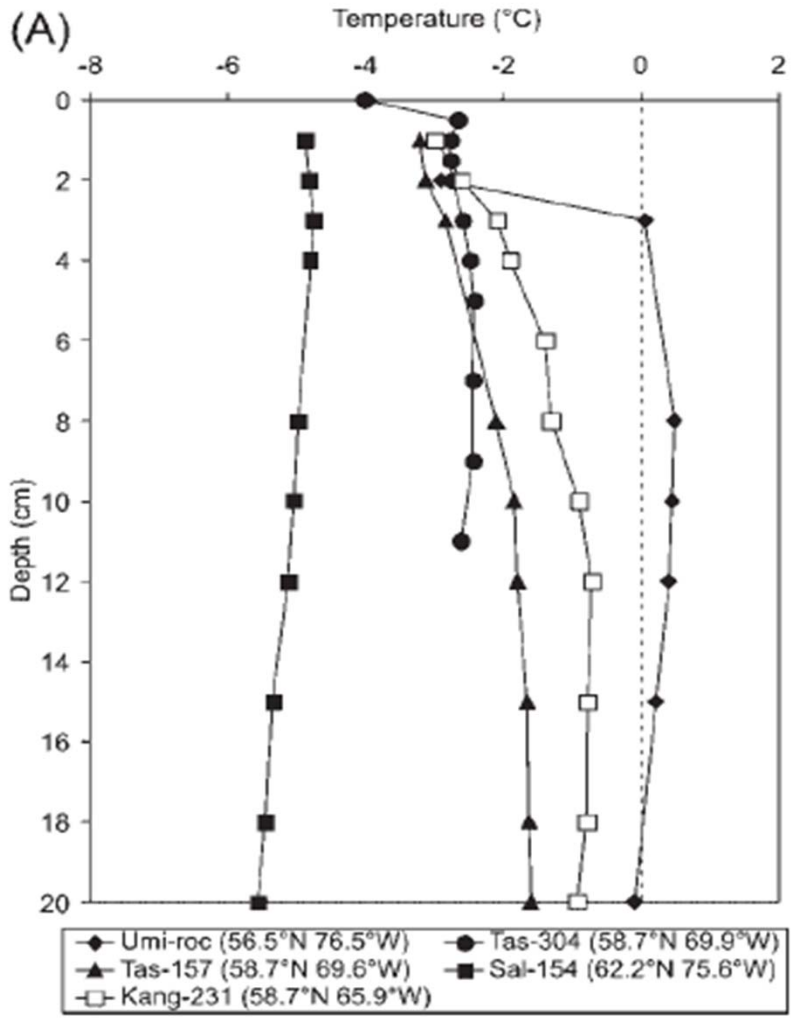
Permafrost temperatures



Permafost temperature monitoring sites in North America

Permafrost temperatures: Eastern Canadian Arctic





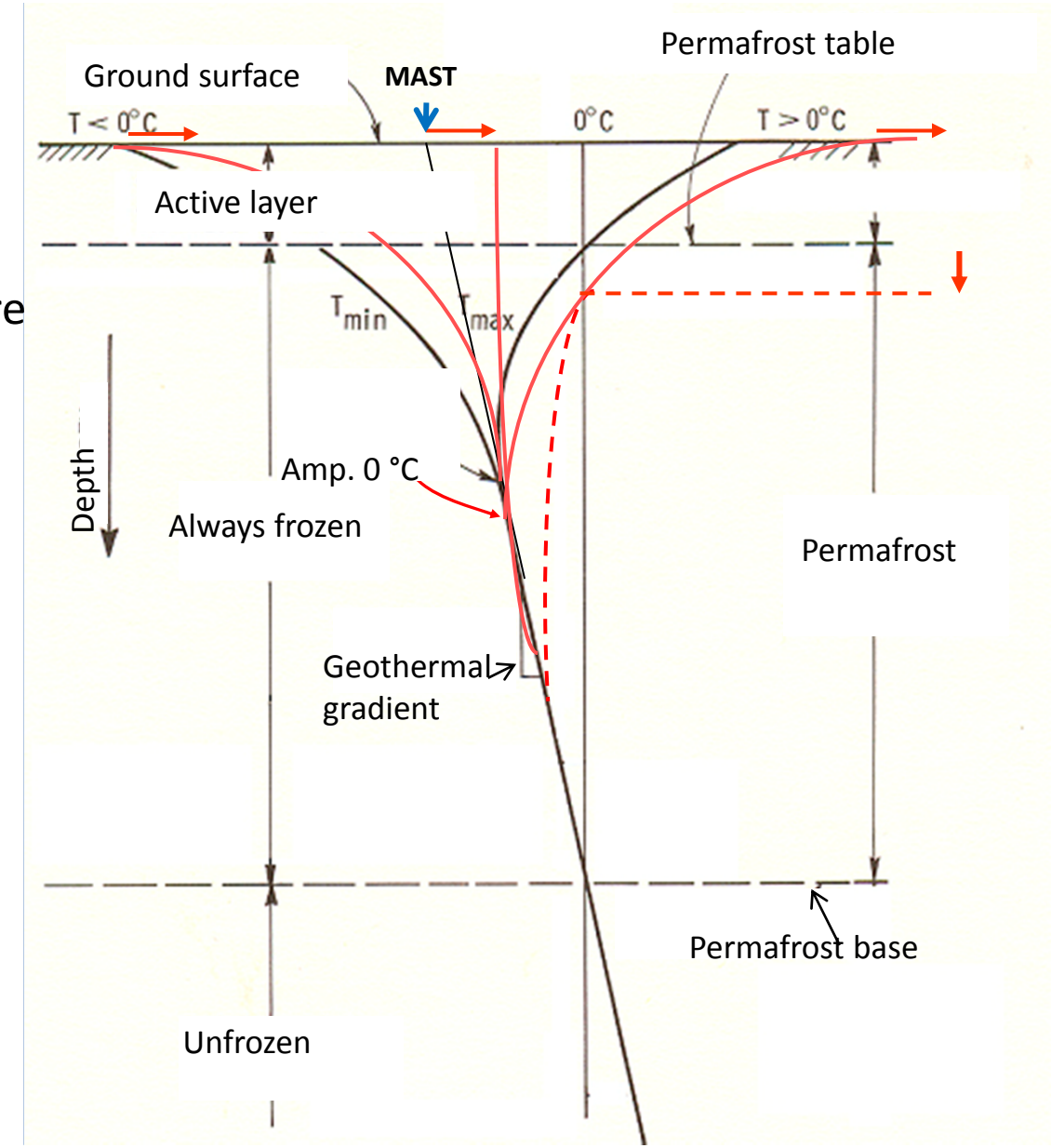
N ← - - - - - - - - - - - - - - - - - - **S**

Nunavut **Nunavik**

Basics of the permafrost thermal regime and impact of surface warming

Surface warming

- + air temperature
- + snow
- man induced (construction)



Modified from Everdingen 1988

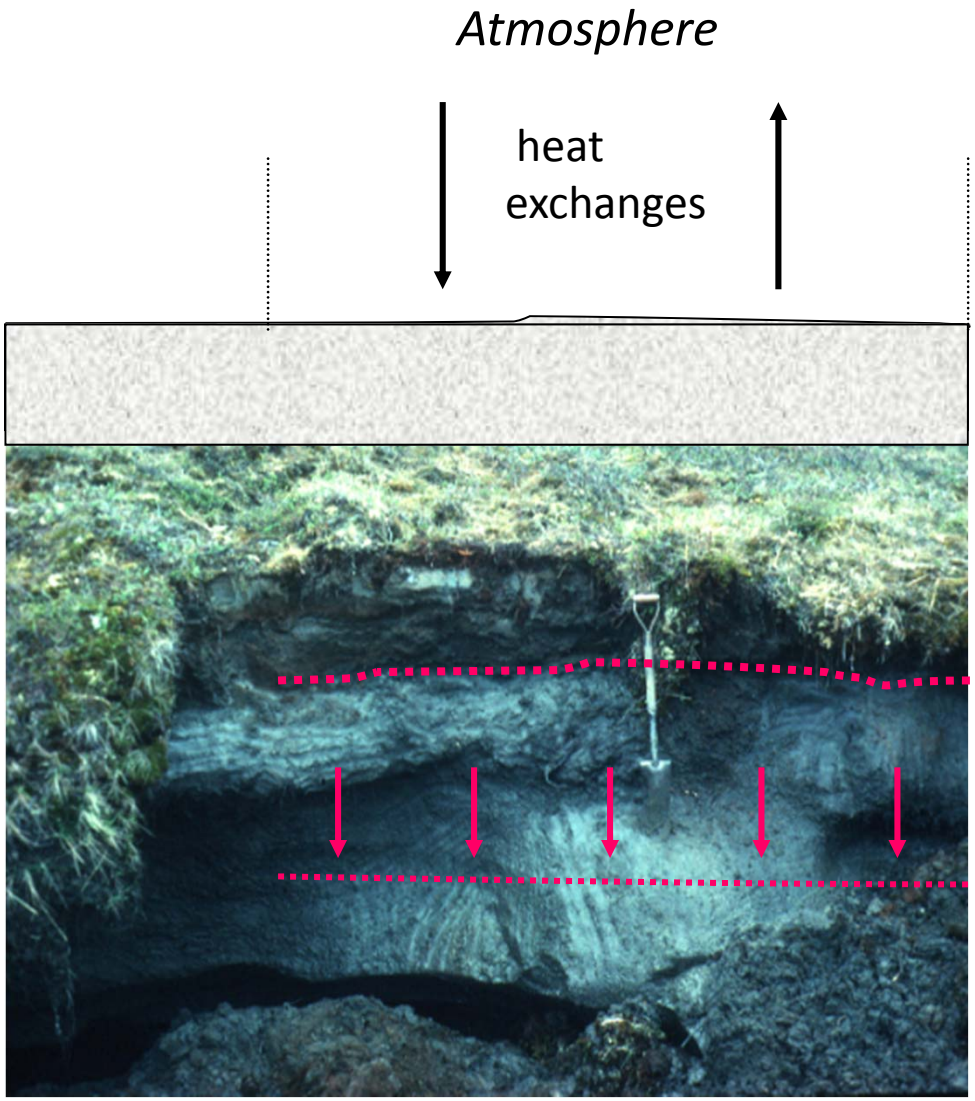
Snow cover

Tundra

Active layer

Permafrost

Properties
P, κ, C, α, L

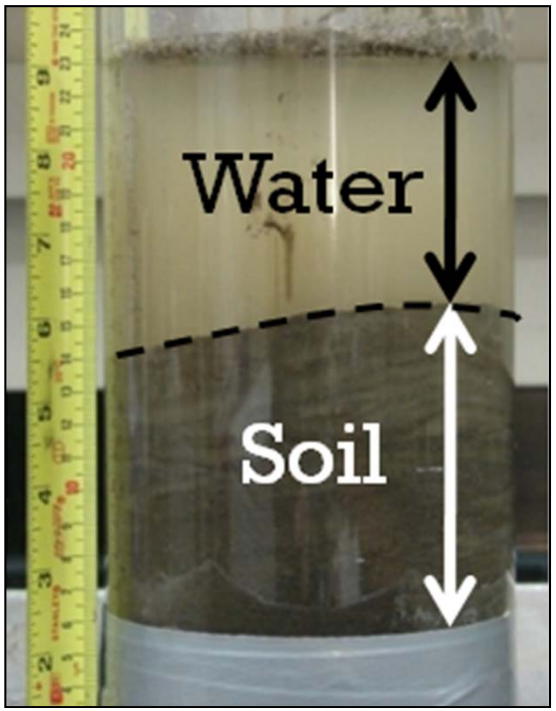


Active layer thawing. Deeper depth of thaw induces melting of the ice in the permafrost

Thaw test

Frozen core

Thawed



E. Stephani

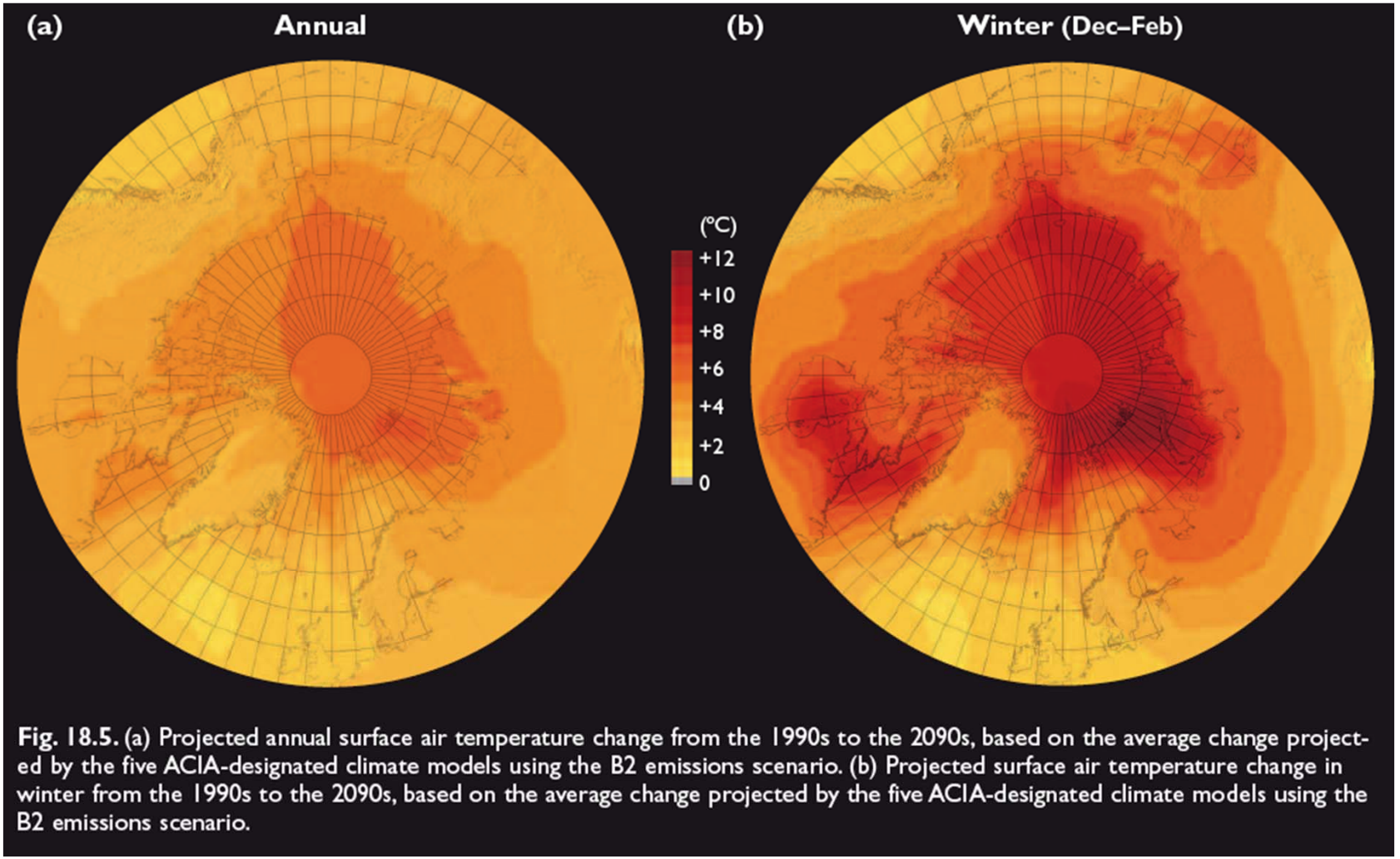
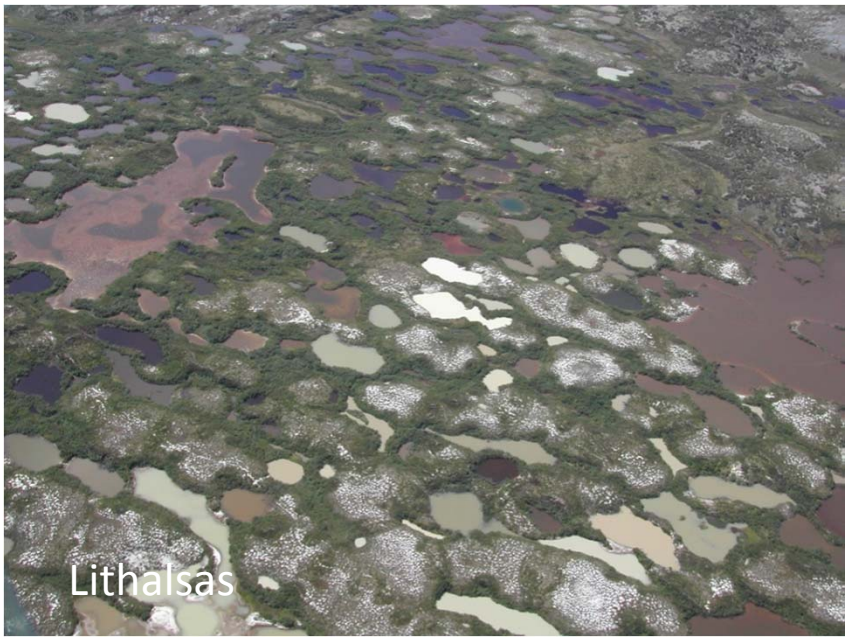


Fig. 18.5. (a) Projected annual surface air temperature change from the 1990s to the 2090s, based on the average change projected by the five ACIA-designated climate models using the B2 emissions scenario. (b) Projected surface air temperature change in winter from the 1990s to the 2090s, based on the average change projected by the five ACIA-designated climate models using the B2 emissions scenario.

Landforms and associated ground ice types


Ice wedge

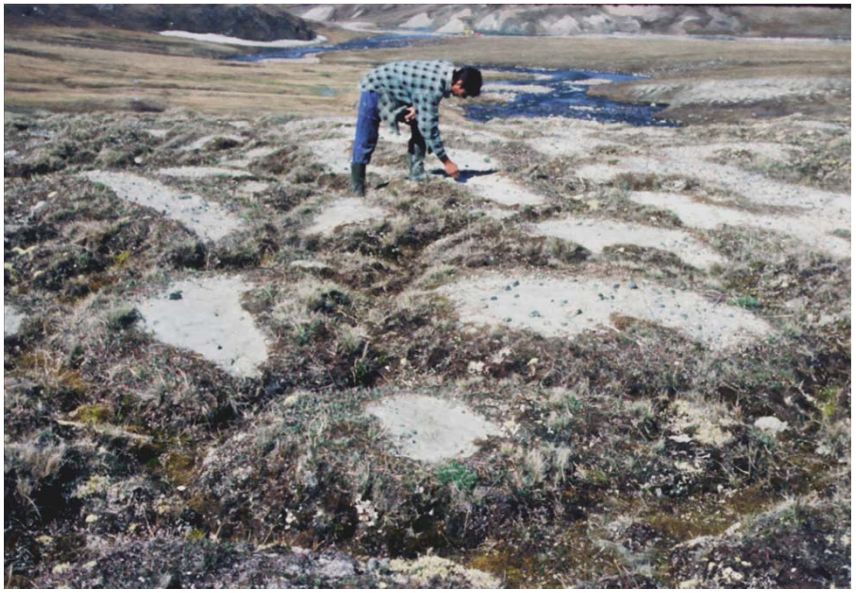

Tundra polygons


Lithalsas

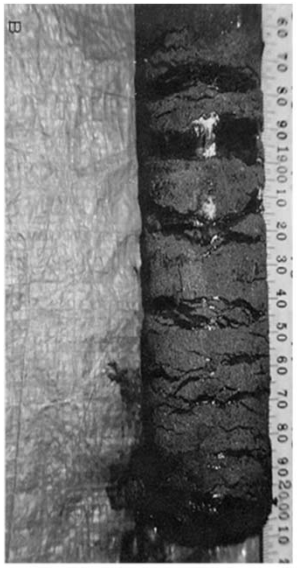

Segregation ice (aggradation)

Palsas

Peat

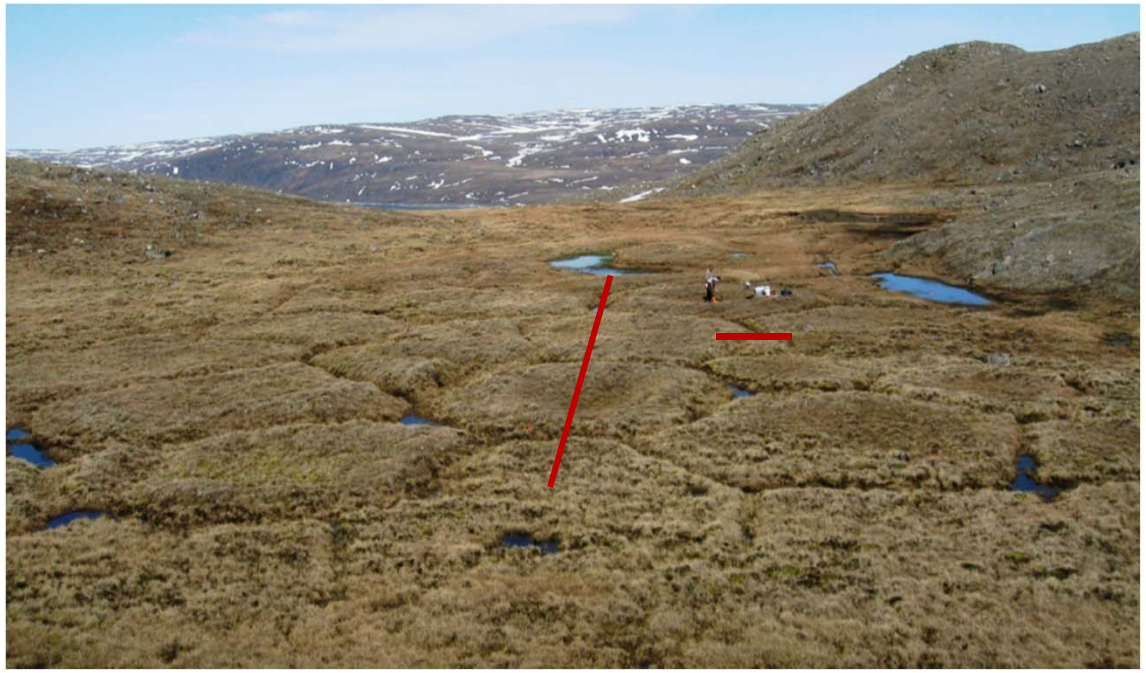


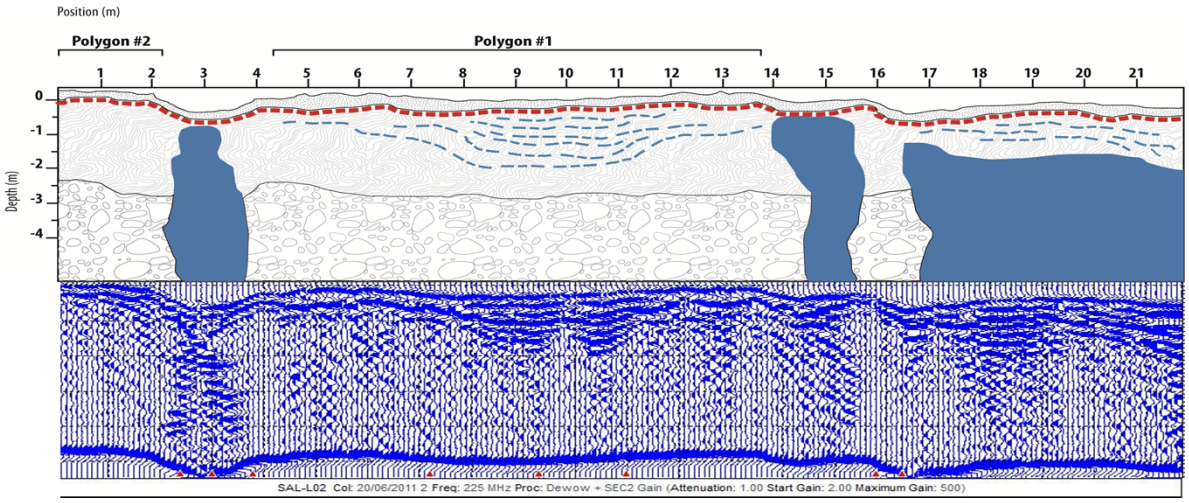
Frostboils

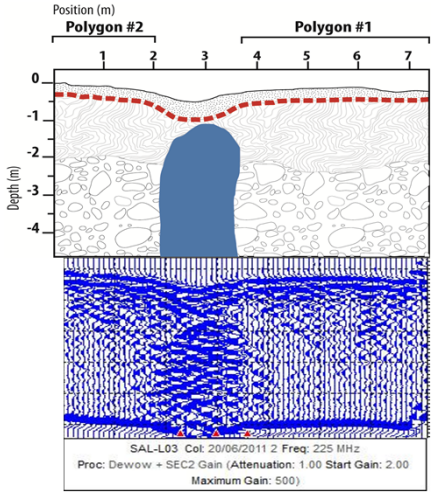


Ice lenses

Tundra polygons and ice wedges







Ground penetrating radar profiles

Examples of impacts of thawing permafrost

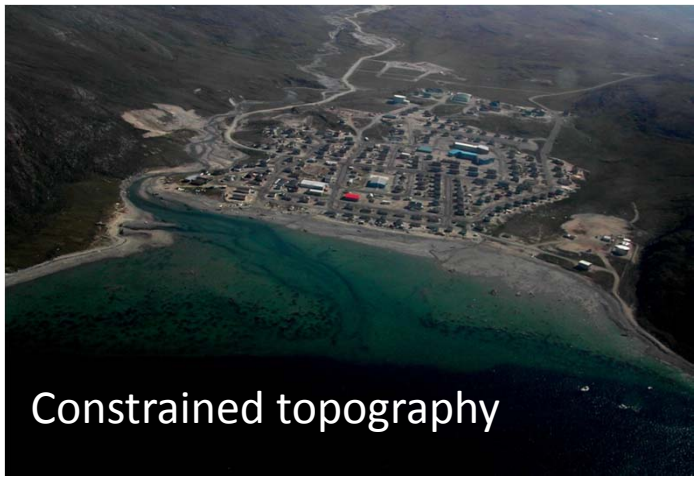
Terrain subsidence

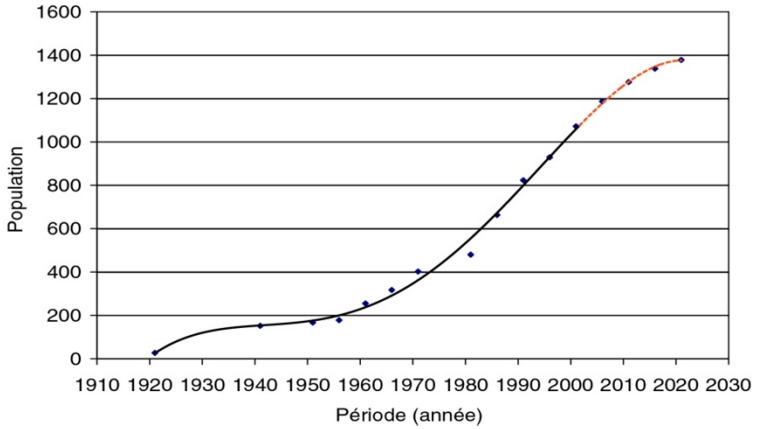
Active layer slides

Salluit, Nunavik

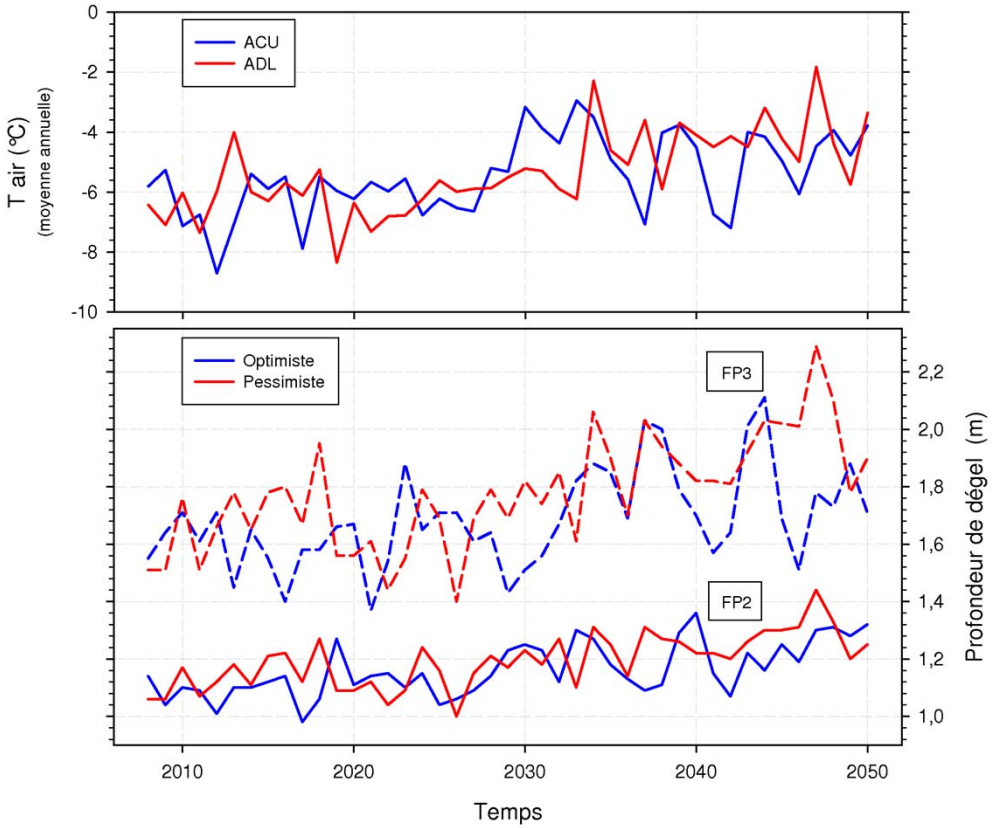
Salluit, Nunavik

Problem statement



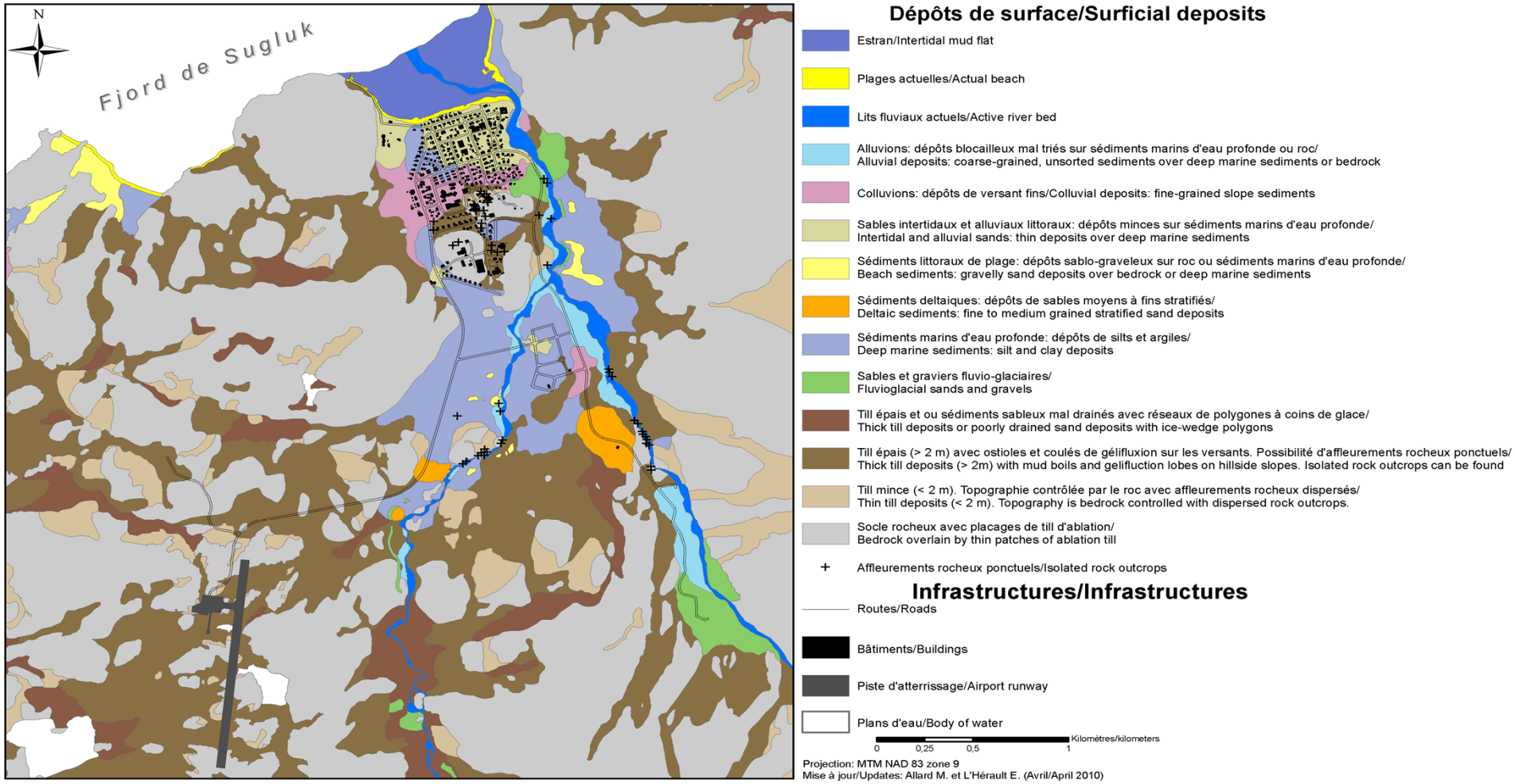


Demographic growth-housing needs

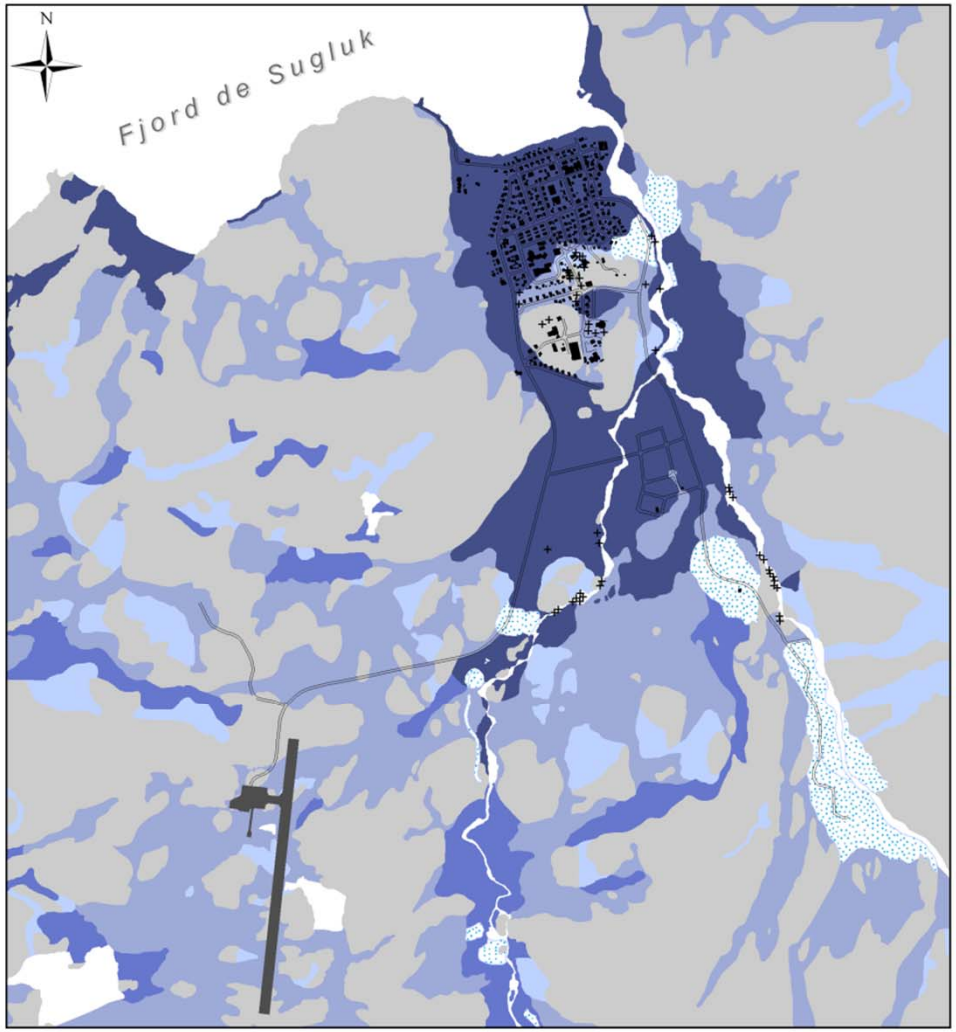


A warming climate

Salluit



Surficial geology



Conditions de pergélisol / Permafrost conditions

Roc et dépôts contenant très peu ou pas de glace / Bedrock and superficial deposits with no or little ice content

\+ Affleurements rocheux ponctuels / Isolated rock outcrops

Socle rocheux massif d'âge précambrien. Surface parsemée de blocs et parfois recouverte d'une mince couche de sable et gravier avec cailloux (till). L'épaisseur de la couche active varie sur le terrain entre 2,5 et 3,5 m.
Massive bedrock of Precambrian age with a very sparse thin and discontinuous cover of sand, gravel and boulders (till). Active layer depth varies across the terrain from 2.5 to 3.5 m.

Dépôts de sable et gravier stratifiés. Contient de la glace interstitielle et possiblement de la glace sous forme de lentilles dans les couches de matériau à granulométrie fine.
Layered sand and gravel deposits. Contain pore ice and occasional ice lenses in fine sand and silty layers.

Dépôts contenant beaucoup de glace / Ice-rich permafrost in superficial deposits

Sable, gravier et blocs en couverture mince sur socle rocheux. L'épaisseur du dépôt est généralement inférieure à 2 m et sa topographie est contrôlée par le roc. Présence d'affleurements rocheux dispersés. La couche active atteint une épaisseur comprise entre 1,5 et 2,5 m. Tassement différentiel lors de la fonte du pergélisol limité à la couche de couverture. Le contenu volumique en glace varie entre 15 et 70 %.
Thin cover of sand, gravel and boulders over bedrock. The thickness of the deposits is generally less than 2 m. Topography is controlled by bedrock. Scattered rock outcrops. Active layer depth varies across terrain from 1.5 to 2.5 m. Thaw settlement of permafrost restricted to the superficial cover. Volumetric ice contents in the surface sediments vary from 15 to 70 %.

Sable, gravier et blocs (till) en couverture épaisse sur socle rocheux. L'épaisseur du dépôt est généralement supérieure à 2 m avec possibilités d'affleurements rocheux ponctuels. La profondeur maximale au roc est estimée à environ 8 m. Présence d'ostioles et de coulés de gélifluxion sur les versants. Sujet au tassement différentiel lors de la fonte du pergélisol. La couche active atteint une épaisseur comprise entre 1,5 et 2,5 m. Le contenu volumique en glace varie entre 15 et 70 %.
Thick cover of sand, gravel and boulders (till) over bedrock. The thickness of the deposits is generally more than 2 m with occasional bedrock outcrops. Estimated maximum depth to bedrock is about 8 m. Frost boils are present and gelifluction lobes occur on slopes. Subject to thaw settlement. Active layer depth varies from 1.5 to 2.5 m across the terrain. Volumetric ice contents vary from 15 to 70 %.

Dépôts quaternaires épais mal drainés à couverture tourbeuse. Épaisseur supérieure à 2 m et pouvant atteindre plus de 6 m. Dépôts riches en glace avec réseaux de polygones à coins de glace bien développés. L'épaisseur de la couche active varie de 0,5 m à 2,5 m.
Thick cover of Quaternary sediments, poorly drained with a peat cover. Thickness is more than 2 m and can be as much as 6 m. The deposits are ice rich and a polygonal network of ice wedges is present. Active layer depth vary from 50 cm to 2.5 m.

Dépôts à granulométrie fine d'origine marine (silt et argile) très riches en glace. Parfois recouvert d'une couche mince de sable ou gravier. Sujet aux tassements différentiels et aux ruptures de mollisol sur les pentes. Surface fréquemment recouverte d'ostioles. La couche active atteint une épaisseur comprise entre 0,5 m et 1,2 m. La teneur volumétrique en glace du pergélisol dépasse régulièrement 30 % et peut attendre près de 100%.
Fine-grained sediments of marine origin. Occasionally covered by a thin layer of sand or gravel. Subject to differential thaw settlement and to active layer failures on slopes. Often surface is pitted with frost boils. Active layer thickness vary in the terrain from 50 cm to 1.2 m. Volumetric ice content in the permafrost is constantly above 30% and may be as high as close to 100%

Infrastructures / Infrastructures

Routes / Roads

Bâtiments / Buildings

Piste d'atterrissage / Airport runway

Plans d'eau / Body of water

Projection: MTM NAD 83 zone 9
Mise à jour/Updates: Allard M. et L'Hérault E. (juillet/july 2009)

0 0,25 0,5 1 Kilomètres/kilometers

Map of permafrost conditions

Construction potential

(GIS application)

Criteria:

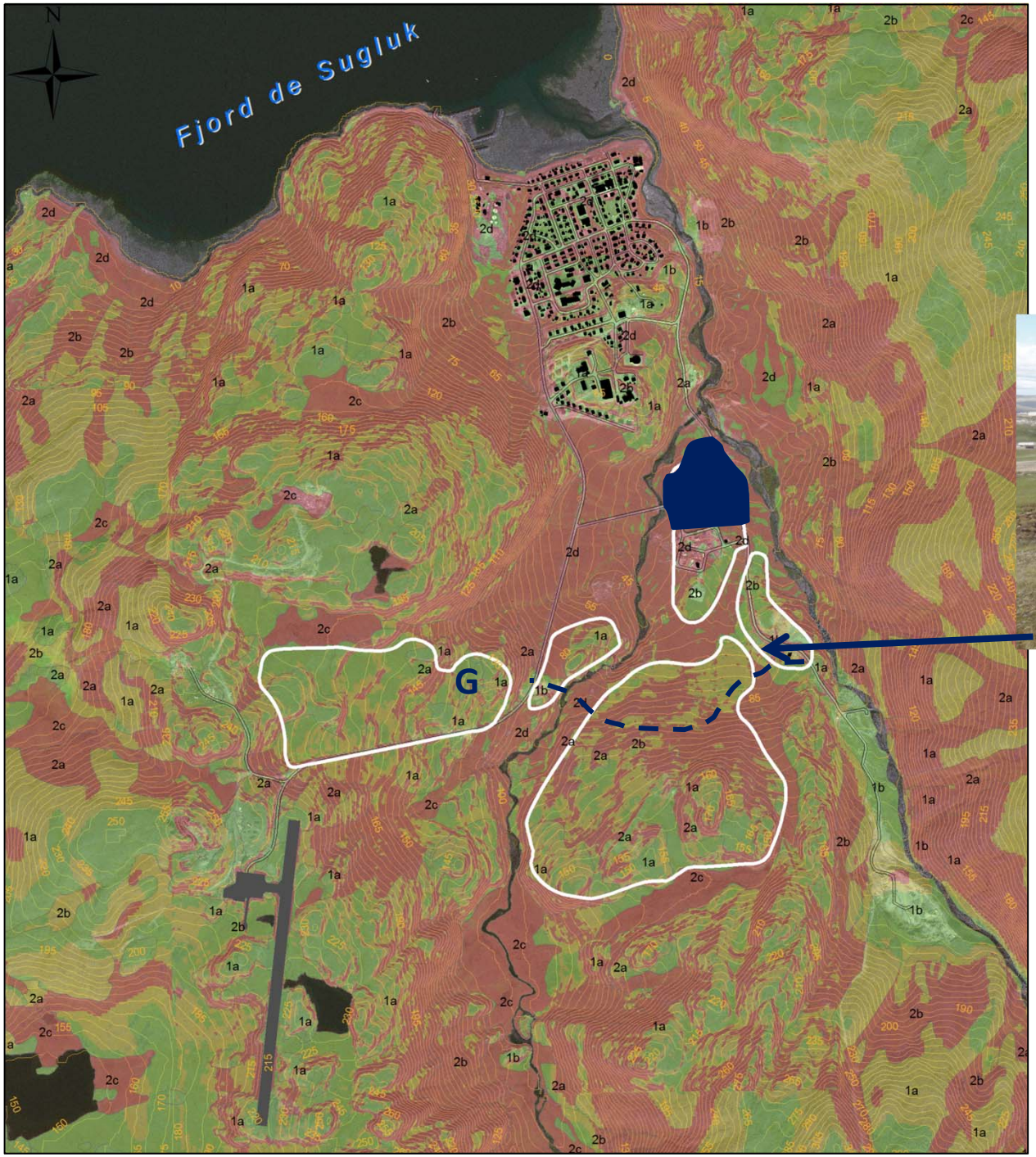
- **Sediment type**
- **Thickness/bedrock**
- **Ice content**
- **Slopes**
- **Signs of instability**

  (active layer failures, gelifluctio
- **Surface drainage**

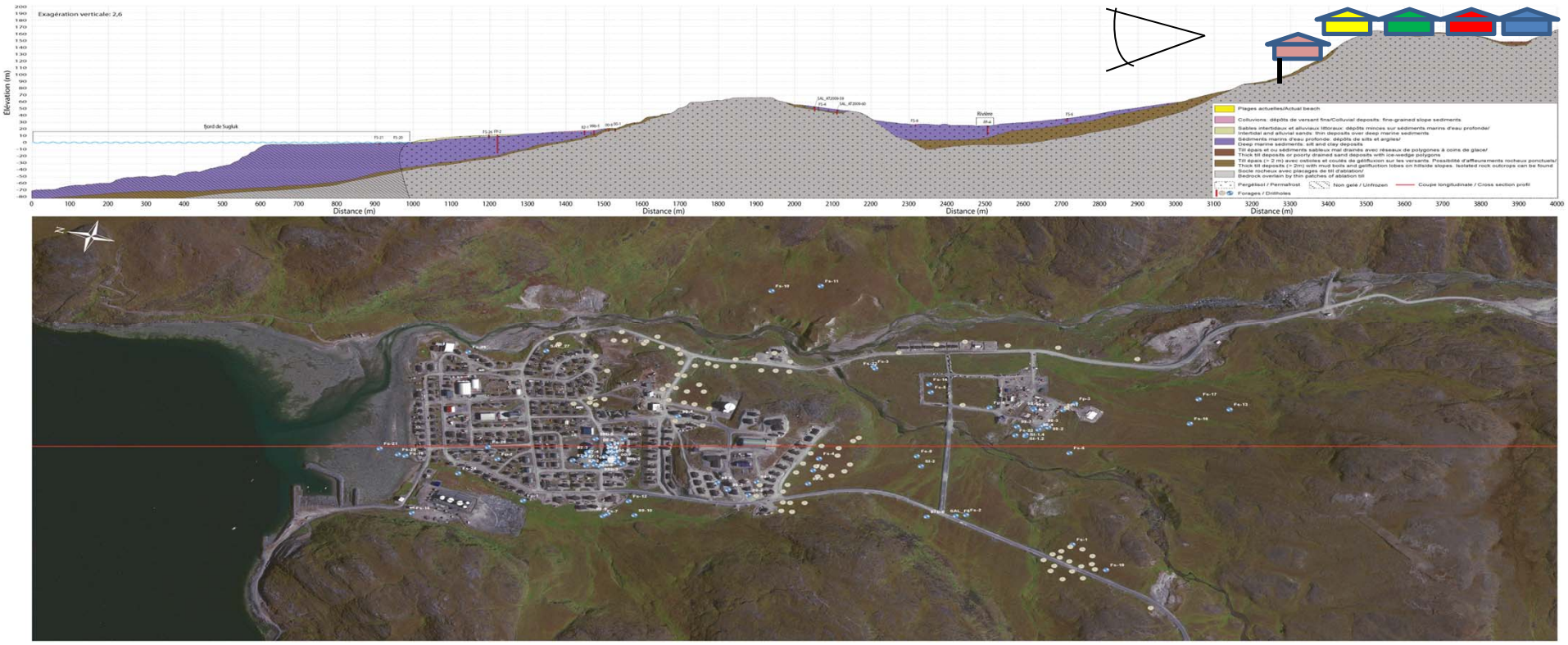
  (water tracks, thermal erosion

Selected expansion areas

Reclamation of lots in built area


N
Fjord de Sugluk
G

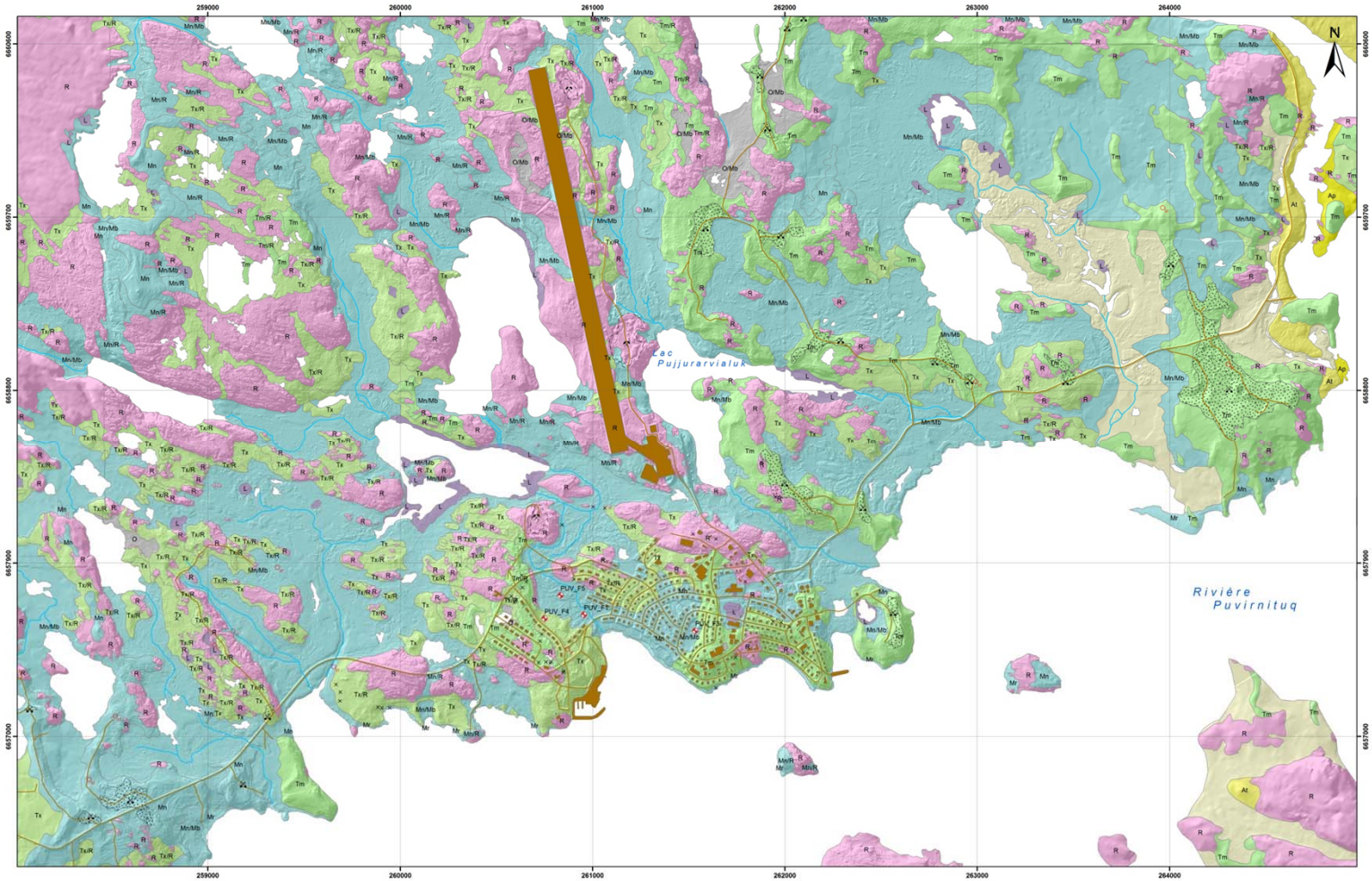
Decision making



Geological cross-section

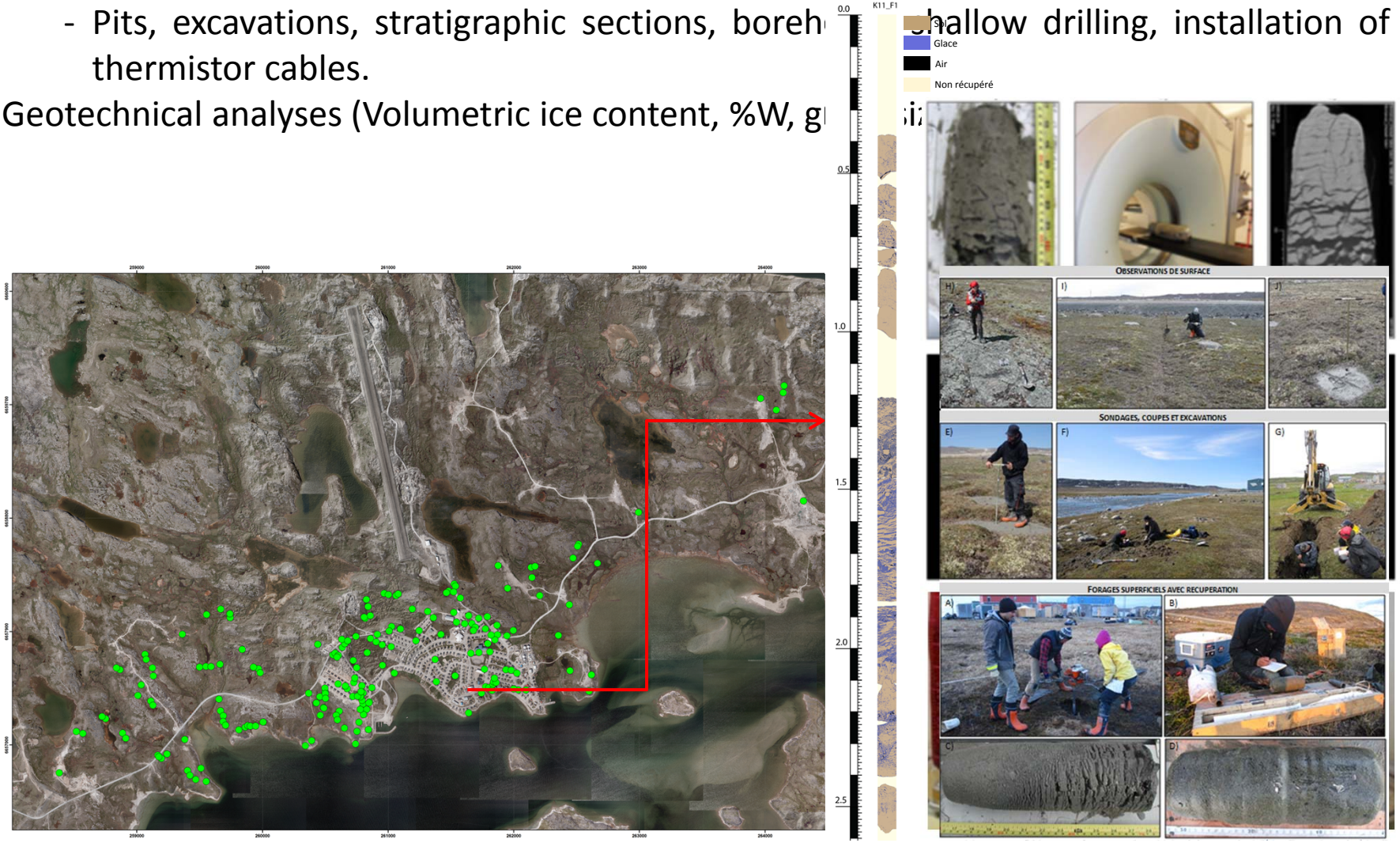
Steps in mapping permafrost at the community scale

1. Surficial geology: basic requirement!



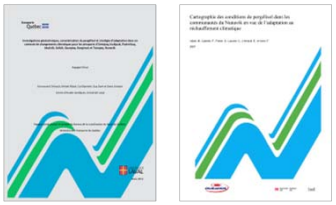
Puvirnituq

2. Field work
   - Meeting with community leaders and members
     - Get informed on community needs and expectations for development.
     - Discuss ongoing instabilities, problematic cases, buildings, services, etc.
   - Validate surficial geology mapping and map permafrost condition
     - Pits, excavations, stratigraphic sections, boreh shallow drilling, installation of thermistor cables.
3. Geotechnical analyses (Volumetric ice content, %W, g si

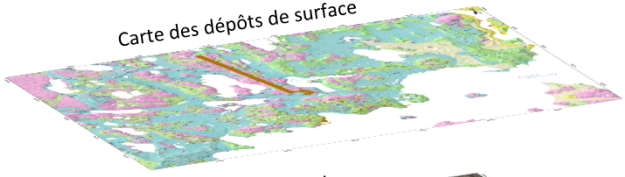


4. Making permafrost conditions maps
   - Compilation and integration of any other geoscientific information.

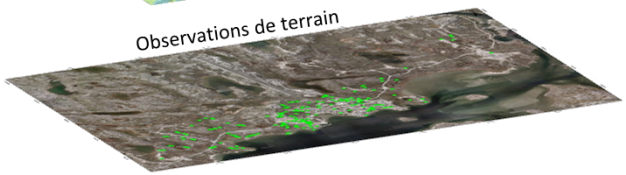
Rapports antérieurs



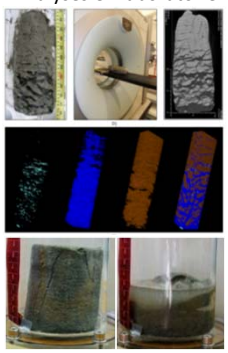
Carte des dépôts de surface



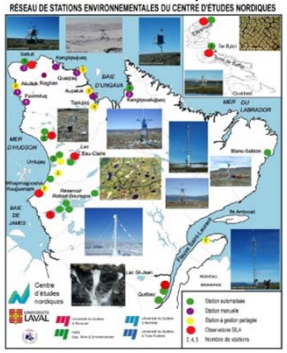
Observations de terrain



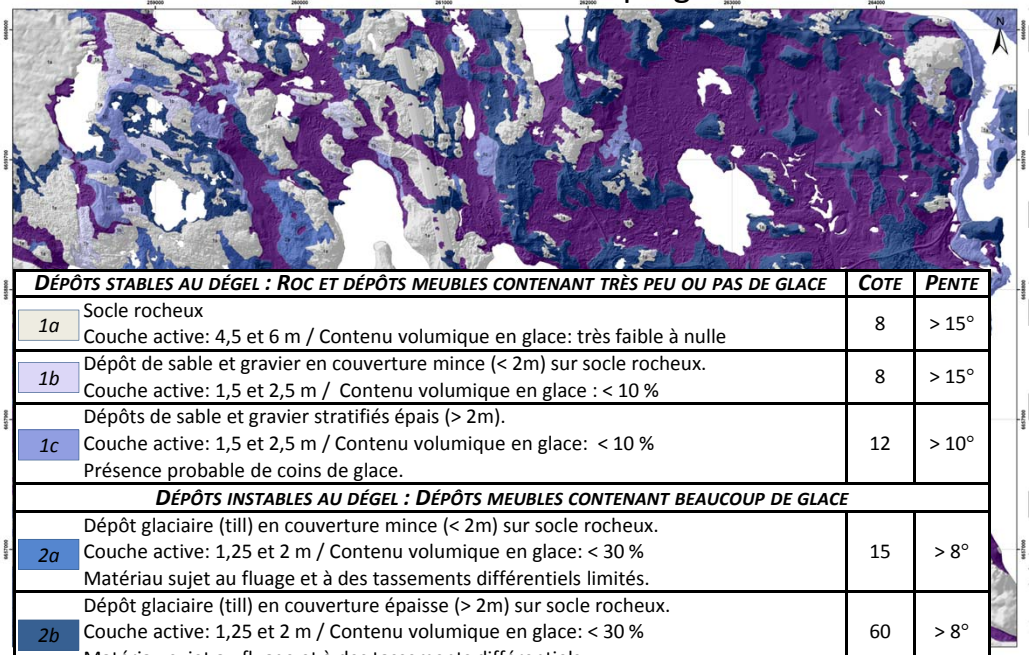
Analyses en laboratoire



Données thermiques

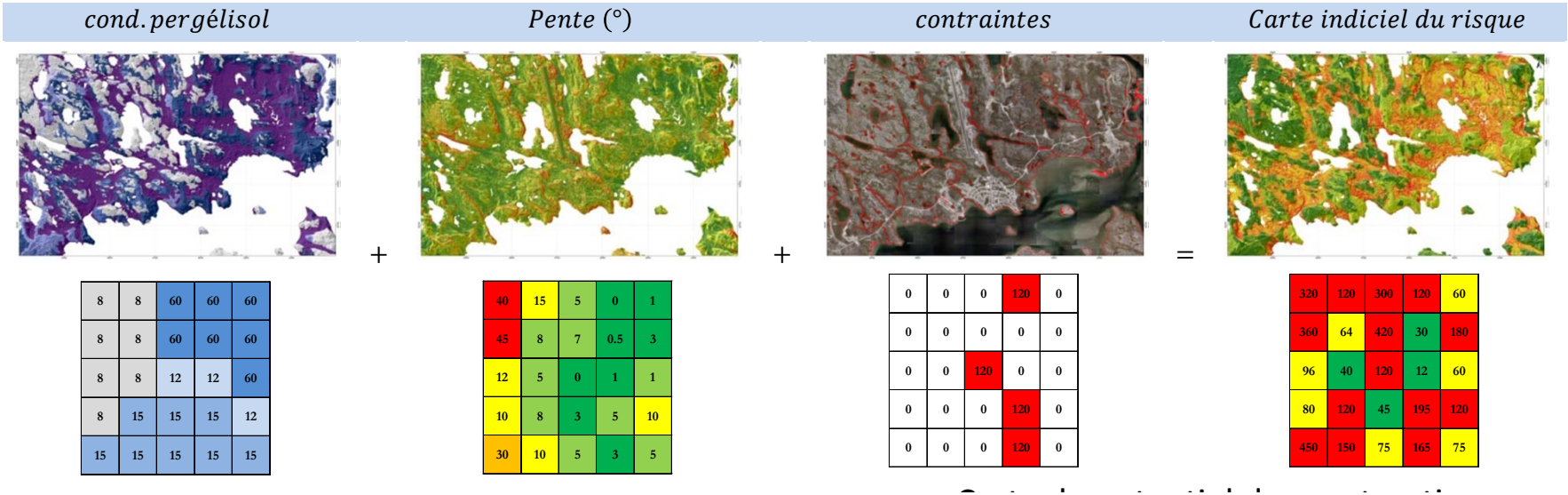


Carte des conditions de pergélisol

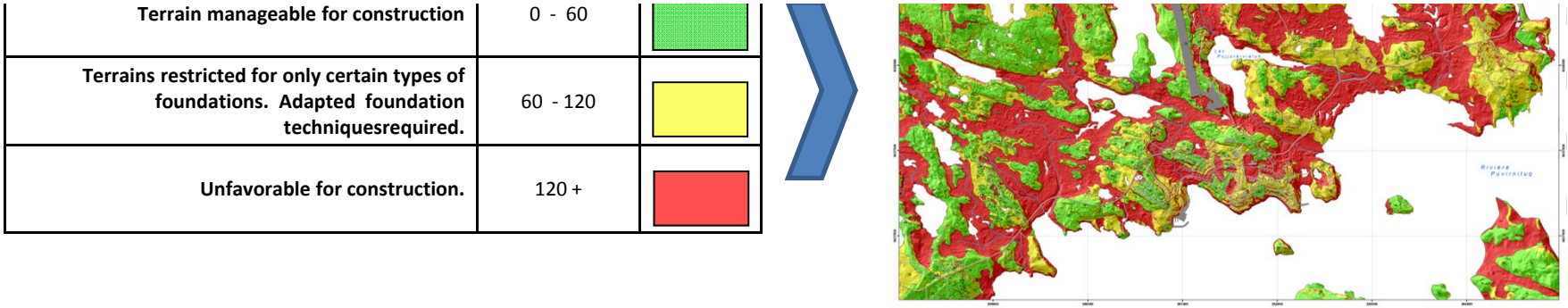


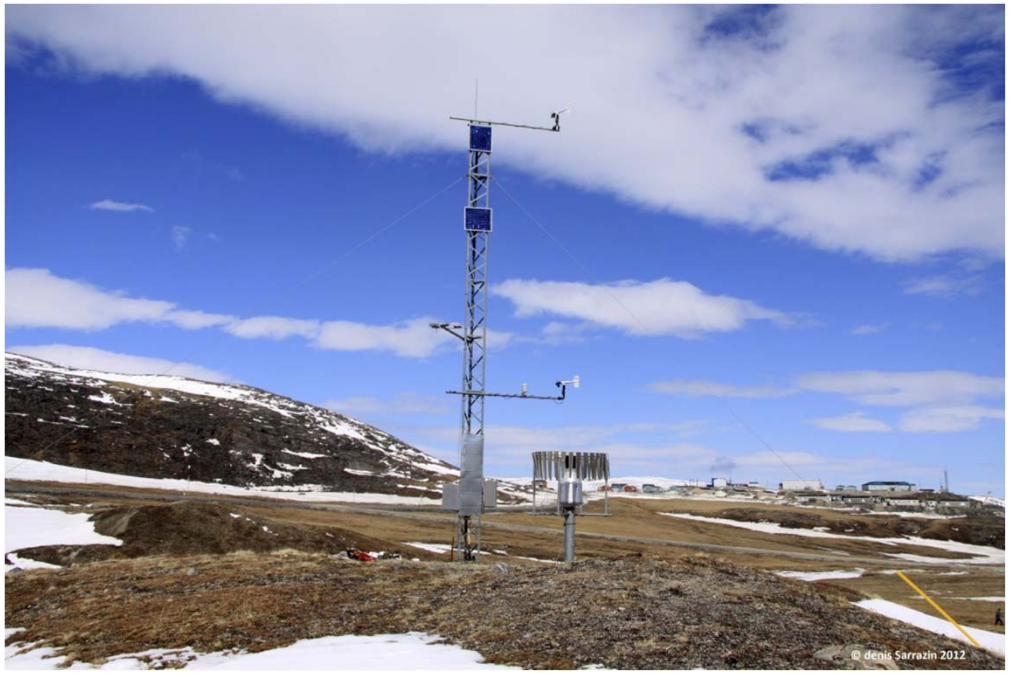
DÉPÔTS STABLES AU DÉGEL : ROC ET DÉPÔTS MEUBLES CONTENANT TRÈS PEU OU PAS DE GLACE		COTE	PENTE
1a	Socle rocheux Couche active: 4,5 et 6 m / Contenu volumique en glace: très faible à nulle	8	> 15°
1b	Dépôt de sable et gravier en couverture mince (< 2m) sur socle rocheux. Couche active: 1,5 et 2,5 m / Contenu volumique en glace : < 10 %	8	> 15°
1c	Dépôts de sable et gravier stratifiés épais (> 2m). Couche active: 1,5 et 2,5 m / Contenu volumique en glace: < 10 % Présence probable de coins de glace.	12	> 10°
DÉPÔTS INSTABLES AU DÉGEL : DÉPÔTS MEUBLES CONTENANT BEAUCOUP DE GLACE			
2a	Dépôt glaciaire (till) en couverture mince (< 2m) sur socle rocheux. Couche active: 1,25 et 2 m / Contenu volumique en glace: < 30 % Matériau sujet au fluage et à des tassements différentiels limités.	15	> 8°
2b	Dépôt glaciaire (till) en couverture épaisse (> 2m) sur socle rocheux. Couche active: 1,25 et 2 m / Contenu volumique en glace: < 30 % Matériau sujet au fluage et à des tassements différentiels.	60	> 8°
2c	Dépôts à granulométrie fine d'origine marine. Couche active : 0,5 et 1,2 m / Contenu volumique en glace: 30 % à 100 % Matériau sujet à des tassements différentiels importants et glissements de terrain.	120	> 2°

5. GIS application for making risk assessments maps and maps of potential for construction.



6. Revisit the community. Present and discuss results. Provide support.





Let’s keep Monitoring!

Opportunity for training.

Thank you very much!
Merci beaucoup!

ArcticNet
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Transports Québec

Ressources naturelles Canada
Natural Resources Canada
Canada

Transport Canada
Transports Canada

Affaires municipales, Régions et Occupation du territoire Québec

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