Detection of massive-ice and ice-rich soils using Gravimetry

BENOÎT LORANGER MSc., PhD **Candidate**
NTNU - Norwegian University of Science and Technology - NTNU
Laval University

GUY DORÉ ing. PhD, CEN / Laval University

DANIEL FORTIER PhD., CEN / Université de Montréal

ARQULUK SYMPOSIUM Whitehorse, February 21st, 2018

Collaboration

Thomas Ingeman-Nielsen
and Sonia Tomasvicova, DTU, Danemark

Dany Santiago, Scintrex

Benoît Loranger

Massive-ice

Soil with ice content > 250%

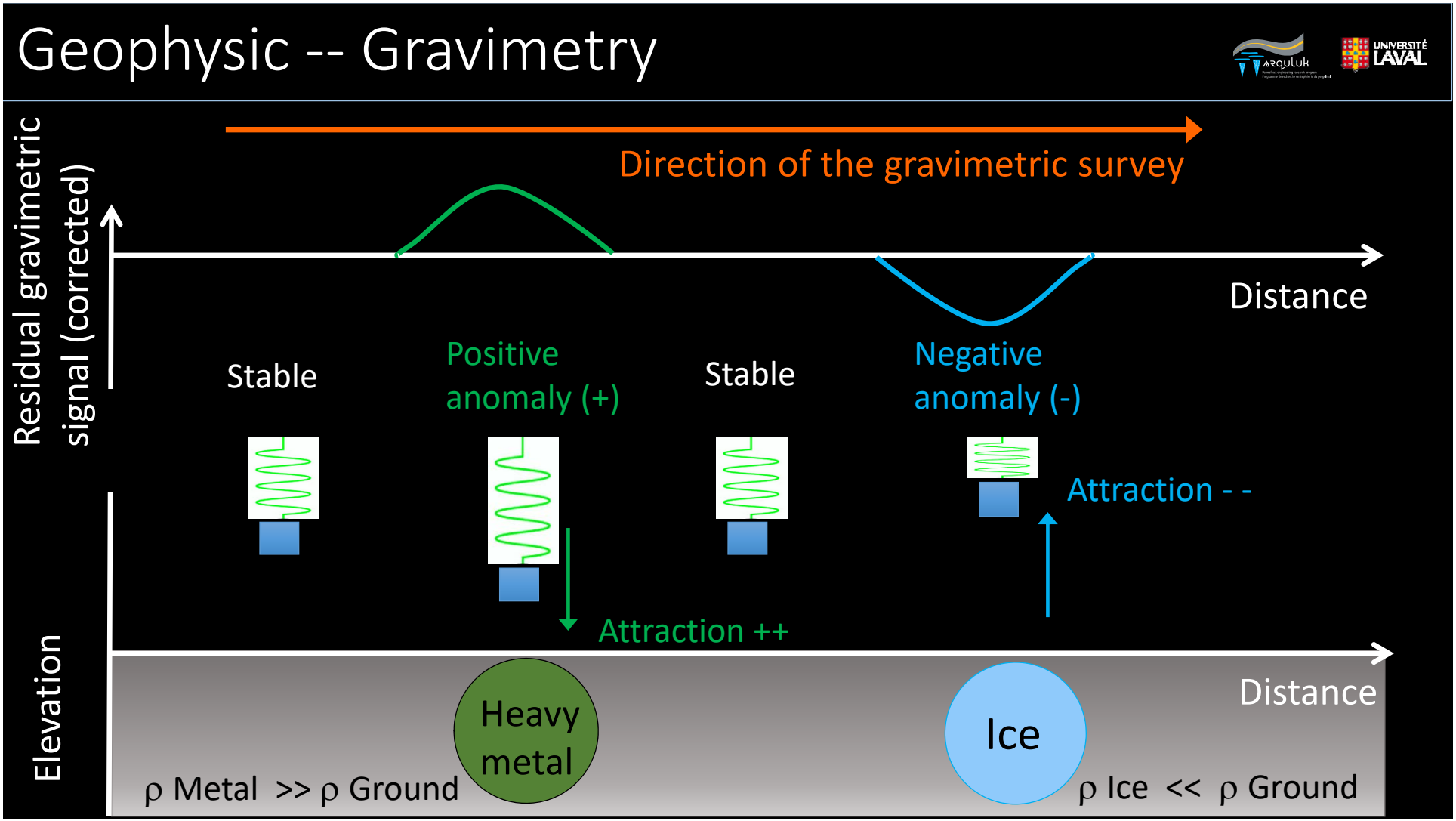
Source: Yukon Highways and Public Works

Source: Don Hayley

Massive-ice -- Degradation

Source: V. Romanovsky (Alaska)

Geophysic -- Gravimetry



Geophysic -- Gravimetry

Use of gravimeter Scintrex CG-3+ Auto Grav

Requires several corrections during data treatment:

- Altitude
- Instrumental drift
- Regional trends
- Bouguer anomaly
- Earth tide
- Topography (Hammer)

Objectives

Demonstrate the feasibility of using high-precision gravimetry for massive-ice detection in permafrost areas.

Develop a simple model for 2D interpretation of gravimetric data.

Study sites

Alaska Highway, Yukon

- Dry Creek

Study sites

Alaska Highway, Yukon

- Dry Creek
- Beaver Creek

Study sites

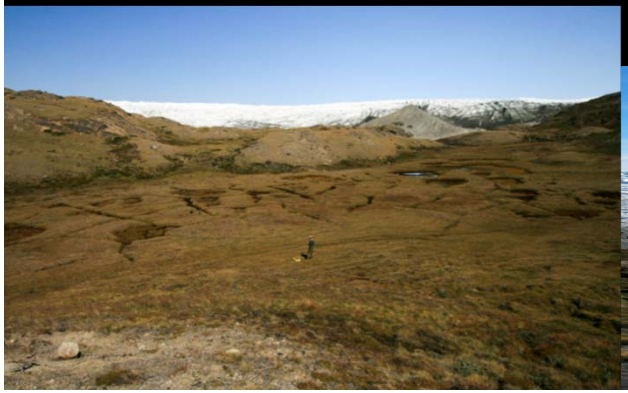
Alaska Highway, Yukon

- Dry Creek
- Beaver Creek

Ice-wedges site, DTU

Site at the margin of the ice cap

Greenland, 35 km from Kangerlussuaq



Dry Creek, Yukon

Dry Creek, Yukon

11 gravimetric surveys

10 drill holes:

4 with ice

6 without ice

Dry Creek, Yukon – Drilling (DC-04)

0 – 1 m : Fill material, Sandy Gravel

1 – 2 m : Sandy Gravel with cobbler and silt. Ice-rich (estimated at 80% of ice)

2 – 9.5 m : Massive-ice

9.5 – 12 m : Sandy Gravel with cobbler and silt
Ice-rich (estimated at 80% of ice)

12 – 12.5 m : Silt with gravel

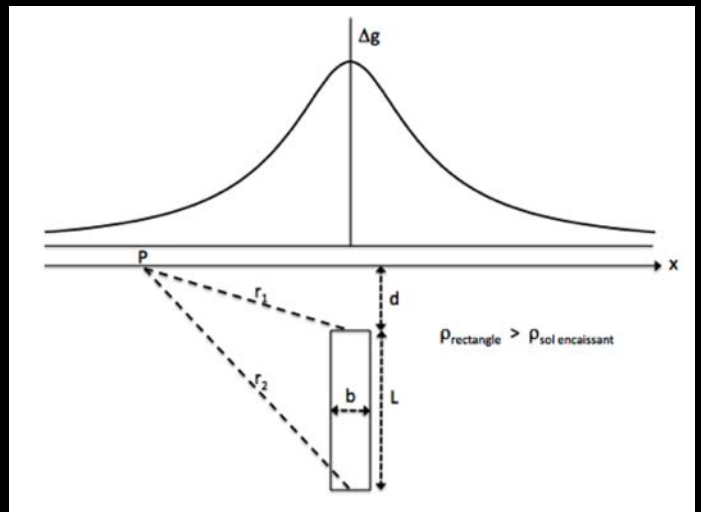
Model

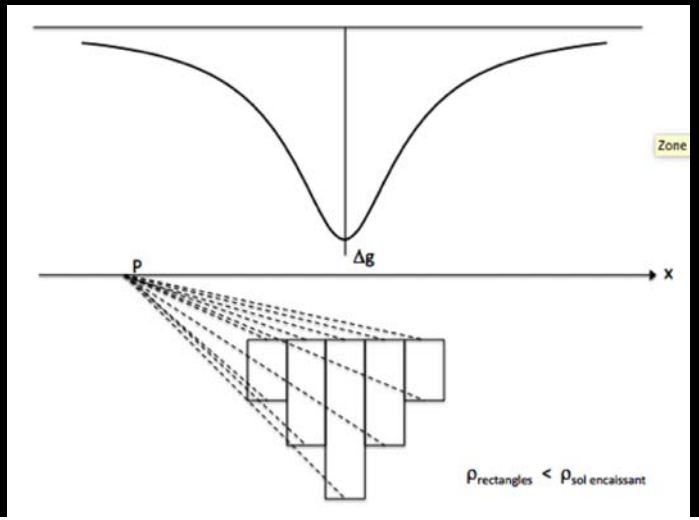
2D model: elongated vertical columns (Dobrin et Savit, 1973)

Adapted from R. Allen, Berkeley Seismological Laboratory, 2004

Model:

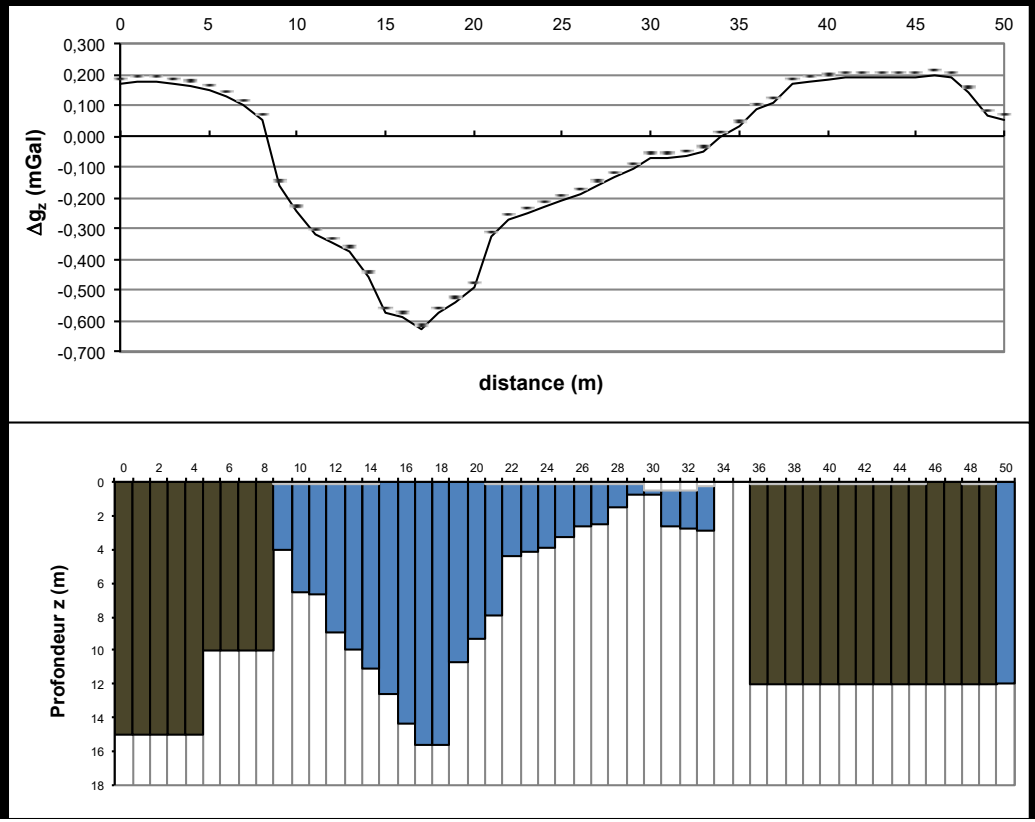
$$\Delta g_z = 2\,G\,\Delta\rho\,b\,\ln(r_2 / r_1) \longrightarrow \Delta g_z = \Sigma \Delta g_{zi}$$





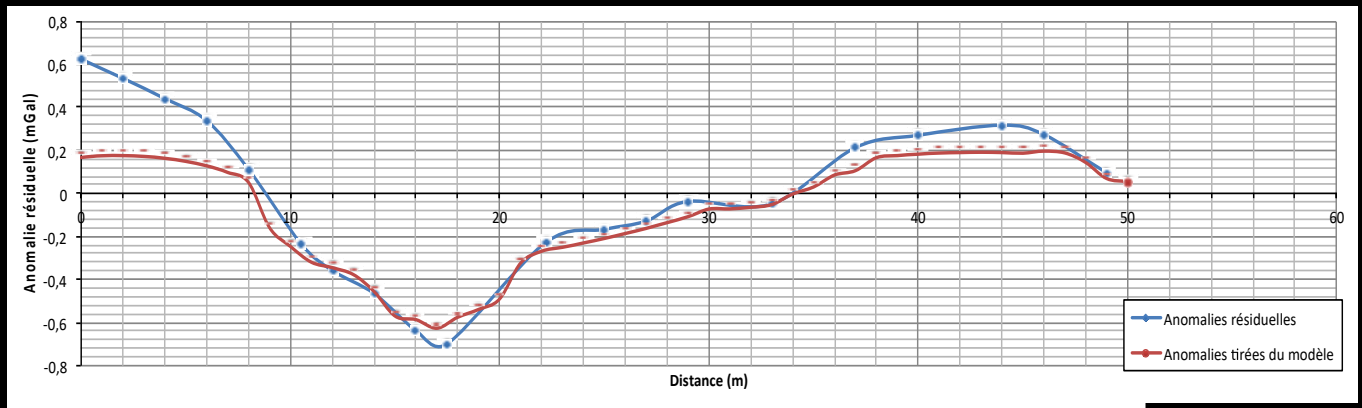
Results – Dry Creek, Yukon

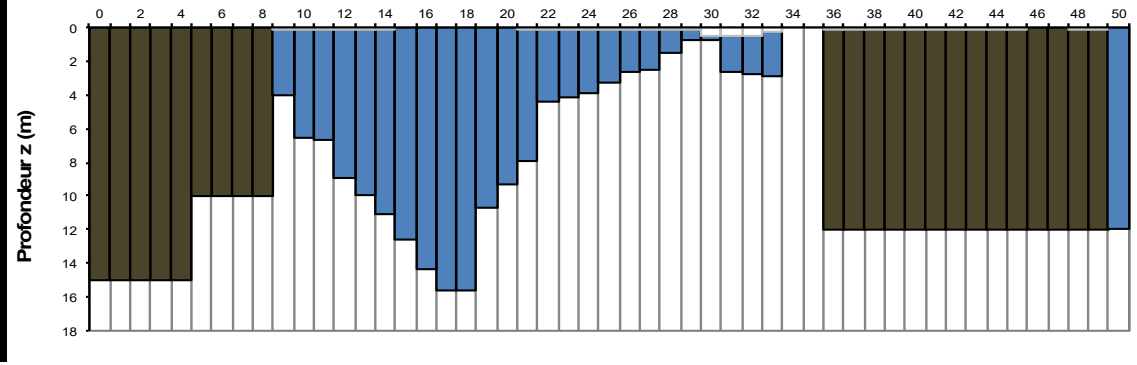
Calculated anomaly with the elongated vertical columns model



Results – Dry Creek, Yukon

Comparison between the residual anomaly (blue line) and the anomaly calculated with the elongated vertical columns model





Conclusion

A model has been developed and validated using borehole information. The model is consistent with the gravimetric anomalies measured.

Promising technique for the detection of massive ice and ice-rich permafrost

The detection limit of the anomaly body is a function of :

- Volume and depth of the anomaly body
- Density difference between the anomaly body and surrounding soils

Benefits

Micro-gravimetry has been adapted and has proven to work for the detection of massive-ice and ice-rich soils.

The geophysical technique should help identifying thaw-sensitive permafrost under existing infrastructure or in natural ground.

Arquluk
Permafrost engineering research program
Programme de recherche en ingénierie du pergélisol

THANK YOU!

Université Laval
KRYOTEK
KATIVIK
Transports, Mobilité durable et Électrification des transports Québec
GHD
YUKON RESEARCH CENTRE Yukon College
Cold Climate Innovation YUKON RESEARCH CENTRE - Yukon College
Université de Montréal
CRSNG NSERC
TETRA TECH
WSP
COLAS
NIPPO
Yukon Highways and Public Works
OURANOS
CENTRE D'ÉTUDES NORDIQUES