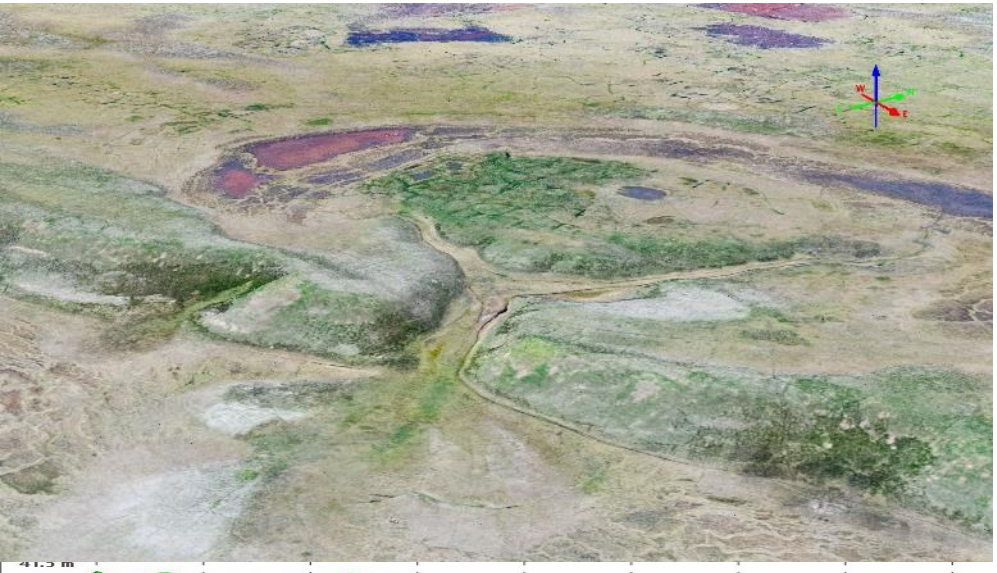
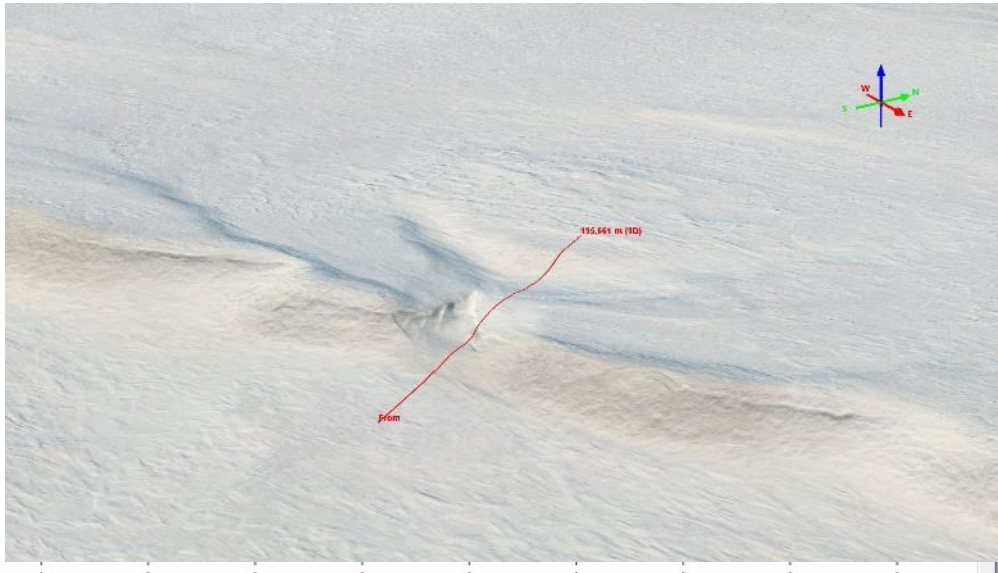
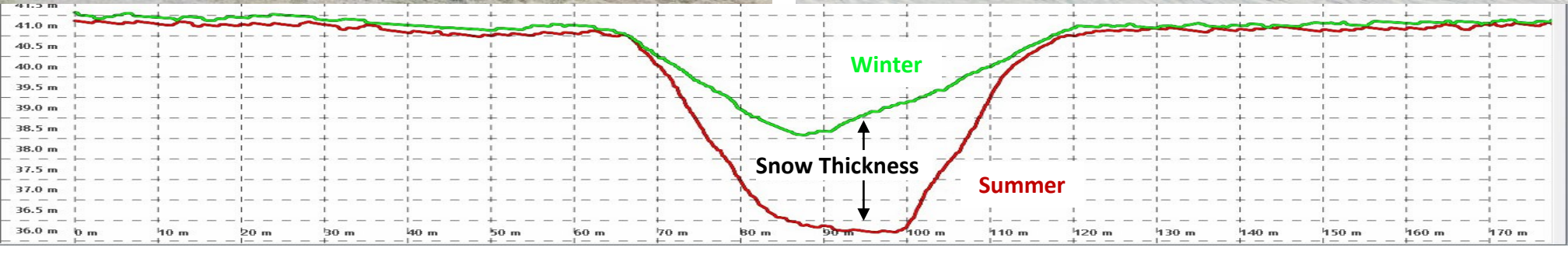
50 Billion Measurements of Snow Depth in Arctic Alaska with Fodar

Dr. Matt Nolan
Fairbanks Fodar



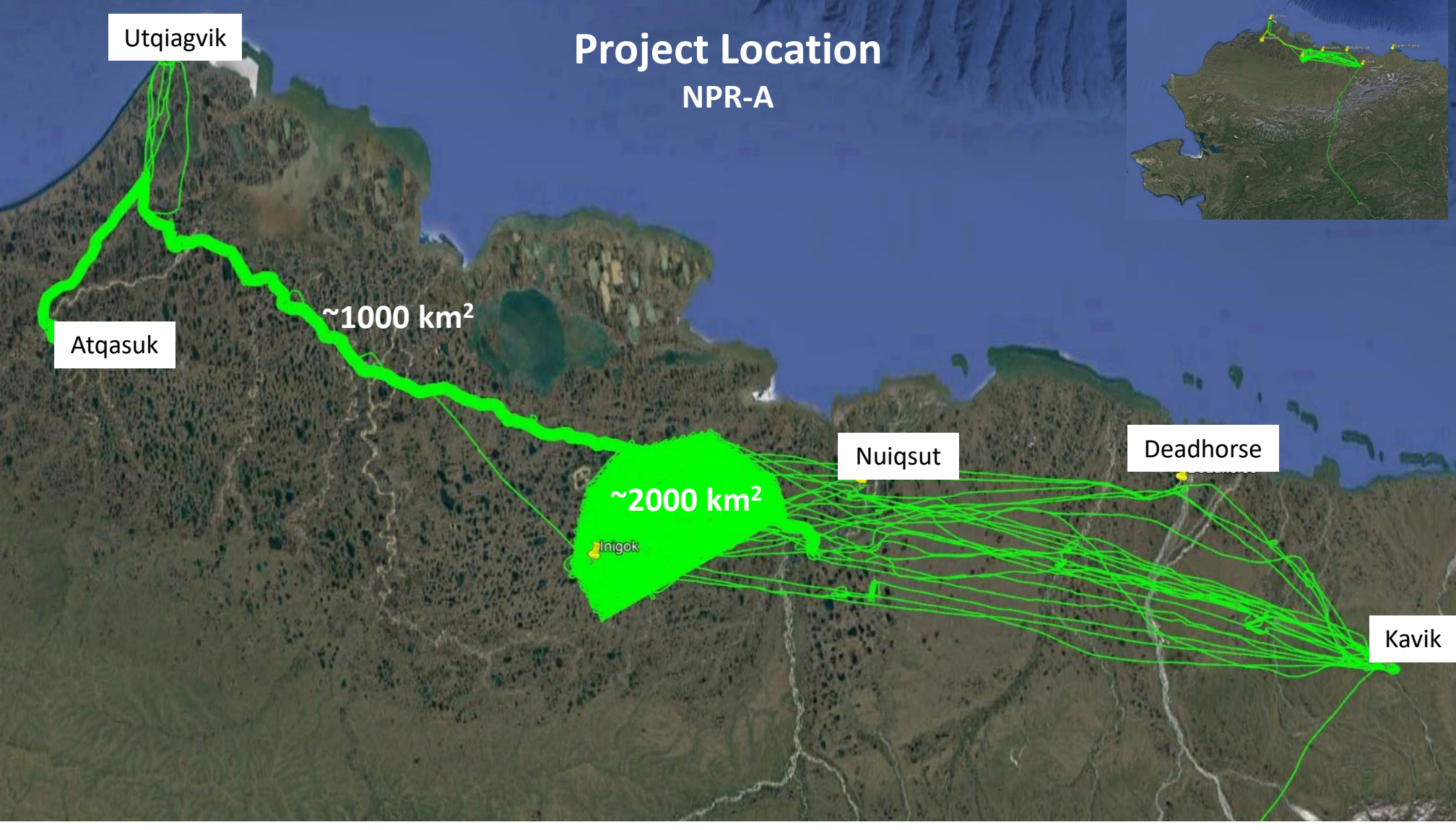


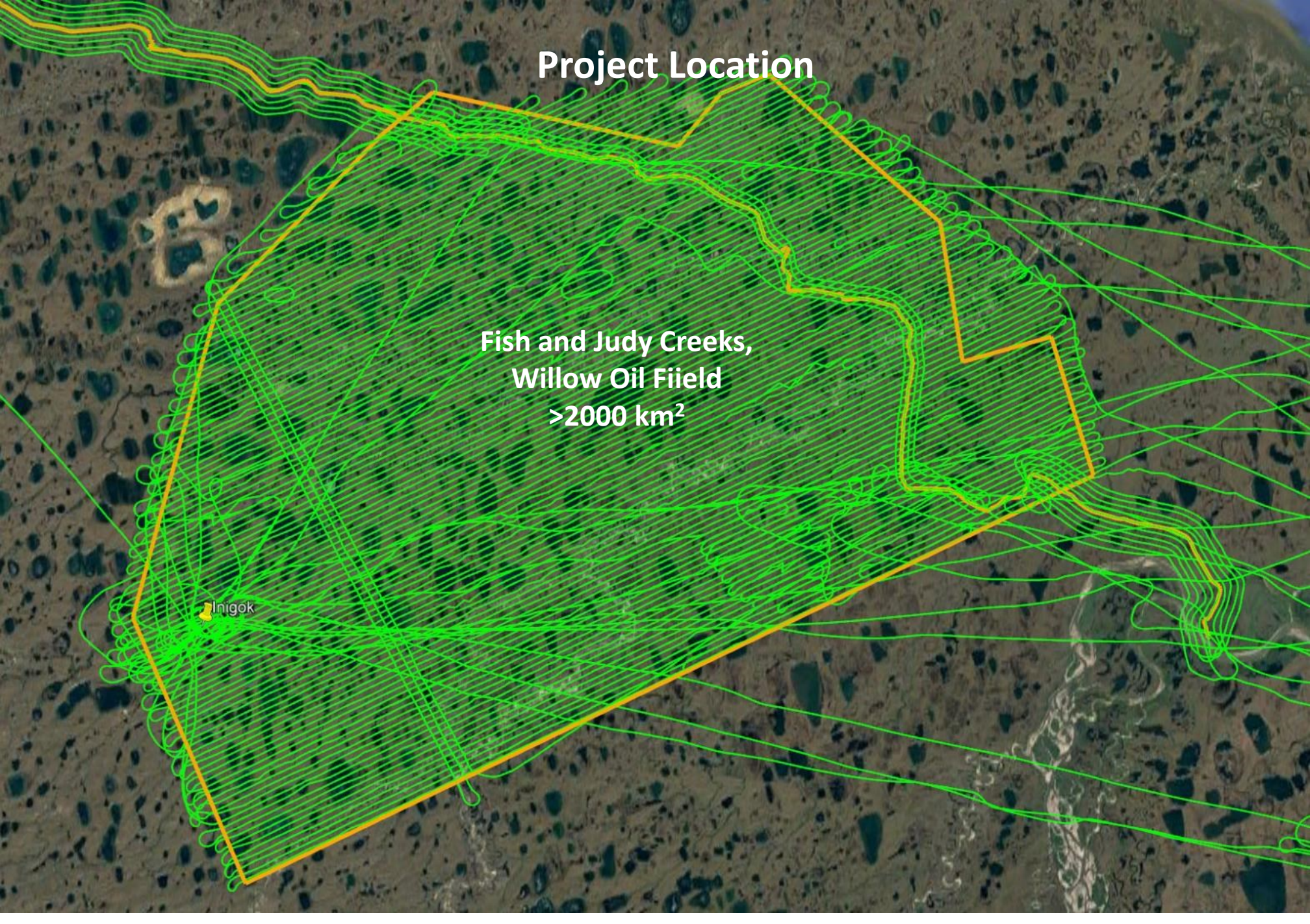


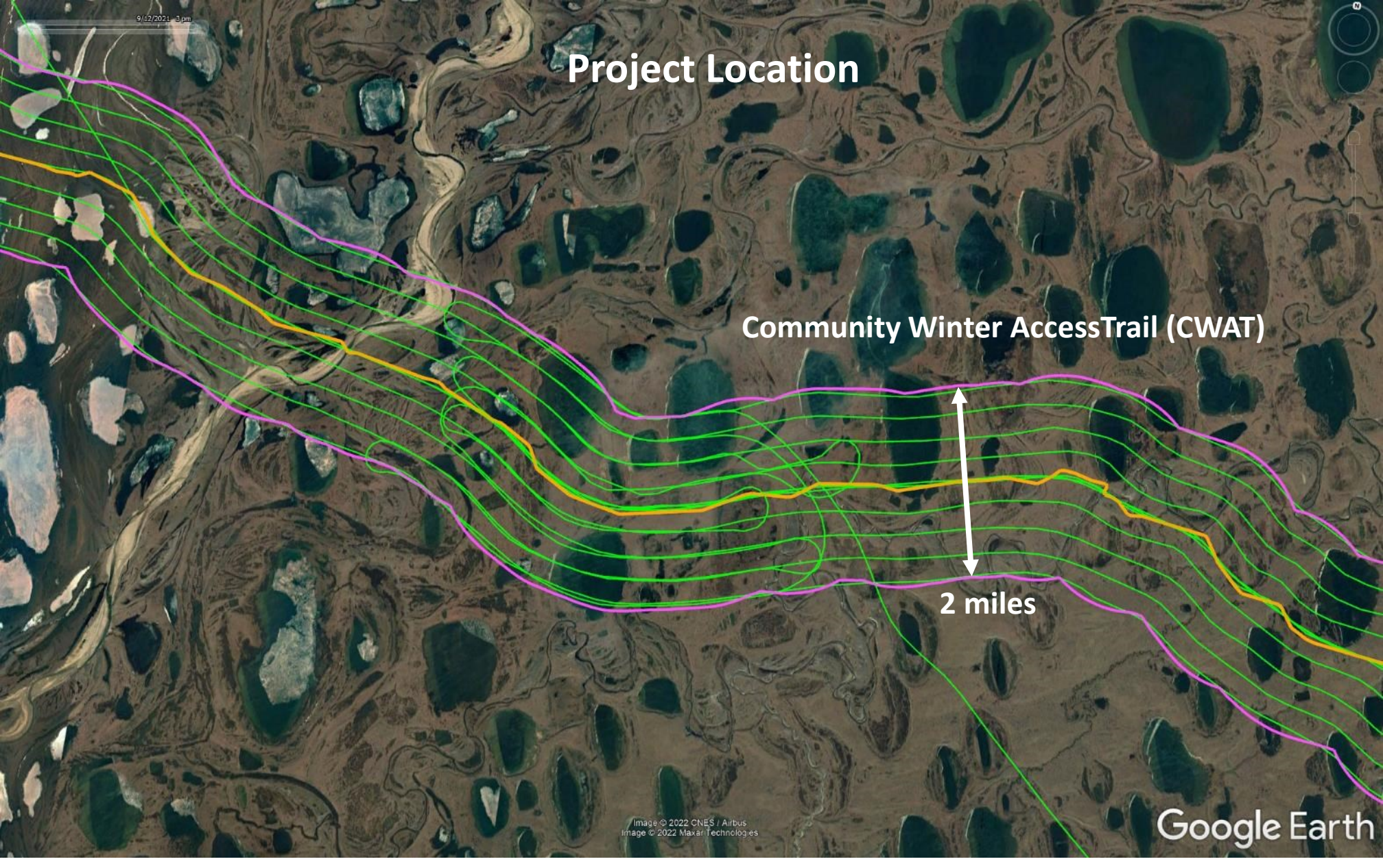
Here is a synthetic 3D visualization of a small drained lake mapped in summer (left) and winter (right) in 2021 using fodar on over 3000 sq. km of NPR-A. The difference between the winter and summer elevations is snow depth, which we can measure in transects (above) or as maps with 25 cm pixels.

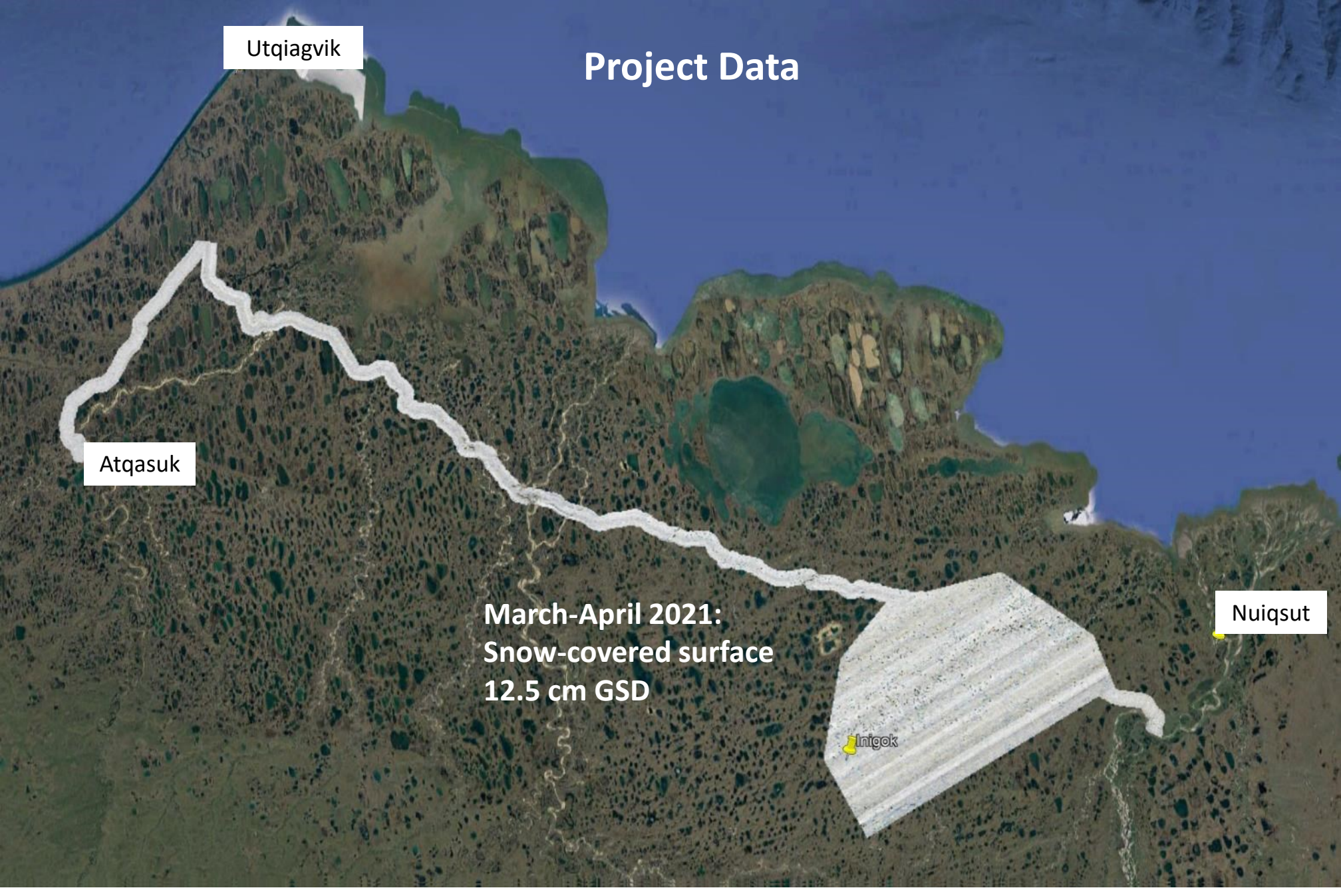
I've been mapping snow depths annually in Arctic Alaska for 10 years across 1000s of square kilometers.

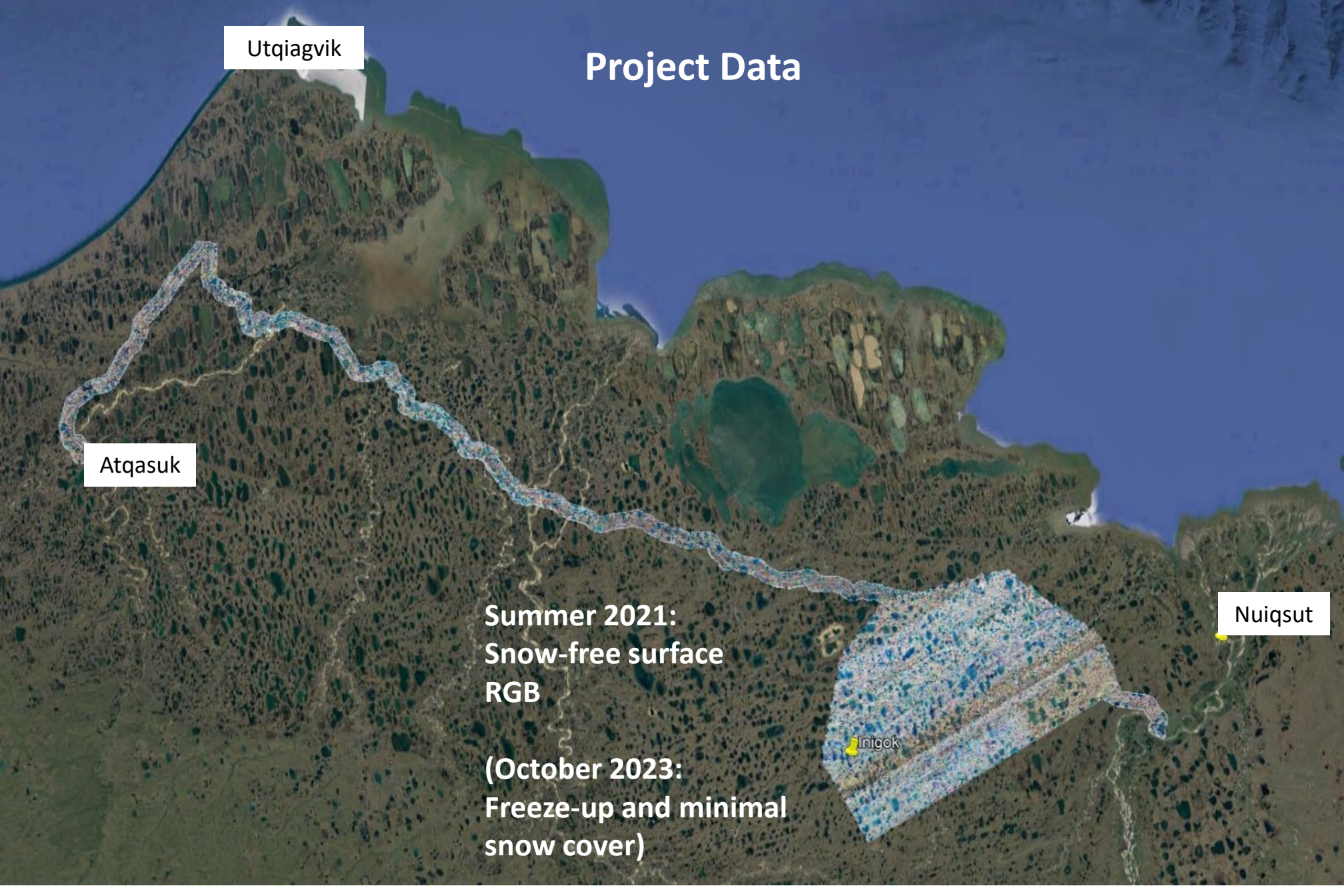
Visit www.fairbanksfodar.com to learn about this project (and many more) in great detail.

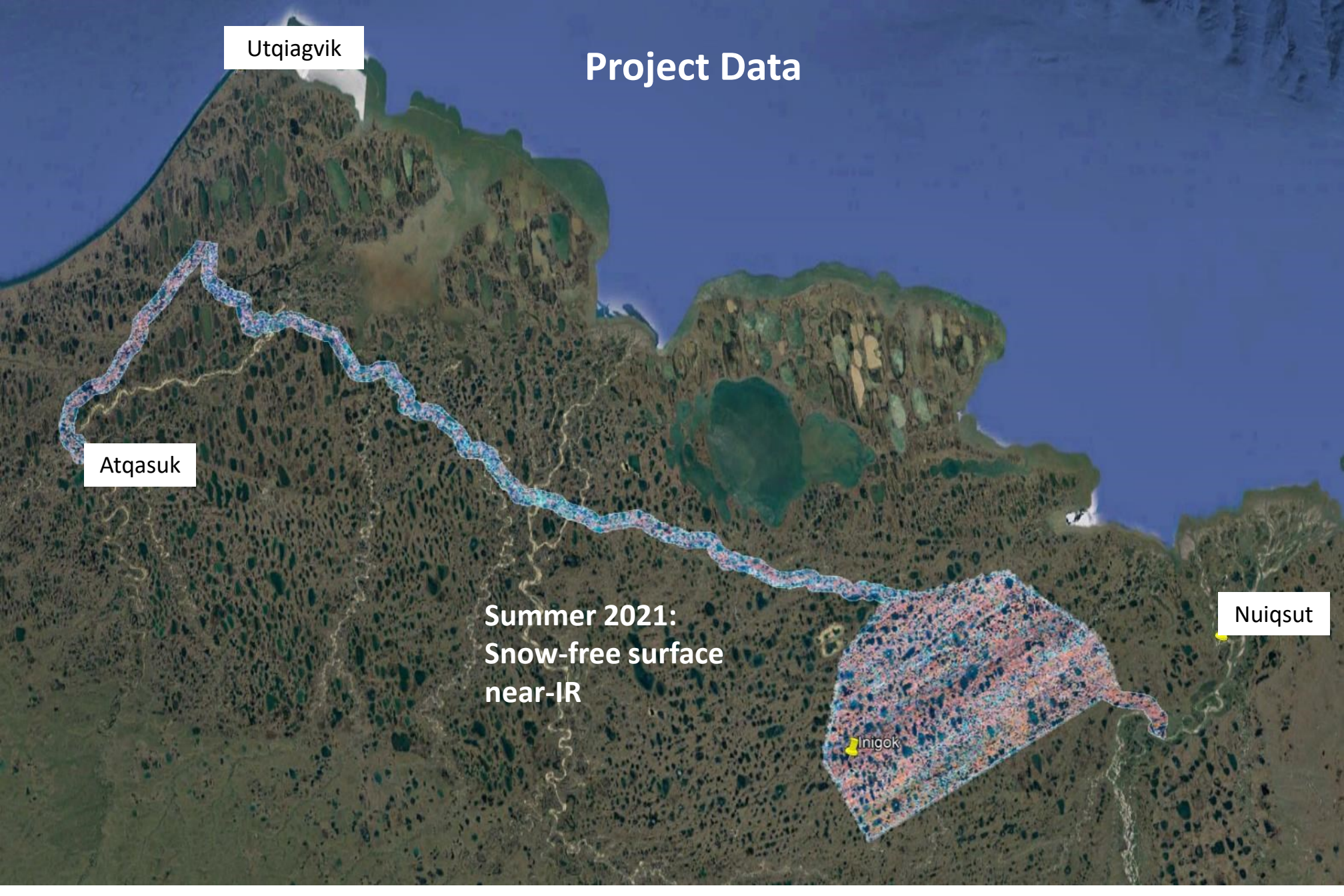

Project Location
NPR-A
Utqiagvik
Atqasuk
~1000 km²
~2000 km²
Nuiqsut
Deadhorse
Kavik
Inigok

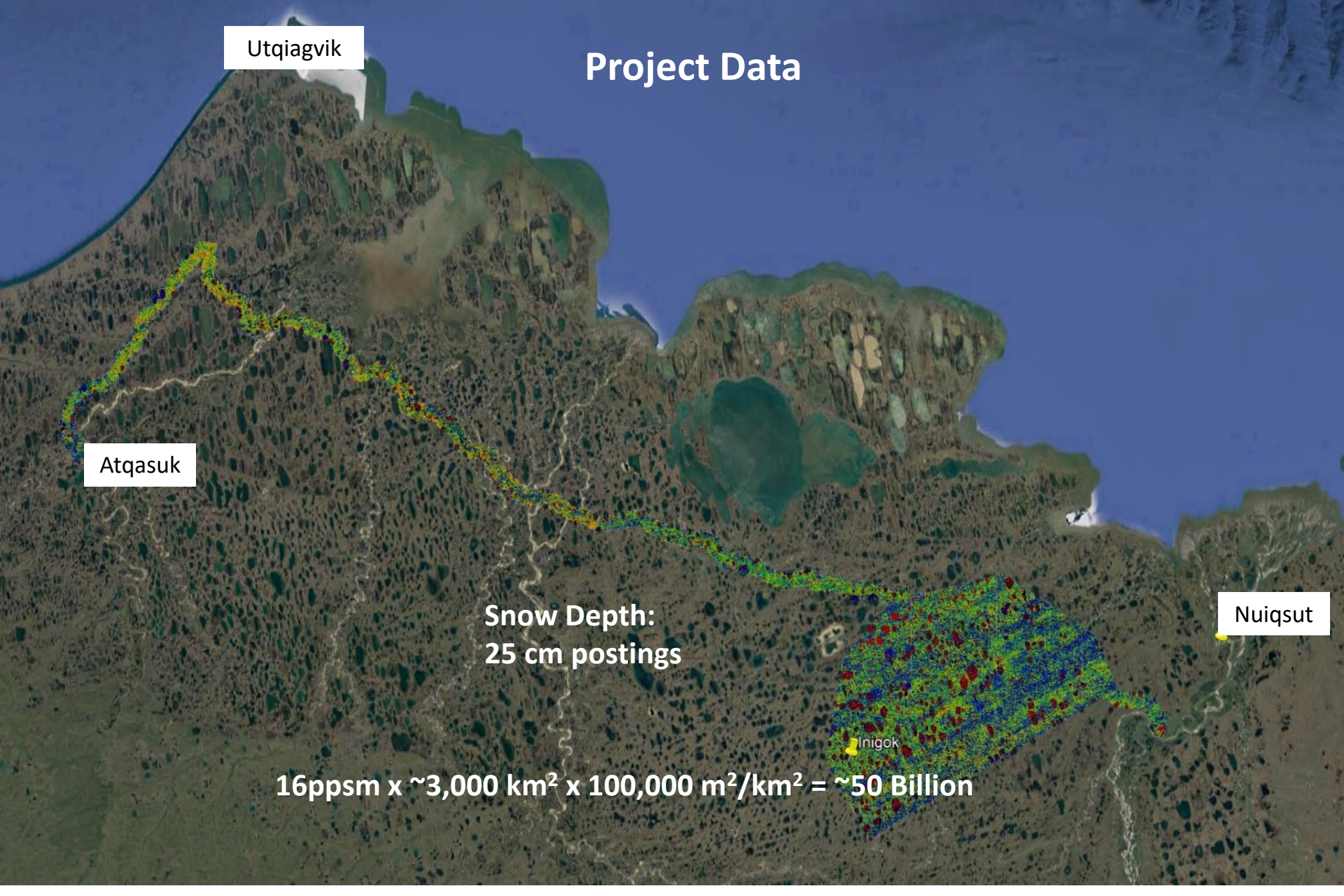

Project Location
Fish and Judy Creeks,
Willow Oil Fiield
>2000 km²
Inigok


Project Location
Community Winter AccessTrail (CWAT)
2 miles
Image © 2022 CNES / Airbus
Image © 2022 Maxar Technologies
Google Earth


Utqiagvik
Project Data
Atqasuk
March-April 2021:
Snow-covered surface
12.5 cm GSD
Nuiqsut
Inigok

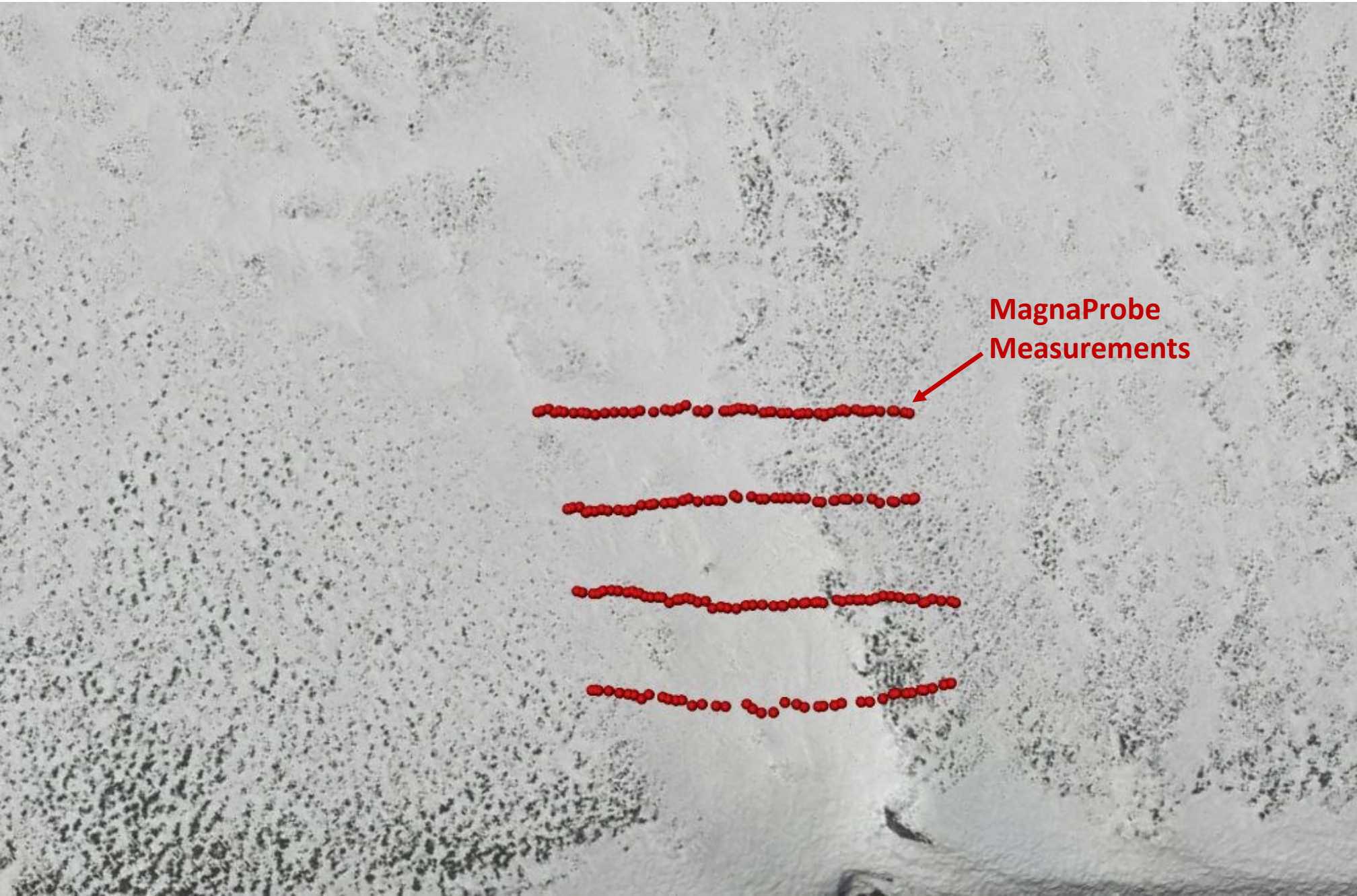

Utqiagvik
Project Data
Atqasuk
Nuiqsut
Summer 2021:
Snow-free surface
RGB
Inigok
(October 2023:
Freeze-up and minimal
snow cover)


Utqiagvik
Project Data
Atqasuk
Summer 2021:
Snow-free surface
near-IR
Nuiqsut
Inigok


Utqiagvik
Project Data
Atqasuk
Snow Depth:
25 cm postings
Nuiqsut
Inigok
16ppsm x ~3,000 km² x 100,000 m²/km² = ~50 Billion

Evaluating Fodar Snow Depth Accuracy

Fodar vs Ground Probe

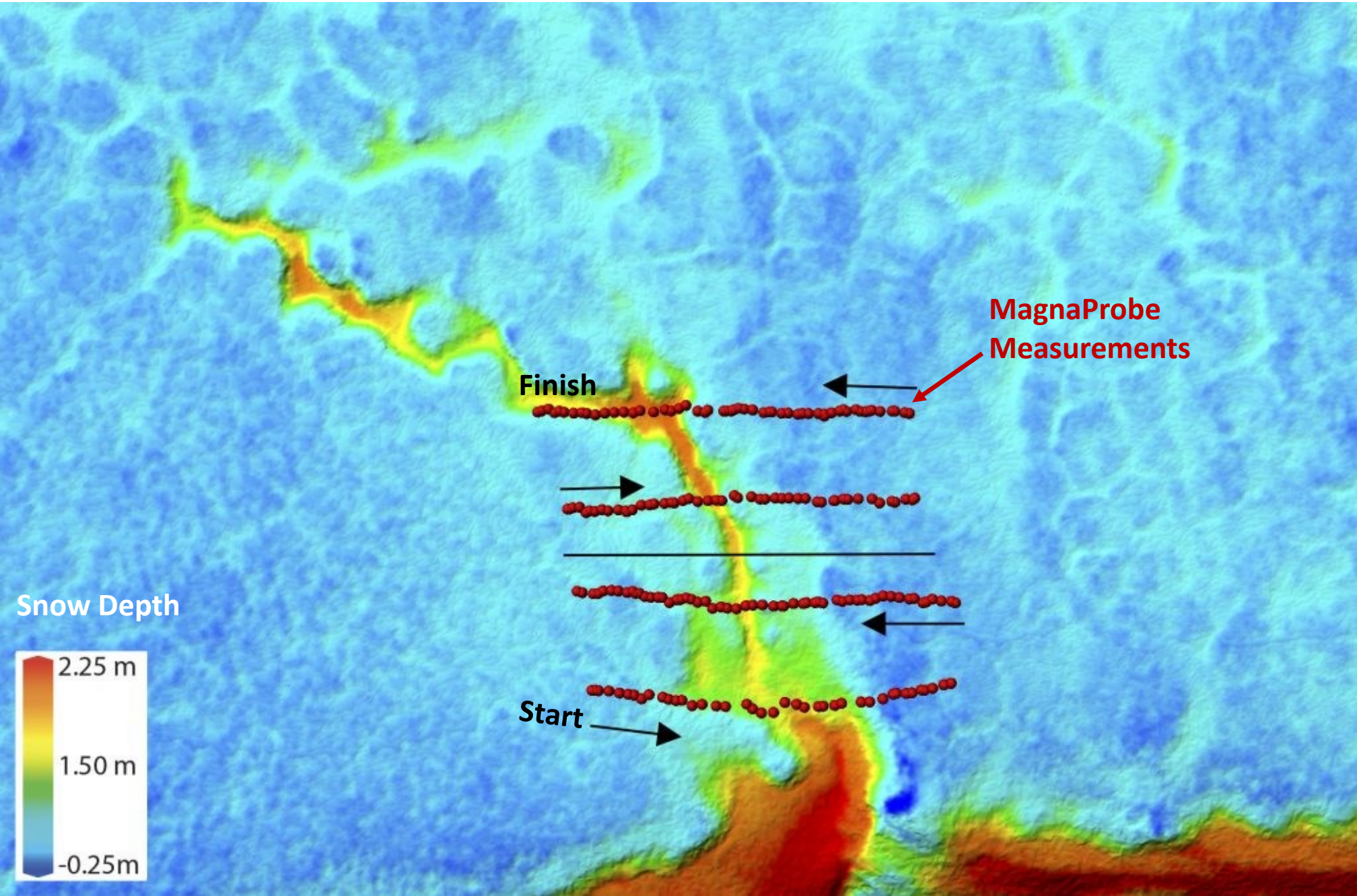


Evaluating Fodar Snow Depth Accuracy

Fodar vs Ground Probe

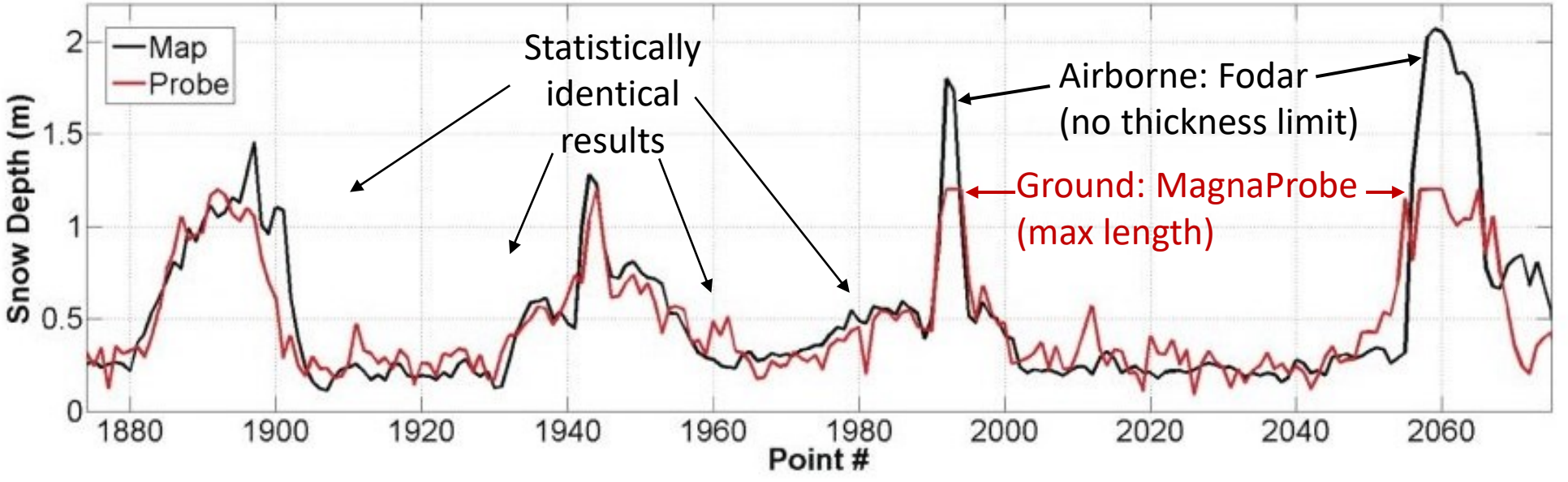
Evaluating Fodar Snow Depth Accuracy

Fodar vs Ground Probe



Evaluating Fodar Snow Depth Accuracy

Fodar vs Ground Probe



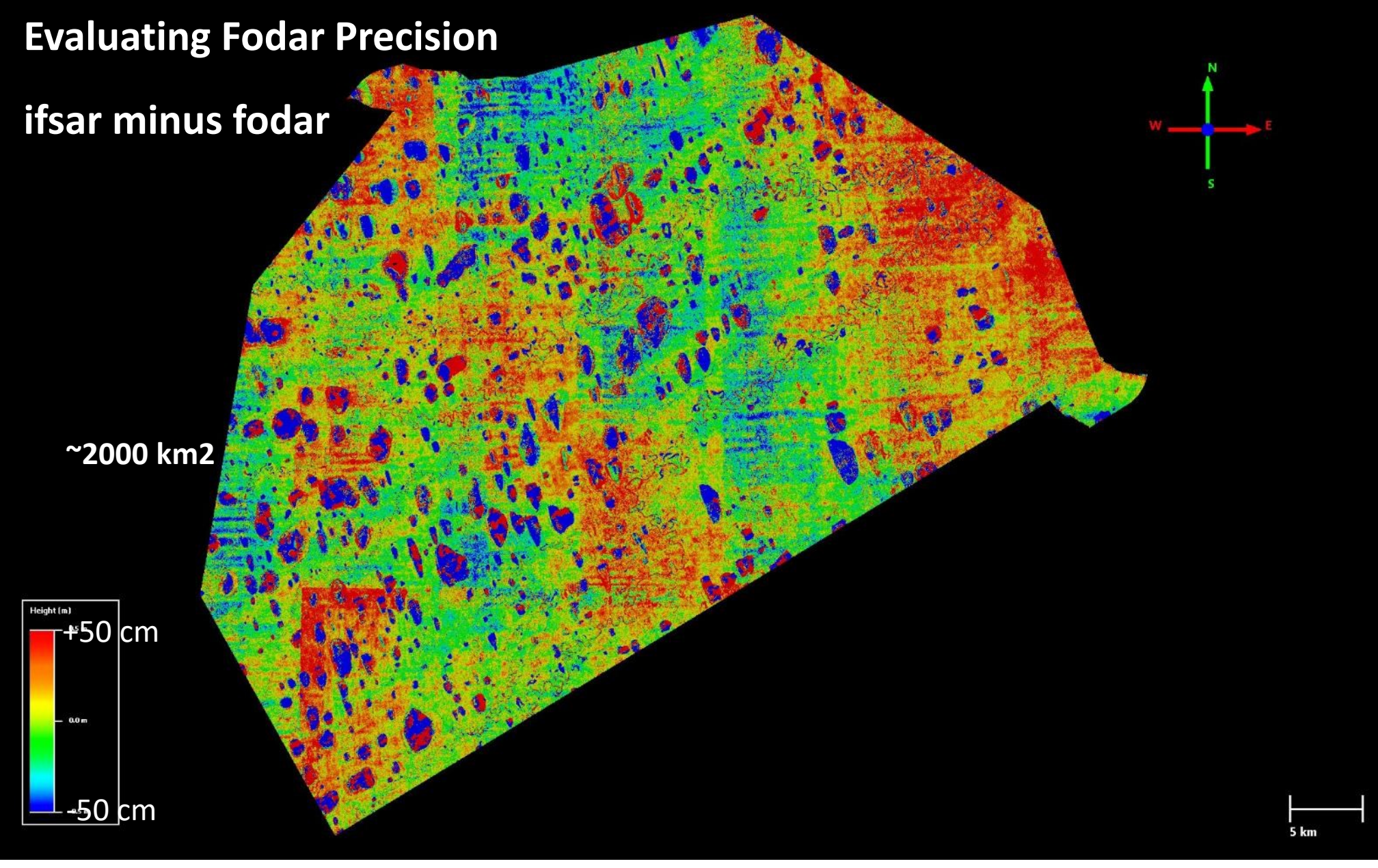
Fodar can measure a billion points/day and do so **more accurately than can be done on the ground**.

That snow depth is so accurate means that
the precision of a single fodar map (summer and winter) is as good as any lidar.

Nolan, Matt, Chris Larsen, and Matthew Sturm. "Mapping snow depth from manned aircraft on landscape scales at centimeter resolution using structure-from-motion photogrammetry." *The Cryosphere* 9, no. 4 (2015): 1445-1463.

Evaluating Fodar Precision

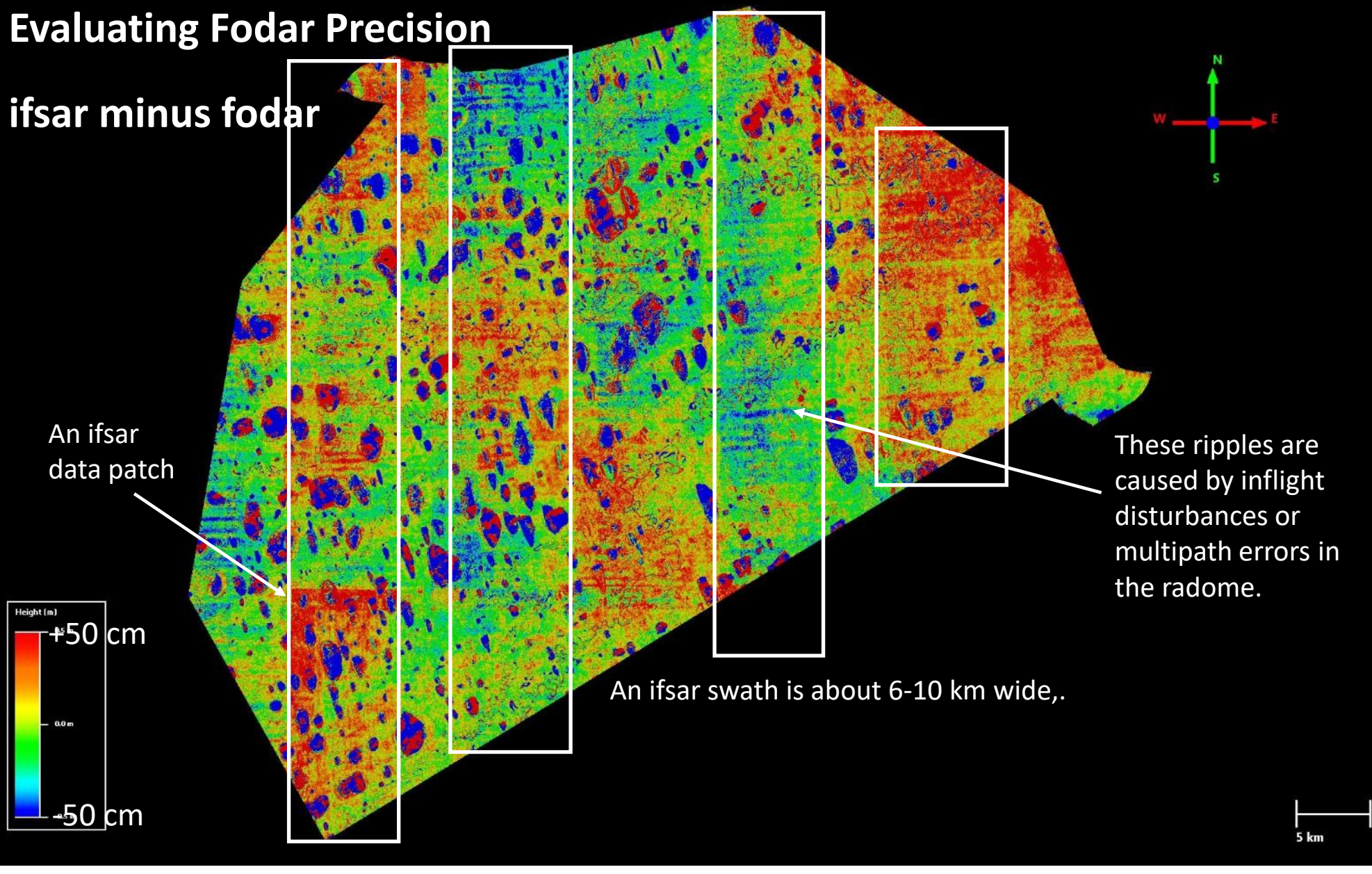
ifsar minus fodar



If both data products were perfect, there would be no color variations.

Evaluating Fodar Precision

ifsar minus fodar

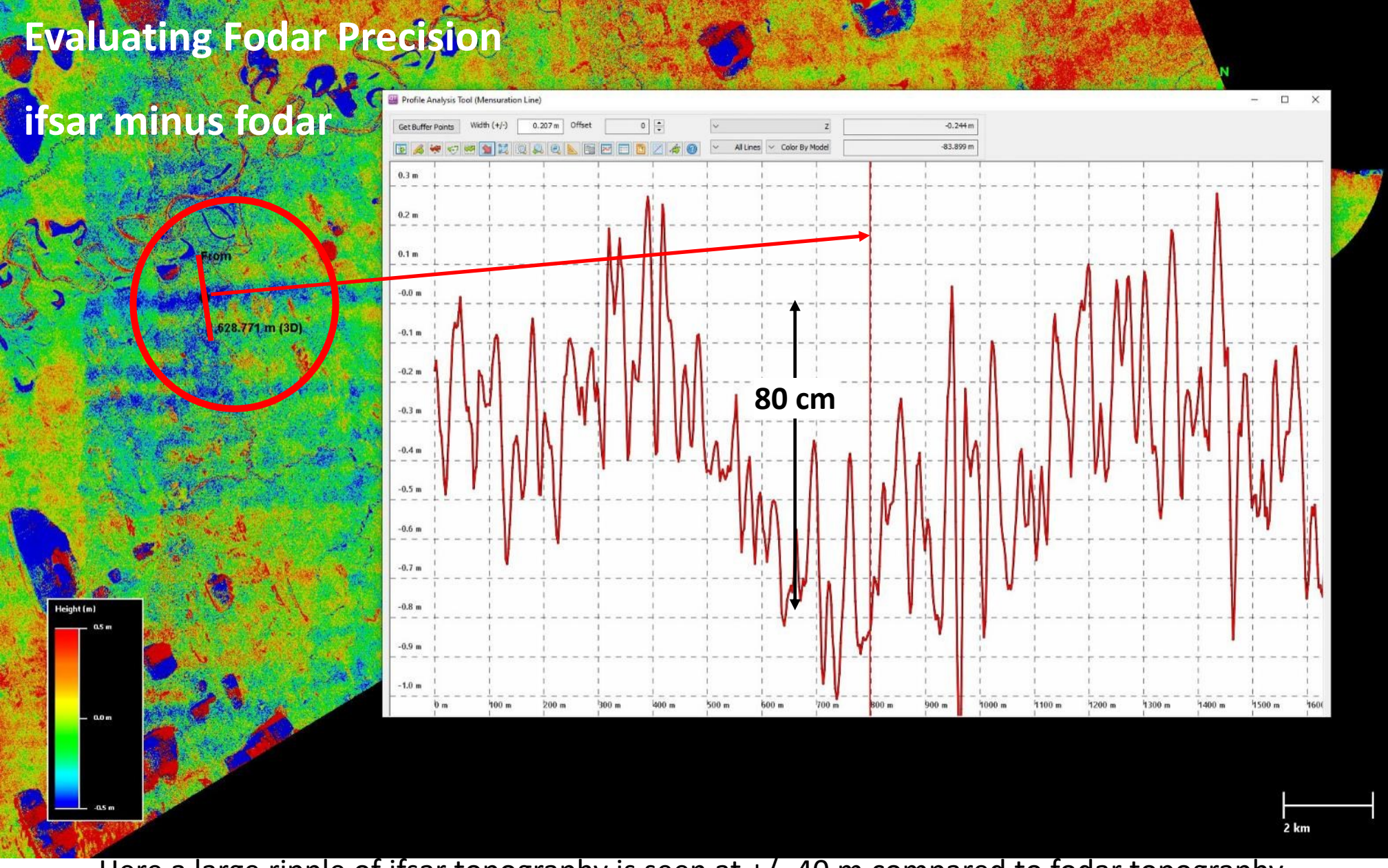


If both data products were perfect, there would be no color variations.
Nearly all of the color variation here is due to errors in the IfSAR.

These IfSAR artifacts could only be revealed if the fodar was substantially more precise.

Evaluating Fodar Precision

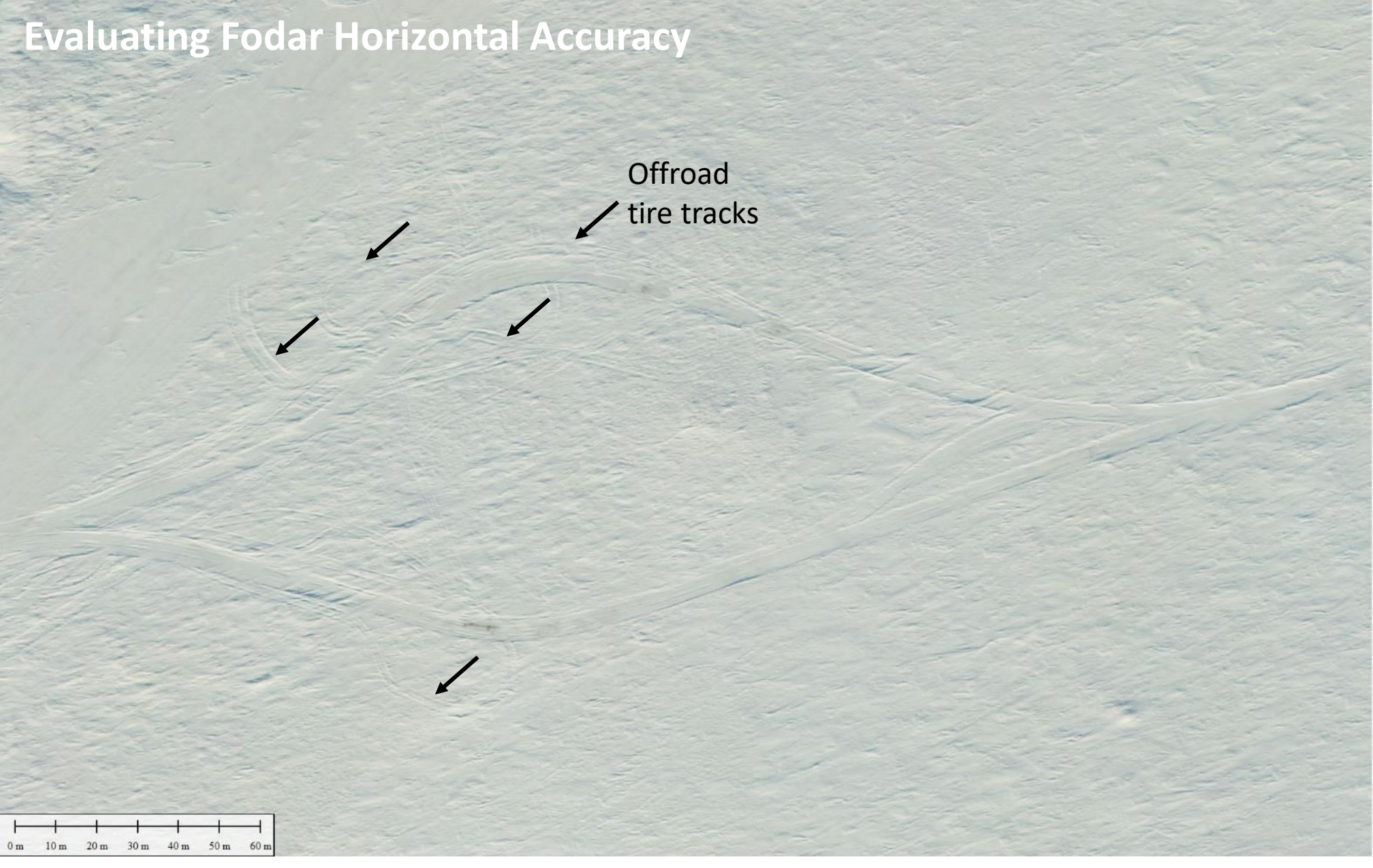
ifsar minus fodar



Here a large ripple of ifsar topography is seen at +/- 40 m compared to fodar topography, and ripples much smaller than this are clearly seen in the imagery.

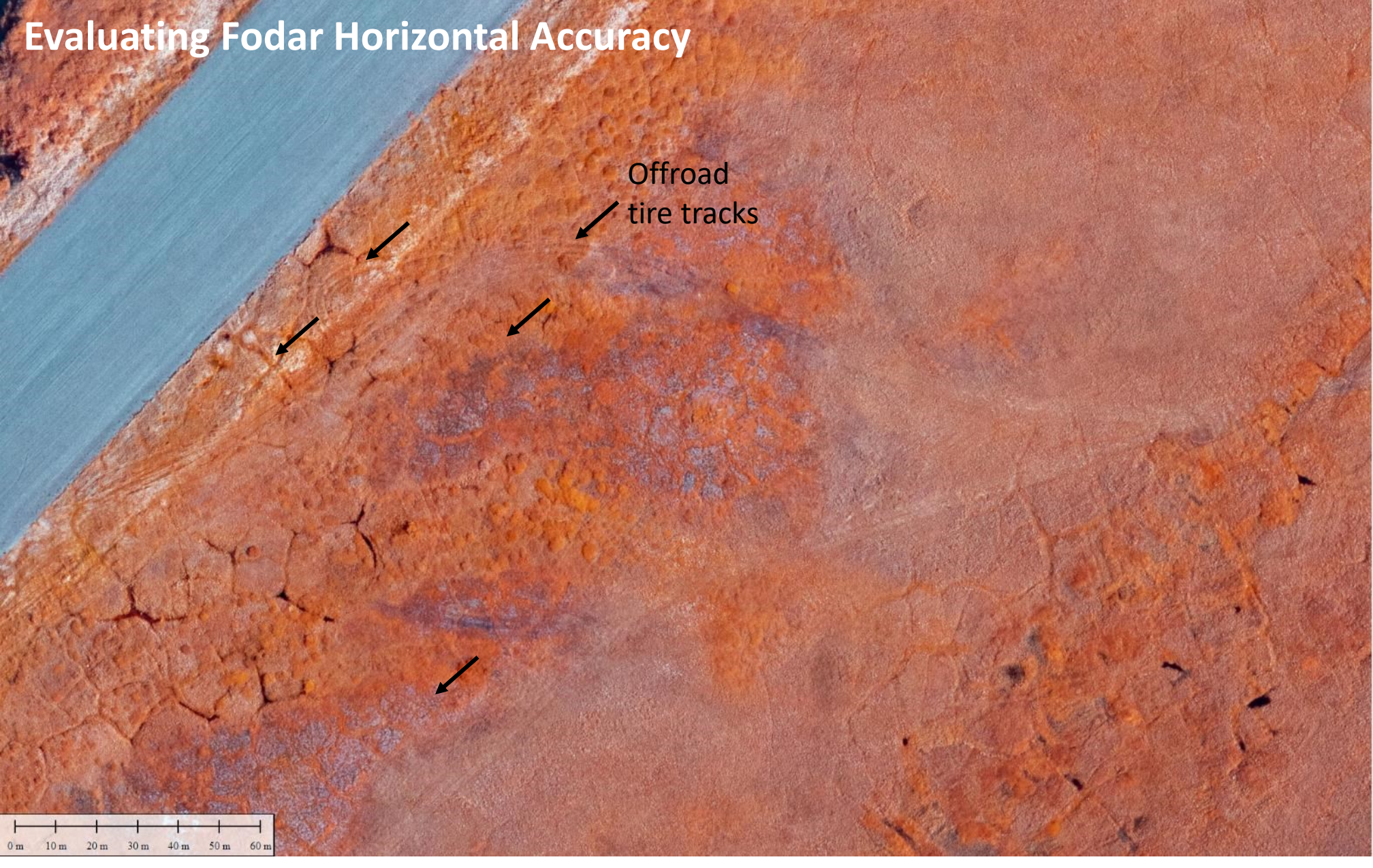
Fodar topography therefore must have a precision substantially better than +/- 40 cm. Nearly all of our studies have found fodar precision to be 8-12 cm std.

Evaluating Fodar Horizontal Accuracy



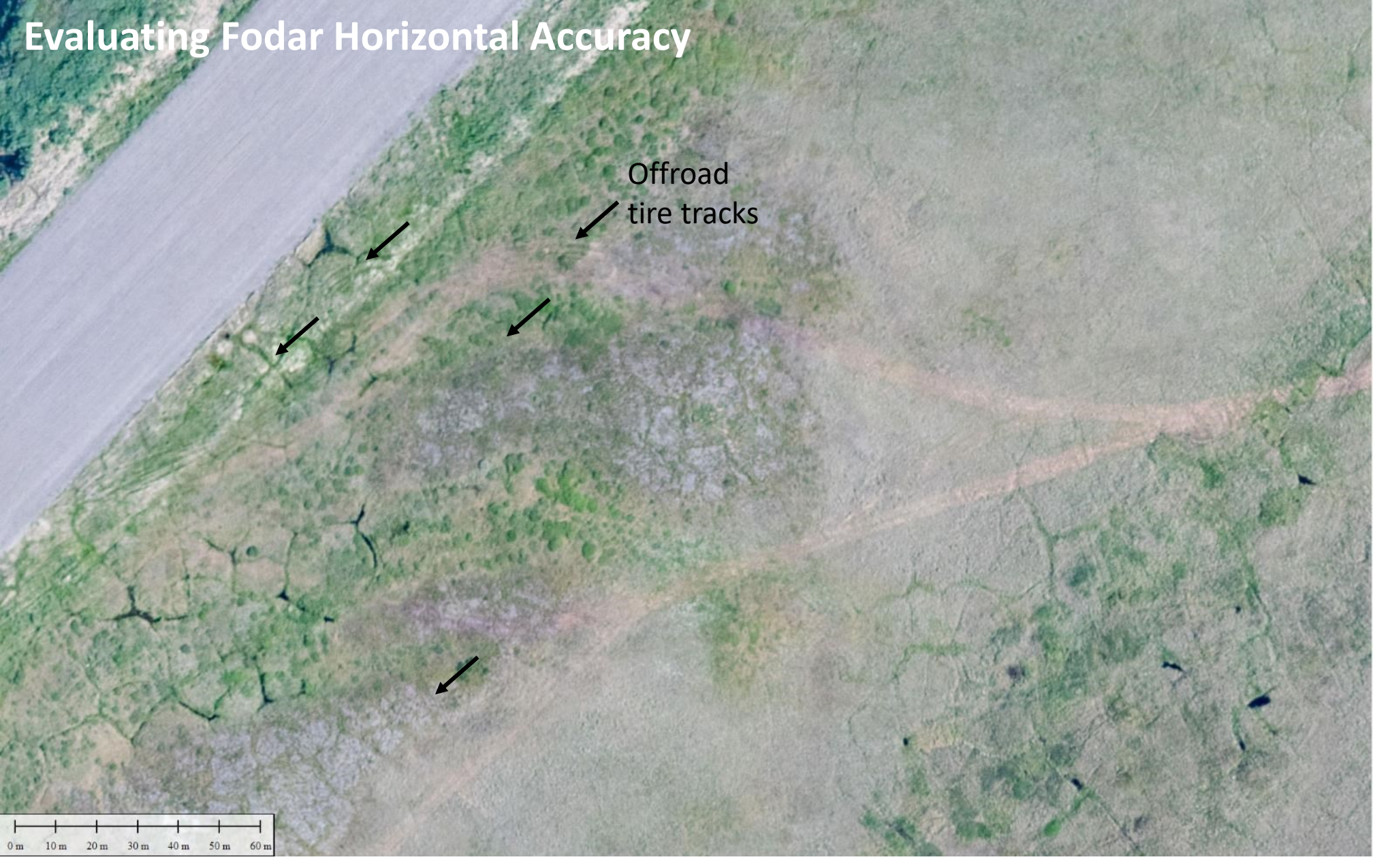
Horizontal alignment between summer and winter maps is essentially perfect.

Evaluating Fodar Horizontal Accuracy



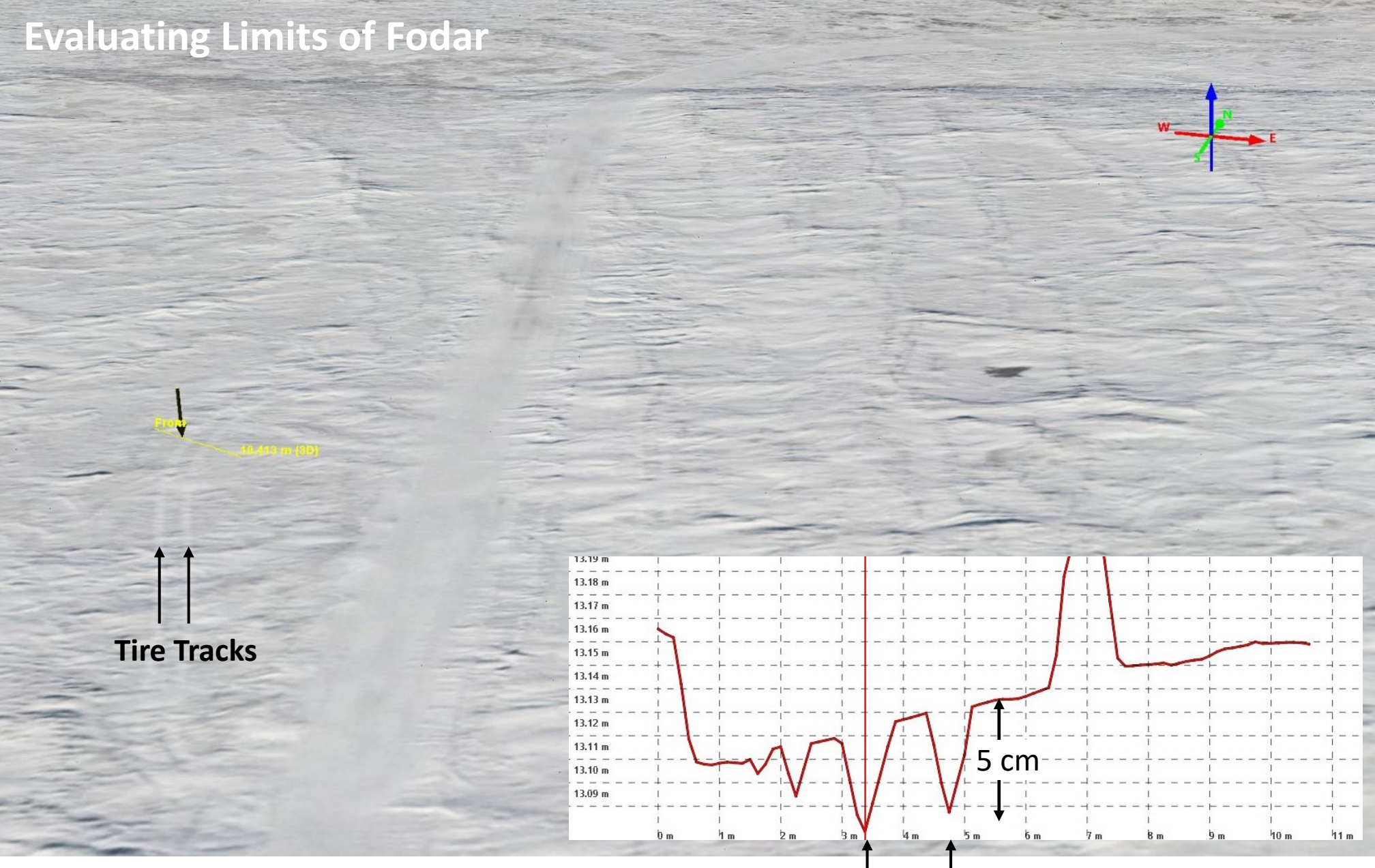
Horizontal alignment between summer and winter maps is essentially perfect.

Evaluating Fodar Horizontal Accuracy



Horizontal alignment between summer and winter maps is essentially perfect.

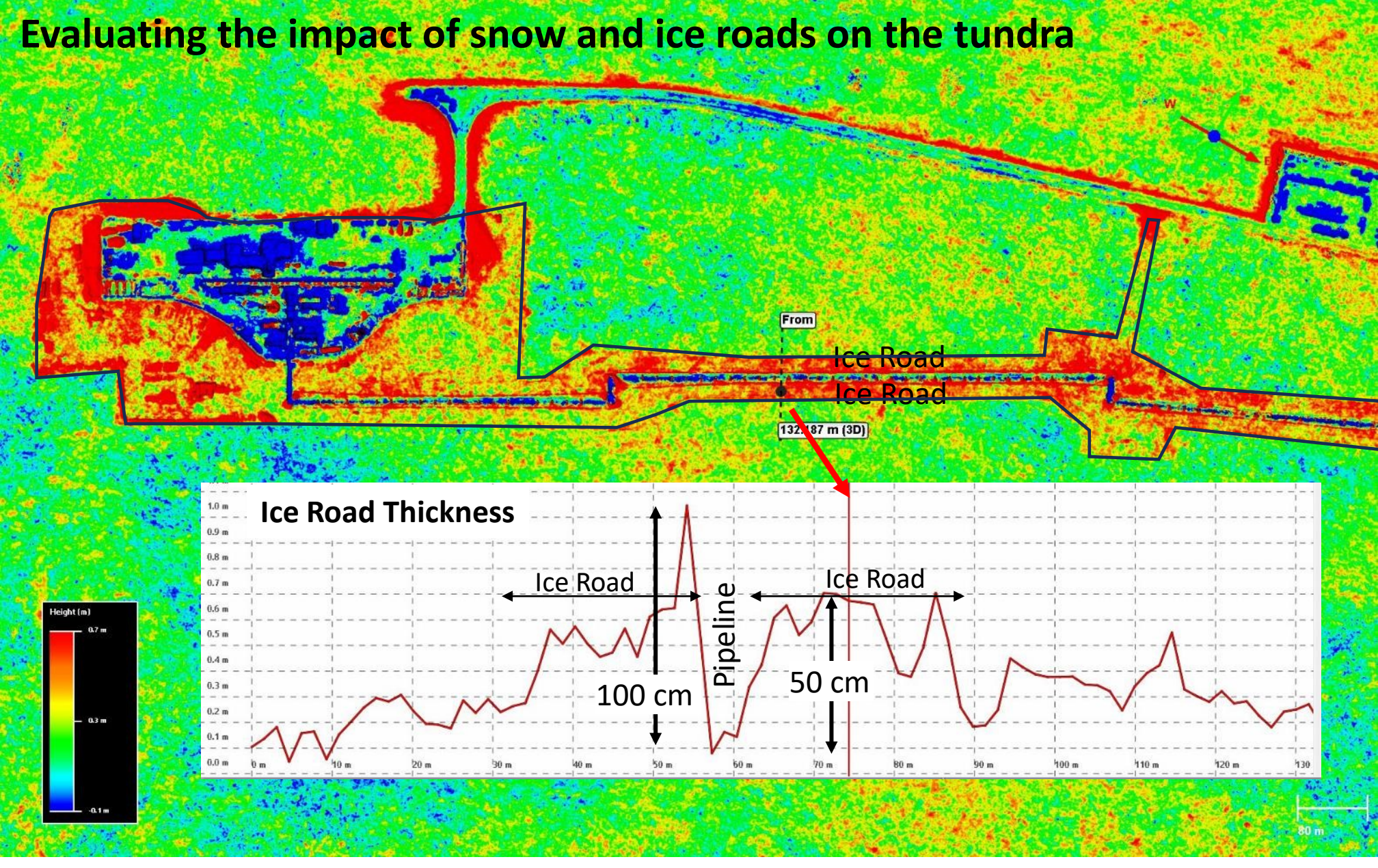
Evaluating Limits of Fodar



Evaluating the impact of snow and ice roads on the tundra

A pipeline was being built during my acquisitions,
with ice roads surrounding the pipeline corridor and pad (black line).

Evaluating the impact of snow and ice roads on the tundra



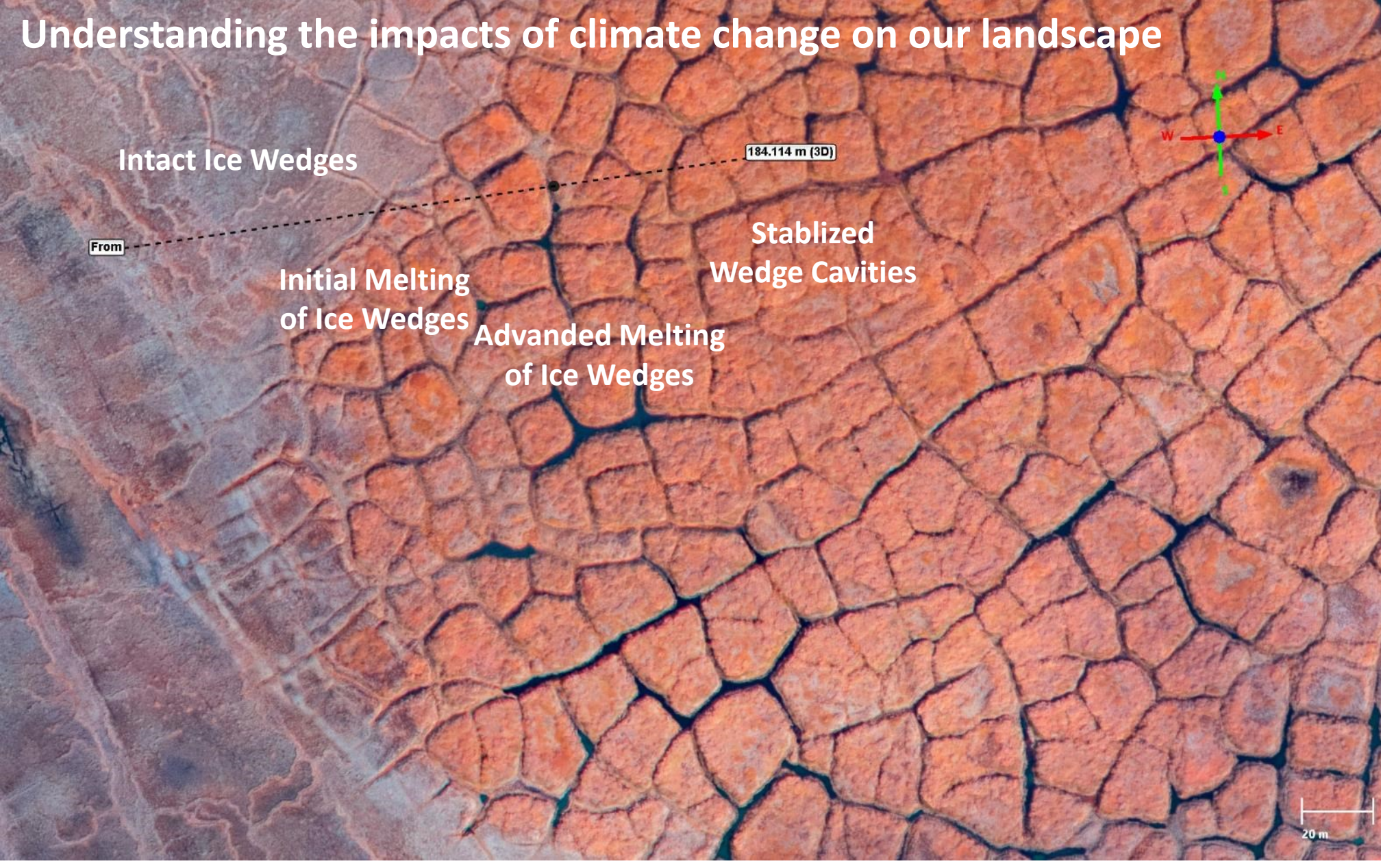
Now we can study the impacts of snow/ice roads on the tundra as a function of snow/ice thickness.

Evaluating the impact of snow and ice roads on the tundra

Snow and ice roads clearly have a lasting impact on the tundra.

Understanding the correlation between snow/ice road thickness and these impacts will presumably improve protocols and best practices in the future.

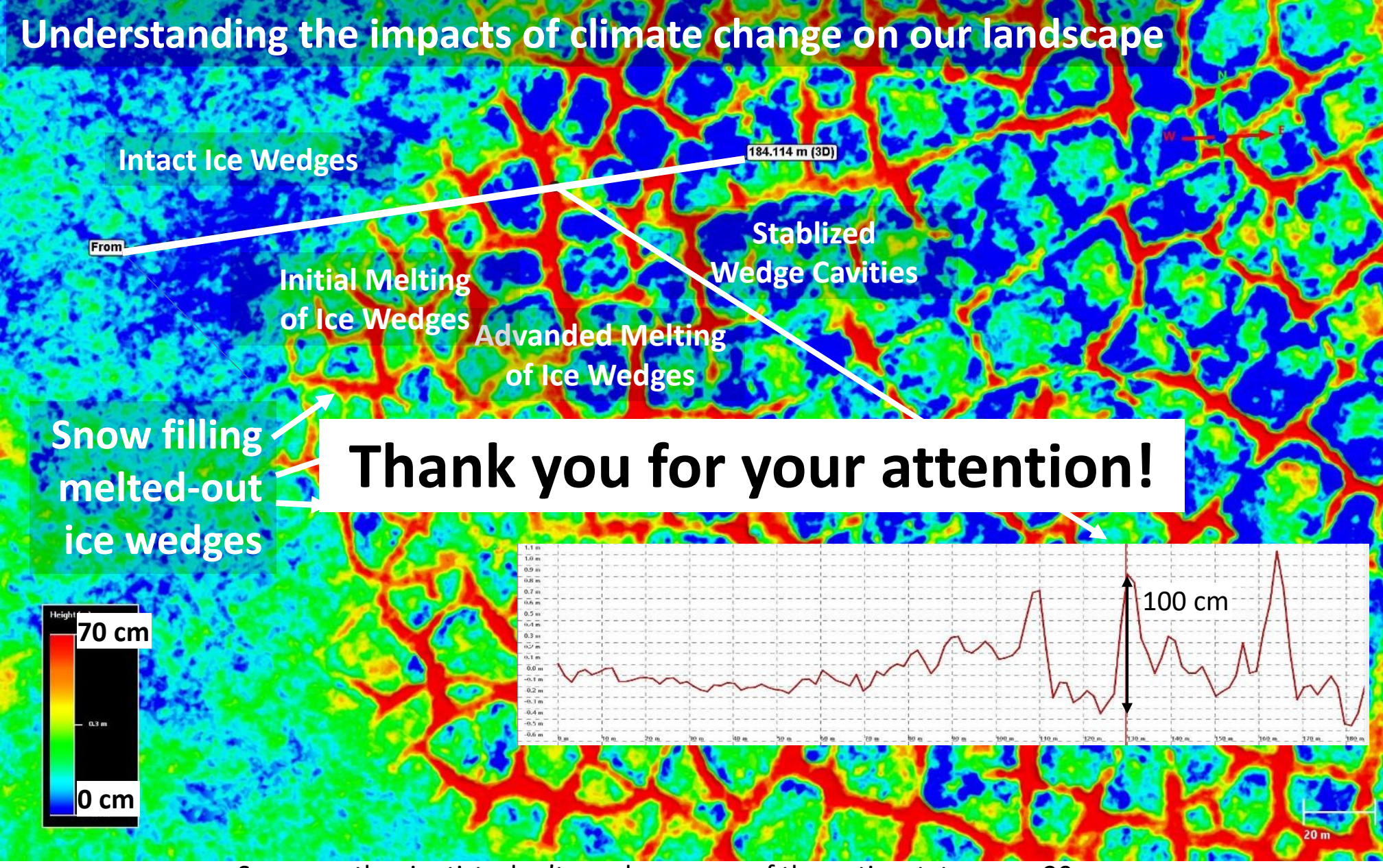
Understanding the impacts of climate change on our landscape



Here ice wedges surrounding polygons are in various stages of decay due to climate warming.

We cannot understand the **processes** of change without **measurements** of change on the **spatial** and **temporal** scales that they occur.

Understanding the impacts of climate change on our landscape



So we earth scientists don't need one map of the entire state every 20 years,
we need excellent maps of tens of thousands of square kilometers
***annually* or *seasonally at the spatial scale that these processes occur*.**

Such time-series are possible and affordable – I've been making them on my own for more than a decade, but in terms of advocating this need/solution it's been like bringing a knife to a gunfight in the Wild West I work in...