# Using High-Resolution Satellite Imagery and Ground Penetrating Radar to Avoid Crevasses Along the Greenland Inland Traverse (GrIT) Route

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# Greenland Inland Traverse (GrIT)


~ 740 miles

Fuel and Cargo resupply from deep water ports to inland stations

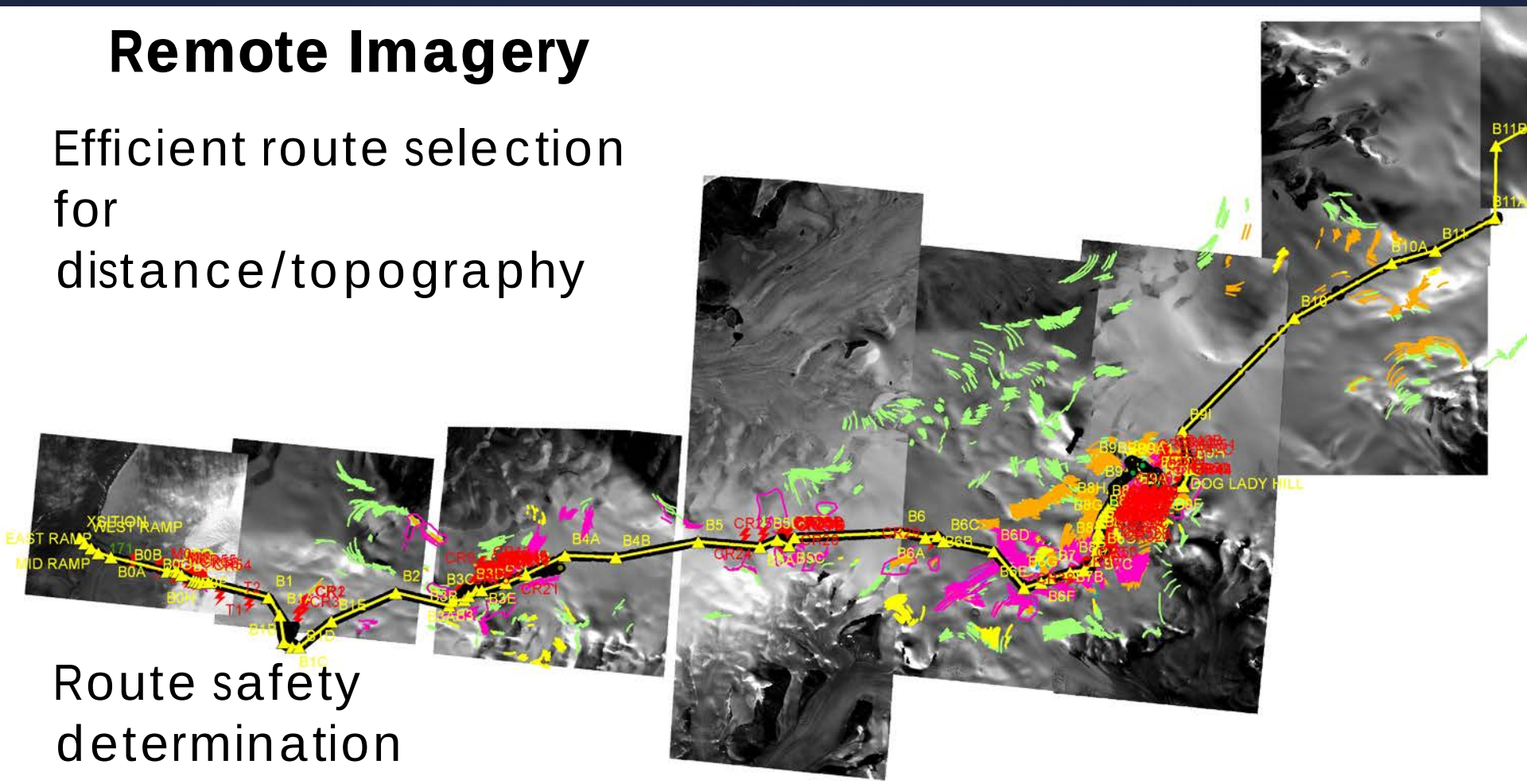
First ~70 miles heavily crevassed (with lots of terrain features)

Greenland Crevasse Bridges Are Assumed to be Weak, So Any With Widths Exceeding our Criteria Must Be Avoided

-Criteria follows rule of crossing open cracks (1/3 of effective track length)

# Remote Imagery

Efficient route selection for distance/topography



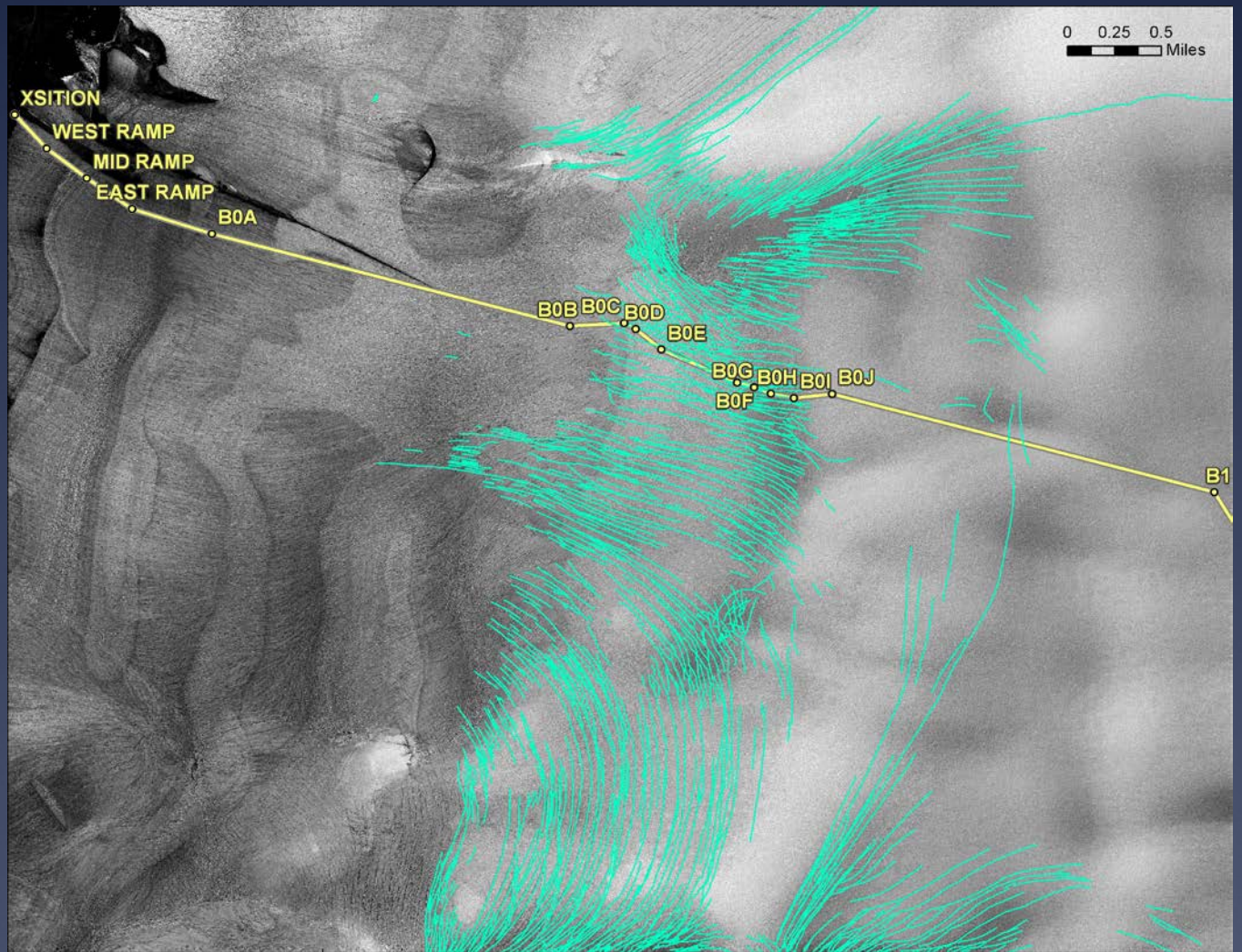

Route safety determination (Crevasse Detection)

# 2-STEP PROCESS

STEP 1:

-Using 0.5 or 1.0 M Resolution Imagery, Digitize all Crevasses (Tedious Process-Takes Time)

-Compare Previous Route and Identify New Challenges/Route Deviations



# 2-STEP PROCESS

STEP 2:
-Using GPR and a Strategic Crevasse Avoidance Team, Ground-Truth and Install Route


*In Previous years, follow vehicle was a snow mobile

# WHAT IS A STRATEGIC CREVASSE AVOIDANCE TEAM?

# SCAT CAMP

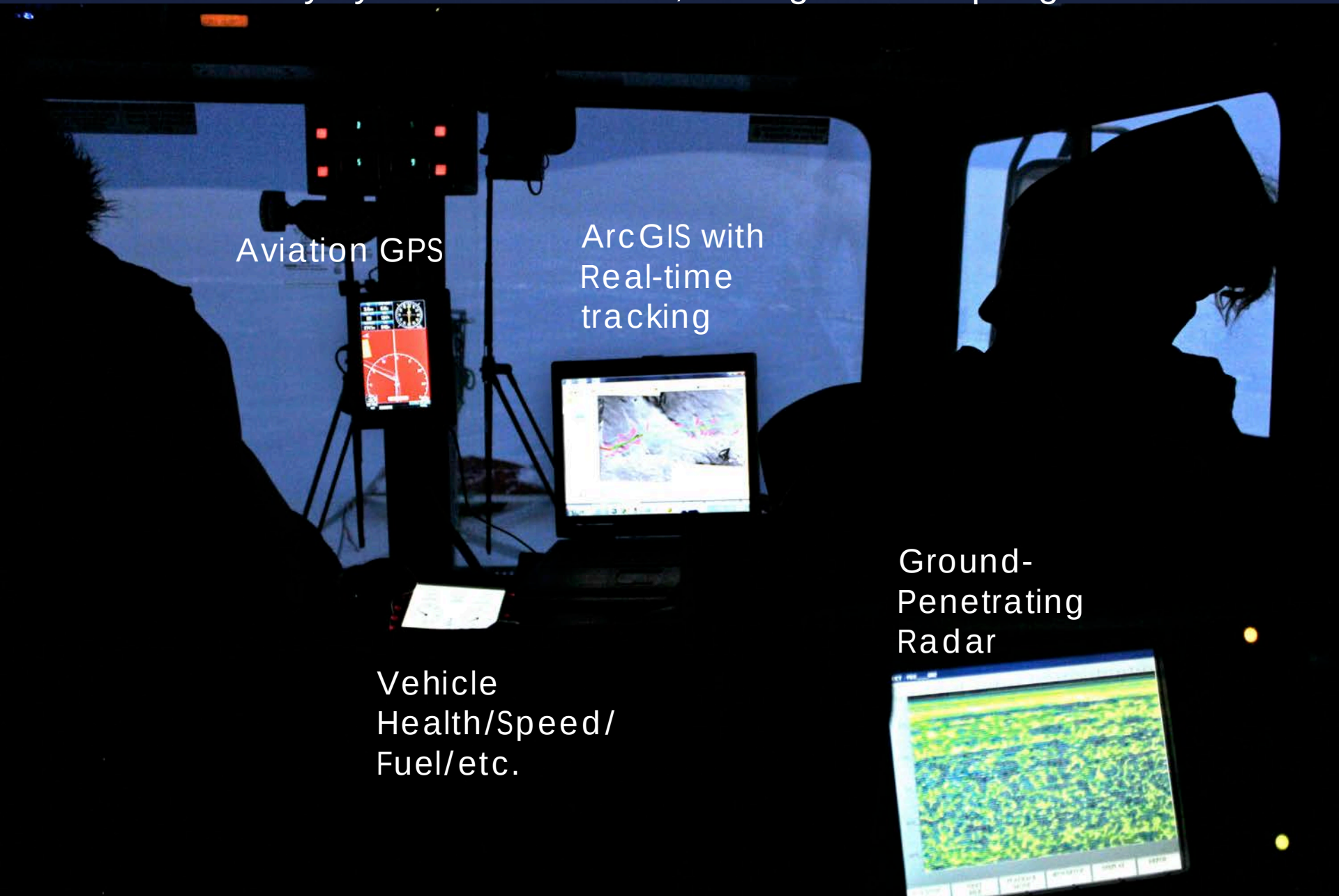
PREVIOUS YEARS: Slept in Tents (TEMPS ~ -30F)

# SCAT CAMP

THIS YEAR: Slept in Living Module (camper), TEMPS WERE -50F

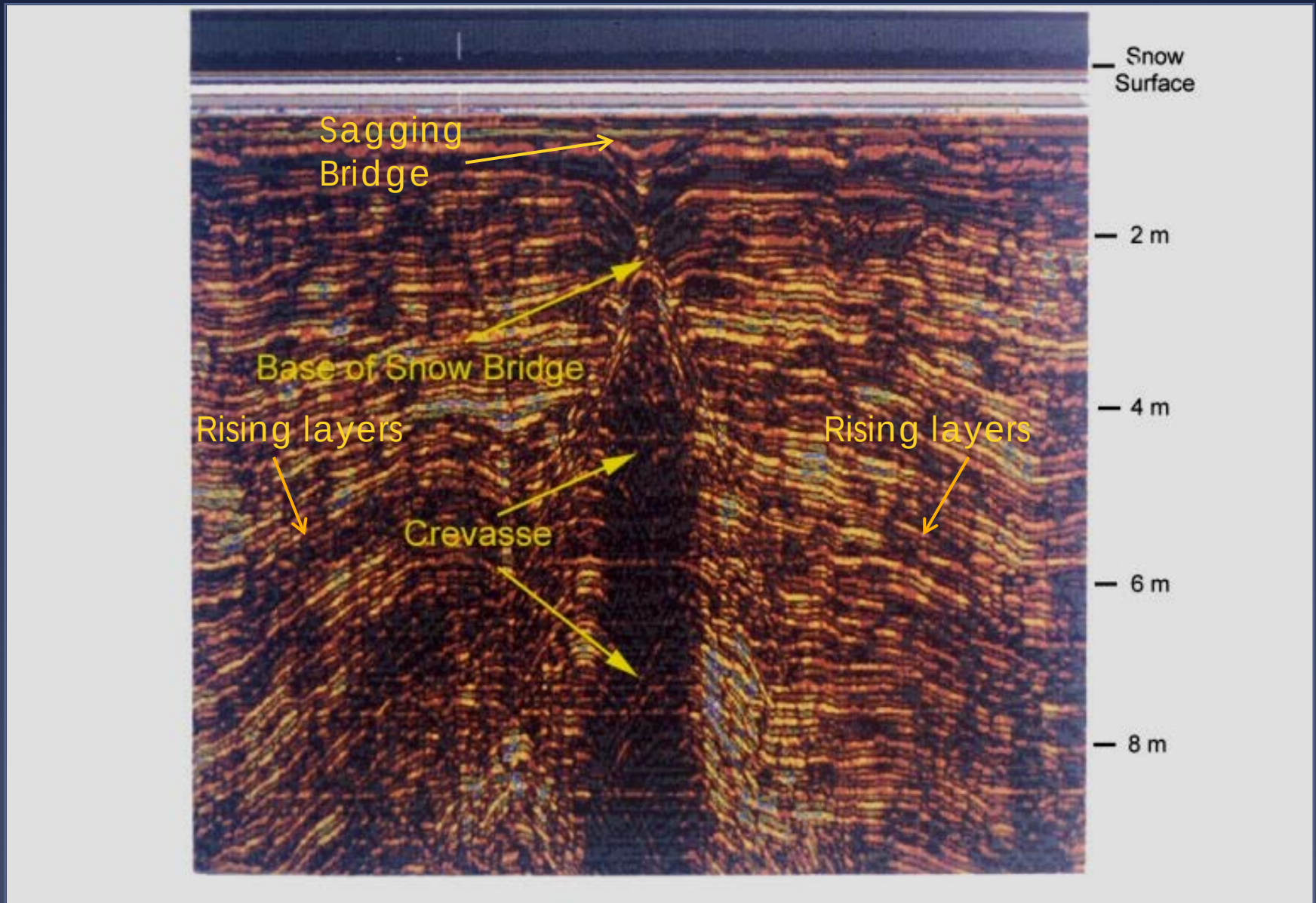
# LOTS OF LOGISTICAL CHALLENGES

# Multiple Instruments Monitored Simultaneously, Crevasses are not Visible by Eye on the Ground, During Winter/Spring



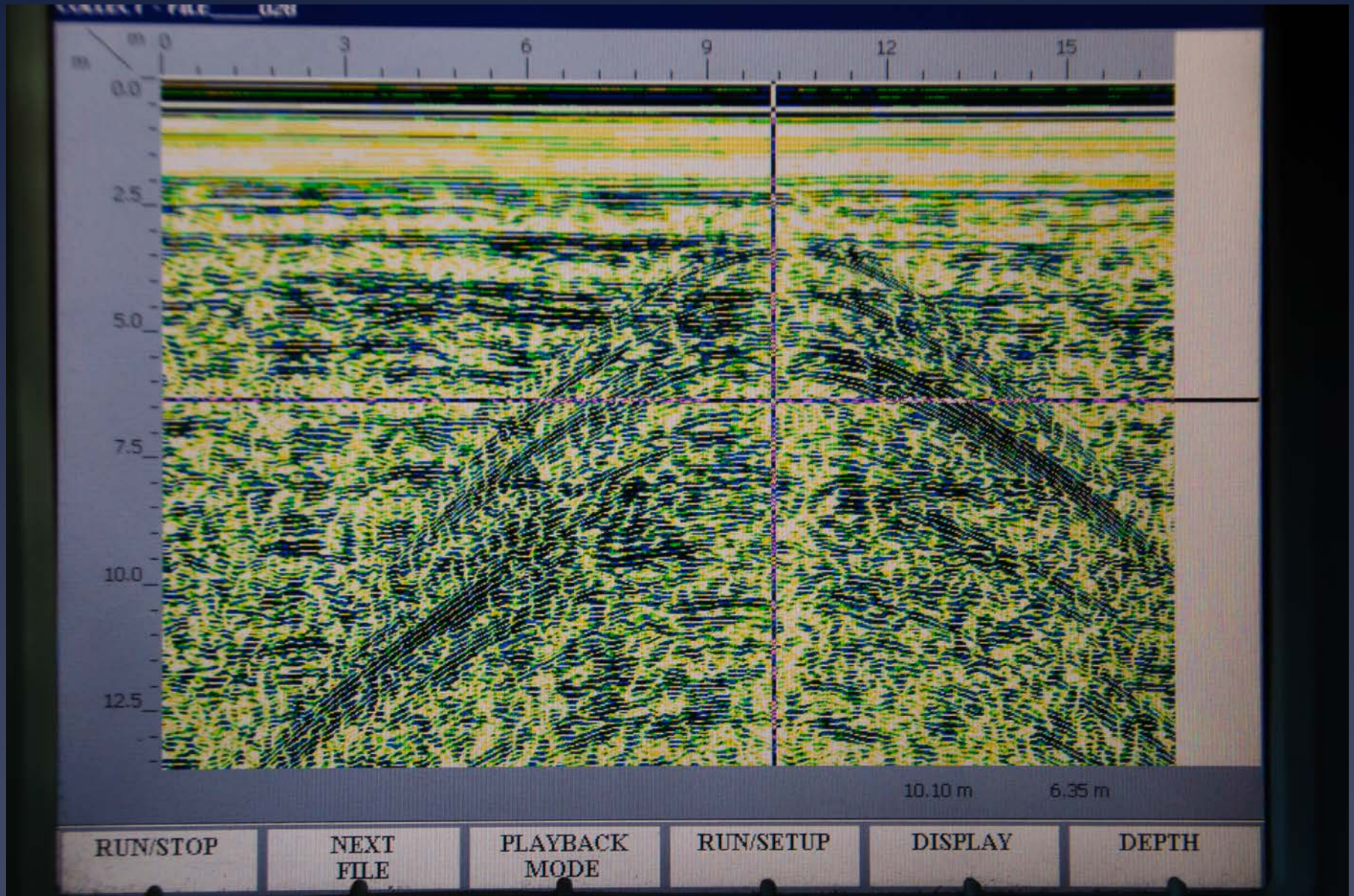
# GPR View of Crevasses

Antarctic Crevasse (clear void, clear bridge)



# GPR View of Crevasses

Arctic Crevasse (Obvious rising layers, less obvious voids, deep bridges)



# Aerial View of Crevasses in Late Summer

- Drifting fills sections of voids and then bridges the crevasse
- Crevasses are v-shaped, can have multiple bridges and extend tp depths of 30-50 feet

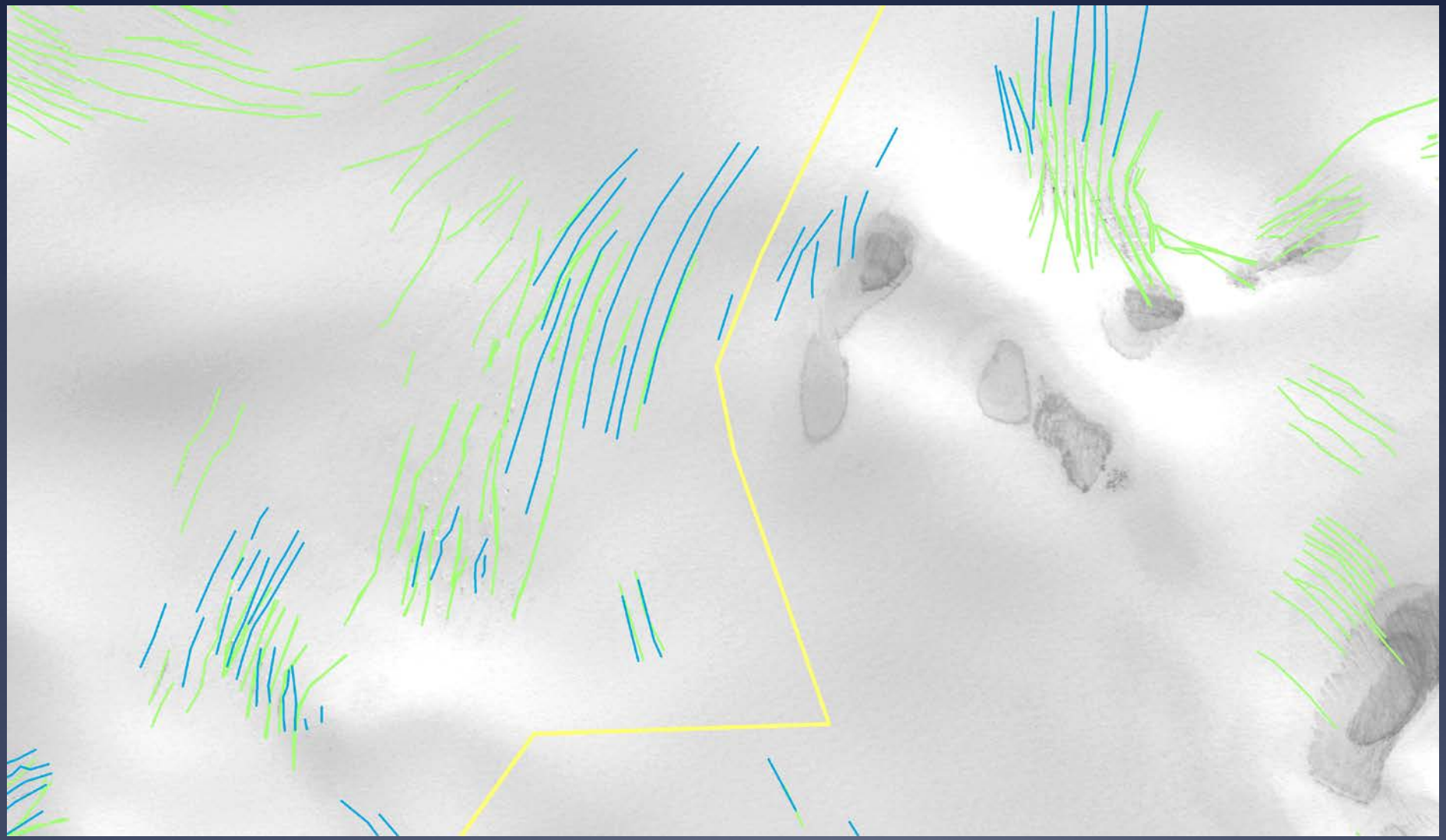
# Three Case Studies

- Crevasse Field #1
  - Only 1 mile from transition area, developed over past 4 years
- The ‘Needle’
  - 2 mile long section threaded between 2 parallel crevasses, 300 feet wide at entrance, 160 feet wide at exit
- The ‘Bear Claw’
  - Area where 2 crevasse fields have joined together and are encroaching on a third crevasse field

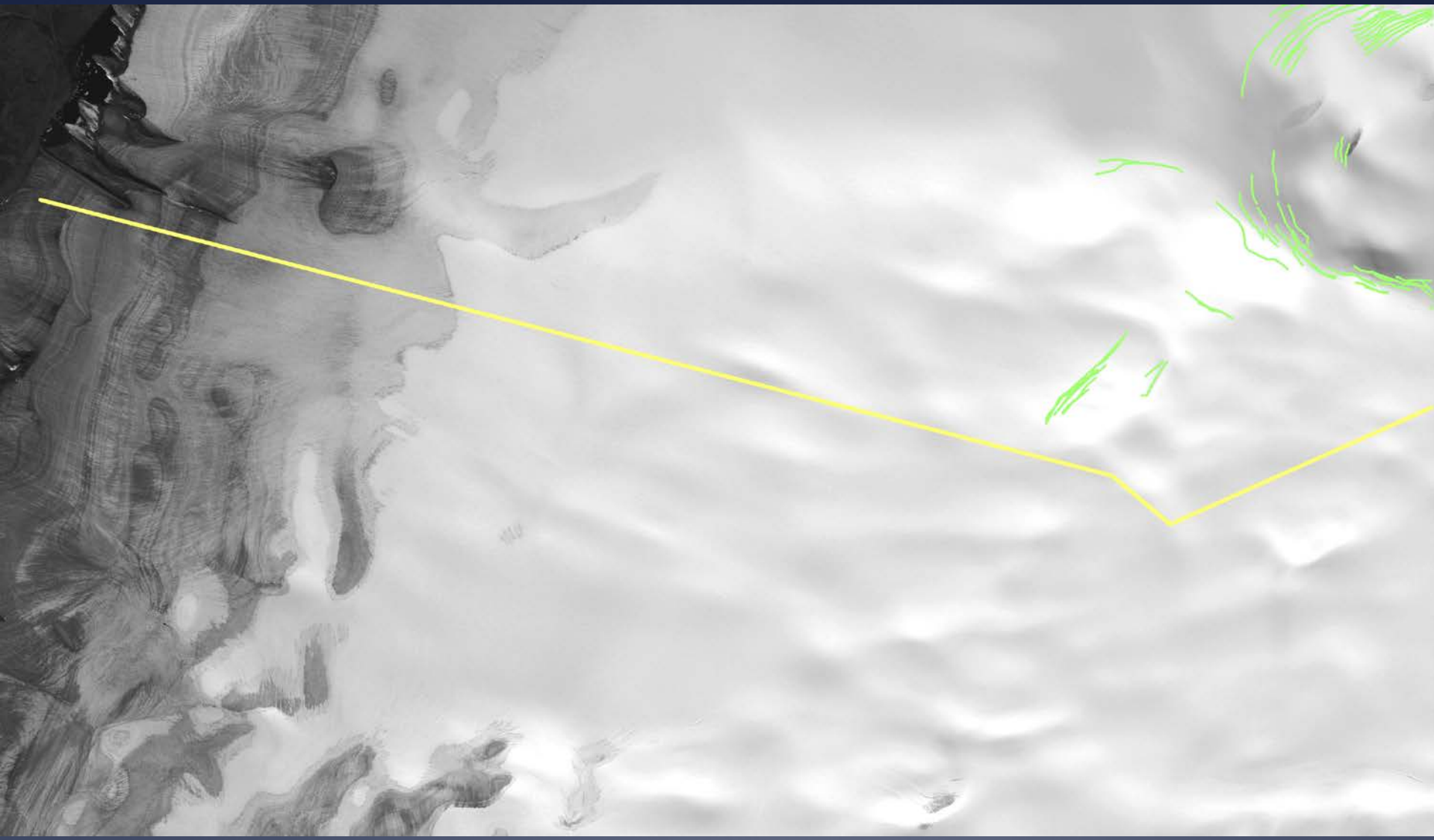
FIRST YEAR OF GRIT (08):

5.0 M Resolution Imagery from Previous summer was used

SCAT Ground-truthing was time-consuming, but not intimidating as there were also less crevasses “Ignorance was Bliss-we just drove around all over out here”-SCAT founding member

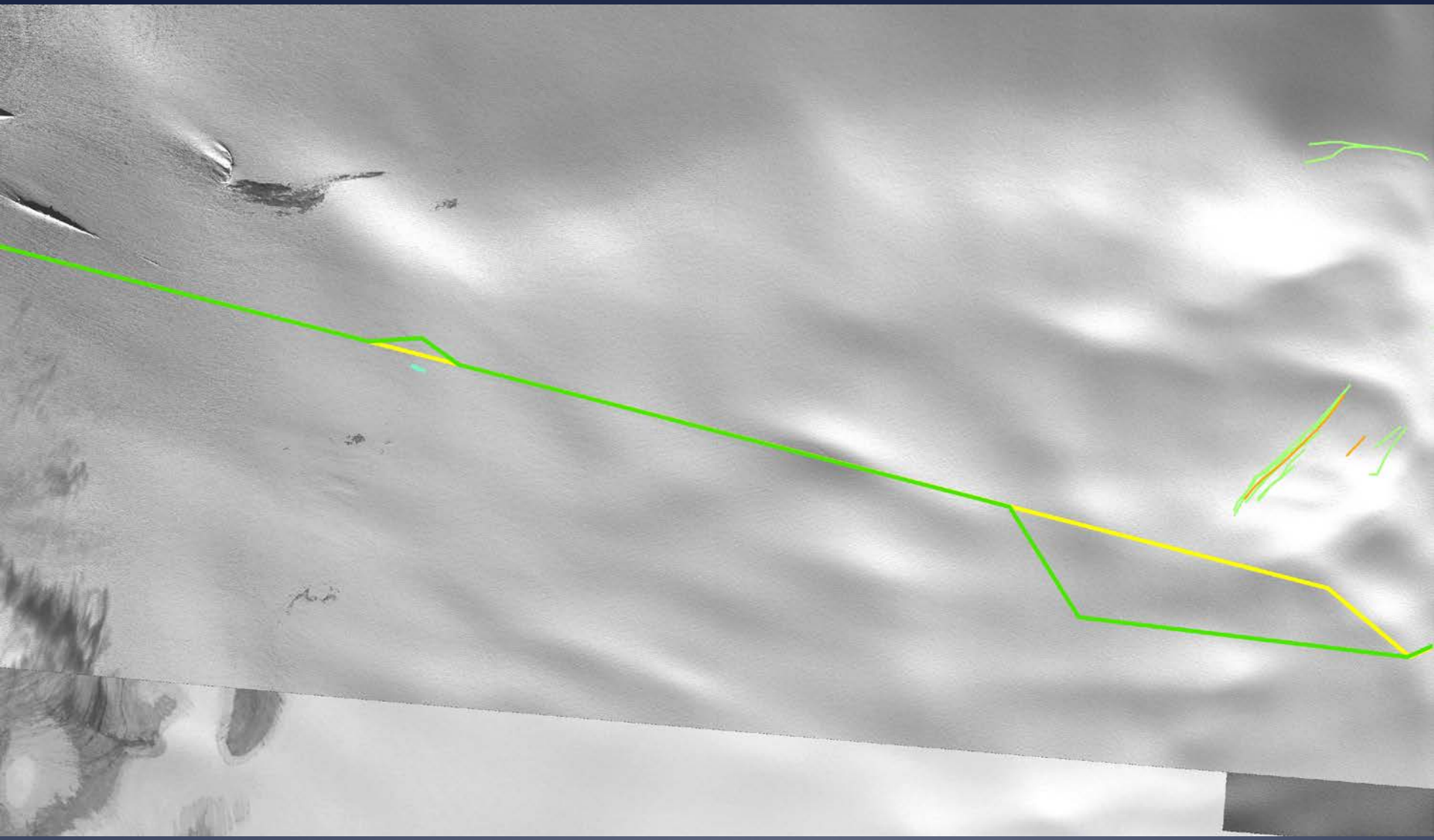


# IN 2009, No Traverse, But Operation on Ice Sheet *FOUND* New Crevasses in Two Locations



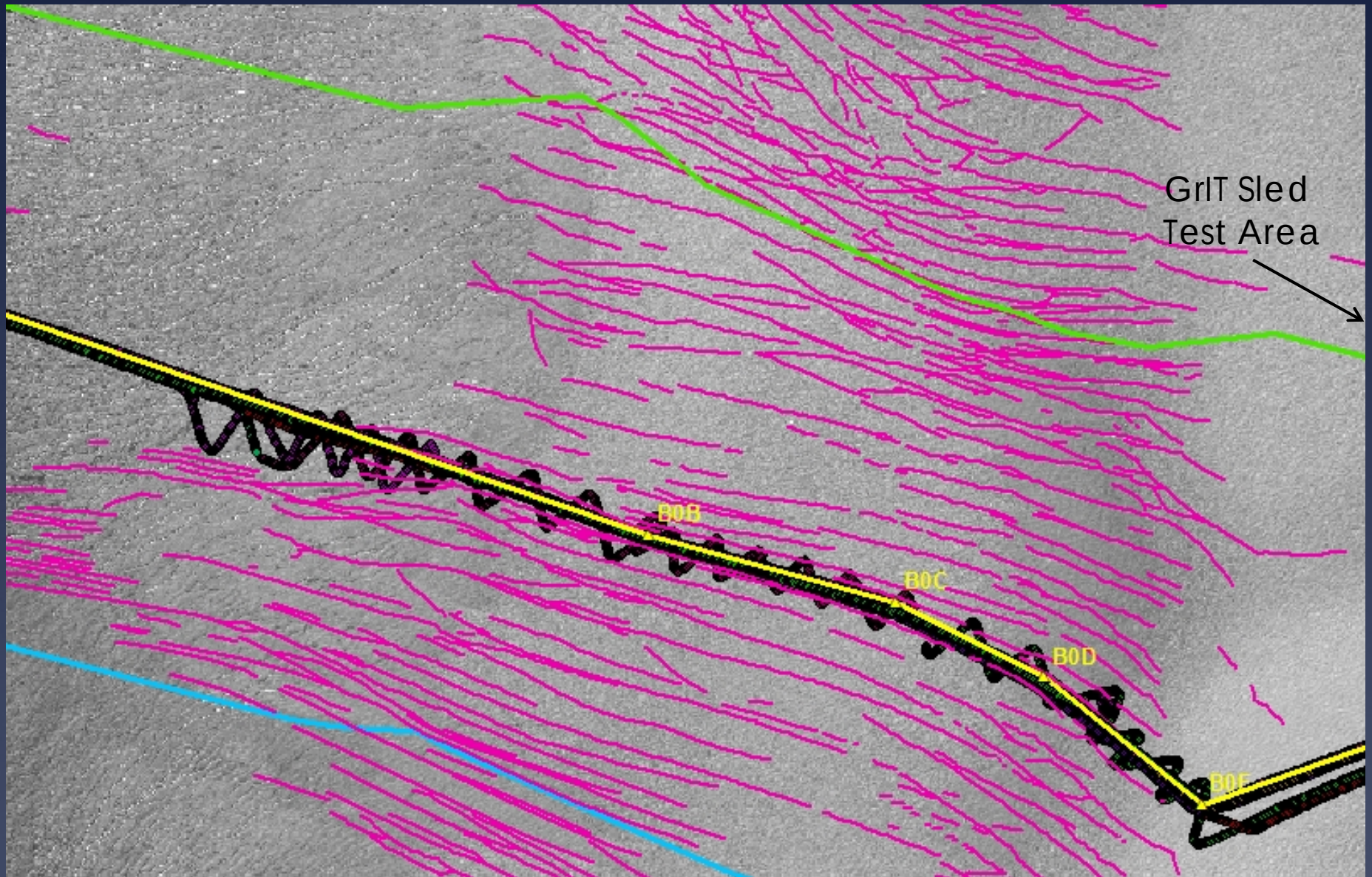
2010, New crevasses not yet visible in 0.5 m resolution imagery, but evident in GPR scans

Why not visible? Sizes were at threshold of imagery resolution

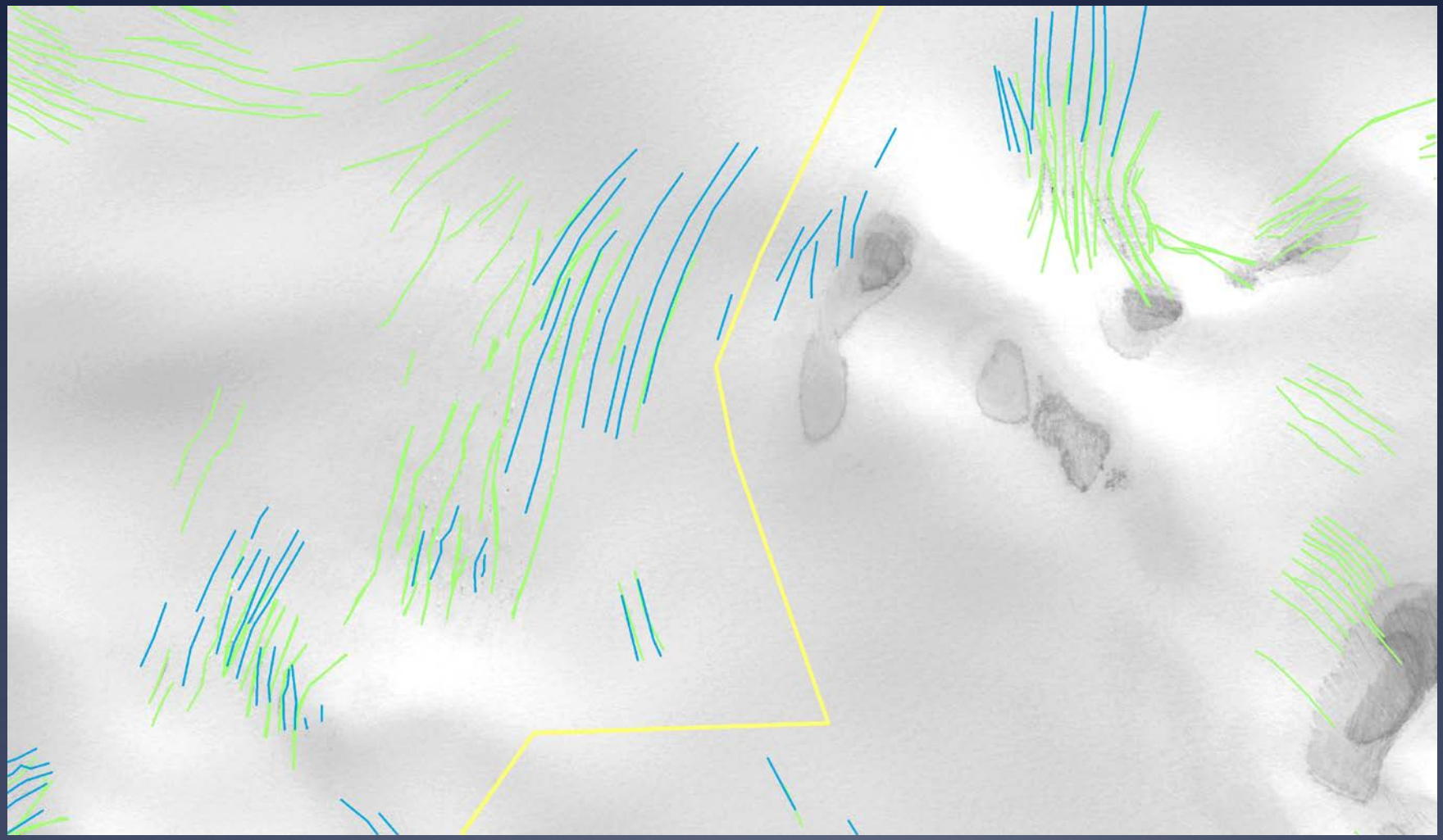


2012

Area has significantly degraded over 4 years, crevasses now large enough to be seen in imagery

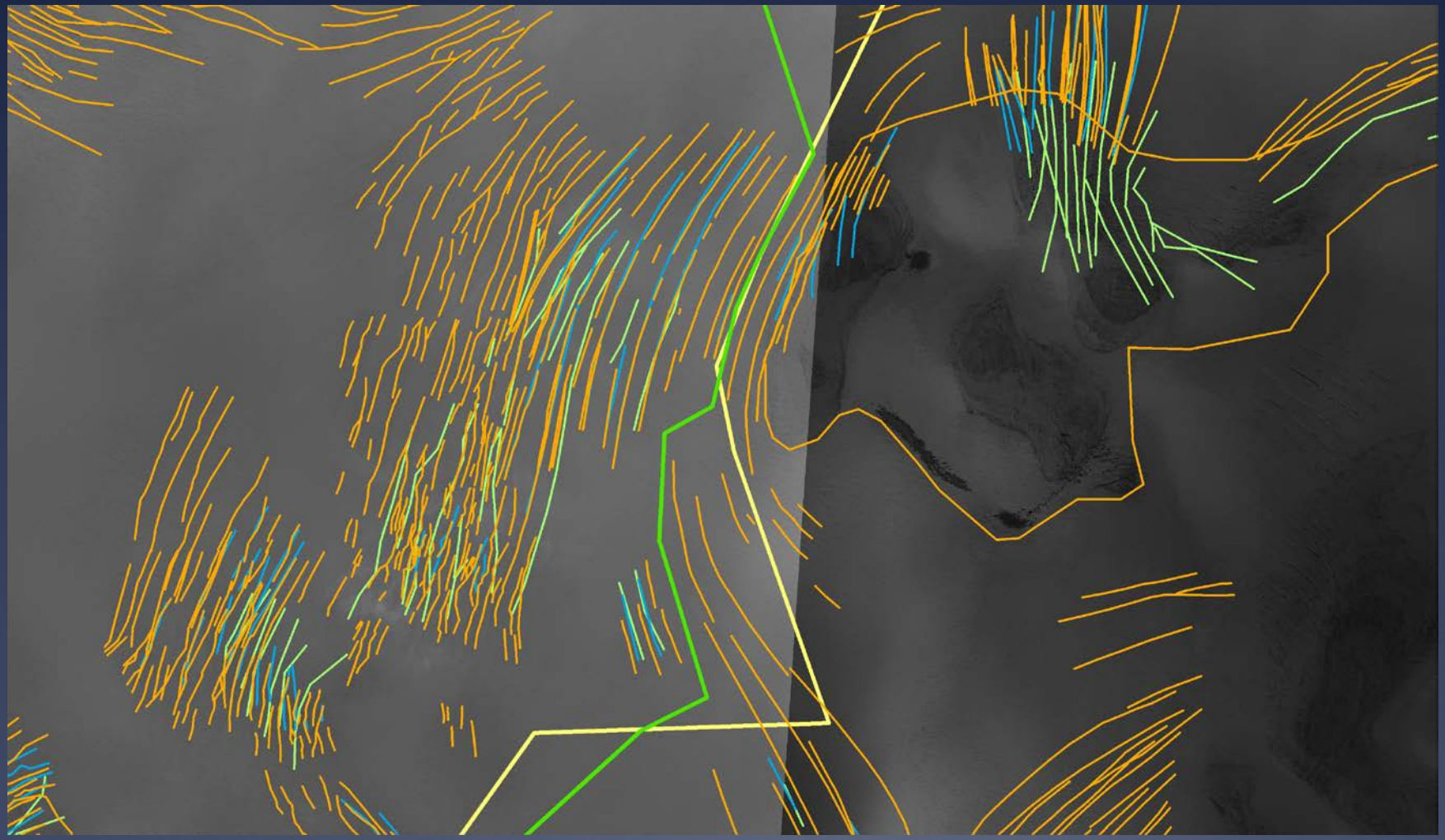


2008
The Needle



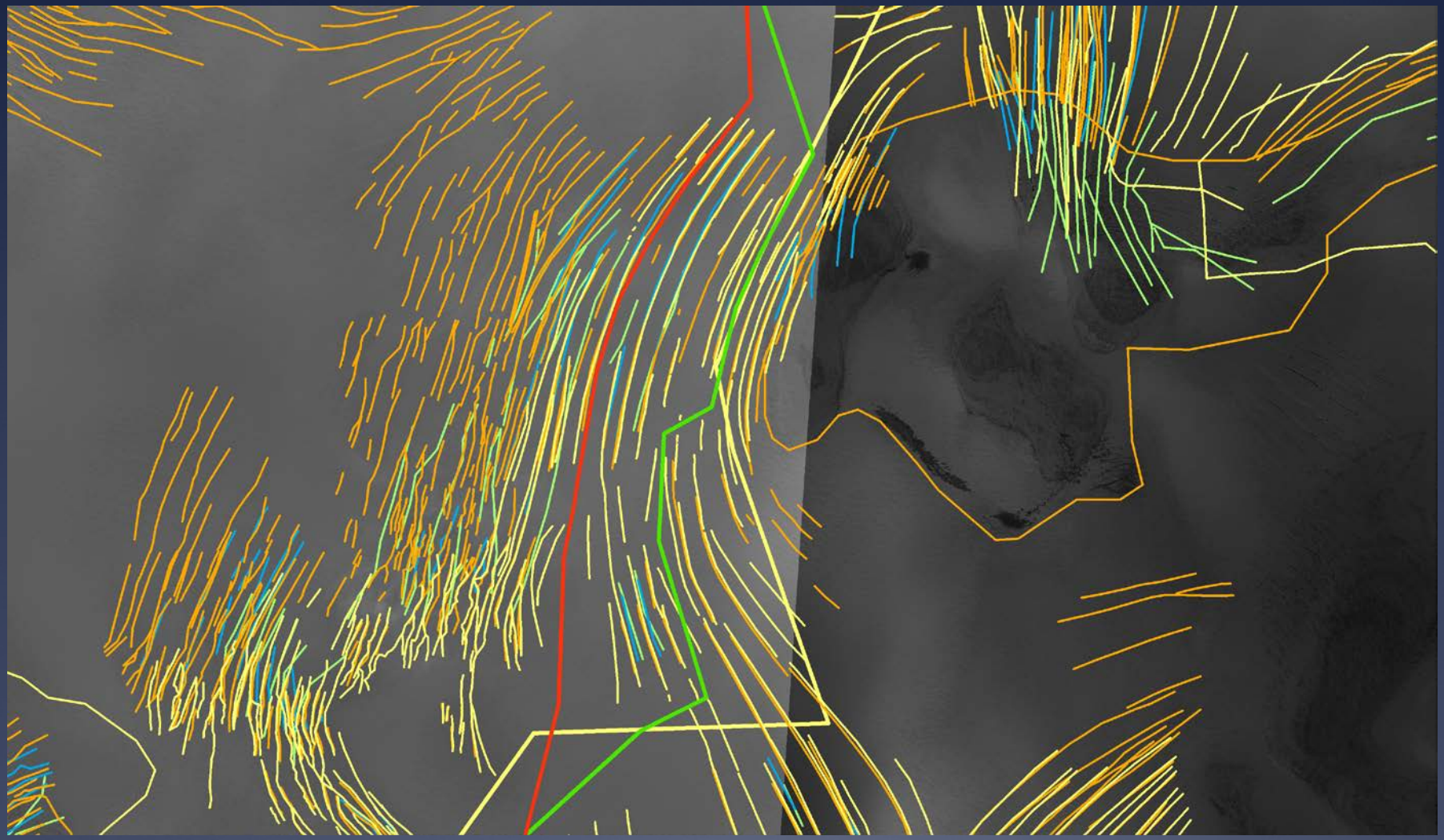
2010

The Needle-0.5m imagery showed many additional crevasses



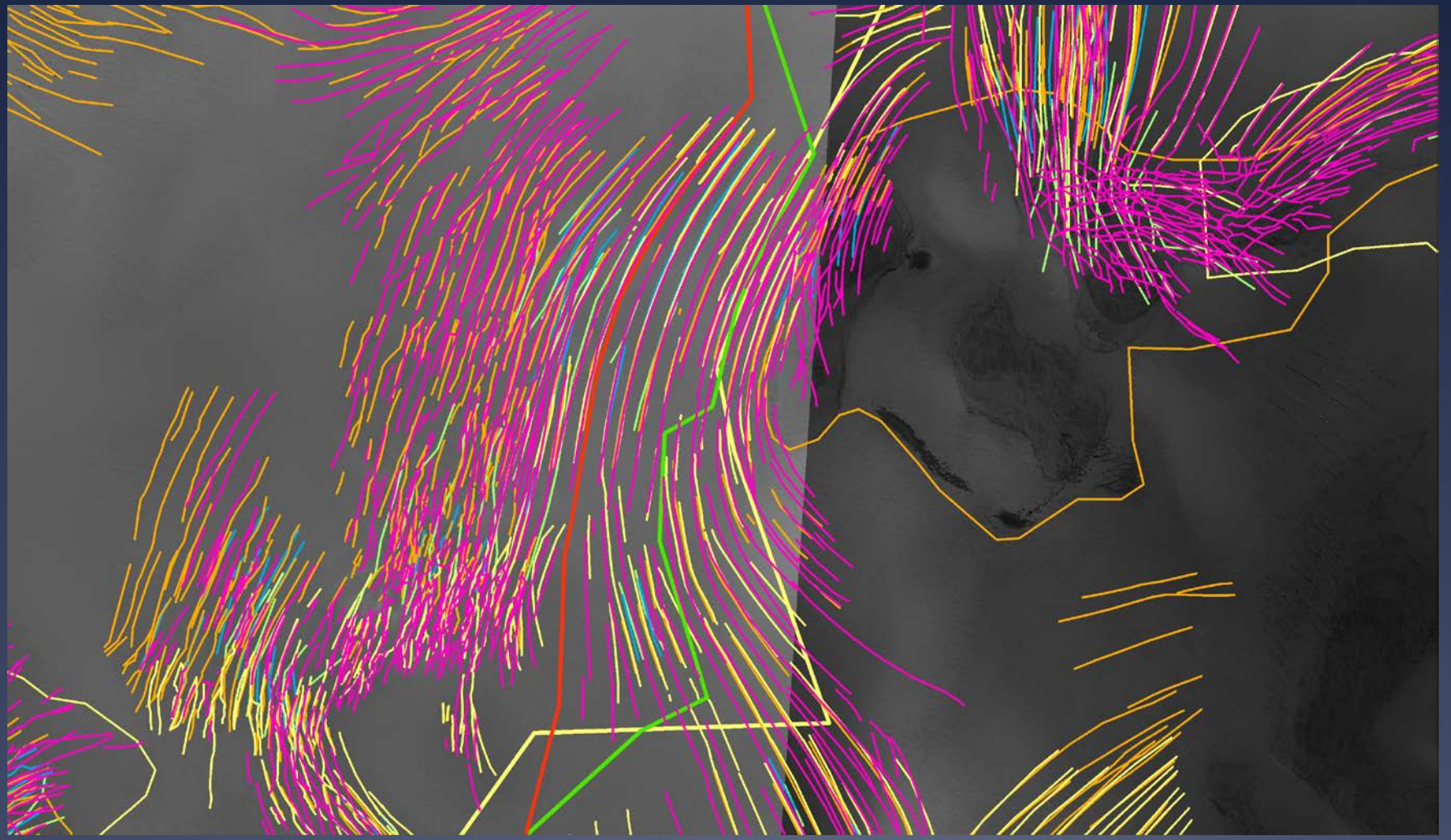
2011

The Needle-Previous area inaccessible (crevasses too wide), moved to the west



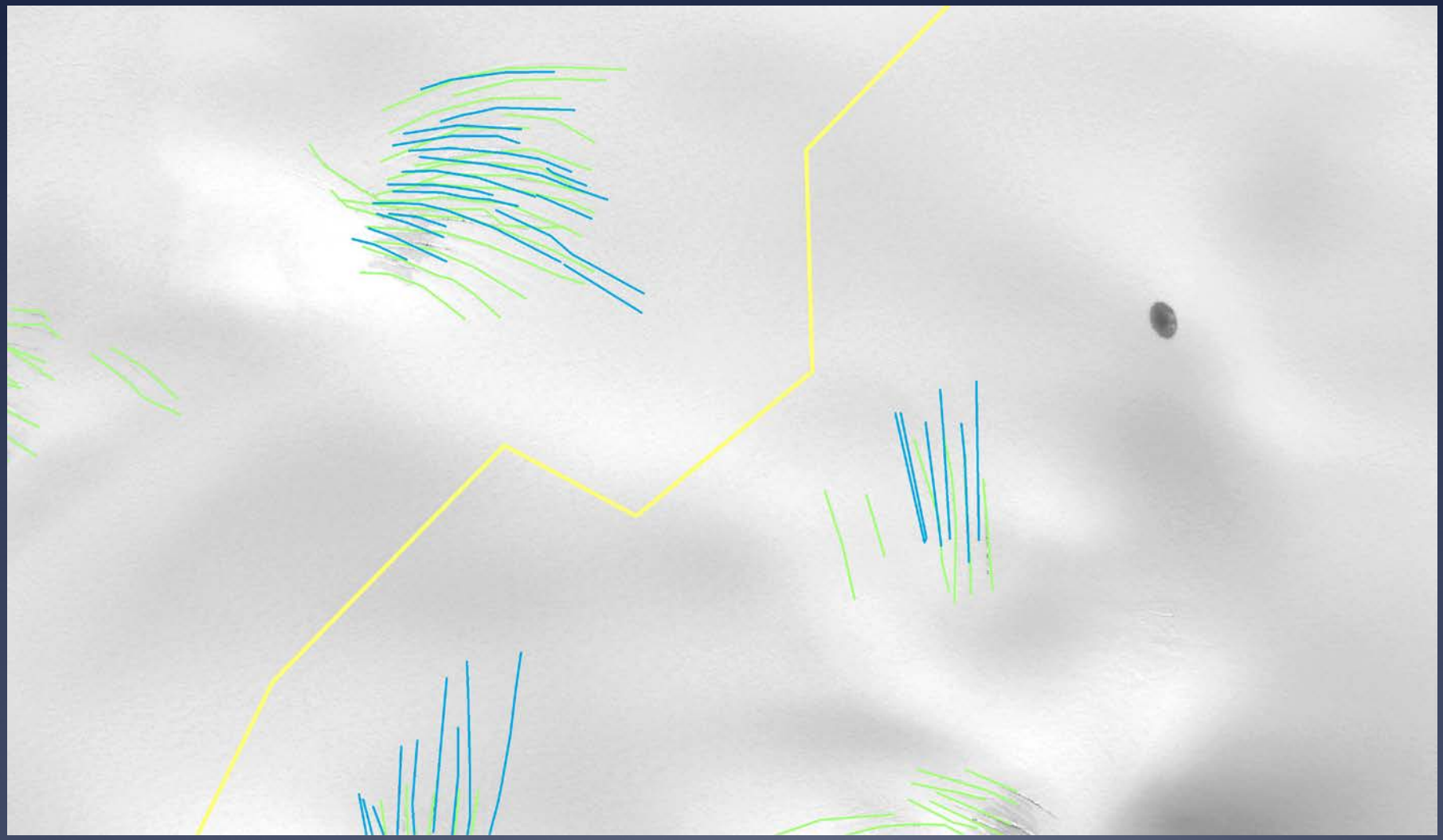
2012

The Needle-New location is still viable, but a center crack is forming, narrowing passage to 60ft.



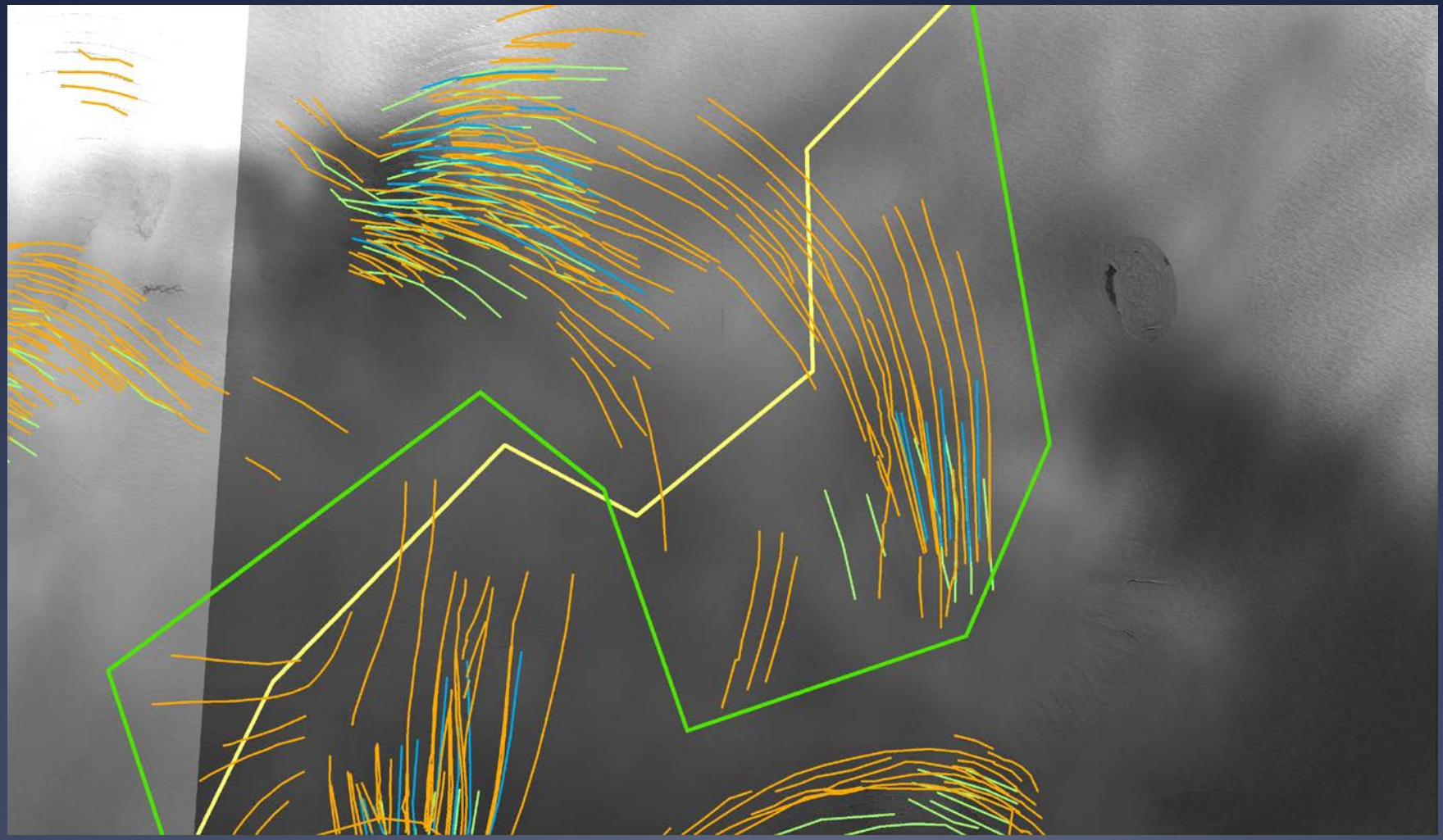
2008

The Bear Claw-5.0 meter imagery used, traversed between 2 crevasse fields

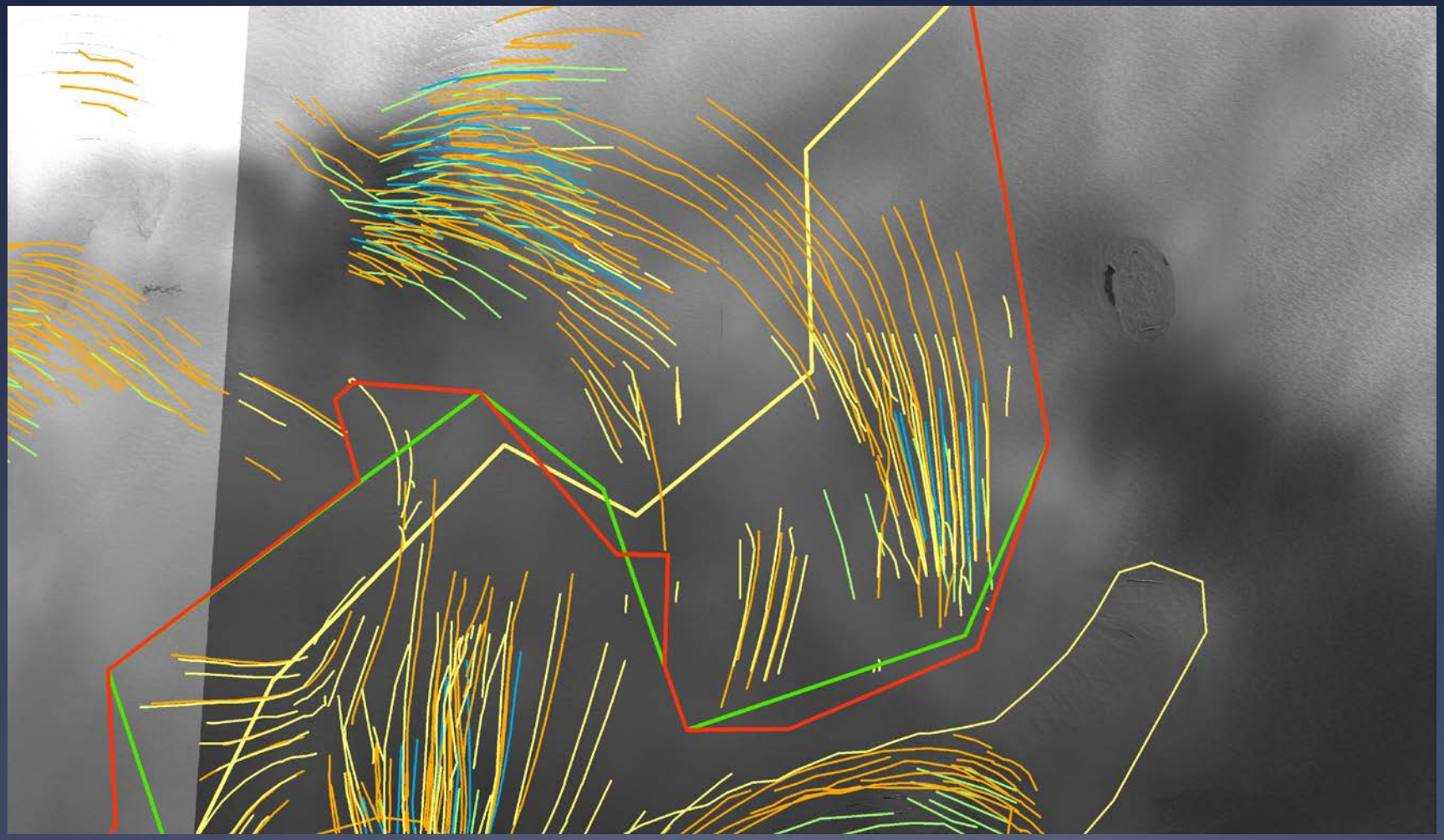


2010

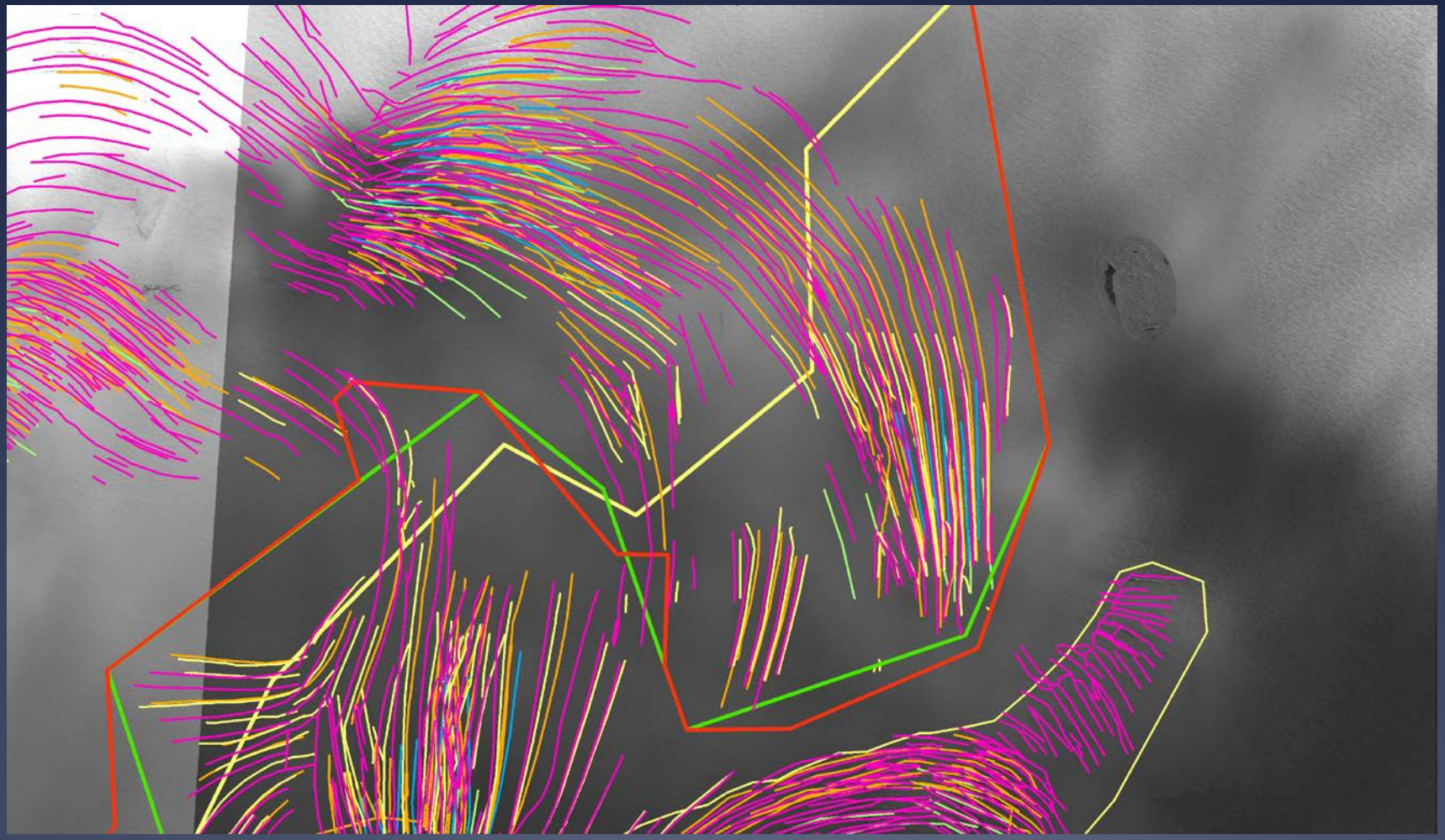
The Bear Claw-0.5m imagery showed crevasse fields had joined. GPR showed wide crevasses, not crossable



2011
The Bear Claw-Additional crevasses formed/extended to the south

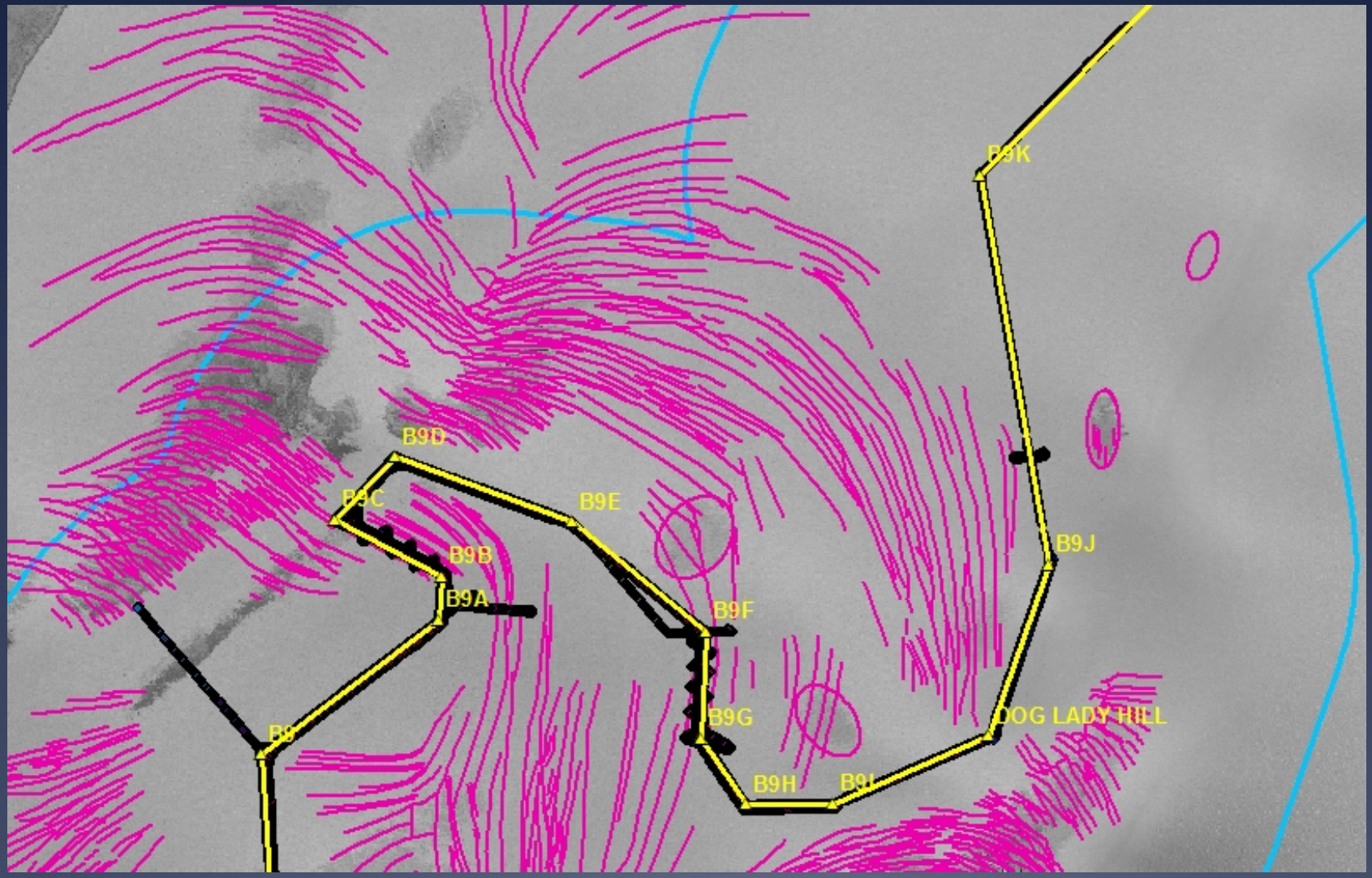


2012
The Bear Claw-Similar Additional Crevasses Formed/Extended to the South

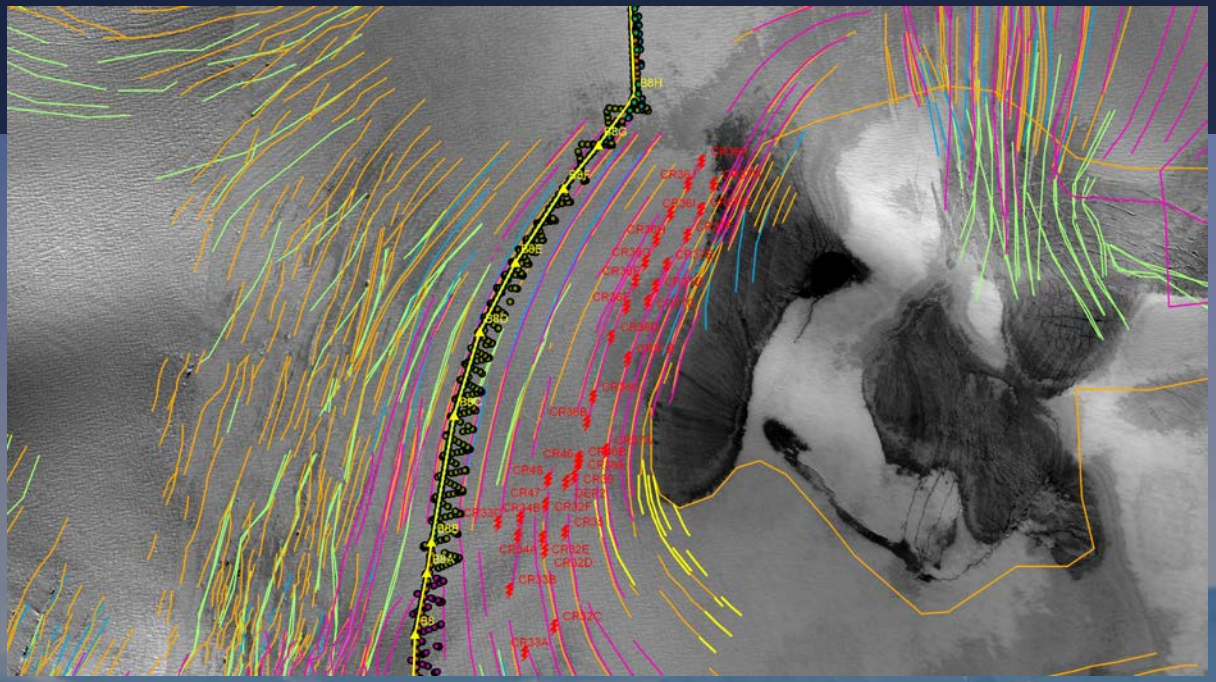


2012

The Bear Claw-Threaded between 2 adjacent crevasses



# How precise is the method?



# IN SUMMARY
(Lessons Learned)

- HIGH-RESOLUTION IMAGERY SHOWS MOST CREVASSES THAT ARE GREATER THAN ~18 INCHES IN WIDTH (SOME EXCEPTIONS)

- CREVASSES ARE GROWING ANNUALLY (IN WIDTH AND LENGTH)

- CREVASSE FIELDS HAVE INCREASING NUMBERS OF CREVASSES ANNUALLY

- A LARGE CREVASSE FIELD CAN DEVELOP OVER 1-3 YEARS

- CREVASSE MITIGATION OR BRIDGING WILL NEED TO BE CONSIDERED FOR GRIT TO CONTINUE TO BE VIABLE (We've begun to take strength measurements on these crevasse bridges)

# IN SUMMARY
(Lessons Learned)

- A COMBINATION OF HIGH-RESOLUTION IMAGERY, GPR, AND REAL-TIME TRACKING via AN EXPERIENCED TEAM IS SUREST WAY TO AVOID CREVASSE DANGERS

  - NEW TECHNOLOGY/APPROACHES ARE PROMISING, BUT STILL UNPROVEN

  - WHILE CREVASSES ARE INCREASING, SCAT HAS BECOME MORE SKILLED (BETTER ROUTES YEAR AFTER YEAR) and MORE EFFICIENT (FASTER)-i.e. corporate memory is developing-its possible that GrIT would not have started if these crevasse fields and their rapid growth had been obvious 5 years ago

# MANY THANKS


* National Science Foundation
* CRREL
* CH2MHill/Polar Field Services
* Paul Morin, PGIC
* NGA
* Air Greenland


Video of Crevasse helo reconnaisance