A new stationary radio-echo sounding system for cryospheric studies: instrument, first results, and perspectives

Laurent Mingo[1] & Gwenn E. Flowers[2]

[1]Blue System Integration, Ltd., Vancouver, BC, Canada

[2]Department of Earth Sciences, Simon Fraser University, Burnaby, BC, Canada

IceRadar
www.bluesystem.ca

SFU

SR&ED Canada Revenue Agency

National Instruments Silver Alliance Partner

Canada Research Chairs
Chaires de recherche du Canada

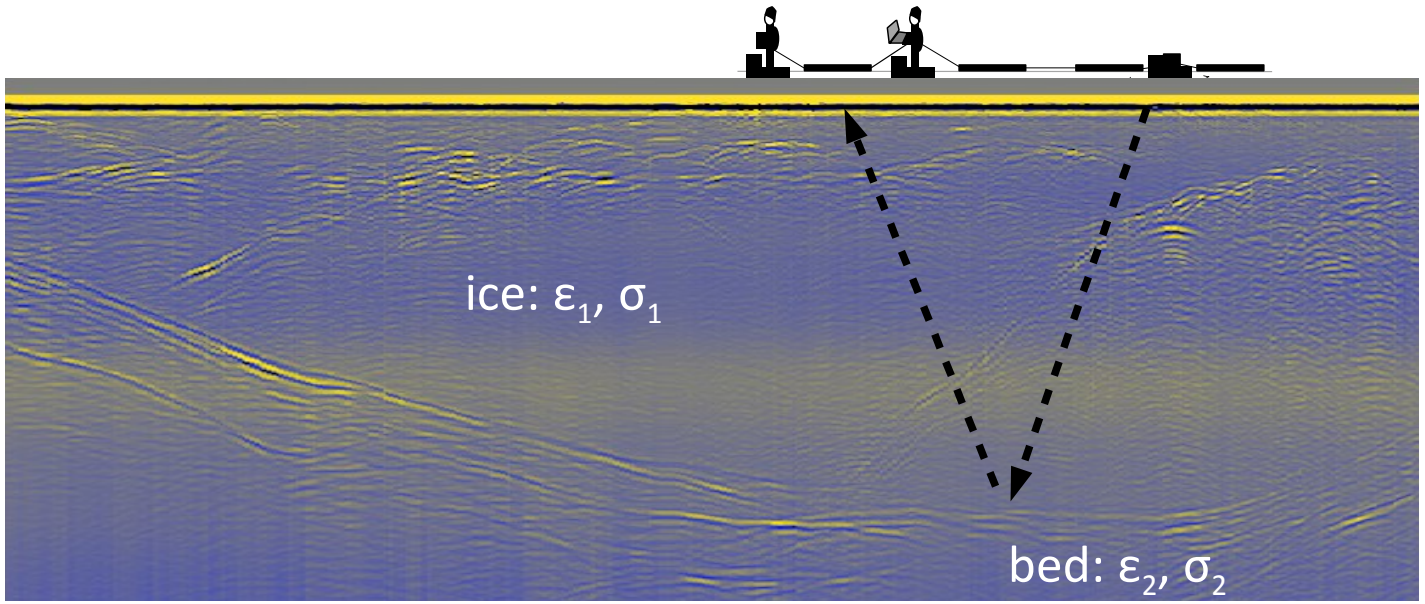
INNOVATION.CA
CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION

Principles of ice-penetrating radar

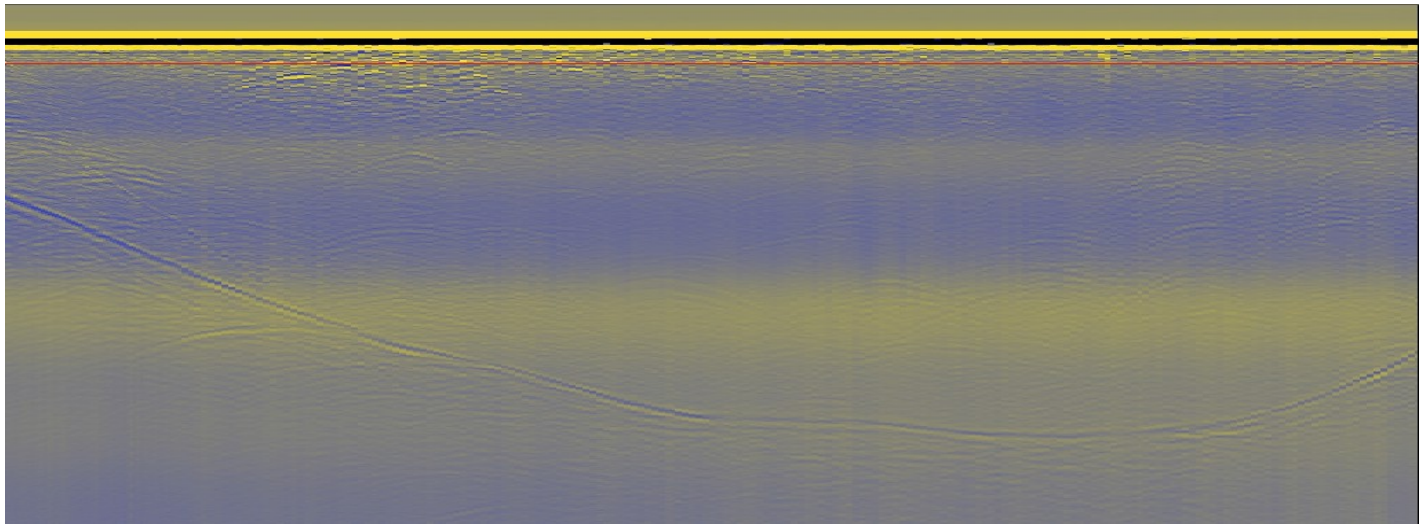
Ice is nearly transparent to radio waves in the MHz range

Same transect acquired in :

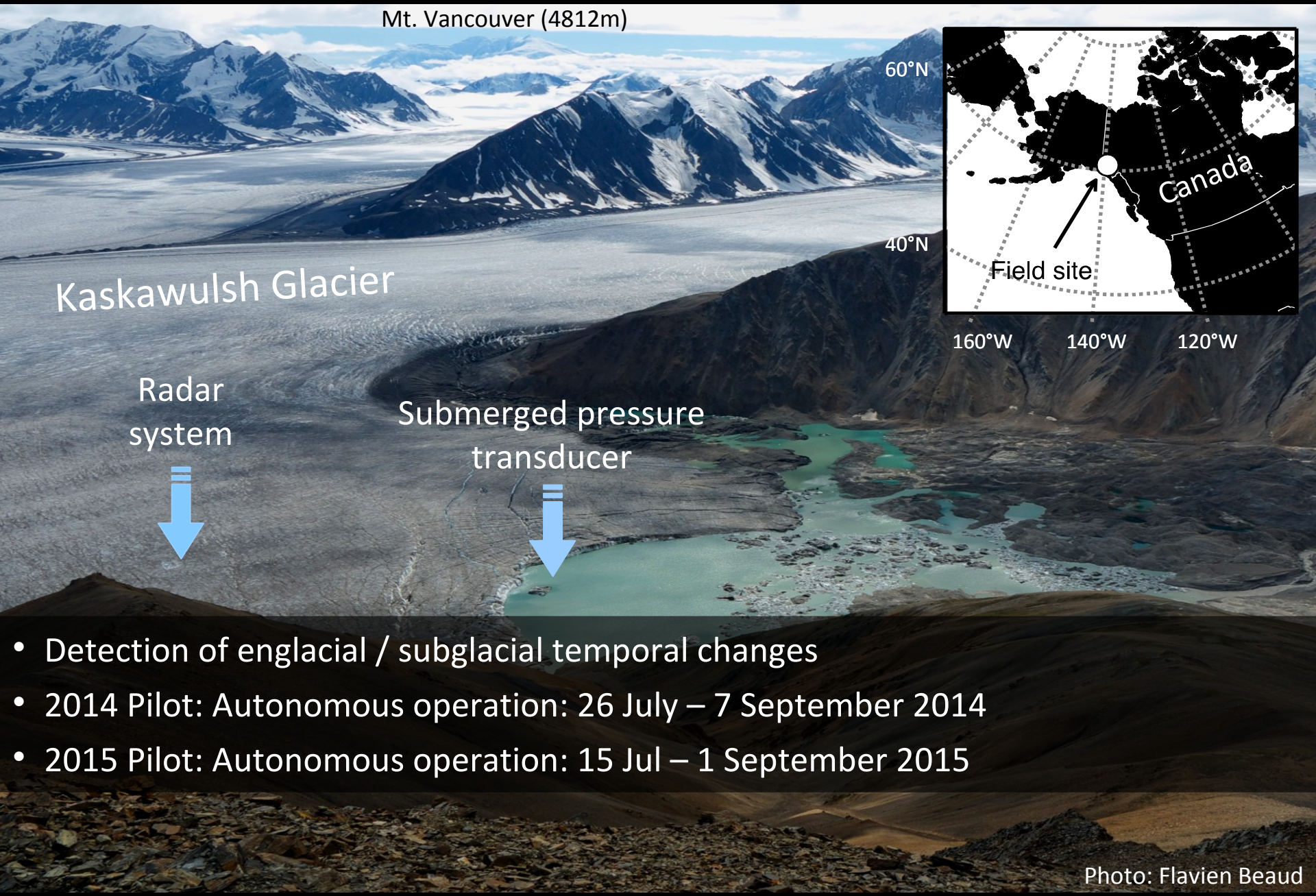
- July 2014



- July 2015



2014 - 2015 Deployment goals and location



- Detection of englacial / subglacial temporal changes
- 2014 Pilot: Autonomous operation: 26 July – 7 September 2014
- 2015 Pilot: Autonomous operation: 15 Jul – 1 September 2015

Photo: Flavien Beaud

Motivation for system development

~24 hrs

Stationary radar system deployment

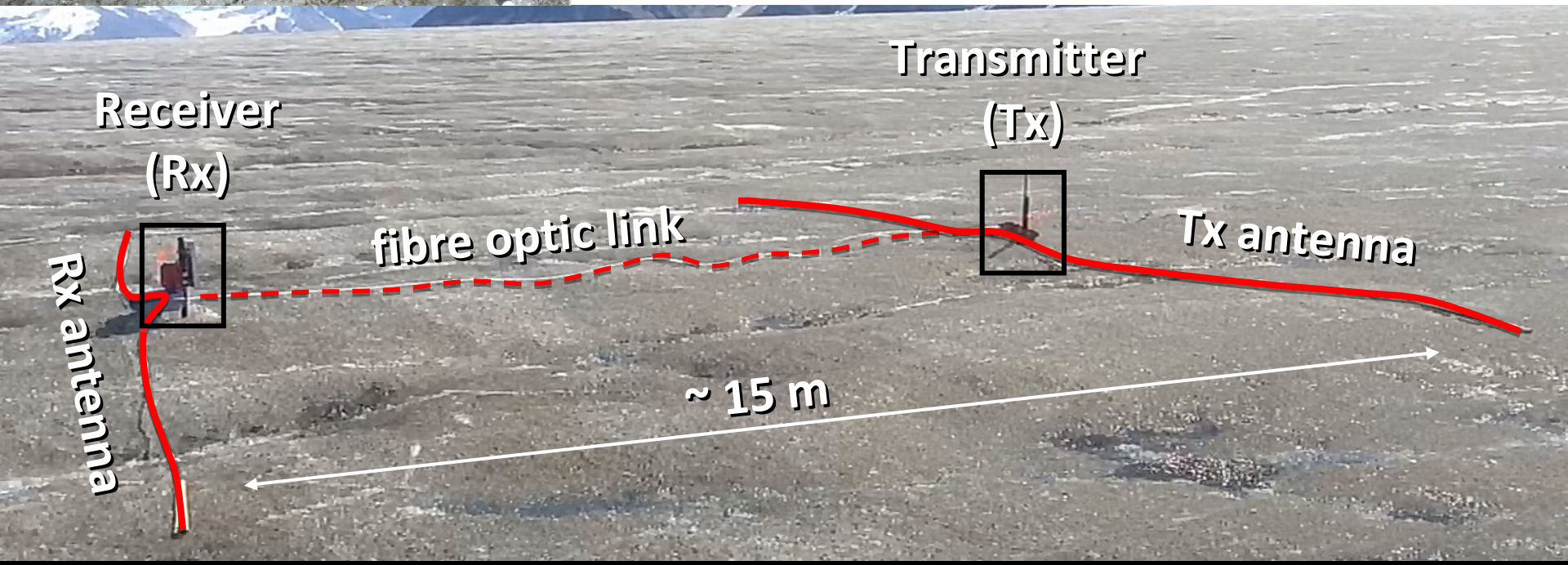
Dual channel input at 125 MS/s,

1024 Stacks,

Meas. Interval 4hrs (2014); 3hrs (2015)

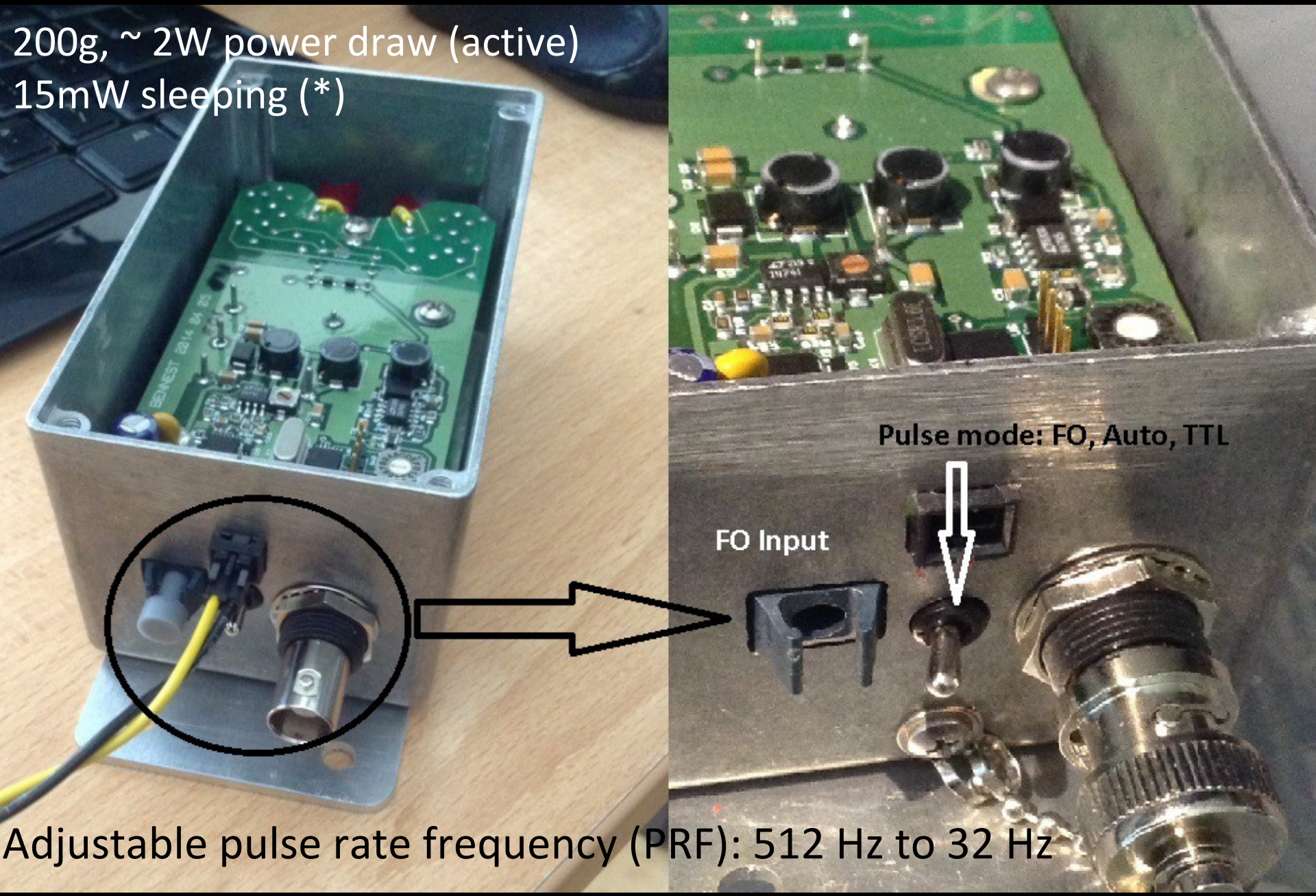
Software for autonomous operation:

- Adaptive trigger level
- Auto-shutdown, and boot sequences
- Deployment and health check
- No user interface



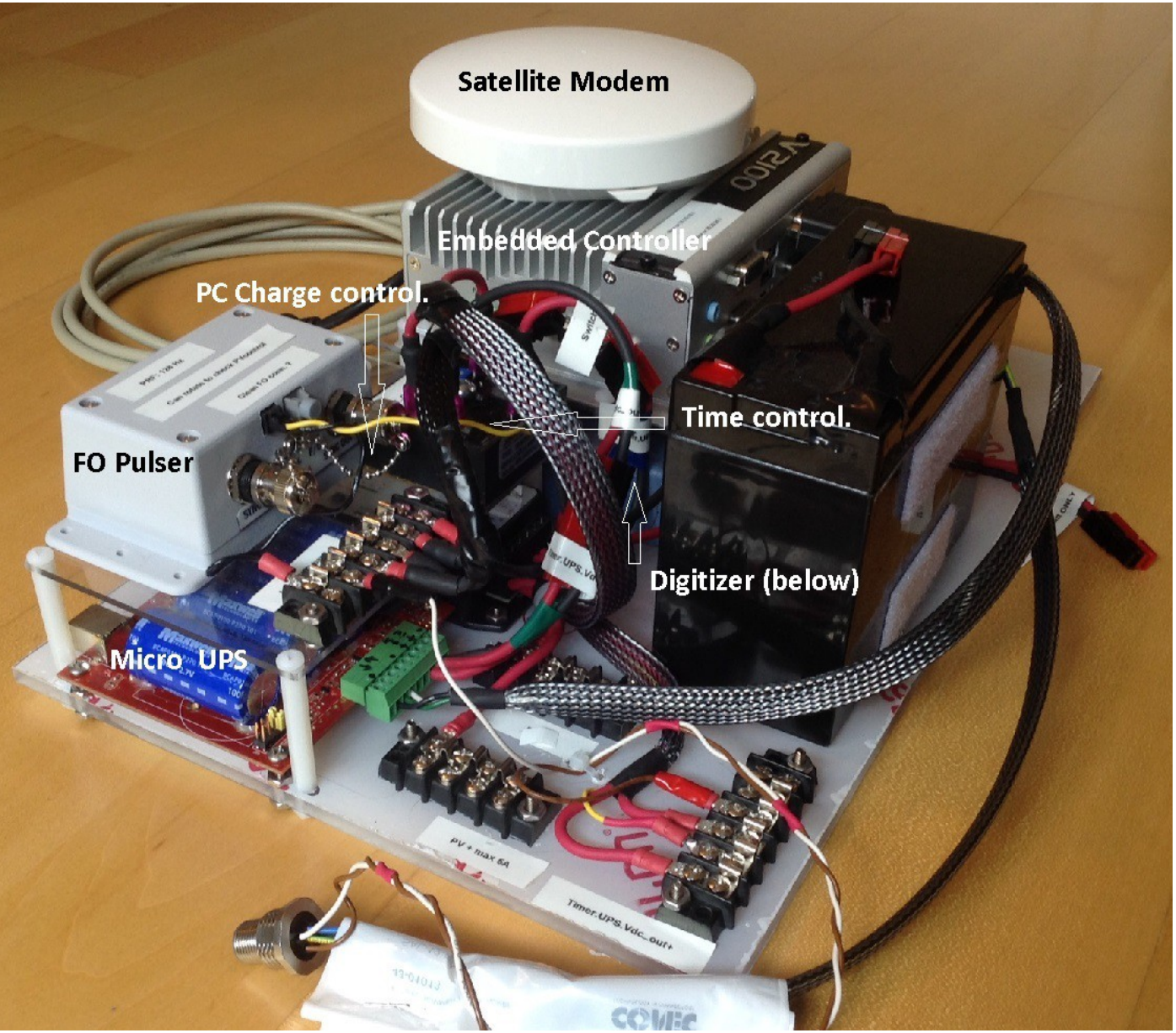
Stationary radar system design: transmitting unit

200g, ~ 2W power draw (active)
15mW sleeping (*)



Adjustable pulse rate frequency (PRF): 512 Hz to 32 Hz

Stationary radar system design: receiving unit

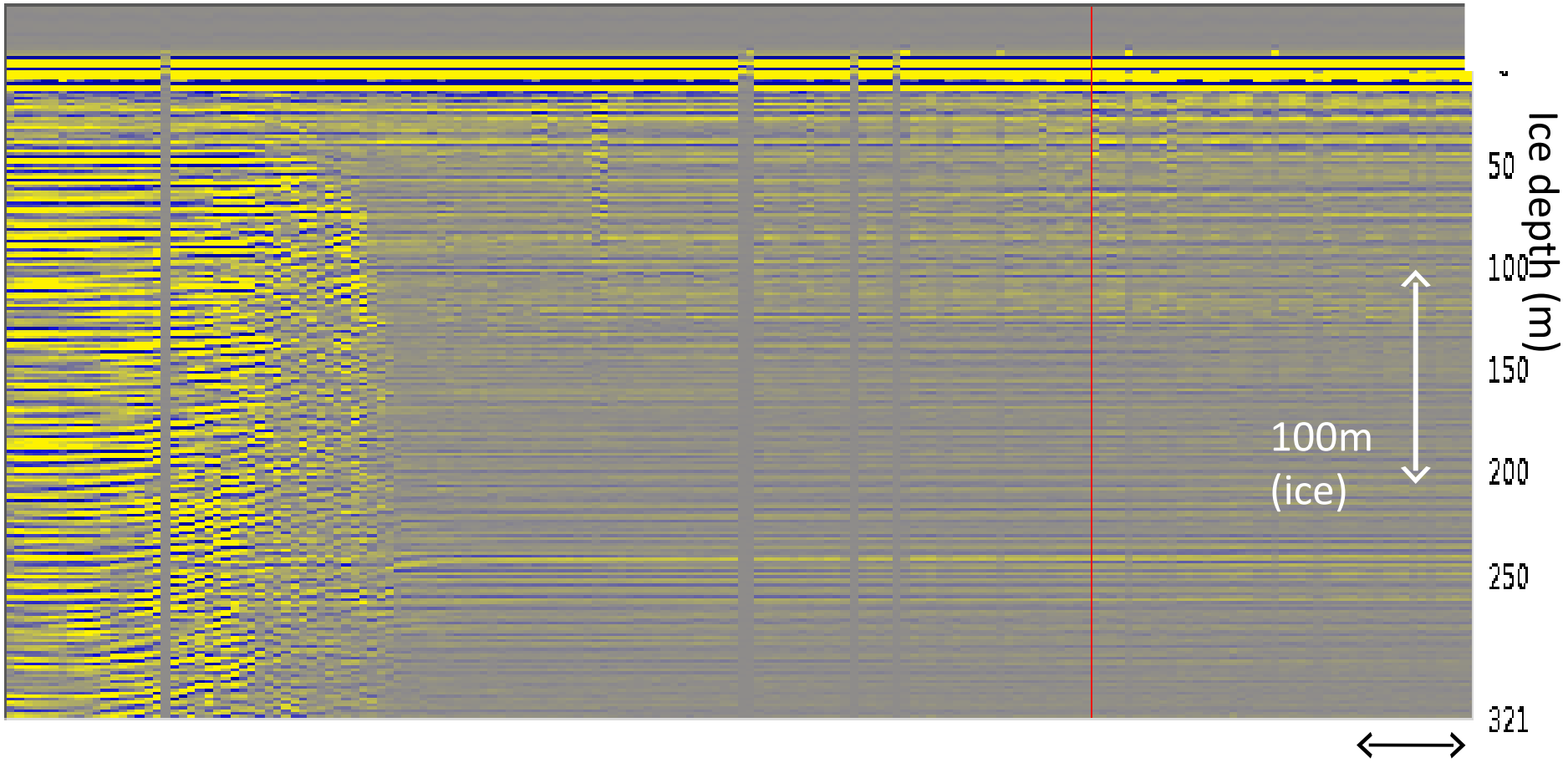


- Based on previously developed roving radar (Mingo, Flowers, 2010)

- Compact, light
- ~ 7W operating
- ~ 4mW sleeping

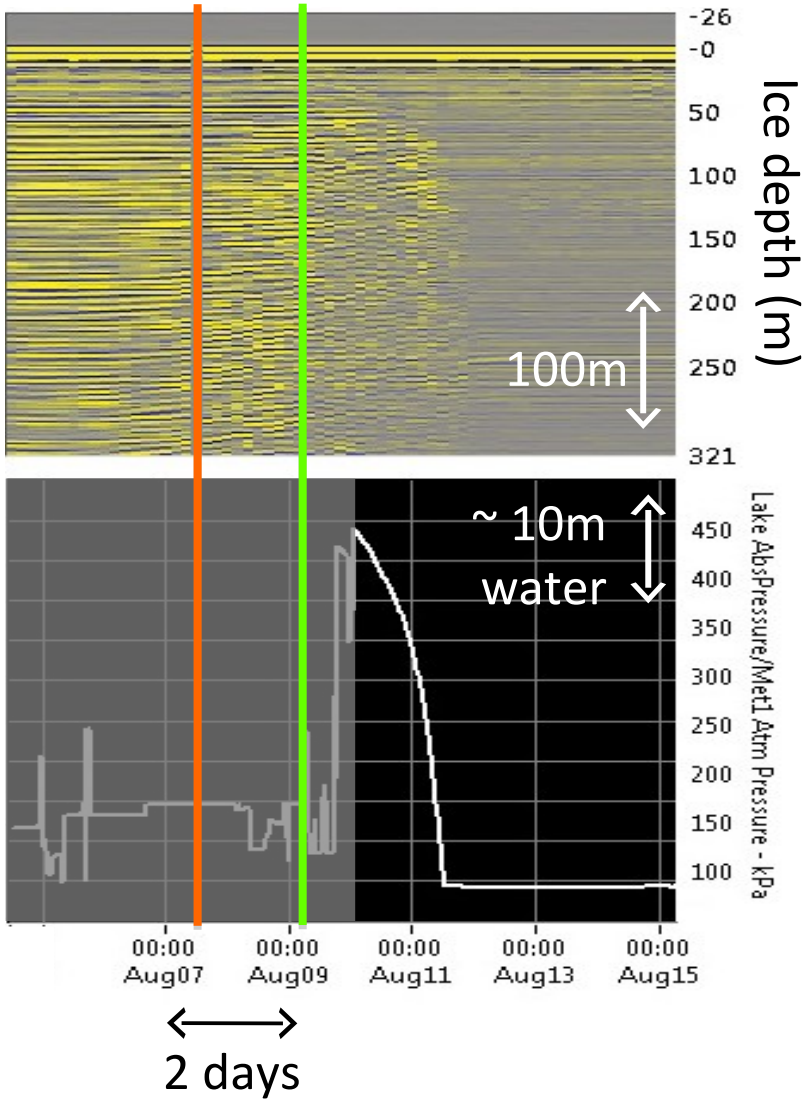
1st Deployment:
- No sat com
- No Micro-UPS

2014 Deployment results – Temporal Radargram



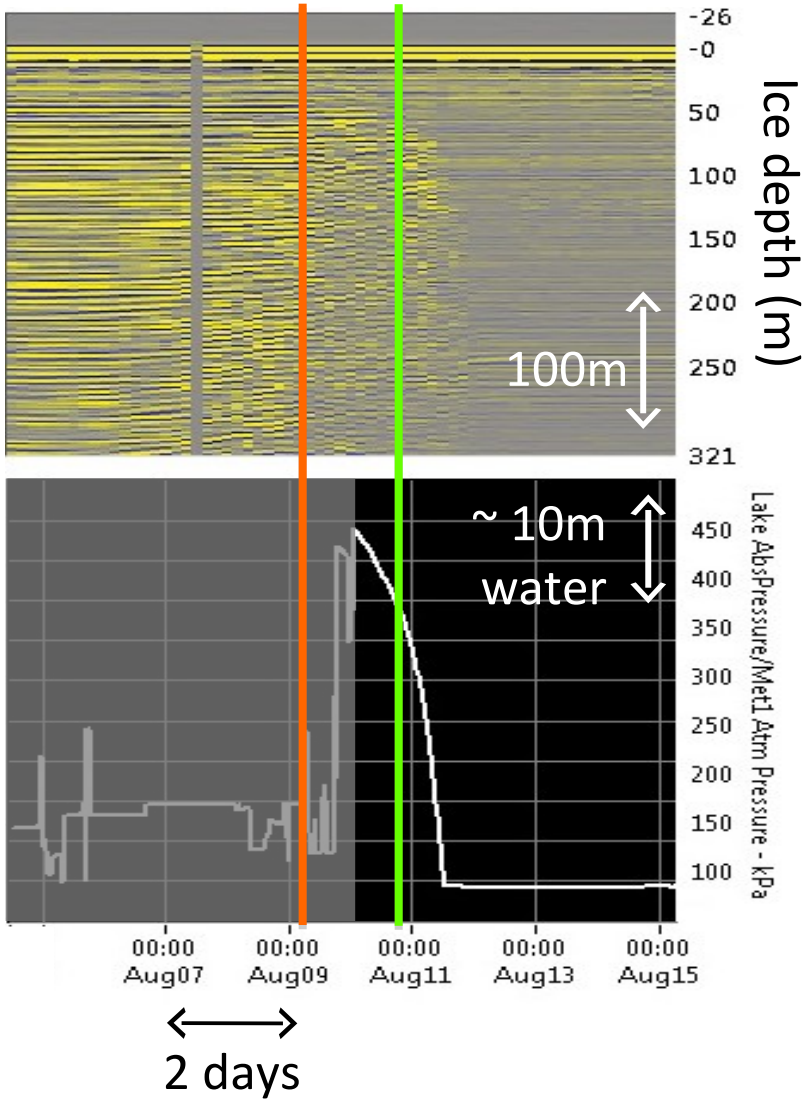
- Zone with strong englacial reflectors
- Zone with “chaotic” reflectors
- Zone with weak englacial reflectors
- Changes at the bed

2014 Deployment results



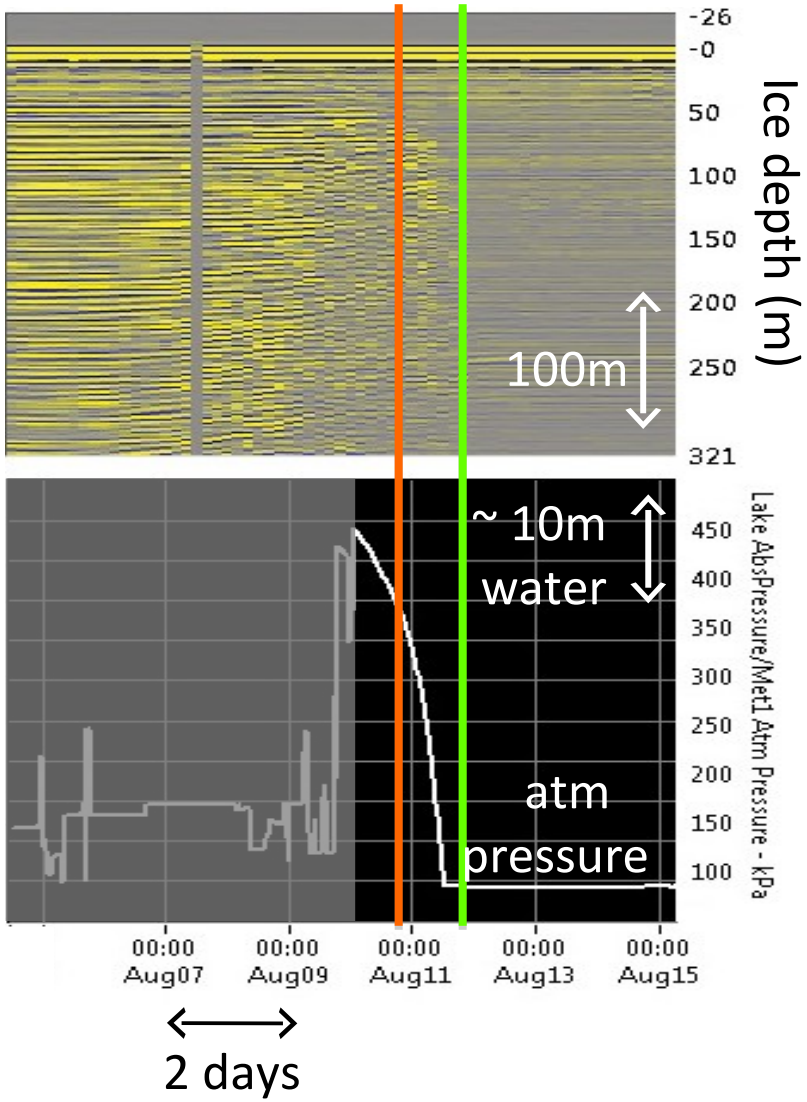
Images courtesy of Christian Schoof and UBC Glaciology

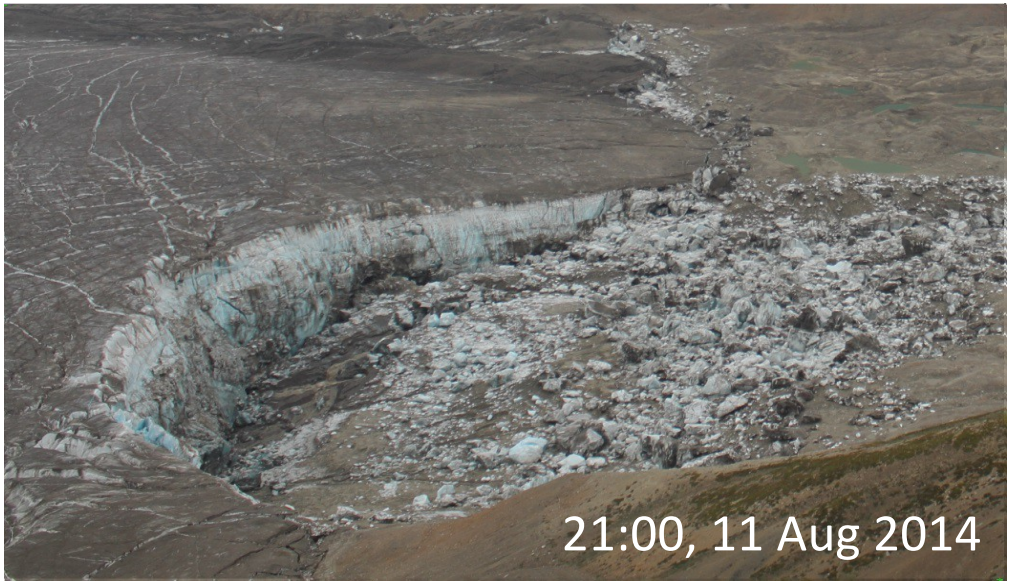
2014 Deployment results



Images courtesy of Christian Schoof and UBC Glaciology

2014 Deployment results

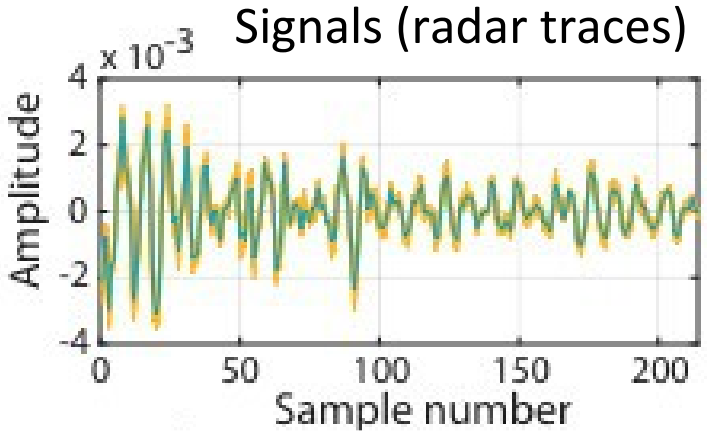


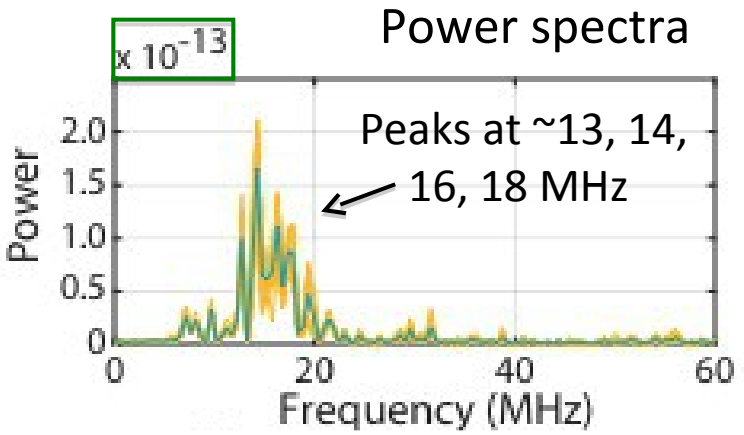


Images courtesy of Christian Schoof and UBC Glaciology

Interpretation

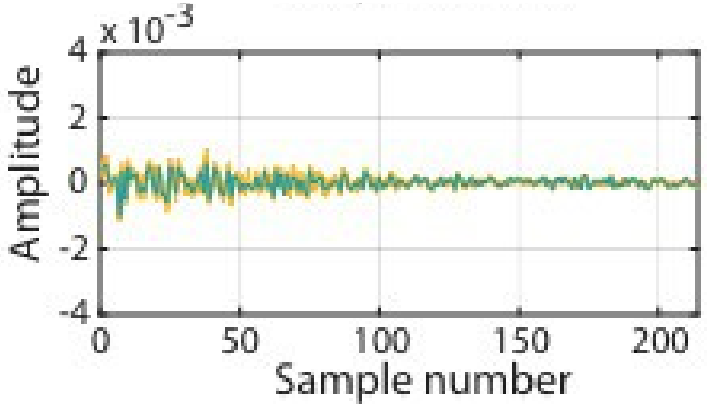
Before

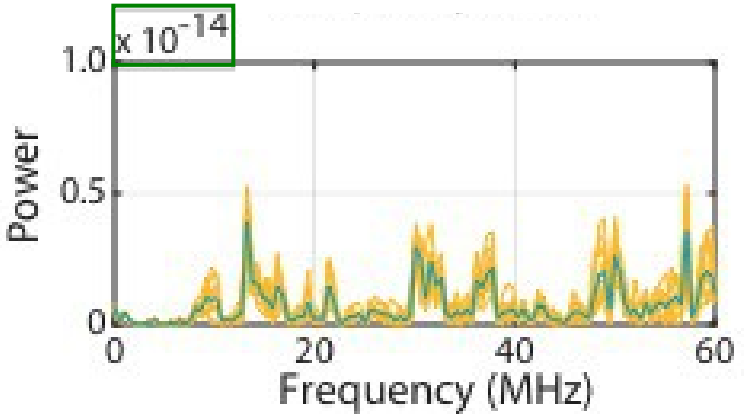




- Strong internal reflectors before drainage consistent with englacial water storage
- Transition from Strong to Weak englacial reflectors consistent with de-watering
- Spectral peaks correspond to water-filled void apertures of ~0.4 to 0.6 m (Jacobel and Raymond, 1984)
- Other evidence of englacial water storage and release?

After

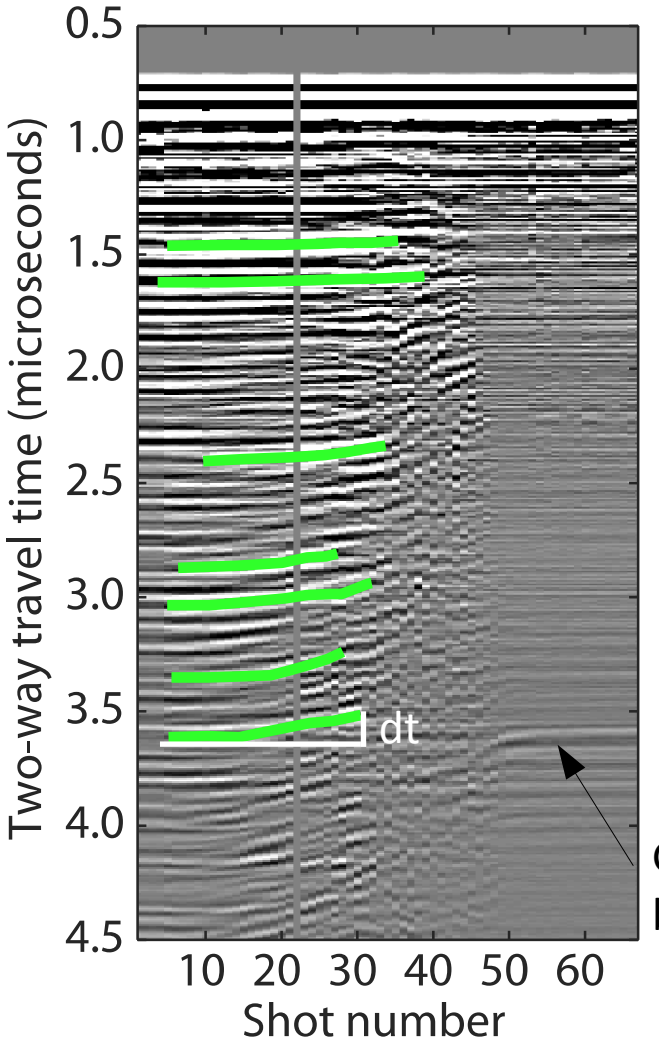


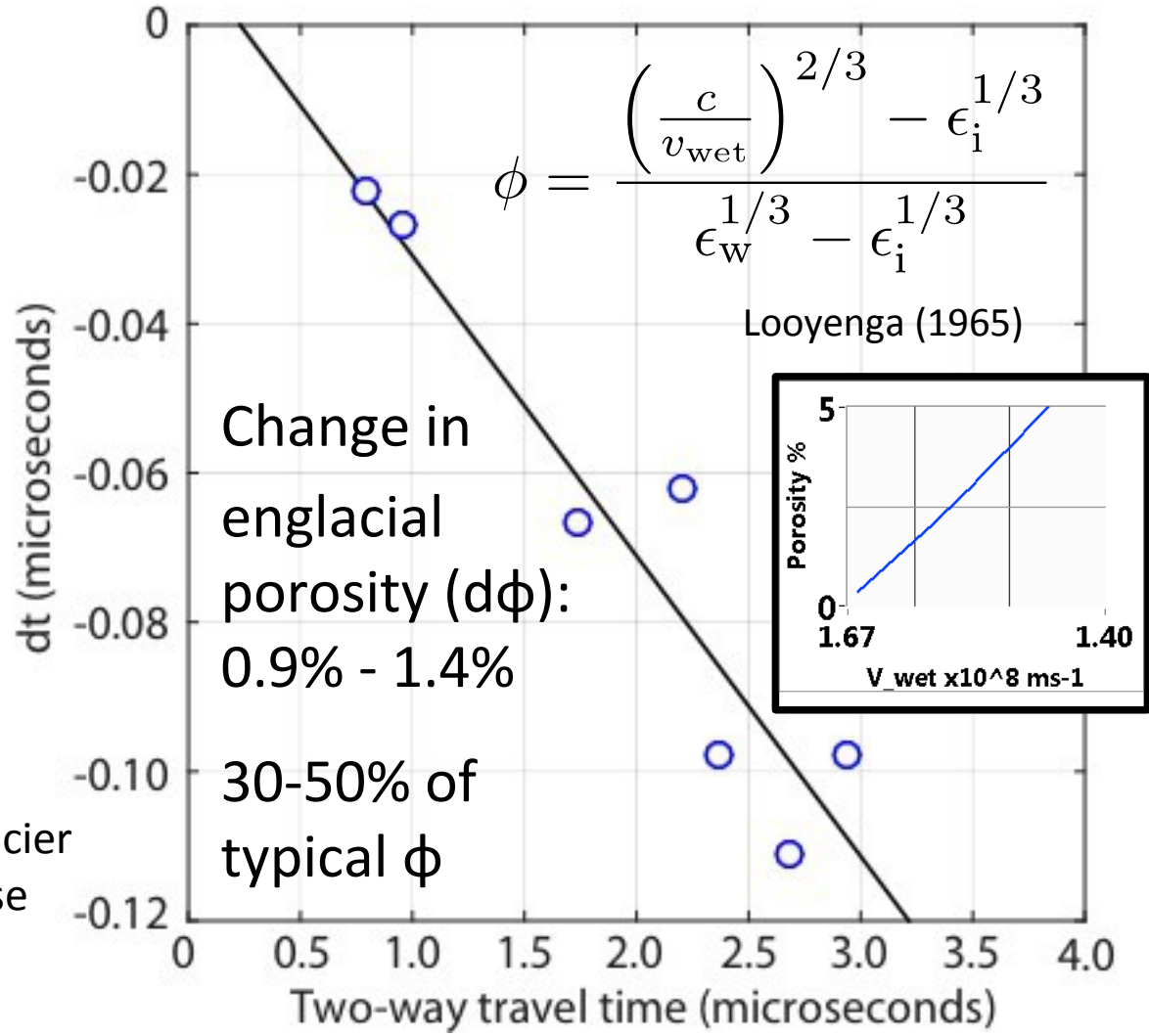


Interpretation: englacial porosity?

Decreasing englacial saturation during flood expressed as upturn in reflectors?

Changes in wavespeed propagation used to estimate bulk porosity:





Ice Island Deployment

Project Collaborators: Anna Crawford, Derek Mueller, Greg Crocker.
WIRL at Carleton University, Ottawa

WATER & ICE RESEARCH LAB
WIRL

- 14 sq.km Petermann II A-1-f, off Baffin Island
- WIRL: Ice island deterioration modeling project
- II deterioration poses risk to off-shore infrastructure and shipping industry

Photo : Gabriel Joyal

Stationary Radar on Petermann II – A- 1-f

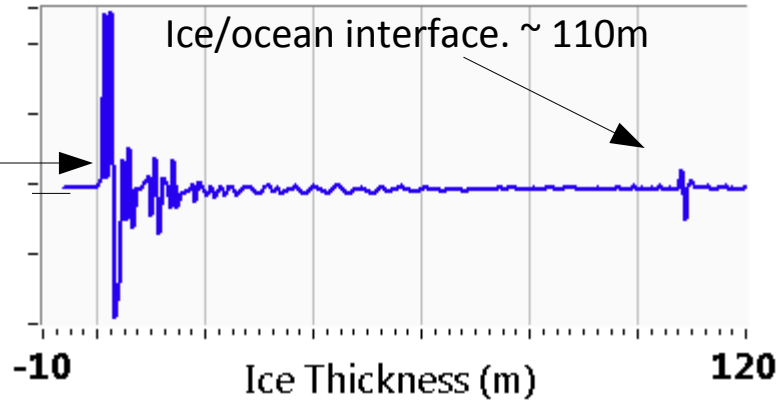
Daily Data since Oct 20.

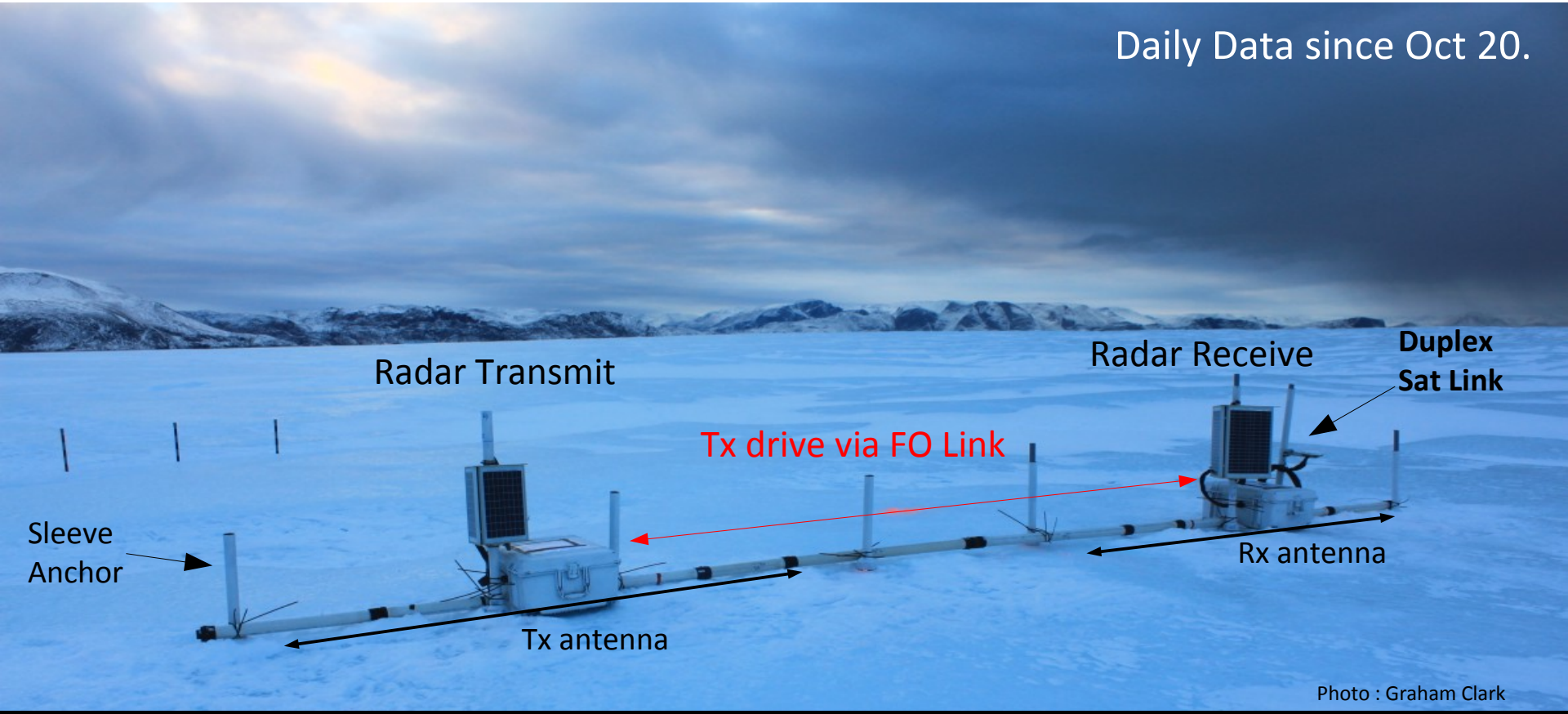
Acquisition Steps:

- Manage unsent sat messages if any
- Wake up Tx & pulse
- Acquire new data on Rx on dual input

- Pack:
  1. radar data x2
  2. acq. Info
  3. system health info
- Add metadata
- Parse
- Compress
- Send

000502
002e00
0500b2
dfeeae
acf862
dbd0d
8ccbc0
dbe612
1dcd8f
e24





Summary

- Successful operation of a stationary radar system during two 7-week deployments
- First jökulhlaup event captured with autonomous radar system from 2014 dataset
- On-going ice island deployment

Future work:

Pursue application to ice-islands,

Extend application to subglacial geothermal areas

Phase sensitive radar. Other ideas ?

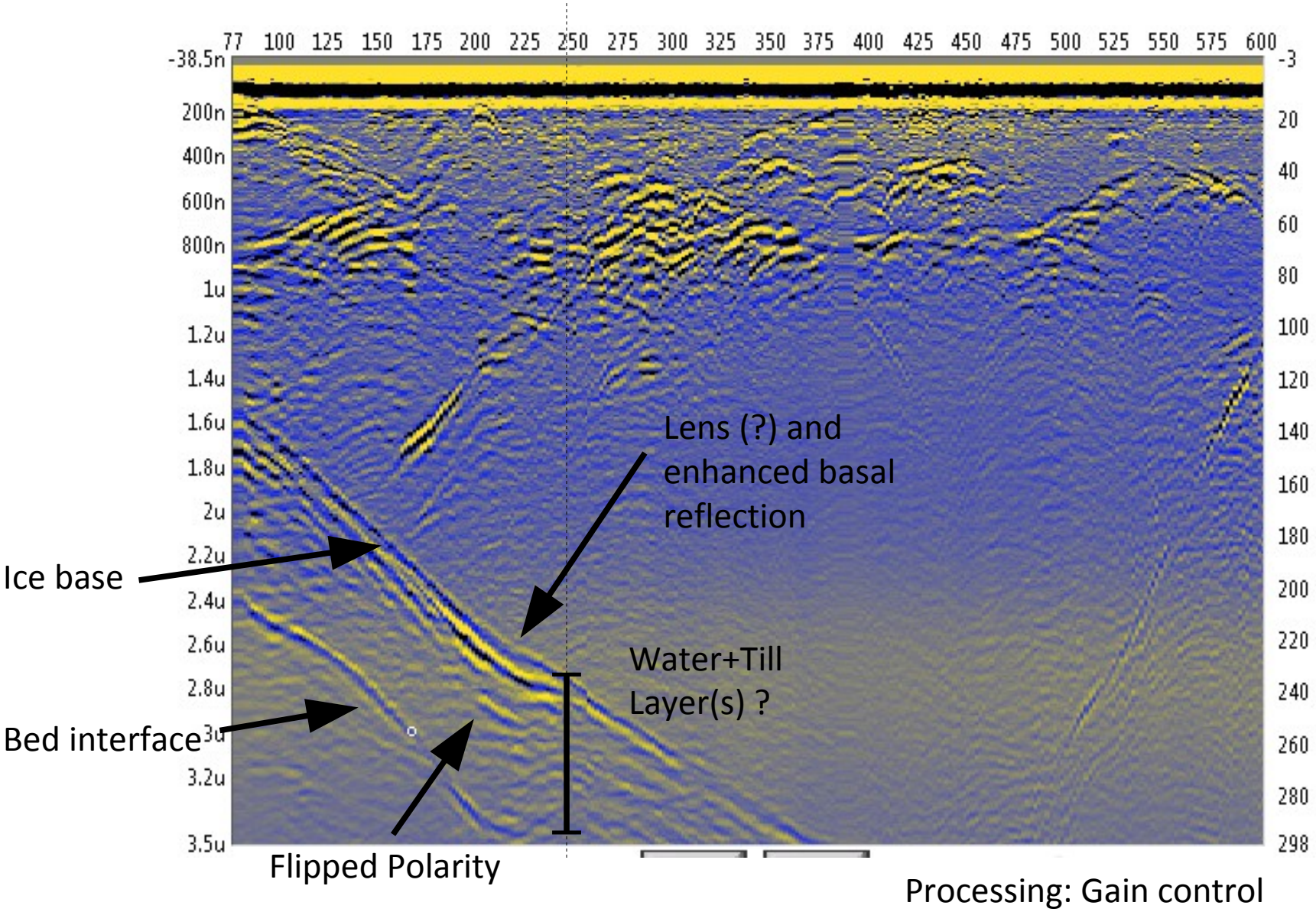
IceRadar
www.bluesystem.ca

SR&ED Canada Revenue Agency

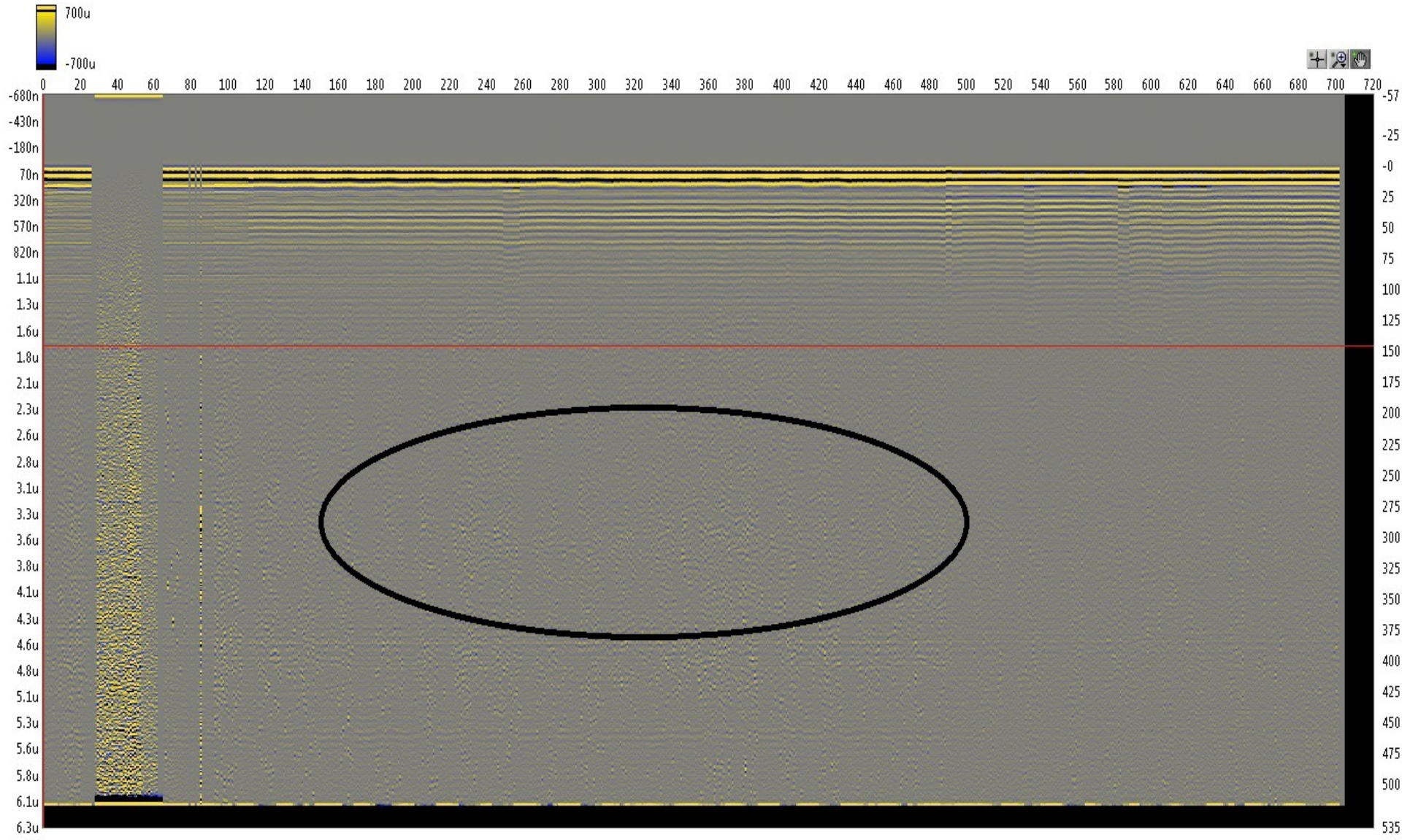
SFU

Acknowledgments: C. Schoof, C. Rada (time lapse imagery); A. Whiteford, J. Gilchrist (roving radar survey); F. Beaud and J.Crompton (retrieval of radar system, pressure sensor); AINA Kluane Lake Research Station (field support); Kluane First Nation, Parks Canada, Yukon Territorial

Location of Stationary system on Transect



2015 Kaskawulsh Data Set



Previous work using impulse (*) ice-penetrating radar for temporal studies

	Jacobel & Raymond (1984)	Jones (1987)	Gades et al. (1998)	Kulessa et al. (2008)
Time span	**3 weeks**	**3 days**	**Several weeks**	**10 hours**
Glacier, type	Variegated, temperate	Trapridge, polythermal	Variegated, temperate	Alps, likely polythermal
System	3Mhz, tape recorder	8MHz, first automated recording	3-5 MHz, automated recording	50MHz, automated recording
Meas. interval	A few hours	20 minutes	1 hour	10 minutes
Auto-nomous?	**No**	**No**	**No**	**No**
Current draw	A few A @ 12V	~ 2A @ 12V	A few A @ 12V	~ 3A @ 12V

(*): FMCW Phase Sensitive radar: Brennan & Al (2013) , University College London & BAS: Autonomous system. Center Freq 300 Mhz.