(Semi) Automatically Detecting Layers From Polar Radar Imagery

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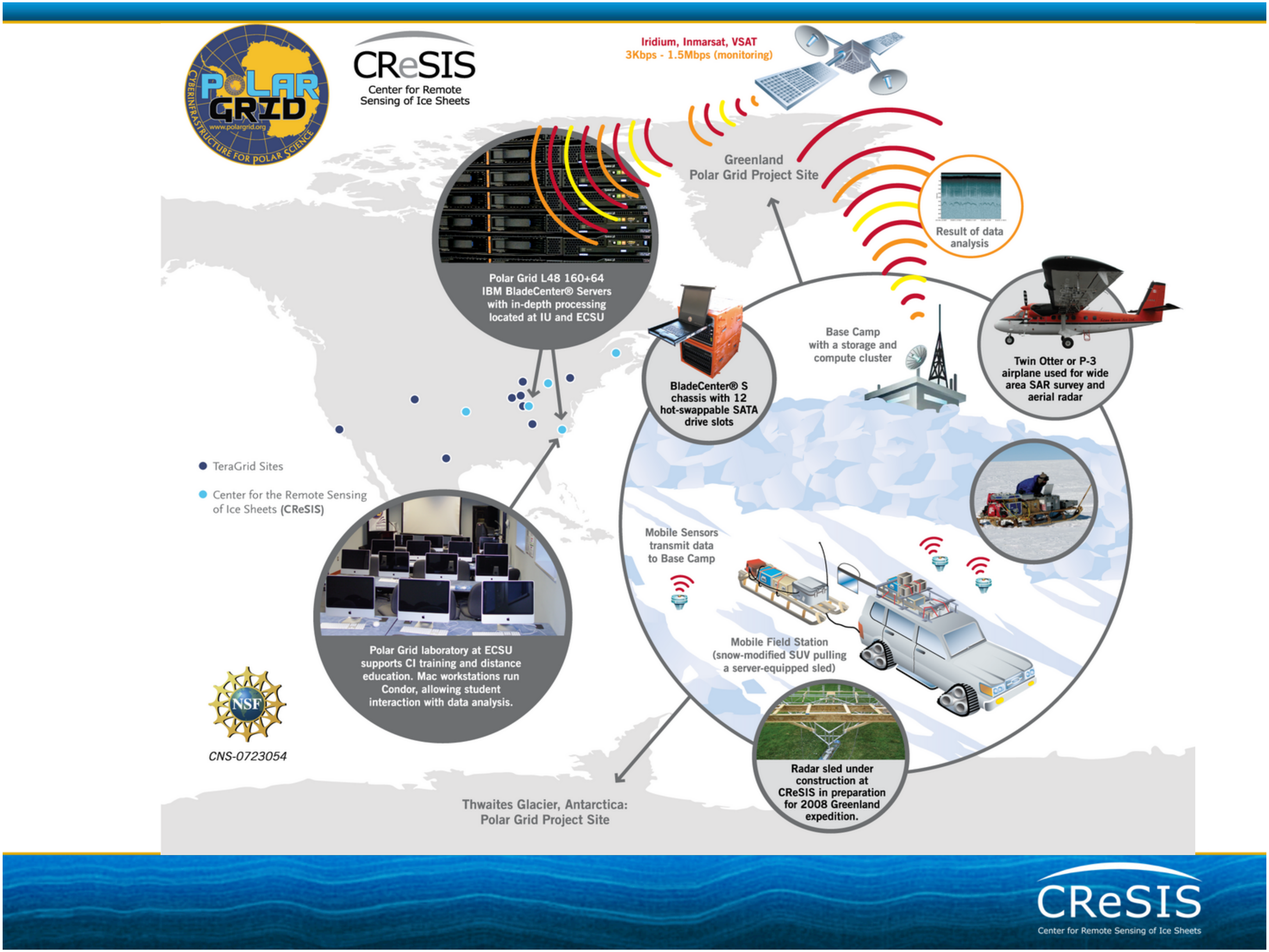
Radio Echo Sounding Tracing Workshop

Centre for Ice and Climate

CReSIS
Center for Remote Sensing of Ice Sheets

CReSIS Instruments

Instrument	Measurement	Freq./ Wavelength	BW/ Res.	Depth	Power	Altitude	Antenna	Installs
HF Sounder Under development	Ice Thickness	14 MHz 35 MHz	1 MHz 5 MHz	3 km	100 W	TBD	Dual-Freq Dipole	Yak Small UAV
UWB Radar Under development	Ice Thickness Int. Layering Bed Properties	Adjustable 350 MHz	Up to 450 MHz	4 km	800 W	TBD	Array	Basler
MCoRDS/I Radar Depth Sounder	Ice Thickness Int. Layering Bed Properties	195 MHz 1.5 m	30 MHz 4 m	4 km	800 W	30000 ft	Dipole Array Wing Mount Fuslage	Twin-Otter P-3 DC-8
Accum. Radar	Internal Layering Ice Thickness	750 MHz 40 cm	300 MHz 40 cm	300 m	10 W	20000 ft	Patch Array Vivaldi Array	Twin-Otter P-3
Snow Radar	Snow Cover Topography Layering	5 GHz 7.5 cm	6 GHz 4 cm	80 m	200 mW	30000 ft	Horn	P-3 DC-8
Ku-Band	Topography Layering	15 GHz 2 cm	6 GHz 4 cm	15 m	200 mW	20000 ft	Horn	Twin-Otter DC-8


POLAR GRID
CYBERINFRASTRUCTURE FOR POLAR SCIENCE
www.polargrid.org
CReSIS
Center for Remote Sensing of Ice Sheets
Iridium, Inmarsat, VSAT
3Kbps - 1.5Mbps (monitoring)
Greenland Polar Grid Project Site
Result of data analysis
Polar Grid L48 160+64 IBM BladeCenter® Servers with in-depth processing located at IU and ECSU
BladeCenter® S chassis with 12 hot-swappable SATA drive slots
Base Camp with a storage and compute cluster
Twin Otter or P-3 airplane used for wide area SAR survey and aerial radar
TeraGrid Sites
Center for the Remote Sensing of Ice Sheets (CReSIS)
Mobile Sensors transmit data to Base Camp
Mobile Field Station (snow-modified SUV pulling a server-equipped sled)
Polar Grid laboratory at ECSU supports CI training and distance education. Mac workstations run Condor, allowing student interaction with data analysis.
NSF
CNS-0723054
Radar sled under construction at CReSIS in preparation for 2008 Greenland expedition.
Thwaites Glacier, Antarctica: Polar Grid Project Site
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Overview

- Introduction
- Related Literature
- Methodology
- Applications
  - near surface internal layers
  - surface and bedrock layers
- Conclusion
- Future Work

Introduction

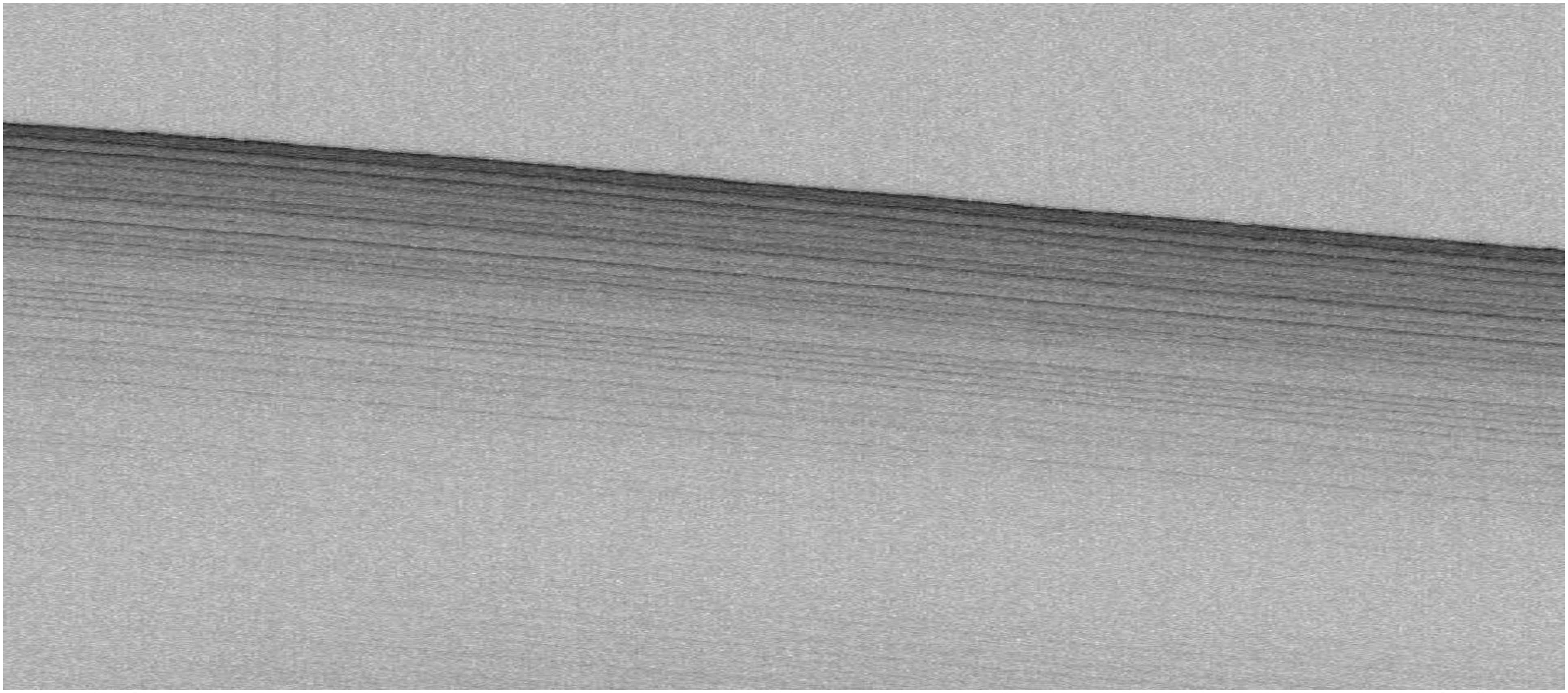
- The Problem
- Understanding Layers in the radar images:
  - helps compute the ice thickness and accumulation rate maps
  - help studies relating to the ice sheets, their volume, and how they contribute to climate change.
- Develop an automated tool for tracing Layers in radar imagery

Related Literature

- Internal Layers
  - Fahnestock et al (2001)
  - MacGregor et al (2013)
  - Sime et al (2011)
  - Panton
  - Lora Koenig
- Surface and Bedrock
  - Gifford et. al (2010)
  - Crandall et. al (2011)
  - Ilisei et al (2012)

Active Contours Models

- Active contour models, computer generated curves, which move within images to detect object boundaries
- Used in Image Segmentation
- Examples
  - Snakes, Intelligent Scissors, Level Sets



Estimating Near Surface Internal Layers

Snakes

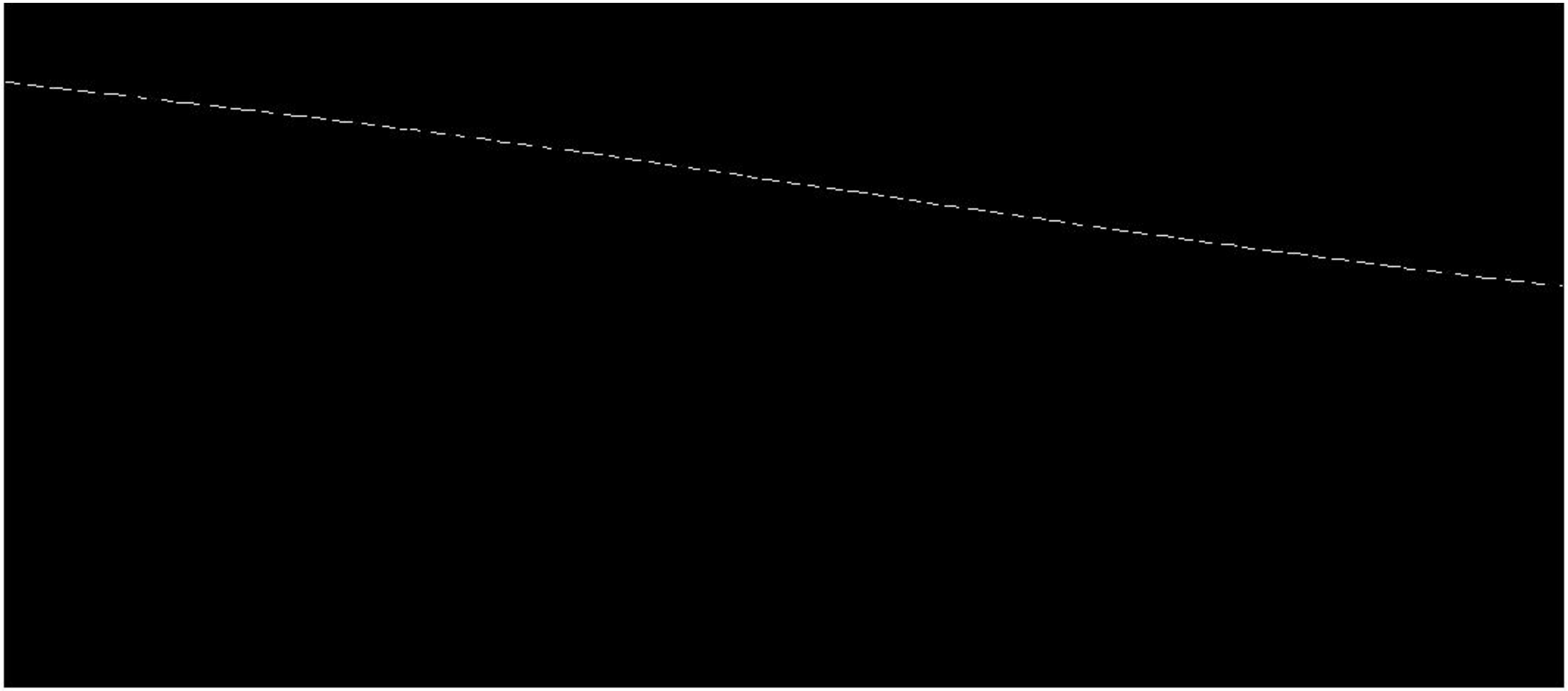
- A snake is defined in the (x,y) plane of an image as a parametric curve

$$v(s) = (x(s), y(s)), s \in [0,1]$$

- A contour has an energy (E_{snake}), which is defined as the sum of the three energy terms.

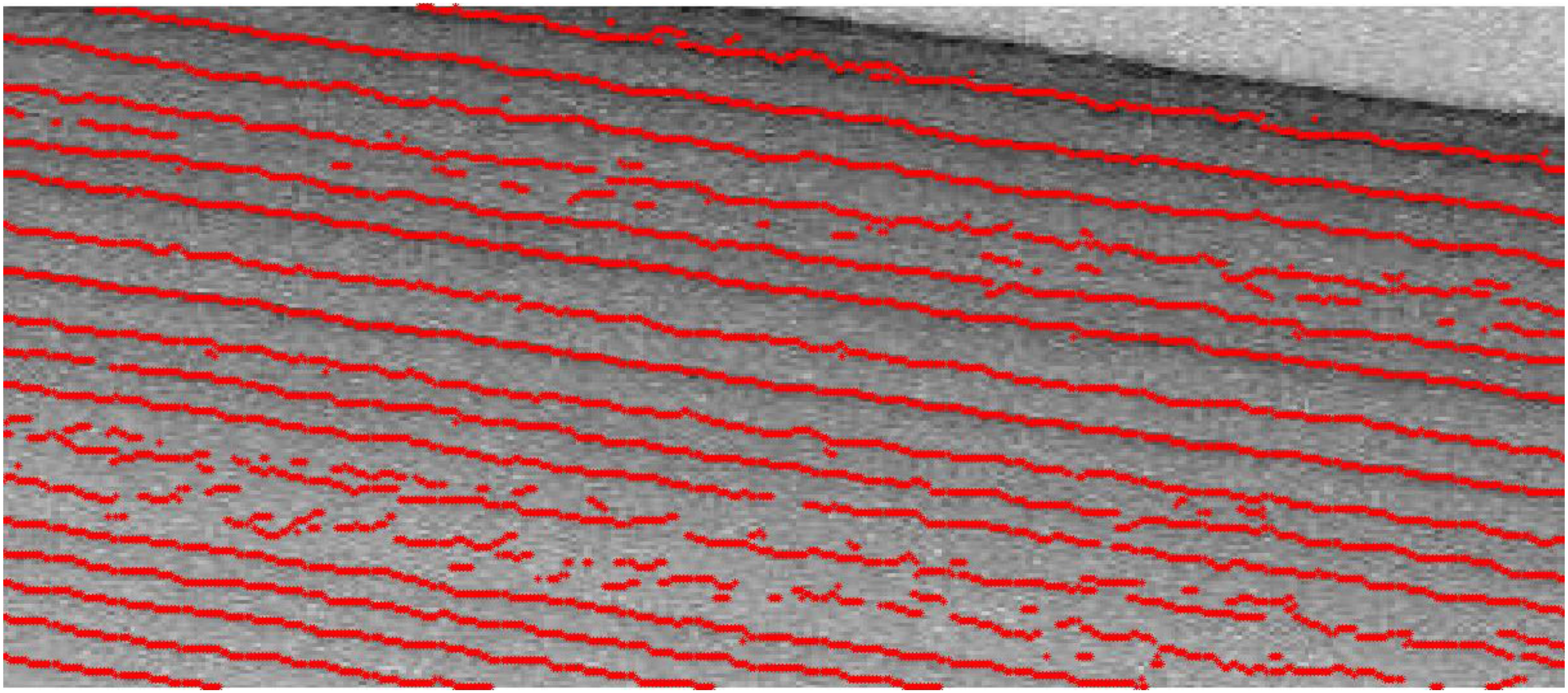
$$E_{snake} = \int (\alpha E_{elastic(v(s))} + \beta E_{bending(v(s))} + \gamma E_{image(v(s))}) ds$$

- Detecting Layers reduces to an energy minimization problem.



Algorithm for Estimating Near Surface Internal Layers

1. Identify Ice Surface
2. Classify Curve Points
3. Active Contours (Snakes)



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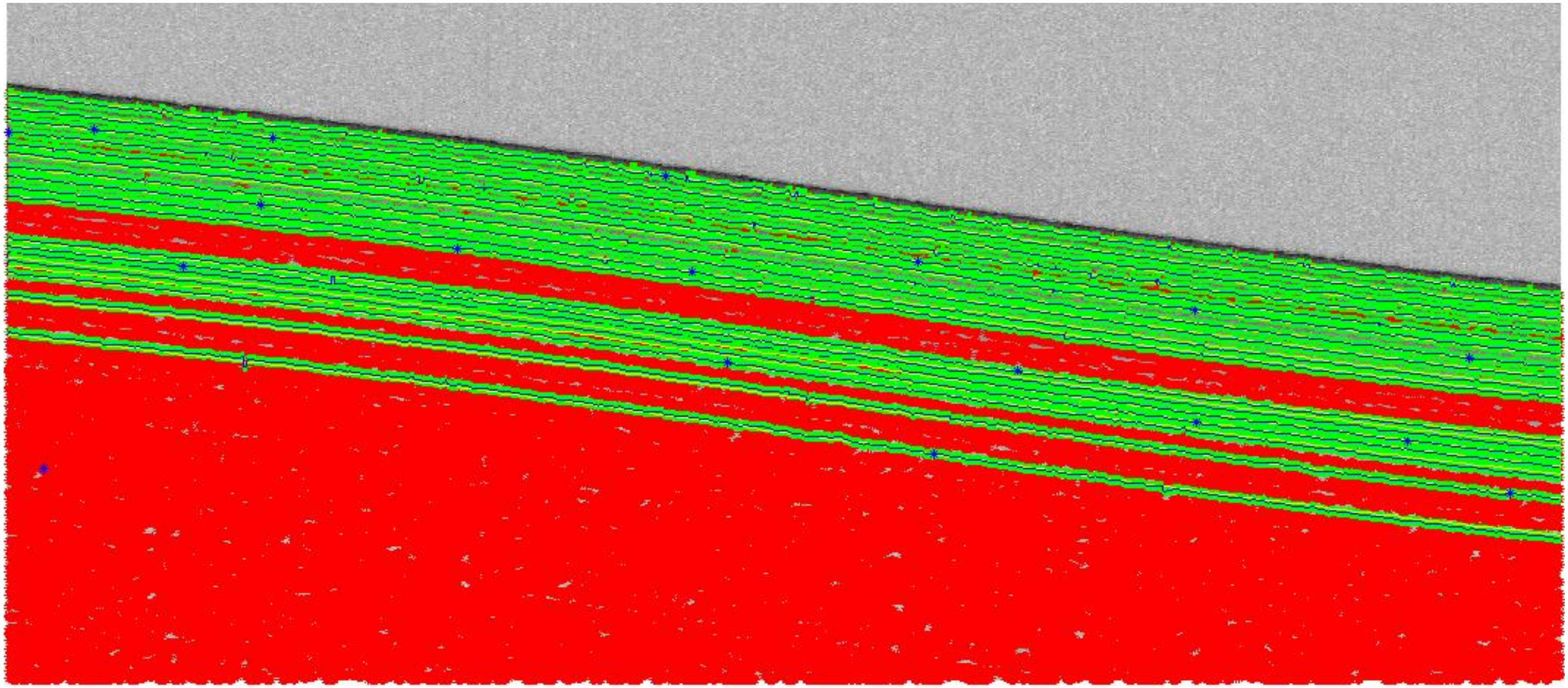

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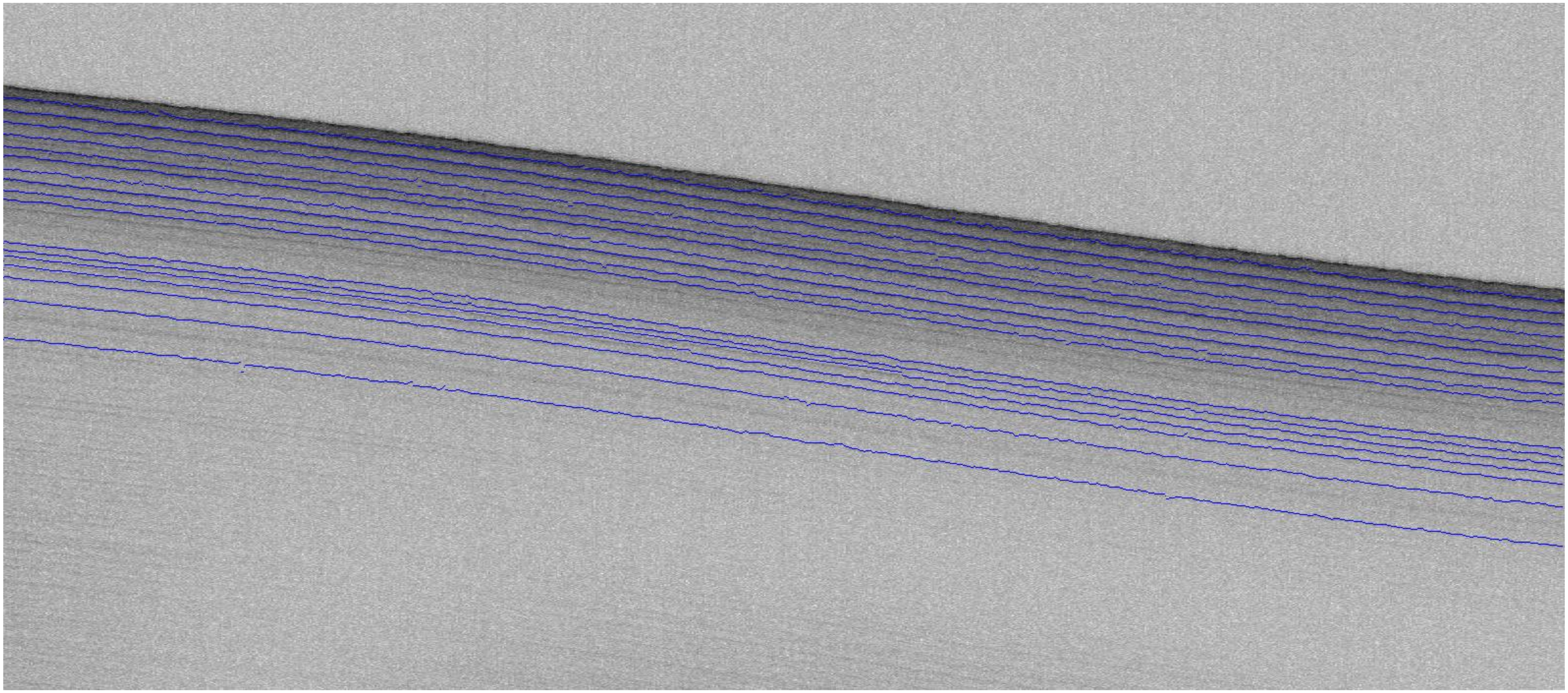

Algorithm for Estimating Near Surface Internal Layers

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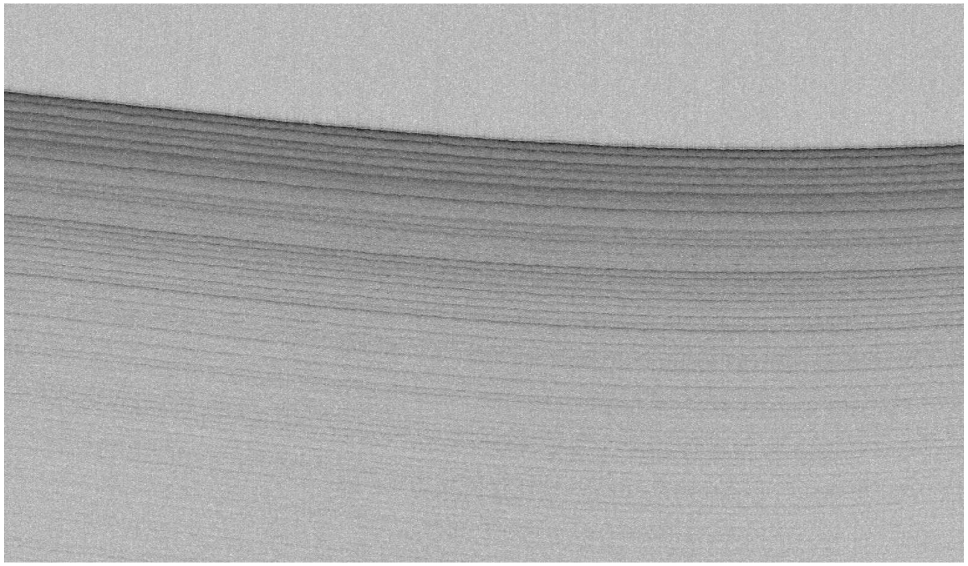
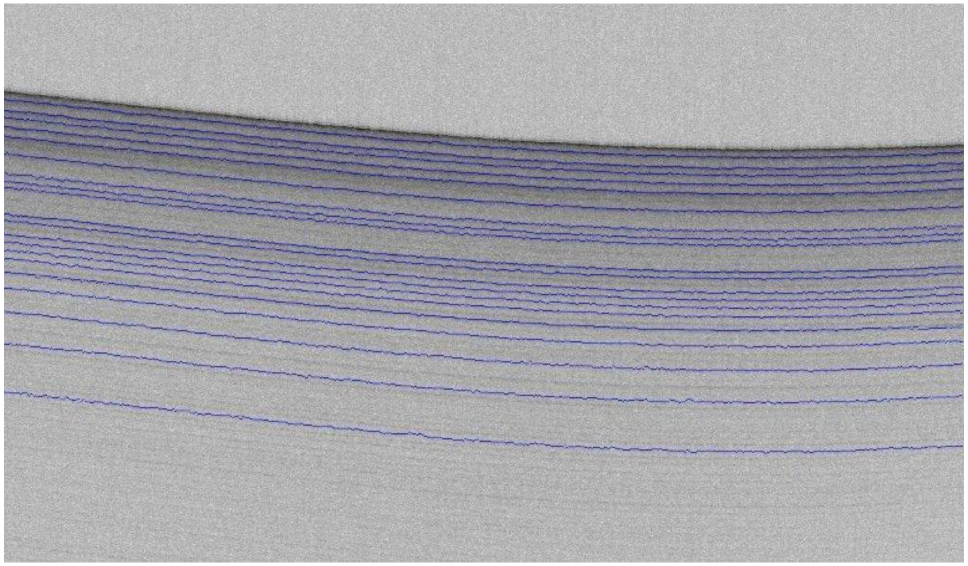
Original Echogram

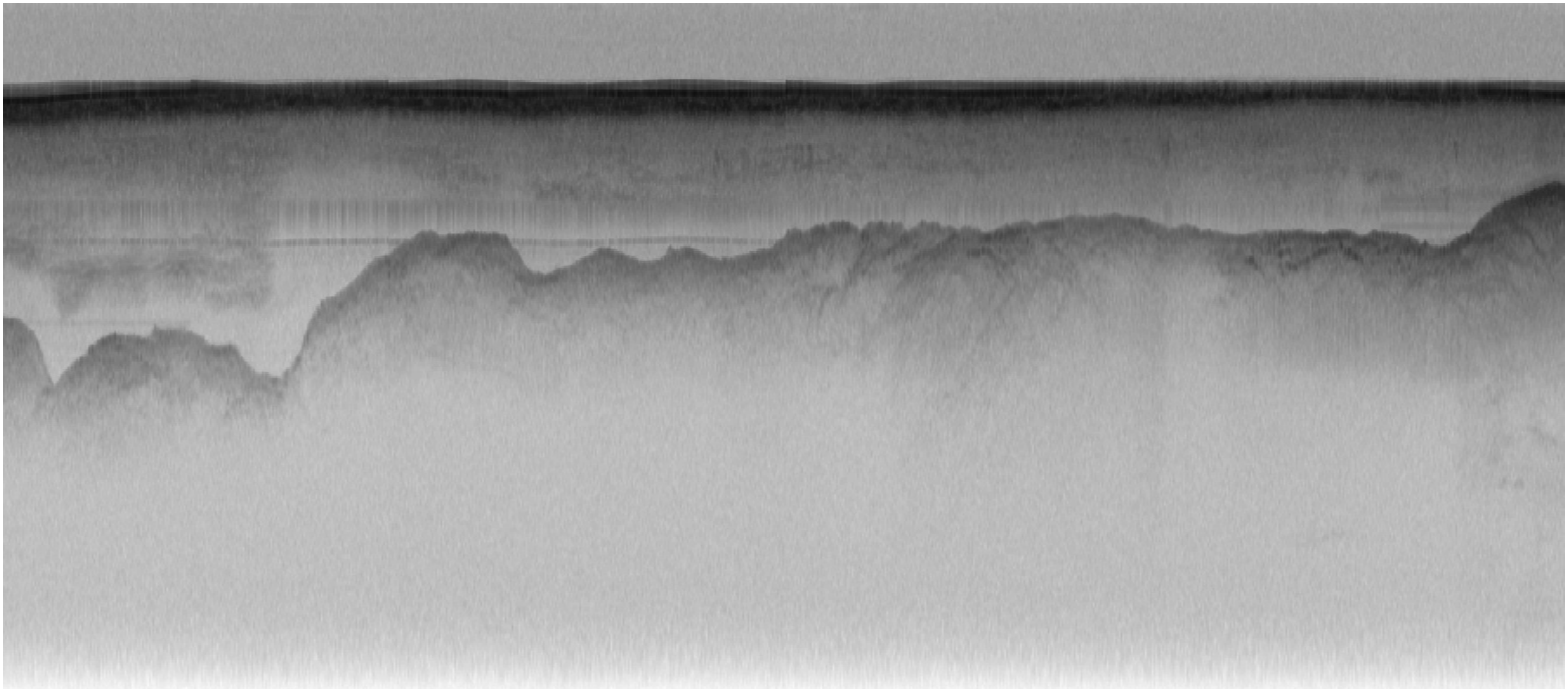


Detected Near Surface Internal Layers Echogram



Quality Issues

- Backscatter introduces clutter
- Near Surface Internal Layers
  - Fuse into other Layers
  - Dis/Reappear
- Near Surface Internal Layer intensity decrease as depth increases
  - Gaps in the bottom lower portion of echogram



Estimating Surface and Bedrock Layers

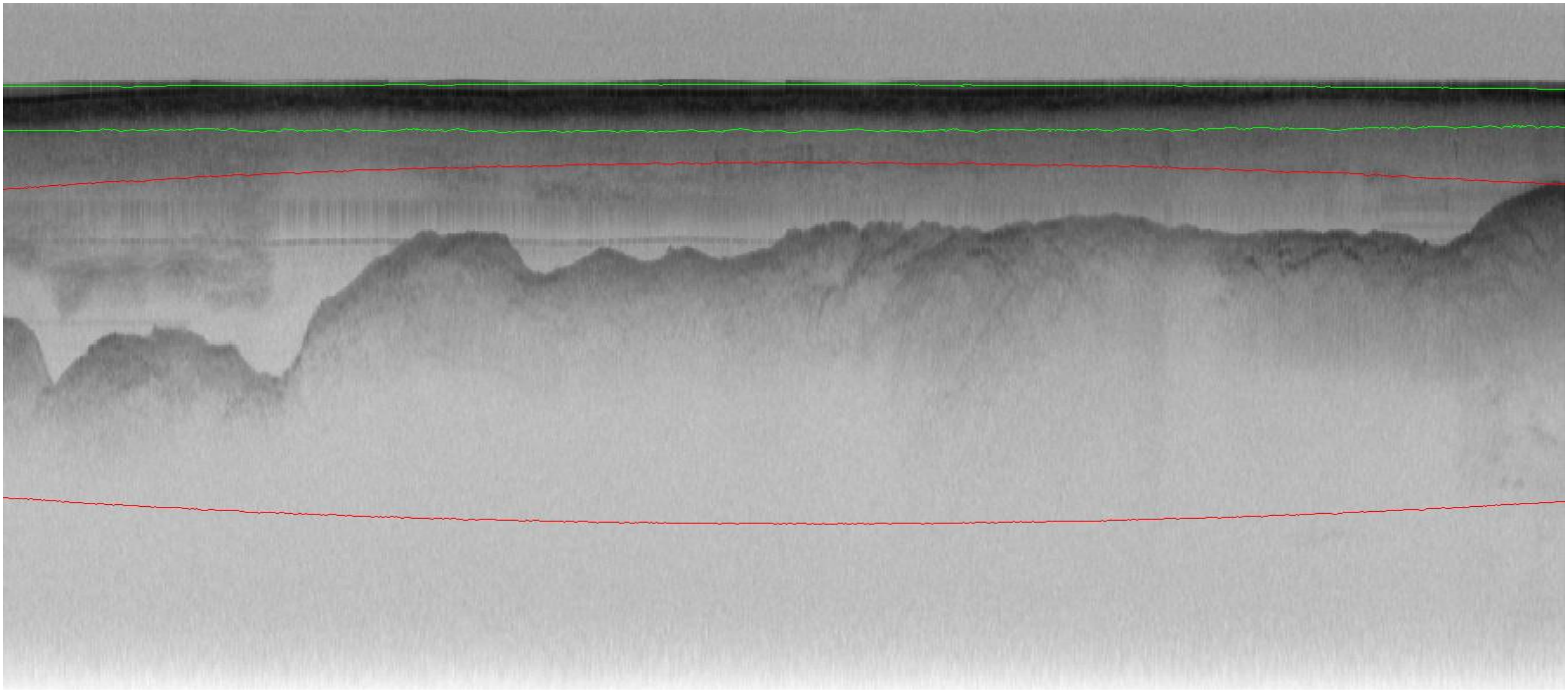
Level Sets

- A level set is defined by a set of points, where the functions is constant (the boundary is zero):

$$\Gamma = \left\{ (x, y) \mid \phi(t, x, y) = 0 \right\}$$

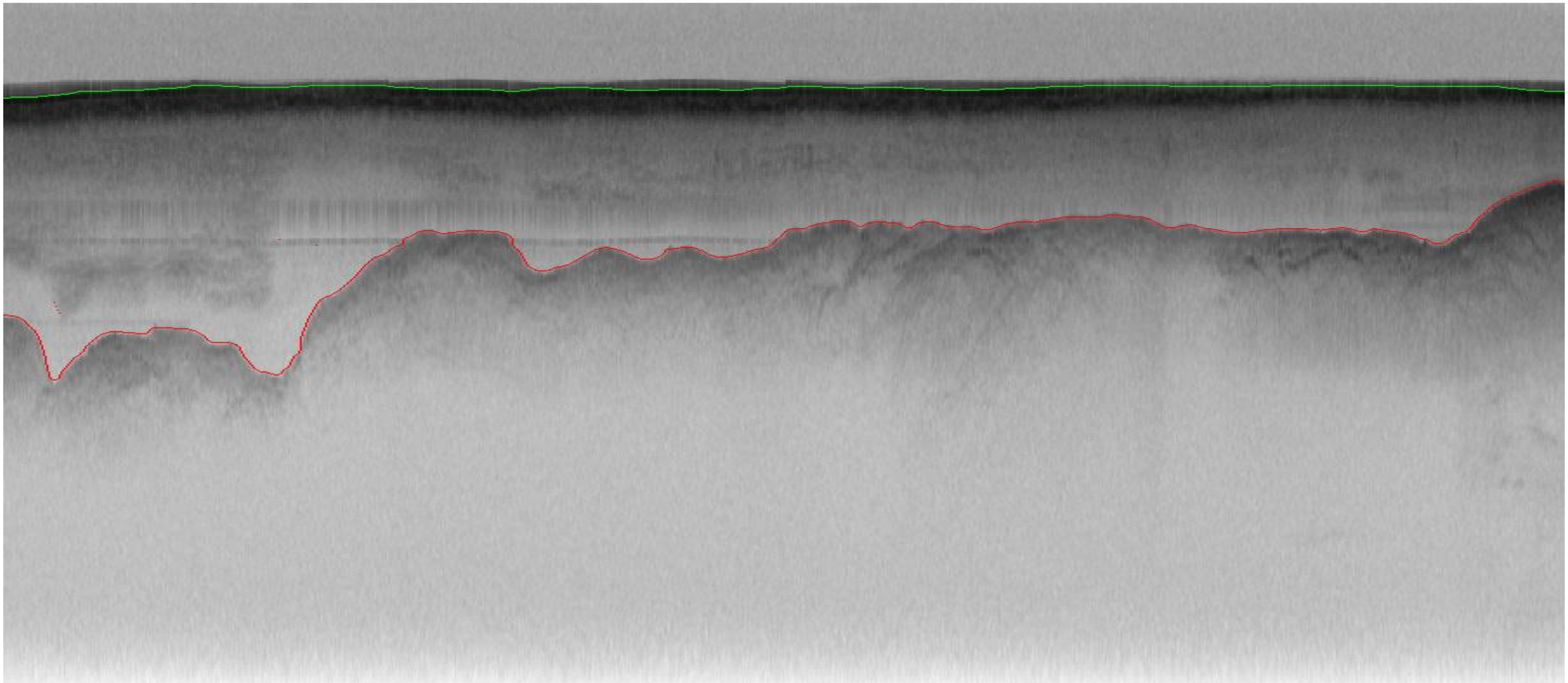
- The level set evolves in a direction normal to a gradient, which is determined by a PDE in order to minimize the cost function

$$g(I) = \frac{1}{(1 + |\nabla G_{\sigma} * I|)^2}$$



Algorithm for Estimating Surface and Bedrock

1. Identify an Ellipse
2. Active Contours (Level Sets)



Algorithm for Estimating Surface and Bedrock

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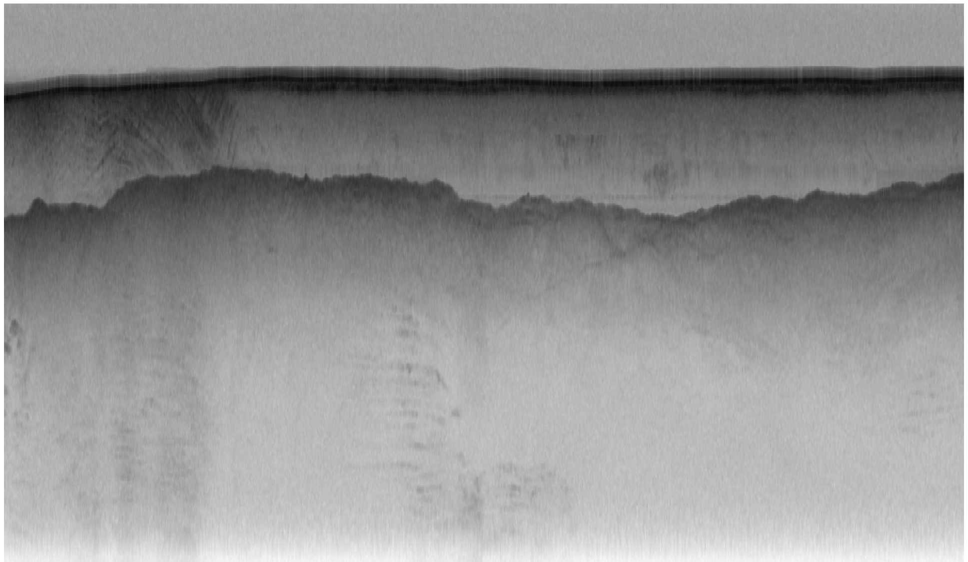
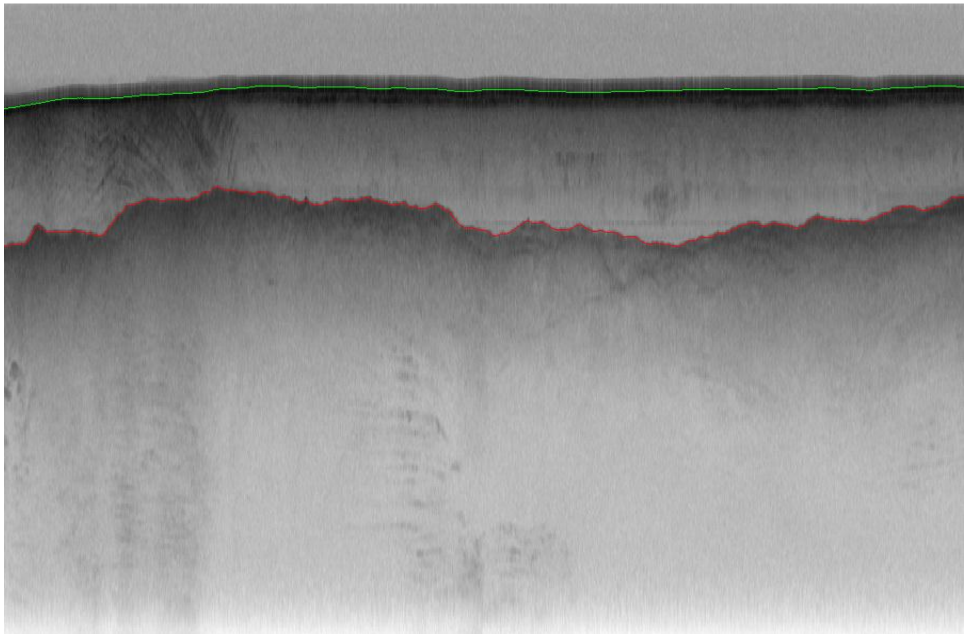
Original Echogram



Detected Surface and Bedrock Echogram



Quality Issues

- Backscatter introduces clutter
- Faint and Discontinuous Bedrock Reflections
- Surface Multiples considered to be the Idea Surface

Conclusion

- Identified Near Surface Internal Layers
  - 2011 Greenland P3 snow radar echograms
- Identified Surface and Bedrock Layers
  - 2009 Antarctica multichannel coherent radar depth sounder echograms

Future Work

- Improve internal, surface, and bedrock Layer detection algorithms for more data products
  - learning algorithms
  - incorporate meta data
  - identify non layers

Questions

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