A Survey of Techniques for Detecting Layers in Polar Radar Imagery

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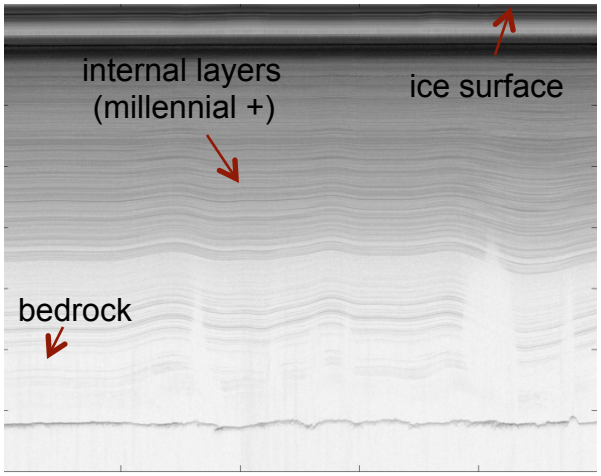
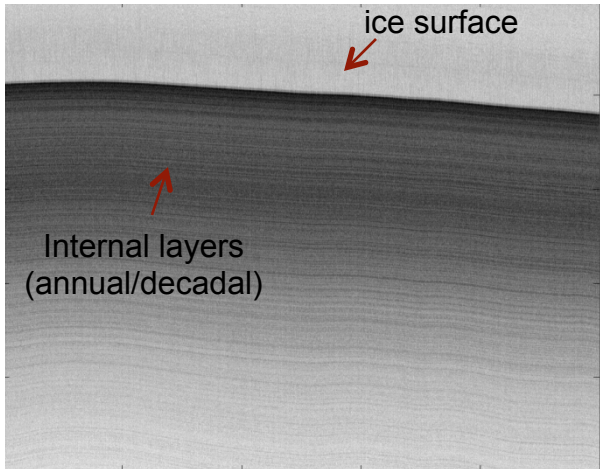
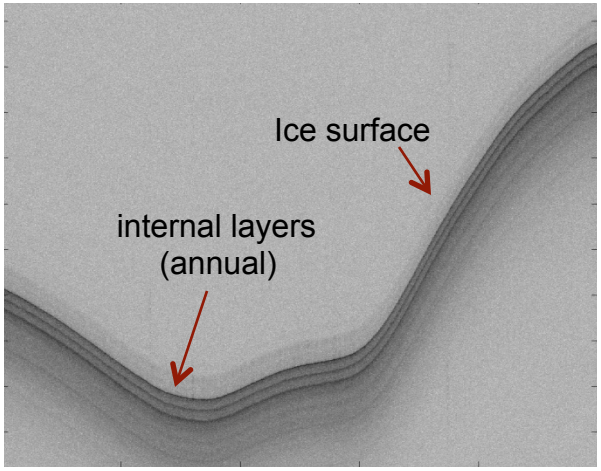
Depth Sounder



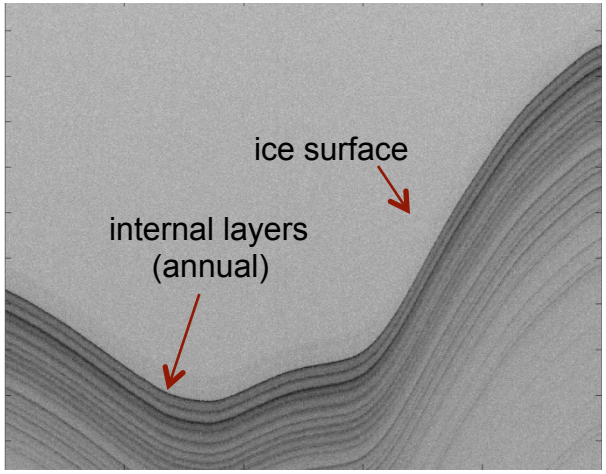
Accumulation



Ku-Band Altimeter



Snow Radar



Introduction

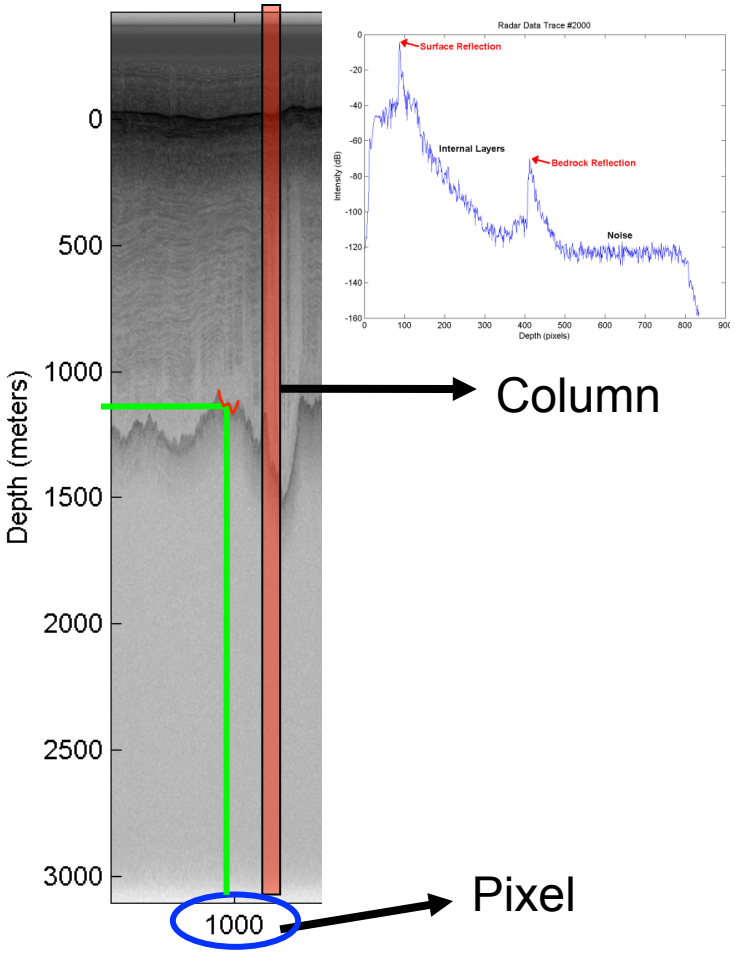
- The Problem
- Understanding Layers in the radar images:

  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 semi-automated and automated tools for tracing Layers in radar imagery

RADAR Imagery

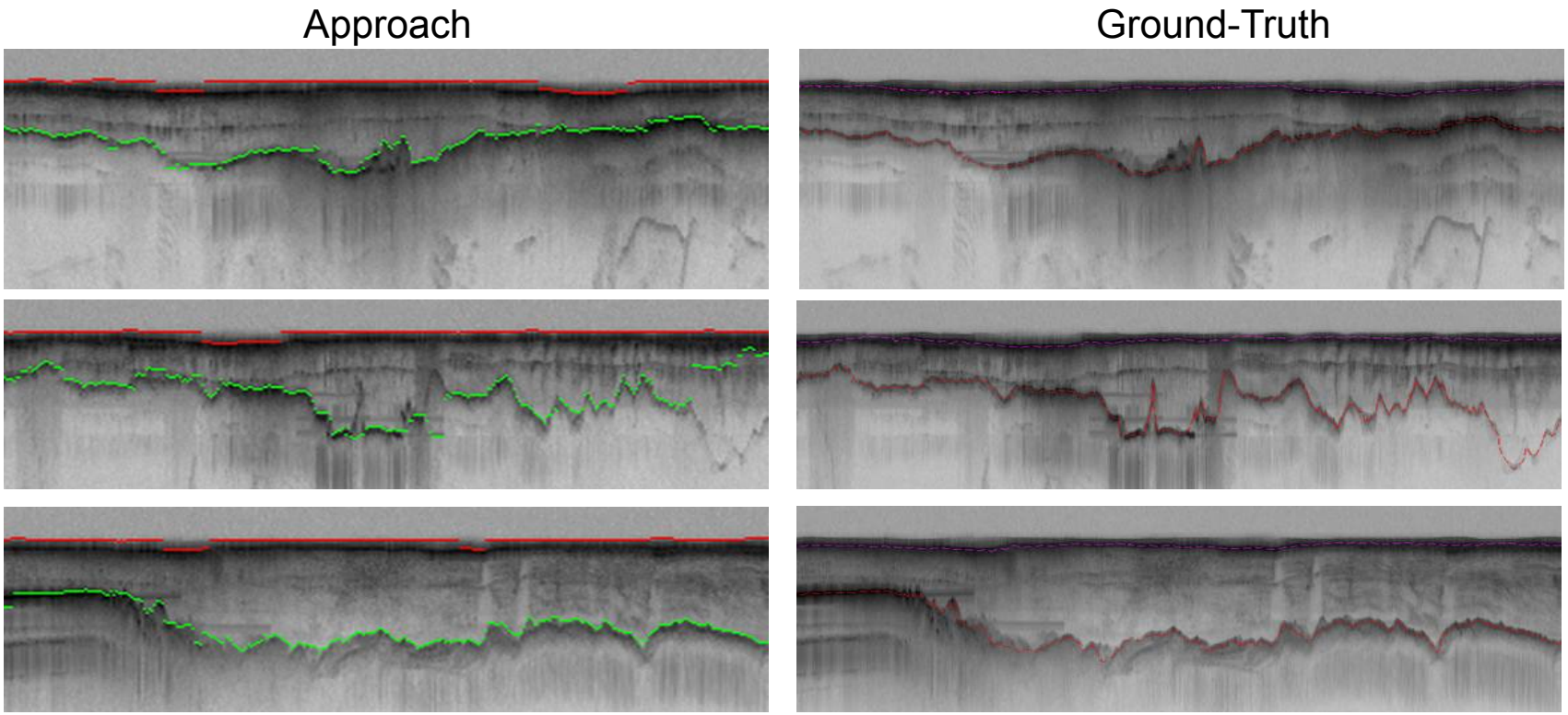
- A radar trace consist of signals, representing energy due to time.
- In an image, a trace is an entire column of pixels, each pixel represents a depth.
- Each row corresponds to a depth and time for a measurement, as the depth increases further down.



Challenges in Processing RADAR Imagery

- Bedrock/Surface Layers
  - Two Layers (but, false positives)
  - Low magnitude, faint, or non-existent bedrock reflections
  - Strong surface reflections can be repeated in an image causing surface multiples
- Near Surface Internal Layers
  - Multiple Layers (a couple dozen)
  - Fuse into existing Layers
  - Disappear and Reappear

Bedrock (Hidden Markov Model)



Crandall, Fox, Paden, "**Layer-finding in Radar Echograms using Probabilistic Graphical Models**", International Conference on Pattern Recognition (ICPR), 2012.

Active Contours

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

  Level Sets, Intelligent Scissors, Snakes

Level Sets

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

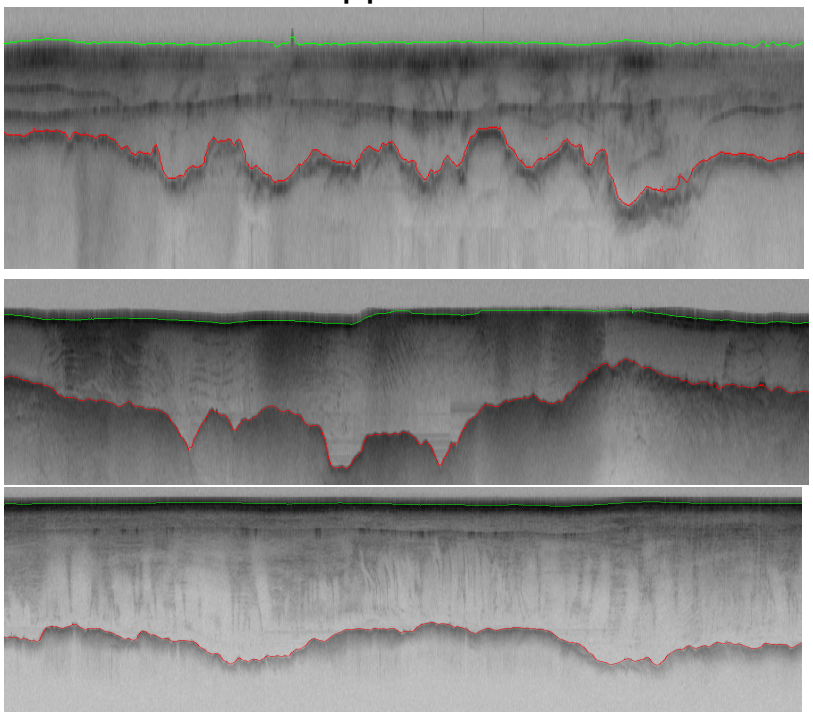
$$\Gamma = \{(x, y) \mid \phi(t, x, y) = 0\}$$

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

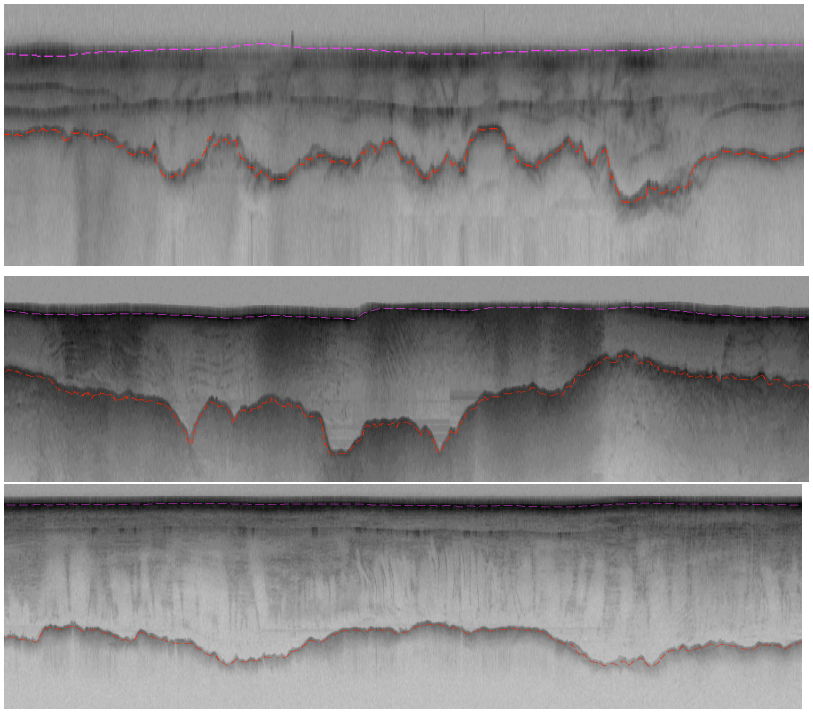
$$g(I) = \frac{1}{(1 + |\nabla G_\sigma * I|)^2}$$

Bedrock (Level Set)

Approach



Ground-Truth



Mitchell, Crandall, Fox, and Paden, "**A Semi-Automatic Approach for Estimating Bedrock and Surface Layers from Multichannel Coherent Radar Depth Sounder Imagery,"** SPIE Remote Sensing, 2013

Bedrock: Level Sets vs. Hidden Markov Model

Approach	Bedrock		Surface	
	ME	MSE	ME	MSE
Level Set	7.1	342.0	4.1	31.8
Hidden Markov Model	37.5	11700.0	14.6	490.3

We performed 5 and 3.5 times better, on average, than the hidden markov model for tracing bedrock and surface layers, respectively.

Bedrock Approaches…

- Active Contours (“Snakes”)

Automated Polar Ice Thickness Estimation From Polar Radar Imagery

Christopher Gifford, Gladys Finyom, Michael Jefferson, MyAsia Reid, Eric Akers, and Arvin Agah

- Statistical Map Generation and Segmentation

A Technique for the Automatic Estimation of Ice Sheet Thickness and Bedrock Properties from Radar Sounder Data Acquired at Antarctica

Ana-Maria Illsei, Adamo Ferro and Bruzzone

Snakes

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

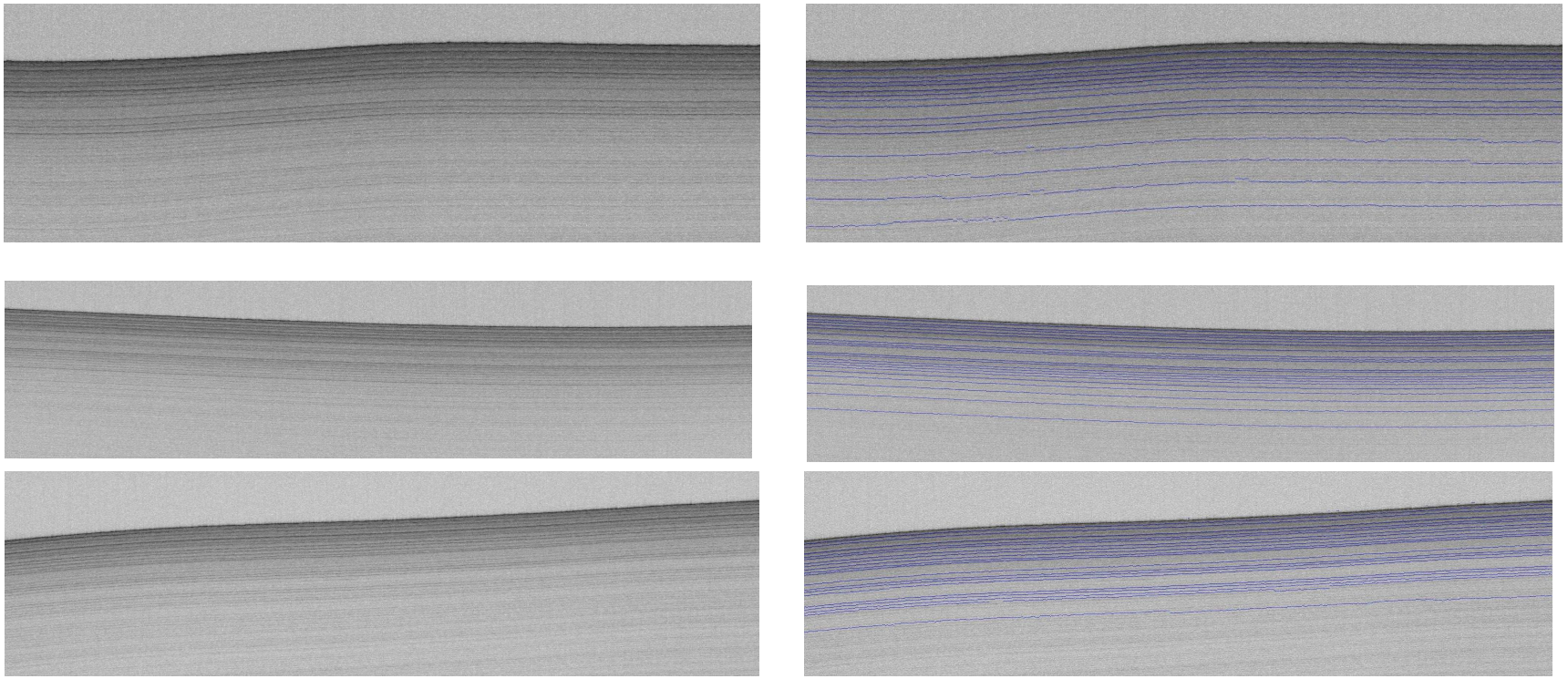
$$v(s) = (x(s), y(s)), s \in [0,1]$$

- 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.

Near Surface Internal Layers



Mitchell, Crandall, Fox, and Paden, **"A Semi-Automated Approach to Estimating Near Surface Internal Layers from Snow Radar Imagery",** International Geoscience and Remote Sensing (IGARSS), 2013.

Internal Layer Approaches…

- Cross-correlation and a Peak following routine

Internal Layer Tracing and Age Depth Accumulation Relationships for the Northern Greenland Ice Sheet

M. Fahnestock, W. Abdalati, S. Luo, and S. Gogineni

- Ramp based function

Tracing the Depth of the Holocene Ice in North Greenland from Radio-Echo Sounding Data

Nanna B. Karlsson, Dorthe Dahl-Jensen, S. Prasad Gogineni, and John D. Paden

- ARESP 6 Phases

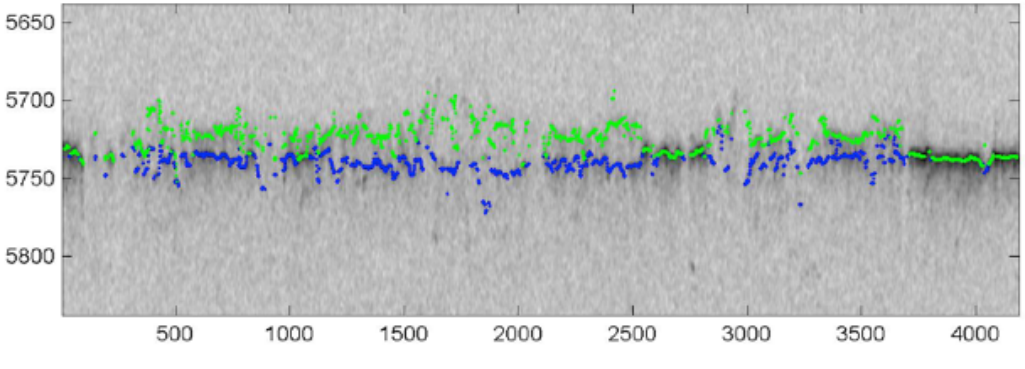
Automated Processing to Derive Dip Angles of Englacial Radar Reflectors in Ice Sheets

Louise C. Sime, Richard C.A. Hindmarsh, Hugh Corr

SNOW RADAR DERIVED SURFACE ELEVATIONS AND SNOW DEPTHS MULTI-YEAR TIME SERIES OVER GREENLAND SEA-ICE DURING ICE BRIDGE CAMPAIGNS

Dragana Perkovic-Martin, Michael P. Johnson, Benjamin Holt, Ben Panzer, Carl Leuschen

Method:
Support Vector Machine
Training/Testing
Results:
56.08% of the 430,000 measurements were determined to be tracked



Other Techniques for Detecting Layers…

- Finding, following, and linking edge fragments to construct curve corresponding to either one or more image feature

R. Czerwinski, D. Jones, and W. O'Brien, Jr., "Line and boundary detection in speckle images," IEEE Trans. Image Process., vol. 17, no.12, pp. 1700–1714, Dec. 1998.

- Pyramid-based edge detection for identifying image objects and lines

P. S. Wu and M. Li, Pyramid edge detection based on stack filter," Pattern Recognit. Lett., vol. 18, pp. 239–248, 1997.

- Image texture used as a descriptor for segmenting images into constituent parts or identifying image regions

M. Tuceryan and A. K. Jain, The Handbook of Pattern Recognition and Computer Vision (2nd Edition). Singapore: World Scientific, 1998, ch. 2.1, pp. 207–248.

P. Xu, M. Dai, and A. Chan, "A comparison on texture classification algorithms for remote sensing data," in Proc. IEEE Int. Geoscience Remote Sensing Symp., Sep. 2004, vol. 2, pp. 1057–1060.

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Conclusion

- Identified representation of estimating layers in
  - Bedrock and Surface
  - Internal Layers
  - Interface Layers (air/snow, snow/ice)
- Discussed techniques, which can aid in solving the Layer problem

Discussion/Questions?