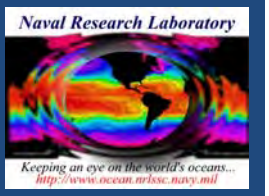

Effects of Sea Ice Surface Roughness on Remotely Sensed Thickness Values

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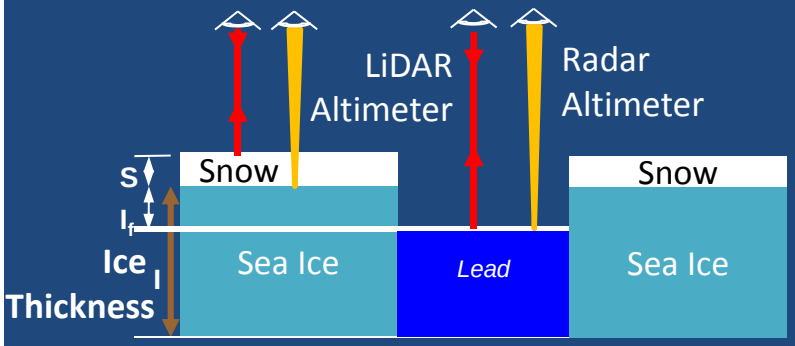
[3]Cold Regions Research and Engineering Lab – Hanover, NH

Overview

- Sea Ice Thickness using Altimeter Data
- Physical Waveform Model
- Barrow 2014 Fieldwork – Early Results
- Summary

Measuring Sea Ice Thickness Using Altimeter Data



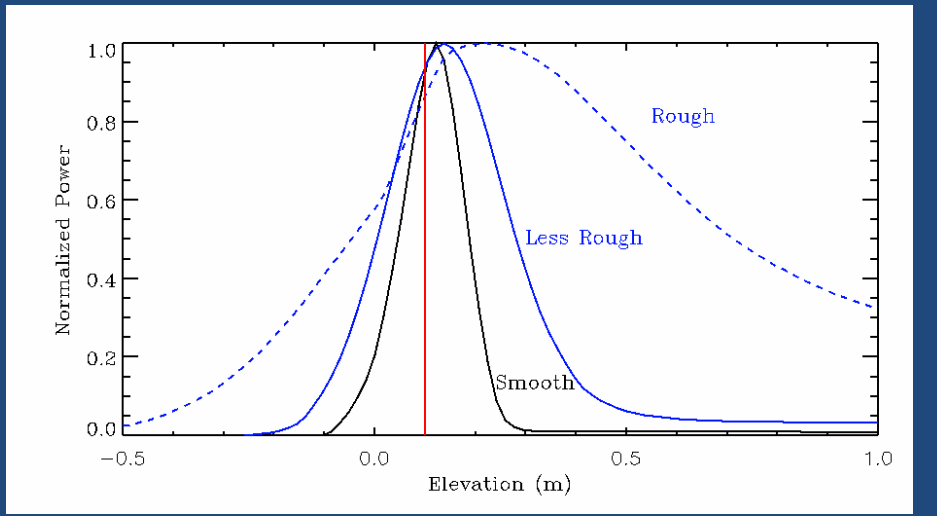
Technical Approach

- **Altimeters are used to measure the snow/ice freeboard**
- **Lead is used as a reference surface**
- **Mass balance is used to infer ice thickness (I)**

$$I = \frac{\rho_w}{\rho_w - \rho_i} I_f + \frac{\rho_s}{\rho_w - \rho_i} S$$

Two Fundamental Questions Remaining:

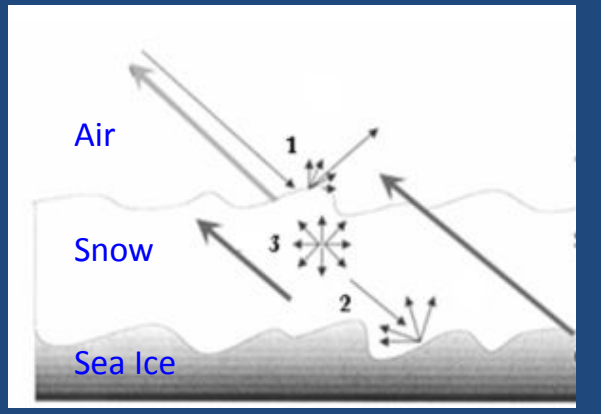
- **Where is the surface position in the returned echo?**
  - » **Depends on the surface roughness**
- **Can the roughness effect be account for?**
  - » **Need a rough surface scattering model for the waveform**



NRL Physically-Based Waveform Model

Combined Snow Volume and Ice/Lead Surface Scattering

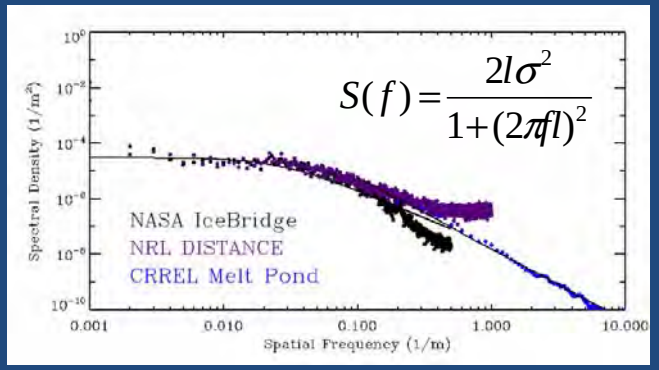
- The radar returned waveform has three contributions
  1. Snow Surface
  2. Sea Ice Surface
  3. Snow Volume



- Surface Scattering depends on rough surface power spectra density function (PSD)
  - Sea ice PSD is largely unknown. Use limited surface data from airborne/ground based LiDAR.
  - PSD is parameterized Lorentzian Model
    - Surface RMS Height (σ)/slope(σ_s), correlation length (l)

Surface Elevation $y(x)$ → Power Spectra Density(PSD) *Fourier Transform* $S(f) = \left| \int y(x) \cos(2\pi f) dx \right|^2$ → Parameterization: Use a small number of variables to describe PSD

Lorentzian Model

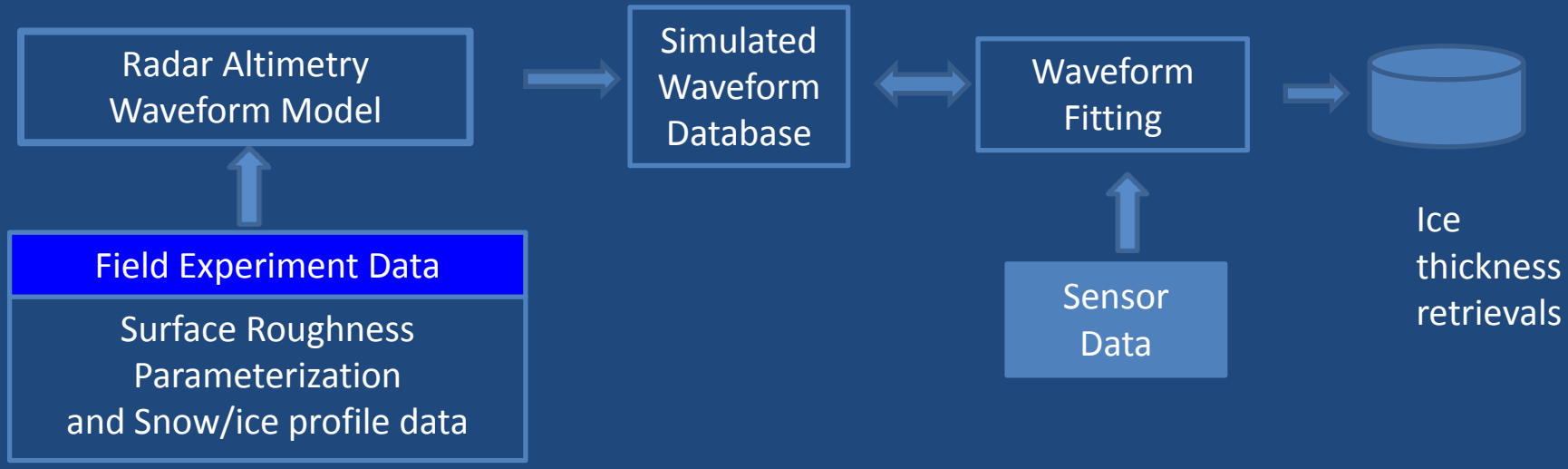


- The volume scattering known from land snow research

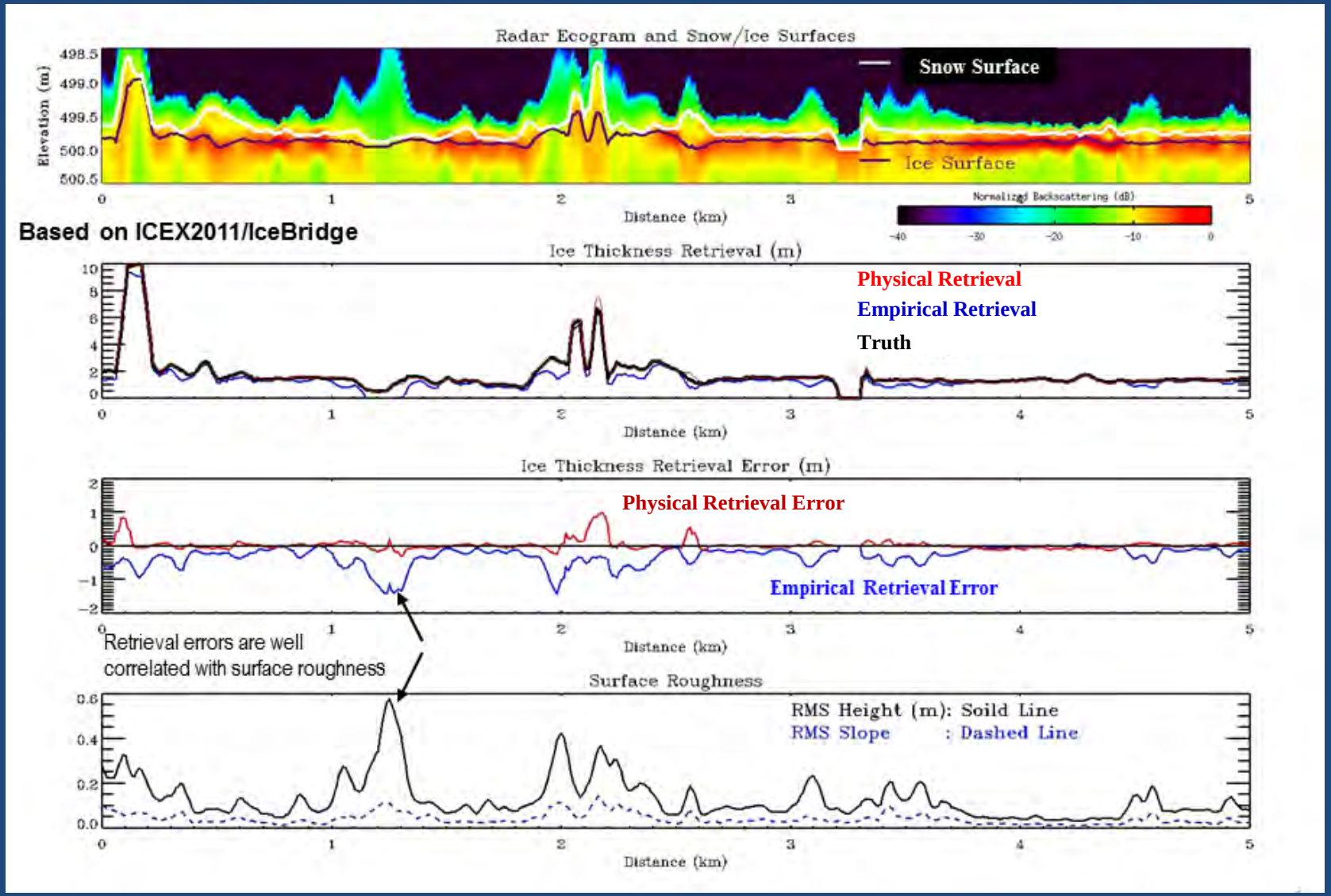
A Physically Based Sea Ice Thickness Algorithm

Approach: fitting the radar returns with the physically based waveform model

- Simulated waveform database using field experiment data
  - Surface roughness parameterization
  - Snow depth/density and ice freeboard/surface roughness
- Matching radar returns to simulated waveform in database
  - Simultaneous retrieval of surface elevation and roughness

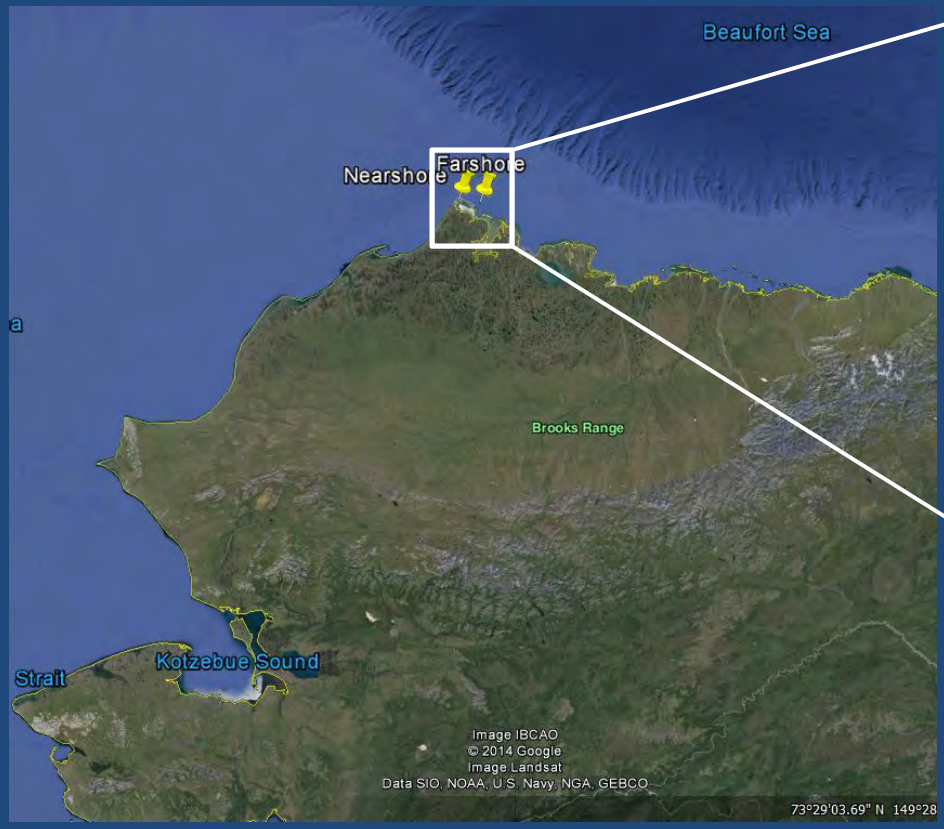


Results – waveform



Barrow Fieldwork 2014

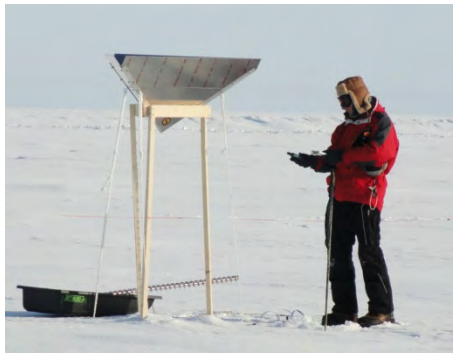
Two field sites: nearshore and farshore



- Nearshore: Just off “Point Barrow”
- Farshore: 20 miles from Barrow
- Both sites were “fast” ice
- “Fast” = Landfast = not moving
  (Not “fast moving”)

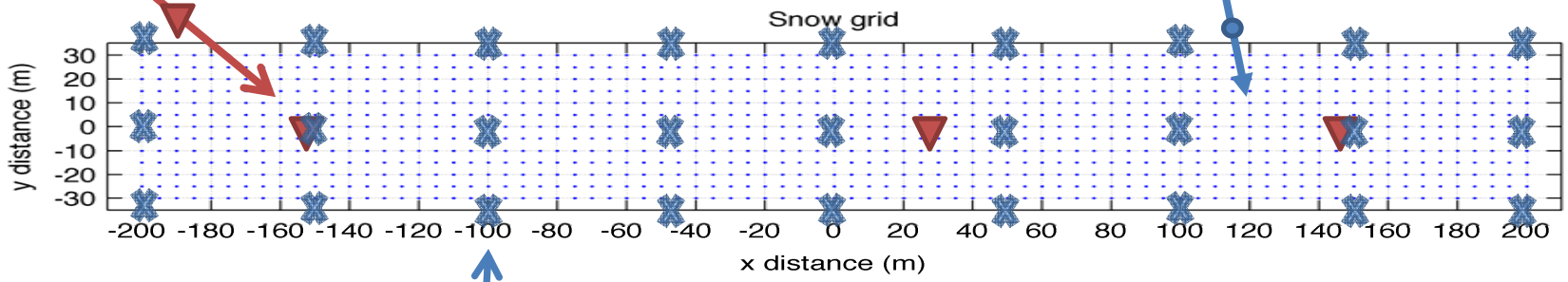
Barrow Fieldwork 2014

Radar Reflectors



Snow Depth Every 5 meters

400m x 60m

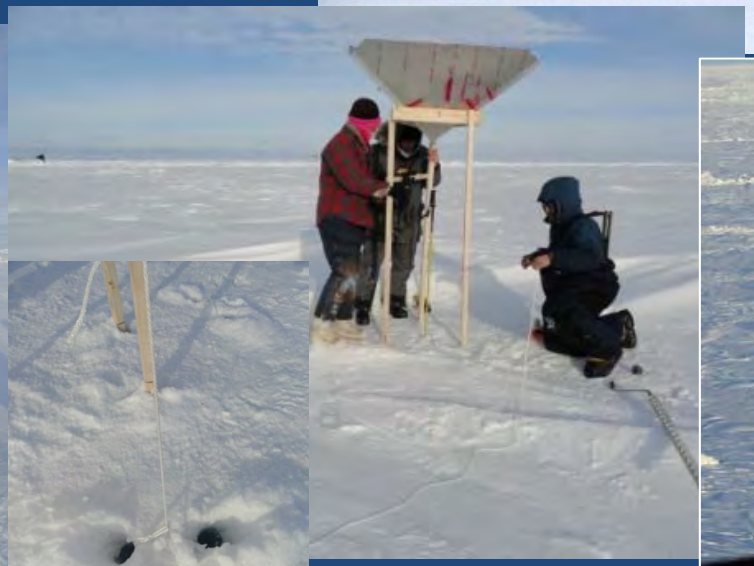


Ice Thickness Every 50 Meters

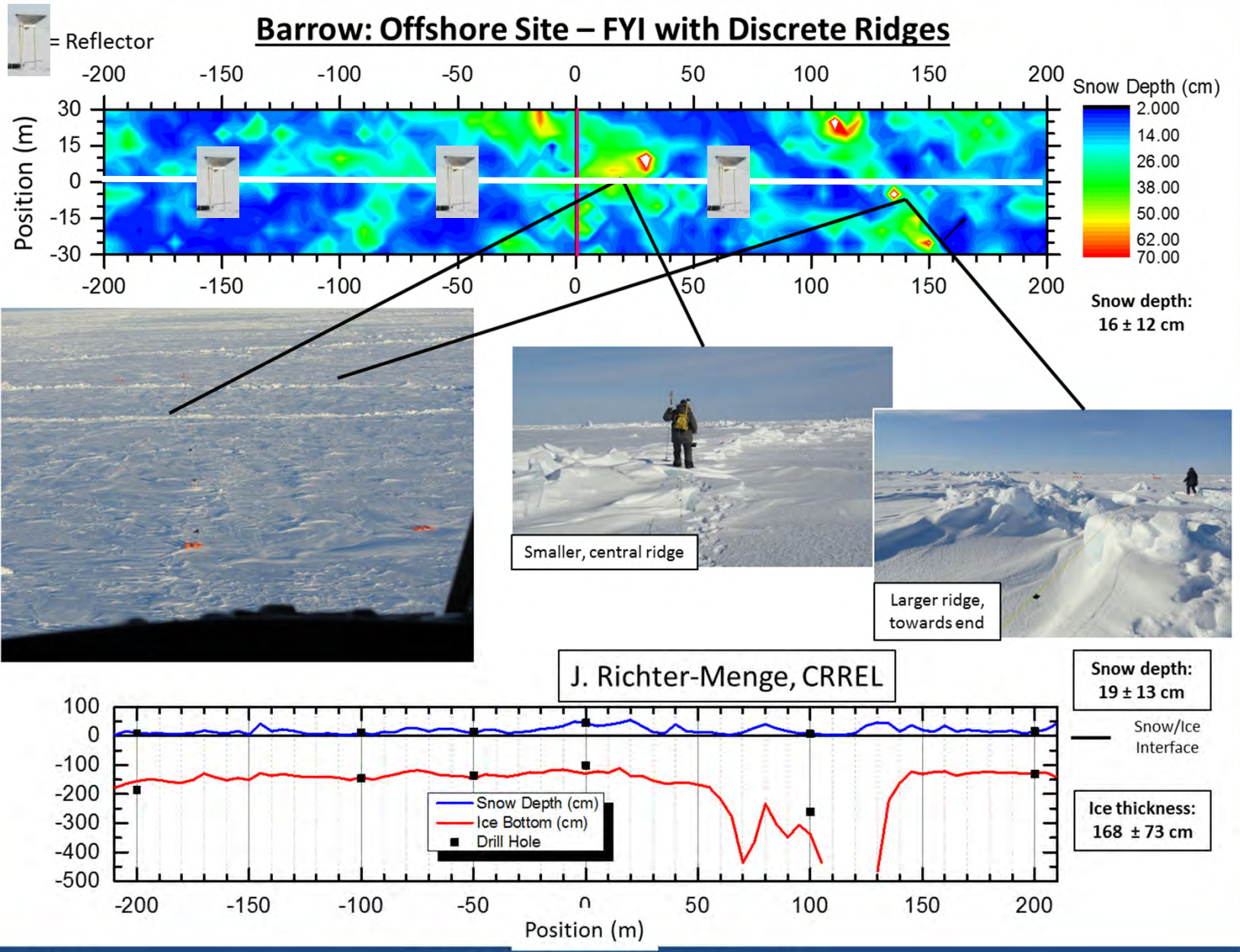
LIDAR of each site

EM Ice Thickness 5 meters along centerline

Ground Site Setup

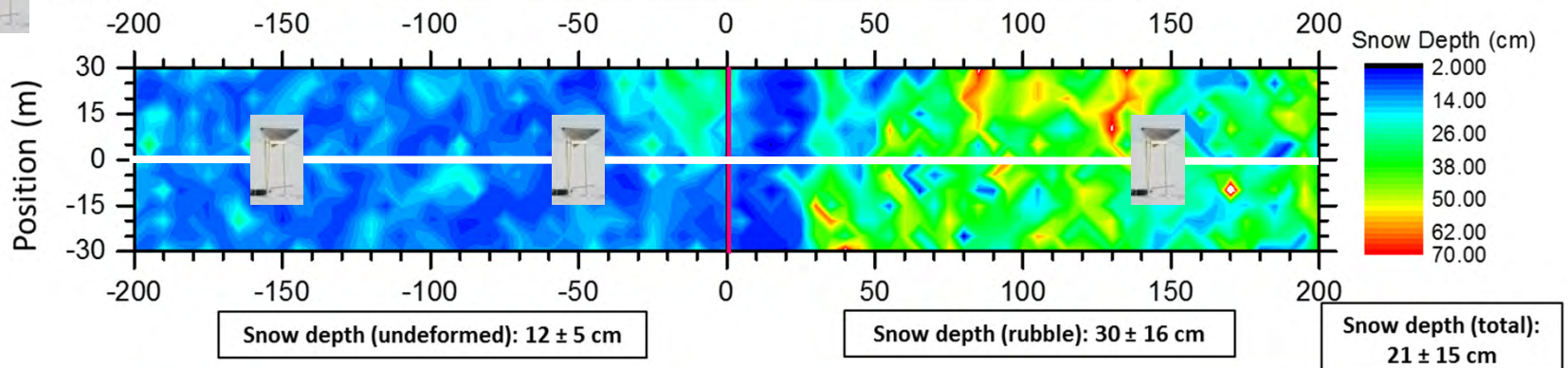


Barrow: Offshore Site – FYI with Discrete Ridges



Barrow: Nearshore Site – FYI with Rubble


= Reflector



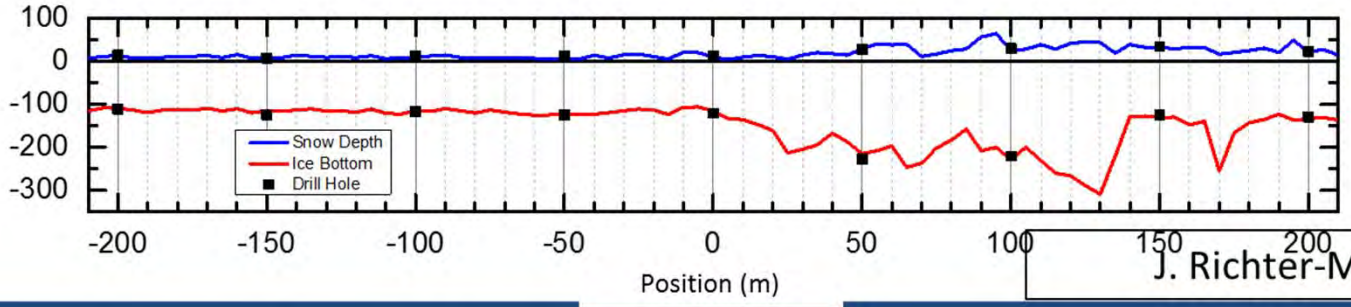
Snow depth (undeformed): 12 ± 5 cm

Snow depth (rubble): 30 ± 16 cm

Snow depth (total): 21 ± 15 cm


Undeformed


Rubble



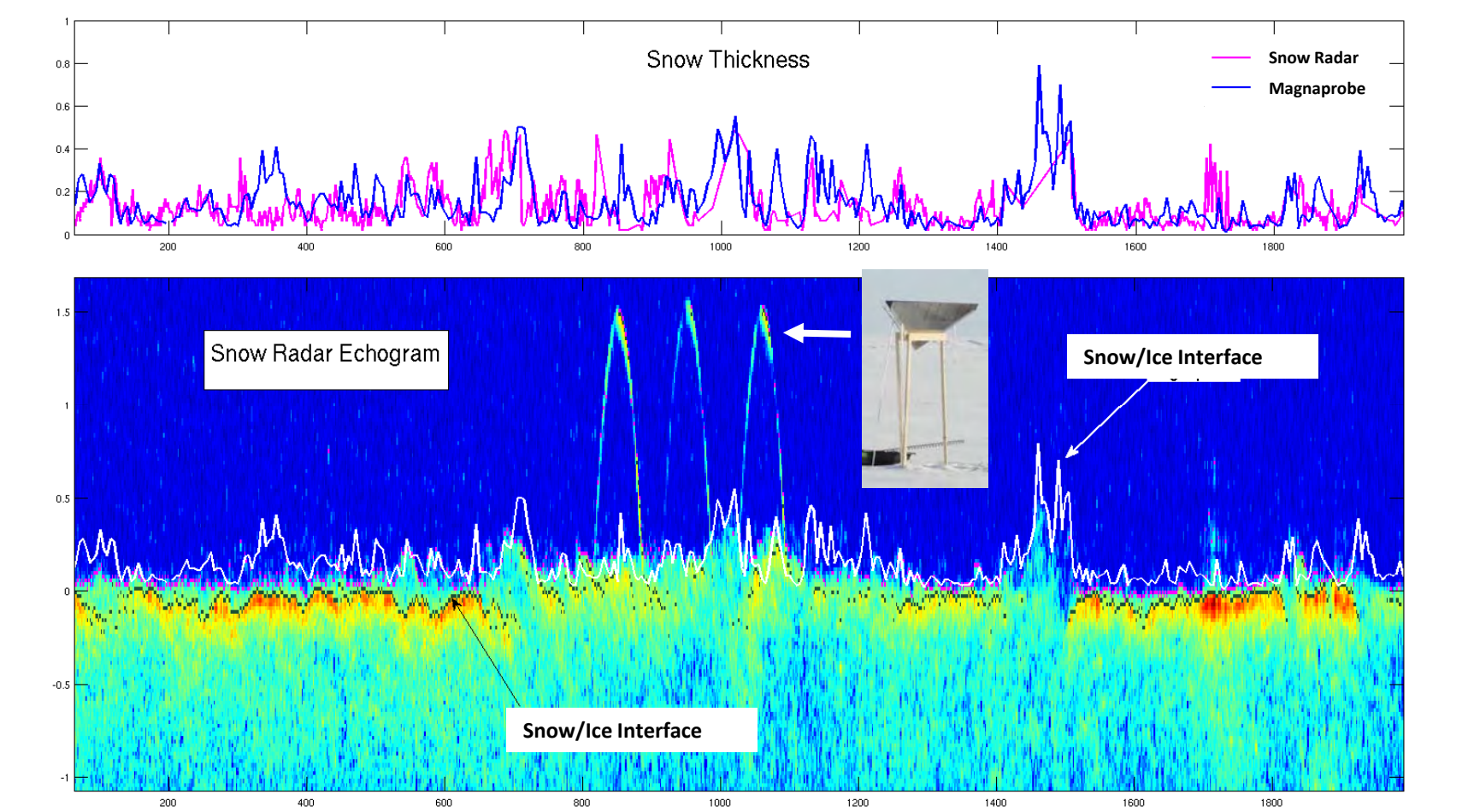
Snow depth: 19 ± 13 cm

Snow/Ice Interface

Ice thickness: 151 ± 50 cm

J. Richter-Menge, CRREL

Results – Aircraft



Joan Gardner, NRL-DC

Summary

- Surface roughness affects the shape of radar returned waveform
- Currently empirical formulations based on smooth surface used to determine ice thickness
- Developed new physically based radar retrieval
- Significantly reduced ice thickness error from IceBridge data
- Physically based algorithm being tested on Airborne and Ground LiDAR data from field data Barrow 2014

Thank You