Characterizing the Location and Extent of the Thwaites Glacier Grounding Zone Using Airborne Radar Sounding

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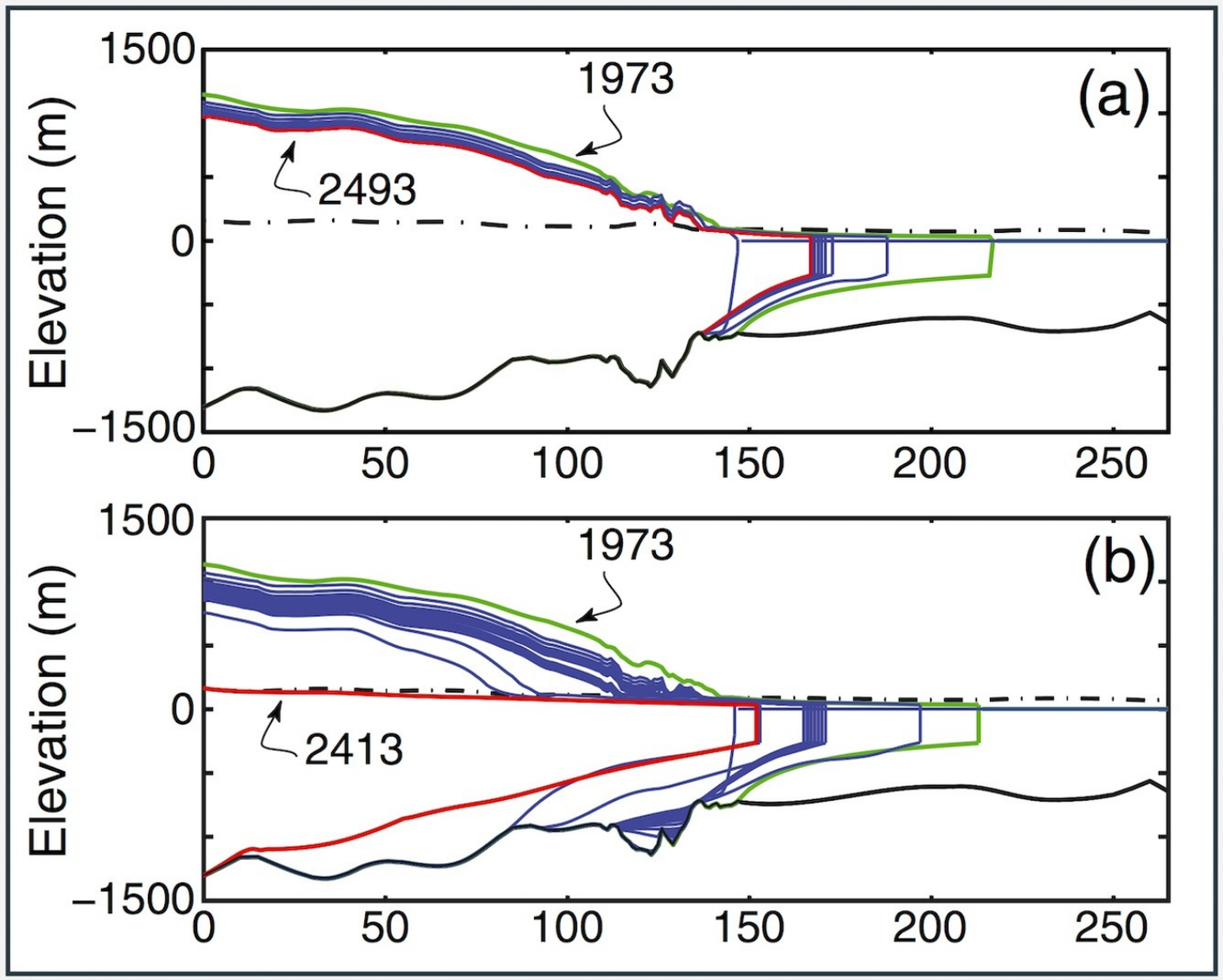
Grounding Zone Extent and Ice Sheet Stability

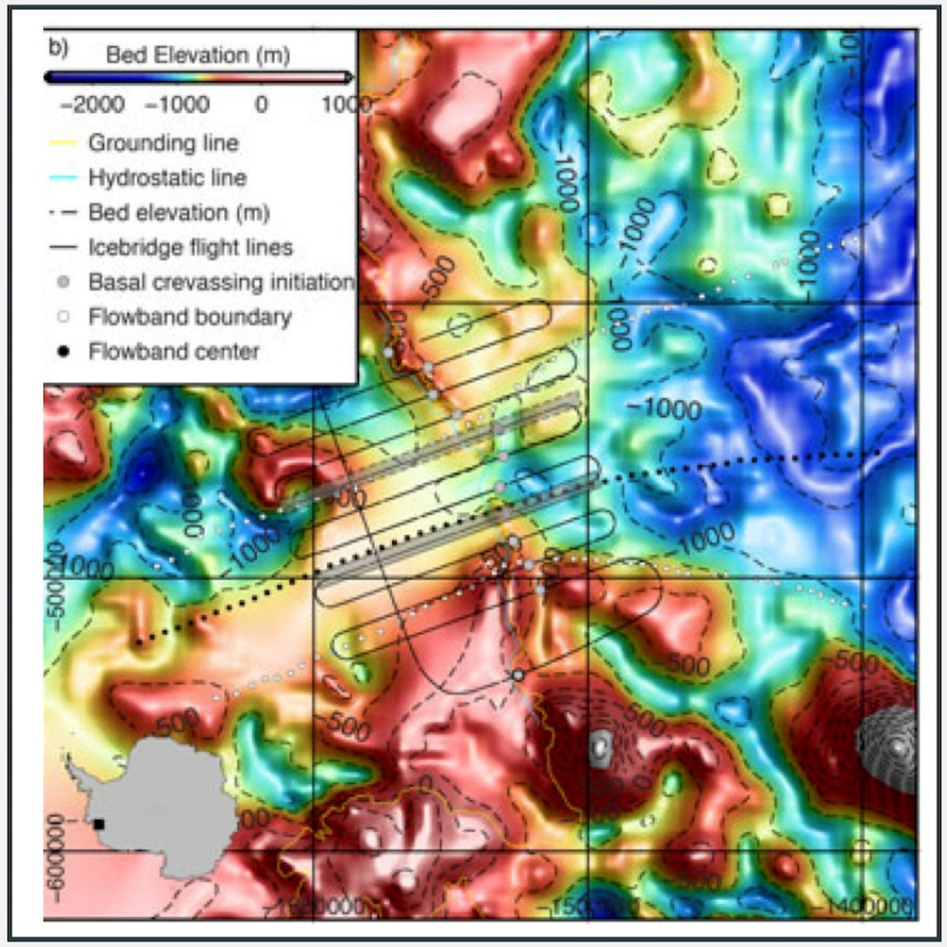
A Dynamically Critical Parameter at the Kilometer Scale

Grounding Zone Extent vs. Stability



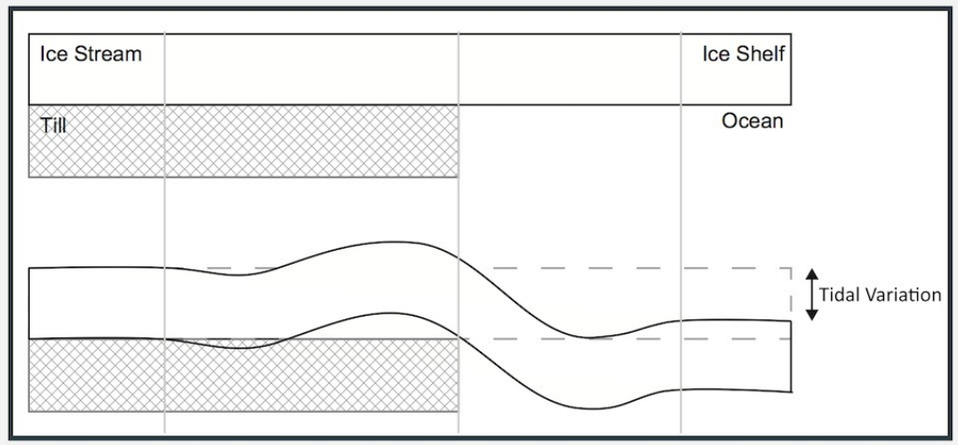
Parizek et al, *JGR*, 2014

Grounding Zone Geometry



Parizek et al, *JGR*, 2014

Tidal Flexure

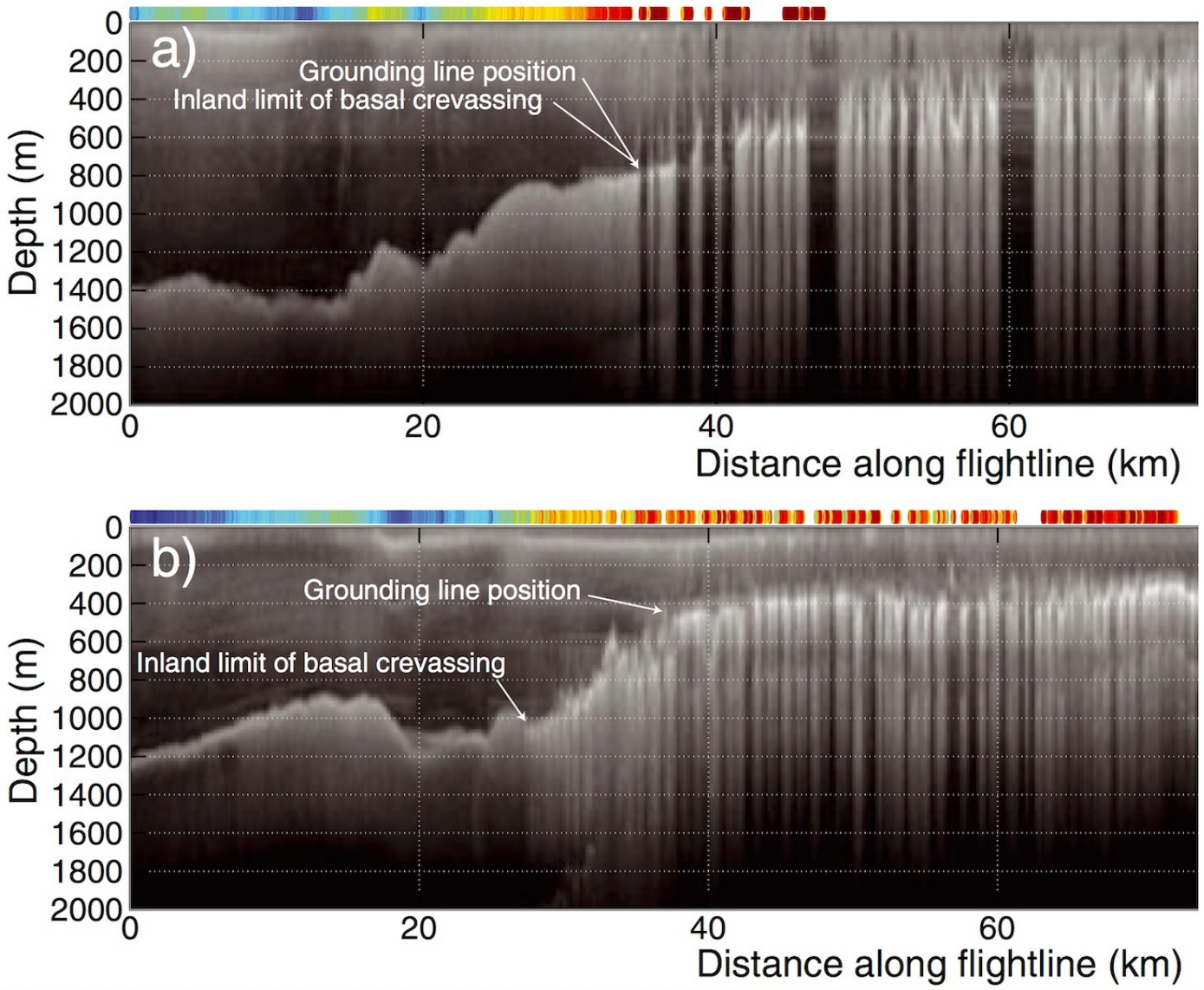


Walker et al, *EPSL*, 2013

Radar Sounding Interpretation of the Grounding Zone

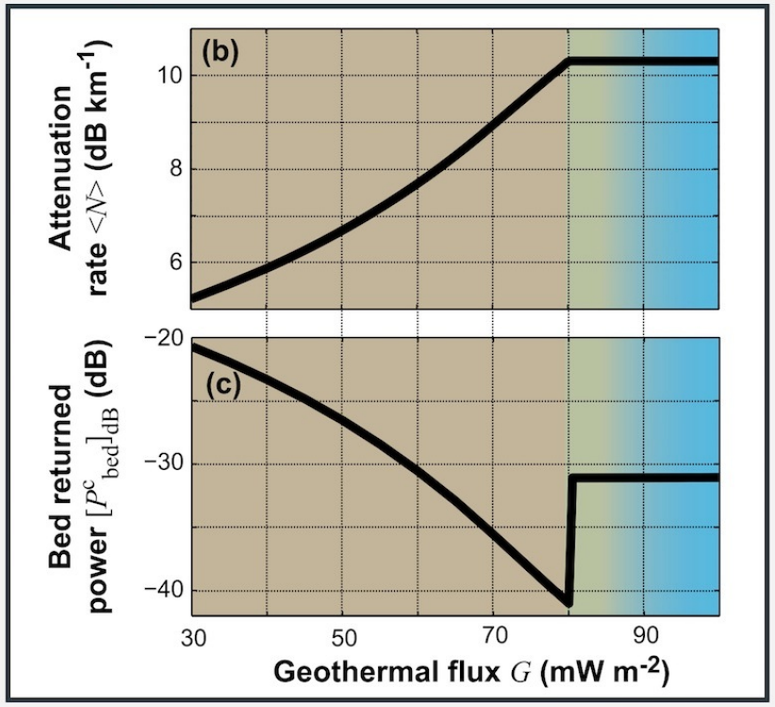
Finding a 10-dB/10-km Needle in Thermal and Geometric Haystack

Grounding Zone Radar Sounding Data



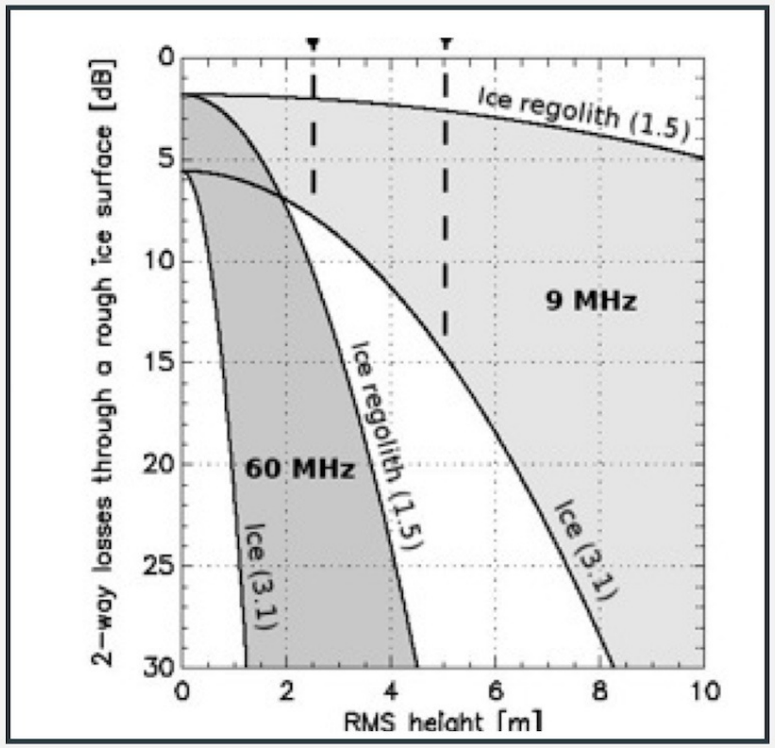
Parizek et al, *JGR*, 2014

Englacial Attenuation



Matsuoka , *GRL*, 2011

Surface Losses



Can Radar Sounding Echo Strengths be Used to Unambiguously Characterize Grounding Zones?

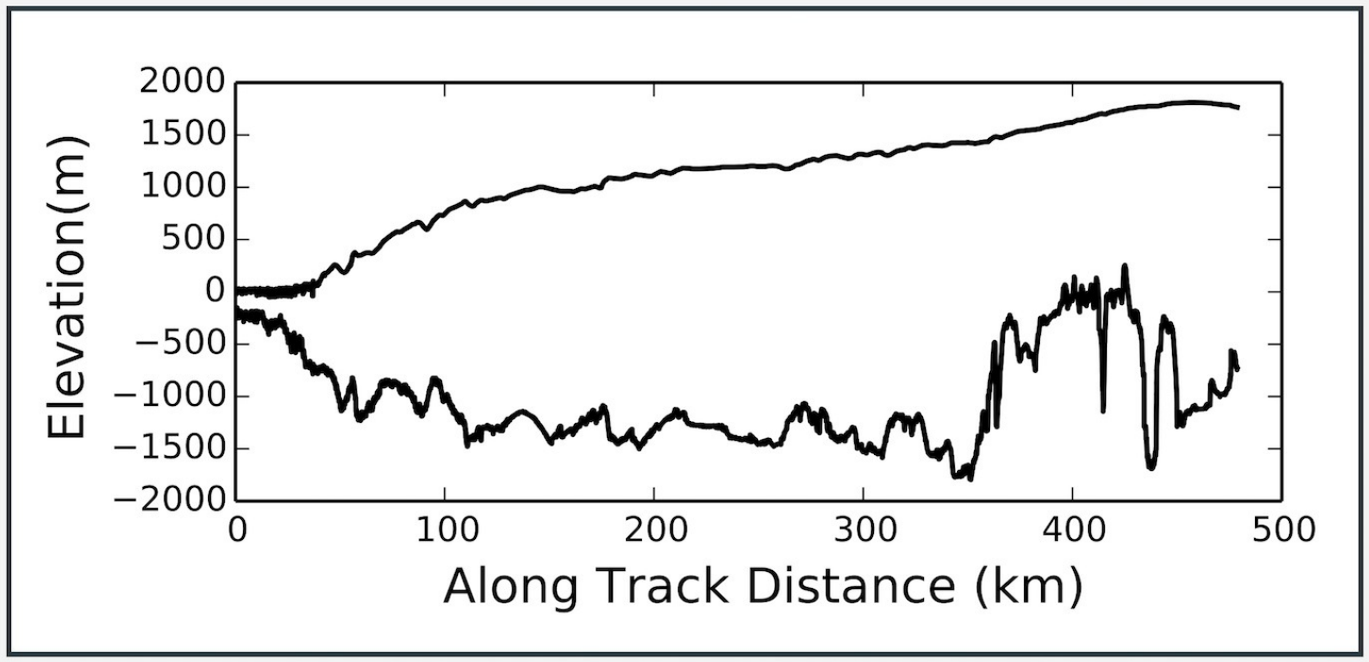
Is there Evidence of Ocean Water Upstream of the Hydrostatic Line?

What is the Extent of the Grounding Zone of Thwaites Glacier?

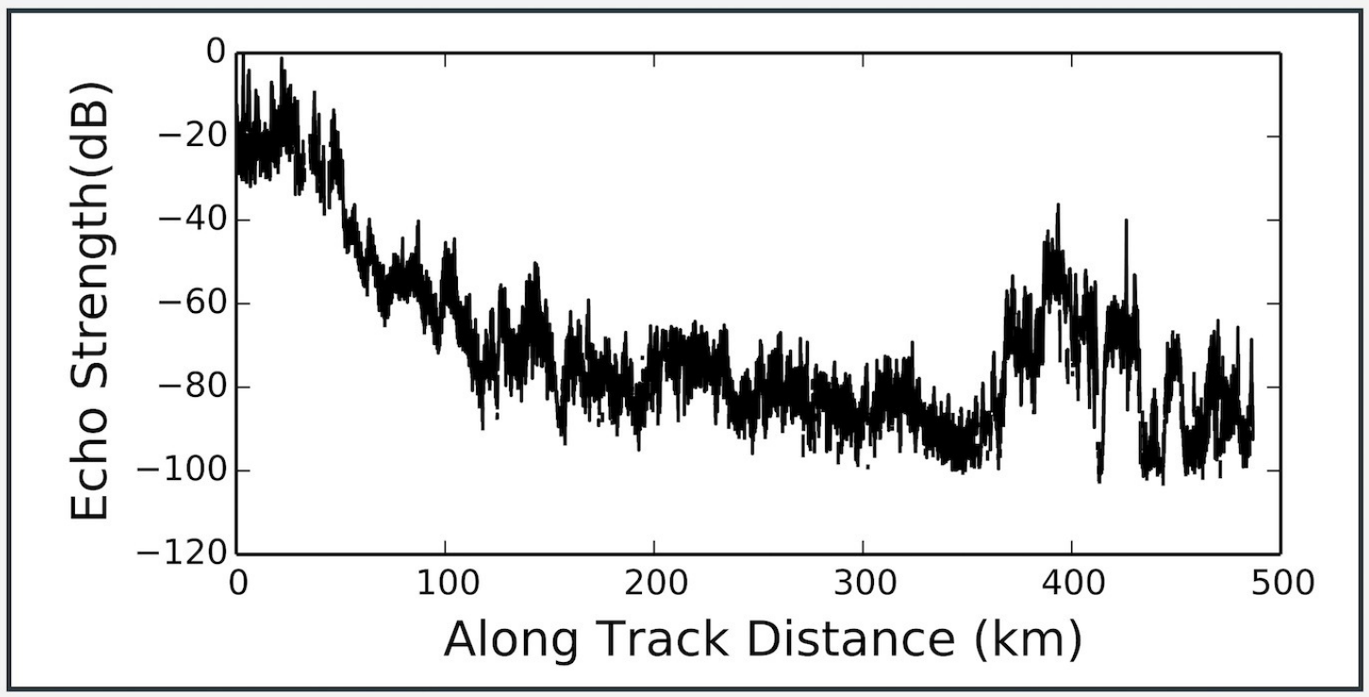
Case-Study Survey Track (THW/SJB2/DRP08a)

A Flow-Aligned Profile from the Divide to the Ocean

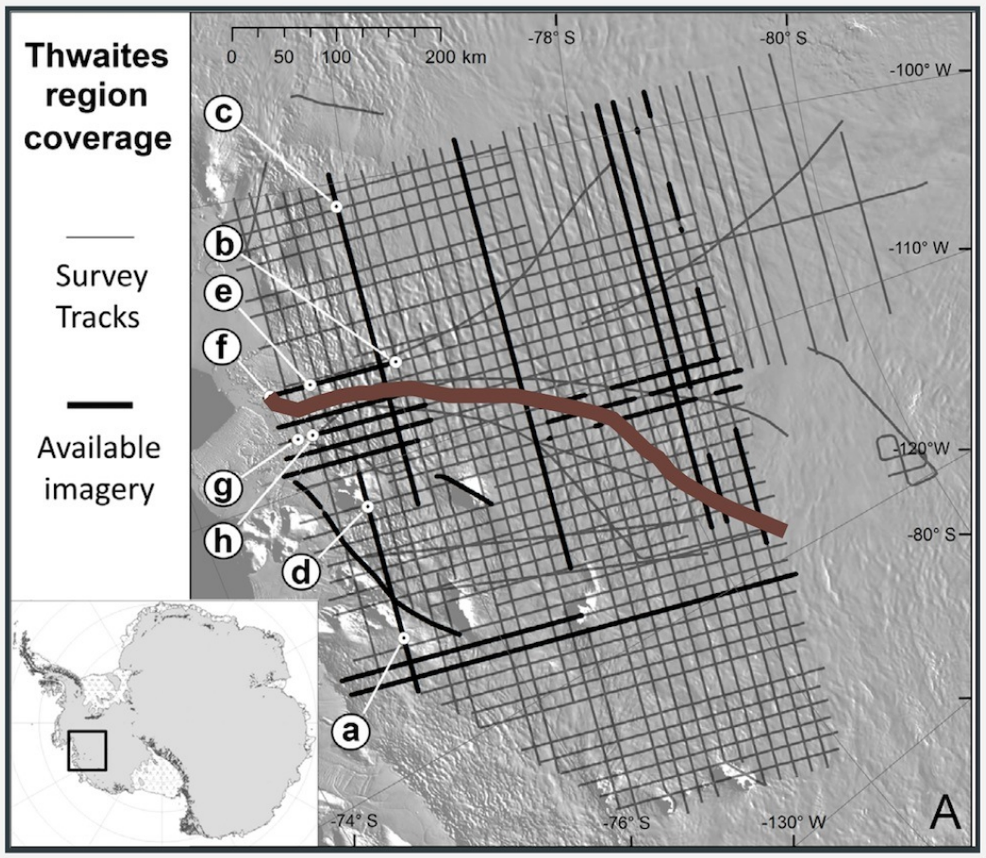
Ice Thickness and Bed Profile



Geometrically Corrected Bed Echoes



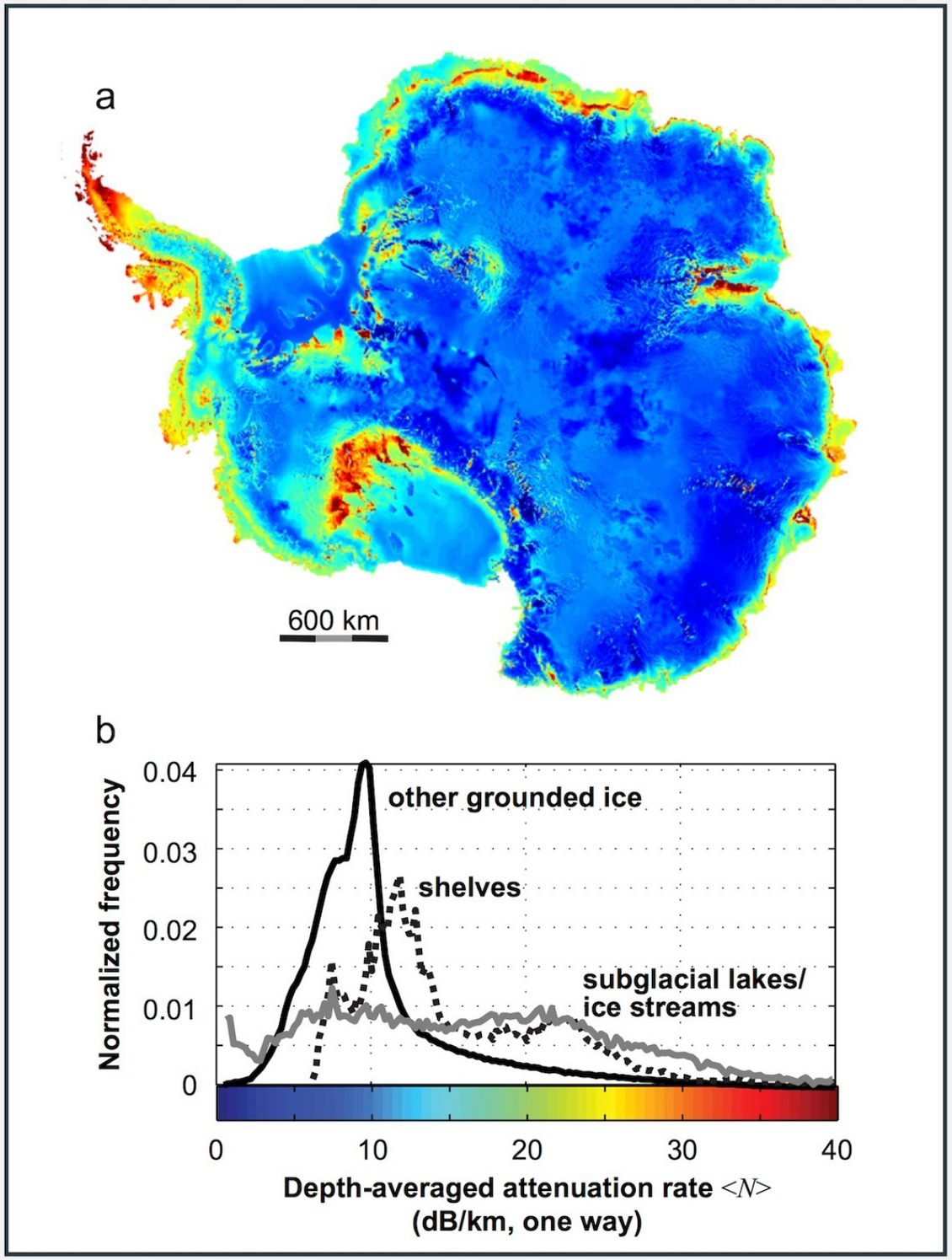
Flow-Line Survey Track



Modeled Englacial Attenuation

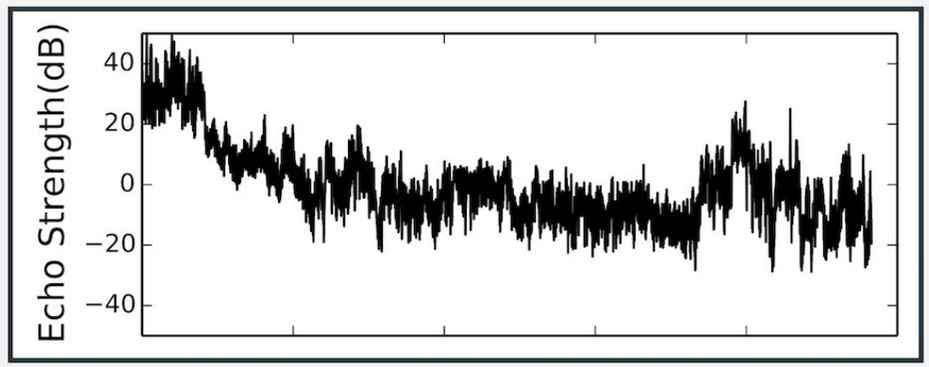
A Large Range of Corrections that Change the Entire Answer

Modeled Attenuation Rates

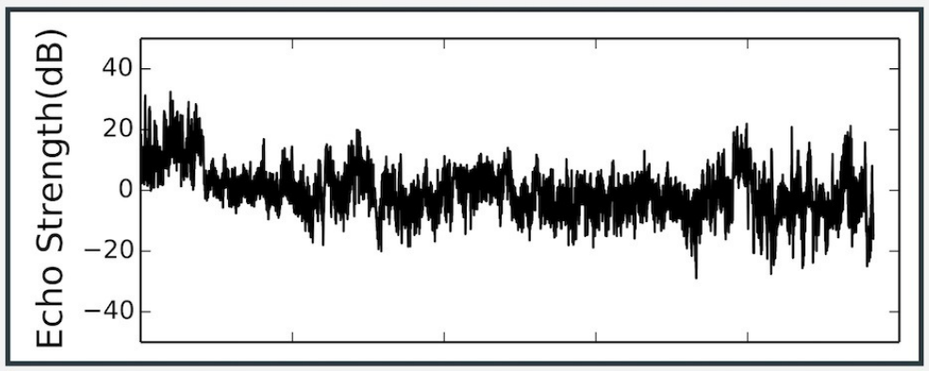


Attenuation Correction

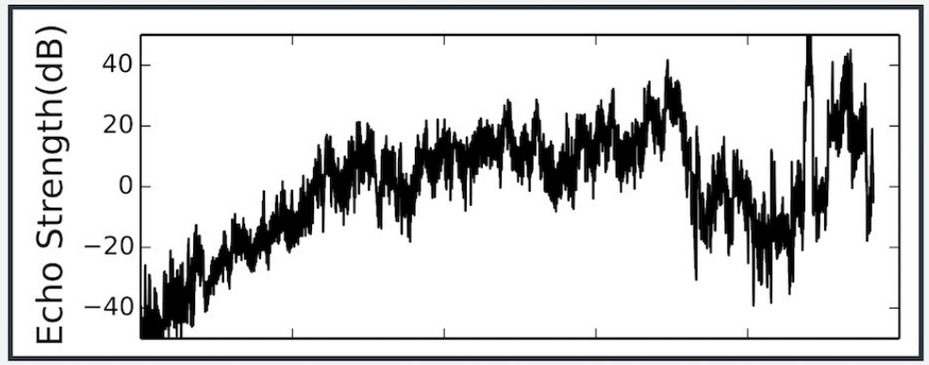
5 dB/km



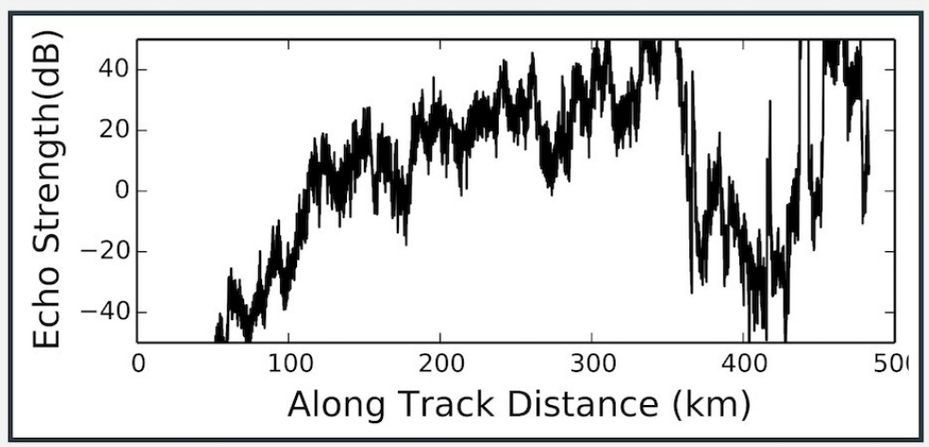
10 dB/km



25 dB/km



40 dB/km

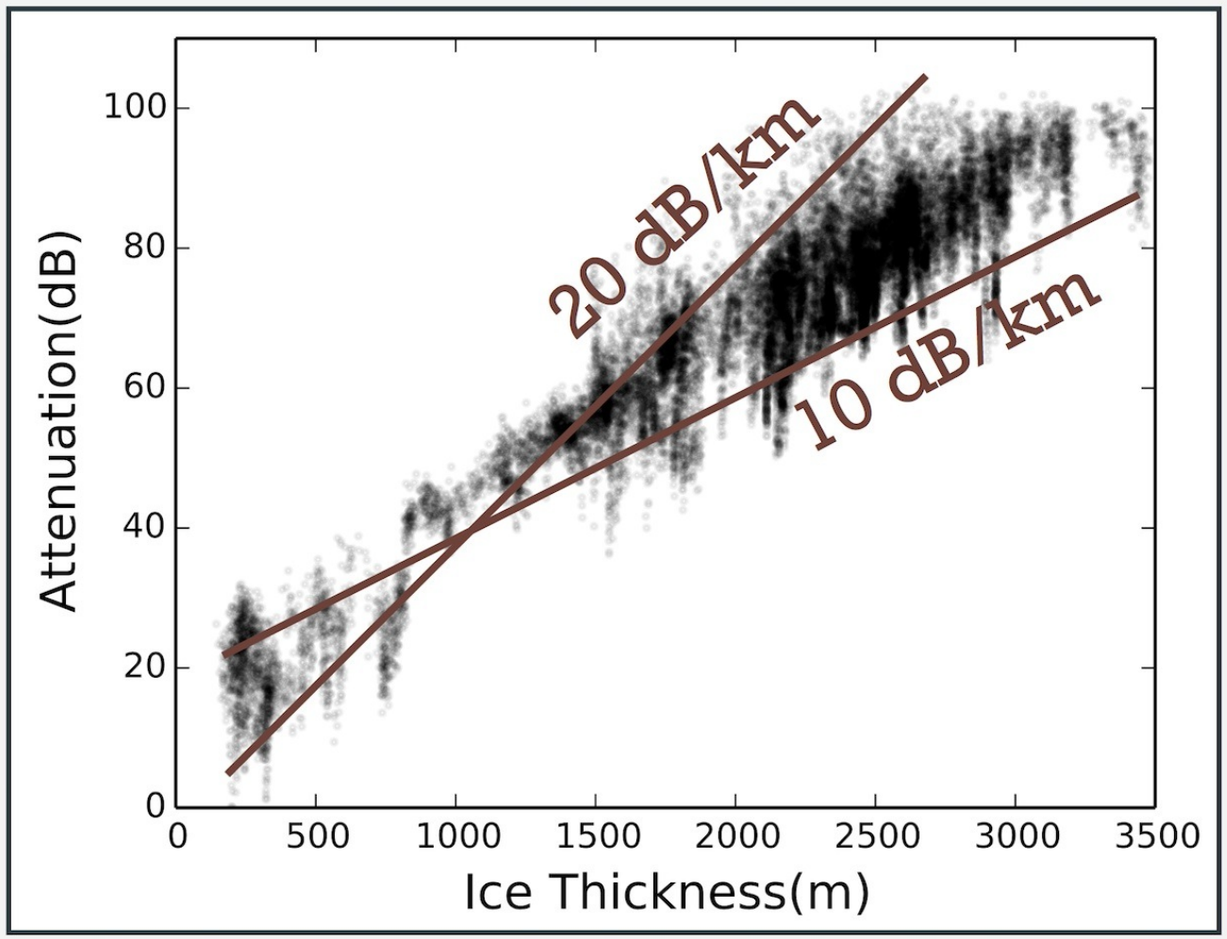


Matsuoka , *GRL*, 2011

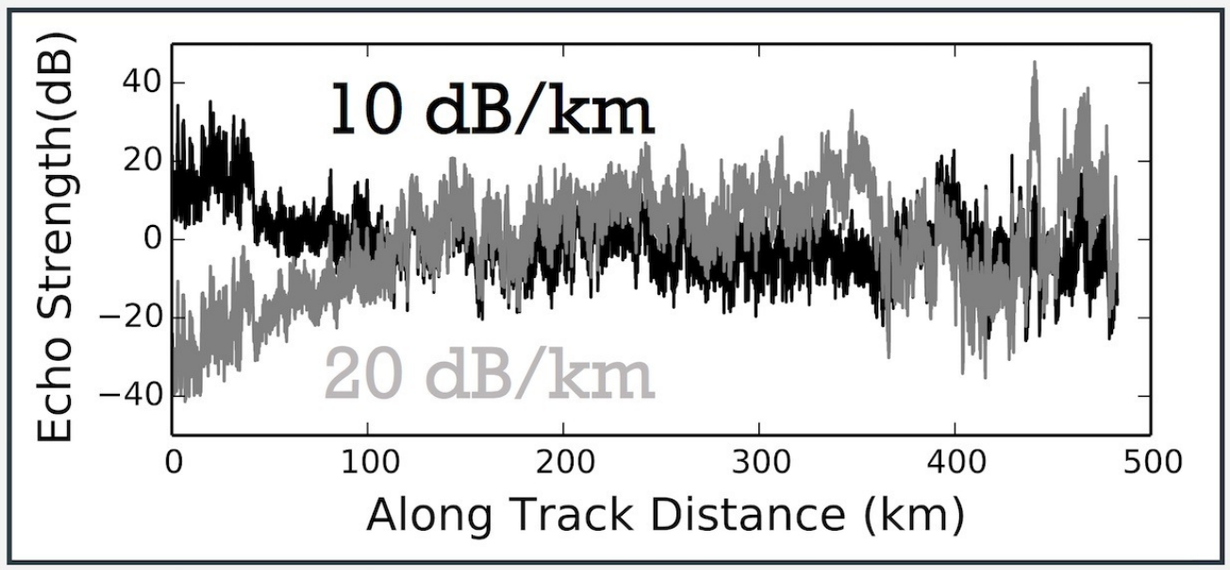
Scatter Based Empirical Attenuation

A Smaller Range of Corrections that Still Change the Entire Answer

Empirical Attenuation Rates



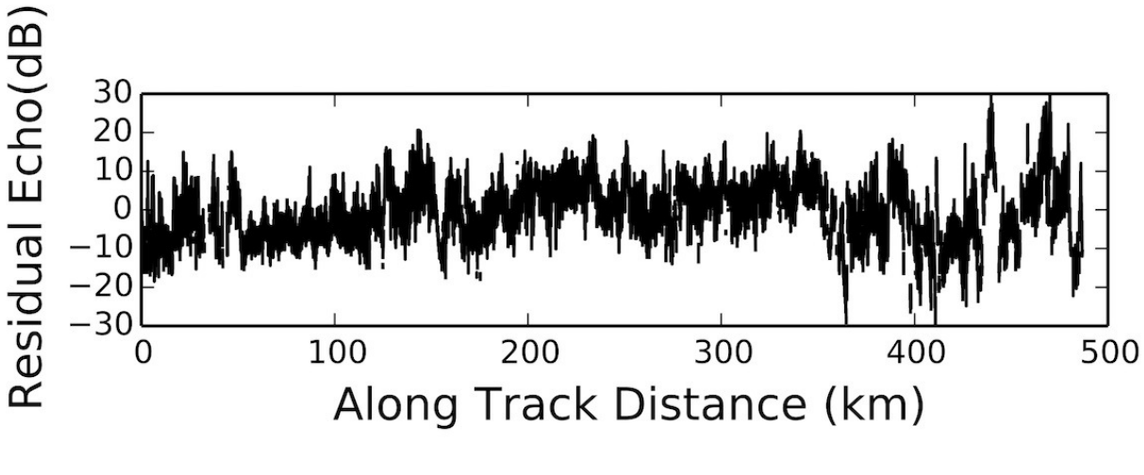
Attenuation Correction



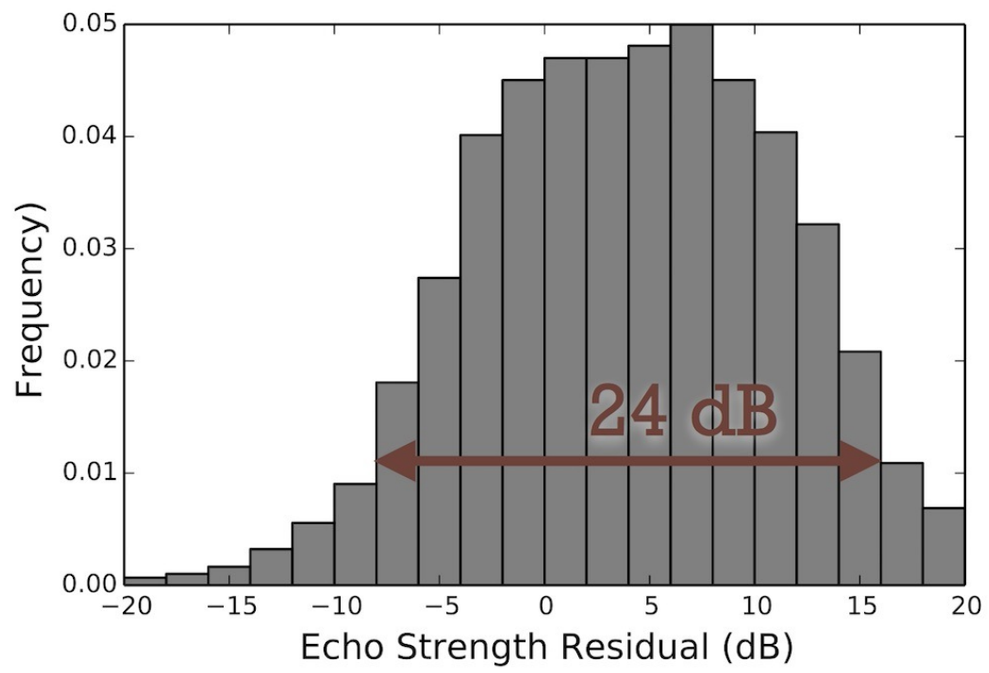
Scatter Based Attenuation Correction

A Dubiously Wide Range of Residual Echo Strengths

Residual Bed Echoes



Residual Echo Distribution

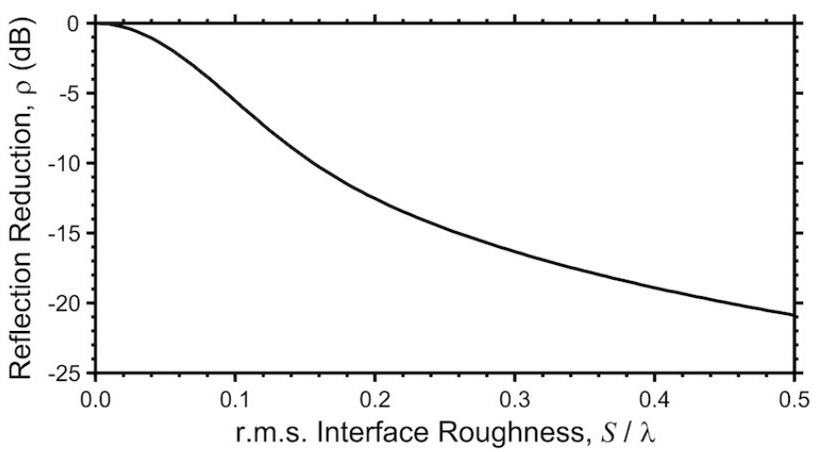


Reflection Coefficient of Bed Materials

Subglacial Material	ε_{3r}	tan δ_3	$\lvert\tilde{R}_{23}\rvert^2$, dB
Seawater	77	11.3	−1
Groundwater (gw)	80	1.4	−2
Fresh water	80	0.002	−3
Unfrozen till (40% gw)	18	0.82	−6
Unfrozen bedrock (15% gw)	6.6	0.41	−13
Frozen till (40% gw ice)	2.8	0.035	−30
Frozen bedrock (15% gw ice)	2.7	0.022	−28
Marine ice	3.43	0.05	−33

Peters et al, *JGR*, 2005

Bed Roughness

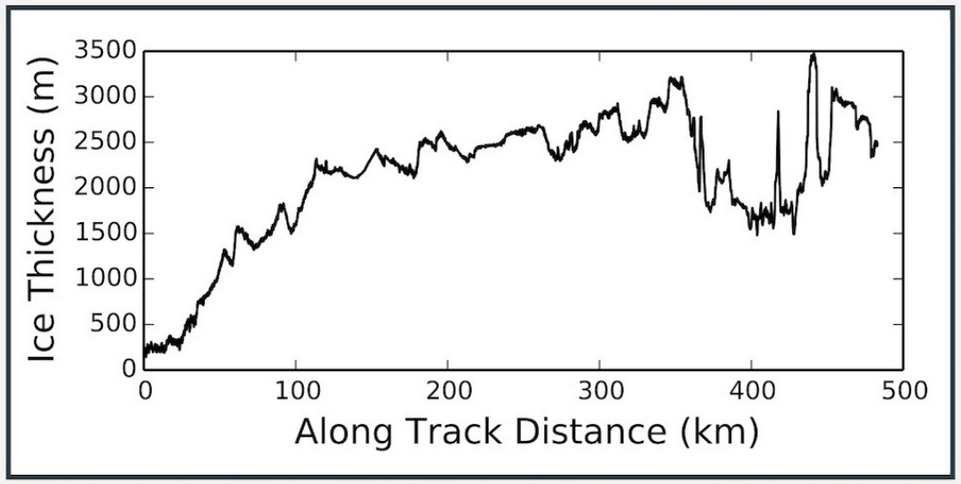


Peters et al, *JGR*, 2005

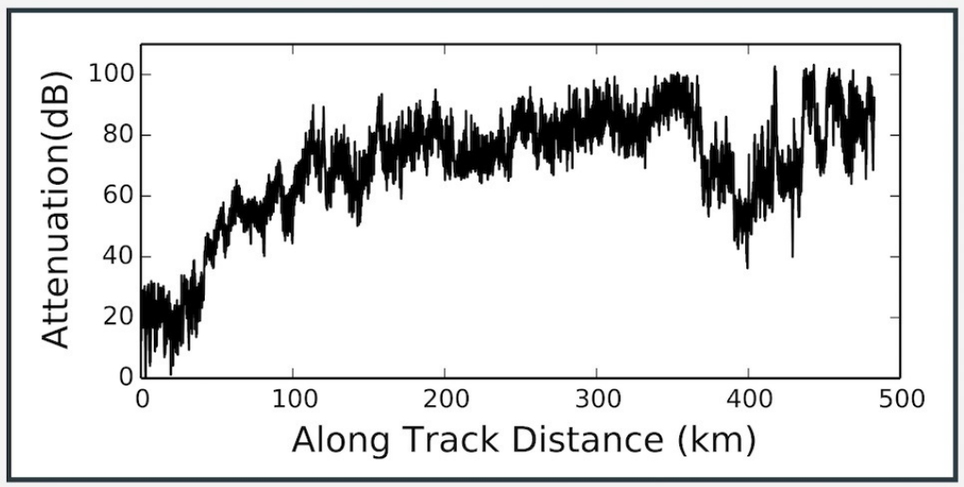
Time Series Based Empirical Attenuation

Using Adjacent Ice to Better Constrain the Attenuation Profile

Ice Thickness

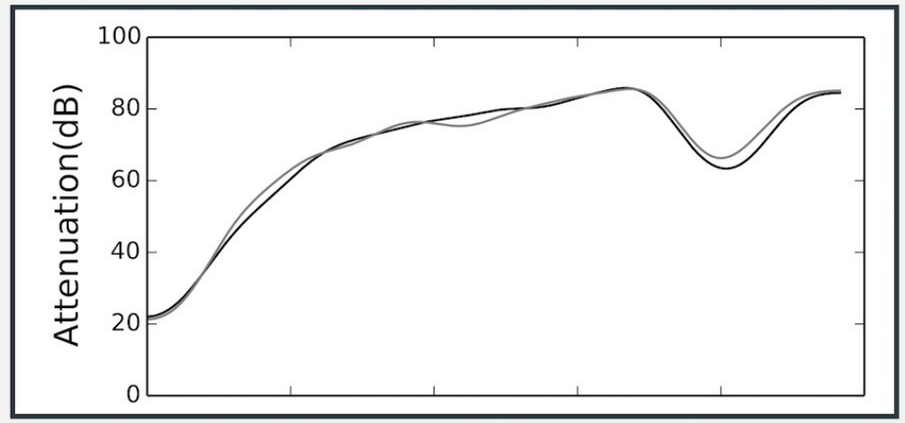


Attenuation

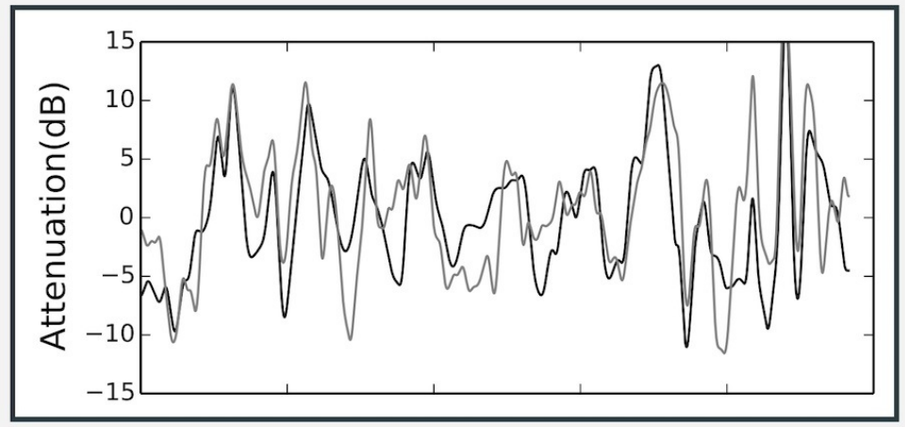


Attenuation Signal: Measured and Fit

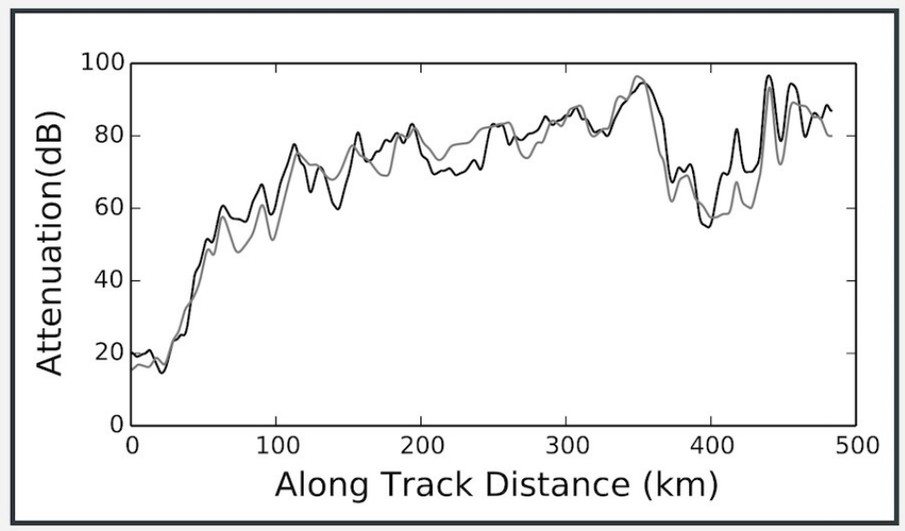
Low Frequency



High Frequency



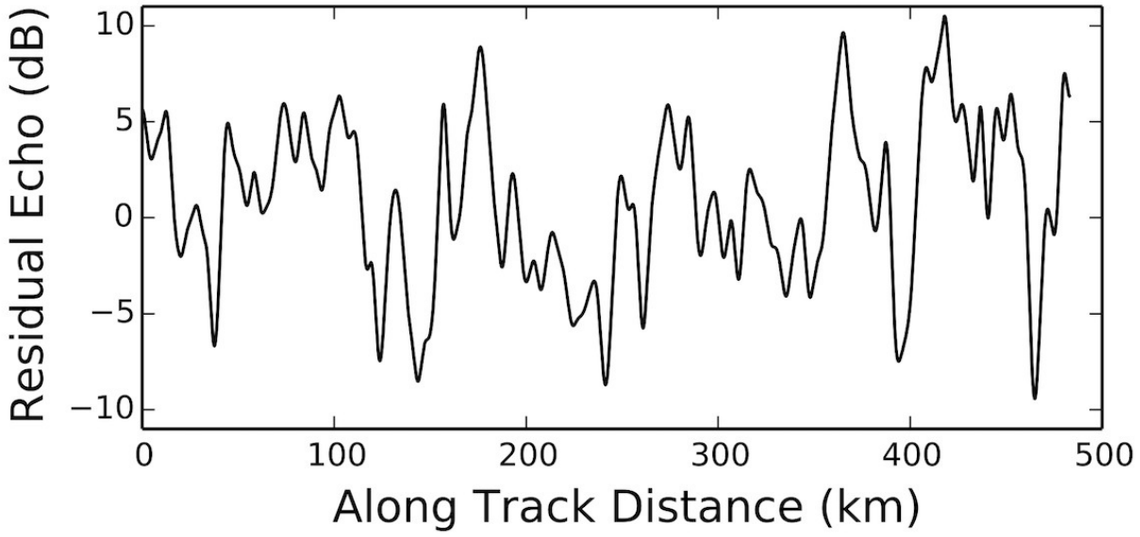
Combined



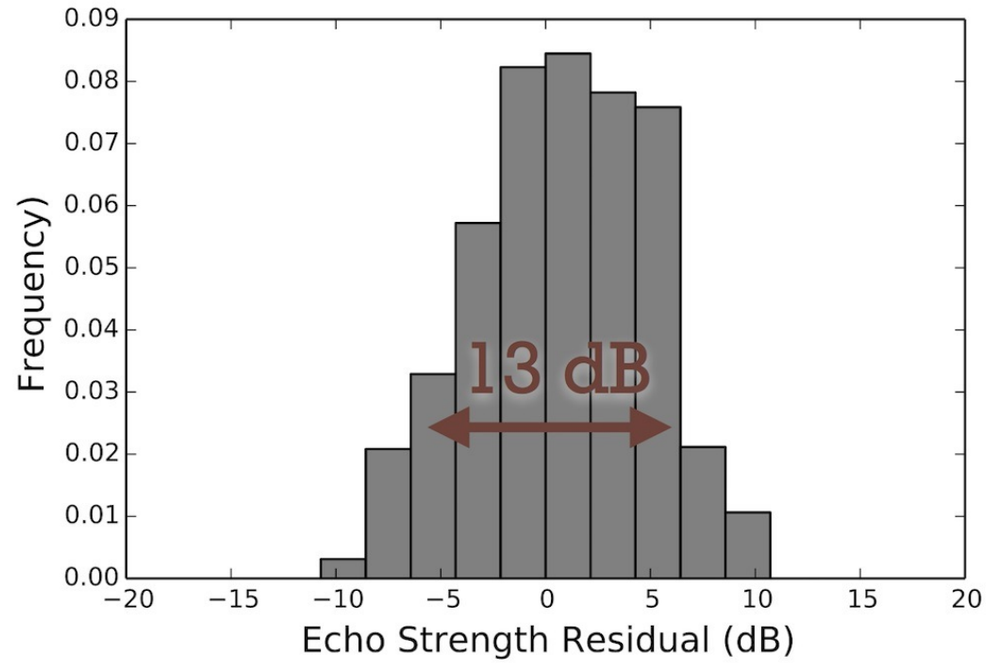
Time Series Based Attenuation Correction

A More Physically Realistic Range of Residual Echo Strengths

Residual Bed Echoes



Residual Echo Distribution



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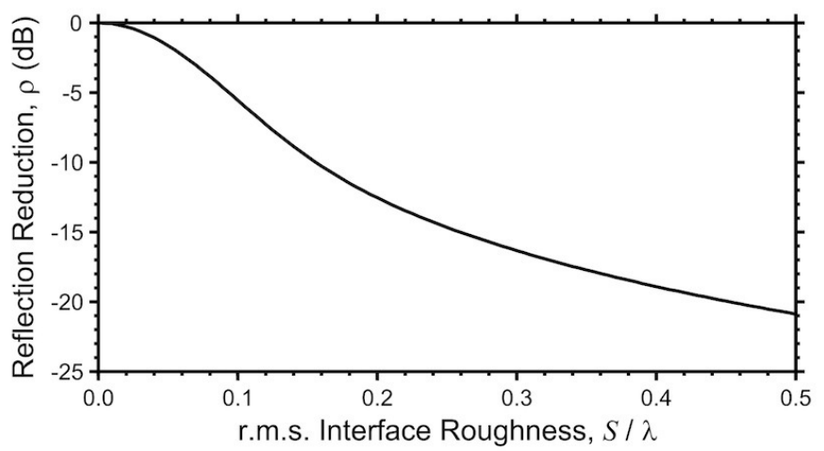
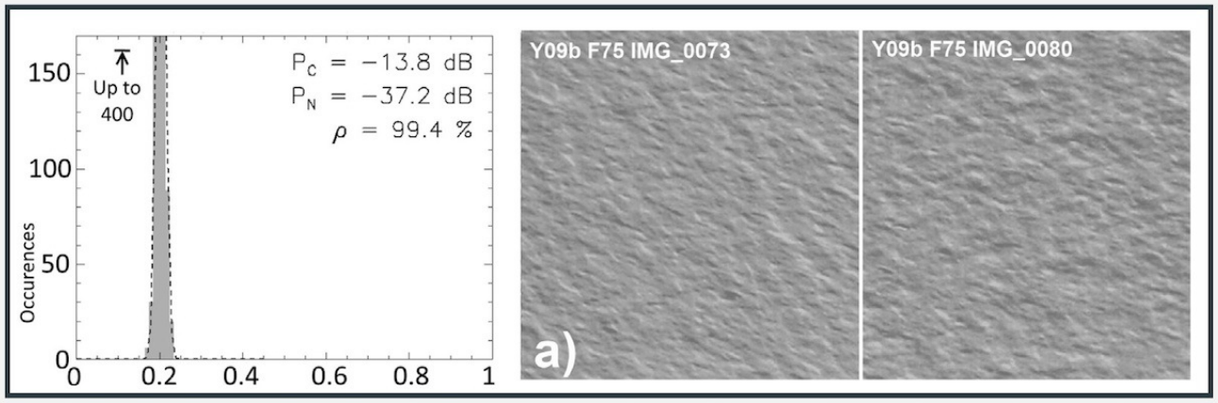


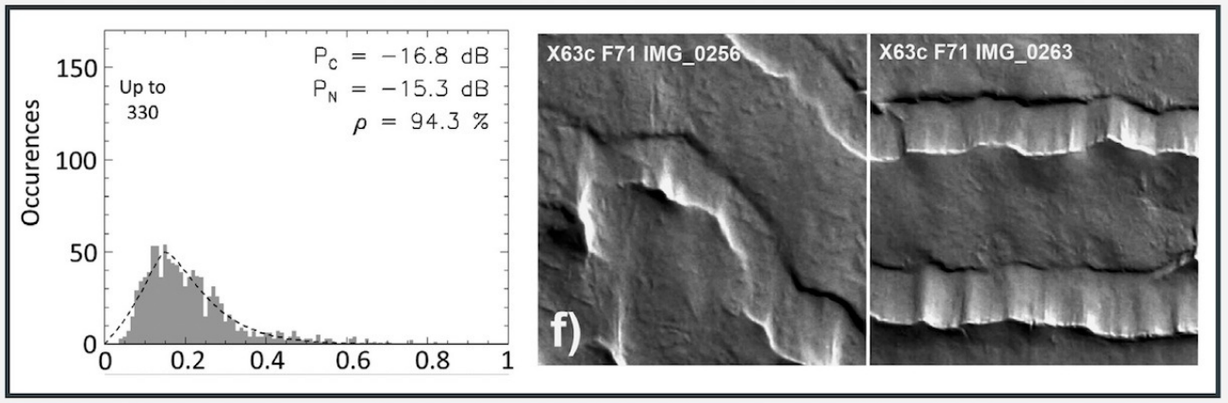
Peters et al, *JGR*, 2005

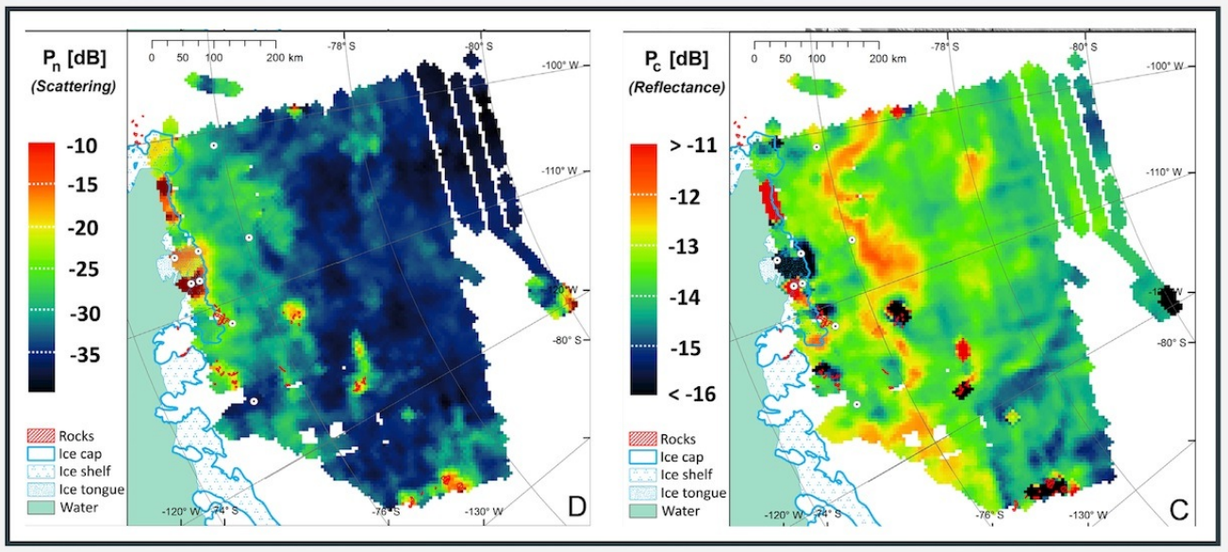
Loss of Coherence and Power in Transmission/Scattering

A Necessity for Echo Strength Interpretation in the Grounding Zone

Surface Echo Amplitude Statistics

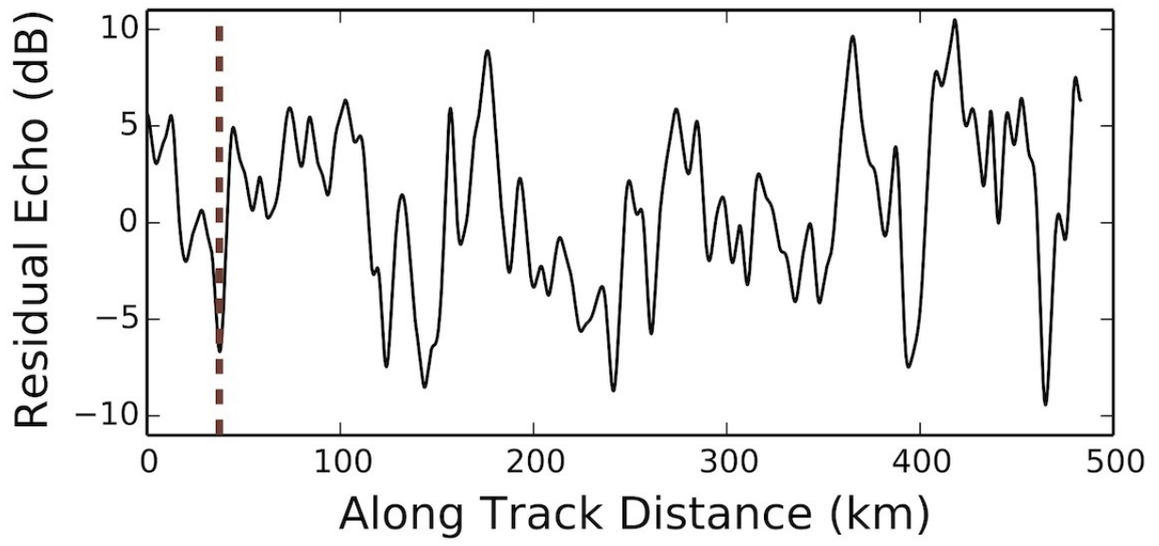




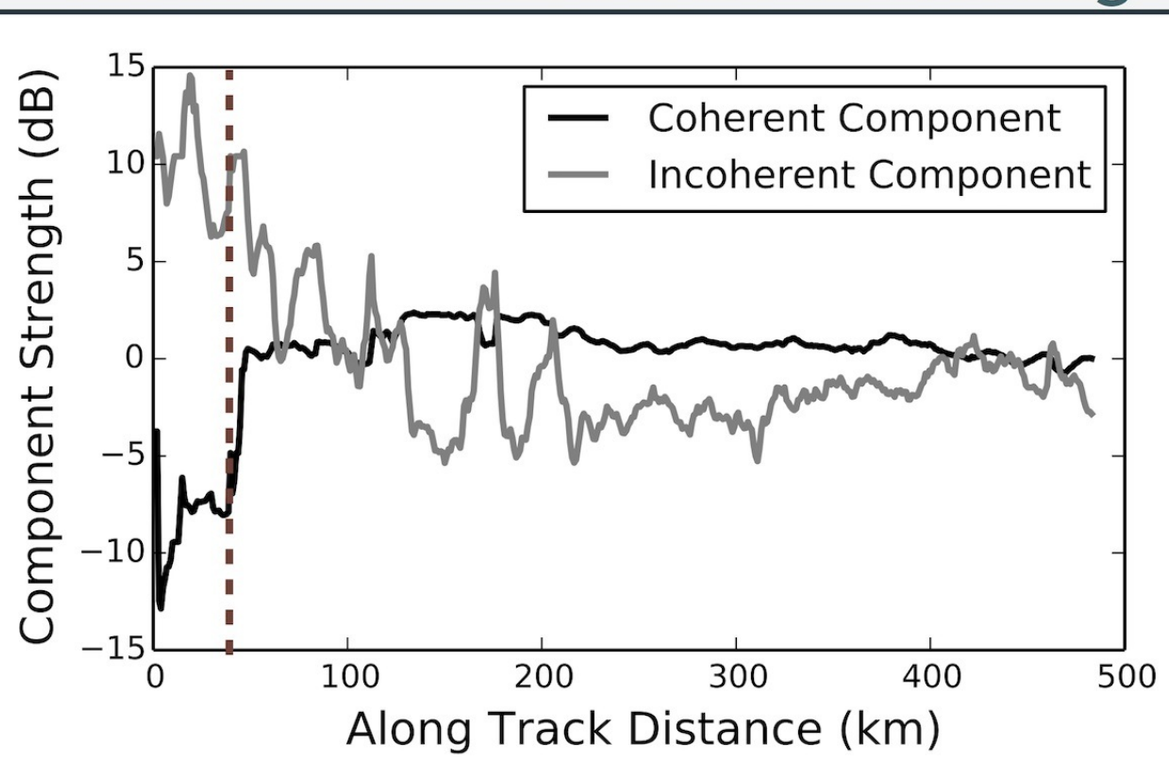


Grima et al, *PSS*, 2014

Attenuation Corrected Echoes



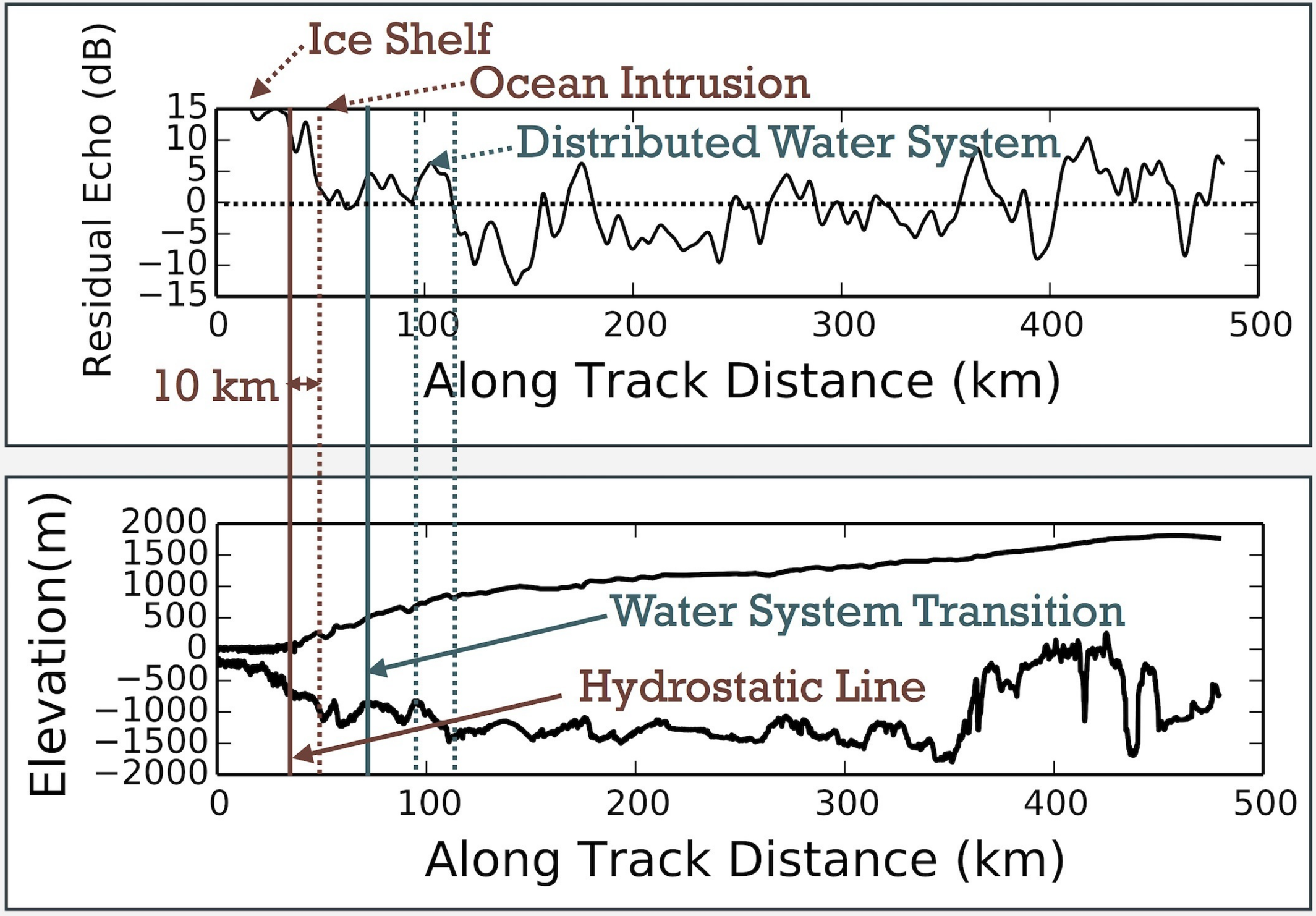
Coherence Loss and Scattering



Combined Correction for Attenuation and Scattering

Time Series Showing Ocean Intrusion and a 10 km Grounding Zone

Attenuation and Scattering Corrected Bed Echoes



Can Radar Sounding Echo Strengths be Used to Unambiguously Characterize Grounding Zones?

No: If Using Standard Radar Sounding Analysis Techniques.

Yes: If Echo Strengths are Treated as a Time Series and Loss of Coherence from Transmission/Scattering is Included.

Is there Evidence of Ocean Water Upstream of the Hydrostatic Line?

Yes.

What is the Extent of the Grounding Zone of Thwaites Glacier?

~10 km.

[Thank You]

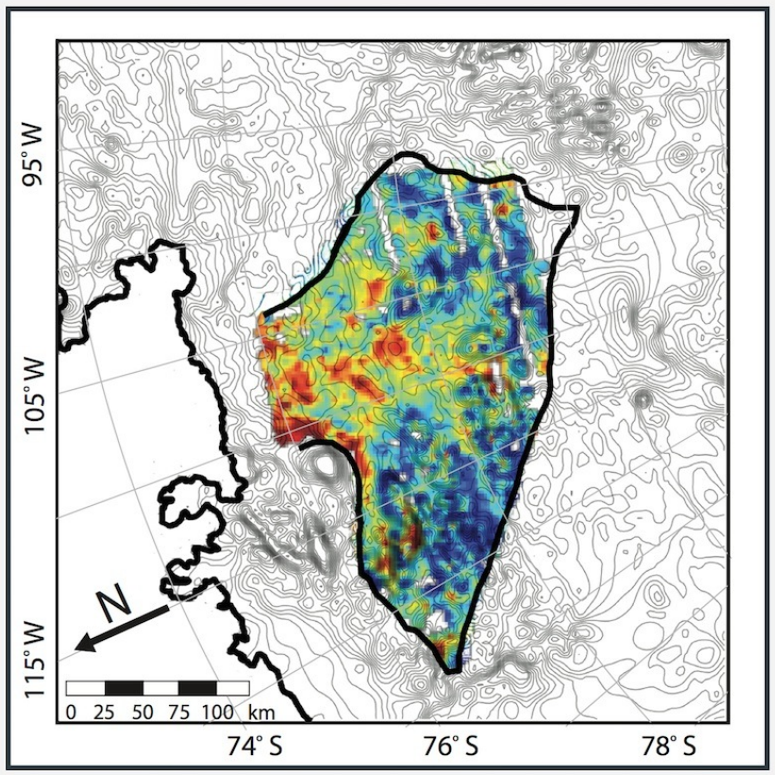
Supported by: NASA Cyosphere, NSF OPP, The Vetlesen Foundation

[Epilogue: Geothermal Flux]

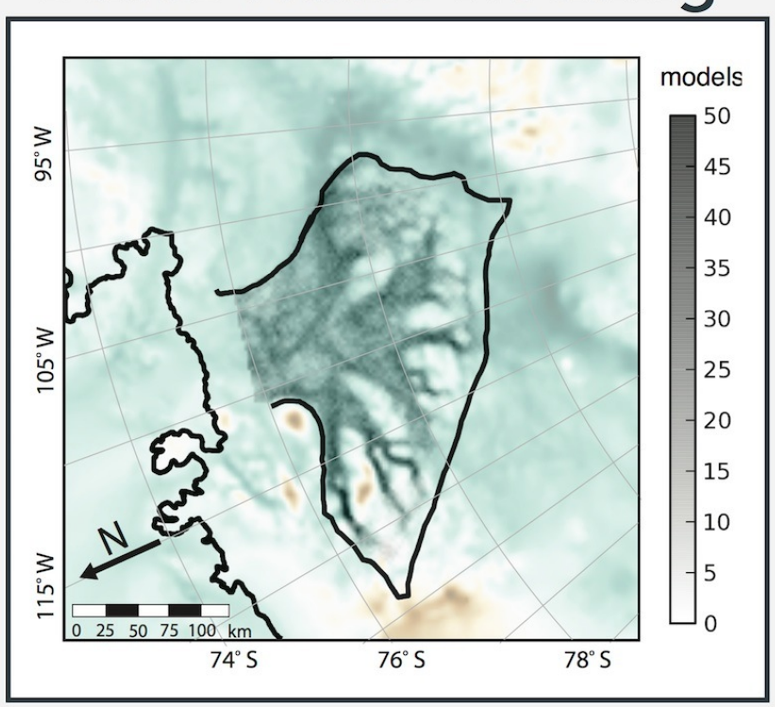
Radar Inferred Melting, and Geothermal Flux

Using Plan-View Spatial Information to Improve Echo Interpretation

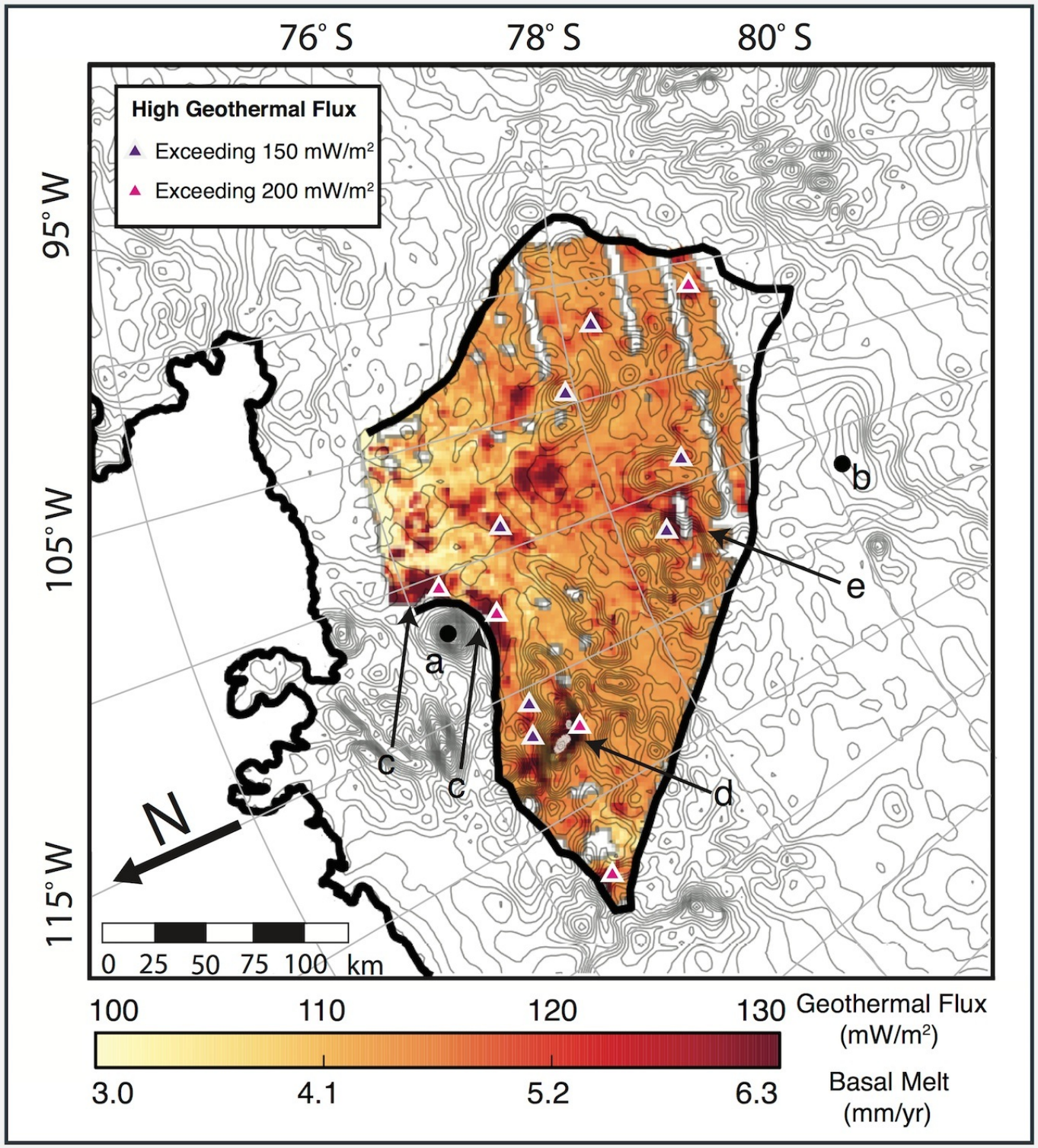
Relative Bed Echo Power



Basal Water Routing



Estimated Geothermal Flux



Schroeder, et al, *PNAS*, 2014