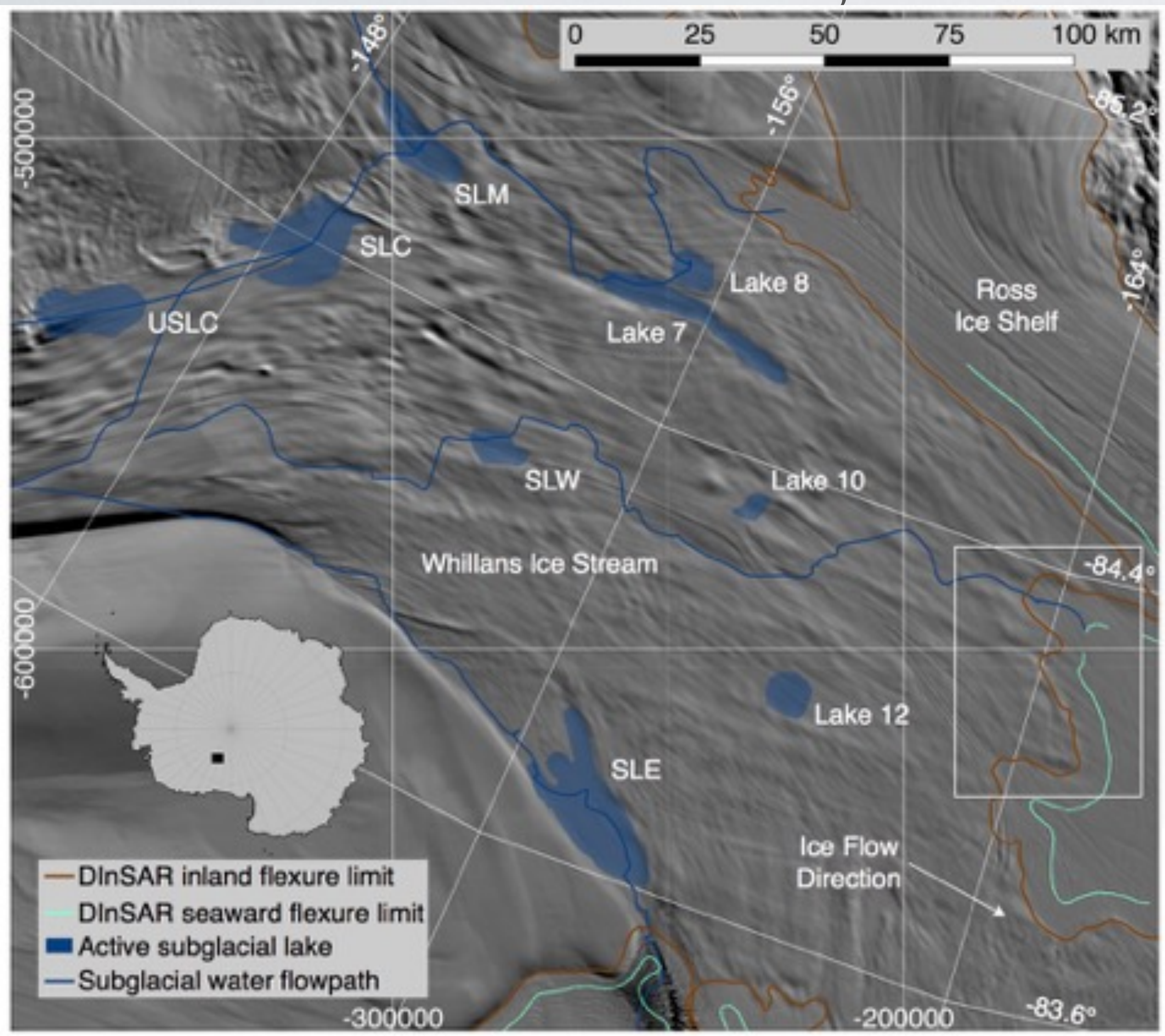
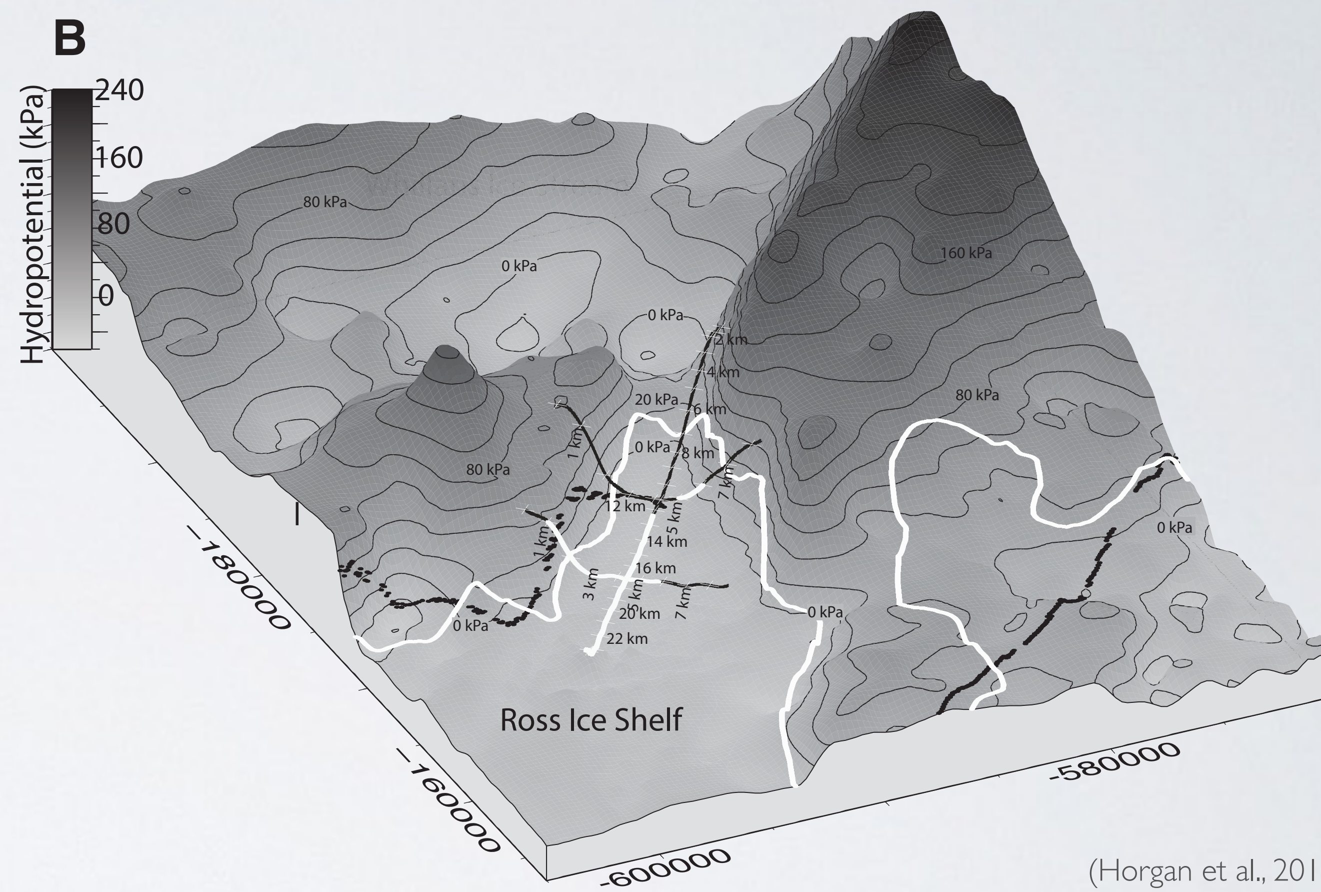
# INFERENCE OF GROUNDING-ZONE PROPERTIES FROM RADAR BASAL REFLECTIVITY, DIELECTRIC MODELING, AND BASAL-ECHO ANALYSIS



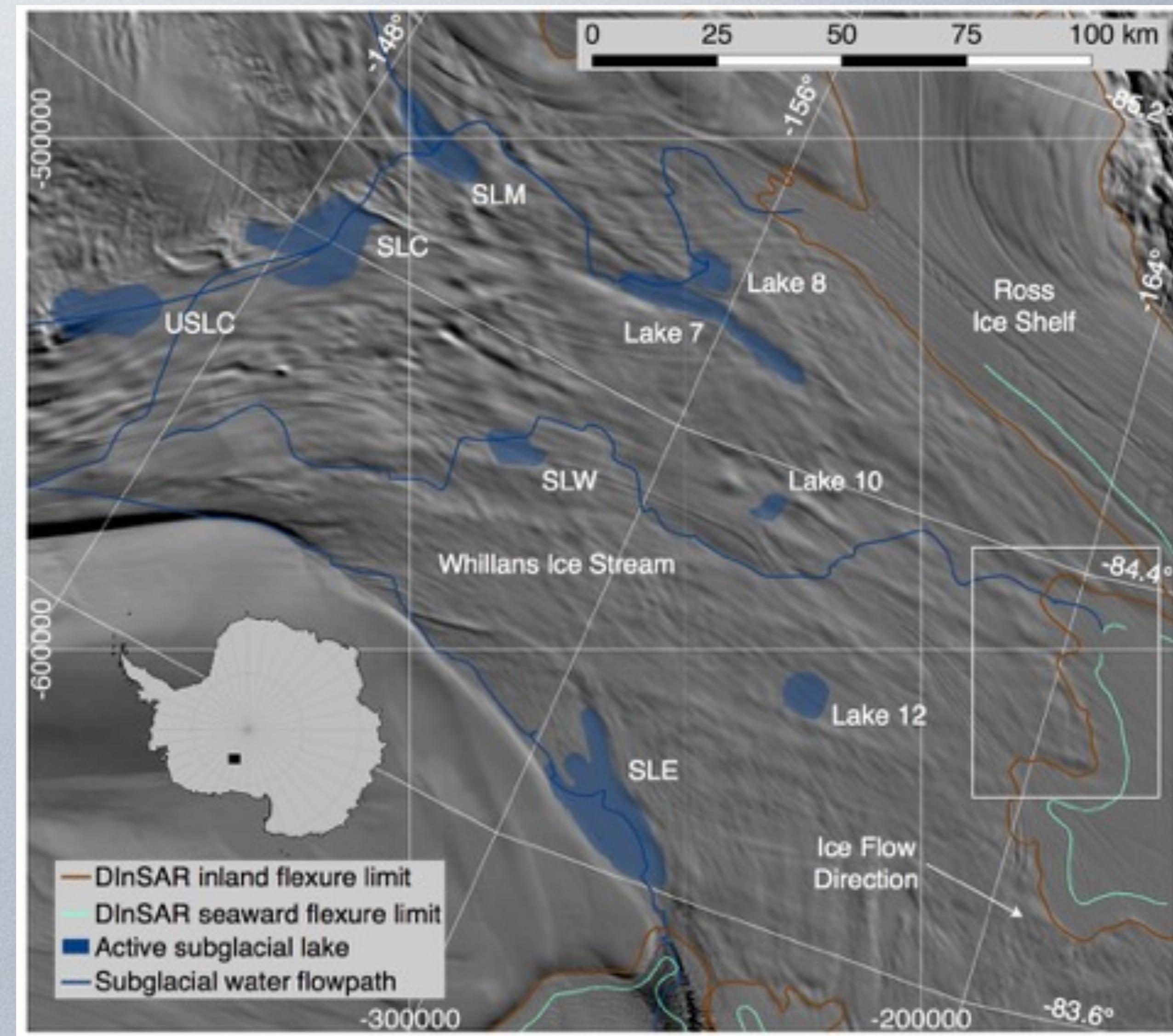



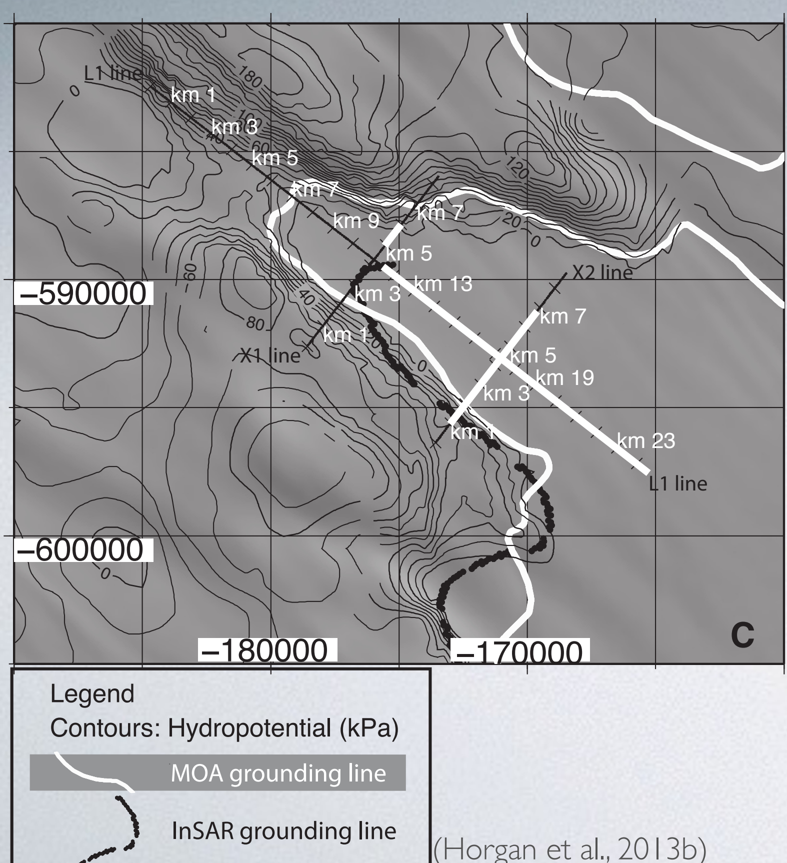

(Horgan et al., 2013b)


Knut Christianson, Robert W. Jacobel, Huw J. Horgan, Sridhar Anandakrishnan, David M. Holland, and Richard B. Alley

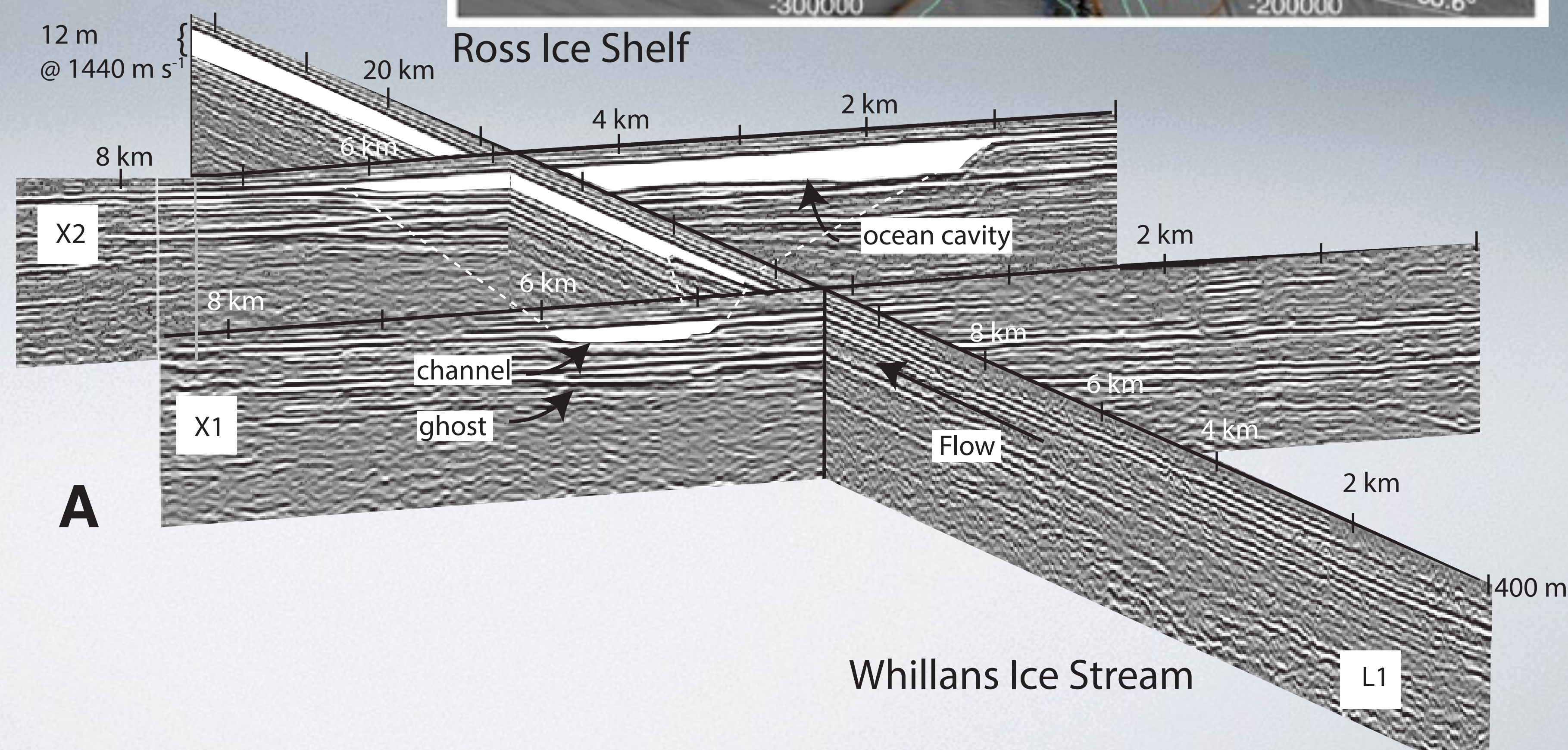
# WISSARD Grounding-Zone Survey

- Seismic results
- Determining basal reflectivity
  - Estimating englacial attenuation
  - Estimating basal reflectivity
- Interpreting basal reflectivity
  - Hydropotential and basal reflectivity
  - Basal reflectivity and englacial features
  - Bed-echo analysis
  - Dielectric modeling
- Conclusions



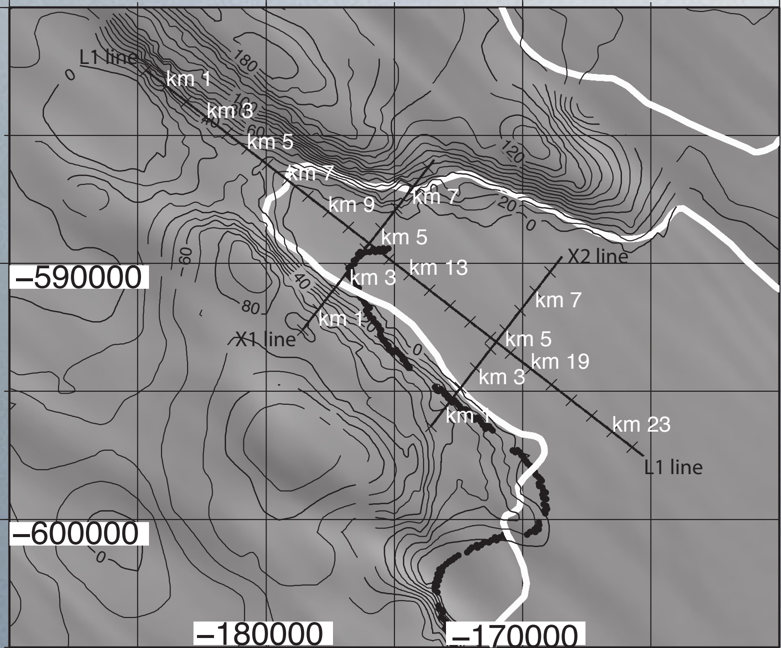



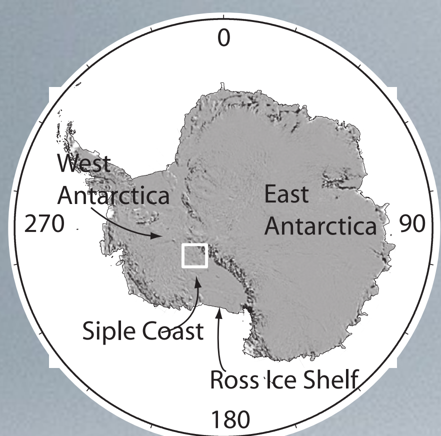

(Horgan et al., 2013b)



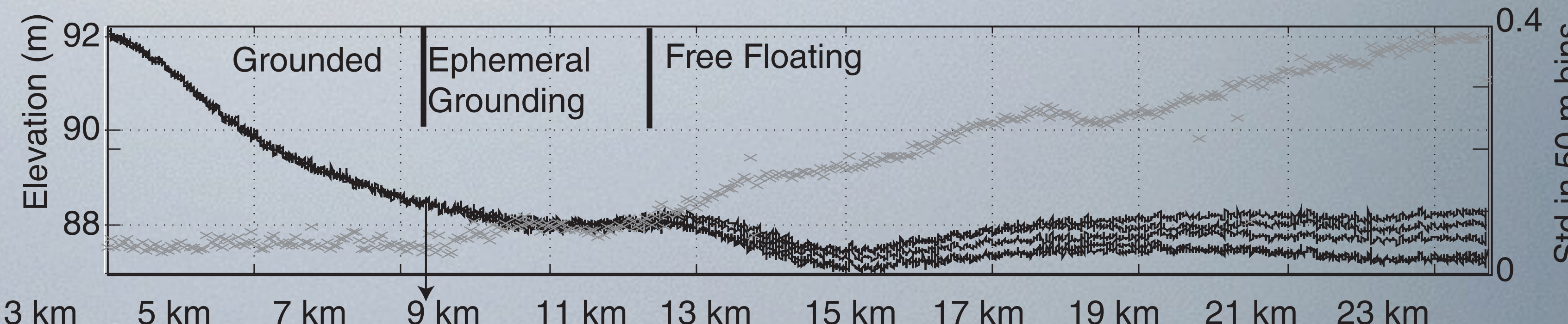

(Horgan et al., 2013b)

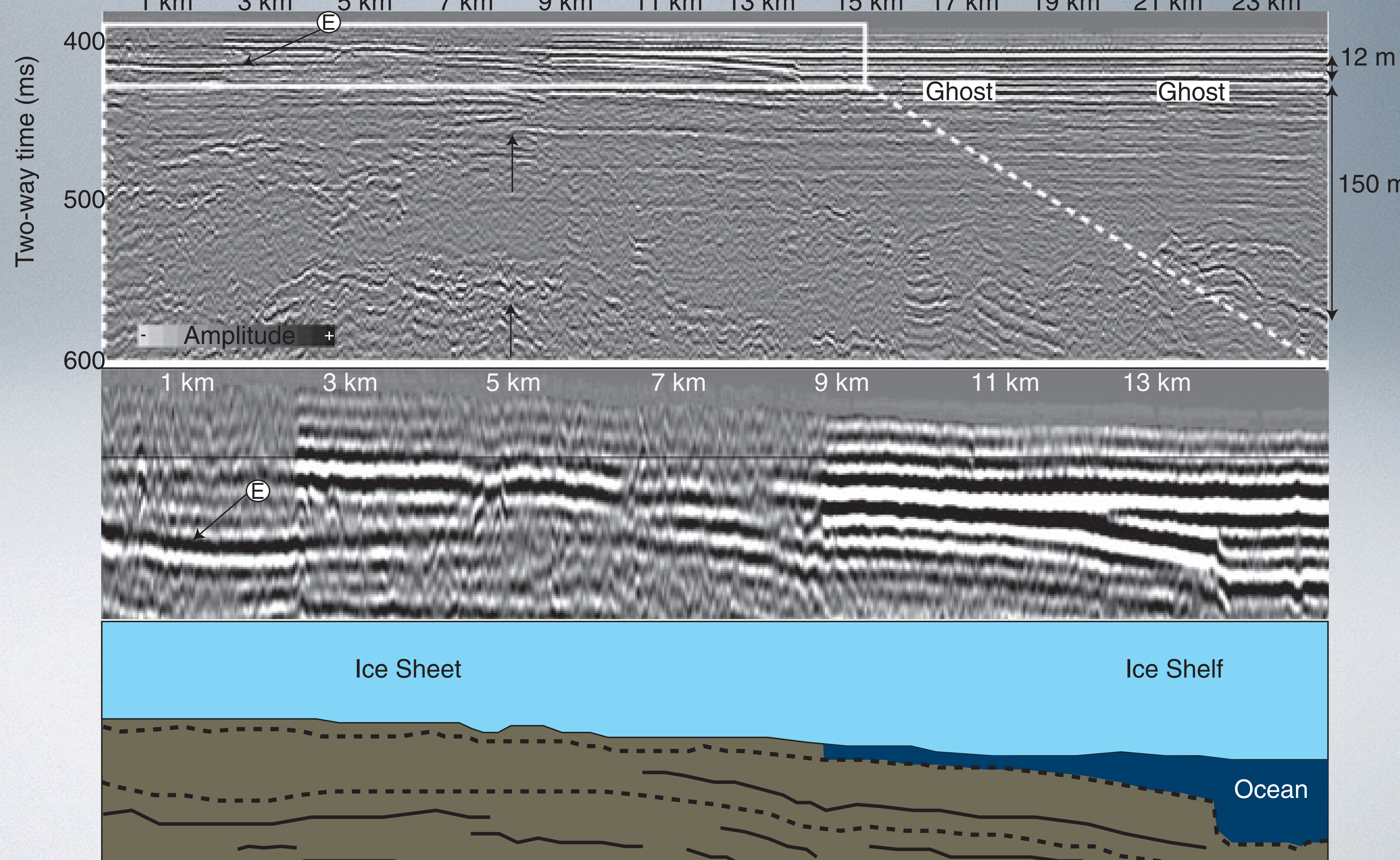
# EMBAYMENT SEISMIC LINE: ACTIVE SEDIMENTATION LIKELY; NO WEDGES



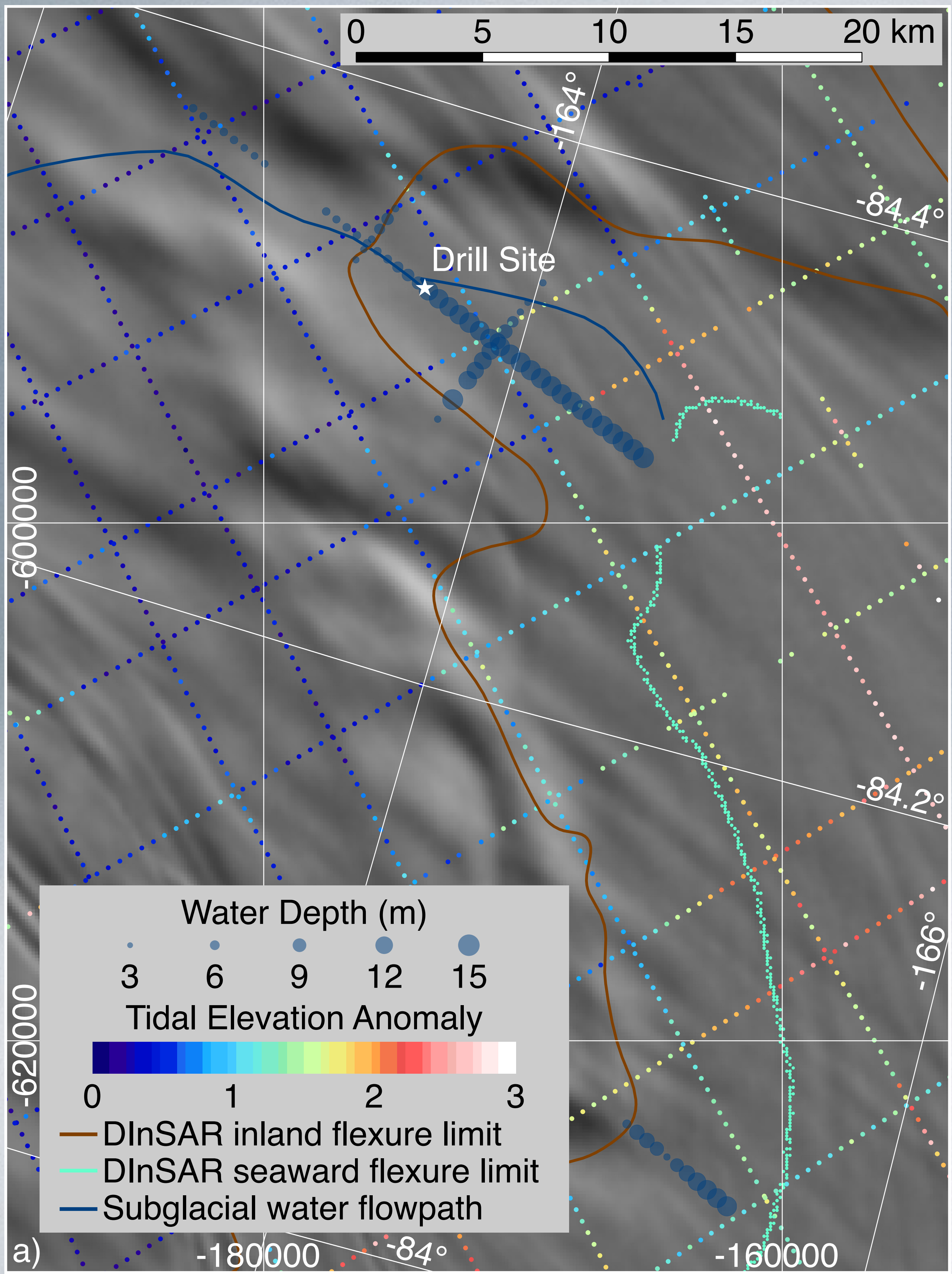




Embayment Longitudinal Profile (L1).

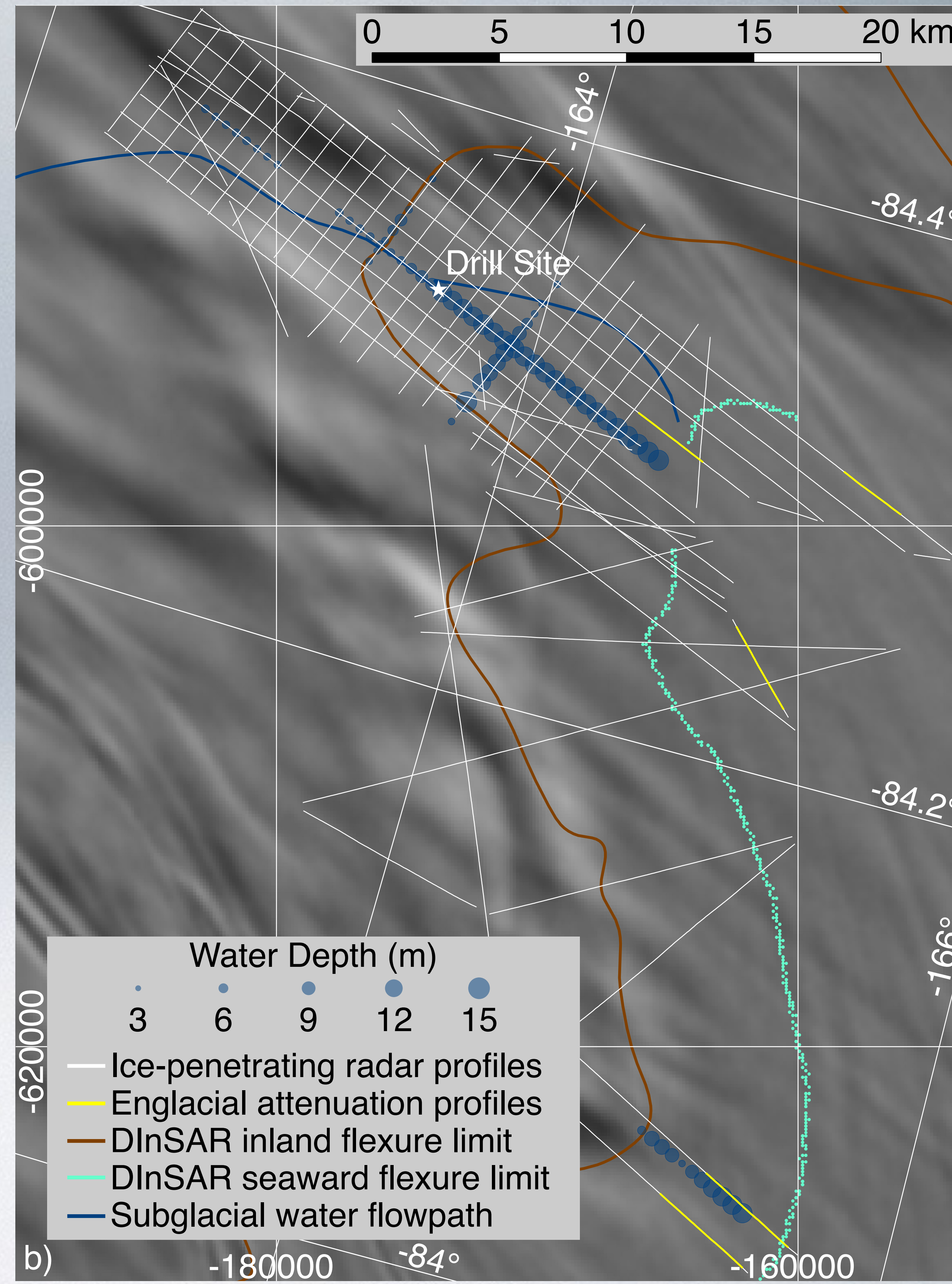


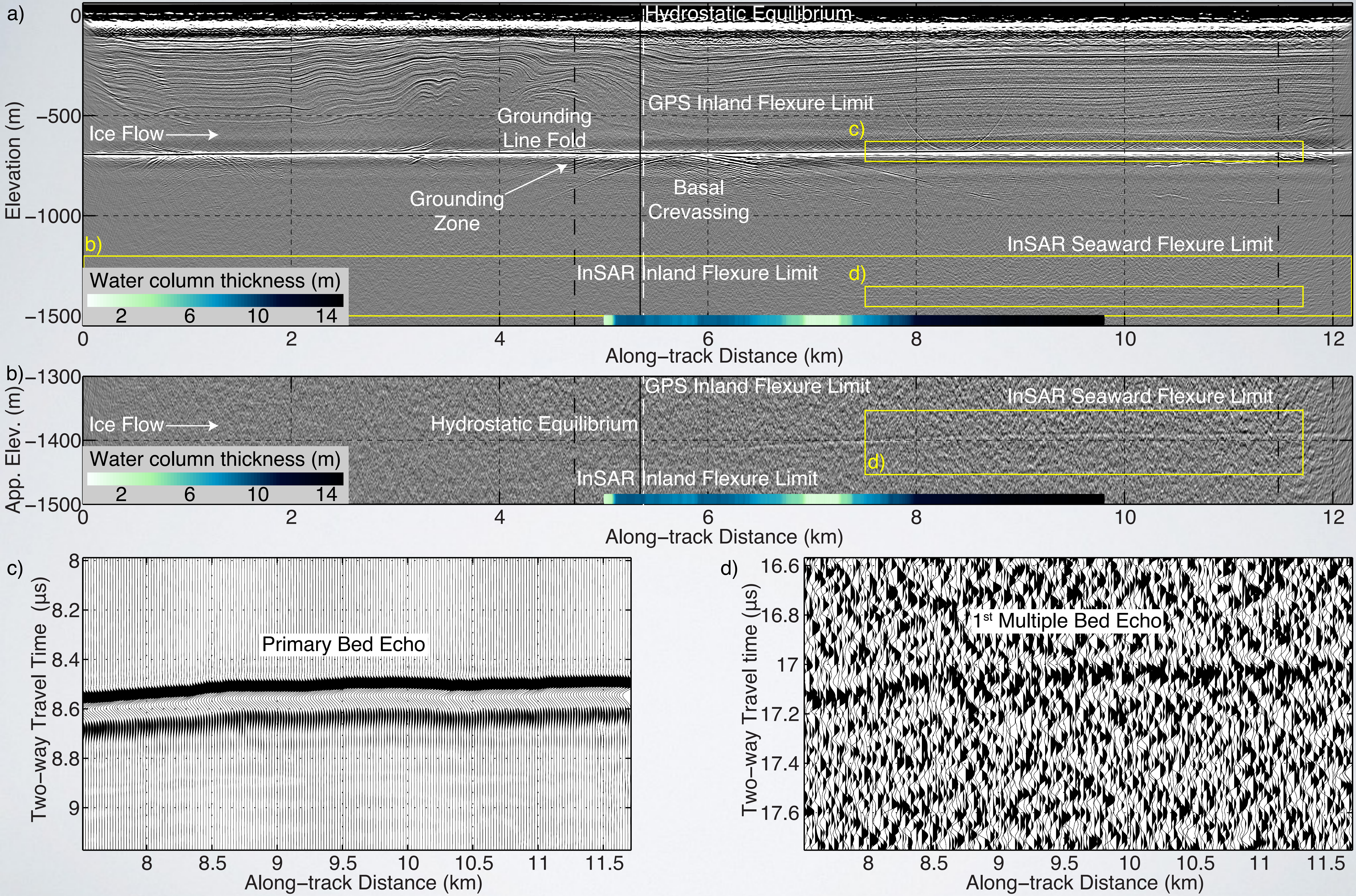
# TIDAL AMPLITUDE




# RADAR SURVEY

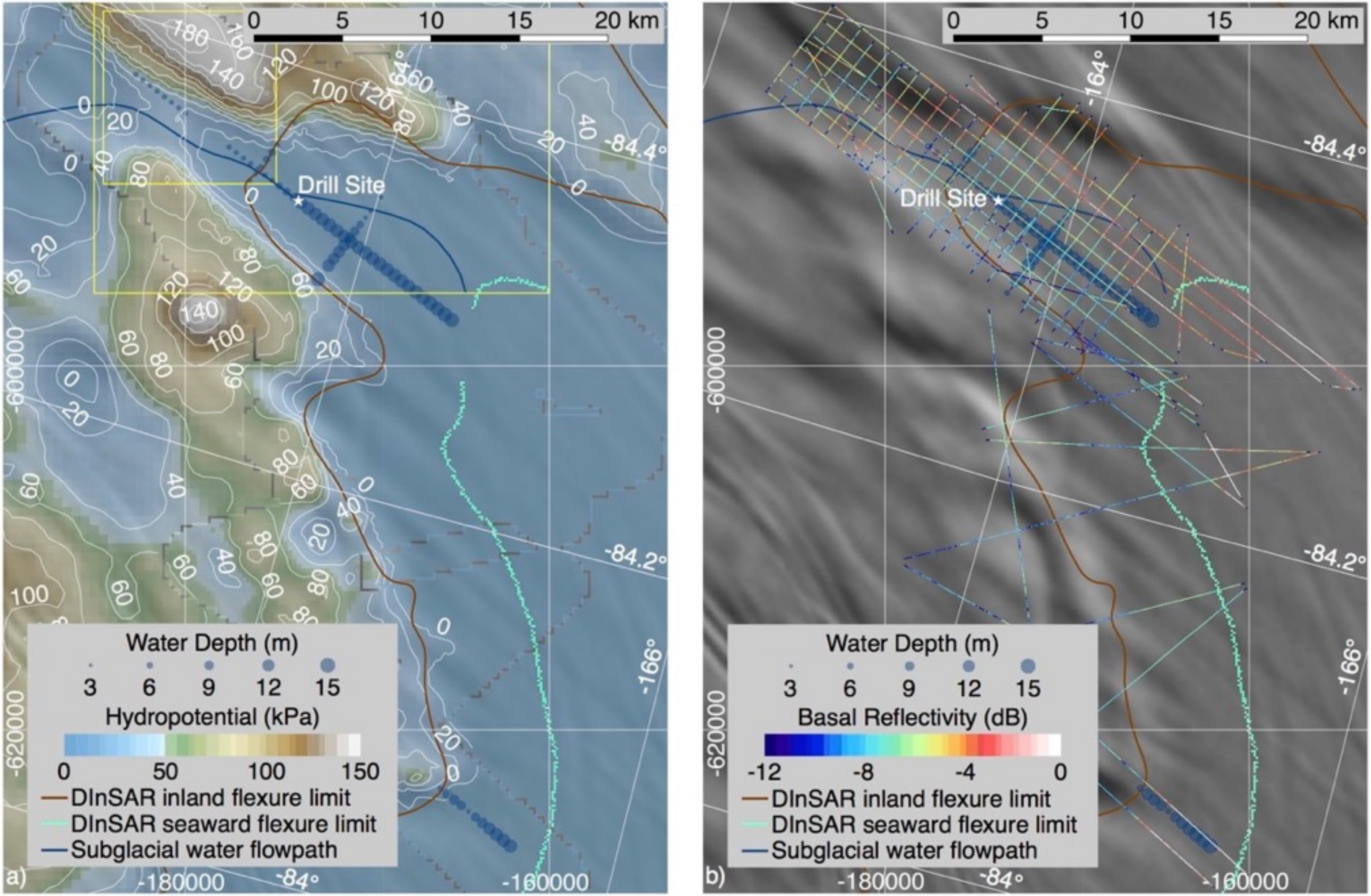


# ESTIMATING ENGLACIAL ATTENUATION FROM THE MULTIPLE



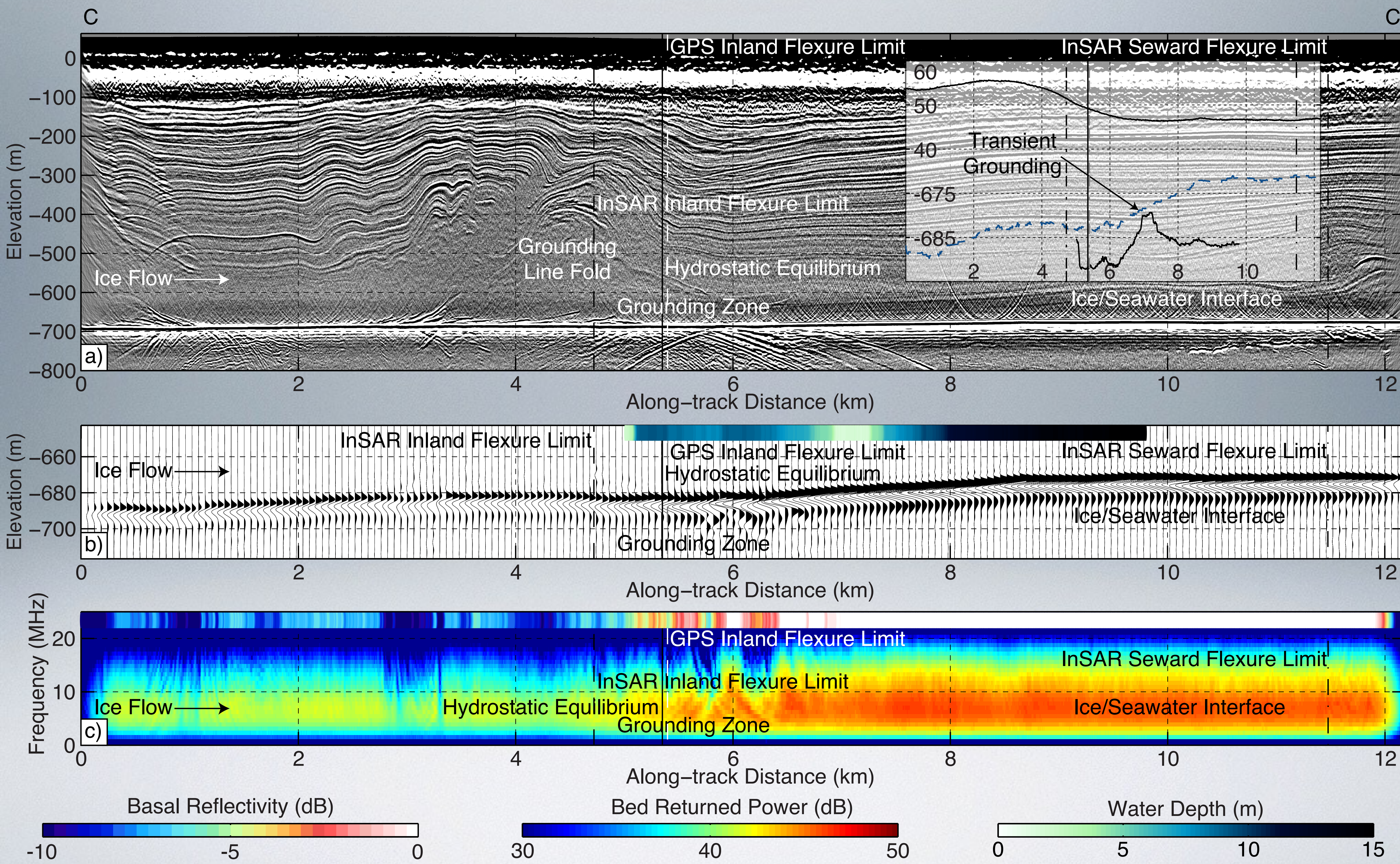

- Depth-averaged englacial attenuation rate: 16.6±2.4 dB/km

# HYDROPOTENTIAL AND BASAL REFLECTIVITY

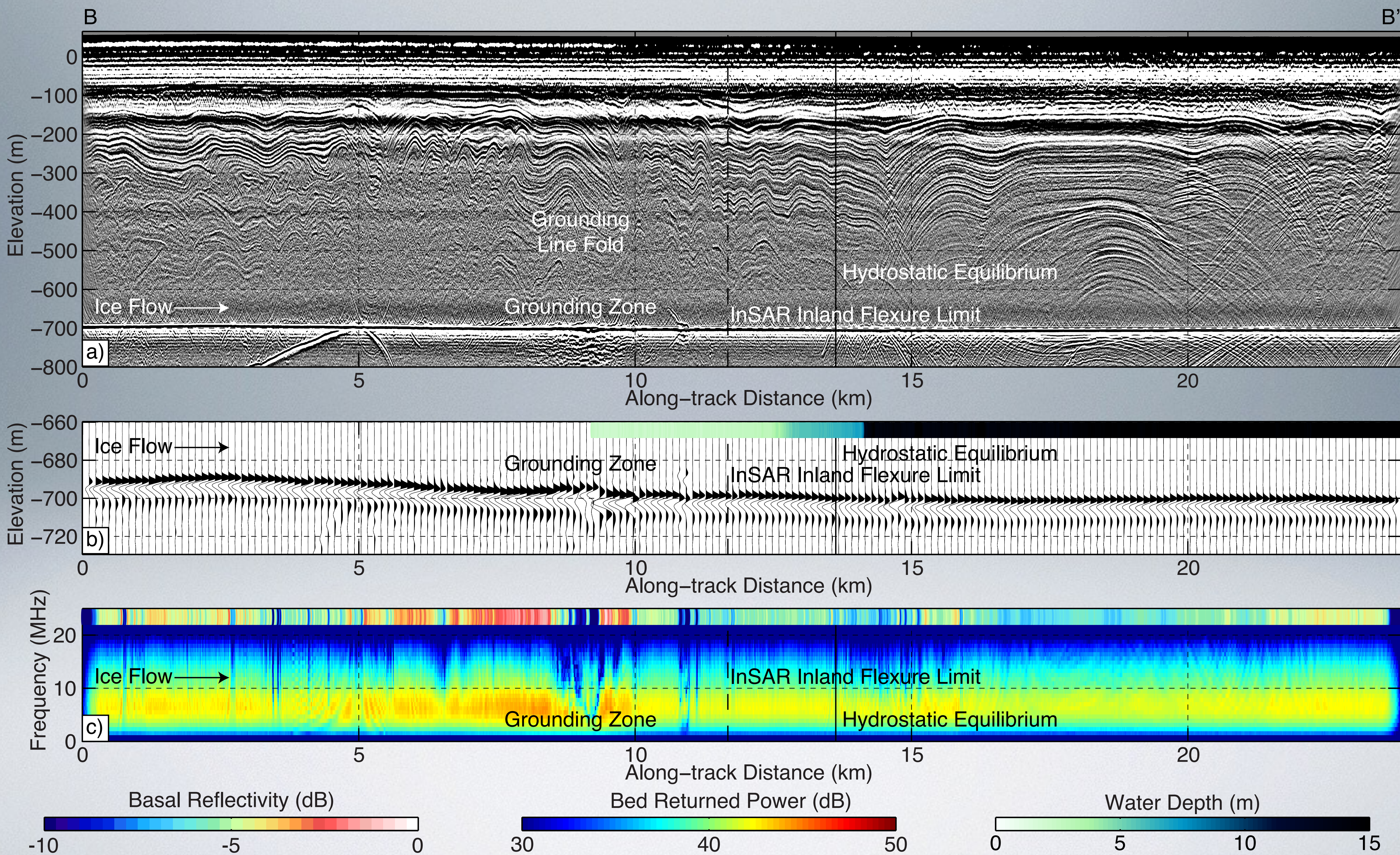



- Why are floating areas so dim?

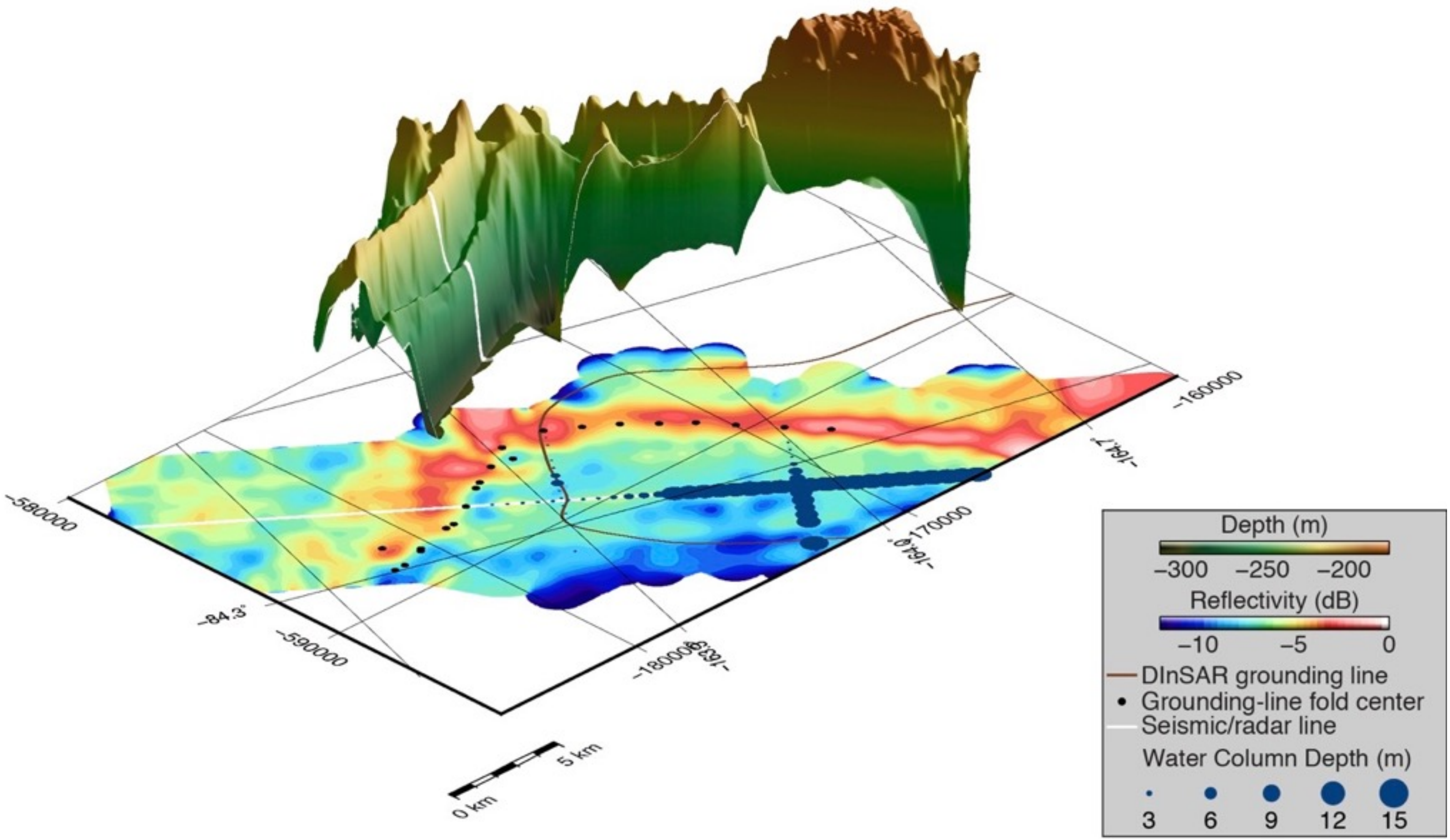
# THE SIMPLE CASE: REFLECTIVITY AT A SUBGLACIAL PENINSULA



# A MORE COMPLEX CASE: REFLECTIVITY IN SUBGLACIAL EMBAYMENT



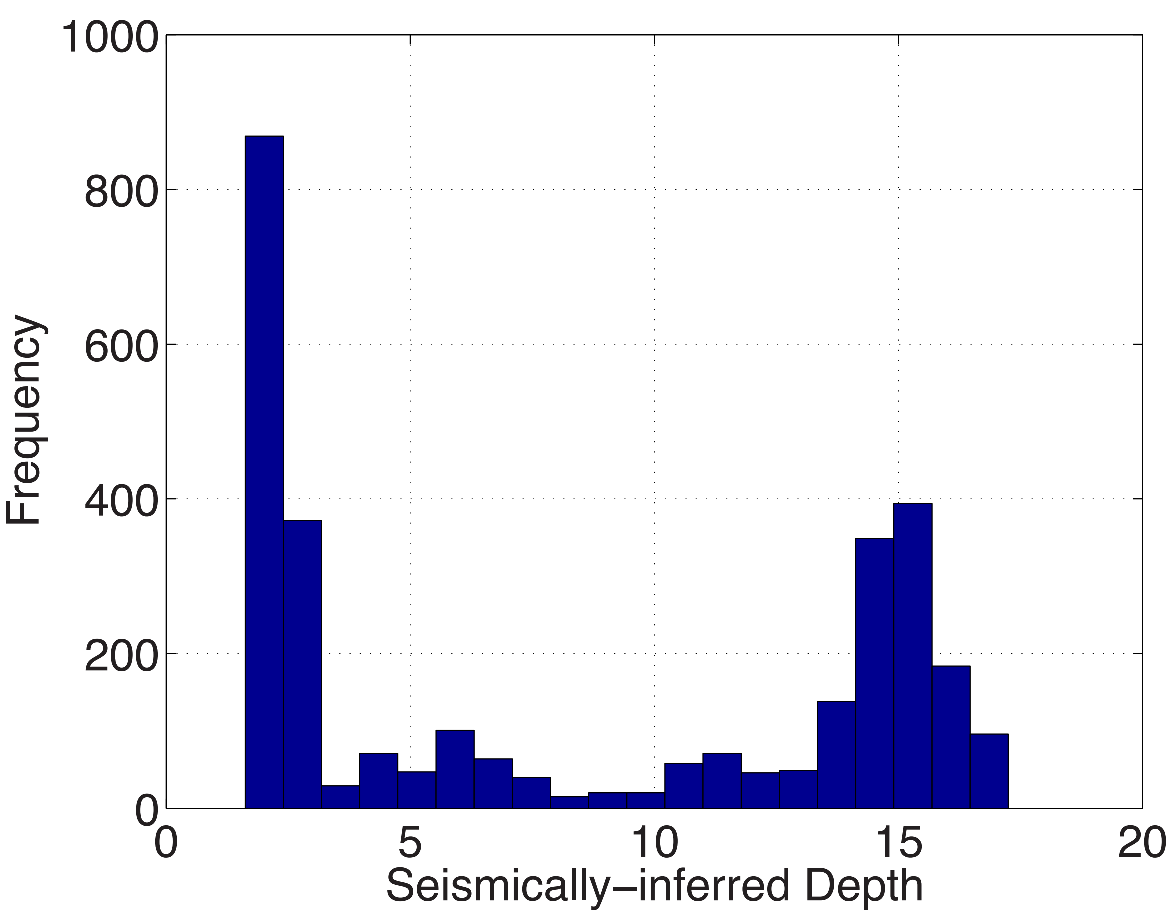
# BASAL REFLECTIVITY AND FOLD IN RADAR INTERNAL LAYERS



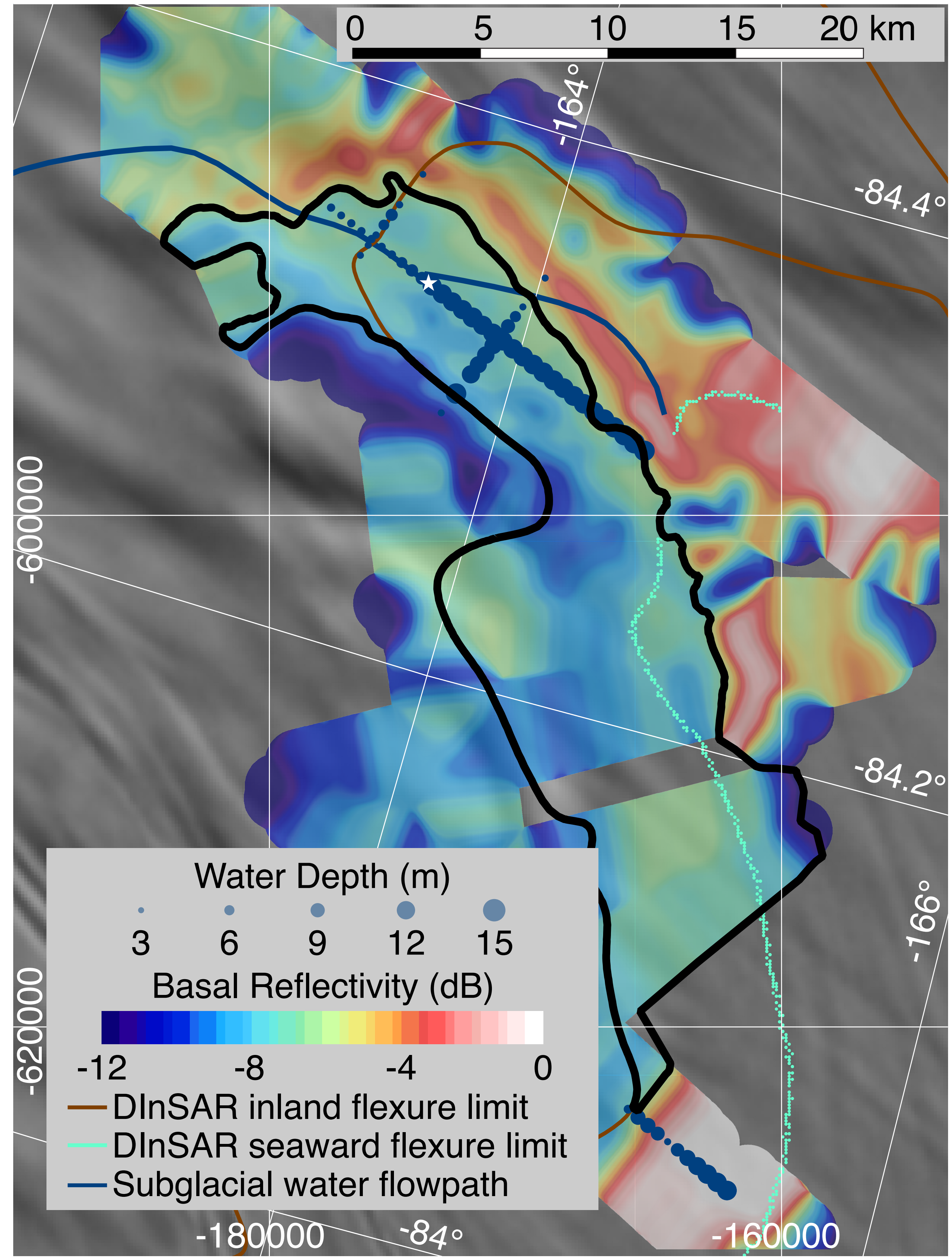
# BASAL REFLECTIVITY CONUNDRUM

- Why so dim?
  - System fault
  - What is the interface?
    - Appearance of basal interface, roughness, temperature
    - Two layers or more?
    - Attenuation/skin depth
  - Reflectivity modeling
  - Synthetics

WATER DEPTH DISTRIBUTION




EMBAYMENT REFLECTIVITY DISTRIBUTION



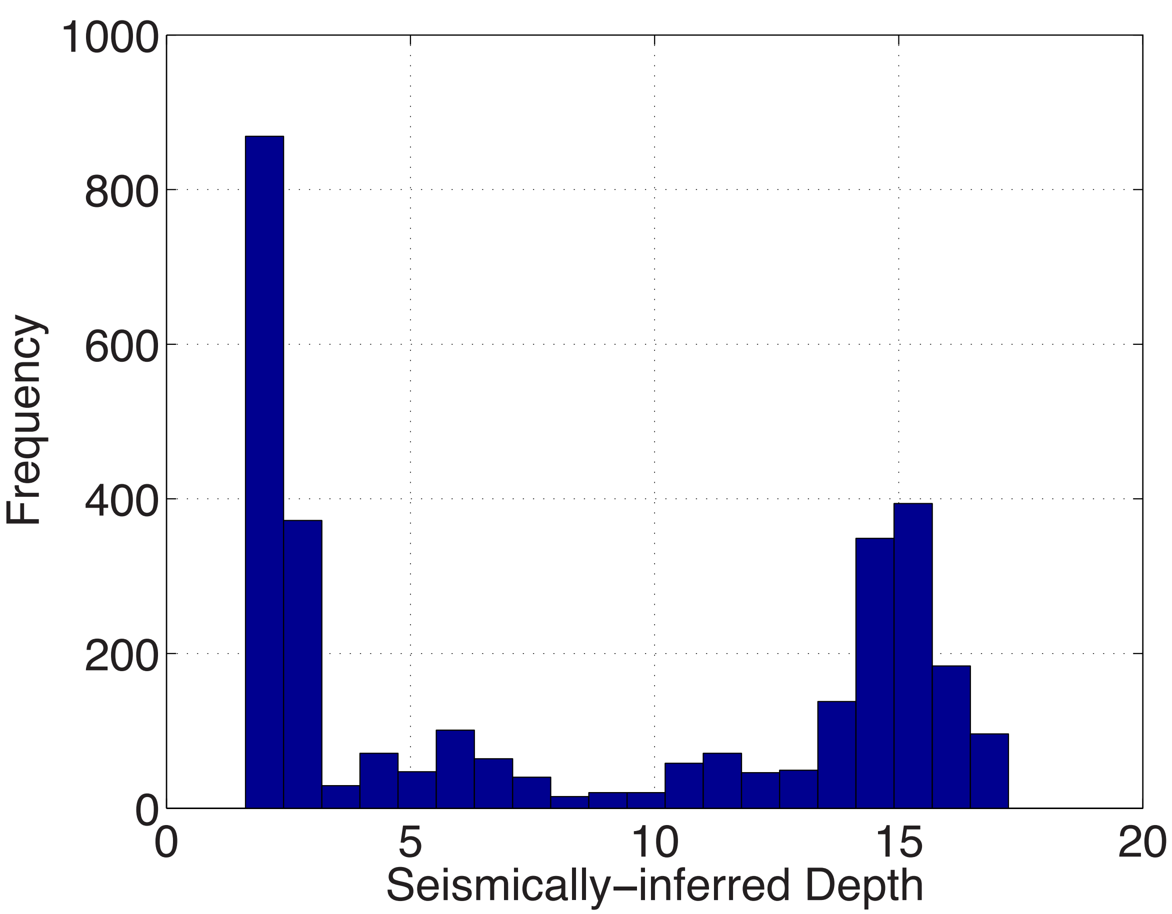
# BASAL REFLECTIVITY CONUNDRUM

- Why so dim?
  - System fault
  - What is the interface?
    - Appearance of basal interface, roughness, temperature
    - 2-layers or more?
    - Attenuation/skin depth
  - **Reflectivity modeling**
  - **Synthetics**

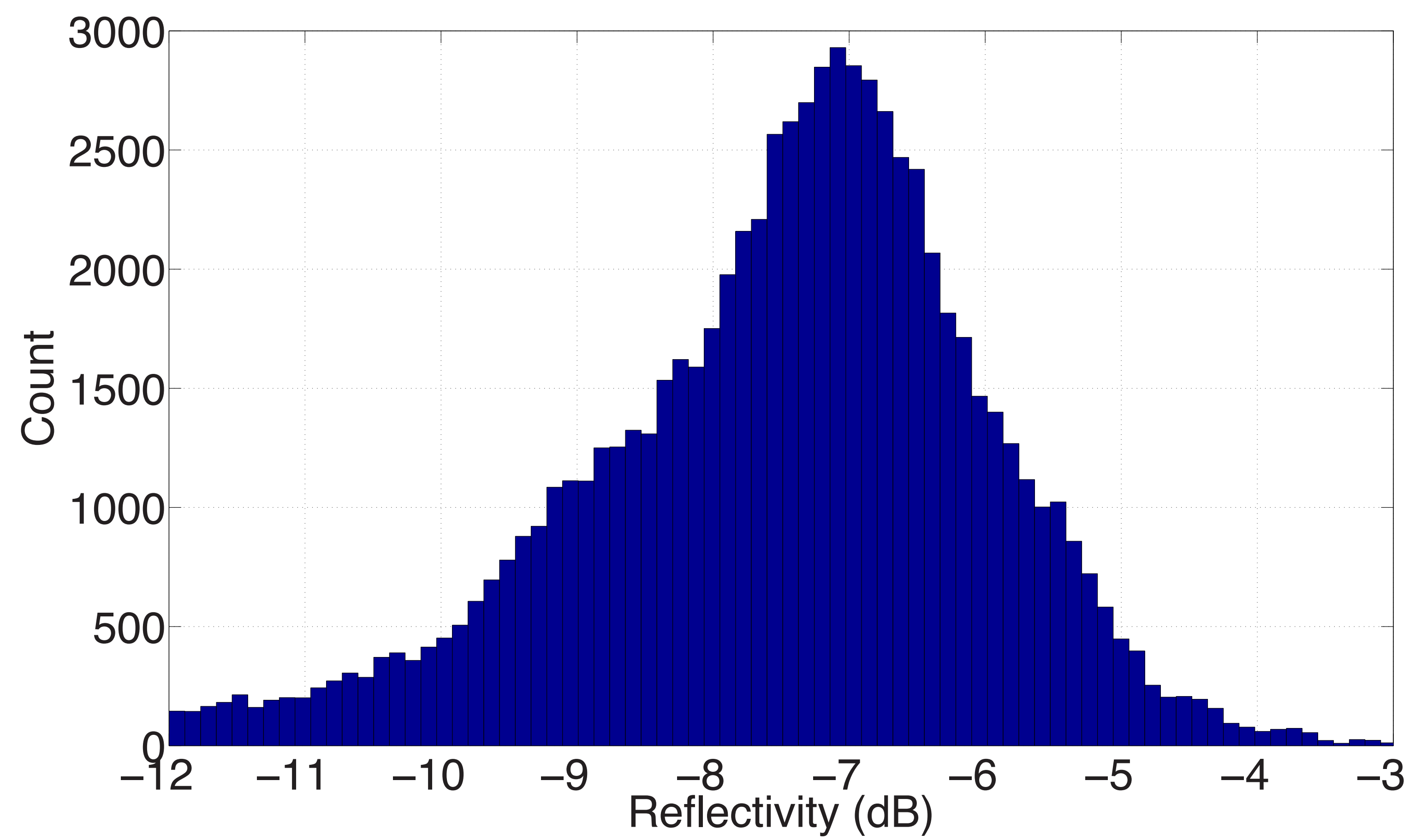
Table 1. Dielectric properties of common subglacial materials at for a 5 MHz radar wave

| Material | Permittivity | Conductivity (S m$^{-1}$) | Power Reflectivity (dB) | tan $\delta$ | Skin Depth (m) |
|---|---|---|---|---|---|
| Freshwater | 79.7 | $1 \times 10^{-6}$ | -3.5 | 0.002 | 225 |
| Seawater | 79.7 | 2.7 | -0.23 | 11.3 | 0.14 |
| Groundwater | 79.7 | $3\ .1 \times 10^{-2}$ | -2.4 | 1.4 | 1.3 |
| Unfrozen till (40% gw) | 18 | $4\ .1 \times 10^{-3}$ | -6.3 | 0.82 | 3.5 |
| Unfrozen till (15% fw) | 12 | $3\ .3 \times 10^{-5}$ to $3.3 \times 10^{-4}$ | -9.9 | 0.01 to 0.1 | 12 to 39 |
| Unfrozen till (45% fw) | 30 | $8\ .3 \times 10^{-5}$ to $8.3 \times 10^{-4}$ | -5.9 | 0.01 to 0.1 | 7.8 to 25 |
| Unfrozen bedrock (15% gw) | 6.6 | $7\ .5 \times 10^{-4}$ | -14 | 0.41 | 8.2 |
| Frozen till (40% gw ice) | 2.8 | $2\ .7 \times 10^{-5}$ | -30 | 0.035 | 43 |
| Frozen bedrock (15% gw ice) | 2.7 | $1\ .7 \times 10^{-5}$ | -27 | 0.022 | 55 |
| Marine ice | 3.43 | $4.8 \times 10^{-5}$ | -35 | 0.05 | 33 |
| Sand | 2.6 | $1.1 \times 10^{-5}$ | -25 | 0.015 | 68 |

WATER DEPTH DISTRIBUTION

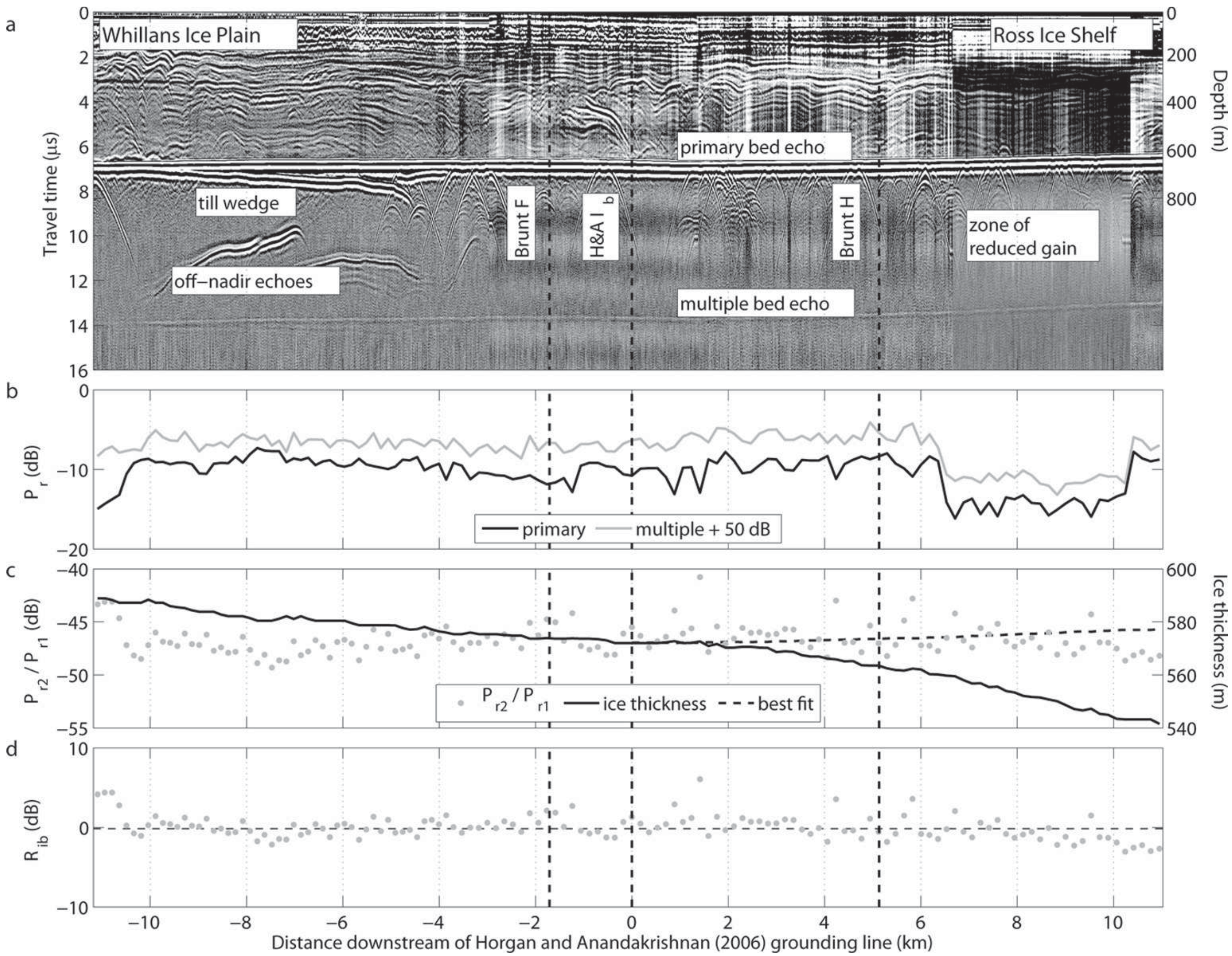



EMBAYMENT REFLECTIVITY DISTRIBUTION

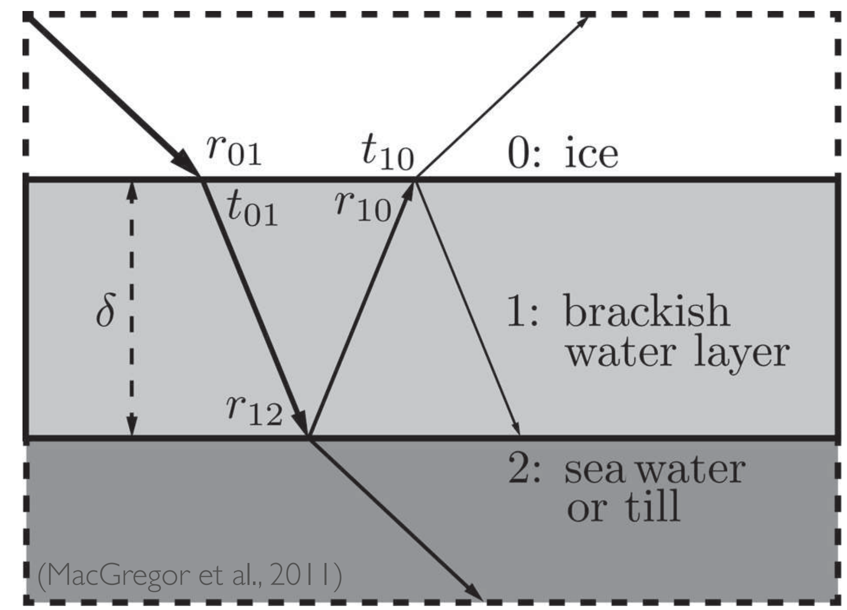


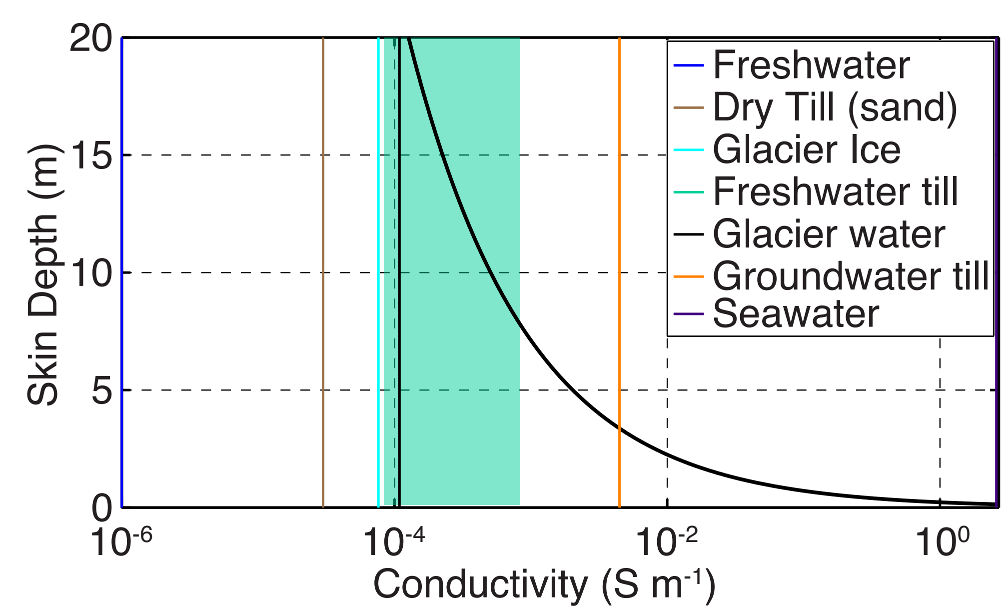
# TWO OR THREE LAYERS?

$$R_{ab} = 20\log_{10}\left|\frac{\sqrt{\epsilon_a}-\sqrt{\epsilon_b}}{\sqrt{\epsilon_a}+\sqrt{\epsilon_b}}\right| \qquad R_{abc} = 20\log_{10}\left|r_{ab} + t_{ab}r_{bc}t_{ab}\frac{\exp(-2ik_b\delta)}{1-r_{bc}r_{ab}\exp(-2ik_b\delta)}\right|$$

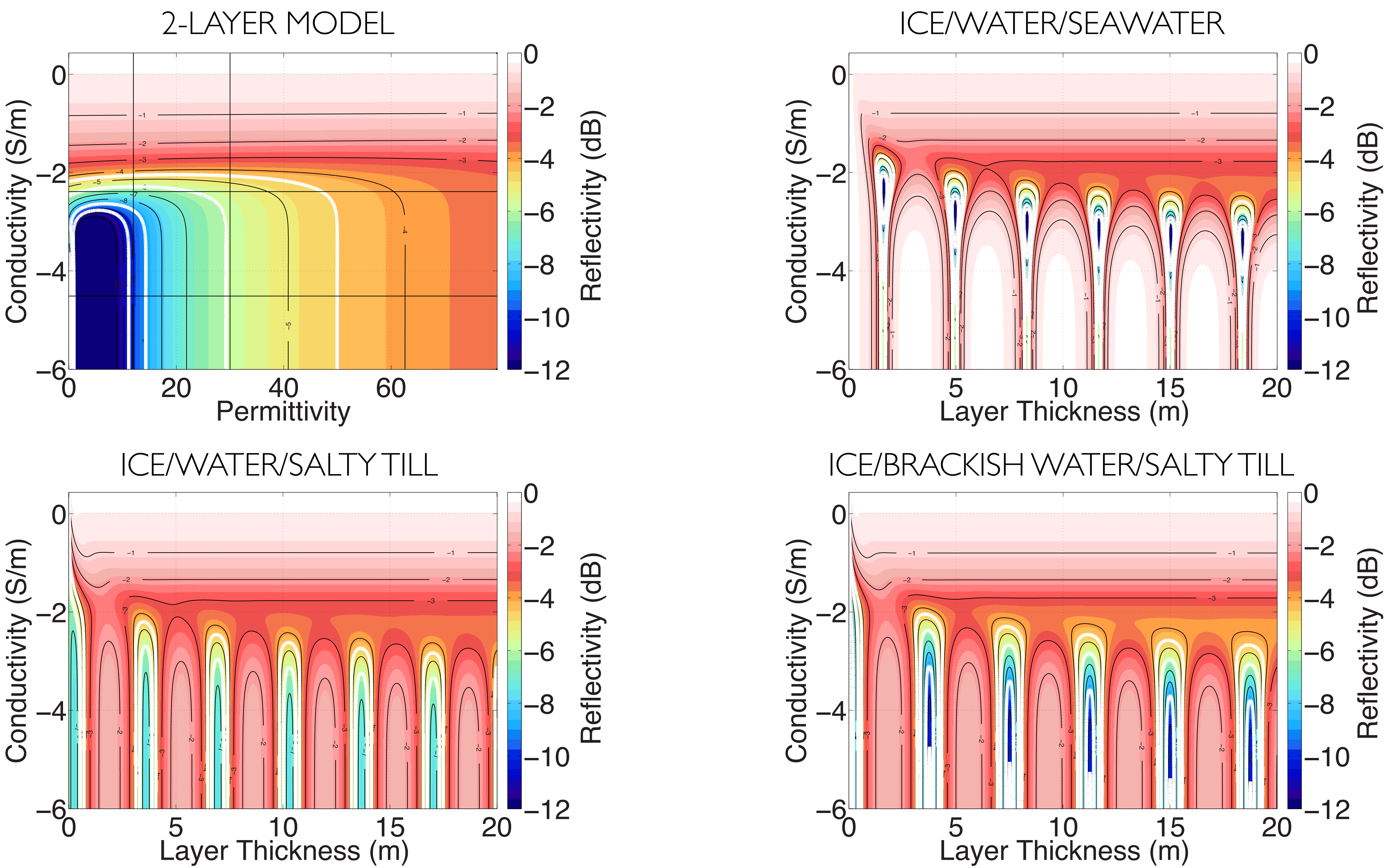



(MacGregor et al., 2011)

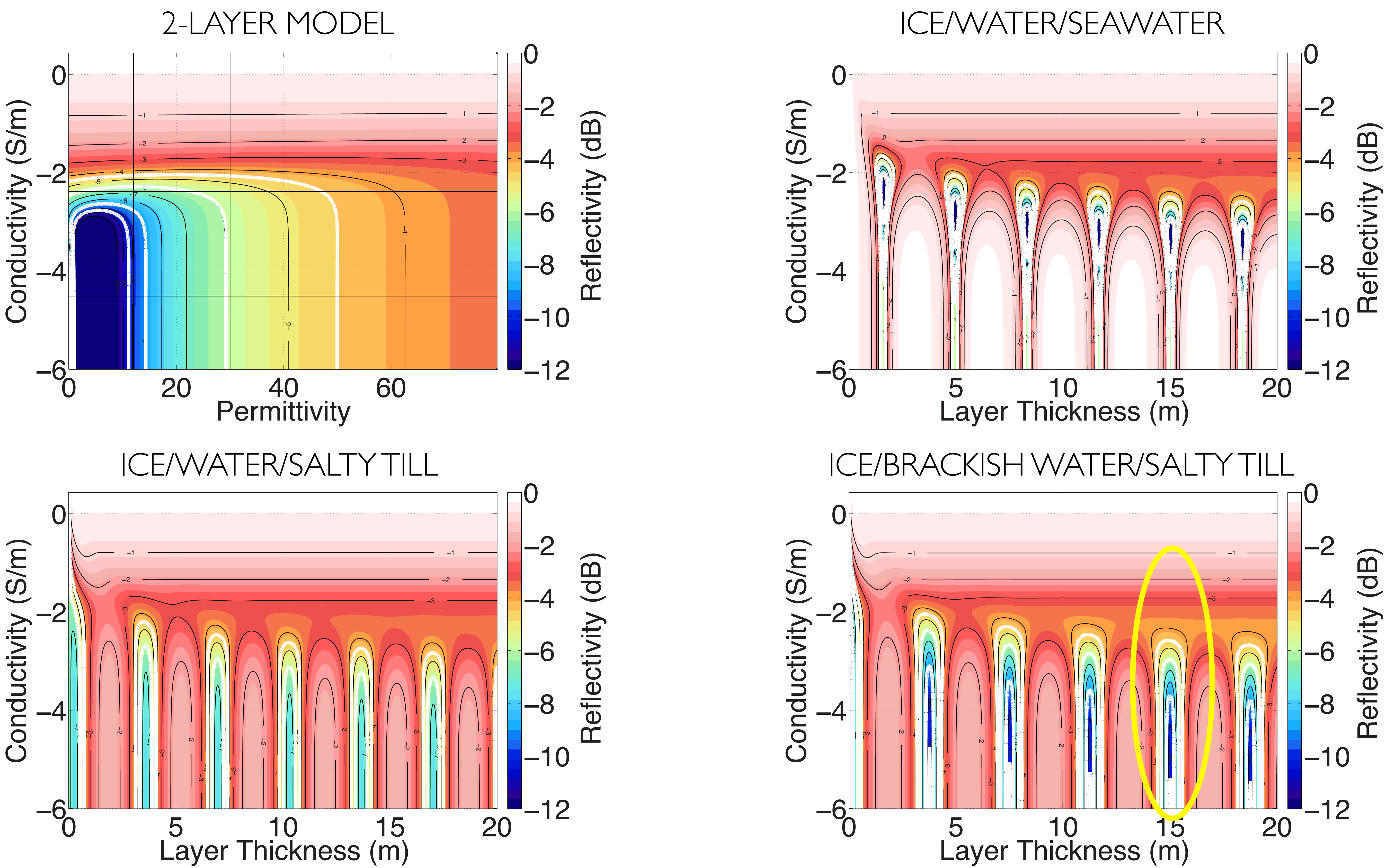


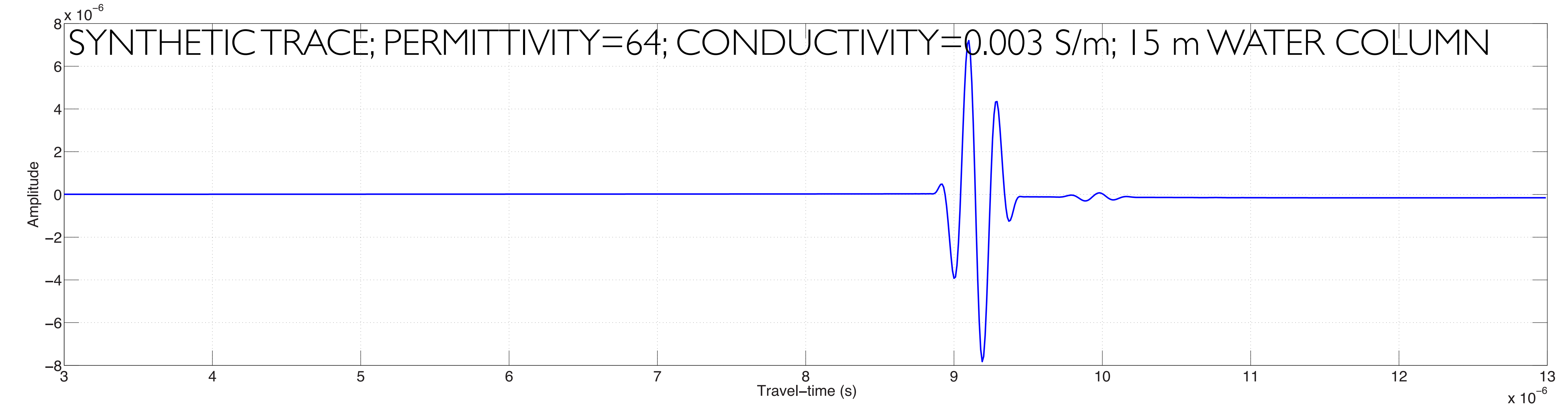
# BASAL REFLECTIVITY: TWO- and THREE-LAYER MODELS

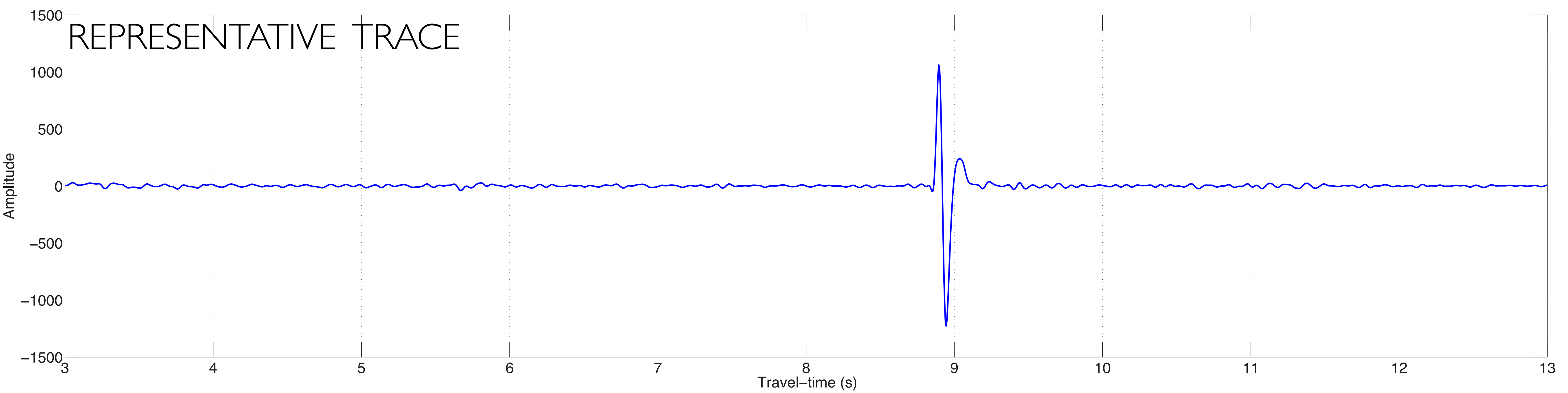


# BASAL REFLECTIVITY: TWO- and THREE LAYER MODELS



# SYNTHETIC MODELING




- Conductivity is ~0.001–0.01 S/m (brackish; ~10% sediment)

# CONCLUSIONS

- Dim reflectivity indicates large area of brackish water?
    - ~10% sediment content
    - Brackish
- Lagged water exchange in shallow water column
    - Abruptly brightens in other areas and seaward of embayment
    - Lobe ~10 m step, would take us out of a node; stepped basal topography
    - Tidal anomaly larger seaward of reflectivity step
    - Regional geologic control?
- Low basal-melt rate
    - No strong plume circulation
    - No subglacial channel melted into ice
    - No accommodation space for wedges–flat deposits imaged by reflection seismology