



Orbital Radar Imaging Of Europa's Subsurface Properties and Processes : The View from Earth

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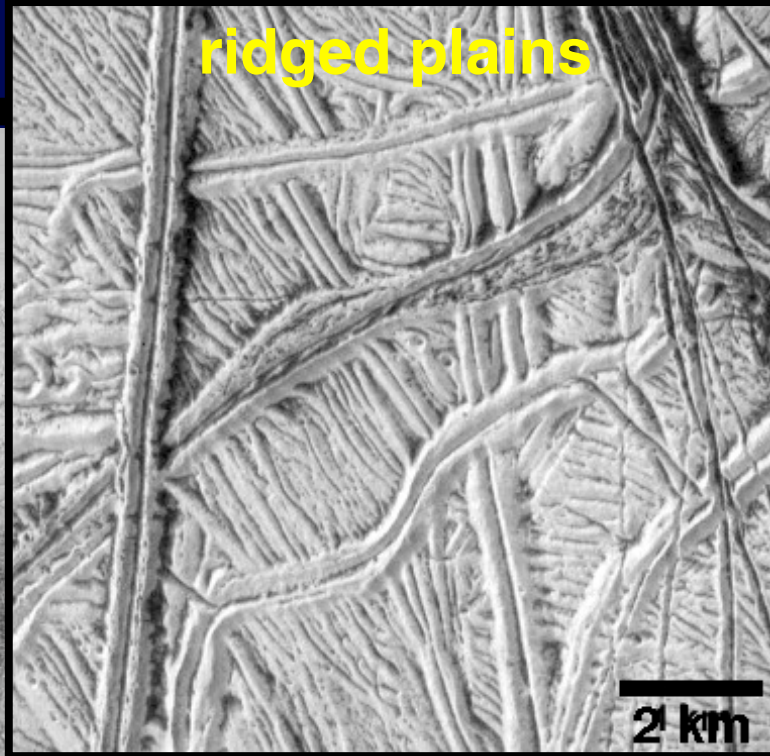


**Return to Europa:
How do we prepare?**

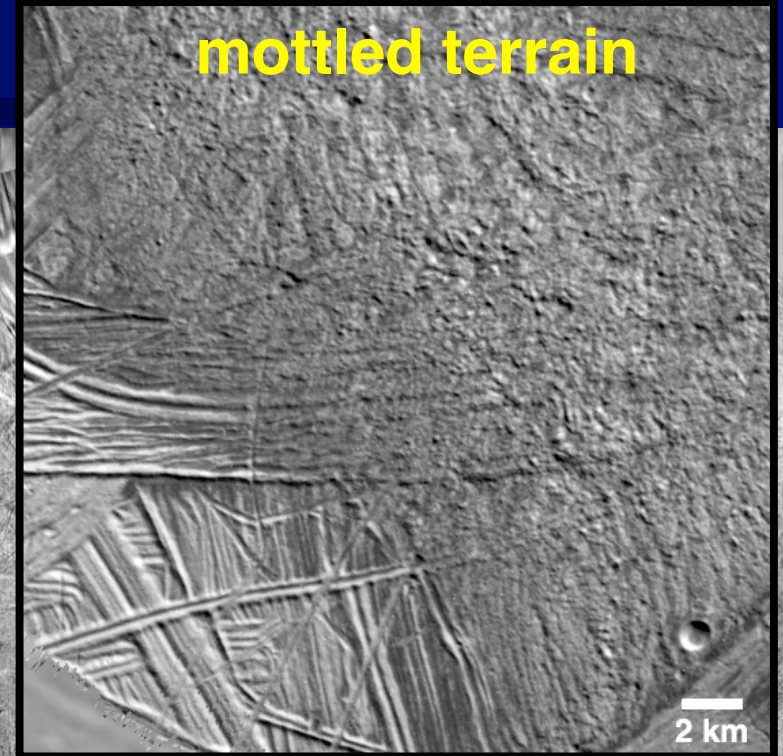


Background: Europa's Geology

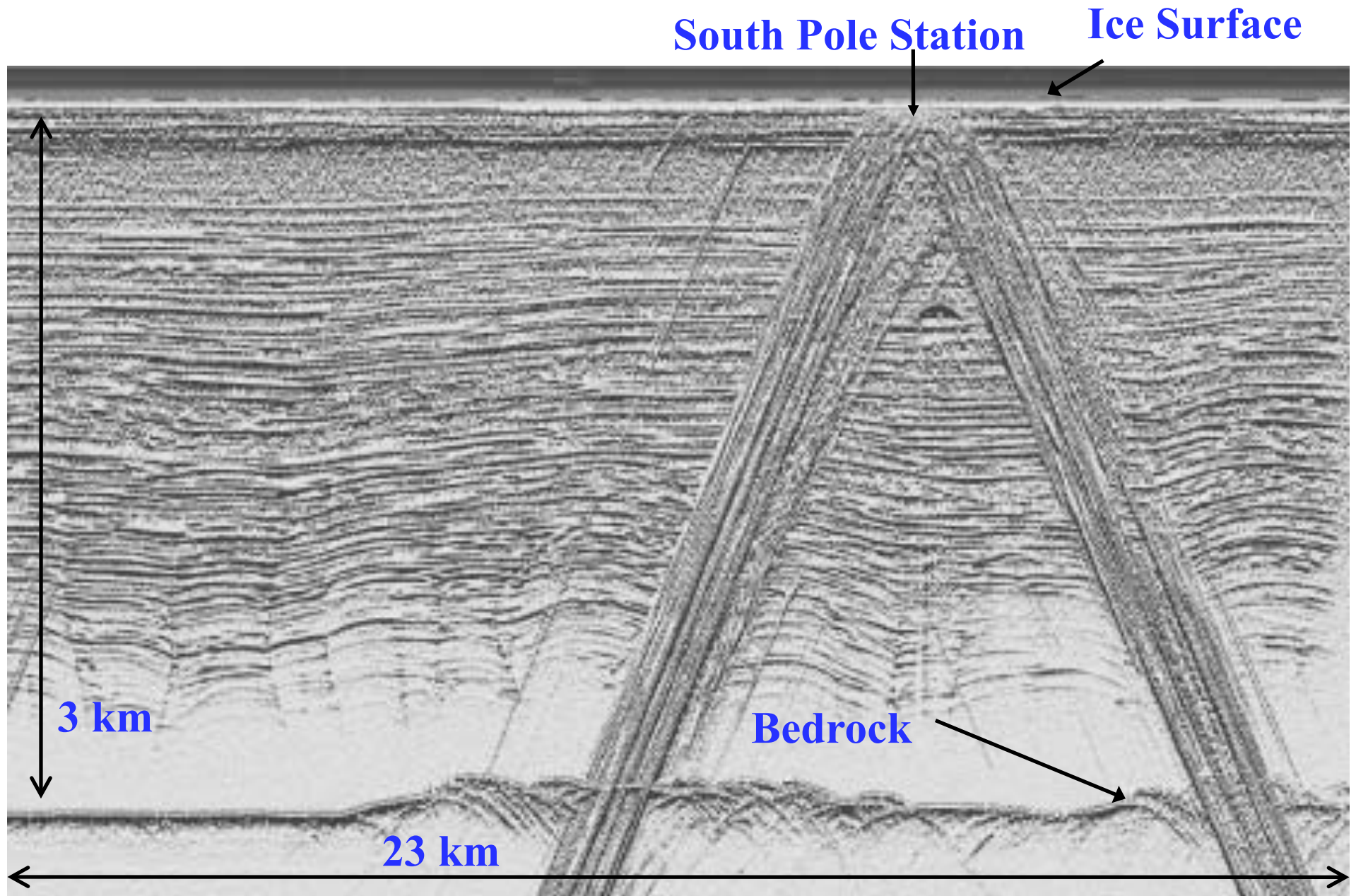
ridged plains



mottled terrain



Radar sounding of Earth's ice sheets is routine...

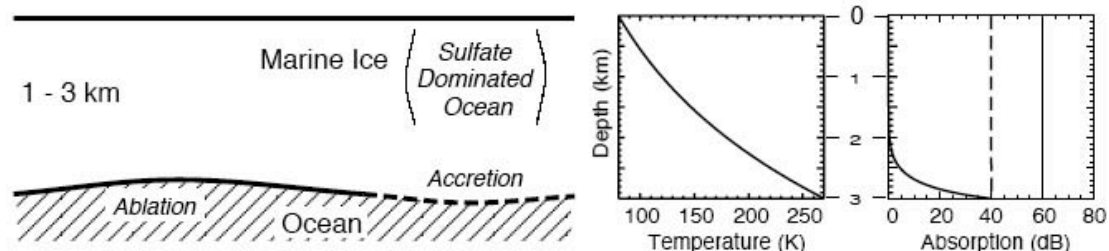




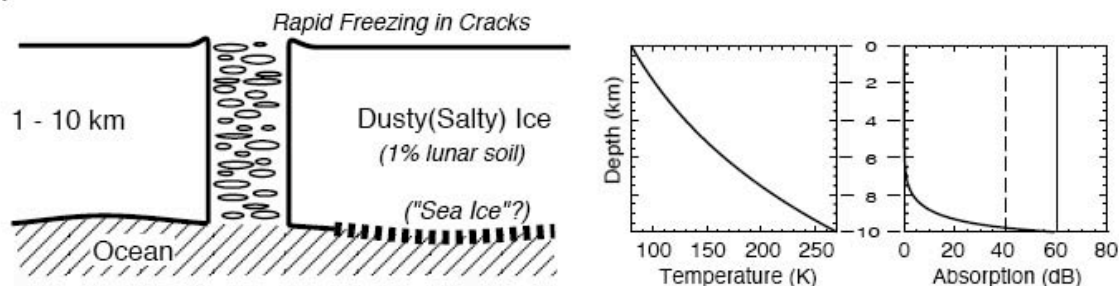
Jupiter-Europa Orbiter: Ice Shell Science Investigations

- Characterize the distribution of any shallow subsurface water.
- Search for an ice-ocean interface.
- Correlate surface features and subsurface structures to investigate processes governing communication among the surface, ice shell and ocean.

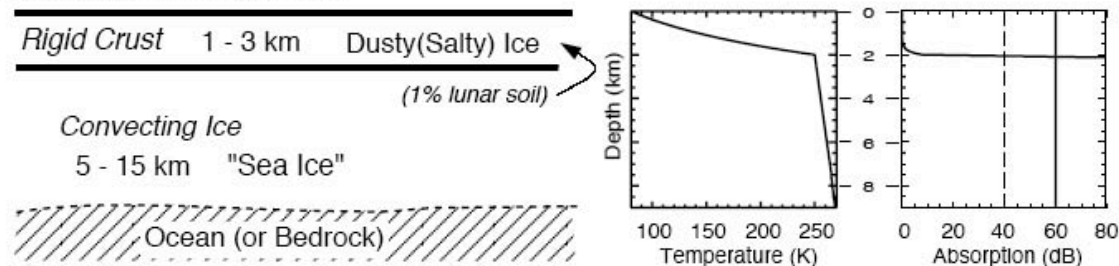
A) Marine Ice Processes



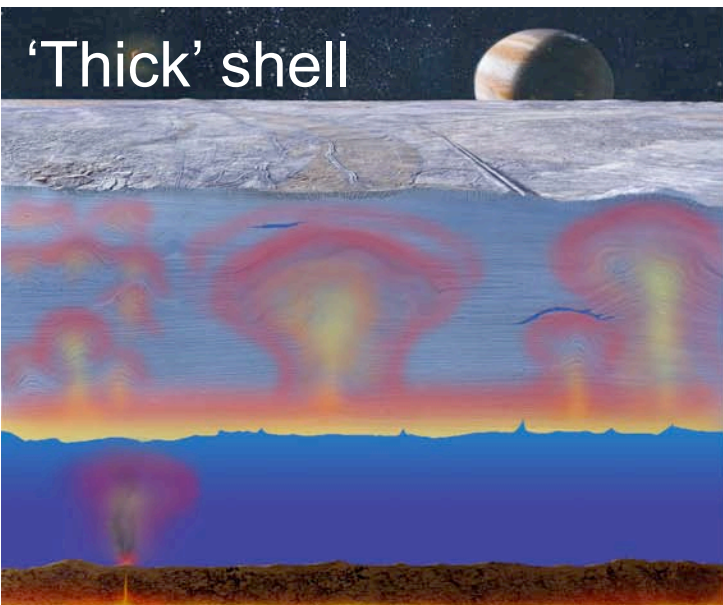
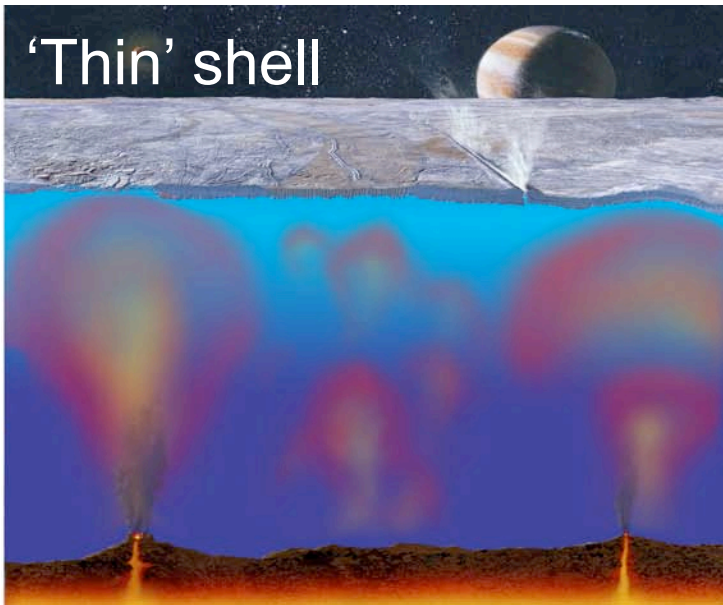
B) Tidal/Tectonic Processes



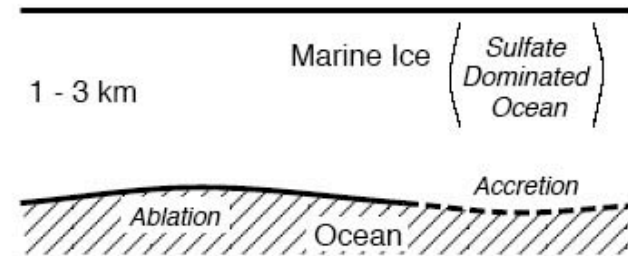
C) Convection Processes



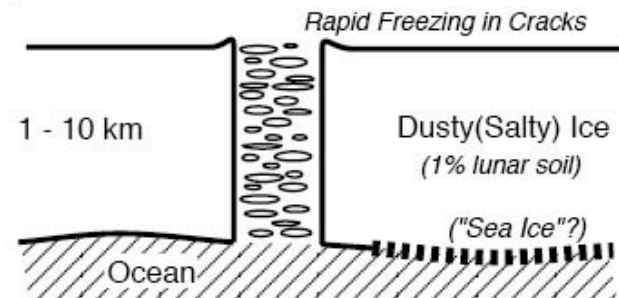
Orbital radar sounding of Europa is feasible; what do we need to learn?



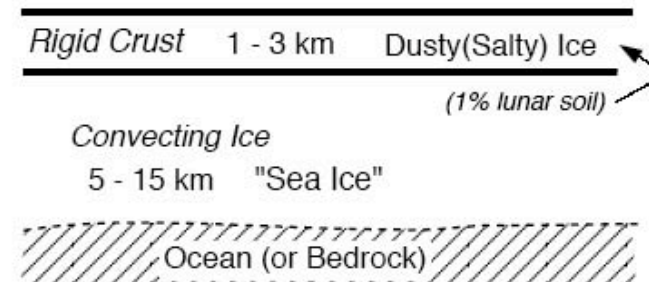
A) Marine Ice Processes



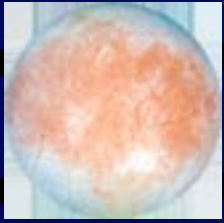
B) Tidal/Tectonic Processes



C) Convection Processes

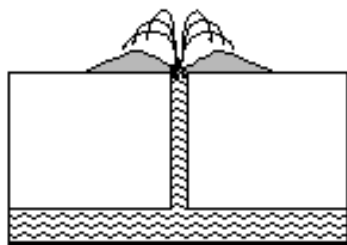
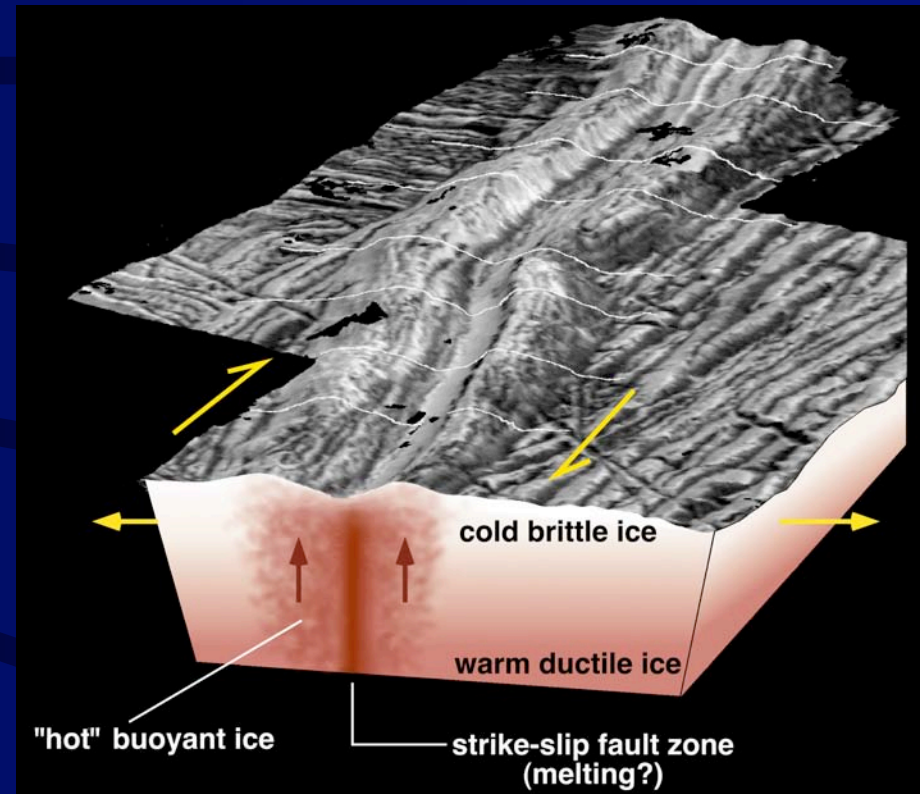


Chyba et al., (1999); Moore (2000),
Blankenship et al (1999, in press).

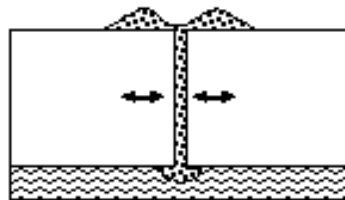


Ridge Formation Models

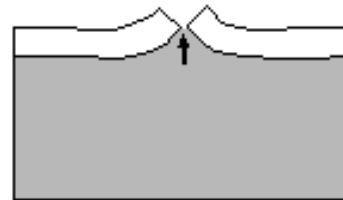
- Several candidate models
- Shear heating along fracture plains is a leading model.



volcanism



tidal squeezing



diapirism

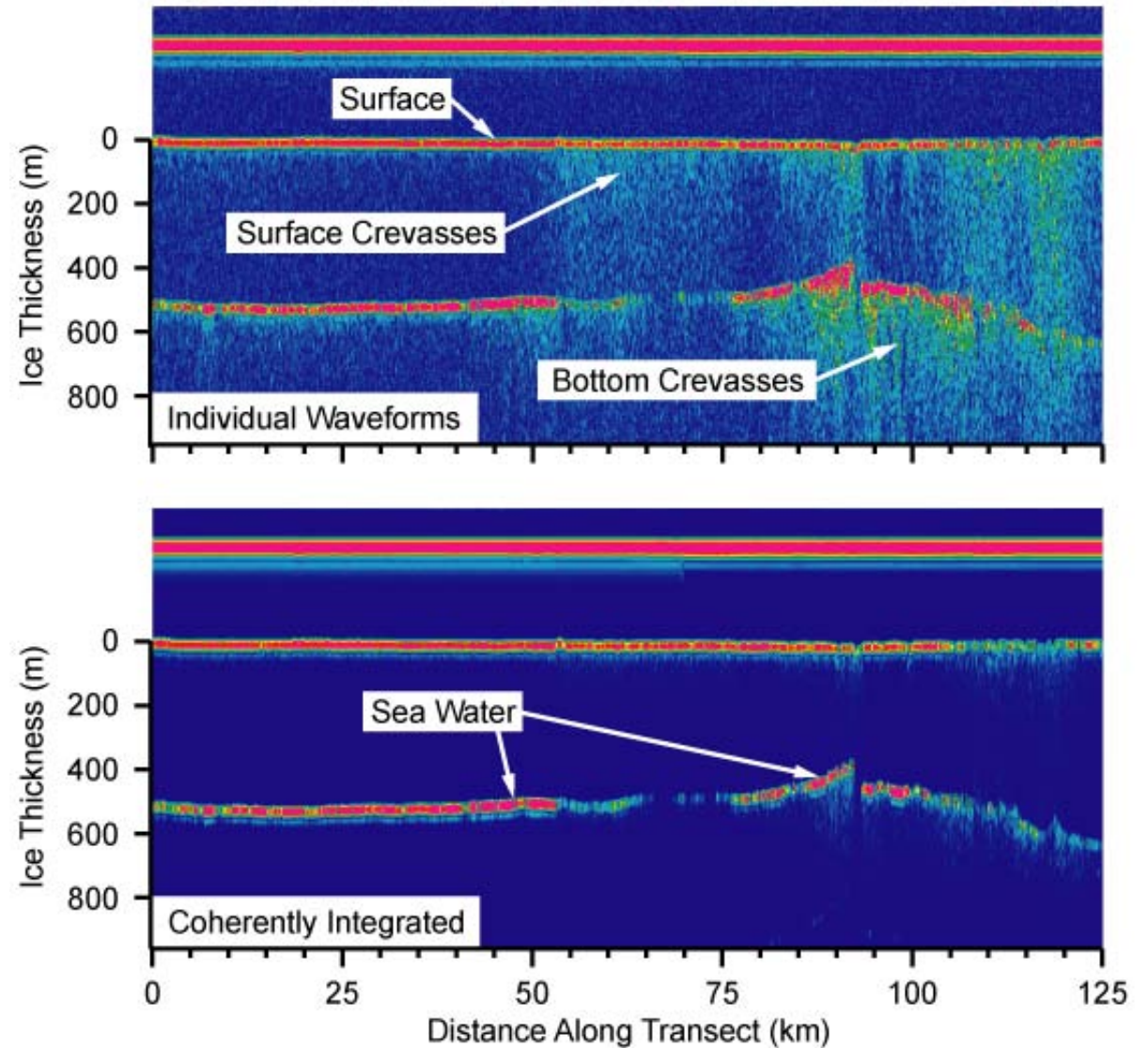
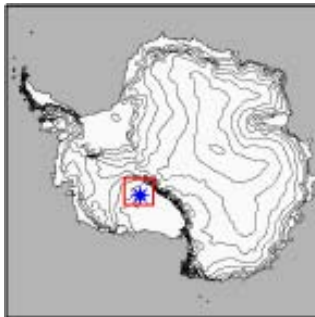
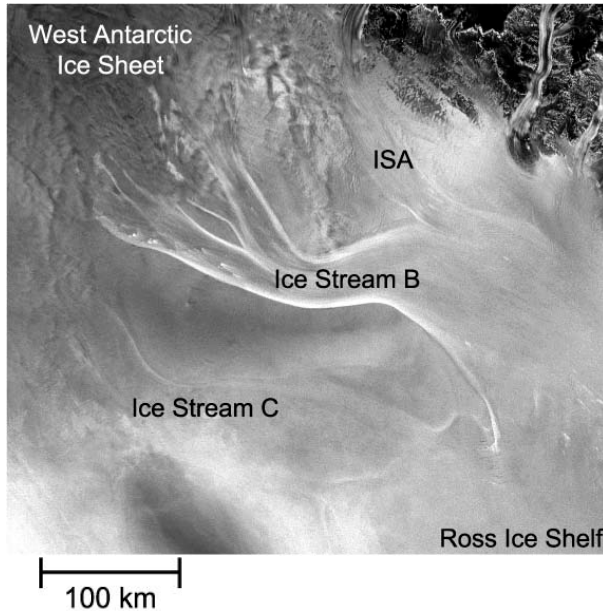


compression



wedging

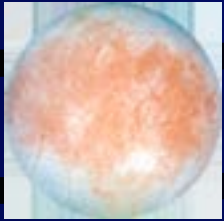
Antarctic Ice Shelves (fracture/infiltration)



Peters et al., J. Glac. (submitted).

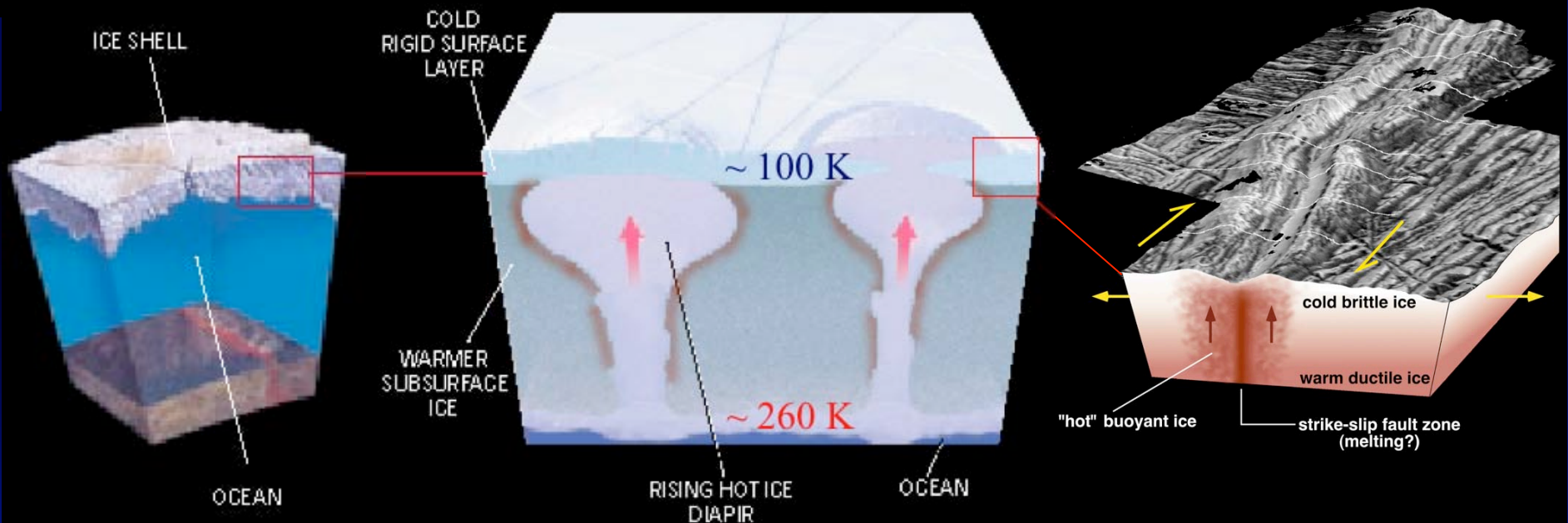
Earth: ice/ocean interface and tidal cracking near ice shelf origin

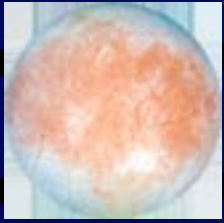
Europa: ice/ocean interface and ridge/band formation



Convection in Europa's Ice Shell

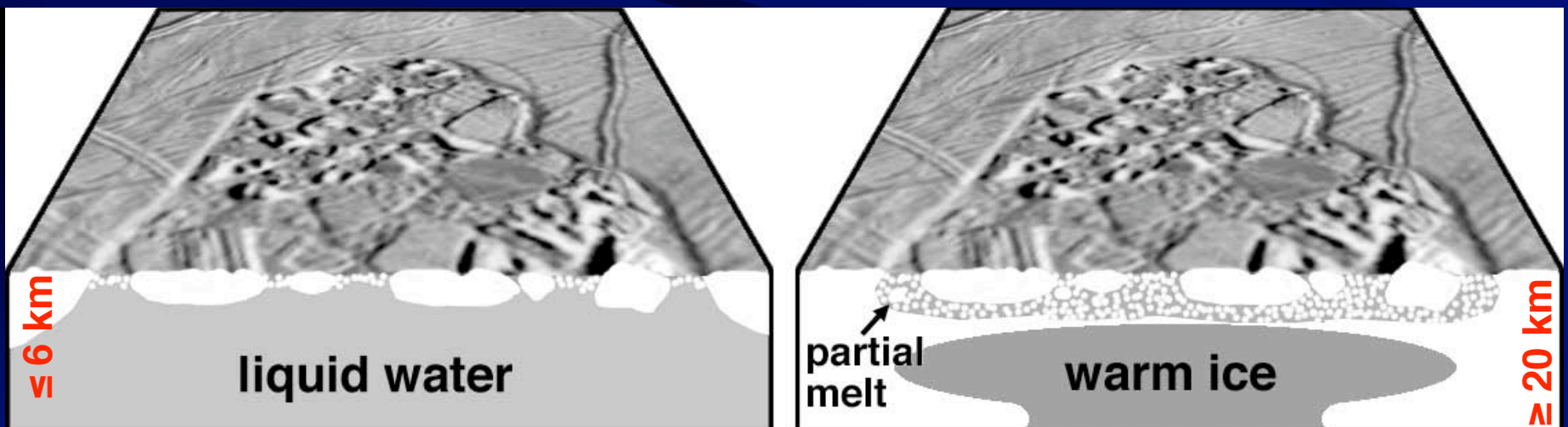
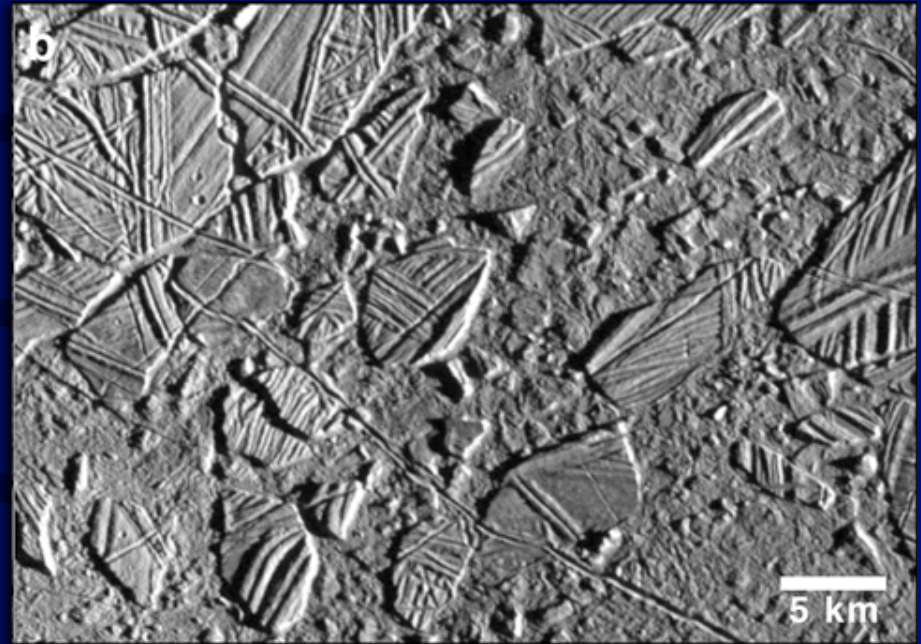
- Pits, spots, and domes suggest ice convection.
- Near-surface melt?
- Salts may be expelled from warm plume cores.





Chaos Models

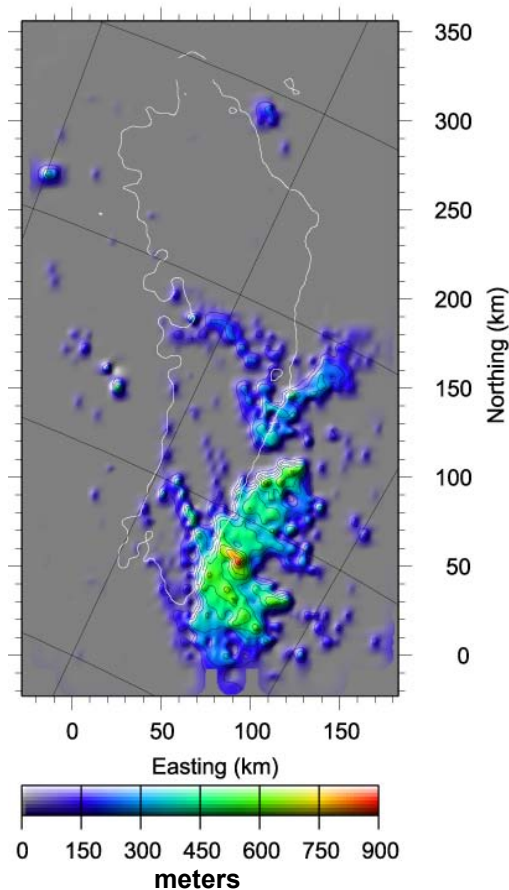
- *Melting model:*
 - ✧ Ice shell thins and melts above oceanic megaplumes.
- *Diapirism model:*
 - ✧ Ice convection partially melts salty ice.



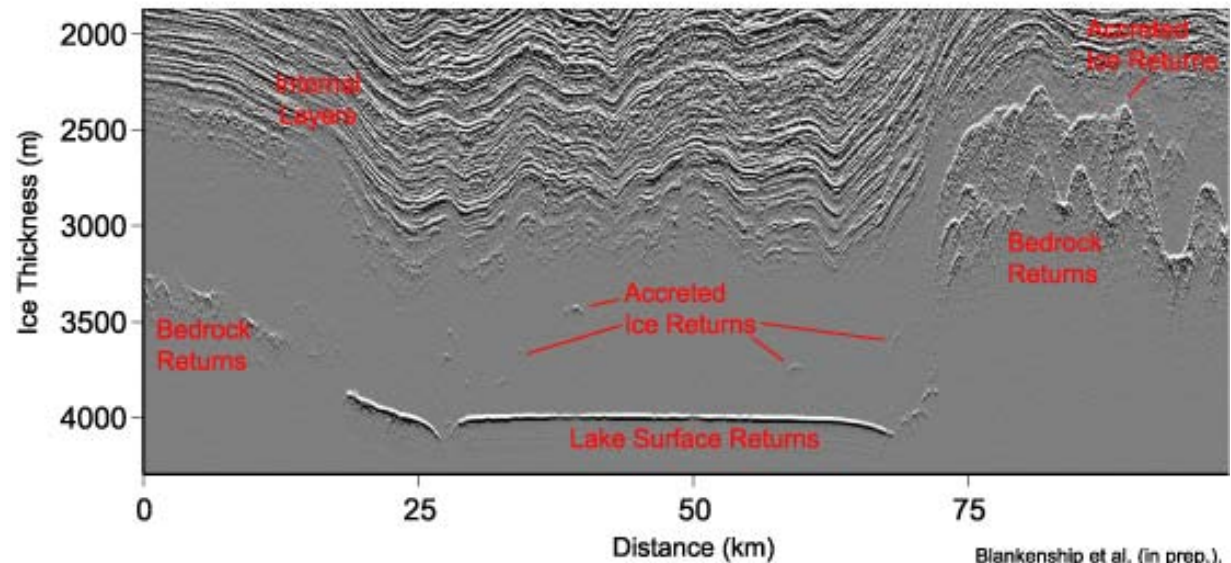
Antarctic sub-ice hydrology (melt/accretion)

Accreted Ice Thickness

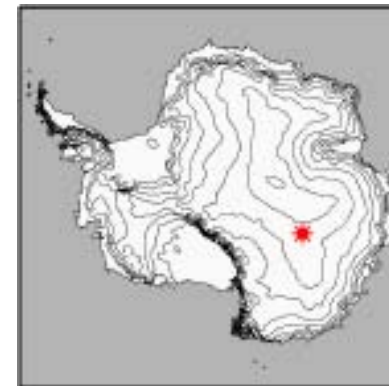
contour interval: 100 m



Subglacial Lake Vostok, East Antarctica (airborne radar sounding at 60 MHz)



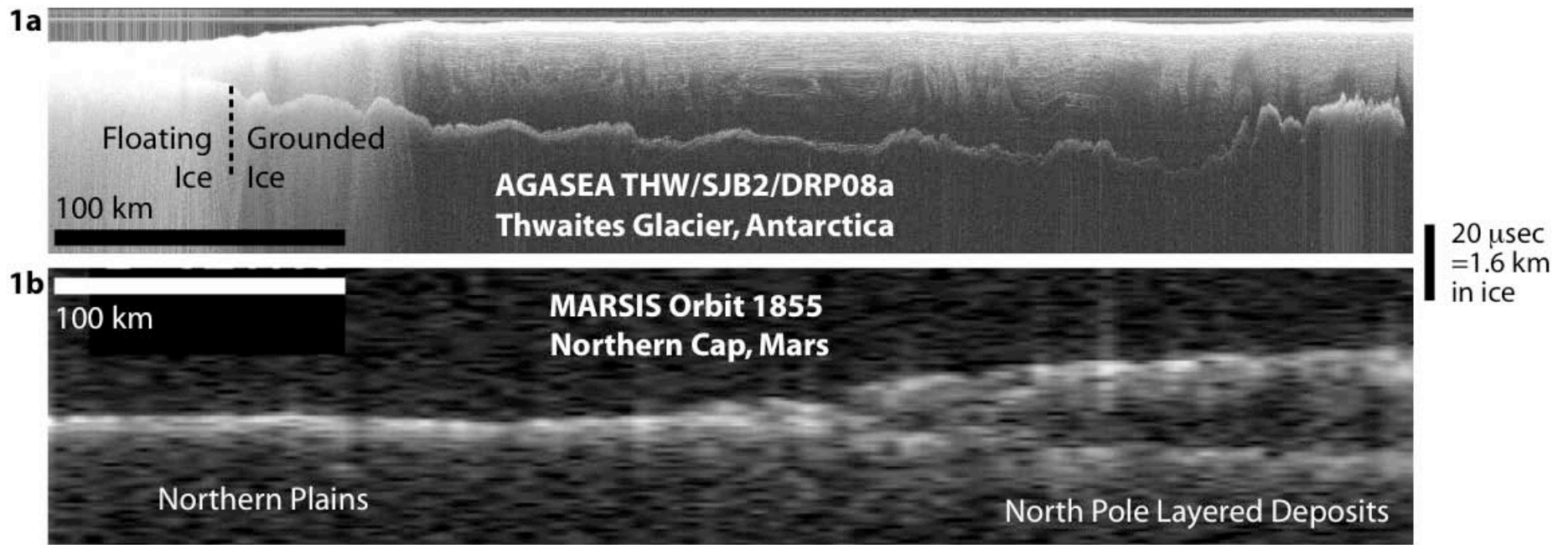
Blankenship et al. (in prep.).



Earth: sub-ice lakes/ivers and lake-ice accretion

Europa: plume hydrology and rigid shell accretion (chaos matrix?)

Airborne and Orbital radar sounding work!
Earth/MARSIS profiles at the same scale



UTIG Instrumentation: Ice-Penetrating Radar

Twin otter



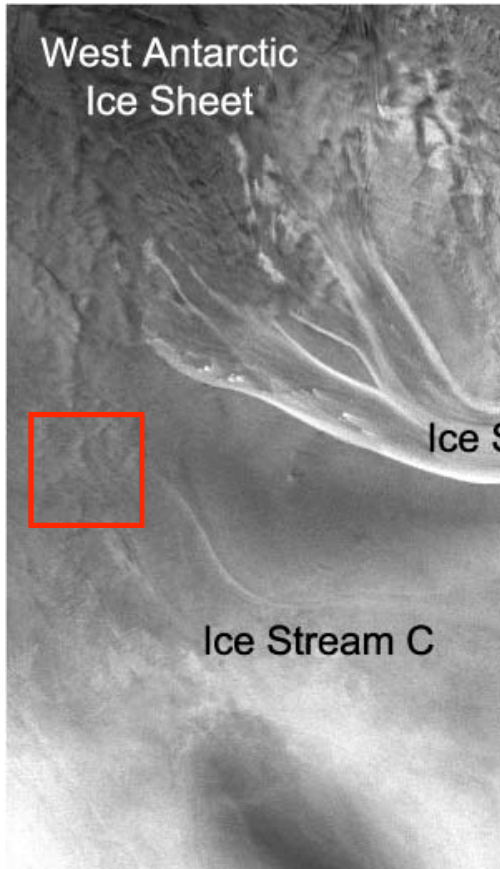
phase coherent
60 MHz center frequency
15 MHz bandwidth
8 MW peak power
6.4 kHz PRF



Basler (DC-3)

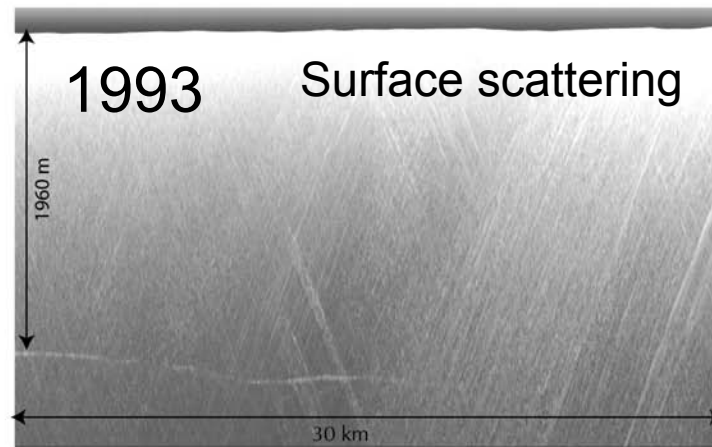
Europa has inspired development of new radar acquisition and imaging technologies.

...

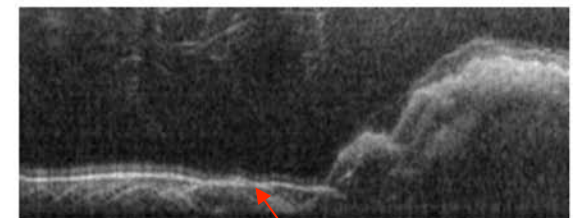


(Peters et al. 2005, 2007)

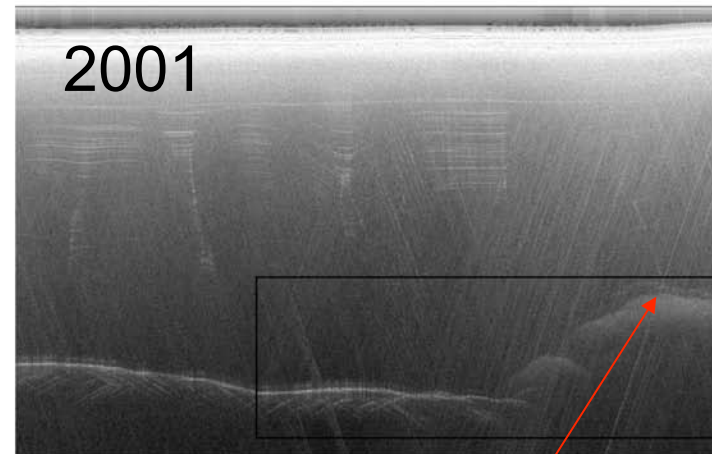
UTIG Airborne Radar across a West Antarctic Ice Stream shear margin



Incoherent acquisition



Full 2-d focused SAR processing



Coherent acquisition

Water on bedrock
resolved

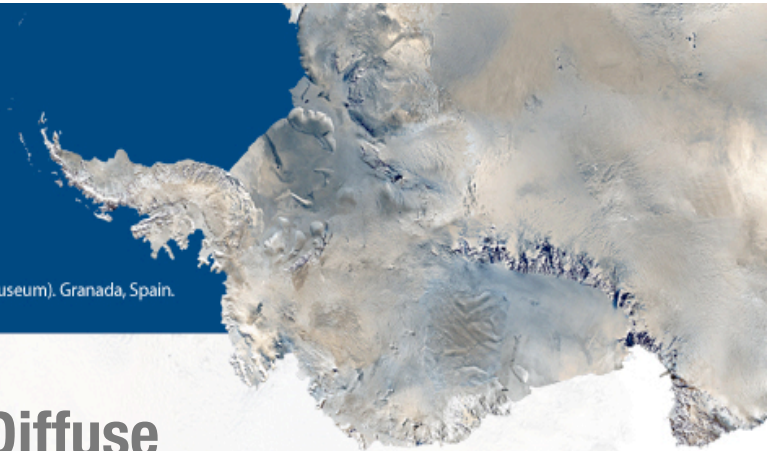
New features seen with reduced scattering

FIRST ANTARCTIC CLIMATE EVOLUTION SYMPOSIUM

www.acegranada2009.com

7-11 September, 2009.

Parque de las Ciencias (Science Museum), Granada, Spain.



Reflecting Interfaces: Specular and Diffuse

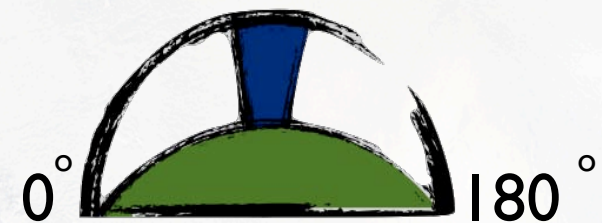
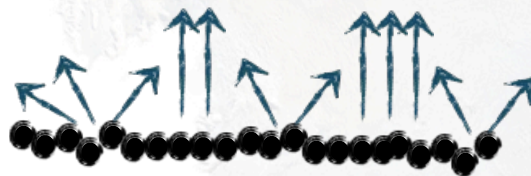
Specular Reflection



Diffuse Reflection



Both Diffuse and Specular



Basal Interface

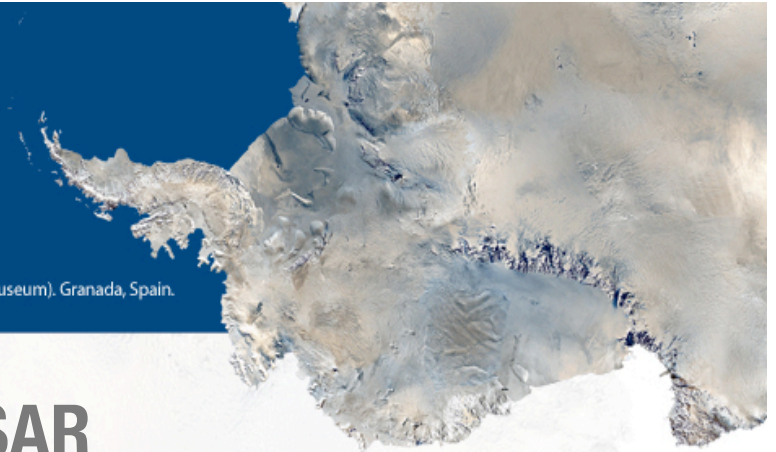
Angular Visibility

FIRST ANTARCTIC CLIMATE EVOLUTION SYMPOSIUM

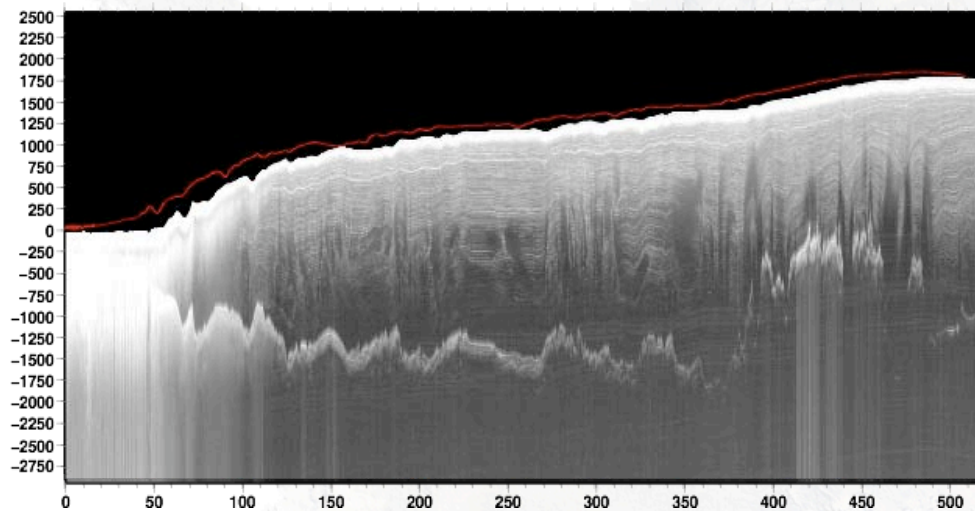
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Radar Data Products: 1D Focused SAR



Focused Radar Profile

$\sim 700 \text{ m}$
 $\sim 15^\circ$



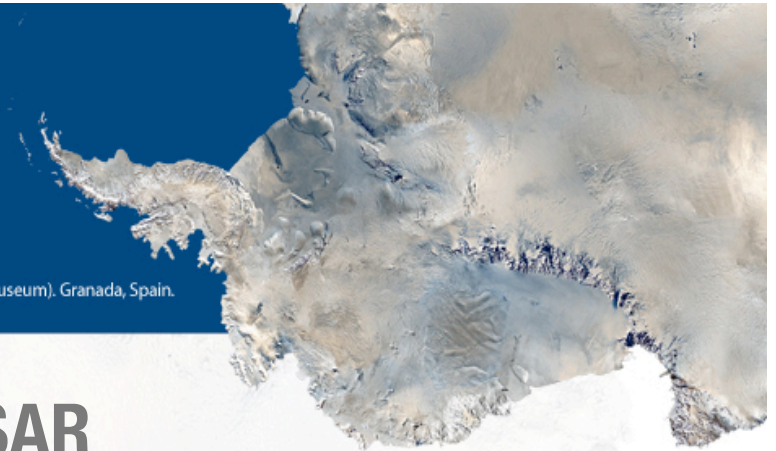
Focusing Window Extent

FIRST ANTARCTIC CLIMATE EVOLUTION SYMPOSIUM

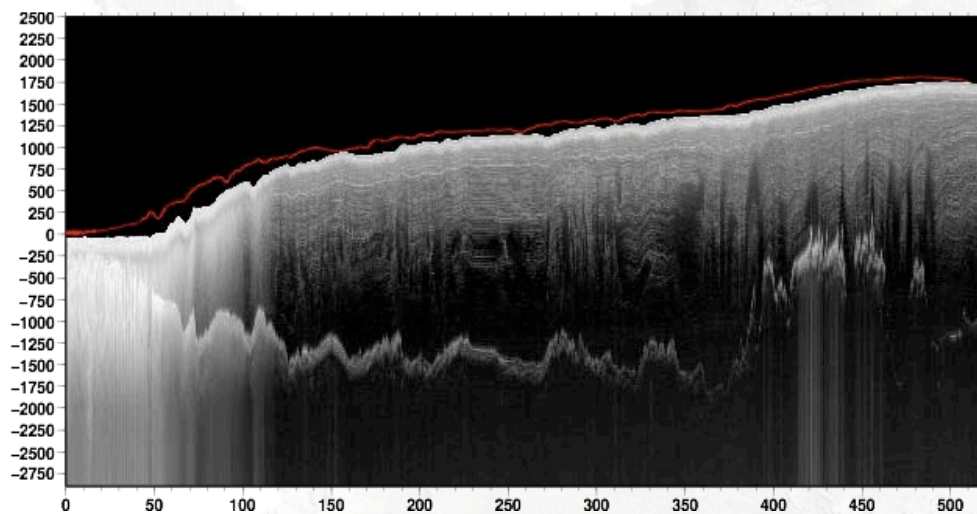
www.acegranada2009.com

7-11 September, 2009.

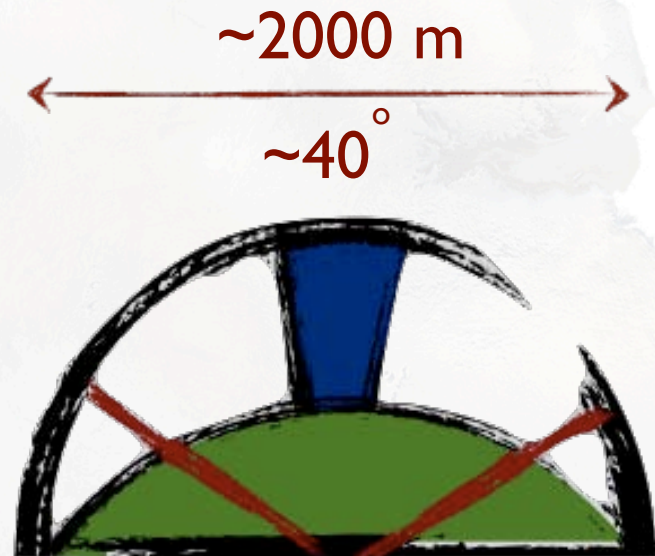
Parque de las Ciencias (Science Museum), Granada, Spain.



Radar Data Products: 2D Focused SAR



Focused Radar Profile

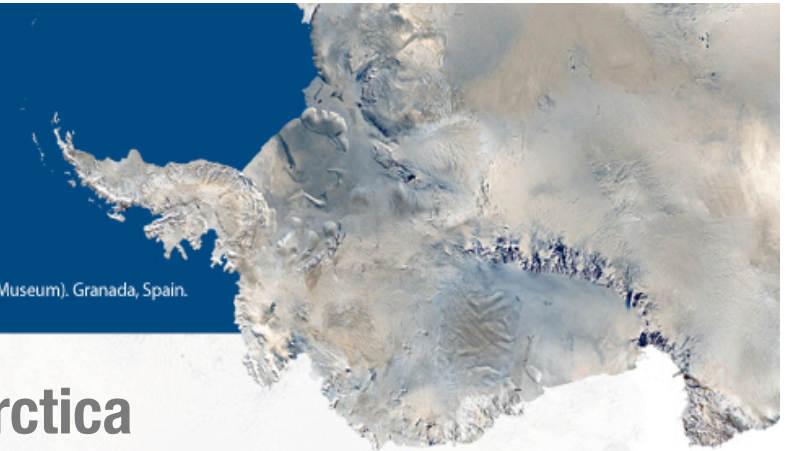


Focusing Window Extent

FIRST ANTARCTIC CLIMATE EVOLUTION SYMPOSIUM

www.acegranada2009.com

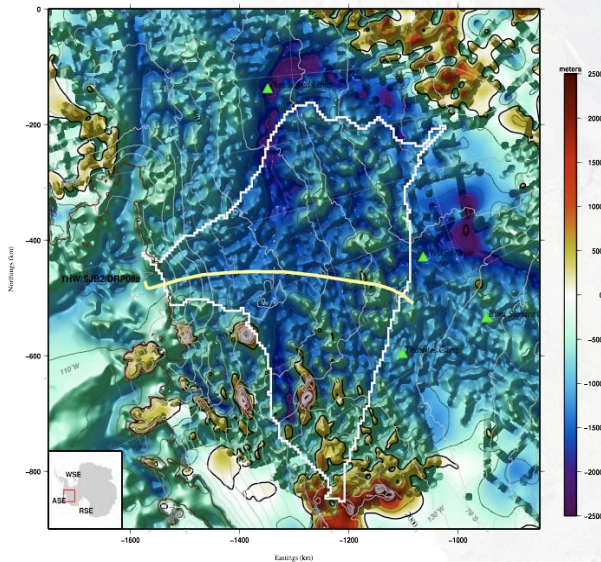
7-11 September, 2009.
Parque de las Ciencias (Science Museum), Granada, Spain.



Application: Thwaites Glacier, West Antarctica



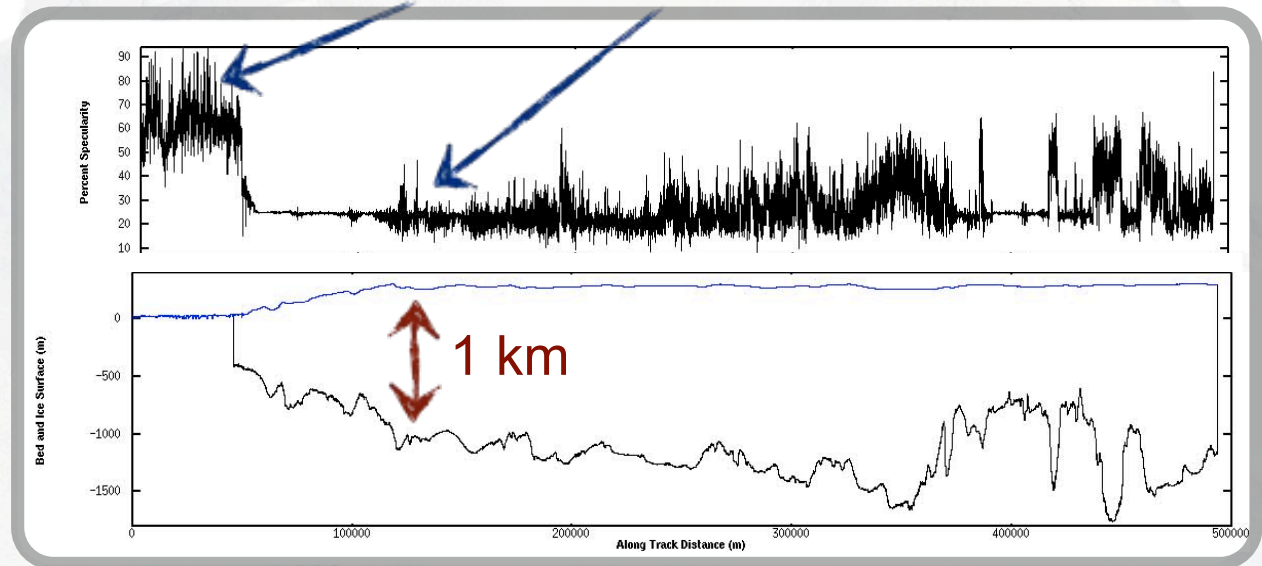
Bed elevation (Holt et al., 2006)



Percent Specularity

80%

20%



Surface & Bed Profile

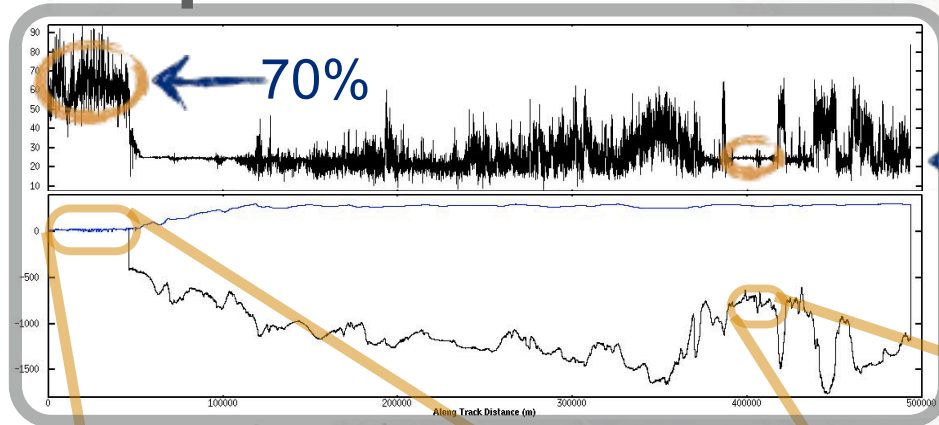
100 km

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Parque de las Ciencias (Science Museum), Granada, Spain.

Interpretation: Thwaites Glacier, West Antarctica



Percent Specularity

20%

500 m

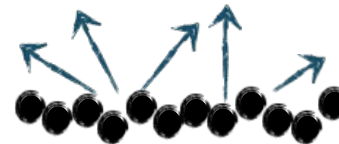
Surface & Bed Profile

100 km

Floating Ice



Highlands



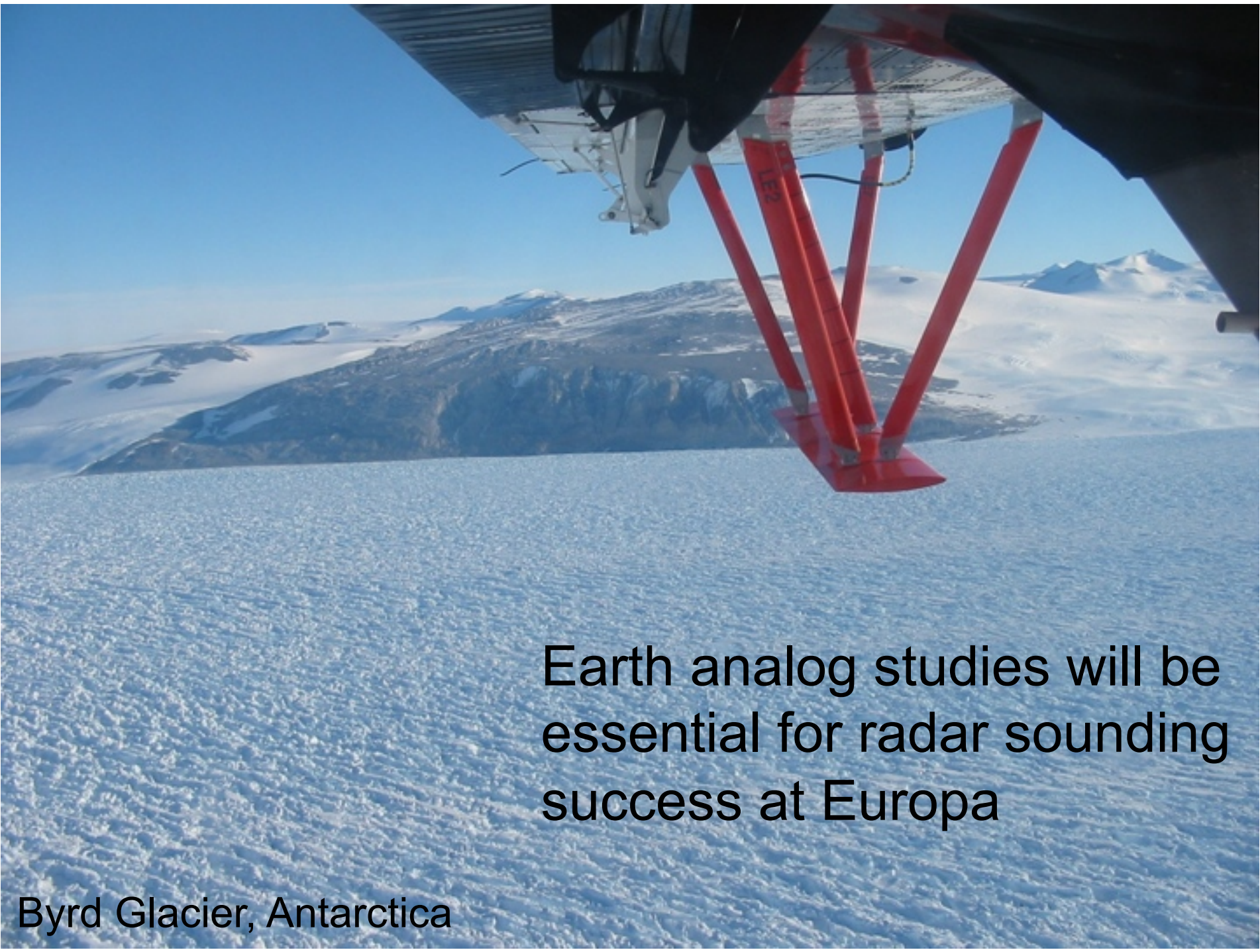
A Path

Antarctic Analogs for Shallow Subsurface Water on Europa

- Ice shelf origins and margins → ice-ocean boundary and brine infiltration / water filled ridges
- Sub-ice lakes/rivers → accretion ice and plume hydrology with implications for the formation of chaos matrix

Radar Sounding Approach - Use multiple radar focusing windows to calculate percent specularity, which is a likely proxy for free water.

- provides a metric to characterize patchy water that is independent of ice temperature structure.
- Thwaites Glacier analog in Antarctica shows features on scales from hundreds of meters to hundreds of kilometers.
- more experience is needed in using this approach in the presence of extreme surface scattering.

A photograph taken from the perspective of someone inside an aircraft, looking out over a vast, textured expanse of a glacier. The glacier's surface is covered in numerous small, white ice floes or crevasses, giving it a granular appearance. In the background, dark, rugged mountains rise from the glacier's edge, their peaks partially covered in snow. The sky above is a clear, pale blue. In the upper right corner, the underside of the aircraft is visible, showing a red landing gear strut and other mechanical components. The text "Earth analog studies will be essential for radar sounding success at Europa" is overlaid in the lower right quadrant of the image.

Earth analog studies will be
essential for radar sounding
success at Europa

Byrd Glacier, Antarctica