

EGM703 – Advanced Active and Passive Remote Sensing

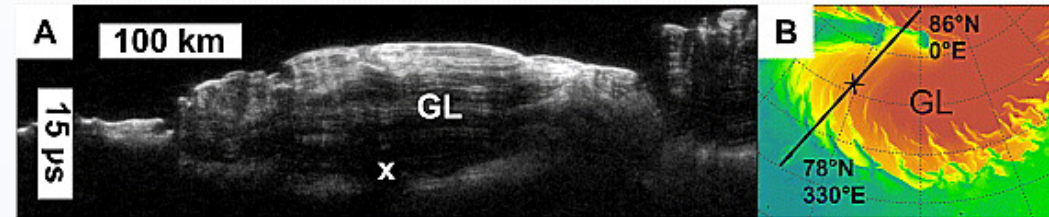
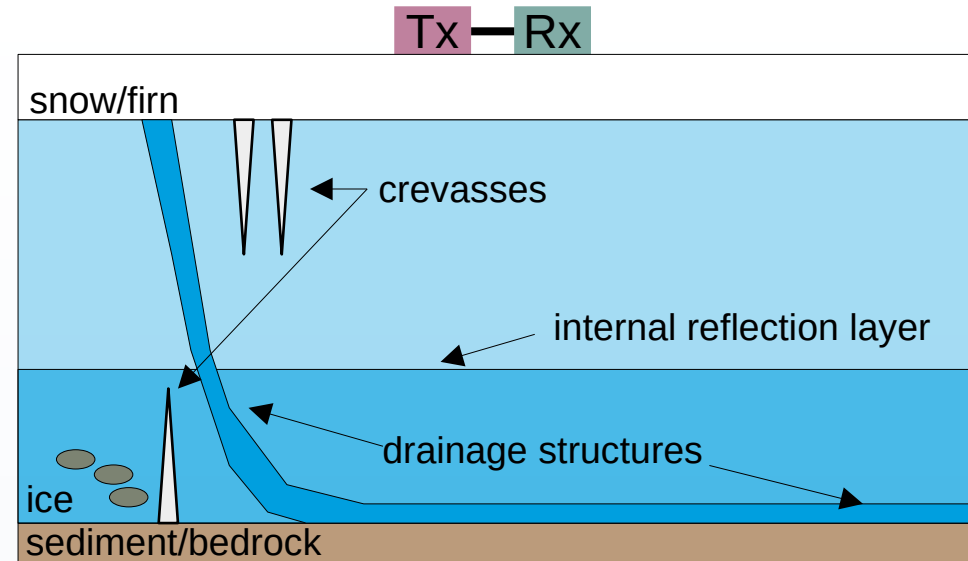
Week 5, Part 3: GPR Application: Glaciology

Why GPR for glaciology?

- Ice thickness is critical for:
 - Estimating current glacier volume (water resources)
 - Glacier/ice sheet modelling
- Glaciers are heavy (can't just lift them up)
- Boreholes are time-consuming, provide sparse measurements

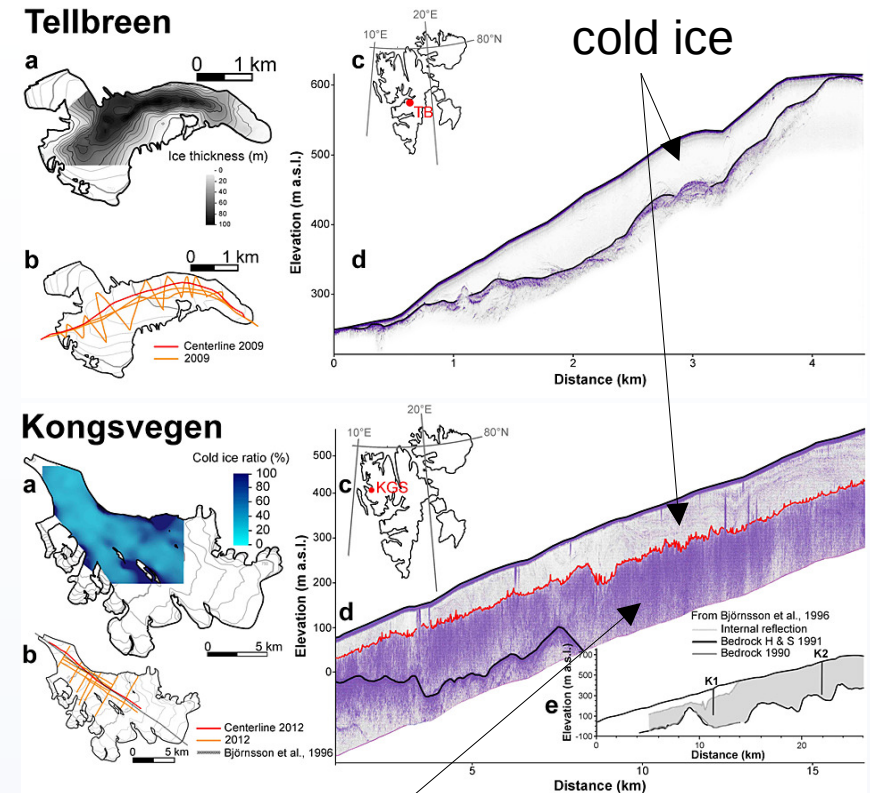
“Radio echo sounding”

- Dates back to pre-1930s
- Use range of frequencies depending on application:
 - HF (3-30 MHz)
 - VHF (30-300 MHz)
 - UHF (300 MHz – 3 GHz)
- Used to study:
 - Ice thickness and bed topography
 - Internal layers
 - ... and more!
- Not limited to Earth!



Grima et al., 2009

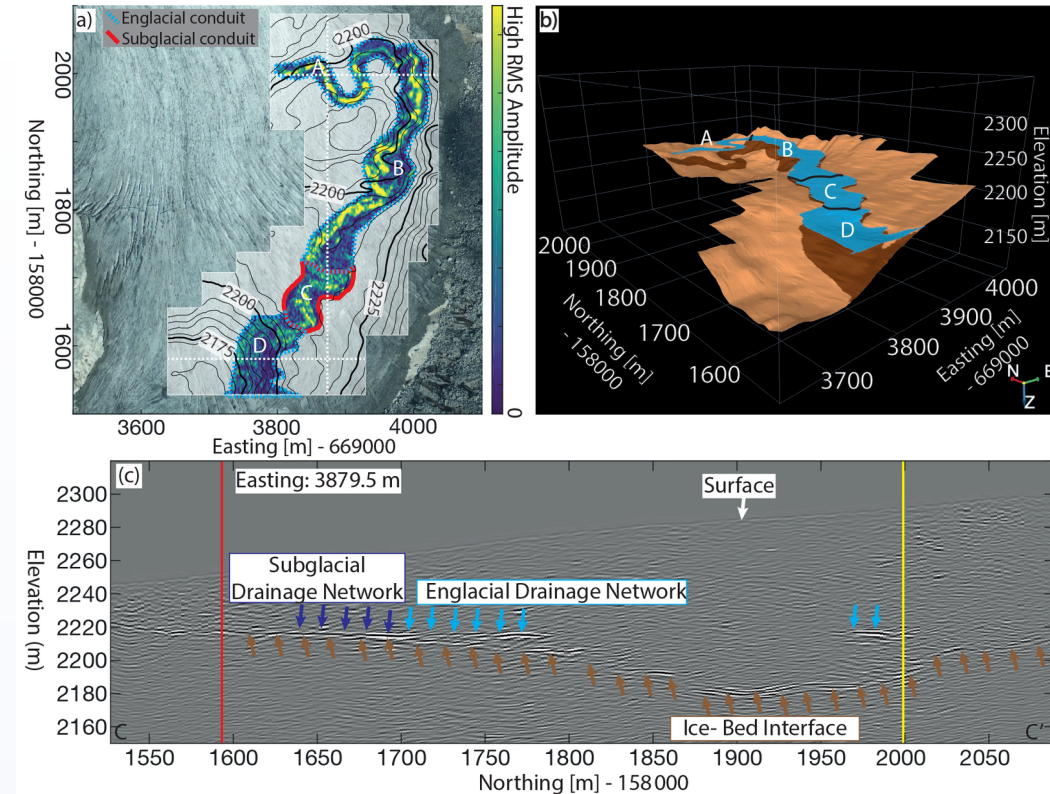
- Temperature varies within glacier
 - Seasonally
 - With depth
- Classify ice/glaciers based pressure melting temperature T :
 - Cold: below T
 - Temperate: at (or near) T (except near surface in winter)
 - Polythermal: mix of cold, temperate
- In polythermal glaciers, location of cold-temperate transition surface (CTS) tells us about bed conditions



temperate ice

Sevestre et al., 2015

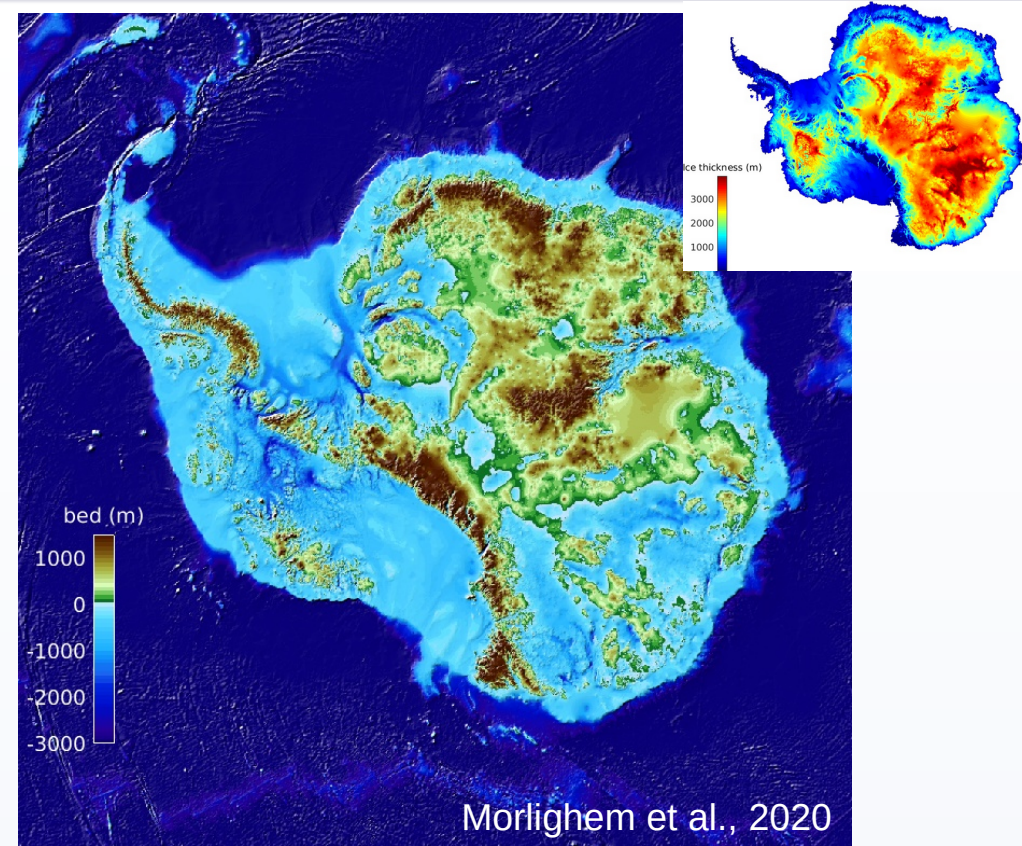
- As ice melts, water creates drainage network
 - On top (supraglacial)
 - Inside (englacial)
 - Under (subglacial)
- Englacial, subglacial tunnels create reflections that can be mapped
- Can tell us about how water is routed, how glacier “slides” over bed



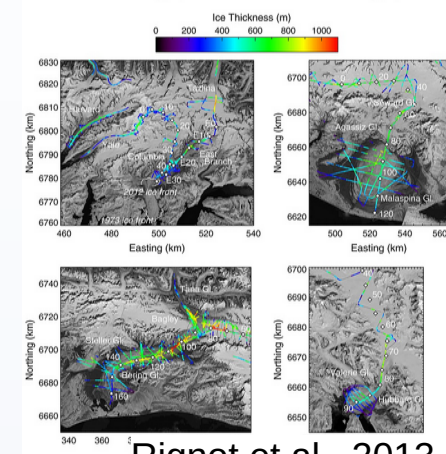
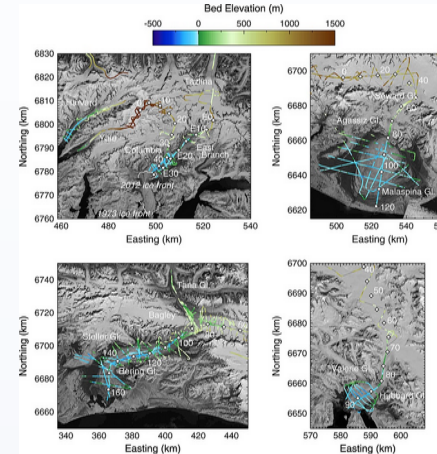
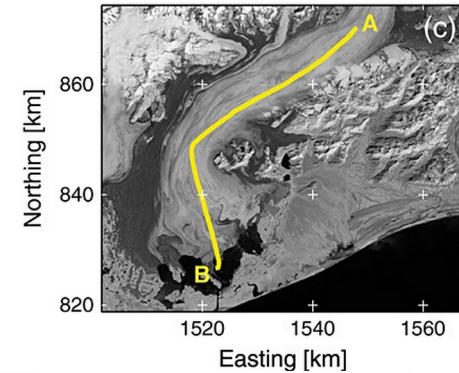
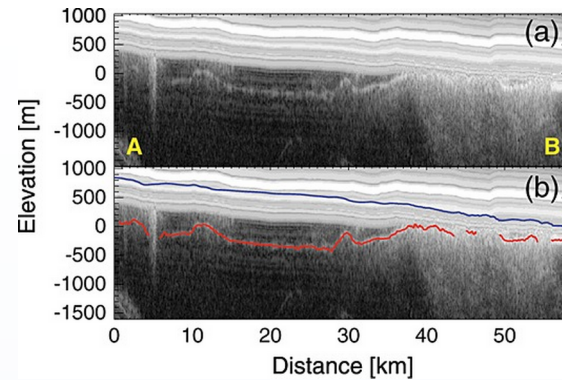
Church et al., 2021

Ice thickness and bed topography

- With 50+ years of measurements, can map continent-scale
- Interpolate using mass conservation
 - Model ice flow using measured ice thickness, surface velocity
- Resolution limited by spacing of GPR survey lines



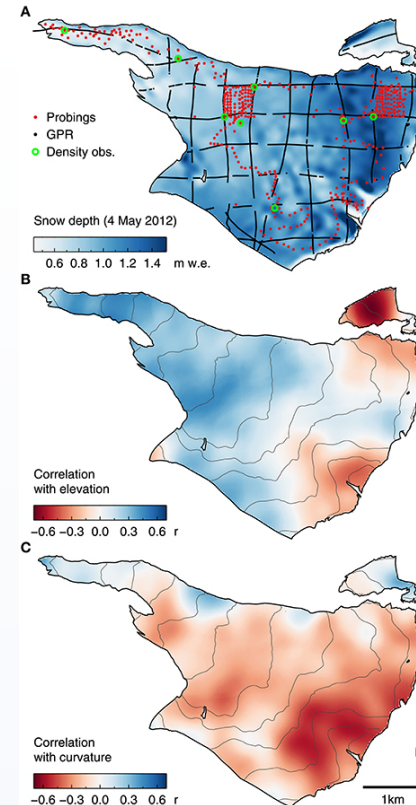
- Very difficult to map large-scale from ground
 - Large areas
 - Dangerous surfaces
- Solution: use airborne instruments



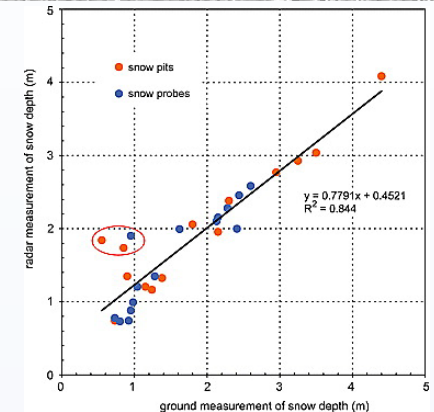
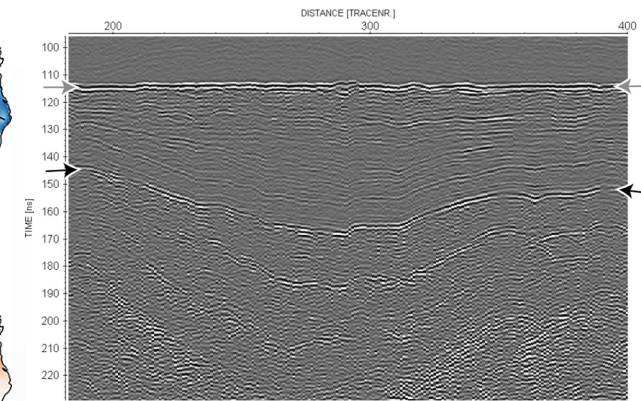
Rignot et al., 2013

Snow-penetrating radar

- High-frequency GPR used to measure snow depth
 - Melt layers
- With density measurements, can estimate snow-water equivalent
- Compare with snow probe, density measurements



Sold et al., 2016



Machguth et al., 2006

- GPR use has a long history in glaciology
- Applications to many different issues, including:
 - Englacial temperature
 - Subglacial drainage
 - Ice thickness and volume, bed topography
 - Snow depth
- Key inputs for modelling, predicting future glacier changes

- Schroeder et al., 2020 [[Ann. Glaciol.](#)]
- Bedmap Himalayas [[British Antarctic Survey](#)]
- Grima et al., 2009 [[Geophys. Res. Lett.](#)]
- Sevestre et al., 2015 [[J. Geophys. Res. Earth Surf.](#)]
- Church et al., 2021 [[The Cryosphere](#)]
- Morlighem et al., 2020 [[Nature](#)]
- Rignot et al., 2013 [[Geophys. Res. Lett.](#)]
- Machguth et al., 2006 [[Geophys. Res. Lett.](#)]
- Sold et al., 2016 [[Front. Earth Sci.](#)]