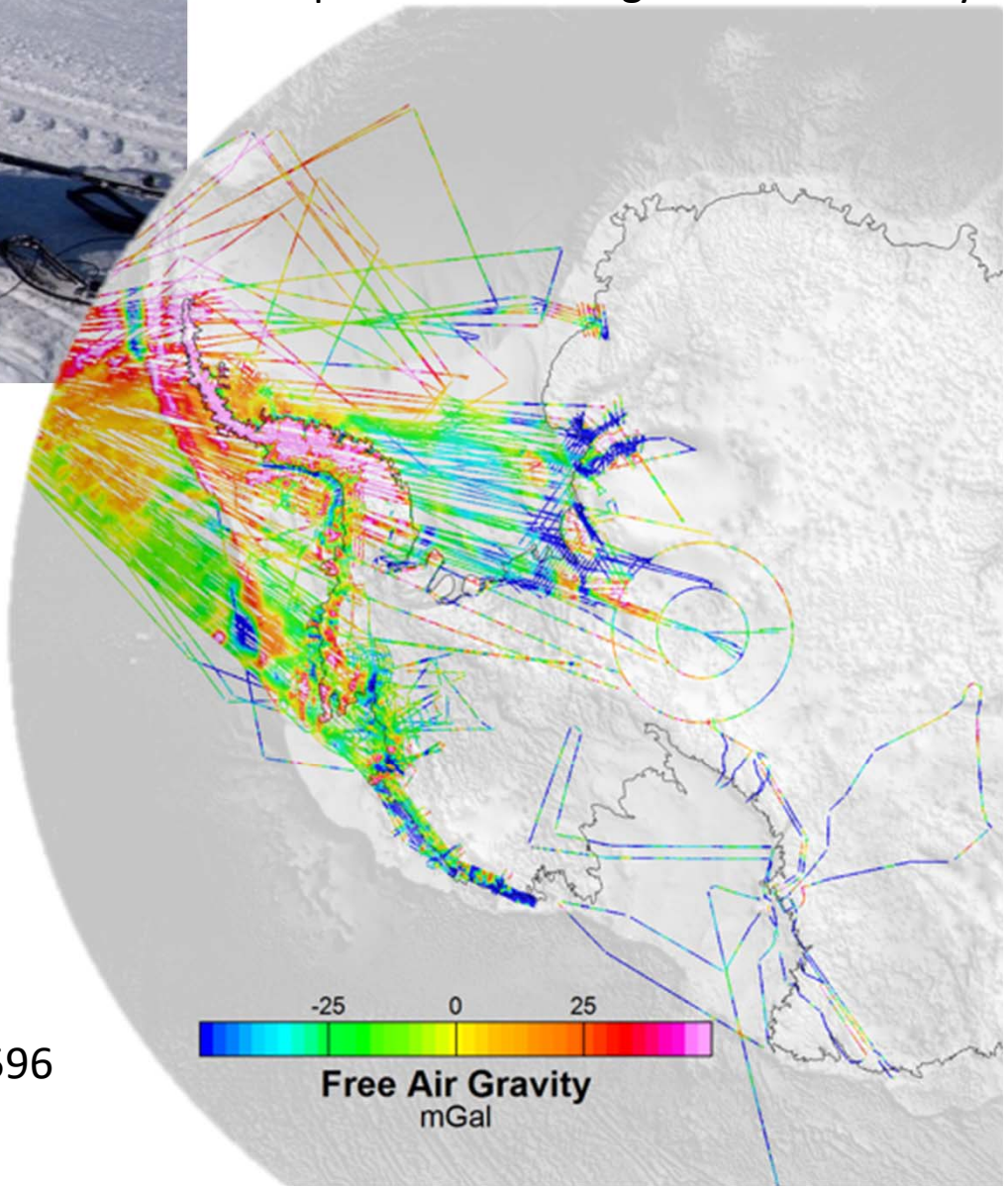
Gravity survey on McMurdo Ice Shelf

Operation IceBridge Free Air Gravity

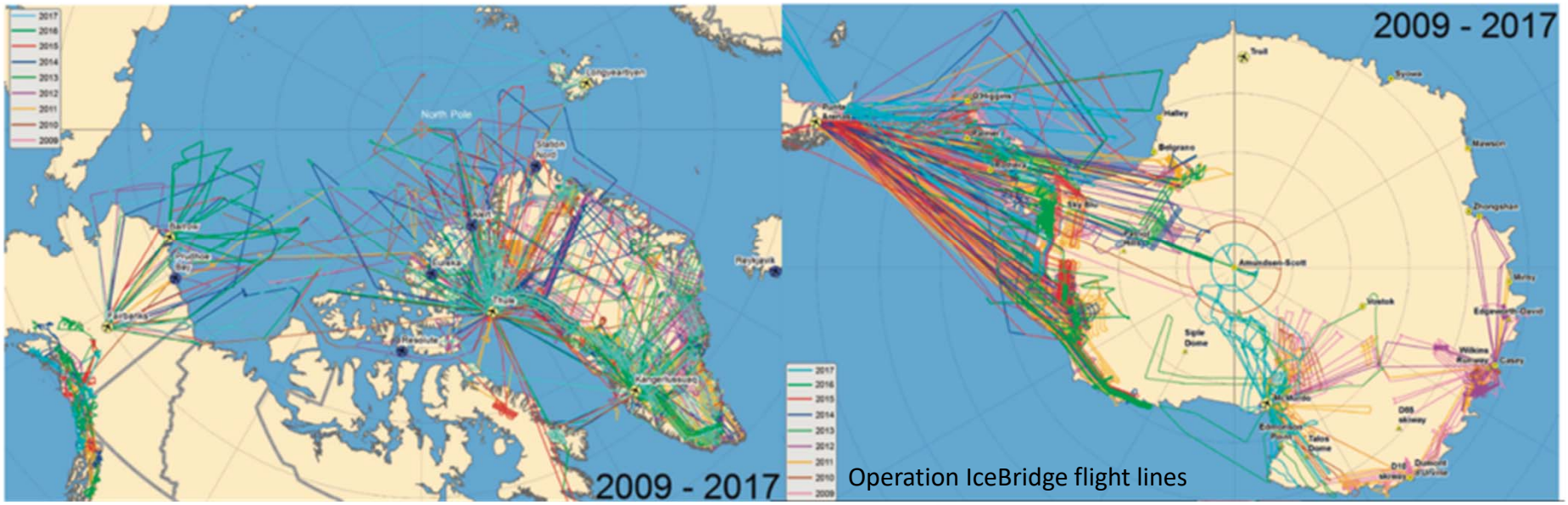


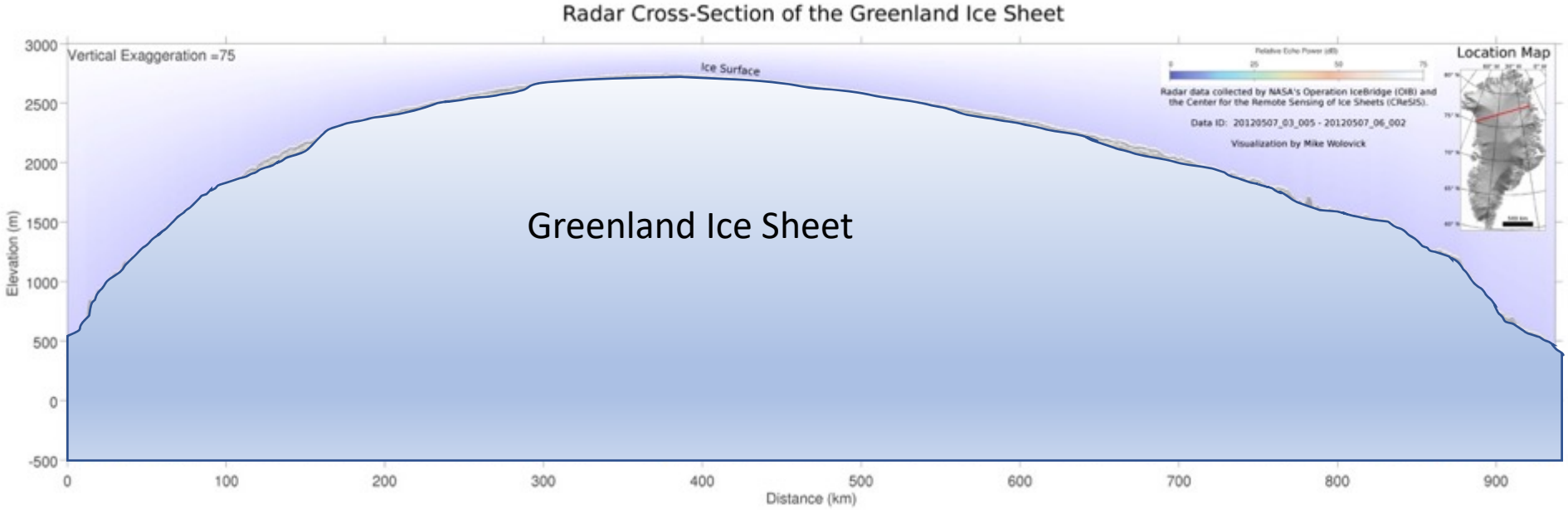
Airborne surveys connecting ground based measurements and satellite observations to understand ice sheet change

https://icebridge.gsfc.nasa.gov/?page_id=596

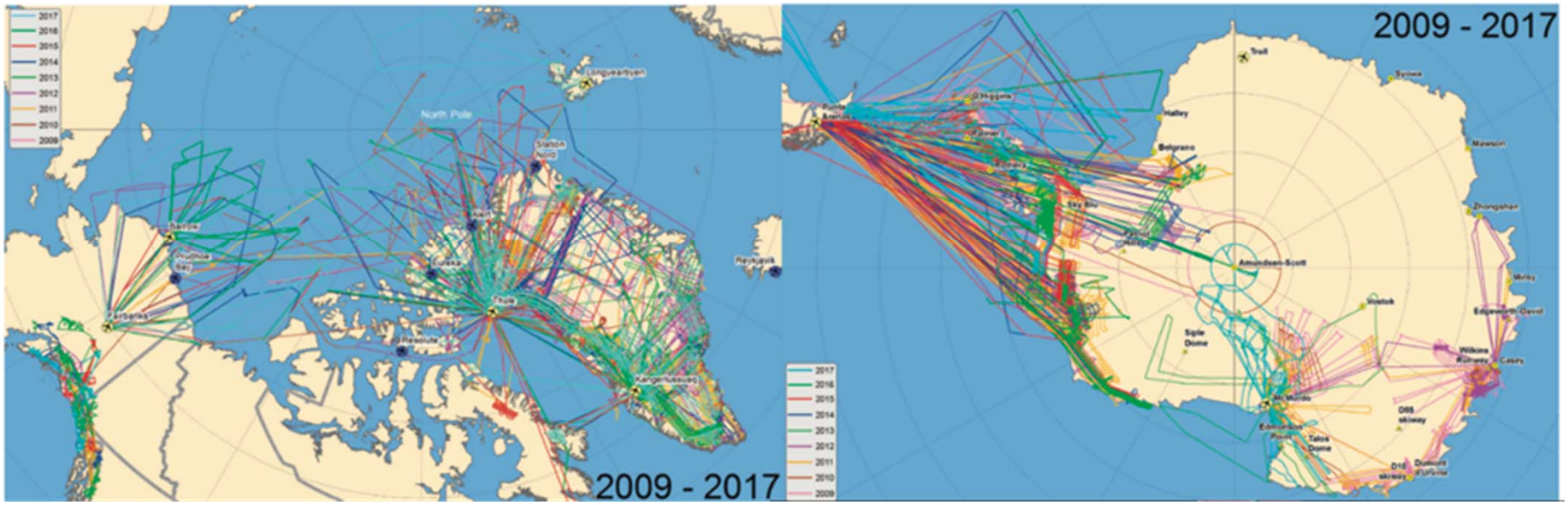
OIB publications list 76 in 2019 alone

Aerogeophysical surveys allow us to look inside ice sheets

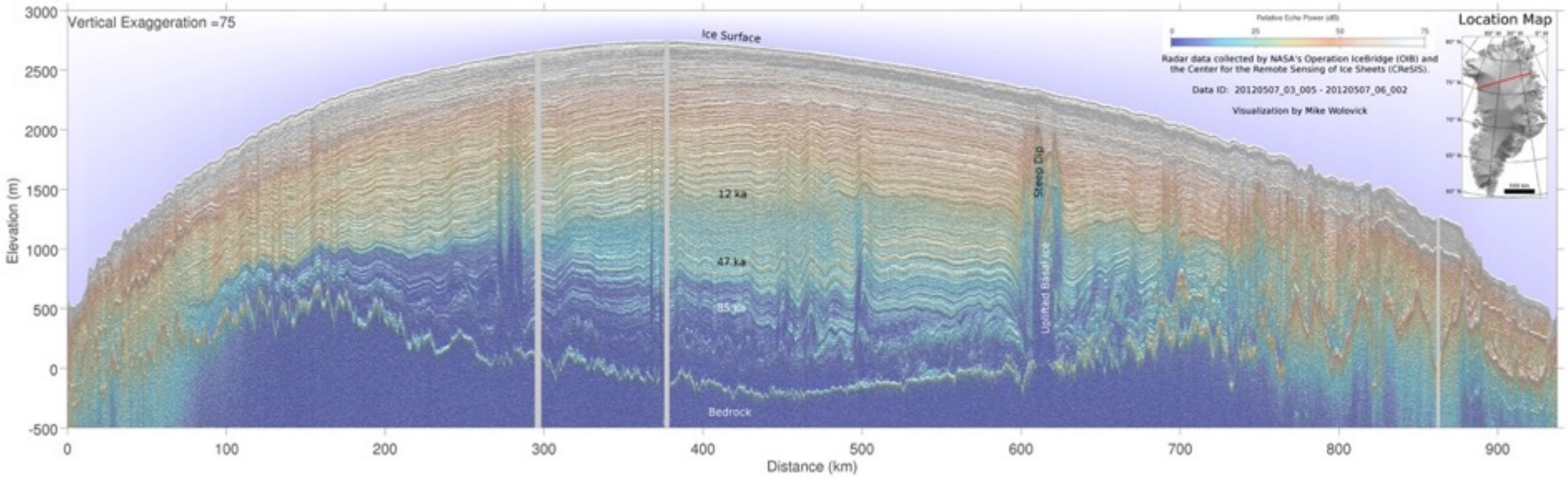




Aerogeophysical surveys allow us to look inside ice sheets



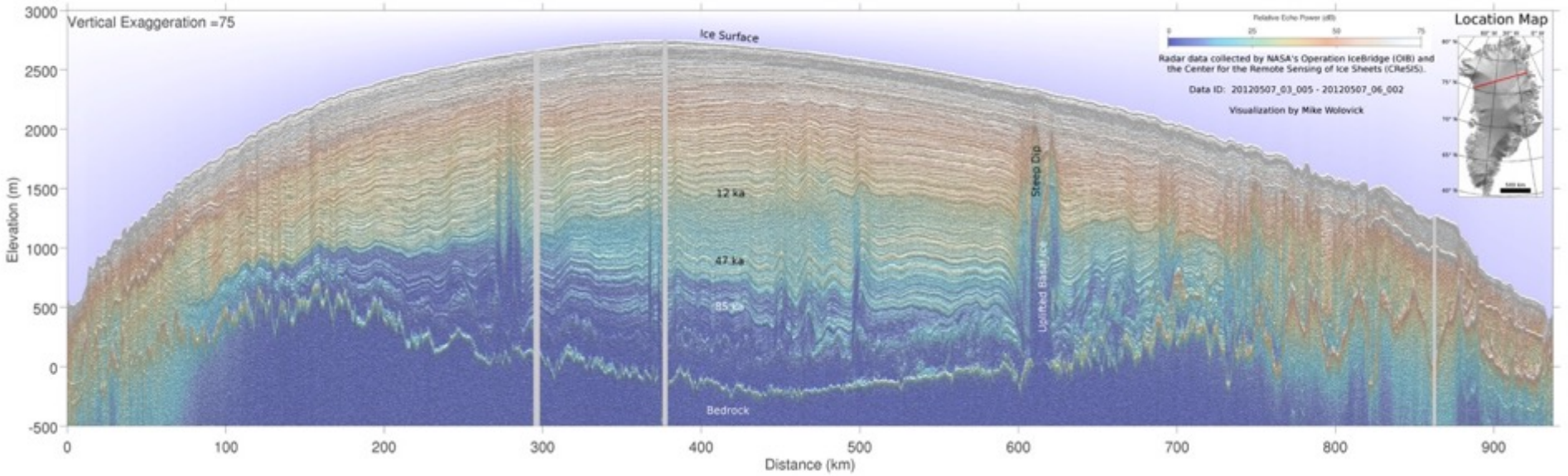
Radar Cross-Section of the Greenland Ice Sheet



Surface processes

Firn compaction
Accumulation and Ablation history
Surface hydrology
Firn acquifers
Fracturing

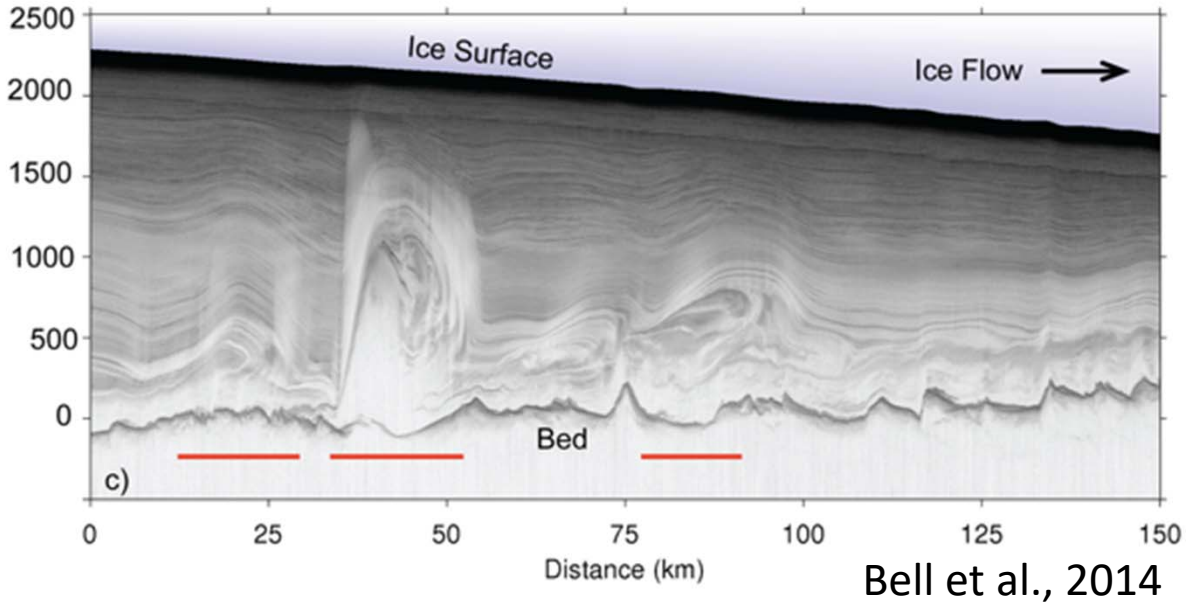
Radar Cross-Section of the Greenland Ice Sheet



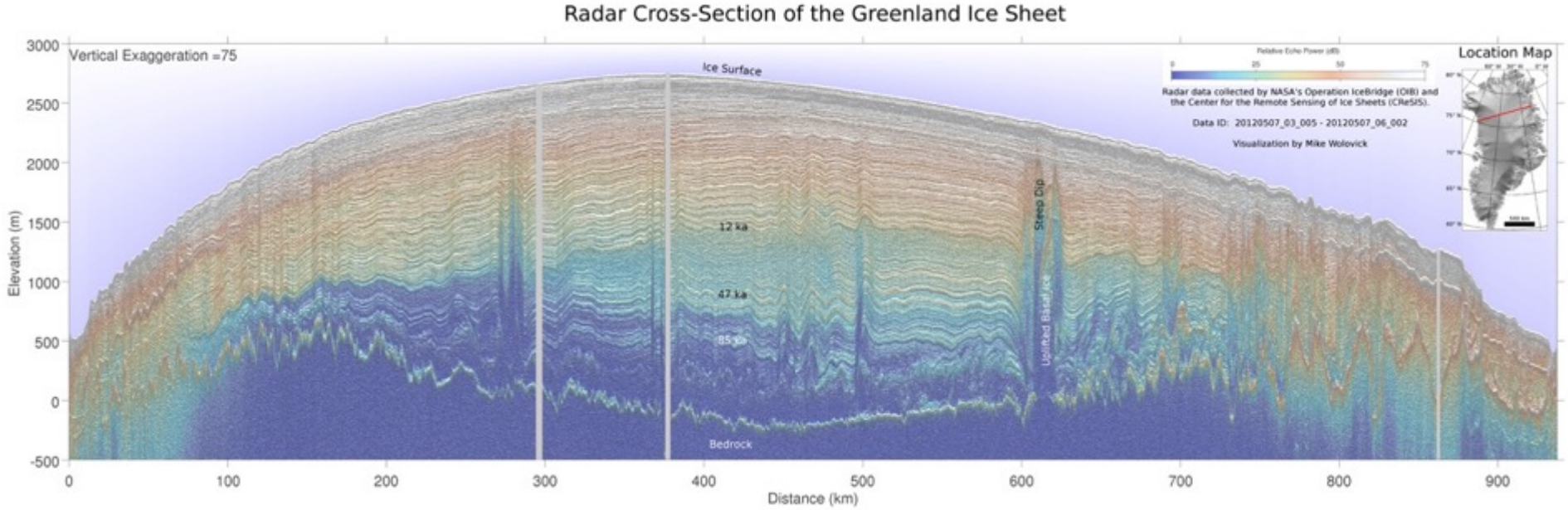
Internal structure

Ice sheet stratigraphy
Correlating ice cores
Flow history
Deformation

CreSIS radar from northern Greenland

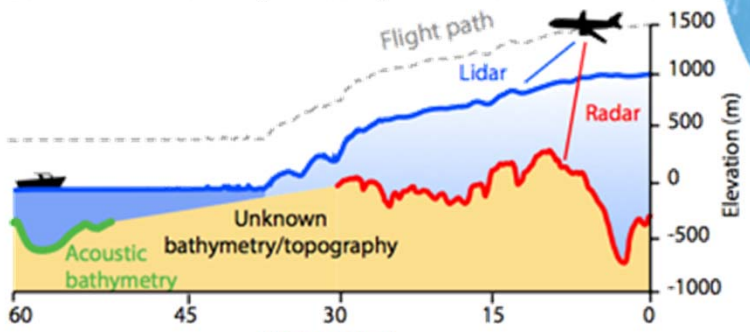


Bell et al., 2014

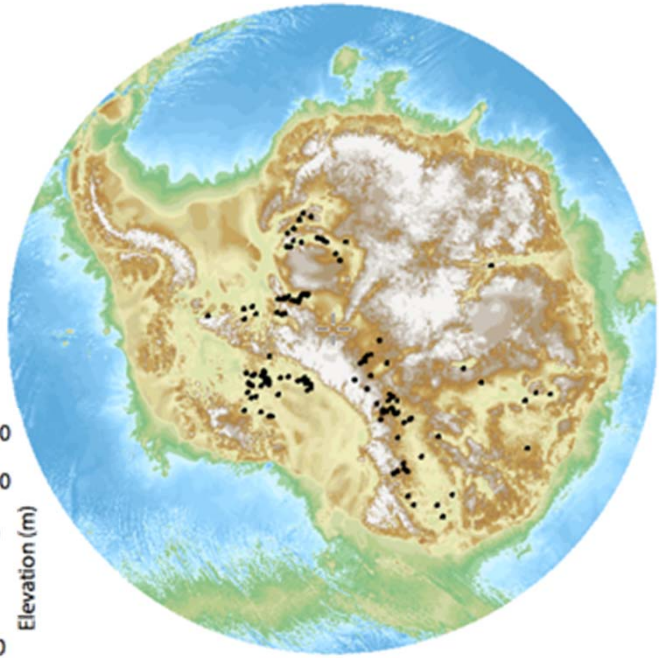


Ice sheet base

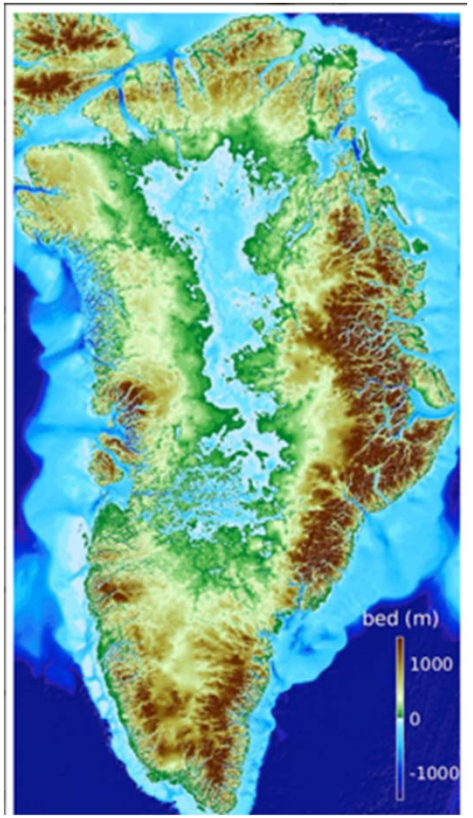
Bed mapping
Basal hydrology
Bed geology
Grounding zone bathymetry
Coastal bathymetry



Boghosian et al., 2015

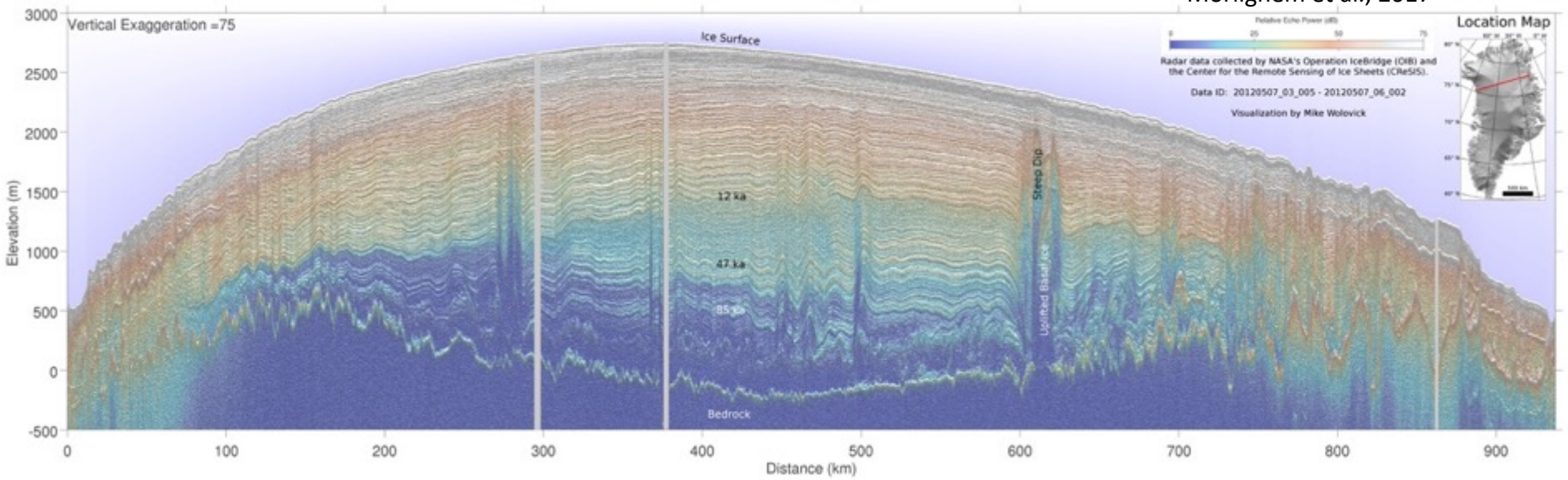


ICESat Lakes



Morlighem et al., 2017

Radar Cross-Section of the Greenland Ice Sheet

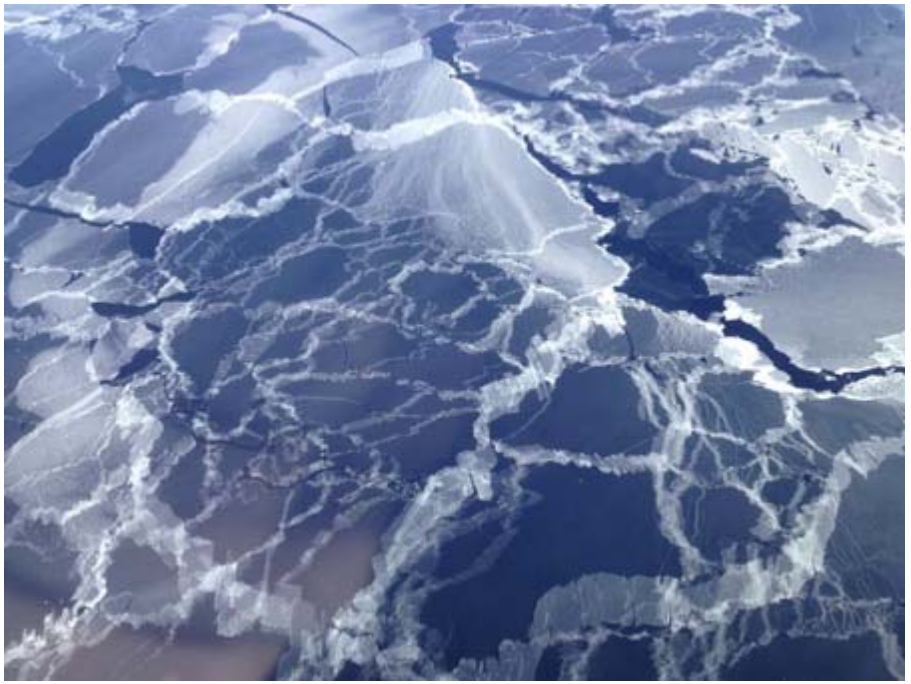


Ice shelves

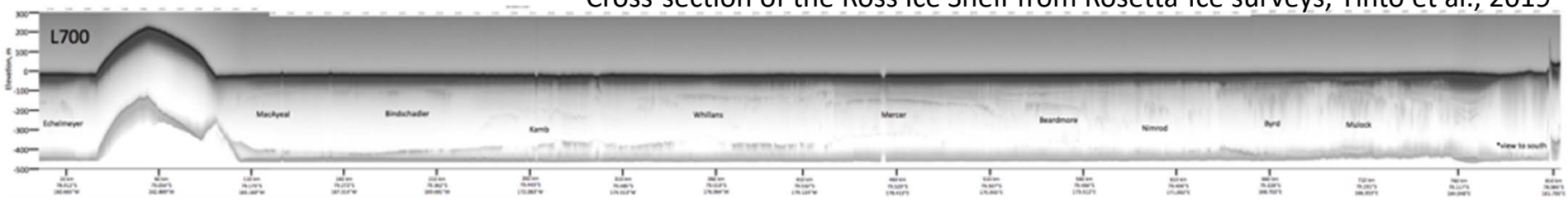
Buttressing flow of grounded ice
Ocean-ice interactions
Archive of flow history

Sea ice

Connecting satellite observations and field measurements
Snow depth constraints essential to understand thickness from freeboard



Cross-section of the Ross Ice Shelf from Rosetta-Ice surveys, Tinto et al., 2019



Long-range aircraft

DC8

P3

GV

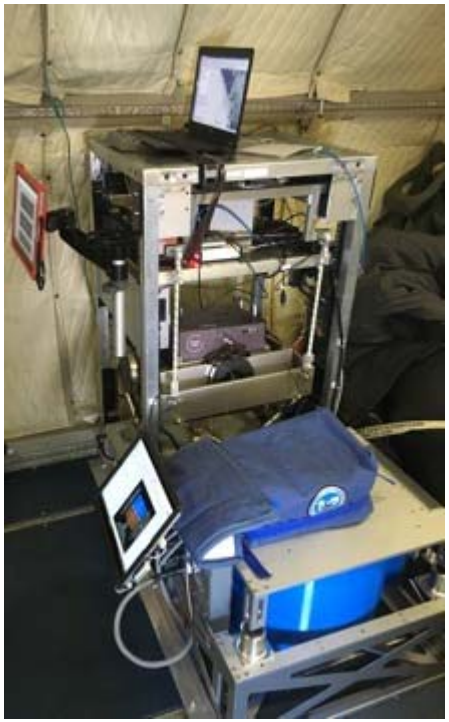
On continent surveys

Credit: John Sonntag

https://espo.nasa.gov/sites/default/files/images/IMG_3226.jpeg

Credit: Michael Studinger

Developing capability – instruments and people



Credit: NASA

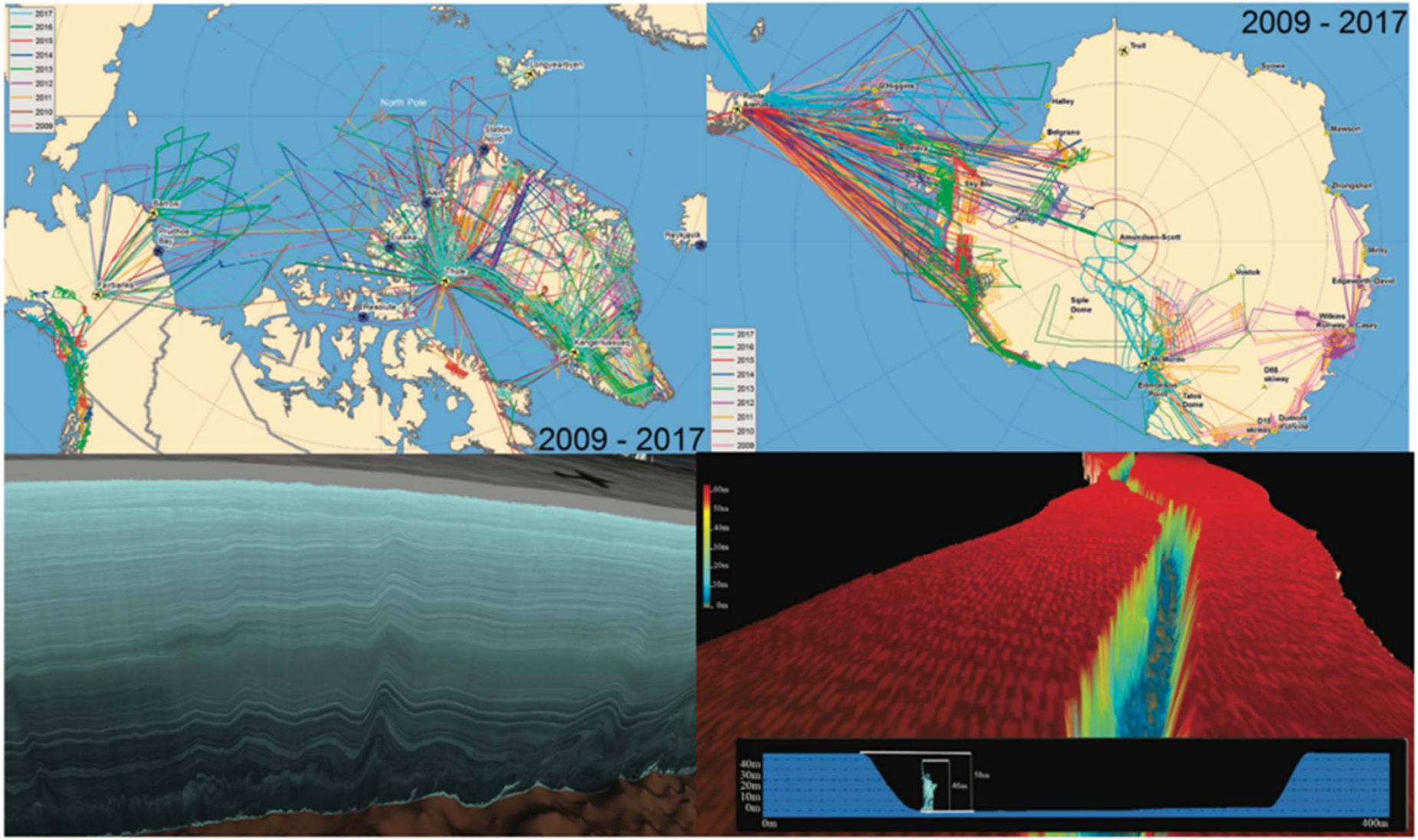
Credit: NASA / Jefferson Beck

- Satellites
  - changing surface elevation
  - flow velocity
  - gravity field (total mass)
- Airborne surveys
  - See inside the ice sheet
  - Extend ground truth
  - Reach inaccessible regions
- Key instruments
  - Lidar and cameras
  - Radars – multiple frequencies
  - Gravity and magnetics
  - Air-deployable sensors
- Aircraft
  - Multi-instrument
    - Integrated science
    - Instrument compromises
  - On continent – high-resolution surveys
  - Off-continent – versatile targets
  - Large-scale programs help build capacity

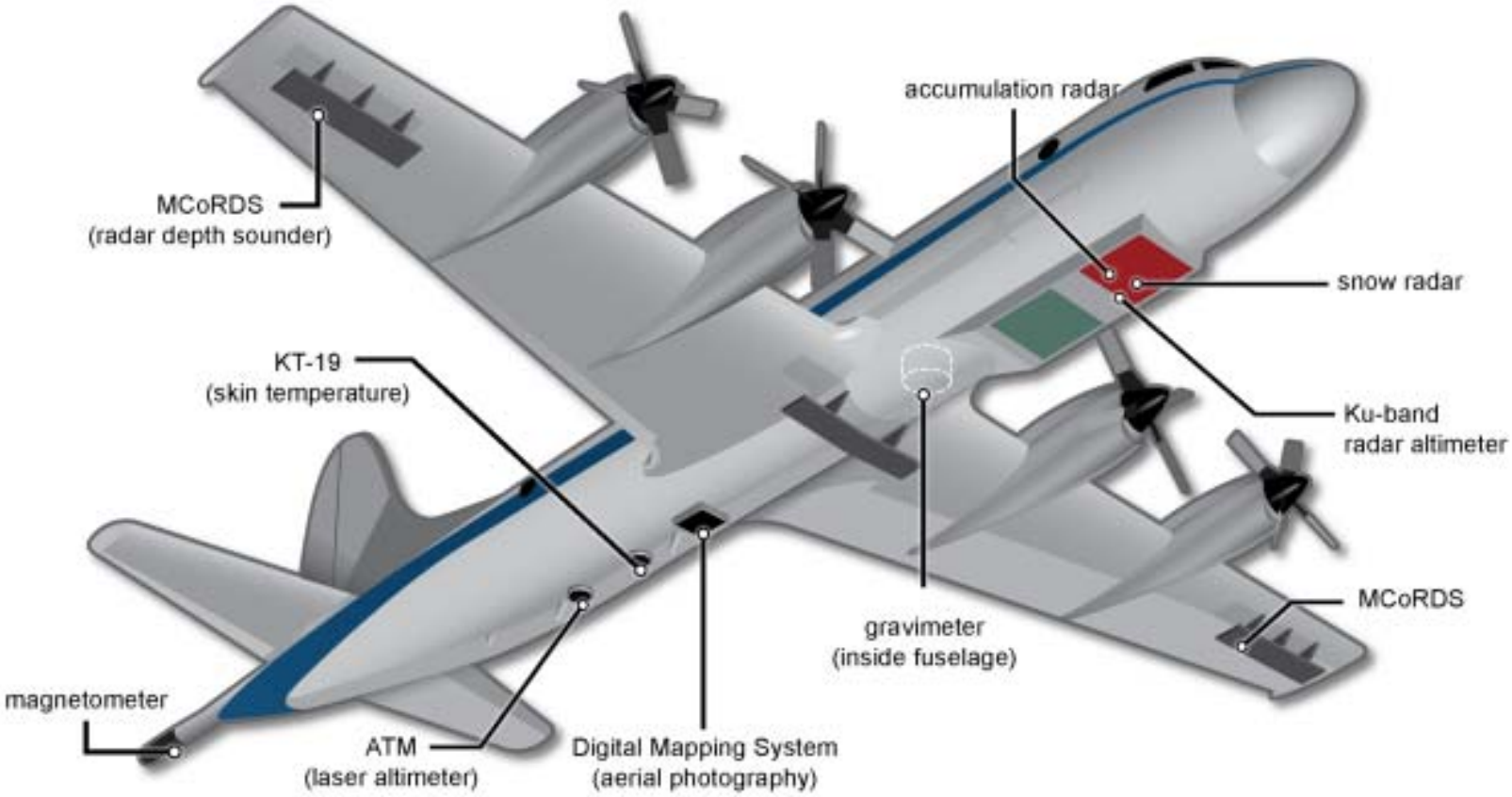
Operation IceBridge: 2009 - 2020

Airborne measurements bridge the satellite gap – and much more…

Image from: National Academies of Sciences, Engineering, and Medicine 2018. *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24938.



Operation IceBridge: Multi-instrument aircraft



Laser altimetry
Cameras
- Ice surface

Radars
- ice thickness/bed mapping
- Snow and ice structure

Gravity
Magnetics
- Offshore bathymetry
- Bed geology

https://icebridge.gsfc.nasa.gov/wp-content/uploads/2012/07/IceBridge_P3_cartoon_white_background_2014.png

Ice sheet mass change 2003-2019 from satellite laser altimetry

Smith et al., 2020 *Science*

ICESat (September 2003 – October 2008)
ICESat-2 (October 2018 – February 2019)

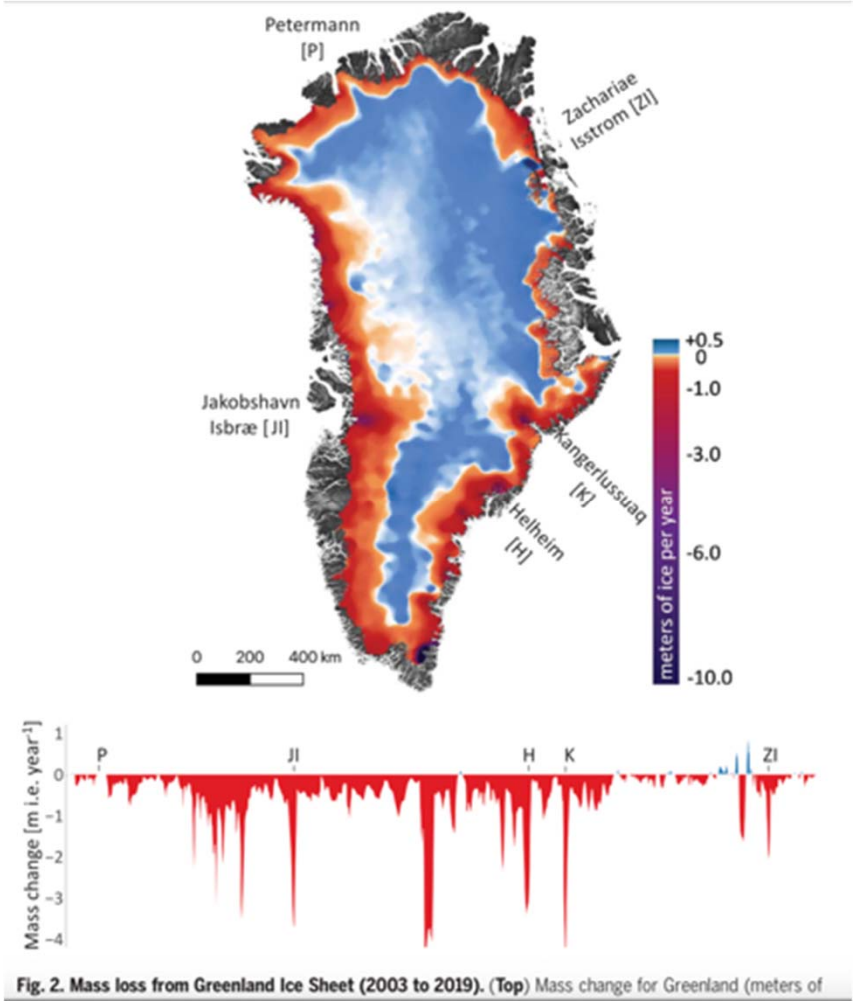


Fig. 2. Mass loss from Greenland Ice Sheet (2003 to 2019). (**Top**) Mass change for Greenland (meters of

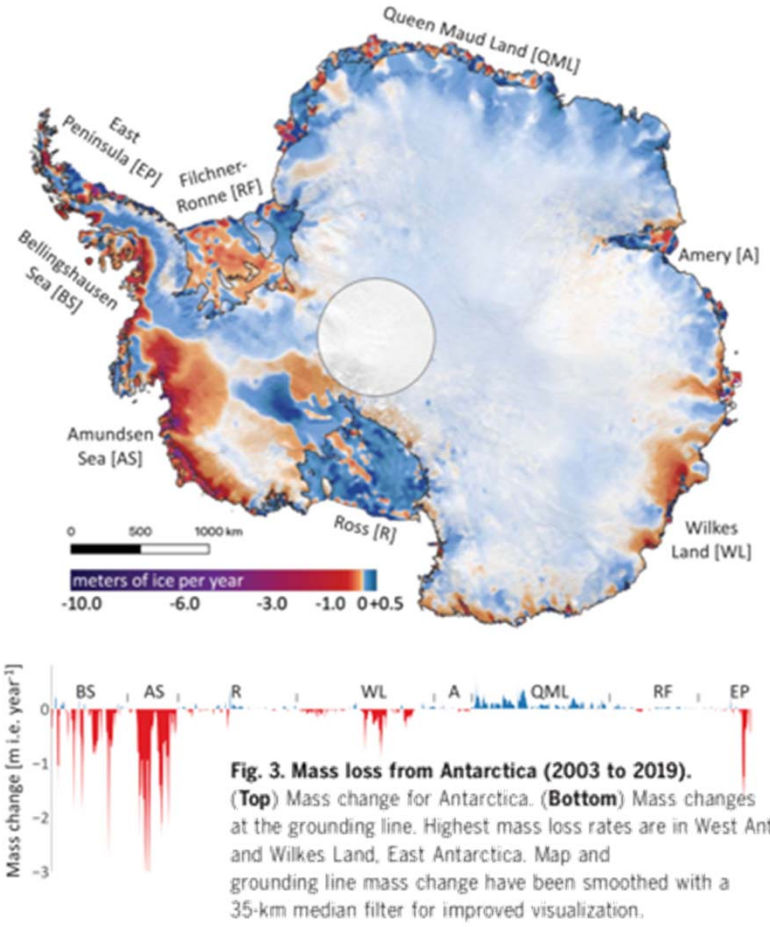


Fig. 3. Mass loss from Antarctica (2003 to 2019).
(**Top**) Mass change for Antarctica. (**Bottom**) Mass changes at the grounding line. Highest mass loss rates are in West Antarctica and Wilkes Land, East Antarctica. Map and grounding line mass change have been smoothed with a 35-km median filter for improved visualization.