

ICESat-2

*Global STEM Education:
What's Next
@ Harvard Graduate School of
Education,
Cambridge MA
May 24, 2019*



Frank Martin

Standing Review Board Chair for ICESat-2

Details provided by Tom Neumann, Project Scientist and the entire ICESat-2 Team

The Polar Regions, Ice sheets?

- Formed by snow accumulation
- Up to 4000m thick
- Move slowly (up to km/year)
- Either melt or make icebergs
- Greenland, Antarctica





The Polar Regions, Sea Ice?

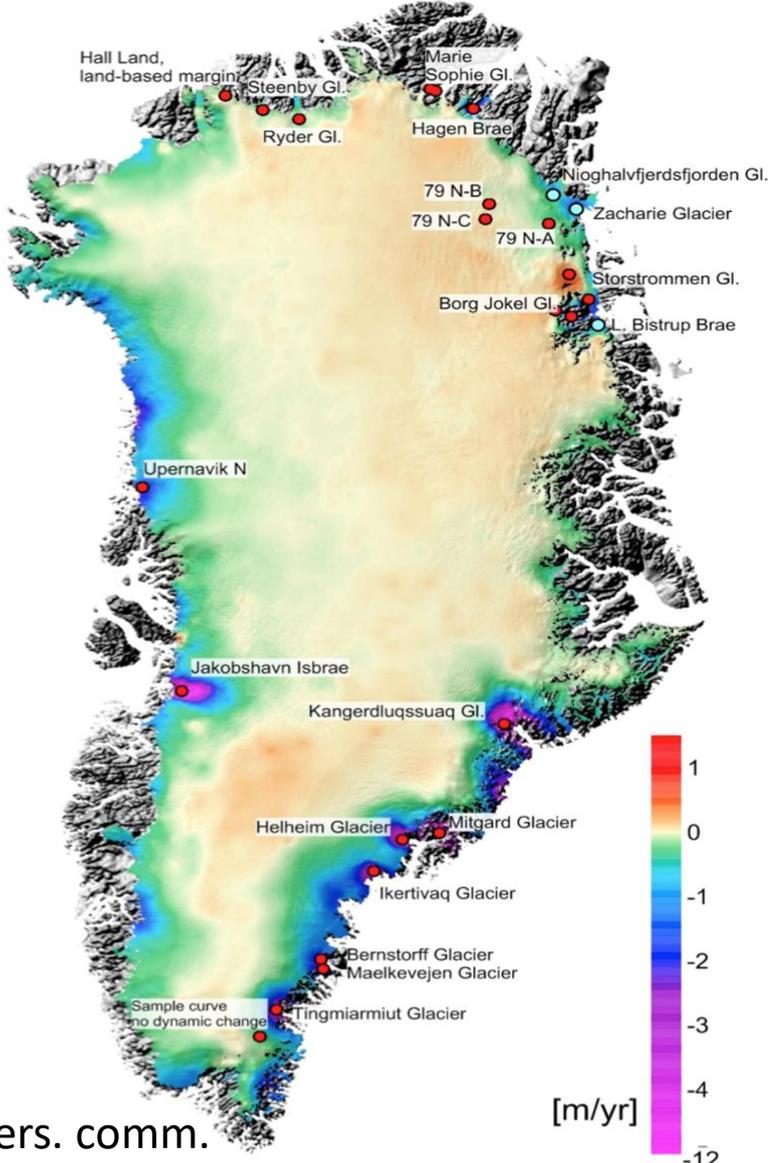


- Formed by freezing ocean water
- Up to 20m thick
- Move quickly (km/day)
- Melt seasonally
- Arctic and Antarctic seas





Ice Sheet Changes: Greenland



Ice mass loss is concentrated near the coast in both Greenland and Antarctica

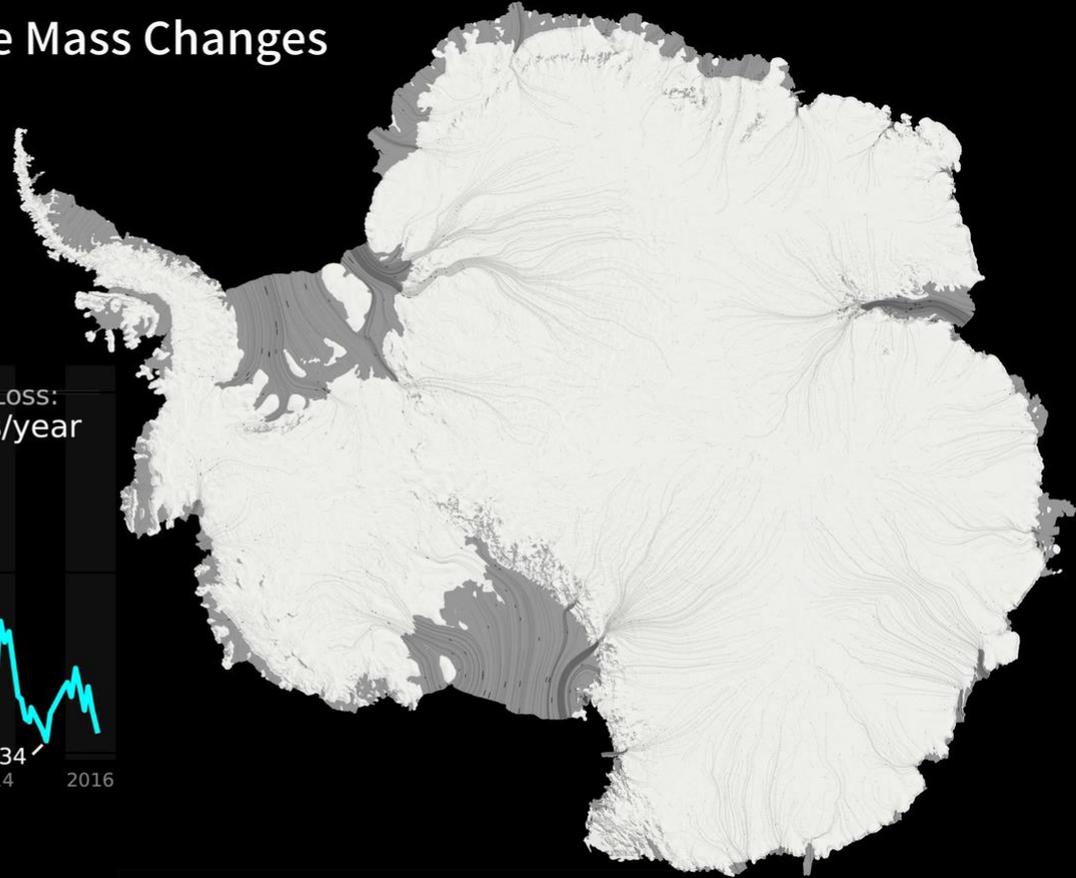
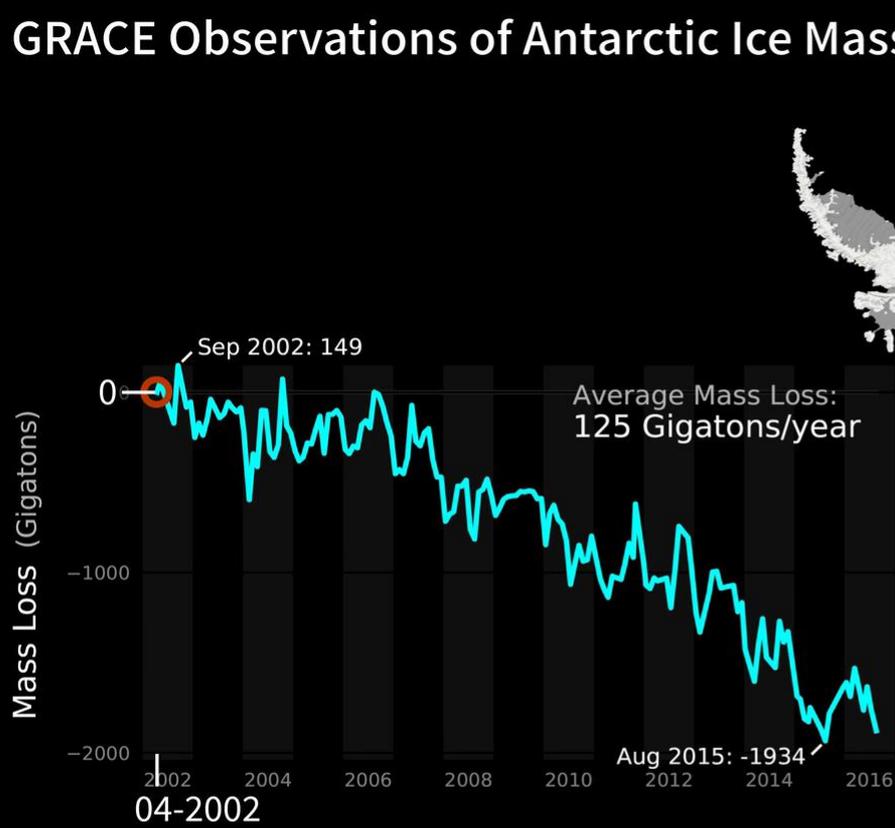




Ice Sheet Changes: Antarctic



GRACE Observations of Antarctic Ice Mass Changes



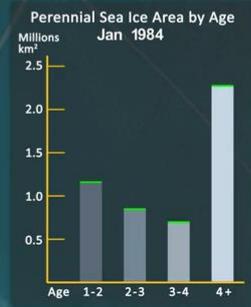


Sea Ice Changes: Arctic



Jan 1984

Sea Ice Age





Sea Ice Changes: Arctic

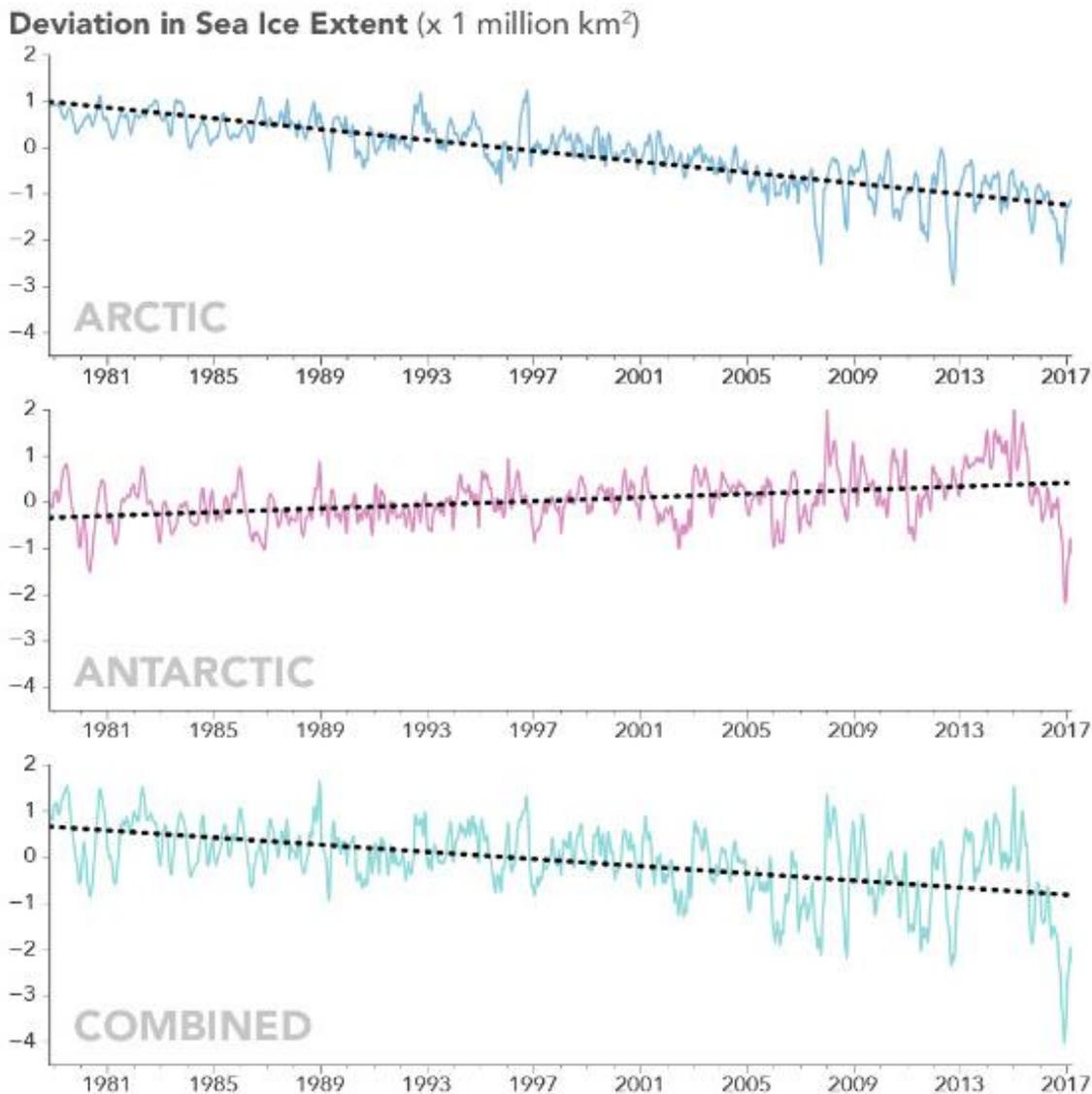




Sea Ice Changes: Antarctica

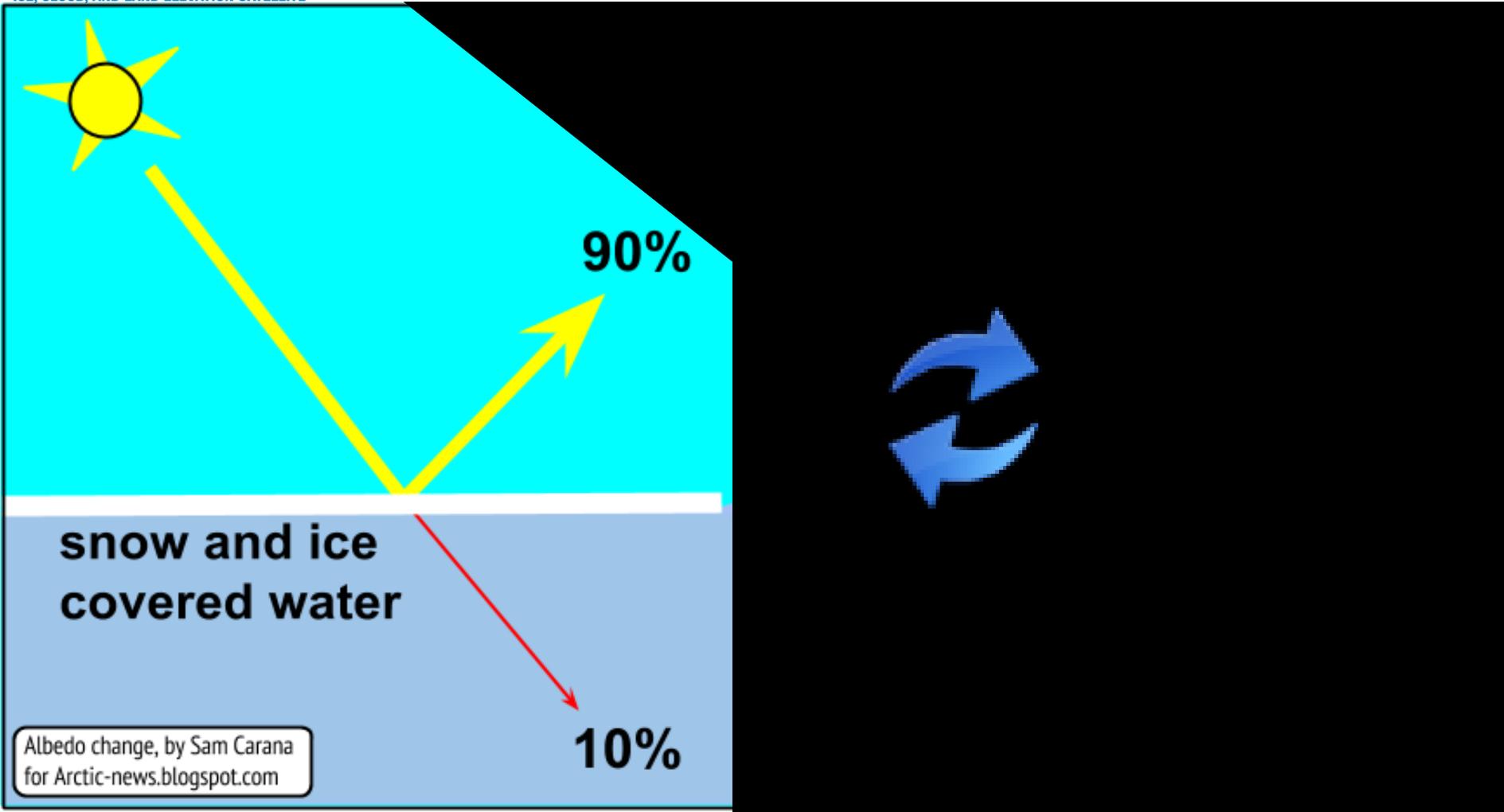
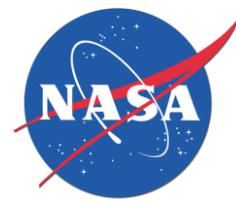


We can readily measure sea ice *extent*, but not thickness





Self-reinforcing Feedback Loop



Impacts polar-equatorial temperature gradients →
jet-streams and ocean circulators.



Two New Missions!



Gravity Recovery and Climate Experiment

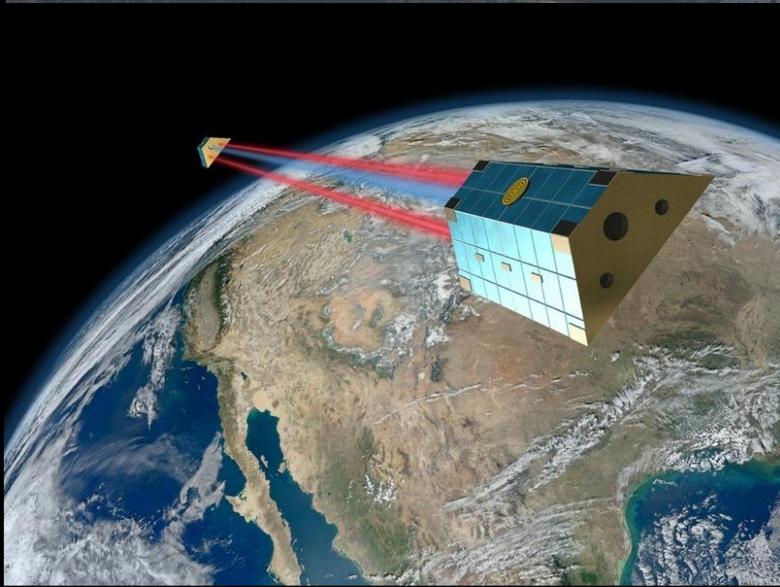
GRACE-Follow On

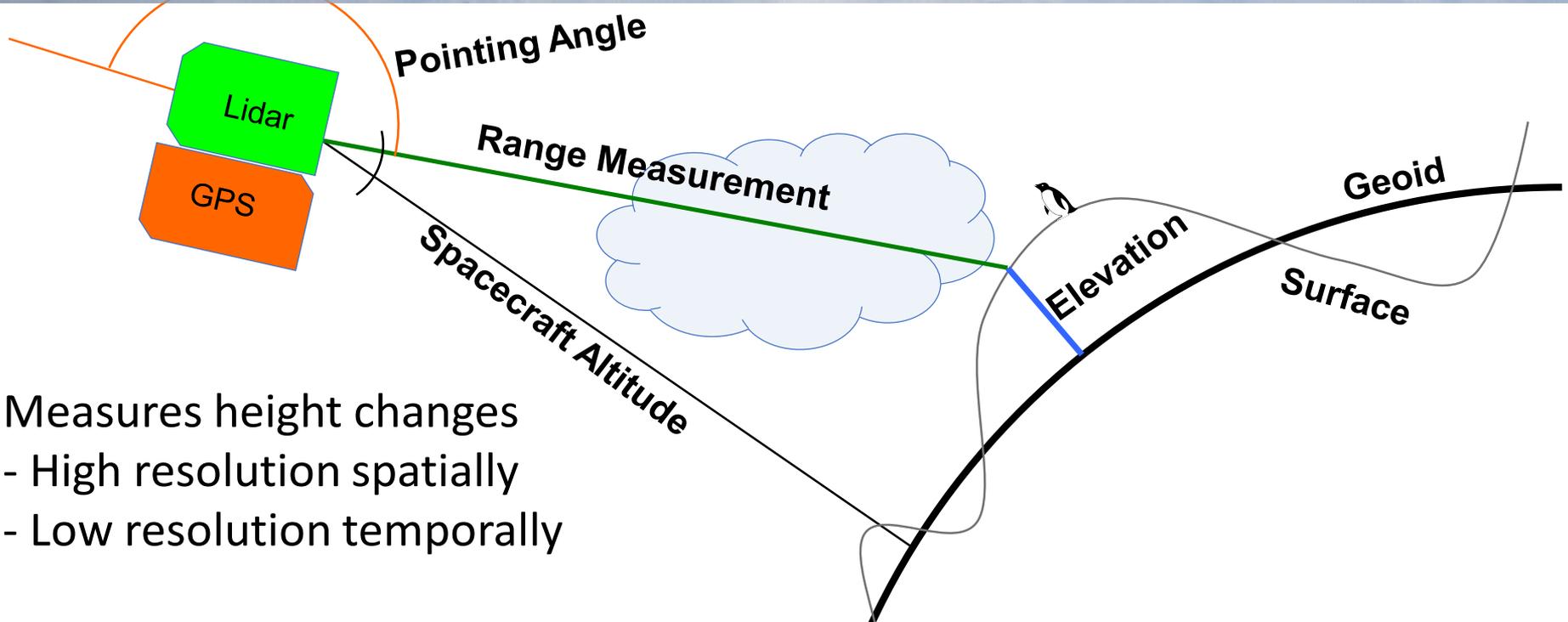
22 May 2018

NASA JPL



ICESat-2
15 Sept 2018





Measures height changes

- High resolution spatially
- Low resolution temporally

We want to measure **elevation**

Lidar measures **range (time of flight)** and **absolute pointing angle**

GPS measures position in orbit

Ground processing puts the pieces together



ICESat-2 Measurement Concept



ICESat-2 uses *micro-pulse multi-beam photon counting* approach to making height measurements.

Provides:

Dense cross-track sampling to resolve surface slope on an orbit basis.

High repetition rate (**10 kHz**) generates dense along-track sampling (**~70 cm**).

Different beam energies to provide necessary dynamic range (bright / dark surfaces).

Advantages:

Improved elevation estimates over high slope areas and very rough (e.g. crevassed) areas. Improved lead detection for sea ice freeboard.

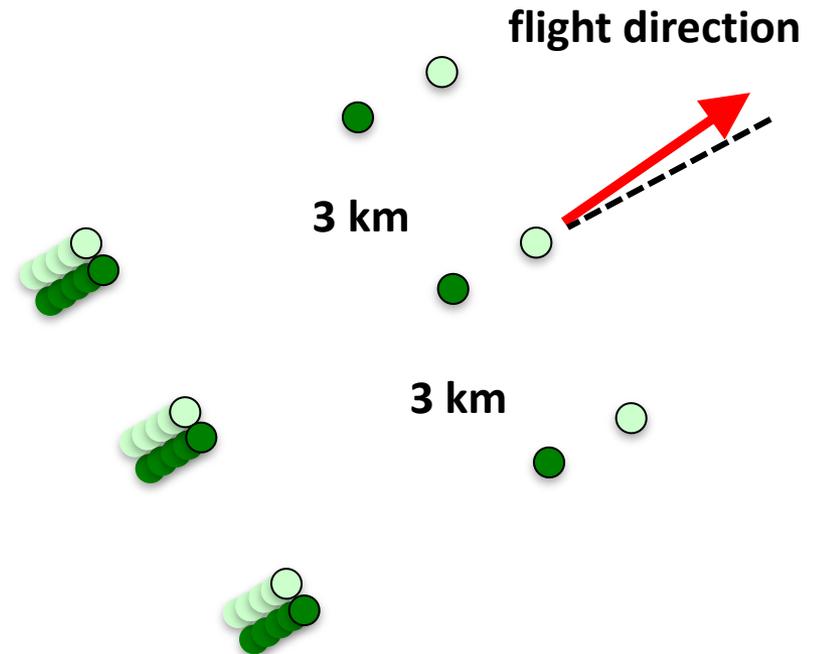
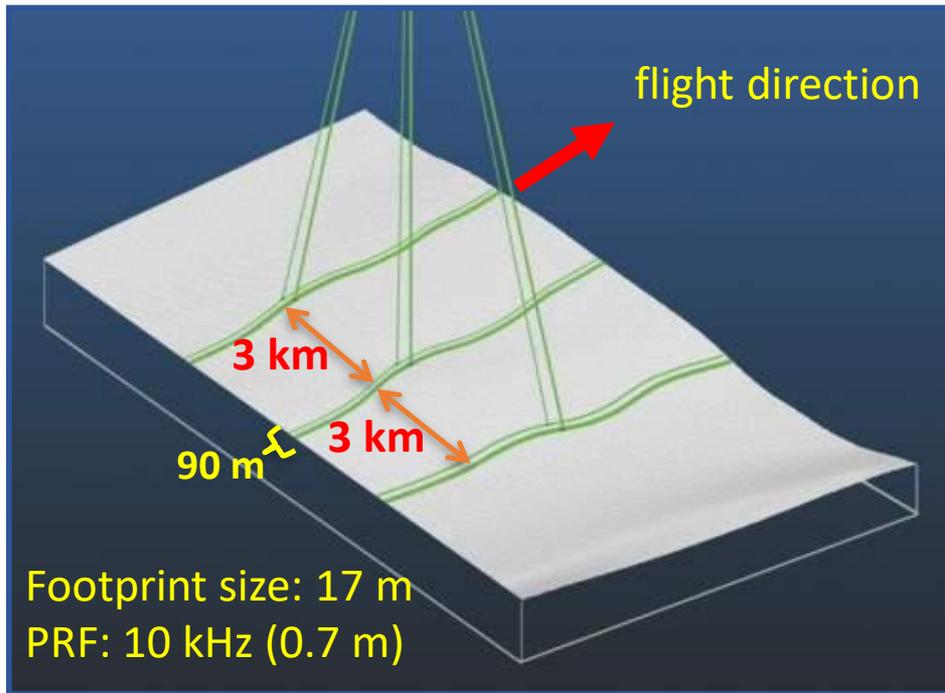




ICESat-2 Measurement Concept



Single laser pulse at 532nm, split into 6 beams. Single-photon sensitive detection.



3 km spacing between pairs provides spatial coverage

90 m pair spacing for **slope determination** (2° yaw)

High-energy beams (4x) for better performance over low-reflectivity targets.



ICESat-2!



Orbit

310 miles altitude,
92-degree inclination,
91-day repeat

Speed

4.3 miles per second (15,480 mph)

Power

4 Solar panels
average of 1320 Watts

Data

Onboard recorder stores 580 gigabits/day,
X-band downlink sends 220Mbits a second.



ATLAS (Laser Instrument) 550kg ,
Spacecraft Dry Mass 906 kg,
Propellant 134 kg (7 years)



ICESat-2!



7:00 PM PST



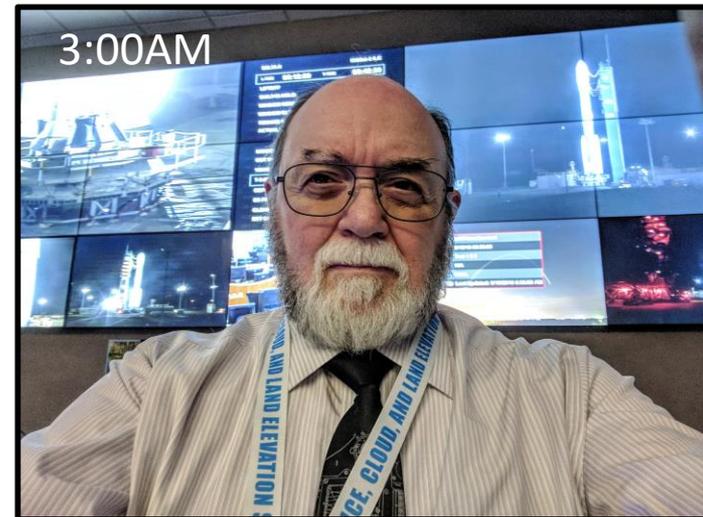
11:30 PM PST



Team Members spend years, sometimes decades devoting careers and lives to space missions.

Launch day is a personal and deeply human experience.

3:00AM



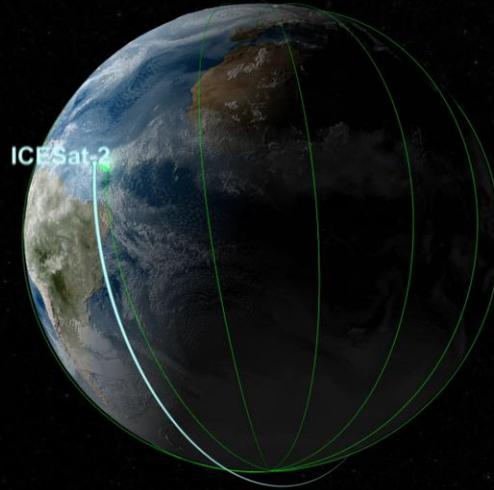


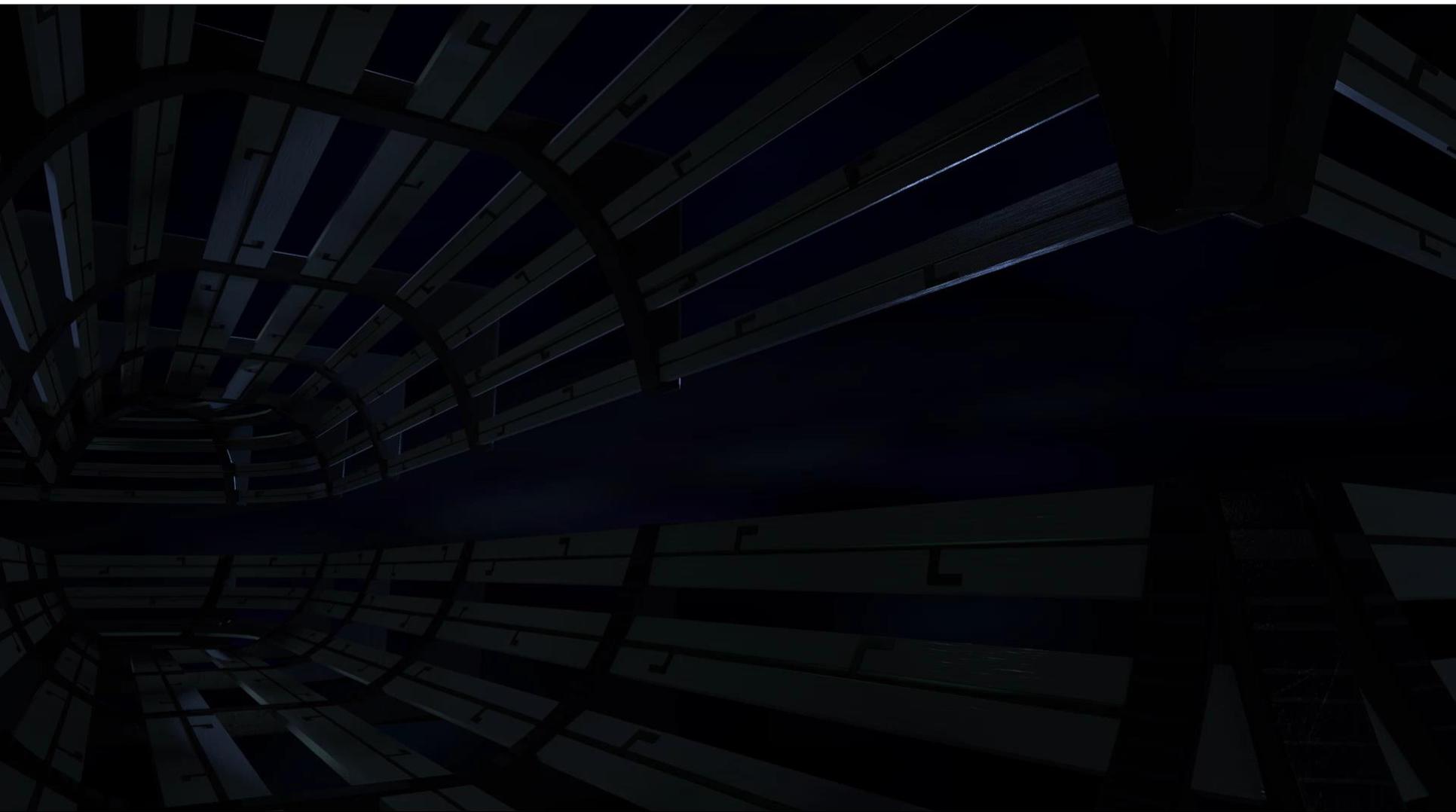
Launch and Separation



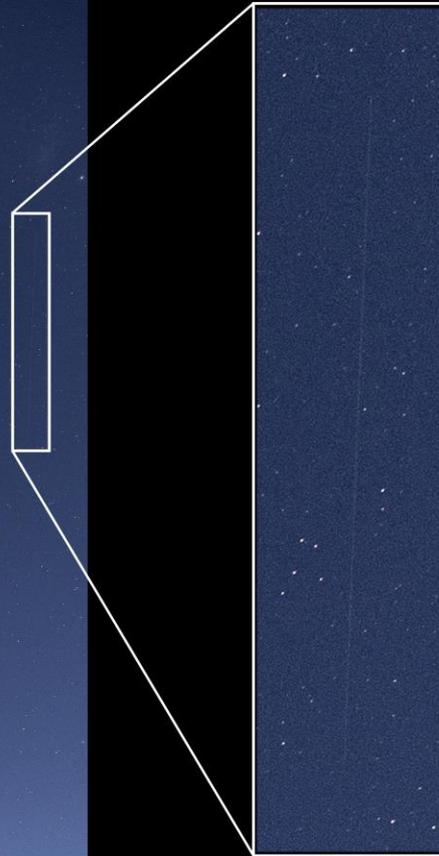
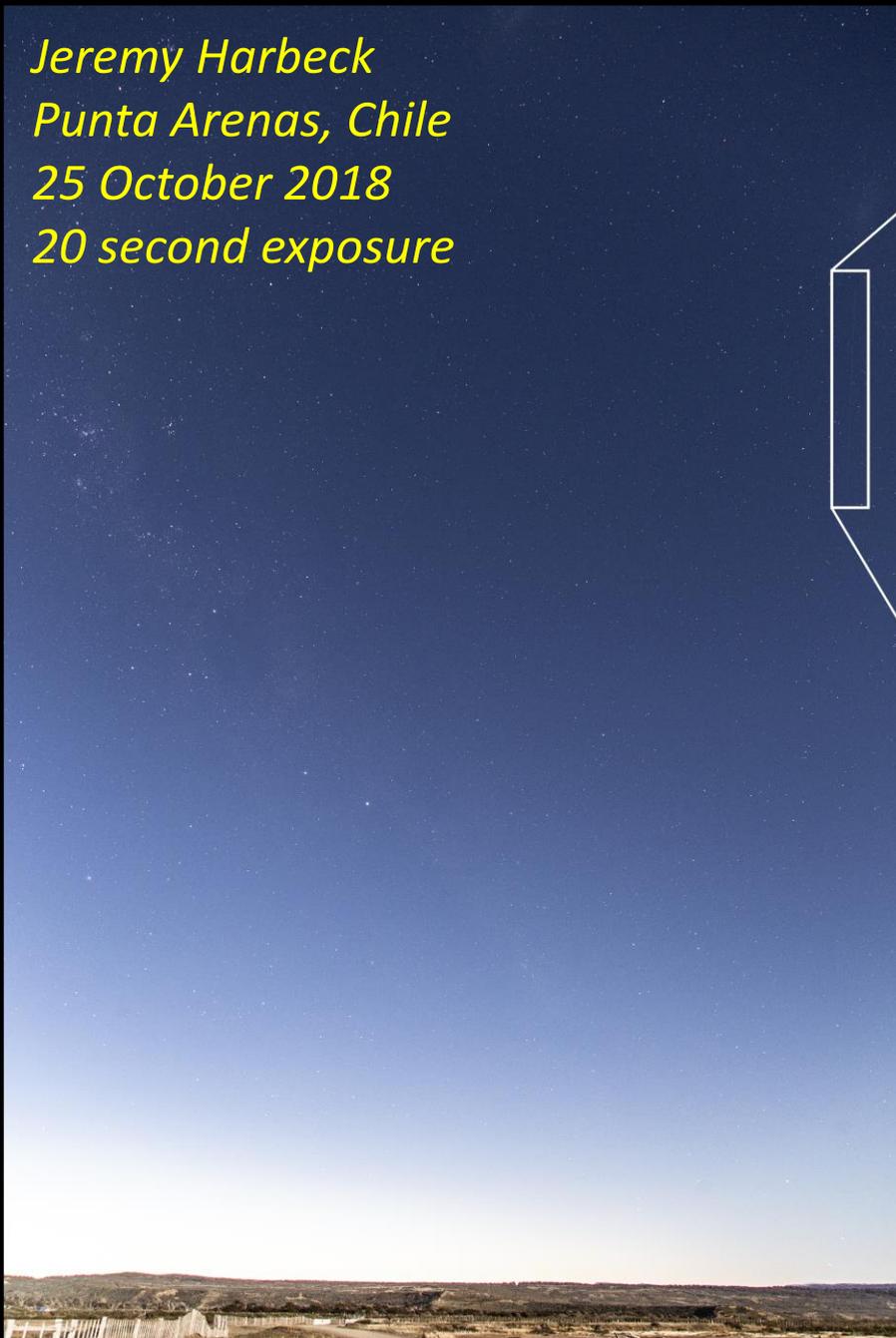


Orbit Coverage



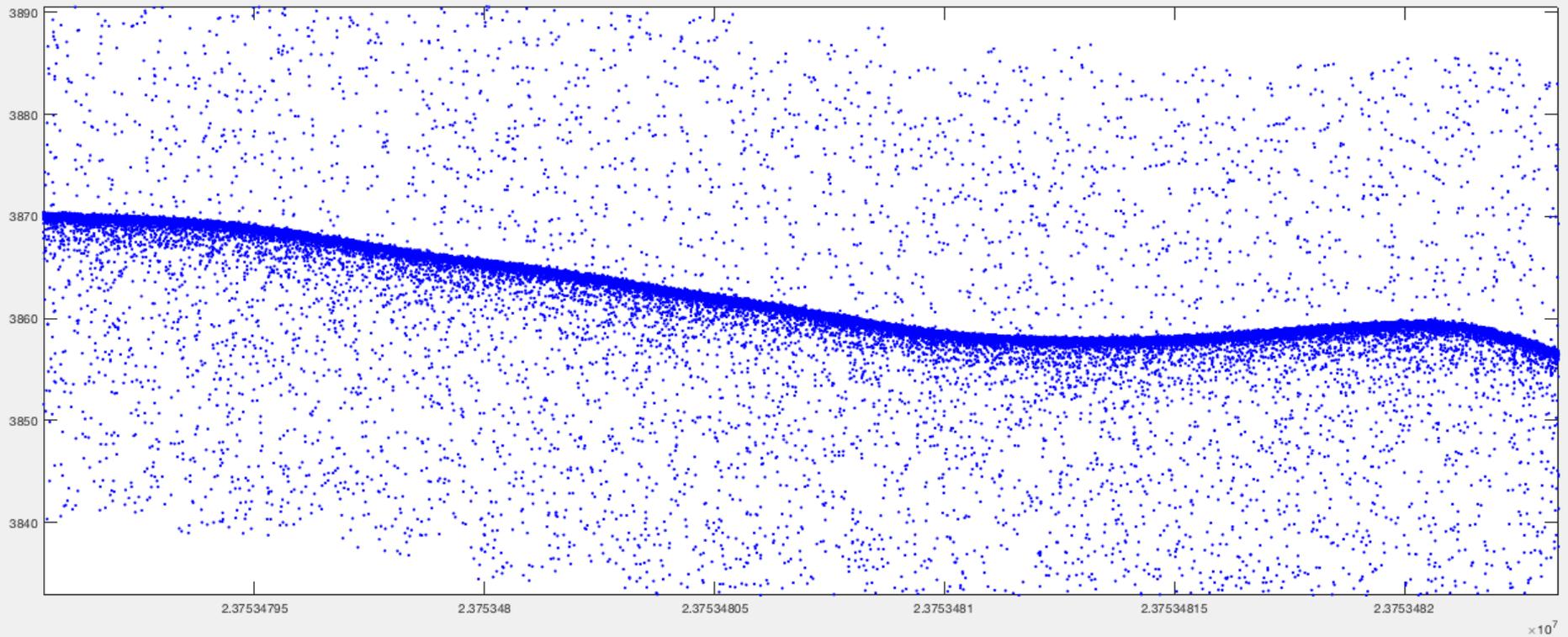


*Jeremy Harbeck
Punta Arenas, Chile
25 October 2018
20 second exposure*



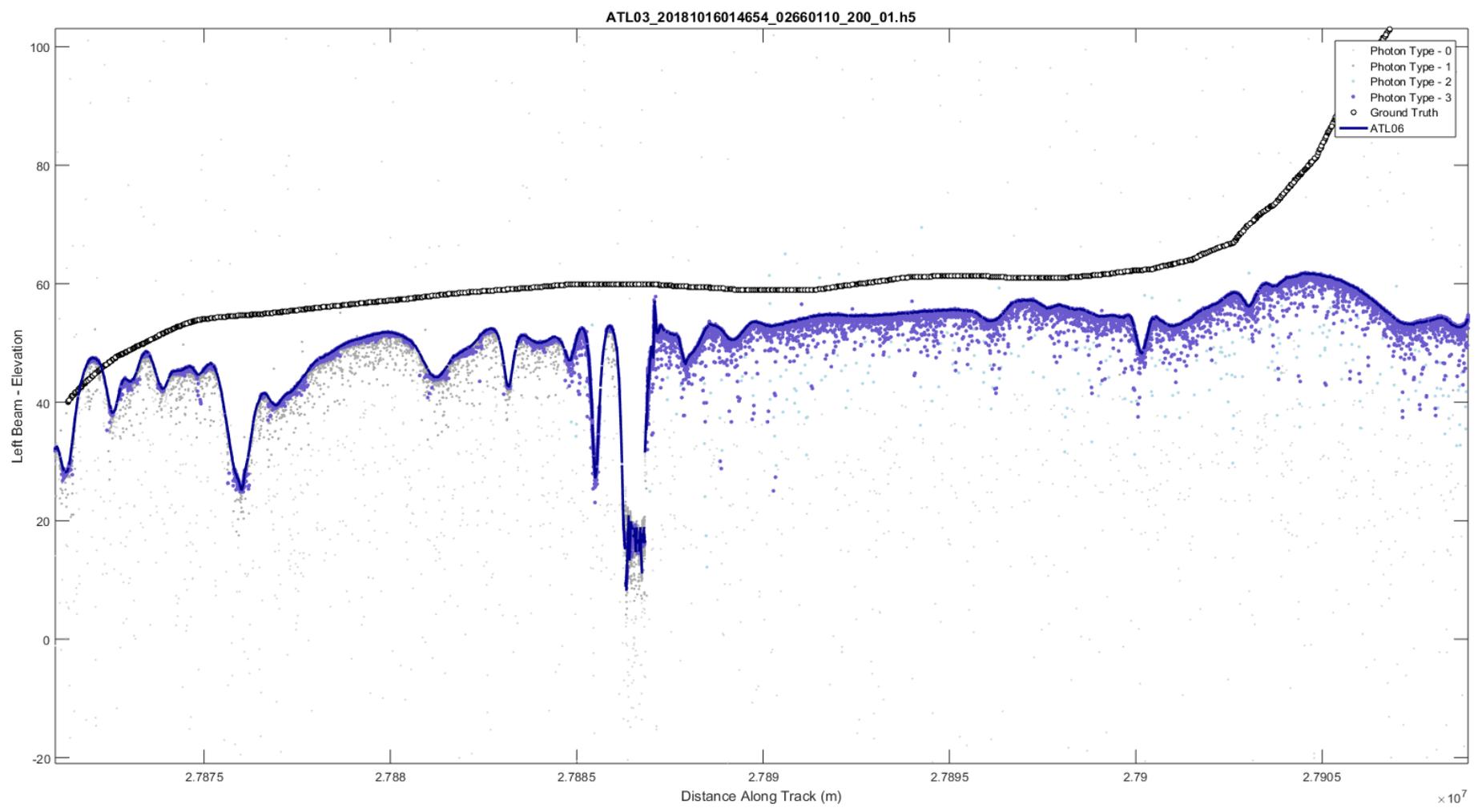


What DOES the data look like?



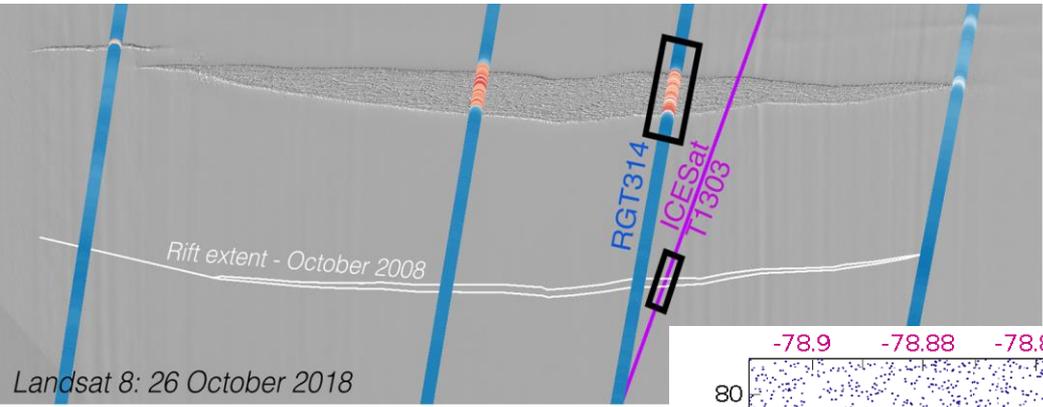


What DOES the data look like?

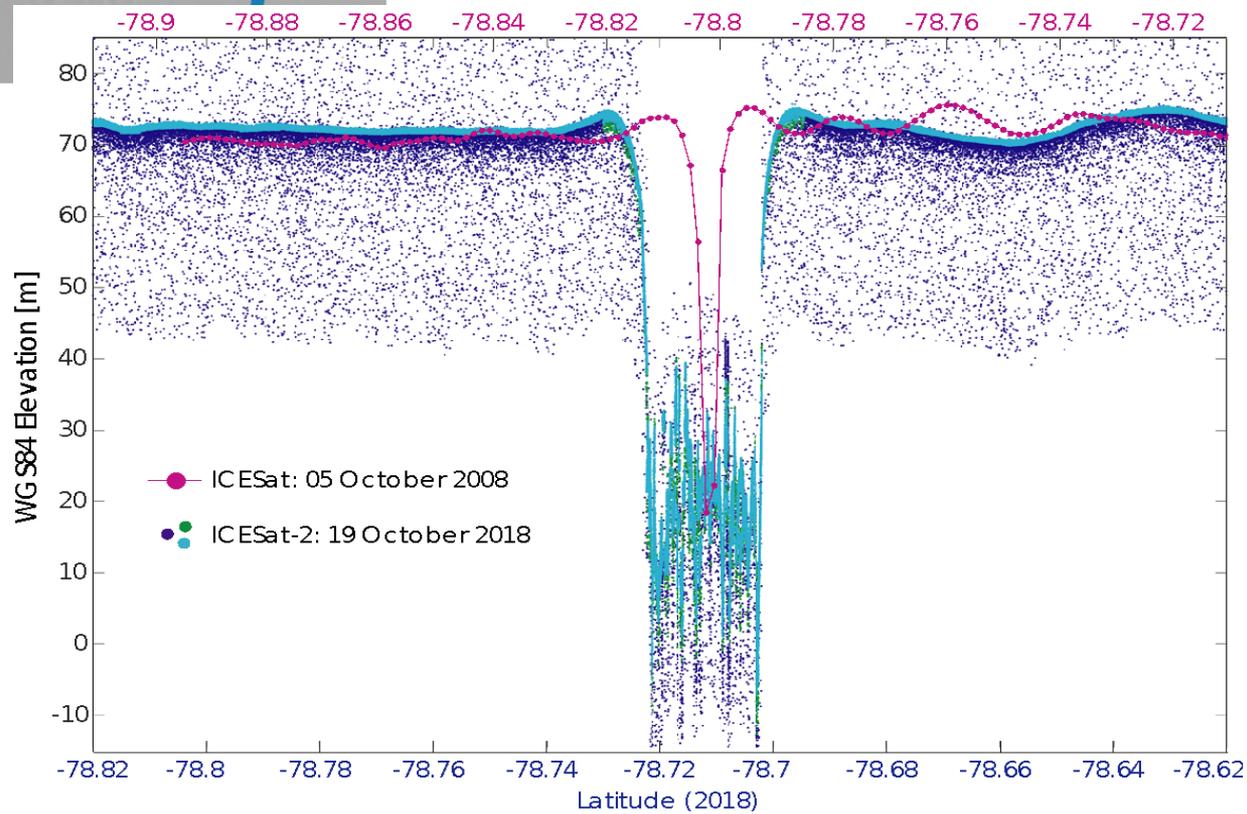




What DOES the data look like?



Filchner Ice Shelf, West Antarctica





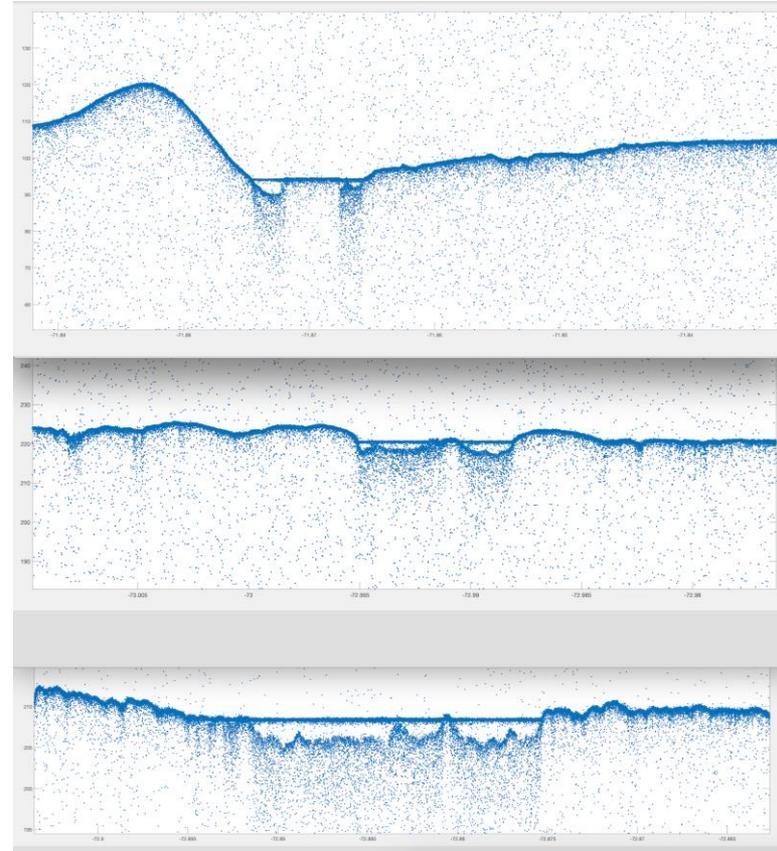
What DOES the data look like?



Amery Ice Shelf undergoes extensive surface melt each summer, which flows as melt streams

ICESat-2 penetrates the water and allows us to estimate the depth of melt ponds

Combined with satellite imagery, this will provide meltwater volume estimates

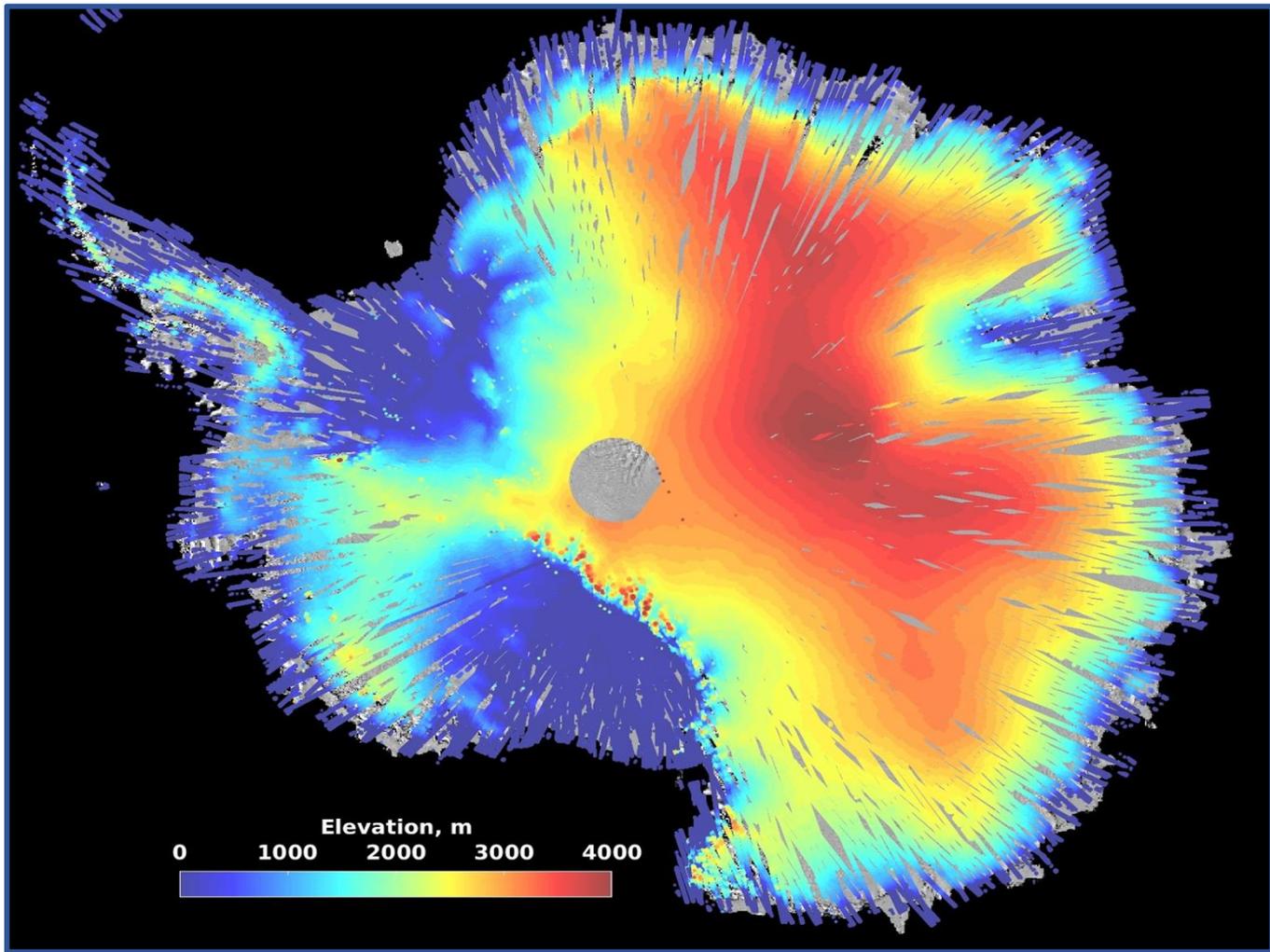




What DOES the data look like?



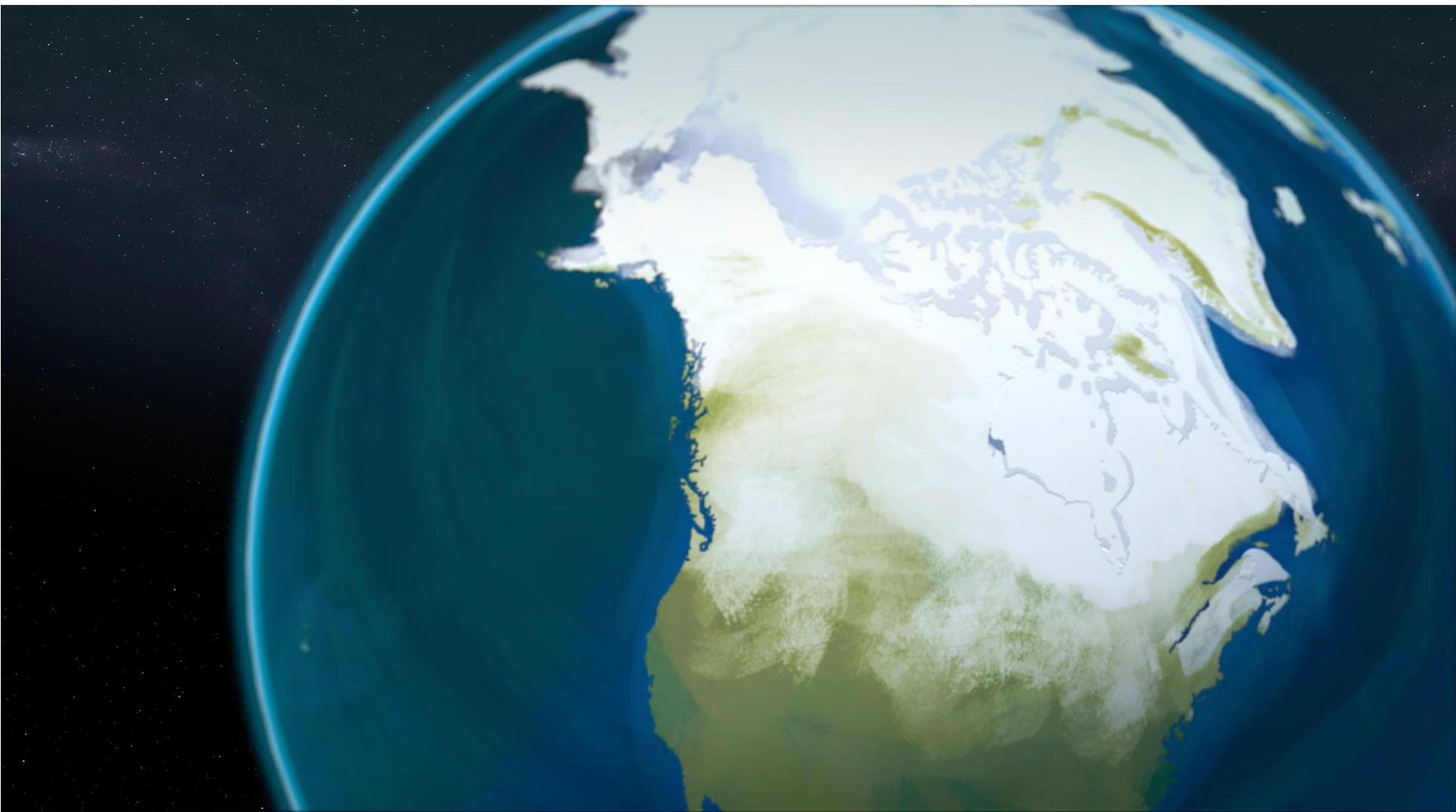
First three weeks of observations over Antarctica



Ben Smith, University of Washington

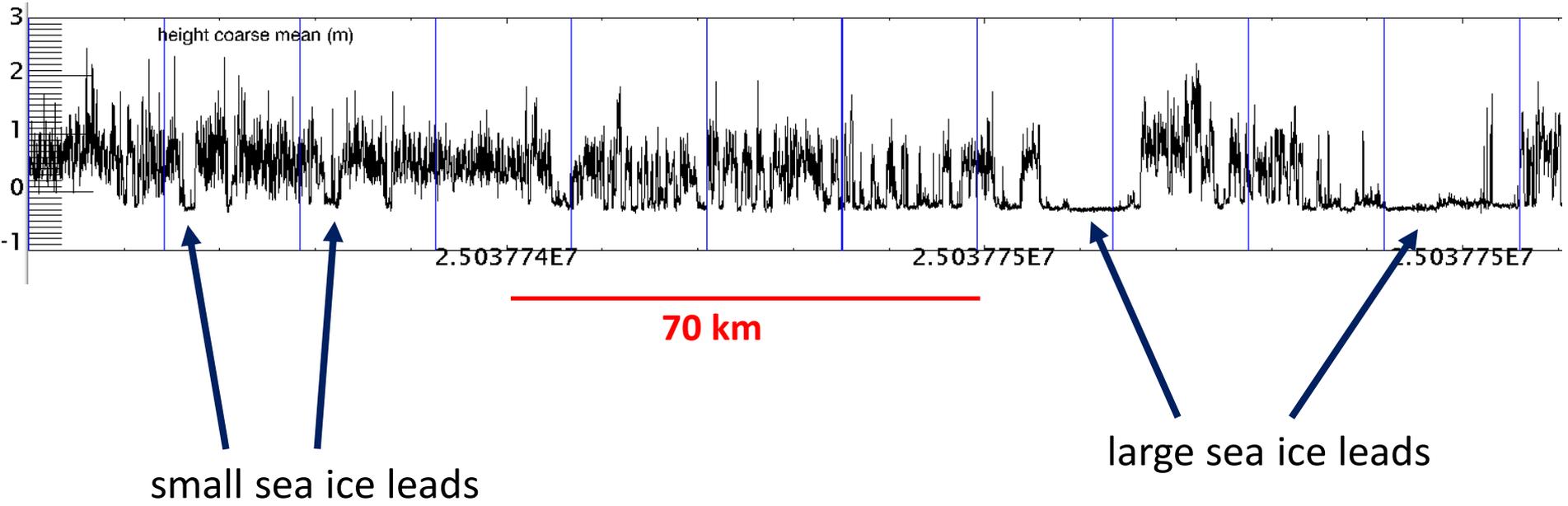


Sea Ice Objectives (they're a little different)

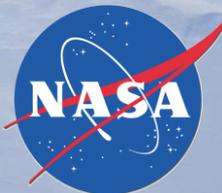




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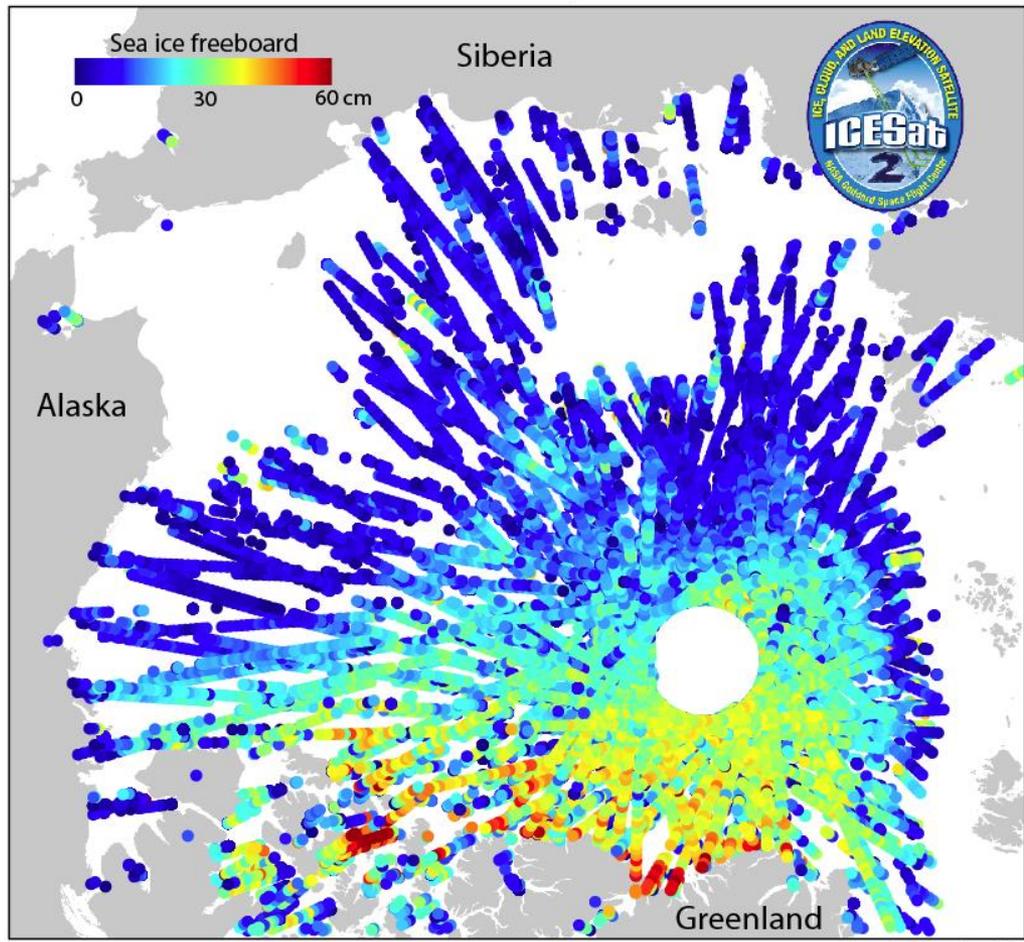


9/10ths of sea ice is below the water line.
This opens up the third dimension:
sea ice thickness



What DOES the data look like?

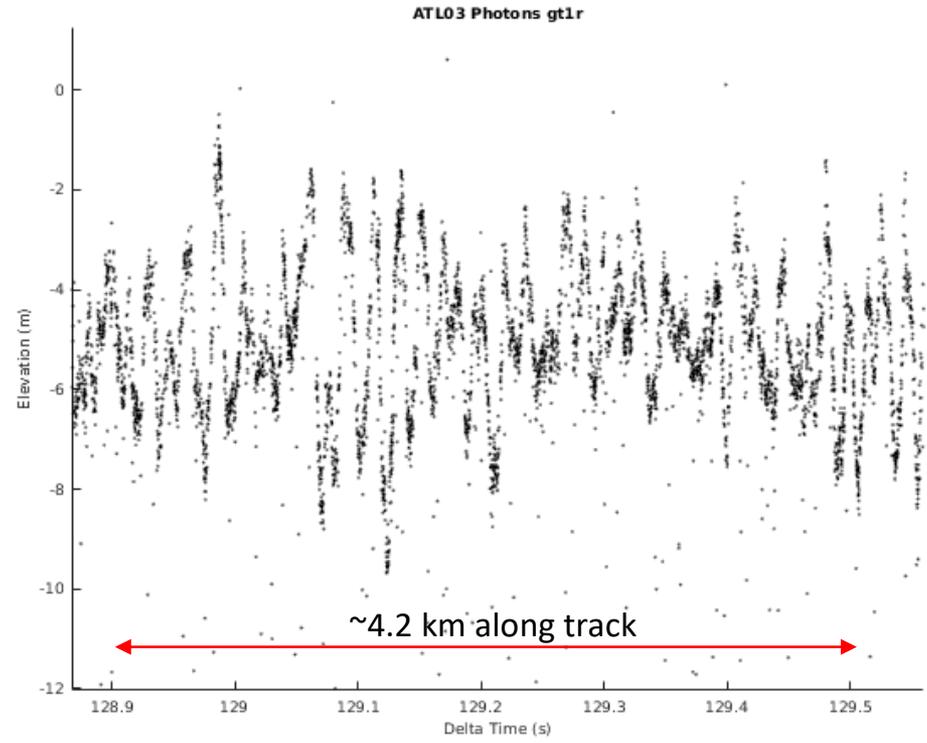
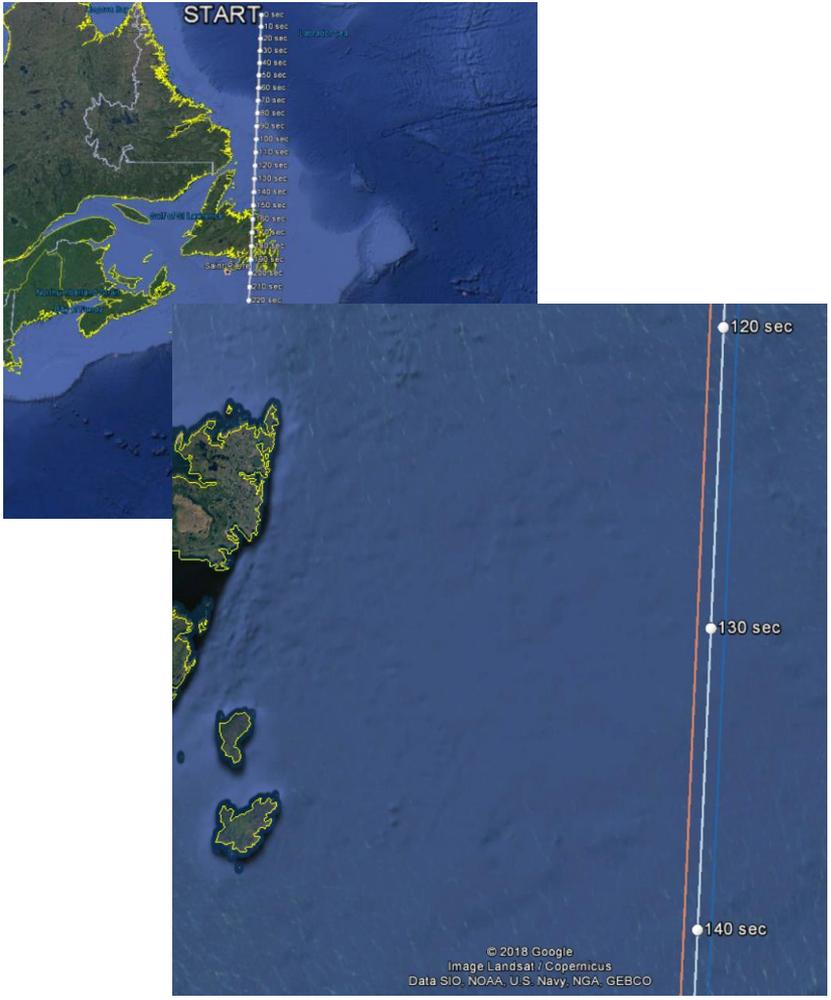
Oct 14 - Oct 28, 2018



Sea Ice Freeboard of the Arctic Ocean in the Late Fall from 14 days of ICESat-2 data

What DOES the data look like?

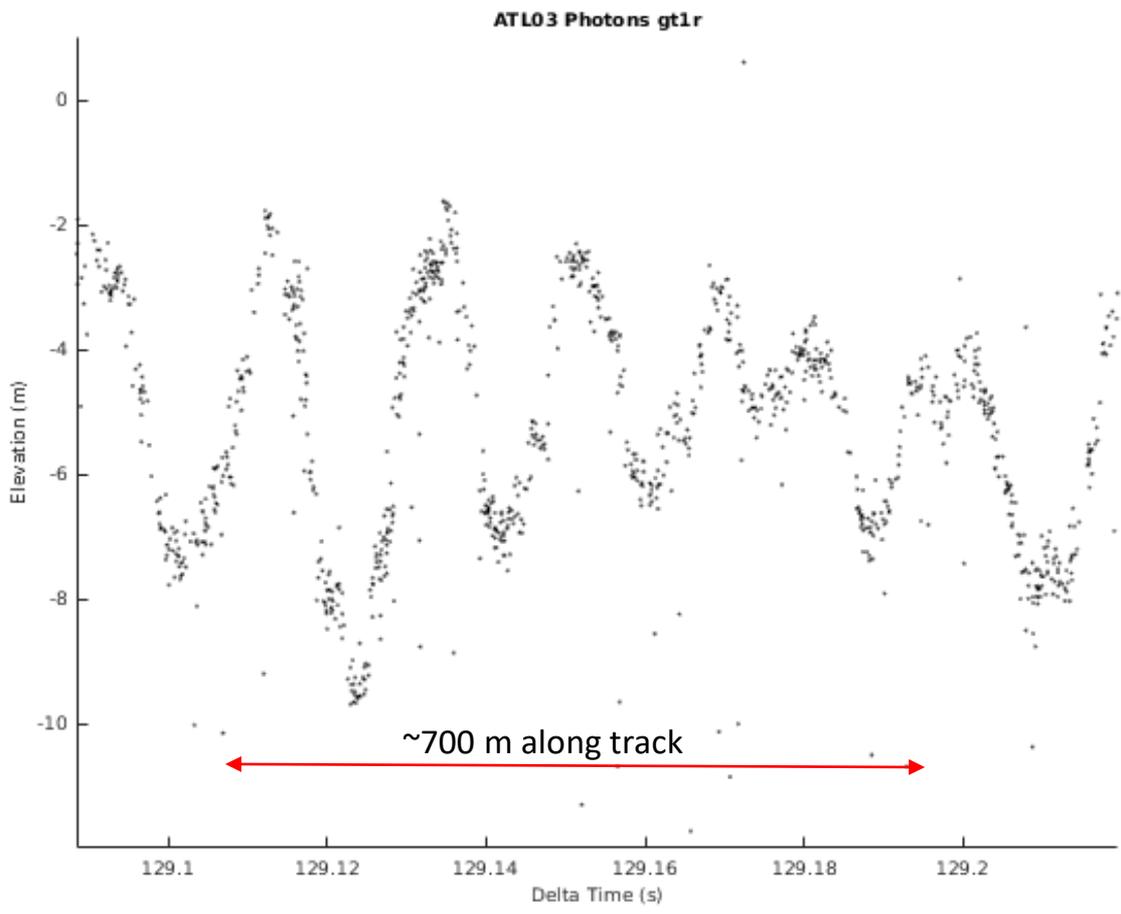
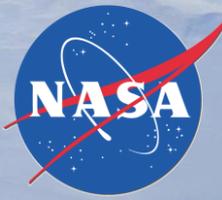
Example from 17 October, Start time 070948 UTC



Ocean Waves



What DOES the data look like?



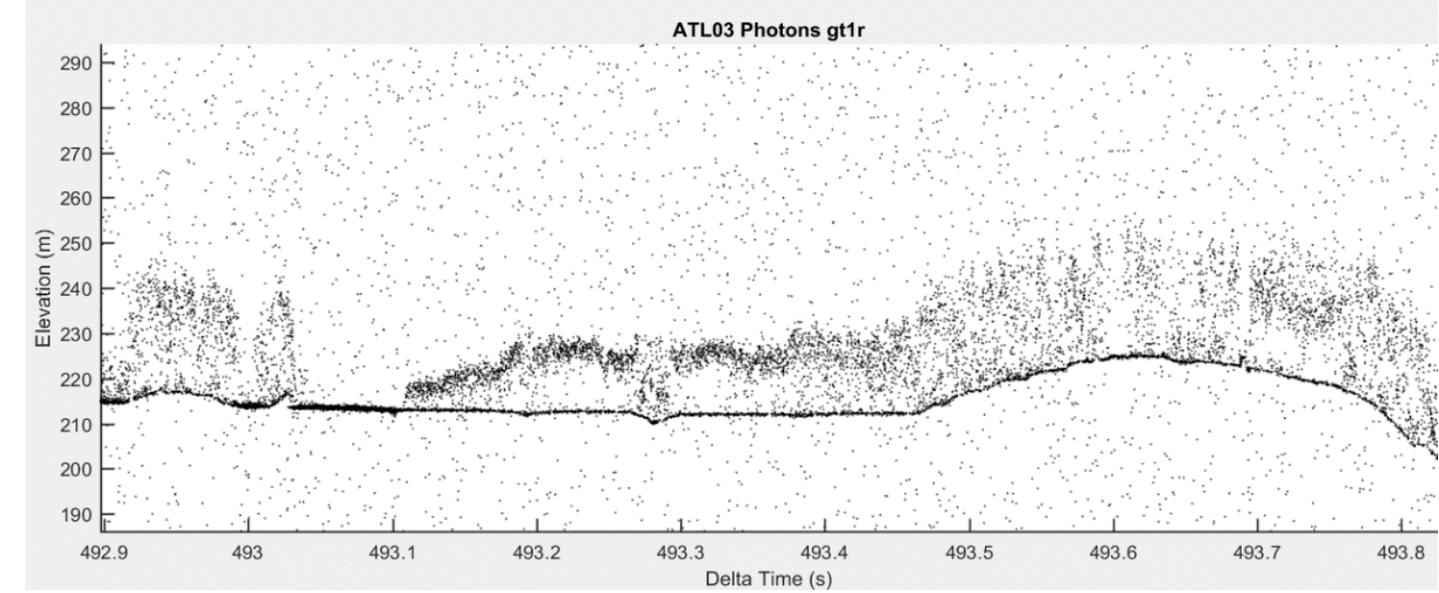
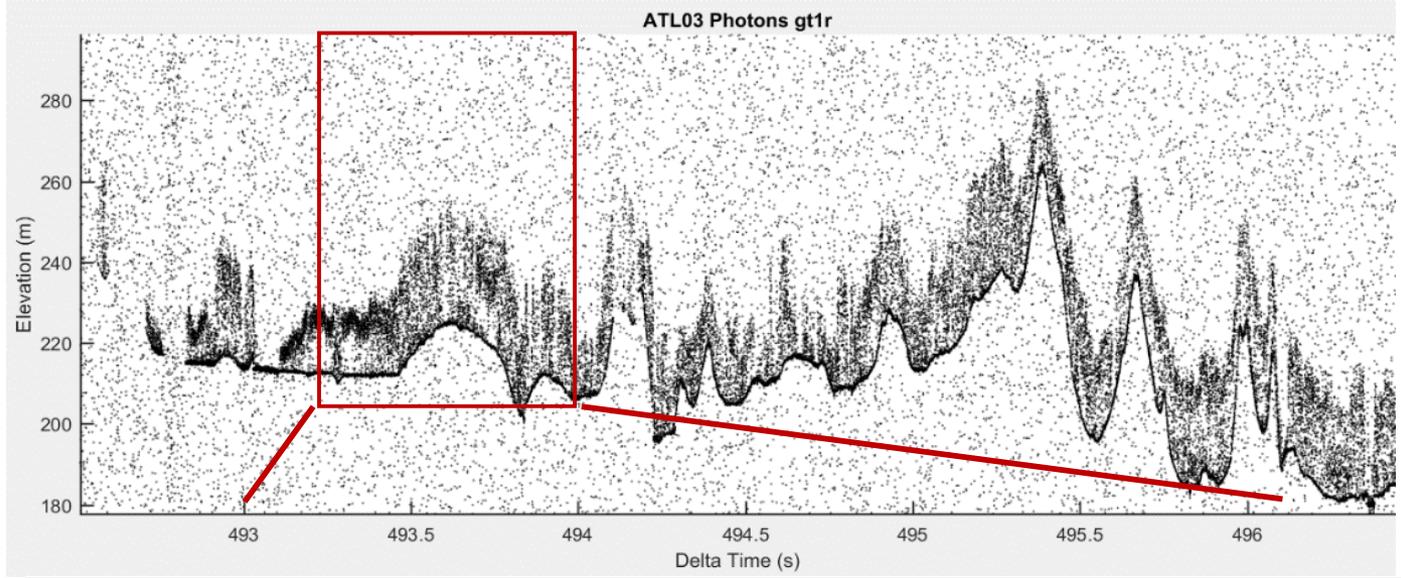
- With the strong beams, there is a well defined wave structure
- This example depicts wavelengths on the order of 140 m

Ocean Waves

Figures courtesy of Brad Klotz

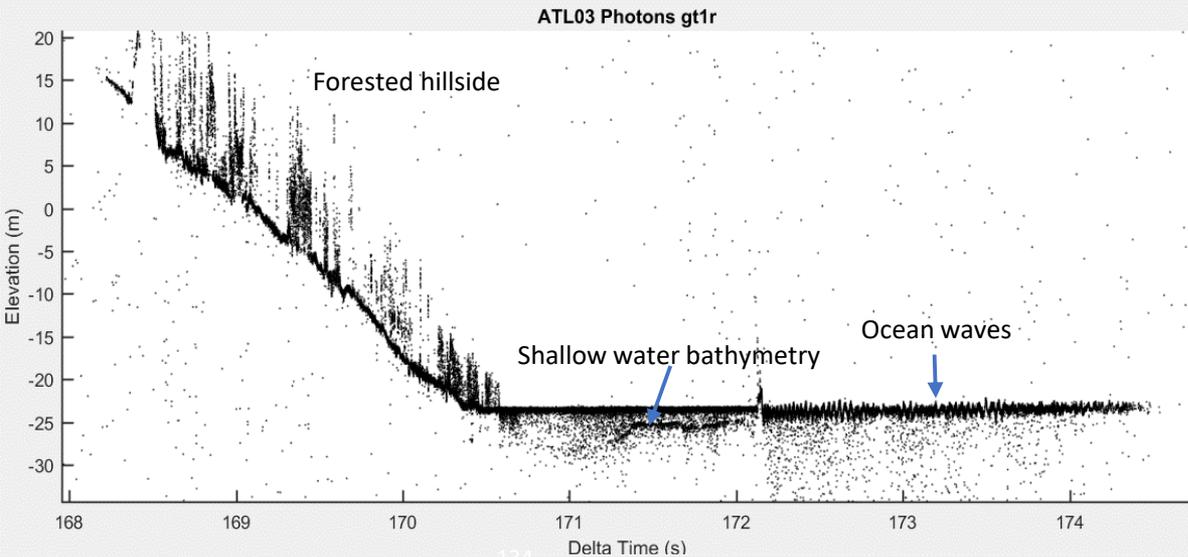


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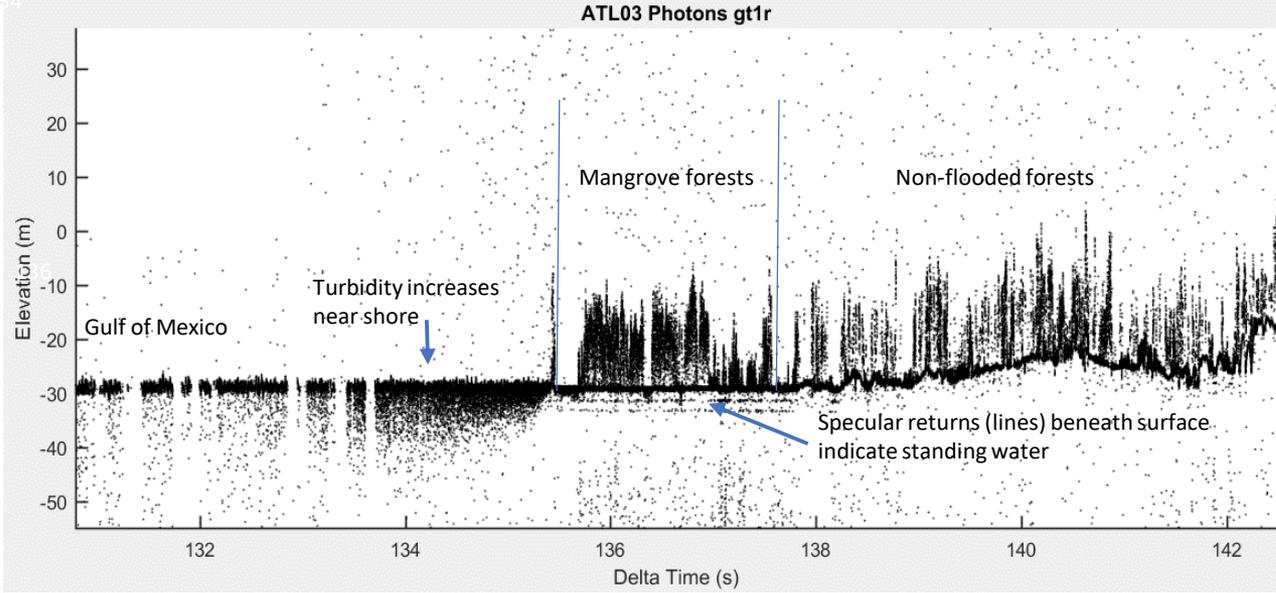
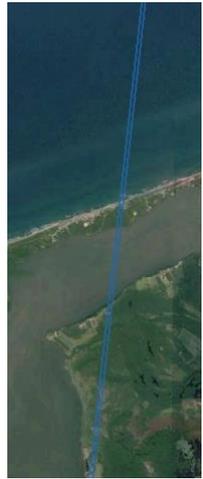




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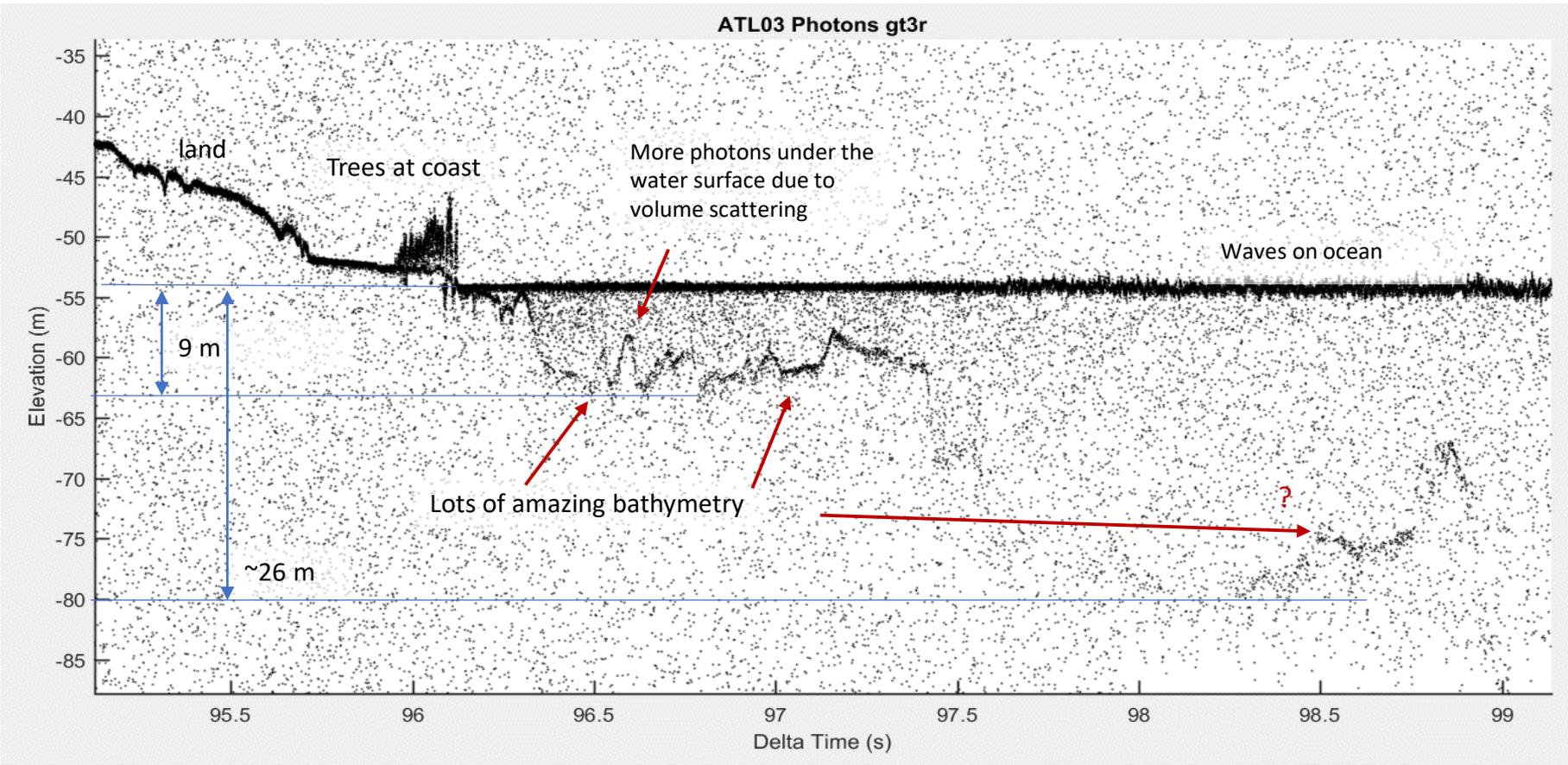


Ground track through Mexico. Mountains in interior are cloud covered, but coastal areas are cloud-free





What DOES the data look like?



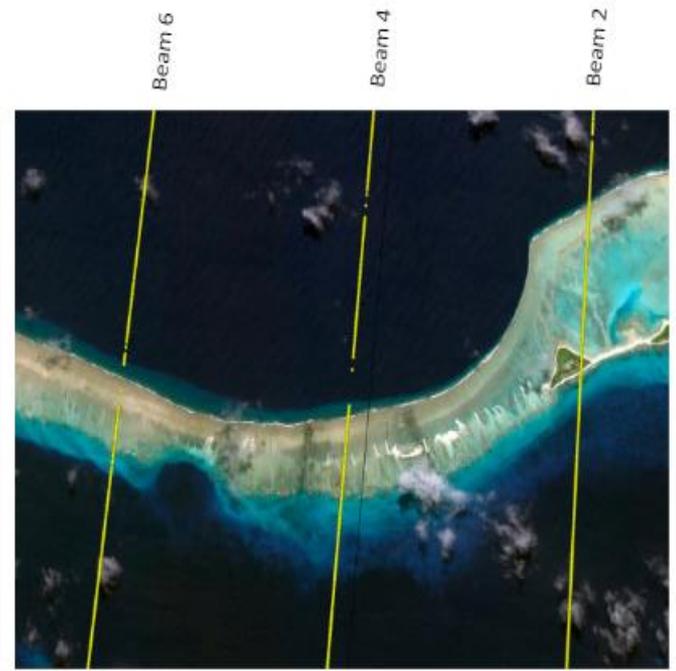
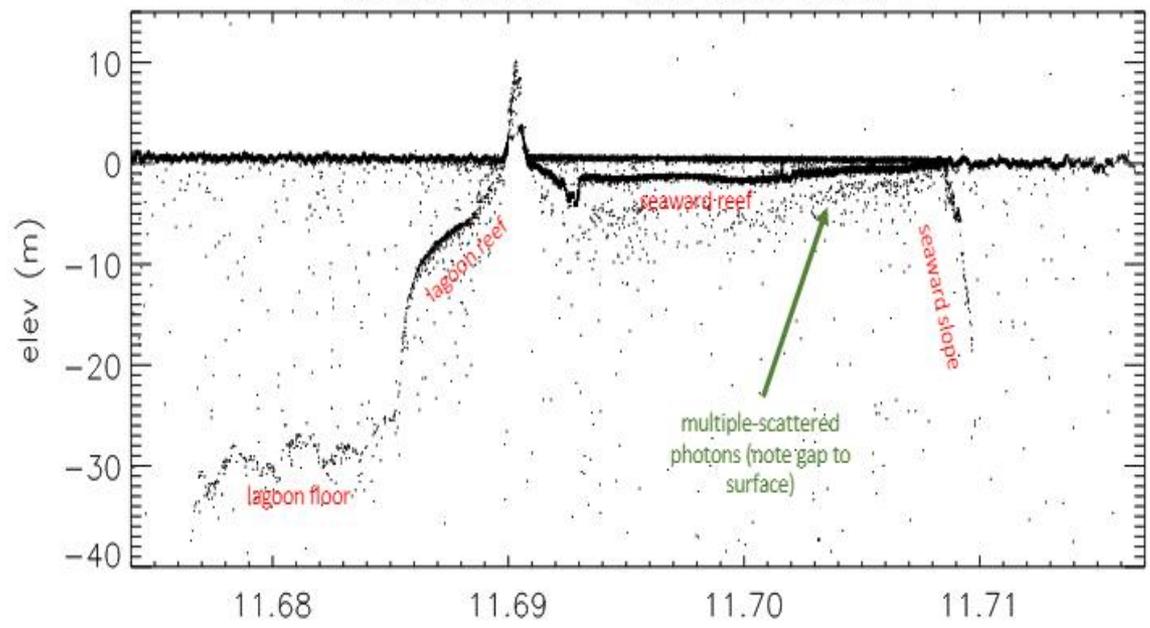


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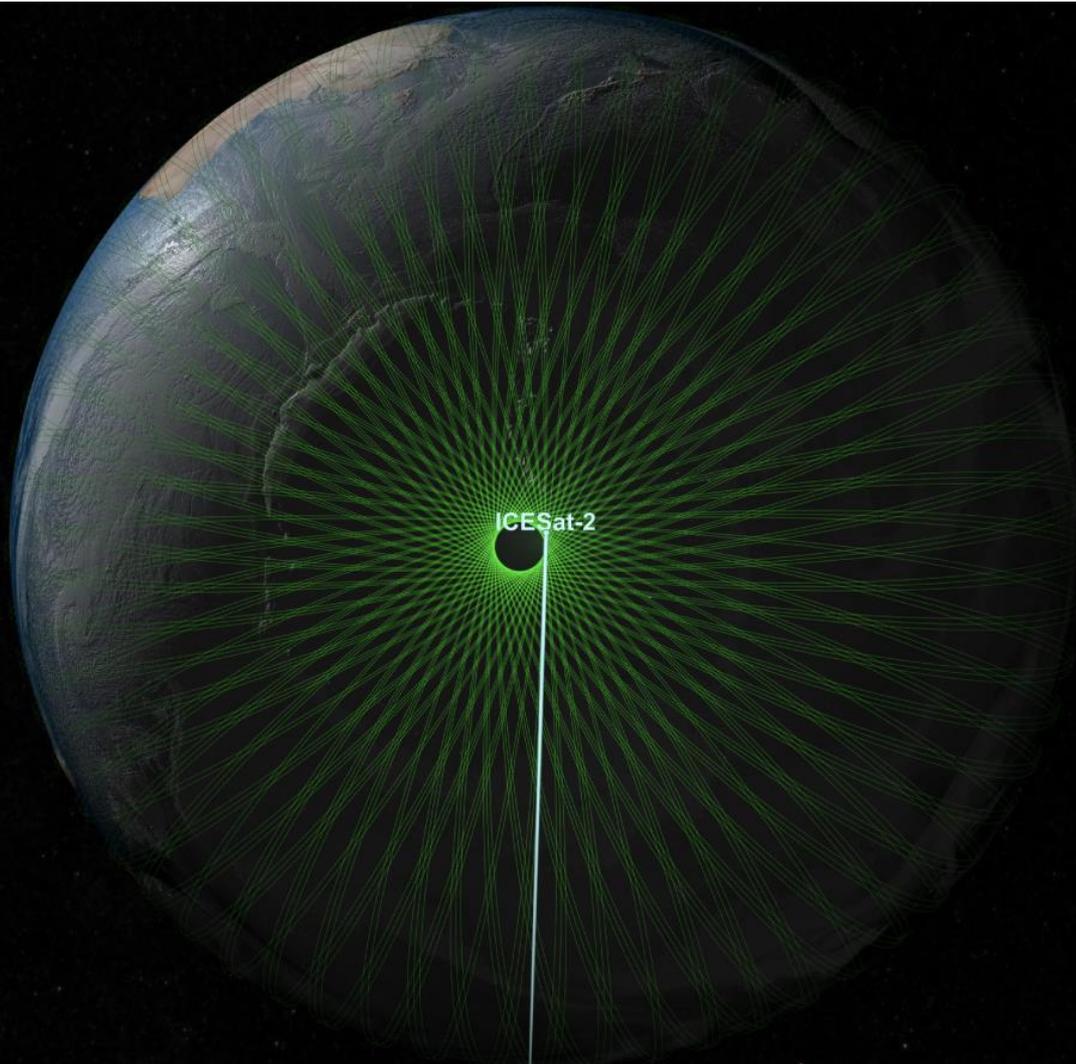
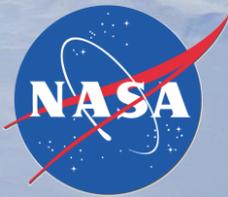
RGT 306 – Bikini Atoll

BIKINI ATOLL – RGT 306 BEAM 2





ICESat-2 Pole Hole



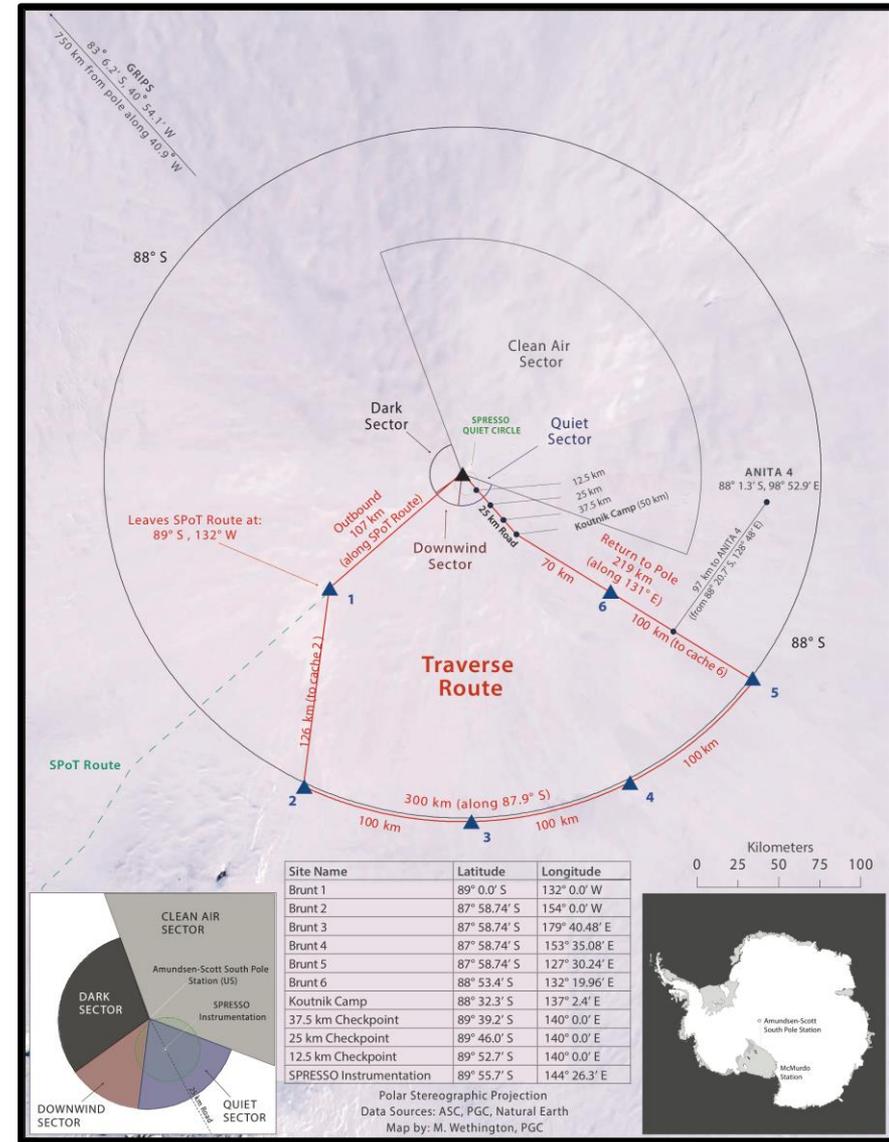


ICESat-2 Pole Hole



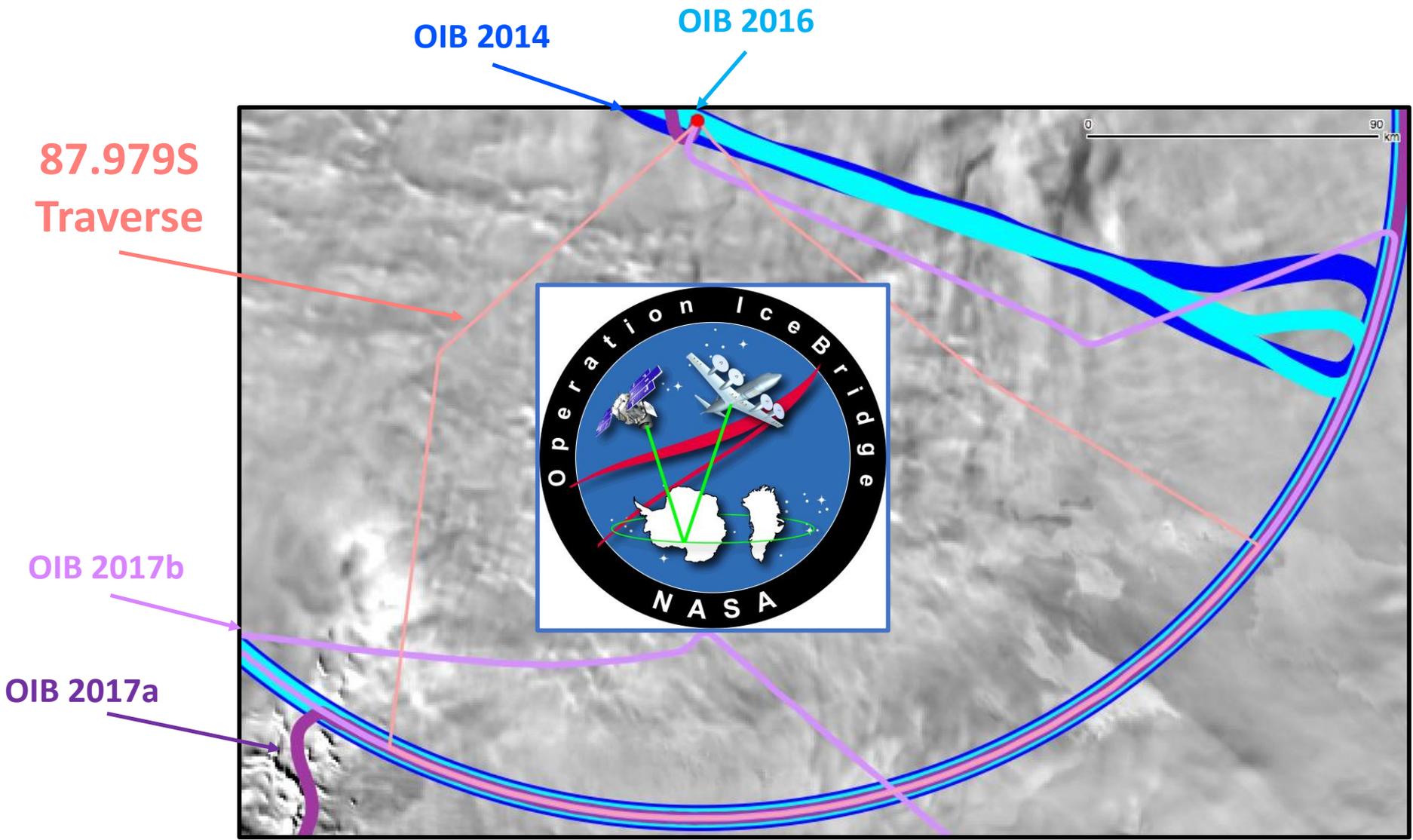
87.979S Traverse for ICESat-2 validation:

- Annual traverse, next 4 years
- 300 km along 87.979S (*long length scale*)
- Intersects 277 of 1387 ICESat-2 ground tracks
- 20% of the ICESat-2 tracks (*long time scale*)
- Survey-quality GPS data
- PPP post-processing
- <1 cm accuracy and $< \pm 8$ cm precision





87.979S and Operation IceBridge





ICESat-2 Pole Hole





ICESat-2 Pole Hole



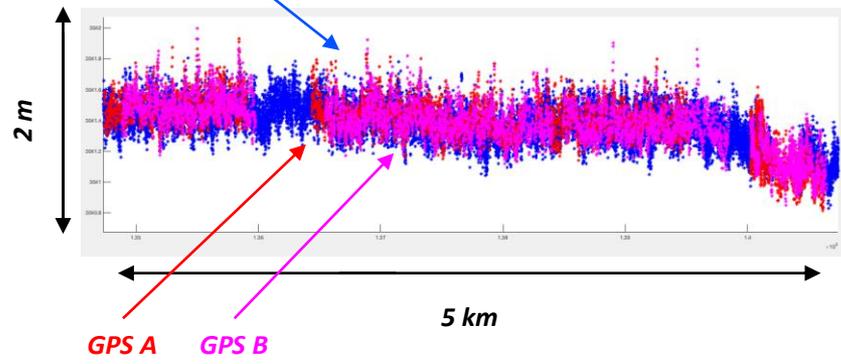


ICESat-2 Pole Hole

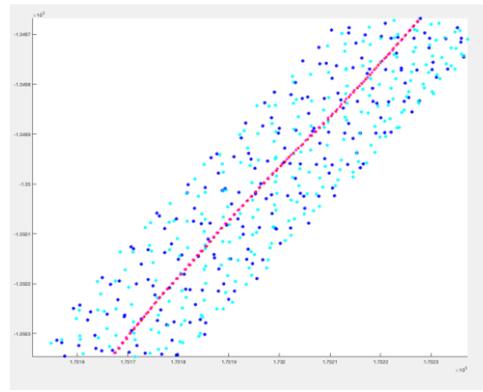


GPSA vs GPSB: 1.6 ± 4.1
GPS vs ATM: -2.7 ± 14.1

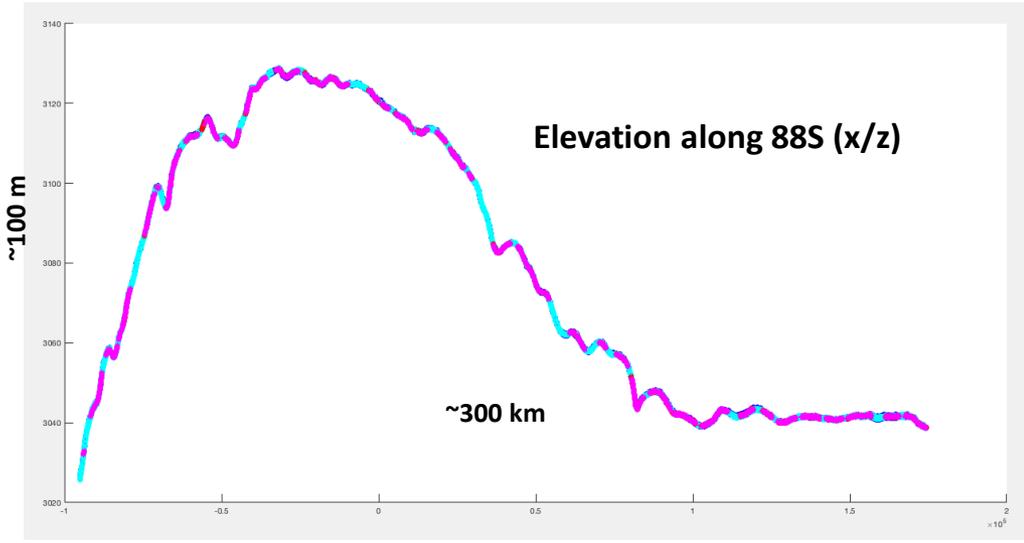
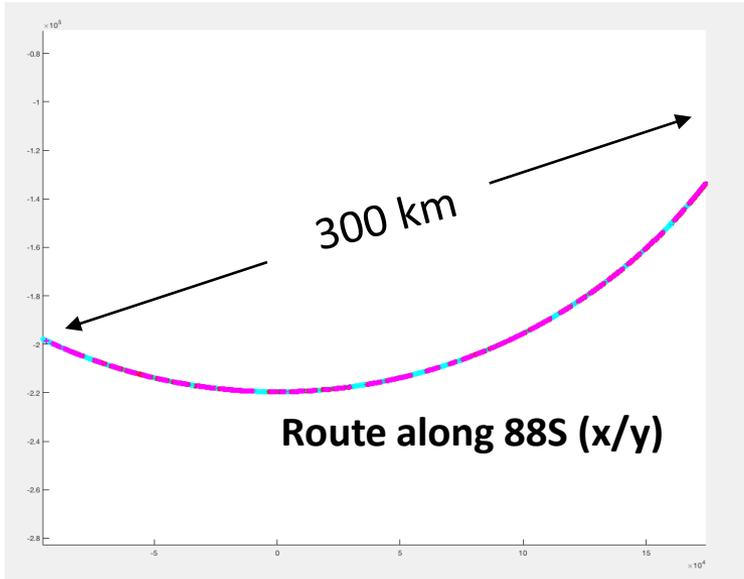
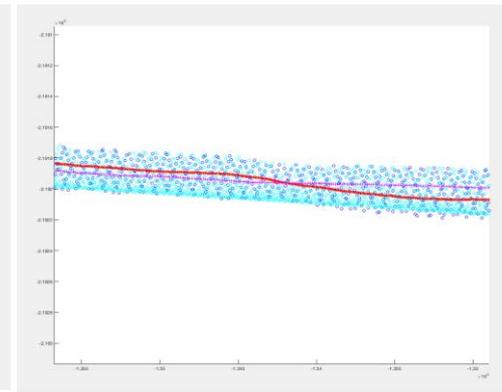
ATM 2014



In each other's tracks



Crossing each other's tracks





The Future is Here!



The beginning of a new era in polar science begins!

GRACE Follow On is now up and running after some initial issues.
ICESat-2 is well on it's way to nominal science data production.

