ICESat-2
Global STEM Education:
What’s Next
@ Harvard Graduate School of Education,
Cambridge MA
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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.

Csatho, pers. comm.
GRACE Observations of Antarctic Ice Mass Changes

- Mass Loss (Gigatons)

04-2002

-2000

Sep 2002: 149

Average Mass Loss: 125 Gigatons/year

Aug 2015: -1934

Antarctic Ice Loss
(meters water equivalent relative to 2002)

-3 -2 -1 0 1
Sea Ice Changes: Arctic
Sea Ice Changes: Arctic

Arctic Sea Ice Area

Millions km²

1979

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

Footprint size: 17 m
PRF: 10 kHz (0.7 m)

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

Launch day is a personal and deeply human experience.
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

Catherine Walker, NASA-GSFC
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)
What DOES the data look like?

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?

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

Figures courtesy of Brad Klotz
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
What DOES the data look like?
What DOES the data look like?

- Forested hillside
- Shallow water bathymetry
- Ocean waves
- Turbidity increases near shore
- Mangrove forests
- Non-flooded forests
- Specular returns (lines) beneath surface indicate standing water

Ground track through Mexico. Mountains in interior are cloud covered, but coastal areas are cloud-free.
What DOES the data look like?

- **Land**
- **Trees at coast**
- **Waves on ocean**
- More photons under the water surface due to volume scattering
- Lots of amazing bathymetry

- **9 m**
- **~26 m**
What DOES the data look like?
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 < ± 8 cm precision
ICESat-2 Pole Hole
ICESat-2 Pole Hole
ICESat-2 Pole Hole

ATM 2014

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

In each other’s tracks
Crossing each other’s tracks

Route along 88S (x/y)

Elevation along 88S (x/z)

~100 m

300 km

~300 km

~300 km

~100 m

2 m

5 km

GPS A

GPS B

ICESat-2
ICE, CLOUD, AND LAND ELEVATION SATELLITE

NASA
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 its way to nominal science data production.