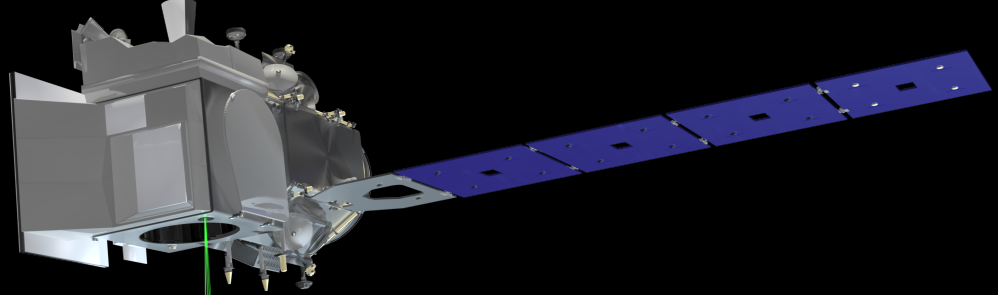

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Ben Smith[1]
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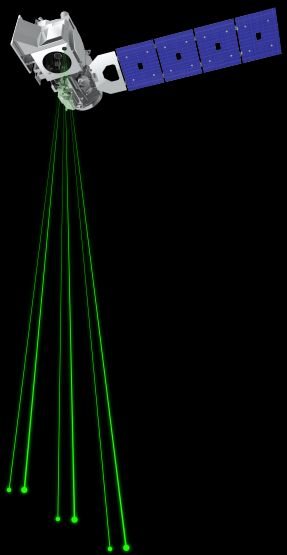
email: tsutterl@uw.edu

ICESat-2 Products: *from photons to grids*

*with materials from ICESat-2 PSO, Science Team, SlideRule team, and collaborators

ICESat-2 Science Objectives



- Quantify polar ice sheet contributions to current and recent sea level change and the linkages to climate conditions
- Quantify regional signatures of ice sheet changes
  - Quantifying the regional evolution of ice sheet change
  - Assess mechanisms driving recent changes
  - Improve predictive ice sheet models
- Estimate sea ice thickness to examine ice-ocean-atmosphere exchanges of energy, mass and moisture
- Measure vegetation canopy height as a basis for estimating large-scale biomass and biomass change

ICESat-2 Along-Track Sampling

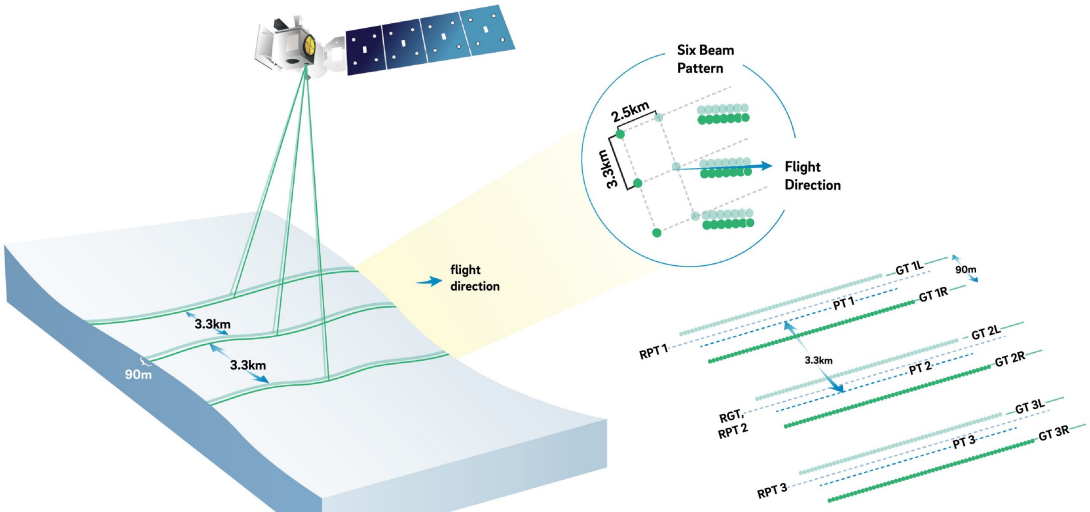
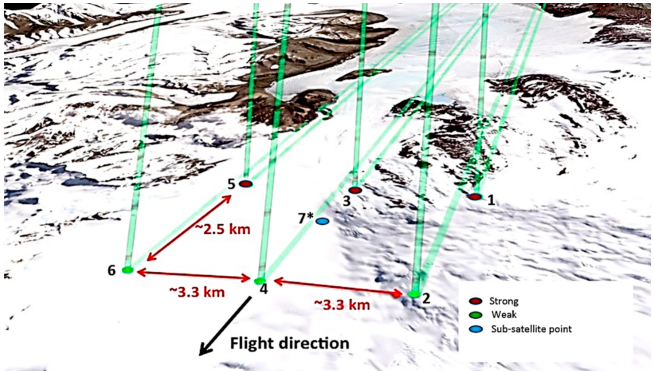


Figure 1 from Smith et al. [2019]

Advanced Topographic Laser Altimeter System (ATLAS)



- Single 10kHz 532nm laser micro-pulse → split into 6 beams
- Detectors sensitive to green light returns at the single photon level
- On-the-ground 3 km spacing between pairs to increase spatial coverage
- On-the-ground 90 m pair spacing for slope determination
- Different beam energies to provide dynamic range for varying surface reflectances

Figure 2 from Neuenschwander and Magruder [2019]

ICESat-2 Data Production

Data Production Keywords:

ATLAS: Advanced Topographic Laser Altimeter System

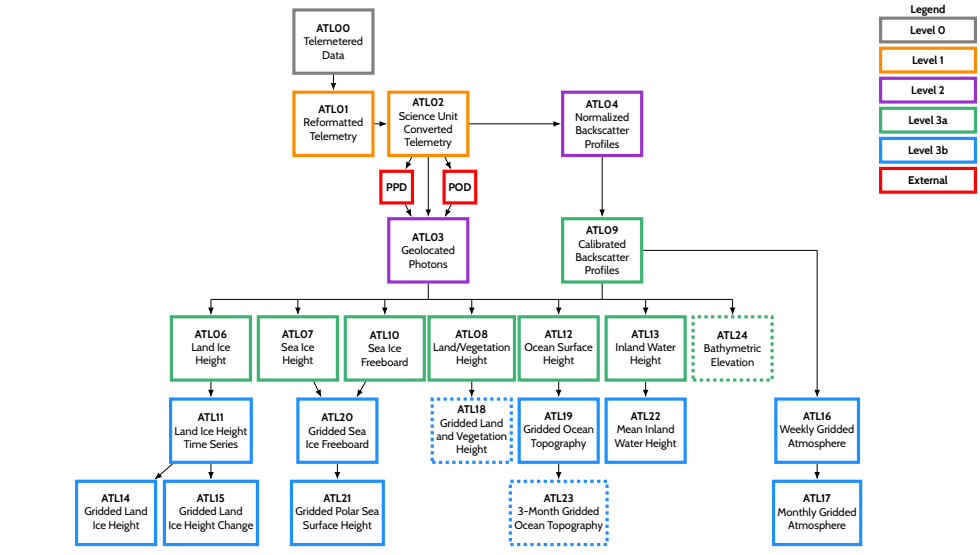
ASAS: ATLAS Science Algorithm Software

PGE: Product Generation Executive

SIPS: Science Investigator-led Processing System

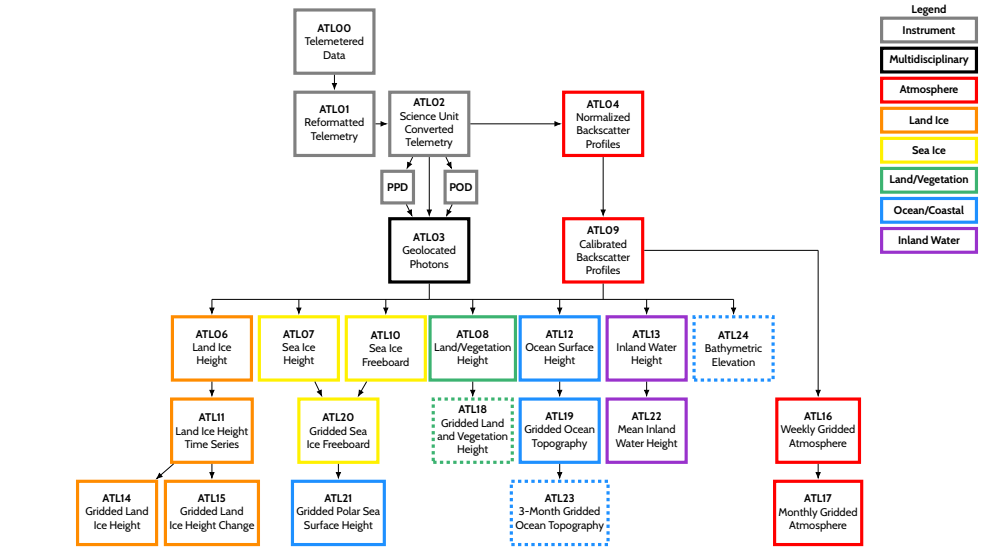
SCF: Science Computing Facility

ICESat-2 Product Chart



ANC: Ancillary Data, **CAL:** Calibration Product, **POD:** Precision Orbit Determination, **PPD:** Precision Pointing Determination

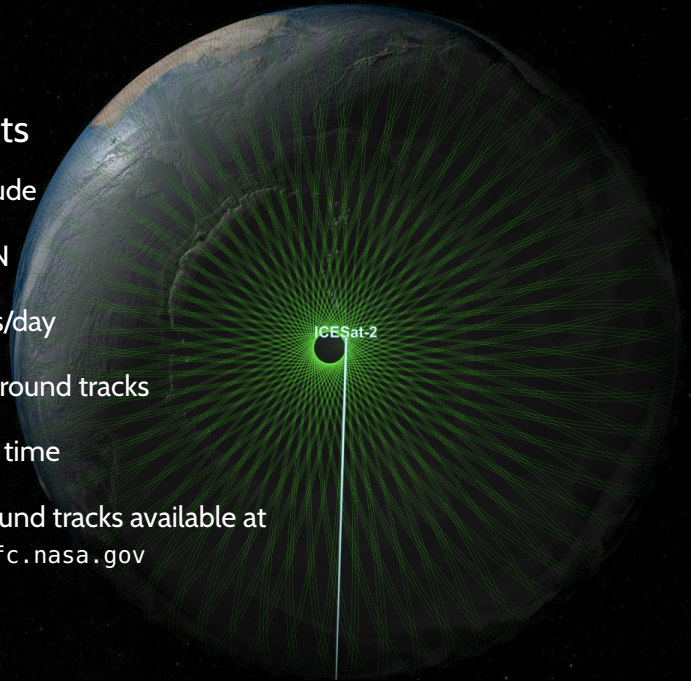
ICESat-2 Product Applications Chart



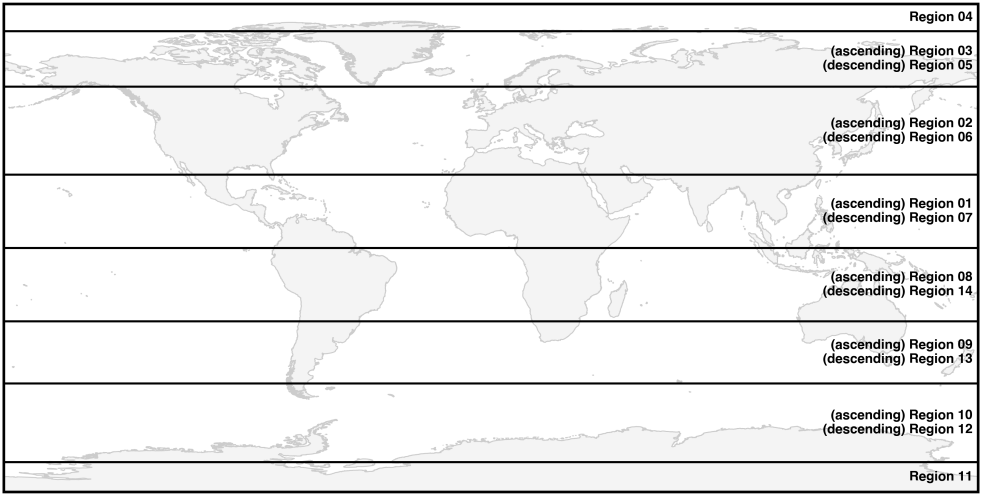
ANC: Ancillary Data, **CAL:** Calibration Product, **POD:** Precision Orbit Determination, **PPD:** Precision Pointing Determination

ICESat-2 Orbits

- 500 km altitude
- 88° S to 88° N
- 15 revolutions/day
- 1387 repeat ground tracks
- 91-day revisit time
- Predicted ground tracks available at `icesat-2.gsfc.nasa.gov`

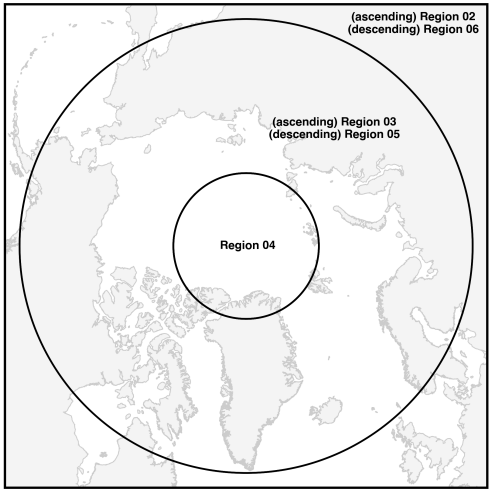


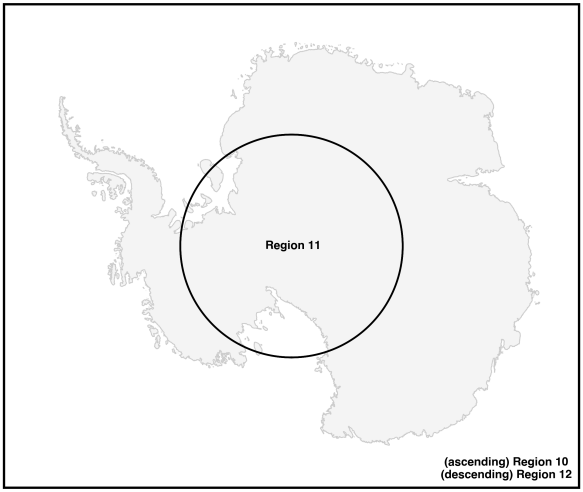
Granule Regions



Each orbit of ICESat-2 data is broken up into 14 granules in order to limit the overall file sizes and to reduce the number of files that need to be processed to create the higher-level science products

Granule Regions





Each orbit of ICESat-2 data is broken up into 14 granules in order to limit the overall file sizes and to reduce the number of files that need to be processed to create the higher-level science products

File Naming Conventions

`ATL[xx]_[yyyymmdd][hhmmss]_[tttt][cc][nn]_[vvv]_[rr].h5`

- `xx` : ATLAS product number
- `yyyymmdd` : year, month and day of data acquisition
- `hhmmss` : start time, hour, minute, and second of data acquisition
- `tttt` : Reference Ground Track (RGT, ranges from 1–1387)
- `cc` : Orbital Cycle (91-day period)
- `nn` : Granule number (ranges from 1–14)
- `vvv` : data version number
- `rr` : data release number

* used for ATL03, ATL04, ATL06, ATL08, ATL09, ATL10, ATL12, ATL13, ATL16, ATL17, ATL19, and ATL22

File Naming Conventions: Sea Ice

`ATL[xx]-[hh]_[yyyymdd][hhmmss]_[tttt][cc][nn]_[vvv]_[rr].h5`

- `xx` : ATLAS product number
- `hh` : Sea ice hemisphere flag (01=north, 02=south)
- `yyyymmdd` : year, month and day of data acquisition
- `hhmmss` : start time, hour, minute, and second of data acquisition
- `tttt` : Reference Ground Track (RGT, ranges from 1–1387)
- `cc` : Orbital Cycle (91-day period)
- `nn` : Granule number (for sea ice: 01)
- `vvv` : data version number
- `rr` : data release number

*used for ATL07, ATL10, ATL20, and ATL21

ATL03: Global Geolocated Photon Data

Contains:

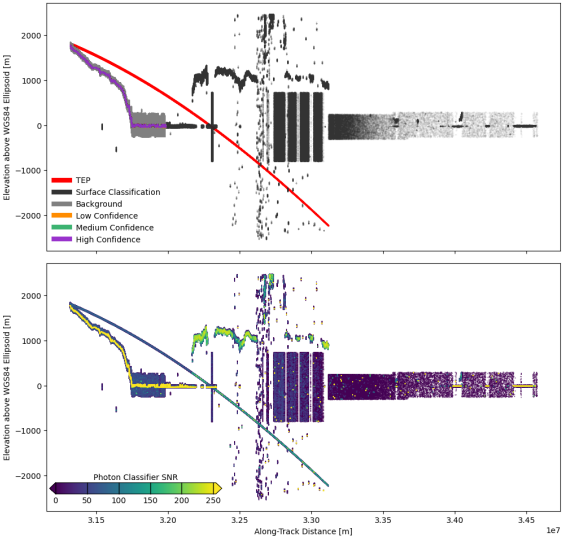
- Geolocation, time and elevation for all photons telemetered from ATLAS
- Photon classifications for each surface type
- Geophysical and atmospheric corrections
- Instrumental parameters

Advantages:

- Every photon is there, and every parameter
- Can derive information for all surface types

Use if you want to:

- Look at surfaces at a scale unresolved in higher-level products
- Look at processes the higher-level products were not designed to observe



ATL06: Land Ice Height Data

Contains:

- Overlapping 40-meter linear segments fit to land-ice photons
- Height error and segment quality estimates

Advantages:

- Lighter product than ATL03
- Provides estimated surface heights with cm-level corrections

Disadvantages:

- 40-m resolution is too coarse for some research applications (such as crevassing)

Use if you want to:

- Make large-scale repeatable measurements of glaciers and ice sheets

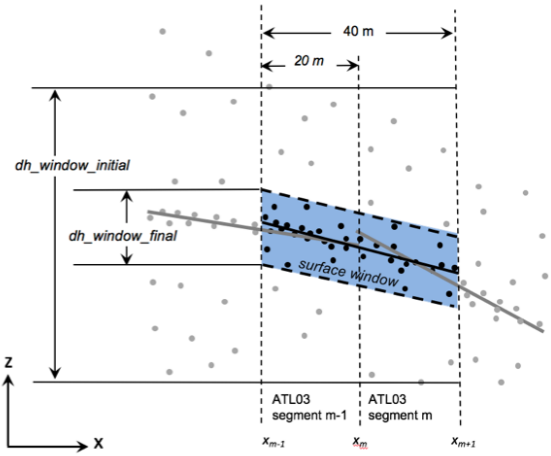


Figure 3 from Smith et al. [2019]

ATL11: Slope-Corrected Land Ice Height Time Series

Contains:

- 120-meter along-track segments for each beam pair corrected for across-track slope
- Crossover estimates from ATL06 at reference points

Advantages:

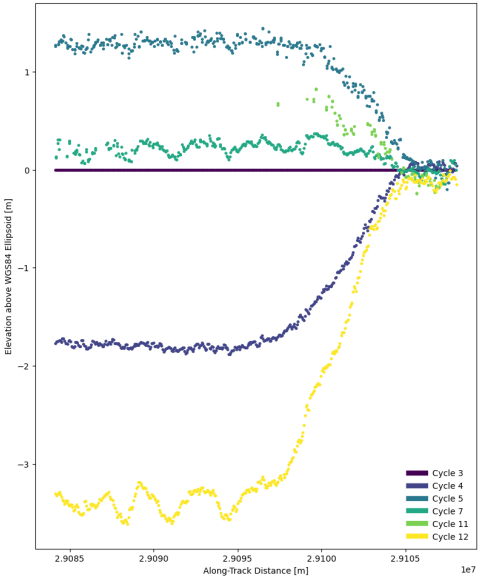
- Contains data for all cycles with along-track data following the Reference Ground Tracks (RGTs)
- Easy calculation of height change through time

Disadvantages:

- 120-m resolution is too coarse for some applications

Use if you want to:

- Make large-scale estimates of glacier and ice sheet height change



ATL14 and ATL15: Gridded Land Ice Height and Height Change

Contains:

- ATL14: gridded digital elevation model (DEM) and height uncertainty at 100m posting
- ATL15: gridded land ice height change estimates at 1km, 10km, 20km, and 40km posting

Advantages:

- Gridded product combining all available along-track ATL11 data
- Simplifies volume change calculations using ICESat-2 data

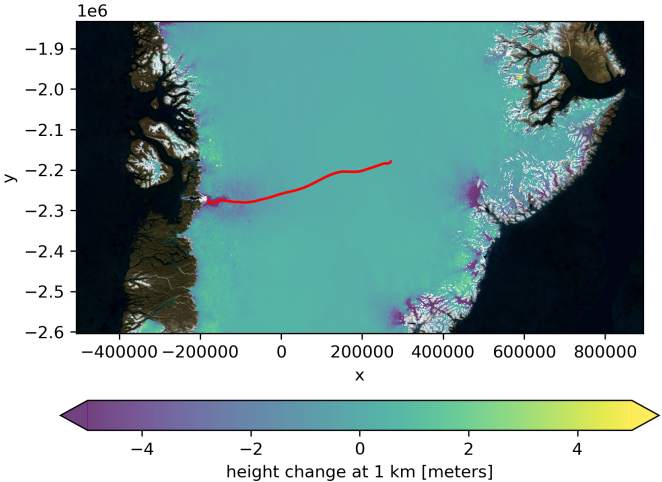
Disadvantages:

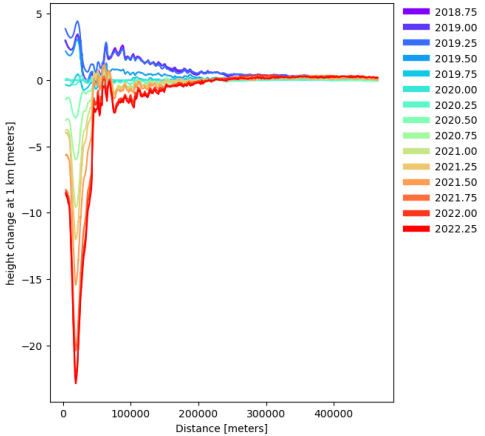
- ATL14 estimates degrade where measurements are unavailable
- Quarter-annual temporal sampling might not be high enough for certain applications

Use if you want to:

- Use gridded estimates of height change for ice sheet models
- Start creating land ice mass balance estimates from ICESat-2
- Extract land ice height change estimates along transects

Investigating ATL15 Gridded Land Ice Height Change Data





`IS2view` display of ATL15 height change data and extracted transect using glacier flowlines from Felikson et al. [2020]

ATL07: Sea Ice Height Data

Contains:

- Along-track profiles derived from Gaussian decomposition of height distributions
- Height error and segment quality estimates

Advantages:

- Lighter product than ATL03
- Classifications for varying surface types (open water leads, sea ice)
- Provides estimated surface heights with cm-level corrections
- 150-photon aggregates provide a height precision of ~2 cm over flat surfaces

Disadvantages:

- Height segments are variable length

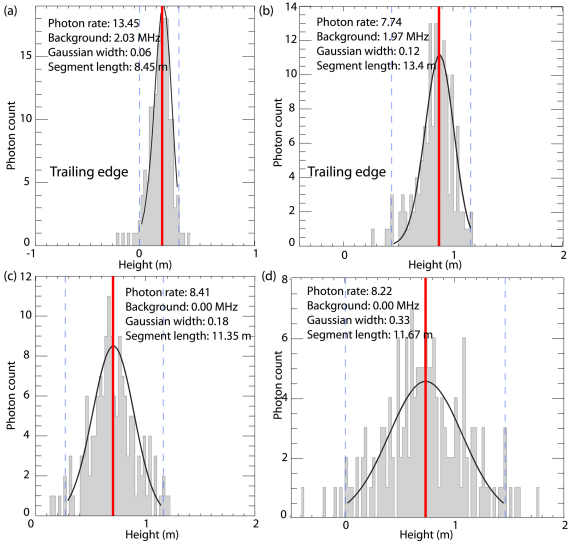


Figure 2 from Kwok et al. [2019]

ATL10: Sea Ice Freeboard Data

Contains:

- Freeboard estimates and statistics calculated at the ATL07 segment length (when open water can be defined within 10km along-track segments)
- Calculated using three different approaches

Advantages:

- Lighter product than ATL03 and ATL07
- Includes most of the ATL07 variables of interest
- Freeboard estimates are pre-computed

Disadvantages:

- Uncertainties with dark leads and melt ponds

Use if you want to:

- Start creating sea ice thickness estimates from ICESat-2

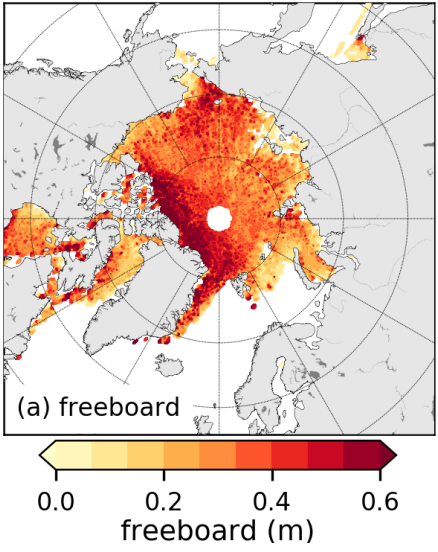
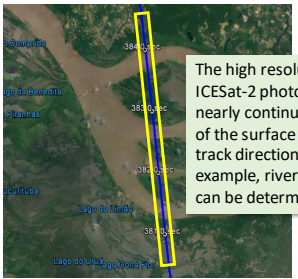


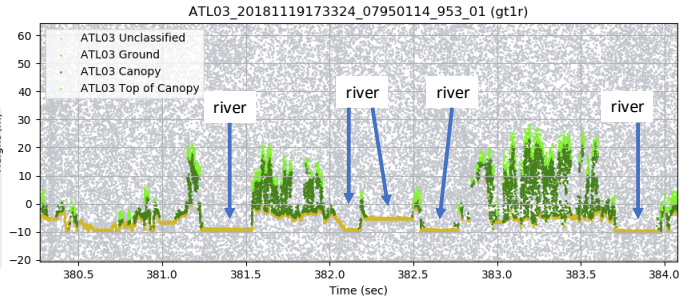
Figure 6 from Petty et al. [2020]

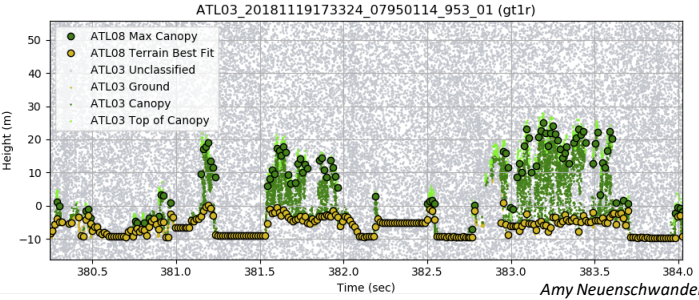
Example of ATL03 and ATL08

Amazon Floodplain



The high resolution of the ICESat-2 photons provide a nearly continuous sampling of the surface in the along-track direction. In this example, river stage levels can be determined.





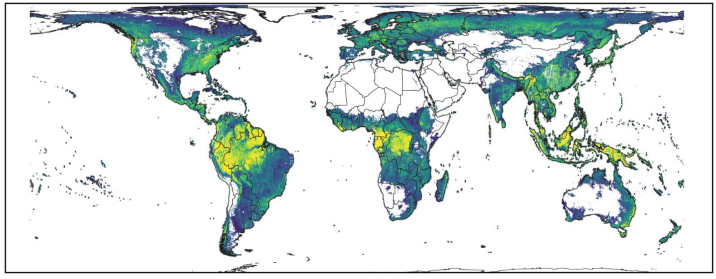
Photons from ICESat-2 are color-coded by the ATL08 (Land and Vegetation) algorithm. Data are from a day acquisition.

Bottom plot includes the same photons as the top panel, but the ATL08 100 m canopy height and terrain heights are superimposed

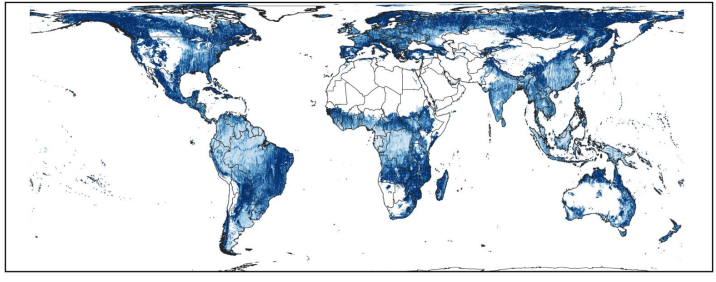
Amy Neuenschwander, U Texas

Gridded Canopy Heights from ICESat-2

The official ATL18 (gridded Terrain and Vegetation Heights) will be at a 1 km resolution and available with Release 007 of the data.



Using Machine Learning and the SlideRule architecture, we are also exploring methods to create on-demand terrain and vegetation products at user-specified resolutions.



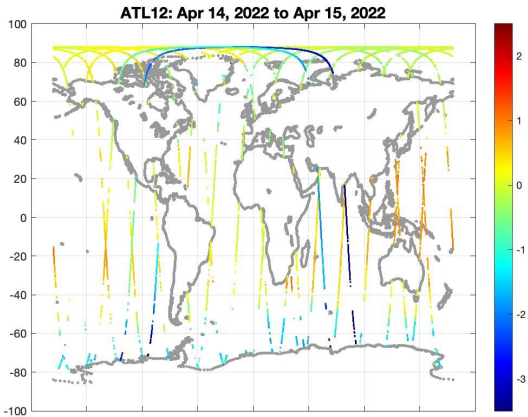
ICESat-2 ATL12 Along-track Sea Surface Heights (SSH)

ATL12 sea surface heights in files of 4-orbits over the world ocean >10-m deep. Include:

a) Ocean segment averages, the distribution, and first four moments of SSH for 6 beams plus the averages of pertinent geophysical variables and corrections. Ocean segments are 0.5 to 7-km long to reduce uncertainty over wave covered surfaces.

b) 10-m bin averages of DOT=SSH-geoid within ocean segments. In addition to higher resolution, 10-m bin statistics provide sea state bias, harmonic fits and wave statistics. Release 7 will add first photon bias and DOT in sea ice.

Ocean segment average DOT from four 4-orbit ATL12 files, April 14-15, 2022



J. Morison, Dickinson, Hancock, Roberts, Robbins, 7/29/2023

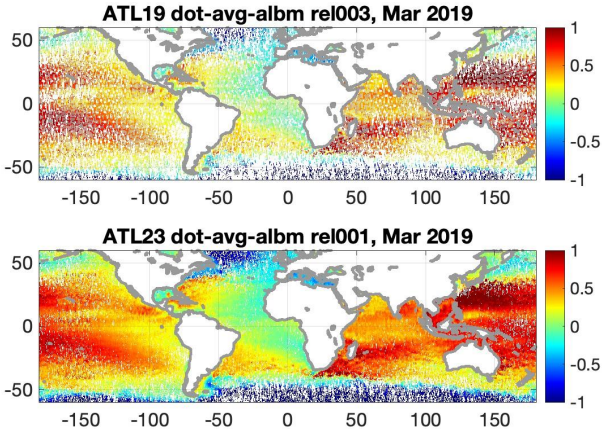
ICESat-2 ATL19 and ATL23 Gridded Dynamic Ocean Topography (DOT)

ATL19 are monthly grid-averages of ATL12 DOT plus related variables.

a) In ¼° Mid-Latitude Grid and 25-km polar stereographic N. & S. Polar Grids
b) Include individual beam averages (checks inter-beam bias), all-beam averages, cell-centered averages, and in Rel 4, minimum uncertainty centered averages.

ATL23 (new Rel. 1) are monthly 3-month grid-averages of ATL12 DOT plus related variables. Similar to ATL19 but extending over 3 months to cover the ~91 day repeat of ICESat-2 and fill more grid cells.

DOT over the Mid-Latitude Grid from (top) ATL19 for March 2019 and (bottom) ATL23 for average over, Feb-March-April 2019



ICESat-2 Feature Find!

https://demo.slideruleearth.io

Indoor bathymetry at Tropical Islands Resort
Former airship hanger at Brand-Briesen Airfield
Resort located at 52.0375°N, 13.748611°E
Original ATL03 feature find by Kelly Brunt (UMD)