ICESat-2 data products

Ben Smith

ICESat-2 HackWeek 2022

3/22/2022

Outline

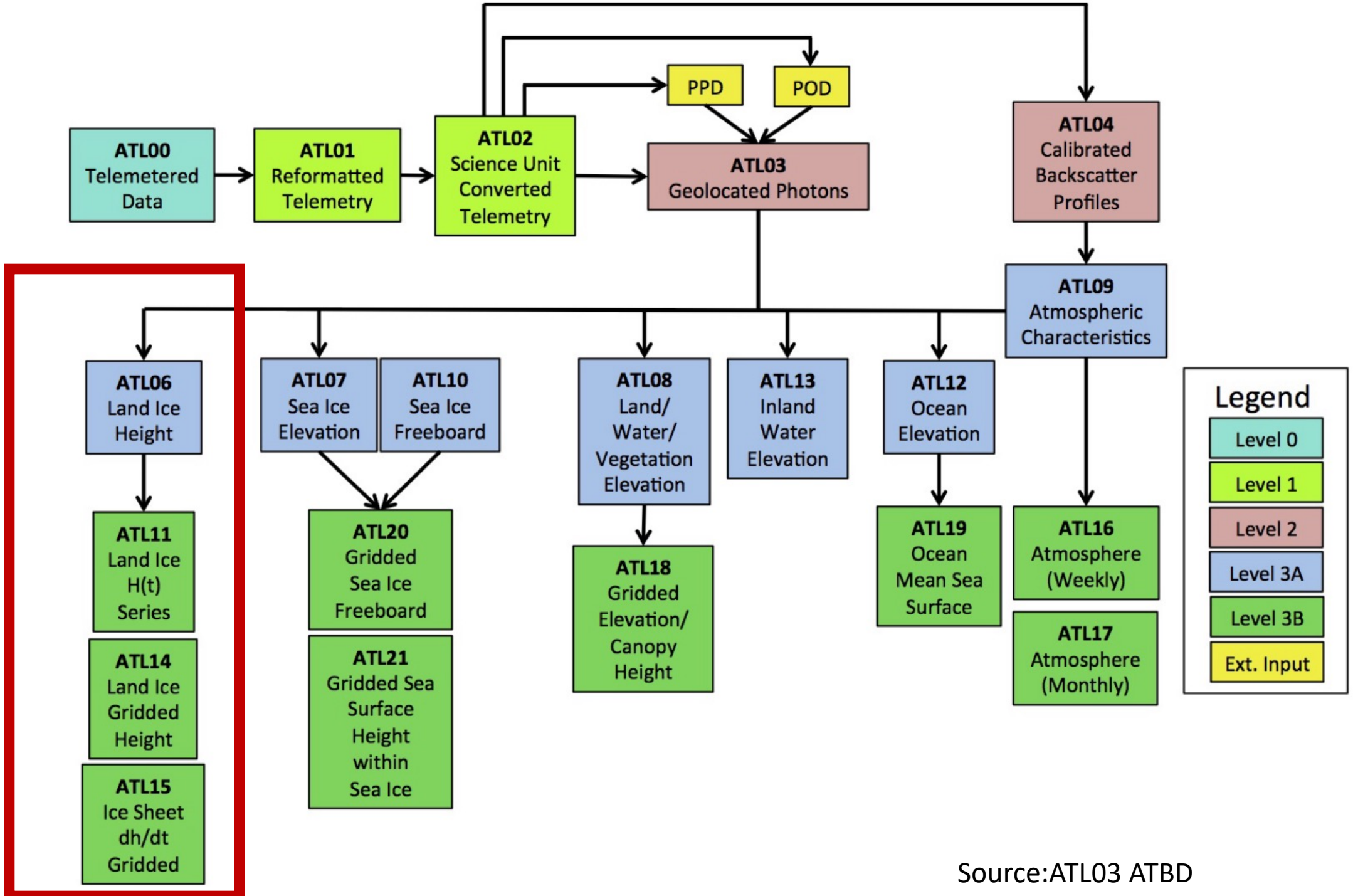
- What are ICESat-2 products?
- Features common to ICESat2 products
  - Beams, spots, and tracks
  - Along-track coordinates
  - Product regions
- How do I learn about ICESat-2 products?
  - NSIDC resources
  - Data dictionaries
  - ATBDs
- A brief tour of data products
  - Land-ice products
  - Sea-ice products
  - Vegetation products
  - Atmospheric products

ICESat-2 measurements vs. products

- ICESat-2 measures timings of transmitted pulses, the timing of received photons, and the position and orientation of the observatory

- Level-2 processing converts these measurements into photon locations, heights, and times (ATL03)

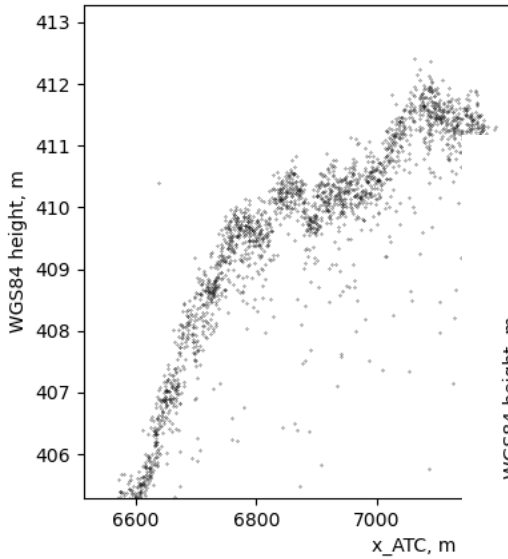
- Higher-level processing (level 3+) provides geophysical variables:
  - Surface-type specific along-track products (ATL06, ATL07, ATL08)
  - Value-added along-track products (ATL10)
  - Change products (ATL11)
  - Gridded products (ATL14, 15, 18, 20, 21, etc)



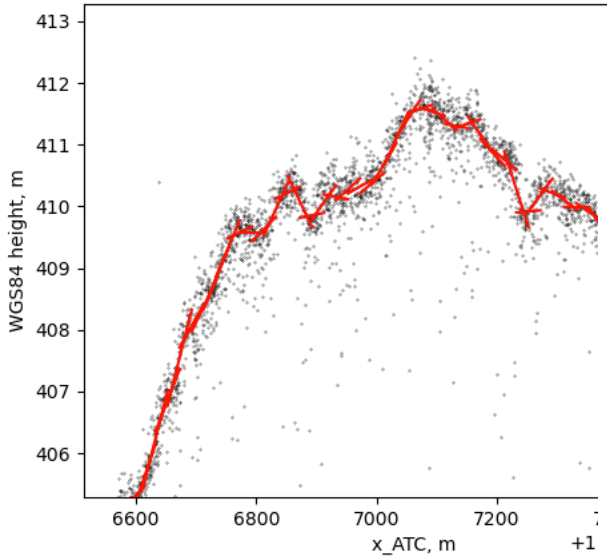
Source:ATL03 ATBD

Land-ice products: from photons to maps

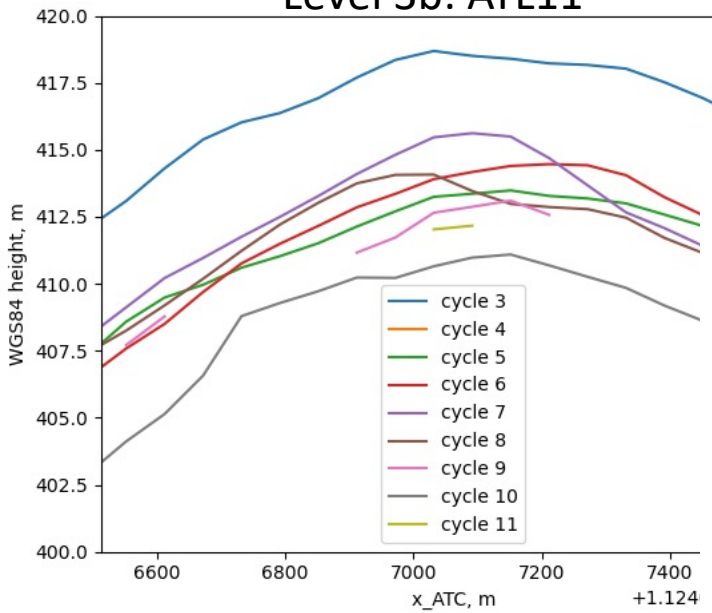
Level 2: ATL03



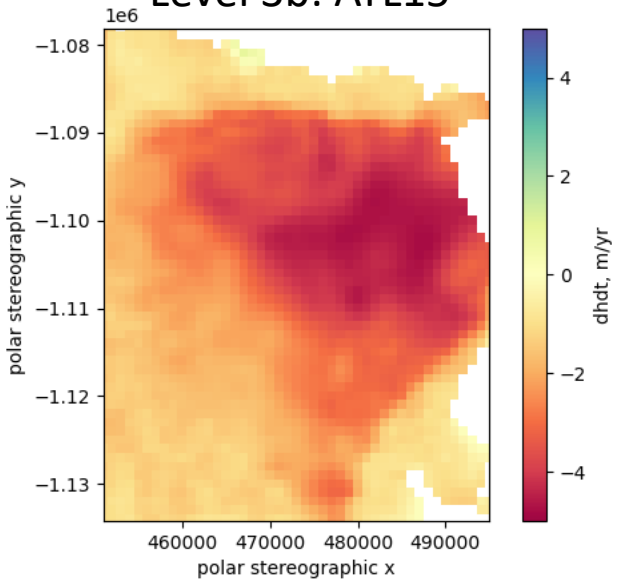
Level 3a: ATL06



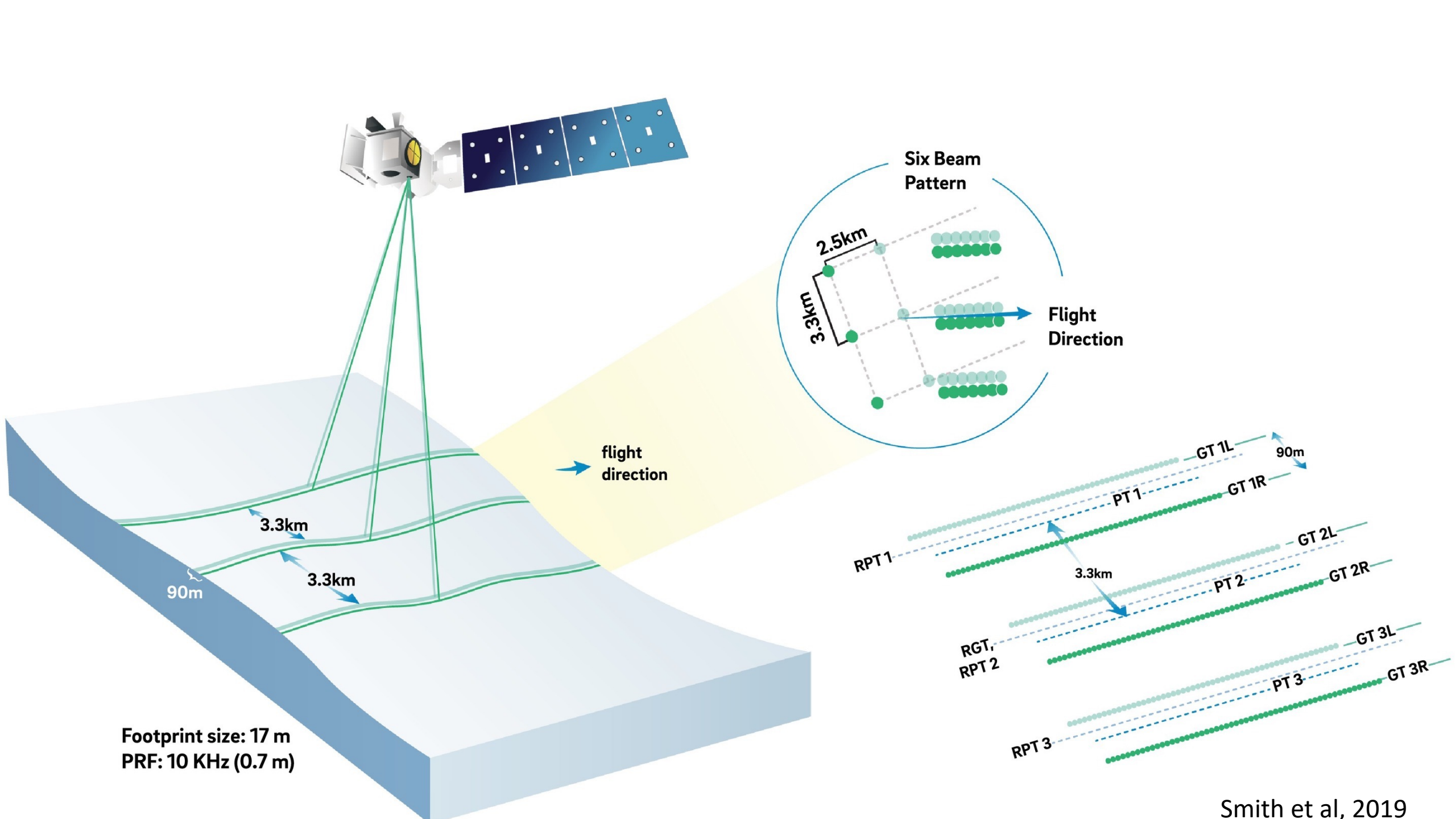
Level 3b: ATL11



Level 3b: ATL15

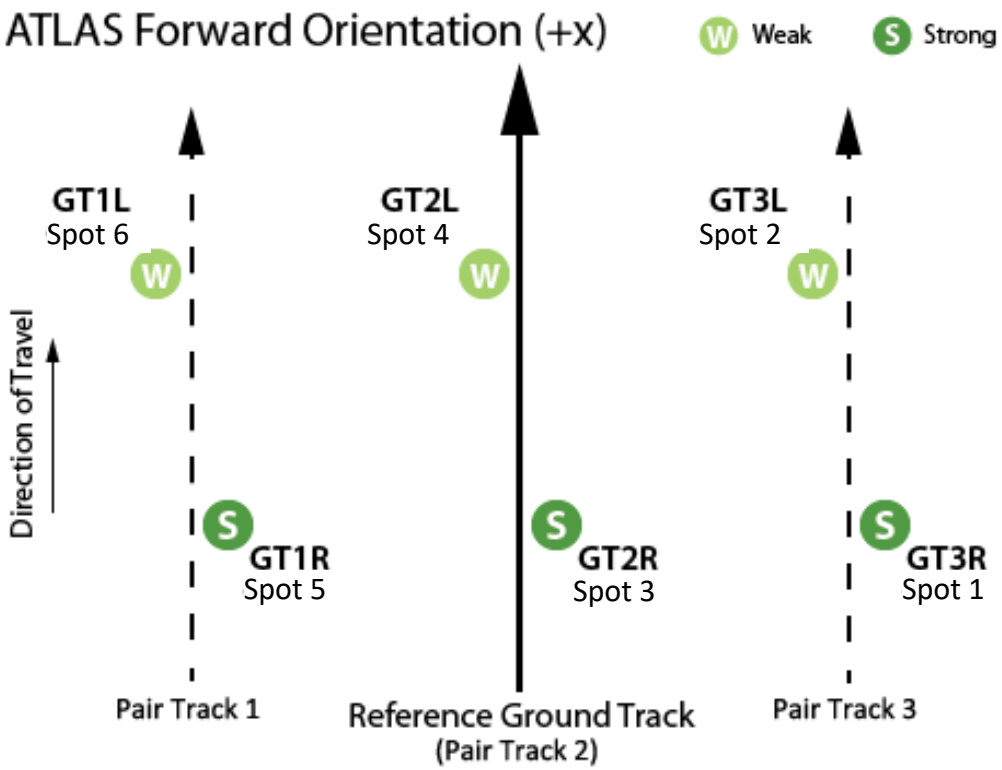


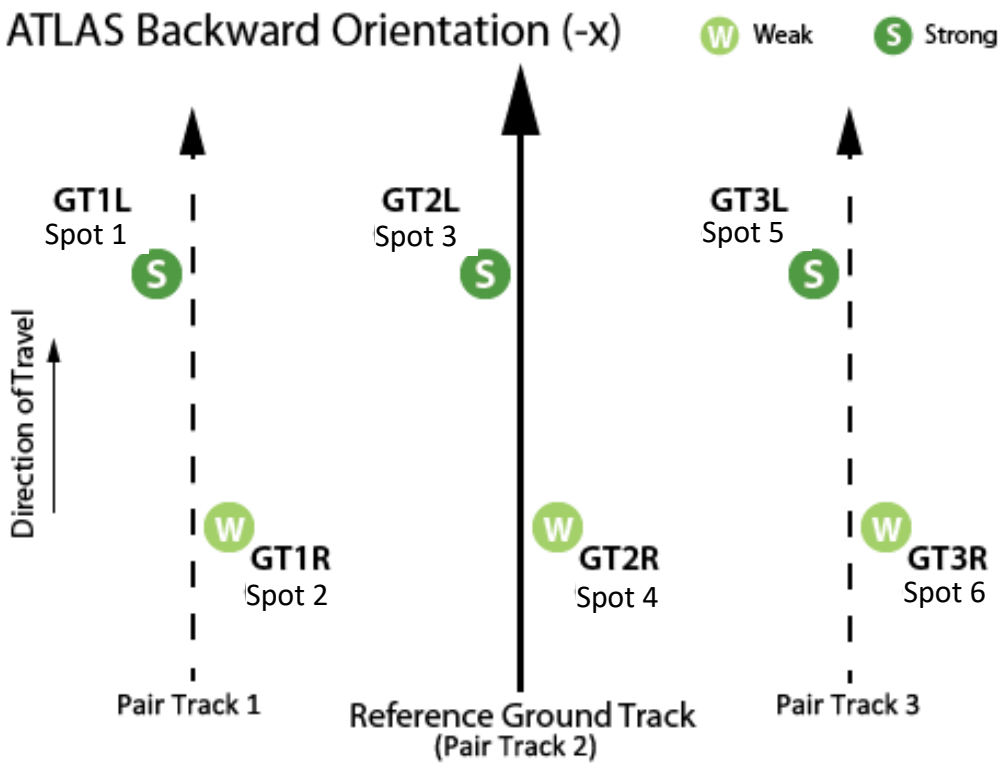
General features of ICESat-2 products: Ground tracks and along-track products



Smith et al, 2019

ICESat-2 in its two orientations

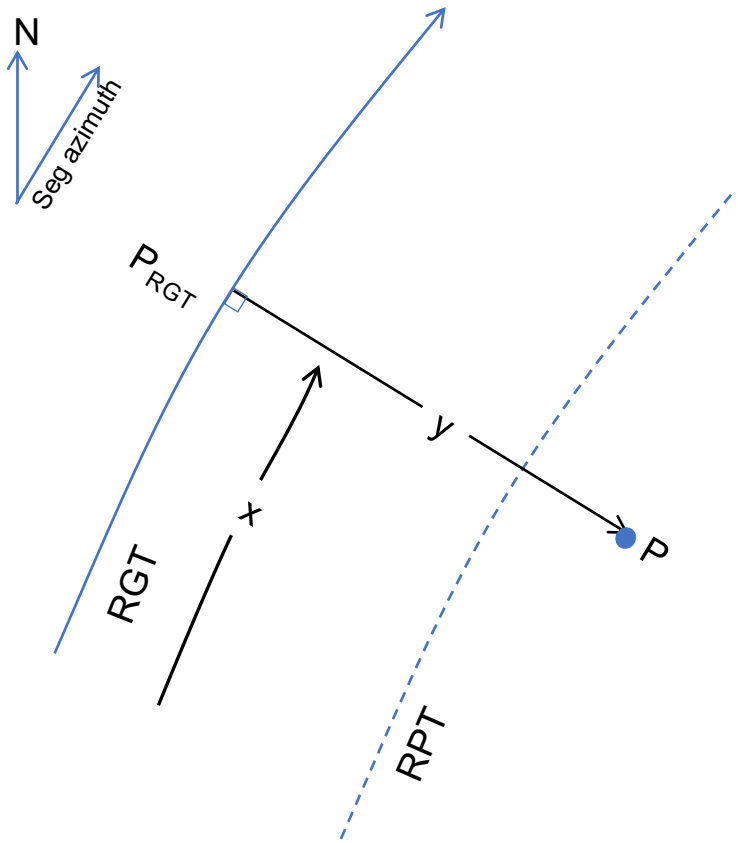




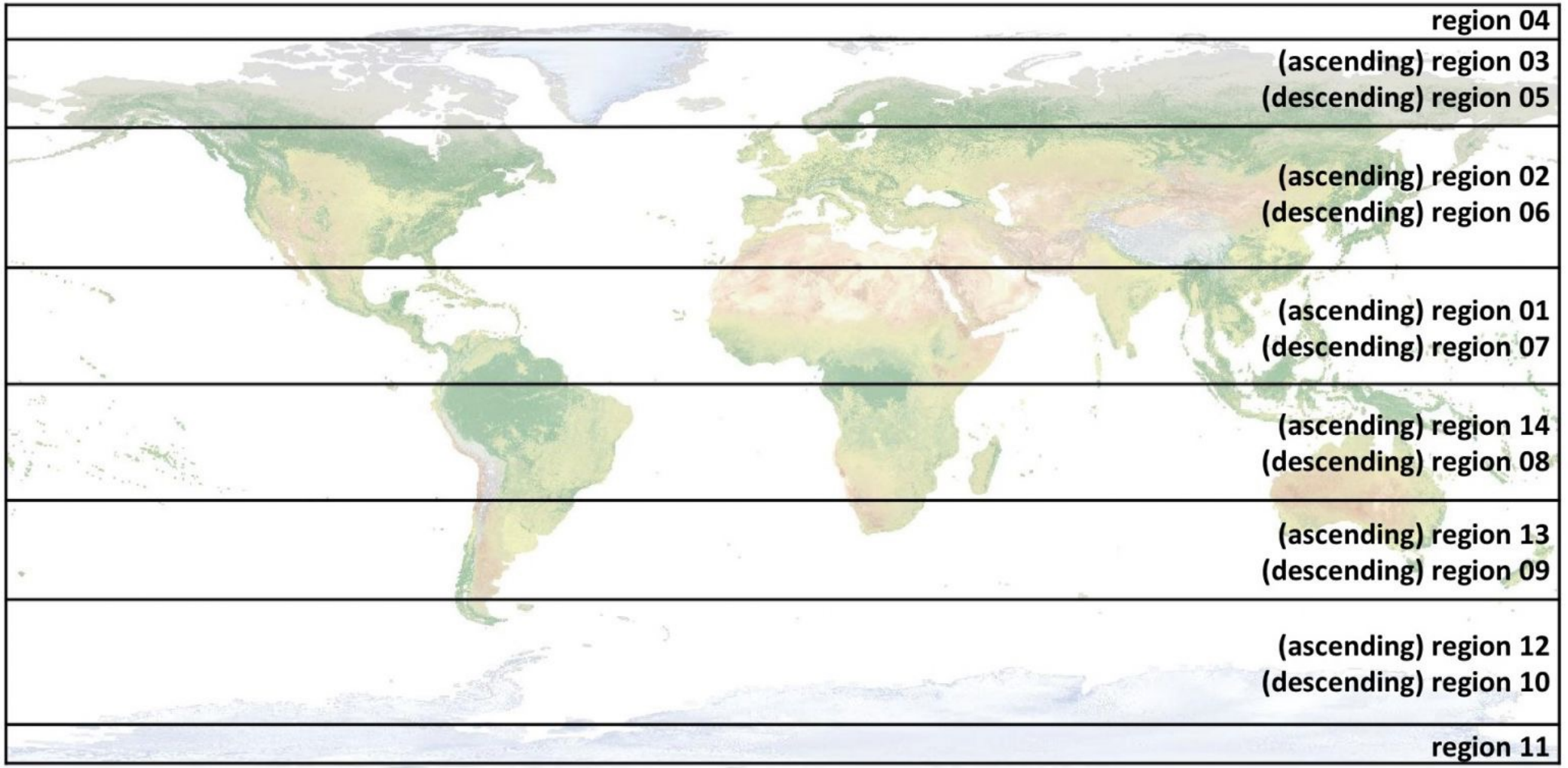
Credit: NSIDC

Along and across-track coordinates

- Along-track coordinates (x_rgt) are measured parallel to each reference ground track, starting at the equator, heading North:
  - 0: First equator crossing
  - ~ 6500 km: Southern Greenland, heading north
  - ~10,000 km : Polehole North
  - ~13,000 km : Southern Greenland, heading south
  - ~27,000 km: Northern Antarctica, heading south
  - ~30,000 km : Southern polehole
  - ~33,000 km: Northern Antarctica heading north
- Across-track coordinates (y_rgt) are measured perpendicular to the RGT, to the left:
  - Gt1x: +3200 m
  - Gt2x : ~0 m
  - Gt3x : -3200 m



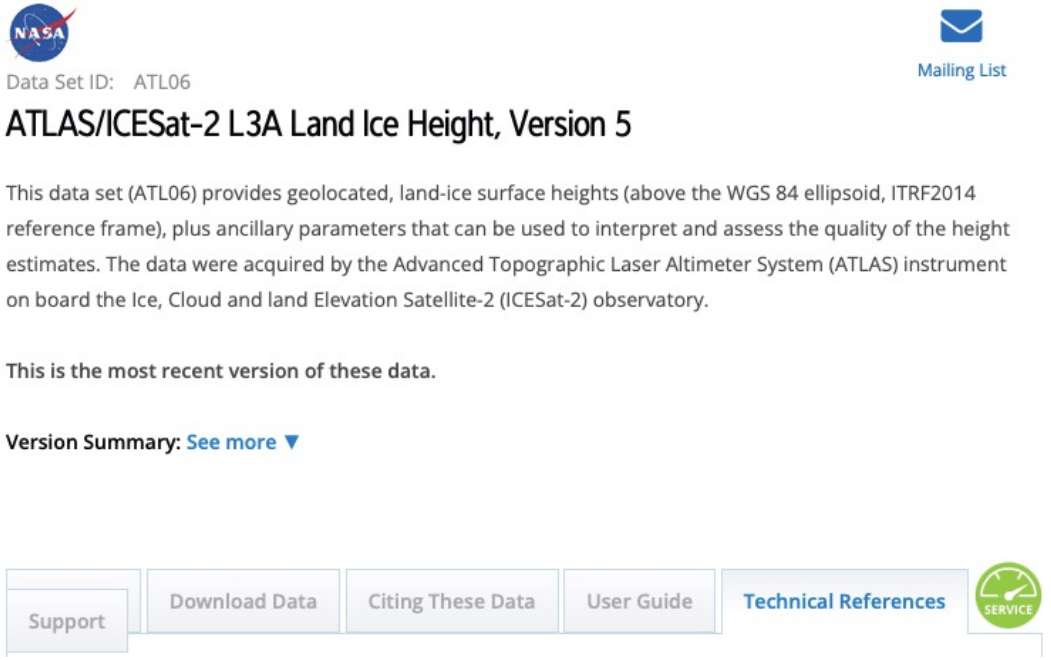
General considerations for along-track products: regions



Credit: Kaitlin Harbeck

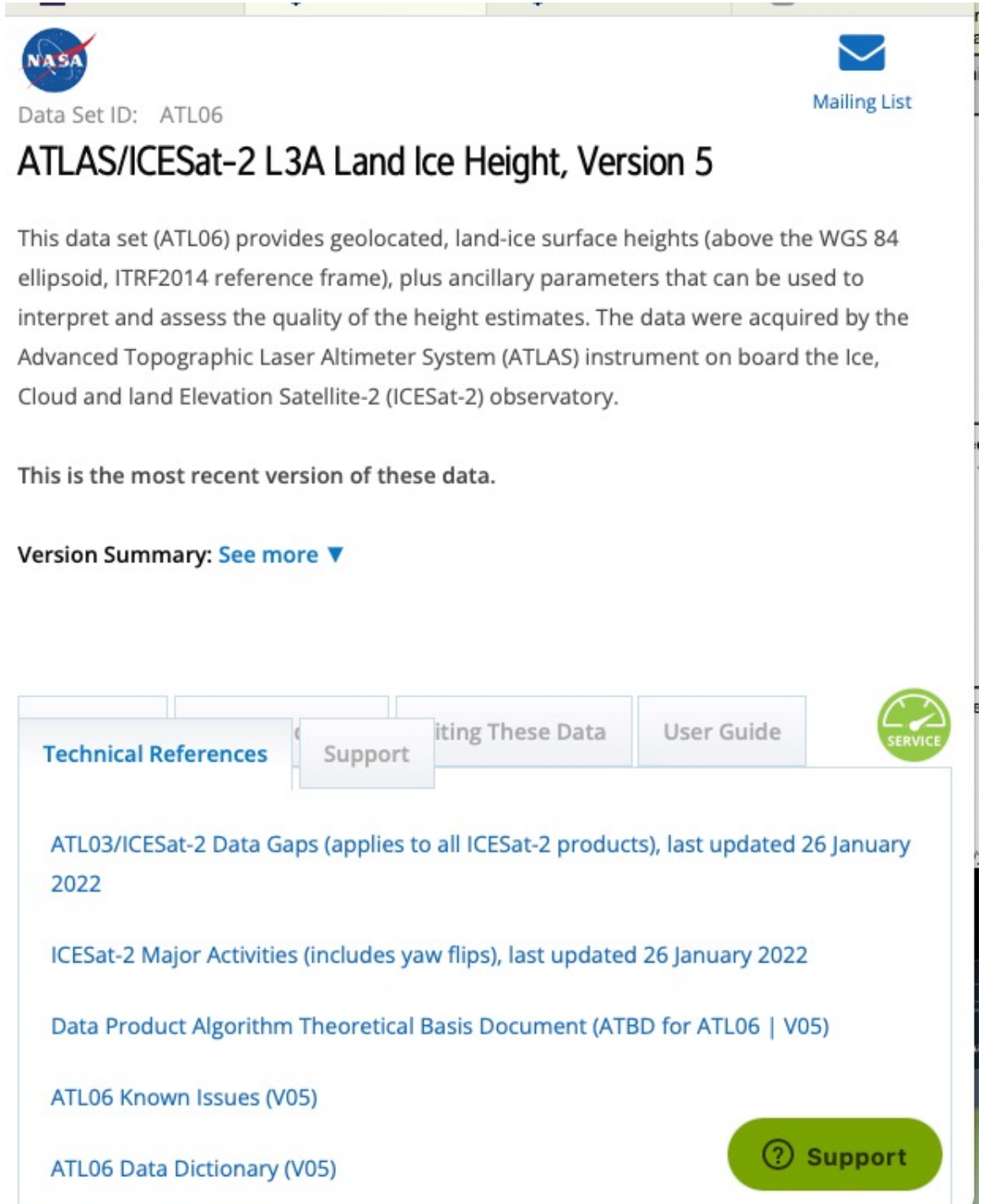
Where do I learn about ICESat-2 products?

- NSIDC has a set of landing pages for ICESat-2 products:
  - https://nsidc.org/data/icesat-2/products/
- Each product has its own landing page:
  - https://nsidc.org/data/atl06
- Each landing page includes links to technical descriptions of the product:
  - Algorithm Theoretical Basis Document:
    - Detailed description of the algorithm used to generate the product
    - https://nsidc.org/sites/nsidc.org/files/technical-references/ICESat2_ATL06_ATBD_r005.pdf
  - Data Dictionary:
    - Description of every variable in the product
    - https://nsidc.org/sites/nsidc.org/files/technical-references/ICESat2_ATL06_data_dict_v005.pdf



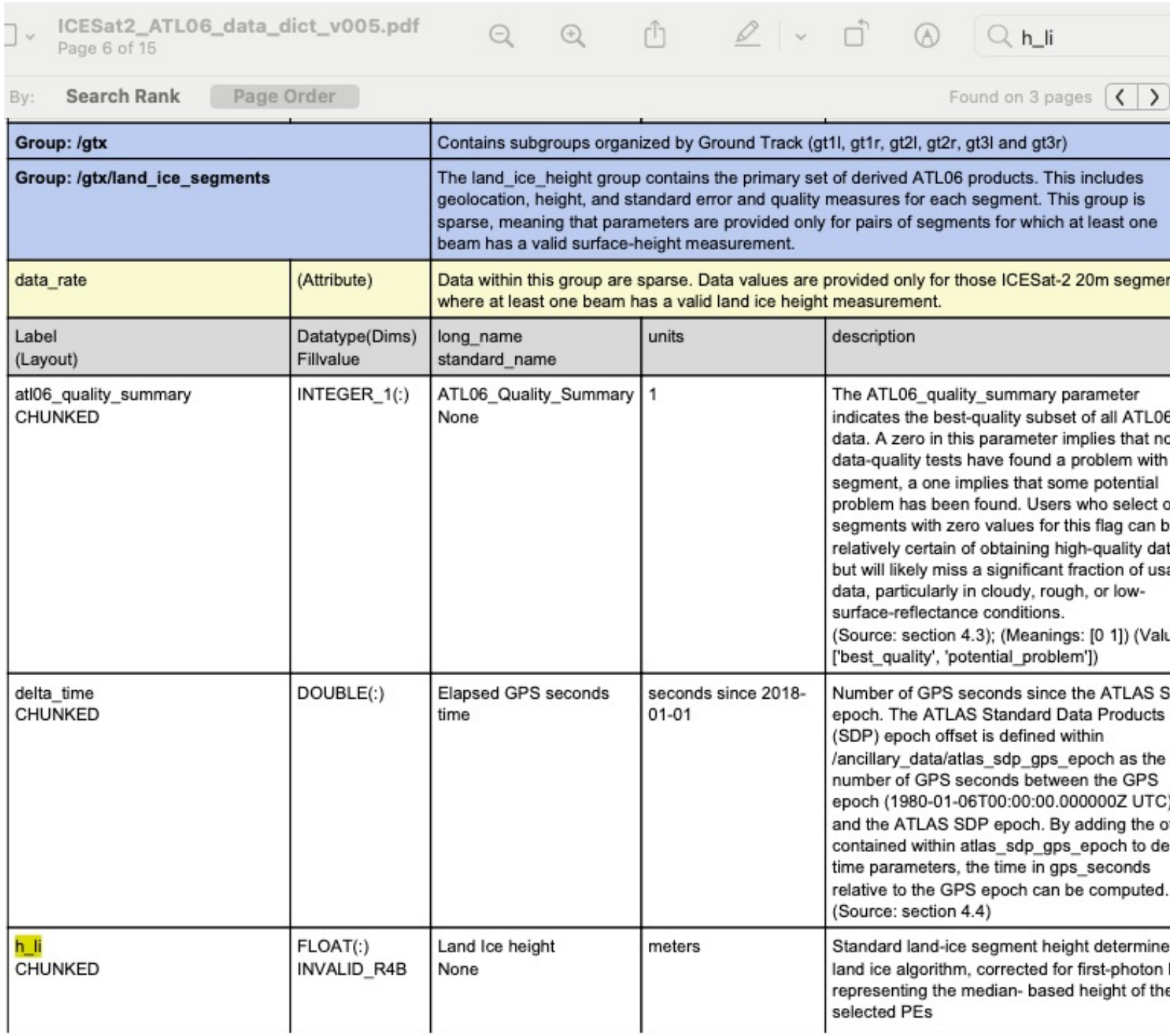
Example: ATL06 landing page

- Technical references tab contains links to:
  - The Algorithm Theoretical Basis Document
  - The Data Dictionary
  - Users guides
  - Known issues



Example: ATL06 data dictionary

- Descriptions for every variable in the product
- The dictionary is organized by the group structure of the product, variables are in alphabetical order

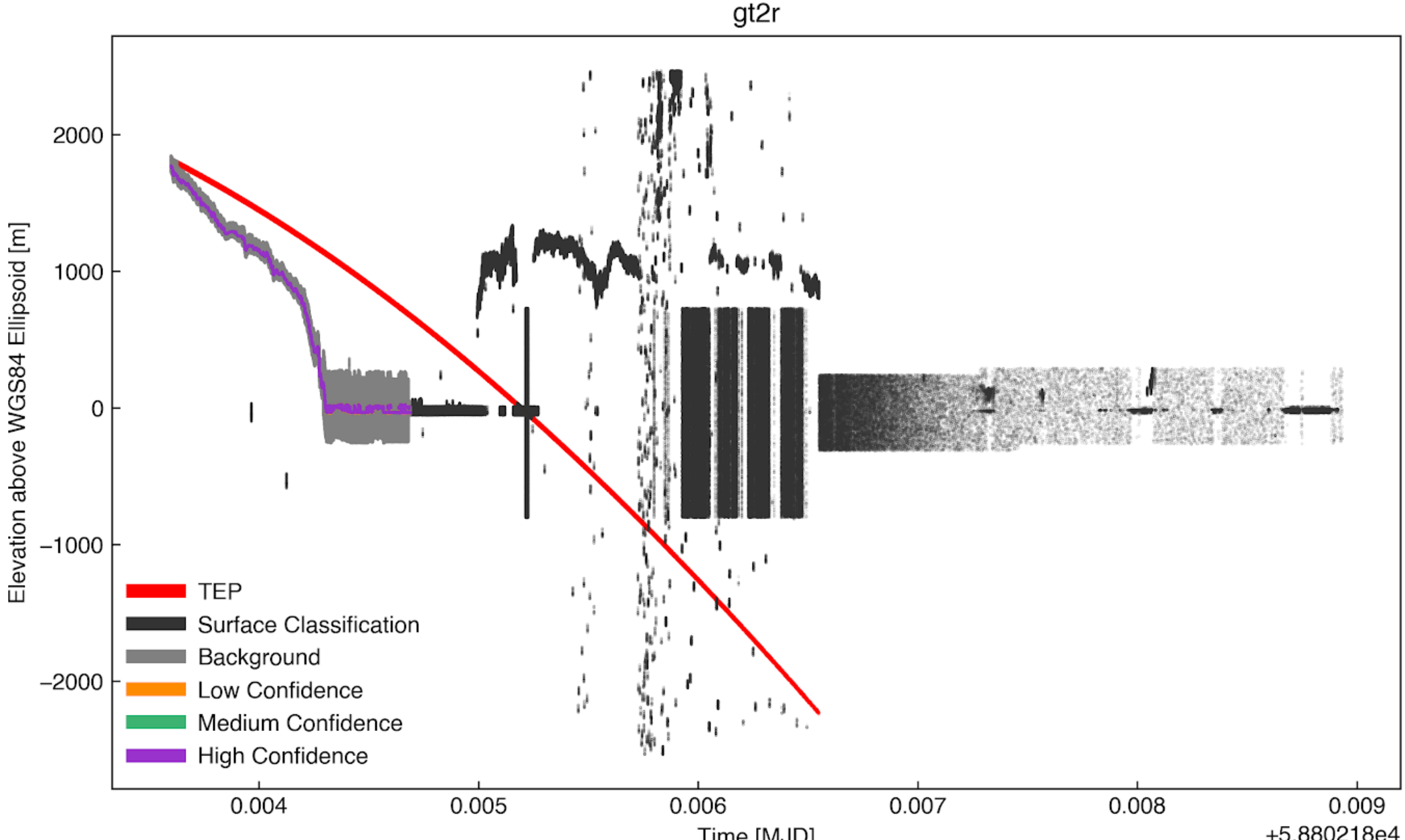


Group: /gtx		Contains subgroups organized by Ground Track (gt1l, gt1r, gt2l, gt2r, gt3l and gt3r)		
Group: /gtx/land_ice_segments		The land_ice_height group contains the primary set of derived ATL06 products. This includes geolocation, height, and standard error and quality measures for each segment. This group is sparse, meaning that parameters are provided only for pairs of segments for which at least one beam has a valid surface-height measurement.		
data_rate	(Attribute)	Data within this group are sparse. Data values are provided only for those ICESat-2 20m segmer where at least one beam has a valid land ice height measurement.		
Label (Layout)	Datatype(Dims) Fillvalue	long_name standard_name	units	description
atl06_quality_summary CHUNKED	INTEGER_1(:)	ATL06_Quality_Summary None	1	The ATL06_quality_summary parameter indicates the best-quality subset of all ATL06 data. A zero in this parameter implies that no data-quality tests have found a problem with segment, a one implies that some potential problem has been found. Users who select o segments with zero values for this flag can b relatively certain of obtaining high-quality dat but will likely miss a significant fraction of usa data, particularly in cloudy, rough, or low-surface-reflectance conditions. (Source: section 4.3); (Meanings: [0 1]) (Valu ['best_quality', 'potential_problem'])
delta_time CHUNKED	DOUBLE(:)	Elapsed GPS seconds time	seconds since 2018-01-01	Number of GPS seconds since the ATLAS S epoch. The ATLAS Standard Data Products (SDP) epoch offset is defined within /ancillary_data/atlas_sdp_gps_epoch as the number of GPS seconds between the GPS epoch (1980-01-06T00:00:00.000000Z UTC) and the ATLAS SDP epoch. By adding the o contained within atlas_sdp_gps_epoch to de time parameters, the time in gps_seconds relative to the GPS epoch can be computed. (Source: section 4.4)
h_li CHUNKED	FLOAT(:) INVALID_R4B	Land Ice height None	meters	Standard land-ice segment height determine land ice algorithm, corrected for first-photon representing the median- based height of the selected PEs

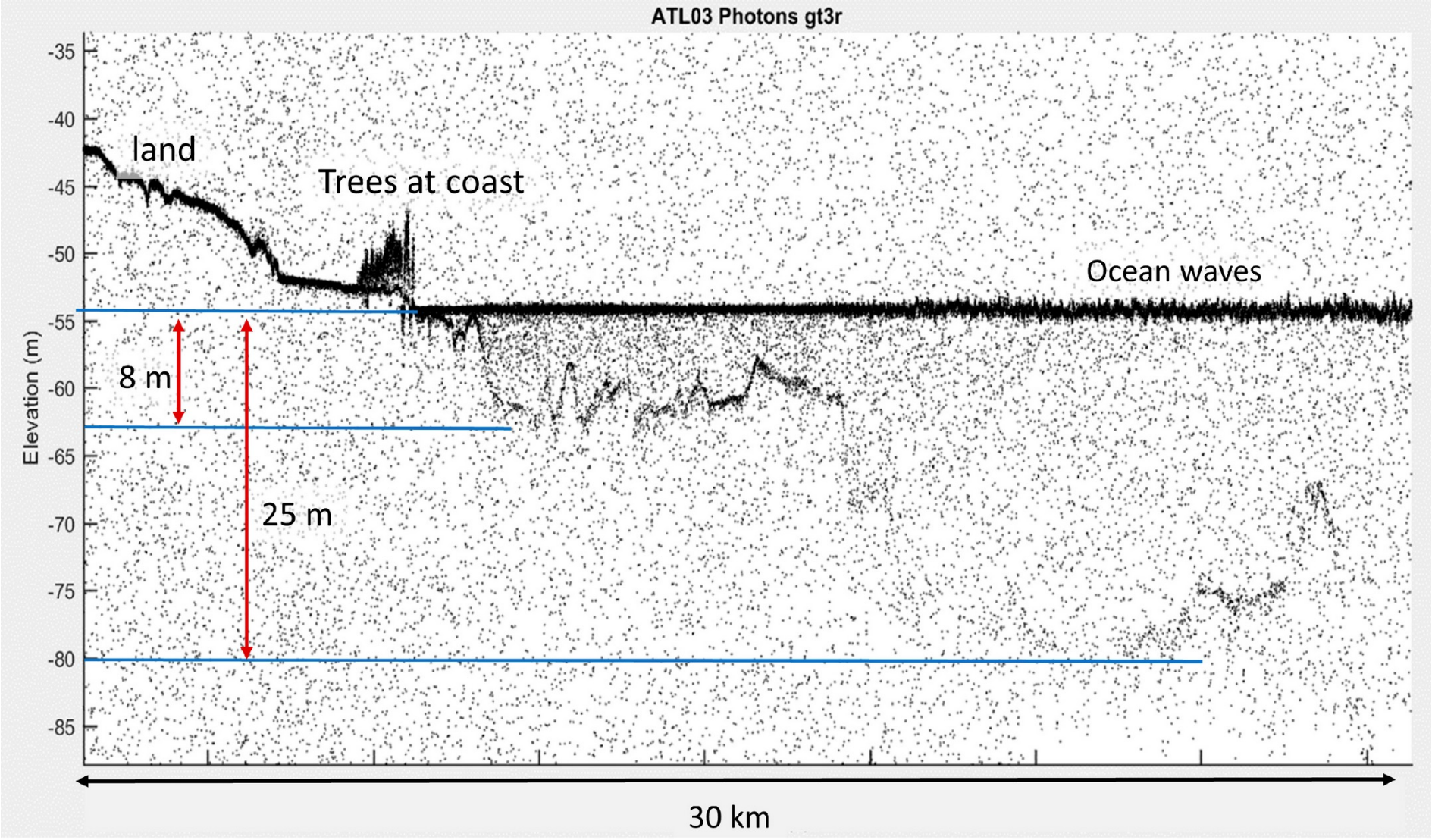
ATL03- geolocated photons

- Contains
  - Latitude, longitude, and elevation for photons telemetered form ATLAS
  - Photon classifications for different surface types
  - Tides and atmospheric corrections
  - Instrumental parameters
- Advantages:
  - Every photon is there, and every parameter
- Disadvantages:
  - Same as advantages: This is a large and complex product
- Use it if:
  - You want to understand where other products come from
  - You want to look at surfaces at a scale than that resolved on higher-level products
  - You have lots of storage space and lots of time

ATL03 example: Big, complex data

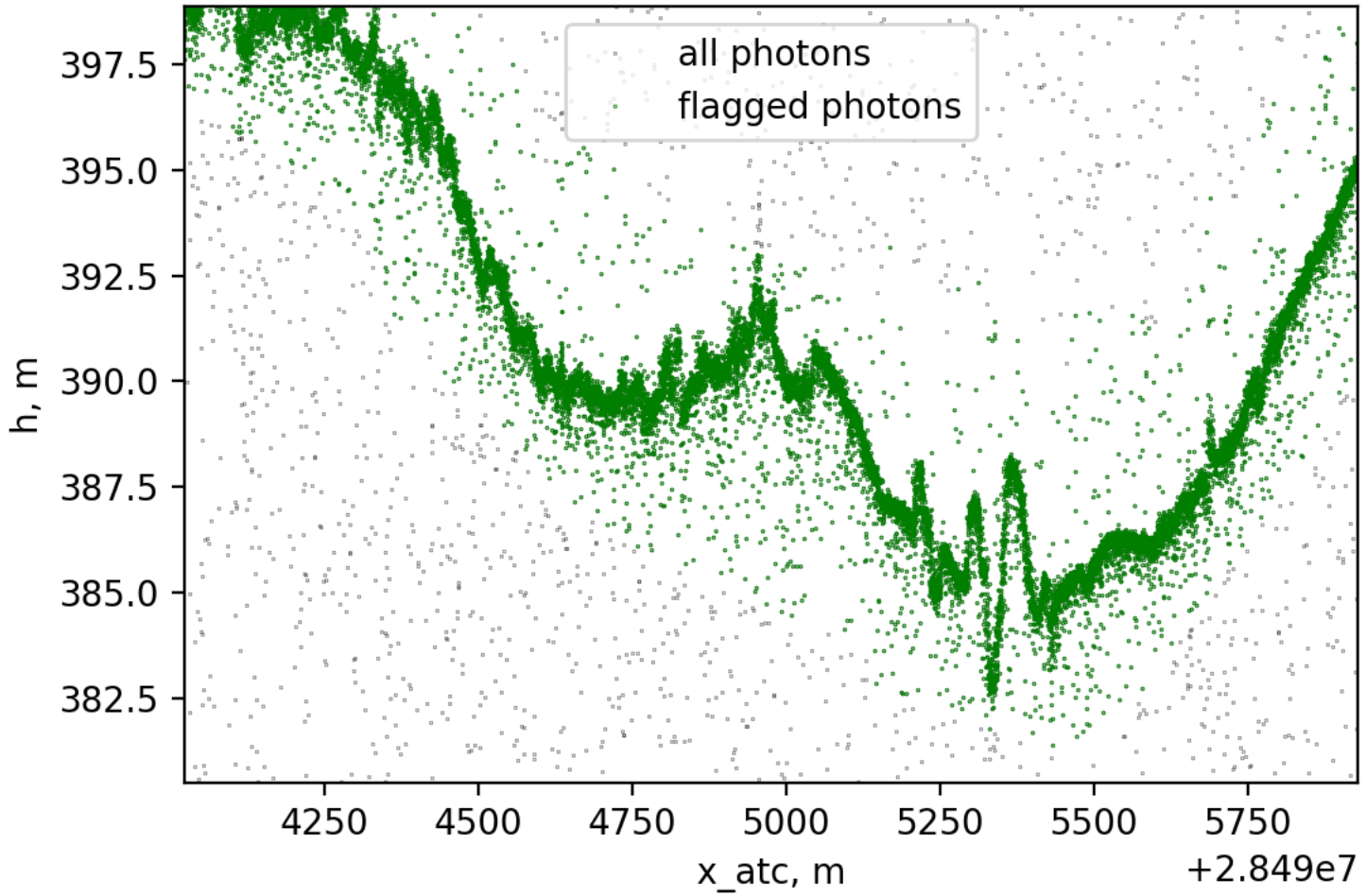


ATL03: Bathymetry



Credit: Parish et al, 2019

ATL03: Complex glacier surfaces

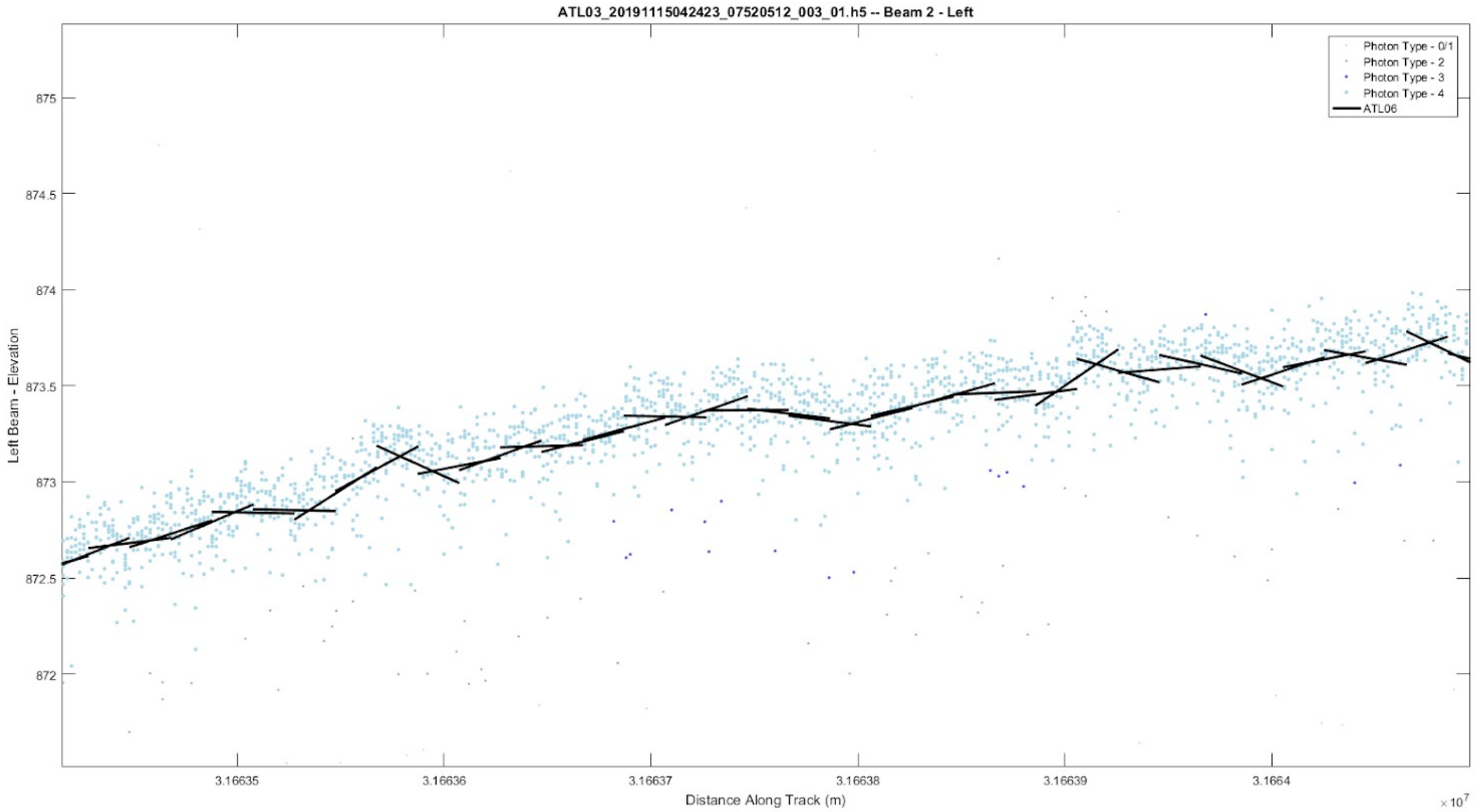


Land-ice products

ATL06: Land-ice height

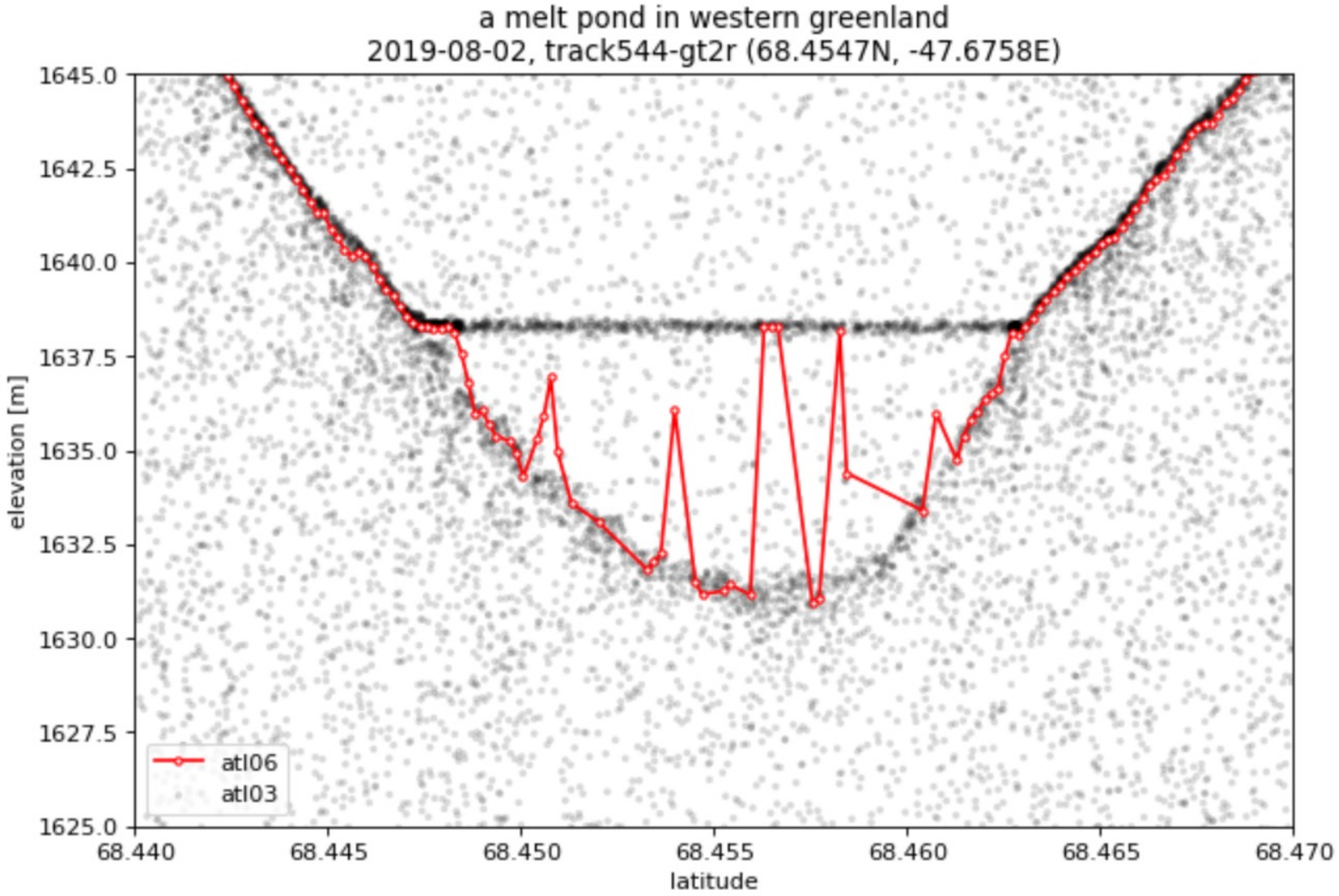
- Contains:
  - 40-meter linear segments fit to land-ice photons (slopes and heights)
  - Error estimates
  - Tides and instrumental corrections
  - Segment quality parameters
- Advantages:
  - Lighter product than ATL03
  - Provides surface heights (not just photon heights)
  - Provides repeatable parameters (can be compared from cycle to cycle)
- Disadvantages:
  - 40-m resolution is too coarse for some applications (crevasses, bare rock)
  - 40-m resolution is too fine for some large-scale studies
- Use it if:
  - You want to make large-scale repeatable measurements of glaciers

ATL06 example: along-track slopes



Credit: Holschuh / Sutterley

ATL06 example: problems with surface water in Greenland

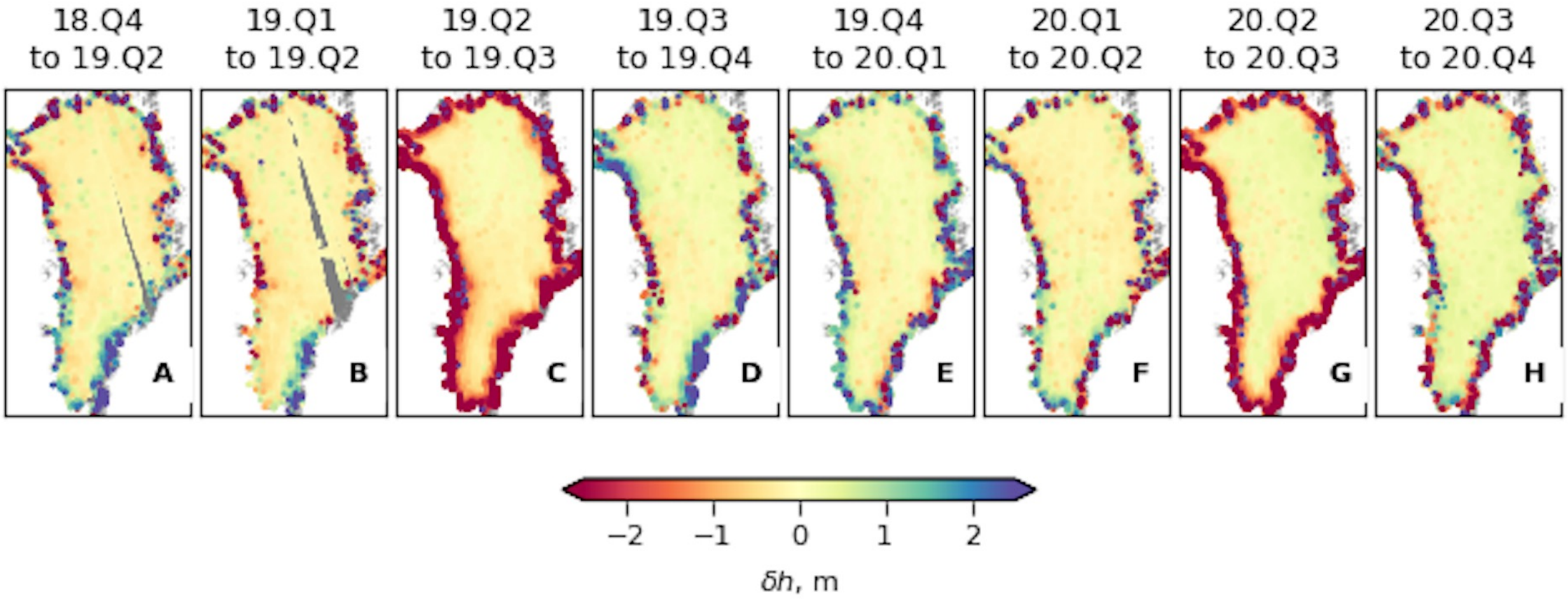


Credit: Philipp Arndt

ATL11: Slope-Corrected Land Ice Height Time Series

- Provides:
  - Repeat measurements of glacier surfaces, corrected for across-track displacements, accumulated over reference tracks
  - Quality and error assessments
- Advantages:
  - Brings together multiple repeats of ATL06, removes signals that are not related to elevation change
  - Smaller, easier-to-use product than ATL06
- Disadvantages:
  - Loss of detail relative to ATL06 (fewer paramters)
  - May not work well over very complex surfaces
- Use it if:
  - You want to measure large-scale glacier change

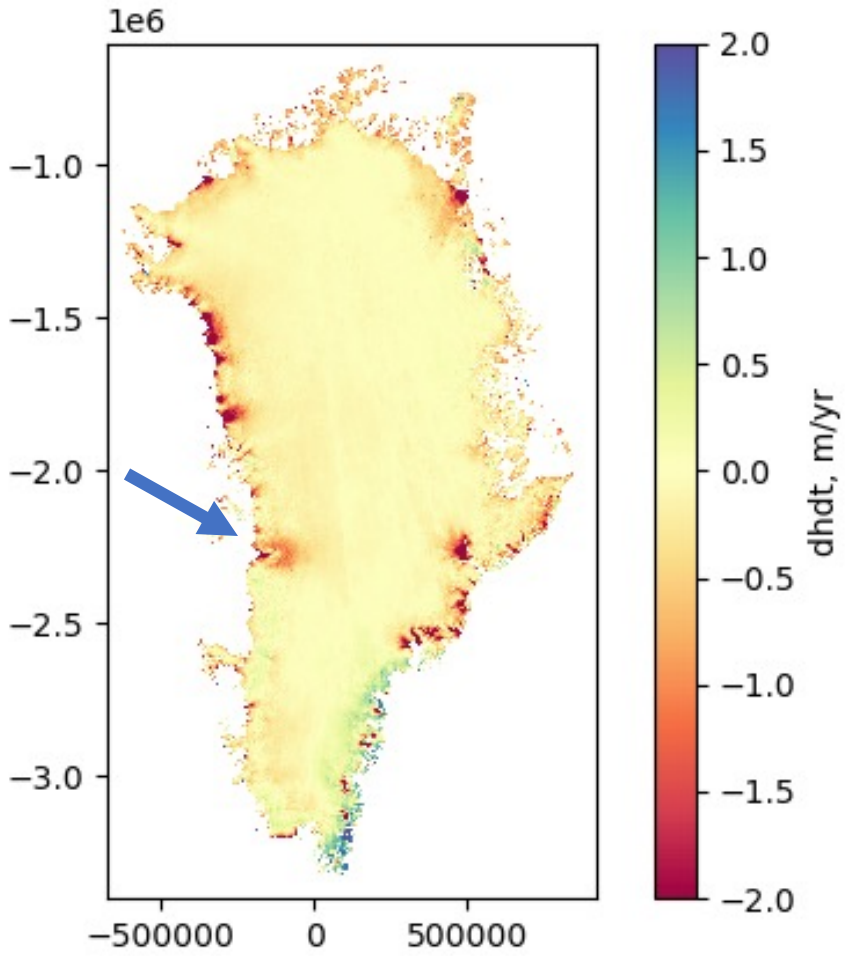
ATL11: Mapping elevation change

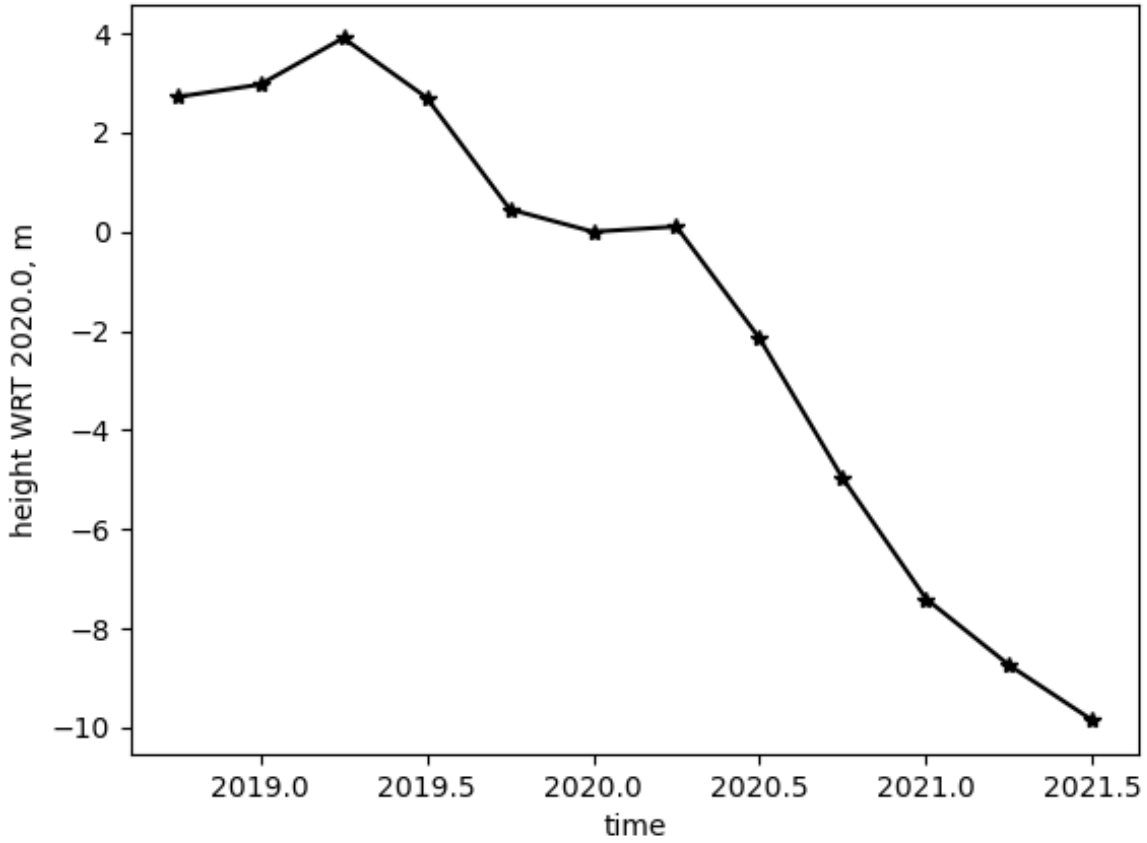


ATL14/15: land ice DEM and elevation change

- Provides:
  - Gridded DEM and elevation-change estimates
- Advantages:
  - Brings together repeat measurements from different tracks to map surface-height changes
  - Compact products that are quick to download
- Disadvantages:
  - Can obscure the details of height changes
  - Sometimes edits out real changes
- Use it if:
  - You want to map height change for a specific area
  - You want to calculate ice-sheet volume changes

ATL14/15 example: Greenland





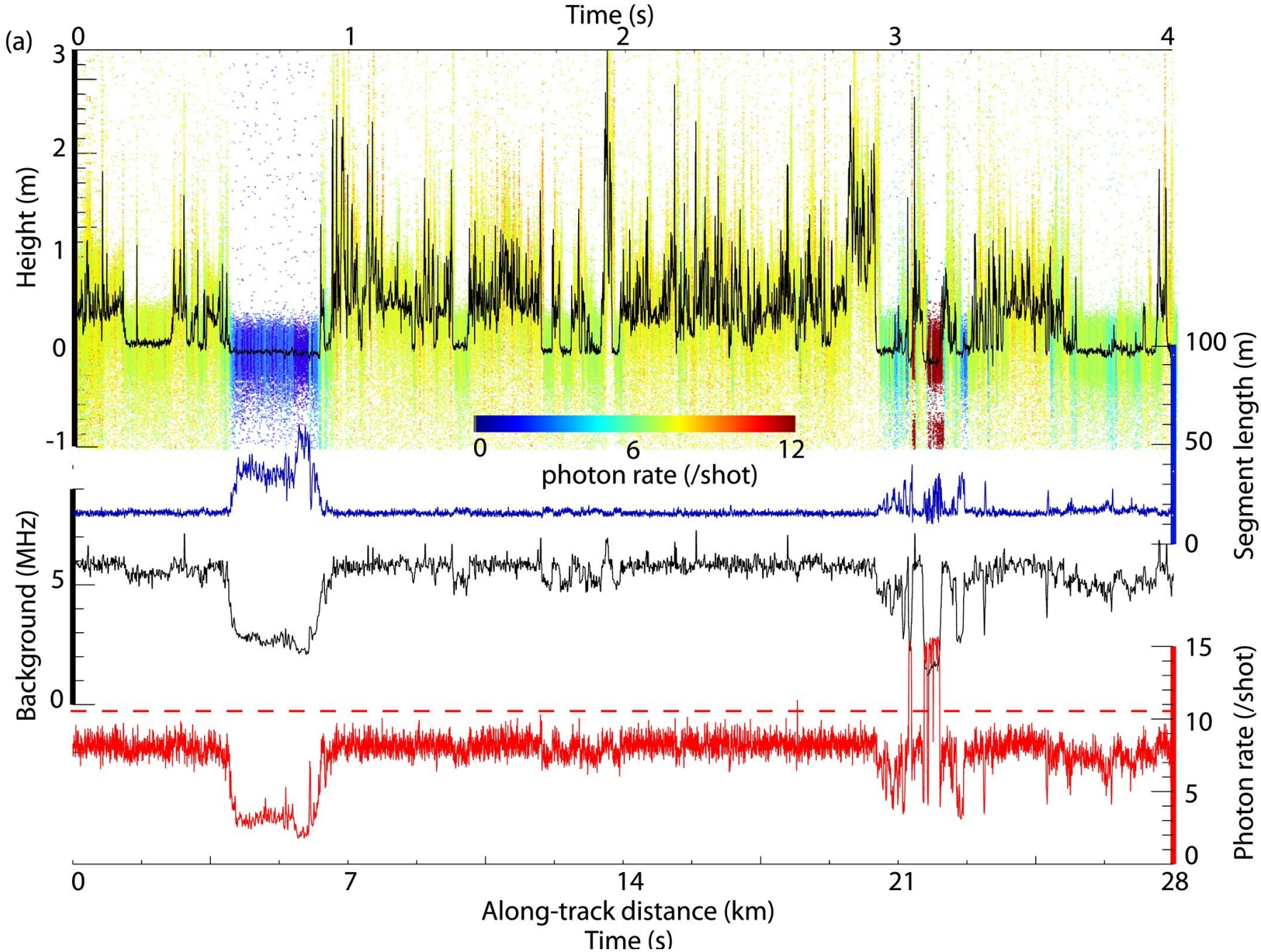
Sea-ice products

ATL07: Sea-ice height

- Provides:
  - Along-track sea surface and sea ice height and type
  - Each segment is an aggregate of 150 photons, segment length varies
- Advantages:
  - Adaptive length scale allows for resolving the sea surface in leads
  - Includes a lot of surface statistics
  - Lighter product than ATL03
- Disadvantages:
  - Only calculated where sea ice concentration is > 15%
  - Loses resolution of small-scale features
  - Height statistics must be weighted by variable segment lengths
  - Surface type classification less accurate in summer on a melting sea ice surface
- Use it if:
  - You are doing any kind of sea ice study!

ATL07 Example:

Leads and sea ice, showing how the photon rate varies from ice to open water to specular reflections within leads. The ATL07 provides higher along-track resolution in high-reflectivity areas, but still captures the statistics of dark open-water areas.

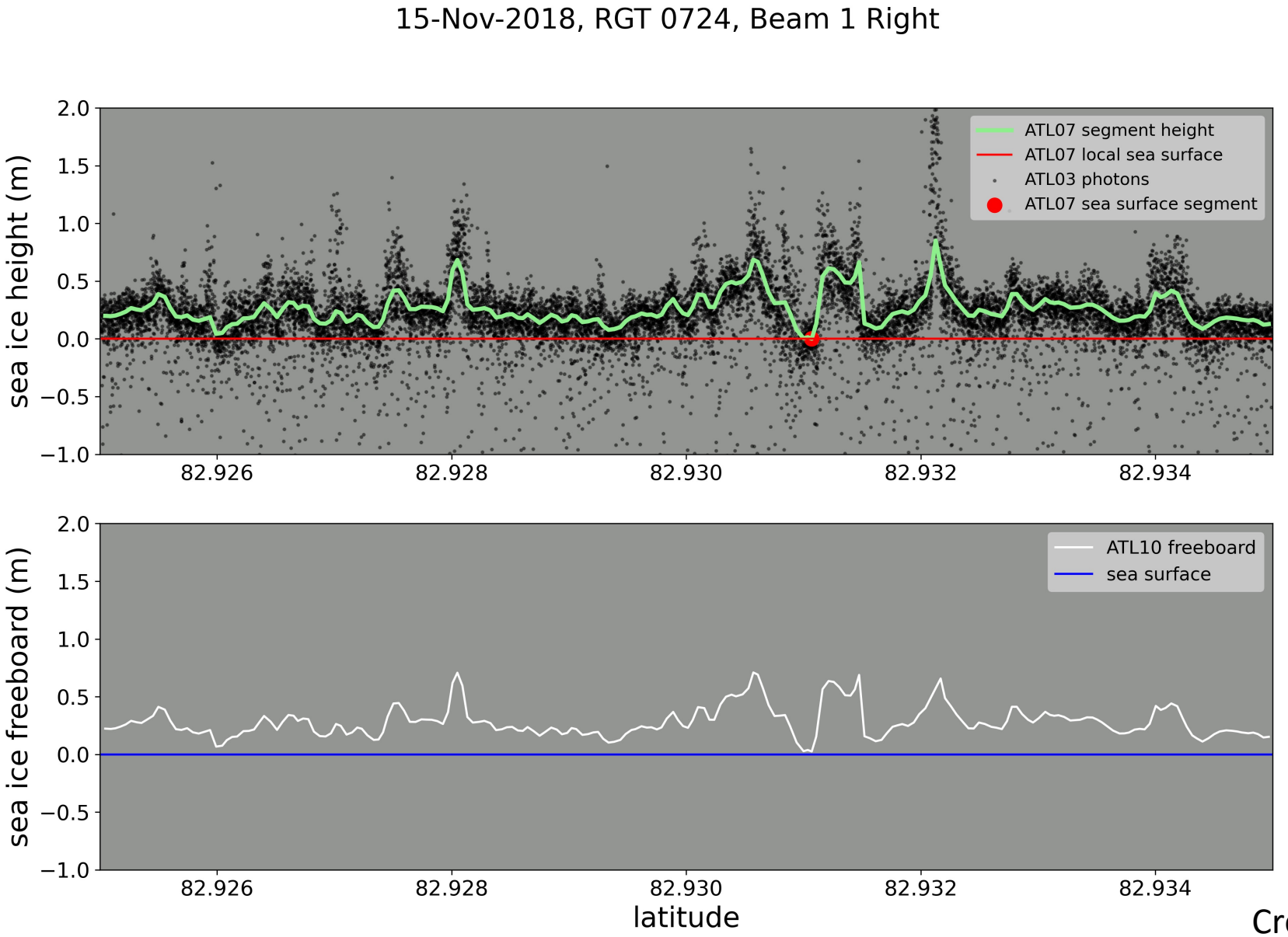


Kwok et al, 2019, https://doi.org/10.1029/2019JC015486

ATL10: Sea-ice freeboard

- Provides:
  - Along-track sea ice freeboard (height of the sea ice above local sea surface)
  - Calculated in 10 km segments if that segment contains a sea surface reference
- Advantages:
  - High spatial resolution and wide coverage
- Disadvantages:
  - Same variable length scale as ATL07
  - Only provided where sea ice concentration > 50% and 50 km from coast
  - Freeboard near ice edge affected by sea state- scattering in troughs of waves result in low sea surface and anomalously high freeboard
- Use it if:
  - You are doing Artic-wide studies or are focused on consolidated ice regions
  - You want to calculate sea ice thickness

ATL07 and ATL10 example:



Credit: Ellen Buckley

Vegetation products

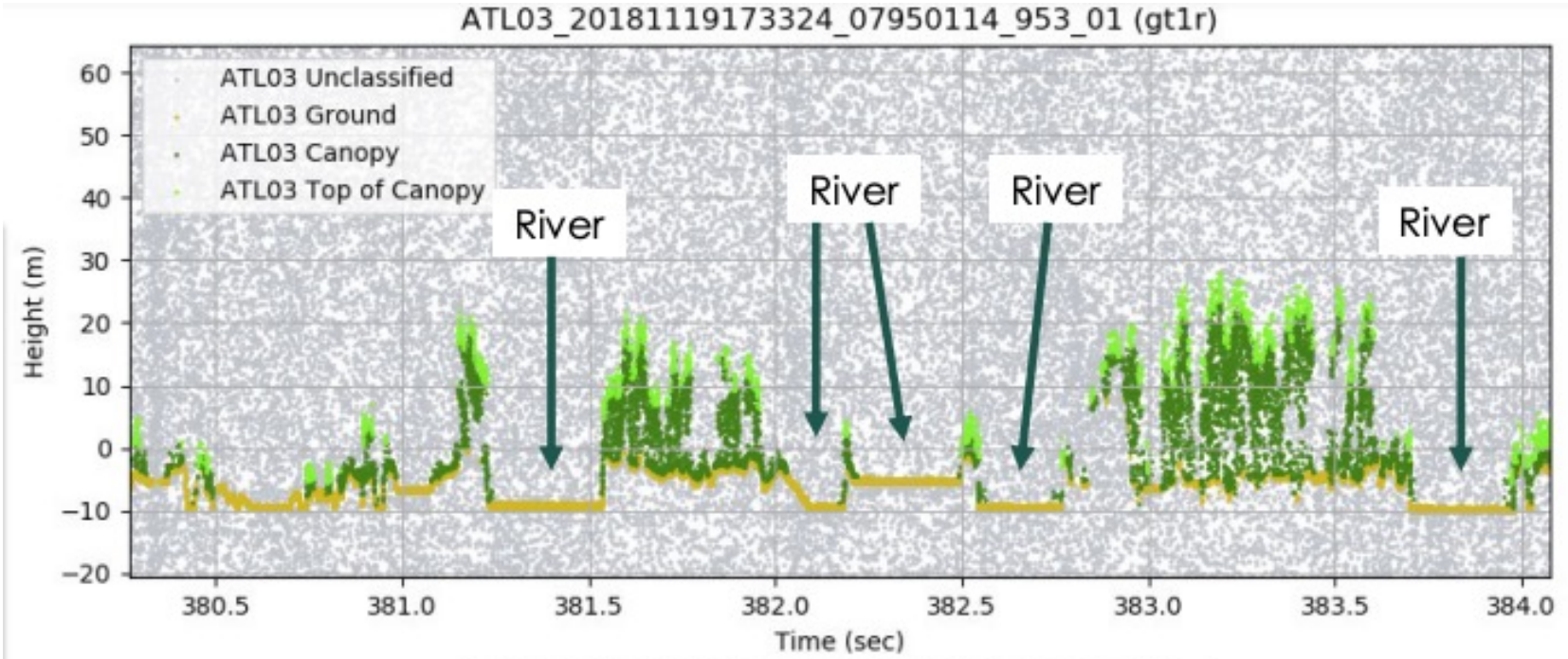
ATL08: Land/water vegetation elevation

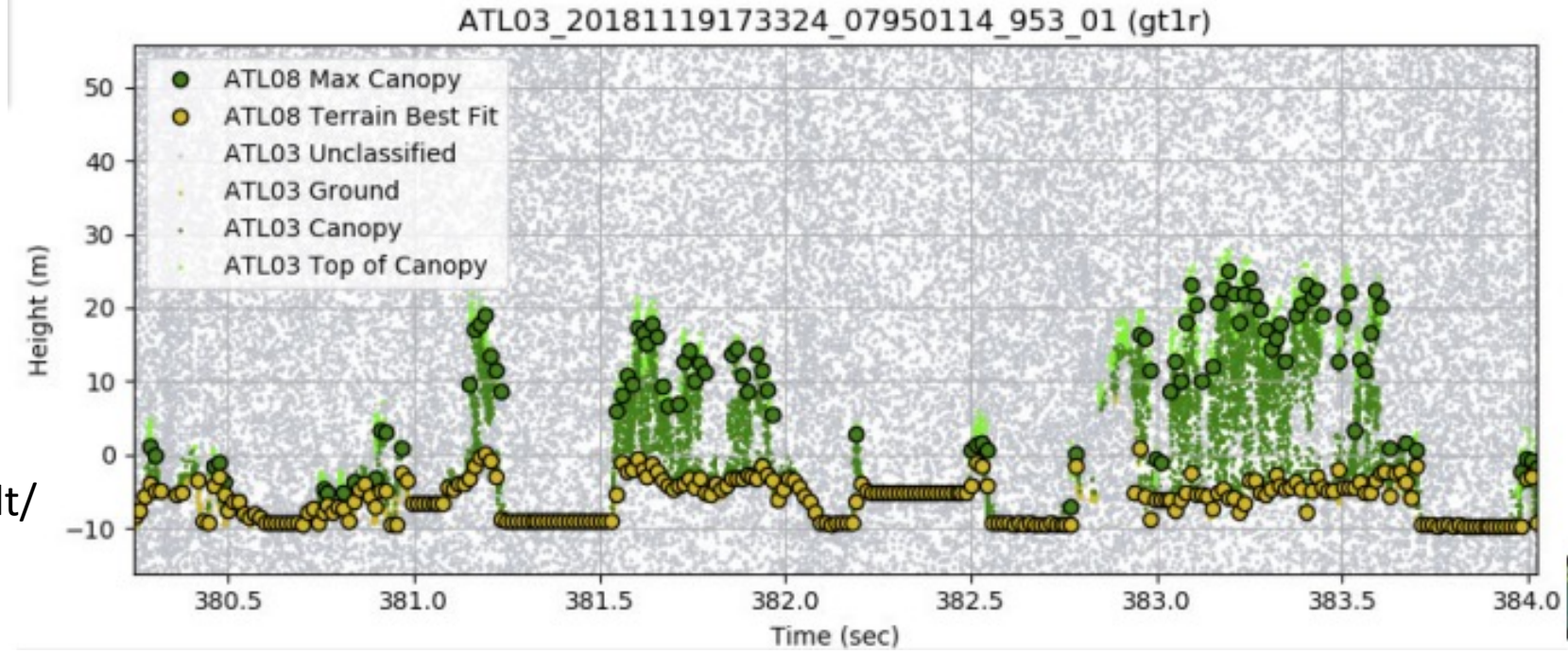
- Provides:
  - Alternate surface-detection methods
- Advantages:
  - Can sometimes detect the surface in complex terrain better than ATL06
  - Does a better job of handling multiple returns than does ATL06
  - Provides an advanced photon classification for ATL03 photons
- Disadvantages:
  - Can produce unpredictable results over sloping surfaces
- Use it if:
  - You need to detect multiple surfaces
  - You want to measure elevations of land around glaciers
  - You are looking at vegetated terrain

ATL08 example

Estimated canopy heights in for a section of the Amazon floodplain

Top: classified photons
Bottom: Interpreted heights





Credit: Amy Neuenschwander: https://appliedsciences.nasa.gov/sites/default/files/2021-03/SIF_LIDAR_Neuenschwander_Final.pdf

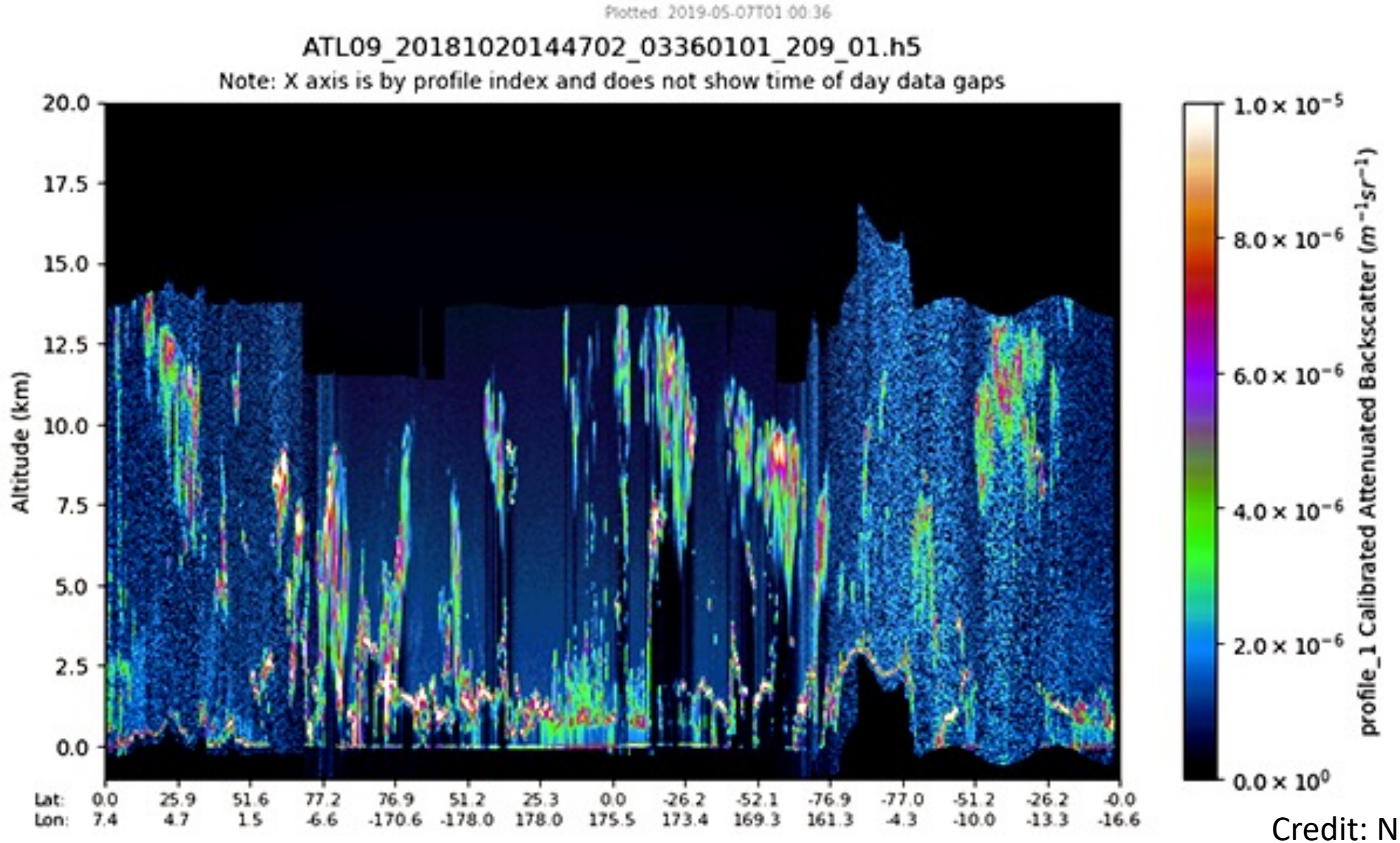
Atmospheric products

ATL04/09: Calibrated backscatter / Atmospheric characteristics

AKA: Cloud-o-grams

- Provides:
  - Profiles of atmospheric backscatter
  - Layer heights and optical properties
- Advantages:
  - Shows global cloud properties
- Disadvantages:
  - Complicated product
  - Not presented in the same along-track coordinates as along-track products
- Use it if:
  - You want to know why you can’t see the ground
  - You want to understand atmospheric effects on surface products
  - You’re interested in clouds

ATL09 example



Credit: NSIDC

Custom subsetting and product generation

- OpenAltimetry, SlideRule, and IcePyx/NSIDC all offer on-demand subsetting of standard products
  - OpenAltimetry and SlideRule offer real-time (~seconds) geographic subsetting with reduced-parameter output
  - IcePyx/NSIDC offer custom parameter subsets with slightly more (~minutes) latency
- SlideRule (http://icesat2sliderule.org) offers custom ATL06-like products on demand through cloud processing
  - Users can choose the sampling interval, segment length, and input photon classification.
- ATL03 and product ATBDs offer the blocks needed to generate alternate versions of the existing products

---BUT WAIT---

- Land-ice calibration and validation studies have evaluated the standard ATL03 and ATL06 products. With custom products, you're on your own!