ICESat-2 Sea Ice Product Improvements and Updates

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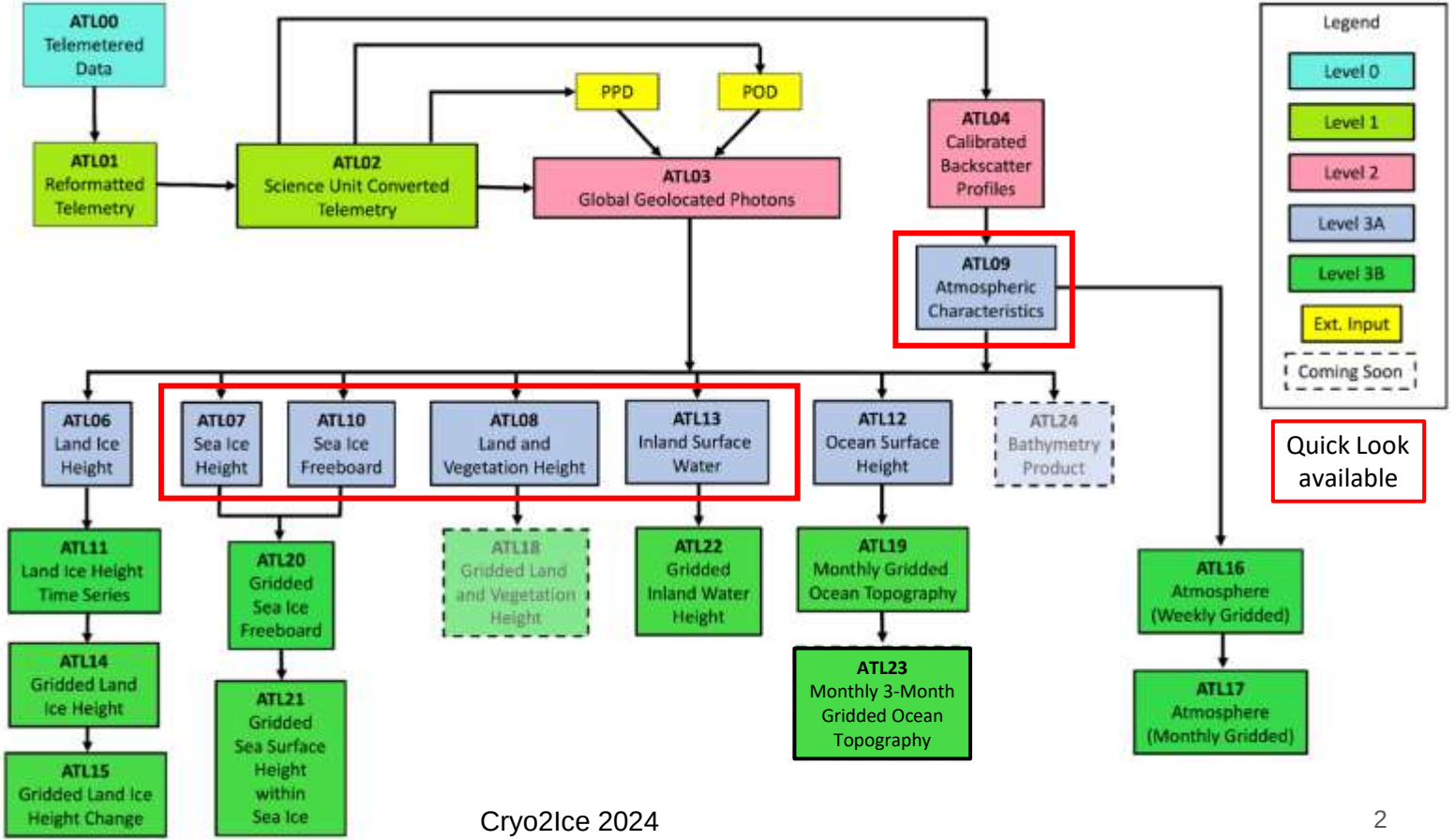
September 23, 2024

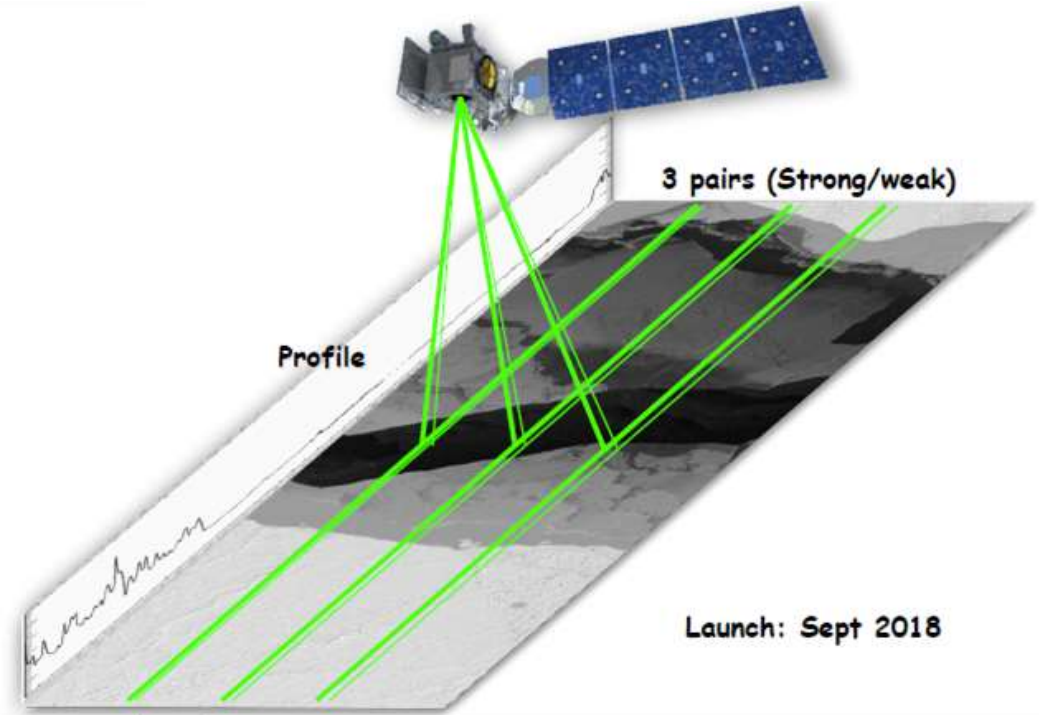
Data Products



Sea ice product overview

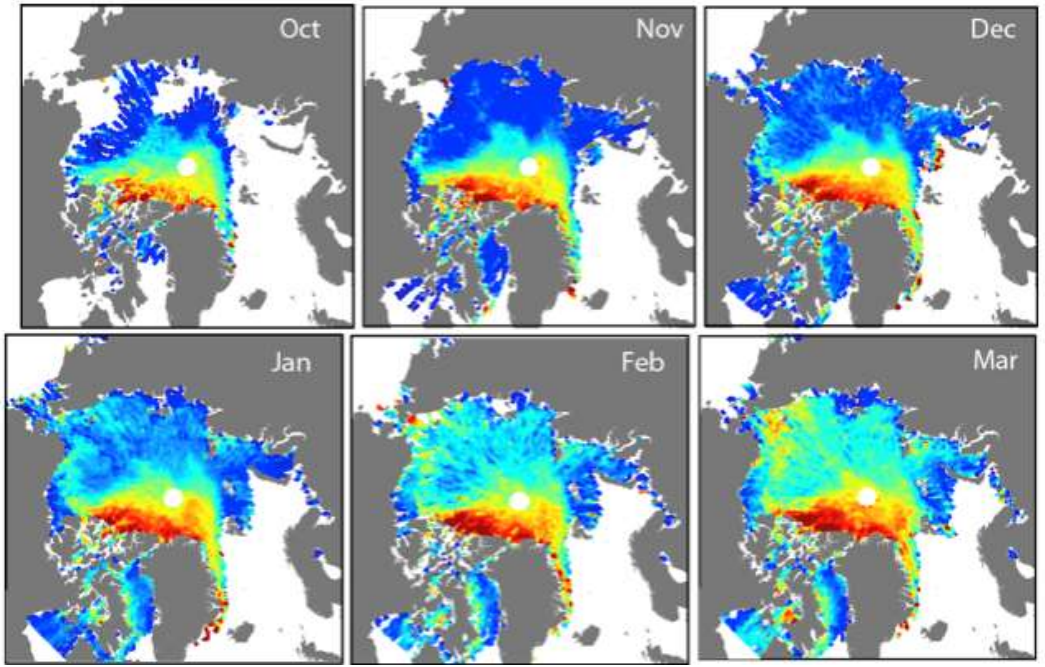
Sea ice surface heights provided by aggregating 150 signal photons along-track (ATL07) for both strong and weak beams

Sea ice freeboard provided along-track (ATL10) by determining sea surface height from lead returns and subtracting from sea ice surface heights



Sea ice product updates and timeline

- Rel007 sea ice products to be available Spring 2025
- **Rel007 major updates:** new geophysical corrections (DAC, tides), improved height retrievals of rough surfaces, 10 meter height segments, DDA-bifurcation
- **ATL03 updates**: possible reduction of beam-to-beam biases, New tide model - FES series (FES2014b) same as CryoSat-2, consistent transition to ITRF2020, cloud optimization, new signal class and quality flags



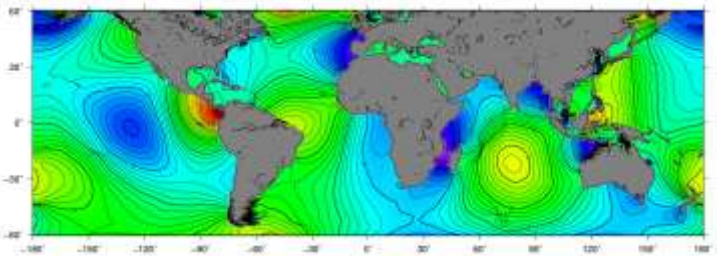
Release 007: New Features & Improvements

Replacement of Ocean Tide Model: from GOT4.8 to FES2014b

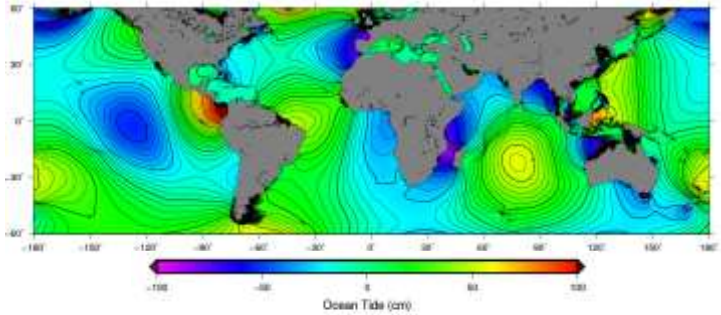
ICESat-2 mission initially adopted Richard Ray's GOT4.8 ocean tide model. Used from rel001 through rel006.

- It was among the best available at that time (2014)
- It suffered from tidal edge issues, especially along coasts
- 10 short-period constituents; 15 long-period spectral lines
- Harmonic grids with a geographic resolution of ¼°
- Includes ocean loading

GOT4.8 ocean tides at 00h on April 1, 2024



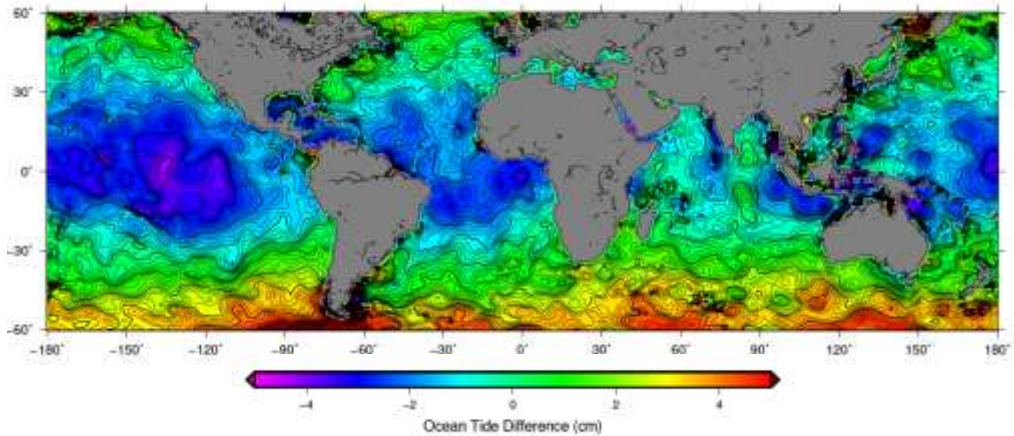
FES2014b ocean tides at 00h on April 1, 2024



For rel007, the mission adopted the FES2014b ocean tide model.

- FES2022b was released after the decision to adopt FES2014b
- Edge issues are mitigated by using the extrapolated version which will include estimates of tides in fjords, estuaries and inlets
- 34 short- and long period constituents
- Harmonic grids with a geographic resolution of 1/16°
- Includes ocean loading
- Consistent with CryoSat2 modeling

Ocean tide Difference: FES2014b minus GOT4.8 at 00h on April 1, 2024



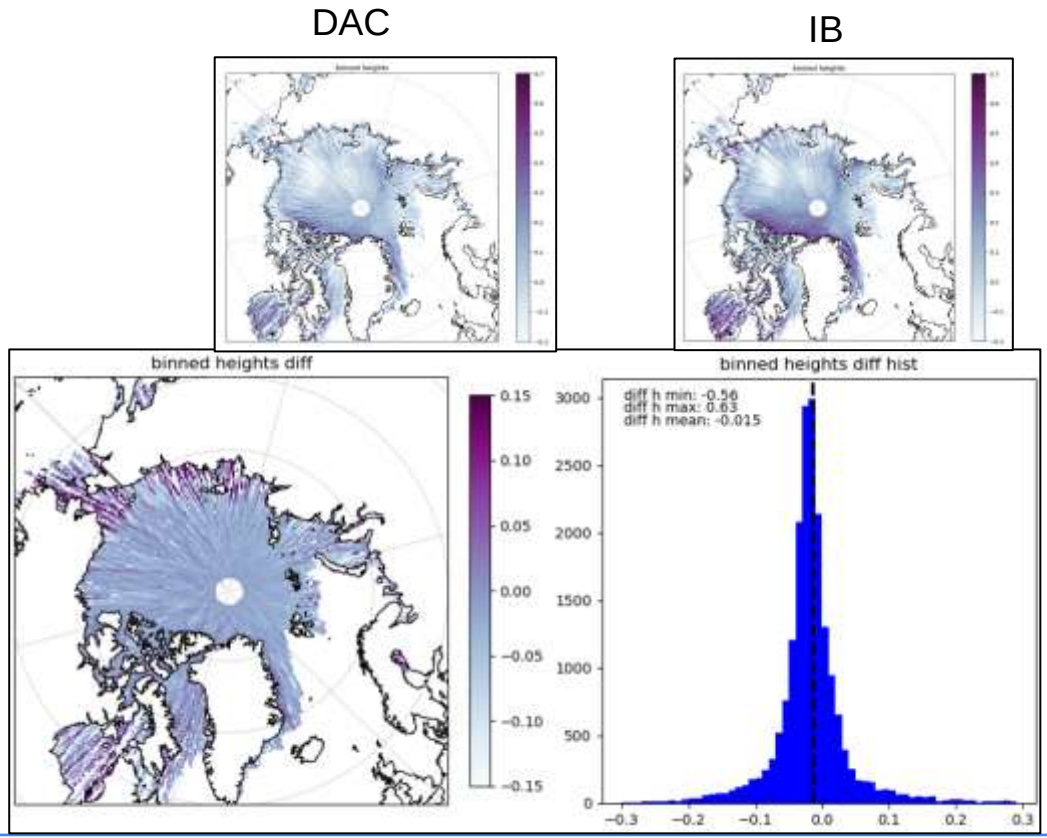
Mean: -0.28 ± 2.16 cm

Both GOT4.8 and FES2014b are global models – only mid-latitudes shown in graphics

Courtesy of John Robbins

Switch from Inverted Barometer to DAC

- Rel006 and earlier used computed inverted barometer to correct sea ice surface heights
- Rel007 will switch to use Dynamic Atmospheric Correction model to correct sea ice surface heights (same as CryoSat-2)
- Will bring ATL07 heights into better agreement with other data products, specifically the Oceans product (ATL12) allowing for a reconciled global ocean surface height product



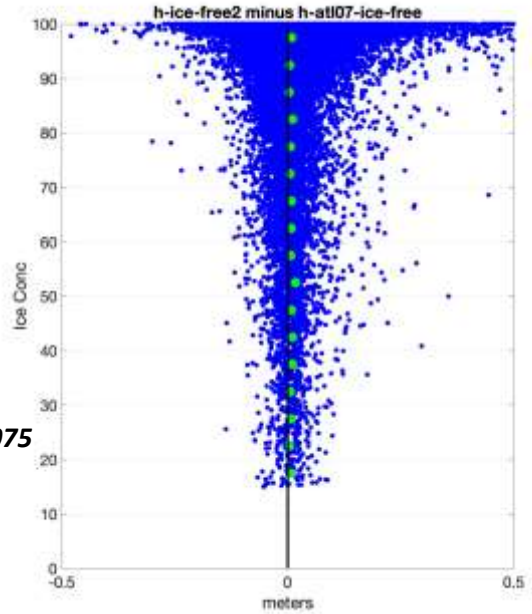
Release 007: New Features & Improvements

ATL12 Dynamic Ocean Topography (DOT) will be unbiased by sea ice freeboard.

- ATL12 10-m bins in ATL07 bright leads are identified, and there, DOT from ATL12 (*h_ice_free*) and ATL07 (*h_atl07_ice_free*) agree.
- ATL12 ocean segment DOT averages will be of *h_ice_free* for IC<77.5% and

  h_atl07_ice_free for IC>77.5%
- ATL19/23 gridded averages will incorporate *h_ice_free or h_atl07_ice_free for IC>15%.*

ATL12 h_ice_free - h_atl07_ice_free versus IC
~142 ATL12s, many ocean segments



Ice Conc	Mean Diff	STDev Diff
2.5		
7.5		
12.5		
17.5	0.0069	0.0344
22.5	0.0041	0.0340
27.5	0.0076	0.0377
32.5	0.0063	0.0269
37.5	0.0103	0.0373
42.5	0.0108	0.0436
47.5	0.0084	0.0412
52.5	0.0170	0.0824
57.5	0.0067	0.0414
62.5	0.0075	0.0429
67.5	0.0086	0.0523
72.5	0.0052	0.0439
77.5	0.0064	0.0448
82.5	0.0110	0.1375
87.5	0.0038	0.0583
92.5	0.0045	0.1106
97.5	0.0090	0.0712

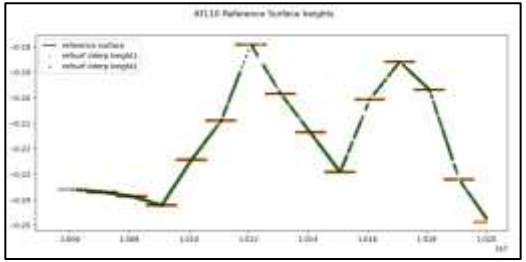
Overall
ATL12-ATL07 = 0.0086 ±0.075

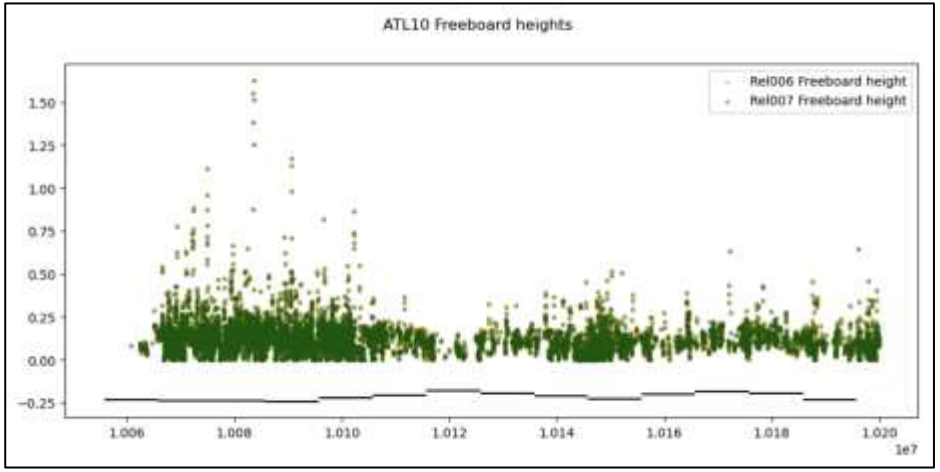
Up To IC = 77.5%
Bias = ~ 1 cm ± 4 cm

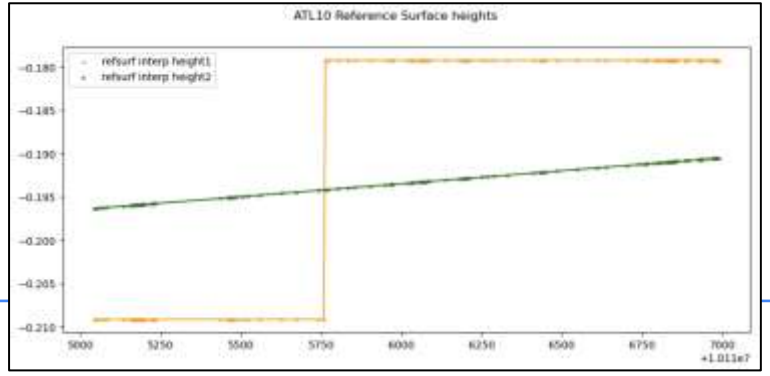
Courtesy of Jamie Morison

Interpolated sea surface reference heights

- Provide smoother freeboard distribution by interpolating reference surface heights before calculating freeboard height

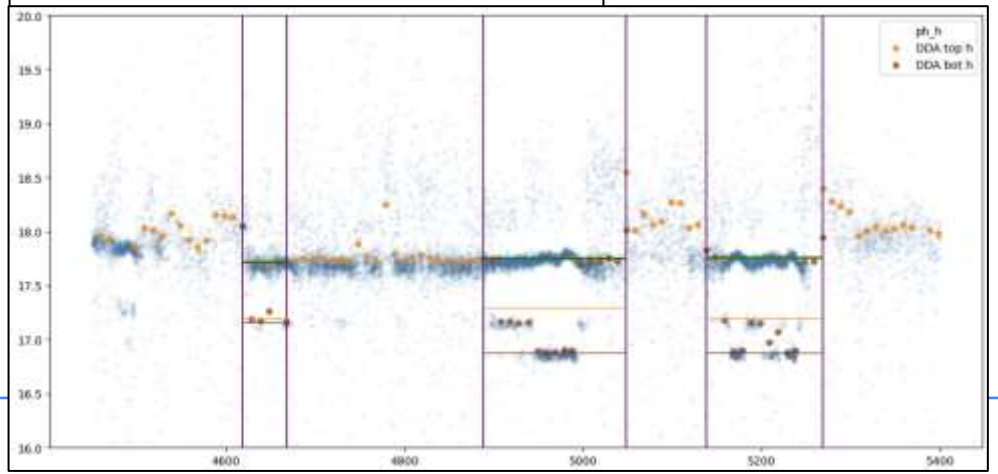


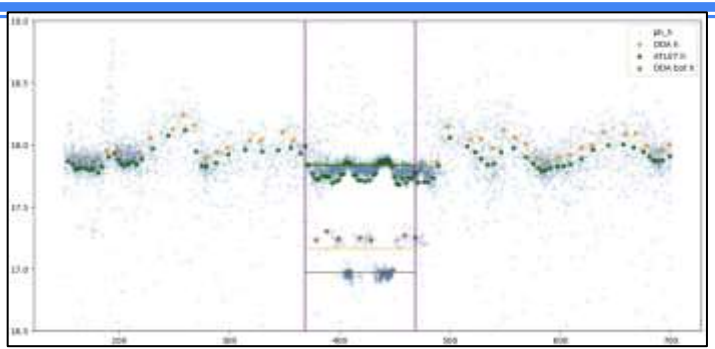




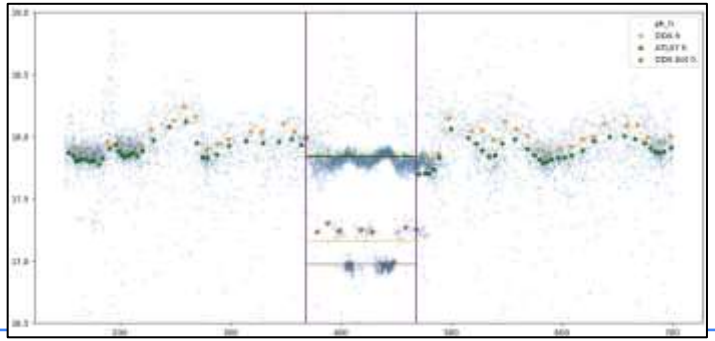
DDA-Bifurcation

- Implement DDA surface finding algorithm (Ute Herzfeld, Tom Trantow, Jeff Lee) into ATL07
- Includes Bifurcated Surfaces, allowing detection of potential melt ponds and retrieval of melt pond depth



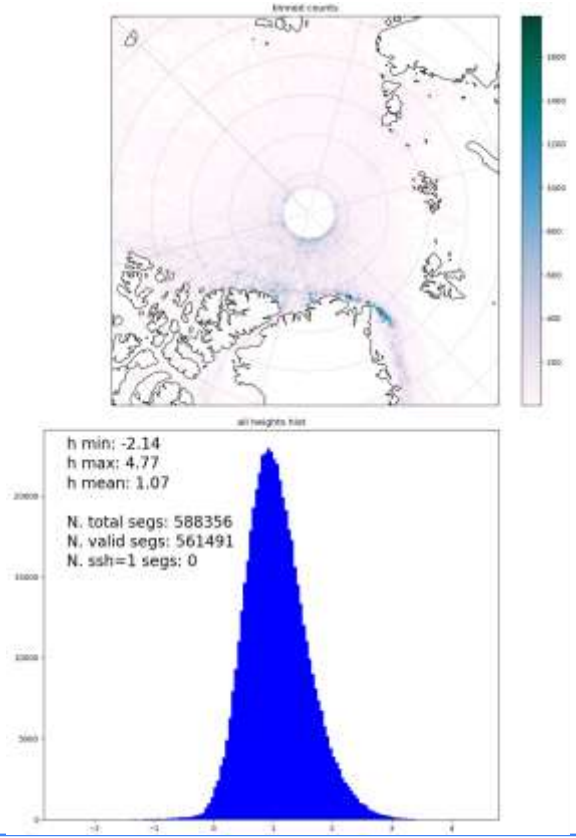


ATL07 heights in bifurcation surfaces flagged

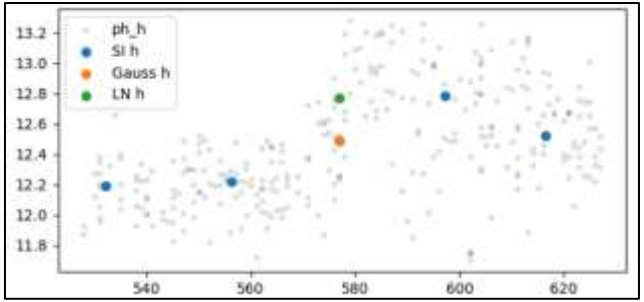


Improving retrievals with bad fits

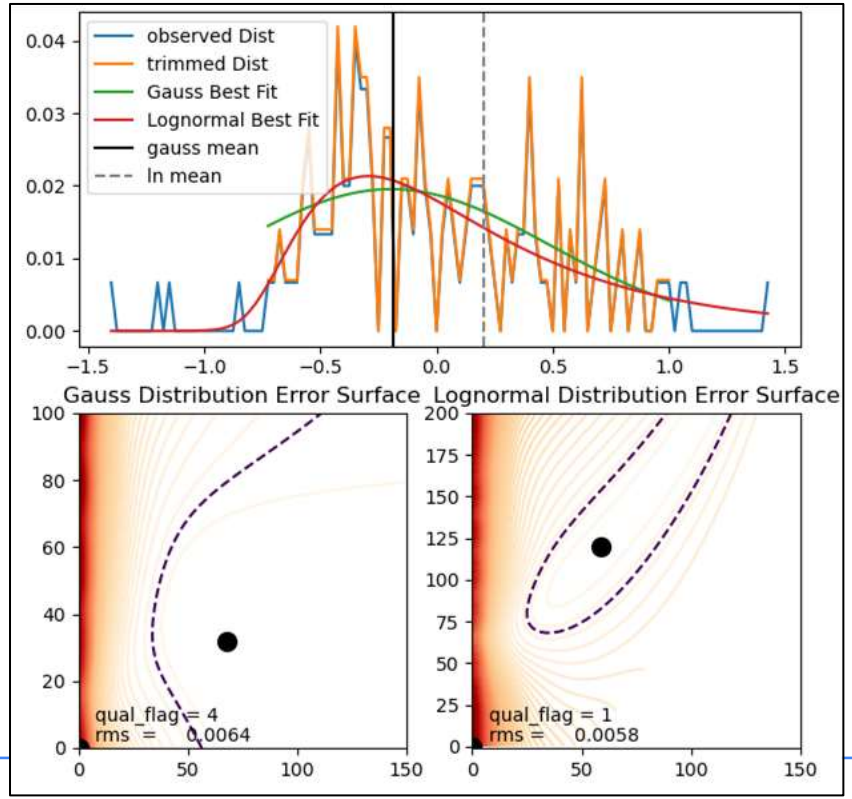
- Sea ice height retrievals in ATL07 assume a Gaussian surface height distribution and attempt to find the best fit waveform by convolving a Gaussian function with the ICESat-2 impulse response
  - Then “skew-corrected” using a dual-Gaussian fit
- Sea ice height retrievals in ATL07 provide an associated fit quality flag (fit quality flag from 1-5)
- Height retrievals with bad fits (fit quality flag = 5) are excluded from sea ice freeboard results in ATL10
  - Affects ~1-3% of data, but varies spatially

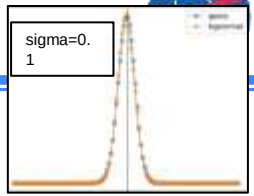


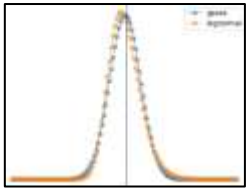
Lognormal distribution

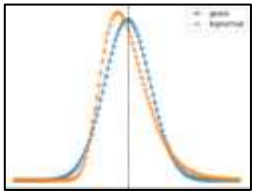


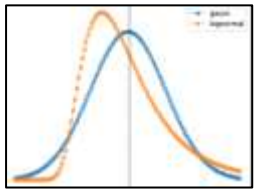
- Investigated whether using a lognormal distribution can provide better quality fits with similar quality fit flags
- Improves ICESat-2 retrievals of ridged and rough surface height and freeboard for about ⅔ of quality fit flag = 5 points

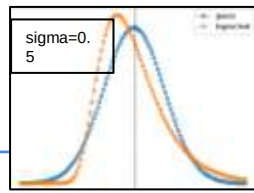


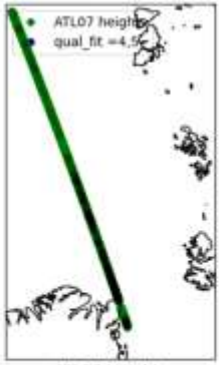


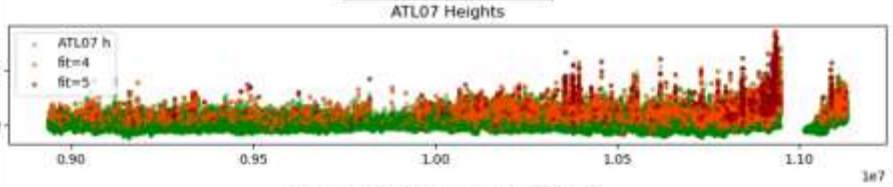


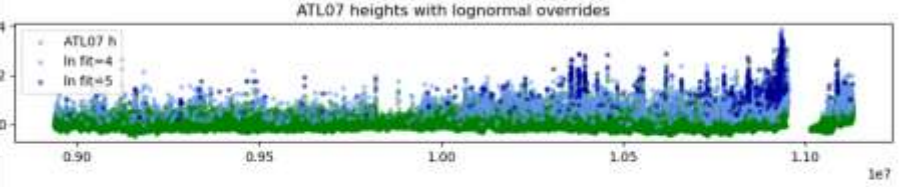


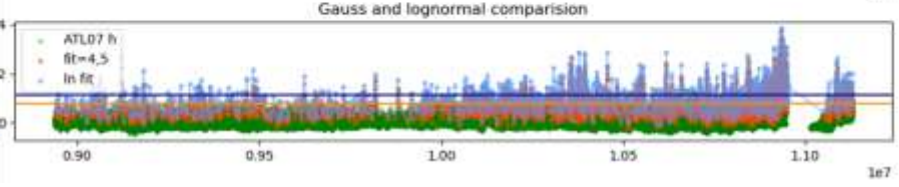


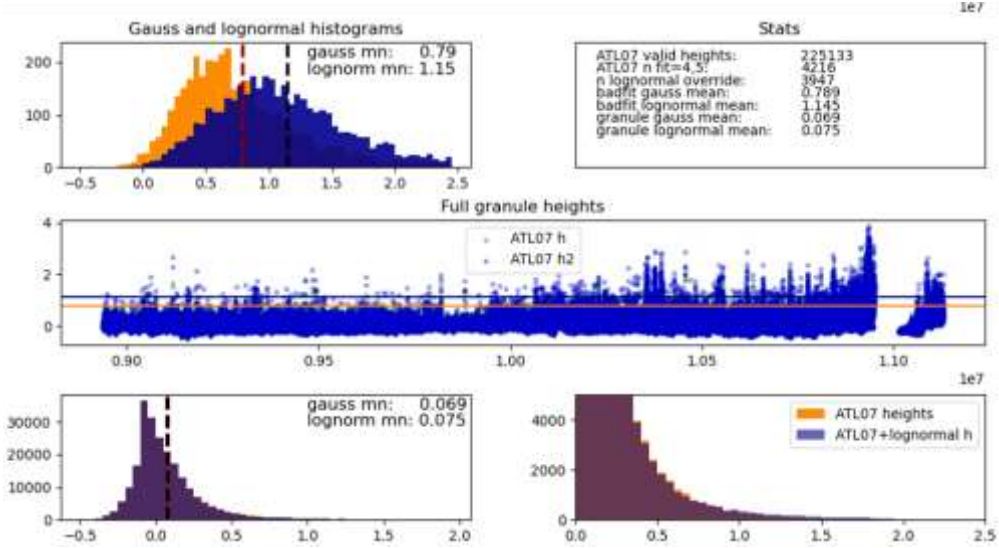



ATL07 heights
qual_fit =4,5


ATL07 Heights
ATL07 h
fit=4
fit=5
0.90
0.95
1.00
1.05
1.10
1e7

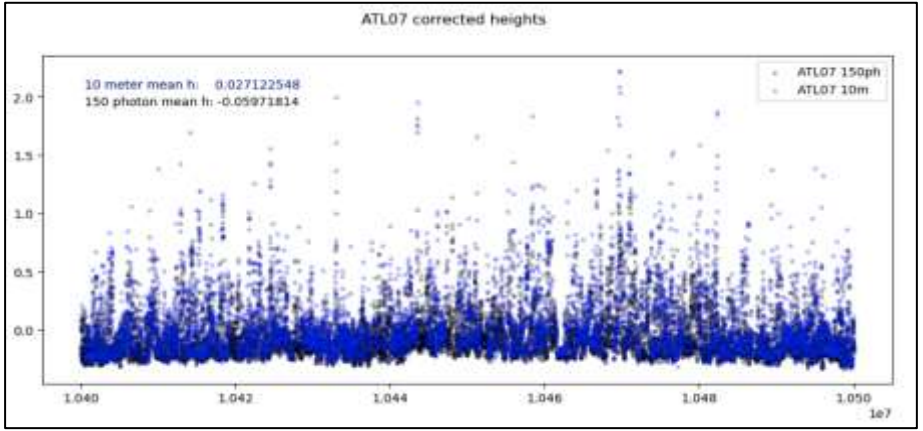

ATL07 heights with lognormal overrides
ATL07 h
ln fit=4
ln fit=5
0.90
0.95
1.00
1.05
1.10
1e7

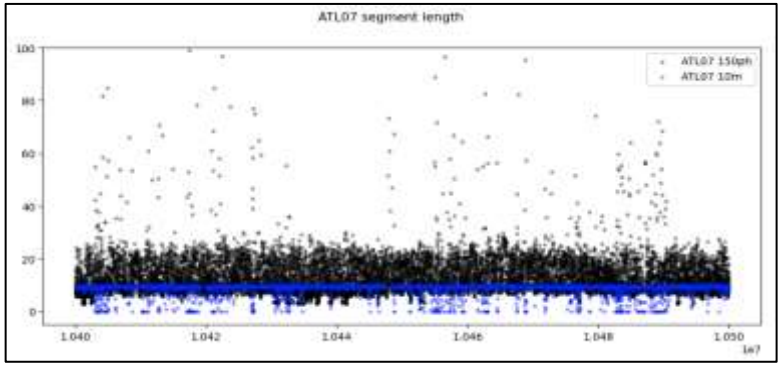

Gauss and lognormal comparision
ATL07 h
fit=4,5
ln fit
0.90
0.95
1.00
1.05
1.10
1e7

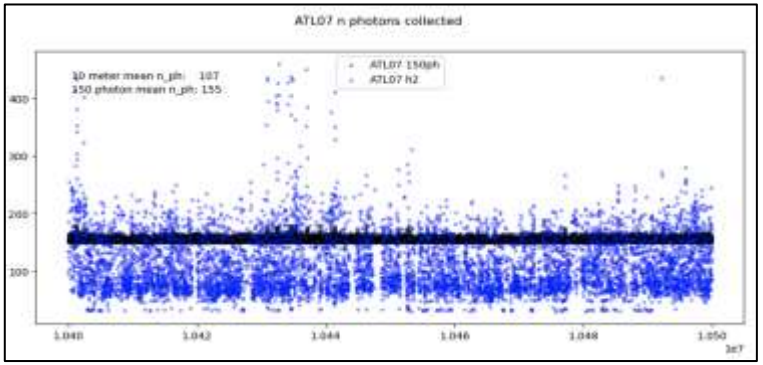

Gauss and lognormal histograms
gauss mn: 0.79
lognorm mn: 1.15
Stats
ATL07 valid heights: 225133
ATL07 n fit=4,5: 4216
n lognormal override: 3947
badfit gauss mean: 0.789
badfit lognormal mean: 1.145
granule gauss mean: 0.069
granule lognormal mean: 0.075
Full granule heights
ATL07 h
ATL07 h2
1e7
gauss mn: 0.069
lognorm mn: 0.075
ATL07 heights
ATL07+lognormal h

10m heights

- ATL07 sea ice heights are computed by gathering 150 photons, resulting in variable length segments
- Introduce option to process heights in constant-length segment finding to increase spatial resolution to scale of ICESat-2 footprint





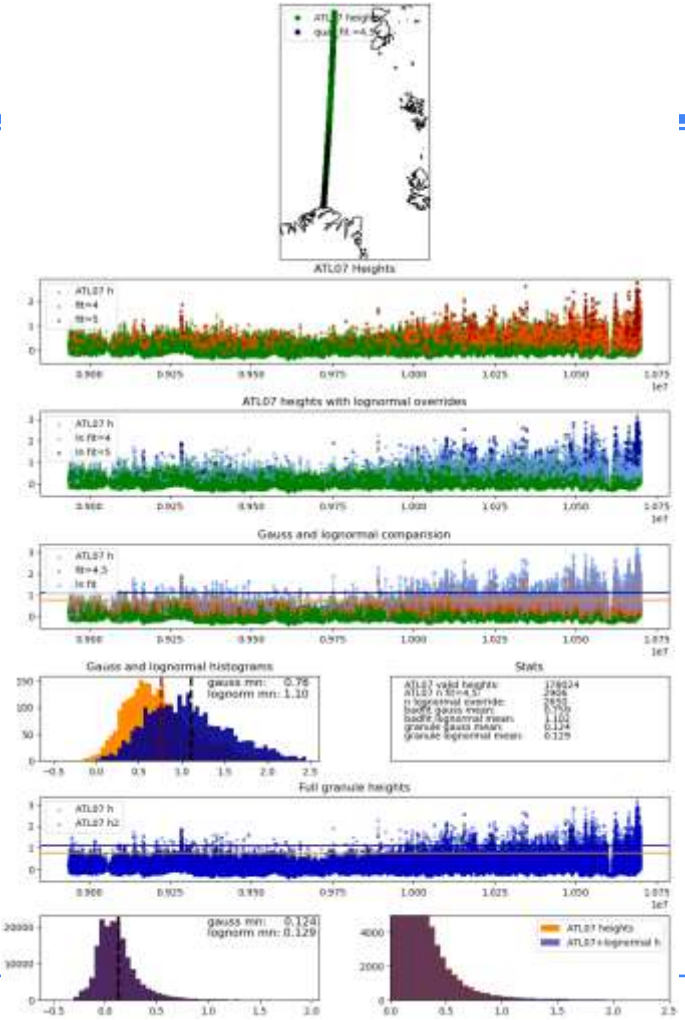


Future work

Rel007 processing will allow for assessments of 10 meter heights and lognormal retrievals (and reduced biases in rough ice areas), DDA-bifurcation for summer sea ice and melt ponds, beam-to-beam bias reductions

Work for rel008: Near-coastal sea ice freeboard, dark lead detection, summer sea ice retrieval improvements, multi-beam freeboard determination, more sophisticated SSH interpolation?

Other desires for rel008?


ATL07 Heights
ATL07 h
fit=4
fit=5
ATL07 heights with lognormal overrides
ATL07 h
ln fit=4
ln fit=5
Gauss and lognormal comparision
ATL07 h
fit=4.5
ln fit
Gauss and lognormal histograms
gauss mn: 0.78
lognorm mn: 1.10
Stats
ATL07 valid heights 178024
ATL07 n fit=4.5 2906
n lognormal override: 2855
bad fit gauss mean: 0.703
bad fit lognormal mean: 1.102
granule gauss mean: 0.124
granule lognormal mean: 0.129
Full granule heights
ATL07 h
ATL07 h2
gauss mn: 0.124
lognorm mn: 0.129
ATL07 heights
ATL07 n lognormal h