The ICESat-2 Mission: Land, Ocean, and Inland Water Data Products for Middle and Low Latitude Science and Applications

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NASA Goddard Space Flight Center
Greenbelt, MD

2020 Annual Meeting of the Unión Geofísica Mexicana

RAUGM

MISSION

Mission Summary

http://icesat-2.gsfc.nasa.gov

Instrument:

- Advanced Topographic Laser Altimeter System (ATLAS)
- Micro-pulse instr w/single-photon detection
- 532nm
- 6 beams: arranged in 3 pairs low and high energy (25/100 μJ)
- 10 kHz pulse repetition rate
- 17m footprint
- ground speed ~ 7000m/s

Orbit:

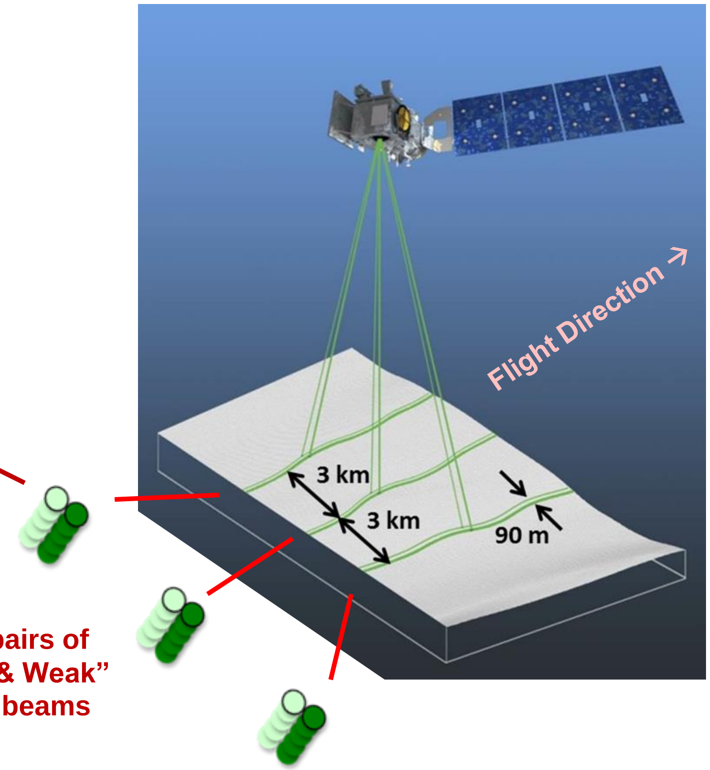
- 500 km, non-sun-sync, 92° inclination
- 91 day exact repeat, ~30 day subcycle

Status

450 days on orbit

Laser energy stable, spacecraft & ATLAS healthy

Data Products since Oct 15, 2018



Implementation

Lifetime: 3 years, with consumables for 5+

Orbit: 496 km, non-sun-synch, 92° inclination

Repeat: 91 day exact repeat, ~30 day sub-cycle

Science Data: 1 TB/day

System Pointing: Control = 45 m (14.3 m, CBE)

Geolocation Knowledge = 6.5 m (4.0 m, CBE)

ICESat-2 Mission Overview

<u>Payload</u>

ATLAS – Advanced Topographic Laser Altimeter System developed at Goddard Space Flight Center, Greenbelt, MD.

Measures time of flight of laser pulses

Measures pointing direction

Single-photon sensitive detection

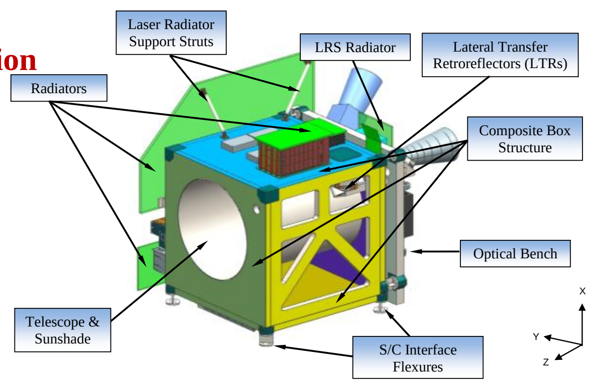
6 beams, arranged in 3 pairs

10 kHz pulse-rep. rate

11 m footprint

spaced 0.7m along-track

532nm wavelength



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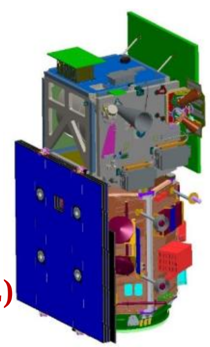
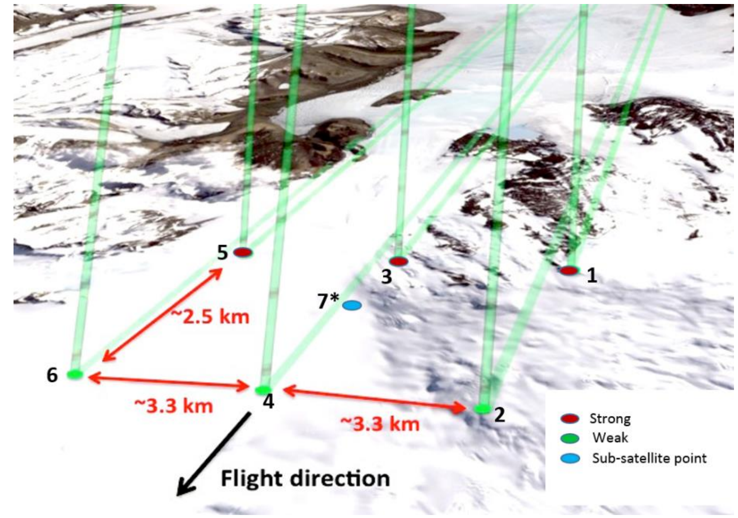


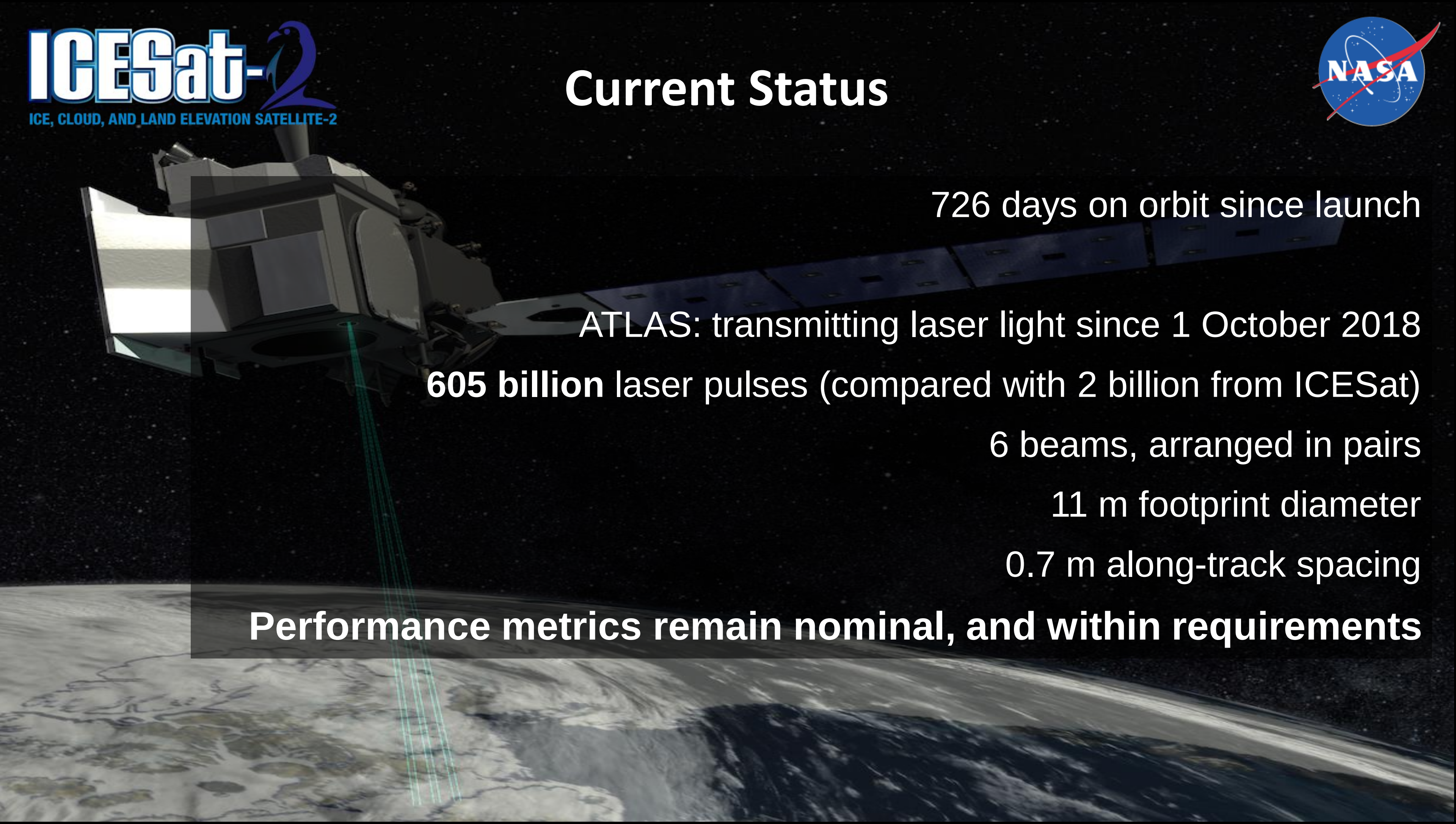


~3 km spacing between pairs provides spatial coverage

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

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

Magruder, L.A., Neumann, T. A., Brunt, K., Farrell, S., Fricker, H., Gardner, A., Neuenschwander, A., et. al., (2019) New Earth orbiter provides a sharper look at a changing planet. *EOS*, 100, https://doi.org/10.1029/2019EO133233



Current Status

726 days on orbit since launch

ATLAS: transmitting laser light since 1 October 2018

605 billion laser pulses (compared with 2 billion from ICESat)

6 beams, arranged in pairs

11 m footprint diameter

0.7 m along-track spacing

Performance metrics remain nominal, and within requirements

Orbit and Coverage

500 km altitude

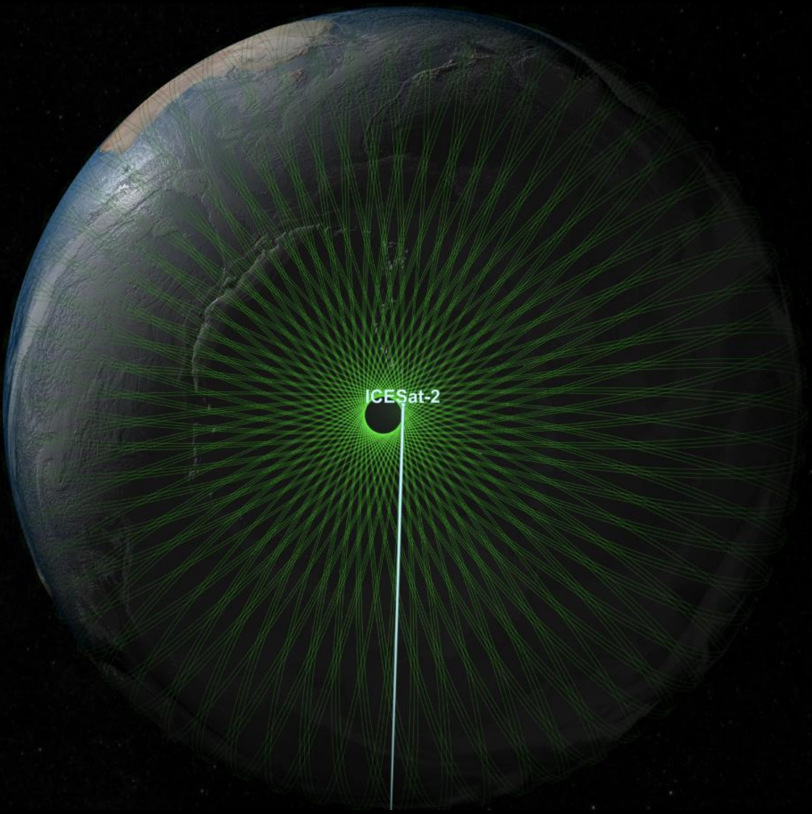
88S to 88N

15 revs/day

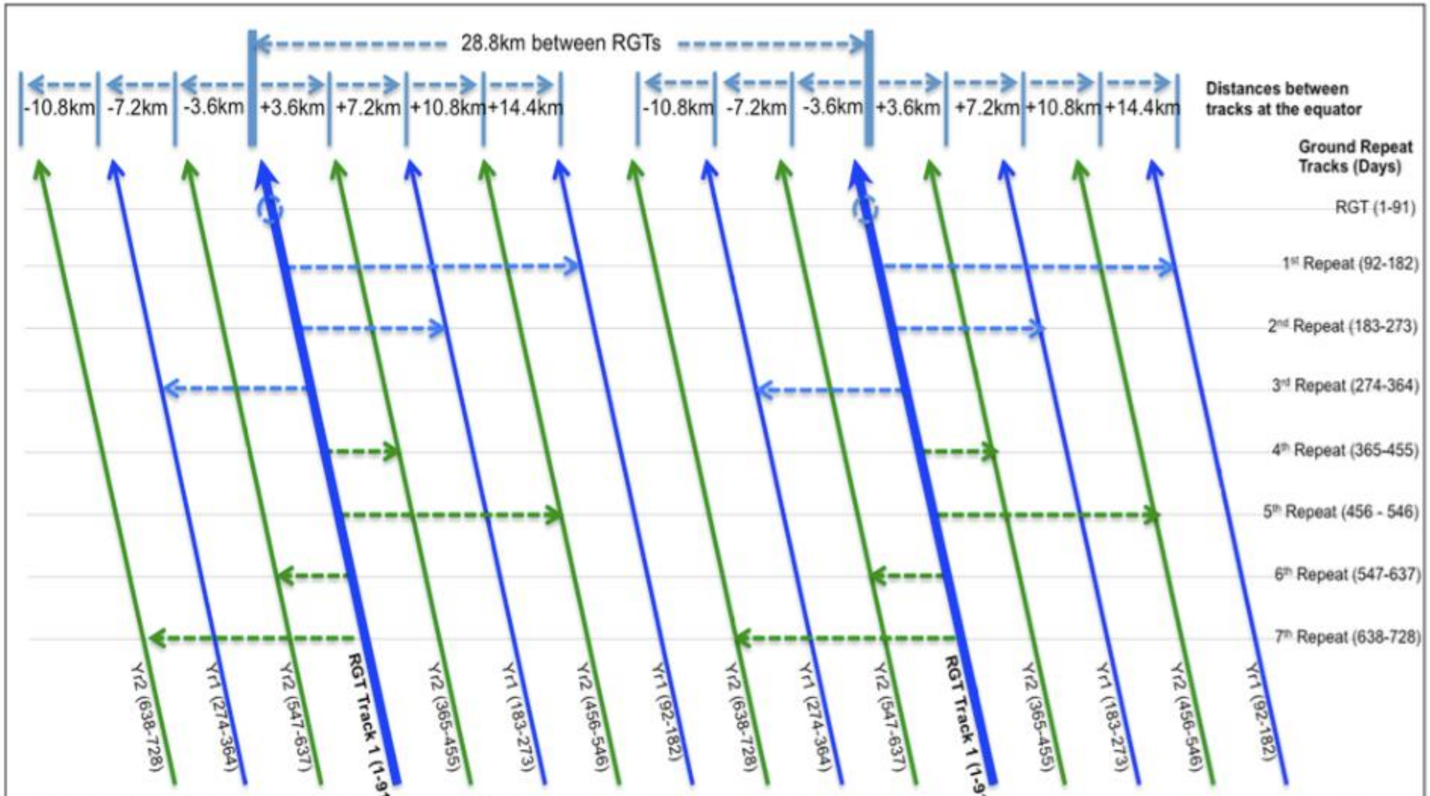
1387 tracks

91-day revisit

Ground tracks at
icesat-2.gsfc.nasa.gov



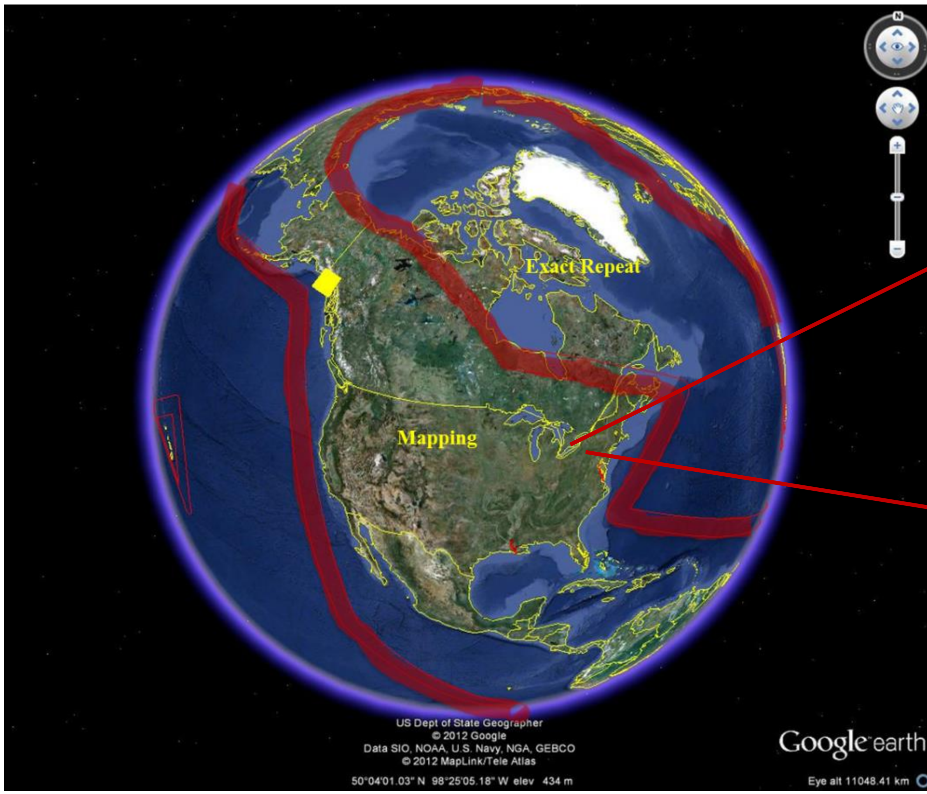
Off Pointing in Mid-Latitudes



Notional Off-Track Pointing for vegetation data collection
Note: Actual time order of tracks will be determined by the Science and Operations Teams.

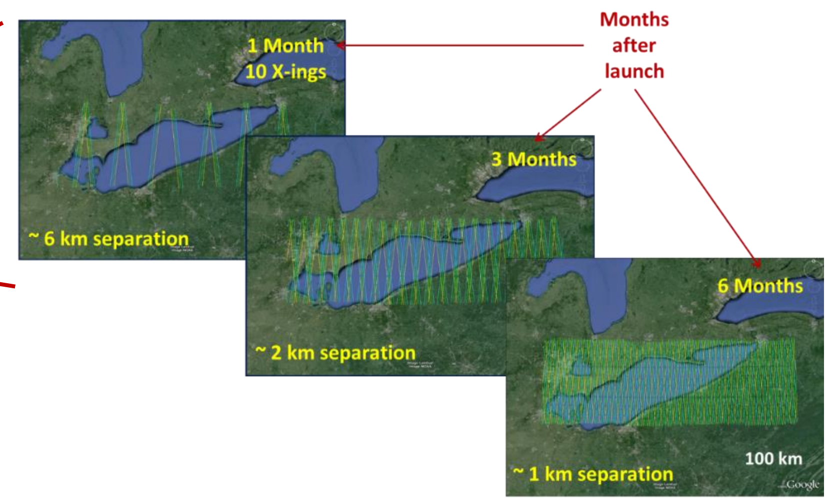
ICESat-2 Orbital Sampling

"Mapping" and "Repeat" Zones



Consequences for Inland Water

E.g. Lake Erie, USA ~42 deg N



ICESat-2 Mission

NASA's Earth observing altimetry mission

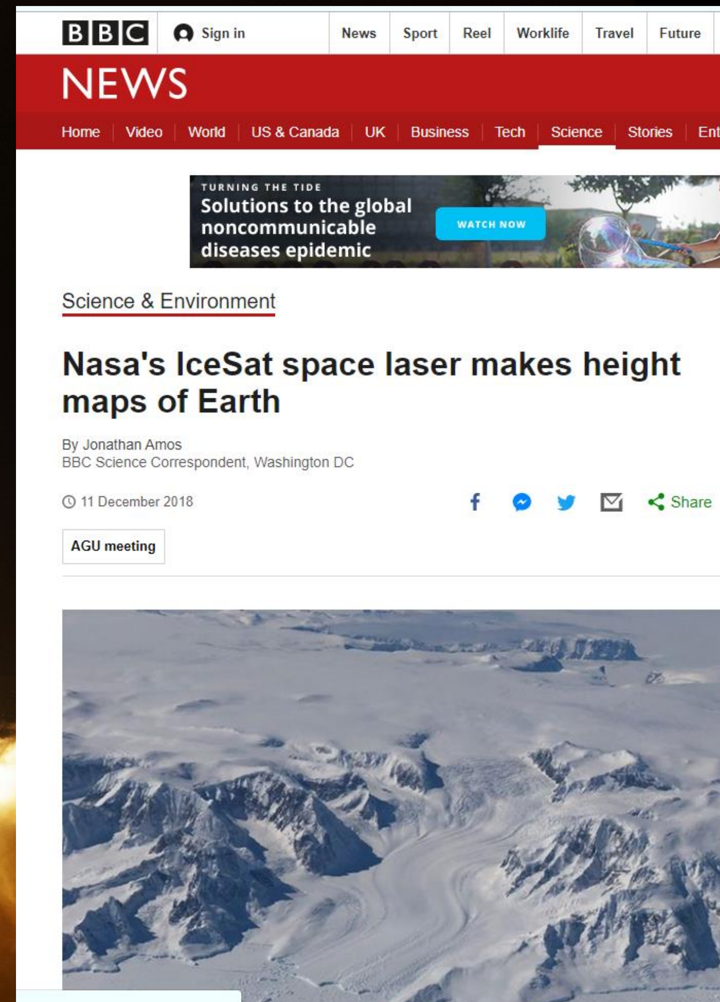
Successor to ICESat (2003-2009)

Designated as a top priority in Earth Science Decadal Survey

Launched successfully September 2018

More than a trillion measurements to date

All data available at National Snow and Ice Data Center (nsidc.org)


BBC Sign in News Sport Reel Worklife Travel Future

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Science & Environment

Nasa's IceSat space laser makes height maps of Earth

By Jonathan Amos
BBC Science Correspondent, Washington DC

11 December 2018

Share

AGU meeting

Purpose

i) Improve understanding of:
- high-latitude hydrology and lake storage dynamics within pan-Arctic basin and globally, including the role of small lakes, in response to melting permafrost and thermokarst.
- quantification of freshwater fluxes into the Arctic and other oceans, ocean salinity/circulation.

ii) Enable other science and application studies that may benefit from global, seasonal, high resolution observations of inland water dynamics.

iii) Provide hydraulic properties for remote estimation of stream discharge and lake storage/elevation, including bathymetry where possible.

iv) Serve as an accurate high-resolution calibration for other radar altimeters.

v) Provide synergy with upcoming SWOT mission.

MEXICO


Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


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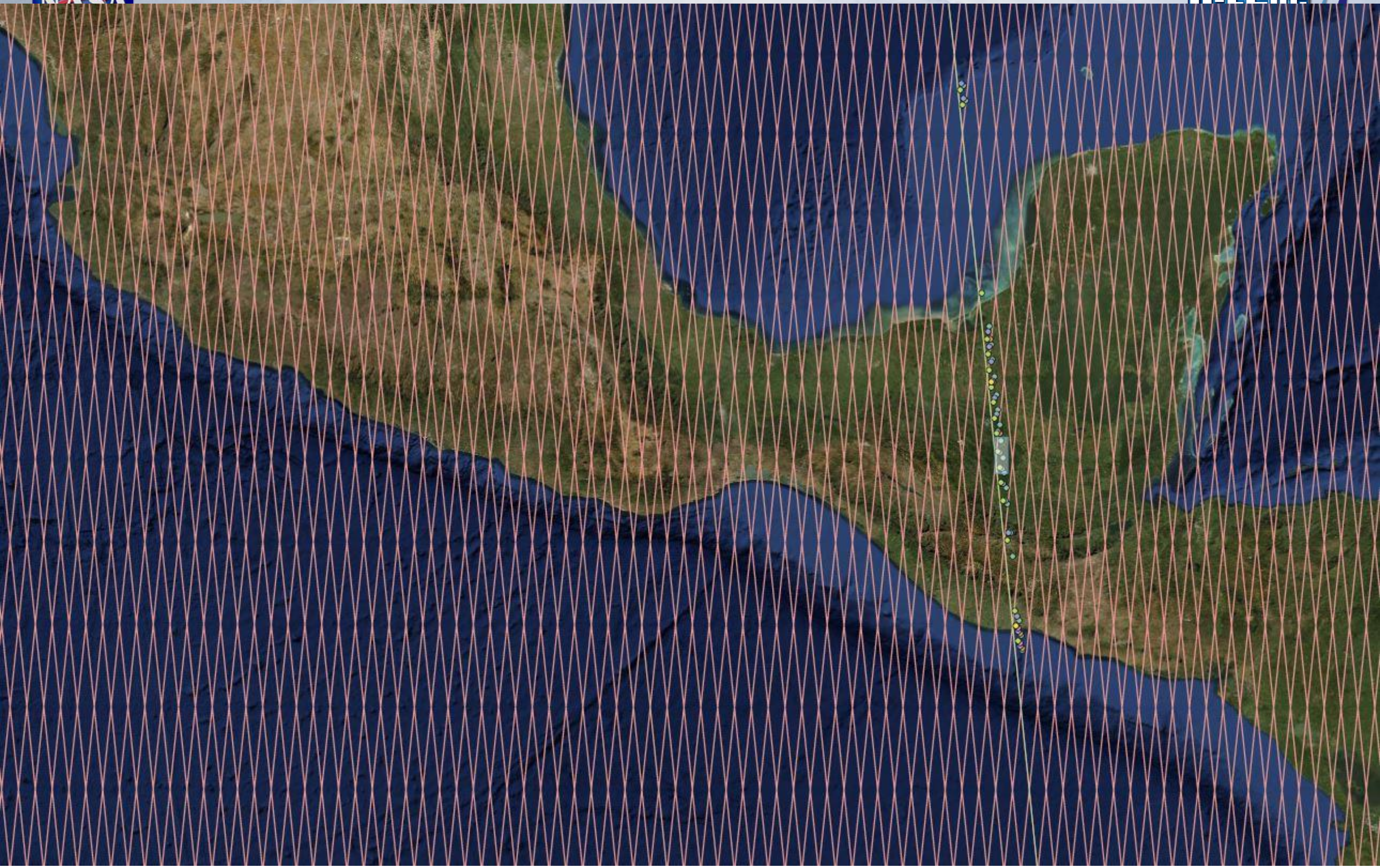
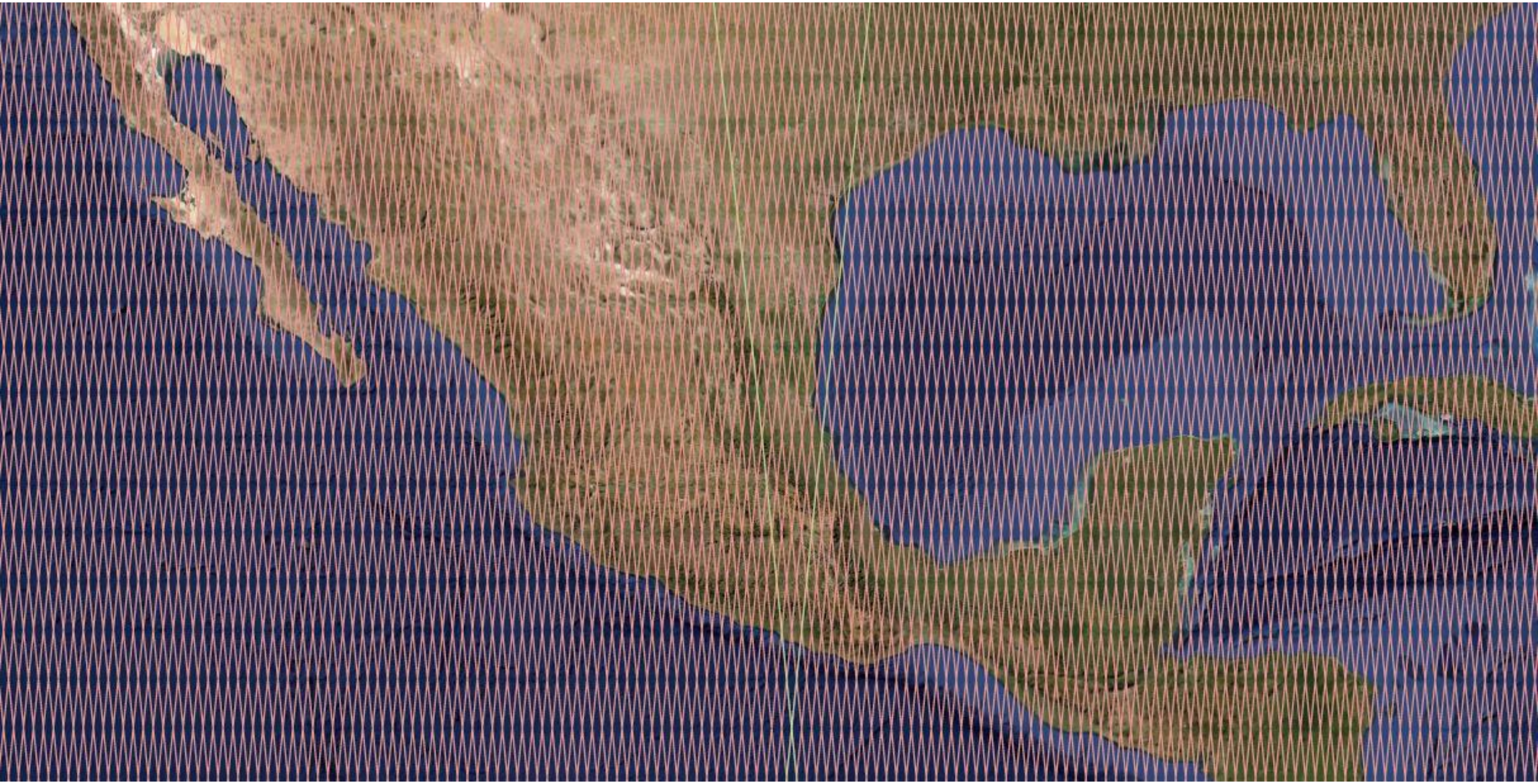
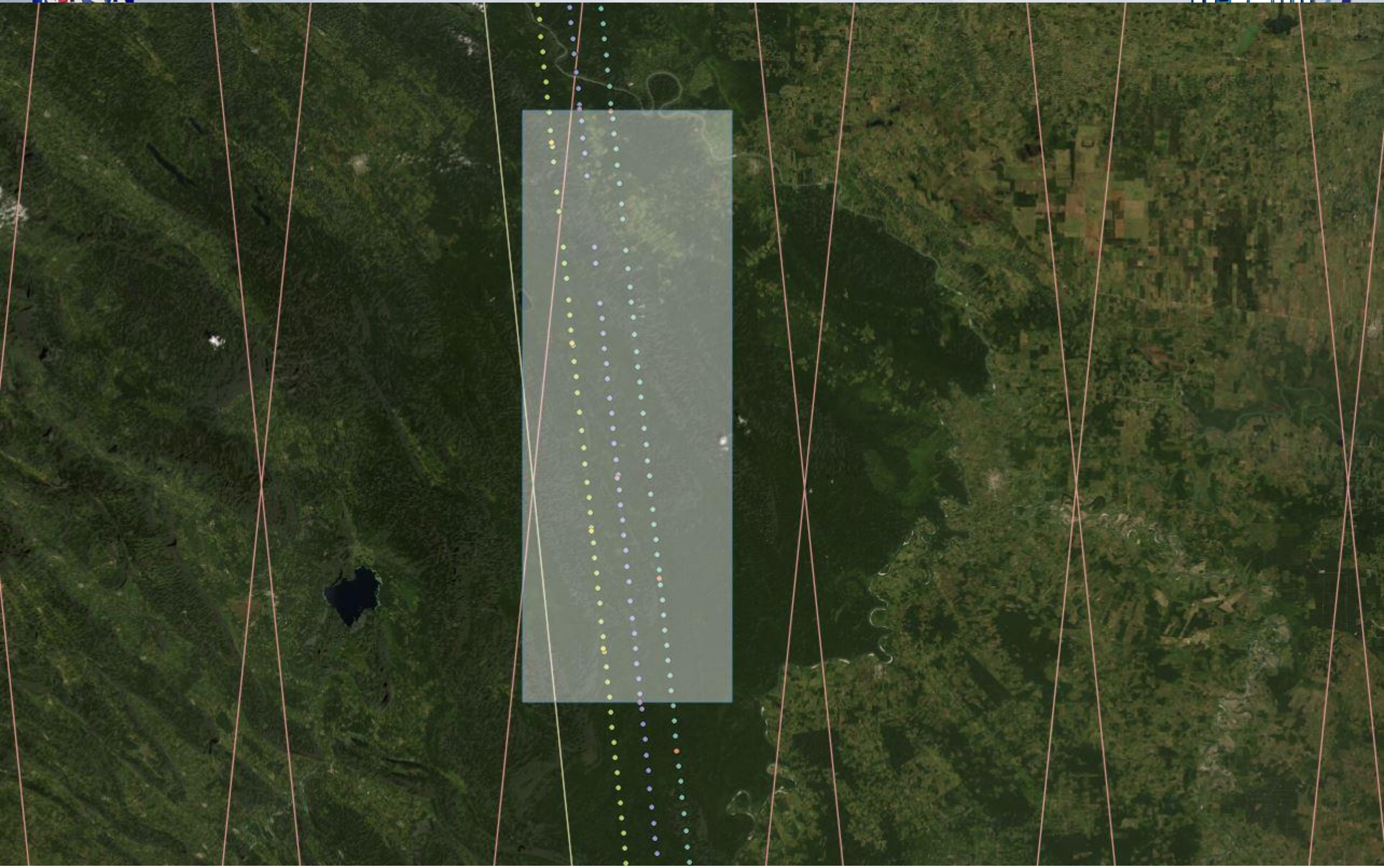
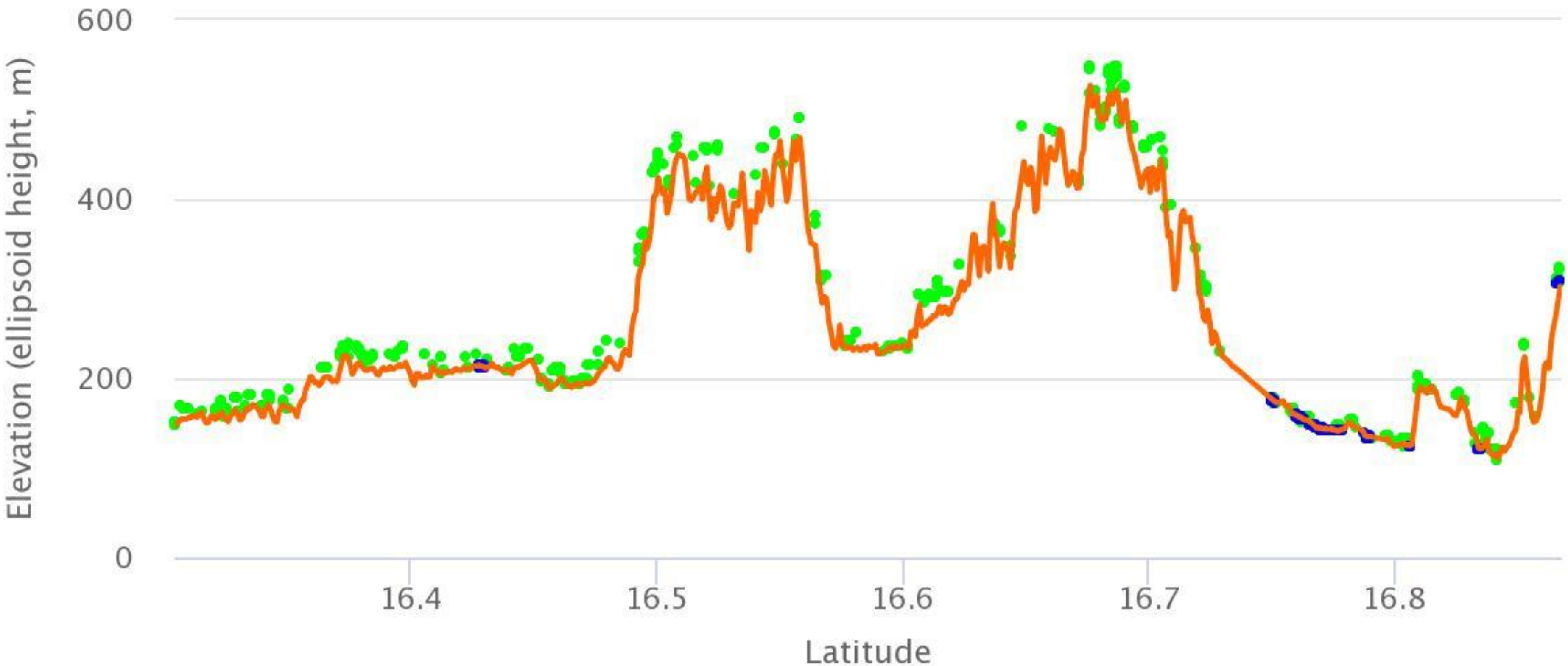






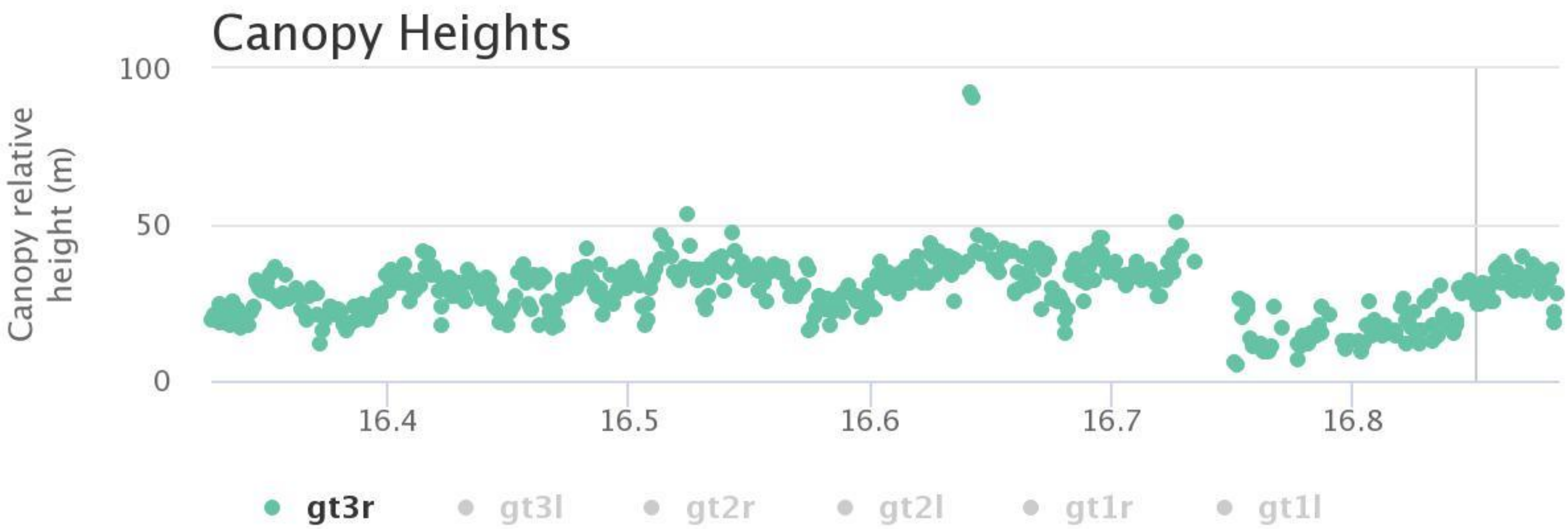
Return Signal Photons

Return Signal Photons

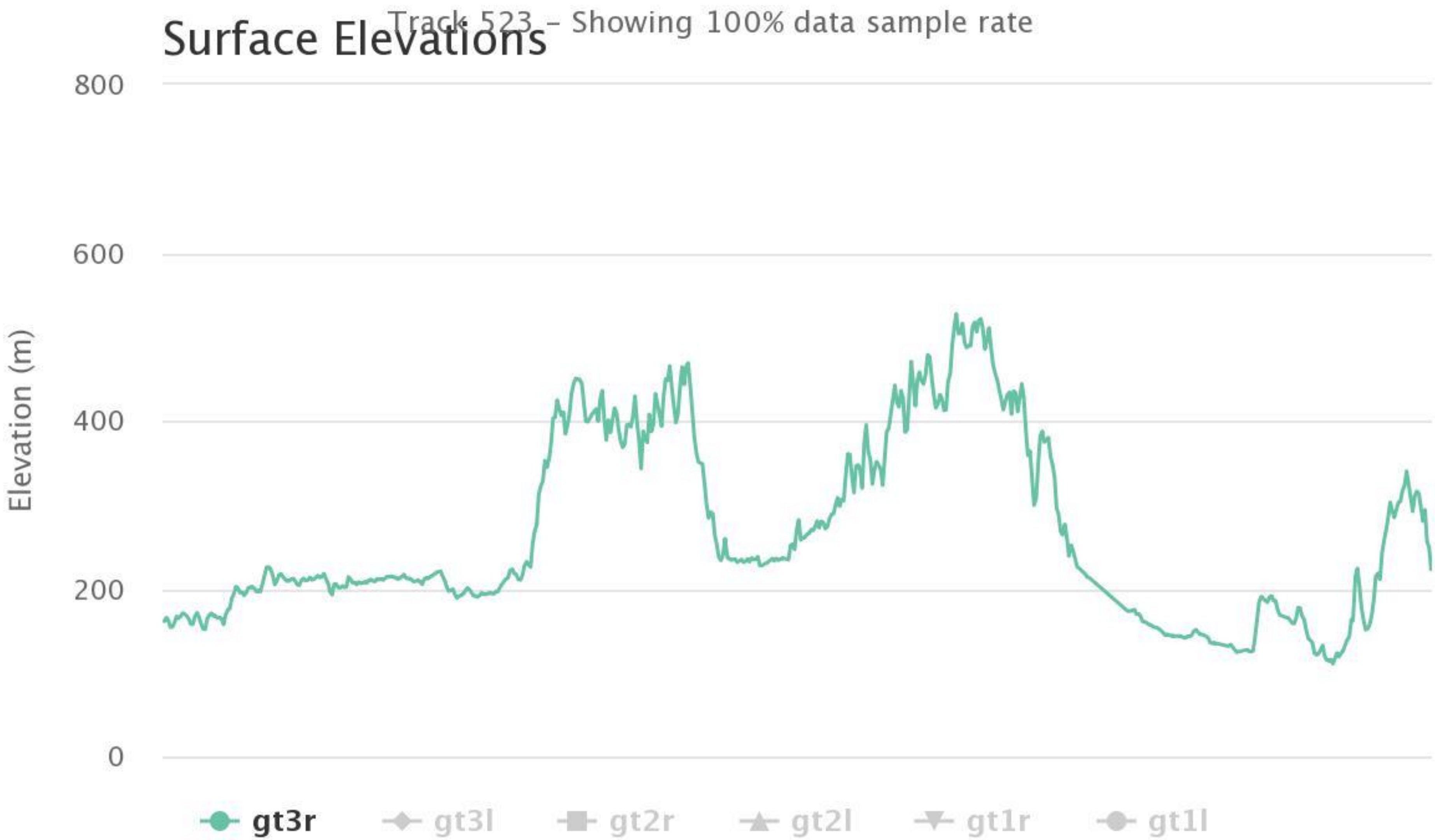


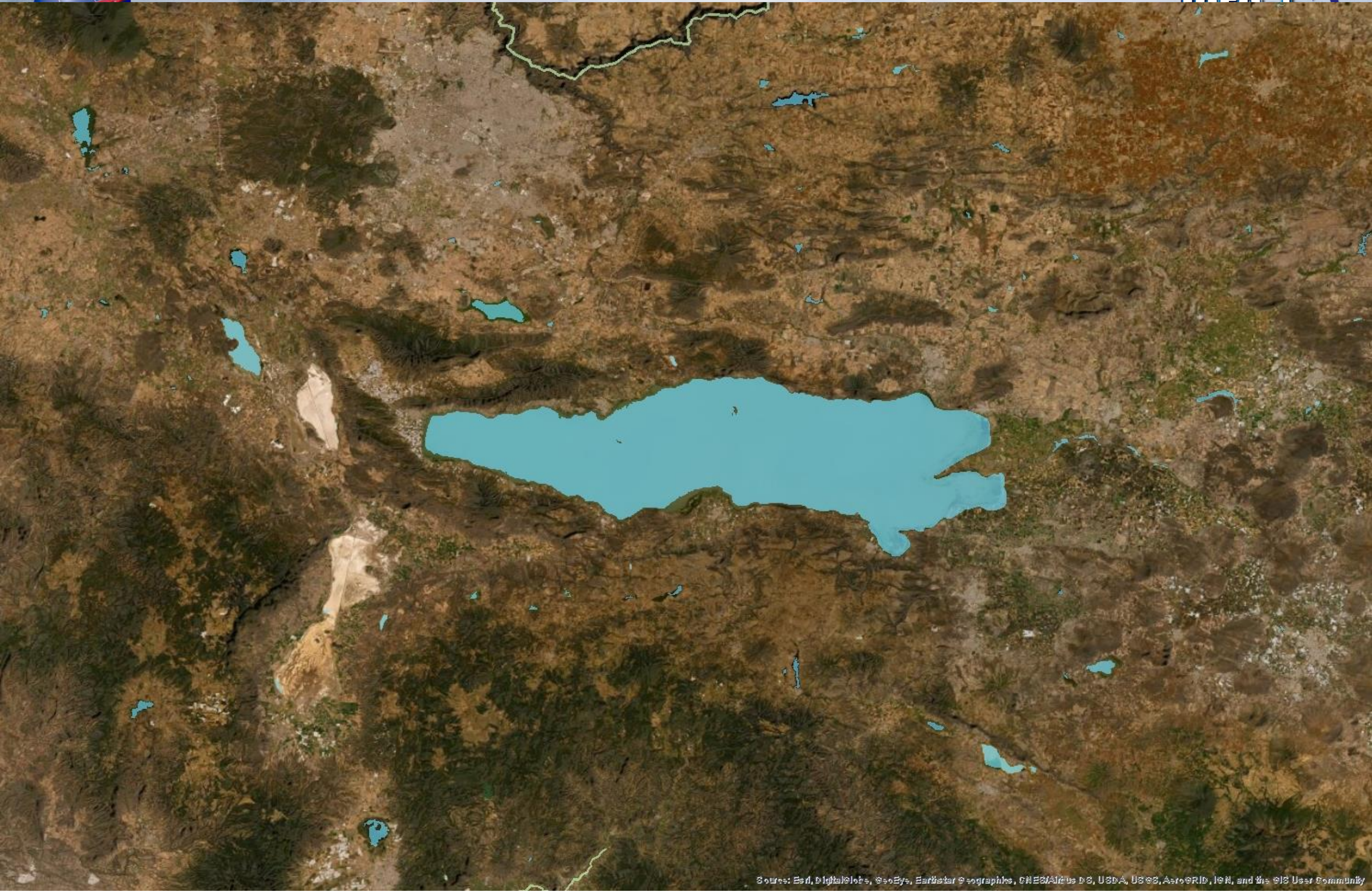
Confidence:

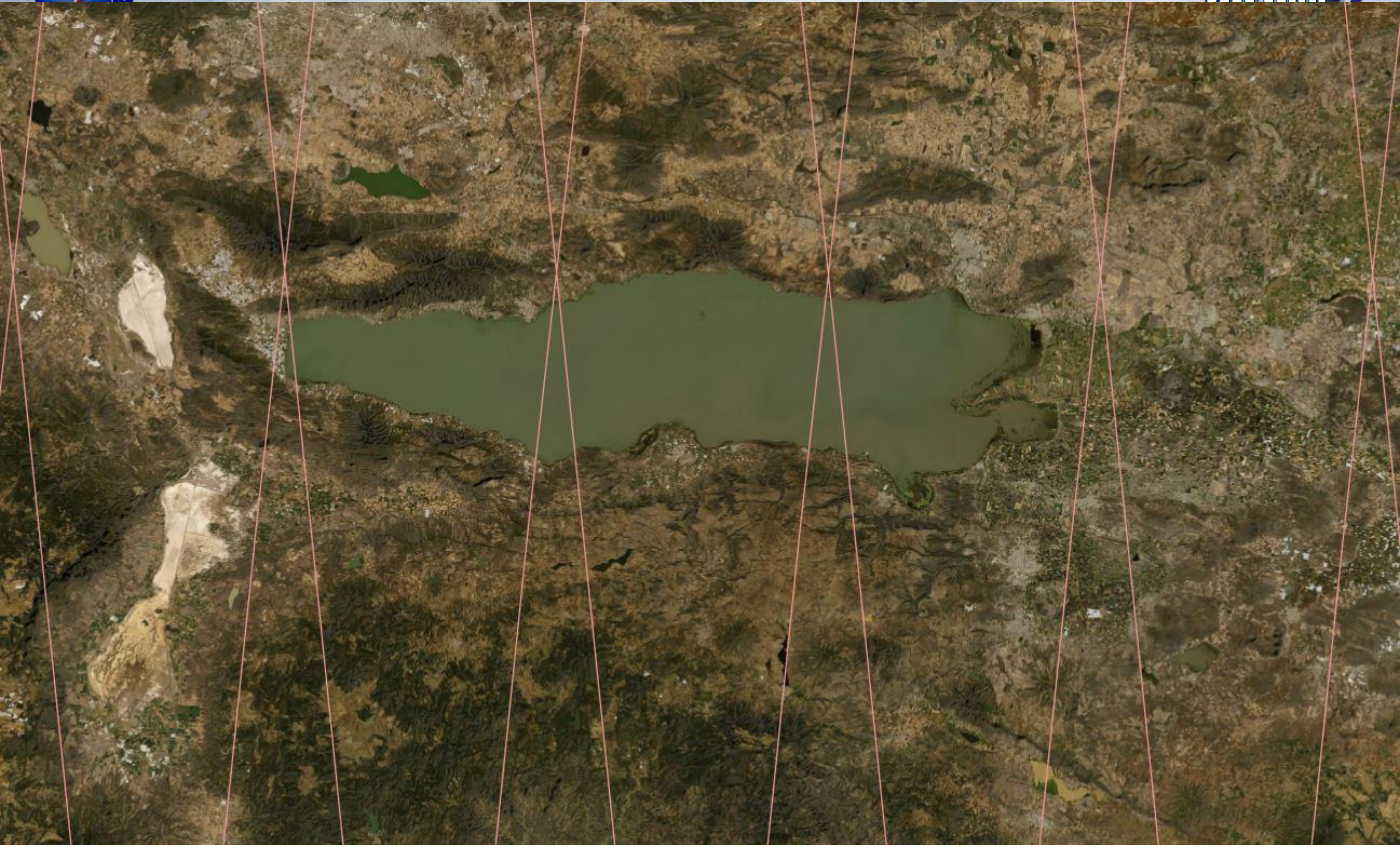
- Noise [41325]
- Buffer [746]
- Low [9957]
- **Medium [848]**
- **High [520]**

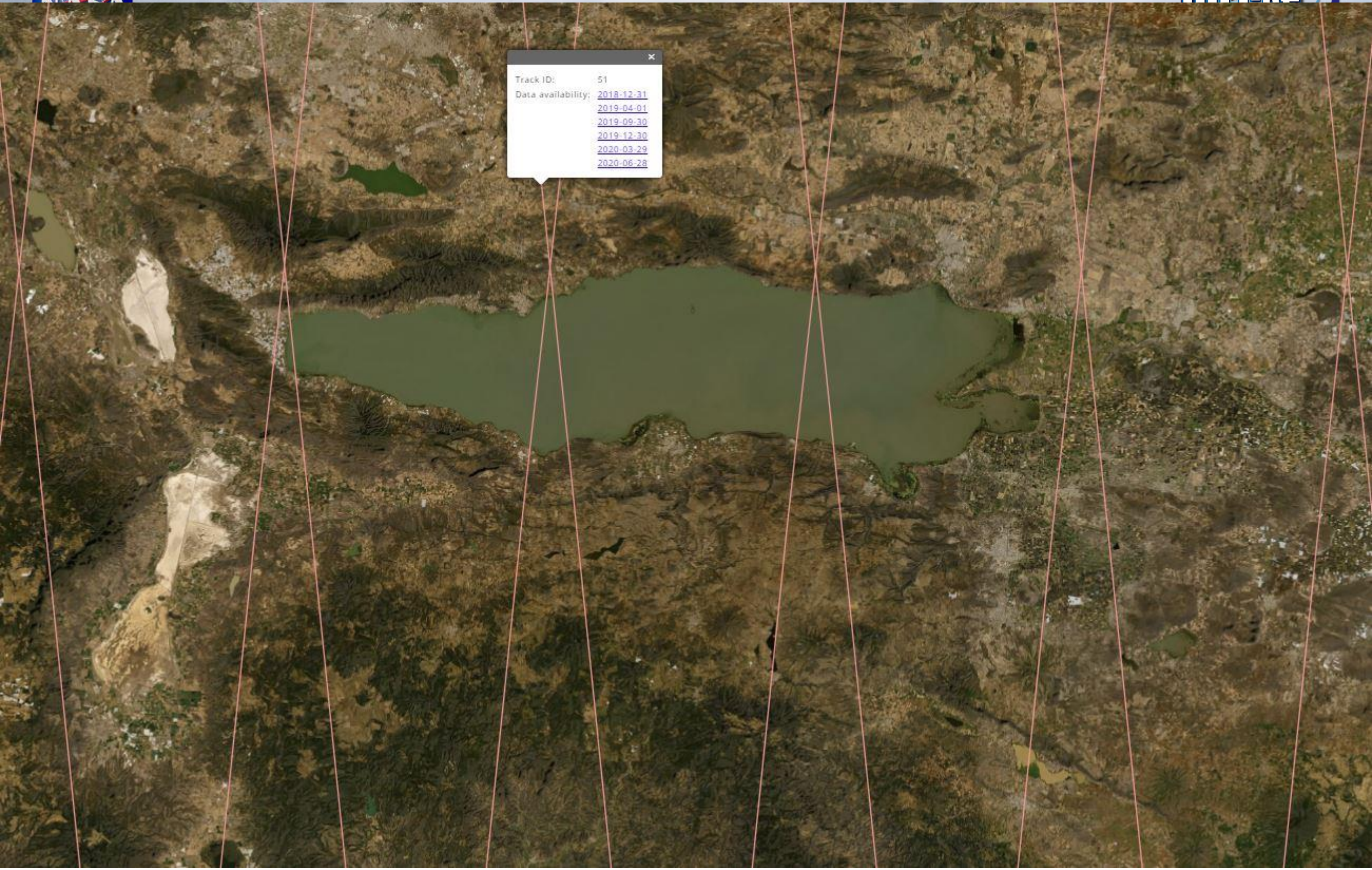

Canopy Heights
Canopy relative height (m)
100
50
0
16.4
16.5
16.6
16.7
16.8
gt3r
gt3l
gt2r
gt2l
gt1r
gt1l

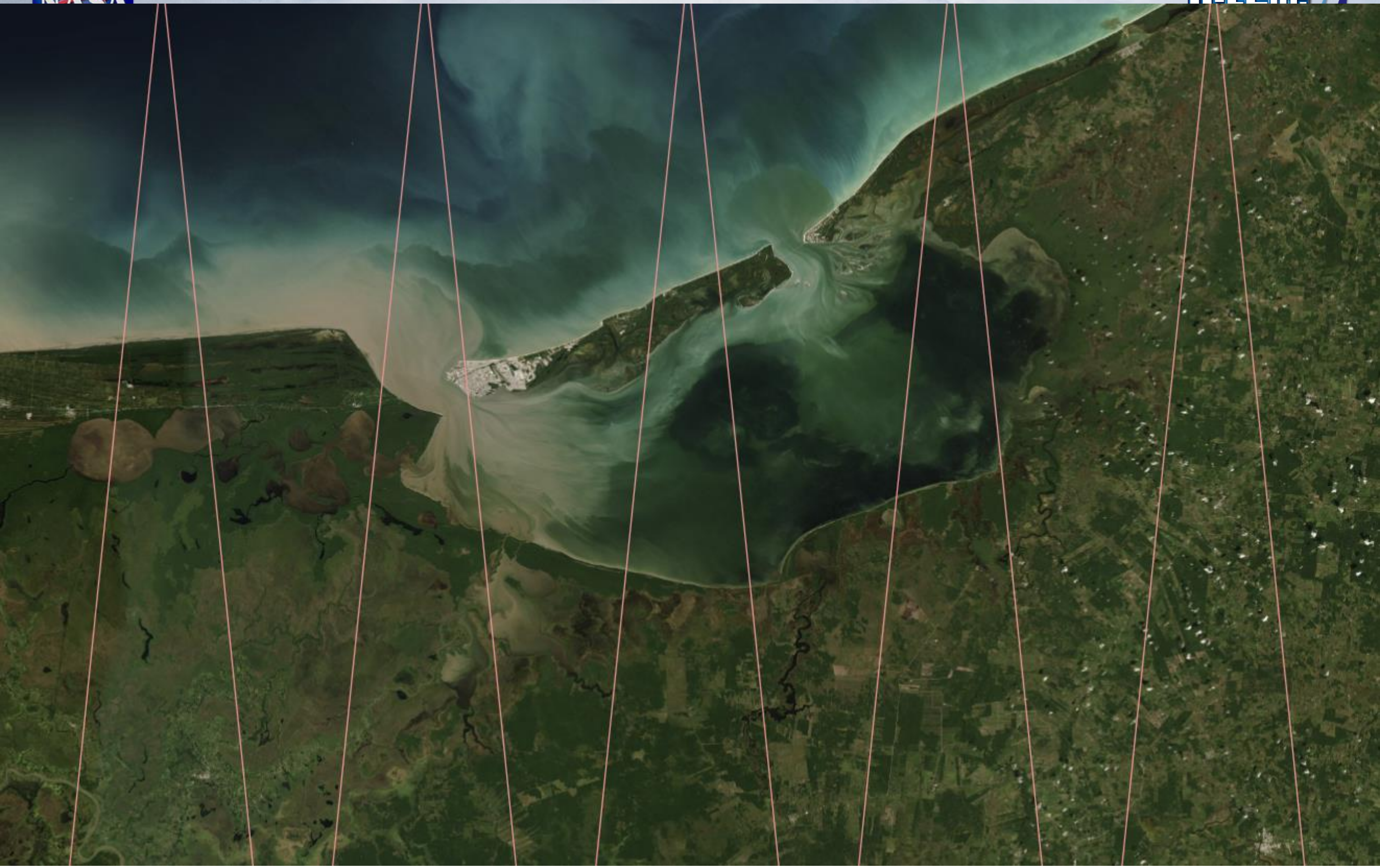
ATL08: Ground Elevation and Canopy Surface




Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community




Track ID: 51
Data availability: 2018-12-31
2019-04-01
2019-09-30
2019-12-30
2020-03-29
2020-06-28

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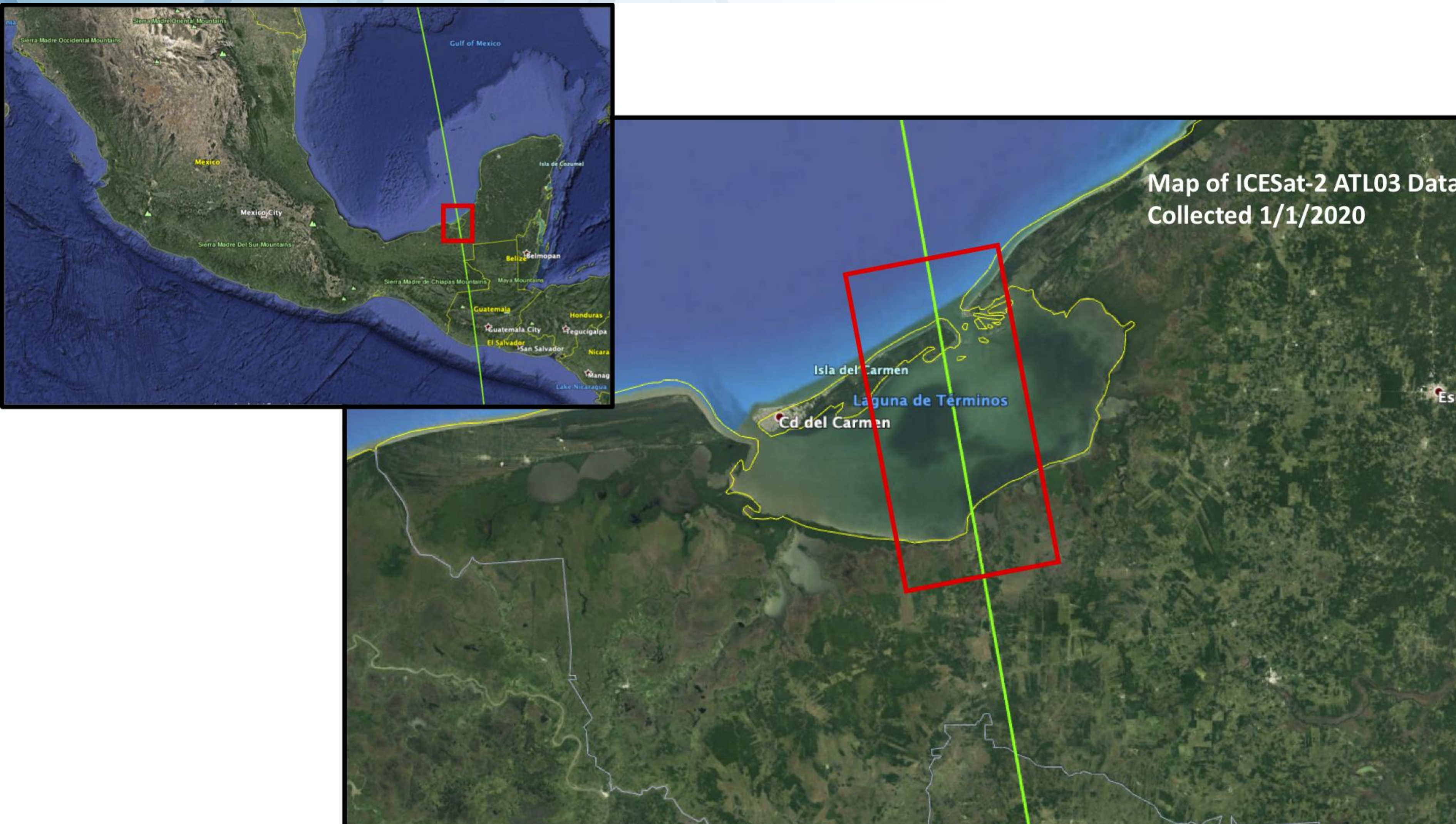
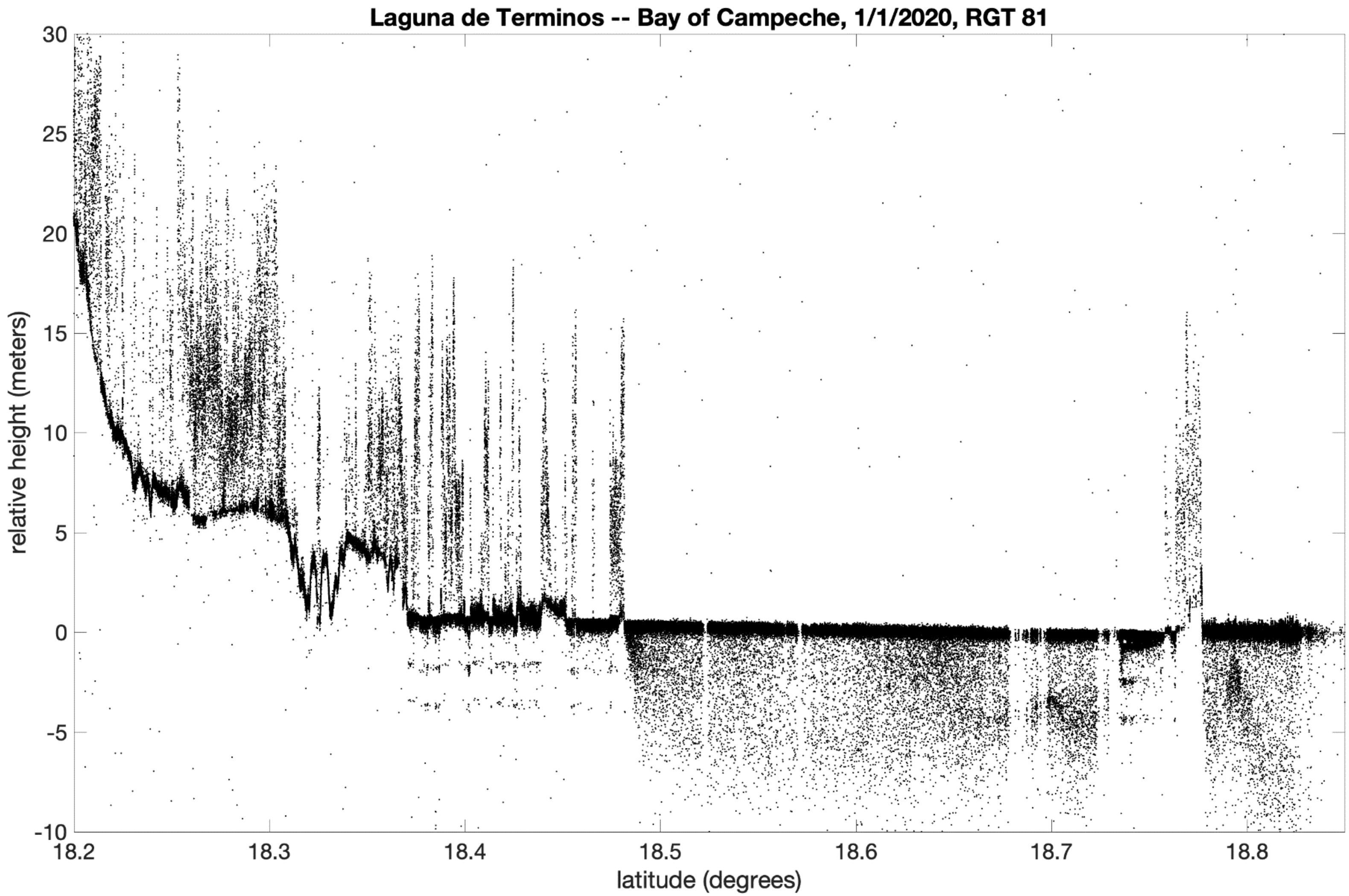

Map of ICESat-2 ATL03 Data
Collected 1/1/2020
Gulf of Mexico
Mexico
Mexico City
Sierra Madre Occidental Mountains
Sierra Madre Oriental Mountains
Sierra Madre Del Sur Mountains
Sierra Madre de Chiapas Mountains
Maya Mountains
Isla de Cozumel
Belize
Belmopan
Guatemala
Guatemala City
Honduras
Tegucigalpa
El Salvador
San Salvador
Lake Nicaragua
Isla del Carmen
Laguna de Términos
Cd del Carmen


Laguna de Terminos -- Bay of Campeche, 1/1/2020, RGT 81
relative height (meters)
latitude (degrees)
30
25
20
15
10
5
0
-5
-10
18.2
18.3
18.4
18.5
18.6
18.7
18.8

Acknowledgements

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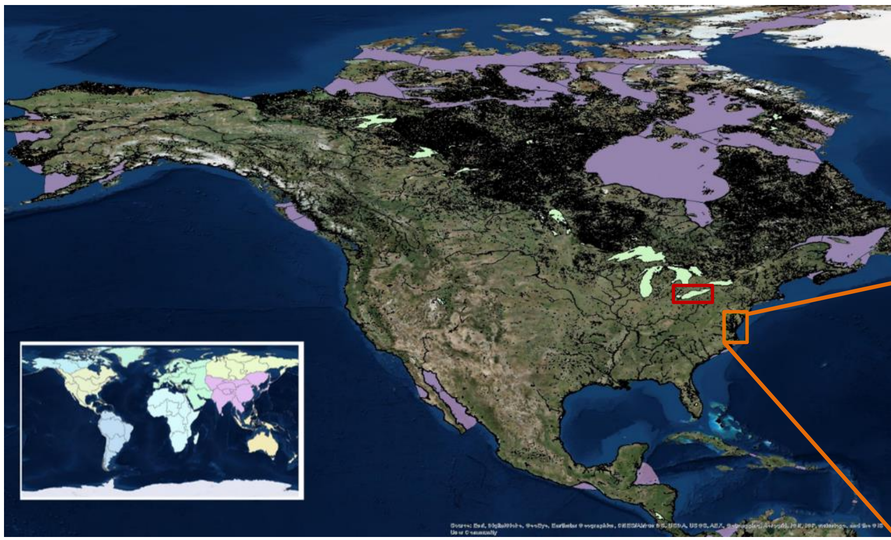
Benjamin Jones, U Alaska
Michael Ondrusek, NOAA STAR
Christopher Parrish, Oregon State
Huilin Gao, Texas A&M U
Charon Birkett, NASA GSFC
Bernhard Lehner, McGill U
Tom Wagner, NASA HQ

Thorsten Marcus, NASA HQ
Tom Neumann, NASA GSFC
Jared Entin, NASA HQ
Jeffrey Lee, NASA
Lisa Callahan, NASA
Kelly Brunt, NASA GSFC
Christopher Hiemstra, CORREL
Sabrina Delgado-Arias, NASA GSFC
Anita Brenner, NASA GSFC
Yao Li, Texas A&M U
Jeffrey Danielson, USGS
Kaitlin Harbeck, NASA GSFC
Eric Stengel, NOAA STAR

Bill Cook, NASA
Yongwei Sheng, UCLA
David Harding, NASA GSFC
Jeremy Kasper, USGS
Krista Bartz, USGS
Jennifer Wozencraft, JALBTCX
Mark Carroll, GSFC
Claudia Carabajal, GSFC
Richard Kelly, U Waterloo
Jeffrey Gerber, GSFC
ICESat-2 Science Team

INLAND WATER

Global Inland Water Coverage



Water Body Types

- Lakes and Reservoirs $\geq$ 1 km^2
- Rivers > ~ 100-200 m
- Transitional water including estuaries, bays & near shore

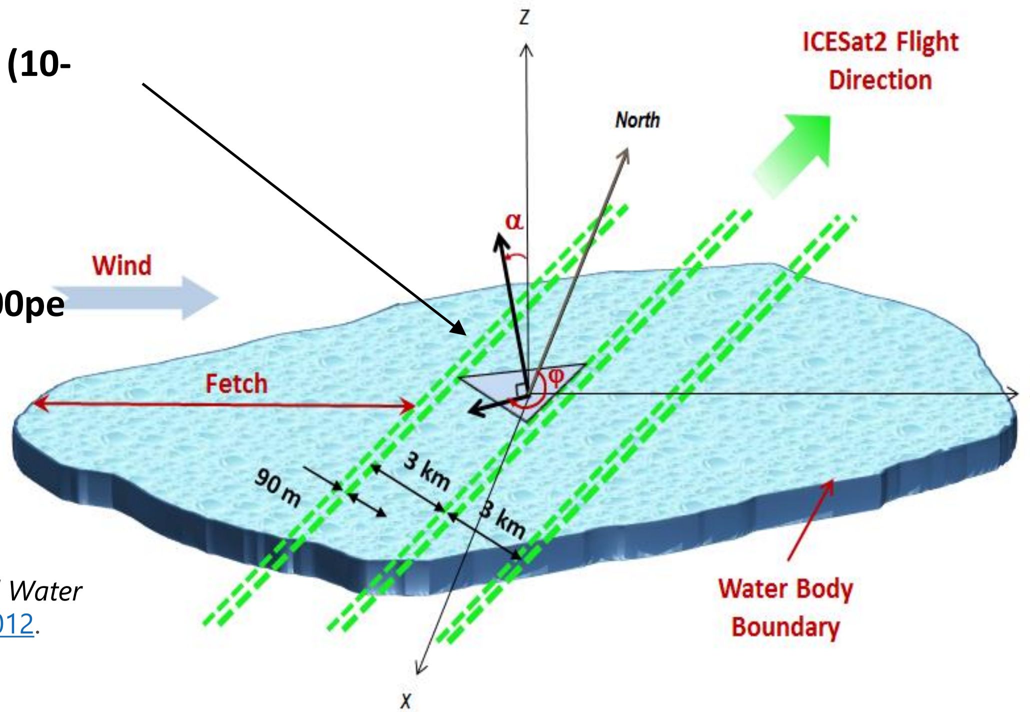
Identification

ATL13 water body mask merged from several databases, each w/unique ID
(E.g. HydroLAKES, GRWL, GSHHG Shoreline)

ATL13 Inland Water Data Product

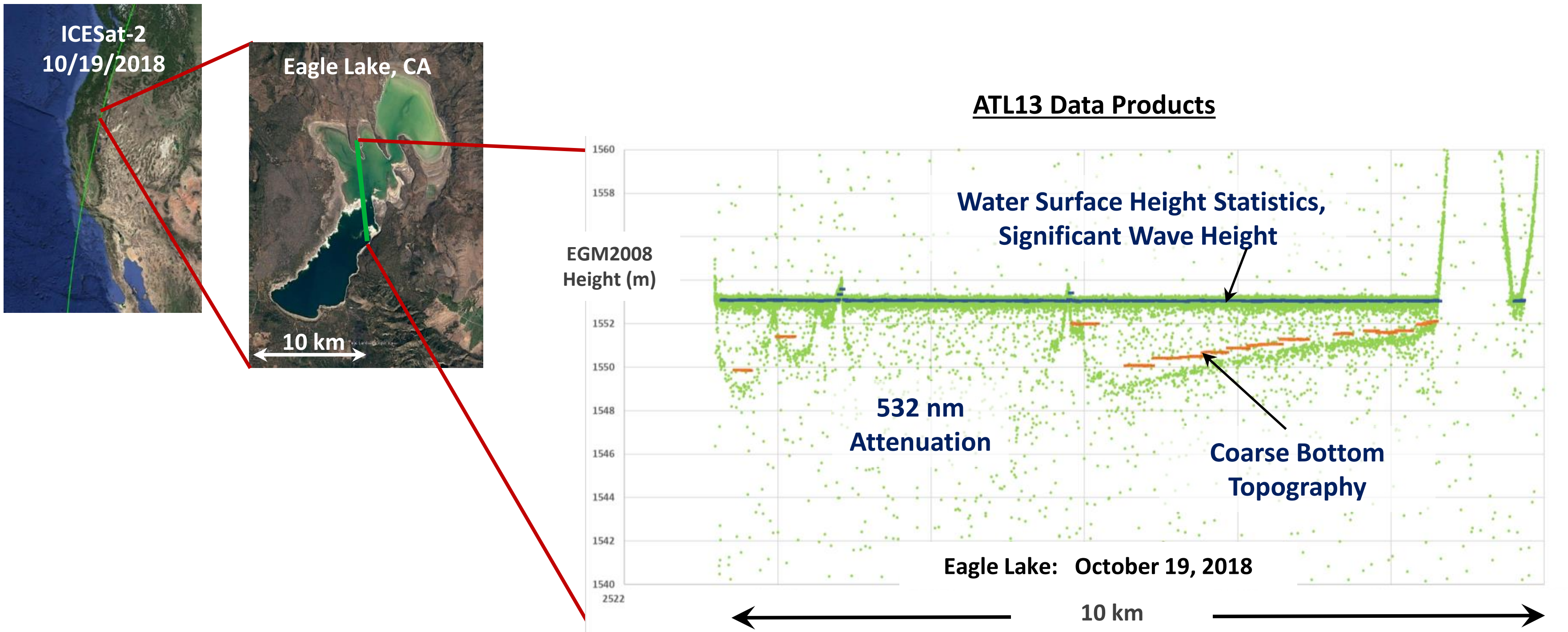
<u>Principal ATL13 products</u>

- Along track surface height stats
Reporting at ~100 pe segment lengths (10-200m)
- Significant Wave height
- Subsurface attenuation
- Coarse Bottom Detection
- Estimated vertical accuracy: 5-10cm/100pe



Jasinski, Stoll, and Coauthors. 2019: *ICESat-2 Inland Water ATBD*, doi: https://doi.org/10.5067/ATLAS/ATL13.0012.

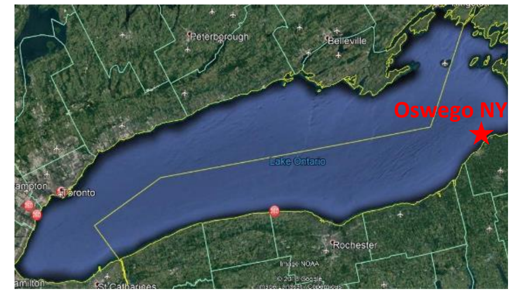
Eagle Lake, October 19, 2018

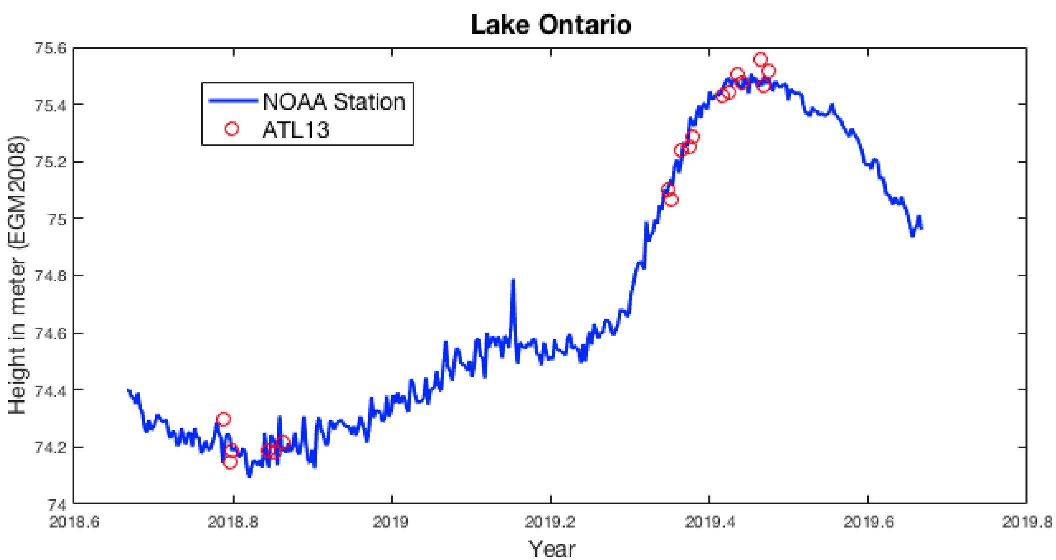


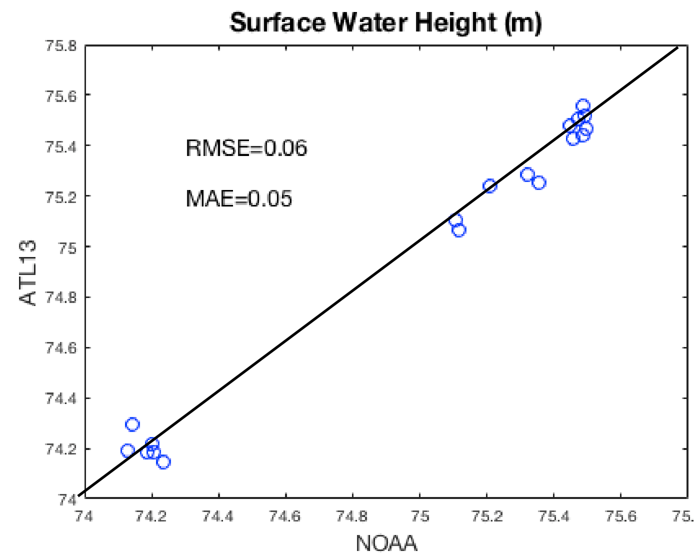
Jasinski, Stoll, Hancock, Robbins, Nattala. 2019: *ICESat-2 Inland Water ATBD*, doi: https://doi.org/10.5067/ATLAS/ATL13.002.

Lake Ontario ATL13 vs NOAA gauge

- Lake Ontario (HydroLake ID=7)
- Oswego, NY – NOAA Station ID: 9052030
- ATL13 Rel 002, EGM2008, median values)
- Evaluation metrics: RMSE = 0.06m, Absolute Mean Error =0.05m
- Evaluation period: 9/1/2018 – 11/18/2018; 5/1/2019 - 6/26/2019







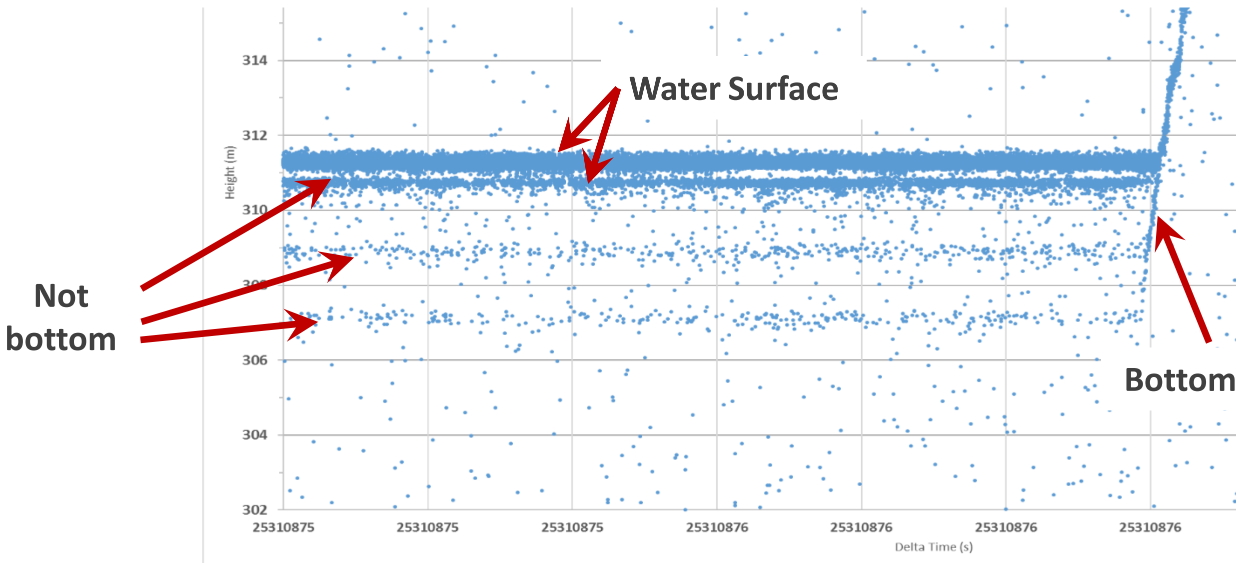
ATL13 Status

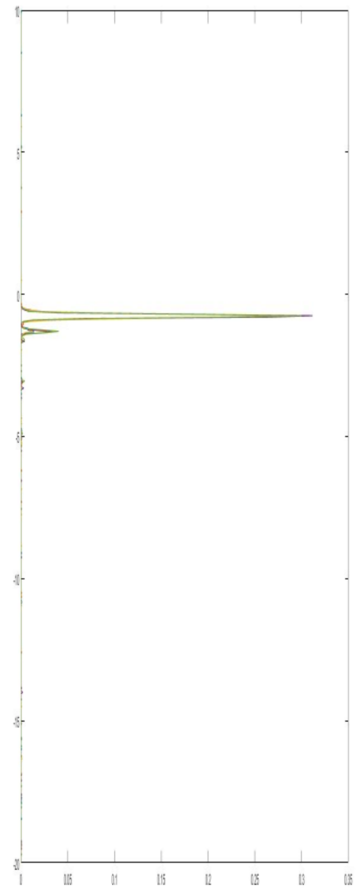
ATL13 Version	Release Date	Water Body Types	Description & Principal Features
1	May 2019	Lakes > 10 km^2 (19,634 lakes)	- Surface water height statistics (mean, StdDev, slope), significant wave height, subsurface attenuation, and supporting variables, reported at short segment length scale (~30-200m) - Employs GLWD (Lehner & Doll 2004)
2	November 2019	Lakes & reservoirs $\geq$ 1 km^2; (185,181 lakes) Estuaries and bays, Near shore buffer (7km)	- Replaces GLWD with HydroLAKES (Messager & Lehner, 2016) - Adds coarse bottom finding algorithm - Adds dynamic shore finding - Employs Named Marine Water Bodies (ESRI) - Employs GSHHG Shoreline (Wessel et al, 1996)
3	April 2020	Above plus rivers; All lakes > 0.01 km^2	- Employs GRWL (After Allen and Pavelsky, 2018) to create river mask - Adds Ice on/off flag from multi-sensor NOAA product - Flags/corrects dead-time error
ATL22	April 2020	All water bodies	- Transect mean and supporting quantities

ATL13 Status

Inland Water ATBDs	Release Date	Water Body Types	Description & Principal Features
ATL13 Ver 1	May 28, 2019	Lakes > 10 km^2 (19,634 lakes)	- Computes full surface water statistics at short segment lengths - Uses GLWD (Lehner & Doll 2004)
ATL13 Ver 1	December 2019	Lakes & reservoirs $\geq$ 1 km^2; (185,181 lakes) Adds estuaries and bays, near shore buffer	- Replaces GLWD with HydroLAKES (Messager & Lehner, 2016) - Adds coarse bottom finding algorithm - Adds dynamic shore finding
ATL13 Ver 1	April 2020	Adds rivers; Incl. HydroLAKES >0.1km^2	- Uses GRWL (After Allen and Pavelsky, 2018) to create river mask - Adds Ice on/off flag from multi-sensor NOAA product - Flags/corrects dead-time error
ATL22 Ver 1	April 2020	All	- Adds transect mean quantities

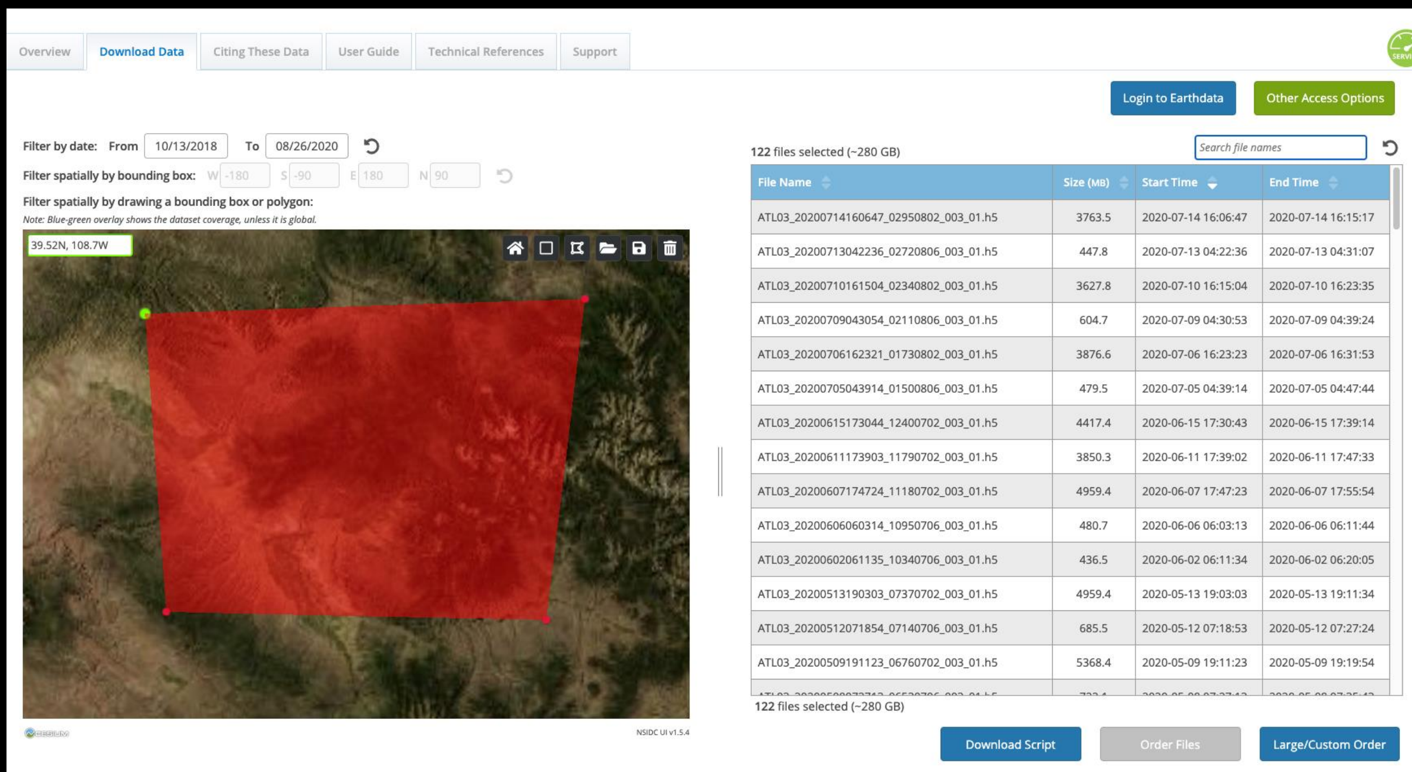
Known Issue:
Striping in high surface reflectance





Grand Mesa, CO

via NSIDC spatial search tool



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ATL03_20200709043054_02110806_003_01.h5	604.7	2020-07-09 04:30:53	2020-07-09 04:39:24
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ATL03_20200607174724_11180702_003_01.h5	4959.4	2020-06-07 17:47:23	2020-06-07 17:55:54
ATL03_20200606060314_10950706_003_01.h5	480.7	2020-06-06 06:03:13	2020-06-06 06:11:44
ATL03_20200602061135_10340706_003_01.h5	436.5	2020-06-02 06:11:34	2020-06-02 06:20:05
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ATL03_20200509191123_06760702_003_01.h5	5368.4	2020-05-09 19:11:23	2020-05-09 19:19:54

Grand Mesa, CO

Reference Ground Tracks
repeat every 91 days

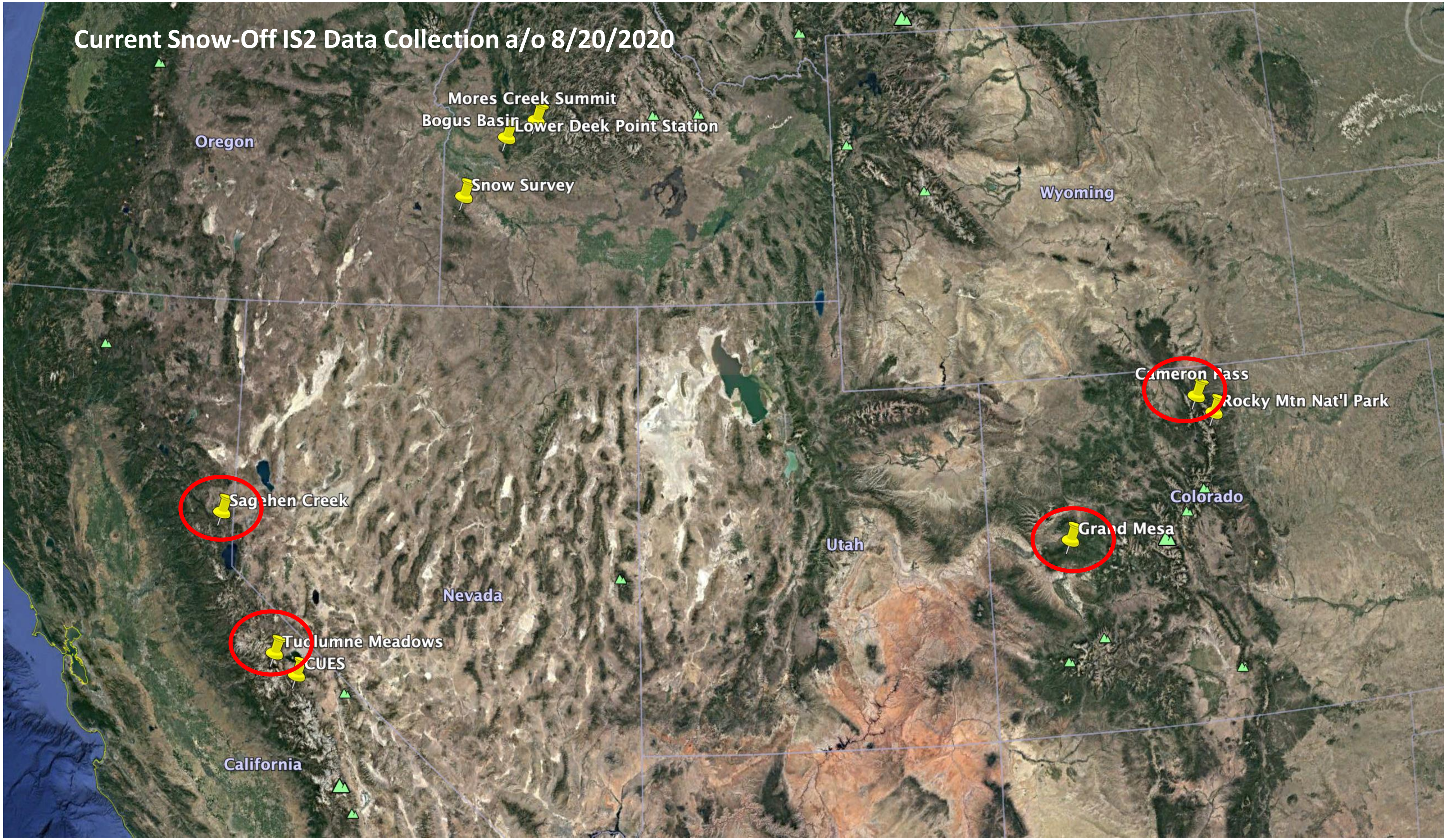
Cycle 9 begins late September 2020

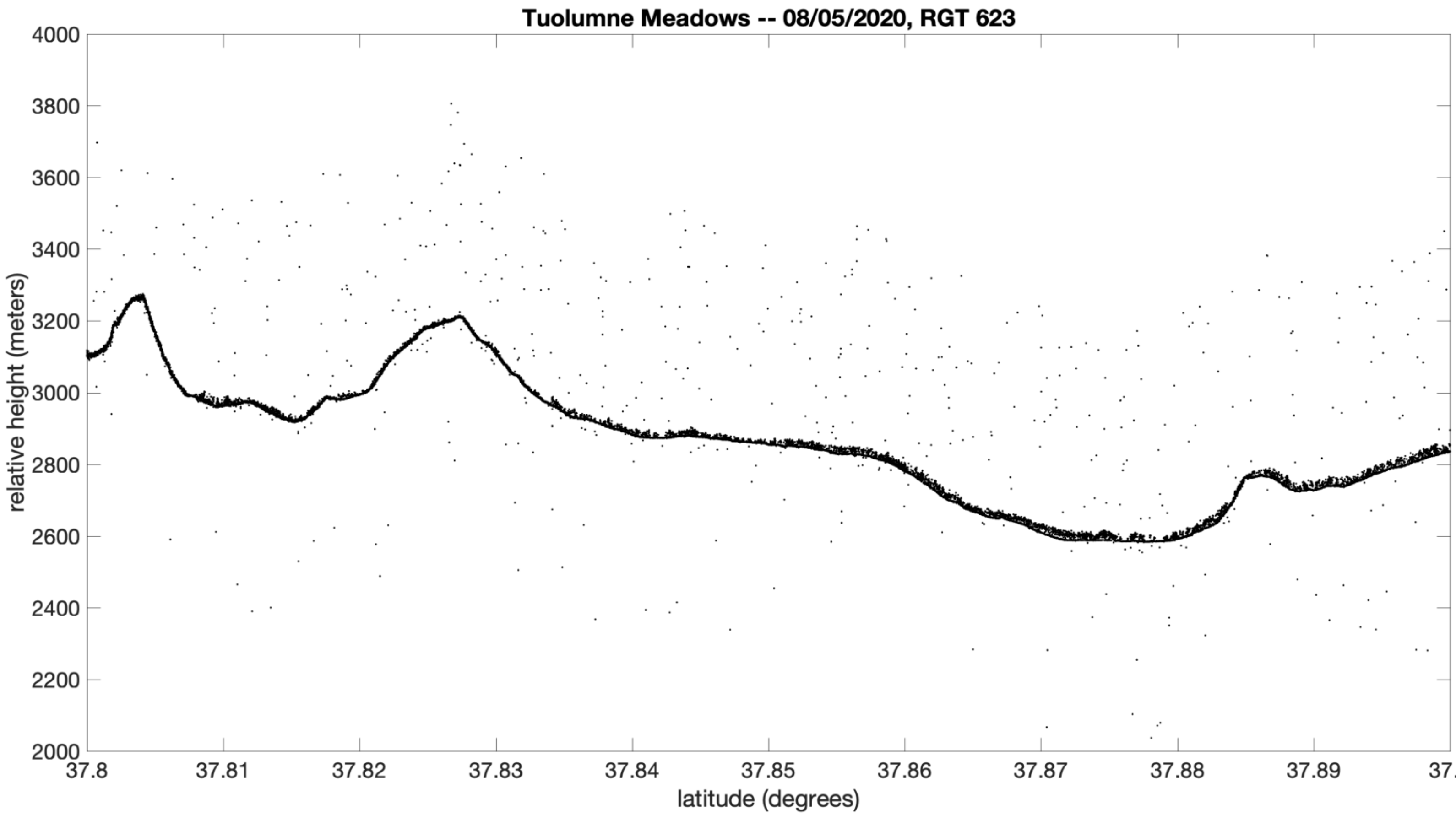
5 RGTs intersect Grand Mesa every 91 days:

211
714
737
1156
1179

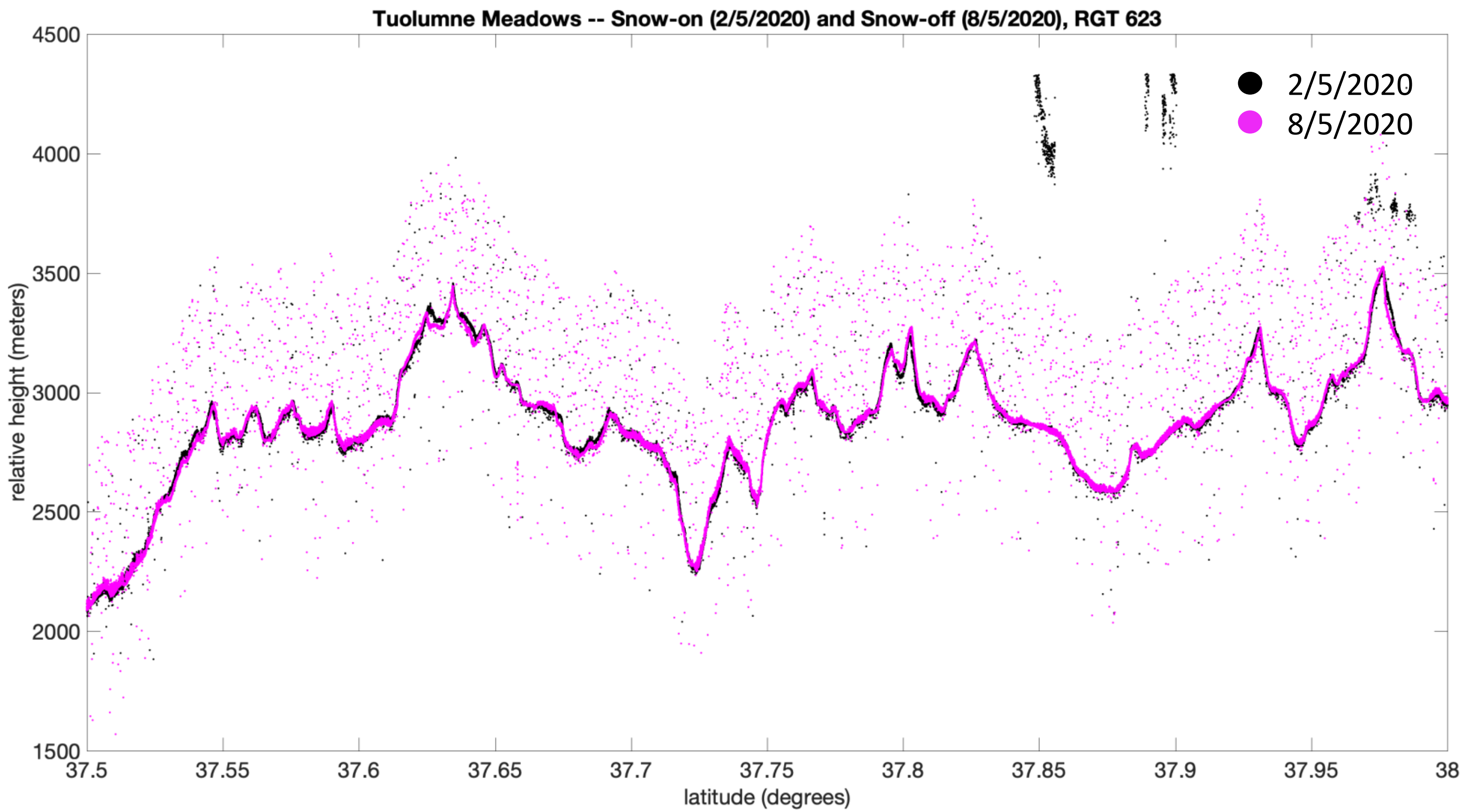
Some are ascending passes, some descending

Yellow is right pair
Green is center pair
Blue is left pair
Tracks from Cycle 1 through Cycle 6 are shown

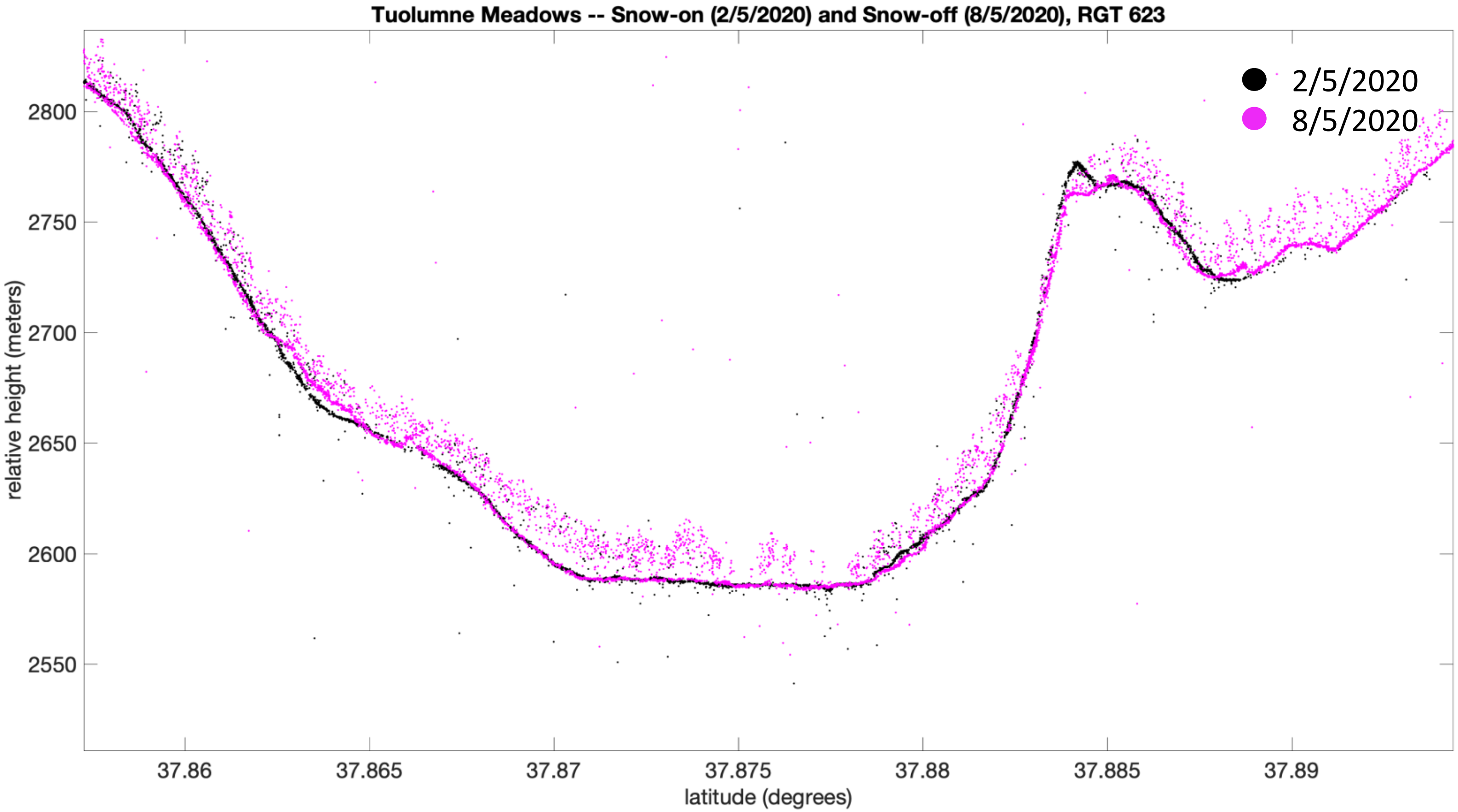

Current Snow-Off IS2 Data Collection a/o 8/20/2020
Mores Creek Summit
Bogus Basin
Lower Deek Point Station
Snow Survey
Oregon
Wyoming
Cameron Pass
Rocky Mtn Nat'l Park
Sagehen Creek
Colorado
Grand Mesa
Utah
Nevada
Tuolumne Meadows
CUES
California



Tuolumne Meadows -- 08/05/2020, RGT 623
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
relative height (meters)
37.8
37.81
37.82
37.83
37.84
37.85
37.86
37.87
37.88
37.89
37.9
latitude (degrees)



Tuolumne Meadows -- Snow-on (2/5/2020) and Snow-off (8/5/2020), RGT 623
2/5/2020
8/5/2020
relative height (meters)
4500
4000
3500
3000
2500
2000
1500
37.5
37.55
37.6
37.65
37.7
37.75
37.8
37.85
37.9
37.95
38
latitude (degrees)


Tuolumne Meadows -- Snow-on (2/5/2020) and Snow-off (8/5/2020), RGT 623
2/5/2020
8/5/2020
relative height (meters)
2800
2750
2700
2650
2600
2550
37.86
37.865
37.87
37.875
37.88
37.885
37.89
latitude (degrees)

ICESat-2
ICE, CLOUD, AND LAND ELEVATION SATELLITE-2

Pointing at SnowEx Sites

NASA

Idaho Snow On Status

Name	Date of Orbit	Site group(s)*					TOO STATUS
RGT 341	18 Jan 2020	Banner Summit	Bull Trout Lake	Canyon Creek	Fox Tail Ridge		Performed; cloudy.
RGT 379	20 Jan 2020	Banner Summit	Bull Trout Lake	Canyon Creek	Fox Tail Ridge		Performed; cloudy.
RGT 402	22 Jan 2020	Bogus Basin	Lower Deer Point Station				Performed; cloudy.
RGT 440	24 Jan 2020	Bogus Basin	Lower Deer Point Station				Not performed; exceeded pointing constraints (6.30 d
RGT 463	26 Jan 2020	Snow Survey	Scan 1	Scan 2	RCEW HQ	cabins at RME	Performed; cloudy.
RGT 501	28 Jan 2020	Snow Survey	Scan 1	Scan 2	RCEW HQ	cabins at RME	Performed; cloudy.
RGT 783	15 Feb 2020	Banner Summit	Bull Trout Lake	Canyon Creek	Fox Tail Ridge		Not performed; exceeded pointing constraints (7.08 d
RGT 821	18 Feb 2020	Banner Summit	Bull Trout Lake	Canyon Creek	Fox Tail Ridge		Not performed; exceeded pointing constraints (7.08 d
RGT 844	19 Feb 2020	Bogus Basin	Lower Deer Point Station				Fatal; exceeds pointing constraints.
RGT 882	22 Feb 2020	Bogus Basin	Mores Creek Summit	Mores Creek Summit - SNOTEL			Looks AWESOME in rapid ATL03!
RGT 905	23 Feb 2020	Snow Survey	Scan 1	Scan 2	RCEW HQ	cabins at RME	Looks AWESOME in rapid ATL03!
RGT 943	26 Feb 2020	Snow Survey	Scan 1	Scan 2	RCEW HQ	cabins at RME	Looks AWESOME in rapid ATL03!
RGT 1286	19 Mar 2020	Mores Creek Summit	Mores Creek Summit - SNOTEL				Performed; comically cloudy over your TOO.
RGT 1324	22 Mar 2020	Mores Creek Summit	Mores Creek Summit - SNOTEL				Looks AWESOME in rapid ATL03!
RGT 1385	26 Mar 2020	Lower Deer Point Station					Looks AWESOME in rapid ATL03!

Summer Snow Off Status

Name	Date of Orbit	Site	Latitude	Longitude	TOO Status	TOO ID	
RGT 211	7/9/2020	Grand Mesa MM Tower	39.0395	-107.942	confirmed	1571	clear and good data quality
RGT 272	7/13/2020	Grand Mesa MW Tower	39.0339	-108.214	confirmed	1572	looks like it was cloudy right over your target :(
RGT 295	7/14/2020	Grand Mesa MW Tower	39.0339	-108.214	confirmed	1573	much better!
RGT 531	OFF LIMITS	Cameron Pass	40.5186	-105.8917	OFF LIMITS		
RGT 554	7/31/2020	Cameron Pass	40.5186	-105.8917	confirmed	1623	clear and good data quality
RGT 623	8/5/2020	Tuolumne Meadows	37.875962	-119.363387	confirmed	1627	clear and good data quality
RGT 745	8/13/2020	Sagehen Creek	39.43021	-120.23960	confirmed	1652	clear and good data quality
RGT 768	8/14/2020	Sagehen Creek	39.43021	-120.23960	confirmed	1653	cloudy throughout the region :(
RGT 882	8/22/2020	Bogus Basin	43.932074	-115.665987	confirmed	1673	
RGT 905	8/23/2020	Snow Survey	43.066476	-116.757682	confirmed	1674	
RGT 943	8/26/2020	Snow Survey	43.066476	-116.757682	submitted	1675	
RGT 996	8/29/2020	Rocky Mountain National	40.3129	-105.6483	submitted	1688	
RGT 1065	9/3/2020	CUES	37.643	-119.029	submitted	1698	
RGT 1126	9/7/2020	Tuolumne Meadows	37.875962	-119.363387	submitted	1699	
RGT 1187	9/11/2020	Sagehen Creek	39.43021	-120.23960			
RGT 1324	9/20/2020	Mores Creek Summit	43.932074	-115.665987			
RGT 1385	9/24/2020	Lower Deer Point Station	43.737047	-116.122066			

California Snow On Status

Name	Date of Orbit	Site	TOO Status
RGT 120	3 Jan 2020	CUES	
RGT 181	7 Jan 2020	Tuolumne Meadows	
RGT 204	9 Jan 2020	CUES	
RGT 242	11 Jan 2020	Sagehen Creek	
RGT 265	13 Jan 2020	Tuolumne Meadows	
RGT 326	17 Jan 2020	Sagehen Creek	
RGT 623	5 Feb 2020	Tuolumne Meadows	Looks AWESOME in rapid ATL03!
RGT 623	5 Feb 2020	CUES	Not performed; exceeded pointing constraints (6.80 d
RGT 707	11 Feb 2020	Tuolumne Meadows	Fatal; exceeds pointing constraints.
RGT 707	11 Feb 2020	CUES	Fatal; exceeds pointing constraints.
RGT 745	13 Feb 2020	Sagehen Creek	Looks AWESOME in rapid ATL03!
RGT 768	15 Feb 2020	Sagehen Creek	Looks AWESOME in rapid ATL03!
RGT 1065	5 Mar 2020	CUES	Looks AWESOME in rapid ATL03!
RGT 1126	9 Mar 2020	Tuolumne Meadows	Looks AWESOME in rapid ATL03!
RGT 1149	10 Mar 2020	Tuolumne Meadows	Performed; cloudy.
RGT 1149	10 Mar 2020	CUES	Not performed; too close in proximity to TOO ID 1358
RGT 1187	13 Mar 2020	Sagehen Creek	Looks AWESOME in rapid ATL03!
RGT 1210	14 Mar 2020	Sagehen Creek	Performed; cloudy.

Colorado Snow On Status

Date	Orbit	Site	Lat	Lon		TOO Status
1/30/2020	531	Cameron Pass	40.5186	-105.8917	Crossing of two tracks (531/554)	Looks good in rapid ATL03!
1/31/2020	554	Cameron Pass	40.5186	-105.8917	Crossing of two tracks (531/554)	Looks *maybe* good in rapid ATL03!
2/11/2020	714	Grand Mesa SWESARR north intersect	39.032990	-108.180517		Not performed; exceeds offpointing constraints (7.18 deg)
2/12/2020	737	Grand Mesa SWESARR south intersect	39.016432	-108.161671		Not performed; exceeds offpointing constraints (7.34 deg)
2/28/2020	973	Rocky Mountain National Park	40.3129	-105.6483	Crossing of two tracks (973/996)	Rejected; request was for off-limit RGT
2/29/2020	996	Rocky Mountain National Park	40.3129	-105.6483	Crossing of two tracks (973/996)	Looks AWESOME in rapid ATL03!
4/9/2020	211	Grand Mesa MM Tower	39.0395	-107.942	met tower with snow depth obs	Looks awesome in rapid ATL03!
4/10/2020	234	Grand Mesa ME Tower	39.1037	-107.884	met tower with snow depth obs	Rejected; request was for off-limit RGT
4/13/2020	272	Grand Mesa MW Tower	39.0339	-108.214	met tower with snow depth obs	Looks good in rapid ATL03!
4/14/2020	295	Grand Mesa MW Tower	39.0339	-108.214	met tower with snow depth obs	Looks AWESOME in rapid ATL03!

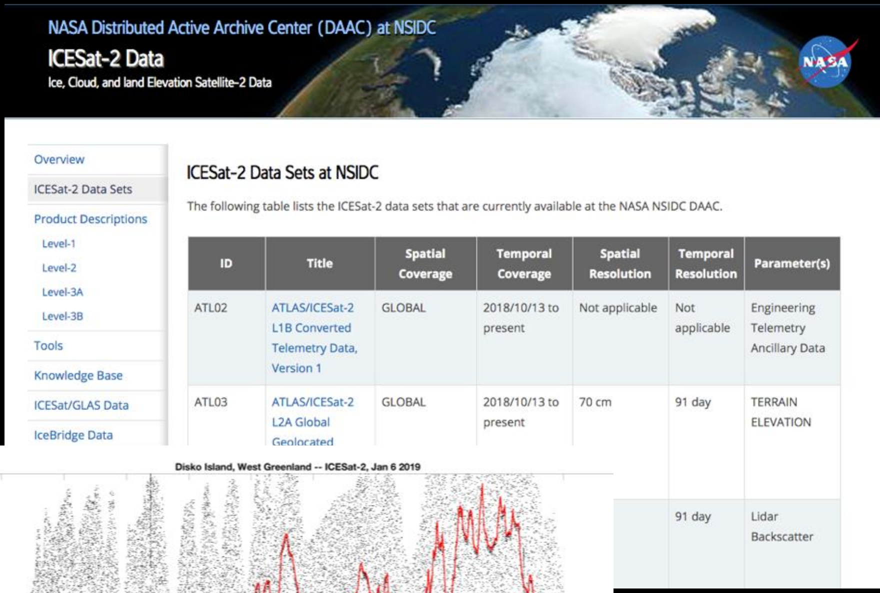
ICESat-2 Data are Publicly Available

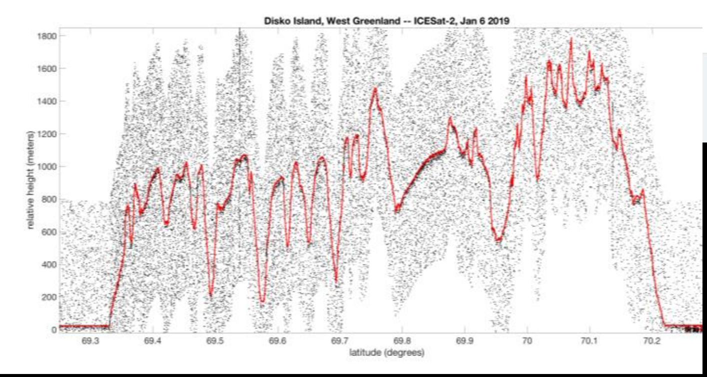
National Snow and Ice Data Center (NSIDC DAAC)

Data Products:

- **Geolocated Photons (ATL03)**
- Land Ice Elevation
- Sea Ice Elevation and Freeboard
- **Land Elevation (ATL08)**
- Atmospheric Backscatter
- Ocean Surface Height
- Inland Water Elevation

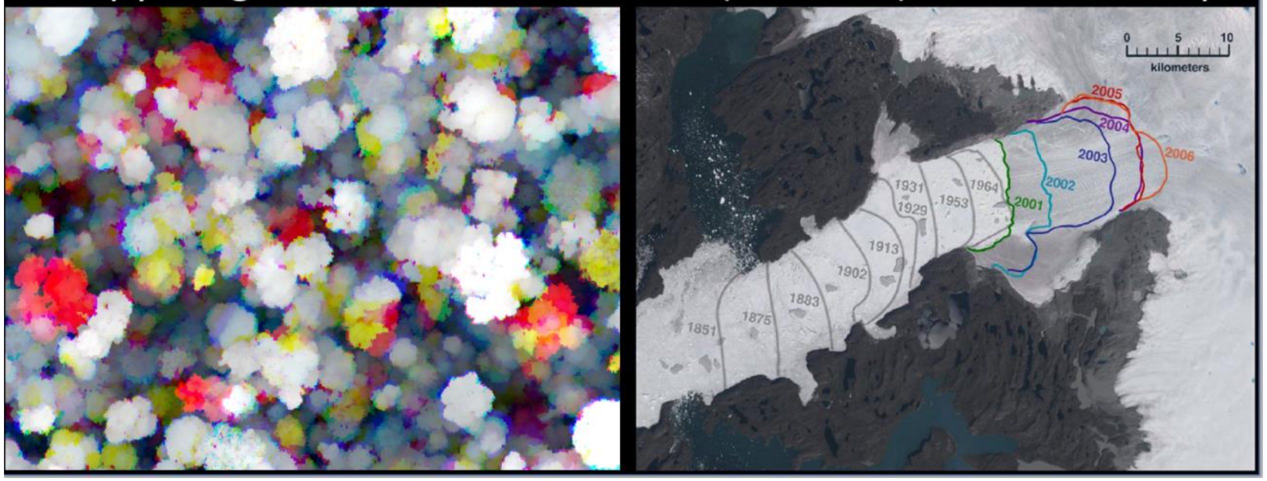
Rel003 data out 5 May 2020
Data through 15 July 2020
2297 unique data users to date
7,712,619 files served from since May 2019





Rugged topography in Greenland

Canopy Height and Glacier Elevation (CHANGE) Mission Concept



PIs: Cook, Morton, Neumann
Collaborators: Scott, Neigh, Yin, Martino, Vuyovich (GSFC)
Shean (Univ. of Washington), Morin (Univ. of Minnesota), Howat (Ohio St.),
Gardner (JPL), Smith (Univ. of Washington)

CHANGE: Concept paper for Decadal Survey

Lidar-Optical Fusion for High-resolution Measurements of Ice and Vegetation Change

Douglas Morton[1], Tom Neumann[1], Bruce Cook[1], Kelly Brunt[1], Lola Fatoyinbo[1], Thorsten Markus[1], Paul Montesano[1], Chris Neigh[1], Jon Ranson[1], Michael Studinger[1], Lee Vierling[2], Randy Wynne[3], Paul Morin[4], Ian Howat[5], Ben Smith[6], Ron Kwok[7], Alex Gardner[7], Michael Keller[8], Robert Hawley[9]

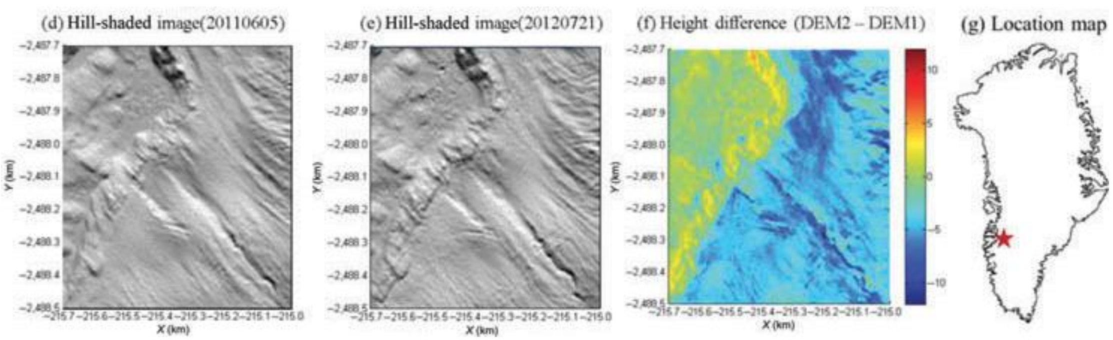
Summary: Climate change has accelerated the loss of ice and dynamism of vegetation in the Earth system. Melting ice sheets and glaciers, receding sea ice, forest disturbances and dieback, and biome boundary shifts constitute critical changes in the Earth system with concomitant impacts on hydrological cycling, biogeochemical cycling, surface energy budgets, and natural hazards. Mapping, monitoring and characterizing changes in ice and vegetation targets key cryospheric and biospheric science objectives. Quantifying polar ice sheet mass balance is

One of ~125 such White Papers
One of ~handful of laser altimetry white papers

CHANGE Science

- Full time stereo & lidar operation
- Seasonal (90 day) repeat ground tracks to assess fine-scale changes in ice topography and vegetation structure
- 1064 nm laser for vegetation profiles, ice sheet elevation
- Fusion: lidar-derived control points in image swath; knowledge of features in lidar footprint.

Noh & Howat, 2015

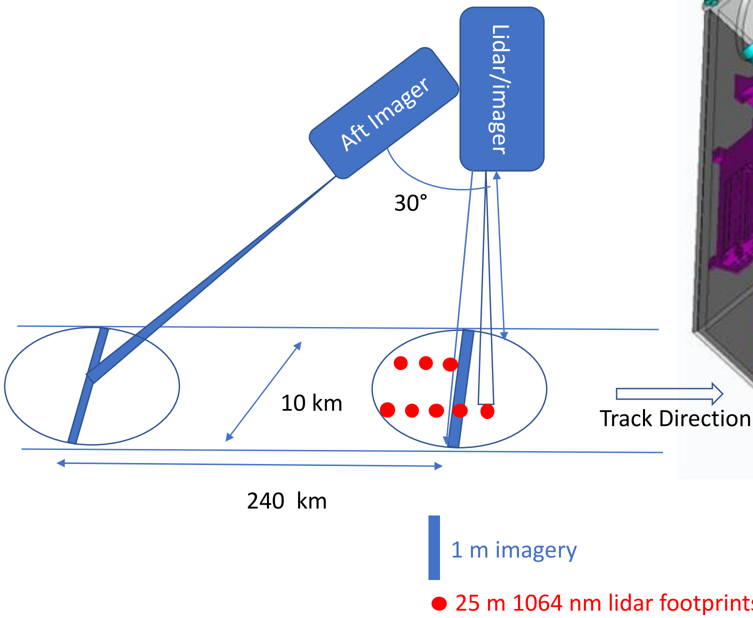


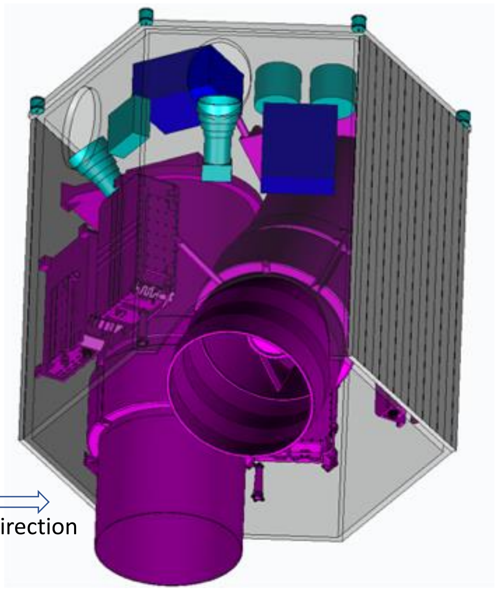
ATL13 Status

Version	Release Date	Water Body Types	Description & Principal Features
1	May 2019	Lakes > 10 km^2 (19,634 lakes)	- Surface water height statistics (mean, StdDev, slope), subsurface attenuation, and supporting variables at short segment length - Employs GLWD (Lehner & Doll 2004)
2	November 2019	Lakes & reservoirs $\geq$ 1 km^2; (185,181 lakes) Estuaries and bays, Near shore buffer (7km)	- Replaces GLWD with HydroLAKES (Messager & Lehner, 2016) - Adds coarse bottom finding algorithm - Adds dynamic shore finding - Employs Named Marine Water Bodies (ESRI) - Employs GSHHG Shoreline (Wessel et al, 1996)
3	April 2020	Above plus rivers; All lakes > 0.01 km^2	- Uses GRWL (After Allen and Pavelsky, 2018) to create river mask - Adds Ice on/off flag from multi-sensor NOAA product - Flags/corrects dead-time error
ATL22	April 2020	All water bodies	- Transect mean and supporting quantities

CHANGE Measurement Concept

Concept in development for Earth System Explorers Announcement of Opportunity





COMPASS Lab at GRC, Aug 2018

ICESat-2 Measures the Earth

ICESat-2 well on it's way to meeting science requirements:

ice sheet elevation, sea ice freeboard, vegetation canopy height

30+ science papers already in print; many more in review

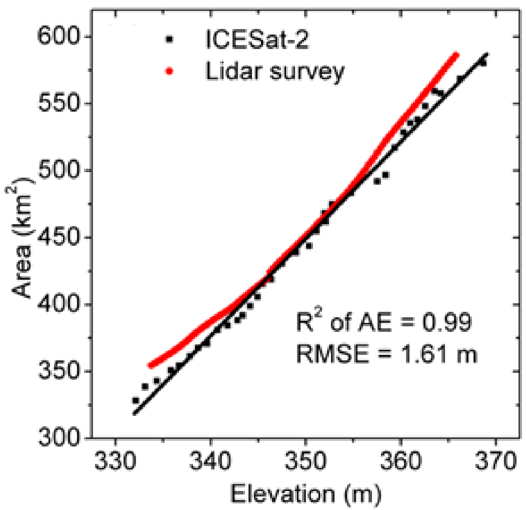
Initial data quality: < 10 cm vertical, < 10 m horizontal

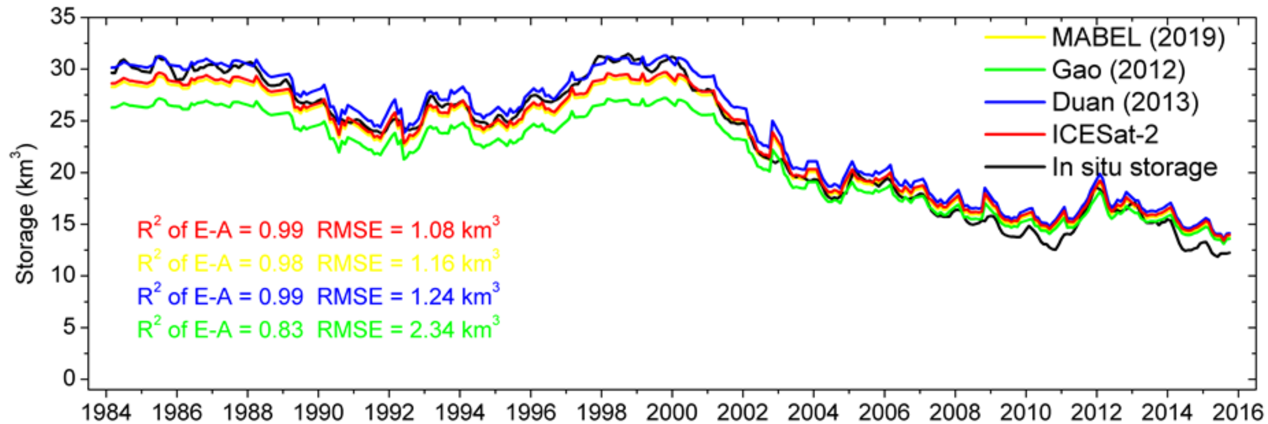
Spacecraft and instrument remain nominal

APPLICATIONS

ICESat-2 Applications Program

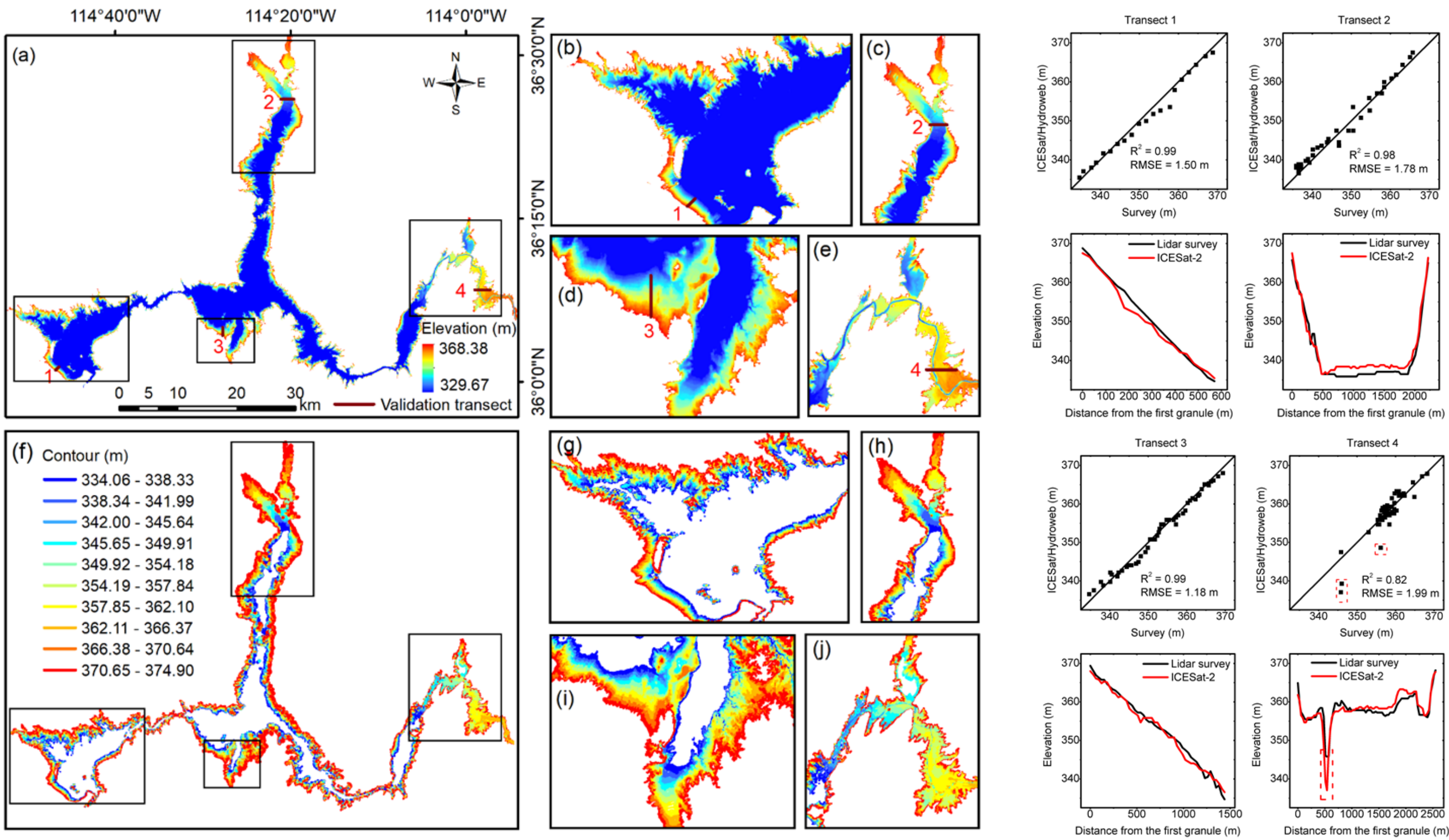
Application results over Lake Mead





Algorithm from Li et al., IEEE-TGRS, 2019.

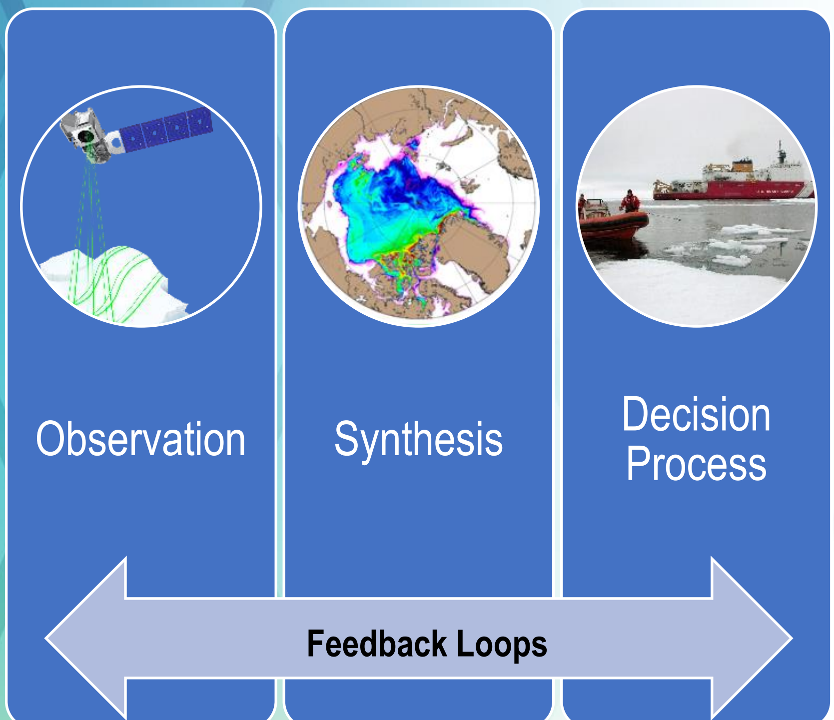
Application results over Lake Mead



ICESat-2 Applications Program

https://icesat-2.gsfc.nasa.gov/applications

Identify and strengthen links between:



Why Applications?

- Applications research provides fundamental knowledge of how mission data products can be scaled and integrated to inform resource management, policy development, and decision making.
- We define applications as **innovative uses** of mission data products in **decision-making** activities for **societal benefit**
- As of October 2020, we have **651 members** in our Applications Community, including **24 Early Adopters and 6 Applied Users**

How are you using ICESat-2 data?

- ATL08 analyses for bottom roughness and topography studies in Mexico, with application to numerical modelling of wind energy resources (**PI: Vanesa Magar, CICESE**). Analyze data from the ATL08 product to generate bottom roughness and topography and **assess the effect of these assumptions on wind energy resources at several locations around Mexico**.

- National Power Company Iceland (**PI: Andri Gunnarsson, Manager of Hydrological Research**). Using ICESat-2 data to improve winter mass balance estimates and short/midterm melt seasons **forecasting for hydro power operations in Iceland**.

Learn about current research & join the Applied Users Program

https://icesat-2.gsfc.nasa.gov/early_adopters
https://icesat-2.gsfc.nasa.gov/applied_users

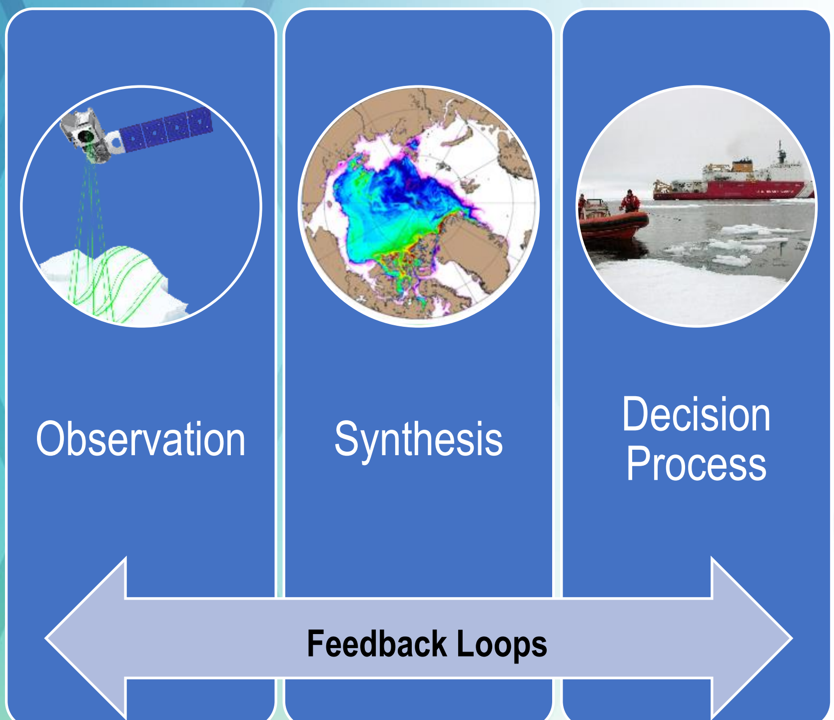
ICESat-2 Applications Program

ICESat-2 Applications Program

https://icesat-2.gsfc.nasa.gov/applications

ICE, CLOUD, AND LAND ELEVATION SATELLITE-2

Identify and strengthen links between:



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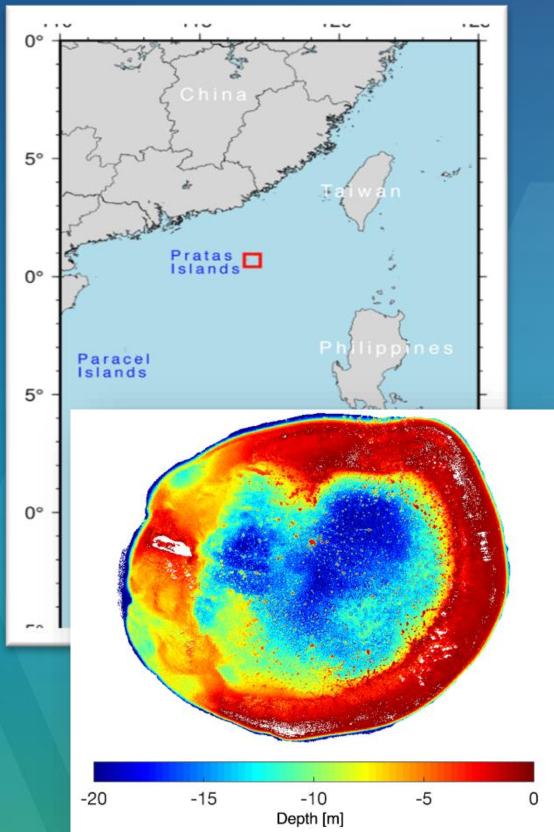
Island Near-shore Bathymetry for Navigation



Key Question: How can we improve Electronic Navigation Charts for navigation in South China Sea if we integrate water depth data from ICESat-2 with optical imagery from Sentinel-2?

Synthesis: is it possible to model underwater terrain of South China Sea islands with ICESat-2? Yes, it is! Water clarity in the region allows for penetration of photons down to 20-30 meters.

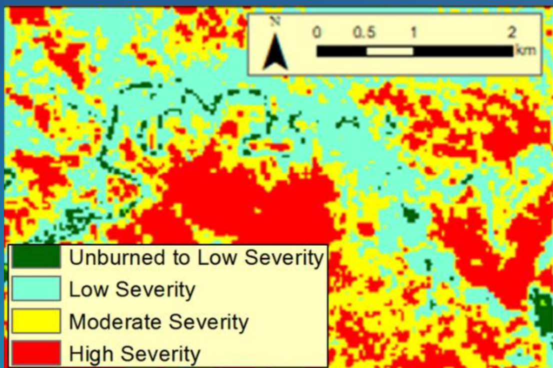
Next Steps:

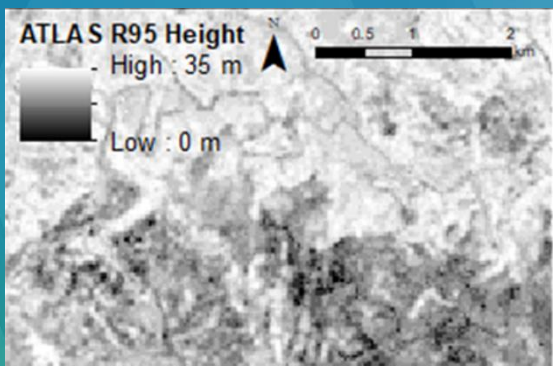
1. Currently have mapped 6 islands with promising results. In 2021, work with the Ministry of Interior to produce 10-20 more maps to increase reliability.
2. In 2022, aim to operationalize SDB fusion method to map all islands in South China Sea.
3. Show capability of satellite technology to monitor changes in underwater terrain due to sand and coral dredging near protected islands.

Early Adopter PI: **Steven Kuo-Hsin Tseng**, Taiwan National Central University, Center for Space and Remote Sensing Research

Wildland Fire Management

ICESat-2
ICE, CLOUD, AND LAND ELEVATION SATELLITE-2





Early Adopter PI: **Birgit Peterson**, US Geological Survey, Earth Resources Observation and Science Center

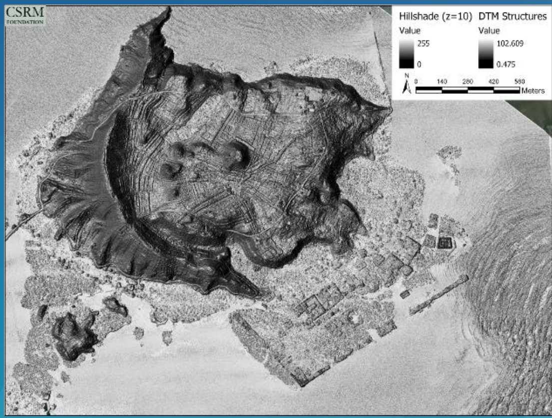
Key Question: How can we make better burn severity assessments if we integrate vegetation structure data (e.g. from ICESat-2, GEDI) with spectral data from (e.g. Landsat, Sentinel?

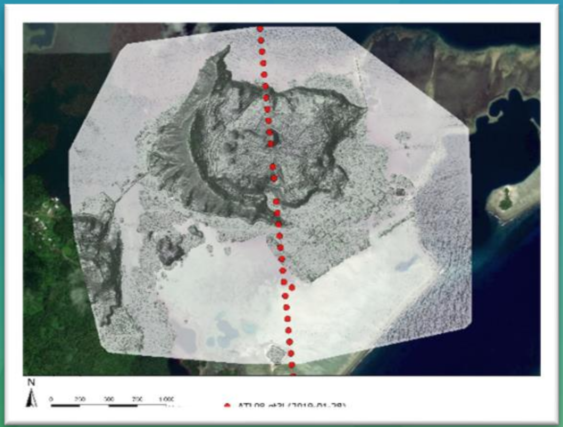
Synthesis: Does the ICESat-2 data have enough sensitivity to distinguish between pre-and post-fire structure, particularly in areas where the fire hasn't been severe? Yes, it does!

Next Steps:

1. What is the next step to integrating structure information into existing operational burn severity programs?
   - **Monitoring Trends and Burn Severity Program**: https://www.mtbs.gov/
   - **LANDFIRE Program**: https://landfire.gov/
2. How does all this scale? From local measurements to space-based observations?

Archeological Discovery





Early Adopter PI: **Douglas Comer**, CSRM Foundation

Key Question: How can we advance the state of knowledge in Micronesian archeology, to improve cultural and natural resource conservation, if we integrate vegetation structure and bathymetry data from ICESat-2?

Synthesis: Can topographic profiles derived from ICESat-2 be used for archeological discovery in heavily vegetated environments?

Next Steps:

1. Use a combination of ICESat-2 and Sentinel-2 data to derive regional- or island-scale bathymetry maps
2. Validate ICESat-2 and GEDI topographic profiles across the LiDAR surveys to assess the utility of current satellite altimeters for characterizing archaeological landscapes.

OBTAINING DATA

How are you using ICESat-2 data?

ICESat-2
ICE, CLOUD, AND LAND ELEVATION SATELLITE-2

- ATL08 analyses for bottom roughness and topography studies in Mexico, with application to numerical modelling of wind energy resources (**PI: Vanesa Magar, CICESE**). Analyze data from the ATL08 product to generate bottom roughness and topography and **assess the effect of these assumptions on wind energy resources at several locations around Mexico**.
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Learn about current research & join the Applied Users Program

https://icesat-2.gsfc.nasa.gov/early_adopters
https://icesat-2.gsfc.nasa.gov/applied_users

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| National Snow and Ice Data C

https://nsidc.org/data/icesat-2/tools

NASA Distributed Active Archive Center (DAAC) at NSIDC

ICESat-2 Data

Ice, Cloud, and land Elevation Satellite-2 Data

- Overview
- ICESat-2 Data Sets
- Product Descriptions
  - Level-1
  - Level-2
  - Level-3A
  - Level-3B
- Tools
- Knowledge Base
- ICESat/GLAS Data
- IceBridge Data

ICESat-2 Tools and Services

The following table lists the tools and services available for ICESat-2 data.

Name	Description	Access Type	Service Outputs	Source
OpenAltimetry	Discover, access, and visualize ICESat and ICESat-2 data. Key functions include on-the-fly plotting of segment elevations and photon clouds based on date and region of interest, ground track filtering and visualization, and data access in CSV or subsetted HDF5 format.	Web application	• Downloadable elevation and photon plots • Spatially subsetted HDF5 data • CSV output of key parameters	A NASA funded collaborative project between the Scripps Institution of Oceanography, San Diego Supercomputer Center, NSIDC DAAC, and UNAVCO.

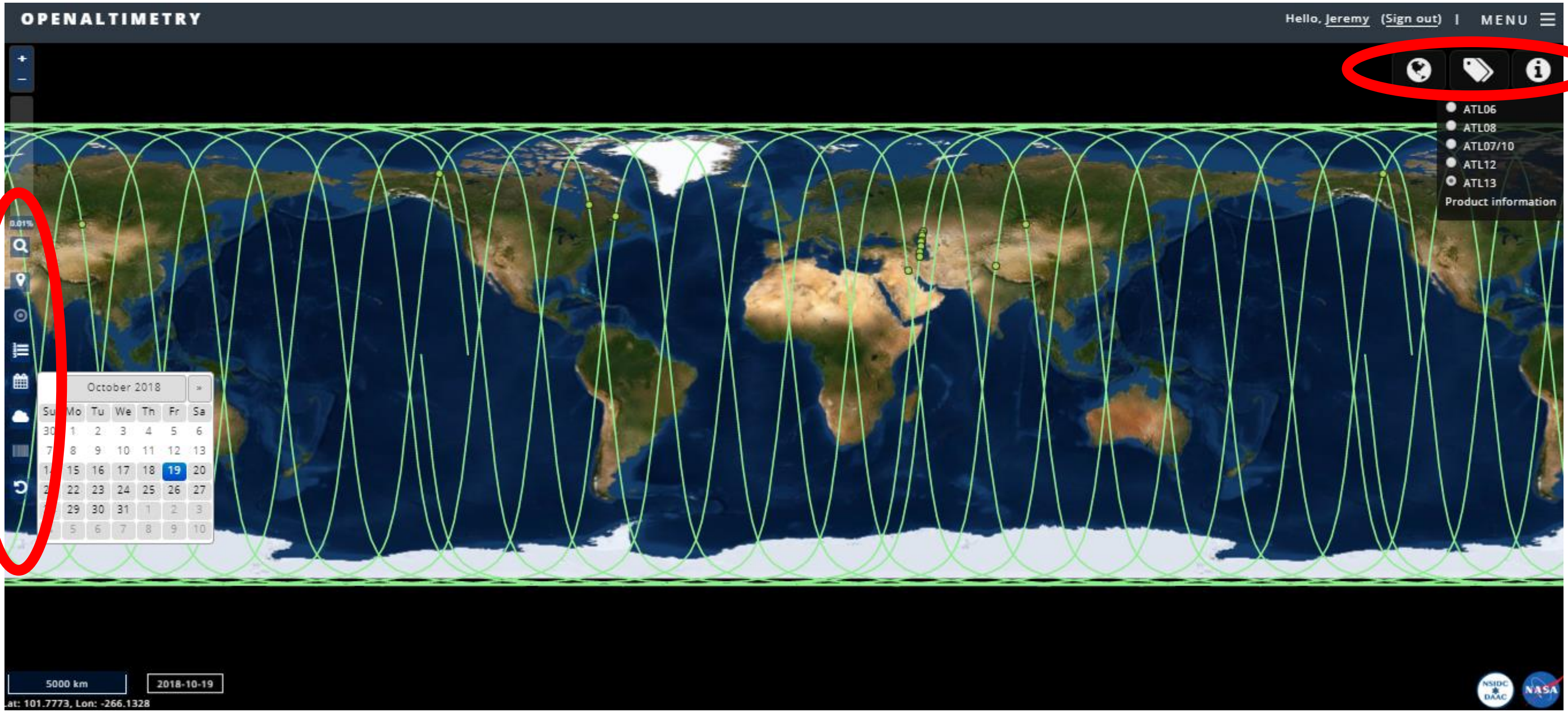
Support

ICESat-2 Tools and Services

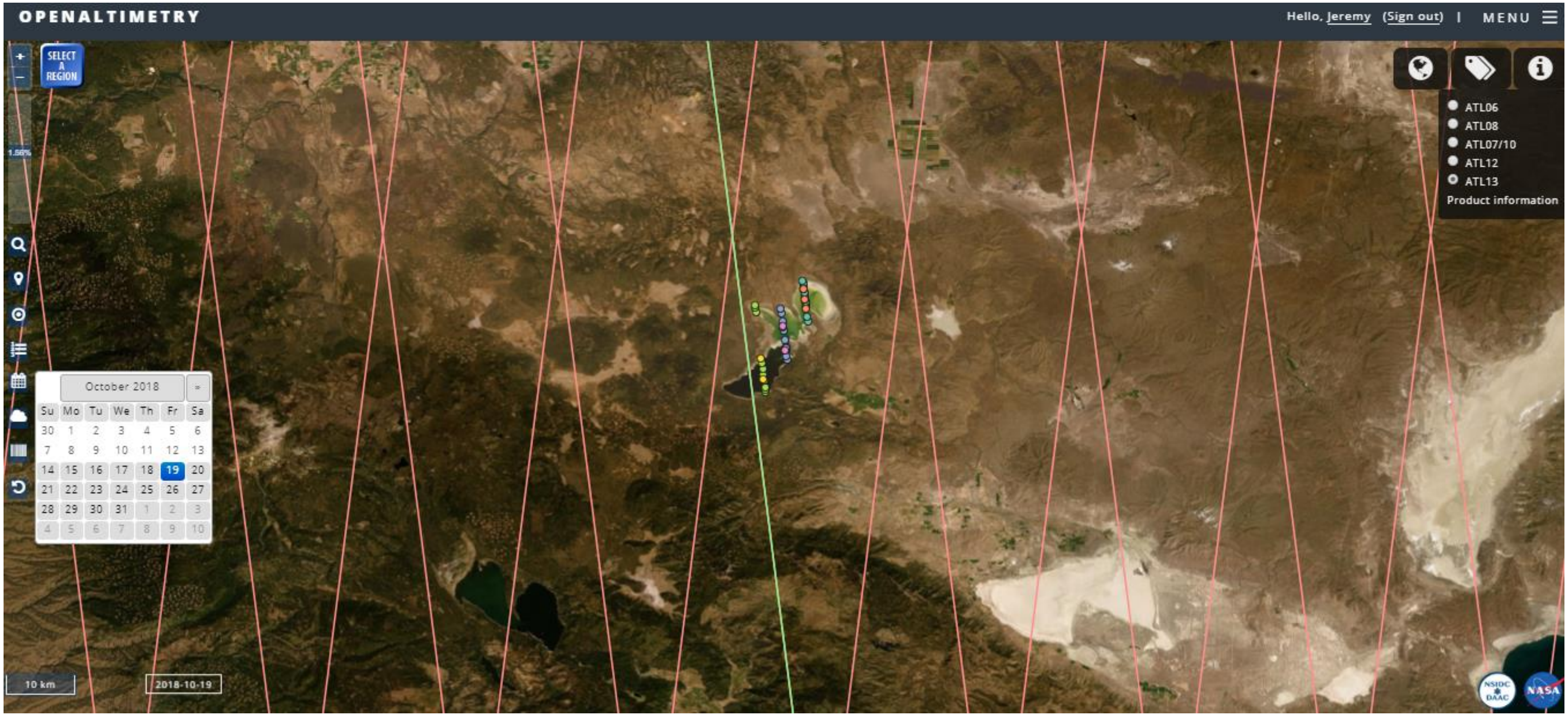
NSIDC DAAC
Distributed Active Archive Center

Name	Description	Access Type	Service Outputs	Source
OpenAltimetry	Discover, access, and visualize ICESat and ICESat-2 data. Key functions include on-the-fly plotting of segment elevations and photon clouds based on date and region of interest, ground track filtering and visualization, and data access in CSV or subsetted HDF5 format.	Web application	•Downloadable elevation and photon plots •Spatially subsetted HDF5 data •CSV output of key parameters	A NASA funded collaborative project between the Scripps Institution of Oceanography, San Diego Supercomputer Center, NSIDC DAAC, and UNAVCO.
NASA Earthdata Search	Search, visualize, and access data across thousands of Earth science data sets, including ICESat, IceBridge, and ICESat-2. Customization services are available for most ICESat-2 data sets, including subsetting and reformatting.	Web application	•Data access via shell script and zip links •Visit this page for details on subsetting and reformatting services available for each ICESat-2 data set.	NASA EOSDIS, supported by NSIDC DAAC.
Data Subscription	Subscribe to have new ICESat-2 data automatically delivered to you as they become available at NSIDC. Customization services including subsetting and reformatting can be applied to your subscription request.	Online subscription request form	•Automated emailed data delivery •Visit this page for details on subsetting and reformatting services available for each ICESat-2 data set.	NSIDC DAAC
Data Access and Service API	The NSIDC DAAC's Application Programming Interface, or API, provides spatial and temporal filtering as well as customization options as a single access command, without the need to script against our data directory structure.	API	•Visit this page for details on subsetting and reformatting services available for each ICESat-2 data set.	NSIDC DAAC
NSIDC DAAC Data Access Jupyter Notebook	A Jupyter notebook exploring data coverage, size, and customization service availability along with direct data download utilizing the NSIDC DAAC's access and service API.	Downloadable tool	•Visit this page for details on subsetting and reformatting services available for each ICESat-2 data set.	NSIDC DAAC
Panoply	Plot arrays and geo-referenced data from NetCDF and HDF files.	Downloadable tool	•Downloadable plots as GIF, JPEG, PNG, TIFF bitmap images, PDF, or PostScript graphics files, as well as lon-lat map plots as KMZ files. •Animations as MP4 video or as a collection of individual frame images.	NASA Goddard Institute for Space Studies
HDFView	Browse, visualize, and edit HDF (HDF5 and HDF4) files. Key functions include viewing HDF file hierarchy in a tree structure, opening data and metadata arrays, image creation, and HDF file modification.	Downloadable tool	•Save data values to a text or binary file •Save HDF image to JPEG, GIF, PNG, or BMP file	The HDFGroup

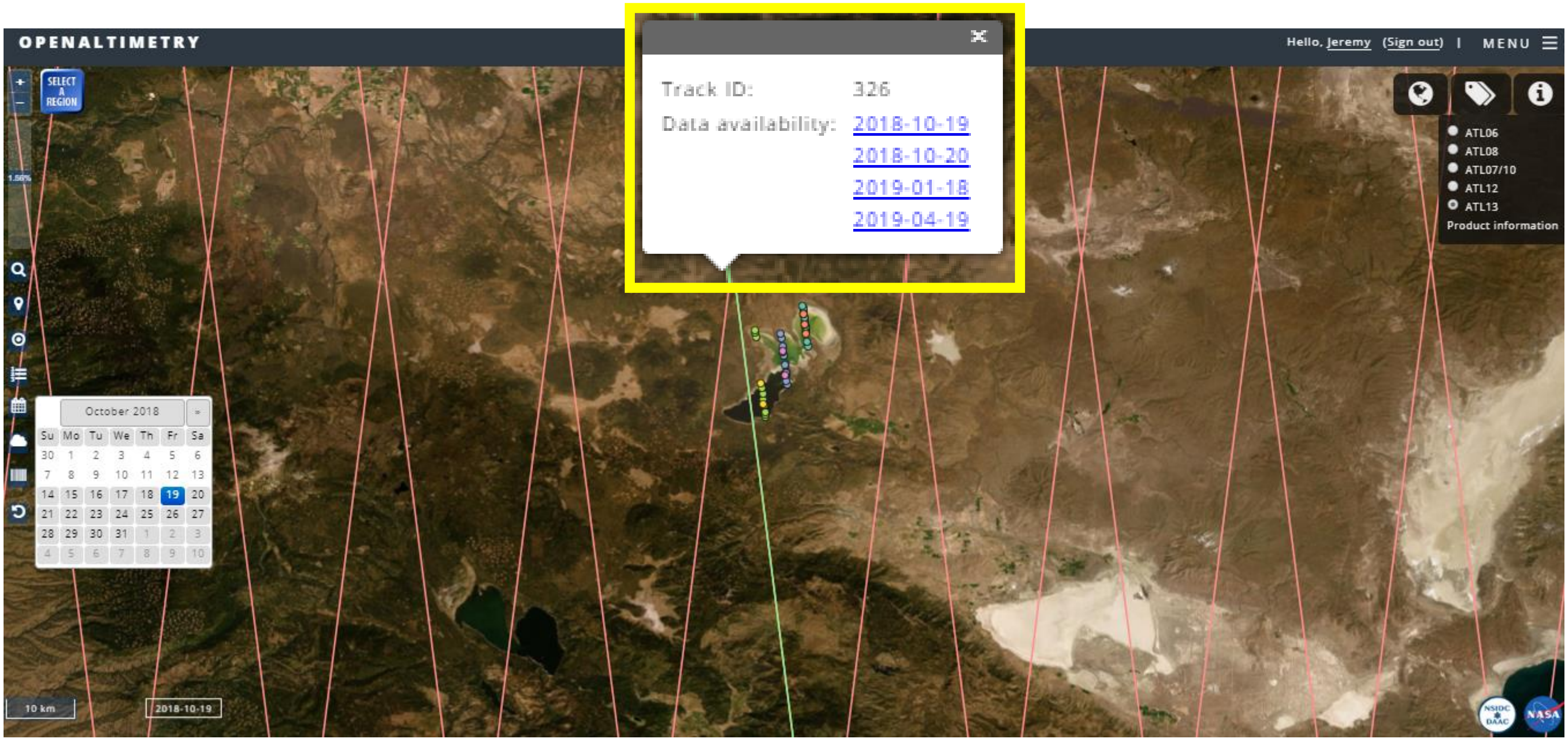
Data Access:
OpenAltimetry



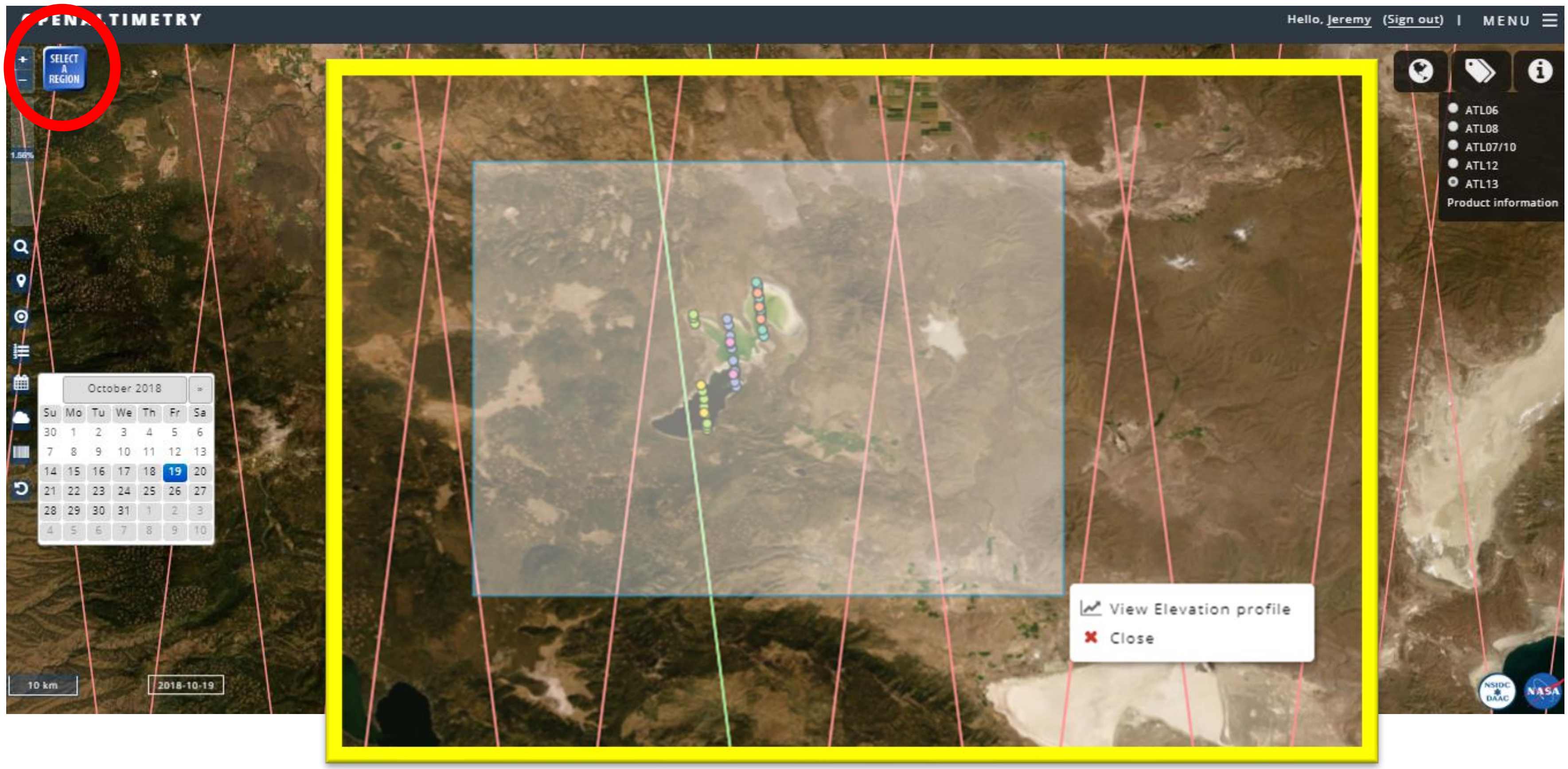
Data Access:
OpenAltimetry



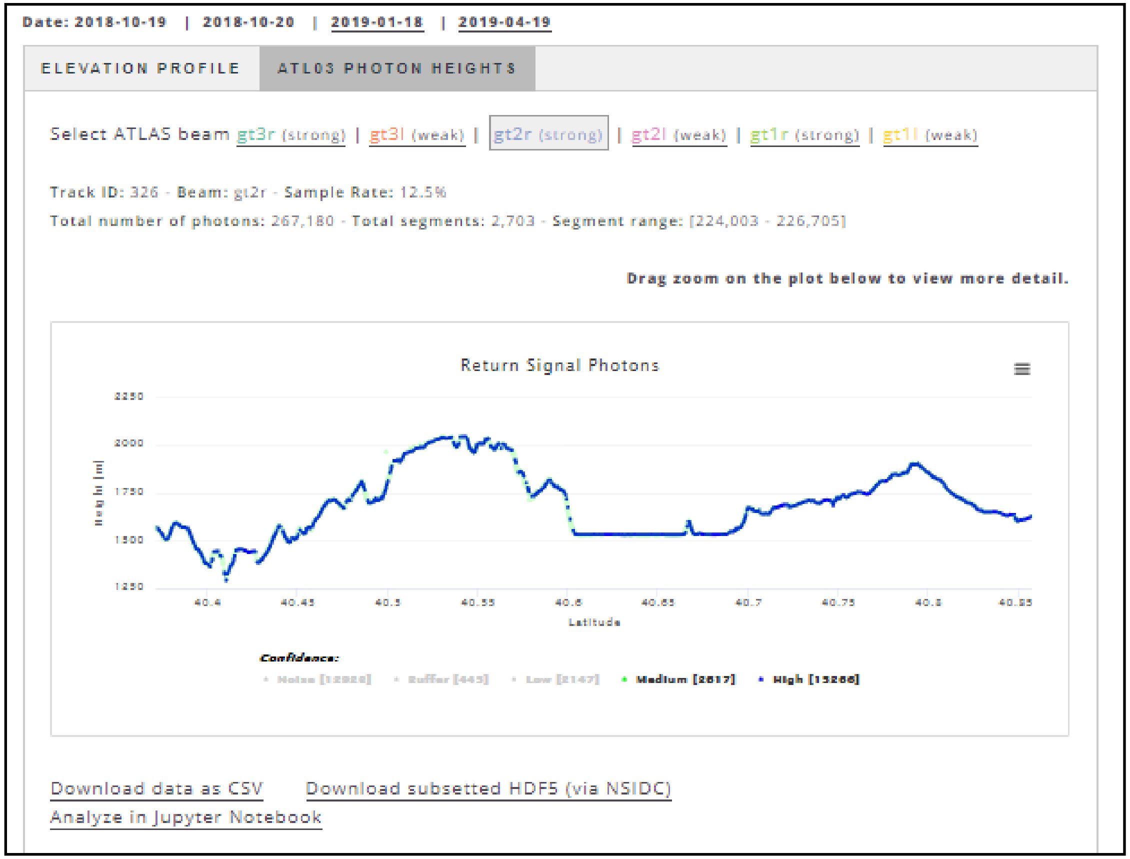
Data Access:
OpenAltimetry



Data Access:
OpenAltimetry



Data Access: OpenAltimetry



Overpass Dates

Beams

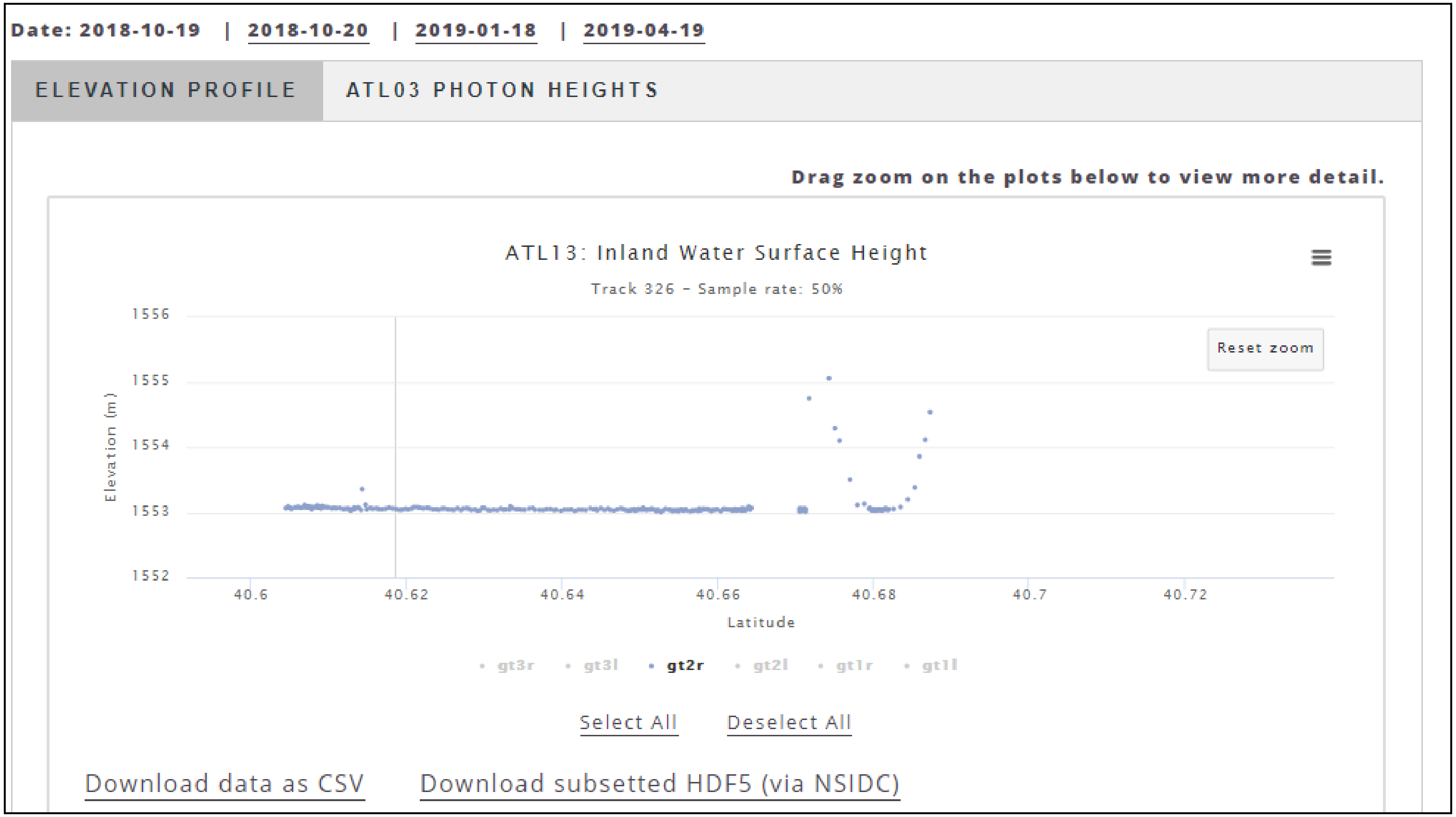
Sampling Profile

Zoomable Quick-Look

Signal Confidences

Acquisition Options

Data Access: OpenAltimetry



Data Access: NSIDC DAAC

Data Set ID: ATL13

ATLAS/ICESat-2 L3A Inland Water Surface Height, Version 1

This data set (ATL13) contains along track surface heights of inland water bodies, including lakes, estuaries and rivers. Water surface slope and descriptive statistics are also provided. The data were acquired by the Advanced Topographic Laser Altimeter System (ATLAS) instrument on board the Ice, Cloud and land Elevation Satellite-2 (ICESat-2) observatory.

This is the most recent version of these data.

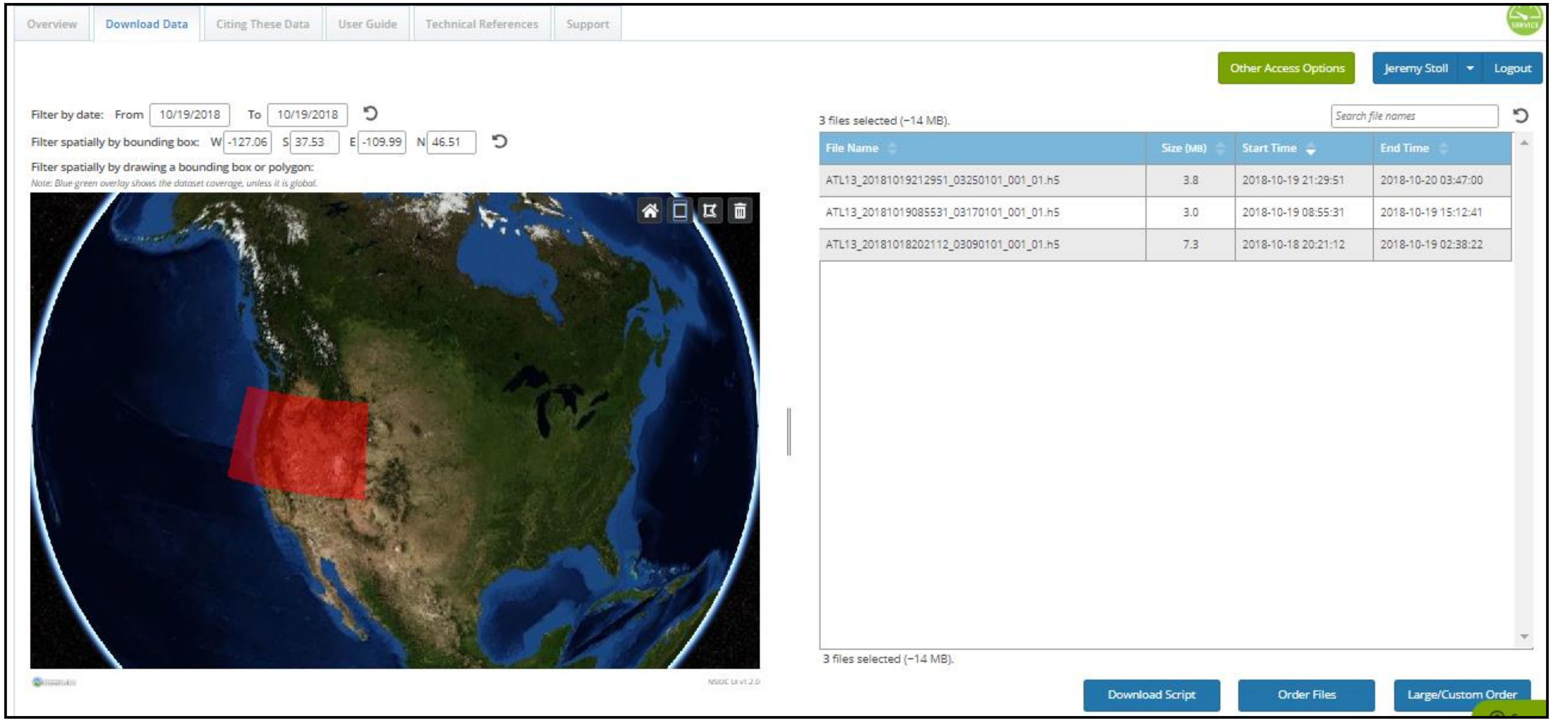
Version Summary: See more ▼

Overview | Download Data | Citing These Data | User Guide | Technical References | Support

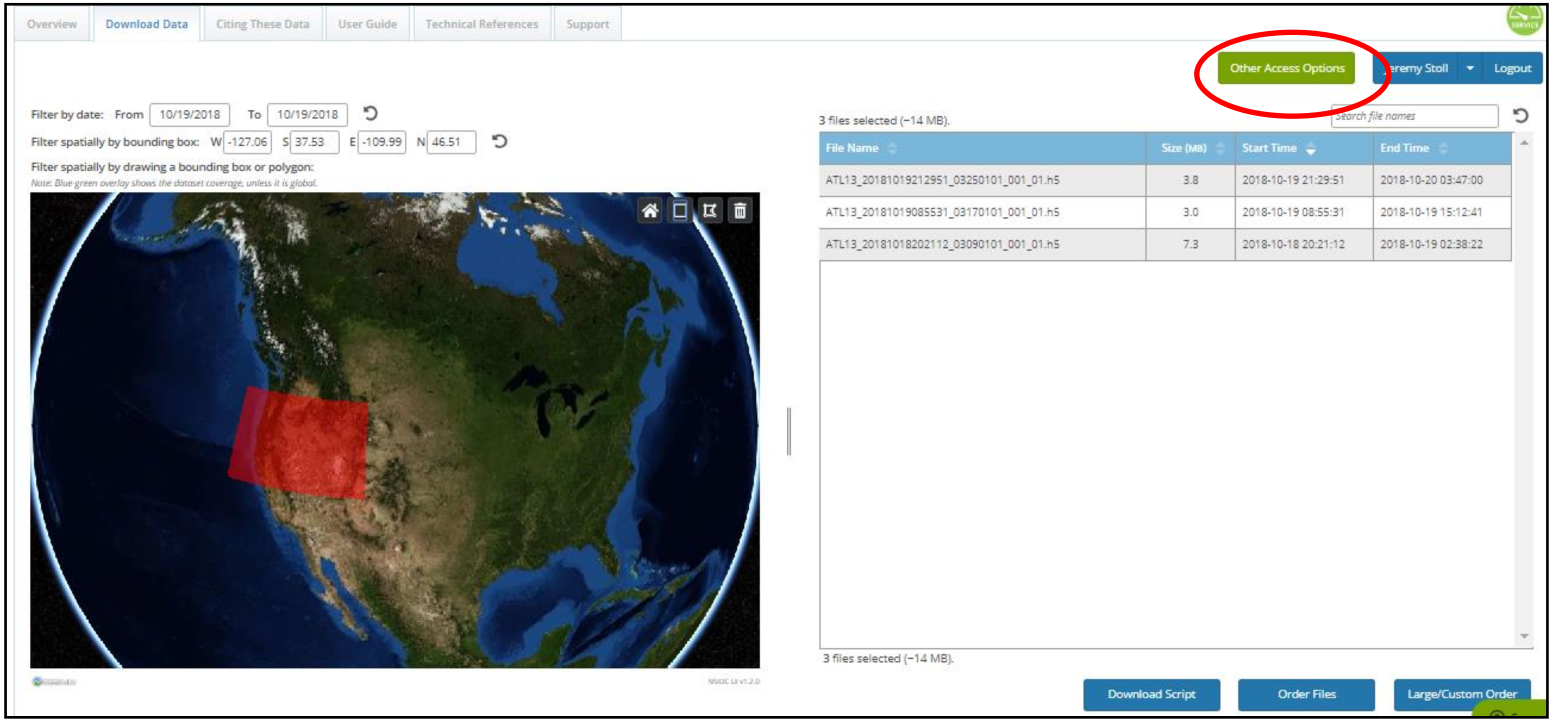
Parameter(s):	SURFACE WATER > SURFACE WATER FEATURES > LAKES/RESERVOIRS > Elevation SURFACE WATER > SURFACE WATER FEATURES > RIVERS/STREAMS > Elevation	**Data Format(s):**	HDF5
Spatial Coverage:	N: 90, S: -90, E: 180, W: -180	**Platform(s):**	ICESat-2
Spatial Resolution:	Varies	**Sensor(s):**	ATLAS
Temporal Coverage:	13 October 2018 to present	**Version(s):**	V1
Temporal Resolution	91 day	**Metadata XML:**	View Metadata Record
Data Contributor(s):	Michael Jasinski, Jeremy Stoll, David Hancock, John Robbins, Jyothi Nattala, et al		

Geographic Coverage

Data Access: NSIDC DAAC



Data Access:
NSIDC DAAC



ICESat-2 Tools & Services: https://nsidc.org/data/icesat-2/tools
NISDC DAAC tutorial video (YouTube): https://bit.ly/2rHdQz7

Data Format:
Product Layout

- ATL13_20190719082904_03250401_002_01.h5
  - METADATA
  - ancillary_data
  - gt1l
  - gt1r
  - gt2l
  - gt2r
  - gt3l
  - gt3r
  - orbit_info
  - quality_assessment

GRANULE DELINEATION

-~5 files per day (several RGTs)

-data exist only over water bodies

NAMING CONVENTION

-date+time, RGT, cycle, release

6-BEAM STRUCTURE

-along-track hierarchy

IMPORTANT METADATA

-ancillary_data > RGT, time start & end

-orbit_info > sc_orient

Data Format: Product Layout

- ATL13_20190719082904_03250401_002_01.h5
  - METADATA
  - ancillary_data
  - gt1l
  - gt1r
  - gt2l
  - gt2r
  - gt3l
  - gt3r
  - orbit_info
  - quality_assessment

- gt2r
  - atl13refid
  - cycle
  - delta_time
  - err_ht_water_surf
  - err_slope_trk
  - ht_ortho
  - ht_water_surf
  - ice_flag
  - inland_water_body_id
  - inland_water_body_region
  - inland_water_body_size
  - inland_water_body_source
  - inland_water_body_type
  - qf_bckgrd
  - qf_bias_em
  - qf_bias_fit
  - qf_cloud
  - qf_ice
  - qf_iwp
  - qf_lseg_length
  - qf_spec_width
  - qf_sseg_length
  - qf_subsurf_anomaly
  - rgt
  - segment_dac
  - segment_geoid
  - segment_id_beg
  - segment_id_end
  - segment_lat
  - segment_lon
  - segment_slope_trk_bdy
  - segment_tide_equilibrium
  - segment_tide_ocean
  - significant_wave_ht
  - sseg_mean_lat
  - sseg_mean_lon
  - sseg_mean_time
  - stdev_water_surf
  - subsurface_attenuation
  - water_depth

Product Highlights

atl13refid	Unique water body identifier
ht_ortho	Water ht above EGM2008
ht_water_surf	Water ht above WGS84
stdev_water_surf	Water surface standard dev
subsurface_attenuation	Water profile ph attenuation
water_depth	[ht – corrected bottom ht]

Data Format: Product Rate

ATL13refid

81	1410003682
82	1410003682
83	1410002095
84	1410002095
85	1410002095
86	1410002095
87	1410002095
88	1410002095
89	1410002095
90	1410002095
91	1410002095
92	1410002095
93	6033000122
94	6033000122

ht_ortho

81	237.68318
82	237.65822
83	23.176842
84	23.179201
85	23.164207
86	23.173082
87	23.140081
88	23.16066
89	23.16881
90	23.1775
91	23.172443
92	23.184858
93	0.13068293
94	0.18919733

stdev_water_surf

81	3.4028235E38
82	3.4028235E38
83	0.065
84	0.065
85	0.065
86	0.065
87	0.065
88	0.065
89	0.065
90	0.065
91	0.065
92	0.065
93	0.125
94	0.125

-Short Segment rate

-1-D arrays

-Mapped by ATL13refid

-Long Segment-derived products repeat

Questions, Discussion, Feedback

Thank You !