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Using high-resolution ICESat-2 point clouds to evaluate 1-3 arc second global digital elevation models

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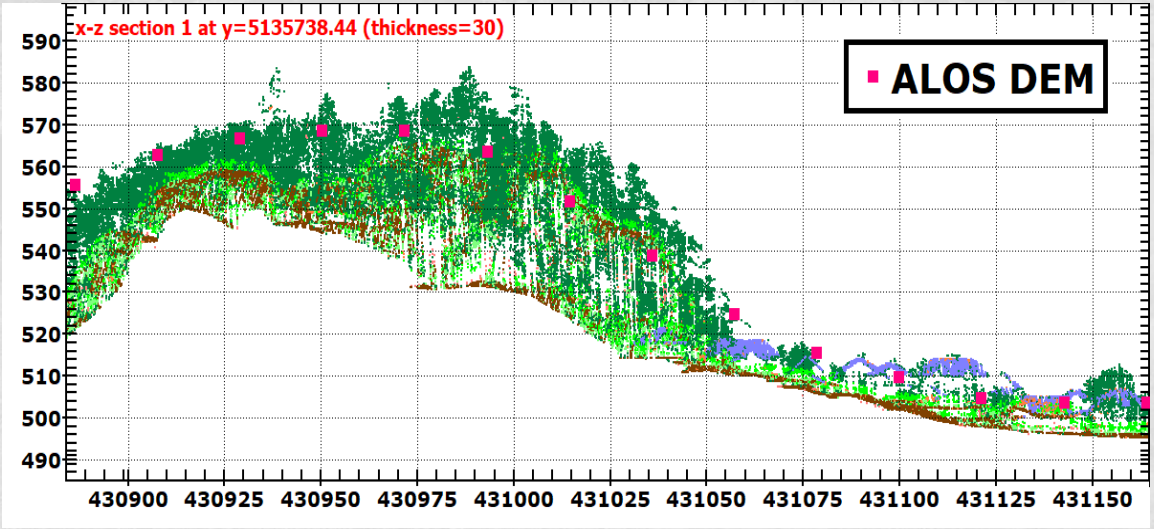


Published version

Two papers were published in the book from the 2020 conference, and then they were combined in a paper in Transactions in GIS which also incorporated the NASADEM and the Copernicus DEM that appeared after the conference papers were published, and restricted the discussion to 1" DEMs.

- Peter Guth (2020) Using high-resolution lidar point clouds to evaluate 1-3 arc second global digital elevation models: in Massimiliano Alvioli, Ivan Marchesini, Laura Melelli & Peter Guth, eds., Proceedings of the Geomorphometry 2020 Conference, https://doi:10.30437/GEOMORPHOMETRY2020_31 .
- **Tera Geoffroy and Peter Guth (2020) Using high-resolution ICESat-2 point clouds to evaluate 1-3 arc second global digital elevation models: in Massimiliano Alvioli, Ivan Marchesini, Laura Melelli & Peter Guth, eds., Proceedings of the Geomorphometry 2020 Conference, https://doi:10.30437/GEOMORPHOMETRY2020_29 .**
- Guth, P. L., & Geoffroy, T. M. (2021). LiDAR point cloud and ICESat-2 evaluation of 1 second global digital elevation models: **Copernicus wins**. Transactions in GIS, 00, 1–17. https://doi.org/10.1111/tgis.12825. Paper as submitted in January 2021.

1” (aka 30 m DEMs)

Free Global DEMs

Free Global DEM	Spacing	Primary Source	Producer	Vertical Datum	Precision	Longitudinal spacing	Acquired
SRTM (v3)	1", 3"	C band radar	NASA	Orthometric EGM96	Integer	Constant	2000 (11 days)
ASTER GDEM (v3)	1"	Stereo NIR imagery	NASA / METI	Orthometric EGM96	Integer	Constant	2000-2013
ALOS World 3D AW3D30 v3.2	1"	Stereo pan imagery	JAXA	Orthometric EGM96	Integer	Variable	2006-2011
NASADEM	1"	Reprocessed C band radar	NASA	Orthometric EGM96	Integer or floating point	Constant	2000 (11 days)
Copernicus DEM GLO30 and GLO90	1", 3"	X band radar, Edited commercial WorldDEM	ESA/Airbus	Orthometric EGM2008	Floating point	Variable	2010-2015
Tandem_X	3"	X band radar	DLR	Ellipsoidal WGS84	Floating point	Variable	2010-2015
MERIT	3"	Radar + Stereo pan imagery	Univ. Tokyo	Orthometric EGM96	Floating point	Constant	2000-2013

Notes:

1. All are WGS84 horizontal datum
2. All name tiles for SE corner (USGS NED/3DEP names for NW corner)

ICESat-2

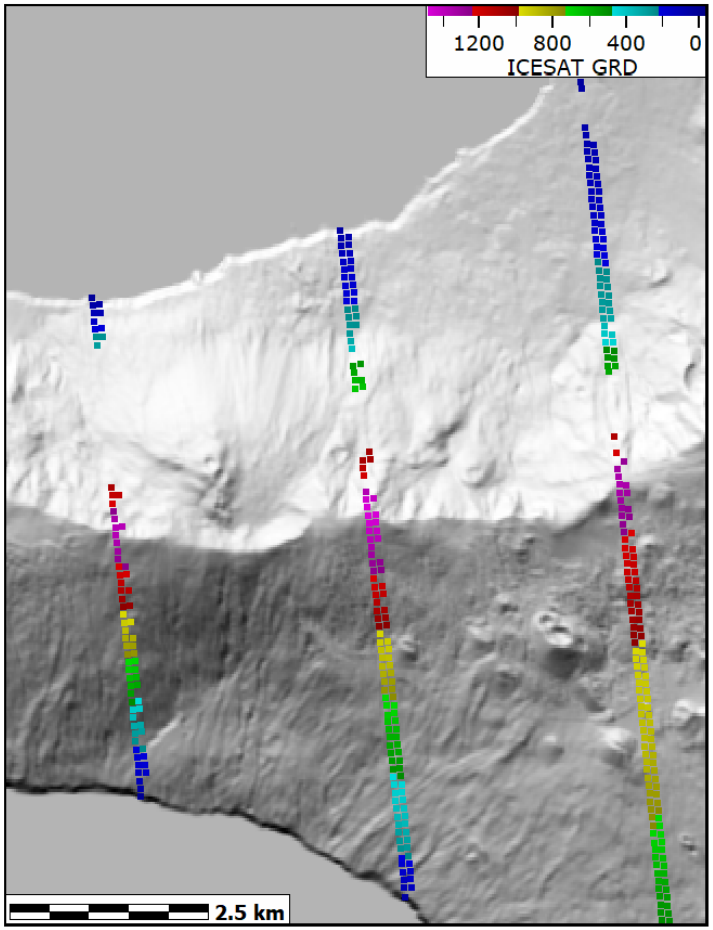
Table 2. ICESat-2 study regions

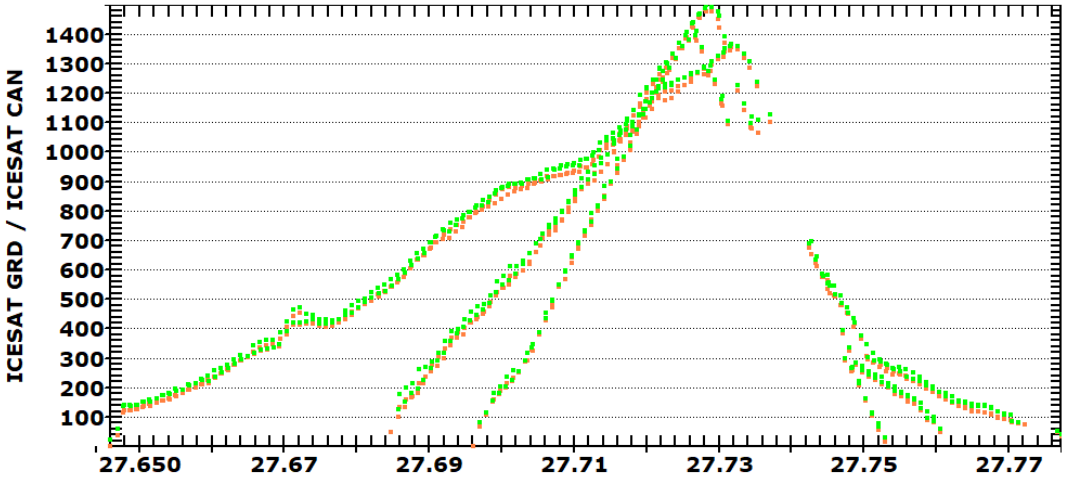
AREA	LOCATION	1" CELLS	Points per cell	ICESat-2 elevations (m)	SRTM slope (%) and std dev	Canopy height (m) and std dev
Brazil-elevation	S13.31° W59.28°	26,717	2	182 to 713		8.78±21.52
CA-elevations	N40.27° W124.02°	37,845	2	-15 to 1060		24.31±13.97
VA-elevation	N39.17° W78.57°	4790	2	225 to 820		18.37±13.58
Brazil-photons	S14.14° W60.73°	4321	40	-76 to 1329	4.42±3.73	20.51±69.76
CA-photons	N39.86° W123.8°	122,872	87	-310 to 1749	10.95±15.57	58.21±111.25
VA-photons	N38.47° W78.23°	74,250	91	15 to 1114	7.46±7.87	7.67±11.91

- Regions used from student's conference paper last year
- Our combined TGIS paper used two of these areas, and 6 others (no free lidar in Brazil)
- Points in the cell are on linear orbital track
- Data source openaltimetry.org

Region	Lidar 1" cells	ICESat-2 1” cells	Percentage 1" cells with ICESAT-2 return	Köppen classification
Kristianland, Norway N58.17° E8.02°	709428	9407	1.33%	Cfb
Bled, Slovenia N46.37° E14.08°	29327	450	1.53%	Cfb
Redwoods, CA, USA N39.85° W123.77°	49728	805	1.62%	Csb
Canyon Mtns, UT, USA N39.36° W112.23°	163293	1951	1.19%	Cfb/Dfb
Blue Ridge, VA USA 38.71° W78.28°	278641	3375	1.21%	Cfa
Icod, Tenerife, Spain N28.37° W16.7°	33485	508	1.52%	BSh
El Hiero, Spain N27.74° W18.02°	317341	3602	1.14%	BSh
Oahu, HI, USA N21.49° W158.19°	61186	591	0.97%	Am

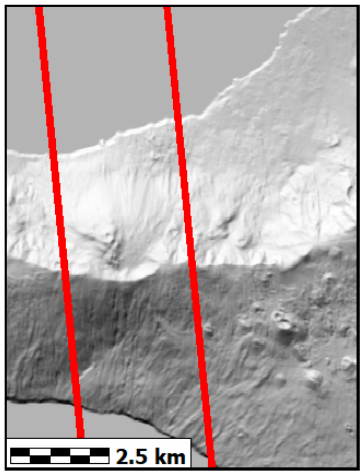
ATL08: ellipsoidal terrain height & canopy height; convert to EGM2008 ground and canopy top

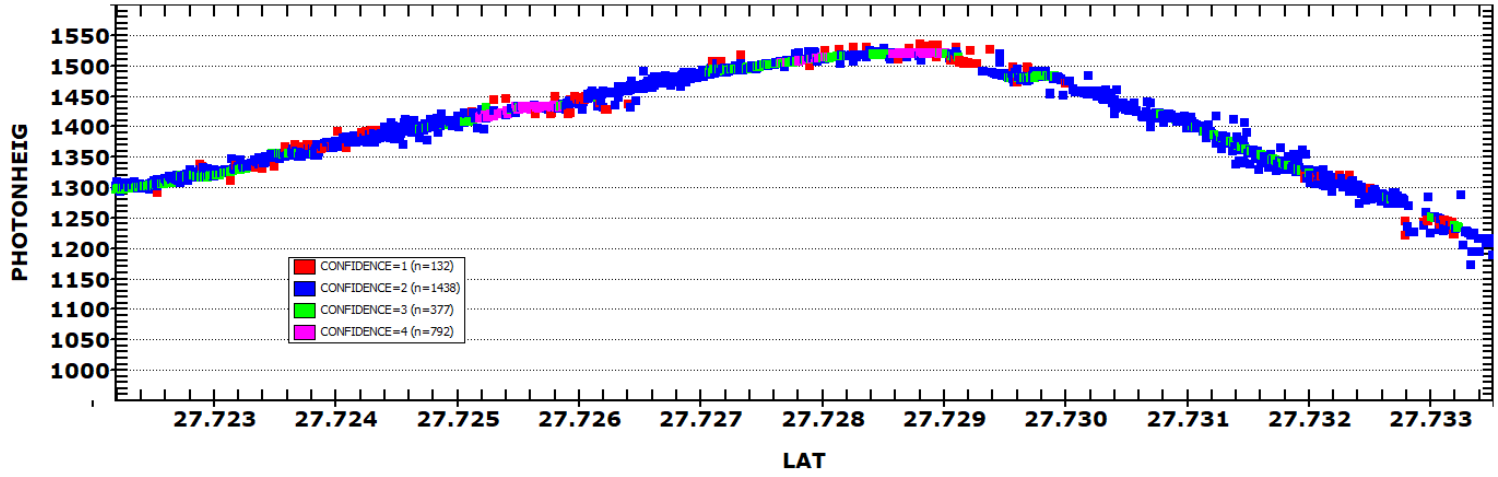


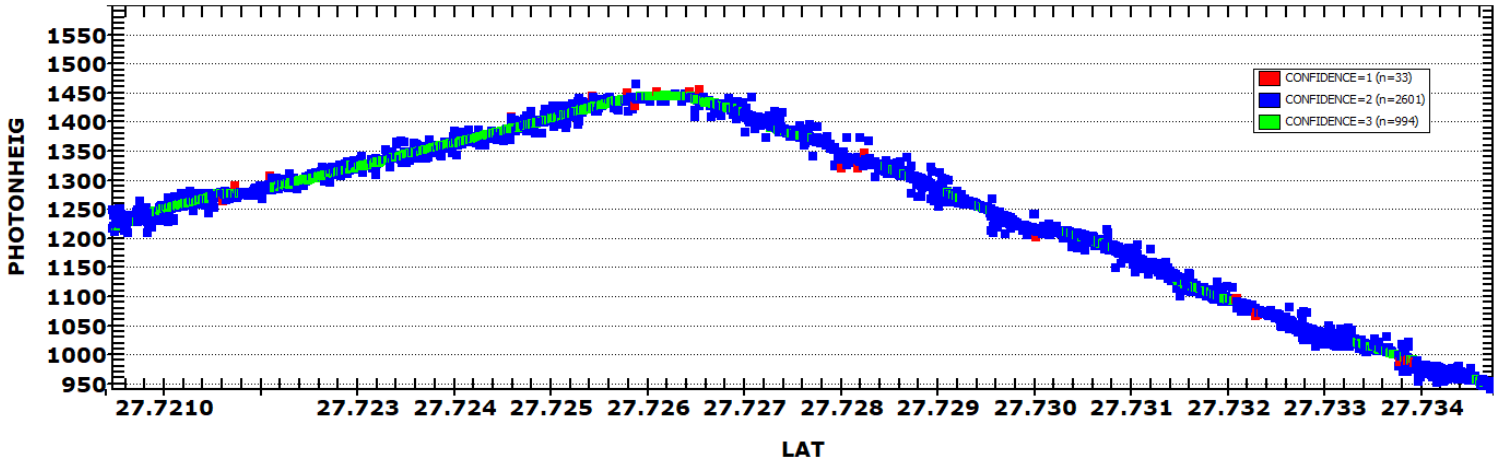


- Interpolate 1” global DEMs to locations of ICESat-2 data

ATL02: photon height (ellipsoidal) data, with quality metric







- Treat photon heights as point cloud, and average to create sparse 1” DEM to compare to global DEMs

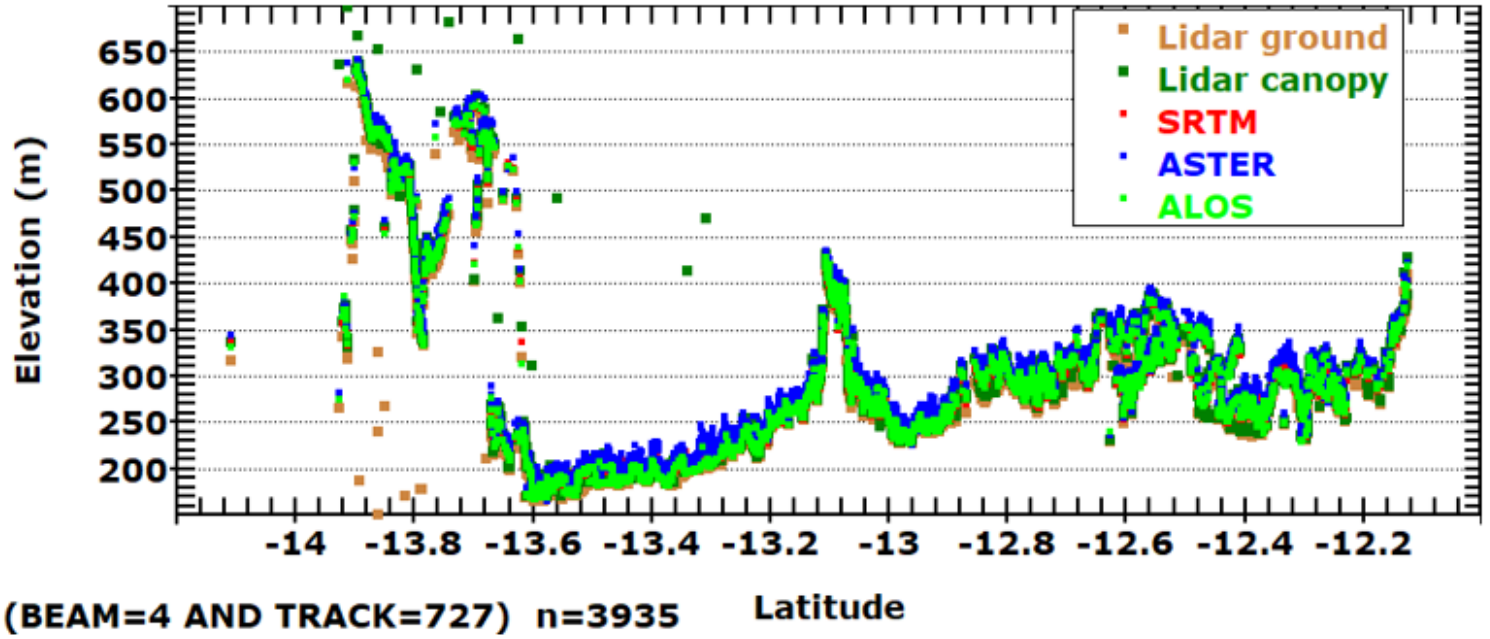


Figure 1. ICESat-2 photon data in Brazil and the three global DEMs.

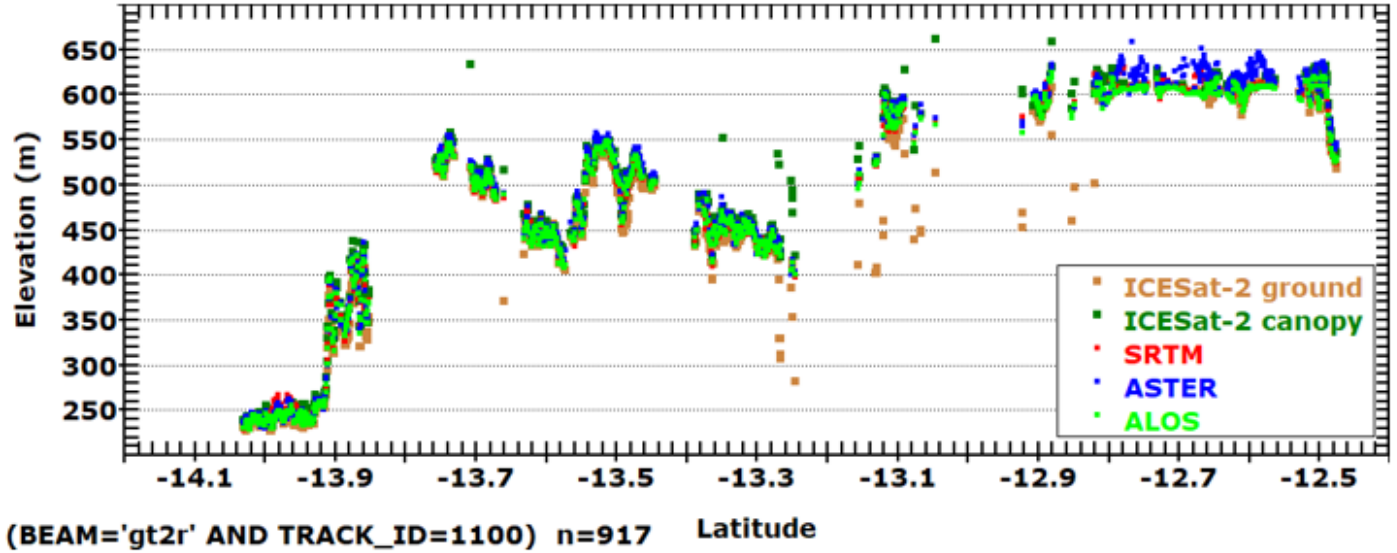
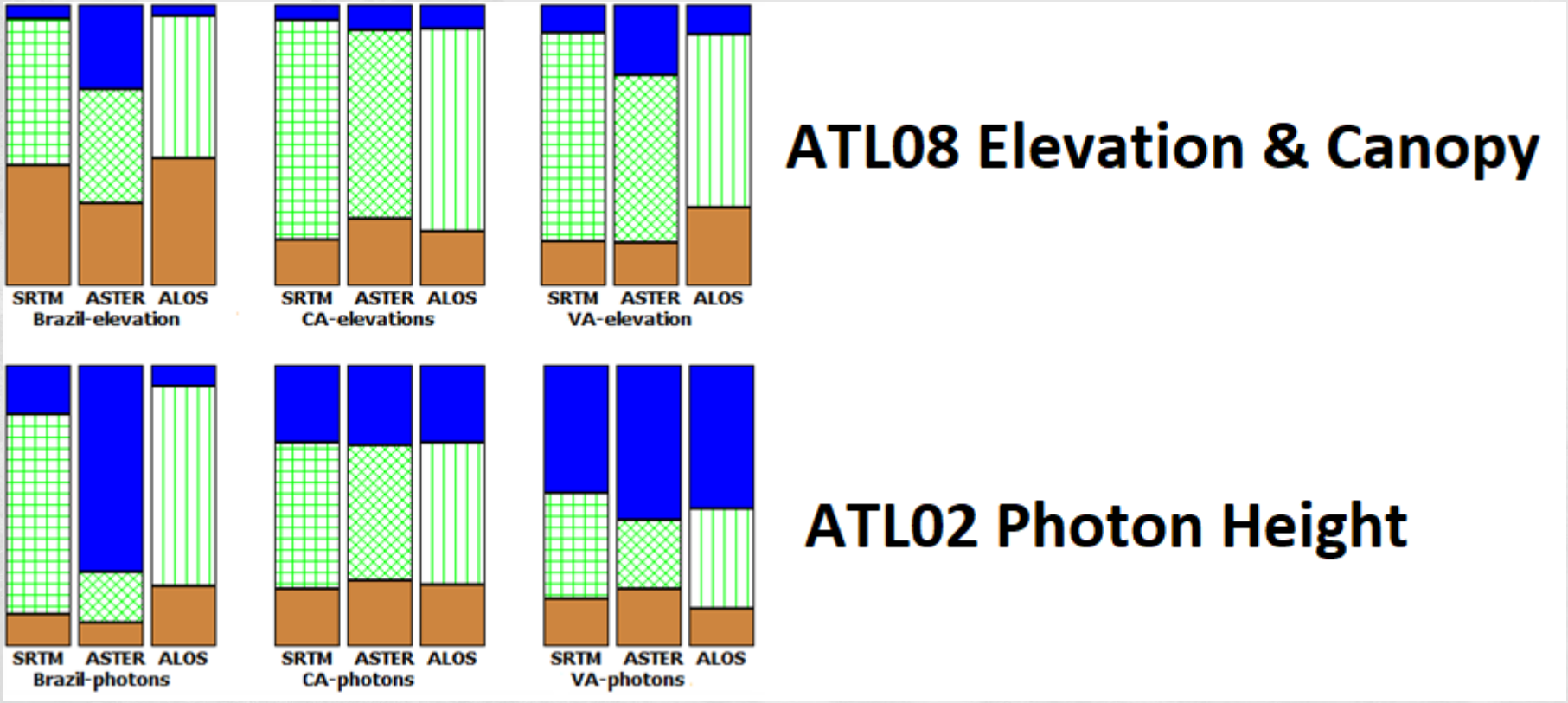
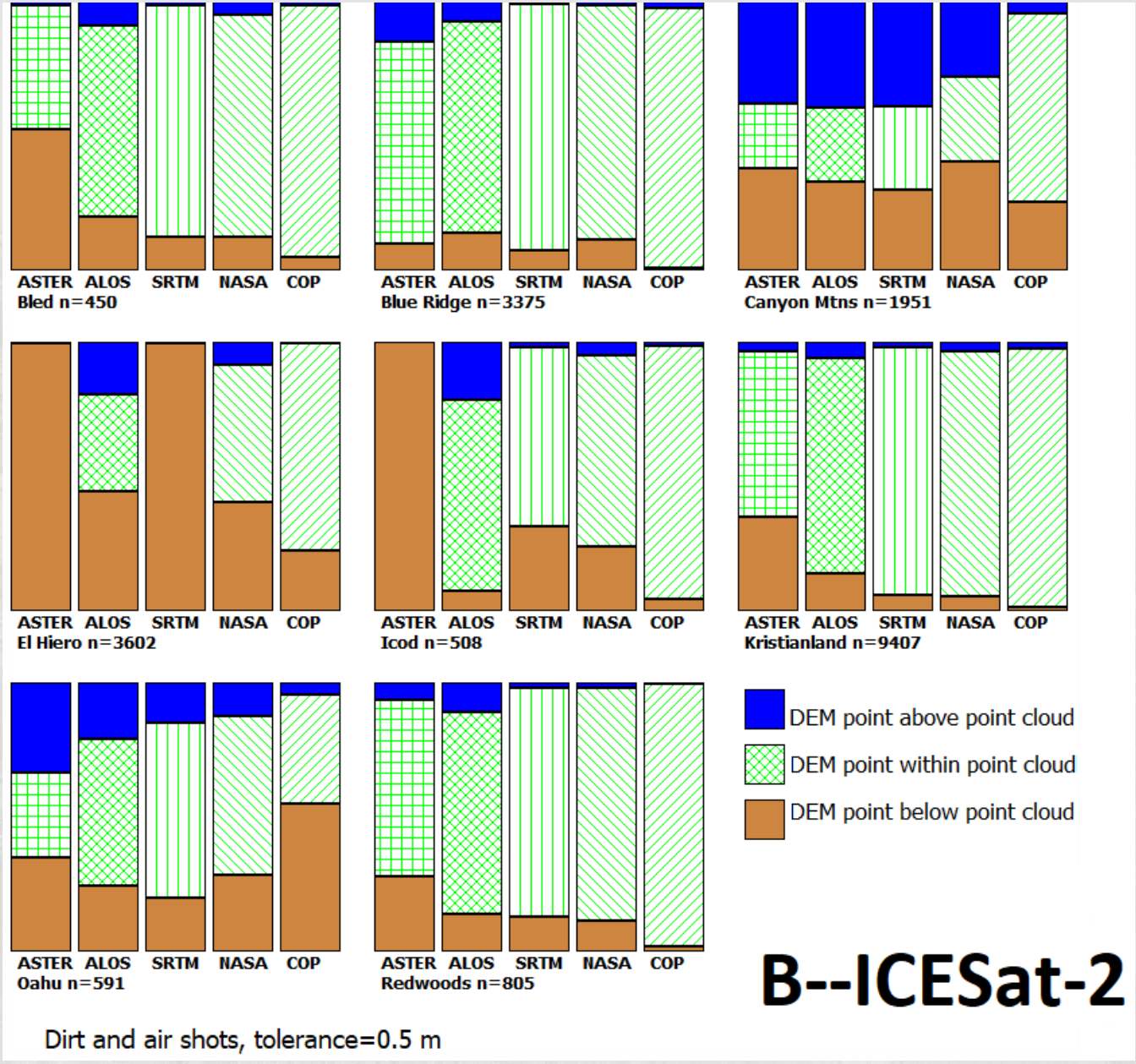


Figure 2. ICESat-2 elevation data in Brazil and the three global DEMs.

Compare ICESat-2 Products—Photons Noisier



ATL08


ASTER ALOS SRTM NASA COP
Bled n=450
ASTER ALOS SRTM NASA COP
Blue Ridge n=3375
ASTER ALOS SRTM NASA COP
Canyon Mtns n=1951
ASTER ALOS SRTM NASA COP
El Hiero n=3602
ASTER ALOS SRTM NASA COP
Icod n=508
ASTER ALOS SRTM NASA COP
Kristianland n=9407
ASTER ALOS SRTM NASA COP
Oahu n=591
ASTER ALOS SRTM NASA COP
Redwoods n=805
DEM point above point cloud
DEM point within point cloud
DEM point below point cloud
B--ICESat-2
Dirt and air shots, tolerance=0.5 m

Many fewer points in each 1” pixel compared to lidar (<100 to >1000-10000)

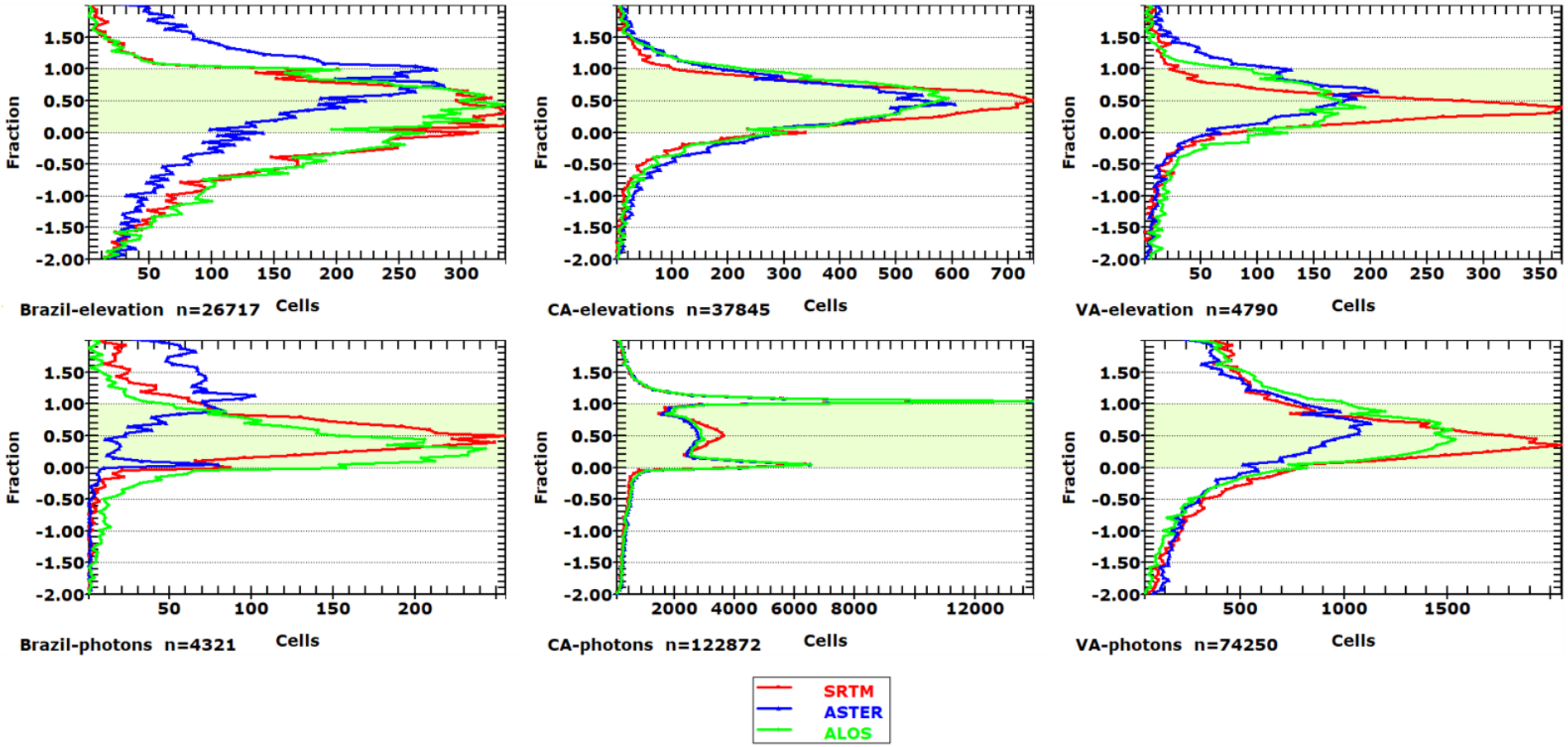
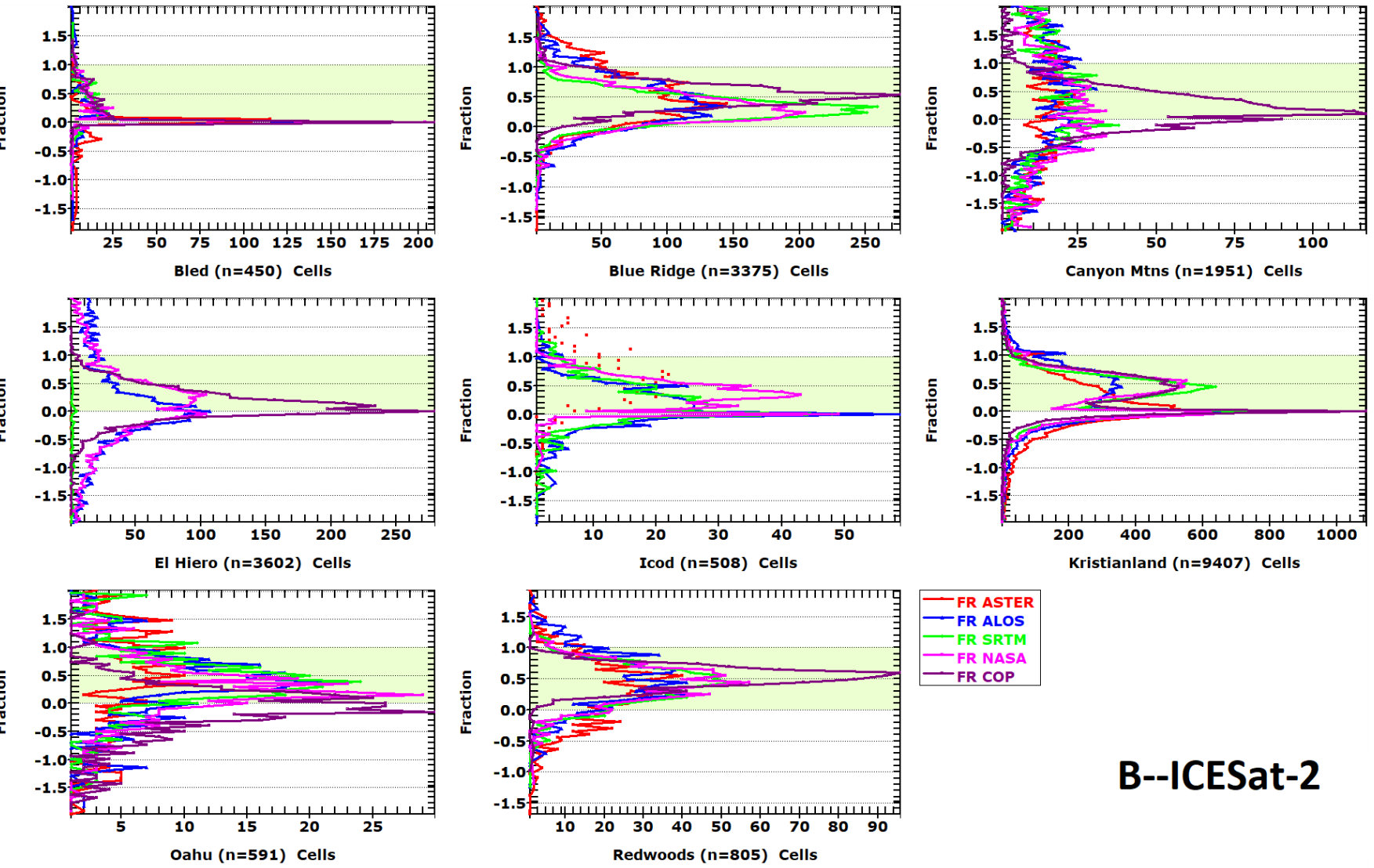
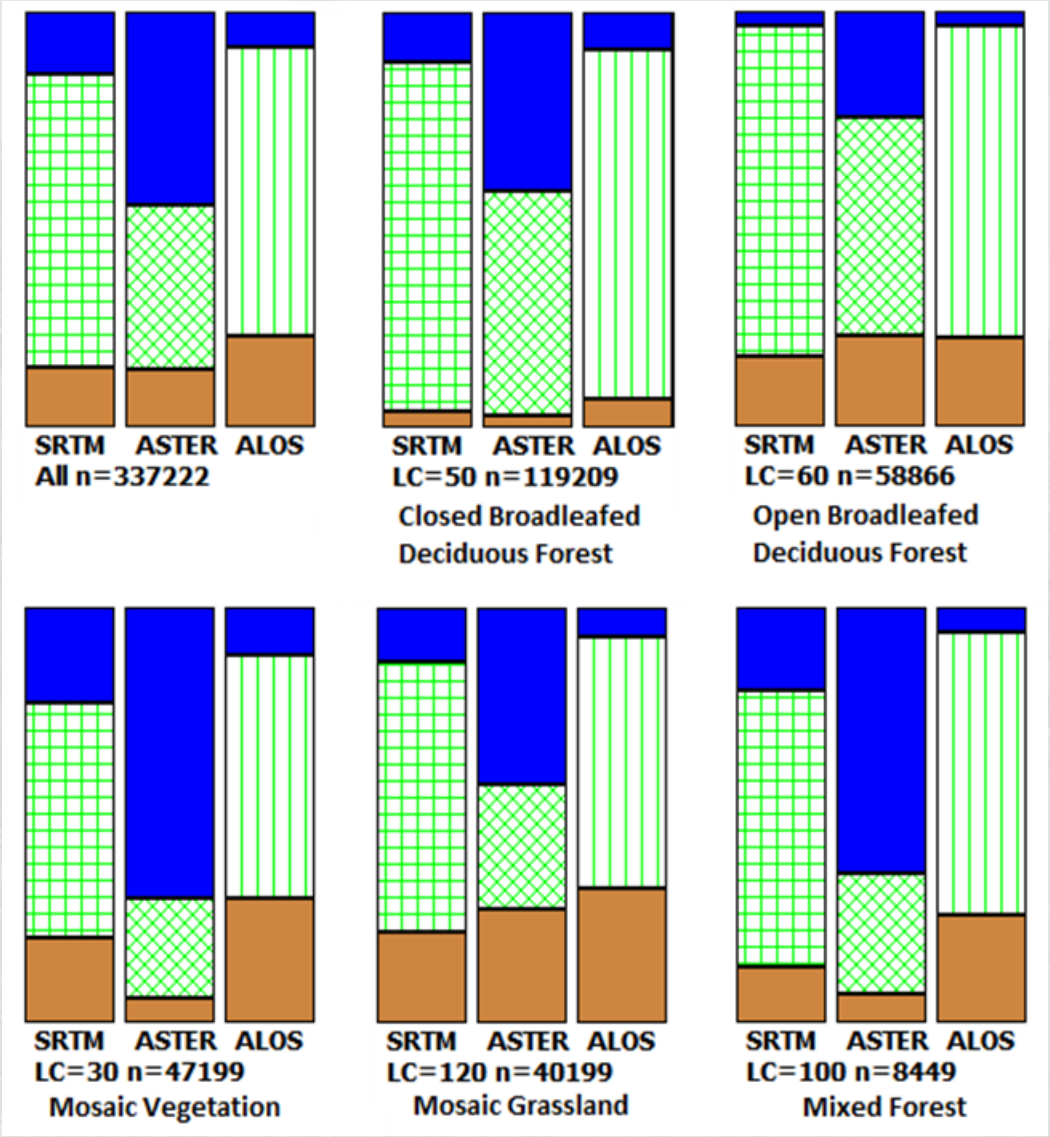


Figure 4. Fraction of data that falls within the elevation envelope and photon point cloud.

ATL08 data

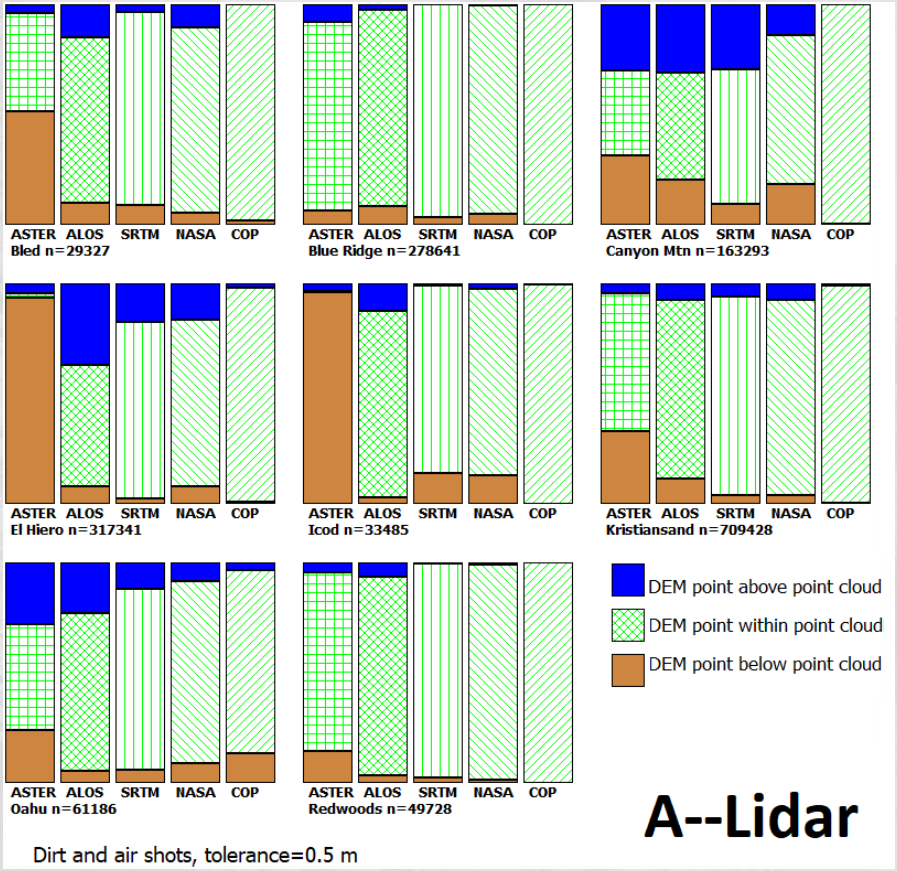

Fraction
Bled (n=450) Cells
Blue Ridge (n=3375) Cells
Canyon Mtns (n=1951) Cells
El Hiero (n=3602) Cells
Icod (n=508) Cells
Kristianland (n=9407) Cells
Oahu (n=591) Cells
Redwoods (n=805) Cells
FR ASTER
FR ALOS
FR SRTM
FR NASA
FR COP
B--ICESat-2

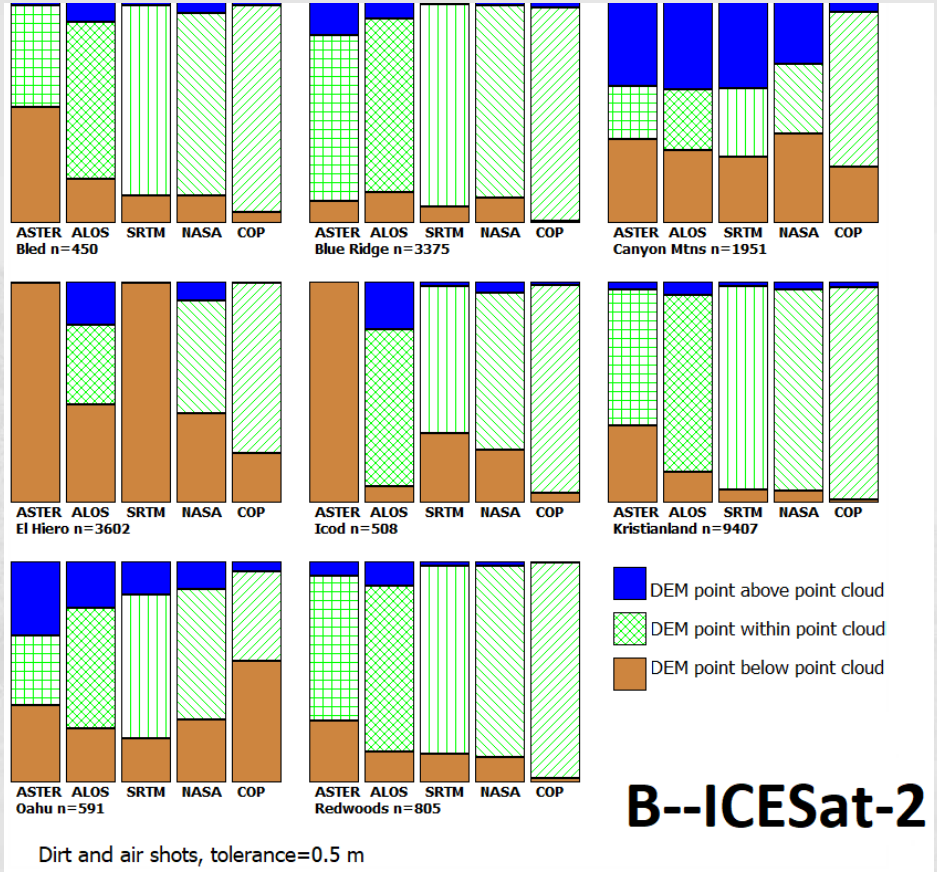
ICESat-2 compared to Sentinel-2 Landcover

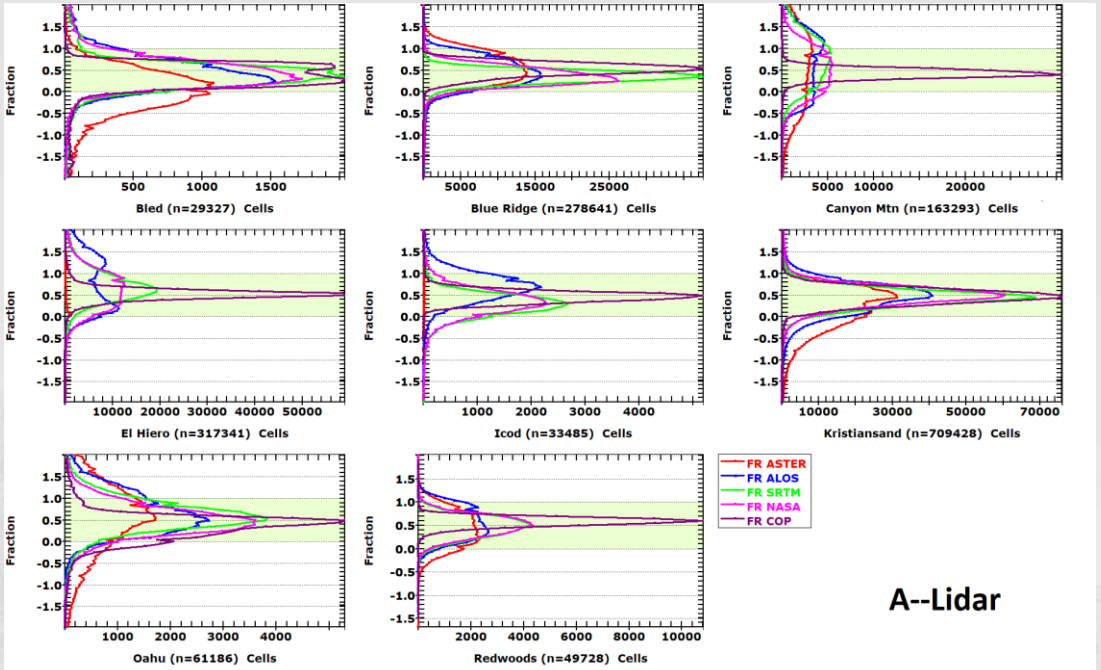


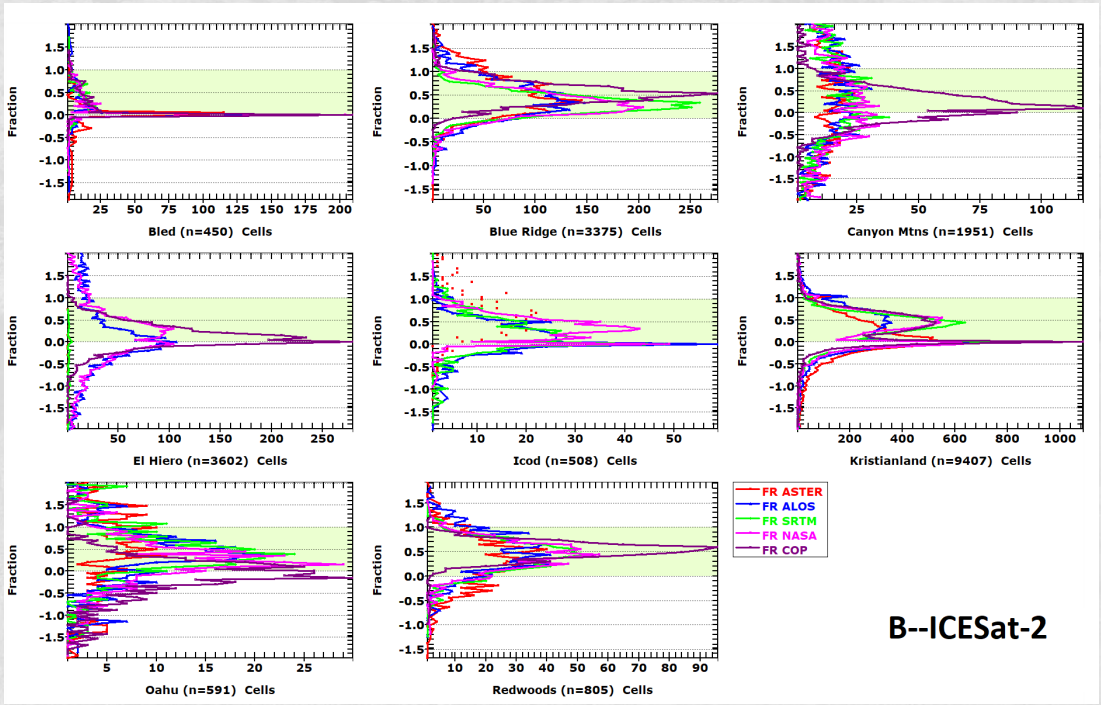
- **Air ball**
- **Within canopy**
- **Gutter ball—in the dirt**

Compare Lidar to ICESat-2



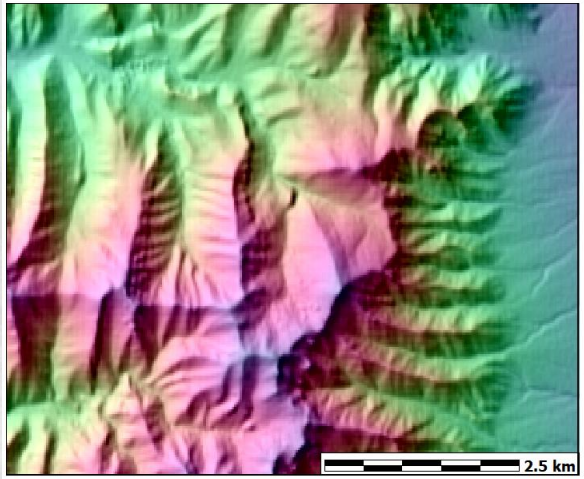




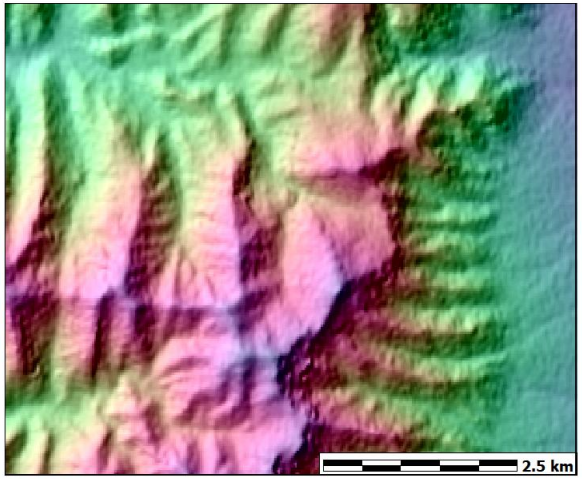


50x times more 1” cells

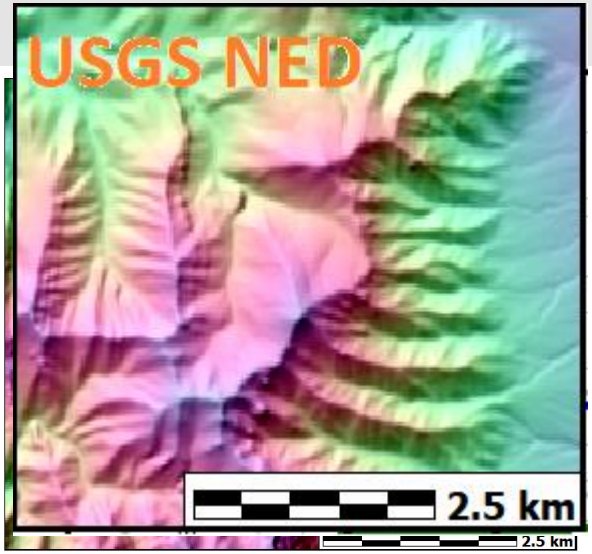
Visual comparison, 1” DEMs Utah



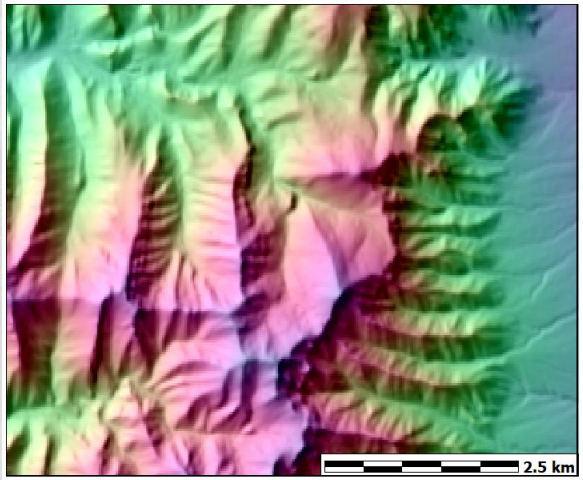
ALOS



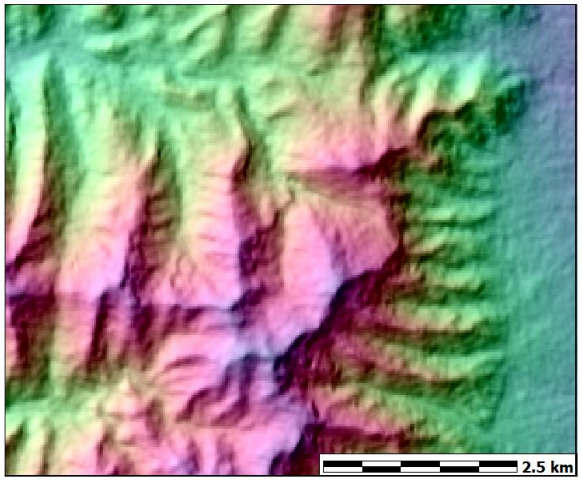
NASA



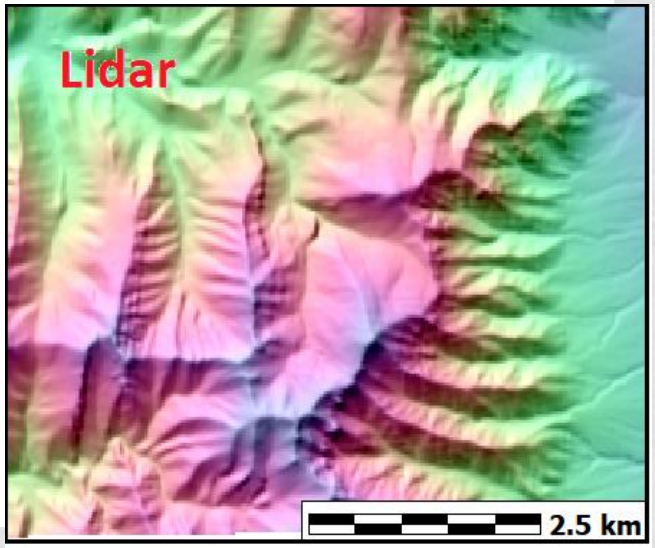
SRTM



COP



ASTER



Concluding thoughts

- 1” DEM ranking: Copernicus, ALOS, SRTM/NASADEM tie, Aster
- 1” DEMs are mostly within the “canopy” defined by the lasers, and thus intermediate between DSM and DTM
- Little advantage to using ATL02 instead of ATL08 data for ICESat-2
- Lidar is better than ICESat-2, but ICESat-2 has global if sparse coverage