

Determination of local slope using photon-counting laser altimetry

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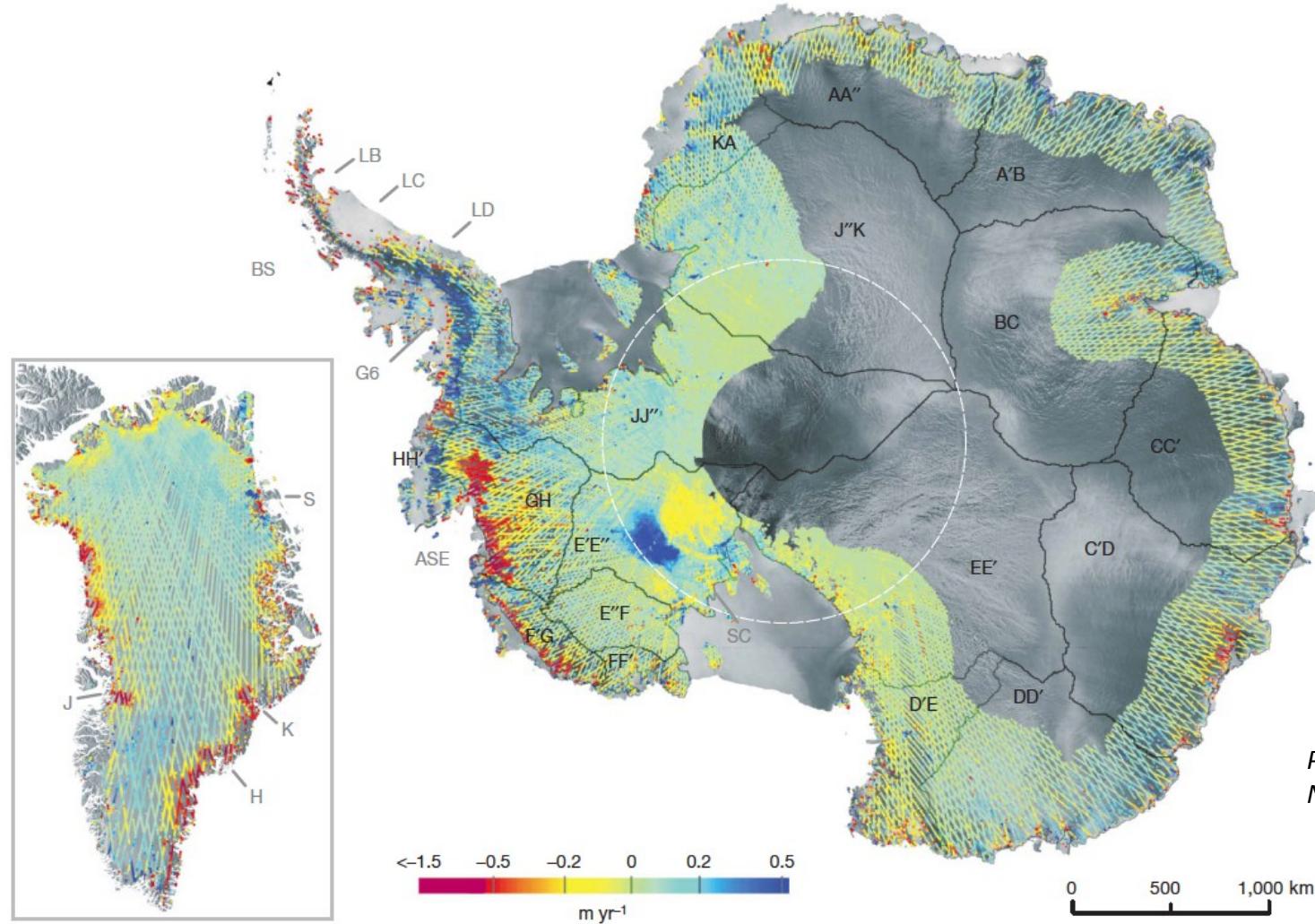
Sermiligaaarsuk, Greenland

20 Apr 2012

Photo: Tim Williams, NASA, DFRC

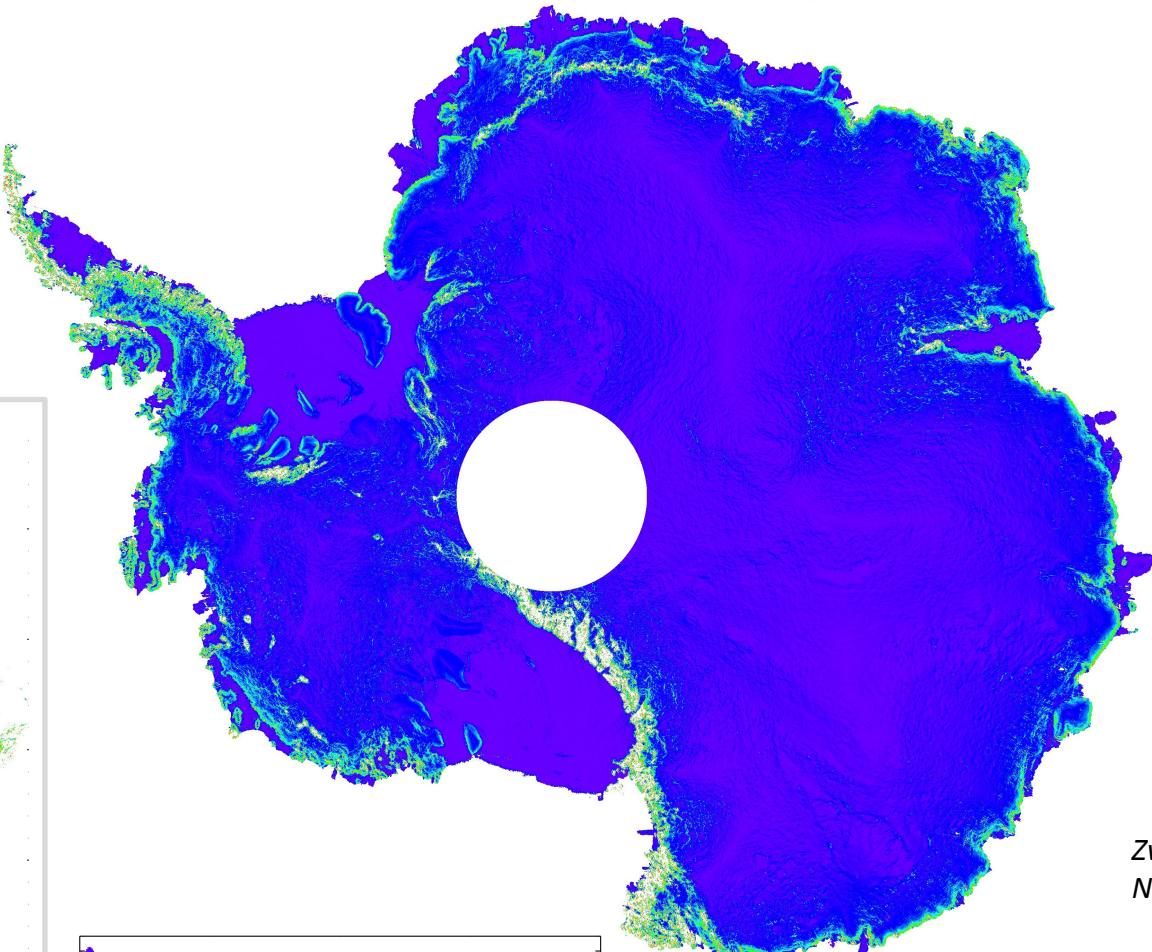
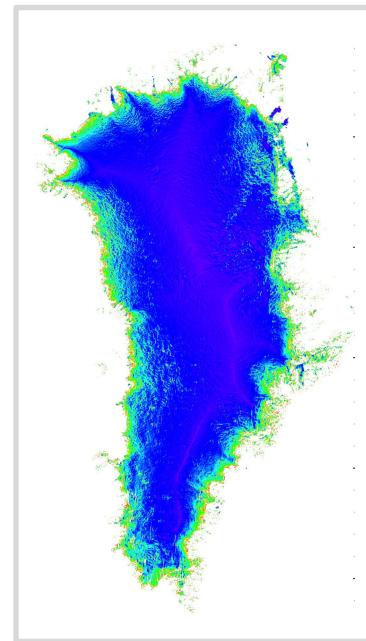


ICESat surface change (2003 to 2009)

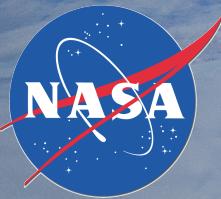




ICESat surface slope



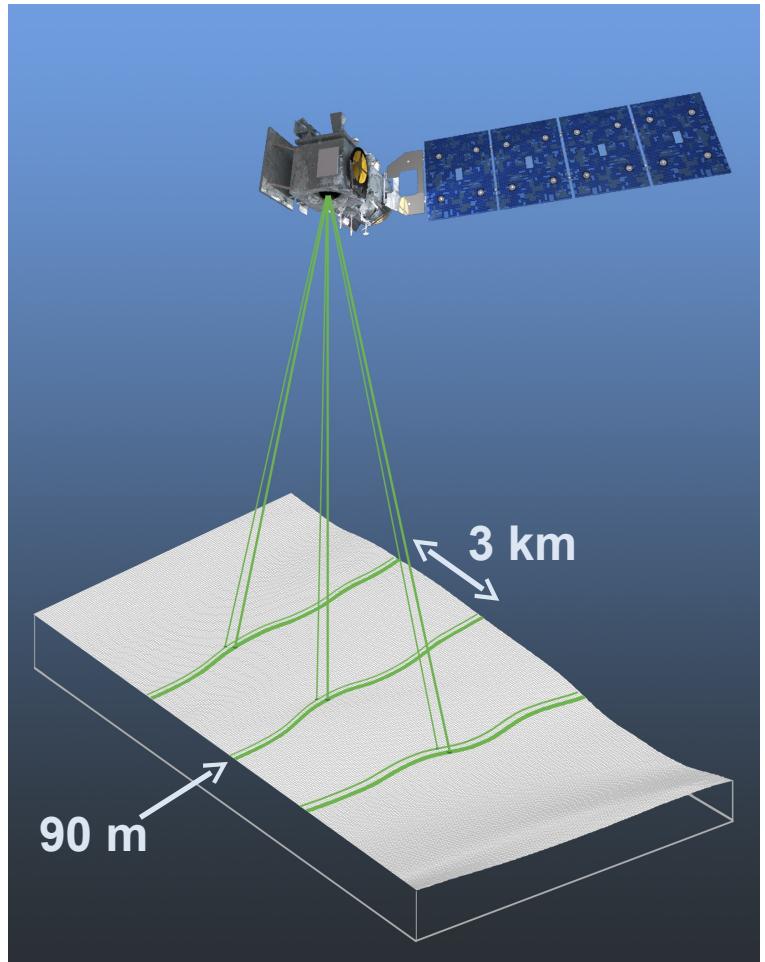
Zwally *et al.*, 2012
NSIDC



ICESat-2 (2016/2017) measurement concept

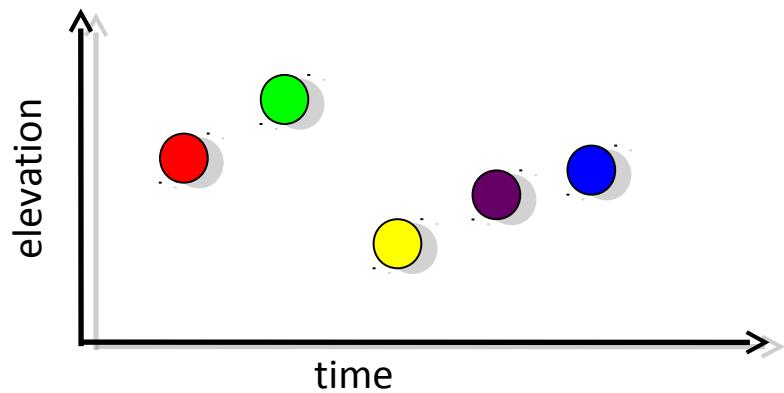
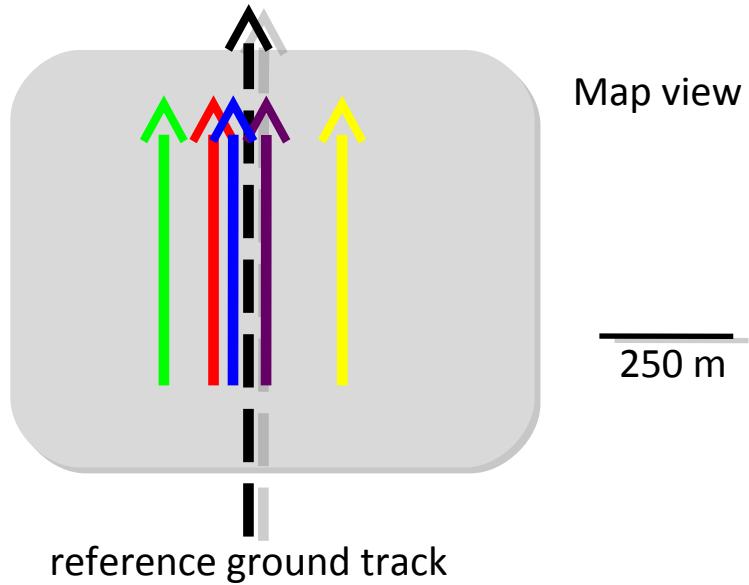
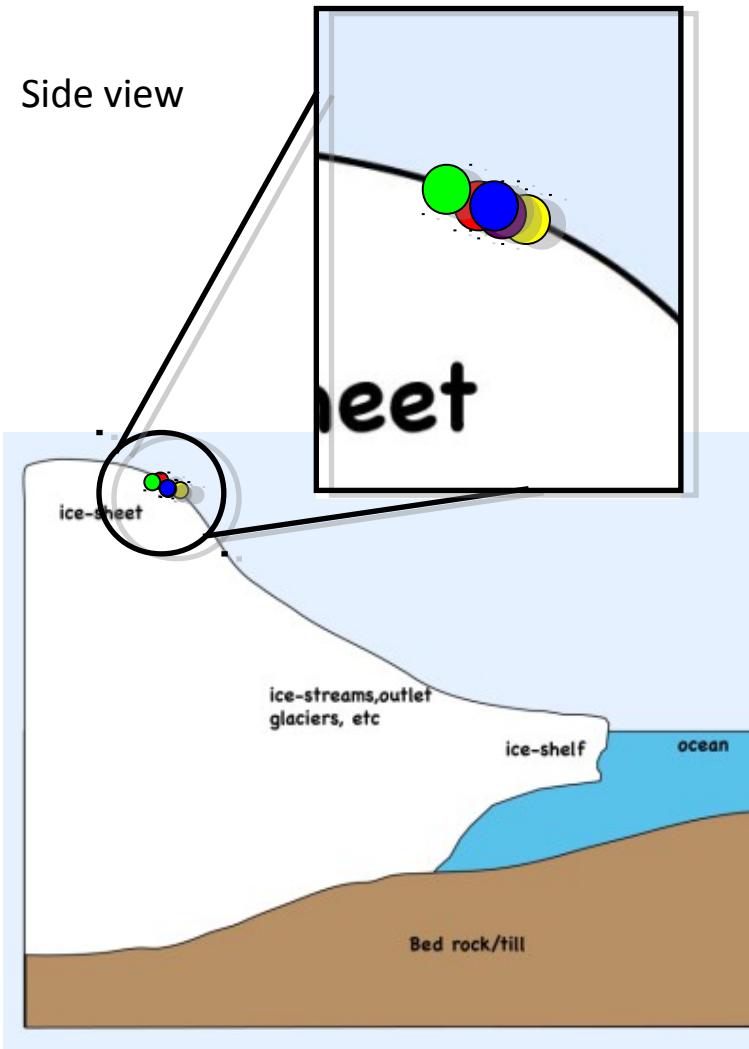
- Micro-pulse photon counting laser altimeter
- 532 nm
- High repetition rate (10 kHz)
- Dense along-track sampling (70 cm)
- Small (10 m) footprint
- ~1400 tracks, repeated every 91 days
- Multi-beam sampling (3 pairs of beams)
- 3 km spacing between pairs for spatial coverage
- 90 m spacing within pairs for slope determination

<http://icesat.gsfc.nasa.gov/icesat2/>



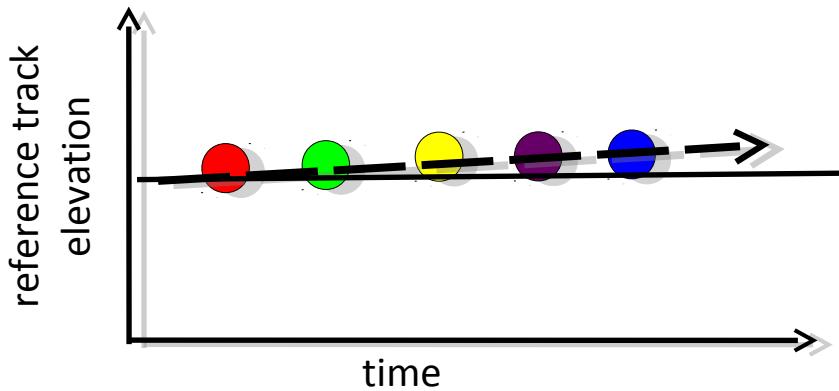
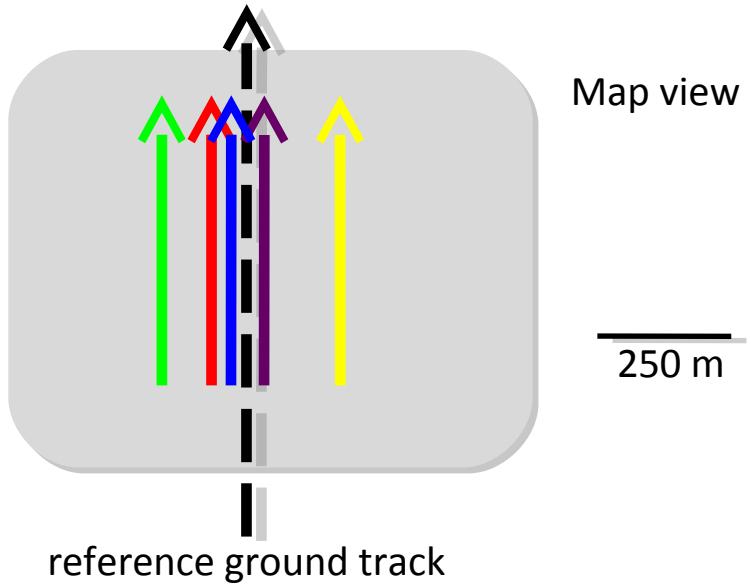
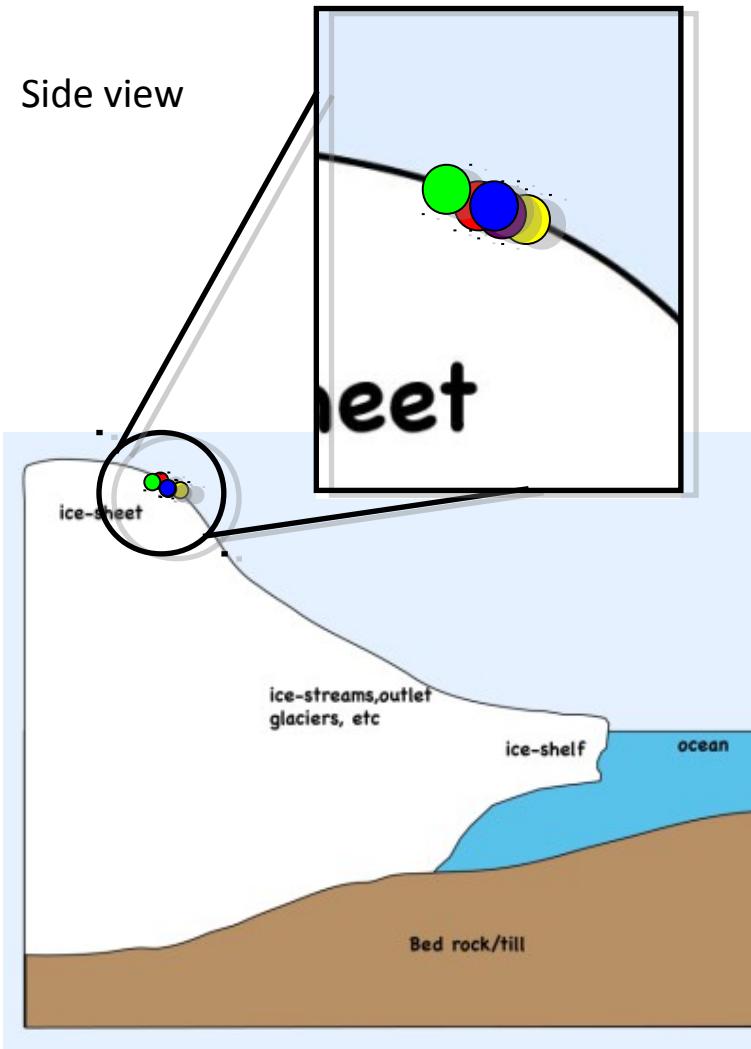


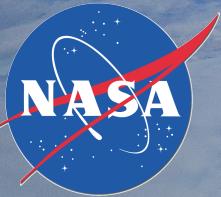
ICESat surface slope



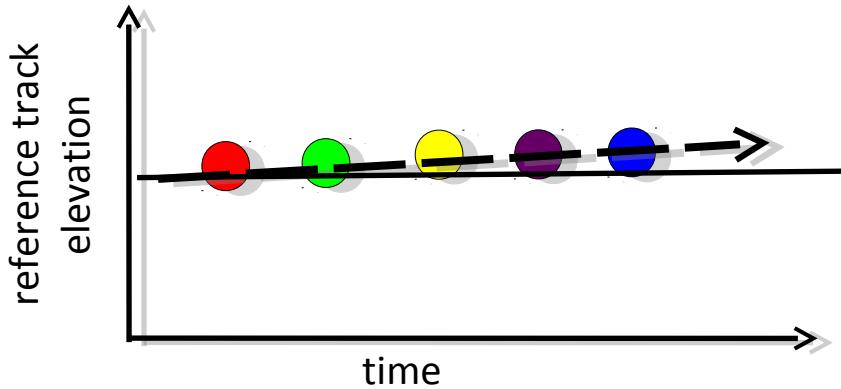
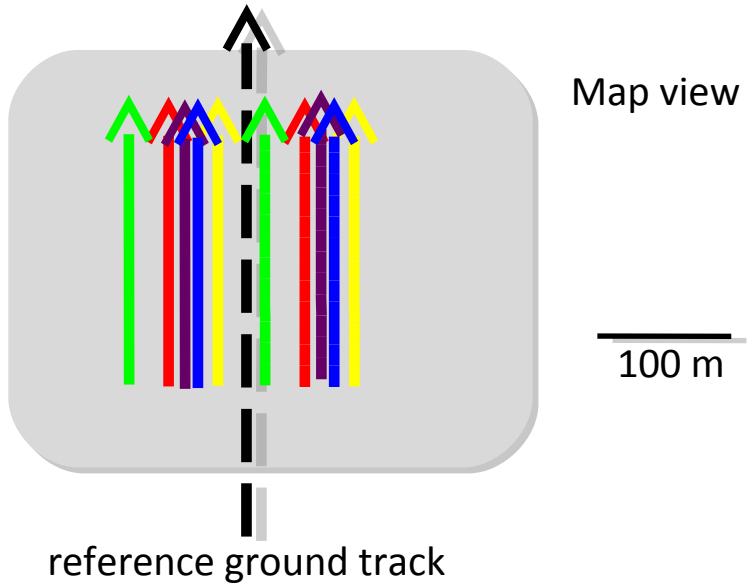
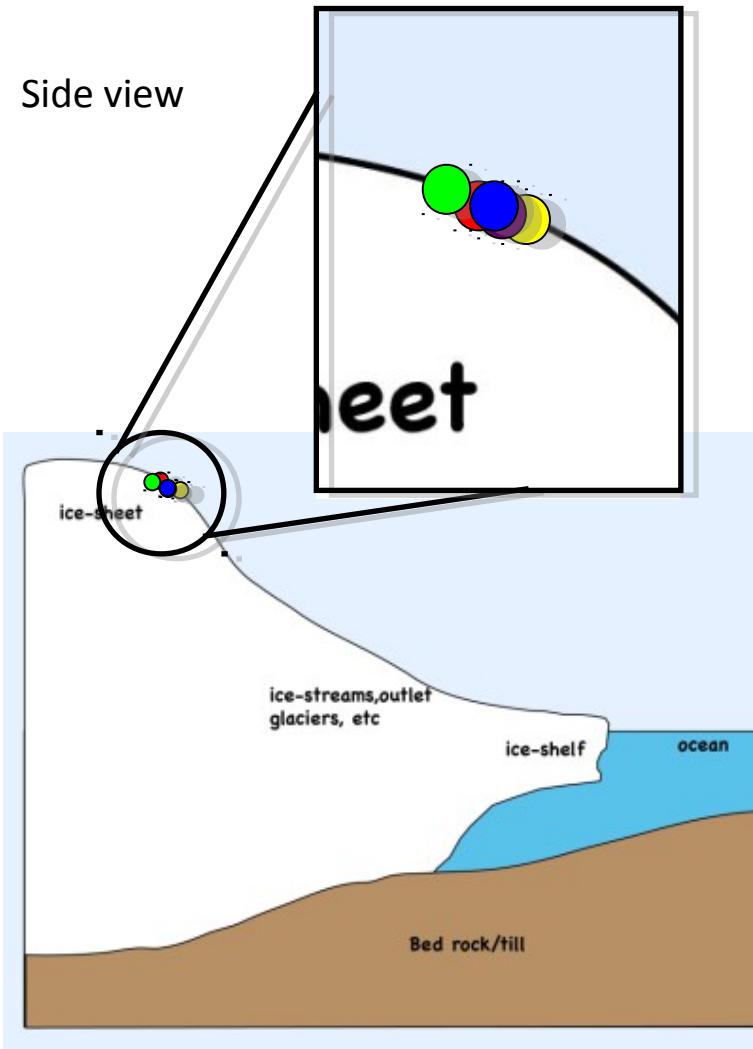


ICESat surface slope





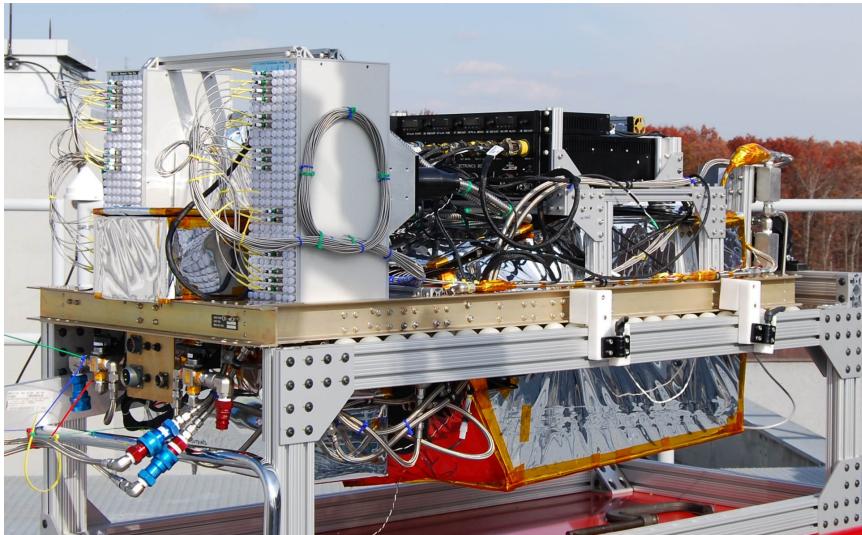
ICESat-2 surface slope





Multiple Altimeter Beam Experimental Lidar (MABEL)

- Photon counting lidar
- Variable beam configuration (± 1 km swath)
- 532 (16 channels) and 1064 (8 channels) nm
- Variable repetition rate (5-25 kHz)
- For **Greenland 2012** deployment:
 - NASA ER-2 (~20 km, 200 m/s)
 - Dense along-track sampling (4 cm)
 - Small footprint (2 m)



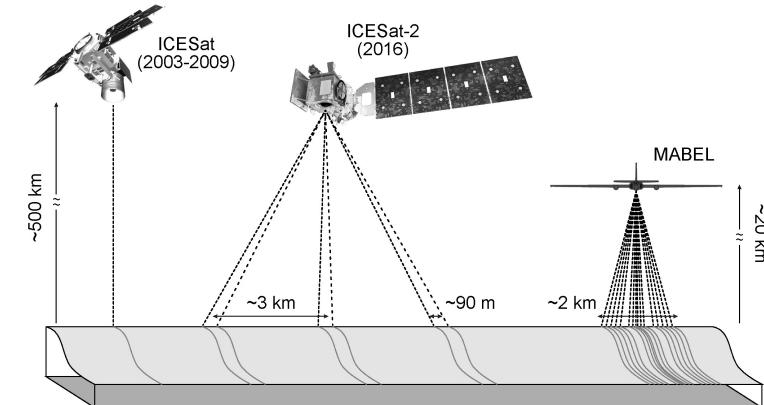
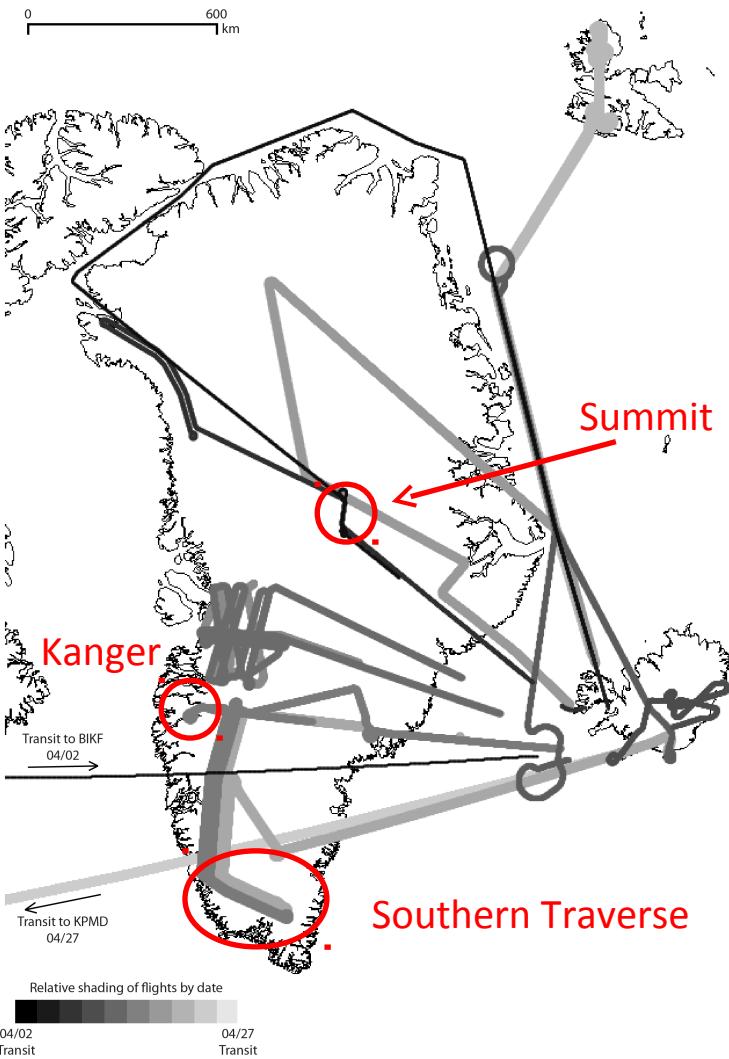
NASA ER-2



Scaled Composites Proteus



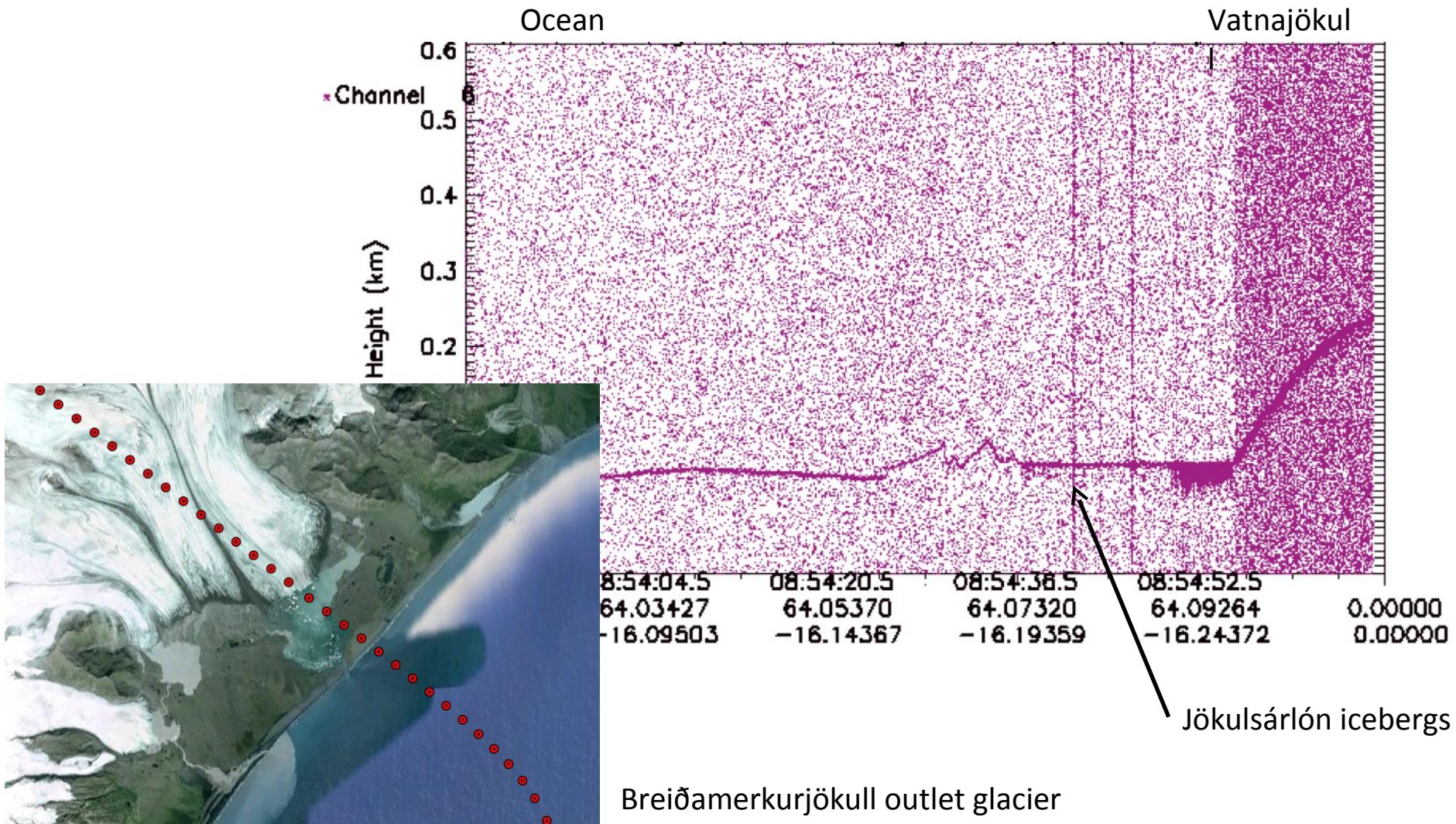
MABEL 2012 Greenland deployment (Keflavik, Iceland)



NASA/ARC, Airborne Science Program, Airborne Sensor Facility, UCSC-UARC



MABEL photon counting lidar data, 'Iceland'





Precision and beam biases of MABEL

OIB ATM GPS survey of Kangerlussuaq airport runway ramp

Differentially post-processed (RMS < 5cm)

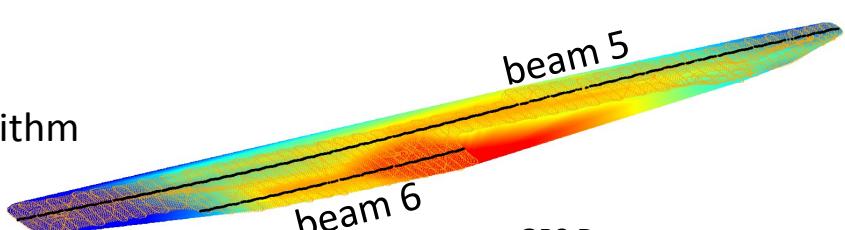
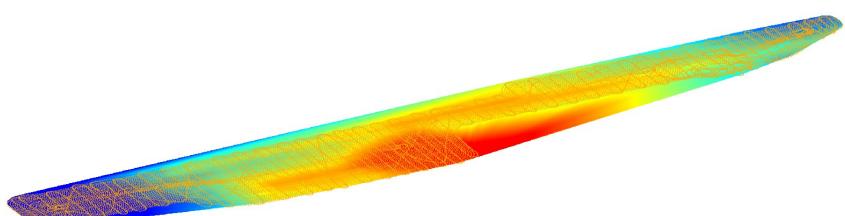
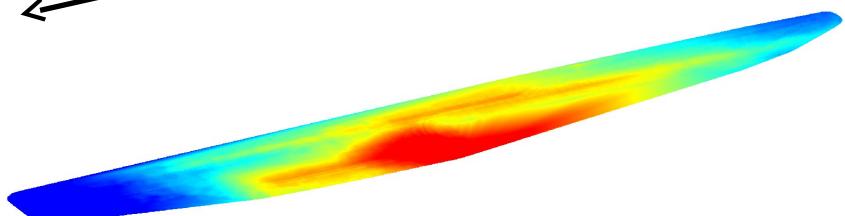
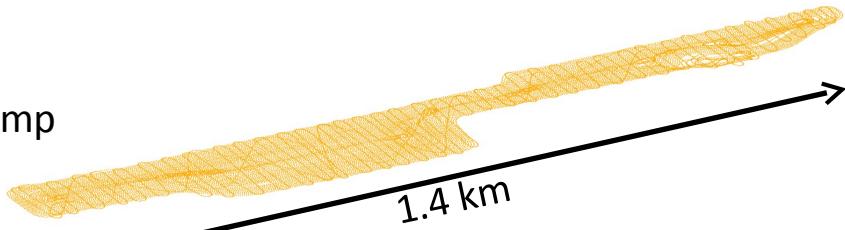
Grid this in MATLAB ('TriScatteredInterp')

MABEL 20 Apr 2012 flight

Version 8, beams 5 and 6 (~90 m spacing)

MABEL elevations from NASA GSFC ground-finding algorithm

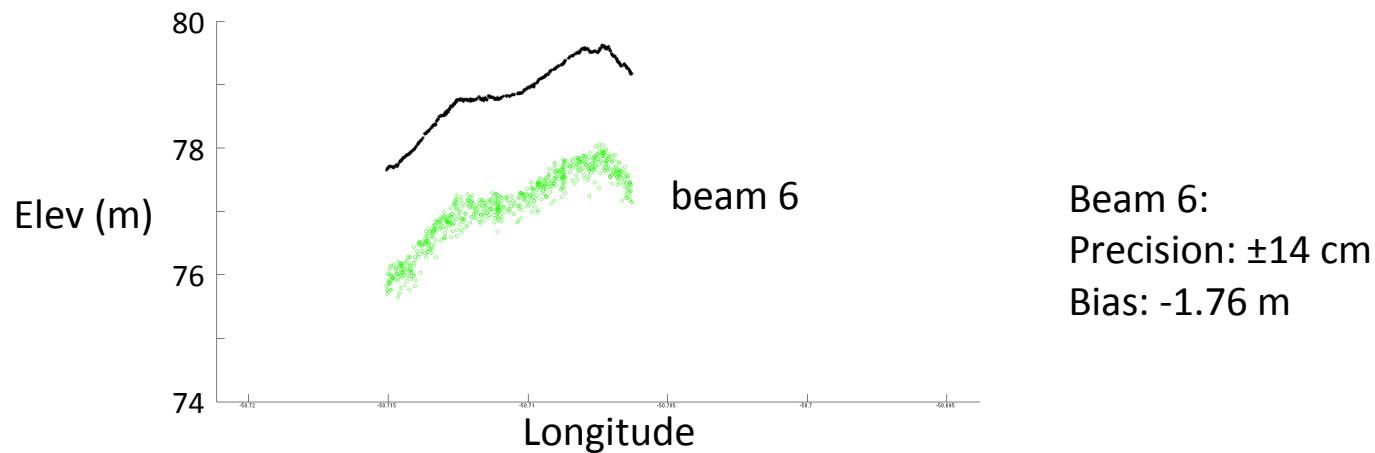
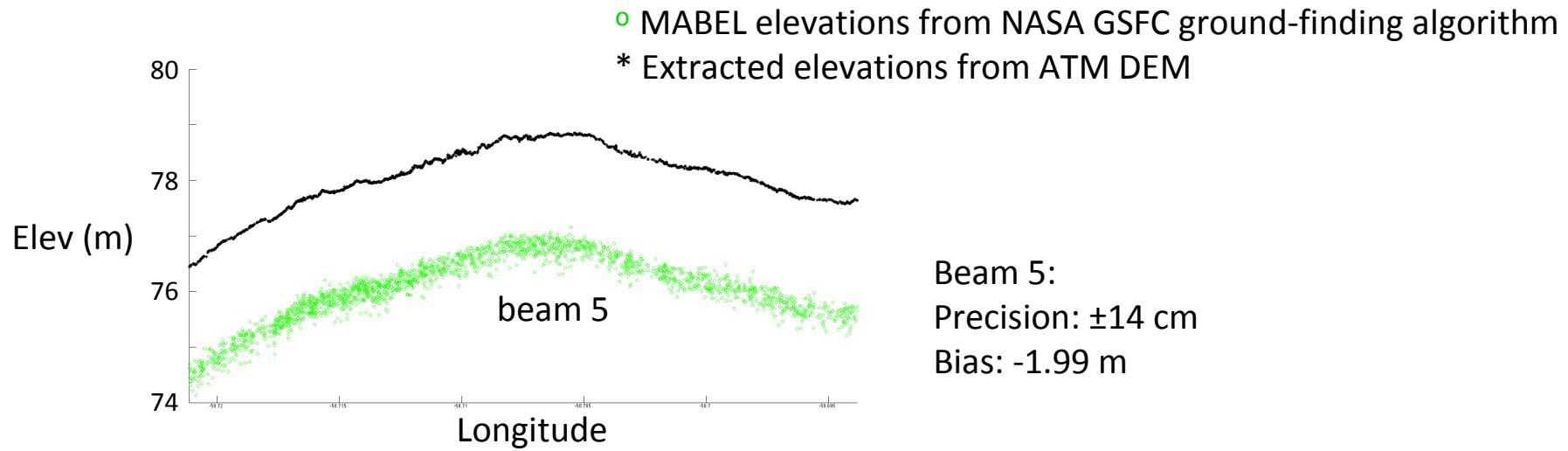
Extracted elevations from Kanger DEM



GPS Data:
Kyle Krabill, NASA, WFF

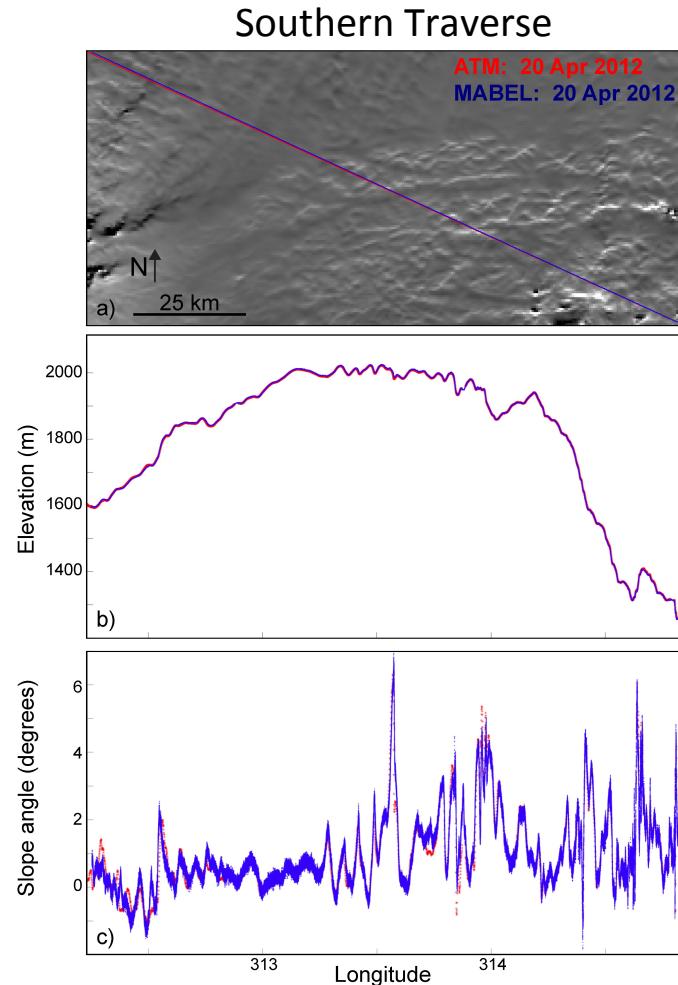


Precision and beam biases of MABEL





Comparison of MABEL and ATM across-track slope assessments

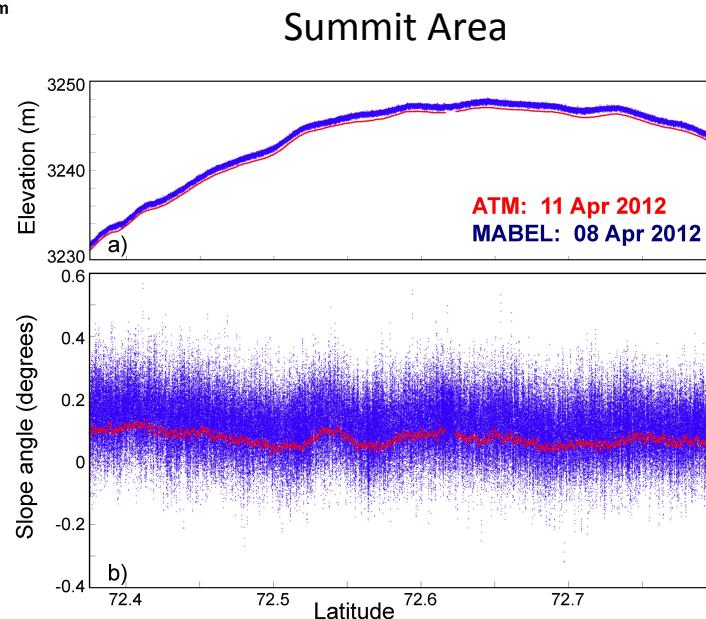
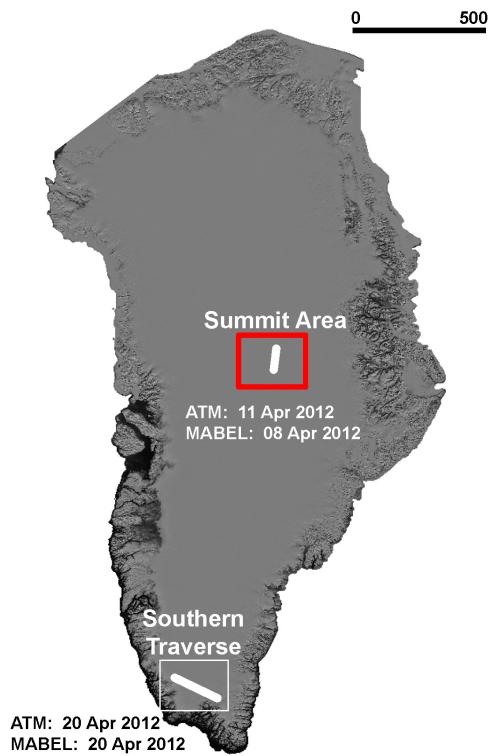


- 2 beams, ICESat-2-like spacing
- interpolated along-track by time
- calculated across-track slope

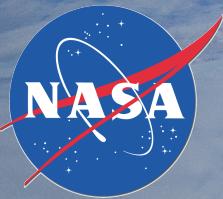
- ATM mean slope: 0.99°
- MABEL mean slope: 1.03°
- mean slope residual: 0.03°



Comparison of MABEL and ATM across-track slope assessments

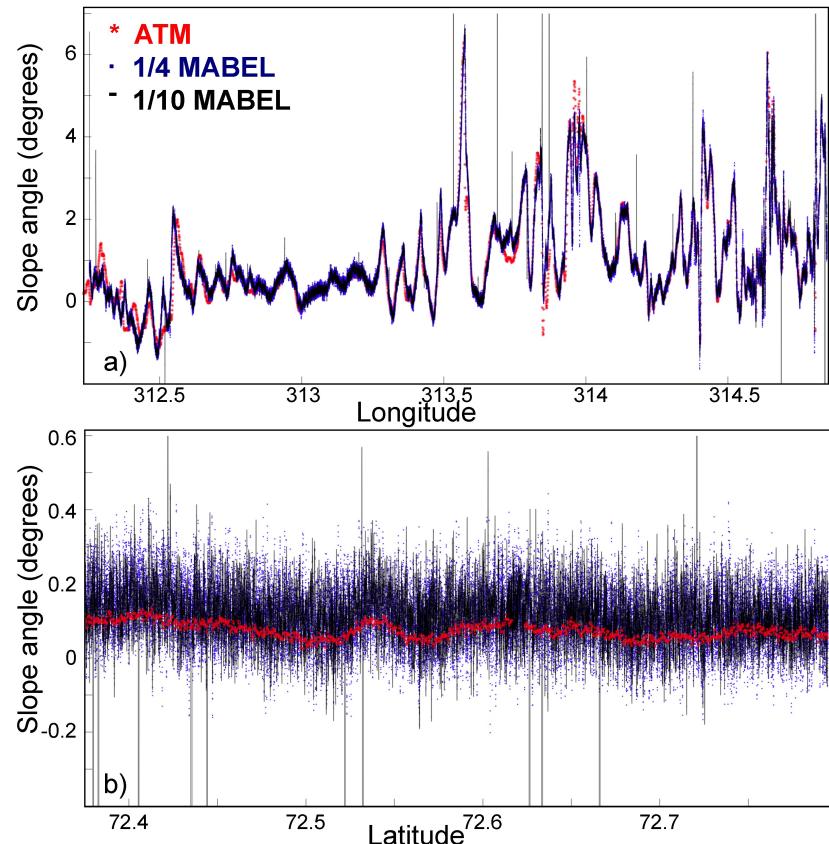


- ATM mean slope: 0.07°
- MABEL mean slope: 0.11°
- mean slope residual: 0.04°



Comparison of MABEL and ATM across-track slope assessments

- Simulated strong/weak beam pair
- Downsampled HDF5 MABEL data, factors 4 and 10
- Rerun through ground-finding algorithm
- MABEL ~50% of model ICESat-2 performance
- For factor of 10, we break ground-finder
- standard deviation (South): 1.14° increases to 2.41°
- standard deviation (Summit): 0.09° increases to 5.87°





Summary

- MABEL precision (20 Apr 2012): ± 14 cm
- MABEL and ATM comparison using a wide range of slopes (0° to 6°), similar to WAIS extremes
- Mean MABEL and ATM slope residuals: $<= 0.04^\circ$
- Slope results break down when subsampling by a factor of 10; associated with ground-finding

MABEL results in Greenland give us confidence that the ICESat-2 sampling strategy (90-m spacing and the strong/weak beam relationship) will allow for the separation of the effects of local slope from true ice-sheet elevation change with just 2 satellite passes; this strategy is ideal for change determination on WAIS.

Brunt, Neumann, Walsh, & Markus (accepted) Determination of local slope on the Greenland Ice Sheet using a multibeam photon-counting lidar in preparation for the ICESat-2 mission. IEEE Geoscience and Remote Sensing Letters (doi:10.1109/LGRS.2013.2282217)

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ICESat-2: <http://icesat.gsfc.nasa.gov/icesat2/>

MABEL: http://icesat.gsfc.nasa.gov/icesat2/data/mabel/mabel_docs.php