

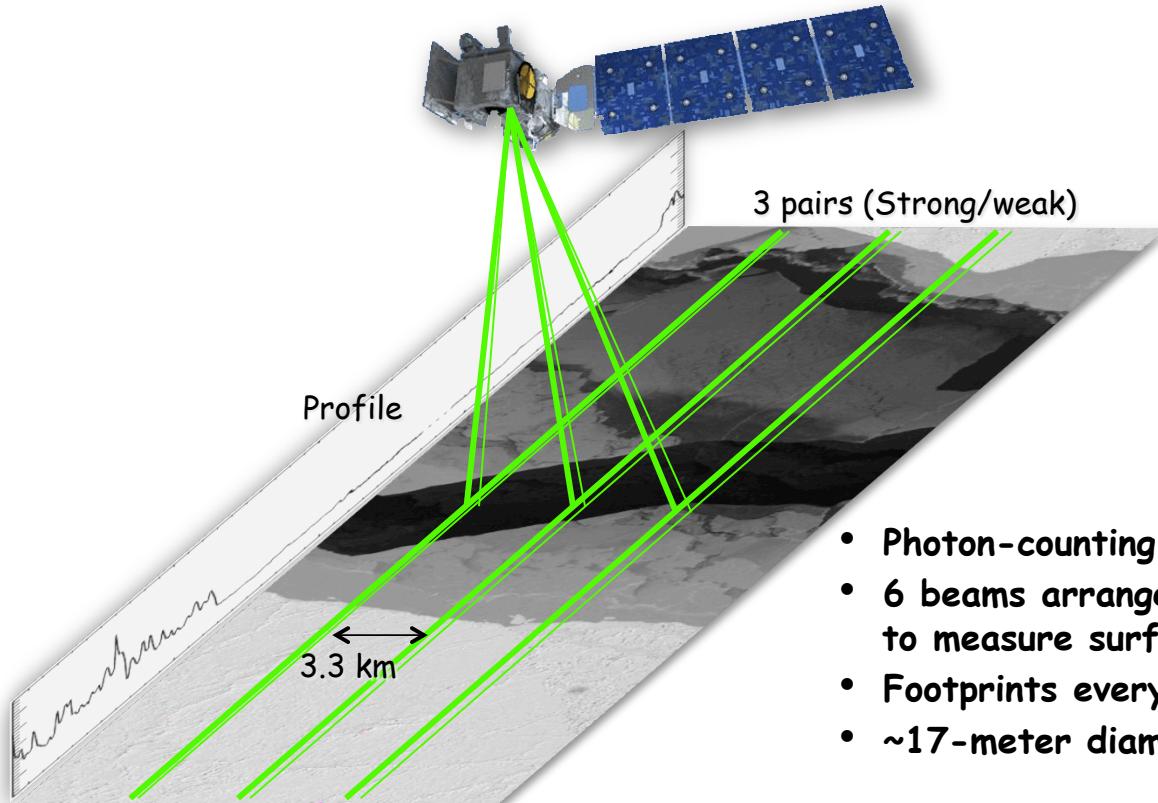
Introduction to ATL07 (Sea Ice Surface Heights) and ATL10 (Sea Ice Freeboards)



Ron Kwok
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA

ICESat-2 Hackweek
University of Washington
June 17-21, 2019

Multibeam Photon Counting Altimetry



- Photon-counting lidar
- 6 beams arranged in 3 (Strong/weak) pairs to measure surface slope directly
- Footprints every 0.7 m (ICESat-1 167 m)
- ~17-meter diameter (ICESat-1 50-70 m)

- Heights
 - Sampling along-track
 - Photon rates
 - background
 - Distributions
- Freeboards
 - lead spans
 - Arctic coverage
 - data quality

$$h = h_{ph} - h_{MSS} - h_{ocean_tide} - h_{IB}$$

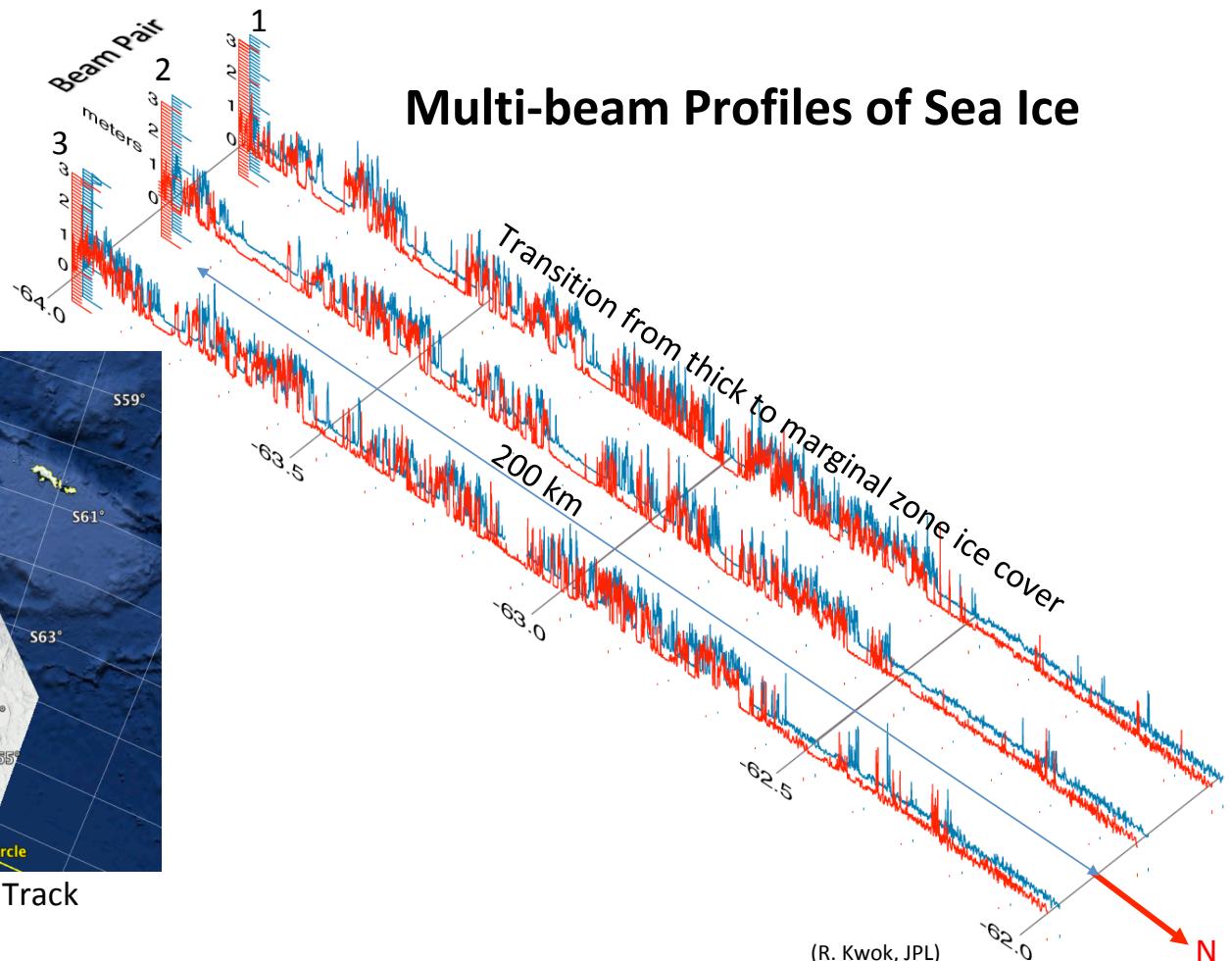


ICE, CLOUD, AND LAND ELEVATION SATELLITE-2



October 17, 2018 – Ascending Track

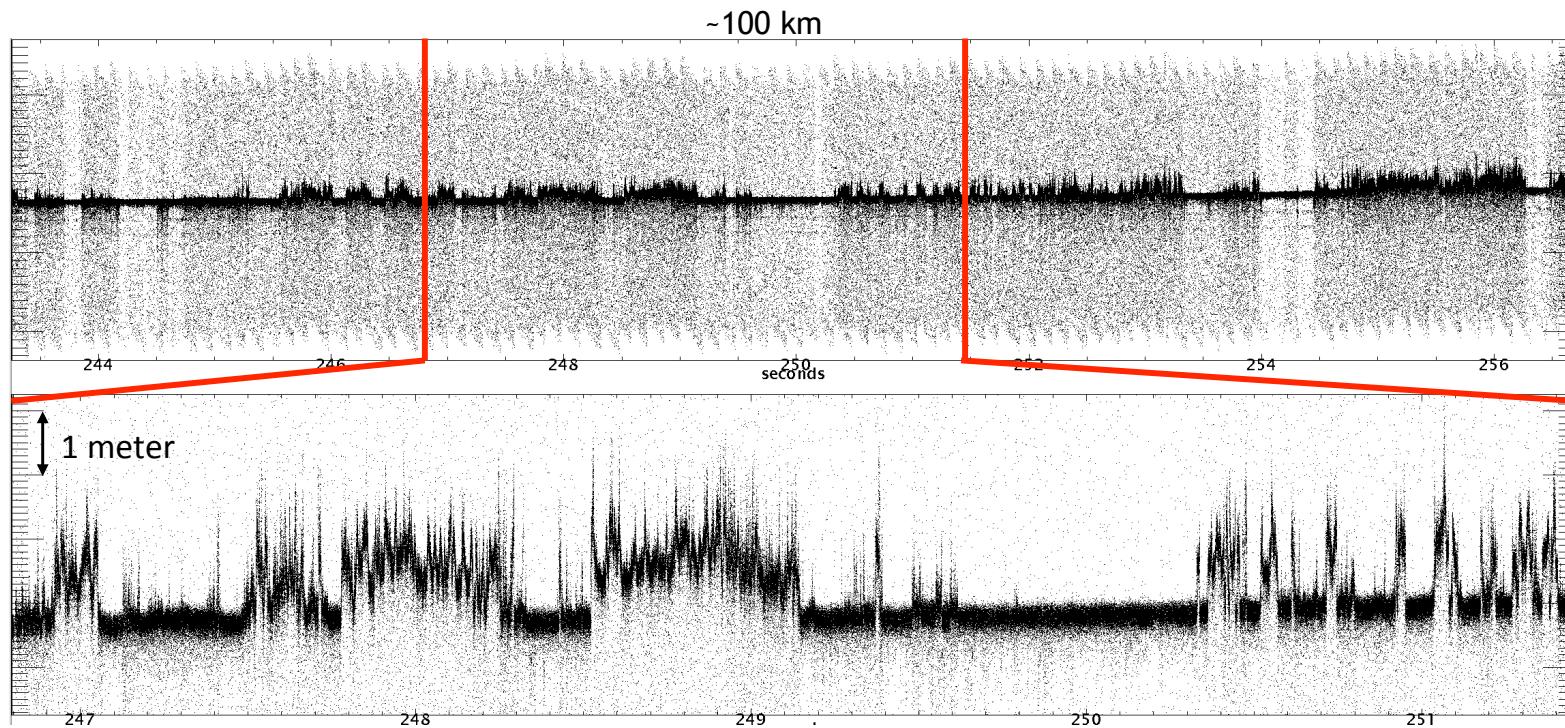
ICESat-2 Hackweek, June 17-21, University of Was



(R. Kwok, JPL)



Photon Cloud (Returns from sea ice)





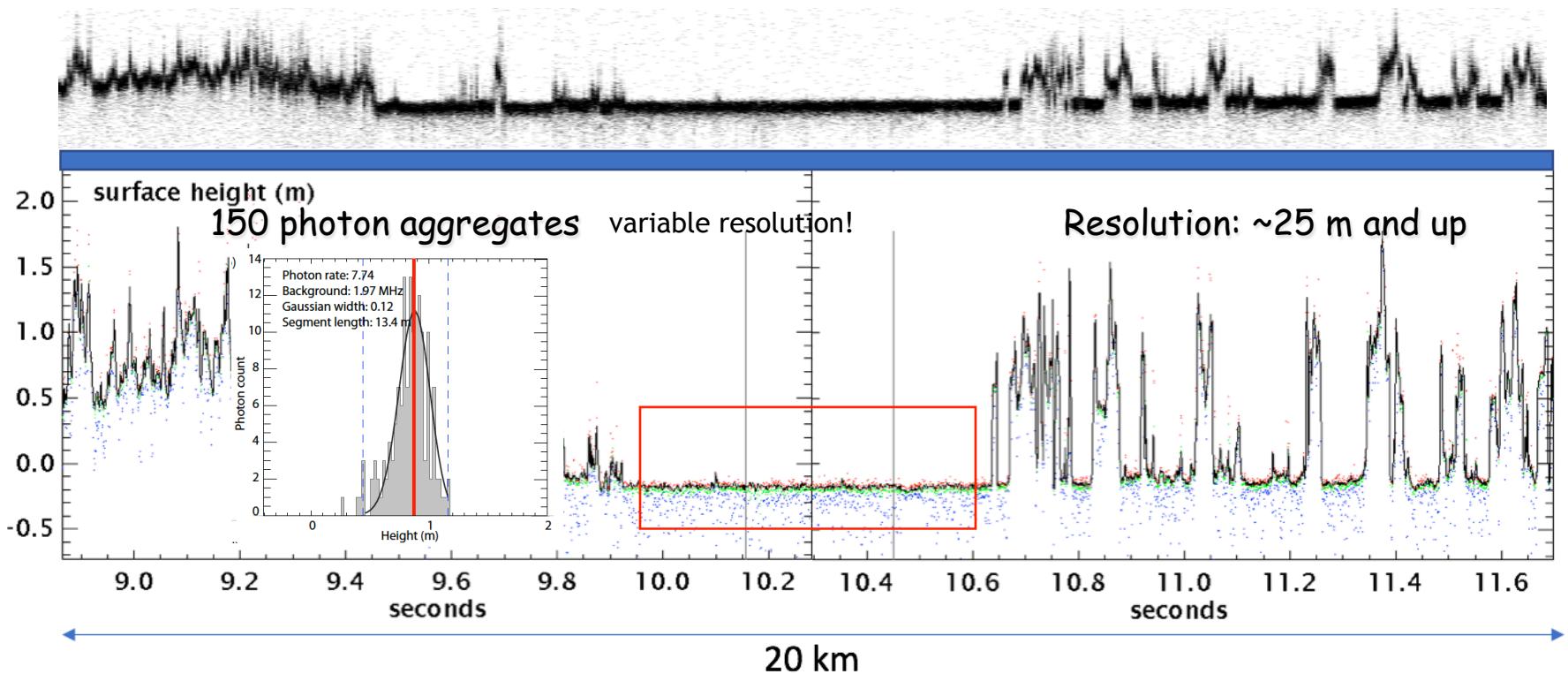
Expected returns from the surface



Target type	Lambertian surface reflectance (532nm)	N signal photons per shot (weak beam)	N signal photons per shot (strong beam)
Sea Ice	0.8 - 0.9	0.6 - 2.1	2.3 - 8.5
Leads	* - 0.2 (much higher when specular)	0.05 - 0.2	0.2 - 1.0

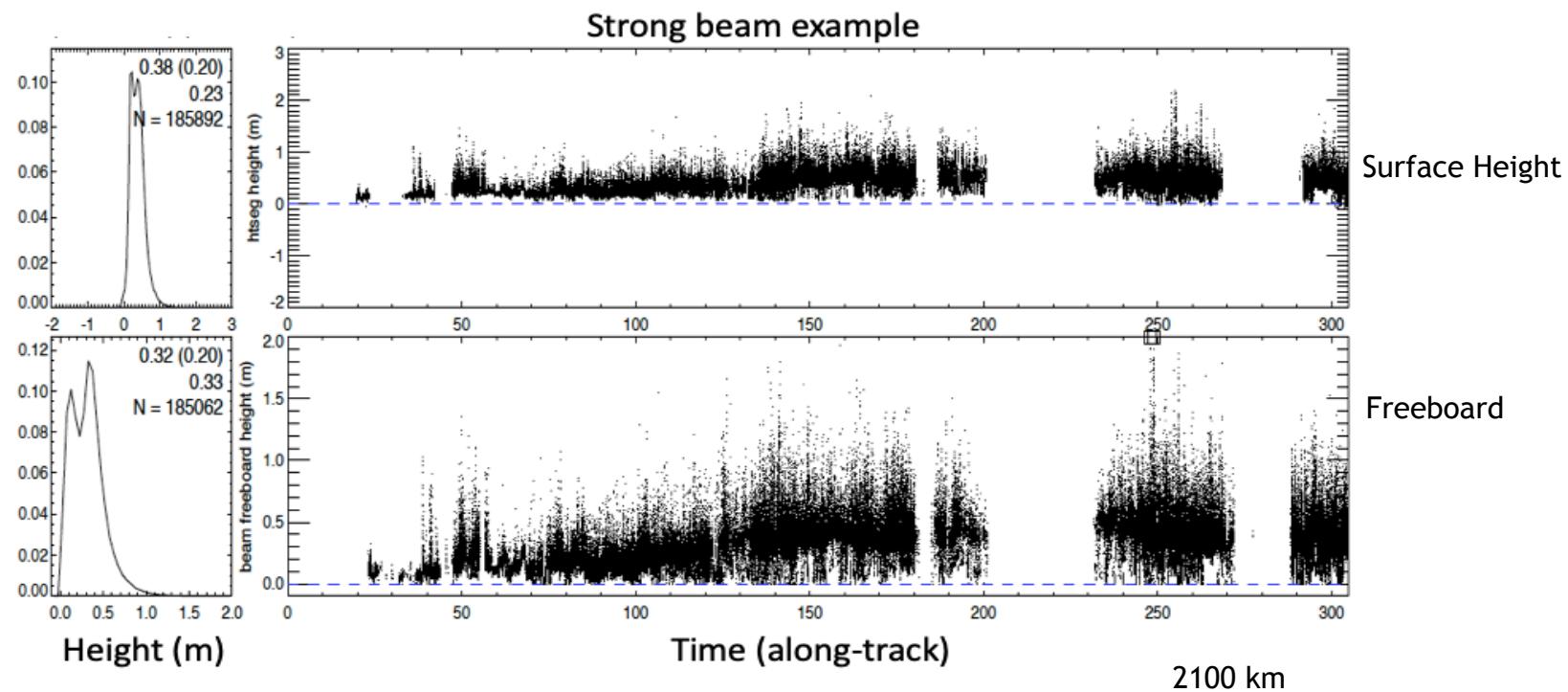


Surface finding



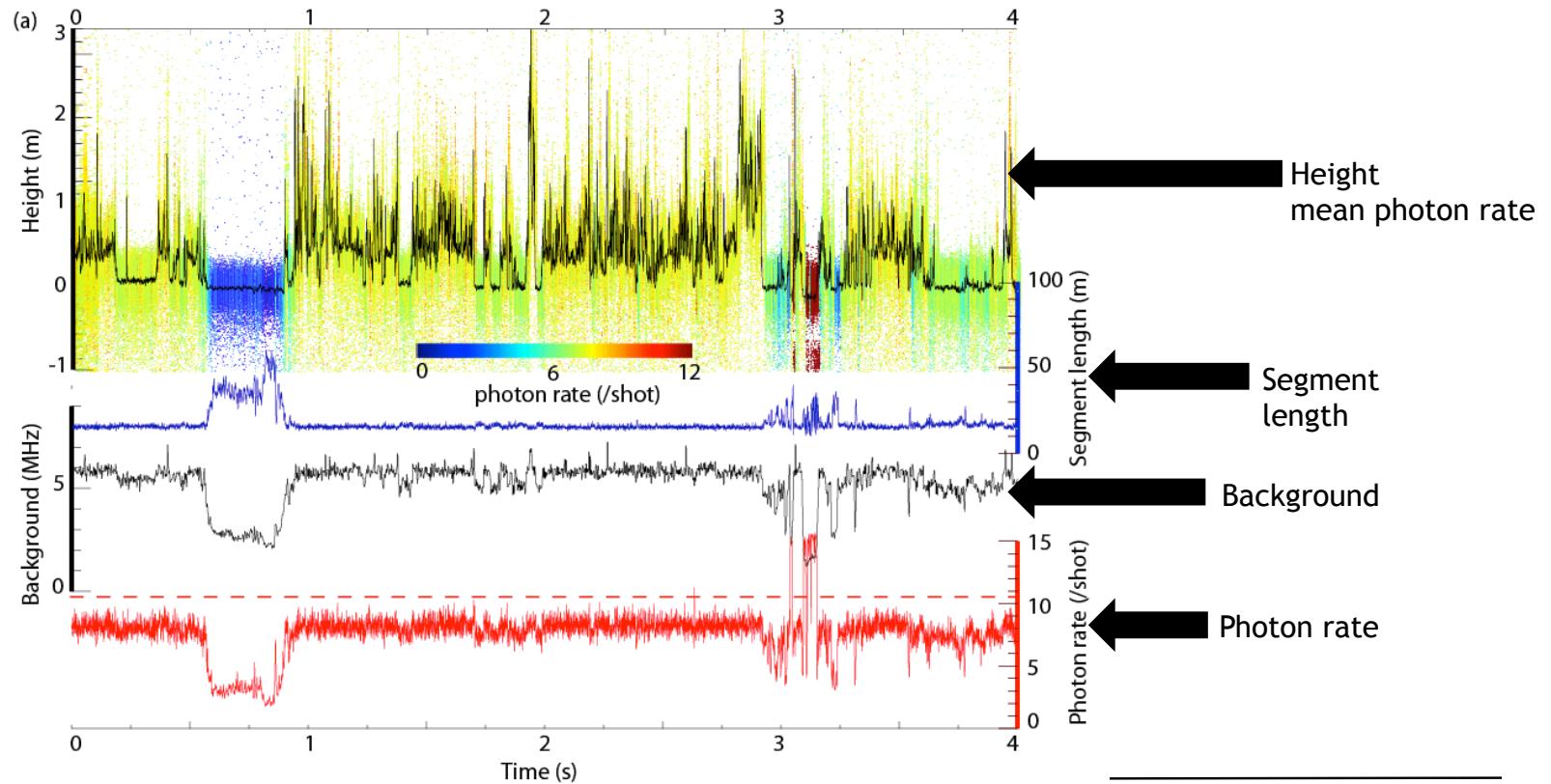


Surface Height (ATL07) and Freeboard (ATL10)

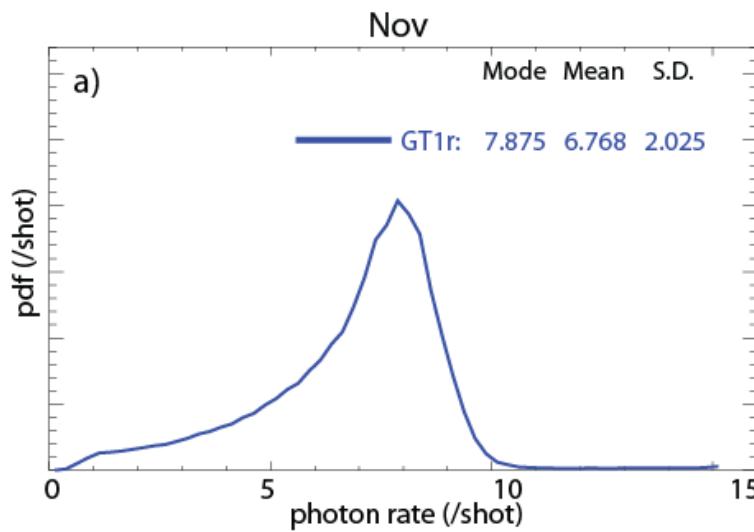




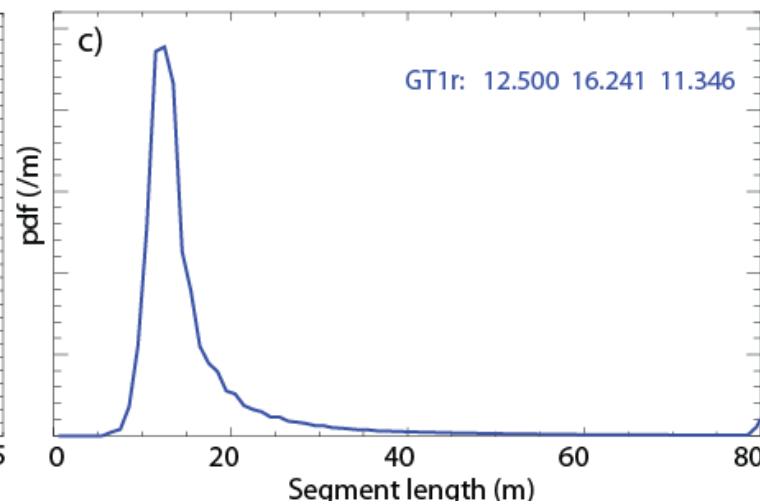
Sample data from ATL07



Photon rate (/shot)



Segment length (m)





Calculation of statistical parameters with variable length segments

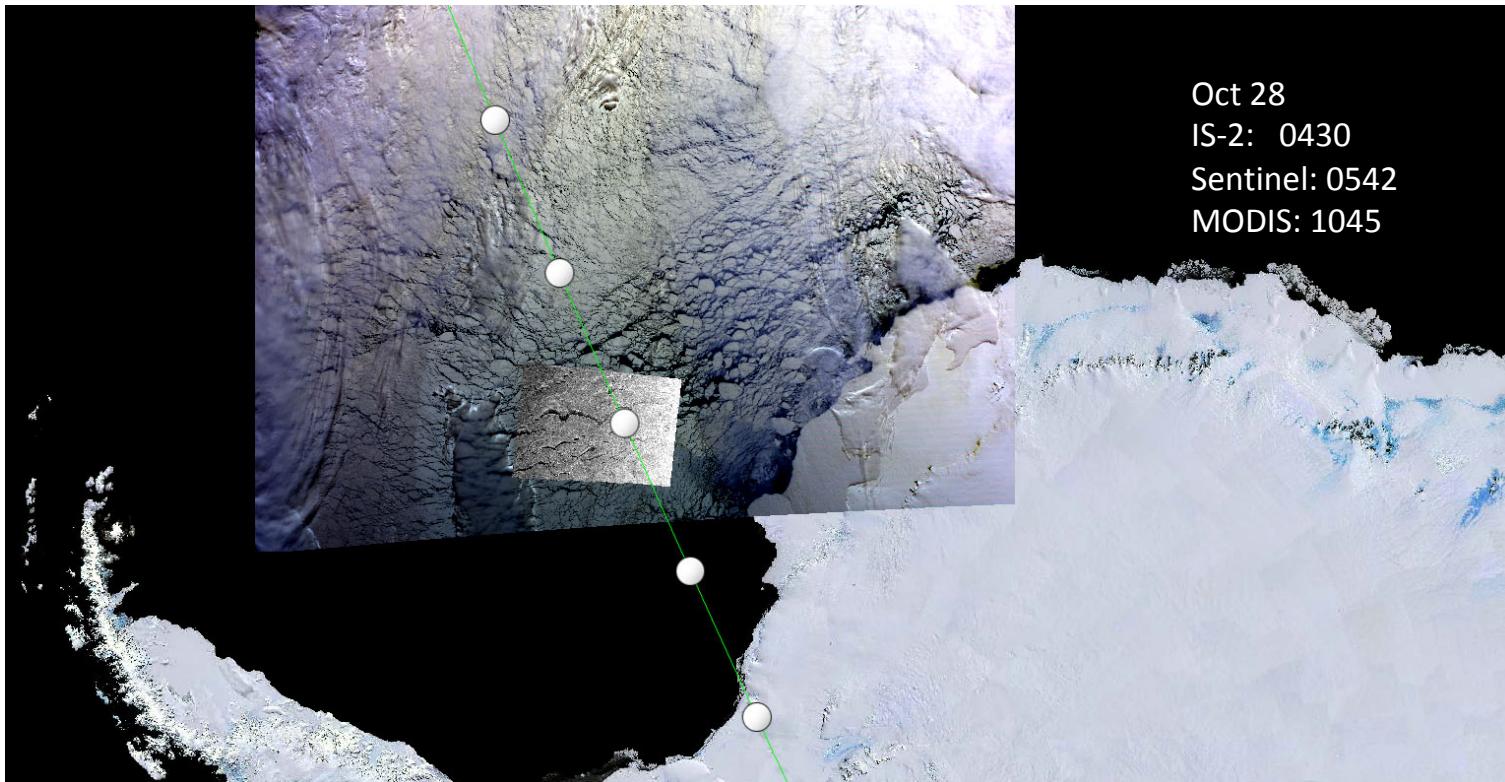


$$\bar{h} = \frac{\sum_{N} L_s^i h_s^i}{\sum_{N} L_s^i} \quad \sigma^2 = \frac{\sum_{N} L_s^i (h_s^i)^2}{\sum_{N} L_s^i} - \bar{h}^2$$

L_s^i = Height segment length



Near Coincident IS-2, Sentinel, and MODIS coverage



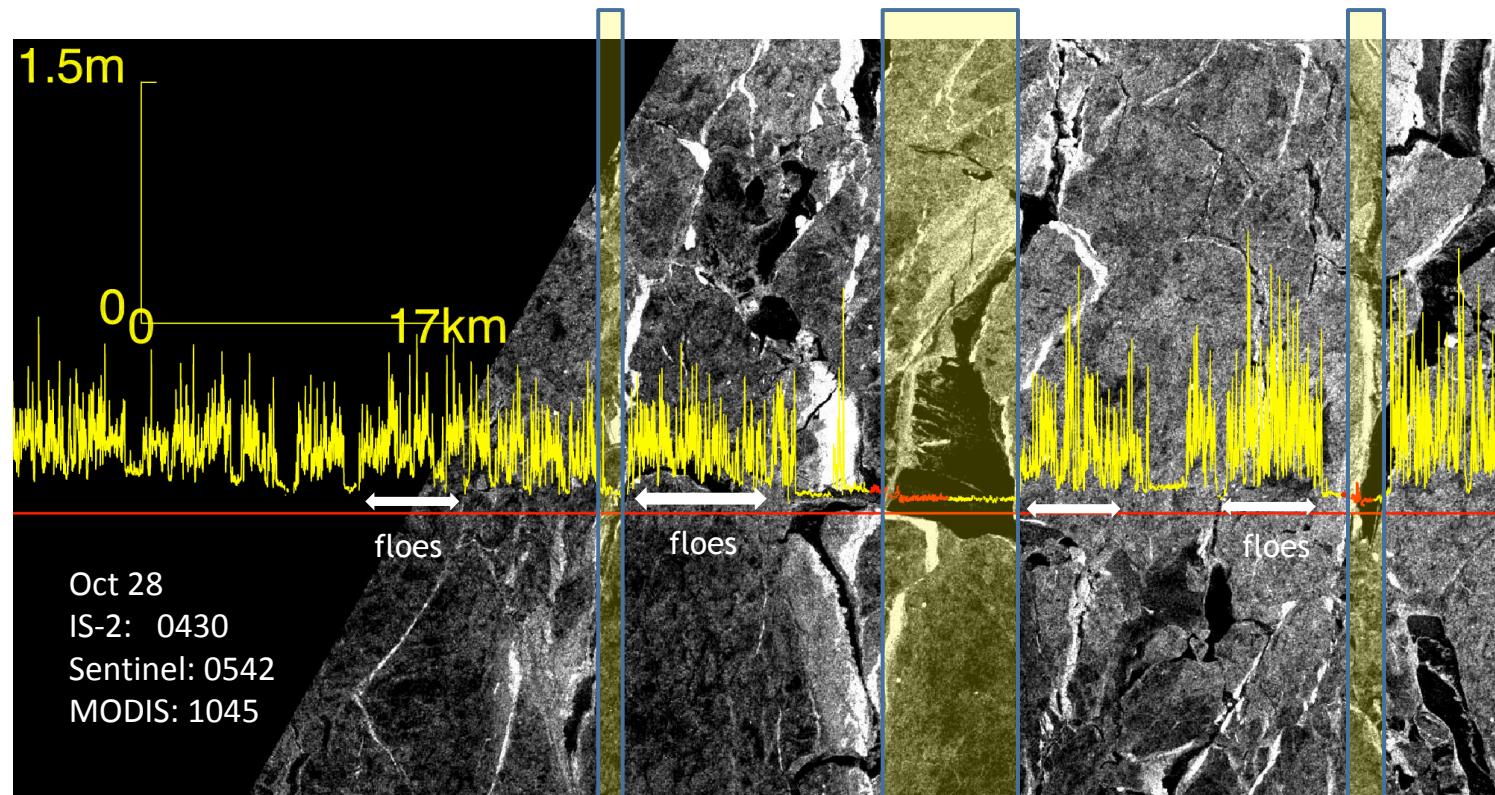
ICESat-2 Hackweek, June 17-21, University of Washington

Copernicus Sentinel data 2018, processed by ESA.

Kwok 12



Heights of thin ice and leads (sample floes)



ICESat-2 Hackweek, June 17-21, University of Washington

Copernicus Sentinel data 2018, processed by ESA.

Kwok 13



Freeboard from IS-2



ICESat-2 Hackweek, June 17-21, University

Sea Ice Freeboard from Space Ice/Water discrimination

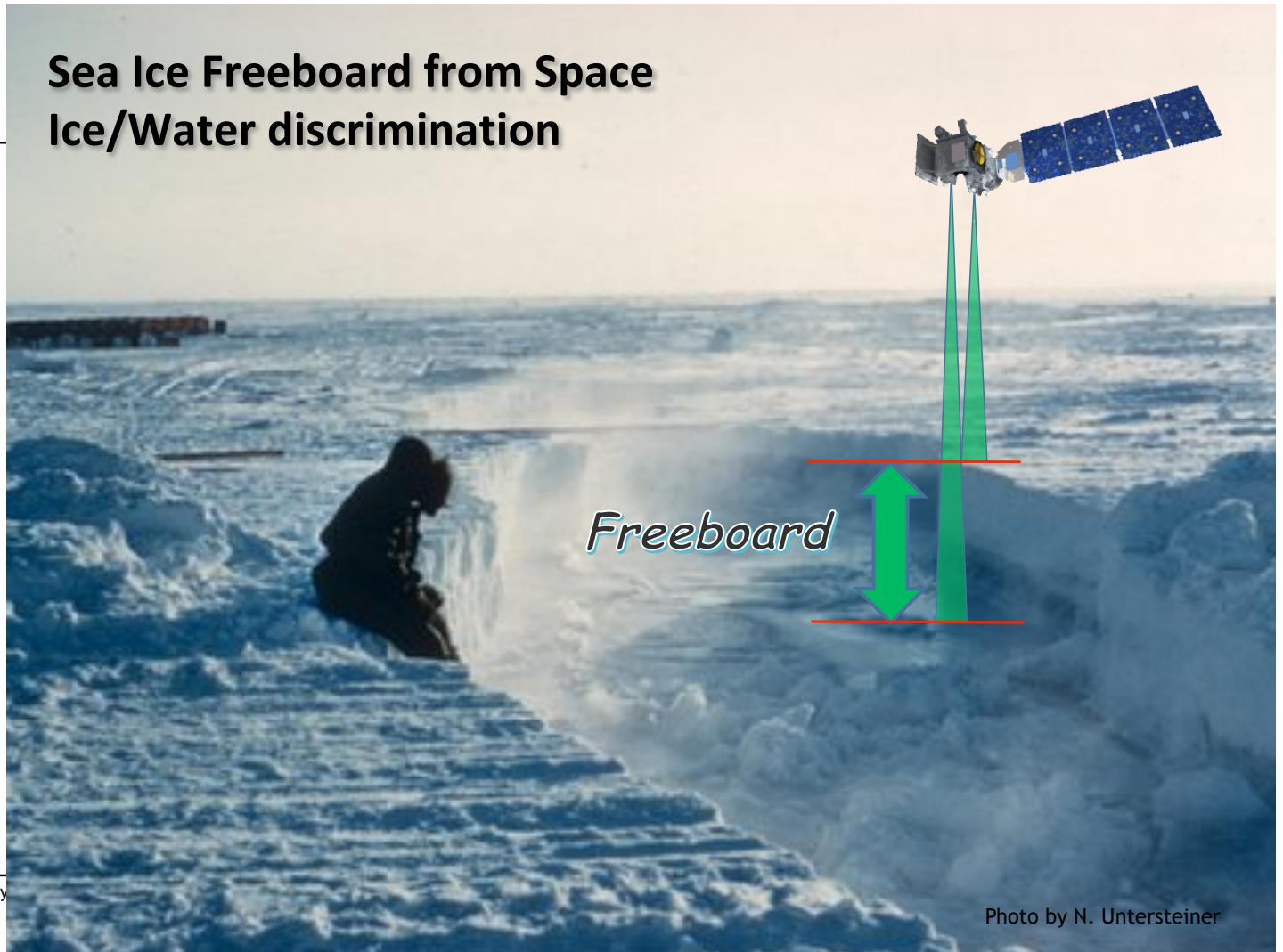
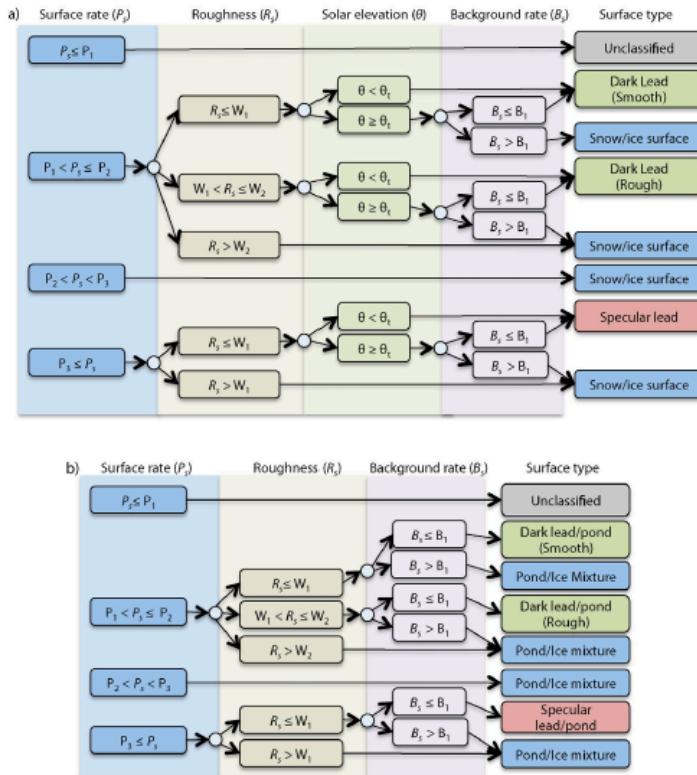


Photo by N. Untersteiner

Separation of Ice/water samples for freeboard calculations

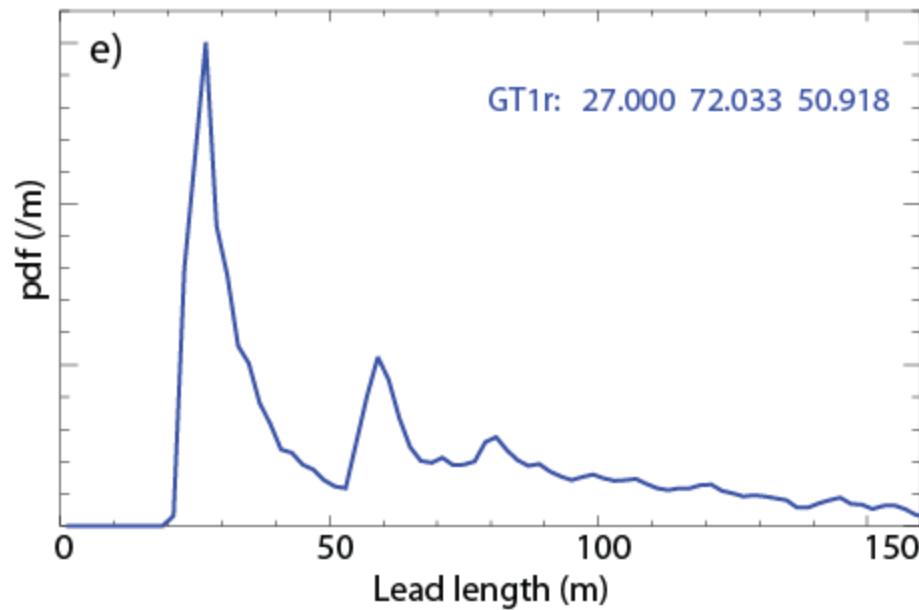


ICESat-2

Fig. 5. Decision tree for ice-water classification in (a) winter and (b) summer.

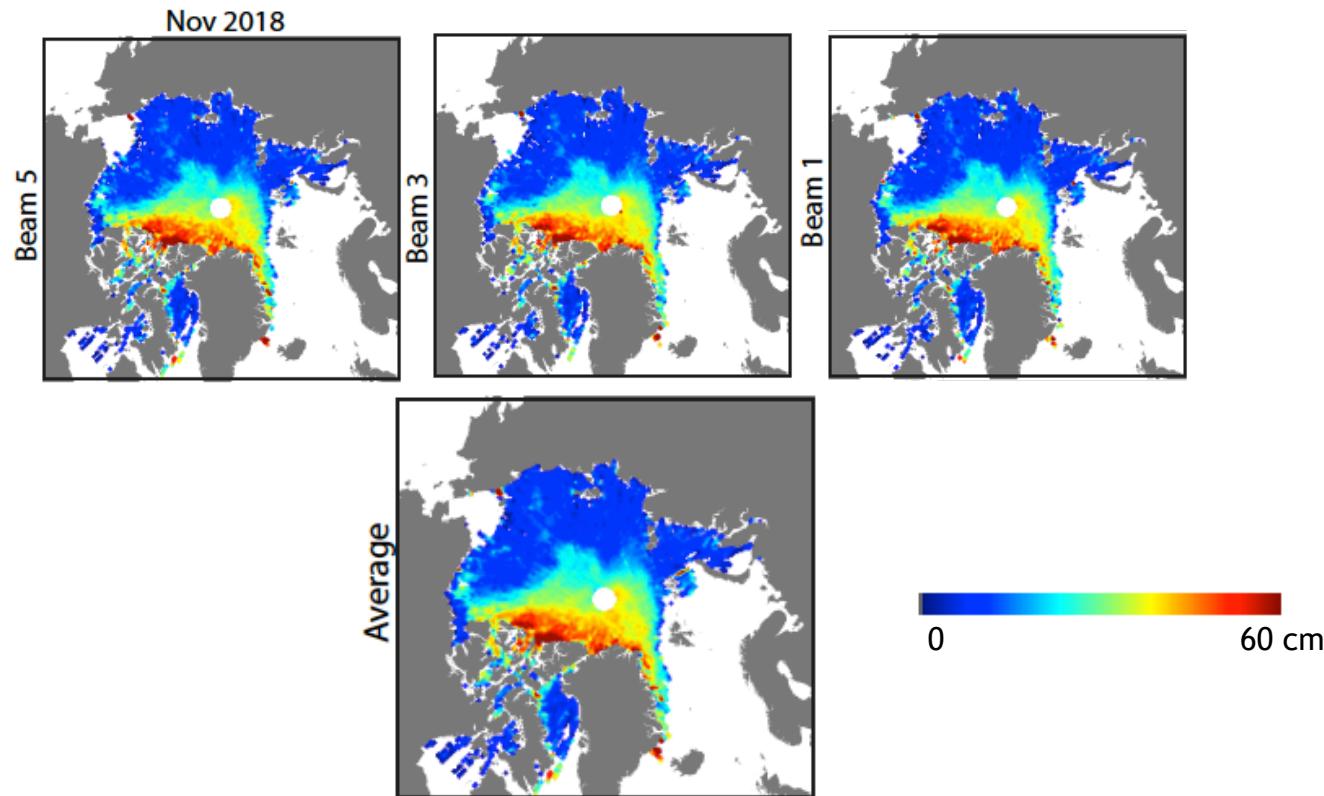
- Based on contrasts in:
 - Photon rate (average count/per shot); apparent surface reflectance
 - Surface roughness
 - Background rate
 - When sun elevation is high
 - Varies along an orbit
- Surface types
 - Dark lead (smooth, rough)
 - Snow covered ice
 - Shadow
 - Specular (open water)
 - Rough surface

Lead lengths





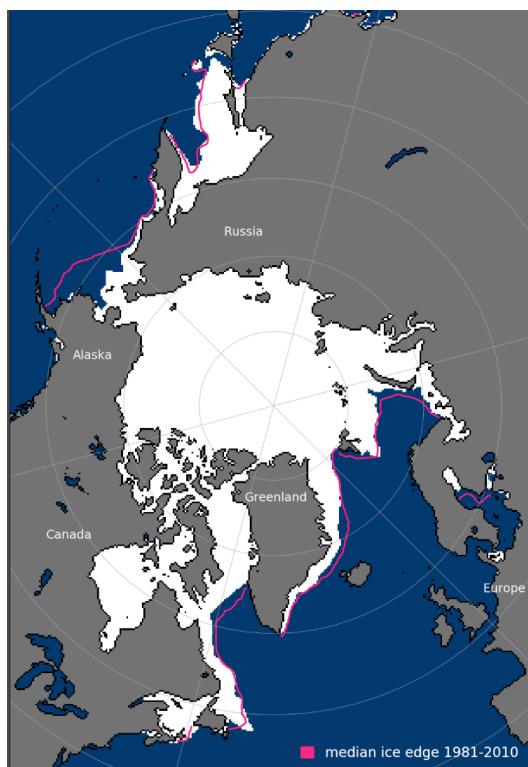
Three Strong Beams - Gridded Composites



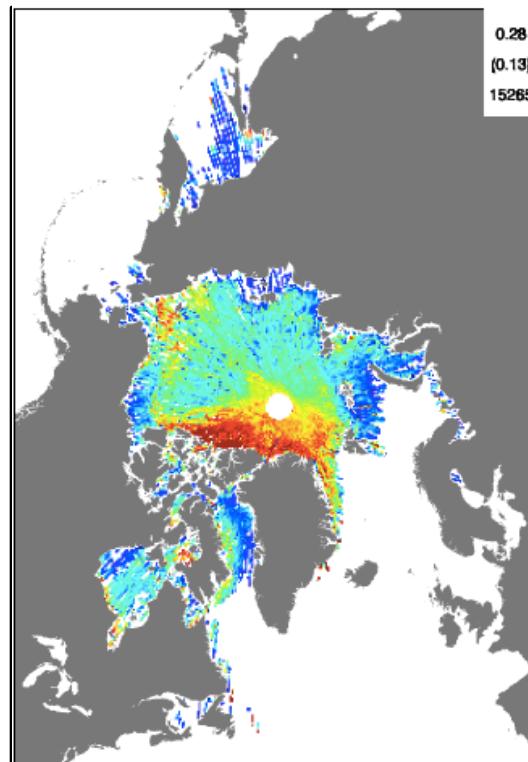


Northern Hemisphere sea ice freeboard

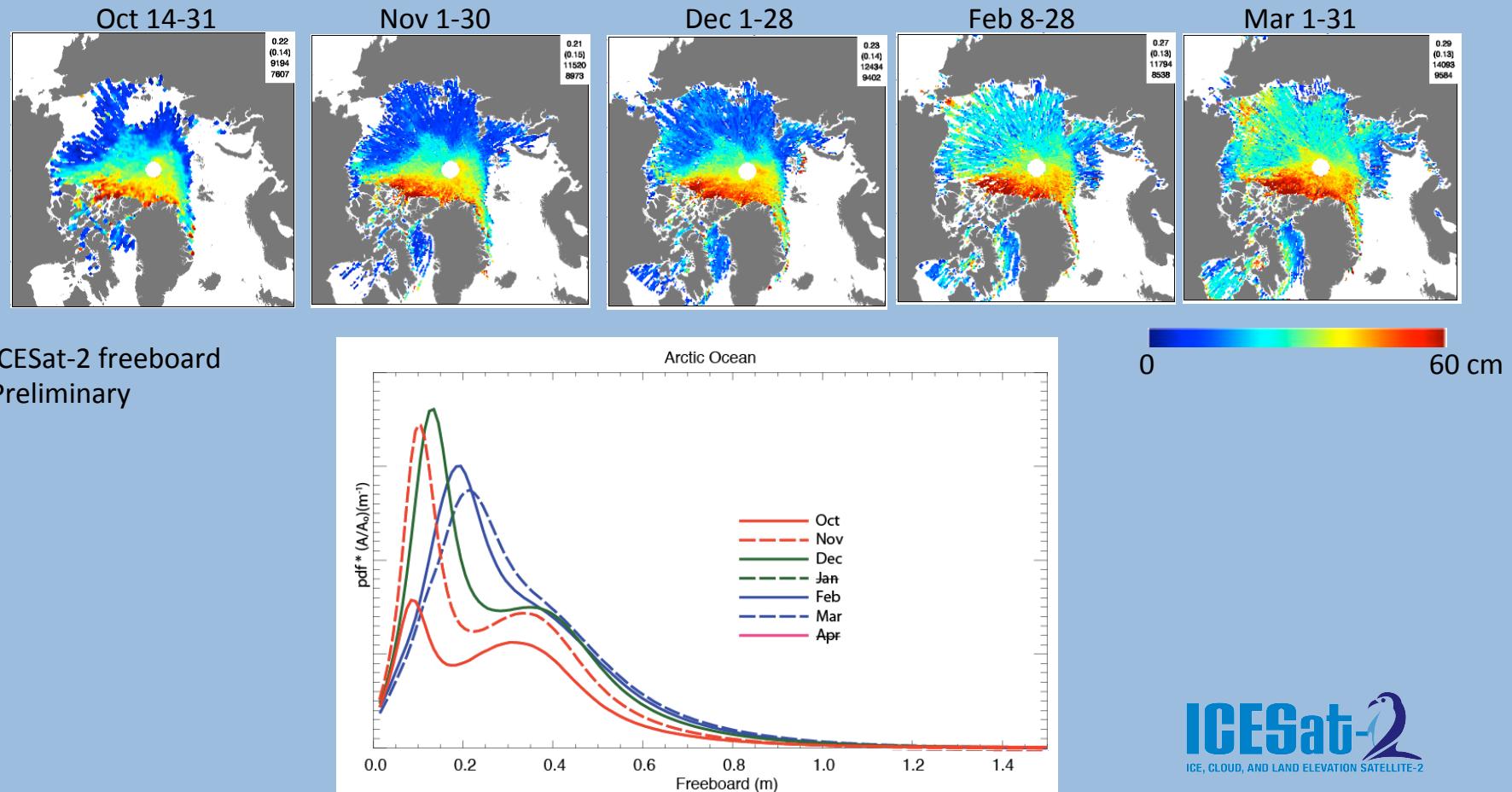
March 2019



sea ice extent -NSIDC

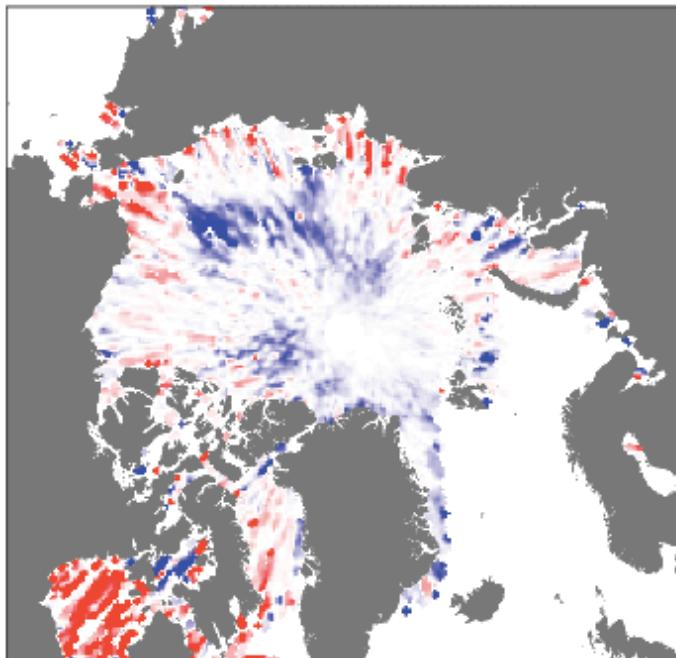


0 60 cm

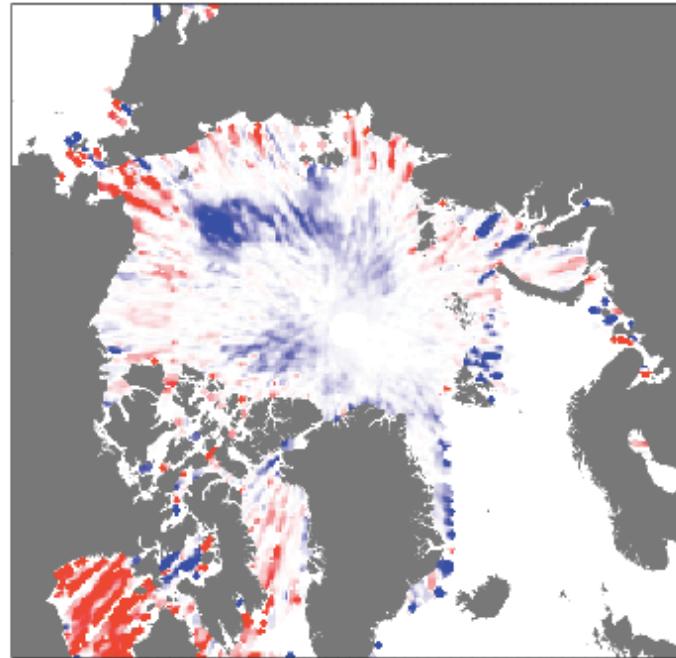




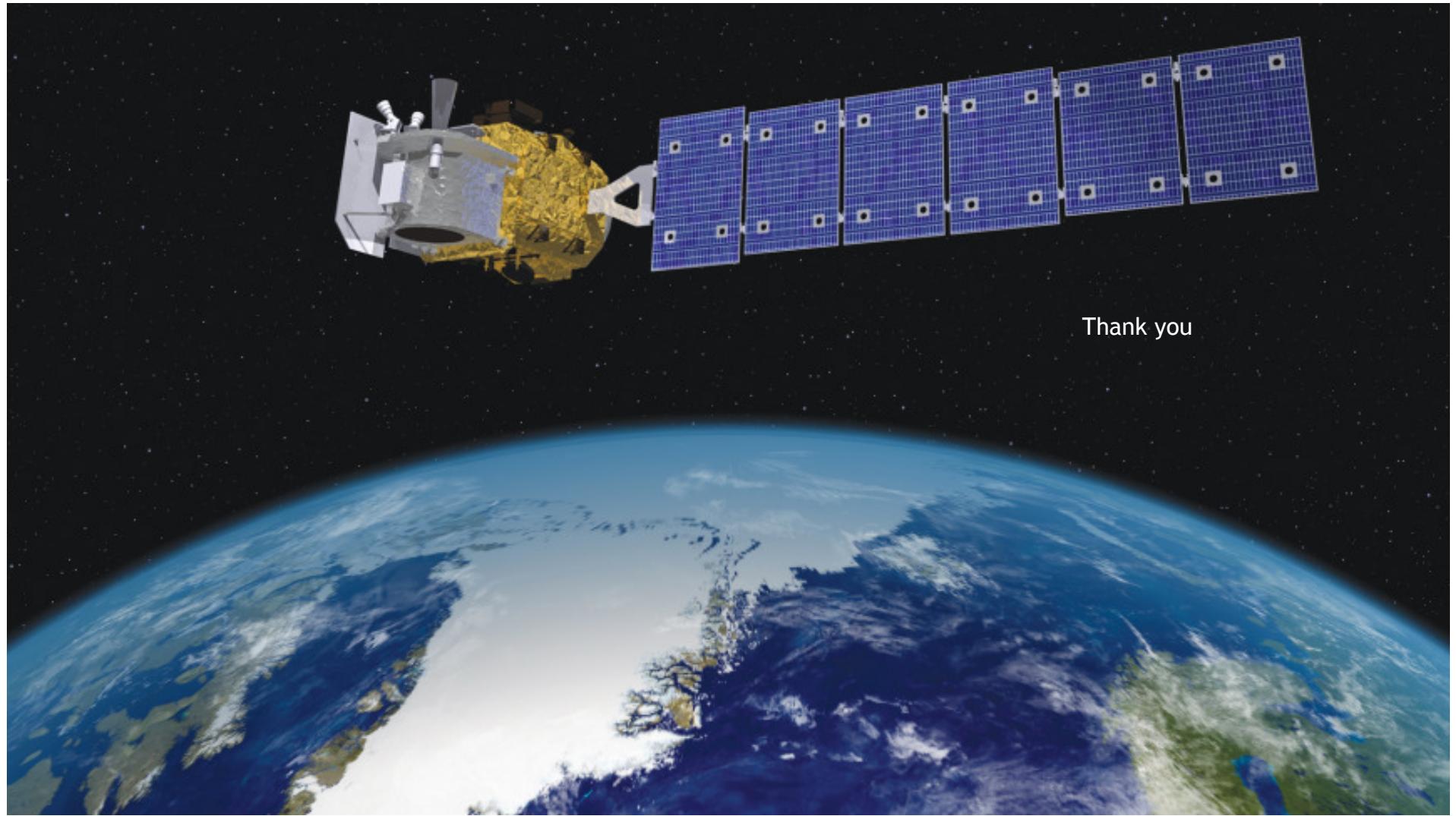
SSH anomalies (Nov)



Weak



Strong
+/- 20 cm



Thank you