ICESat-2 sea ice data products

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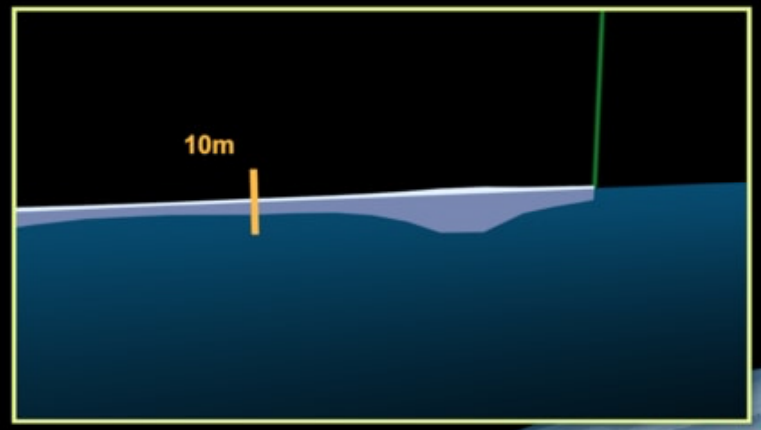
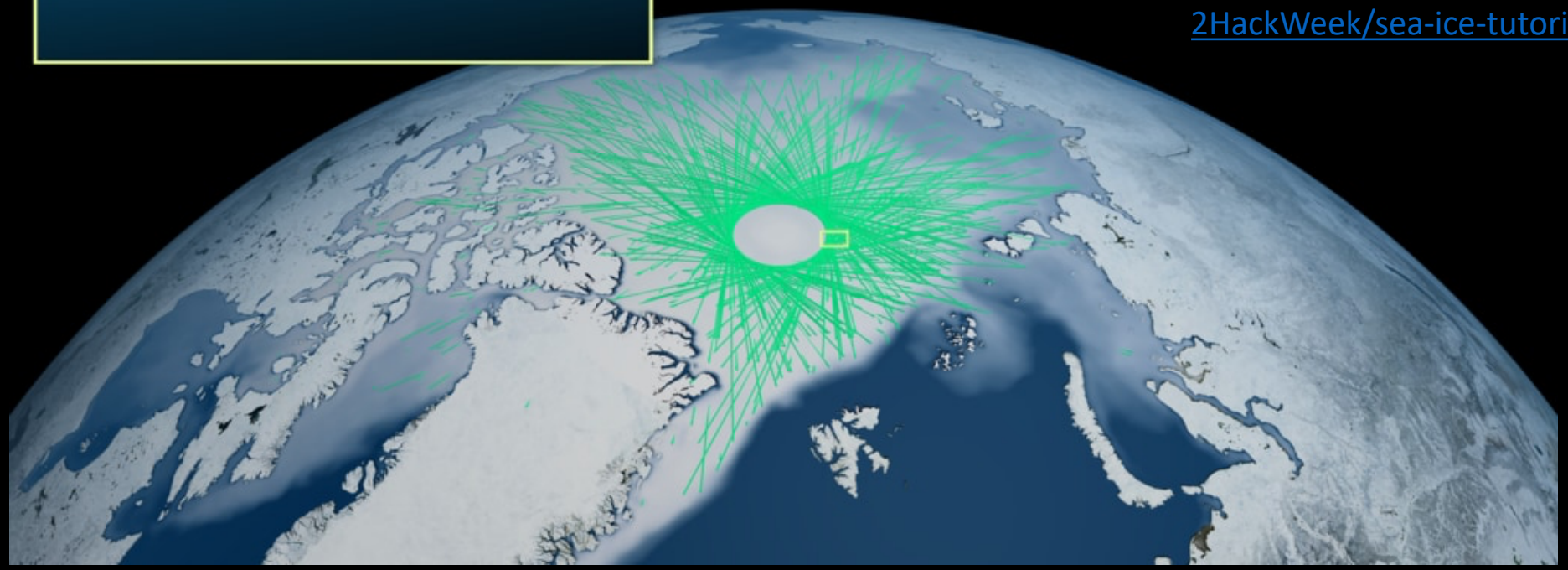
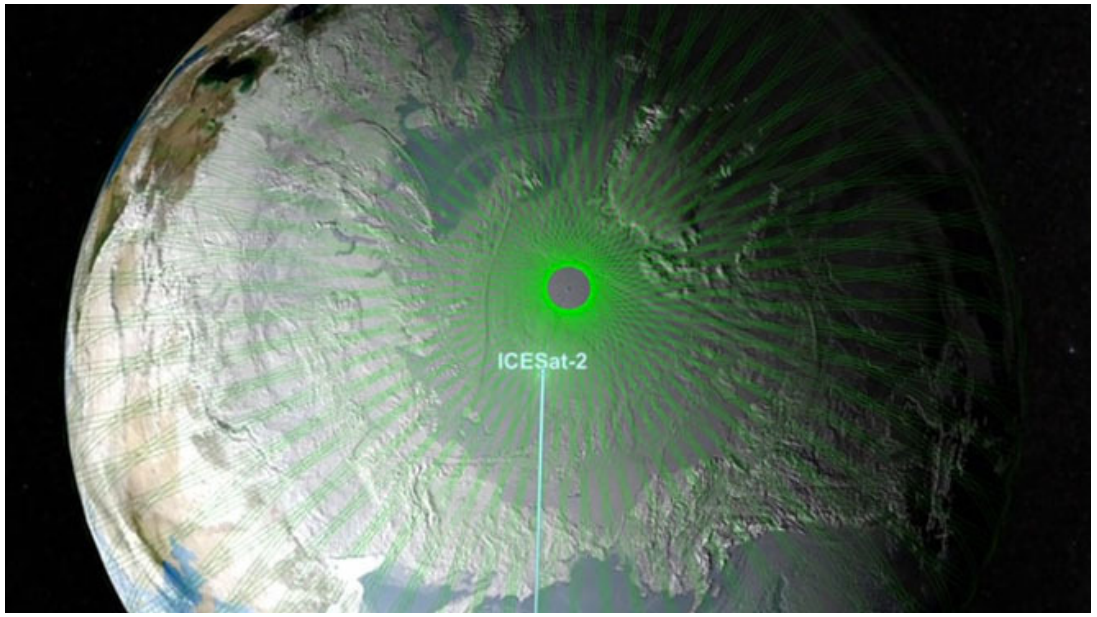


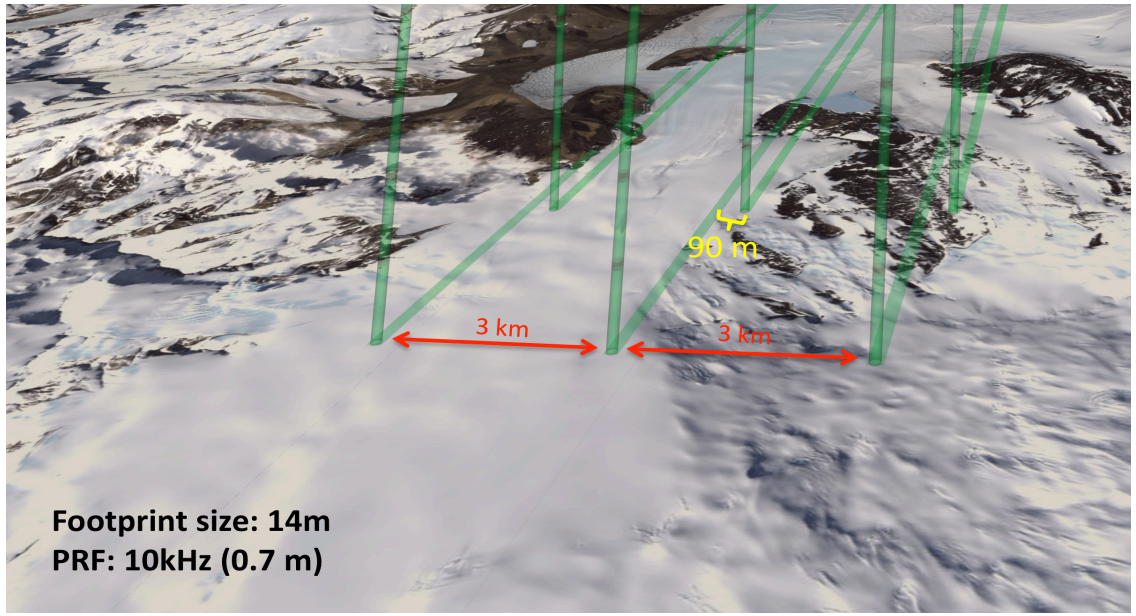


Ellen Buckley (UMD) is leading the sea ice tutorial on Tuesday. Notebooks are already posted at https://github.com/ICESAT-2HackWeek/sea-ice-tutorials

ICESat-2 background

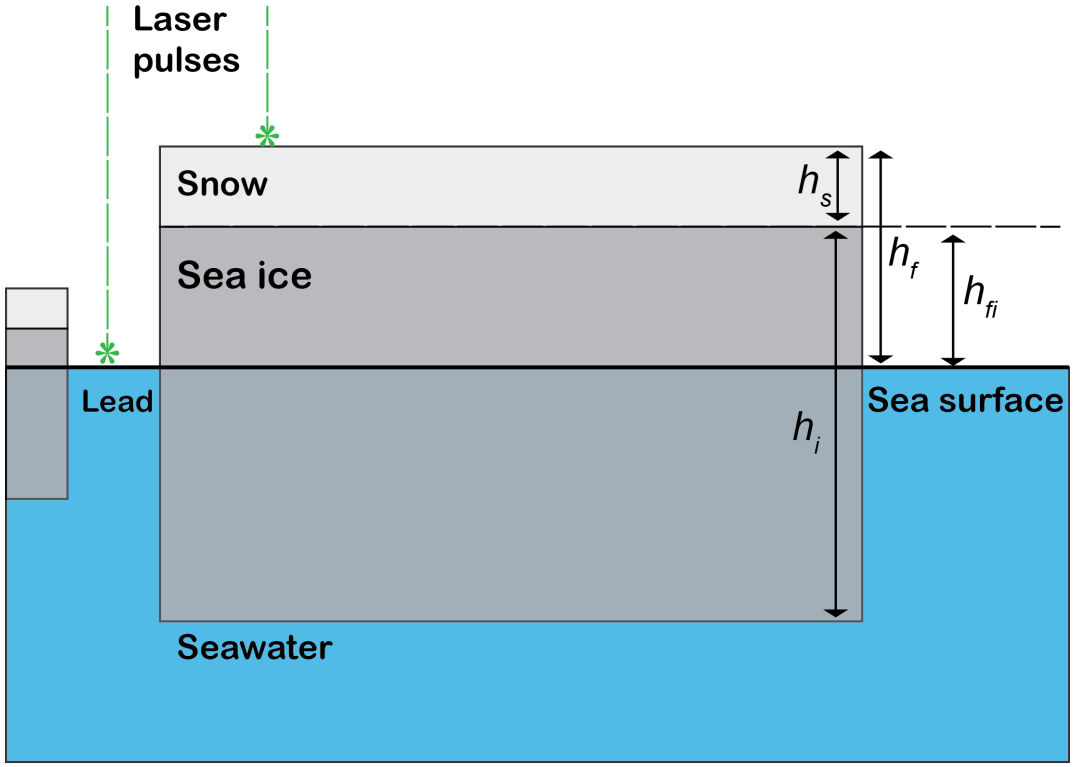
- 3 beams pairs, separated by 3 km across-track.
- A strong and weak beam (strong beam with 4x the energy pulse strength of the weak beam) 90 m apart but 2.5 km along-track.





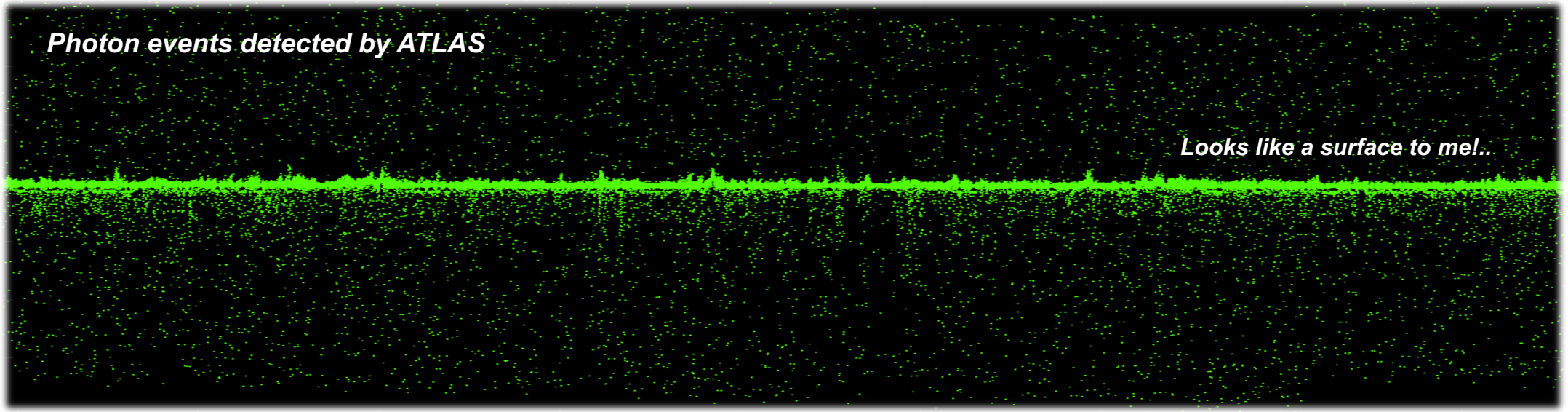
ICESat-2 for sea ice

- ATL03/ATL07/ATL10 (along-track products). ATL07 also utilizes ATL09 (atmosphere).
- ATL20 (gridded freeboard) and ATL21 (gridded sea surface) are on the way.
- Release003 sea ice data (ATL07/10) is being sent to NSIDC as we speak.



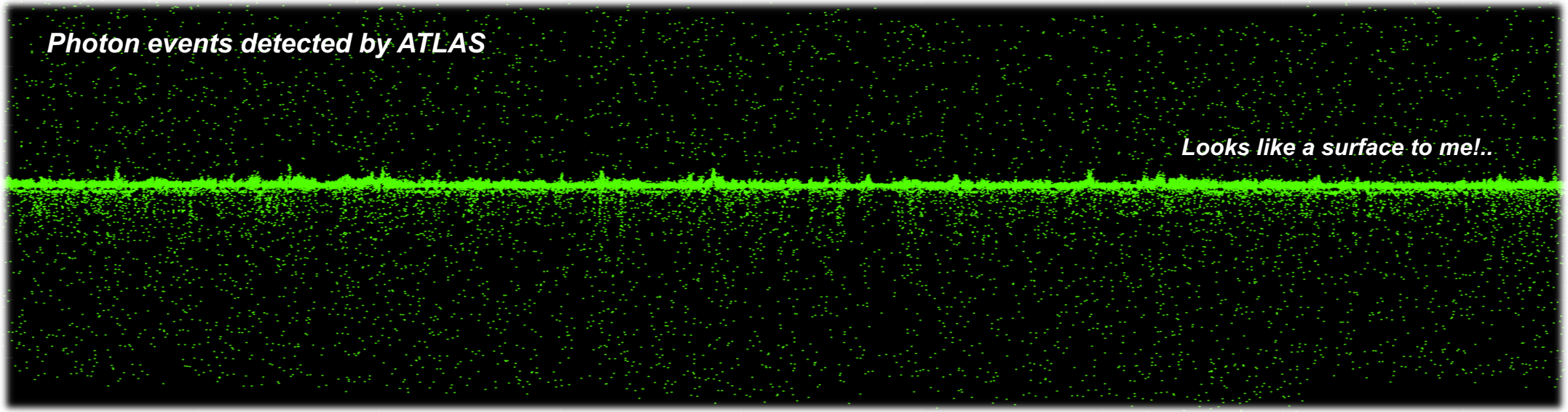
Photon heights (ATL03)

- Photon-counting laser altimeter provides heights of individual photons.
- Lower energy than analog laser systems, more flexibility in precision & resolution.
- Generally quite challenging to use due to high data volume and lack of sea ice focus (e.g. corrections/filtering).



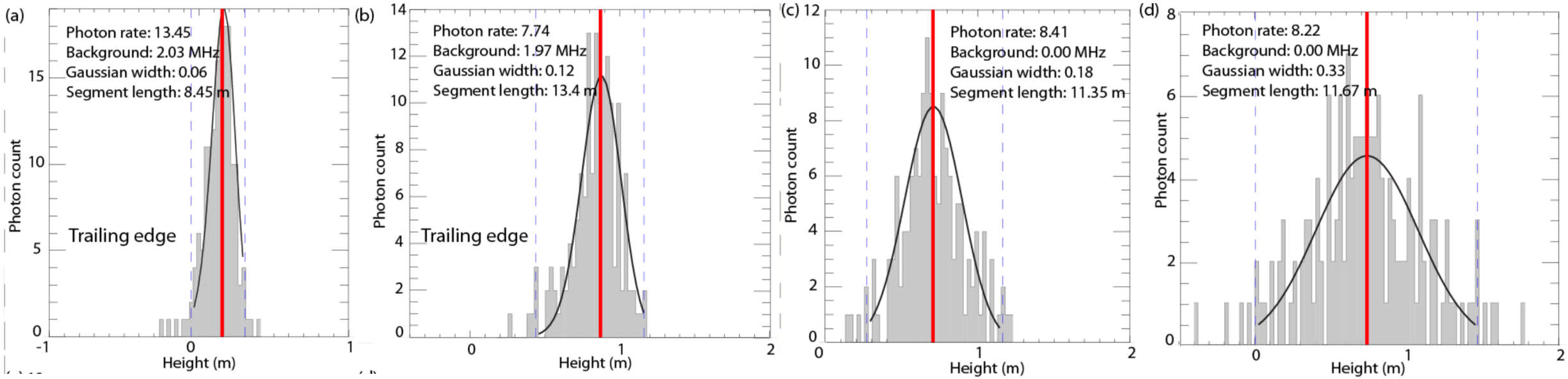
Photon heights (ATL03) – corrections applied..

▪ Ocean loading deformations (H_{OL})	*tide_load* (ATL03)	*height_segment_load (ATL07)*
▪ Solid Earth pole tides (H_{SEPT})	*tide_pole* (ATL03)	*height_segment_pole (ATL07)*
▪ Ocean pole tides (H_{OPT})	*tide_oc_pole* (ATL03)	Not currently included
▪ Solid Earth tides (H_{SET})	*tide_earth* (ATL03)	*height_segment_earth (ATL07)*
▪ Total column Atm. Delay corr. (H_{TCA})	*neutat_delay_total* (ATL03)	*ref_atm_delay (ATL07)*



Photon heights (ATL03) to segment heights (ATL07)

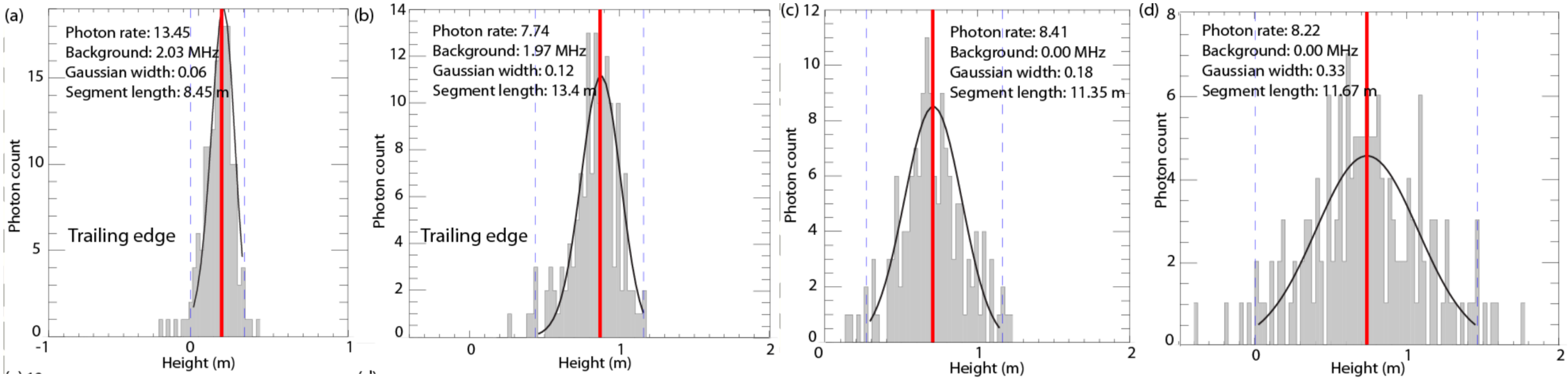
- A Gaussian (actually two but let's not dwell on that here) is fit to a number of the ATL03 photons (currently a default of 150).
- From this we get a mean segment height and Gaussian width (proxy for surface roughness).



from Kwok et al., 2019

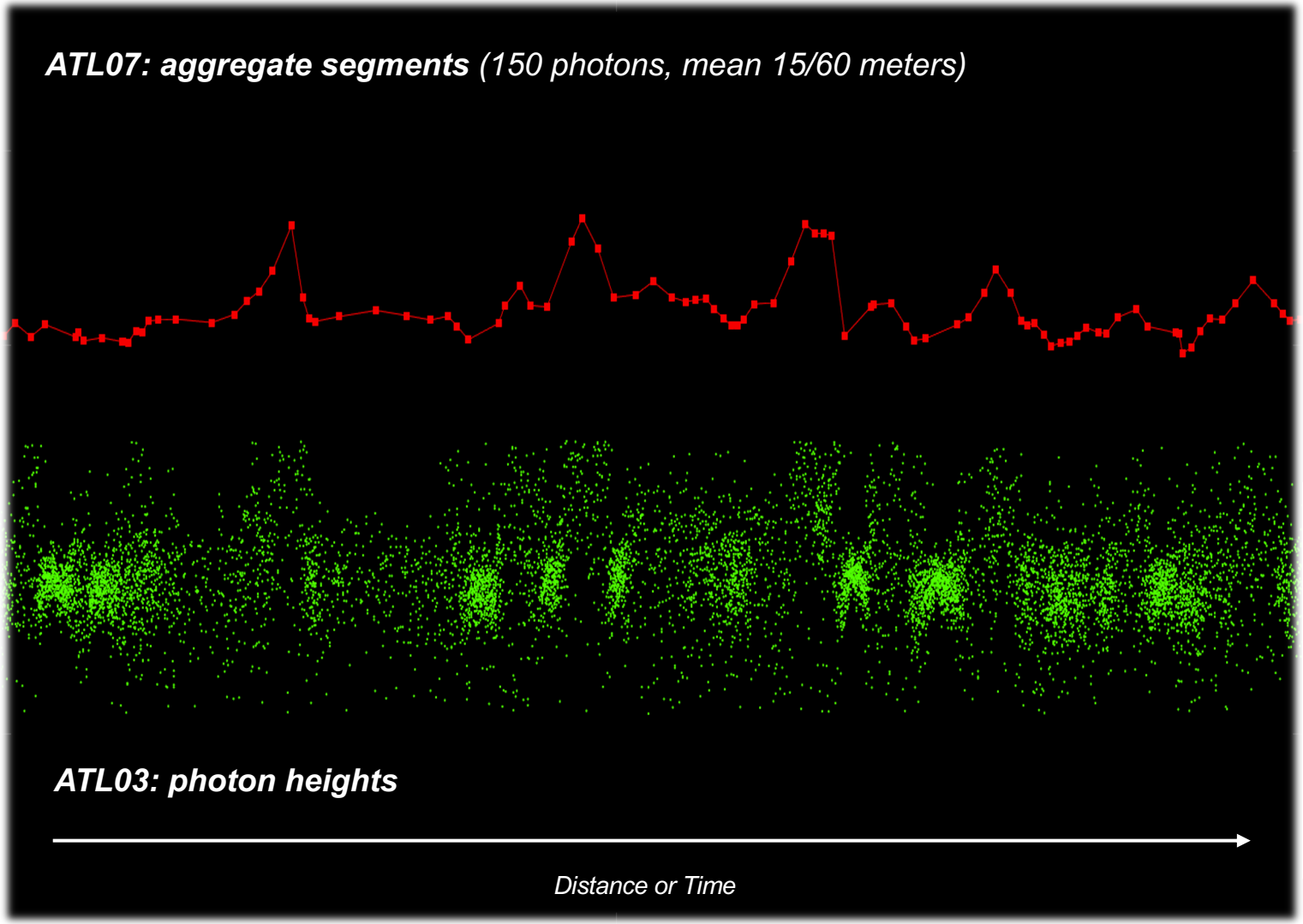
ATL07 includes the following (extra) height corrections…

- Mean Sea Surface Height (H_{mss}) — *height_segment_mss (ATL07)*
- Ocean Tide correction (H_{ocean_tide}) — *height_segment_ocean (ATL07)*
- Long Period Equilibrium Tide corr. (H_{lpe_tide}) — *height_segment_lpe (ATL07)*
- Inverted barometer corr. (H_{IB}) — *height_segment_ib (ATL07)*

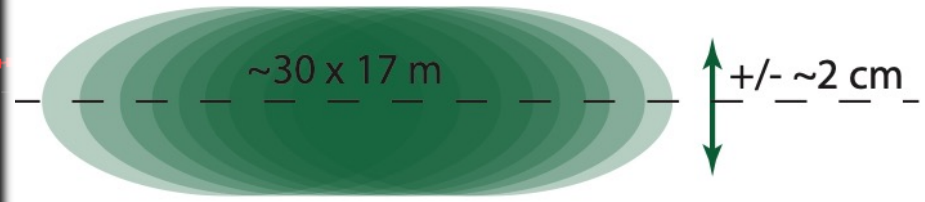


from Kwok et al., 2019

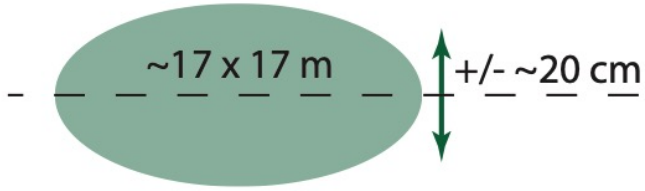
ATL07 segment heights



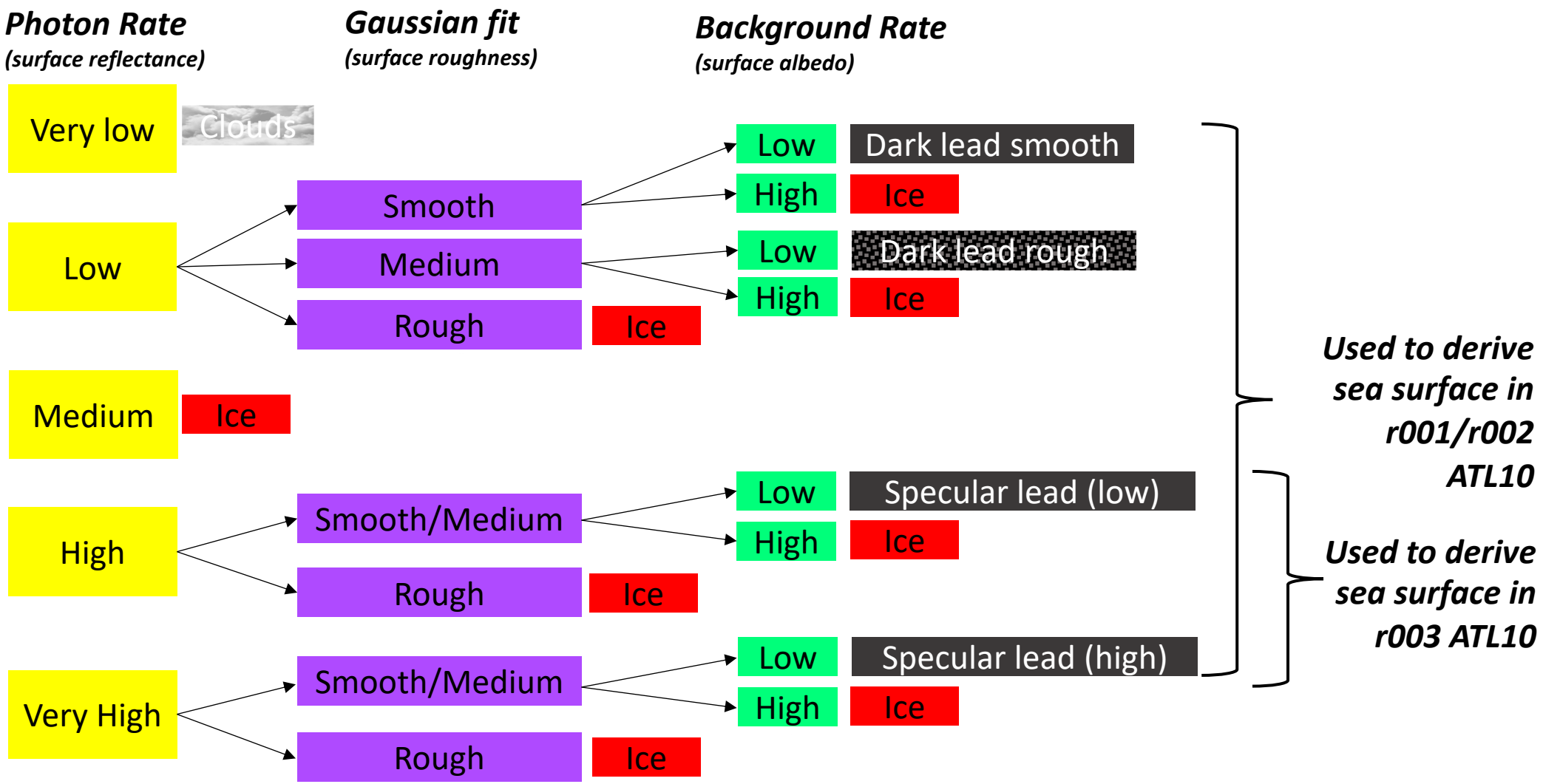
ATL07
- Aggregate of 150 along-beam photons.
- Lowers vertical precision to ~2 cm?
- Mean along-track resolution of ~30 m (strong)



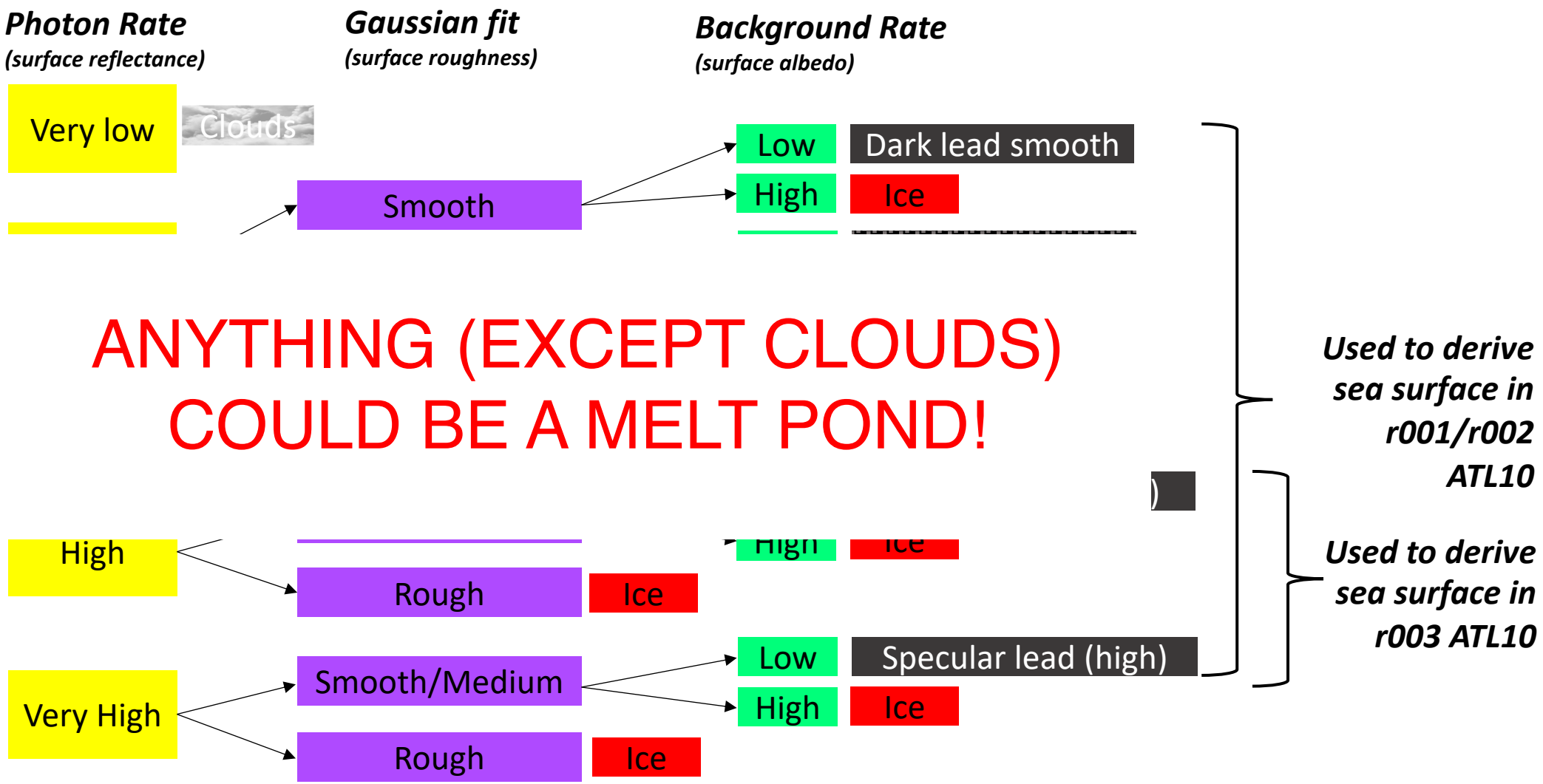
ATL03
- Individual photon heights.
- Vertical uncertainity of ~20 cm?
- Footprint diameter of ~17 m.



Surface type (radiometric) classification (ATL07)



Summer surface type (radiometric) classification (ATL07)

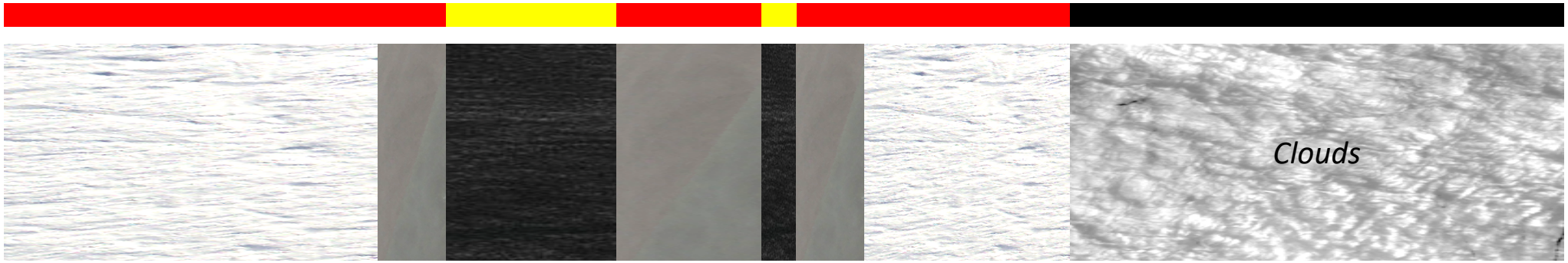


ATL07 to ATL10 sea ice freeboard

- To become a sea surface tie-point the radiometric leads have to pass a final test: the segment height must be <2% of the 10 km segment height distribution.
- A mean local sea surface is then derived from these ssh tie-points to calculate freeboard.
- This is especially important for summer freeboards as melt ponds can look like leads!

SSH_flag = 0 : sea ice

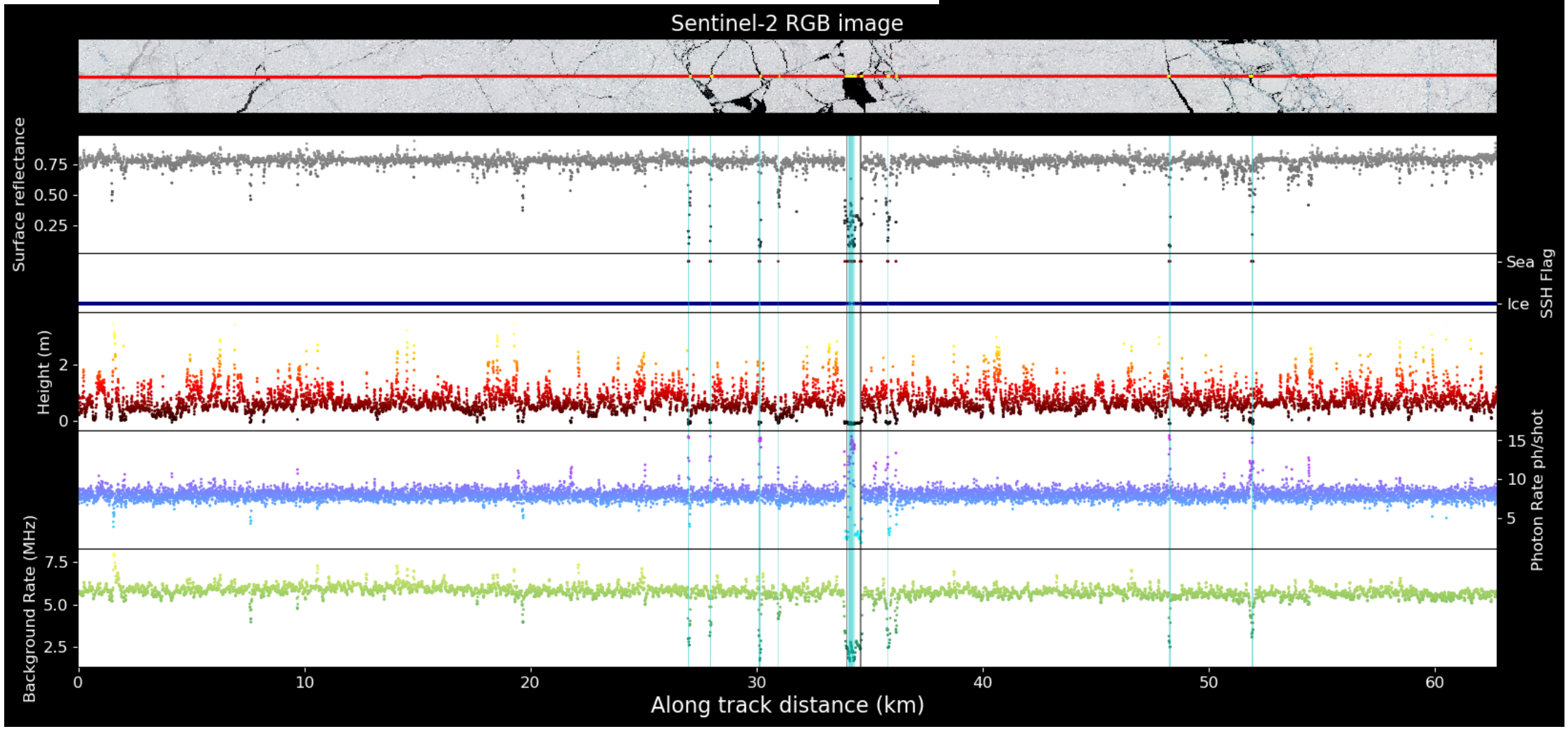
SSH_flag = 1 : sea surface (in ATL10 r003 we have introduced ssh_flag=2 to indicate it is actually used as sea surface!)



- NB: ATL10 includes most of the ATL07 variables of interest.
- Concentration filter increased to 50% (from 15%) and coastal mask of 25 km.

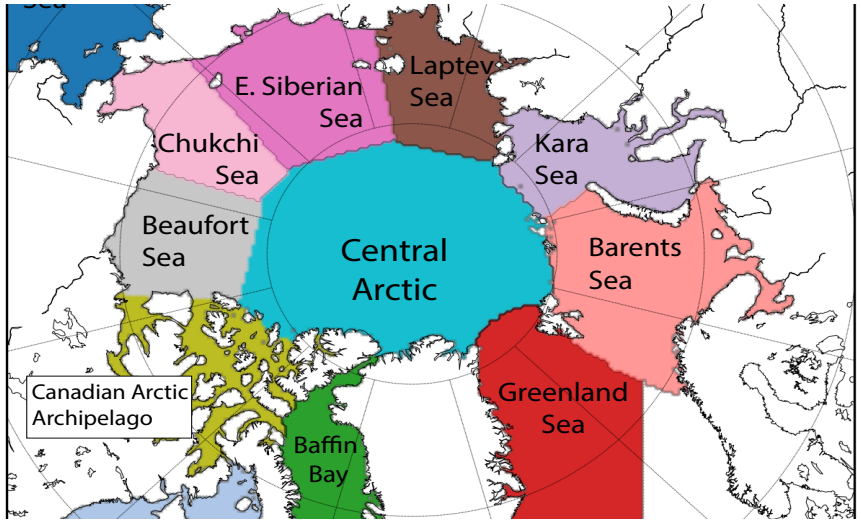
ATL07 validation

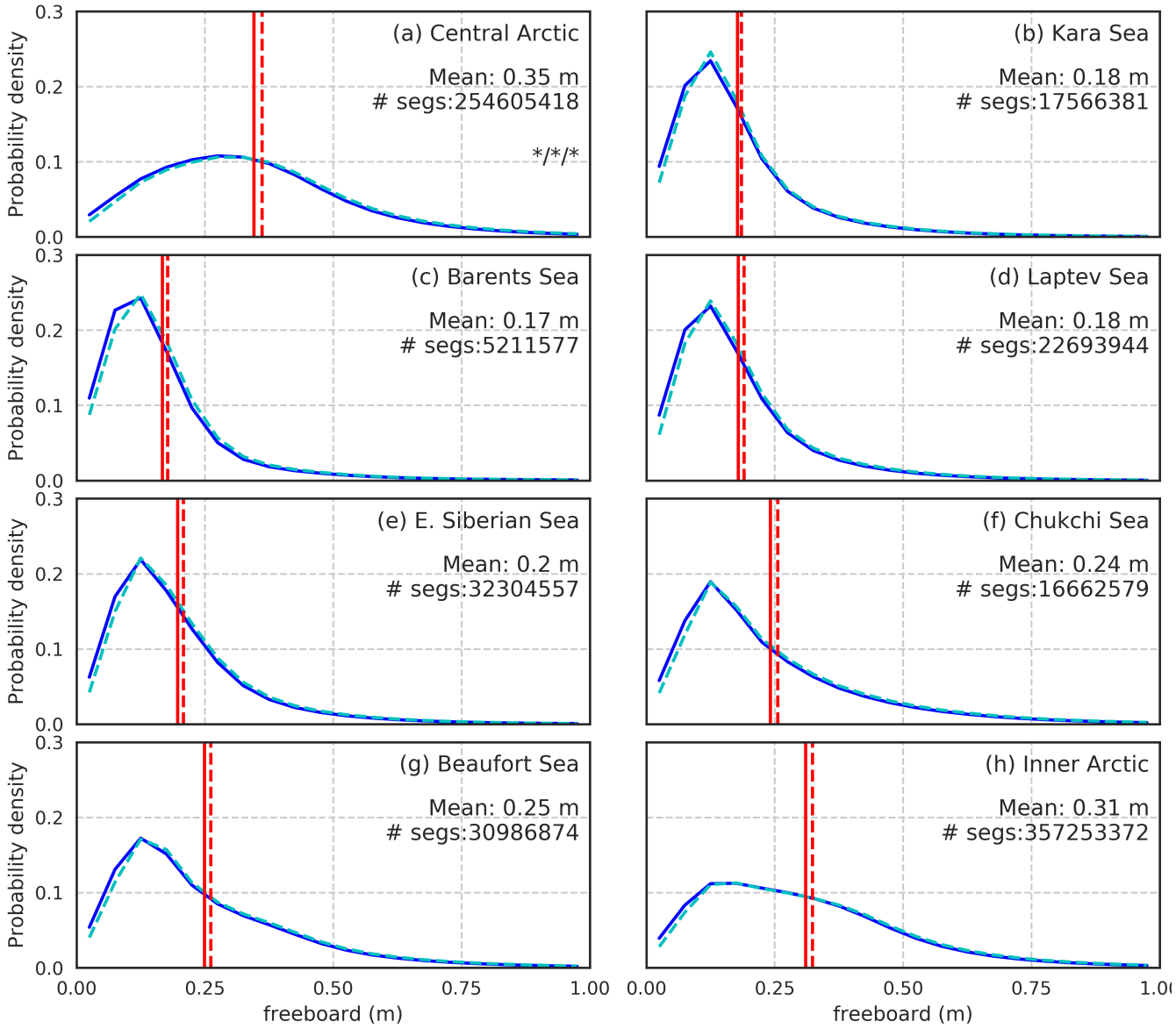
May 25th 2019
Lincoln Sea (Arctic Ocean)
Time difference: 94 minutes
Beam: GT1L (strong)



Sea ice freeboard (ATL10)

- ATL10 Arctic (and Antarctic) sea ice freeboards are looking pretty good!
- We are also looking to improve these in r003 by removing biased dark leads from the ssh determination.

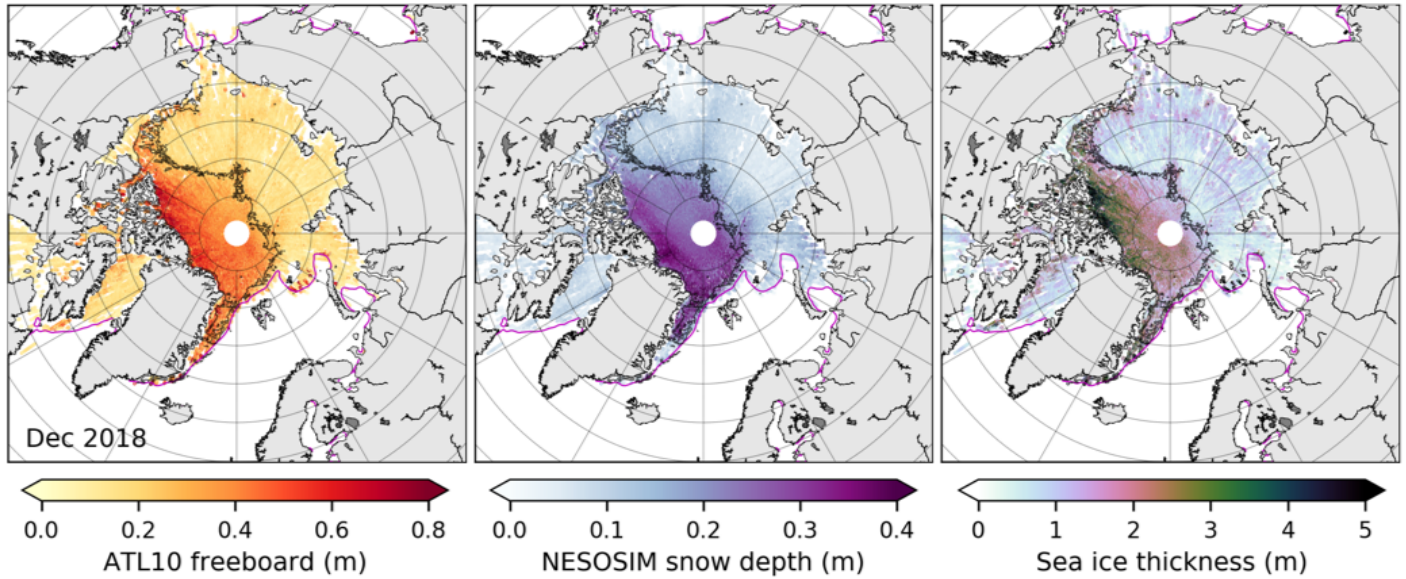




From sea ice freeboard (ATL10) to thickness

'Classic' snow loading approach

- Use either a model or snow climatology to infer how much of the total freeboard (ATL10) is snow (Petty et al., 2020)



'New' laser/radar differencing

- Dominant return from CryoSat-2 radar thought to from the snow-ice interface. Differencing this from the snow-air interface (ICESat-2 ATL10) gives snow depth directly (Kwok et al., 2020).

Data availability and potential pitfalls?

- Read the Known Issues document (available on the ATL07 and ATL10 NSIDC product pages)!
- There are three different freeboards in the freeboard dataset! Make sure you know which one you are using.
- One of these (the multi-beam freeboard) is erroneously included in r002. This should only be valid when the beams are ‘aligned’ and a reference sea surface can be derived from all the beams (a swath sea surface).
- ATL07/10 have a variable along-track resolution. Be aware of this when generating statistics.
- There are significant data gaps, often due to clouds! Waves can also cause interesting issues. ‘Bad’ granules are removed prior to posting to NSIDC but this is still somewhat subjective.

Summary

- ICESat-2 is providing great sea ice data!
- Sea ice (ATL07/10) algorithm tweaks are on-going, so read the known issues/ATBD.
- Also ongoing work to understand inter-mission calibration/reconciliation – especially with CS-2/OIB.
- Release003 ATL07/ATL10 imminent, gridded freeboards (ATL20) and sea surface (ATL21) coming soon.
- Currently working on 2019/2020 winter thickness data.