PolarMonitoring study:

Perspectives

Suggestions of potential studies for preparing CRISTAL mission

1 - Improvement & evaluation of snow simulations (sea-ice & ice sheet)

2 - Sensitivity studies to be conducted at global scales (sea-ice & ice sheet)

3 - Comparison to in-situ measurements

4 - Exploitation of in-orbit multi-mission observations (altimetry LRM/SAR & Ku/Ka + ICESat-2)

5 - Synergy between altimeter and radiometer measurements

6 - Analysis, Definition, Implementation of level-2 algorithms for estimating the different parameters of the snow pack (elevations, snow depth, etc …) :

- **Sea-ice problematic:** estimation of snow depth & precise elevations over leads & floes
- **Ice sheet problematic:** estimation of ice sheet surface elevation / relocation
- **Common problematic:** Efficient exploitation of simultaneous Ku/Ka measurements to retrieve snow parameters

1 – Improvement & evaluation of snow simulations

See IGE perspectives for simulation improvements & evaluation

Other improvements

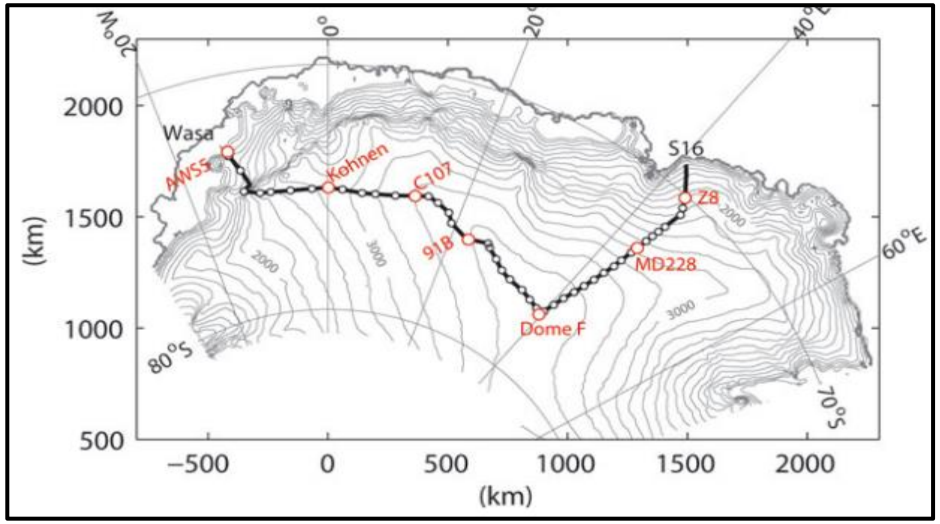
- Simulation of the speckle noise
- Simulation of a realistic waveform power, to analyze SNR

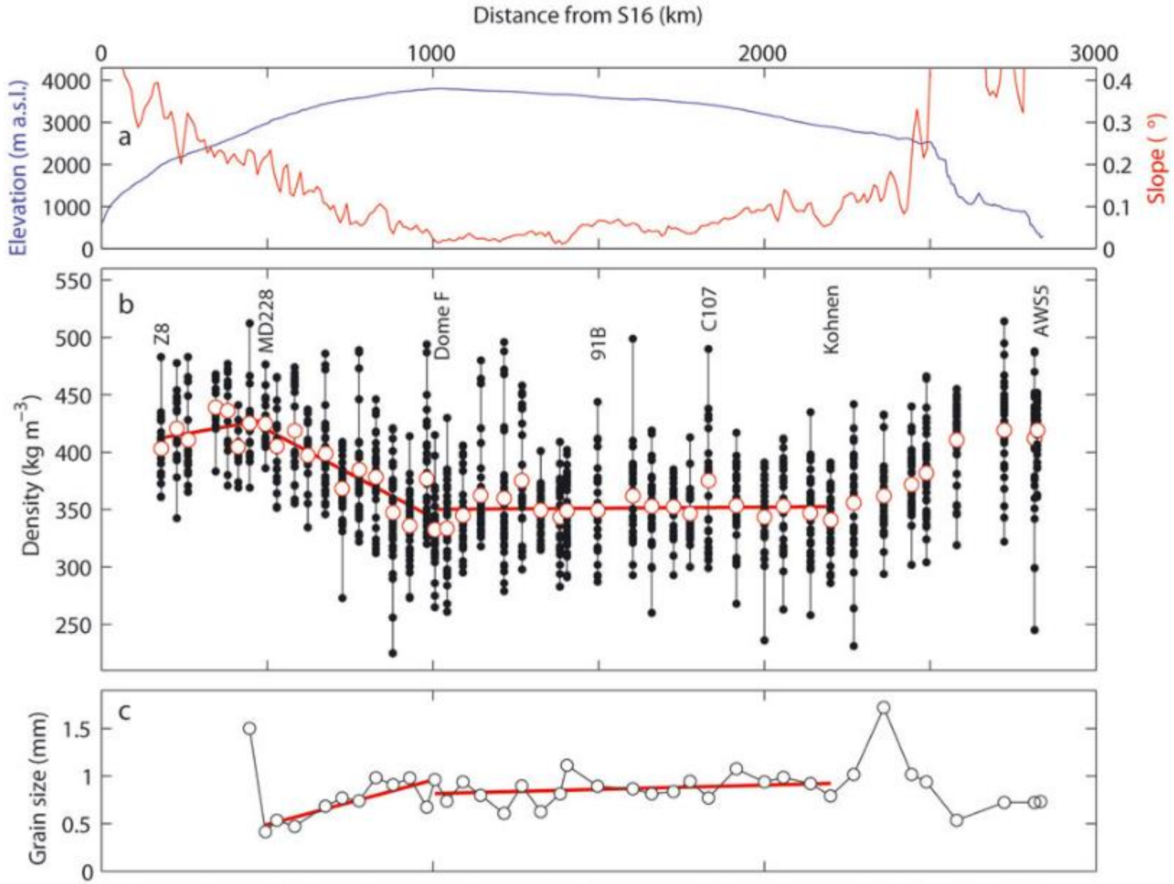
=> Sensitivity to instrumental noise to be studied !

2 – Sensitivity studies at global scales – sea-ice

2 – Sensitivity studies at global scales – ice sheet

Seasonal snow variations and impacts on altimeter measurements must be studied.





From Sugiyama et al. [2009]: (top) Surface elevation (blue) and slope (red); (middle) snow density; (bottom) snow grain size, from measurements taken along an Antarctica traverse

3 – Comparison to in-situ measurements

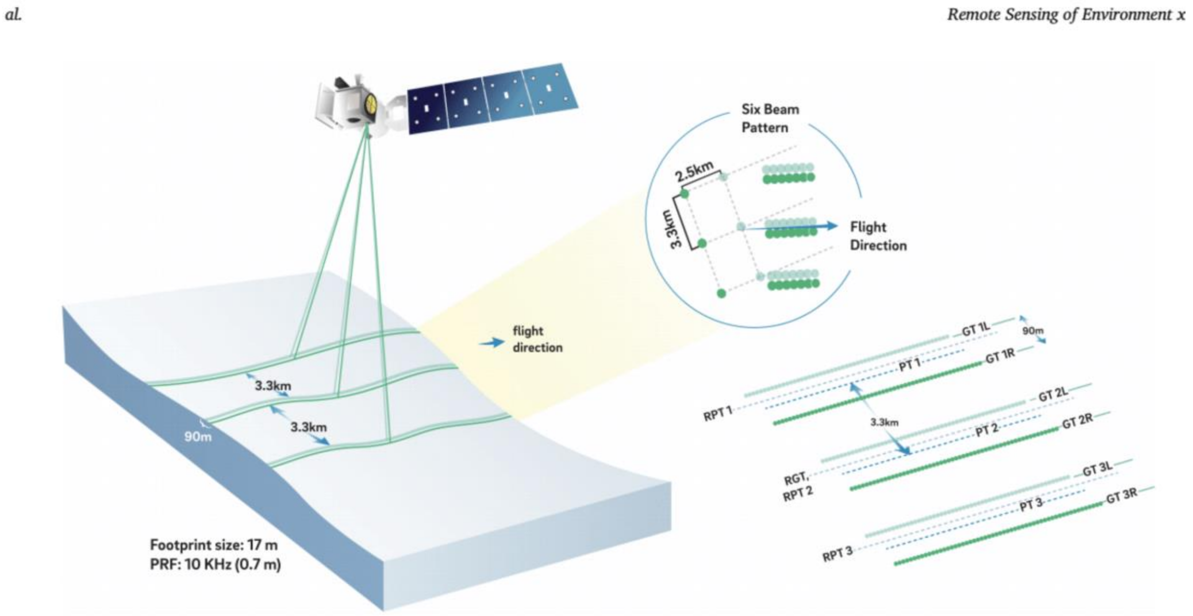
- **Significant need of in-situ data, especially over sea-ice** *(snow depth, surface roughness, GNSS, snow properties such as: density, grain size, temperature, snowpack stratification…).* **Will be beneficial for simulation.**

- **Analysis of the CryoVex airborne campaign data**, especially to get SAR Ka measurements. How good & exploitable are the data?

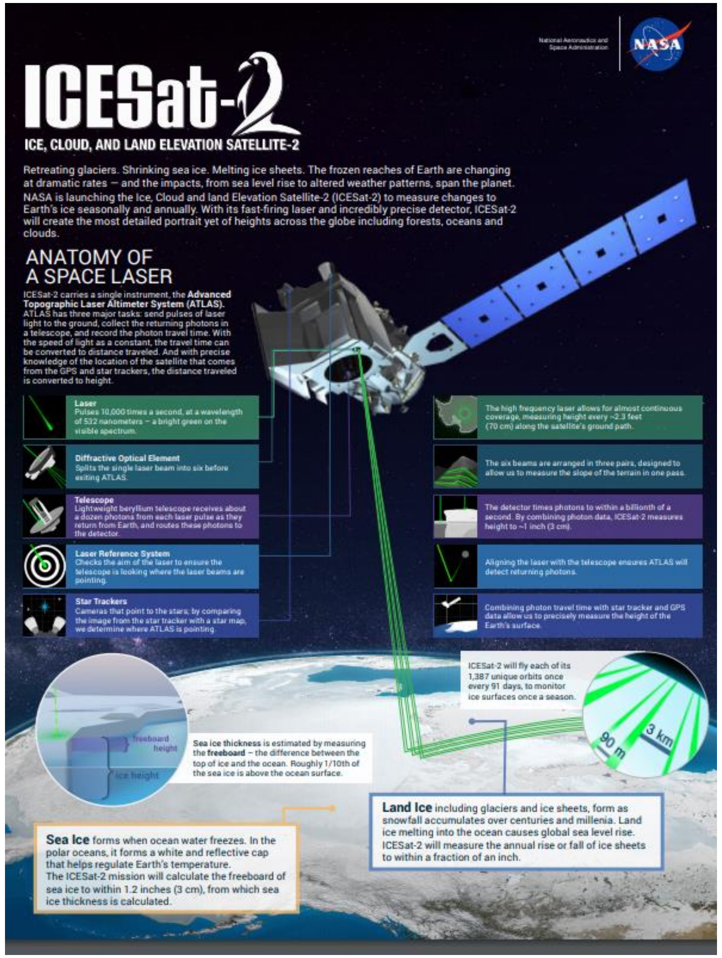
4 - Exploitation of in-orbit multi-mission observations

Great opportunity to compare Ku/Ka measurements to ICEsat-2 measurements

- ❑ Over land ice
- ❑ Over sea ice (over sea ice floes and water leads)



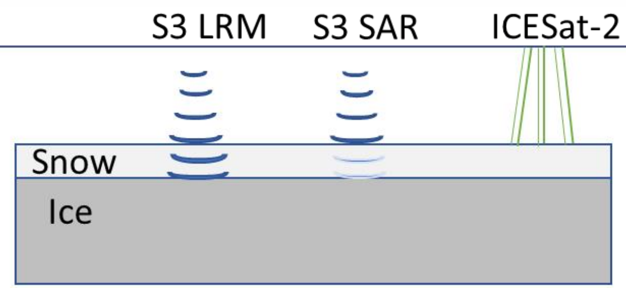
Orbit	310 miles altitude, 92-degree inclination, 91-day repeat
Speed	4.3 miles per second
Power	4 Solar panels average of 1320 Watts
Data	Onboard recorder stores 580 gigabits/day, X-band downlink sends 220Mbits a second.

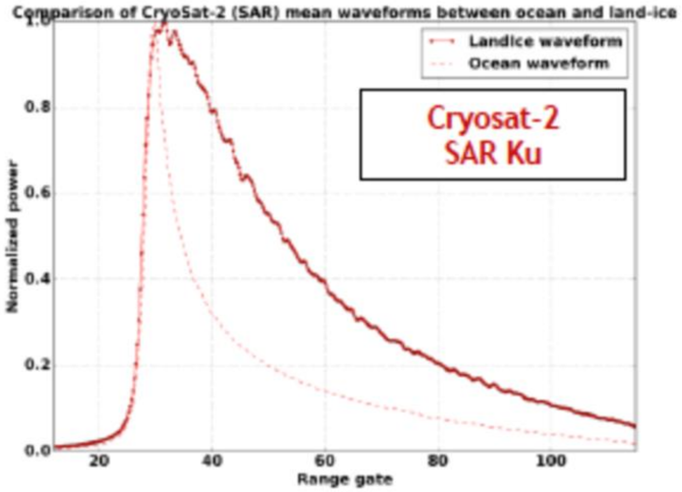


4 -Exploitation of in-orbit multi-mission observations

ICESat-2 provides very accurate & precise elevations over snow surfaces (no or weak penetration, footprint of 17 meters diameter). Potential studies :

- Precise assessment of LRM Ka (Saral mission) penetration into the snowpack, and to what extent (by comparison with Icesat-2)
- Assessment of how SAR leading edge waveform is impacted by the penetration effect (volume scattering of snow). *First studies show a week impact over lake Vostok [Aublanc et al., 2018] + ESA SPICE project [MacMillan et al., 2019])*
- Analysis over different types of snow/surface (sea-ice & ice-sheet)
- **Analysis of physical retracker outputs (LRM and SAR) <u>over the leads</u> to characterize the performance of SLA estimation (crucial for ocean studies – SLA/MSS but also for computing the freeboard)**
- **Over the ice pack, analysis of different level-2 retrackers (empirical & physical).**

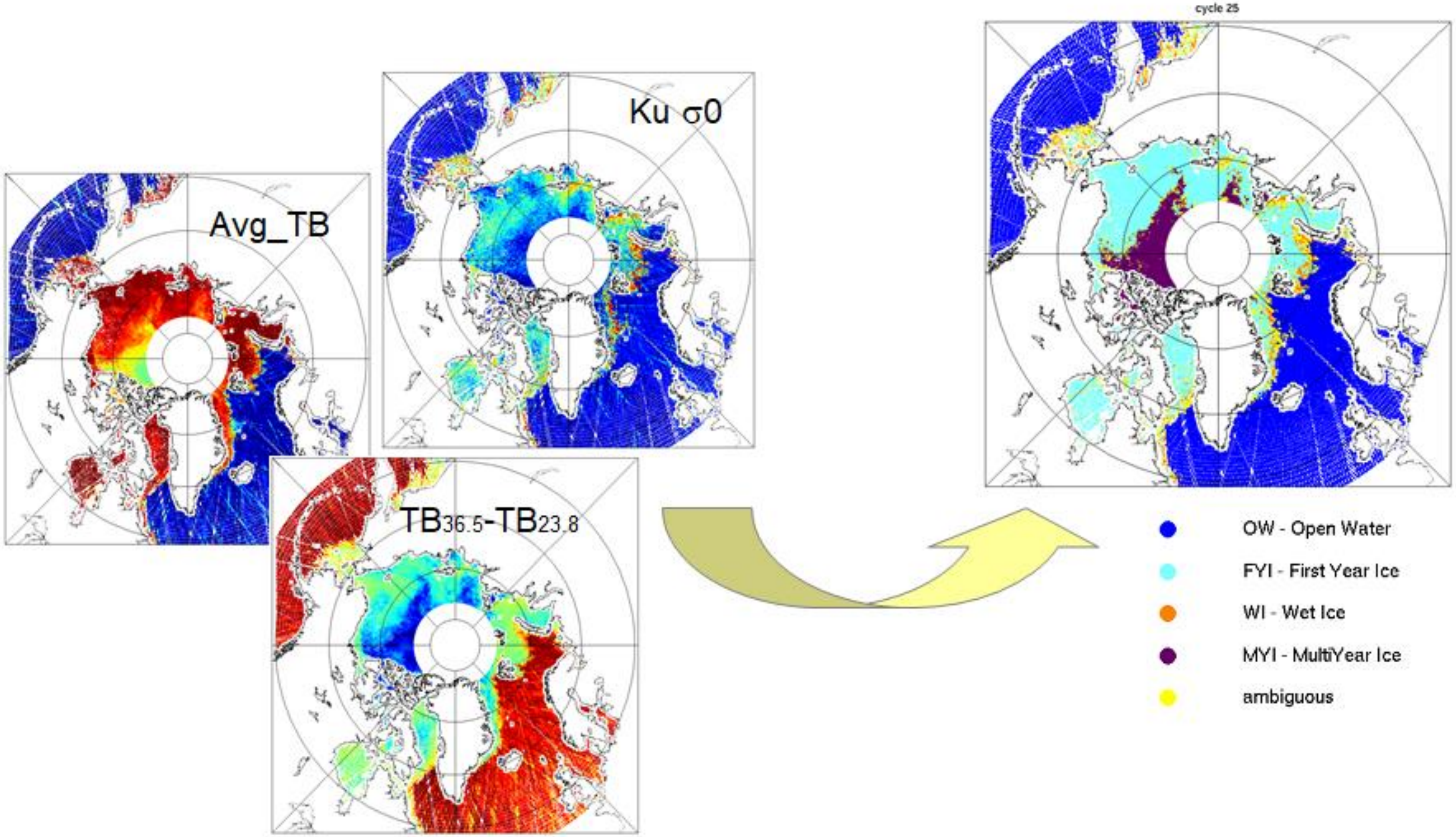




SPICE study (CLS) showed that volume echo (penetration) has minimal effect on the SAR Ku leading edge and so S3 SAR Ku tracks close to the surface.

5 – Synergy between altimeter and radiometer measurements

Synergy between altimeter and radiometer should be exploited (Ensivat measurements) Tran et al, 2010



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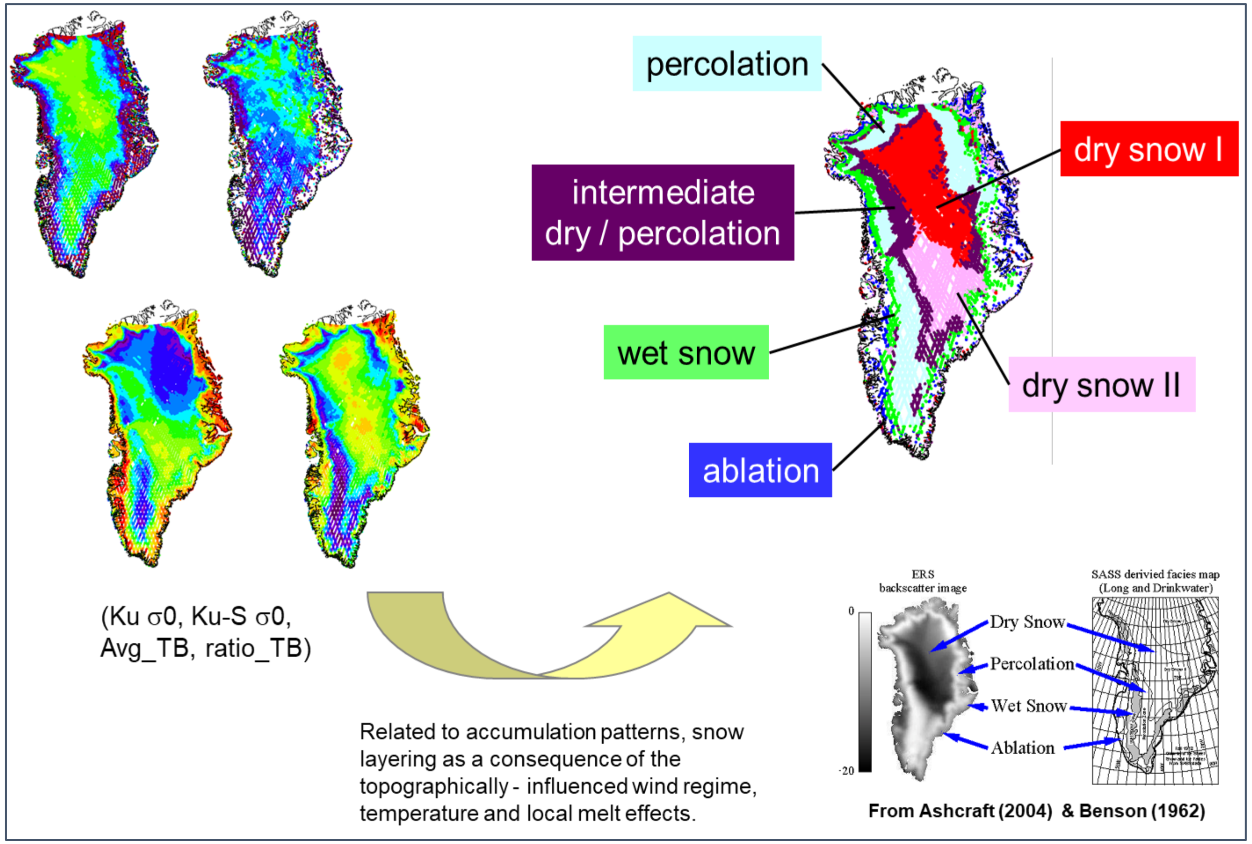
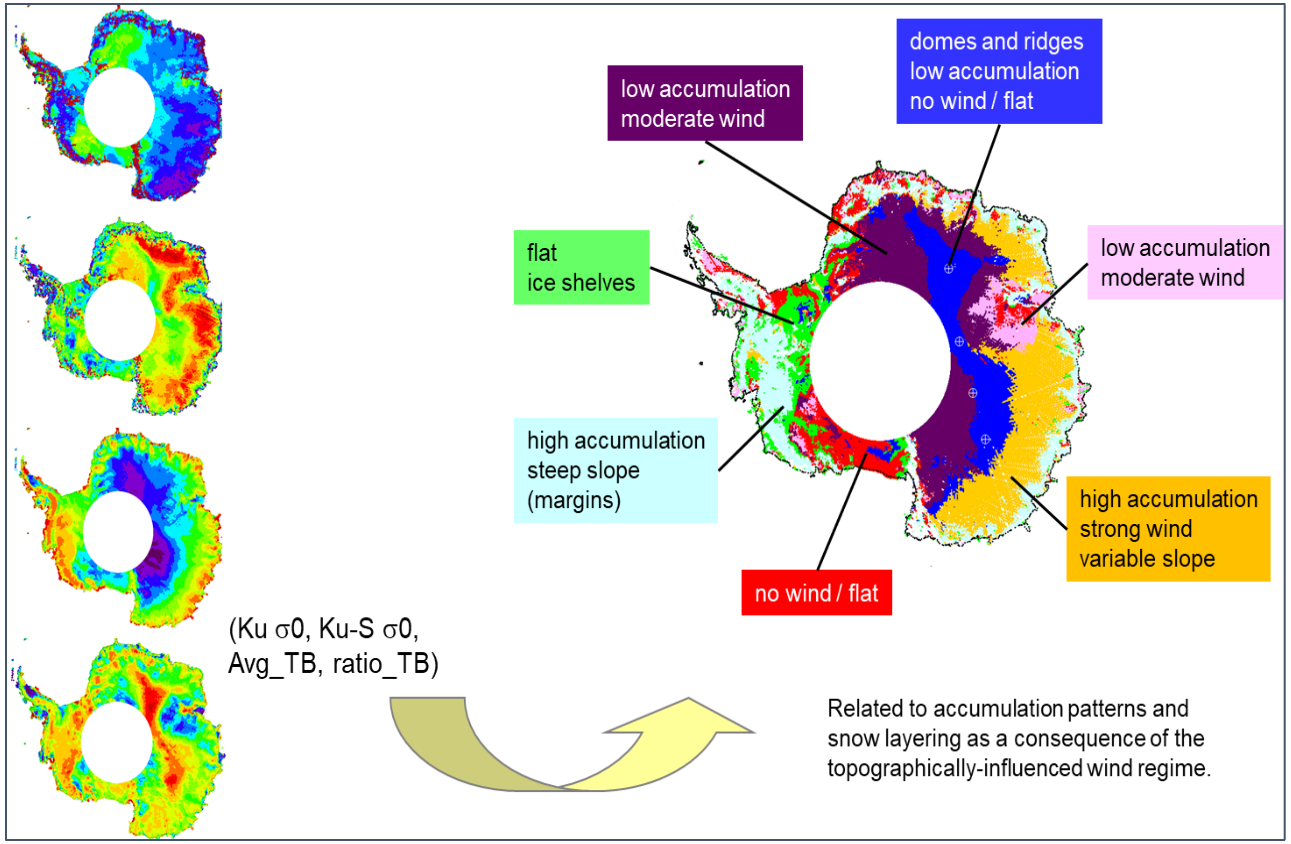




6 – Definition/Development of level-2 algorithms / sea-ice

- **Simulations studies** will help us to understand how the dual Ku/Ka frequency measurements (+ radiometer measurements) can be efficiently exploited to discriminate and estimate geophysical snow parameters. Simulation will be also beneficial for defining/tuning level-2 algorithms.

- **Improvement or definition of sea-ice retracker** (Emprirical retracker, CLS Adaptive, SAMOSA++) to:
  - account for large scales roughness
  - account for penetration effects & retrieve the effective range altimeter at snow/ice interface (Ku band)
  - estimate the snow depth and potentially other parameters of the snow pack

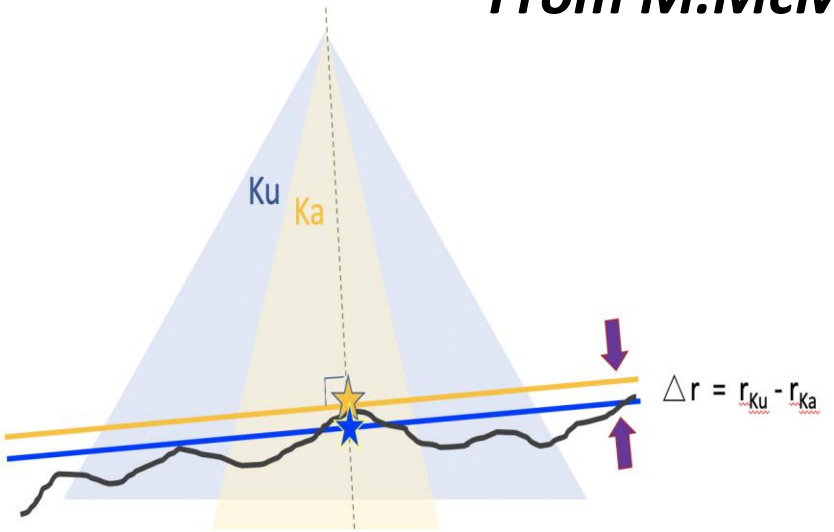
=> Current threshold retrackers are inaccurate as they do not account for any geophysical variation of the surface (snow & surface roughness parameters) !

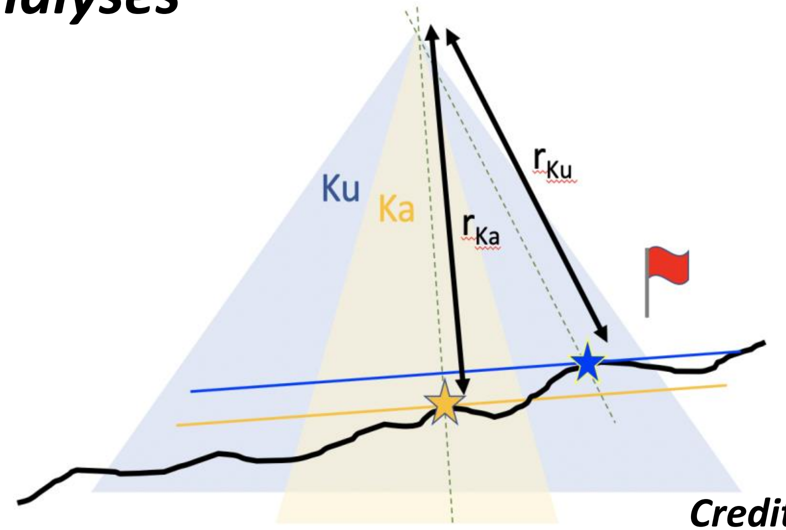
Surface elevation retrieval from Ku/Ka measurements over ice sheets

- Similar job as sea-ice! Problematic is to estimate a reliable surface elevation at snow/air interface
- Simulation studies to understand how the dual Ku/Ka frequency measurements (+radiometer measurements) can be efficiently exploited to to discriminate and estimate geophysical snow parameters.
- SARIn mode will be valuable to account for topographic effects, but be careful with Ku/Ka comparisons ! (see next slide)

6 – Impact of surface topography for simultaneous Ku/Ka measurements

From M.McMillan analyses





Credits to M.McMillan

- ➢ How does the surface slope & the topographic variations impact:
  - ❑ The waveform shape in Ku/Ka bands (considering the different antenna gain pattern)
  - ❑ Consequently, the POCA location estimated from the waveforms
- ➢ This must be assessed because the Ku SARIn information could lead to errors in Ka (POCA Ku ≠ POCA Ka)

Possibility to integrate real topography into AltiDop with REMA DEM to make a precise assessment