Analysis of AltiKa waveforms data over Antarctica

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Introduction

- One important aim of the AltiKa mission to continue the historical series provided by ERS-1, ERS-2 and ENVISAT (20 years)

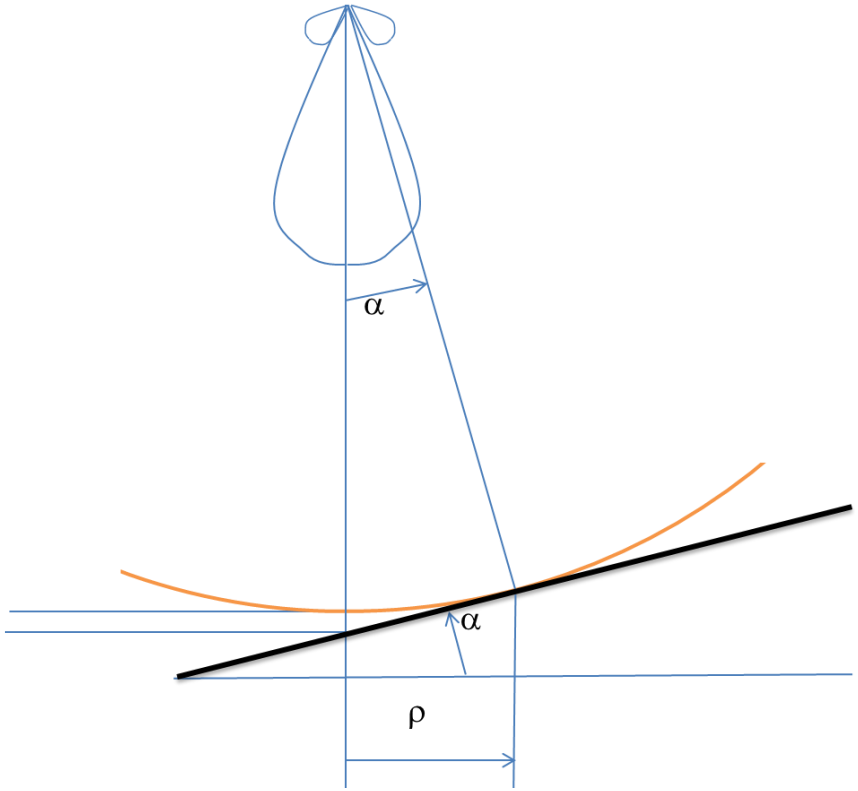
- But there are important differences between AltiKa and its predecessors
  - Radar frequency Ka (35 GHz) versus Ku (13.6 GHz)
    - Antenna beam : 0.6 degrees vs. 1.3 degrees
    - Lower penetration of the signal in the snowpack
  - Sampling of the waveforms : 0.3 meter vs. 0.47 meter
    - Better sampling of the leading edge of the waveforms
    - Reduced size of the tracking window : 30 meters vs. 60 meters
  - Ground sampling : 165 meters versus 330 meters
    - Associated to the reduced footprint, should improve the spatial resolution
  - Equator crossing : 6 h 00 – 18 h 00 vs 10 h 30 – 22 h 30

- Need investigations in order to use AltiKa data and the historical series in a consistent way

Outline

- Impact of the topography
  - Reminder
  - Case study : subglacial lake
- Wave penetration in the snowpack
  - Case study : Vostok lake
- Retracking : impact of instrument tracking mode
  - Case study : around Astrolab Glacier
- Conclusions and perspectives

Reminder: impact of the topography



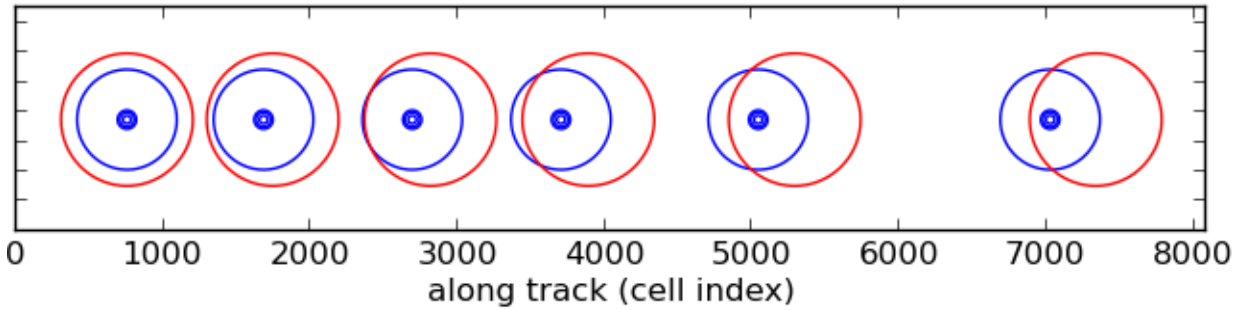
For AltiKa & Envisat
Altitude (~ 810 km)
over Antarctica

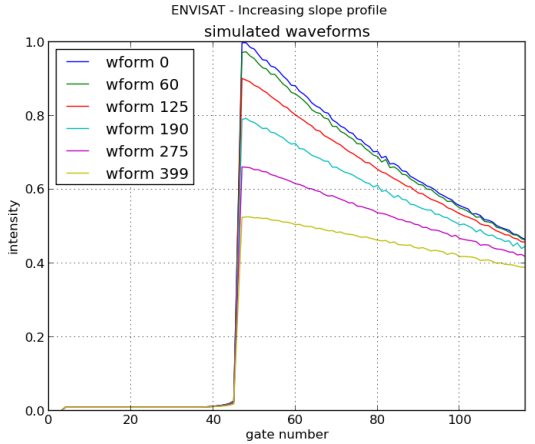
α	y	dh
deg	km	m
0,0	0,0	0
0,2	2,8	5
0,4	5,6	19
0,6	8,4	44
0,8	11,2	78
1,0	14,0	122
1,2	16,8	175

- Generally, the altimeter manage to track the closest point *not the nadir*
- ***Geophysical corrections are needed***
- This is not a new subject (Brenner [1983], Rapley [1986], Remy [1989], …)

Impact of terrain slope on the waveforms (simulation)

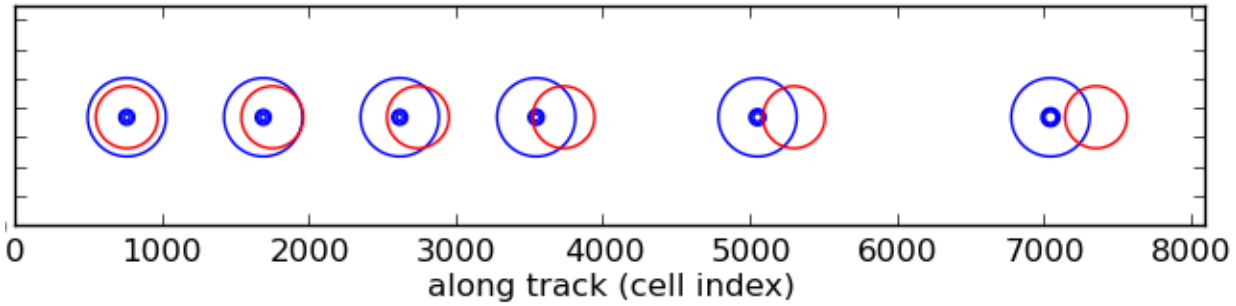
Envisat

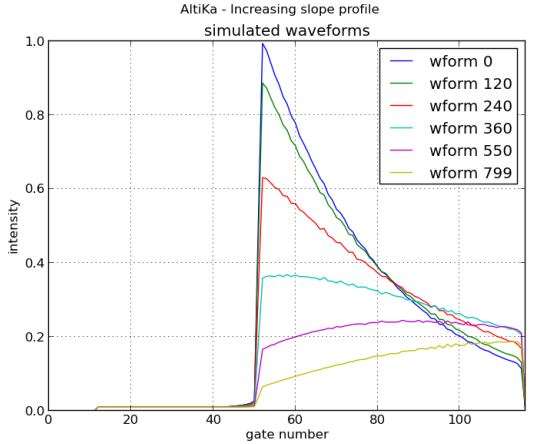




Red : 3dB beam, Blue : selected range gates

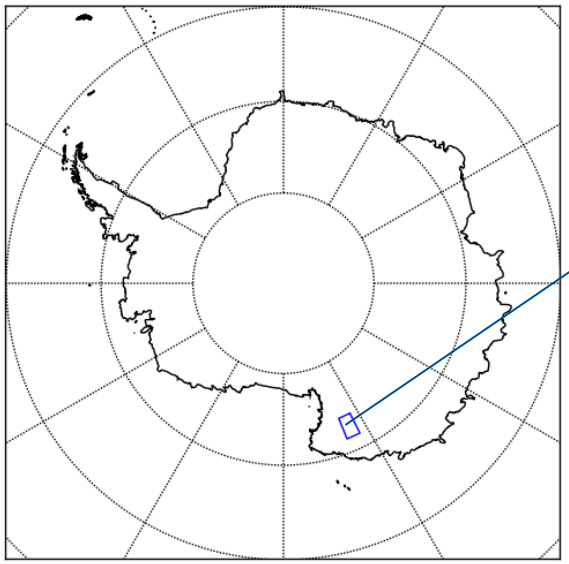
AltiKa

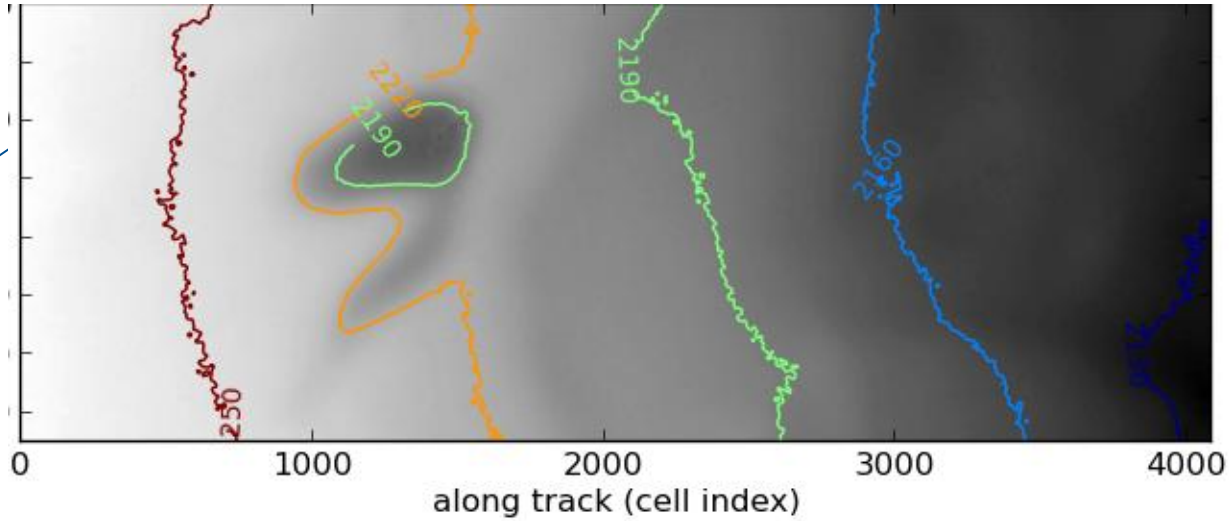


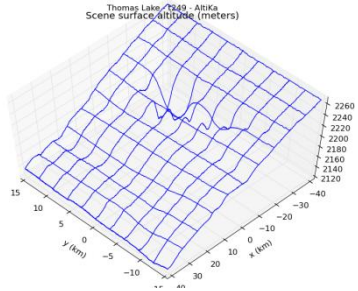


Angle	0°	0.1°	0.2°	0.3°	0.4°	0.5°
slope	0	0.17 %	0.35%	0.52%	0.70%	0.87%

Case study #1 : a subglacial lake



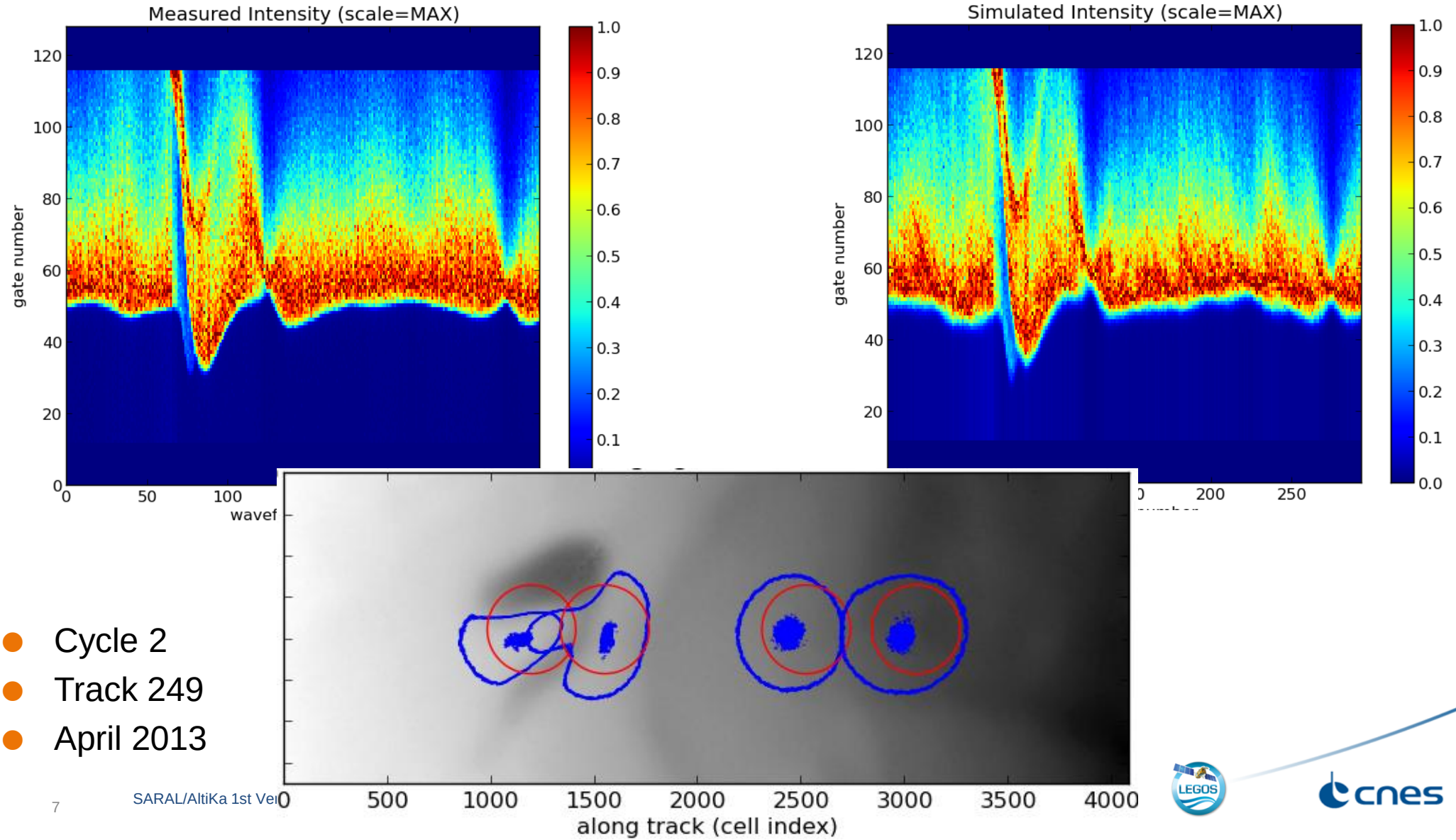




- Subglacial lake recently documented
  - Flament (in review)
  - McMillan (2013)
- Rapid discharge in year 2006
  - Surface variation : - 70 m
- Surface uplift in progress

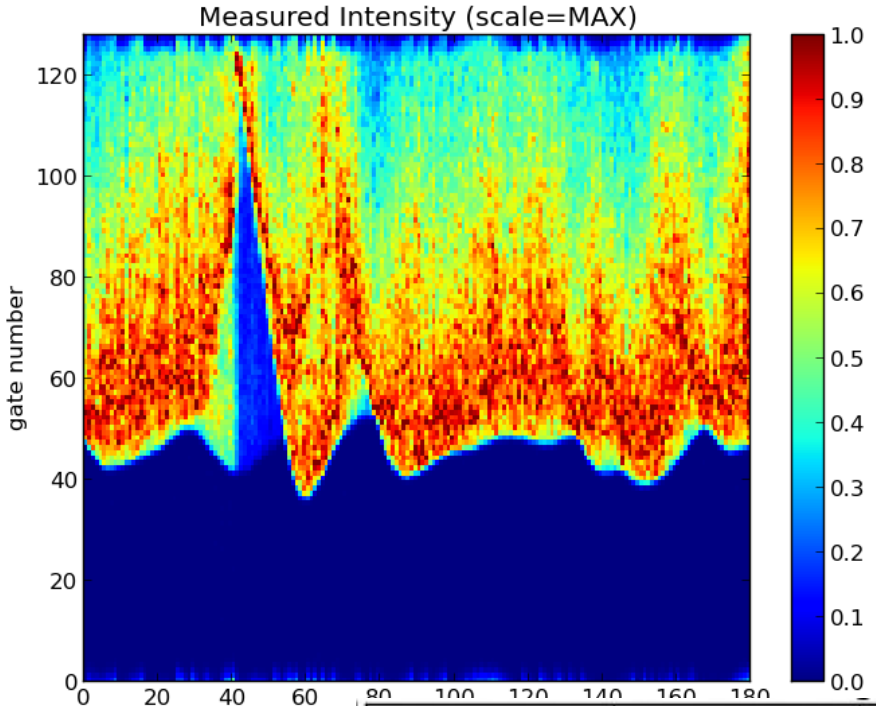
- Precise DEM available (resolution 40 m)
  - Courtesy E.Berthier, CNES and SPOT IMAGE (now Astrium Geomatic Service)
  - In the frame of the SPIRIT Project founded by CNES

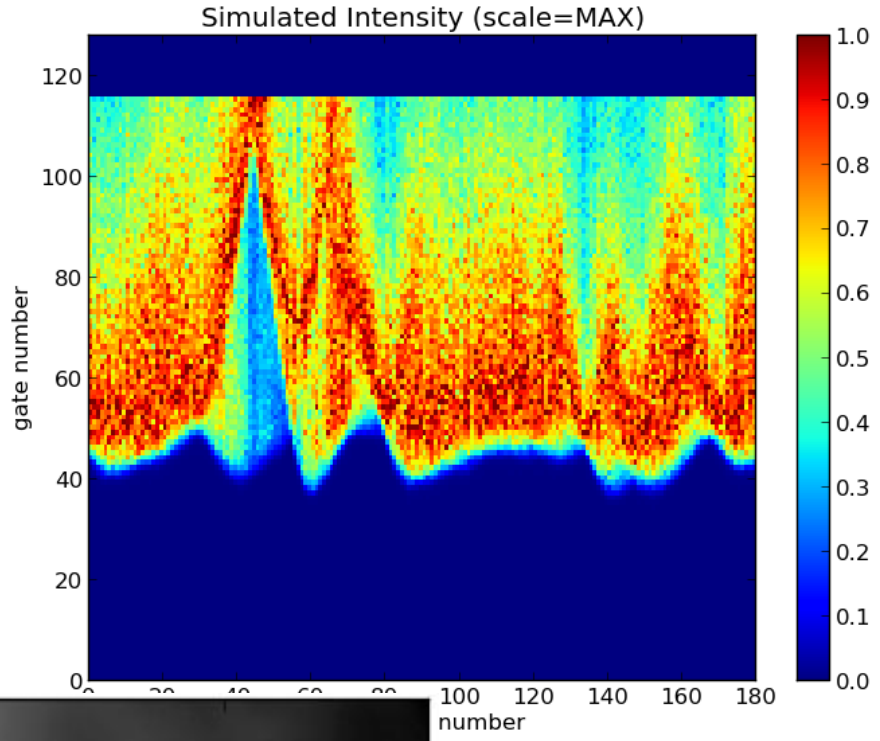
AltiKa waveforms simulation

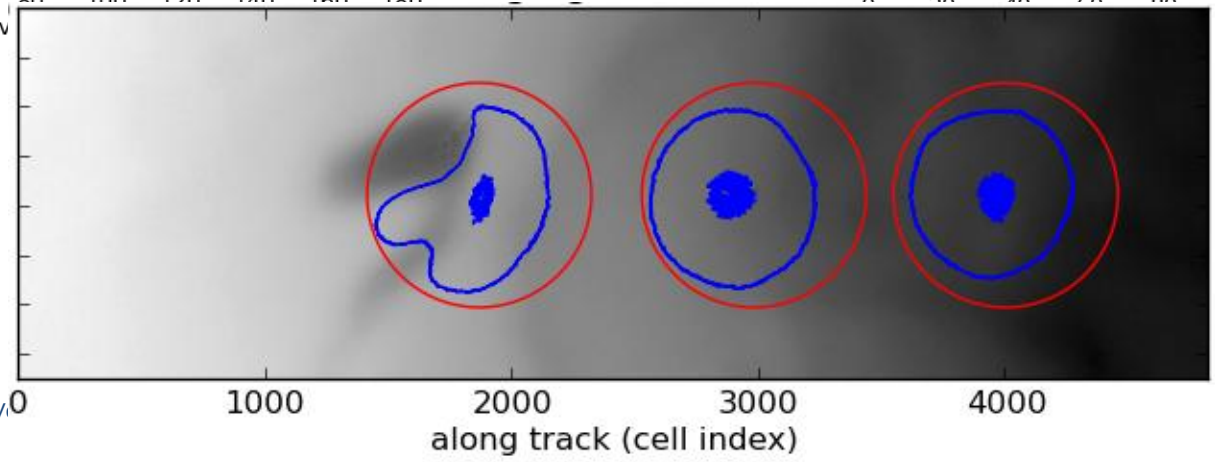


- Cycle 2
- Track 249
- April 2013

Envisat waveforms simulation

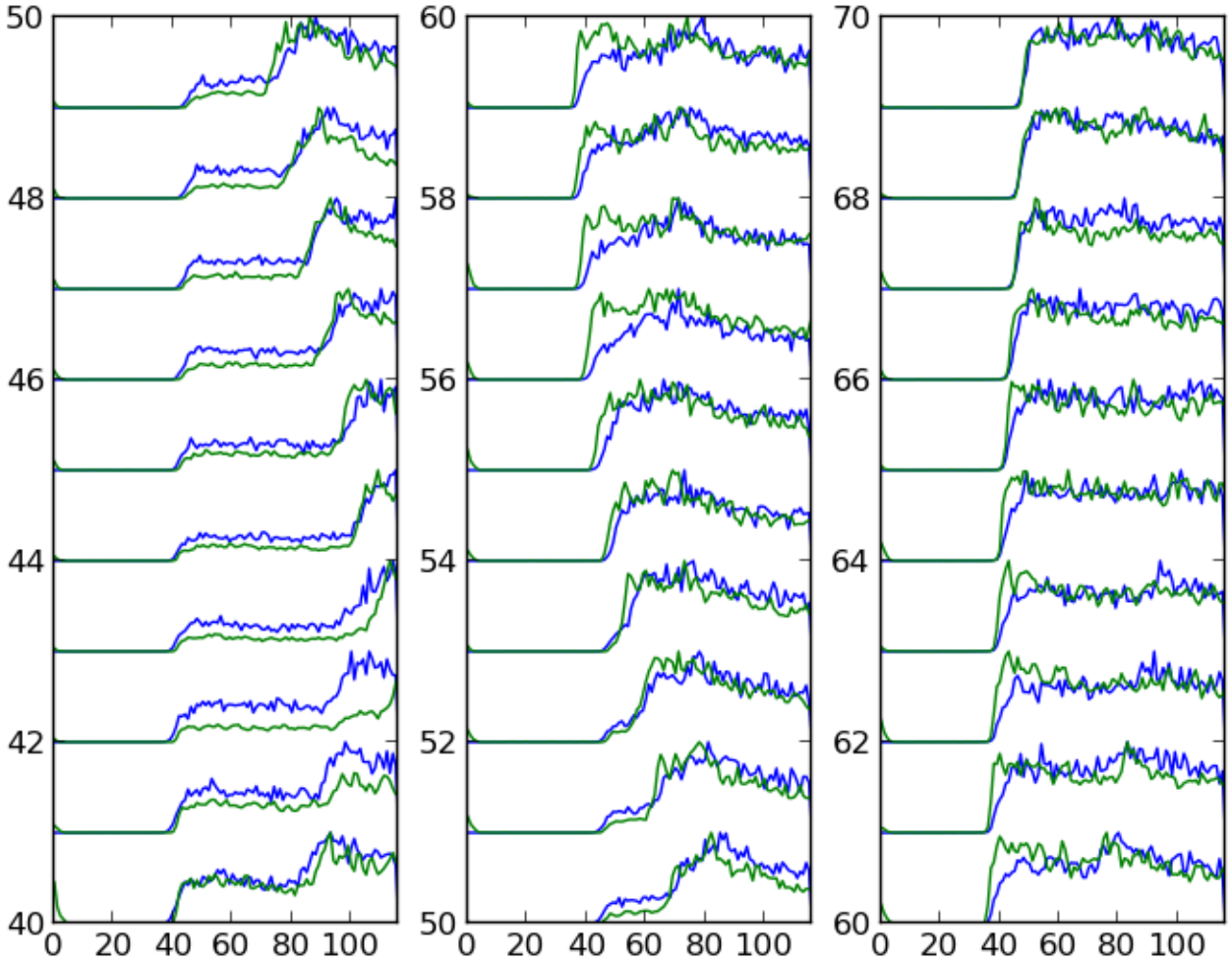






- Cycle 88
- Track 249
- March 2010

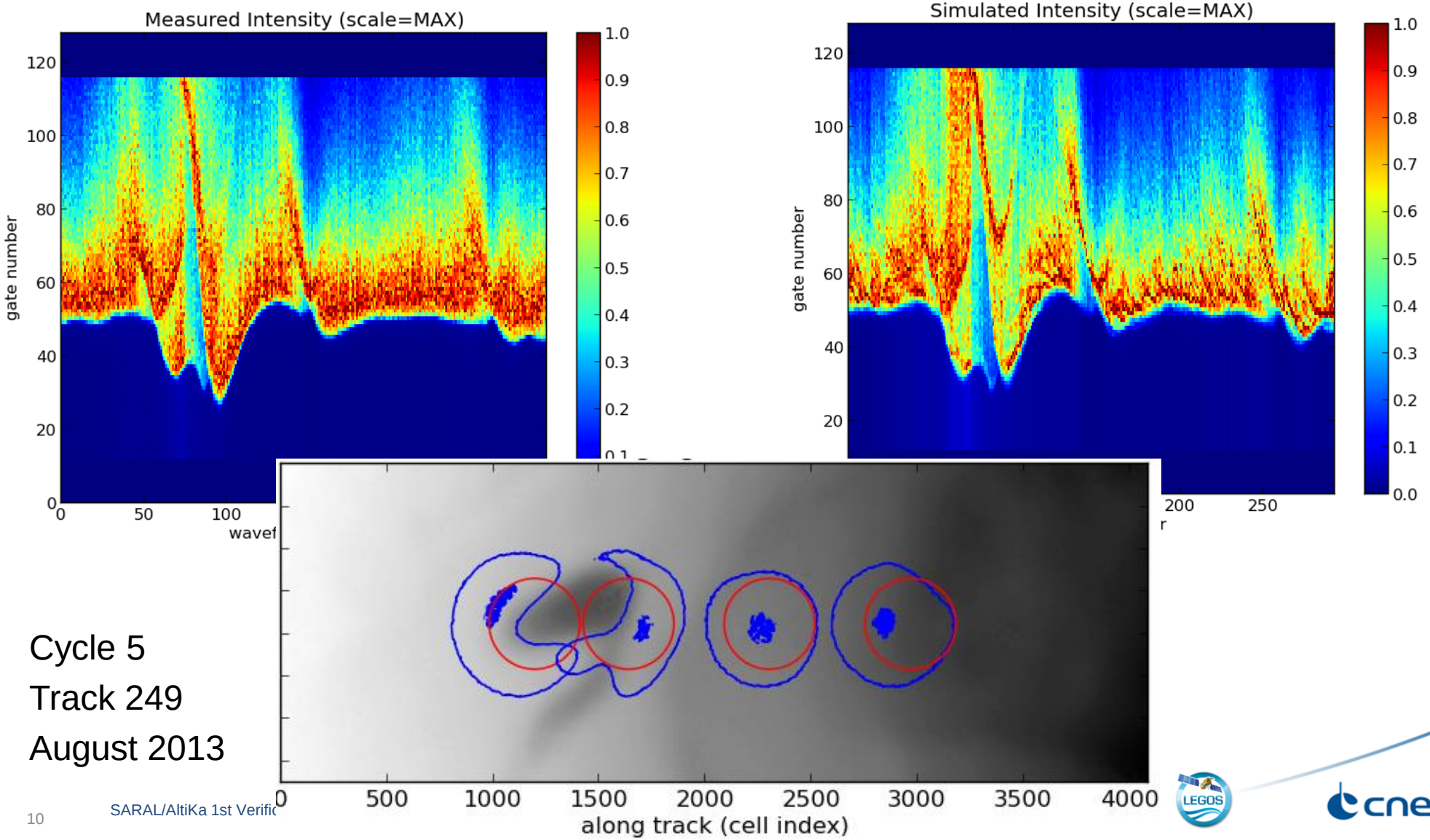
Exemples of Envisat waveforms



- Green : measurements
- Blue : simulation

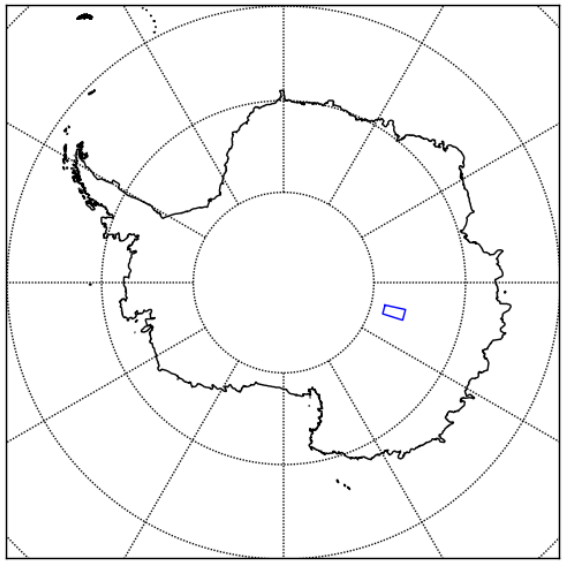
- Cycle 88
- Track 249
- March 2010

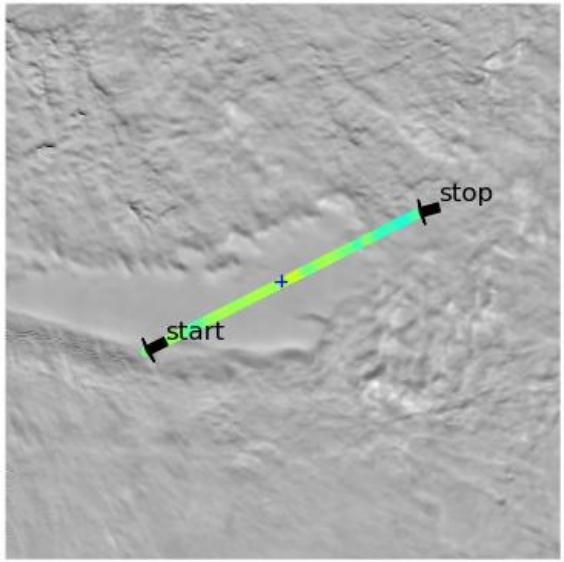
AltiKa waveforms simulation (after orbit change)

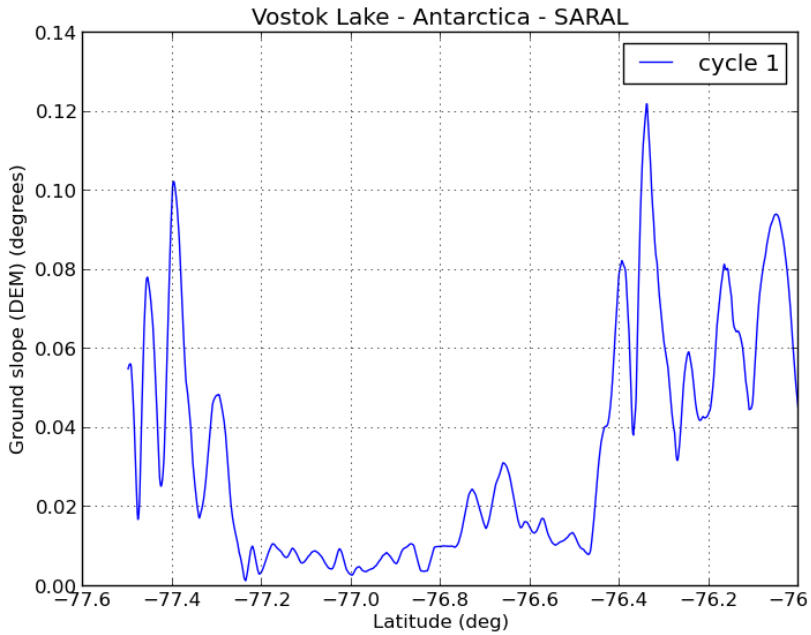


- Cycle 5
- Track 249
- August 2013

Case study #2 : Lake Vostok



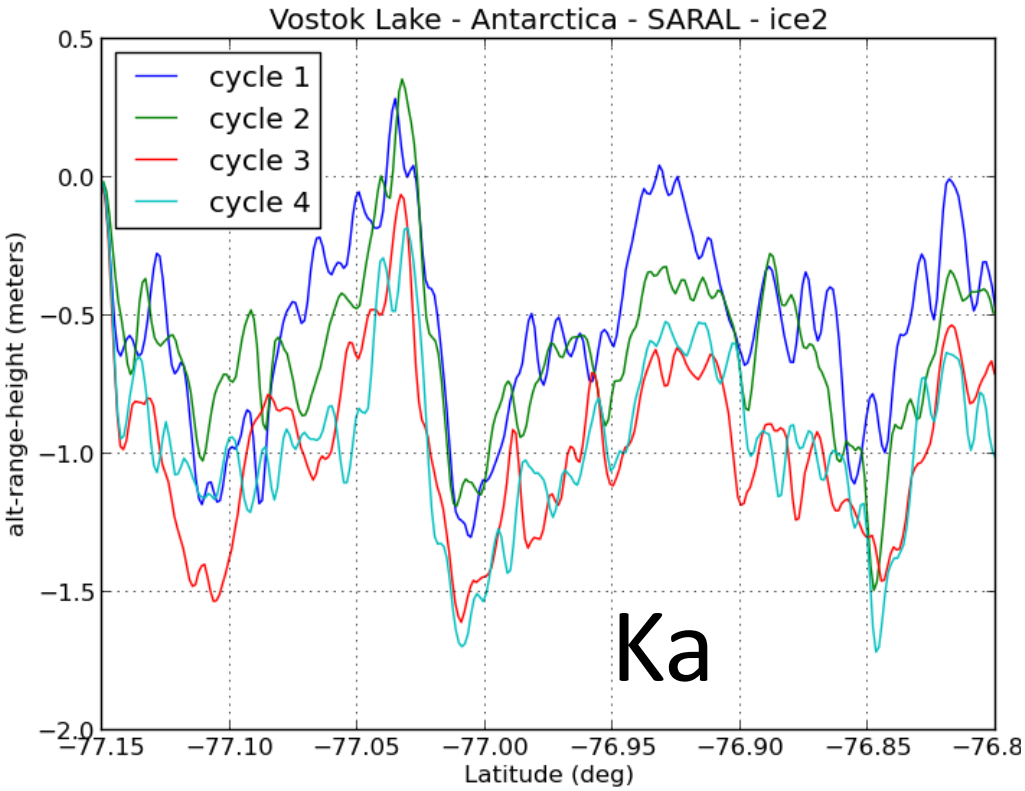


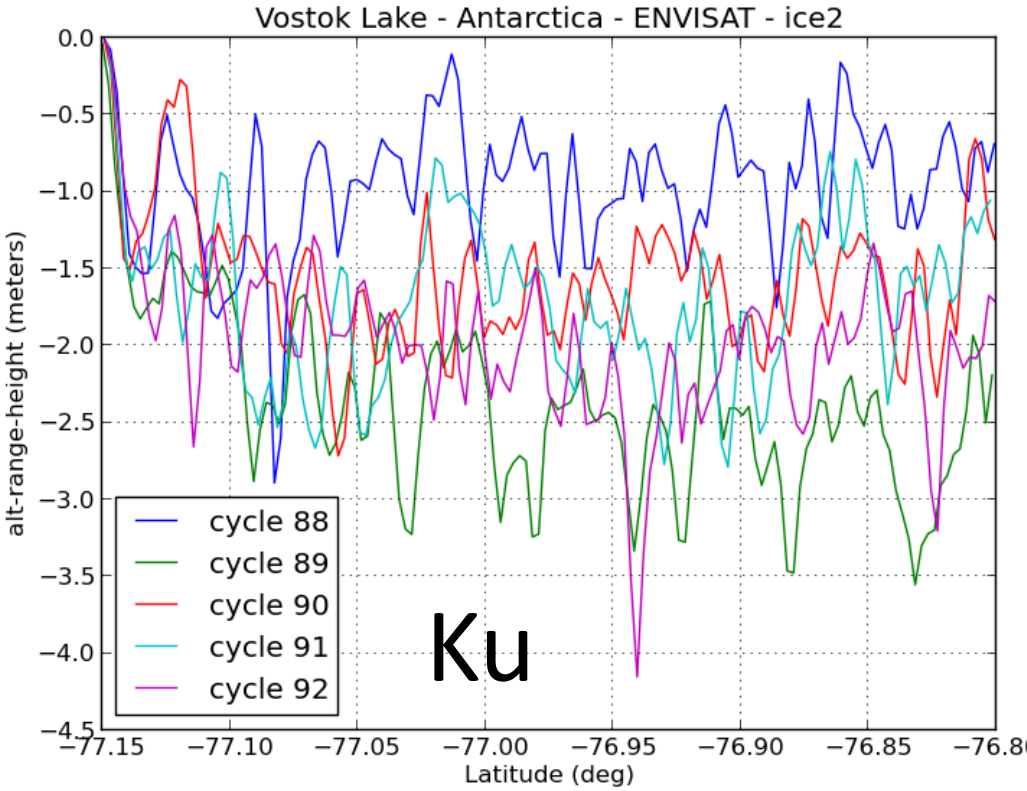


Track 483

- about 270 km x 70 km
- very flat area (conditions induced by the subglacial lake)
- very suitable for instrument related investigations or physics of the measurements studies

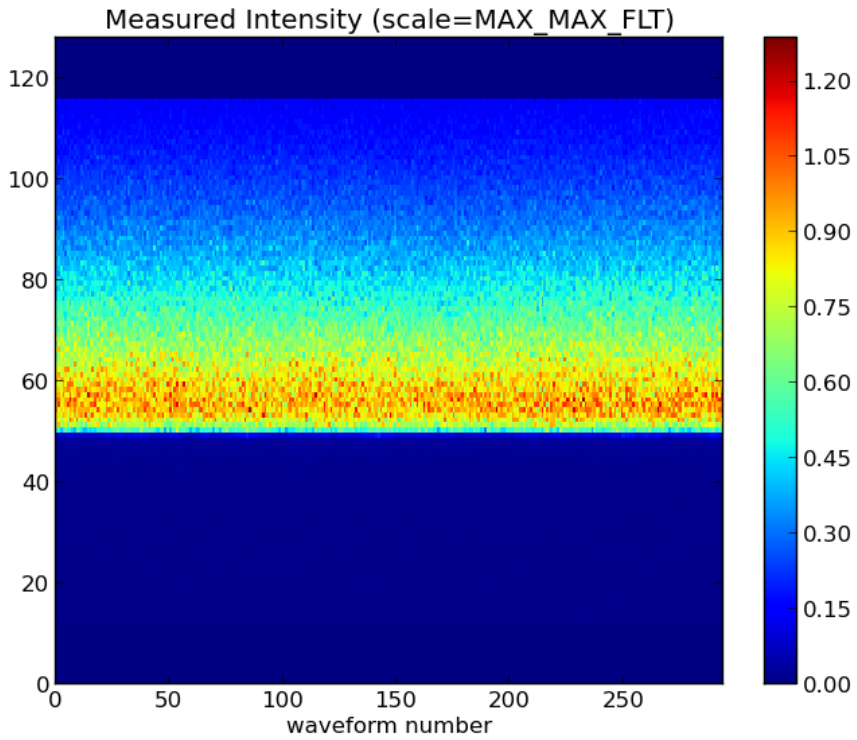
Lake Vostok : retrackings behaviour

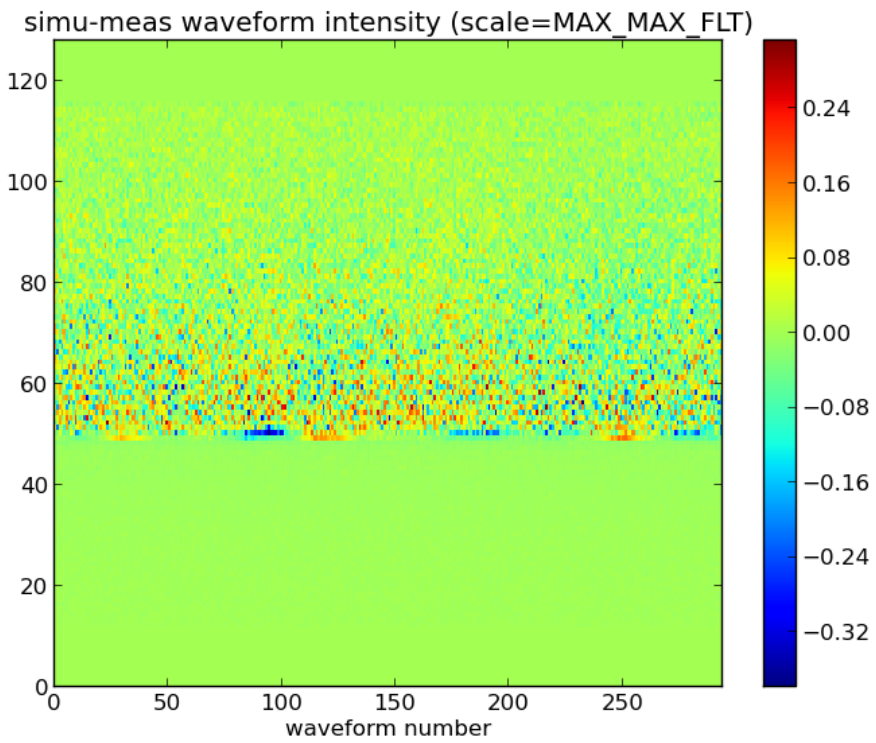




- Altika March to July 2013, Envisat March to August 2010
- AltiKa retrackings of range much more stable than those of Envisat (all retrackings)
  - effect believed to be linked to snow penetration (see below)
- Bias different between Ka and Ku (all retrackings)

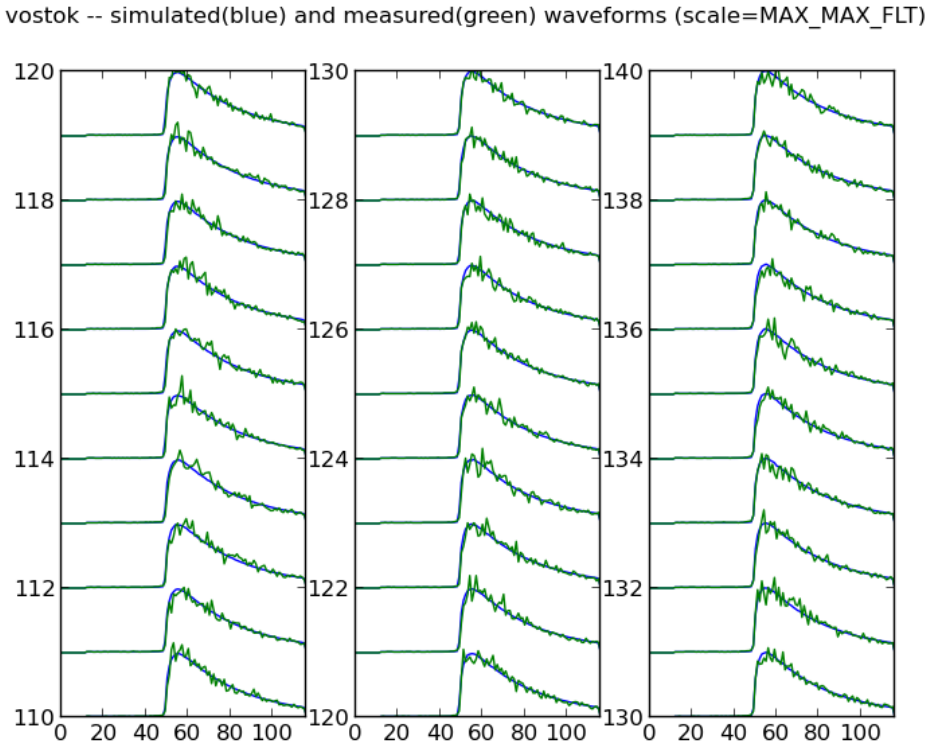
Vostok lake cycle 2 : comparison measurements vs. simulations

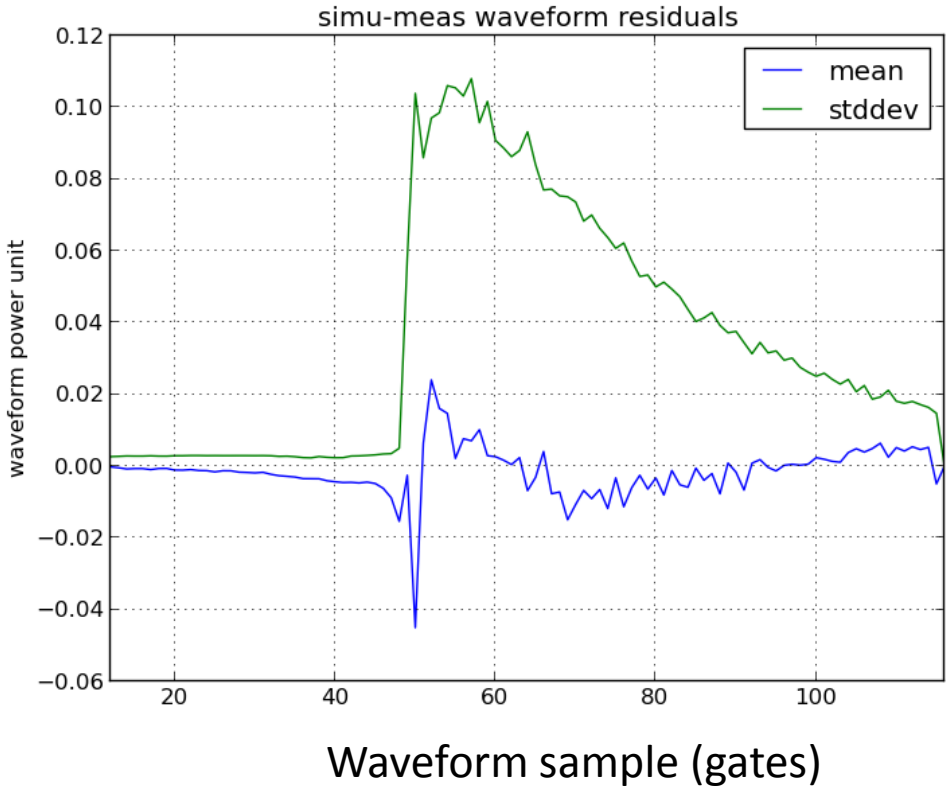




- DEM used Bamber 2009
- Very good fit
- Some error signal visible in the map of the differences
  - correspond to height variation in the DEM (not seen in the measurements)

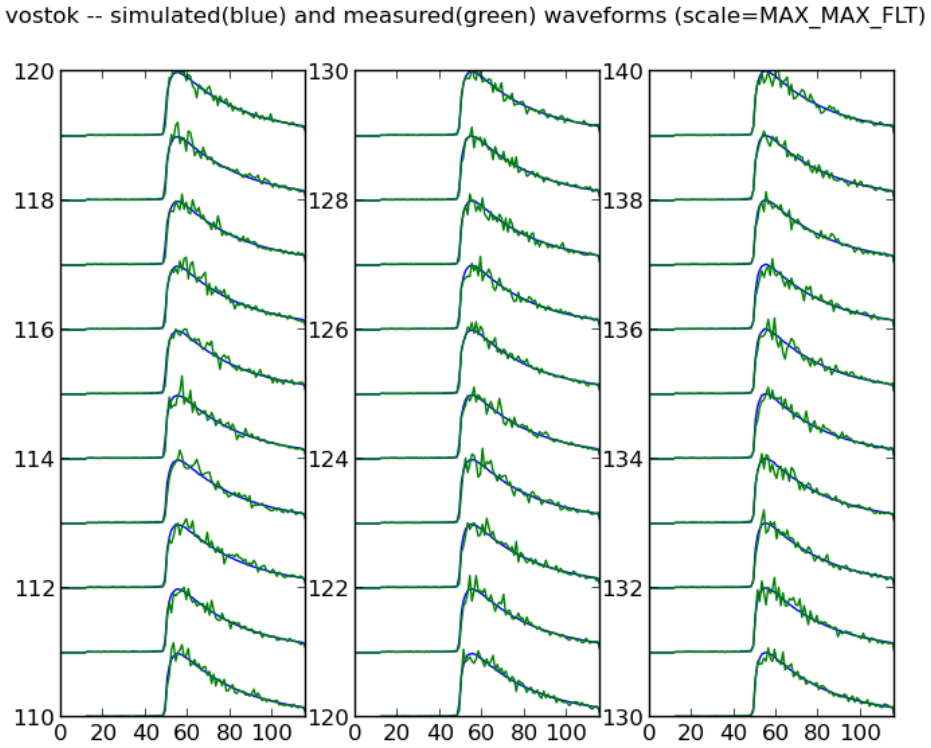
Vostok lake cycle 2 : comparison measurements vs. simulations

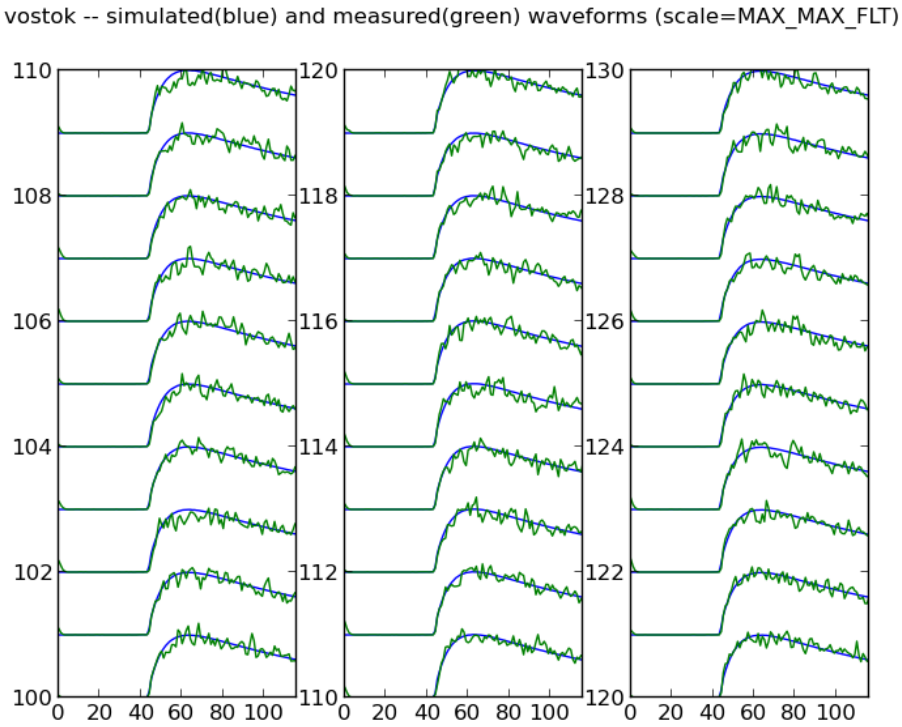




- Another view of the goodness of fit
  - Standard deviation of the residuals compatible with speckle statistics
  - Mean value of the residuals less than 4 % of the waveform amplitude
- Better statistical test ongoing …

Vostok lake cycle 2 : comparison AltiKa vs Envisat





- Effect of antenna diagram and wave penetration in the snowpack clearly visible

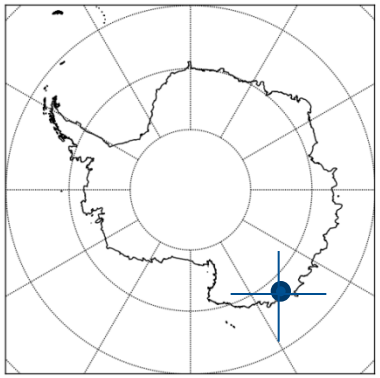
Results of fitting the model

AltiKa (Ka)			
cycle	height corr.	alpha	svol
	m	m-1	
2	0	0,21	1

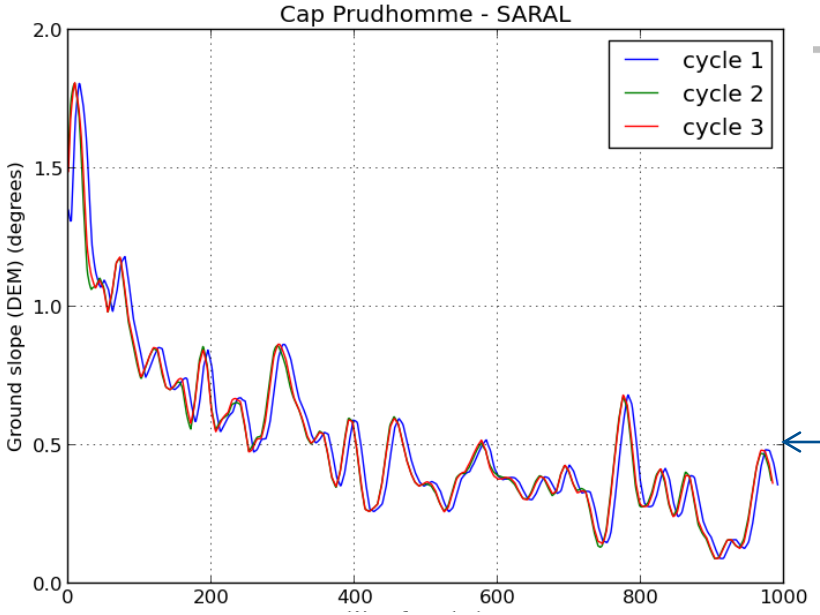
Envisat (Ku)			
cycle	height corr.	alpha	svol
	m	m-1	
88	0,83	0,061	1,25
89	0,49	0,051	1,25
92	0,63	0,053	1,25

- Simple model of the wave penetration in the snowpack (2 parameters)
  - α : extinction coefficient
  - svol : control the ratio between retrodiffusion by the surface and retrodiffusion by the volume
- Verification over a large range of conditions that the results of a state-of-the-art radiometric model (surface and volume retrodiffusion) can be summarized by this simple parametric model
  - snow grain size, stratification, etc.
- Height retrievals stability much improved wrt to classic retrakings

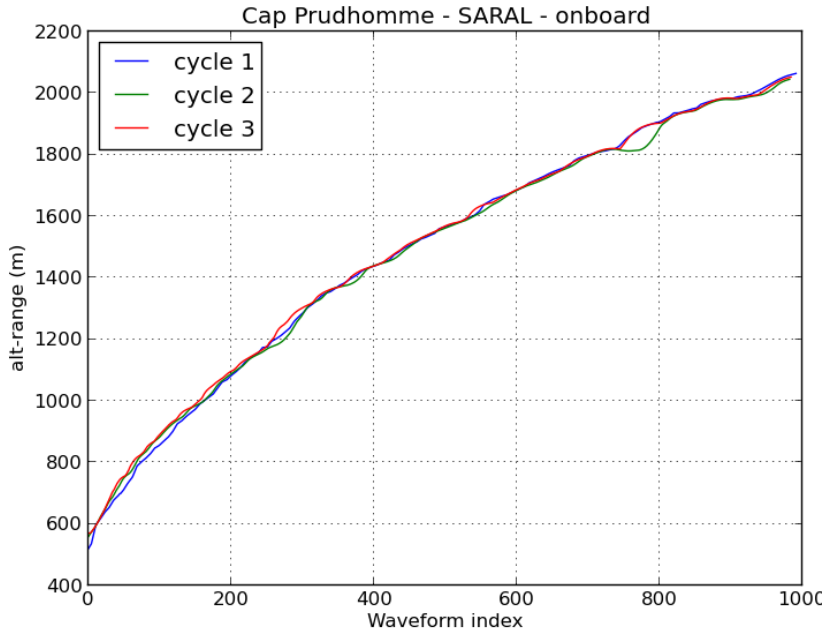
Case study #3 : around the Astrolab Glacier

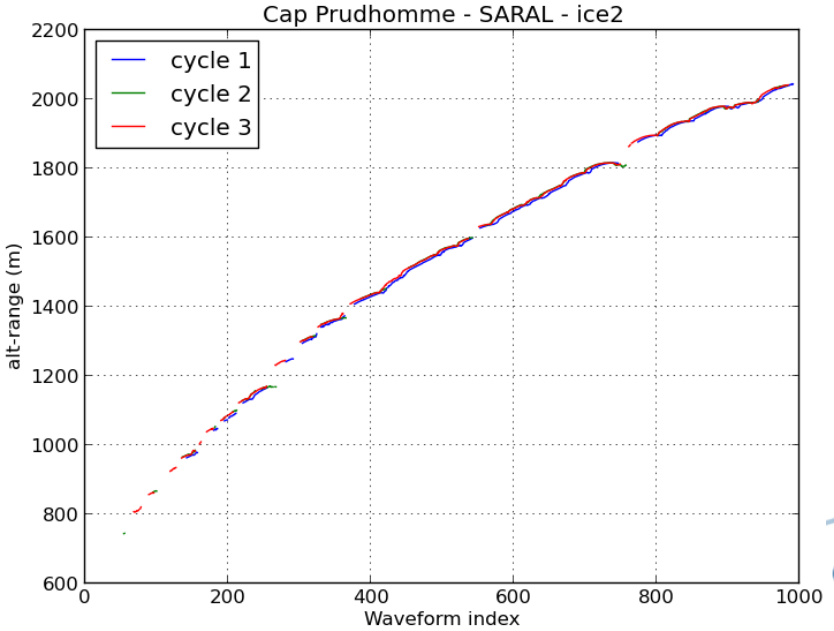


- Track 632
- Tracking mode
  - Cycle 1 : mode MNT
  - Cycle 2 : median
  - Cycle 3 : EDP
- Onboard range available !!!

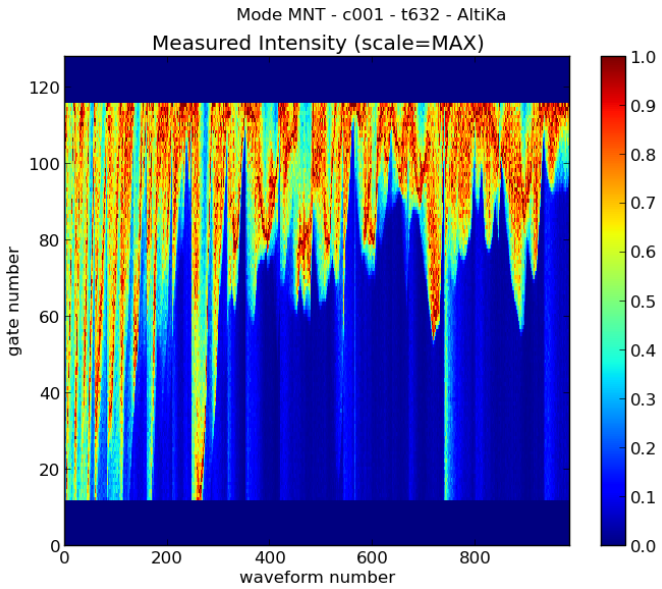


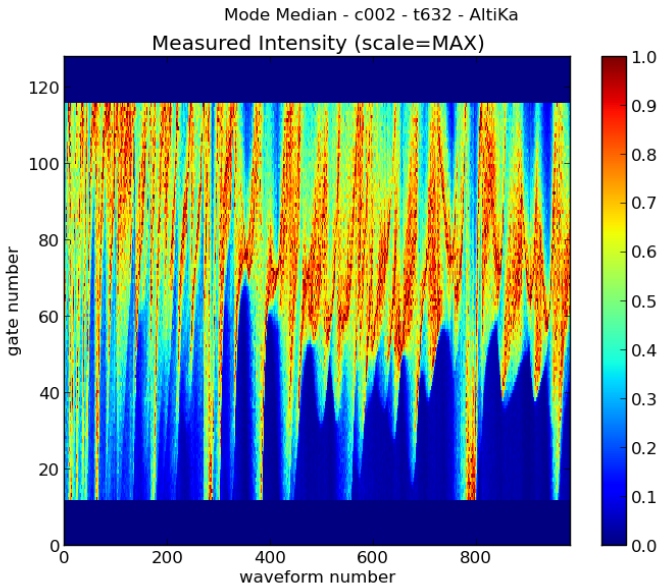
Slope
0.5 deg

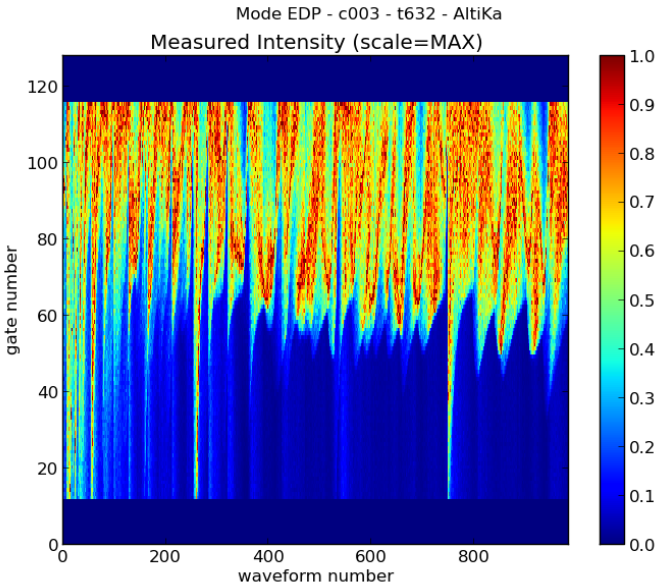




Case study #3 : measured waveforms in the 3 tracking modes



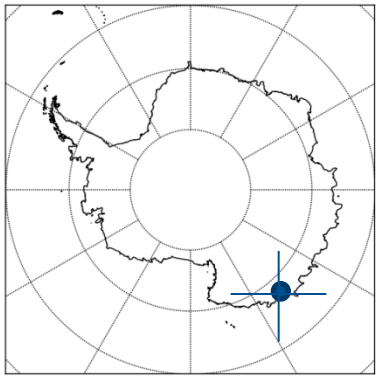


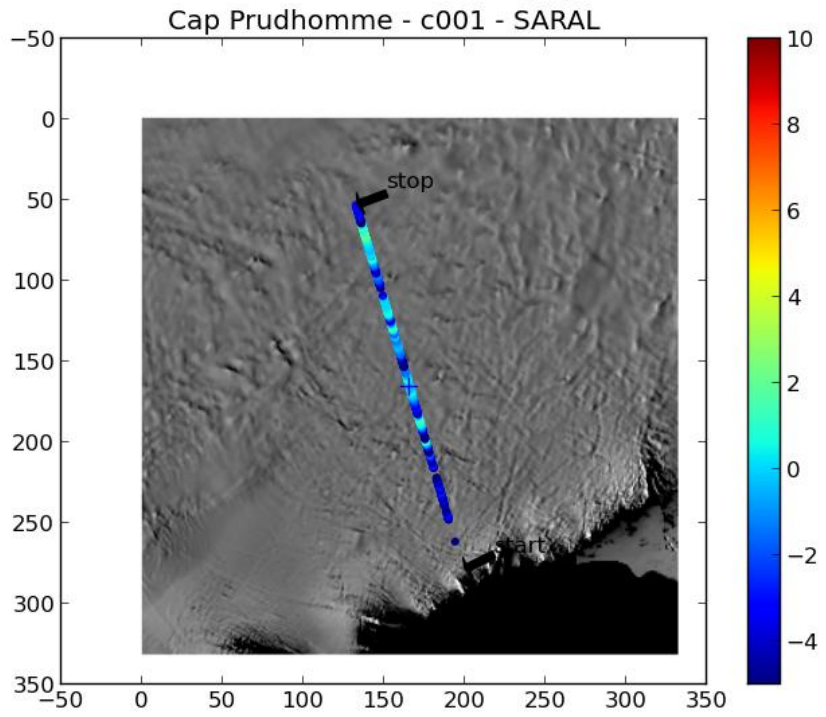


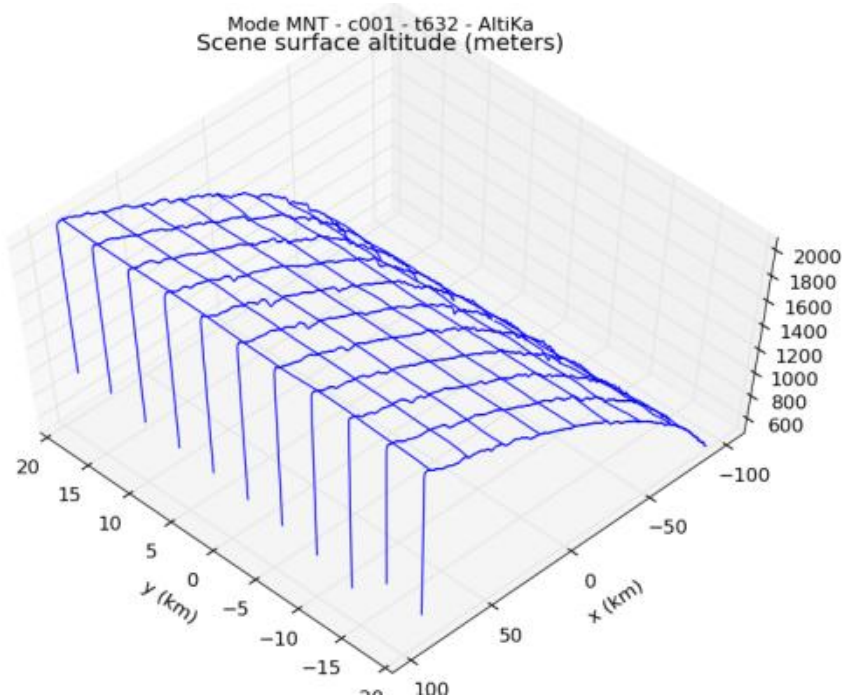
- AltiKa provides waveforms data even when terrain slope is larger than antenna 3 dB beam
  - For the 3 tracking modes MNT, median and EDP
  - Epoch stability is better for the EDP tracking mode (as expected)
  - Loss of tracking is also less frequent with EDP tracking mode (as expected)

- Do these measurements correspond to surface echo ?
- If yes, do they provide meaningful information for geophysical studies ?

Case study #3 : around Astrolab glacier

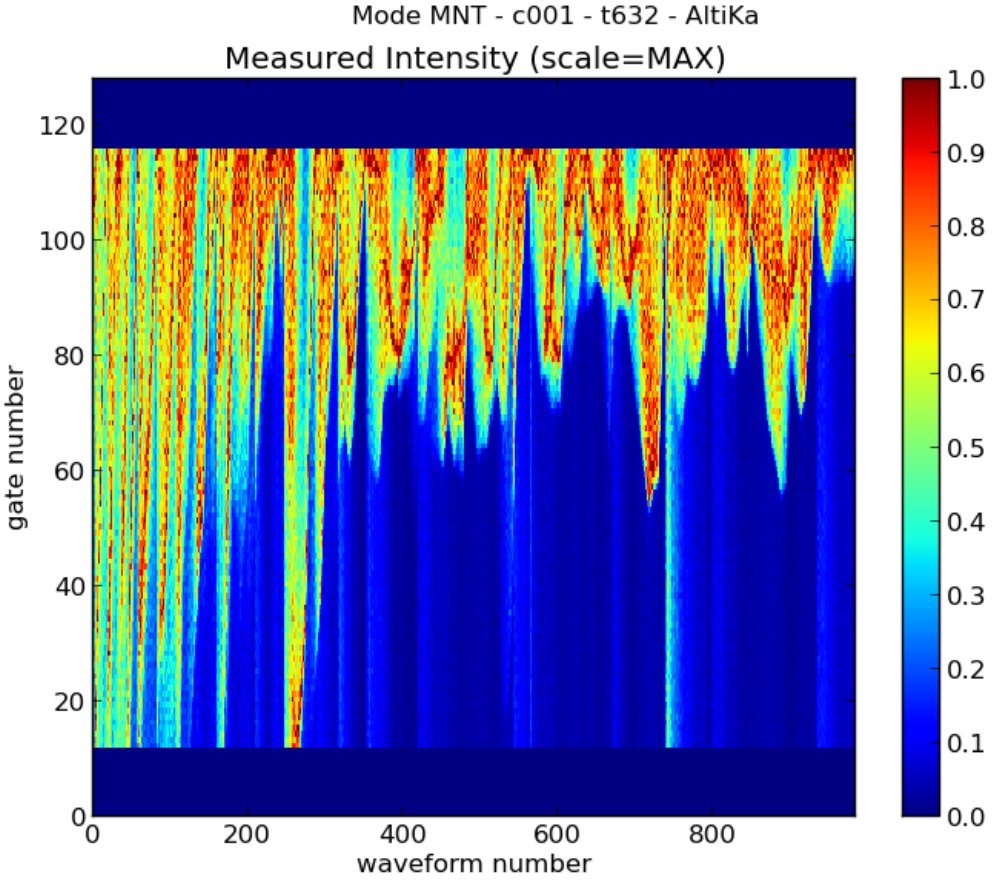


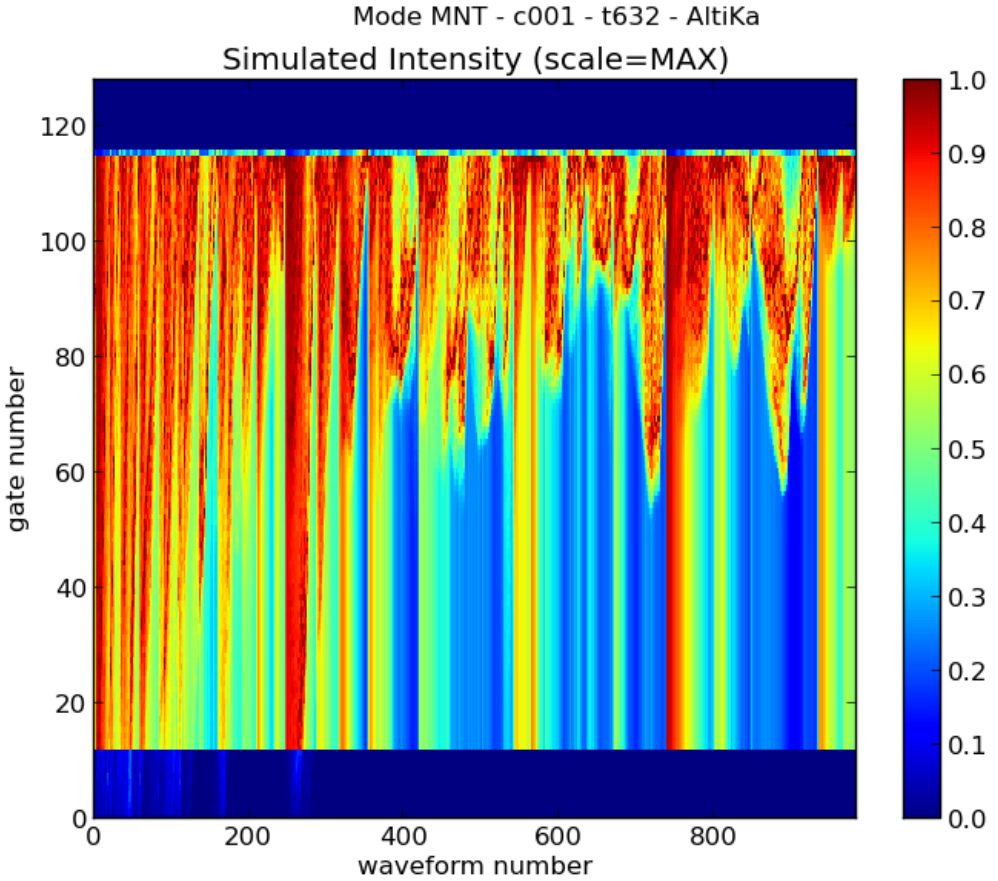




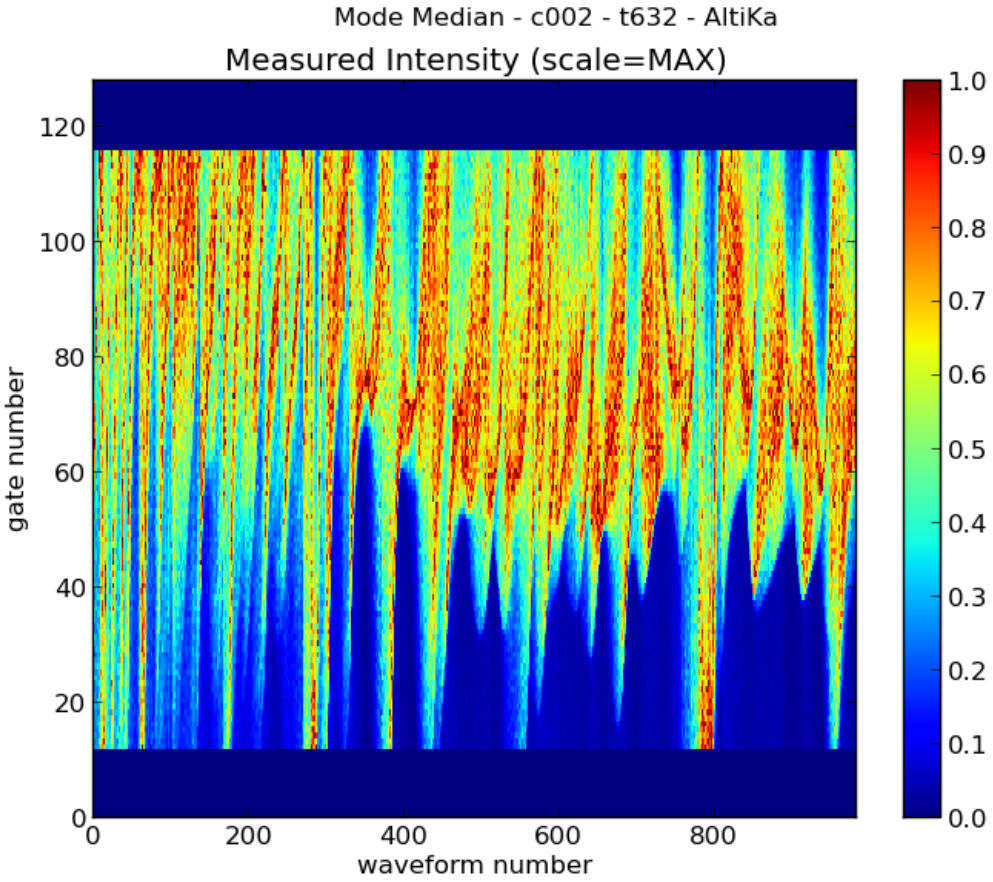
- Precise DEM available (resolution 40 m)
  - Courtesy E.Berthier, CNES and SPOT IMAGE (now Astrium Geomatic Service)
  - In the frame of SPIRIT Project founded by CNES

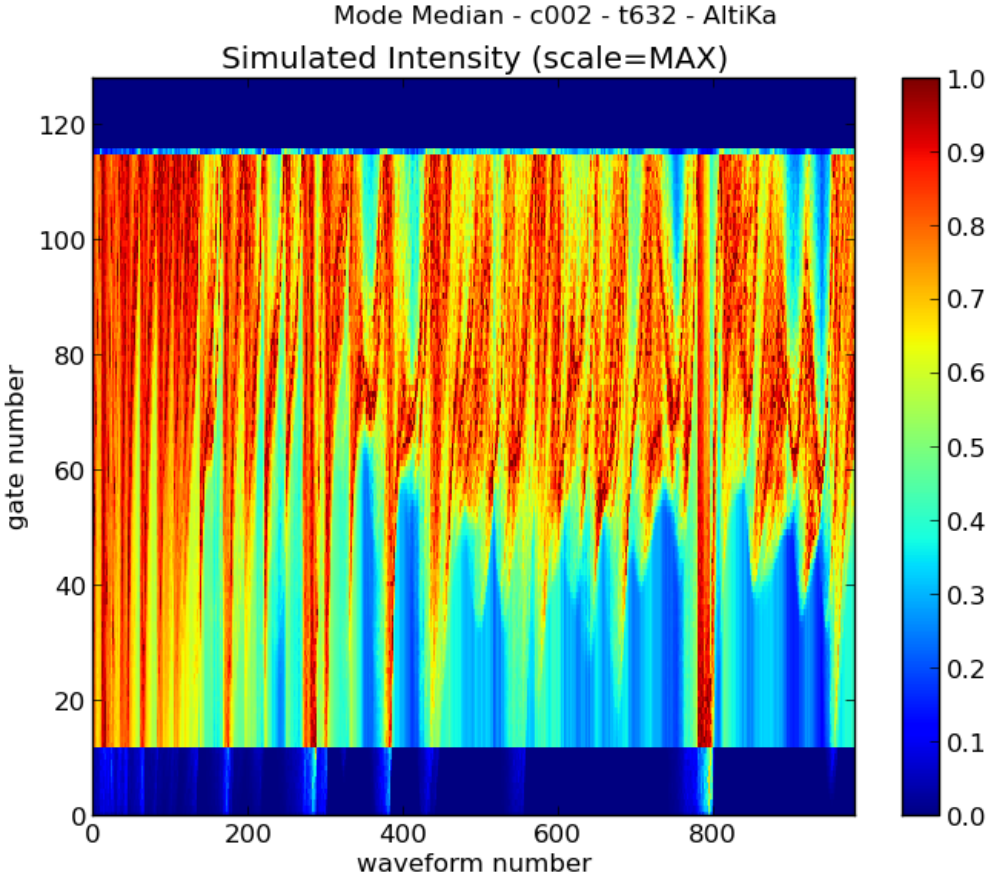
Tracking mode : MNT (cycle 1)



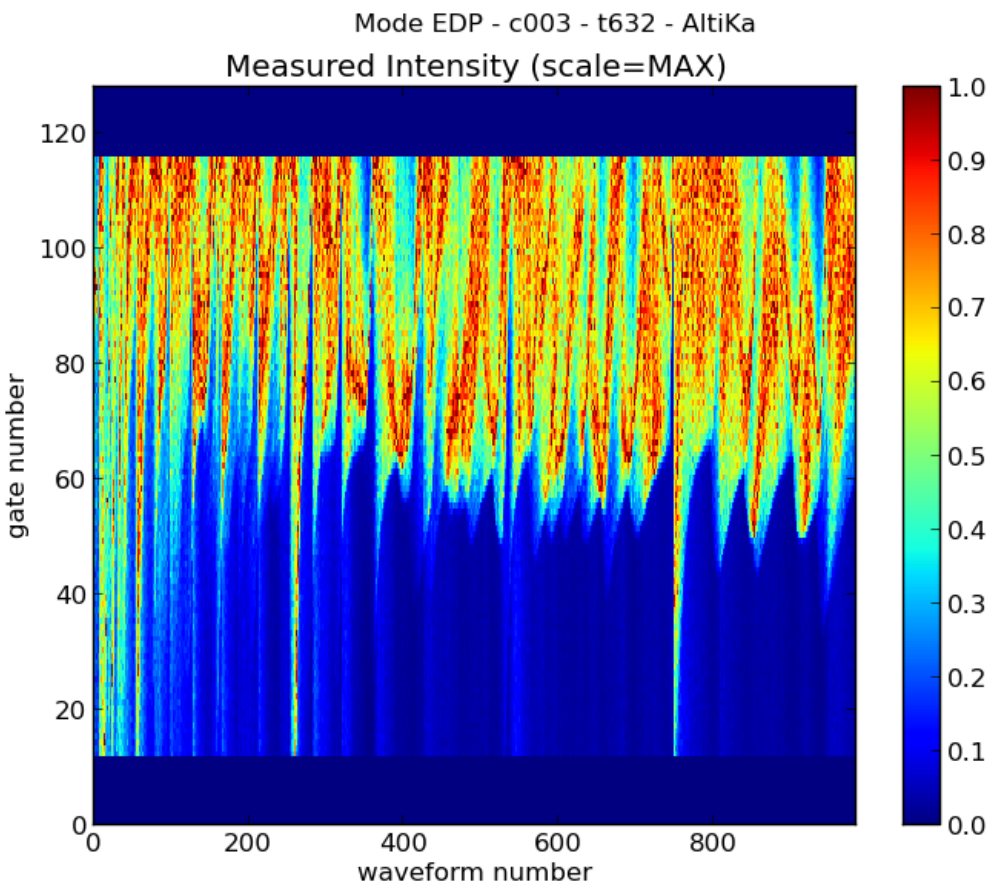


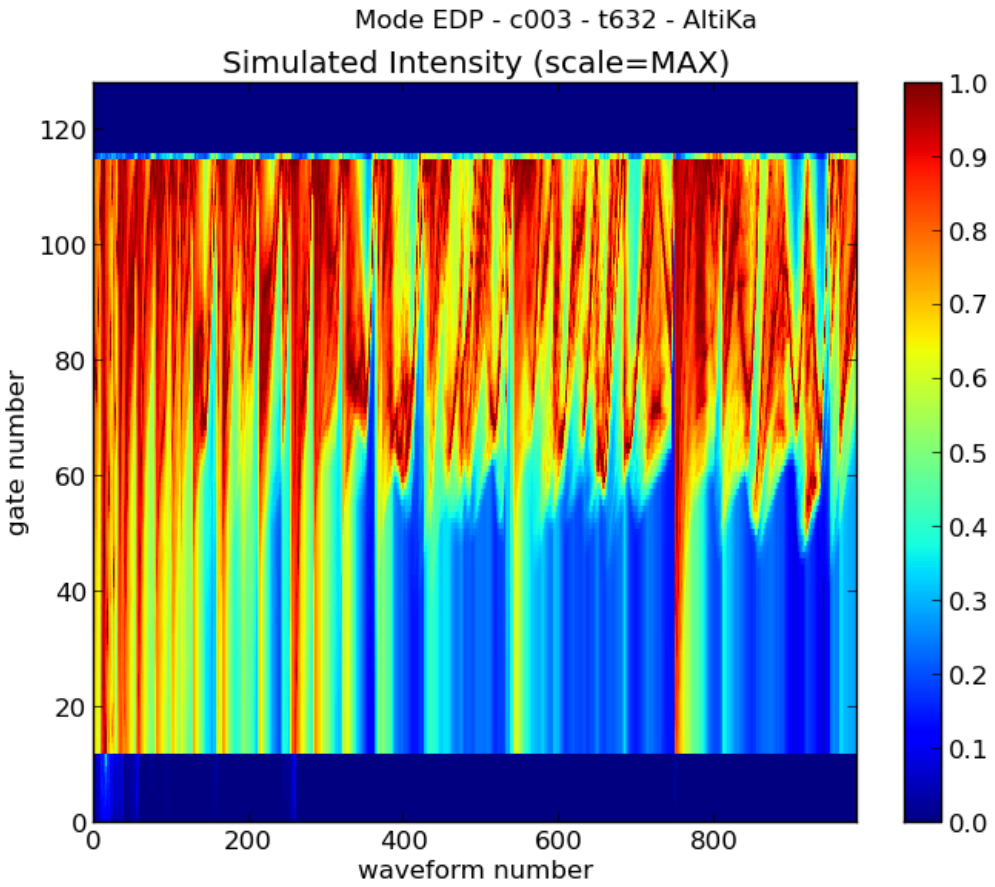
Tracking mode : median (cycle 2)





Tracking mode : EDP (cycle 3)





- Conclusion : the instrument is really tracking the surface (all tracking modes)
- Interest of this measurements for geophysical studies is the subject of an ongoing investigation

Conclusions and perspectives

- Comparison of the radar wave penetration in the snowpack for Ku and Ka
  - More than 3 times less in Ka than in Ku (Vostok lake)
  - Consequence : retracking ranges temporal stability is improved for AltiKa
  - Stability of terrain heights retrieved by direct analysis of the waveforms is even better
  - R&T study funded by CNES (CLS / CAPGEMINI / LEGOS)
- AltiKa provides measurements even when slope of the terrain exceed 0.3 deg
  - There is signal in the residuals
  - Conversion of this signal into geophysical information will ultimately be limited by the uncertainties brought by the instrument in these measuring conditions
  - We must not forget that AlitKa like other nadir altimeters is designed to take measurements at nadir

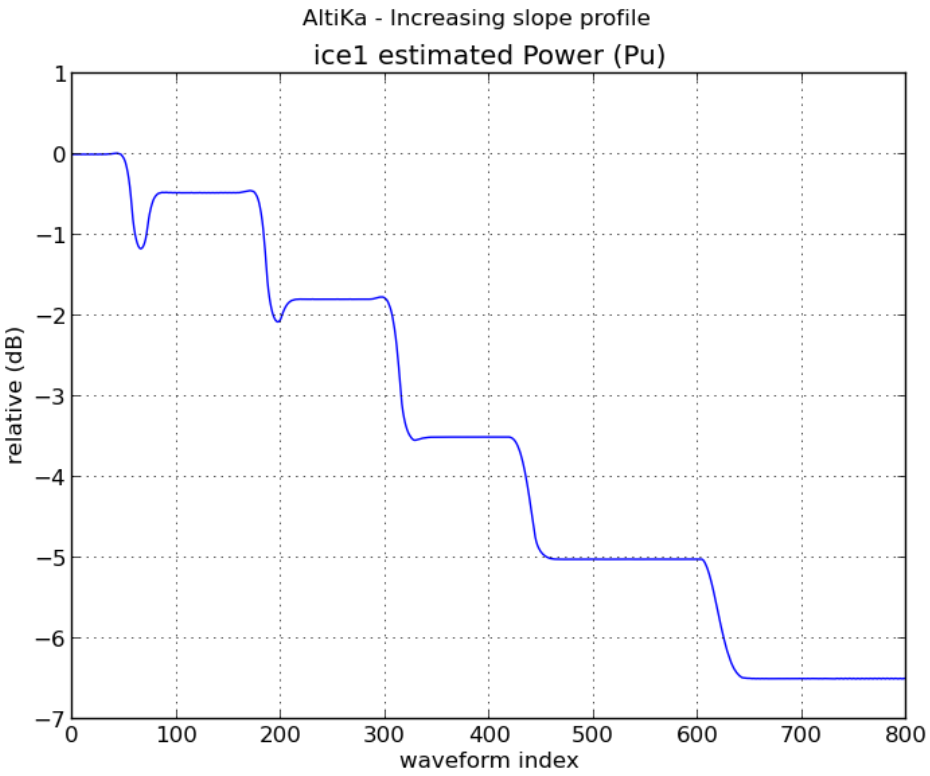
- This is still work in progress
  - Validation of the proposed Ice2 retracking modification and parameters tuning
  - ANR project SUMER (glaciology)
  - TOSCA/OSTST project RESIPE/AltiWaveforms (coastal altimetry and hydrology)

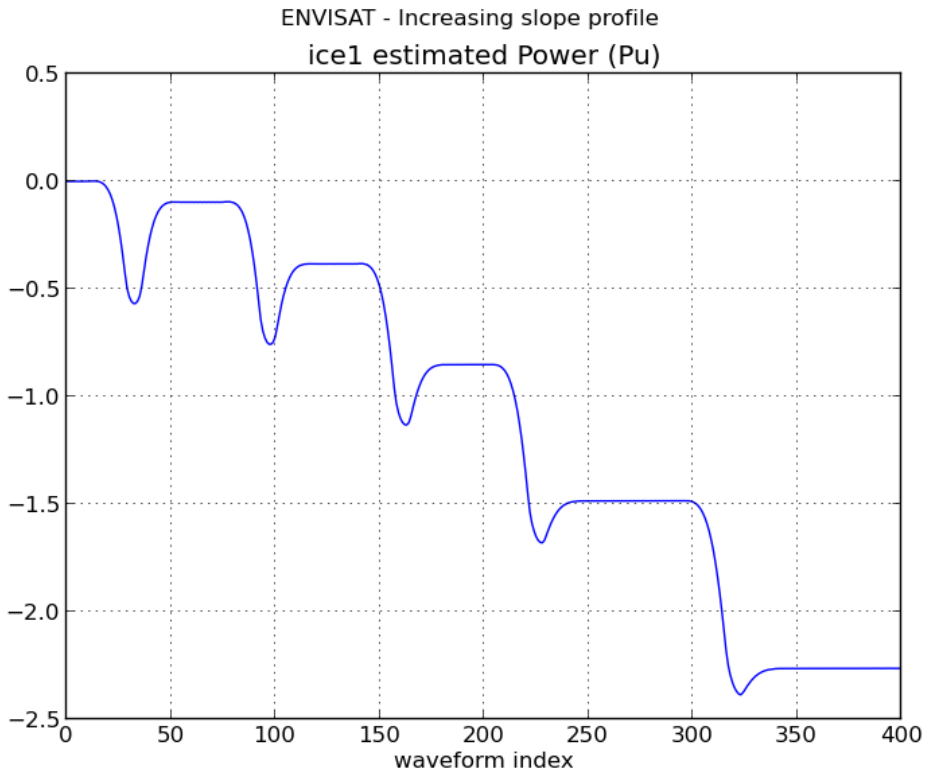
Thank you for your attention !

Backup slides

Impact of terrain slope on the apparent sigma0

- Computed with a synthetic antenna diagram (gaussian)





0° 0.1° 0.2° 0.3° 0.4° 0.5°

0° 0.1° 0.2° 0.3° 0.4° 0.5°