D2.6: Develop Processing for Snow Depth

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Abstract

The current document gather the results of the study done to investigate the feasibility of snow depth retrieval by means of Altimeter data. The main idea is to investigate the sensitivity of SLAR to snow and if it would be possible to correlate changes in snow depth with changes in the waveforms parameters.
To conduct the study some areas covered by both SAR and SARIN data were selected. The areas are characterized by flat topography to easy the data analysis. Model data over these area have been found and used to compare the results.
In the following data analysis and main results will be detailed and discussed.

1. Analysis of SIRAL data over snow covered areas

The LOTUS project aims at developing novel SAR altimeter products in preparation for the upcoming ESA Sentinel-3 mission. The development of such products will necessarily be carried out from CryoSat-2 products, the only in orbit SAR-Altimeter at the time of writing, Dec. 2013. The aim of this document is describe the investigation done in order to establish the feasibility of snow depth retrieval by means of Altimeter data.

1.1 Dataset description

In this section are described the data used for the study.

Test areas

For the study reported hereafter two test site have been selected (“Area-1” and “Area-2”).
The analysis of the data started from Area-2, located at the border between Canada and U.S (see Fig 1). The site was chosen due to its flat topography and presence of snow with considerable thickness in winter.
Test Area-1 has been then used to test the results obtained over the area 2. Also this area presents a flat topography, which helps the analysis of Altimeter data.

Figure 1: Test Area-2

Figure 2: Test Area-1

Ground-truth data

Over the area chosen for the analysis of the SIRAL data are available snow cover and depth maps provided by the U.S. "National Operational Hydrologic Remote Sensing Center". The maps are generated using a multi-layer, physically based snow model operated at 1 km² spatial resolution and hourly temporal resolution. The model is run assimilating all operationally available ground, airborne, and satellite observations of snow water equivalent, snow depth, and snow cover.

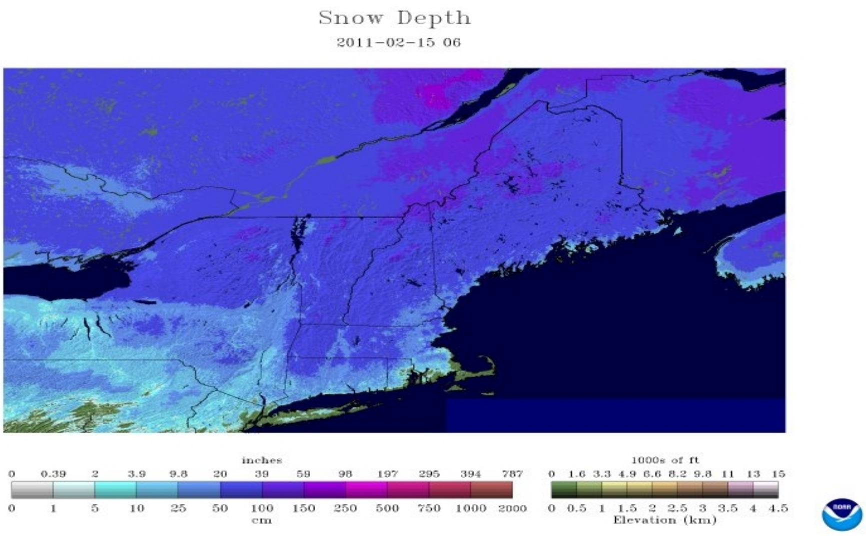

Figure 3: NOHRSC snow depth map over test area-2

From the

database of available variables snow-depth data covering the time period coincident with the SIRAL dataset were downloaded. In figure 2 is shown as an example the snow depth map for February 15 2011 covering the test Area-2.

SIRAL data

Over the areas of interest have been found Cryosat-2 data covering the period between December 2010 and January 2014. In details data between December and June of each year were selected to cover as much as possible the snow season. The data analysed are of L1B (SAR and Sin) type.

About 6000 measurements have been selected over Area 2 and about 300 over Area 1

1.1 Data Processing

As the repeat cycle of SIRAL is about 365 days there is almost no overlap of the data samples through a snow season. Thus we had to leave the idea of a “repeat pass approach” and look for neighbouring points, within a given threshold.

Preprocessing

Before starting the analysis SIRAL data have been converted from counts to calibrated watts values [2].

Additionally the OCOG retracker has been implemented and run over the whole dataset. The obvious advantage of the OCOG retracker is that it works everywhere over all surfaces, consequently, it will always enable the estimation of a range to the surface. However, the dis-advantage is that this retracker is very crude and very in-accurate. The retracker is frequently used when all other retrackers fails.

1 Hz data analysis

The analysis started taking the month of June 2011 as reference and looking for points within a radius of about 5 km belonging to the remaining months. In Figure 4 are shown in blue the June tracks, while in yellow red and green the tracks for the months of January, February, and March respectively. Points falling over water were manually removed.

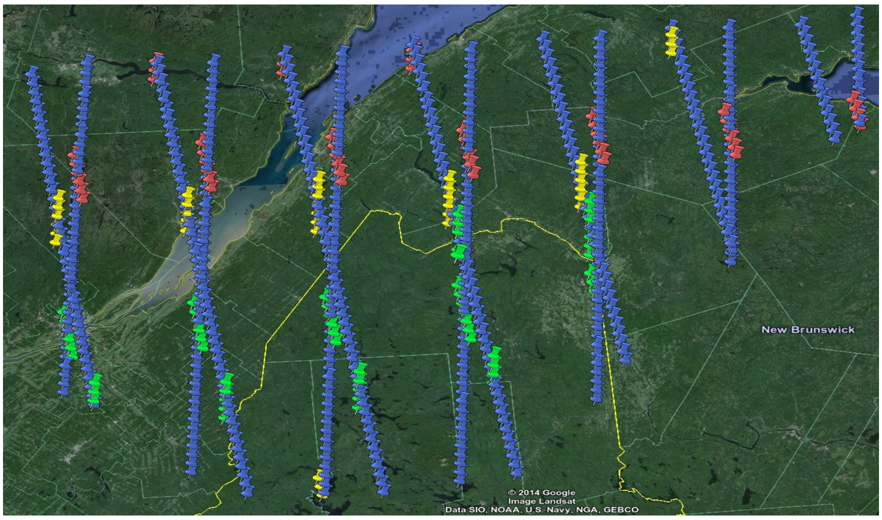

Figure 4: data collocation

We began the analysis using the 1 HZ data mean power. In figure 5 to figure 8 are shown the plots of the mean power for June (blue) and January, February, March and April (red).

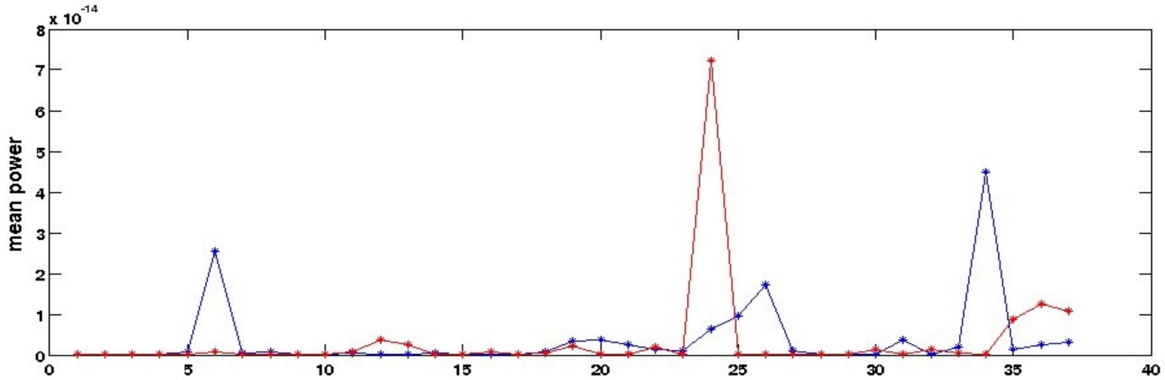

Figure 5: Mean power of collocated data (Jun. Blue; Jan. red)

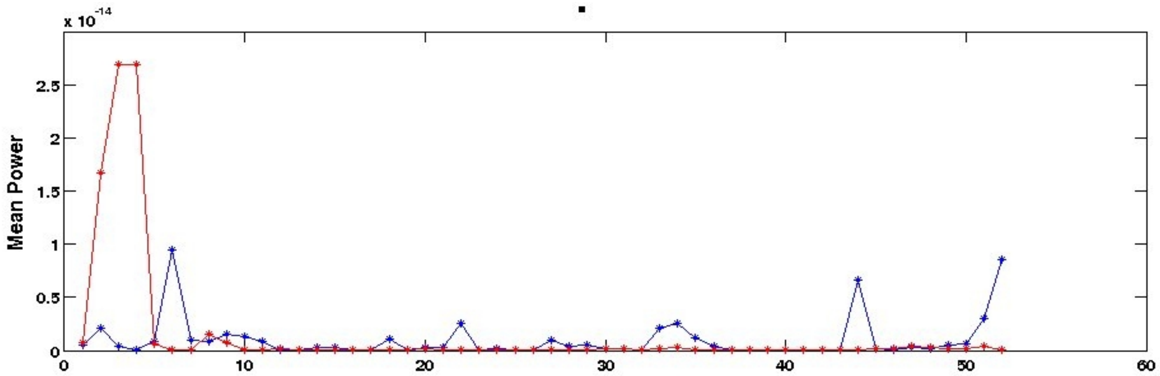

Figure 6: Mean power of collocated data (Jun. Blue; Feb. red)

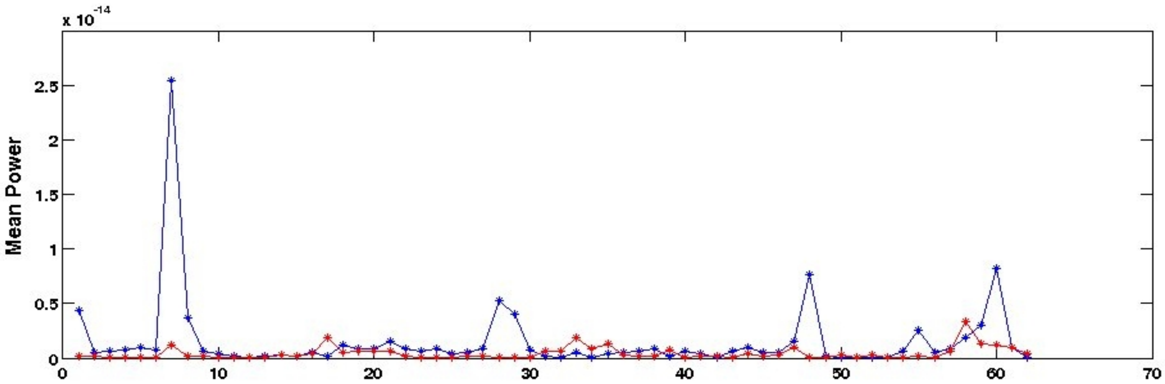

Figure 7: Mean power of collocated data (Jun. Blue; Mar. red)

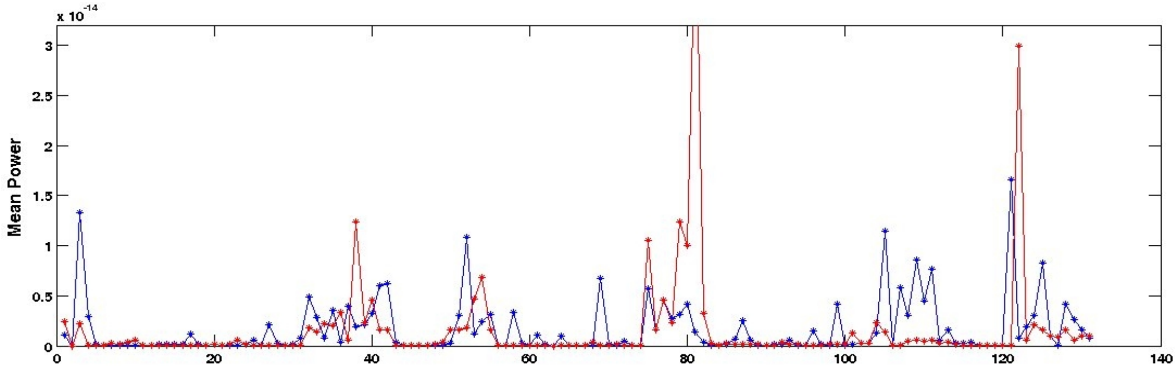

Figure 8: Mean power of collocated data (Jun. Blue; Apr. red)

The analysed data show that there is no correlation between contiguous SIRAL measurements and changes in snow-depth during the season.

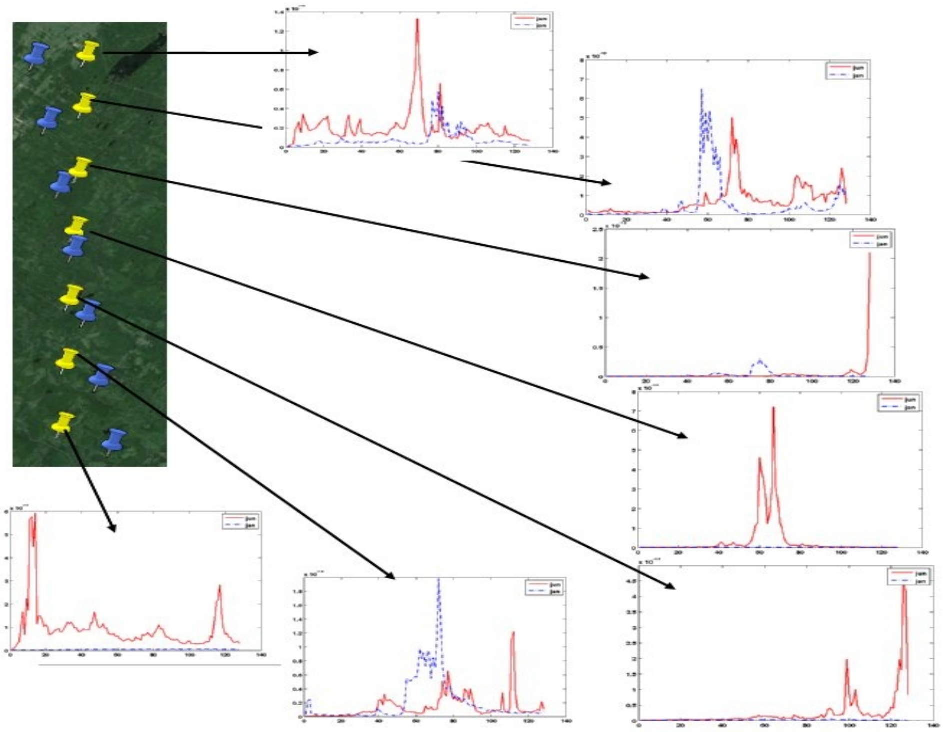

Figure 9: Waveforms comparison along track

As following step was decided to have a look at the waveform shapes along the tracks. In figure 9 is shown an example taken from the matching between the months of June and January 2011. Also in this case one can observe that there is a high variability in the waveform shape and amplitude between one couple of measurements and the followings along the track.

In figure 10 to figure 13 are shown a series of plots of some relevant statistical parameters in function of the time (in months) for the seasons 2011. Mean, standard deviation, max. and min. value have been computed for the mean power, and OCOG amplitude, width and center of gravity.

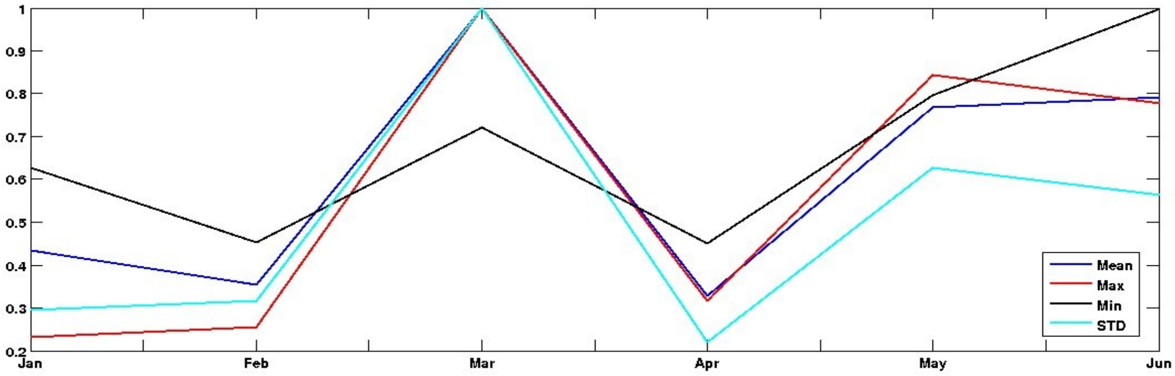

Figure 10: Area-2 1Hz Mean Power 2011

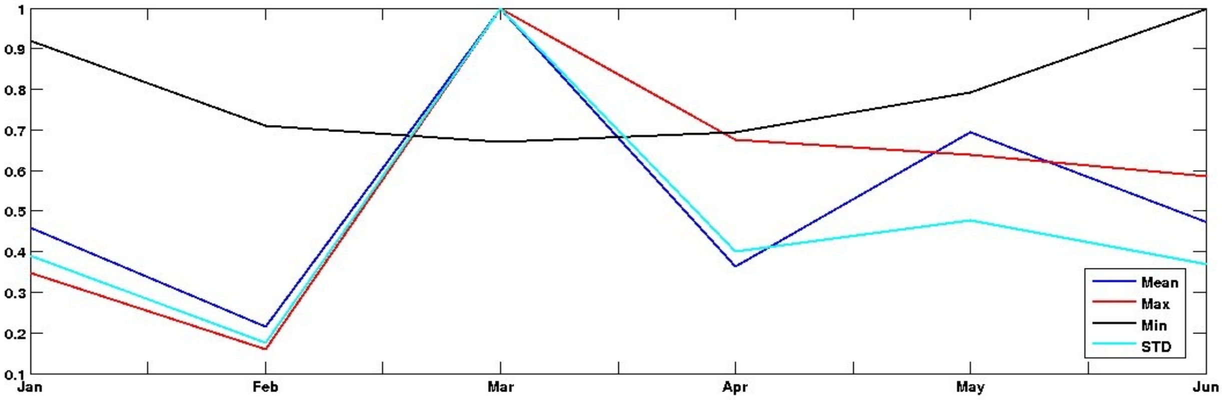

Figure 11: Area-2 1Hz OCOG Amp. 2011

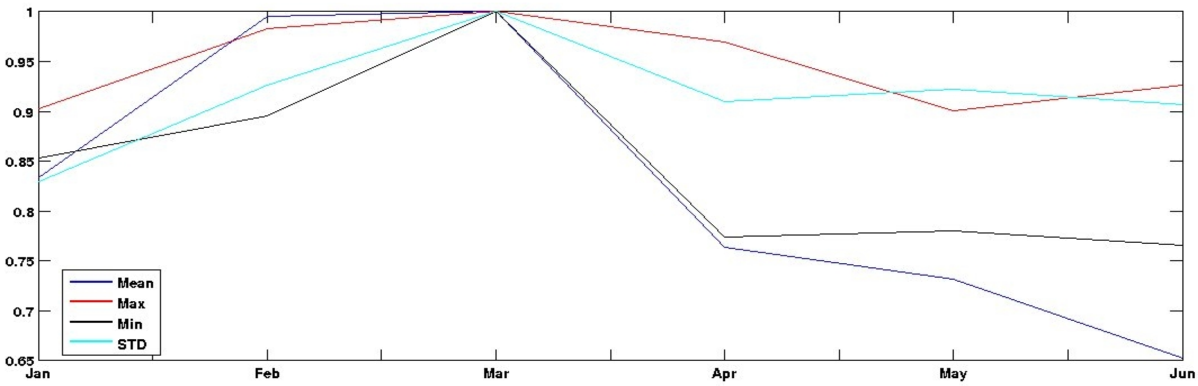

Figure 12: Area-2 1Hz OCOG Width 2011

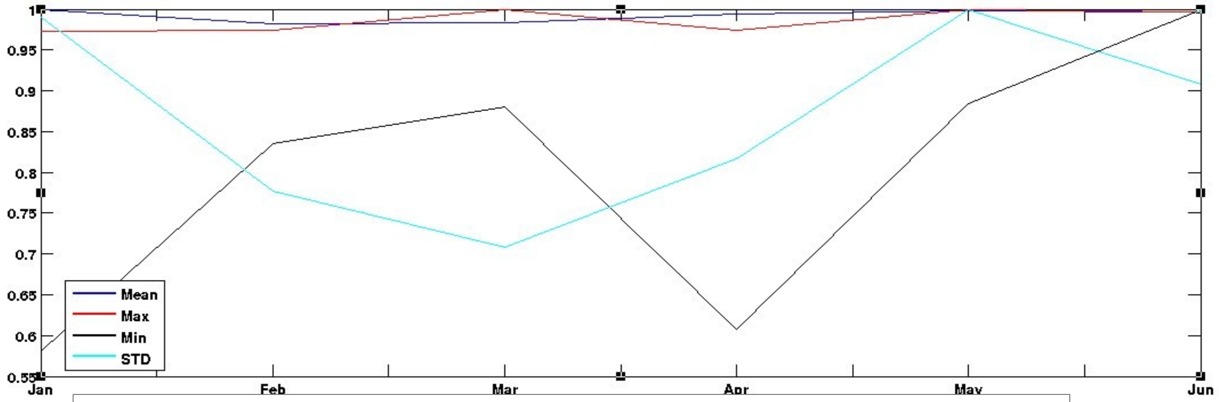

Figure 13: Area-2 1Hz OCOG CG 2011

From the analysis of the data no clear trends were found when looking to mean power statistics; while the mean value of the "OCOG width" parameter looks to follow the snow depth variations in time, plotted in figure 14 and figure 15.

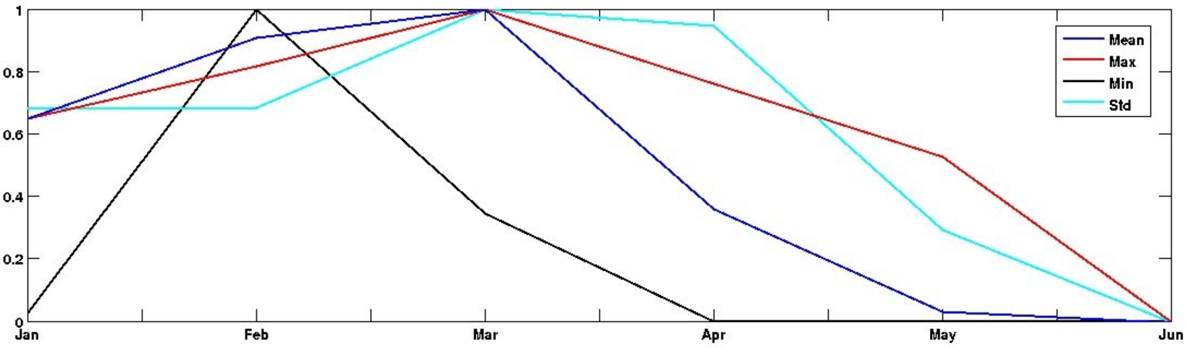

Figure 14: Area-2 Snow statistics 2011

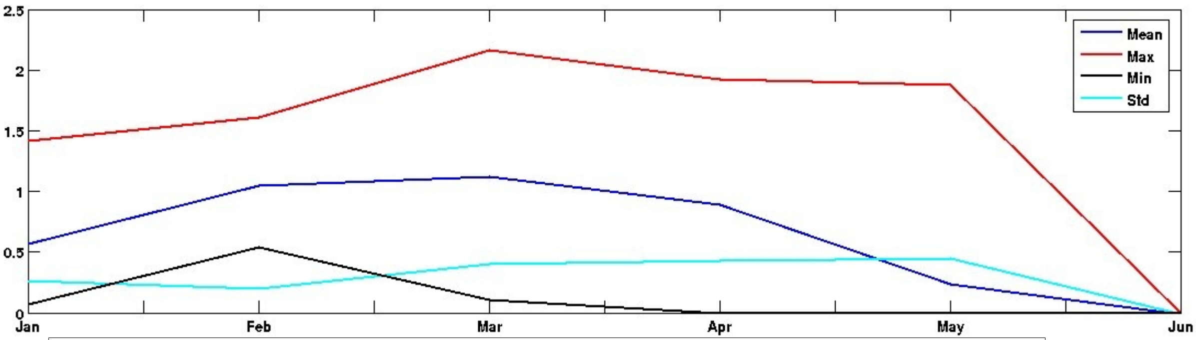

Figure 15: Area-2 Snow statistics 2011 linear unit

The statistical analysis of OCOG parameters has been done also for the year 2012 (figure 16 to figure 18), and the same trend of the OCOG width has been found when comparing to snow depth variations (see figure 18 and figure 19).

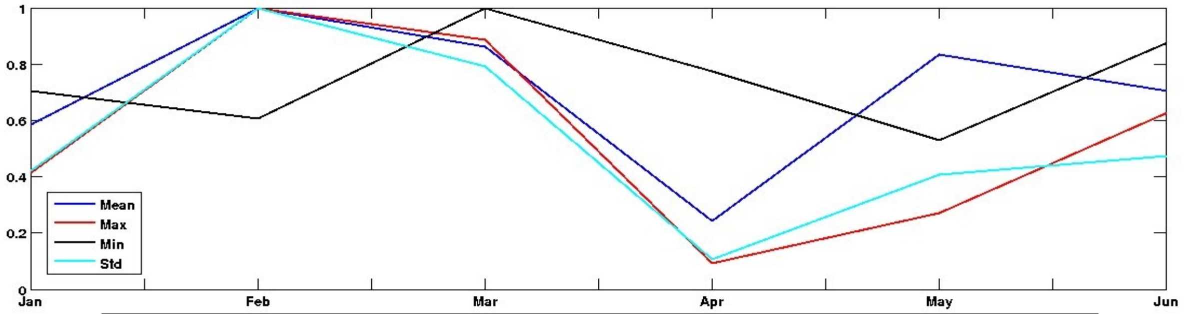

Figure 16: Area-2 1Hz OCOG Amp. 2012

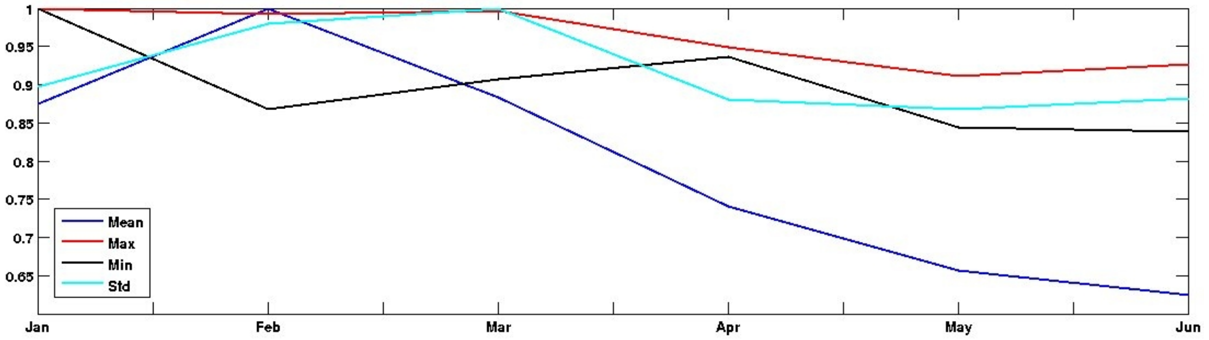

Figure 17: Area-2 1Hz OCOG Width 2012

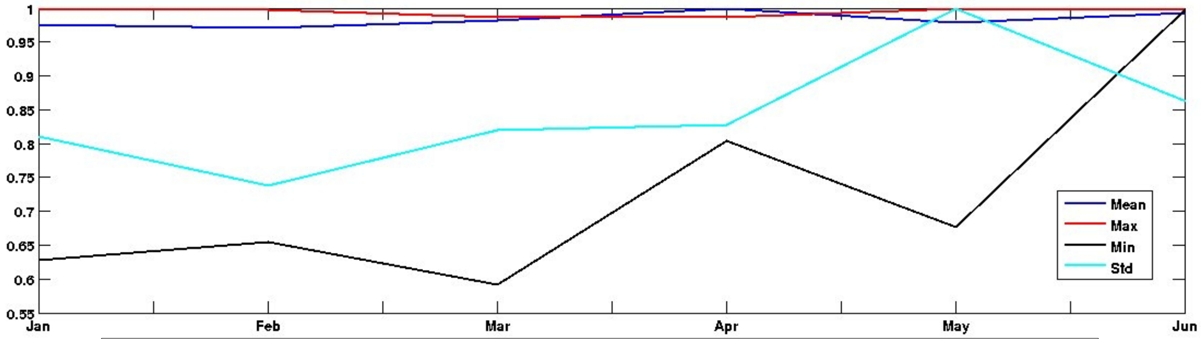

Figure 18 Area-2 1Hz OCOG CG 2012

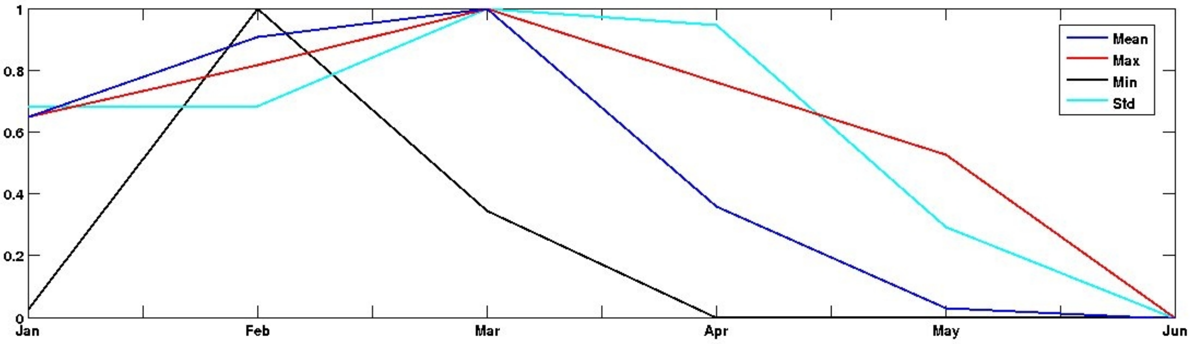

Figure 19: Area-2 Snow statistics 2012

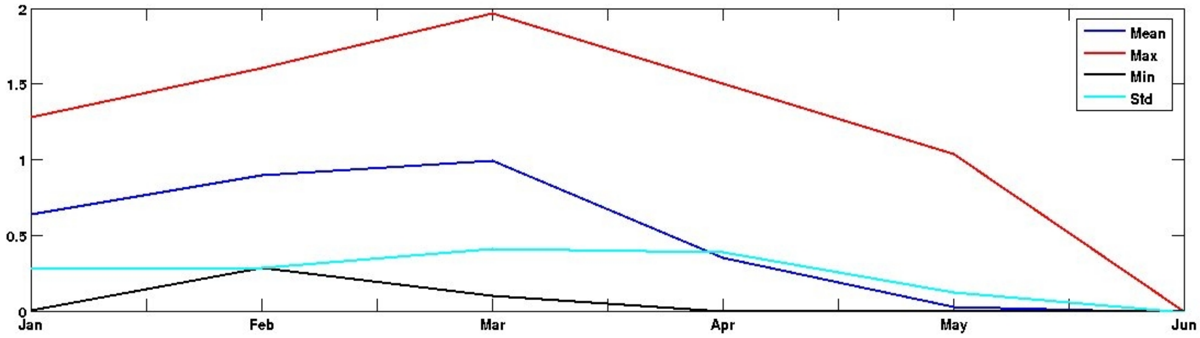

Figure 20: Area-2 Snow statistics 2012 linear unit

to asses the results found over test Area-2 the statistical analysis has been repeated over a dataset covering the test Area-1. The time period chosen for the tests goes from December 2012 to March 2013, being the one with more snow presence. In figure 21 to figure 24 are shown the results

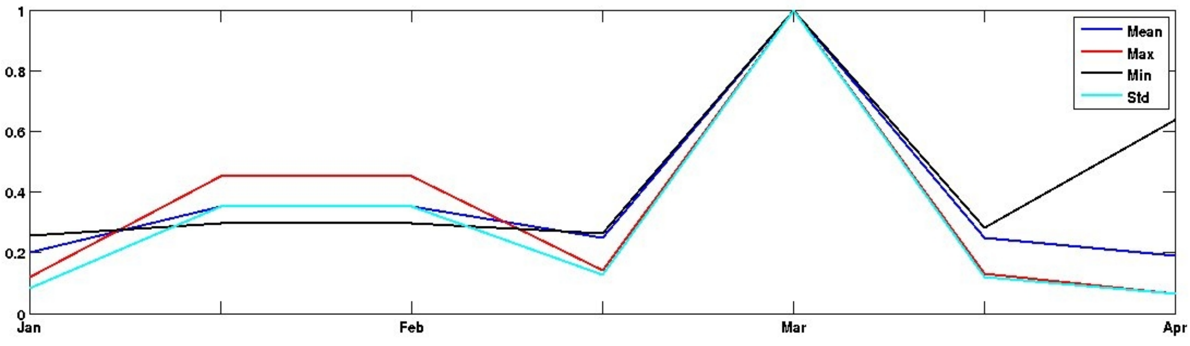

Figure 21: 1Hz Area-1 Mean Power 2013

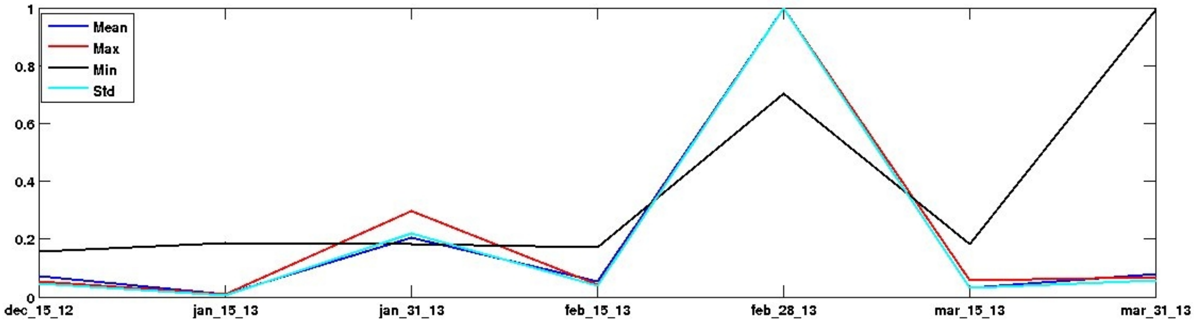

Figure 22: 1Hz Area-1 OCOG Amp 2013

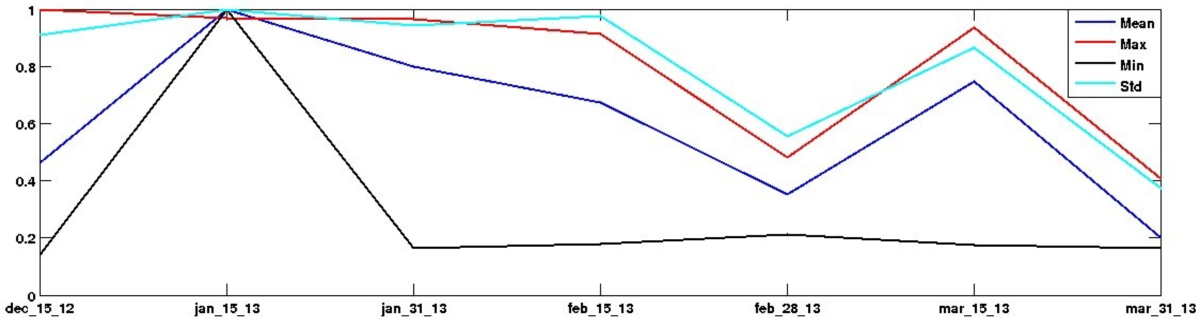

Figure 23: 1Hz Area-1 OCOG Width 2013

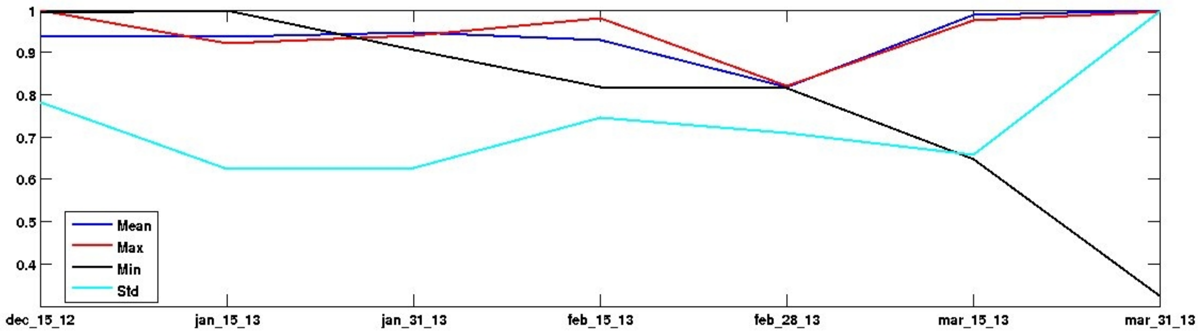

Figure 24: 1Hz Area-1 OCOG CG 2013

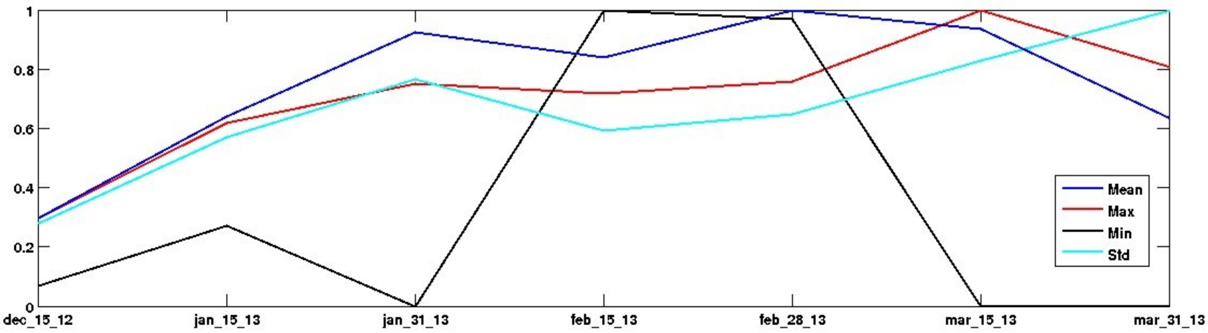

Figure 25: Area-1 Snow Depth 2013

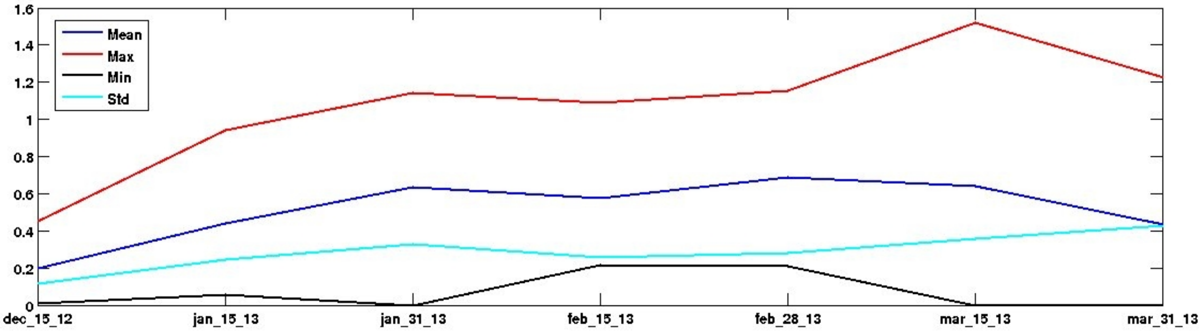

Figure 26: Area-1 Snow Depth 2013 linear unit

Over this area the trend found with data covering area 2 has been not found. This is probably due to the relative small number of data covering the area, and to the snow depth that is not exceeding the 60 cm (see figure 26), which limits the effect of the snow attenuation on the radar echoes.

20 Hz data analysis

The analysis of the 20 Hz data started looking at the waveform shapes of the single bins and comparing their mean value to the 1 Hz product. In Figure 27 are shown the plots of the 1 Hz waveform (left) of two neighbour measurements (distance between them less than 5 Km) taken in January and June and the corresponding waveforms for each bin of the 20 Hz product (right). In Figure 28 is shown on the left the mean power of the waveforms plotted on the right, while in figure 29 is shown the waveform obtained doing the mean of all bins of the 20 Hz product (right) and the corresponding 1 Hz waveform. Several points were analysed and the main feature found are:

- Strong variability of the single waveforms in 20Hz product.
- Often waveforms with multiple peaks are present.
- In most of the cases the 1Hz product looks to be very different in terms of shape and magnitude with respect to the single 20Hz waveforms and to their mean.

This probably due to the fact that the waveforms are recentered according to the tracker range of the altimeter, which displaces the center of the correlation window.

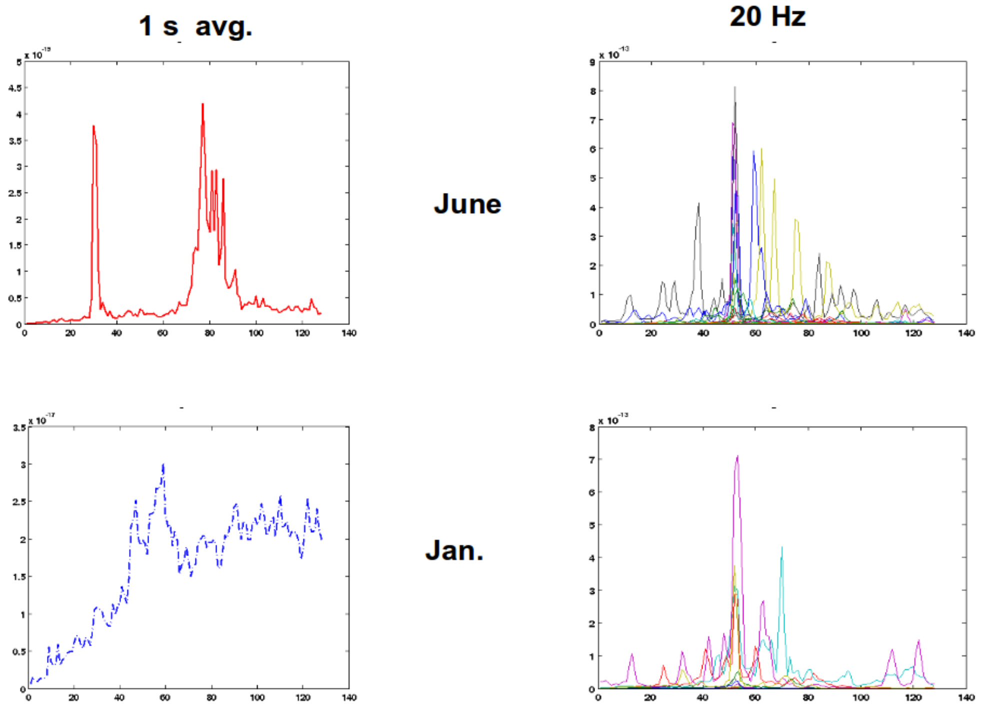

Figure 27: 1Hz. (Left) Vs 20Hz product (Right)

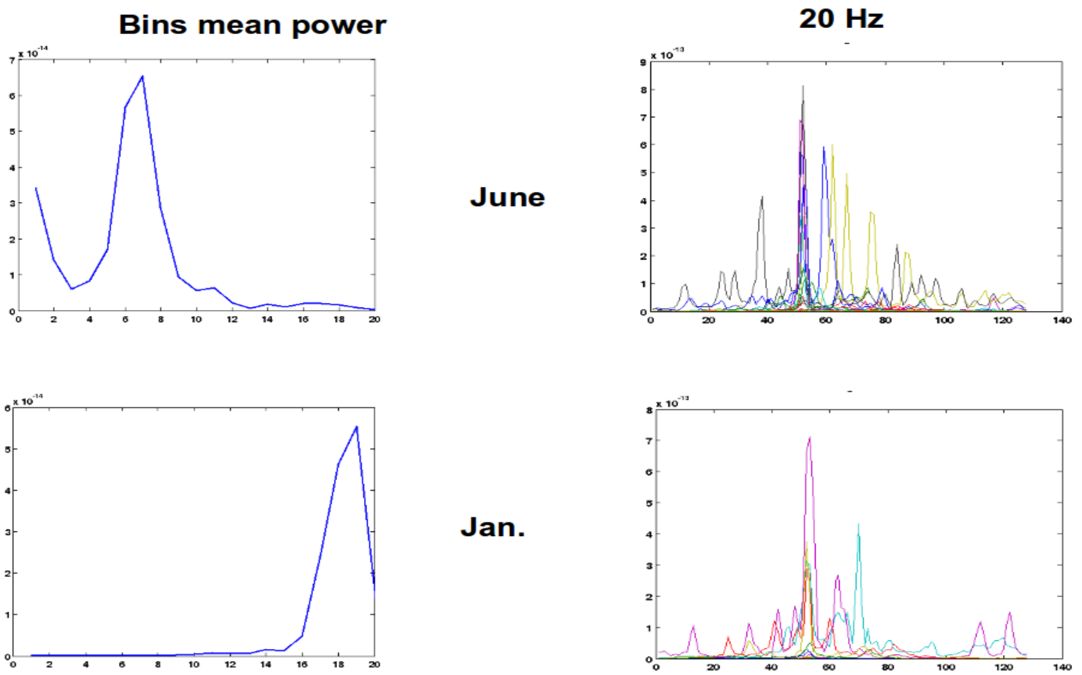

Figure 28: Mean power of waveforms contained the 20Hz product (Left)

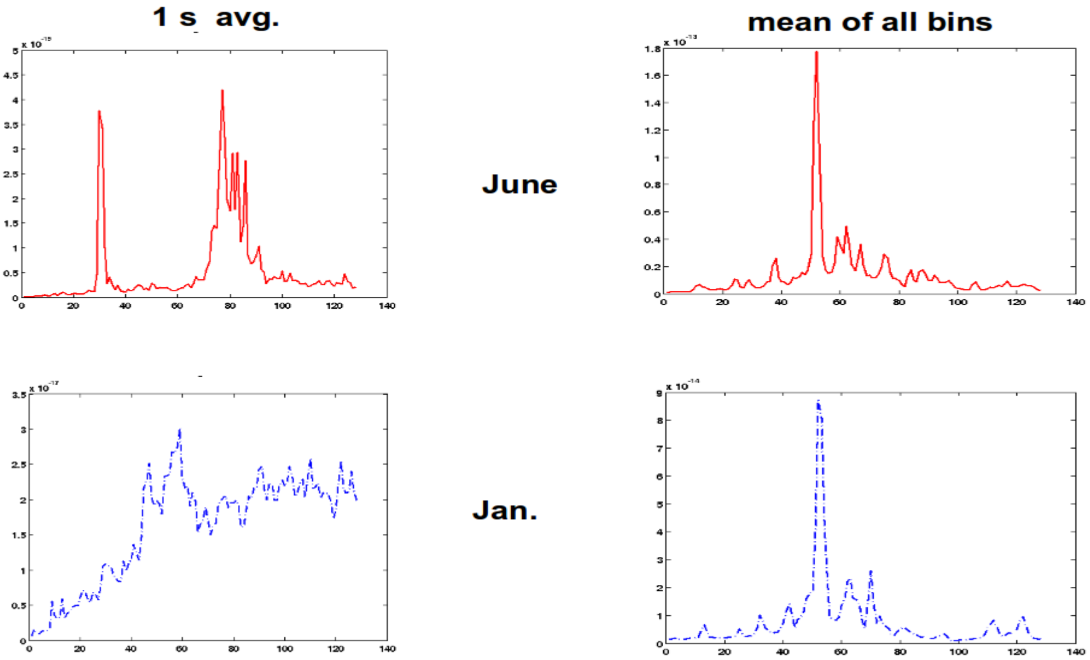

Figure 29: 1Hz product (Left) vs mean of 20Hz product (Right)

As for the 1 Hz product, in figure 30 to figure 29 are shown the variation of the mean, standard deviation max. and min. values in function of the time for the mean power and the OCOG parameters. The analysis was done using all available the data for the year 2011.

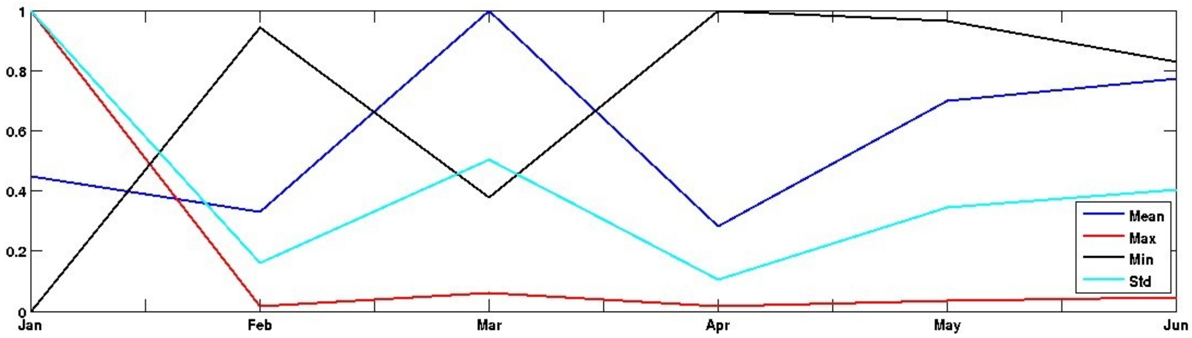

Figure 30: SAR mean power statistics variations

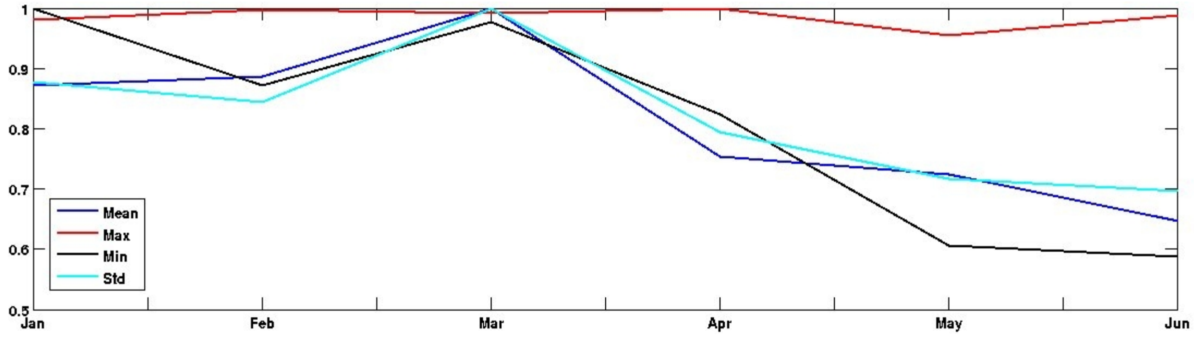

Figure 31: SAR OCOG Amp statistics variations

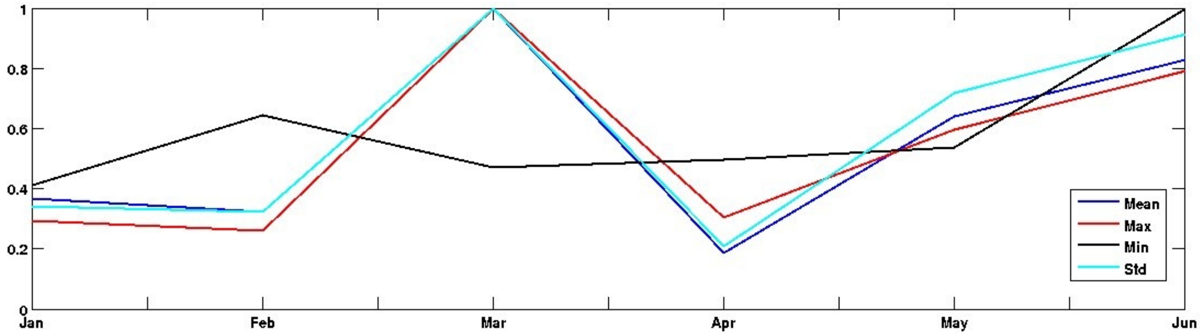

Figure 32: SAR OCOG Width statistics variations

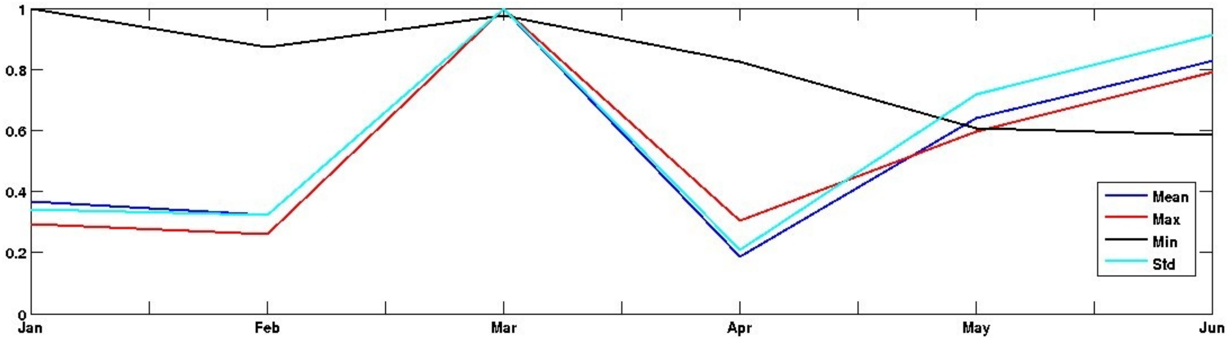

Figure 33: SAR OCOG CG statistics variations

Also in this case the parameter that looks to have a certain sensibility to snow depth variations is the OCOG width.

2 Conclusions

The current document gather the results of the study done to investigate the feasibility of snow depth retrieval by means of Altimeter data.
The analysis started with a preprocessing phase, where data were collected and calibrated in order to obtain power watts values. Over the two dataset used for the study data covering the 2011, 2012 and 2013 season have been found, a total of about 7000 measurements has been selected.
Additionally the OCOG retrtacker has been implemented and run over the selected points.
The analysis started studying the correlation between mean power values and snow depth changes, followed by an investigation of the waveforms shapes. As final step a data statistic of the mean power, and OCOG parameters was for each month of the analysed period has been done.
General conclusions:
- It has been found in this study that the waveform total power, OCOG amplitude/area, do not show any trend or relationship with changes in the snow depth.
- The only parameter considered in this analysis with a correlation equal to 0.64 with the snow depth is the OCOG width parameter, on Area 2, for years 2011 and

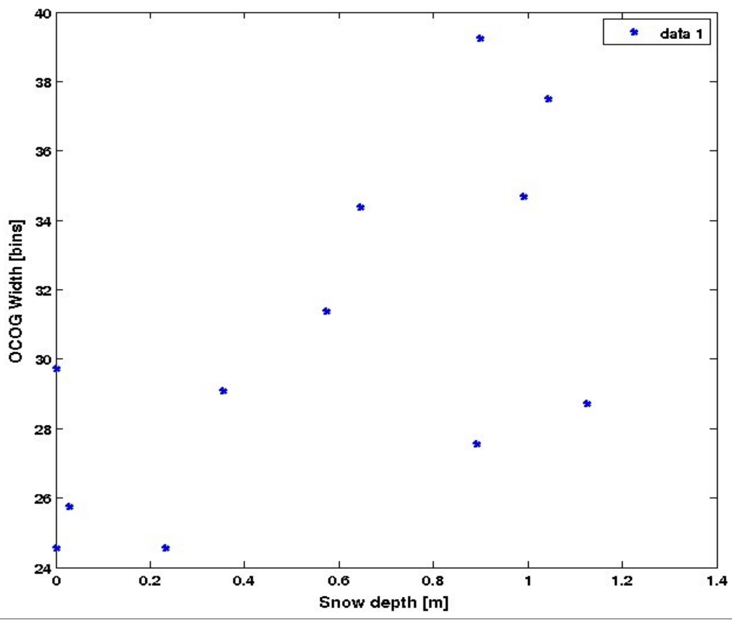

Figure 34 OCOG width vs snow depth variations

2012, as shown in figure 34.

- In any case, the correlation found is too weak to develop an operation snow depth retrieval algorithm based on these parameters.
- The reason we find for this, is that the geometry of the observations changes significantly between sequential observations of the same area, due to the fact

that the CryoSat-2 orbit is not a repeat pass orbit. Therefore, the topography and changes in the terrain can have important effects on the echo returns can have a stronger impact than any other geophysical parameters.
- We believe this could be different in the case of Sentinel-3, as in this case the satellite will have a monthly repeat pass orbit, that could potentially allow the application of change detection techniques, to mitigate the effect of geometry and topography.

3 Bibliography

[1] LOTUS D1.3: Test Site Areas Selection.
[2] Guidelines for sigma nought extraction from CryoSat-2 SAR data, v1.9
[2] Wingham, D.J., Rapley, C.G., Griths, H., New techniques in satellite tracking system, *Proc. IEEE IGARSS, Zurich, 1986.*
[4] Stenseng, L., "Polar Remote Sensing by CryoSat-type Radar Altimetry", *Ph.d. Thesis, 2011*