SARAL/AltiKa observations of the Antarctic ice sheet: A comparison between the Ku-band and the Ka-band.

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Abstract: The AltiKa altimeter onboard SARAL is a joint CNES/ISRO mission launched in February 2013 that has the same 35 days repeat orbit of the previous European altimeters, Envisat and ERS-1/2. SARAL/AltiKa is thus a unique opportunity to extend the repeat observations of this orbit that have been surveyed since 1991. However, the altimeter operates in Ka-band, which is higher than the previous frequencies, and offers new paths of investigation. The penetration depth is theoretically reduced from around 10 m in Ku-band, to less than 1 m in Ka-band, such that the volume echo originates m the near subsurface. Second, the sharper antenna aperture leads to a narrower leading edge that reduces the impact of the ratio between surface and volume echoes of the height retrieval. Indeed, the spatial and temporal observations of AltiKa at cross-over points and along-track indicate that the impact of backscatter changes on the height decreases from 0.3 m/dB for the Ku-band to only 0.05 m/dB for the Ka-band. Therefore, the height measurement is really very stable over time. Moreover, the volume echo in the Ka-band results from the near subsurface layer and is mostly controlled by ice grain size, unlike the Ku-band.

Waveform parameters for Ku-band (Envisat) and Ka-band (AltiKa)

Theoretical Ku-band and Ka-band for surface et volume echoes

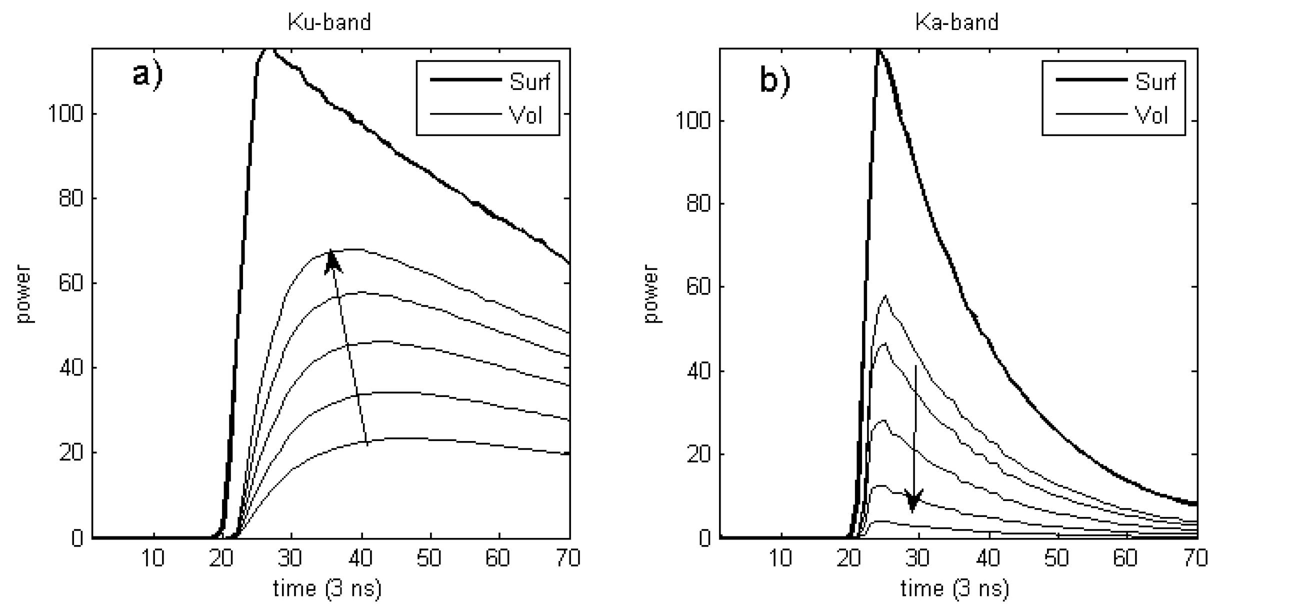

Figure 1. Waveform shapes for the surface echo (in bold) and volume echo of the Ku-band (a) and Ka-band (b). The arrow direction indicates the effect of increasing the ice grain size from 0.5 to 1 mm. The ratio of the surface and volume echoes is not scaled.
One of the major error is due to the penetration of the radar wave within the dry and cold snowpack. This induces one of the major limitations of ice sheet surveying..

→ The aim of the poster is to evaluate the volume echo in Ka-band and to look at the impact in term of height retrieval with the help of both temporal changes and difference at cross-over.

Height and backscatter patterns over Antarctica

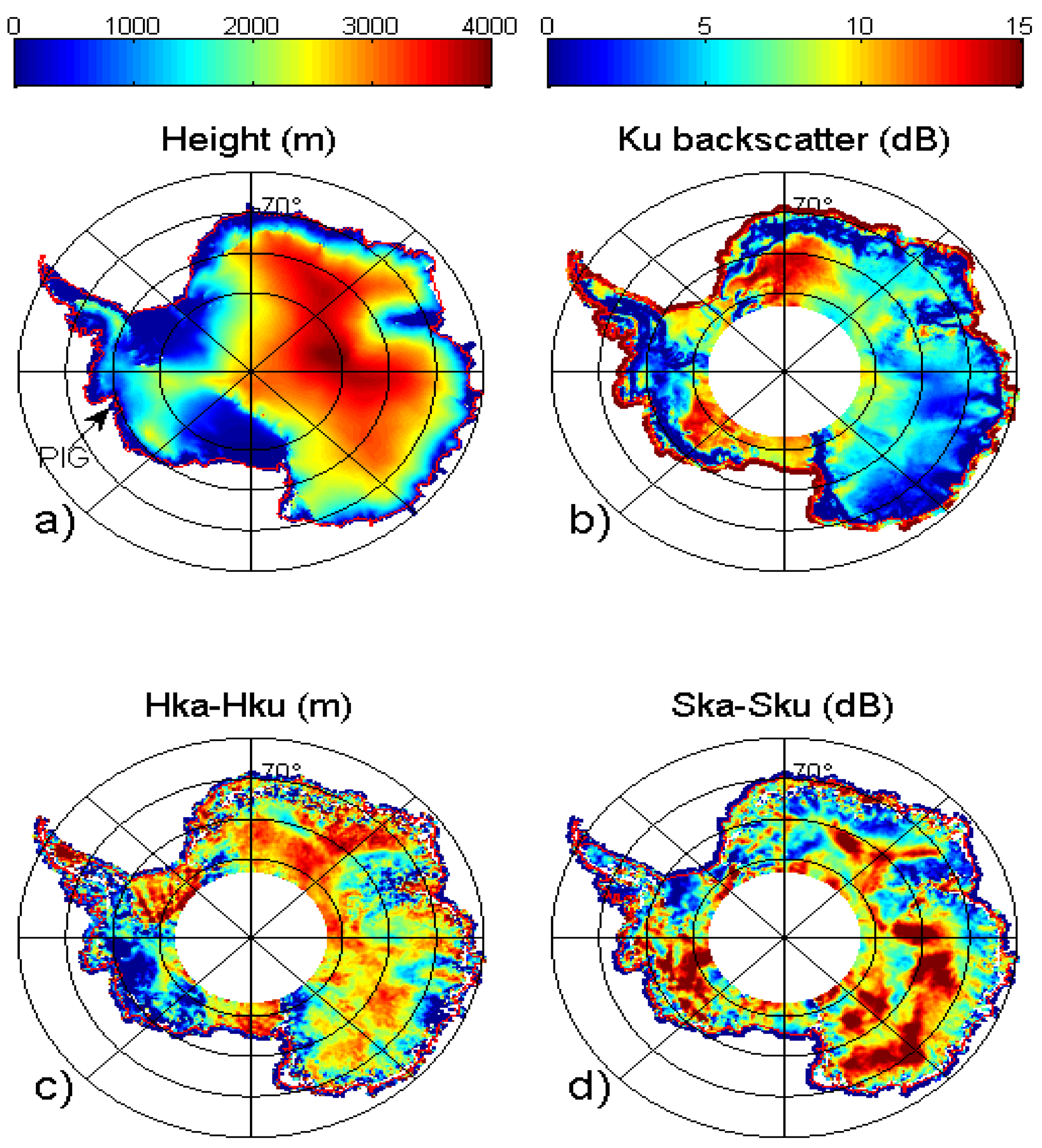

Figure 2. Topography (a) and backscatter (b) of the Antarctic ice sheet as measured with Envisat in the Ku-band.. Height (c) and backscatter (d) differences between the Ka-band as measured by AltiKa/SARAL and the Ku-band as measured by Envisat for the same season.
To the first order, the general patterns of height and backscatter for the Ka- and Ku-band are similar (see Figure 2.a and 2.b). However, the difference between both parameters (Ka minus Ku observations) exhibits a clear geographical pattern (respectively Figure 2c and 2d). The difference in height varies from 1 m to -2 m, with a std of 0.9 m, while the difference in backscatter varies from 0 to -6 dB. The mean difference is 2.7 dB, which is relatively close to the oceanic value.
Two different signals of the height difference are observed. In East Antarctica (EAIS), the Ka-band detects the surface a few tens of centimeters above the Ku-band. The difference reaches 50-60 cm for high altitude and decreases toward 0 near the coast. Note that we remove observations where the surface slope is greater than the Ka-band's half antenna aperture because the impact point is outside the antenna gain pattern and the waveform is too distorted. Elsewhere, particularly in the WAIS, we mostly observe the loss of volume of the Pine Island and Thwaites outlet glaciers during the period.

Behavior of waveform parameters

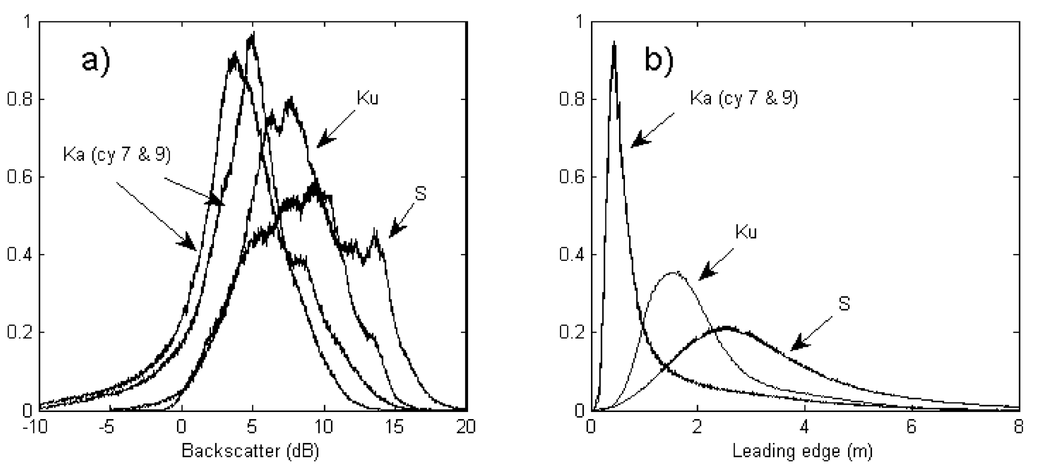

Figure 3. Histogram of the backscatter in dB (a) and of the leading edge in m (b) for the S-, Ku- and Ka-band over Antarctica.
The histogram of the backscatter for different frequencies and for two different cycles in the Ka-band (cycle 7 in October 2013 and cycle 9 in December 2013, see Figure 3a) demonstrates that the temporal changes in the Ka-band is of the same order of magnitude as that in the Ku-band and can reach 1 dB in 70 days. The std of the backscatter estimated for all the available cycles is 1.2 dB. In the central region, the value does not exceed 0.5 dB and can reach 2.5 dB near the coast in the western region
We plot of Figure 5a, the impact of change in backscatter on the height retrieval. The impact is around 0.3 m/dB for Ku-band while it is only of 0.05 m/dB.

Difference at cross-over points

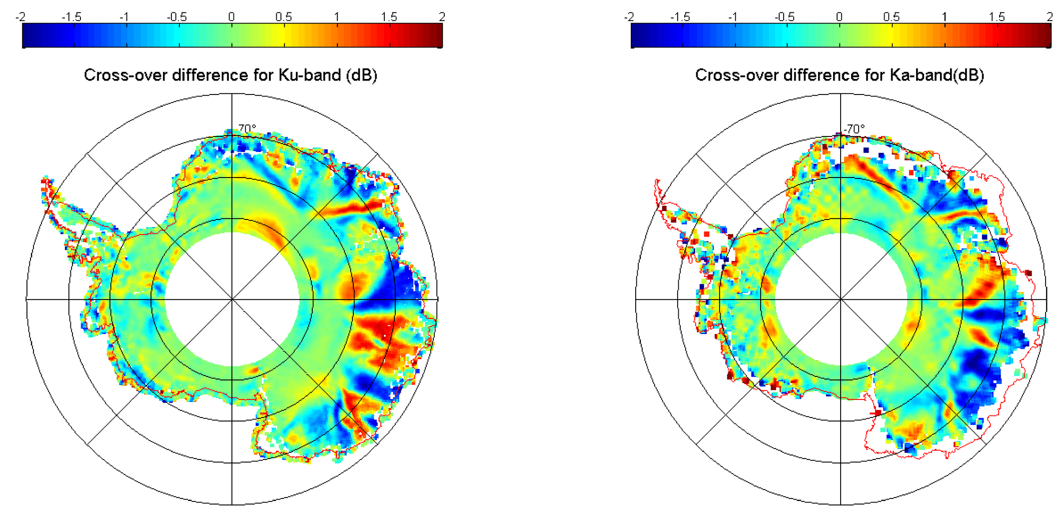

Figure 4. Cross-over difference for backscatter in the Ku-band (a) and in the Ka-band (b). . It is likely the most mysterious and least understood error of altimetry above the ice sheet. The pattern is due to a complex convolution between the volume echo and antenna polarization. Depending on the angle between the antenna polarization direction and the anisotropic features direction, such as sastrugi created by the persistent katabatic wind, the signal penetrates more or less in the snowpack.
The backscatter difference ranges from -2 to 2 dB for the Ku-band, while it ranges from -2.5 to 2.5 dB for the Ka-band.
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Impact of volume echo on height

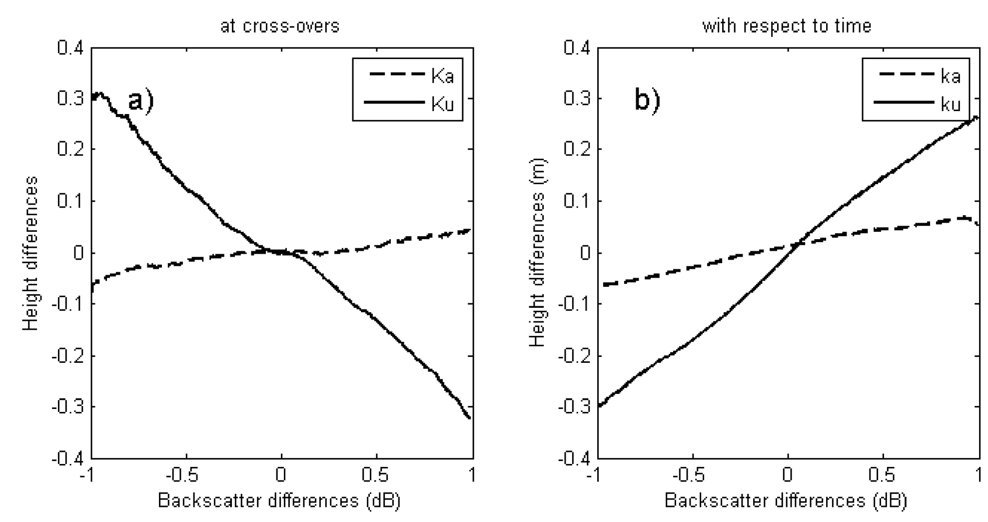

Figure 5. Relationship between changes in backscatter and induced changes in heights at the cross-over point (a) and with respect to time (b). . Cross-over differences are due to a modulation of the volume component between the ascending and descending tracks. We observe a slightly larger impact on the Ka-band backscatter. However, the impact on the height is less than -0.05 m/dB for the Ka-band compared with -0.3 m/dB for the Ku-band, i.e., the Ka-band value is six times smaller than that of the Ku-band. Temporally, we know that backscatter and height increase or decrease together, the positive correlation implies that the changes occur either in the surface echo or in the near subsurface echo.

→ The results are similar for both methodology; the amplitude of the sensibility is 0.05 m/dB instead of 0.3 m/dB for the Ku-band.

Conclusion & Prospectives

Theory, cross-over differences analysis and temporal changes analysis converge toward the same conclusion; thus, we have confidence in our results. Both suggests that the volume scattering should be greater for the Ka-band than for the Ku-band but that the impact on height is much shallower.
The volume echo is clearly detectable in the Ka-band and has, at minimum, the same order of magnitude as that of the Ku-band. However, the penetration depth is smaller, approximately 0.7 m instead of 5-12 m for the Ku-band. Thus, the volume echo originates from the upper subsurface. Moreover, due to the antenna pattern, the Ka-band leading edge (see Figure 3b) is few times smaller and is thus less sensitive to the volume echo, which is added after the leading edge that corresponds to the surface component.
Ice sheet mass balance estimations require long temporal series. Using our data processing simulator, we can demonstrate that the convergence toward a precise height trend will be rapid, at approximately 20 cycles (Remy et al, 2014). Indeed, the geographical error is well corrected with the knowledge of the across-track slope around the Envisat nominal orbit and the "echo" correction; a six times smaller sensitivity than in Ku allows for a faster convergence.
Comparisons of the Ka-and Ku-band can help improve our understanding of phenomena such as the cross-over or the seasonal phase pattern. For snowpack characteristics studies, the largest uncertainty regarding the Ku-band lies in the roughness spectrum knowledge. However, the seasonal altimetric signal is known to originate from volume echo that are controlled by ice grain sizes. SARAL /AltiKa provides an opportunity to detect this mostly unknown parameter.

References

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