# EFFECTS OF SURFACE ROUGHNESS ON SEA ICE FREEBOARD RETRIEVAL WITH AN AIRBORNE KU-BAND SAR RADAR ALTIMETER

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## 1. INTRODUCTION

Remote sensing of sea ice thickness on a basin scale is solely realized with freeboard measurements by satellite altimeter platforms (e.g. [1] and [2]. Freeboard, the part of the sea ice respective snow above the water level, only represents a small fraction of the total thickness column, thus demanding high accuracy of range measurements. For the upcoming CryoSat-2 mission [3], a synthetic aperture and interferometric radar altimeter system of the European Space Agency (ESA), two range related error sources of the freeboard retrieval have to be taken into account: 1) The variability of radar penetration depth into the snow layer, and 2) sub-footprint-scale surface roughness. Both error sources are tackled with validation activities utilizing airborne radar altimeters. The penetration of Ku-Band radars into the snow layer is the focus of several studies [4], [5], [6] and [7]. Here, we focus on the range retrieval of airborne altimeters over level and deformed multiyear sea ice, with the aim of a better discrimination between penetration and topography errors of radar freeboard.

## 2. DATA AND METHODS

Within the ESA CryoSat Validation Experiment (CryoVEx) project, an airborne interferometric and synthetic aperture radar altimeter (ASIRAS) was flown in conjunction with a sidescanning laser altimeter over multiyear ice (MYI) in the Greenland and Lincoln Sea. The Greenland Sea with the Fram Strait is the major outflow region for MYI of the Arctic Ocean, while the coastline and major ice drift pattern result in heavily deformed sea ice in the Lincoln Sea, where the oldest and thickest sea ice can be found in the Arctic Ocean. The surveys took place in early may before the onset of melt in 2006 and 2008. Analyzed were several hundred kilometers of profile data in each year. The dataset consists of digital elevation models (DEM's) of both laser and radar altimeter. The calibration of both instruments was checked along overpasses over runways and defined features, such as buildings. The DEM's were converted by manual detection of open water into freeboard, whereas the higher resolution laser DEM was gridded onto the radar footprint, yielding comparable laser- and radar-freeboard.

## 3. RESULTS

The freeboard histograms differ most at lower freeboard values in all regions, where the airborne SAR altimeter responds more sensitive to small spots of open water than the laser altimeter. The general apparent radar penetration calculated from the range difference between laser und radar freeboard over level ice is variable but never equals the expected snow thickness. In general the difference in the modes of laser and radar freeboard is 5 – 15 cm in the Greenland Sea while there is no significant difference in the statistics of laser and radar freeboard over level ice in the Lincoln Sea. The apparent penetration shows a rough correlation with QuikScat backscatter (QB) maps, where high QB coincides with no penetration and lower QB with partial penetration of the Ku-Band radar waves into the snow.

The effect of sub-footprint scale surface roughness is most prominent in the Lincoln Sea, where the point-to-point comparison shows significant amounts of higher radar than laser freeboard in ice deformation zones. In the Greenland Sea, where the total freeboard of deformed ice is smaller, higher radar freeboard can be found occasionally but are not as persistent as in the Lincoln Sea.

These results show that the airborne SAR altimeter underestimates freeboard when small spots of open water are present and is biased towards higher freeboard in heavy ice deformation zones. This has to be taken into account, when comparing the airborne radar freeboard statistics to satellite products with higher footprints.

## 4. REFERENCES


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