

## ***Interactive comment on “Simulation of the satellite radar altimeter sea ice thickness retrieval uncertainty” by R. T. Tonboe et al.***

**Anonymous Referee #2**

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This paper deals in a novel way with the issue of radar penetration into snow covered sea ice and the effects of hydrostatic equilibrium on the retrieval of sea ice thickness from satellite radar altimeter measurements of sea ice freeboard. There are issues related to the relevance of the results to existing and upcoming satellite radar missions and the models and field data used. The paper is unclear regarding some important aspects of the analysis performed, the validity of the models employed, and the significance of the results need to be put in context against the objectives and methodologies currently employed to obtain space-borne data on ice thickness from radar altimeters. The paper needs significant modification before it can be made acceptable for publication in Cryosphere. In particular the following 'Major Issues' must be addressed before the paper can be accepted:

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### Major Issues:

P519: The authors state that : "The forward model uses a set of snow and ice micro-physical parameters for each layer : temperature, layer thickness, density, correlation length ( a measure of the snow grain size or the ice inclusion size), interface roughness, salinity, and snow wetness to compute the effective scattering surface." Are all of these available for all of the campaigns or just the Antarctic? If the former then the values should be tabulated for all campaigns, if the latter then does the waveform modeling rely only on data from the Antarctic, in which case the results of this study may not be applicable to Arctic ice. The equations relating the permittivity to each of the physical parameters listed in tables 2-5 should be provided.

P520 Eqn. 2: This equation from Fetterer et al. originates from a paper by Ulander and Carlstrom (UC referenced by Fetterer paper) which states that the model is based on the assumption that the reflection originates from a small area fraction (the fraction used in this paper is 0.5%) of scatterers (or 'patches') a few metres across with an rms height less than one tenth of a wavelength (i.e. a few mm). Fetterer further states that this equation describes that this equation may be used when the 'patches' are sufficiently large to generate a narrow peaked echo waveforms in a space-borne altimeter. This poses two problems: (i) If the authors consider the model for the surface geometry described above as a reasonable representation for snow covered first or multi-year sea ice and if so they should provide evidence for this as anyone with field experience in the Arctic would almost certainly disagree (In fact the intention of both Fetterer and UC was to use this model to represent scattering from a small fraction of leads and new ice within the ice pack); (ii) Reflections from ice floes (as opposed to thin ice or open water) do not in fact generate narrow peaked waveforms in space-borne radar altimeter data but instead produce diffuse waveforms as shown in a number of papers (Fetterer, Fig 7-20b; Laxon, IJRS, 1994, Peacock and Laxon, JGR, 2004, etc.). The authors must explain why this model may also be suitable for 'diffuse' altimeter waveforms.

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P525:L27: The authors use a value of 25dB for the backscatter co-efficient over new ice. However Fetterer et al show a backscatter range of 25-40dB over new ice (i.e. an upper range up to 30 times higher). At the upper range the new ice reflection would dominate the return echo and indeed this is the principle used in freeboard retrieval (e.g. Laxon, et al.). Indeed the processing of satellite radar altimeter data rejects any returns which appear to originate from more than one surface within the footprint (Peacock and Laxon, JGR, 2004).

P529 L8-10: The authors conclude that on the basis of their study that radar penetration is as important an error as factors affecting buoyancy. However this conclusion is based on analysis using field data gathered outside of the normal season (October - March) when space-borne altimeter estimates are normally used because it is known that penetration uncertainties start to become a problem during spring and summer that these data are discarded(e.g. Laxon et al, 2003; Giles et al., 2008). Evidence from both field (Conner et al, 2008) and modelling (Makynen, TGRS, 2009) indicates that during the winter period (relevant to the CryoSat mission aims) that reflection occurs at the snow-ice interface. This conclusion is therefore valid only for periods outside the normal observing period, or for the Antarctic.

#### Minor Issues

Abstract/P515: The authors should clarify that the objective of the CryoSat mission is to provide data on changes in thickness measured in the Arctic over the winter period. They should also clarify that previous studies on ice thickness change have made measurements in winter (October-March) and that the results presented in this paper are relevant to spring measurements in the Arctic and to measurements in the Antarctic.

P151L16-19: The authors do not discuss the implications that the ice floe might be in hydrostatic equilibrium on a local scale in sections 4.5 and 4.6.

P516 L1-4: The authors should make reference to papers by Giles et al., RSE, 2007

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and Conner et al., RSE, 2008 which suggest penetration to the ice/snow interface in airborne under-flights of space-borne altimeters and discuss the implications of those results for the analysis in this paper.

Section 2: It is not clear how the measurements from the different campaigns are combined to produce table 2. The physical parameters from each field experiment (or set of experiments (e.g. Sever) should be tabulated separately.

P524 L7-9: Section 4.5 does not discuss the effects of surface roughness on backscatter.

P527 L12: The authors discuss the potential effects of melt-ponds on the altimeter return. Whilst this may be interesting it has no relevance to retrieval of ice freeboard during winter when meltponds are absent.

P528: The authors should make reference to Giles et al 2008 whose results suggest variable penetration over Antarctic sea ice.

P531 L18-20: The authors should make reference to the work of the CryoSat Cal/Val team and the CryoSat Calibration and Validation document. The authors should also make reference to the need for in-situ experiments needed to test radar penetration issues directly.

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Interactive comment on The Cryosphere Discuss., 3, 513, 2009.

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