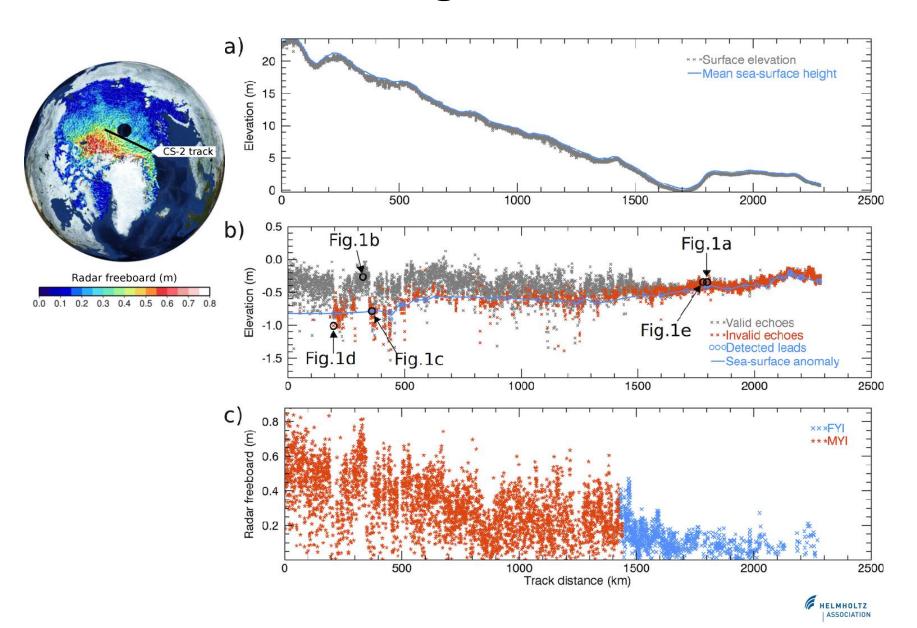


International Sea Ice Concentration and Thickness 19. September 2014, University of Hamburg Evaluation and Intercomparison Workshop Uncertainties of Sea Ice S. Hendricks, R. Ricker, V. Helm, C. Haas, M. Davidson Thickness from CryoSat-2



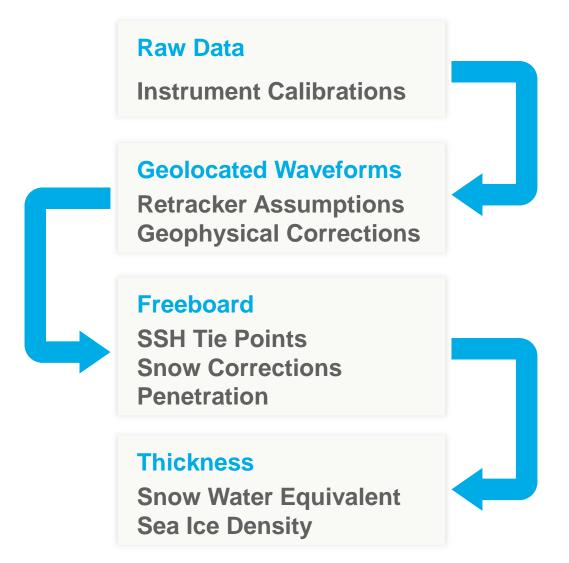
What are we looking at?





Sources of Uncertainty







Sources of Uncertainty



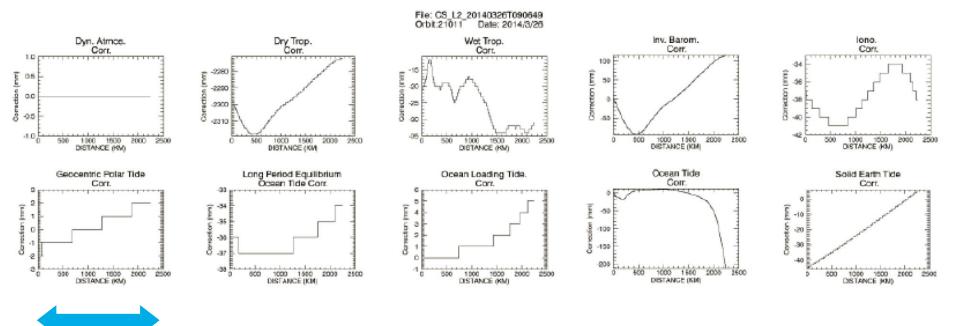
Raw Data **Instrument Calibrations Geolocated Waveforms Retracker Assumptions Geophysical Corrections CryoSat-2 Specific Freeboard SSH Tie Points Snow Corrections Penetration Thickness Snow Water Equivalent Sea Ice Density**



Geophysical Corrections

2500 km





Geophysical Corrections (mm to cm) vary on the scale of freeboard / thickness gradients



Retracker



Waveform shape is dependent on surface roughness, backscatter, snow properties

Treshold

Fixed 'threshold' of (first) maxima as first arrival

Same threshold for ice / water (AWI) of combination of thresholds (UCL)

robust but probably to simple

Waveform Fitting (Kurtz et al.)

SAR waveform model fitted to waveform

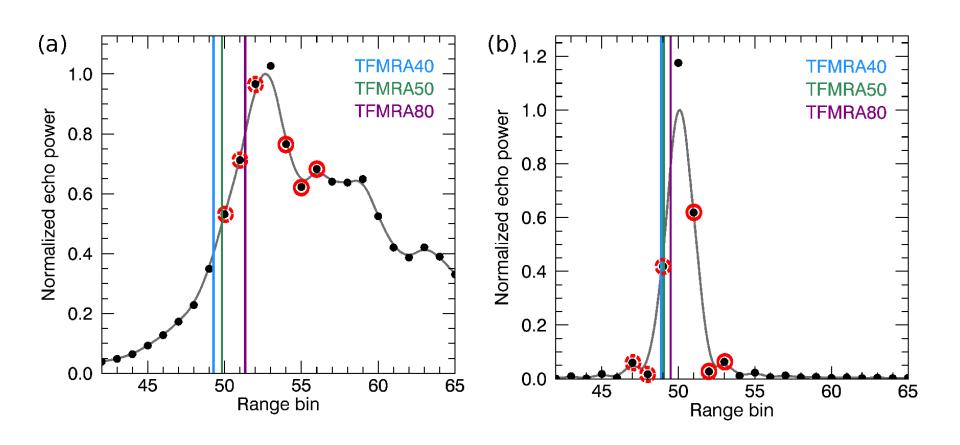
Takes into account changes of leading edge slope

Based on backscatter model, yields range & roughness



Threshold Retracker



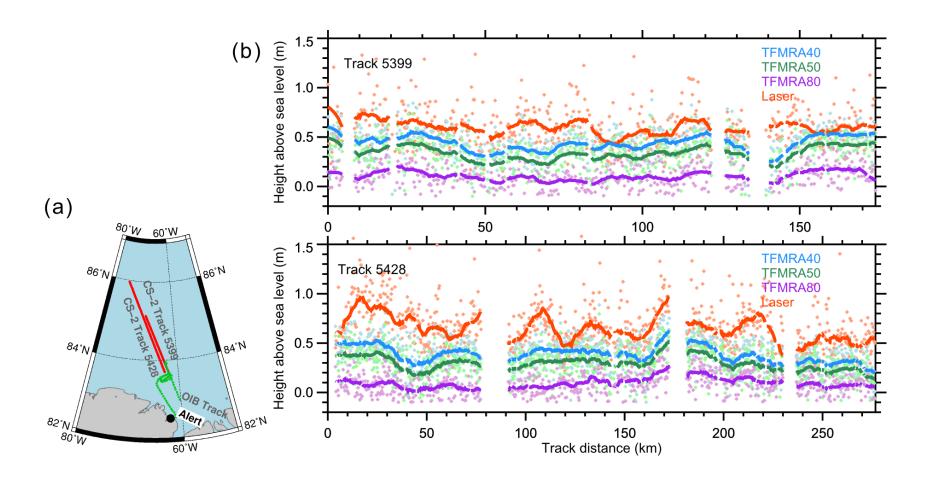


TFMRA: Threshold First Maximum Retracker Algorithm



Threshold Retracker



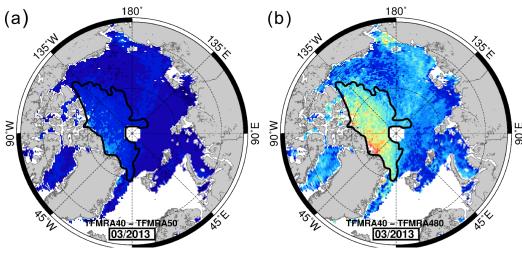




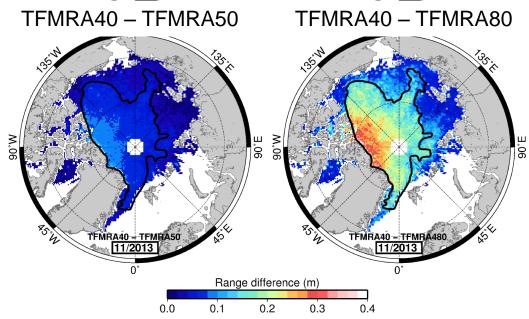
Threshold Retracker



March 2013



November 2013





What is Penetration?

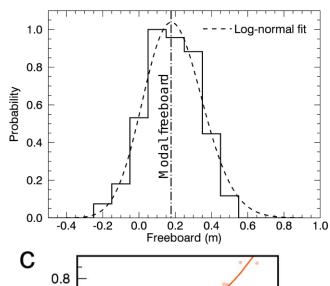


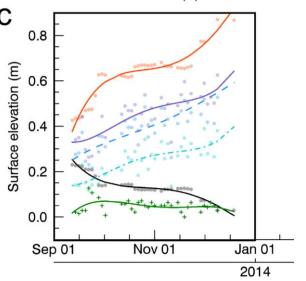
How to separate physical penetration limitations from algorithm properties?

Radar Freeboard near IMB +/- 1 day, radius 50 km

Temporal Evolution of radar freeboard vs IMB snow & ice freeboard



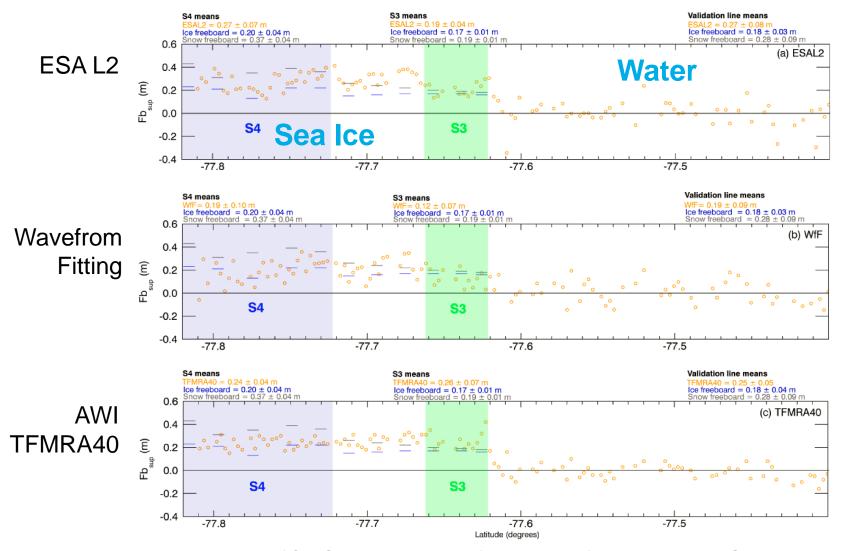






Retracker Intercomparison





D. Price et al., Evaluation of CryoSat-2 derived sea ice freeboard over fast-ice in McMurdo Sound, Antarctica , submitted to Annals of Glaciology



Freeboard Retrieval Remarks



Radar Freeboard

SAR altimeter waveforms needs to better understood (role of snow)

More validation data than for sea-ice thickness

Algorithms

Waveform-model based approaches to be preferred if not outright beneficial (snow properties, roughness)

But how good is your model?

Retrievable snow information in the leading edge?

Freeboard uncertainty is the main contributor to thickness uncertainty



Concept of Uncertainties



Each Parameter may have a bias (offset) and uncertainty (variability)

Uncertainty

Regional: Data Noise, SSH Interpolation Error

Near-insignificant after gridding

Temporal: Yearly variations of mean snow densities

Bias

Constant offsets: Retracker Uncertainty, Snow Depth, Density,

Biases have to added, if sign is not known

Not reduced by gridding, Covariance?



Uncertainty & Bias



Freeboard uncertainties

Gaussian propagation of uncertainty

Sea-surface height 5-50 cm

Speckle noise SAR: 10 cm

(Wingham et al. (2006) SARIn: 14 cm

Retracker threshold +

Physical signal penetration +

Surface roughness

FYI: 6 cm

MYI 12 cm

Random freeboard uncertainty

Freeboard bias

Thickness uncertainties

Gaussian propagation of uncertainty

Random freeboard 0.5 – 4 cm

uncertainty

Ice density FYI: 35.7 kg/m³

(Alexandrov et al. (2010) MYI: 23 kg/m³

Snow depth (ice type classification)

Ice density (ice type classification)

 $-13 - 13 \text{ kg/m}^3$

-10 - 10 cm

Snow density (inter-annual variability)

 $50 - 150 \text{ kg/m}^3$

Snow depth (inter-annual variability)

4.0 - 6.2 cm

Retracker threshold +

Physical signal penetration+

FYI: 60 cm MYI: 120 cm

Surface roughness

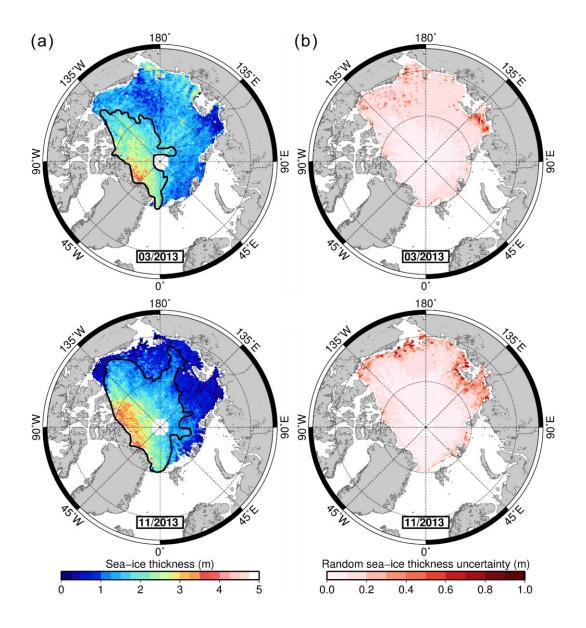
Sea-ice thickness bias

Random sea-ice thickness uncertainty



Thickness Uncertainties

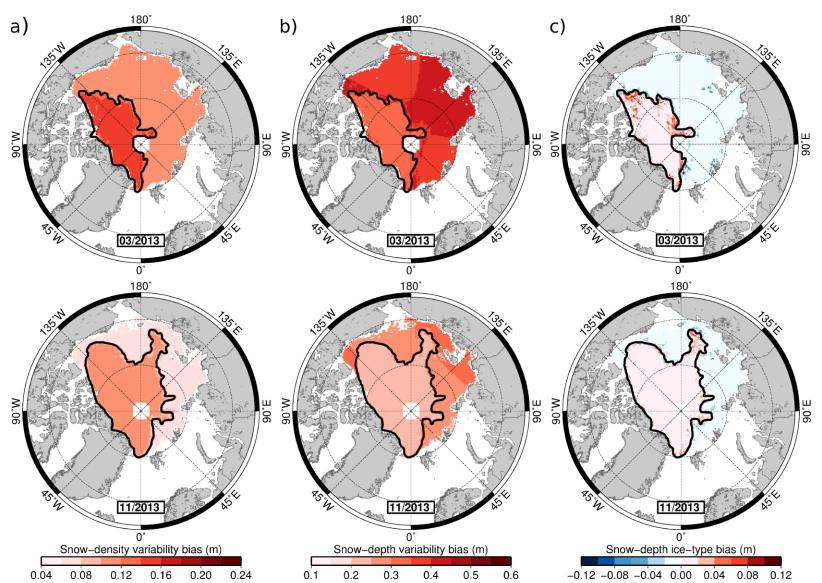






Thickness Biases







Summary Remarks



CryoSat-2 sea ice thickness

Uncertainty & Biases

There is not one uncertainty but many
Gridding reduces only random uncertainties
Unknown Bias direction (Knowledge Gap)

All sources added together: Uncertainty much higher then reported in comparison with thickness validation data

CryoSat-2: Freeboard validation is important Unknowns of retracking algorithms are a source of uncertainty

