Analysis of small icebergs (<10km²) size and freeboard around Greeland and Antarctica using Cryosat SARin data

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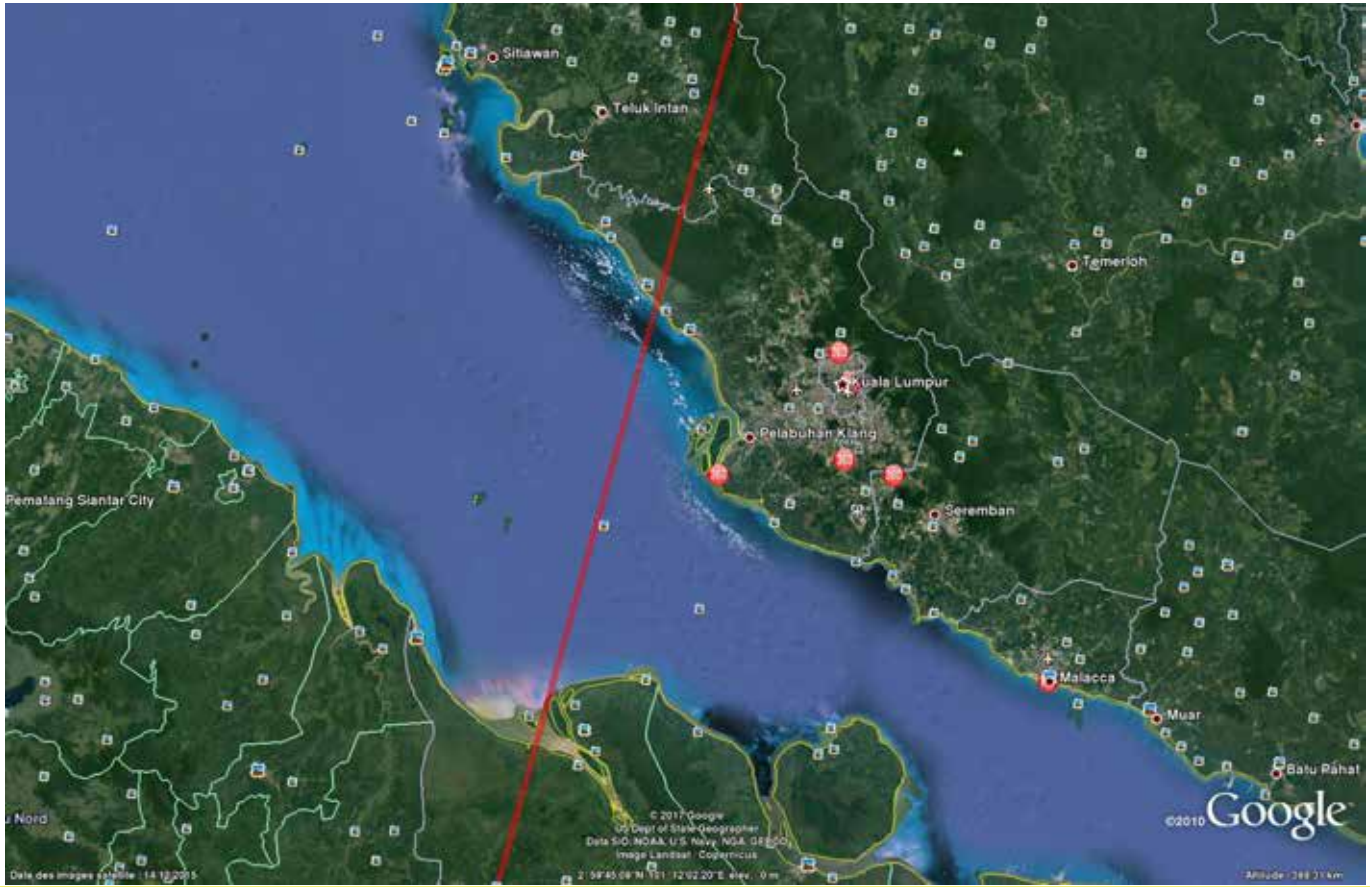
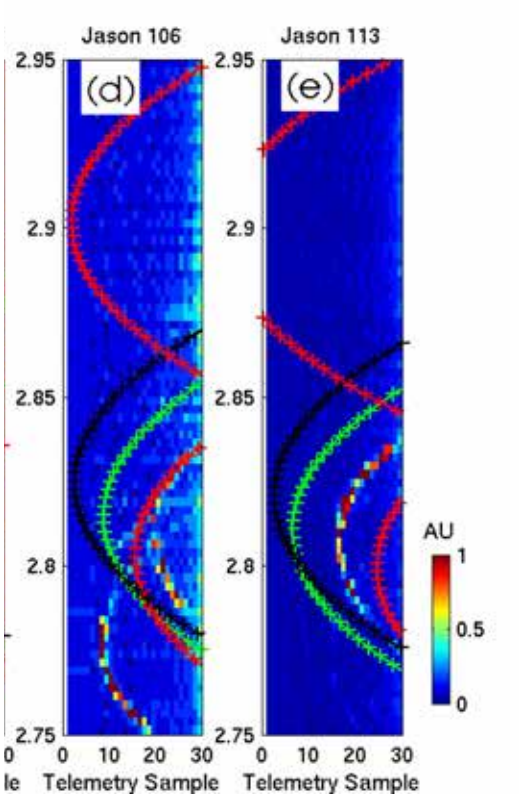
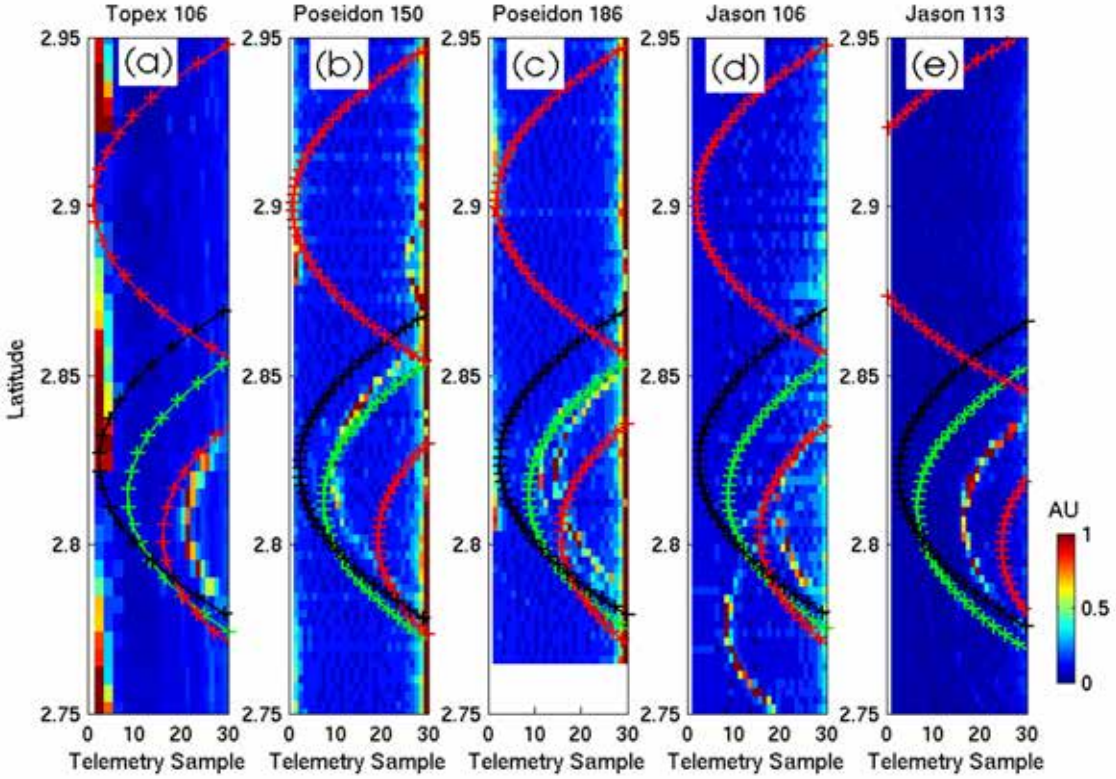
Where does it come from? Jason1 pass 1



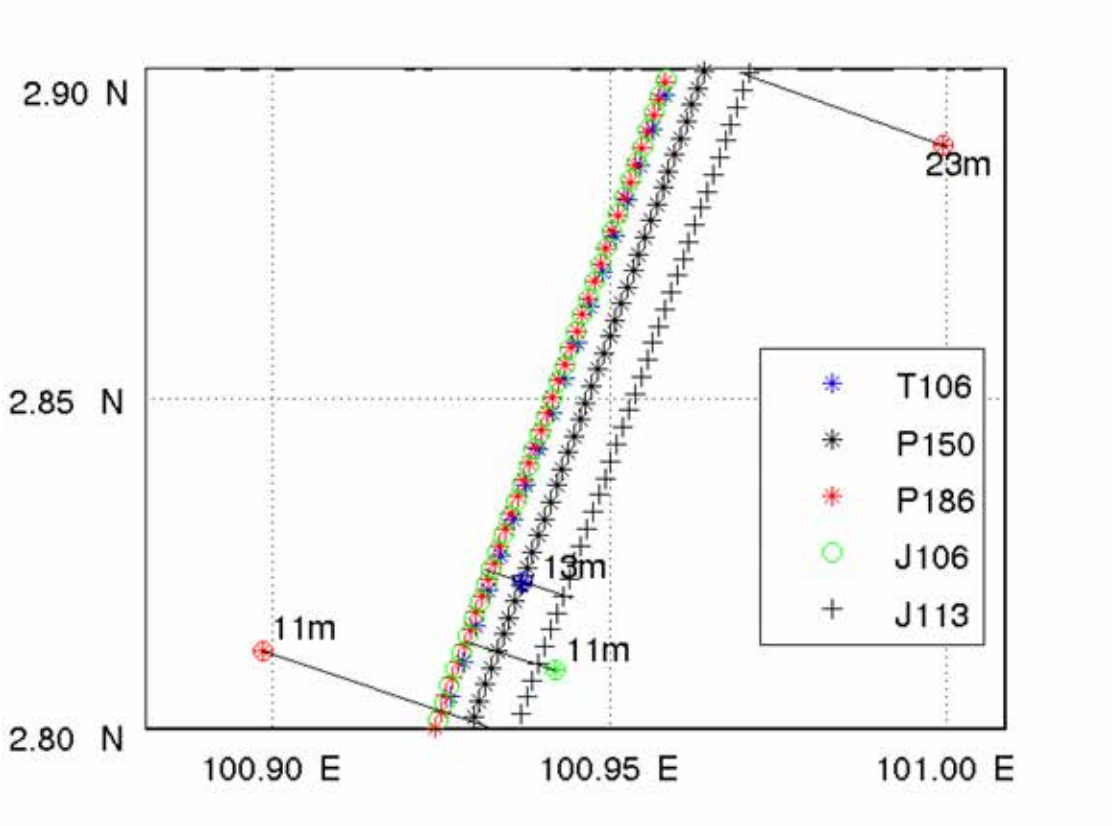


What are these parabolas in the noise part of the waveforms?

Also in Topex and Poseidon waveforms



Beacon towers marking the shipping lanes

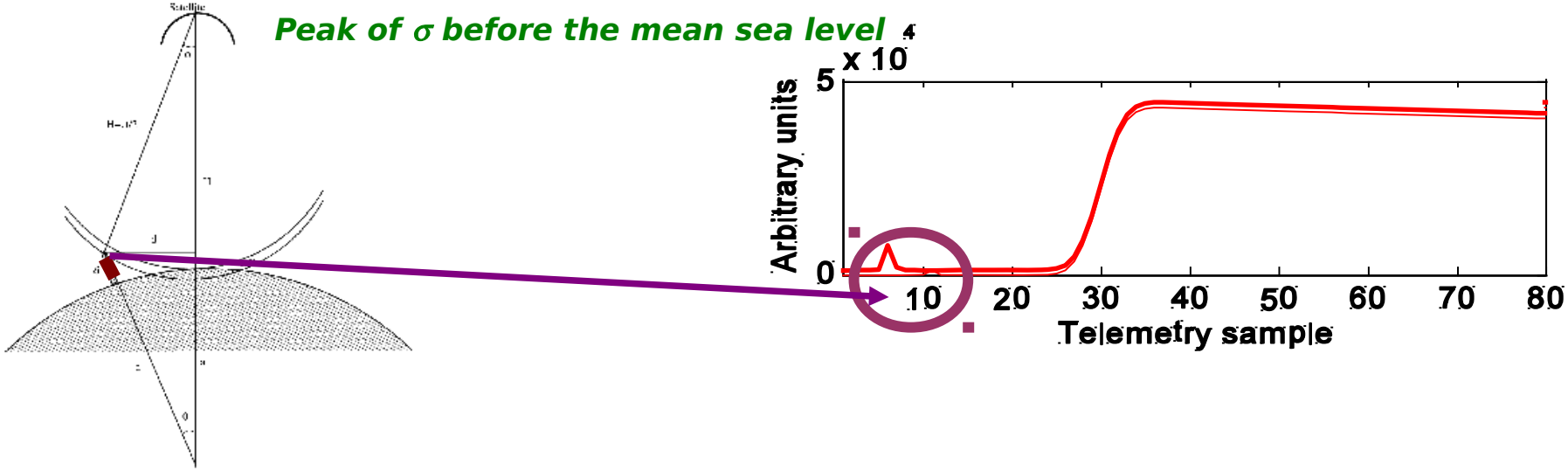


Scientific context

- Icebergs are a key component of the Ocean circulation at high latitude and could have a strong impact climate.
- They represent about half of the mass loss of the Antarctic Ice cap (Rignot et al 2015, Depoorter et al 2015).
- They can transfer fresh water far away from the coast into the ocean interior
- Large Icebergs transport the major part of ice while small icebergs are the main component of fresh water flux through melting
- Previous studies have shown that classical pulse limited altimeters are powerful tools to detect and characterize “small” (<3km in length) icebergs .
- **Cryosat** offers a unique opportunity to compare the merits of 3 different operating modes for the detection and analysis of small icebergs.
    - LRM : pulse limited altimeter (over open ocean)
    - SAR (Delay Doppler Altimetry) near and over sea ice
    - SARin DDA and Interformetry

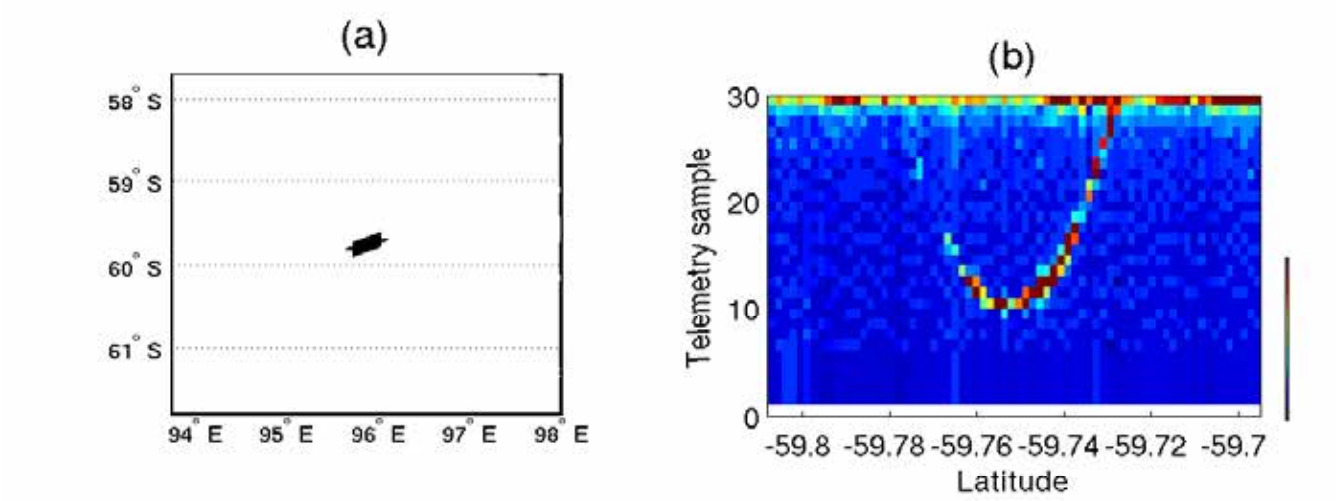
Icebergs detection using Pulse Limited Altimeter (LRM data)

- Targets emerging from the sea (iceberg, ships, lighthouse) : detectable signature in the noise part of Altimeter WF [*Tournadre et al , 2008, 2012*].
- In the waveform space the signature is a parabola determined by the orbital parameters.
- Detection algorithm: detection of parabola in the WF ***thermal noise part*** (TNP).
- Works only in open water



Example of iceberg signature in LRM WF TNP

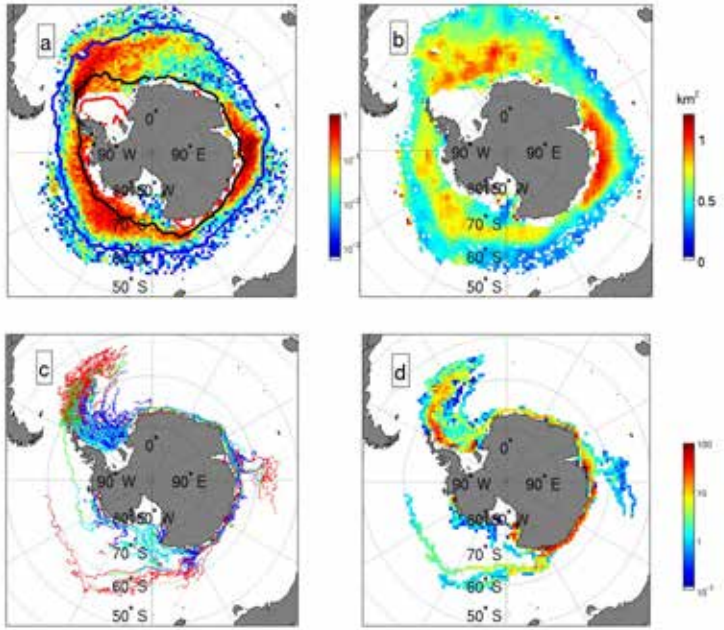
- In the waveform space the signature is purely deterministic and depends on the orbital parameters (like a transponder response).



ALTIBERG Small iceberg Data base

- A small iceberg data base from 1992 to present. Nine pulse limited altimeters used .
- Climatology of iceberg area and Volume of ice
- Large icebergs (length >16km) data base (2002-2012), size and freeboard from NIC/BYU and altimeters (J1-J2, Envisat)
- LRM: estimate of iceberg surface from backscatter and range (hypotheses on ice backscatter and freeboard)

Mean Ice volume (km^3) Mean Iceberg area (km^2)

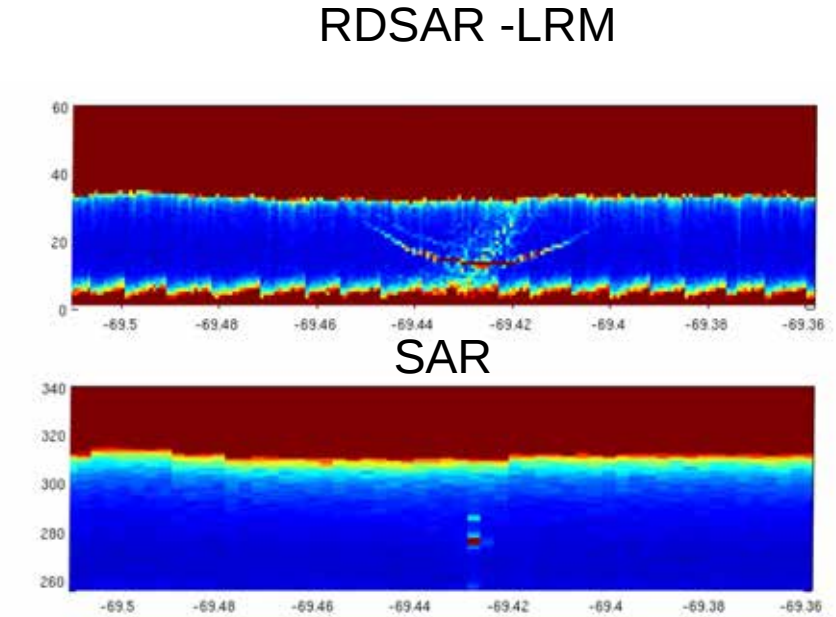


Large iceberg traj.

Large iceberg mean volume.

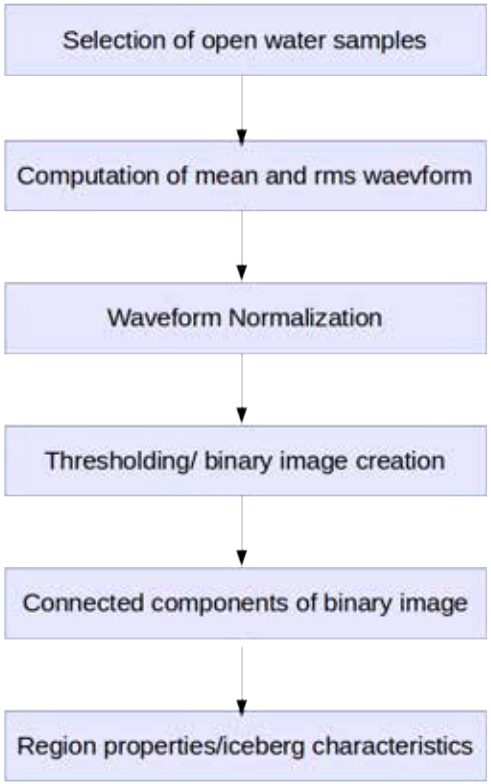
Iceberg signature in SAR echoes

- range alignment including slant, tracker and Doppler range corrections , stacking and incoherent summation of stacks of co-located Doppler beams are used to produce L1B echoes.
- The parabolic signature in LRM reduces to a bright spot in SAR echoes
- Several image processing algorithms have been developed to detect bright spots in imagery (especially for medical applications)



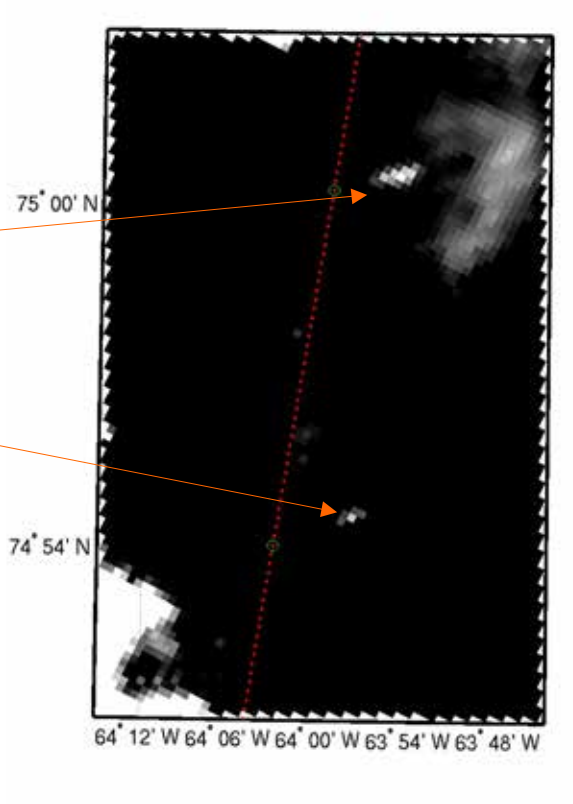
Iceberg/ship detection algorithm

- Select only open water samples
- Compute mean and rms of waveforms
- Normalized WF
- Compute binary image, by thresholding normalized WF at 4
- Compute connected components (CC) of binary image
- Compute region properties of CC



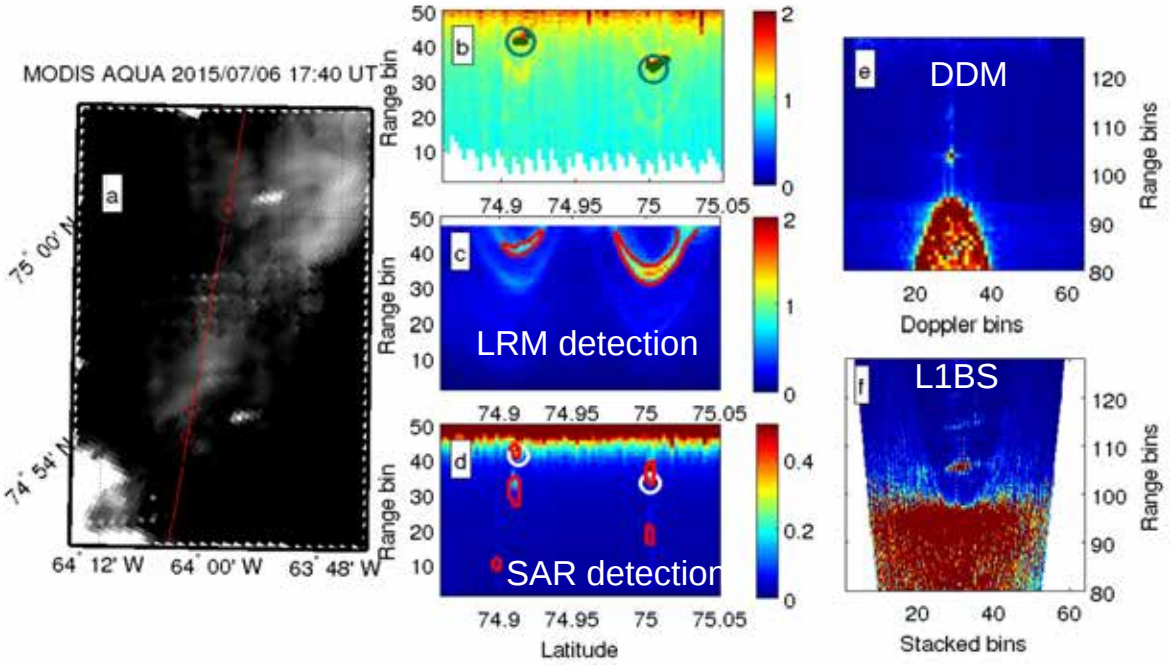
SAR data: Icebergs near Greenland

- Modis image July 10th 2015 17:40 UT
- Cryosat-2 pass 6 hours latter
- Two icebergs



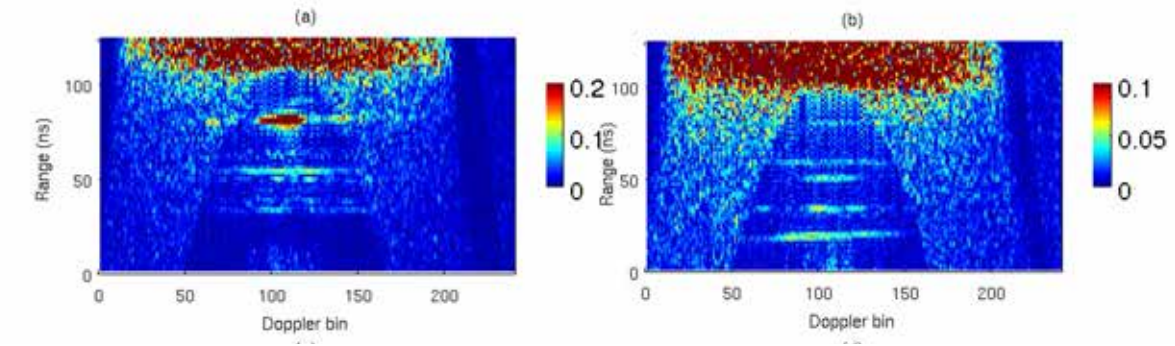
- Detection performs very well
- Detect a small iceberg whose signature to weak for LRM detection
- Estimation of size from signature size : problem with size in range depending on distance from nadir
- Size from backscatter
- Intercalibration between LRM and SAR possible using both detection (will be done using S3 data in Ku and C band)

Reduced SAR ~=LRM

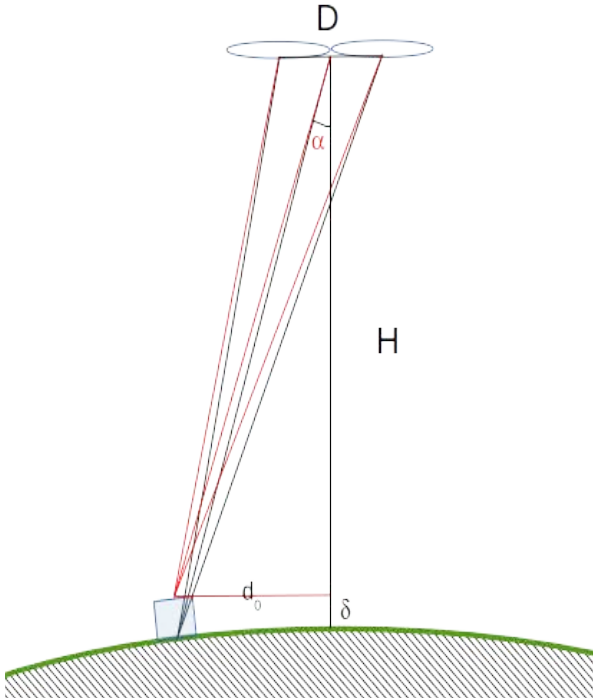


Iceberg signatures in L1BS (stacked) data

- Signature of the larger iceberg (near 75°N) and the smaller one near 74.9°N Iceberg near. Configurations 1 (top) to 4 (bottom)
- In stacked data signature should be a *straight line of constant backscatter* because of range correction
- High specularity of ice reduces the signature to lower incidence
- Clear signature of the different elevations within the iceberg



Use of coherence and phase difference



Phase difference between the signals from the 2 antennas

$$\theta = \frac{2\pi D}{\lambda}\sin(\alpha)$$

Off-nadir angle gives the position of the scatterer

$$\alpha = \frac{\theta\lambda}{2\pi D}$$

Distance from nadir

$$d_0 = H\alpha$$

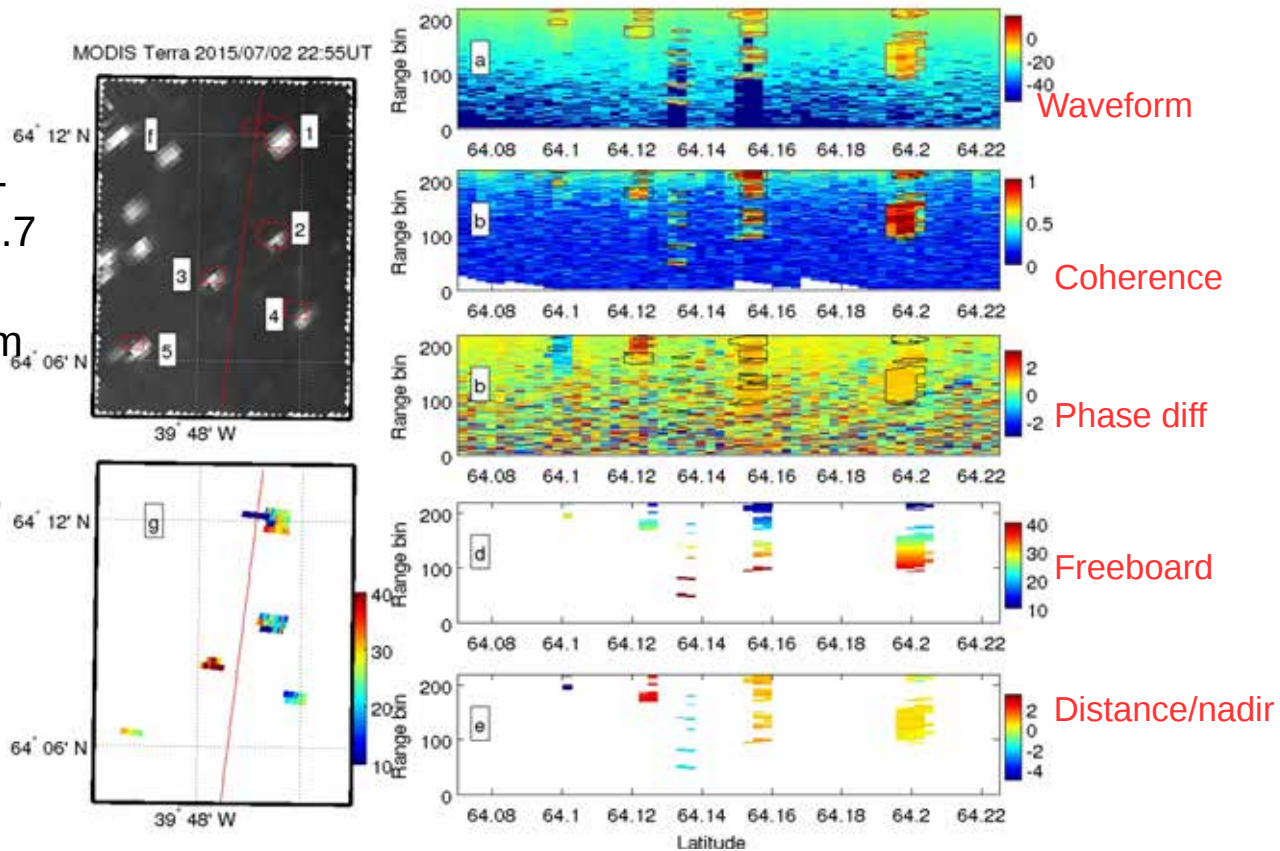
From waveform range bin t_0 of signature

$$\frac{ct_0}{2} = -\delta + \frac{d_0^2}{2H''} \qquad \delta = \frac{d_0^2}{2H''} - \frac{ct_0}{2}$$

Before the surface the 2 signals are incoherent, high coherence : presence of scatterer

SAR interferometry detection

- Detection with SAR algo + condition of coherence >0.7
- Estimation of freeboard
- Remapping on a 300x50 m geographical grid
- Estimation of the iceberg characteristics (freeboard, sigma0, size)

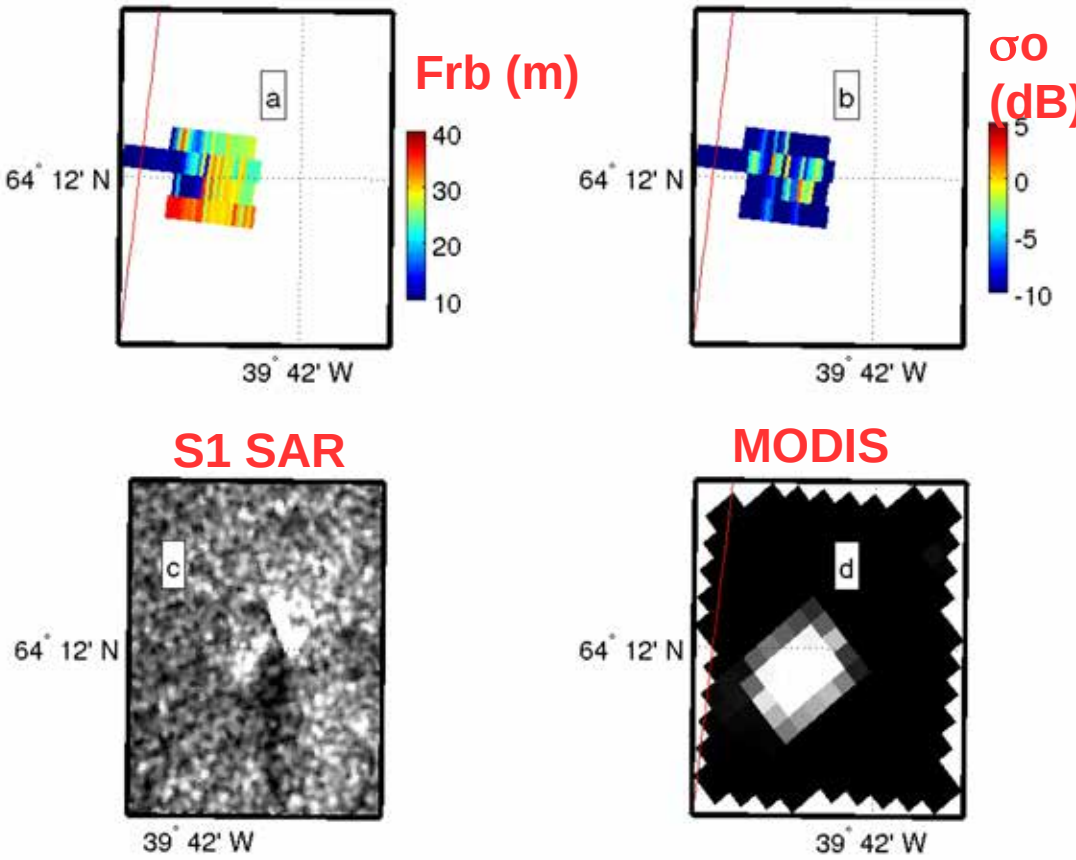


SARrin detection

Detail of iceberg 1

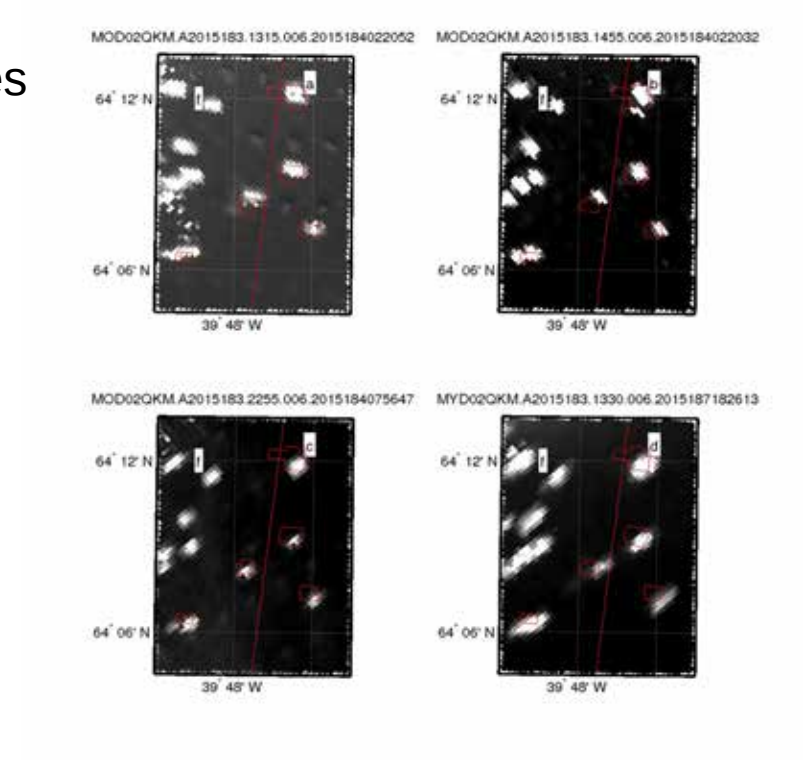
Geographical remapping at 300*50m resolution

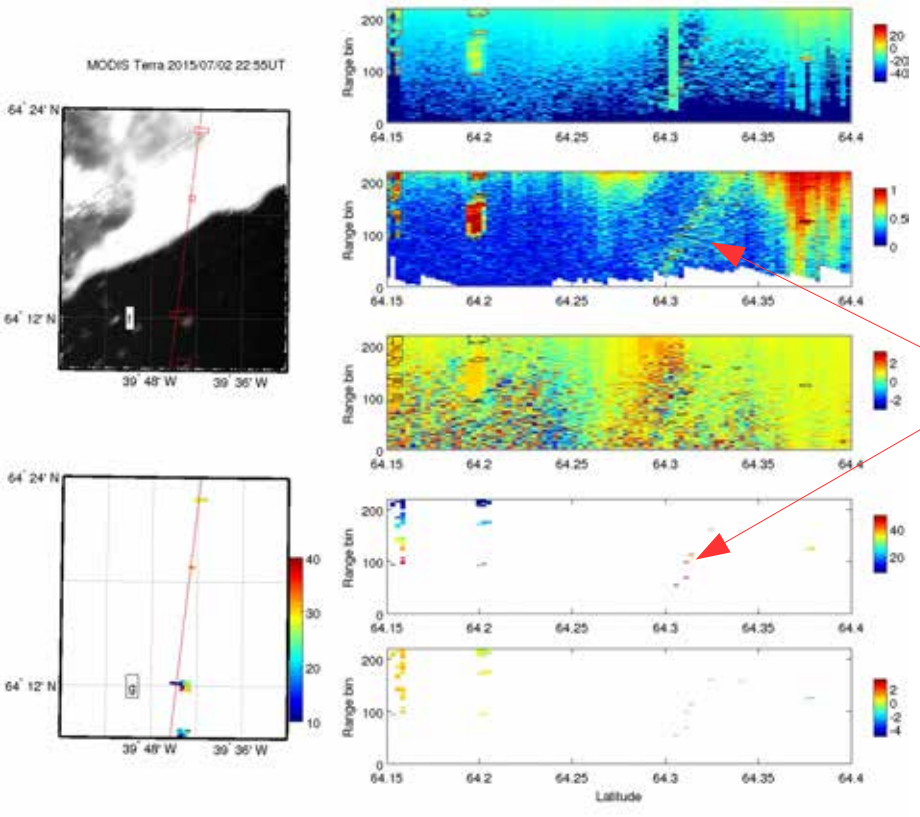
- Large variation of freeboard from 18 to 45 m
- Large variations of backscatter (corner reflection)
- Good agreement with SAR (S1) and MODIS data for size



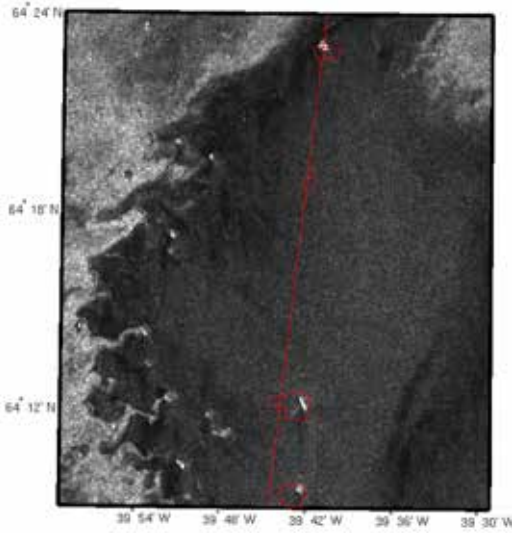

gettyimages
Michael Melford

4 MODIS images during this day

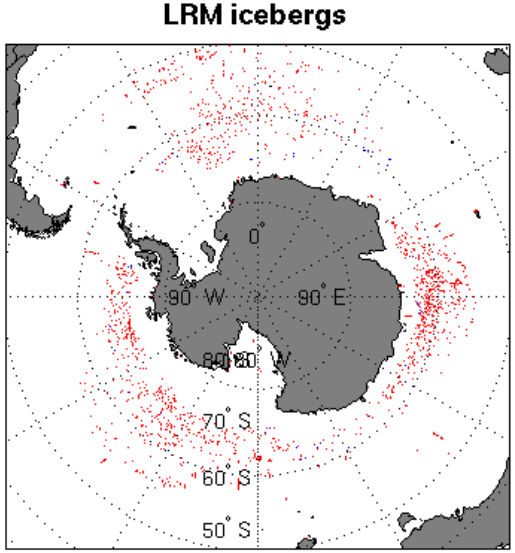




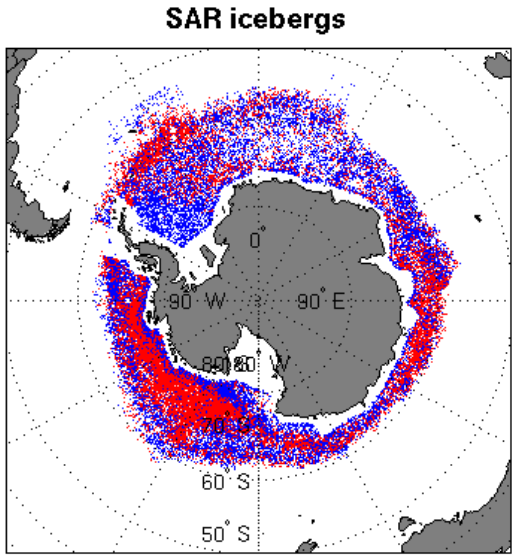
- Detection in sea ice possible but noise level significantly higher (==> larger iceberg)
- Problem with sea ice edge that create spurious signatures



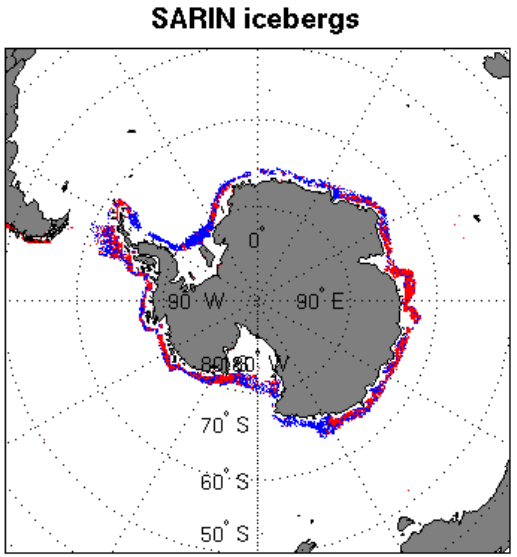
- Processing of the Cryosat-2 archive: LRM, SAR, SARin
- Still some problems to solve with small islands (1000's near Greenland) and sea ice flag.



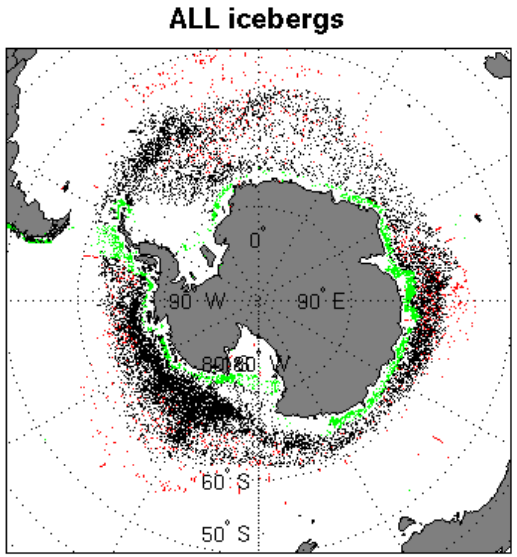
LRM Detection 2010-2016



SAR Detection 2010-2016
Red . Open water
Blue sea ice



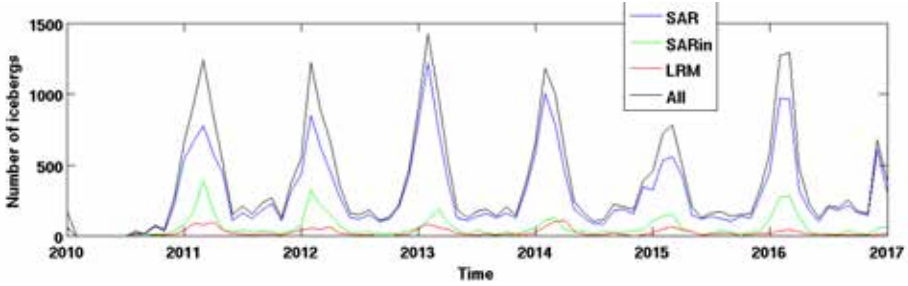
SARin Detection 2010-2016
Red . Open water
Blue sea ice



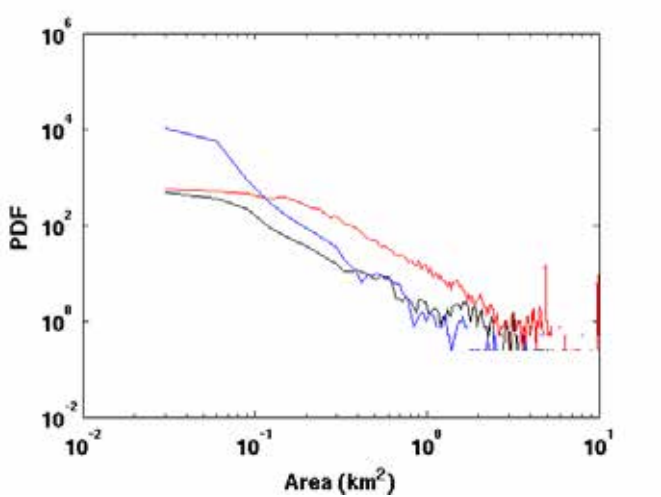
All detection
Red LRM
Black SAR
Green SARin

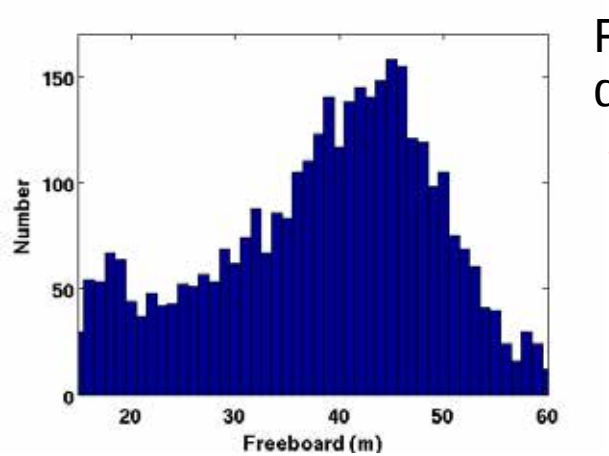
Work in progress

Number of detected icebergs

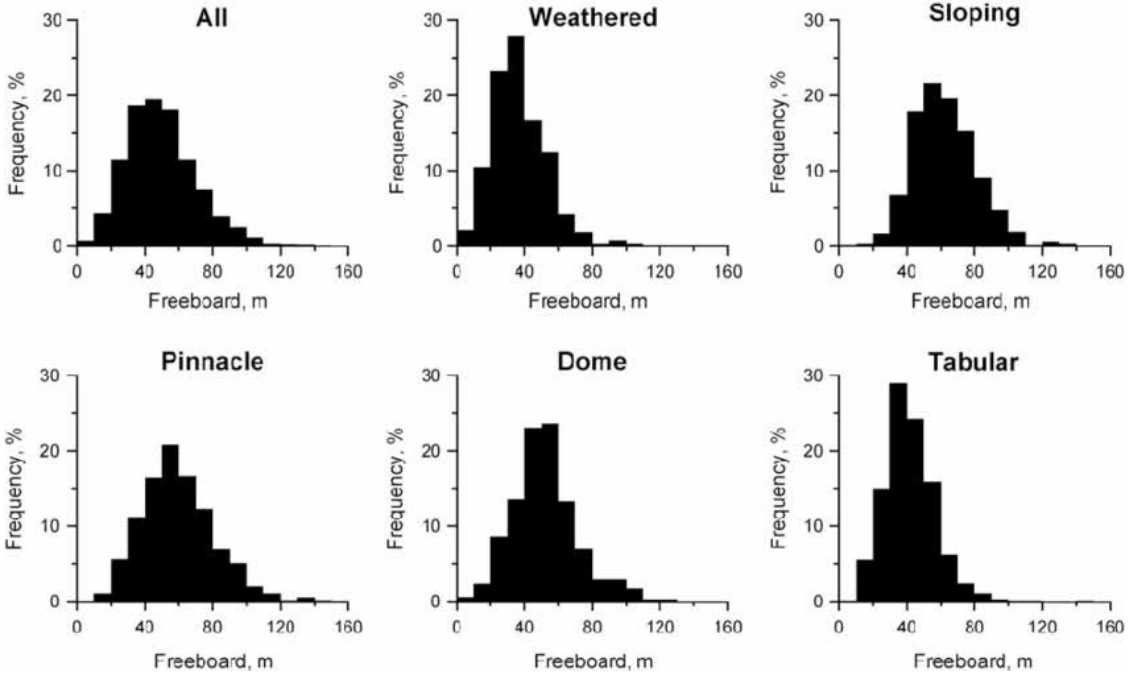


Size distribution
Black LRM
Blue SAR
Red SARin





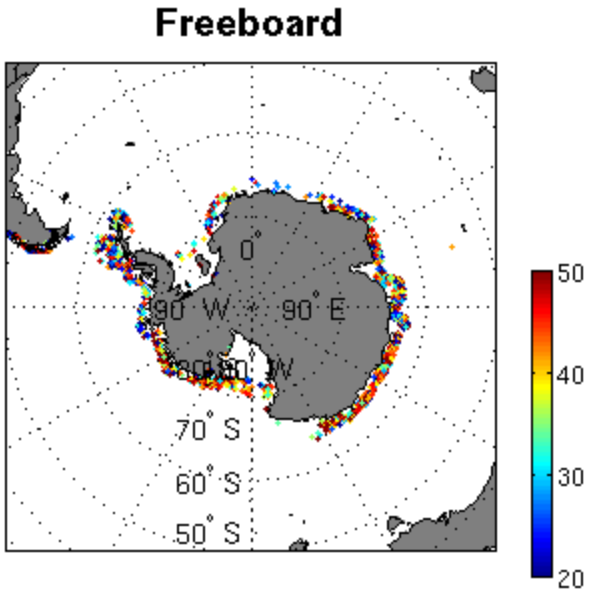
Freeboard distribution
SARin

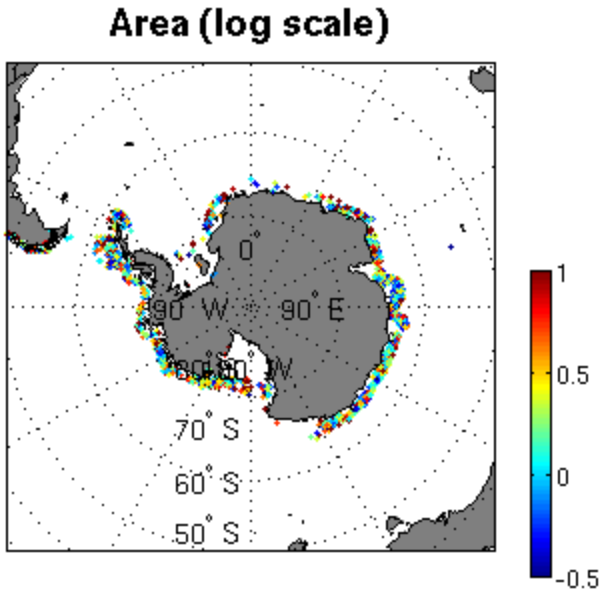


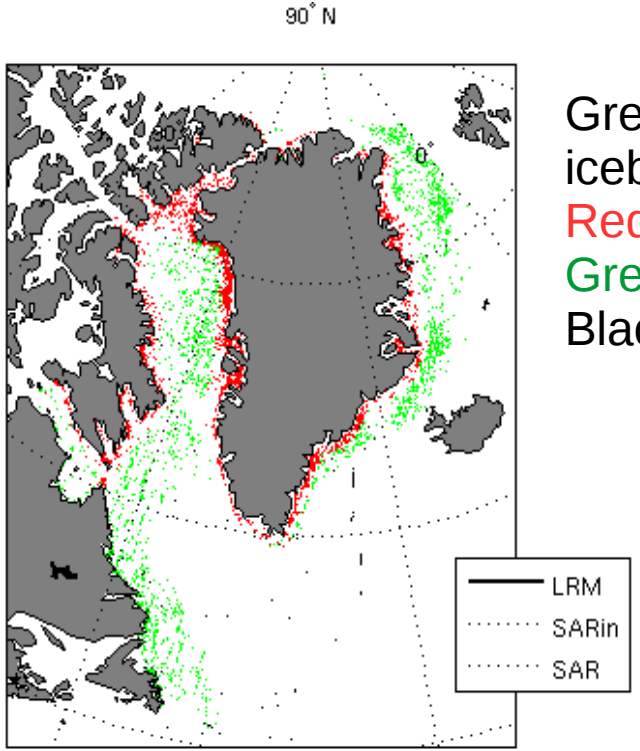
Good agreement with ship -borne radar measurement of small iceberg freeboards

SARin Freeboard and area

SARin open water detected icebergs Freeboard and area

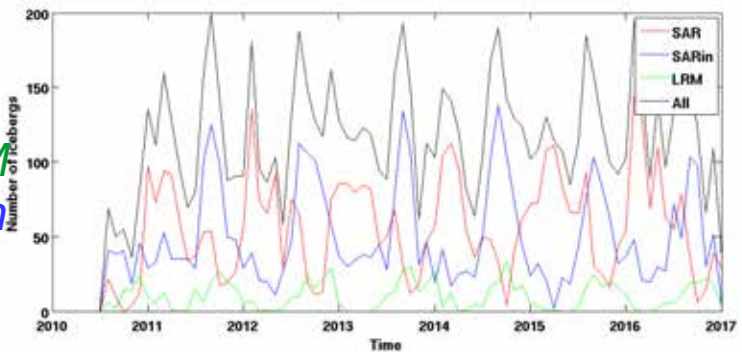




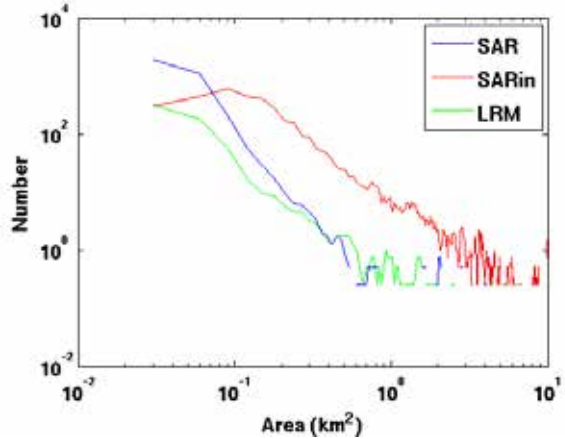


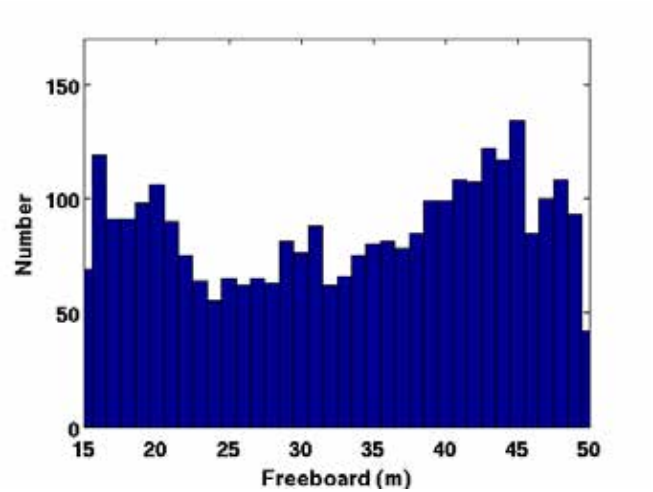
Greenland icebergs
Red SARin
Green SAR
Black LRM

Monthly #
Red SAR
Green LRM
Blue SARin
Black All

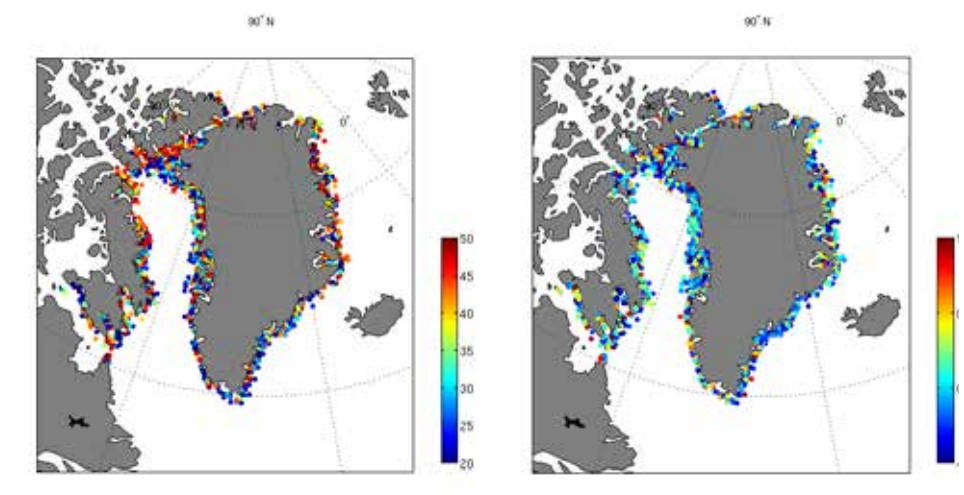


Size distribution
Red SARin
Green LRM
Blue SARin





Freeboard
Greenland

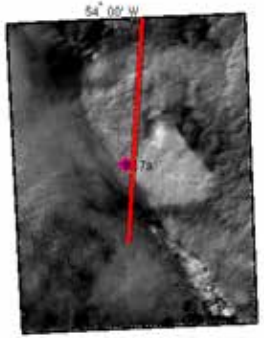


Freeboard

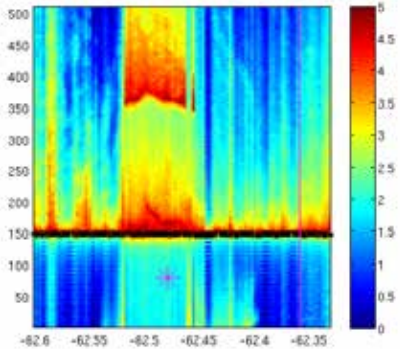
Area

SARin and large iceberg

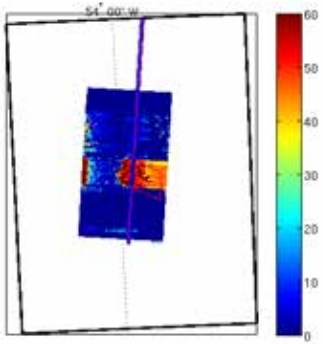
WF

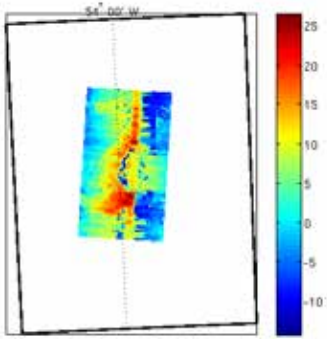


elevation

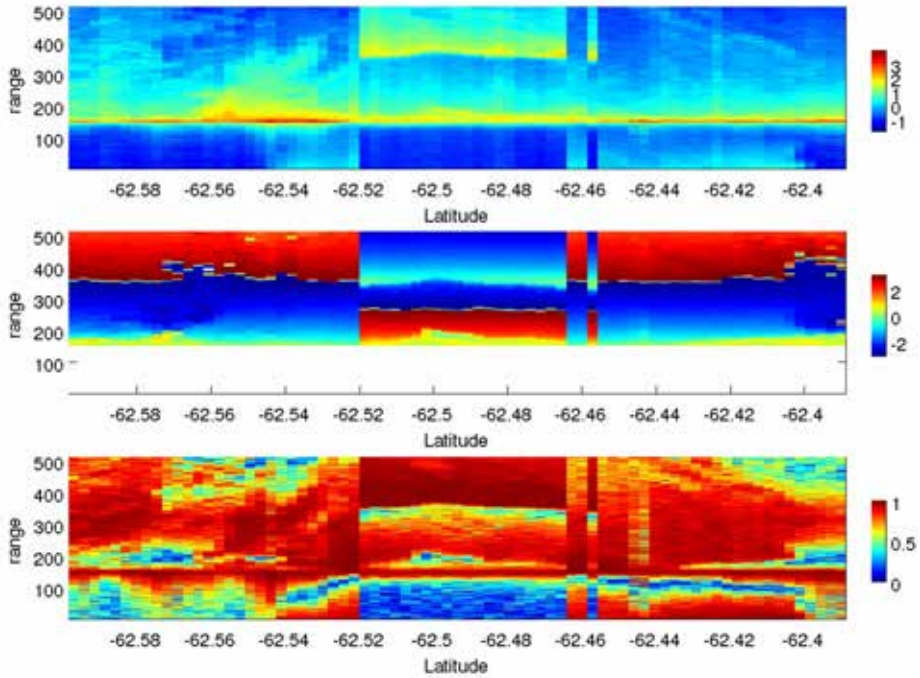


σ0





- Pass over a large iceberg (B17a) ~40x30km^2
- Fine scale topography of the iceberg
- Need other image to locate the pass over the iceberg
- Can be used to compare phase difference and range (using tracker position)



WF

Phase difference

coherence

Summary

- The 3 modes performs well to detect icebergs
- SAR and SARin lower noise, better detection of smaller icebergs
- SARin is the only sensor that allows the estimate of freeboard and area
- More to come on
  - Distribution of freeboard and size
  - Analysis of the evolution of the iceberg and volume distribution
  - Analysis of relationships freeboard/area/backscatter