



A 2D retracker to estimate sea ice freeboard from SAR altimetry

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1. Context & Methodology



- **Sea Ice Thickness estimation from SAR**
(Synthetic Aperture radar) **altimetry**
- (ESA missions)
 - **CryoSat-2** (2010-)
 - **Sentinel-3** (2016-)

Methodology



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SAR ~ 300m along track
resolution
LRM ~ 7km radius resolution



1. Context & Methodology

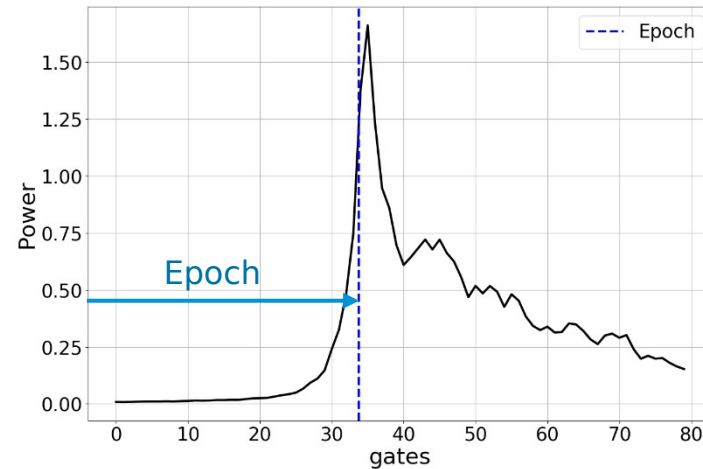


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- **2 retracking methods**
 - **empirical**: % of the peak (*TFMRA, ICE1..*)
 - **Physical** : e.g **SAMOSA+** (*Dinardo et al, 2017*)



grid processing on demand

Methodology



- Retracking : epoch calculation



1. Context & Methodology

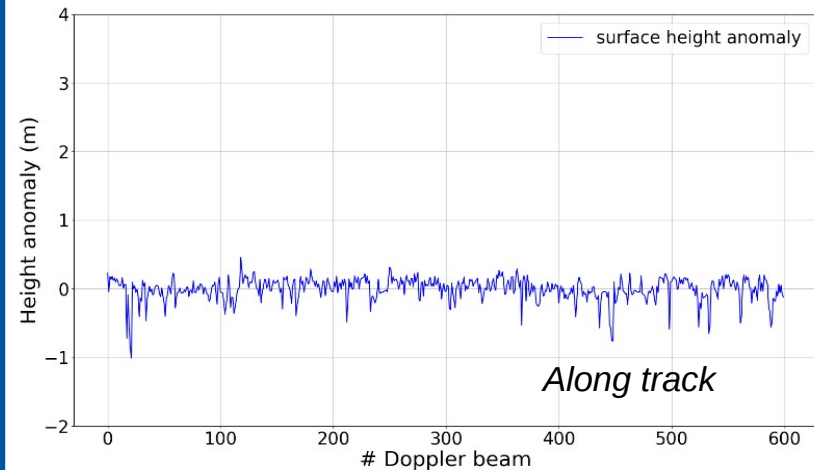


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- Height anomaly relatively to the Mea sea Surface (MSS)

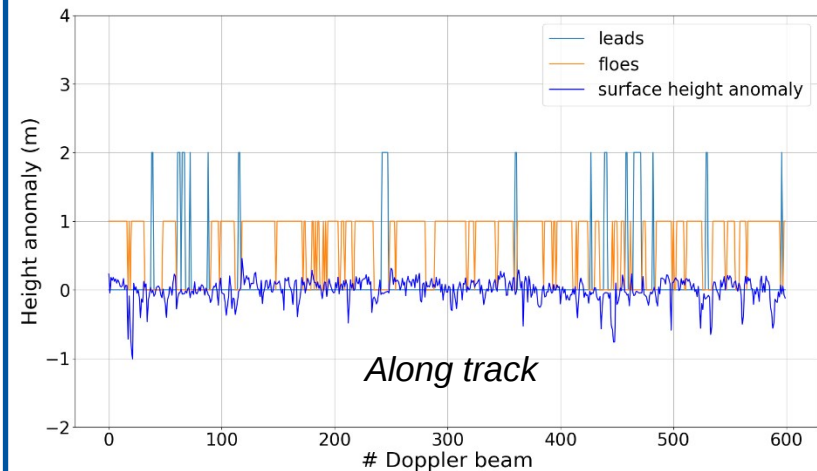


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Methodology



Leads : cracks in the ice (SLA)

Floes : top of the sea ice surface

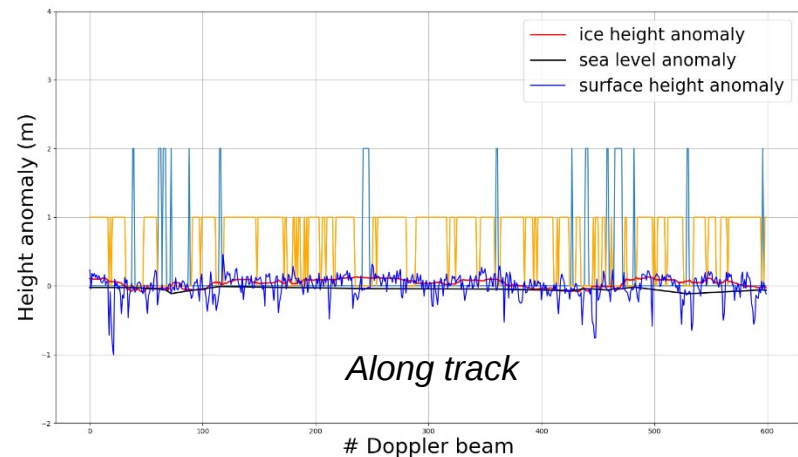


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- Median interpolation on floes
- Linear interpolation between leads

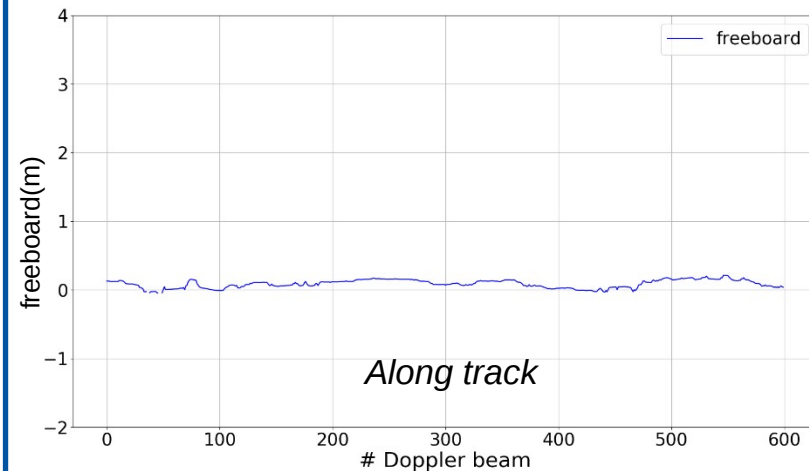


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- **Freeboard methodology** (Laxon et al, 2004)
 $Fb = \text{height of floes} - \text{height of leads}$

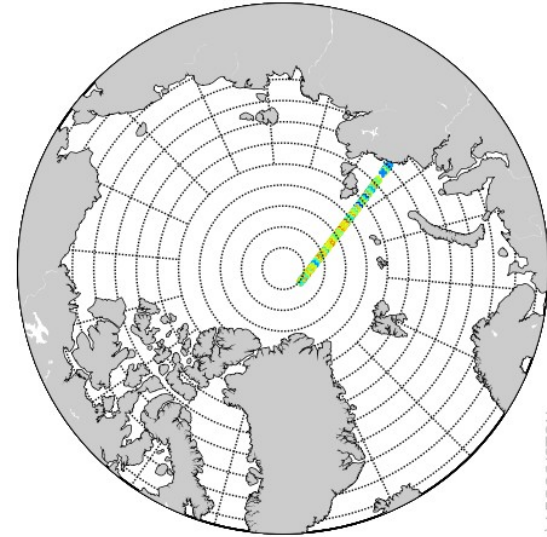


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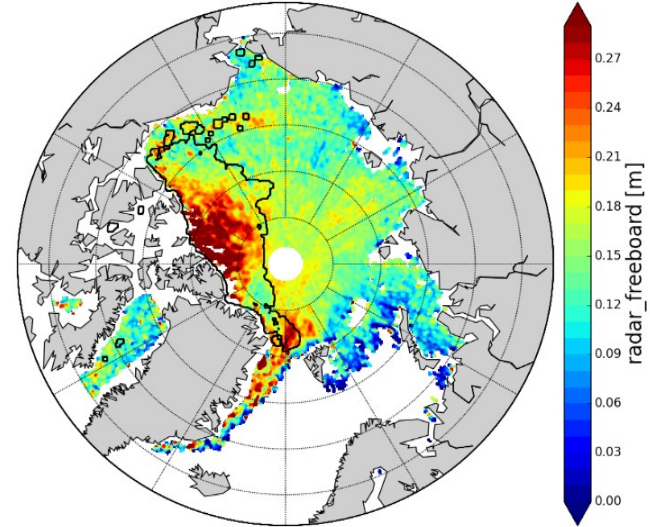
- Along-track freeboard

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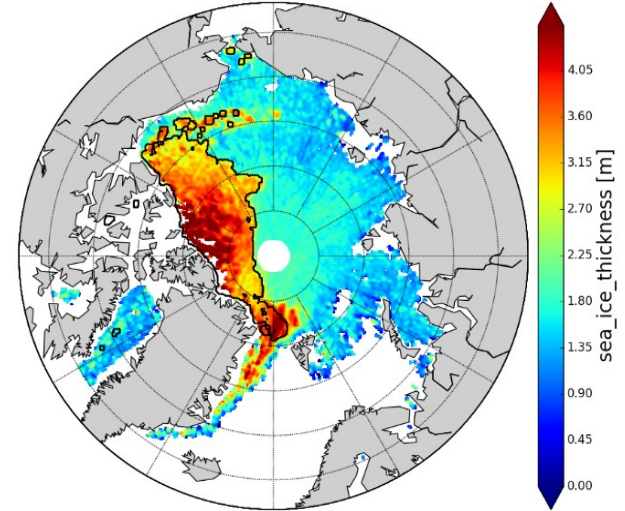


- gridded freeboard



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Methodology



- **Hydrostatic equilibrium** :
- SIT conversion



2. Sources of errors



- **Freeboard to thickness conversion** : Snow depth, Ku penetration, densities etc...

- **Retracking errors**

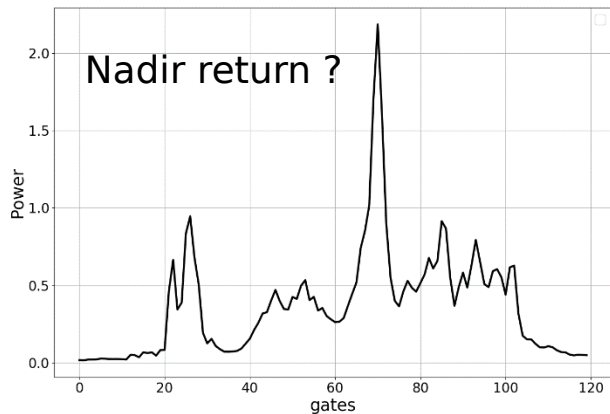
- **Complexity of waveforms : Off-nadir / Side-lobe (only in SAR) -> 2D Retracker**

First peak detection

Hamming

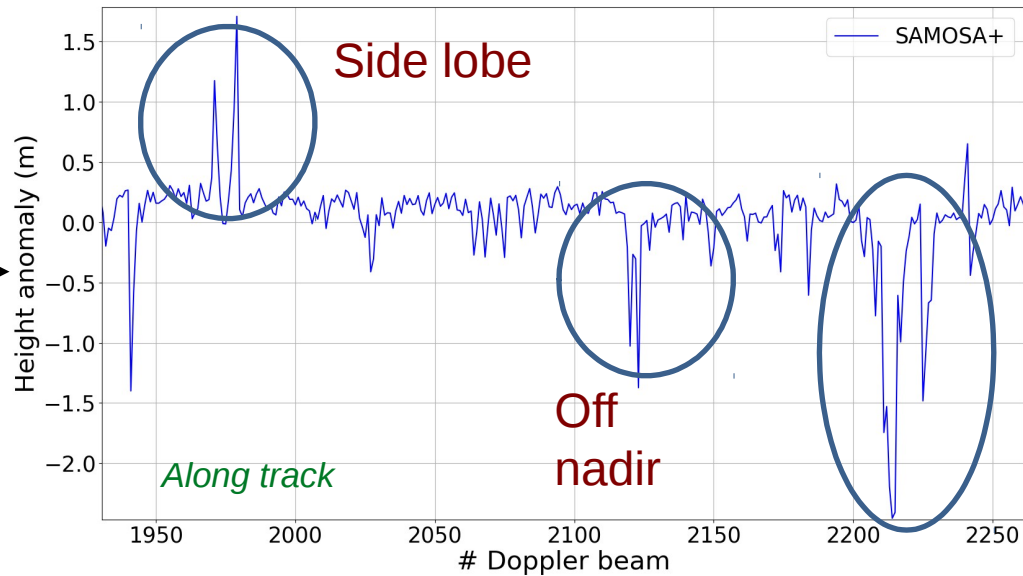


Retracking errors on multi peak waveforms



One waveform

Retracking

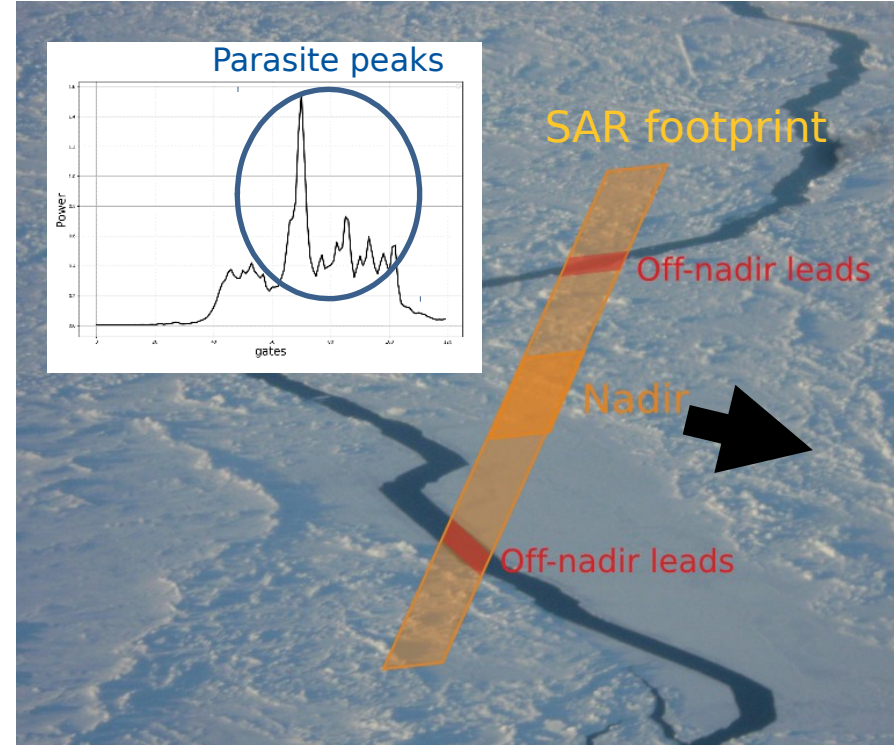




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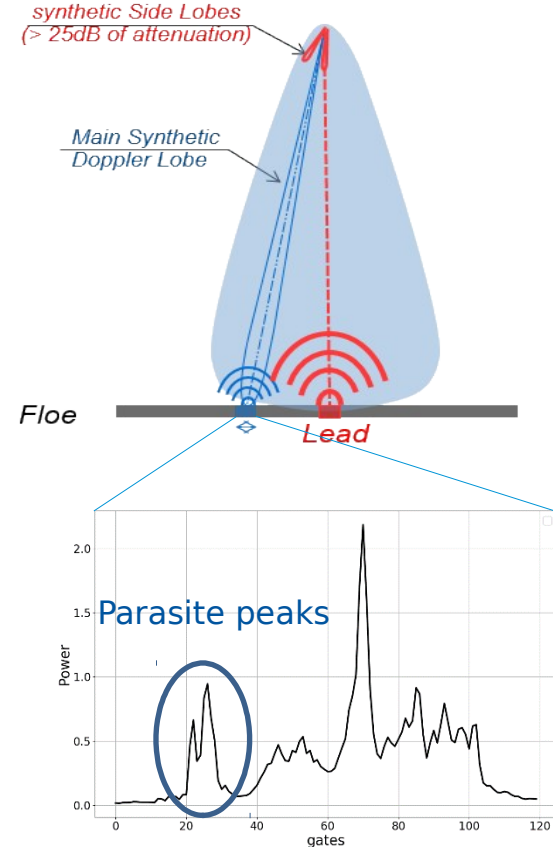
Off-Nadir effects

- Across track highly reflective surfaces (leads)
- Induce parasite peaks behind the Nadir peak



Side Lobe effect

- Specific to SAR mode
- Parasite signal coming from secondary lobes of synthetic antennas
- Produce a **parasite peak in front** of researched **leading edge**





3. R2D Methodology



Observation: the sea ice is globally flat ($\sim 1\text{m}$ of amplitude)

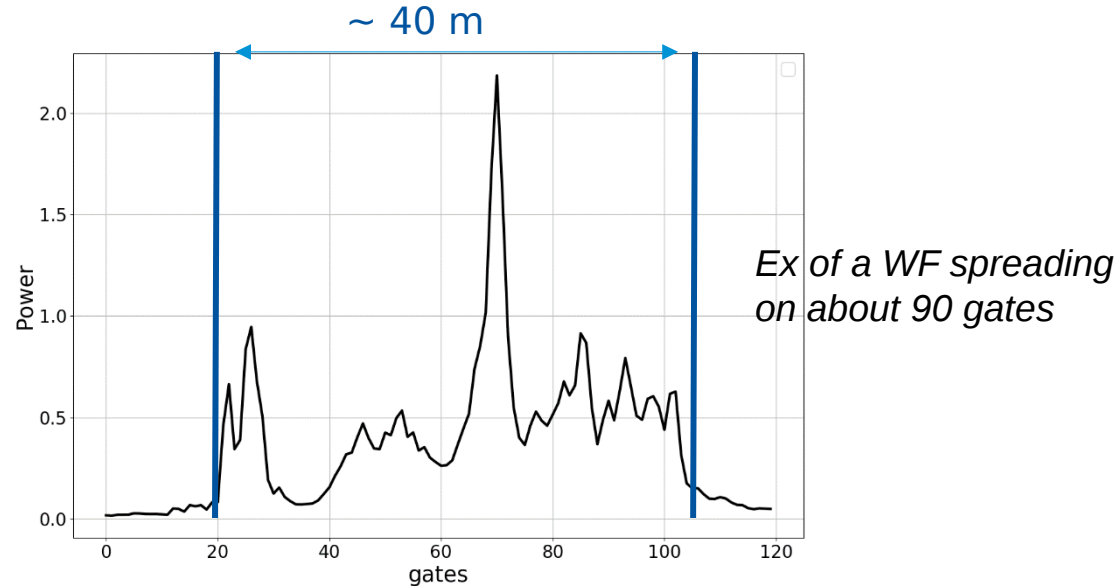


3. R2D Methodology



Objective: Focus the research of the epoch within the waveform (WF) taking into account the small sea ice topography ($\sim 1\text{m}$)

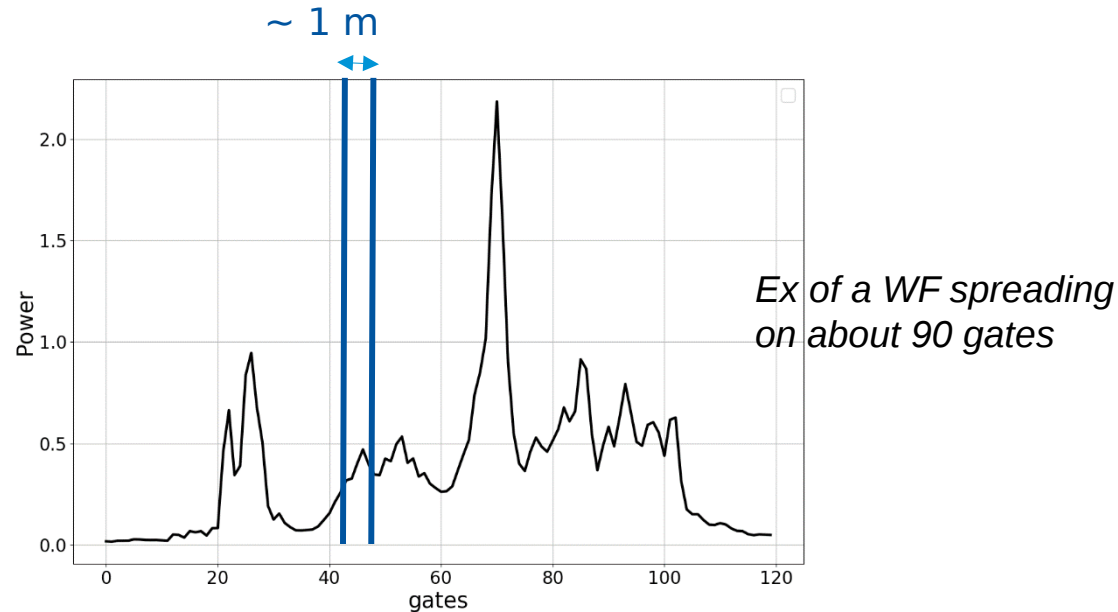
Total WF = 256 gates
 $\sim 125\text{ m}$



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3. R2D Methodology

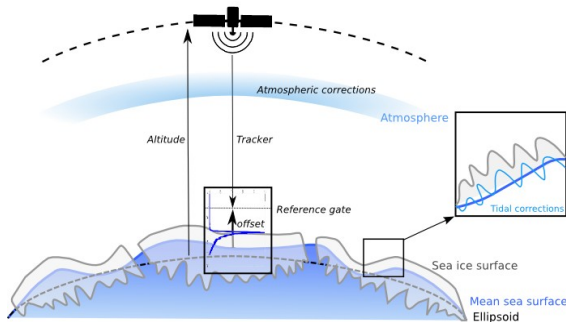


How ? We Align the WF relatively to a same surface reference, the MSS, similarly to what is done to compute the Sea Level Anomaly (SLA):

$$SLA = \text{altitude} - \text{range} - \text{geophysical corrections} - MSS$$

For the waveform :

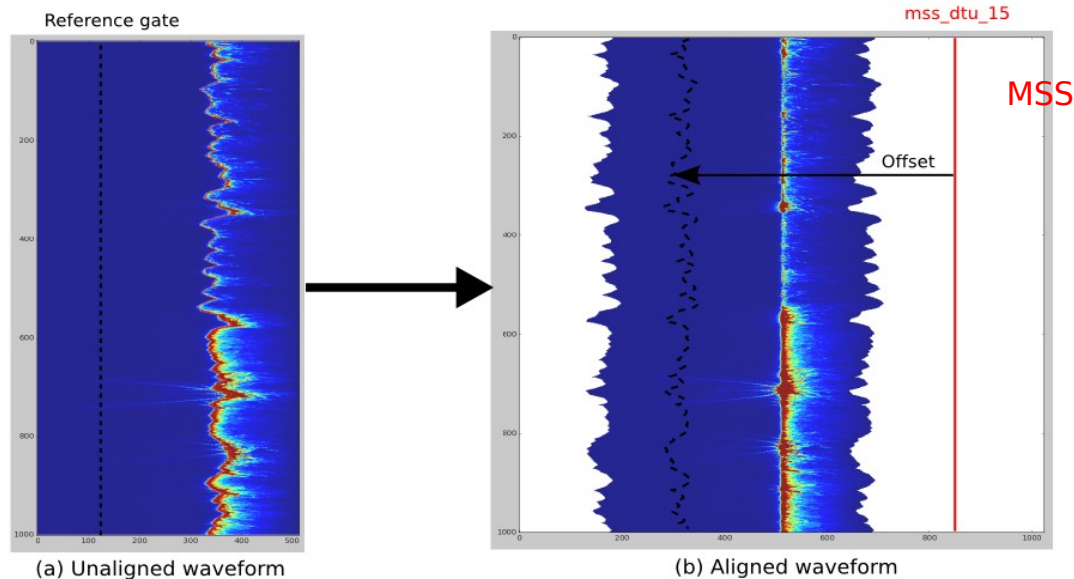
$$WF \text{ Offset} = \text{altitude} - \text{on board tracker} - \text{geophysical corrections} - MSS$$



3. R2D Methodology



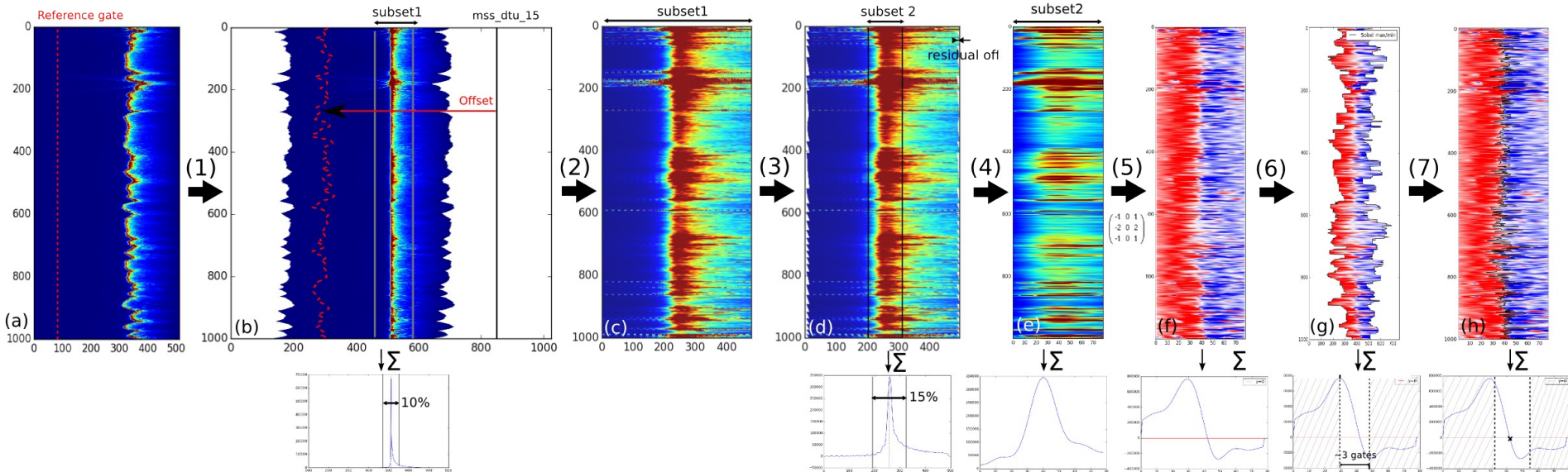
How ? We Align the WF relatively to a same surface reference, the MSS, similarly to what is done to compute the Sea Level Anomaly (SLA):



- R2D extracts the vertical line of max power which correspond to the mean sea ice surface



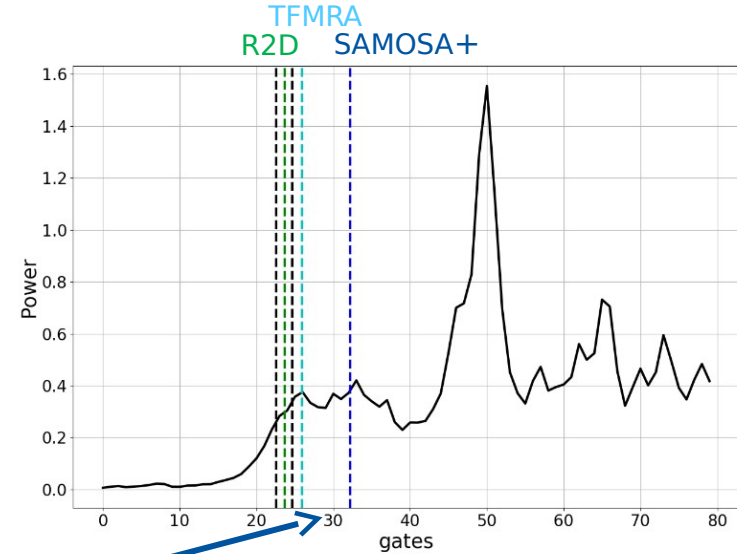
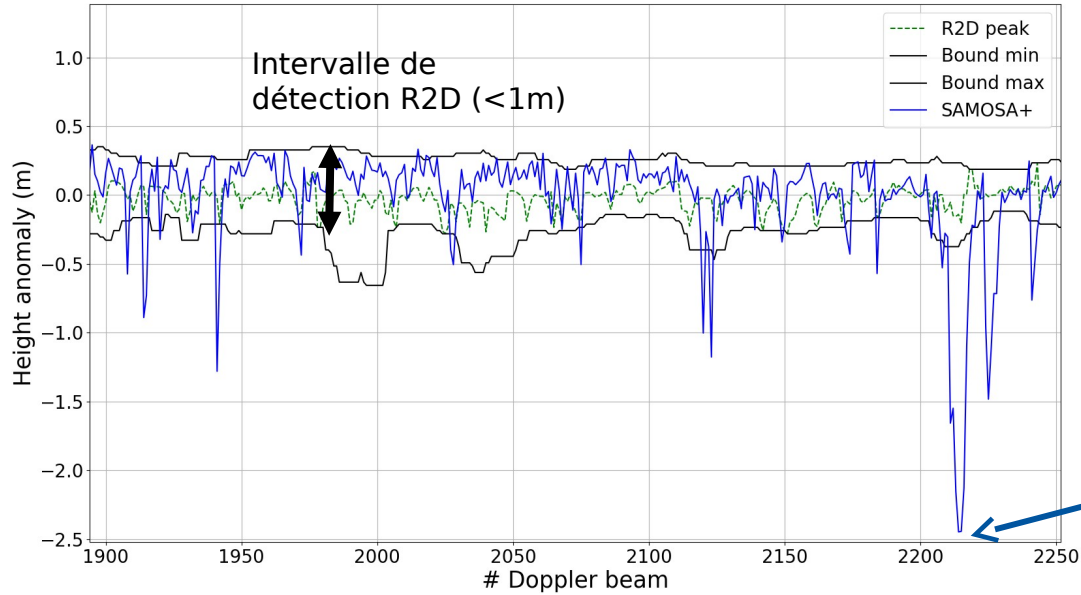
3. R2D methodology



- 1/ WF alignment with the offset integer part (in #gates)
- 2/ Zoom (10%)
- 3/ sub-sampling (down-scaling) and apply the offset residu (in #gates*10)
- 4/ Zoom (15%)
- 5/ Vertical lines detection (Sobel filter)
- 6/ central peak interval
- 7/ peak detection (Sobel = 0)



3. R2D Methodology : Results





3. R2D methodology: Results



2 uses of R2D

- **A posteriori filtering of range outside the R2D interval**
- A Prior constrain on the epoch for retrackers (Currently tested at GPOD)

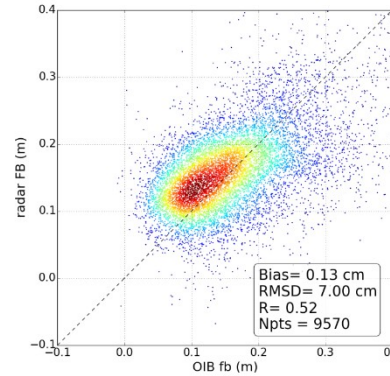


3. R2D methodology : Results

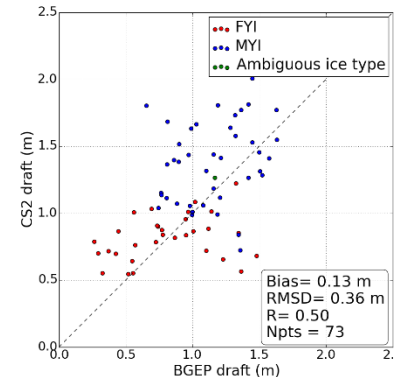
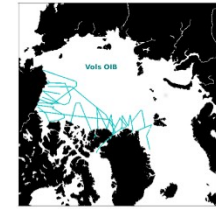


After a postero filtering of SAMOSA+ outputs

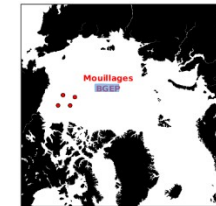
- 15% Off Nadir errors eliminated
- Good results vs in-situ
- CS-2 freeboard product available in Arctic
- at the CTOH and soon AVISO+



Operation IceBridge
(2013, 2014, 2015, 2017)



Beaufort Gyre
Exploration Project
moorings (2013 -2017)





Conclusions



- Fonctionnal algorithm to detect the epoch
 - ✓ No empirical threshold
 - ✓ No Hamming
 - ✓ **Very fast (is applied simultaneously on the whole track)**
- Allow to accurately filter out SAMOSA+ errors (and all retrackers)
 - ✓ Product available at the CTOH (during the CS-2 time period)
- Ongoing work: improving SAMOSA+ solutions

For further informations please contact Sara.fleury@legos.obs-mip.fr



Summary



- 1) Sources of errors
- 2) 2D Retracker methodology
- 3) R2D freeboard calculation
- 4) Conclusion



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