Intercomparison of SAR processings & C2-S3 continuity for sea-ice observation

A. Laforge [1] , S. Fleury [1],
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[1] LEGOS, [2] EUMETSAT, [3] ESRIN

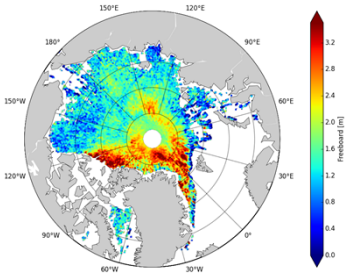
Cryo-SEANICE

Context

- **Goal? :** long series of sea-ice volume observation :
  - An essential climate variable

- **Means? :** Altimetric missions :
  - CryoSat-2/SIRAL (2010-)
    - Polar orbit : < 88°N
    - Gate width ~ 0.47 m
  - Sentinel-3/SRAL (2016-)
    - Orbit : < 81.5°N
    - Gate width ~ 0.43 m

- **How? :** Sea-ice freeboard estimation



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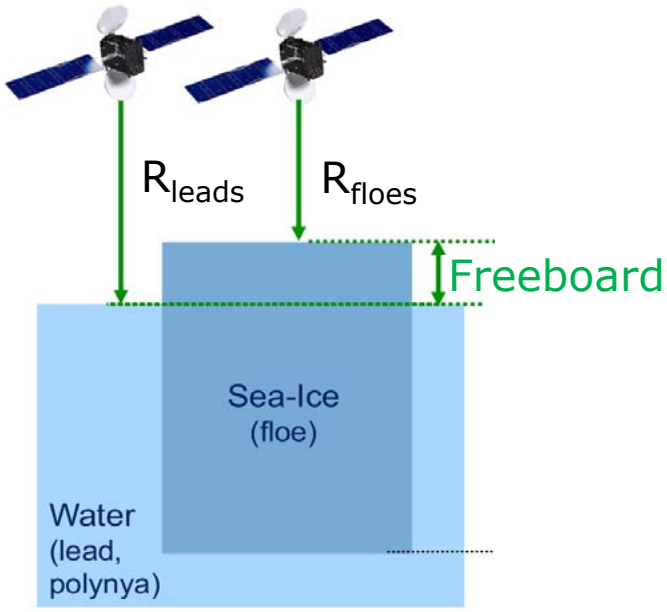
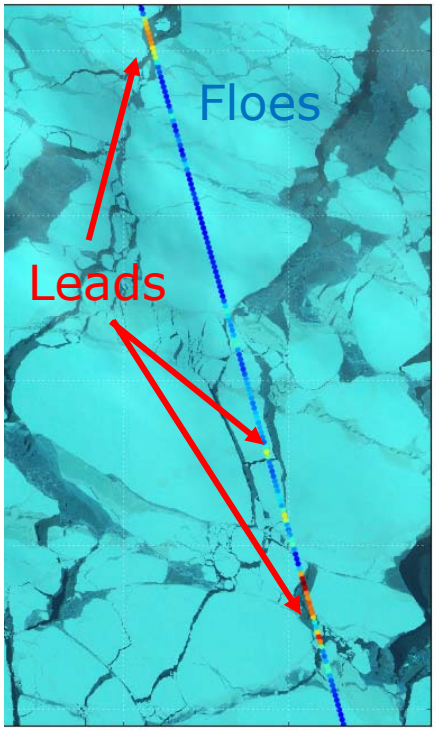
Freeboard estimation method

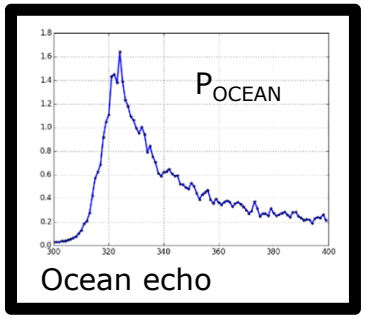


1. Classification of leads/floes
2. Retracking on leads/floes
3. Freeboard = H_{floes} - H_{leads}

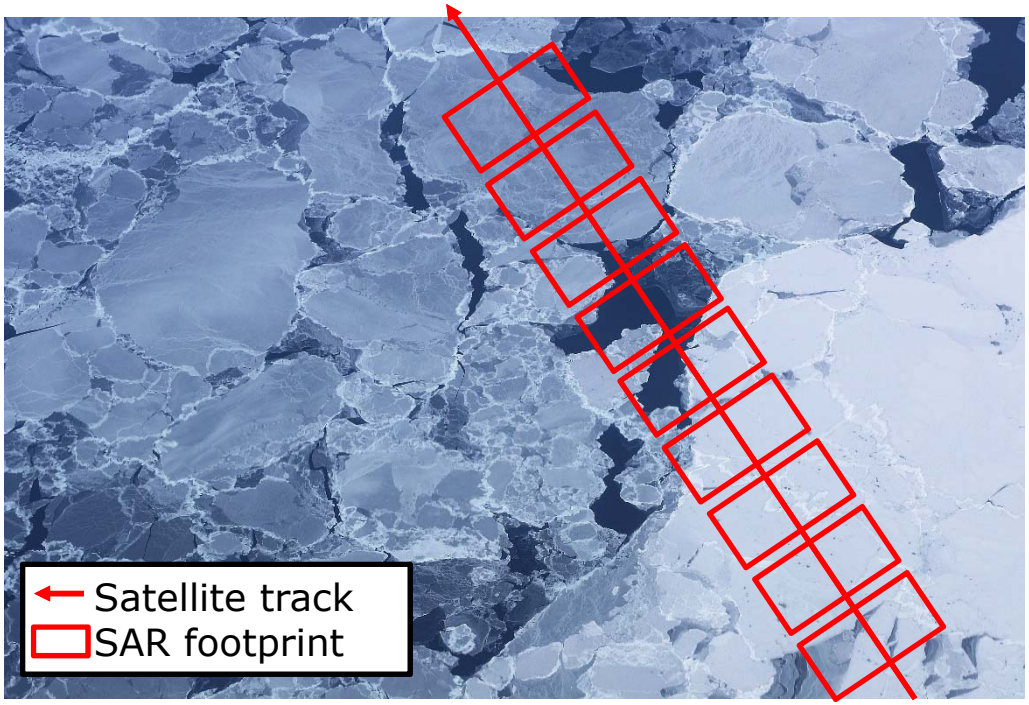


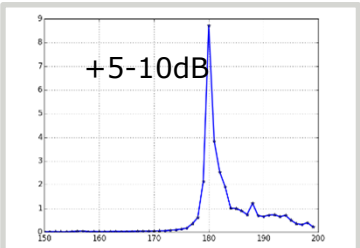
Difficulties

- Specularity difference between ice (floes) and cracks in the ice (leads)

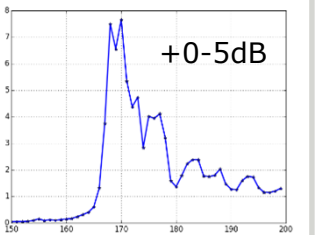


Ocean echo

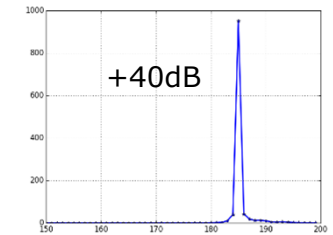




Thin ice echo (FYI)



Thick ice echo (MYI)



Lead echo

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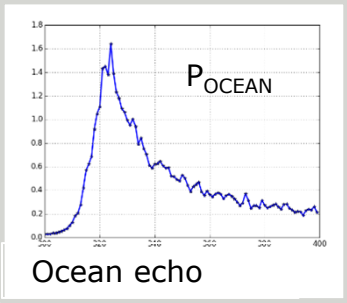

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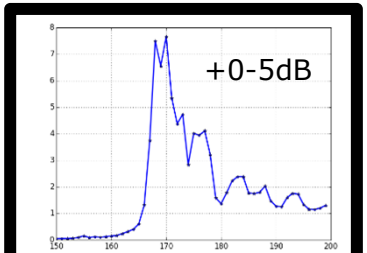

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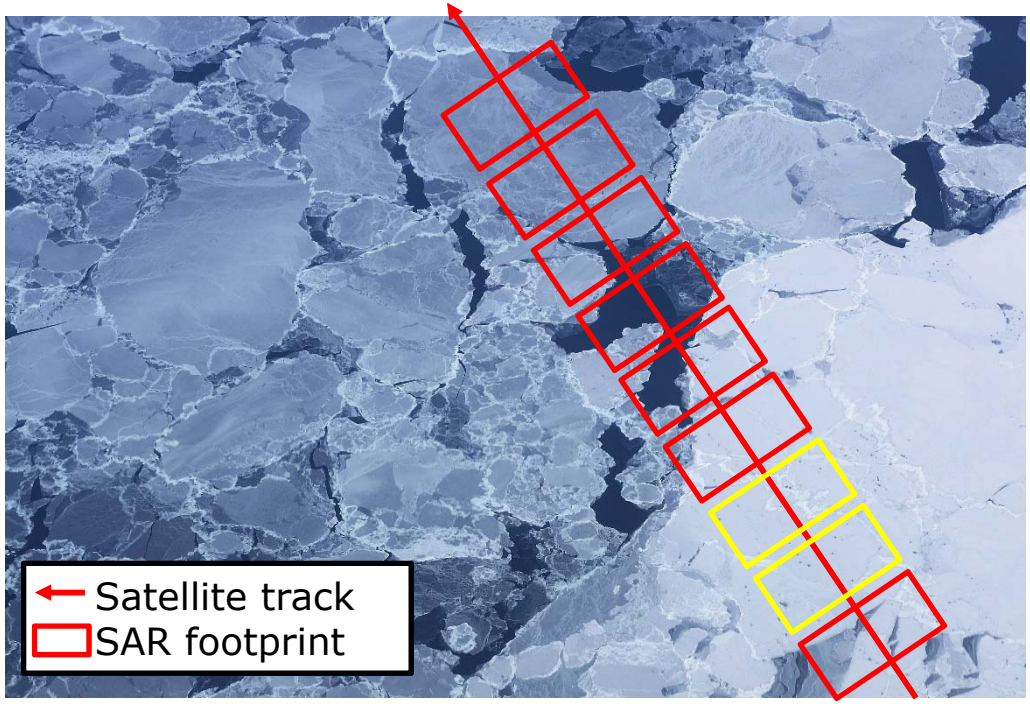

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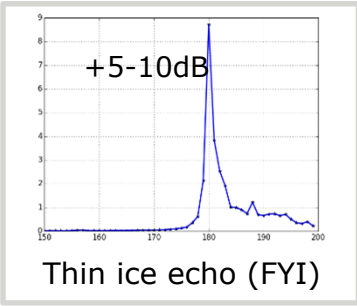

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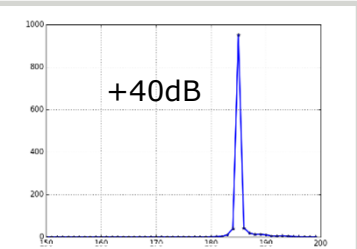

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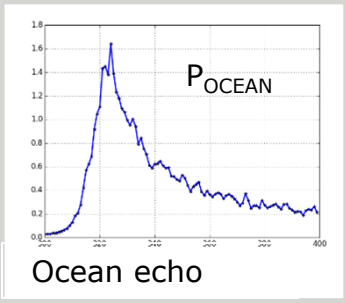

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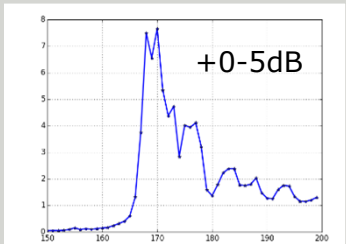

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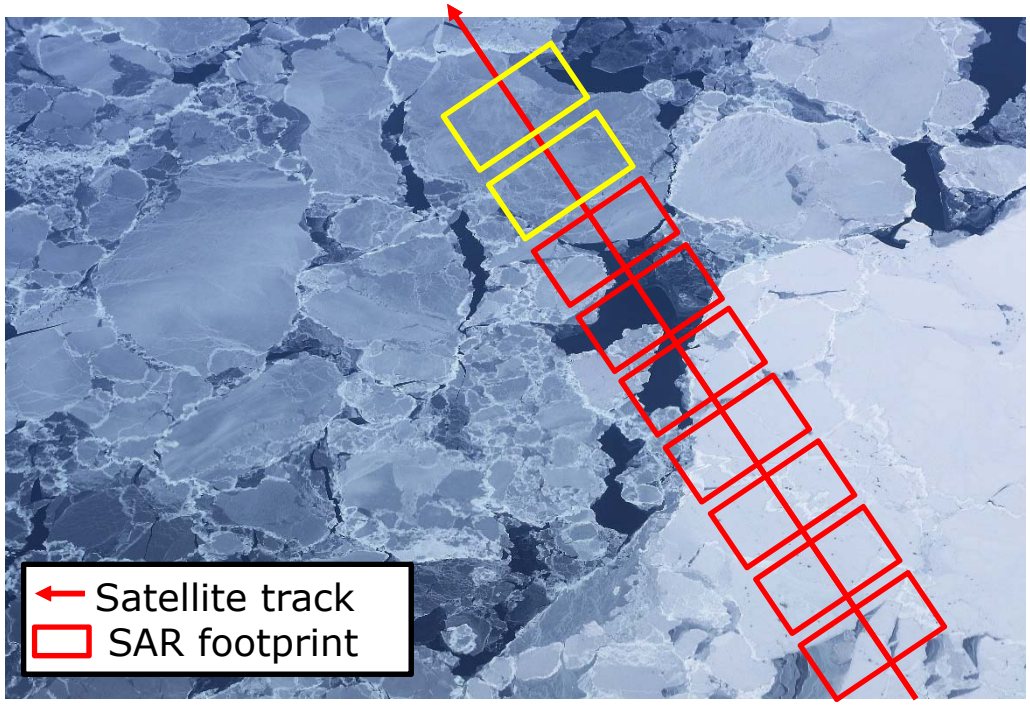

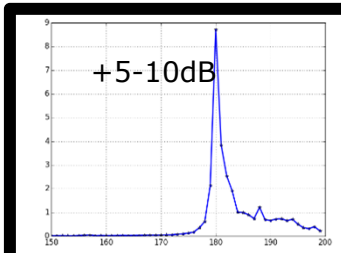

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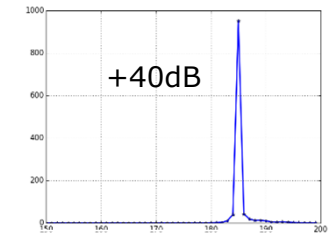

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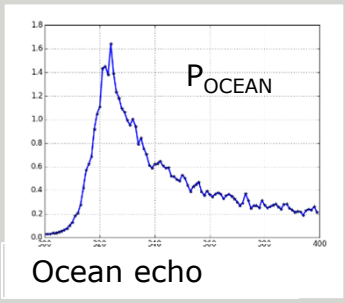

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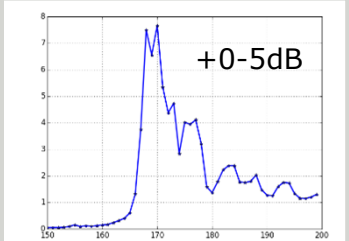

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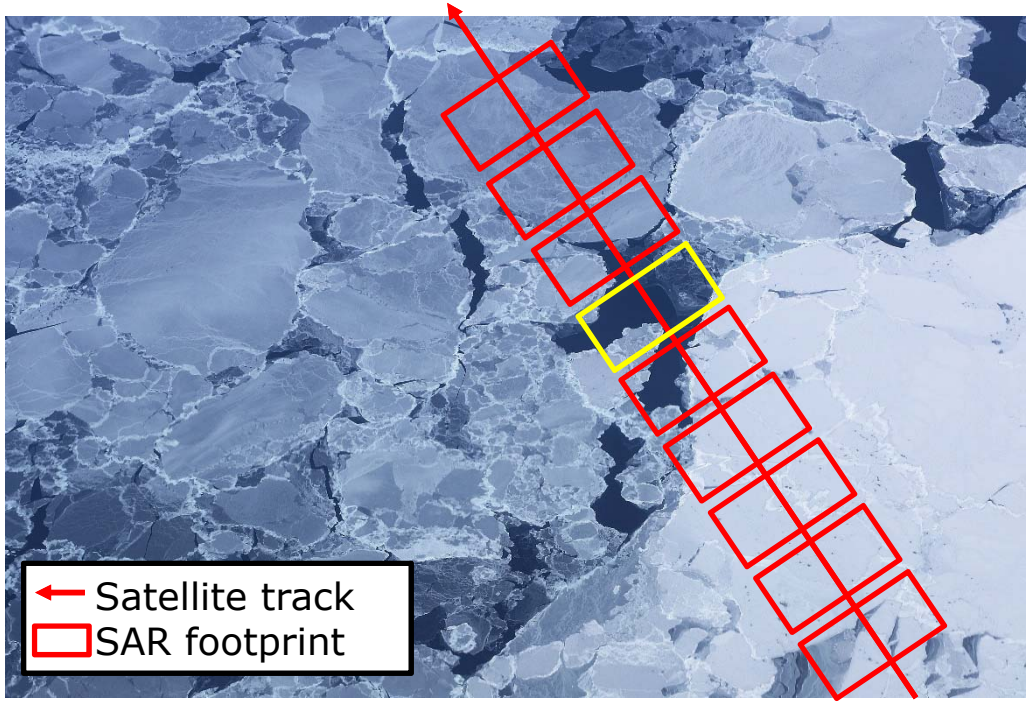

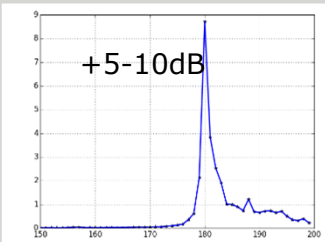

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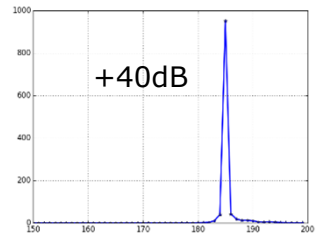
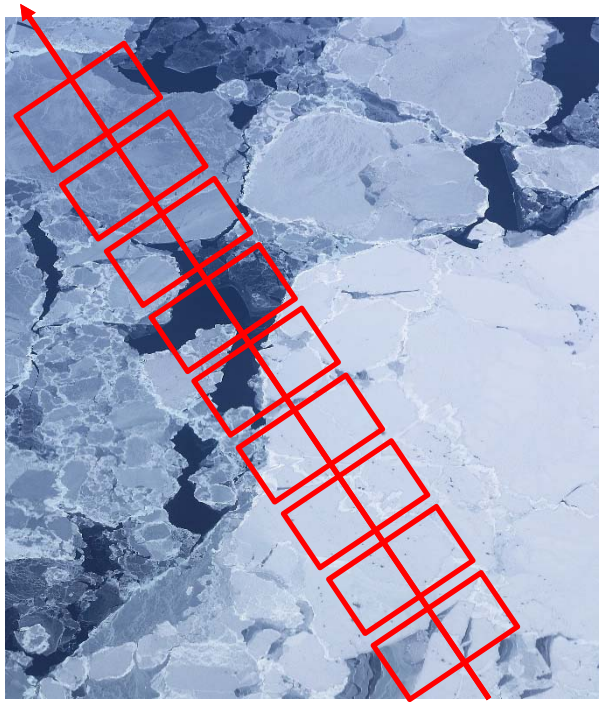


Lead echo

Consequences

- Ocean retrackers (MLE3,MLE4) don’t work on sea-ice
- Lack of resolution on specular waveforms
- Accross-track ambiguity: Off-nadir effect
- Along-track ambiguity : sidelobe effect



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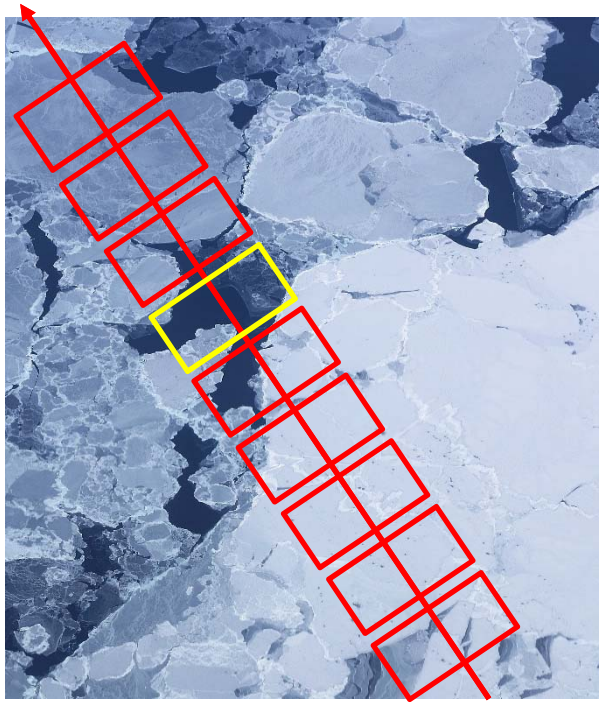

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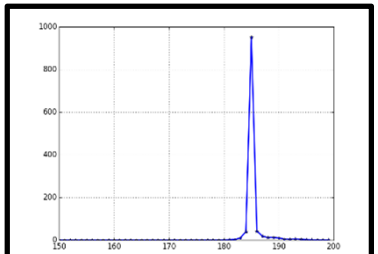

Lead echo

Waveform defined by 1 or 2 samples

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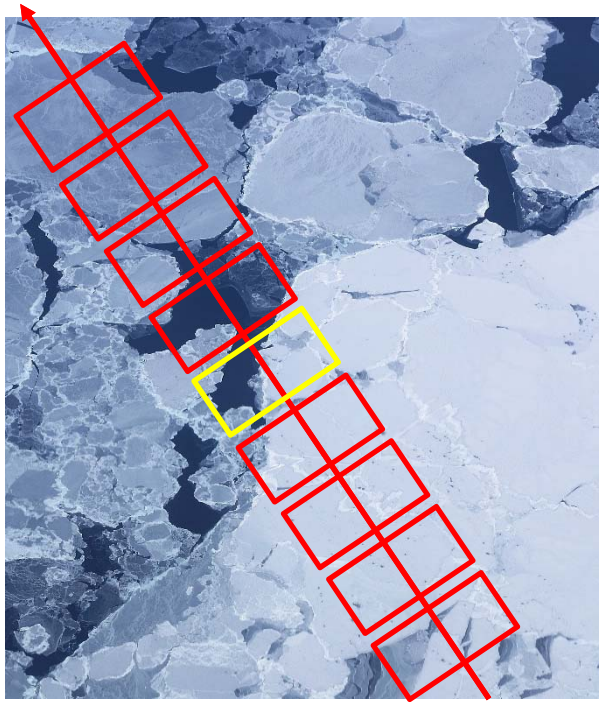

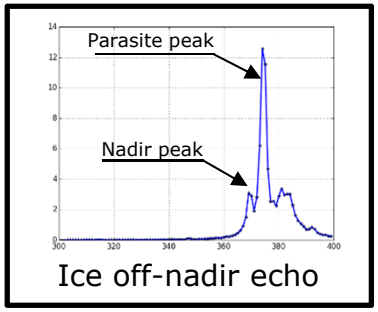

Ice off-nadir echo

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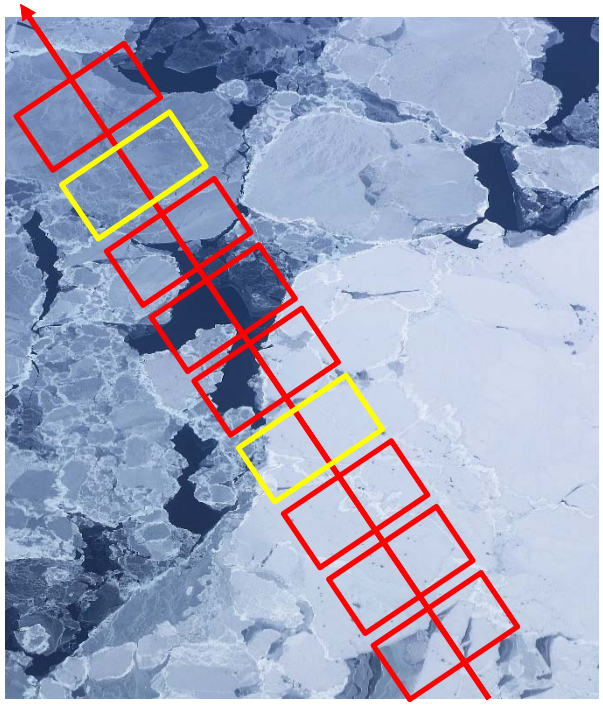

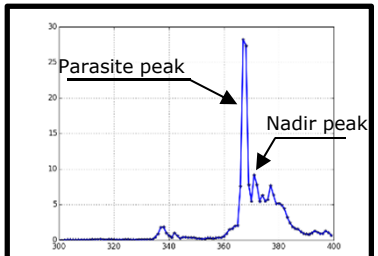

Ice echo parasited by adjacent leads

Technical solutions

- Ocean retrackers (MLE3,MLE4) don’t work on sea-ice
- Lack of resolution on specular waveforms
- Accross-track ambiguity: Off-nadir effect
- Along-track ambiguity : sidelobe effect

Technical solutions

- Ocean retrackers (MLE3,MLE4) don't work on sea-ice

→

Adapted retrackers :

- Heuristic : Ice1, OCOG, TFMRA (AWI)
- Model based : IceNew (CLS), SAMOSA+ (GPOD-ESA)

- Lack of resolution on specular waveforms
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Technical solutions

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  - First peak detection algoritms (TFMRA)
  - Other filtering techniques
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- Lack of resolution on specular waveforms →
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  - First peak detection algoritms (TFMRA)
  - Other filtering techniques
- Along-track ambiguity : sidelobe effect →
  - Hamming window
  - RIP line detection method (RLD)(1)

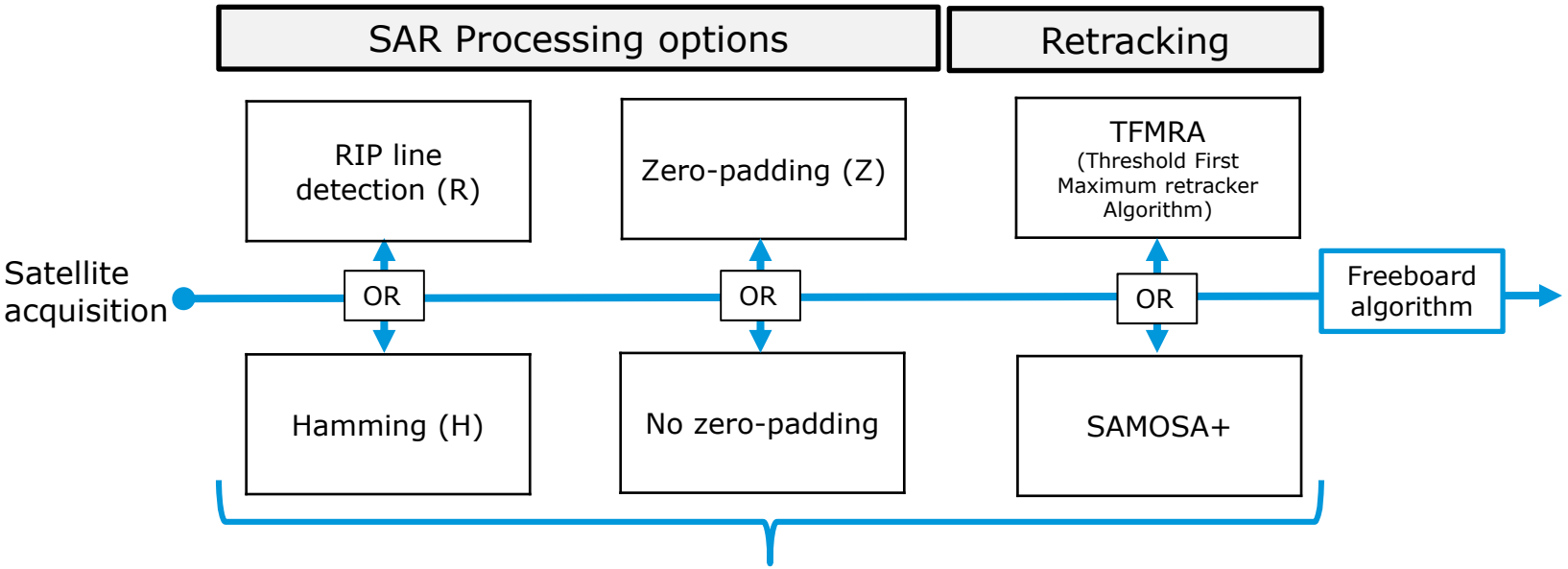
(1) (Laforge et al, 2018 in preparation)

Technical solutions

- Ocean retrackers (MLE3,MLE4) don't work on sea-ice →
  Adapted retrackers :
  - Heuristic : Ice1, OCOG, **TFMRA** (AWI)
  - Model based : IceNew (CLS), **SAMOSA+** (GPOD-ESA)
- Lack of resolution on specular waveforms →
  - **Zero-padding** (order 2)
- Accross-track ambiguity: Off-nadir effect →
  - First peak detection algoritms (**TFMRA**)
  - Other filtering techniques
- Along-track ambiguity : sidelobe effect →
  - **Hamming window**
  - RIP line detection method (RLD)[1]

[1] (Laforge et al, 2018 in preparation)

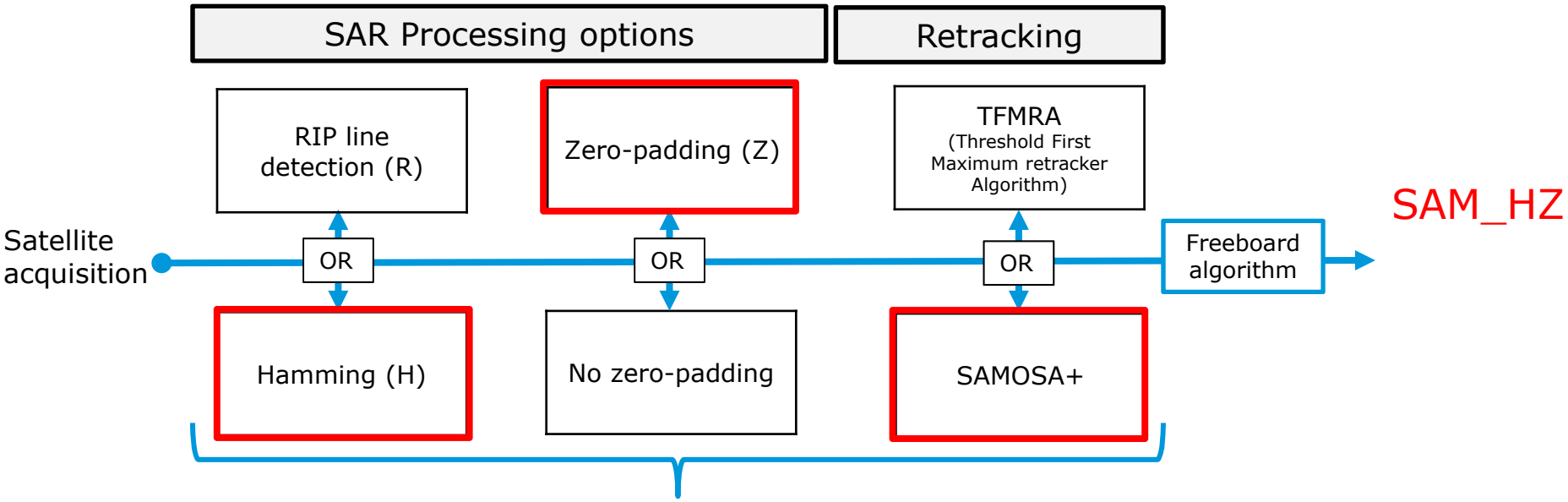
Production of freeboard solutions



*GPOD processing plateform (*https://gpod.eo.esa.int/*)*

g-pod
grid processing on demand

Production of freeboard solutions



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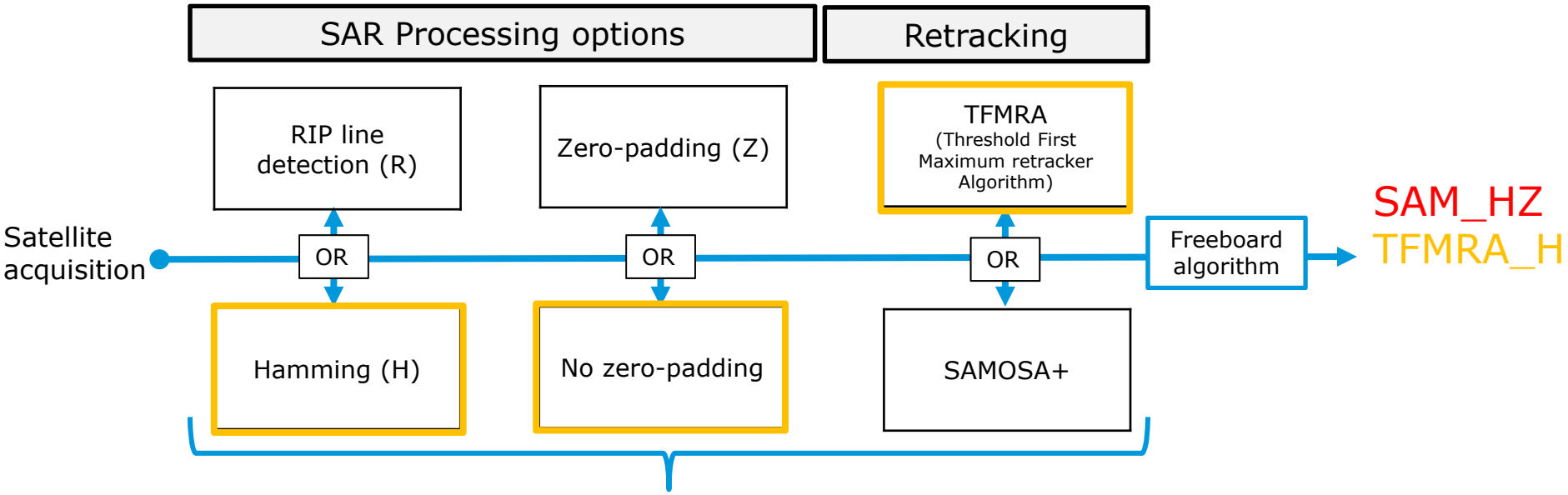

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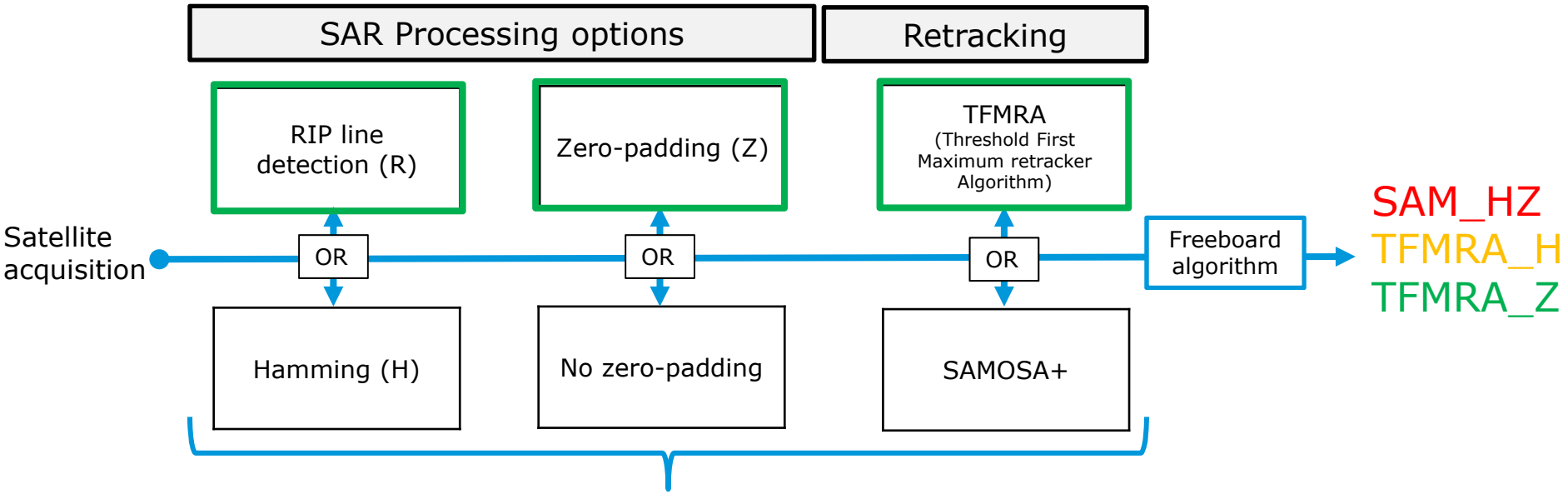

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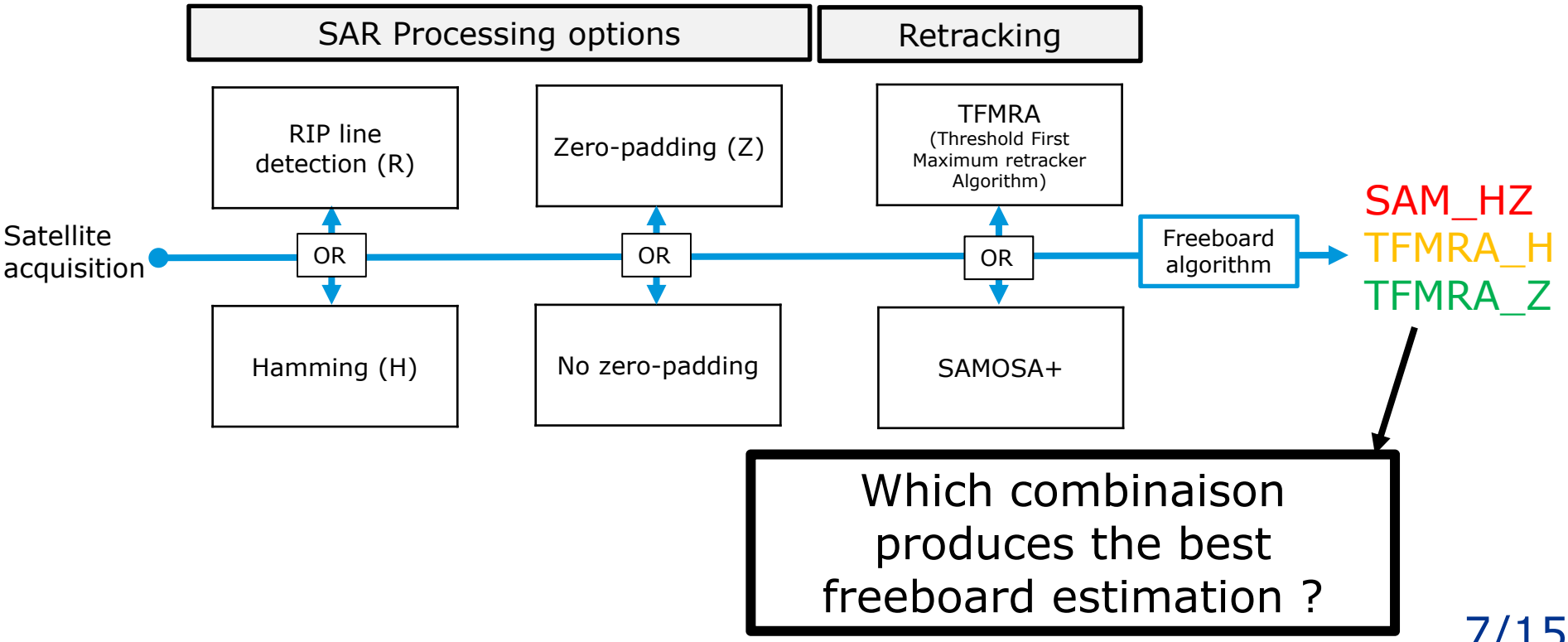
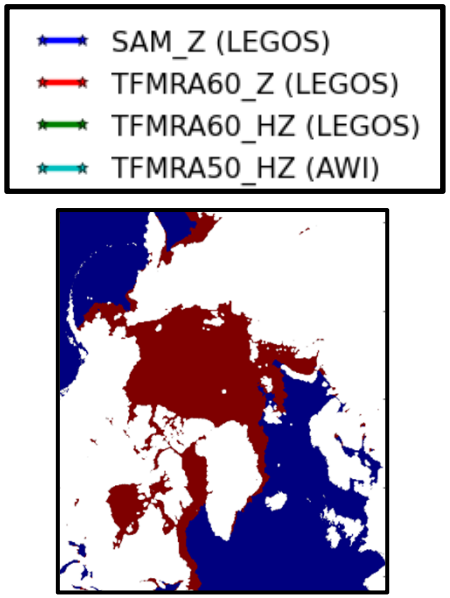
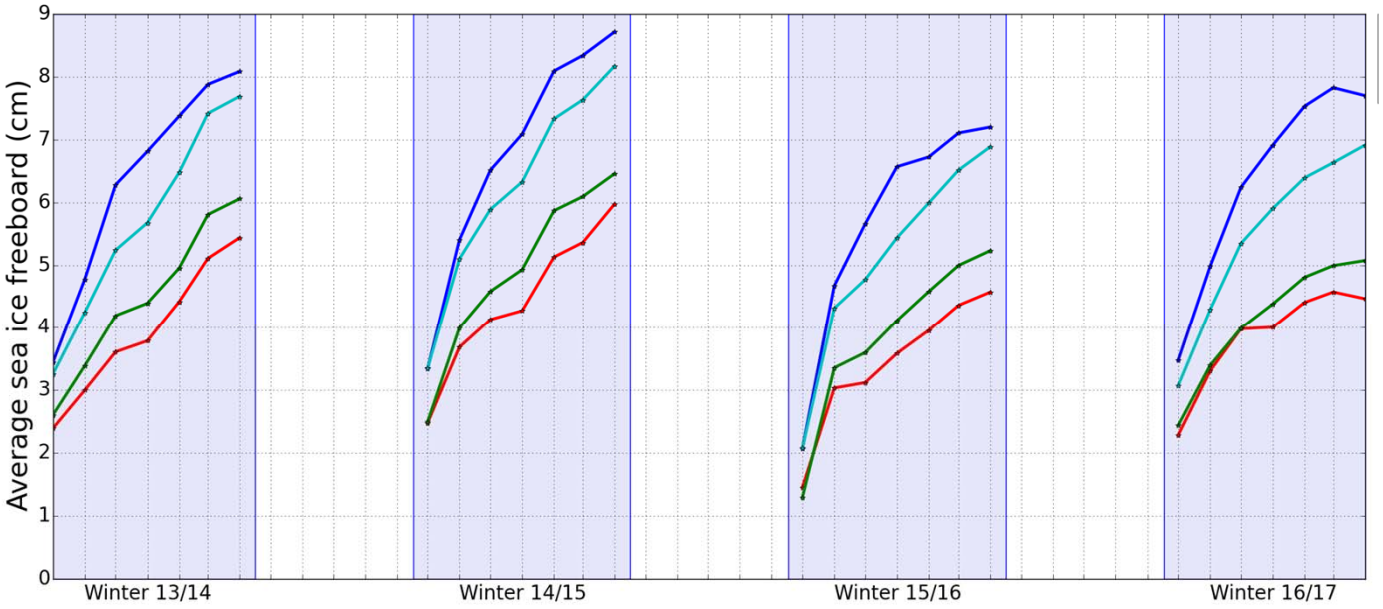


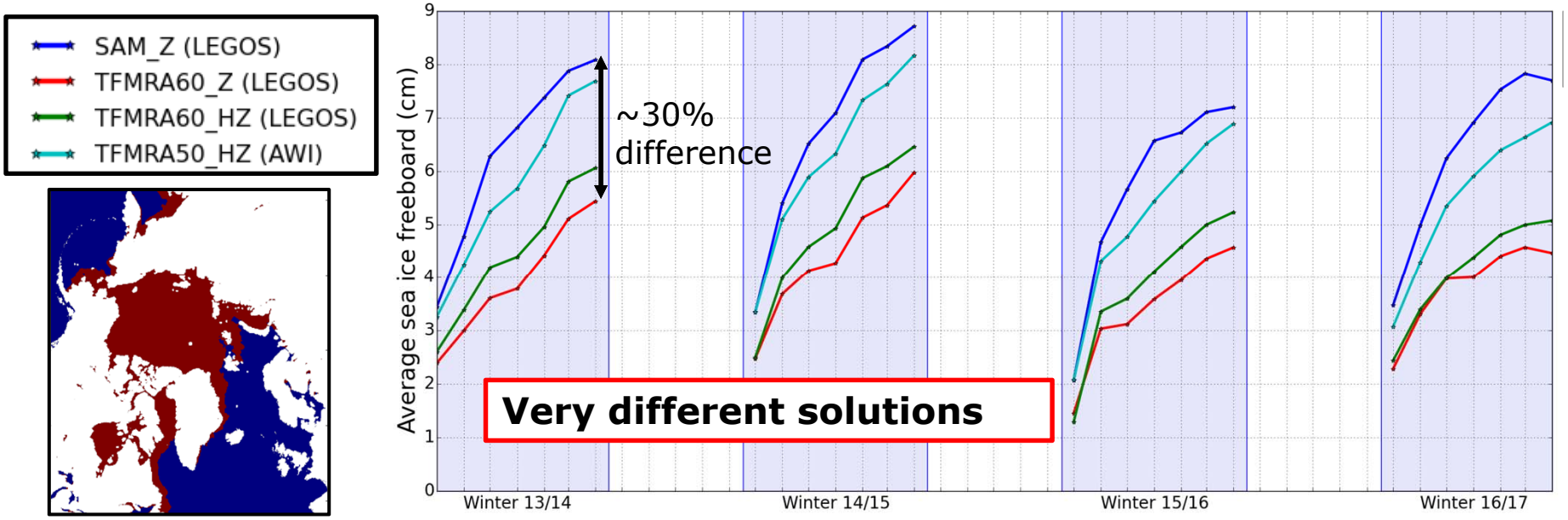
Freeboard solutions for Cryosat-2





Temporal series of observed freeboard (2013 – 2017)

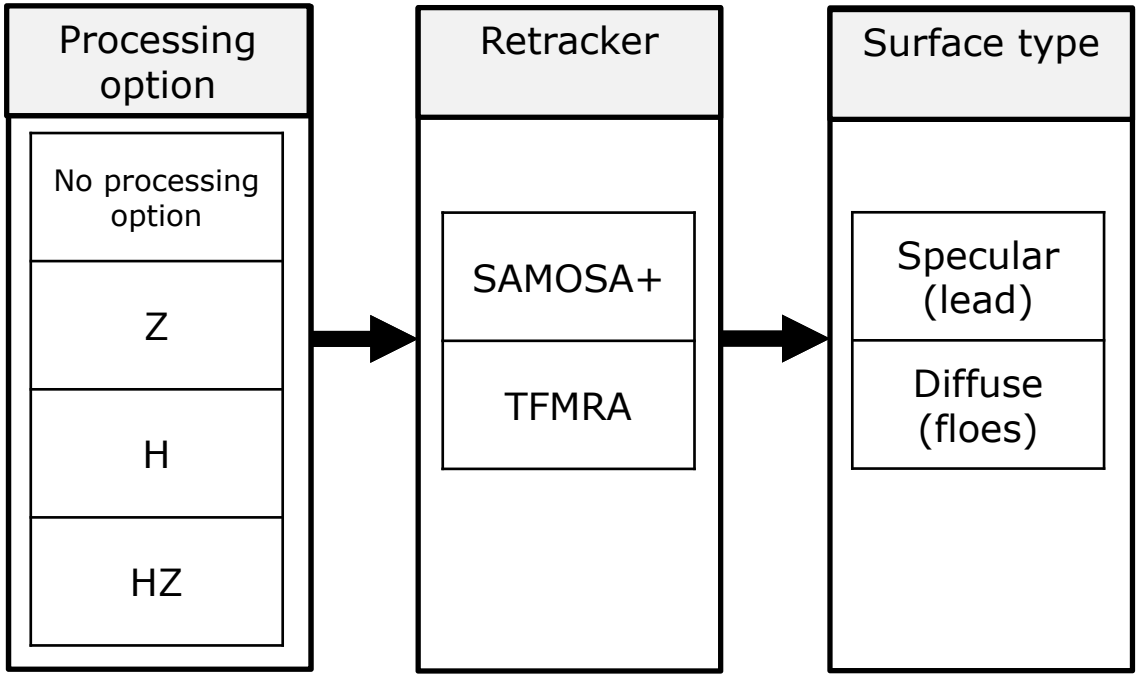
Various freeboard solutions for Cryosat-2



Temporal series of observed freeboard (2013 – 2017)

Method of analysis

Example : Impact of the **Hamming** with **TFMRA** over diffusive surfaces (**floes**)



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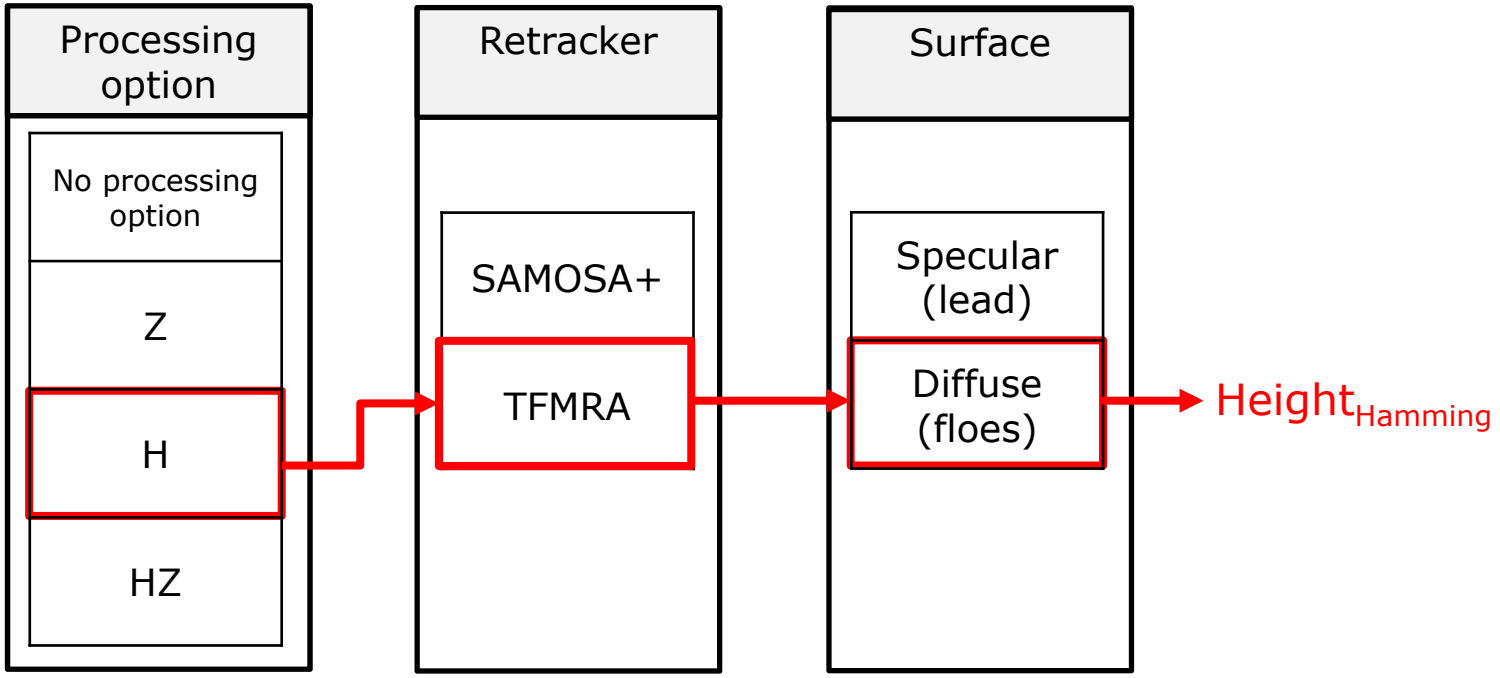

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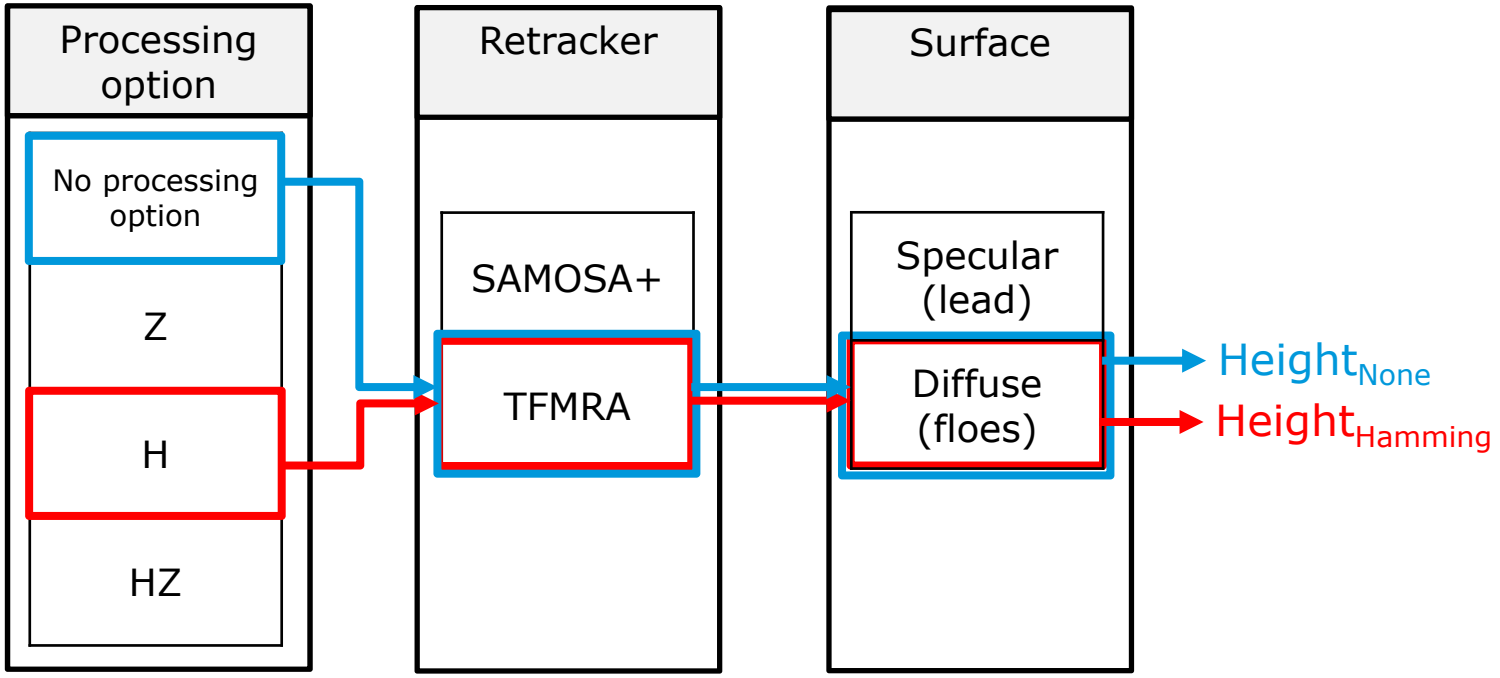

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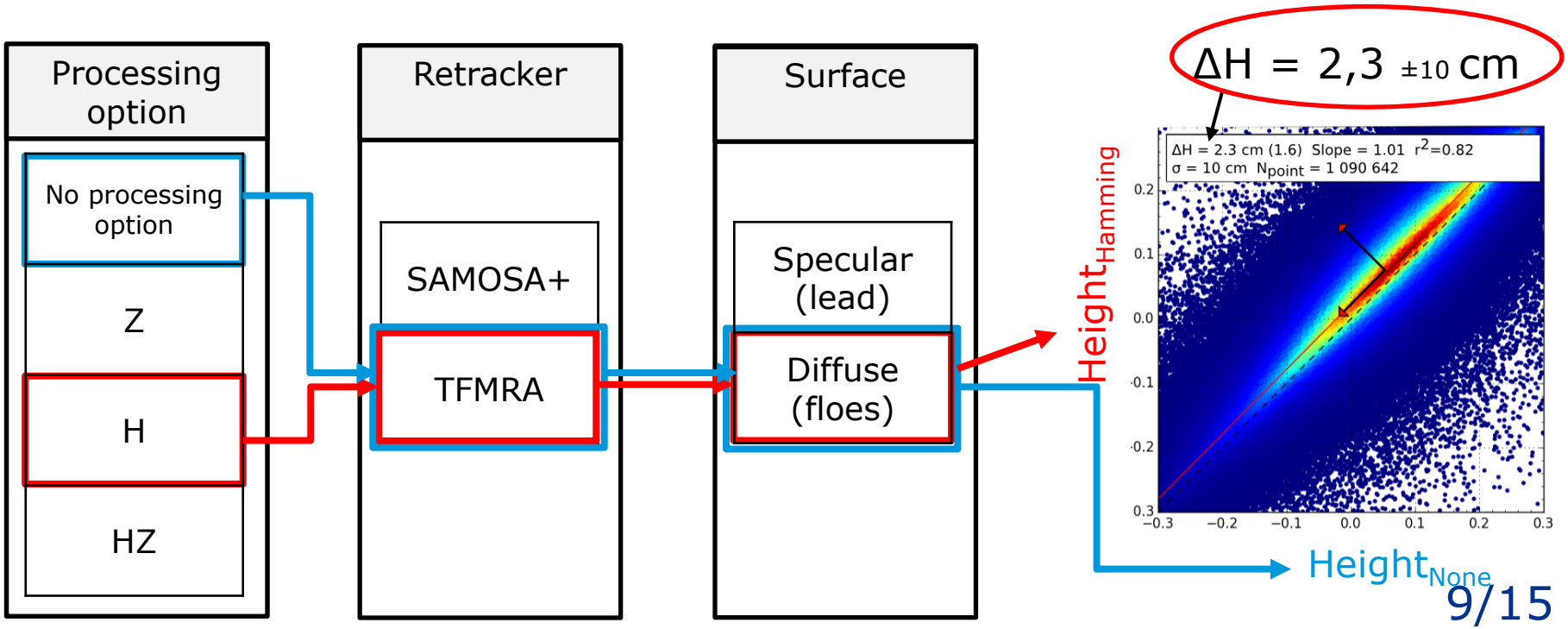


Results

Required precision : ± 1 cm (~10%)

Bias (cm)	TFMRA			SAMOSA+		
	ΔH_{floes}	ΔH_{leads}	ΔFB	ΔH_{floes}	ΔH_{leads}	ΔFB
Z vs N	-3.2 (±10)	-1.9 (±9)	-1.3	0 (±10)	-1.3 (±9)	1.3
H vs N	2.3 (±10)	0 (±9)	2.3	0.3 (±10)	-6 (±9)	6.3
HZ vs Z	2.1 (±10)	0.6 (±6)	1.9	-0.4 (±10)	-1.6 (±7)	2

Summary table of the various impacts of the SAR processing options on the retracking for each surface (leads/floes)

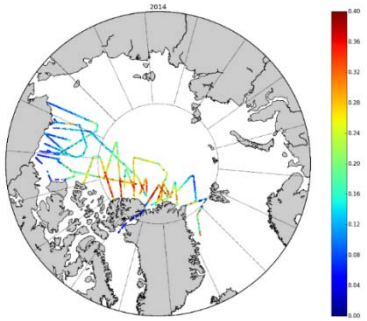
IceBridge comparisons

Nasa's Operation Icebridge :

Aeroported mission taking place every spring

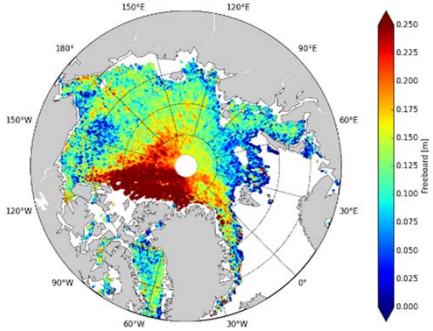
(April 2009-2017)

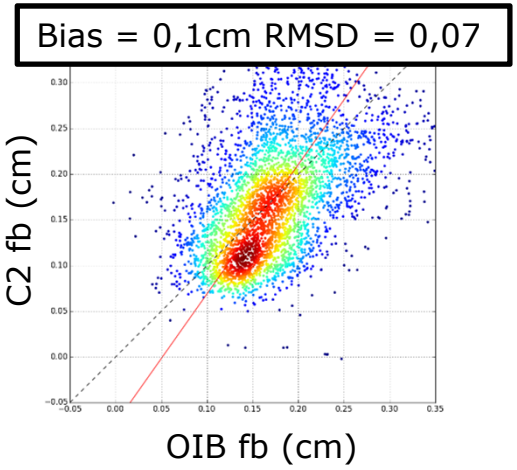
Ice freeboard corrected from Ku-slowdown in snow layer



Cryosat-2 freeboard map :

SAMOSA+/Z





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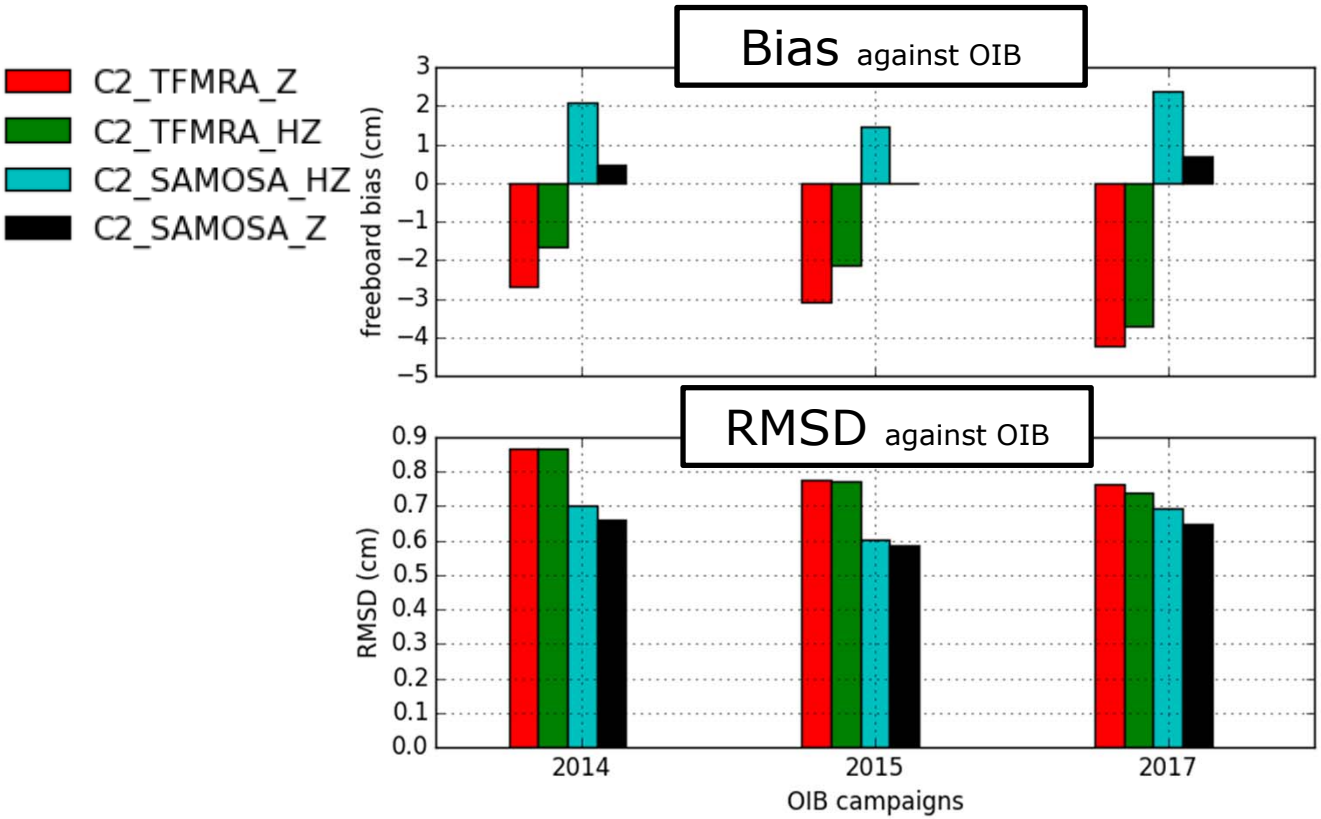
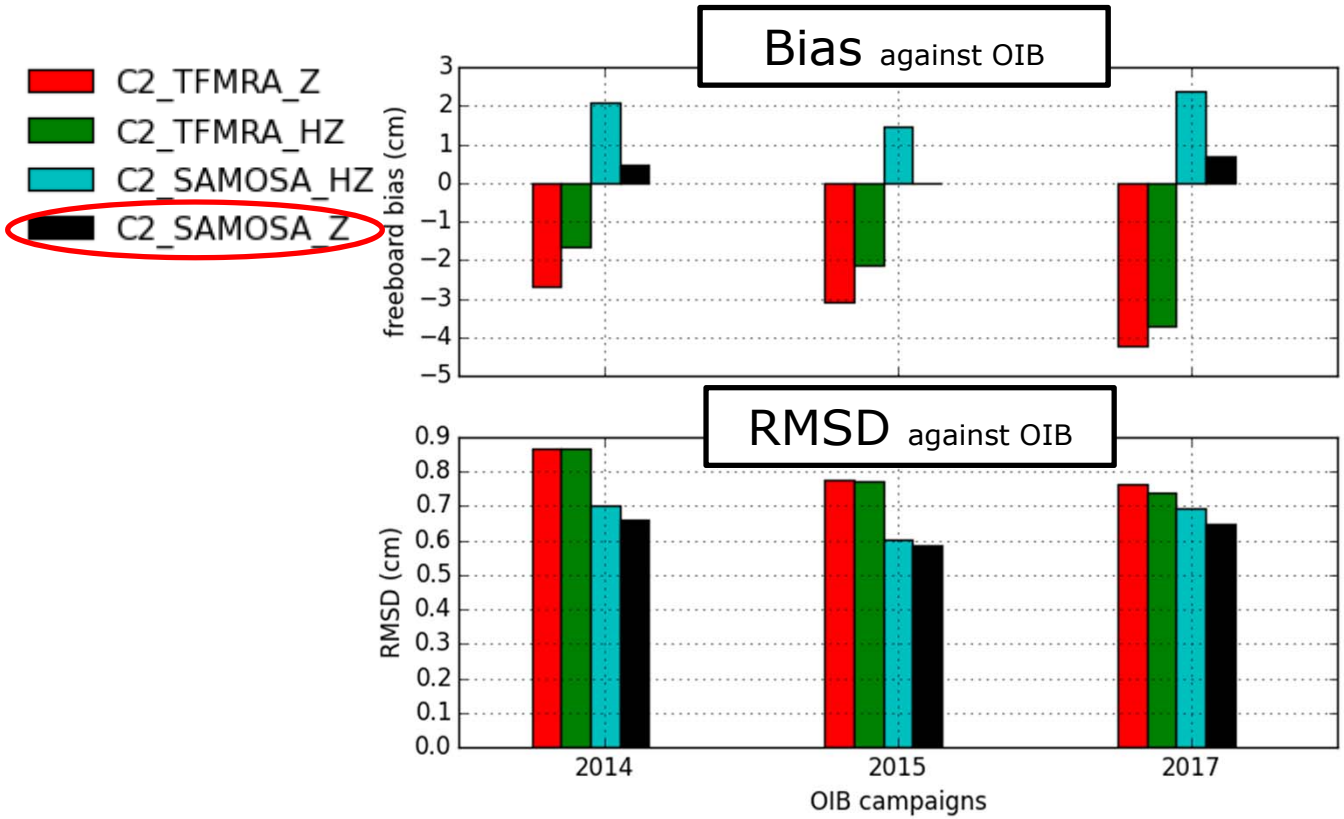
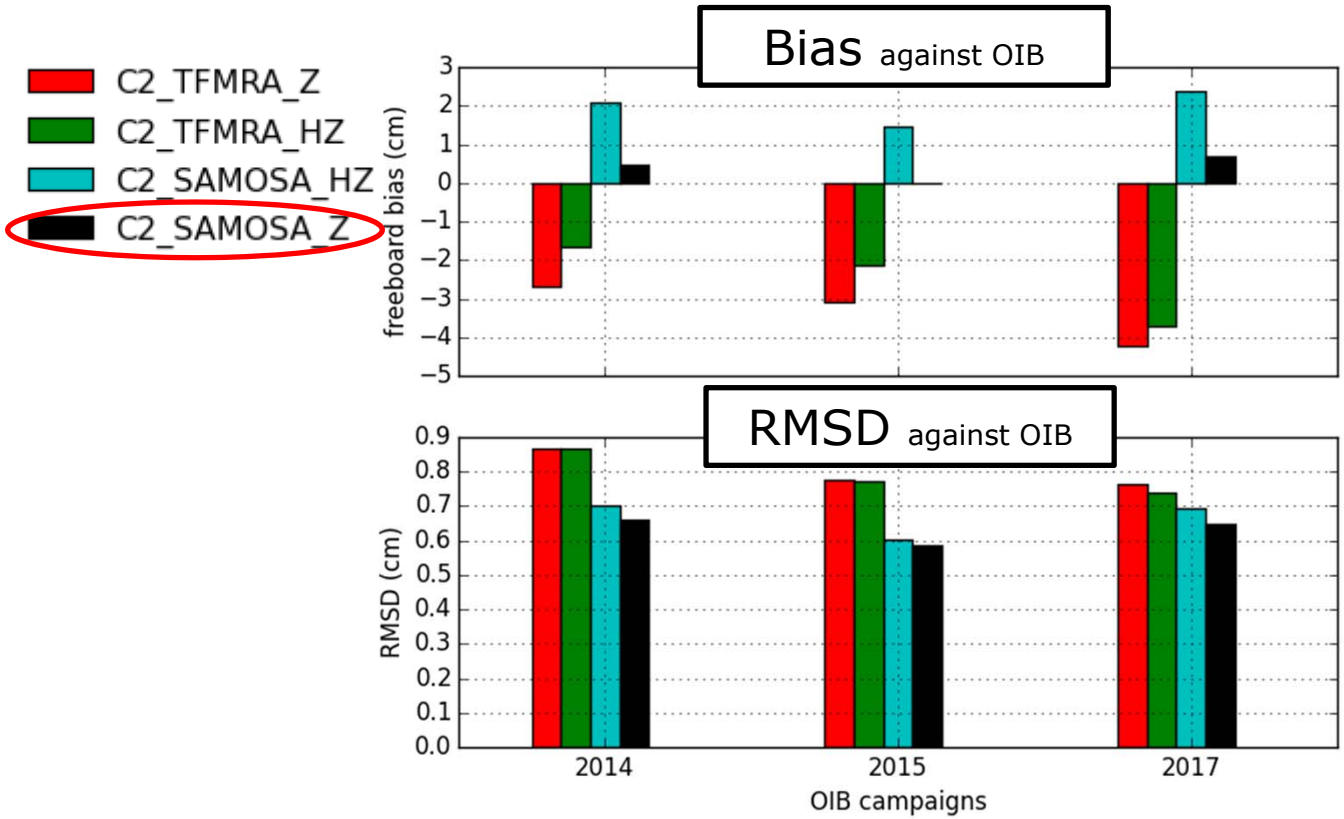


IceBridge comparisons



IceBridge comparisons



IceBridge (QL) uncertainties:

(Farrell and al, 2012)
(Webster et al, 2014)

$\varepsilon_{\text{snow-depth}}$ = 5,7 cm

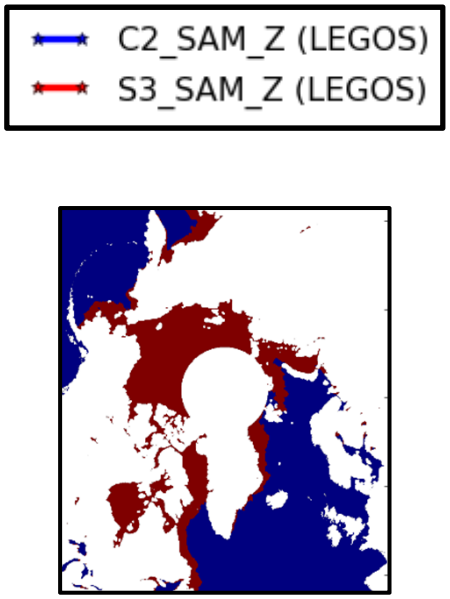
$\varepsilon_{\text{freeboard-total}}$ = 1,4 cm

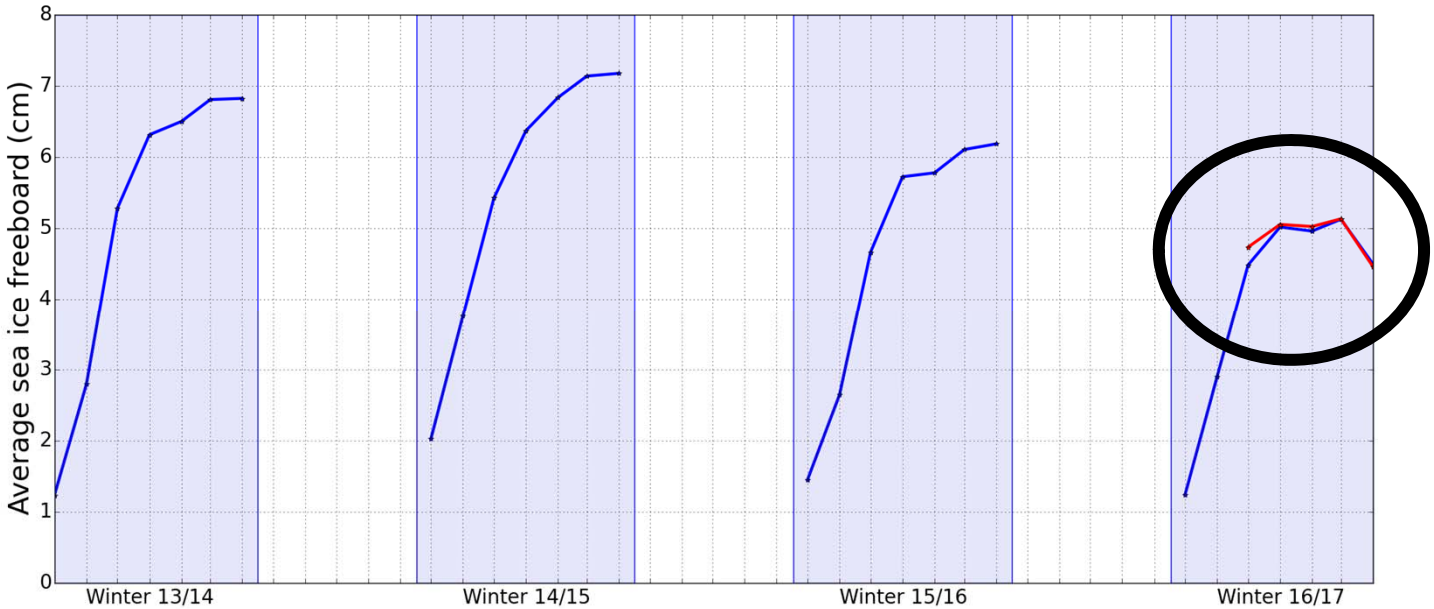
$\varepsilon_{\text{freeboard-ku}}$ = 5,9 cm

Eq : $FB_{Ku} = FB_T - SD - (1-\alpha)SD$

CryoSat-2 – Sentinel-3 continuity

- Continuity CryoSat-2 • Sentinel-3 acquired with (best) solution

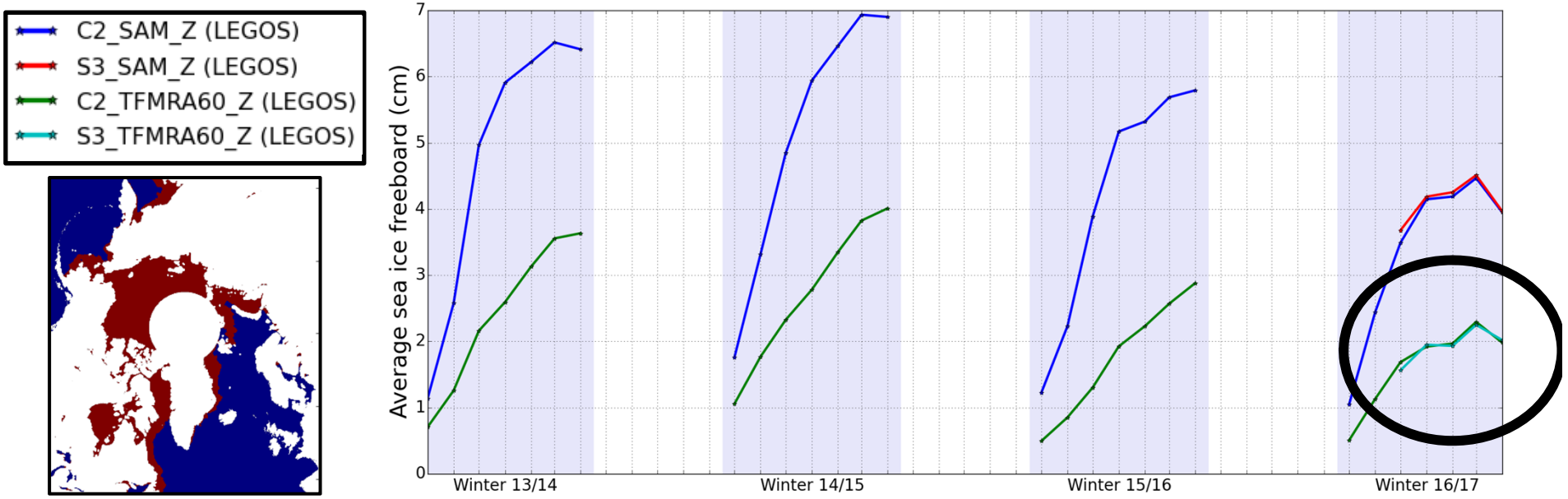




Temporal series of observed freeboard (2013 – 2017)

CryoSat-2 – Sentinel-3 continuity

- Continuity CryoSat-2 • Sentinel-3 ALSO acquired with other solution



Temporal series of observed freeboard (2013 – 2017)

Conclusions & perspectives

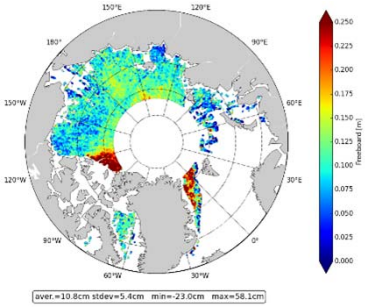
Conclusions

1. Sentinel-3 is able to ensure the continuity of Cryosat-2 for freeboard retrieval up to 81.5°N
2. High need for basin-scale observation of snow depth for sea-ice thickness monitoring and products validation
3. Zero-padding (order 2) is always beneficial [1]
4. Good hopes in the ability of SAMOSA+ to provide an accurate retracking on sea-ice
5. SAMOSA+ works on coastal (*Dinardo et al, 2018*) and open ocean regions

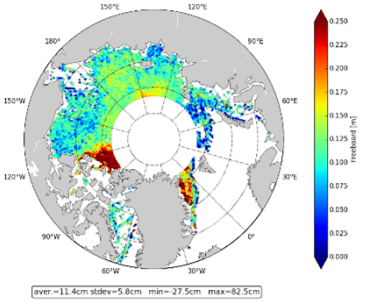
Perspectives

1. Evaluate a order 3 zero-padding
2. Investigate and test alternatives to Hamming (*Smith, 2018 - Laforge et al, 2018 in preparation*)
3. Results can be re-used for hydrology

[1] (Laforge et al, 2018 in preparation)



CryoSat-2 – Dec16



Sentinel-3 – Dec16

Thank you for your attention

Thanks to the CryoSeaNICE project

Special thanks to the GPOD team:

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