DLR

esa

living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

Lead detection method from Sentinel-6 FF-SAR combined with imagery data

Samira Amraoui , Thomas Moreau , Marta Alves , Charles Pereux, Pietro Guccione, François Boy , Claire Maraldi , Nicolas Picot , Craig Donlon

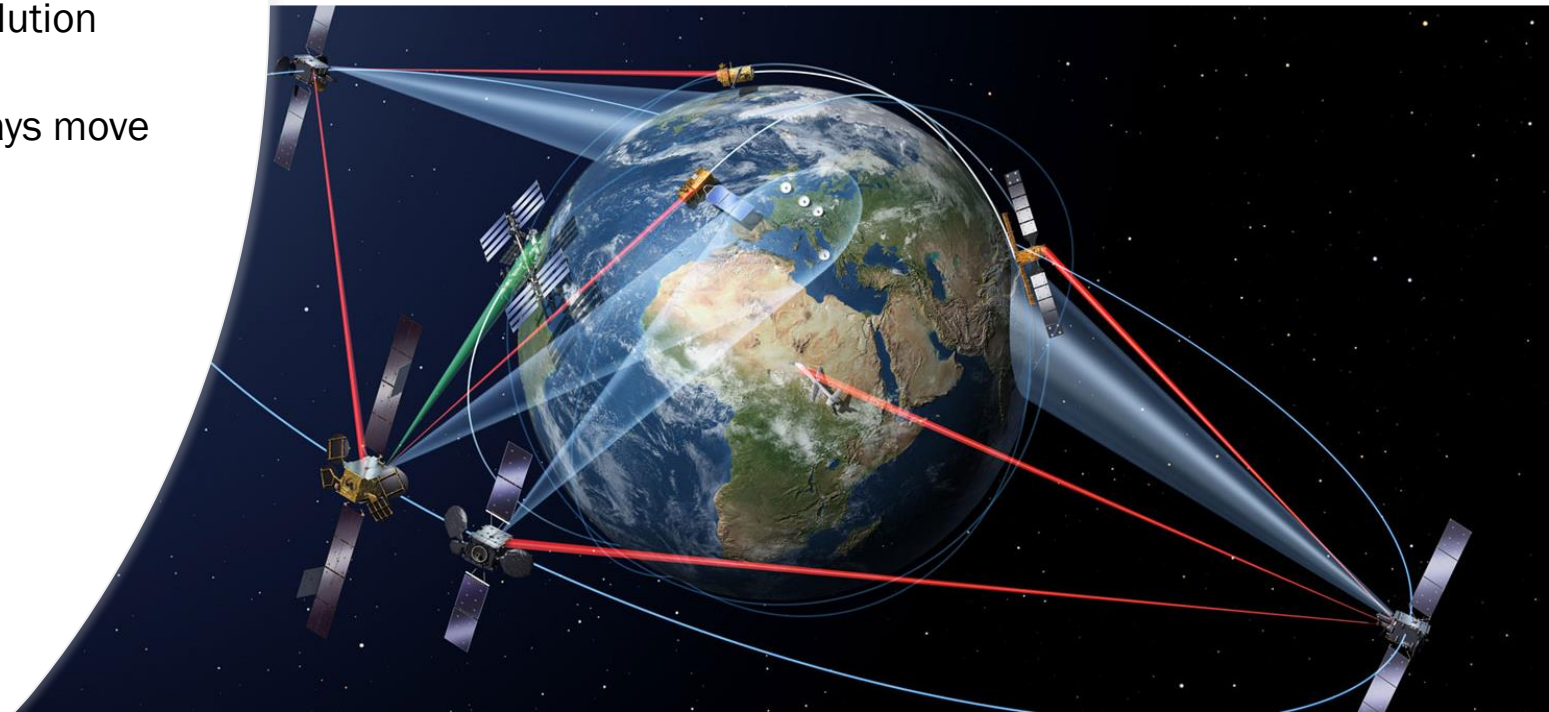
27/05/2022

Sentinel lead detection

- **Definition** : a lead is a fracture in the sea-ice

- **Challenges** :
  - Leads are very **thin** surface requiring high resolution methods
  - No prior knowledge of leads position, they always move though time due to **drifting** surface effect

- **Exploiting Sentinel mission constellation** :
  - on imagery : Sentinel-1 and Sentinel-2
  - on altimetry : Sentinel-3 and Sentinel-6



How to detect lead on Sentinel 1 image ?

The detector has been designed by [Longépé, 2019] and adapted for Sentinel-1 SAR images

Lead signature :

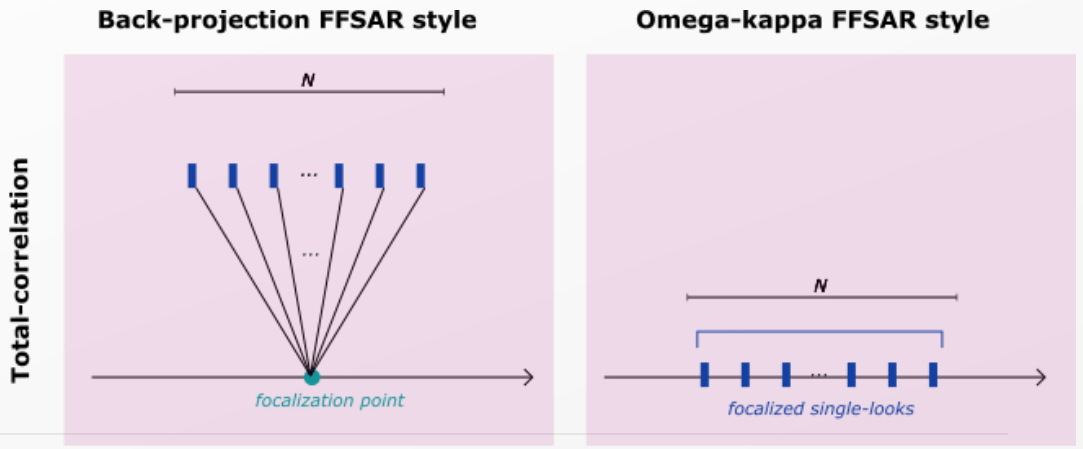
- ❖ dark areas
- ❖ relatively high backscatter background (sigma0)

Methodology :

- start from EW GRDM S1-a and b data as input
- reduce the speckle noise by applying a Lee denoising filter to the sigma0
- detect dark regions (minima points) by using a gray-scale reconstruction algorithm
- each local minima is considered a single lead and is “filled-in” up to a certain threshold (of sigma0 and sea-ice concentration) to recreate the lineic

How to detect lead on Sentinel 6 radargram ?

Without an available classification (of the backscattered waveforms) on S6, lead detection will be based on coherence theory



Lead signature :

- ❖ high level of coherence (with a given threshold)
- ❖ high decorrelation time (see [Boisot, 2016])

Methodology :

- Generate :
  a) N focalized pulses (back-projection ”style”)
  b) Generate N single-looks (omega-kappa ”style”)

- Compute the coherence between the N pulses [Abileah, 2017]

$$c_n(z) = \frac{\left|\sum_{k=1}^{N} \bar{z}_{k+n} e^{\theta_{k+n}}\right|^2}{N \sum_{k=1}^{N} |\bar{z}_{k+n}|^2},$$

- Shift to the next packet of N pulses

How to detect lead on Sentinel 6 radargram ?

Without an available classification (of the backscattered waveforms) on S6, lead detection will be based on coherence theory

Lead signature :

- ❖ high level of coherence (with a given threshold)
- ❖ high decorrelation time (see [Boisot, 2016])

Methodology :

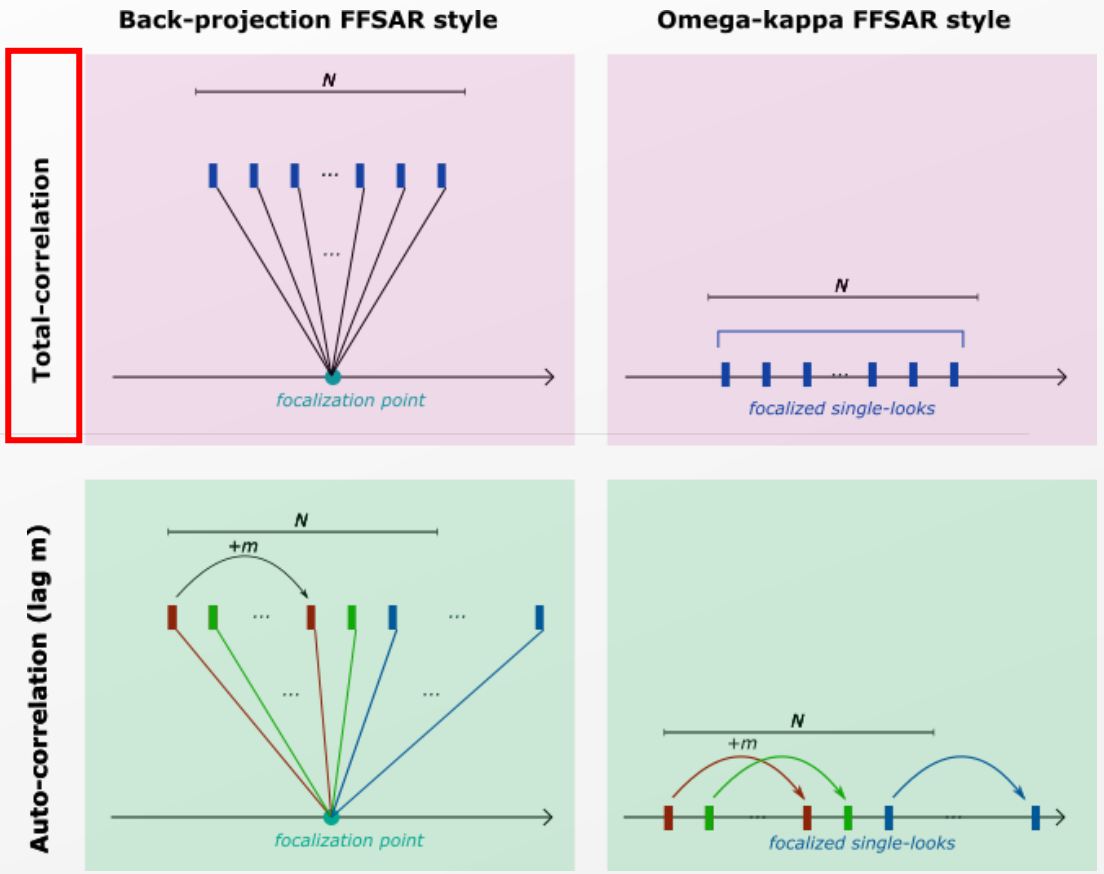
- Generate :
  a) N focalized pulses (back-projection ”style”)
  b) Generate N single-looks (omega-kappa ”style”)

- Compute the coherence between the N pulses [Abileah, 2017]

$$c_n(z) = \frac{\left|\sum_{k=1}^{N} \bar{z}_{k+n} e^{\theta_{k+n}}\right|^2}{N \sum_{k=1}^{N} |\bar{z}_{k+n}|^2},$$

$$c_n(z) = \frac{\left|\sum_{k=1}^{N} \bar{z}_{k+n} \bar{z}_{k+n+m} e^{\theta_{k+n} - \theta_{k+n+m}}\right|^2}{\sum_{k=1}^{N} |\bar{z}_{k+n}|^2 \sum_{k=1}^{N} |\bar{z}_{k+n+m}|^2},$$

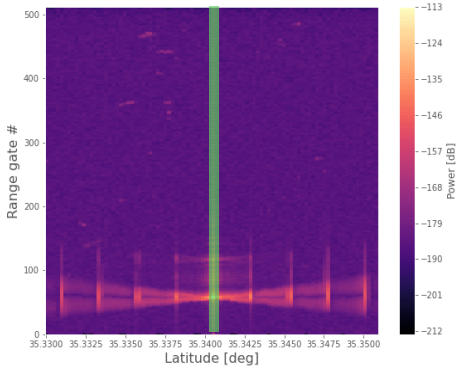
- Shift to the next packet of N pulses

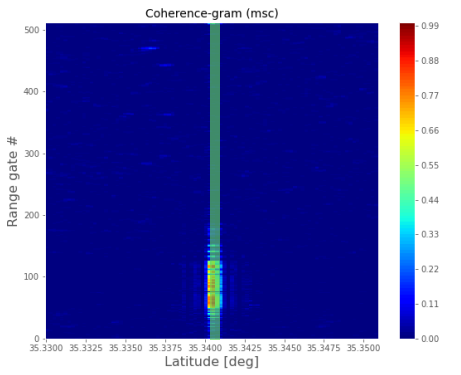


How to detect lead on Sentinel 6 radargram ?

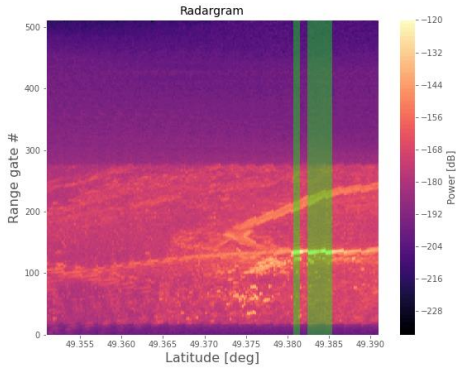
Validation of the method

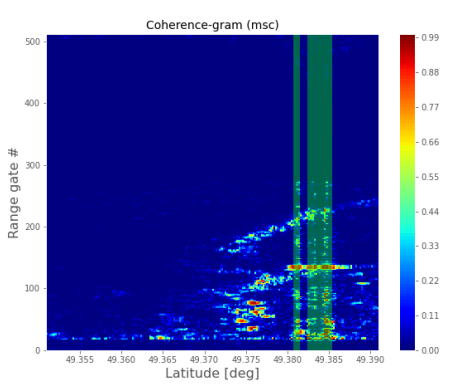
CDN1 transponder



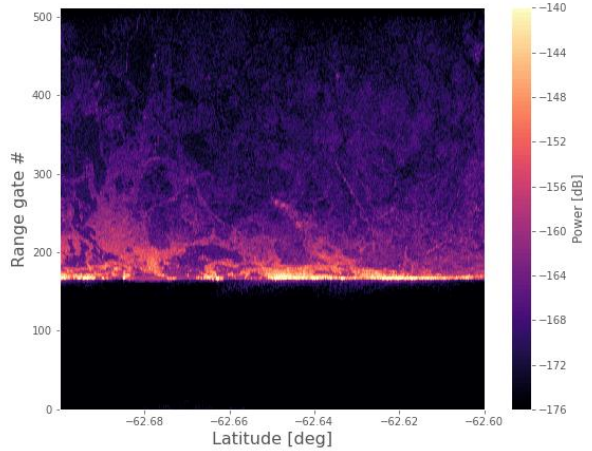


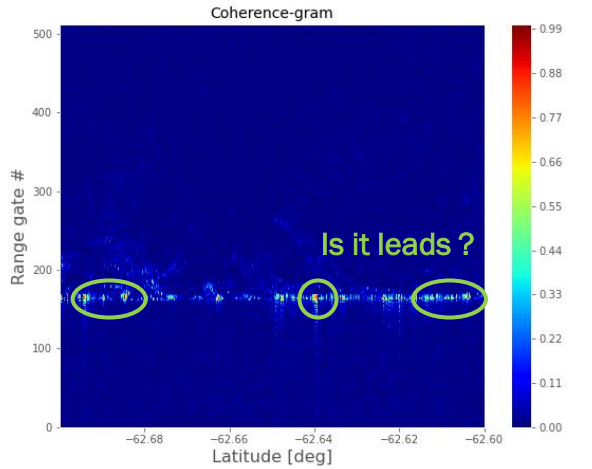
Seine river (France)



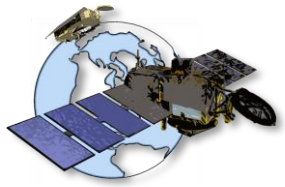


Application to sea-ice





Synergy between Sentinel-1 and 6

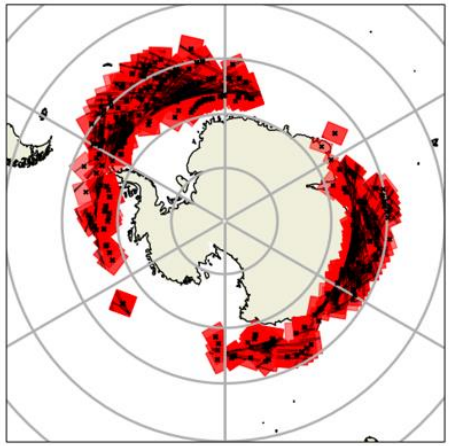


Step 1 : Selection collocation points (Sentinel-1 images and Sentinel-6 FFSAR) with a time lag less than 15 minutes to avoid drift problem.

Step 2 : **Launch the lead detector** on Sentinel-1 images colocated with Sentinel-6

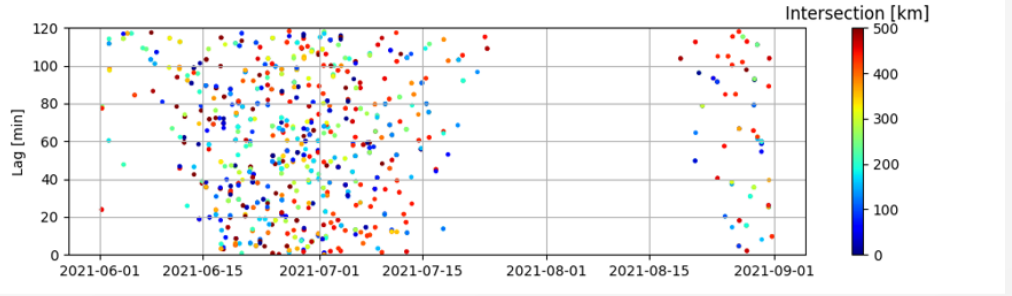
Step 3 : provide **two indicators** :

- ❖ the distance of S1 lead to S6 nadir
- ❖ the percentage of S1 leads inside S6 FFSAR footprint area



Antarctic colocation S1 and S6
From 1st June 2021 to 1st September 2021

1213 colocations founded
In red : S1 images
In black : S6 tracks



Three concluant examples will be studied more deeply here :

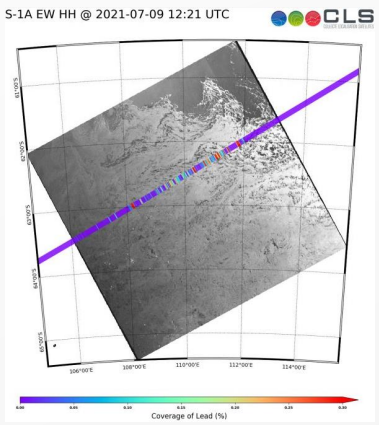


Image : 1431

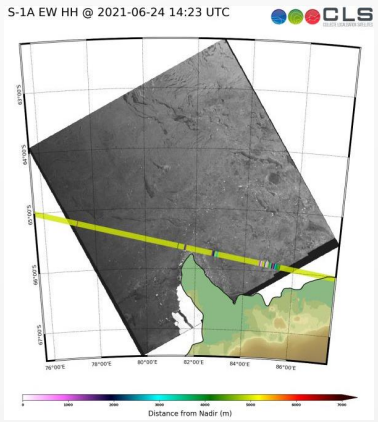


Image : 8A49

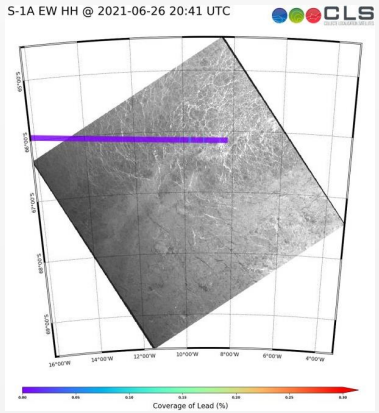
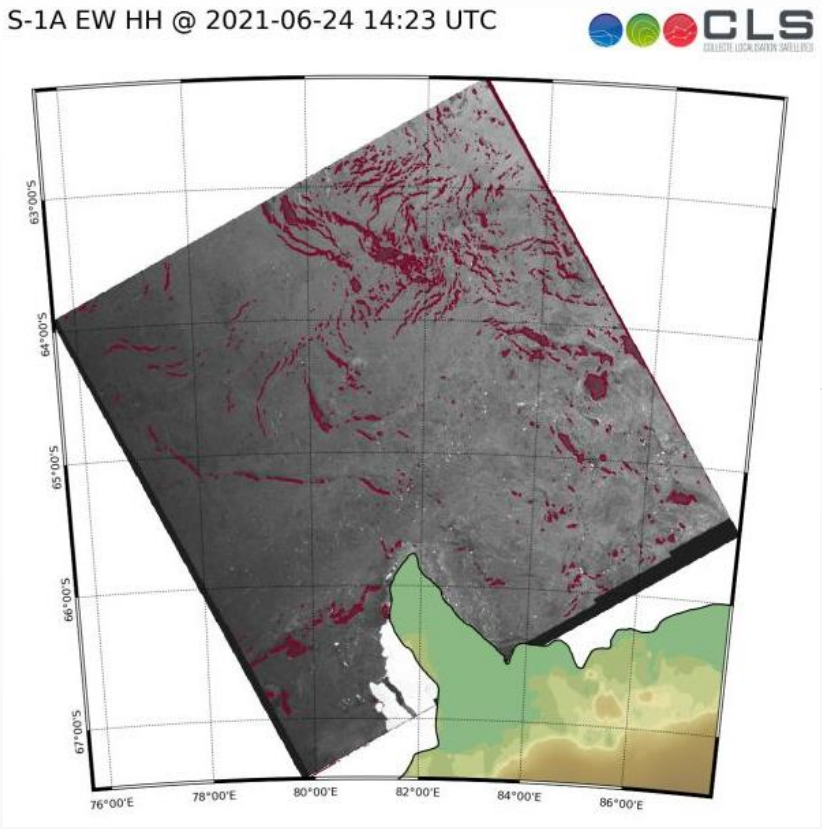
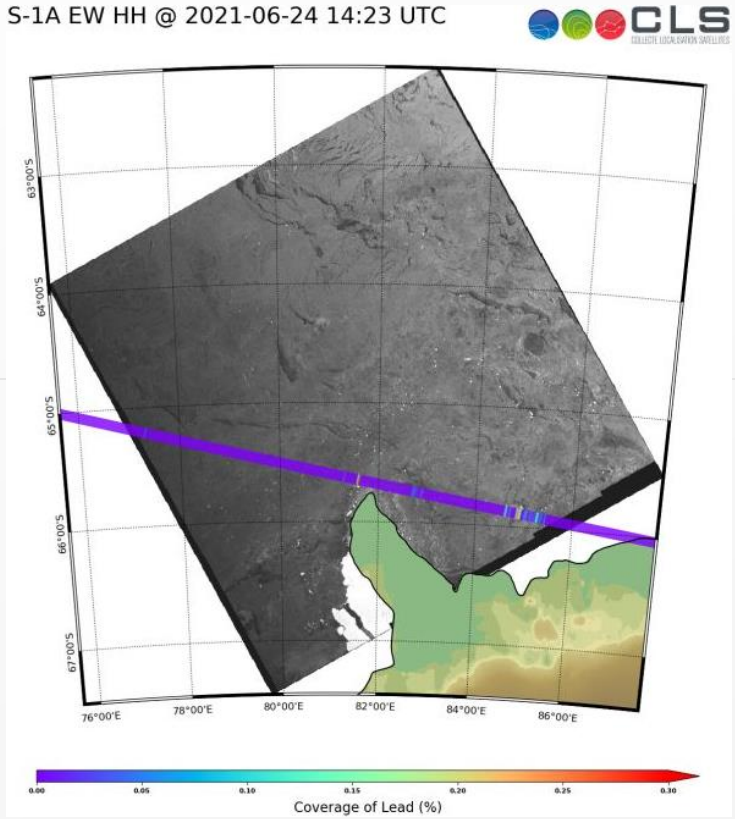
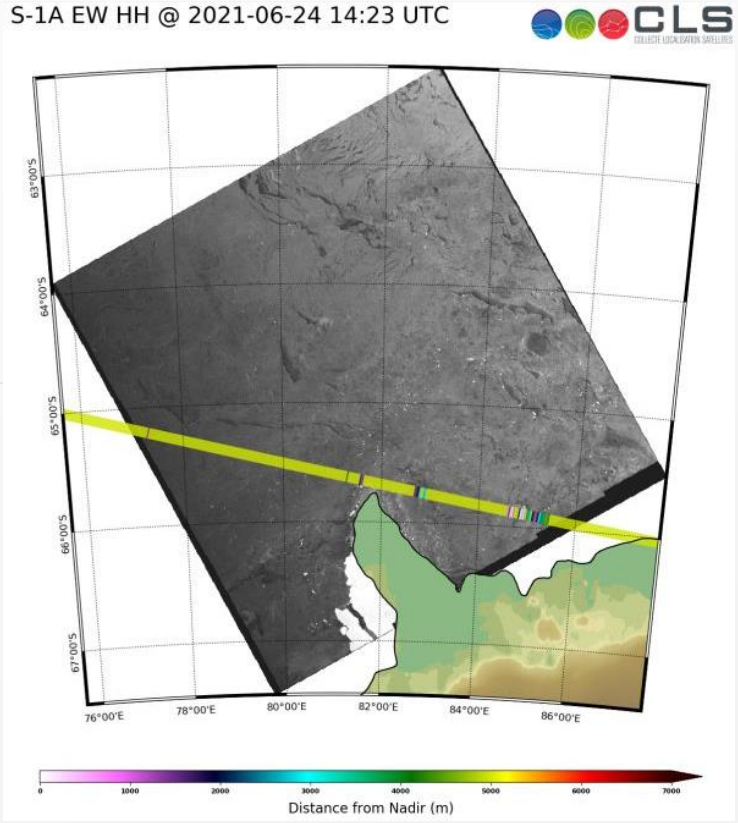


Image : 5AE2

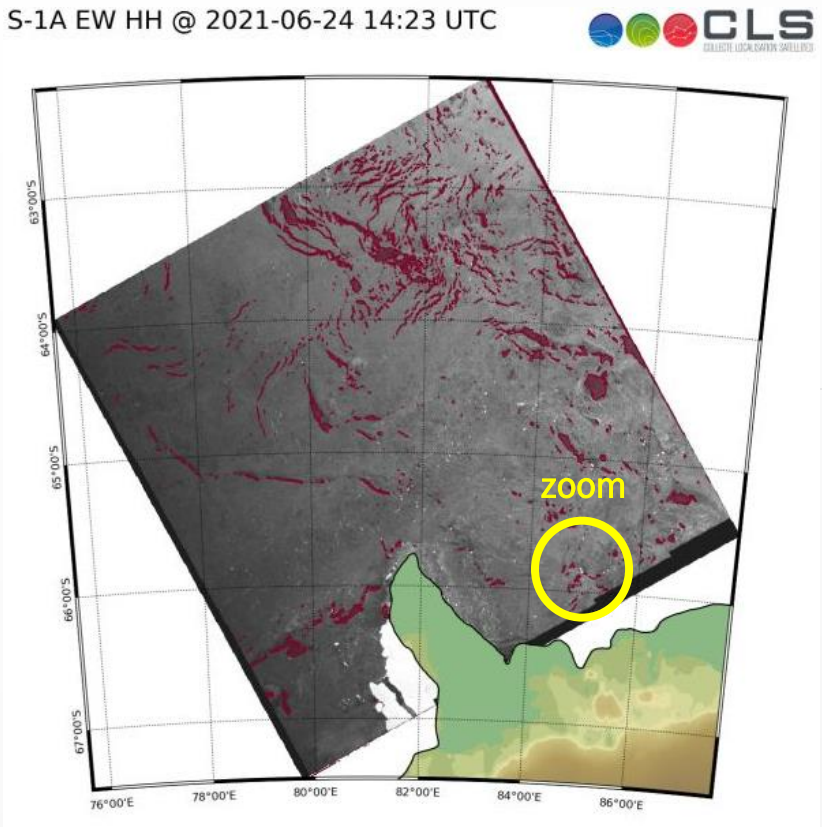
Synergy between Sentinel-1 and 6 : Image *8A49*

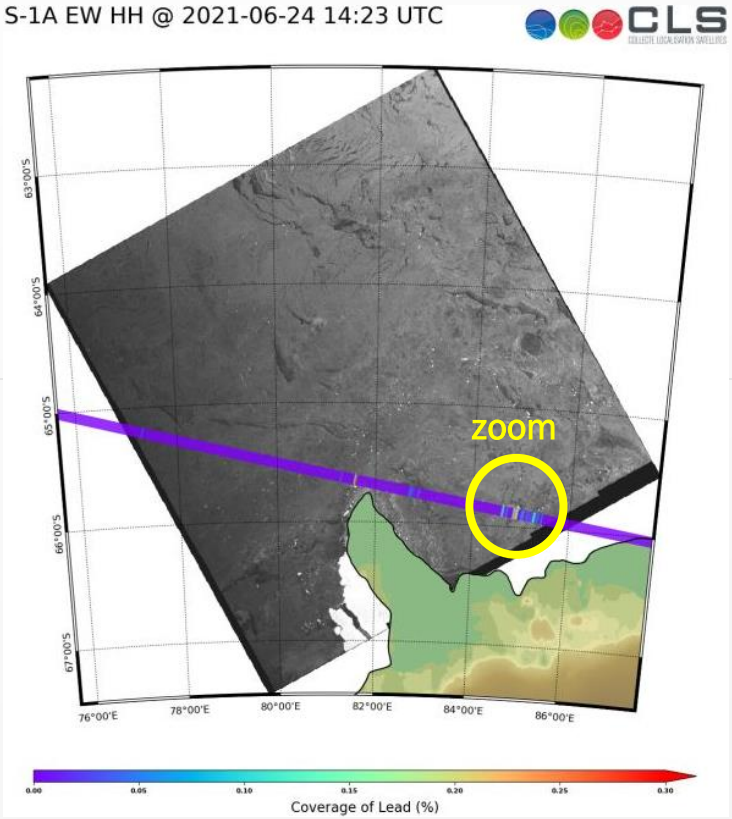


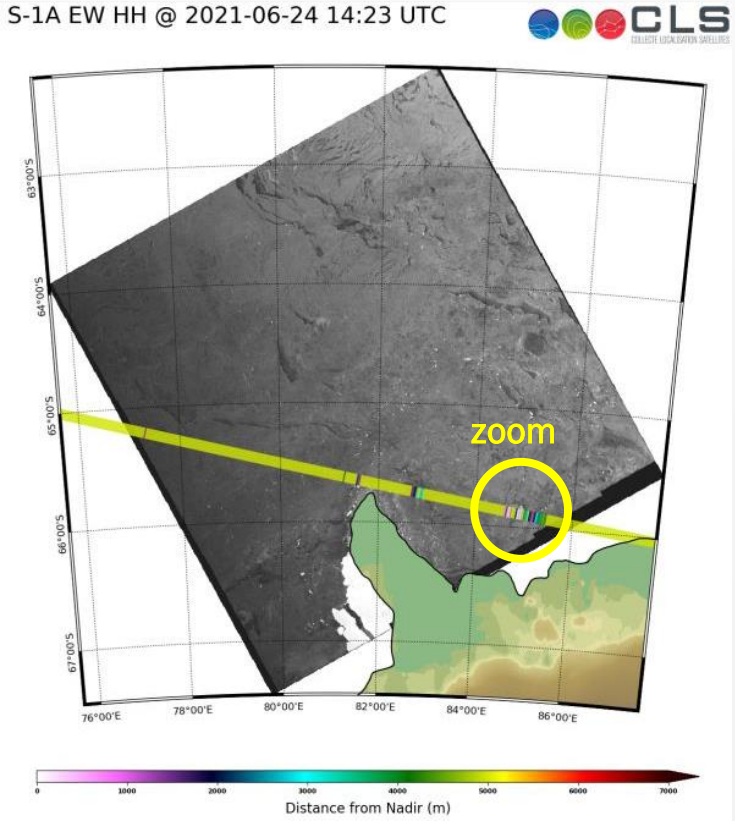




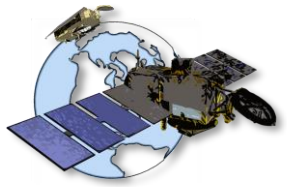
Synergy between Sentinel-1 and 6 : Image *8A49*



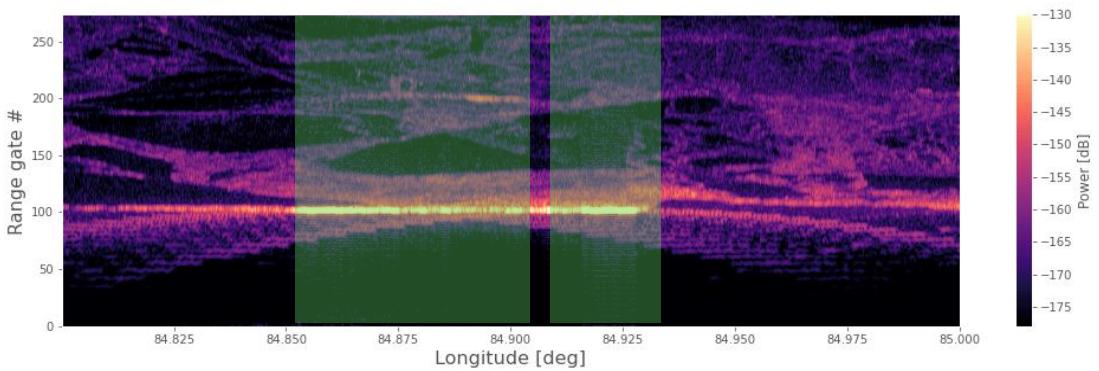




Synergy between Sentinel-1 and 6 : Image *8A49*



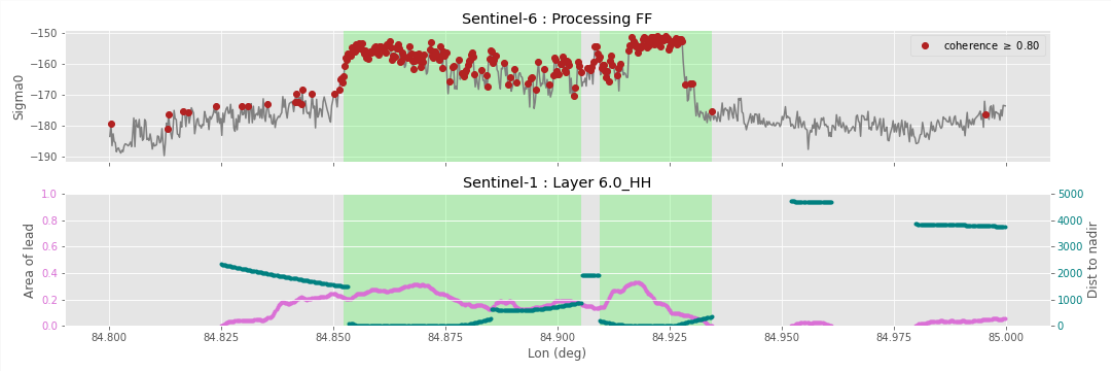
Omega-kappa FFSAR 500hz



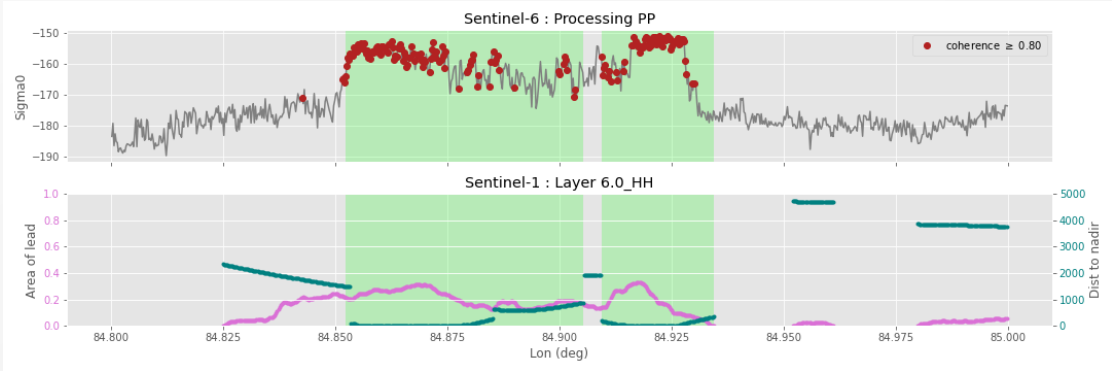
Sentinel-1 lead : area of lead <40% and distance to nadir <1500m

Sentinel-6 lead : coherence>0.8

Omega-kappa «style»

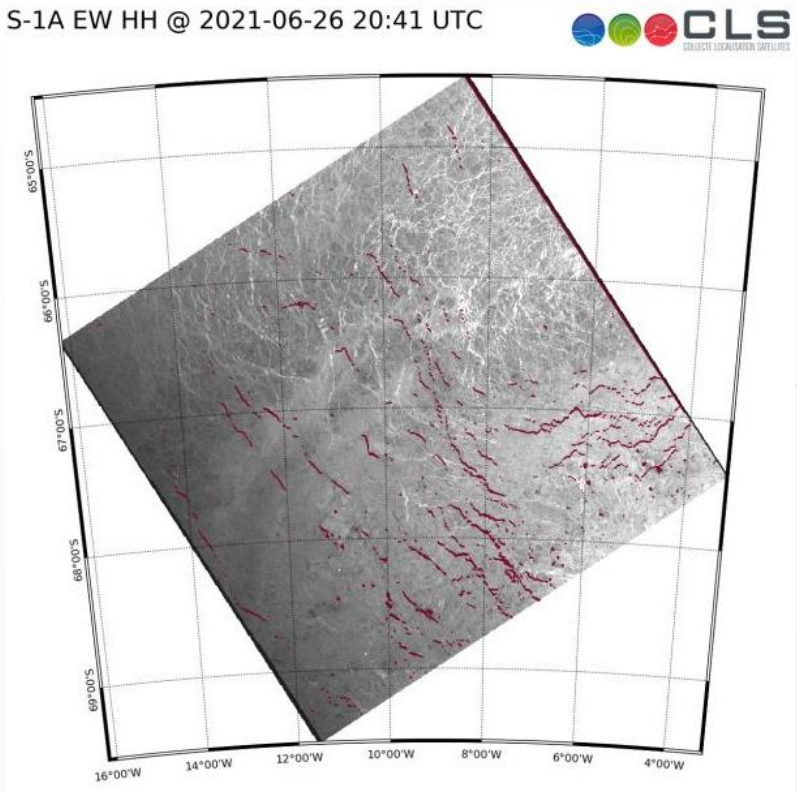


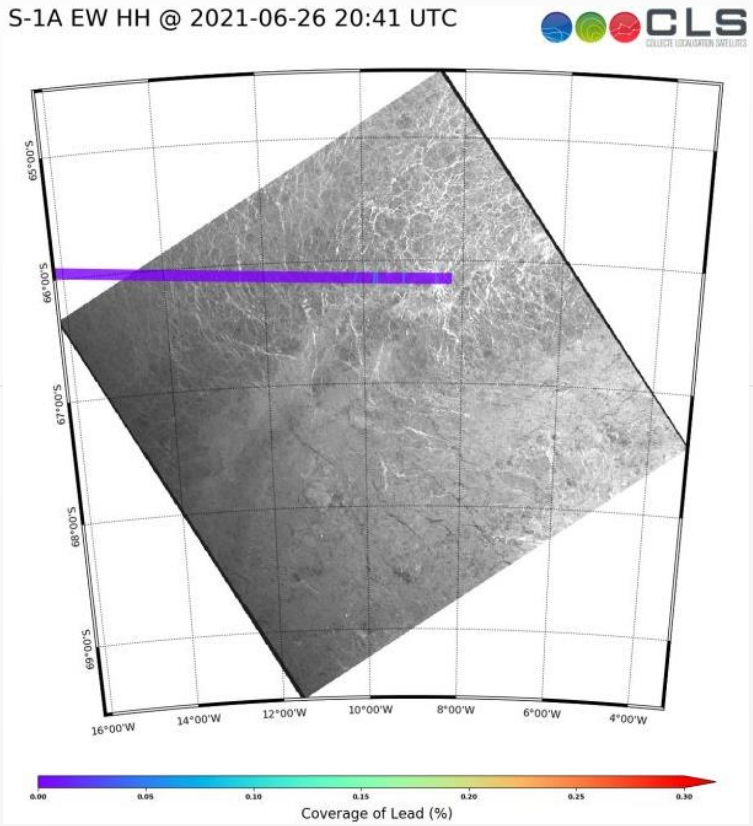
Back-projection «style»

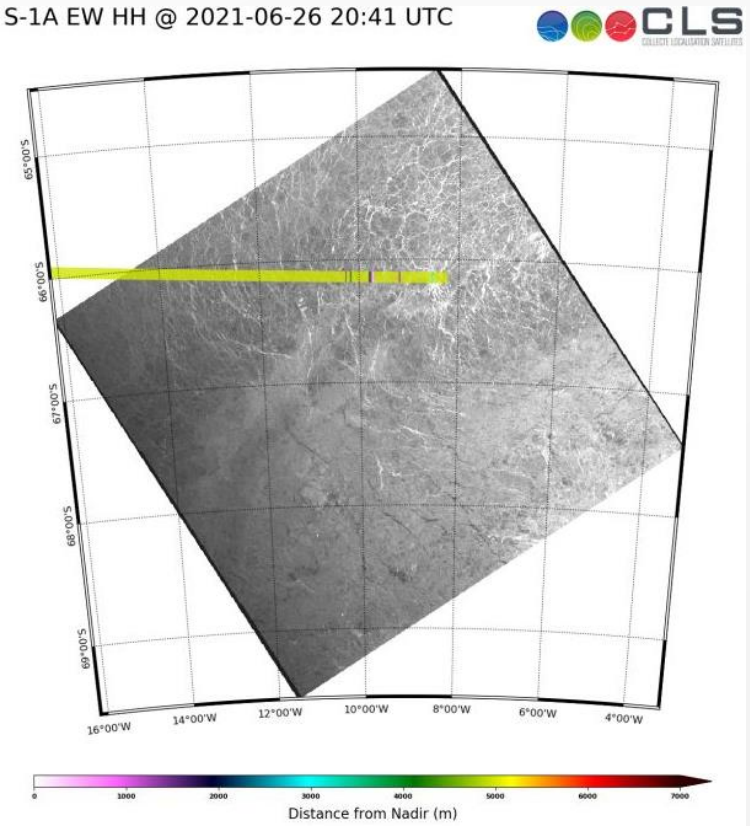


S1 and S6 lead detector is in very good agreement with both techniques

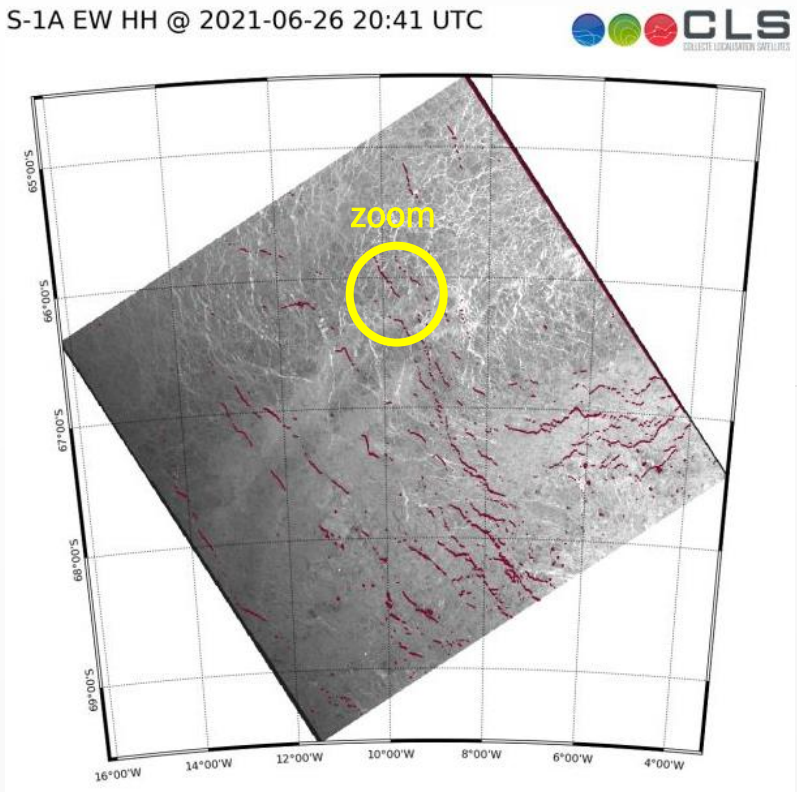
Synergy between Sentinel-1 and 6 : Image *5AE2*

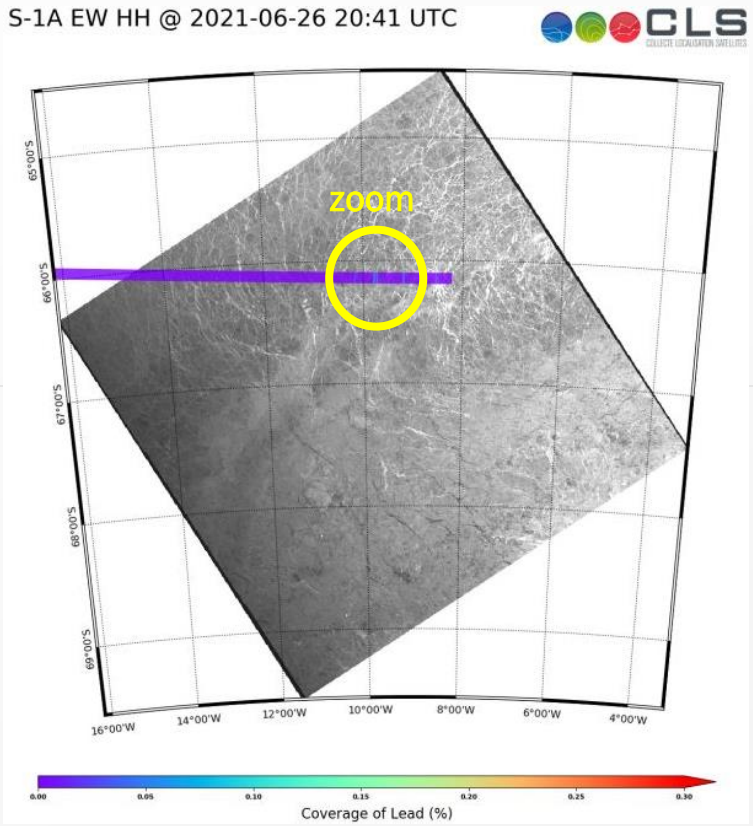


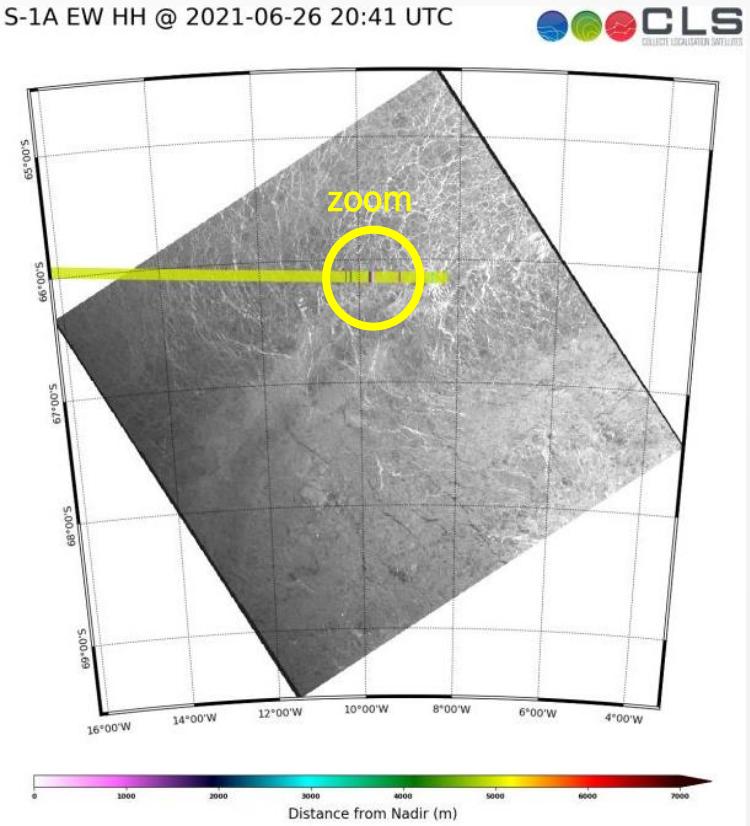




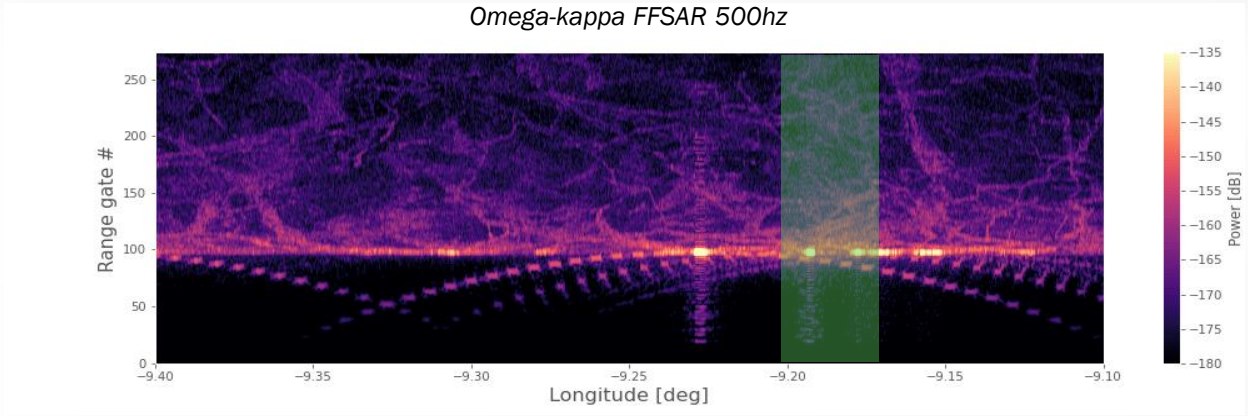
Synergy between Sentinel-1 and 6 : Image *5AE2*







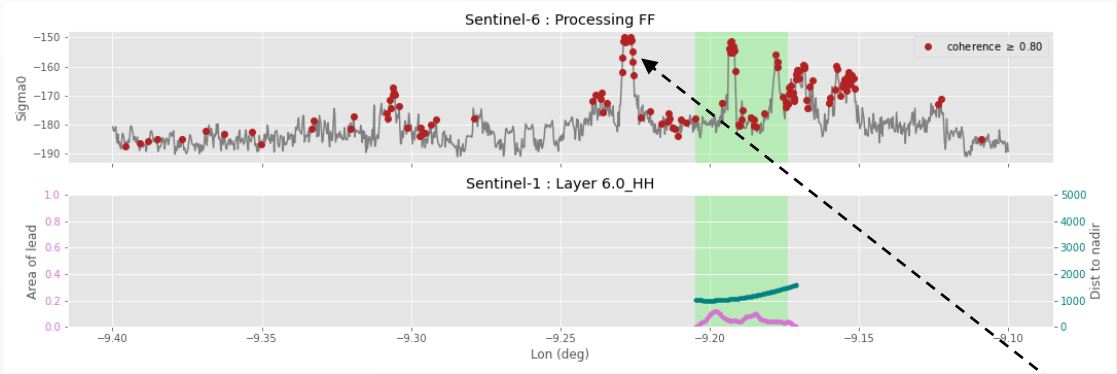
Synergy between Sentinel-1 and 6 : Image *5AE2*



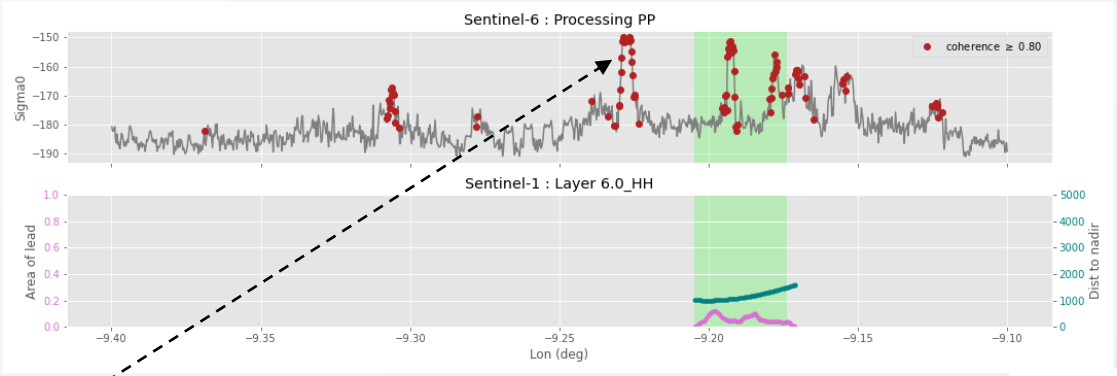
Sentinel-1 lead : area of lead <40% and distance to nadir <1500m

Sentinel-6 lead : coherence>0.8

Omega-kappa «style»

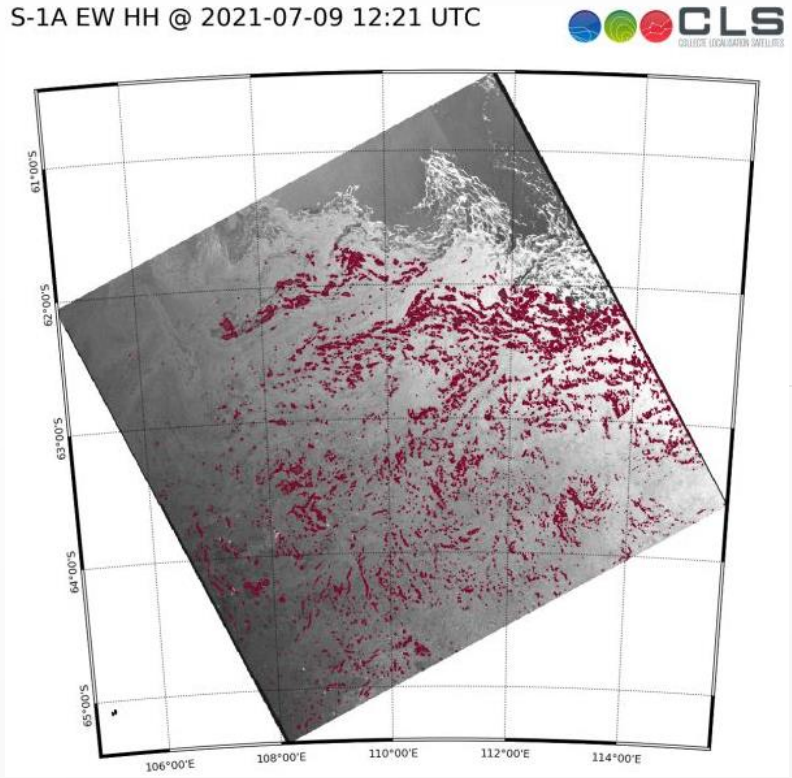


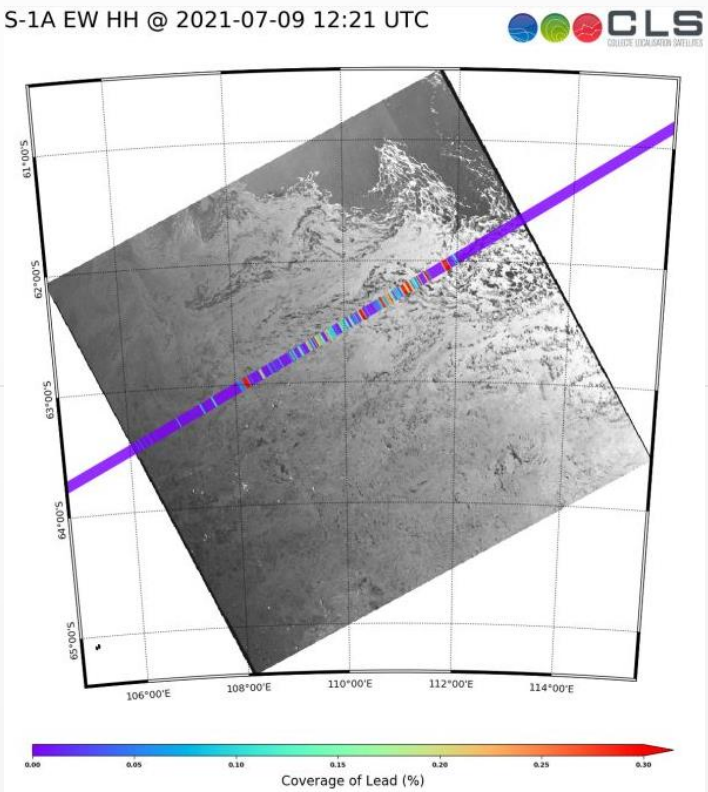
Back-projection «style»

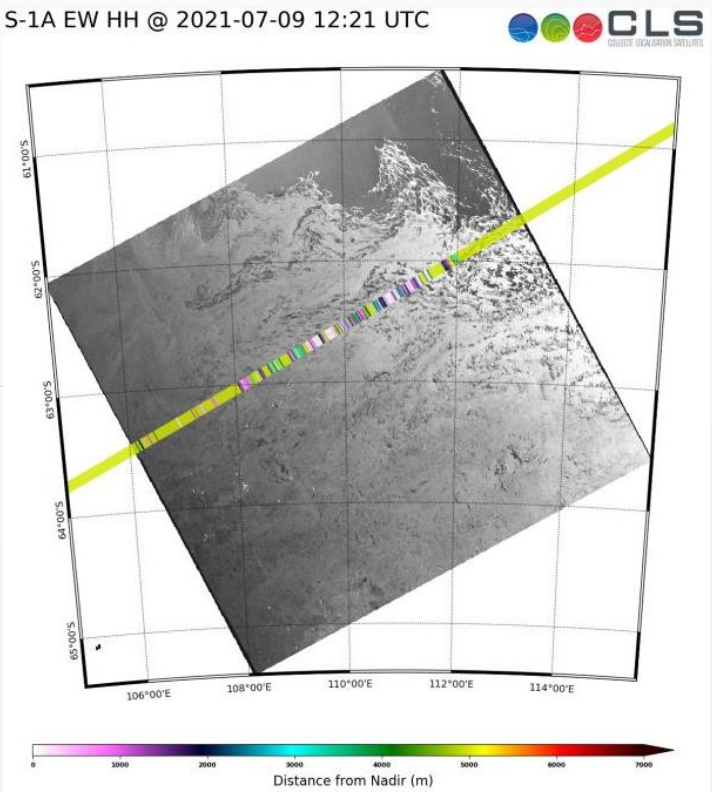


Presence of small leads detected by S6 and not by S1 !

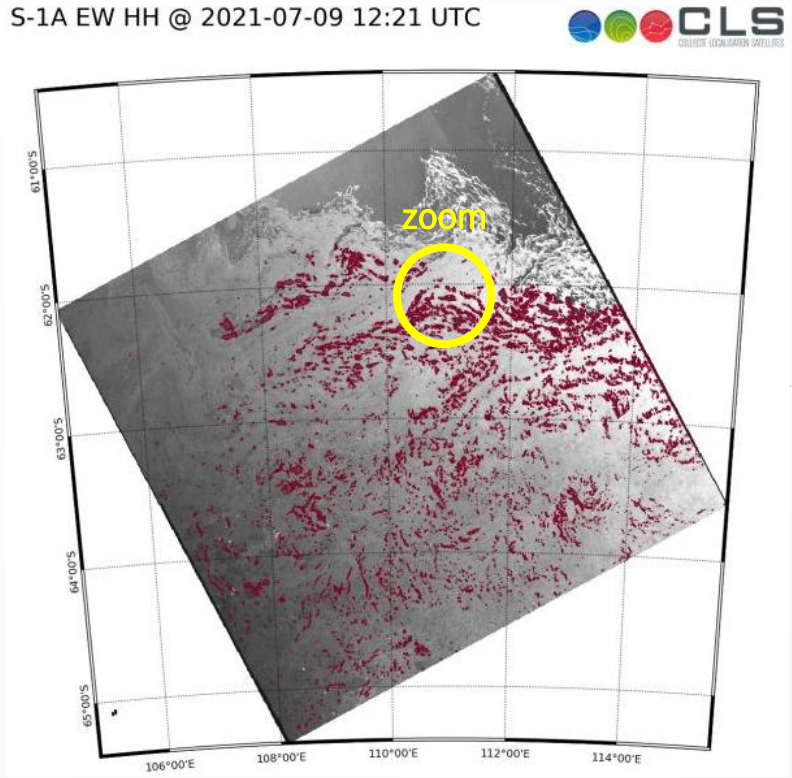
Synergy between Sentinel-1 and 6 : Image 1431

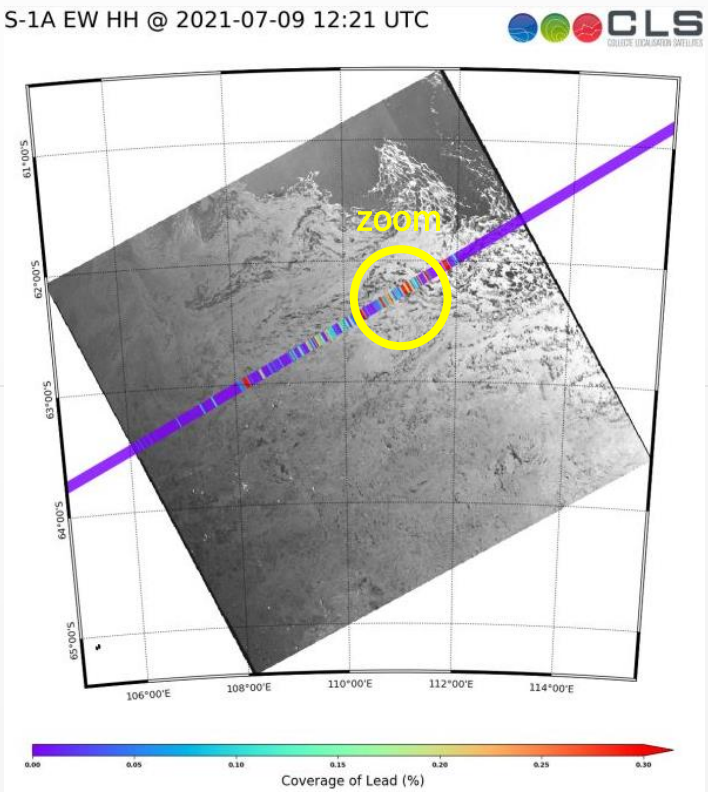


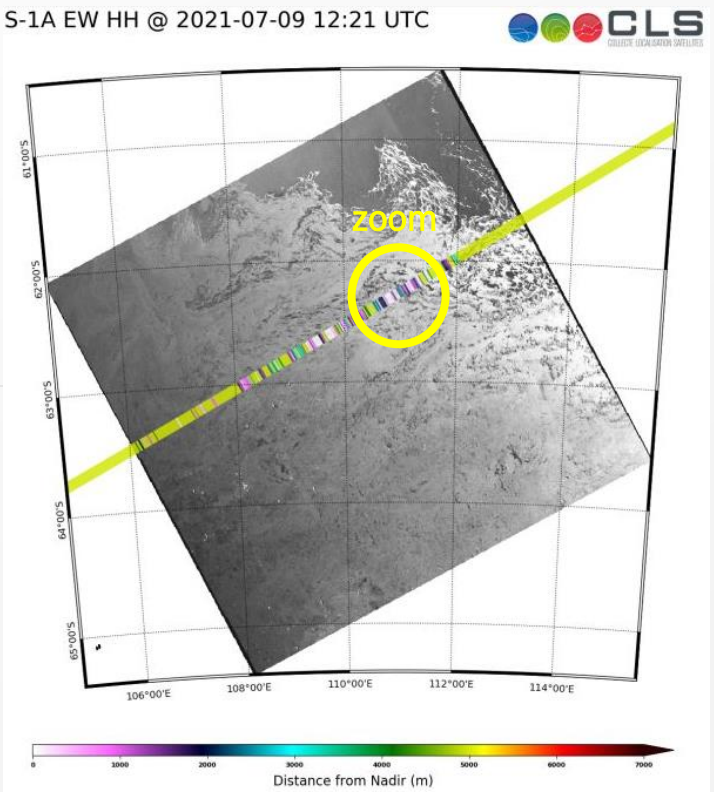




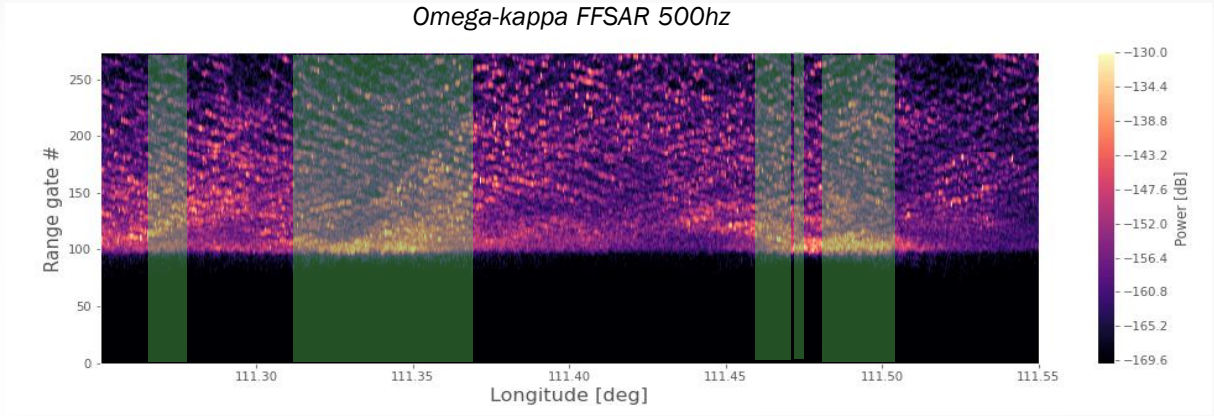
Synergy between Sentinel-1 and 6 : Image 1431







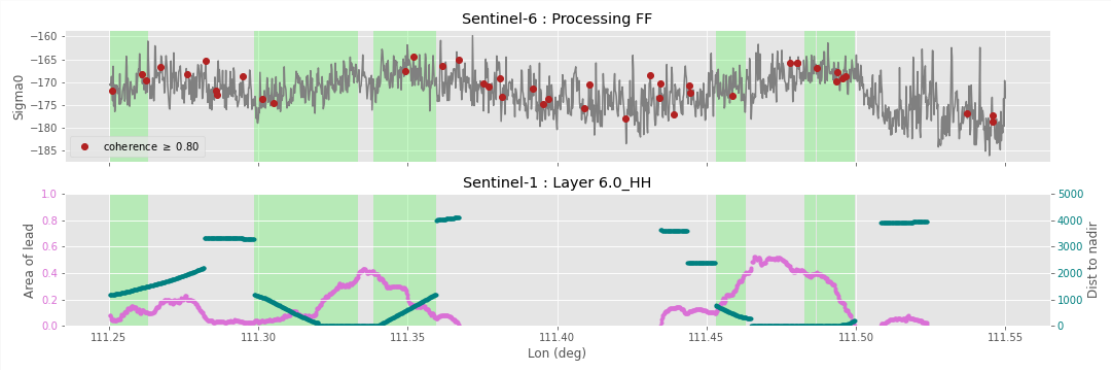
Synergy between Sentinel-1 and 6 : Image 1431



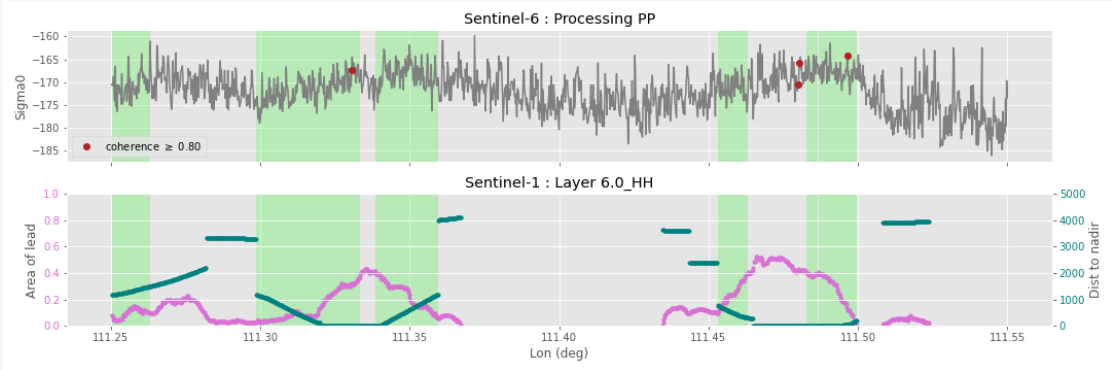
Sentinel-1 lead : area of lead <40% and distance to nadir <1500m

Sentinel-6 lead : coherence>0.8

Omega-kappa «style»

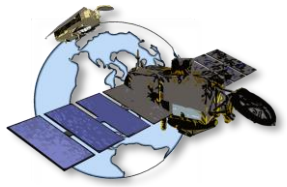


Back-projection «style»

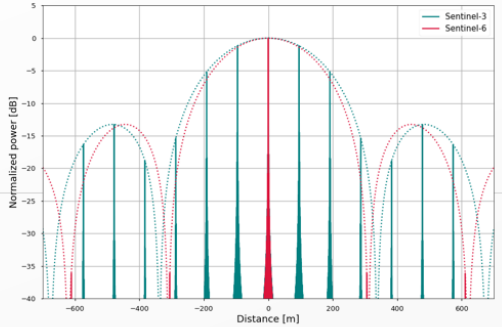


S1 and S6 lead detector is not matching (rough surface)

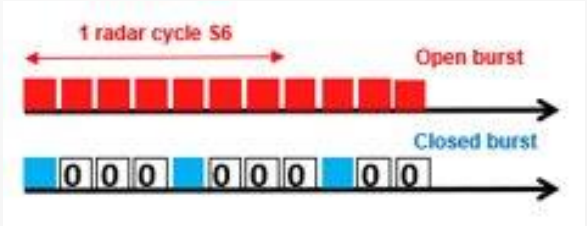
Problematic of the closed-burst mode



Closed-burst mode is present in altimetry missions like Cryosat-2 and Sentinel-3. It is very problematic for the use of fully-focused SAR lead detection, since it creates artefacts of the main signal every 100m

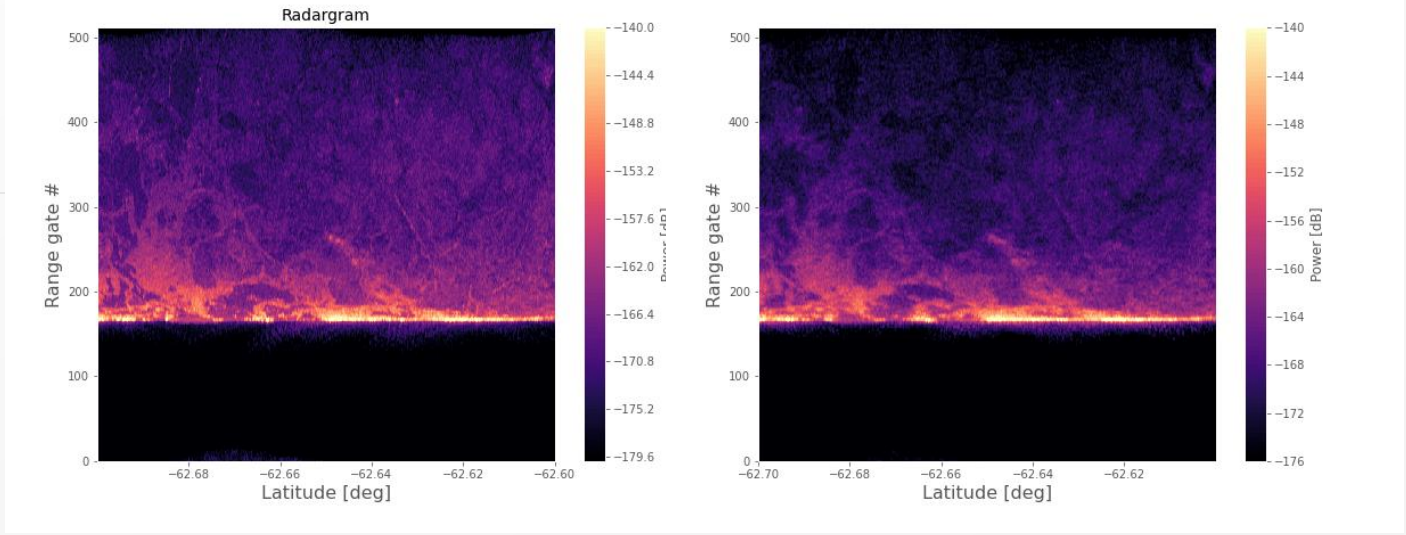


Reproduce the closed-burst by removing bursts to open-burst Sentinel-6 and compare direclty the performances of the two modes on the same surface points

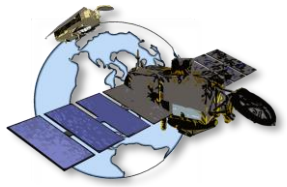


S6 open-burst

S6 closed-burst

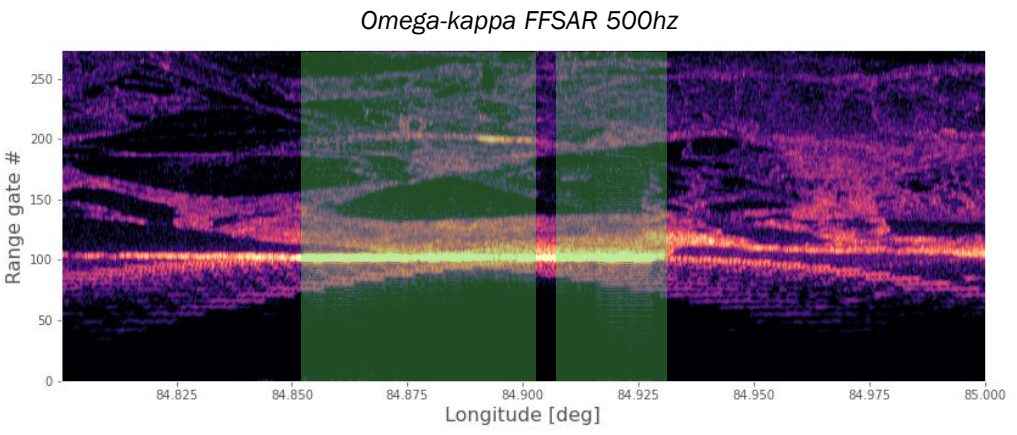


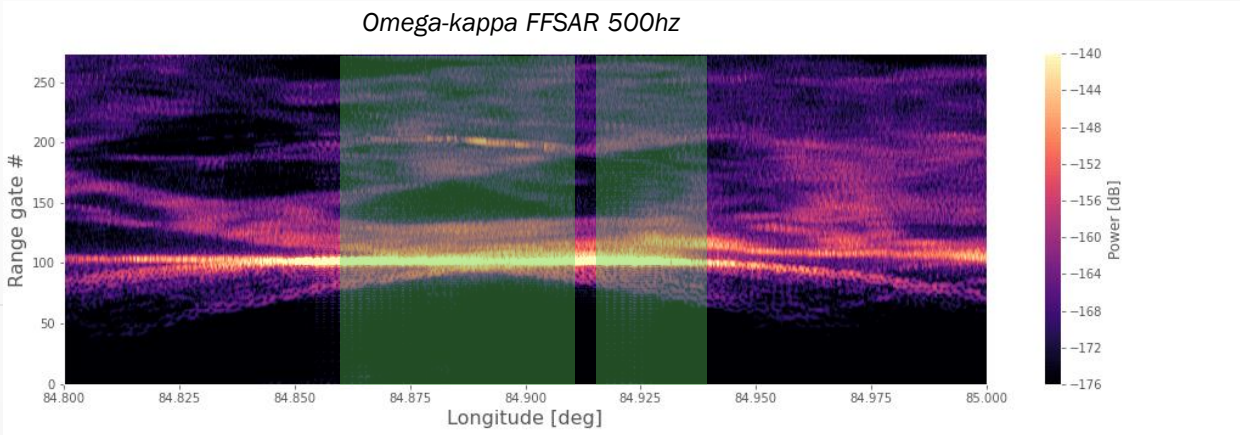
Problematic of the closed-burst mode : Image *8A49*

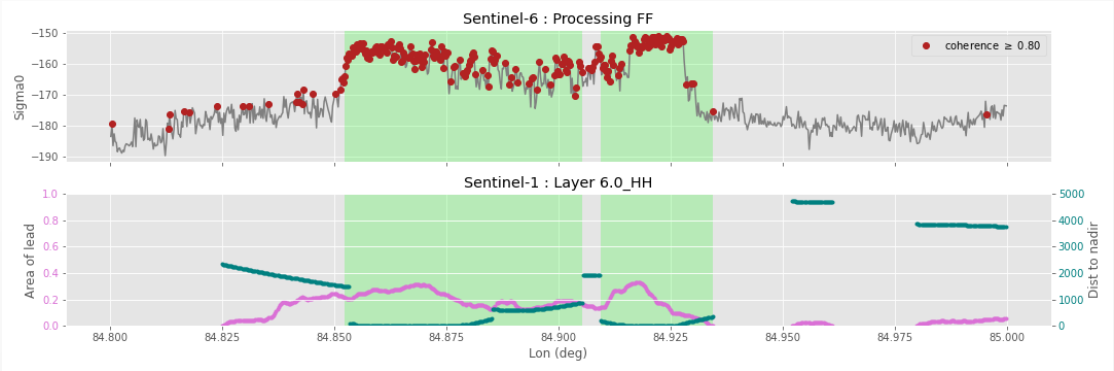


Open-burst mode

Closed-burst mode

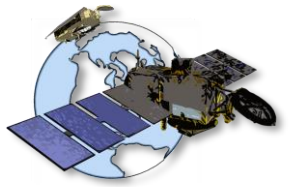






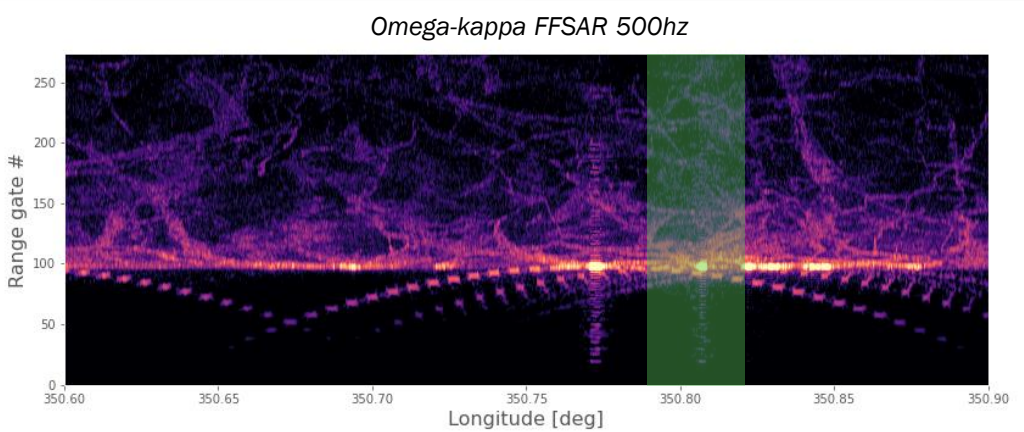
Overflow and oscillations of the coherence in closed-burst (due to replica interference)

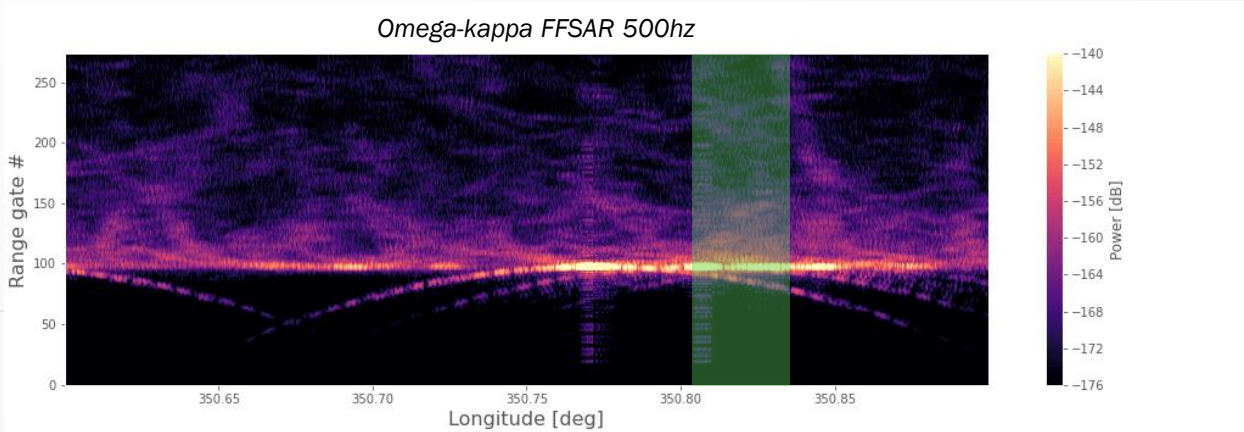
Problematic of the closed-burst mode : Image *5AE2*

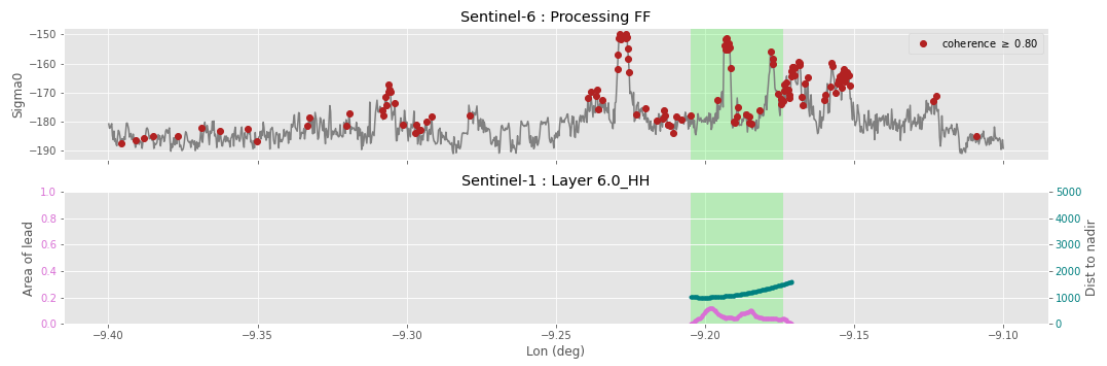


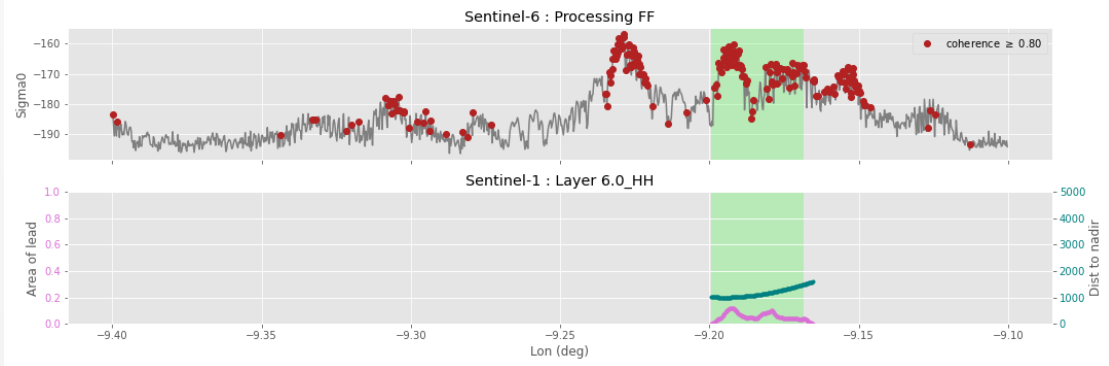
Open-burst mode

Closed-burst mode



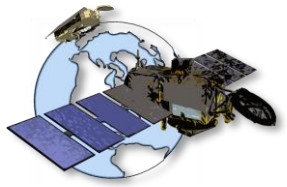






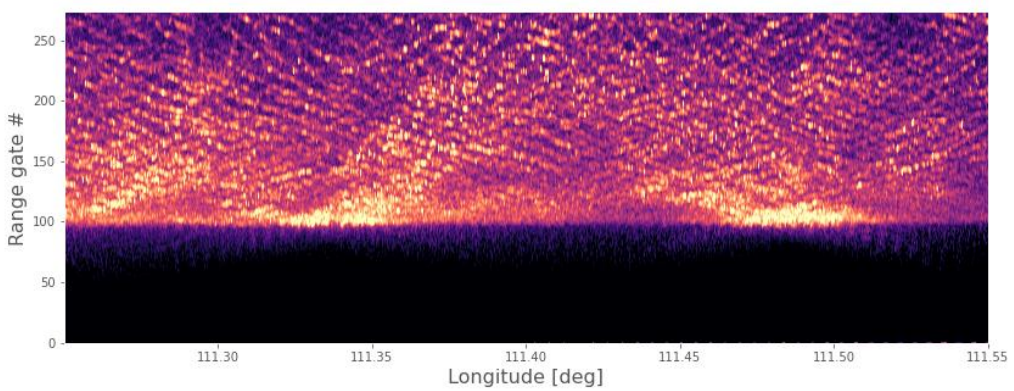
Overflow the coherence in closed-burst (due to replica interference)

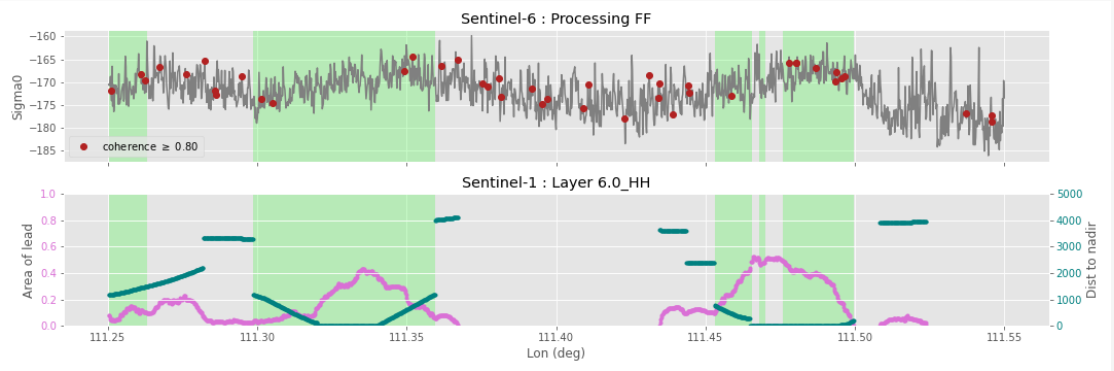
Problematic of the closed-burst mode : Image 1431



Open-burst mode

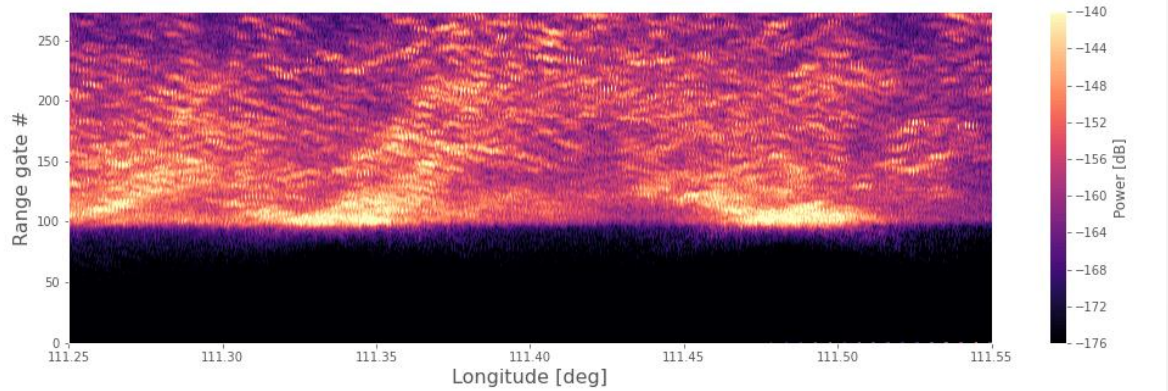
Omega-kappa FFSAR 500hz

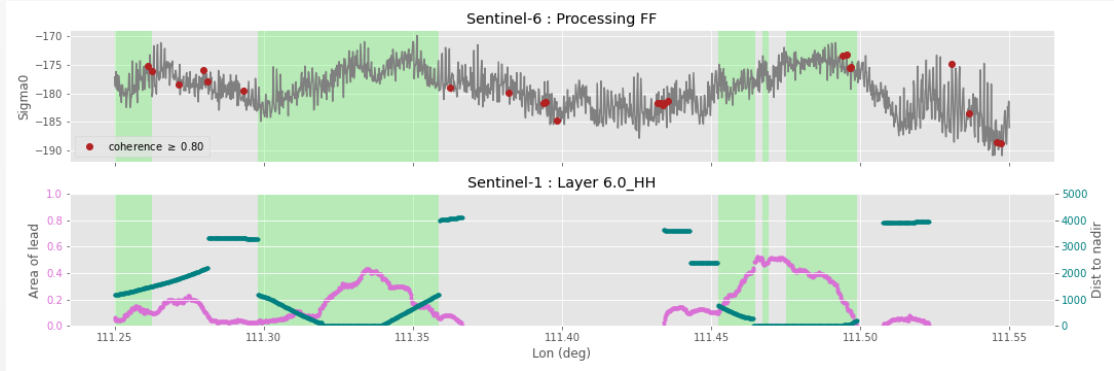




Closed-burst mode

Omega-kappa FFSAR 500hz



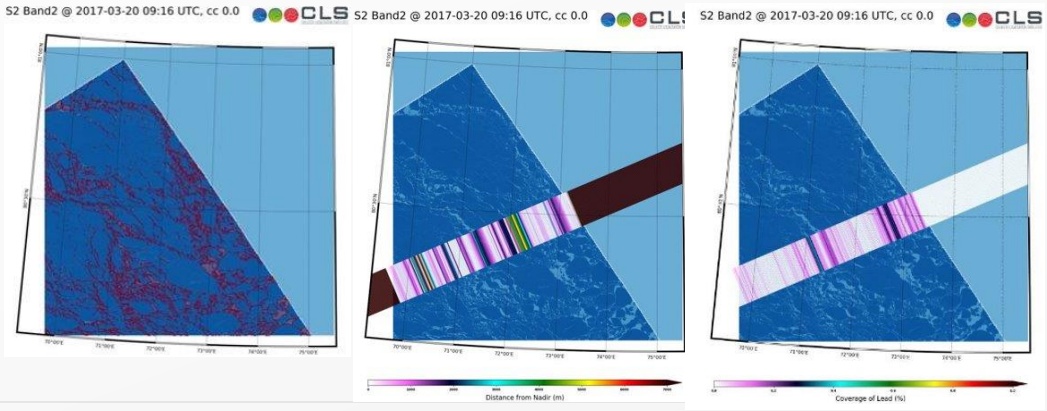


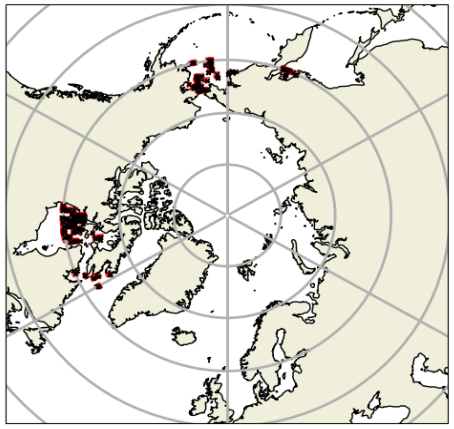
Conclusion and perspectives 1/2 :

Synergy SAR Imagery and SAR Altimetry:

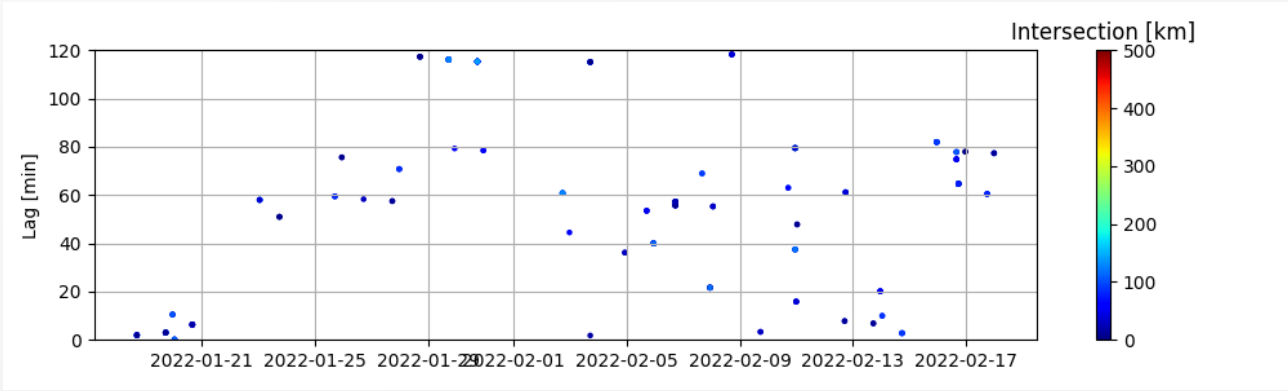
- Various results found out about the S1-S6 synergy. It is hard to tell if S1 is the reference, given the **different resolution** of between S1 and FFSAR S6
- **Next step** : collocation S2-S6 since S2 has a resolution of 10m times 10m

Previous results of S2 and S3 collocation

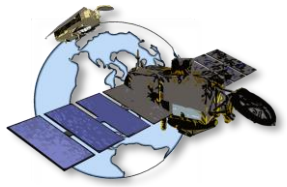




215 collocation points found between S2 and S6 (Arctic)

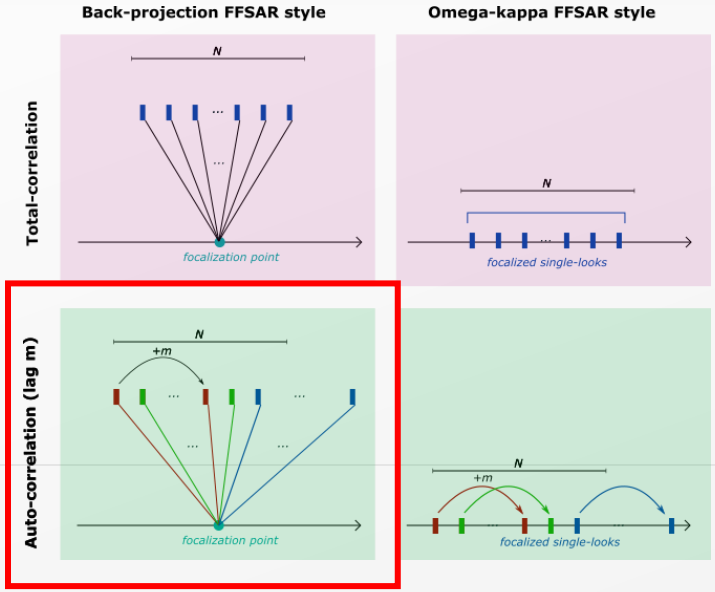


Conclusion and perspectives 2/2:



Closed-burst mode :

- ❖ Overflow but also a **constructive-destructive** effects due to interference
- ❖ Huge problem for the use of FFSAR on Cryosat-2, **Sentinel-3 A/B/C/D**
- ❖ Use a non-impacted method by replicas, theoretically speaking **auto-correlation** of focalized pulses are **not jeopardized by replicas**



Total-correlation :

$$\sum_{n=0}^{N_b-1}\int_{-\infty}^{+\infty} \Pi\left(\frac{\eta - nBRI}{T_b}\right)\exp\left(-2i\pi f_d\eta\right)d\eta = T_b\exp(-i\pi(N_b-1)BRI\,f_d)\frac{\sin(\pi N_b BRI\,f_d)}{\sin(\pi BRI\,f_d)}\mathrm{sinc}(T_b f_d)$$

Auto-correlation (with a lag of $\Delta\eta$) :

$$\sum_{n=0}^{N_b-1}\int_{-\infty}^{+\infty} \Pi\left(\frac{\eta - nBRI}{T_b}\right)\exp\left(-2i\pi f_d\eta\right)\exp\left(2i\pi f_d(\eta+\Delta\eta)\right)d\eta = N_b T_b\exp\left(2i\pi f_d\Delta\eta\right)$$