Asssessment of the capabilities of S-1 and Altika for lead detection

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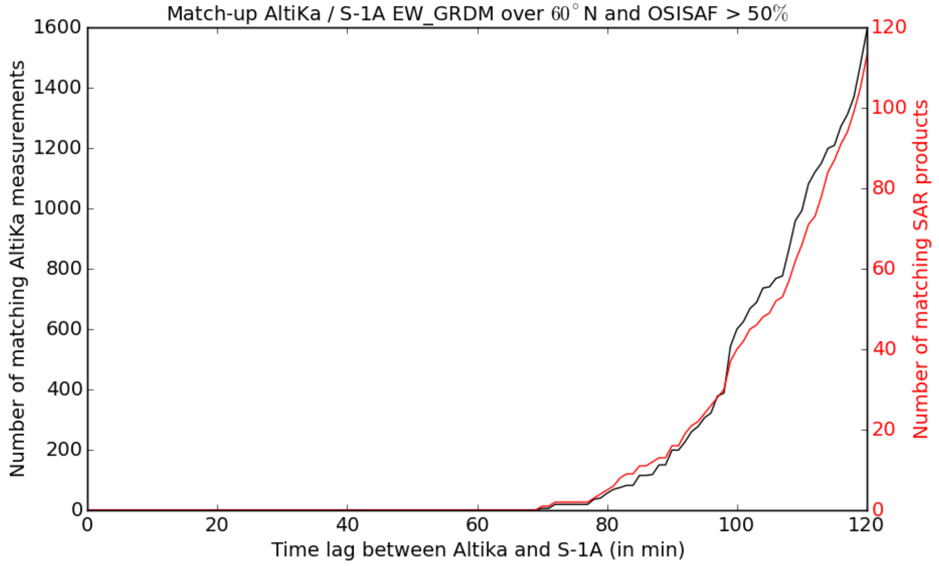
Objective

- Improve altimeter lead detection via a complementary approach based on SAR imagery
  - More generally improve our knowledge of SAR imagery but also altimeter signals acquired over sea ice

- General steps:
  - Pre-select a sub-set of matching (time and space) S1 and Altika
  - Implement a S1-based lead detection methodology
  - Compare results on selected use cases and systematic approach
  - Provide recommendations
    - Improve altimeter-based lead detection ? (WF class 2 + sig0 > 20db)
    - Improve S-1 based lead detection ?
    - Combined S1-S3 products ?

Data subset

- Collocation between AltiKa tracks and S-1 data - winter 2015-2016 in North Hemisphere
  - In Arctic sea, mostly Extra Wide (EW) S1
    - Swath width : 400 km
    - Incidence angle range:18.9° - 47.0°
    - Number of Sub-swaths: 5
    - HH/HV polarization



- Sub-setting methodology
  - Automatic query of all the frames of the acquired images wrt. acquisition date and region of Interest (above > 60°N)
  - Filtering the S1 frames
    - Above > 60°N
    - With Altika measurements (maximum time lag: +- 2 hours)
    - With OSISAF Sea Ice Concentration data: for consolidated sea ice (SIC > 50%)

-> A subset of 109 S1 images

Spatial and temporal coverage

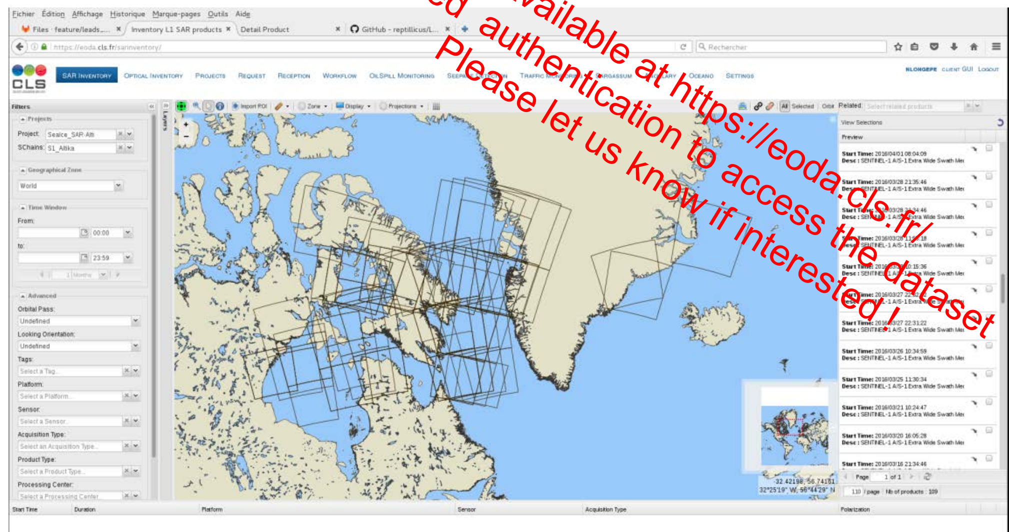
- Geographical location of matchups
  - Labrador (51) and/or Hudson bay (47) – some covering both
  - Bering sea (7)
  - White sea / South Kara sea (5)
  - East Greenland (3)
  - Gulf of Bothnia (3)
  - Beaufort sea (2)
- Seasonality of matchups
  - Oct – Dec 2015 (17)
  - Jan. – March 2016 (48)
  - April – July 2016 (44)

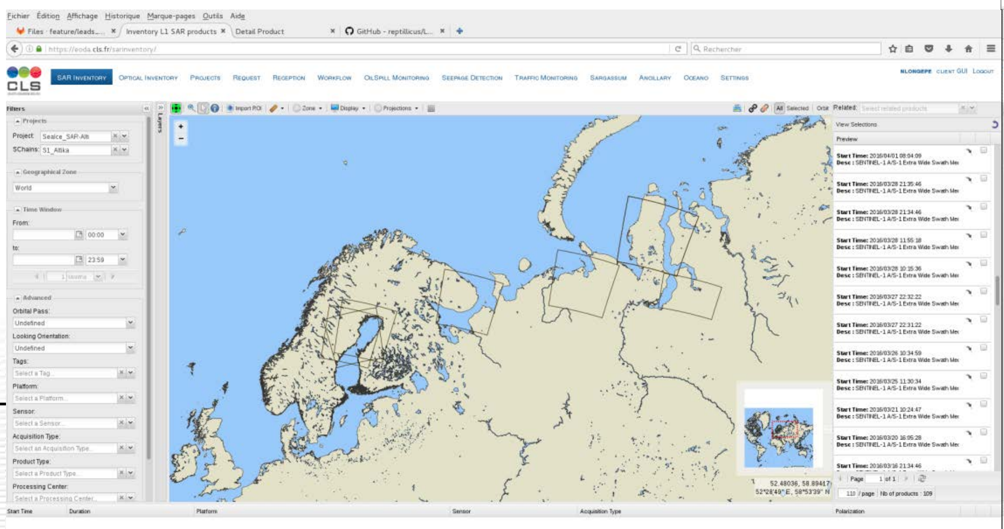
-> only First Year Ice in our Altika/S1 matchup database

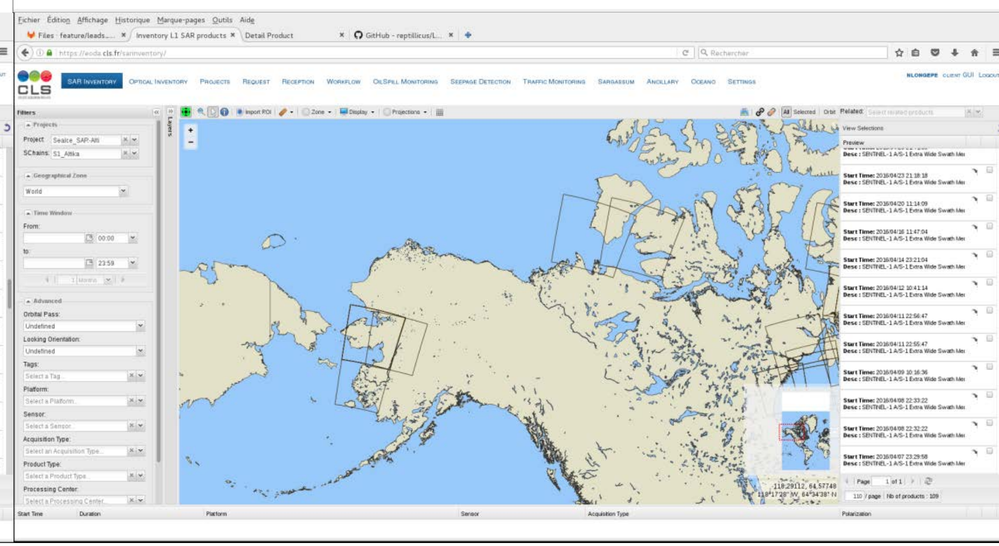
Available at https://eoda.cls.fr/

Need authentication to access the dataset

Please let us know if interested !

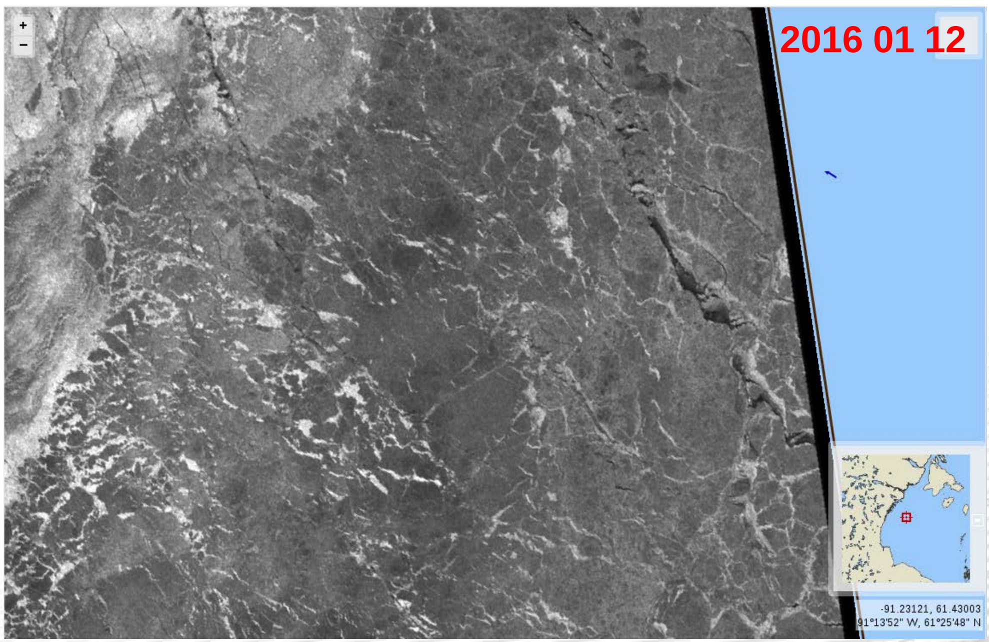


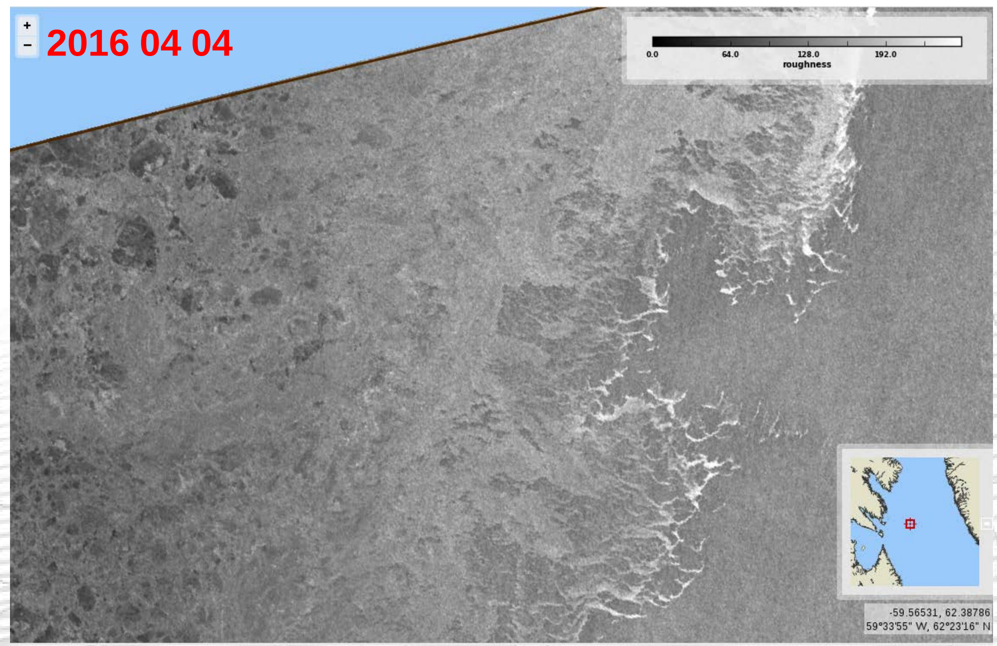




Lead detection methodology (1/9)

- Leads in sea ice as imaged by C-band SAR sensors
  - Depend on many geophysical parameters (synoptic wind, lead size and shape with respect to wind direction, presence of a newly formed thin ice, salinity content...), not to forget sensor configuration (polarization, incidence angle...).
  - Contrast depend on surrounding sea ice (type, age, deformation, melting…)
  - But generally speaking: lower sigma0 values over leads compared to sea ice





Lead detection methodology (2/9)

- Simple threshold on sigma0 not satisfactory
- (Ivanova et al. 2016) used characteristics of backscatter distributions in each SAR image in order to determine a threshold adapted to the each scene. (less than 1.5 x Standard deviation below the mean value)
  - But high local variability of sigma0 over sea ice, depend on Sea Ice Concentration
- (Zakhvatkina et al. 2017) explored a support machine vector (SVM) approach based on texture features of the image.
  - May be adequate for sea ice versus water classification but not in the context of lead detection
  - Leads may be thin, whereas texture calculation may need large window of analysis, while mixing of water and sea ice within the window of analysis is an issue
  - Difficulty to find relevant features, robust for all sea ice type, seasonality
  - Time consuming approach

Here approach based on the morphological grayscale reconstruction which is adequate to detect local extrema

Ivanova, N., Rampal, P., and Bouillon, S. "Error assessment of satellite-derived lead fraction in the Arctic." *The Cryosphere* 10 (2016): 585-595.
Zakhvatkina, N., Korosov, A., Muckenhuber, S., Sandven, S., and Babiker, M. "Operational algorithm for ice–water classification on dual-polarized RADARSAT-2 images." The Cryosphere 11 (2017): 33-46.

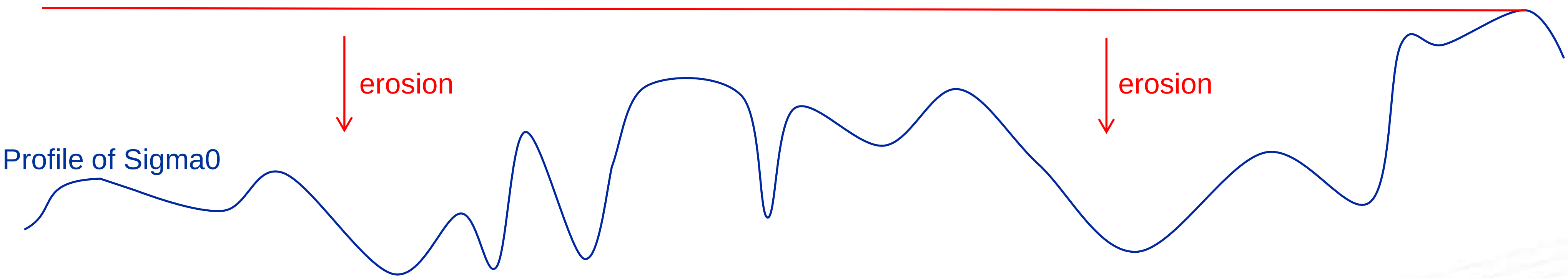
Lead detection methodology (3/9)

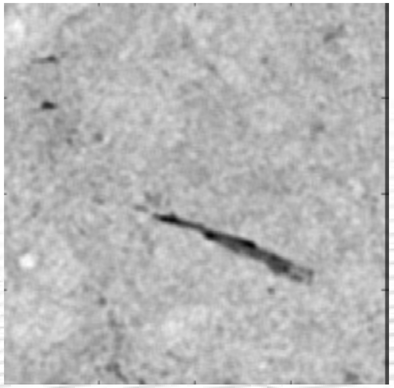
- Step1: Data multi-looking, calibration and ancillary data pre-processing
  - Data multilooking resulting in pixel size of 100 meters
  - Refined Lee Speckle filter preserving edges while keeping narrow leads
  - Calibration: from DN to sigma0 values
  - In our approach: no range compensation of sigma0
    - Depend on sea ice type which is often unknown for one given image

  - OSISAF ice mask information is projected onto the SAR image grid
    - No lead detection if SIC < 50%
    - No lead detection near coastal areas (buffer of 25 km)

Lead detection methodology (4/9)

- Step2: Identifying local minima, the morphological grayscale reconstruction algorithm

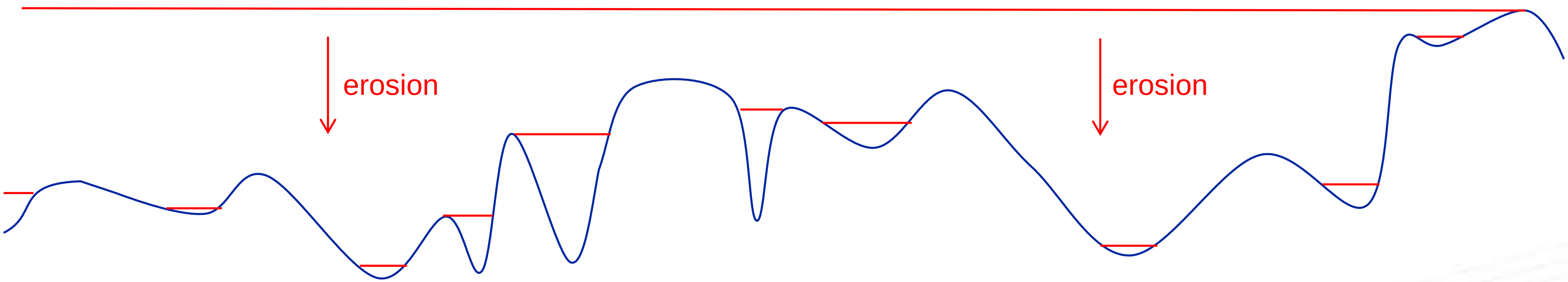


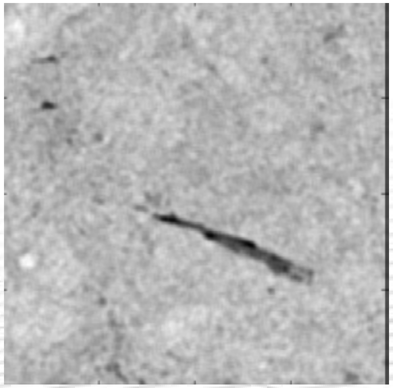


Sigma0 map

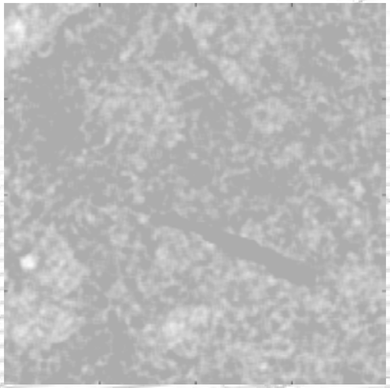
Lead detection methodology (5/9)

- Step2: Identifying local minima, the morphological grayscale reconstruction algorithm





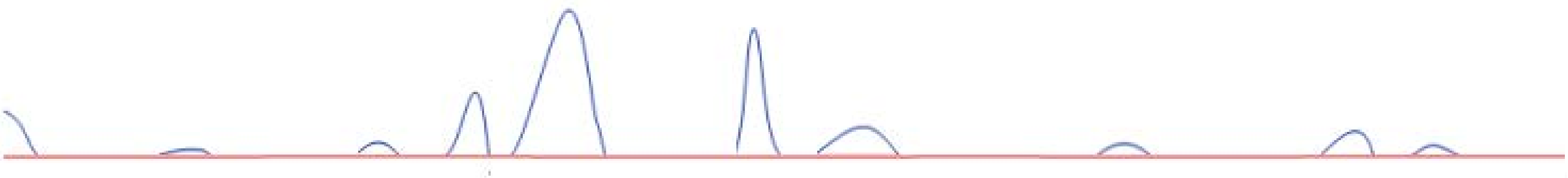
Sigma0 map

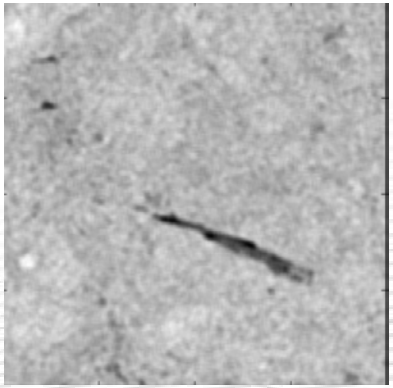


Reconstructed map

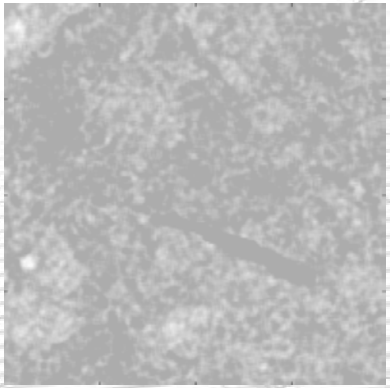
Lead detection methodology (6/9)

- Step2: Identifying local minima, the morphological grayscale reconstruction algorithm
  - Keep the highest peaks

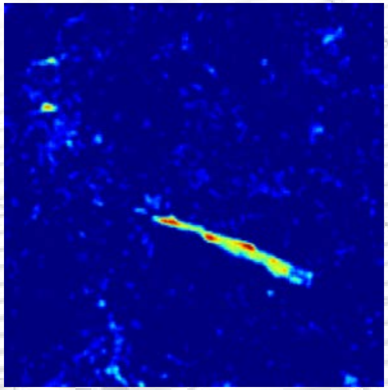




Sigma0 map



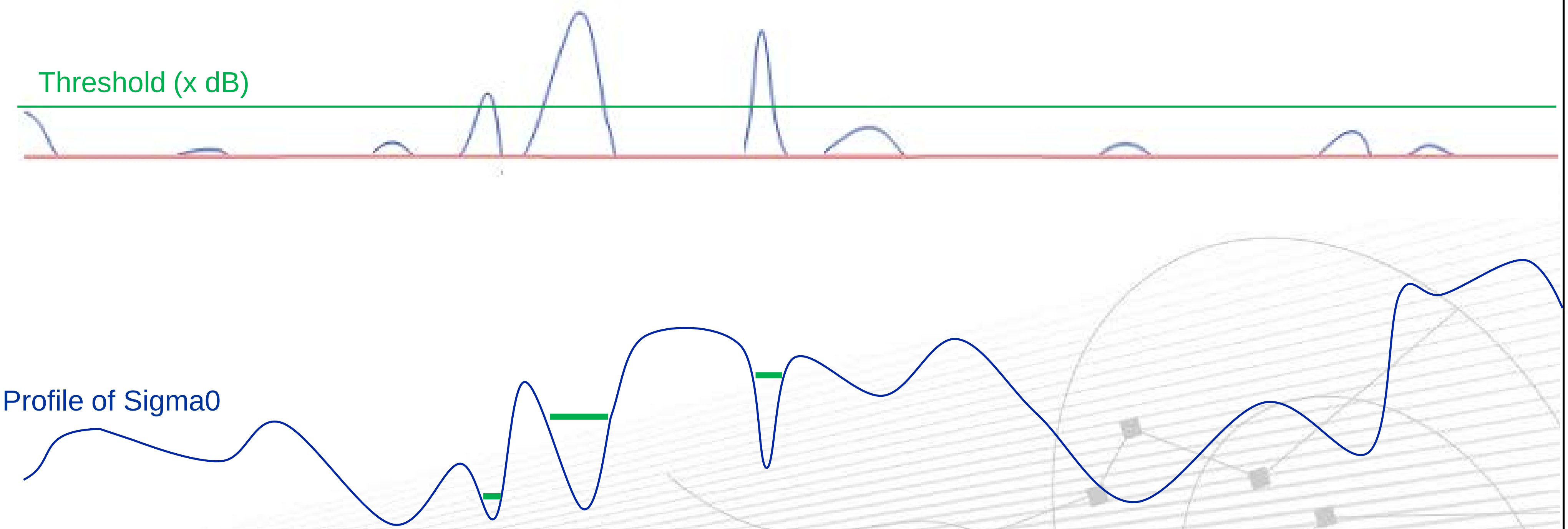
Reconstructed map



Local minima map

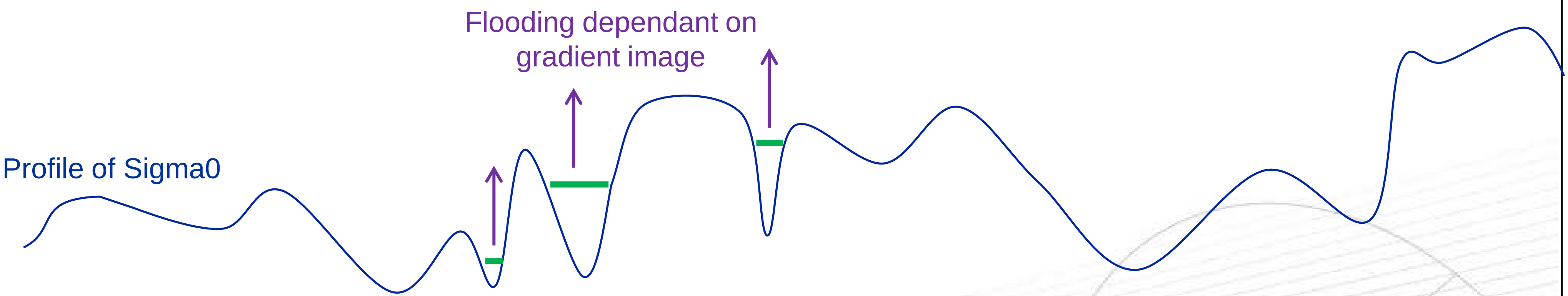
Lead detection methodology (7/9)

- Step2: Identifying local minima, the morphological grayscale reconstruction algorithm
  - Keep the highest peaks

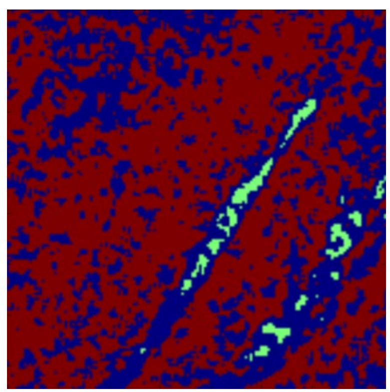


Lead detection methodology (8/9)

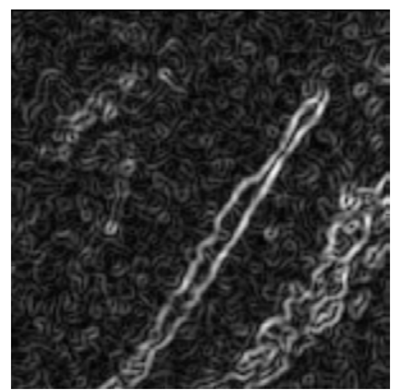
- Step 3: Watershed segmentation
  - "Flood" the areas detected from the previous step using the gradient image (from Sobel filter) as an elevation map
  - Maximum flooded map can not extend up to the mask corresponding to the values above the median value of sigma0 over sea ice (to be discussed as potential issues)



Sigma0 map



Threshold on morph. reconstruction



Gradient image based on Sobel filter

Lead map

Lead detection methodology (9/9)

- Step 4: Exporting the results
  - In geotiff format for mask and sigma0 value
  - In shapefile for generated contour of leads
    - limiting storage memory
    - Produce set of lead maps depending on the values of the internal threshold

On the sea ice drift

- Attempt to counterbalance SAR/alti time-lag with simple spatial advection of altimeter measurements corresponding to displacement effect due to sea ice drift
  - Use sea ice drift from ancillary products
    - So far: low resolution OSISAF drift resolution products (Sea Ice Motion Maps with 48 hours span, on 62.5 km Polar Stereographic Grid), based on DMSP/SSMIS, Metop/ASCAT and GCOM-W/AMSR-2
    - Eventually consider IFREMER products:
      - AMSR-2 based products at medium resolution (31 km) span 48 hours, but with holes de resolution, and only 2 channels used, estimations from Oct. to Apr.
      - ASCAT-A-B-SSMI low resolution (62 km) 3 days: less holes (more than 90% of estimated vectors from Nov to April), more accurate as 3 sensors integrated with estimations from Sept to May
  - For each altimetric position, interpolate mean sea ice drift speed vector
  - Considering time lag between SAR and altimetric acquisition time, compute displacement vector
  - Apply this vector to each altimetric measurement

Symbology:

Red: measured Altika data detected as lead,

Orange: drift measured Altika data detected as lead

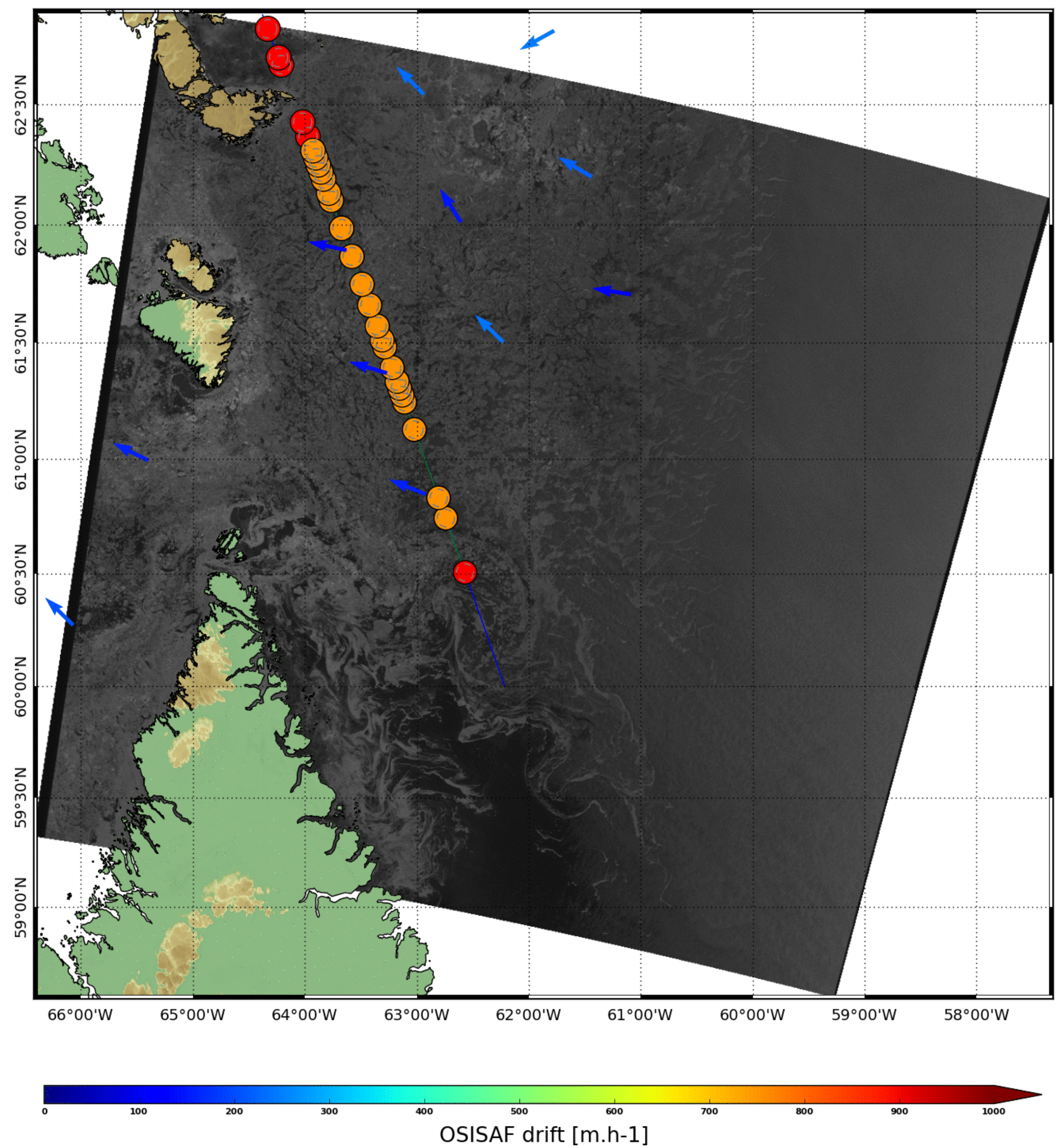
Drift negligible for most of our matchups database with less than 120 min time lag … generally less than 1 km

Issue with coastal areas with no data or large uncertainties

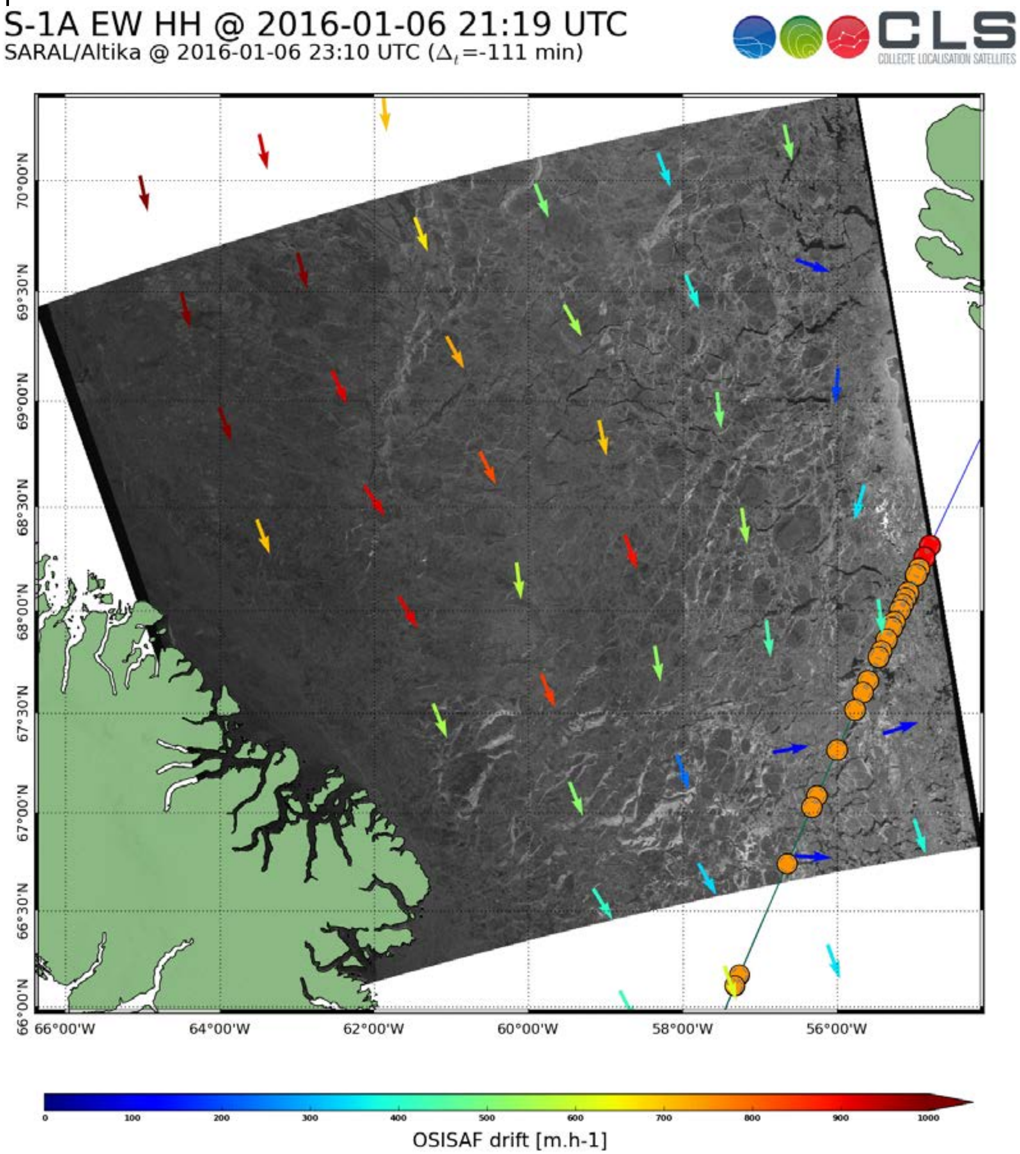
-> in the following, no drift considered

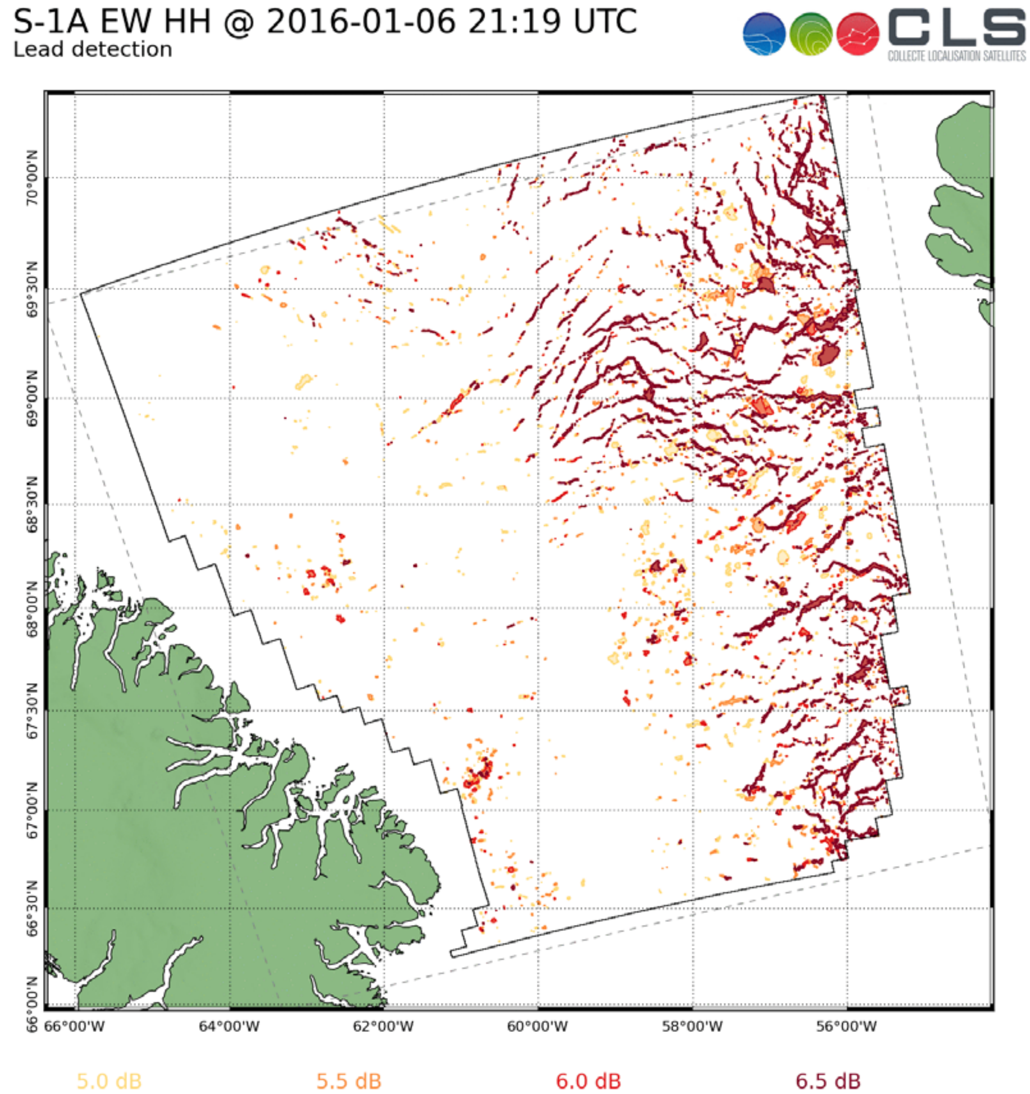
S-1A EW HH @ 2015-12-09 10:35 UTC

SARAL/Altika @ 2015-12-09 09:12 UTC (Δ_t=82 min)



Some results

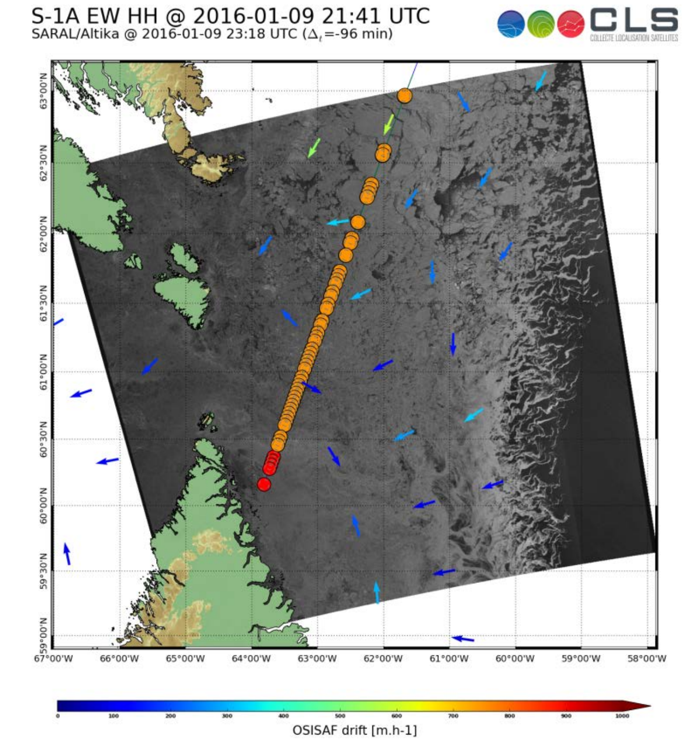


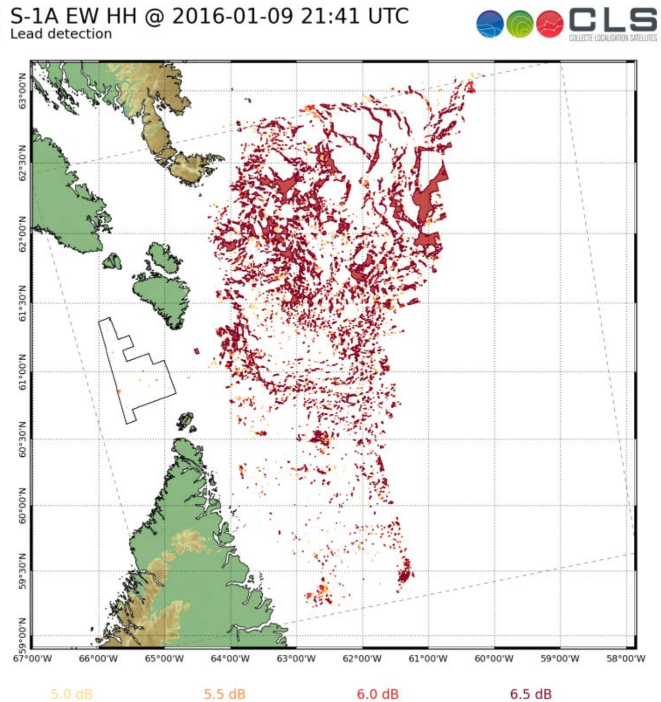


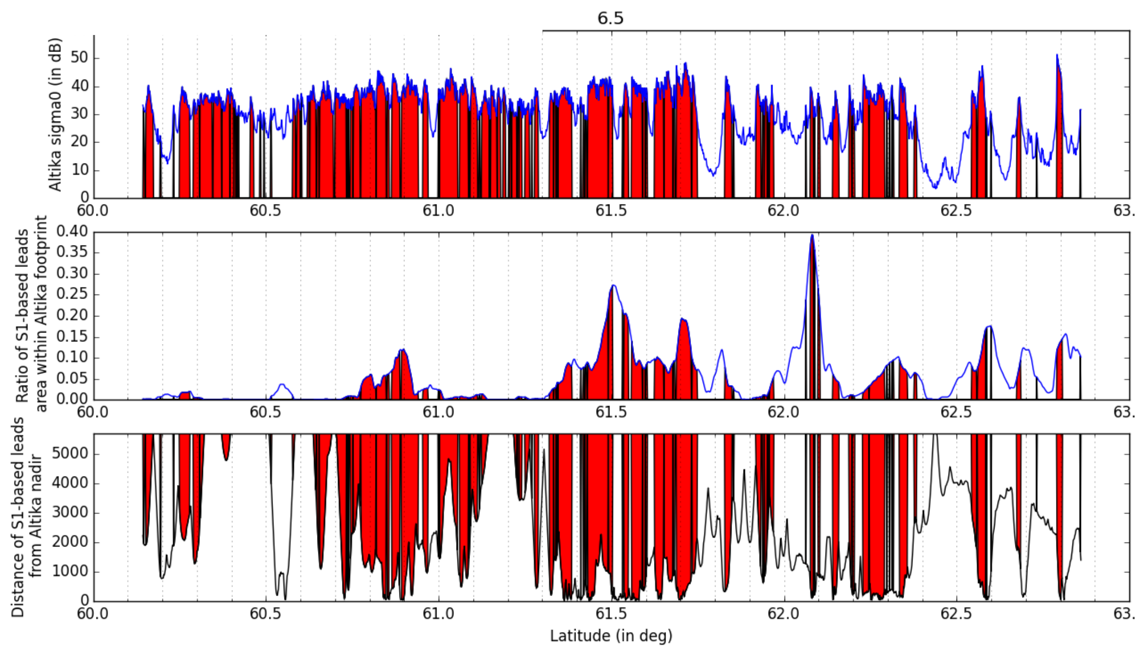
Towards an effective method for lead detection comparison

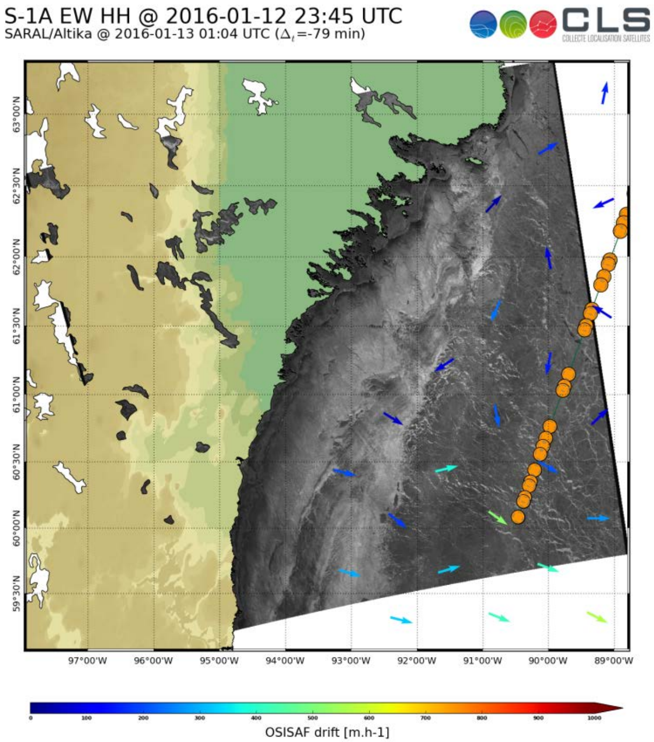
- How to compare 2D SAR-based information with 1D altimeter flag ? False alarm rate, good detection ? 2 possible criteria:
  - % of coverage: ratio of SAR-based lead surface within alti WF footprint
    - 0
      - if no lead detected by alti: consistent non detection by the 2 sensors,
      - if lead detected by alti: contradictory detection by alti
    - > 0
      - if no lead detected by alti: contradictory detection by SAR all the more important as this % is important
      - if lead detected by alti: consistent detection by the 2 sensors
  - Distance to nadir: closest distance between nadir and SAR-based leads

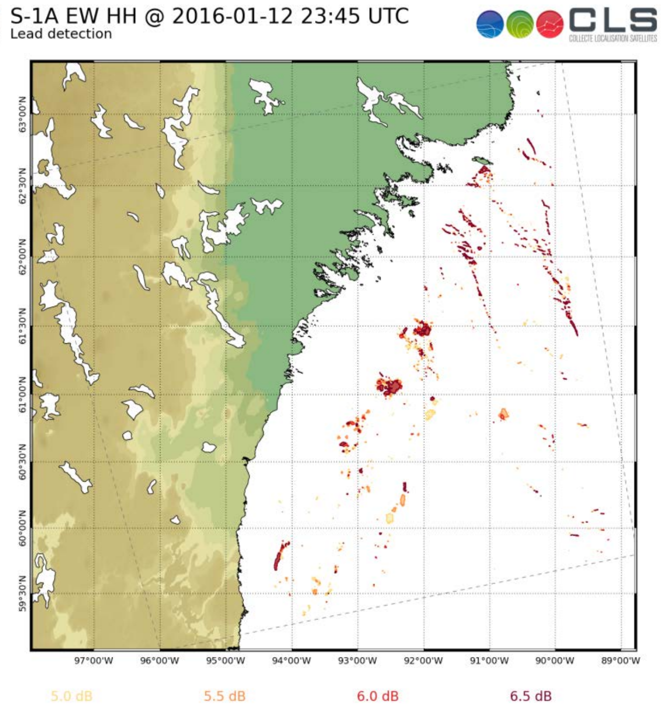
- *In fine* find a way to get one single criteria to assess the rate of good and wrong agreements
  - Ongoing ….

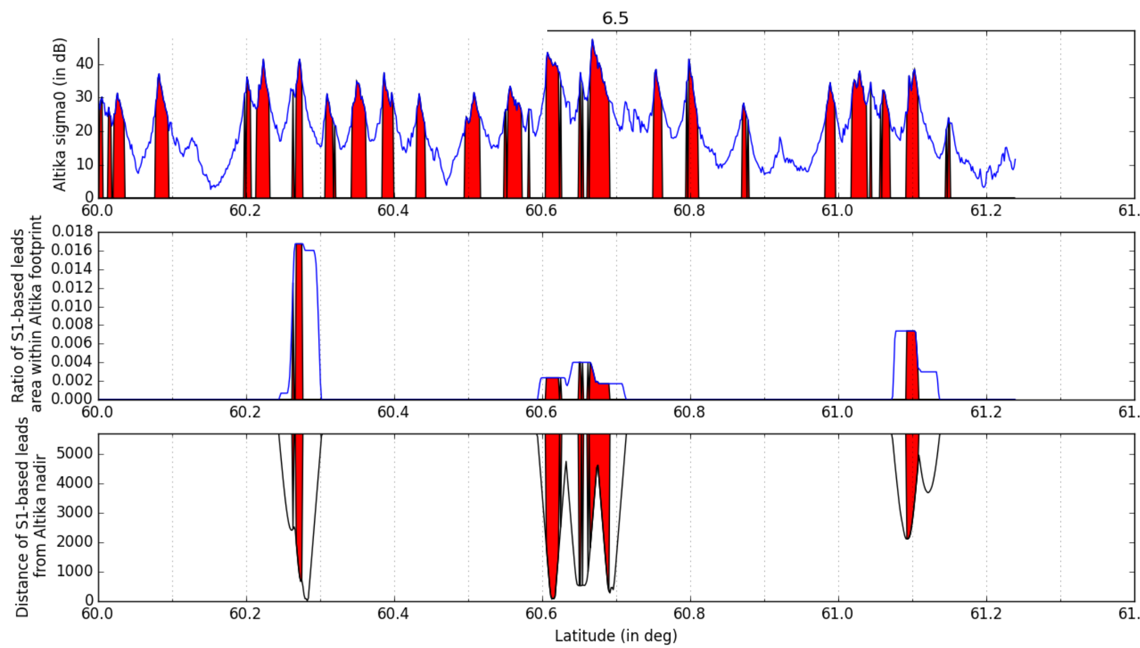

S-1A EW HH @ 2016-01-09 21:41 UTC
SARAL/Altika @ 2016-01-09 23:18 UTC (Δ_t=-96 min)
CLS
OSISAF drift [m.h-1]


S-1A EW HH @ 2016-01-09 21:41 UTC
Lead detection
CLS
5.0 dB
5.5 dB
6.0 dB
6.5 dB


6.5
Altika sigma0 (in dB)
Ratio of S1-based leads area within Altika footprint
Distance of S1-based leads from Altika nadir
Latitude (in deg)


S-1A EW HH @ 2016-01-12 23:45 UTC
SARAL/Altika @ 2016-01-13 01:04 UTC (Δt=-79 min)
CLS
OSISAF drift [m.h-1]


S-1A EW HH @ 2016-01-12 23:45 UTC
Lead detection
CLS
5.0 dB
5.5 dB
6.0 dB
6.5 dB


6.5
Altika sigma0 (in dB)
Ratio of S1-based leads area within Altika footprint
Distance of S1-based leads from Altika nadir
Latitude (in deg)

Conclusion

- A sub-set of matching (time and space) S1 and Altika data has been found (SIC > 50%, 2 hours lag max)

- A S1-based lead detection methodology is now prototyped, can be run systematically

- Qualitative evaluation can be already performed
  - Help to refine detection internal thresholds within the alti or the SAR process,
  - Improve our knowledge of SAR imagery and altimeter signals acquired over sea ice

- First approach toward a quantitative assessment

- Provide recommendations
  - Improve altimeter-based lead detection ? (WF class 2 + sig0 > 20db)
  - Improve S-1 based lead detection ?