Iceberg detection and characterization using Wave Mode SAR images: a complementary approach to Altimeter

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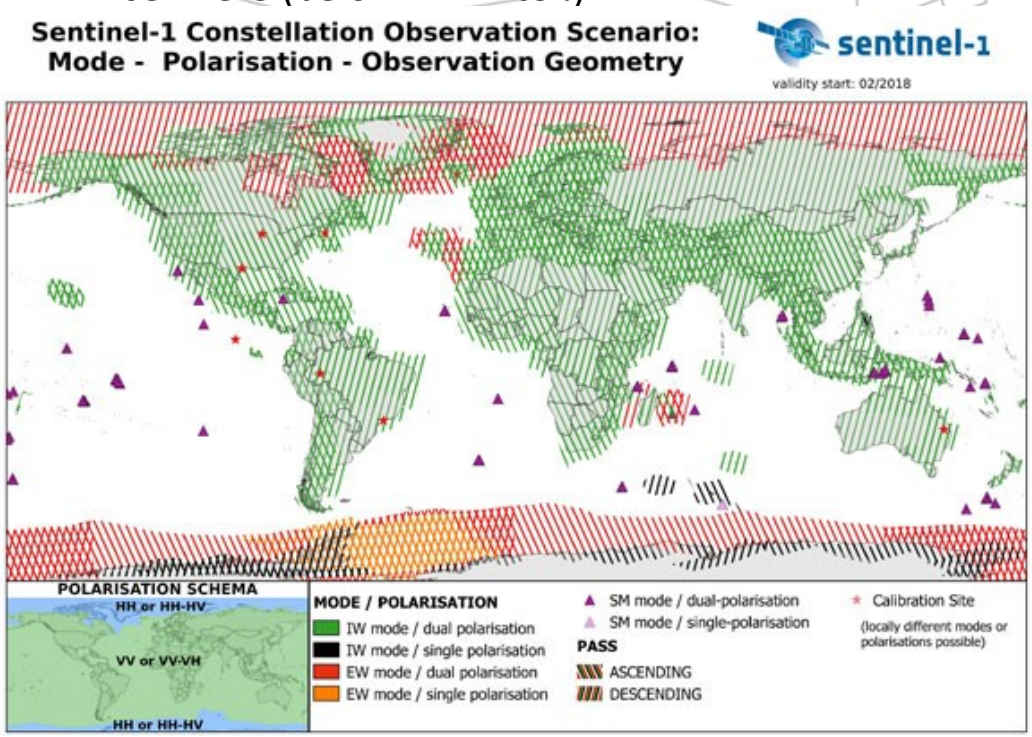
Wave Mode of Sentinel-1 SAR ?

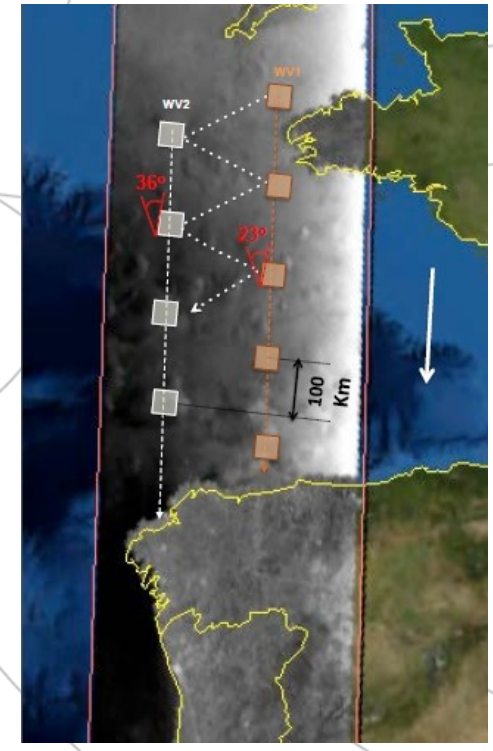
2 satellites in orbit: S-1a from April 2014 and S-1b from April 2016

High resolution radar images with systematic acquisitions:

- Mode IW, 10 meter resolution, 250 km swath width, 29.1° - 46.0°
  - Terrestrial and coastal areas
- Mode EW, 40 meter resolution, 410 km swath width, 18.9° - 47.0°
  - Arctic sea and Antarctic
- Mode Wave Mode (WM), < 5 meter resolution, imagette of 20 * 20 km, @23° or @36°
  - Elsewhere (below in white !)



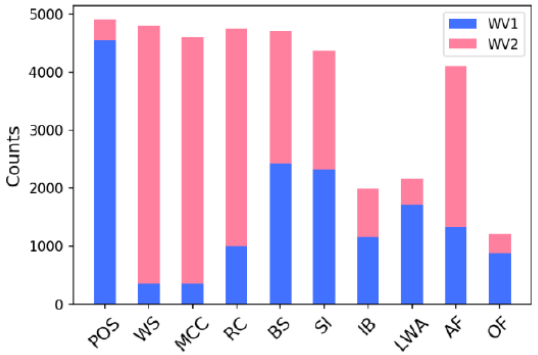
Current observation scenario

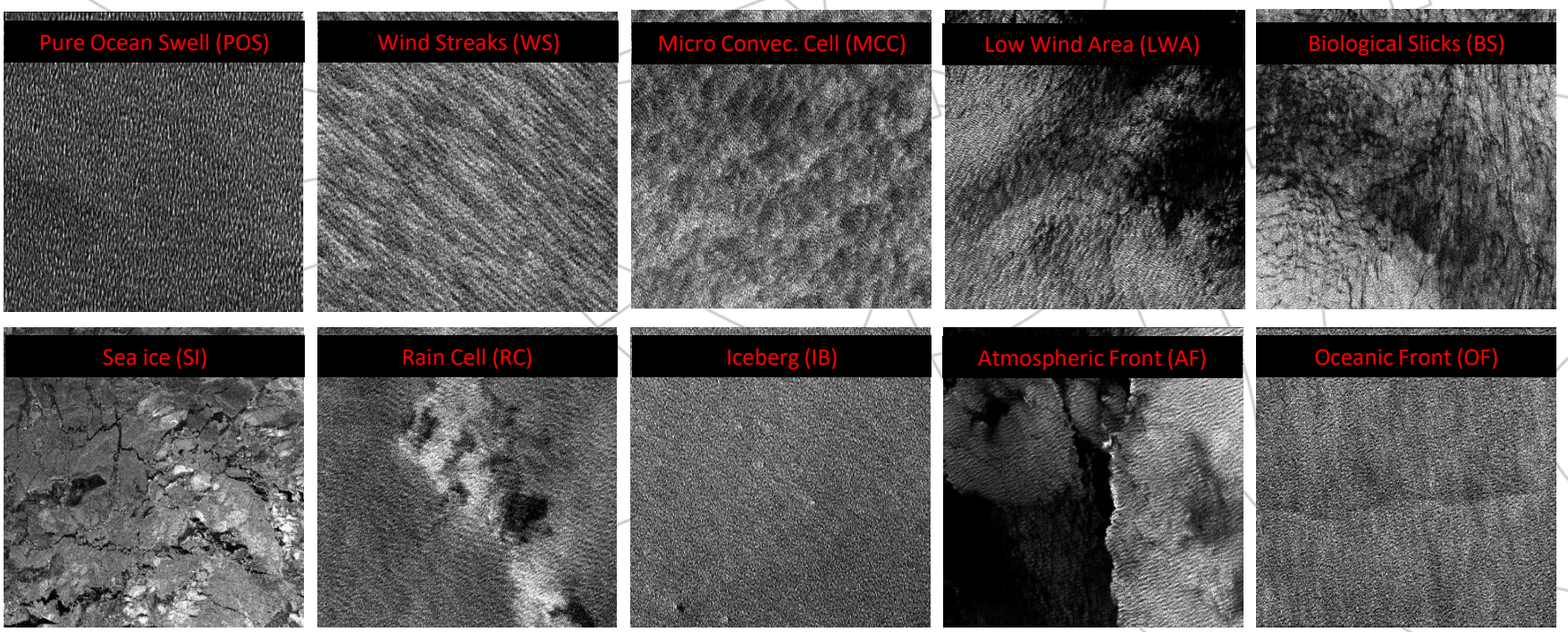


Wave Mode (WM) acquisitions

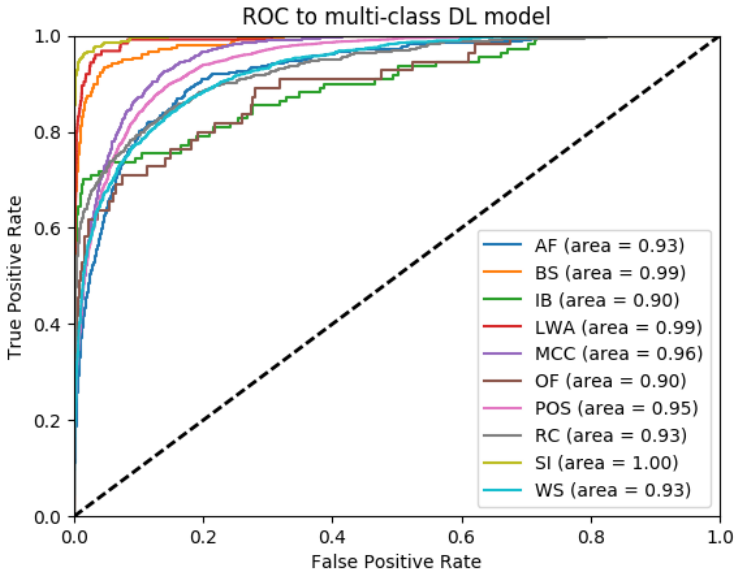
Approach for iceberg pre-detection

- At WM imagette level
  - Based on DL techniques and TenGeoP-SARwv database (https://doi.org/10.17882/56796)
    - 37k labelled imagettes with one label per imagette, 10 classes (about 2000 IB)
  - Data preprocessing
    - SLC WM converted in tif format, resampled with 50 m spatial resolution
    - Radar intensity normalized with:
      - Mean angular dependencies wrt. wind
      - Fixed clipping for all database
      - Coded with 16 bits

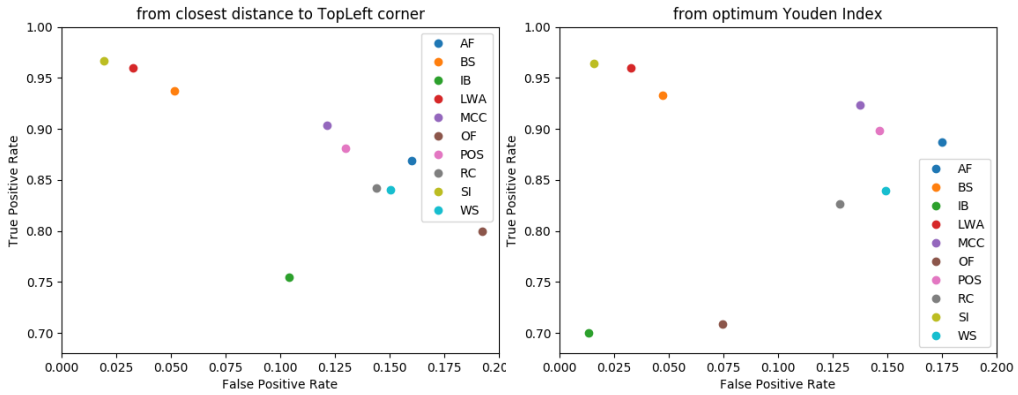




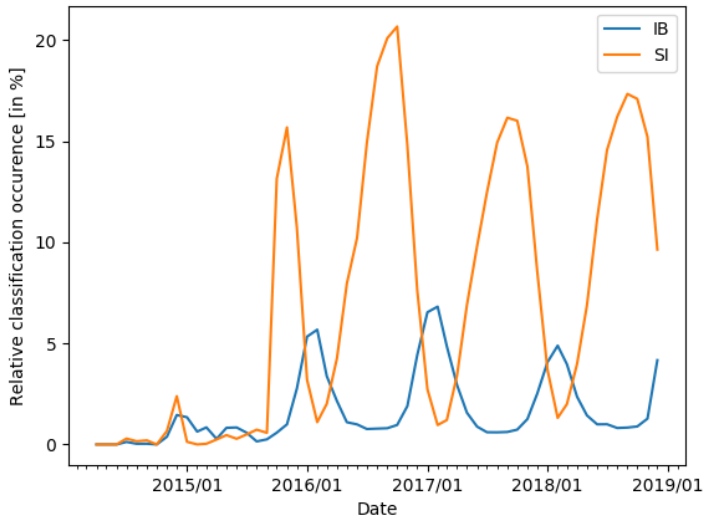
Approach for iceberg pre-detection



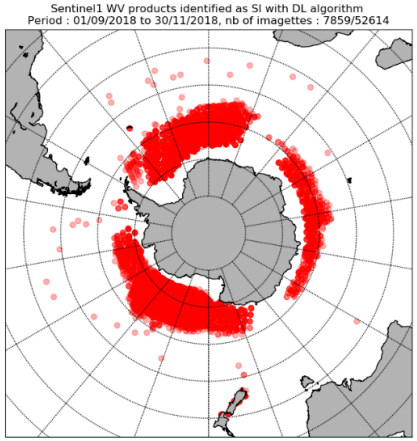
ROC curves using independent 10k dataset



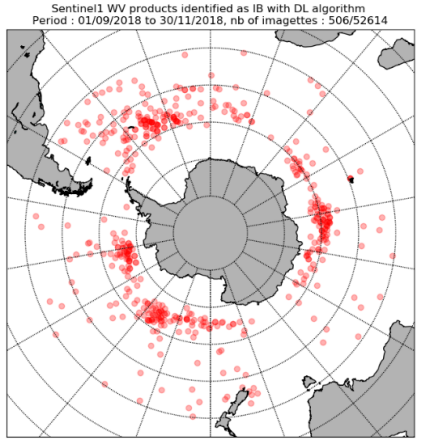
Optimal thresholds



Occurrence of classification below 40°S



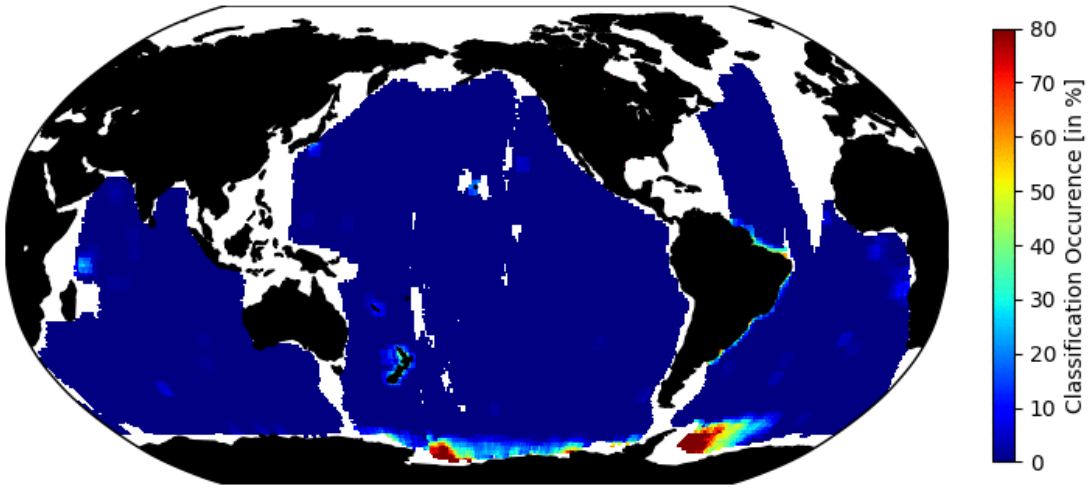
Sea ice (SI)



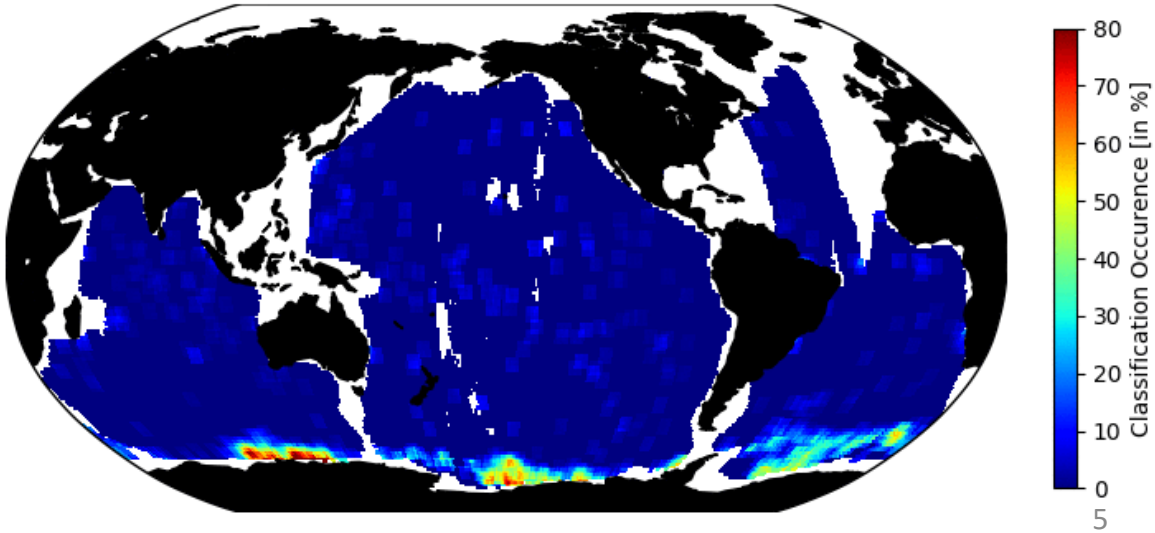
Iceberg (IB)

Overview of classification results

Sea Ice in January 2016

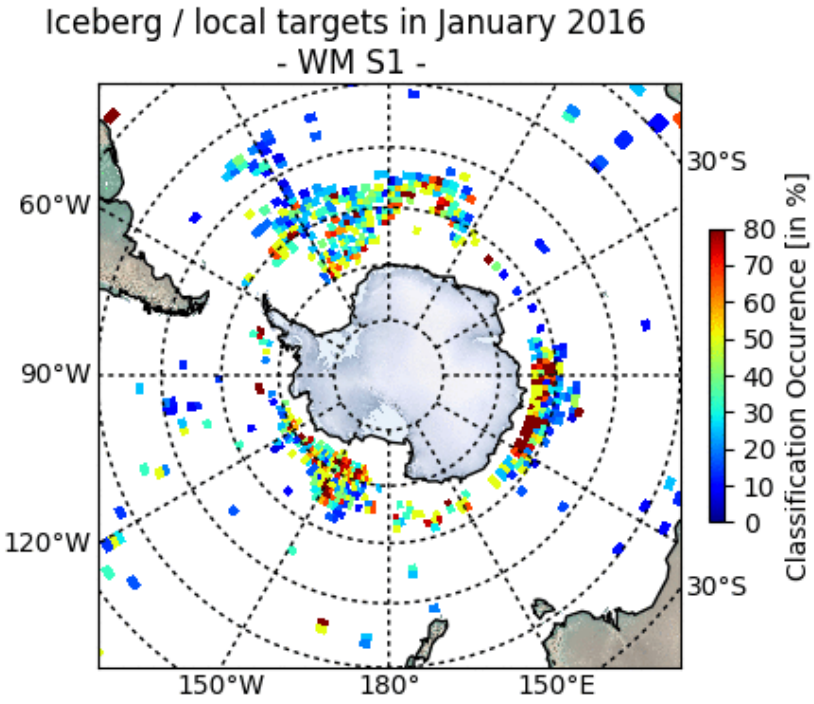


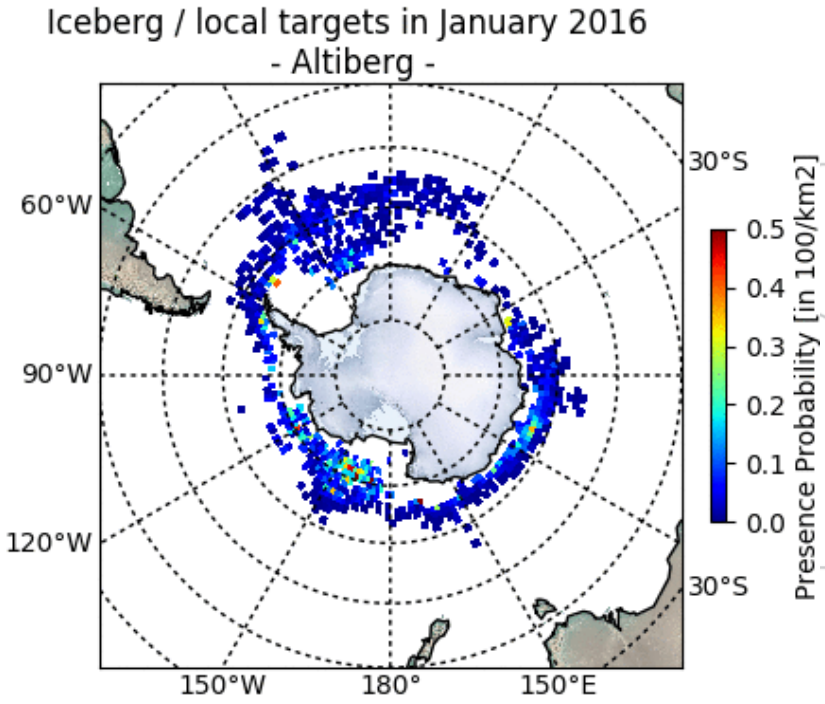
Iceberg / local targets in January 2016



Comparison with Altiberg

- Altiberg
  - Processed independently for the following altimetry missions : GeoSAT, ERS-1, ERS-2, Jason-1, Jason-2, Jason-3, HY-2A, CryoSat-2, Topex, Envisat and AltiKa.
  - The merged product combining all the available altimeters is used here.





Identification of individual iceberg

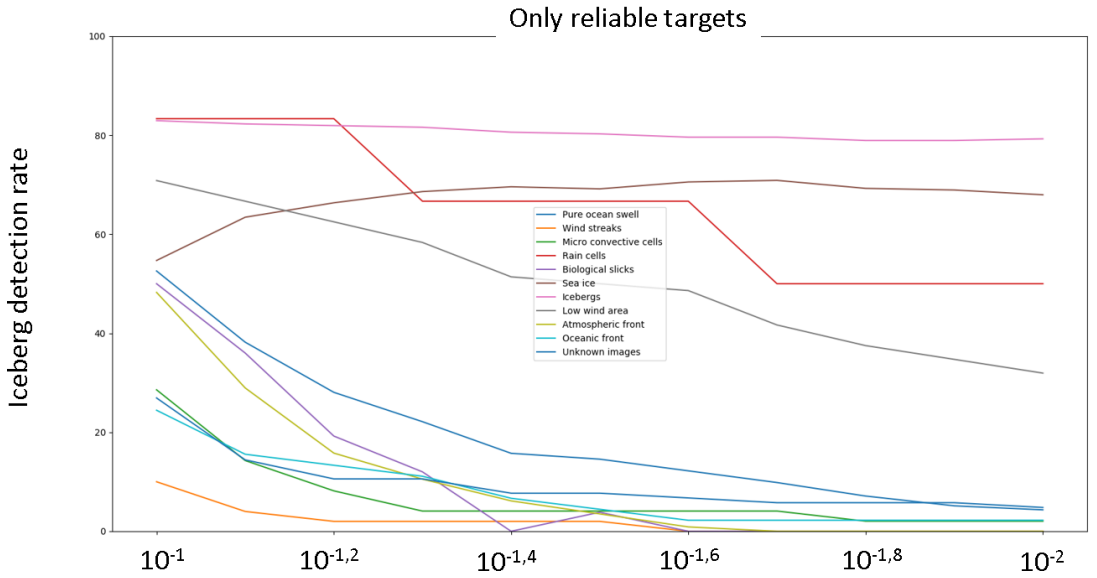
- Detection with CFAR
  - When Deep learning flags an imagette as « Iceberg » then CFAR approach is then used to locate each individual iceberg within the imagette
- Standard and inverse CFAR approach for bright and black icebergs, respectively
  - In WM1, most iceberg appear as black, few bright ones
  - In WM2, presence of black and bright ones
- Parameterization of CFAR
  - Possible for each detection scheme (WM1 bright detector, WM2 bright detector, WM1 black detector, and WM2 black detector)
  - 3 keys variables to adjust:
    - Minimum size of iceberg to detect
    - Maximum size of iceberg to detect
    - Probability of False Alarm

Analysis of sources of false alarms

Category for annotated imagettes	Nb imagette	Nb proc. only below 40°S)	imagette with reliable targets	imagette with detections	Rate of false alarms	Rate of good detection	Potential improvements
Pure ocean swell	640	493	198	289	40,2%		Use Hs information from OCN L2 products, and optimized threshold depending on wave
Wind streaks	640	108	1	1	0,9%		OK
Micro convective cells	640	102	24	28	23,5%		
Rain cells	640	6	4	5	66,7%		Nb occurrence should remain small
Biological slicks	640	56	24	31	42,9%		Use a filter on mean average speed (below 2 m/s)
Sea ice	640	620	538	567	86,8%		Use a sea ice mask
Icebergs	640	587	477	516		81,3%	Can get higher if pfa increases, but risk of higher false alarms -> need optimization with IFREMER cluster
Low wind area	640	122	79	94	64,8%		Use a filter on mean average speed (below 2 m/s)
Atmospheric front	640	189	32	47	17,0%		See improvements from other categories first
Oceanic front	640	68	5	10	7,4%		
Unknown images	640	164	23	29	14,0%		See improvements from other categories first

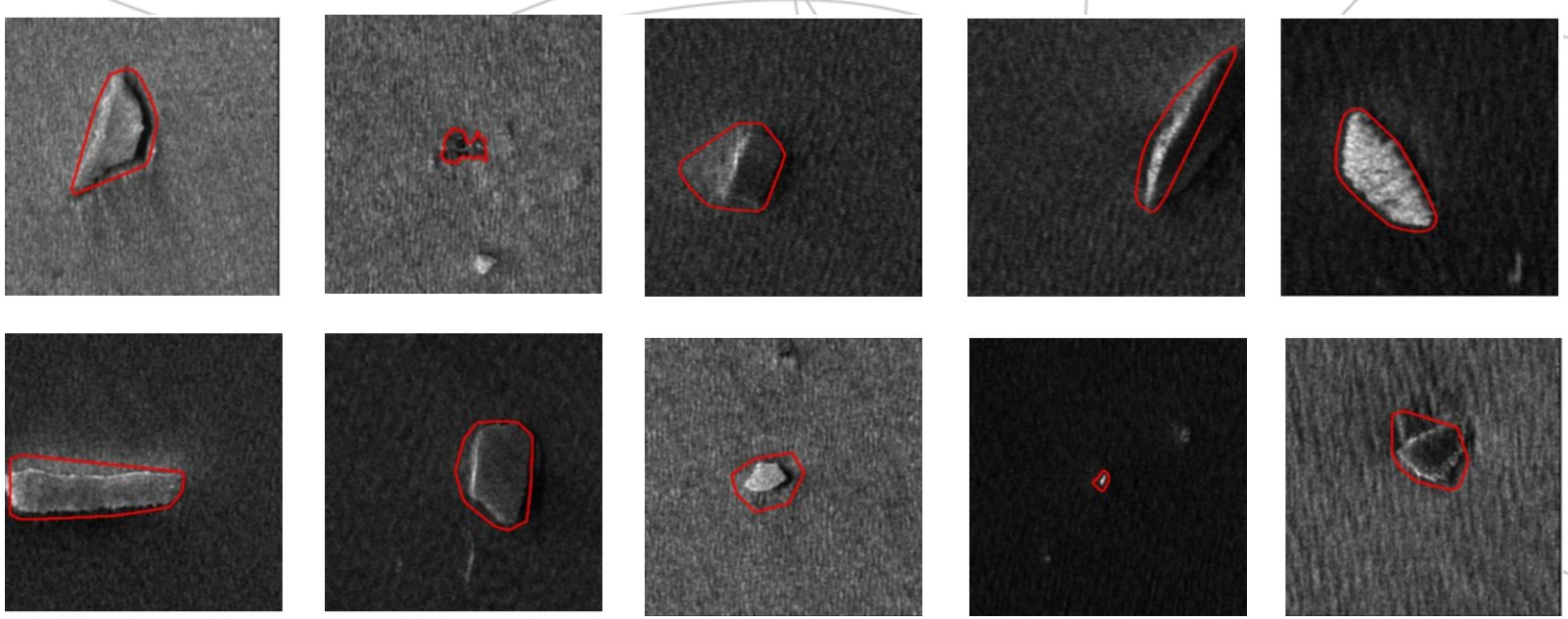
Reliability of CFAR detection / parameterization

- Target classified as non-reliable:
  - For dark target:
    - Equivalent wind speed over target (from SAR inversion) < 2 m/s
  - For bright target:
    - False alarm in low sigma0 area where gaussian CFAR assumption does not hold -> Equivalent wind speed over target (from SAR inversion) < 1 m/s
    - In case of swell -> Hs > 1,5 m (from L2 product) AND sub-look coherence test fails (non stationary target -> breaking wave)
- Parameterization of CFAR
  - For now, just False Alarm Probability has been tuned (required massive computing)



Segmentation of each individual iceberg

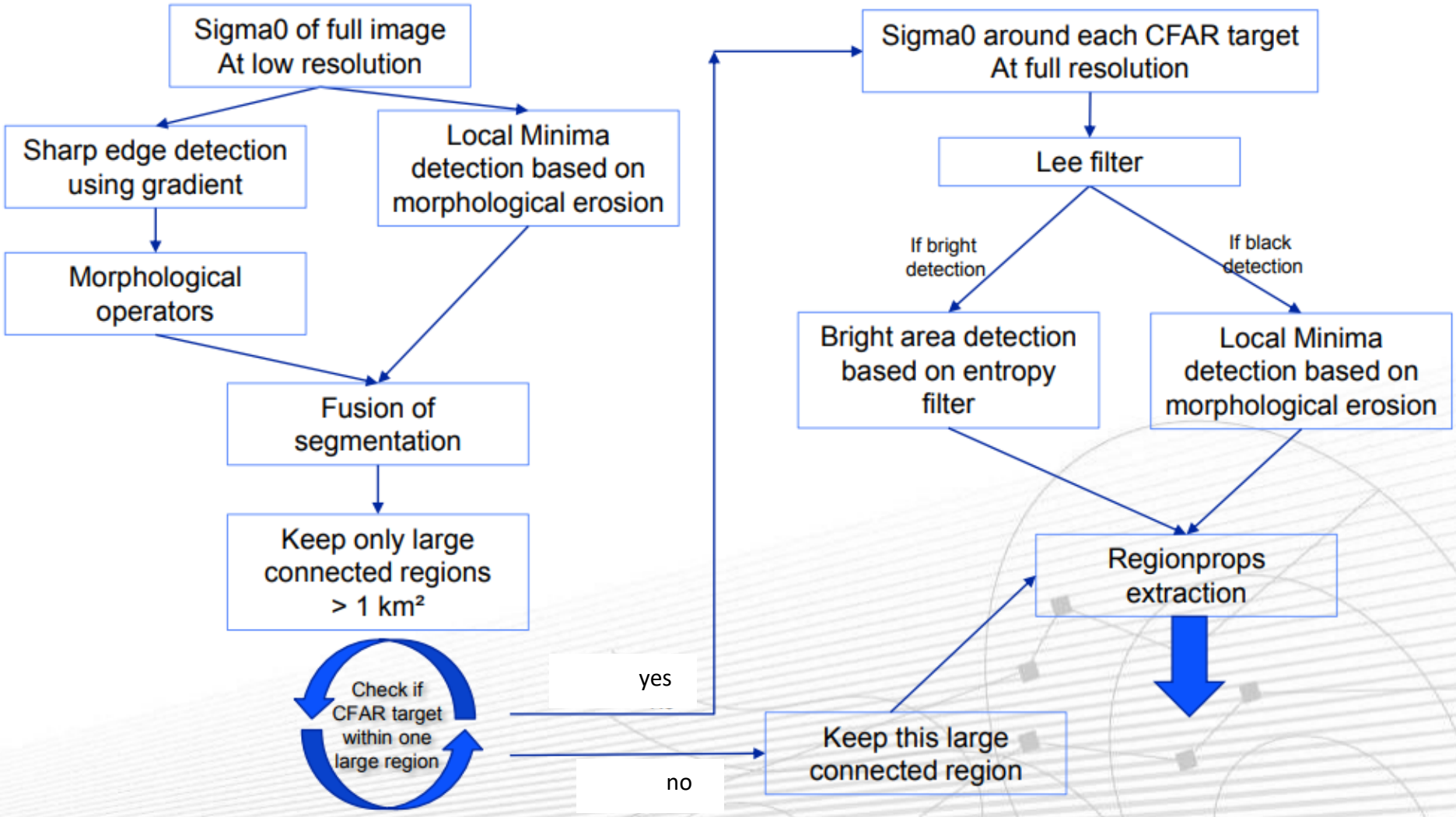
- Each iceberg is now spotted by CFAR technique within imagette tagged as « Iceberg » by DL
- Segmentation approach to delineate the contour of each individual iceberg
  - Why? Extraction of parameters (area, max dimension, shape…)
- Iceberg as seen by SAR S1 @23° and 36°
  - Bright, black, large, small, dot, bright edge for tabular, …



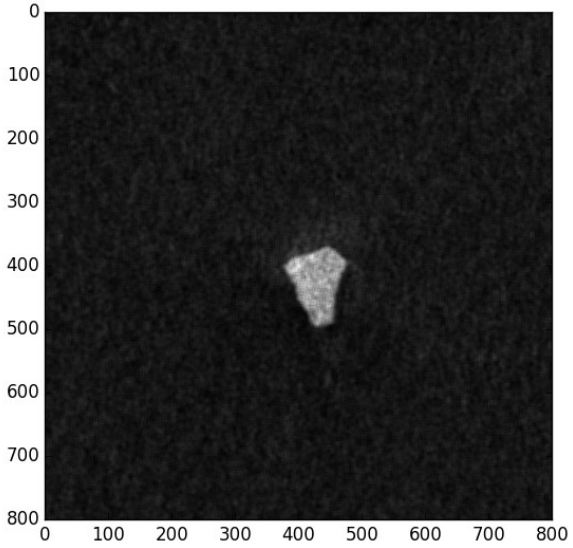
Some segmentation results

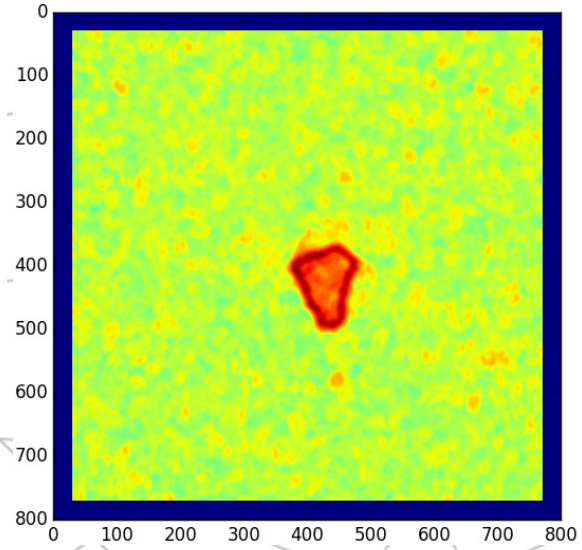
Segmentation of each individual iceberg

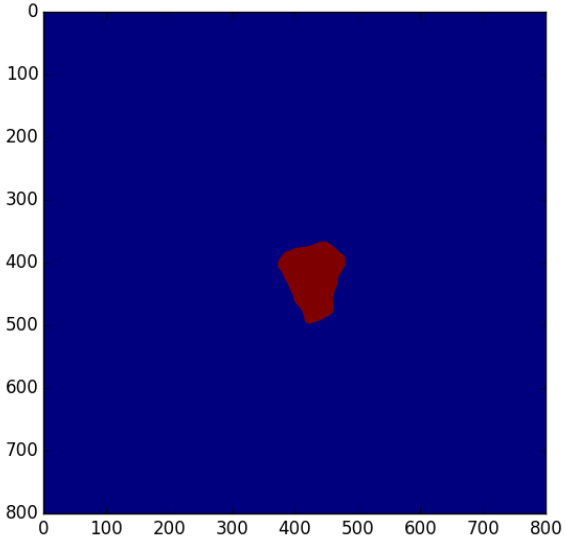
- Multi-scale approachs of approach (both large/small and bright/dark)



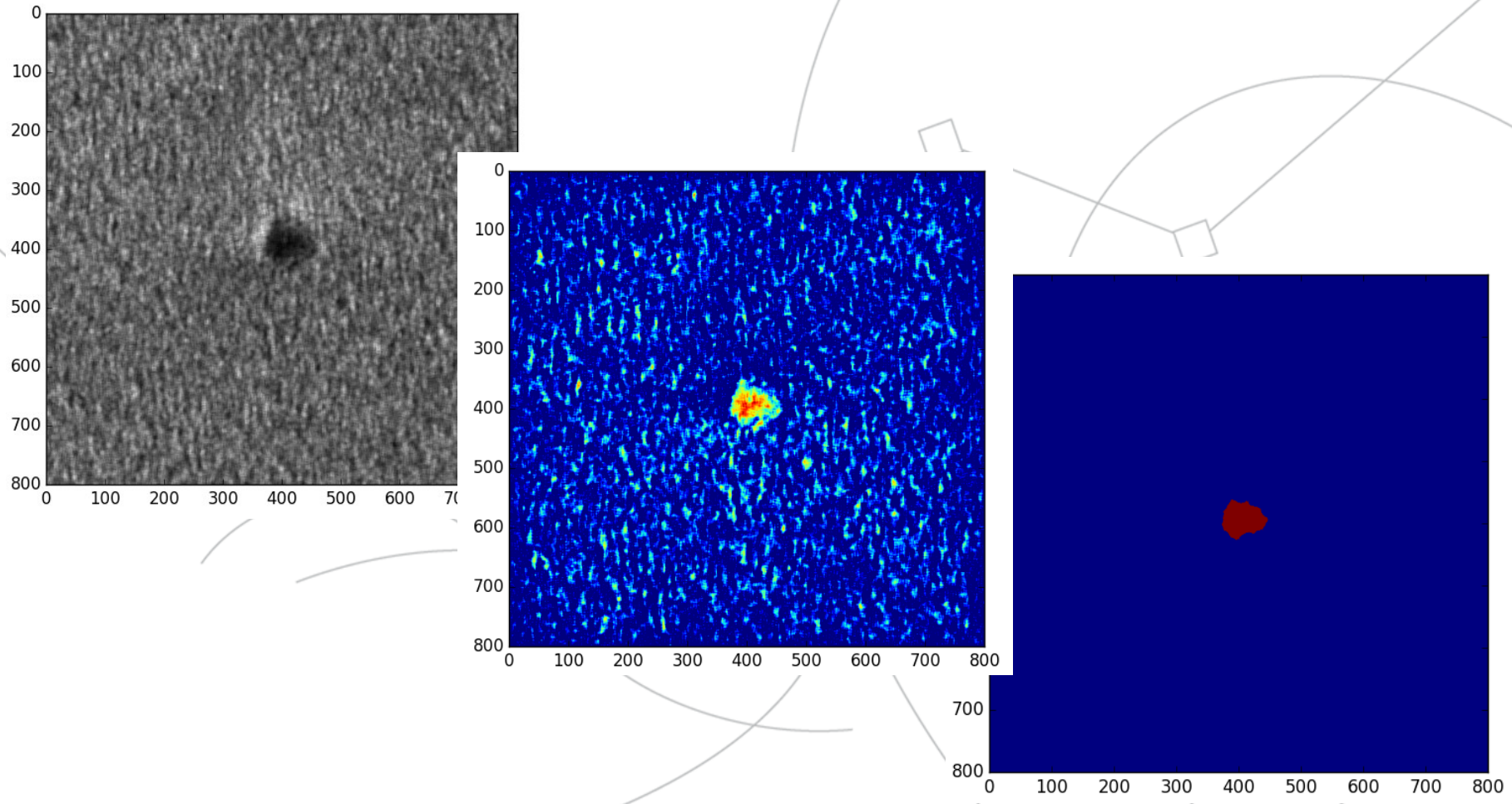
Bright icebergs (entropy filter)



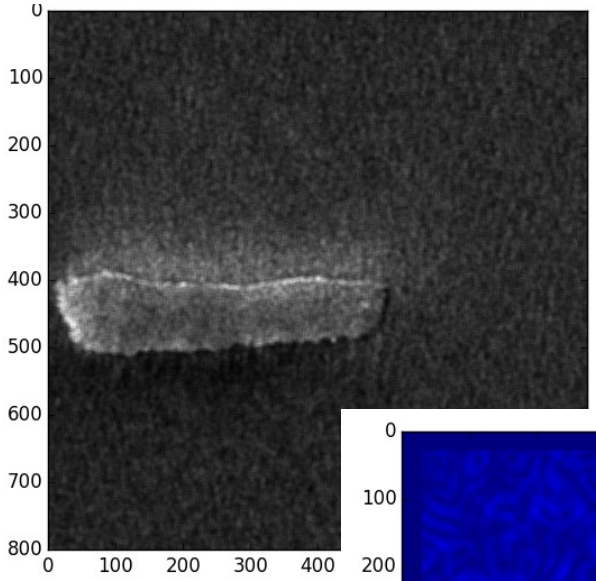


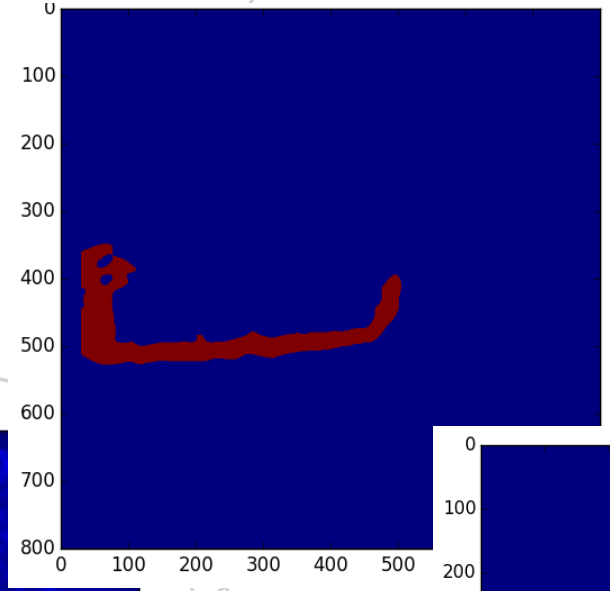


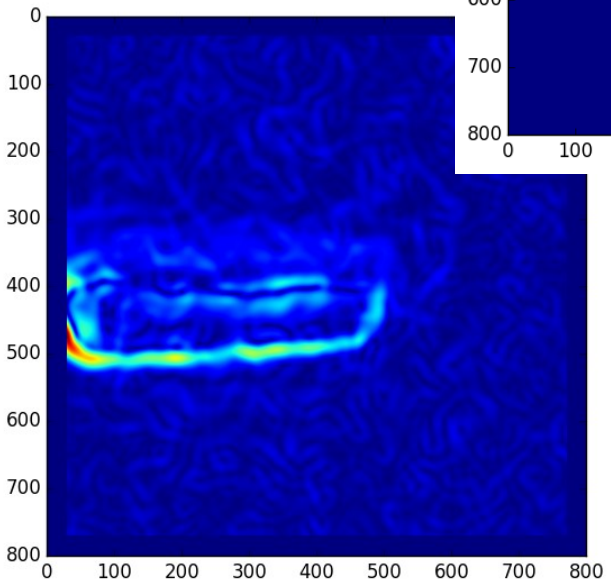
Dark icebergs (morphological erosion to detect local minima)

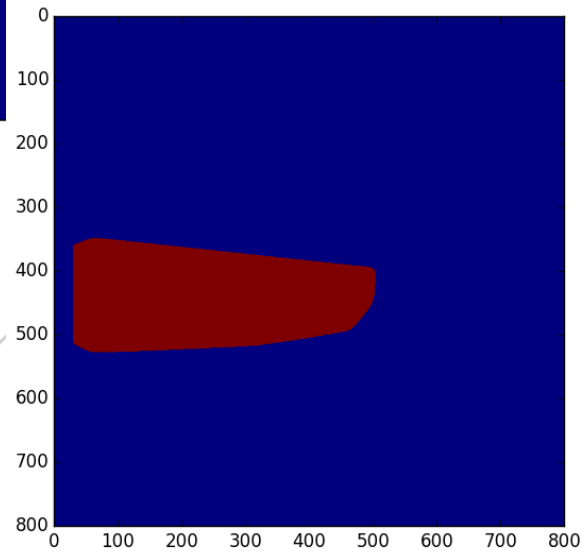


Large icebergs (Sharp edge detection)

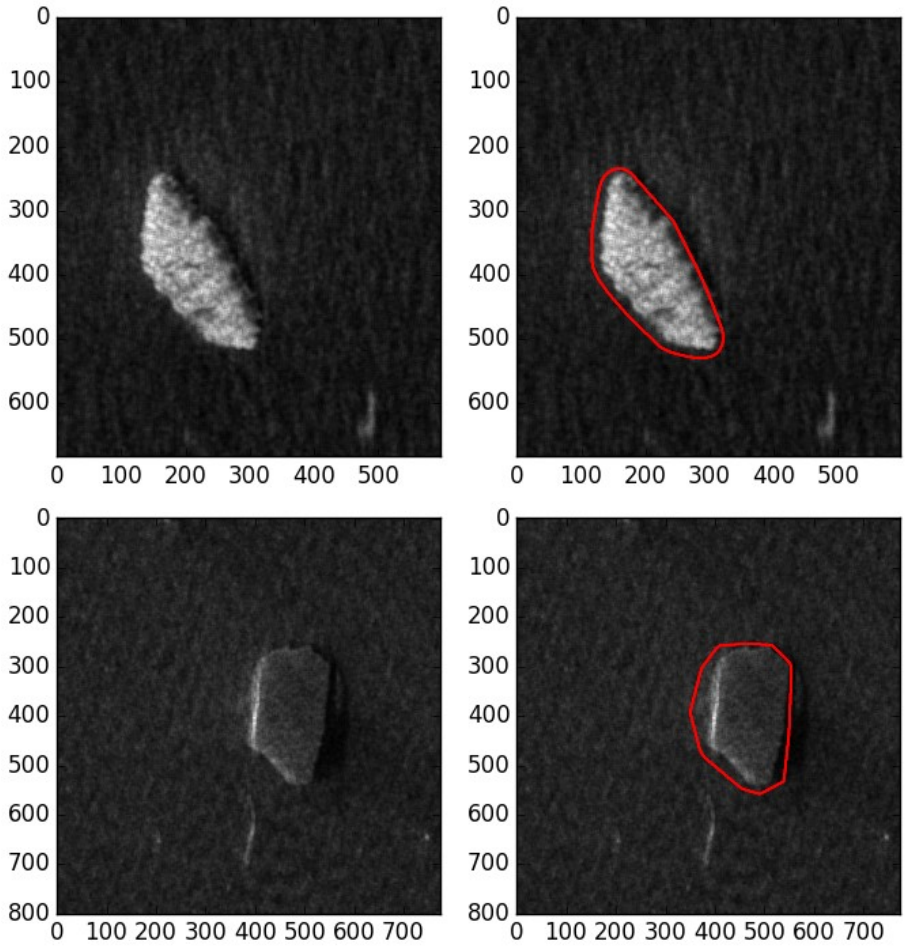


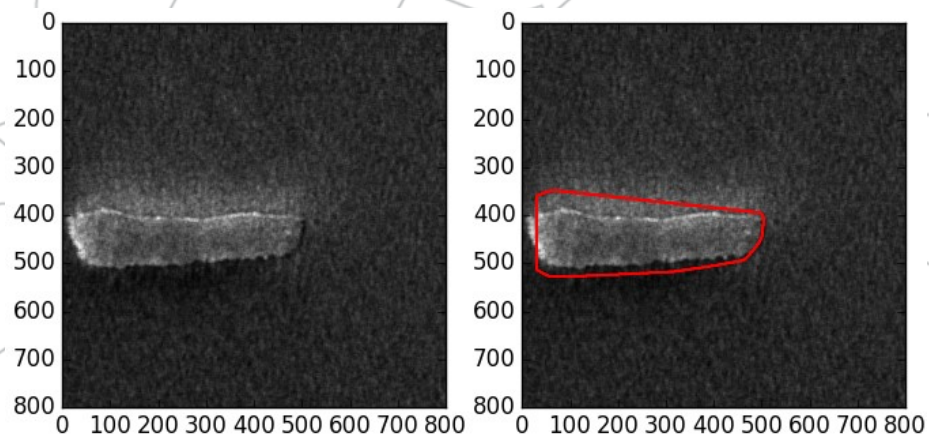




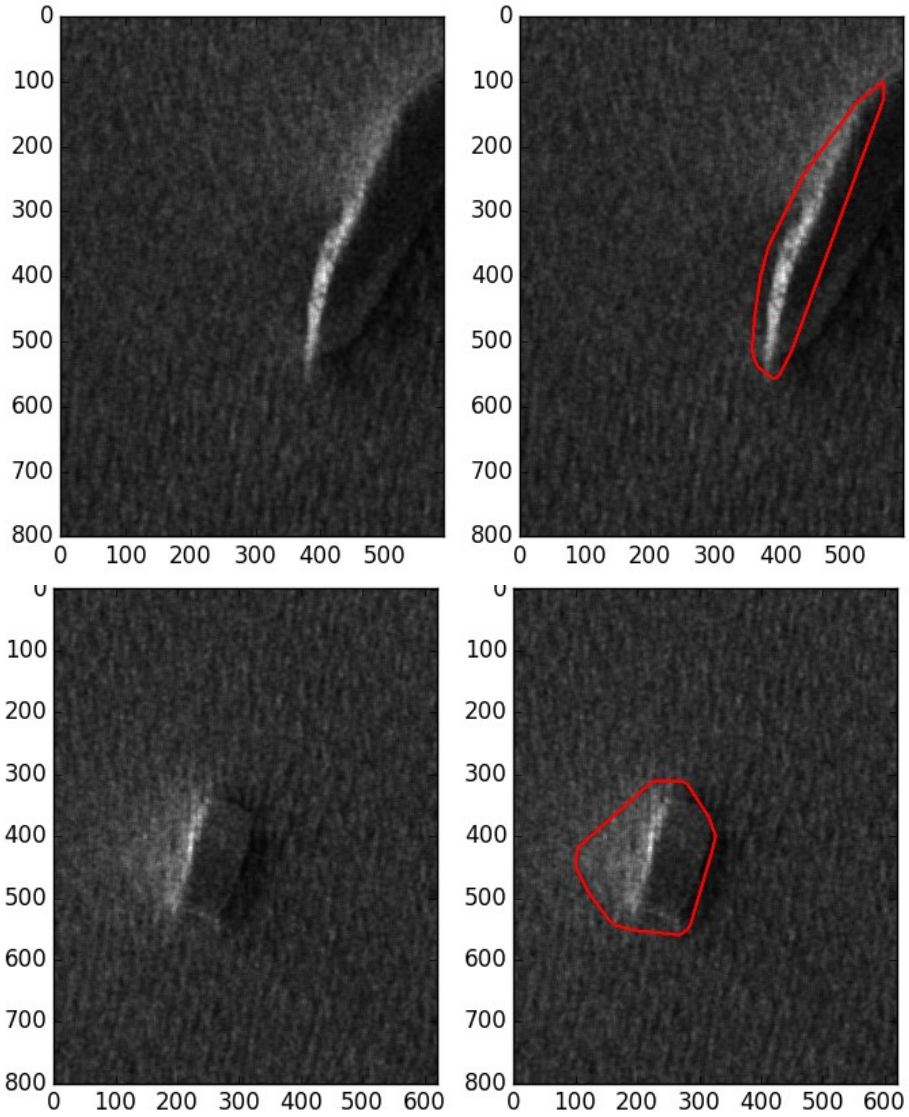


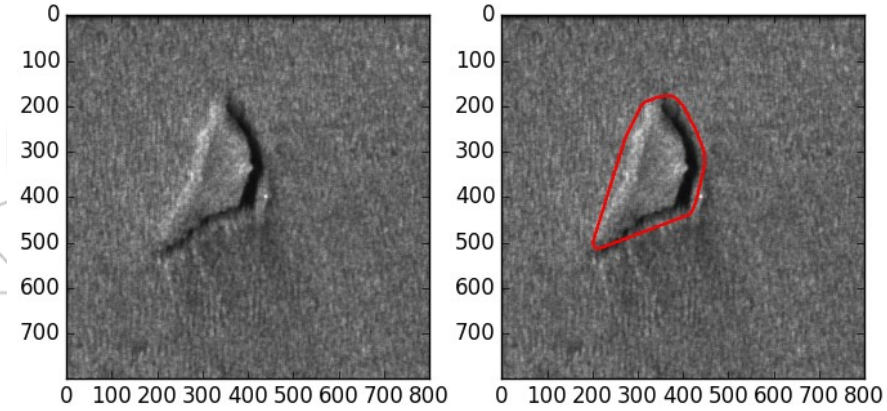
Some results (medium-size icebergs)

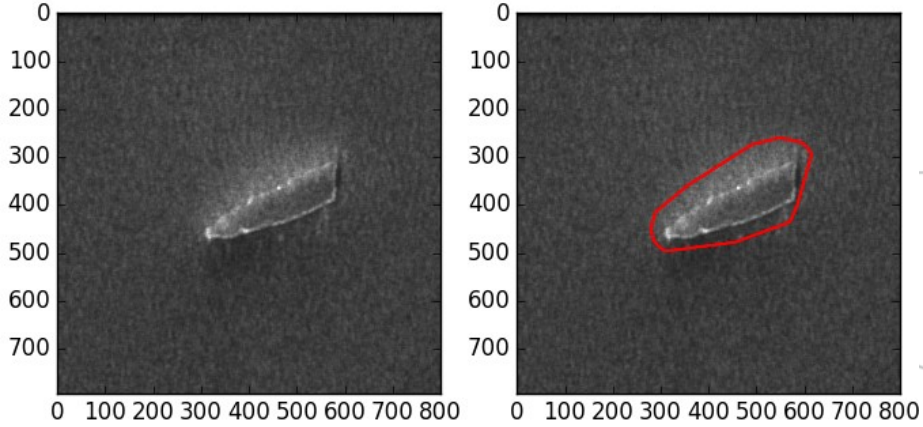




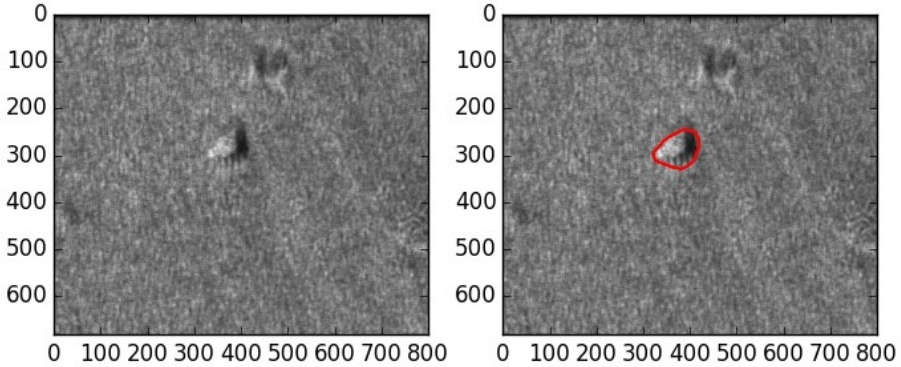
Some results (medium-size icebergs)

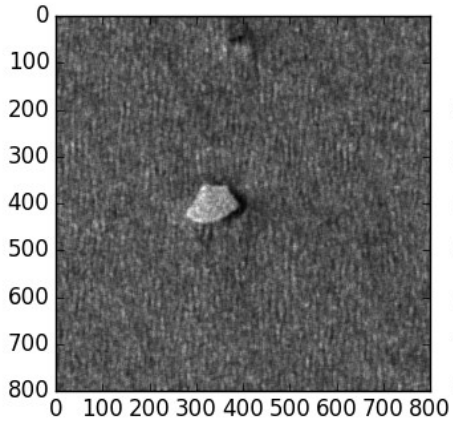


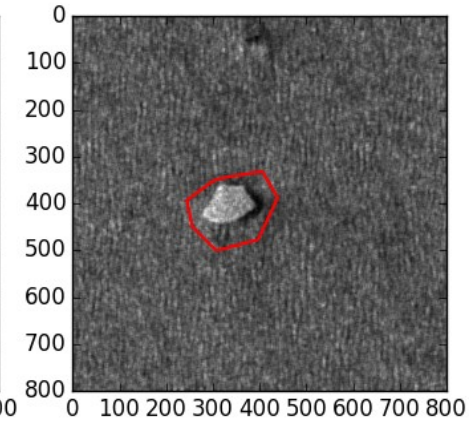


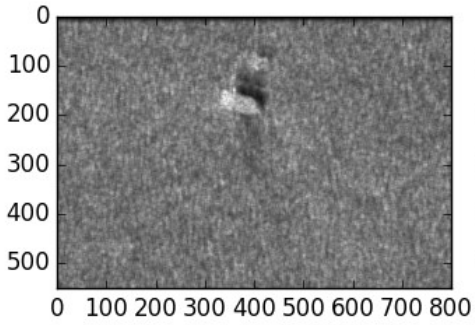


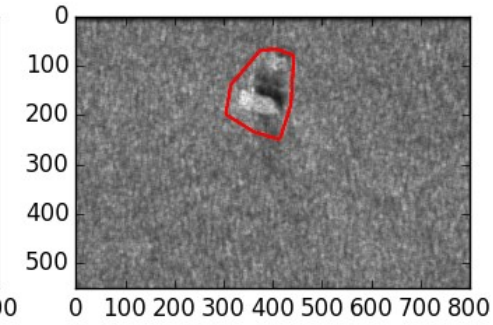
Some results (dark small-to-medium-size)

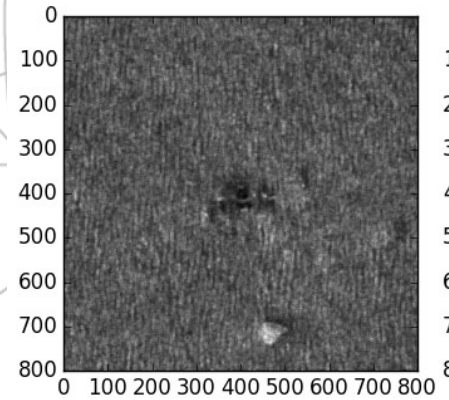


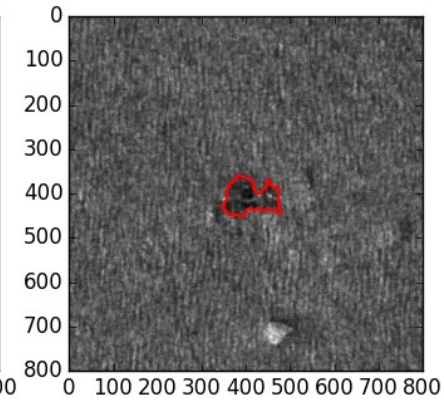


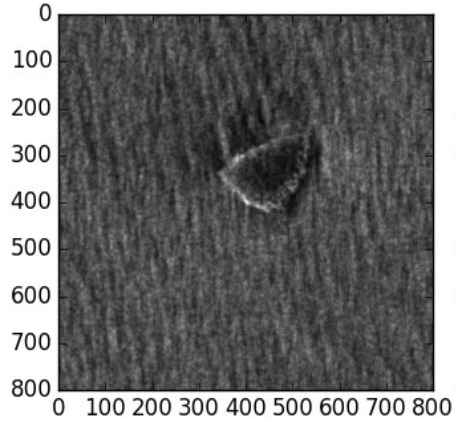


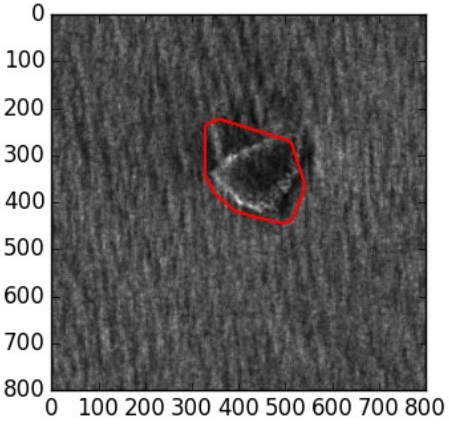




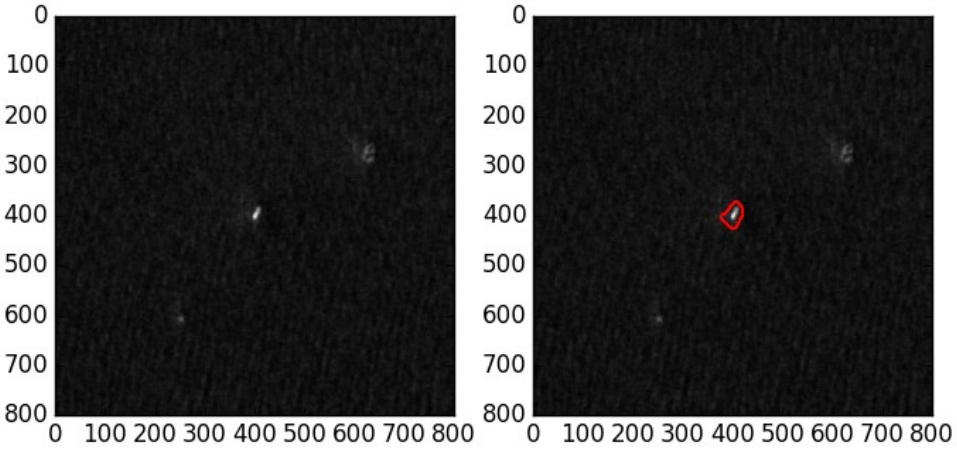


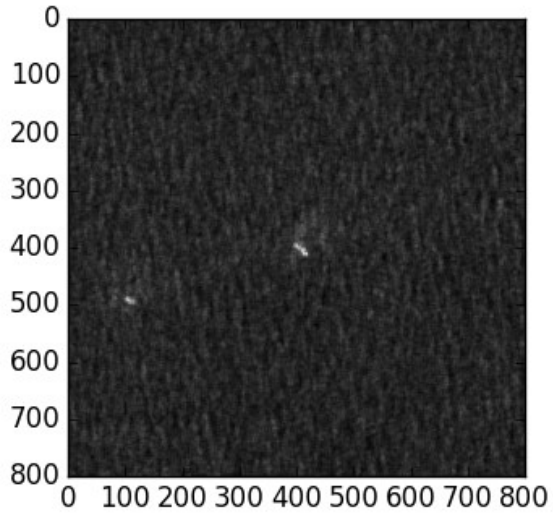


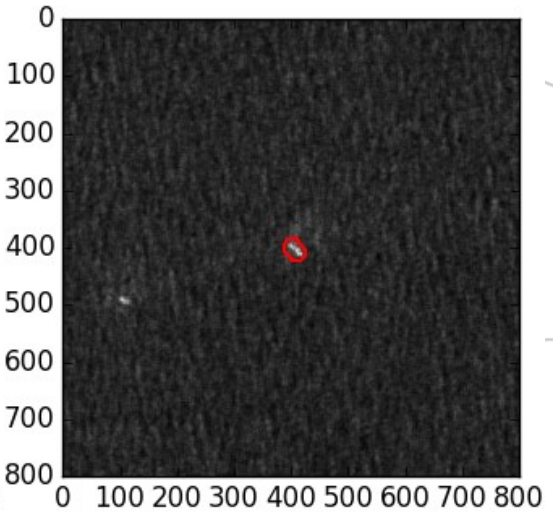




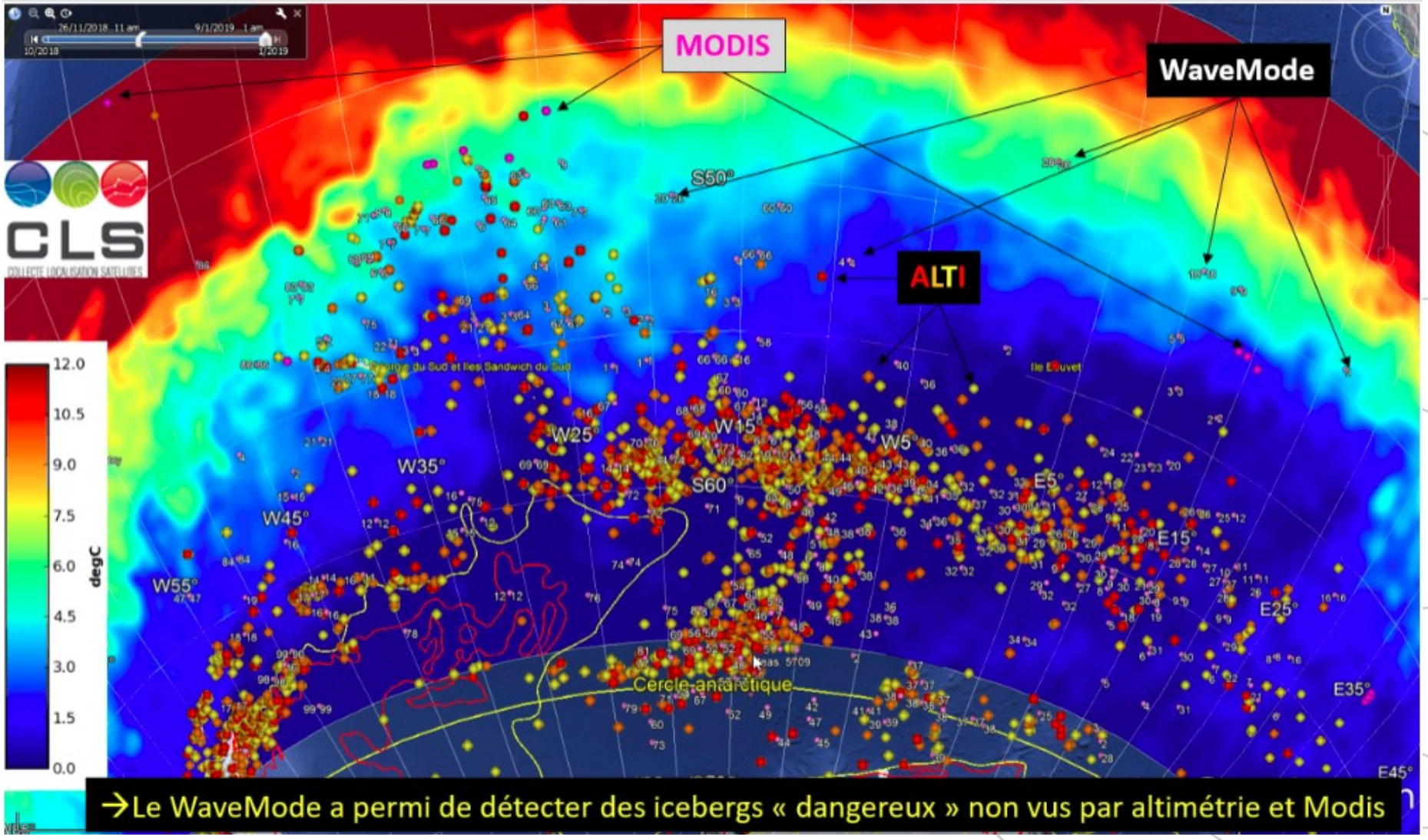
Some results (bright small-size iceberg)







Atlantique Sud – Décembre 2018 Détections Icebergs Alti (AltiKa, JA3, S3A) + MODIS + S1 WaveMode



Some processing statistics

- In 2018:
  - 23 749 products (12 036 S1A and 11 713 S1B) for all latitudes with 792 148 imagettes
  - About 2 000 products per month (2041 for Sep., 2087 for Oct., 2 031 for Nov., 1142 for Dec.)
- 200 GB per day per sensors -> > 70 TB per year per sensor
- Average jobs running on datarmor: ~180
- Processing time by imagette:
  - For CFAR between 1 and 4 minutes, up to 15min for rare cases
  - For DL lower than a second, but need a QL generated in a few seconds
- Generated data volume for one month:
  - ~ 30 Go for DL (QL ~ 0.5Mo + QL_Summary.xml ~ 10ko + DL_Summary.xml ~ 20 ko)
  - ~ 80 Go for CFAR (QL ~ 0.5Mo, QL seg ~ 0.25Mo, Summary.xml ~ 10ko, pkl up to several Mo, and iceberg_png for each detected target o(10Mo))
  - --> 110 Go for one month

Dataset to be analyzed jointly with AltiBerg (distribution of iceberg size, location …)

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