IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

CLS
COLLECTE LOCALISATION SATELLITES

SEMANTIC SEGMENTATION OF SAR OCEANIC AND METEOROLOGICAL PROCESSES

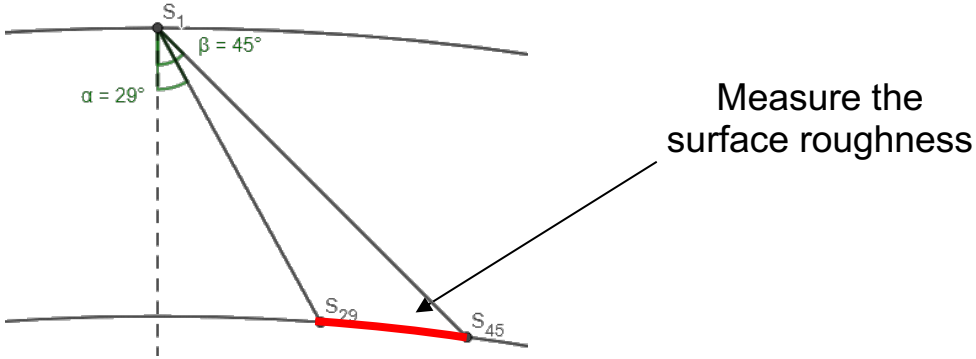
AURÉLIEN COLIN,
PHD STUDENT AT IMT ATLANTIQUE AND CLS

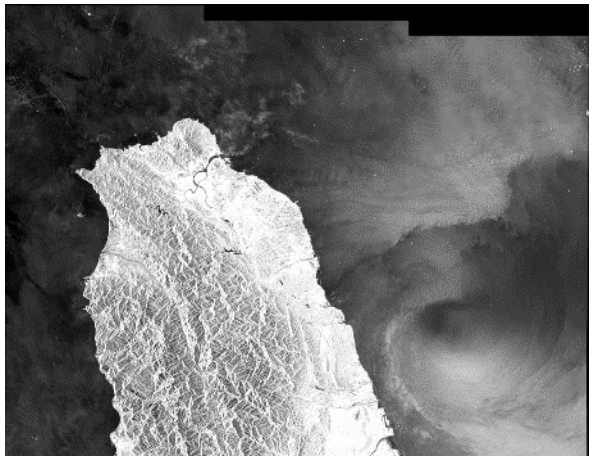
INTRODUCTION TO SAR IMAGERY

Sentinel-1A & ~~Sentinel-1B~~

- Observation at 700 km of elevation.
- Passage every 13 days (per satellite)
- Very high resolution (up to 5x5 meters, but we downscale them 50 or 100 meters)

- SAR is able to image the rain, the wind, biological slicks, …

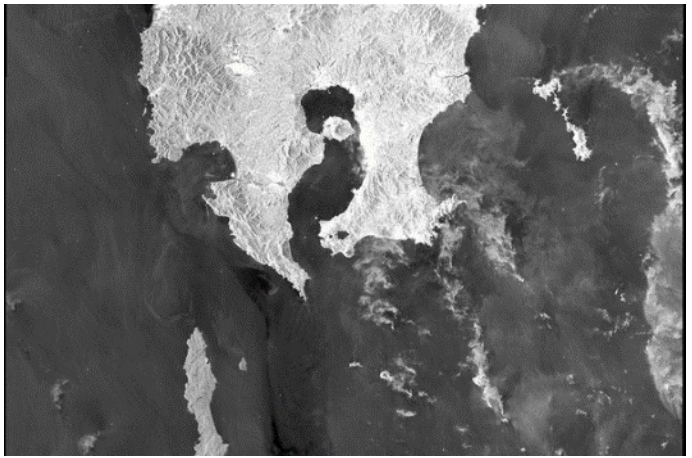




250 km

Observation of the tropical storm Lupit, near Taiwan (2021-08-06).

Observation of the Kagoshima bay (2021-08-16).



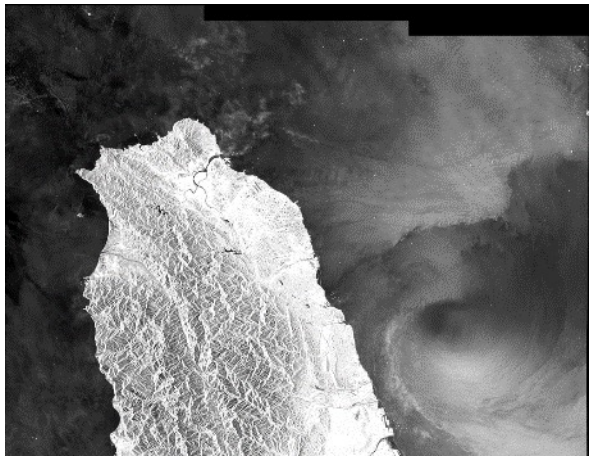
250 km

INTRODUCTION TO SAR IMAGERY

Sentinel-1A & ~~Sentinel-1B~~

- Observation at 700 km of elevation.
- Passage every 13 days (per satellite)
- Very high resolution (up to 5x5 meters, but we downscale them 50 or 100 meters)

- SAR is able to image the rain, the wind, biological slicks, …



Observation of the tropical storm Lupit, near Taiwan (2021-08-06).

Wind turbines near Shangai, (2021-09-16)

IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

CLS
COLLECTE LOCALISATION SATELLITES

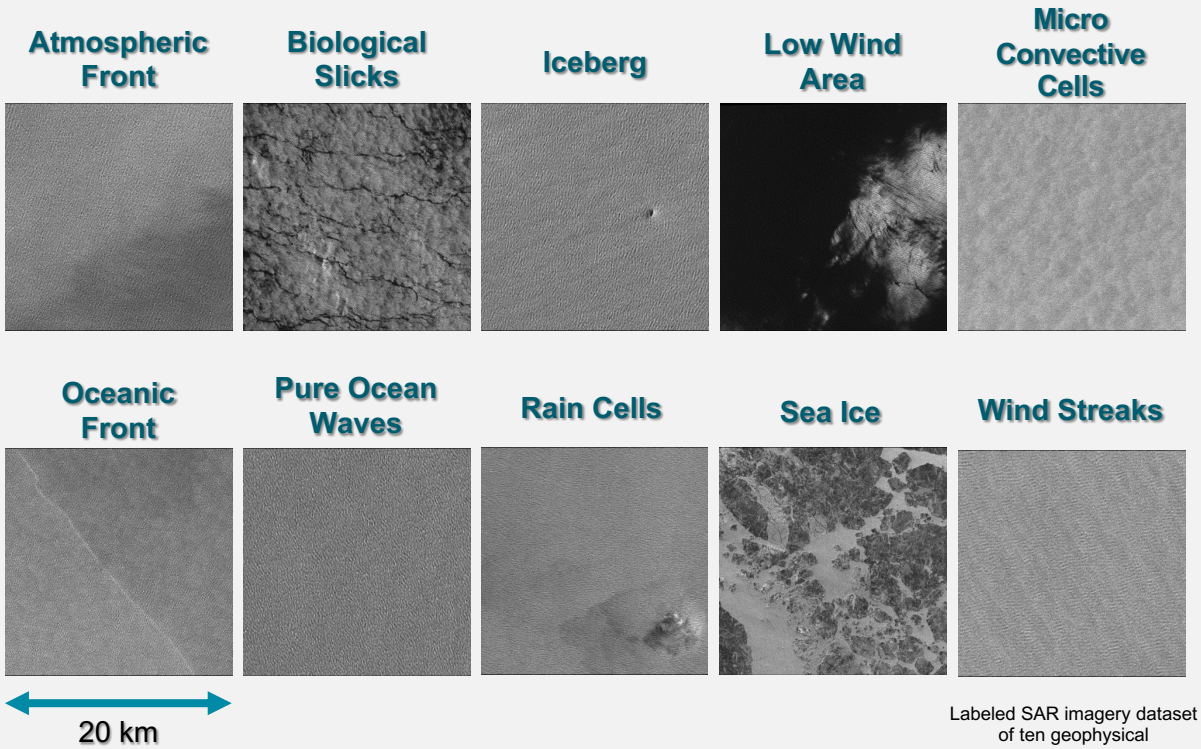
I. INTRODUCTION TO SAR IMAGERY

II. SEGMENTATION OF HIGH-LEVEL PROCESSES

III. RAINFALL ESTIMATION FROM SAR/NEXRAD COLOCALIZATION

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES

HIGH-LEVEL PROCESSES



Labeled SAR imagery dataset of ten geophysical phenomena from Sentinel-1 wave mode (Wang & al. 2019)

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES

HIGH-LEVEL PROCESSES

IMT Atlantique

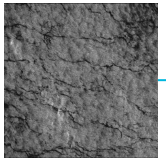
- Machine Learning expertise

Chen
WANG

- Built the TenGeoP dataset (2018)
- Design & train a categorizer

IFREMER

- Metocean/SAR expertise



$\mathcal{M}$

Biological slick

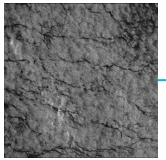
[0, 1, 0, 0, 0,
0, 0, 0, 0, 0]

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES

HIGH-LEVEL PROCESSES

IMT Atlantique

- Machine Learning expertise



$\mathcal{M}$

Biological slick

[0, 1, 0, 0, 0, 0, 0, 0, 0, 0]

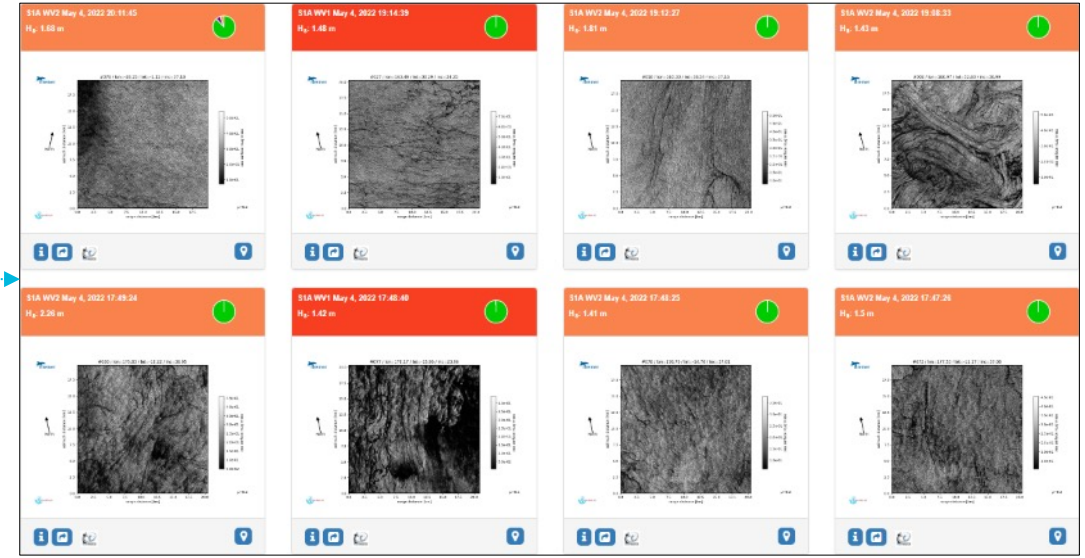
Chen WANG

- Built the TenGeoP dataset (2018)
- Design & train a categorizer

IFREMER

- Metocean/SAR expertise
- Routine categorization of new WV

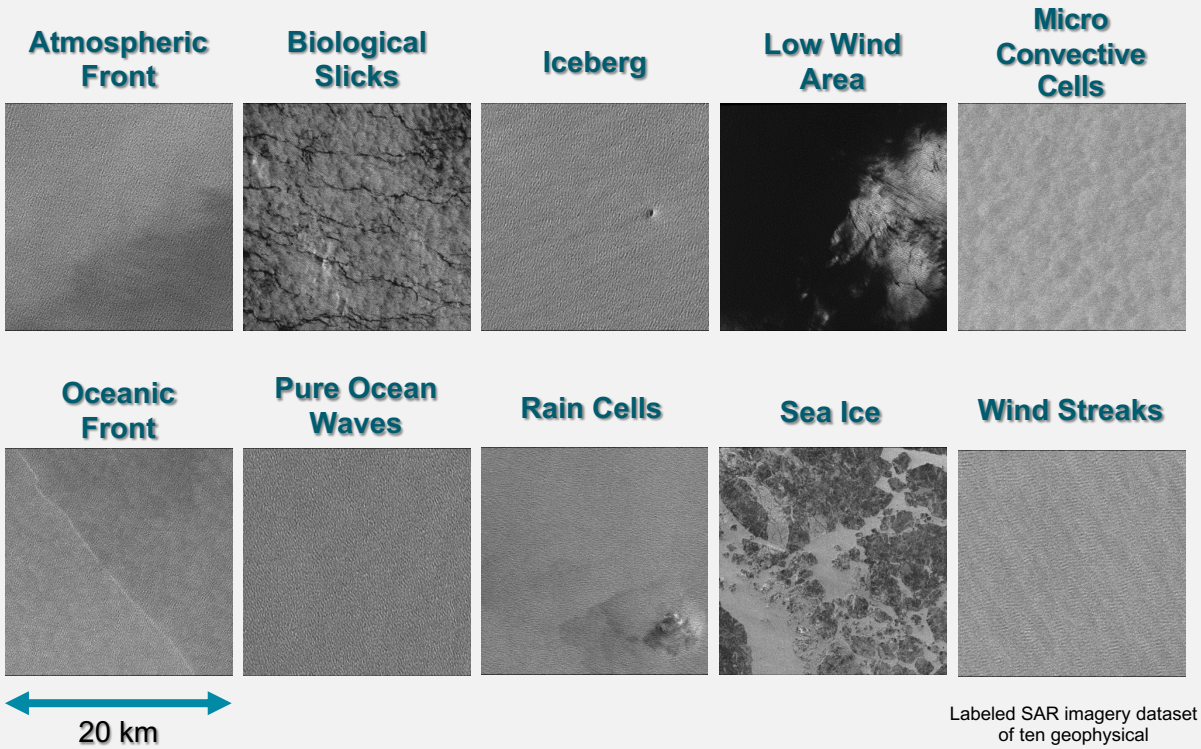
Possible to search an observation from a specific meteocean class



https://xwaves.ifremer.fr/#/quicklook

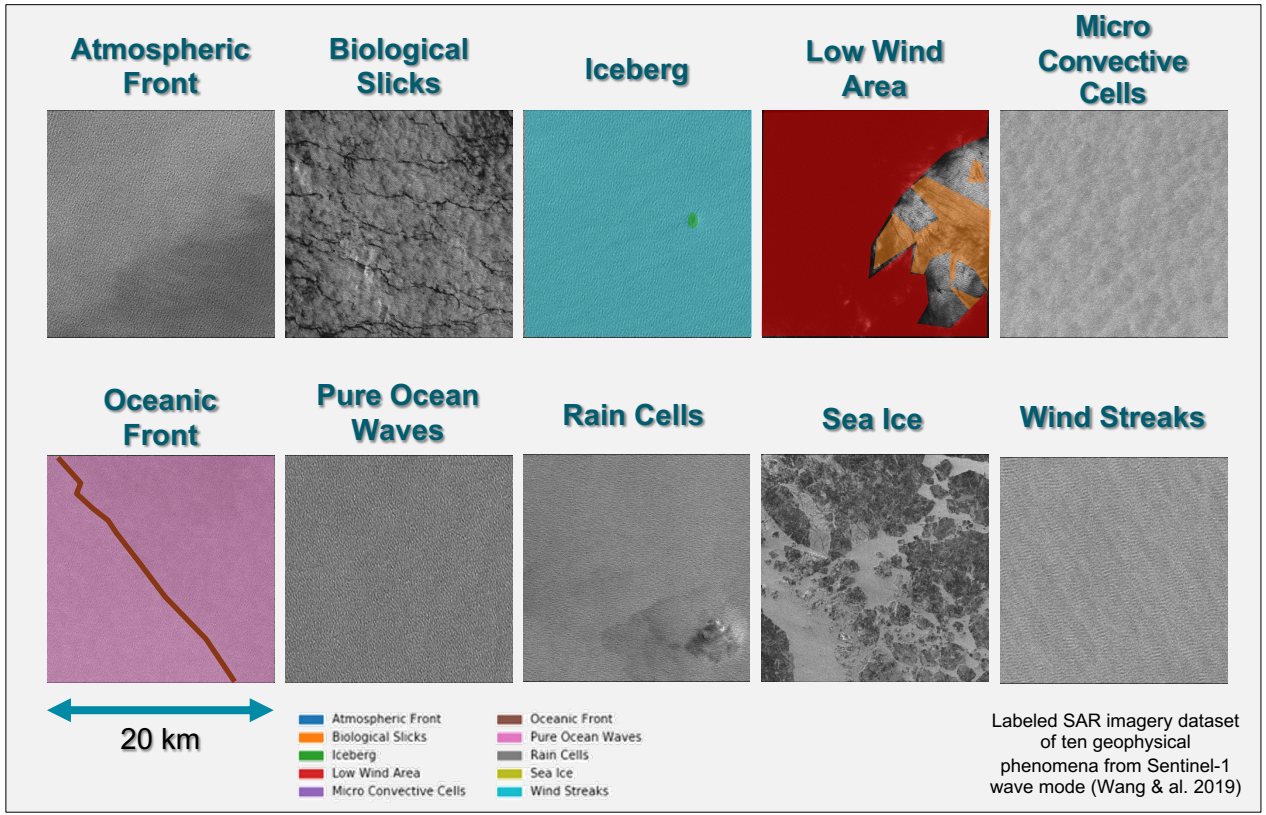
SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES

HIGH-LEVEL PROCESSES



Labeled SAR imagery dataset of ten geophysical phenomena from Sentinel-1 wave mode (Wang & al. 2019)

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
HIGH-LEVEL PROCESSES

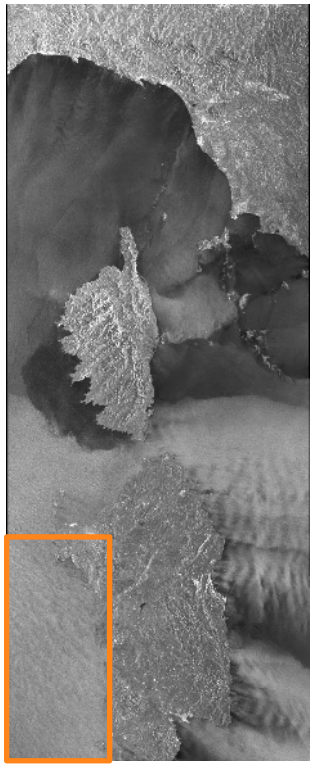


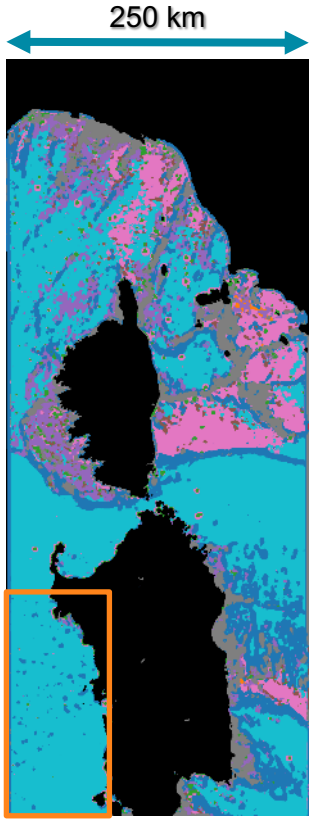
Labeled SAR imagery dataset of ten geophysical phenomena from Sentinel-1 wave mode (Wang & al. 2019)

- Goal : To not only obtain a image-level information, but a pixel-wise categorization.

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
HIGH-LEVEL PROCESSES

Some processes are significant to obtain SAR-derived data :





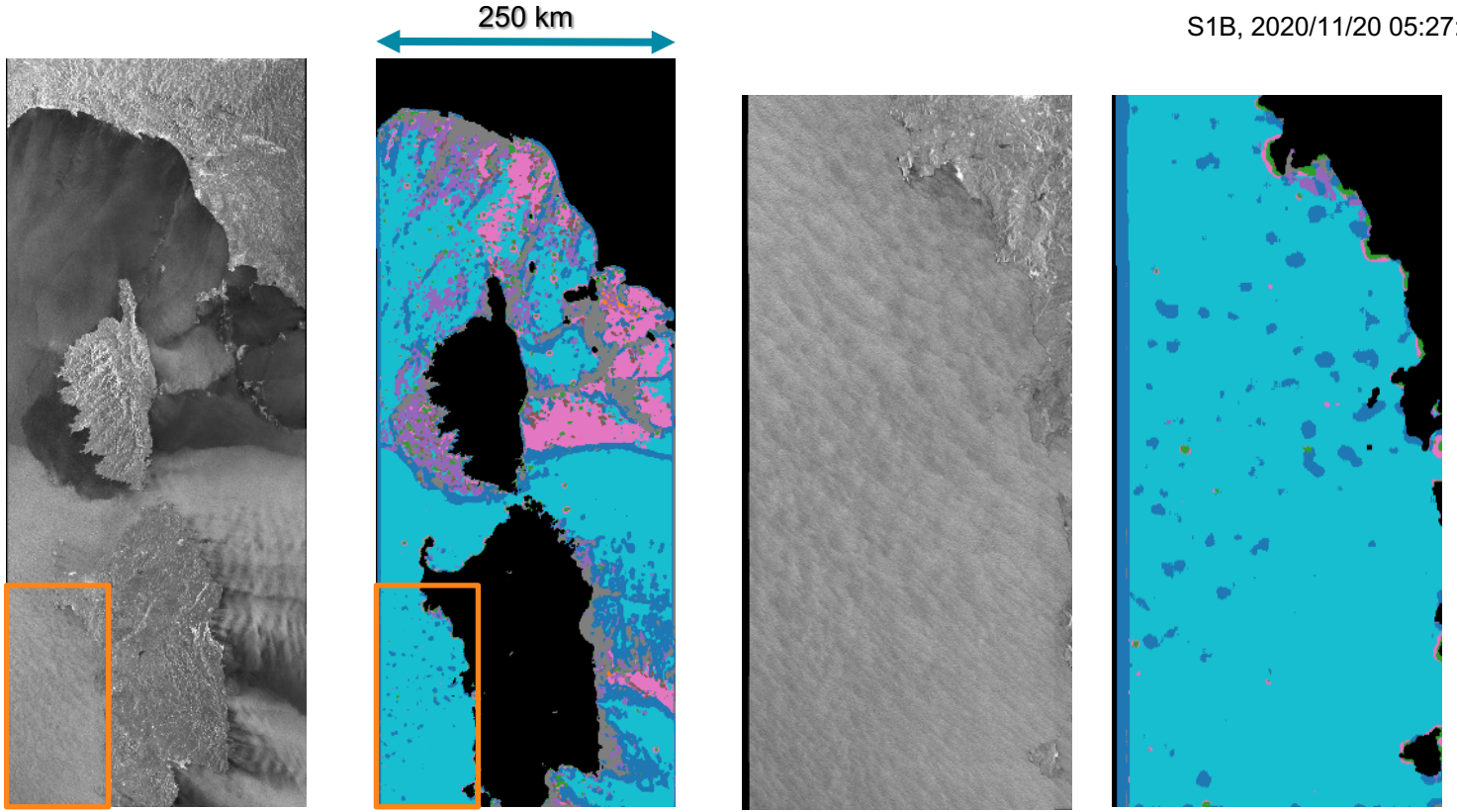
S1B, 2020/11/20 05:27:11

- Atmospheric Front
- Biological Slicks
- Iceberg
- Low Wind Area
- Micro Convective Cells
- Oceanic Front
- Pure Ocean Waves
- Rain Cells
- Sea Ice
- Wind Streaks

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
HIGH-LEVEL PROCESSES

Some processes are significant to obtain SAR-derived data :

- Wind streaks indicates lower MSE in wind direction estimation [1]

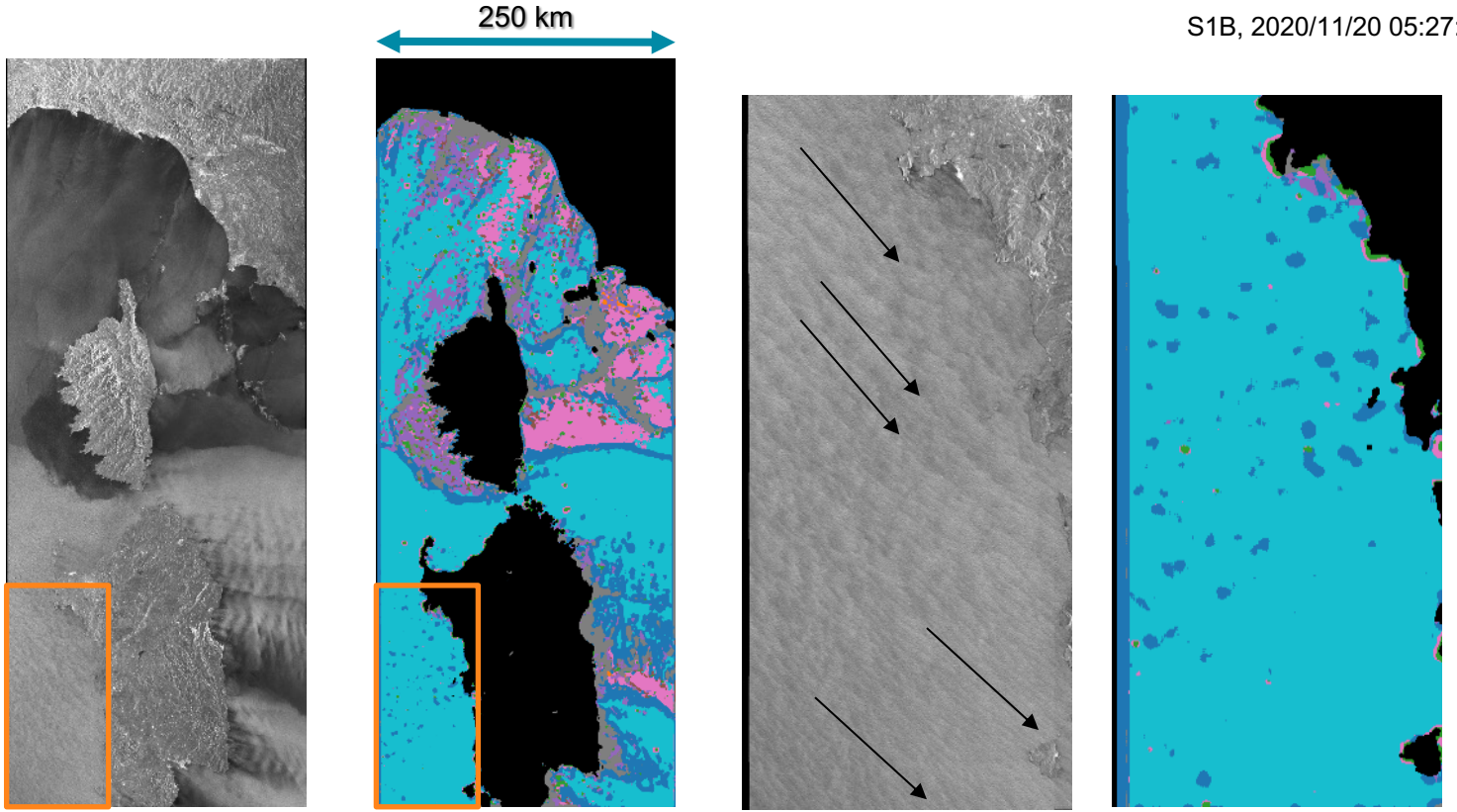


[1] R. Husson, N. Longepe, A. Mouche, H. Berger, C. Lin, O. Archer, & A. Colin (2021). Wind Direction Estimation and Accuracy Retrieval from Sentinel-1 SAR Images Under Thermal and Dynamical Unstable Conditions. In *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*. IEEE.

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
HIGH-LEVEL PROCESSES

Some processes are significant to obtain SAR-derived data :

- Wind streaks indicates lower MSE in wind direction estimation [1]

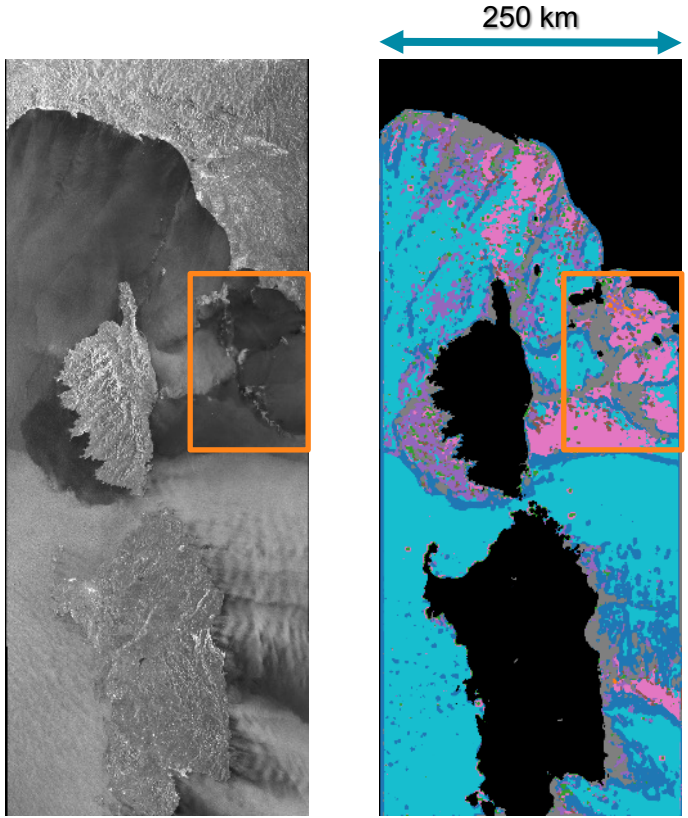


[1] R. Husson, N. Longepe, A. Mouche, H. Berger, C. Lin, O. Archer, & A. Colin (2021). Wind Direction Estimation and Accuracy Retrieval from Sentinel-1 SAR Images Under Thermal and Dynamical Unstable Conditions. In *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*. IEEE.

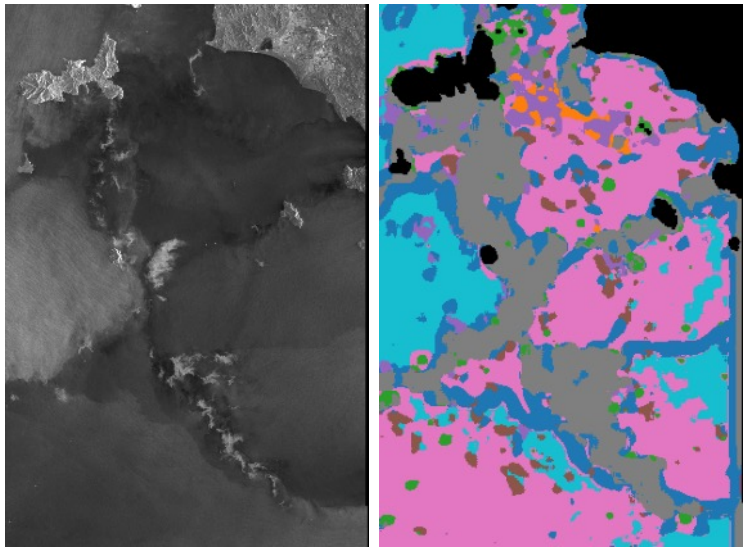
SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
HIGH-LEVEL PROCESSES

Some processes are significant to obtain SAR-derived data :

- Wind streaks indicates lower MSE in wind direction estimation [1]
- Rainfall led to overestimation of the wind speed.



S1B, 2020/11/20 05:27:11

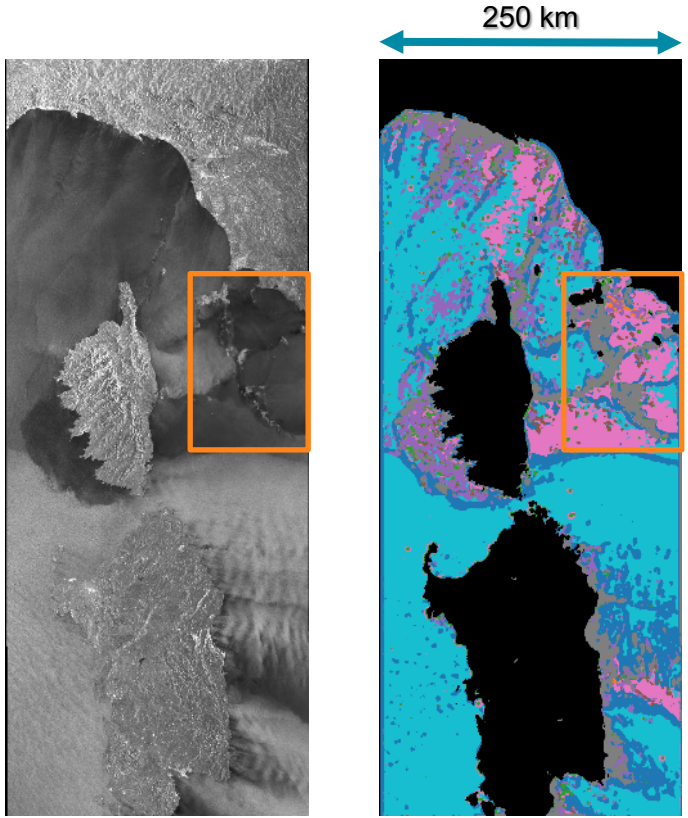


[1] R. Husson, N. Longepe, A. Mouche, H. Berger, C. Lin, O. Archer, & A. Colin (2021). Wind Direction Estimation and Accuracy Retrieval from Sentinel-1 SAR Images Under Thermal and Dynamical Unstable Conditions. In *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*. IEEE.

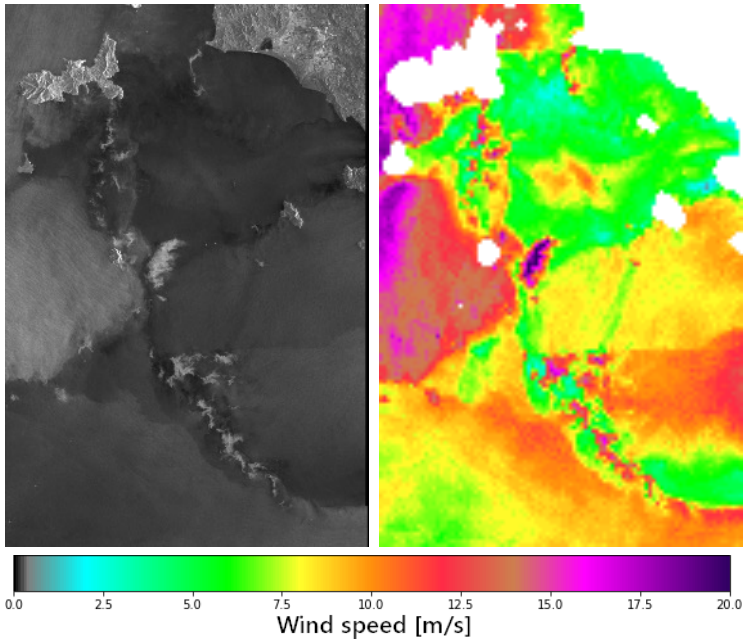
SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
HIGH-LEVEL PROCESSES

Some processes are significant to obtain SAR-derived data :

- Wind streaks indicates lower MSE in wind direction estimation [1]
- Rainfall led to overestimation of the wind speed.



S1B, 2020/11/20 05:27:11



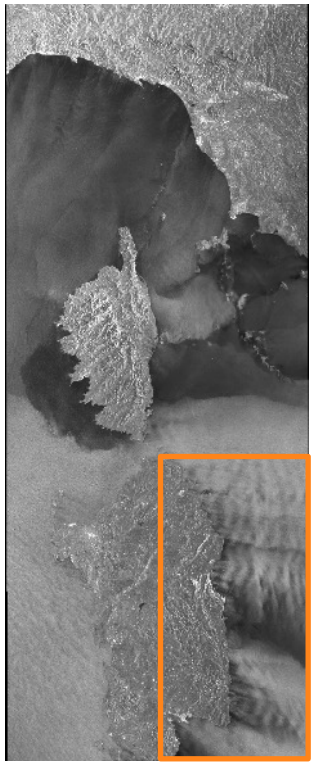
[1] R. Husson, N. Longepe, A. Mouche, H. Berger, C. Lin, O. Archer, & A. Colin (2021). Wind Direction Estimation and Accuracy Retrieval from Sentinel-1 SAR Images Under Thermal and Dynamical Unstable Conditions. In *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*. IEEE.

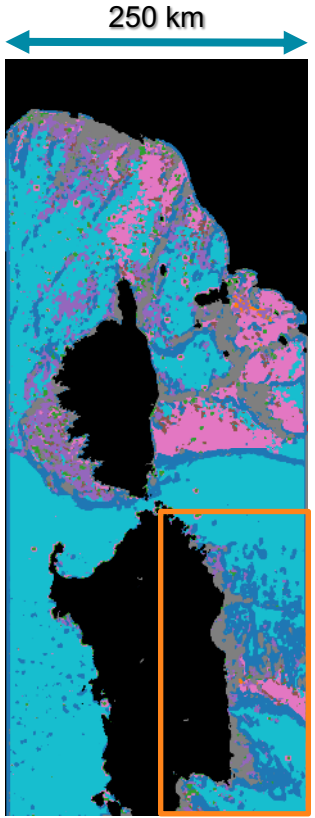
SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
HIGH-LEVEL PROCESSES

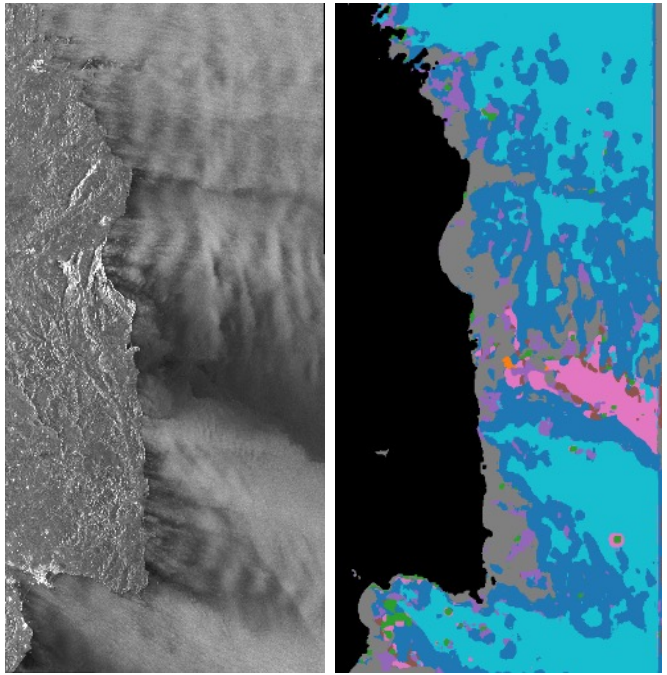
S1B, 2020/11/20 05:27:11

Some processes are significant to obtain SAR-derived data :

- Wind streaks indicates lower MSE in wind direction estimation [1]
- Rainfall led to overestimation of the wind speed.





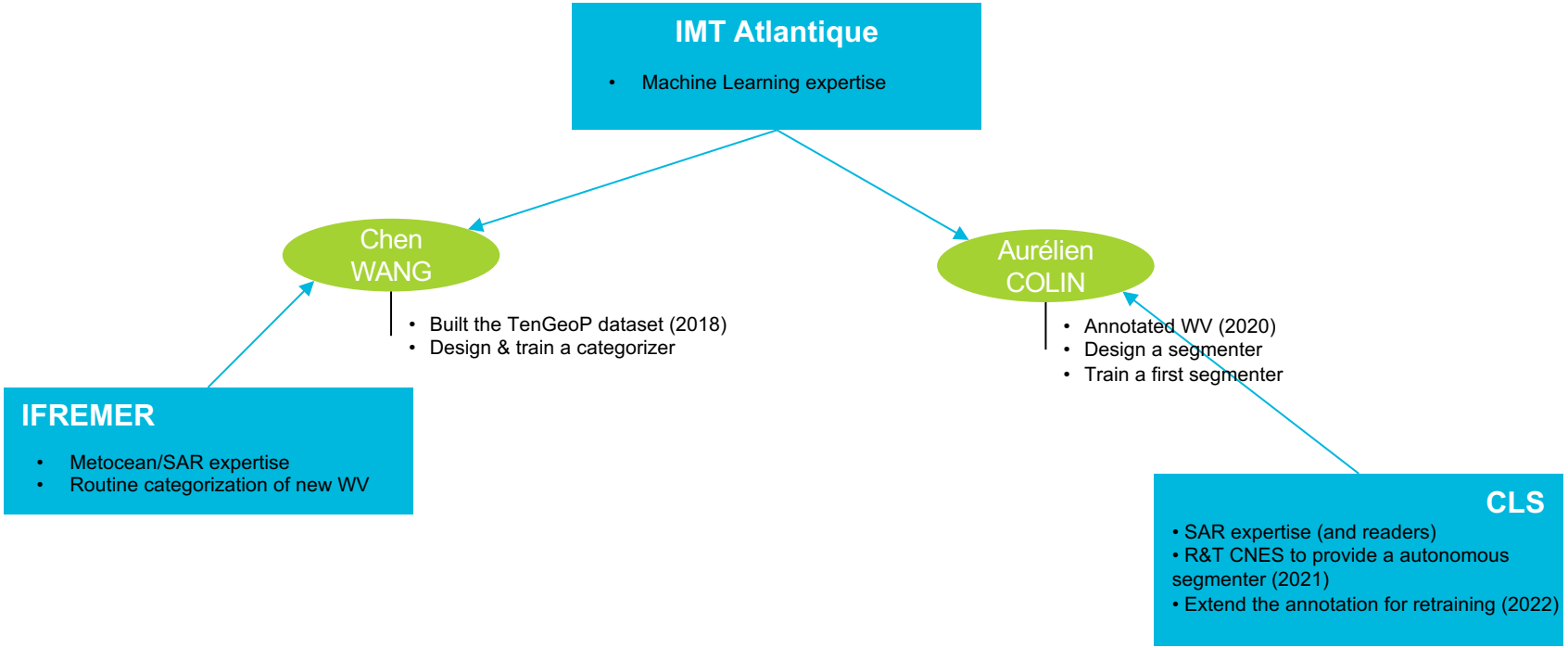


Atmospheric Front
Biological Slicks
Iceberg
Low Wind Area
Micro Convective Cells
Oceanic Front
Pure Ocean Waves
Rain Cells
Sea Ice
Wind Streaks

[1] R. Husson, N. Longepe, A. Mouche, H. Berger, C. Lin, O. Archer, & A. Colin (2021). Wind Direction Estimation and Accuracy Retrieval from Sentinel-1 SAR Images Under Thermal and Dynamical Unstable Conditions. In *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*. IEEE.

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES

HIGH-LEVEL PROCESSES



IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

CLS
COLLECTE LOCALISATION SATELLITES

I. INTRODUCTION TO SAR IMAGERY

II. SEGMENTATION OF HIGH-LEVEL PROCESSES

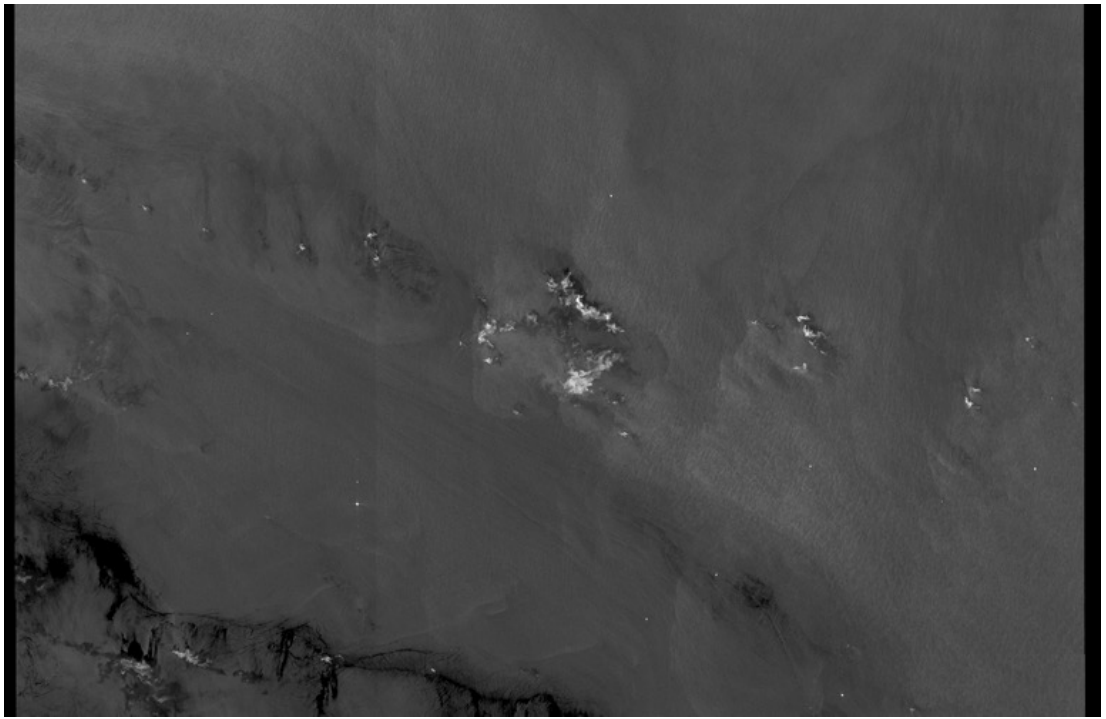
III. RAINFALL ESTIMATION FROM SAR/NEXRAD COLOCALIZATION

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES

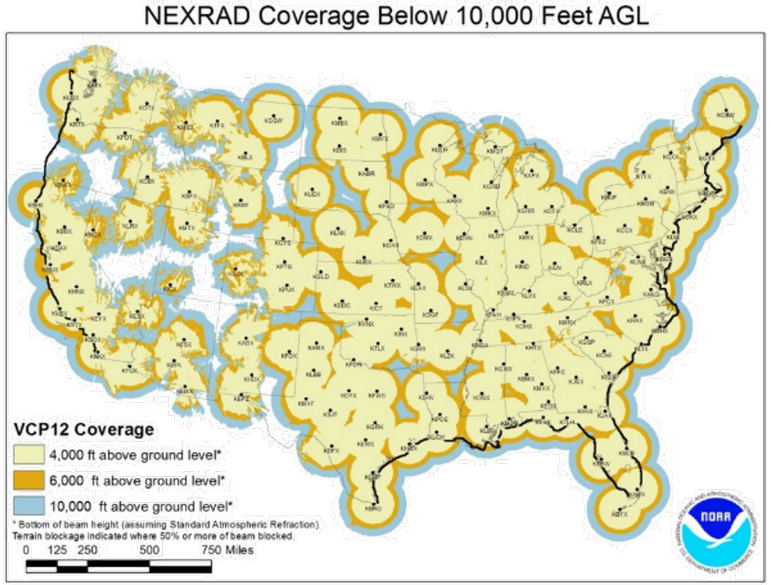
RAINFALL ESTIMATION

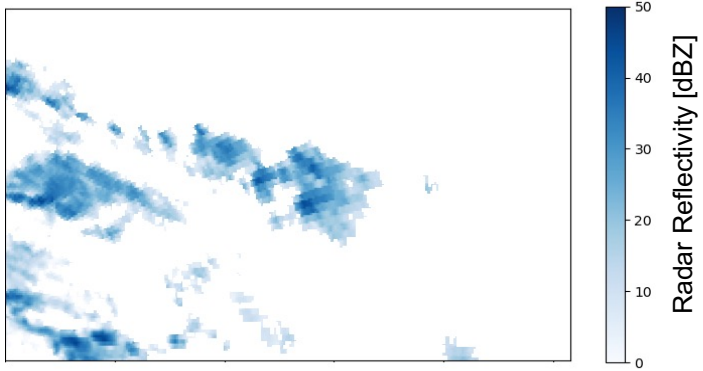
Can we estimate the rainfall from the SAR observations ?

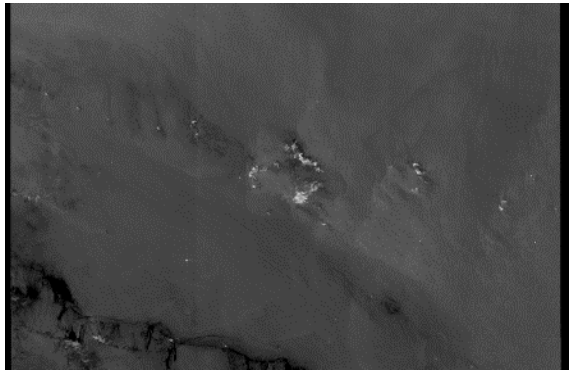
SAR observation from 2018-05-05 23:05:20



NEXRAD : Reflectivity of the air column (volume)
Sentinel-1 : Reflectivity of the ocean surface

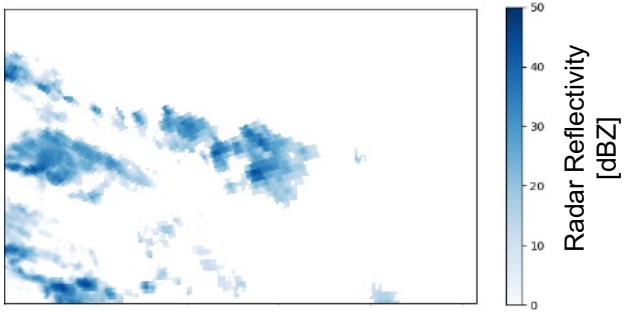






SAR observation from
2018-05-05 23:05:20

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
RAINFALL ESTIMATION



Radar equation :

$$Z = \int_0^{D_{max}} N(D) D^6 dD$$

$$= \int_0^{D_{max}} N_0 e^{-\lambda D} D^6 dD$$

- N_0 the number of droplets
- D the size of the droplets
- λ the parameter of the exponential distribution

Marshall-Palmer formula :

$$R = \left(\frac{10^{L_Z/10}}{200} \right)^{5/8}$$

- R the rain rate (mm/h)
- L_Z the logarithm reflectivity (dBZ)

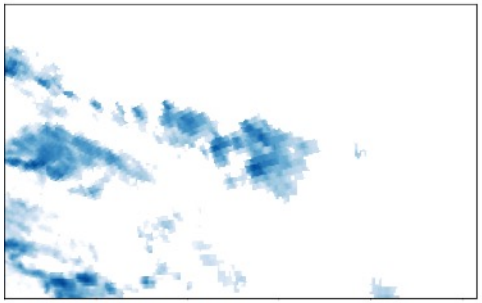
➢ The radar reflectivity can be converted to rain rate.

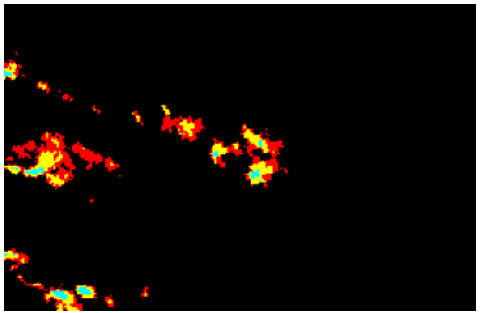
Works well for stratiform rain events in mid-latitudes

*Colocalization performed by Ifremer

Zhao, Y., Longépé, N., Mouche, A., & Husson, R. (2021). Automated Rain Detection by Dual-Polarization Sentinel-1 Data. In Remote Sensing (Vol. 13, Issue 16, p. 3155). MDPI AGCCC

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
RAINFALL ESTIMATION



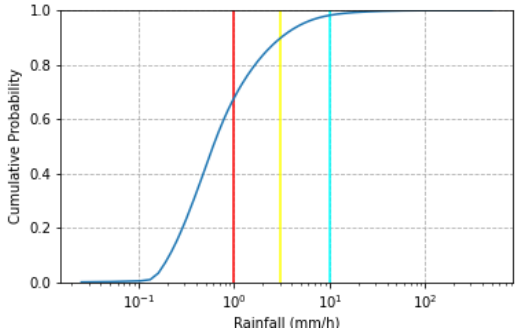


Radar equation :

$$Z = \int_0^{D_{max}} N(D) D^6 dD$$

$$= \int_0^{D_{max}} N_0 e^{-\lambda D} D^6 dD$$

- N_0 the number of droplets
- D the size of the droplets
- λ the parameter of the exponential distribution



Marshall-Palmer formula :

$$R = \left(\frac{10^{L_Z/10}}{200}\right)^{5/8}$$

- R the rain rate (mm/h)
- L_Z the logarithm reflectivity (dBZ)

➢ The radar reflectivity can be converted to rain rate.

Works well for stratiform rain events in mid-latitudes

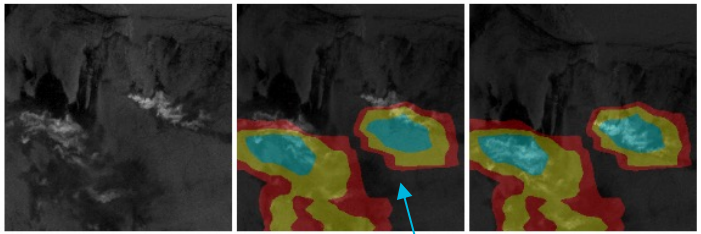
*Colocalization performed by Ifremer

Zhao, Y., Longépé, N., Mouche, A., & Husson, R. (2021). Automated Rain Detection by Dual-Polarization Sentinel-1 Data. In Remote Sensing (Vol. 13, Issue 16, p. 3155). MDPI AGCCC

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
RAINFALL ESTIMATION

1. 1570 patches of 20x20 km are extracted from 53 IW at 100 m/px

2. The patches are manually relocalized to maximise the overlap between NEXRAD's measurement and the SAR rain signature.

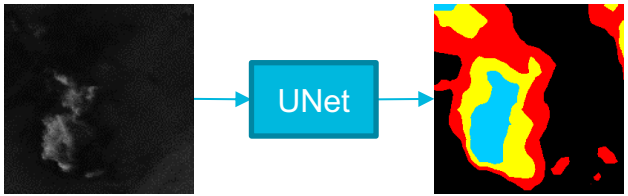


Imperfect alignement would lead to fuzzy segmentation and, in particular, hinder segmentation of the strongest rainfalls.

3. Dataset are splitted in train/val/test, being careful to keep the same wind/rain distributions.

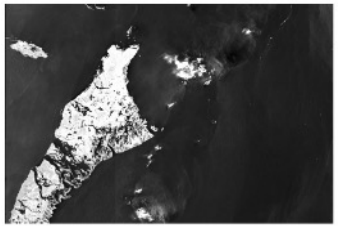
Dataset		Train (39 IW)	Validation (7 IW)	Test (7 IW)	% of the total
Reflectivity	$[0, 24.7[$ dBZ $[0, 0.13[$ mm/h	79.5 %	9.6 %	10.9 %	85.1 %
	$[24.7, 31.5[$ dBZ $[1, 3[$ mm/h	79.9 %	9.6 %	10.5 %	7.7 %
	$[31.5, 38.8[$ dBZ $[3, 10[$ mm/h	79.3 %	9.7 %	11.0 %	5.4 %
	≥ 38.8 dBZ ≥ 10 mm/h	79.0 %	9.8 %	11.2 %	1.8 %
Wind Speed	$[0, 4[$ m/s	79.3 %	9.7 %	11.0 %	11.7 %
	$[4, 8[$ m/s	79.1 %	9.7 %	11.1 %	69.7 %
	$[8, 12[$ m/s	79.1 %	9.5 %	11.3 %	17.1 %
	$[12, 16[$ m/s	100 %	0.0 %	0.0 %	1.5 %
	≥ 16 m/s	100 %	0.0 %	0.0 %	0.1 %

4. We train a U-Net model to minimize the MSE on three channels, based on thresholds at 1, 3 and 10 mm/h.

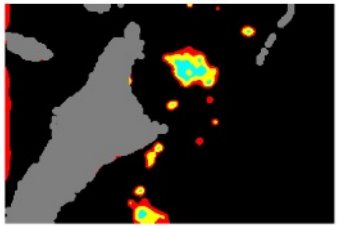


SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
RAINFALL ESTIMATION

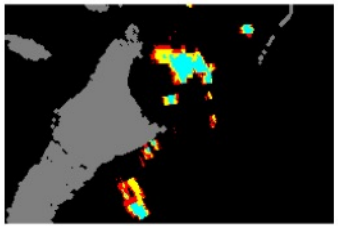
Observation from 2018/04/24 11:10:12



U-Net model



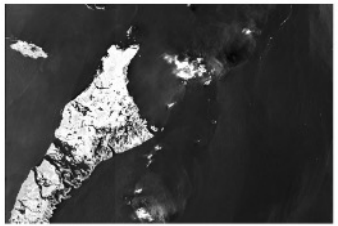
NEXRAD



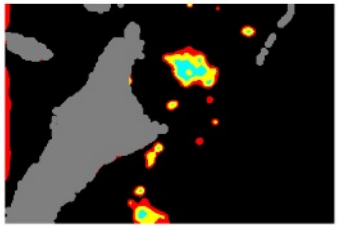
With the NEXRAD colocalisations, strong winds are rare.

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
RAINFALL ESTIMATION

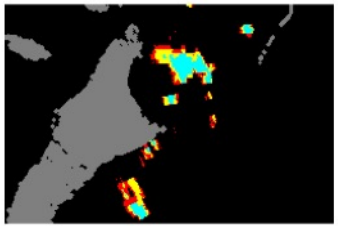
Observation from 2018/04/24 11:10:12



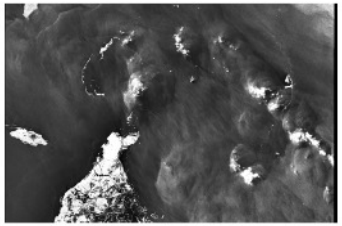
U-Net model



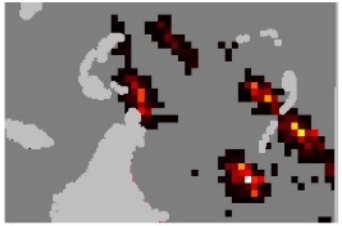
NEXRAD

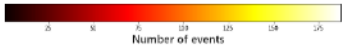


Observation from 2019/09/04 11:09:34

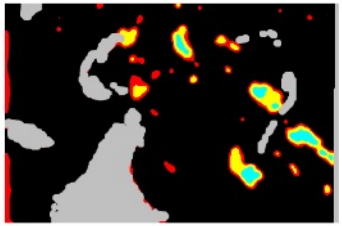


Lightning events





U-Net model

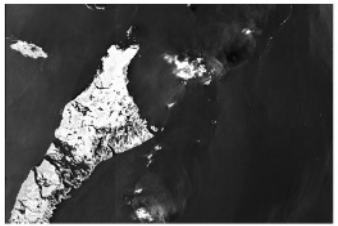


With the NEXRAD colocalisations, strong winds are scare.

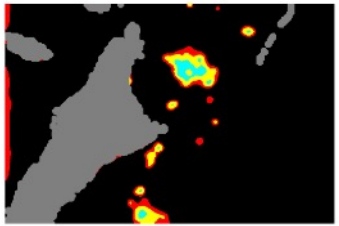
- We use the Geostationnary Lightning Mapper as a proxy of rain detection.

SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
RAINFALL ESTIMATION

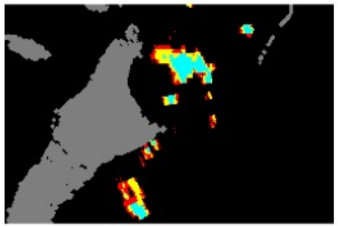
Observation from 2018/04/24 11:10:12



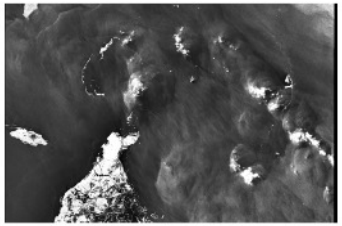
U-Net model



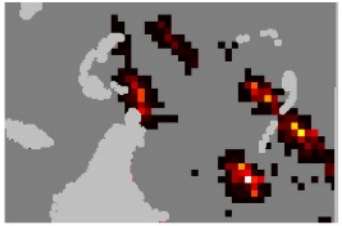
NEXRAD



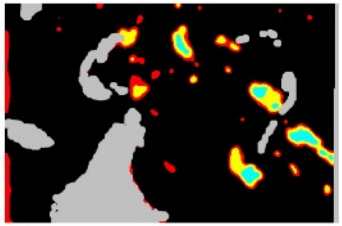
Observation from 2019/09/04 11:09:34



Lightning events



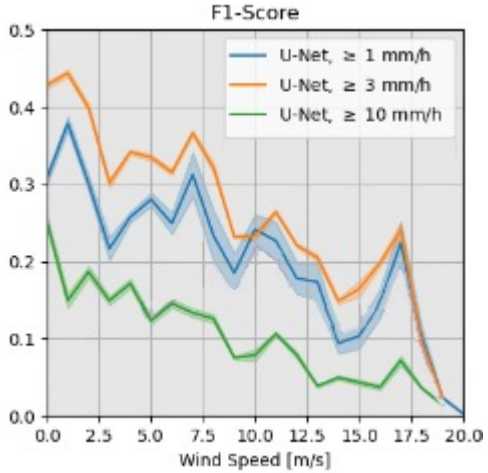
U-Net model



With the NEXRAD colocalisations, strong winds are scare.

- We use the Geostationnary Lightning Mapper as a proxy of rain detection.

Current focus on retrieving colocalize with new weather radars (e.g. GPM-DPR) to expand the dataset to higher wind speeds.



SEMANTIC SEGMENTATION OF SAR METOCEAN PROCESSES
CONCLUSION

General categorization and segmentation of meteorological and oceanic processes

- IMT Atlantique provide PhD students and machine learning expertise ;
- Ifremer build a categorization dataset (Chen Wang, PhD student at IMT Atlantique), put it to routine work ;
- CLS for the extention to pixel-level segmentation

Rain rate estimation

- Ifremer got the SAR/NEXRAD colocalization.
- Previous Ifremer/CLS paper on rain detection
- At CLS for the extension to quantitative information (me, PhD student at the IMT Atlantique). Hope to see the model be put in production before finishing.