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Bretagne-Pays de la Loire
École Mines-Télécom



CLS

COLLECTE LOCALISATION SATELLITES

SEGMENTATION OF METOCEAN PROCESSES USING SAR IMAGES

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SEGMENTATION OF METOCEAN PROCESSES USING SAR IMAGES

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INTRODUCTION

WHY TO SEGMENT SAR IMAGES?



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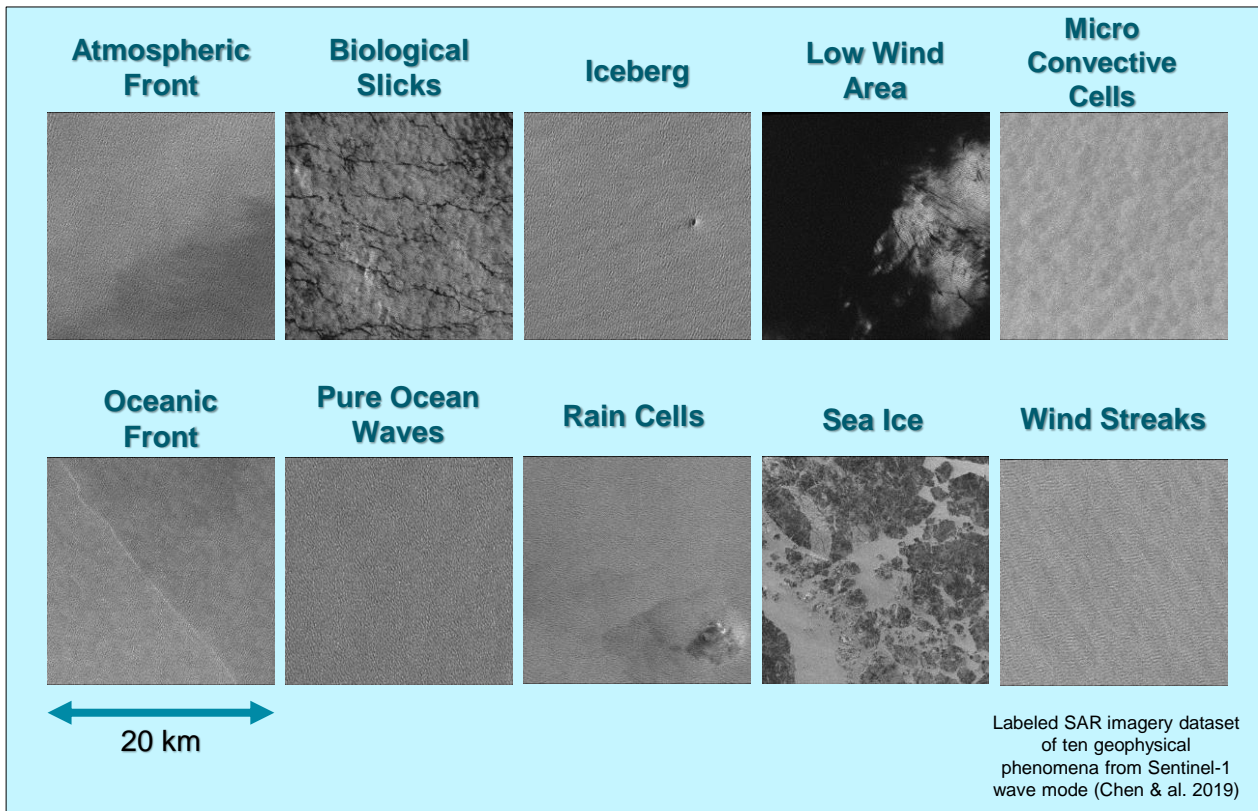
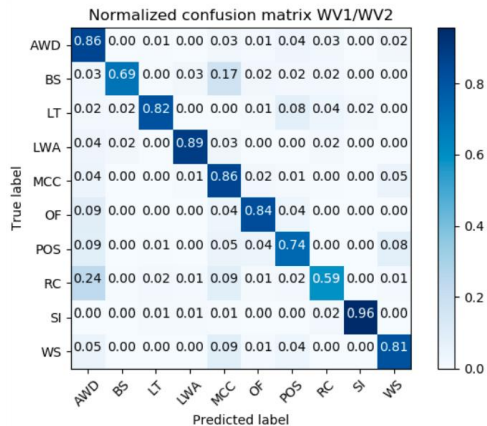
SEGMENTATION OF METOCEAN PROCESSES

TENGEOP-SARWV – A SAR CATEGORICAL DATASET

TenGeoP-SARwv

- 37k Wave mode images,
- 10 classes
- 20 x 20 km at 50m/px

Overall accuracy = 82.6%

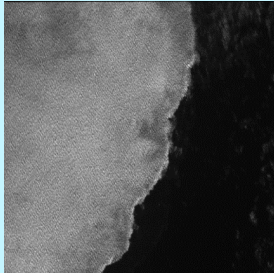
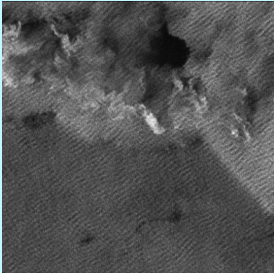
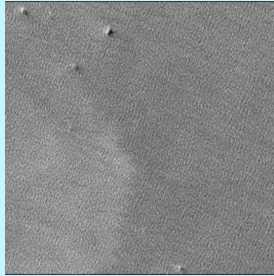
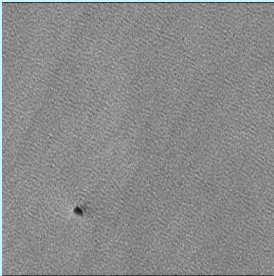


Labeled SAR imagery dataset of ten geophysical phenomena from Sentinel-1 wave mode (Chen & al. 2019)

GOING FURTHER: IS THE CATEGORIZATION ENOUGH?

A categorical dataset assume that the classes are **mutually exclusive**.

This is not true for the metocean processes.

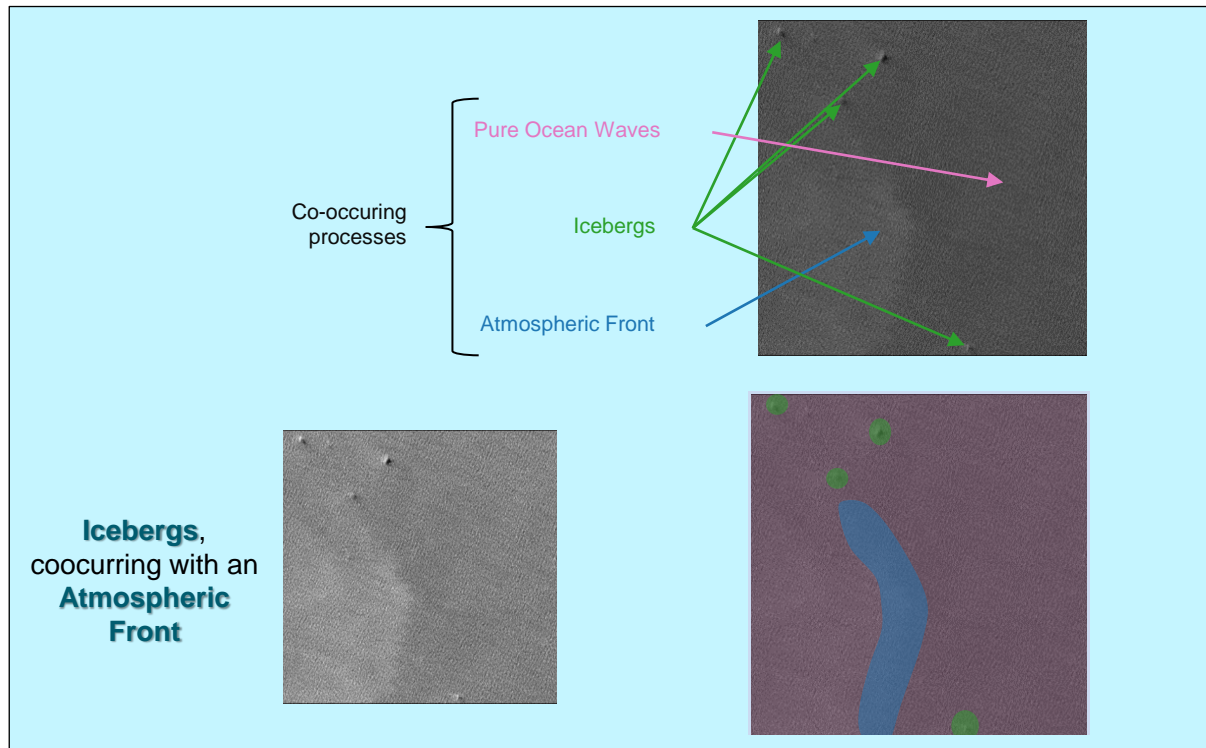
<p>Atmospheric Front, cooccurring with a Low Wind Area</p>		<p>Rain Cells, often contain Atmospheric Fronts</p>	
<p>Icebergs, cooccurring with an Atmospheric Front</p>		<p>The Iceberg is less than 1% of the observation, which mainly depict Pure Ocean Waves</p>	

GOING FURTHER: IS THE CATEGORIZATION ENOUGH?

A categorical dataset assume that the classes are **mutually exclusive**.

This is not true for the metocean processes.

Even more complex:
How to obtain the **segmentation**?



FULLY SUPERVISED LEARNING



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How to obtain the segmentations?

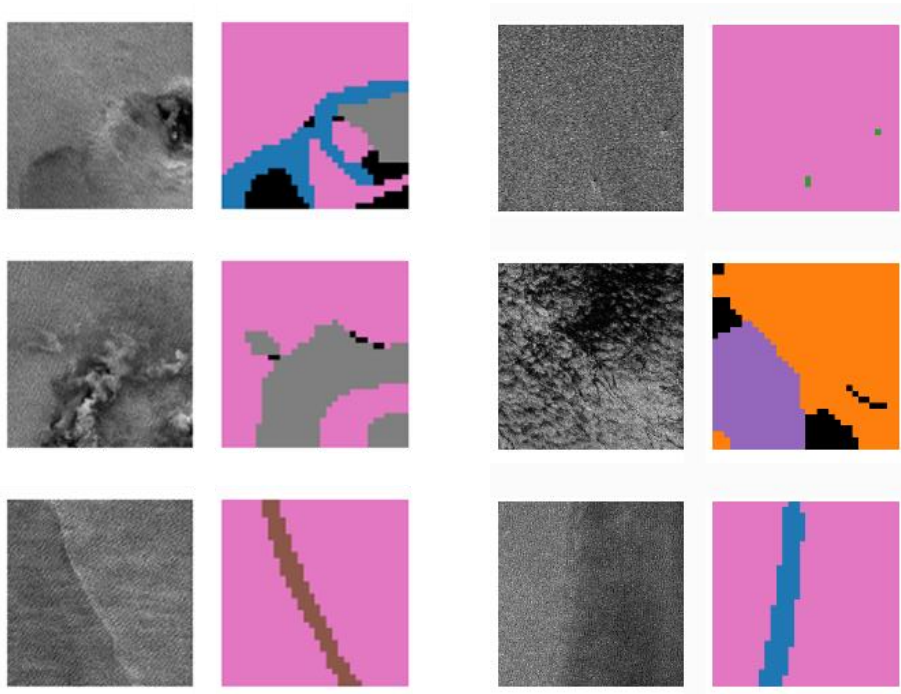
➤ Weakly-supervised

Lot of image-level annotations: the full TenGeoP dataset

➤ Fully-supervised

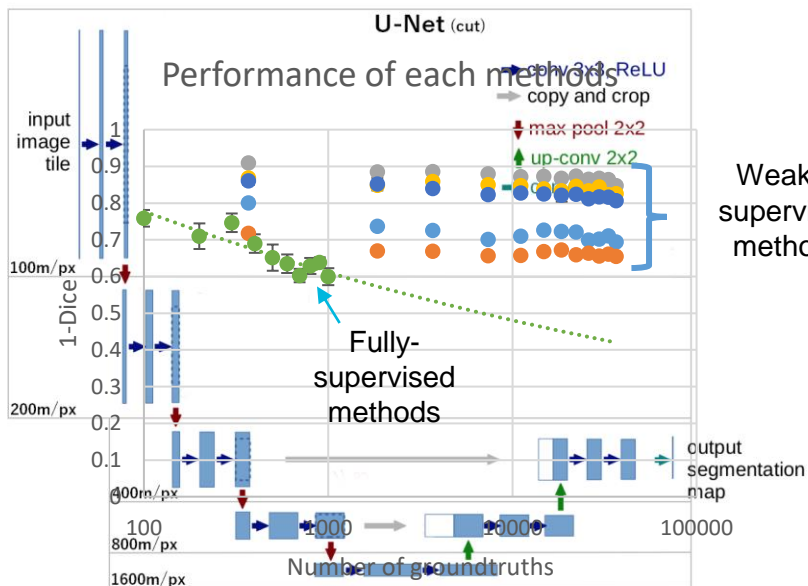
Few pixel-level annotations: 1000 manually annotated groundtruths

Samples of manually annotated groundtruths



SEGMENTATION OF METOCEAN PROCESSES

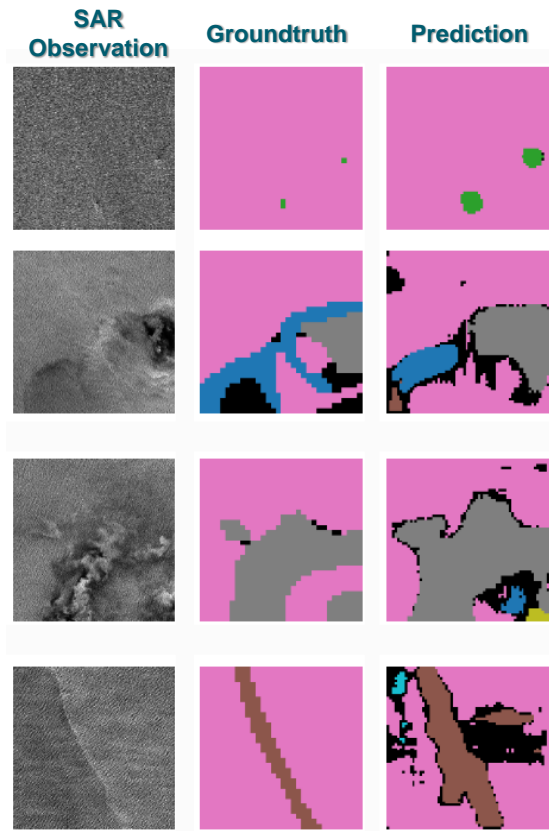
SUPERIORITY OF THE FULLY-SUPERVISED FRAMEWORK



Weakly-supervised methods

Fully-supervised methods

$$Dice(y, \hat{y}) = \frac{2y \cdot \hat{y}}{y + \hat{y}}$$

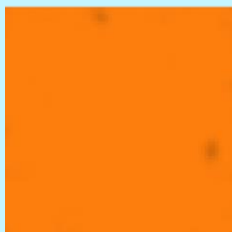
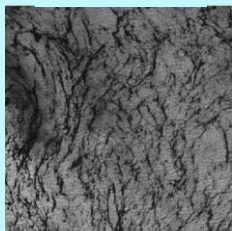


SEGMENTATION OF METOCEAN PROCESSES

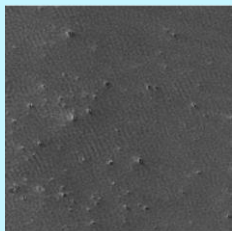
NEW WAYS TO WORK WITH WAVE MODE DATA

Search by most prediction of a particular phenomenon

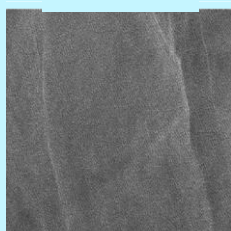
Biological Slicks



Icebergs

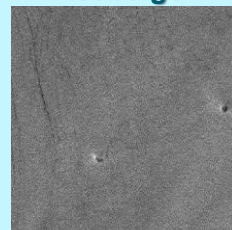


Oceanic Front

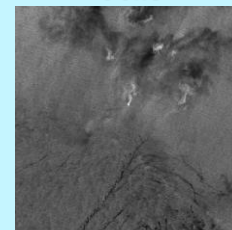


Search by most prediction of multiple phenomena

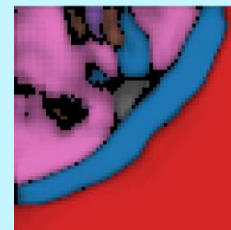
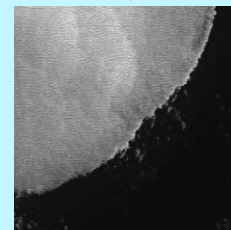
Biological Slicks & Icebergs



Biological Slicks & Rain Cells



Low Wind Area & Atmospheric Front

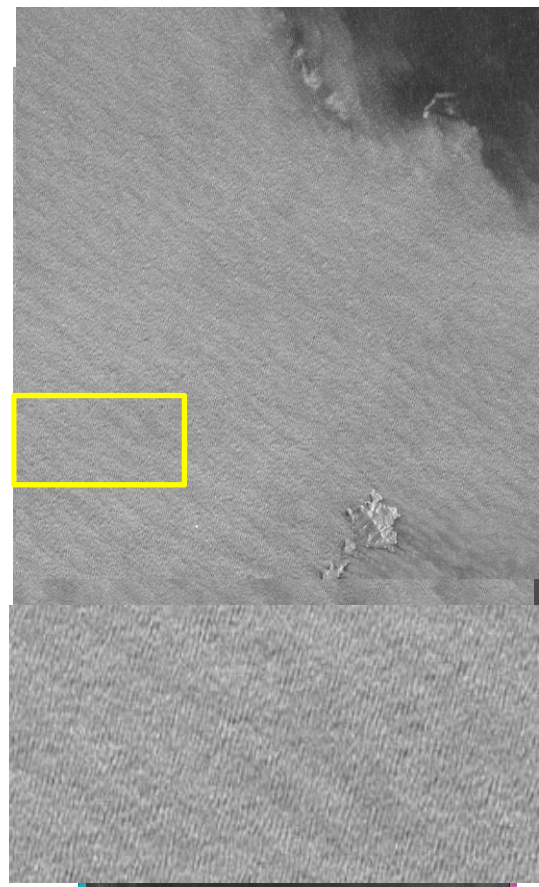
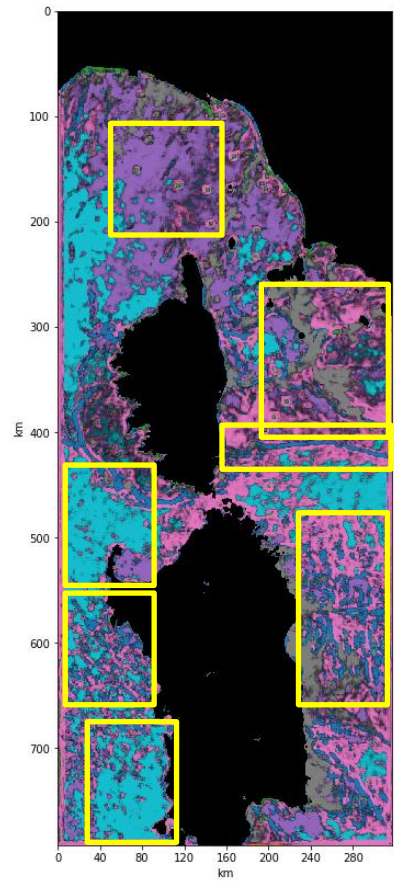
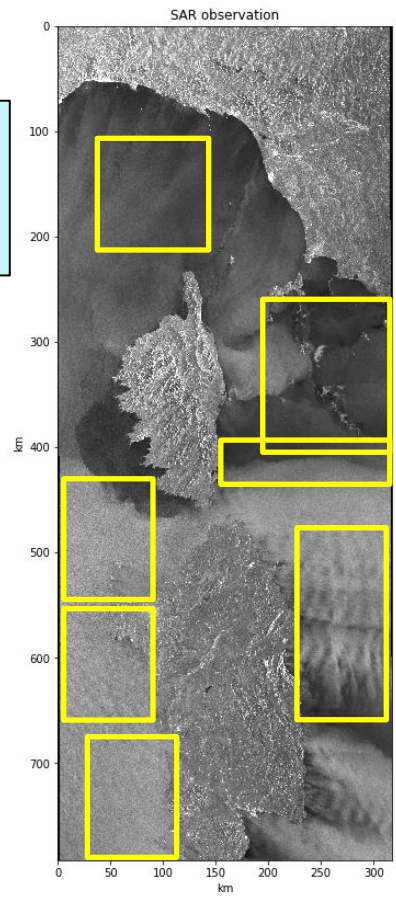


SEGMENTATION OF METOCEAN PROCESSES

A LITTLE FURTHER: SEGMENTATION OF WIDE SWATH

Once the **Interferometric Wide swath** are normalized in range, models trained on Wave Mode can be used

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



A LITTLE FURTHER: SEGMENTATION OF WIDE SWATH

Things that work

- Wide Swath can be segmented in a few seconds
- Most phenomena are accurately segmented
- Search by cooccurrences

Things that do not work (yet)

- Segmentation of Wind Streaks fails if the wavelength is around 10 km
- Ships are segmented as Icebergs (the phenomenon can be renamed is Local Targets)
- Icebergs are always segmented as surrounded by Pure Ocean Waves
- There is a lot more than 10 metocean processes. Some of them do not appear on Wave Mode images (orographic waves, internal waves, ...)
- Superposition of multiple phenomena (on the same pixels) could be solved with hyperbolic wavelet decomposition.

SEMANTIC SEGMENTATION AND BEYOND



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SEGMENTATION OF METOCEAN PROCESSES

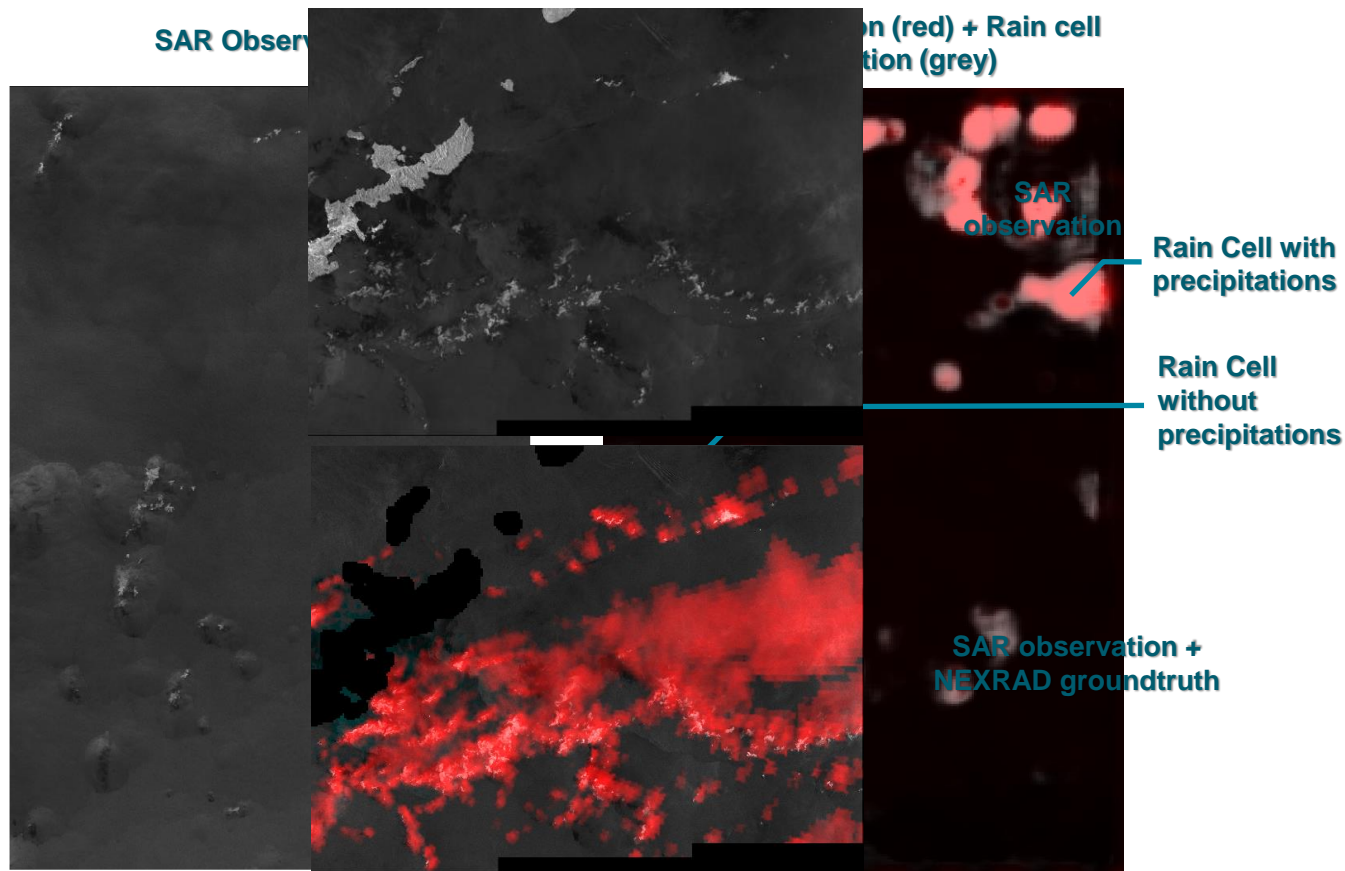
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EVEN FURTHER: SEGMENTATION FROM NEXRAD

With another dataset, we train a model to reproduce **NEXRAD radar reflectivity**

Rather than train a new model, we **transfer the weights** from the segmenter, and only **train the last layer**

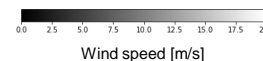
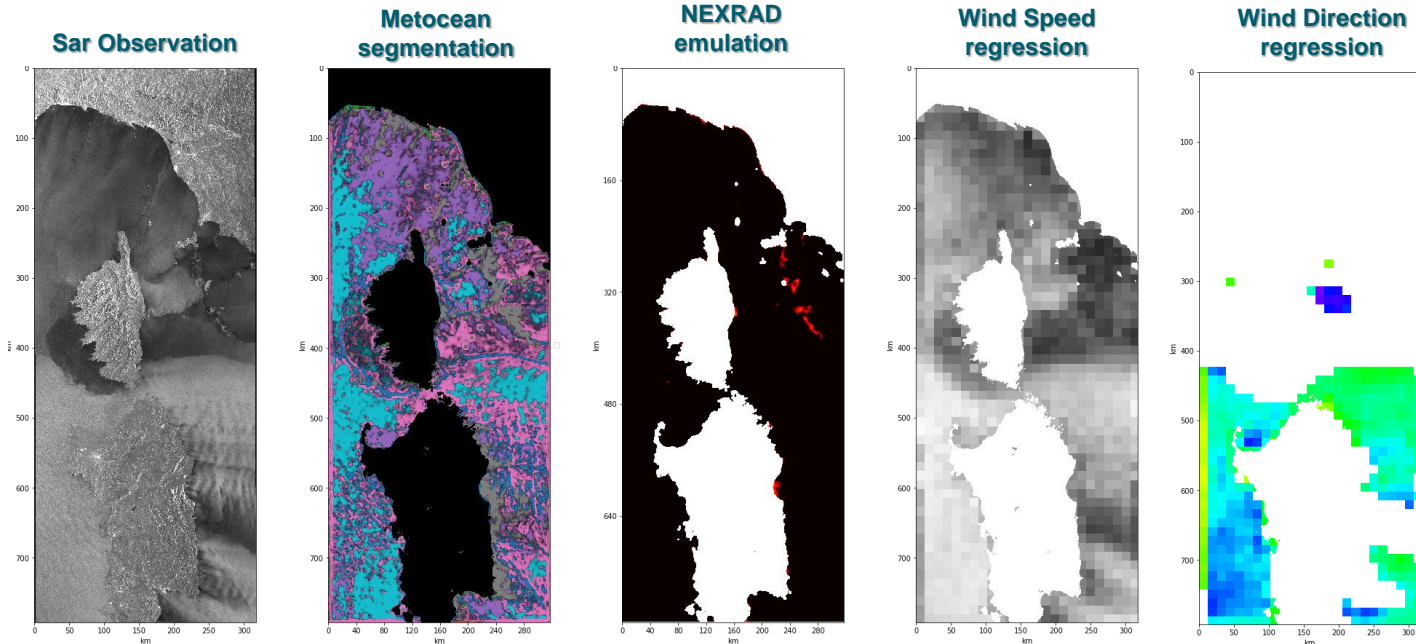
We combine the output of the **NEXRAD emulator**, trained on Wide Swath, with the **segmenter** trained on Wave Mode



SEGMENTATION OF METOCEAN PROCESSES

FURTHEST: REGRESSION OF WIND SPEED & DIRECTION

Colocalisation of TenGeoP-SARwv with **ECMWF** gives one Wind Speed and one Wind Direction per Wave Mode.



CONCLUSION



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CONCLUSION

- With 1000 pixel-level annotated groundtruth, we are able to segment ten metocean processes
- Even with 40k image-level groundtruth, the weakly-supervision methods are outperformed (information quality is important)
- Metocean processes are not the only information that can be inferred from SAR observation: wind speed/direction, precipitations



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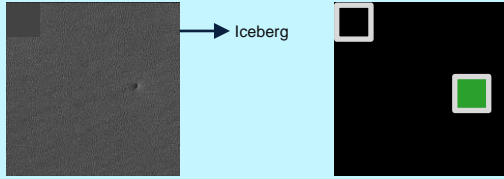


CLS

COLLECTE LOCALISATION SATELLITES

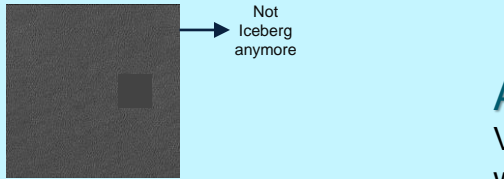
ANNEXES

MASKS AND WINDOWS

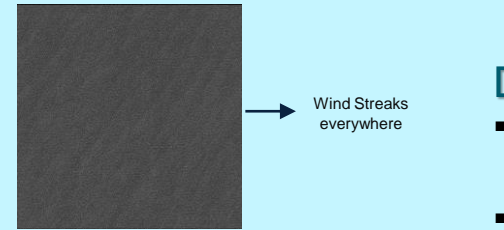


Solution 1

Moving a **mask** over the input, we compute the variation of the output



Not
Iceberg
anymore



Wind Streaks
everywhere

Advantages:

Very local phenomena are well segmented

Drawbacks :

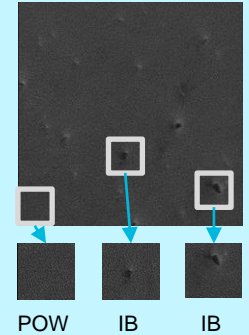
- Global phenomenon are not well segmented
- Time complexity is high

Solution 2

Moving a **window** over the input, we run a classifier over parts of the input

How to obtain the smaller classifier ?

- The InceptionV3 classifier is fully convolutional : the weight number doesn't depend on the input size
- Training on (512, 512), running on (75, 75)



Drawbacks:

- Lack of context lead to lot of misclassification
- Time complexity is high

Advantages :

- Obtains the best segmentation overall. In particular, can segment global phenomena

CAM & CATEGORIZATION AS NOISY SEGMENTATION

Solution 3 (CAM)

We remove the **Global Average Pooling** (GAP) layer from the InceptionV3 architecture to connect the last convolution with the dense layer

Categorizer

$$y = f(x \cdot W + B)$$

$$\left. \begin{array}{l} x: (2048,) \\ W: (2048, n) \\ B: (n,) \end{array} \right\} \Rightarrow y: (n,)$$

Advantages:

- Good segmentation on local phenomena
- Quite quick

CAM

$$y = x' \cdot W + B ; x = GAP(x')$$

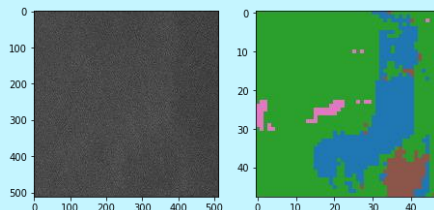
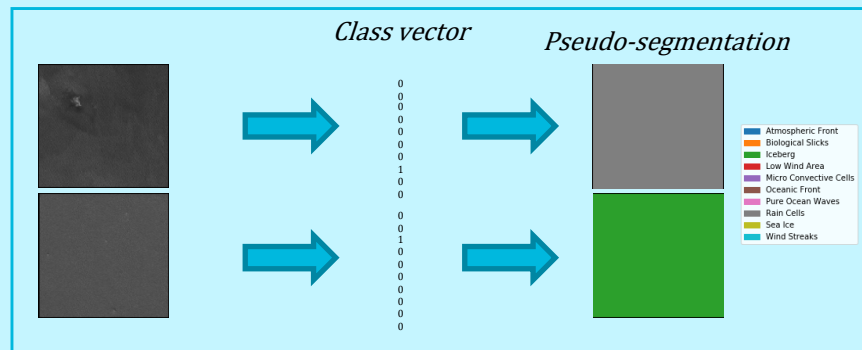
$$\left. \begin{array}{l} x': (w, h, 2048) \\ W: (2048, n) \\ B: (n,) \end{array} \right\} \Rightarrow y: (w, h, n)$$

Drawbacks :

- Weaker on global phenomena

Solution 4

We consider the categorization to be a **noisy segmentation**



Advantages:

- Good results on global phenomena
- Quickest

Drawbacks :

- Confusion between POW, IB and OF