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On the detection and segmentation of metocean features on SAR images using Deep Learning: perspectives for SWOT



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1 - Context

With the upcoming launch of SWOT, new Ka-band near-nadir SAR image will be produced. Whereas the legacy of ocean SAR imaging is huge for L-C- or X-band SAR sensors with intermediate incidence angle, the interaction of Ka-band near-nadir EM waves and its associated SAR image formation lead to some uncertainties on how metocean features will be imaged on SWOT image. To name a few, atmospheric fronts, ocean fronts, rain cells, convective microcells, internal waves, gravity waves, biological slicks, upwelling or wind trails are phenomena that will be imaged by SWOT. These phenomena could be a source of errors and bias for SSH products. Meanwhile, they are of potential interest for the scientific communities.

In this study, we aim to propose a methodology to flag and detect these phenomena to 1) mask them when generating L2 ocean products (SSH, wind...) and thus avoid any additional errors, 2) improve our understanding of Ka-band near nadir ocean SAR imaging while 3) being of interest for scientific community.

This study is based on Sentinel-1 C-band SAR images for which the 3 above objectives are still relevant. Within the frame of Copernicus S-1 mission, high-resolution SAR images are produced each day, representing a daily average of 3.45 TB of published data.

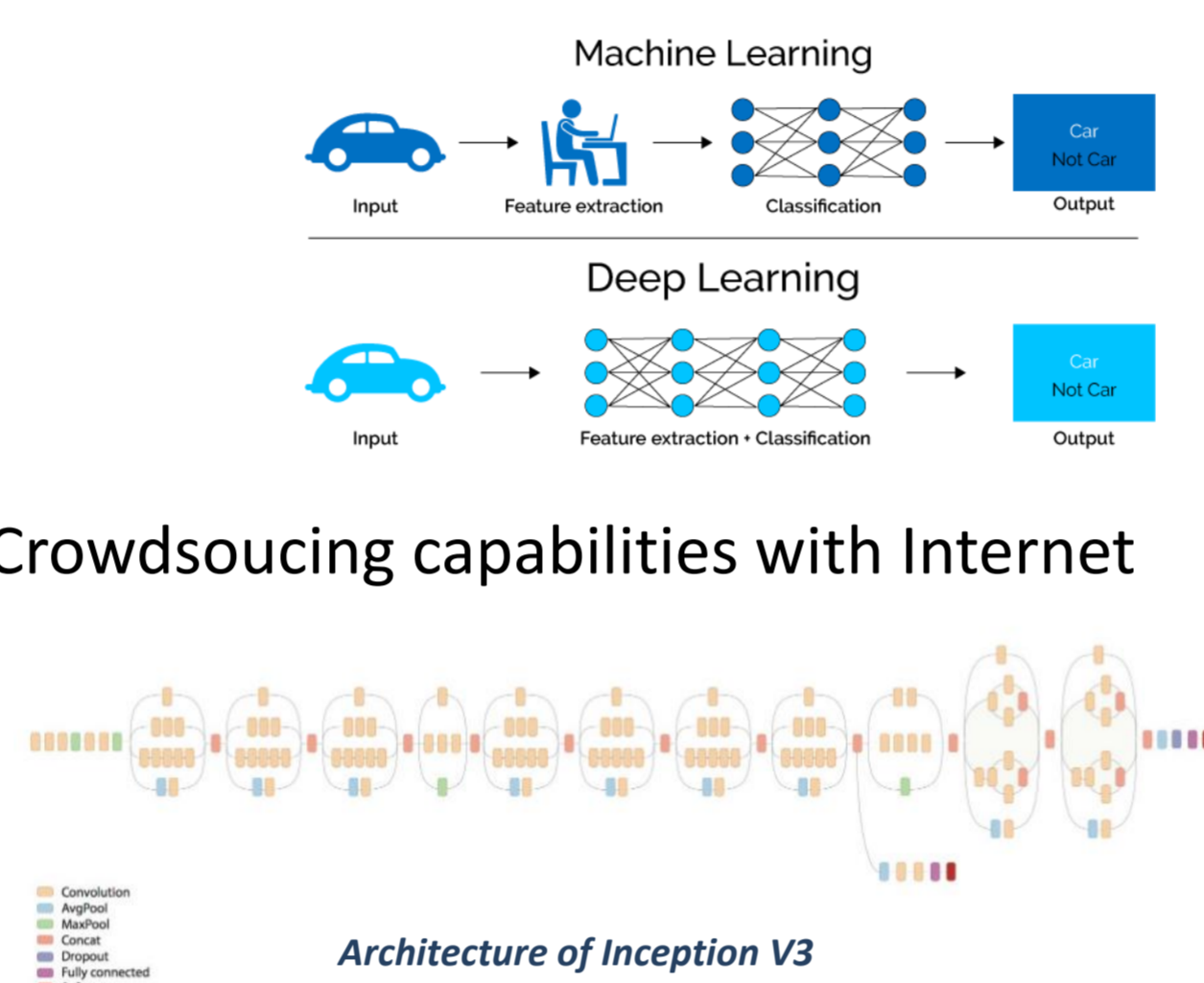
2- Deep Learning technics

Classification/segmentation of images and Machine Learning ? -> Need for handcrafting features
ML applicable to oceanic SAR images ?

- Intrinsic variability for a given phenomenon
 - Depending on metocean and observation conditions
- Deep Learning -> data-based feature extraction + classification
DL applicable to oceanic SAR images?

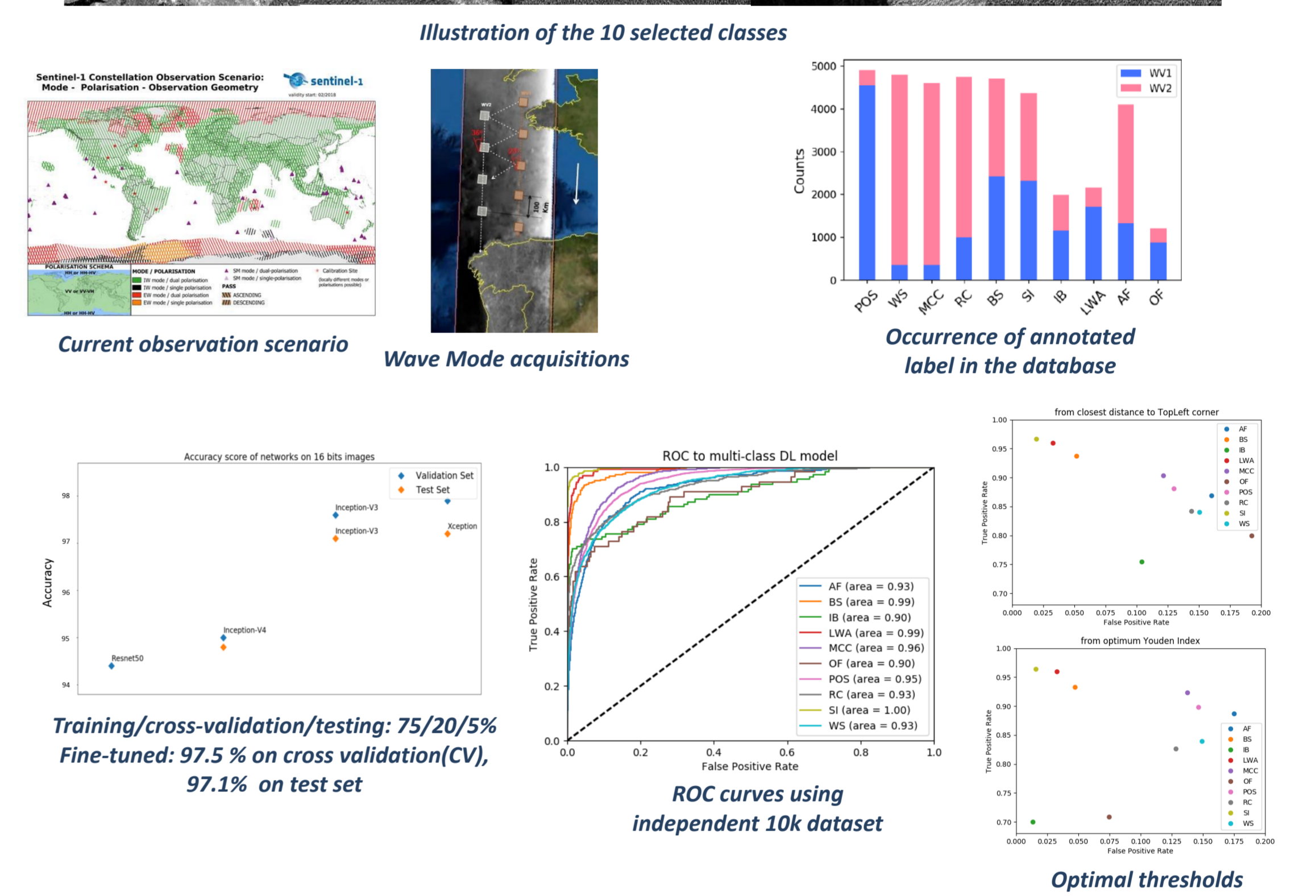
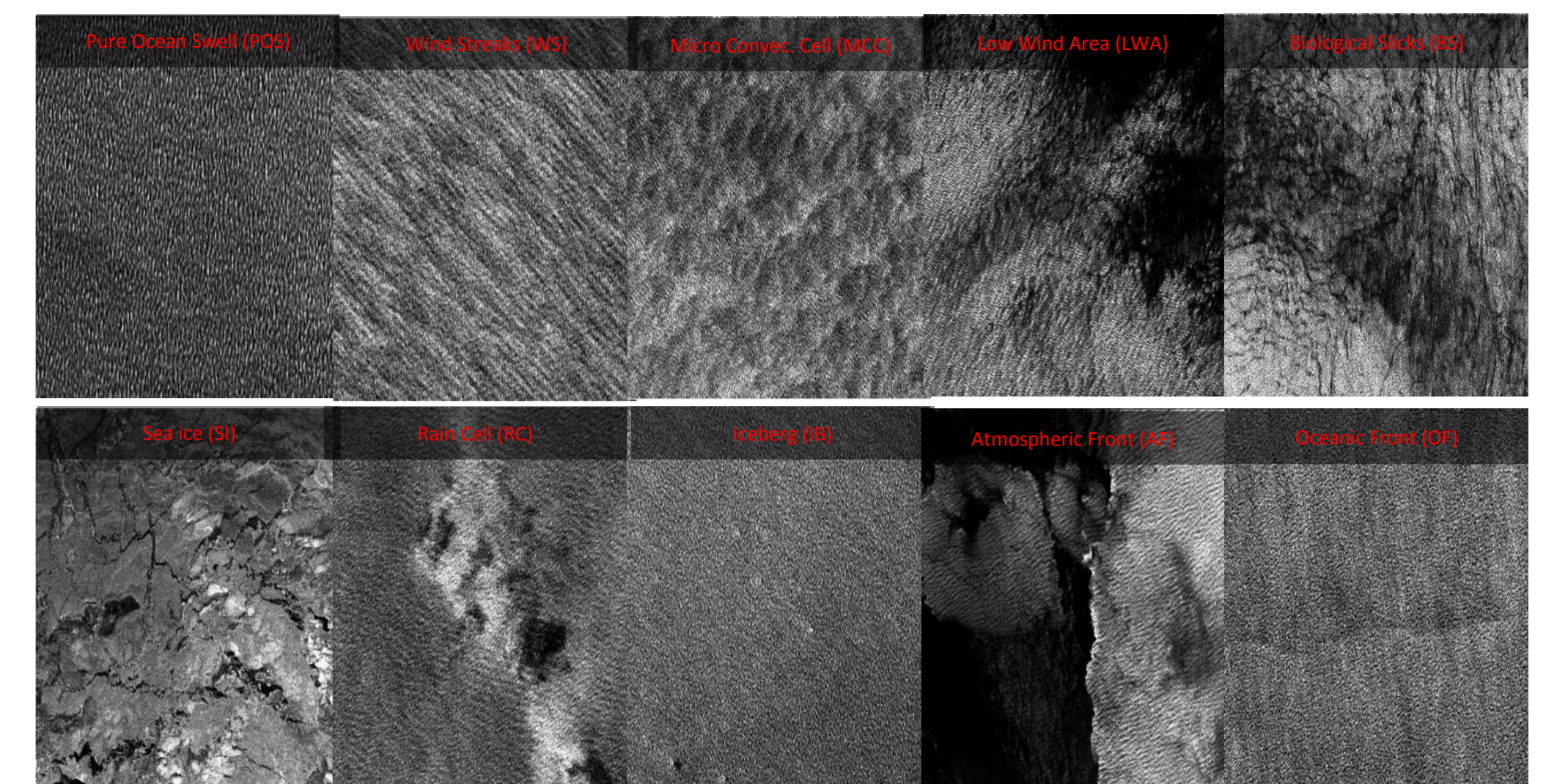
- Need for training database with annotated/labelled SAR images
- Computing Power (GPU...) + Frameworks by Google/Facebook/... + Crowdsourcing capabilities with Internet (ImageNet) + Data availability => Boom of Deep Learning

Challenge classification ILSVRC (ImageNet)
1001 classes, 1M+ images
Deep Convolutional Neural Network (CNN)



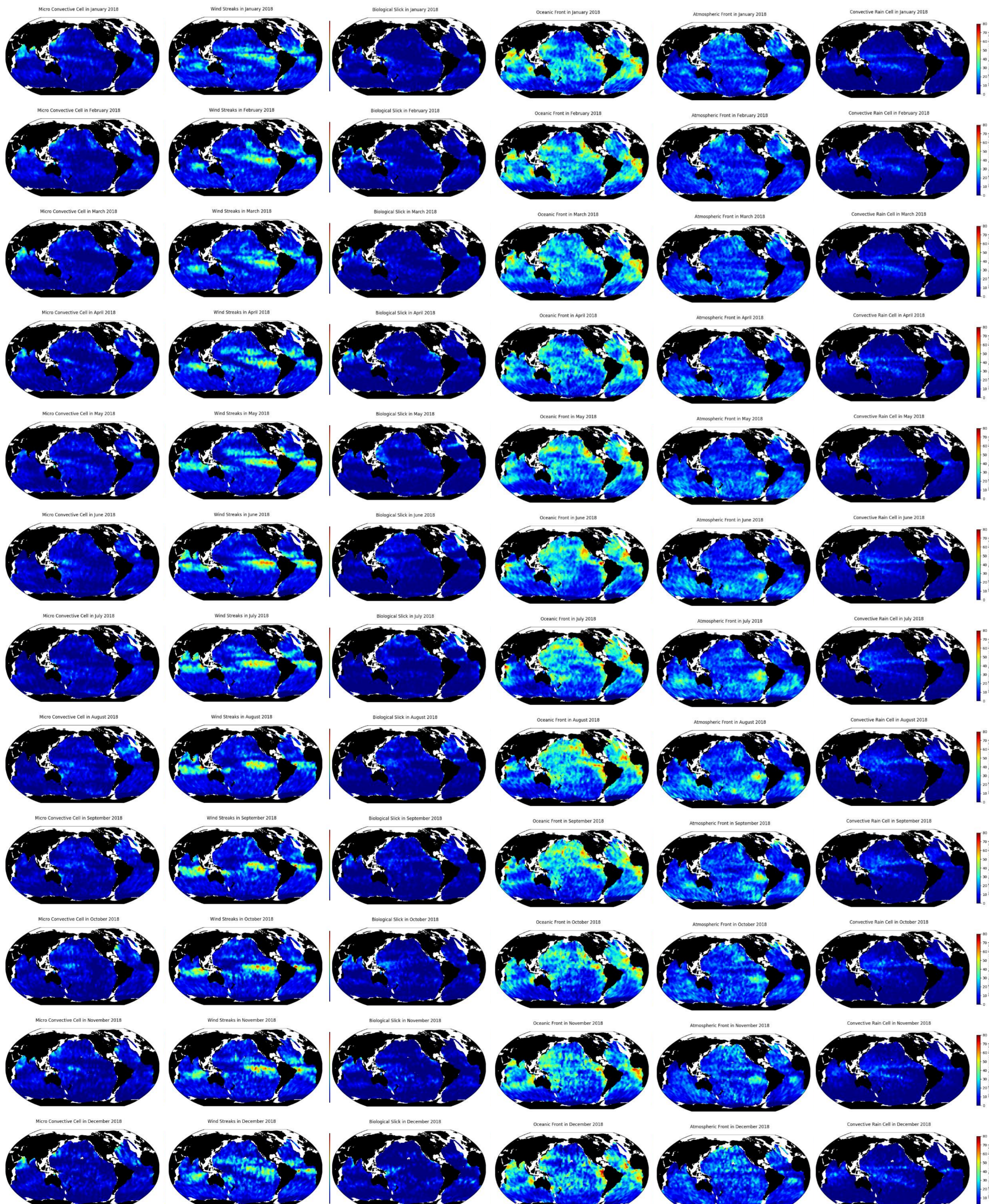
3 – Classification of Wave Mode S-1 imagerettes

Based on Wave Mode imagerettes (20 x 20 km)
37 000 labelled imagerettes with one label per imagerette: 10 classes, resampled with 50 m spatial resolution
Fixed clipping for all database and coded with 16 bits



4 – Database of classified WM imagerettes

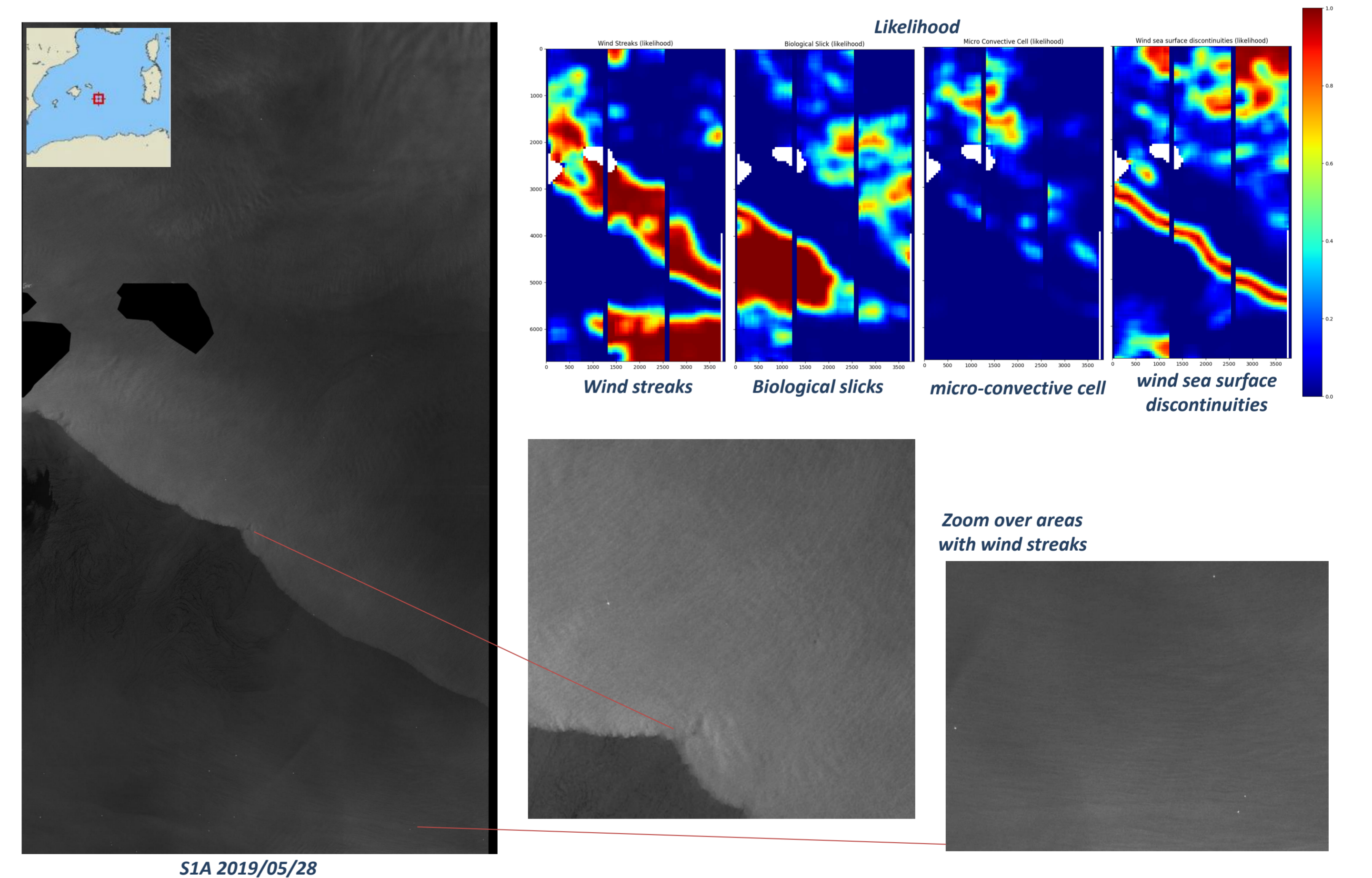
The entire S-1 Wave Mode archive from 2016 is being processed. Below the occurrence of each class as classified by the DL model is provided on a monthly basis.



This classified database could be used as input for a systematic collocation process with SWOT data. That will 1) help to understand Ka-band near nadir imaging processes for a given phenomenon, 2) serve during the Cal/val campaign, and 3) be used to build a training database with tagged SWOT images serving also DL model.

4 – Semantic segmentation of SAR image

The above classification model (one 20x20 km imagerette = one label) is then used over a full Wide Swath S-1 image using local class estimates with a convolution approach to provide a semantic segmentation.



Multi-class (and multi-label, i.e. one pixel several classes) semantic segmentation is now feasible with DL, pending starting with a good and sufficient training database, and active learning process to enrich it. To this end, annotation tools and adequate framework should be consolidated and tuned to our problematic: 1) massive processing needed to raise specific issues (for instance, "sea ice" North of Madagascar should be re-tagged as internal waves), 2) additional information from ancillary metocean data might be provided, ...

5 – Conclusion

Opening new horizons for L1 SWOT understanding, Cal/val activities, enhancement of L2 data products (mask where non relevant), and sciences with possibility in fine to systematically detect ocean front, internal waves, biological slicks "trackers of submesoscale eddies, etc, ...

Classification/segmentation of Sentinel-1 data can help building collocated SWOT database with given phenomena, and provide SWOT community references given C-band SAR legacy.