LISA LAM

CYCLONE DETECTION FROM IASI DATA USING THE YOLO MODEL

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MOTIVATION

- Cyclone detection is a challenging task. First, cyclone events are dynamic i.e. they evolve rapidly in shape and size over time. Second, there is a lack of annotated examples by experts[1], this makes training of Machine Learning models difficult.
- The prevalent physical models for cyclone detection are TSTORMS[2] and Stride Search[3] which are near real time two stages detectors (spatial search & temporal correlation) based on thresholded criteria using high res' climate data (vorticity, vertical temperatures, sea-level temperature and pressure). On the Deep Learning side, ClimateNet (Deeplab v3+) is an U-Net architecture[1] trained on the same data (500 images) that achieves a mean IoU of 0.5247.
- In that work, we will try to detect cyclones from the **IASI satellite data** usually used to retrieve gaz concentrations. To reach that goal, we will use the **YOLO model**, used for autonomous driving cars' object detection. The **HURDAT hurricane data base** will allow the labelling of the training dataset.
- More than 4 millions IASI spectra are measured per day. About 70% of the data are contaminated by clouds and usually thrown away. In this work, we will exploit all the IASI data and attempt to dectect cyclones in the North Atlantic Basin.

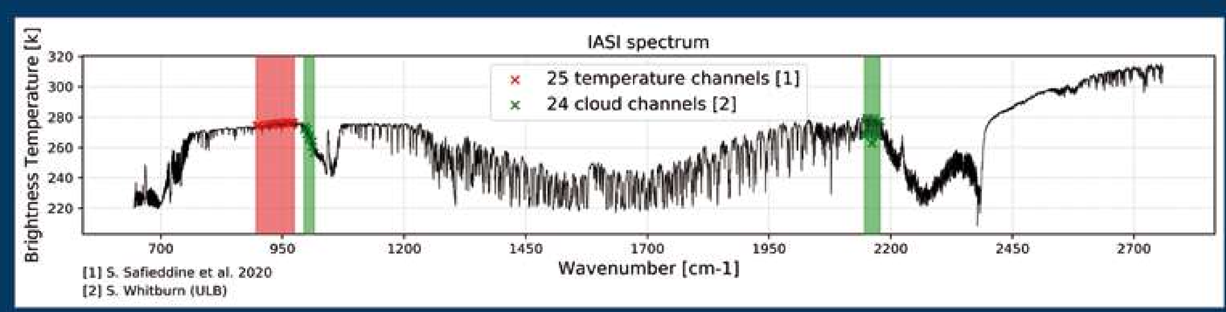
1. Prabhat et al, "ClimateNet: an expert-labelled open dataset and Deep Learning architecture for enabling high-precision analyses of extreme weather", Geoscientific Model Development Discussions, pp. 1–28, 2020.

2. Vitart et al, "Simulation of Interannual Variability of Tropical Storm Frequency in an Ensemble of GCM Integrations", J. Climate, vol. 10, no. 4, pp. 745-760, 1997.

3. Bosler et al, "Stride Search: a general algorithm for storm detection in high-resolution climate data", Geoscientific Model Development, vol. 9, no. 4, Art. no. 4, 2016.

IASI DATA

IASI (Infrared Atmospheric Sounding Interferometer) flies onboard the three Metop satellites. IASI measures the infrared radiation from Earth twice a day (around 9:30 AM/PM local time).



Each observation is composed of brightness temperatures (T_b) for 8460 channels.

As input for the model, we choose to use T_b for 25 channels sensitive to temperature, T_b for 24 channels sensitive to clouds, as well as the water vapour total column, for a total of 50 features.

IMAGE PREPARATION

- **STEP 1**: For each track of cyclone of the HURDAT database, find colocated IASI data.
- **STEP 2**: Data extraction, averaging in a 0.5° x 0.5° grid, interpolation to fill Nan cells.

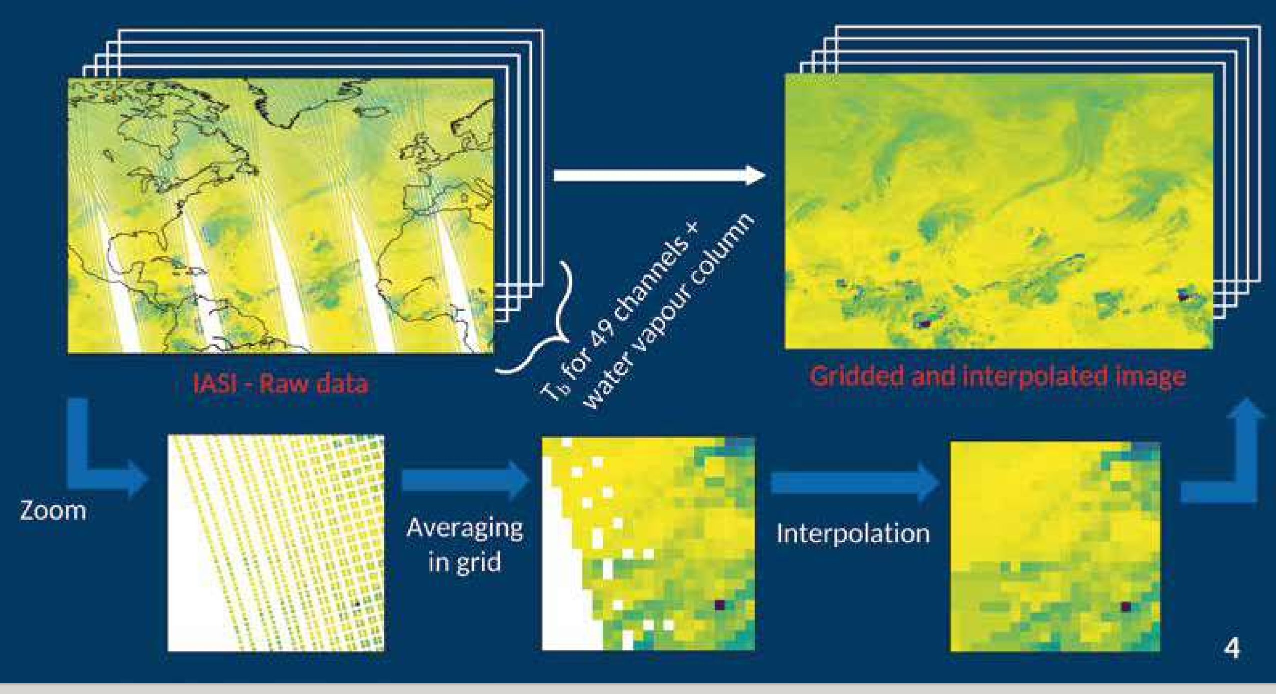
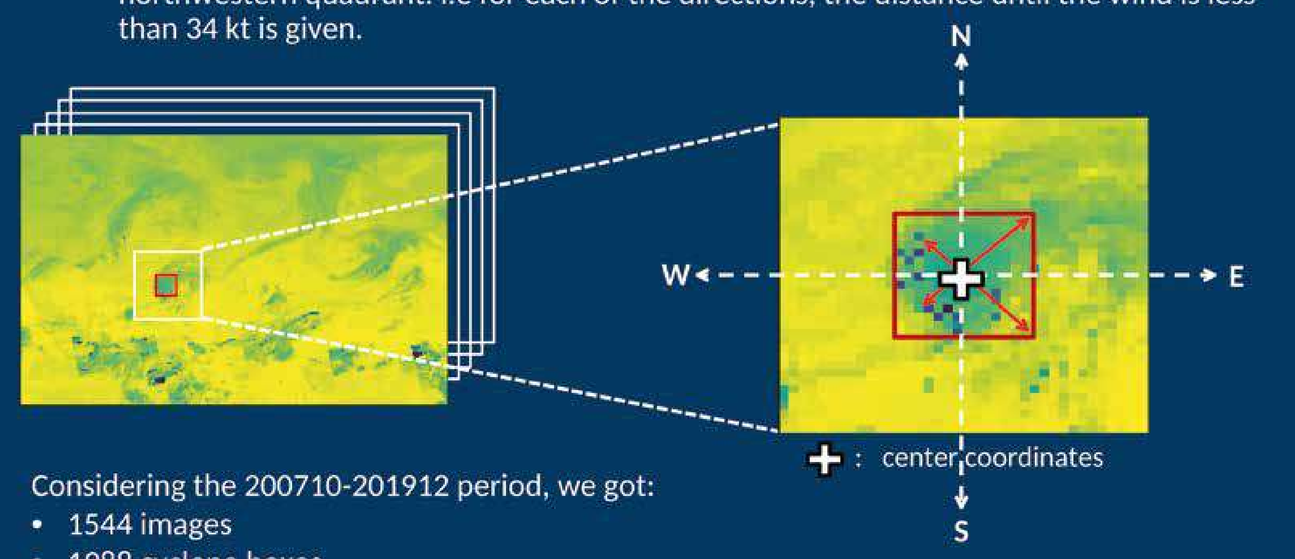


IMAGE LABELING

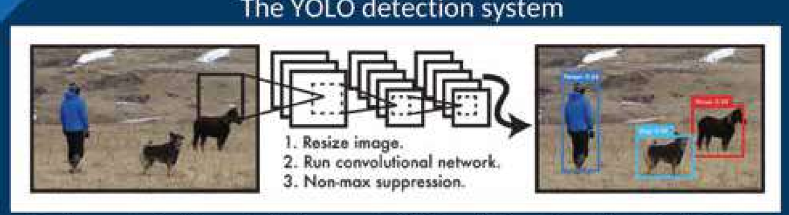
- **STEP 3**: Infer cyclone boxes thanks to HURDAT/NOAA data, which provides
  - coordinates of cyclone center, at 0, 6, 12 and 18h UTC
  - 34 kt wind radii maximum extent in northeastern, southeastern, southwestern and northwestern quadrant. i.e for each of the directions, the distance until the wind is less than 34 kt is given.



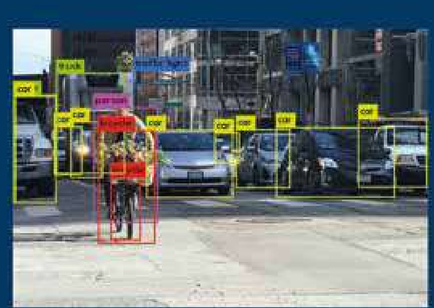
Considering the 200710-201912 period, we got:
- 1544 images
- 1988 cyclone boxes

YOLO MODEL

The YOLO detection system



J. Redmon et al., "You only look once: Unified, real-time object detection", 2015.



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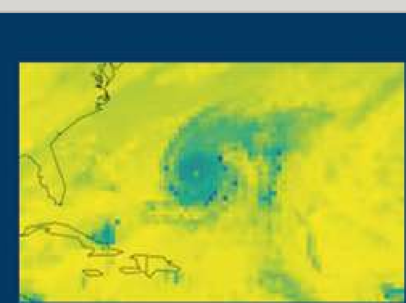
- One stage object detector, version 3
- 106 layers (75 CNN layers + 31 layers combining shortcut, route, upsample)
  - 53 layers for features extraction
  - 53 more layers for detection
- Detection at 3 scales to detect big objects as well as small ones
- Metrics: Average Precision (AP) and mean Average Precision (mAP)
- Fast predictions, real time inference
- Applied to autonomous driving cars and video surveillance

PERSPECTIVES



- For the rest of the internship:
  - Model adaptation/implementation using Tensorflow
  - Training on supercomputer Jean Zay (IDRIS), and performance evaluation
  - Add 2020 data in the training dataset (2020 HURDAT data available since May 2021)
- Long term perspectives :
  - Use Autoencoder instead of channels selection
  - XAI to try to understand what the model is looking at, which channels are the most relevant
  - Expand database to the entire world
  - Cyclone prediction

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