Automatic detection of weather events in high-resolution NWP outputs

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Plan

1 - Context

▷ The classical use of EPS includes

- a visual examination of each member : time-consuming
- point-based probabilities and percentiles : lack of spatial consistency, mostly univariate, hide some small-scale multivariate features (e.g. MCS)

▷ Automatic detection of relevant weather patterns in NWP outputs could provide an additional useful information

- Occurrence of some events in ensemble members
- Pattern-based probabilities
- Pattern-based verification, weighting and clustering of ensemble members

1 - Detection methods

▷ Object detection is not new ... but the methods have evolved

▷ 2 main approaches can be used to automate this task

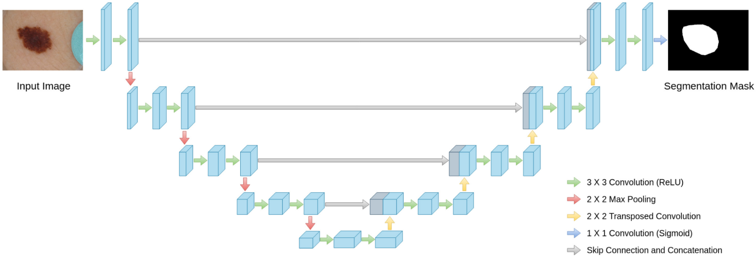
- Expert systems
  a set of empiral rules are specified by the expert (e.g. size and intensity thresholds)

- Supervised machine learning
  classification rules are learnt by the algorithm from the statistical properties of the data

1 - Weather objects detection

▷ Several objects detected in the French Arome/Arome-EPS outputs : rainfall patterns (intensity, texture), tropical cyclones, bow echoes (A. Mounier's poster), weather fronts (L. Rottner's poster)

▷ Detection is performed with a standard convolutional neural network : the U-Net encoder-decoder (Ronneberger et. al 2015)



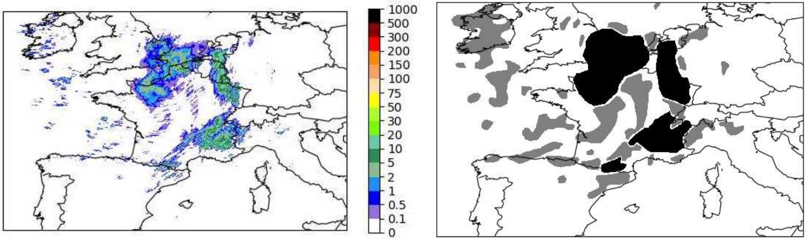
▷ The U-Net is known to work well with small training datasets

Plan

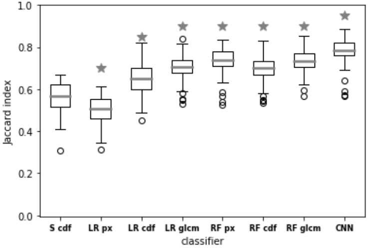
2 - Training

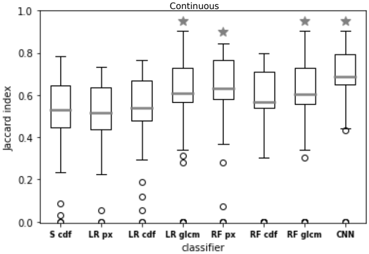
▷ Detection of categories ‘no precipitation’, ‘continuous precipitation’ and ‘intermittent precipitation’

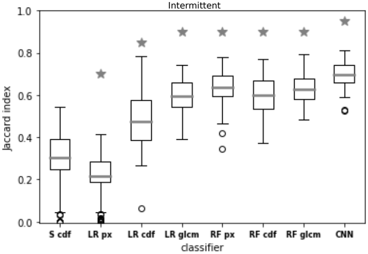
▷ Training database : 180 Arome 1hr-accumulated rainfall forecasts + corresponding manual labels



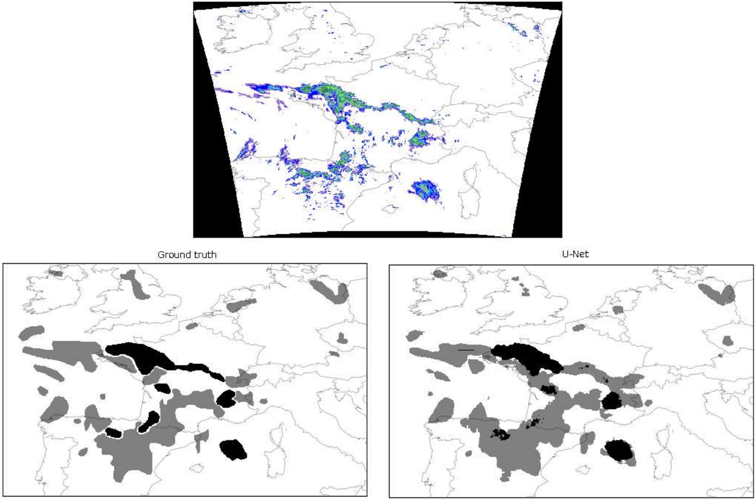
▷ U-Net is trained on small patches randomly extracted from each Arome image





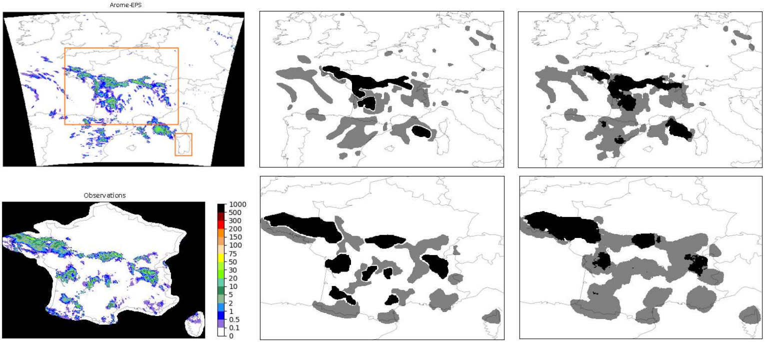


▷ U-Net performs best, but it is only slightly better than RF


Ground truth
U-Net

2 - Transfer learning

- ▷ Similar detections can be done on Arome-EPS and observations
- ▷ Transfer learning is efficient and removes the need for new databases



Plan

3 - TC trackers

▷ Existing TC trackers are based on expert systems

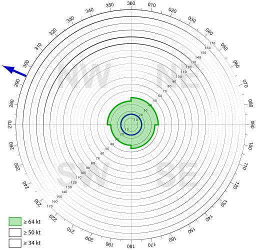
▷ Heming, 2017 : TC tracking and verification techniques at UKMO

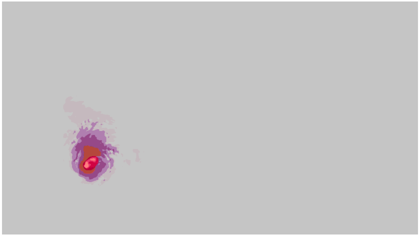
"1. The 850RV must be above a predetermined threshold
2. The nearest point of lowest MSLP must be below a predetermined threshold
3. A closed isobar check is applied
4. The TC centre detected must be equatorwards of 37.5 latitude
5. The TC centre must be over or very close to sea points in the model
6. The TC centre must be over sea with a model analysed SST above a predetermined threshold."

▷ If all these conditions are met a TC is considered to have been detected in the model forecast.

▷ TC trackers can be complex to develop and computationally expensive.

▷ TC trackers also report cyclonic (64kt) and maximum winds radii
▷ Only in each quadrant of the storm

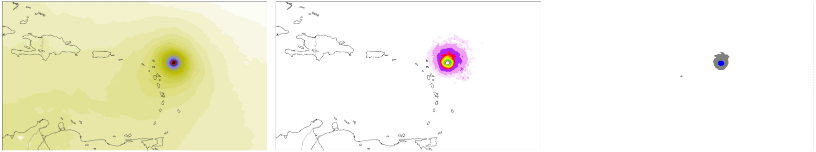




▷ The U-Net can be used to get a finer description of wind structure by directly identifying areas of cyclonic and maximum winds

3 - Training

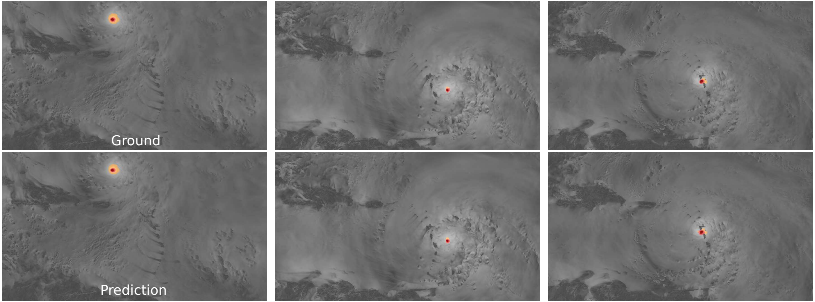
▷ Training : 311 Arome-West Indies forecasts of 10-meter wind speed and Z850 + corresponding manual labels of wind areas



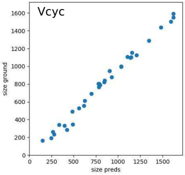
▷ Training data are highly imbalanced : $\sim 5\%$ of pixels are labeled as TC

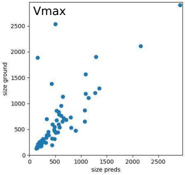
- we impose a ratio ‘empty’ patches/‘TC’ patches $= 2$
- we use the weighted cross-entropy :
  $\Rightarrow$ higher weights are given to TC categories

- On 77 validation TCs : no miss, 2 false alarms on Vmax
- Jaccard(Vcyc)=0.87, Jaccard(Vmax)=0.72

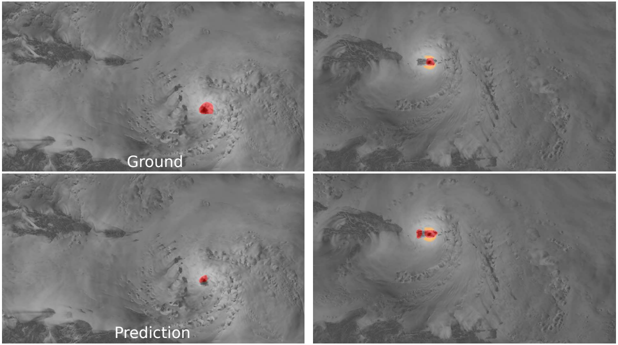


- Good correspondance of object sizes



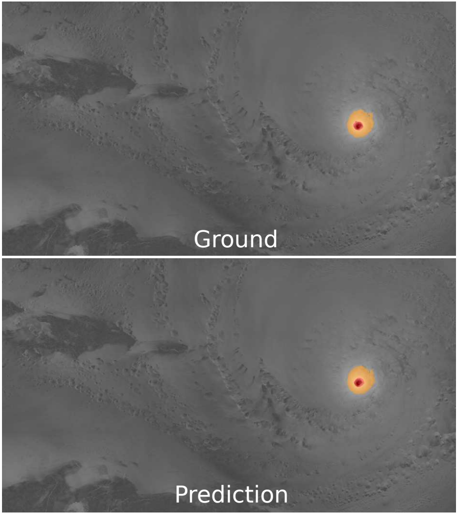


▷ Some problems to fix for e.g. for low-intensity TCs and landing

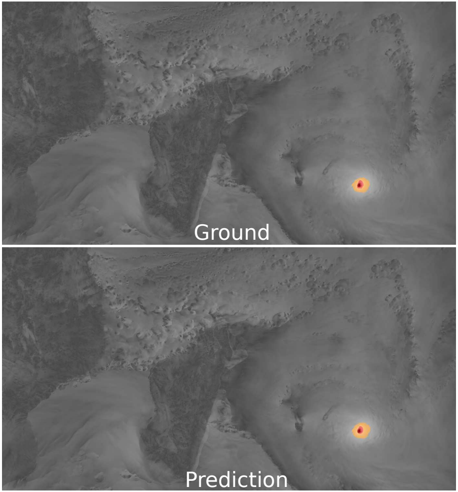


▷ Refine the training data and re-tune weights

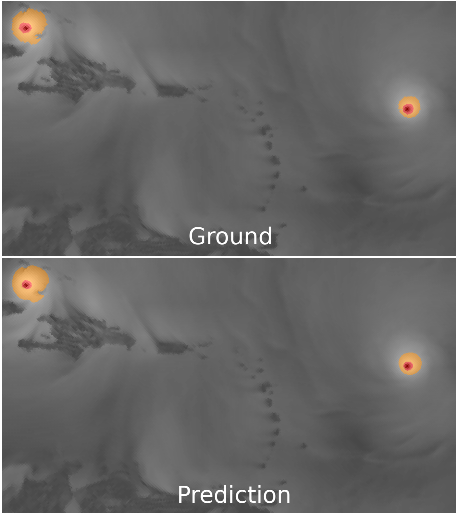
▷ From Arome 2.5km outputs to Arome 1.3km outputs



▷ From the West Indies domain to the Indien Ocean domain



▷ From Arome outputs to Arpège outputs



4 - Conclusions and future works

▷ The U-Net is an efficient method for the detection of a variety of complex, multivariate objects
▷ But a lot of efforts has to be put on the labelling of training data
▷ Transfer learning is very promising

▷ Extend the detection to other objects (e.g., ongoing work on supercells, weather fronts)

▷ Introduce and promote the use of objects in daily forecasters practice :

- "Direct" use : help for zoning, identifying and caracterizing areas of risk
- "Indirect" use : objet-based metrics for weighting (Raynaud et al. 2019), clustering and verification of EPS members