Hybrid Machine Learning Approach for Tropical Cyclones Detection

Davide Donno[1,2], Gabriele Accarino[1,3], Donatello Elia[1], Enrico Scoccimarro[1], Silvio Gualdi[1]

[1] CMCC Foundation - Euro-Mediterranean Center on Climate Change, Lecce, Italy
[2] Department of Engineering of Innovation, University of Salento, Lecce, Italy
[3] Department of Earth and Environmental Engineering, Columbia University, New York, U.S.A.

Introduction

Tropical Cyclones (TCs) are considered among the most disruptive Weather Extremes, and changing climate is making them stronger and longer lasting. Accurate TC Tracking in large climate datasets is traditionally based on deterministic algorithms.
Here, we propose a Hybrid Machine Learning (ML) approach that consists in combining ML-based TC localization with deterministic tracking. This work is a follow-up of Accarino et al., 2023.

Methodology

Dataset

The TC formation basins targeted in the study are the East and West North Pacific (ENP, WNP). 6-hourly ERA5 reanalysis dataset (1980 to 2019) was used for model training and testing jointly with the *International Best Track Archive for Climate Stewardship* (IBTrACS) records.

Drivers and Dataset Preprocessing

Input Drivers:

- Relative Vorticity at 850mb (RV)
- Mean Sea Level Pressure (MSL)

ERA5 drivers were tiled into 40x40 non-overlapping patches (Figure 1), and labeled in TC/noTC.

Machine Learning Models

Two Convolutional Neural Networks (CNNs) work together:
i) *Classification model* - detection of a TC.
ii) *Localization model* - find the TC eye.
For both the models, VGG-like networks were used (Figure 2). The former model uses a sigmoid in output.

Tracking Algorithm

The output TC eye locations from the *classification* and *localization* models were aligned in time through a deterministic tracking scheme. The tracking algorithm is taken from Scoccimarro et al., 2017.

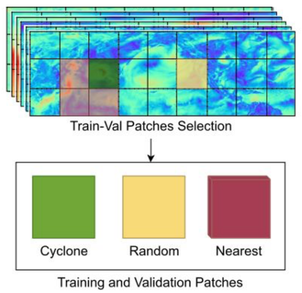

Figure 1 - Training and Validation patches selection process

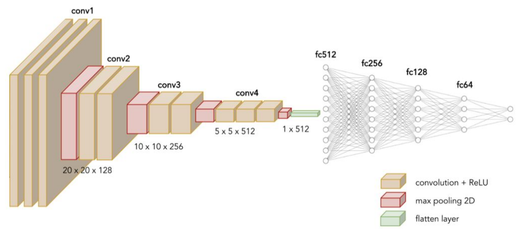

Figure 2 - Visual Geometric Group (VGG) CNN used for this setup

Results

Our Hybrid ML model has been compared with deterministic trackers (i.e., OWZ, TRACK, UZ, CNRM). Raw track records have been taken from Bourdin et al., 2022 and compared with respect to our IBTrACS filtered dataset.

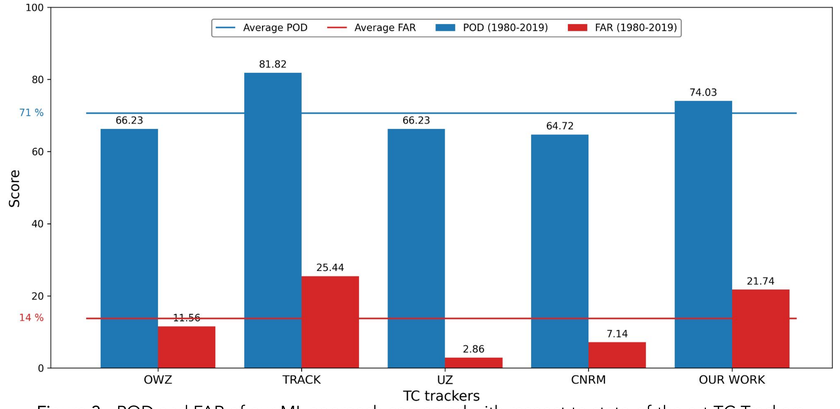

Figure 3 - POD and FAR of our ML approach compared with respect to state-of-the-art TC Trackers on the joint West and East North Pacific basins

Interannual Variability

August month is the most active during the year, in terms of TC occurrence in ENP and WNP basins.

Pearson correlation coefficient has been computed to compare the ML models with respect to IBTrACS observations, during August month of the 40 years.

P-value is always below 0.05, meaning that the correlation values have high statistical significance.

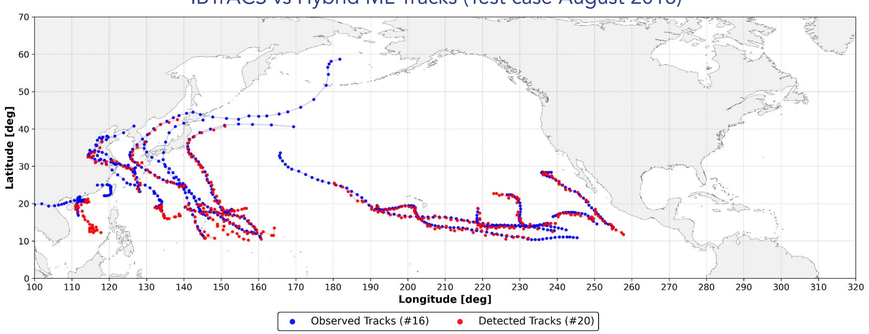

Figure 5 - Detected tracks (in red) obtained with the Hybrid ML approach during August 2018 overlaid with IBTrACS observed tracks (blue)

Probability Of Detection and False Alarm Rate

Considering the average Probability of Detection (POD) and False Alarm Rate (FAR), our ML model has:

- POD higher than OWZ, UZ and CNRM
- FAR comparable with TRACK tracker

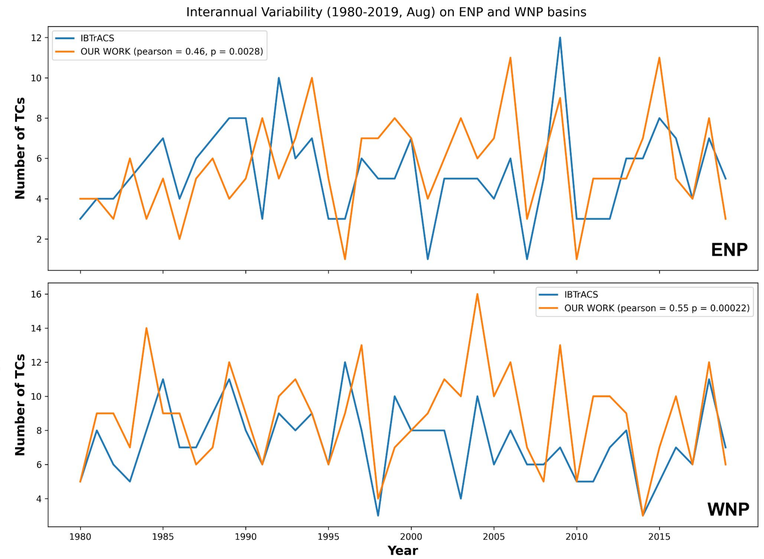

Figure 4 - Hybrid ML model and IBTrACS Interannual Variability on East (top) and West (bottom) North Pacific basins during August month during 40 years (1980 - 2019)

Conclusions

Although this is still a work in progress, Hybrid ML TC Tracking is promising, as it provides a more computationally efficient solutions w.r.t. deterministic approaches showing comparable results (POD and FAR). In addition, Interannual Variability on both the ENP and WNP basins are highly correlated with the IBTrACS observations.
In addition, the proposed approach can be easily relocated to other basins worldwide, with small re-training effort and few changes in the setup.

References
Accarino et al., (2023). An ensemble machine learning approach for tropical cyclone localization and tracking from ERA5 reanalysis data. Earth and Space Science, 10, e2023EA003106. https://doi.org/10.1029/2023EA003106
Scoccimarro et al., (2017). Tropical cyclone interaction with the ocean: The role of high-frequency (subdaily) coupled processes. Journal of Climate, 30(1), 145–162. https://doi.org/10.1175/jcli-d-16-0292.1
Bourdin et al., (2022). Intercomparison of four algorithms for detecting tropical cyclones using ERA5. Geoscientific Model Development, 15(17), 6759–6786. https://doi.org/10.5194/gmd-15-6759-2022

This work has been supported as part of the interTwin project (https://www.intertwin.eu). The interTwin project is funded by the European Union Horizon Europe Programme – Grant Agreement number 101058386.