Temporal evolution of features that control 10-m wind gusts in moist baroclinic wave simulations identified using non-linear regression

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Introduction

A majority of insured losses over Europe are related to ***Extra-Tropical Cyclones (ETC)*** which are characterised by strong winds, heavy precipitation and powerful ocean waves. ***Baroclinic Wave Simulation (BWS)*** are used to study ETC by varying their background state and measuring their different intensities. This study proposes to run a BWS on OpenIFS with full Physics and in the moist case scenario. Using a ***wrapper Feature Selection Algorithm (wFSA)*** combined with a nonlinear regressor applied to the 10-m wind gust, the evolution of the simulated cyclone through time is analysed to evaluate the feasibility of huge ensemble processing.

Materials

- Open Integrated Forecast System (OpenIFS) Cy43r3v2 developed by ECMWF was used in these settings:
  - ***Full Physics***, ***moist case***, aqua-planet
  - Spatial resolution: TL319/L137
  - Time resolution: 20 minutes for 15 days
- ***The initial background state*** was taken from Jablonowski and Williamson[1]
- Initial Gaussian perturbation for the zonal wind:
  - Location: 40°N 20°E
  - Radius: a tenth of the Earth's radius
- ***90 variables -called features-*** were extracted. 10-m wind gust was selected as the intensity measure
- All computation were ran on Puhti from the CSC[2]

Method

- The ***weighted Random Forest*** Regressor is used for the Northern Hemisphere
- The wFSA algorithm is presented Figure 1 for every 12 hours

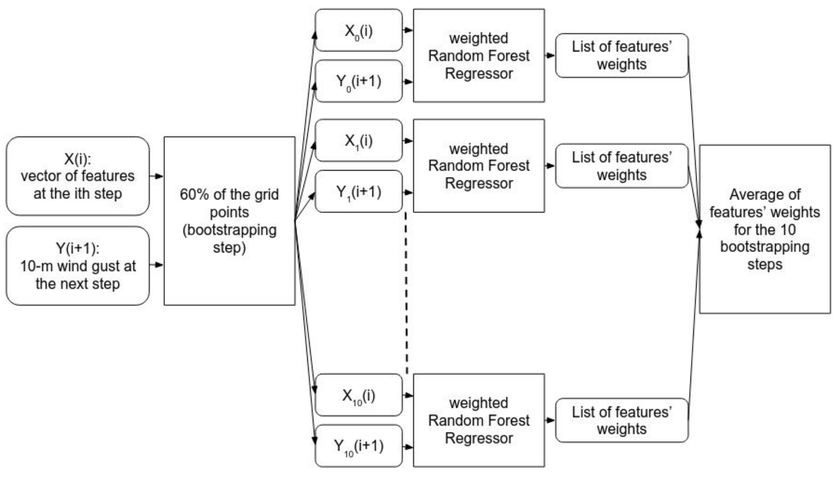

Figure 1: Flowchart of the wFSA using Stable Selection[3] and weights of Random Forest Regressor

Results

- The BWS in moist case scenario is presented Figure 2:
  - The main cyclones are located in the mid-latitudes
  - Powerful 10-m wind gusts are developing in the extreme latitudes
  - The 10-m wind gust begins its increase on the 6th day on mid-latitudes
  - The computation time for the whole simulation is 1h 05min

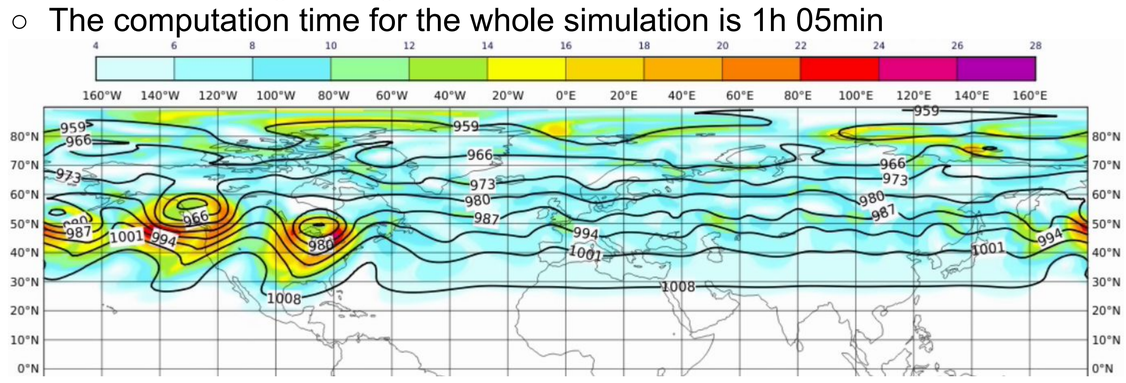

Figure 2: MSLP (black lines) and 10-m wind gust (rainbow shades) in the Northern Hemisphere after 12 days since the initial perturbation, the coastlines are only shown for reference ; there is no land in aquaplanet setup

- The Figure 3 presents the evolution of weight for the 10 first features through all time steps to predict the 10-m wind gust:
  - The average coefficient of determination is 0.79 with a variance of 0.005
  - The variance of weights is below 10^{-4} for all bootstrapping steps

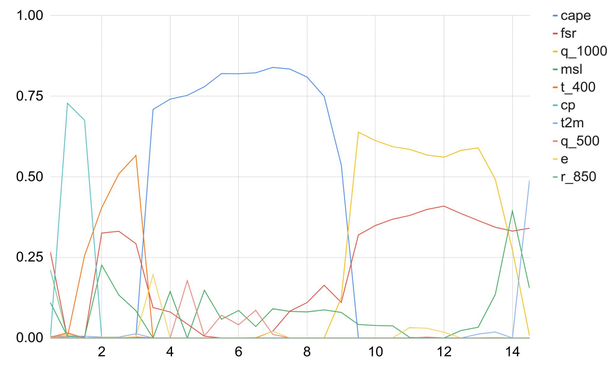

Figure 3: The weight of the 10 first features through all time steps. The weight go from 0 (irrelevant) to 1 (relevant) for the wRF Regressor.

- Three phases are observable:
  - For the first three days: ***forecast surface roughness (FSR), temperature at 400 hPa (T_400) and convective precipitation (CP)*** are predominant
  - ***Convective Available Potential Energy (CAPE)*** become predominant for the next 6 days
  - ***FSR and specific humidity at 1,000 hPa (q_1000)*** are predominant for the remaining of the BWS

Conclusions

- The background state[1] allows deep cyclones development in the moist case.
- However, the lows in the extreme latitude can disturb the Machine Learning Application in the mid latitudes. This is due to the surface fluxes caused by the gradient between SST and 2-m Temperature in the extreme latitudes.

➔ Future work will aim at developing a new background state.

- The regression has a high R^2 because of the step to the next processing.
- Temperature at 400 hPa and convective precipitation are important measures to predict the 10-m wind gust during the cyclogenesis in the moist case. Then CAPE become essential during the maturation phase.

➔ The method will be extend for multiple features and intensity measures. Moreover, different background states will be used on tracked cyclones.

References:

[1] Jablonowski, Christiane, and David L. Williamson. "A baroclinic instability test case for atmospheric model dynamical cores." *Quarterly Journal of the Royal Meteorological Society: A journal of the atmospheric sciences, applied meteorology and physical oceanography* 132.621C (2006): 2943-2975.
[2] https://docs.csc.fi/computing/systems-puhti/
[3] Meinshausen, Nicolai, and Peter Bühlmann. "Stability selection." *Journal of the Royal Statistical Society: Series B (Statistical Methodology)* 72.4 (2010): 417-473.

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