# airport-sCAle seveRe weather nowcastinG project ('CARGO')


## Executive summary

Monitoring and predicting extreme atmospheric events, is very challenging especially when they develop locally in a short time range. Several studies have shown in the past the capabilities of ground based Global Navigation Satellite System (GNSS) for studying and predicting severe weather events. The GNSS allows the measurement of the zenith total delay (ZTD) strictly related to the atmospheric Integrated water vapour, which is the engine of the convection. Moreover, there is evidence that an abrupt increase in the total lightning discharge rate, often precedes severe weather occurrences on the ground.

The Lombardy region, in North Italy, is often affected by severe weather events with an increase of frequency and intensity in the last decades. Milano Malpensa airport is located in Lombardy and it is the second largest airport of Italy in terms of passengers (after Roma Fiumicino) and the first in terms of freight, so it is a good hotspot to develop a nowcasting algorithm for severe weather and to understand the impact of the severe weather on air traffic.

The objective of the project is to develop a nowcasting algorithm based on Neural Networks using input data from weather stations, lightning detectors and ground based GNSS receivers located in the area of interest and to create as output a polygon highlighting the risk for air safety.

We have selected more than 600 severe/extreme weather cases affecting the area of Malpensa in the period 2011-2019. The selection of severe weather events is based on echo radar intensity and rain rate from weather stations. For the predictive task required by this project, a feed-forward fully connected neural network has been chosen since it is the most versatile and is easily adaptable to our needs. Neural networks can in fact learn a wide variety of non-linear behaviours, as long as there are enough data for the training. The number of extreme events is small by definition and thus difficult to identify. The strong imbalance between meteorological circumstances that produce no occurrence of events, occurrence of average storms and occurrence of extreme storms makes the task extremely difficult. The neural network that we have chosen can capture non-linear behaviours between variables and is capable of accomplishing both regression and classification tasks with minor modifications.

We have run several different neural network configurations to understand which one could be the best for our case and we obtained the best algorithm accuracy by using all the variables as inputs (GNSS ZTD from 6 stations, meteorological parameters, lightning). However, the use of a smaller number of GNSS receivers, slightly lowers the accuracy, so an optimisation of the network setting must be evaluated considering both the computational and the economic cost. The ZTD alone has a large impact on the prediction of the events, but the additional parameters help to improve the nowcasting by at least 20%. From the algorithm runs, it looks like the wind information decreases the capabilities of the nowcasting, however we wanted to deepen the analysis to understand the reason. A statistical analysis based on 40 case studies randomly chosen in the same period, shows that 78% of the extreme events are characterised by wind field convergence, just 25% of the cases have a decreasing trend of ZTD 30 minutes before the rainfall, and there is a never decreasing ZTD trend 30 minutes before the event corresponding to wind field divergence. This means that the wind direction and intensity contain a great value to forecast the extreme events, but neural network architecture that we implemented is not able to capture the relevant information. Thus, the algorithm can be improved to understand how to correctly provide the wind direction and intensity as inputs.

Other than the scientific results, several issues were highlighted during the project which will be the background for future studies and projects.

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