Forecasting the weather to assist ATC and ATM operations

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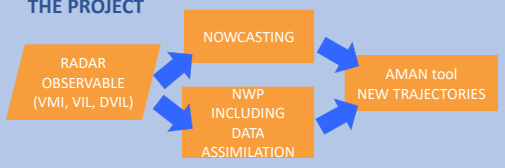
ABSTRACT

In EUROCONTROL's recent summary report on Climate Changes Risks for European Aviation, several weather-related impacts were highlighted. There is a strong relation between highly impacting weather events and disruptions to the aviation network resulting in additional fuel consumption and CO_2 emissions. In Europe, severe weather is responsible for up to 7.5% of the total en-route delays. In this respect, the H2020 Satellite-borne and IN-situ Observations to Predict The Initiation of Convection for ATM (SINOPTICA) project aims to demonstrate that very high-resolution and very short-range numerical weather forecasts, benefiting from the assimilation of radar data, in-situ weather stations, GNSS and lightning data, can improve the prediction of extreme weather events to the benefit of Air Traffic Management (ATM) and Air Traffic Control (ATC) operations.

The assimilation of radar, GNSS, and lightning data shows a positive impact on the forecast of the convective cells for the four selected severe weather events. Moreover, two radar-based nowcasting strategies, PhaSt and RaNDeVIL, are tested to predict storm structures. Both methods are able to follow the more intense cells (VIL > 10 kg/m^2) in all the case studies, as shown by the MODE results and the eye-ball verification. The forecasts are used in an arrival management system (AMAN) to compute 4D trajectories around convective areas, integrate the affected aircraft into the arrival sequence, and to assist air traffic controllers in implementing the approaches through just in time advisories and a dynamic weather display. With the help of real traffic scenarios and the enhanced weather models of SINOPTICA, the weather-dependent approach planning strategies were evaluated.

THE PROJECT

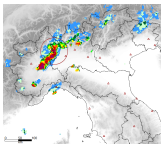


SINOPTICA is a project funded under the European Horizon 2020 program and dedicated to the assimilation of data for the improvement of mathematical models used in the prediction of extreme events, in order to support air traffic management. In particular, the project aims to exploit the data obtained from remote sensing, both satellite and ground-based, from the Global Navigation Satellite System (GNSS) and in situ weather stations.

The idea is to provide a more accurate prediction of severe weather events in order to support air traffic managers and to give an alternative landing trajectory.

MILANO - MALPENSA CASE OF STUDY 11/05/2019

An intense squall line formatted in the lee of the Italian Alps hitted the Milano Malpensa airport. The event was characterized by an **intense hailstorm,** intense lighting activity and strong wind gusts. The airport had to close for 40 minutes Because the hail completely covered the runways. The presence of hail on the runways causing some flight delays. In addition, 9 planes are diverted to other airports



Max of DVIL 14:35 - 14:50 UTC

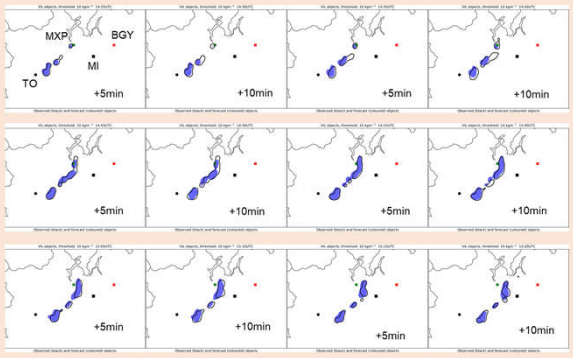
NOWCASTING EXPERIMENTS

PhaSt nowcasting technique

This approach has been developed at CIMA for the meteo-hydrological chain (Metta et al., 2009; Poletti et al., 2019) but is it possible to apply this technique for ATM purposes. Since the hypothesis of the algorithm is the slow variation of energy (power spectrum) in time, we investigated the change in the spectra distribution of other radar products compared to the Surface Rainfall Intensity (SRI) which is used in PhaSt:

- Vertical Integrated Liquid (VIL)
- Vertical Integrated Liquid Density defined as VIL/ETM where ETM is the Echo Top, the height (in m) where the signal is 20 dBZ
- Vertical Maximum Intensity (VMI)

VMI, VIL density and VIL showed very small variations in the energy spectrum for the different time intervals, same as for SRI.
This makes them suitable for the application of PhaSt algorithm for the extrapolation of the structures evolution .

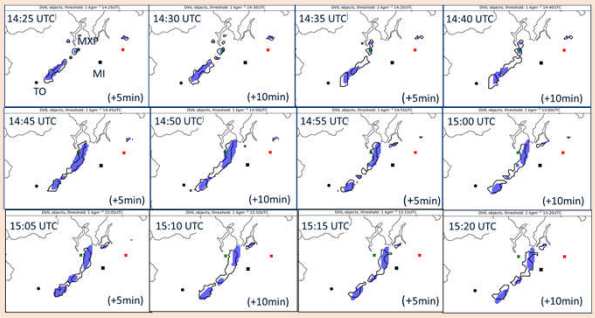


Observed (black) and forecast (blue coloured) objects with PhaSt (VIL > 10 mm) for Malpensa case of study (14:25 - 15:20 UTC). The green dot locates the Malpensa airport (MXP), in Black there are the cities of Milan (square) and Torino (circle) and in Red is the Bergamo airport.

RaNDeVIL nowcasting technique

- GAMA research group from the University of Barcelona developed this algorithm using their expertise on the analysis and forecast of Mediterranean severe storms.
- It is a purely radar based nowcasting algorithm targeting potentially severe storms
- The storm identification is based on the 2D product Density of VIL (DVIL) with the purpose to simplify the calculations without resigning to multilevel information

$$DVIL = \frac{VIL}{ETM}\left[\frac{g}{m^3}\right]$$



Observed (black) and forecast (blue coloured) objects with RaNDeVIL (DVIL > 1g/m³) for Malpensa case from 14:25 to 15:20 UTC. The green dot locates the Malpensa airport (MXP), in Black there are the cities of Milan (square) and Torino (circle) and in Red is the Bergamo airport.

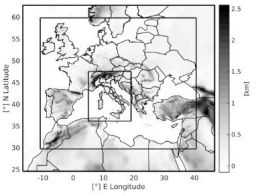
NUMERICAL WEATHER SIMULATIONS WITH DATA ASSIMILATION

The Weather Research and Forecasting (WRF) model configuration used operationally at CIMA is considered.
Initial and boundary conditions are provided by Global Forecast System (GFS) – 0.25°

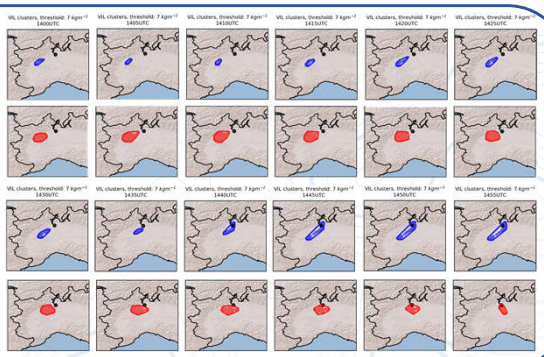
Five numerical simulations are performed for each case study, assimilating the following data every three hours:

Experiment	Description
CTL	No assimilation
RDR	Radar data have been assimilated
RDR+GNSS	Radar and GNSS data have been assimilated
RDR+WS	Radar data and temperature measured by Civil Protection weather stations have been assimilated
RDR+Lightning	Radar and lightning data have been assimilated

Domain	Horizontal grid dimensions	Horizontal grid spacing	Vertical levels
D01	216x191	22.5 km	50
D02	523x448	7.5 km	50
D03	430x469	2.5 km	50



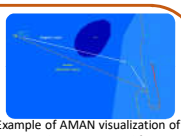
Object-based verification for the RDR + lightening simulation. The displayer areas are VIL > 7 kg/m^2 between 14:00 and 4:55UTC



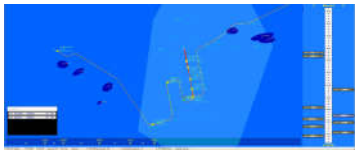
ATM-MET INTEGRATION

Air traffic controller arrival systems (AMAN) organize arriving air traffic. Now, they take current and forecasted weather situations into account:

- Calculates and adapts individual 4D arrival trajectories considering weather measurements, weather nowcast, and air traffic changes
- Provides aircraft target times for significant way points
- Generates advisories for controllers to guide aircraft along adapted routes



Example of AMAN visualization of a storm and trajectory modification



Methodology of the MET extended AMAN

- Imports georeferenced MET-polygons of actual and forecasted severe weather areas
- Tests conflicts between polygons and current trajectories
- Moves waypoints outside of actual and forecasted polygons
- Calculates 4D trajectories following new waypoints from actual aircraft position down to runway

CONCLUSIONS

- The case studies were selected considering weather impacts on the major Italian airports (based on traffic passengers)
- VIL and DVIL are suitable predictors for radar nowcasting to provide weather organization forecasts in airport approaching airspace and adjacent sectors
- Nowcasting software is rather fast so the Rapid Update Cycle (RUC) approach seems sustainable
- PhaSt algorithm was able to follow the more intense cells (VIL > 10 kg/m^2) in all the case studies
- RaNDeVIL has shown promising results in the analysed study cases with good capabilities to forecast intense storms based on DVIL information.
- 3D-VAR assimilation system can support the ATM activities
- Prediction of the exact location, timing and intensity of convective cells is still a challenge in NWP
- The integration of the meteorological information into an Arrival Manager to generate 4D trajectories avoiding severe weather areas enables early detour routing and improves ATM efficiency

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