The main project result is WinDMiL, a laboratory scale functional prototype of a software solution for meteorological data mining and assisting decision-making processes in meteorology. WinDMiL integrates data mining methods for fast and precise remote sensing data analysis, machine learning methods for weather forecasting and a component for results visualisation, easily interpretable for meteorologists and aimed to facilitate meteorological decision-making.

The WinDMiL system supports meteorological researchers and operational meteorologists in carrying out their daily tasks, by offering relevant information from past similar situations and assisting them in decision-making tasks such as predicting the areas affected by severe meteorological phenomena, precipitation forecasting and for various climatological analysis. The direct beneficiary of WinDMiL is the National Meteorological Administration, Romania.

SYSTEM DESCRIPTION

WinDMiL includes three main subsystems: (1) *subsystem for data acquisition and storage*; (2) *subsystem for data analysis*; and (3) *visualization subsystem*. Figure 1 illustrates the WinDMiL system architecture.

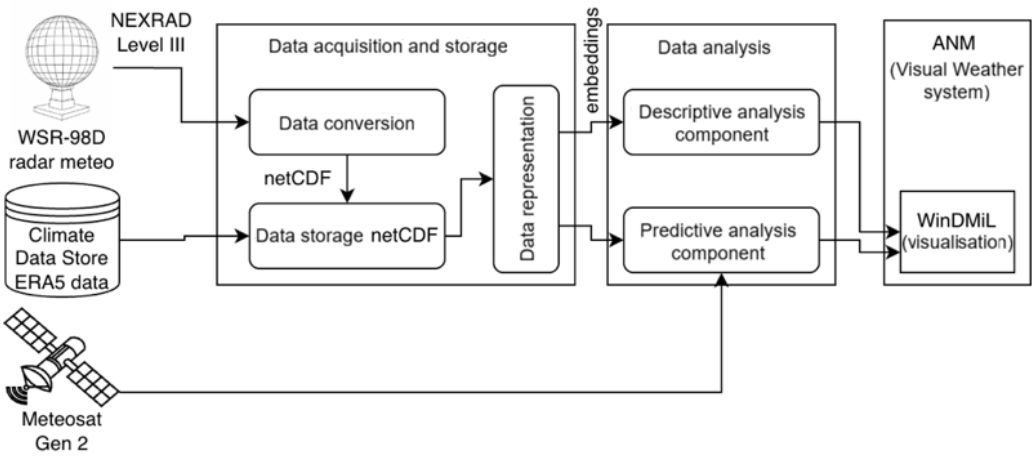


Figure 1 – WinDMiL system architecture diagram.

WinDMiL's meteorological data analysis subsystem includes an **unsupervised analysis** (descriptive) component and a **supervised analysis** (predictive) component. The unsupervised analysis component relies primarily on self-supervised extraction of compact representations (embeddings) of reanalysis data and the identification of similar past events based on the similarity between these representations. The two core predictive components of WinDMiL's supervised analysis subsystem are: (1) the prediction of weather maps derived from radar data and (2) short-term precipitation forecasting (*nowcasting*) for lead times of up to six hours, using heterogeneous meteorological data (reanalysis data, GRIB fields, WKL predictors, observations from weather stations, etc). WinDMiL also includes a **visualisation subsystem** that provides intuitive graphical representations of the results produced by both analysis subsystem's components in the form of easy-to-interpret maps. These visualisations support meteorologists in making informed decisions regarding high-impact weather events.

Figure 2 illustrates such an example. For a given moment's data, 4 past time moments with data similar to the current data can be visualised. The search is performed using the Euclidean distance between embeddings. Similarity scores are expressed on a scale from 0 to 100 (100 indicates identical representations and 0 indicates the greatest difference between any 2 images in the reanalysis dataset).

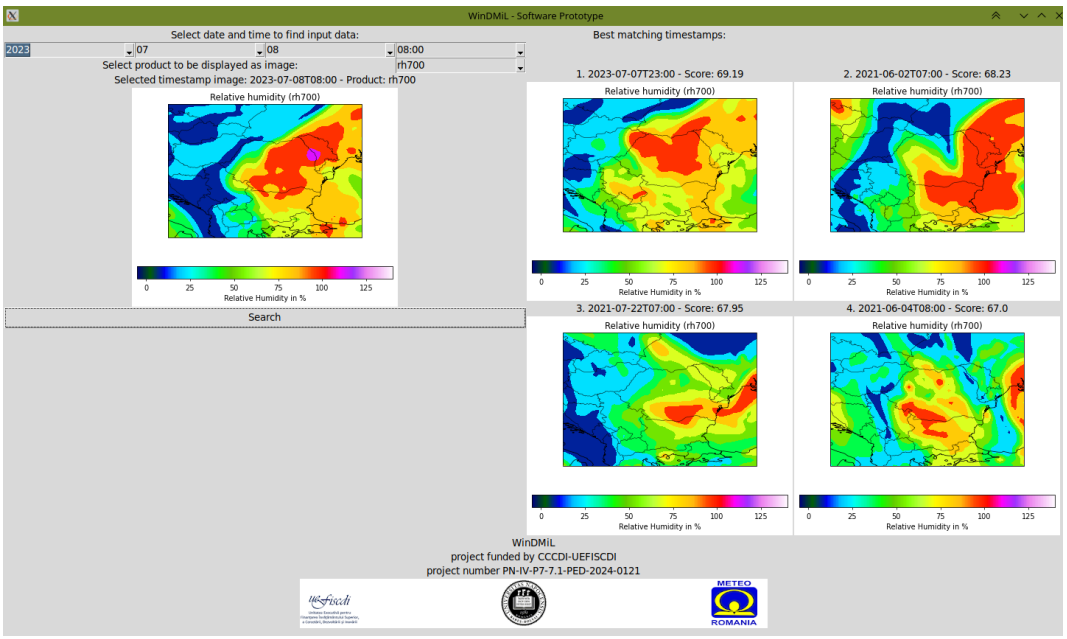


Figure 2 – WinDMiL: Component for identifying similar past events.

The images in Figure 3 present a direct comparison between the actual composite reflectivity derived from data captured by the Bobohalma weather radar (left panel) and the composite reflectivity estimated by the radar map prediction model (right panel). The plots were generated with Visual Weather, the operational visualisation software used by the National Meteorological Administration, Romania. The illustrated event took place on the 15th of November 2023, with data collected between 00:36 – 09:03 UTC, both during the temporal evolution of the phenomena (Figures 3(a)–(c)) and at the end of the event (Figure 3(d)).

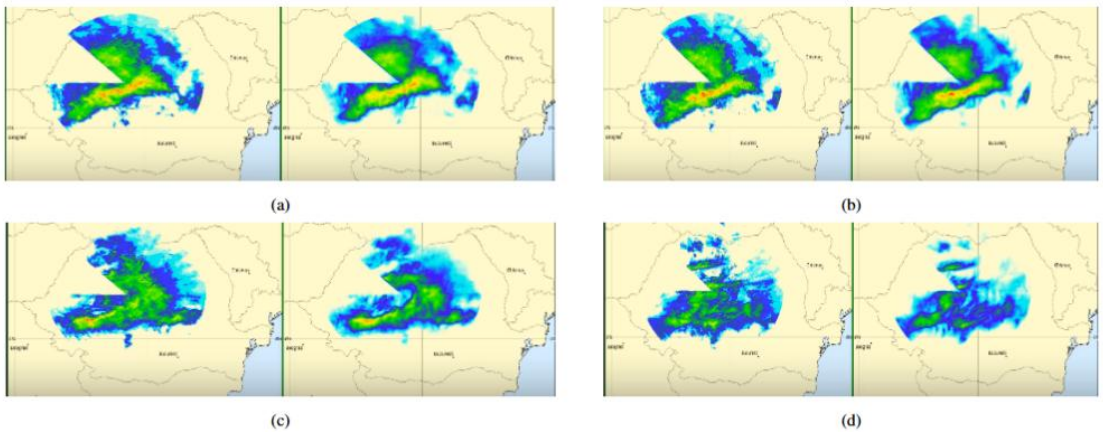


Figure 3 – WinDMiL: Radar map prediction component.

Precipitation forecasting is performed using a hybrid model that combines temporal attention mechanisms with Fourier transform operations for spatial relationships across the entire domain and convolutional local features. Figure 4 provides a comparative illustration of the radar estimates, the model forecast initialised at 17:00 UTC, and the SYNOP (Surface Synoptic Observations), for the event on the 26th of August 2026, covering the period from 17:00 to 20:00 UTC. The star marks the location of Predeal, while the colours indicate precipitation amounts in mm/3 h.

The prototype developed for the precipitation forecasting component is capable of generating hourly forecasts for Romania and of supporting the interpretation of precipitation patterns and weather types. The system is currently in pre-production, with better performance during the first few forecast hours and limitations in predicting intense precipitation at longer lead times.

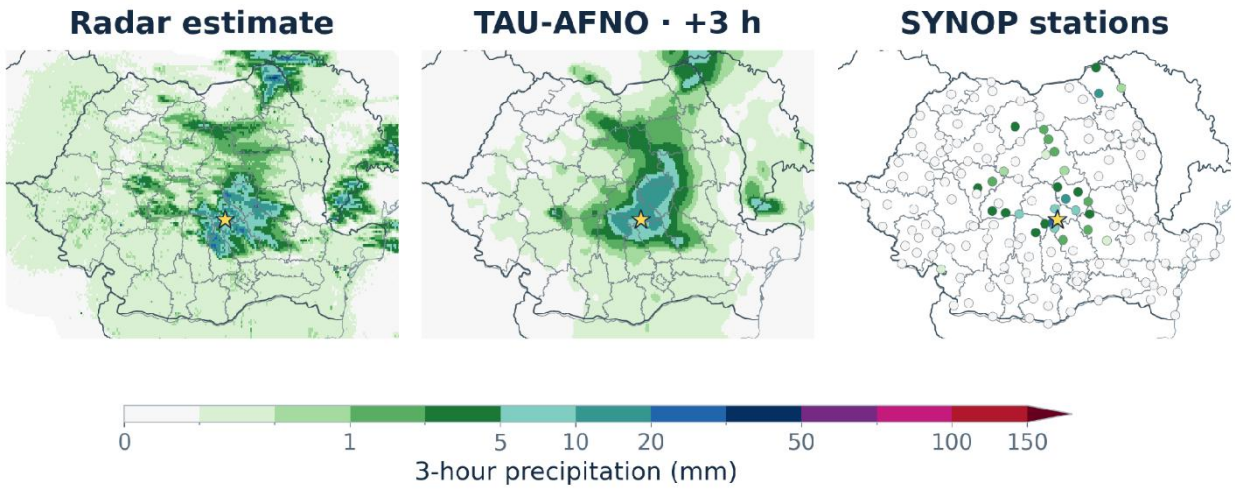


Figure 4 – WinDMiL: Precipitation forecasting component. This figure illustrates the event on the 26th of August 2026, 17-20 UTC. From left to right: radar estimate, forecast produced by the hybrid model (TAU-AFNO) initialised at 17:00 UTC, and SYNOP observations. The star marks the location of Predeal. The colours indicate precipitation amounts in mm/3 h.