



Decision support software for weather forecast powered by machine learning, data fusion and data mining techniques applied on remote sensing data

Scientific and technical report 2025

- SUMMARY -

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CONTRACT: 13PED/2025

2025

PHASE SUMMARY

According to the World Meteorological Organisation, many natural disasters that cause damage and loss of life are due to weather, and especially severe weather. Most of the meteorological decision-making processes rely to a great extent, at least at the national level, on the experience of operative meteorologists, but due to the chaotic character of the atmosphere, effectively and accurately analyzing a large volume of meteorological data is a difficult task for meteorologists. WinDMiL project aims to contribute to improving meteorological decision support at the national level in terms of faster decision times and higher precision, providing a working prototype of a software solution for remote sensing data mining and assisting decision-making processes in meteorology. The direct beneficiary of WinDMiL is the Romanian National Meteorological Administration. WinDMiL will integrate data mining methods for fast and precise remote sensing data analysis, machine learning methods for weather forecast and a component for visualizing the results of the mining, easily readable for meteorologists and aimed to facilitate meteorological decision-making.

The main objective of the project is to improve the meteorological decision-making processes by use of data mining (DM) techniques applied on remote sensing data, with a specific target on combining radar and satellite data. The focus is on providing meteorologists relevant information from past similar situations and assisting them in various decision-making tasks (e.g., predicting the areas affected by severe meteorological phenomena, precipitation and hail forecasting, short term quantitative precipitation forecast) and for various climatological analysis. The project's main goal is to create the WinDMiL data mining software for assisting operational meteorologists in their daily tasks by offering them easily readable visualizations of the mining results

The estimated results of the project are: (1) scientific and technical reports containing the original data mining methods developed for meteorological data analysis; (2) scientific publications for disseminating the obtained scientific results; (3) software modules (included in the WinDMiL system) implementing the developed machine learning models for developed for meteorological data mining.

The current report presents the original results obtained during the research carried out within the WinDMiL project for achieving the scientific and technical objectives proposed in the project plan for 2025. The report highlights the current status of the project implementation, the way in which the activities undertaken in the work plan were carried out and how the results obtained in the current project phase (2025) were disseminated. To summarize, the results obtained within the WinDMiL project in 2025 are:

- The architecture and design of the WinDMiL system.
- Software module for data acquisition and storage.
- Project website (<https://www.cs.ubbcluj.ro/windmil/>).
- 4 published papers and 1 publication under review at a Web of Science (WoS) indexed journal, Q2 quartile; 1 paper in a WoS indexed journal, Q4 quartile; 1 paper accepted for publication in a Scopus journal, indexed in WoS - CPCI; 1 paper published in the proceedings of a WoS indexed international conference (B-ranked according to CORE classification); 1 paper accepted for publication in the proceedings of a WoS indexed international conference (B-ranked according to CORE classification).

The project objectives for 2025 have been achieved, as highlighted by the annual report for 2025. The planned objectives, together with the related activities have been totally fulfilled and carried out according to the project implementation plan. The minimum performance criteria regarding the results dissemination for 2025 (one paper accepted for publication in a journal/conference) has been accomplished.

1. INTRODUCTION

1.1 WINDMiL PROJECT

The WinDMiL project aims to contribute to the improvement of decision-making processes in meteorology, as well as to provide a functional prototype of a software system for the analysis of meteorological data and the support of meteorological decision-making. The direct beneficiary of WinDMiL is the National Meteorological Administration (ANM) of Romania. WinDMiL will integrate methods for extracting knowledge from remote-sensing and reanalysis data for their rapid and accurate analysis, machine-learning methods for weather forecasting, and a component for visualizing the results in a way that is easy for meteorologists to interpret, intended to facilitate meteorological decision-making.

1.2 SCIENTIFIC AND TECHNICAL OBJECTIVES

The main objective of the project is to improve the decision-making process in meteorology by using machine learning techniques and knowledge discovery from meteorological data (remote sensing, reanalysis), with a specific focus on combining reanalysis data with radar data and satellite imagery. The goal is to provide meteorologists with relevant information from similar past situations and to assist them in decision-making (for example, predicting areas affected by severe weather events, forecasting precipitation and hail, short-term quantitative precipitation forecasting) as well as in conducting climatological analyses. The WinDMiL software system envisioned in the project will assist operational meteorologists in their daily tasks by providing them with relevant visualizations of the DM techniques' results. This project is applied and interdisciplinary, having two main scientific and technical objectives:

O1. Development and scientific validation of new DM techniques specially designed for remote sensing data analysis, with a specific emphasis on radar and satellite data fusion. Following our previous scientific results in the UL based analysis of meteorological data as in DL-based weather nowcasting, methods such as deep k-nearest neighbor (kNN), deep CBR and deep convolutional AEs and deep recurrent encoder-decoder architectures specially tailored for remote sensing data will be targeted as DL models for components of the WinDMiL software.

O2. Development and user evaluation of the WinDMiL system for descriptive and predictive DM and for graphical visualization of the mining results. This objective will be achieved using the methods developed as part of O1 and is expected to support meteorological decision-making.

O3. Contribution to the development of scientific knowledge by disseminating the obtained theoretical and applicative scientific results through scientific publications.

2 DISSEMINATION

2.1 PROJECT WEBSITE

The project website is dedicated to the presentation of the project, the research team and the results obtained. Two versions of the website can be accessed: one in English (<https://www.cs.ubbcluj.ro/windmil/>) and one in Romanian (<https://www.cs.ubbcluj.ro/windmil/ro/>).

The website is organized into several sections, and each of them can be visited at any moment using the tab navigation at the upper right corner of the pages. First, there is the main page with a brief overview of the project (**About/Despre** – Figura 1). Following that, information regarding the project plan (**Project Plan/Planul Proiectului** page) and the project team (**Project Team/Echipa** page) is provided. The Dissemination section (**Dissemination/Diseminare**) is divided into three pages: one for project publications (**Publications/Publicații**), another for the annual scientific and technical reports (**Annual Reports/Rapoarte Anuale**), and a third for conference presentation files and video clips (**Presentations/Prezentări**). The project coordinator's contact information is also available on the **Contact** page.

The main page of the website (**About/Despre**) includes a brief summary of the project and its objectives, whilst the **Project Plan/Planul Proiectului** page lists the tasks defined within each of the five work packages of the plan. The **Project Team/Echipa** page includes academic biographies and links to Google Scholar profiles for the project team members.

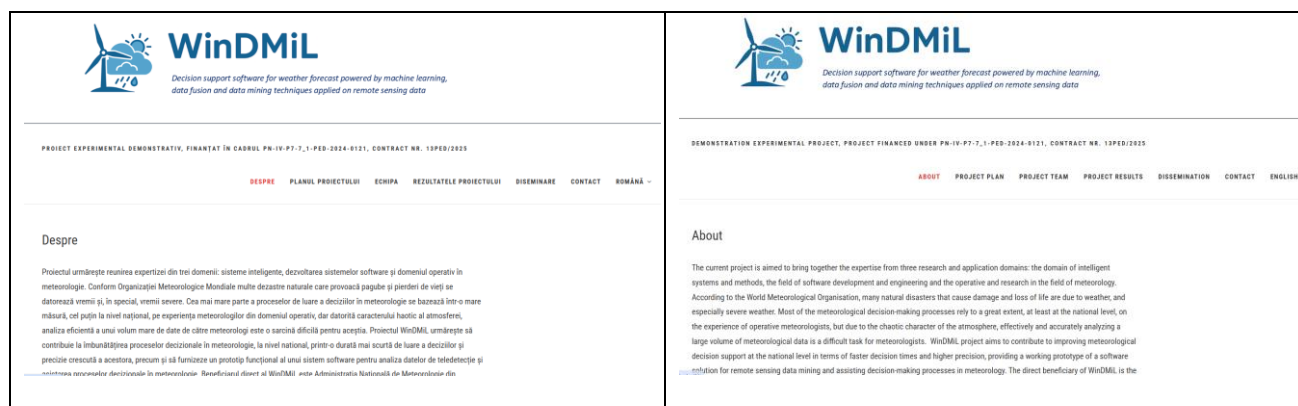


Figura 1 - Prima pagină a site-ului proiectului, versiunea în limba română (stânga) și engleză (dreapta)

The section on **Dissemination/Diseminare** is divided into three pages: (1) **Publications/Publicații**, which contains a list of project publications and a list of related publications, both up to date and the first continuously updated to include the latest works published within the project; (2) **Annual Reports/Rapoarte Anuale**, which will contain the summaries of all annual scientific and technical reports; and (3) **Presentations/Prezentări**, which contains conference presentation files and video clips that can be viewed and, in the case of presentation files, downloaded.

2.2 SCIENTIFIC PUBLICATIONS AND PRESENTATIONS

Tables 1 and 2 present the list of scientific publications and presentations obtained within the first phase (2025) of the WinDMiL project.

[L1]	Orășan Paul-Dumitru, Albu Alexandra-Ioana, Czibula Gabriela, <i>Diff-SySC: An approach using diffusion models for semi-supervised image classification</i> , International Conference on Agents and Artificial Intelligence (ICAART 2025) 2025, pp. 132-139 (B-ranked according to CORE classification, indexed WoS)
[L2]	Eugen Mihuleț, Gabriela Czibula, Ștefan Alexandrescu, Ana-Maria Mardaloescu, Alexandra-Ioana Albu, Mariana-Ioana Maier, <i>Using deep learning for enhancing the performance of ground-based cloud images classification</i> , Studies in Informatics and Control, 34(1) 123-134, March 2025 (WoS journal, Q4)
[L3]	Orășan Paul-Dumitru, Czibula Gabriela, Albu Alexandra-Ioana, <i>Using diffusion models for enhancing the performance of semi-supervised image classifiers</i> , Lecture notes in Artificial Intelligence, 2025, in press (WoS - Clarivate Analytics, Conference Proceedings Citation Index)

[L4]	Sîrbu Alexandru-Gabriel, Gabriela Czibula, <i>Code-ASG: An approach for extracting code embeddings from Abstract Syntax Graphs</i> , 31th International Conference on Cooperative Information Systems, CoopIS 2025, in press (B-ranked according to CORE classification, indexed WoS)
[L5]	Gabriela Czibula, Ștefan Alexandrescu, Alexandra-Ioana Albu, Eugen Mihuleț, <i>An in-depth study on using vision transformer-based models for classification of cloud images</i> , IEEE Access, 2025, submitted (WoS journal, Q2)

Table 1 - List of scientific publications obtained within the first phase of the WinDMiL project

Eugen Mihuleț, <i>Weather-data driven models for regional energy forecasting: integrating photovoltaic production, consumption patterns, and climate change projections</i> , 5th Workshop on Applied Deep Learning, WeADL 2025, June 6, 2025 [link]
Raluca Ștefan, <i>The Accumulation of MTG LI Level 2 Products</i> , 5th Workshop on Applied Deep Learning, WeADL 2025, June 6, 2025 [link]
Claudiu Adam, <i>Adapting COALITON-4 Nowcasting ML model to the NMA's operational context</i> , WeADL 2025, June 6, 2025 [link]
Alexandrescu Ștefan, <i>A study on using generative deep learning architectures for classification of ground-based cloud images</i> , 5th Workshop on Applied Deep Learning, WeADL 2025, June 6, 2025 [link]
Sîrbu Alexandru-Gabriel, <i>Code-ASG: An approach for extracting code embeddings from Abstract Syntax Graphs</i> , 31th International Conference on Cooperative Information Systems, CoopIS 2025 [link]

Table 2 - List of presentations within the first phase of the WinDMiL project

3 CONCLUSIONS

This report presented the original results obtained from the research carried out within the project in order to meet the scientific and technical objectives proposed in the implementation plan for 2025 (Phase 1). For each partner (UBB and ANM) we indicated the way in which the activities from the project plan were accomplished. We summarize the results obtained within the project for 2025 as follows: (1) the architecture and design of the WinDMiL system; (2) software module for data acquisition and storage; (3) project website (<https://www.cs.ubbcluj.ro/windmil/>); and (4) scientific articles through which the original results obtained in Phase 1 of the project implementation were disseminated.

The dissemination of the results obtained within the project in 2027 was achieved by 4 published papers and 1 publication under review at a Web of Science (WoS) indexed journal, Q2 quartile: 1 paper in a WoS indexed journal, Q4 quartile; 1 paper accepted for publication in a Scopus journal, indexed in WoS - CPCI; 1 paper published in the proceedings of a WoS indexed international conference (B-ranked according to CORE classification); 1 paper accepted for publication in the proceedings of a WoS indexed international conference (B-ranked according to CORE classification).

As a result, the minimum performance criteria provided (at least one paper published in a journal/conference) was met. Furthermore, the project objectives for 2025 have been met, and all associated activities have been completed and carried out in accordance with the project implementation plan.