Numerical Weather Prediction activities at DGM

6th All Staff Workshop, 13-17 April 2026, Marrakech

NWP Team, Casablanca, Morocco

HPC System : AMTAR (A peak performance of **1.069 Petaflops)**

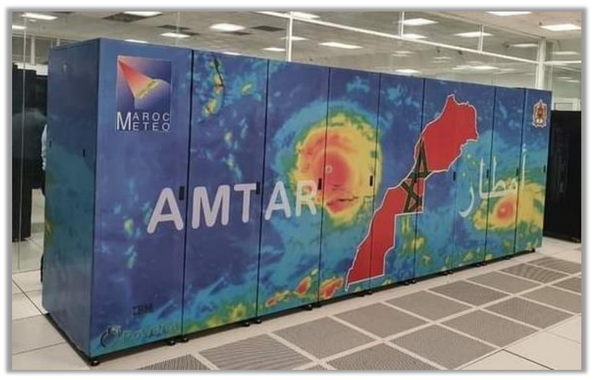
- 120 "LENOVO SR850" Computing Nodes: 11 520 physical cores, 46 TB of RAM
- 8 "LENOVO SR630" services Nodes
- 24 Mellanox Infiniband Switches **EDR 100 Gb/s**
- 8 GbE Management Switches
- 4 10GbE Network Switches
- 2 24-Port 16 Gb/s SAN Switches

Storage Systems :

- IBM Storwize V5000 : 200 TB.
- IBM V7000 : 205 TB ALL Flash, 315 TB NL SAS

IBM ESS Elastic Storage System :

- One management Node
- Two Protocol Nodes
- Two Data Servers
- Six Disk Enclosures
- Net Capacity : 7 PB



Operational configurations based on AROME

	AROME2.5	AROME1.3	PEMAROC
Horizontal resolution	2.5km (1000x1000)	1.3km (1800x1800)	2.5km (1000x1000)
Vertical levels	90	90	90
LBCs, Frequence	Arpège, IFS 1h	Arpège, IFS 1h	IFS ENS, 16 members 3h
Forecast range	102h, 90h	102h, 90h	144h
Model version	cy46t1, cy48t1_op1	cy46t1, cy48t3	cy48t1_op1
Starting times	00, 12 UTC	00, 12 UTC	00 UTC

AROME 3DVAR

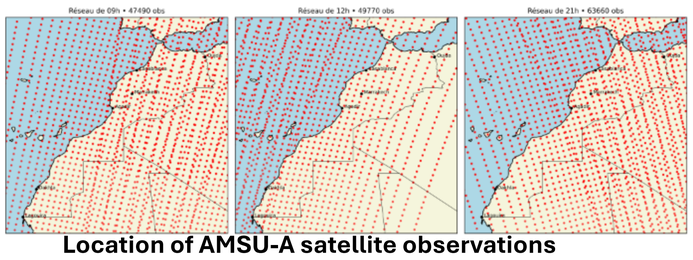
- 3DVAR for upper air analysis
- OI-MAIN for surface
- Ensemble B matrix
- SYNOP (manual and automatic), TEMP and AMDAR
- Cycle 43t1
- 1h coupling frequency
- LBCs from ARPEGE
- Production at 00 UTC and 12 UTC

PEMAROC Ensemble Prediction System

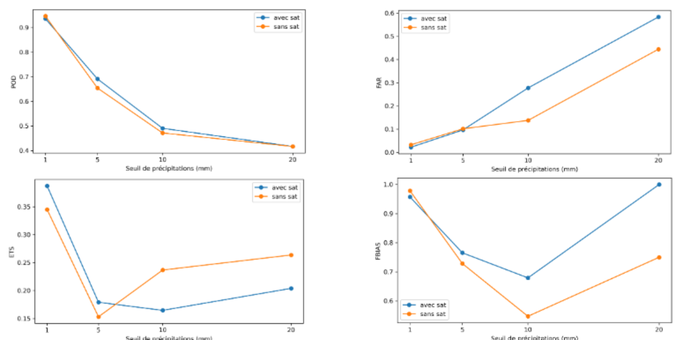
- Based on AROME 2.5 km horizontal resolution and 90 vertical levels
- 16 perturbed members
- 1 run/day (00 UTC) up to 144h, post processing every hour
- LBCs : subset of IFS-ENS members, 3h coupling frequency
- Initial states : A mix from AROME 3D-Var analysis and ARPEGE Initial file downscaling
- Perturbation method : SPPT scheme + RPP (Random Perturbation Parameters) approach

Satellite Data Assimilation in the AROME-MAROC NWP Model

This study aims to evaluate the impact of assimilating AMSU-A satellite radiances from NOAA polar satellites and MetOp into the AROME-MAROC numerical weather prediction model.
Two configurations were compared for the period from March 8 to 27, 2025: a reference configuration using only conventional observations (SYNOP, TEMP, AIREP), and an enhanced configuration also incorporating AMSU-A microwave radiances.
Data assimilation was performed using the 3D-Var variational method, including a rigorous quality control procedure and adaptive bias correction via the VarBC scheme. The Degrees of Freedom for Signal (DFS) diagnostics were analyzed to quantify the informational contribution of each type of observation, while forecast performance was evaluated using the HARP verification system, comparing forecasts to surface and upper-air observations. The results highlight a moderate reduction in bias during satellite data assimilation, without a significant improvement in RMSE. An improvement is observed in the detection of low to moderate precipitation events, as indicated by the categorical scores (POD, ETS), although this improvement is accompanied by an increase in the false alarm rate (FAR) for higher precipitation thresholds.



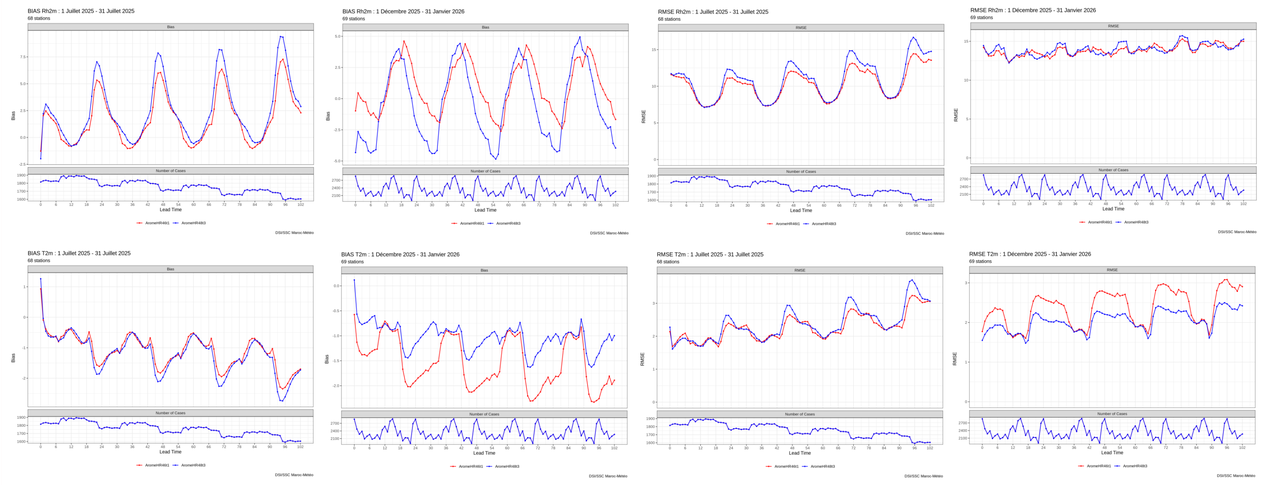
Location of AMSU-A satellite observations



Categorical scores by 24-hour precipitation accumulation threshold: POD (top left), FAR (top right), FBIAS (bottom left), and ETS (bottom right) for experiments with and without assimilation of satellite data for the period from March 8 to March 27, 2025

Cycle installation and Model Quality Assessment:

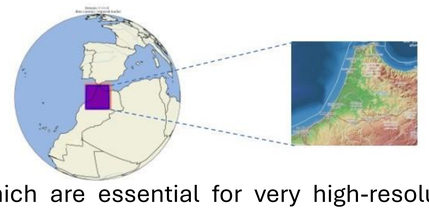
- Both cy48t3 and cy48t1_op1 are installed on our AMTAR HPC
- Simple precision is used in all our running codes (46t1, 48t3 and 48t1_op1) (approximately 30% improvement in execution time for arome model)
- An arome1.3 esuite using cy48t3 is running since 1st Decembre 2025
- An arome2,5 esuite using cy48t1_op1 is running since 1st January 2026
- Our ensemble suite PEMAROC use as code cy48t1_op1 where SPPT and RPP schemes are activated
- Verification against SYNOP, between cy46t1 and cy48t3, was conducted using arome1.3km for two periods (a summer period from 1st to 31th July 2025, and a winter period from 1st December 2025 to 31th January 2026)
- BIAS and RMSE scores against SYNOP for T2m and RH2m, for those two periods, are presented below :

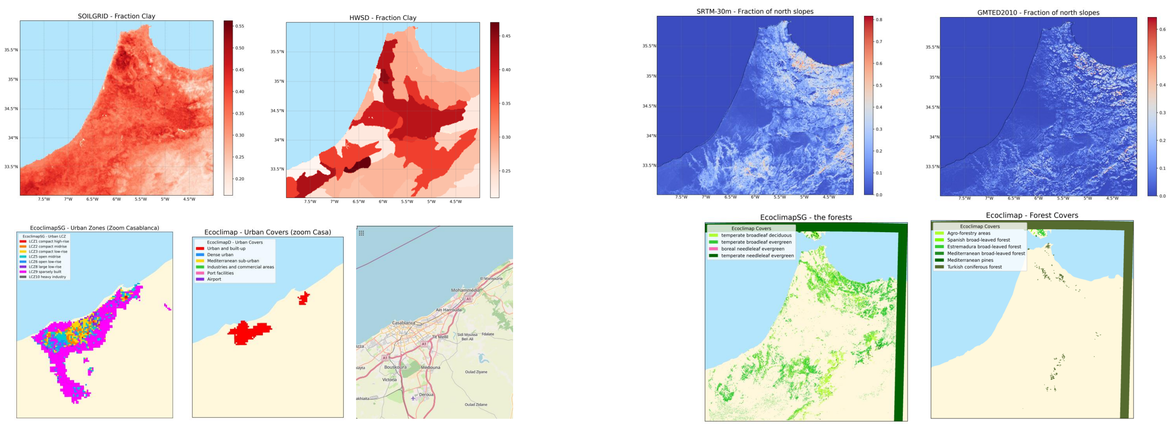


Surface parameter scores (Bias and RMSE) for RH2m (top) and T2m (bottom) for AROME1,3 cy46t1 (in red) and cy48t3 (in blue) over a summer period and a winter period

Impact of physiographic data and orography truncation on AROME 500m

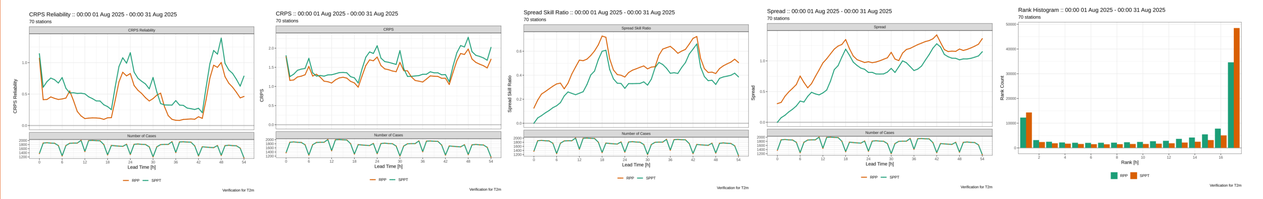
This work builds upon the development of the AROME model at very high spatial resolution in Morocco, with the implementation of AROME-500 m based on the 48t1 cycle.
The study focused on evaluating the impact of new physiographic databases (SoilGrids, SRTM-30m, and ECOCLIMAP-SG) as well as various spectral truncations applied to orography and dynamic fields. The results show that improving the description of soil, land cover, and relief allows for a more realistic representation of surface-atmosphere interactions and small-scale structures, which are essential for very high-resolution forecasting. Furthermore, the analysis of sensitivity to spectral truncations highlights a trade-off between the reproduction of fine details, numerical stability, and computational cost. This work is part of a progressive approach to improving the AROME-500 m configuration, and provides useful elements of analysis for modeling local meteorological phenomena in Morocco.





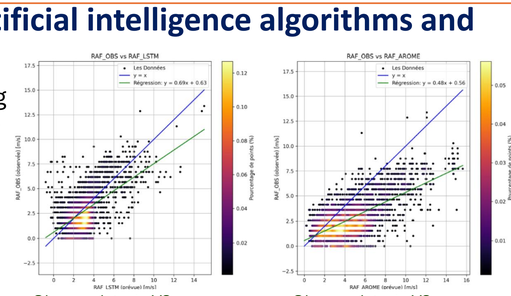
Implementation of Random Perturbation Parameters in the PEMAROC Ensemble Forecasting System

In ensemble weather forecasting systems, accurate representation of modeling errors is essential to improve forecast quality. Currently, uncertainty is managed operationally using the SPPT scheme, which adds random perturbations to tendencies derived from physical parameterizations. To overcome the limitations of SPPT, a new approach called RPP (Random Perturbation Parameters) has been developed, adding perturbations to uncertain model parameters. Unlike SPPT, which acts on global physical tendencies, RPP applies perturbations directly within the parameterization schemes, making it a more physically consistent and interpretable approach. This new approach, combined with SPPT, was tested in PEMAROC. Evaluations and scores were done over August 2025. This combination (RPP+SPPT) significantly improves forecast performance on weather variables such as 2m temperature, 2m relative humidity and 10m wind. The impact is also noticeable on some convective cases.



Wind gust forecasting in Morocco by integrating artificial intelligence algorithms and the AROME model.

Wind gusts can cause significant damage, making their forecasting essential for meteorological services. The AROME model, used for high-resolution forecasts, has limitations in predicting gusts.
A study was conducted exploring the integration of machine Learning (ML) algorithms with AROME model outputs to align forecasts with observed gusts. Five ML algorithms were tested: Random Forest, Extreme Gradient Boosting, Gradient Boosting, Artificial Neural Network, and Long Short-Term Memory (LSTM).
Data from 27 synoptic stations, covering 2016 to 2024, were used to develop and validate the models.
The results show that the LSTM model performed significantly better, predicting gusts with greater accuracy.



Observed gusts VS gusts corrected by LSTM

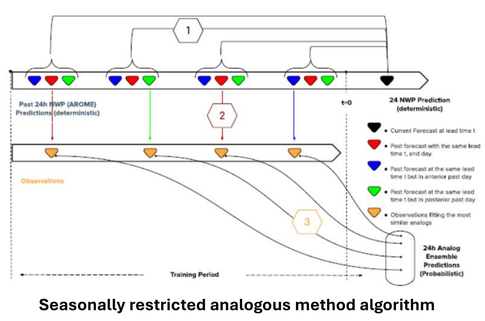
Observed gusts VS gusts predicted by AROME

Integrated water vapor as a diagnostic tool for fog detection and classification

Fog significantly affects transport safety and aviation. Traditional detection methods rely on visibility sensors and satellite observations, but relative humidity is not effective since it saturates just before fog forms. This study investigates using Integrated Water Vapor (IWV) from GPS as an alternative for fog detection. Analyzing six years of data from Nouasseur, Morocco, the study finds distinct IWV patterns during different fog types, with sharp decreases at fog onset and increases during dissipation. Seasonal analysis shows higher fog occurrences in winter and autumn. Decision tree classifications based on IWV yield accuracies of 66.7% for no fog and 63.9% for fog, indicating potential for operational forecasting, although detailed classifications require multi-variable approaches. Overall, GPS-derived IWV offers valuable insights into fog dynamics, enhancing detection algorithms and improving safety in fog-prone areas.

Leveraging Artificial Intelligence to improve local ensemble forecasting of reduced visibility conditions over Morocco using Ensemble Analog Method

This study focuses on improving forecasts of surface weather and low-visibility conditions, which are important for transportation safety and socio-economic activities.
Because traditional deterministic forecasting methods have high uncertainty, the researchers developed an ensemble forecasting system using the analogs method (AnEn).
The system uses past forecasts from the AROME model and corresponding observations to predict conditions at major Moroccan airports (2016–2019 data).
Two key improvements were introduced:
a machine-learning-based predictor weighting approach (using linear regression, XGBoost, and random forest), and an enhanced analog search that considers nearby grid points and seasonal variations. Results show significant improvements over existing methods, reducing bias by up to 50% and RMSE by 30%. While spatial expansion generally improves performance, it depends on local geography. The system still shows some limitations, such as underestimating variability and slight positive bias for fog and haze, but overall performs well, with good probabilistic accuracy.



Seasonally restricted analogous method algorithm

Post-processing using artificial intelligence to adjust the minimum and maximum temperatures simulated by the AROME model

While NWP models are effective, they have limitations in local forecasting of daily minimum and maximum temperatures. With the increasing availability of data, artificial intelligence (AI) approaches provide a complementary solution to enhance forecast accuracy. This study focused on adjusting temperatures predicted by the AROME model at 2 meters (T2m) and the daily Tmin and Tmax values using supervised learning models (Random Forest, XGBoost) that combine model outputs and synoptic observations. After preprocessing and statistical analysis, the AI models were trained and evaluated using station-by-station cross-validation. The results indicated a significant reduction in bias and improved performance (RMSE) at several sites, highlighting the effectiveness of these methods for locally correcting forecasts.