

Overview

The Royal Meteorological Institute of Belgium (RMI) operates a **seamless nowcasting and forecasting** infrastructure that integrates radar, surface observations, satellite data and lightning detection with **convection-permitting ensemble prediction**. Deterministic **INCA-BE** analyses and probabilistic **pySTEPS-BE** nowcasts are combined with a **1.3 km ALARO-AROME mini-EPS** to provide rapidly updating forecasts from **minutes to 48 hours** ahead. The system feeds **impact-based services** including extreme-rainfall warnings, severe-weather alerts, road-weather forecasts and offshore wind-power applications. Ongoing R&D explores **AI/ML and deep-learning blending** to further improve forecast skill from **sub-hourly to sub-seasonal** time scales.

OBSERVE

Dense observation network

RADQPE radar composite, automatic weather stations, satellite, BELLS lightning network.

PREDICT

Seamless 0 – 24 h forecasting

INCA-BE & pySTEPS-BE nowcasts blended with a 1.3 km ALARO + AROME mini-EPS.

SERVE

User-tailored products

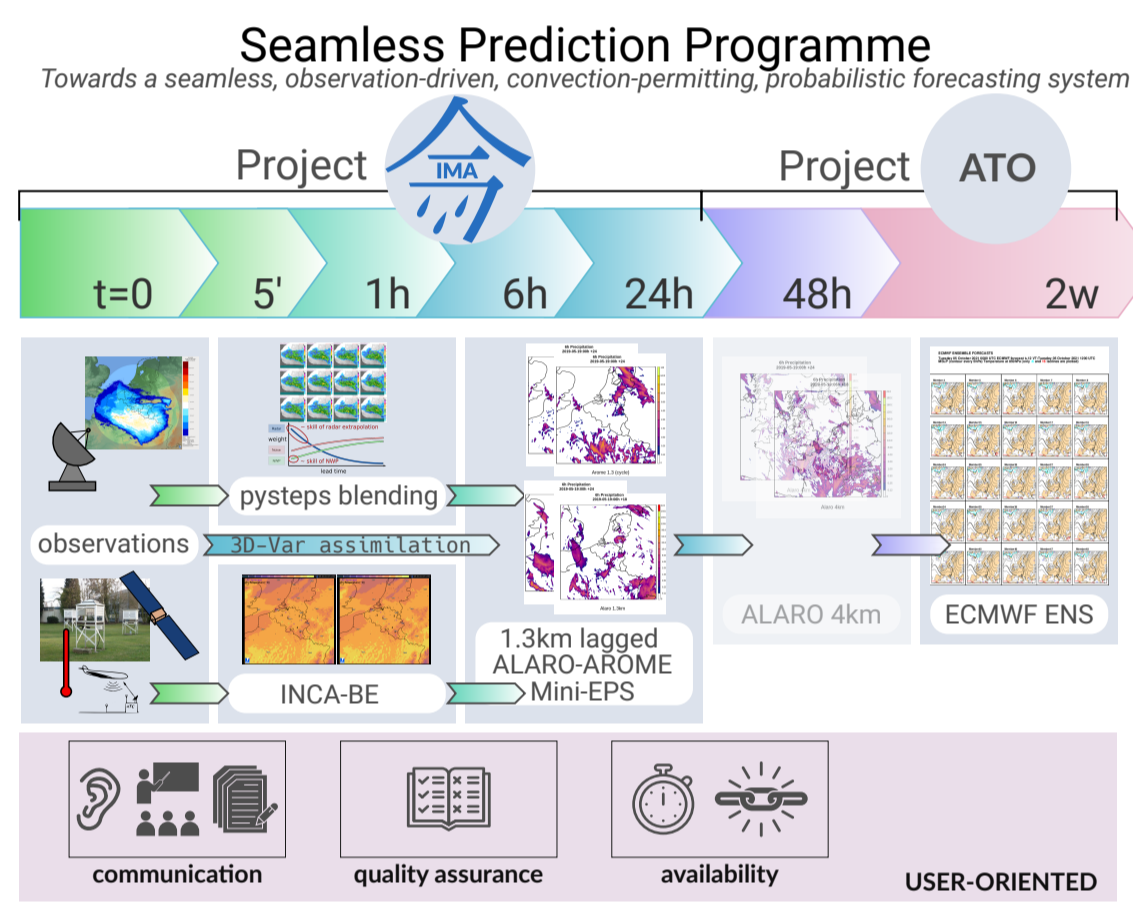
pyRainWarn, app notifications, road weather, offshore-wind power & ramping forecasts.

Systems & Applications — Technical Overview

CHARACTERISTIC	NOWCASTING & VERY SHORT-RANGE FORECASTING			DOWNSTREAM APPLICATIONS		
	INCA-BE	pySTEPS-BE	Mini-EPS (ALARO+AROME)	pyRainWarn	Storm Forecast Tool	Road-Weather
Type	Deterministic nowcast of T, RH, wind, clouds, precipitation & types	Probabilistic radar-NWP blended ensemble nowcast (24 members)	Convection-permitting lagged mini-EPS NWP (ACCORD)	Probabilistic municipal extreme-rainfall warnings	Offshore wind-power & ramping forecasts for TSO Elia	1D radiative balance physics-based road weather model
Status	Operational	Operational	Operational	Operational	Operational	Operational
Inputs	RADQPE radar, AWS, satellite, BELLS lightning	RADQPE + ALARO/AROME mini-EPS	ECMWF IFS + 3 h surface DA	pySTEPS-BE ensemble + return-level statistics	ALARO 4 km + ECMWF IFS-ENS	Road Weather Station data + INCA-BE / mini-EPS
Resolution	1 km	1 km	1.3 km, 45 s timestep	Municipal	Wind-farm location point forecasts	Road Weather Station location point forecasts
Update / range	10 min / + 4 h (precip) + 12h (other)	15 min (will become 5 min) / + 6 h	00/06/12/18 UTC / + 48 h	15 min (will become 5 min) / + 6 h	4-hourly / + 7 days	Hourly / + 24 h
Output	Deterministic gridded fields	Probabilistic ensemble fields	Lagged ensemble of NWP fields	Return-period exceedance probabilities	Probabilistic power & ramping	Surface temperature & condition, water & ice amount on the road

Project IMA · Seamless Prediction

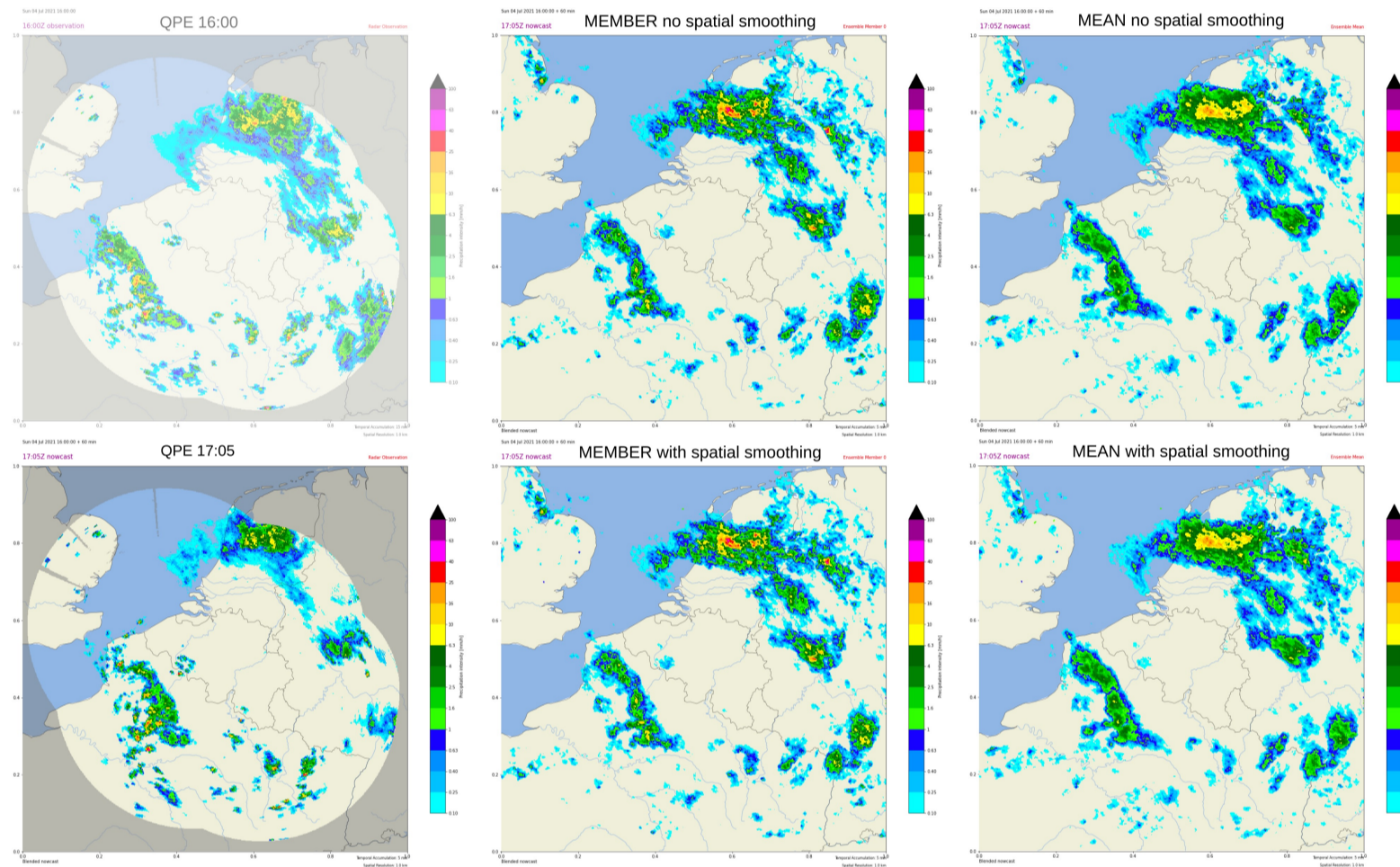
- A unified forecasting chain providing rapidly-updating, observation-driven, convection-permitting probabilistic forecasts from minutes to days ahead
- Targets hydrology, civil protection, renewable-energy sector and the public



Seamless Prediction Programme including the full forecast chain: radar nowcasts → pySTEPS blending → ECMWF ENS.

pySTEPS-BE · Probabilistic Precipitation Nowcasts

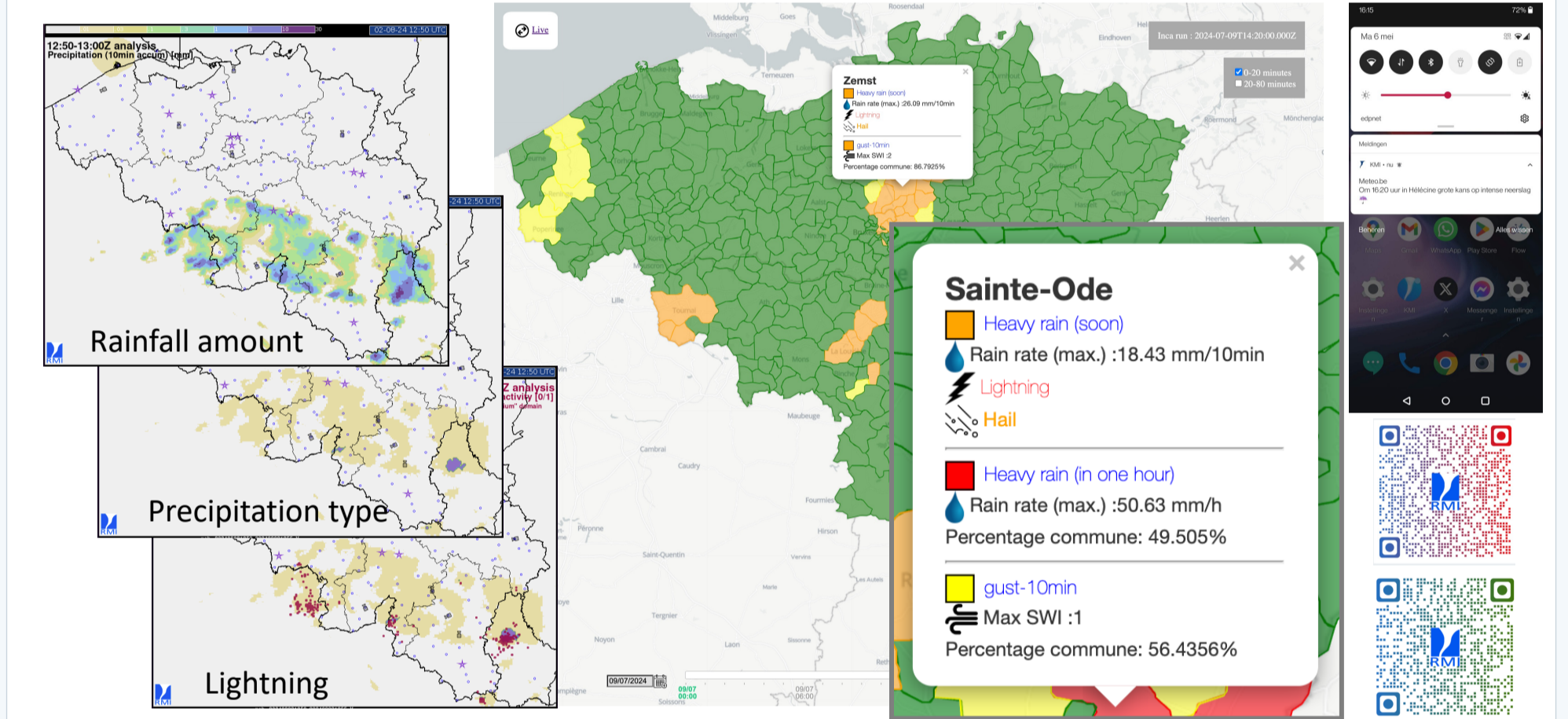
- Built on the open-source pySTEPS framework github.com/pySTEPS/pySTEPS
- 24-member ensemble at 1 km, 5 min timestep, + 6 h lead time
- Scale-dependent stochastic perturbations blended with the mini-EPS
- pySTEPS-BE developments: faster I/O, smoother radar-NWP blending, intensity-preserving postprocessing, modular plugins



pySTEPS-BE smoothing vs. non-smoothing experiments

Severe Weather Notifications in RMI app

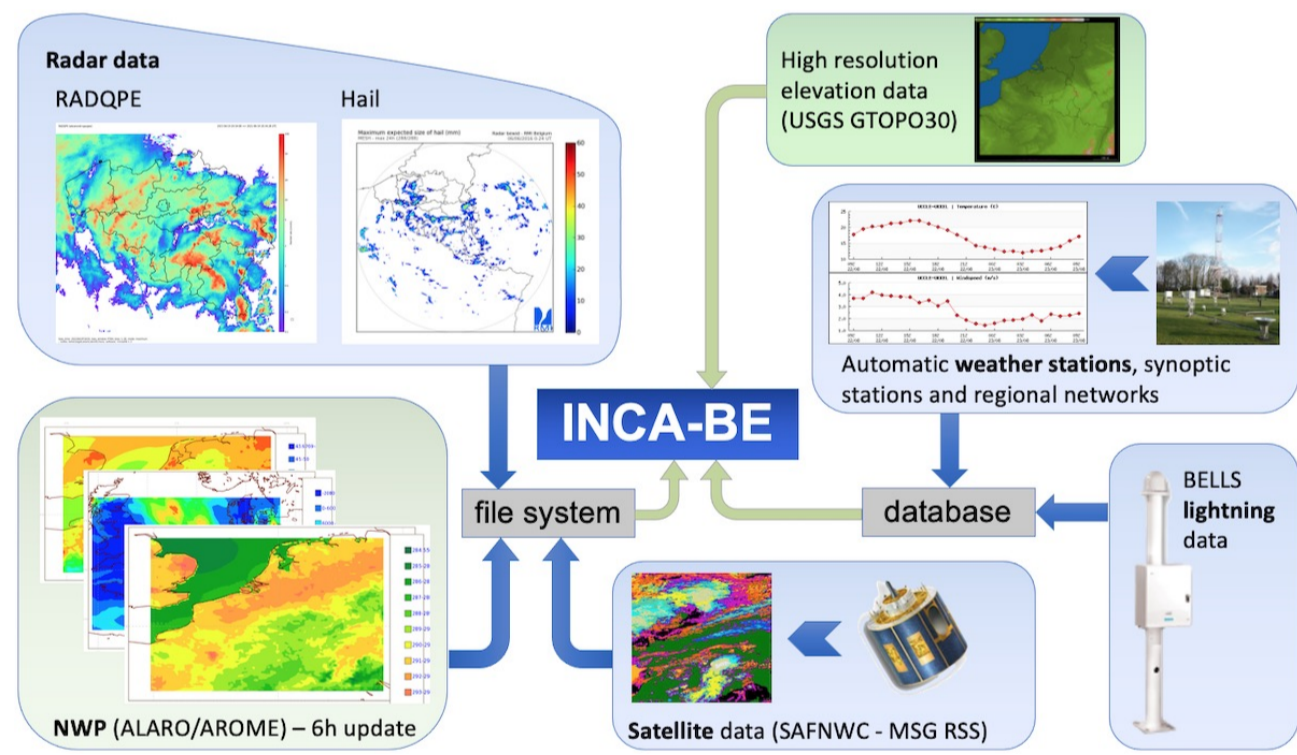
- Push notifications (“flashes”) at municipal level via the RMI weather app
- Four types: heavy rain (+ lightning / hail), snowfall, freezing precipitation, convective gusts
- Convective-gust alerts derived from radar-based severe-weather contours and rotation detection
- Near real-time (0 – 20 min) and short-term (20 – 80 min) lead times



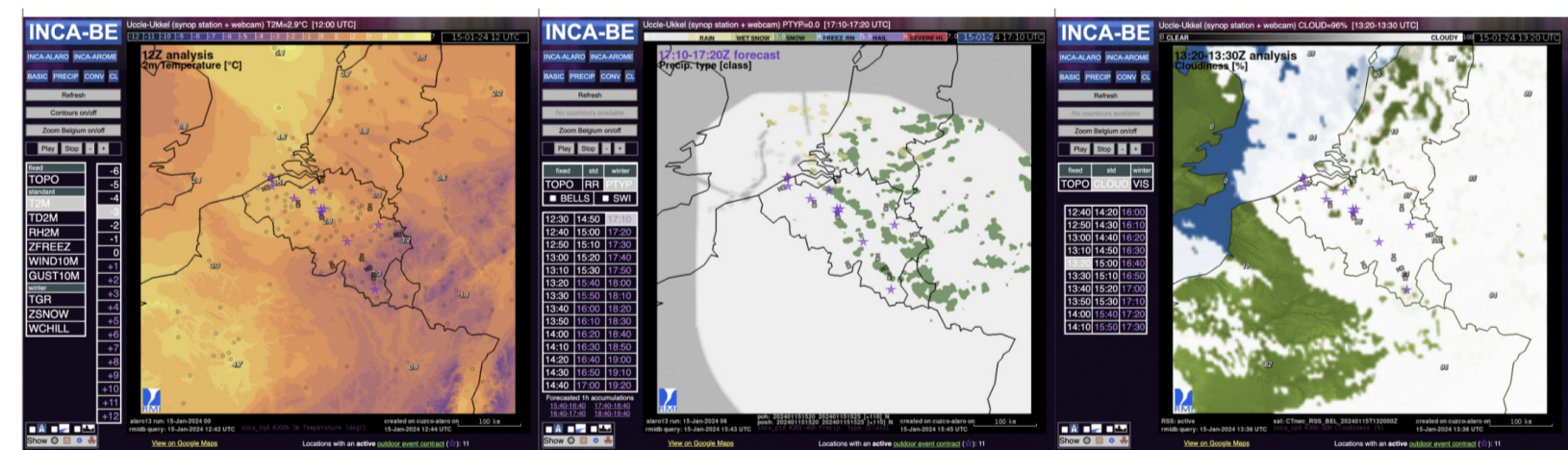
INCA-BE nowcasts → aggregation to municipalities → RMI app notifications

INCA-BE · Deterministic Nowcasts

- Operational since 2012; base code from GeoSphere Austria
- 1 km gridded fields every 10 min: T, RH, wind, clouds, precipitation, precipitation type, gusts, hail, lightning
- Two parallel versions coupled to the mini-EPS: INCA-ALARO & INCA-AROME

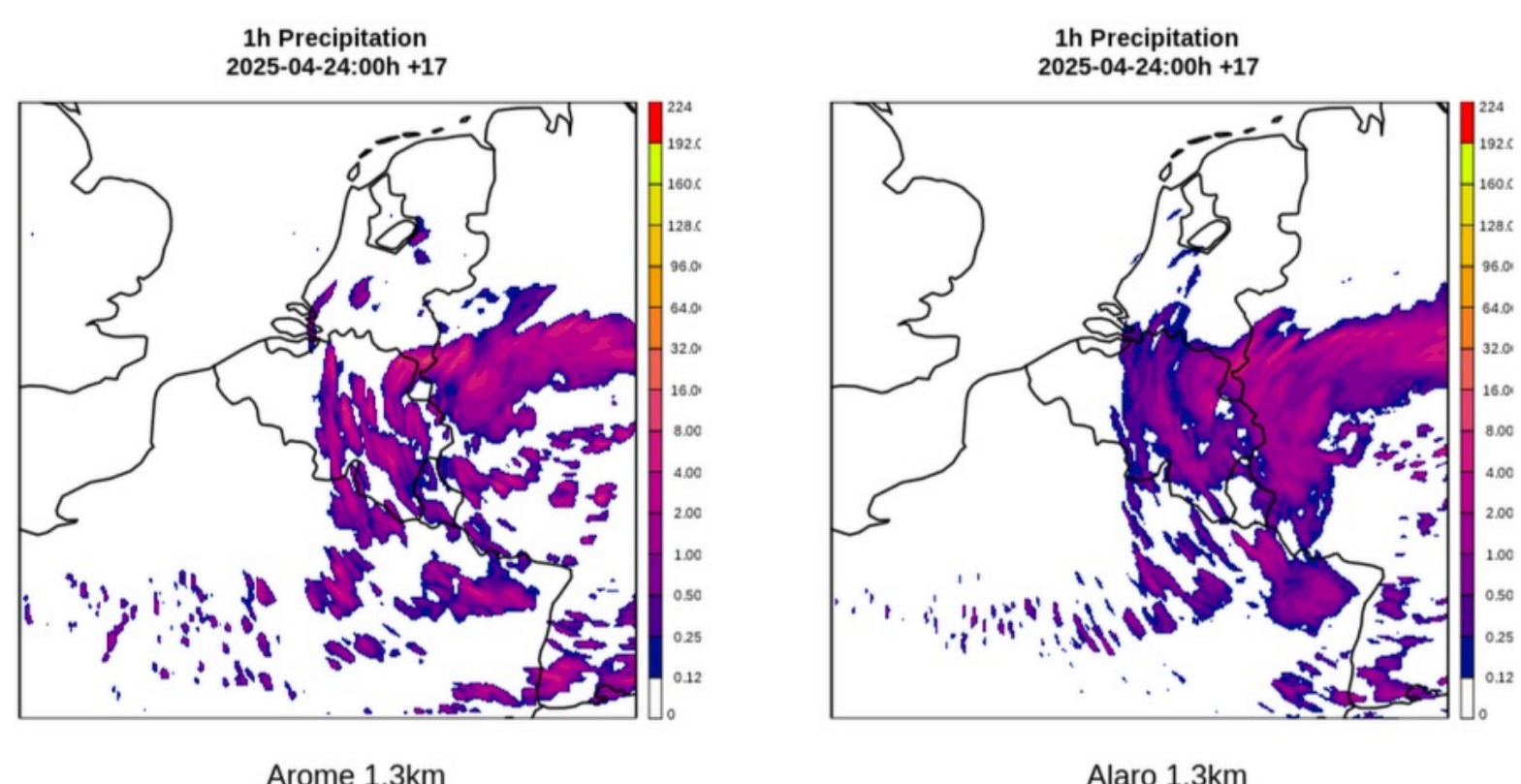


INCA-BE integrates radar QPE, AWS, satellite, lightning and high-res NWP into a unified analysis ↑ INCA-BE internal webpage ↓



Mini-EPS · ALARO + AROME at 1.3 km

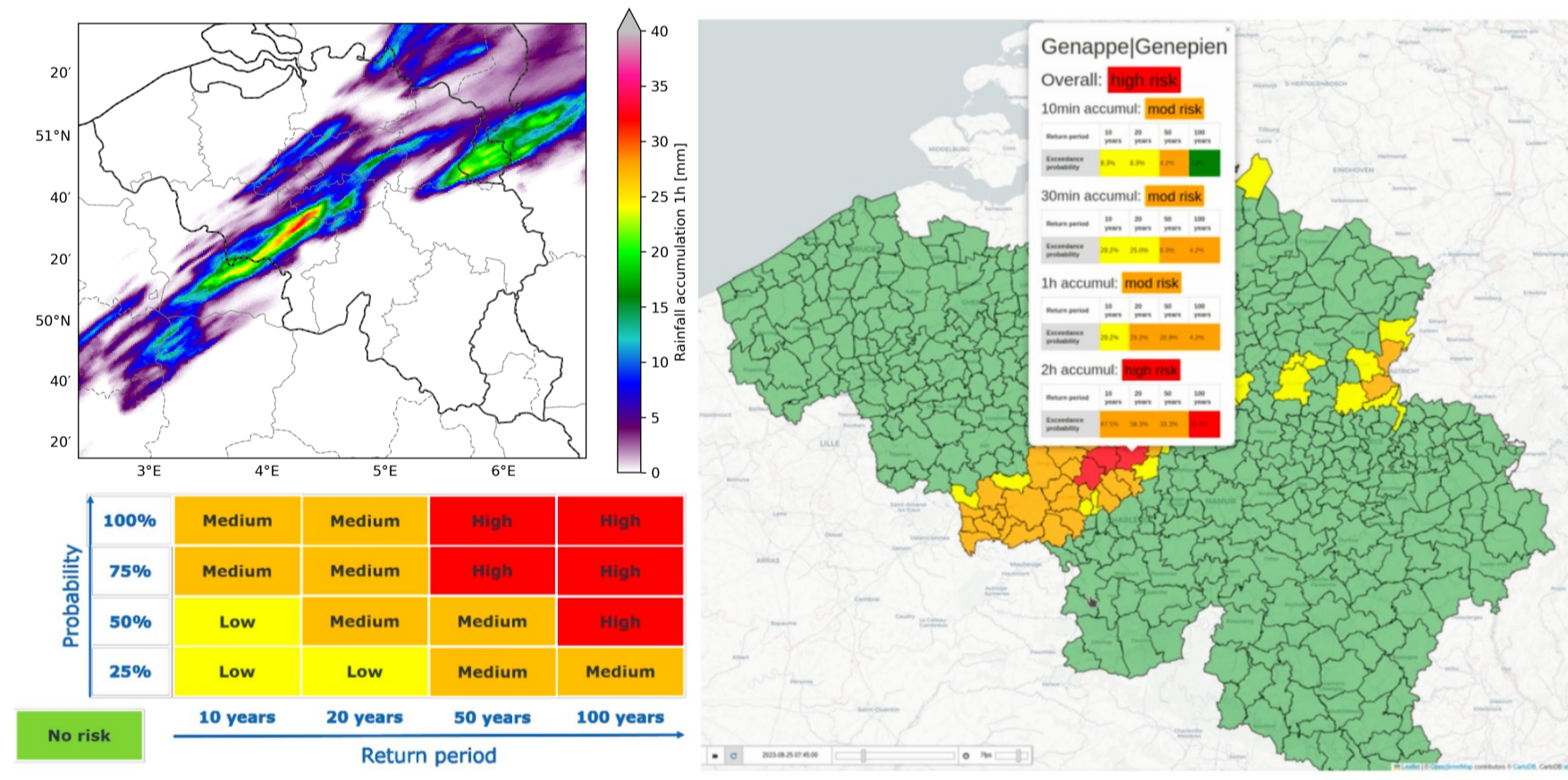
- Canonical configurations of the ACCORD NWP system, coupled to ECMWF IFS (will be replaced by ARPEGE)
- Different physics: scale-aware (ALARO) vs. resolved convection (AROME)
- 4 runs / day, + 48 h range, 3 h surface data assimilation, 45 s timestep



AROME 1.3 km vs. ALARO 1.3 km — 1 h precipitation forecast (24 April 2025, + 17 h)

pyRainWarn · Probabilistic Municipal Precipitation Alerts

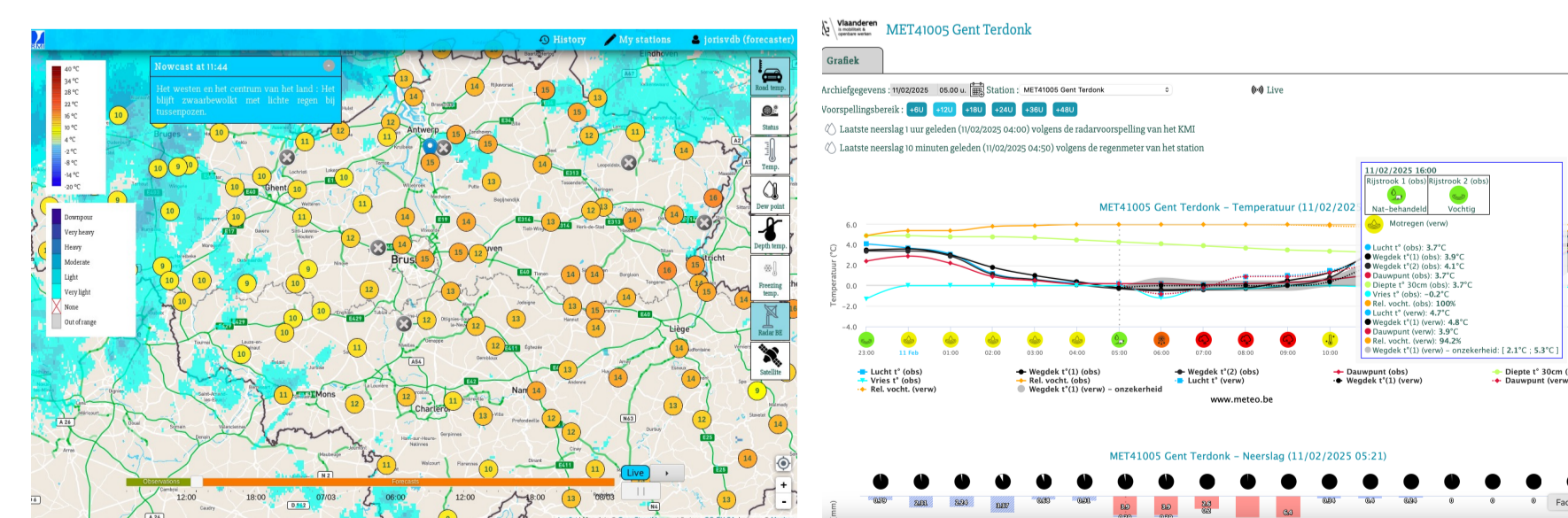
- Converts pySTEPS-BE ensembles into probabilistic municipal-level extreme rainfall warnings by aggregating 1 km pixel exceedances across ensemble members
- Assigns three warning levels (yellow/orange/red) based on exceedance probability and return period thresholds



Colour-coded municipal warnings at 07h45 UTC for 10 / 20 / 50 / 100 yr return periods; top left: 1h accumulation at 08h00 UTC

Road Weather Model (RWM)

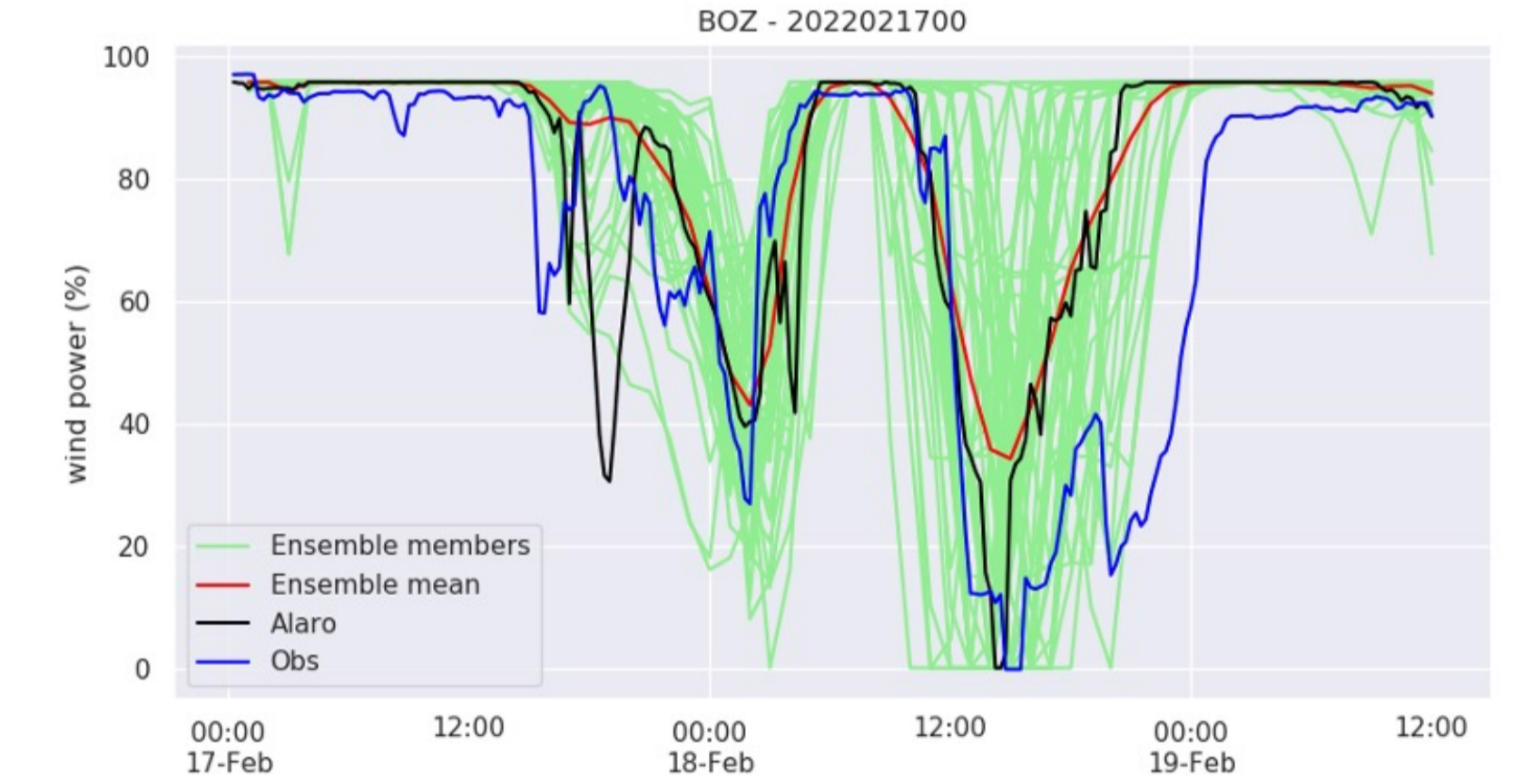
- Operational RWM over Belgium, with dynamically chosen NWP model + INCA-BE nowcast input
- Input from and output at Road Weather Stations (RWS): 55 stations in Wallonia, 100 stations in Flanders
- One RWM run per hour, assimilating the latest observations from RWS real time transmission, update every 10 min
- Visualized through GIS interface, access through login for RMI Weather Office and regional road management agencies



RMI's RWM web portal: overview map and forecast detail at an RWS location

Renewable Energy · Storm Forecast Tool

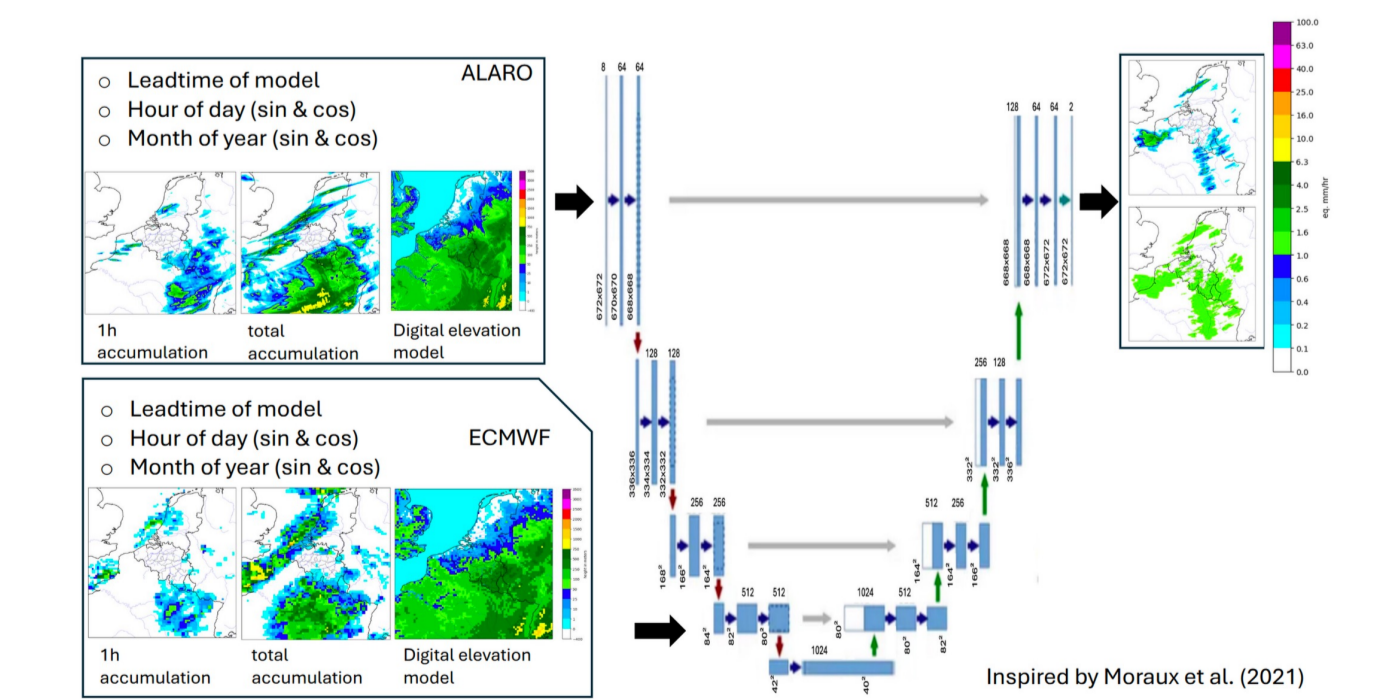
- Operational probabilistic wind-speed, wind-power & cut-out event forecasts for the Belgian Offshore Zone (BOZ)
- BOZ: 9 wind farms with 2.2 GW capacity covering ~10 % of Belgian electricity production
- ALARO 4 km combined with ECMWF IFS-ENS
- Fitch wind farm parameterisation tested in ALARO



Storm Eunice (17 - 19 Feb 2022): ensemble wind-power forecast vs. observation in the Belgian Offshore Zone (BOZ)

AI / ML & DL NWP-Blending

- BELSP0 DERISC & EXPRIMA R&D projects: deep-learning multimodal precipitation estimation, downscaling, calibration & blending
- Coupling with hydraulic & hydrological models for impact-based warnings
- U-Net blending extends lead time from + 6 h towards days-weeks ahead
- ML wind-power forecasting — BeFORECAST, InStaFlex, E-TREND, STORM



U-Net-based deep-learning blending — towards sub-seasonal lead times

Conclusions & Outlook

TODAY

RMI integrates a deterministic and a probabilistic 1 km nowcasting system with a 1.3 km lagged mini-EPS, feeding tailored products for hydrology, civil protection, road safety and renewable energy.

NEXT · OPERATIONS

Operational 3D-Var assimilation of MODE-S, AMDAR, GNSS and radar; 1-h cycling with Incremental Analysis Update; operational ALARO with the Fitch wind-farm parameterization.

NEXT · RESEARCH

Deep-learning precipitation estimation, downscaling, calibration & blending; coupling with hydraulic / hydrological models; sub-seasonal blending with U-Net.

Acknowledgements

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To know more about ...

INCA-BE: Reyniers et al. (2021), The INCA-BE system: ten years of operational nowcasting at RMI Belgium, zenodo.org/records/5798952.
pySTEPS-BE: Imhoff et al. (2023), Scale-dependent blending of ensemble rainfall nowcasts and NWP in pySTEPS, *QJRM* 149, 1335.
pyRainWarn: Erdmann et al. (2025), PyRainWarn: pySTEPS-BE ensemble nowcasts for extreme rainfall warnings in Belgium, *ECSS2025-49*.
Road Weather Model: Van den Bergh et al. (2023), The RMI Road Weather Forecasting System (No. EMS2023-334), Copernicus Meetings.
Severe weather notifications: Reyniers (2024), Radar-based convective gust warnings in the INCA-BE system, contribution ENWFC-2024.

To know more about ...

Storm forecast tool: Van den Bleeken et al. (2025), Improving wind power forecasts in the Belgian North Sea with a wind farm parameterization and a neural network, *ASR* 22, 59.
AI/ML research: Bonte et al. (2026), Spread/Error relationship and spatial error structure of precipitation ensemble nowcasting: Comparison of STEPS and generative AI, doi.org/10.5194/egusphere-2026-1460.
Hydraulic & hydrological models: Villarreal Jaime et al. (2024), Hydrological Modeling of Probabilistic Rainfall Forecasting for Impact-Based Flood Warning Systems, *ERAD2024*.