SWING: A Post-Processing Algorithm for Improved Nowcasting and Environmental Safeguard

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Abstract

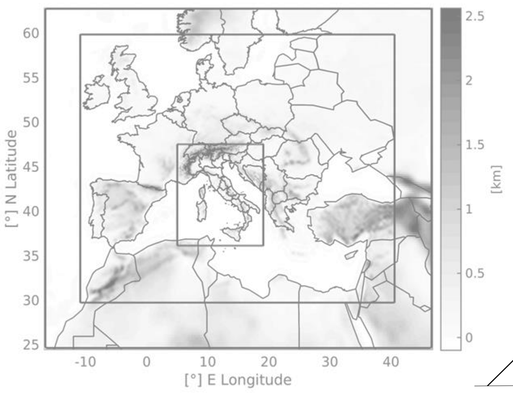
This work presents SWING (Score-Weighted Improved NowcastinG), a novel post-processing algorithm designed to improve the accuracy and reliability of very short-term rainfall forecasts (nowcasting). SWING enhances the spatial and temporal predictability of convective rainfall events by combining high-resolution numerical weather prediction (NWP) outputs from the WRF model with radar-based nowcasting from the PhaSt system. The algorithm operates by merging three forecasts over a 6-hour time window, updated every three hours, and weighing them based on recent performance. This evaluation is performed through an object-based comparison of modelled and observed rainfall fields using merged radar and rain gauge data. Each forecast is assigned a Reliability Score (RS) derived from spatial overlap, rainfall intensity, and object morphology, ensuring the final blended forecast maximizes accuracy while minimizing false alarms. SWING has been running continuously for over a year, integrating high-resolution forecasts from the WRF model—updated every three hours using 3DVAR radar reflectivity assimilation and lightning data nudging—with radar-based nowcasting from the PhaSt system through a blending technique. A seasonal-scale validation of SWING against the standalone deterministic model run has been continuously performed since the system became operational.

SWING is fully automated and capable of generating rainfall scenarios and impact-based warnings through the output of a hydrological model (Continuum). Its rapid update cycle (3-hourly) makes it particularly suitable for operational early warning contexts where expert manual intervention is not feasible.

This research is conducted within the PNRR RAISE initiative - Spoke 3, which develops innovative technologies for environmental safeguard in water, air, and soil domains over the Ligurian region.

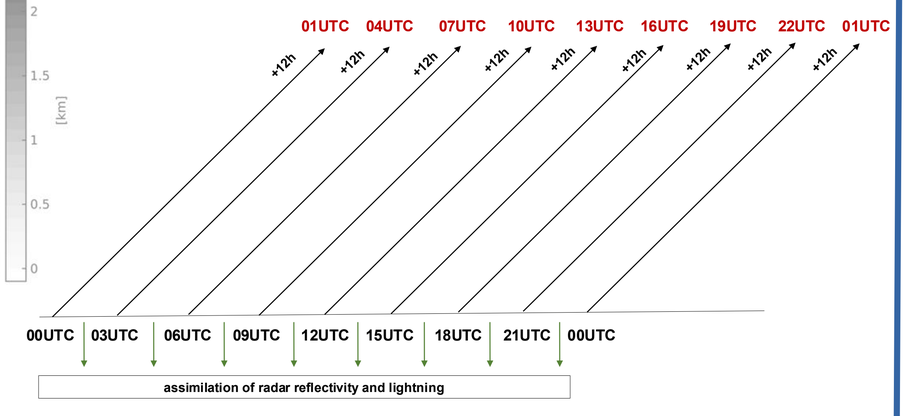
WRF-DA domains (@CIMA)

3 nested domains: 22.5, 7.5, and 2.5 km. 50 vertical levels. Initialized with GFS data.



RUC (Rapid Update Cycle) WRF nowcasting

Rapid Update Cycle (RUC) scheme with 8 runs per day up to +12h: assimilation of radar data (reflectivity) and lightning from the LAMPINET network

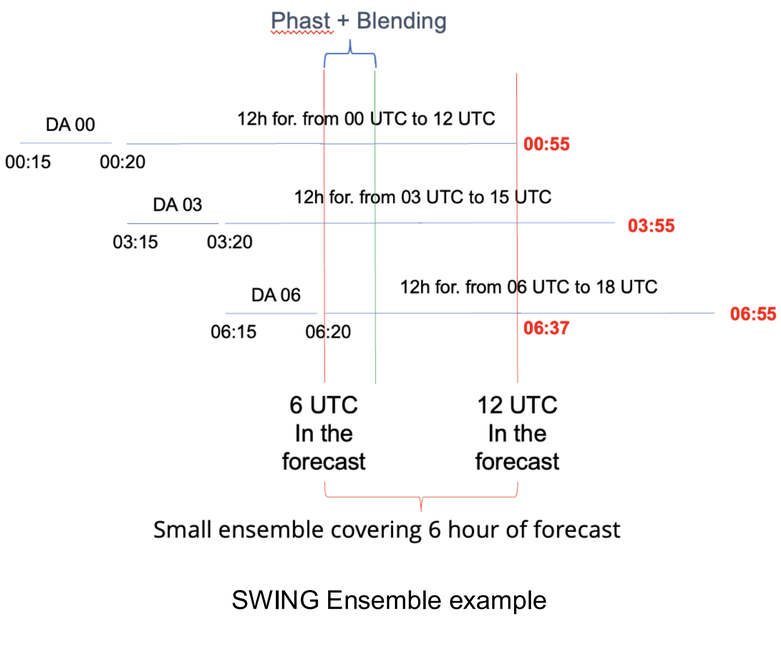


Swing in a nutshell

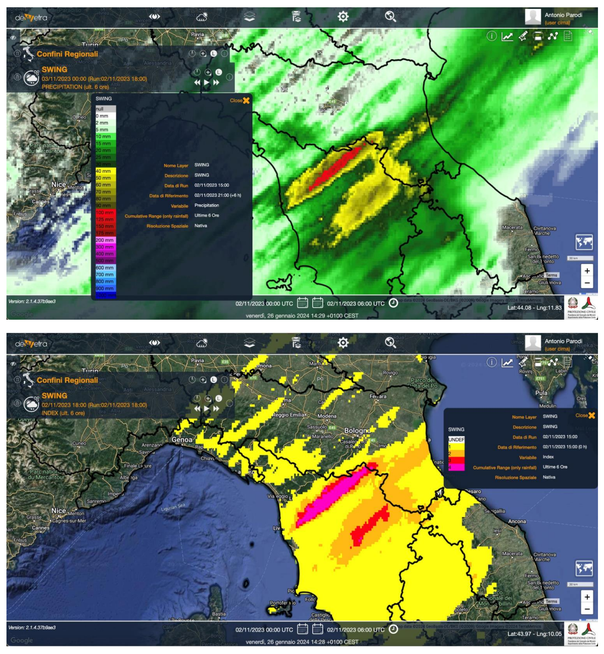
SWING (Score-Weighted Improved NowcastinG) combines recent NWP runs (WRF with frequent radar 3DVAR and lightning nudging) and radar-based nowcasting (PhaSt) to deliver an hourly 0–6 h precipitation forecast, refreshed every 3 h using three forecasts that span the same 6-hour window. PhaSt can update at 10-min steps; WRF cycles with data assimilation every 3 h.

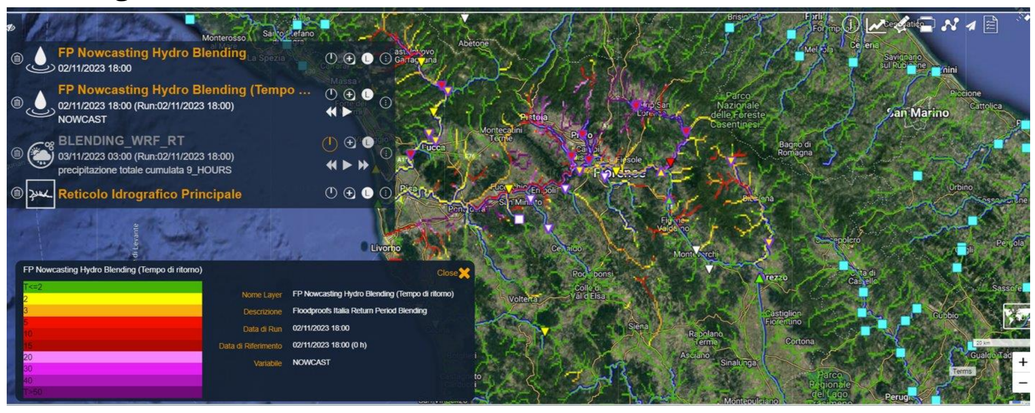
How it works: Before each update, the previous 3 hours are used to compare modeled rainfall "objects" against observations (radar and gauges). Objects are defined where rainfall exceeds a low threshold and are characterized by volume, area, centroid distance, orientation, and spatial intersection. These comparisons produce scores summarized into an Overall Field Score (OFS) and a Missed-Object Score (MOS). OFS and MOS are combined into a Reliability Score (RS), which weights the three candidate forecasts; the RS-weighted mean provides the final hourly 0–6h rainfall field. From the rainfall Each grid cell is classified into four severity classes using the rain-gauge warning thresholds available for the 6h cumulated rainfall to obtain a synthetic information.

Embedded hydrologic chain: The RS-weighted rainfall (Δt = 1 h) forces the distributed Continuum model to produce streamflow forecasts at control sections for early-warning operations. In the national configuration, Continuum runs at ~0.05° (~480 m) spatial resolution with 1-hourly time step and covers 350+ control sections published in the operational Mydewetra platform. Additionally, model-based return-period (T) maps of streamflow, showing the maximum T over the combined 6(SWING)+6(Hydro routing) h forecast window are visualized. Beyond the control sections, this fine-grained output highlights at a glance the areas most affected on the ground.

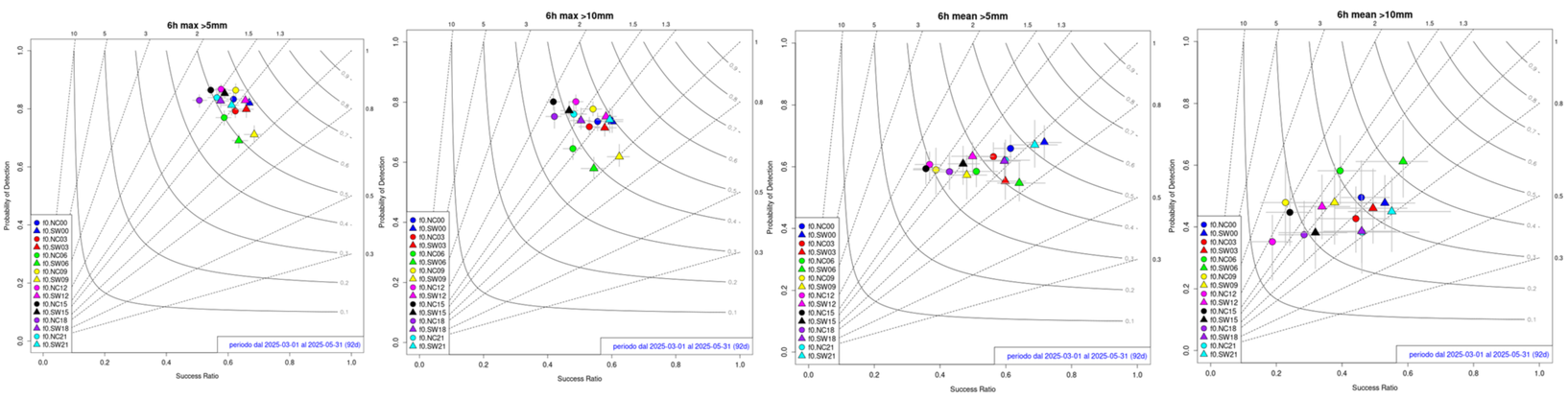


SWING Ensemble example





Example of visualization on Mydewetra platform of the SWING meteorological forecast both in terms of cumulated rainfall and hazard index (left panels) and example of streamflow prediction in terms of return period (right panel).



SWING is validated seasonally using performance diagrams computed over the Italian meteorological vigilance areas. For each season we evaluate both area-mean and area-maximum 6-h precipitation, across multiple thresholds (e.g., ≥5 mm and ≥10 mm). Seasonal scores are aggregated over events and compared against a simple model output to quantify SWING's added value.

Example (March-April-May spring season):

Performance diagrams for MAM compare the simple model (dots) with SWING (triangles) for 6-h forecast for minimum and maximum values on vigilance areas above 5 mm and 10 mm.

SWING (triangles) tends to sit further toward the upper-right than the simple model (dots), indicating higher Probability of Detection at similar or better Success Ratio.

PhaSt nowcasting extrapolates the evolving radar rainfall every 10 minutes and is adaptively blended with 3-hourly WRF updates to cover the full 0–6 h window. On top of this, SWING applies an object-based reliability weighting (RS) to recent forecasts and derives a synthetic warning index, so severity reflects both intensity and confidence. In tests on convective cases, SWING cut false alarms of the events while preserving — and in some windows slightly improving — detection skill for impactful events. The resulting reliability-aware fields drive the distributed hydrologic chain to produce streamflow forecasts and fine-grained impact maps, giving earlier and more actionable guidance on where the worst effects will be.

References

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