SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2025
Project Title:	Re-analysis and Re-forecasting of Extreme Weather Events Using the ICON-LAM Model
Computer Project Account:	SPITGARB
Principal Investigator(s):	Valeria Garbero (mcy0), valeria.garbero@arpa.piemonte.it
Affiliation:	ARPA PIEMONTE
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Alessio Golzio, alesgolz@arpa.piemonte.it Massimo Milelli (mcy), massimo.milelli@cimafoundation.it
Start date of the project:	January 2025
Expected end date:	December 2027

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	/	/	900000	207.322
Data storage capacity	(Gbytes)	/	/	400	400

Summary of project objectives (10 lines max)

Despite recent advancements in Numerical Weather Prediction (NWP) through improved data assimilation, increased computing power, and a deeper physical understanding, accurately forecasting the spatial and temporal patterns of precipitation and other extreme weather events remains a significant challenge. This project aims to improve future forecasts of severe events—including heavy precipitation, heat waves, and strong winds—by analysing recent extreme weather case studies with advanced numerical modelling. We will use the ICON-LAM model at high resolution (from 2 km down to 500 m). To optimize its performance different model configurations will be tested, varying initial/boundary conditions, physical parameterizations, and urban schemes. For validation, temperature, relative humidity, and wind forecasts will be compared against observations from both meteorological stations and citizen networks. Precipitation forecasts will undergo a rigorous fuzzy verification technique.

Summary of problems encountered (10 lines max)

None.

Summary of plans for the continuation of the project (10 lines max)

The project will continue with an in-depth analysis of extreme weather case studies at very high resolution. We'll investigate both heavy precipitation events across Italy and urban heat waves.

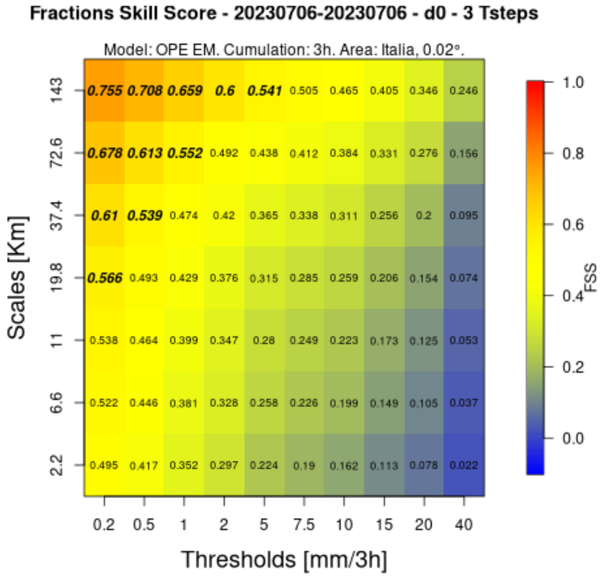
Our primary goal is to identify the optimal model configuration for accurately reproducing these phenomena. We'll systematically test different model setups to determine which best captures the observed events, ultimately contributing to more reliable and precise forecasts of severe weather at local scales.

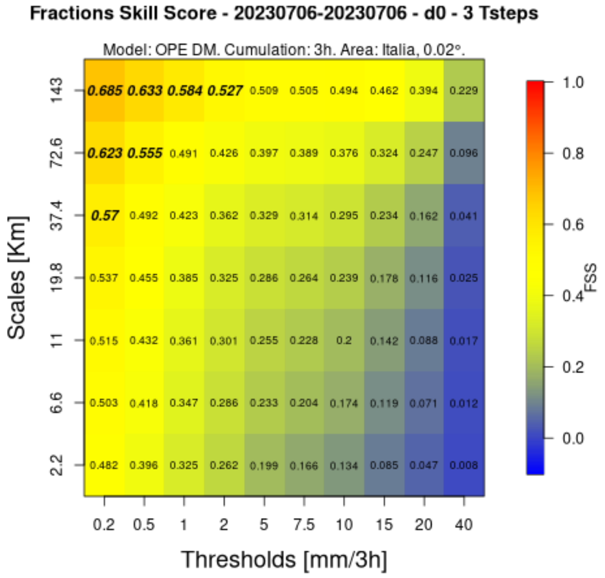
List of publications/reports from the project with complete references

Summary of results

An event that was poorly predicted has been selected as a case study: the supercell thunderstorm that occurred over central Piedmont on July 6, 2023. Four re-forecasts of this event were conducted using ICON at 2 km resolution, each one differing by the combination of microphysical parameterisation scheme and assimilation technique used. ICON was compiled with the --enable-emvorado configuration, in order to have the reflectivity that more closely matches what is used for assimilation (Mie scattering).The first run mimics the operational settings of ICON-2I implementing a bulk-moment microphysics scheme, but no assimilation (OPE EM); the second one adopts a double-moment microphysics scheme without assimilation (OPE DM), while the third and fourth experimental sets run the 24-hour LHN data assimilation on a bulk and double-moment scheme, respectively (OPE LHN, OPE DMLHN).

The performance of the different configurations in simulating severe convective storms was evaluated. Weather radar observations, complemented by radio soundings and ground weather stations, provided the target for this assessment. Notably, fuzzy verification revealed that 24-hour Latent Heat Nudging (LHN) assimilation significantly improves the model's performance in these simulations.


Fractions Skill Score - 20230706-20230706 - d0 - 3 Tsteps
Model: OPE EM. Cumulation: 3h. Area: Italia, 0.02°.
0.755 0.708 0.659 0.6 0.541 0.505 0.465 0.405 0.346 0.246
0.678 0.613 0.552 0.492 0.438 0.412 0.384 0.331 0.276 0.156
0.61 0.539 0.474 0.42 0.365 0.338 0.311 0.256 0.2 0.095
0.566 0.493 0.429 0.376 0.315 0.285 0.259 0.206 0.154 0.074
0.538 0.464 0.399 0.347 0.28 0.249 0.223 0.173 0.125 0.053
0.522 0.446 0.381 0.328 0.258 0.226 0.199 0.149 0.105 0.037
0.495 0.417 0.352 0.297 0.224 0.19 0.162 0.113 0.078 0.022
Scales [Km]
143 72.6 37.4 19.8 11 6.6 2.2
0.2 0.5 1 2 5 7.5 10 15 20 40
Thresholds [mm/3h]
FSS
1.0 0.8 0.6 0.4 0.2 0.0


Fractions Skill Score - 20230706-20230706 - d0 - 3 Tsteps
Model: OPE DM. Cumulation: 3h. Area: Italia, 0.02°.
0.685 0.633 0.584 0.527 0.509 0.505 0.494 0.462 0.394 0.229
0.623 0.555 0.491 0.426 0.397 0.389 0.376 0.324 0.247 0.096
0.57 0.492 0.423 0.362 0.329 0.314 0.295 0.234 0.162 0.041
0.537 0.455 0.385 0.325 0.286 0.264 0.239 0.178 0.116 0.025
0.515 0.432 0.361 0.301 0.255 0.228 0.2 0.142 0.088 0.017
0.503 0.418 0.347 0.286 0.233 0.204 0.174 0.119 0.071 0.012
0.482 0.396 0.325 0.262 0.199 0.166 0.134 0.085 0.047 0.008
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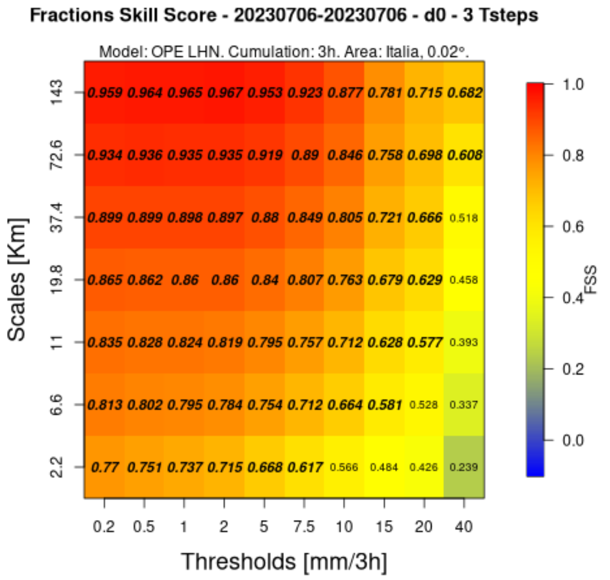
Fractions Skill Score - 20230706-20230706 - d0 - 3 Tsteps
Model: OPE LHN. Cumulation: 3h. Area: Italia, 0.02°.
0.959 0.964 0.965 0.967 0.953 0.923 0.877 0.781 0.715 0.682
0.934 0.936 0.935 0.935 0.919 0.89 0.846 0.758 0.698 0.608
0.899 0.899 0.898 0.897 0.88 0.849 0.805 0.721 0.666 0.518
0.865 0.862 0.86 0.86 0.84 0.807 0.763 0.679 0.629 0.458
0.835 0.828 0.824 0.819 0.795 0.757 0.712 0.628 0.577 0.393
0.813 0.802 0.795 0.784 0.754 0.712 0.664 0.581 0.528 0.337
0.77 0.751 0.737 0.715 0.668 0.617 0.566 0.484 0.426 0.239
Scales [Km]
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Thresholds [mm/3h]
FSS
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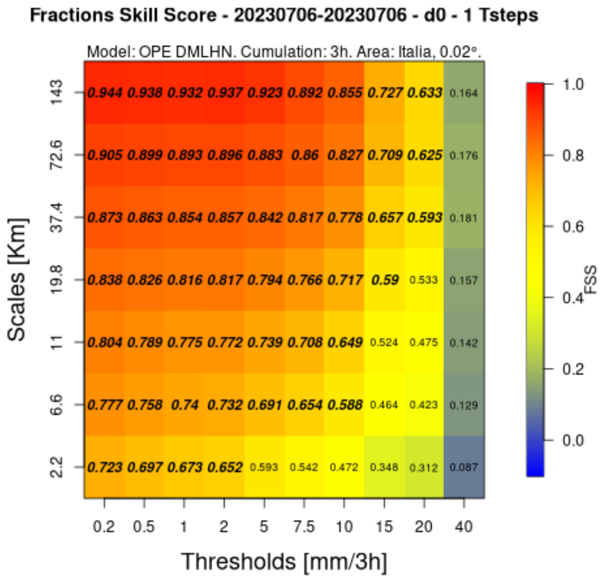
Fractions Skill Score - 20230706-20230706 - d0 - 1 Tsteps
Model: OPE DMLHN. Cumulation: 3h. Area: Italia, 0.02°.
0.944 0.938 0.932 0.937 0.923 0.892 0.855 0.727 0.633 0.164
0.905 0.899 0.893 0.896 0.883 0.86 0.827 0.709 0.625 0.176
0.873 0.863 0.854 0.857 0.842 0.817 0.778 0.657 0.593 0.181
0.838 0.826 0.816 0.817 0.794 0.766 0.717 0.59 0.533 0.157
0.804 0.789 0.775 0.772 0.739 0.708 0.649 0.524 0.475 0.142
0.777 0.758 0.74 0.732 0.691 0.654 0.588 0.464 0.423 0.129
0.723 0.697 0.673 0.652 0.593 0.542 0.472 0.348 0.312 0.087
Scales [Km]
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0.2 0.5 1 2 5 7.5 10 15 20 40
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