Status and developments in data assimilation for the ICON-2I model

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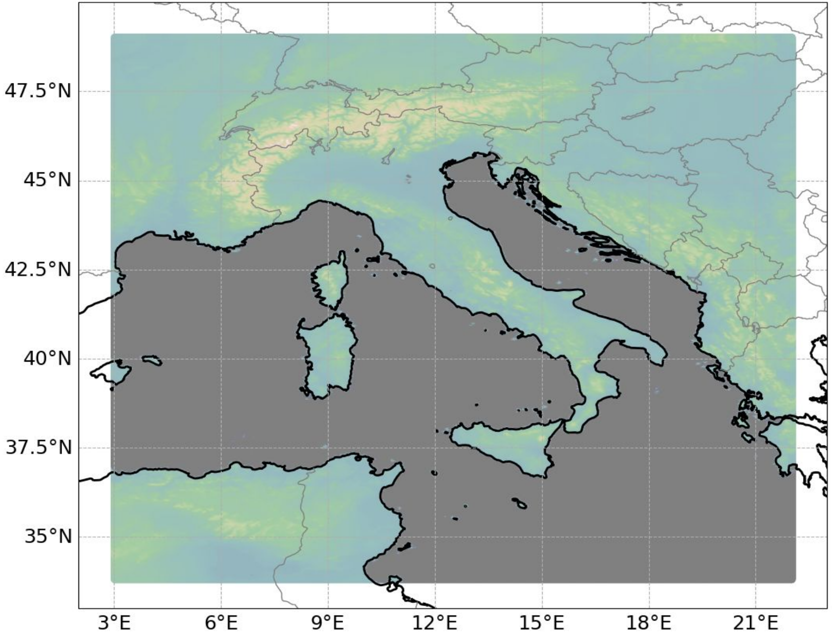
Current status

ICON-2I model fully operational since 18/06/2024.

Model domain:



Model version: 2.6.5.1

Horizontal resolution: 2.2 km

NWP system:

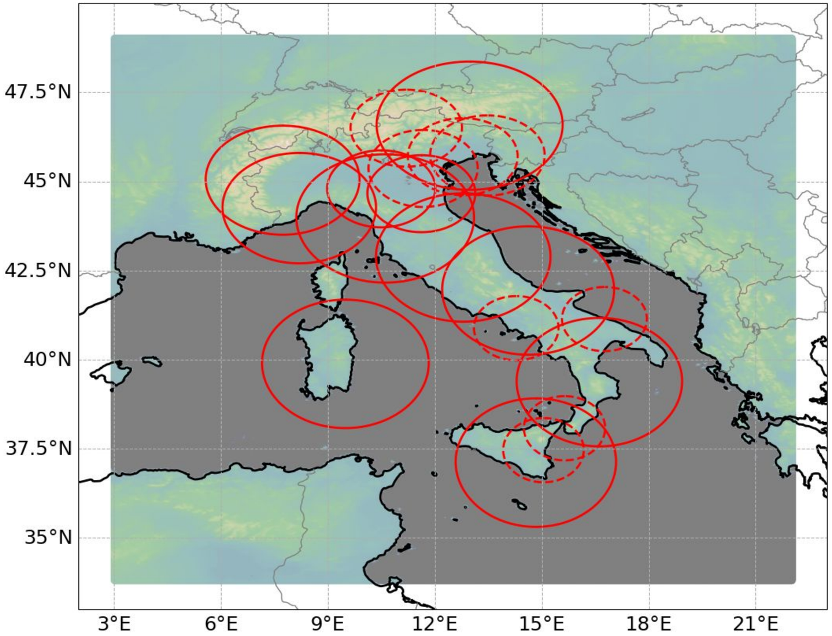
Model	Forecast type	Forecast range	Initial time (UTC)
ICON-2I	deterministic	+72h	00, 12
ICON-2I-RUC	deterministic	+24h	03, 06, 09, 15, 18, 21
ICON-2I-EPS	ensemble, 20 members	+51h	21

The development of the NWP system is performed in collaboration with Agenzia ItaliaMeteo.

Current status

ICON-2I model fully operational since 18/06/2024.

Model domain:



KENDA implementation:

- 40 members + deterministic run
- 1h assimilation cycles, employing IAU
- RTPS
- Assimilation up to 200 hPa
- Control vector: pf, t, q, u, v, qcl, qci, qr, qs, qg

Assimilated observations:

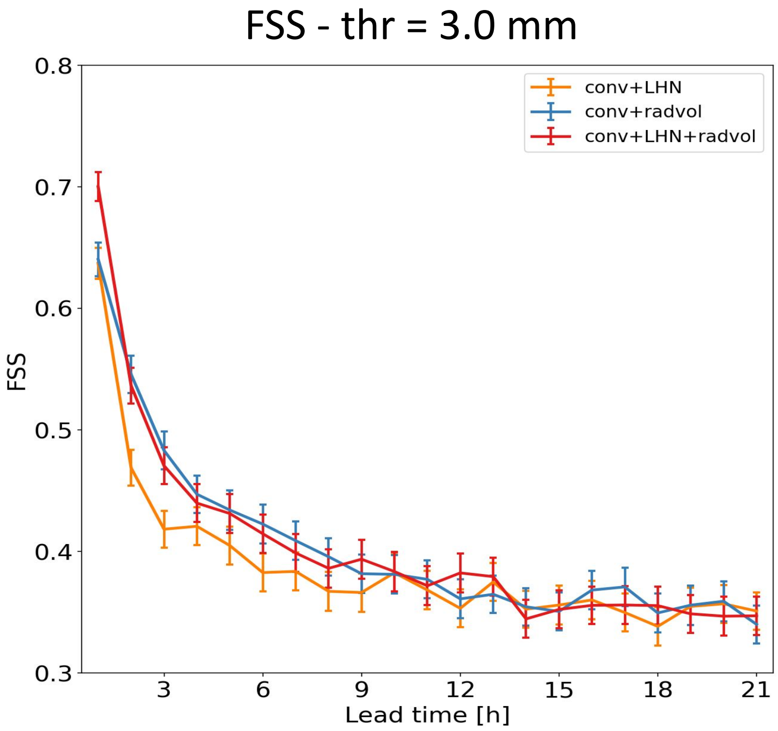
- AIREP, TEMP, SYNOP (wind and surface pressure) and radar volumes (solid lines) of reflectivity and radial wind through KENDA
- radar estimated precipitation via LHN using the composite of all radars (solid+dashed lines)

Work done this year

- Assimilation of radar volumes in the operational set-up
- Improvement of LHN impact
- Implementation of LHN monitoring
- Beginning of the work on the assimilation of satellite data

Assimilation of radar volumes

- Overall, the assimilation of radar volumes of reflectivity and radial winds improves forecast accuracy compared to employing only LHN.
- Best results in terms of precipitation are obtained when combining assimilation of radar volumes with LHN, especially for weak precipitation (≤ 1 mm/h)
- Best scores for upper-air variables are obtained when assimilating only radar volumes, without applying LHN.

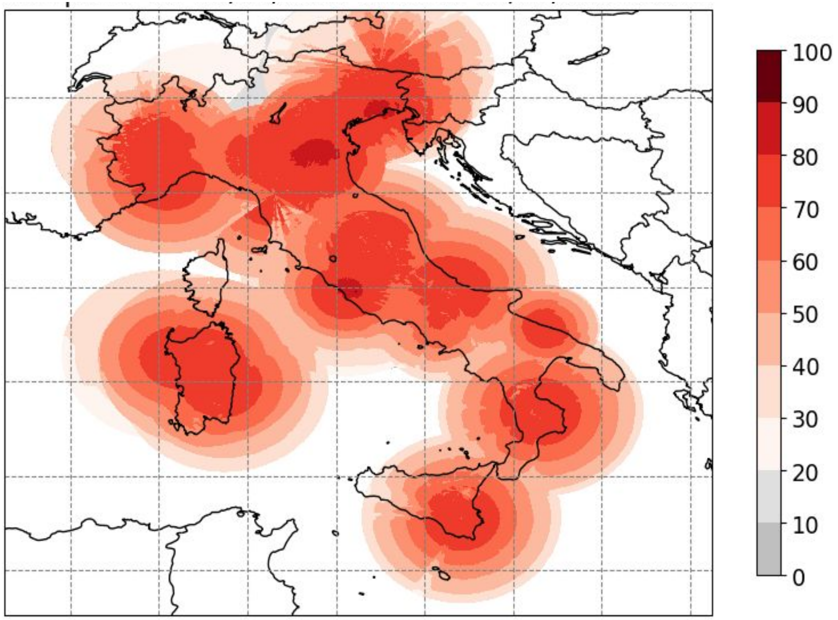


Assimilation of radar volumes in combination with LHN is operational since 17 April 2024

Improving LHN impact: SRI quality

The work carried out in 2023 on the quality of the LHN has been taken up, resolving some bugs encountered at that time.

SRI quality



Radar precipitation (surface rainfall intensity: SRI), provided by Civil Protection Department and employed by us as input for LHN, is associated to a quality ranging 0-100 (average over 1 year in figure).

Improving LHN: SRI quality and LHN

Experiments:

- **w/o KENDA**: 24h forecast initialized from IFS analysis every 6 hours, without any kind of data assimilation (no KENDA, no LHN)
- **w/o KENDA + LHN:** as “w/o KENDA” but assimilating all SRI data via LHN for the whole forecast, regardless of quality.
- **w/o KENDA + LHN q > 50**: as “w/o KENDA” but assimilating all SRI data with quality > 50 via LHN.
- **w/o KENDA + LHN q > 70**: as “w/o KENDA” but assimilating all SRI data with quality > 70 via LHN.

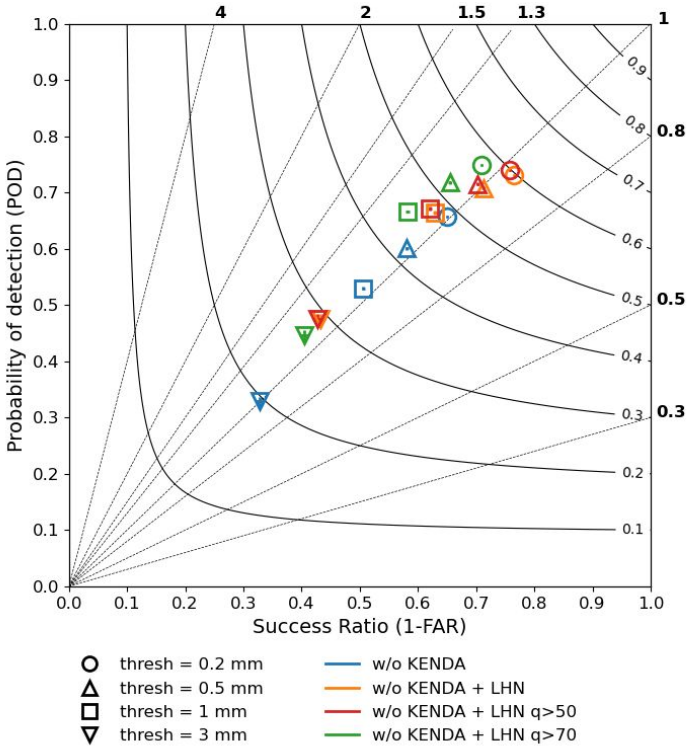
Evaluation period:

From 01/04/2023 to 23/05/2023. Forecast every 6h, in total 208 for each experiment.

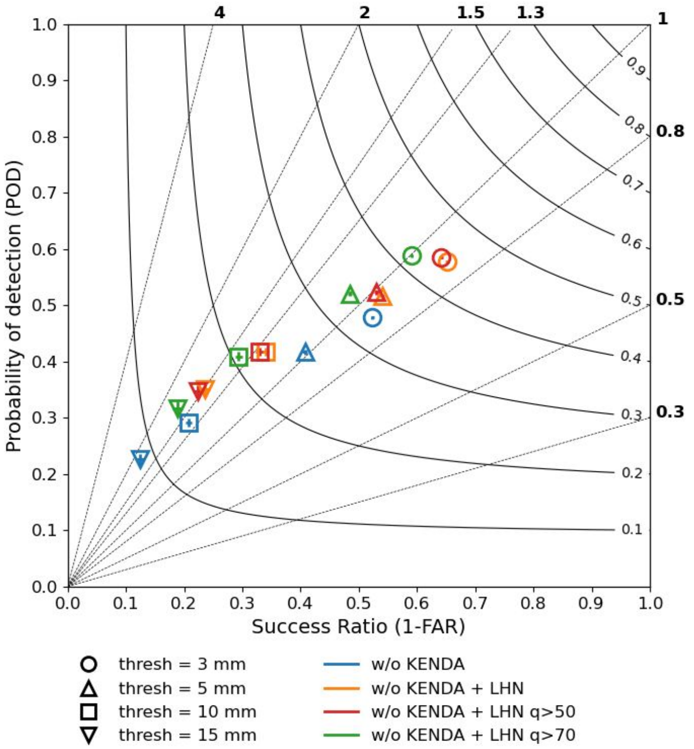
Improving LHN: SRI quality and LHN

Verification of 1h accumulated precipitation, using rain-gauges as observations and computing average and maximum values over Italian alerting areas. Scores from lead time +3h to +24h are merged.

Average



Maximum



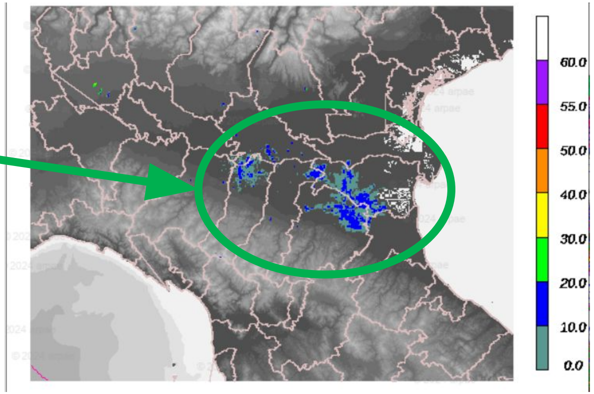
Improving LHN impact: conclusions

Tests are ongoing to improve the impact of LHN on forecast and analysis accuracy. In particular, we are focusing on the quality of input data. Next steps:

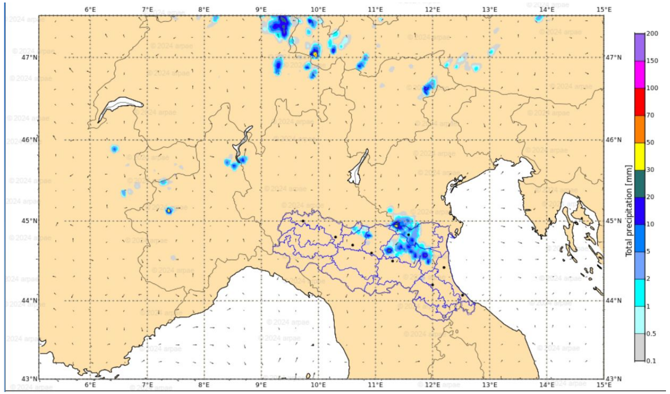
- improve SRI pre-processing and quality mask; sometimes unremoved clutter causes wrong forecast precipitation:

unremoved clutter

Rdar-estimated precipitation



Forecast +1h

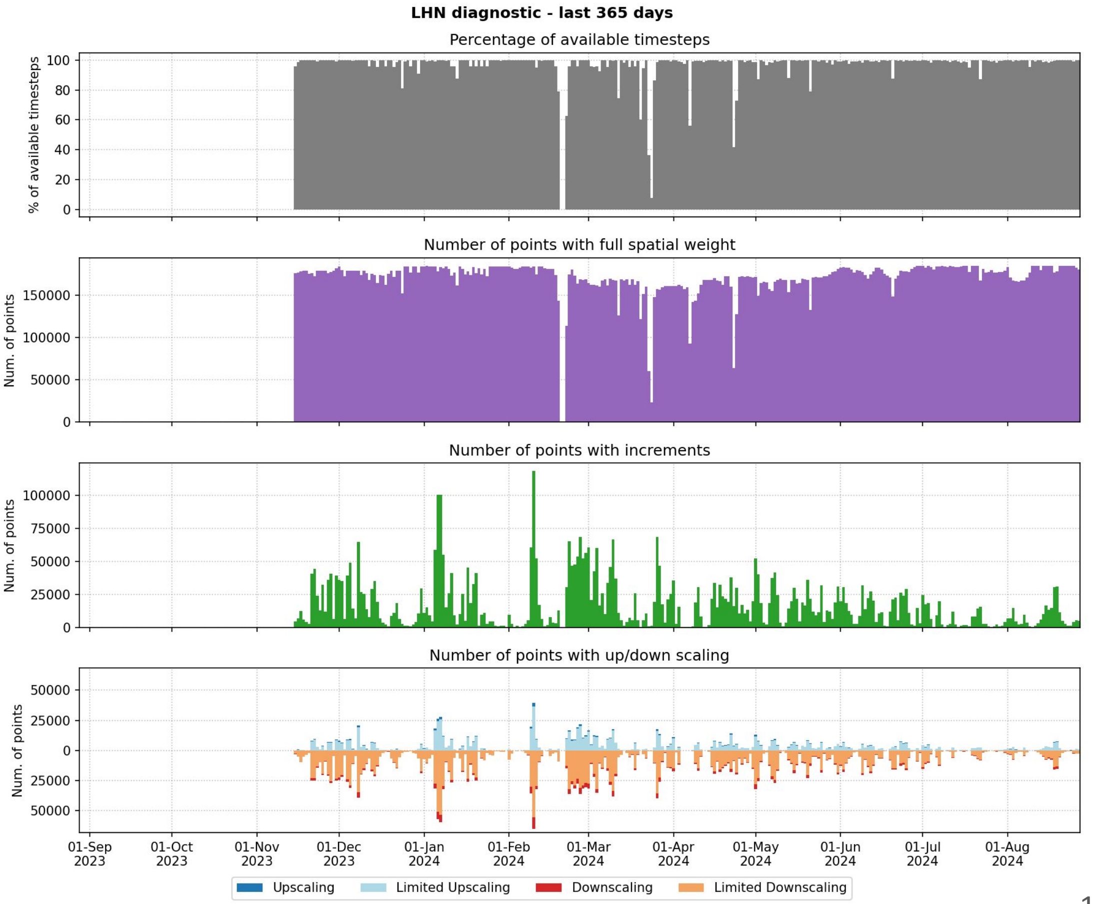


- Test different parameters of LHN namelist in ICON

Monitoring of LHN

In addition to the monitoring of KENDA based on EKF files, a monitoring is performed also on LHN employing lhn.log file. In this case, plots provide information on:

- number of available data
- number of grid points in which LHN modifies vertical profiles
- number of grid points in which LHN increases/decreases precipitation



PhD project towards satellite DA

Study the impact of assimilating **satellite observations**, with a special focus on the representation of convective systems, within the convection-permitting model **ICON**.

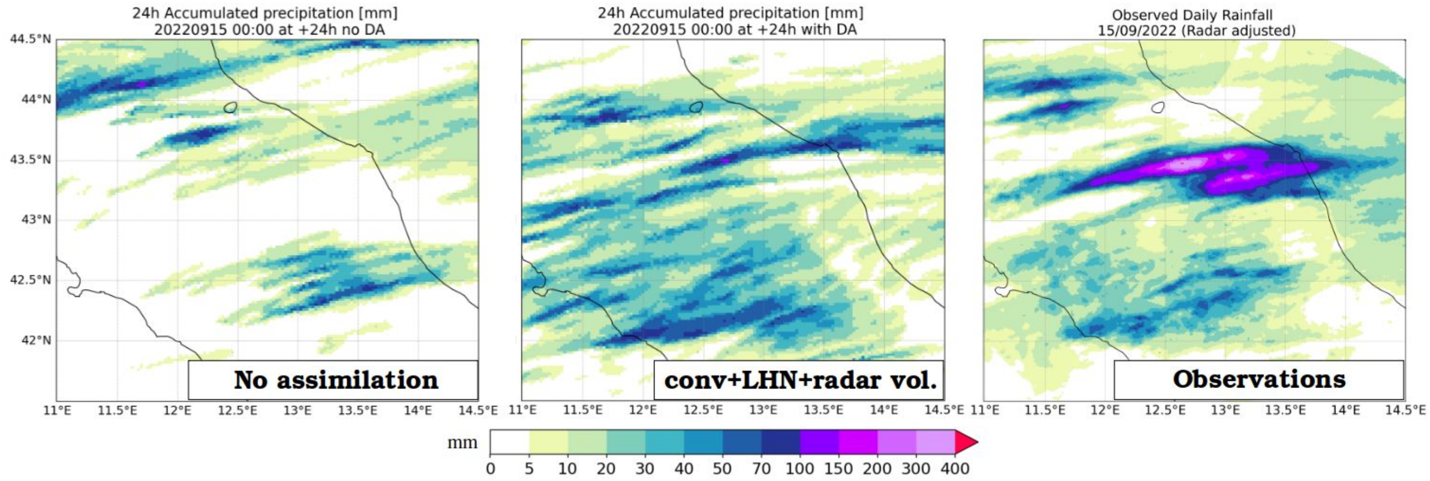
Focusing on a special case study - the flood in Marche region (Central Italy), on the 15th September 2022 - very poorly predicted by the majority of numerical models.

?

- *How do different sources of data (conv, LHN, radar vol, satellite) contribute to the forecast of this event?*
- *Will satellite DA of humidity-sensitive MW channels give a special contribution on the initiation, evolution and intensity of the storm?*
- *How will they impact on other meteorological fields?*

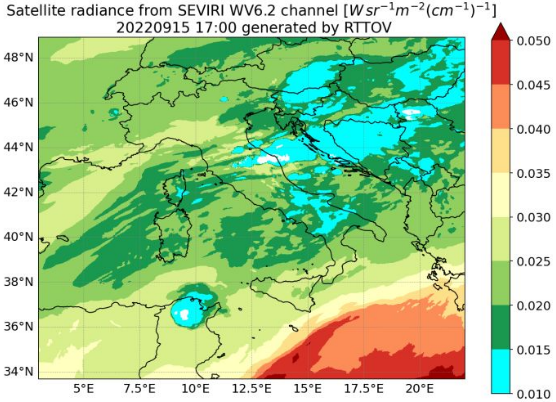
1. Compilation of ICON and DACE with **RTTOV v13.2** forward operator
2. Running experiments with DA of conventional (**SYNOP, TEMP, AIREP**) and radar data (**LHN, vol.**) on the Marche case study
3. Working on the implementation of the Basic Cycling (**BACY**) system for the setup of satellite DA experiments

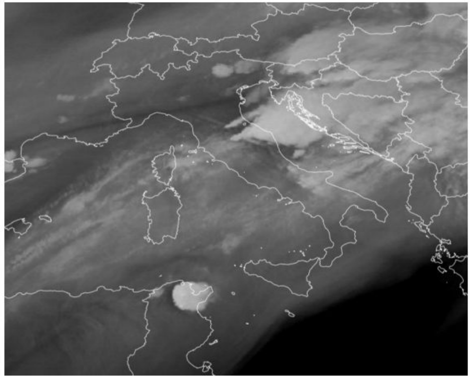
PhD project towards satellite DA



Two panels on the left: daily accumulated rainfall **without and with DA.** Forecasts lead time: 15/09/2022 at 00UTC (the day of the Marche flood).

On the right: comparison with **radar-estimated** daily rainfall





On the left, **simulated radiance of MSG-SEVIRI water vapor channel at 6.2µm**, generated by RTTOV from the KENDA analysis at 15/09/2022 17UTC.

On the right, SEVIRI real observation at 17UTC.

Future plans

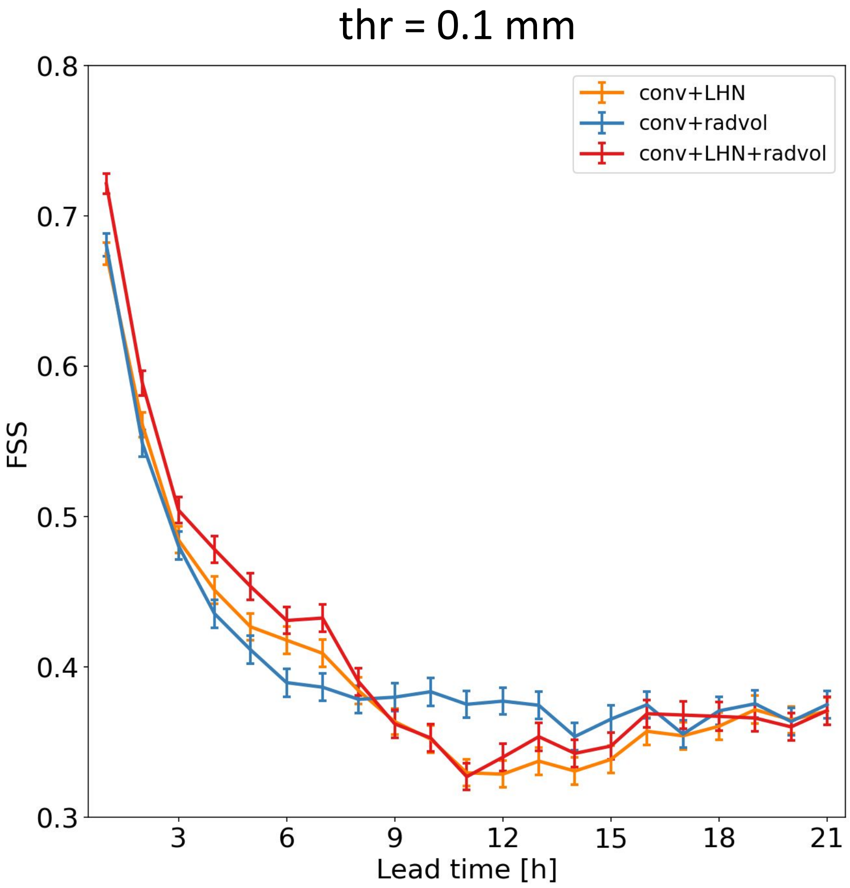
From 2025, the maintenance and development of the ICON-2I model will be the responsibility of ItaliaMeteo and Arpae will collaborate on these tasks.

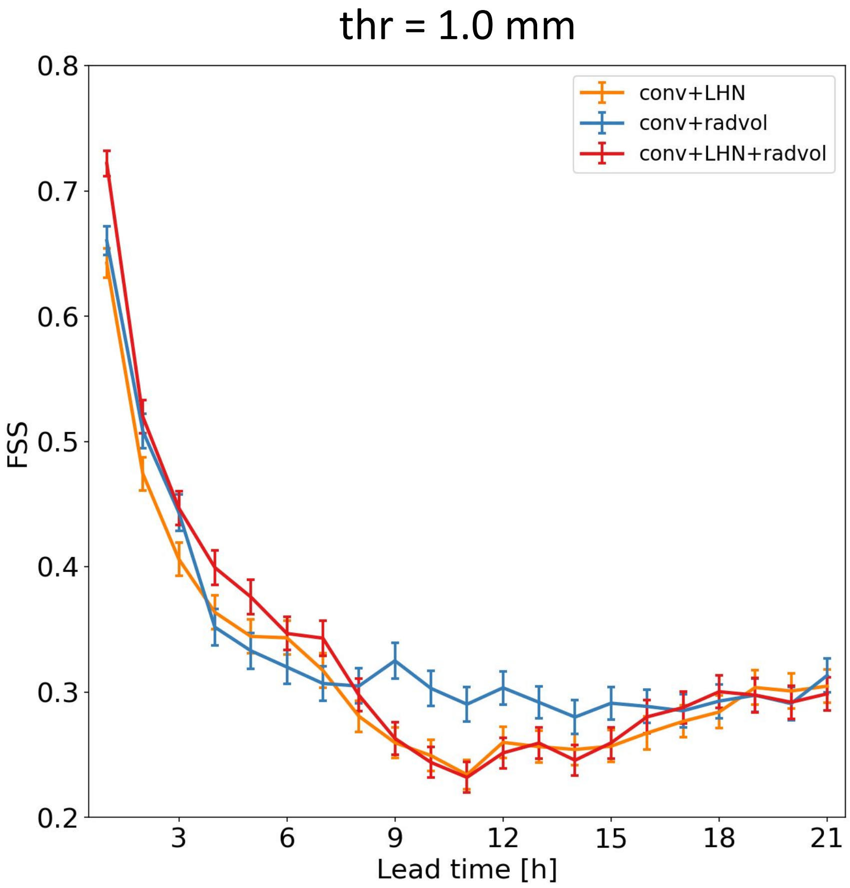
We will work on:

- Assimilation of T2M and RH2M from SYNOP stations (from Q4-2024 to Q2-2025)
- Assimilation of near-surface variables (T2M, RH2M, surface pressure and 10m wind) from other Italian neworks, like Civil Protection and Regions (from Q3-2025 to Q4 2026).
- Improvement of the impact of LHN (from Q4-2024 to Q4-2025)
- Assimilation of MODE-S data (from Q3-2025 to Q4-2025)
- Assimilation of water vapor-sensitive microwave (MW) channels from polar satellites in clear-sky conditions (from now to Q4 2025) and all-sky conditions (from Q1 2026 to Q4 2026)
- Assimilation of MTG-FCI and MTG-IRS observations (from Q1-2026 to Q4-2026).

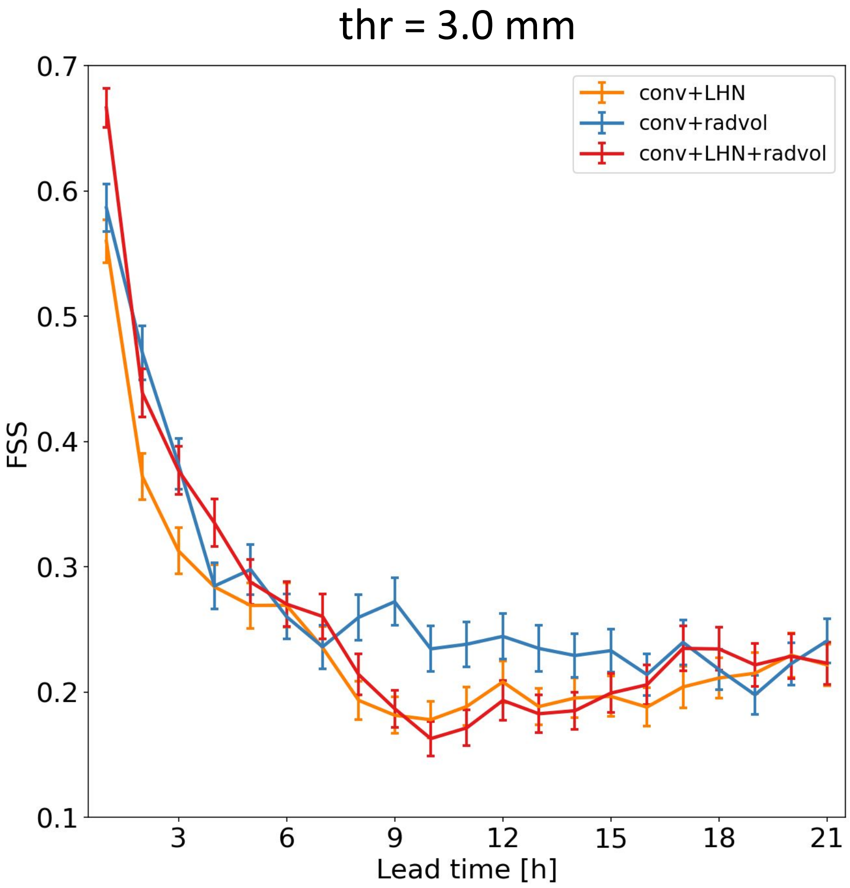
Thank you for the attention!

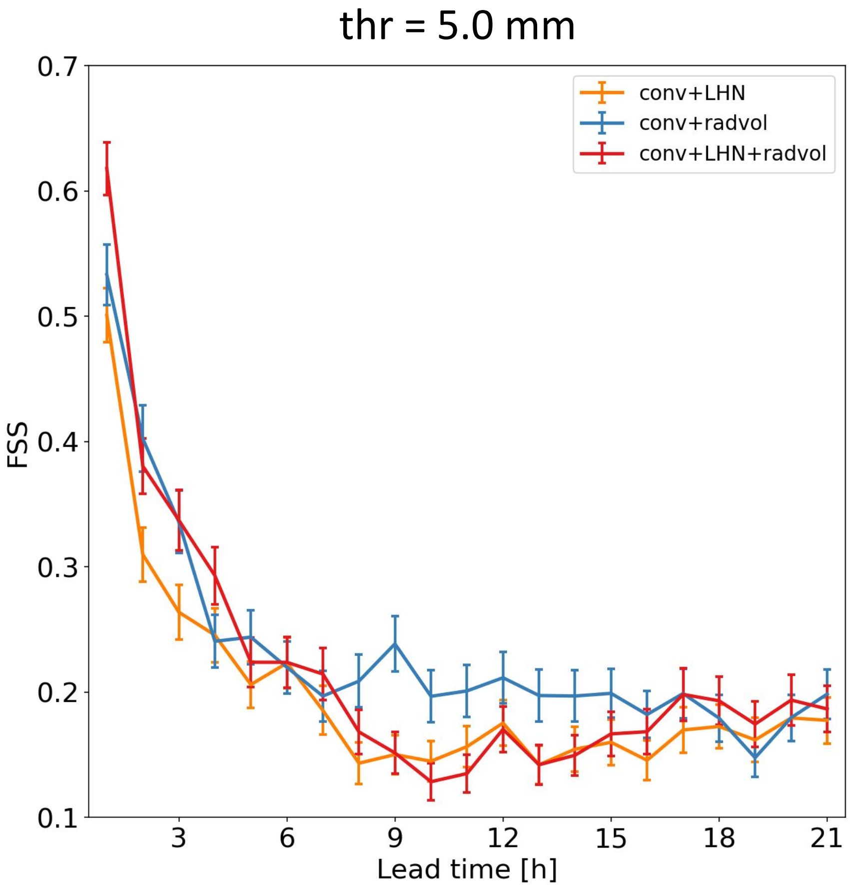
Forecast precipitation (FSS): aug2022



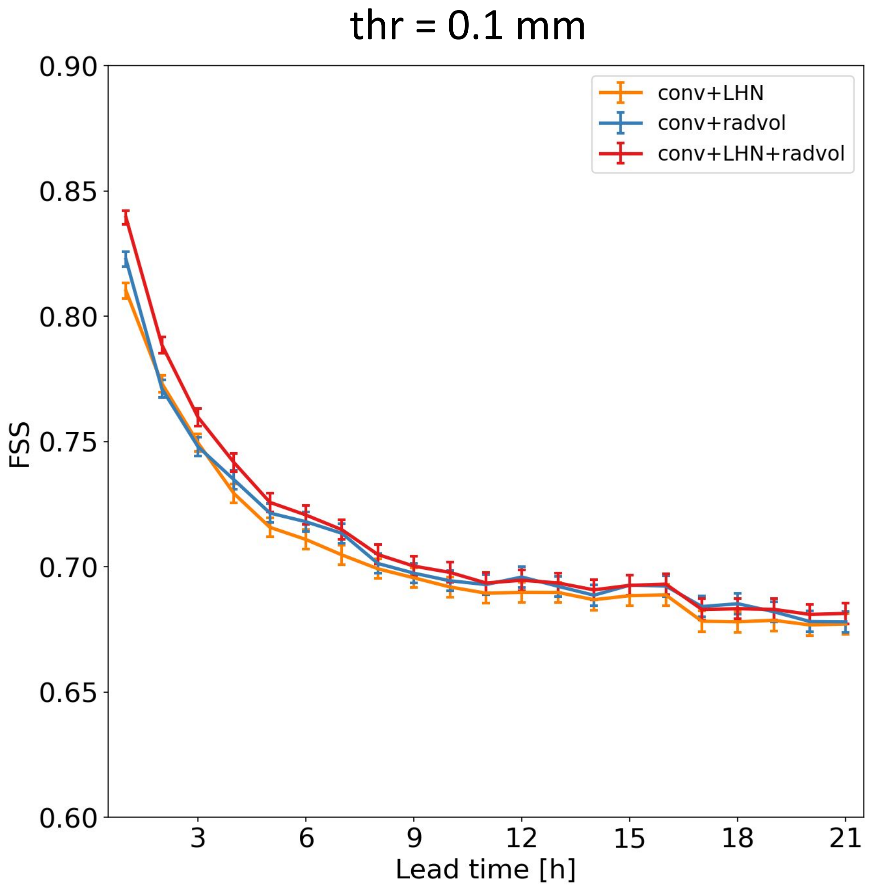


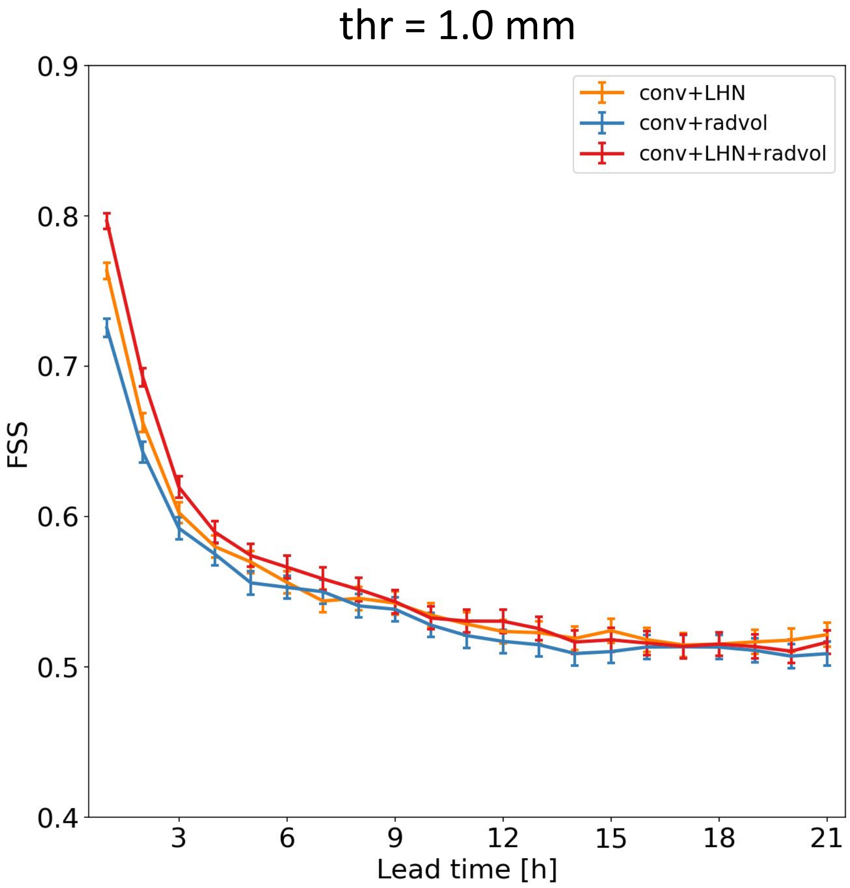
Forecast precipitation (FSS): aug2022



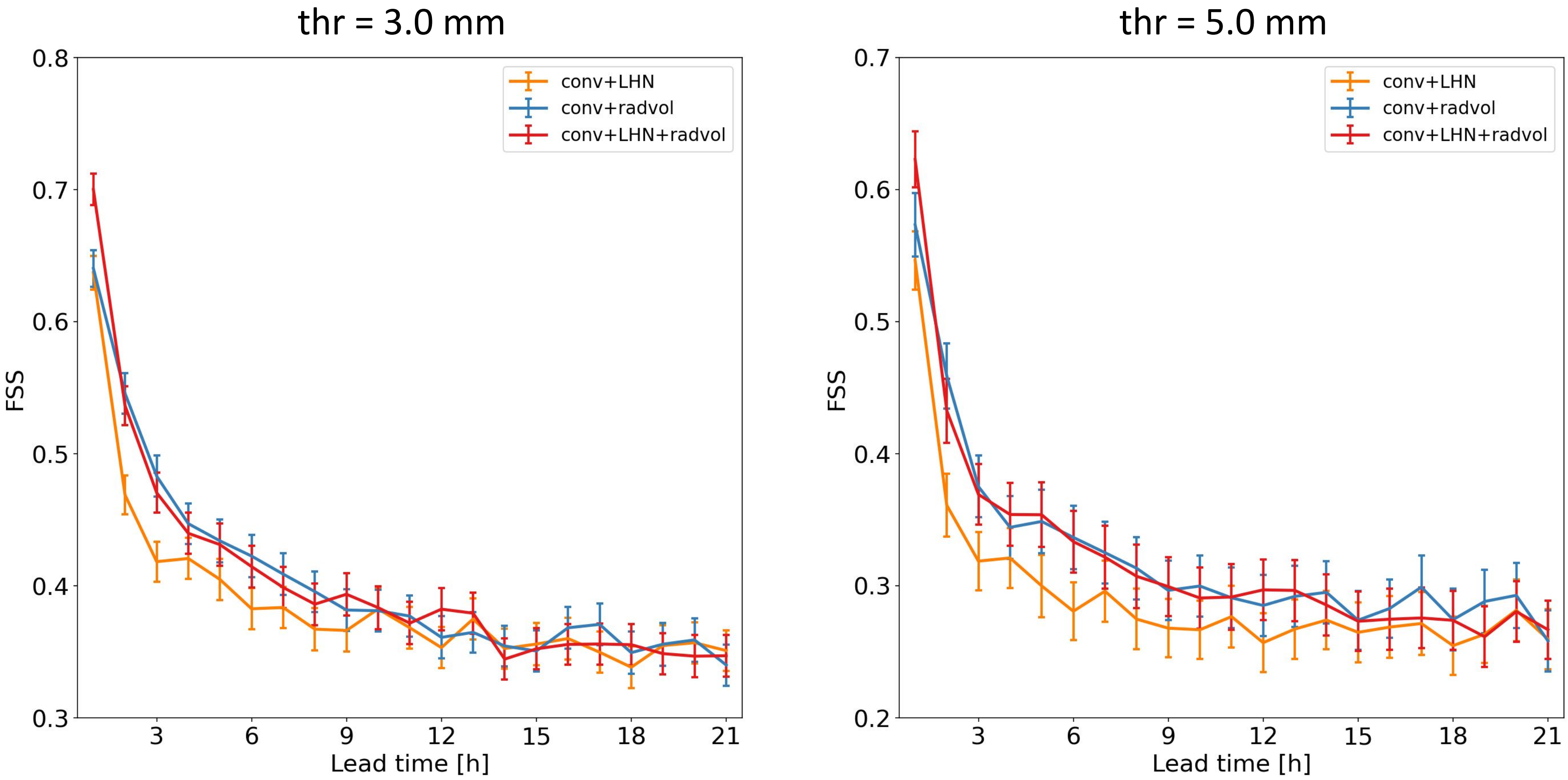


Forecast precipitation (FSS): may2023



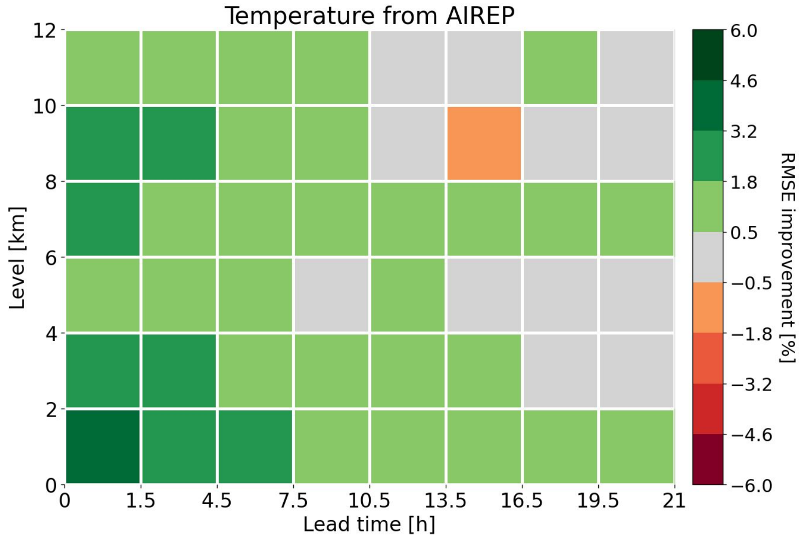


Forecast precipitation (FSS): may2023



Upper-air temperature

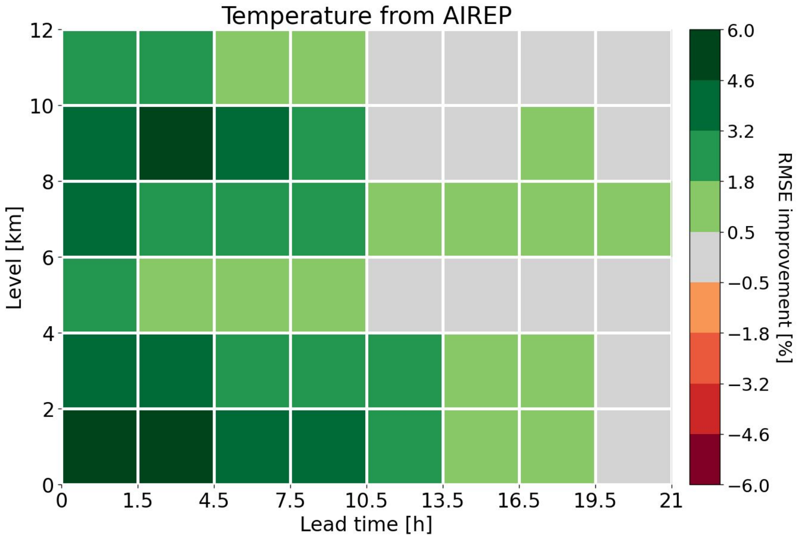
RMSE(*conv+LHN*) - RMSE(*conv+LHN+radvol*)



Average number of obs.: 76503 (ranging from 21322 to 216555)
Average RMSE for conv+LHN: 0.842 K (ranging from 0.662 K to 1.161 K)
Average RMSE for conv+LHN+radvol: 0.834 K (ranging from 0.645 K to 1.156 K)

Positive values (green): *conv+LHN+radvol* better than *conv+LHN*

RMSE(*conv+LHN*) - RMSE(*conv+radvol*)



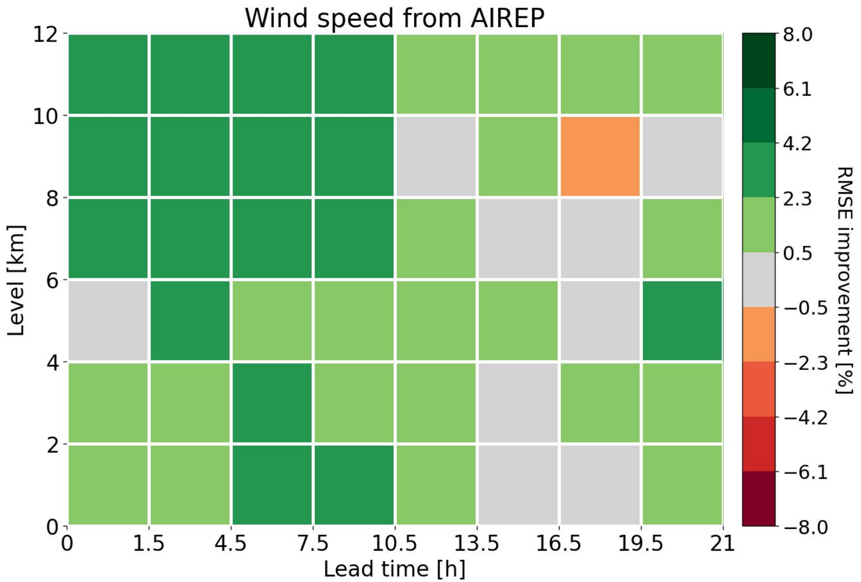
Average number of obs.: 76503 (ranging from 21322 to 216555)
Average RMSE for conv+LHN: 0.842 K (ranging from 0.662 K to 1.161 K)
Average RMSE for conv+radvol: 0.827 K (ranging from 0.637 K to 1.156 K)

Positive values (green): *conv+radvol* better than *conv+LHN*

Similar results for upper-air wind speed and relative humidity

Upper-air wind speed

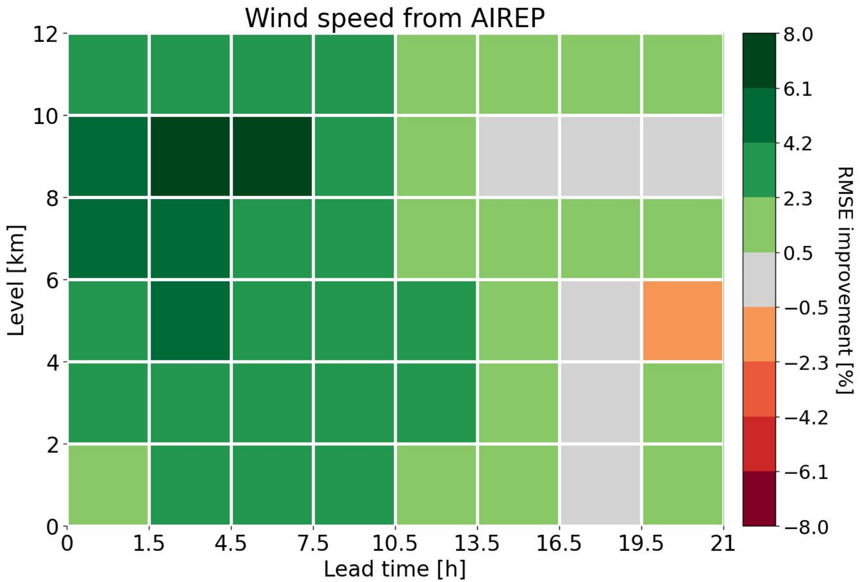
RMSE(*conv+LHN*) - RMSE(*conv+LHN+radvol*)



Average number of obs.: 33320 (ranging from 11445 to 91239)
Average RMSE for conv+LHN: 2.569 m/s (ranging from 2.137 m/s to 3.421 m/s)
Average RMSE for conv+LHN+radvol: 2.531 m/s (ranging from 2.136 m/s to 3.408 m/s)

Positive values (green): *conv+LHN+radvol* better than *conv+LHN*

RMSE(*conv+LHN*) - RMSE(*conv+radvol*)

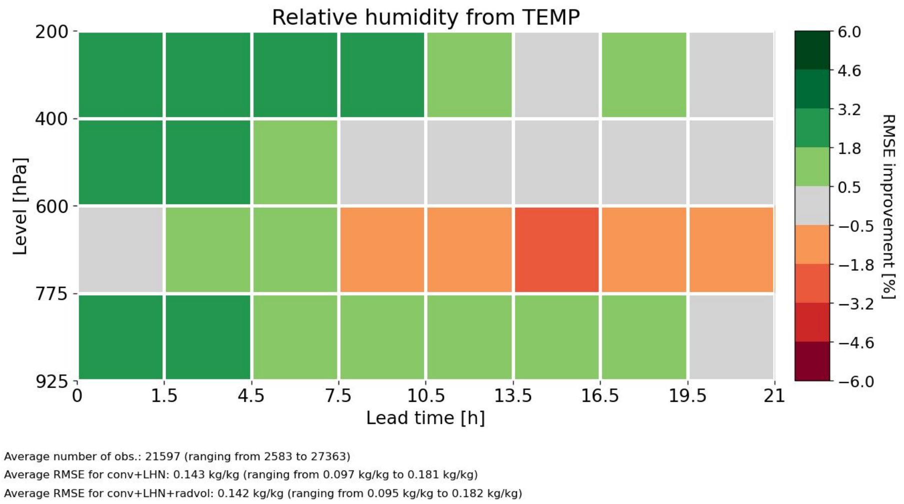


Average number of obs.: 33320 (ranging from 11445 to 91239)
Average RMSE for conv+LHN: 2.569 m/s (ranging from 2.137 m/s to 3.421 m/s)
Average RMSE for conv+radvol: 2.508 m/s (ranging from 2.061 m/s to 3.408 m/s)

Positive values (green): *conv+radvol* better than *conv+LHN*

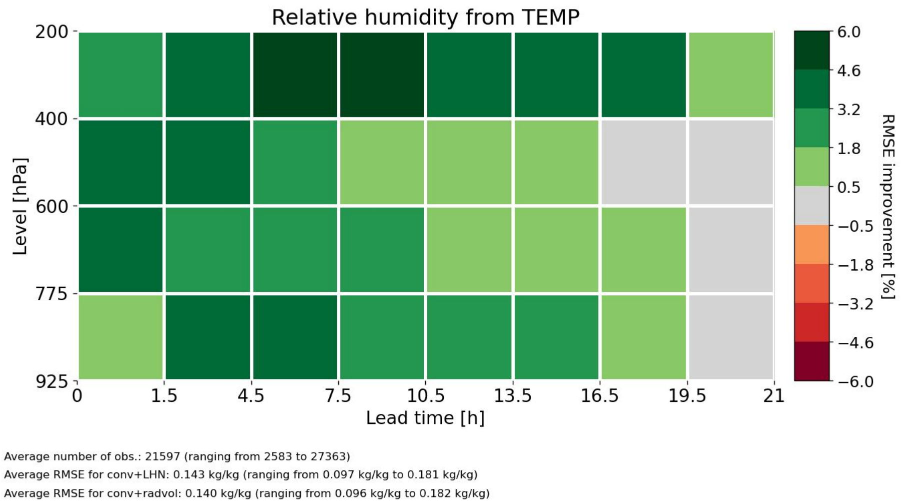
Upper-air relative humidity

RMSE(*conv+LHN*) - RMSE(*conv+LHN+radvol*)



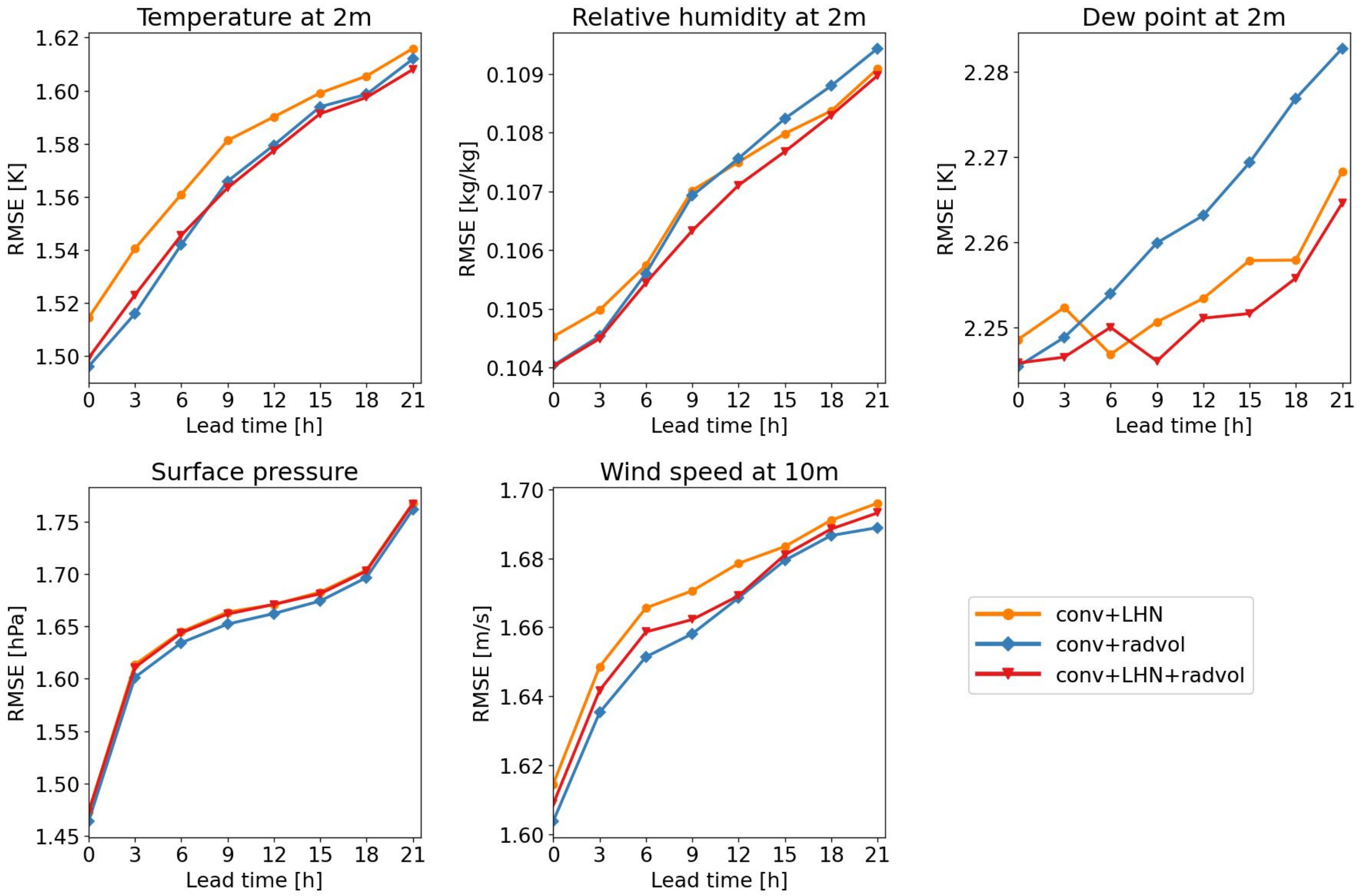
Positive values (green): *conv+LHN+radvol* better than *conv+LHN*

RMSE(*conv+LHN*) - RMSE(*conv+radvol*)

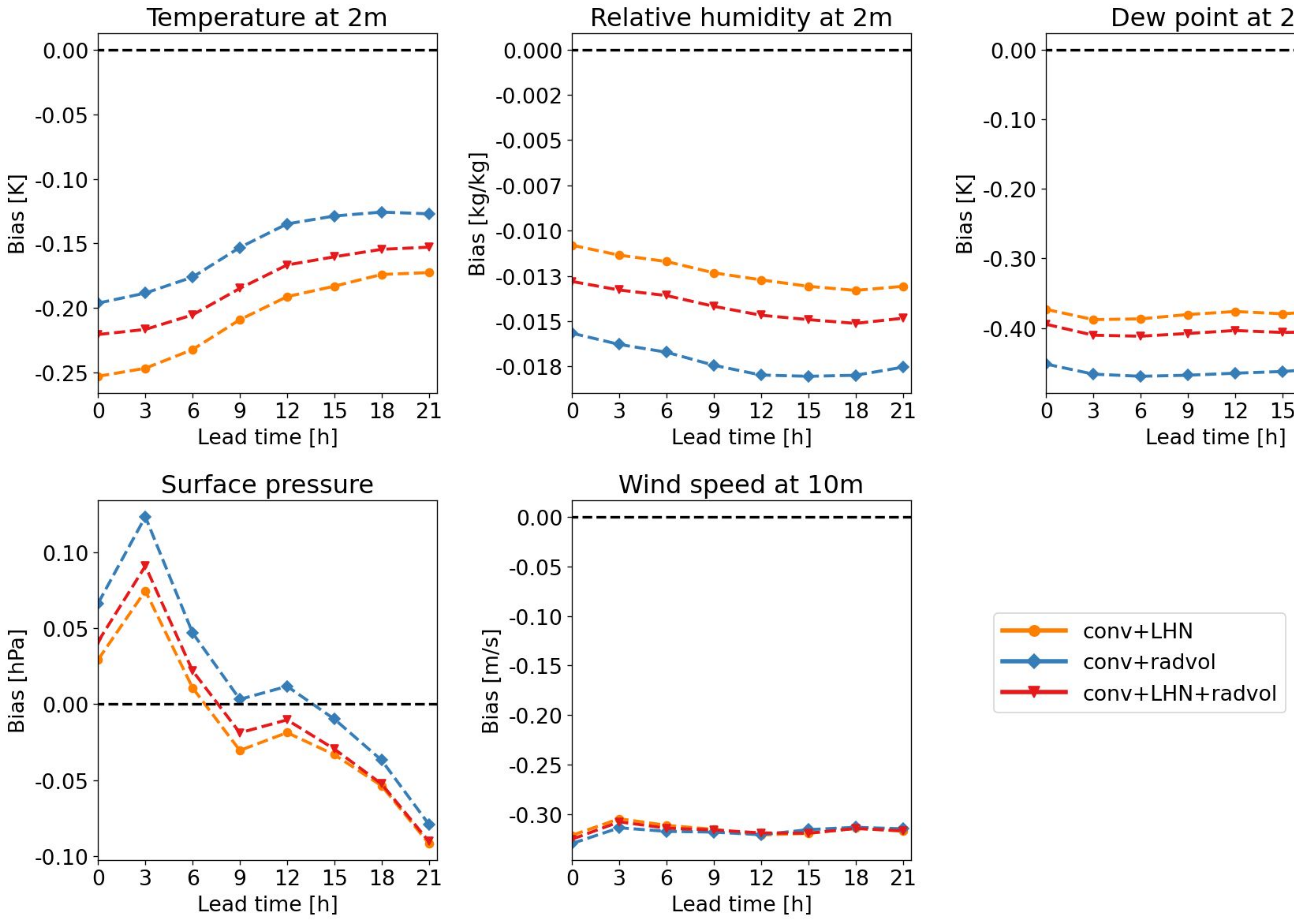


Positive values (green): *conv+radvol* better than *conv+LHN*

Near-surface variables: RMSE



Near-surface variables: bias



Assimilation of radar volumes: conclusions

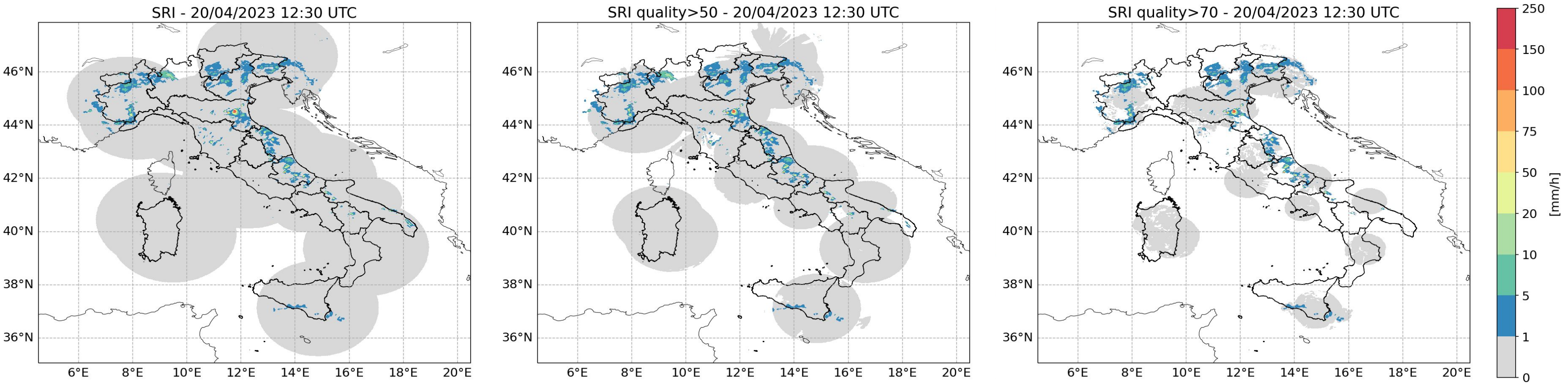
- Overall, the assimilation of radar volumes of reflectivity and radial winds improves forecast accuracy compared to employing only LHN.
- Best results in terms of precipitation are obtained when combining assimilation of radar volumes with LHN, especially for weak precipitation ($\leq$ 1 mm/h)
- Best scores for upper-air variables are obtained when assimilating only radar volumes, without applying LHN.

Configuration *conv+LHN+radvol* is operational since 17 April 2024

Improving LHN impact: SRI quality

Example of a SRI field with different threshold on quality

all data | **quality > 50** | **quality > 70**



Improving LHN impact: SRI quality

Verification against rain-gauges is performed considering average and maximum precipitation over the alerting areas, which are homogeneous with respect to the type and intensity of hydro-meteorological phenomena that may occur and their effects on the territory.

- Nearly 3000 rain-gauges;
- 3h precipitation;
- different thresholds for average and maximum precipitation.

Improving LHN impact: SRI quality