Assimilation of reflectivity volumes at Arpae

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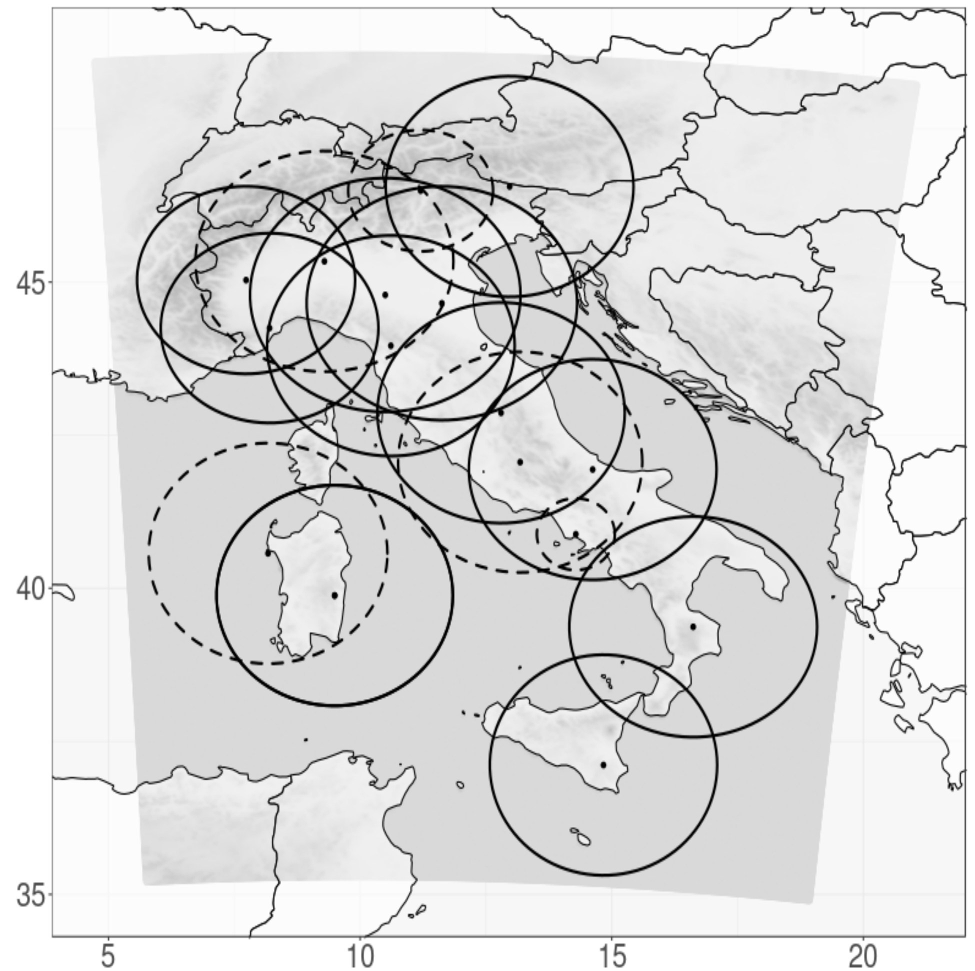
Operational set-up

- COSMO 5.05 at 2.2 km horizontal resolution;
- Just moved **from 20 to 40 members** + deterministic run;
- 3h assimilation cycles;
- assimilation of conventional data (AIREP, TEMP, SYNOP) through KENDA;
- LHN performed on each member of the KENDA ensemble. Precipitation field is provided by the Department of Civil Protection and it is based on all radars in the figure (both solid and dashed circles).



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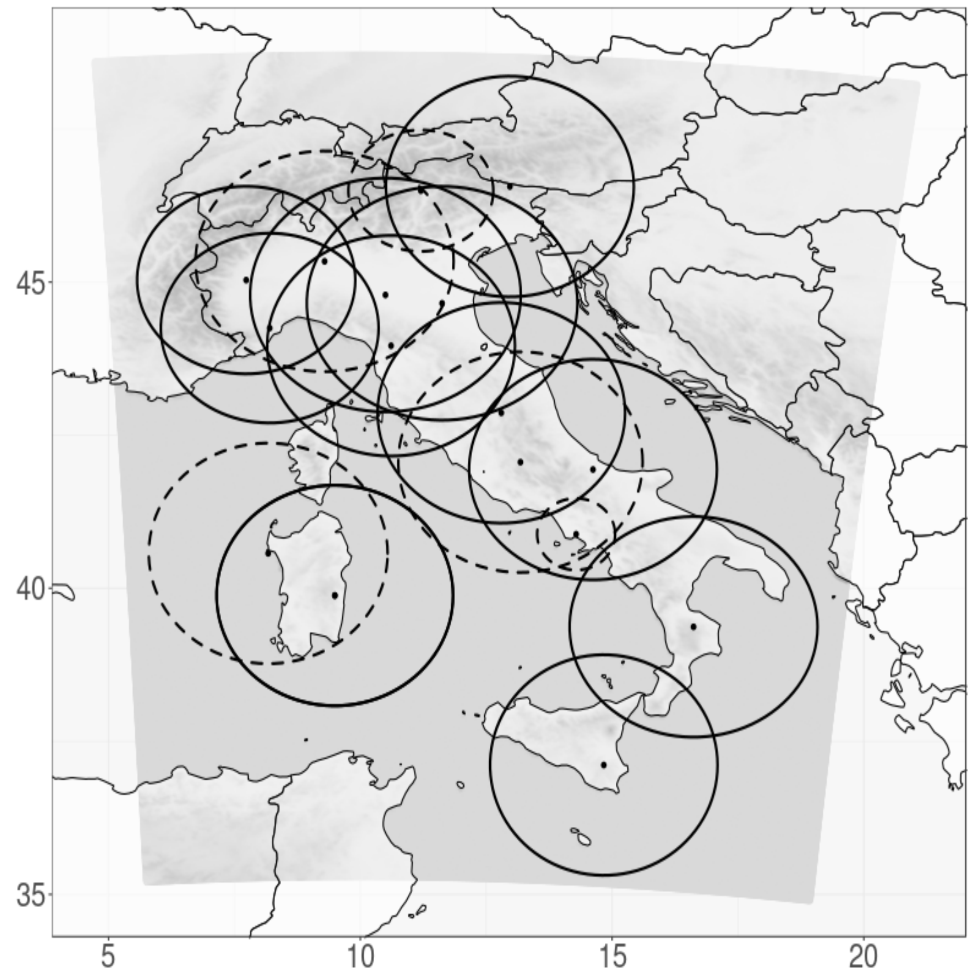
Experimental set-up

conv+LHN: same as operational set-up but with:

- 20 members + deterministic run;
- 1h assimilation cycles.

conv+radar: same set-up as conv+LHN but replacing LHN with direct assimilation of reflectivity volumes. Only radars depicted with a solid circle are employed. We use

- observation error of 10 dBZ for all data;
- superobbing at 10 km;
- 5 dBZ threshold on reflectivities;
- for each radar, only the reflectivity volume closest to analysis time is assimilated.



Differences between LHN and reflectivity datasets

Strictly speaking, since we are not employing the same radars in conv+LHN and conv+radar, the results provided here does not show a comparison between LHN and the assimilation of reflectivity volumes but simply between **OUR** implementation of LHN and **OUR** implementation of the assimilation of reflectivity volumes. However:

- The areal coverage of the 2 datasets is very similar. Some differences can be observed over the sea or neighboring countries which are **not considered for forecast precipitation verification.**
- There are very few cases in which part of reflectivity data are not available to us while precipitation field for LHN derived from same radars or neighboring radar are available. In such cases, **we excluded the "problematic" regions from verification**.

Overall, it is reasonable to consider this comparison as a comparison between the two schemes (LHN vs. direct assimilation of reflectivity volumes), even if it should be considered that **LHN is likely to be advantaged in our verification scores.**

Experimental set-up (2)

Among **conv+radar** experiments, we performed 3 experiments with different EMVORADO configurations:

- **conv+radar_Ray**: Rayleigh scattering
- **conv+radar_Mie**: Mie scattering
- **conv+radar_Mieatt**: Mie scattering + attenuation

Case study

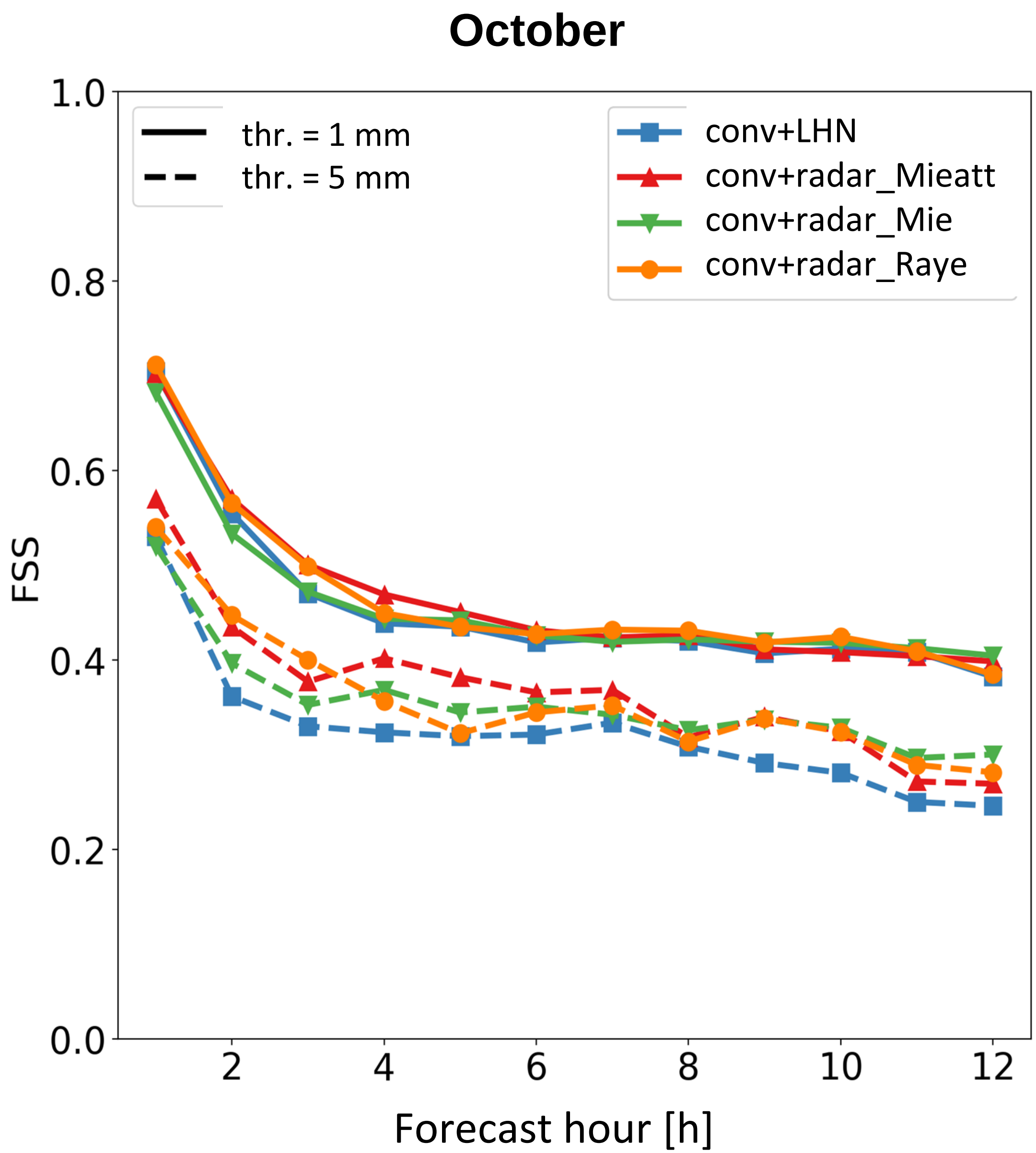
Event	Start	End	Type of event
September 2018	31/08 - 00UTC	09/09 - 00UTC	thunderstorms
October 2018	30/09 - 15UTC	14/10 - 00UTC	organized thunderstorms
Novembre 2018	26/10 - 12UTC	11/11 - 00UTC	Stratiform precipitaton

Each 3 hours, **deterministic analyses** generated by all experiments are employed to perform a 12h deterministic forecast. Therefore, we have approximately 72 forecasts for September 2018, 106 for October 2018 and 123 for November 2018.

Verification of forecast precipitation with FSS

- Domain covered with boxes: 0.2 X 0.2 degrees
- Fixed boxes: we have verified that using fixed boxes instead of moving boxes does not affect significantly the score, since we are considering a large number of forecasts.
- Verification of hourly precipitations
- Verification of all the forecasts at the same forecast time
- Observations are hourly rainfall fields from the Italian radar composite adjusted by rain-gauges
- Only the Italian mainland is considered
- Events were defined by different precipitation thresholds

FSS: impact of the scattering scheme



All conv+radar experiments perform better than conv+LHN. Best scores are obtained with conv+radar_Mieatt configuration.

Quite surprising that conv+radar_Mieatt performs better than conv+radar_Mie since our observations are corrected for attenuation. Why? Are we correcting some kind of bias?

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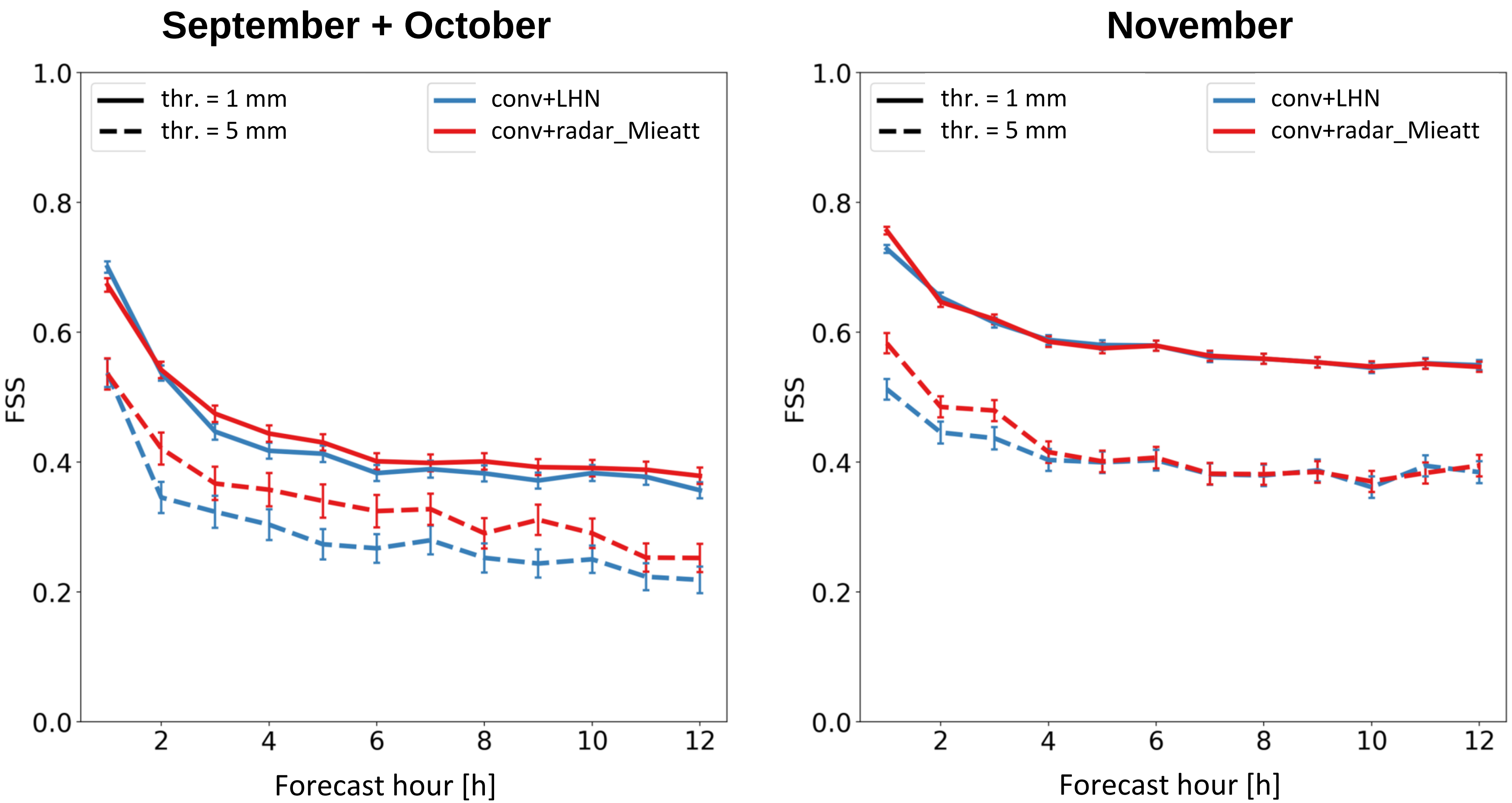
FSS: LHN vs radar volumes assimilation



Vertical bars represent 95 levels of confidence computed with bootstrap

Verification of forecast precipitation with dichotomous scores

Verification of forecast precipitation is performed over areas, defined by the Civil Protection Department, which are homogeneous with respect to the type and intensity of hydrometeorological phenomena that may occur and their effects on the territory.

- **Rain gauges as observations** (~3000 each hour);
- all cases considered together;
- hourly precipitation;
- different threshold for average and maximum precipitation .

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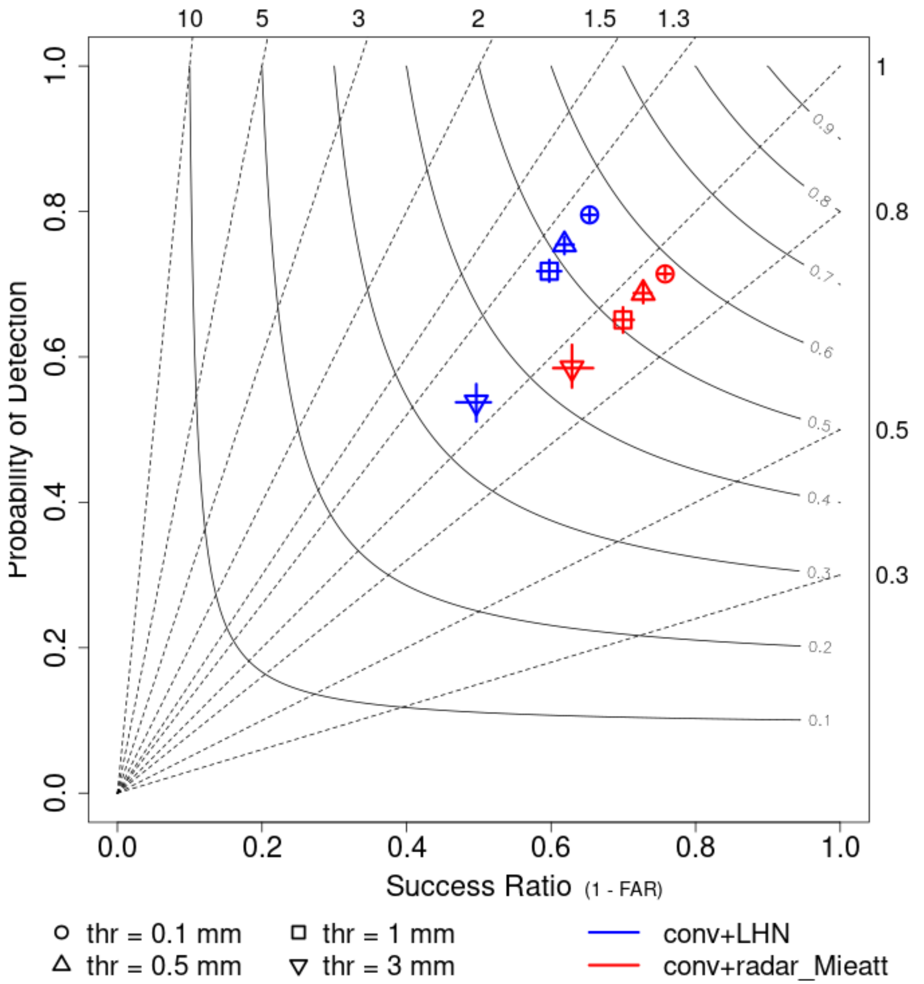
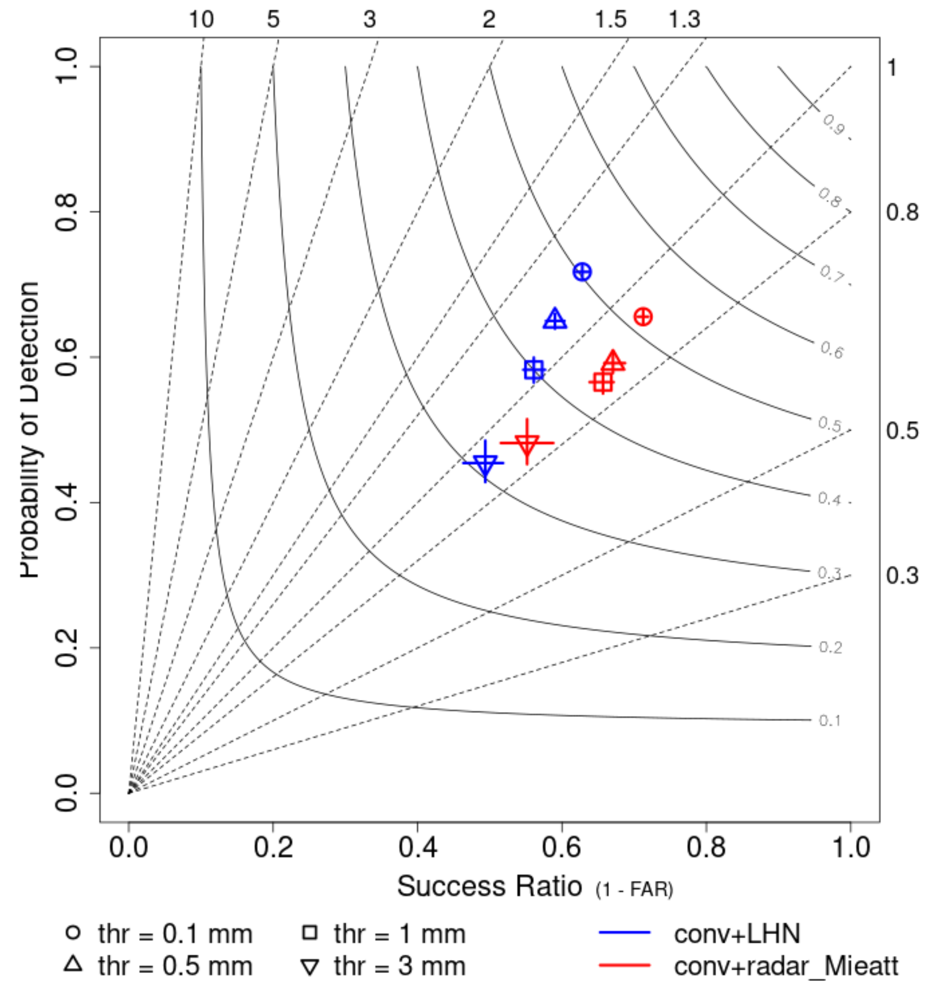
Performance diagram: average hourly precipitation

+1h



+2h



Bias = straight dashed lines
Threat score (TS) = labelled ”hyperbolic” solid lines

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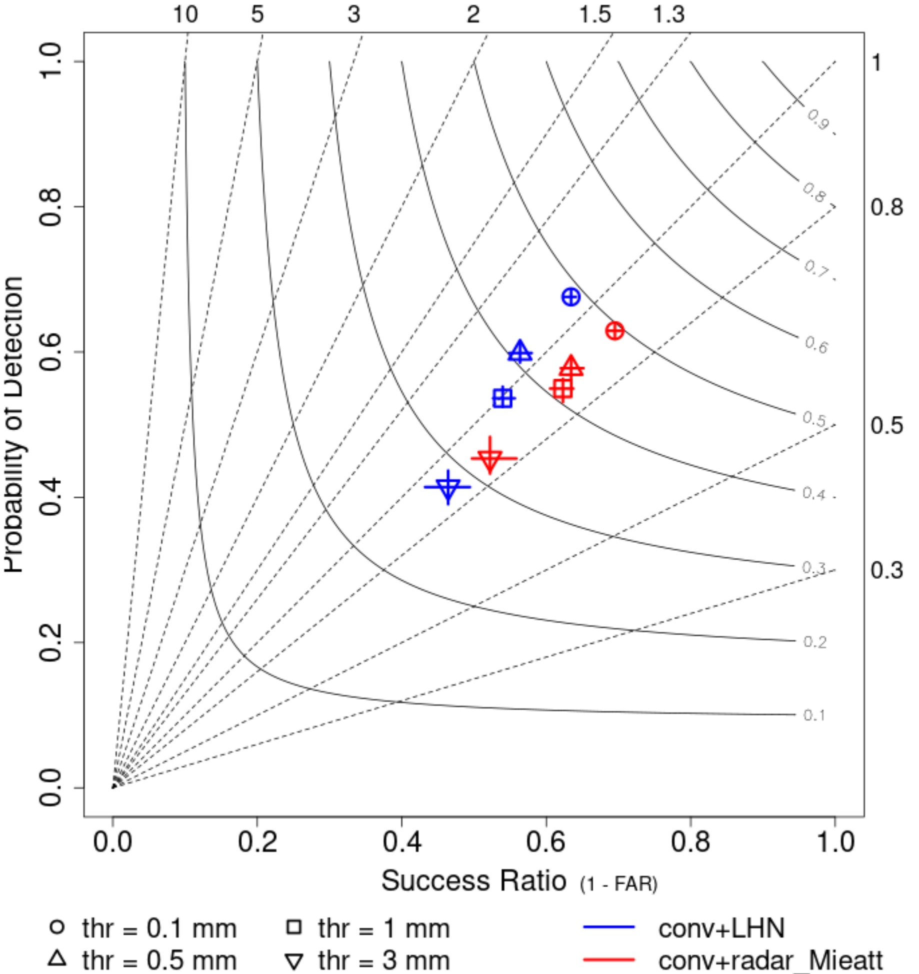
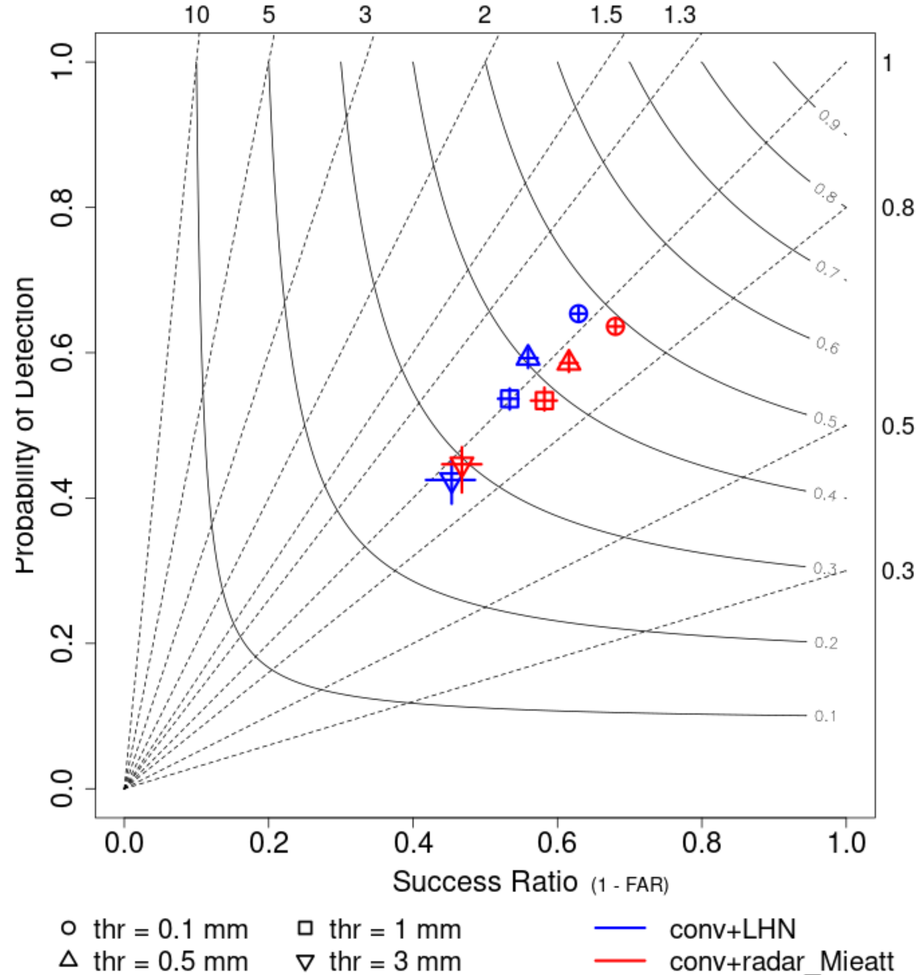
Performance diagram: average hourly precipitation

+3h



+4h



Bias = straight dashed lines
Threat score (TS) = labelled «parabolic» solid lines

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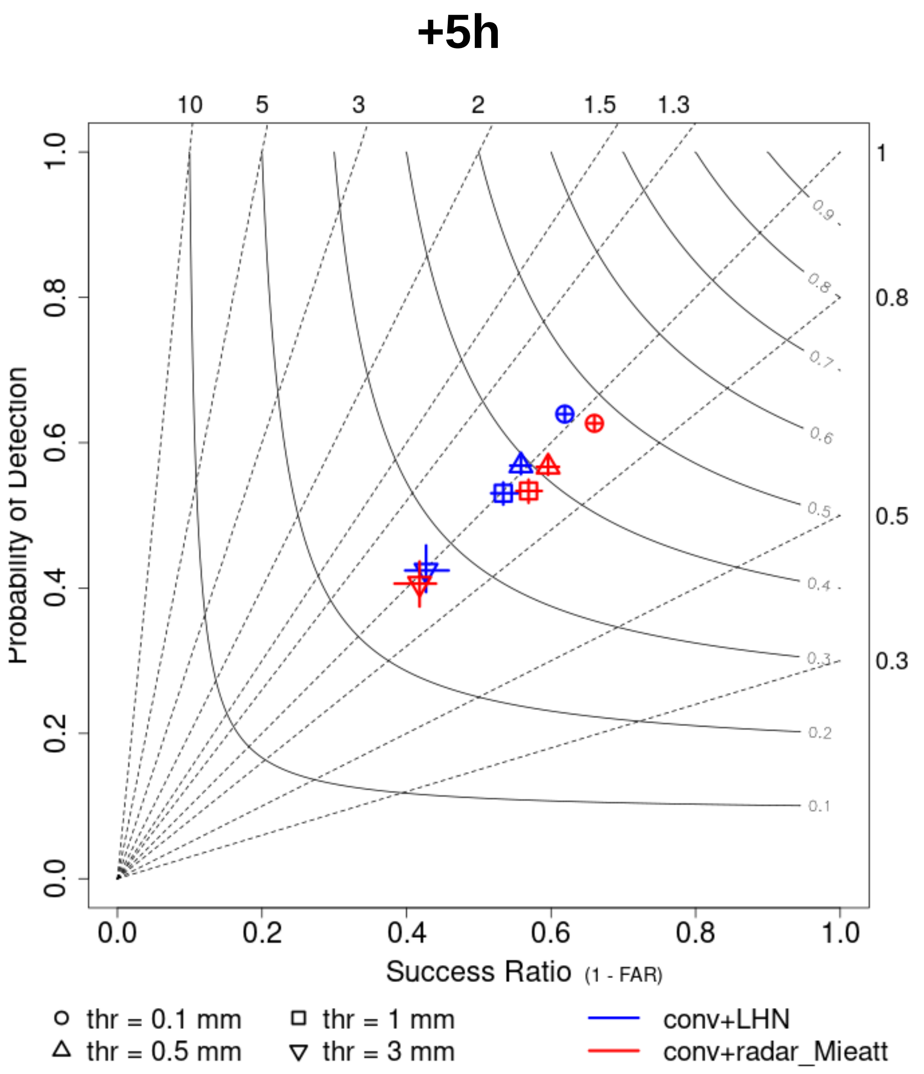
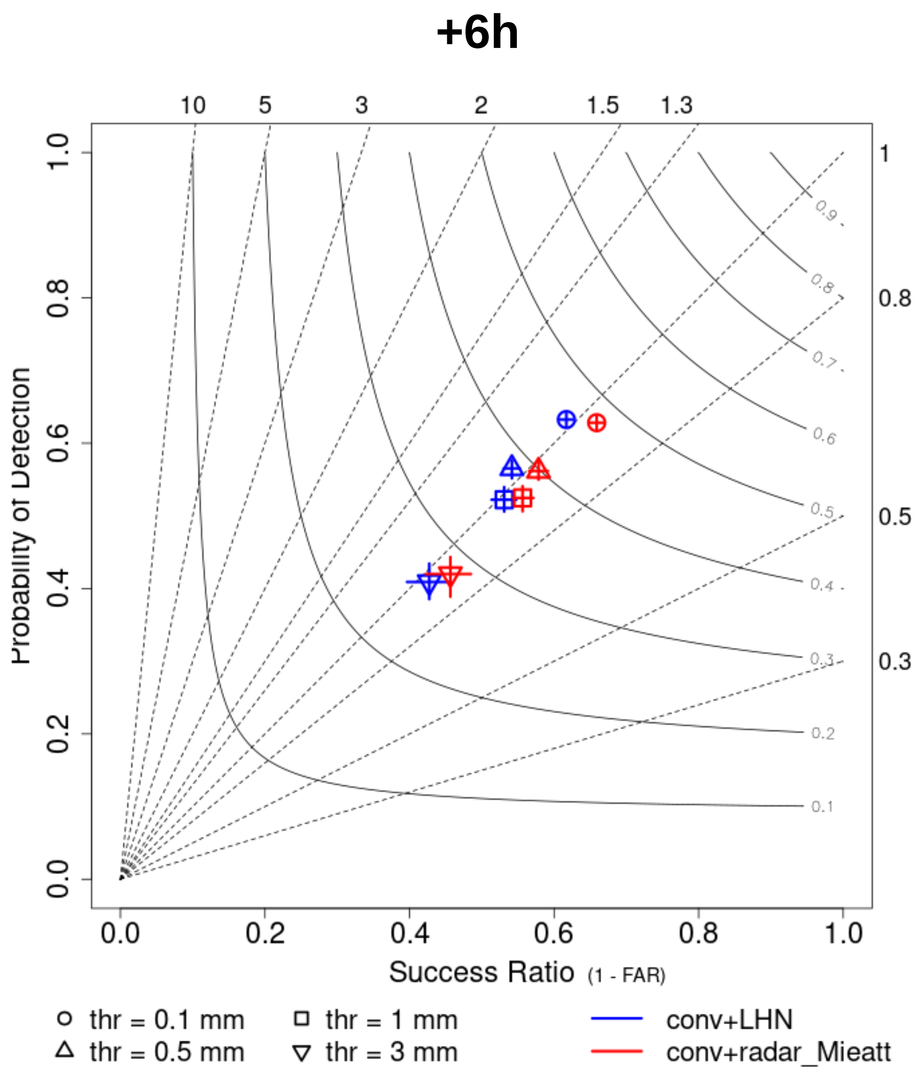
Performance diagram: average hourly precipitation





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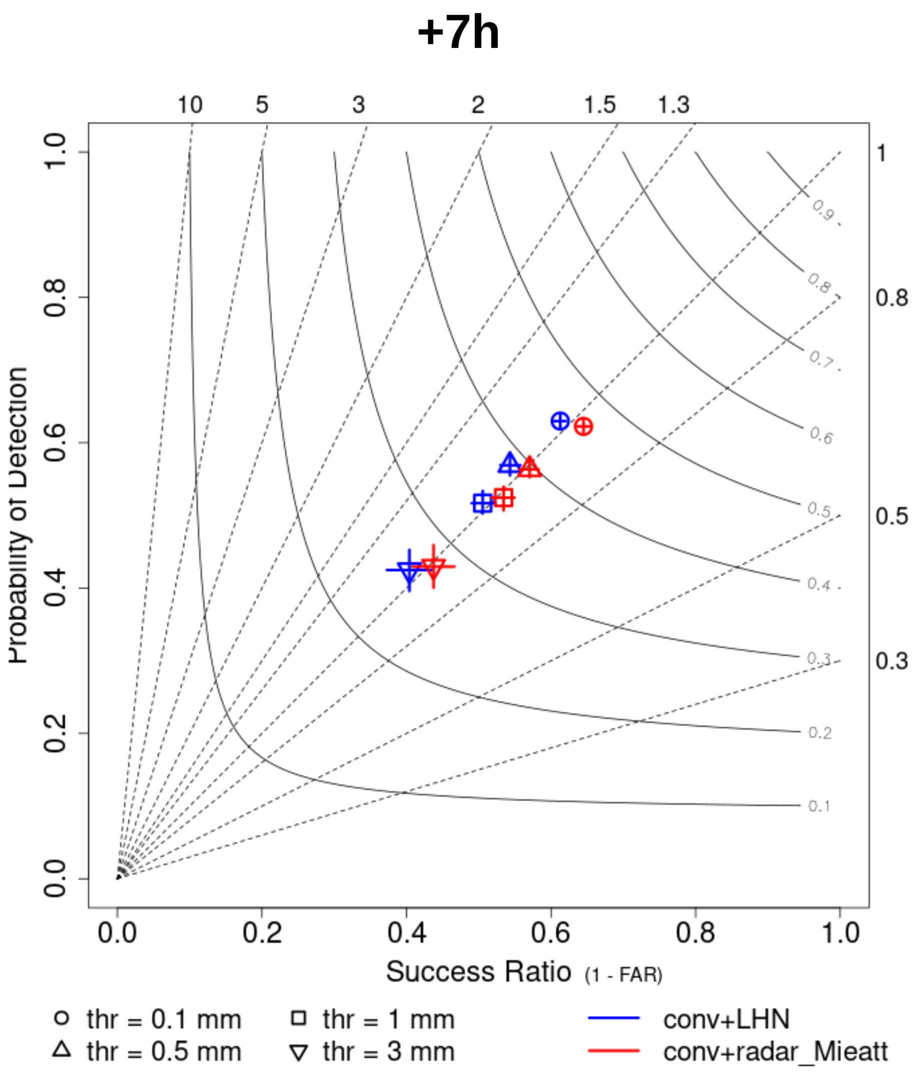
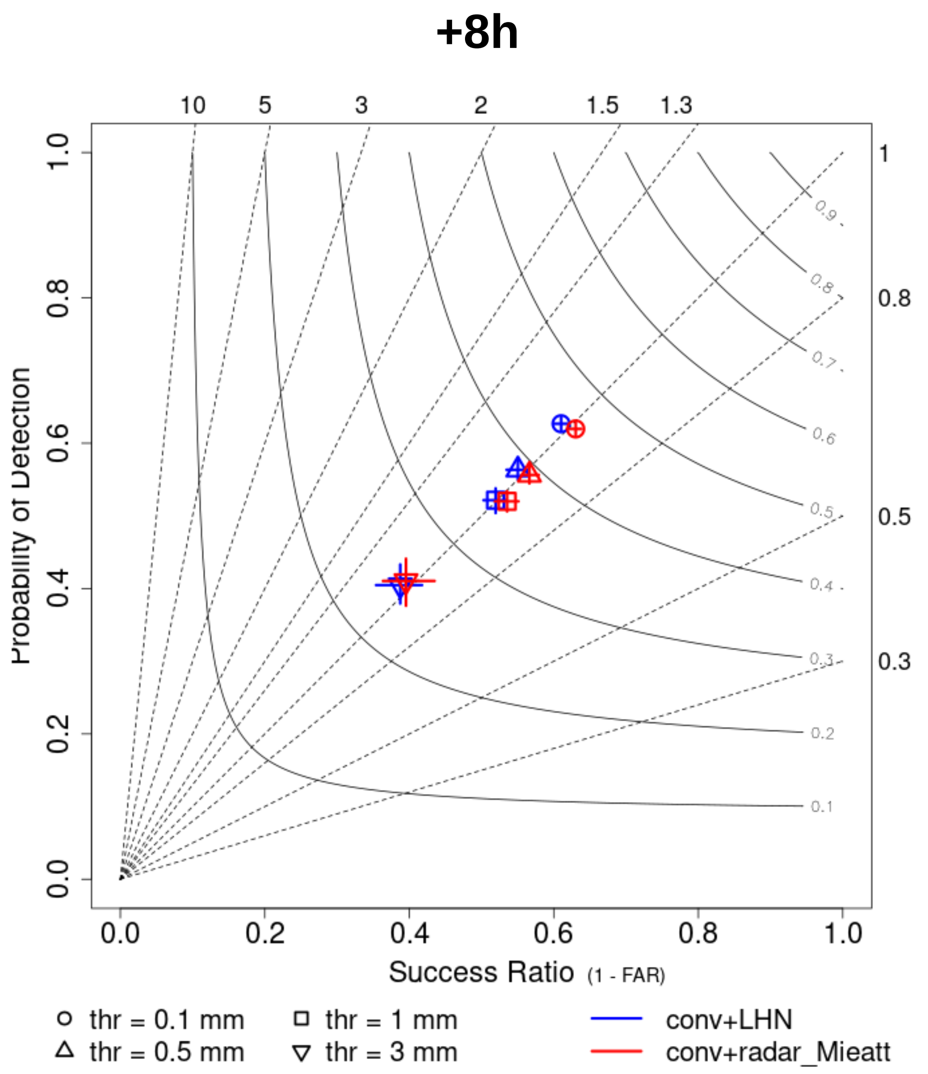
Performance diagram: average hourly precipitation





Bias = straight dashed lines
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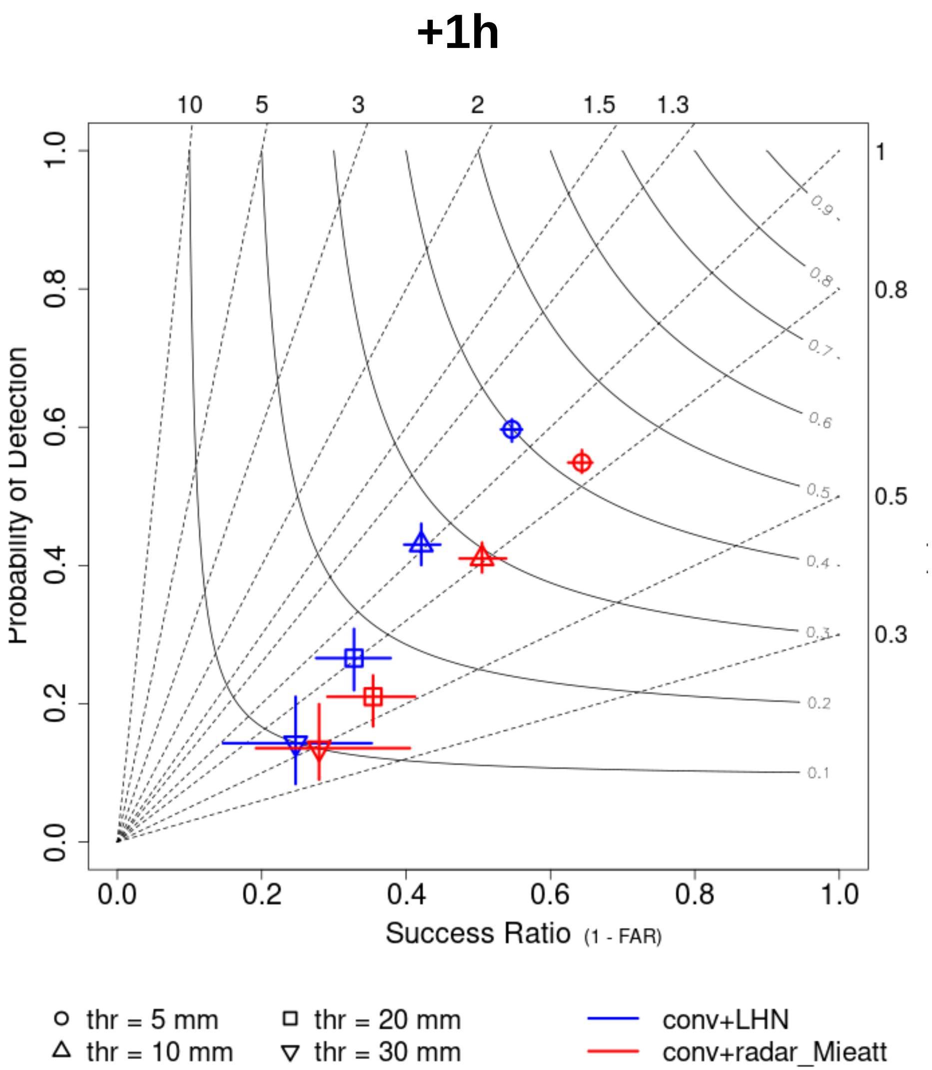
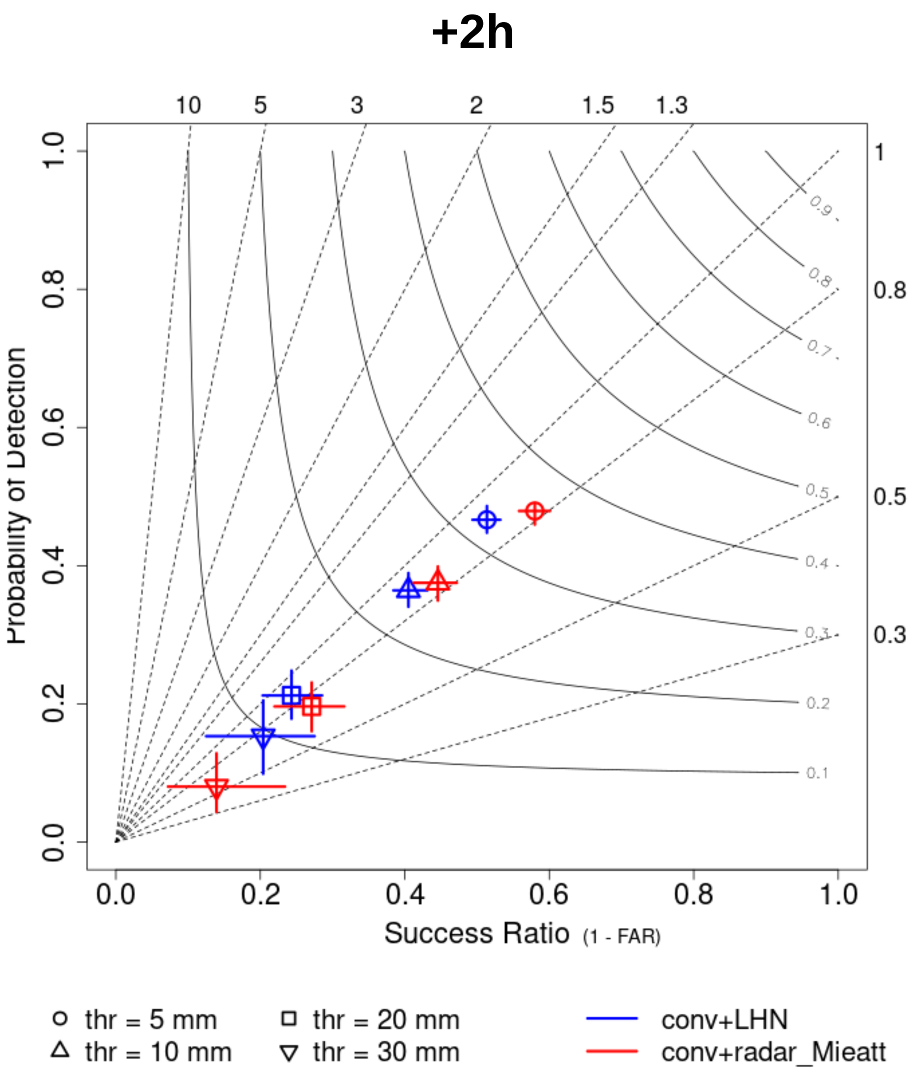
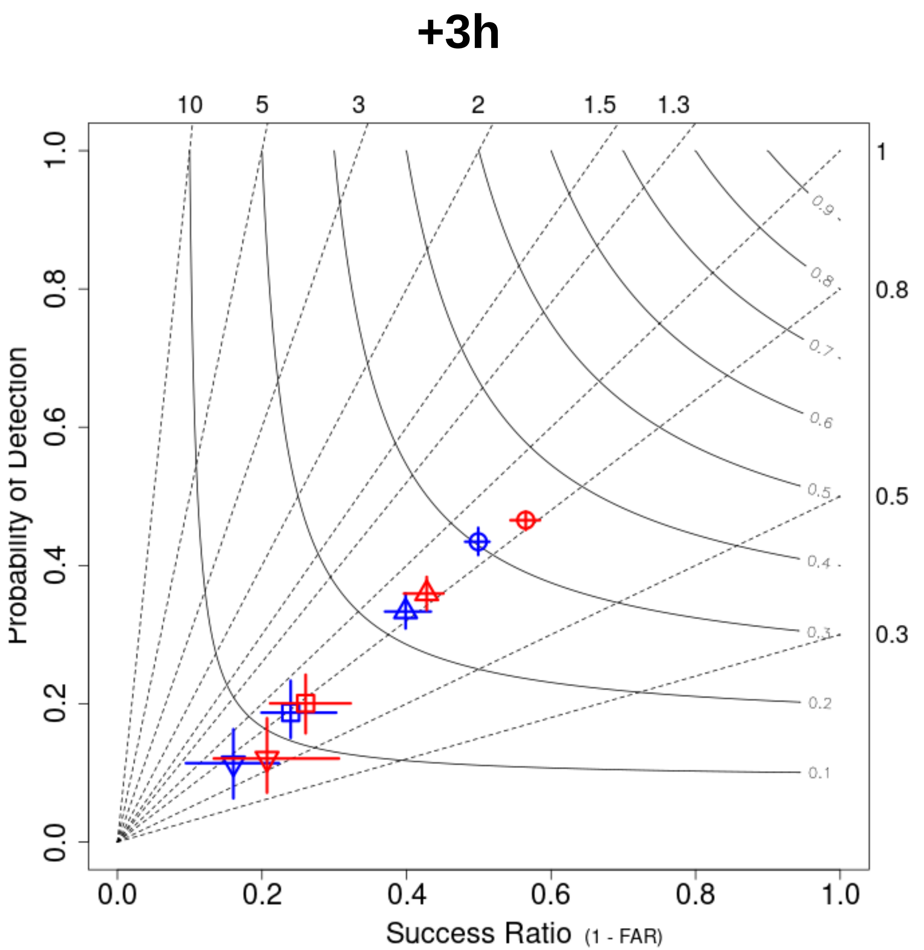
Performance diagram: maximum hourly precipitation

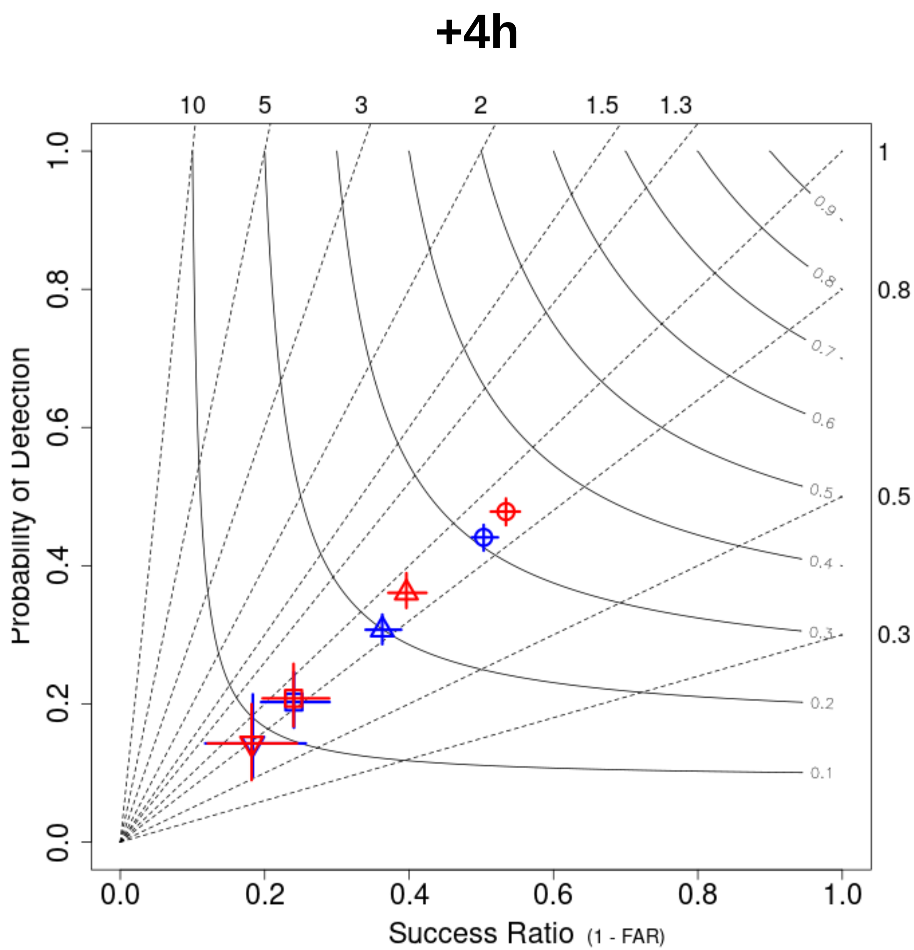




Bias = straight dashed lines
Threat score (TS) = labelled «parabolic» solid lines

Performance diagram: maximum hourly precipitation





○ thr = 5 mm
△ thr = 10 mm
□ thr = 20 mm
▽ thr = 30 mm
conv+LHN
conv+radar_Mieatt

○ thr = 5 mm
△ thr = 10 mm
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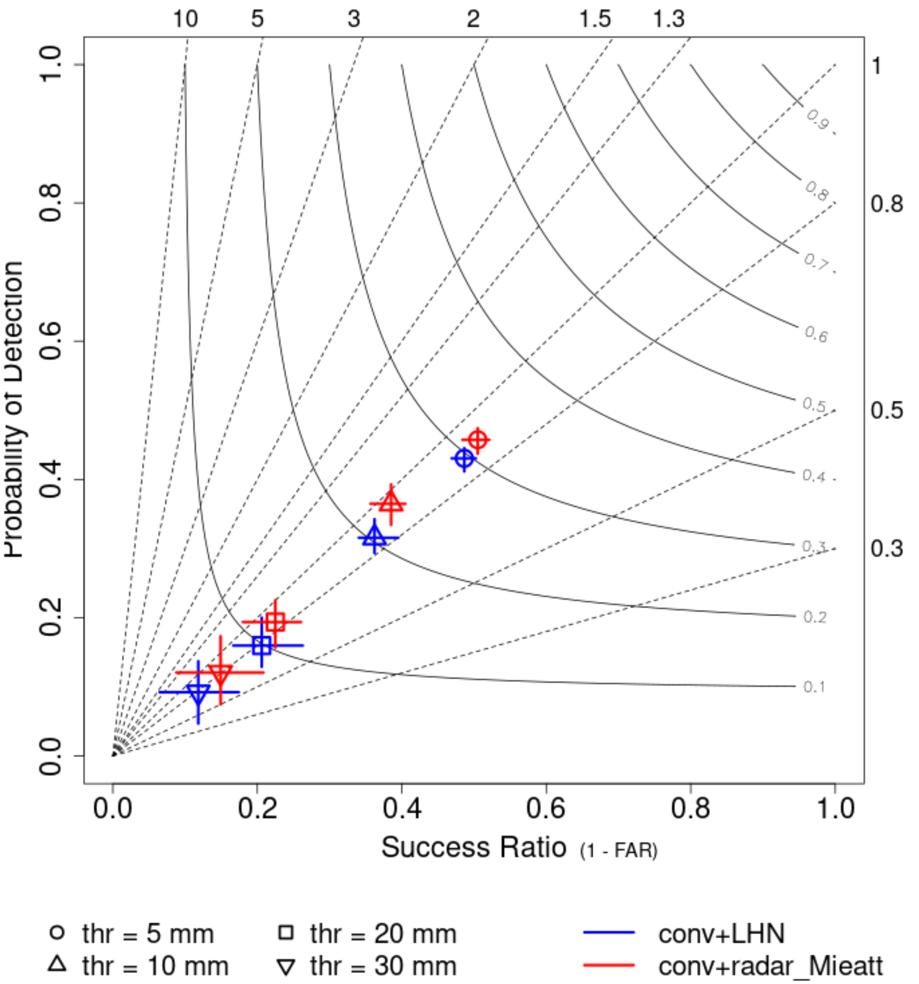
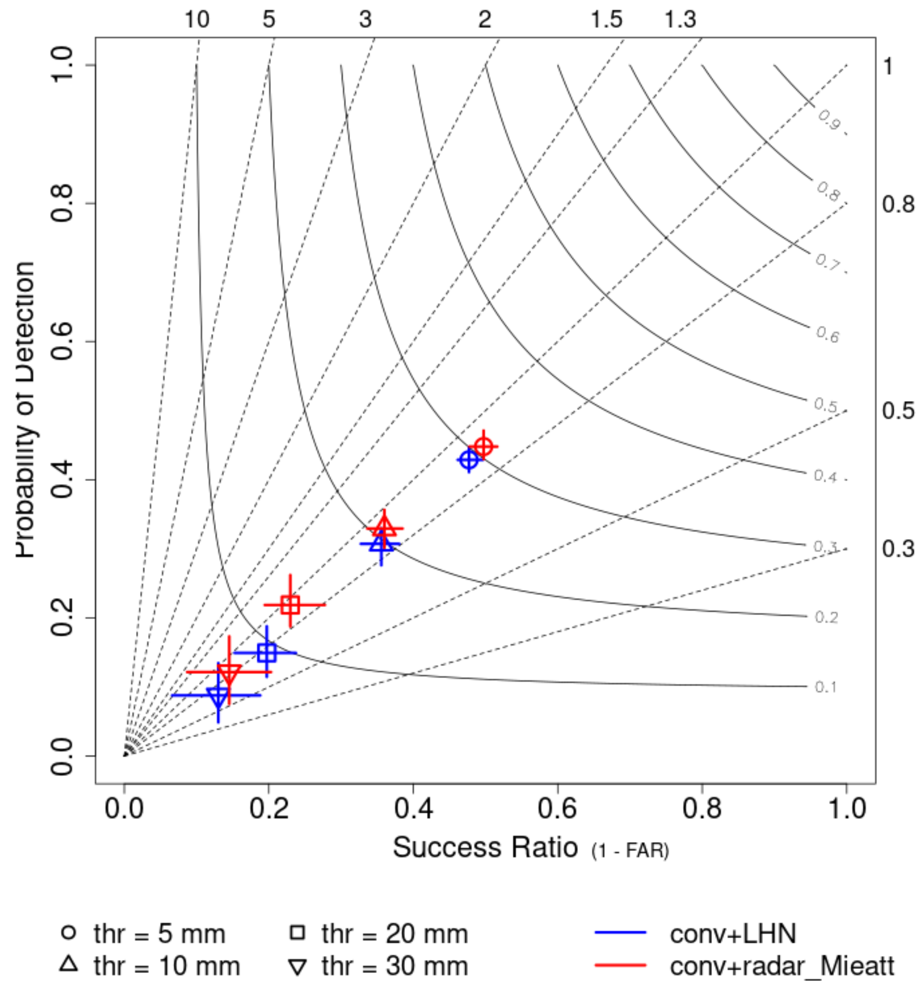
Performance diagram: maximum hourly precipitation

+5h



+6h



Bias = straight dashed lines
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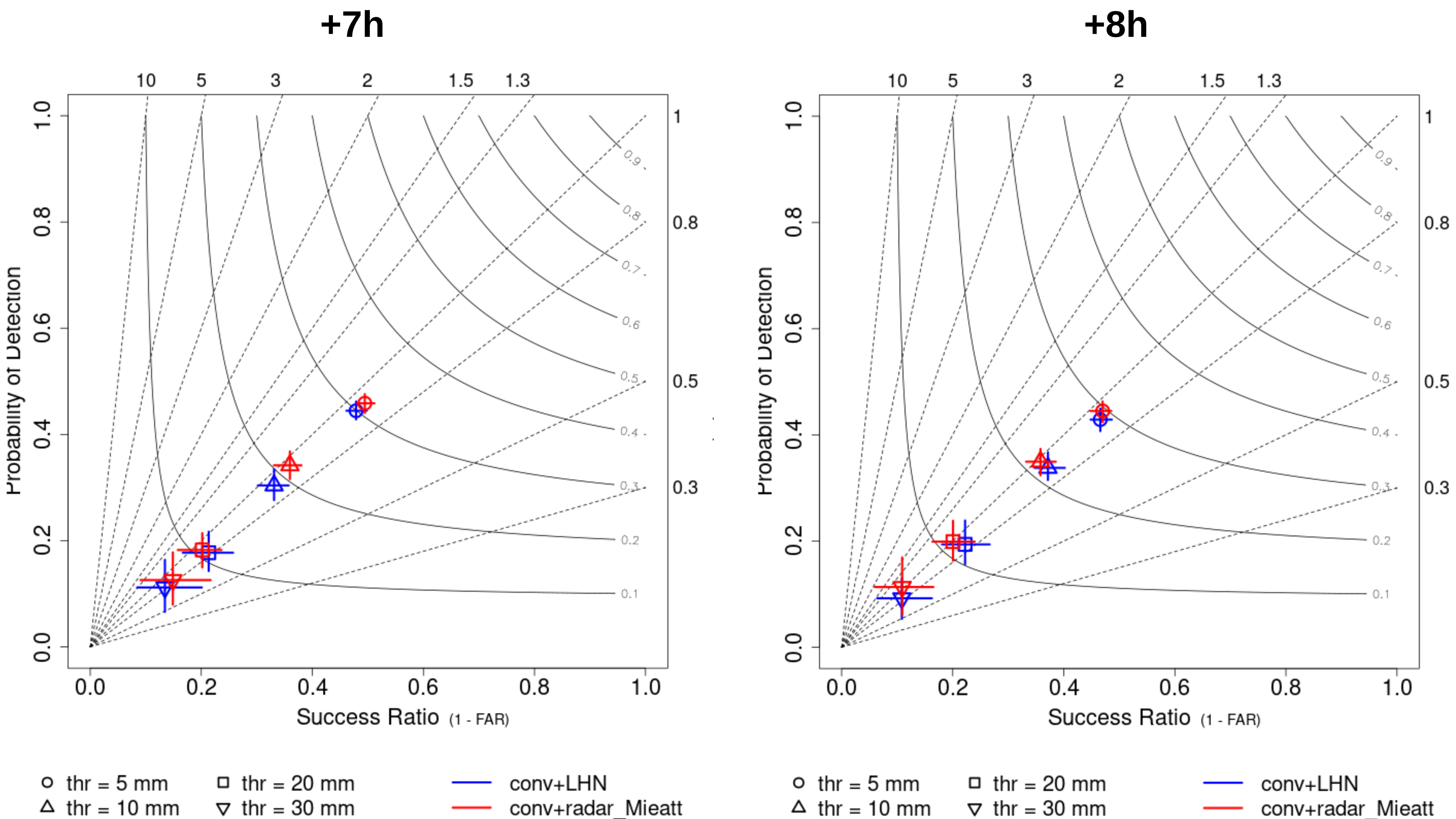
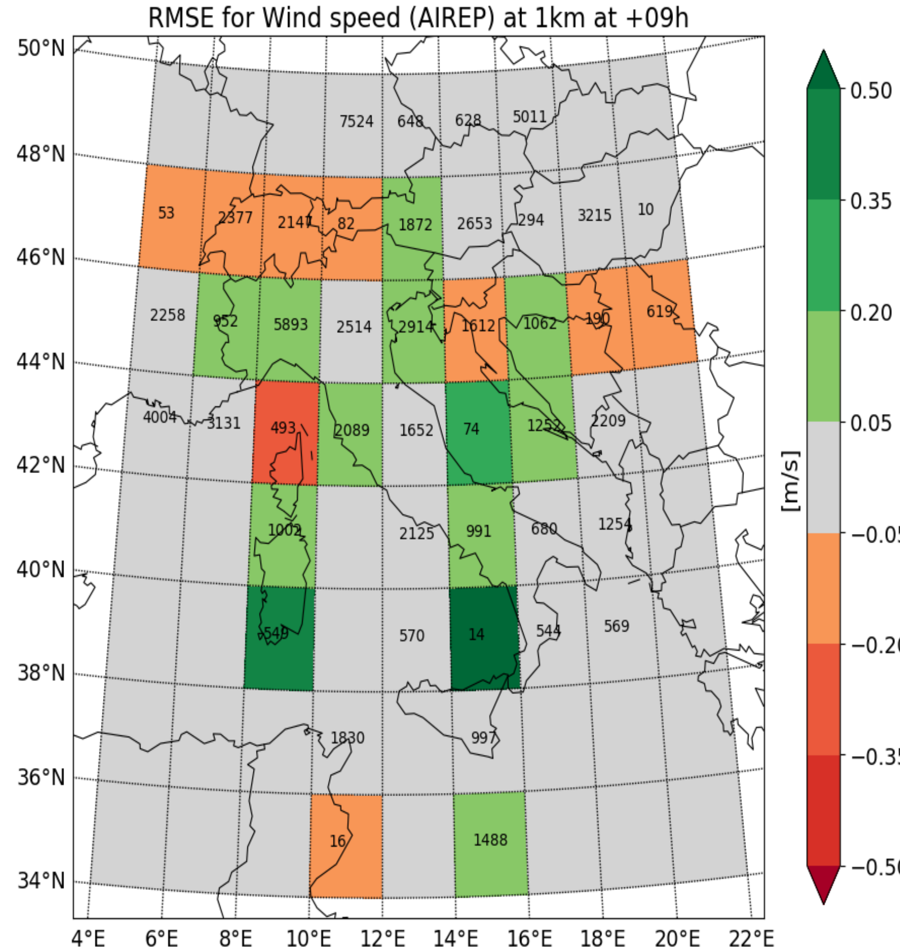
Performance diagram: maximum hourly precipitation



Bias = straight dashed lines
Threat score (TS) = labelled «parabolic» solid lines

Verification of T, RH and WIND velocity over all events

- Domain is divided into horizontal boxes of 2° x 2° and vertical layers.
- RMSE is computed for each horizontal box at each vertical layer and at a specific forecast time interval, provided that ther are at least 100 observations
- For each forecast time interval and each vertical layer, the average of the RMSE values over all horizontal boxes is computed.
- Calculation of the difference between RMSE of conv+LHN and RMSE of conv+radar_Mieatt.



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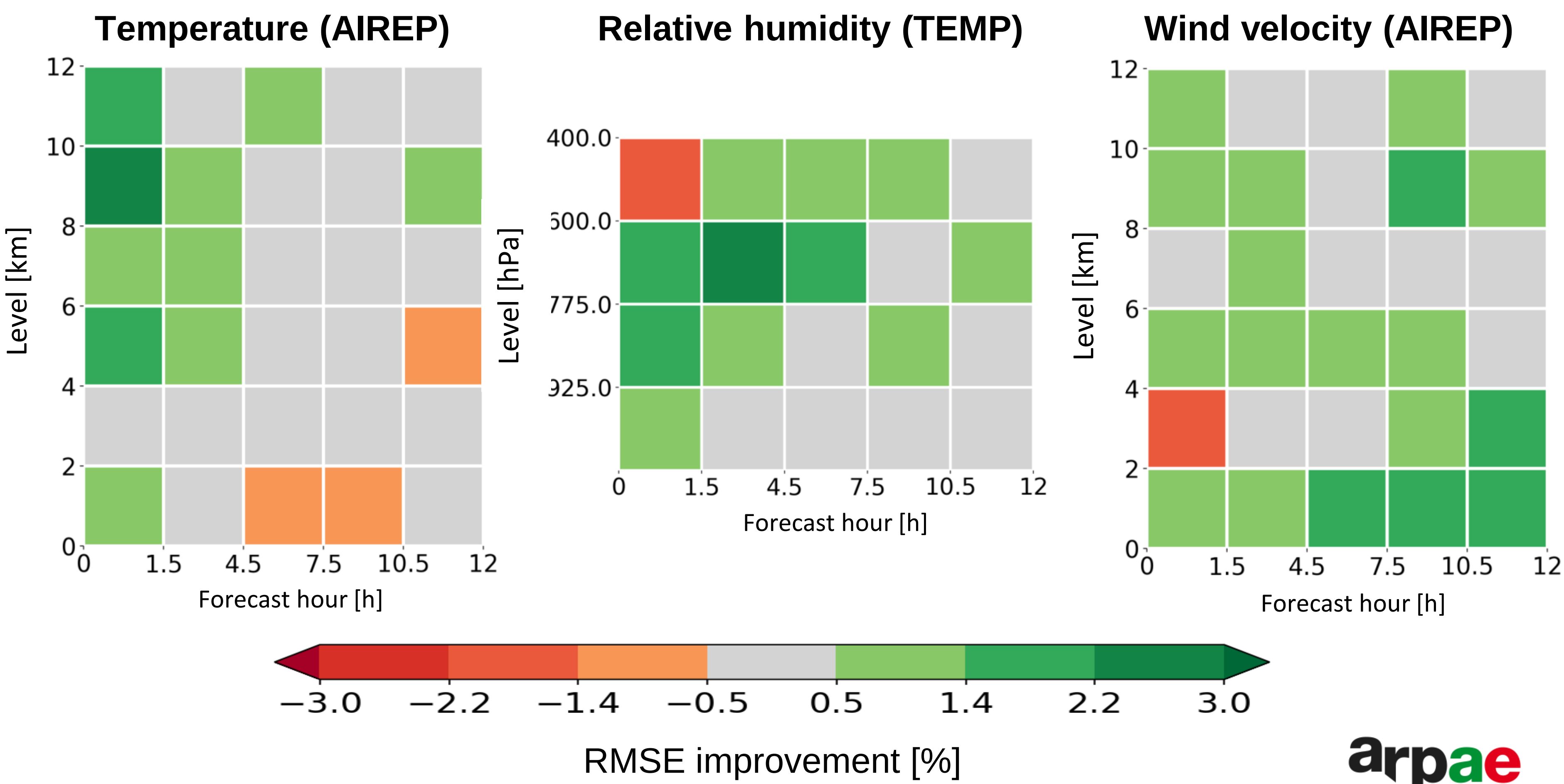
Verification of T, RH and WIND velocity over all events

Difference between RMSE of conv+LHN and RMSE of conv+radar_Mieatt (positive values indicate an improvement of RMSE for conv+radar_Mieatt compared to conv+LHN).



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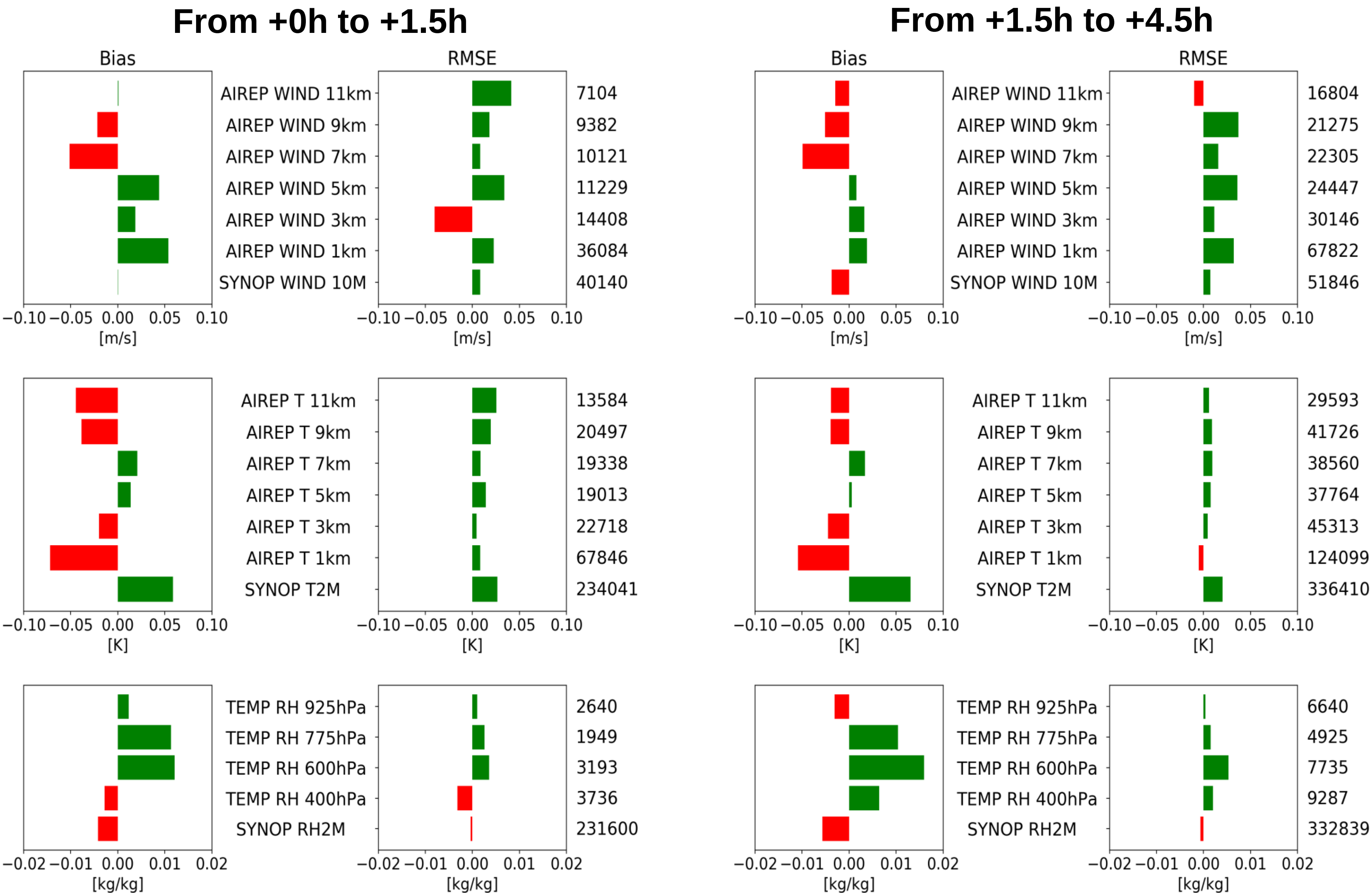
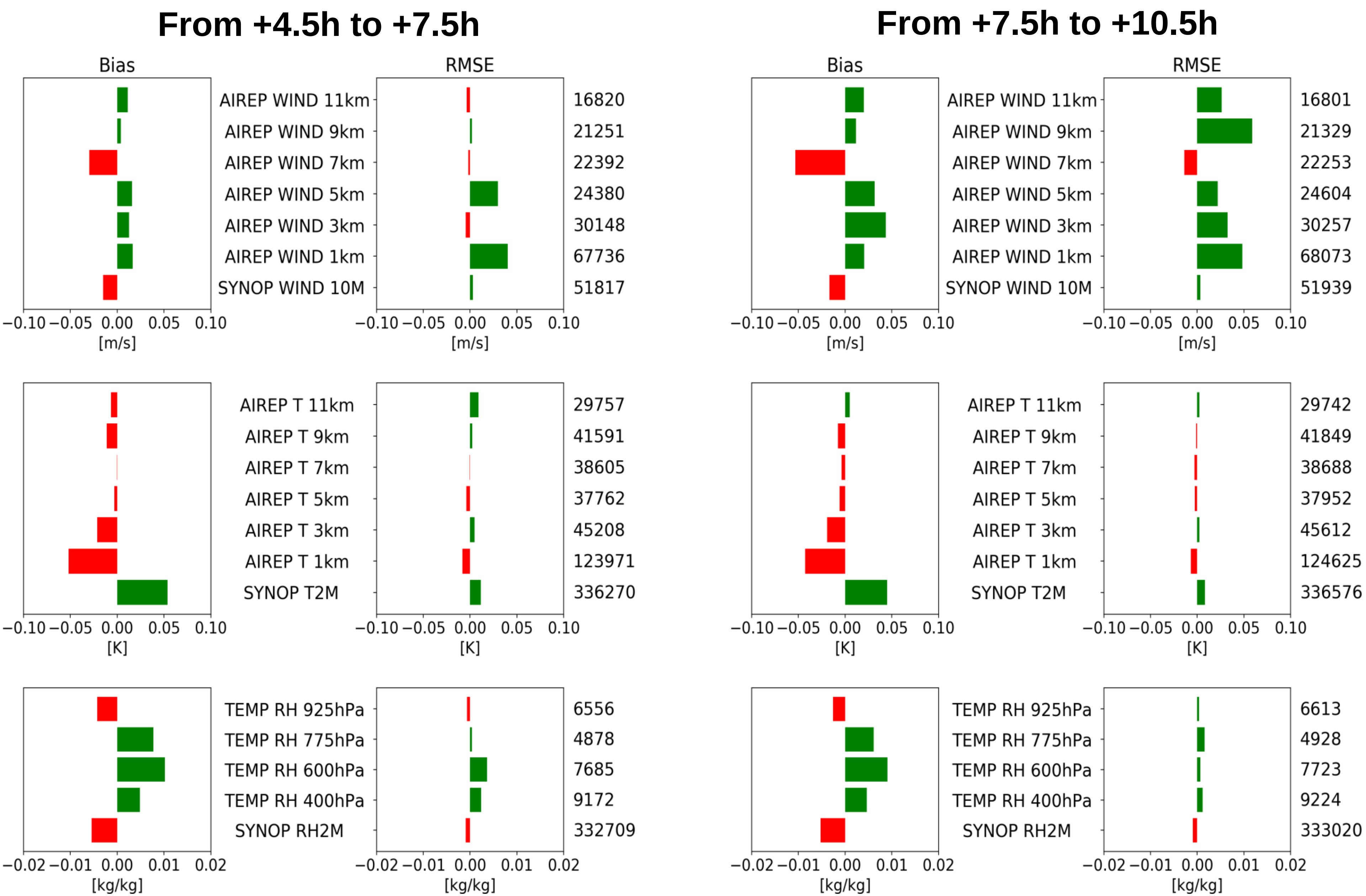
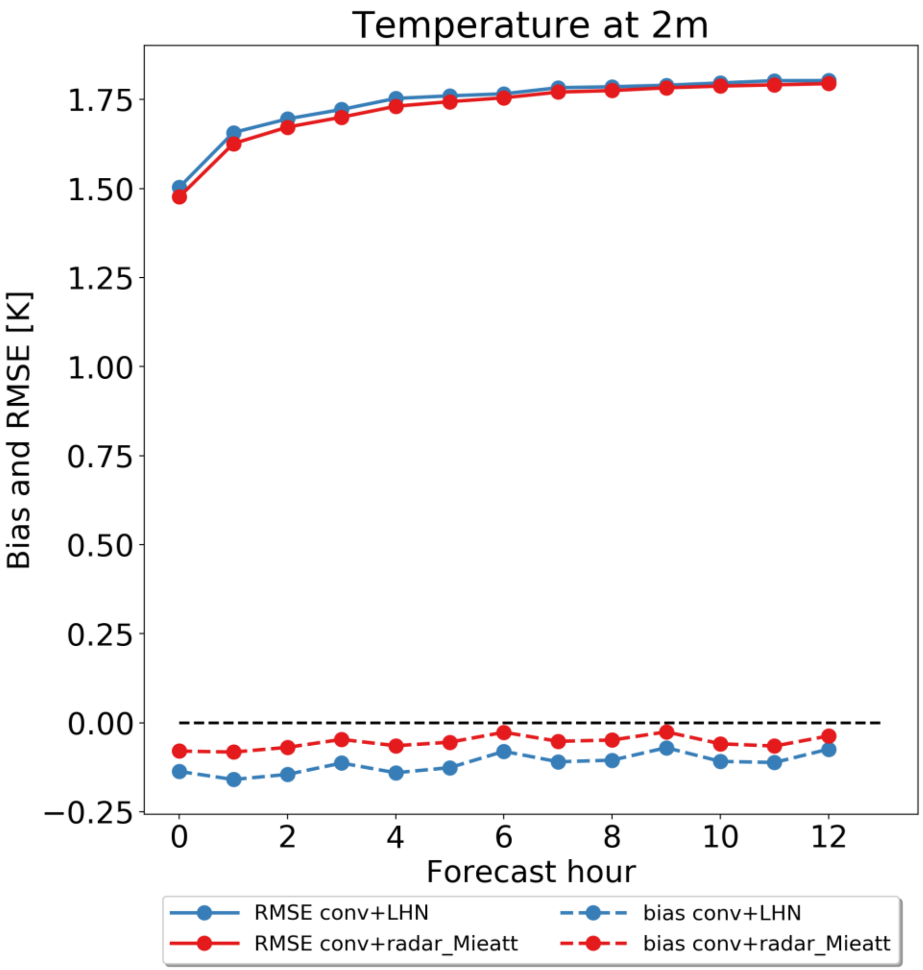
Verification of T, RH and WIND velocity over all events

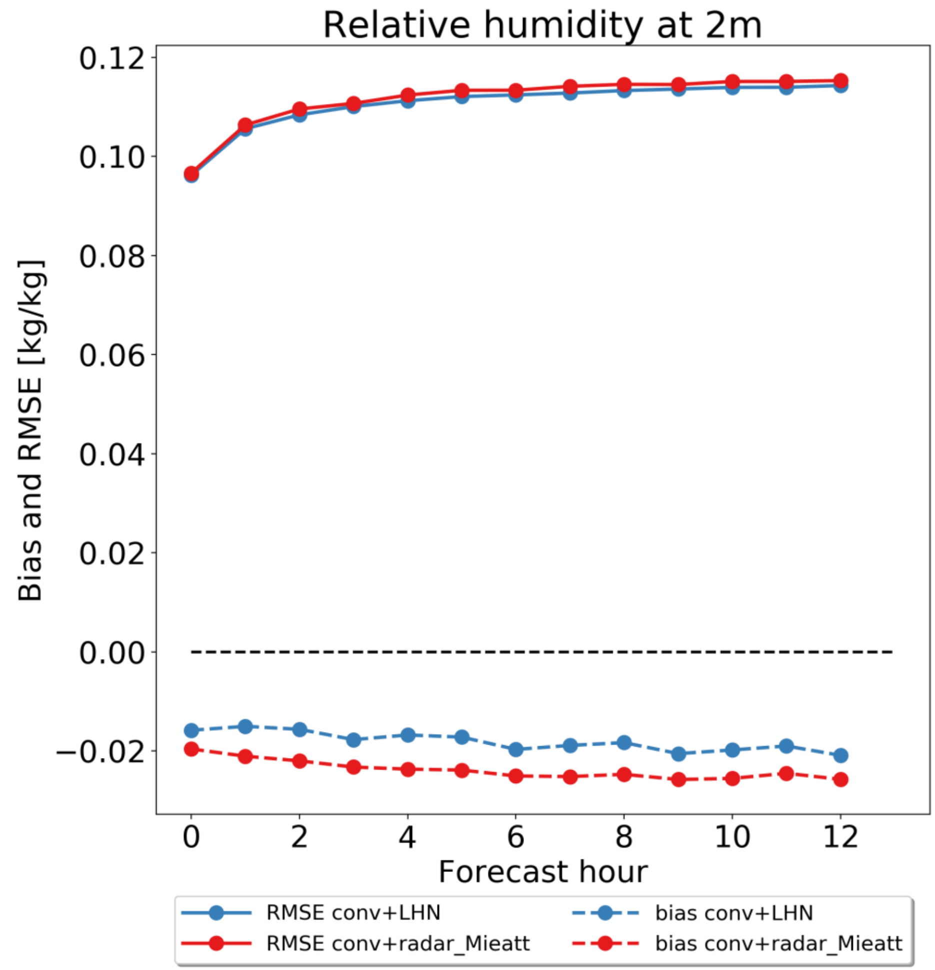


Verification of T, RH and WIND velocity over all events

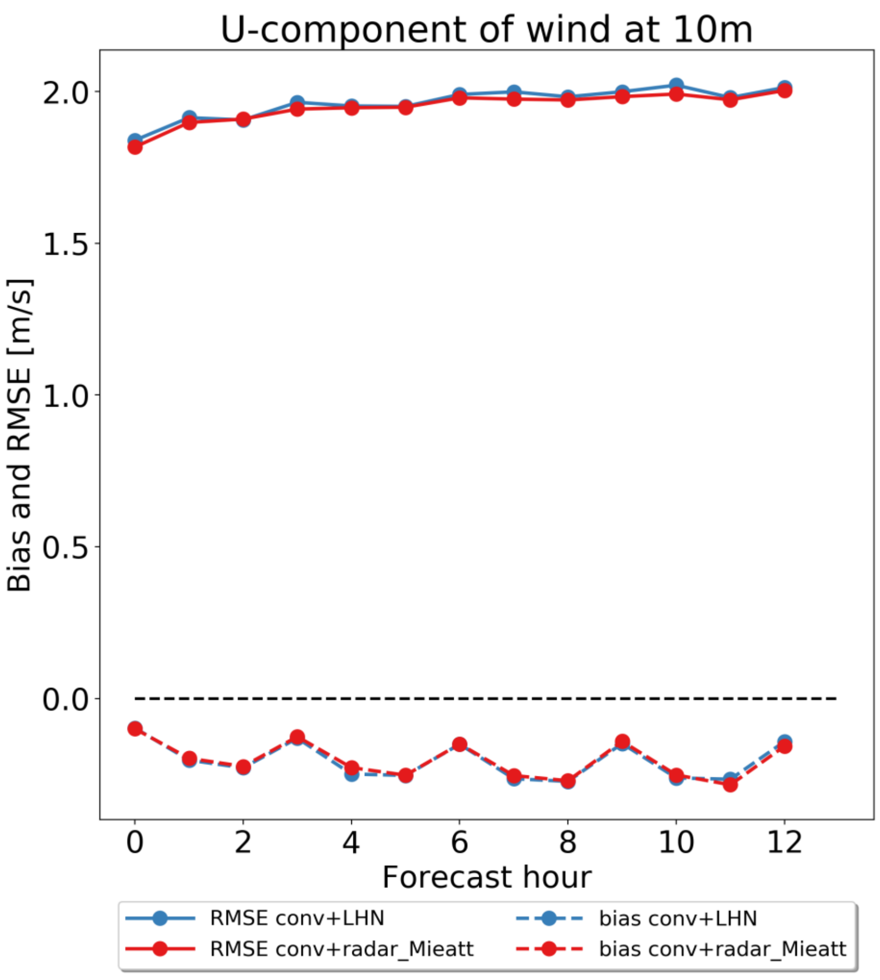


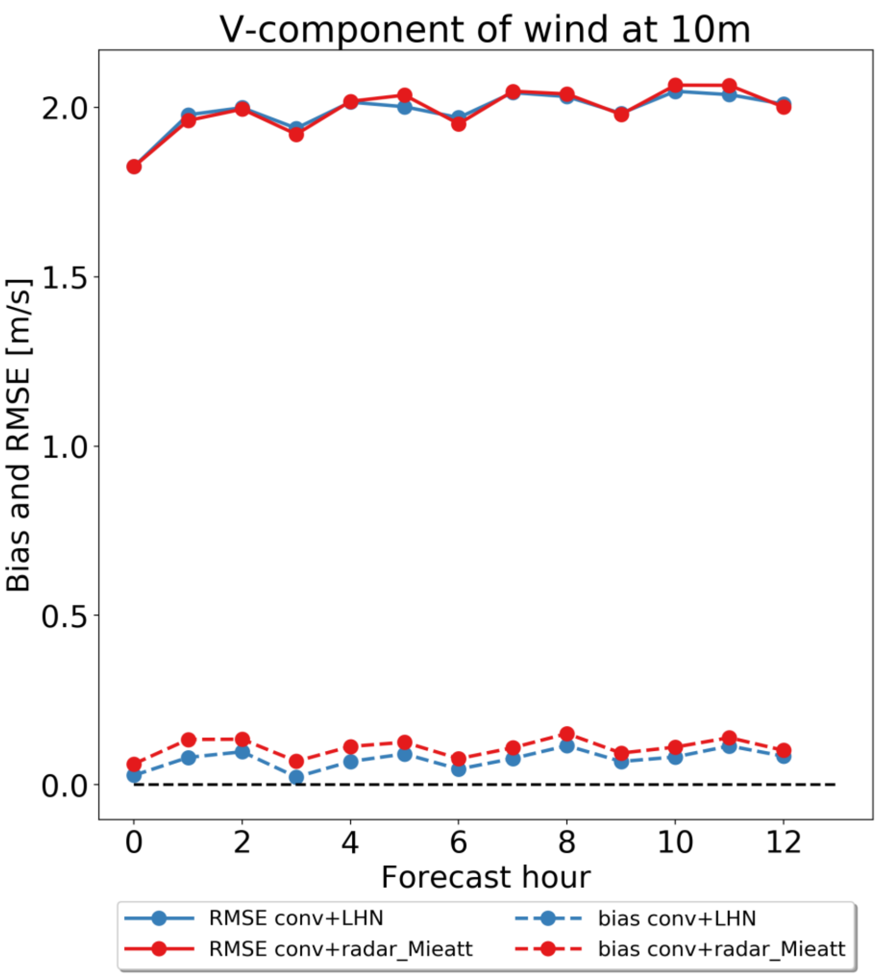
Forecast verification with SYNOP





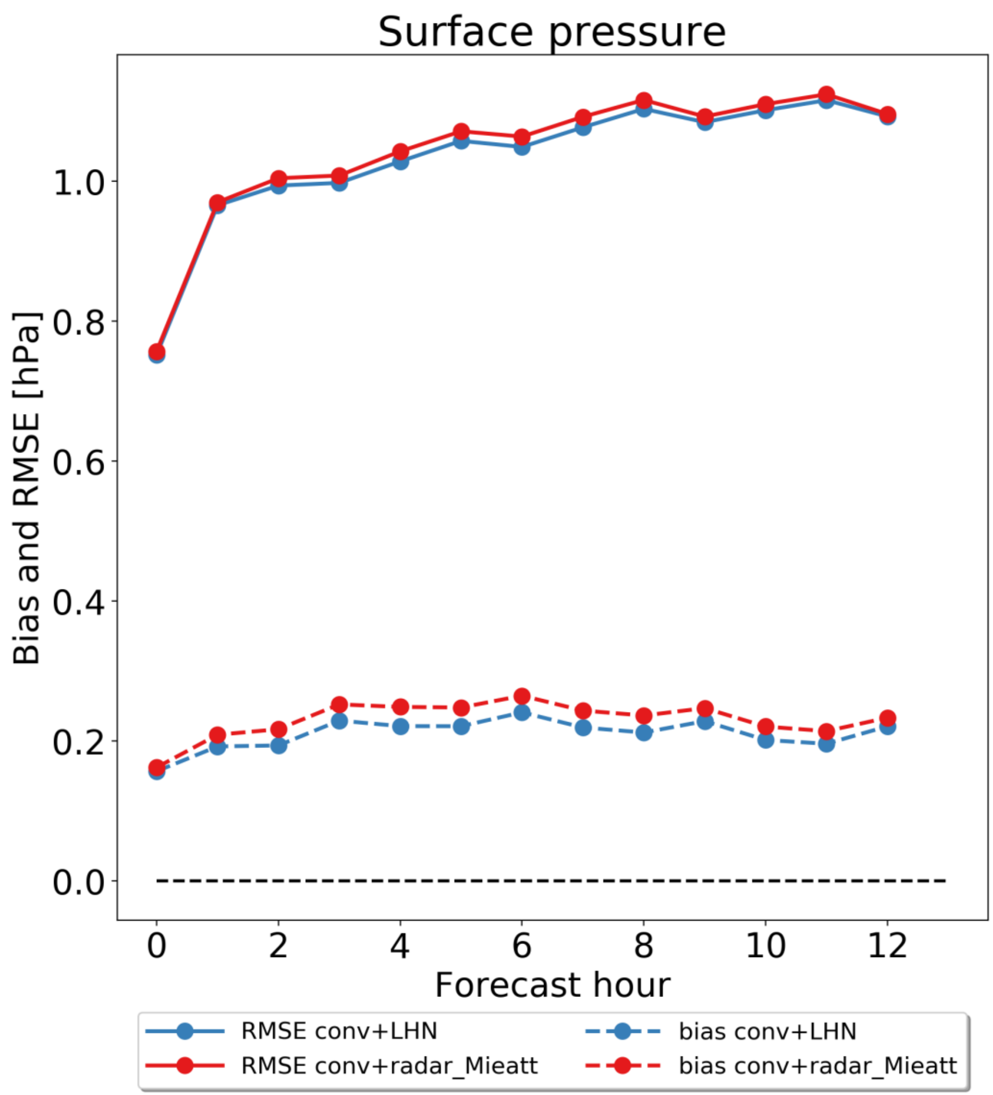
Forecast verification with SYNOP





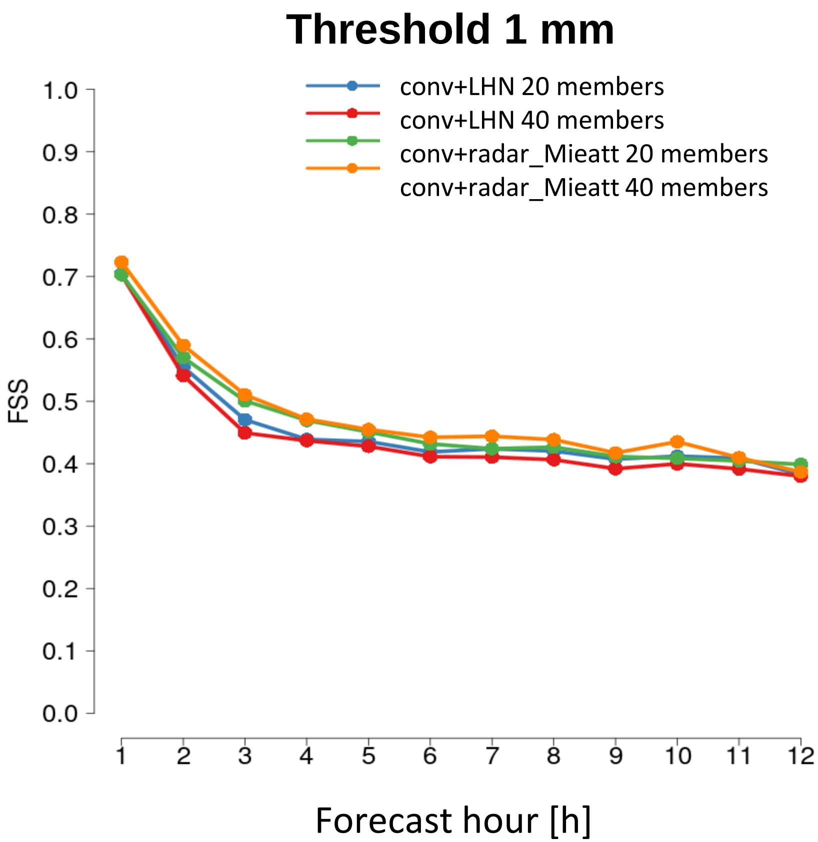
Note that at 00, 03, 06… UTC there are much more SYNOP observations than at 01, 02, 04, 05… UTC

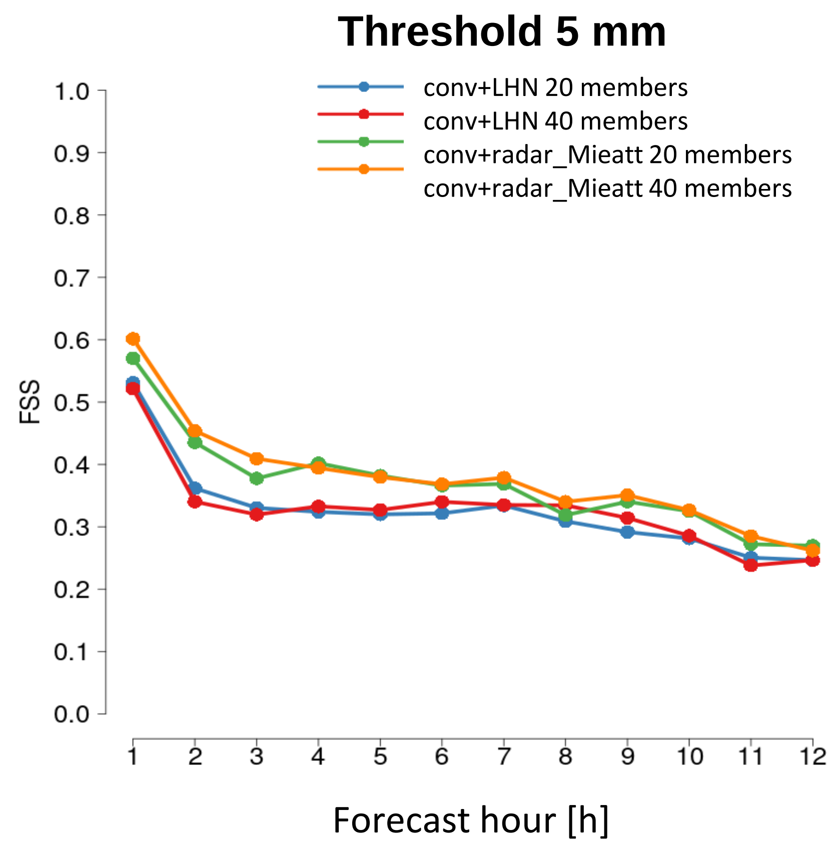
Forecast verification with SYNOP



Impact of ensemble size (FSS verification)

The October event is considered employing a 20 members ensemble (as for all previous experiments) and a 40 members ensemble, in which member 21-40 are generated using 3h older boundary conditions.





For conv+LHN results obtained with a 20 or 40 members ensemble are similar, while for conv+radar a slight improvement in obtained when employing a 40 members ensemble compared to a 20-members ensemble.

Conclusions

The assimilation of reflectivity volumes compared to LHN provides

- a statistically significant positive impact on forecast precipitation, especially when considering heavy rainfall and non-organized precipitation;
- a general positive impact on RMSE for forecast values of T, RH, WIND while bias improves for RH, is substantially neutral for T and slightly degrades for WIND;
- A slight improvement in forecast T2M, a slight worsening in PS and a slight worsening in terms of bias for V10M and RH2M. The impact on U10M is substantially neutral.

A slight further improvement on the results may be observed when doubling the ensemble size from 20 to 40 members.

Problem: it is not clear why Mie_atten performs better than Mie.

Future plans

- further tests on the assimilation of reflectivity volumes on a spring case.
- further tests to better understand how the assimilation of reflectivity volumes may be improved
- implementation of the assimilation of reflectivity volumes in the operational KENDA set-up.
- possibly, first tests on the assimilation of radial winds over the Italian domain.

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