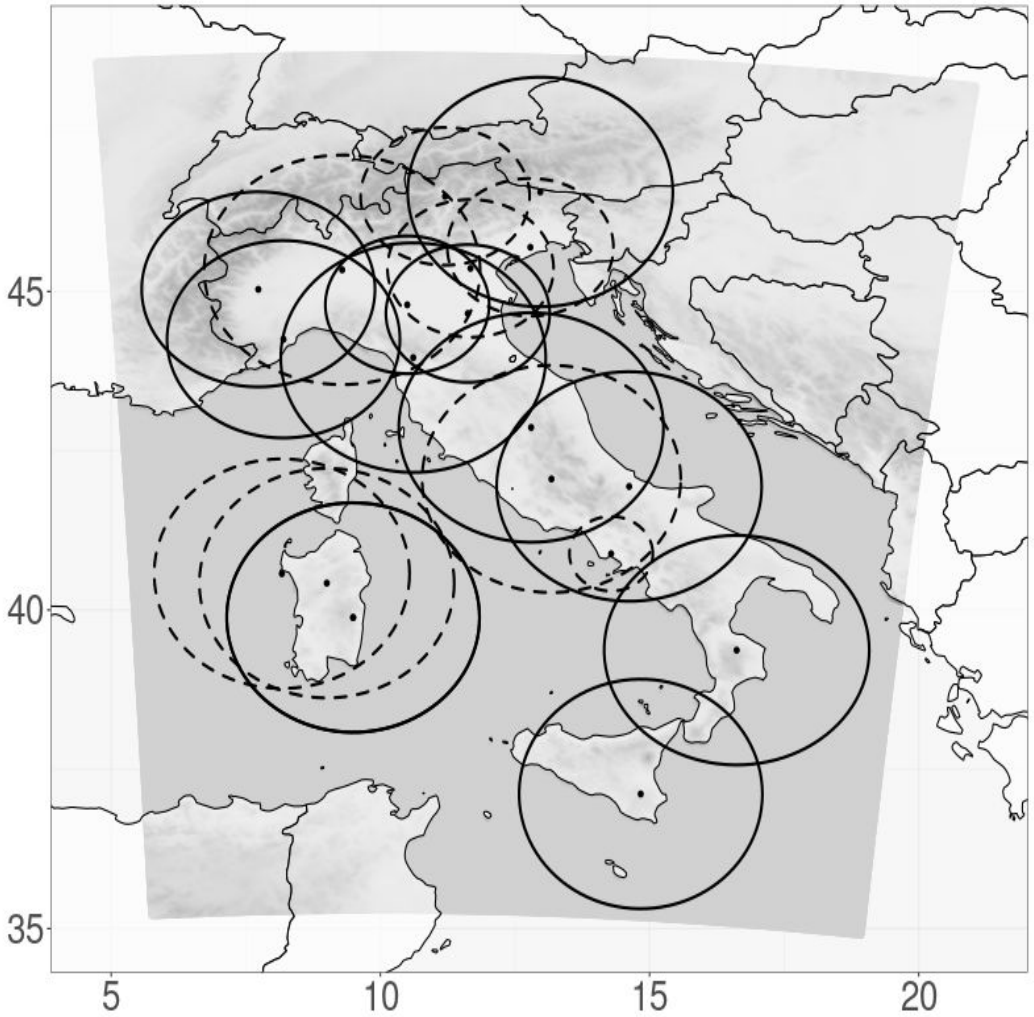
Assimilation of radial wind observations at Arpae

Gastaldo T., Poli V., Cesari D., Marsigli C., Alberoni P.P.

Operational set-up to generate COSMO-2I analyses

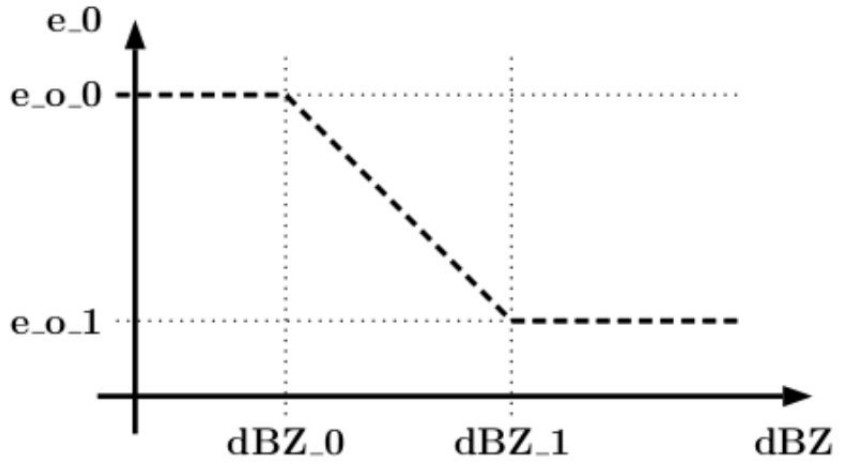
- COSMO 5.08 at 2.2 km hor. res.
- 36 members + deterministic run
- 1h assimilation cycles
- assimilation of AIREP, TEMP, SYNOP (wind and surface pressure) and radar reflectivity volumes (solid circles) through KENDA. Regarding radar data:
  - observation error of 10 dBZ for all data;
  - superobbing at 10 km;
  - 5 dBZ threshold on reflectivities;
  - for each radar, only the reflectivity volume closest to analysis time is assimilated.
- LHN of SRI of the composite of all radars in the figure (both solid and dashed lines)



Implementation of radial wind assimilation

- Modifications to the EMVORADO operator:
  - since Nyquist velocity is not provided in the files of the volumes we assimilate, it is set as the maximum (in absolute value) of the read data;
  - since, for historical reasons, radars of Emilia-Romagna region do not use the usual convention for the radial wind sign, their sign is modified to make it conventional.
- Localization as reflectivity observations:
  - h_loc =16
  - v_loc = 0.3
- Observation error: reflectivity dependent, same as DWD
  - itype_obserr_vr = 2
  - e_0_1 = baseval_obserr_vr = 2.5
  - e_o_0 = maxval_obserr_vr = 25.0
  - dBZ_0 = ramp_lowdbz_obserr_vr = 0
  - dBZ_1 = ramp_highdbz_obserr_vr = 10.0
  - supob_vrw = 10

Multiplied by 1.0 in KENDA



Experimental set-up

Experiments:

- ***refl+LHN:*** operational set-up
- ***refl+rwind+LHN*****:** same as *refl+LHN* but assimilating also radial winds
- ***refl*****:** same as *refl+LHN* but without LHN
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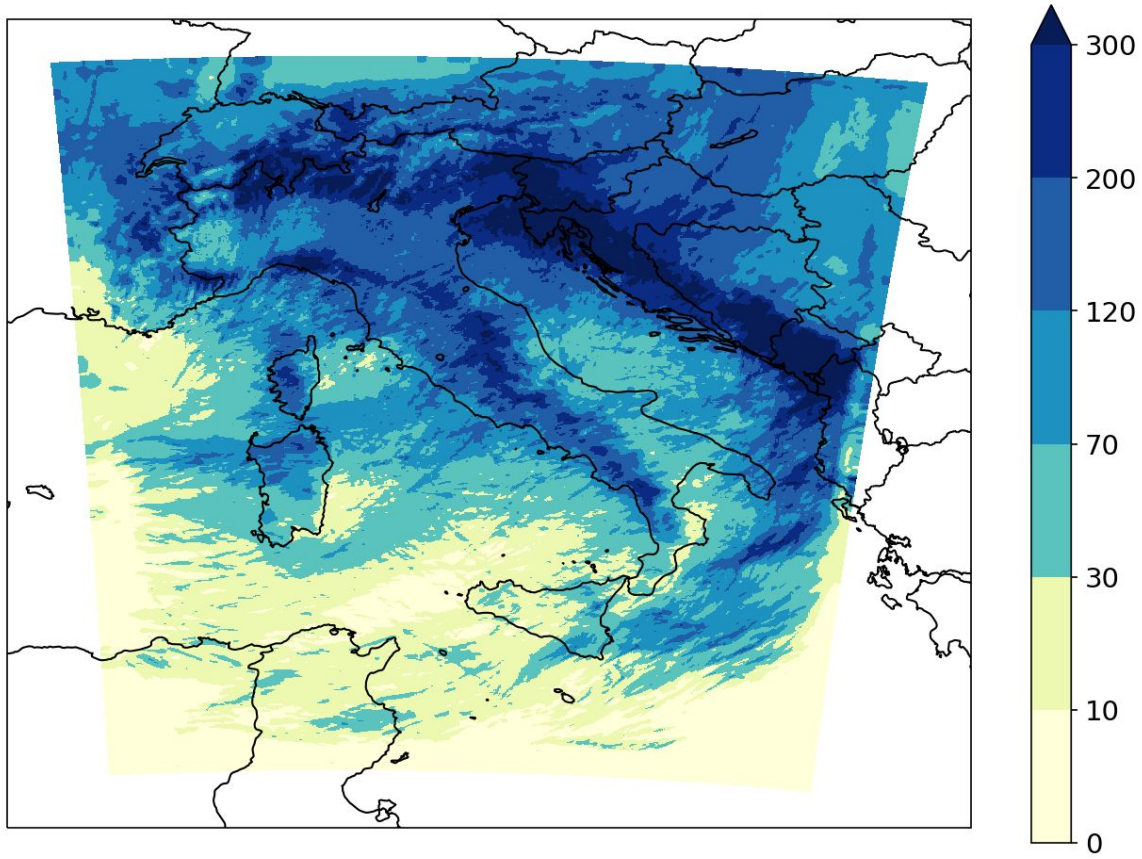
Evaluation period:

- ***sept2020*****:** from 18/09/2020 to 20/10/2020
- ***nov2021*****:** from 11/11/2021 to 13/12/2021

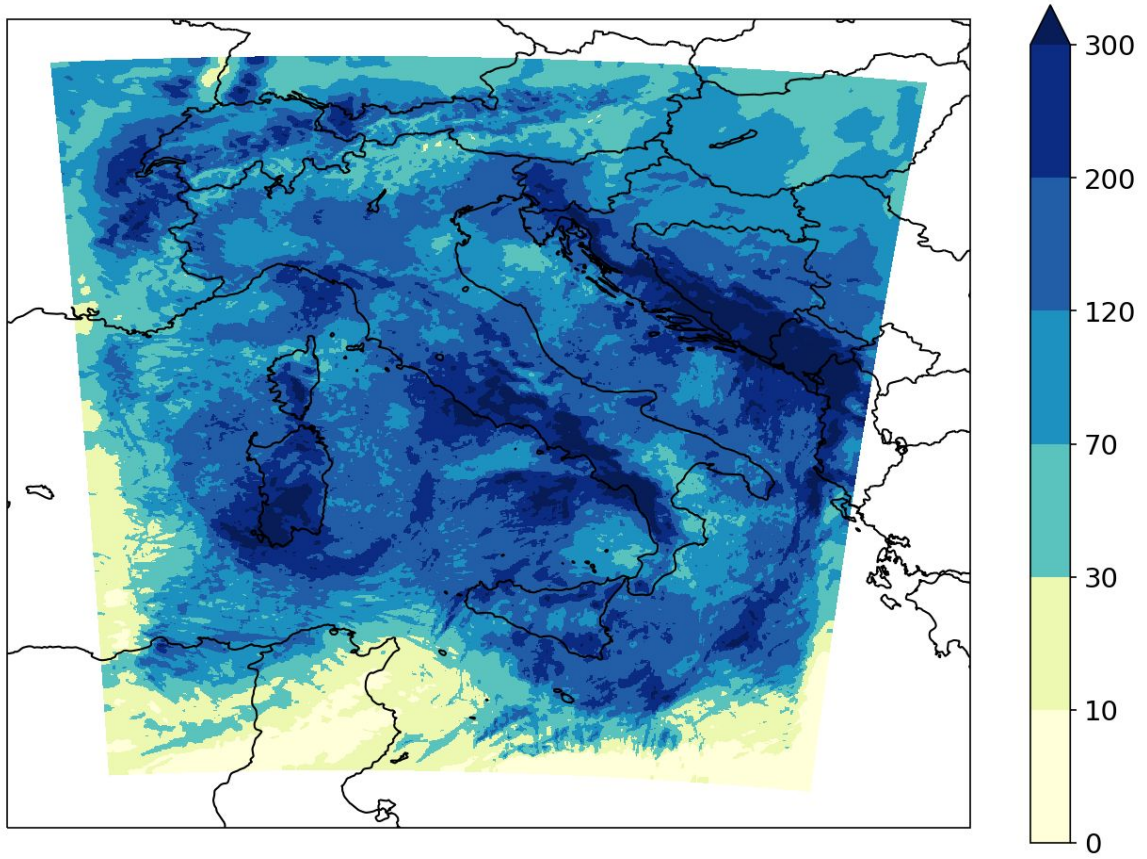
A 12h **deterministic** forecast is initialized every 3h from the deterministic analyses of each experiment (total forecasts: 236 for *sept2020*, 257 for *nov2021*)

Experimental set-up

sept2020



nov2021



Model estimated precipitation (sum of first guess precipitation for the operational run)

Results: assimilation of radial wind with LHN

Experiments:

- ***refl+LHN:*** operational set-up
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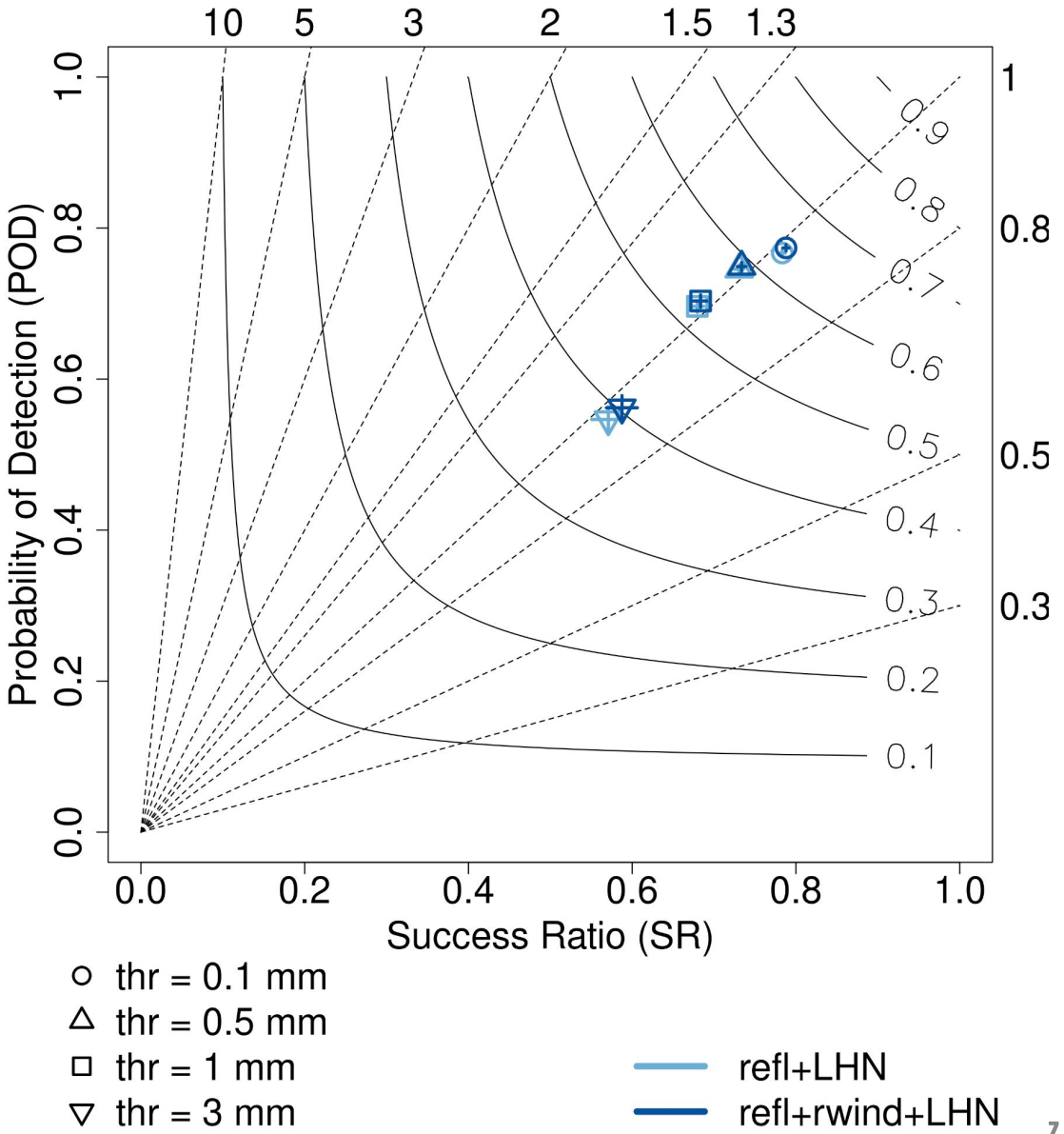
A 12h **deterministic** forecast is initialized every 3h from the deterministic analyses of each experiment (total forecasts: 236 for *sept2020*, 257 for *nov2021*)

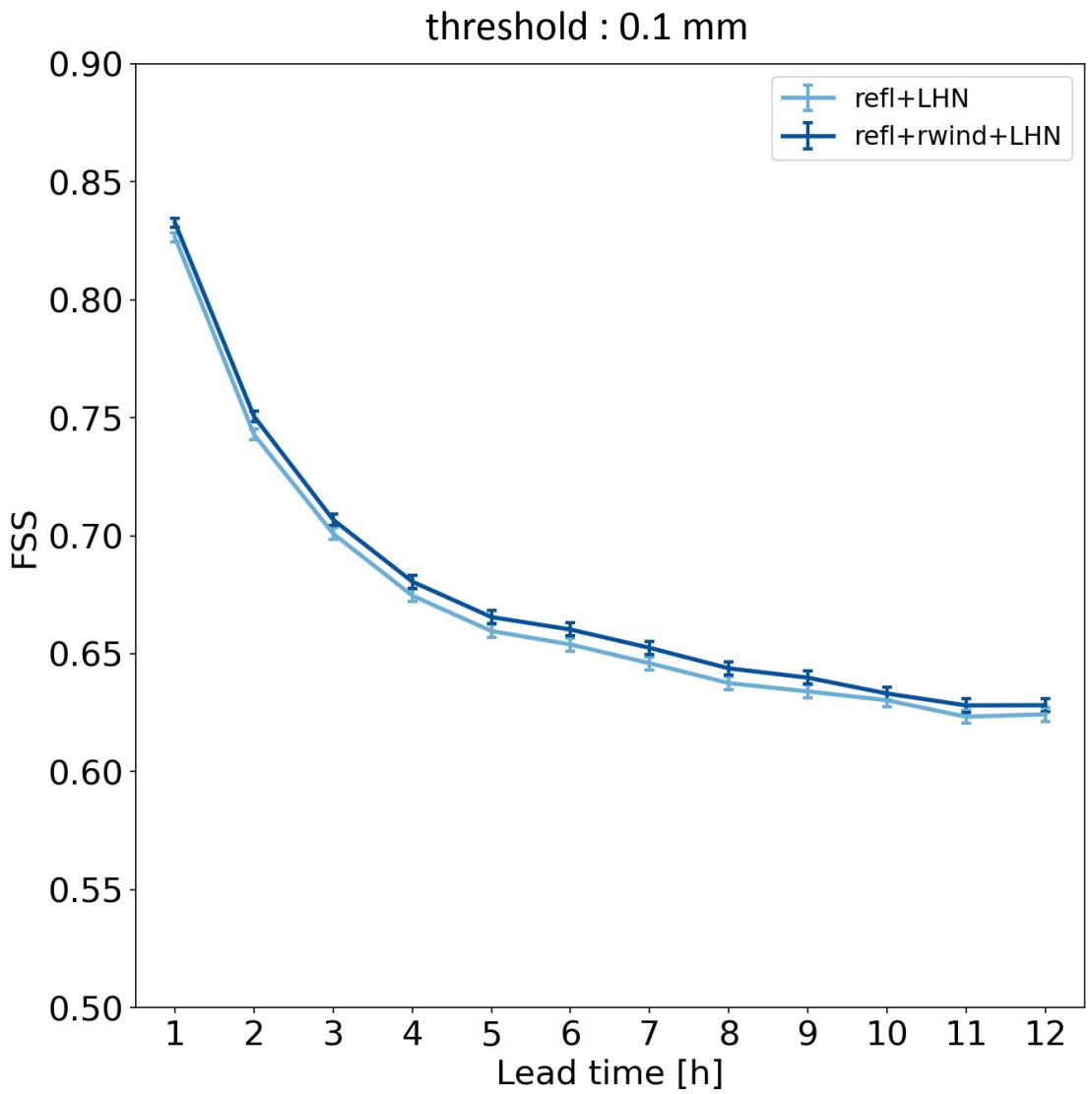
Precipitation during assimilation cycles (first guess)

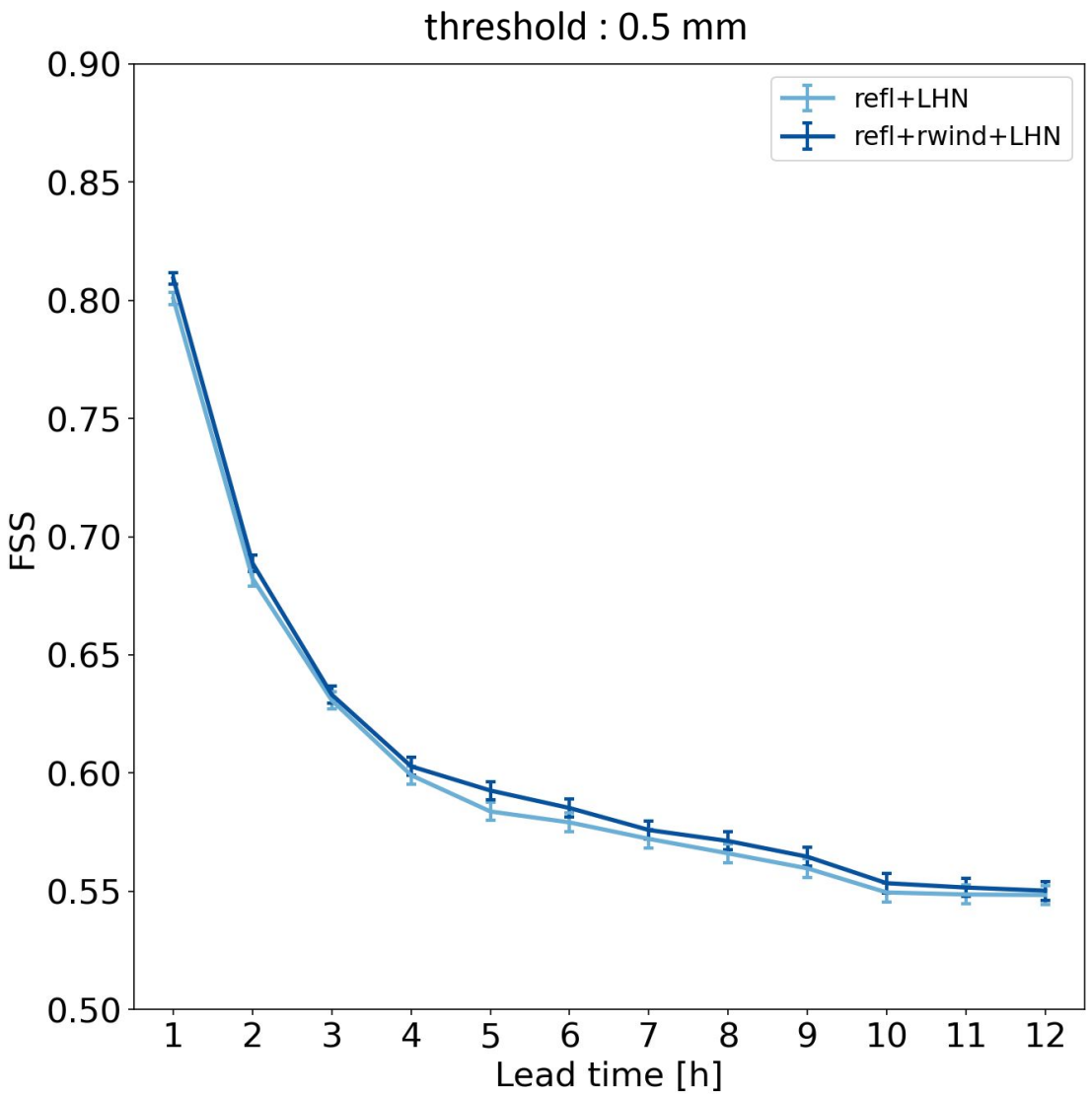
Verification performed over alerting areas, defined by the Civil Protection Department, considering hourly precipitation from rain-gauges.

These areas are homogeneous with respect to the type and intensity of hydrometeorological phenomena that may occur and their effects on the territory.



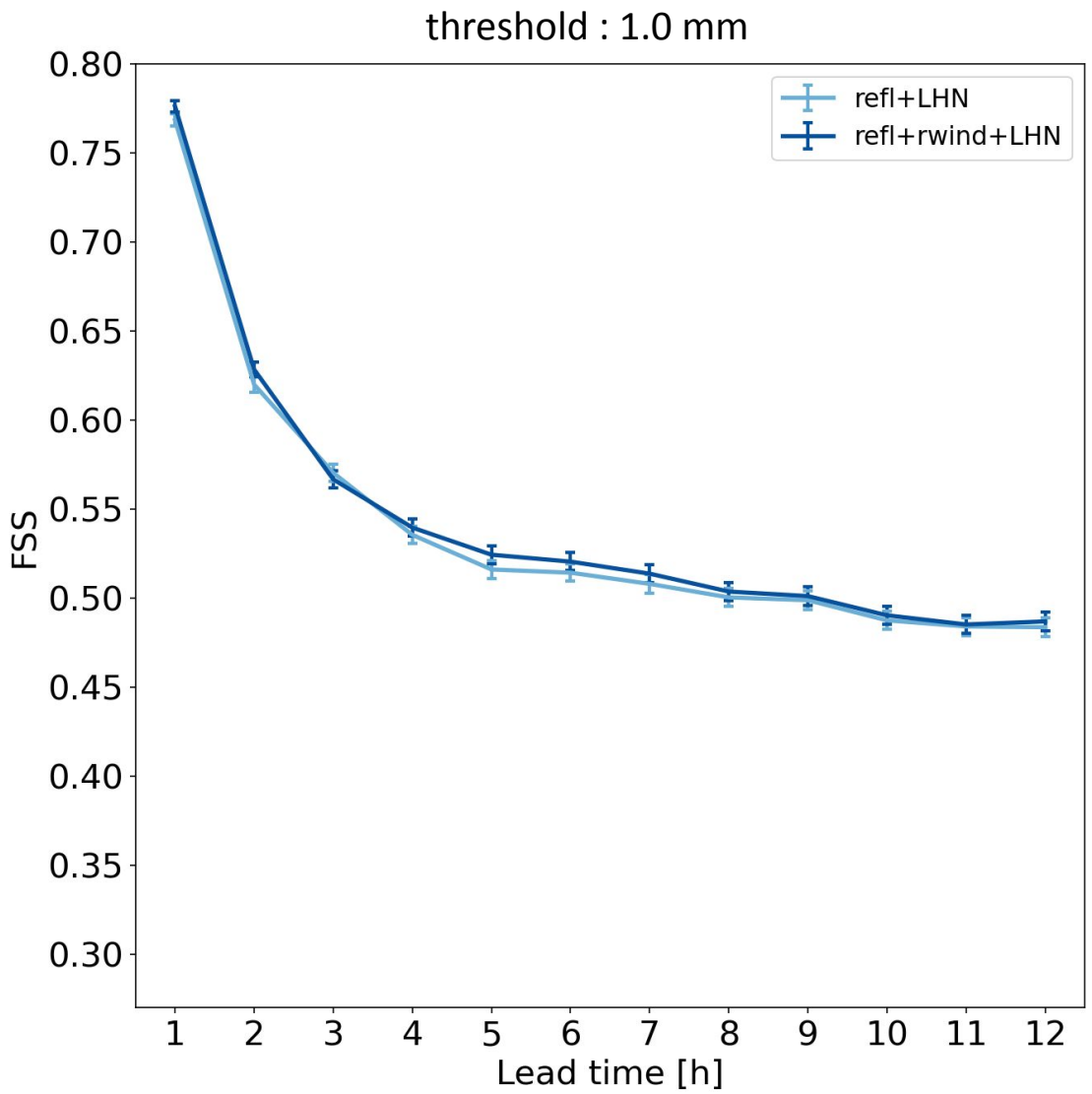
Forecast precipitation (FSS)

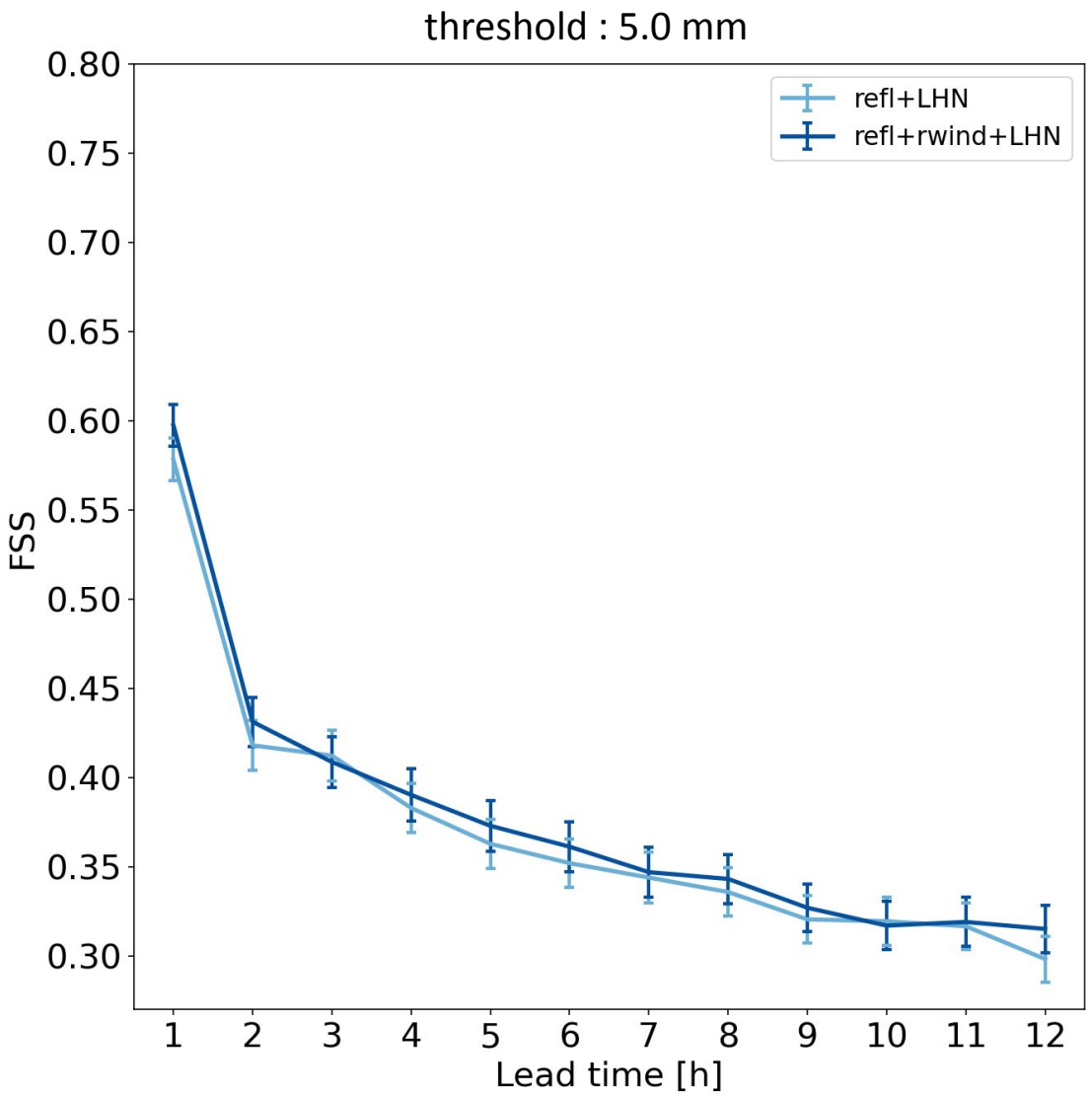




Boxes of 0.2° X 0.2° over the Italian mainland; observations are hourly rainfall fields from the Italian radar composite adjusted by rain-gauges

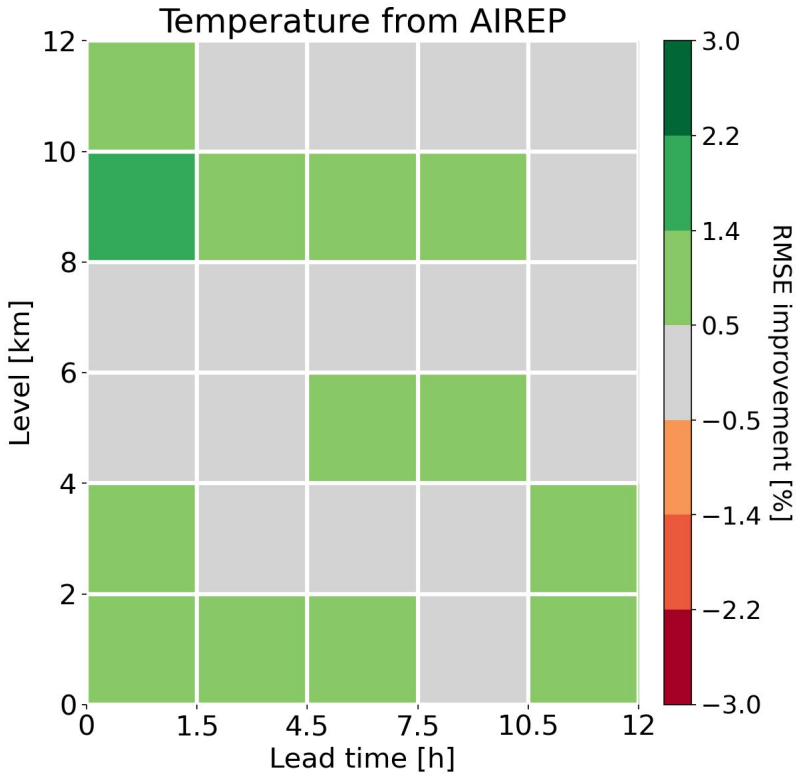
Forecast precipitation (FSS)



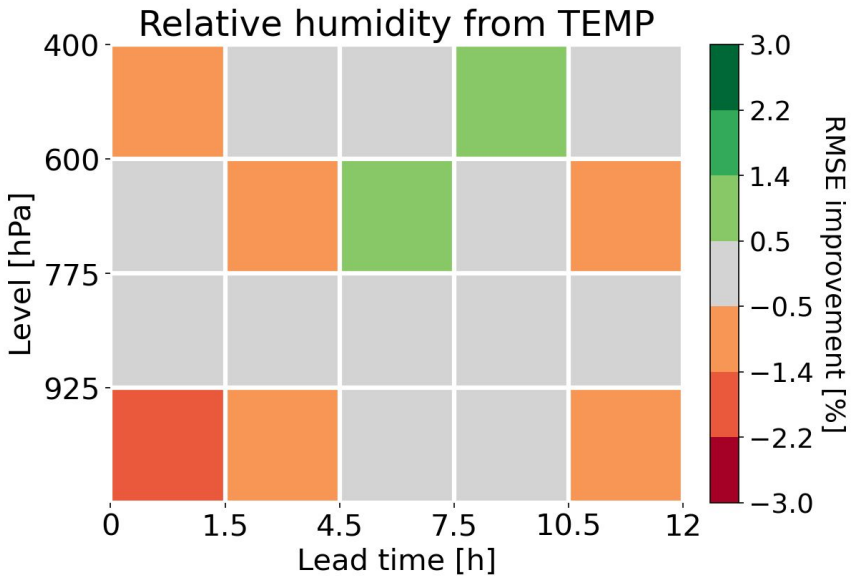


Boxes of 0.2° X 0.2° over the Italian mainland; observations are hourly rainfall fields from the Italian radar composite adjusted by rain-gauges

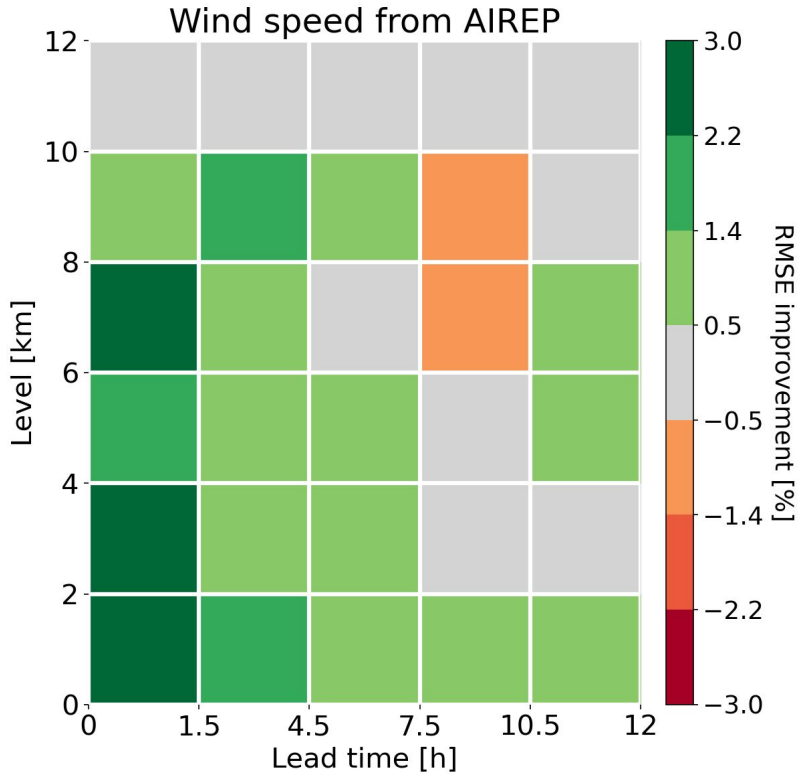
Upper-air variables: RMSE(refl+LHN) - RMSE(refl+rwind+LHN)



Average number of obs.: 42770 (ranging from 14752 to 95157)
Average RMSE (cntr): 1.07 K (ranging from 0.81 K to 1.46 K)



Average number of obs.: 9977 (ranging from 2626 to 15840)
Average RMSE (cntr): 0.19 kg/kg (ranging from 0.12 kg/kg to 0.22 kg/kg)

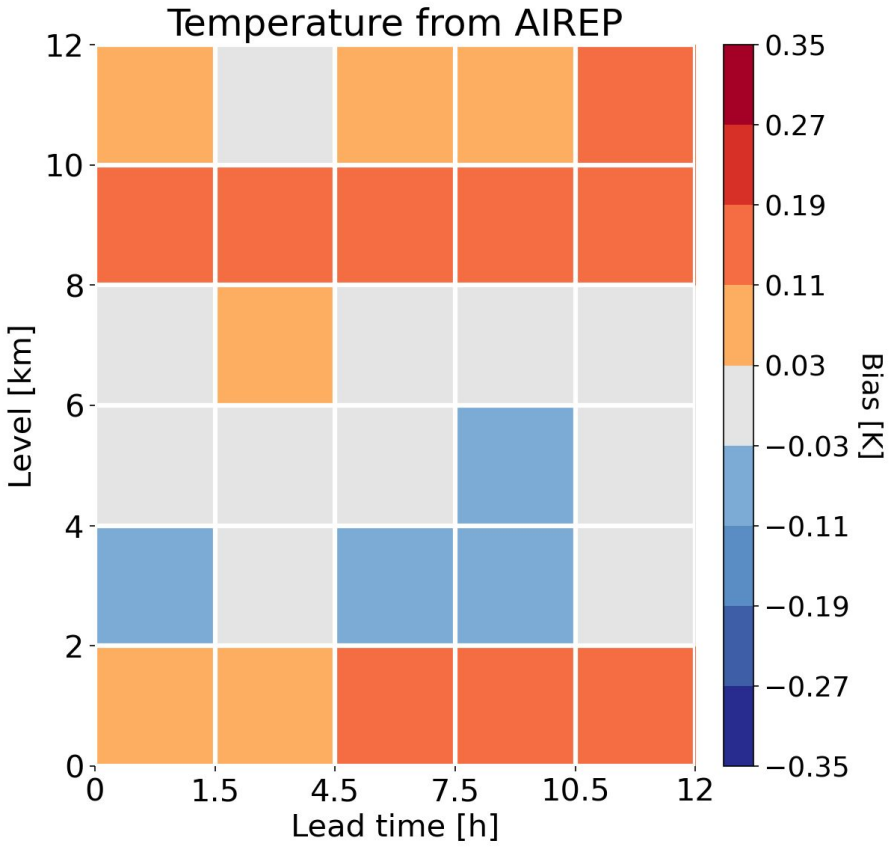


Average number of obs.: 26309 (ranging from 9375 to 61090)
Average RMSE (cntr): 3.08 m/s (ranging from 2.68 m/s to 3.69 m/s)

Positive values (green) -- > *refl+rwind+LHN* better than *refl+LHN*

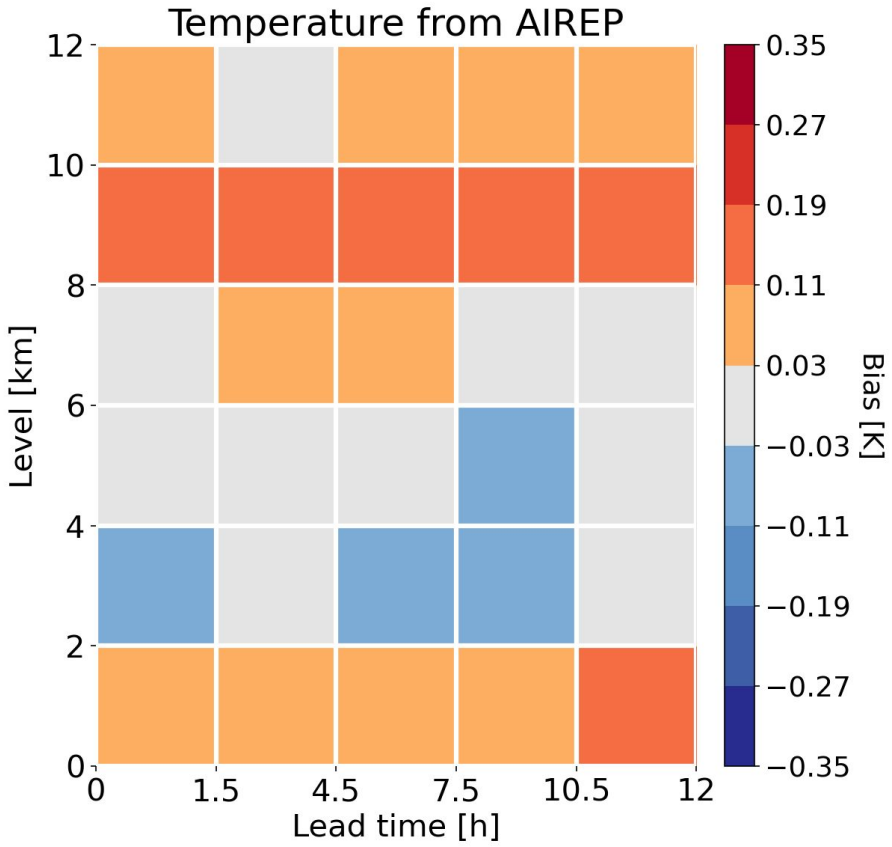
Upper-air variables: bias of temperature

refl+LHN



Average number of obs.: 42770 (ranging from 14752 to 95157)
Average bias: 0.038 K (ranging from -0.060 K to 0.147 K)

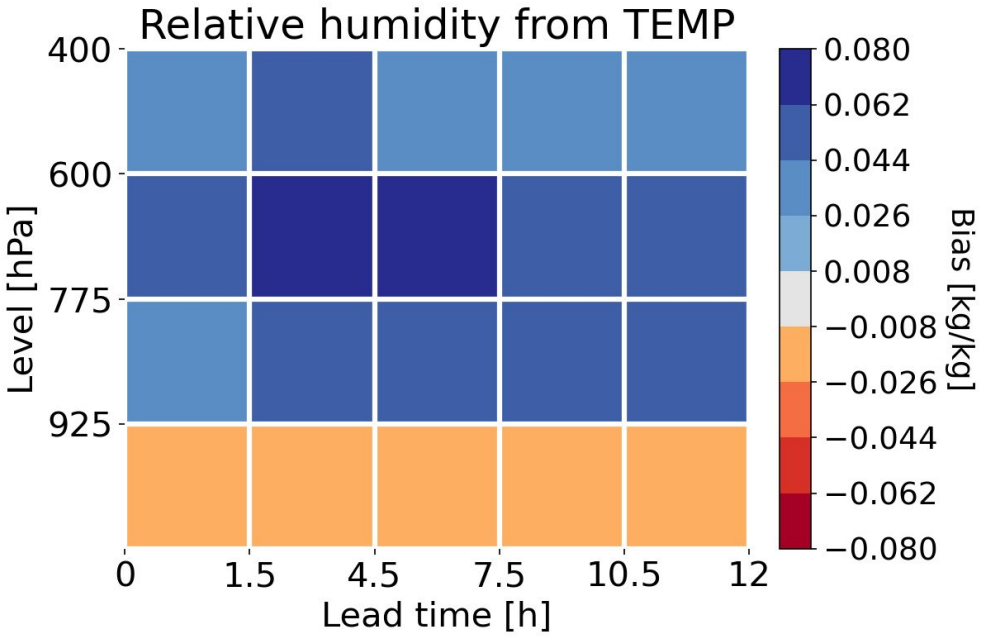
refl+rwind+LHN



Average number of obs.: 42791 (ranging from 14755 to 95291)
Average bias: 0.036 K (ranging from -0.058 K to 0.136 K)

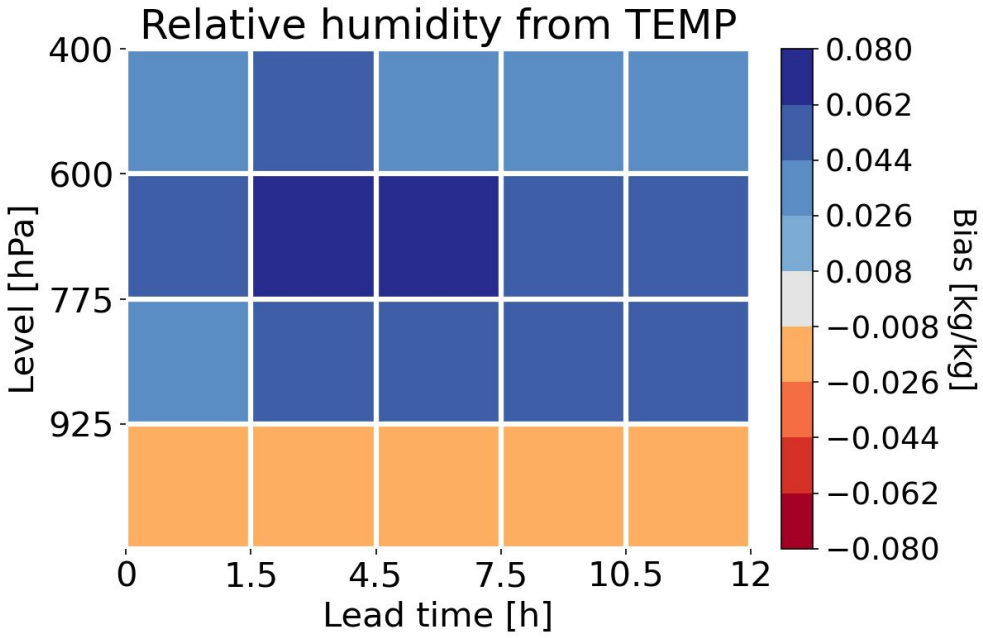
Upper-air variables: bias of relative humidity

refl+LHN



Average number of obs.: 9977 (ranging from 2626 to 15840)
Average bias: 0.034 kg/kg (ranging from -0.013 kg/kg to 0.066 kg/kg)

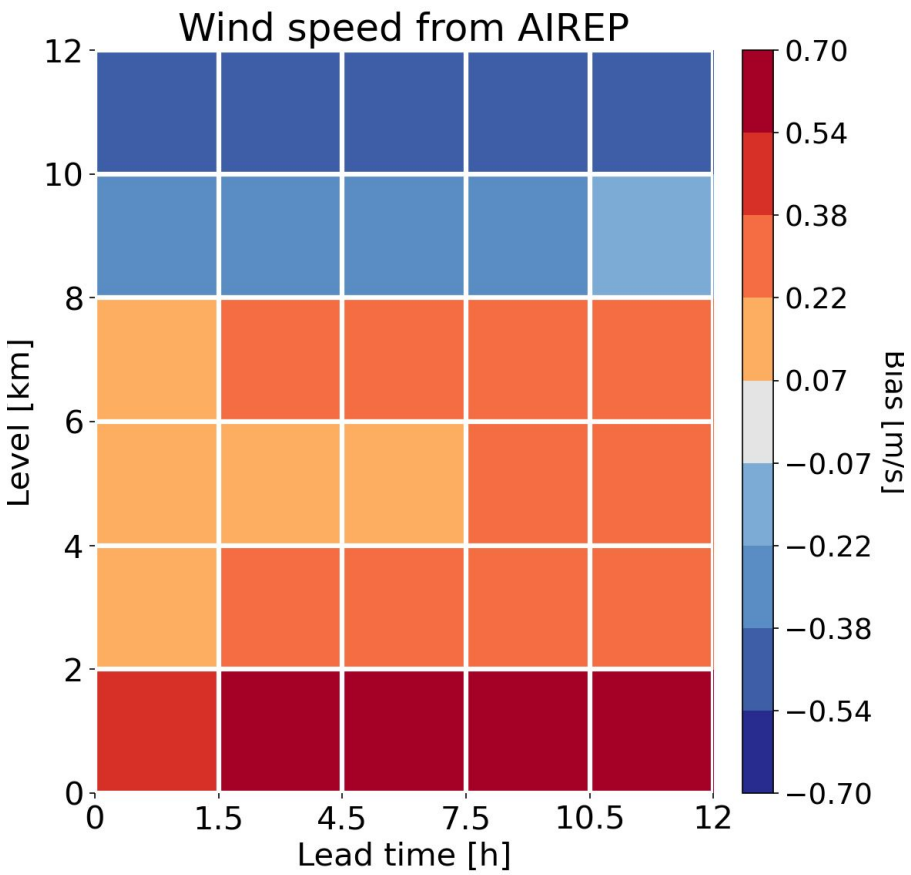
refl+rwind+LHN



Average number of obs.: 9972 (ranging from 2630 to 15885)
Average bias: 0.035 kg/kg (ranging from -0.013 kg/kg to 0.068 kg/kg)

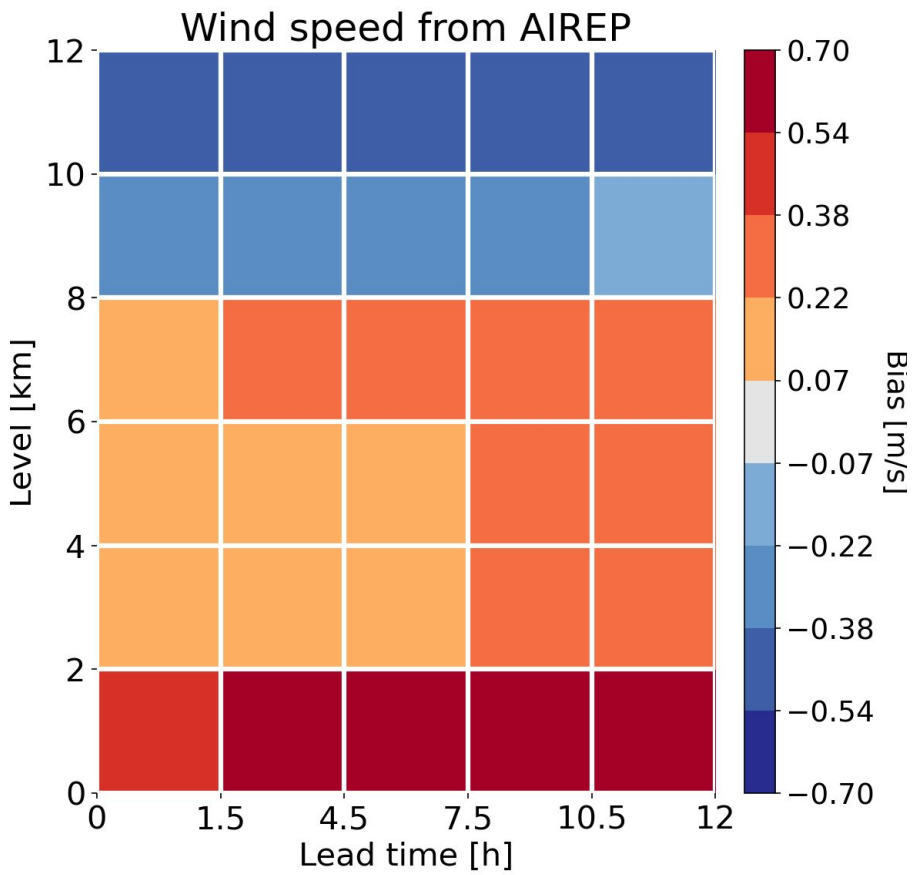
Upper-air variables: bias of temperature

refl+LHN



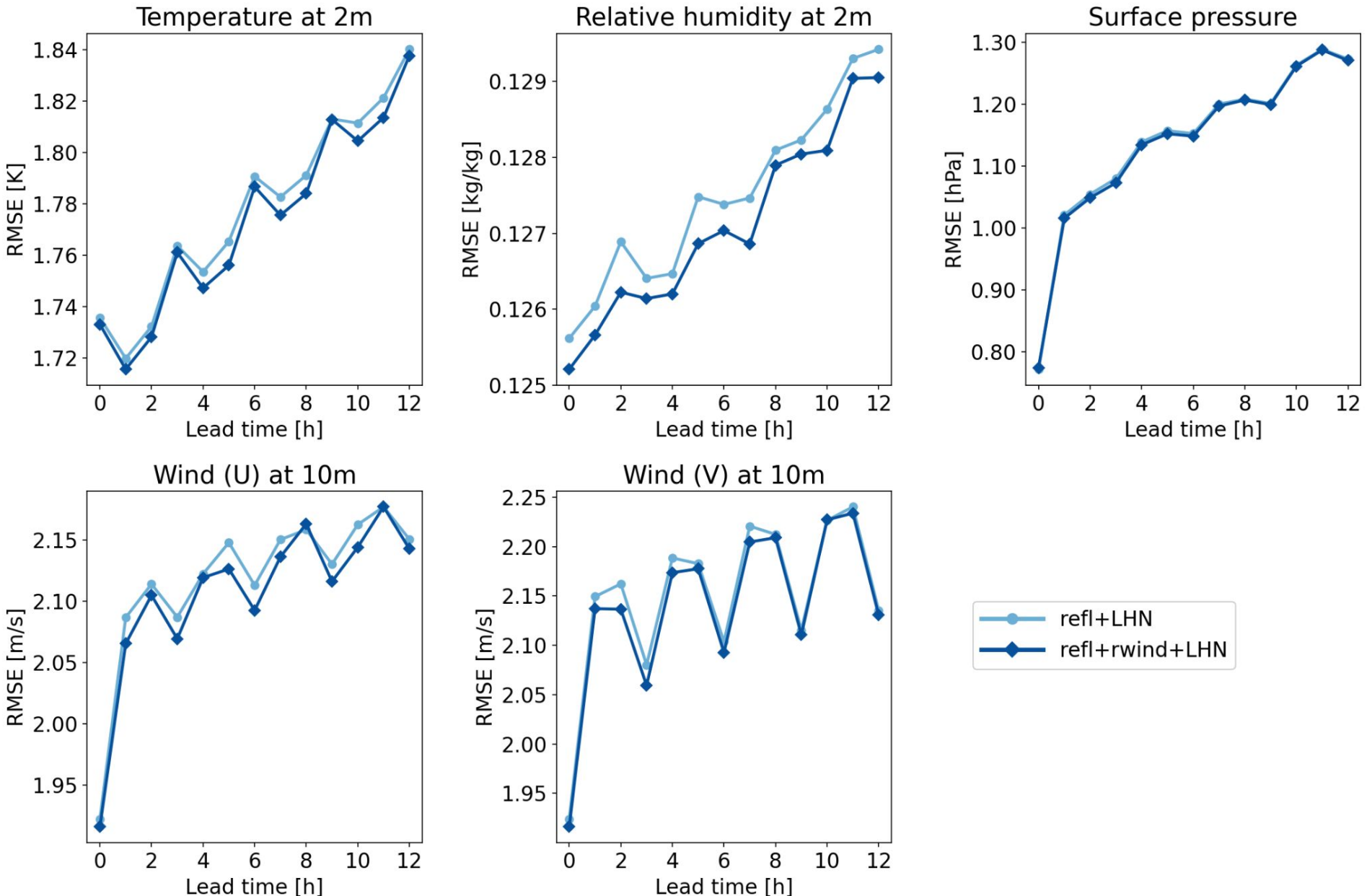
Average number of obs.: 26309 (ranging from 9375 to 61090)
Average bias: 0.088 m/s (ranging from -0.478 m/s to 0.688 m/s)

refl+rwind+LHN

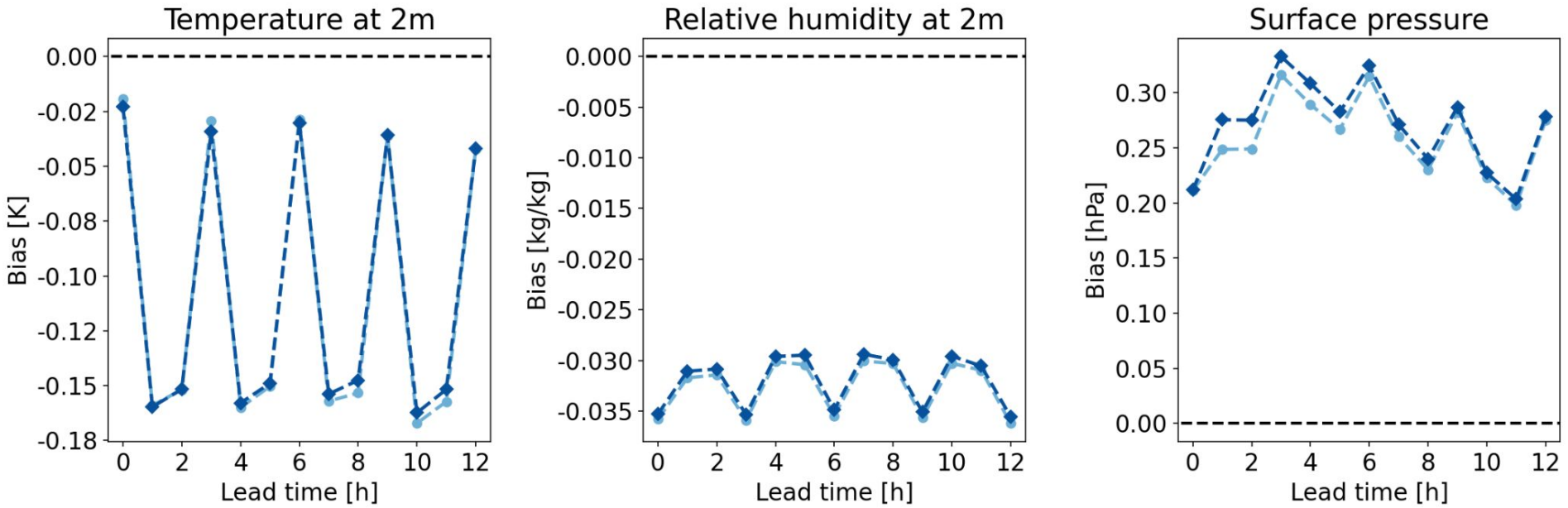


Average number of obs.: 26318 (ranging from 9379 to 61134)
Average bias: 0.069 m/s (ranging from -0.489 m/s to 0.669 m/s)

Near-surface variables: RMSE



Near-surface variables: bias



Assimilation of radial wind with LHN: Summary of results

Assimilation of radial winds has a modest but overall positive impact on forecast accuracy

Variable	***refl+rwind+LHN* vs *refl+LHN***
Precipitation during assimilation cycles	Slightly better
Precipitation during forecasts	Slightly better
Upper-air temperature	Slightly better
Upper-air relative humidity	Neutral / slightly worse
Upper-air wind speed	Better
Near-surface temperature	Slightly better
Near-surface relative humidity	Slightly better
Near-surface pressure	Slightly worse
Near-surface wind speed	Slightly better

refl+rwind+LHN is going to be the new operational configuration!

Results: assimilation of radial wind with and without LHN

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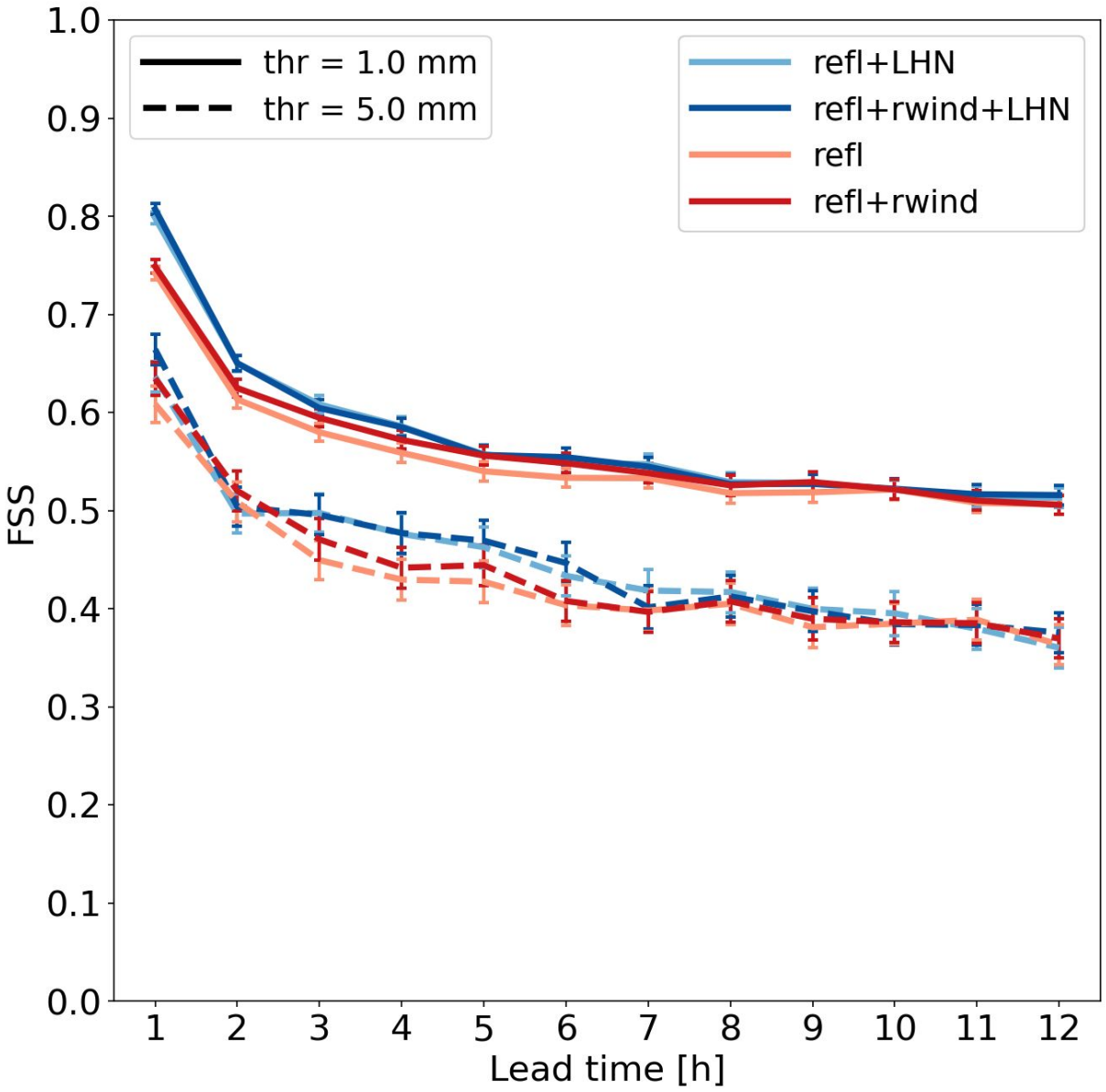
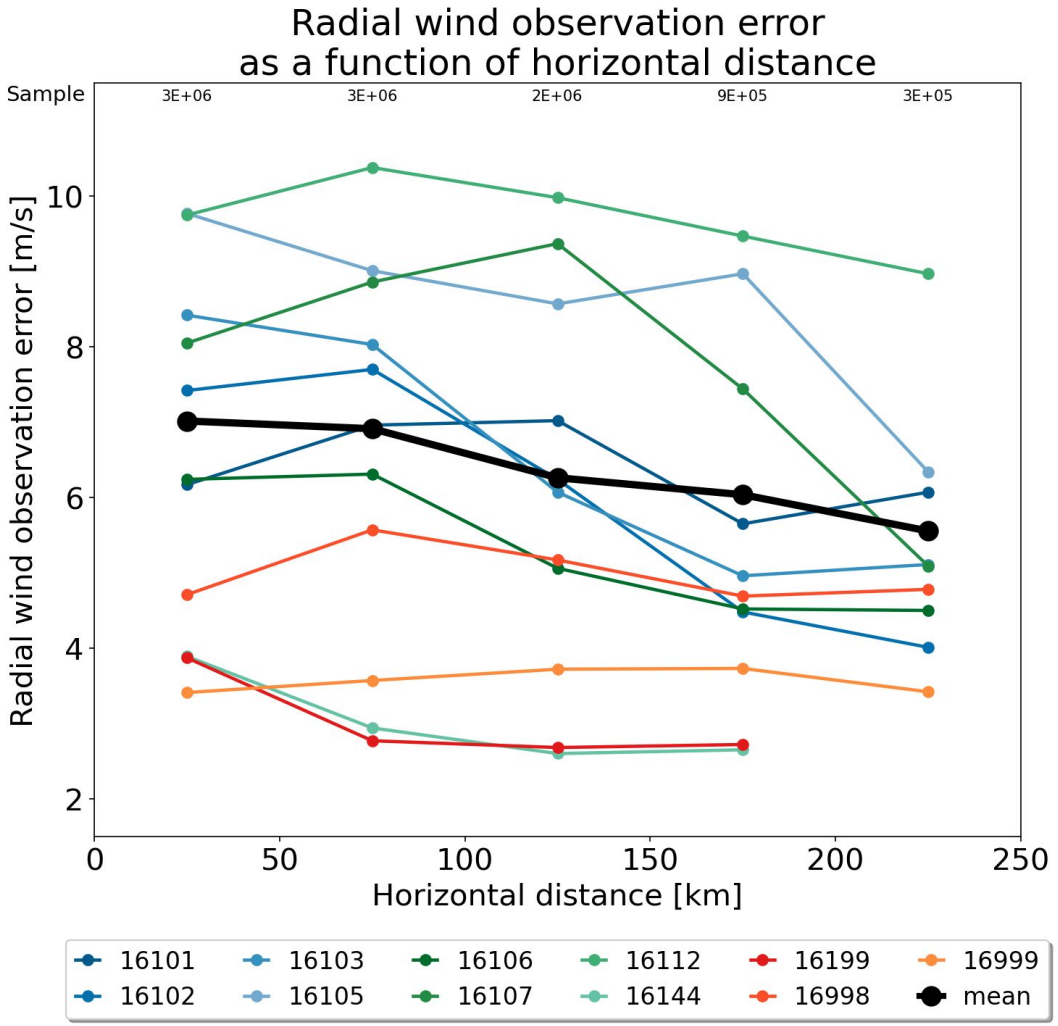


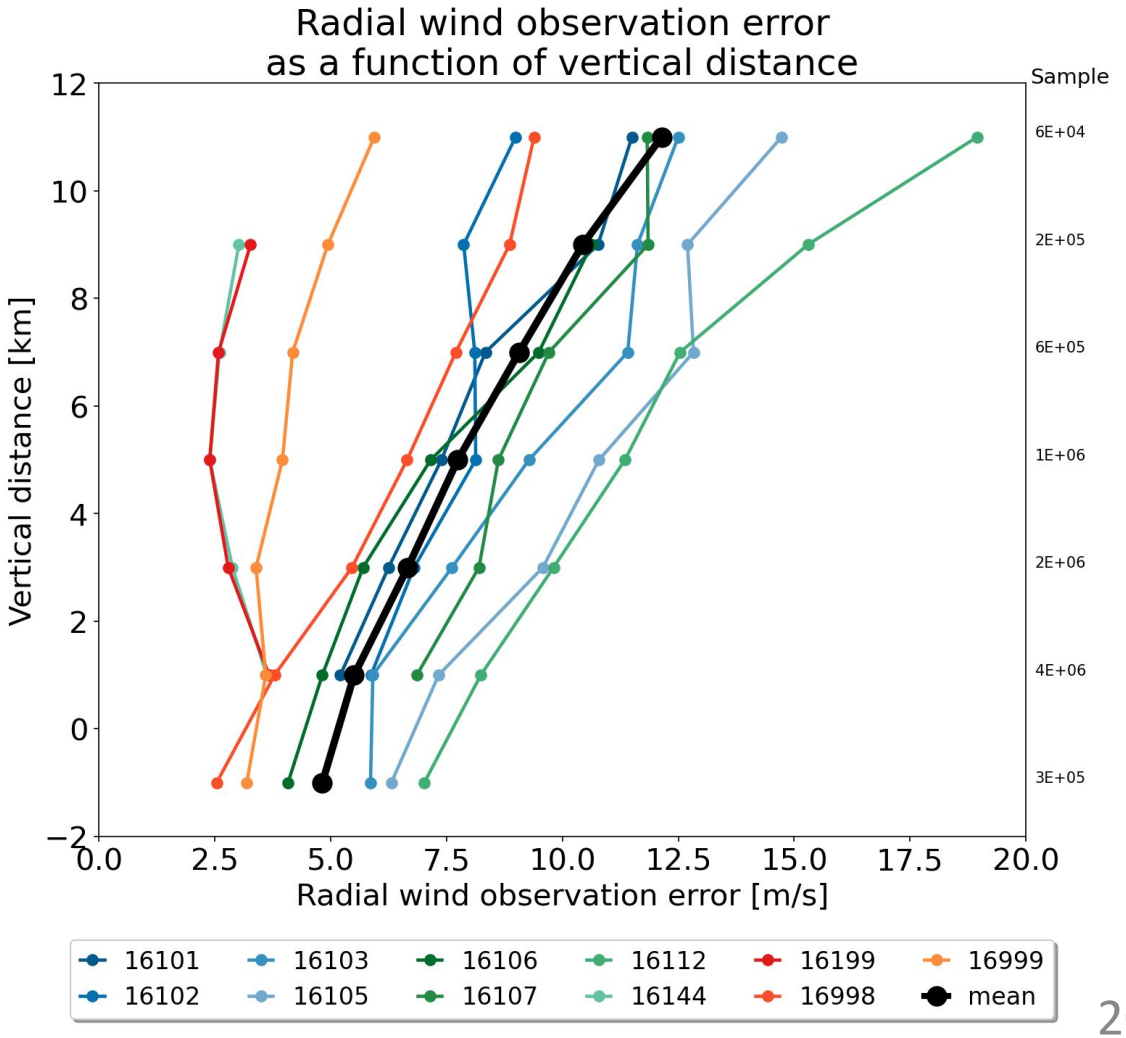
When LHN is not applied, the positive impact of the assimilation of radial winds is more noticeable.

This is observed also for upper-air and near-surface variables, but results are not as good as *refl+rwind+LHN*.

Estimation of the observation error for radial winds

Estimation with Desroziers statistics is performed over *sept2020* period considering *refl+rwind* experiment, binning observations as a function of the horizontal and vertical distance of observations from the radar station. The binning step is, respectively, of 50 km and 2 km.





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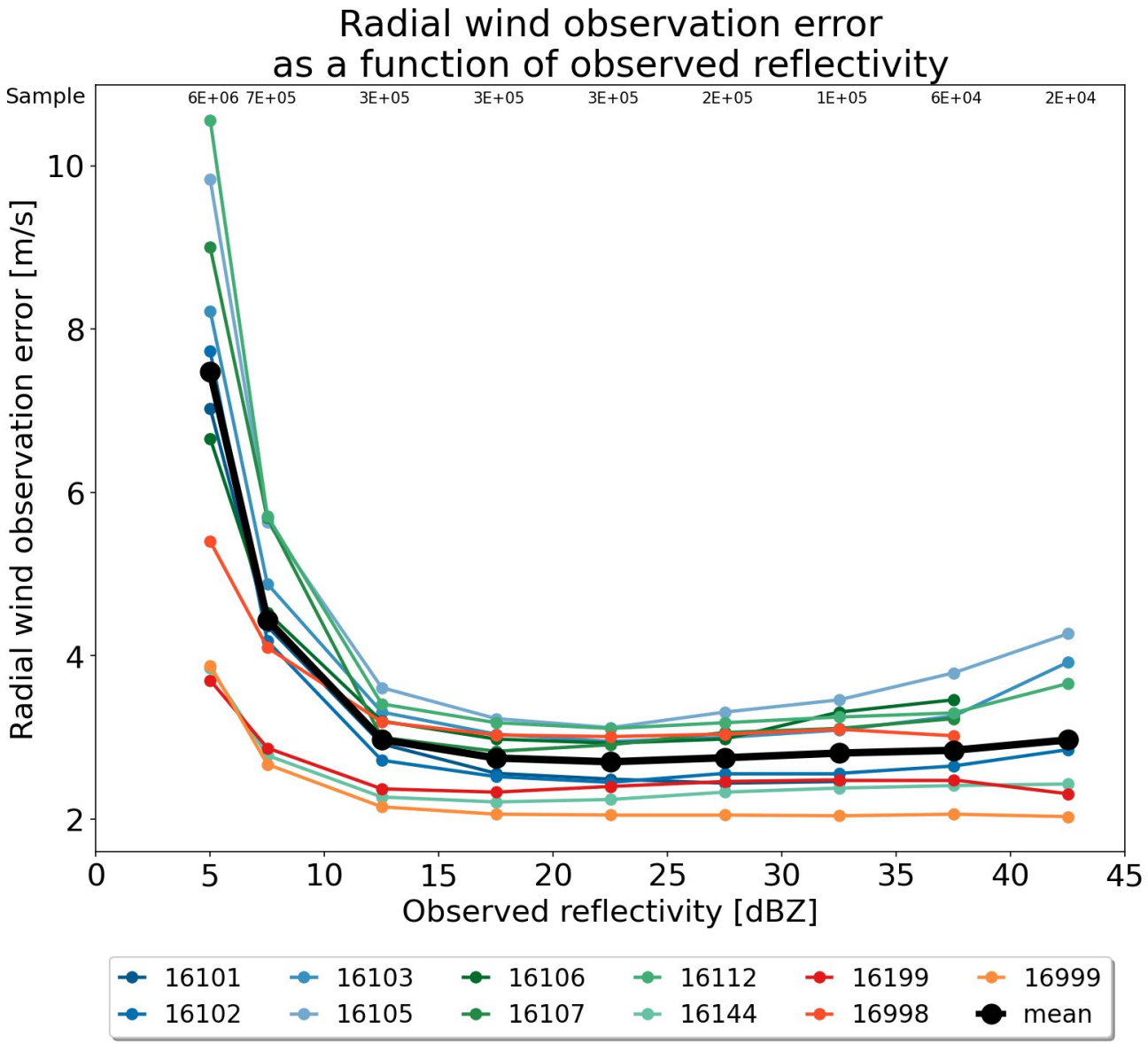
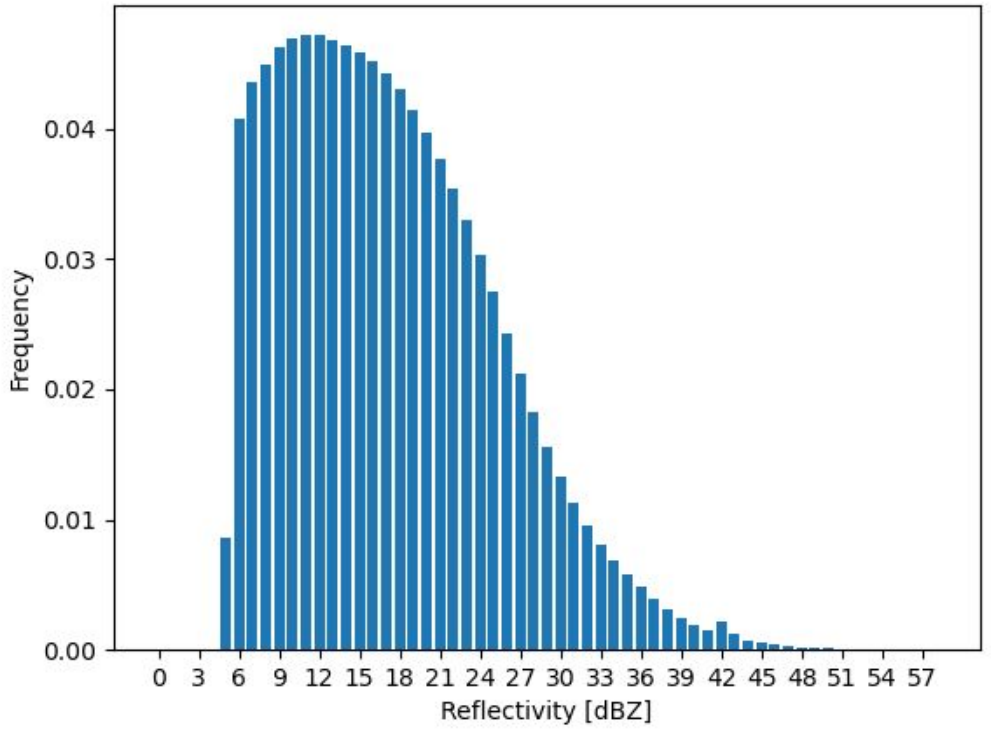


Analysis of radar volume data

Radar volumes assimilated come from Italian Department of Civil Protection:

- there is no official documentation on the data provided (i.e. we do not know exactly what type of cleaning is applied)
- over time there have been changes in the encoding of files (and we usually learn this after changes have already been made)
- the requests made are not always fulfilled (i.e. insertion of Nyquist speed for radial winds in ODIM-hdf5 files)



Sample (all volumes used in assimilation cycles in Nov2021 case study): ~2 10^8

lume data

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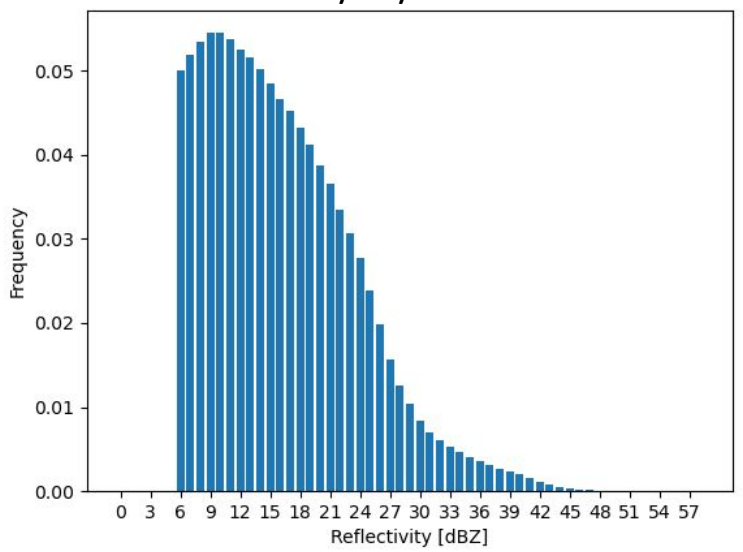
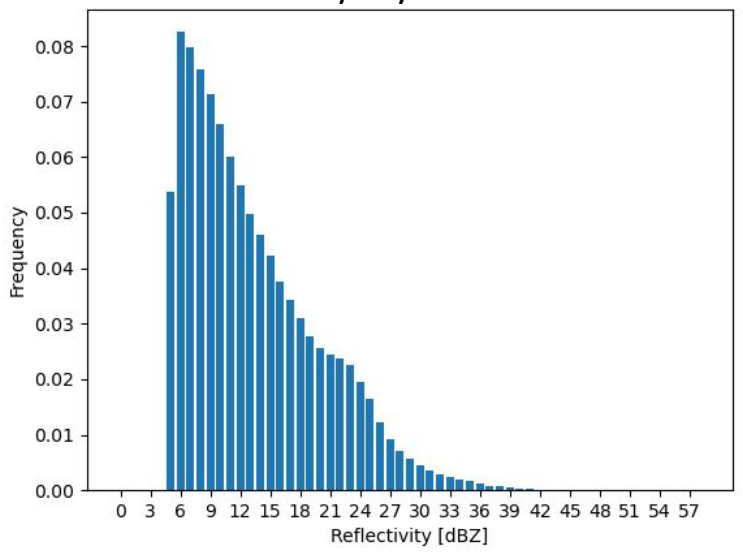
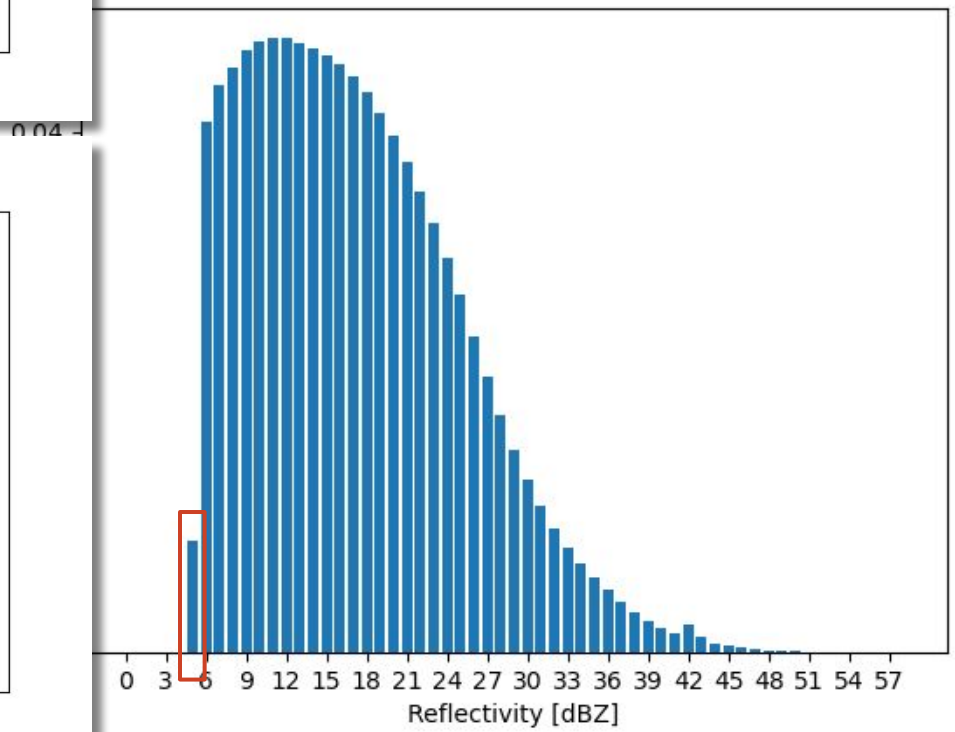
06/12/2021



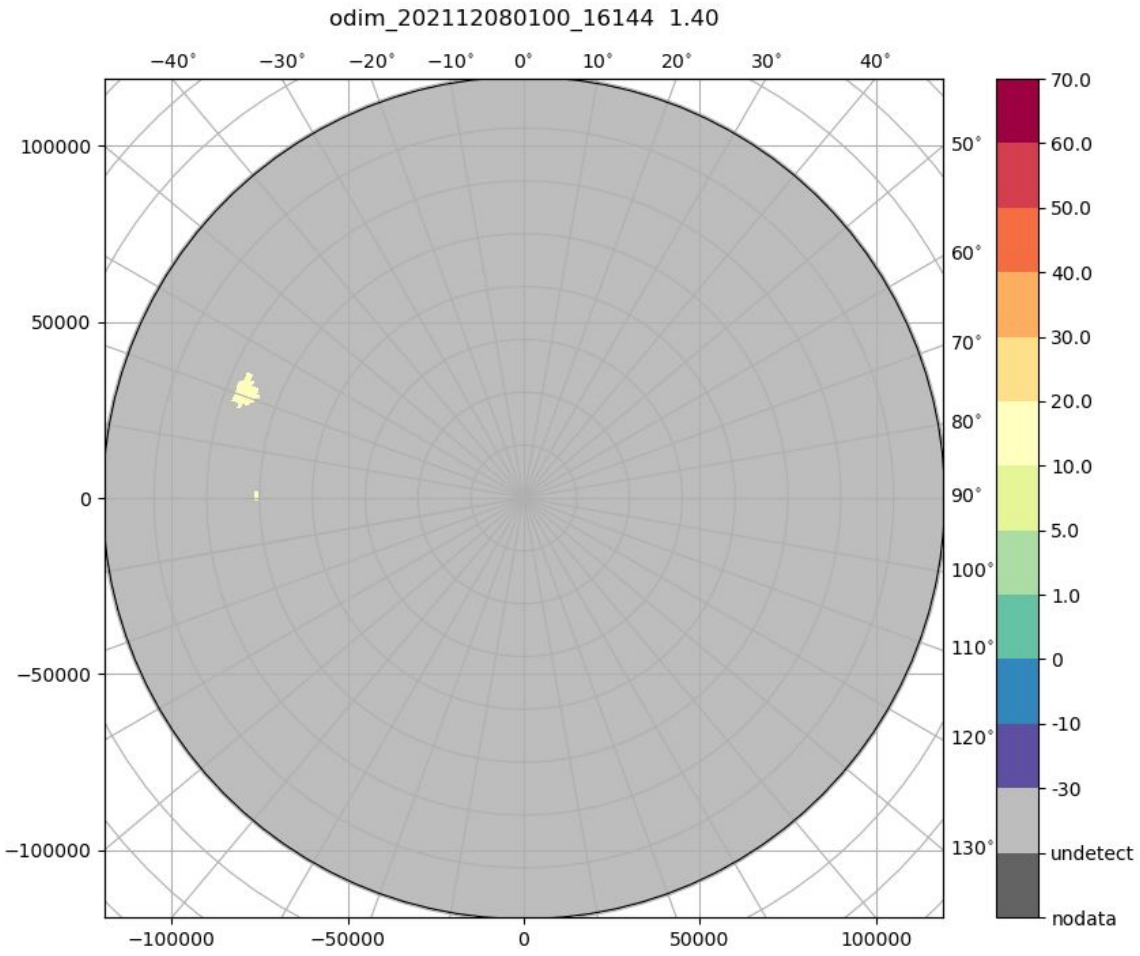
07/12/2021



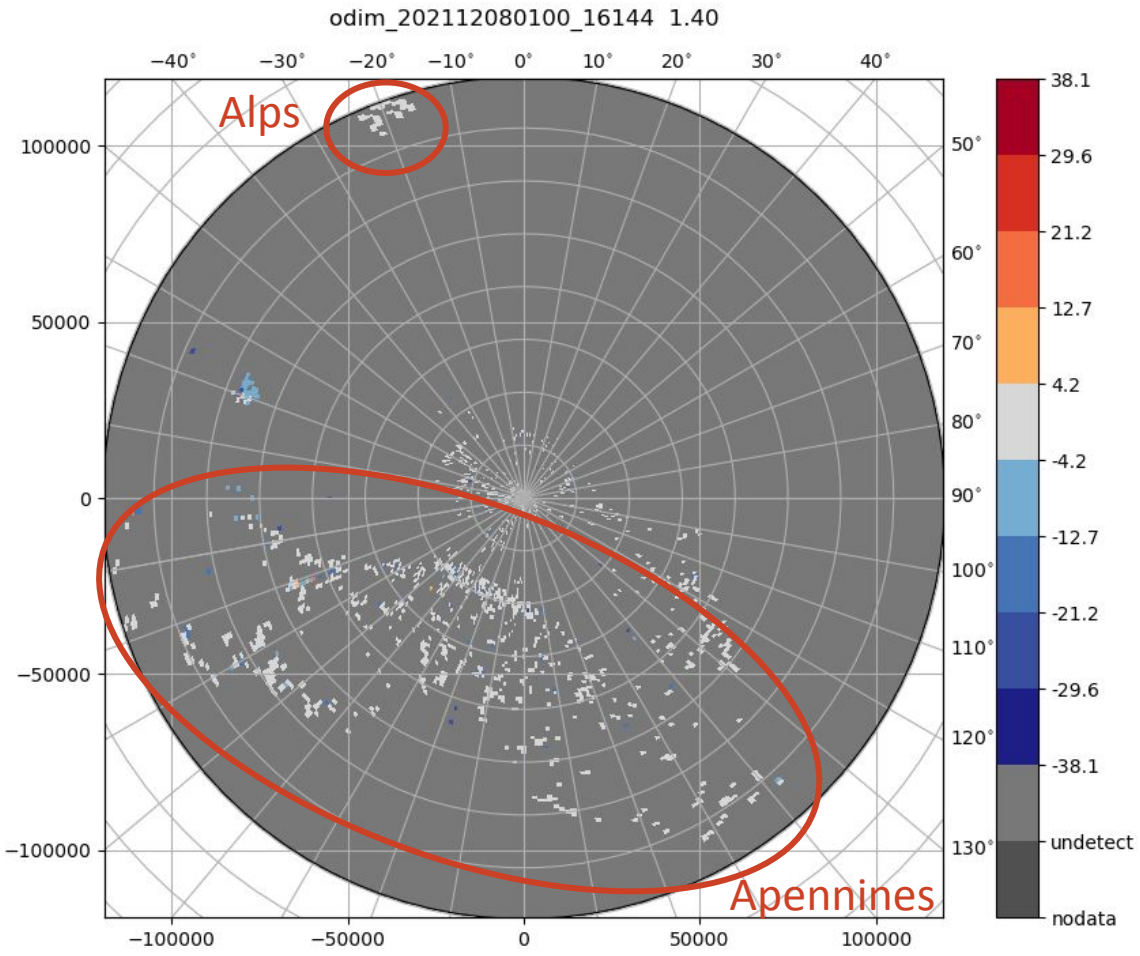


From 07/12/2021 reflectivity values start from 5 dBZ

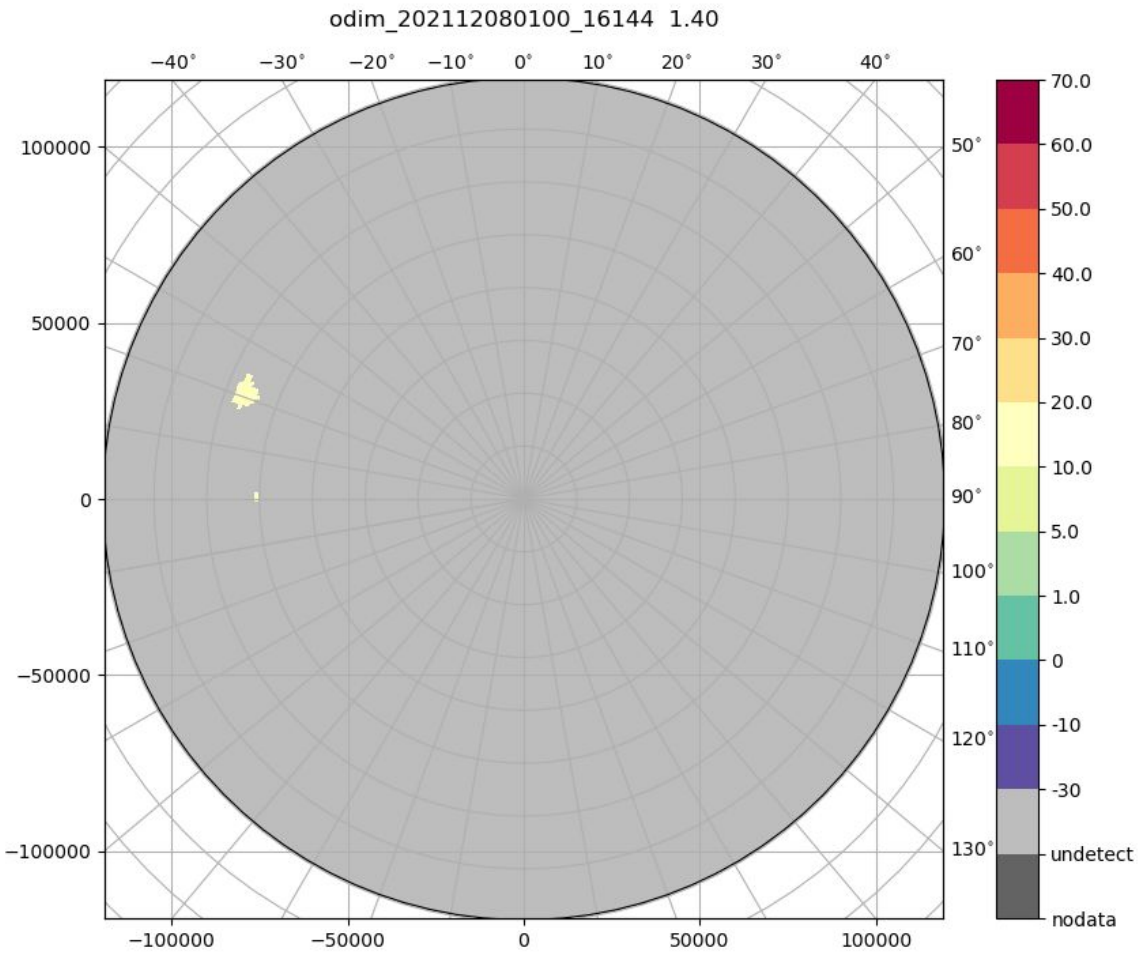
DBZH


odim_202112080100_16144 1.40
−40° −30° −20° −10° 0° 10° 20° 30° 40°
100000
50000
0
−50000
−100000
50° 60° 70° 80° 90° 100° 110° 120° 130°
−100000 −50000 0 50000 100000
70.0
60.0
50.0
40.0
30.0
20.0
10.0
5.0
1.0
0
-10
-30
undetect
nodata

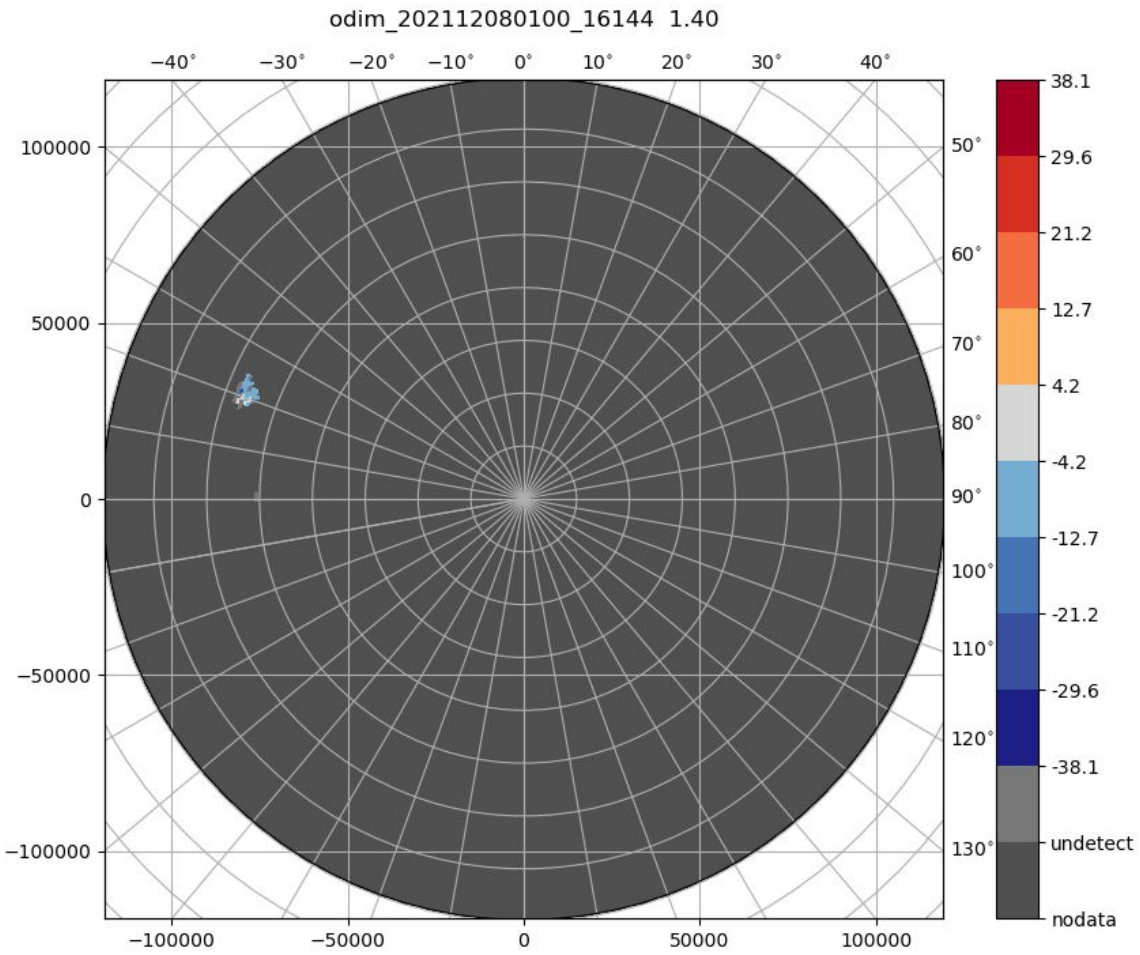
VRAD


odim_202112080100_16144 1.40
Alps
Apennines
−40° −30° −20° −10° 0° 10° 20° 30° 40°
100000
50000
0
−50000
−100000
50° 60° 70° 80° 90° 100° 110° 120° 130°
−100000 −50000 0 50000 100000
38.1
29.6
21.2
12.7
4.2
-4.2
-12.7
-21.2
-29.6
-38.1
undetect
nodata

DBZH


odim_202112080100_16144 1.40
−40° −30° −20° −10° 0° 10° 20° 30° 40°
100000
50000
0
−50000
−100000
50° 60° 70° 80° 90° 100° 110° 120° 130°
−100000 −50000 0 50000 100000
70.0
60.0
50.0
40.0
30.0
20.0
10.0
5.0
1.0
0
-10
-30
undetect
nodata

VRAD


odim_202112080100_16144 1.40
−40° −30° −20° −10° 0° 10° 20° 30° 40°
100000
50000
0
−50000
−100000
50° 60° 70° 80° 90° 100° 110° 120° 130°
−100000 −50000 0 50000 100000
38.1
29.6
21.2
12.7
4.2
-4.2
-12.7
-21.2
-29.6
-38.1
undetect
nodata

Conclusions

- The assimilation of radial winds slightly improves forecast accuracy. It is going to be operational by the end of March.
- The positive impact of assimilating radial wind is stronger when LHN is not applied by results are not as good as with LHN.
- The in-depth analysis of input radar data revealed that:
  - There are no reflectivities below 5 / 6 dBZ
  - There are radial wind observations where reflectivity is undetect, due probably to erroneous clutter removal
- The radar wind observation error:
  - increases with vertical distance of observations from the radar station while slightly decreases with horizontal distance
  - decreases with observed reflectivity, but the estimation is affected by the issue seen in reflectivity distributions

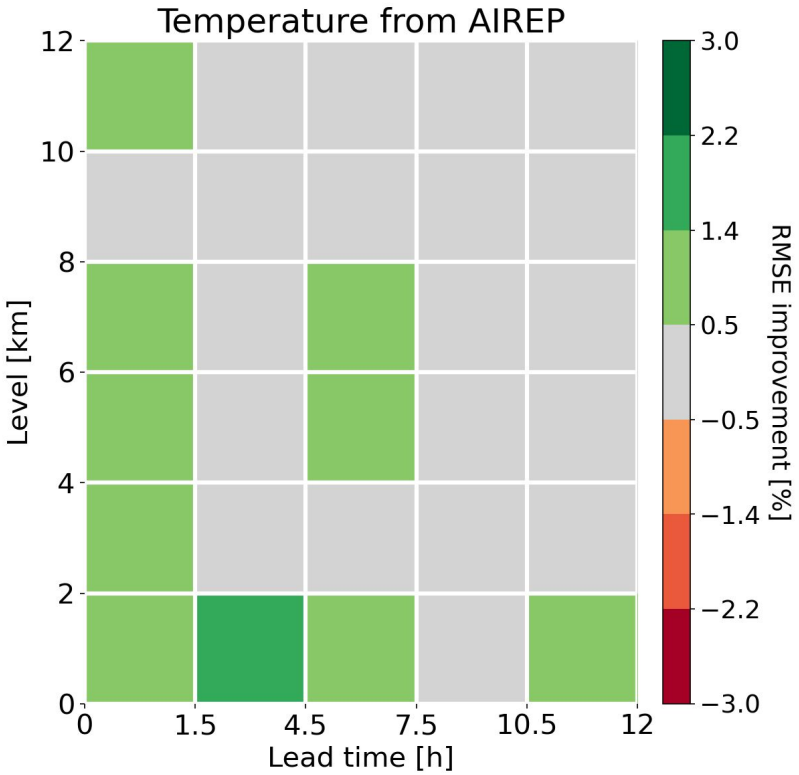
Future plans

- Observation error:
  - estimation as a function of the elevation
  - Extend estimation to *nov202*1 period
- Test a modified version of EMVORADO in which radial wind observations associated to undetect reflectivities are set to undetect
- Experiment with different observation errors.

Thank you!

Upper-air variables: Temperature (RMSE)

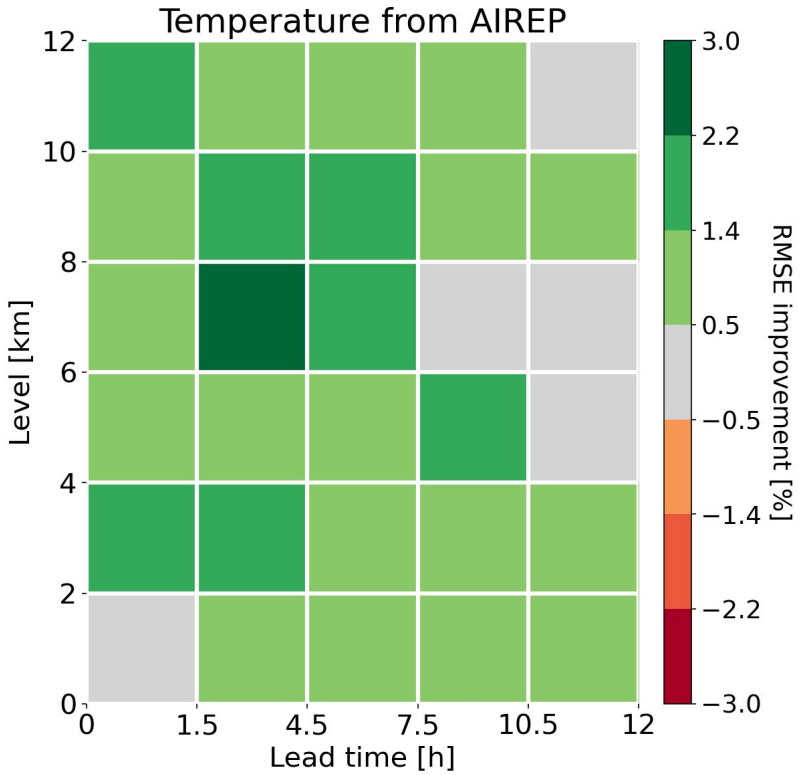
RMSE(*refl+LHN*) - RMSE(*refl+rwind+LHN*)



Average number of obs.: 21621 (ranging from 7370 to 50159)
Average RMSE (cntr): 1.07 K (ranging from 0.82 K to 1.49 K)

Positive values (green) -- > *refl+rwind+LHN* better than *refl+LHN*

RMSE(*refl*) - RMSE(*refl+rwind*)

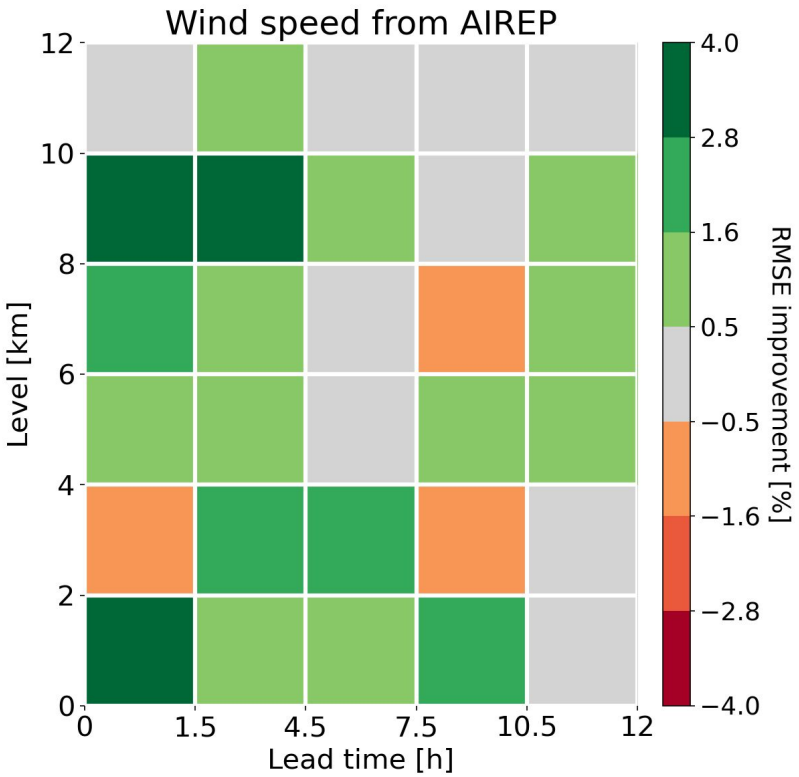


Average number of obs.: 21624 (ranging from 7367 to 50254)
Average RMSE (cntr): 1.08 K (ranging from 0.81 K to 1.49 K)

Positive values (green) -- > *refl+rwind* better than *refl*

Upper-air variables: Wind speed (RMSE)

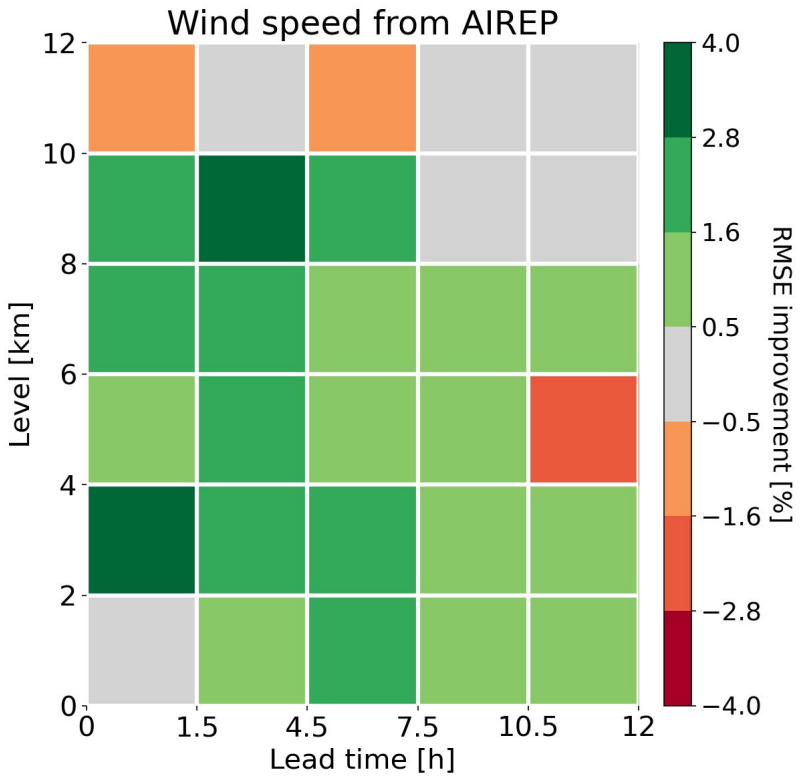
RMSE(*refl+LHN*) - RMSE(*refl+rwind+LHN*)



Average number of obs.: 10867 (ranging from 3356 to 27002)
Average RMSE (cntr): 3.03 m/s (ranging from 2.64 m/s to 3.61 m/s)

Positive values (green) -- > *refl+rwind+LHN* better than *refl+LHN*

RMSE(*refl*) - RMSE(*refl+rwind*)

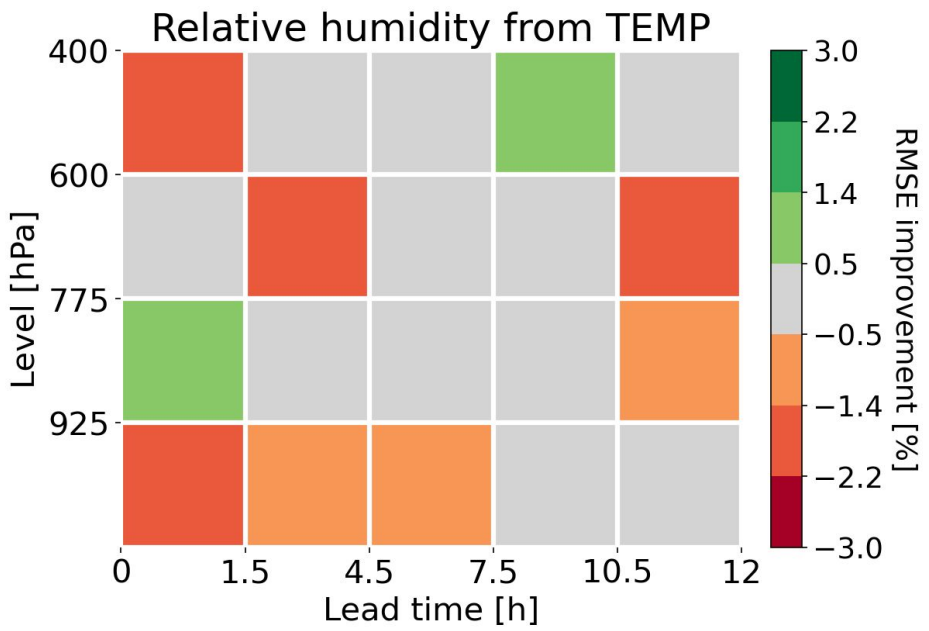


Average number of obs.: 10867 (ranging from 3352 to 27033)
Average RMSE (cntr): 3.01 m/s (ranging from 2.62 m/s to 3.55 m/s)

Positive values (green) -- > *refl+rwind* better than *refl*

Upper-air variables: Relative humidity (RMSE)

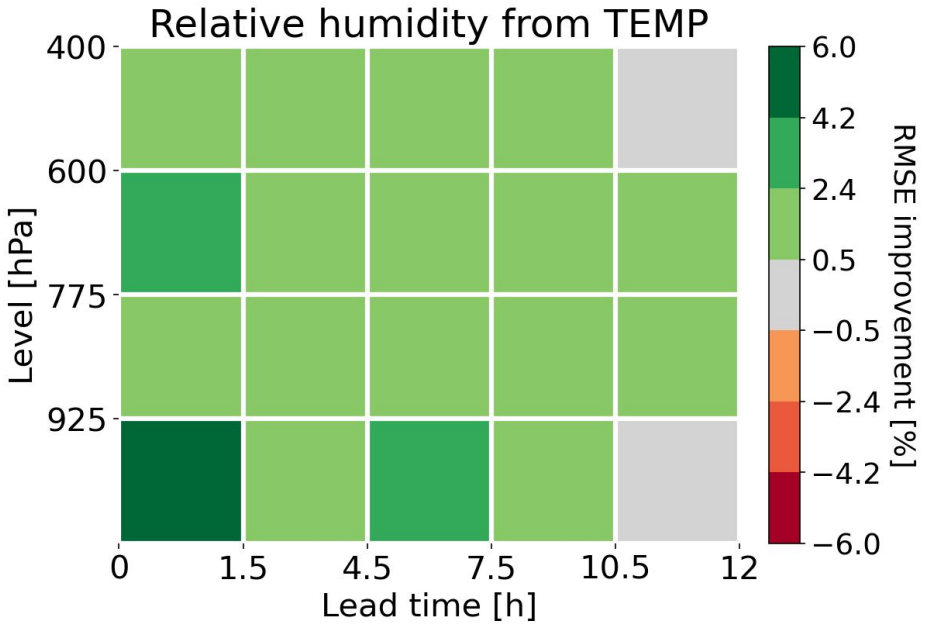
RMSE(*refl+LHN*) - RMSE(*refl+rwind+LHN*)



Average number of obs.: 4958 (ranging from 1343 to 8238)
Average RMSE (cntr): 0.19 kg/kg (ranging from 0.12 kg/kg to 0.22 kg/kg)

Positive values (green) -- > *refl+rwind+LHN* better than *refl+LHN*

RMSE(*refl*) - RMSE(*refl+rwind*)

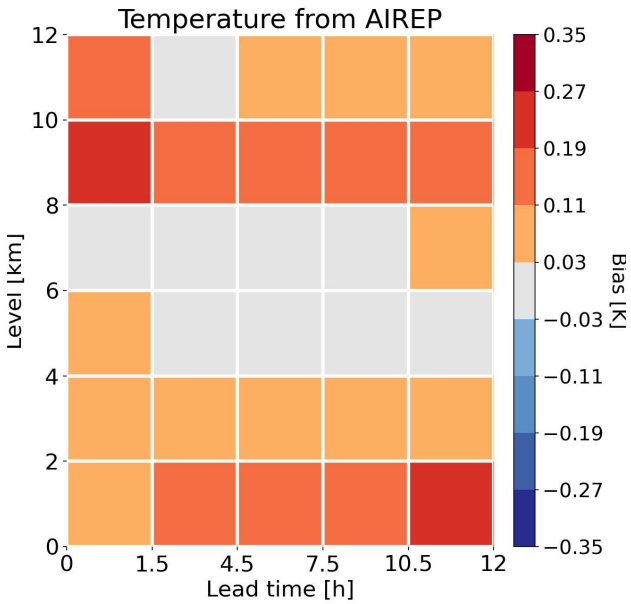


Average number of obs.: 4961 (ranging from 1345 to 8259)
Average RMSE (cntr): 0.19 kg/kg (ranging from 0.13 kg/kg to 0.23 kg/kg)

Positive values (green) -- > *refl+rwind* better than *refl*

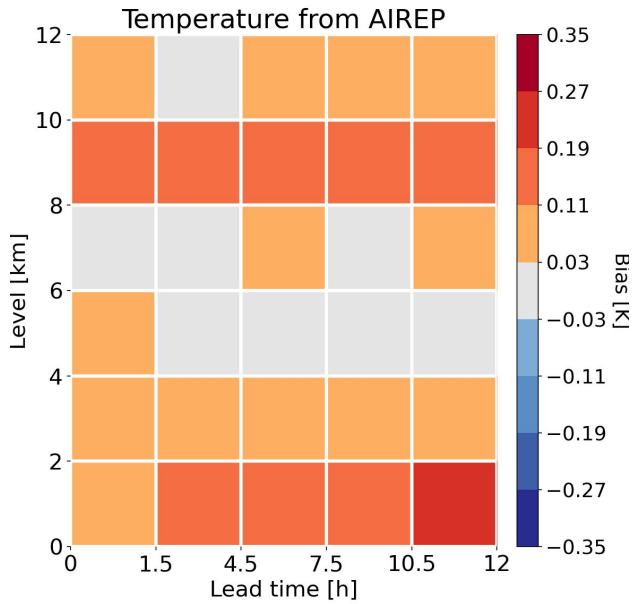
Upper-air variables: Temperature (bias)

refl+LHN



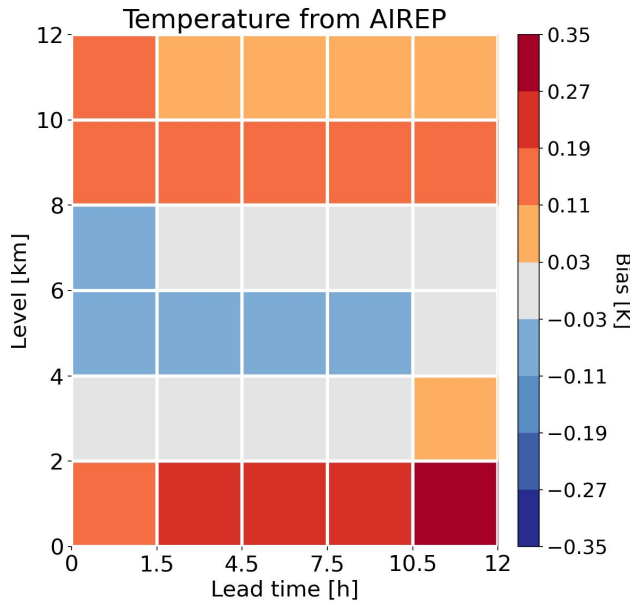
Average number of obs.: 21621 (ranging from 7370 to 50159)
Average bias: 0.072 K (ranging from 0.005 K to 0.210 K)

refl+rwind+LHN



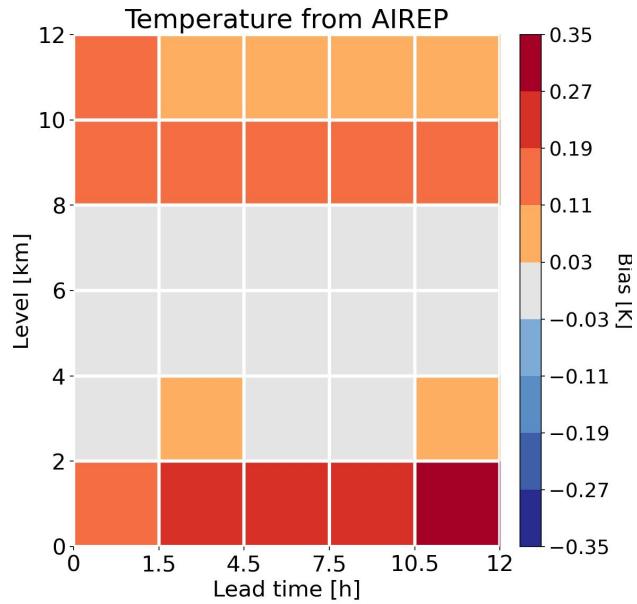
Average number of obs.: 21637 (ranging from 7376 to 50219)
Average bias: 0.070 K (ranging from 0.005 K to 0.216 K)

refl



Average number of obs.: 21624 (ranging from 7367 to 50254)
Average bias: 0.071 K (ranging from -0.040 K to 0.289 K)

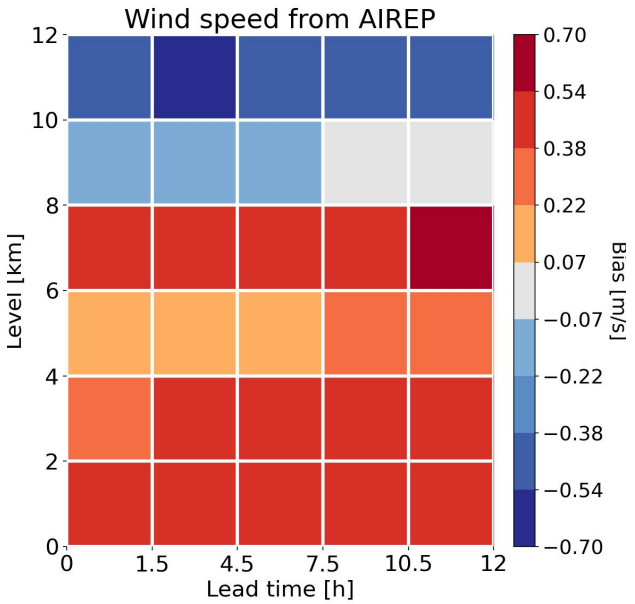
refl+rwind



Average number of obs.: 21638 (ranging from 7373 to 50264)
Average bias: 0.073 K (ranging from -0.023 K to 0.297 K)

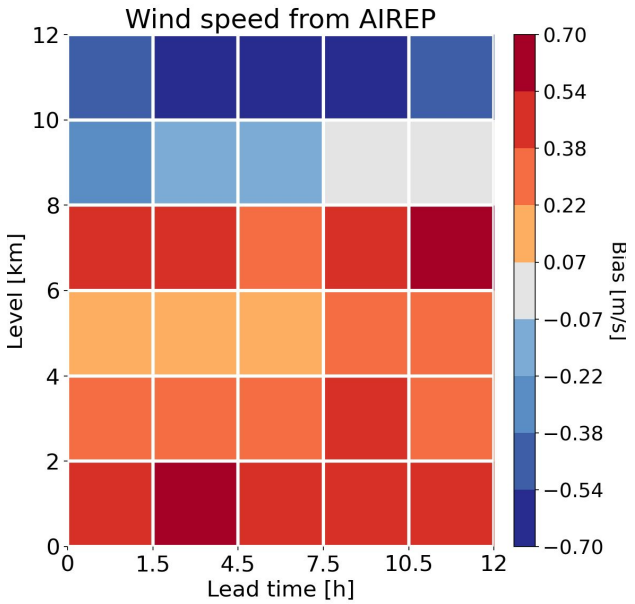
Upper-air variables: Wind speed (bias)

refl+LHN



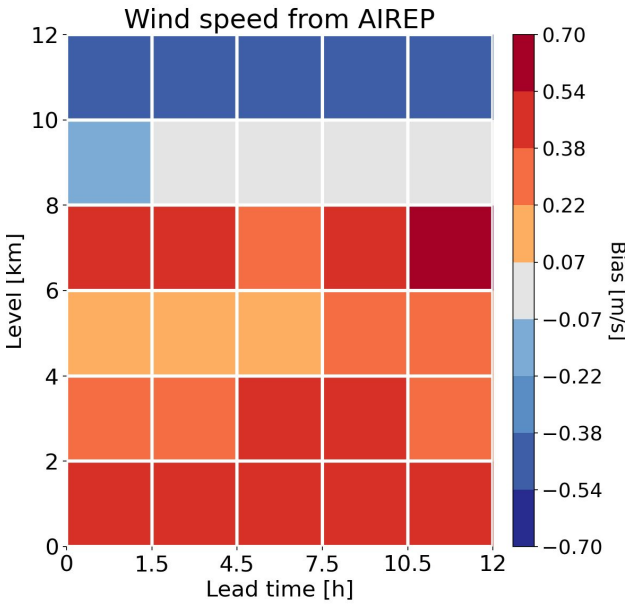
Average number of obs.: 10867 (ranging from 3356 to 27002)
Average bias: 0.144 m/s (ranging from -0.554 m/s to 0.671 m/s)

refl+rwind+LHN



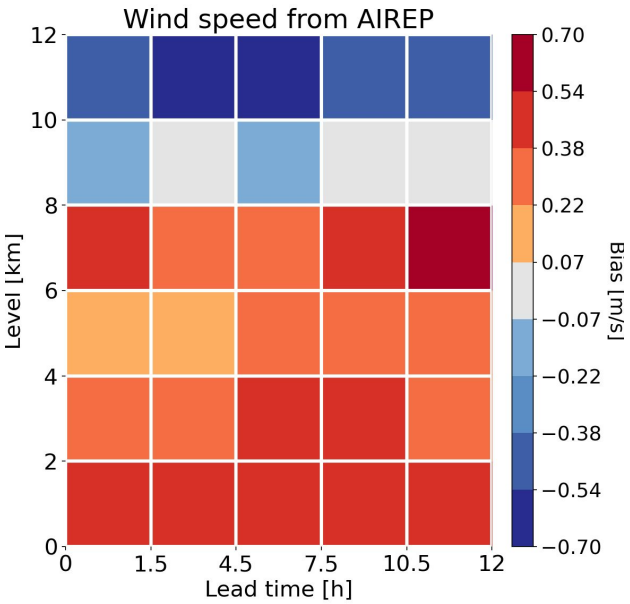
Average number of obs.: 10874 (ranging from 3357 to 27003)
Average bias: 0.125 m/s (ranging from -0.561 m/s to 0.656 m/s)

refl



Average number of obs.: 10867 (ranging from 3352 to 27033)
Average bias: 0.144 m/s (ranging from -0.539 m/s to 0.631 m/s)

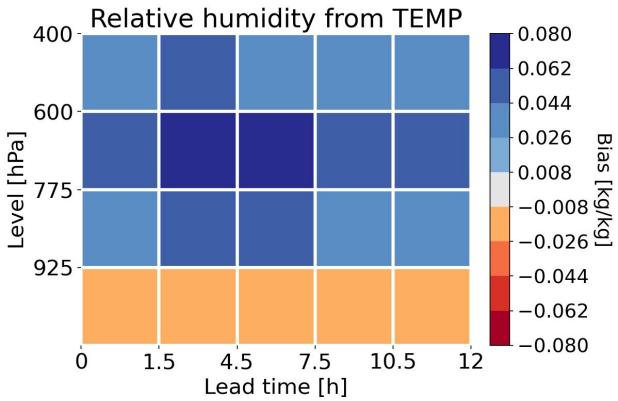
refl+rwind



Average number of obs.: 10867 (ranging from 3367 to 27014)
Average bias: 0.139 m/s (ranging from -0.566 m/s to 0.592 m/s)

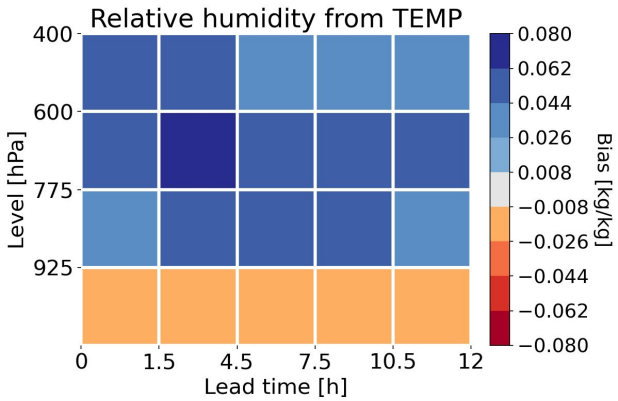
Upper-air variables: Relative humidity (bias)

refl+LHN



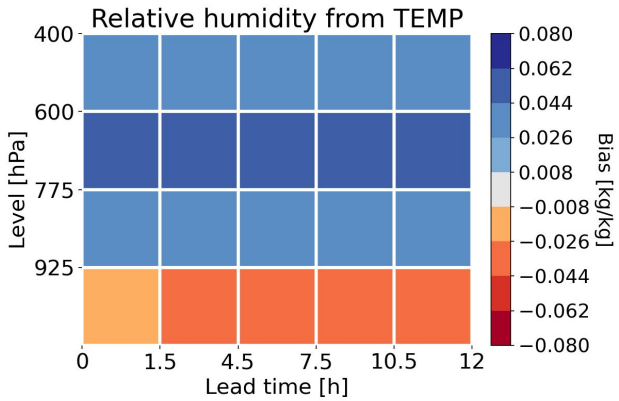
Average number of obs.: 4958 (ranging from 1343 to 8238)
Average bias: 0.030 kg/kg (ranging from -0.024 kg/kg to 0.063 kg/kg)

refl+rwind+LHN



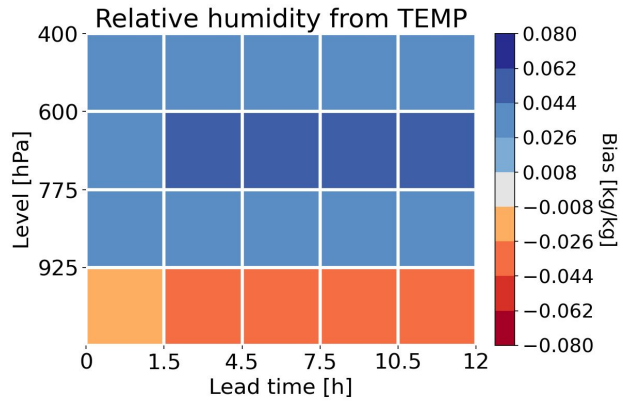
Average number of obs.: 4951 (ranging from 1347 to 8264)
Average bias: 0.031 kg/kg (ranging from -0.026 kg/kg to 0.067 kg/kg)

refl



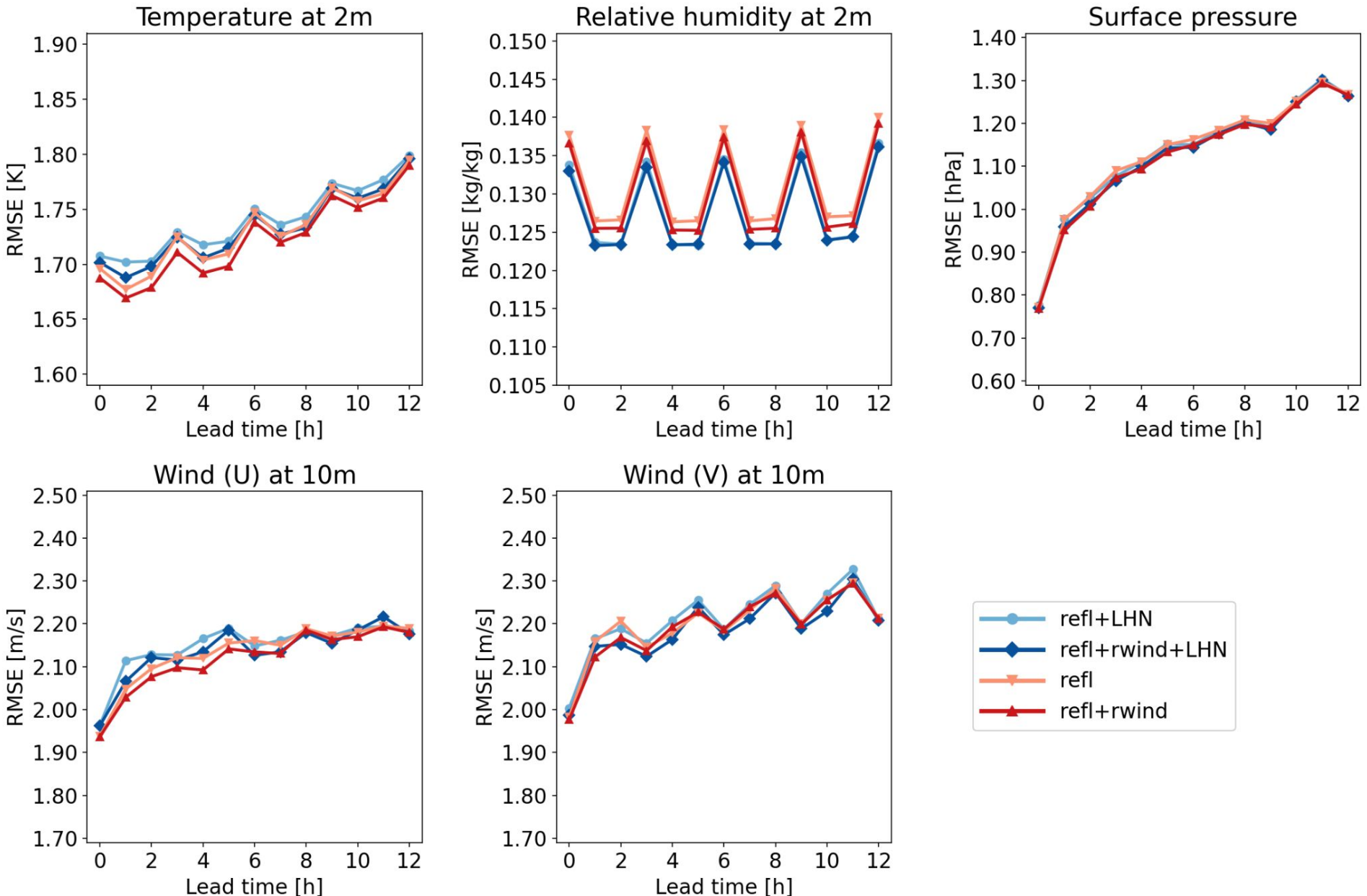
Average number of obs.: 4961 (ranging from 1345 to 8259)
Average bias: 0.023 kg/kg (ranging from -0.032 kg/kg to 0.053 kg/kg)

refl+rwind

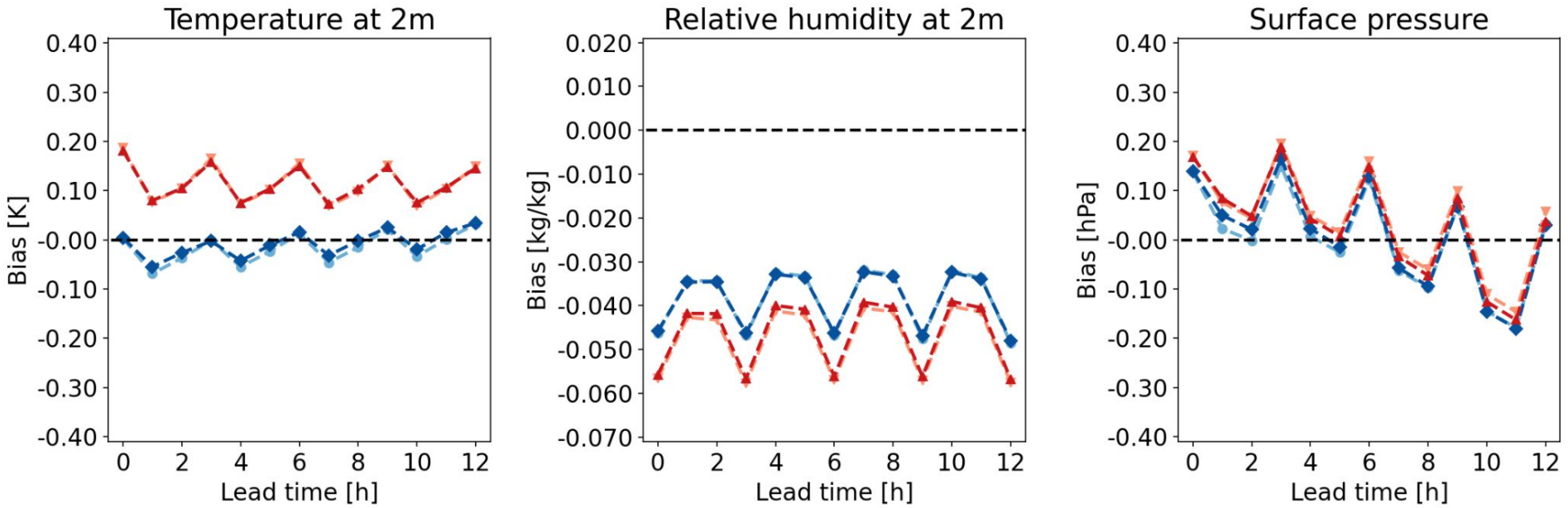


Average number of obs.: 4968 (ranging from 1349 to 8269)
Average bias: 0.021 kg/kg (ranging from -0.030 kg/kg to 0.047 kg/kg)

Near-surface variables: RMSE

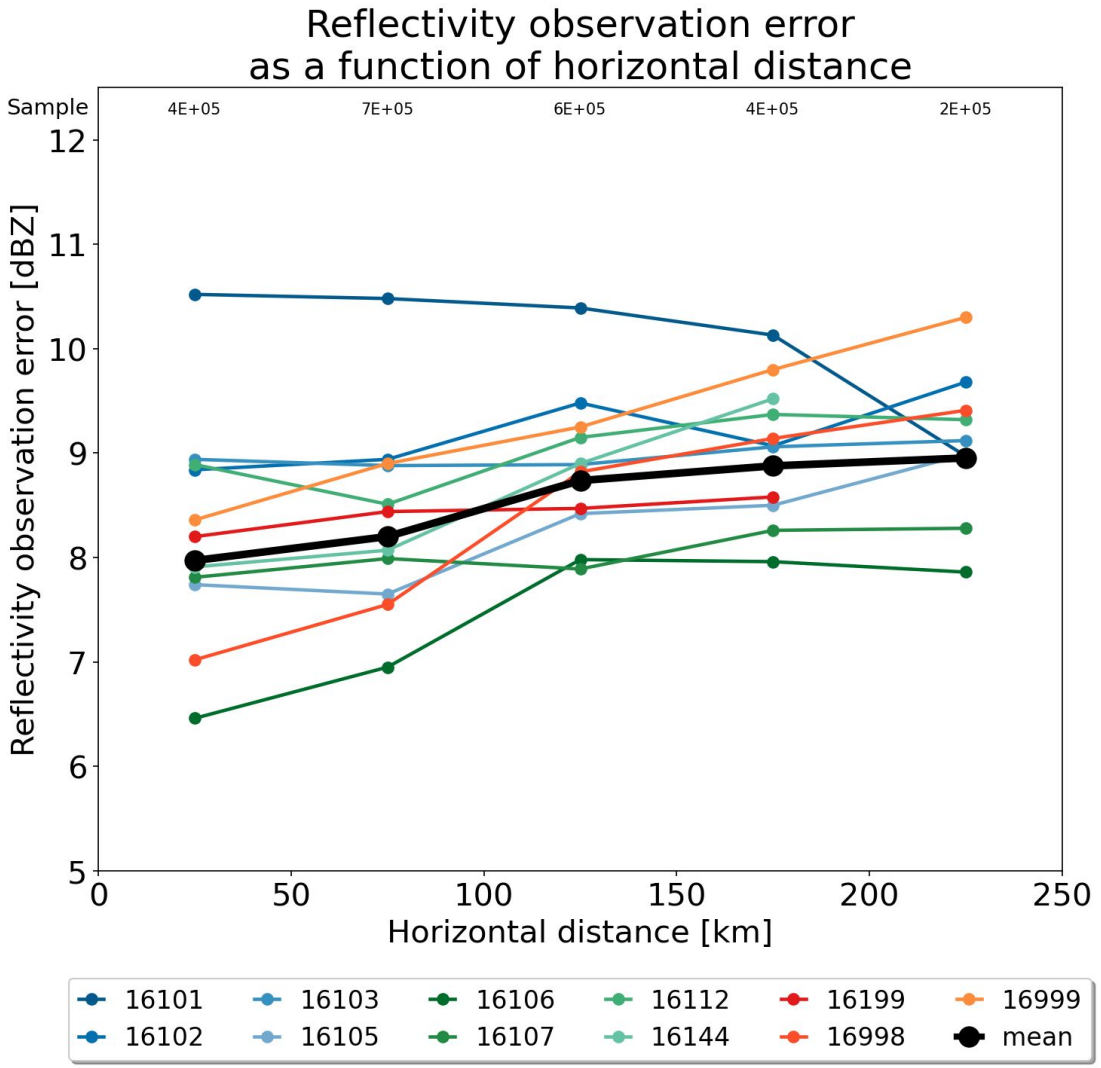


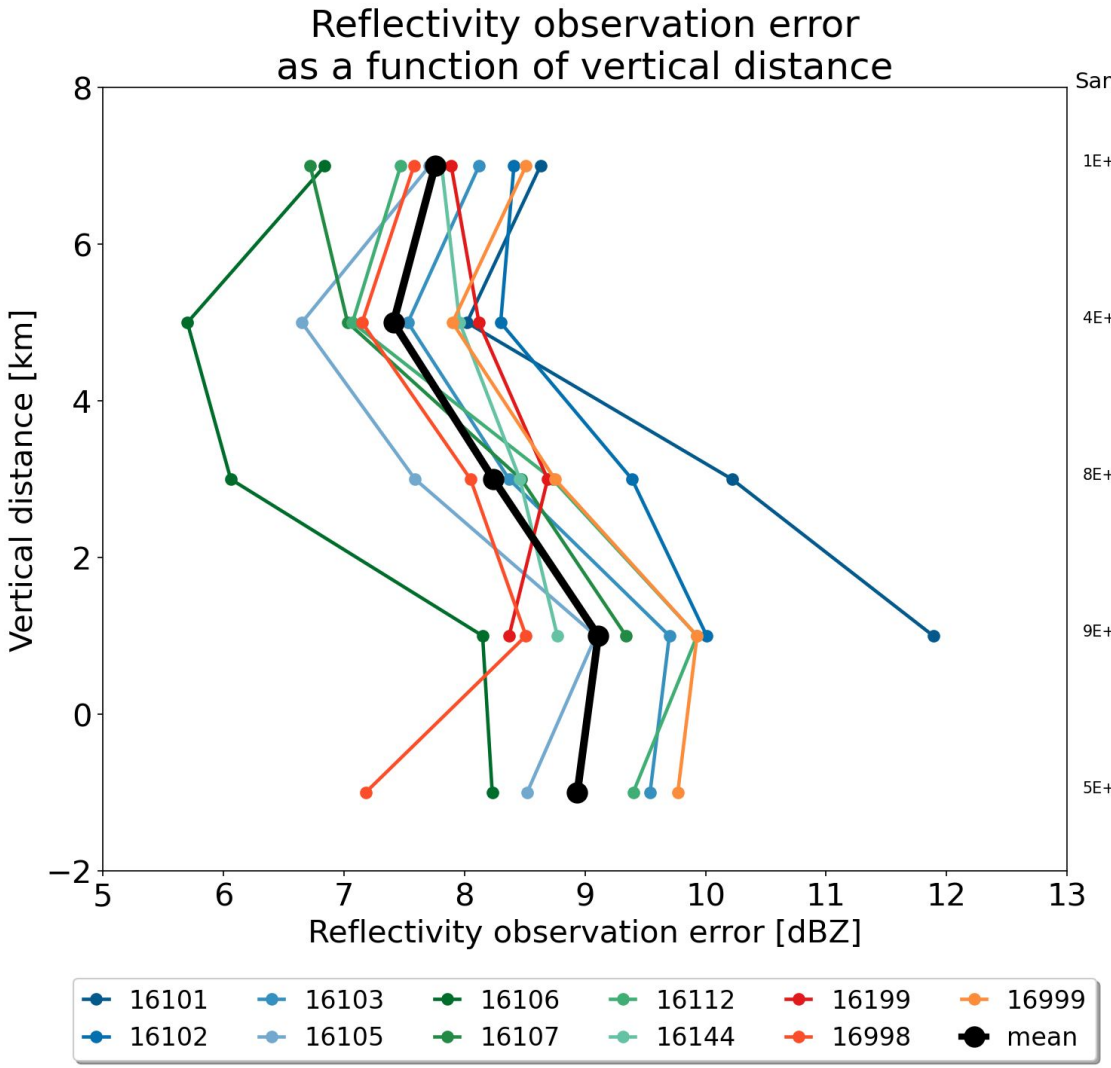
Near-surface variables: bias



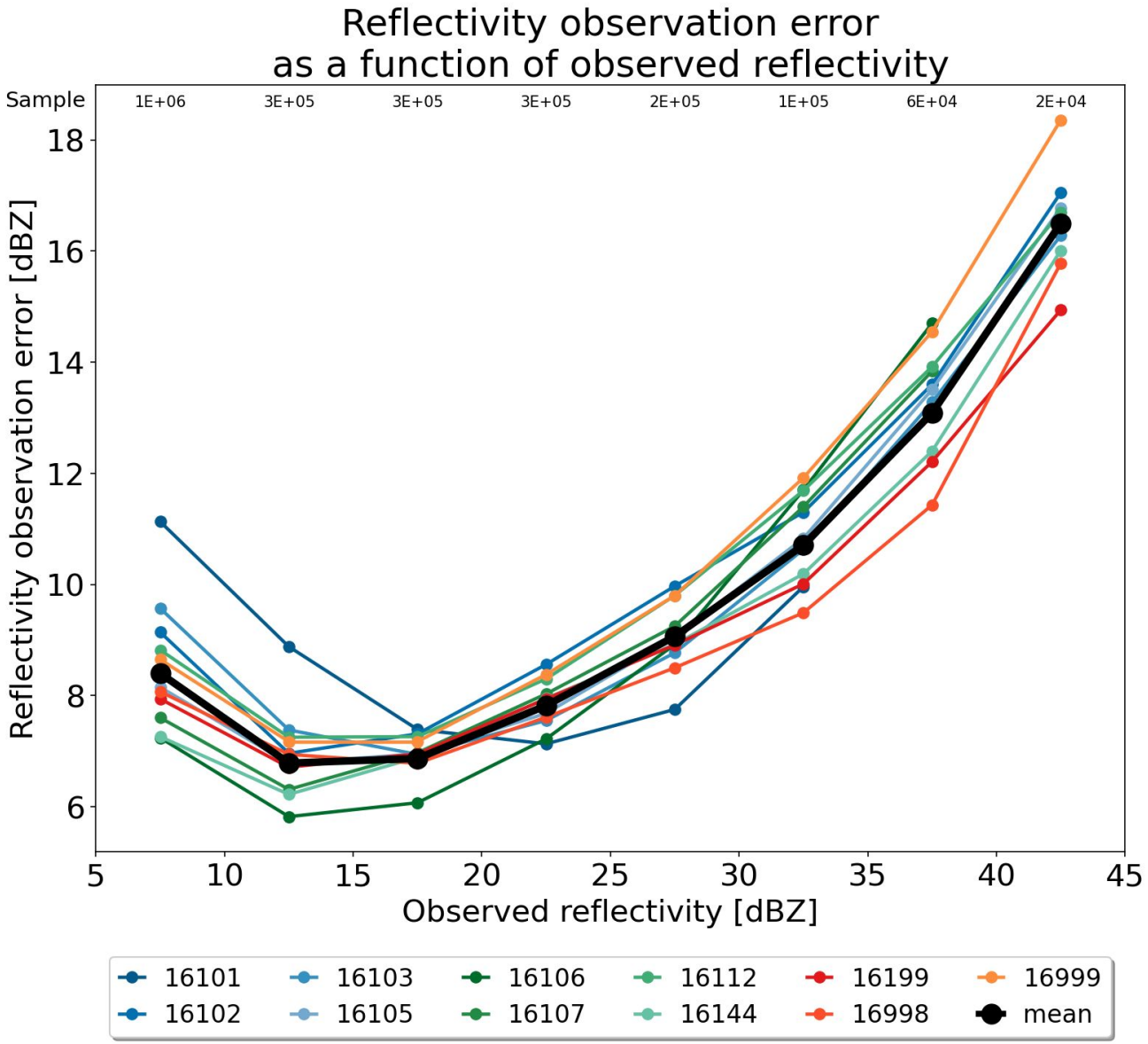
Estimation of the observation error for reflectivity

Estimation is performed over the whole test period considering *refl+rwind* experiment, binning observations as a function of the horizontal and vertical distance of observations from the radar station. The binning step is, respectively, of 50 km and 2 km.





Estimation of the observation error for reflectivity



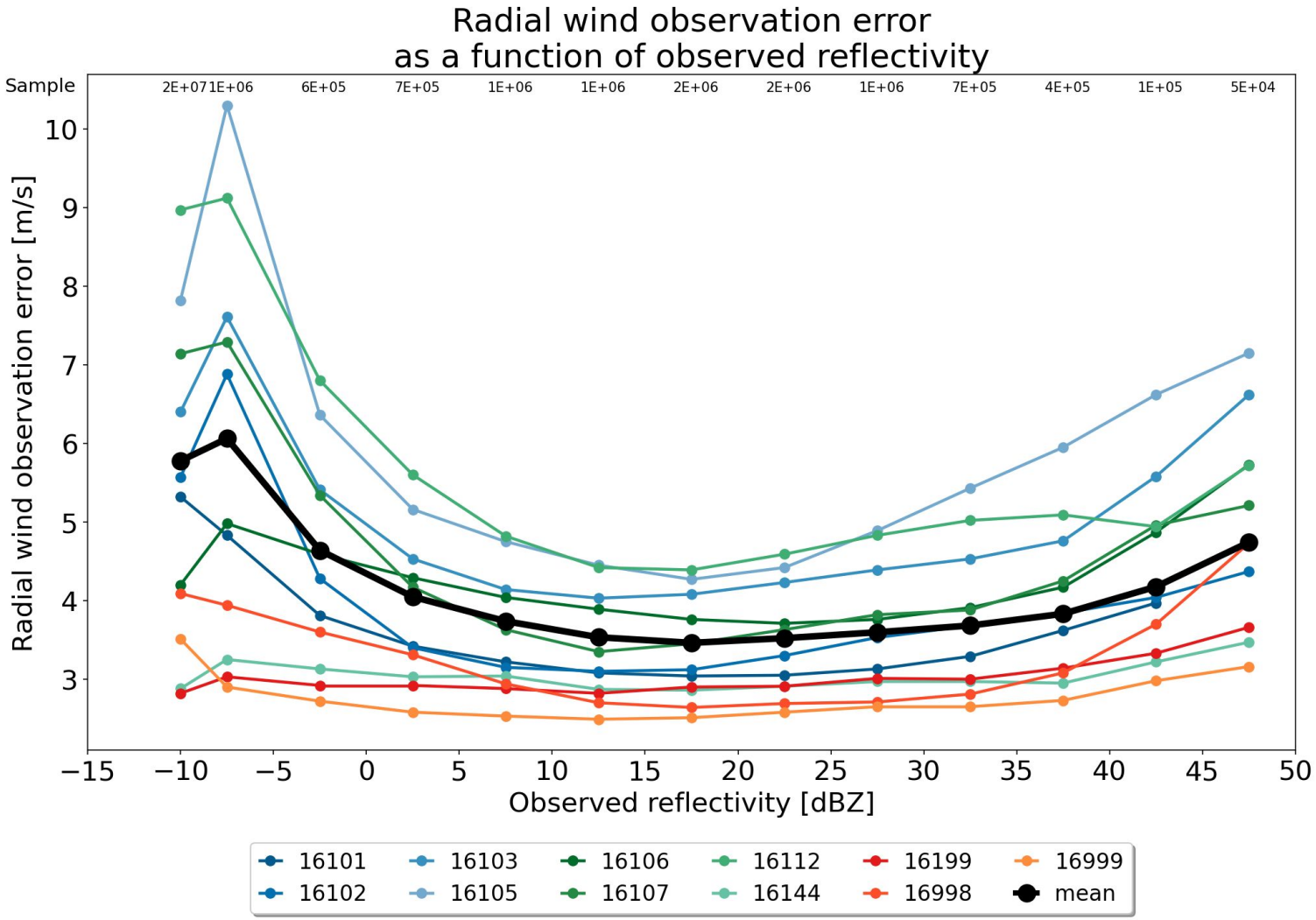
Estimation of the observation error for radial winds

The observation error for radial winds is set before applying the threshold on reflectivities and before applying superobbing.

In an attempt to improve the estimation of the observation error, we performed an experiment equal to *refl+rwind* but with:

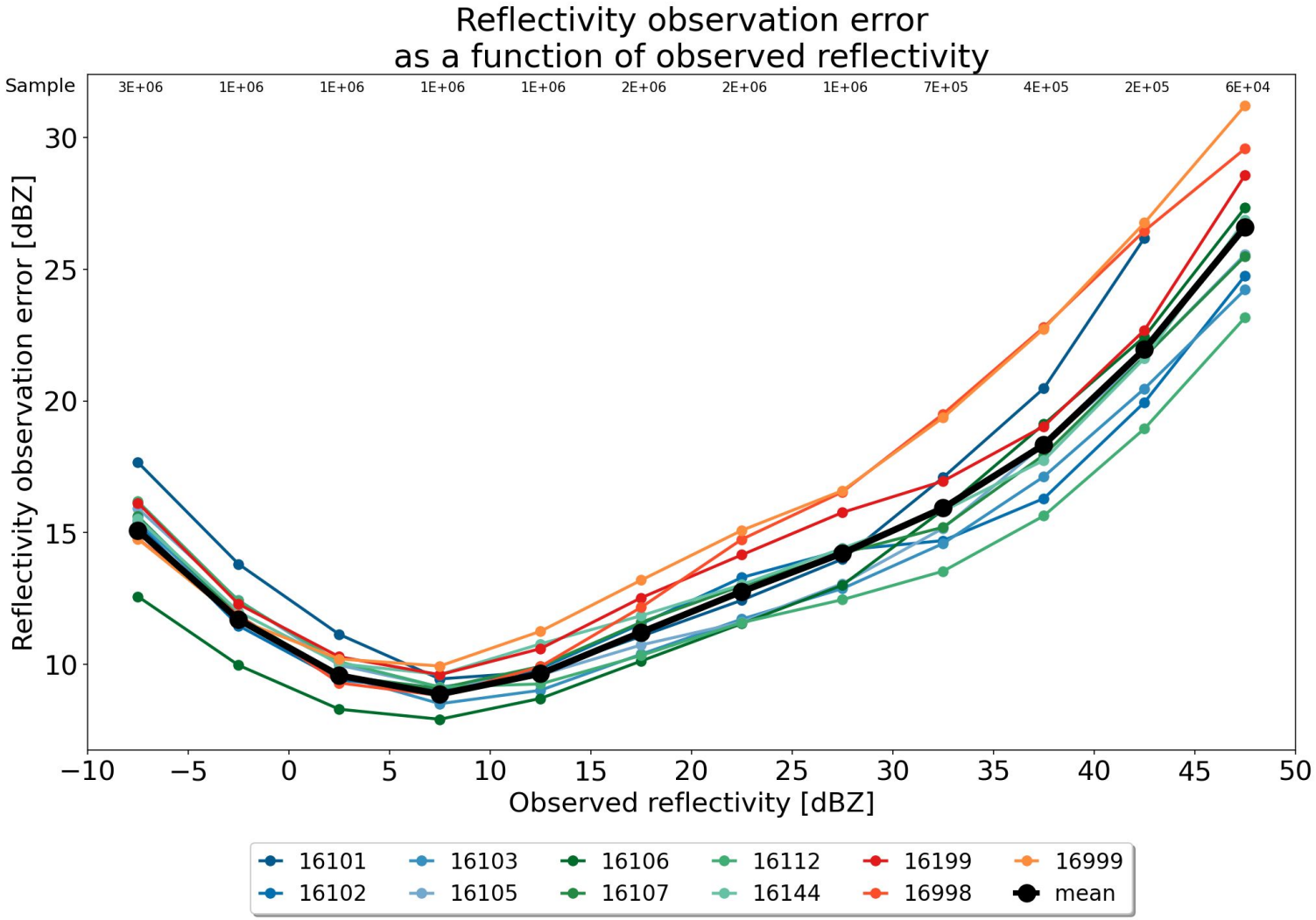
- threshold of -10 dBZ;
- Superobbing of 2km.

The estimation is performed over a shorter period: 18/09/2020 to 27/09/2020.



Estimation of the observation error for reflectivity

Estimation based on an experiment equal to *refl+rwind* but with:

- threshold of -10 dBZ;
- Superobbing of 2km.

The estimation is performed over a shorter period: 18/09/2020 to 27/09/2020.