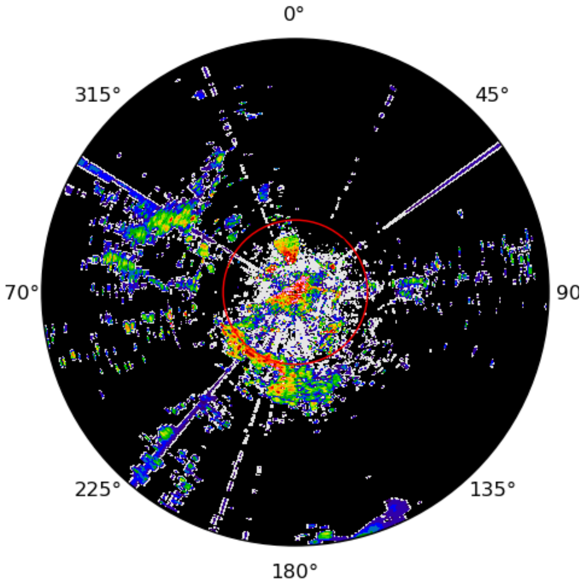
Regional Cooperation for
Limited Area Modeling in Central Europe

LACE
nwp central europe

Radar sensitivity estimation within the OPERA dataset and impact studies



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1 Introduction

The stay is a continuation of efforts dedicated to the assimilation of radar reflectivity data from the OPERA data servers in RC LACE, especially following the results of Panežić (2023). The goal is to provide a consolidated contribution to the common ACCORD code repository at github.com. New approaches improving the 1D+3D-Var method (Wattrelot et al., 2014) are applied for a one-month period in summer 2022.

2 Contribution to the radar assimilation cycle CY49T0

RC LACE local development of radar assimilation reached a state where we decided to contribute to the common cycle CY49T0. Beside minor fixes, there were several suggestions to minimize the drying effect of radar reflectivity assimilation. The most promising ones are included in the contribution. Excessive drying, as shown by reports from previous stays (Panežić, 2022, 2023), is mainly related to the assimilation of undetected observation (here imprecisely called *dry observations*). Undetected observation means that radar only received a signal below its detection threshold (noise level). Bator is used to create an artificial observation from those undetected ones by setting their values to a pseudo detection threshold of the radar at a given distance from the radar. The pseudo detection threshold is computed by the following procedure:

1. The detectable reflectivity factor (DRF) at 1km from the radar is calculated for each (detected) observation at a given elevation angle:

$$\mathrm{DRF}_i = \mathrm{obsValue}_i - 40 - 20.0 * log10\left(\frac{\mathrm{distObs}_i}{100000.}\right), \tag{1}$$

   where $\mathrm{distObs}_i$ is distance of i observation from the radar, obsValue is value of the observation.

2. The minimum of all detectable reflectivity factors is then evaluated:

$$\mathrm{MDRF} = \min(\mathrm{DRF}). \tag{2}$$

3. Finally, the pseudo detection threshold is computed for each undetect observation by the following formula:

$$\mathrm{zthreshold}_k = \mathrm{MDRF} + 40 + 20.0 * log_{10}\left(\frac{\mathrm{distObs}_k}{100000.}\right). \tag{3}$$

As can be seen from the formulas, the result strongly depends on the sample of the measured observation for a given elevation. All the problems related to data quality also propagate into the estimation of the MDRF value, which could be incorrect under specific conditions. Unfortunately, there is no simple solution. It is therefore important to report any data issues back to the OPERA. In the following subsections, the details of all keys added to the code of contribution are explained. The following subsections explain the details of all the keys added to the contribution.

2.1 Air density fix

Air density used in routine `arpifs/op_obs/reflsim_2dop.F90` was fixed 3 years ago because the air density was vertically constant before (value 1.2 $\mathrm{kg\,m^{-3}}$). Unfortunately, it was not a fully correct fix. The PRF5 field contains the specific gas constant of mixed air instead of dry air as expected. The correct formulas are used after adding LRADAR_DENSITYFIX=.T. to the NAMSCC namelist. The impact of this modification is small.

2.2 Store real first guess departure

The key LRADAR_STORE_REAL_FG=.T. (NAMSCC) is used to store the real difference between dry observations (undetect) and guess in odb. Without usage of the key the inversion routine `arpifs/op_obs/inv_refl1dstat.F90` redefines guess reflectivity smaller than observed dry observation to be equal to the dry observation, so the difference (fg_depar) is then zero! Please keep in mind that without LRADAR_STORE_REAL_FG=.T. the statistics taken from odb are misleading for dry observations. Those zeros are then used to identify the dry observations in `arpifs/obs_preproc/flgtst.F90` for sign checks. It would be very difficult to keep the checks there so they were moved to inv_refl1dstat.F90. Using the key LRADAR_STORE_REAL_FG=.T. does not change the analysis results.

2.3 Inflation of the dry observation error

Panežić (2023) proposed to inflate errors of relative humidity observations created by inversion routine `inv_refl1dstat.F90` from dry reflectivity observations (undetect). The error is tunable in bator namelist by the keys:

- LRADAR_DOE - to inflate Dry Obs Error (default F)
- RRADAR_OFFSET_DOE - inflation offset for dry obs error (default 0.)

The idea is very simple. If we use not so good observations (undetected), we can reduce their impact by increasing their errors.

2.4 Assimilate only when considerable precipitation is present in the model or observations

This concept consists of assimilating the radar reflectivity only when considerable precipitation has been observed by the radar or predicted by the model. This means that either observed or modeled reflectivity is greater than a preset threshold. Idea was proposed by Benedikt Strajnar. The concept is set in the NAMSCC namelist:

- LRADAR_RAINTHR - to remove model profiles that have no significant precipitation (DBZ) in observations or in the model (default .F.). If observed or modeled reflectivity is greater than RRADAR_RAINTHR at least at one elevation then this profile is used in assimilation.
- RRADAR_RAINTHR - threshold (in DBZ) for LRADAR_RAINTHR.

2.5 Adjustable distance for searching the model profiles

Before the computation of pseudo observed relative humidity in the inversion routine, we need to define a sufficiently large sample of model places with simulated reflectivity profiles and relative humidity profiles (`arpifs/obs_preproc/radar_profs.F90`). More precisely, we need to define NOBSPROFS profiles for each vertical column of observations. Profiles are regularly distributed in a square box of adjustable size RRADAR_DIST (default 200 km, NAMSCC) around the observation column, see Bučánek (2020). Tuning the number of profiles and distance can significantly influence memory consumption of radar reflectivity assimilation.

2.6 Removal of moistening by dry observations

The value of dry (undetected) observation is created as the expected radar detection threshold (see the beginning of section 2) but in reality, the undetected observation could have any value lower than the radar detection threshold. So the created value is the ceiling for all possible values for undetected observation. This could lead to moistening in areas where it is not desirable. Moistening by undetected (dry) observation is removed when LRADAR_NMBDO=.T. (NAMSCC). The impact should be tested more deeply, initial tests were not promising.

2.7 Checking that model profile is fully defined

During the preparatory work to store real first guess in the inversion routine (subsection 2.2), it was found that not all model profiles are defined at all elevations. This means that in the weighted averaging formula, see Bučánek (2020), undefined values (RMDI = −2147483647) are used in the model profiles. Fortunately, this undesirable behavior does not happen too often. To avoid/fix the problem use LRADAR_PROFCHECK=.T. (NAMSCC).

2.8 Three sigma check

The new logical switch LRADAR_SIGMA3CHECK=.T. (NAMSCC) ensures that model profiles that are "too far" from the observations are removed from the averaging formula. More precisely, if the average reflectivity difference between the model profile and the observation column is greater than three sigma (3*ZRADARXSIG), then the model profile is not used in inversion/averaging. It is a very common situation that observation and model profiles are "too far" from each other. Consequently numerator and denominator in the weighed average are very small numbers which is not the best especially if this is valid for all model profiles. The impact of the switch is not yet tested.

2.9 Checking sign flipping for dry observations

Sign of reflectivity departure and humidity departure is compared in `arpifs/obs_preproc/flgtst.F90`. By default, the reflectivity departure for models drier than dry observations is zero (see subsection 2.2). However, zero departures are not handled by the sign check conditions. As a result, the assimilation can dry the model more even though the reflectivity departure signals that the model is already too dry (`fg_depar[refl]=0 & fg_depar[rh]>0`).

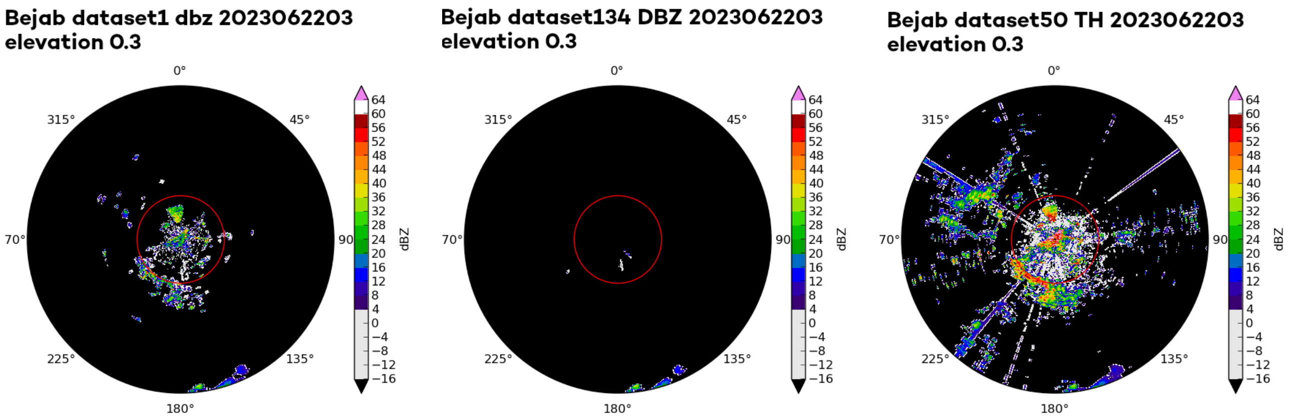
Sign flipping can be checked for undetected observations (dryobs) as well as for normal observations when LRADAR_CDOF=.T. and LRADAR_STORE_REAL_FG=.T. is set in NAMSCC namelist.

2.10 Limiting the maximum height of reflectivity assimilation

Only reflectivity observations up to model level 10 are used in the assimilation by default. This was introduced back in the CY36T1 cycle. The reason was probably the limitation of the height to which the reflectivity assimilation is active. Wattrelot et al. (2014) used 41 model levels in their experiments, which means that model level 10 was somewhere around 12 km at that time. However, now most model configurations have more than 80 vertical levels and subsequently, the height of model level 10 increases up to 16–20 km. This is considerably higher than before, which is why height limit switches are introduced:

- LRADAR_MAXHEIGHT - to limit height for reflectivity assimilation (default F)
- RRADAR_MAXHEIGHT - maximum height in meters when LRADAR_MAXHEIGHT=.T. (default = 100000 to assimilate in "all vertical column")

3 Belgium radar issue



(a) DBZH (b) DBZH2 (c) TH

Figure 1: Belgium radars contain the same elevation in the dBZ dataset twice but with different values.

During the preparatory work, a problem was detected in the radar data from the Belgian radars taken from the Odyssey OPERA Data Centre. The logged horizontally-polarized (corrected) reflectivity factor (DBZH) appears twice in the data file for the same elevation and the same time but with different values, as shown in Figure 1 and Table 1. Bator reads both DBZH data sets and does not make any special handling of them. It is uncertain which data is correct and which is not, so no action has been taken yet. Since the new NIMBUS processing line is expected to be operational in 2024, it is better to wait and check again later.

Table 1: Listing of T_PAZZ42_C_EUOC_20220622030000_bejab.h5 for elevation 0.3°

elevation 0.300000	startdate 20220622	starttime 030420	data1 DBZH	/dataset1
elevation 0.300000	startdate 20220622	starttime 030420	data1 DBZH	/dataset134
elevation 0.300000	startdate 20220622	starttime 030420	data1 TH	/dataset50

4 Experiments

Three proposals for assimilating reflectivity are tested in comparison with the operational setting of the Czech Hydrometeorological Institute (CHMI oper), namely default Meteo-France approach (MF), Suzana Panežić's (Panežić) proposal to inflate the dry observation error and Benedikt Strajnar's (Strajnar) proposal to assimilate reflectivity only when significant precipitation occurs in the model or observations. Reflectivity data are downloaded from the Odyssey OPERA Data Centre. The experimental period is from 2 June to 3 July 2022. The model setup is briefly explained in the following section. The namelist keys are summarized in Table 2 for all experiments, see also Appendix A. Unfortunately, due to lack of time, the experiments were only set up and submitted to the supercomputer and no verification was done.

Table 2: Namelist setting specific for each experiment with the key names as defined in CY49.

screen.namel	CHMI oper	MF	Panežić	Strajnar
ZRADARXSIG	0.2	0.2	0.2	0.2
RRADAR_DIST	200000	200000	200000	200000
LRADAR_RAINTHR	.F.	.F.	.F.	**.T.**
RRADAR_RAINTHR	0	0	0	**12.**
LRADAR_NMBDO	.F.	.F.	.F.	.F.
LRADAR_STORE_REAL_FG	.T.	.T.	.T.	.T.
LRADAR_SIGMA3CHECK	.F.	.F.	.F.	.F.
LRADAR_PROFCHECK	.F.	.F.	.F.	.F.
LRADAR_DENSITYFIX	.T.	.T.	.T.	.T.
LRADAR_CDOF	.F.	.F.	.F.	.F.
LRADAR_MAXHEIGHT	.T.	.T.	.T.	.T.
RMIND_RADAR	16275	16275	16275	16275
RFIND_RADAR	16275	16275	16275	16275
NOBSPROFS(13)	225	225	225	225
XYSHIFT_THIBOX(13)	0.5	0.5	0.5	0.5
namel_bator				
LRADAR_DOE	.F.	.F.	**.T.**	.F.
RRADAR_OFFSET_DOE	0.	0.	**0.35**	0.

4.1 Model setup

All experiments used the ALARO/CZ operational configuration.

- Model: ALARO NH-v1B cy43t2ag_op2
- Domain: ALARO/CZ; $\Delta x = 2.3$ km;
  1069x853 GP; 87 vertical levels; mean orography,
- Coupling: 1h space consistent coupling from ARPEGE; synchronous
- Upper air analysis: BlendVar scheme (DF blending, filtering at truncation E102x81) followed by 3D-Var; 3h Assimilation cycle; REDNMC=0.5, Ensemble data assimilation B matrix based on AEARP;
- Surface is updated by Optimal interpolation with averaged analysis increments from 8 last analyses
- Assimilated observation: SYNOP, TEMP, AMDAR, SEVIRI, Mode-S MRAR/Mode-S EHS, HR-AMV, wind profiler, ASCAT.

5 Conclusion

Consolidated contribution to the cycle CY49T0 at the ACCORD code repository was done during the stay. The specific proposals for assimilation of radar reflectivity observations were submitted to the supercomputer, see section 4, but due to lack of time, the results were not yet fully verified.

References

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Appendix A: Experiments and data on kazi

- Experiment CHMI oper: `kazi2:/home/mma204/SX/scr/exp/zka`
- Experiment MF: `kazi2:/home/mma204/SX/scr/exp/zkb`
- Experiment Panežić: `kazi2:/home/mma257/radar_assim_article/ssp`
- Experiment Strajnar: `kazi2:/home/mma257/radar_assim_article/ssb`