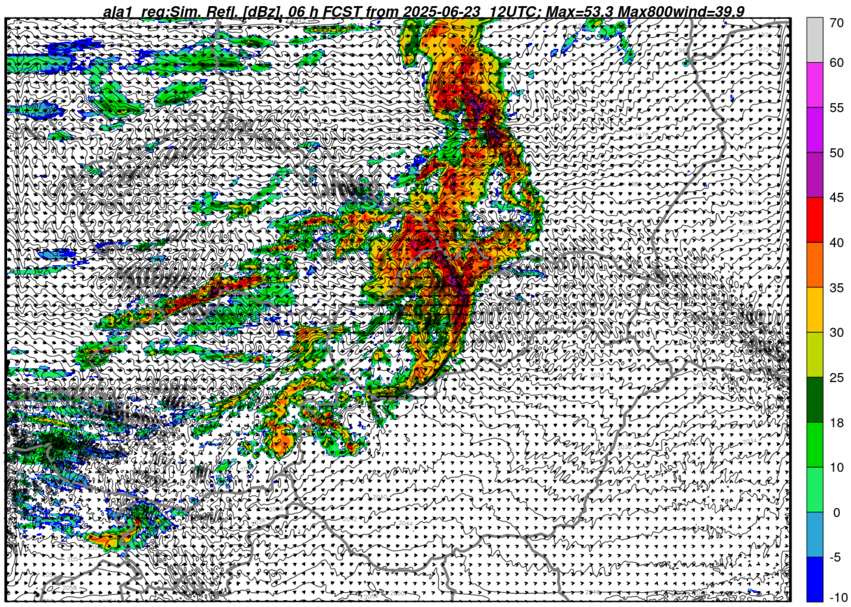
Regional Cooperation for Limited Area Modeling in Central Europe

LACE
nwp central europe

Radar data assimilation: Implementation and evaluation of CY46T1as at SHMU



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Host: Antonín Bučánek (CHMI)

Purpose: Report from RC LACE stay
Place: CHMI, The Czech Republic, Prague
Date(s): 4. 11. – 22. 11. 2024

GeoSphere Austria · DHMZ · Czech Hydrometeorological Institute · IMGW · HungaroMet · Meteo Romania · SHMU · ARSO METEO Slovenia

1. Introduction

The purpose of this stay was twofold. The primary objective was to port news related to radar assimilation from the CHMI cycle cy46t1as to SHMU: 46t1_bf07_oper.11.INTEL.x and to validate its functionality. The second objective focused on evaluating available optimization keys for radar data assimilation with the aim of improving the accuracy of the assimilation process within the existing workflow. This work is following previous radar assimilation stays in RC LACE. So we started our experiments by adopting DHMZ's operational radar assimilation setup.

2. Implementation of cy46t1as at SHMU

Before starting the radar assimilation experiments, it was important to ensure that the local SHMU cycle (46t1_bf07_oper.11) had fully integrated all recent radar-related updates introduced in the CHMI cycle (cy46t1as). We compared the two cycles and updated the assimilation components of 46t1_bf07_oper.11 accordingly. Validation was done by running an identical test case at SHMU (with the updated local cycle) and at CHMI (with cy46t1as), followed by a comparison of the outputs.

This comparison revealed differences in the results of screening and minimization steps. To quickly check if the screening is functioning correctly, we applied the ODB outputs from the CHMI BATOR directly to the SHMU screening. However, this approach failed as the ODB file could not be read. The reason for this issue was identified a few days later (NMXUPD=4).

Therefore, we copied the CHMI:cy46t1as cycle to SHMU and compiled it in the SHMU environment. We ran the test case again and obtained identical results, confirming that we had indeed forgotten to transfer some source code.

Upon consultation with Alena Trojakova, we identified that mf_blacklist.b file differed between cycles cy46t1as and radar-updated 46t1_bf07_oper.11. As a side effect of this consultation, the ODB reading error was also traced back to the compilation process. Specifically, the gmkpack compilation options differ between CHMI and SHMU in the GMK_CFLAGS_ODB flags: CHMI utilizes NMXUPD=4 (the same setting as Météo-France), while SHMU uses the default NMXUPD=1 (as used by ECMWF).

A new local pack, SHMU:46t1_bf07_oper.12.INTEL.x, was created using identical mf_blacklist and NMXUPD settings as in cy46t1as. This configuration finally produced identical results to those from CHMI:cy46t1as.

A summary of the modifications is provided in Appendix 8.2.

The successful installation is located in following directories:

Operational cycle 46t1_bf07_oper.11
SHMU:hpc3aux01: /users/nwp002/pack/46t1_bf07_oper.11.INTEL.x (master pack)

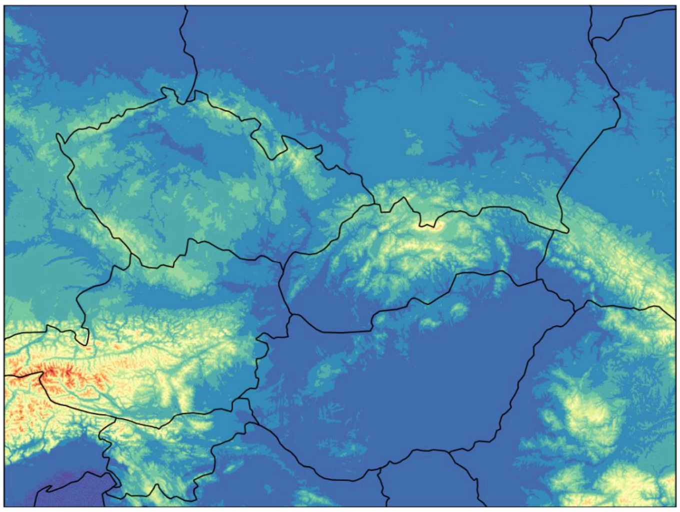
Cycle cy46t1as from CHMI
(The local pack replicating CHMI:cy46t1as at SHMU, including the mf_blacklist from CHMI and NMXUPD=4)
SHMU:hpc3aux01: /work/compile/p5621/pack_scratch/46t1_CY46t1as.11.INTEL.x

SHMU RUC1 test pack for radar DA
(The local pack with radar-related updates from cy46t1as does not reproduce the CHMI results due to the mf_blacklist configuration at SHMU.)
SHMU:hpc3aux01: /work/compile/p5621/pack_scratch/46t1_bf07_oper.11.INTEL.x

SHMU RUC1 test pack for radar DA - mf_blacklist from CHMI
(The local pack with radar-related updates from cy46t1as, including the mf_blacklist from CHMI and NMXUPD=4, successfully reproduces the CHMI results.)
SHMU:hpc3aux01: /work/compile/p5621/pack_scratch/46t1_bf07_oper.12.INTEL.x

3. Model and experimental setup

We used the RUC1 system of ALADIN (ALARO) Slovakia for testing and experimenting.



- Model: ALARO NH-v1B cy46t1_bf11 (with phased CHMU:cy46t1as differences);
- Domain: Δx = 1 km, 1024x768 GP, 87 vertical levels;
- Time-step: 30s;
- Coupling: 1h ARPEGE, time-lagged;
- Analysis: 3D-Var + CANARI, 1h cycle;
- Assimilated observation: SYNOP+AWS, TEMPs, HRW, AMDAR+Mode-S.

The most important namelist switches for radar assimilation settings are listed in Table 1 and 2.

Table 1: Screening namelist setting.

ZRADARXSIG	0.2
RRADAR_DIST	200000
LRADAR_RAINTHR	T
RRADAR_RAINTHR	0.
LRADAR_STORE_REAL_FG	T
LRADAR_SIGMA3CHECK	F
LRADAR_DENSITYFIX	T
LRADAR_MAXHEIGHT	T
RMIND_RADAR	16275
RFIND_RADAR	16275
NOBSPROFS(13)	225
XYSHIFT_THIBOX(13)	0.5

Table 2: Bator namelist setting.

LRADAR_DOE	T
RRADAR_OFFSET_DOE	0.35

Defined experiments

ANB1 – Radar assimilation experiment used to test the LRADAR_SIGMA3CHECK key. Settings are based on Tables 1 and 2, with thinning suppressed (see Section 4). /users/nwp999/app/anb1

ALA1 – Radar assimilation experiment used to tune ZRADARXSIG. Settings are based on Tables 1 and 2, with thinning suppressed (see Section 5). /users/nwp999/app/ala1

ANA1 – Reference assimilation experiment without radars. /users/nwp999/app/ana1

4. Evaluation of LRADAR_SIGMA3CHECK key

The new logical switch LRADAR_SIGMA3CHECK=.T. (NAMSCC) removes model profiles that are "too far" from the observations from the averaging formula (see Bučánek 2023). So called distance D is calculated as following:

$D_k = \frac{1}{N}\sum_{i=0}^{N}\left(O_i - M_{i,k}\right)^2$ where O is observed value, M is model profile value, i is elevation, k is identifier of model profile.

If ($D_k \geq 3 \, * \, ZRADARXSIG^2$) then the model profile k is rejected from evaluation of Bayesian inversion. The situation that observation and model profiles are "too far" from each other happens very often. Consequently the numerator and denominator in the averaging formula are very small numbers which can limit the precision of calculation.

The impact of the switch is evaluated on a single run (2024091206) with 4 different radars in SHMU RUC domain. In order to see well the impact of LRADAR_SIGMA3CHECK the thinning was suppressed in the screening (see Table 3).

Table 3: Thinning suppression

RMIND_RADAR	1.
RFIND_RADAR	1.

The new key LRADAR_SIGMA3CHECK=.T. is removing too many observations mainly in the vicinity of a radar station. The Figure 1 is showing observation columns where the Bayesian inversion was successful. As you can see the reference is in red and LRADAR_SIGMA3CHECK=.T. is in green.

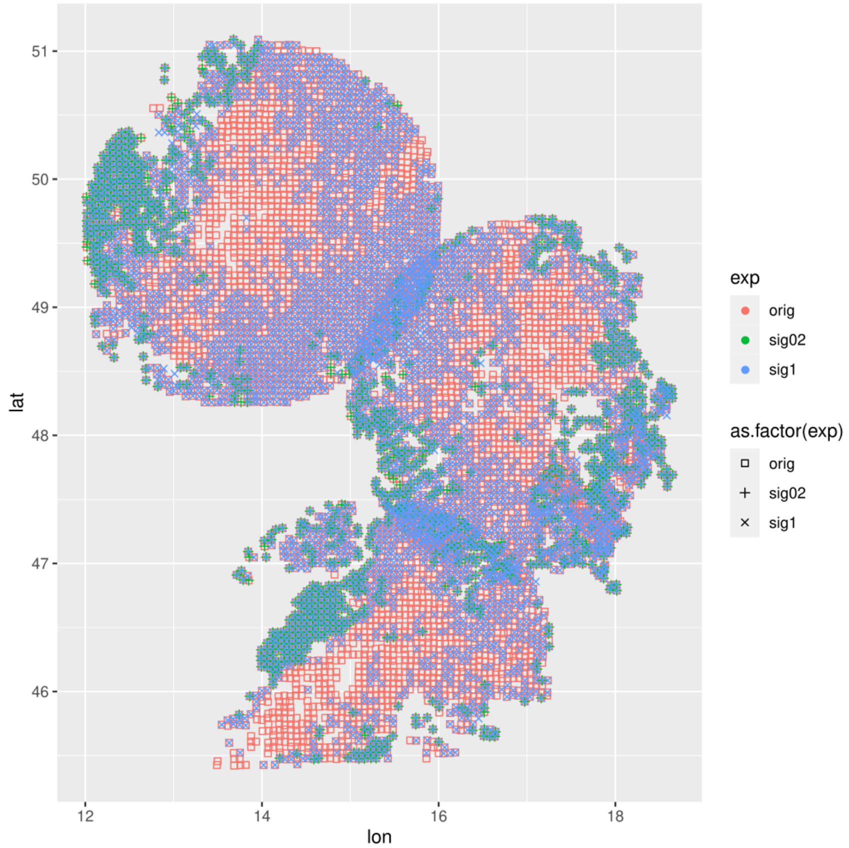


Figure 1: Observation columns where Bayesian inversion was successful. Reference in red, LRADAR_SIGMA3CHECK=T in green and ZRADARXSIG=1.0 + LRADAR_SIGMA3CHECK=T in blue.

Since so many observations were not successfully passing through the inversion process it means that the default ZRADARXSIG is too small which in turn created too big distance D and most of the model profiles get rejected from the inversion. We tried several different setups ZRADARXIG=0.2, 0.6, 1, 1.2, 3. The ZRADARXSIG=3 was having enough observation passing the inversion but it created too broad histogram reflectivity OMG.

The other settings were slowly having more and more observations processed by inversion but all have a common problem which is missing observations near the radar. This is typically caused by the fact that near the radar at high elevation angle an observation can be relatively high in the atmosphere where there is almost no humidity (reflectivity). The NWP model can produce reflectivity around -300DBZ in such heights while radar minima is around -40DBZ (see Figure 2). This big discrepancy is explaining why we did not find any model profile fulfilling the criteria of 3*ZRADARXSIG near the radar itself. With distance the situation gets better since radar observations are not so high. **The use of the key LRADAR_SIGMA3CHECK=T is NOT recommended**.

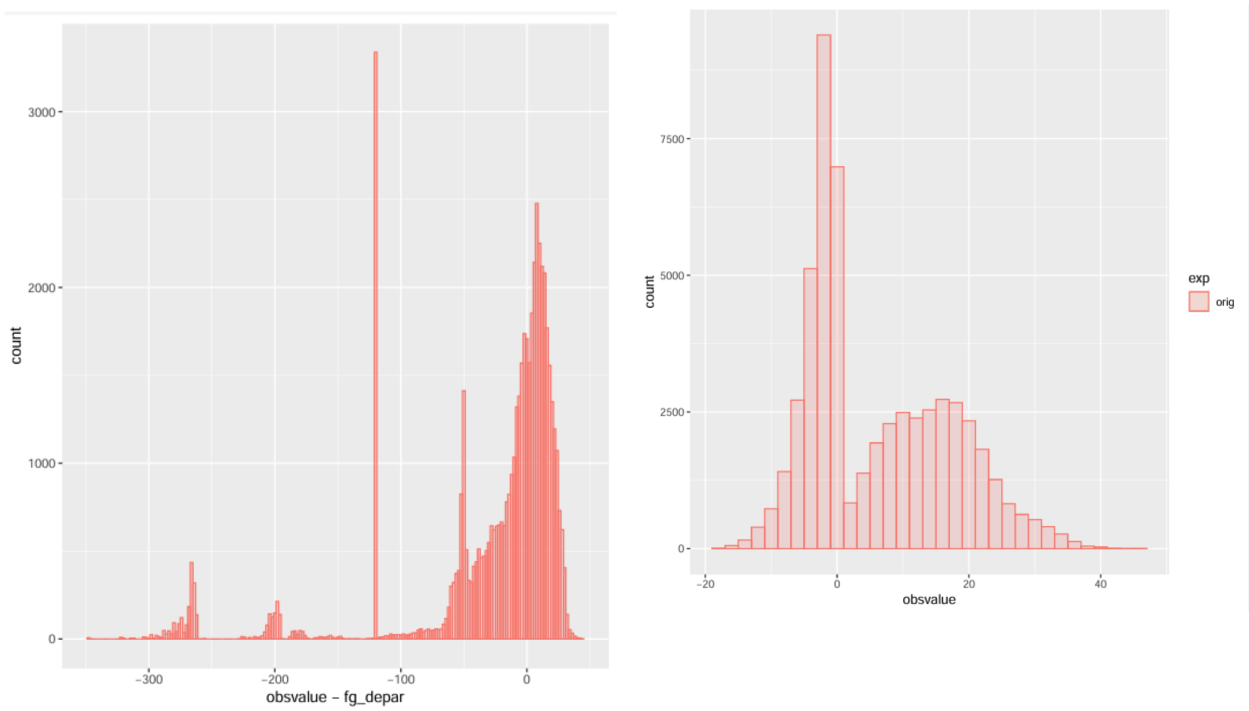


Figure 2: Histogram of model reflectivity on the left and histogram of observed reflectivity on right.

5. Evaluation of different ZRADARXSIG values

Since the evaluation of the LRADAR_SIGMA3CHECK key showed significant sensitivity of Bayesian inversion to ZRADARXSIG values we decided to search for optimal setup. The LRADAR_SIGMA3CHECK=.F. in the following section.

First we decided to use ZRADARXSIG= 0.2, 1.0, 3.0 and compare the fit of pseudo-observed reflectivity to the observation itself by histogram of RMSE which is shown on Figure 3. The best would be if most of the pseudo-observed reflectivities were close to observation and RMSE would be close to zero. As can be seen the ZRADARXSIG=3.0 is having too high values of RMSE with a heavy tail. While ZRADARXSIG=1.0 beside a slightly heavier tail allows for much better fit to observed reflectivity.

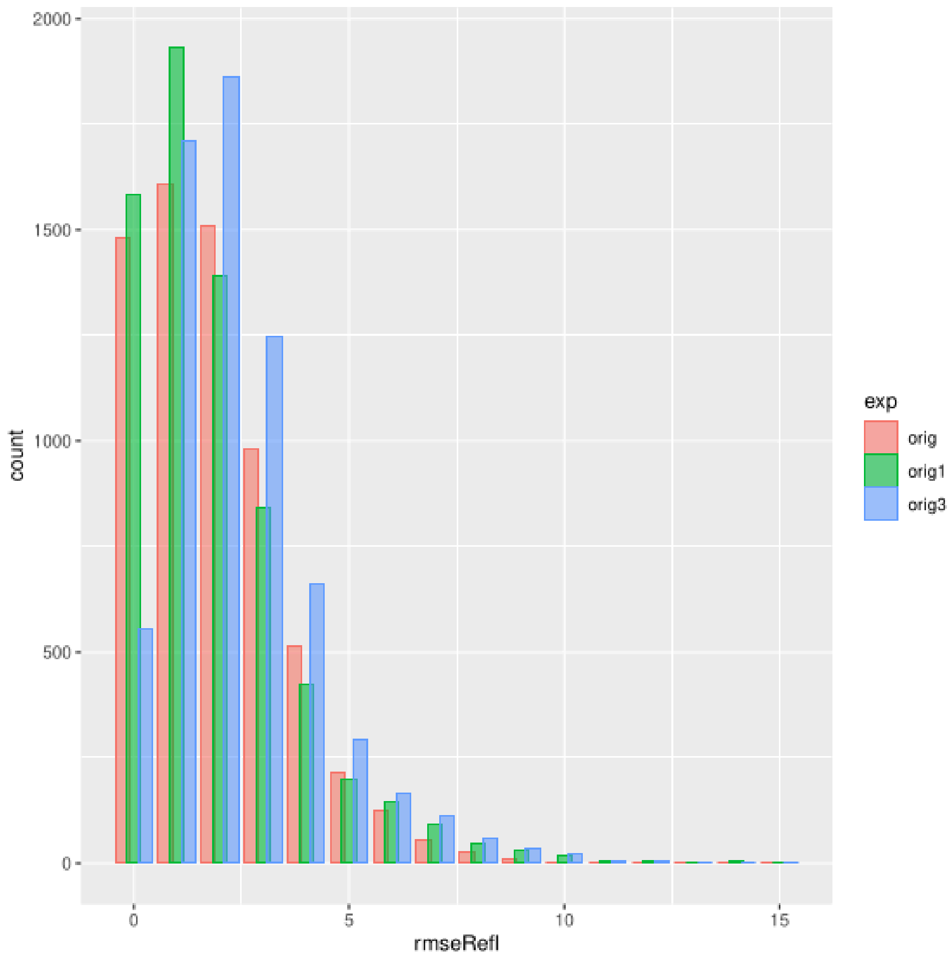


Figure 3: Histogram of RMSE of observed reflectivity minus pseudo-observed reflectivity for three different ZRADARXSIG values. ZRADARXSIG=0.2 is shown in red, 1.0 is shown in green and 3.0 is shown in blue.

Since we know that Bayesian inversion is made in a way that dry observations (flgdyn=0) are perfectly fitted by model reflectivity, those points are excluded from the following comparison. A new set of ZRADARXSIG is used (0.2, 0.6, 1.0, 1.2) in the histograms.The Figure 4 shows histograms of RMSE and you can see that ZRADARXSIG=1.2 is already shifting the histogram farer from the zero. ZRADARXSIG=0.6 on the other hand is not improving much compared to ZRADARXSIG=1. We can agree that ZRADARXSIG=1 is a good candidate for further testing in a full assimilation cycle.

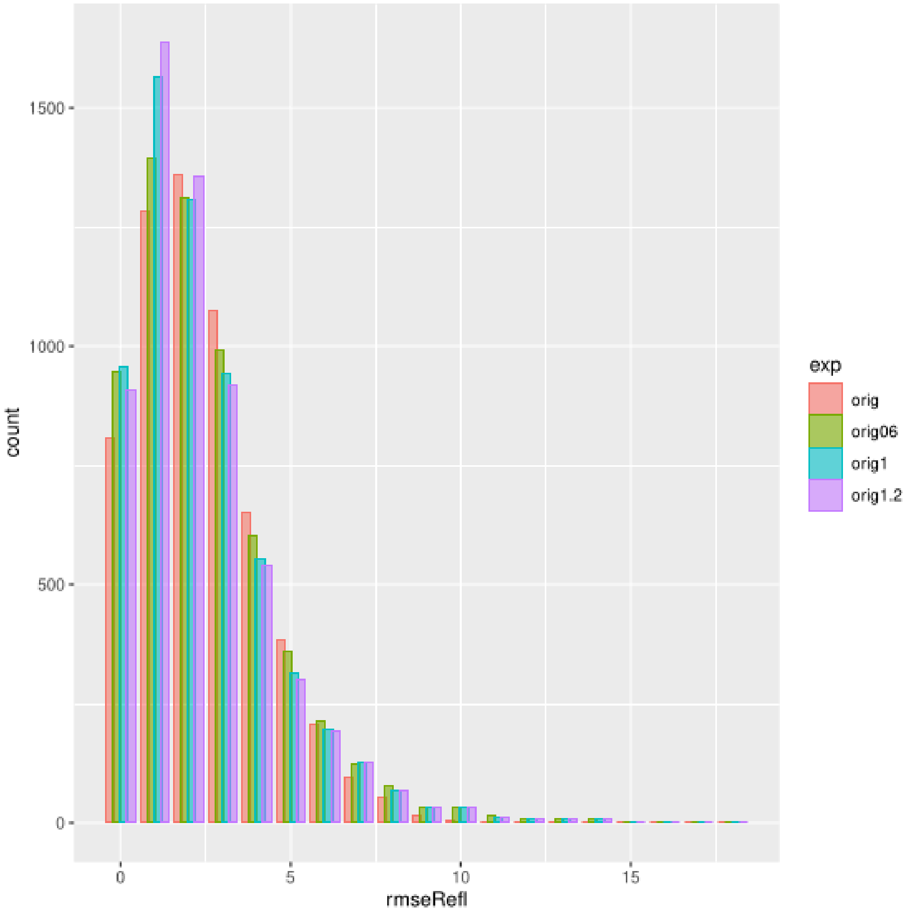


Figure 4: Histogram of RMSE of observed reflectivity minus pseudo-observed reflectivity for four different ZRADARXSIG values. ZRADARXSIG=0.2 is shown in red, 0.6 is shown in green, 1.0 is shown in blue and 1.2 is shown in violet.

6. Conclusions

During the stay, the cycle CY46t1as from CHMI was successfully ported to SHMU, and its functionality was validated. As a second objective, the use of the key LRADAR_SIGMA3CHECK was assessed. We do not recommend using this key, as almost no observations pass through the inversion process in the vicinity of the radar stations (see Section 4). Additionally, several values of ZRADARXSIG were tested to evaluate their impact on the Bayesian inversion. As a result, ZRADARXSIG = 1 is proposed as a candidate value for further testing, which could not be completed during the stay due to time constraints.

7. References

Antonín Bučánek. Radar sensitivity estimation within the OPERA dataset and impact studies. RC LACE report, 2023. URL: https://www.rclace.eu/media/files/Data_Assimilation/2023/repStay_ABucanek_RadarAssim_DHMZ_2023.pdf

8. Appendix

8.1. CHMI ODB files not readable in SHMU system

In the first phase of testing, we were not able to use the ODB created at CHMI for our experiments on the SHMU system. A consultation with A. Trojáková revealed that the incompatibility stemmed from the ODB compilation process. The discrepancy was traced to the `.gmkfile`, where the `GMK_CFLAGS_ODB` flags were different between the two systems. Specifically, the CHMI configuration uses the `NMXUPD=4` setting (consistent with the Météo-France standard), whereas the SHMU environment follows the standard used at ECMWF (NMXUPD=1).

The differing flags were as follows:
SHMU:
GMK_CFLAGS_ODB = -DSTATIC_LINKING -DXPRIVATE=PRIVATE -DINTERCEPT_ALLOC -DUSE_ALLOCA_H -DCANARI -DHAS_LAPACK

CHMI:
GMK_CFLAGS_ODB = -DSTATIC_LINKING -DXPRIVATE=PRIVATE -DINTERCEPT_ALLOC -DUSE_ALLOCA_H -DCANARI -DHAS_LAPACK -DNO_CURSES **-DODB_NMXUPD=4**

In source code we are in
arpifs/module/yomcma.F90 ! NMXUPD I MAX. NO. OF UPDATES

8.2. Modified files in SHMU RUC1 test pack compared to operational cycle 46t1_bf07_oper.11

arpifs/module/yomscc.F90
```
D. Nemec 2024-07-11 Added kyes for ALARO microphysics size distributions
! LRADAR_ALARO_RAIN - Use ALARO size distribution for rain
! LRADAR_ALARO_SNOW - Use ALARO size distribution for snow
! LRADAR_ALARO_GRAUPEL - Use ALARO size distribution for graupel
```

arpifs/namelist/namscc.nam.h

```
! D. Nemec 11/07/2024 Alaro hydrometeor size distributions
&LRADAR_ALARO_RAIN, LRADAR_ALARO_SNOW, LRADAR_ALARO_GRAUPEL, &
```

arpifs/obs_preproc/defrun.F90

```
! 07-24 D. Nemec: ALARO size distributions for hydrometeors
USE YOMSCC
& XYSHIFT_THIBOX, LRADAR_ALARO_RAIN, LRADAR_ALARO_SNOW, LRADAR_ALARO_GRAUPEL
```

arpifs/op_obs/reflsim.F90

```
! D. Nemec: July 2024 CY46 Added ALARO microphysics size distributions
USE YOMSCC,ONLY : LRADAR_ALARO_RAIN, LRADAR_ALARO_SNOW, LRADAR_ALARO_GRAUPEL

IF (LRADAR_ALARO_RAIN) …
IF (LRADAR_ALARO_SNOW) …
IF (LRADAR_ALARO_GRAUPEL) …
```

arpifs/op_obs/reflsim_2dop.F90

missing in 46t1_bf07_oper.11.INTEL.x:

```
USE YOMSCC, ONLY: LRADAR_DENSITYFIX, LRADAR_ALARO_RAIN, LRADAR_ALARO_SNOW,
LRADAR_ALARO_GRAUPEL

! abuc rho_d * r_i = rho * q_i = q_i * p/(R*T)
IF (LRADAR_DENSITYFIX) THEN
    ZCRWF5(JLEN,JLEV,JPROF)=PCRWF5(JLEN,JLEV,JPROF)*PPRESF5(JLEN,JLEV,JPROF) &
                & /(PRF5(JLEN,JLEV,JPROF)*PTF5(JLEN,JLEV,JPROF))
    ZCIWF5(JLEN,JLEV,JPROF)=PCIWF5(JLEN,JLEV,JPROF)*PPRESF5(JLEN,JLEV,JPROF) &
                & /(PRF5(JLEN,JLEV,JPROF)*PTF5(JLEN,JLEV,JPROF))
    ZCSWF5(JLEN,JLEV,JPROF)=PCSWF5(JLEN,JLEV,JPROF)*PPRESF5(JLEN,JLEV,JPROF) &
                & /(PRF5(JLEN,JLEV,JPROF)*PTF5(JLEN,JLEV,JPROF))
    ZCGWF5(JLEN,JLEV,JPROF)=PCGWF5(JLEN,JLEV,JPROF)*PPRESF5(JLEN,JLEV,JPROF) &
                & /(PRF5(JLEN,JLEV,JPROF)*PTF5(JLEN,JLEV,JPROF))
   ELSE
```

odb/pandor/module/bator_lectures_mod.F90
odb/pandor/module/bator_ecritures_mod.F90 (same as 46t1mp_op3_radarDA)

missing in 46t1_bf07_oper.11.INTEL.x:

```
IF ( LLNDIAP ) THEN
  CALL bator_saisielndiap(jobs,iotp,icodmes,iformat,ilndiap)
ELSE
    ilndiap(:)=0
ENDIF
```

After the stay we must consult this part of source code changes

???!!! atro due to CHMI special observation processing we skip this

```
if (.not.LSIGMA_CHMU) then
 IF ((iovnm == VARNO%Q) .AND. (iotp /= NSATEM)) THEN   ! humidite relative  synop/temp ! not satem for
BAYRAD
```

???

```
! AIREP, SATOB, TEMP, PILOT
…
```

```
!abuc
  IF (LSIGMAO_BF .AND. (LSIGMA_CHMU .OR. iovnm /= VARNO%Q) ) THEN
     ROBODY(iwagon,MDBOER) = ROBODY(iwagon,MDBOER) * SIGMAO_COEF(iotp)
  ENDIF
…

! Mode-S EHS temperature needs larger obs-error
   IF (icodmes == NMDEHS.AND.iovnm==2 .AND. LOBSERREHS ) THEN


! RADAR RETRIEVAL RELATIVE HUMIDITY
…
  IF (LRADAR_DOE .AND. ZDATAWAG(iwagon,3) == 0._JPRD) THEN
     ! inflate error of radar dry obs (flgdyn==0)
     ROBODY(iwagon,MDBOER) = ROBODY(iwagon,MDBOER) + RRADAR_OFFSET_DOE
  ENDIF
```

odb/pandor/module/bator_module.F90

missing in 46t1_bf07_oper.11.INTEL.x:

```
!       04/10/2022 A.Trojakova  : add LOLDOBSOULFMT & backphase SEVIRI/GRIB

! inflation of errors for radar dry observations (flgdyn==0)
LOGICAL        :: LRADAR_DOE       ! to inflate Dry Obs Error (default F)
REAL(KIND=JPRD) :: RRADAR_OFFSET_DOE ! inflation offset for dry obs error (default 0.)
LOGICAL        :: LRADAR_MDS_CY43  ! to set default MDS to -39 as on CY43
```

odb/pandor/module/bator_decodhdf5_mod.F90

missing in 46t1_bf07_oper.11.INTEL.x: (in 46t1mp_op3_radarDA miss only LRADAR_MDS_CY43)

```
USE BATOR_MODULE, ONLY
                  & ObsThinning, LRADAR_DOE, RRADAR_OFFSET_DOE, LRADAR_MDS_CY43
```

After the stay we must consult this part of source code changes

```
???! atro there is sometime a strange error with undefined size()
! but I do not understand why  ???
        if (associated(FullDatasetList(NumGDataset)%GQuality)) then
```

odb/pandor/module/bator_init_mod.F90

??? read(batnam, NML=RADAR,IOSTAT=iret) … why when already HDF5 part ???

odb/pandor/namelist/bator_namelist.nam.h

in 46t1mp_op3_radarDA miss only LRADAR_MDS_CY43

missing in 46t1_bf07_oper.11.INTEL.x:

```
! 04/10/2022 : A. Trojakova : add LOLDOBSOULFMT & backphased SEVIRI/grib
```

also

```
NAMELIST / RADAR /  LRADAR_DOE, RRADAR_OFFSET_DOE, LRADAR_MDS_CY43
```