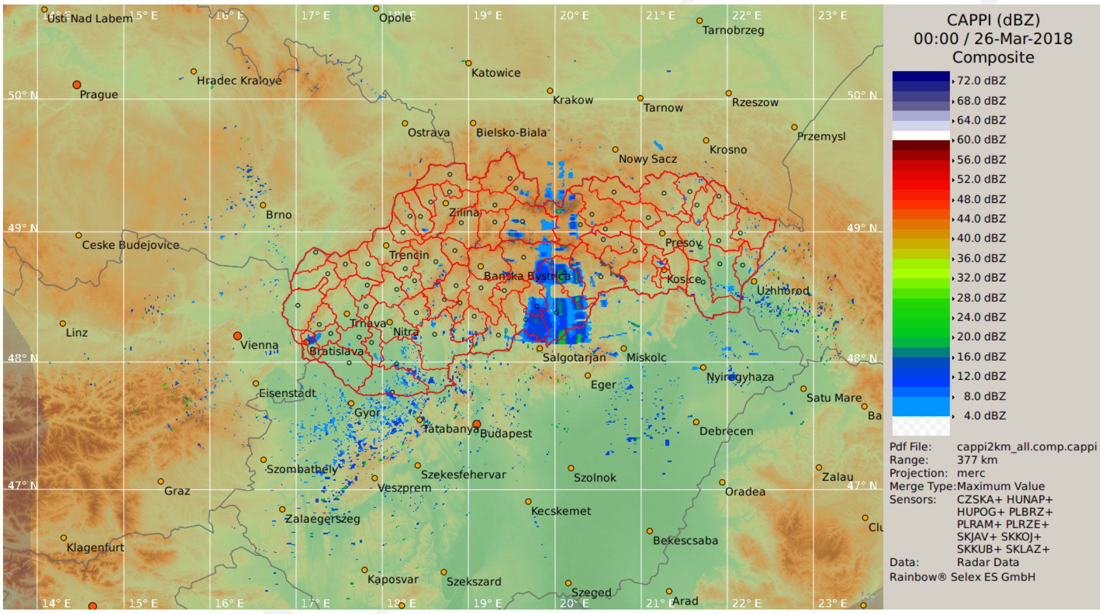
Regional Cooperation for
Limited Area Modeling in Central Europe

Evaluation of OPERA data quality for NWP



report from RC LACE stay in Bratislava, 21/05/ - 1/06/2018
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1 Introduction

Data assimilation of meteorological observations is essential for initialization of mesoscale Numerical Weather Prediction (NWP) models. Particularly assimilation of radar reflectivity showed potential to improve the analysis and short-range weather forecast (Wattrelot *et al.*, 2014).

In 2013-2014 a considerable work was devoted to radar data processing and quality control (QC) within RC LACE. In spite of a good progress in using local data at some LACE countries, the use of foreign radar observations remained challenging mainly due to differences in data content and file format issues (Neštiak (2013)). Furthermore, Neštiak and Mile (2014) studied a feasibility of a common quality control by INCA2. Several tasks were identified, e.g. increase operational efficiency of radar QC tools, replace MF-BUFR format in Carthesian grid by direct use of polar volume in HDF5 format, mitigate risk of bad identification of non-meteorological targets, ...), but this work was not finalized due to lack of manpower.

Circumstances changed significantly since then. In 2015, radar networks were upgraded to new dual-polarization radars in several countries (e.g. in the Czech Republic and Slovakia). In June 2016, OPERA program (EUMETNET, 2018) started to provide volume radar data and an additional quality control was progressively implemented utilizing OPERA Data Information Model (ODIM) in HDF5 format. Last not least, there has been a progress in an implementation of direct processing of HDF5 format via BATOR by HIRLAM and Météo France.

Coordinated efforts were planned within RC LACE for 2018 (Mile, 2018) to enhance the progress in implementation of radar data assimilation (DA). Given the new circumstances is it relevant to evaluate OPERA data quality for NWP DA purposes. At the first stage we aim to get familiar with OPERA radar data. A comprehensive validation of quality flags is beyond the scope of this short stay. Two case studies are used to quickly asses OPERA data and their quality information. An evaluation is provided by a comparison to radar quality tool operationally used at SHMU. The data used in this study are presented in section 2. Comparison results are described in section 3 and the summary is given in the last section.

2 Data

This section briefly describes European weather radar data collected and redistributed by OPERA and radar data and quality indices computed at SHMU. The latter are considered as a reference.

2.1 OPERA-OIFS data

OPERA objective is to generate and distribute high-quality products to various users (EUMETNET, 2018). Volume radar data of reflectivity and radial velocity with quality flags are provided via OPERA Internet File Server (OIFS). The frequency of the data is 5' or 15'. More details can be found in Martet (2016) and main characteristics of the data content are described below.

OPERA OIFS data contains:

- reflectivity with ground clutter suppression (DBZH)
- "raw" reflectivity (only noise filtered) (TH)
- Doppler velocities (VRAD)
- QC indices based on PPIs filtering
  - se_beamblockage - beam blockage attenuation correction

- fi_ropo - Bropo module (non-precipitation echo detection and removal)
- mf_satfilter - satellite filtering (using Precipitating Clouds product from SAF-NWP)
- pl_total - total quality index (minimum of all the quality indexes)

2.2 SHMU radar data

Volume radar data of reflectivity available at SHMU are based on a bilateral exchange with neighboring countries - the Czech Republic, Hungary and Poland. Radar data are processed using a quality control tool (QRAD) to generate quality indexes identifying common sources of radar measurement errors. Their main characteristics are as follows.

SHMU radar data + QC contains:

- reflectivity (DBZH)
- QC indices based on PPIs filtering
  - QI_CONST - constant flag (overall index of radar site to characterize the radar hardware)
  - QI_DIST - dependency on distance from radar
  - QI_SIM - quality index describing the similarity with neighborhood
  - QI_BEAMB - beam blockage
  - QI_BEAMH - beam height above orography
  - QI_TIME - scan time dependency
  - QI_AVER - time average of QI indices
  - QI_CT - NWCSAF Cloud Type
  - QI_CTOP - NWCSAF Cloud Top height

3 Comparison of quality indices

Due to a lack of documentation of both OPERA and QRAD quality indices (QI) it was difficult to find their proper correspondence. It is assumed that the beam blockage can be compared directly, the satellite indices are based on different SAF products - the OPERA uses Precipitating Clouds product while QRAD uses cloud type and cloud top height products. The OPERA Bropo module (fi_ropo) has no correspondence in the QRAD tool - maybe some combination of QI_CT, QI_CTOP, QI_AVER, QI_SIM can be used (*personal communication Ladislav Méri*). The OPERA total index (pl_total) is a minimum of other modules, so it is not specifically evaluated. Considering that absolute value of QI depends on its definition, the QIs are compared only qualitatively.

The evaluation was done only for two case studies over central Europe where the reference (QRAD QIs) was available. Based on the OPERA composit and rain-gauges measurements we selected one non-precipitation and one precipitation case, see Figure 1. The lowest elevations of 11 radar sites listed in Table 1 were studied.

Location	ODIM code	WMO code	country
Praha-Brdy	czbrd	11480	Czech Republic
Skalky	czska	11718	Czech Republic
Napkor	hunap	12892	Hungary
Poganyvar	hupog	12921	Hungary
Szentes	husze	12985	Hungary
Brzuchania	plbrz	12568	Poland
Ramza	plram	12514	Poland
Kubinska hola	skkub	11887	Slovakia
Kojsovska hola	skkoj	11958	Slovakia
Maly Javornik	skjav	11812	Slovakia
Spani laz	sklaz	11923	Slovakia

Table 1: Radar sites used for the evaluation.

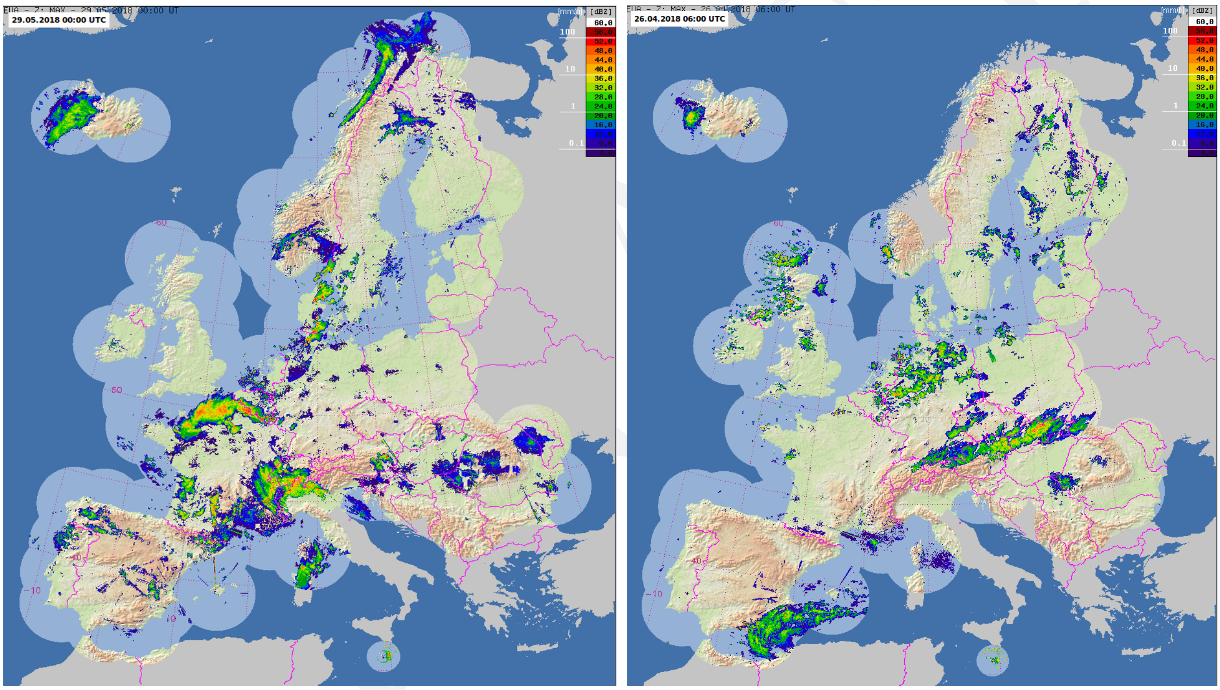

Figure 1: OPERA composit for 29 May 2018 (left) and 26 April (right).

3.1 Case study without precipitation

The first case of 29 May 2018 00UTC without precipitation over central Europe was selected to evaluate a detection of non-meteorological echos. Quality indices of the two lowest elevations were evaluated.

The OPERA beam blockage (se_beamblockage) is qualitatively comparable with the reference QI_BEAMB for all radar sites. There are similar structures in spite of differences in absolute QI values, see Figure 2 for illustration.

Comparison of satellite based QIs showed no signal for radars without spurious DBZH, e.g radars from Slovakia and Napkor from Hungary. Other radars had differences in satellite QIs, which might be explained by use of different SAF products in OPERA and QRAD satellite modules, see Figures 3, and/or differences in DBZH which are not yet understood completely, see Figures 4. The DBZH differences might come from data producers directly or some filtering might be applied by OPERA.

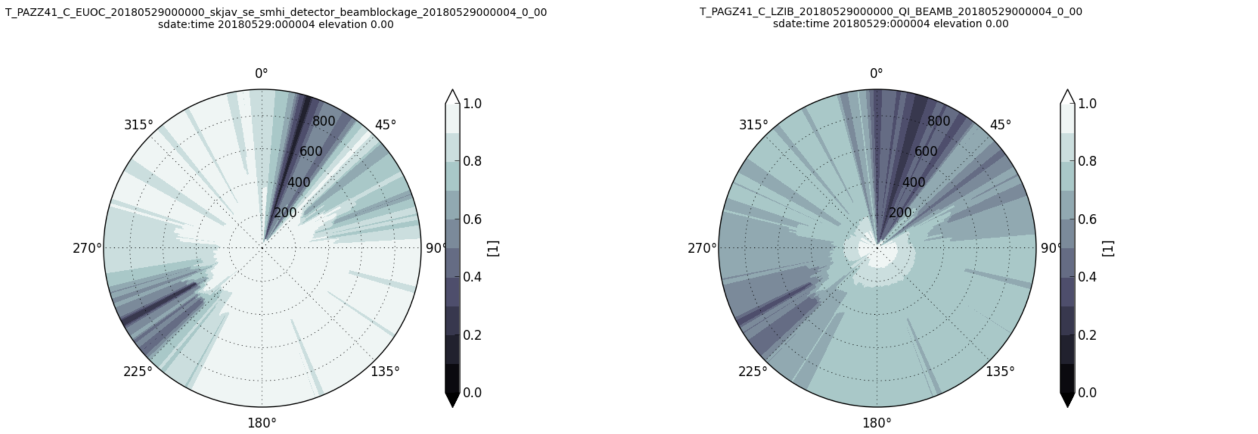

Figure 2: Beam blockage: OPERA (left) and QRAD (right) for skkoj (Kojsovska hola).

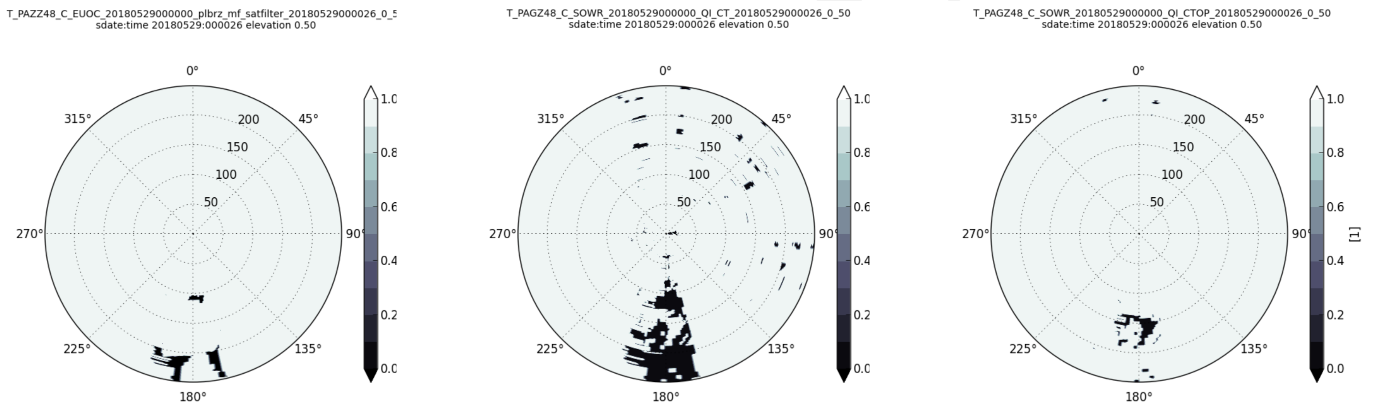

Figure 3: Satellite filters: OPERA (left), QRAD QI_CT (middle) and QI_CTOP (right) for plbrz (Brzuchania).

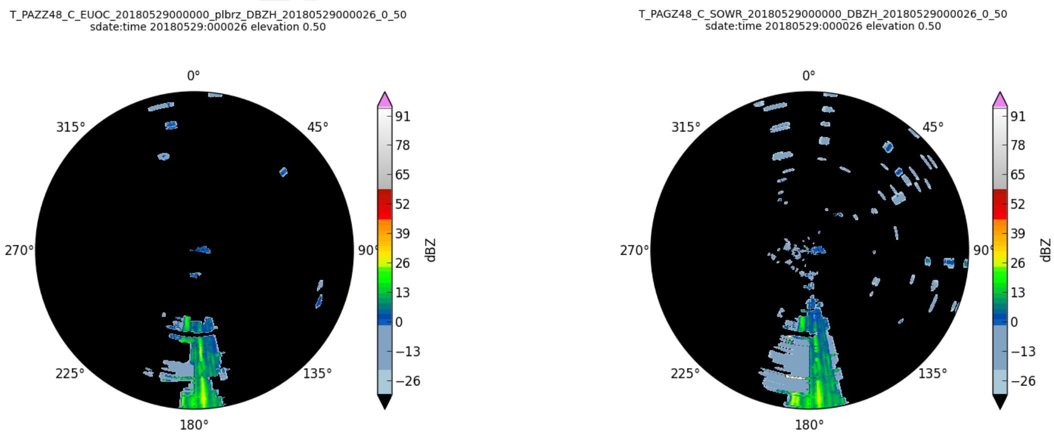

Figure 4: Reflectivity DBZH from OPERA (left) and SHMU (right) for plbrz (Brzuchania).

The QRAD tool has no direct correspondence to the OPERA non-precipitation echo detection and removal module (fi_ropo). Some resemblance was found with QRAD satellite QI_CT index (Figure 3) and QRAD similarity index (Figure 5).

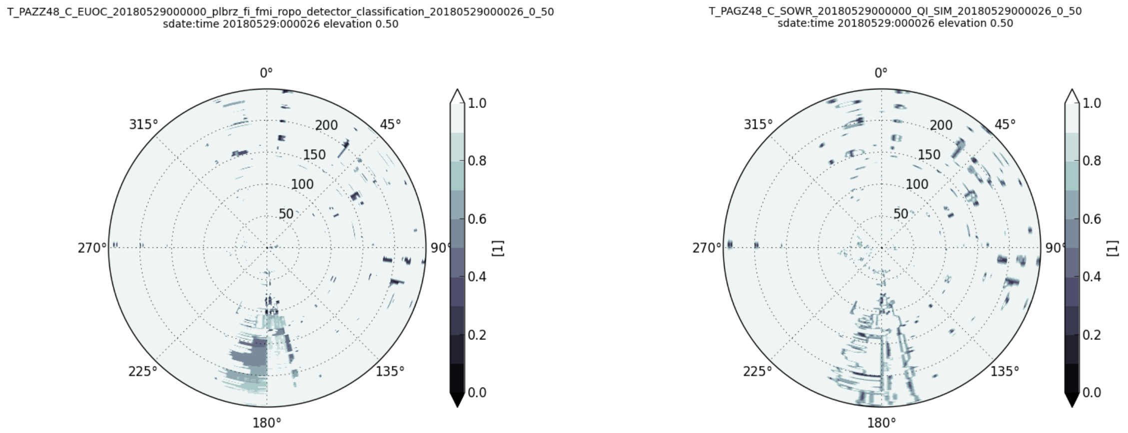

Figure 5: Non-met echo filter: OPERA (left) and QRAD QI_SIM (right) for plbrz (Brzuchania).

Finally, a filtering of DBZH was applied based on various thresholds of the OPERA total quality index (pl_total) to simulate the data after the quality control, see Figure 6.

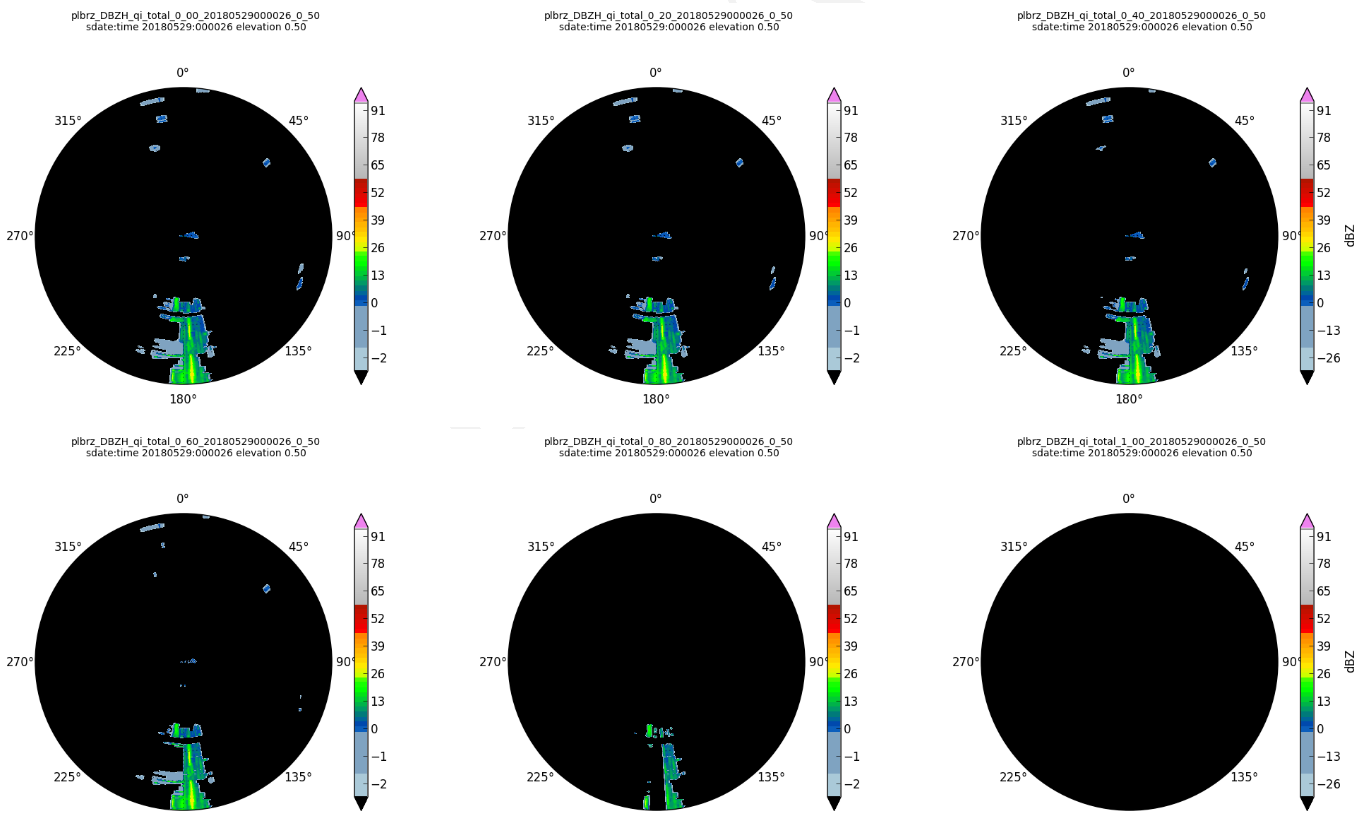

Figure 6: Filtered DBZH values below the threshold of 0, 0.2, 0.4 (top) and 0.6, 0.8 and 1 (bottom) of the OPERA total quality index (pl_total) for plbrz (Brzuchania).

This case is non-precipitation one - no rain was detected by rain-gauges Slovakia and IR image from MSG showed no cloudiness over Slovakia. The signal from radar plbrz is non-meteorological and the OPERA quality control is not able to fully clean this spurious signal.

3.2 Case study with precipitation

The second case of 26 April 2018 did not revealed any new findings.

4 Summary

Previous sections provided details on items tackled during the stay and here follows a brief summary and an outlook of the future work.

The stay provided fruitful discussions with remote sensing colleagues about the radar data format and matters of quality control. The OPERA quality information were compared with the radar quality tool QRAD operationally used at SHMU. The OPERA beam blockage is qualitatively comparable with the reference and it is difficult to make any conclusions regarding satellite based and non-meteorological echo filter QIs. The comparison was done only for the two case studies, so results should be are considered as preliminary ones. But it was showed for the radar site plbrz (Brzuchania) that spurious echos can remain even for large thresholds of the total quality index. It suggests that we can't fully relay on the OPERA QIs and a special attention to the data quality is necessary when assimilating OPERA radar reflectivity.

This QC study can be extended for more countries but the reference is an open question. The QRAD tool could be used also for other countries (Slovenia, Croatia, Germany, ...), but a feasibility of using input data from OPERA has to be checked and a sufficiently large domain of NWCSAF should be ensured. The quality control of radar data might seems beyond the scope of NWP, but it is essential for data assimilation. NWP community is the main user of OPERA volume radar data and it is hard to expect a progress in the quality control without a relevant user's feedback.

Another step to advance in the radar DA within RC LACE is a detailed validation of radar data processing by BATOR. It has technical constraints (metadata and HDF5 structure have to be compliant).

Acknowledgment
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A Experiments

This appendix contains details of performed experiments on SHMU server **hpcdev02** based on cy40t1_bf06.oper03 compiled using GNU compiler. The aim was a technical implementation of BATOR cy43t2 which contains ODIM HDF5 processing. Considering that ODB is cycle dependent and that the export of cy43t2 is not yet available, only BATOR sources were extracted from cy43t2 and compiled using the operational pack based on cy40t1. Following user pack was created:

- **BATOR cy40t1_bf06.oper03#bator_43t2**

  - with BATOR back-phased from CY43T2_bf08 (+ minor modifications to make sources from cy43t2 compilable within the cy40t1 user pack)

  - can be found on **hpcdev02:/home/nwp301/pack/cy40t1_bf06.oper03#bator_43t2**.

  - BATOR linking requires HDF5 libraries to be added to ics_bator script:

```
# LOW-LEVEL LIBRARIES (from top to bottom) :
cat <<end_of_bator_sys> $GMKWRKDIR/.bator_sys
  ...
-L/usr/local/lib64 -lhdf5_fortran -lhdf5
  ...
```

Furthermore, a run-time error was encountered:

./BATOR: error while loading shared libraries: libhdf5_fortran.so.8: cannot open shared object file: No such file or directory"

and it was fixed by setting following environmental variables:

```
export LD_PRELOAD=/opt/ibmhpc/pe1309/mpich2/gnu/fast/lib64/libmpi.so
export LD_LIBRARY_PATH=/opt/ibmhpc/pecurrent/mpich2/gnu/lib64:
                       /opt/ibmhpc/pecurrent/pempi/gnu/lib/libmpi64:
                       /usr/local/lib64:$LD_LIBRARY_PATH
$MPIMONO ./BATOR
```

Only a few BATOR tests were executed, but **no comprehensive validation was done** due to lack of time! Scripts can be found on **hpcdev02:/home/nwp301/scr/sample_3dvar/scr/**.

- test_bator_merge - **reference experiment using conventional data**

  - using operational BATOR executable

- test_bator43_hdf5 - **trial for single radar site "silis"** and conventional data

  - technical test of the back-phased BATOR

  - modifications:

    - script adaptation for radar data processing

    - BATOR_LAMFLAG=0 to keep radar data out of the small AROME domain

    - namelist43/namel_bator

    - namelist43/param.cfg

Data used in this study:

```
# SHMU OPERA
HPC2: /data/users/nwp301/radar/shmu/opera
# SHMU radar composit saved from rainbow@10.40.4.6
HPC2: /data/users/nwp301/radar/shmu/radar_composit
# OIFS OPERA
HPC2: /data/users/nwp301/radar/oifs
```