☐ **STSM-report.md**

Introduction:

From 11-16 October 2016 Adriaan Dokter (University of Amsterdam) and Hidde Leijnse (Royal Netherlands Meteorological Institute, KNMI) visited the Swedish Meteorological and Hydrological Institute (SMHI) in Norrköping, Sweden, for two short-term scientific missions (STSMs). The aim of the STSMs was to integrate the bird algorithm developed by Dokter et al. that produces VPBs (vertical profile of birds) into the BALTRAD toolbox. This integration is carried out in collaboration with BALTRAD developers of SMHI, in particular Dr. Günther Haase and Dr. Anders Henja. Integration of the algorithm into the BALTRAD toolbox allows straightforward generation of VPBs for all European radars delivering volume data to BALTRAD. A second aim was, after integration of the algorithm, to compile a case study dataset for as many radars and countries as possible.

Fig. 1. Swedish meteorological and hydrological institute (SMHI), Norrköping, Sweden

Most effort was spent into realizing the first aim, which was a prerequisite for completing the aim of compiling a case study dataset. When applying for these STSMs the expectation was that the algorithm would have been tested and implemented on the BALTRAD server already by mid 2015. Refactoring of the code by the Netherlands eScience Centre however took more time than expected. A large part of this STSM was therefore spent on testing the new refactored code, and on adapting the code so that it can be implemented into the BALTRAD toolbox, which is currently the main bottleneck towards the goal of operationally producing bird profiles for all European radars.

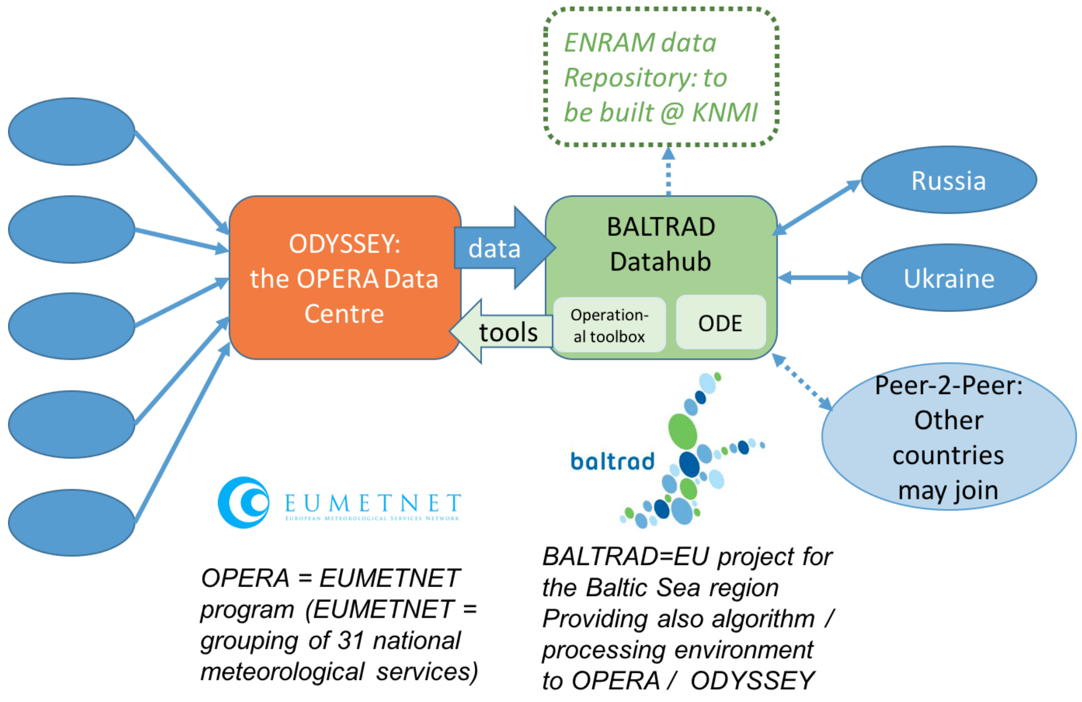


Fig. 2. OPERA, ODYSSEY and BALTRAD

Figure 2 shows the current radar infrastructure we propose to use and develop within ENRAM. The bird algorithm is to be implemented in the BALTRAD toolbox. The BALTRAD server is to receive a copy of all volume data sent to the OPERA data centre. BALTRAD has a very flexible infrastructure for implementing operational algorithms acting on radar volume data, which makes implementation of the bird algorithm there feasible. BALTRAD is to produce the VPBs for all European radars. These VPB products are to be forwarded to KNMI and collected within the KNMI data centre.

We first identified a to-do list for this week:

1. Define output format of the bird algorithm and nomenclature of quantities
2. Implement output format in ODIM-h5
3. Compile base and refactored versions of the algorithm on the ODE (Opera Development Environment) of BALTRAD
4. Compare output of both versions, to validate the output of the refactored version.
5. Select a suitable time period for the case study dataset, including a major migration event across Europe
6. Generate composite images of European radars to make a horizon scan of which radars provide data suitable for quantifying bird migration.
7. Make an inventory of Z and V data availability and Nyquist intervals for each radar
8. Determine strategy for handling data requests and support by ENRAM members
9. Following a discussion with Anders Henja (lead programmer of BALTRAD), we identified an important modification of the algorithm that was required to integrate it into the production system of BALTRAD. Due to the refactoring by the Netherlands eScience centre the code was no longer thread-safe, which is not acceptable because BALTRAD runs in a parallel computing environment. The `vol2bird` code therefore needed to be adjusted, such that global objects are no longer used to contain the data.

composite imagery

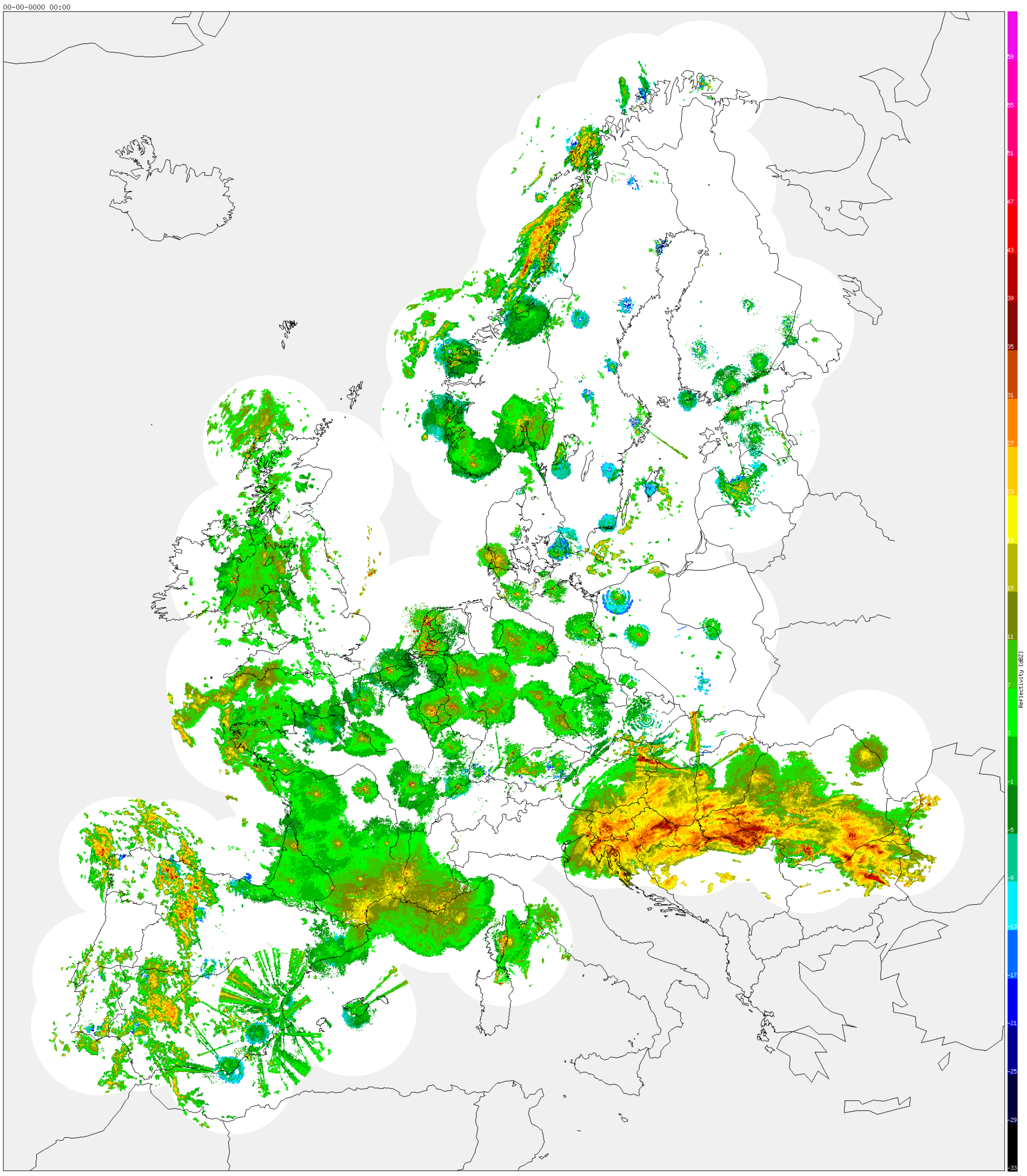


Fig. 3. Reflectivity composite for 2015-10-10 20:00 UTC

Figure 3 shows the OPERA maximum-reflectivity composite for a night with a lot of bird migration across Europe. Several noteworthy features of the reflecitivity composite during this migration event were identified:

- Spain, Hungary, Latvia: many sources of radio noise are visible in the imagery (showing as spikes), which will require methods to correct and remove these sources of noise.
- Sweden and Finland show much weaker signals compared to Norway. Especially to close distance between the southern Norwegian and Swedish radars suggest these differences cannot be solely attributed to differences in migration intensity. Likely these countries apply different pre-processing to their data.
- S-band radars southern France show a much longer detection range than C-band radars, suggesting the signal to noise ratio of S-band radars is higher than of C-band radars.

Goals reached:

Algorithm adjustments for implementation in BALTRAD toolbox:

- discussed with Anders Henja the requirements for integrating the algorithm into the toolbox, so that it can be implemented on the BALTRAD server
- in the code, added automated selection of scans based on minimum Nyquist velocity
- in the code, added automated selection of scans based on availability of both DBZ and VRAD

- compiled the BALTRAD toolbox on different operating systems (Mac OSX and Ubuntu Linux)
- adapted the algorithm so that it works with the BALTRAD toolbox, and removed platform-specific functions
- made the code thread safe by removing all global variables, and putting these in structs; the code needs to be thread safe in order for it to be implemented in BALTRAD
- made the code generally applicable to both conventional radars and dual-pol radars
- compiled and tested the code on the OPERA Development Environment (ODE); testing the code here can lead to quick implementation at the BALTRAD server
- debugged the code for memory leaks introduced by the modifications and refactoring
- installed the code on the OPERA Development Environment (ODE) in Karlstad.

Compilation of case study dataset

- selected a time period for testing the algorithm in a case study: 9-11 October
- produced OPERA radar composite images for this period
- secured data from the 10 countries that have made both DBZ and VRAD available (BE, DK, EE, FI, FR, HR, NL, SE, SI, UK)
- secured data from Angelholm radar for the intercomparison campaign period
- made an inventory of the data availability and Nyquits velocities

documentation

- made an open access github repository with the code and its documentation
- on github, defined a list of issues and desired future changes to the code for implementation on the BALTRAD server
- discussed how the output of the algorithm could be made available for users
- defined the data structure of the HDF5 representation of the bird profiles

Milestones

Milestone 1: a more generic version of the bird algorithm

It is now much easier to produce bird density profiles from OPERA data. The algorithm is more generic so that it can deal with a wider range of radars.

Milestone 2: defined a standard output format, compatible with ODIM-h5

HDF5 is a file format that makes possible the management of extremely large and complex data collections. Using HDF5 as a file format, OPERA has defined the HDF5 representation of the OPERA Data Information Model ODIM_h5 for the storage of radar data. Using the conventions of ODIM-h5 we have defined a data model for the storage of vertical profiles of birds (VPBs). The data model can be found in appendix 1.

Milestone 3: compilation of the algorithm on the OPERA Development environment (ODE).

The ODE is located on the same server as the operational BALTRAD system, which is therefore a great step towards operationalisation of the algorithm.

In progress / to be completed

1. several small compatibility issues need to be solved: handling data stored not in unsigned char, reading wavelength from file, etc. For a complete list see the issues on github.
2. write routines that write algorithm output to an ODIM-h5 file, using the data model we defined in this STSM
3. write a python wrapper around the algorithm, for integration in the production pipeline. A prototype of this python wrapper has been provided by Anders Henja, which still needs to be adjusted to the bird algorithm.
4. Apply algorithm to all data for 9-11 October
5. Visualize output of the case study

6. Analyze output of the case study
7. Process data from Angelhom radar for the validation campaign
   - conversion EEC data format of SMHI to ODIM-h5
   - calculate VPBs (vertical profiles of birds)
8. Operationally implement the algorithm on BALTRAD server

Individual contributions

Adriaan Dokter

My STSM focussed on compiling, testing and adjusting the qualitative functioning of the code in the new Baltrad environment. I identified a suitable migration period throughout Europe that could be used as a test case. A large portion of my time was spent on repairing the new `vol2bird` version, which no longer produced correct output after refactoring by the Netherlands eScience centre. Using intercomparisons of the output of the refactored version with the base version of the algorithm, bugs and the algorithm workflow was corrected. I set up an open github repository for the algorithm software with associated wiki web page for communicating radar data availability and data requirements to the ENRAM community. Here the installation procedures for the algorithm in the new BALTRAD environment were documented. I adjusted the algorithm to be compatibile with dual-pol radar data. Finally on the last day I managed to compile the code on the Opera Development Environment (ODE), which is the same server as the operational production system for BALTRAD.

Hidde Leijnse

Most of my STSM focussed on streamlining the code to make it compatible with meteorological data:

- defining the ENRAM-ODIM-h5 format
- making the code thread safe
- selection of scans based on Nyquist velocity
- made a start with implementing the output ENRAM-ODIM-h5 format in the code

I also worked on selecting a time period for the case study:

- making composite imagery
- securing data for case study period, including Belgium (for which no VRAD data were available at BALTRAD)

Appendix 1. radar data requirements

1. `vol2bird` requires volume data, i.e. data consisting of a set of scans at different elevations
2. The radar volume data needs to be stored in an HDF5 file, which is structured in OPERA ODIM_h5 format.
3. The volume data needs to contain both reflectivity and radial velocity quantities.
4. The quality of the radial velocity should be sufficient. This means that radial velocities are too heavily folded (which occurs when data is collected at pulse repetition frequencies that produces velocity ambiguity / a low Nyquist velocity.

radar data availability for ENRAM

The vol2bird program is currently installed in the development environment of the BALTRAD datahub. **Only for radar data available at BALTRAD we can extract bird migration information.**

For data to be available in BALTRAD, several conditions need to be met:

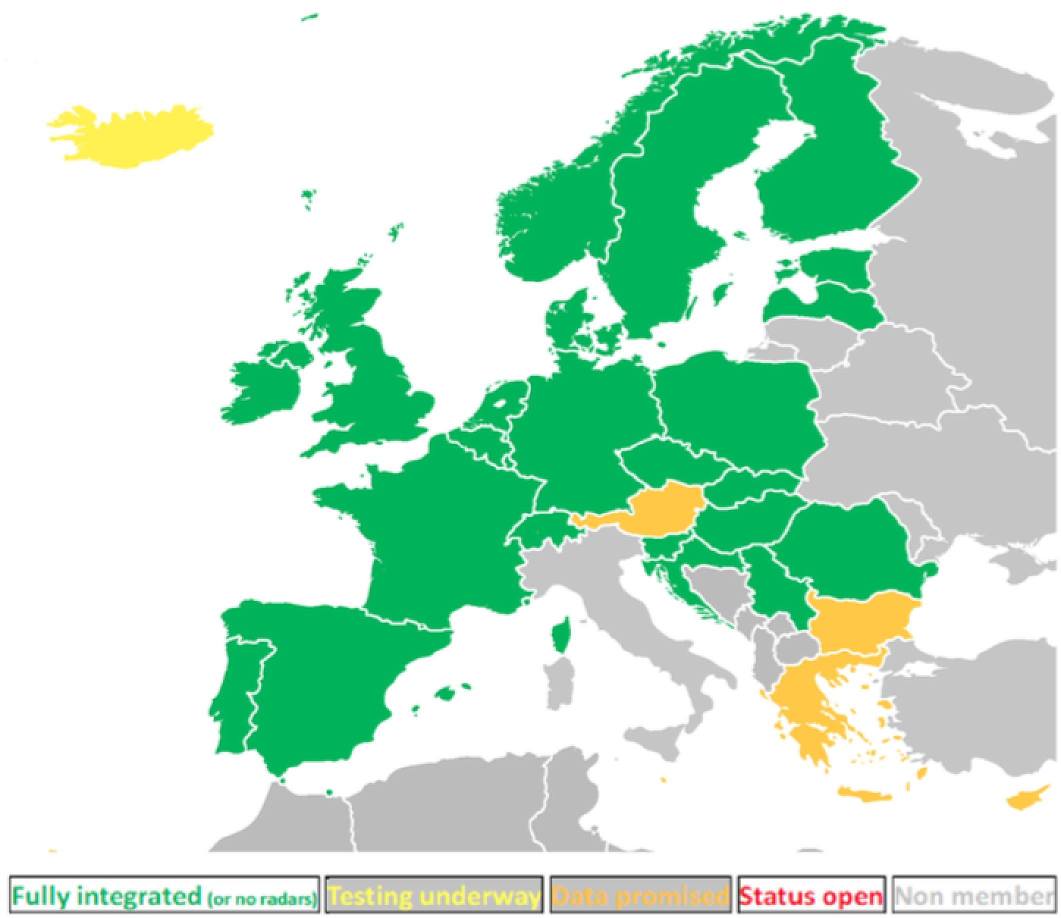
1. A country should send both reflectivity and radial velocity data to the OPERA data centre, which is called ODYSSEY. While many countries are sending reflectivity data, radial velocities are still unavailable for many countries.
2. ODYSSEY should forward these data to the BALTRAD datahub. It is standard policy to do so,

but in practice data is not yet forwarded correctly for some radars/countries.

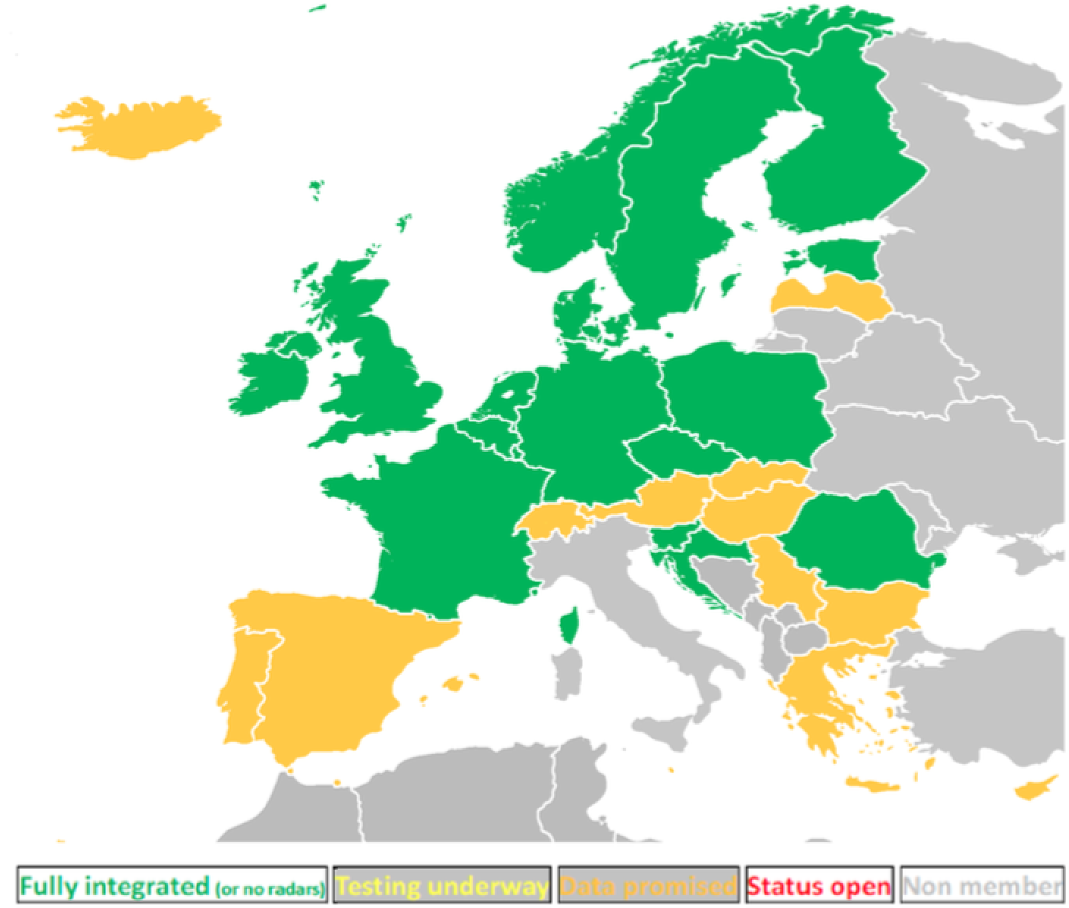
3. Currently BALTRAD and ODYSSEY store data at a 15 minute interval, higher resolution data is not yet available.
4. Countries should have accepted the memorandum of understanding (MoU) between OPERA and ENRAM. The MoU is still under consideration by EUMETNET, and no final agreement is expected before November 2015.

In the figures and table below you can assess what is the current status of the data delivery to OPERA and BALTRAD

The availability of reflectivity data (DBZ) at ODYSSEY:



The availability of radial velocity (VRAD) data at ODYSSEY:



Country status Oct 2015

As of October 2015, the following countries deliver data at BALTRAD for which we can extract bird information:

country	sends DBZ	sends VRAD	VRAD quality ok	data at BALTRAD	vol2bird tested	all OK
Austria	-	-	X	-		-
Belgium	X	X	X	-	X	-
Bulgaria	-	-	?	-		-
Croatia	X	X	-	X		-
Cyprus	X	X	?	-		-
Czech rep.	X	X	-	-		-
Denmark	X	X	X	X		X
Estonia	X	X	X	X		X
Finland	X	X	X	X		X
France	X	X	X	X	X	X
Germany	X	X	X	-		-
Greece	-	-	-	-		-
Hungary	X	-	?	-		-
Iceland	-	-	?	-		-
Ireland	X	X	X	-		-

Italy	-	-	-	-		-
Latvia	X	-	?	-		-
Malta	-	-	?	-		-
Netherlands	X	X	X	X	X	X
Norway	X	X	X	-		-
Poland	X	X	?	-		-
Portugal	X	-	?	-		-
Romania	X	X	X	-		-
Serbia	X	-	?	-		-
Slovakia	X	-	-	X		-
Slovenia	X	X	X	-		-
Spain	X	-	X	-		-
Sweden	X	X	X	X	X	X
Switzerland	X	-	X	-		-
UK	X	X	X	X	X	X

Country national archives time span

Data was collected using a questionnaire filled out at the September 2014 OPERA meeting at KNMI, the Netherlands. Countries were asked in which year they started archiving weather radar data, both in a national archive, and at the ODYSSEY datahub.

country	DBZ national	VRAD national	DBZ ODYSSEY	VRAD ODYSSEY	Comments
Austria	2011	2011	?	?	
Belgium	2002	2002	2013	?	
Bulgaria	?	?	?	?	
Croatia	2008?	2008?	2012	2013	
Cyprus	?	?	?	?	
Czech rep.	2001	2013	?	?	
Denmark	2005	2005	?	?	
Estonia	2009	2009	?	?	
Finland	1999	1999	?	?	
France	2010	2011	2011	2011	national archive in BUFR
Germany	2006	2008	2012	2015	national archive in BUFR
Greece	?	?	?	?	
Hungary	2000	2000	2013	?	
Iceland	?	?	?	?	
Ireland	2012	?	2012	2014	dates to be

					confirmed
Italy	2007	2007	?	?	
Latvia	?	?	?	?	
Malta	?	?	?	?	
Netherlands	2008	2008	2012	2012	
Norway	2006	2006	?	?	
Poland	2011	2011	?	?	
Portugal	?	?	?	?	
Romania	?	?	?	?	
Serbia	?	?	?	?	
Slovakia	?	?	?	?	
Slovenia	?	?	?	?	
Spain	2008	2008	2012	2015	
Sweden	2005	2005	2012	2014	
Switzerland	2004	2004	?	?	
UK	2013	2013	2012	2015	1 year rolling archive

Appendix 2. Specification of bird profile output in ODIM HDF5 format.

The vol2bird output format follows the ODIM_H5 version 2.2 format specification.

```
/Conventions                    "ODIM_H5/V2_2"  [String]    #Conventions
/what                                                       #Group
/what/object                    "VP"            [String]    #Vertical profile
/what/version                   "H5rad 2.2"     [String]    #Version
/what/date                      "YYYYMMDD"      [String]    #Date (copy from volume file)
/what/time                      "HHmmss"        [String]    #Time (copy from volume file)
/what/source                    "WMO:xxxxx"     [String]    #Radar (copy from volume file)
/where                                                      #Group
/where/lon                      5.176           [Double]    #Longitude
/where/lat                      52.101          [Double]    #Latitude
/where/height                   44.0            [Double]    #Height of the radar antenna [m] a.
/where/levels                   20              [Long]      #Number of levels in the profile
/where/interval                 200.0           [Double]    #Height interval
/where/minheight                100.0           [Double]    #Minimum height in the profile [m]
/where/maxheight                4000.0          [Double]    #Maximum height in the profile [m]
/how                                                        #Group => copy all attributes from
/dataset1                                                   #Group
/dataset1/what                                              #Group
/dataset1/what/product          "VP"            [String]    #Vertical profile
/dataset1/what/startdate        "YYYYMMDD"      [String]    #Start date (copy from volume file)
/dataset1/what/starttime        "HHmmss"        [String]    #Start time (copy from volume file)
/dataset1/what/enddate          "YYYYMMDD"      [String]    #End date (copy from volume file)
/dataset1/what/endtime          "HHmmss"        [String]    #End time (copy from volume file)
/dataset1/how                                               #Group
/dataset1/how/minrange          5.0             [Double]    #Minimum range [km] used for profil
/dataset1/how/maxrange          25.0            [Double]    #Maximum range [km] used for profil
/dataset1/how/minazim*          0.0             [Double]    #Minimum azimuth used for profile
/dataset1/how/maxazim*          360.0           [Double]    #Maximum azimuth used for profile
/dataset1/how/rcs_bird*         10.0            [Double]    #Assumed bird radar cross-section [
/dataset1/how/clutterMap        "clutter.h5"    [String]    #File name of clutter map
/dataset1/how/task              "vol2bird"      [String]    #Name of the program that generated
```

```
/dataset1/how/task_args         "{see below}"   [String]    #Arguments of the program that gene
/dataset1/how/comment           "Birds only"    [String]    #Indicator of how these profiles we
/dataset1/data1                                             #Group
/dataset1/data1/what                                        #Group
/dataset1/data1/what/quantity   "HGHT"          [String]    #Height [km???] a.s.l???
/dataset1/data1/what/gain       1.0             [Double]    #Gain
/dataset1/data1/what/offset     0.0             [Double]    #Offset
/dataset1/data1/what/nodata     -9999.0         [Double]    #Nodata indicator
/dataset1/data1/what/undetect   9999.0          [Double]    #Undetect indicator
/dataset1/data1/data            1x20 array      [Dataset]   #Dataset containing profile heights

... --> only changing those variables that are different w.r.t. /dataset1/data1

/dataset1/data2/what/quantity   "dbz_bird"*     [String]    #Bird reflectivity factor [dBZ]
/dataset1/data2/data            1x20 array      [Dataset]   #Dataset containing bird reflectivi
...
/dataset1/data3/what/quantity   "eta_bird"*     [String]    #Bird reflectivity [cm2/km3]
/dataset1/data3/data            1x20 array      [Dataset]   #Dataset containing bird reflectivi
...
/dataset1/data4/what/quantity   "dens_bird"*    [String]    #Bird density
/dataset1/data4/data            1x20 array      [Dataset]   #Dataset containing bird densities
...
/dataset1/data5/what/quantity   "ff_bird"*      [String]    #Bird flight ground speed
/dataset1/data5/data            1x20 array      [Dataset]   #Dataset containing bird flight gro
...
/dataset1/data6/what/quantity   "dd_bird"*      [String]    #Bird flight direction
/dataset1/data6/data            1x20 array      [Dataset]   #Dataset containing bird directions
...
/dataset1/data7/what/quantity   "ff_dev"        [String]    #Standard deviation of VVP fit
/dataset1/data7/data            1x20 array      [Dataset]   #Dataset containing VVP standard de
...
/dataset1/data8/what/quantity   "n_dbz"*        [String]    #Number of samples used for dBZ pro
/dataset1/data8/data            1x20 array      [Dataset]   #Dataset containing number of sampl
...
/dataset1/data9/what/quantity   "n_vrad"*       [String]    #Number of samples used for velocit
/dataset1/data9/data            1x20 array      [Dataset]   #Dataset containing number of sampl
...
/dataset1/data10/what/quantity  "DBZH"          [String]    #Reflectivity profile
/dataset1/data10/data           1x20 array      [Dataset]   #Dataset containing reflecticity pr



task_args string: "variable1=value,variable2=value,...,variableN=value" for example: "AREACELL=
```

SMHI

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Datum: November 11, 2015

Confirmation of the host institution

Hidde Leijnse has visited the Swedish Meteorological and Hydrological Institute (SMHI) from 12 to 16 October 2015 for an STSM in the framework of the COST action ENRAM. He mainly worked on the integration of the bird migration algorithm into the BALTRAD toolbox. Moreover, the method has been tested with radar data from OPERA. A detailed report is provided by Hidde.

Best regards,
Günther Haase