An overview of ODIM HDF5 files from radars within Croatian ALARO NWP model domain.

Tomislav Kovačić, DHMZ
kovacic@cirus.dhz.hr

Introduction.

Radar volume scans from OPERA member states are available every fifteen minutes. The domain of Croatian NWP model encompasses 45 radars from 10 countries. Radar data are stored in HDF5 format and organized according to OPERA Data Information Model for HDF5 . Although all OPERA members use the same format and data model there are still diferences in file contents.
The aim of this survey is to see differences and similarities among files from different countries and to find out if there are any missing data that are needed for radar data assimilation.

Radars.

Radars that enter the model domain are listed in table.

	WMOid	country	node	heigth	lat.	lon.
1	7005	fr	frabb	70	50,1358	1,8347
2	6477	be	bewid	590	49,9143	5,5056
3	12921	hu	hupog	311	46,6604	17,0624
4	12374	pl	plleg	119	52,4052	20,9609
5	14024	si	silis	950	46,0678	15,2849
6	11812	sk	skjav	600	48,2561	17,1531
7	6410	be	bejab	50	51,1917	3,0642
8	7255	fr	frbou	160	47,0586	2,3594
9	14256	hr	hrbil	258	45,8835	17,2009
10	12514	pl	plram	358	50,1517	18,7267
11	14280	hr	hrosi	105	45,5027	18,5613
12	12892	hu	hunap	153	47,9622	21,8867
13	12544	pl	plpas	688	50,8920	16,0395
14	12579	pl	plrze	235	50,1141	22,0370
15	8179	es	esbar	664	41,4081	1,8847
16	12331	pl	plpoz	130	52,4133	16,7971
17	12220	pl	plswi	146	53,7903	15,8311
18	12151	pl	plgda	158	54,3843	18,4563
19	12568	pl	plbrz	453	50,3942	20,0797
20	7658	fr	frnim	70	43,8061	4,5028
21	11718	cz	czska	767	49,5011	16,7885
22	7145	fr	frtra	170	48,7739	2,0075
23	11958	sk	skkoj	1256	48,7829	20,9873
24	7167	fr	frtro	160	48,4622	4,3094
25	7461	fr	frlep	1120	45,2900	3,7094
26	8308	es	espma	130	39,3797	2,7850
27	7569	fr	frbol	310	44,3231	4,7622
28	7745	fr	fropo	700	42,9183	2,8650
29	7381	fr	frniz	910	46,0678	4,4453
30	7671	fr	frcol	640	43,2167	6,3728
31	11480	cz	czbrd	916	49,6583	13,8178
32	10629	de	deoft	245	49,9859	8,7140
33	7774	fr	frale	50	42,1297	9,4964
34	10557	de	deneu	879	50,5001	1,1135
35	7637	fr	frmcl	670	43,9906	2,6097
36	10488	de	dedrs	262	51,1246	13,7686
37	7083	fr	frave	190	50,1283	3,8119
38	7274	fr	frbla	590	47,3553	4,7758
39	7291	fr	frmtc	910	47,3686	7,0192
40	10605	de	denhb	585	50,1097	6,5485
41	10832	de	detur	767	48,5853	9,7828
42	10780	de	deeis	798	49,5407	12,4028
43	10873	de	desna	677	48,1747	12,1018
44	10908	de	deflg	1516	47,8736	8,0036
45	10950	de	demem	725	48,0431	10,2204

OPERA Data Information Model for HDF5 .

Detailed description of OPERA Data Information Model for HDF5 (ODIM HDF5) can be found in OPERA web page (http://eumetnet.eu/wp-content/uploads/2017/01/OPERA_hdf_description_2014.pdf).
Here, just a very brief description is given. ODIM has a hierachical structure similar to direcories and files in UNIX file system. That's why we write it in the same way, just instead of directories and files in HDF5 format elements are groups, datasets and attributes. The groups can contain subgroups and datasets. All os them can be described by attributes, and so on.
The upper most group is called root.
The structure of ODIM HDF5 file with one dataset can be writen like this:

/
/what
/where
/how
/dataset1
/dataset1 /what
/dataset1 /where
/dataset1 /how
/dataset1/data1
/dataset1/data1 /what
/dataset1/data1 /where
/dataset1/data1 /how
/dataset1/data1/data

In upper structure /dataset1/data1/data is a dataset and the rest are groups. Dataset contains measured radar data. Each file can contain more groups named dataset*n* (n is the ordinal number of group dataset*n*; dataset1, dataset2,...) and each group dataset*n* can contain more subgroups named data*m* (m is the ordinal number of group data*m*; data1, data2,...), but each group data*m* has only one datase called data.
The upper structure could be developed further because each group and dataset have attributs. Attributes contain information abut the radar and radar measurement. Our aim is to find out which attributes are used in real ODIM HDF5 files comming from different countries and different radars. ODIM HDF5 files contain quality groups as a subgroups of dataset*n* groups. The quality groups are not discussed here.

Root group.

Root group contains subgooups *how*, *what* and *where*, and a certain number of groups dataset*n*.
Here is geven a dicription of subgroups *how*, *what* and *where*.

/how.
For all countries and all radars this group has only one attribude, the beamwidth.

/what.
The what group has five attributes listeded in the table together with example of attribute values taken from one file from Croastian radar Bilogora.

date	20170625
object	PVOL
source	WMO:14256,RAD:RH42,PLC:Bilogora,NOD:hrbil
time	150000
version	H5rad

/where

This group contains geographical position of radar.

/where
height
lat
lon

Groups /dataset*n*.

/dataset*n*/how.

The most of difference between ODIM HDF5 files from different countries is found in this group. Table shows the list of all atributtes that appear in this group and stars show those attributes that are used by corresponding country.

/dataset*n*/how	be	cz	de	es	fr	hr	hu	pl	si	sk
averaged_bins						*			*	
avgpwr						*			*	
CSR								*		
Dclutter				*		*			*	
gasattn							*			
highprf				*		*	*	*	*	
LOG								*		
lowprf				*		*	*	*	*	
malfunc								*		
MDS				*						
NEW:NEZ				*						
NEW:NyqVel				*						
NEW:NyqWidth				*						
NEW:radar_constant				*						
NEW:samples				*						
NEZ						*			*	
NI						*	*	*	*	
polarization				*		*			*	
ProcMode						*			*	
pulsewidth				*		*	*		*	
radconstH						*	*		*	
radconstV							*			
radhoriz				*		*			*	
rpm				*		*	*	*	*	
RXbandwidth							*			
simulated								*		
SQI								*		
startazA								*		*
stopazA										*
task				*		*		*	*	
Vsamples						*	*	*	*	
XMTphase						*			*	

/dataset*n*/what.

This group is the same for all files/countries. Attributes with examples of their values are listed in table.

/dataset*n*/what	
enddate	20170625
endtime	150233
product	SCAN
startdate	20170625
starttime	150233

/dataset*n*/where.

This group is the same for all files. Attributes with examples of their values are listed in table.

/dataset*n*/where	
a1gate	0
elangle	0,4
nbins	256
nrays	360
rscale	1000
rstart	0,5

/dataset*n*/data*m*/how

Aattributes and usage by countries is shown in table.

dataset*n*/data*m*/how	be	cz	de	es	fr	hr	hu	pl	si	sk
CSR				*		*			*	
LOG				*		*			*	
SQI						*			*	
startazA							*			
stopazA							*			

/dataset*n*/data*m*/what.

Attributes are shown in table and all of them are used by all countries.

/dataset*n*/data*m*/what
gain
nodata
offset
quantity
undetect

Next tables show values found in this group. Each table is for one quantities. Four quantities were found in files, these are: DBZ, TH, UNKNOWN (inly Germany) and VRAD.

DBZH

/dataset/data/what	be	cz	de	es	fr	hr	hu	pl	si	sk
gain	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
nodata	255	255	255	255	255	255	255	255	255	255
offset	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32
quantity	DBZH	DBZH	DBZH	DBZH	DBZH	DBZH	DBZH	DBZH	DBZH	DBZH
undetect	0	0	0	0	0	0	0	0	0	0

TH

/dataset/data/what	be	cz	de	es	fr	hr	hu	pl	si	sk
gain	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
nodata	255	255	255	255	255	255	255	255	255	255
offset	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32
quantity	TH	TH	TH	TH	TH	TH	TH	TH	TH	TH
undetect	0	0	0	0	0	0	0	0	0	0

UNKNOWN

/dataset/data/what	be	cz	de	es	fr	hr	hu	pl	si	sk
gain			1							
nodata			1,80E+308							
offset			0							
quantity			UNKNOWN							
undetect			-1,80E+308							

VRAD

/dataset/data/what	be	cz	cz	cz	de	es	fr	hr	hu	pl	si	sk
gain	0,419685	0,0604331	0,156331	0,103874	1		1	0,00787402			0,00787402	
nodata	255	255	255	255	1,80E+308		1,80E+308	0			0	
offset	-53,7197	-7,73543	-20,0103	-13,2959	0		0	-1,00787			-1,00787	
quantity	VRAD	VRAD	VRAD	VRAD	VRAD		VRAD	VRAD			VRAD	
undetect	0	0	0	0	-1,80E+308		-1,80E+308	0			0	

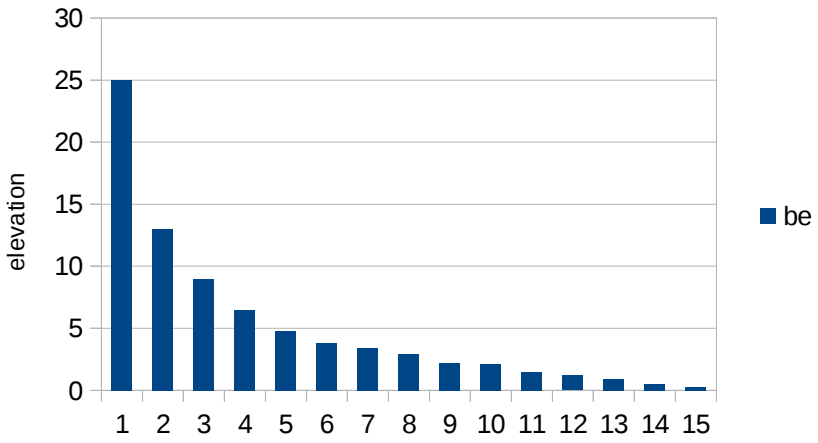
For DBZH, the cleaned reflectivity, and TH, measured reflectivity (raw data), all countries use the same values for gain, offset, undefined and no data.
For VRAD, the radial velocity, gain and offset differ by countries, which is expected, but nodata and undefined data have the same code for all countries except for France and Germany. In Franch and German files velocity is not coded, it is given in m/s and no-data are coded by big positive floating point value while undetected data are coded by big negative floating point value.

The description of volume scans.

The group /datasetn/datam/what gives the description of individual PPIs in volum scan. By sorting datasets by time it is possible to see the way how volume scans were done.
Tabels show the lists of elevations that were repeated in time. The topmost elevation in table was the first in time, elevation in second row was second and so on. Elevations are shown in gragraphs, too. Numbers on x-axis are elevation ordinal numbers in time.
In ODIM HDF5 files from Croatia, Czech and Hungary there were data from only one volume scan. Files from other countries contained data from two or more volume scans.

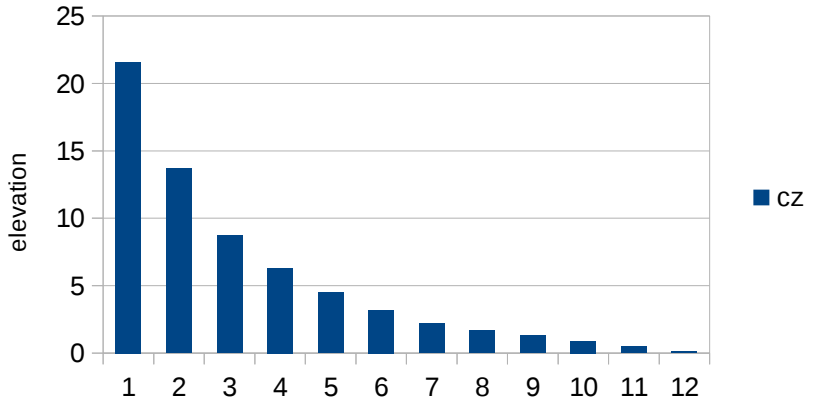
Belgium

coubtry	elangle	quantity	quantity	quantity
be	25,00	DBZH		VRAD
	13,00	DBZH		VRAD
	9,00	DBZH		VRAD
	6,50	DBZH		VRAD
	4,80	DBZH		VRAD
	3,80	DBZH		
	3,40			VRAD
	2,90	DBZH		
	2,20	DBZH		
	2,10			VRAD
	1,50	DBZH		
	1,20			VRAD
	0,90	DBZH		
	0,50			VRAD
	0,30	DBZH		



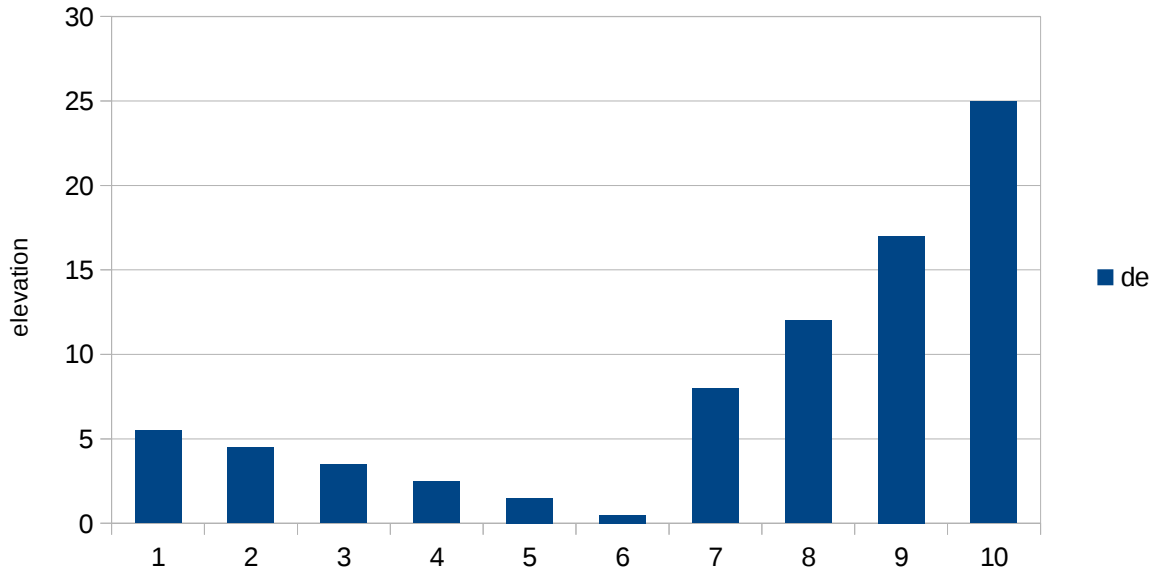
Czech.

coubtry	elangle	quantity	quantity	quantity
cz	21,60	DBZH	TH	VRAD
	13,70	DBZH	TH	VRAD
	8,70	DBZH	TH	VRAD
	6,30	DBZH	TH	VRAD
	4,50	DBZH	TH	VRAD
	3,20	DBZH	TH	VRAD
	2,20	DBZH	TH	VRAD
	1,70	DBZH	TH	VRAD
	1,30	DBZH	TH	VRAD
	0,90	DBZH	TH	VRAD
	0,50	DBZH	TH	VRAD
	0,10	DBZH	TH	VRAD



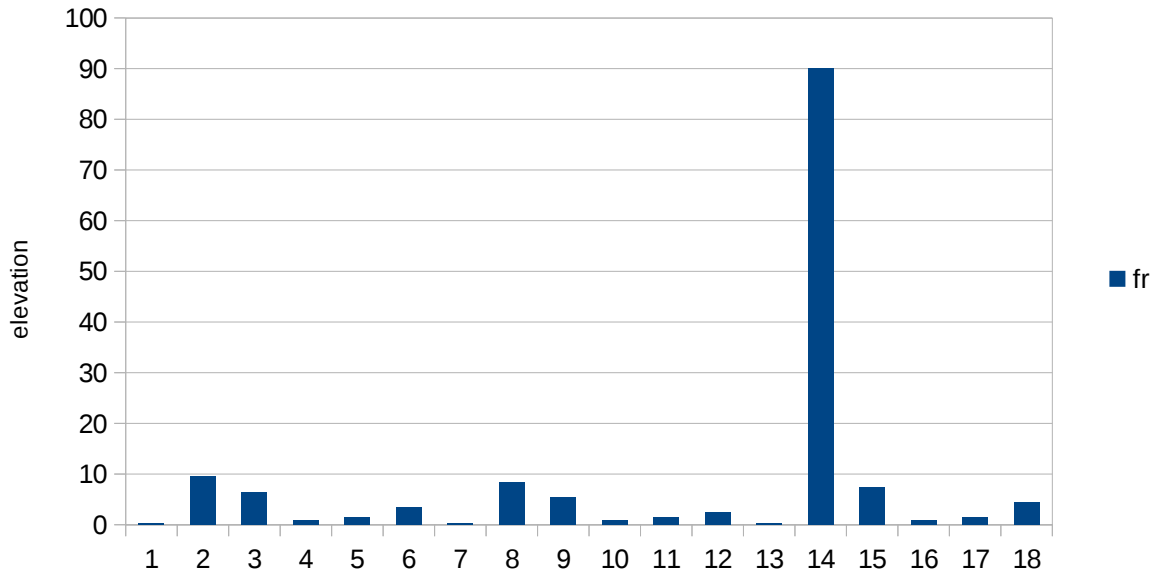
Germany.

	3,49	DBZH		VRAD	UNKNOWN
	2,49	DBZH		VRAD	UNKNOWN
	1,49	DBZH		VRAD	UNKNOWN
	0,49	DBZH		VRAD	UNKNOWN
	7,99	DBZH		VRAD	UNKNOWN
	12,00	DBZH		VRAD	UNKNOWN
	17,00	DBZH		VRAD	UNKNOWN
	24,99	DBZH		VRAD	UNKNOWN

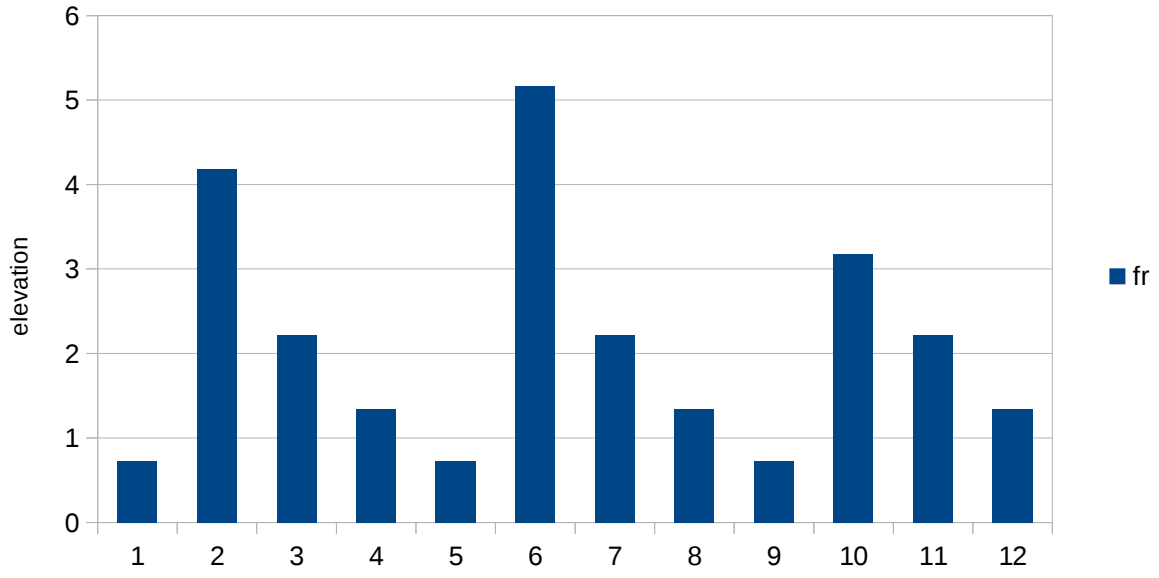


France.
French radars perform similar scans but not equal. Scans from two radars are shown here.

coubtry	elangle	quantity	quantity	quantity
fr	0,40	DBZH	TH	VRAD
	9,50	DBZH	TH	VRAD
	6,50	DBZH	TH	VRAD
	0,90	DBZH	TH	VRAD
	1,51	DBZH	TH	VRAD
	3,50	DBZH	TH	VRAD
	0,40	DBZH	TH	VRAD
	8,50	DBZH	TH	VRAD
	5,50	DBZH	TH	VRAD
	0,90	DBZH	TH	VRAD
	1,51	DBZH	TH	VRAD
	2,50	DBZH	TH	VRAD
	0,40	DBZH	TH	VRAD
	90,00	DBZH	TH	VRAD
	7,50	DBZH	TH	VRAD
	0,90	DBZH	TH	VRAD
	1,51	DBZH	TH	VRAD
	4,50	DBZH	TH	VRAD

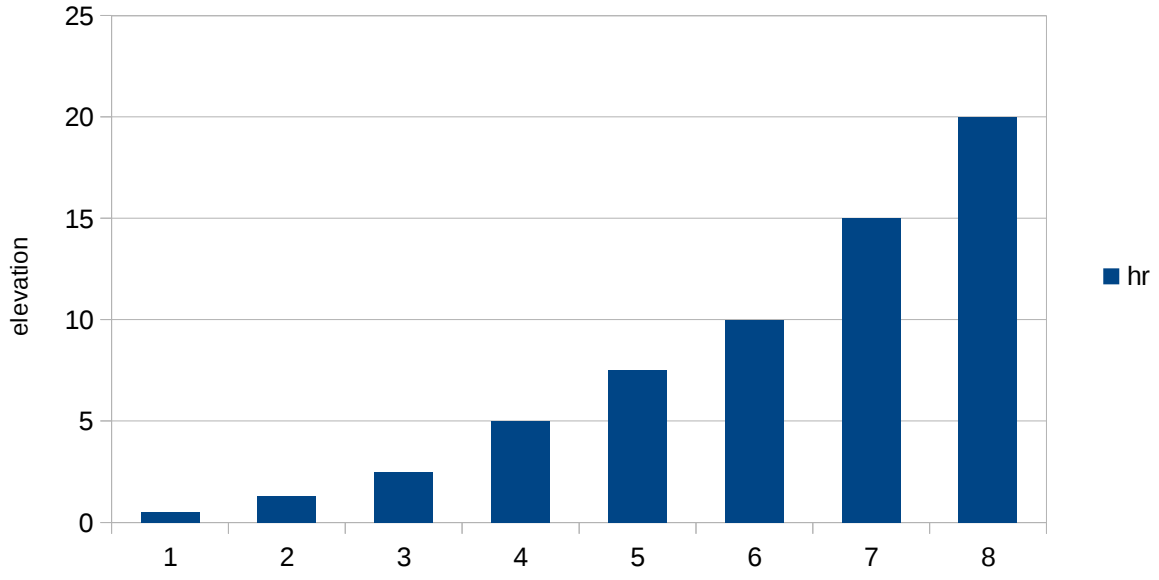


coubtry	elangle	quantity	quantity	quantity
fr	0,72	DBZH	TH	VRAD
	4,19	DBZH	TH	VRAD
	2,22	DBZH	TH	VRAD
	1,34	DBZH	TH	VRAD
	0,72	DBZH	TH	VRAD
	5,16	DBZH	TH	VRAD
	2,22	DBZH	TH	VRAD
	1,34	DBZH	TH	VRAD
	0,72	DBZH	TH	VRAD
	3,18	DBZH	TH	VRAD
	2,22	DBZH	TH	VRAD
	1,34	DBZH	TH	VRAD



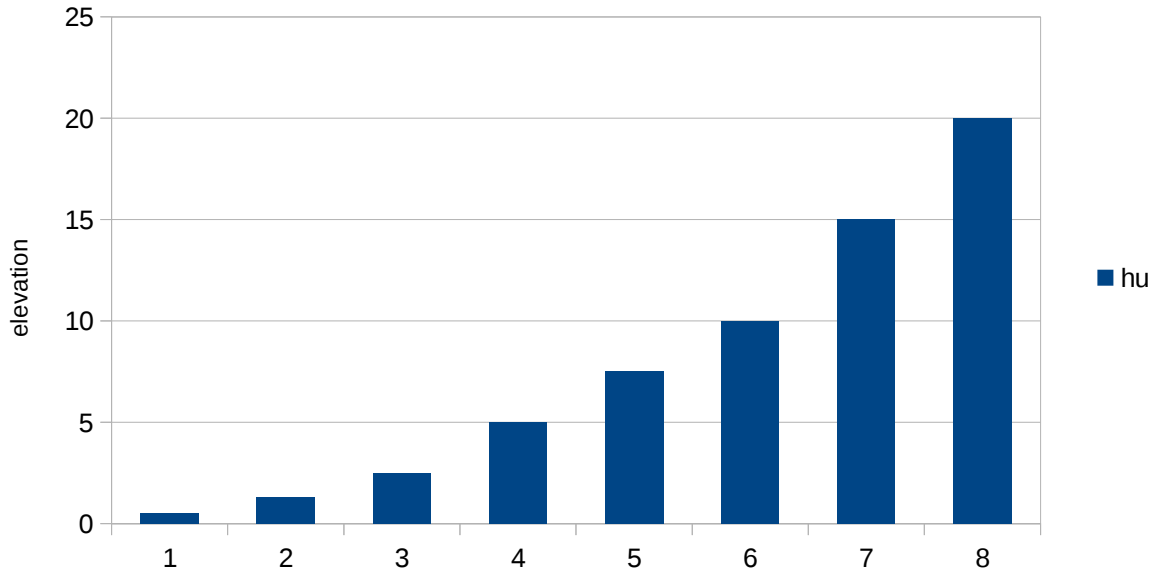
Croatia.

coubtry	elangle	quantity	quantity	quantity
hr	0,50	DBZH	TH	VRAD
	1,30	DBZH	TH	VRAD
	2,50	DBZH	TH	VRAD
	5,00	DBZH	TH	VRAD
	7,50	DBZH	TH	VRAD
	10,00	DBZH	TH	VRAD
	15,00	DBZH	TH	VRAD
	20,00	DBZH	TH	VRAD



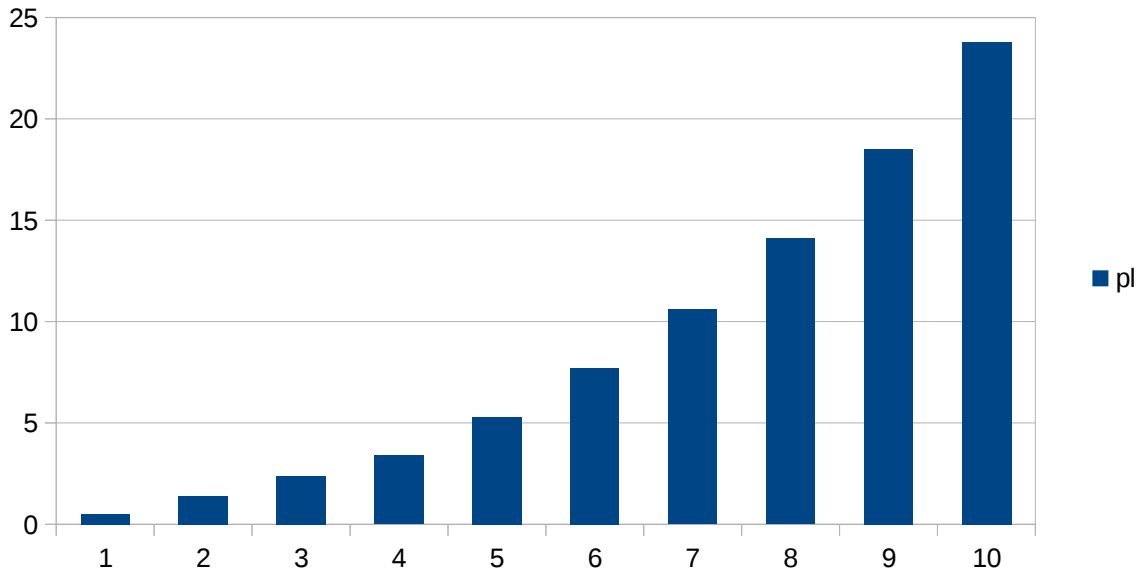
Hungary.

coubtry	elangle	quantity	quantity
hu	0,00	DBZH	TH
	0,50	DBZH	TH
	1,10	DBZH	TH
	1,90	DBZH	TH
	3,00	DBZH	TH
	4,70	DBZH	TH
	7,00	DBZH	TH
	10,00	DBZH	TH
	14,20	DBZH	TH
	20,00	DBZH	TH



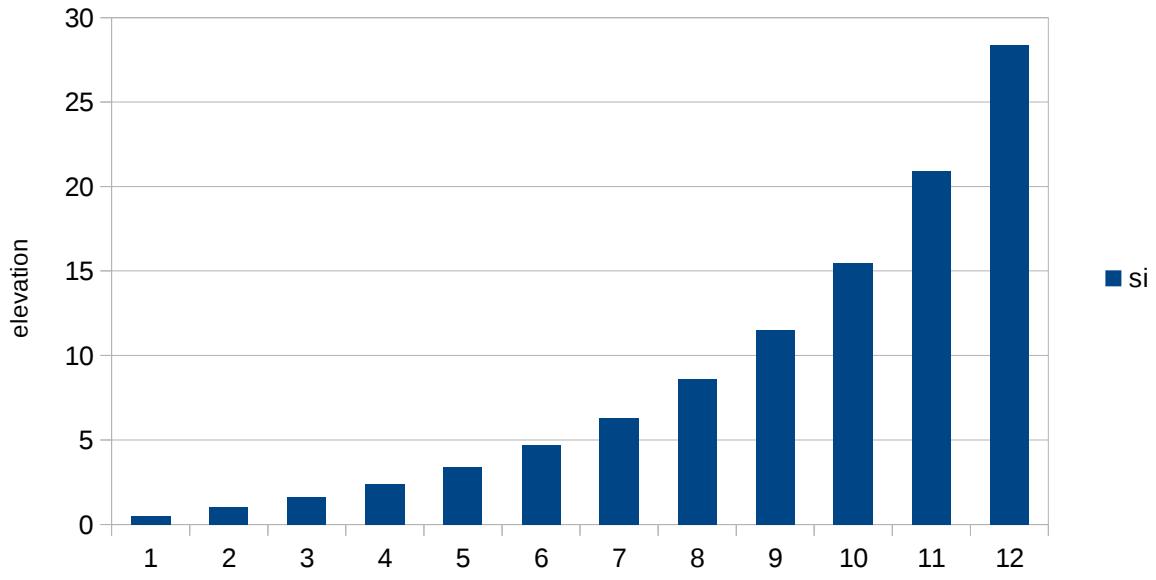
Poland.

coubtry	elangle	quantity
pl	0,5	DBZH
	1,4	DBZH
	2,4	DBZH
	3,4	DBZH
	5,3	DBZH
	7,7	DBZH
	10,6	DBZH
	14,1	DBZH
	18,5	DBZH
	23,8	DBZH



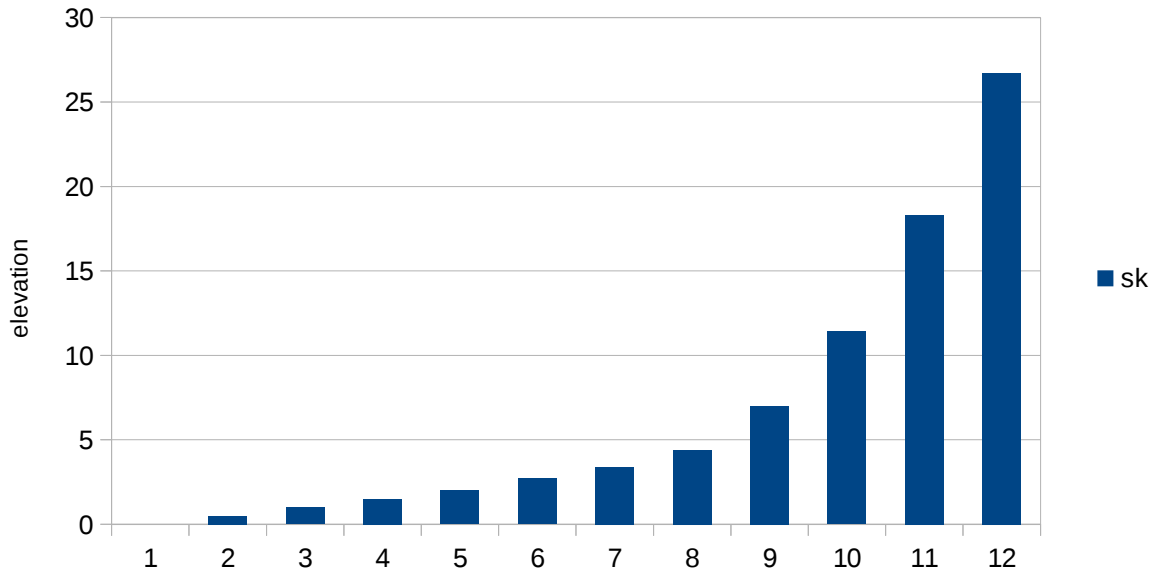
Slovenia.

coubtry	elangle	quantity
si	0,5	DBZH
	1	DBZH
	1,6	DBZH
	2,4	DBZH
	3,4	DBZH
	4,7	DBZH
	6,3	DBZH
	8,6	DBZH
	11,5	DBZH
	15,5	DBZH
	20,9	DBZH
	28,4	DBZH



Slovakia.

coubtry	elangle	quantity
sk	0	DBZH
	0,5	DBZH
	1	DBZH
	1,5	DBZH
	2	DBZH
	2,7	DBZH
	3,4	DBZH
	4,4	DBZH
	7	DBZH
	11,4	DBZH
	18,3	DBZH
	26,7	DBZH


30
25
20
15
10
5
0
elevation
1
2
3
4
5
6
7
8
9
10
11
12
sk

BATOR.

BATOR modification made by Florian Mayer is used in following discussion.

Radial velocity.

Six countries, out of ten, provide radial velocities. Parameters for decoding velocity from values written in files are given in table.

VRAD

/dataset/data/what	be	cz	cz	cz	de	fr	hr	si
gain	0,419685	0,0604331	0,156331	0,103874	1	1	0,00787402	0,00787402
nodata	255	255	255	255	1,80E+308	1,80E+308	0	0
offset	-53,7197	-7,73543	-20,0103	-13,2959	0	0	-1,00786	-1,00787
quantity	VRAD	VRAD	VRAD	VRAD	VRAD	VRAD	VRAD	VRAD
undetect	0	0	0	0	-1,80E+308	-1,80E+308	0	0

In BATOR, the radial velocity is calculated by means of the transformation formula Vr = gain*value + offset. This formula is not valid for the Croatian and Slovenian radar. For these radars the formula is Vr = NI * (gain * value + offset). NI, Nyquist's speed, for these radars is available in /dataset*n*/how groups so speed can be calculated.
Nyquist's speed for other radars, other than French and German, can be calculated using a transformation formula for value 1 (-NI) or 254 (NI). The Nyquist speeds obtained and those from the file (HR, SI) are listed in the table.

	be	cz	cz	cz	hr	si
NI	-53,300015	-7,674997	-19,853969	-13,192026	16,600500	8,100000

Nyquist velocity is not needed in BATOR, it is needed for dealiasing Doppler winds to get correct radial velocities.

To summarize, radial velocity is available from six countries, Belgium, Czech, Germany, France, Croatia and Slovenia.
Dealiasing during preprocessing of data is not possible for German and French radars.

Radar constant and sensitivity.

Radar constant and sensitivity are needed in BATOR to calculate minimum detectable reflectivity.
Radar equation is

$$dBZ = C + 20\log(R) + 10\log(P)$$

where C is the radar constant, R is a distance in km and P is the detected power.
Minimum detectable reflectivity, dBZ_{min}, is the one for which $P = P_{min}$, the minimum detectable power.
The attribute MEZ (/dataset*n*/how/MEZ) gives dBZ_{min} for $R = 1\,km$. Than sensibility, $10\log(P_{min})$ can be calculated as $10\log(P_{min}) = NEZ - C$.
Both values, radar constant and NEZ, are available only for Slovenian and Croatian radars, and corresponding values of sensibility are given in table.

	hr	si
NEZ	-27,875	-36,8125
radconstH	77,08	70,84
sensitivity	-104,955	-107,6525

In BATOR by Florian Mayer, radar constant is calculated. To calculate it, values for wavelength, power, beam width, pulse width, antenna gain and radome loss are needed. These values should be find in group /dataset*n*/how. From the table this group's attributes it can be seen that no country provides all values needed to calculate radar constant.
To conclude, using data available in ODIM HDF5 files taken from ten countries, dBZ_{min} can be calculated only for radars from Slovenia and Croatia.
In new BATOR, from Meteo France, radar constant and sensitivity are hardcoded to values -71 and -110 , respectively, tha values quite similar to those in upper table (just radar constant has a negative value, and in radar equation C must be replaced with -C).

Conclusion.

Radar reflectivity.

- In ODIM HDF5 files radar reflectivity is represented in uniform way by all countries and there is no missing information needed by BATOR.
- The problem is that minimum reflectivity can be calculated only for Croatian and Slovenian radars. All other countries do not provide enough data to calculate it in any way. One possible solution of this problem is to hard code, in BATOR, the values of radar constant and sensitivity since all radars in use have similar values for them.

Radial velocity.

- Six contries provide data of radial velocity Belgium, Czech, Germany, France, Croatia and Slovenia.
- For two countries, Croatia and Slovenia, radial velocity is slightly differently coded, and need preprocessing before use in BATOR.
- Nyquist velocity is not needed in BATOR. It is needed if we want to check aliasing of measured velocity and to do unaliasing. All is done in preprocessing befor use of BATOR.
- Dealiasing is not possible with data from France and Germany