EISCAT Level 3 data storage: the HDF5 files

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Contents

1 Introduction

The standard data products from the EISCAT incoherent scatter radars are the ionospheric parameter data (Level 3 data) obtained through analysis and parameter fitting to the time-integrated power spectral data (Level 2 data). The Level 3 data are physical parameters describing the ionospheric plasma, which is what most users of EISCAT data are using and interested in. Currently, EISCAT uses the Madrigal system to distribute Level 3 data (`https://www.portal.eiscat.se/madrigal`). An upgrade to the current release, Madrigal 3, is planned.

The next generation multistatic radar system EISCAT_3D will replace the current mainland systems and is planned to start operating in 2021, and it will produce orders of magnitude more data than the current radar system. It is therefore important to create Level 3 data storage routines that are structured, storage effective and user-friendly, and compatible with both Madrigal and future EISCAT_3D portal(s).

Consequently, the work of storing and organizing data produced by the current radar systems is also a pre-study for the data handling issues that EISCAT will face in the near future. We have introduced the use of HDF5 files to achieve these goals. HDF (Hierarchical Data Format) and is a container format specifically designed to store and organize large data volumes. The HDF5 library is available for several common programming languages and presents a directory-like structure, hiding the detail of file storage while still allowing many parameters to be tuned for storage optimisation.

A new HDF-based file format for analysed EISCAT data has been developed. Madrigal 3 uses its own HDF5-based format as well, and care has been taken to ensure backward compatibility between the format described here and Madrigal 3 by designing a converter routine.

The purpose of this document is to give an overview of the structure and content of the new EISCAT generated HDF5 files from the current radar system at EISCAT. Analysed EISCAT_3D data will be stored in a similar manner but in higher dimensionality.

2 The HDF5-file

For a given experiment analysis an HDF5-file will be generated, containing all the parameter data obtained from the analysis (parameter fitting) of Level 2 data. There are two types of HDF5-files generated, one for 'older' experiments (data from the pre-2000 Norsk Data mainland systems) and one for 'newer' experiments (data from the present digital receivers), and the differences will be highlighted below. The newer experiments are analysed using the GUISDAP software (Grand Unified Incoherent Scatter Data Analysis Package), whereas the older experiments are analysed by a variety of programmes/softwares collected under the common name On-An.

There are routines to calculate 3D ion velocity vectors using measurements from several receivers when possible. These results will be stored in separate HDF5 files, which will also differ somewhat depending on if they are from 'old' or 'new' experiments. These structures will also be described in this document, section 3. In this section focus is on the standard products and the corresponding

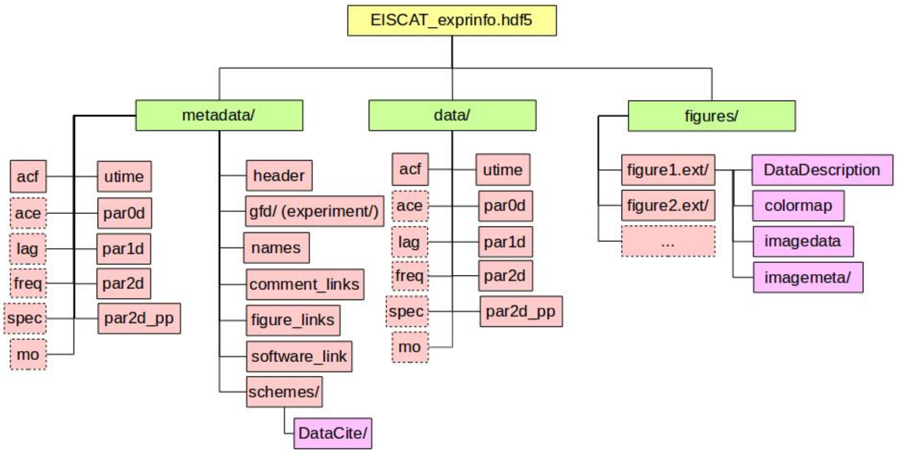

Figure 1: The structures and possible contents of the HDF5-files. The boxes with dashed lines are data that can only be obtained from GUISDAP analyses.

HDF5-files.

2.1 Filename

The name of a generated HDF5-file is unique and of the form `EISCAT_exprinfo.hdf5`, where 'exprinfo' specifies the details about the experiment in the following order: date, experiment name, record integration time [s] and receiving antenna. For example, `EISCAT_2015-02-06_beata_60@uhf.hdf5`, where the antenna is always preceded by an @. The date is the date of the first record in the analysis. If the record integration times are not constant over the whole analysis the median value is used. The antenna name may be followed by a letter (`a,b,c`) for experiments with multiple channels, typically dual-antenna experiments on the Svalbard radar.

2.2 The HDF5-file structures

The structure of an HDF5-file is hierarchical, and the generated EISCAT HDF5 files consist of the groups `/data`, `/metadata`, and `/figures` under which the numerical data, corresponding metadata and figures are sorted. The structure of the HDF5-files is illustrated in Fig. 1, which shows which data, metadata and figure data that may be stored. The structure is slightly different depending on which analysis program has been used (GUISDAP or On-An), and the data that can be obtained and stored from GUISDAP analyses but not from On-An are specified in the figure by dashed box lines.

2.3 Data

The data are mainly divided into different datasets depending on their dimensions. An exception are the record start and stop times. These are collected separately in `data/utime` for practical purposes. Parameters that are constant over the whole analysis of the experiment are referred to as 0d-parameters and

`/metadata/header`

1. Parameter
2. Description
3. Unit
4. (Guisdap parameter name)
5. Madrigal mnemonic
6. Madrigal Id
7. Identifier

Table 1: Listing the parameter metadata content as described by the header. Number 4 (GUISDAP parameter name) is only present for GUISDAP analysed experiments.

stored in `/data/par0d`. A few examples of 0d-parameters are the transmitter and receiver location, different analysis settings etc., and for static experiments the antenna azimuth and elevation angle are constant. If there are *p0* number of 0d-parameters, then `/data/par0d` is a vector of length *p0*.

Parameters that are constant during each single integration record, but not constant from record to record, are 1d-parameters and stored in `/data/par1d` as an $n \times p1$–matrix, where *p1* is the number of 1d-parameters and and n the number of integration records in the analysis. 1d-parameters are for example the system temperature and the peak power of the transmitter.

Most experiments measure over a range interval for every integration time, such that altitude dependent parameters are obtained, which are refered to as 2d-parameters and stored in `/data/par2d`. The 2d-parameter data for one time record compile an $h \times p2$–matrix, where *p2* is the number of 2d-parameters and h the number of range intervals for that specific time record. The corresponding matrices for all records are stacked below each other such that a $H \times p2$–matrix is constructed, where H is the total number of measurement points over all records of the analysis.

There is also a dataset `/data/par2d_pp`, which is data retrieved from the power profiles. It contains the range and uncorrected electron densities and usually the error of the uncorrected densities and the width of the range gate and their dependencies on range. It is also a matrix, compiled in the same manner as `/data/par2d`.

In addition to the data mentioned in the paragraphs above there may be other datasets of individual parameters that are presented with their own matrices for each time record. Therefore they have each been appointed an individual dataset named as the parameter itself. Examples of such parameters are auto correlation functions (ACF) in `/data/acf` and the measured spectrum (spec) in `/data/spec`. For old experiments (On-An) only ACF might be obtained and stored, whereas for Guisdap-analysed experiments there are several in addition (see Fig. 1).

2.4 Metadata

The metadata for the data described above are named the same but ordered within the group `/metadata`. For example, for the dataset `/data/par1d` the corresponding metadata is stored in `/metadata/par1d`.

These metadata give all the relevant information for each parameter, as defined by `/metadata/header` listed in Table 1. The only difference between the headers for the two HDF5-file types is that the GUISDAP parameter name is not included in the On-An analysed experiments. The parameter metadata and the parameter data are organized in the same way in their respective datasets; that is, if the metadata for a certain 1d-parameter are listed in column c in `/metadata/par1d`, the corresponding data are in column c in `/data/par1d`.

There is a metadataset called `/metadata/names`, where the experiment name (*name_expr*), receiving site (*name_site*), receiving antenna (*name_ant*), the location/computer and time of the analysis (*name_sig*), used stategy, such as use of models and altitude limits (*name_strategy*), and the Guisdap version used in the analysis (*gupver*) are stored. For On-An analysed experiments only *name_expr*, *name_ant*, and *name_strategy* are stored.

Parameter	Description
`/metadata/names`	
`name_expr`	Name of experiment.
`name_site`	Code of receiving site.
`name_ant`	Name of receiving antenna, (or alternative code name for multistatic analyses.)
`name_sig`	Location/computer and time of the analysis.
`name_strategy`	Strategy of integration, (or limitations applied and used for velocity-vector calculations.)
`gupver`	Guisdap version.
`name_exps`	Name of the experiments used for velocity-vector calculations.
`name_ants`	Name of receiving antennas used for velocity-vector calculations.
`name_strategies`	Strategies of integration for the experiment analyses used in velocity-vector calculations.

Table 2: The content with descriptions included in metadata `names`.

Experiment setup

Specific experiment metadata (or setups) are also stored. For GUISDAP analysed experiments these metadata are under the group `/metadata/gfd`, and for On-An analysed experiments the corresponding group is named `/metadata/experiment`. They contain somewhat different information and are listed in Table 3 with descriptions.

Schemes

A dataset needs to be uniquely identified in order to be accurately referenced and cited. There are several standardizations for this purpose. We use DataCite as scheme, consisting of a few mandatory (and non-mandatory but recommended)

Parameter	Description
GUISDAP: `/metadata/gfd/`	
`name_expr`	Name of the experiment.
`expver`	Version of the experiment.
`siteid`	ID for the site of the receiving antenna.
`data_path`	Path to the data used for the analysis.
`result_path`	Path to the stored analysis results.
`intper`	Record integration time.
`intper_median`	Median of the record integration time.
`t1`	Start time of the analysis.
`t2`	End time of the analysis.
`rt`	Real time analysis (0/1).
`figs`	Figures displayed.
`path_exps`	Path to the GUISDAP `exps`-folder.
`extra`	List of extra GUISDAP analysis commands.
On-An: `/metadata/experiment/`	
`instrument`	Name of the antenna.
`kindat`	Kind of data, specified by the *kindat* number
`start_time`	Start time of the analysis.
`end_time`	End time of the analysis.
`Cedar_file_name`	Path and name of the Cedar file.
`kind_of_data_file`	Describes the type of data.
`status_description`	Status of the data.
`instrument_latitude`	Latitude of the receiving antenna.
`instrument_longitude`	Longitude of the receiving antenna.
`instrument_altitude`	Altitude of the receiving antenna.
`name_expr`	Name of the experiment.
`intper_median`	Median of the record integration time.

Table 3: Contents of the setup metadata for GUISDAP and On-An analysed experiments, respectively.

pieces of information to be provided in order for any user to access any of the published EISCAT data.

DataCite:
This DataCite information is provided at `/metadata/schemes/DataCite/` and listed in Table 4, with explanations. The GeoLocation is typically (if there are more than 2 unique measurement points in longitude and latitude) the rectangle with minimum area enclosing the datapoints of the dataset, and the longitudes and latitudes of the corners of the rectangle are given in `.../GeoLocation/PolygonLon` and `.../GeoLocation/PolygonLat`, respectively. Figure 2 shows a typical example of such a case. If the longitudinal extent of the rectangle exceeds 180 degrees the centre of the rectangle is set as well at `.../GeoLocation/PointInPolygonLon` and `.../GeoLocation/PointInPolygonLat`. However, if the rectangle area is smaller than 10^{-4} km^2, the spatial region of the data is considered as a single point (the centre point of the rectangle).

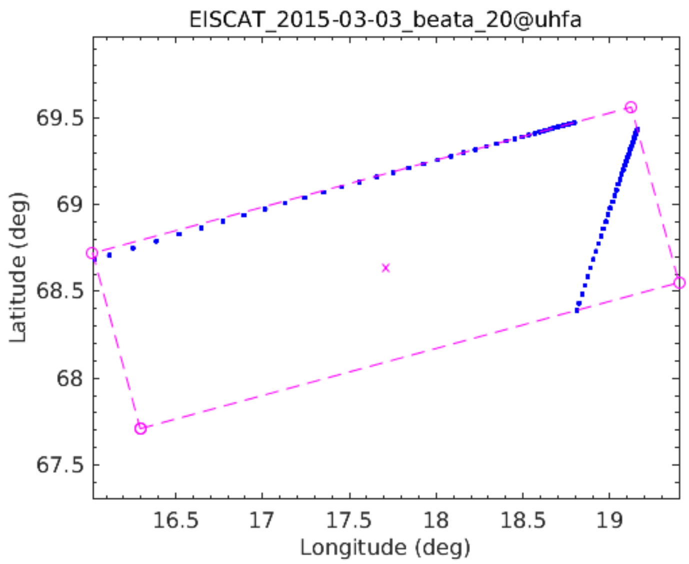

Figure 2: An axample of a rectangle with minimum area (purple) enclosing a dataset (blue). The purple x marks the centre of the rectangle.

Links

As mentioned above the data and corresponding metadata are stored in the HDF5 file. Some information and files connected to the data is however not put into this file but left separately. The software used for the analysis is given by an URL defined in `/metadata/software_link`. As mentioned in the next subsection all figures will be saved as imagedata in the HDF5 file, but there will also a be PDF version of each figure, pointers to which are embedded in `/metadata/figure_links`. When calibration of data is done there are often needs to comment any certain circumstances, and these notes are put in `/metadata/comments`.

2.5 Figures

The image data of figures (not the pdf:s) generated from the analysis are saved as matrices. Each figure is a specific group under `/figures`, such that image data and corresponding metadata for ”figure1.ext” is under `/figures/figure1.ext`, ”figure2.ext” under `/figures/figure2.ext` and so on. The image data is stored as an `m`-by-`n`-by-3 matrix in `/figures/figurename.ext/imagedata`, and the data is described in `/figures/figurename.ext/DataDescription`. Generally, metadata of an image has been stored under the group `/figures/figurename.ext/imagemeta/`, and the different parameters and their descriptions are listed in 5.

As already mentioned, each image that is stored has also been saved as a PDF. These files are not stored in the HDF5 file, but only the links to them: `/metadata/figure_links`.

Parameter	Description
/metadata/schemes/DataCite/	
Identifier	DOI (a random string at the moment).
Creator	Name of the creator (site).
Title	Name of the dataset.
Publisher	The publisher (EISCAT Scientific Associaton).
ResourceType/Dataset	A description of the resource.
Date	Start and stop time of the experiment analysis.
PublicationYear	Year when the dataset was defined.
GeoLocation	Spatial region bounding the dataset.

Table 4: List of DataCite parameters and the descriptions.

Parameter	Description
/figures/figurename.ext/imagemeta/	
Figurename	Name of the image.
Radar	The receiving antenna.
Computer	Computer and date of the image generation.
Experiment	Information about the experiment.
Copyright	The copyright of the image.
Source	Location of data used for plotting.
Results	List of variables plotted in the image.

Table 5: Metadata of a stored image with name `figurename` and extension `ext`.

3 Velocity vectors HDF5-files

The EISCAT HDF5 files generated for ion velocity vectors are named somewhat differently in order to distinguish them from the standard data, namely as `EISCAT_yyyy-mm-dd_[name_expr]_V[n][almd][T]@[name_ant]`, where the different letters correspond to number of antennas (n), if specific altitude (a) and/or latitude (l) selections have been implemented and/or if a model (m), and/or dynasonde (d) data have been used, and the time (T) selection that has been used in the analysis.

The HFD5 structure is very similar to the files for the standard products as described above (and shown in Fig. 1), but with data only present in `utime`, `par0d`, `par1d`, and `par2d`. The metadata content is also very similar, but with the addition of setup data `/metadata/Vinputs/` for newer experiments (Guisdap). The contents and descriptions of `/metadata/Vinputs/` are listed in Table 6.

A few addional parameters (`name_exps`, `name_ants`, and `name_strategies`) are added in `/metadata/names` for multistatic analyses, as described in Table 2. In these cases the definitions of `name_ant` and `name_strategy` are a bit different as noted in the table.

The vector velocity parameters differ between new and old experiments. In new experiments the data are given with east, north and up components, whereas for old experiments the data are given with perpendicular north, perpendicular north and antiparallel components (where pependicular and parallel refer to the local geomagnetic field direction), complemented with the local geomagnetic field and its components in the north, east and down direction.

Parameter	Description
`/metadata/Vinputs/`	
`AltitudeRange`	Handled altitude ranges.
`DynasondeVelocity`	Used Tromsö dynasonde vectors, bitpattern for F,E values.
`InputData`	Directories containing data that were used.
`LatitudeRange`	Handled latitude ranges.
`MinDir`	Minimum no of directories and angel difference.
`TimeSpan`	Maximum time span, time step, and first time.
`UpConstraint`	Constraint on the vertical (from 160 km parallel) component

Table 6: Setup metadata for velocity vectors calculations.

4 Parameter list and metadata

Below follows a list of all possible Level 3 data parameters that are obtained in the analysis and their metadata content of the HDF5-files.

Parameter	Description	Unit	Original parameter	Madrigal Mnemonic	Madrigal Id	Identifier
time1	start time of the integration period, unix time	s	r_time	ut1_unix	11	1
time2	end time of the integration period, unix time	s	r_time	ut2_unix	12	1
ver	Guisdap version	N/A	r_ver	N/A		2
Magic_const	scale factor for rx power	N/A	r_Magic_const	N/A		3
az	antenna mean azimuth angle, 0 to north	deg	r_az	azm	130	4
el	antenna mean elevation angle, 90 to zenith	deg	r_el	elm	140	5
Pt	peak power of transmitter	W	r_Pt	power	486	6
SCangle	half scattering angle	rad	r_SCangle	hsa	190	7
XMITloc1	transmitter location, latitude	deg	r_XMITloc	N/A		8
XMITloc2	transmitter location, longitude	deg	r_XMITloc	N/A		8
XMITloc3	transmitter location, altitude	km	r_XMITloc	N/A		8
RECloc1	receiver location, latitude	deg	r_RECloc	N/A		9
RECloc2	receiver location, longitude	deg	r_RECloc	N/A		9
RECloc3	receiver location, altitude	km	r_RECloc	N/A		9
Tsys	system temperatures, one for each calibrated code set used in analysis	K	r_Tsys	systmp	482	10
code	code sets used (from initialisation)	N/A	r_code	N/A		11
om0	scale factor for om frequency	Hz	r_om0	N/A		12

Parameter	Description	Unit	Original parameter	Madrigal Mnemonic	Madrigal Id	Identifier
om	frequency scale for inverted spectra	N/A	r_om	N/A		13
m0	ion masses in the fit	amu	r_m0	N/A		14
phasepush	phase error in transmitter	Hz	r_phasepush	N/A		15
Offsetppd	pulse propagation delay offset	μs	r_Offsetppd	N/A		16
lag	ACF lag values	s	r_lag	N/A		17
h	weighted mean of the scattering volume altitude	km	r_h	gdalt	110	18
range	weighted mean range to the scattering volume	km	r_range	range	120	19
Ne	electron density	m^{-3}	r_param	ne	510	20
Ti	ion temperature	K	r_param	ti	550	21
Tr	electron to ion temperature ratio	N/A	r_param	tr	570	22
Collf	ion collision frequency	Hz	r_param	col	709	23
Vi	ion drift velocity, positive towards antenna	m/s	r_param	vo	580	24
Dp	ion species content: ion mix [O2+,NO+]/N, oxygen ions [O+]/N	N/A	r_param	N/A		25
wn	broad band noise	K	r_param	N/A		26
dc	DC spike	K	r_param	N/A		27
dNe	error electron density	m^{-3}	r_error	dne	-510	28
dTi	error ion temperature	K	r_error	dti	-550	29
dTr	error electron to ion temperature ratio	N/A	r_error	dtr	-570	30
dCollf	error ion collision frequency	Hz	r_error	dcol	-709	31
dVi	error ion drift velocity	m/s	r_error	dvo	-580	32
dDp	error ion species content: ion mix [O2+,NO+]/N, oxygen ions [O+]/N	N/A	r_error	N/A		33
dwn	error broad band noise	K	r_error	N/A		34
ddc	error DC spike	K	r_error	N/A		35
crossvar	parameter cross variance, order p1p2, p2p3, p3p4, ... , p1pn	N/A	r_error	N/A		36
aprNe	a priori electron density	m^{-3}	r_apriori	N/A		37
aprTi	a priori ion temperature	K	r_apriori	N/A		38
aprTr	a priori electron to ion temperature ratio	N/A	r_apriori	N/A		39
aprCollf	a priori ion collision frequency	Hz	r_apriori	N/A		40
aprVi	a priori ion drift velocity, positive towards antenna	m/s	r_apriori	N/A		41
aprDp	a priori ion species content: ion mix [O2+,NO+]/N, oxygen ions [O+]/N	N/A	r_apriori	N/A		42
aprwn	a priori broad band noise	K	r_apriori	N/A		43
aprdc	a priori DC spike	K	r_apriori	N/A		44

Parameter	Description	Unit	Original parameter	Madrigal Mnemonic	Madrigal Id	Identifier
aprNe_error	a priori error electron density	m^{-3}	r_apriorierror	N/A		45
aprTi_error	a priori error ion temperature	K	r_apriorierror	N/A		46
aprTr_error	a priori error electron to ion temperature ratio	N/A	r_apriorierror	N/A		47
aprCollf_error	a priori error ion collision frequency	Hz	r_apriorierror	N/A		48
aprVi_error	a priori error ion drift velocity	m/s	r_apriorierror	N/A		49
aprDp_error	a priori error ion species content: ion mix [O2+,NO+]/N, oxygen ions [O+]/N	N/A	r_apriorierror	N/A		50
aprwn_error	a priori error broad band noise	K	r_apriorierror	N/A		51
aprdc_error	a priori error DC spike	K	r_apriorierror	N/A		52
status	status of the fit (0=fit ok, 1=max number of iterations exceeded, 2=No fit done, 3=fit fail (outside limits))	N/A	r_status	gfit	430	53
dp	O+ composition [O+]/N	N/A	r_dp	po+	620	54
res1	residual of the fit with standard deviation	N/A	r_res	chisq	420	55
res2	sqrt(2/#measurements)	N/A	r_res	N/A		55
w1	range resolution (90% level)	km	r_w	N/A	122	56
w2	range resolution (2nd moment)	km	r_w	N/A	122	56
w3	width of range gate (total)	km	r_w	N/A	125	56
spec	measured spectrum	K/Hz	r_spec	N/A		57
freq	frequency scale for forward spectrum	Hz	r_freq	N/A		58
ace	error bars for gated ACFs	K	r_ace	N/A		59
acf	gated unbiased ACFs	K	r_acf	acf		60
pprange	power profile range to scattering volume	km	r_pprange	range	120	61
pp	uncorrected electron densities (Te/Ti=1)	m^{-3}	r_pp	pop	500	62
pperr	error of uncorrected electron densities	m^{-3}	r_pperror	dpop	-500	63
ppw	width of the range gate for uncorrected densities	km	r_ppw	rgate	125	64
name_expr	name of the experiment	N/A	name_expr	N/A		65
name_site	code of receiving site	N/A	name_site	N/A		66
name_ant	name of receiving antenna	N/A	name_ant	N/A		67
name_sig	location/computer and time of the analysis	N/A	name_sig	N/A		69
name_strategy	strategy of integration	N/A	name_strateg	N/A§		70
name_exps	name of the experiments used for the velocity-vector calculations	N/A	name_exps	N/A		70
name_sites	code of receiving sites in the velocity-vector calculations	N/A	name_sites	N/A		71

Parameter	Description	Unit	Original parameter	Madrigal Mnemonic	Madrigal Id	Identifier
name_ants	name of receiving antennas used for the velocity-vector calculations	N/A	name_ants	N/A		72
name_sigs	location/computer and time of the analyses of the experiments used for the velocity-vector calculations	N/A	name_sigs	N/A		73
name_strategies	strategies of integration for the experiments analyses used for the velocity-vector calculations	N/A	name_strategies	N/A		74
gfd	analysis setup	N/A	r_gfd	N/A		75
nrec	number of altitude intervals for each integration	N/A	N/A	N/A		76
nrec_pp	number of range intervals for each integration	N/A	N/A	N/A		77
Nsamp	# samples used in time average	N/A	N/A	nsamp	414	78
Nsampi	# samples used in time average; or increment to Nsamp	N/A	N/A	nsampi	415	79
ftrans	transmitted frequency	Hz	N/A	tfreq	490	80
lat	geographic latitude of measurement	deg	N/A	gdlat	160	81
lon	geographic longitude of measurement	deg	N/A	glon	170	82
snr	signal to noise ratio	N/A	N/A	sn	410	83
snrl	log10 (signal to noise ratio)	N/A	N/A	snl	412	84
status	EISCAT data quality code 1	N/A	N/A	eisqc1	476	85
status2	EISCAT data quality code 2	N/A	N/A	eisqc2	477	86
status3	EISCAT data quality code 3	N/A	N/A	eisqc3	478	87
status4	EISCAT data quality code 4	N/A	N/A	eisqc4	479	88
status5	EISCAT data quality code 5	N/A	N/A	eisqc5	480	89
Recdfo	received doppler frequency offset	Hz	N/A	rcdfo	492	90
ppl	log10(uncorrected electron density)	lg(m^{-3})	N/A	popl	500	91
Nel	log10(Ne in m-3)	lg(m^{-3})	N/A	nel	520	92
dNel	error log10(Ne in m-3)	lg(m^{-3})	N/A	dnel	-520	93
Te	electron temperature (Te)	K	N/A	te	560	94
dTe	error electron temperature (Te)	K	N/A	dte	-560	95
Vobi	bisector ion vel (bistatic sys; pos = up)	m/s	N/A	vobi	590	96
dVobi	error bisector ion vel (bistatic sys; pos = up)	m/s	N/A	dvobi	-590	97
Collfl	log10 (ion-neutral collision frequency)	lg(s-1)	N/A	col	720	98
dCollfl	error log10 (ion-neutral collision frequency)	lg(s-1)	N/A	dcol	-720	99
ddpo	error composition – [O+]/Ne	N/A	N/A	dpo+	-620	100

Parameter	**Description**	**Unit**	**Original parameter**	**Madrigal Mnemonic**	**Madrigal Id**	**Identifier**
dpm	composition – ion mix [O2+,NO+]/N	N/A	N/A	pm	690	101
ddpm	error composition – ion mix [O2+,NO+]/N	N/A	N/A	dpm	-690	102
dph	composition – [H+]/Ne	N/A	N/A	ph+	660	103
ddph	error composition – [H+]/Ne	N/A	N/A	dph+	-660	104
Ne_lag0+	electron density, from lag 0+	m^{-3}	N/A	N/A		105
dNe_lag0+	error electron density, from lag 0+	m^{-3}	N/A	N/A		106
Ne_tp	electron density, from true power	m^{-3}	N/A	N/A		107
dNe_tp	error electron density, from true power	m^{-3}	N/A	N/A		108
hw_lor	spectrum half-width from Lorentz fit	Hz	N/A	N/A		109
dhw_lor	error spectrum half-width from Lorentz fit	Hz	N/A	N/A		110
hw_expfit	spectrum half-width from exp. fit to acf	Hz	N/A	N/A		111
dhw_expfit	error spectrum half-width from exp. fit to acf	Hz	N/A	N/A		112
ampl	amplitude of spectrum from Lorentz fit	N/A	N/A	N/A		113
dampl	error amplitude of spectrum from Lorentz fit	N/A	N/A	N/A		114
blev	base level of spectral fit	N/A	N/A	N/A		115
dblev	error base level of spectral fit	N/A	N/A	N/A		116
gain	antenna gain	N/A	r_gain	N/A		117
fradar	transmitted frequency	Hz	r_fradar	tfreq	490	118
vi_east	ion velocity in eastward direction	m/s	Vg	vi1	1210	119
vi_north	ion velocity in northward direction	m/s	Vg	vi2	1220	120
vi_up	ion velocity in upward direction	m/s	Vg	vi3	1230	121
dvi_east	error ion velocity in eastward direction	m/s	Vgv	dvi1	-1210	122
dvi_north	error ion velocity in northward direction	m/s	Vgv	dvi2	-1220	123
dvi_up	error ion velocity in upward direction	m/s	Vgv	dvi3	-1230	124
vi_east_perp	ion velocity in perpendicular (to B) eastward direction	m/s	N/A	vipe	1240	125
vi_north_perp	ion velocity in perpendicular (to B) northward direction	m/s	N/A	vipn	1250	126
vi_antipar	ion velocity in antiparallel (to B) direction	m/s	N/A	vi6	1260	127

Parameter	Description	Unit	Original parameter	Madrigal Mnemonic	Madrigal Id	Identifier
dvi_east_perp	error ion velocity in perpendicular (to B) eastward direction	m/s	N/A	dvipe	-1240	128
dvi_north_perp	error ion velocity in perpendicular (to B) northward direction	m/s	N/A	dvipn	-1250	129
dvi_antipar	error ion velocity in antiparallel (to B) direction	m/s	N/A	dvi6	-1260	130
E_east	eastward component of the electric field	V/m	N/A	ee	1610	131
E_north	northward component of the electric field	V/m	N/A	en	1620	132
E_up	upward component of the electric field	V/m	N/A	eu	1630	133
E_east_perp	electric field perpendicular (to B) eastward direction	V/m	N/A	epe	1640	134
E_north_perp	electric field in perpendicular (to B) northward direction	V/m	N/A	epn	1650	135
E_antipar	electric field in antiparallel (to B) direction	V/m	N/A	eap	1660	136
B_north	northward component of the geomagnetic field	T	N/A	bn	204	137
B_east	eastward component of the geomagnetic field	T	N/A	be	206	138
B_down	downward component of the geomagnetic field	T	N/A	bd	208	139

5 Provenance

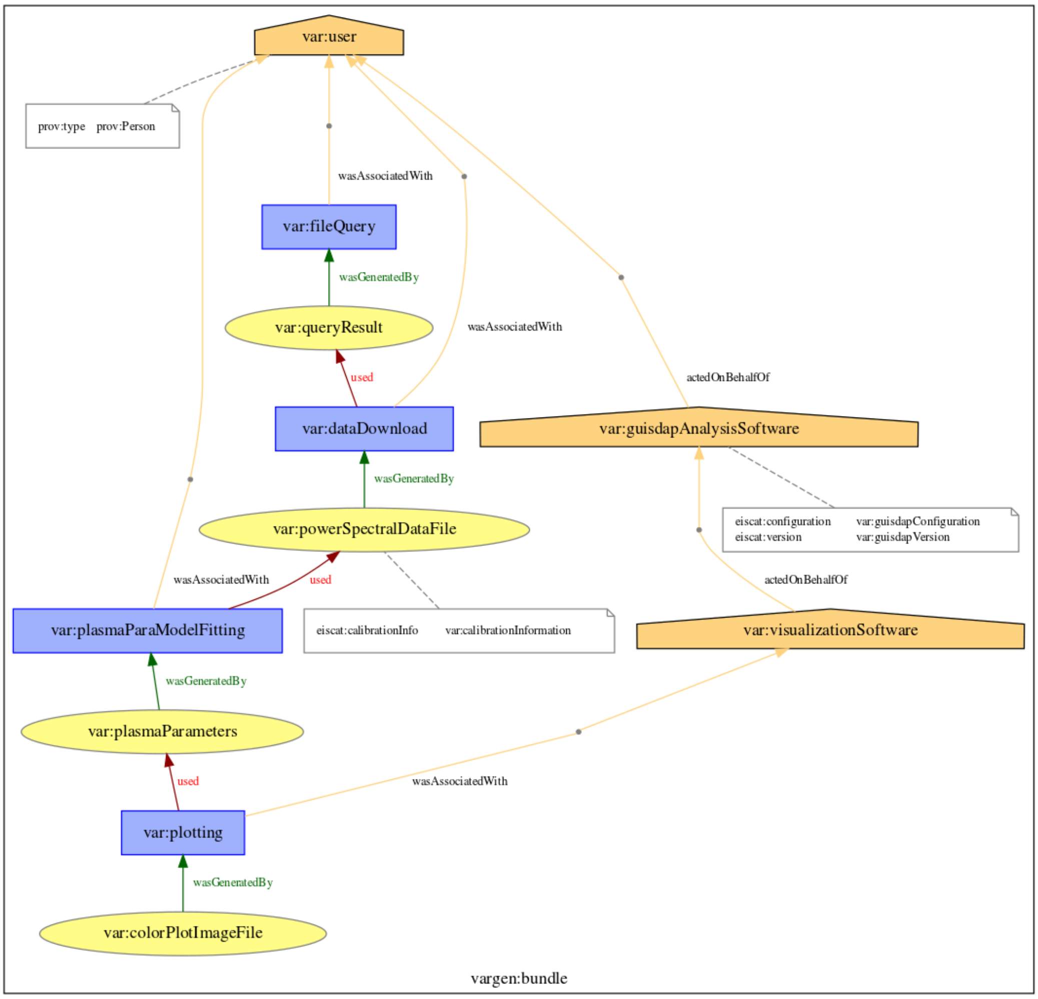

Figure 3: Provenance flow chart for the consume part (user to figure).

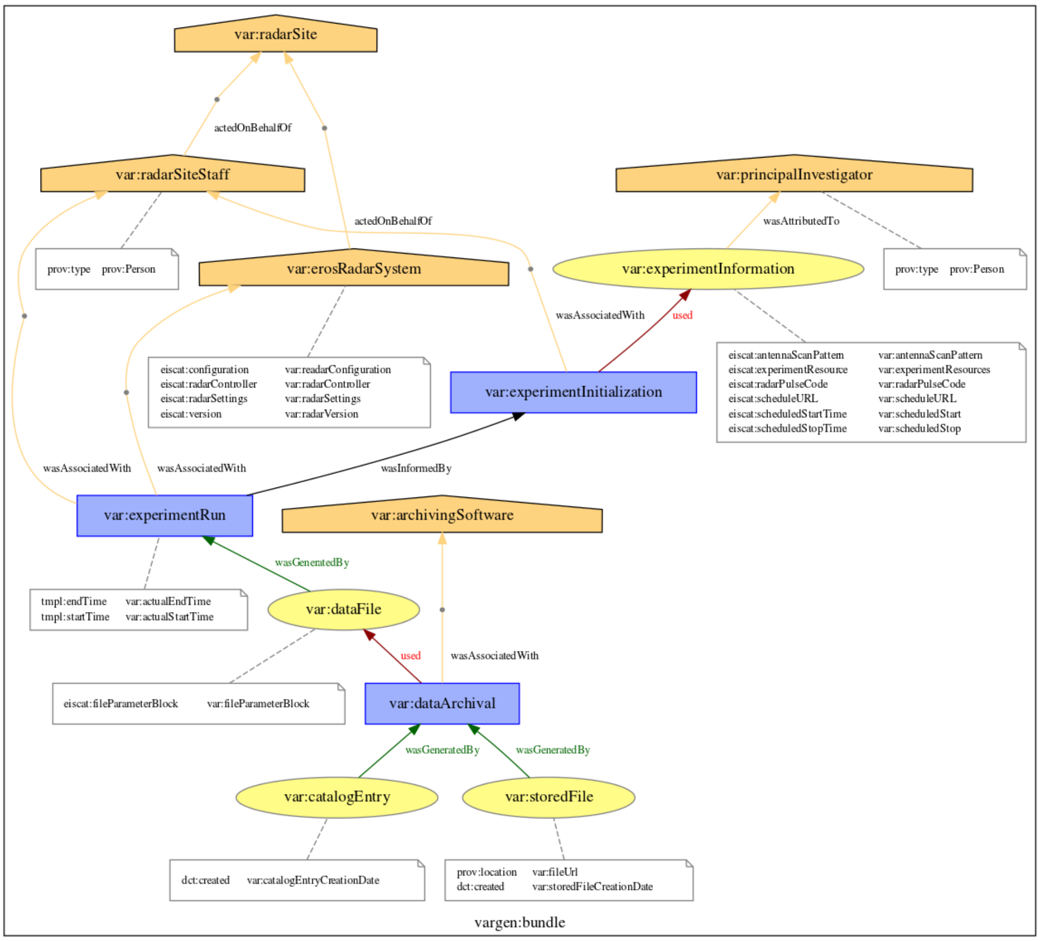

Figure 4: Provenance flow chart for the produce part (site to data).