

EISCAT data product specification

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1. Purpose of this document

This document describes the levels of data produced by the EISCAT radars and ionosondes: where and how the data are produced, and if and how the data are archived. It is assumed that the reader has some experience of radio instruments. The frequency bands in which the instruments operate are indicated by the standard historical abbreviations: HF (3-30 MHz), VHF (30-300 MHz) and UHF (above 300 MHz).

A separate data policy document describes the distribution policies and restrictions that apply to the data products at the different levels.

2. EISCAT instruments

EISCAT operates three incoherent scatter radars (ISRs), two ionosondes (Dynasondes) and an ionospheric heating facility (which now also works as a HF radar) in Northern Fennoscandia and Svalbard. The ISRs generate substantial amounts of data and the other instruments, including the heating facility after the radar upgrades, also produce profiles of ionospheric parameters. Table 1 shows the research instruments operated by EISCAT. There are also guest instruments and other complementary instruments at the EISCAT sites: other radars, active and passive optical instruments, interferometry receivers, magnetometers, etc, but not being EISCAT instruments they will not be listed here.

In the following, the denomination “radar” applies to the ISRs and the receiver capabilities of the HF heating facility, which are conceptually identical with respect to design and operation, and “ionosonde” denotes the Dynasonde ionosonde systems in Tromsø and on Svalbard.

Instrument	Location	In operation
Mainland UHF radar (930 MHz)	Tromsø, Norway	Original receiver 1981-1999 Current receiver from 2000
Mainland VHF radar (224 MHz)	Tromsø, Norway	Original receiver 1986-1999 Current receiver from 2000
Mainland remote receivers	Kiruna, Sweden Sodankylä, Finland	UHF until 2011, VHF from 2012
VHF demonstrator array	Kiruna, Sweden	2007-2012
Svalbard radar (500 MHz)	Longyearbyen, Svalbard	From 1996 Two dish antennas
Heater (4-8 MHz)	Tromsø, Norway	HF radar capabilities since 2009
Dynasonde	Tromsø, Norway	From 1992
Dynasonde	Longyearbyen, Svalbard	From 2008

Table 1: Scientific instruments operated by EISCAT.

3. EISCAT radars

The following sections describe the EISCAT radar receivers and their data products.

To understand the levels of digital data produced by the present EISCAT ISR systems, it is important to understand how the digital receiver parts work, and thus the principles are outlined in some detail before the data products are described.

1. The EISCAT digital radar receiver chain

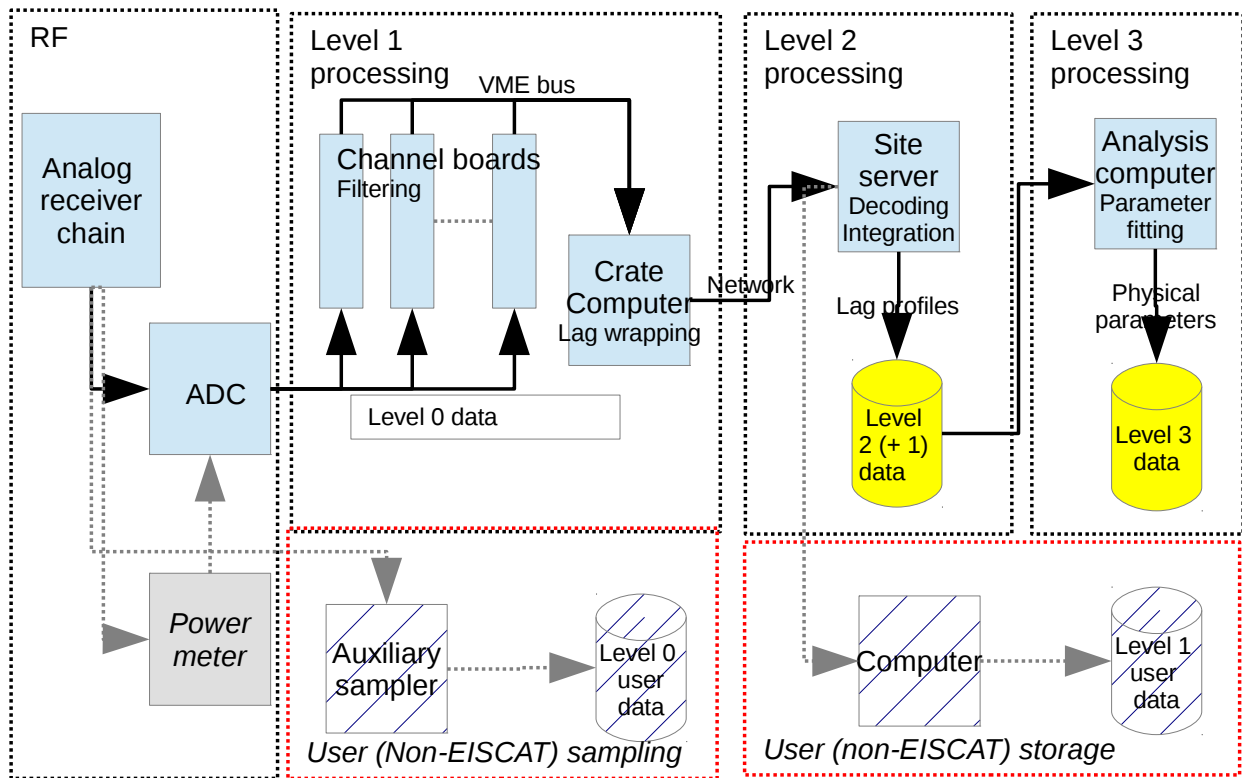


Illustration 1: The EISCAT digital receiver chain (in use since 1999), showing where the different levels of data are produced. Red boxes indicate that some users store level 0 and 1 data by their own means. This is allowed only by negotiation with EISCAT and these data are at present not available to other users.

Illustration 1 shows a schematic overview of the digital parts of an EISCAT ISR receiver of the present (mainland post-1999 and ESR) type. This diagram starts from the analog-to-digital converter (ADC) which samples the downconverted bandwidth-limited radio frequency (RF) signal. The remote receivers in Kiruna and Sodankylä are also used for passive radio astronomy applications such as interplanetary scintillation (IPS) measurements. For this purpose, integrating power meters (with DC voltage outputs proportional to the power integrated over the received bandwidth) are inserted.

The digitized values are sent to a data bus and this signal is the basis for all further standard processing.

2. Data levels in the EISCAT radar receivers

Conceptually and practically, the EISCAT data sampling, storage and analysis systems represent four levels of digital data, out of which some also correspond to archived data products.

The digital data stream of sampled raw RF (or DC for passive measurements) voltages represents the fundamental level of data and will be called level 0. Level 0 voltage samples are not stored by EISCAT, but for certain experiments some users sample data at the raw voltage level by means of their own auxiliary equipment, either from the EISCAT analog receiver or with external antennas (the latter being the case for interferometric radar experiments and radio wave generation by ionospheric heating).

Level 0 data are processed by a set of so-called channel boards, which handle decimation, digital filtering and time gating of the data, and thus act as a filter bank. The filtered digital samples constitute level 1 data. This data stream is processed by a single-board computer in the channel board crate. It wraps the data stream into time lags and feeds it through a dedicated Ethernet connection into the main site server. The level 1 data are normally not stored either due to disk space requirements, but this is possible on request for certain experiments such as passive radio astronomy, interferometry and meteor research. Certain users have also sometimes arranged their own storage of level 1 data in order not to fill the server disks.

The site server decodes the data into time-integrated lag profiles, i.e. transforms the data to the autocorrelation function domain (thus representing the power spectrum). This is data level 2 and is what many users typically see as raw EISCAT data.

In the original EISCAT receivers used on the mainland until 1999, the processing up to and including correlation was handled by dedicated hardware, whereas control and storage ran on Norsk Data computer systems. The data levels are similar; Level 2 data were stored on tape and there were also limited capabilities to store filtered level 1 data. Most of these data have been preserved and converted to the current archive format, but a small fraction has been lost due to aging of the tapes.

Profiles of physical parameters of the ionospheric plasma are retrieved by fitting a multi-parameter model to the lag profile data, usually by means of the Grand Unified Incoherent Scatter Design and Analysis Package (GUISDAP) for Matlab® (<http://www.mathworks.com>). The physical parameters are data at level 3 and this is the data product used by the majority of EISCAT users. Other retrieved parameters from special experiments, such as meteor orbit characteristics, are also examples of level 3 data.

Any value-added data products derived from EISCAT data, including published scientific reports using EISCAT data at any level, can be considered as data at a fifth level or level 4. Examples of properties derived from EISCAT data are ionisation rates, Joule heating rates, electric fields and ionospheric conductivities. Such parameters are routinely calculated and published by EISCAT users, but EISCAT does not provide level 4 data products.

Table 2 shows a summary of these data levels (*italic showing passive measurement data from the remote receivers*)

Data level	Data type	Data products
0	ADC data stream	None
1	Decimated, filtered and time gated samples <i>Sampled power of passively received 1.4 GHz signal</i>	Stored voltage domain data (only for specific experiments) <i>Passive reception data</i>
2	Correlated and time integrated data	Lag profile files
3	Fitted physical parameters	Parameter files
4	Value-added data products	Not currently provided by EISCAT

Table 2: Summary of levels of data in the present EISCAT radar systems.

3. Description of EISCAT radar data formats

Table 3 lists where to find descriptions of the data and file formats on the different levels. Most users will use the physical parameter files (level 3) which contain descriptions of all parameters. When accessing these data through Madrigal, brief help texts on all parameters are also available.

To understand lower level data, it is necessary to know the experiment setup, as it defines the transmission and the filtering of received data. Such parameters are set in the configuration files of the EISCAT Real-time Operating System (EROS): the .elan main programme and antenna scan pattern files, the .tlan files from which radar controller configurations are generated, and the .fil files which define the channel board configurations.

The GUISDAP analysis software must be properly set up to analyse the level 2 .mat files for each type of experiment and thus the format of these files can be unambiguously decoded from the GUISDAP setup.

Data level	Authoritative source of format description
0	15 MHz 14-bit data
1	EROS experiment files (.elan, .tlan, .fil)
2	GUISDAP analysis setup for data files from given experiment
3	NCAR or HDF5 headers
4	Users producing derived data products should always inform and acknowledge EISCAT. Methods should be properly described or cited.

Table 3: List of authoritative sources of descriptions of EISCAT radar data file formats.

4. EISCAT radar data access

Table 4 shows a summary of the accessible radar data products archived by EISCAT. Correlated data are archived as .mat files compatible with Matlab version 4 and several other software libraries. Future systems will instead use the standard Hierarchical Data Format version 5 (HDF5) based format specified by the OpenRadar project (<http://www.openradar.org>) for data archiving. Analysed parameters are archived in a Madrigal (<http://www.openmadrigal.org>) database, which is a system used for data access at many incoherent scatter radar sites worldwide. This database will also be updated to HDF5 in near future.

Data product	Format	Access
Lag profile files (including level 1 samples if stored) <i>Passive data</i>	.mat, compatible with Matlab v4 (pre-2000 files converted)	EISCAT raw data database, accessible through schedule page http://www.eiscat.se/schedule/schedule.cgi
Parameter files	NCAR	EISCAT Madrigal database http://www.eiscat.se/madrigal

Table 4: Summary of EISCAT radar data archive file formats. Both the lag profile archive and the Madrigal database will be converted to HDF5-based data formats.

4. EISCAT ionosondes

1. Description of the instruments

The ionosondes in Tromsø and Svalbard are commercially available Dynasonde instruments from the 1980's (see Rietveld et al., Polar Science 2:55-71, 2008). These Dynasondes are HF radars with wide band transmitting antennas and 2 receivers connected to small phased arrays of 6 antennas in Tromsø and 4 antennas on Svalbard. They operate at frequencies from 1 to about 18 MHz.

The principle of measurement is that the transmitted pulses are reflected back from the whole illuminated ionosphere, and at a critical frequency determined by the plasma parameters and polarization (O or X mode) there is total reflection. Close to the critical frequency the signal is heavily refracted, so the round trip time of a pulse is not directly proportional to the true range of reflection. Therefore the range $ct/2$ is called *virtual* range or height.

Using the two receivers and multiplexed antennas, the Dynasondes are capable of discriminating the reflected echo strengths at different polarizations, frequencies and angles of arrival. The DSND measurement software (J.W. Wright and coworkers, see the above reference publication by Rietveld et al.) then processes this information by echo classification, polynomial fits of electron density profiles, and so on.

2. Ionosonde data levels

Table 5 shows a summary of the ionosonde data. Although a bit artificial, these data are here classified in levels similar to those of the ISR data.

Data level	Data type	Data product
0	In-phase and quadrature signals from all antennas and ranges, ring buffer (Tromsø)	None
1	In-phase and quadrature signals from detected echoes (Tromsø)	Raw binary
2	Spatially resolved echo power, polarization and Doppler shift as function of frequency	Expanded ionograms
3	Ionospheric parameters derived automatically by DSND	Vector velocities, electron density profiles, irregularity parameters

Table 5: Data levels in the EISCAT Dynasonde ionosondes. Note: Svalbard uses hardware signal processing (a DSP board in an MS-DOS computer) at levels 0 and 1, whereas Tromsø uses software. It is planned to upgrade Svalbard to a more modern software receiver as well.

3. EISCAT Ionosonde data access

The EISCAT Dynasonde data at levels 2 and 3 are stored in a MySQL database at the site in Tromsø. This database is browsable online. Registration is required to obtain a username and password. Table 6 shows a summary of available data and their location

Data product	Format	Access
Level 1 raw data (Tromsø)	CD, DVD	List available at http://www.eiscat.uit.no/heating/Dynasonde/logs/cdr-log
Level 2 and 3 DSND products	User-defined listings and plots 3D visualization	Web interface (http://dyserv.eiscat.uit.no) Java browser plugin

Table 6: Description of the EISCAT ionosonde data archive.

5. Restrictions on data use and redistribution

All EISCAT data are the property of EISCAT Scientific Association. EISCAT data are normally free for scientific and educational use, but certain restrictions on the use and redistribution of EISCAT data products apply to some types of experiments (such as the national Special Programmes) as well as to the different instruments and data levels. These policies are subject to change and updates as decided by the Council. See the current data policy document.