Binary Scintillation Exchange Format (BiScEF) - Version 1.0

The format is intended to be used for archiving and exchange of scintillation data. It is intended to be flexible and extensible. Although it defines many parameteres and datasets, only a minimum set of information is mandatory. This allows the file contents to be adjusted for different setups, while guaranteeing the minimum amount of information required to understand and use the data.

File format: NetCDF4 / HDF5

(File is both a valid NetCDF4 file and a valid HDF5 file)

See e.g.: https://docs.unidata.ucar.edu/netcdf-c/current/interoperability_hdf5.html

> "*Assuming a HDF5 file is written in accordance with the netCDF-4 rules (i.e. no strange types, no looping groups), and assuming that every dataset has a dimension scale attached to each dimension, the netCDF-4 API can be used to read and edit the file, quite easily.*"
>
> https://docs.unidata.ucar.edu/nug/current/netcdf_data_set_components.html

File naming convention:

It is recommended to use one of these naming schemes:
[CountryCode][ReceiverCode][yyyy][mm][dd].nc (daily files)
[CountryCode][ReceiverCode][yyyy][mm][dd]_[hh].nc (hourly files)
[CountryCode][ReceiverCode][yyyy][mm][dd]_n[serialnumber].nc (alternative numbering scheme)
[CountryCode][ReceiverCode]_n[serialnumber].nc (alternative numbering scheme)

[ReceiverCode] = 4-character identifier
[CountryCode] = Country code for receiver site. ISO 3166-1 alpha-3 (e.g. "NOR")
[yyyy] = year, 4 digits
[mm] = month, 2 digits
[dd] = day, 2 digits
[hh] = hour, 2 digits
[serialnumber] = An integer. To be used if a different numbering scheme is wanted, e.g. numbering events.

File contents:

Each file contains data from 1 receiver.
The time period contained within is recommended to be 1 day or less, but the format allows for more.

Metadata:

Attributes at root level in the file:

Name	Type	Description	Mandatory?
BiScEFVersion	String	The version of the format used in this file. Consists of a string of the form "1.0", where the first number is the major version and the second number is the minor version. Files of the same major version are backwards compatible.	Yes
		Hardware information	
ReceiverType	String	Model name of receiver	Yes
ReceiverFWVersion	String	Receiver firmware version	No
ReceiverCode	String	Receiver identifier (typically, a 4-letter code)	Yes
ReceiverIdNum	integer	Receiver id number (Not internationally/interagency coordinated. Numbering should be valid within the Agency that collected the data)	No
ReceiverLongitude	float	Approximate geographical Longitude, in degrees East, of the receiver. Should be accurate to 0.01 degrees or better.	Yes
ReceiverLatitude	float	Approximate geographical Latitude, in degrees North, of the receiver. Should be accurate to 0.01 degrees or better.	Yes
ReceiverHeight	float	Approximate geographical Height, in meters, of the receiver. Height is the height above the WGS-84 ellipsoid.	No
ReceiverCoord	float[3]	Approximate geocentric coordinate (x, y, z) of the receiver, in meters.	No
ReceiverSamplingRate	float	Sampling rate of the receiver, in Hz.	Yes
AntennaType	String	Model name of antenna. Not mandatory, but recommended.	No
AntennaSerialNo	String	Serial number of antenna	No
		File contents information	
Constellations	String	A string specifying which constellations are allowed in this file. (i.e. other constellation are excluded) Each constellation is specified with a single character:	No

		'G' = GPS 'E' = Galileo 'R' = GLONASS 'C' = BeiDou 'S' = SBAS 'J' = QZSS 'I' = IRNSS	
SignalStatement	String	A textual description defining what is used as "signal 1", "signal 2" and "signal 3" in this file. Not mandatory, but recommended. Currently we recommend using this definition: *"Sig1" means L1CA for GPS/GLONASS/SBAS/QZSS, L1BC for Galileo, B1 for BeiDou.* *"Sig2" means L2C for GPS/GLONASS/QZSS, E5a for Galileo, L5 for SBAS, B2 for BeiDou.* *"Sig3" means L5 for GPS/QZSS or E5b for Galileo.*	No
		Processing information	
PhaseHighPassFilterFreqCutoff	float	Cutoff frequency of the high-pass filter used for the phase index computation	Yes
PhaseHighPassFilterType	String	Short description of the type of filter used for the high-pass filtering of phase. (e.g. "6th order Butterworth")	Yes
ElevationCutoff	float	Elevation mask [degrees]. All data below this elevation has been excluded from the file.	Yes
SLMHeight	float	Height of the ionospheric Single Layer, used when computing the Longitude/Latitude of the Ionospheric Pierce Point (IPP). In meters. Mandatory if the datasets "Longitude" and "Latitude" are provided.	Sometimes
		Administrative information	
Agency	String	Agency/Organization/Other that collected the data.	No
Country	String	Country code for the country in which the receiver is located, using the standard ISO 3166-1 alpha-3	No
Contact	String	Contact email address	No
DOI	String	Digital Object Identifier (DOI) for data citation	No
Comment	String	Any additional information that does not fit into the other fields.	No

Data:

Data are organized as separate datasets containing 1D arrays in time.
All arrays are of the same length, such that all data at the same index are associated.
The file does not need to contain all types of data.
In fact, none of the scintillation data types are mandatory, but it is recommended to provide at least the main scintillation index parameters ("S4s1" and "Phi60s1").

All datasets in the file share the same dimension "UNIXTime". A dataset/variable named "UNIXTime" also exists, containing the values of that dimension axis. This has been chosen to provide all data on a common time axis which is not dependent on the GNSS constellation, and is supported by all computer systems.

There are datasets defined for the commonly used GPS time parameters (week number and time-of-week), but since these are not used as the dimension variable they are not mandatory.

Name	Type	Description	Mandatory?
		Time parameters	
GPSWeek	integer[]	GPS week	No
TOW	integer[]	GPS second-of-week	No
UNIXTime	integer64[]	Seconds since Jan 01 1970. (UTC)	Yes
		Satellite parameters	
SVID	integer[]	Satellite identifier. See separate section for full description.	Yes
Azimuth	float[]	Azimuth of satellite [degrees]	Yes
Elevation	float[]	Elevation of satellite [degrees]	Yes
Longitude	float[]	Longitude of the Ionospheric Pierce Point (IPP), in degrees East	No
Latitude	float[]	Latitude of the Ionospheric Pierce Point (IPP), in degrees North	No
		Septentrio-specific parameters	
Sept_Rxstate	integer[]	Value of the RxState field of the ReceiverStatus SBF block	No
Sept_sbf2ismrversion	integer[]	sbf2ismr version number	No
		Data, per signal (# = 1, 2 or 3)	
AvgCN0s#	float[]	Average signal # C/N0 over the last minute [dB-Hz]	No
S4s#	float[]	Corrected S4 on signal #	No
S4uncors#	float[]	Uncorrected S4 on signal #	No
S4cors#	float[]	Correction to S4 on signal #	No
Phi01s#	float[]	1-second phase sigma on signal # [radians]	No

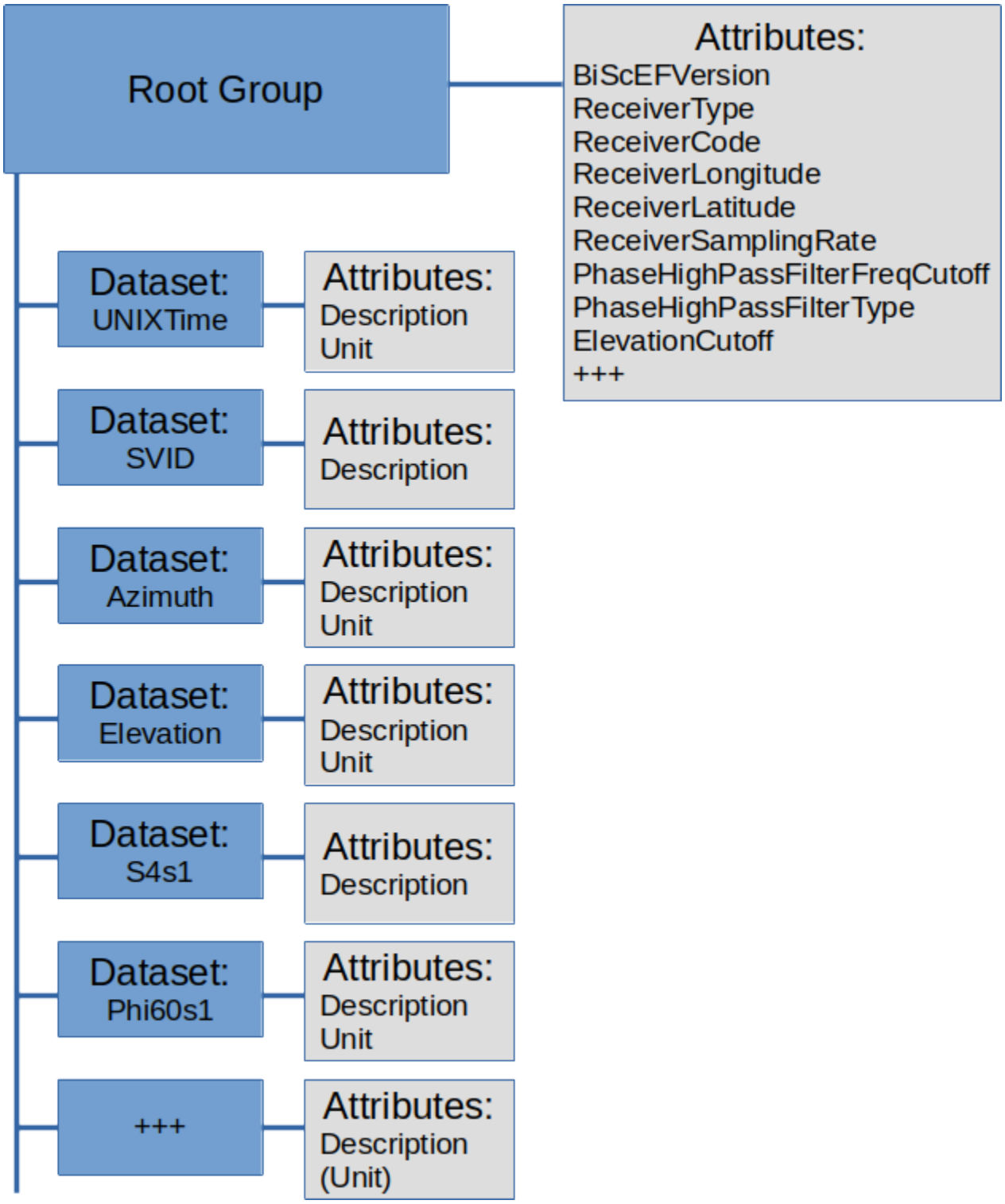
Phi03s#	float[]	3-second phase sigma on signal # [radians]	No
Phi10s#	float[]	10-second phase sigma on signal # [radians]	No
Phi30s#	float[]	30-second phase sigma on signal # [radians]	No
Phi60s#	float[]	60-second phase sigma on signal # [radians]	No
AvgCCDs#	float[]	Average code-carrier divergence for signal # [meters]	No
SigmaCCDs#	float[]	Standard deviation of code-carrier divergence for signal # [meters]	No
lockts#	integer[]	Signal lock time for signal # [seconds]	No
SIs#	float[]	SI index on signal #	No
SInums#	float[]	Numerator of SI index on signal #	No
ps#	float[]	Spectral slope for detrended phase in the 0.1 to 25 Hz range for signal #	No
Ts#	float[]	Phase power spectral density at 1 Hz on signal # [rad^2/Hz]	No
plows#	float[]	Spectral slope for detrended phase in the 0.1 to 8 Hz range for signal #	No
pmids#	float[]	Spectral slope for detrended phase in the 8 to 16 Hz range for signal #	No
phighs#	float[]	Spectral slope for detrended phase in the 16 to 25 Hz range for signal #	No
		Data, from signal combinations	
TEC45	float[]	TEC at TOW-45 sec, with calibration [TECU]	No
dTEC6045	float[]	dTEC from TOW-60 to TOW-45 [TECU]	No
TEC30	float[]	TEC at TOW-30 sec, with calibration [TECU]	No
dTEC4530	float[]	dTEC from TOW-45 to TOW-30 [TECU]	No
TEC15	float[]	TEC at TOW-15 sec, with calibration [TECU]	No
dTEC3015	float[]	dTEC from TOW-30 to TOW-15 [TECU]	No
TECtow	float[]	TEC at TOW, with calibration [TECU]	No
TECtow_uncal	float[]	TEC at TOW, without calibration [TECU]	No
dTEC15tow	float[]	dTEC from TOW-15 to TOW [TECU]	No
locktTEC	integer[]	Lock time on second frequency used for TEC computation [seconds]	No
CN0TEC	float[]	Average C/N0 of second frequency used for TEC computation [dB-Hz]	No
ROTIFullHz	float[]	Rate-of-TEC index, based on full time resolution signal 1 and signal 2.	No
ROTI1Hz	float[]	Rate-of-TEC index, based on signal 1 and signal 2 decimated to 1 Hz resolution.	No

Attributes associated with each dataset:

Name	Type	Description	Mandatory?
Description	String	A short textual description of the variable contained in the dataset. E.g.:	Yes

		"`60-second phase sigma on signal 1`"	
Unit	String	The physical unit of the dataset. Can be omitted for datasets that do not have a physical unit. E.g: "`radians`"	Sometimes

File Structure:



SVID:

Value	Description	RINEX code
0	Do-not-use value	N/A
1-37	PRN number of a GPS satellite	Gnn (nn = SVID)
38-61	Slot number of a GLONASS satellite with an offset of 37 (R01 to R24)	Rnn (nn = SVID-37)
62	GLONASS satellite of which the slot number is not known	N/A
63-68	Slot number of a GLONASS satellite with an offset of 38 (R25 to R30)	Rnn (nn = SVID-38)
71-106	PRN number of a GALILEO satellite with an offset of 70	Enn (nn = SVID-70)
107-119	L-Band (MSS) satellite. Corresponding satellite name can be found in the LBandBeams block.	N/A
120-140	PRN number of an SBAS satellite (S120 to S140)	Snn (nn = SVID-100)
141-180	PRN number of a BeiDou satellite with an offset of 140	Cnn (nn = SVID-140)
181-187	PRN number of a QZSS satellite with an offset of 180	Jnn (nn = SVID-180)
191-197	PRN number of a NavIC/IRNSS satellite with an offset of 190 (I01 to I07)	Inn (nn = SVID-190)
198-215	PRN number of an SBAS satellite with an offset of 57 (S141 to S158)	Snn (nn = SVID-157)
216-222	PRN number of a NavIC/IRNSS satellite with an offset of 208 (I08 to I14)	Inn (nn = SVID-208)
223-245	PRN number of a BeiDou satellite with an offset of 182 (C41 to C63)	Cnn (nn = SVID-182)

Phixx indices

Phi01 is the average of the 60 standard deviations computed over 1-s intervals during the last minute.
Phi03 is the average of the 20 standard deviations computed over 3-s intervals during the last minute.
Phi10 is the average of the 6 standard deviations computed over 10-s intervals during the last minute.
Phi30 is the average of the 2 standard deviations computed over 30-s intervals during the last minute.
Phi60 is the standard deviation computed over the whole last minute.

S4 correction

The S4 correction accounts for the thermal noise contribution to the S4. The corrected S4 index (S4s#) is related to the uncorrected S4 (S4uncors#) and its correction (S4cors#) in this way:

$$S4_{Corrected} = \sqrt{(S4^2_{Uncorrected} - S4^2_{Correction})}$$

If the S4 correction is greater than its uncorrected value, the corrected S4 value is set to zero.

Note on compression

If compression is desired, it is recommended to use the internal compression routines of the HDF5/NetCDF4 format. See e.g.:

https://www.hdfgroup.org/2015/04/hdf5-data-compression-demystified-1/

https://www.hdfgroup.org/2017/05/hdf5-data-compression-demystified-2-performance-tuning/

Plotting script

This format description is distributed with a python script that can be used to generate a selection of plots from this kind of file.

If run with the option "-h", it prints instructions for usage:

```
$ python3 MakeDataPlots.py -h
usage: MakeDataPlots.py [-h] [-G] [-R] [-E] [-C] [-S] [--plot_ts_simple]
                        [--plot_ts_box] [--plot_sky] [--plot_heat_sigPhi]
                        [--elevationCutoff ELEVATIONCUTOFF]
                        filename

BiScEF data plotter

positional arguments:
  filename              Filename of input data file

optional arguments:
  -h, --help            show this help message and exit
  -G, --GPS             Make plots for GPS (default: False)
  -R, --GLONASS         Make plots for GLONASS (default: False)
  -E, --Galileo         Make plots for Galileo (default: False)
  -C, --BeiDou          Make plots for BeiDou (default: False)
  -S, --SBAS            Make plots for SBAS (default: False)
  --plot_ts_simple      Plot simple time series (default: False)
  --plot_ts_box         Plot box-and-whiskers time series (default: False)
  --plot_sky            Plot skyplots (default: False)
  --plot_heat_sigPhi    Plot 2d histogram of sigma phi over time with mean
                        sigma phi (default: False)
  --elevationCutoff ELEVATIONCUTOFF
                        Set elevation angle cutoff (default: 5)

NB: This script assumes that the file contains data from one day (or less)
```

The following figures show examples of plots generated by the script.

The box-and-whiskers plots use the default settings in matplotlib: The box extends from the lower to upper quartile values of the data, with a line at the median. The whiskers extend from the box to show the range of the data. Outlier points are those past the end of the whiskers.

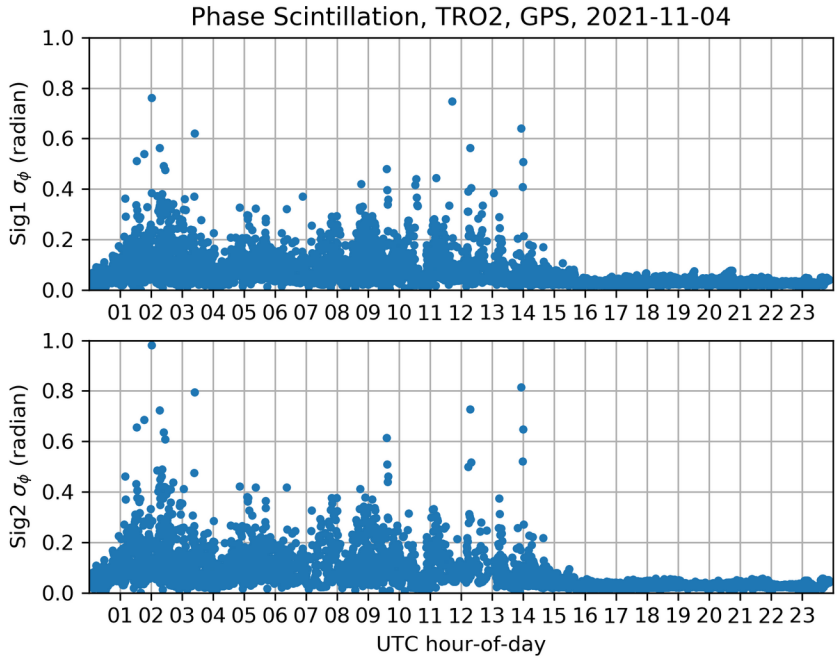


Figure 1: Phase scintillation time series

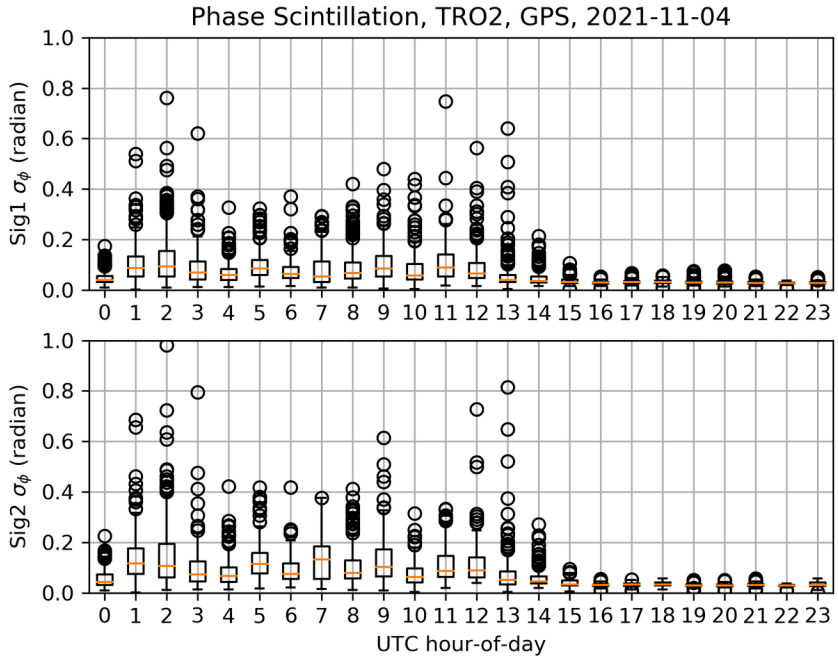


Figure 2: Phase scintillation box-and-whiskers plot

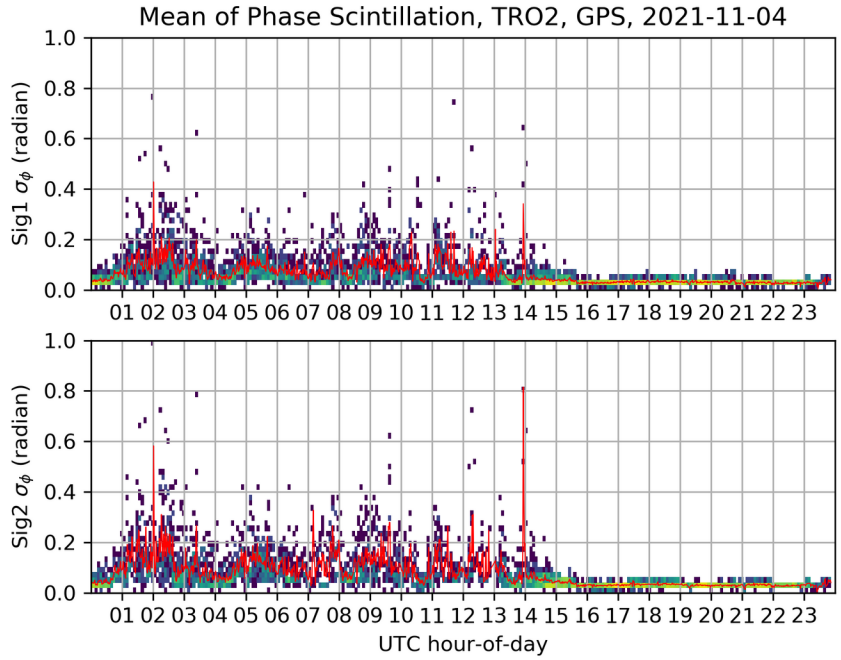


Figure 3: Phase scintillation heat map + mean value at each time step.

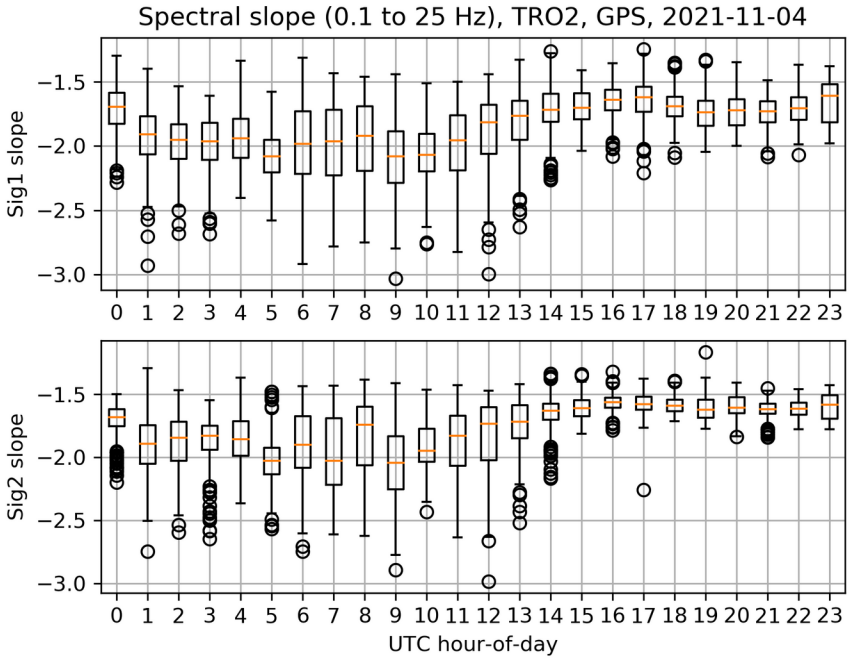


Figure 4: Phase scintillation spectral slope box-and-whiskers plot

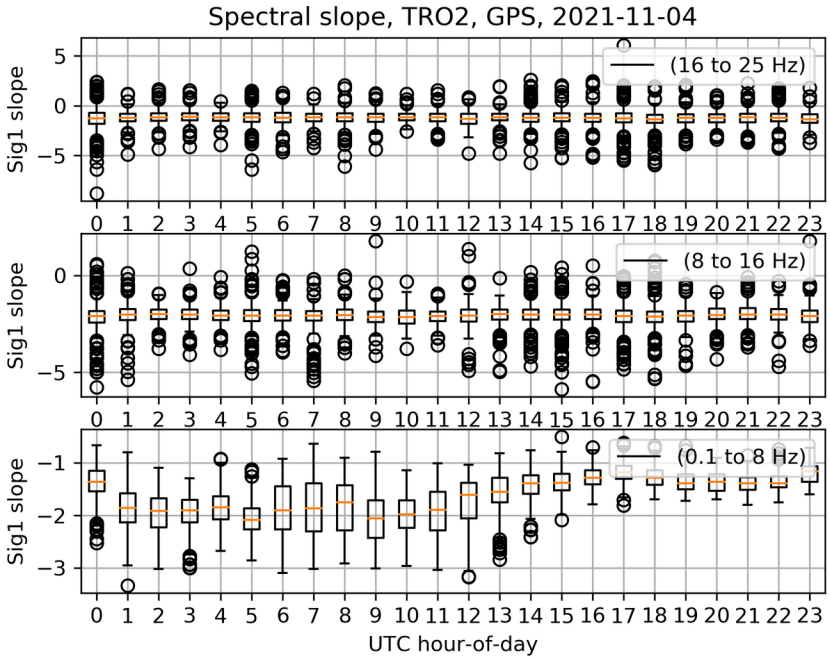


Figure 5: Phase scintillation spectral slope box-and-whiskers plot, split by spectral frequency range.

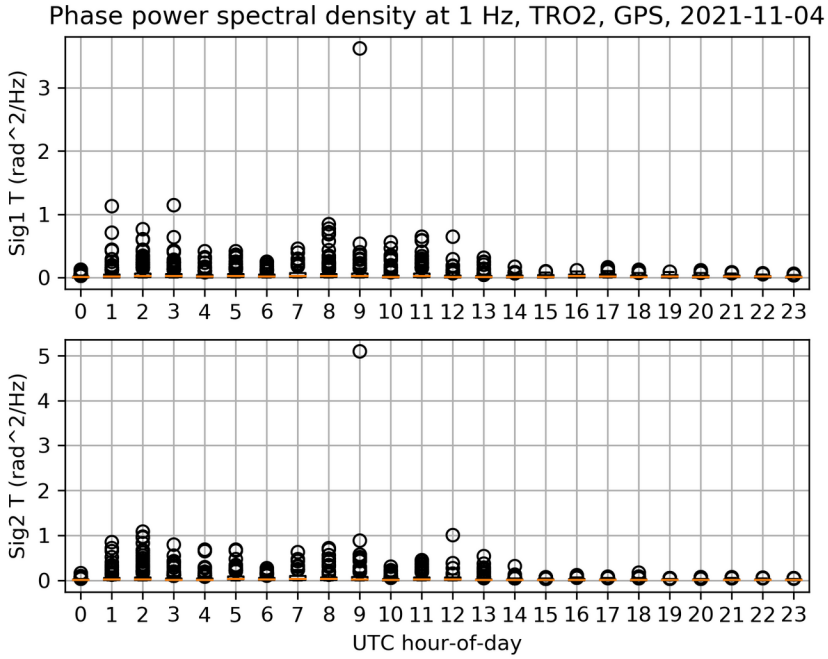


Figure 6: Phase scintillation PSD at 1 Hz box-and-whiskers plot

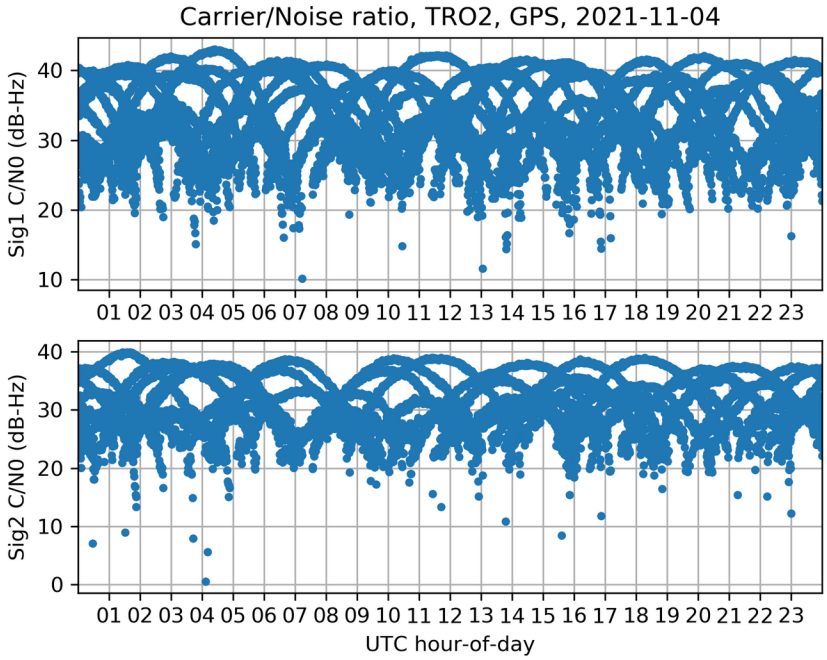


Figure 7: Carrier/Noise ratio time series

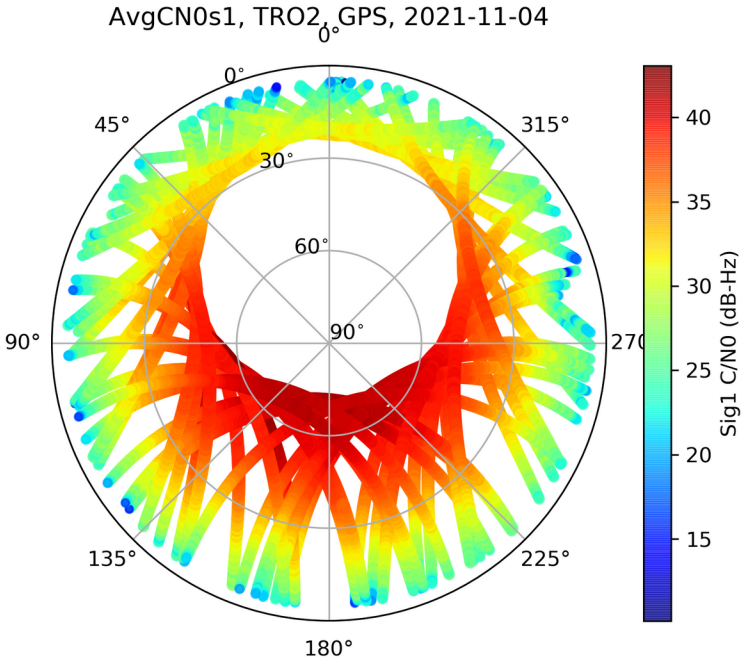


Figure 8: Carrier/Noise ratio skyplot

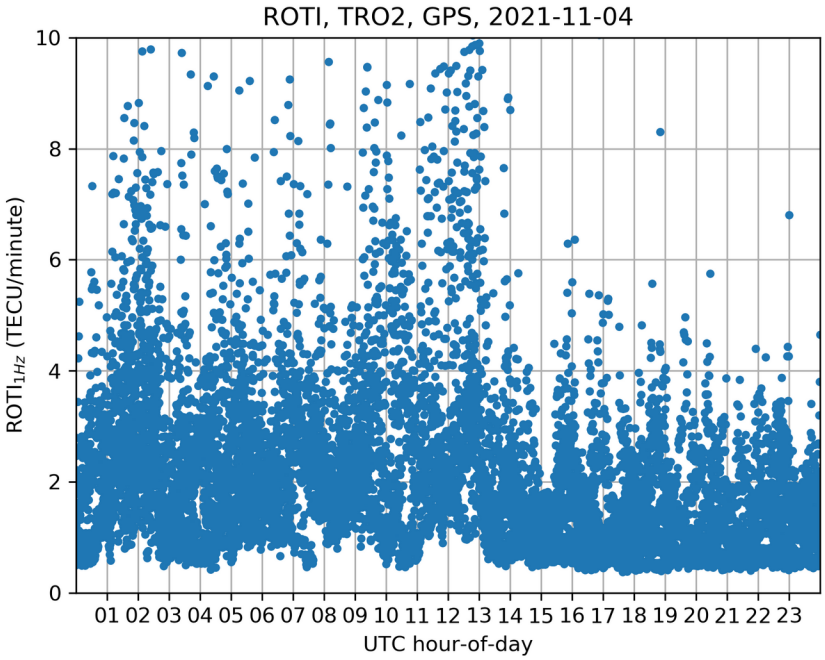


Figure 9: Rate-Of-TEC-Index (ROTI) time series

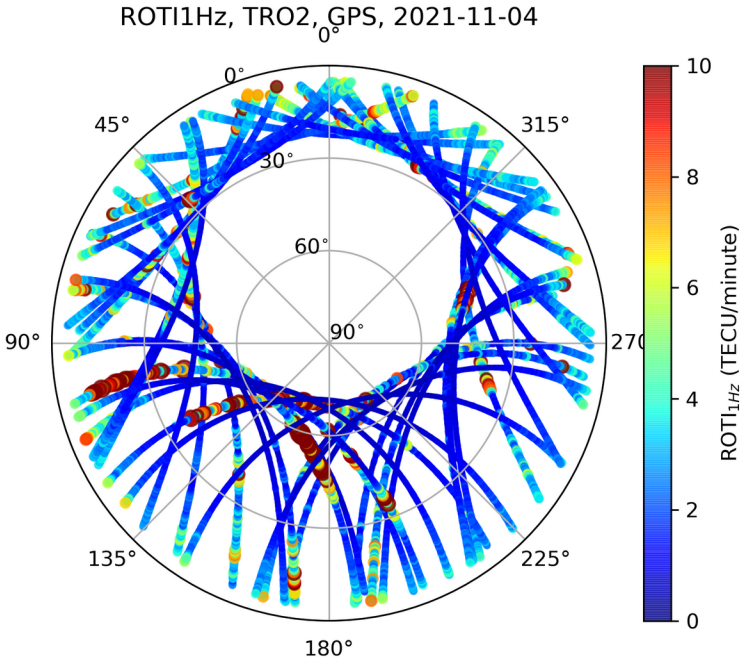


Figure 10: Rate-Of-TEC-Index (ROTI) skyplot