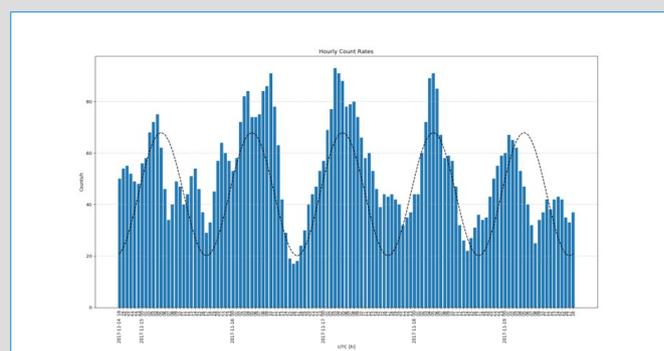
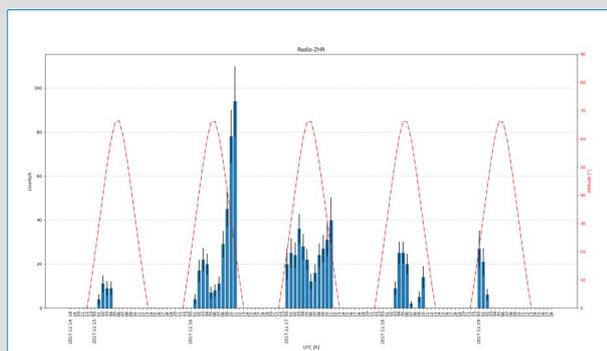
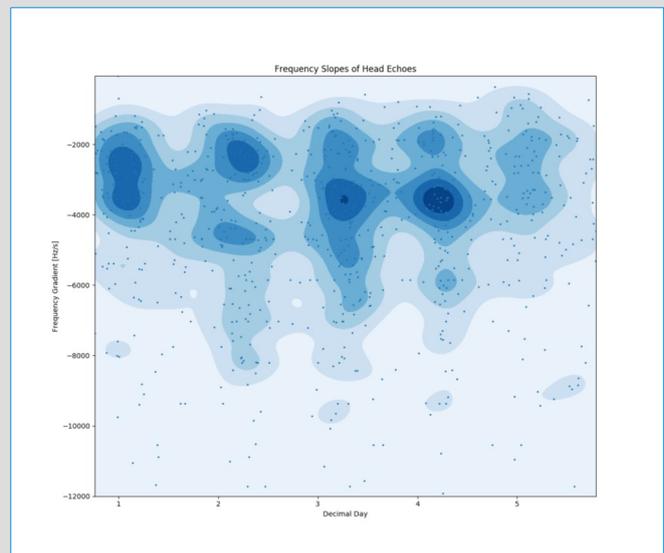
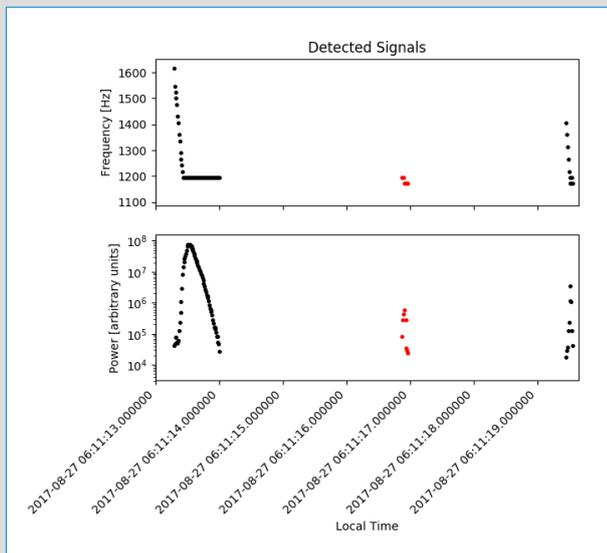


Manual PROCESSDATA

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1. Introduction

The software PROCESSDATA primarily is written to processes the raw data from METEOR LOGGER and provide a number of standard analyses. The raw data from METEOR LOGGER are organised in data sets. Each data set is indexed by a common serial number and represents one meteor reflection. Such a data set henceforth is referred to as a signal.

Attention: Before running PROCESSDATA it is mandatory to set the correct time shift from local time to UTC in CONFIG.TXT. Adapting further parameters in CONFIG.TXT is essential for a correct output of the most of the features of the **B-Functions** and **C-Configuration** menu, see chapter 7. PROCESSDATA detects head echoes of cw-transmission only if the radio signals have been recorded in USB mode.

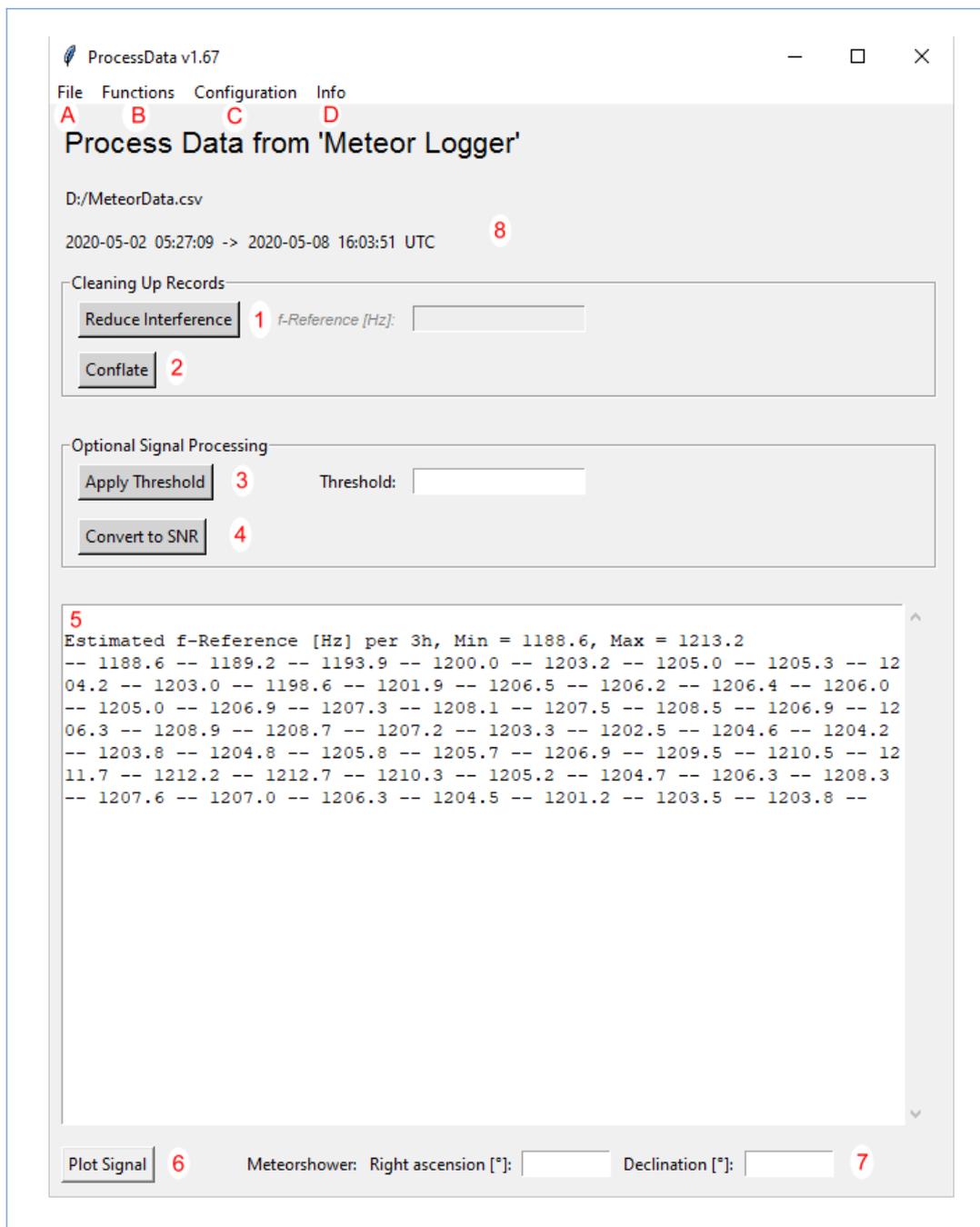


Fig. 1: The graphical user interface of PROCESSDATA

2. Basic Operations, modifying the data set (Fig. 1):

A-Open: Opens a MeteorData.csv-file and eliminates all data lines marked by -1 in the frequency column as well as any text lines that originate from a stop and restart of the monitoring mode of Meteor Logger. In case of repetitive labels the dataset will be renumbered to obtain a series of unique labels. The CONFIG.TXT-file is read and time and date are corrected to UTC, daylight saving is taken into account by check-back. On the basis of the trail echoes the course of the *reference-frequency* (which represents zero Doppler shift) is estimated. These processes are time-consuming, be patient with large files. A colour change of the surface of the buttons to a dark grey indicates the end of the operation.

A-Save as: Saves the data set processed by opening and by the steps (1)-(4) to a csv-file.

1 Press this button for interference reduction. Any signal will be eliminated that does not contain at least one frequency in the vicinity (± 47 Hz) of the reference-frequency. This means any transiting signals (head echoes, satellite transits, plane-echoes) and all meteor trail echoes remain. However, all other types of interference and the very small number of head echoes whose Doppler shifts end far from the reference-frequency were eliminated. The reference-frequency is estimated automatically and displayed in **5**. If the estimation-process fails (too short record period, too large amount of interference), manually a reference frequency can be entered. This is also true if you employ a receiver with extraordinary frequency stability. In all other cases it is strongly recommended to rely on the estimated reference-frequency.

2 Press this button to conflate disrupted signals. Subsequent signals that lie within a pre-defined time span get the same label as its predecessor and will be handled now as one signal. Thereby signals that terminate with an exponential decay will not be merged with its successor and signals starting with a head echo will not be merged with its predecessor. This processing is important in case of deep fading meteors [1]. The time span is set in CONFIG.TXT, see chapter 7.

3 Applies an amplitude threshold to the recorded signals by eliminating all signals that do not contain at least one value that exceeds the chosen threshold. The threshold can be given as power (arbitrary units) or after application of step (4) as signal to noise ratio.

4 Substitutes power (arbitrary units) with the signal/noise ratio (SNR). Noise is taken as the mean of all noise-records of the signal. Can be useful for comparing results produced under diverse (noise-)conditions and with different radio equipment.

3. Visualisations of the data set (Fig. 1):

5 This window informs about the performed operations when opening a data file (**A**) and of steps (**1**)-(3) in tabular form.

6 Pressing this button shows two graphs of the actual data set: a frequency vs. time plot and a power (SNR) vs. time plot. Zooming into one of the plots causes a synchronized zoom in the other plot. Graphs of different processing steps can remain opened on the screen for comparison.

8 Informs about the actual data-file and the time span it covers.

4. Data analysis basing on the processed data set (Fig. 1):

B-Summarise Data: Writes a summary of the data set to disc. Each signal is reduced to one data line, containing date, time and frequency at the peak value of power (/SNR). The value of the power (/SNR)-peak itself as well as the sum of the particular power (/SNR)-values and the duration of the signal are recorded also. The time period between the signals also is noted. If **C-Show Radiant** is activated the altitude derived from right ascension and declination (> **7**) is added to each data line, see **C-Show Radiant**.

B-Export Zero Cross HE: Extracts all registered head echoes that start at high frequencies and reach down to the reference-frequency (= zero crossing head echoes) and writes them to disc for further analysis.

B-Export Overdense Trails: Extracts the overdense meteor trails from the dataset on base of their duration [2]. It is written to disc for further analysis.

B-Export Underdense Trails: Extracts the underdense meteor trails from the dataset on base of their duration [2]. It is written to disc for further analysis. The duration is set in CONFIG.TXT, see chapter 7.

B-Export RMOB-file: Calculates and writes the hourly count rates of signals to disc applying the format of RMOB. This file can be opened by Colorgramme Lab [3]. If the data set covers more than one month only the first month is exported (a RMOB-file is organised by the month). So a transcending data set first must be split up in separate months to make full use of this export feature.

B-Hourly count rates: Calculates, plots and writes to disc the hourly count rates of signals. Depending on the selections in the configuration menu additional pieces of information are displayed and also will be written to disc, see **C-Show Radiant**, **C-Show Trend**.

B-Radio-ZHR: Calculates, plots and writes to disc the radio-ZHR. It is calculated by subtracting the predicted hourly counts of sporadic meteors from the observed hourly counts. Then the resulting hourly meteor shower counts are divided by the sine of the altitude of the shower radiant for zenith correction [4]. Therefore right ascension and declination of the meteor shower have to be entered in **7**, see **C-Show Radiant**. The error is estimated according to [5]. Radio-ZHRs are only calculated for altitudes > 15 degrees This limit can be altered in CONFIG.TXT (see chapter 7).

B-Distributions: Calculates, plots (blue colour) and writes to disc the logarithmic cumulative distribution of the peak amplitudes/SNRs of all signals [6]. For an overview also the slopes are calculated from consecutive segments of the distributions and are indicated as red triangles. A second graph shows the distribution of the time span between the particular signals. This is important for ascertaining an appropriate time span for signal conflation in CONFIG.TXT, see chapter 7.

B-Analyse Zero Cross HE: Calculates the frequency gradient from zero crossing head echoes, i.e. head echoes that start at high frequencies and reach down to the reference-fre-

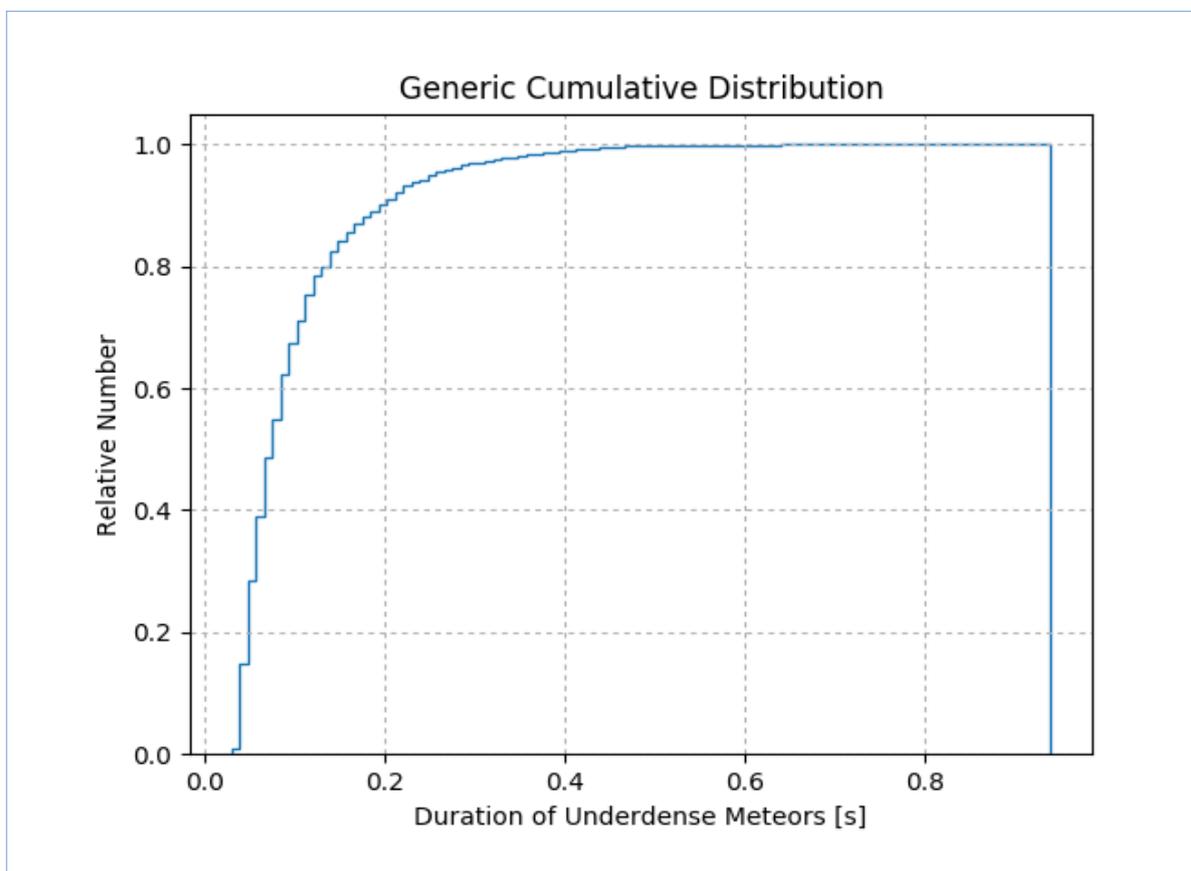
quency). Only this section is considered in the calculation which is performed by means of linear regression. The frequency gradients are displayed as scatter-plot together with an underlaid Gaussian kernel density estimation. From each head echo the frequency range of the considered head echo section, the number of associated data points, the sum of power/SNR and the calculated frequency gradient were written to disc together with date and time of the first detection of the head echo. If activated the altitude and azimuth derived from the entered right ascension and declination (> 7) is added to each data line, see *C-Show Radiant*.

5. Configuration (Fig. 1):

C-Show Trend: A prediction of the hourly count rates of sporadic meteors based on a fixed sine-function [7] or a sine-function fitted to the actual set of data can be chosen. It will be drawn in the plots of **B-Hourly count rates** and **B-Radio-ZHR**. The parameter for the fixed sine-function are set in CONFIG.TXT. The fixed sine function synchronises to 0 h UTC, so your dataset should cover this period of time.

C-Show Radiant: If activated among others the altitude of the radiant of the observed meteor shower will be drawn in the plots of **B-Hourly count rates** and **B-Radio-ZHR**. Right ascension (RA) and declination (DEC) of the radiant of the meteor shower under investigation have to be entered in 7. Most commonly you can use the RA/DEC of the day of the shower peak. Keep in mind that the altitude for the given RA/DEC is correct calculated for the whole time span of the data set, but the radiant of a meteor shower drifts (at least the RA by about 1° per day). So the calculated altitude for the meteor shower is only valid for a limited

Fig. 2: Cumulative Distribution of signal duration of mostly underdense meteor trails.



intervall. Normally a span of ± 5 days is fully acceptable but this depends on your quality requirement. The geographic position where the radio reflection happens is set in CONFIG.TXT. In case of no appropriate entry in 7 a warning message is displayed and nothing is calculated.

C-Apply a Smoother: applies a Gaussian filter or a running mean to the hourly count rates (function **B-Hourly count rates** and **B-Radio-ZHR**).

C-Load Processed Data: If this feature is activated previously created files by **A-Save**, **B-Export Overdense Trails** and **B-Export Underdense Trails** can be opened circumventing time corrections (because data already are corrected to UTC). Files generated by **B-Export Head Echoes** can also be opened this way to plot data (6) or summarise them (**B-Summarise Data**). Keep in mind that these data represent always only a small fragment of a meteor signal, so don't make use of the other features, you will get no meaningful results.

6. Info (Fig. 1):

D-Approximate Limit: This feature produces a cumulative distribution of the duration of mostly underdense meteor trails. Perform it *before* any signal conflation. A regression analysis is used to identify generic underdense trails: a signal that shows an exponential decay from its peak value to its end is regarded as an underdense trail [8] if the coefficient of determination is greater than 0.975. This graph is helpful to find an appropriate value for the duration as distinguishing criterion between underdense and overdense meteor trails (\Rightarrow **B-Export Overdense Trails** and **B-Export Underdense Trails**), see chapter 7.

Fig. 3: The left graph shows the distribution of time lag between the signals before conflation. The fragmentation is clearly seen as a second peak around $10^{-1} = 0.1$ s. Time span is set to $10^{-0.4} = 0,4$ s. The graph at the right shows the result after conflation.

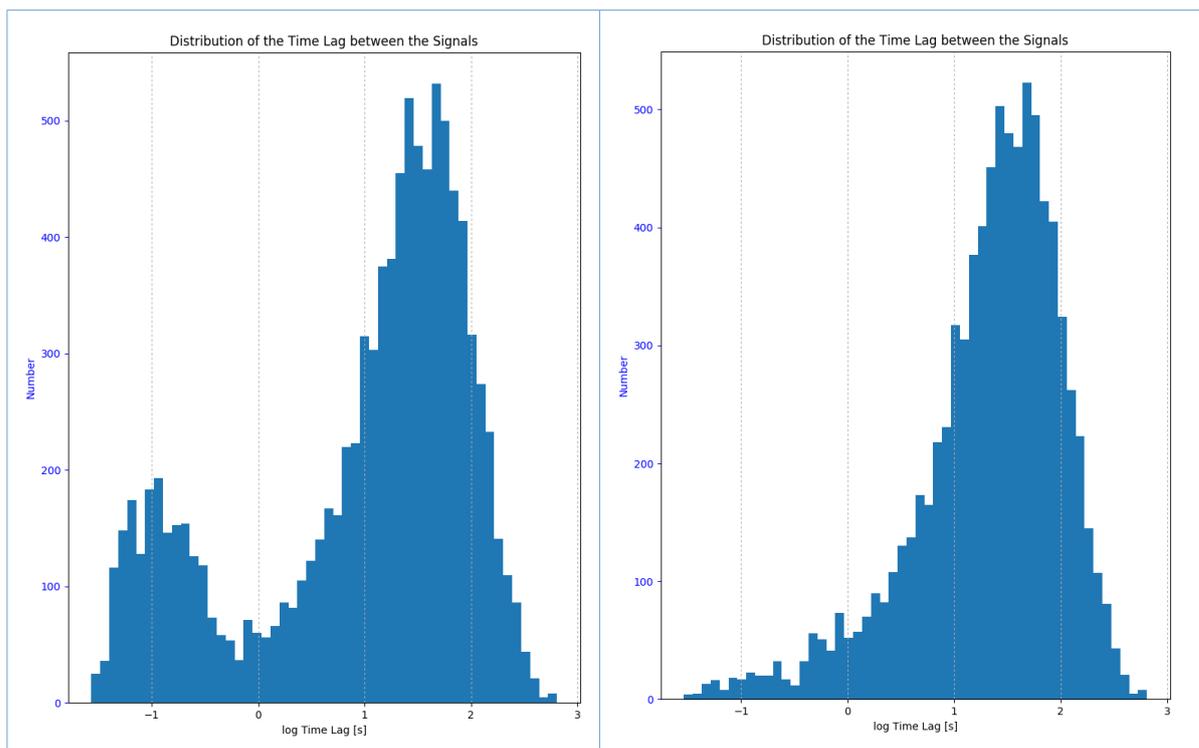


Fig. 4: The content of the file CONFIG.TXT. Entries that may be needed to be changed are marked yellow.

```
# -*- coding: utf-8 -*-
# Configuration-File for ProcessData
# -----
# parameters for the sine-function modelling the diurnal course of sporadic meteors
# amplitude:
28.0
# offset:
59.0
# -----
# timeshift local time -> UTC:
-1
# -----
# position of meteor reflections:
# geographic longitude (decimal degrees), - = west:
5.5151
# geographic latitude (decimal degrees), - = south:
45.11
# elevation above sea (m):
100000
# -----
# Maximum duration of an underdense trail [s]:
0.35
# -----
# Time span, within signals will be conflated [s]:
0.4
# -----
# Altitude limit for radio-ZHR [degrees]:
15.0
# -----
```

7. Calculation Parameters:

Some parameters need to be changed only rarely or never. These are saved in the CONFIG.TXT – file:

- Amplitude and offset of the sine-function for prediction of the hourly cont rates of sporadic meteors. Hint: log shower-free days and activate the sine-fit-function of **C-Show Trend**. It prints the parameters of the fit in window **5**. These can be taken as starting point for adapting amplitude and offset.
- Time shift from local time (regardless of daylight saving!) to UTC.
- Geographic position of the area where the reflection of radio waves at meteor trails occurs (for users of GRAVES-radar there is no need for changing these parameters).
- Maximum duration of an underdense meteor trails. To identify an appropriate value look at the graph of **D-Aproximate Limit**, see Fig. 2. Choose a duration at a rate ≥ 0.95 .

- Time span for conflating signals. Consult the time lag graph of feature **B-Distributions**, see Fig. 3.
- Altitude limit for calculating radio-ZHR. Don't set the limit too low because the zenith correction factor becomes very high for small angles and the uncertainty of the result grows strongly.

To adapt these parameters to your local conditions it is necessary to open CONFIG.TXT with any text-editor, see Fig. 4. Please pay attention to maintain the notation i.e. make use of a decimal notation / an integer as used in CONFIG.TXT. After editing don't forget to save your new entries. You can change the parameters during a running instance of PROCESSDATA. Just reopen the dataset under investigation, thereby the new parameters are read and applied.

8. References

- [1] RENDTEL J. AND R. ARLT (EDS.), 2015: Handbook for Meteor Observers. IMO, ISBN 978-2-87355-026-4.
- [2] <https://www.imo.net/observations/methods/radio-observation/reduction/> (last visited 10-2017)
- [3] <http://radio.meteor.free.fr/fr/en/index.html> (last visited 10-2017)
- [4] RENDTEL J. ET AL., 2016: Quadrantids 2016: observation of a short pre-maximum peak. WGN 44, 101-107.
- [5] DUBIETIS A. AND R. ARLT, 2006: Spectacular Taurid meteor shower in 2005. WGN 34, 3-6.
- [6] VERBEECK C. AND J.-M. WISLEZ (EDS.), 2006: Proceedings of the Radio Meteor School, Oostmalle, Belgium, 2005. IMO, ISBN 2-87355-017-1.
- [7] POWELL C., 2017: Modelling & analysis of diurnal variation in meteor flux. WGN 45, 32-37.
- [8] WEITZEN J.A. AND S. TOLMAN, 1986: A Technique for Automatic Classification of Meteor Trails and other Propagation Mechanisms for the Air Force high Latitude Meteor Burst Test Bed. Rome Air Development Center: RADC-TR-86-117 Interim Report.