Warning and Mitigation Technologies for Travelling Ionospheric Disturbances Effects

TechTIDE

User Manual

HTI method

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1. Some information about the HTI method

The height-time-reflection intensity (HTI) method enables the identification and tracking of the TID activity over each Digisonde station by using ionograms. This technique considers an ionogram as a ‘‘snapshot’’ of reflected intensity as a function of virtual height and Digisonde signal frequency, and it uses a sequence of ionograms to compute an average HTI plot, (for a given frequency bin) that is essentially a 3-D plot of reflected signal-to-noise ratio in dB as a function of height within a given time interval. This reveals dynamic changes in the ionosphere. In the context of the application of the HTI method in this tool, the periodicity of the dominant wave activity is estimated by applying spectral analysis to the points of maximum intensity on the HTI plot (the plot is an optional product of this code). To calculate the periodicity the statistical model fitting technique, Athens Model Independent Analysis Scheme (AMIAS) is applied.

2. Installation of the code

The following steps should be executed for installing the code:

1. This code is designed to work under a Linux platform. The code requires the gfortran compiler, the openmpi library and the grace open-source program. The latter is only used for generating png images and the user can instead use an alternative by editing line 138 of the script file amias.sh described in the following sections.

2. De-compress the downloaded tar file which contains the folder HTI with a number of sub-folders at the desired location.

3. Enter the directory HTI. The HTI method is applied by two executables: createmaxima.sh and amias.sh. These access pre-compiled binaries found in the directory HTI/bin.

3. Contents of the compressed file

The tar file contains the files listed in Table 1.

File	Folder	Type	Short description
User manual	Main folder	PDF	This file contains all necessary information for running the HF-Interferometry code
createmaxima.sh	Main folder	Executable	Bash script which creates the required input files and executes the fortran codes which process the RSF files for the desired station. The station information and location of the RSF files is

			read from the file station.txt.
amias.sh	Main folder	Executable	Bash script which creates input and executes the fortran code which performs the statistical fit analysis (AMIAS) for a selected time and frequency range. The details for the analysis are read from file analysis.txt
station.txt	Main folder	Input file	The station name, timestep and directory containing the RSF files.
analysis.txt	Main folder	Input file	The parameters that will be used the the AMIAS analysis.
compile.sh	Main folder	Executable	Bash script for compiling the fortran source code.
ReadRSF.out	Sub-folder bin	Executable	Real a list of RSF files and extract the heights of maximum intensity
readRSF.f90	Sub-folder src	Source code	FORTRAN source code of readRSF.out
append.out	Sub-folder bin	Executable	Append the collected heights of maximum intensity to a database file of the specific station
append.f90	Sub-folder src	Source code	FORTRAN source code of append.out
IASAMIAS.out	Sub-folder *bin*	Executable	Perform statistical fit analysis for selected time and frequency ranges, for a specific station.
main.f90 global.f90 getdata.f90 makefile	Sub-folder src/AMIAS	Source code	FORTRAN modules with their associated makefile which are used to compile ISAMIAS.out.

Table 1. List of files to run the HTI method with a short description.

4. Compilation of the code

If the provided BIN-file for Linux system does not work, you can re-compile the source codes using the bash script ./compile.sh

The bash script enters the sub-folder 'src' where the source code is found and executes

gfortran -o readRSF.out readRSF.f90

gfortran -o append.out append.f90

For the statistical fit analysis (AMIAS) the source code is found at src/AMIAS/ and is compiled using

make clean

make modules

make

All the executables must then be moved to the subfolder 'bin'

Note that for re-compiling AMIAS you need openmpi.

5. Executing the code

The method is broken down into two parts:

(a) One part of the code is used for collecting data from the RSF files and building an appropriate database for each station and for each frequency interval. This is done by using the executable createmaxima.sh. The details for the station to be analyzed are read from the file station.txt. A folder is created with same name as the station (read from station.txt) and the collected HTI heights are stored in that folder.

(b) The collected HTI heights for each station can then be analyzed for specific periodicities using a statistical fit analysis (AMIAS) method. This is done using the executable script file amias.sh. The specific station, time interval and frequency range to be analyzed is read from file analysis.txt. A folder is created with the same name as the station but ending with _AMIAS.

Some details about each part follow.

Obtaining RSF files

The RSF files must be downloaded and stored in a folder that must be created by the user. RSF files can be downloaded using the SAO explorer software (http://umlcar.uml.edu/SAO-X/SAO-X.html) that can be used to access the Lowell Digital Ionogram DataBase (DIDBase). Instructions on how to access the Lowell Digital Ionogram DataBase using SAO explorer are provided in the following link (http://umlcar.uml.edu/SAO-X/DIDB-connect.html).

Generating data from RSF files

The first part of the code is executed by running the following command:

./createmaxima.sh

The code reads from file station.txt the station name (first line), the folder where the RSF files are located (second line) and the folder where the RSF files will be moved after processing, (third line). **The folder containing the RSF files must be created by the user and the RSF files must be downloaded inside this folder following the procedure described in the above subsection.**

A folder having the name given in the first line will be created that will contain all information generated for the particular station. The script file createmaxima.sh prepares the input files needed for the HTI method executable readRSF.out and executes the code for a specific time-interval and a number of frequency ranges. It then uses the executable append.out which appends the acquired measurements in a preexisting database file for the particular station and for each frequency range. **In order to specify the time interval and frequency ranges the user must edit the file station.txt as described in section 6.**

More advanced modification of parameters related to the HTI technique have default values inside the file createmaxima.sh. In order to change these values createmaxima.sh must be edited. However, modification of station.txt alone is enough for the application of the HTI technique.

Statistical fit analysis

This part of the code is executed by running the following command:

./amias.sh

The code reads from file analysis.txt the station name, the time interval and frequency range that will be analyzed (see more details in section 6.2). The executable ISAMIAS.out is the executable which reads from the database of the station the HTI heights for the specific time interval and applies a model with a number of fit-parameters. The default model is that of a linear superposition of two sin functions. The periodicity of the first sin function is constrained within a range of 0.5 and 3.0 hours and that of the second to a range between 3.0 and 8.0 hours. The fit-parameters are the periodicity, amplitude and phase of each sin function. The command line output of the executable (see Figure 1) is simply the year, day-

of-year, the starting hour of the analysis followed by the two periods and the two amplitudes. More output is written in folder <stationname>_AMIAS (see section 7.2). There is a large number of method specific parameters which take default values within the amias.sh batch script and can be edited by the advanced user.

Figure 1. Execution of amias.sh. The command line output is a single line. In the example shown, the results is for year 2017, day 91, starting at 0 hours UT. The periodicity of each of the two sin functions is 1.826 and 5.222 hours and the corresponding amplitudes are 4.816 and 7.964 km.

6. Description of the input files

6.1. station.txt

The file *stations.txt* is the only input file needed by createmaxima.sh. It is a simple file composed of three lines

- first line: Station name. This is decided by the user and a folder with this name will be created after executing ./createmaxima.sh
- second line: The directory containing the RSF files for the particular station. This directory is created by the user and must contain the RSF files downloaded following the procedure described in section 5.
- third line: The directory where the RSF files will be moved after processing.

Figure 2 is an example that will be used in order to illustrate the execution of the code.

Figure 2. The station.txt file. The folders created will begin with NI135 and the rsf files are in directory /home/leontiou/rsf/NI135. After processing they will be moved to /home/leontiou/rsf/NI135/processed.

6.2. analysis.txt

This is the main input file for the statistical fit analysis. Its role is to define the time interval where the fit-analysis will take place. **This file is found in the main folder and must be edited by the user.** An example for NI135 is given in figure 3. This file contains the following lines:

- first line: Station name. This must match the name of a preexisting folder, created with createmaxima.sh e.g NI135
- second line: Year (only two last integers for the moment)
- third line: Starting day-of-year of the time interval
- fourth line: Starting hour of the time interval
- fifth line: Second day-of-year (can be the same as the first one)
- sixth line: Stopping hour
- seventh line: Which frequency range/s to analyze. These can be found in listed in createmaxima.sh (see figure 4)

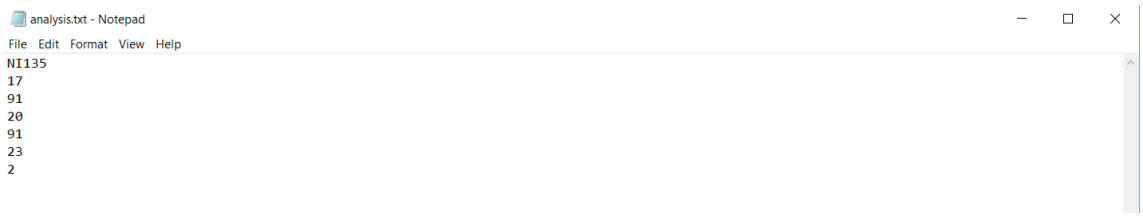

Figure 3. An example for the analysis.txt file for station with name NI135.

Figure 4. The section of the script file createmaxima.sh where the various frequency ranges can be found. Seven different frequency ranges are used in this case.

7. Description of the output files

Each of the two parts of the HTI method provides output files written into a folder. The script file createmaxima.sh will write into folder XXX and amias.sh into folder XXX_AMIAS, where XXX is the station name as read form the input files. Using as an example the input files of figures 2 and 3 the two folders created will be NI135 and NI135_AMIAS (i.e. XXX=NI135). Each run of the script files createmaxima.sh and amias.sh will append these folders. The type of files generated are listed in table 2.

OUTPUT FILE	**FOLDER**	**DETAILS**
XXX_collectedmaxima_x.dat	XXX	All the collected heights of maximum intensity for station with name XXX for the frequency range x (see figure 3)
XXX_maxima_x.dat	XXX	The collected heights of maximum intensity from the latest execution of readRSF.out. These will be overwritten every time the code runs and are only kept for debugging purposes.
output_XXX	XXX	The command line output of readRSF.out. Only needed for debugging purposes.
YY_D_F_H1-H2_reconstructed.png	XXX_AMIAS	png file showing the output of the HTI method and the fit analysis result. YY is the year

		(two digits), D is the starting day of the analysis, F the frequency range (see figure 3) and H1-H2 the range in UT hours.
	XXX_AMIAS/technical	Various technical output files that can be used for debugging and optimizing the AMIAS method.

Table 2. List of output files generated by the HTI method with a short description of its respective content.

Apart from the command line output of amias.sh (figure 1) the two key output files that are directly related to the HTI method are XXX_collectedmaxima_x.dat and the png file YY_D_F_H1-H2_reconstructed.png.

7.1. XXX_collectedmaxima_x.dat file

The collected values of the heights of maximum intensity generated by applying the HTI method to RSF files. XXX is the station name and x (at present a number from 1 to 7) the frequency range. Each of these files contains the collected data of a given station and frequency range. Each line reads with the following format (Figure 4):

Year, day, hour, minute, bin1, HTI_values, bin2, timestep

Where,

- *Year is a two-digit integer*.
- *Day is the day-of-year.*
- *Hour/minute is the UT hour/minute of the day.*
- *bin1 and bin2 are not used for the moment but can take values that can be of use later on. For example bin2 can be assigned a statistical significance to the measurement according to the fit-analysis model.*
- *timestep is the time step used at the tie of the measurement for the specific ionosonde*.

7.2. YY_D_F_H1-H2_reconstructed.png file

The output file YY_D_F_H1-H2_reconstructed.png provides a graphical representation of the AMIAS analysis (see figure 5). In red appear actual measurements as taken from the RSF file and in black is the fit-function used.

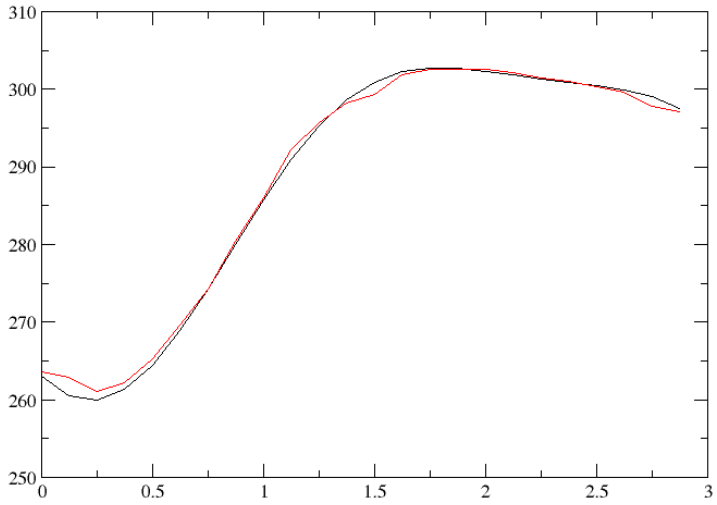

Figure 5. The output file 17_91_2_20-23_reconstructed.png created by using the analysis file of figure 3.