Warning and Mitigation Technologies for Travelling Ionospheric Disturbances Effects

TechTIDE

User Manual
The 1D EDD version of the TSM-assisted Digisonde (TaD) Profiler

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Author(s):	Kostas Tziotziou, Pencho Marinov, Ivan Kutiev, Anna Belehaki
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1. Some information about the TSM-assisted Digisonde (TaD) Profiler

The TaD model is a topside profiler for the electron density profile based on empirical equations derived from topside sounding data of the Alouette/ISIS database and ingests the Digisonde observations at the height of the maximum electron density and the TEC parameters to adjust the profiler with the actual conditions of the ionosphere. The model has three components: (a) the Topside Sounders Model (TSM) subroutine (Kutiev & Marinov 2007; Kutiev et al. 2006) that provides the empirical functions for the O^+-H^+ transition height (h_T), the topside electron density scale height (H_T) and their ratio $RT = H_T/h_T$, derived solely from the Alouette/ISIS data; (b) the Topside Sounders Model Profiler (TSMP) subroutine (Kutiev et al. 2009a, 2009b) that offers analytical formulas for obtaining the shape of the vertical plasma distribution in the topside ionosphere and plasmasphere based on TSM parameters and on the F layer maximum density (NmF2), its height (hmF2) and its scale height (H_m) at its lower boundary, derived from Digisondes. This profiler models separately the O^+ and H^+ density distributions in transition region between the topside F region and plasmasphere, extracted from the analysis of the electron density profiles from ISIS-1; (c) the final TaD subroutine that performs the necessary transformations to the Digisonde autoscaled scale height so that the integrated TSMP electron density from the F layer peak to GNSS orbits can be finally adjusted to the measured GNSS TEC at the Digisonde location (Belehaki et al. 2012; Kutiev et al. 2012).

References

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2. The 1D EDD version of the TaD

The 1D EDD version takes as input (a) the ionospheric characteristics at the hmF2 altitude, from a Digisonde sounder that can be retrieved from the SAO file and (b) the TEC parameter, which is the vertical electron content at the station location (i.e., the height integral of the electron density from 90 to 22000 km); the vertical TEC can be extracted from a TEC map such as the maps released by DLR or CODE, but it can also be calculated based on a single station solution code, with RINEX data received by a GMSS received co-located with the Digisonde.

The topside profile is extrapolated with the TaD model as described in section 1.

This version does not provide the electron density profile (Ne) below hmF2 but calculates the bottomside TEC (bTEC) by approximating Ne distribution by the a-Chapman formula. It is up to the user, to make the required adjustments if there is a need to replace the bottomside reconstruction subroutine, with the electron density profile calculated with one of the profilers built-in the Ionosondes software (such as ARTIST, POLAN, AUTOSCALA, etc.).

The output of the code is the electron density profile over the ionosonde station.

3. Installation of the code

The following steps should be executed for installing the code:

1. Create a directory where the code will be installed (hereafter, “main directory”)
2. Un-tar the downloaded tar in the main directory
3. If subdirectories tid/ and ion/ do not exist or are not created during step 2 then create them in the main directory. These subdirectories hold the input and output files of the code respectively

4. Contents of the tar file

The tar file contains the following files:

File	Directory	Type	Short description
User manual	Main directory	PDF	This file. Contains all necessary information for running the TAD code
TADM.BIN	Main directory	Executable	Static Executable file for Unix-like (Linux) systems. See below on further information concerning compilation of this file on your Linux machine
TADM.FOR	Main directory	Source code	Source file (written in FORTRAN)
TADM.INI	Main directory	Input file	INI-file with FORMATs and necessary file names for running the code
TADM.PAR	Main directory	Input file	PAR-file with some parameters for adjusting part of program
TADM.CF3	Main directory	Input file	Parameters for He (Helium part in model)
TADM.CF4	Main directory	Input file	Parameters for 5-dimesional Hs-model
TADM.CF5	Main directory	Input file	Parameters for 5-dimensional tH (Hs/tH) model
TADM.CF6	Main directory	Input file	Parameters for 4-dimensional Hp model
TADM.HLP	Main directory	Help file	Some general information about the structure of the TAD code provided

			by the developer Pencho Genov Marinov
TADM.LAT	Main directory	Input file	File with gLAT as a fuction of Lat and Long
TADM.OUT	Main directory	Output file	File with information about how many files and recordings have been considered during the TAD run (NFile, NRec, NRec1, NSTA)
TADM.SFK	Main directory	Input file	Input file with Kp and Solar flux values
TADM.INP	Main directory	Input file	List of input files within /tid to be run by TAD
IXXXXX.dat	tid/	Input file	Input files for TAD with Date, Time, Lat, Long, foF2, hmF2, TEC etc
IXXXXX.dat	ion/	Output file	Output files from TAD with information about Ne as function of height

It also contains two subdirectories (with some example files):

- tid/ which is the subdirectory for input files
- ion/ which is the subdirectory for output files

Concerning the input files:

1. Files highlighted by light blue are input files NOT to be touched by the user as they concern important information about the TAD code and the models it uses.
2. Files highlighted with light orange are input files to be modified by the user to run the TAD code for the desired period/stations etc

Some further information concerning the above files:
1. Without TADM.INP the TAD code does not work
2. TADM.INI, TADM.PAR, TADM.CF3, TADM.CF4, TADM.CF5, TADM.CF6, TADM.LAT, TADM.SFK are required files (with important information for the models used within the TAD code)

5. Compilation of the code

If the already provided BIN-file for Linux system does not work, then you can re-compile it using the following command:

gfortran -o TADM.BIN TADM.FOR -Wall -W -static

You may have to install gfortran or some other necessary libraries requested by your system.

6. Executing the code

The code is executed by running the following command:

./TADM.BIN

It reads from the following files:

1. TADM.INI, TADM.PAR, TADM.CF3, TADM.CF4, TADM.CF5, TADM.CF6, TADM.LAT, TADM.INP and TADM.SFK
2. The input files within sub directory tid/

It writes to the following files:

1. TADM.DAT
2. The output file within ion/

7. Description of input files to be modified by the user before running the TAD code

7.1. *File: IXXXXX.DAT*

Important notes:

1. This file should always be placed within the /tid subdirectory
2. Its name should always start with the letter "I" followed by whatever name you like e.g. IAT148.dat or I20180630.DAT etc

Structure of the file

This file is the main input file for the TAD code. It contains as many lines as you like with the following information separated by commas:

Year, Month, Day, Hour, Minutes, Lat, Long, foF2, hmF2, TEC_D, TEC_M, HsD

where:

- *Year, Month, Day, Hour, Minutes* are the Date and UT time information
- *Lat* is the Latitude of the station
- *Long* is the Longitude of the station
- *foF2* is the corresponding foF2 value
- *hmF2* is the hmF2 height (in km)
- *TEC_D* is the TEC value from Digisonde data (this is the ionosonde TEC that is made automatically available by the Digisonde SAO files and it is calculated with the Reinisch and Huang model)
- *TEC_M* is the TEC value interpolated from Maps (DLR or CODG). If you do not have this value or you do not want to use a different TEC value than the one recorded in Digisonde data then you can simply register again TEC_D in this column (see also comment below).
- *HsD* is the Scale Height from Digisonde and correspond to the hmF2 altitude.

Example of lines in such a file:

```
2017,04,21,00,00, 50.10,  4.60, 2.000,313.7,  1.0,  0.5, 48.0
2017,04,21,00,05, 50.10,  4.60, 2.000,344.8,  1.4,  0.5, 68.0
```

This file contains two lines for the same station but for different times (in this case minutes)

Some further important information:

- The TEC value which is registered under TEC_M is executed within the code. So, if you want to use the TEC_D value instead you either a) simply exchange the two columns if you also have TEC_M information or b) you register under TEC_D and TEC_M the same TEC_D value
- The file can contain as many lines as you like from one station (e.g. for different dates or times) or several stations. You can also have within the /tid subdirectory and run as many files as you like. What you run is decided by the TADM.INP file (see respective file description). So, it is up to you how you organize and name your input files (e.g. by station, date, time etc)

7.2. *File: TADM.INP*

Structure of the file

This file defines which input files within the tid/ subdirectory should be executed by the TAD code. It contains as many lines as you like with the file names of the files to be executed, with the filename also including the "tid/" subdirectory path.

Example of such a file:

```
tid/IJR055.dat
tid/IAT138_2017_DOY_113.dat
```

In this case the TAD code will be executed for input files IJR055.dat and IAT138_2017_DOY_113.dat

7.3. *File: TADM.SFK*

Important notes:
This file is not necessary to be modified all the time (see comment below)

Structure of the file

This file contains information about the Kp indices every three hours for a specific day or days and every line has the following format:

Year, Month, Day, Kp00, Kp03, Kp06, Kp09, Kp12, Kp15, Kp18, Kp21, SFlux

where *KpXX* is the value for UT time XX, e.g. Kp03 is the Kp index for 03UT.

Example of such a file:

```
2017, 1, 1,33,37,27,23,23,30,20,17, 701
2017, 1, 2,17,23,20,17,13,20, 3, 7, 706
```

Some further important information:

- All Kp and SF values correspond to the ***integer values of the indices multiplied by 10.*** E.g if the actual values of Kp for 03 UT is "1.3" then Kp03 should be "13"
- This file should contain ***at least*** all Kp and SF values for the time periods demanded in the input files within tid/.
- The user can include a whole year or years and thus not modify this file at all if his/her runs involve time periods within these years. For example, the provided TADM.SFK included all

values for year 2017, so it can be used for any input files requiring runs for time intervals within 2017.

8. Description of the output file IXXXXX.DAT

Important notes:

1. All output files are automatically stored within subdirectory ion/ .
2. For every input file IXXXXX.dat within tid/ that the TAD code is requested to execute through TADM.INP an output file with the same filename IXXXXX.dat is created within subdirectory ion/.

Structure of the file

This file is the output file for the TAD code. It contains as many lines (blocks) as the lines within then input file with the same filename. Each line in the output file has the following format:

Year,Month,Day,Hour,Min,gLat,Lat,Long,foF2,hmF2,Hs,tH,Hp,TEC,TECD,HsD,Precision,UTime, Ne(100),Ne(150),Ne(200),Ne(250),Ne(300),Ne(350),Ne(400),Ne(450),Ne(500),Ne(550),Ne(600), Ne(650),Ne(700),Ne(750),Ne(800),Ne(850),Ne(900)

where:

- *Year, Month, Day, Hour, Minutes* (values 1-5) are the Date and UT time information taken from the input file
- *gLat, Lat, Long, foF2, hmF2* (values 6-10) are also respective values from the input file
- *Hs, tH, Hp* (values 11-13) are respectively the Scale Height, Transition Level and Scale plasma derived from TADM
- *TEC, TEC_D, HsD* (values 14-16) are respectively the values of TEC from TEC maps, from Digisonde and the HS from Digisonde
- *Precision* (value 17) is the precision (after TEC-adjustment)
- *UTime* (value 18) is the UT in hours
- *Ne(100)…Ne(900)* (values 19-35) are the 17 Ne values for altitudes h= 100, 150,…,900 taken every 50 km.

Example of lines in such a file:

```
2017,04,21,00,00, 34.63, 38.00, 23.50, 3.550,329.3,227.2, 1412.0, 3161.6,  9.8,  2.8, 43.5,
0.16092E-02, 0.0000, 0.12749E+06, 0.13977E+06, 0.14888E+06, 0.15480E+06,0.15771E+06,
0.15696E+06, 0.14626E+06, 0.12939E+06, 0.11073E+06,0.92799E+05, 0.76769E+05,
0.63020E+05, 0.51516E+05, 0.42038E+05,0.34304E+05, 0.28031E+05, 0.22964E+05
2017,04,21,00,05, 34.63, 38.00, 23.50, 3.550,326.4,227.9, 1409.4, 3156.0,  9.8,  2.6, 39.7,
0.51894E-02, 0.0833, 0.12849E+06, 0.14052E+06, 0.14939E+06, 0.15509E+06,0.15782E+06,
0.15664E+06, 0.14549E+06, 0.12849E+06, 0.10988E+06,0.92070E+05, 0.76184E+05,
0.62568E+05, 0.51178E+05, 0.41793E+05,0.34131E+05, 0.27914E+05, 0.22889E+05
```

This file contains two lines for the same two lines of the input file.