User Manual for
PETOOL v2.0 (Parabolic Equation Toolbox v2.0)

January 01, 2020

CONTENTS:

1. Introduction

Program Description

PETOOL v2.0 (Parabolic Equation Toolbox v2.0) is a MATLAB-based one-way and two-way split-step parabolic equation software tool with a user-friendly graphical user interface (GUI) for the analysis and visualization of radio-wave propagation over variable terrain and through homogeneous and inhomogeneous atmosphere.

What's New in v2.0

(a) Several evaporation duct models have been developed.
(b) Real atmosphere data have been included in the form of "Binary Universal Form for Representation (BUFR)" data.
(c) Real terrain data have been incorporated into the toolbox in the form of "Digital Terrain Elevation Data (DTED)".
(d) A special add-on has been developed to generate a 3D coverage map of propagation factor/loss on real terrain data.

Licensing Provisions

GNU General Public License 3

System Requirements

MATLAB Release R2017a or higher installed on Windows 7 or 10.
Partial Differential Toolbox", "Curve Fitting Toolbox" and "Mapping Toolbox" are required.

Installation

1) Install MATLAB (http://www.mathworks.com/) Release R2017a or higher on your system.
2) Extract the file "PETOOL_v2.rar" to your hard disk.
3) Run MATLAB software and choose the folder where you have initially extracted PETOOL.
4) To run PETOOL, type **petool** in the MATLAB command window, or open **petool.m** with MATLAB editor and press F5.
5) Click the 2D or 3D analysis button on the small window opened after running the PETOOL. Depending on your choice, the main window of 2D or 3D analysis will appear.
6) Enter the input parameters and click "Run" button to start the analysis.

Journal Reference of the First Version

O. Ozgun, G. Apaydin, M. Kuzuoglu, and L. Sevgi, PETOOL: MATLAB-based one-way and two-way split-step parabolic equation tool for radiowave propagation over variable terrain, Computer Physics Communications 182 (2011) 2638–2654.

2. Start PETOOL

To run PETOOL v2.0, type **petool** in the MATLAB command window, or open **petool.m** with MATLAB editor and press F5.

When PETOOL v2.0 is run, a small window is opened as shown in Fig. 1. The user selects either 2D or 3D analysis. The 2D analysis means that the analysis is performed on the range-height plane, which can be considered as a single elevation plane cut from a 3D coordinate system. When the user selects “2D analysis”, the window shown on the top of Fig. 1 is opened. This window is similar to one developed in the first version of the program except for two major modifications: (i) The evaporation duct window has been updated to include the evaporation duct models. (ii) The “Load Map” button has been included to load DTED data from a directory and plot it using the mapping toolbox of MATLAB. When the user clicks “3D analysis”, the window shown on the bottom of Fig. 1 is opened. This is a new window added to PETOOL v2.0 to perform 3D analysis by sweeping the paraxial direction over 360 degrees on DTED terrain data. The 2D and 3D analysis windows will be discussed in Sec. 3 and 4, respectively.

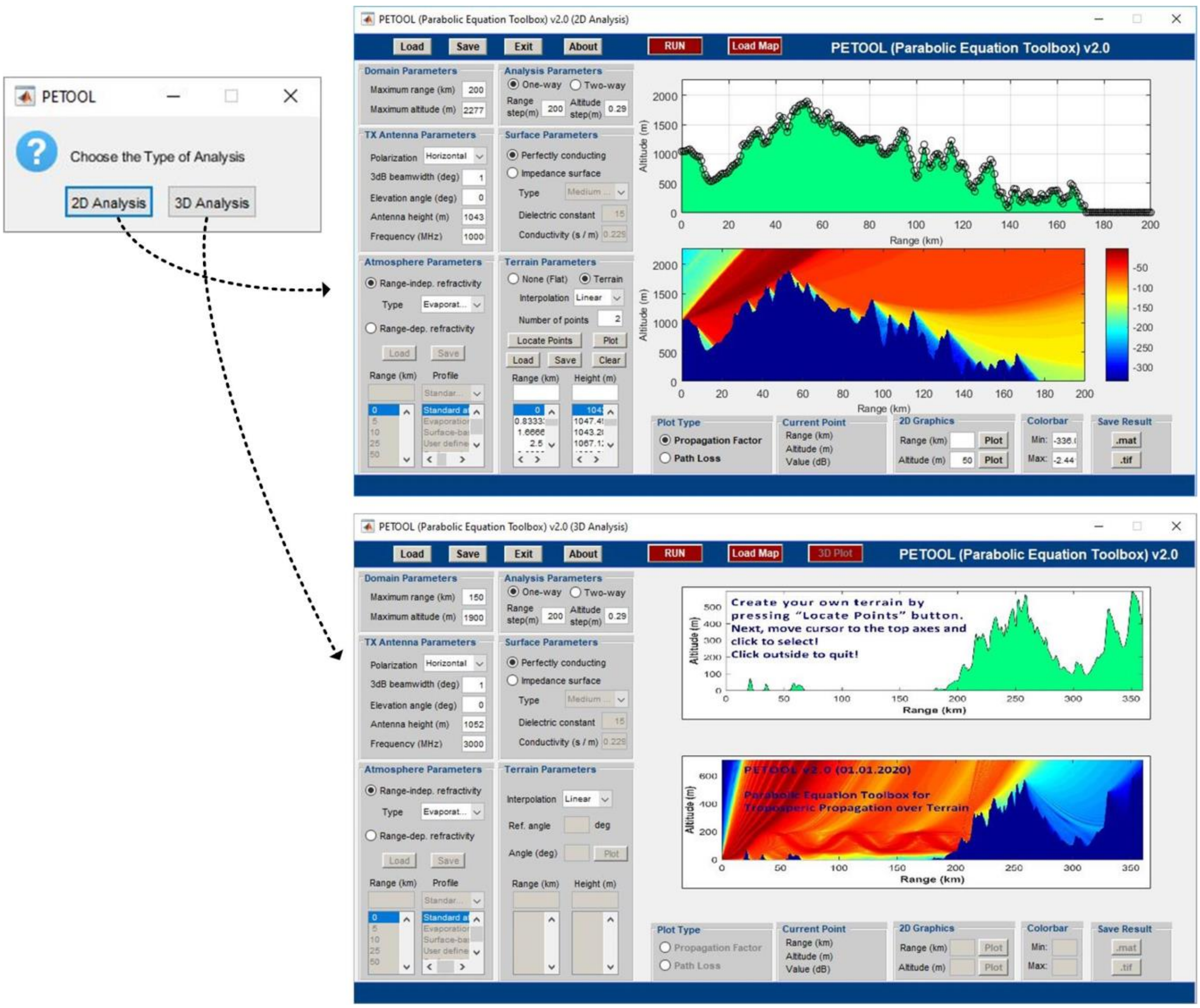

Fig. 1 PETOOL v2.0 with 2D and 3D analysis windows.

3. PETOOL (2D Analysis)

Main Window

The main window for 2D analysis is shown in Fig. 2. PETOOL v2.0 has been enhanced with the ability of reading DTED data and plotting it with the mapping toolbox of MATLAB. In addition, several evaporation duct models have been developed and incorporated into the evaporation duct window.

The window is divided into four panels. The left and right panels are located on a large gray background; and the top and bottom panels are located on thin blue backgrounds. These panels are defined below.

The **top blue panel** is reserved for six operational pushbuttons (load, save, exit, about, run, load map). The load and save buttons are used for *all* input parameters of the simulation. Once clicked, a modal dialog box is opened to select or specify a file the user wants to create or save. While exiting PETOOL, the user is also warned whether or not s/he wants to save the parameters.

The **bottom blue panel** is used to show warning text messages whenever needed, especially in case of inappropriate input entrance.

On the left panel, there are six sub-panels (domain, analysis, antenna, surface, atmosphere, terrain), where the input parameters are defined by the user. The input parameters are summarized in Table 1.

On the **right panel**, there are two graphics (top graphics where the terrain is specified, and the bottom graphics showing the colored 3D map of the propagation factor/loss), together with five sub-panels (plot type, current point, 2D graphics, colorbar, save result) related to the visualization or storage of output parameters.

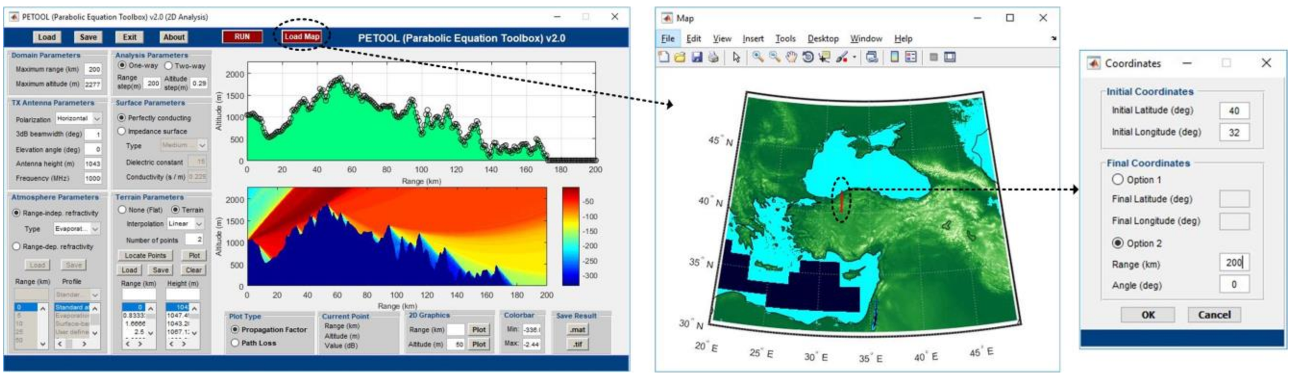

Fig. 2 PETOOL v2.0 window for 2D analysis with DTED terrain map loading.

Table 1: Input parameters of PETOOL

Domain Parameters:	Maximum range (km) Maximum altitude (m)
Antenna Parameters:	Polarization (Horizontal or Vertical) 3dB beamwidth (degree) Elevation angle (degree) Antenna height (m) Frequency (MHz)
Analysis Parameters:	One-way or Two-way (which algorithm is to be performed) Range step (m) : horizontal step size Altitude step (m) : vertical step size
Surface Parameters:	Perfectly conducting or impedance surface If impedance surface is chosen: Type: Sea, fresh water, wet ground, medium dry ground, very dry ground, user-defined ground. If user-defined ground is chosen: • Dielectric constant • Conductivity (S/m)
Atmosphere Parameters:	Range-independent or range-dependent refractivity If range-independent refractivity is chosen: Type: standard atmosphere, surface duct, surface-based duct, elevated duct, evaporation duct, and user-defined duct If range-dependent refractivity is chosen: Refractivity type for each range value defined in list-boxes
Terrain Parameters:	None (Flat surface) or Terrain If Terrain is chosen: • Interpolation type (None, Linear, Cubicspline) • Number of points: Number of points to be placed on top graphics to define the terrain profile • Range and Height values for terrain points defined in list-boxes

Refractivity Profile

In specifying a **refractivity profile**, the user selects an atmosphere type from a menu list, and a new window is opened accordingly, enabling the user to enter the modified refractivity (M) values for the specified atmosphere type. The available atmosphere profiles are standard atmosphere, surface duct, surface-based duct, elevated duct, evaporation duct, and user-defined duct. The windows to define the atmosphere types are illustrated in Fig. 3.

The novel window developed to define an evaporation duct model in PETOOL v2.0 is shown in Fig. 3(f). The available models are as follows:

- Beljaars-Holtslag
- Businger-Dyer
- Babin-Young-Carton (BYC)
- Cheng-Brutsaert
- Liu-Katsaros-Businger (LKB)
- Naval Postgraduate School (NPS)
- Naval Research Laboratory (NRL)
- Naval Warfare Assessment (NWA)
- Russian State Hydrometeorological University (RSHMU)
- SHEBA
- Toga-Coare
- Paulus-Jeske

The refractivity profile of evaporation duct can be defined in three different ways: (i) The user can define the evaporation duct height (EDH) manually, and the M-profile is plotted with a logarithmic function. (ii) The user can define the atmospheric parameters manually and choose one of the evaporation duct models. The program computes the EDH and the M-profile according to the selected model, and plots the profile. (iii) The user can load the atmospheric parameters from a file in the BUFR data format. The general format of BUFR data is provided in the program directory (see *BUFR Generation.pdf*). Apart from the PETOOL software, a special external program has been developed to generate BUFR data, which can be run by typing **BUFR Generation** in the MATLAB command window. The window for this program is shown in Fig. 4.

If the range-dependent refractivity profile is to be defined, the above-mentioned selection is performed for each range value. The profiles lying between two consecutive range values are computed automatically through linear interpolation. The user can load/save the atmosphere parameters separately. Once clicked, a modal dialog box is opened to select or specify a file the user wants to load or save. The user can easily modify or delete the parameters in the profile and range lists, by means of a special dialog box that is opened when the user clicks an item from the list.

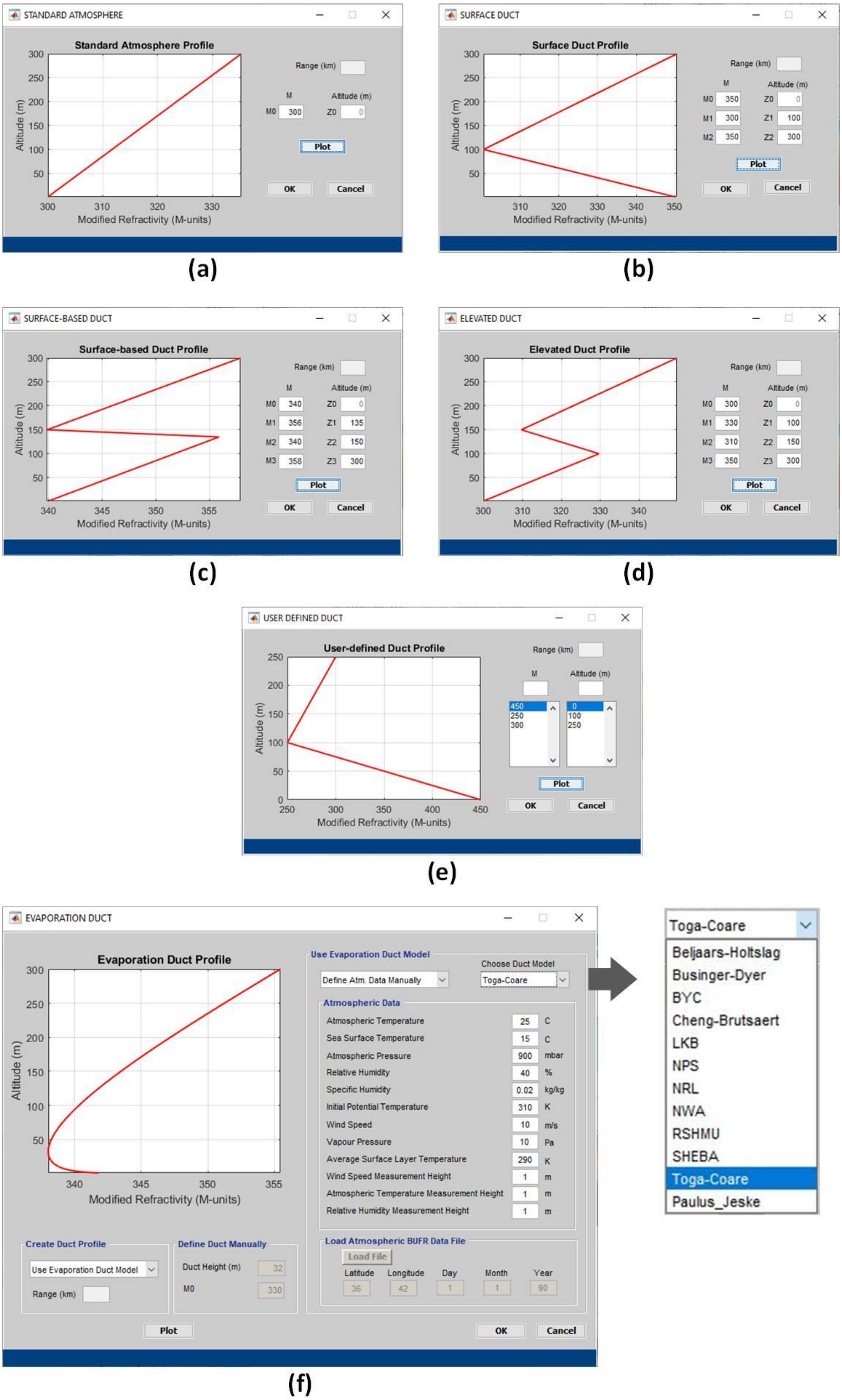

Fig. 3 Windows for specifying atmosphere types: (a) Standard atmosphere, (b) Surface duct, (c) Surface-based duct, (d) Elevated duct, (f) User-defined duct, (f) Evaporation duct (**NEW**).

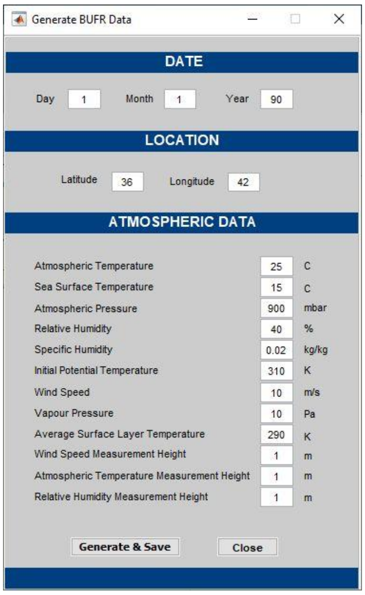

Fig. 4 External program for BUFR generation

Terrain Profile

In specifying a **terrain profile**, the user has four options:

(i) S/he can locate a number of points on the top graphics of the right plane by clicking “Locate Points” button (see Fig. 5),

(ii) S/he can define the terrain points manually by entering the values into the range-height list boxes,

(iii) S/he can load a user-generated text file including the terrain parameters.

(iv) (**NEW**) S/he can load DTED data.

In all cases, the user can save/load/clear/plot the terrain profile.

PETOOL v2.0 has the ability of reading DTED data and plotting it with the mapping toolbox of MATLAB. When the user clicks “Load Map” button, the user is enabled to load DTED data from a directory and to plot the map (see Fig. 2). After the map is loaded, a window is opened to define the initial and final coordinates of the analysis. The final coordinates can be determined either by defining the latitude-longitude pair or the range-angle pair. In the latter option, the angle is referenced by north. After the user defines the initial and final coordinates, the defined path is shown by a red line on the map.

If the user prefers to create her/his own terrain by locating points on the graphics, the values of the selected points are automatically placed into the range and height list boxes. Hence, it is possible to store the graphically-generated terrain profiles in files, as well as to modify or delete the parameters in the list boxes.

Once the terrain points are specified by using one of the above-mentioned ways, the overall terrain profile is created by performing a kind of interpolation (linear or cubic-spline) between two consecutive terrain points along range. If the interpolation method is chosen to be 'none', the terrain profile appears as a collection of knife-edges.

After defining the terrain profile, the user must click on the 'Run' button to see the analysis results of the new geometry.

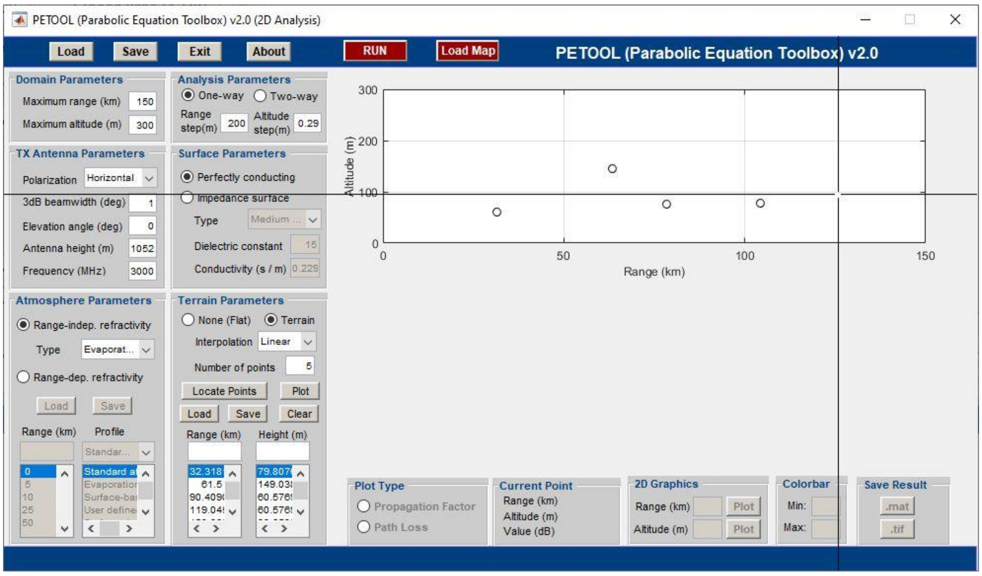

Fig. 5 Defining terrain profile by using "Locate Points" button.

Visualizing and Saving Output Parameters

Once the user clicks on the 'Run' button, the code performs the one-way or two-way split-step algorithm. After the analysis finishes, the program plots the 3D propagation factor map on the bottom graphics of the right panel. Although the default is propagation factor (PF), the user can switch to path loss (PL) map by clicking the appropriate button in the 'plot type' panel.

Whenever the user moves the mouse over the bottom graphics, the values (range, height, PF/PL) automatically appear in the 'current point' panel.

The user can plot the 2D graphics (PF/PL versus range for fixed altitude, or PF/PL versus altitude for fixed range) either by entering the values into the boxes in '2D graphics' panel, or by right-clicking the mouse on the desired point of the 3D map (see Fig. 6).

The 'colorbar' panel is used to adjust the colorbar scale of the 3D map for better visualization.

The ‘save result’ panel is used to store the PF/PL maps in the form of a MATLAB file (.mat) or a picture file (.tif). The .mat file includes the following parameters: path_loss_final, prop_fact_final, range_vec, z_user.

The 2D graphics in Fig. 6 can also be saved in text files by using the ‘save’ button.

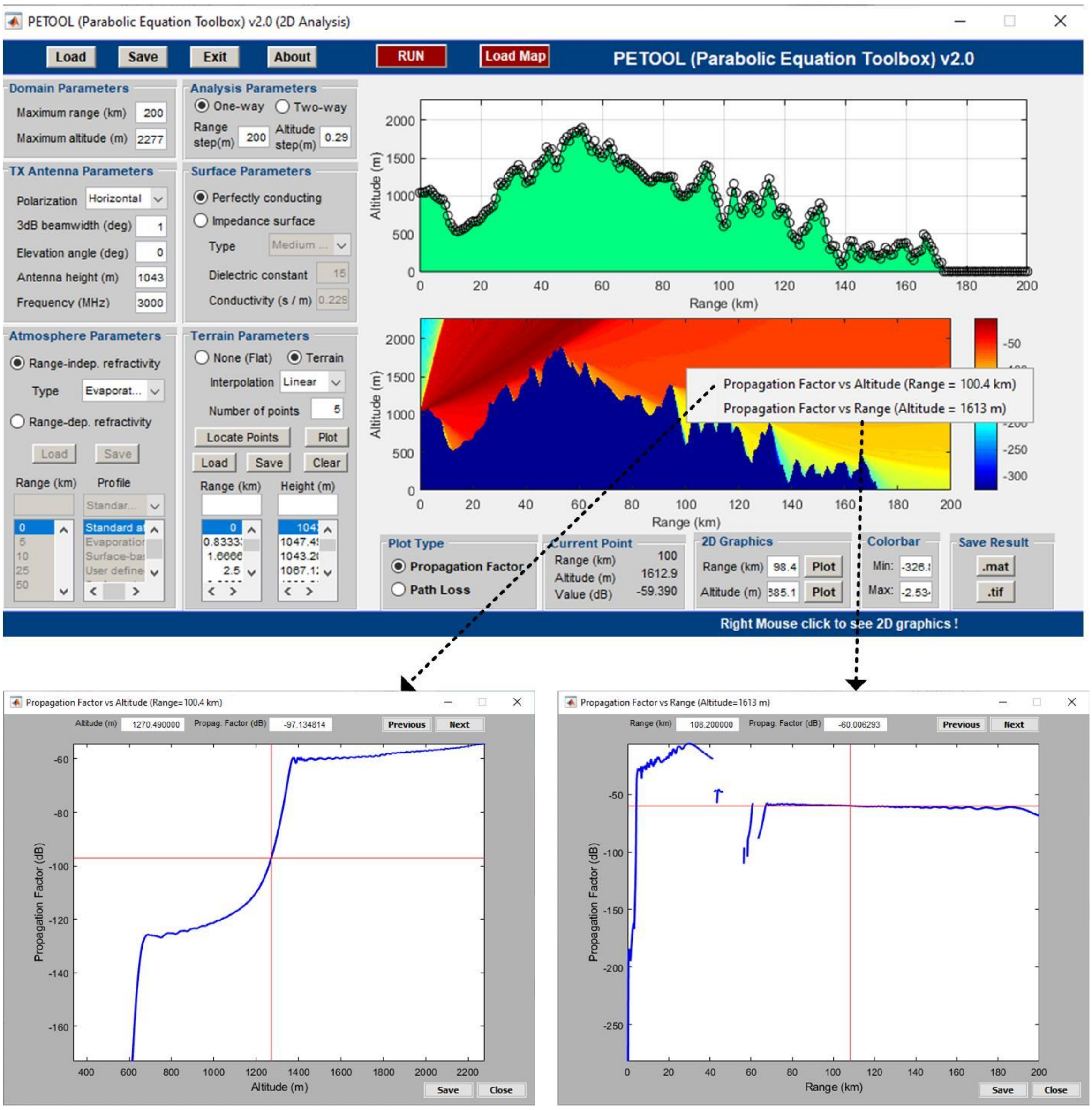

Fig. 6 2D graphics windows obtained by right-clicking the mouse on the field map.

4. PETOOL (3D Analysis)

In PETOOL v2.0, a special add-on has been developed as shown in Fig. 7. In the 3D analysis window, the user begins by defining all relevant parameters, including DTED terrain data, similar to the 2D analysis window.

When the user clicks the “run” button, a small window (see Fig. 7) is opened to define the “angle step size” and “scanning sector size” in degrees. The program sweeps the paraxial direction over the scanning sector size by incrementing the angle with respect to the angle step size. In other words, the program starts from the initial path and rotates in the clockwise direction over the scanning sector size with the angle step size. At each angle step, 2D analysis is run and the propagation factor/loss is calculated. In this manner, a 3D matrix is obtained (corresponding to each of the propagation factor or path loss), which stores propagation factor/loss values for each range, altitude and rotation angle. After the analysis is completed, the user can plot the propagation factor/loss maps and terrain profile corresponding to each rotation angle by using the “plot” button located on the “terrain parameters” panel in the main window.

When the user clicks the “3D plot” button, a window (see Fig. 7) is opened for 3D coverage map. This window allows the user to plot the propagation factor/loss values in polar form at a specific altitude. Whenever the user moves the mouse over the coverage map, the values (range, angle, and propagation factor/loss) automatically appear in the “current point” panel. The user can also save the results in the form of a MATLAB file (.mat) or a picture file (.tif).

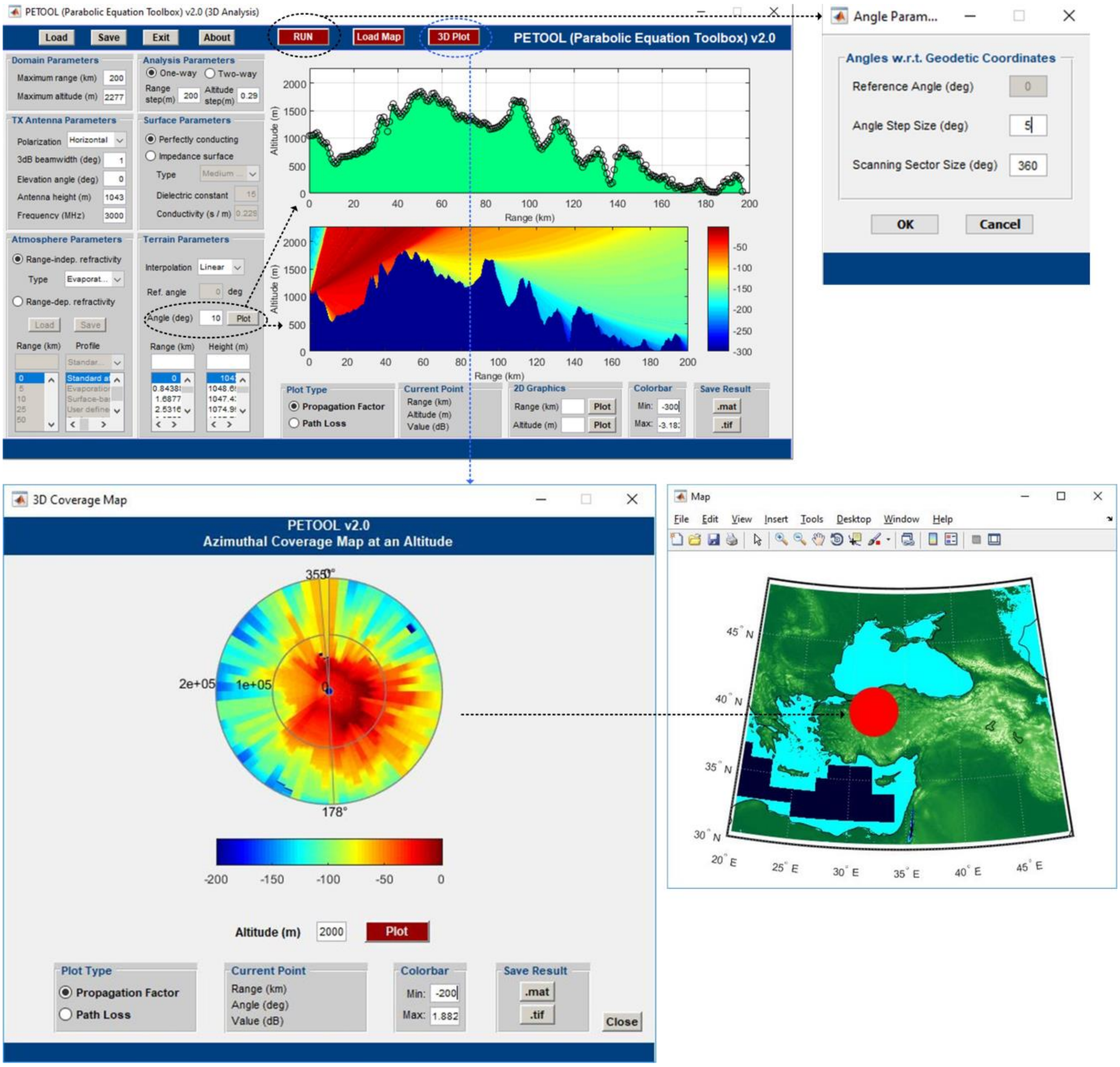

Fig. 7 PETOOL v2.0 window for 3D analysis with a special window for azimuthal coverage map.