Bedforms Analysis Tool for Multiscale Modeling (Bedforms-ATM v1.1) User Guide

(Rev. 1: December, 2016 by Ronald R. Gutierrez)

Contents

Chapter 1

Introduction

1.1 About Bedforms-ATM v1.1

Gutierrez et al. (2013) introduced a wavelet and robust spline filter based method to discriminate bed forms. The method uses the continuous wavelet transforms package developed by Torrence and Compo (1998) and allows for a quantitative characterization of bed form hierarchies. **Bedforms-ATM (Bedforms Analysis Tool for Multiscale Modeling)** represents an improved version of the method proposed by Gutierrez et al. (2013).
Bedforms-ATM V1.1 is presented as a free MATLAB software and comprises the following applications: [1] Bed forms wavelet analysis, [2] Power Hovmöller analysis, [3] Bed forms multiscale discrimination, and [4] Three-dimensionality analysis.
Bedforms-ATM is intended to standardize the scale-based discrimination of bed forms. It was developed as a joint collaboration between the Pontifical Catholic University of Peru (Pontificia Universidad Católica del Perú, PUCP); the University of Technology and Engineering (Universidad de Ingeniería y Tecnología), Peru; and the Technical University of Braunschweig (Technische Universität Braunschweig), Germany.

1.2 Credits

- Dr. Ronald R. Gutierrez (Pontificia Universidad Católica del Perú, PUCP): programing, algorithm design, user manual, and technical advisory for Applications 1, 2, 3, and 4;
- Jose Mallma (PUCP): programing, user manual, instructional video;
- Dr. Francisco Núñez-González (Technische Universität Braunschweig, Germany): programing and algorithm design for App 4.
- Dr. Jorge D. Abad (Universidad de Ingeniería y Tecnología, Perú): technical advisory.

1.3 Code

The software code can be obtained from the following link:
`https://sourceforge.net/projects/bedforms-atm/`

1.4 Test data

Two types of data accompany Bedforms-ATM, namely:

- Bed form data from the Parana River (Argentina), which comprises 150 bedform profiles. For details on this data, the reader in kindly referred to Parsons et al. (2005).
- Synthetic bed form fields for both rectangular and curved plots (see Section 3.4.5).
  ⚠ The synthetic data is solely intended to be used as test case data. Each hierarchy is mathematically described by the relationships presented by Gutierrez et al. (2013) and Gutierrez and Abad (2014).

The aforementioned data can be downloaded from the link below:
`https://sourceforge.net/projects/bedforms-atm/`.
It is important to note that for the case of the synthetic data, .MAT extension files from curved plots as well as an script to generate .TXT extension files being expressed in the supported data format are provided from such link.

1.5 Instructional video

An instructional video can be found at the post link below:
`www.pucp.edu.pe/tnbVV8`

1.6 Error report

If you find any bug, please send an email to **rgutierrezl@pucp.pe** attaching the file listed below which is distributed along with this guide: `BedformsATM_ErrorReport.docx`

1.7 Acknowledgments

- This software was funded by the School of Civil Engineering of the Pontificia Universidad Católica del Perú. We acknowledge the support from Dr. Ramzy Kahhat for providing such funding.
- We greatly appreciate the permission from Dr. Gilbert Compo and Dr. Christopher Torrence to use the wavelet software they developed back in 1998. For details on the technical aspect of such software, please refer to Torrence and Compo (1998).
- We also thank Dr. Daniel Parsons and Dr. Jim Best for providing permission to include bed form data from the Parana River for a test case of Bedforms-ATM. Such data accompanies the support information of this software and the reader is kindly referred to Parsons et al. (2005) for details on it.
- We thank funding from the Katholischer Akademischer Ausländer-Dienst to complete this software.

About this User Manual

This User Manual is provided as an aid to users of Bedforms Analysis Toolkit for Multidimensional Modeling (Bedforms-ATM). This user manual is organized as follows. This Chapter focuses on the general information about the software. Chapter 2 provides instructions related to the installation of Bedforms-ATM. Chapter 3, 4, 5, and 6 describe the functionality aspects of Application 1 (Wavelet Analysis), Application 2 (Hovmøller Analysis), Application 3 (Scale-based Discrimination), and Application 4 (Three-dimensionality Analysis), respectively. Finally, Chapter 6 presents the flow charts of the mains functions that encompass the software.

It is worth to point out that Bedforms-ATM is an evolving software package. This documentation describes the 1.1 release from 2016. Intermediate releases may include bug fixes. Bedforms-ATM is also be able to accept new applications through the contribution of the users community. If you have code you would like to contribute, we will gladly consider your contribution. Please send email to: **rgutierrezl@pucp.pe**.

This User Manual was prepared by the developers of Bedform-ATM, namely Ronald R. Gutierrez and Jose A. Mallma.

Chapter 2

Installing BedformsATM

Bedforms-ATM (Bedforms Analysis Tool for Multiscale Modeling) is based on MATLAB functions and Graphical Unit Interfaces (GUIs). To make it running you should have MATLAB installed in your computer.
To use this program, please copy the folder **Bedforms ATM v1.1**, which is distributed along with this guide, in the folder where you want to save all the files related to this program. We suggest you pasting it in the *MyDocuments* folder.
The Bedforms ATM v1.1 folder contains all the necessary functions to execute Bedforms-ATM. We suggest you not to modify any of the files to avoid any malfunctioning of the software.
Bedforms-ATM is divided into four interfaces. To call them, you should execute the following scripts according the interface you want to run from the MATLAB console:

- `BedformsATM_App1_WaveletAnalysis.m`
- `BedformsATM_App2_HovmollerAnalysis.m`
- `BedformsATM_App3_ScaleBasedDiscrimination.m`
- `BedformsATM_App4_3DAnalysis.m`

⚠ **Make sure not to execute the files with .fig extension having the same name. In the following chapters we explain how to use each of the software interfaces**.

Chapter 3

Application 1: Wavelet Analysis

The `BedformsATM_App1_WaveletAnalysis.m` script allows for:

- Creating a new folder to save the project data.
- Importing files to be analyzed.
- Defining parameters for the statistical analysis.
- Defining the type and properties of the wavelet function to be used in the analysis.
- Saving the resulting plots.

3.1 Home screen

The program is divided into two tabs. The first one contains general information and the copyright statements, and the second one allows you to execute the program. When executed, the window presented in Figure 3.1 will pop up:

3.2 Beginning the analysis

To start the program you must select the *Wavelet Analysis* tab. Then, the window shown in Figure 3.2 will pop up (the steps to properly run the analysis are indicated at the bottom area of such window):

3.3 Creating a new project

In order to keep the files properly organized, the program creates automatically the *BedformsATM* folder inside the default MATLAB folder in MyDocuments (Fig. 3.3).

All existing projects as well as the new ones will be located inside the aforementioned folder. To choose a name for a new project click on the *Create a new project* button (Fig. 3.4).

The project name (Fig. 3.5) must contain alphanumeric characters (e.g., a - z, A - Z, 0 - 9). Otherwise, the program will request a new name.

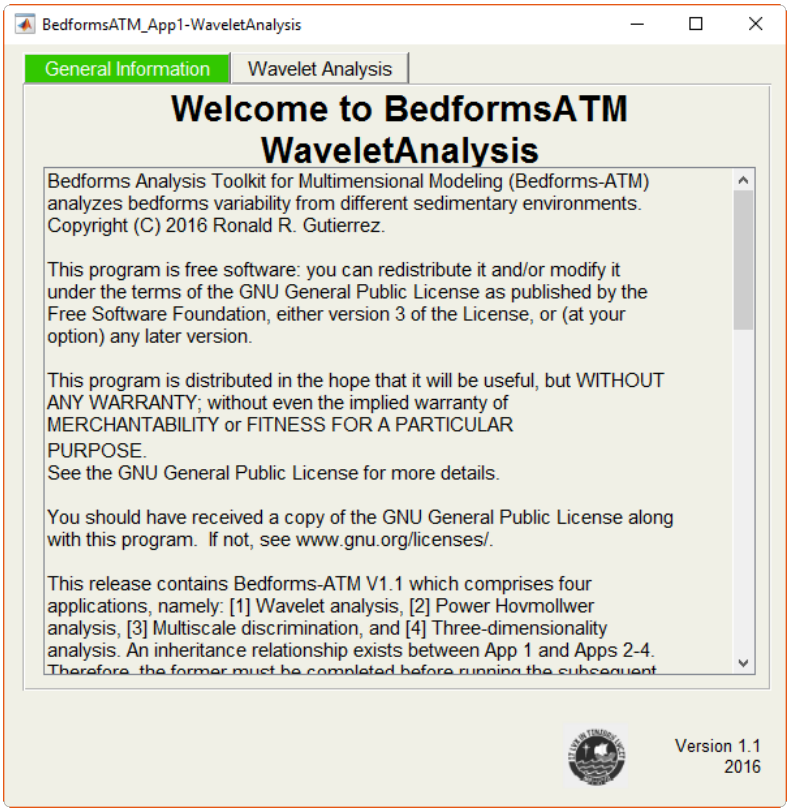


Figure 3.1: Information Tab

If the name you entered belongs to a previously defined project, the program gives the option to rename the new project or delete the existing project to be replaced by the new one (Fig. 3.6).

⚠ *NOTE: When choosing to rewrite the project, please make sure not to have any file or folder of the project being replaced opened, otherwise the program will not continue.*

Finally, the program creates the *MyProject* folder in the Projects directory. The program will store all the generated data in such folder.

3.4 Input files

After creating the project, the *Select Data Files* button is enabled and will allow you for accessing to the next window (Fig. 3.7):

To run the application, it is required to enter longitudinal profiles of the bed forms field being analyzed. These profiles should satisfy the following requirements:

- Each profile should be equally spaced discretized;
- The sampling period (i.e., distance between points) should be constant for all the profiles being analyzed;
- The distance between consecutive profiles must be constant; and
- All the profiles must have the same length (i.e., same number of points).

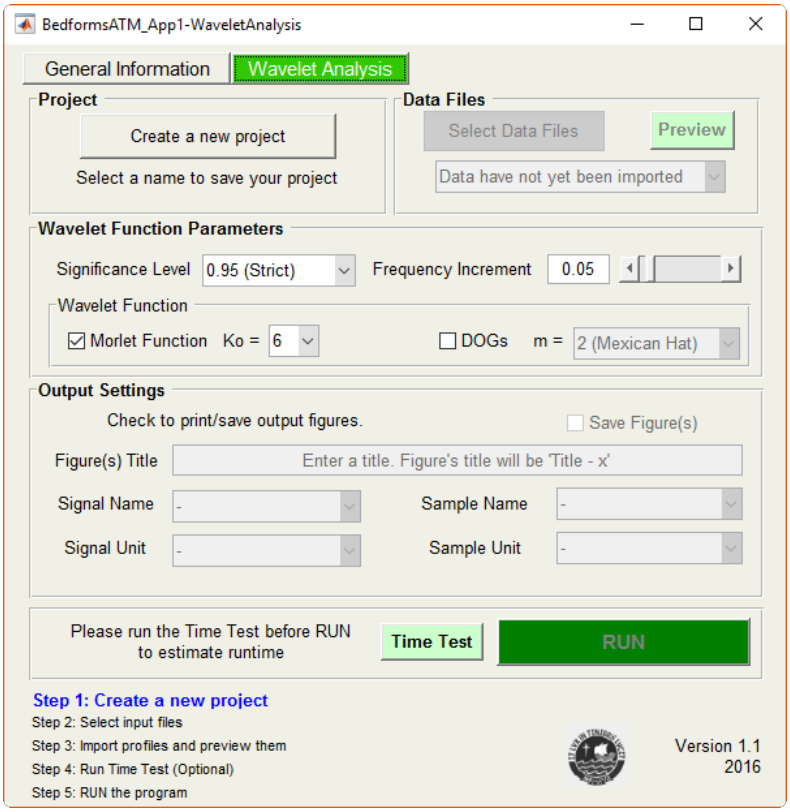


Figure 3.2: Wavelet Analysis tab

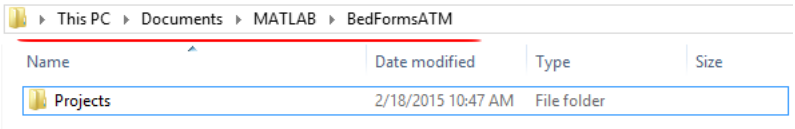


Figure 3.3: Project folder

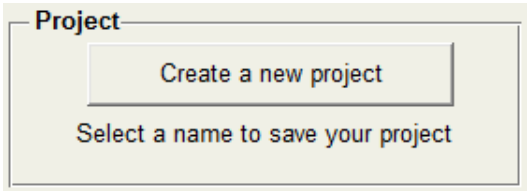


Figure 3.4: Project folder

The files will be loaded using the application *uipickfiles* (Fig. 3.8). The program provides several options for uploading files as discussed on sections 3.4.1 through 3.4.4.

⚠NOTE: A set of both synthetic data and field data (Parana River, Argentina) being expressed in all the supported formats accompanies this software. A tagging system that represents meta-data from each type of data and file extension is listed in brackets in sections 3.4.1 to 3.4.4.

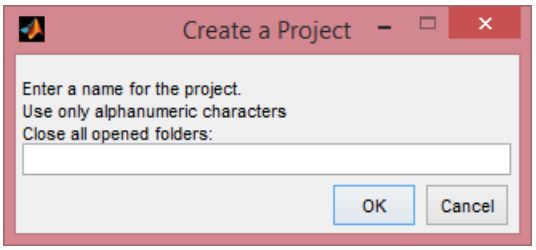


Figure 3.5: Enter a name

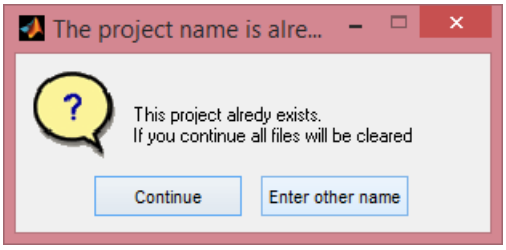


Figure 3.6: A project with the same name exists

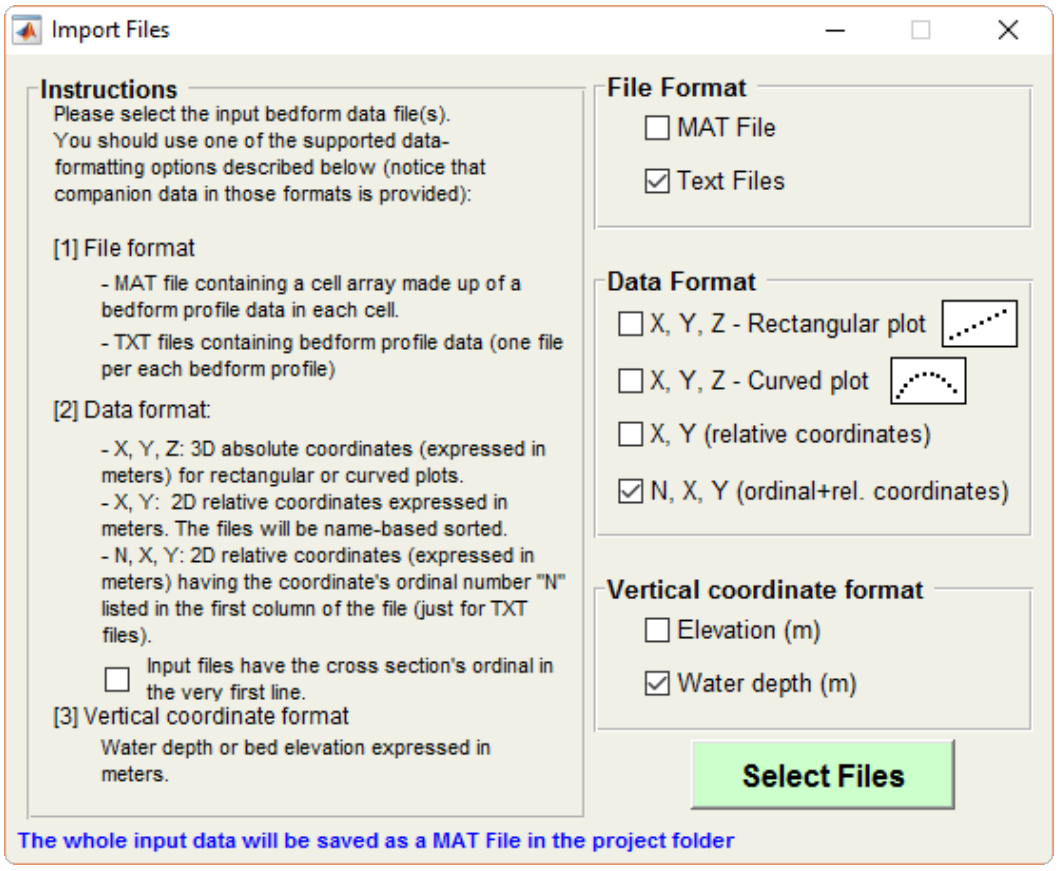


Figure 3.7: Select Data Files window

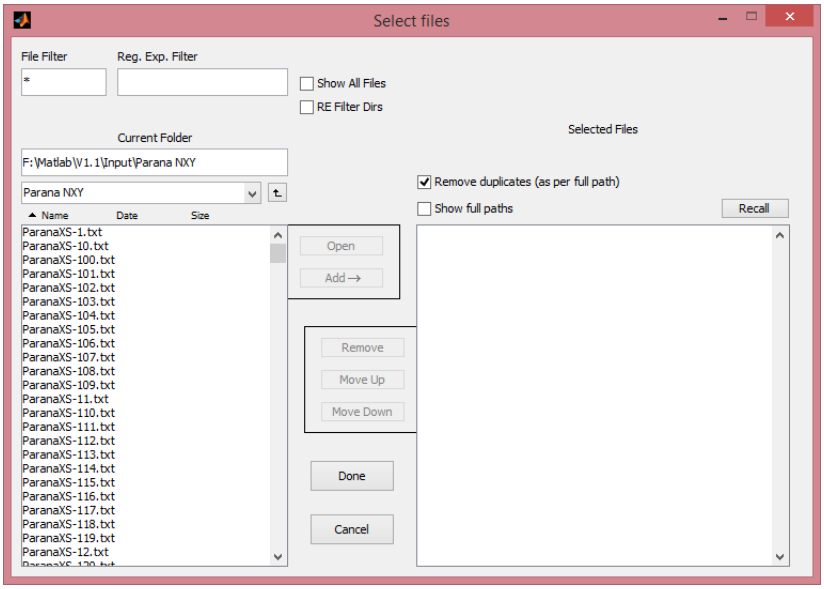


Figure 3.8: uipickfiles application

3.4.1 Profile-ordinal-headed data (tagged as N)

The profiles will be processed in the order they are entered via the *uipickfiles* application. To avoid any problem when determining the order of input files, the program also supports files containing the profile's ordinal number at the file's very first line, as shown in Fig. 3.9.

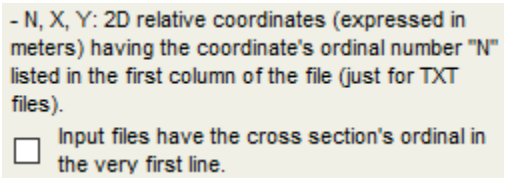


Figure 3.9: Enter the ordinal number

If you have selected such option, please notice that:

- All profiles must be selected. A profile whose ordinal number is greater than the number of uploaded files will not be accepted.
- There cannot be more than one profile having a given ordinal number.

3.4.2 Supported file extensions

The program can upload two different file extensions, namely:

1. .MAT file extension (tagged as M)
   - A single .MAT file format that contains a CellArray of size [1xnFiles].
   - Each cell must contain a matrix with information from a profile.
   - The profiles must be sorted, so the option to enter the ordinal number is disabled.

2. .TXT file extension (tagged as T)

    - A text file representing each profile.
    - The coordinates of each point must be located in the same line.
    - Select all the profiles you want to analyze.

If the option to enter the ordinal number is not enabled, the profiles will be sorted in the order defined by uipickfiles. By default, they will be ordered lexicographically wise, which may result in errors such as that presented in Fig. 3.10 a. To avoid this problem, it is recommended to sort the files by date. To do so, click on the "Date" tag. The files will be sorted (Fig. 3.10b), provided that they were were orderly generated.

3.4.3 Supported data format

The following data formats are supported:

- **Linear XYZ (tagged as 1)** representing 3-dimensional coordinates, where the values of X and Y represent the position, and Z, either the elevation or water depth. Use this option when the profiles are extracted from a rectangular plot;
- **Curved XYZ (tagged as 2)**, similar to the previous case but the profiles are extracted from a curved plot;
- **XY (tagged as 3)**. Each profile is represented by relative coordinates (i.e. cumulative coordinates), where X is the longitudinal position, and Y is either elevation or water depth; and
- **NXY (tagged as 4)**, similar to the previous case but each line begins with the ordinal number of the point, namely N.

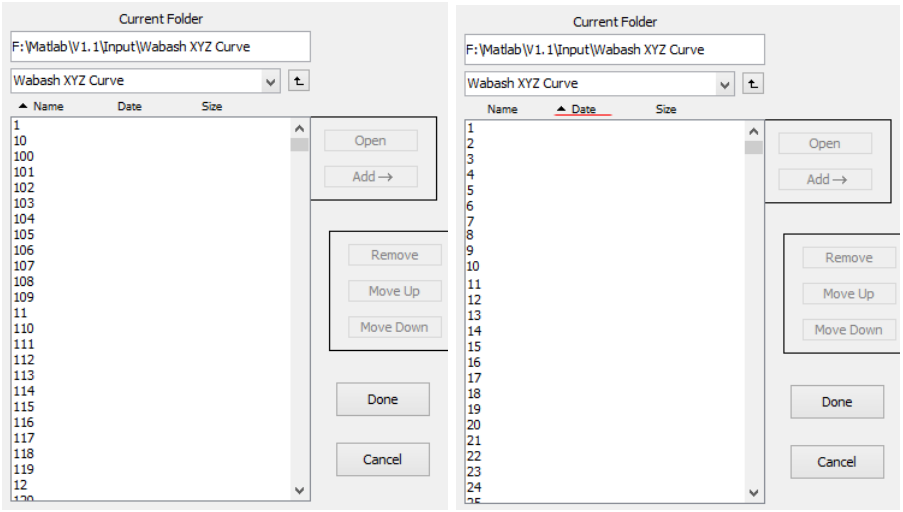


Figure 3.10: a) Unordered files (left), b) Ordered files (right).

3.4.4 Supported vertical coordinate formats

The elevation data format can be:

- **Elevation bed form field (tagged as E)** expressed in meters above sea level (MASL) units.
- **Water depth bed form field (tagged as D)** in which vertical coordinates are represented by negative values and expressed in meters.

⚠ NOTE: If the data format is XY or NXY the user is prompted to enter the distance between consecutive profiles (Fig. 3.11), thus, such formats are only applicable to rectangular plots.

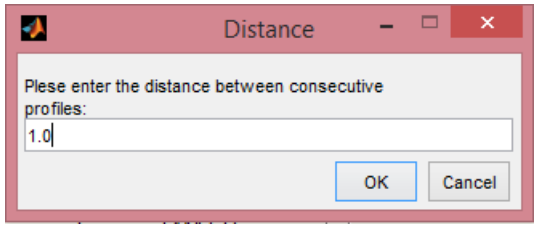


Figure 3.11: Enter spacing between profiles

⚠ After loading the files, they are saved in the input folder in the project folder. Two .MAT file extension are generated, namely: *inputfile.mat* and *XYZdata.mat*. Both of them will be used during the analysis, so they must not be modified or deleted; however, you can use a copy of *inputfile.mat* file as input for other projects.
After loading the files, the window will close automatically and report the amount of uploaded files and the average sampling frequency (Fig. 3.12).

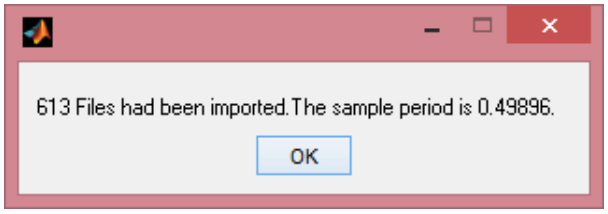


Figure 3.12: Files are successfully loaded

3.4.5 Synthetic data that accompanies Bedforms-ATM

Synthetic bed form data from both curved plots (Fig. 3.13) and a rectangular plot (Fig. 3.14) are provided to test the program. Curved plots present the following sinuosities: 1.1, 1.5, 2.0, 2.5, 3.5, 4.0, 4.5, 5.0, 5.5, and 6.0. According to the tagging system we use, a bedform field from a curved plot being presented in a .MAT file extension could have, for instance, the following file ID: $M2E - S25$, namely, M for the .MAT file extension, 2 for the data represents a curved plot, E for the data represents an elevation bed form field, and $S25$ for the plot has a sinuosity of 2.5. Likewise, if the same plot is presented in a .TXT file extension, each profile has one of the following file IDs:

- NT2E-n (N is the heading of the text file and represents the profile's ordinal): T indicates that the file is in .TXT file format, 2 for the plot is curved, E for it represents an elevation bed form field, and if $N = n$, the file describes the $n - th$ profile.
- T2E-n: T indicates that the file is in .TXT file format, 2 for the plot is curved, E for the it represents an elevation bed form field, and the $n - th$ profile is described.

The same criteria applies to rectangular plots.

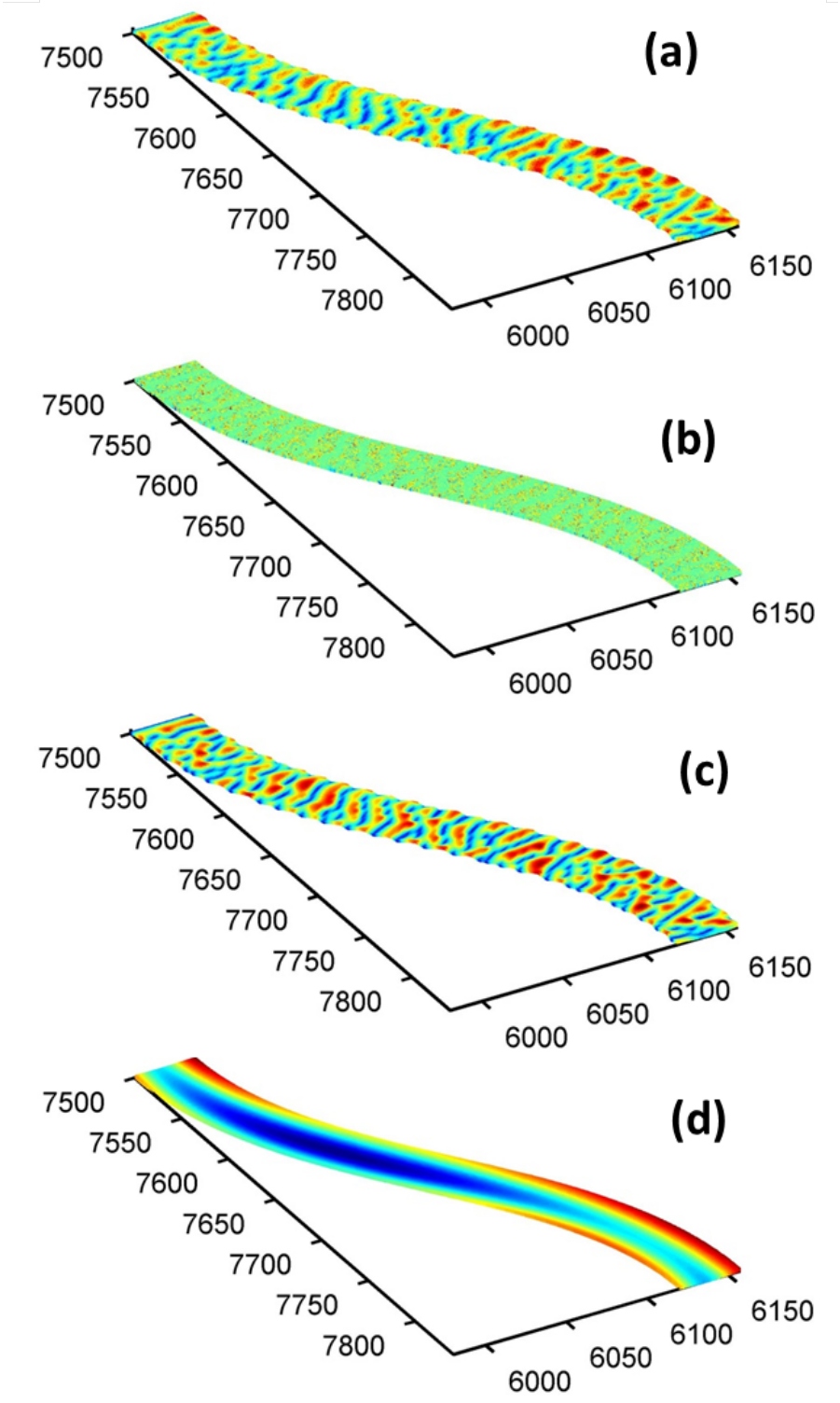


Figure 3.13: (a) An instance of synthetic bed form data from a curved plot having a sinuosity of 1.1 and representing an elevation bed form field which is made up of: (b) a ripple field, (c) a dune field, and (d) a bar field. See (Gutierrez et al., 2013; Gutierrez and Abad, 2014).

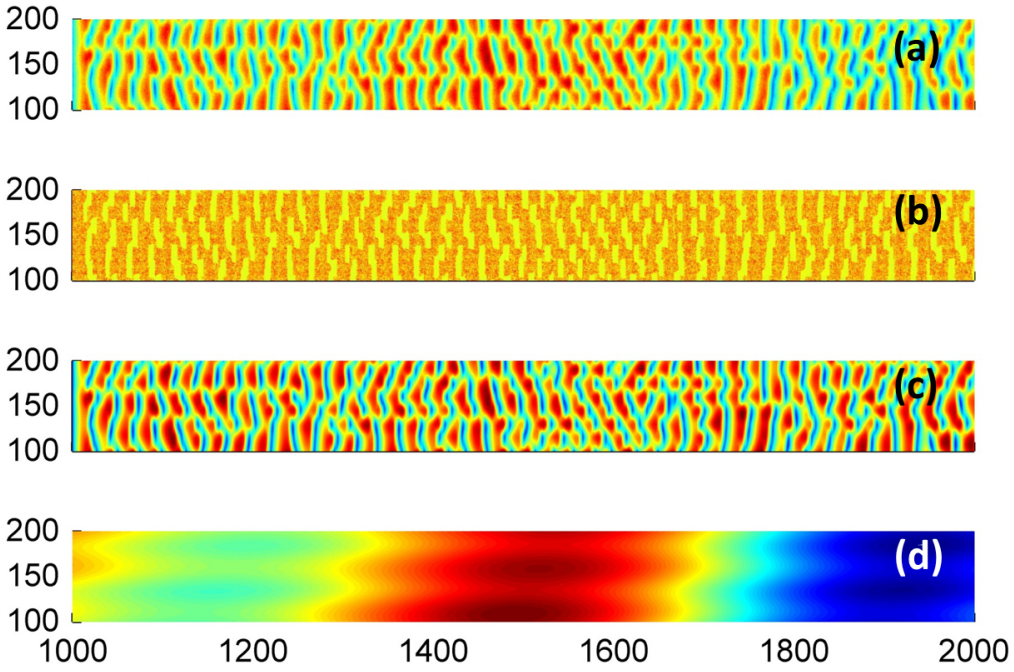


Figure 3.14: (a) An instance of synthetic bed form data from a rectangular plot representing an elevation bed form field which is made up of: (b) a ripple field (1st hierarchy), (c) a dune field (2nd hierarchy), and (d) a bar field (3rd hierarchy). See Gutierrez et al. (2013) for details on the mathematical description of these hierarchies.

3.5 Visualizing the input data

After selecting the files, the *Preview* button is enabled. When pressed, all the selected profiles will be loaded in a pop-up menu such that presented in Fig. 3.15.

If the data is in "XYZ curved" format (Fig. 3.16-a), a plan view of the section is also displayed (Fig. 3.16-b).

3.6 Input parameters for the wavelet analysis

3.6.1 Significance level

You can choose between:

- 0.95 (Strict)
- 0.80 (Relaxed)
- 0.60 (Low)

3.6.2 Frequency increment

You can set values from 0.01 to 0.50 for the frequency increment by using the slider. Notice that the smaller the value, the greater the run time, although a higher resolution results are obtained.

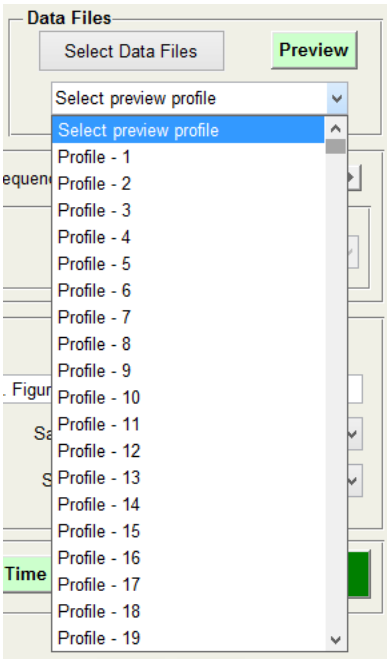


Figure 3.15: Loaded profiles

3.6.3 Wavelet function

Two wavelet functions are available (Fig. 3.18), namely:

- Morlet function having the k_0 parameter ranging between 6 up to 10. We recommend using $k_0 = 6$.
- DOG's (derivatives of Gaussian wavelets): for the second (also known as Mexican Hat) up to the 6th derivative.

For more information about the parameters defining the wavelet functions, the user is kindly referred to Torrence and Compo (1998).

3.7 Output settings

To view the output data (Fig. 3.19), it is necessary to define the following fields:

1. Figure(s) Title, which must be typed by the user.
2. Signal Name. Can be either "Depth" or "Elevation".
3. Signal Unit. The following units can be selected: m, km, feet, mile, dimensionless.
   ⚠ Only international system units are supported in this version.
4. Sample Name. The following names can be selected: Abscise, Length, X
5. Sample Unit. The following units can be selected: m, km, feet, mile, dimensionless.
   ⚠ Only international system units are supported in this version.

An example of selected values is displayed in figure 3.20.

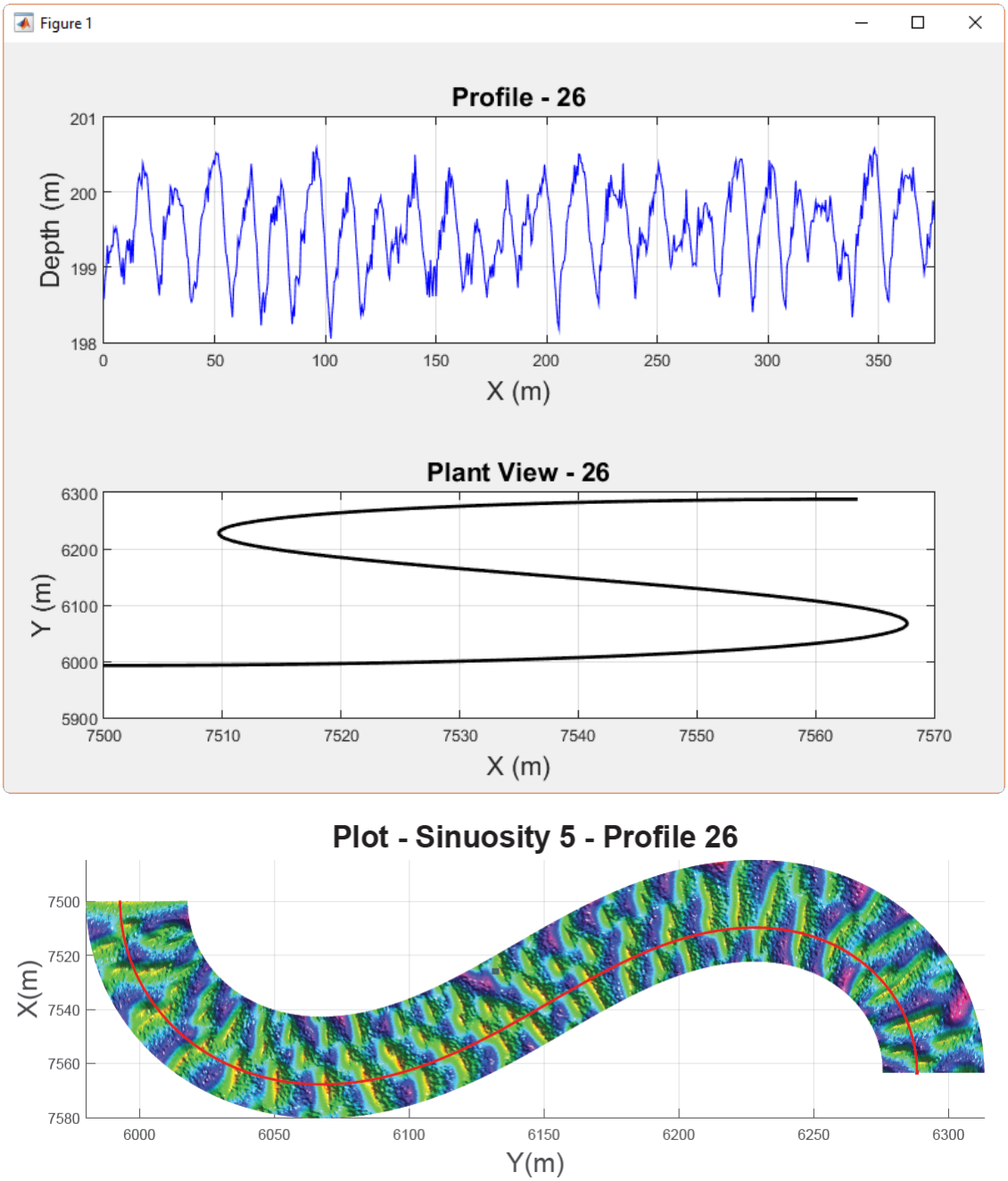


Figure 3.16: Preview for Curve XYZ format

3.8 Saving output plots

3.8.1 Saving plots while Application 1 is active

The output data can be saved while Application 1 is active. To do that, click on the *Save Figure* check-box and automatically you will be asked to select the format in which you want to save them (Fig. 3.21).

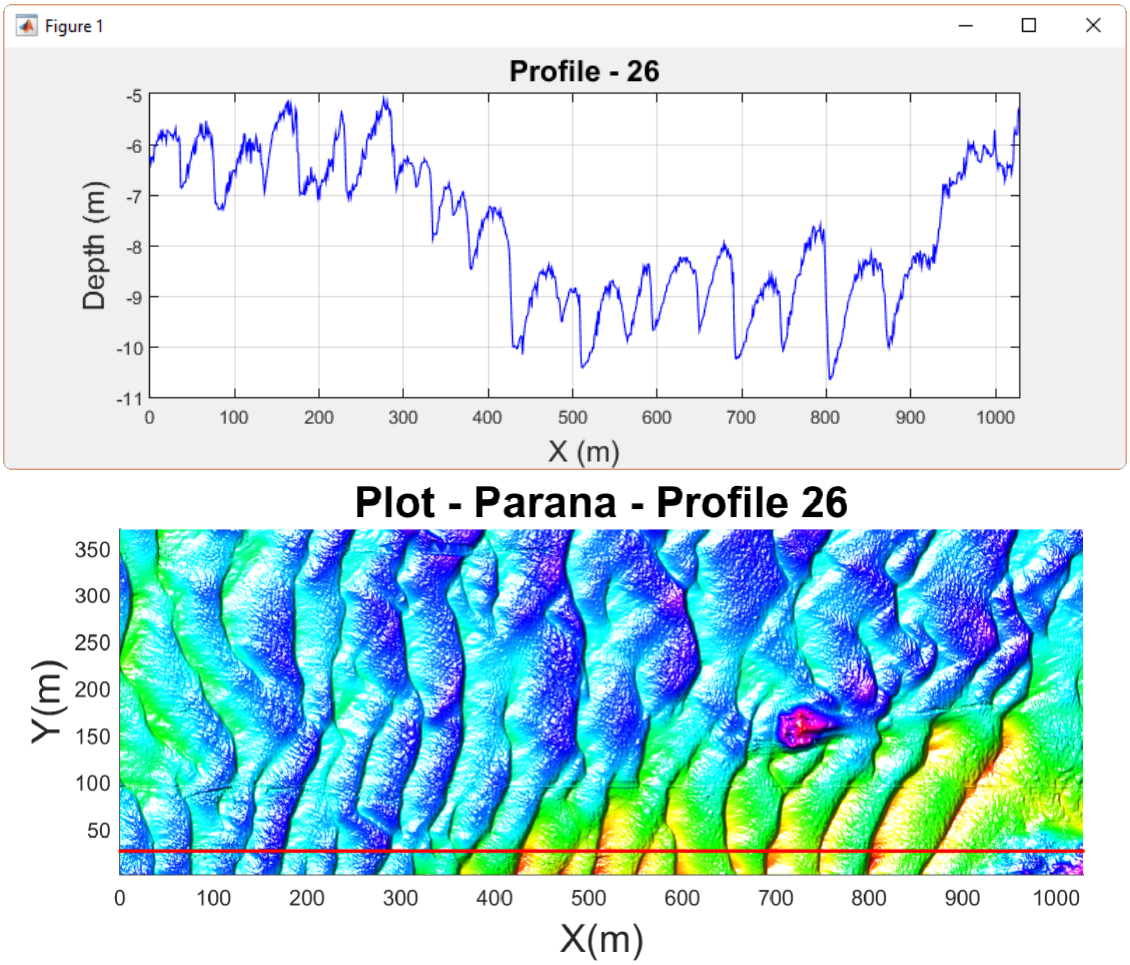


Figure 3.17: Preview for Rectangular XY format

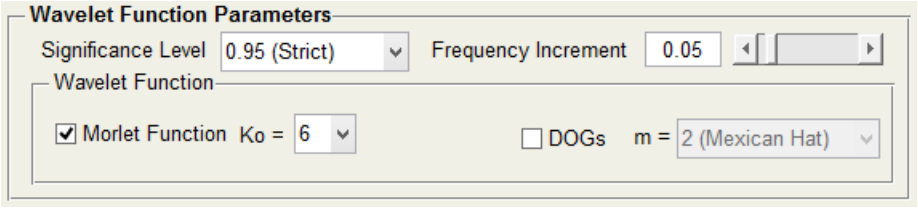


Figure 3.18: Parameters of analysis

⚠ The execution time can be increased if the images are saved while the program runs.

3.8.2 Saving plots after Application 1 was executed

To generate the output plot after running Application 1, run the `plotWltAnalysis` script from the MATLAB console. Such function requires defining the output plots format. After calling such function, select the .MAT files representing the profiles you want to print which will be located in the following folder:

$$\backslash MATLAB\backslash BedFormsATM\backslash Projects\backslash Myproject\backslash Wavelet\_Output\backslash Data\_Output$$

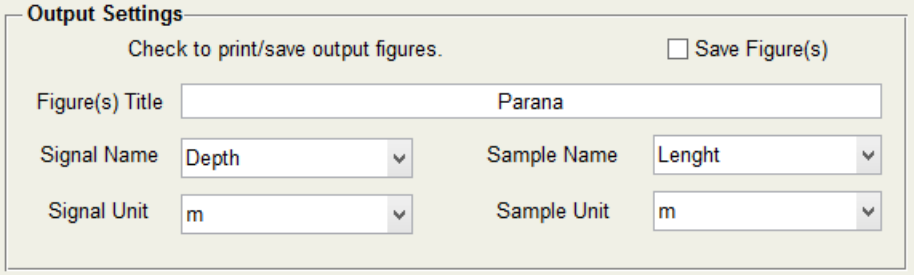


Figure 3.19: Output settings

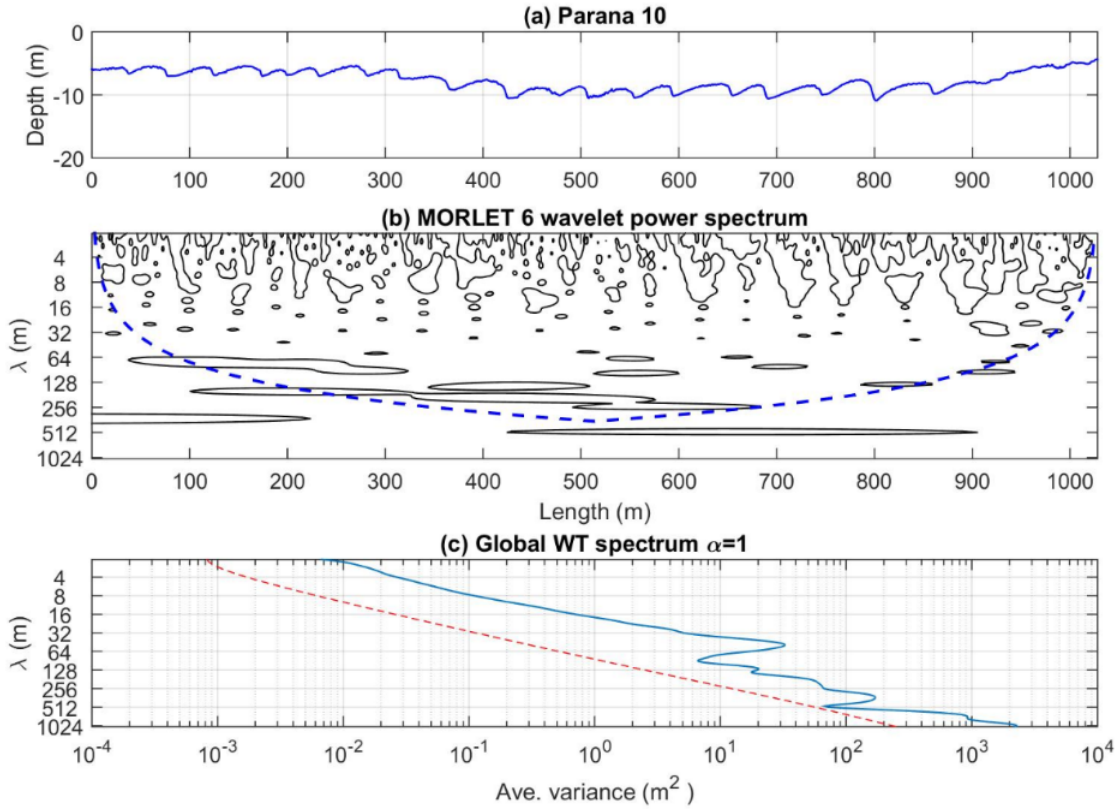


Figure 3.20: Output graphic

3.9 Time test

To estimate the program execution time, please select the *Time Test* option. The program will run one of the profiles and estimate the time it may take to run all the loaded data depending upon the figures format you select (Fig. 3.22).

⚠⚠It is strongly recommended to run the program without saving the figures to subsequently generate them as needed. Notice that the execution time will depend on the number of programs and processes running in parallel with MATLAB. We recommend closing other programs to reduce the runtime.

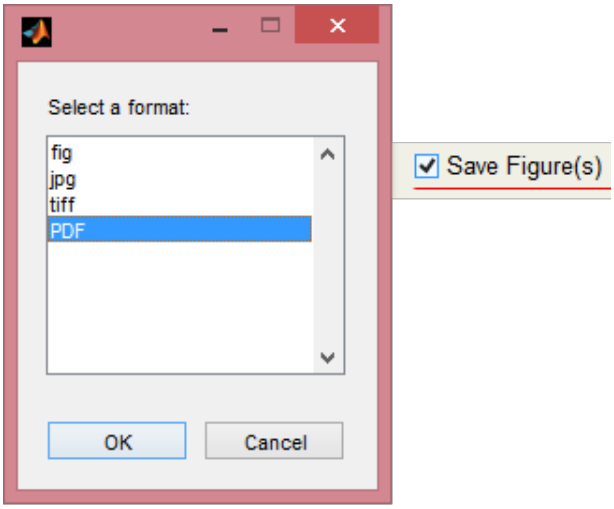
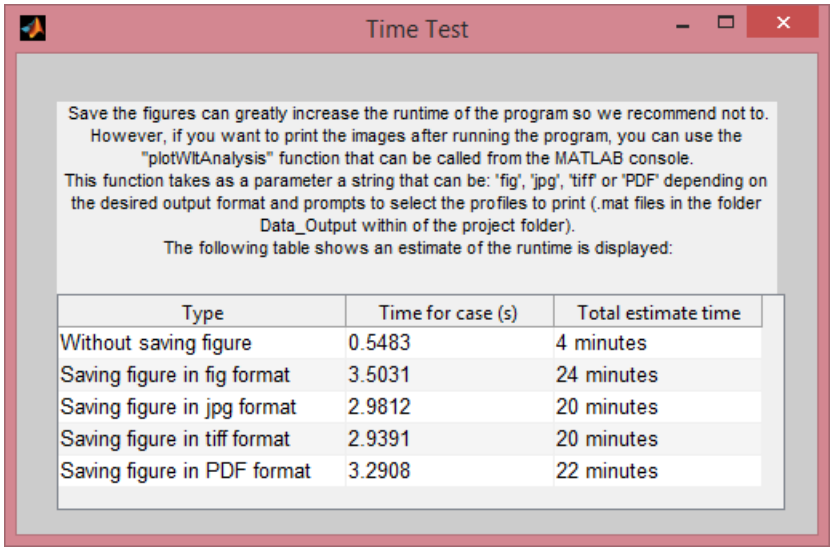


Figure 3.21: Output graphic format



Type	Time for case (s)	Total estimate time
Without saving figure	0.5483	4 minutes
Saving figure in fig format	3.5031	24 minutes
Saving figure in jpg format	2.9812	20 minutes
Saving figure in tiff format	2.9391	20 minutes
Saving figure in PDF format	3.2908	22 minutes

Figure 3.22: Time Test

3.10 Executing Application 1

If the Save figure(s) option has not been activated, you will be asked whether you want to continue (Fig. 3.23). After that the program automatically closes the window, runs, and subsequently displays the progress window (Fig. 3.24).

The program execution can be stopped at any time by clicking the Cancel button. Signals processed until then not be removed from the output folder.

The output data are stored as .MAT files in the following folder (3.25):

$$\backslash MATLAB\backslash BedFormsATM\backslash Projects\backslash Myproject\backslash Wavelet\_Output\backslash Data\_Output$$

The file name is defined by the following structure:

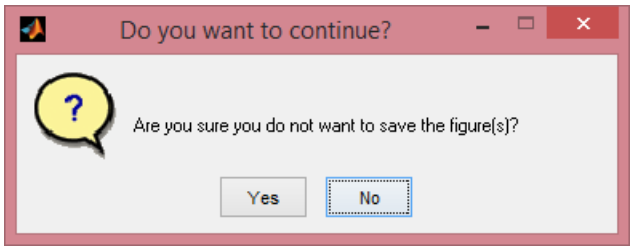


Figure 3.23: Run without saving figure(s)

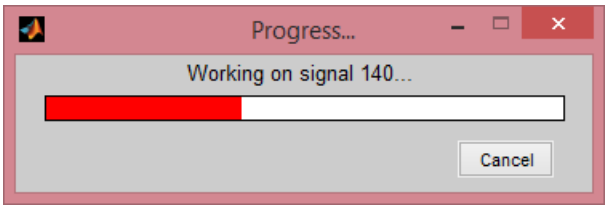


Figure 3.24: Progress of the analysis

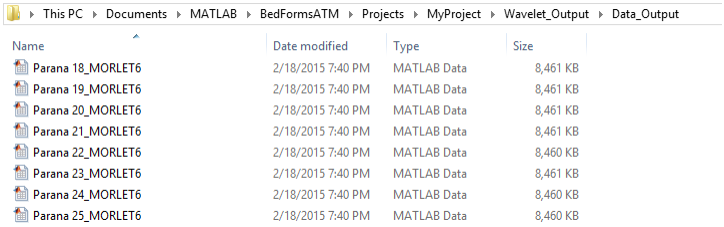


Figure 3.25: Output directory

Title $n - thprofile\_WaveletFunctionWaveletParameter$

⚠⚠WARNING! These files should not be relocated because they are used by the subsequent applications.

Chapter 4

Application 2: Hovmøller Analysis

The second application of Bedforms-ATM is presented in the `BedformsATM_App2_HovmollerAnalysis.m` script.
⚠ To run Application 2 you must have completed the wavelet analysis (Application 1) for the entire bed form field. It stems from the fact that Application 2 uses the .MAT extension files that are generated after running Application 1.

4.1 Homescreen

When you run the `BedformsATM_App2_HovmollerAnalysis.m` script, the home screen window shown in 4.1 is opened.

4.2 Project selection

Firstly, you need to select the data to be analyzed (Fig. 4.2).

The *uipickfiles* application automatically loads the "projects" folder where all past projects are saved. The files to be selected are the .MAT files located in the following folder:

$$Projects\backslash Myproject\backslash Wavelet_Output\backslash Data\_Output$$

All files must be selected. You can use the Ctrl+A command to select all files in the list (Fig. 4.3).

The program will report the loading progress (Fig. 4.4) and the report the number of loaded files, the significance level, the incremental frequency and wavelet function used in the analysis (Fig. 4.5).

4.3 Executing Application 2

The program suggests the interval length and maximum scale for the Hovmøller Analysis. Please be aware the using different values than those suggested in the home screen may increase the runtime or return irrelevant results (Fig. 4.6).

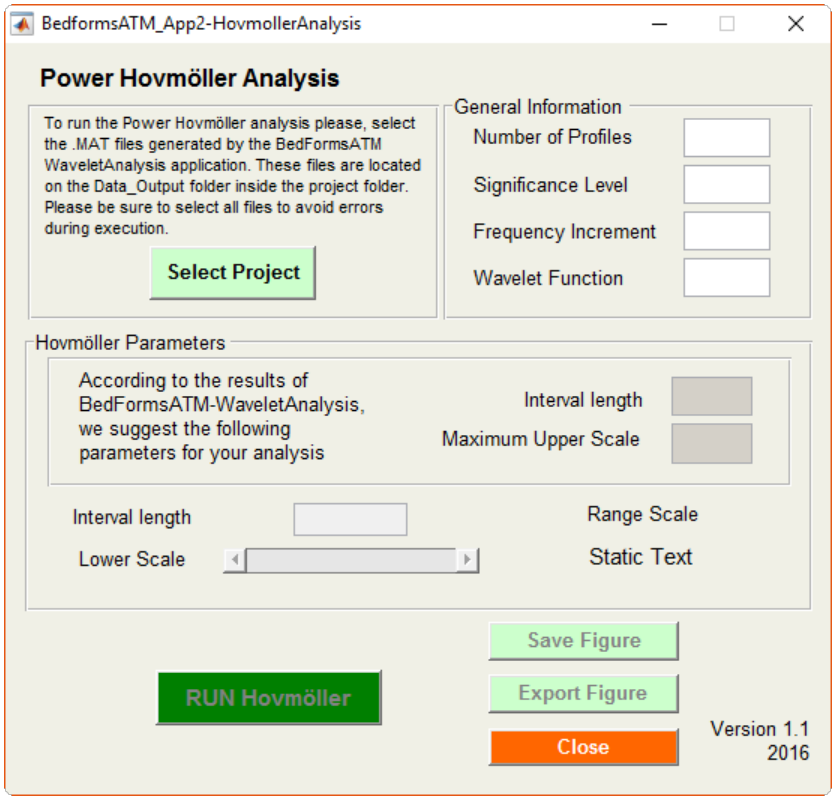


Figure 4.1: Hovmøller Analysis home screen

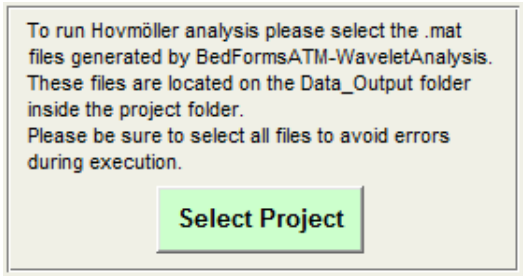


Figure 4.2: Select project

The user sets the analysis interval by indicating both its length and range by using the slider (Fig. 4.7). The program is executed once the range of scales of the analysis are fully defined.

4.4 Saving and exporting the output plots

The resulting plot can be saved as: [1] PDF, tiff or jpg; [2] exported as a Matlab .FIG file; or [3] Tecplot format (Fig. 4.8).

The File will be saved in the following folder (Fig. 4.9):

$$\backslash BedFormsATM\backslash Projects\backslash MyProject\backslash Wavelet\_Output\backslash Hovmoller\_Analysis$$

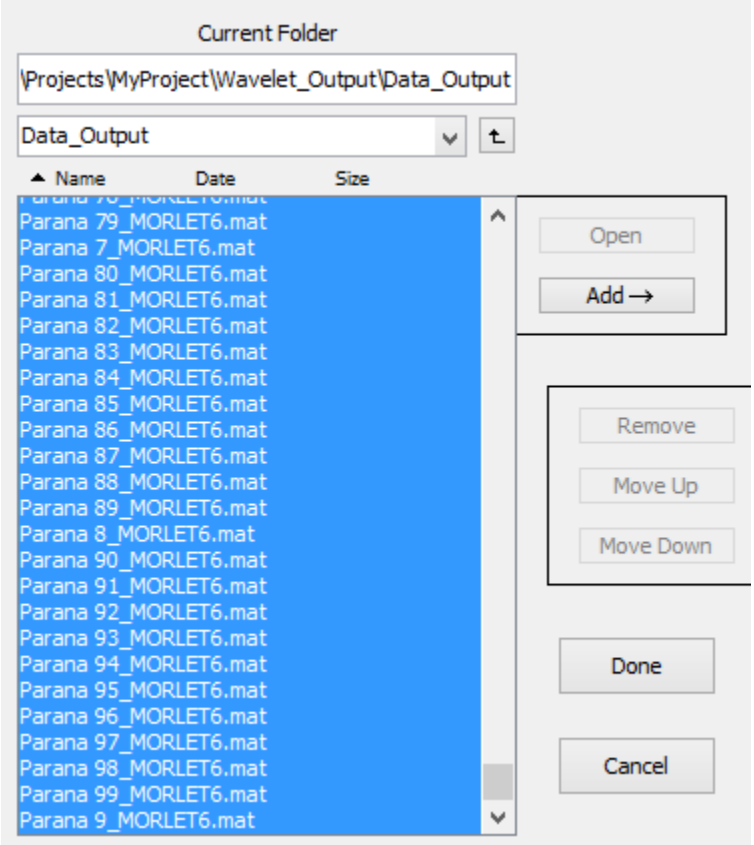


Figure 4.3: Select all generated files

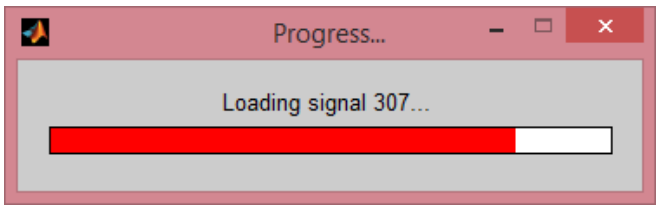


Figure 4.4: Loading progress

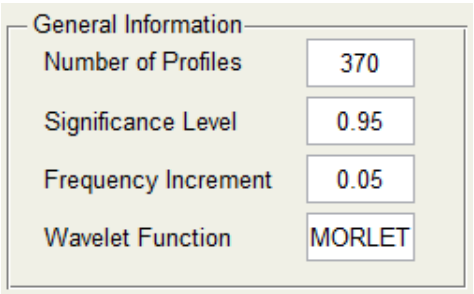


Figure 4.5: Wavelet analysis information

An output example is presented in 4.10.

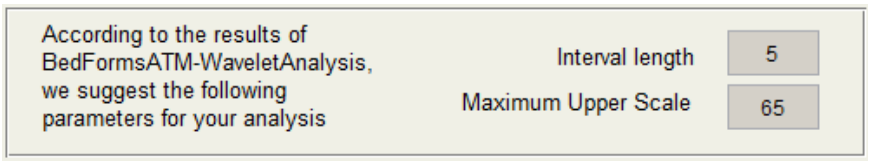


Figure 4.6: Suggested parameters

Figure 4.7: Suggested parameters, slider

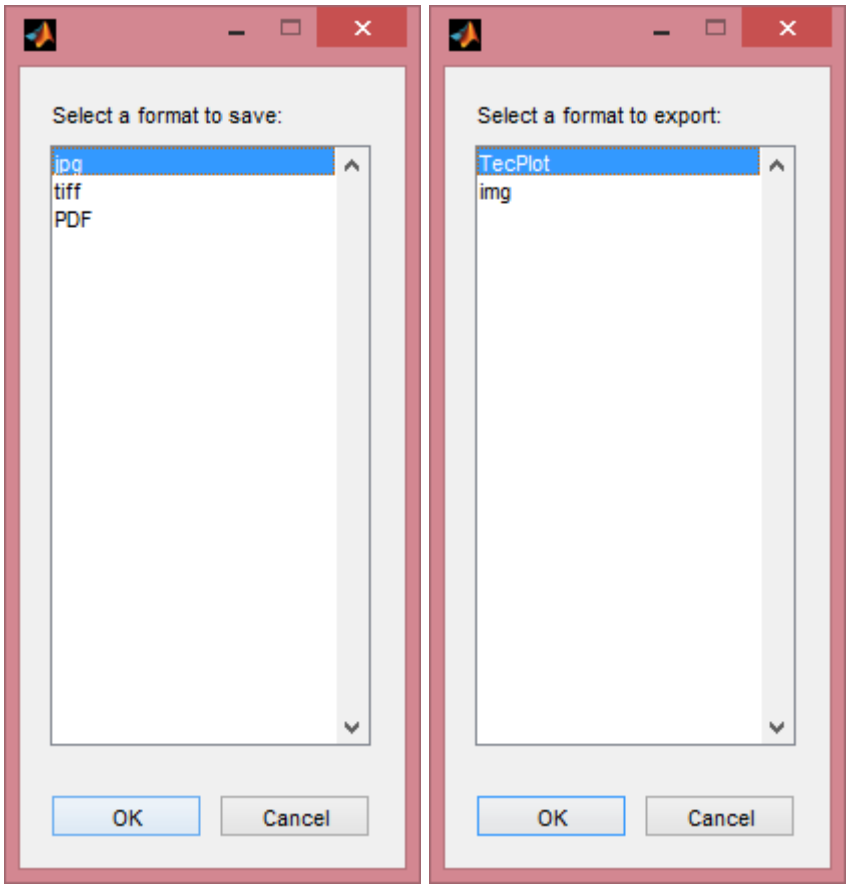


Figure 4.8: Save and Export interface

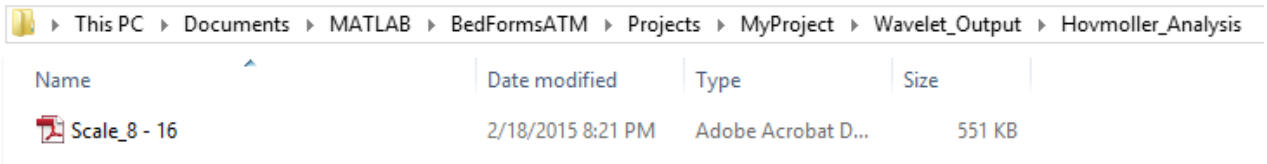


Figure 4.9: Output path

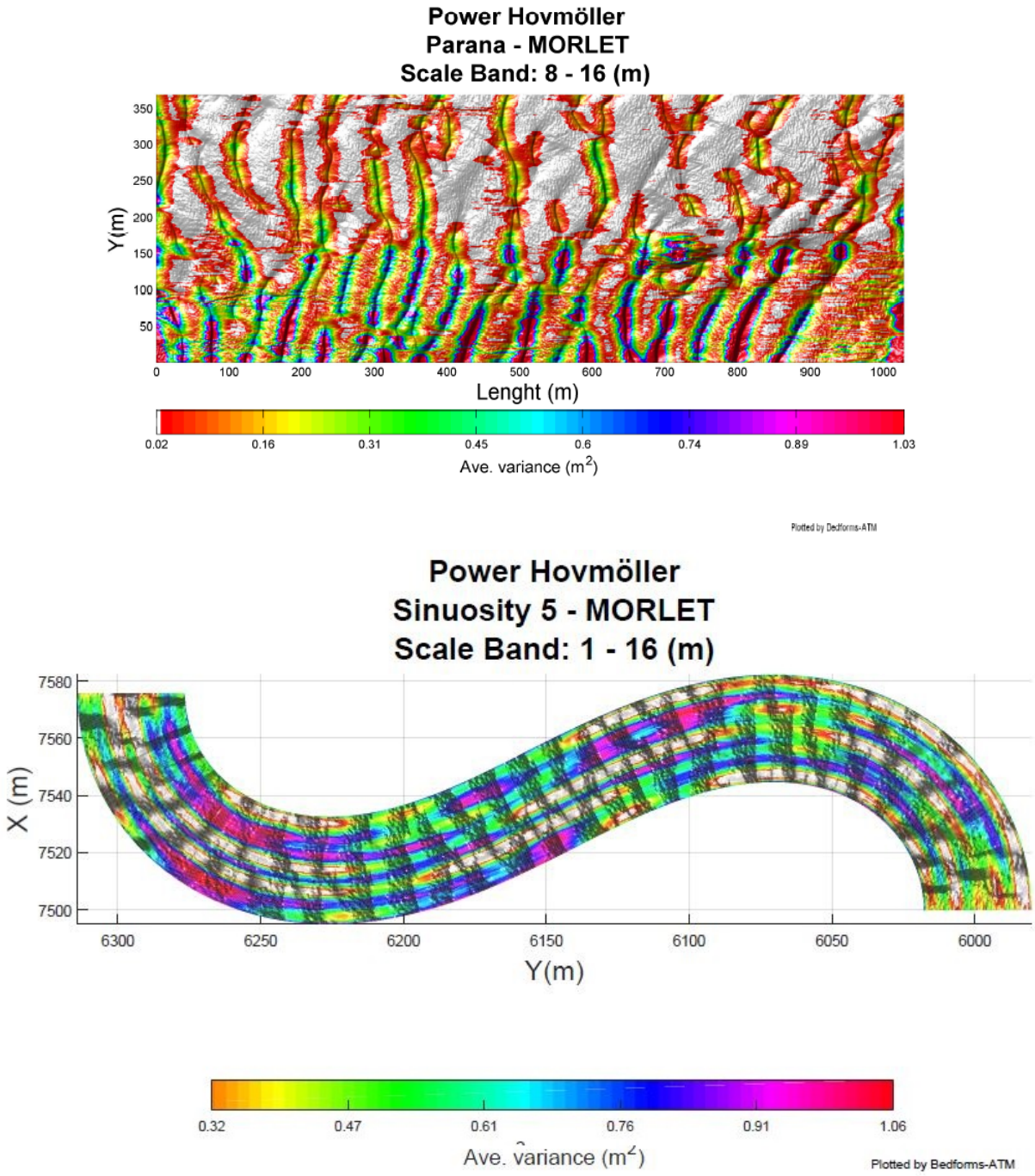


Figure 4.10: Hovmøller analysis for rectangular (Parana River, Argentina) and curved plot (synthetic data)

Chapter 5

Application 3: Scale-based Discrimination

Application 3 is presented in the `BedformsATM_App3_ScaleBasedDiscrimination.m` script which discriminates bed form hierarchies. Application 3 is based on Application 1 (wavelet analysis) output; thus, it is not mandatory to run Application 2 (Power Hovmøller analysis) to run it.

5.1 Homescreen

When you run the `BedformsATM_App3_ScaleBasedDiscrimination.m` script, the window presented in Fig. 5.7 is opened.

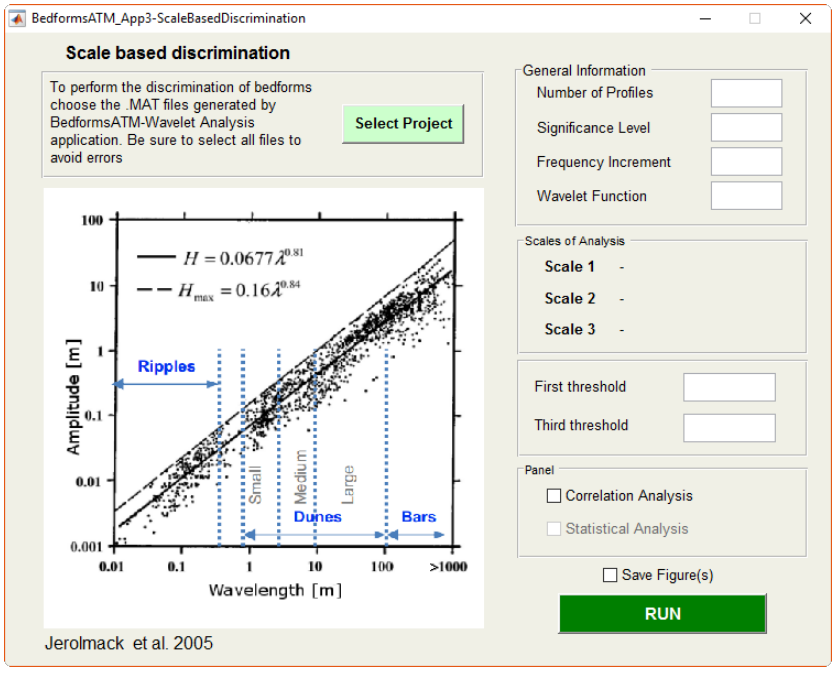


Figure 5.1: BedformsATM_App3_ScaleBasedDiscrimination (Application 3) homescreen

5.2 Project selection

As a first step you need to select the project to be analyzed. The *uipickfiles* application automatically loads the "projects" folder where all past projects are saved. The files to be selected are the .MAT files (Fig. 5.2) in the following folder:

$$Projects\backslash Myproject\backslash Wavelet\_Output\backslash Data\_Output$$

Similar to the Power Hovmøller Analysis, all files must be selected. You can use the Ctrl+A command to select all the listed files.

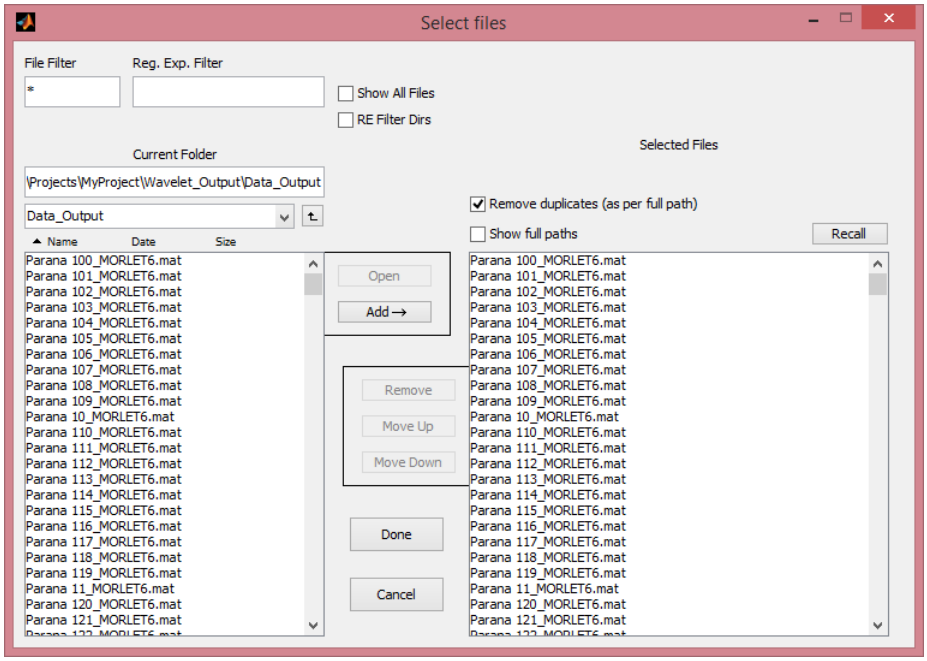


Figure 5.2: uipickfiles application

The program will report the number of loaded files, the significance level, the incremental frequency and wavelet function used in loaded data (Fig. 5.3).

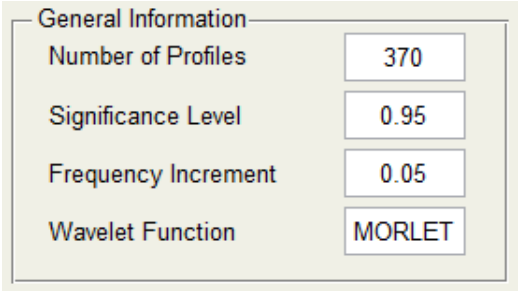


Figure 5.3: Wavelet analysis information retrieved from Application 1

5.3 Discrimination scales

Once the input files are uploaded, the discrimination scales, which are obtained from the wavelet analysis, will be shown (Fig. 5.4). The profiles will be discriminated into three scales (i.e., three hierarchies).

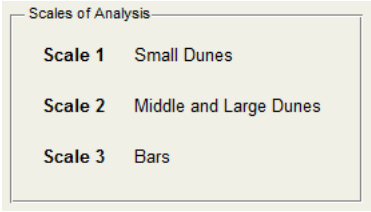


Figure 5.4: Scales for Discrimination

Scale-based bed from hierarchies are determined by the following criteria:

- Ripples: entities having wavelengths shorter than 0.60m.
- Small Dunes: entities having wavelengths between 1m-5m.
- Medium Dunes: entities having wavelengths between 5m-10m.
- Large Dunes: entities having wavelengths between 10m-100m.
- Bars: entities having wavelengths longer than 100m.

The proposed range is shown in the graphic interface by the red lines as presented in Figure 5.5. For details on the aforementioned scale, the user is kindly referred to Jerolmack and Mohrig (2005).

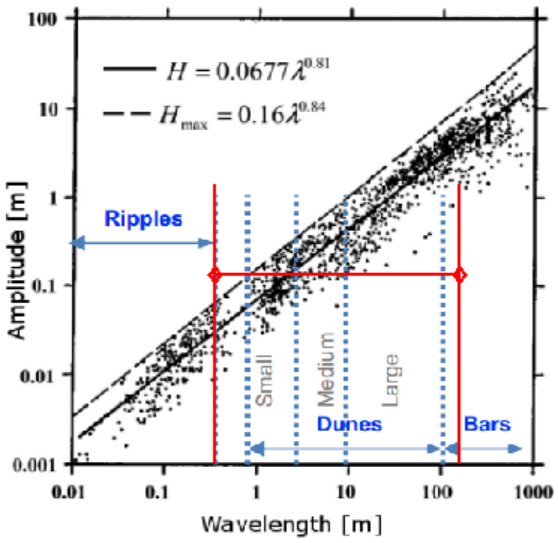


Figure 5.5: Analysis interval (after Jerolmack and Mohrig (2005).)

5.4 Executing Application 3

Finally, the program allows for executing two additional analysis (Fig. 5.6):

- Correlation Analysis: Only available for data representing a water depth bed form field.
- Statistical Analysis (⚠ **Not available in this version)**

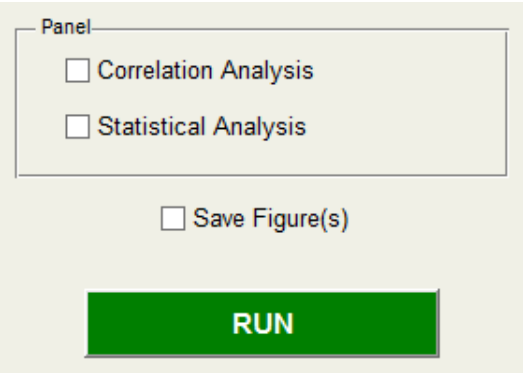


Figure 5.6: Correlation and Statistical Analysis checkbox

Similarly to the Wavelet Analysis, the output data can be plotted while being processed. To save the output files, click on the *SaveFigure* check-box and automatically you will be asked to select the format of your preference.
To print the figures after running the program, please run the function *plotBFDiscrimination* from the MATLAB console. You will be asked to select the plot format. After calling the function, please select the .MAT files generated by Application 3 which will be located in the following folder:

$$\backslash Projects\backslash MyProject\backslash BFPDiscrimination\backslash Output$$

After executing the program, the window will be closed and the analysis progress will be shown (Fig. 5.7). If you chose to save the graphics, the progress of printing is shown after the execution (Fig. 5.8).

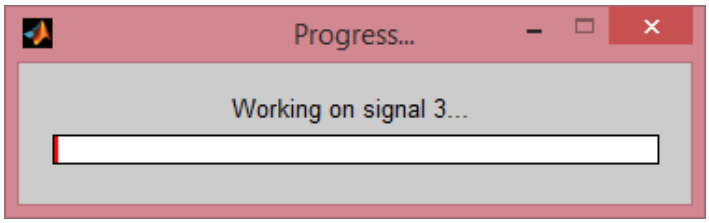


Figure 5.7: Progress of the discrimination

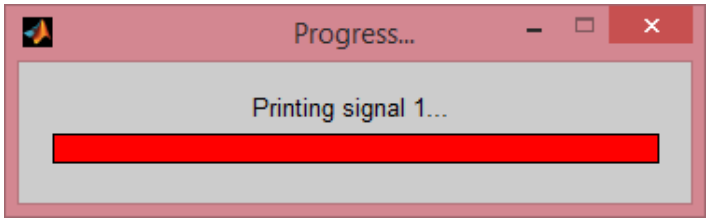


Figure 5.8: Progress of the printing

5.5 Outputs

The program will generate .MAT files that store information related the scale-based discriminated profiles. They are saved in the following folder:

$$\backslash Projects\backslash MyProject\backslash BFPDiscrimination\backslash Output$$

Additionally, a MyProjectDiscrimination_ForAnalysis.mat file is created. This file should be chosen to perform the statistical (not included in this version) or correlation analysis after running the program from the console and by calling the following functions:

- *runCorrelationAnalysis*
- *runStatisticalAnalysis* (⚠ not available in this version)

The discriminated profiles will be saved in the *Figures* folder and will have the format presented in Fig. 5.9.

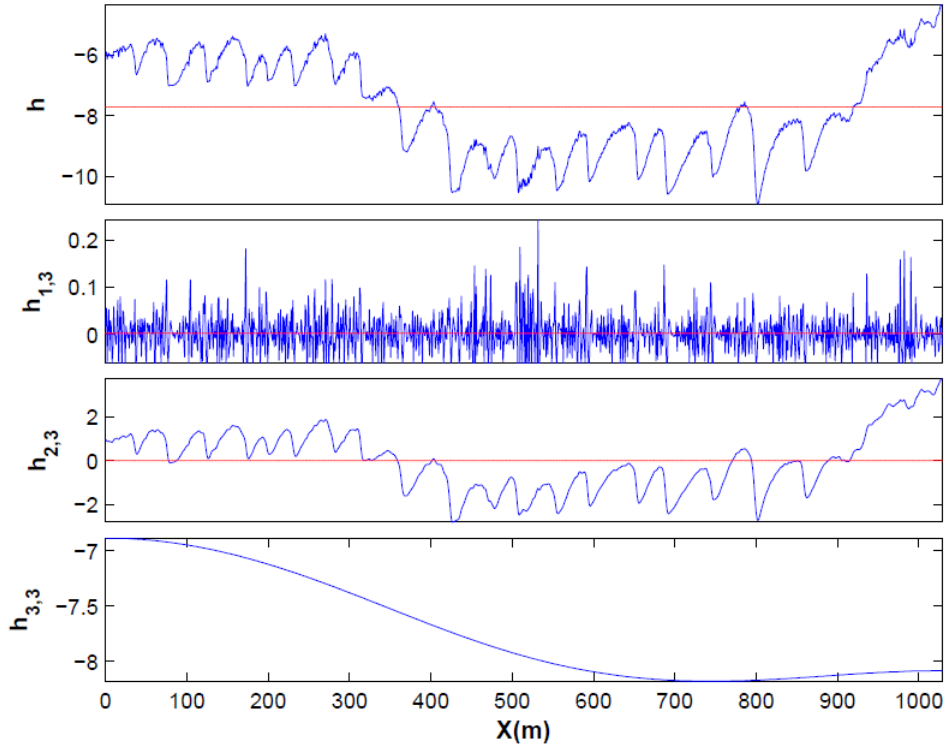


Figure 5.9: An instance of Application 3 output for a bed form profile from the Parana River (top), which is discriminated into 3 hierarchies, namely: Hierarchy 1, $h_{1,3}$ (small dunes); Hierarchy 2, $h_{2,3}$ (medium and large dunes); and Hierarchy 3, $h_{3,3}$ (bars).

Finally, the program plots each level separately and print this surfaces in PDF format in the folder:

$$\backslash Projects\backslash MyProject\backslash BFPDiscrimination$$

Hierarchy 1 field will be plotted above the original surface in a 2D view (Fig. 5.10), while the other two Hierarchies will be plotted in a 3D view (Fig. 5.11 and5.12).

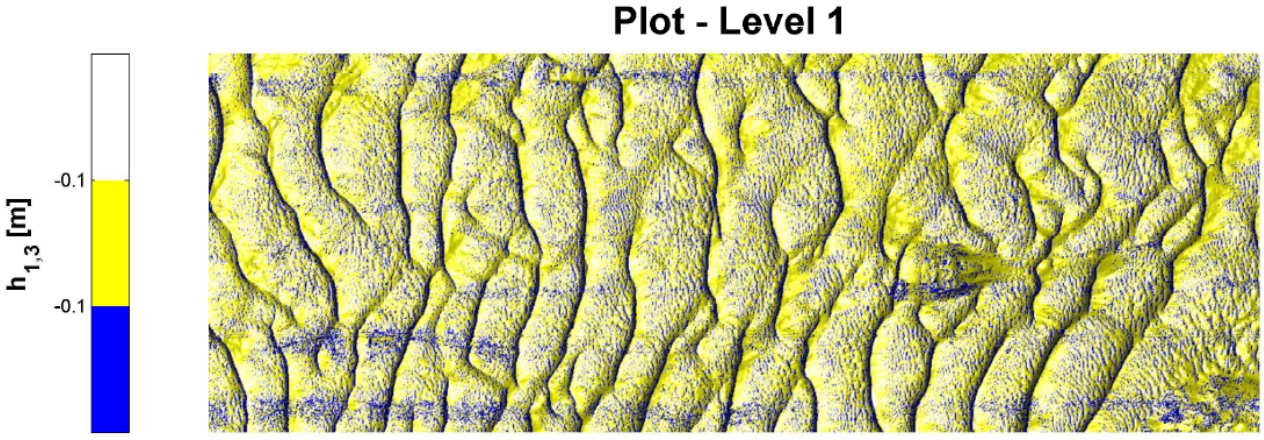


Figure 5.10: Hierarchy 1 field ($h_{1,3}$) of the Parana River

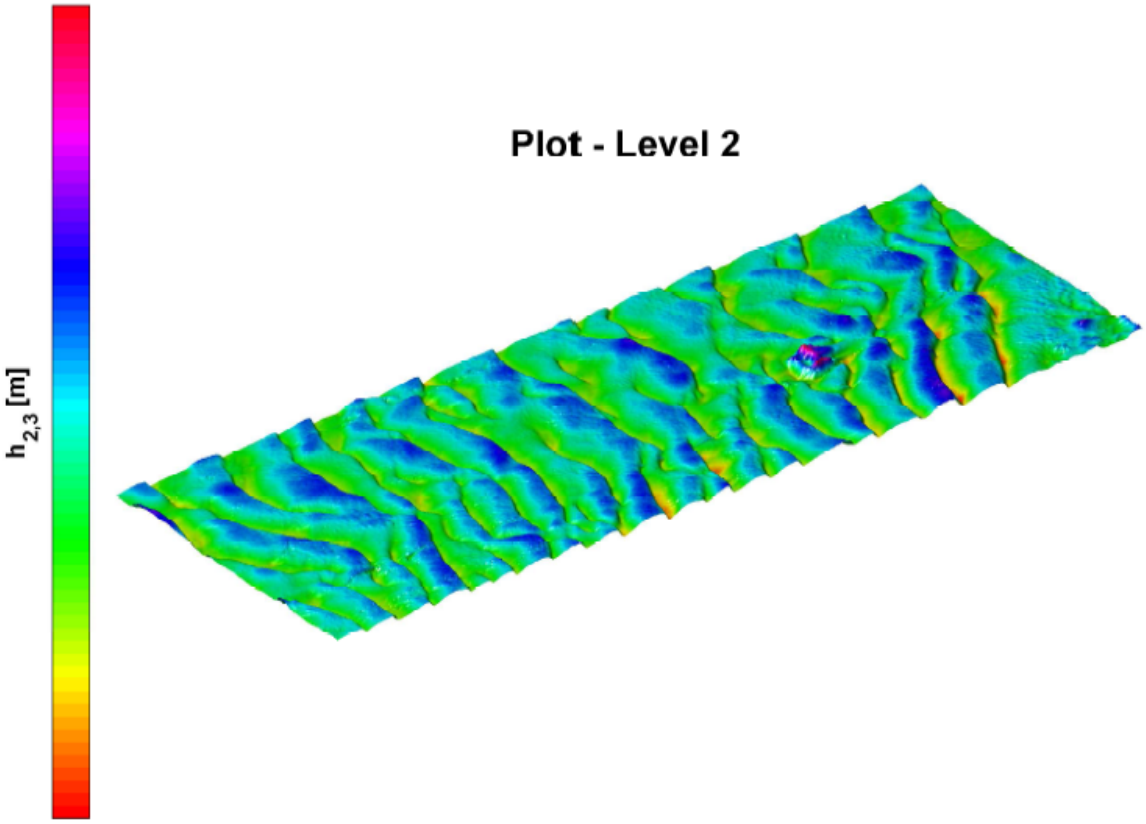


Figure 5.11: Hierarchy 2 field ($h_{2,3}$) of the Parana River

With this interface the whole discrimination process finishes. All the generated .MAT files could be open with MATLAB.

Finally, the plot showing the correlation analysis (Fig. 5.13) can be visualized.

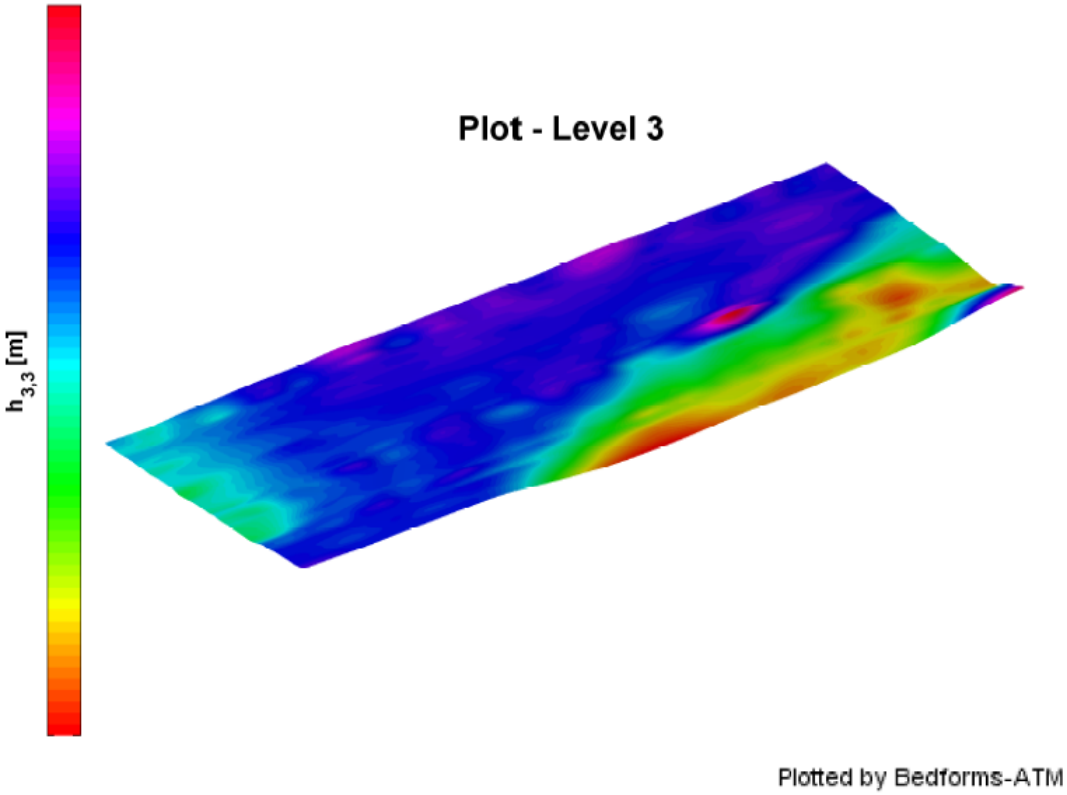


Figure 5.12: Hierarchy 3 field ($h_{3,3}$) of the Parana River

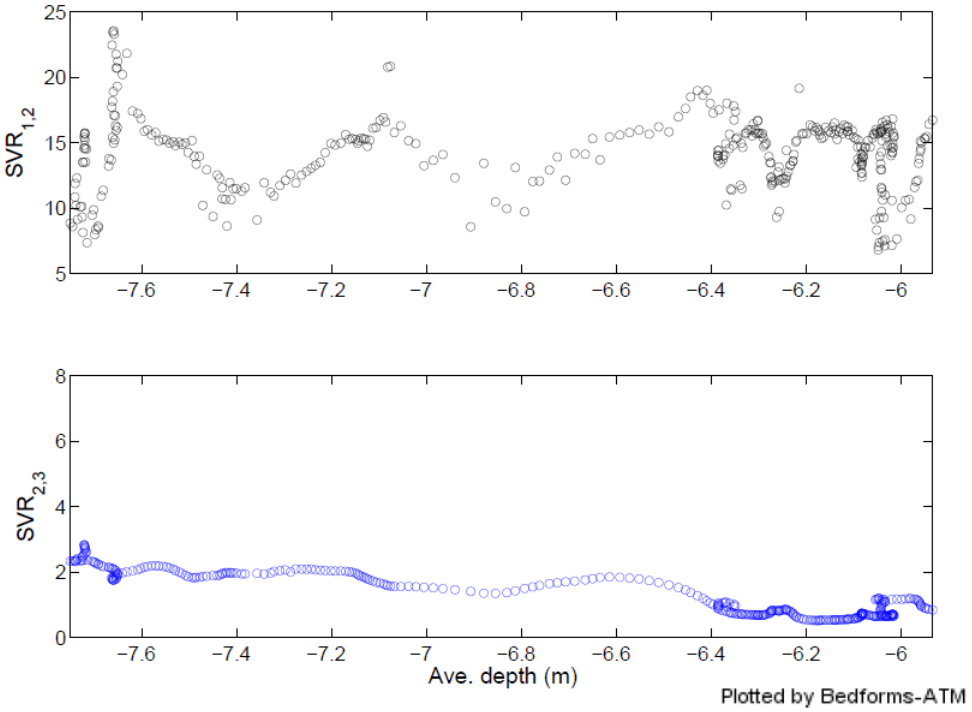


Figure 5.13: Correlation Analysis

Chapter 6

Application 4: Three-dimensionality Analysis

The fourth application of Bedforms-ATM is presented in the `BedformsATM_App4_3DAnalysis.m` script. Application 4 is based on based on the results of the Application 1 and use some of its functions.

6.1 Homescreen

When `BedformsATM_App4_3DAnalysis.m` is executed, the window presented in Fig. 6.1 is displayed.

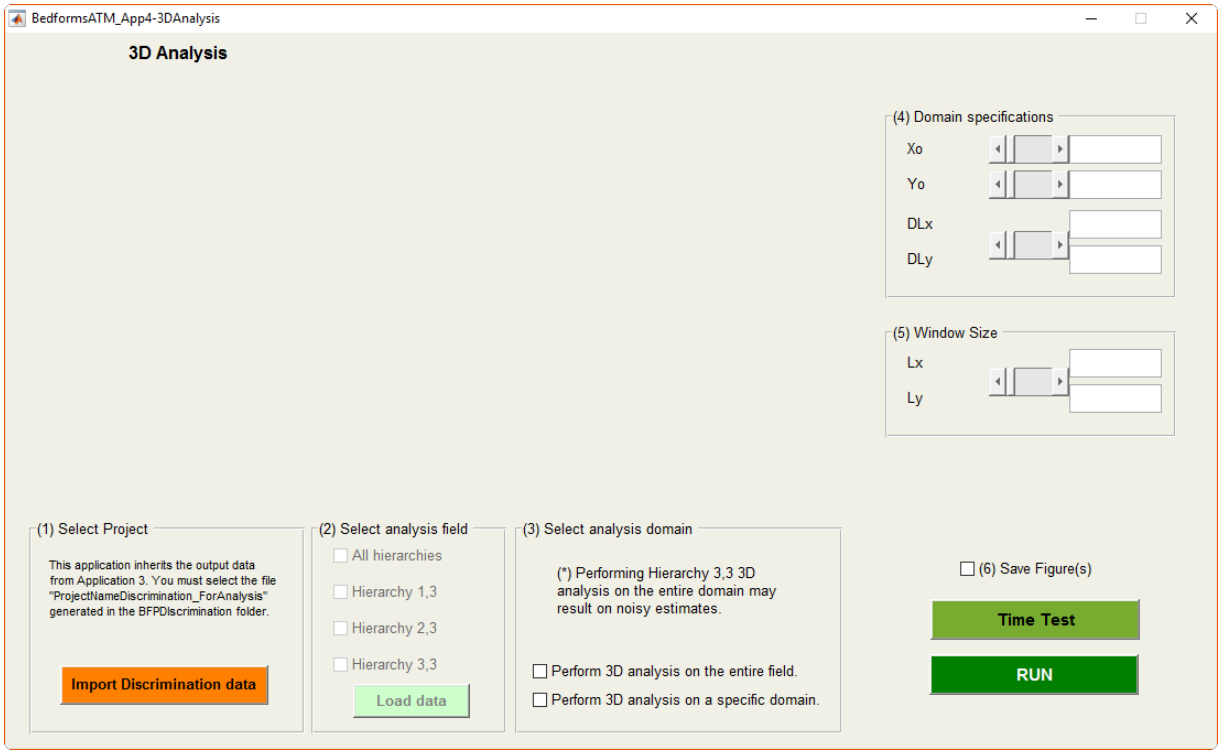


Figure 6.1: BedformsATM_App4_3DAnalysis home screen

6.2 Project selection

As a first step you need to select the project to be analyzed. Press the **Import Discrimination data** button in the first panel. The *uipickfiles* application automatically loads the "projects" folder where all past projects are located.

This program uses the output file generated by the Application 3 which has .MAT extension (Fig. 6.2) and is stored in the following folder:

$$Projects\backslash Myproject\backslash BFPDiscrimination\backslash NameProjectDiscrimination\_ForAnalysis$$

⚠ Make sure you select the correct file, otherwise the program will stop working. Once the data is loaded the button blocks, to load other project you have to reopen the application.

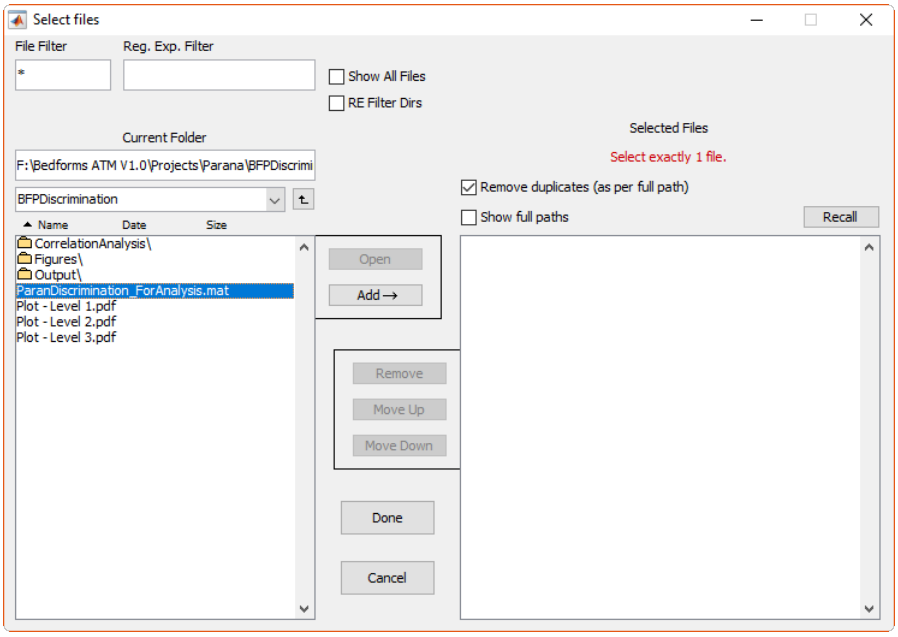


Figure 6.2: uipickfiles application

6.3 Selecting the analysis field

After loading the input file described in the previous section, the second panel (Fig. 6.3) will be enabled.

The program is designed to perform this analysis in the original plot or in one of the bed form hierarchies. Once you select the analysis field, press the **Load data** button. The program will display a 2D view of the chosen plot (Fig. 6.4).

6.4 Selecting the analysis domain

Once the plot is displayed the **Select Analysis Domain** panel is enabled (Fig. 6.5). The 3D Analysis is performed using a **window** on a **domain**. The window is defined as a square which sides are determined

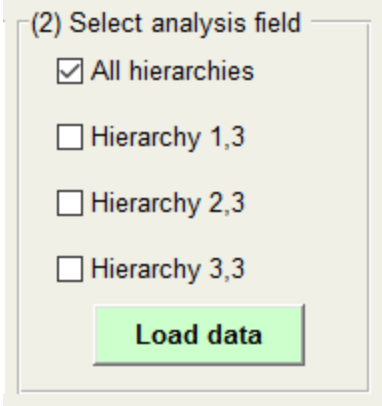


Figure 6.3: Select Analysis Field panel

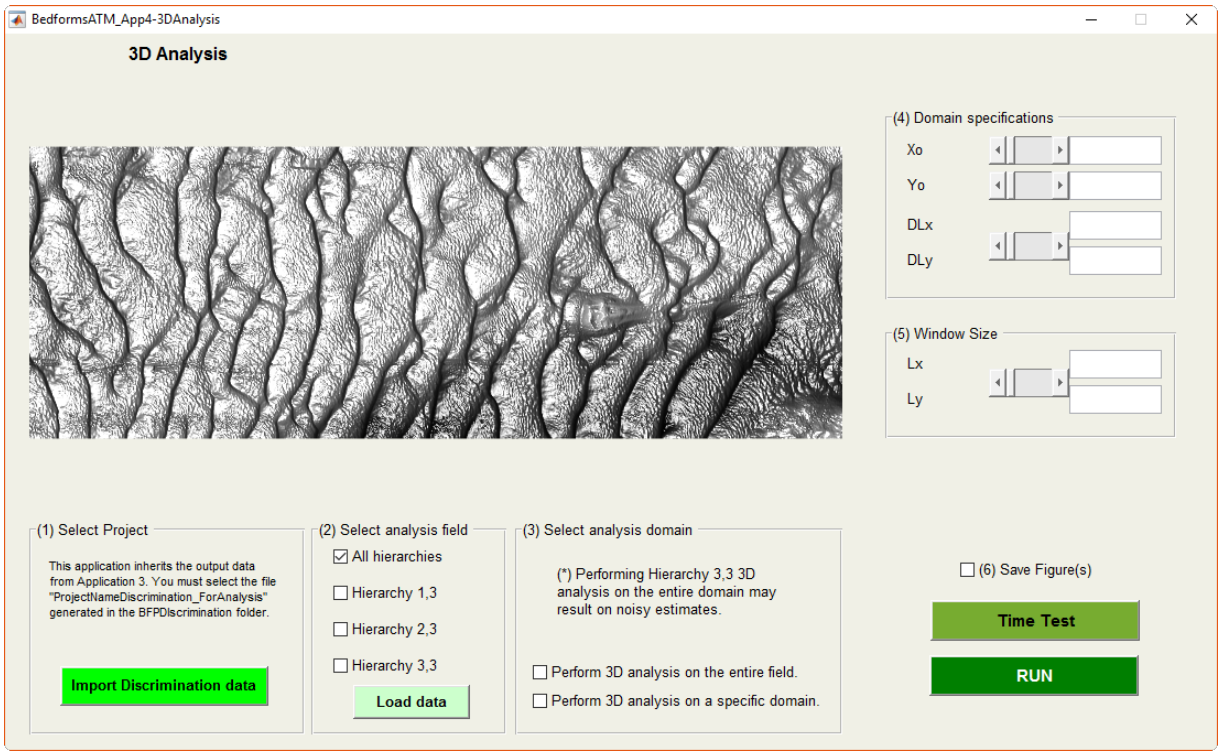


Figure 6.4: Plot displayed

by the wavelet analysis of the chosen plots: let's call this distance *WSize*. Using *WSize* the program makes sure that at least one entire characteristic entity is retrieved anywhere the window is located throughout the domain. However, since it is also necessary to make sure that the window fits in the plot, a second bound is applied: a quarter of the smallest dimension in the X or Y direction.

The program allows to set the size of the window or domain. When the option **Entire field** is chosen the domain is set as all the plot and you could vary the size of the window from $Wsize$ up to $3 \times Wsize$. Otherwise, if the option **Specific Domain** is checked, the size of the window is set and you could modify the size of the domain from $2 \times Wsize$ up to $3 \times Wsize$. This domain could be placed anywhere it fits on the entire field.

In order to modify the available dimensions and move the domain, the program has tree sliders located in

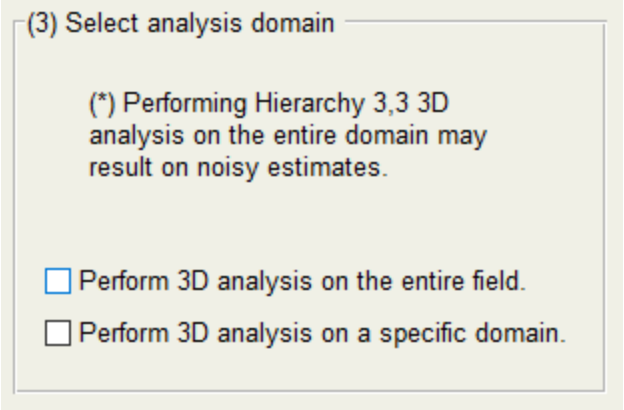


Figure 6.5: Select Analysis Domain panel

the **Domain Specifications** and **Window Size** panels, Fig. 6.6. This sliders are enabled depending on the selected analysis field.

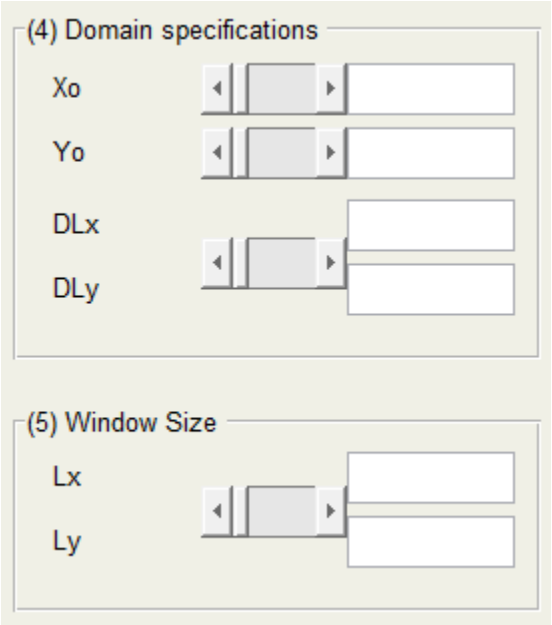


Figure 6.6: Slider's panels

Each time you select one of the options or modify some dimension, the plot displays two rectangles on the 2D surface as shown in Fig. 6.7. The red rectangle represents the window and the blue one, the domain.

6.5 Executing Application 4

Finally, the program allows to perform a run time test. To do it, just press the **Time Test** button. The time will be shown in a box (e.g., Fig. 6.8). This time depends on your computer resources at that moment. Sometimes the time could be excessive (hours), just execute the time test multiple times until the predicted time is constant.

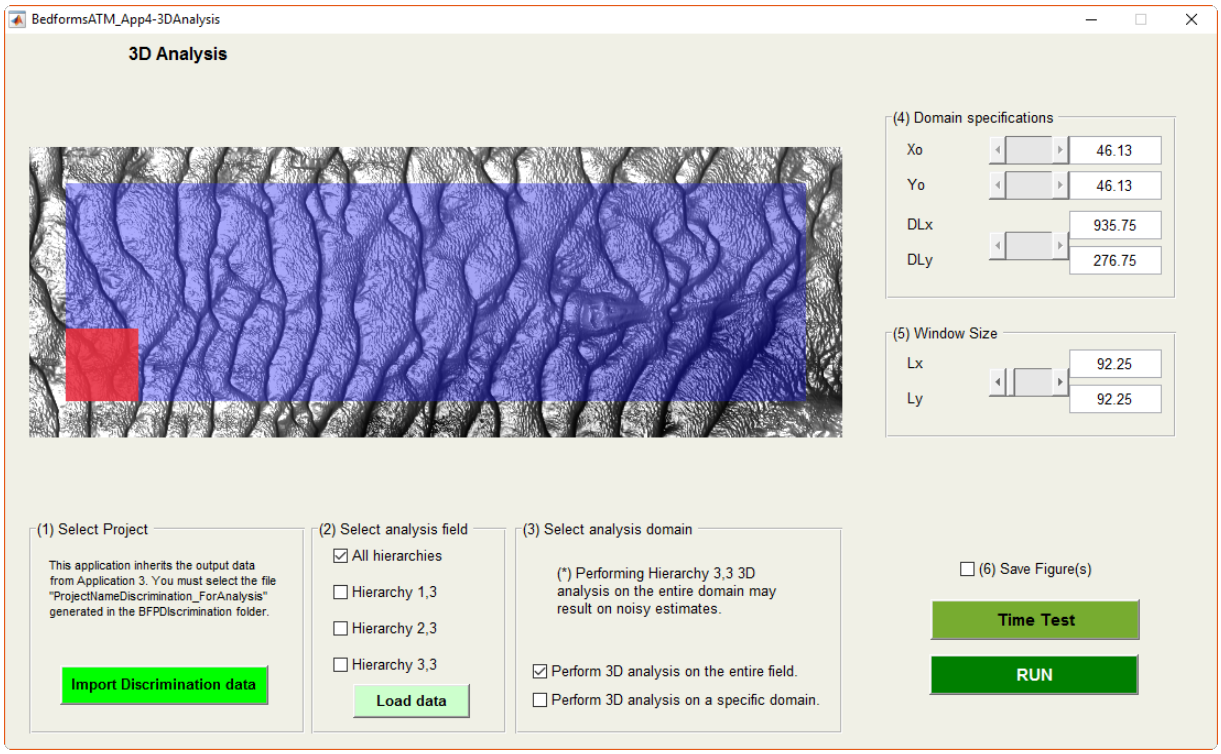


Figure 6.7: Window and Domain

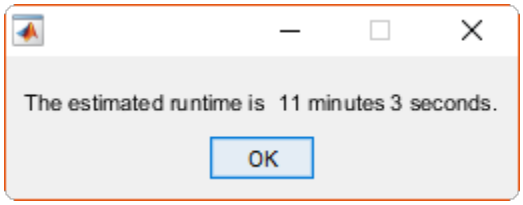


Figure 6.8: Progress of the discrimination

Similarly to other applications, the output data can be plotted while Application 4 is active. To save the output plot, click on the check-box *SaveFigure* and automatically you will be asked to select the plot format.

To execute the program press the **RUN** button. The progress bar will be shown (Fig. 6.9) on screen. Once the analysis is completed a figure is open and shows the resulting plot (Fig. 6.10). If you chose to save it, the program will generate the file on the following folder:

$$\backslash Projects\backslash MyProject\backslash 3DAnalysis$$

The name of the file is defined based on the chosen field of analysis and the size of the window (Fig. 6.11). The figure window will not be closed, so you could modify it.

The program interface will remain open to execute other analysis, you could change the analysis field, domain specification or window size.

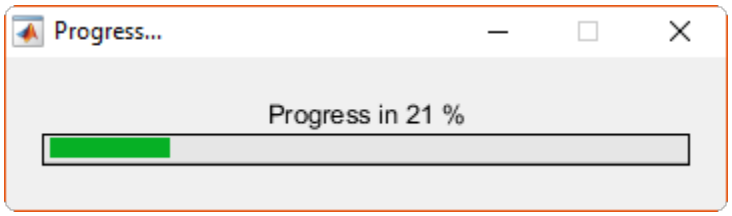


Figure 6.9: Time Test

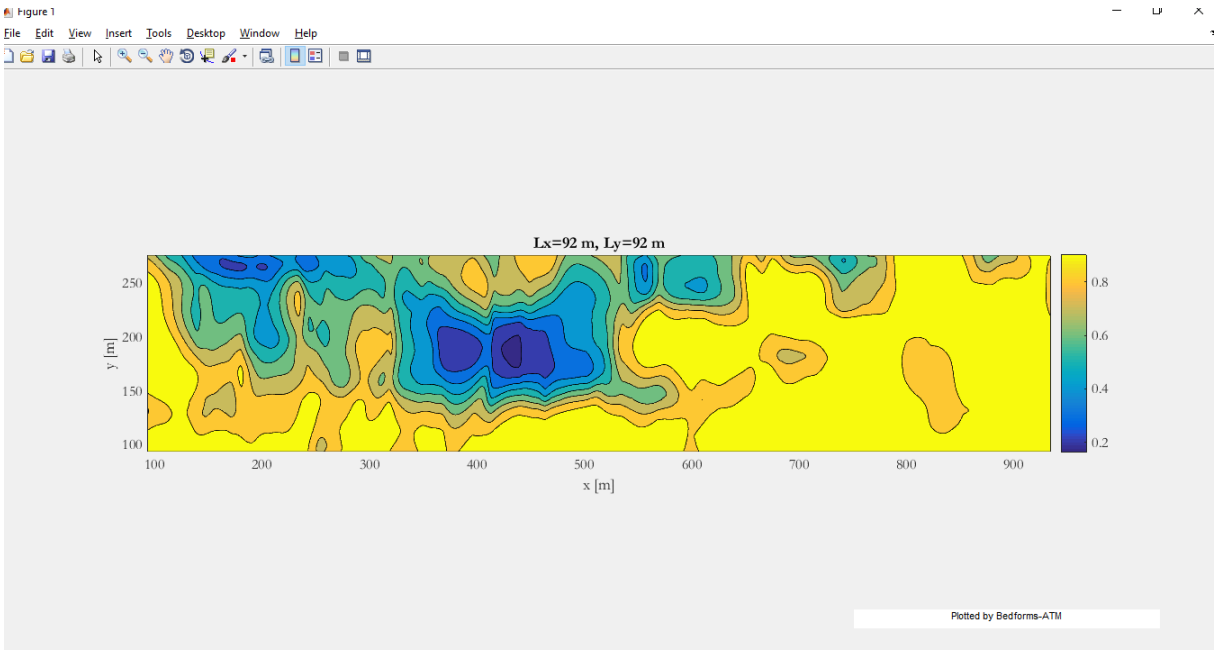


Figure 6.10: Output figure

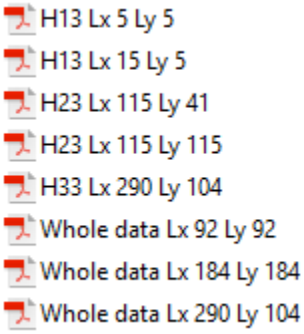


Figure 6.11: Output figure

Bibliography

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Gutierrez, R. R., Abad, J. D., Parsons, D. R., and Best, J. L. (2013). Discrimination of bed form scales using robust spline filters and wavelet transforms: Methods and application to synthetic signals and bed forms of the Río Paraná, Argentina. *Journal of Geophysical Research: Earth Surface*, 118(3):1400–1418.

Jerolmack, D. and Mohrig, D. (2005). Interactions between bed forms: topography, turbulence, and transport. *J. Geophys. Res.*, 110. doi: 10.1029/2004JF000126.

Parsons, D. R., Best, J. L., Orfeo, O., Hardy, R. J., Kostaschuk, R., and Lane, S. N. (2005). Morphology and flow fields of three-dimensional dunes, Rio Parana, Argentina: Results from simultaneous multibeam echo sounding and acoustic Doppler current profiling. *J. Geophys. Res.*, 110. doi:10.1029/2004JF000231.

Torrence, C. and Compo, G. P. (1998). A practical guide to wavelet analysis. *Bulletin of the American Meteorological Society*, 79:61–78.

Chapter 7

Flow charts

Flow charts of the main functions used in the program are presented herein as supplementary information.

7.1 Wavelet Analysis

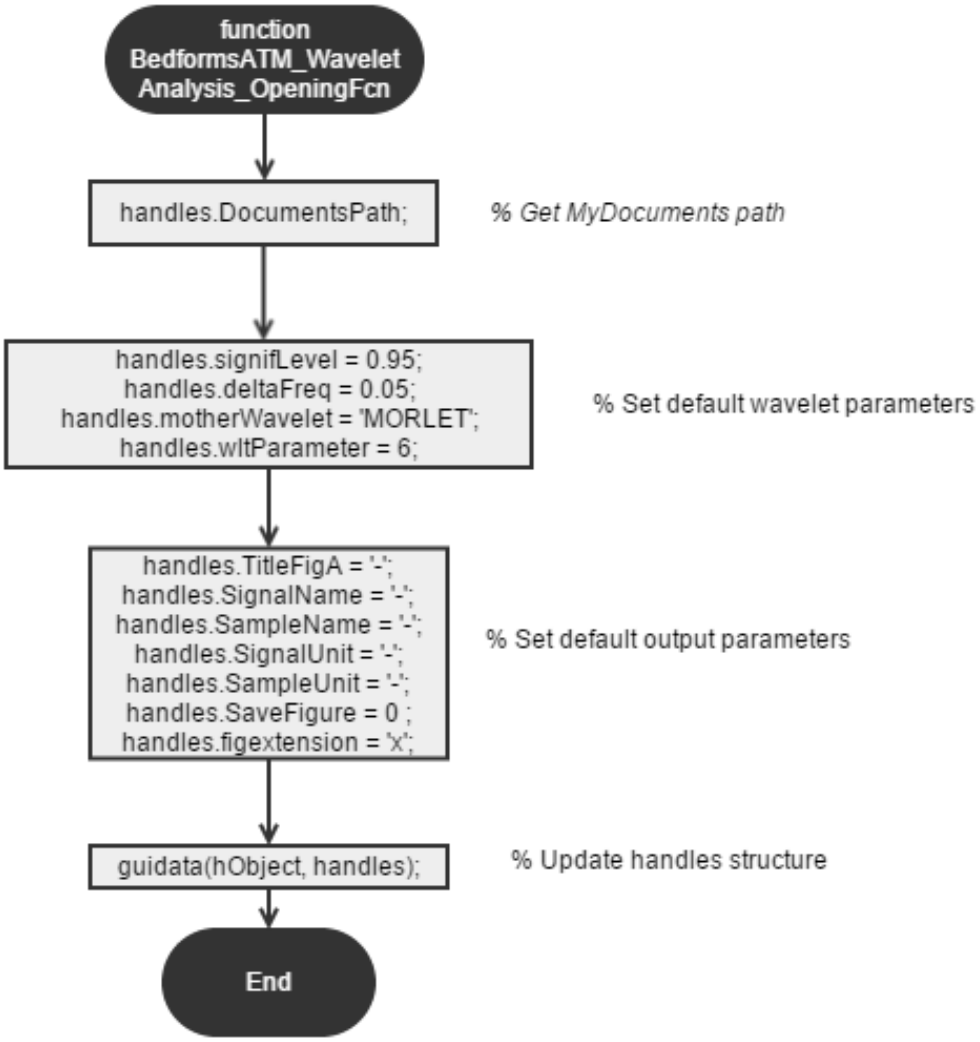

Figure 7.1: BedformsATM Wavelet Analysis openingfcn

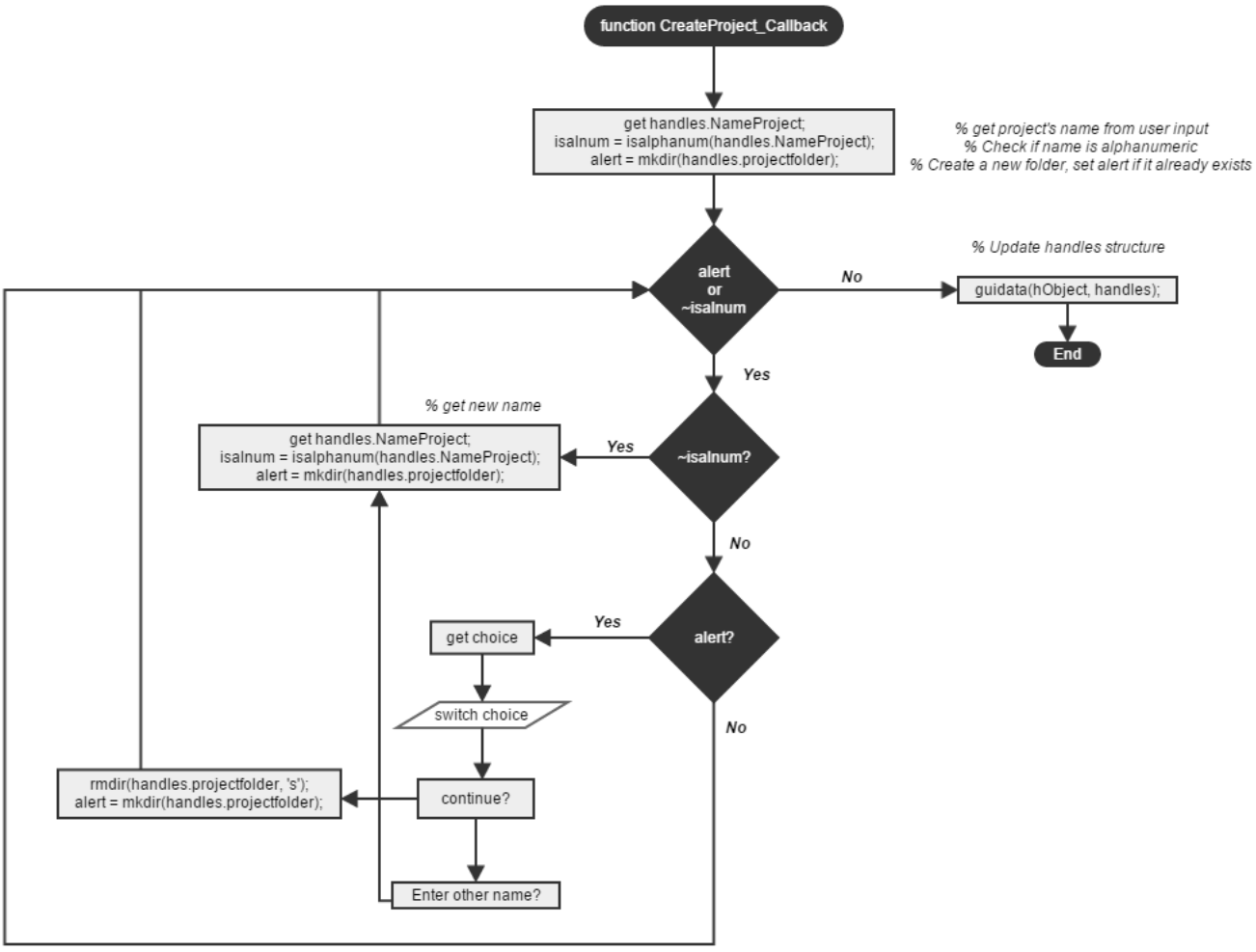

Figure 7.2: createproject callback

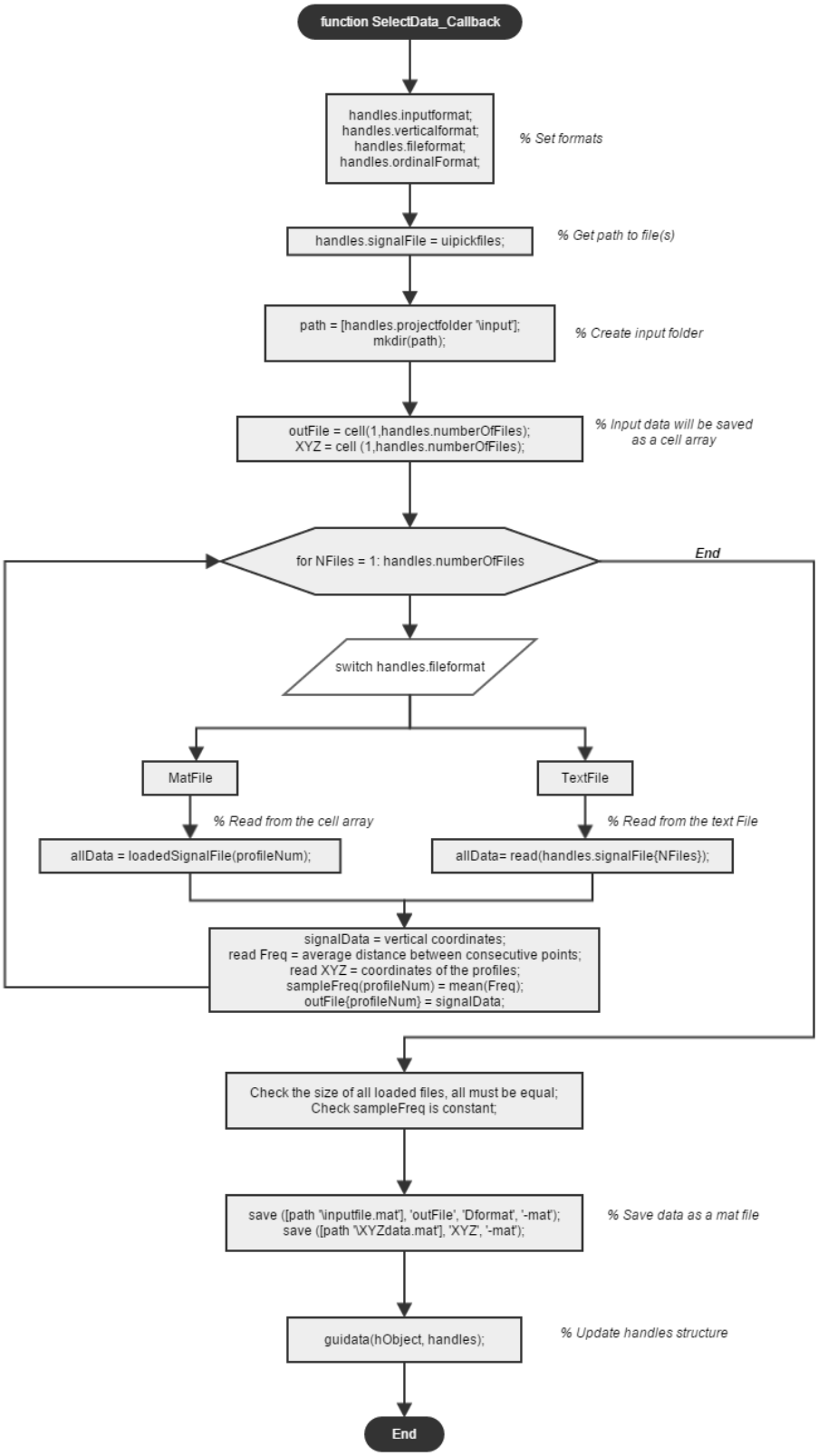

Figure 7.3: function selectdata callback

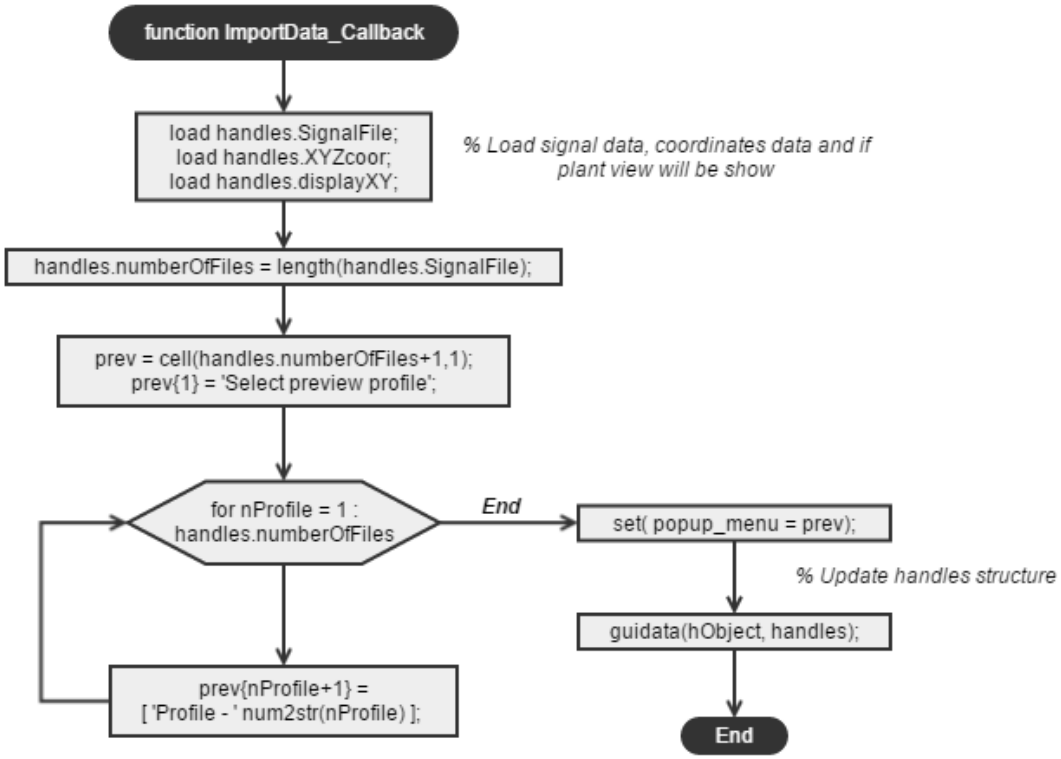

Figure 7.4: function importdata callback

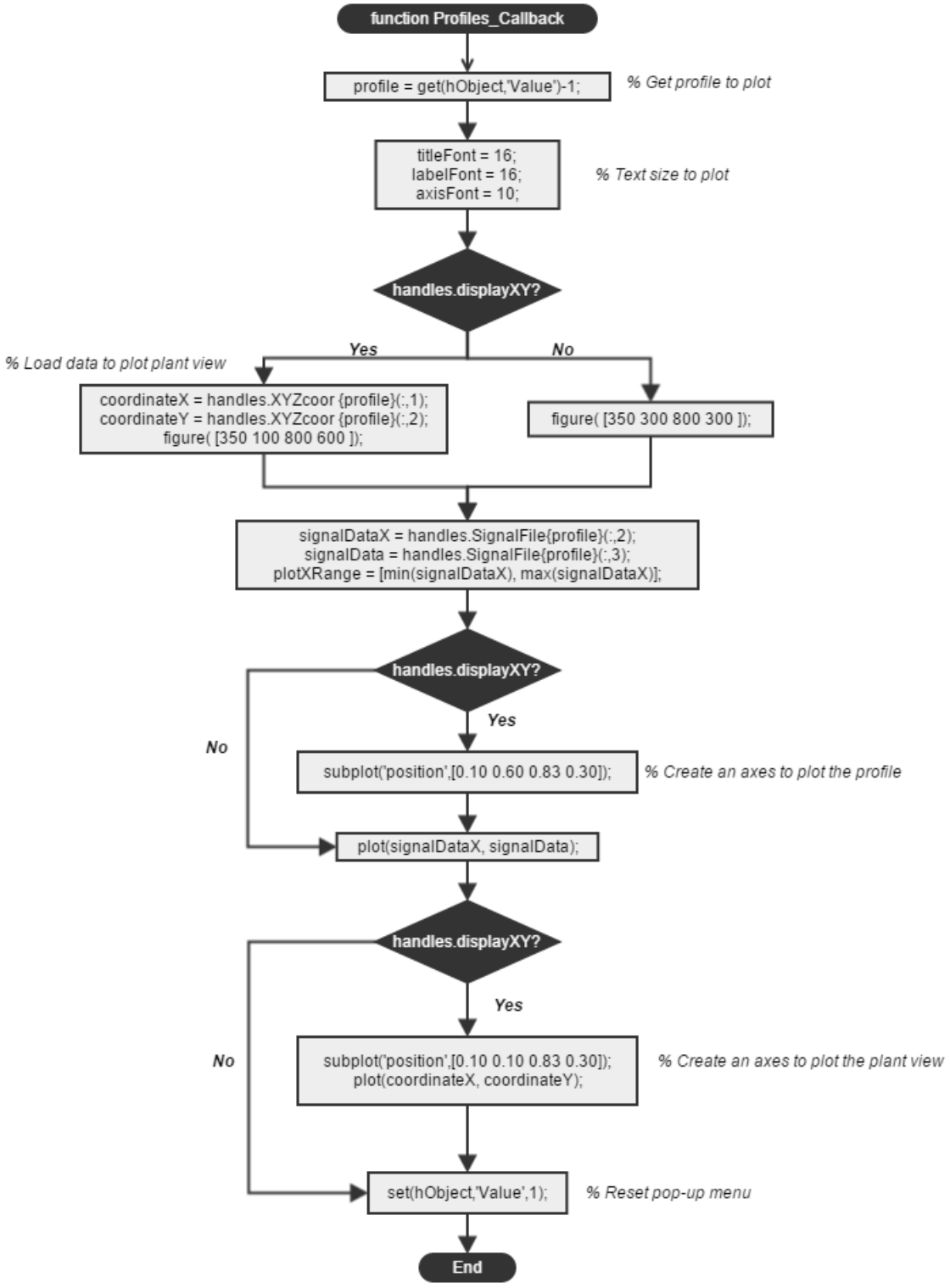

Figure 7.5: function profiles callback

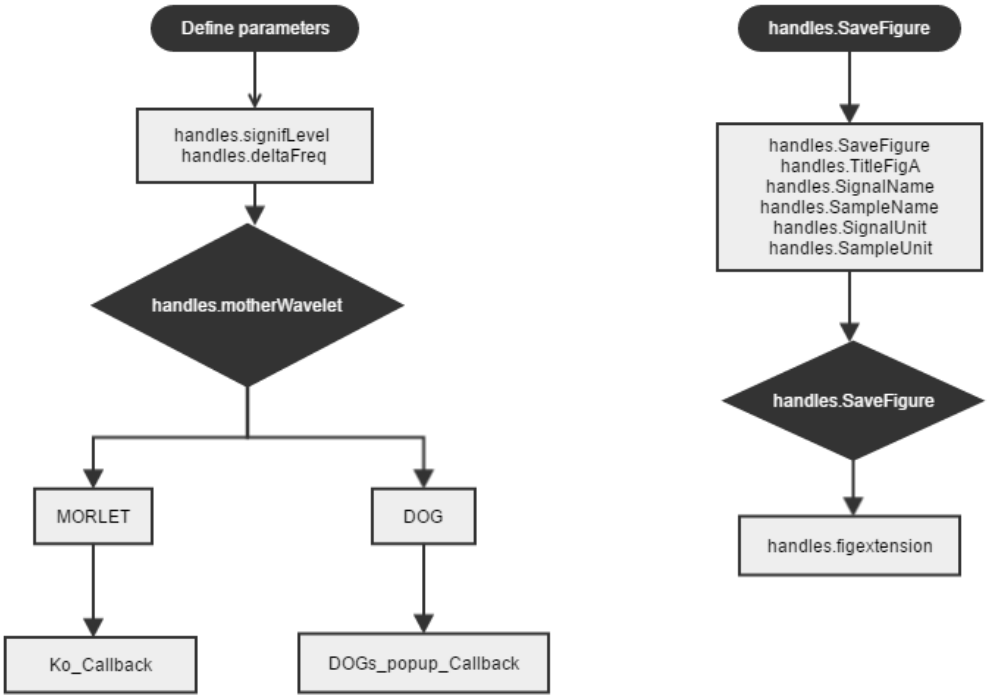

Figure 7.6: define parameters and output settings

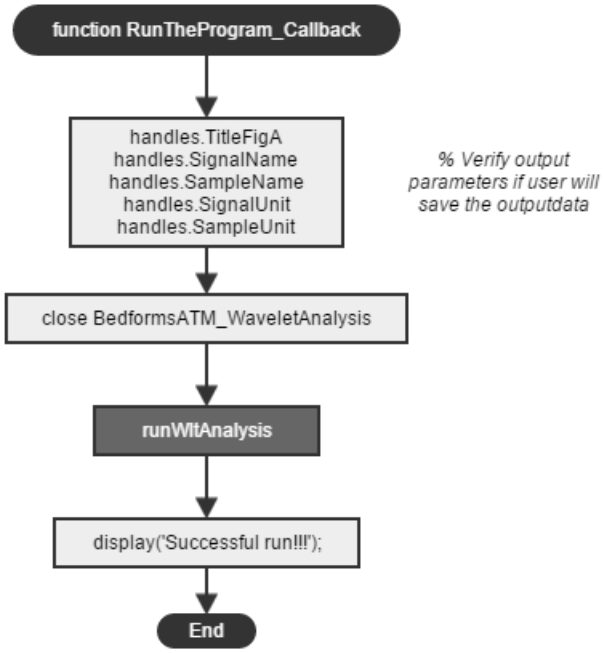

Figure 7.7: function runtheprogram callback

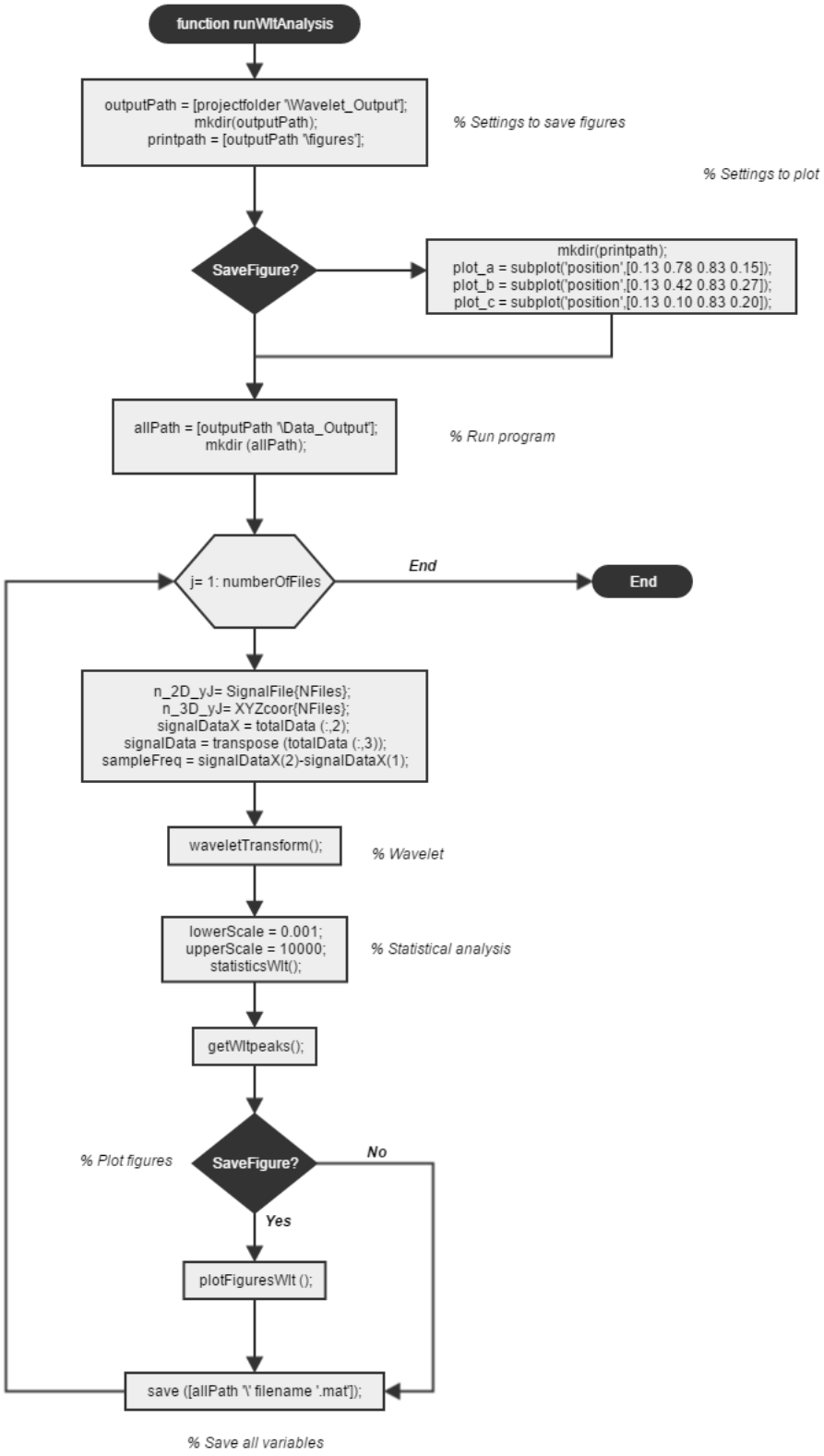

Figure 7.8: function runwltanalysis

7.2 Hovmoller Analysis

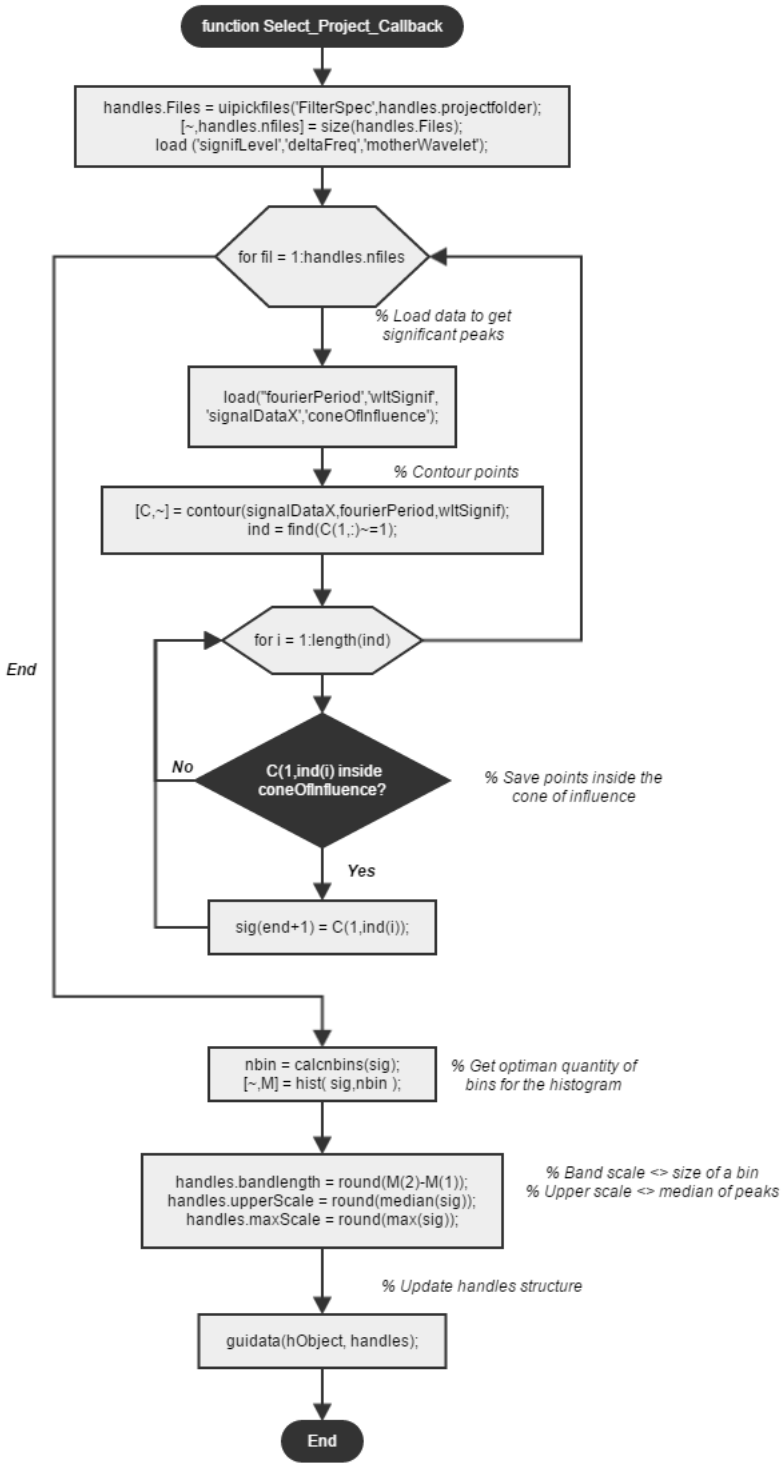

Figure 7.9: function select project callback

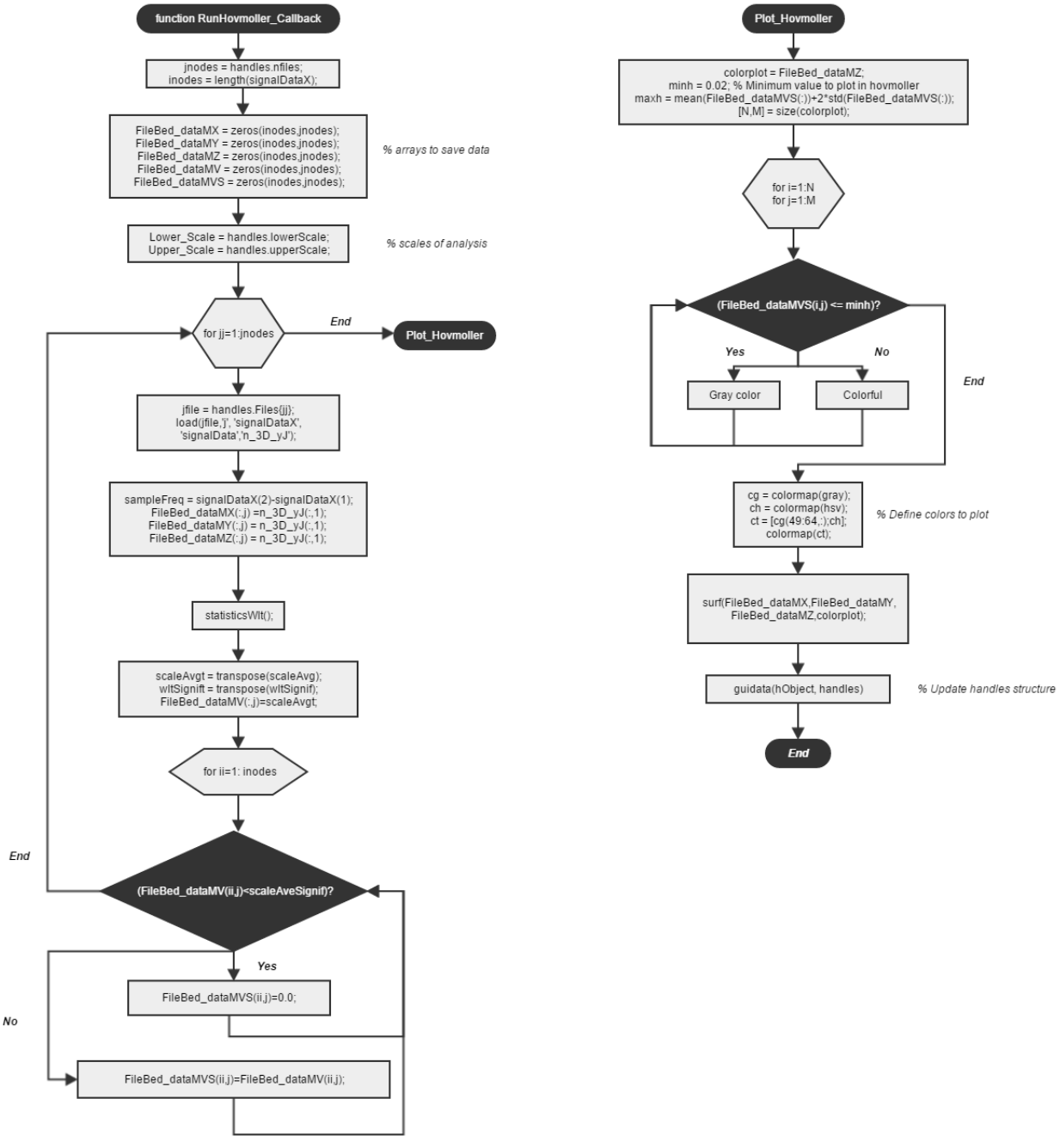

Figure 7.10: runhovmoller callback

7.3 Scale Based Discrimination

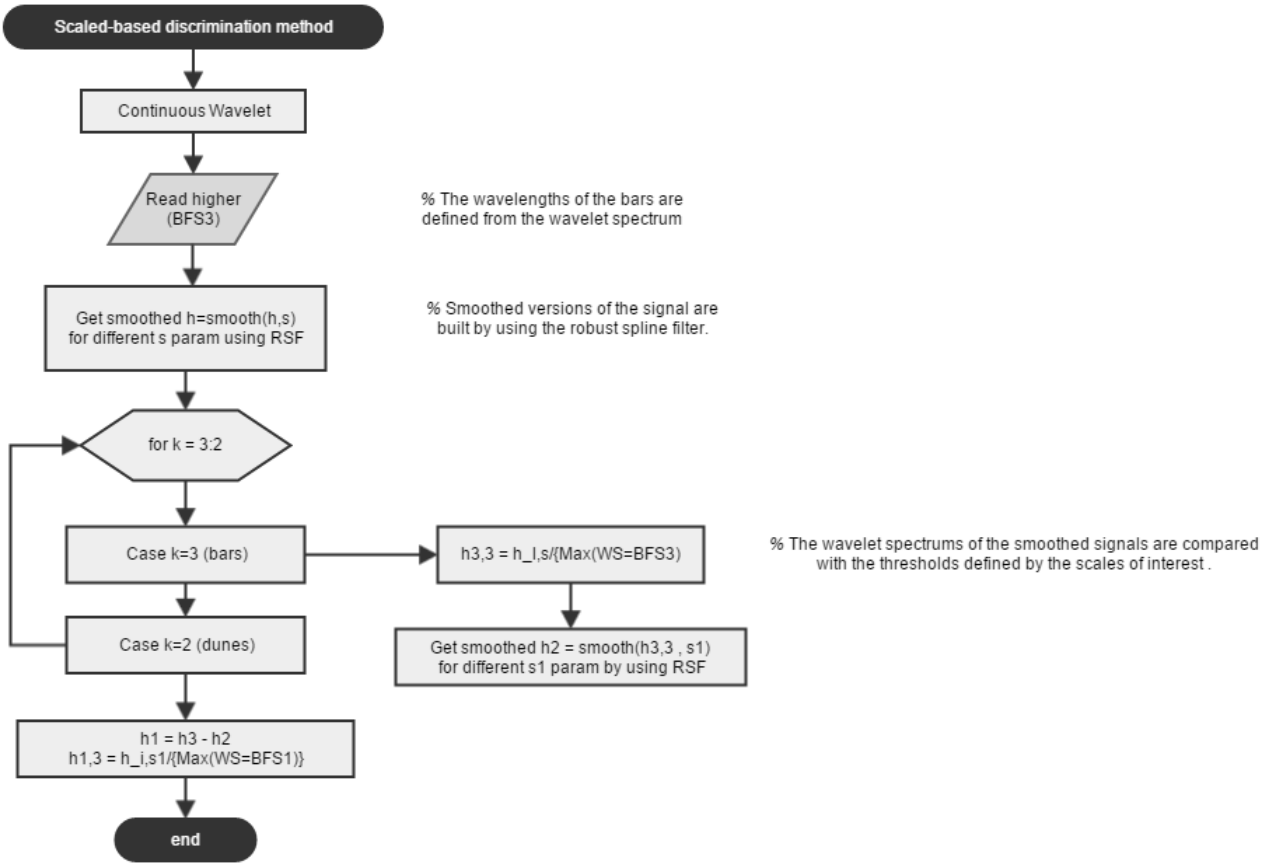

Figure 7.11: Chart flow of discrimination app

7.4 3D Analysis

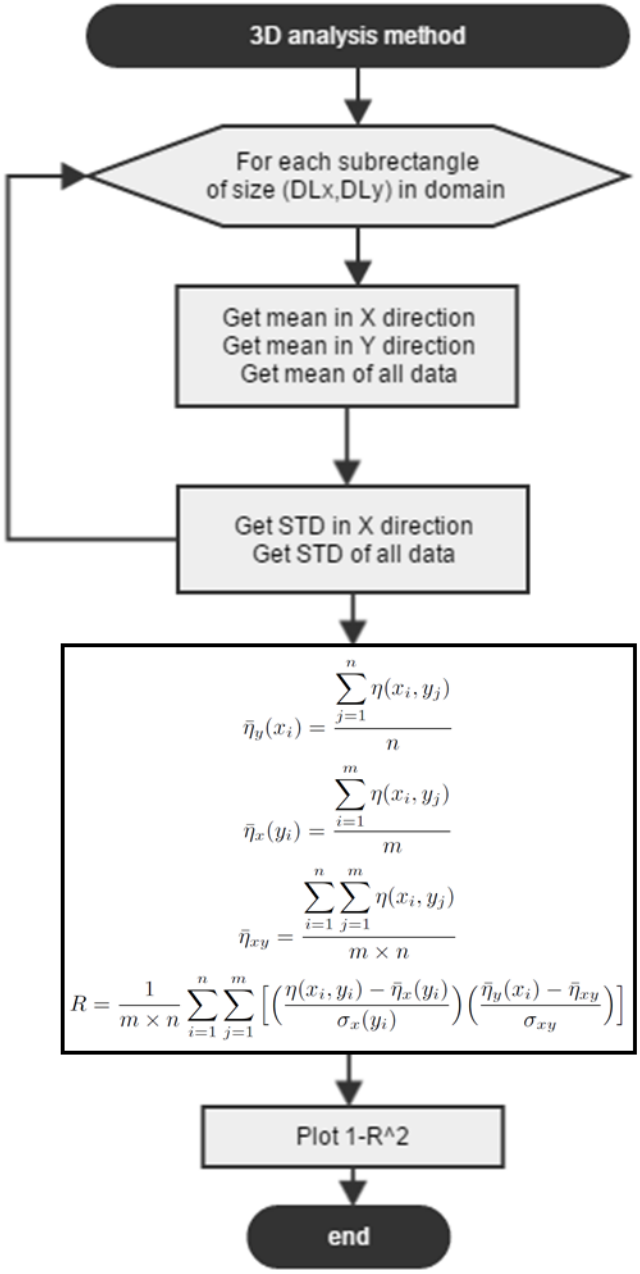

Figure 7.12: Chart flow of 3D analysis app