

NPL REPORT MS 12

MADAT v5.1 Software Manual

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February 2011

MADAT v5.1 Software Manual

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ISSN 1754-2960

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1 INTRODUCTION

1.1 STRUCTURE AND PURPOSE OF THIS DOCUMENT

This document is the manual associated with the MADAT software v 5.1. It aims to define the capabilities and limits of the software and to guide users through the GUIs and menus that control the software.

The introduction defines the purpose of the software and identifies its limitations and potential problems with the software.

The second section specifies the contents and the format of the various data files required to run the software.

The third section gives a detailed walk-through of the software, explaining the various different ways in which the software can be used. This section should be followed the first few times that the software is used, to ensure that the user understands what information each GUI is requesting.

The fourth section gives a summary or reminder of the contents of section 3 that is aimed at guiding more experienced users through the running of the software. It does not contain details and is not intended for novice users.

It should be noted that the structure of the software has changed significantly since v4.0 and so even experienced users may need the full walk-through initially.

1.2 THE PURPOSE OF THE MADAT SOFTWARE

The MADAT software processes and visualises multi-angular measurement data acquired by the Gonio RAdiometric Spectrometer System (GRASS). GRASS is capable of acquiring spectral measurements (i.e. a range of wavelengths) as digital numbers from a series of different spectrometers, and these measurements can be used to calculate the bidirectional reflectance factor (BDRF, BRDF, or reflectance R) of a target.

The measurement points effectively lie on the surface of a hemisphere, so that each measurement point is defined by a zenith angle between 0° and 90° and an azimuth angle between 0° and 360° . The measurements gathered at each point are stored in separate files, each file containing the spectral measurements for a single point. The software can merge data sets taken at different times and held in different directories, provided that the angular definitions are consistent and the only repeated measurements are at nadir (zenith = 0).

For some spectrometers, the measurements at different wavelengths require different normalisations to make them directly comparable. The relevant normalisation coefficients are supplied in the data file headers and are automatically read in and used by the software.

Reflectance calculations require two sets of these measurements: one set using the target of interest and one set using a calibrated panel. There are two ways of supplying the panel measurements made on site: either a full set of measurements taken at the same angular positions as the target measurements must be given, or a single measurement of the panel at nadir (zenith = 0) can be given along with a set of coefficients that generate measurement values at other angles. and a single column of calibration coefficients. The required file formats for the various sets of coefficients are given in section 2 of this document.

The MADAT software reads in the measurement data and the locations at which the data were gathered for the target and the panel, and if required it then calculates the reflectance R at each wavelength from

$$R_t(\theta_i, \varphi_i; \theta_r, \varphi_r) = \frac{f_t(\theta_i, \varphi_i; \theta_r, \varphi_r)}{f_p(\theta_i, \varphi_i; \theta_r, \varphi_r)} R_p(\theta_i, \varphi_i; \theta_r, \varphi_r) \quad (1)$$

where (θ_r, φ_r) are the incident light angles, (θ_i, φ_i) are the reflected angles, $f_t(\theta_i, \varphi_i; \theta_r, \varphi_r)$ is the measured digital number of the target at the point (θ_r, φ_r) , $f_p(\theta_i, \varphi_i; \theta_r, \varphi_r)$ is the measured digital number of the panel at the point (θ_r, φ_r) , and $R_p(\theta_i, \varphi_i; \theta_r, \varphi_r)$ is the calibrated reflectance of the panel which is a function of wavelength and incident and reflected zenith angle (interpolated from values supplied by the user). Note that this formula is wavelength dependent although it is not explicitly stated to be so.

If the user is defining the panel measurements from a single panel measurement $f_p(\theta_i, \varphi_i; 0, 0)$, a set of coefficients $c_a(\theta_i, \varphi_i; \theta_r, \varphi_r)$ to correct for different angles and a set of calibration coefficients $c_l(\lambda)$, then the reflectance R is calculated, for a given wavelength, from

$$R_t(\theta_i, \varphi_i; \theta_r, \varphi_r) = \frac{f_t(\theta_i, \varphi_i; \theta_r, \varphi_r)}{f_p(\theta_i, \varphi_i; 0, 0)} c_l(\lambda) c_a(\theta_i, \varphi_i; \theta_r, \varphi_r). \quad (2)$$

The angular correction coefficients and the panel measurements are not explicitly dependent on the incident angles (θ_i, φ_i) , and it is important that the user ensures that the measurement and the correction coefficients are fit for purpose given the incident angles.

If required, the calculated values can be plotted against wavelength at each measurement point. If repeated measurements were taken at nadir (zenith = 0) then these measurements can be output to a spreadsheet to investigate the repeatability of the measurements. The full set of results at the measurement points can be output to a spreadsheet.

Linear interpolation and extrapolation techniques are used to generate approximated digital number or reflectance values at 1° intervals in the azimuth and zenith directions. The user can opt to interpolate between the first and last azimuth points or can restrict the visualisation and subsequent calculations to the region containing measurement values alone.

The resulting surface can be visualised in two or three dimensions, and line plots of the variation across a diameter can be created. All of the plots can be restricted to show only the interpolated zenith values (extrapolation beyond the final zenith measurement can lead to unrealistic and unphysical values which distort the visualisation). If the measurements lie entirely between azimuth angles of 0 and 180 or between 180 and 360, the data can be reflected to create a symmetric plot. The 2d plots are shown as line contours and filled contours, and the values at which the line contours are plotted can be controlled by the user.

Once the initial data set has been processed, the user can choose subsets of the measurement points and corresponding data values to be processed and visualised in the same way. The interpolated and extrapolated values at each point on the 1° grid from the full and partial data sets are compared, and a value of the sum of squares of the absolute errors caused by using a partial set, S^2 , is calculated, where

$$S^2 = \sum_{j=1}^N (R_f(\theta_i, \varphi_i; \theta_{r,j}, \varphi_{r,j}) - R_p(\theta_i, \varphi_i; \theta_{r,j}, \varphi_{r,j}))^2,$$

where R_f is the value of the BRF calculated from interpolation of the full data set, R_p is the value of the BRF calculated from interpolation of the partial data set, and $(\theta_{r,j}, \varphi_{r,j})$ is the j th point in the 1° grid. The value of S^2 is written to a text file, along with the number of points in the subset and their angular positions. If the processing of subsets is carried out on results that have not been interpolated to form a full circle in the azimuth direction, any subset MUST contain the first and last azimuth lines. If this

restriction is not obeyed, the software will crash because the full and partial data sets will not be the same size.

1.3 DATA STRUCTURE AND CORRECTIONS

This software has been developed to work with ASD Field Spec data or V-SWIR data.

The ASD measurement instrument generates digital numbers optimised over the VNIR spectral region (350-1000 nm). The data are corrected for dark current over VNIR within the instrument's software, but the other wavelengths are not corrected. The instrument software outputs the integration time over VNIR and the gains and offsets over the other two regions (SW1 and SW2) to the data file header. The regions SW1 and SW2 are typically 1000-1800 nm and 1800-2500 nm respectively, but the actual splice values are supplied by the user during the running of the software described in this document. The software described in this document reads the integration time t_{int} and the gains g_1 and g_2 from the file header and applied the following data normalisations to the digital number (DN) before further processing:

$$DN(\lambda) = \begin{cases} DN(\lambda)/t_{\text{int}} & \lambda \in \text{VNIR}, \\ DN(\lambda)/(2048/g_1) & \lambda \in \text{SW1}, \\ DN(\lambda)/(2048/g_2) & \lambda \in \text{SW2}. \end{cases}$$

The V-SWIR data are corrected for integration time and gains before output and so no normalisation is carried out. The data files include downwelling data. The downwelling data are read and the variation over time of the measured downwelling at the wavelength closest to 550 nm is plotted for the user. The downwelling data is taken from target and panel measurements.

1.4 LIMITATIONS AND POSSIBLE PROBLEMS

The software cannot currently calculate radiance values. The options are present in the GUIs in order to make future development simple, but at present the calculations are not possible since no format has been set for the camera calibration coefficient data.

Matlab appears to have an occasional problem displaying windows for choosing a directory or a file name. The problem typically occurs the first time that MADAT is run in a given Matlab session. Every effort has been made to avoid such problems, but until a cause is found it is possible that a session may crash. If this occurs, please attempt to restart MADAT, and if the problem recurs please contact the person responsible for this software (Louise Wright, 1/3/11).

The panel calibration coefficients are linearly interpolated in incident angle, reflected angle, and wavelength to generate values for the required solar zenith angle, reflected angles, and wavelengths. If linear interpolation is likely to be insufficient to fully characterise the panel, the user should ensure that enough values are available to characterise the panel correctly. Alternatively, the user can supply a file defining a typical shape for the dependence of the panel calibration coefficients on wavelength along with the measured calibration coefficients, and the software will find the best offset that fits the shape to the measurements and use the shifted shape for subsequent calculations. The shape will be linearly interpolated with respect to wavelength if a required wavelength is not a specified point.

Each wavelength at which a panel calibration coefficient is measured must have exactly one value of the panel calibration coefficient associated with it for each pair of incoming and outgoing angles. The linear interpolation routine used in the software cannot handle functions with multiple values at one wavelength. Similarly the shape file must have one measurement value per wavelength.

Note that throughout this manual, if a stated requirement uses the word “must”, then the software will either crash or generate inaccurate results. This is particularly true of the required contents and formats of the various data files. The author of the software is not responsible for any problems associated with results generated by data files that do not satisfy the stated requirements, nor for an inability to generate results due to data files not satisfying the stated requirements.

2 BEFORE USING THE SOFTWARE

2.1 INPUT FILES REQUIRED BY THE SOFTWARE

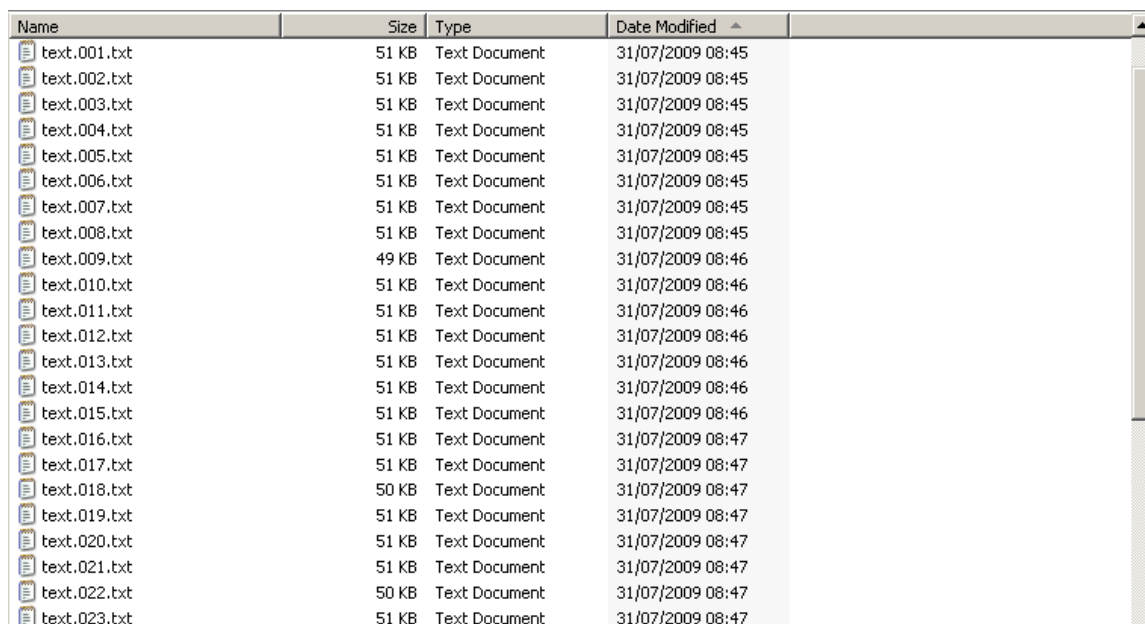
The various ways of using MADAT require different input files. This section discusses the various files required to run the software in each way.

2.1.1 Measurement data files: single or multiple groups of data

As was stated in section 1, the software reads in measurement data made on site from a set of text files. The full set of text files can be arranged in different groups of data sets, each group stored in a different directory. The requirements outlined in this section apply to each directory that contains data files. If BRF is to be calculated from multiple panel measurements, there must be the same number of groups of target data as panel data.

Each directory containing data files (target or panel) to be read should contain a set of text files (one from each camera) containing the measured values, and a single comma separated value (csv) file linking the file number, the angular position of the camera, and the camera number. The csv file need not end “.csv”, but must be in the required file format as explained below. All of the files (target and panel, whether there are multiple or single panel measurements) containing measurement values must conform to one of the two file naming conventions described below.

Two naming conventions are used for the text files containing the measured values. Files must have names either of the form *Fname.nnn.txt*, or of the form *Fnamennn.asd.txt*. In both cases, *Fname* is a string common to all of the data files within a folder and *nnn* is a three-digit number, including leading zeroes if necessary. The user is asked to supply *Fname* for each group of data sets when the software is run, and must also identify the csv file associated with each data set linking the different values of *nnn* with the camera positions. A typical example of file named using the first convention is shown in figure 1. Here *Fname* is “text”. The numbers *nnn* need not be consecutive. Note the leading zeroes.



Name	Size	Type	Date Modified
text.001.txt	51 KB	Text Document	31/07/2009 08:45
text.002.txt	51 KB	Text Document	31/07/2009 08:45
text.003.txt	51 KB	Text Document	31/07/2009 08:45
text.004.txt	51 KB	Text Document	31/07/2009 08:45
text.005.txt	51 KB	Text Document	31/07/2009 08:45
text.006.txt	51 KB	Text Document	31/07/2009 08:45
text.007.txt	51 KB	Text Document	31/07/2009 08:45
text.008.txt	51 KB	Text Document	31/07/2009 08:45
text.009.txt	49 KB	Text Document	31/07/2009 08:46
text.010.txt	51 KB	Text Document	31/07/2009 08:46
text.011.txt	51 KB	Text Document	31/07/2009 08:46
text.012.txt	51 KB	Text Document	31/07/2009 08:46
text.013.txt	51 KB	Text Document	31/07/2009 08:46
text.014.txt	51 KB	Text Document	31/07/2009 08:46
text.015.txt	51 KB	Text Document	31/07/2009 08:46
text.016.txt	51 KB	Text Document	31/07/2009 08:47
text.017.txt	51 KB	Text Document	31/07/2009 08:47
text.018.txt	50 KB	Text Document	31/07/2009 08:47
text.019.txt	51 KB	Text Document	31/07/2009 08:47
text.020.txt	51 KB	Text Document	31/07/2009 08:47
text.021.txt	51 KB	Text Document	31/07/2009 08:47
text.022.txt	50 KB	Text Document	31/07/2009 08:47
text.023.txt	51 KB	Text Document	31/07/2009 08:47

Figure 1: Example of files named using the first convention.

If the full data set is created from several different groups of data sets, the naming convention must remain the same in all directories, but the names and file numbers can be repeated or can vary from

directory to directory. The only restrictions are that the definitions of the angular positions must be consistent across the directories and that there can be repeated measurements only at nadir (zenith=0).

2.1.2 Measurement data file contents

All files must contain GPS location and timing information in the following form:

- o A line starting “GPS-Lat” containing the latitude, written as ddmm.mmm, where dd is the degrees of latitude and mm.mmm is the minutes.
- o A line starting “GPS-Lon” containing the longitude, written as ddmm.mmm, where dd is the degrees of longitude and mm.mmm is the minutes.
- o A line starting “GPS-Alt” containing the altitude in m.
- o A line starting “GPS-UTC” containing the date and UTC time. The date must be written ddmmyy where dd is the day, mm is the month and yy is the last two digits of the year (assumed to be after 2000). The UTC time must be written hhmmss.sss where hh is the hour in the 24 hour clock, mm is the minutes, and ss is the seconds.

The relevant lines are highlighted in green in figure 2. The spectrometer files use N/S and E/W to denote the direction of position measurement.

Text file saved by the NPL GRASS instrument Version 0.3 beta

```
-----
The instrument number was 6401
New ASD spectrum file: Program version =N\A file version = N\A
Spectrum saved: 7/31/2009 at 9:45:09 AM
VNIR integration time : 544 ms
VNIR channel 1 wavelength = 350.0 wavelength step = 1
There were 25 samples per data value
xmin = 350.0 xmax= 2500.0
ymin= -63.857422 ymax= 1403.997925
The instrument digitizes spectral values to 16 bits
SWIR1 gain was 16 offset was 2059
SWIR2 gain was 16 offset was 2081
Join between VNIR and SWIR1 was 1000 nm
Join between SWIR1 and SWIR2 was 1830 nm
VNIR dark signal subtracted
25 dark measurements taken 7/31/2009 9:44:52 AM
DCC value was 0
Data is not compared to a white reference
The GRASS foreoptic attached
Spectrum file is raw data
GPS-Latitude is 5125.4747 N
GPS-Longitude is 20.5476 W
GPS-Altitude is 18.8
GPS-UTC is 310709 084447.176
```

```
Wavelength Data
350.000000 4.494263
351.000000 0.603638
352.000000 -1.138306
```

Figure 2: A typical ASD data file with key features highlighted.

Each ASD data file must contain the following features:

- o A line starting “VNIR i” that contains the VNIR integration time,

- o A line starting “SWIR1” that includes the gain for region SW1,
- o A line starting “SWIR2” that includes the gain for region SW2,
- o A set of pairs of wavelength and measured digital number separated by a space, starting on the line directly after the first line in the header that starts “Wavelength”.

An example of a data file is shown in figure 2, with the key lines highlighted in yellow. This type of file is automatically generated by the instrument software, but if the instrument software is updated then these key features must be retained if the software described in this document is to be compatible with the new output.

The V-SWIR files must contain the GPS information as defined above and must also contain three columns of data: wavelength, upwelling and downwelling. The data must start directly after the first line beginning “Wavelength”. An example, with key points highlighted in blue, is shown in figure 3.

Text file saved by the NPL NERC GRASS instrument Version 0.4 beta

```

-----
The instrument number was 00
NERC VSWIR spectrum file: Program version =N\A file version = N\A
Upwelling and Downwelling Spectra saved: 8/23/2010 at 6:44:18 PM
VNIR Upwelling integration time : 0.500000
VNIR channel 1 wavelength = 395.7 wavelength step = 3
There were 10 samples per data value
xmin = 395.7 xmax= 1729.0
ymin= -40.000000 ymax= 27582.500000
The instrument digitizes spectral values to 16 bits
SWIR Upwelling Integration time: 0.400000
SWIR Downwelling Integration time: 0.350000
VNIR Downwelling Integration time: 0.350000
Offset was 0
Join between VNIR and SWIR1 was 900.53 nm
Join between SWIR1 and SWIR2 was 1728.99 nm
Spectra dark signal subtracted
10 dark measurements taken
DCC value was 0
Data is not compared to a white reference
The GRASS foreoptic attached
Spectrum file is raw data
GPS-Latitude is 3847.2922 N
GPS-Longitude is 3324.8081 E
GPS-Altitude is 907.5
GPS-UTC is 230810 184419.000

```

Wavelength	Up Data	Dn Data
395.723385	26.000000	245.714286
396.843200	26.000000	257.142857
397.962681	26.000000	271.428571
399.081827	24.000000	300.000000

Figure 3: A typical V-SWIR data file with key features highlighted.

No splices or normalisation coefficients are required for the V-SWIR files.

The file linking angular position, file number *nnn*, and camera number, need not have a name that ends in csv but must be a comma separated value file. It must have a header row (in most cases this will identify the order of the data so that the file is readable for the user), and then it must give four quantities for each measurement file, separated by commas. In order, these are the camera name, the zenith angle, the azimuth angle, and the file number. The information for each file must be on a different row. An example of the start of a file is shown in figure 4. A file of this type must exist for each directory containing target or panel data to be read by the software.

```

Camera name,Zenith Angle,Azimuth Angle,File number
4.0,0,270,001
1.1,10,180,002
1.2,20,180,003
1.3,30,180,004

```

Figure 4: The first few lines of a typical csv file linking camera number, angular position, and file number.

This file provides the easiest way to filter out any unsuitable data: if a file number is not listed, the file will not be read by the software. Hence any invalid measurements from one or more cameras can be removed by deleting the relevant line from the csv file.

2.1.3 Calculating panel digital number values from a single nadir measurement.

If the panel digital number values are to be calculated from a single set of measurements taken at the nadir (zenith=0) and a set of coefficients, three files are required:

- o a single measurement data file of the form given in section 2.1.2, with a name following one of the naming conventions described in section 2.1.1,
- o a file called “PanelBRDFCoeff.csv”, the form of which is defined below,
- o a file containing a single column of calibration coefficients.

The file “PanelBRDFCoeff.csv” contains the angular correction coefficients, c_a in equation (2) of section 1.1. The coefficients form an $nwave$ by $npts$ array, where $nwave$ is the number of wavelengths at which measurements are made and $npts$ is the number of target measurement positions. The file format is

- o First line contains a header that can be used to identify the coefficients. This must be present even if it is a dummy header.
- o Second line contains a comma-separated list of azimuth angles. These must correspond exactly to the azimuth angles at which target measurements were made.
- o Third line contains a comma-separated list of zenith angles. These must correspond exactly to the zenith angles at which target measurements were made.
- o Subsequent $nwave$ lines contain the coefficients. The i th line contains the comma-separated angle correction coefficients for the i th wavelength. The coefficients are listed in the order specified by the azimuth and zenith angles in the first two lines, so that the j th entry in the i th row is the angle correction coefficient for the i th wavelength at the j th zenith and azimuth point as given by the first two rows.

The angles can be listed in any order, provided there is a one-to-one correspondence between the measurement points and the angles in the headers. The rows must be listed in the same order as the wavelengths in the measurement data file. It is expected that the coefficients in the file “PanelBRDFCoeff.csv” are all of order of magnitude 1 (or smaller).

The file containing calibration coefficients can have any name. The coefficients must be in a single column, separated by carriage returns. The values of the coefficients are expected to be close to 1 rather than close to 100. If the values are close to 100, the results displayed subsequently will be two orders of magnitude too large. There must be exactly one coefficient per wavelength and the coefficients must be listed in the same order as the wavelengths are listed in the data files.

2.1.4 General panel calibration coefficients file format

If the BRF is to be calculated in the case where there are multiple panel measurements, a set of panel calibration coefficients are required. These coefficients must be supplied by the user in the format described in this chapter.

The calibration coefficients are expected to take values close to 1 rather than close to 100. Calibration coefficients are assumed to be independent of azimuth angle and so each coefficient relates to a specified incident zenith angle, reflected zenith angle, and wavelength.

Linear interpolation is used to obtain coefficients for the required incident (solar zenith) angle and the required reflected angles and wavelengths. If the panel is likely to exhibit behaviour that cannot be captured by linear interpolation, this behaviour should be captured by the data given in the calibration coefficient file.

The data are grouped within the file such that measurements gathered at the same pair of incident and reflected angles at different wavelengths are kept together. Each group of data is headed by the incident and reflected angles and is then listed as pairs of wavelength and the associated calibration coefficient. The groups of data are separated by blank lines.

The values measured at different angles need not be measured at the same wavelengths: the software interpolates linearly to obtain calibration coefficients at the required wavelengths.

The first line of the file must be a single number specifying how many groups of data (i.e. pairs of incident and reflected angles) the file contains. The rest of the data file consists of groups of data separated by carriage returns. An example showing the start of a typical file containing six data sets, including the first two data sets and the angles of the third set, is shown in figure 5. Blank lines are intentionally blank. Pairs of incident and reflected angles are highlighted in yellow. Incident angle is listed first throughout.

```
6
30, 0
409, 1.0454
501, 1.0428
600, 1.0431
700, 1.0431
801, 1.0432
904, 1.0430
1001, 1.0426
```

```
37, 0
409, 1.0289
501, 1.0311
600, 1.0313
700, 1.0312
801, 1.0313
904, 1.0305
1001, 1.0304
```

```
47, 0
```

Figure 5: Opening part of a calibration coefficients file.

Incident angle is equivalent to solar zenith angle for on-site measurements, and reflected angle is equivalent to the zenith angle at which on-site measurements were made.

If no shape file is supplied by the user, then interpolation of the panel calibration coefficients is carried out in three stages. Linear interpolation is used throughout. Extrapolation is not used: instead a nearest neighbour approach is used. For instance, if the first wavelength at which coefficients have been gathered is 450 nm, then all wavelengths below 450 nm will be assumed to have the same coefficient value as was measured at 450 nm. An identical approach is taken with regard to interpolation with respect to zenith angle: angular values outside of the range at which calibration coefficients were measured are assigned the measured value at the nearest measured angle.

The first interpolation step is that the data gathered at each pair of incoming and outgoing angles is interpolated linearly with respect to wavelength so that an appropriate coefficient exists for every wavelength at which on-site measurements were made.

Next, the incoming angles are compared to the solar zenith angle. If the solar zenith angle lies between two of the available incoming angles, the coefficients generated at those incoming angles in the first interpolation step are interpolated with respect to outgoing angle so that an interpolated value is created at every zenith angle at which on-site measurements were made. If the solar zenith angle is smaller than the smallest incoming angle or larger than the largest incoming angle, then only the data measured at the smallest or largest (as appropriate) incoming angles are interpolated with respect to the outgoing angle.

In all cases, if only one outgoing angle is available for a given incoming angle then no interpolation takes place and it is assumed that the calibration coefficient takes the measured values for all outgoing angles.

The third interpolation step takes the effects of the solar zenith angle into account. If the solar zenith angle is between two of the incoming angles at which coefficients have been measured, linear interpolation is used between the two sets of results generated in the previous step to generate a set of calibration coefficients for all wavelengths and zenith angles that have been measured on site. If the solar zenith angle is smaller than the smallest incoming angle or larger than the largest incoming angle then the single set of interpolated values created in the previous step are returned as the interpolated coefficients.

It is clear from the account of the interpolation process that the quality of the results is strongly dependent on the angles and wavelengths at which the calibration coefficients are measured. If it is likely that linear interpolation without extrapolation is insufficient to characterise the panel behaviour, a suitable characterisation should be used outside of MADAT to generate estimates of calibration coefficients that MADAT can then interpolate linearly. Alternatively, the user could supply a shape file to describe the dependence of the calibration coefficients on the wavelength in addition to the measured calibration coefficients.

The file format for the shape file is two columns of numbers separated by a space. Each line consists of a wavelength and the corresponding shape value. Shape values, since they are effectively calibration coefficients, must have values around 1 rather than values around 100.

The software fits the contents of the shape file to the measured calibration coefficients by allowing the shape coefficient values to shift by a constant amount. The shift is calculated to minimise the root mean square difference between the measured calibration coefficients and the shifted shape value at the same wavelengths. The optimal shift is determined separately for each pair of incoming and outgoing angles. Suppose that a set of calibration coefficients $c_1, c_2, \dots, c_N$ were measured at a set of wavelengths $\lambda_1, \lambda_2, \dots, \lambda_N$, for a fixed pair of incoming and outgoing angles, and suppose that the shape function $S(\lambda)$ has values $S_1, S_2, \dots, S_N$ at the wavelengths $\lambda_1, \lambda_2, \dots, \lambda_N$. Then the software finds a value of k such that the sum

$$\sum_{i=1}^N (c_i - S_i - k)^2$$

is minimised. The minimum is given by

$$k = \frac{1}{N} \sum_{i=1}^N (c_i - S_i).$$

The calibration coefficients then used for that pair of angles in subsequent interpolations is then $S(\lambda)+k$, and a different value of k is determined for each pair of incoming and outgoing angles. The shape may be linearly interpolated between wavelengths if a value is required for a wavelength that is not one of the $\lambda_1, \lambda_2, \dots, \lambda_N$.

2.1.5 Important requirements and restrictions

If the full set of data is gathered from multiple directories, there must not be any points, other than possibly the nadir, at which more than one measurement has been made. The easiest way to omit measurement data files from the calculations (and hence avoid such repetitions) is to edit the file linking file number and angle: any data file not referenced in the linking file will not be read by the software.

If the BRF is being calculated and there are multiple panel measurements, the panel measurements must be made at exactly the same angles as the target measurements. Any difference will result in either odd results (if there are the same number of measurements taken at different angles) or a software crash (if there are different numbers of panel and target measurements). Similarly the wavelengths at which the two sets of measurements are gathered must be identical.

If the BRF is being calculated from a single panel measurement, there must be an angle correction coefficient for every combination of (azimuth, zenith, wavelength) at which a measurement is made and a calibration coefficient for every wavelength.

All calibration coefficients are expected to have values close to 1 (rather than close to 100). For a given pair of angles, there can be at most one calibration coefficient per wavelength.

2.2 RESTRICTIONS ON THE MEASUREMENTS

Ideally, the measurement data should be recorded on a grid of points on the hemisphere with each ring of measurements at a given zenith angle occurring at the same azimuth angles. The software can handle deviations from this ideal, but ideally the data set should only have a few points missing from the regular grid.

The measurement data may include multiple points gathered at nadir (zenith = 0). The software handles cases with zero, one, or multiple points separately, and if multiple points are used then an average value is displayed during visualisations.

The software makes a complete list of all azimuth and zenith angles at which measurements were taken. It then uses linear interpolation in the azimuth direction to create points on a regular grid. As an example, consider the arrangement shown in figure 6. If the filled-in diamonds represent positions at which measurements were made, then the hollow squares represent points at which values would be linearly interpolated between the measured values at zenith = 20°.

This approach means that there must not be any value of the zenith that only has one azimuth measurement point, other than possibly nadir (zenith=0). If there are any such values, the software will give inaccurate results (because it will interpolate between the wrong values) and may crash.

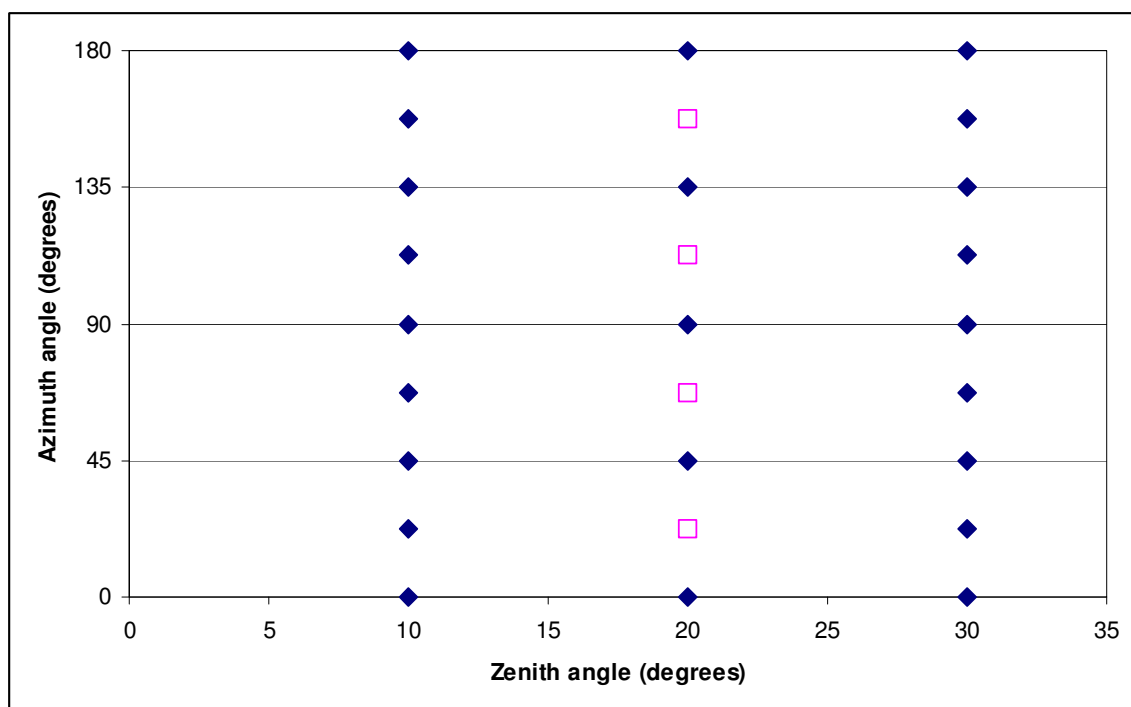


Figure 6: Possible measurement positions.

3 RUNNING THE SOFTWARE

To run the software, double click on the supplied executable. The software uses a set of GUIs to obtain the user input throughout. Most GUIs were designed for a single purpose and will be shown as the software is explained in this section, but two types of GUI recur throughout. The GUI appearing when the user needs to select a file is shown in figure 7, and the GUI that appears when a user needs to select a directory is shown in figure 8. In both cases, the text indicating which file is required is circled in red. In some cases the text may be partially truncated. If that is the case, the user should either expand the window or consult the manual.

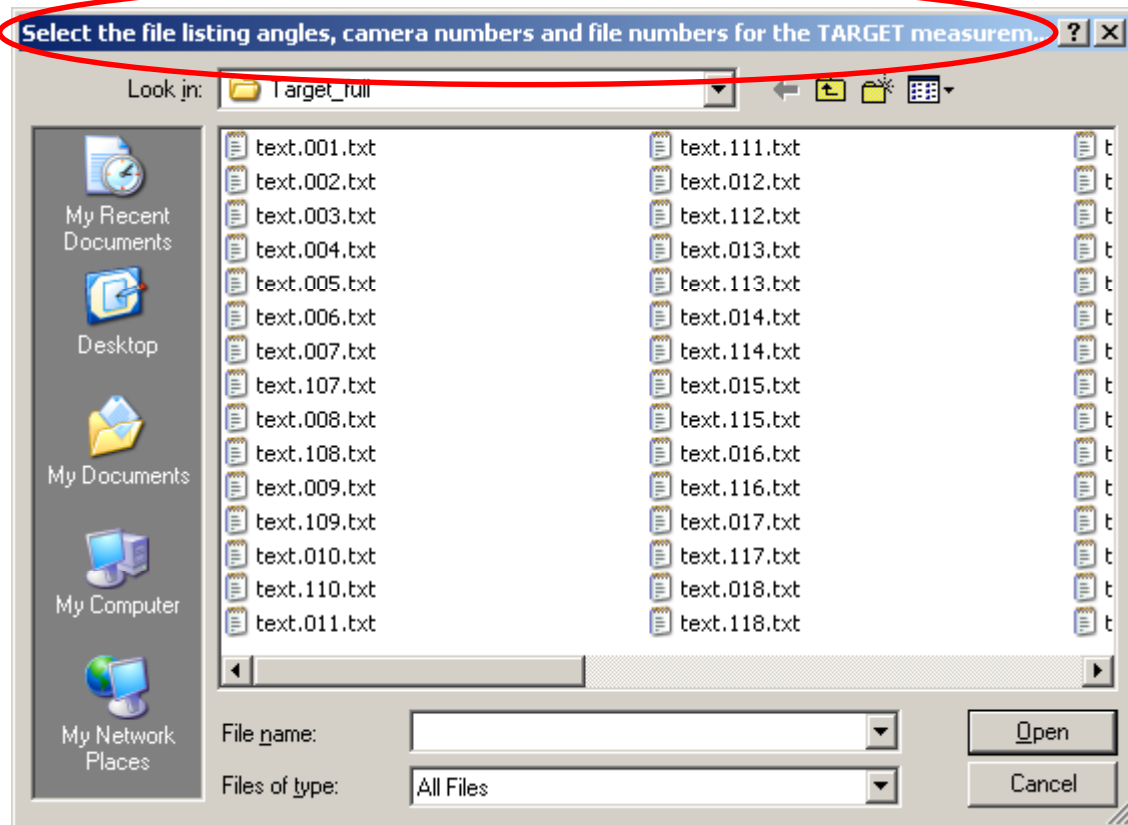


Figure 7: A typical GUI for selecting a file. Circled text indicates which file is required.

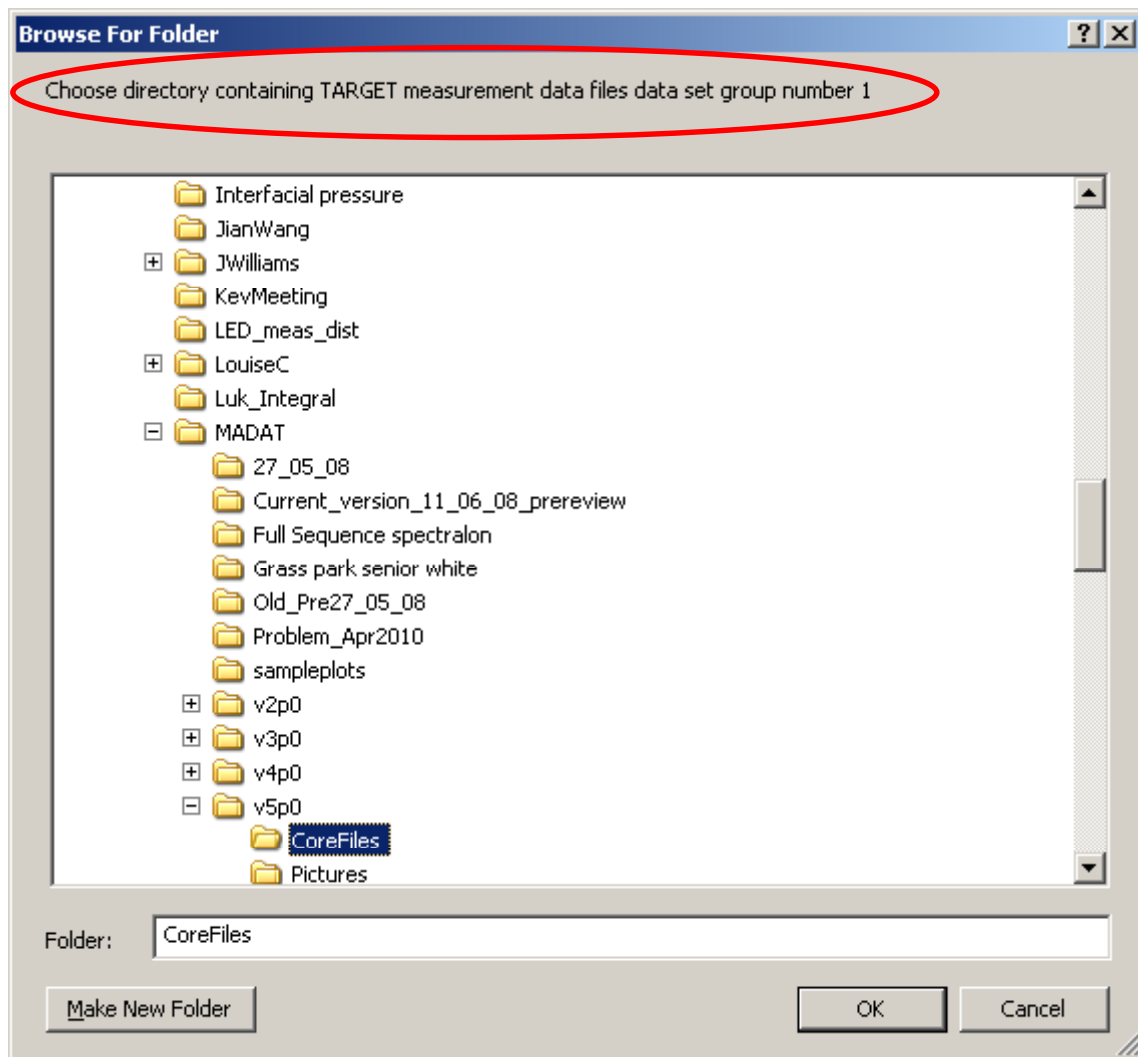


Figure 8: A typical GUI for selecting a directory. Circled text indicates which directory is required.

There are three “paths” through the software that differ significantly in the GUIs displayed. This section of the manual will discuss each path separately to ensure the user understands what is required at each stage. The three paths are:

- o calculation from raw data with multiple panel measurements,
- o calculation from raw data with a single panel measurement, and
- o reloading of a previously processed data set.

In all cases, the software is started by double-clicking on the supplied executable, and the first window the user sees is shown in figure 9. This GUI shows the user which version of the software is being used. If the window does not resemble that in figure 9, the user is not using v5.1 of the software and should consult a different manual. The software continues when the user presses “Run MADAT”.

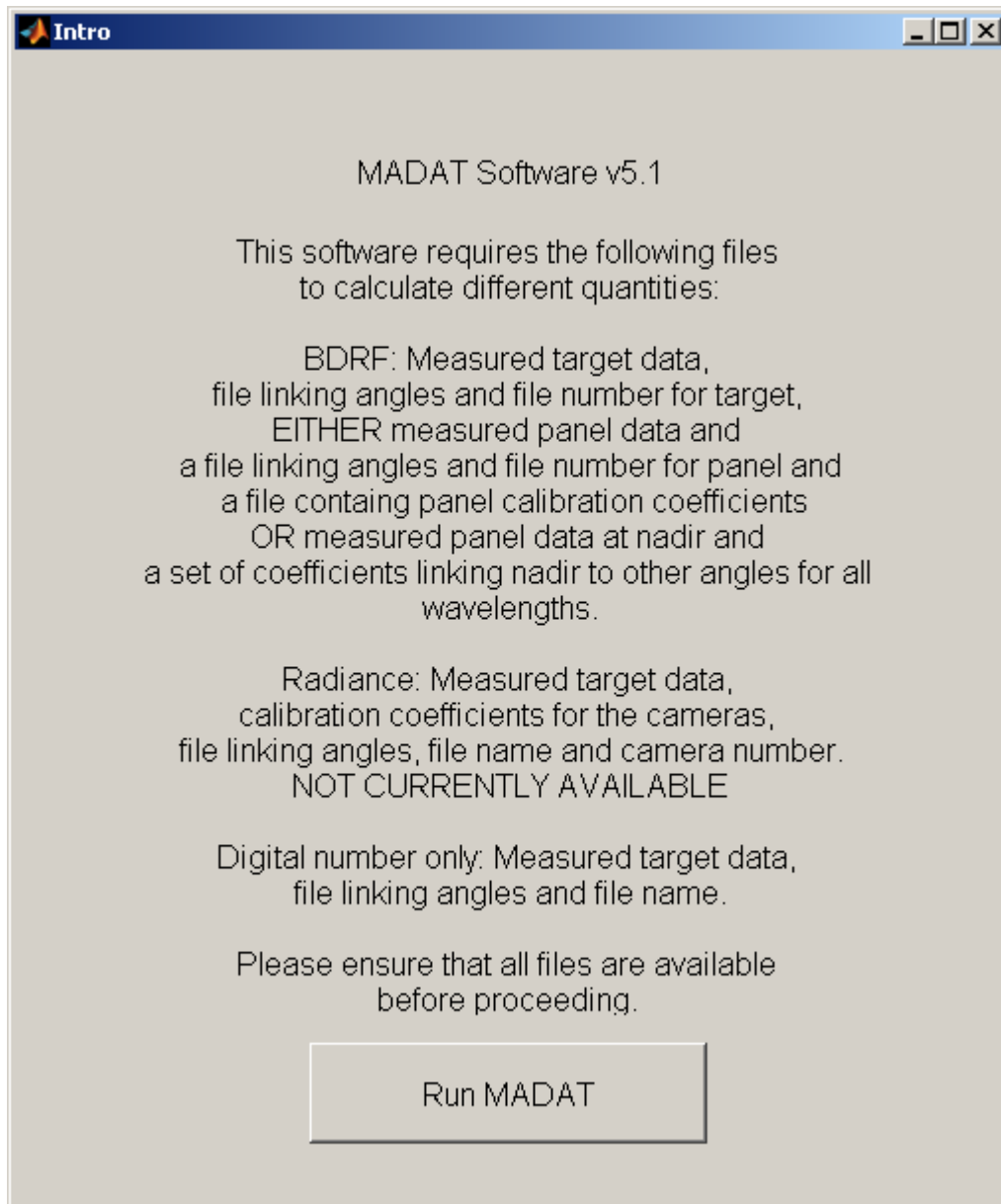


Figure 9: Introductory window.

The next GUI is shown in figure 10. Choosing yes allows the user to revisit old data, for instance to process a different wavelength or to interpolate using different subsets of the data. The data to be reloaded must have been saved by MADAT as a .mat file. Choosing no allows the user to read in a new data set.

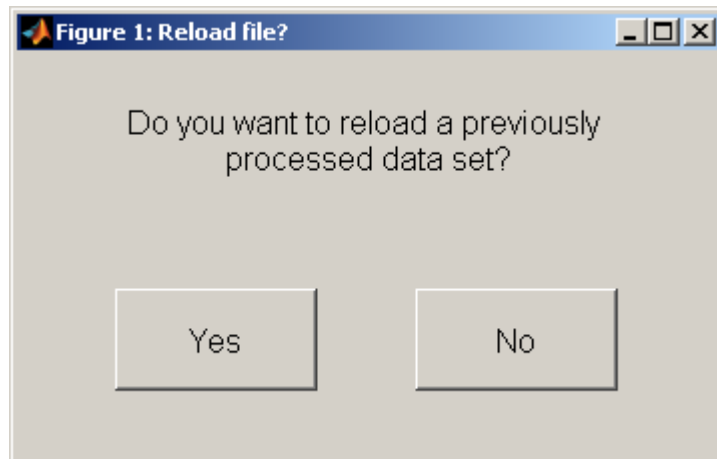


Figure 10: GUI allowing the user to reload previously processed data or to read in new data.

3.1 CALCULATION USING RAW DATA

If the user selects “No” from the GUI shown in figure 10, all subsequent calculations will be carried out using raw data chosen by the user. The next GUI to appear is shown in figure 11. This GUI allows the user to select which quantity is to be calculated from a drop-down menu. If the user chooses radiance, a warning message will be displayed and the user must choose another quantity.

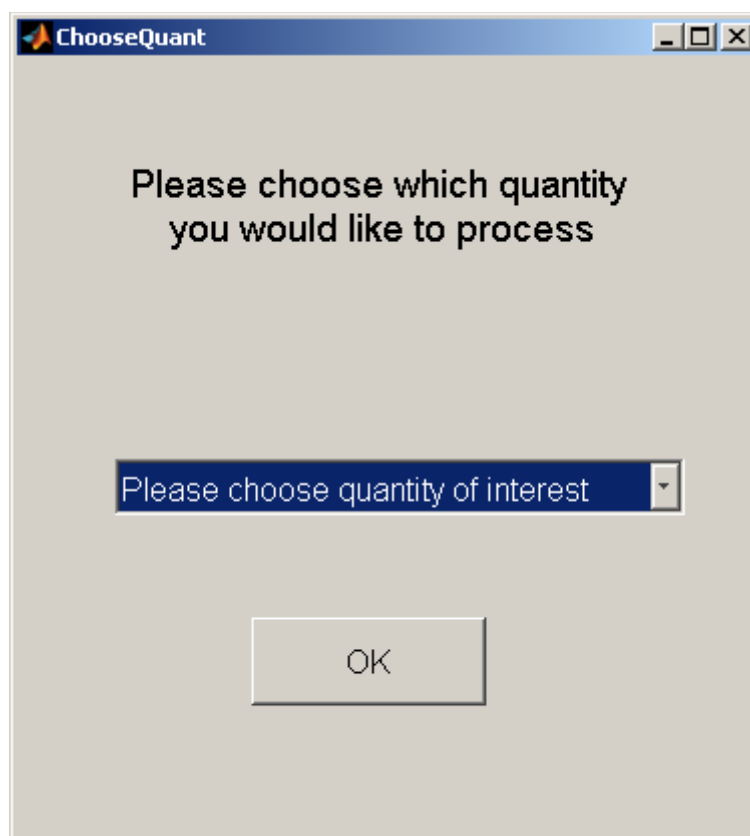


Figure 11: GUI to choose the quantity of interest.

Once the user has selected a quantity of interest, the sensor type is chosen using the GUI shown in figure 12. This GUI has a drop-down menu listing available sensor types.

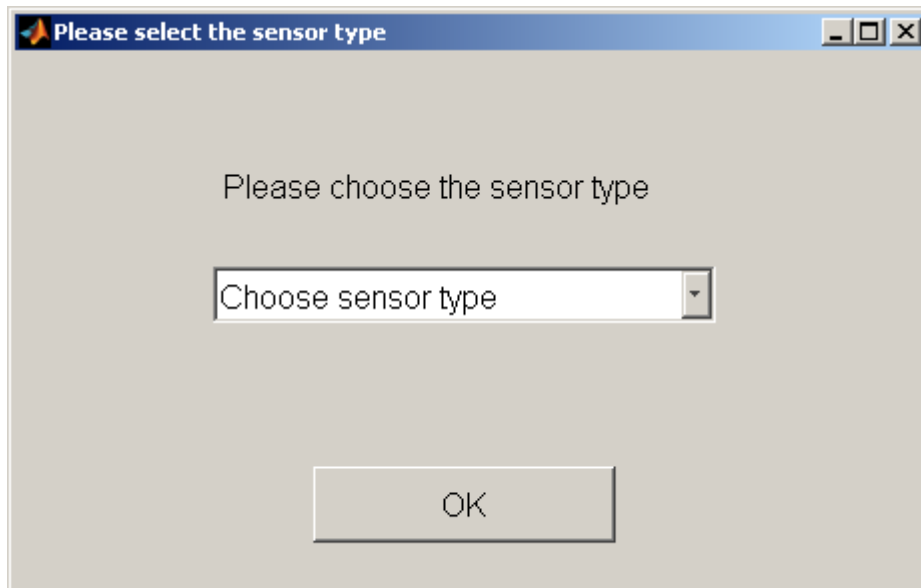


Figure 12: GUI to select sensor type.

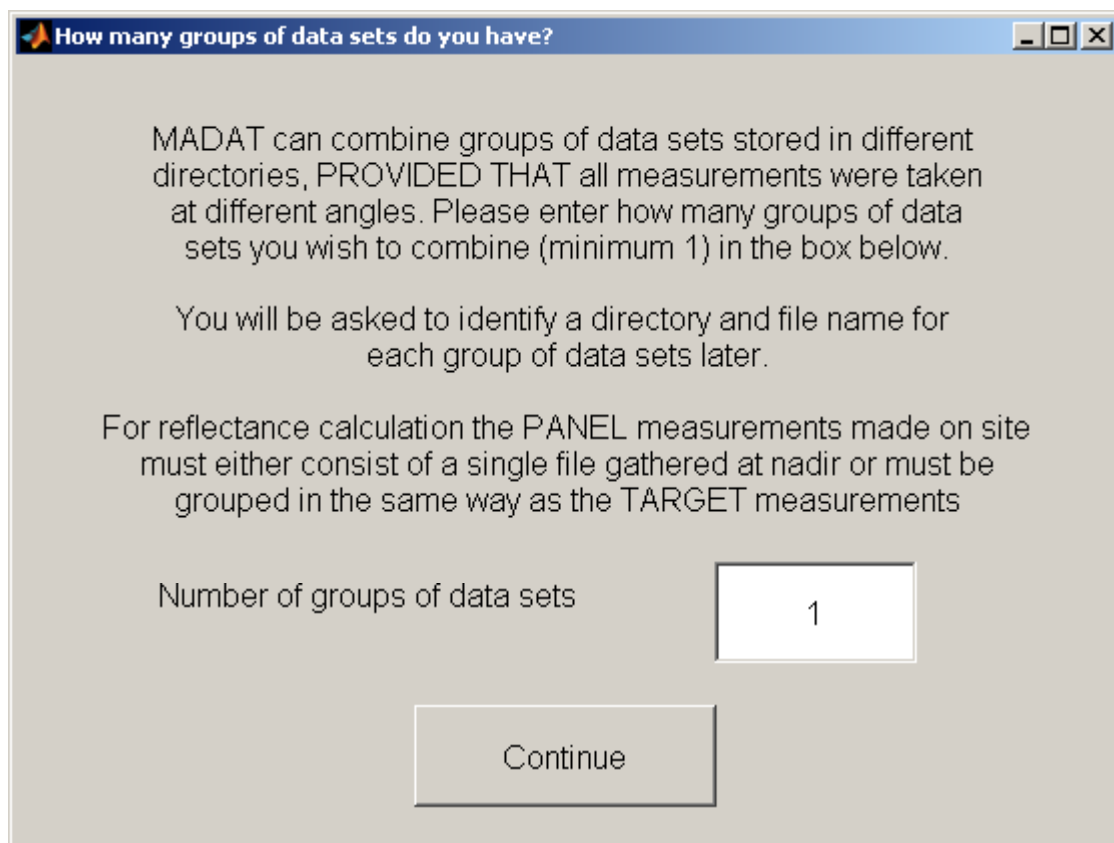


Figure 13: GUI to select the number of groups of files.

Next the user selects how many groups of data files are to be processed using the GUI in figure 13. If BRF is being calculated from multiple panel measurements made on site, there must be the same number of groups of target data sets and panel data sets. Call this number **ngroups**.

Once **ngroups** has been defined, various of the subsequent GUIs are repeated **ngroups** times in order to gather information about the files within each group.

The data file naming convention must remain the same throughout for each type of measurement file. The GUI shown in figure 14 allows the user to choose the convention for the target files.

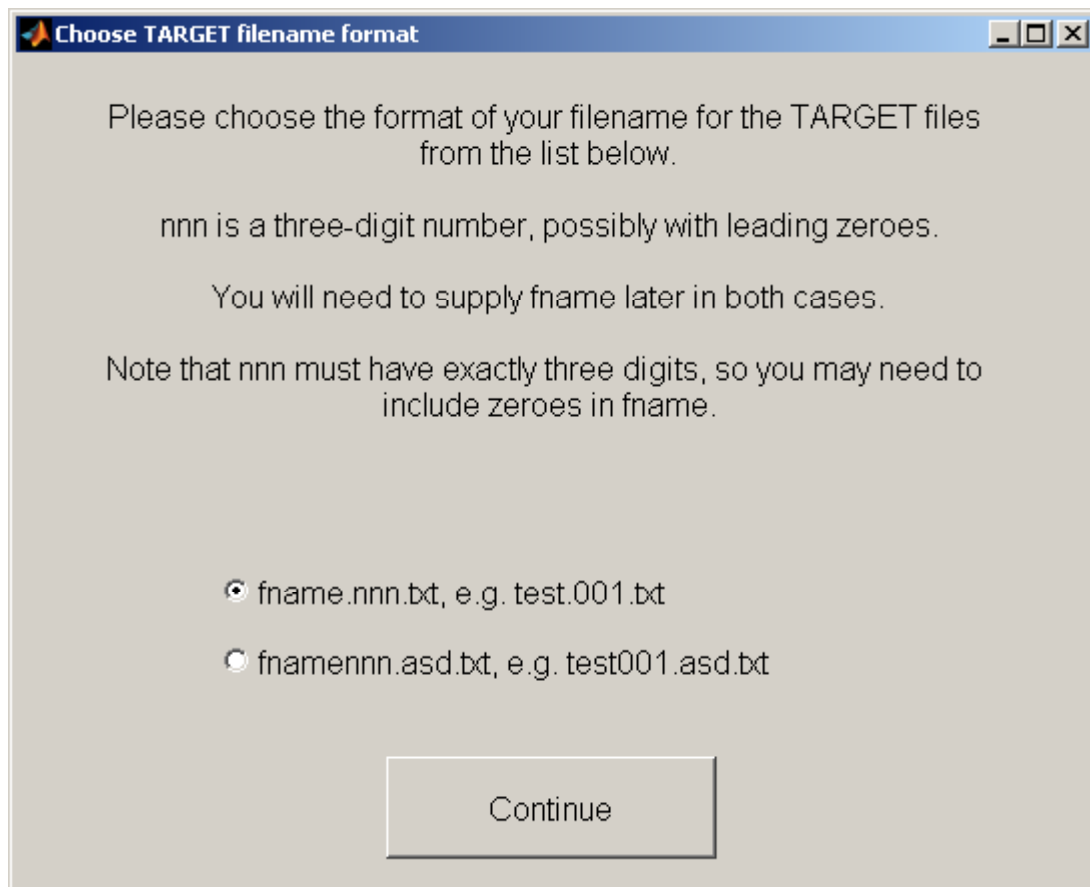


Figure 14: GUI to select target file naming convention.

If BRF is being calculated, the user is then asked to choose whether the panel has been measured on site once (at nadir) or repeatedly (at the same angular positions as the target measurement were made), using the GUI shown in figure 15. This choice determines the path followed later in the software since different sets of coefficients are required for the two options.

Once the file naming convention for the panel files has been selected from the GUI in figure 16, the software repeats the following steps n groups times (n here indicates the number of times the software has performed the repeated steps):

- o Ask the user to select a directory containing the files for the n th group of target data using a GUI similar to that shown in figure 8.
- o Ask the user to supply the main part of the target file names for the n th group of data using the GUI shown in figure 17. The main part of the name can vary between groups of data but it does not have to.

Ask the user to select the csv file linking the angles and file numbers for the n th group of data using a GUI similar to that shown in figure 7.

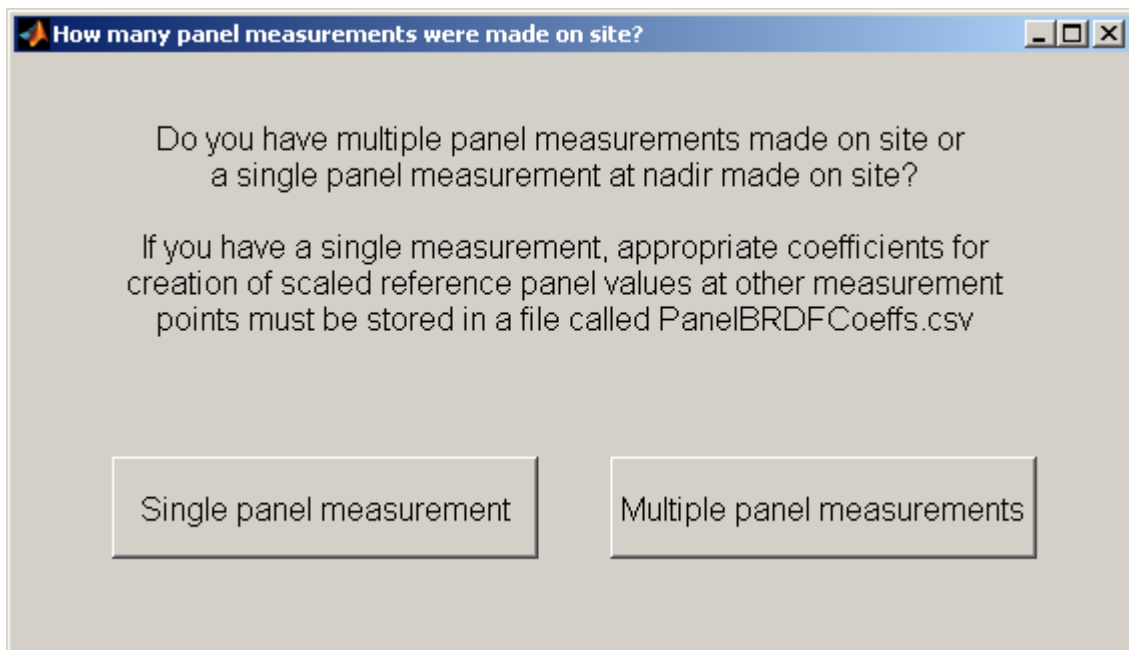


Figure 15: GUI to select single or multiple panel measurements.

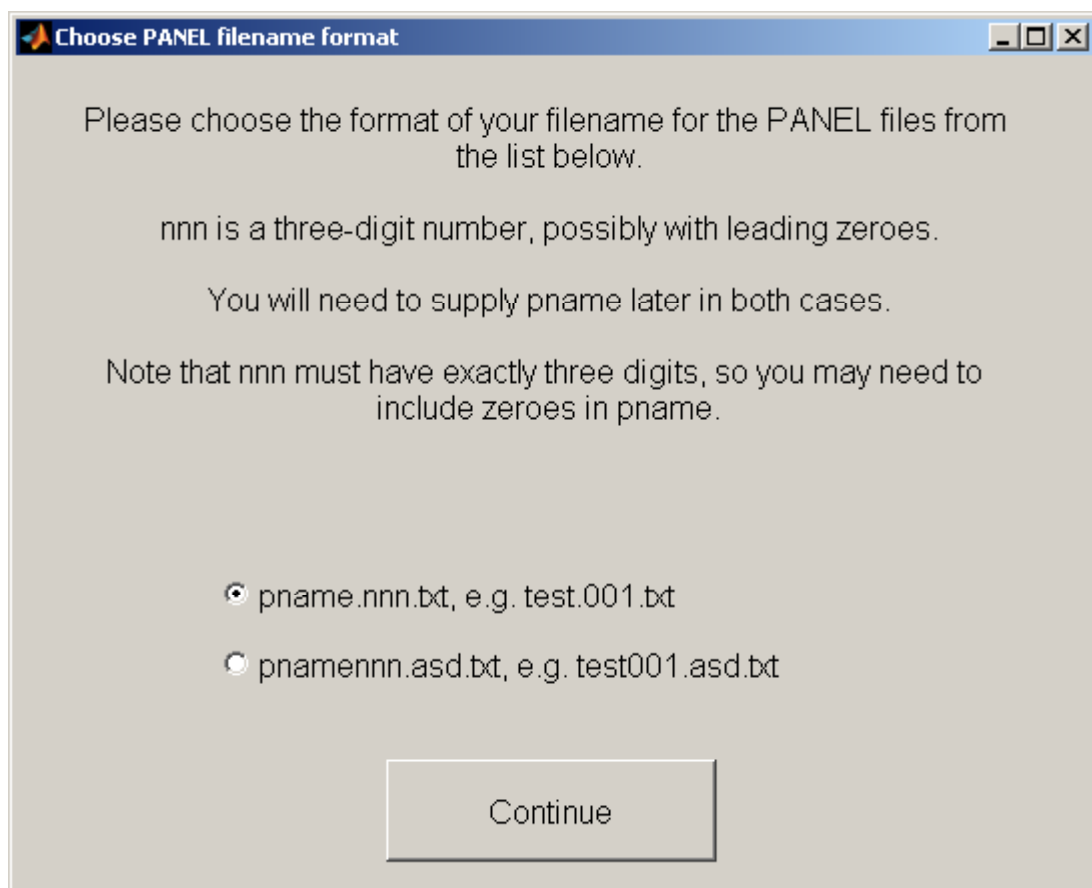


Figure 16: GUI to select panel file naming convention.

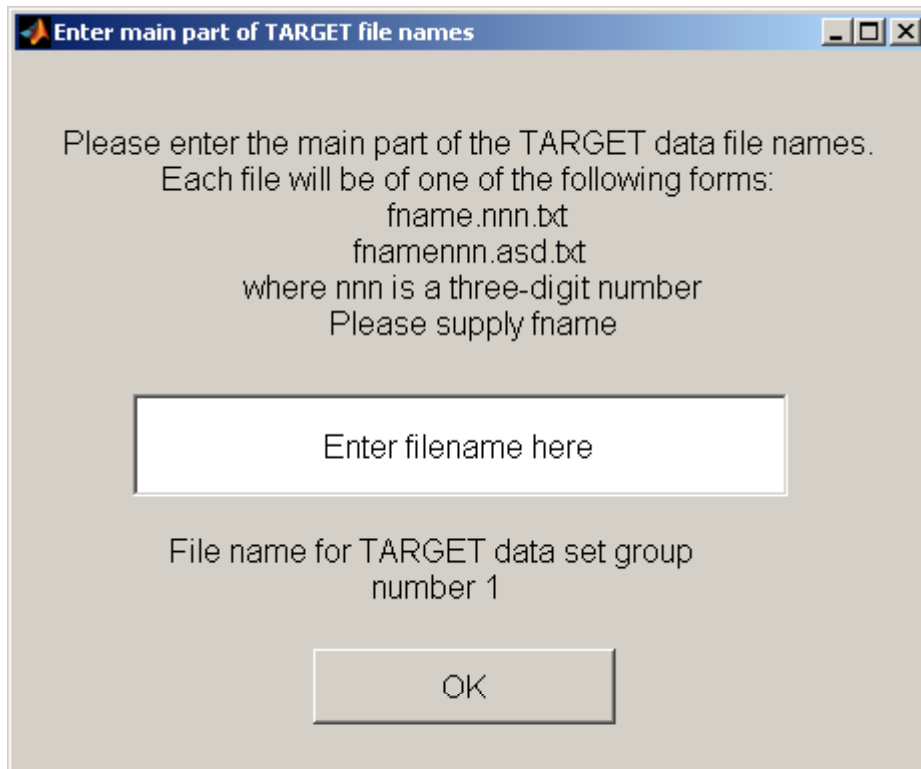


Figure 17: GUI to supply the main part of the target file names.

Once the information has been collected about the target files, similar information is collected about the panel files. For multiple panel measurements, the software repeats the following steps *ngroups* times (*n* here indicates the number of times the software has performed the repeated steps):

- Ask the user to select a directory containing the files for the *nth* group of panel data using a GUI similar to that shown in figure 8.
- Ask the user to supply the main part of the target file names for the *nth* group of data using the GUI shown in figure 18. The main part of the name can vary between groups of data but it does not have to.
- Ask the user to select the csv file linking the angles and file numbers for the *nth* group of data using a GUI similar to that shown in figure 7.

If the user has chosen the option for a single panel measurement, the correct response to the GUI in figure 18 is to enter the full file name of the nadir measurement file without the final .txt or .asd.txt. For this option, the GUI will only appear once and the request for a file linking angles and camera numbers will be replaced by a request to identify the directory containing the file “PanelBRDFCoeff.csv”, as defined in section 2.1.3, using a GUI similar to that shown in figure 8.

Next the software reads in the various angle linking files and re-sorts them into a more suitable form. Any crashes at this point are likely to be caused by the angle linking files being in the wrong place or the wrong format.

Once the files have been read in, the user is asked how they want to obtain the GPS data and solar zenith angle, using the GUI shown in figure 19. If the user reads in the GPS data from the files then the solar zenith angle will be obtained using the routine `sun_position.m` as described in

Reda, I., Andreas, A. (2003) Solar position algorithm for solar radiation application. National Renewable Energy Laboratory (NREL), Technical report NREL/TP-560-34302.

This document is available at www.osti.gov/bridge. (Checked 1/3/11: search for “solar position algorithm”)

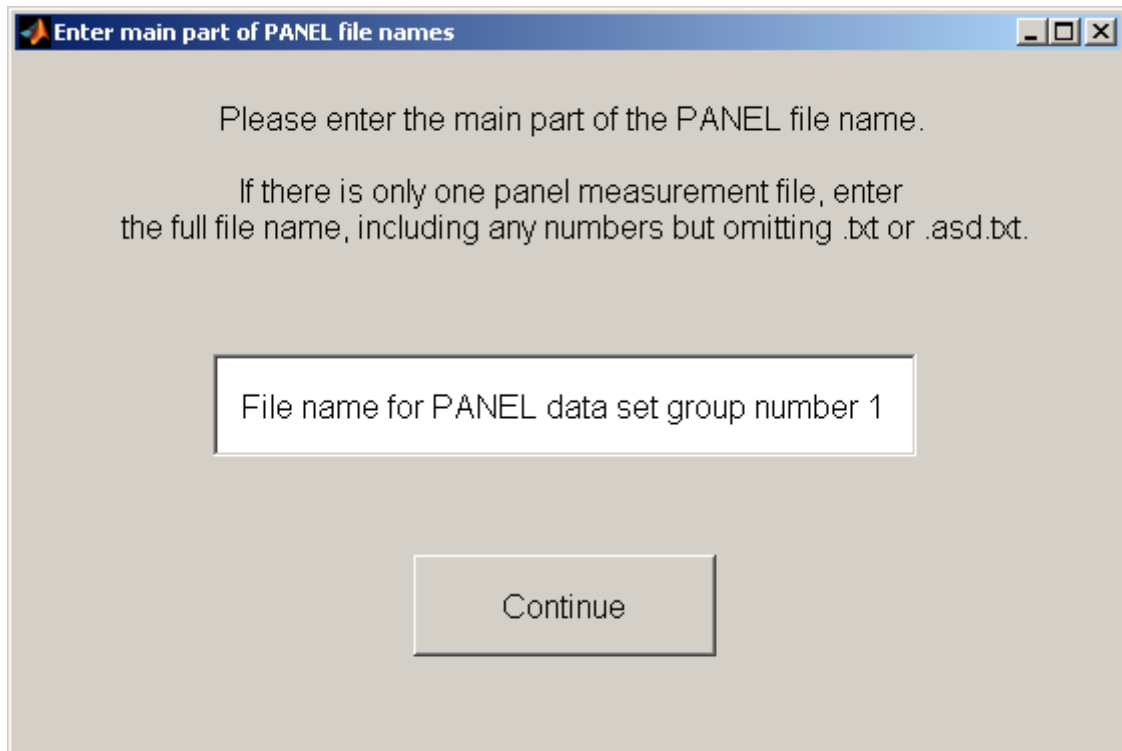


Figure 18: GUI to supply the main part of the panel file names.

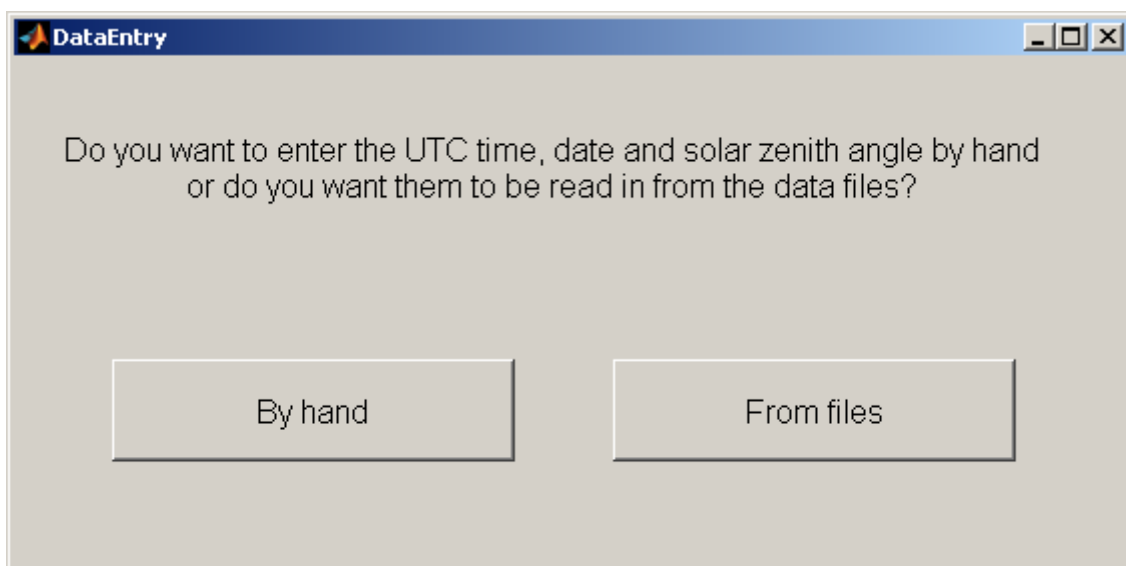
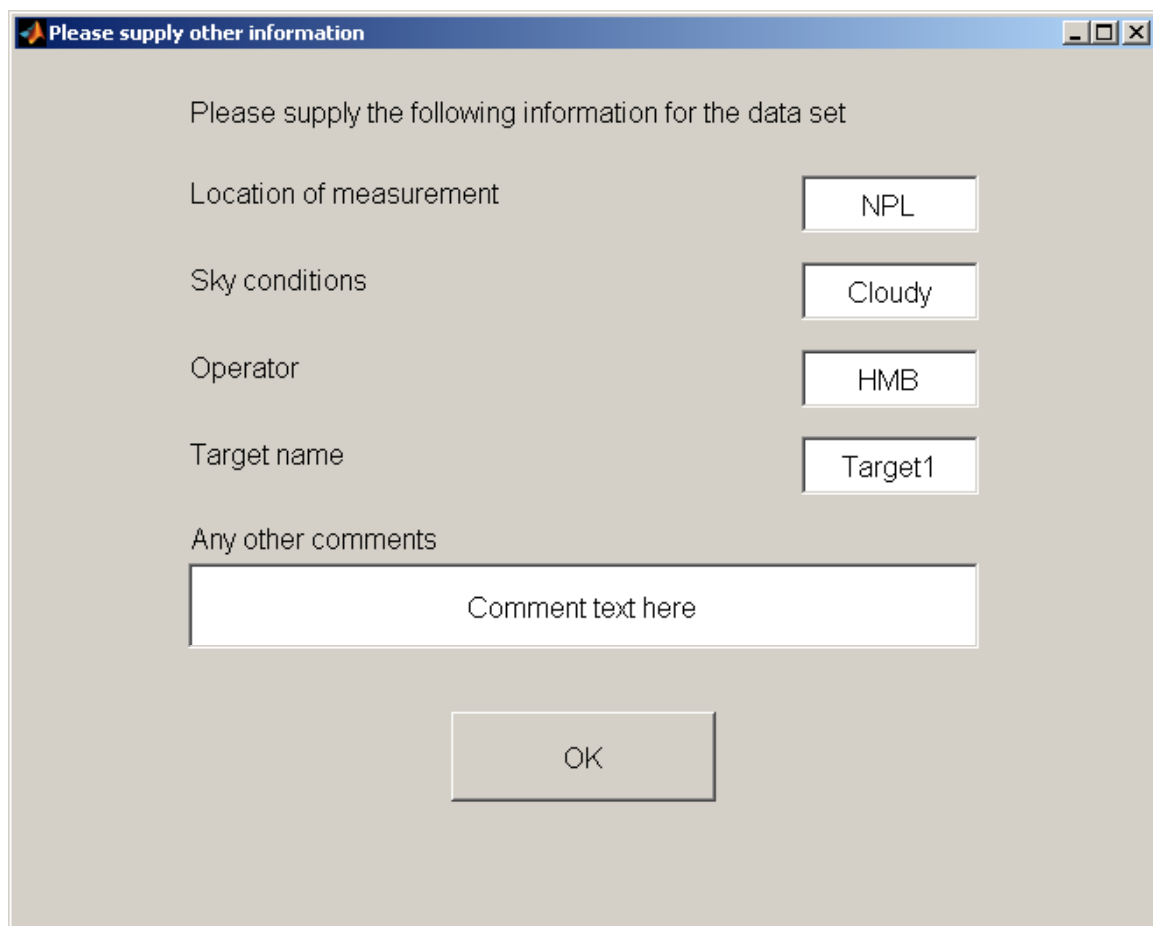


Figure 19: GUI allowing the user to choose how solar zenith angle is to be obtained.

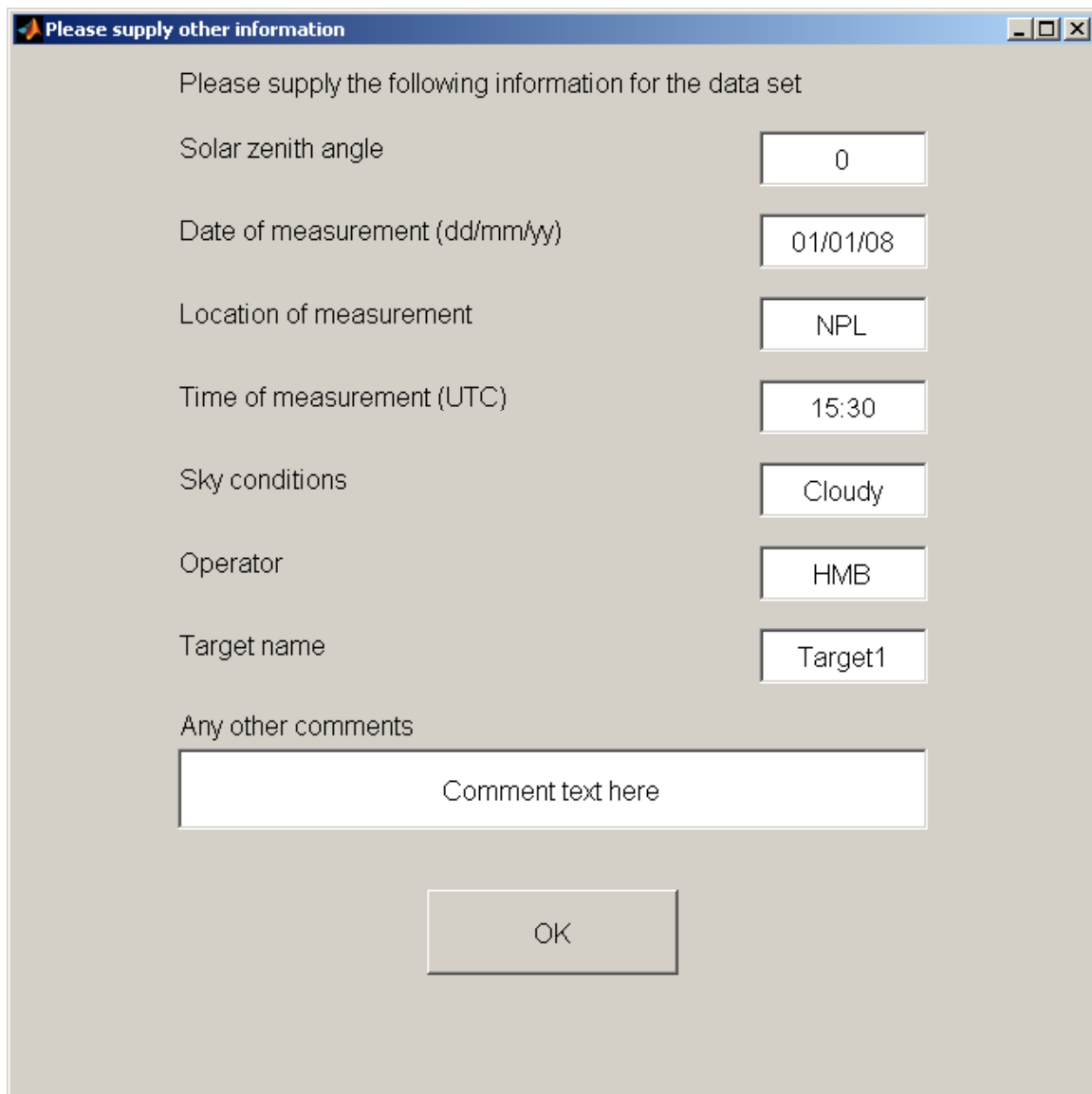
If the user chooses to read the GPS data in from the files, the GUI in figure 20 appears and can be used to add additional comments to the stored data. If the user wishes to input the UTC time, location and solar zenith angle by hand then the GUI shown in figure 21 appears.



The image shows a graphical user interface (GUI) window titled "Please supply other information". The window has a blue title bar with standard window controls (minimize, maximize, close). The main area is light gray and contains the following elements:

- A text prompt: "Please supply the following information for the data set".
- A label "Location of measurement" followed by a text box containing "NPL".
- A label "Sky conditions" followed by a text box containing "Cloudy".
- A label "Operator" followed by a text box containing "HMB".
- A label "Target name" followed by a text box containing "Target1".
- A label "Any other comments" followed by a larger text box containing the placeholder text "Comment text here".
- An "OK" button centered at the bottom of the window.

Figure 20: GUI allowing the user to enter extra information if GPS is read from files.



Please supply the following information for the data set

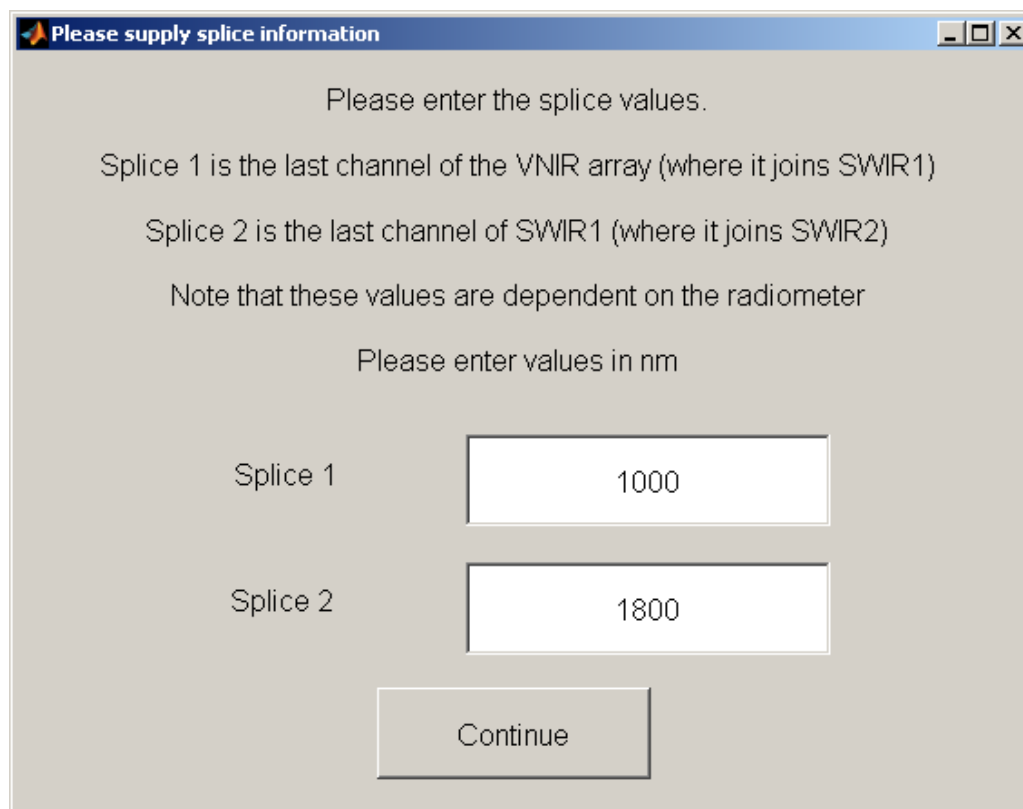
Solar zenith angle	0
Date of measurement (dd/mm/yy)	01/01/08
Location of measurement	NPL
Time of measurement (UTC)	15:30
Sky conditions	Cloudy
Operator	HMB
Target name	Target1
Any other comments	Comment text here

OK

Figure 21: GUI allowing the user to enter UTC time, date, solar zenith angle, and other information.

If ASD sensors are being used, the user is asked for splice points (as described in section 1.3) using the GUI shown in figure 22.

The software then reads in the measurement data files and (if required) the GPS data and downwelling values. If the user has chosen to read the GPS data in automatically, the GPS data are displayed, as shown in figure 23, and the user can choose to edit the data if they are wrong. The editing window is shown in figure 24. If a crash occurs before the GUI in figure 23, the software is likely to have been unable to find one of the measurement data files, or one or more of the files may not follow the requirements stated in section 2, so it is worth rechecking that all files are present and complete.



Please supply splice information

Please enter the splice values.

Splice 1 is the last channel of the VNIR array (where it joins SWIR1)

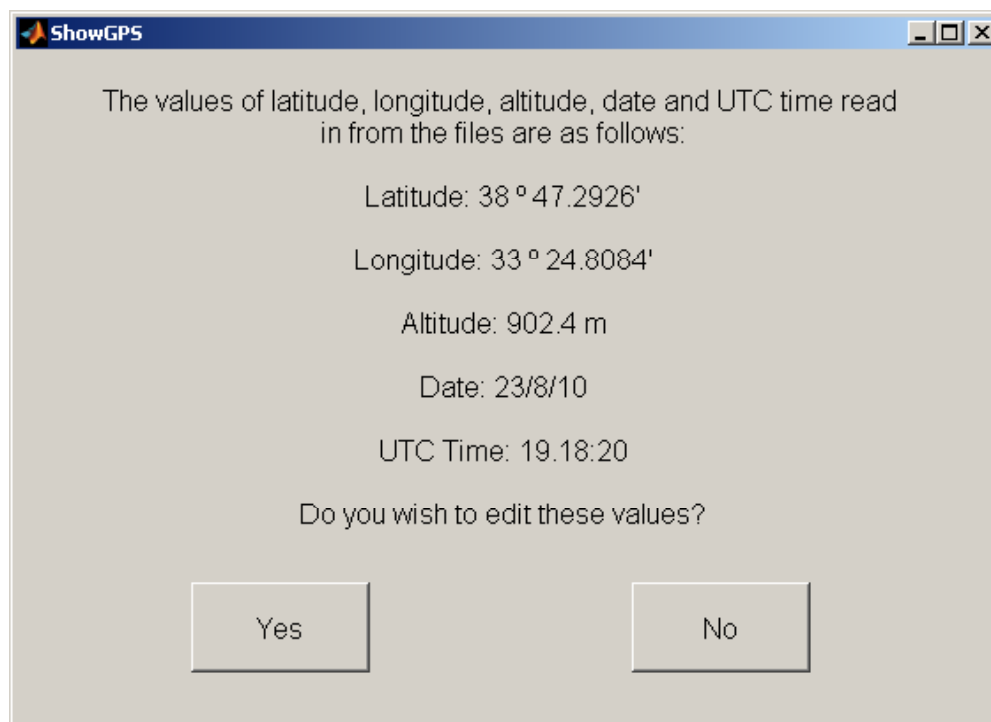
Splice 2 is the last channel of SWIR1 (where it joins SWIR2)

Note that these values are dependent on the radiometer

Please enter values in nm

Splice 1	1000
Splice 2	1800

Figure 22: GUI requesting splice points for ASD data.



ShowGPS

The values of latitude, longitude, altitude, date and UTC time read in from the files are as follows:

Latitude: 38 ° 47.2926'

Longitude: 33 ° 24.8084'

Altitude: 902.4 m

Date: 23/8/10

UTC Time: 19.18:20

Do you wish to edit these values?

Figure 23: GUI displaying the GPS data

The screenshot shows a window titled "EditGPS" with a light gray background. It contains five input fields, each with a label and a text box. The labels are: "Enter latitude in the form ddmm.mmm where dd is degrees and mm is minutes", "Enter longitude in the form ddmm.mmm where dd is degrees and mm is minutes", "Enter altitude in metres", "Enter date in the form ddmmyy where dd is the day, mm is the month, and yy is the year", and "Enter UTC time in the form hhmmss where hh is the hour, mm is the minute, and ss is the seconds". The text boxes contain the values: "3847.2926", "3324.8084", "902.4", "230810", and "191820" respectively. A "Continue" button is located at the bottom center of the window.

Field Label	Value
Enter latitude in the form ddmm.mmm where dd is degrees and mm is minutes	3847.2926
Enter longitude in the form ddmm.mmm where dd is degrees and mm is minutes	3324.8084
Enter altitude in metres	902.4
Enter date in the form ddmmyy where dd is the day, mm is the month, and yy is the year	230810
Enter UTC time in the form hhmmss where hh is the hour, mm is the minute, and ss is the seconds	191820

Figure 24: GUI to edit the GPS data before calculating the solar zenith angle.

If the GPS data is to be edited, the format of the numbers must be correct. The format for each entry is specified in the GUI shown in figure 24, and is the same as the numerical format specified for GPS data in section 2.1.2. The user should compare the information shown in figures 23 and 24 to understand the required format properly: the two figures show the same information.

Once the GPS data has been finalised, the solar zenith angle is calculated if it was not entered by hand. Following this calculation, if the BRF is being calculated, the panel measurements are read in. The details of the GUIs depend on the number of panel measurements and will be described separately. The two paths converge at the plotting of the downwelling data if V-SWIR sensors are used (figure 25), or at the option to output to results at nadir (zenith=0) to a spreadsheet (figure 26) if ASD sensors are used.

3.1.1 Calculations with multiple panel measurements

If the user has selected to use multiple panel measurements taken on site, the only extra coefficients required are a set of panel calibration coefficients as specified in section 2.1.4 of the manual. The user is asked to identify the file containing the coefficients using a GUI similar to that shown in figure 7. The software reads in the measured panel data, asks the user to identify the coefficient file, and reads in the coefficients. The user can then choose to use a shape file for the panel calibration coefficients by clicking yes in the GUI shown in figure 25. The user is then asked to choose a file containing the shape information using a GUI similar to that shown in figure 7.

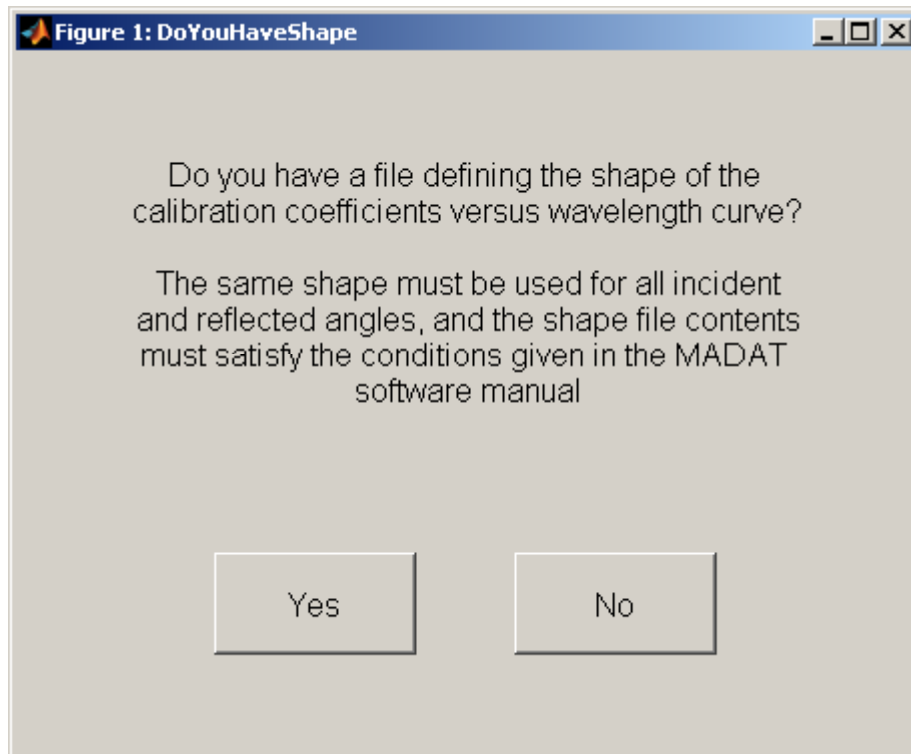


Figure 25: GUI allowing the user to use a shape file to define the calibration coefficients.

If the user has a shape file, a set of calibration coefficients with the correct shape are fitted to the measured values. The coefficients are then interpolated to obtain a set of values appropriate for the measurement zenith angles, the solar zenith angle, and the measurement wavelengths. These values are then used to calculate the BRF.

3.1.2 Calculations with a single panel measurement

The files required to calculate using a single panel measurement made on site were described in section 2.1.3. The required files are a single measurement file (file name supplied via the GUIs shown in figures 16 and 18), a file called “PanelBRDFCoeff.csv”, and a file containing coefficients to calibrate the measurements at nadir with respect to wavelength.

The user has already identified the directory containing the measurement file and its name, as well as the directory containing the file “PanelBRDFCoeff.csv”. When these two files have been read in, the user is asked to identify the file containing the calibration coefficients for wavelength (coefficients c_l in equation (2)) using a GUI similar to that in figure 7. Equation (2) is then used to calculate the BRF.

3.2 OUTPUT AND VISUALISATION OF RESULTS

Once the BRF has been calculated, the software displays the downwelling data if V-SWIR sensors have been used. The plot shows the downwelling data gathered across all measurements plotted against time for the wavelength closest to 550 nm. An example plot is shown in figure 26.

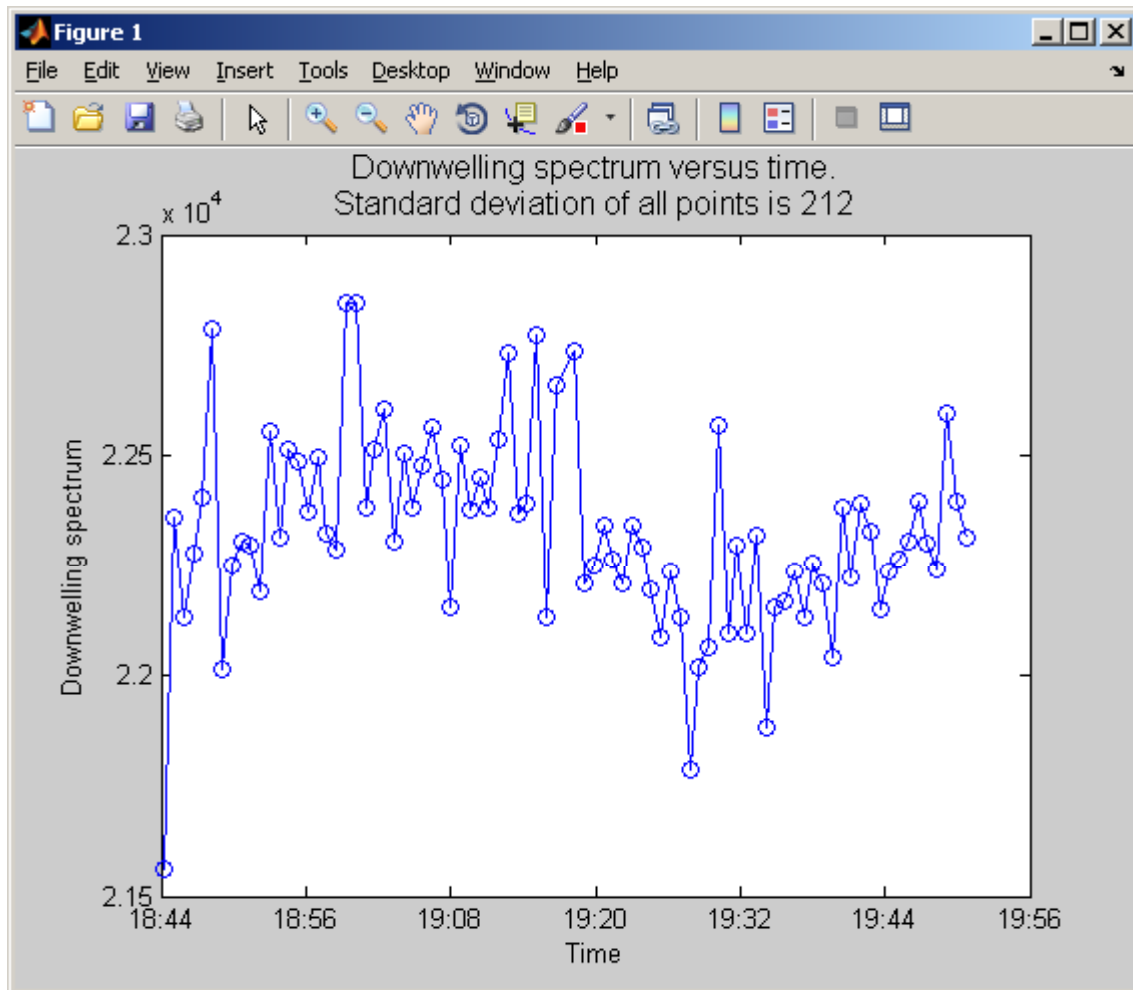


Figure 26: A typical plot of downwelling data.

Next the software offers the user the chance to output results to an Excel spreadsheet. The user can write just the results at nadir (zenith=0) to a sheet using the GUI shown in figure 27, and can output all results to a spreadsheet using the GUI shown in figure 28. No check is made to see if the stated filenames exist already, so the user must take care not to overwrite existing results.

The spreadsheet headers for the full set of results identify the angles to which the results refer and include extra information including solar zenith angle and measurement UTC time and location. The spreadsheet for results at nadir (zenith=0) contains no headers, just calculated results.

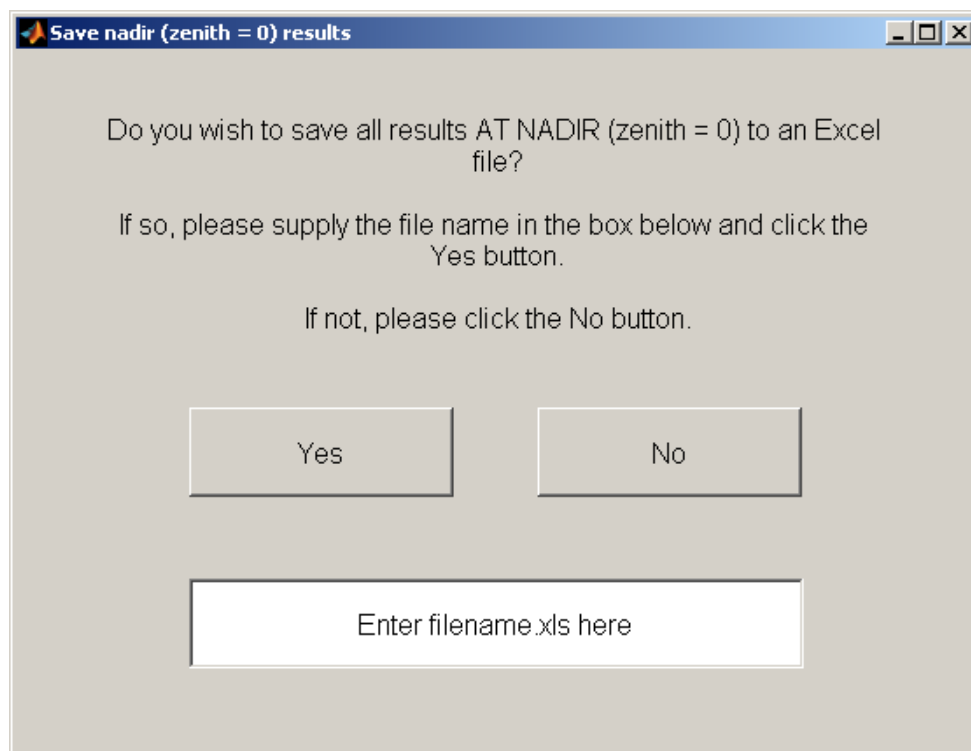


Figure 27: GUI for outputting results at nadir (zenith = 0) to a spreadsheet.

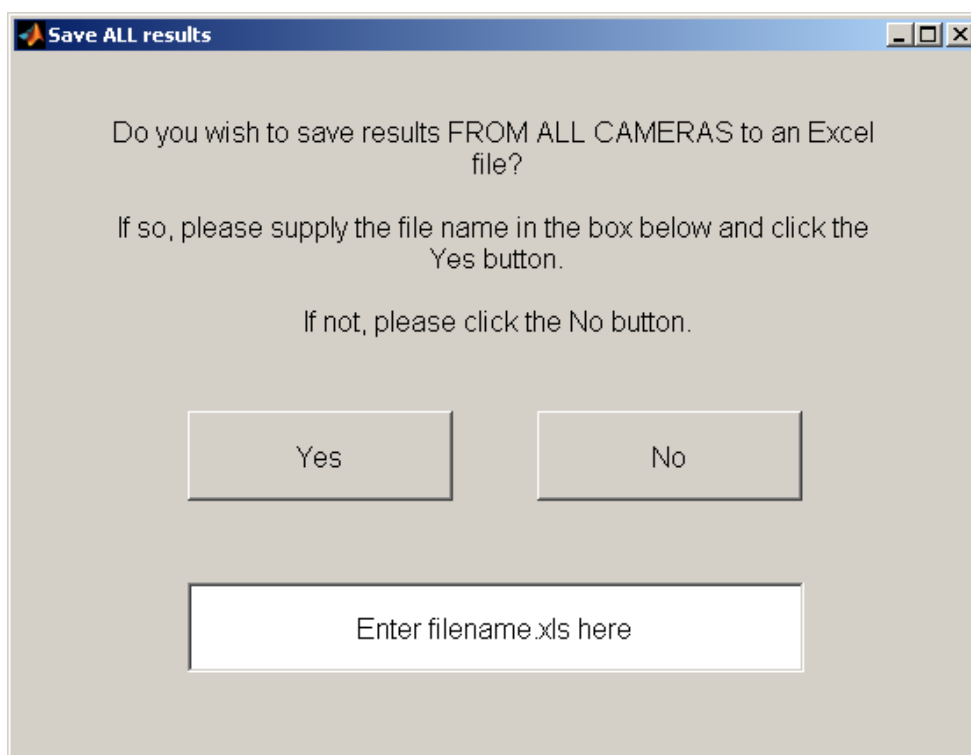


Figure 28: GUI for outputting all results to a spreadsheet.

The user can then choose to plot results at one or more locations against wavelength using the GUI shown in figure 29.

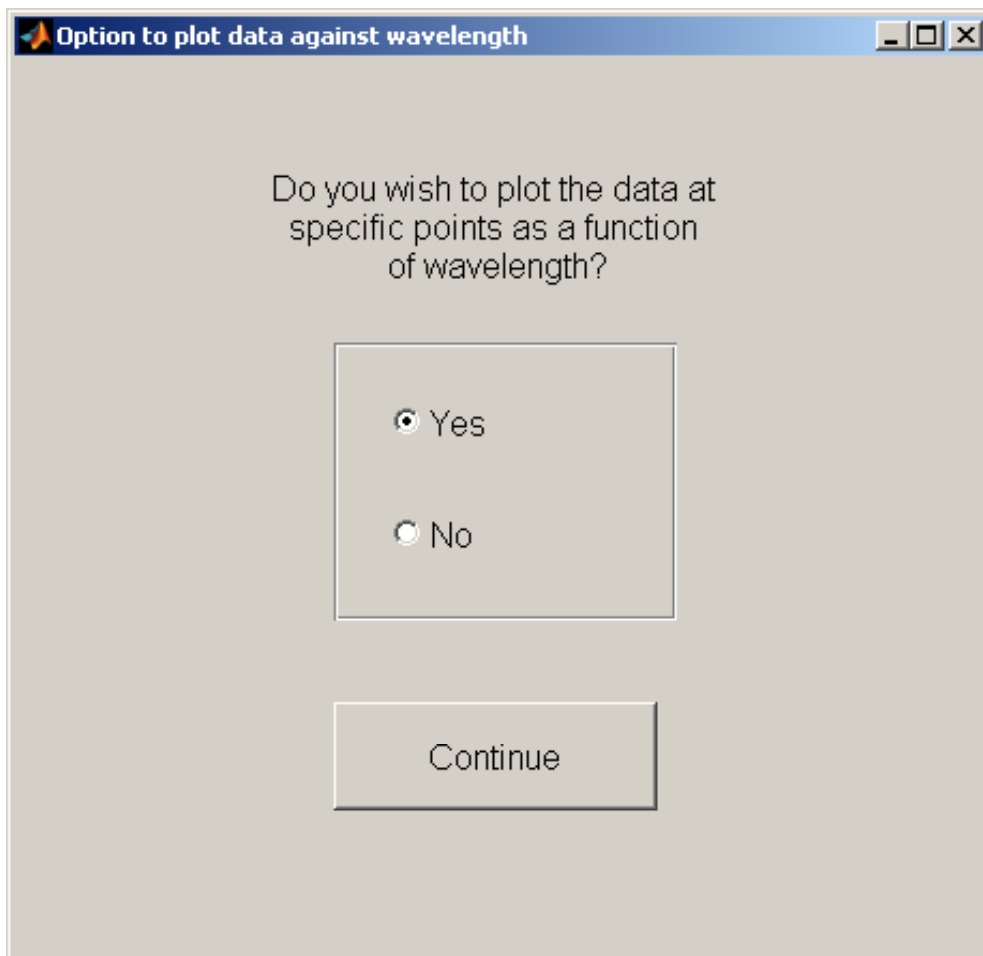


Figure 29: GUI allowing the user to plot results at fixed locations against wavelength.

Selecting “Yes” produces the GUI shown in figure 30. This GUI lists the angular positions of every measurement point (zenith then azimuth) and allows the user to select a point for plotting. The list shown in the figure contains “000 270” repeatedly because repeated measurements were taken at nadir (zenith=0).

The user can choose to smooth the data in a sub-region of the range of wavelengths by using the GUIs shown in figures 31 and 32. The smoothing is for visualisation purposes only and the smoothed data are not saved anywhere. The smoothing is achieved by fitting a quadratic curve to the user-specified number of points (21 points is recommended, as in the GUI in figure 32), and evaluating the curve at the centre point. Figure 33 shows smoothed and unsmoothed plots of the same data.

A typical plot of data against wavelength is shown in figure 34(a). This figure can be interacted with in the same way as other Matlab figures: the axes can be altered to zoom in or the scale can be switched to logarithmic. Figure 34(b) shows that the data above 1000 nm is very noisy. The software allows the user to select a subset of the data to be replotted via the GUI shown in figure 35. The user selects the wavelengths to be kept in the plot. Use of the Shift and Ctrl keys help select the relevant subset.

The user can then repeat the process at different measurement points and superimpose plots at different points for ease of comparison. Figure 36 shows data from several points plotted with all wavelengths above 1000 nm omitted. The legend gives the angular position of each measurement point.

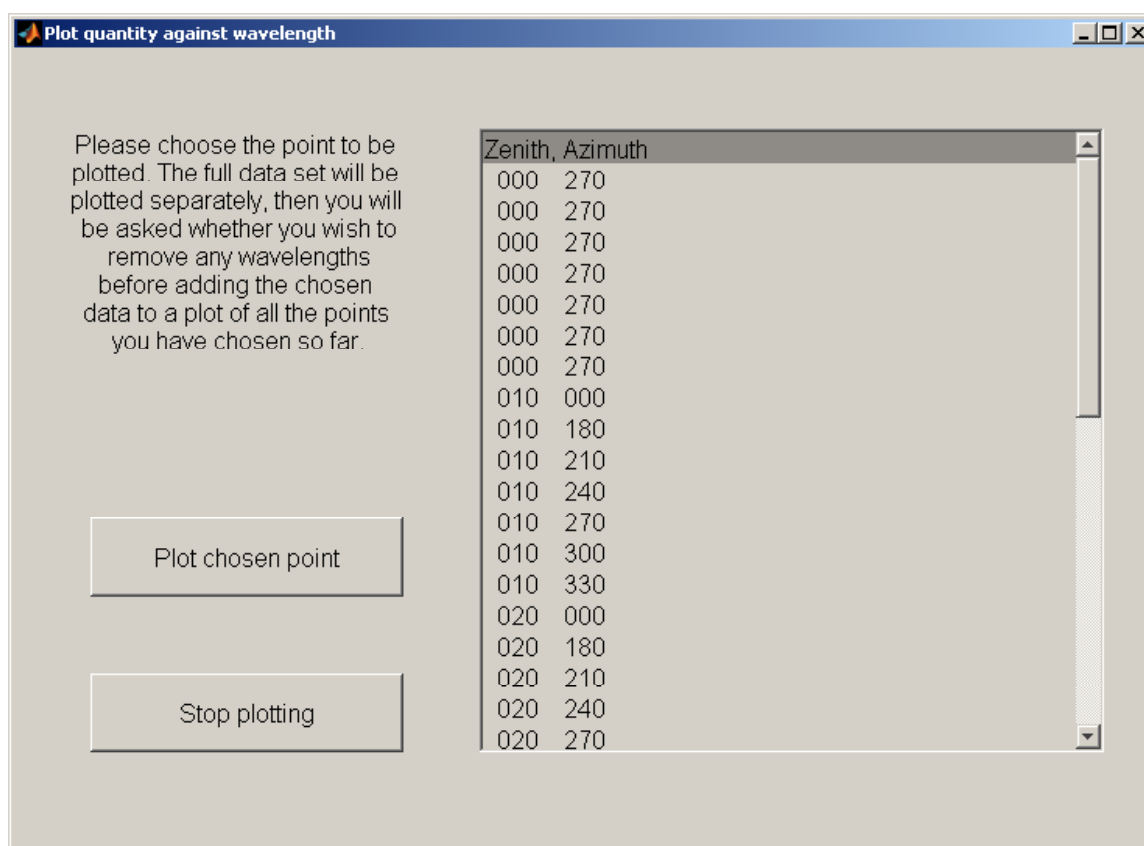


Figure 30: GUI to select points for plotting against wavelength.

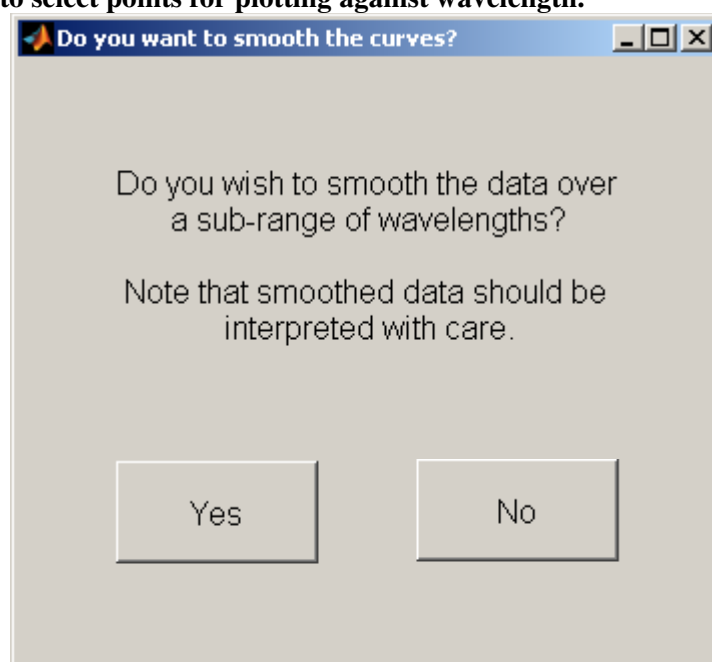
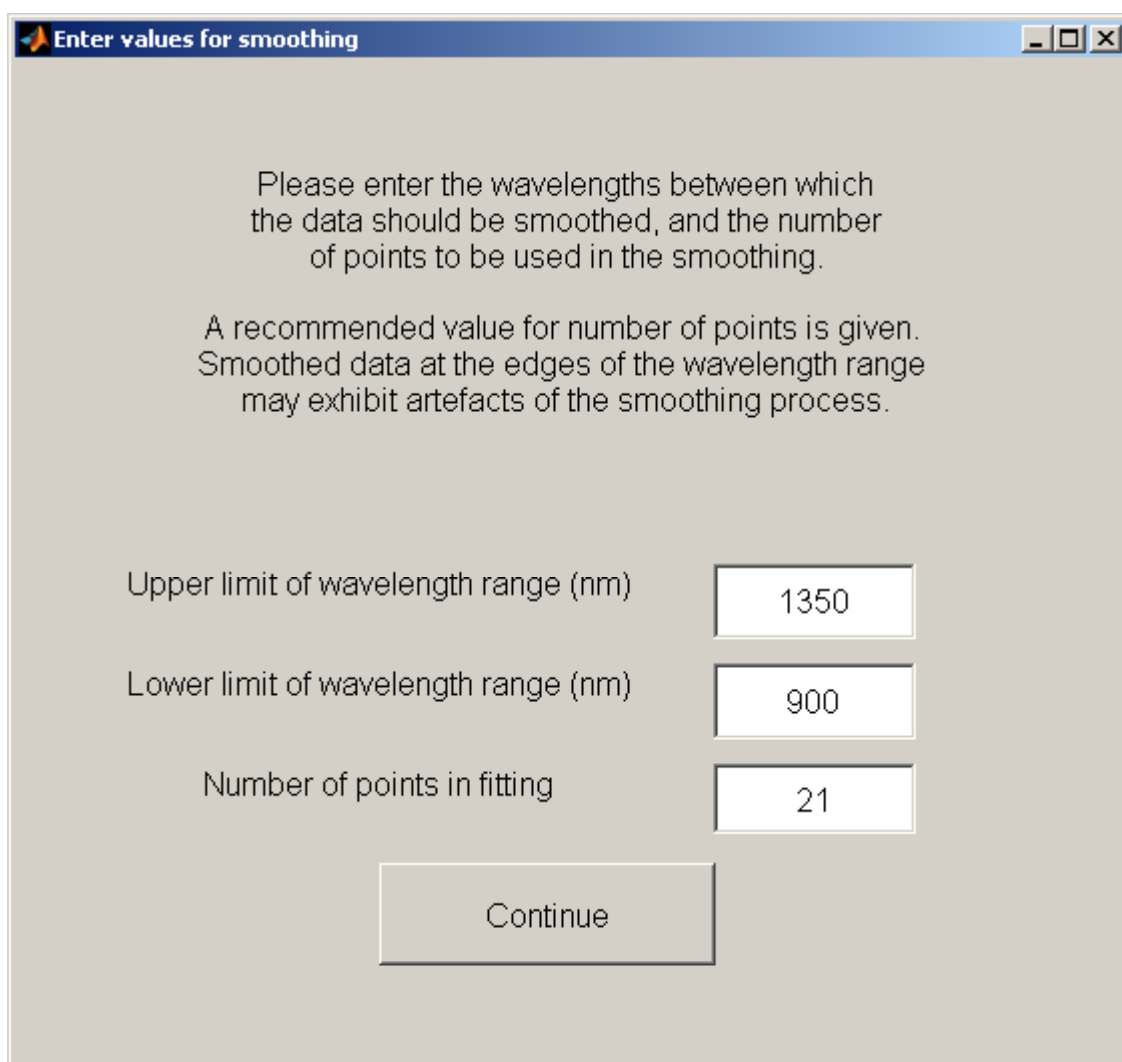


Figure 31: GUI to allow the user to smooth part of the curve.



The screenshot shows a window titled "Enter values for smoothing" with a blue header bar. The window has a light gray background. Inside, there is instructional text: "Please enter the wavelengths between which the data should be smoothed, and the number of points to be used in the smoothing." followed by "A recommended value for number of points is given. Smoothed data at the edges of the wavelength range may exhibit artefacts of the smoothing process." Below this, there are three input fields. The first is labeled "Upper limit of wavelength range (nm)" and contains the value "1350". The second is labeled "Lower limit of wavelength range (nm)" and contains the value "900". The third is labeled "Number of points in fitting" and contains the value "21". At the bottom center, there is a "Continue" button.

Enter values for smoothing

Please enter the wavelengths between which the data should be smoothed, and the number of points to be used in the smoothing.

A recommended value for number of points is given. Smoothed data at the edges of the wavelength range may exhibit artefacts of the smoothing process.

Upper limit of wavelength range (nm) 1350

Lower limit of wavelength range (nm) 900

Number of points in fitting 21

Continue

Figure 32: GUI allowing the user to select the range of wavelengths to be smoothed.

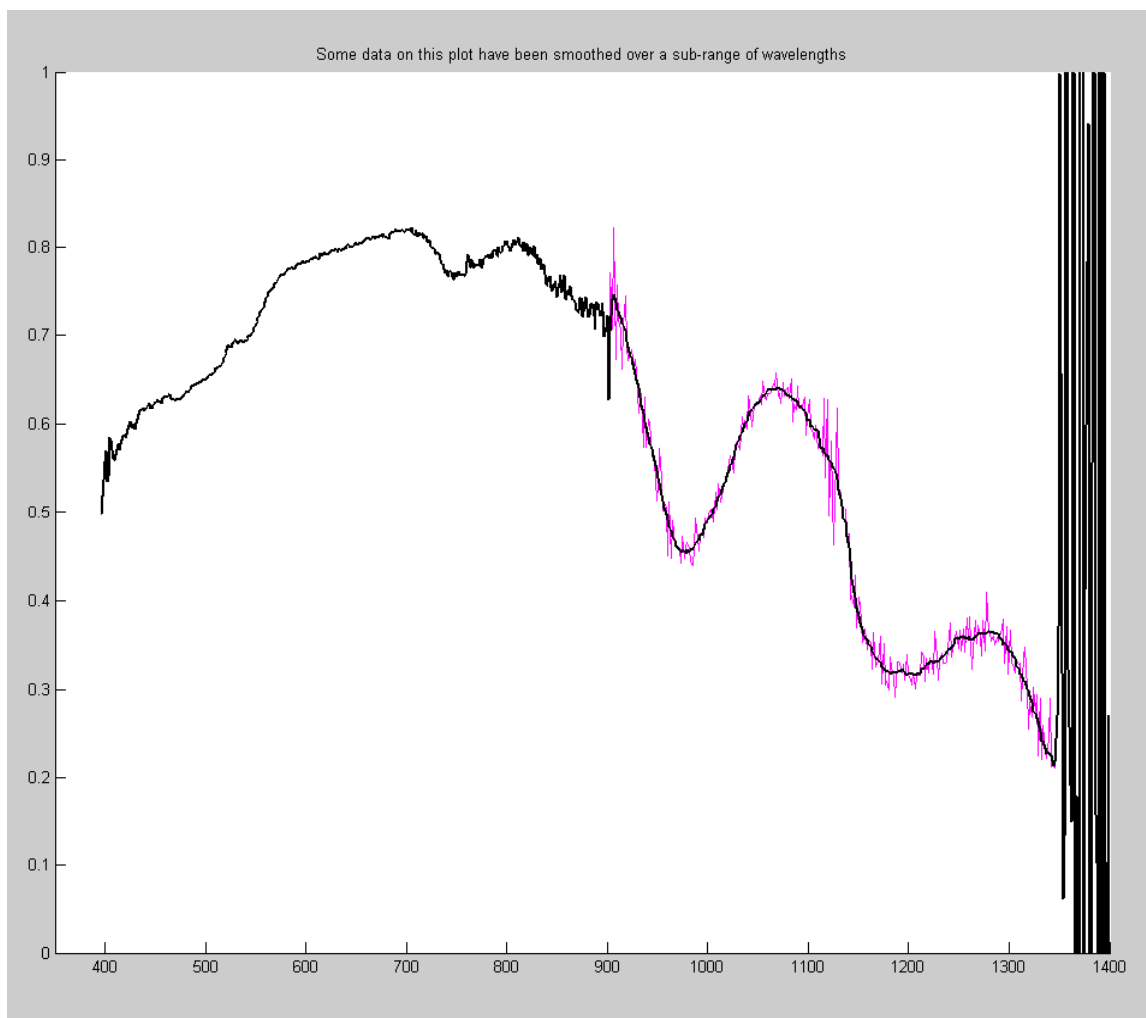


Figure 33: Plot showing smoothed (black line) and unsmoothed (pink line) data. Smoothing parameters used are those in figure 32.

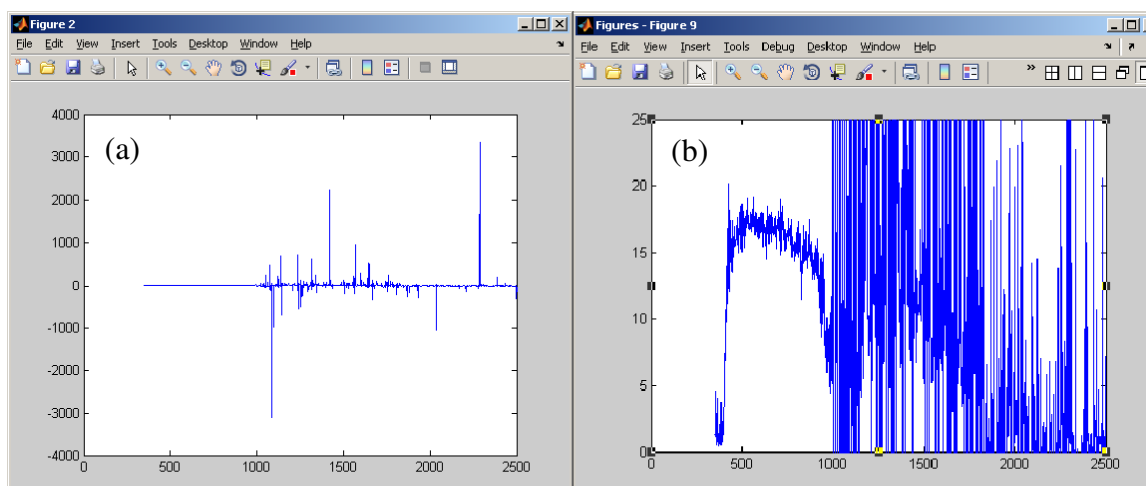


Figure 34: A typical plot of measured data vs. wavelength (a) and a zoomed-in version (b).

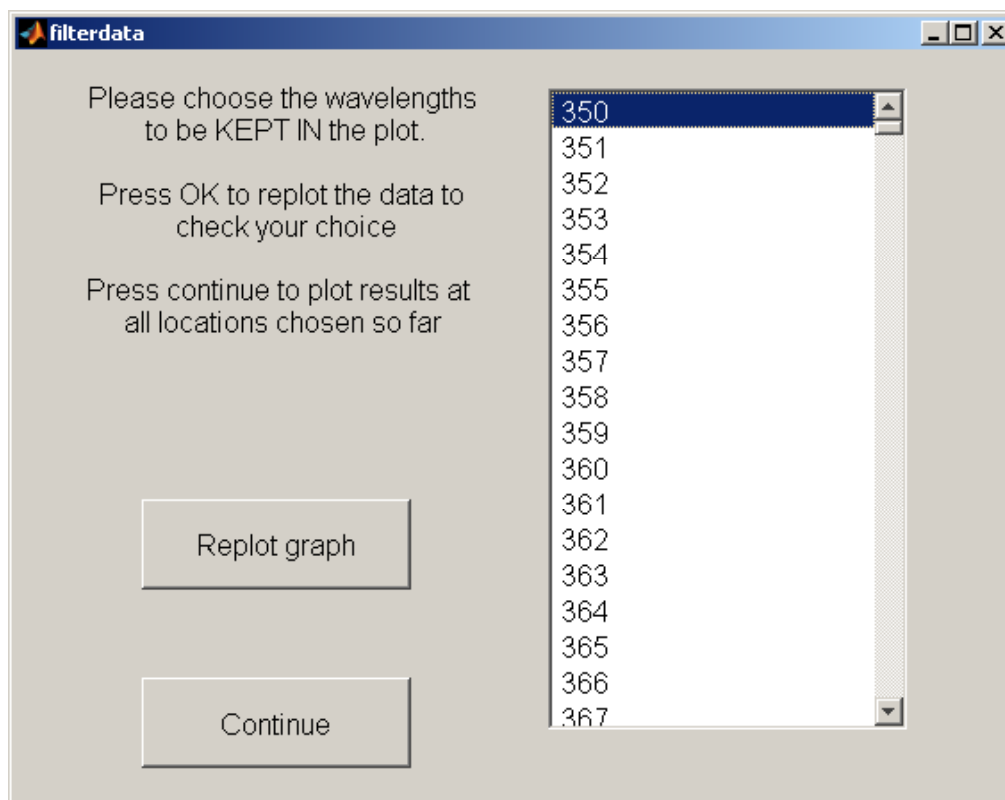


Figure 35: GUI allowing the user to select a subset of wavelengths to be plotted.

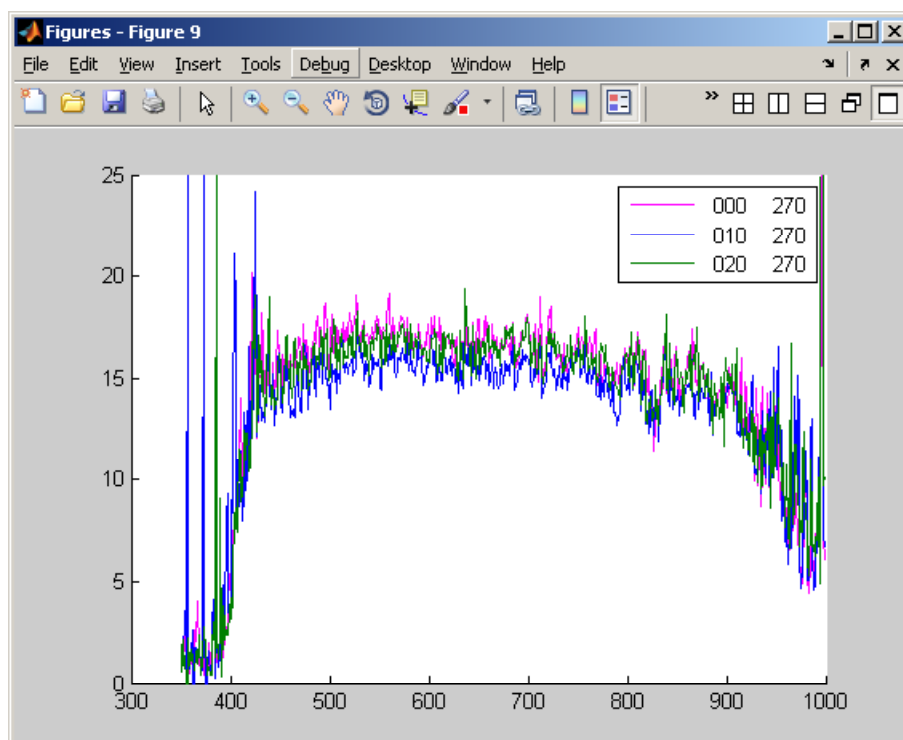


Figure 36: Subset “wavelength<1000 nm” of several data sets, including that shown in figure 34.

When the user has finished plotting results at individual positions, the user selects a single wavelength for further processing via the GUI shown in figure 37. When this wavelength has been chosen, a full interpolation of the results with respect to the angles starts.

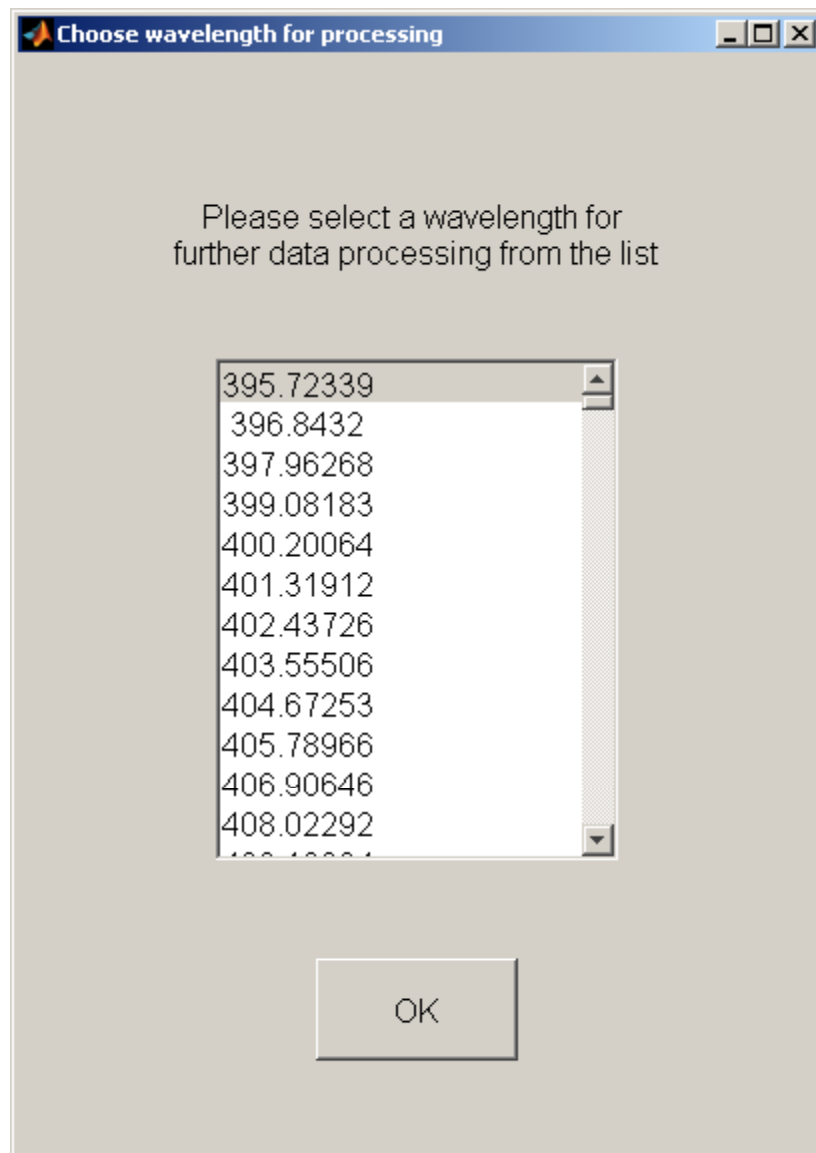


Figure 37: GUI allowing the user to select a wavelength for further processing.

The maximum and minimum azimuth angles at which measurements were made are identified by the software, and the user is offered the opportunity, via the GUI shown in figure 38, to interpolate between them to complete a full 360° plot. This is of most use if, for example, data have been measured every 30° between 0° and 330° , so that the extra interpolation is no more than has already been carried out. If interpolation is chosen over a significantly larger angle, care should be taken when interpreting the results.

Once the interpolation has been completed, the user is asked to name a *.mat file to save the results using a GUI similar to that shown in figure 7. The file can be reloaded later for further processing. Once a file name has been supplied, the main visualisation GUI appears.

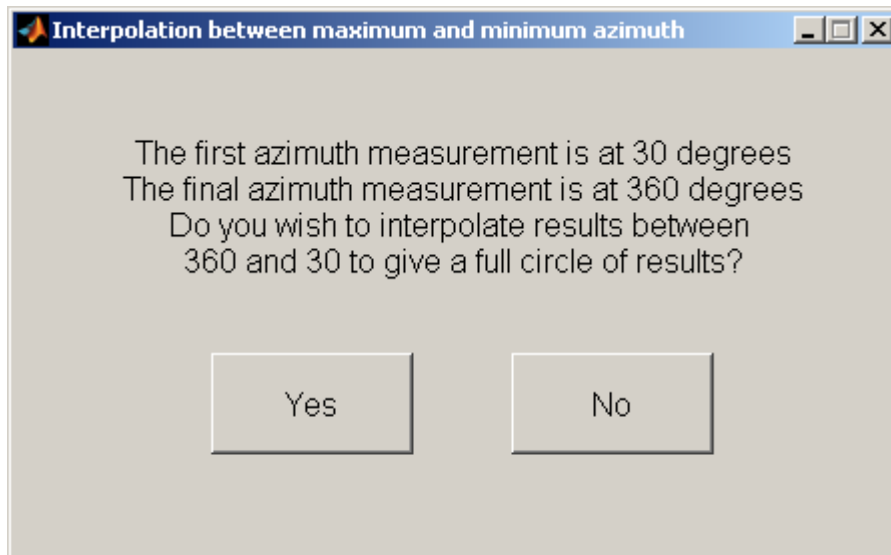


Figure 38: GUI allowing the user to interpolate between maximum and minimum zenith angles.

The main GUI for the visualisation is shown in figure 39. The GUI in figure 39 offers four types of plot, and a number of options for controlling plot appearances. Examples of each type of plot are shown in figures 40-45. The black filled circles on the 2D and 3D plots represent the locations at which measurements were made and on the 3D plot their vertical location corresponds to the result at that point. If the user has chosen to interpolate between the first and last azimuth measurements then the surface plots will appear as complete circles.

Each 2D contour plot creates two separate plots: one filled contour plot and one line contour plot. The user can specify the values of the line contours and the limits of the filled contours by entering comma separated values in the text box circled in figure 39. Note that this box should only contain numbers and commas: the e.g. should be removed. Figure 46 shows a plot that gives little information due to an unrealistic maximum. The specification of contour levels produces the more useful plot shown in figure 47.

The 2D reflected contour plot is designed for use with data that has been measured over a quarter-sphere, where it is expected that the other half of the hemisphere will be symmetric relative to the solar principle plane. The plots reflect the data in the line azimuth = 0 to create a symmetric plot.

Multiple diameter plots can be created on a single set of axes by using the “Add diameter to existing plot” option on the GUI shown in figure 39. An example is shown in figure 45.

Each type of plot can be created with or without extrapolated points in the zenith direction. The difference between figures 40 (without) and 48 (with) illustrates the effect of this choice. The plotted surface extends beyond the measurement points (marked with filled circles), and the colour scale has changed.

If the user has chosen not to interpolate between the minimum and maximum value, the range of plots that can be chosen is different. The reflected 2D plots will only be created if the measurement data have been gathered solely within one half of the circle (i.e. azimuth angles are all between 0° and 180° or all between 180° and 360°). Any plots across a diameter must lie entirely within the measurement region. Warning messages will appear if these criteria for reflected 2D or diameter plots are not satisfied.

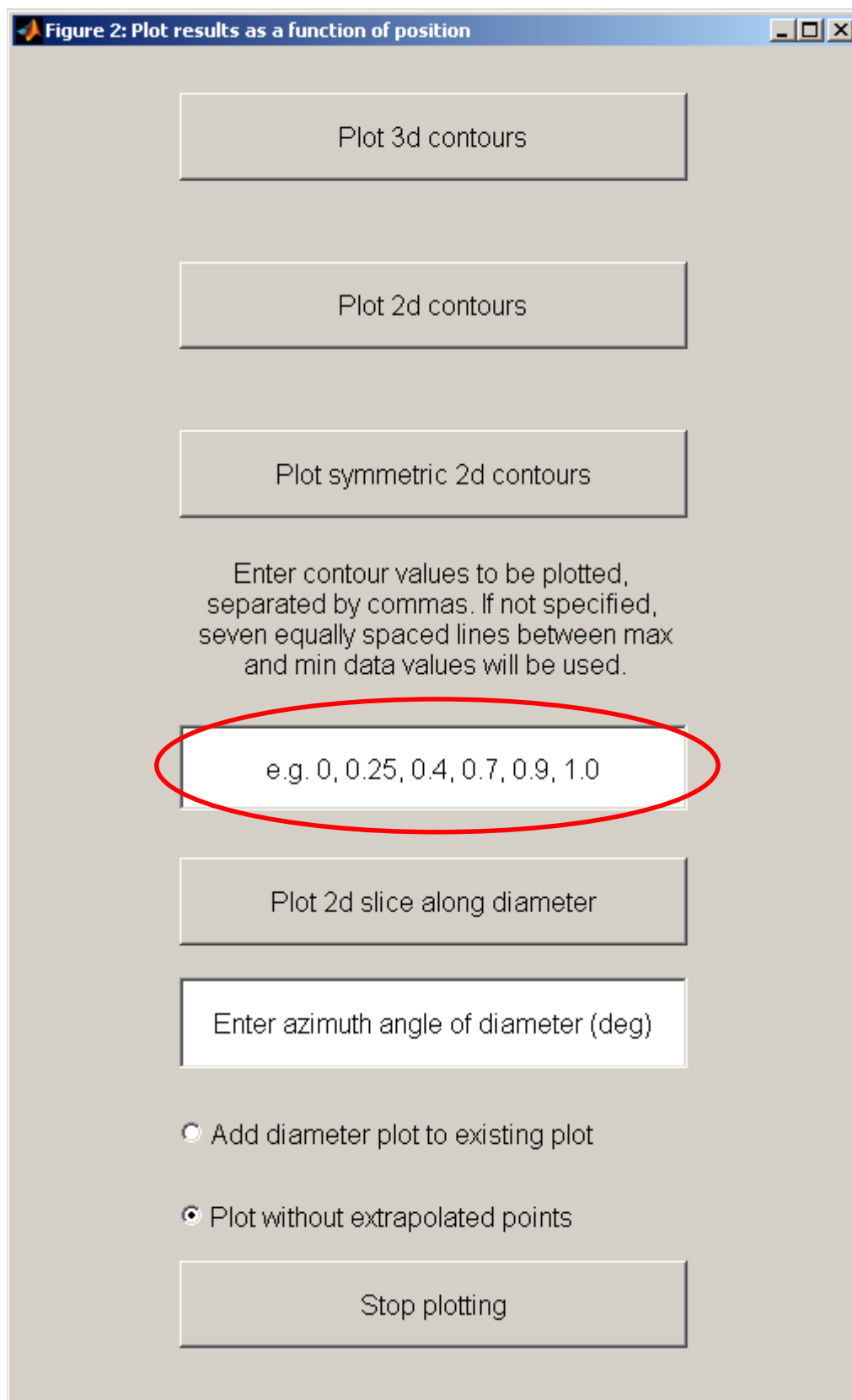


Figure 39: Main visualisation GUI. Circled box controls contour levels.

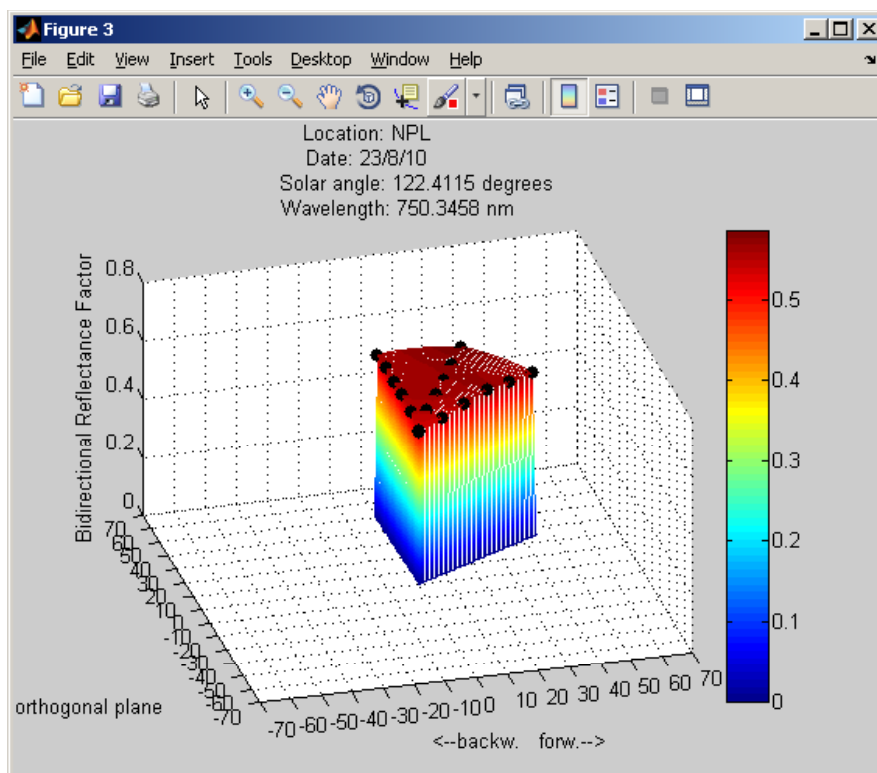


Figure 40: 3D contour plot of results

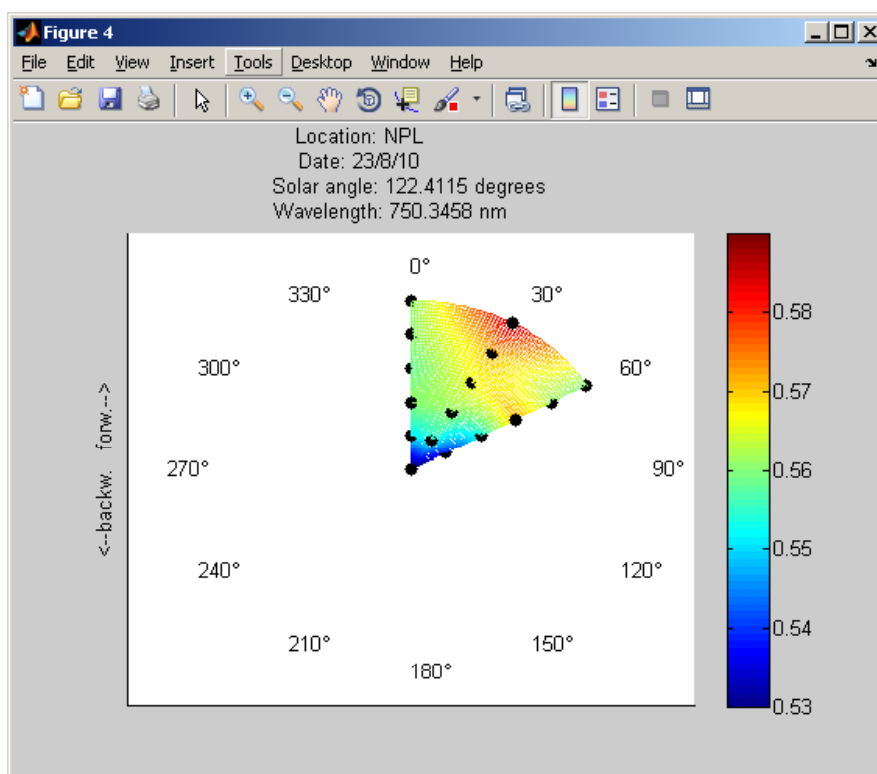


Figure 41: 2D filled contour plot of results.

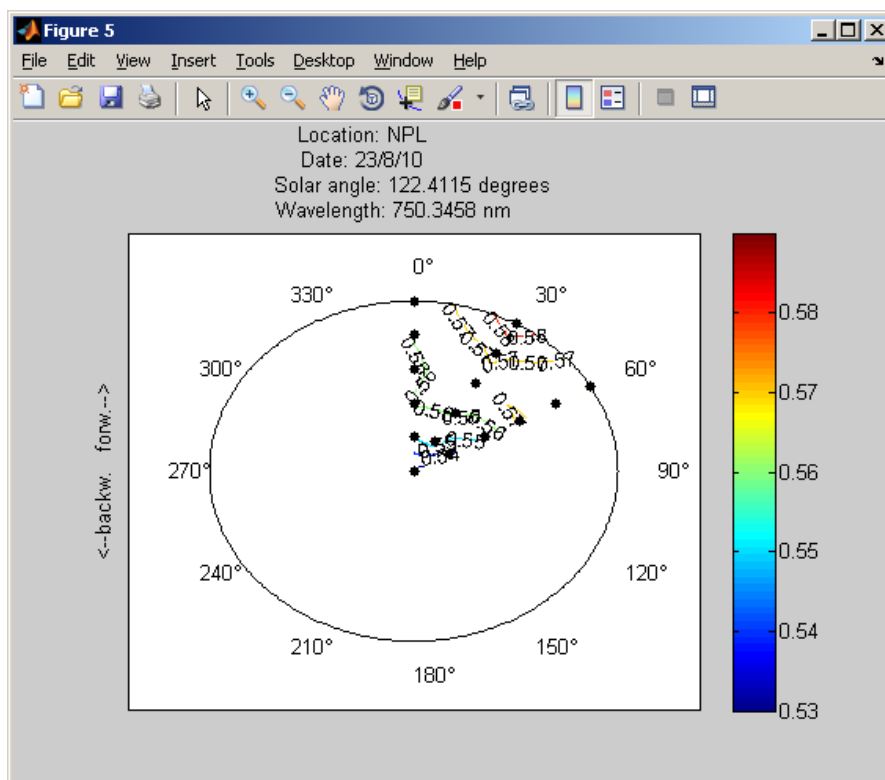


Figure 42: 2D line contour plot of results.

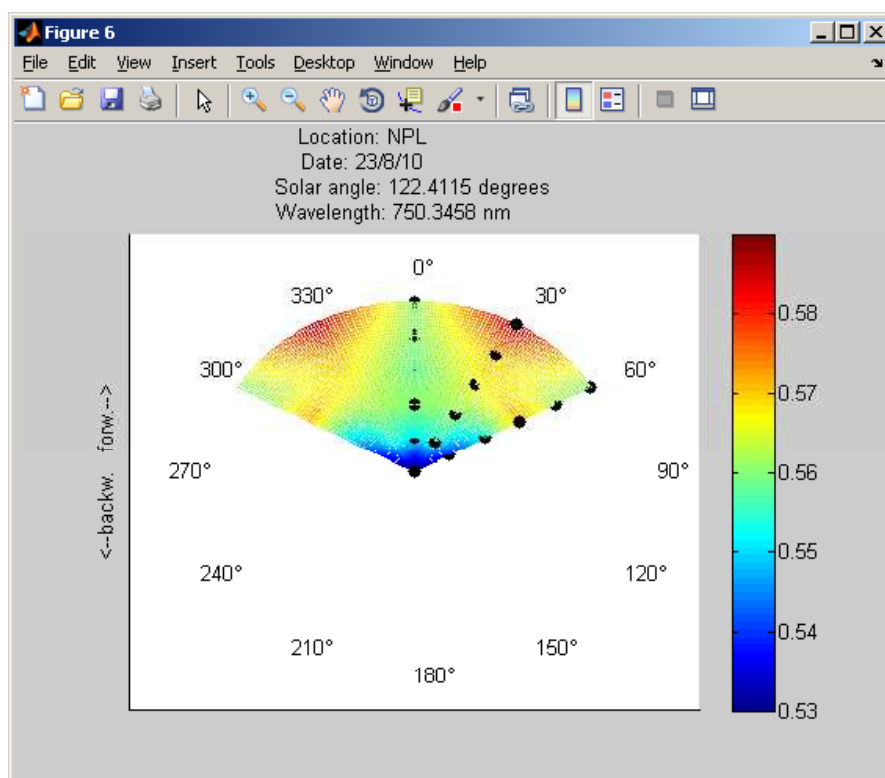


Figure 43: Reflected 2D filled contour plot of data shown in figure 37.

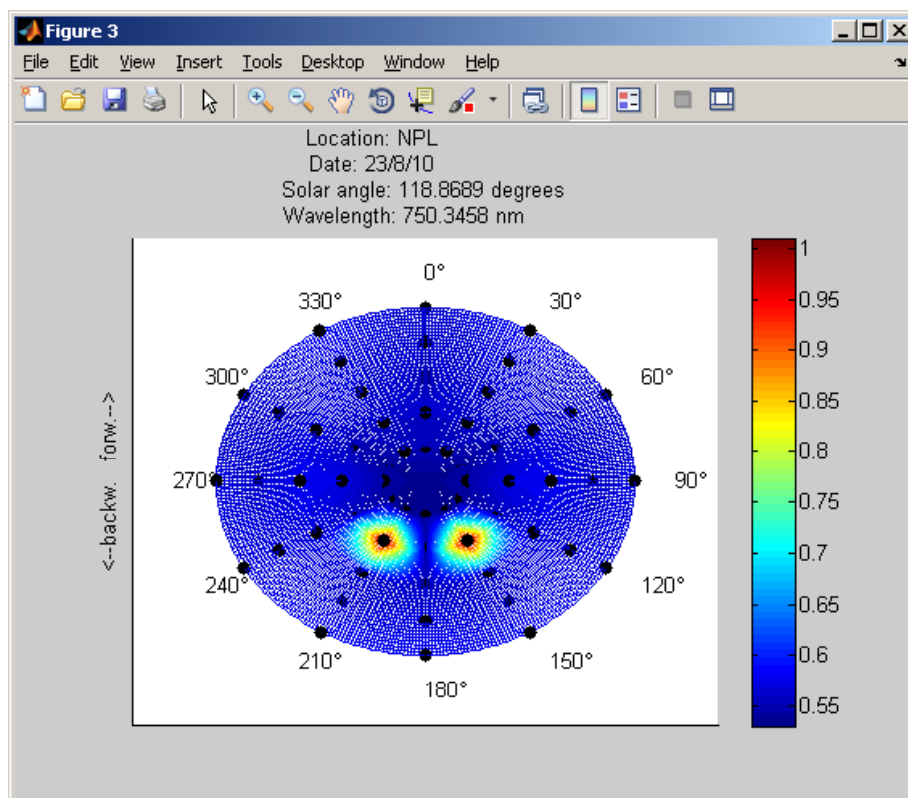


Figure 46: 2D filled contour plot with local maximum and unhelpful contour values.

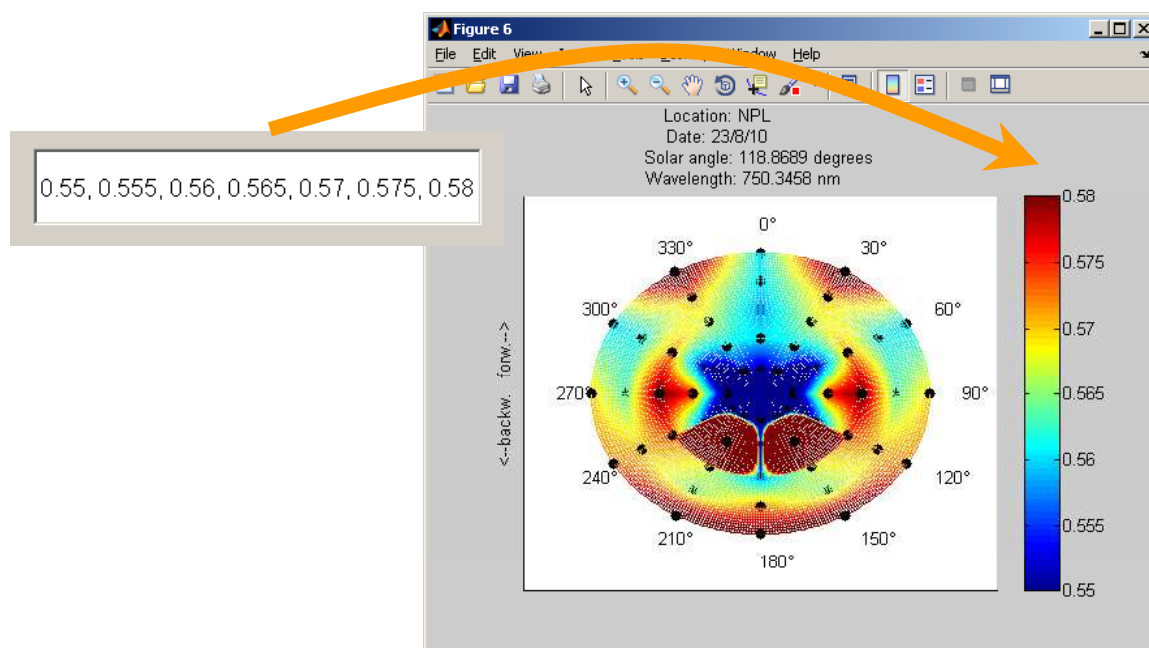


Figure 47: 2D filled contour plot of data shown in figure 42, plotted with specified contour values. Left hand box shows the values that were input to the GUI in figure 35.

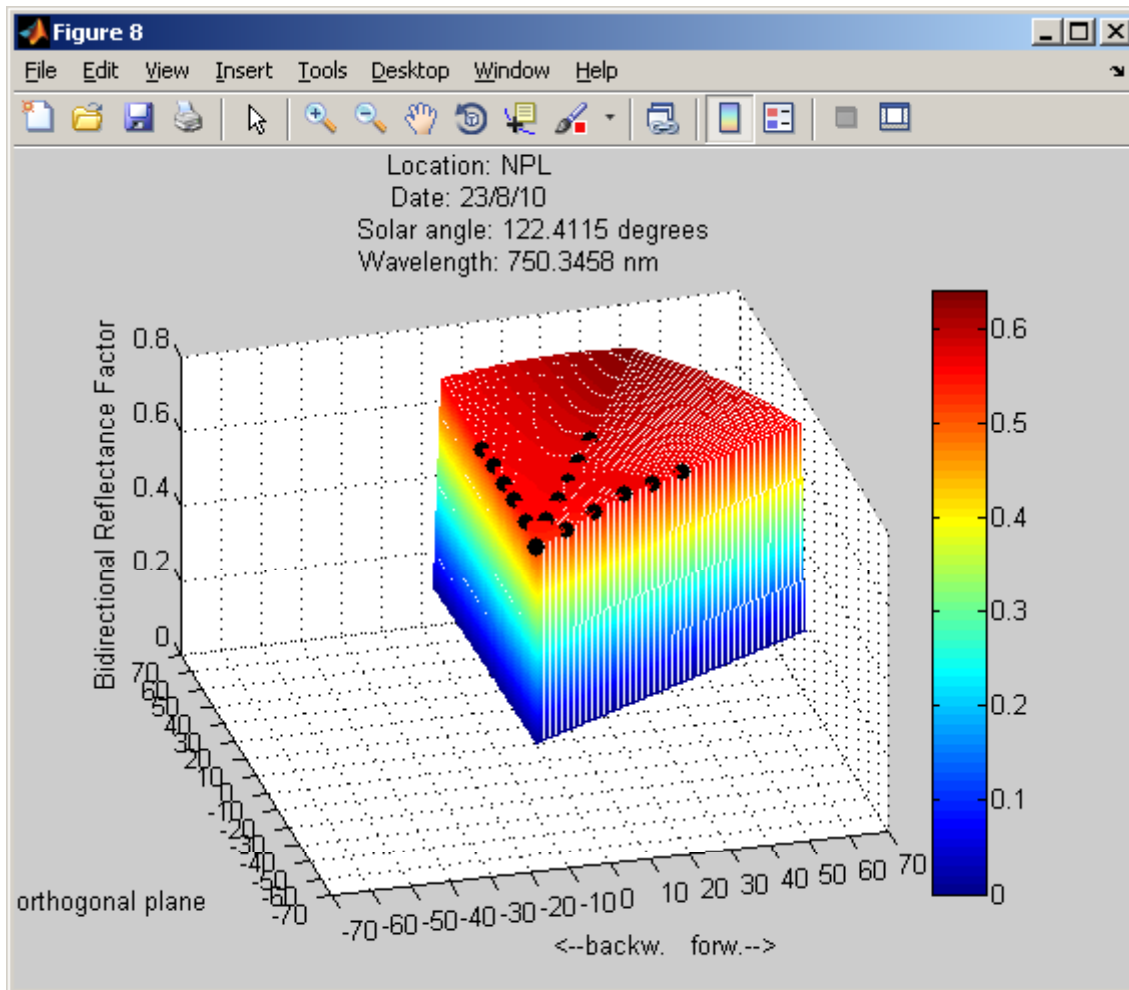


Figure 48: 3D filled contour plot of results including extrapolated results in the zenith direction.

When the plotting is complete the user can repeat the processing and plotting for a different wavelength via the GUI shown in figure 49. If the user chooses yes, the code returns to the GUI shown in figure 37 and continues from that point. Once the user selects “No” from the GUI in figure 49, the module that processes subsets of the data starts.

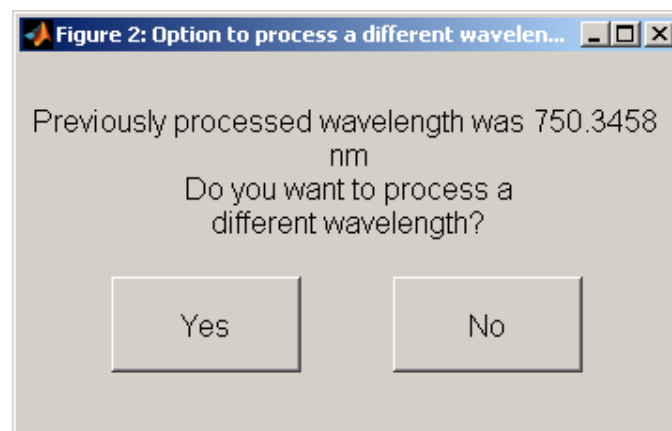


Figure 49: GUI allowing the user to choose another wavelength.

3.3 PROCESSING SUBSETS OF DATA.

The GUI in figure 50 allows the user to choose to interpolate over the surface using a subset of the data. The results of the interpolation of a partial data set are then compared to the results of the interpolation of the full data set, and a sum of squares difference S is calculated (as explained in section 1). The value of S^2 for each subset is written to a text file chosen by the user using a GUI similar to that shown in figure 7. This text file also contains the number of points in each subset and a list of the selected angles.

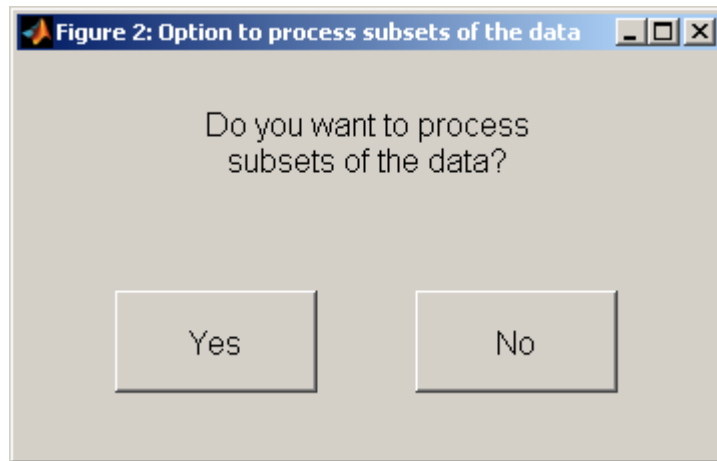


Figure 50: GUI allowing the user to process subsets of the data.

The choice of angles within each subset is made using the GUI in figure 51. The lists in the boxes contain all azimuth and zenith angles at which measurement data were gathered. The user can select any subset of angles. If the data has not been interpolated between the maximum and minimum azimuth angles, the selected subset must contain the maximum and minimum azimuth angles. If this does not occur, the software will attempt to compare arrays of two different sizes and will crash. Also note that the S^2 value written to file includes the values for zenith extrapolated to 90° and so may not be a good reflection of the quality of fit over the measurement area.

Once the selected subset of the data has been interpolated and extrapolated, the value of S^2 is calculated using the equation given in section 1 and written to the text file chosen by the user. The user is then offered the option to display the new interpolated surface via the menu in figure 39, resulting in plots similar to figures 40-45. After plotting, the user is returned to the menu in figure 51 and can select further subsets for processing and plotting. This loop of actions occurs until the “Stop processing and return” button is pressed.

When the processing of subsets has stopped, MADAT finishes. The processed subsets are not saved to a *.mat file because not all of the variables necessary for a full restart are available to that part of the software.

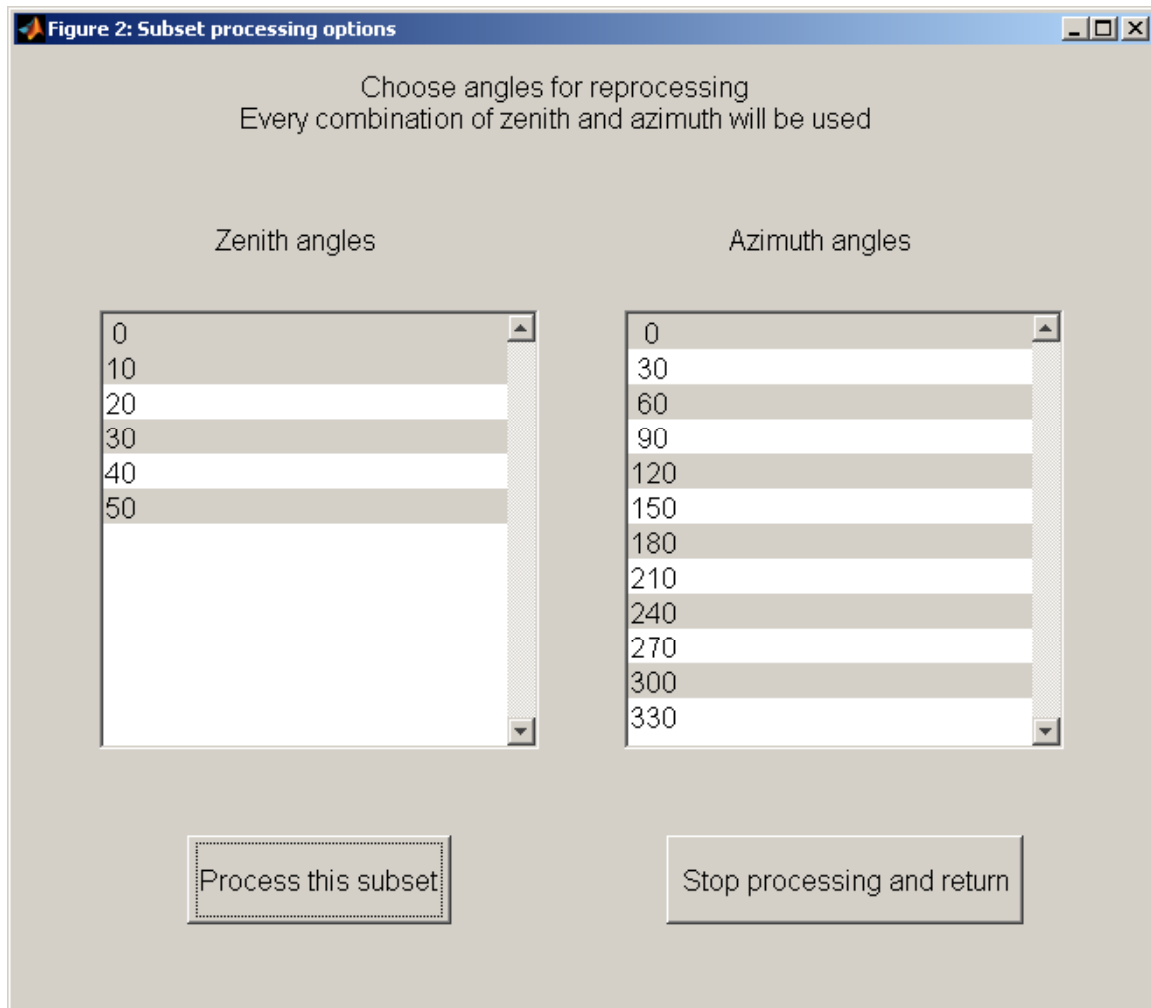


Figure 51: GUI allowing the choice of a subset of angles for further processing. The greyed angles have been selected.

3.4 RELOADING AN OLD DATA SET

If the user chooses to reload an old data set by pressing “Yes” on the GUI shown in figure 10, a GUI similar to that shown in figure 7 appears so that the user can select the file to be reloaded. Only .mat files are shown, since MADAT saves data in that form. Once the data file has been chosen and loaded, information about the loaded data is displayed on-screen in the form shown in figure 52. The date and UTC time displays are in the same format as the GPS data described in previous sections.

After the information about the loaded data has been displayed and the user has clicked “Continue”, the user follows the same path through the software as is described in section 3.2, from figure 39 onwards. The user can reprocess different wavelengths and can process subsets of the data.

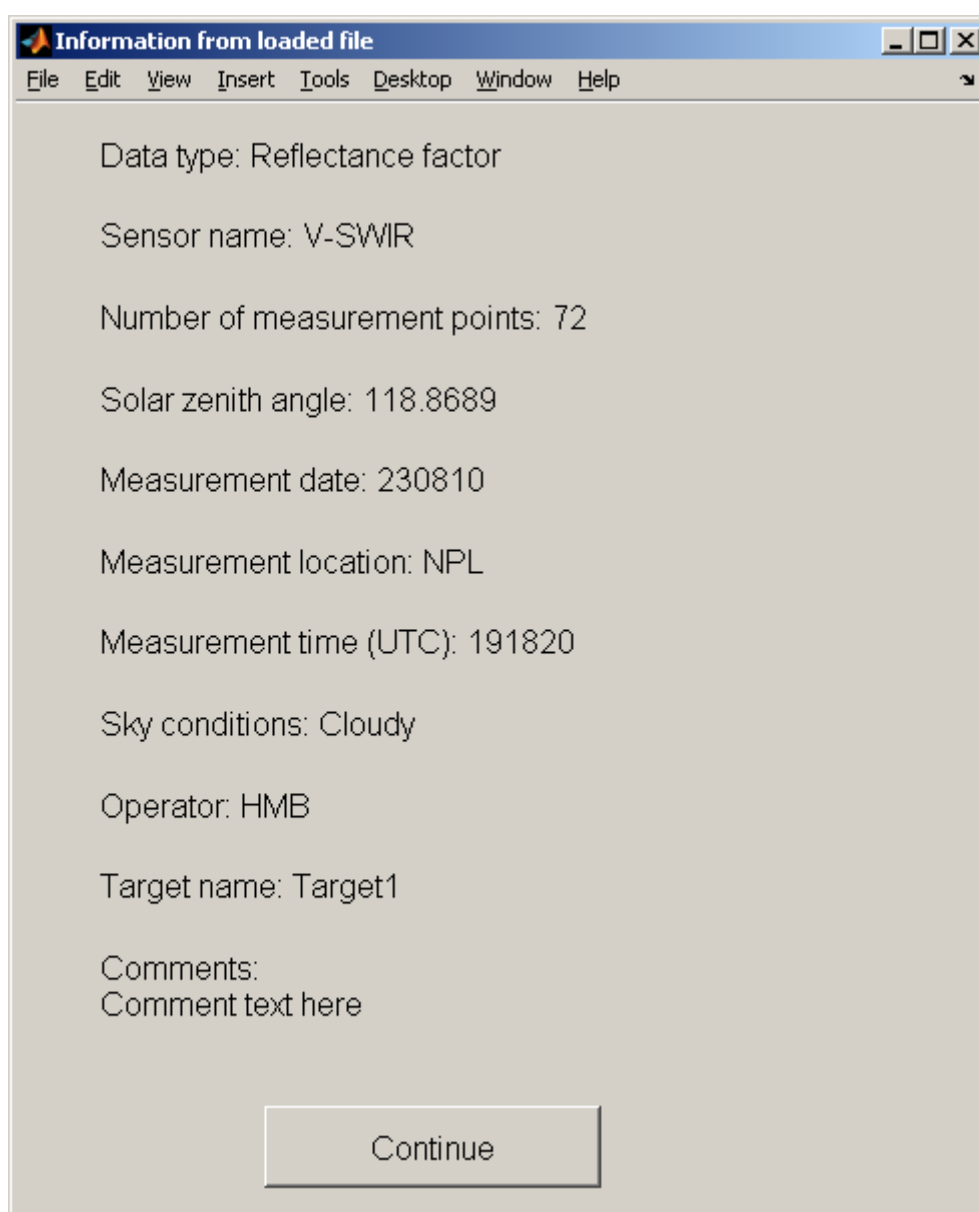


Figure 52: Display of information about the loaded data set.

4 QUICK GUIDE TO RUNNING THE SOFTWARE

To run the MADAT software for calculation of reflectance you will need the following:

1. A full set of target measurement data.
2. A .csv file listing the camera number, file number, and reflected angles (azimuth and zenith) for the panel measurement data files.
3. EITHER
 - a. A full set of panel measurement data (gathered at the same angles as the target measurement data),
 - b. a .csv file listing the camera number, file number, and reflected angles (azimuth and zenith) for the target measurement data files, and
 - c. a set of calibration coefficients for each of the measurement angles at all wavelengths, and possibly a shape file.
4. OR
 - a. a single set of panel measurement gathered at the nadir,
 - b. a set of coefficients for calculation of the panel measurements at the other points in a file called "PanelBRDFCoeff.csv", and
 - c. a set of calibration coefficients for the nadir measurements for all wavelengths.

Display of digital number requires only the first two items. The sets of data can be contained in several separate directories with different names if required. All file formats and required contents are listed in section 2 of this manual.

To run the software, double click on the executable. An introductory window introducing MADAT v5.1 will appear. Click "Run MADAT" to continue.

Next steps:

1. You will be asked if you wish to reload a previously processed data set. If you choose yes, you will be asked to choose the file (must be a Matlab .mat file), you will be given some information about the file, and you will skip to step 19 below. If you choose no, you will proceed to step 2.
2. You will be asked to choose a quantity to process. Please choose either reflectance factor or diffuse irradiance: the radiance option is currently unavailable.
3. You will be asked to choose a sensor type. At present ASD and V-SWIR are the only possibilities.
4. You will be asked to select how many groups of data files are to be processed. There must be either the same number of groups for target and panel, or there must be a single panel measurement taken at nadir.
5. You will be asked to choose the file name format for the target measurement files. These should be text files of the form *fname.nnn.txt* or *fnamennn.asd.txt* where *fname* is a text string to be supplied later and *nnn* is a three digit number.
6. You will be asked whether there are multiple or single panel measurement files. If there are multiple files, these must have been gathered at the same angles as the target measurement files. If there is only one file, it must have been gathered at nadir.
7. You will be asked to choose the file name format for the panel measurement files. These should be text files of the form *pname.nnn.txt* or *pnamennn.asd.txt* where *pname* is a text string to be supplied later and *nnn* is a three digit number.

8. You will be asked, for each group of target data sets, to supply the directory containing the files, the main part of the file name (i.e. *fname* in point 5), and the file linking angles and file numbers.

9. If there are multiple panel measurements, you will be asked, for each group of panel data sets, to supply the directory containing the files, the main part of the file name (i.e. *pname* in point 7), and the file linking angles and file numbers. If there is only one panel data file, you will be asked to supply the directory containing the measurement file, the full name of the data file (without the .txt or .asd.txt), and the directory containing the file "PanelBRDFCoeff.csv".

10. You will be asked whether you want to enter the solar zenith angle, measurement UTC time, and measurement date by hand, or to read the UTC time and date in from the measurement files and calculate the solar zenith angle from the timing and positional information.

11. You will be asked to supply other information about the measurements. If it is not being calculated automatically, solar zenith angle is the most important information required as it is used in the calculations.

12. If using an ASD Field Spec, you will be asked to enter the splice values where the different normalisation regimes change over. The default values are 1000 nm and 1800 nm, but the information may be available in the measurement file header. It is not read in automatically.

13. If the UTC time and date were read in automatically, the latitude, longitude, altitude, UTC time and date will be displayed and you will be asked to confirm that they are correct or to edit them. Editing must be done in accordance with the formatting given in section 2.1.2.

14. If there are multiple panel measurements, you will be asked to identify the file containing panel calibration coefficients as defined in section 2.1.4, you will be asked if you have a shape file, and if so you will be asked to identify the shape file. If there is only one panel data file, you will be asked to identify the file containing calibration coefficients for the nadir measurement as defined in section 2.1.3.

The software will then calculate the quantity you requested and offer to display it in various ways. If using V-SWIR, a plot of the downwelling data against time at approximately 550 nm will be displayed. The calculation can be lengthy due to the necessary interpolation of the calibrated panel data. When the calculation is complete, you will be offered the chance to save all measurements made at nadir (zenith=0) to a spreadsheet and the chance to save all measurements at all angles to a spreadsheet.

15. You will be asked if you want to plot at points as a function of wavelength.

If you choose yes:

15.1 You will be asked to choose an angular point to plot.

15.2 You will be offered the chance to smooth the data and to select a range of wavelengths over which to smooth the data. You will be shown a plot of the full data set and will be asked to choose which wavelengths to retain in subsequent plots by highlighting them from a list. This option enables the user to remove noisy data. You can replot the selected wavelengths until you are happy with your choice.

15.3 All points selected are plotted on one set of axes, to enable comparison.

Press "stop plotting" to end.

16. You will be asked to select a wavelength for further processing. This is the wavelength at which all subsequent plots will be generated.

17. You will be offered the option of interpolating between the last and first azimuth measurement angles in order to form a full circle of data. If you choose no, some of the subsequent plot options may not be available to you (2D reflected and diameter plots may not be available).

18. You will be asked to provide a file name for saving the full data set. This file must be a Matlab .mat file. Data sets can be reloaded for further processing at a later date.

19. You will be offered a plotting menu of the various plot types available (3D contours, 2D contours, reflected 2D contours, diametric slice through the data). Each plot appears in a new window, other when diameter plotting is requested (in which case successive plots can be shown on a single set of axes). You can specify contour values and limits by entering numbers, separated by commas, in the text box. Some options may not be available for data not interpolated to a full circle. To leave the plot menu, press "stop plotting".

20. You will be told which wavelength was processed and offered the choice to process another wavelength. If you choose yes, you will go back to step 16.

21. If you choose no, you will be offered the chance to process subsets of the data. If you choose no, the program stops.

22. If you choose yes, you will be asked to choose a text file name for saving the goodness of fit information to.

23. You will be shown the lists of azimuth and zenith measurement points and can select a subset of these values for reprocessing. Choosing a list of azimuth and a list of zenith angles will reprocess based on every combination of two values from those lists. If the data have not been interpolated to a full circle, the subset must contain the first and last azimuth angles or the programme will crash.

24. Once the processing has been done, the plotting menu from step 19 will appear and you can plot the results.

25. When you choose to stop processing subsets, the software stops.