



Web Interface for Data Exploration

Version 1.0

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Contents

1	Quick introduction of WIDEa	3
2	WIDEa installation procedure	4
2.1	Preliminary informations	4
2.2	Auto tasks	4
2.3	Manual tasks	6
3	Partition of WIDEa into several panels	7
4	Detailed description of P1	10
4.1	Data presentation	10
4.2	Data loading procedure	11
4.3	Graph type selection	12
4.4	Variable selection	13
4.5	Adding a model	16
5	Detailed description of P2	23
5.1	Graphic tab	23
5.2	Flag tab	25
5.3	Statistics tab	28
6	Detailed description of GA	31
6.1	Action buttons	31
6.2	Graph examples	33
	References	41

1 Quick introduction of WIDEa

WIDEa is a R-based software aiming to provide users with a range of functionalities integrated into a web interface to explore, clean and analyse “big” environmental and (in/ex situ) experimental data. More specific data can be used with WIDEa, such as data measured on a temporal scale and infrared spectral of near/mid regions. WIDEa requires no programming knowledge and no internet connection once installed on your computer.

Among fonctionnalités, WIDEa offers a fully interactive data visualization (multiple graph types, 2D/3D) and a simplified management of atypical data (manual selection and classification by quality code). As a decision support tool, WIDEa allows to perform statistical calculations on visualized data (basic statistics, linear regression, hypothesis tests, etc.) and apply normally distributed models (mixed effects, weighted residuals) to check residual assumptions and their robustness.

In next sections, the manual explains how install WIDEa on your computer (Windows, Mac OS, Linux), describes all fonctionnalités available on WIDEa and presents some examples of the use of the software by using different data types.

2 WIDEa installation procedure

2.1 Preliminary informations

WIDEa requires that a R version 3.5 or greater is previously installed on your computer (if not, see <https://cran.r-project.org/bin/>).

A total of 15 R packages are necessary for the proper functioning of WIDEa: shiny [3], shinyBS [2], shinyjs [1], shinyFiles [10], shinythemes [4], shinybusy [11], V8 [13], plotly [14], htmltools [5], htmlwidgets [15], bindrcpp [12], scales [16], data.table [6], arrangements [8], car [7]. The installation of all R packages is scheduled during the WIDEa installation procedure.

Two types of procedure are proposed to users to install WIDEa. They are based on auto (with installer files) or manual (with R console) tasks. All required files to execute these procedures are available from <https://github.com/PhilippeSantenoise/WIDEa>. The procedure with installer files only applies to the following operating systems: Windows and Mac OS.

2.2 Auto tasks

WIDEa can easily be installed on your computer by using an installer file for Windows/Mac OS operating systems. The installer file is an exe/app file named respectively **WIDEa_setup_win** and **WIDEa_setup_macos** (see github link in section 2.1). A list of automated tasks is then executed by the installer file, as follows:

1. Paste the **WIDEa** directory (including R scripts, batch/bash scripts used by the installer file, WIDEa logo images and the license file) at the desired location in your computer;

2. (Windows only) Create the **WIDEa files** directory in user's documents and add to it a txt file including the R software location (R.exe) on your computer (essential to load WIDEa R scripts);
3. Install R packages mentioned in the section 2.1;
4. Copy/paste the WIDEa logo (**WIDEa_header_img**) in the R shiny library (www folder precisely) used as the header of the web interface;
5. (Windows only) Create a **WIDEa** shortcut (locations: WIDEa directory, Start Menu, Desktop) used to launch the web interface;
6. Create an uninstaller file (exe/jar file named **uninstall**) in the WIDEa directory (see Uninstaller folder for Mac OS).

As no shortcut file is created by the Mac OS installer, the web interface is launched from the exe file named **launcher_macos** and located in the WIDEa directory. An optional task can be (manually) executed to change the appearance of the previous exe file, as follows:

- Open the png picture **WIDEa_icon** located in the WIDEa directory (see Image folder);
- Click on **Select All** in **Edit** tab and copy the selection;
- Select **Get Info** with a right-click on the exe file;
- Click on the picture in top-left of the **Get Info** window and paste the previous selection.

The uninstaller file for Mac OS is a jar file. It requires that a java version 1.8 or greater is installed on your computer. If not, WIDEa can be also uninstalled as follows:

- Double-click on the exe file named **uninstall_macos** and located in the WIDEa directory (see Command folder);
- Remove the **WIDEa** directory.

The `uninstall_macos` exe file allows to remove the WIDEa logo located in the R shiny library (task 4).

2.3 Manual tasks

A list of manual tasks are necessary to install WIDEa on your computer, such as:

- Copy/paste the **WIDEa** directory, available from the github link in the section 2.1, at the desired location in your computer;
- Load the **install_packages** R script located in the WIDEa directory (see `R_script` folder) by using the `source` function in a R console;
- Follow the task 4 mentionned in the section 2.2.

After completing all tasks, the WIDEa launcher (given by the **WIDEa_launcher** R script, same location as the previous R script) can be executed by entering the following codes in a R console:

```
# Path corresponding to WIDEa directory (named s_WIDEa_path)
# A trailing slash is placed at the end of the path
s_WIDEa_path <- "enter/the/path/to/WIDEa/"

# Loading WIDEa_launcher R script (with the source function)
# The paste0 function is used to concatenate strings together
source(paste0(s_WIDEa_path, "R_script/WIDEa_launcher.r"))
```

3 Partition of WIDEa into several panels

The screenshot displays the WIDEa web interface, which is divided into four main panels: P0, P1, P2, and GA.

- Panel P0:** Located at the top left, it features a blue header with the WIDEa logo and a navigation bar with tabs for "Graphic", "Flag", and "Statistics".
- Panel P1:** Located below P0, it contains several sections:
 - Data type selection:** Includes radio buttons for "Normal" (selected), "Temporal", and "IR".
 - Data loading:** Includes a checkbox for "With flags" and a "Select data:" field with "Browse" and "Load" buttons.
 - Normal plot selection:** Includes a "Type:" section with radio buttons for "Plot", "Histplot", and "Corplot", and a "Dimension number:" section with radio buttons for "2" and "3".
 - Model parameter loading:** Includes a "Model:" section with radio buttons for "None", "Validation", and "Calibration", and a "Select model parameter:" field with "Browse" and "Load" buttons.
- Panel P2:** Located to the right of P1, it contains a large form with various input fields and buttons:
 - Y scale:** Includes radio buttons for "None" (selected), "Auto: fraction", and "Manual: min".
 - Label:** Includes input fields for "Title:", "X:", "Y:", and "Z:", each with "Yes" and "No" radio buttons.
 - Buttons:** Includes an "Apply" button and a "Close" button.
- Panel GA:** Located at the bottom right, it is a large empty area labeled "(GA)".

Figure 1. Web interface divided into 4 panels: P0, P1, P2 and GA

The web interface is divided into 4 panels called GA, P0, P1 and P2 (Figure 1). Panels are described below:

(GA) Panel dedicated to the graph area.

(P0) Panel with 2 functions:

- Inform users about the loading of actions performed on the web interface (Figure 2) ;
- Show/hide P1 and P2 to resize GA with the corresponding buttons (Left = P1, Top = P2 and Both = P1 + P2).

For the first function, it is advisable to wait until the end of loading before performing a new action on the web interface.

(P1) Panel used to load data, to select the graph type and variables and to display the result in GA.

(P2) Panel containing 3 tabs with the following functions:

Graphic The tab allows changing basic graphics settings (appearance, label, scale, etc.);

Flag The tab allows managing/saving atypical data (named flag data hereafter) manually added on the graph with a left mouse click. The graph is then updated after saving flag data;

Statistics The tab is used to perform statistical calculations and display them on the graph.

Otherwise, each action performed on the web interface can cause a warning/error message window located at the bottom-right of GA and colored in yellow/red. In the next sections, “input controls” is used as a generic term to designate a set of inputs including text field, check box and radio/action button.



Figure 2. Loading animation

4 Detailed description of P1

4.1 Data presentation

The web interface accepts data file in txt/csv format with the column headings contained only in the first row and a dot character used as a decimal separator. As the function *fread* (in package *data.table*) is used to load data, the separator between columns is automatically detected from a set of 6 characters: white space, comma, tabulation, vertical bar, colon, semicolon. Otherwise, missing values are designated with NA characters.

Variables are separated into 3 groups in the following sections: quantitative (floating-point and integer values), qualitative (string and integer values) and date (time units). An integer variable can be designated as a quantitative/qualitative variable.

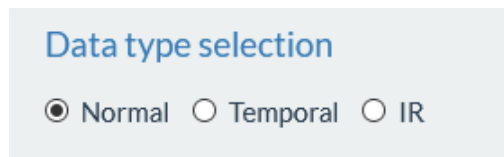


Figure 3. Radio button used to select the data type

A total of 3 data types can be selected from the radio button in Figure 3: normal, temporal and IR. One to two datasets (noted D_1 and D_2) are required depending on the selected type and are described as follow:

- Normal D_1 is a collection of quantitative/qualitative variables. An *ID* variable with unique values can be added to data and will be used to identify atypical values saved from Flag tab in P2 (row number if no *ID* variable precised).
- Temporal D_1 is composed of a date variable with unique values (used as *ID* variable) and quantitative variables measured over the given time interval.

By considering codes $\%Y$, $\%m$, $\%d$, $\%H$, $\%M$ as units of years, months, days, hours and minutes respectively, the combination of time units allowed for the date variable is $\%Y\%m\%d$, $\%d\%m\%Y$, $\%Y\%m\%d\%H\%M$ and $\%d\%m\%Y\%H\%M$. In addition, the separator between time units is the following set of 6 characters: white space, h letter, dash, forward slash, colon, dot.

IR Type corresponding to absorption spectral data on near/mid infrared (NIR/MIR) region collected from a set of l_1 (> 1) and l_2 (> 1) equidistant frequencies (called also wave number in cm^{-1}) respectively. Each infrared region is studied separately and corresponds to 2 datasets.

D_1 contains spectra arranged in rows and qualitative variables used as supplementary information (ID variable and/or others). Column names assigned to spectra are frequencies, coded “ $M1$ ”, \dots , “ Ml_1 ” (resp. “ $N1$ ”, \dots , “ Nl_2 ”) for MIR (resp. NIR) region.

D_2 contains two columns named “*Code*” and “*Frequency*” and values are codes/frequencies of the whole spectrum.

In case the number of frequencies is reduced in D_1 related to spectra pre-processings (derivative and Savitzky-Golay methods, deletion of noisy frequency intervals, etc.), then missing frequencies will be automatically added using codes/frequencies in D_2 (except for frequencies lying to interval limits) in order to keep a break in line graph.

4.2 Data loading procedure

Input controls in Figure 4 allow to:

- Add flag data related to D_1 (if existing: see section 5.2 for its creation from the Flag tab) by checking the corresponding box. The flag data will be loaded at the same time as D_1 ;

- Enter D_1 (D_2 resp.) file path in the text input field manually or with the browse button;
- Load D_1 (D_2 resp.) with the corresponding button once the text input field is filled.

Figure 4. Input controls used to load all data (D_1 , D_2 and flag)

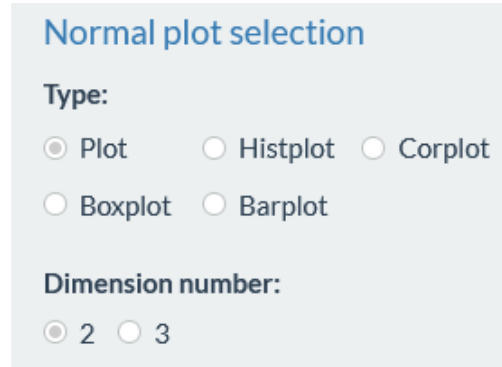
If a problem occurs while loading data, then the corresponding text input field will be colored in red (green in the opposite case) and accompanied by an error message (e.g. incorrect path, missing variables for IR data type, flag data not found, etc.).

After loading D_1 , a warning message will appear if an associated flag data exists but the corresponding box is not checked. In this case, the existing flag data will be replaced by another one if new values are saved during the current session.

4.3 Graph type selection

Radio buttons shown in Figure 5 are enabled only for the normal data type and a total of 6 graph types is available: 2D/3D scatter-plot (type = plot and dimension number = 2 or 3, named 2D/3D plot in the following), box-plot (type = boxplot) with a linear

method used to compute quartiles (“H&L-2” listed in Langford et al. 2006 [9]), histogram (type = histplot), bar-plot (type = barplot) and the correlation matrix (type = corplot) calculated from Pearson’s method (*cor* function). A simple mouse-click on each cell of the correlation matrix allows to create a combined graph in a new window (2D plot and histplot of the selected pair of variables).



The image shows a light blue dialog box titled "Normal plot selection". It contains two sections. The first section, labeled "Type:", has five radio buttons: "Plot" (selected), "Histplot", "Corplot", "Boxplot", and "Barplot". The second section, labeled "Dimension number:", has two radio buttons: "2" (selected) and "3".

Figure 5. Radio buttons used to select different types of graphics for the normal data type. The 2D plot (default value) is fixed for the other data types.

A point-to-point graph (2D plot with connected points or not) is used to represent quantitative variables (NIR/MIR spectra resp.) over a given time (frequency resp.) interval for the temporal (IR resp.) data type. A range slider is added below the main graph to select a custom time/frequency interval.

4.4 Variable selection

The selection of variables is carried out from the corresponding input fields (Figure 6) named: *ID*, *X*, *Y*, *Z* and *Group*. Each input field is enabled/disabled depending on the selected data/graph type and accepts a certain type (quantitative, qualitative and date) and number of variables (Table 1).

X, *Y* and *Z* input fields concern only the normal/temporal data type and define variables to be plotted on the corresponding graph axes in GA. As NIR/MIR spectra data

are automatically selected by combining D_1 and D_2 , all previous input fields are disabled for the IR data type. Moreover, other inputs controls are available to manipulate variables selected from X , Y and Z input fields or add a complementary information, such as:

- A function $f(x)$, $g(y)$ and $h(z)$ can be applied to quantitative variables using the Yes/No radio button (not available for corplot). The function entered in the text input field must be known by R software (without loading any new packages) and the corresponding variables must be designated by lowercase letters x , y and z (examples: \sqrt{x} , $\log(y + 1)$, etc.). If several variables are selected, then the same function will be applied on each variable;
- A *concatenation* checkbox allows you to increase the number of qualitative variables to be filled in the X input field (one variable by default). A new variable named “.concat1.” is then created into D_1 when the display button is pressed and correspond to the concatenation of the selected variables. The concatenation process is not possible if this new variable already exists in D_1 (a warning message appears after D_1 loading);
- The *format* of the date variable selected from X input field needs to be specified and corresponds to 4 combinations of time units mentioned in section 4.1.

ID and $Group$ input fields are optional (Yes/No radio button) and are only available for the normal/IR data type. The ID input field considers a variable described in section 4.1 and will be automatically filled (in a disabled state) if a flag data including an ID variable is loaded in the current session. In case the flag data are identified from row numbers (no ID variable), then the ID input field will be empty and disabled. The $Group$ input field is used to color/split data into groups of the considered qualitative variable. The data splitting is generally displayed on the same graph, except for the corplot where a correlation matrix is calculated for each group using a new input field created in GA after the display button is pressed. A *concatenation* checkbox is also available next to this

second input field and allows to create the “.concat2.” variable into D_1 .

These two last input fields are not available for the temporal data type because the role of the ID variable is already given by the date variable and the data coloration/splitting is performed from Y quantitative variables. Moreover, the ID input field is only available for 2D/3D plot of the normal data type. The reason is that flag data are created from these two graph types (section 5.2).

The figure shows a 'Variable selection' interface with two columns of controls. The left column includes:

- ID:** Radio buttons for 'Yes' and 'No' (with 'No' selected), and a text input field.
- Random:** Radio buttons for 'Yes' and 'No' (with 'No' selected), a text input field, and a red trash icon.
- X:** A checkbox for 'Concatenation' (unchecked), a text input field, and a red trash icon.
- f(x):** Radio buttons for 'Yes' and 'No' (with 'No' selected), and a text input field.
- format:** A dropdown menu.
- Y:** A text input field and a red trash icon.
- g(y):** Radio buttons for 'Yes' and 'No' (with 'No' selected), and a text input field.

 The right column includes:

- Z:** A dropdown menu.
- h(z):** Radio buttons for 'Yes' and 'No' (with 'No' selected), and a text input field.
- Weighted residuals:** Radio buttons for 'Yes' and 'No' (with 'No' selected), a checkbox for 'with groups' (unchecked), a text input field, and a red trash icon.
- variance function:** A text input field.
- Group:** Radio buttons for 'Yes' and 'No' (with 'No' selected), a checkbox for 'Concatenation' (unchecked), a text input field, and a red trash icon.

 The 'Random' and 'Weighted residuals' sections are highlighted in red.

Figure 6. Input fields used to select a set of variables: ID (flag data identification for normal/IR data), variables attributed to X -, Y - and Z -axis and $Group$ (splitting D_1 into groups for normal/IR data). Input fields ($Random$ and $Weighted residuals$) colored in red are only enabled if a model is specified (discussed in details in the next section 4.5).

Data/graph type	ID	X	Y	Z	$Group$
2D plot	1	1	1	0	≥ 1
3D plot	1	1	1	1	≥ 1
Normal	boxplot	≥ 1	1	0	≥ 1
	histplot	1	0	0	≥ 1
	barplot	≥ 1	0	0	≥ 1
	corplot	0	> 1	0	≥ 1
Temporal	0	1	≥ 1	0	0
IR	1	0	0	0	≥ 1

Table 1. Summary of the availibility of ID , X , Y , Z and $Group$ input fields per data/graph type and the type/number of variables to be filled in. A zero value means that the input field is not available. Quantitative, qualitative and date variables are designated with a cell colored in red, green and blue, respectively. No type is required for the ID variable. A number colored in red means that the variable have unique values.

4.5 Adding a model

The web interface can be used to apply (not calibrate: see Zuur et al. 2009 [17]) a wide range of statistical models following a normal distribution: linear/non-linear mixed effects models with/without interaction between random effects and/or weighted residuals. Different results are provided depending on the chosen strategy: calibration (study of residual assumptions) and validation (observed vs fitted values). The assumptions about residuals (calibration strategy) are checked from a list of graphs, such as: the comparison of residual empirical-theoretical distributions (Q-Q plot: normality), (standardized or not) residuals vs fitted values/independent variables (homoscedasticity and independency). This list of graphs will be available from a new input field created in GA, once the model is integrated in P1 and validated with the display button.

The model integration is realised in 4 steps, briefly detailed below:

- Creating of model parameters data (D_3) file;
- Enabling input controls used to load D_3 ;
- D_3 loading;
- Model description (form, variables) using variable selection input controls.

The D_3 file format is the same as D_1 and D_2 files (section 4.1). D_3 contains a minimum of 2 columns named “*parameter*” and “*value*” corresponding to the list of parameters present in the model with their values. A code is assigned to each model parameter (Table 2) and the following Gompertz model of H-D relationship is used as an example:

$$y = 1.3 + (A1 - 1.3) \cdot \exp\left(-\exp\left(a2 \cdot \frac{a3 - x1}{A1 - 1.3} + 1\right)\right) + \epsilon \quad (\text{Eq 1})$$

$$A1 = a1 + a1|re1:re2$$

With y the tree height (H in meter), $x1$ the diameter at breast height (D in cm), ($a1, a2, a3$) model coefficients (called also fixed effects coefficients), $re1:re2$ random effects of the interaction between the site and the species (2×2 categories) and $a1|re1:re2$ random effects coefficients (applied to $a1$) normally distributed with mean 0 and a certain variance. The residual term ϵ is also normally distributed with mean 0 and variance σ^2 weighted by the following function Φ :

$$\Phi(\sigma^2) = (\sigma \cdot x1^{d1|gr1})^2 \quad (\text{Eq 2})$$

With $d1|gr1$ are coefficients varying between sites (designated with $gr1$).

Values of the “*parameter*” column from the H-D Gompertz model are a , ($a|re, d|gr$) and σ codes (Table 2). Each ($a|re, d|gr$) code is duplicated by the given number of categories and new columns are added to D_3 to define different categories. These new

columns are then named with (re, gr) codes (3 columns in the present case: *re1*, *re2* and *gr1*). Table 3 represents D_3 created from the H-D Gompertz model.

Code	Description	Example
<i>a</i>	fixed effects coefficients	<i>a1, a2, a3</i>
<i>re</i>	qualitative variable used in random effects	<i>re1, re2</i>
<i>d</i>	coefficients of the residual weighting function	<i>d1</i>
<i>gr</i>	qualitative variable used in the residual weighting function	<i>gr1</i>
<i>(a re,d gr)</i>	coefficients varying between qualitative variable categories (random effect coefficients or not)	<i>a1 re1:re2, d1 gr1</i>
<i>sigma</i>	residual standard deviation	<i>sigma</i>

Table 2. Description of model parameter codes illustrated with an example given by the H-D Gompertz model: Eq 1 and Eq 2

The *sigma* parameter is used to calculate standardized residuals and check the normality assumption (Q-Q plot) in case the calibration procedure is selected. As only fitted values are calculated from the validation procedure, this parameter is not necessary and can be removed from D_3 . Furthermore, if the *sigma* parameter is missing in D_3 for the calibration procedure, the Q-Q plot will be removed from the list of graphs and residuals will be not standardized.

After D_3 creation, a series of actions must be executed to enable input controls related to its loading (detailed in Figure 7). A first part is to follow steps presented in the section 4.2 using the normal data type and selecting a 2D plot as graph type. D_1 represents the model data (dependent/independent variables and qualitative variables assigned to *re* and *gr* codes) and a flag data can also be loaded (section 5.2 for its creation). A second

part is to select the model strategy (calibration/validation) with the radio button from the normal graph type selection.

parameter	value	gr1	re1	re2
$a1$	35.7	NA	NA	NA
$a2$	1.75	NA	NA	NA
$a3$	10.05	NA	NA	NA
σ	8.02	NA	NA	NA
$d1 gr1$	-0.24	Site 1	NA	NA
$d1 gr1$	-0.25	Site 2	NA	NA
$a1 re1:re2$	5.86	NA	Site 1	Species 1
$a1 re1:re2$	-4.79	NA	Site 1	Species 2
$a1 re1:re2$	-2.14	NA	Site 2	Species 1
$a1 re1:re2$	1.07	NA	Site 2	Species 2

Table 3. Example of D_3 created from the H-D Gompertz model: Eq 1 and Eq 2. D_3 size increases with the model complexity: only fixed effects model (red), adding of a residual weighting function (green) and random effects (blue). Empty cells are represented by NA characters (in R).

A first check is carried out while loading D_3 about: parameter code assignment, column names and the presence of the σ parameter for the calibration strategy. A warning/error message will be displayed in GA if the σ parameter is missing or the D_3 structure is incorrect, respectively. In case D_3 is loaded without any error, a certain number of input controls are then enabled depending on the model strategy (calibration/validation).

Figure 7. List of necessary actions to enable D_3 : (1) select the normal data type, (2) load D_1 and select the (3) 2D plot as graph type and (4) the model strategy. The txt file named *data_tree* are described in the section 6.2.

These input controls are illustrated with the H-D Gompertz model in Figure 8 (calibration strategy) and are described below:

- The *Random* input field is optional (Yes/No radio button) and allows to add qualitative variables associated to *re* codes ;
- X and $f(x)$ input fields are used to introduce the independent variables (required type: quantitative) and the model form respectively ;
- The Y input field define the dependent variable (required type: quantitative) and a $g(y)$ function can be specified ;
- The *Weighted residuals* input controls is also optional (Yes/No radio button) and

only applies to the calibration strategy. A first input field considers the variance function and a second input field (enabled with a checkbox above) allows you to designate qualitative variables associated to *gr* codes.

Figure 8. Integration of the H-D Gompertz model using the calibration strategy. Model variables (*re1*, *re2*, *x1*, *y* and *gr1*) are filled in *Random*, *X*, *Y* and *Weighted residuals* input fields. Eq 1 and Eq 2 are entered in *f(x)* and *variance function* input fields. *A1* is replaced by *a1 + a1|re1:re2* in the *f(x)* input field. *ID* and *Z* input fields (colored with a red area) are disabled in this section.

The number assigned to each (*re*, *gr*) code depends on the order of the introduction of qualitative variables in the corresponding input fields. Independent variables (*X* input

field) follow the same rule as (*re*, *gr*) codes and the dependent variable (*Y* input field) is always designated by the lowercase letter *y*. Moreover, the *Group* input field can be used to change the color of data points in the graphs (except the Q-Q plot), depending on categories of the considered qualitative variable.

A last check is executed after the display button is clicked. It verifies the concordance between D_3 and informations filled in the variable selection input controls and the calculation of model results.

5 Detailed description of P2

5.1 Graphic tab

A total of 7 options are available from the Graphic tab (Figure 9) and are enabled/disabled depending on the data/graph type used after loading all required data (D_1 , D_2):

- | | |
|-----------|---|
| WebGL | The option allows to increase the loading speed of the graph in GA and improves the ability to display more elements and their interactivity. Briefly, some non-essential elements are removed from the graph about the temporal/IR data type (duplicated graph inside the range slider). This option is then recommended when the D_1 size is huge but it is only available for the 2D plot for now. |
| Mode | The option only applies to the temporal/IR data type and is used to connect/disconnect points of each Y variables or NIR/MIR spectra represented in the graph: line+points (= line+marker), only points (= marker) or line. |
| Opacity | The option allows to modify the opacity of elements corresponding to the selected graph type, except for the corplot (disabled). A custom value between 0 and 1 (0.7 for hisplot and barplot) can be entered in the <i>manual</i> input field (the decimal symbol is a comma). |
| Bin width | The option is used to set a custom bin width of histplot. The <i>manual</i> input field considers a value between 0 and the X range (i.e. the difference between max-min values and noted r_X). If a <i>Group</i> variable is added, then r_X is calculated for each group and the maximal value is retained. |
| Y scale | The option allows to manage the Y -axis scale for the temporal/IR data type which is disabled (by default) because of the range slider added on X -axis (time/frequencies interval). Thus, the Y -axis scale can be manually set with <i>min/max</i> input fields (the decimal symbol is a dot) or automatically calcu- |

lated from the local X -axis interval. The *fraction* input field available from the auto scaling is to add a top/bottom margin corresponding to a ratio of the local Y range. Its value is between 0 and 0.1 (the decimal symbol is a comma).

- Decimal number The option allows to modify the decimal number of (X, Y, Z) coordinates obtained with a mouseover (integer values required from the *manual* input field). This option is disabled for histplot, barplot and corplot.
- Label The option allows to add a main title and replace the default label of (X, Y, Z) axes by a custom label. The “`
`” code can be used to break lines. Input fields are controlled by a Yes/No radio button.

The image shows a software interface with three tabs: 'Graphic', 'Flag', and 'Statistics'. The 'Graphic' tab is active. It contains several sections of controls:

- WebGL:** Radio buttons for 'Yes' (selected) and 'No'.
- Mode:** Radio buttons for 'Line+marker' (selected), 'Marker', and 'Line'.
- Opacity:** Radio buttons for 'Auto' (selected) and 'Manual:'. The 'Manual' option has a numeric input field and a right arrow button.
- Bin width:** Radio buttons for 'Auto' (selected) and 'Manual:'. The 'Manual' option has a numeric input field and a right arrow button.
- Y scale:** Radio buttons for 'None' (selected), 'Auto: fraction' (with a small input field), and 'Manual: min' (with an input field) and 'max' (with an input field). A right arrow button is next to the 'Manual' options.
- Decimal number:** Radio buttons for 'Auto' (selected) and 'Manual:'. The 'Manual' option has a numeric input field and a right arrow button.
- Label:**
 - Title:** Radio buttons for 'Yes' and 'No' (selected). Below is a text input field.
 - X:** Radio buttons for 'Yes' and 'No' (selected). Below is a text input field.
 - Y:** Radio buttons for 'Yes' and 'No' (selected). Below is a text input field.
 - Z:** Radio buttons for 'Yes' and 'No' (selected). Below is a text input field.

An 'Apply' button is located at the bottom right of the 'Graphic' tab.

Figure 9. List of options available from the Graphic tab

The different options are taken into account as soon as the graph is created in GA with the display button (P1). The graph is then automatically updated if the value of one of these options is modified, except for adding custom values of *manual*, *title*, *X*, *Y* and *Z* fields (5 options concerned: opacity, bin width, *Y* scale, decimal number and label). Custom values are validated with the double right-arrows and apply buttons (only enabled when a graph is displayed in GA).

5.2 Flag tab

The Flag tab (Figure 10) is available under certain conditions (numeroted 1 to 4 below) as soon as a graph is displayed in GA. A click event listener is also added to the current graph corresponding to the manual selection (left mouse click) of data points considered as outliers. All commands related to Flag tab are then disabled when:

1. The 2D/3D plot type is not selected (normal data type concerned);
2. *X*, *Y* or *Z* is transformed with $f(x)$, $g(y)$ or $h(z)$ respectively (normal/temporal data type concerned);
3. A calibration/validation model is used (normal data type concerned);
4. An option is selected in the Statistics tab (normal/IR data type concerned).

The selected data points are highlighted in black and can be removed (one by one or all) or saved with buttons available from this tab: clear, clear all and save, respectively. Once the save button is clicked, a serie of actions is executed in the following order:

- The selected data points are collected in new flag data or the existing flag data loaded from the corresponding check box (named *with flags*, P1);
- Flag data are written in a csv/txt file (same format as D_1) at the D_1 location. The filename is the same as D_1 followed by the code “*norm_flag*”, “*temp_flag*” or

“*ir_flag*” if the data type is normal, temporal or IR, respectively. A supplementary code “*_withID*” is added at the end of the filename if an *ID* variable is used to identify the selected data points;

- The flag box (P1) is automatically checked if no flag data was previously loaded;
- The current graph is updated with information based on the previous selected data points. A new color is assigned to these data points depending on the quality code (option described more precisely below).

The 5 options in the Flag tab allows to manage the manual selection of data points (rule, type) and provide additional information in flag data as follows:

Quality code	The option is used to categorize selected data points according to a quality code (<i>qc</i>) numeroted 1 and 2. Data points saved in flag data with a $qc = 2$ are deleted on the graph (not in the file corresponding to D_1) and colored in red. Data points designated by a $qc = 1$ are only highlighted in orange. A unique $qc (= 2)$ is retained for the normal data type. In addition, these new data points highlighted in orange/red will not be displayed on the graph when one of the three first conditions cited above is effective. However, the deletion of data points saved with a $qc = 2$ will always be taken into account and a warning message will inform about the number of concerned points.
Action	The option is used to assign a rule on the click event. The first rule (add new flags) authorizes the selection of points not already saved in flag data. The second rule (replace $qc = 1$ with 2) only accepts the selection of points previously saved in flag data with a $qc = 1$ and changes the qc value after clicking on the save button. This second rule is disabled for the normal data type (only $qc = 2$).
Variable	The option is used to designate which variables (X, Y, Z) are considered as outliers. This option is only available for the normal data type and must be specified before starting the selection of data points.

- Draw** The option is used to change the type of selection between single point (point) and point-to-point (interval). The point-to-point selection is only available from the temporal data type and requires to click twice on the graph to define the interval boundaries. Multiple intervals will be automatically created if missing values exist in the selected interval. The single point selection is different for the IR data type and allows you to select a whole MIR/NIR spectrum by clicking on one of these data points.
- Commentary** The option is used to add a commentary in flag data related to the selected data points. No comment will be added if the corresponding text field is left blank. This option is disabled for the normal data type.

The image shows a software interface with three tabs: 'Graphic', 'Flag', and 'Statistics'. The 'Flag' tab is active. Below the tabs, there are several sections:

- Action:** Two radio buttons: 'Add new flags' (selected) and 'Replace qc = 1 with 2'.
- Variable:** Three checkboxes: 'X', 'Y', and 'Z'.
- Draw:** Two radio buttons: 'Interval' and 'Point' (selected).
- Quality code:** Two radio buttons: '1' and '2' (selected).
- Commentary:** A large text input field.
- Buttons:** 'Clear', 'Clear all', and 'Save' at the bottom right.

Figure 10. List of options available from the Flag tab

The flag data is organized differently depending on the used data type (column name precised into quotes below), such as:

- Normal** Selected points are described by a first column corresponding to the *ID* variable or the D_1 row number ("*.row_num.*"). The others columns are (*X*, *Y*, *Z*) variables concerned and forms a binary matrix with 1 used to identify

these points.

- | | |
|----------|--|
| Temporal | Selected points/intervals are introduced row by row and are described by start/end dates (“ <i>date_start</i> ” and “ <i>date_end</i> ” respectively), the <i>Y</i> variable concerned (“ <i>var_name</i> ”), a <i>qc</i> and a comment (NA characters if not precised). |
| IR | Informations on selected MIR/NIR spectra are also entered row by row and are given by the same first column as the normal data type, a <i>qc</i> and a comment. |

5.3 Statistics tab

The Statistics tab offers several statistical calculation methods for the normal/IR data type (Figure 11). This tab is disabled when data points (related to the Flag tab) are currently selected on the graph. Data points saved in flag data with a $qc = 2$ are obviously not used in the different statistical calculations performed from this tab. Adding a *Group* variable (P1) allows to apply separately these methods on each of its modalities. Moreover, some methods are available depending on the selected graph type (2D/3D plot, boxplot, histplot) or model strategy after loading all required data (D_1 , D_2 , D_3) and are described as follows:

Normal	<u>2D/3D plot</u>
--------	-------------------

The methods that can be applied to a 2D plot are the linear regression method (*lm* function), the 95 % confidence ellipse (*dataEllipse* function used under the package *car*) and the centroid. These previous options are all disabled when a calibration model is selected in P1. As the two first methods require a two-dimensional plan, they are also disabled for a 3D plot. Otherwise, supplementary information is displayed with a mouseover on the regression line, such as the equation, the intercept/slope value, R^2 and *RMSE*. The regression line information are partly modified if a validation model is used. The *RMSE* value is then replaced with the p-value of two

equality tests based on a Student's t-distribution, such as hypotheses are: $\text{intercept} = 0$ and $\text{slope} = 1$.

Boxplot

A unique method is available and allows to add the mean/standard deviation (*sd*) on each box as new information.

Histplot

The methods available are the density curve of the X variable distribution (*density* function with a Gaussian kernel smoothing) and the density curve following a normal distribution with the mean/*sd* of the X variable (*dnorm* function). Two vertical lines are added to the density curve (first method) corresponding to the mean/median (dashed and plain lines respectively). Additional information are displayed with a mouseover on this density curve, such as a set of values used to describe the X variable distribution (size, mean, median, *sd*) and the p-value of two normality tests: Shapiro-Wilk (*shapiro.test* function) and Kolmogorov-Smirnov (*ks.test* function). The p-value of the Shapiro-Wilk test may be missing because of a restriction on the maximum sample size (= 5000). Other p-values are added to information if a *Group* variable is used and concern variance equality tests (between samples defined for each modality): Bartlett (*bartlett.test* function) and Levene (*leveneTest* function with mean/median center).

IR

A unique method is available and allows to calculate the mean spectrum.

Graphic	Flag	Statistics
---------	------	------------

Normal:
Plot:
☐ Add linear regression
☐ Add confidence ellipsoid
☐ Add centroid
Boxplot:
☐ Add mean/sd

Histplot:
☐ Add density curve
☐ Add normal density curve

IR:
☐ Add mean spectrum

Figure 11. List of statistical calculation methods available from the Statistics tab

6 Detailed description of GA

6.1 Action buttons

A list of buttons is available above the graph depending on the data/graph type and the Statistic tab option used. Their functions can be arranged in three main categories: saving graphs as a picture file (2 buttons), data visualization management (14 buttons) and adding new elements on the graph (1 button). Buttons are described in the order of main categories as follows:



The button open a new window (Figure 12) corresponding to the management of picture parameters, such as the filename, the height/width (in pixel) and the format (png, jpeg and svg). The ok button available from this window is used to validate new parameters. All parameters are reseted if a new graph is created on GA with the display button (P1).



The button allows to save the picture file at the location specified by the web browser used.



The button concerns the zoom mode (only available from the normal data type: 2D/3D plot and histplot). Areas can be manually selected on the graph when the mode is activated.



The button is a mode used to move horizontally/vertically the plane (same availability as the zoom mode).



The two buttons allow to zoom in/out on the graph (only available from the normal data type: 2D plot and histplot).



The two buttons are used to select different rotation modes for the 3D plot.



The button is a mode used to enable/disable the mouseover event (only available from a 3D plot).



The button is used to return the last saved camera position from the 3D plot. A camera position is saved after each update of the graph.



The two buttons return the same result and allow to reset axes corresponding to the whole graph (other button used for the temporal data type and cited below).

1 month

3 months

6 months

all

The four buttons only concern the temporal data type. A time interval (X -axis) can be manually/automatically selected on the graph. Different time periods are considered for the second selection: 1 month, 3 months, 6 months or all (reset X -axis).



The button only appears when the linear regression option is selected in the Statistics tab and allows to access to a new window (Figure 13). The regression line information can then be filled in an input field from the previous windows and added to a custom position on the graph (validation with the ok button). The reset button is used to remove information added on the current graph.

Figure 12. Window used to change picture parameters (default values above)

Figure 13. Window used to add linear regression information on the graph

6.2 Graph examples

A list of pseudo-data have been specifically created to help users to test the different functionalities cited in sections above. These datasets (detailed in Table 4) are available from <https://github.com/PhilippeSantenoise/WIDEa> (see Data folder) and are

illustrated from several graph examples below.

Data type	Code (loading field)	Github data name
Normal	$psD_1 (D_1)$, $parD (D_3)$	<i>data_tree</i> , <i>data_param</i>
<u>Details:</u> Three variables have been randomly generated following known equations (Gompertz, Power) for two (broadleaved) tree species based on two sites: total height (H in m), diameter at breast height (D in cm) and stem biomass (kg). The data size is 400 trees, i.e. 100 trees for each combination of species and sites. Data have been used to calibrate the H-D Gompertz model (Eq 1 and Eq 2) with $parD$ as the inventory of estimated parameters.		
Normal	$psD_2 (D_1)$	<i>data_water_table_chemistry</i>
<u>Details:</u> The content of 11 mineral elements (in ppm) of a water table have been randomly generated following a linear relation between several pairs of elements: F, Cl, S, P, Fe, Mn, Mg, Al, Ca, Na and K. The data size is 300 samples.		
Temporal	$psD_3 (D_1)$	<i>data_weather</i>
<u>Details:</u> Data are the random simulation of the daily temperature (degree Celsius) and the daily humidity (%) in 2020 at Nancy (France). The simulation have been realized from some measured daily values to retain global trends for each month.		
IR	$psD_4 (D_1)$, $cfD (D_2)$	<i>data_MIR_spectra</i> , <i>data_MIR_code_freq</i>
<u>Details:</u> Data are randomly simulated MIR spectra (size = 100) and informations on MIR code/frequency (cm^{-1}) respectively. A set of spectra obtained with the Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS) technique on tree branch bark powder samples have been used for the random simulation. The considered MIR interval is 4000 to 550 cm^{-1} with a 4 cm^{-1} resolution (i.e. 1790 frequencies).		

Table 4. Presentation of all data available from <https://github.com/PhilippeSantenoise/WIDEa/tree/main/Data> and description of generated pseudo-data (psD_1 , psD_2 , psD_3 , psD_4 , psD_5). Pseudo-data correspond to a specific type mentioned in the section 4.1: normal (psD_1 , psD_2), temporal (psD_3), IR (psD_4). The loading field (D_1 , D_2 and D_3) is the location where data must be loaded in P1 (see sections 4.2 and 4.5).

Example (psD_1):

psD_1 can be used to create a list of graphs after selecting the normal data type, loading data (D_1 text field: Figure 4) and providing the requested variables (X , Y , Z , $Group$). Figure 14 presents an example of 4 graphs displayed in GA. The procedure used to generate these graphs is detailed in Table 5.

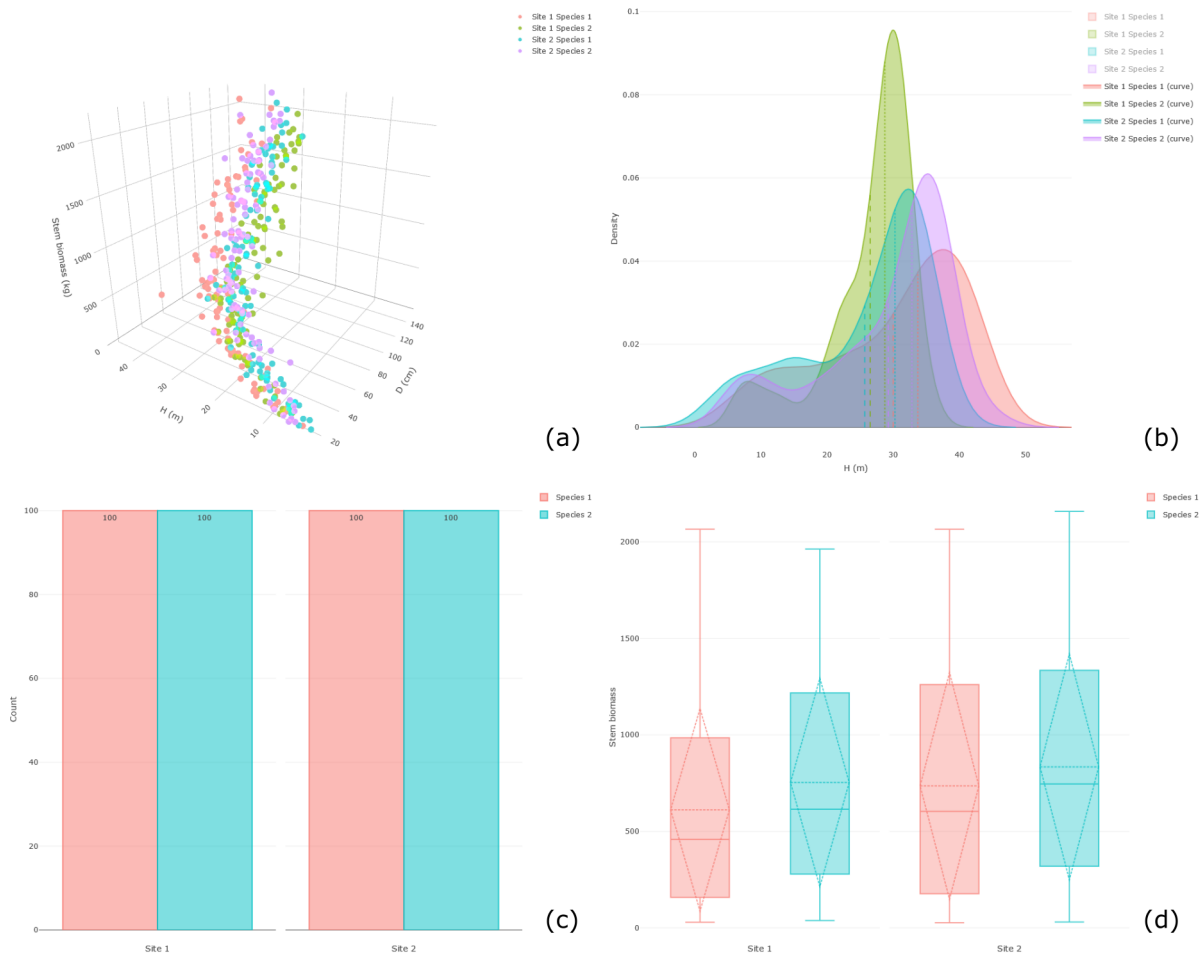


Figure 14. Graphs created from psD_1 : (a) 3D plot with (D, H, Stem biomass) as (X , Y , Z) variables, (b) histplot (deselected) with H as X variable and the associated density curve (Statistics tab), (c) barplot with Species as X variable and (d) boxplot with (Site, Stem biomass) as (X , Y) variables and informations on mean/sd values (Statistics tab) represented by a dot line and diamond top/bottom vertices respectively. A $Group$ variable is used for each graph: Site \times Species (concatenation) for (a) and (b) and only Site for (c) and (d).

Step	Panel (Section/Tab)
1	P1 (Data type selection, Data loading)
	(all): Select “Normal” as data type and load psD_1 from D_1 text field.
2	P1 (Normal plot selection)
	<p>Select the graph type (Model = “None”),</p> <p>(a): “Plot”; (b): “Histplot”;</p> <p>(c): “Barplot”; (d): “Boxplot”.</p> <p>Select “3” as the dimension number for the graph noted (a).</p>
3	P1 (Variable selection)
	<p>Select variables to be displayed on the graph,</p> <p>(a): “D”, “H” and “Stem_biomass” from X, Y and Z input fields;</p> <p>(b): “H” from the X input filed;</p> <p>(c): “Site” from the X input filed;</p> <p>(d): “Site” and “Stem_biomass” from X and Y input fields.</p> <p>Add a <i>Group</i> variable by enabling the input field with the “Yes” radio button.</p> <p>Select “Site” and “Species” for graphs noted (a) and (b) after checking the concatenation box. Select only “Species” for graphs noted (c) and (d).</p>
4	P2 (Graphic)
	<p>Edit axis labels after enabling the text field with the “Yes” radio button,</p> <p>(a): “D (cm)”, “H (m)” and “Stem biomass (kg)” for X, Y and Z axes.</p> <p>(b): “H (m)” for X-axis.</p>
5	P2 (Statistics)
	<p>Add supplementary informations by checking the box named,</p> <p>(b): “Add density curve”; (d): “Add mean/sd”.</p>
6	P1
	(all): Create the graph with the display button.

Table 5. Detailed procedure to create graphs noted (a), (b), (c) and (d) in Figure 14. The legend of the graph (b) is partly deselected by clicking on it.

The H-D Gompertz model results (Figure 15) can also be displayed in GA, by using psD_1 and $parD$ as D_3 file. The procedure is fully described in Figure 7 and Figure 8.

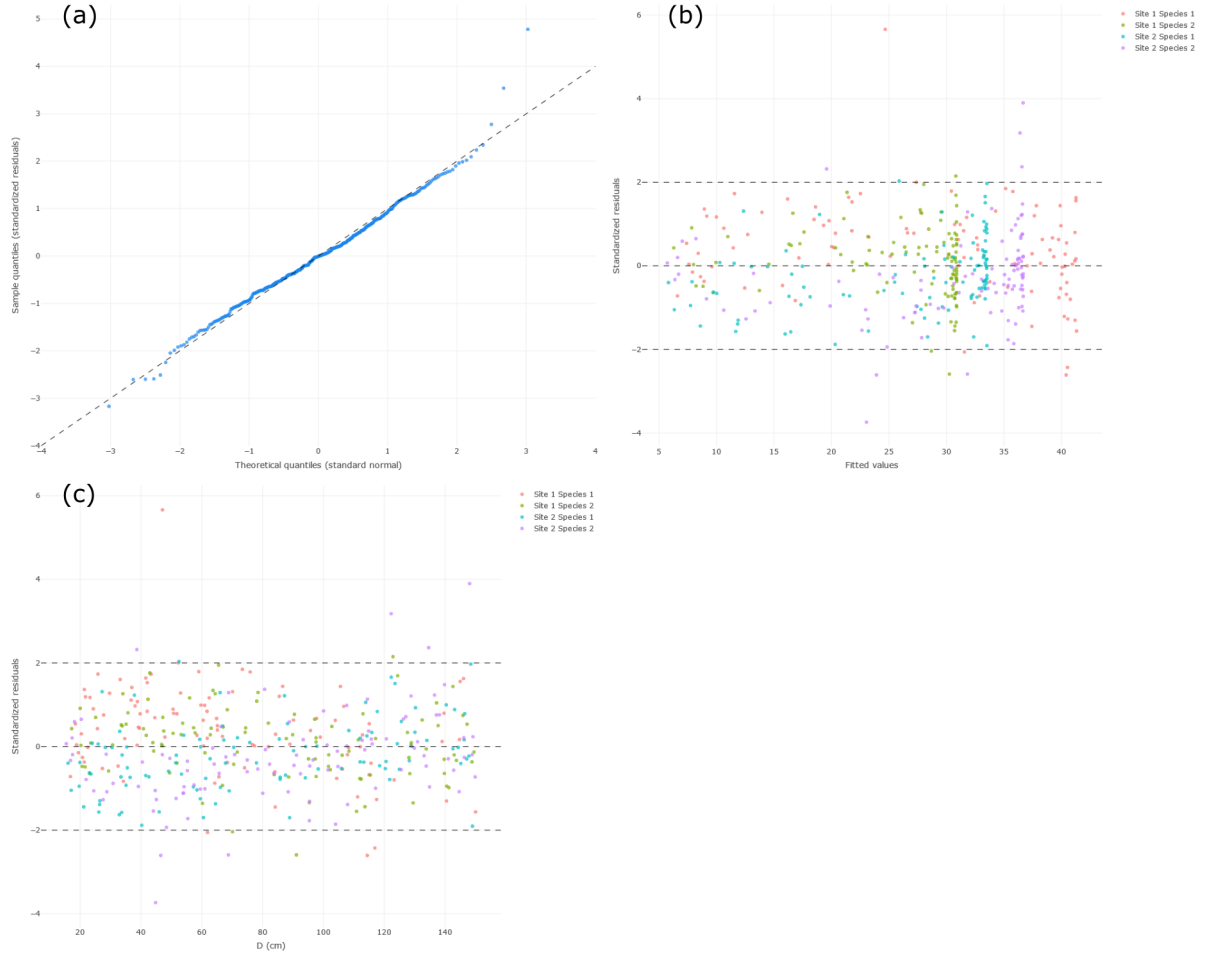


Figure 15. Graphs used to study assumptions on the H-D Gompertz model (psD_1 and $parD$) residuals: (a) qqplot on the standardized residuals distribution, (b) 2D plot on standardized residuals vs fitted values and (c) 2D plot on standardized residuals vs D . A *Group* variable is also added to color data per Site \times Species (concatenation) for (b) and (c).

Example (psD_2):

A correlation matrix (Figure 16) can be built from spD_2 , by following the procedure below:

- (Step 1) Select “Normal” as data type and load psD_2 from D_1 text field (P1: Data type selection, Data loading);
- (Step 2) Select “Corplot” as the graph type (P1: Normal plot selection);
- (Step 3) Select all variables in psD_2 from the Y input field (P1: Variable selection);
- (Step 4) Create the correlation matrix with the display button (P1).

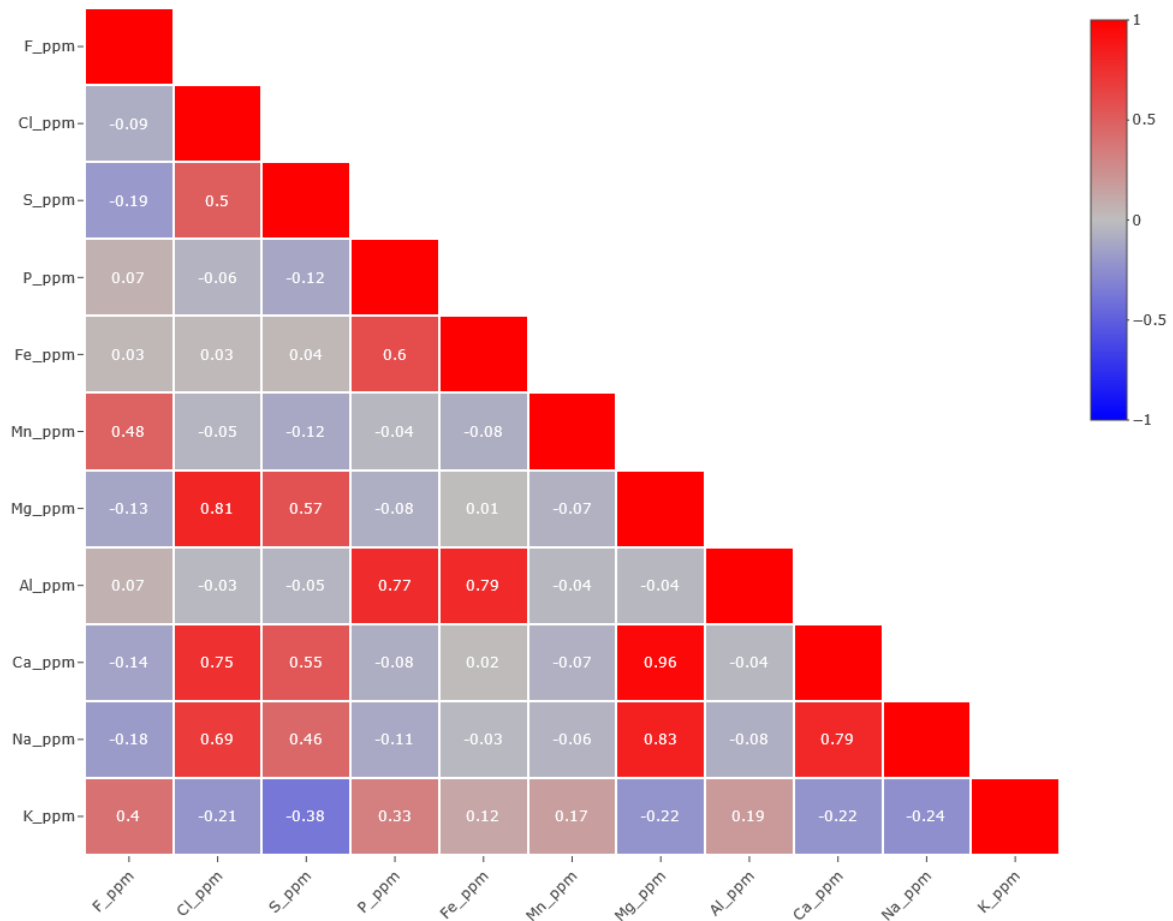


Figure 16. Corplot created from psD_2 : study of linear correlations of the content of 11 mineral elements of a water table.

Example (psD_3):

psD_3 are used as an example of temporal data. The Daily temperature/humidity in 2020 can then be displayed in GA (Figure 17) by following the procedure below:

- (Step 1) Select “Temporal” as data type and load psD_3 from D_1 text field (P1: Data type selection, Data loading);
- (Step 2) Select “Date”, “%Y%m%d” and the pair (“Temperature”, “Humidity”) from X , $format$ and Y input fields respectively (P1: Variable selection);
- (Step 3) Click on “No” and “Line+marker” from WebGL and Mode radio buttons respectively (P2: Graphic);
- (Step 4) Create the graph with the display button (P1).

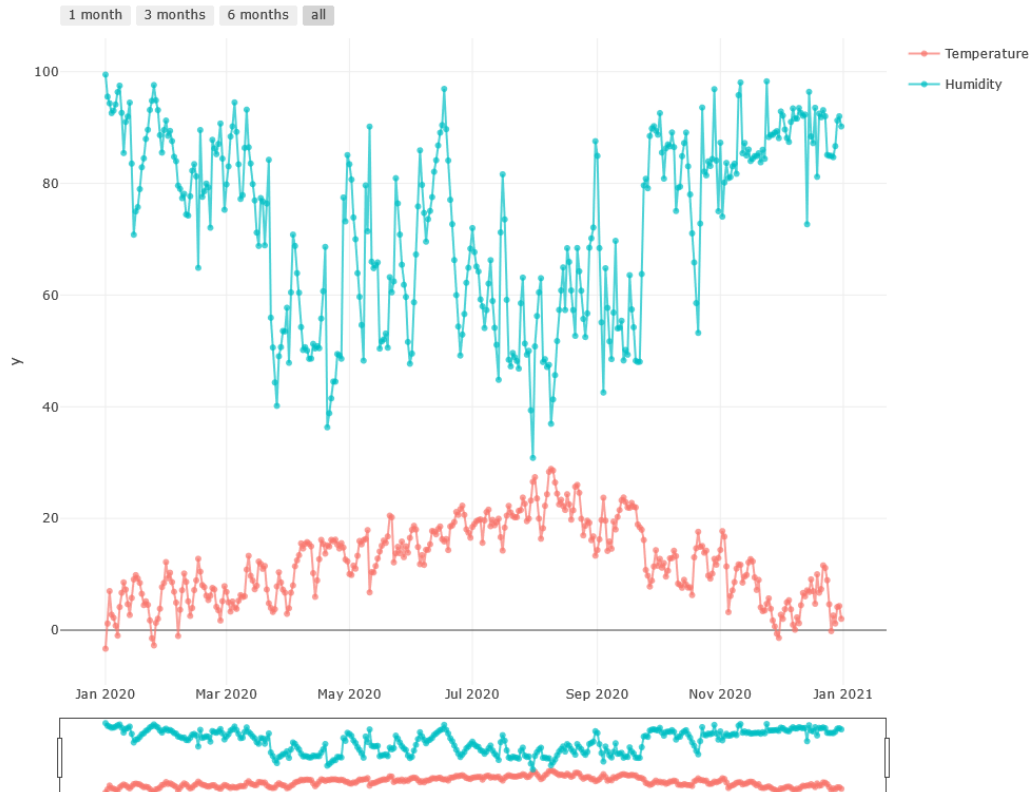


Figure 17. 2D plot created from spD_3 : the daily temperature and the daily humidity (Y variables) in 2020 (X variable: Date with the %Y%m%d format) at Nancy.

Example (psD_4):

psD_4 and cfD are used as an example of IR data. MIR spectra of absorption can be directly displayed in GA (Figure 18) by following the procedure below:

- (Step 1) Select “IR” as data type and load psD_4 and cfD from D_1 and D_2 text fields respectively (P1: Data type selection, Data loading);
- (Step 2) Click on “Yes” and “Line” from WebGL and Mode radio buttons respectively (P2: Graphic);
- (Step 3) Create the graph with the display button (P1).

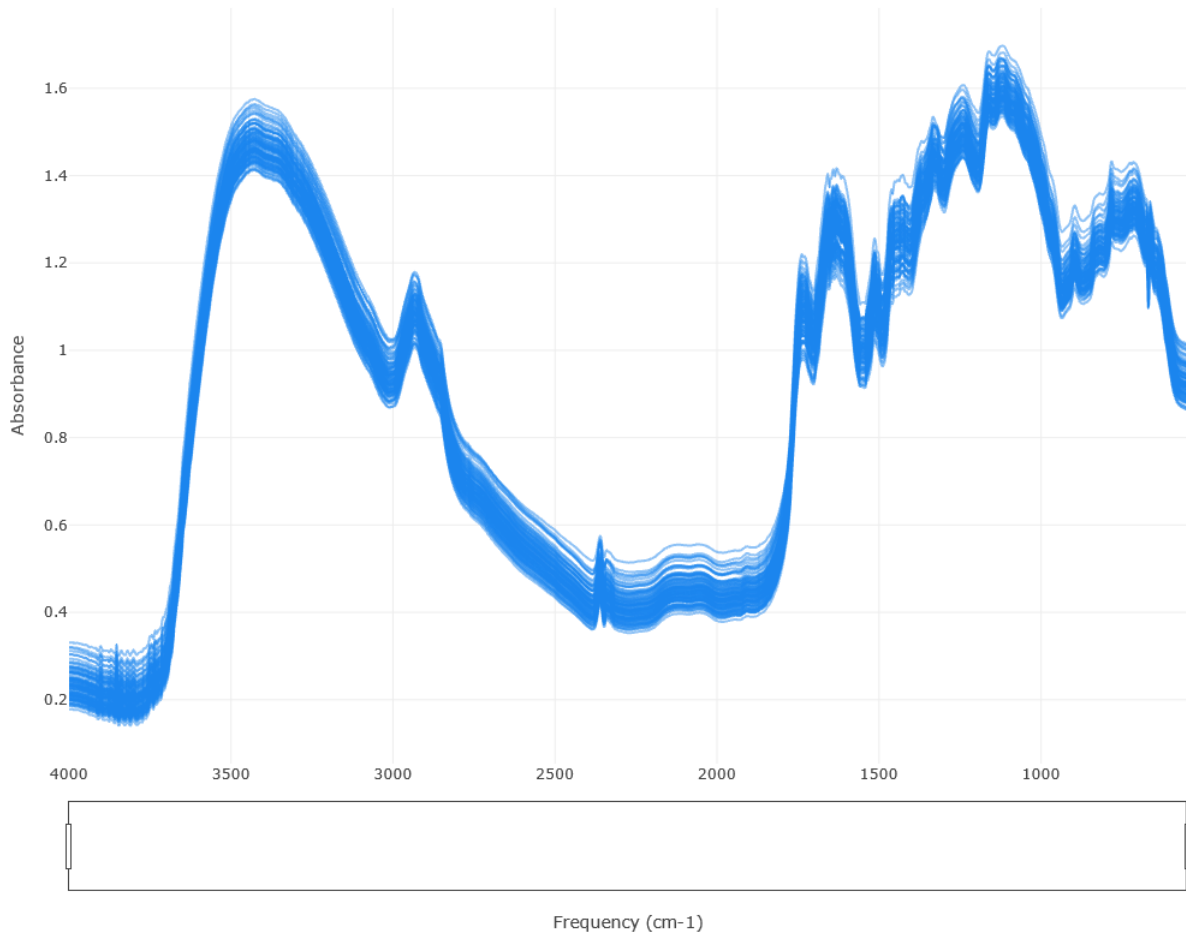


Figure 18. 2D plot created from psD_4 and cfD : MIR spectra of absorption on the considered frequency interval.

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