ArcStereoNet – User guide

1. Introduction to ArcStereoNet

ArcStereoNet (ASN) is an ArcGIS® Python-toolbox whose main features include the projection and the analysis of oriented data, mainly for structural geology and mineralogy purposes. Oriented data can be acquired on field (e.g. beddings, fault lines etc.) by means of classic geologist instruments like compass but also extracted from thin section high-resolution images (e.g. mineral preferred orientations). However, ASN is potentially suitable to work with any type of oriented data.

ASN can be installed on ArcGIS® 10.3+ versions (see Installation for details) and it is devised for working on ArcMap®. This allows the user to take advantage of the powerful geospatial analysis functions provided by ArcGIS®, minding the gap between spatial orientation of data and their georeferenced positions.

The available tools within the ArcStereoNet Python-toolbox are: *Stereoplots* tool (for stereographic projections and oriented data analysis), *Rose Diagrams* tool (for rose histograms creation) and *Graph To Hyperlink* tool (to link plots with the corresponding geographic position in map).

1.1 Requirements

ArcStereoNet requires any working ArcMap® version ≥ 10.3 to be installed on a Windows® operative system (XP, Vista, 7, 8, 8.1, 10). **NB**: ArcMap® 10.3 *pre-release* version is not supported.

2. Installation

ASN core Python library, *mplstereonet* (Kington, 2016), gathers all the main functions to generate stereographic projections. Such library does not come with the default installation of Python 2.7.x for ArcGIS®, therefore it must be specifically installed for ASN to work. The most canonical way to carry out the installation is by mean of *pip* (i.e. the most known Package Installer for Python). The toolbox has been programmed to fully automate this procedure. If your ArcMap® version is 10.3 or 10.3.1, please follow the instructions at <u>Installation with ArcMap® 10.3</u> section before reading on.

The user must copy the file "ArcStereoNet.pyt" inside ArcGIS® toolboxes folder. By default, the full path is: "**C:/Program Files (x86)/ArcGis/Desktop10.x/ArcToolbox/Toolboxes**". Once the file is copied, the user can open the ArcToolbox window inside ArcMap®, right-click and then select "Add Toolbox" option to import ASN.

The installation will automatically start; this requires an internet connection. A pop-up window will inform the user whether the components have been successfully installed or not.

[Kington, J. (2016). Mplstereonet. Available at <u>https://github.com/joferkington/mplstereonet</u>].

2.1 Installation with ArcMap® 10.3

By default, ArcGIS® 10.3 and 10.3.1 versions do not include *pip* in their Python directory, therefore, it needs to be installed manually. To achieve this, go to <u>https://bootstrap.pypa.io/get-pip.py</u>, right-click and select "Save As" to download the "get-pip.py" script on your computer. The file must be saved in the Scripts directory, which is located by default in "**C:\Python27\ArcGIS10.3\Scripts"**. Then, follow the installation steps described above. If, for any reason, the automatic installation routine happens to fail, refer to the manual installation of *pip* at <u>https://pip.pypa.io/en/stable/</u>.

3. Getting started

In order to launch ASN tools, an ESRI shapefile storing oriented data is needed. **It can be created directly inside ArcMap® through the "Create Feature" window**, but a tabular data file that contains two columns storing latitude and longitude coordinates can also be imported and then converted into a shapefile. This can be performed through the following steps:

1. Click on File > Add Data > Add XY Data (**a**) and select the tabular data sheet and the coordinates fields (**b**) The coordinate system can also be here specified.
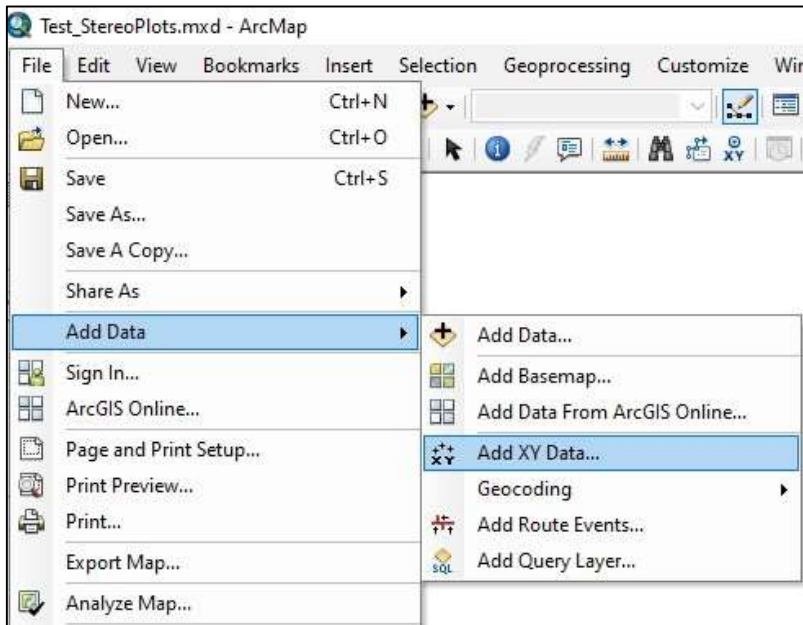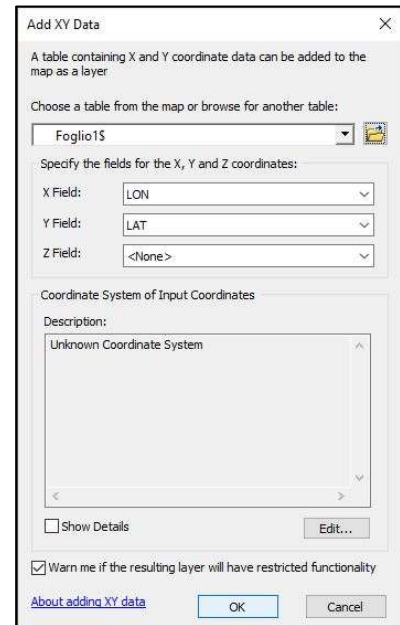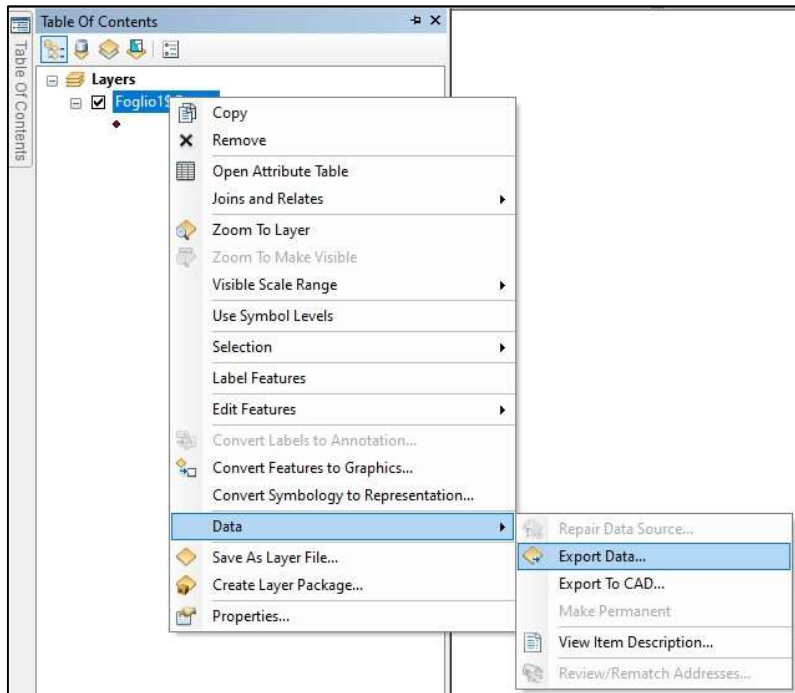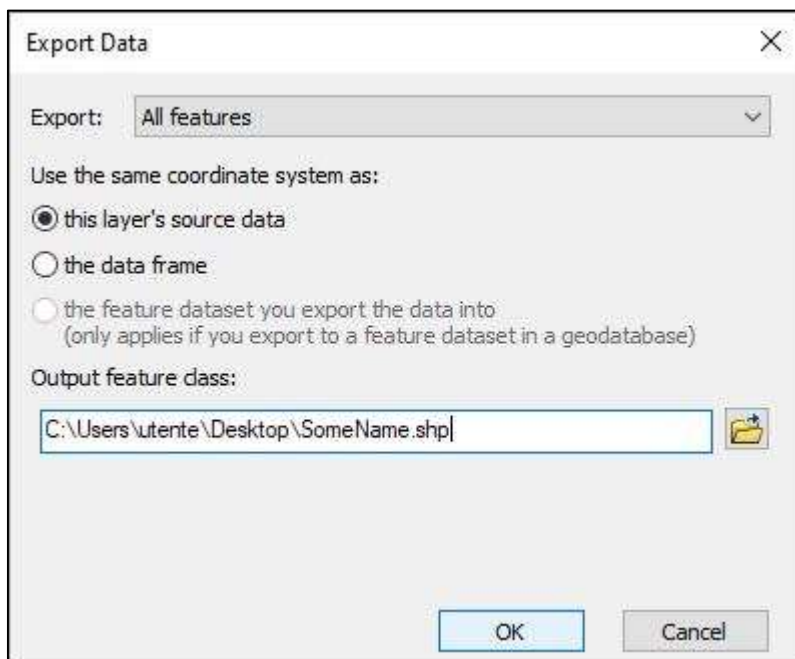

(**a**) (**b**)

2. In the Table of Contents, right-click on the imported file, then select Data > Export Data (**c**) and choose an output path for the new shapefile (**d**).

(**c**)

(**d**)

For more information please refer to ESRI official guidelines here.

3.1 Fields formatting

ASN tools require as input the following information:

- Azimuth angle (both *Stereoplots* tool and *Rose Diagrams* tool)
- Dip angle (only *Stereoplots* tool)
- Sampling method (only *Stereoplots* tool)
- Feature type (both *Stereoplots* tool and *Rose Diagrams* tool)

These must be stored in different fields within the attribute table of the oriented data shapefile. ASN tools can automatically fill the required inputs if such fields are renamed as follows (not case sensitive):

- *Azimuth* – here azimuthal values (i.e. direction, dip direction or trend) shall be stored as numeric values.
- *Dip Angle* or *Dip_Angle* – here inclination values (i.e. dip or plunge) shall be stored as numeric values.
- *Method* – here the data format must be specified as text values, choosing from "RHR", "DD" and "TP" (must be written in uppercases), indicating, respectively, the following conventional sampling methods: Right Hand Rule, Dip Direction/Dip and Trend-Plunge.
- *Type* – here the user should indicate the feature type as text values (e.g. "Main Foliation"). Such information is not mandatory, though highly recommended. It is functional for the legend labels but also guides the toolbox to a correct grouping and graphical representation of the different types of data.

The user can also populate with such information a tabular data file and then import it, as described in Getting started section; each column will be treated as a different field by ArcMap®. The attribute table can also be edited at any time. If the fields are not renamed as suggested above, it is still possible to select manually the corresponding ones within the tools interface (see Tools for details). Other fields can also be added in the attribute table according to user's needs and preferences.

4. Tools

Once the oriented data shapefile has been created, any ASN tool can be launched. The *Stereoplot* tool is useful to obtain lower hemisphere stereographic projections, showing cyclographic traces and poles for the selected planar measurements and points for the linear ones. Several contouring and statistical functions can also be applied on oriented data. The *Rose Diagrams* tool can be chosen to create weighted and unweighted rose diagrams and to extract mean vectors directions. Finally, the *Graph To Hyperlink* tool allows to link realised graphs to the georeferenced position of plotted data.

4.1 Stereoplots tool

The following screenshots illustrate the *Stereoplots* tool layout. A detailed description for each parameter is provided below. **Green dots indicate required parameters**.

a) Oriented dataset input parameter. A shapefile is required: point, line and polygon feature types are supported. If the user has selected some features, the tool will not consider the unselected ones. Otherwise, all data stored within the oriented data shapefile will be taken into account.

b) *Azimuth*, *Dip Angle*, *Method* and *Type* fields input parameters. If the user has formatted the shapefile fields names as recommended (see <u>Getting started</u>), these parameters will be automatically filled, otherwise they can be selected manually through the drop-down menus.

c) Plotting data Value Table. The feature types can be added through the drop-down menu. For each feature type, the user can specify the plotting colour, pole or vector symbol and size, cyclographic trace style and width (Value Table columns). <u>If a linear datatype is added, the corresponding cyclographic trace style and width entries will be ignored by the tool.</u> A linear datatype is automatically identified by checking the *Method* field.

d) Output image settings. By unchecking the "Store Image Output" checkbox, the user can prompt the tool to save a temporary output image file and automatically open it after the tool execution. Otherwise, the output image file path can be specified in the "Output Image" parameter box. The DPI value can be set through the parameter below.

e) Contour & Statistics sub-menu (collapsed). See <u>Contour & Statistics</u> for details.

f) Plot customisation sub-menu (expanded). The following parameters can be set (from top to bottom): the title label that will appear in the final plot (if not specified, it will be the name of the shapefile); the number of tick marks surrounding the plot and their type (i.e. angular values, cardinal points or a mix of them); whether to enable or disable the appearance of the stereonet grid, the legend and the number of plotted data.

g) Plotting options sub-menu (expanded). The stereonet type can be chosen between equal-area (Schmidt net) and equal-angle (Wulff net). The "Write Log File" option can be checked to prompt the tool to compile a text file storing statistical information concerning the plotted data and the functions applied on it. If the "Store Image Output" option (**d**) is not enabled, a temporary log file will be created and automatically opened together with the image. Otherwise, the log file will be saved in the same output directory selected for the image.

4.1.1 Contour & Statistics

Expanded Contour & Statistics sub-menu of Stereoplots tool.
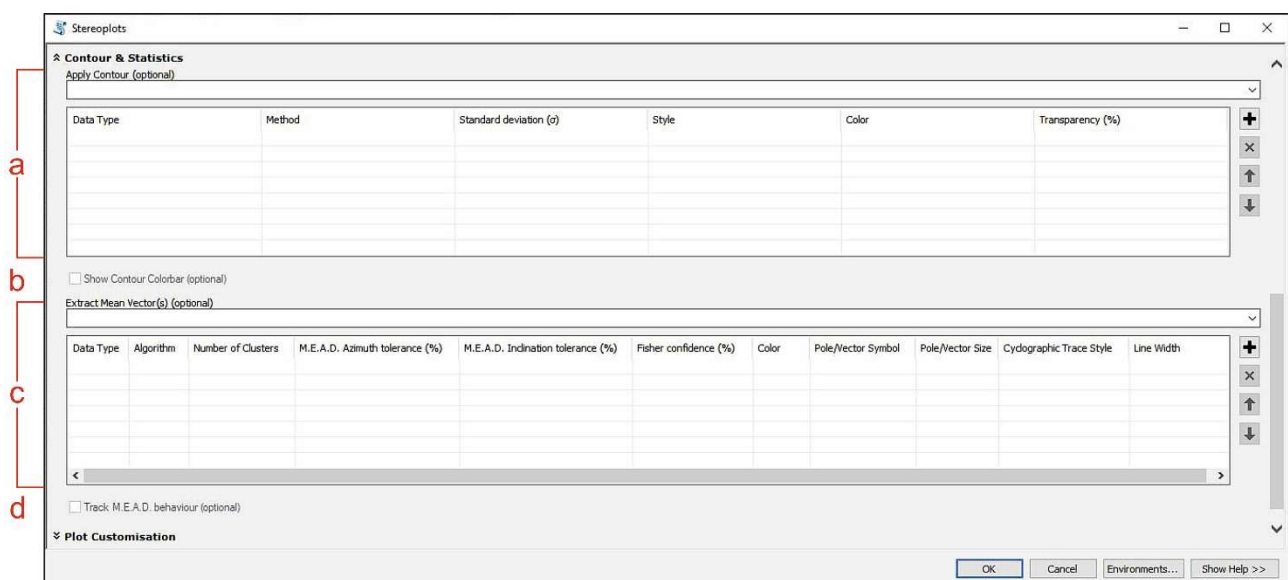
a) "Apply Contour" Value Table. The feature types can be added through the drop-down menu. The user can choose the preferred contour density function under the "Method" column, but she/he can also set other parameters such as standard deviation, style ("filled" or "unfilled"), colour and transparency of the contour through the corresponding columns. **Tip:** A warning message will pop-up if two or more contour functions are applied contemporaneously. However, it is still possible for the users to prompt for multiple contour functions if they really want to. An "unfilled" contour style is recommended.

b) Show a colour bar referred to the applied contour. This setting will be enabled after the "Apply Contour" Value Table has been populated. If two or more contours are applied at the same time, the colour bar will be referred to the last one.

c) "Extract Mean Vectors" Value Table. The feature types can be added through the drop-down menu. Multiple feature types can be analysed contemporaneously, and the same feature type can be analysed with different algorithms as well. Under the "Algorithm" column the preferred algorithm can be chosen. The choices are: **M.E.A.D.**, **M.E.A.D. + Fisher**, **K-means**, **Bingham**.

> ➤ The M.E.A.D. algorithm can be used for a fully user-controlled clustering extraction, thanks to the azimuth and inclination tolerances parameters.
> ➤ The M.E.A.D. + Fisher algorithm adds to the previous one the extraction of Fisher statistics (mean vector magnitude, confidence radius and dispersion factor – Fisher *et al.*, 1993) that will be stored into the log file (if prompted by the user). A confidence cone surrounding the pole to extracted mean plane will also be plotted.
> ➤ The K-means algorithm employs a k-means approach (MacQueen, 1967) modified for spherical data.
> ➤ The Bingham algorithm allows to extract the best fit plane of a "girdle-like" distribution pattern (Bingham, 1974) of poles to planes or lines.

The algorithm-control parameters can be set through the following columns (from left to right): "Number of Clusters", to specify the number of families to split data into; "M.E.A.D. Azimuth tolerance" and "M.E.A.D. Inclination tolerance", to constrain the algorithm to define more or less dispersed clusters; "Fisher confidence", that influences the Fisher confidence radius computed by M.E.A.D. + Fisher algorithm. Each of these control parameters affects only some of the algorithms as summarised in the following table.

	M.E.A.D. + Fisher	M.E.A.D.	K-means	Bingham
Number of Clusters	X	X	X	-
M.E.A.D. Azimuth tolerance	X	X	-	-
M.E.A.D. Inclination tolerance	X	X	-	-
Fisher Confidence	X	-	-	-

If a not affecting parameter is specified, it will simply be skipped by the tool. The next columns within the Value Table gather graphic-related parameters such as plotting colour, pole or vector symbol and size, cyclographic trace style and width. <u>If a linear datatype is added, the corresponding cyclographic trace style and width entries will be ignored by the tool</u>. A linear datatype is automatically identified by checking the *Method* field.

Tip: If the user is uncertain on the number of clusters to insert, a possible workaround is to prompt for a high number (e.g. 20 or more). In such a way the algorithms affected from the "Number of Clusters" parameter will extract the highest number of plausible clusters (which are likely less than 20+).

d) Track M.E.A.D. clustering behaviour. This option will be enabled after the "Extract Mean Vectors" Value Table has been populated and will only apply on clusters extracted through the M.E.A.D. clustering process (M.E.A.D. and M.E.A.D. + Fisher algorithms). If checked, the tool will plot the clustered data with different symbols for each extracted cluster. The users can take advantage of this option to identify the M.E.A.D. tolerance parameters best suited to their preferences and needs.
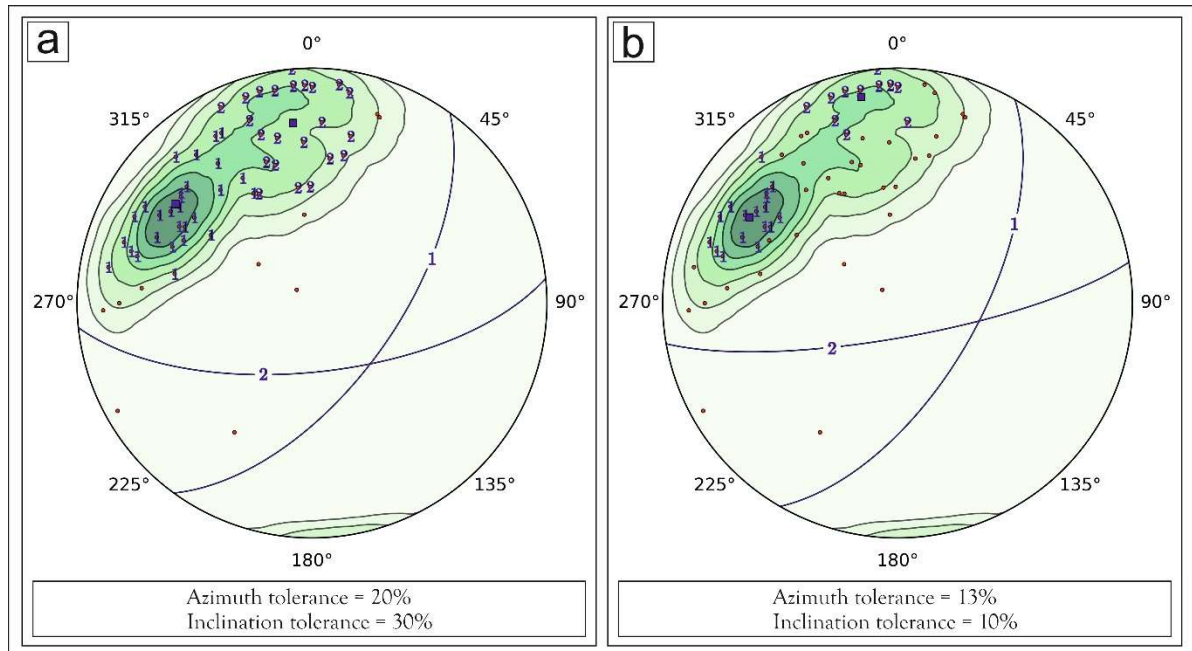
Influence of Azimuth and Inclination tolerance parameters on M.E.A.D. clustering process, highlighted by the "Track M.E.A.D. behaviour" option.

Tip: It is likely that the users will test the ASN algorithms several times, modifying the control parameters repeatedly, until finding the ones that better suit their preferences and needs. During this phase (*testing phase*), we highly recommend using the ArcMap® "Results" window to recall any previously launched tool. In such a way the user can quickly modify only the desired parameter without having to set all the others each time. We also recommend deselecting the "Store Image Output" option during the testing phase, in order to rapidly view the graphic result and save memory space on the disk.

[Bingham, C. (1974). An antipodally symmetric distribution on the sphere. The Annals of Statistics, 1201-1225].

[Fisher, N. I., Lewis, T., & Embleton, B. J. (1993). Statistical analysis of spherical data. Cambridge university press].

[MacQueen, J. (1967). Some methods for classification and analysis of multivariate observations. In Proceedings of the fifth Berkeley symposium on mathematical statistics and probability (Vol. 1, No. 14, pp. 281-297)].

4.2 Rose Diagrams tool

The following screenshot illustrate the *Rose Diagrams* tool layout. A detailed description for each parameter is provided below. **Green dots indicate required parameters**.
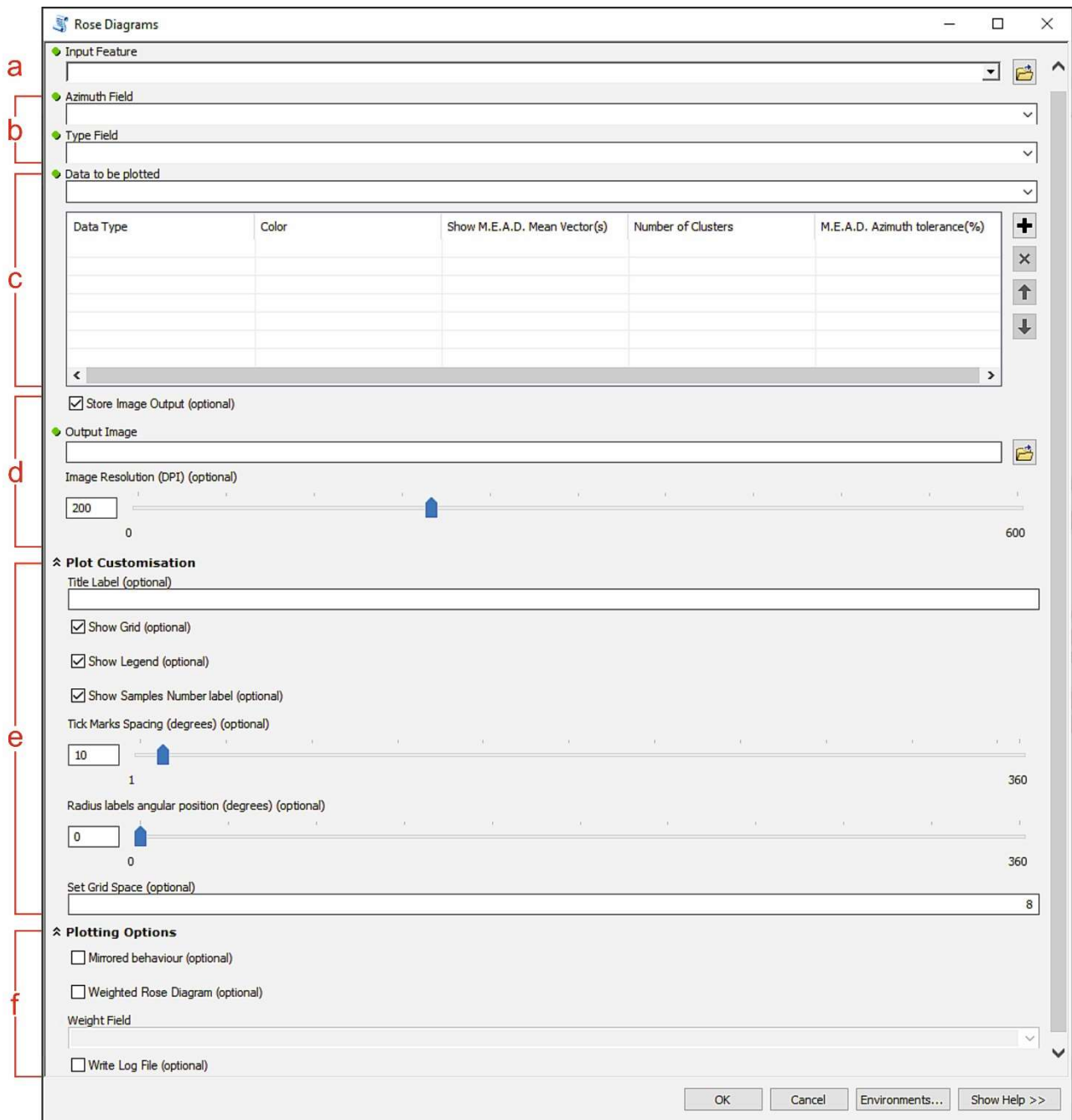
a) Oriented dataset input parameter. A shapefile is required: point, line and polygon feature types are supported. If the user has selected some features, the tool will not consider the unselected ones. Otherwise, all data stored within the oriented data shapefile will be taken into account.

b) *Azimuth* and *Type* fields input parameters. If the user has formatted the shapefile fields names as recommended (see <u>Getting started</u>), these parameters will be automatically filled, otherwise they can be selected manually through the drop-down menus.

c) Plotting data Value Table. The feature types can be added through the drop-down menu. For each feature, the user can specify the bar colour and whether to show the mean vectors or not, with a determined number of clusters and azimuth tolerance (Value Table columns).

d) Output image settings. By unchecking the "Store Image Output" checkbox, the user can prompt the tool to save a temporary output image file and automatically open it after the tool execution. Otherwise, the output image file path can be specified in the "Output Image" parameter box. The DPI value can be set through the parameter below.

e) Plot customisation sub-menu (expanded). The following parameters can be set (from top to bottom): the title label that will appear in the final plot (if not specified, it will be the name of the shapefile); whether to enable or disable the appearance of the polar grid, the legend, and the number of plotted data; the spacing (in degrees) of the tick marks surrounding the diagram; the orientation of the radial scale (in degrees from N); the grid spacing (i.e. spacing of the radial scale).
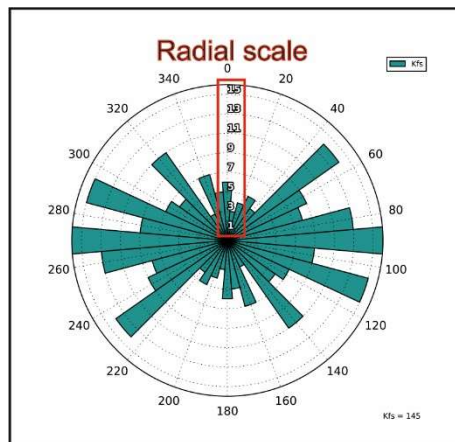

Example of a radial scale oriented 0° and with a spacing of 8 (default values).

f) Plotting options sub-menu (expanded). If the "Mirrored behaviour" option is checked a specular rose diagram will be generated. A warning message will popup if the azimuthal dataset spreads for more than 180°. If the "Weighted Rose Diagram" option is selected, the below "Weight Field" parameter enables and must be filled with a field of the input shapefile storing weight data. A warning message will appear if one or more weights are negative values. The "Write Log File" option can be checked to prompt the tool to compile a text file storing statistical information concerning the plotted data. If the "Store Image Output" option (**d**) is not enabled, a temporary log file will be created and automatically opened together with the image. Otherwise, the log file will be saved in the same output directory selected for the image.

4.3 Graph To Hyperlink tool

The following screenshot illustrate the *Graph To Hyperlink* tool layout. **All parameters are here required.**
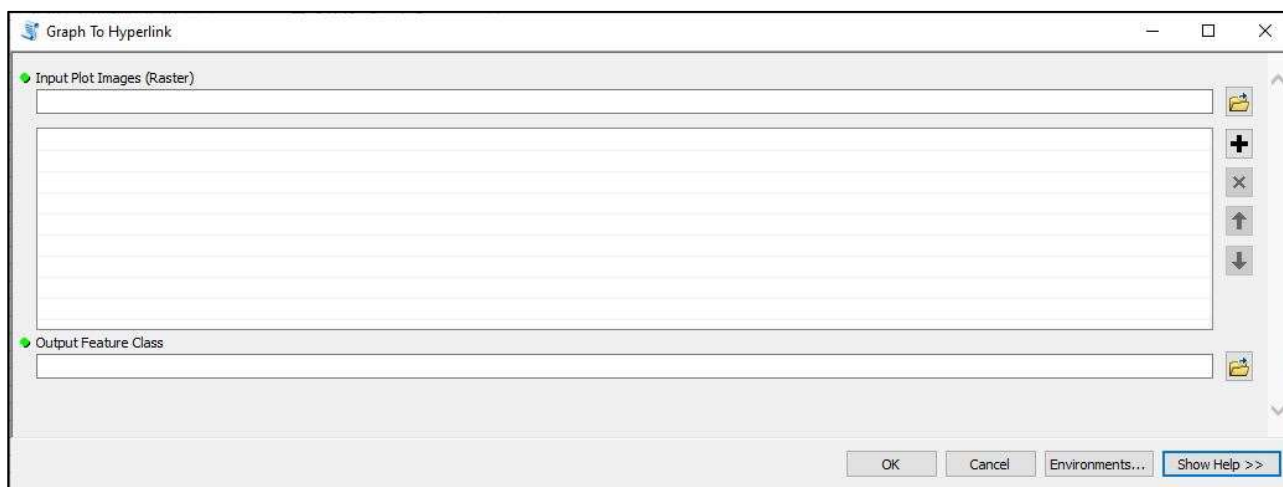
- The Input Plot Images parameter requires one or more raster images to be provided. The files can be selected through the drop-down menu. Such images are meant to be the plots resulting from the application of the *Stereoplots* and/or the *Rose Diagrams* tool. Each time a new stereoplot or rose diagram is saved **as a PNG image**, a text file (named as "*imageName_*xy.txt") is automatically compiled and stored in the same output directory. Such file contains the spatial information referred to the corresponding plot. Make sure to not delete or move these files, as they are required by the *Graph To Hyperlink* tool to link each image to the correct georeferenced position. If the user selects an image whose *_xy.txt* file is missing, an error message will popup.
- The output file path can be chosen through the Output Feature Class parameter. A new point shapefile, gathering all the links to the selected images and their corresponding latitude and longitude values, will be created.

The spatial information attached to each plot is computed as the mean latitude and the mean longitude (centroid) of the processed data. **Please note that if the user does not operate any selection of data before running the *Stereoplots* or the *Rose Diagrams* tool, all dataset will be considered during the computation.** The adopted reference system will be the same as the dataset from which the plots were extracted.

Once the *Graph To Hyperlink* tool has been executed and the new resulting shapefile imported within ArcMap®, the user can enable the hyperlink or the HTML popup view. This can be done by right-clicking on the new shapefile and selecting the Properties option (**a**).
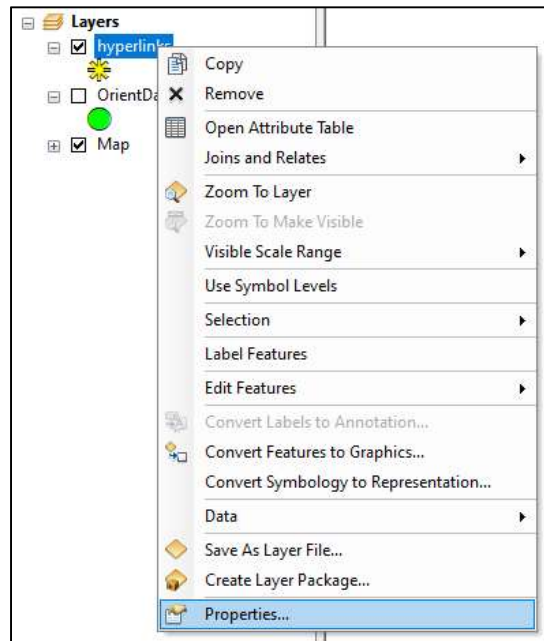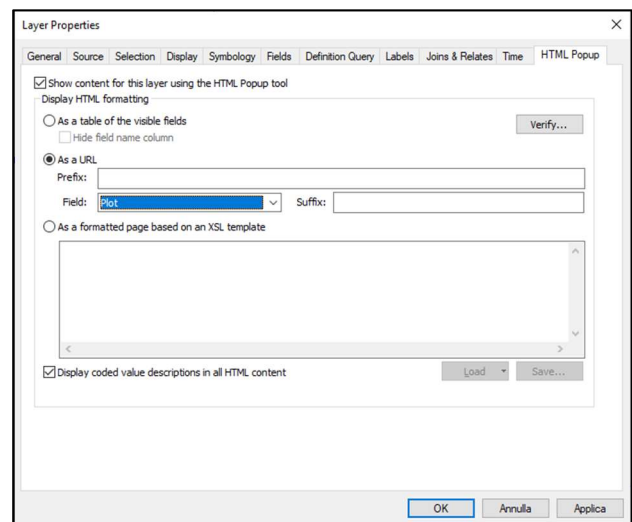

(**a**)

Under the Display tab, enable the "Support Hyperlinks using field" option (**b**), then select the "Plot" field and check the "Document" option to allow hyperlinks. Otherwise, enable the "Show content for this layer using the HTML Popup tool" option (**c**) under the HTML Popup tab, then specify to display HTML formatting as a URL and select the "Plot" field to allow HTML popup view.
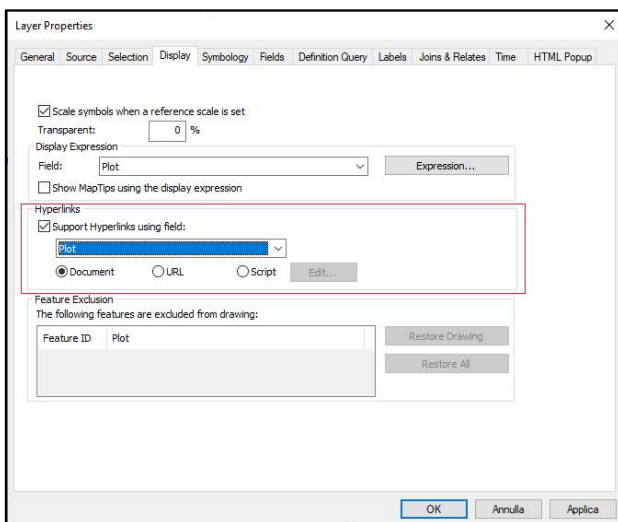

(**b**)

(**c**)

If hyperlinks are allowed (**b**), each feature of the new shapefile created with the *Graph To Hyperlink* tool can be clicked on map and the corresponding image will be opened with your default image viewer. If HTML popups are allowed (**c**), plots will pop up directly on map at their corresponding georeferenced positions. Both functionalities can be triggered by selecting the related button on the Tools toolbar (**d**).
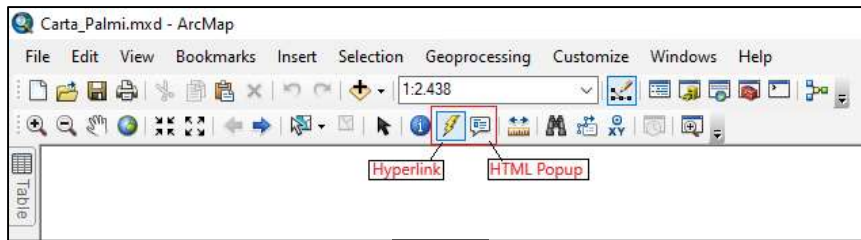
(**d**)

The following screenshot shows an example of HTML popups displaying georeferenced stereoplots on map. **Tip:** Ctrl + mouse wheel to zoom in and out the popup images.
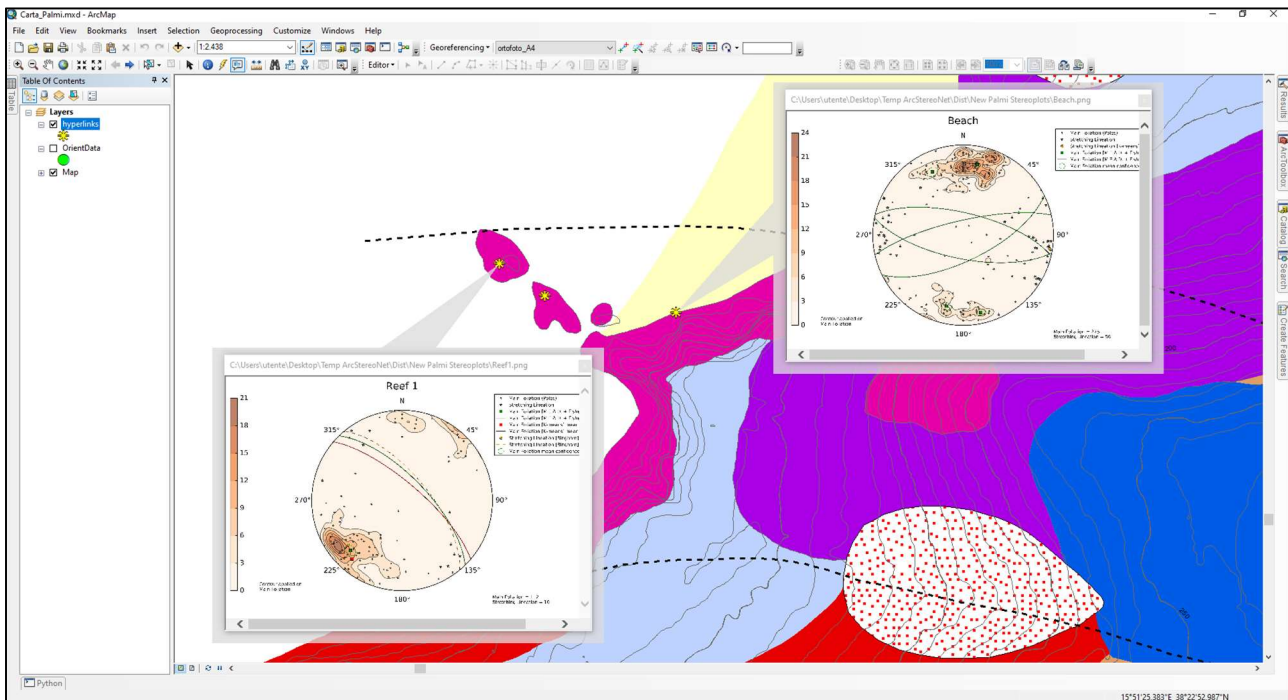
For more information about hyperlinks and HTML popups in ArcGIS®, refer to ESRI official guides here and here, respectively.

5. Troubleshooting

This section lists known errors and bugs that can occur while installing and using ASN, along with the possible workarounds.

5.1 Installation issues

ASN can sometimes report an *installation error* with the following pop up message:

This type of error can be triggered for several reasons. The most common causes are here listed:

- No internet connection. Your device must be connected to the internet to download the ASN external Python packages.
- Not supported ArcGIS® version; in this case the *installation error* message is preceded by the following *version error* popup. See <u>Requirements</u> for further details on supported versions.

- Missing "get-pip.py" file. Users running ASN on ArcMap® 10.3 and 10.3.1 need to install the *pip* package in order to successfully achieve the installation of all ASN required components. The *pip* installation is a semi-automated procedure: the user needs to manually download a Python script named "get-pip.py" and save it into the "Script" folder within the Python directory (see <u>Installation with ArcMap® 10.3</u> for further details). If such file is not downloaded or stored in the correct directory, a *missing get-pip.py error* will be reported.

- Other unknown installation issues can be bypassed with a complete manual installation of all ASN packages through *pip* launched by command prompt (follow official PyPA guidelines here). The required package is *mplstereonet* version *0.6.2*, but *tornado* version *4.** needs to be prior installed if working with ArcGIS® 10.3 and 10.3.1 versions.

Tip: If any installation error occurs, before trying again we recommend removing and then re-adding ASN to ArcToolbox window.


5.2 Usage issues

When using ASN tools, some common bugs have been reported:

- Missing output file extensions when trying to save the output image file on both *Stereoplots* and *Rose Diagrams* tools. The workaround for this bug is to show the file name extensions on your computer as explained here.
- Tool execution fails when a temporary image is requested ("Store Image Output" option deselected, see Tools for details). Such issue may occur because ArcMap® automatically imported and showed in the Table of Contents a previous temporary image and, therefore, cannot overwrite it. To solve this problem, simply remove the previous temporary image from the Table of Content and then re-launch the tool. For a permanent resolution of this issue click on Geoprocessing > Geoprocessing Options and uncheck the "Add results of geoprocessing operations to the display" option as shown below.
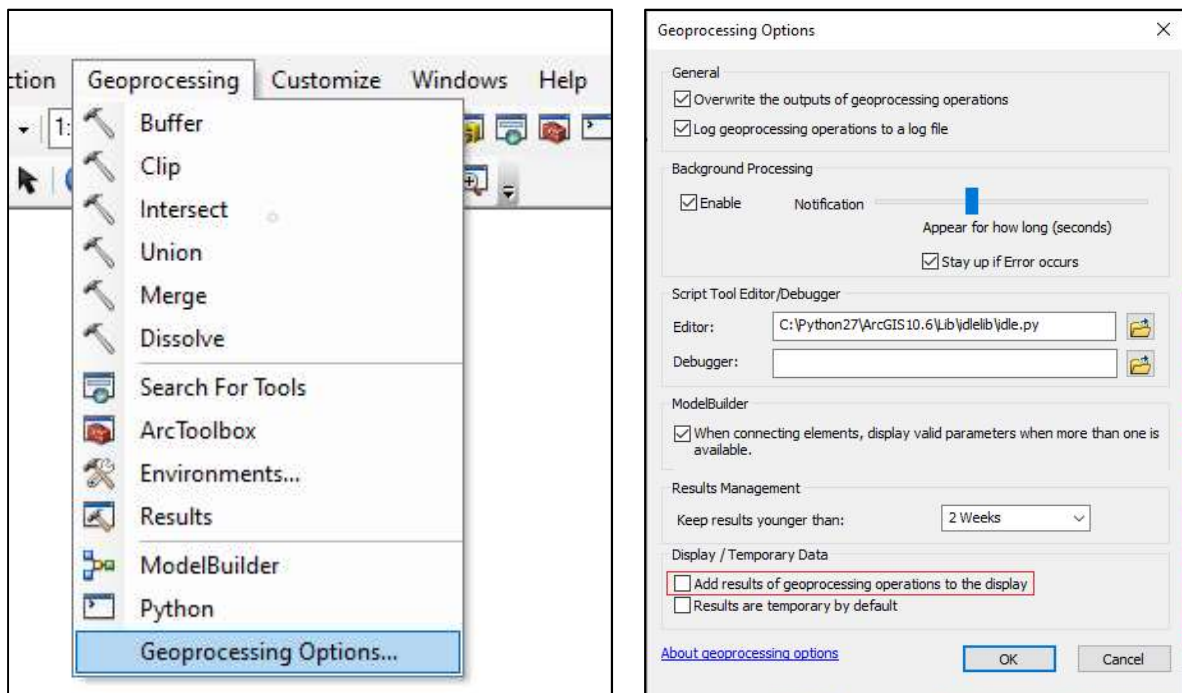
- Blank image output when a temporary image is requested ("Store Image Output" option deselected, see Tools for details). This bug seems to be linked to the default image viewer rather than ASN itself. The simple workaround is to re-launch the tool.

- Microsoft Visual C++ Runtime Library error when closing ArcMap® after a work session with ASN.
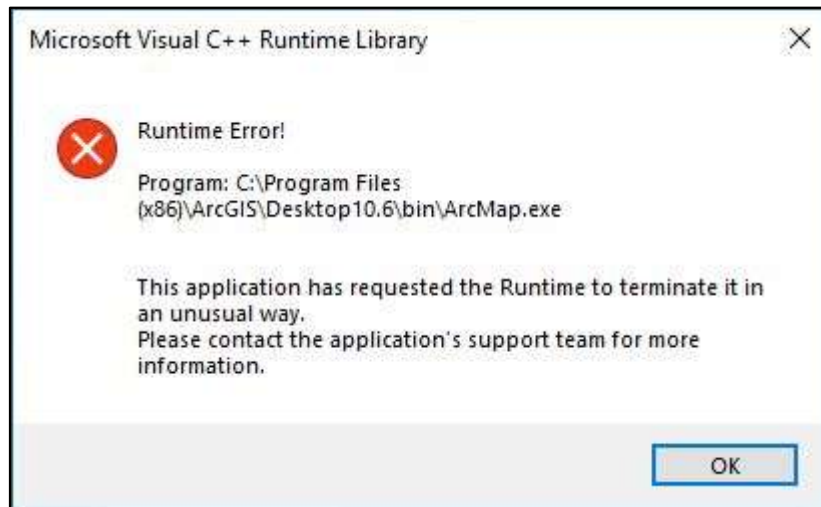
This error is caused by a miscommunication between ArcGIS® and the *matplotlib* Python library, but it is totally unharmful for your ArcGIS® software and your computer. At the moment the only solution is to simply ignore it; we are trying to find a workaround.