Archaeological TGIS for ArcGIS
User Guide

The function of the TGIS

The TGIS that is the subject of this user guide was created by Chris Green at the University of Leicester for his PhD project. Generically, TGIS are GIS that take account of time as well as space. This particular TGIS has been created for archaeologists, taking into account the particular idiosyncrasies and complexities of their temporal data. It is, in essence, designed to display and analyse the probabilities of different types of dating evidence.

Archaeological dates take a variety of forms, each with their own differing uncertainties and characteristics. The TGIS has been designed to work with the most commonly used dating techniques in British archaeology. Specifically, that would be typological, numismatic / historical, dendrochronological, radiocarbon, and thermoluminescence / OSL dates. The various probability models implemented for these techniques in the TGIS would also be applicable to the majority of other techniques.

To make it as understandable and user-friendly as possible, the TGIS has been implemented in an element of ESRI's ArcGIS: ArcMap. This implementation also makes available to the TGIS user the large raft of spatial analysis tools built into ArcGIS. To use the TGIS, the user must already have a working copy of ArcGIS on their computer. It has been tested under ArcGIS 9.1 on Windows based machines: the author makes no promises for its functionality under different installations of ArcGIS.

The TGIS is distributed as an ArcMap document template. When a user wishes to use the TGIS, they must create a new map document in ArcMap using the TGIS_v1.4.mxt template. The implementation of the TGIS as a template allows easy distribution and straightforward access for users to the source code.

Data format

Dating data should be entered into the GIS as a series of layers. Dating layers need to be in **shapefile** format to work properly with the TGIS. They also need to contain **at least** the following information in their attribute tables: some kind of identifier field (if using OxCal data - usually the lab code); (generally) x and y co-ordinates to enable the GIS to plot the data on the map; two fields containing the minimum and maximum dates associated with each item.

FID	Shape	LABCODE	EASTING	NORTHING	BAYESSTART	BAYESEND	PHASE
0	Point	Comb_[1328]<64>	427811.71	327241.14	-2130	-1942	Tree-throw/usage
1	Point	Comb_[291]<25>A	427714.16	327093.81	-3515	-3363	Tree-throw/usage
2	Point	Comb_Trough	427954	327246	-1257	-1047	Burnt Mound II
3	Point	GrA-31468	427957.63	327172.93	-2919	-2699	Pollen Column
4	Point	GrA-31770	427817.68	327237.67	-3351	-3030	Tree-throw/usage
5	Point	GrA-31785	427810.93	327243.17	-2455	-2058	Tree-throw/usage
6	Point	[illegible]	[illegible]	327233.34	-2194	[illegible]	[illegible]
7	Point	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The minimum and maximum dates operate on the assumption that archaeological dates will generally be expressed as a period of time. These dates should be in whole years, with negative numbers used for BC / BCE / BP and positive numbers for AD / CE (it is best practice to stick to a single calendar system for a map, BC / AD or BP).

Each value in the maximum field needs to be greater than (or equal to for single year dates) its corresponding value in the minimum field.

For dates expressed as a mean and error band, the user needs to input these into the data layer using the ±2 standard deviation figures; e.g. for the date AD1000±50, the TGIS would require a minimum value of 900 and a maximum of 1100.

All entries in these two columns need to be complete: if only a minimum or maximum date is known for an item, the other entry will have to be estimated.

If the user wishes to examine all of their dates together at the same time, then they will have to appear in a single layer. If the user wishes to use different probability calculation methods (see below) for different types of date, then each type will have to appear as a separate layer.

OxCal data

If the user is working with radiocarbon dates, the complex probability output from OxCal v.4.0 can be used to make probability calculations in the TGIS (see below). In this case, a separate data table will be needed that can be linked to the main radiocarbon data layer in the GIS. This should contain: an identifier field for each date that can be linked to a field in the main layer (usually the lab code); the year bands and associated probabilities output from OxCal for each date.

LabCode	DateBand	Prob
Comb_[1328]<64>	-2154.5	0
Comb_[1328]<64>	-2149.5	0.000001
Comb_[1328]<64>	-2144.5	0.000002
Comb_[1328]<64>	-2139.5	0.000021
Comb_[1328]<64>	-2134.5	0.000224
Comb_[1328]<64>	-2129.5	0.000970
Comb_[1328]<64>	-2124.5	0.001999
Comb_[1328]<64>	-2119.5	0.003015
Comb_[1328]<64>	-2114.5	0.004155
[illegible]	-2109.5	[illegible]

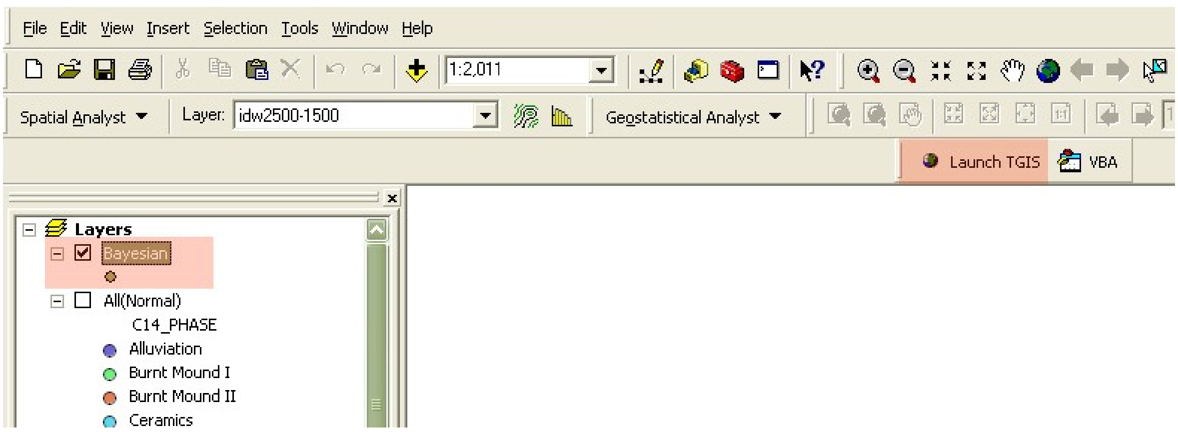
These probabilities are output from OxCal for each individual date (using the View_Raw option) and then copied and pasted to a new data table in spreadsheet software. Construction of this table can be somewhat time intensive, but is not overly onerous. Hopefully, new versions of OxCal will contain the ability to output all of this raw probability data *en masse*. This spreadsheet is then exported as a .csv for use in the TGIS.

Loading your data into the TGIS

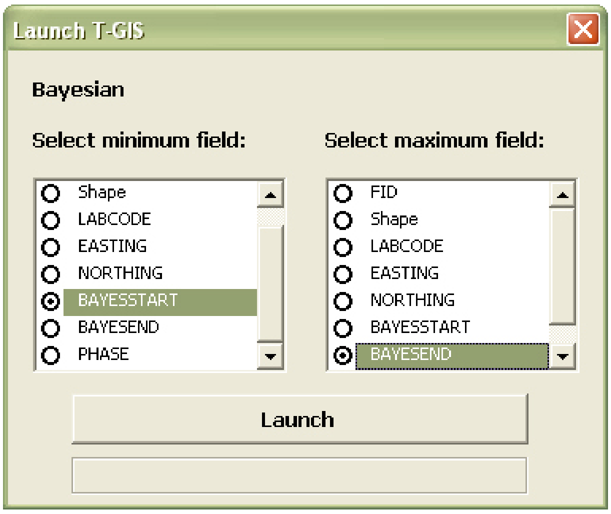
Firstly, create a new map document in ArcMap using the TGIS_v1.4.mxt template.

Then add the shapefile layers containing the date data to your new map in the normal way, together with any other geographical information that you wish to include in your maps.

When you wish to begin using the TGIS, click on the date layer which you wish to work with in the Table of Contents in ArcMap and then click the "Launch TGIS" button.

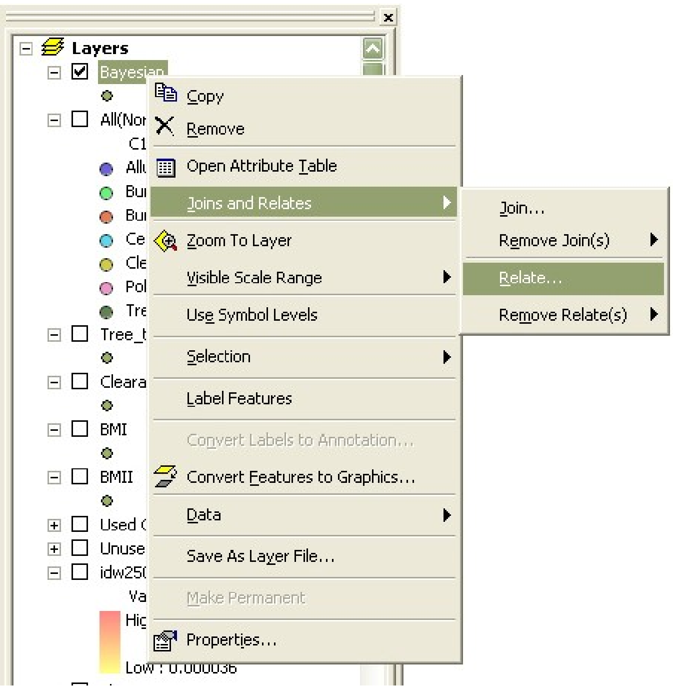


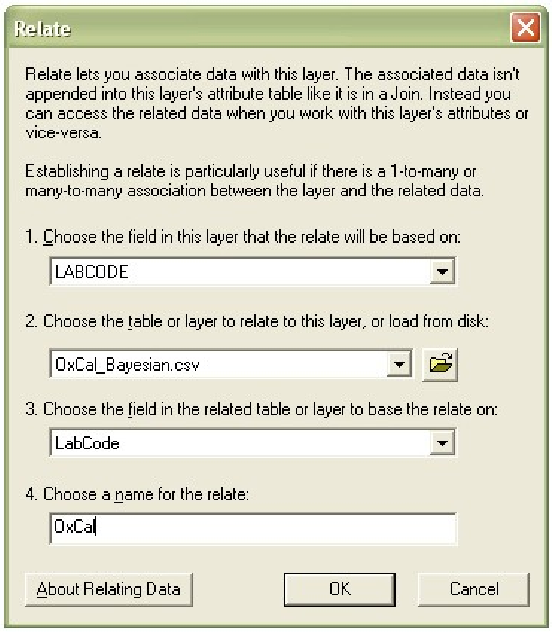
A new form will pop up in which you must select the two fields in the layer's attribute table that contain the minimum and maximum date data. Then click on the "Launch" button. The TGIS will make various checks upon the data and, if no error is discovered, the main TGIS user interface (UI) will open up.



OxCal data

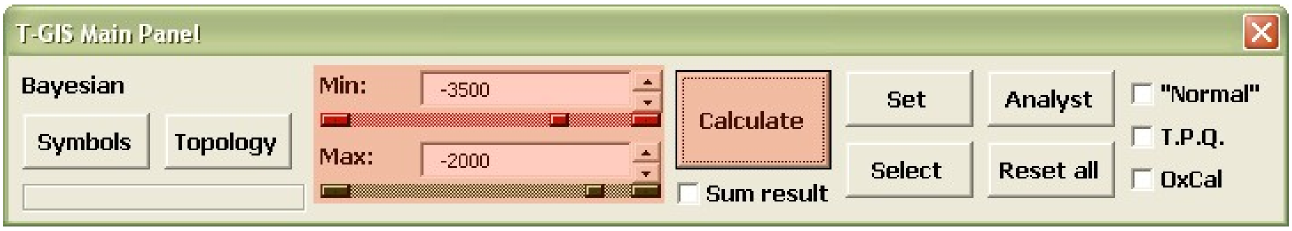
If you are working with OxCal data, you will need to add the data table containing the probabilities to the map in the conventional fashion. This must then be linked to the main radiocarbon data layer using a one-to-many relate. To do so, right click on the main data layer in the Table of Contents and select “Joins and Relates” and then “Relate”. Follow the instructions to link the two tables together using the identifier field (usually the lab code).





Making basic probability calculations

To make a calculation of simple percentage probability for a period of time, first set the period using the Min and Max tools. The scrollbars, the spinners, or text entry in the text boxes may all be used for this: remember that years BC / BCE / BP should be proceeded by a minus symbol.



Then, when you are ready, click on the “Calculate” button. The TGIS will then calculate the probability of each date in the layer falling within the currently selected period, based upon the percentage overlap between the date’s range and the selected period. This will be written to the attribute table for the current layer (see “TGIS output” below) for analysis by the user.

Multiple layers

In order to allow maximum flexibility with regard to multiple types of date, it is possible to load several layers into the TGIS and switch between them at will. This is done by following the loading procedure above for each layer of interest. Then, by selecting a layer in the Table of Contents and clicking the “Launch TGIS” button, the user is able to switch between layers loaded into the TGIS. Settings will be preserved. The same is true when the TGIS is closed, unless the “Reset all” button is first pressed.

The one exemption from this system is when working with OxCal probabilities: switching between layers in that situation will force a TGIS data reset, due to the extra complexities involved.

As a general tip, working with multiple layers can also be useful when considering data divided onto different layers thematically.

TGIS output

The TGIS outputs two pieces of information to the attribute table of the layer being studied: the probability and the temporal topological relationship between the date and the selected period.

The probability is recorded as a decimal varying from 0.0 (i.e. 0%) to 1.0 (i.e. 100%) and is rounded to two decimal places (i.e. 1%). For example, a probability of 0.55 would be 55%, or 0.68 would be 68%, etc.

The topology may be any of the following, where the bold text is the recorded attribute:

The date falls **before** the period of interest (0.0 probability);

The date **overlaps** the **minimum** of the period of interest (0.0-1.0 probability);

The date **overlaps all** of the period of interest (0.0-1.0 probability);

The date falls **within** the period of interest (1.0 probability);

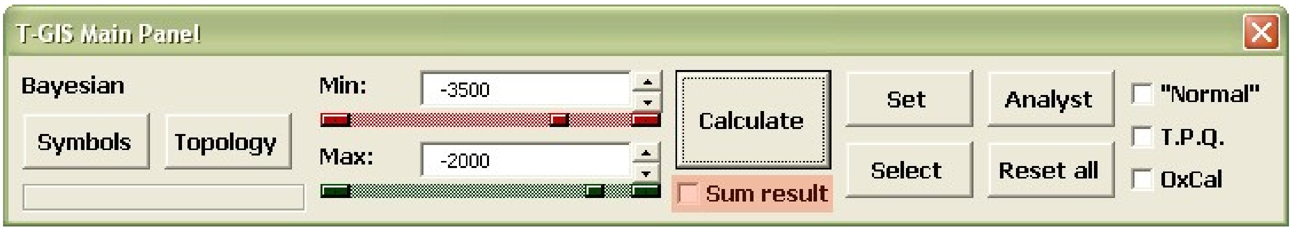
The date **overlaps** the **maximum** of the period of interest (0.0-1.0 probability);

The date falls **after** the period of interest (0.0 probability).

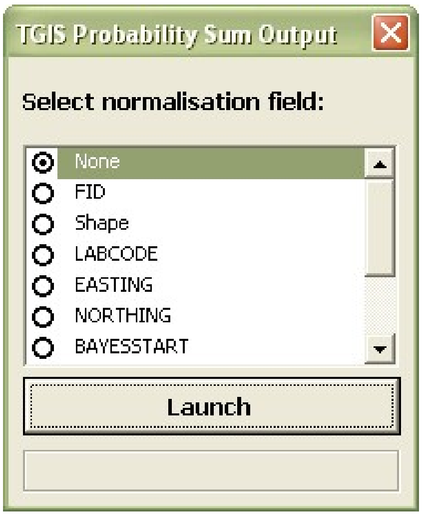
By recording this information to the layer’s attribute table, this data is available for use in spatial analyses, for visualisation, or for export to external software. Users are encouraged to experiment!

FID	Shape	LABCODE	EASTING	NORTHING	BAYESSTART	BAYESEND	PHASE	TGIS_Prob	TGIS_Topol
0	Point	Comb_[1328]<64>	427811.71	327241.14	-2130	-1942	Tree-throw/usage	0.54	Overlaps Max
1	Point	Comb_[291]<25>A	427714.16	327093.81	-3515	-3363	Tree-throw/usage	0.95	Overlaps Min
2	Point	Comb_Trough	427954	327246	-1257	-1047	Burnt Mound II	0	After
3	Point	GrA-31468	427957.63	327172.93	-2919	-2699	Pollen Column	1	Within
4	Point	GrA-31770	427817.68	327237.67	-3351	-3030	Tree-throw/usage	1	Within
5	Point	GrA-31785	427810.93	327243.17	-2455	-2058	Tree-throw/usage	1	Within
6	Point	GrA-31786	427813.47	327233.34	-2194	-1931	Tree-throw/usage	0.73	Overlaps Max
7	Point	GrA-31787	427901	327225	-1877	-1614	Clearance	0	After
[illegible]			427833.72	327130.39		-1985	Clearance	0.98	Overlaps Max

Sum result



When the "Sum result" checkbox is ticked, the TGIS will sum the results of its output according to spatial concurrence. This is useful where multiple dates occur on single geographical locations, a common occurrence when working with field survey data. A field in the attribute table may be selected to act as a weighting (called 'normalisation' in the TGIS) for the summed probabilities: this is intended to work primarily with ceramic dates, where the probabilities would be usefully multiplied by sherd counts, weights or densities.



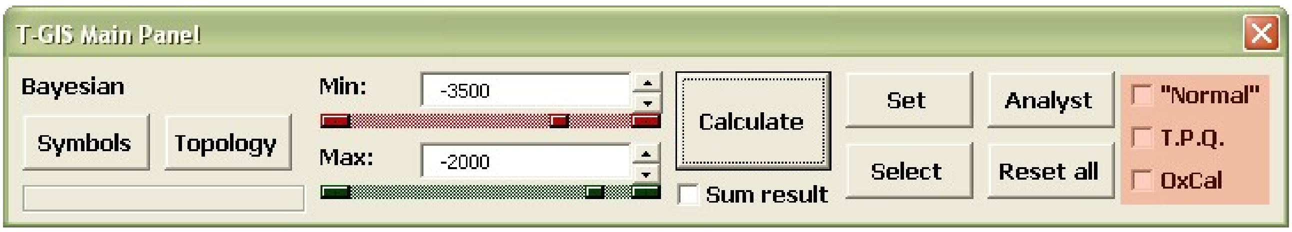
The results are written to a new shapefile (saved in your current working directory) and added to the map. If you wish to re-run this summing procedure for the same layer and selected time period, you must first delete the previous shapefile using ArcCatalog.

Summing results makes visualisation easier (due to lack of overlapping points) and may be necessary for spatial interpolation. It is, however, not recommended when working with radiocarbon dates on statistical grounds (see Bayliss *et al.* 2007).

Probability models

To reflect the different models of probability possessed by different archaeological dating techniques, the TGIS is able to calculate probabilities in four different ways.

Where a dating object has only a single year (i.e. its minimum and maximum are the same), the probability will be calculated as either 0.0 or 1.0 dependent upon whether the date falls within the selected time period: this is independent of the selected probability model.



Percentage probability

This is the standard 'catch all' probability used by the TGIS when none of the probability checkboxes are ticked. It is a straightforward percentage overlap between the date and the selected period.

The calculation method is intended for fast initial analyses, for typological dates, for layers containing many types of dates, and for other dates where more detail regarding the form of their internal probability is not known.

'Normal' probability

This probability is calculated on the basis that the dates' probabilities form 'Normal' (or 'Gaussian') distributions. It is calculated according to the area of each date's normal curve that overlaps with the currently selected period.

The TGIS works on the assumption in this case that the minimum and maximum date recorded for each dating object are at -2 and +2 standard deviations.

This form of probability (and thus calculation method) is applicable to uncalibrated radiocarbon dates, thermoluminescence dates, and most other forms of uncalibrated scientific date.

Terminus post quem ("T.P.Q.") probability

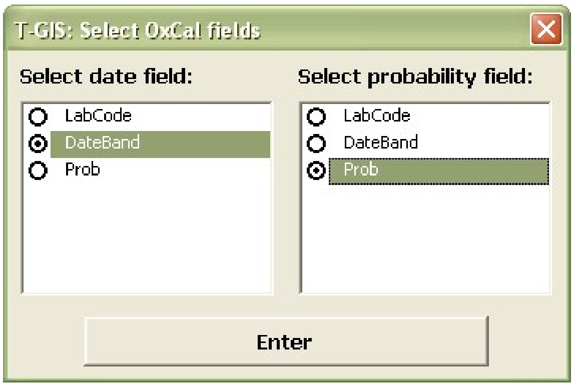
This probability is calculated as a triangle of decreasing probability, with its peak at each date's minimum value, dropping down to zero probability at its maximum value, and with a total area under the triangle of 1.0 (i.e. 100% probability).

It is calculated as the area of the triangle falling within the currently selected period, using elementary trigonometry.

This form of probability is intended for dating objects that could be given a single calendar year for their manufacture, but where the date of deposition was less certain. It is intended to be used with dating objects such as coins, dendrochronological determinations, or epigraphy. Generally speaking, the maximum value would likely be a considered estimate.

OxCal probability

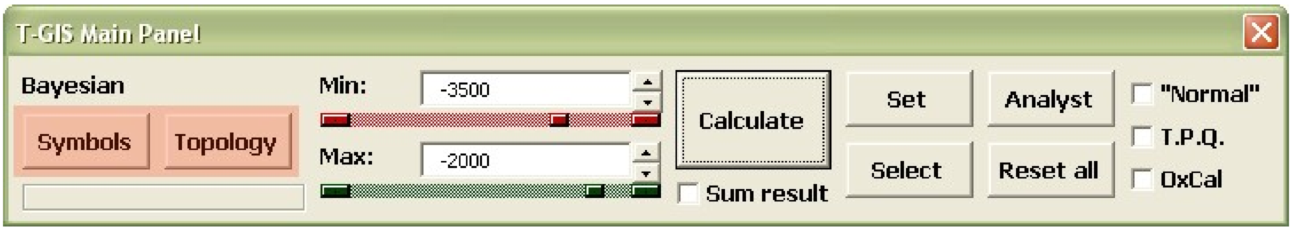
This probability is looked up from a sub-table containing outputs from OxCal v.4.0. For instructions on how to create and link the sub-table, see above. When the user ticks the OxCal checkbox, a dialogue window pops up in which they must select the two fields in the sub-table that contain the year bands and their associated probabilities.



This form of probability calculation only works with calibrated dates output from OxCal: that would cover calibrated radiocarbon dates and also inferred dates created through Bayesian modelling. As noted above, when working with OxCal probabilities, the user must reload the TGIS when switching layers.

Handling symbologies

The user may use ArcGIS's cartographic functionality to display the probabilities or topological relationships recorded using the TGIS in any way that they wish. However, two built in symbologies are included within the function of the TGIS.



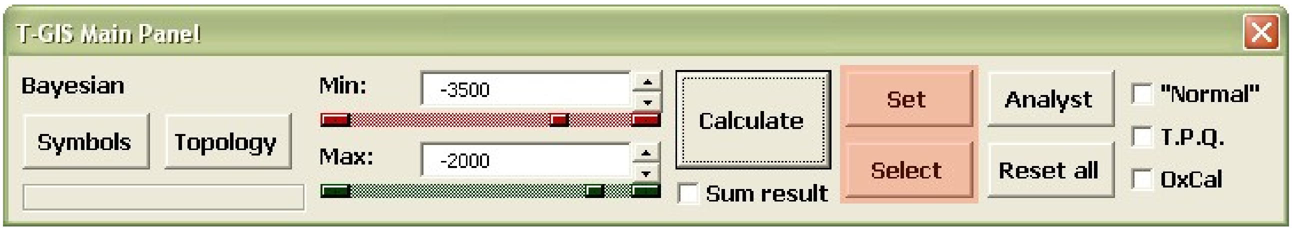
By clicking on the "Symbols" button, the dates will be coloured along a grading scale according to probability. They will be clear if of zero probability, ramping up through yellow to red as probability increases.

By clicking on the "Topology" button, the dates will be coloured categorically according to their temporal topology.

Permanent adjustments to these colour schemes can be made by editing the source code (to frmTgisPanel) where labelled.

Working with selections

Two tools are included with the TGIS for working with selections.



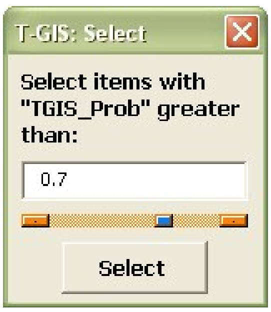
"Set" tool

If the user makes a selection of a dating object (or objects) using ArcGIS's tools for working with selections (e.g. via a query or by using the manual selection tool), they can then set the minimum and maximum values of the period of interest to that of the object (or objects) selected.

This provides a simple form of temporal buffering. For example, the user may wish to interrogate their data to see how likely it is that other dates on a site relate to one particular date: this tool makes such a query routine.

"Select" tool

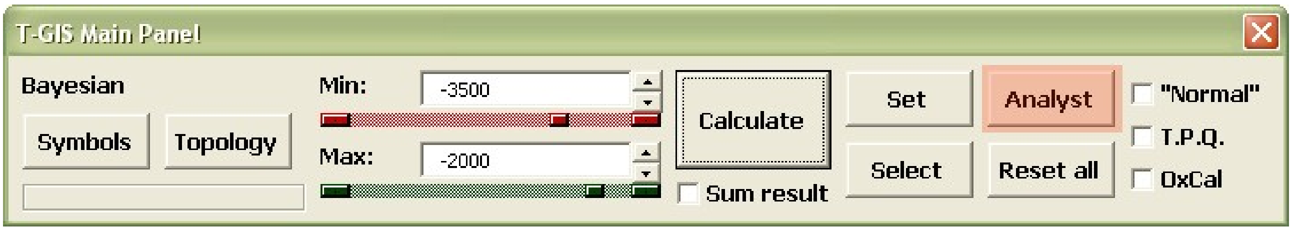
The "Select" button launches a form used to create a selection of dates in the current layer of greater than a particular probability.



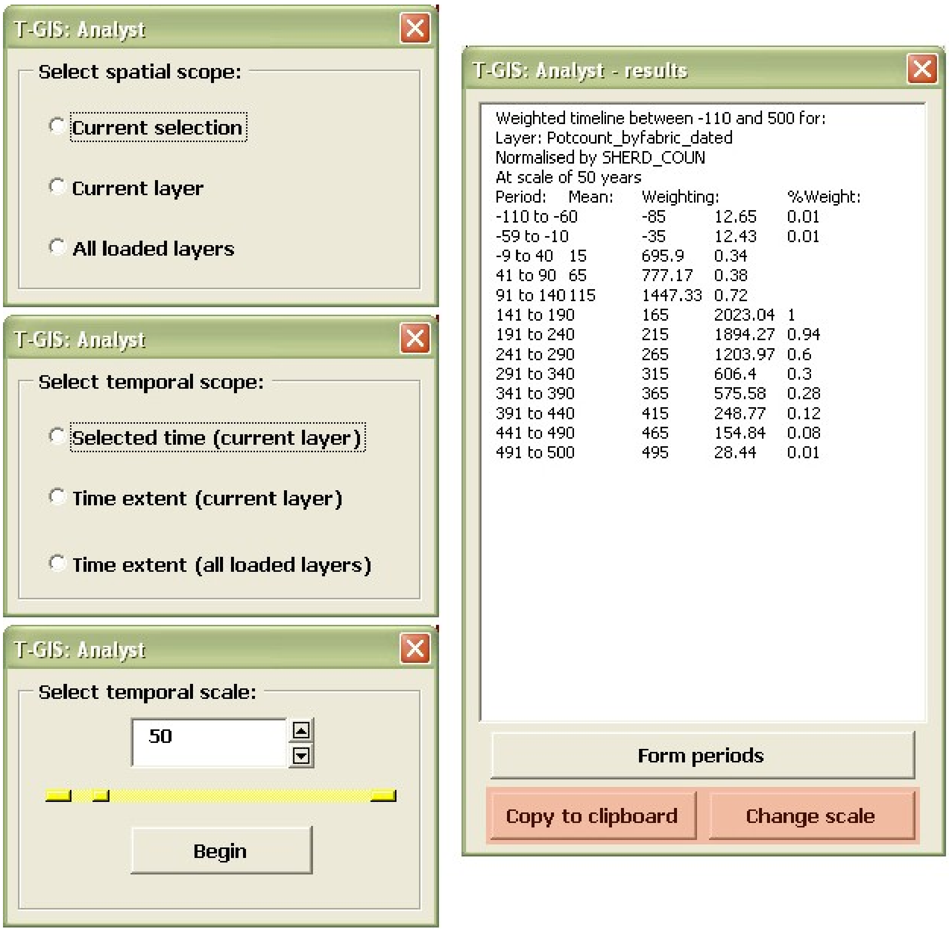
The user simply selects the minimum probability of interest and all dates of greater than that value will be selected by ArcGIS. This selection can then be exported or studied further in the usual way.

The Analyst tool

The TGIS also contains a tool that can be used to study the cumulative probability of a layer or layers, or a subset selection of a layer.



By clicking on the “Analyst” button and following the instructions in the following forms, a cumulative probability profile is output to a results table.



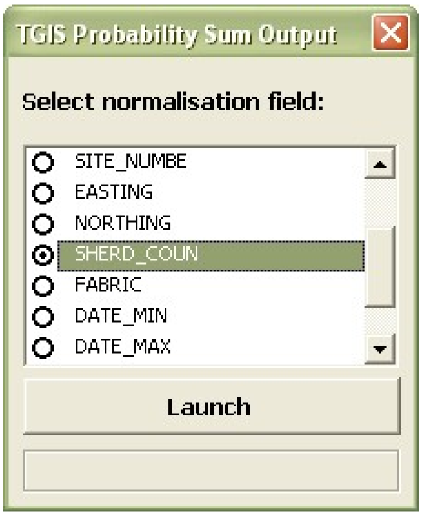
These results may then be copied to the clipboard by clicking the “Copy to clipboard” button. You can then paste the results into spreadsheet software for further analysis or graphing.

The temporal resolution of the analysis can be adjusted by clicking on the “Change scale” button.

This analytical tool may be used to study the detailed probability profiles of a dataset or subsets of a dataset. Feel free to experiment! Again, however, it is not necessarily an statistically correct approach to work with cumulative probabilities in radiocarbon data (see Bayliss *et al.* 2007).

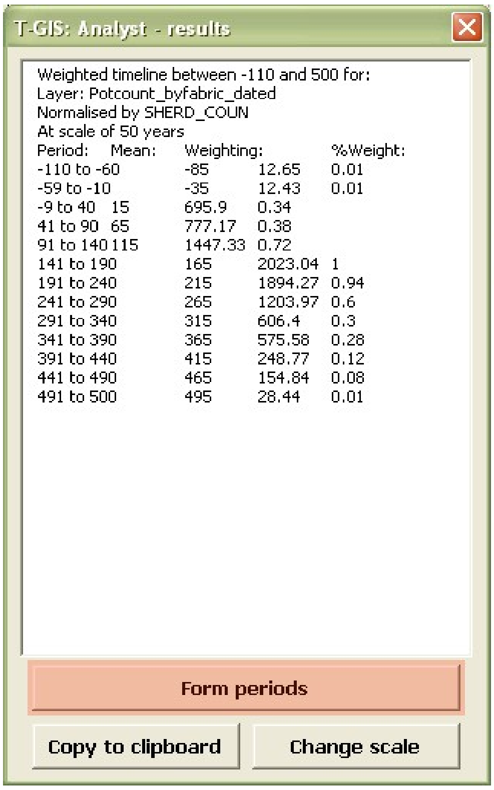
Normalisation

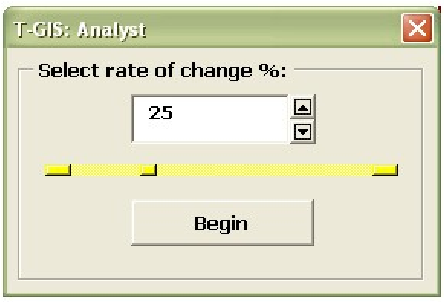
In a similar fashion to when working with the “Sum result” function (see above), this cumulative probability may be weighted (called ‘normalisation’ in the TGIS) by another field in the layer’s attribute table. This allows the user to take into account factors such as sherd counts / weights / densities when working with field survey data.



“Form periods” tool

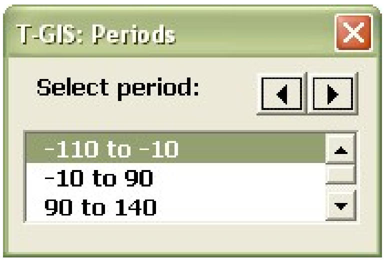
The final function of the TGIS Analyst enables the user to form a series of periods for analysis in the main TGIS based upon the rate of change of the cumulative probability profile. To do so, click on the “Form periods button” and then select the desired rate of change.





The TGIS will then work through the probability profile and create a new phase each time either (a) the profile reaches 0.0 probability; or (b) the profile reaches the selected percentage of the maximum cumulative probability.

For example, if we had a profile that varied smoothly up from 0.0 to 10.0 and we selected 25% rate of change, periods would be formed for 0.0 to 2.5, 2.5 to 5.0, 5.0 to 7.5, 7.5 to 10.0. This is, of course, a very simple example!



Again, the probabilities used for this process may be weighted by another variable.

When finished, a form will pop up showing the periods formed. The user may then scroll through them using the arrow buttons, or select a period from the list. The TGIS will then automatically undertake the calculation procedure and update the display.

However, due to inherent restrictions in the way VBA works with forms, the functionality of the main TGIS will not be available until this sub-form is closed. In practice, it may be easier to write the period dates down and enter them manually.

Tidying up

When finished with the TGIS, the "Reset all" button will remove all of the probability and topology fields from the layers being studied, clear the settings in the TGIS, and exit. It will not, however, delete any shapefiles output using the "Sum results" function: if you wish to delete these, you will need to do so using ArcCatalog in the conventional fashion.

Contact details

The author of the TGIS can currently be contacted at ctg3@le.ac.uk - he may also be contacted at archtgis@googlemail.com

Further reading

Bayliss, Alex, Bronk Ramsey, Christopher, Van der Plicht, J. and Whittle, Alastair. 2007. "Bradshaw and Bayes: towards a timetable for the Neolithic." *Cambridge Archaeological Journal*, **17**(1), pp. 1-28.

Green, Chris. Forthcoming. "It's about time: temporality and intra-site GIS" In *Proceedings of the 36th Annual Conference on Computer Applications and Quantitative Methods in Archaeology, Budapest, Hungary, 2008*.