WC-GPE: Global Position Estimator Program Suite

Wildlife Computers
Innovative Tags for Innovative Research

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Wildlife Computers
Global Position Estimator

Overview

Wildlife Computers Global Position Estimator (GPE) is a suite of programs that use light-level readings from either PAT or archival (Mk7, Mk8 or Mk9) tags to estimate daily longitude and latitude. This estimation of position using light level readings is often called "geolocation". See Appendix A for a description of the theory used to perform this estimation.

There are two main phases of GPE:

Phase I: Data extraction

Input data can be from one of two sources.

Transmitted data from PAT tags

> The program WC-AMP (Argos Message Processor) extracts the dawn/dusk light level (Location) messages produced by the PAT's on-board processing. These location messages are extracted either from either Argos Dispose message files (these Argos files usually have a ".dat" extension), or from the image of the transmitted messages files stored and downloaded from recovered PAT tags (.wch files).
>
> Depth and temperature data are decoded and stored in an Excel spreadsheet (.xls file).

Archived light level readings from either PAT tags or archival (Mk7, Mk8 or Mk9) tags

> The program WC-TSP (Time-Series Processor) extracts data from downloaded archival files. These archival data files generally have a ".wch" extension. The light-level readings from the .wch files are examined and reduced to dawn and dusk light level curves that are very similar to those that are transmitted to Argos by PAT tags.
>
> An Excel spreadsheet is created to hold the locations that will be created in the Geolocation phase.

Both of the above programs format the extracted light level data in an intermediate file for use in the Geolocation phase. This intermediate file has ".wcg" for the file name extension. The .wcg file contains encoded light level curves, along with other data required for the location calculations.

Phase II: Geolocation

Daily longitude and latitudes are calculated based on the encoded light-level curves stored in the .wcg files. The calculated locations are stored in additional sheets in the Excel spreadsheet created by either WC-AMP or WC-TSP.

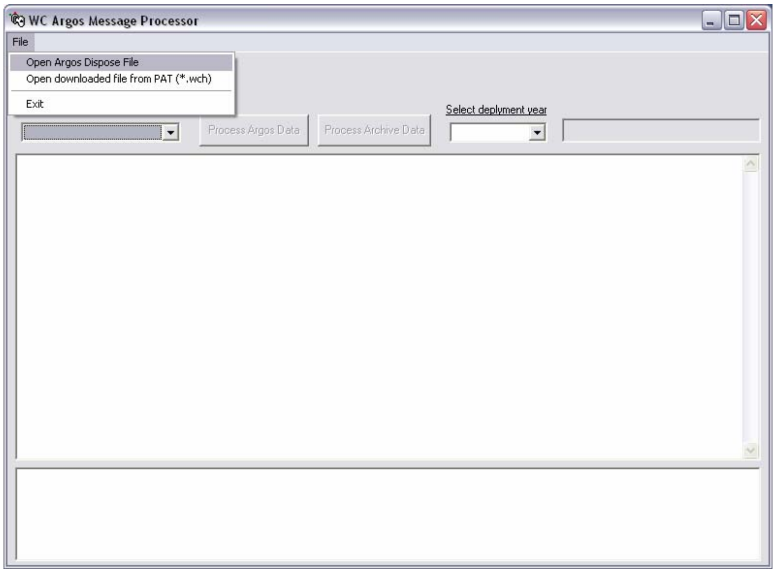
Note:

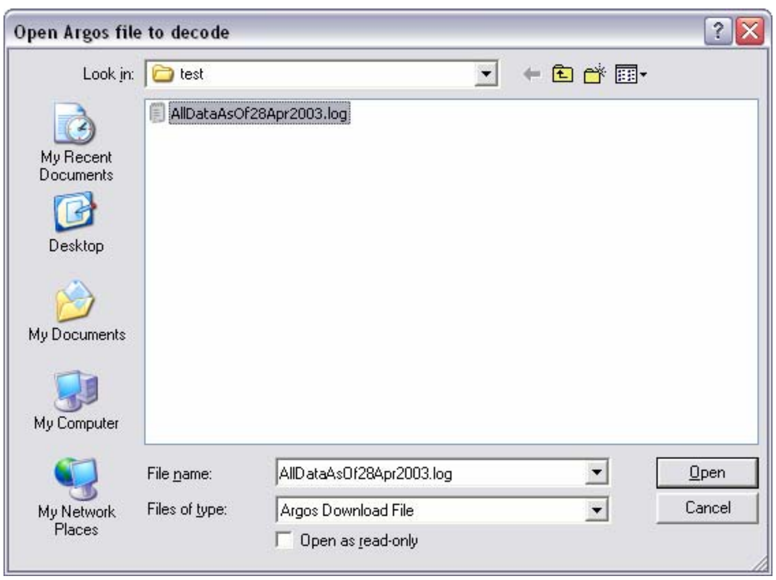
Geolocation techniques are constantly being improved. The GPE suite of programs also contain functions that allow individual fine-tuning of the generated locations. This fine-tuning should only be performed by those who have a firm understanding of Geolocation, and with the understanding that such fine-tuning may introduce a personal bias.

This manual describes the basic functions only. Documentation of the fine-tuning functions is contained in the Appendices.

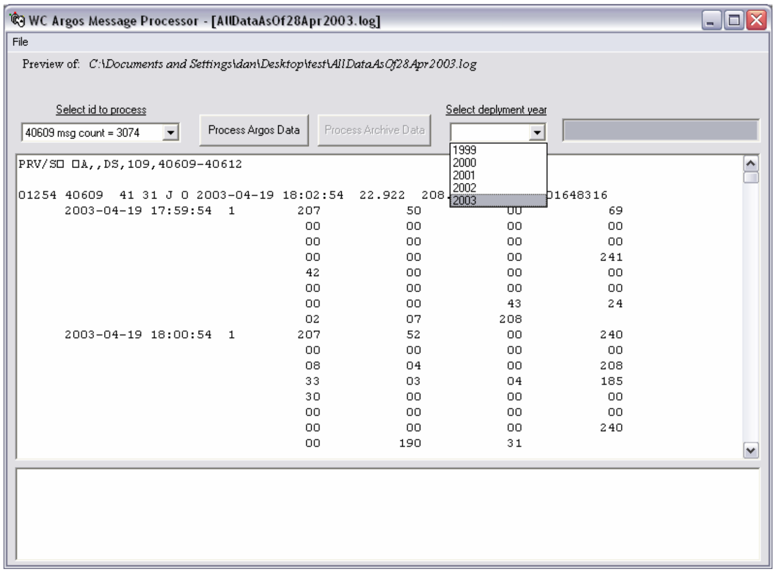
How to run WC-AMP

1) Open either an Argos download or a *.wch file.

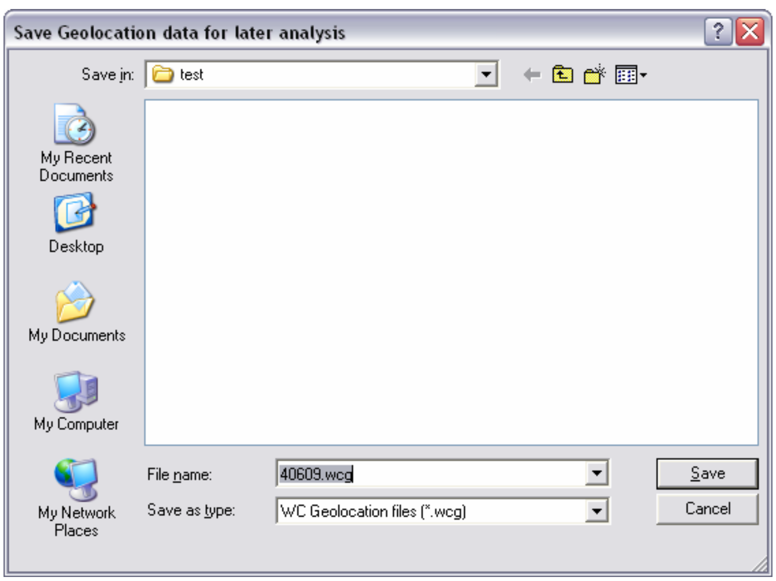




2) Next choose the Ptt id you would like to decode, select the year of deployment and press the appropriate process data button.

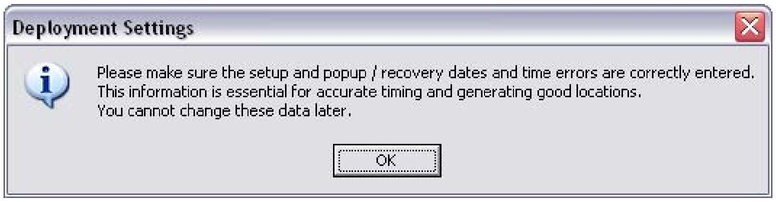


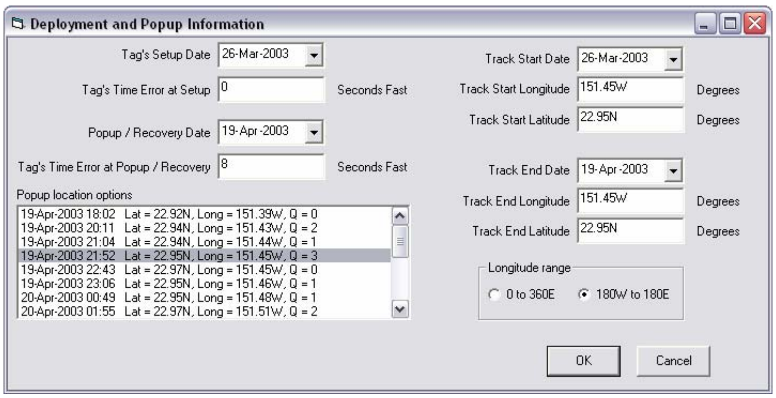
3) You will next be asked to provide a file name for the intermediate .wcg file.



At this time, an Excel spreadsheet will also be created.

4) The program will start to process the data, then prompt you for the deployment and popup information.





The two most important dates are the *Tag's Setup Date* and *Popup/Recovery Date*. The *Tag's Date* should correspond to the date that the tag was first turned on and started to collect data. The *Popup/Recovery Date* should correspond to the date of pop off, or in the event of recapture, the date the tag was killed.

The above two dates are important since the program will correct for any time error over the life of the tag and thus it needs these dates to be accurate. If these dates are entered incorrectly, there is no way to fix the file after the creation of the *.wcg file and therefore the data will need to be re-processed.

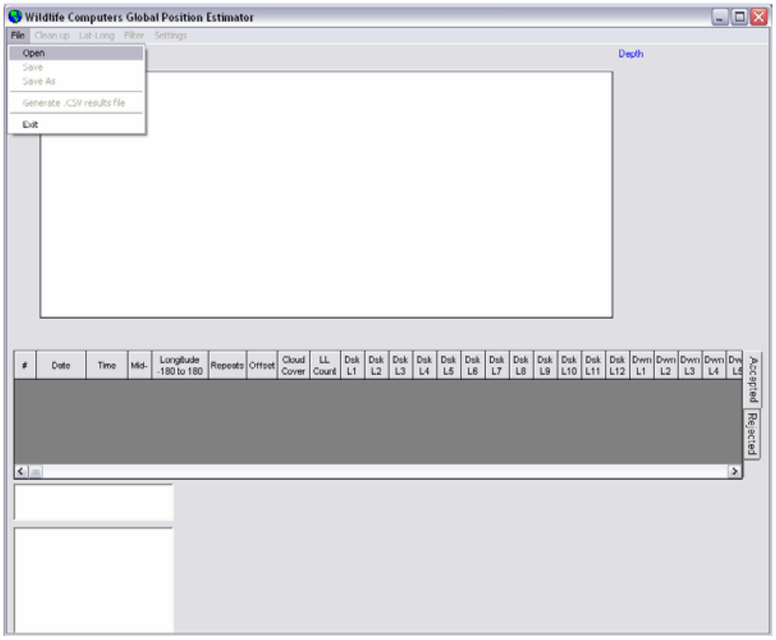
You will also need to enter the *Track Start Date*, *Track Start Longitude*, *Track Start Latitude*, *Track End Date*, *Track End Longitude*, and *Track End Latitude.* These dates correspond to when the PAT was actually attached to the animal, and when the PAT no longer collected good light-level curves (e.g., the PAT was recovered before the popup date and tossed in a wheelhouse without being turned off). For the most part, these dates will be the same as the Tag's Setup Date and Popup/Recovery Date. These dates and locations can be changed at any time from within the WC-GPE program.

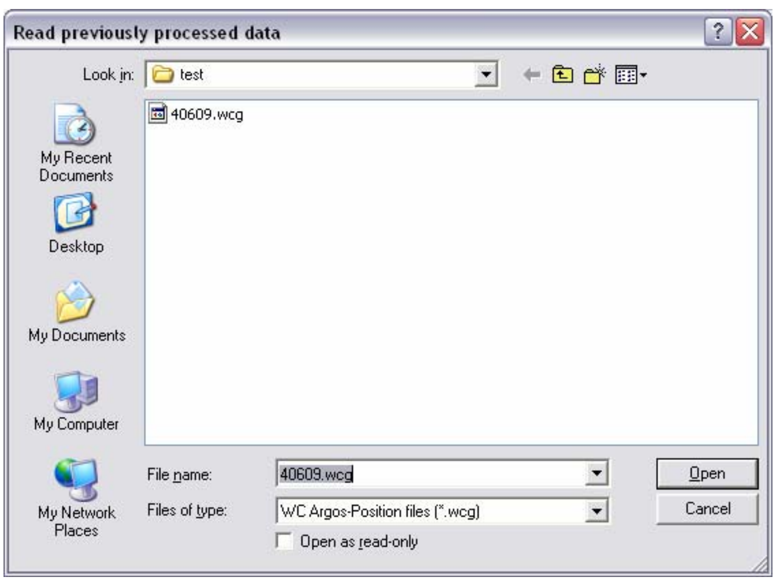
5) The program will then finish processing the data and close the *.xls file. If you are curious about the data, the *.xls file can be opened and viewed, but before further processing with WC-GPE, the *.xls file will need to be closed.

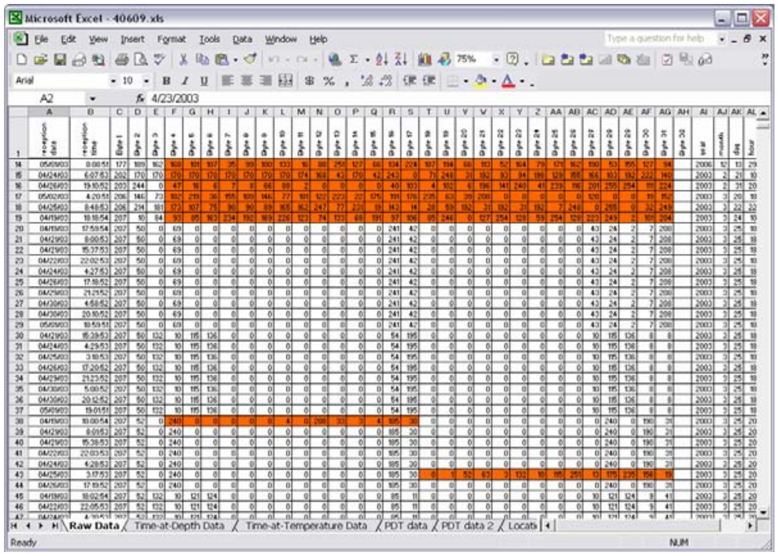
If you wish to see the non-location data (i.e., the histograms and PDTs), the *.xls file can be opened and viewed. Note, however, the *.xls file will need to be closed before using WC-GPE to process the location data.

How to run WC-GPE

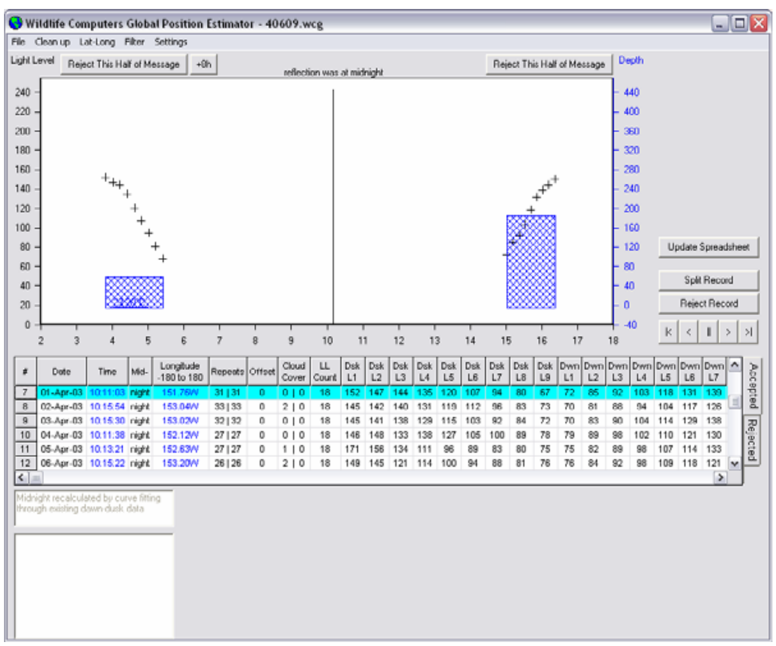
1) Start by opening any *.wcg file. The program will open the associated Excel spreadsheet as well as display the light curves from the *.wcg file.







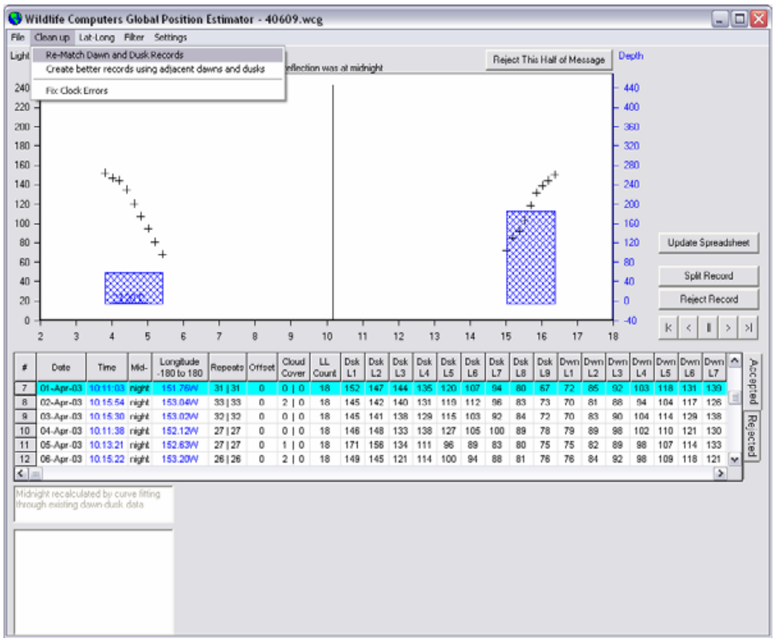
2) The dusk and dawn light level curves are displayed one day at a time. The “+” marks represent the light level readings, and the blue hash-marked box represents the depth the animal traversed during the dusk and dawn events. Below is an example of “good” light level curves.



Step through each day by using the “>” button. Delete any obviously bad light level curves. You either reject the entire day by clicking the *Reject Record* button, or just the dusk or dawn curves by using the *Reject This Half of Message* buttons. “Bad” curves do not exhibit smoothly sloping of light levels from high to low or low to high. Often deep diving behavior during the dusk and dawn events causes “jagged” curves, as the movement can compromise the correction of light attenuation with depth algorithms.

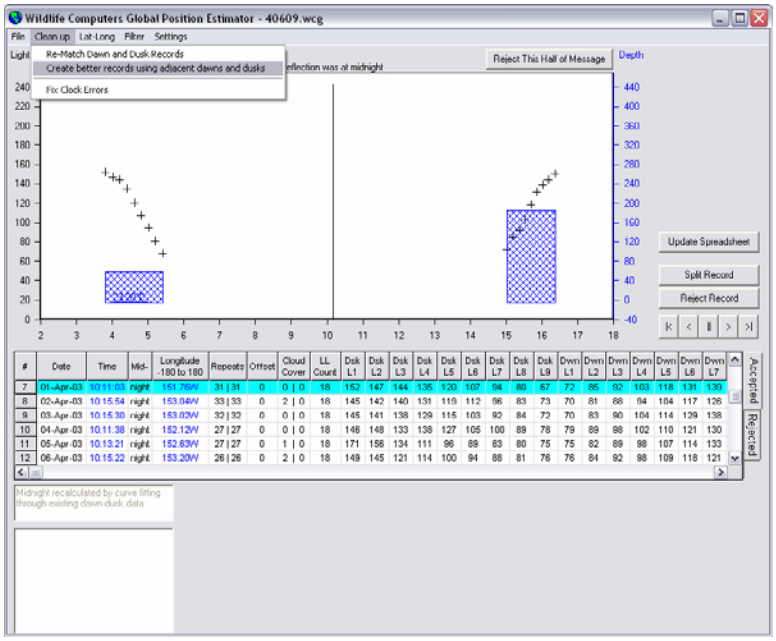
Note that rejected days are not deleted, but moved to the *Rejected* tab. You can recover previously rejected records by clicking the *Rejected* tab, selecting the desired record, and clicking the *Accept record* button. You also can enter comments regarding the day in the text box that appears in the lower-left portion of the screen.

3) Next, from the C*lean-up* menu, select *Rematch Dawn and Dusk Records*

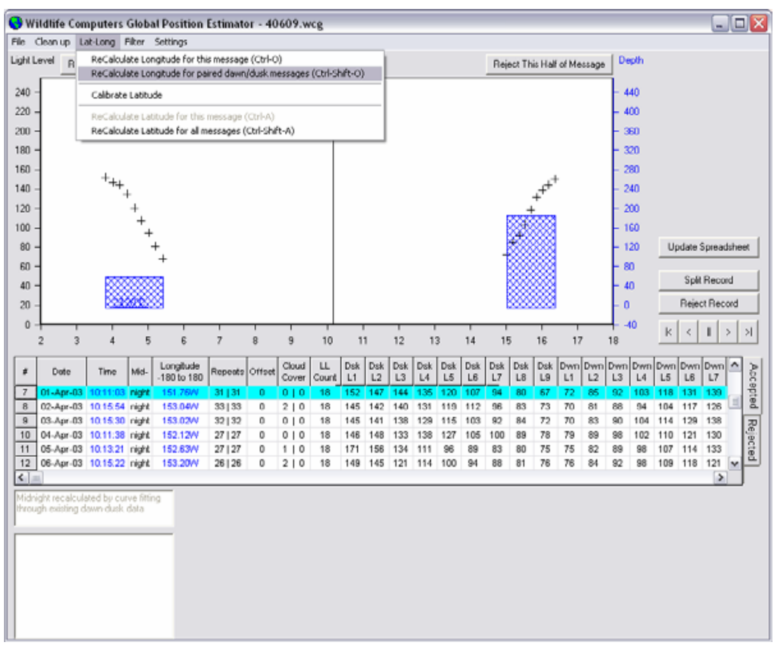


This will move through the data and match up records and recalculate their longitude estimates.

4) Next, again from the *Clean-up* menu, select *Create better records from adjacent dawns and dusks*. This will again move through the record set and match up dawn and dusk records and recalculate their longitudes.



5) From the *Lat-Long* menu, select *Recalculate Longitude for paired dawn/dusk messages* (ctrl + shift + o).

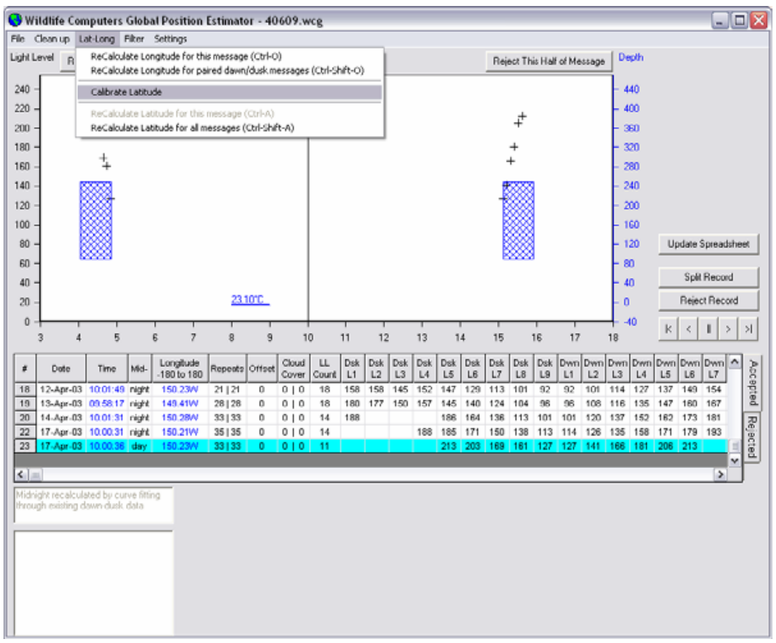


WC-GPE has better algorithms for calculating longitude than can be performed by the PAT's on-board processor.

Once the longitudes are recalculated, save your work. This can be done from the file menu. At the same time as it is saving, WC-GPE also will update the *.xls file with the calculated longitudes.

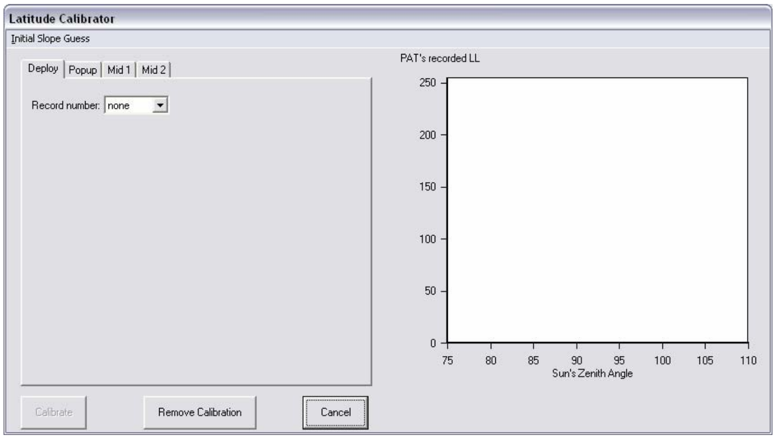
6) Step through each day and examine the calculated longitudes. Identify any outliers. Good Latitude estimates depend on good longitude estimates; if the longitude estimate is bad, the latitude estimate will be even worse. Generally, outliers are days whose longitude estimate is unreasonably far from the preceeding/following days (i.e., it was not possible for the animal to have traversed that distance). The best way to delete these outliers is to make a note in the bottom left-hand text box and reject the record.

7) Once all of the longitude outliers have been rejected, it is time to calibrate the Latitude. From the Lat-Long menu, select "calibrate latitude". This will bring up a form with four possible tabs, one for deploy, pop off and two for additional points.



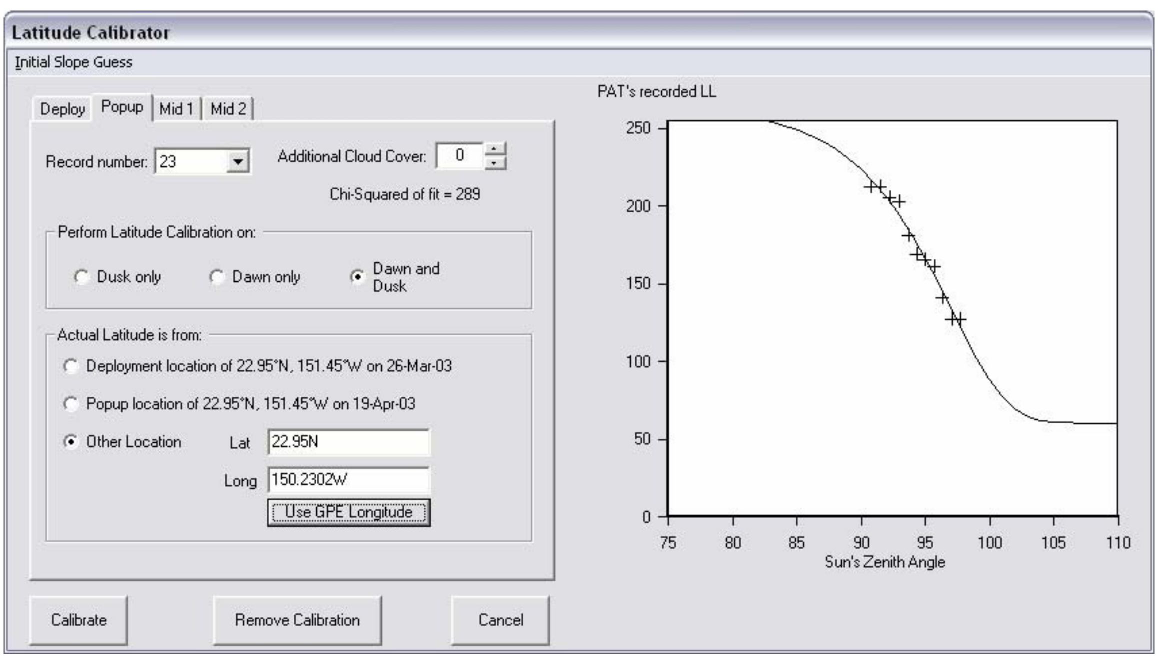
Latitude is calibrated by correlating the actual light-level curves collected by the tag for a known day at a known location with theoretical curves generated by the geolocation algorithms. Therefore, good latitude calculations depend upon selecting good light level curves for use in the latitude calibration.

8) You will want to calibrate off of the best data that are closest to either your deployment or pop off dates. First select the *Deploy* tab.



Use the drop-down *Record number* box to select an appropriate day for the Deployment. This will be the record number of the day you released the animal. The light level readings for that day will appear on the graph (dusk, and the mirror of dawn overlayed). If the file does not contain a good light-level curve for the deployment date, choose "none" for the record number.

9) Similarly, select a day with good light level curves for which you have a popup location.

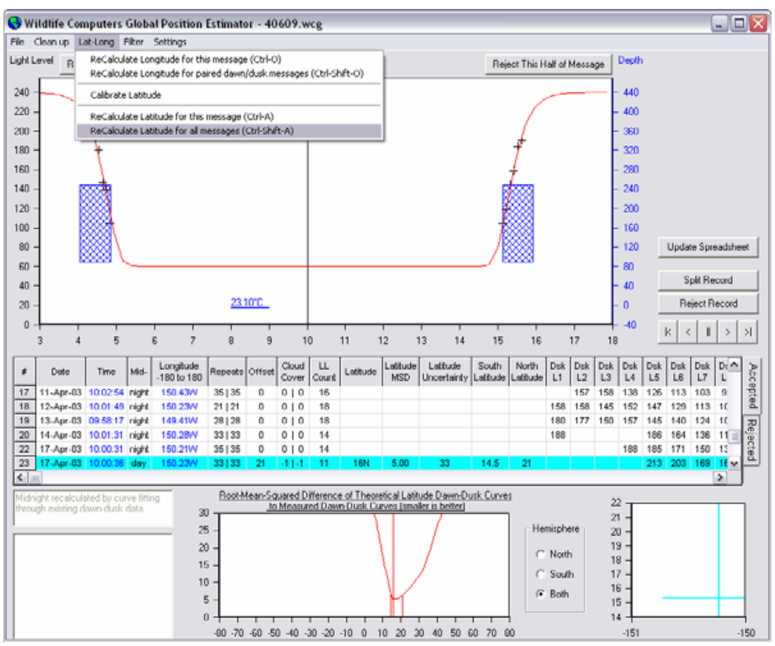


You may need to increase the *Additional Cloud Cover* parameter to accommodate for an overall attenuation of the light levels due to clouds. This parameter should be selected such that the *Chi-Squared of fit* is minimized. Make sure you minimize the *Chi-Squared of fit* for each day you are using for calibration.

If the date of the data you are using is a few days from the deploy or pop off or if the GPE determined longitude is sufficiently different from that of deploy or pop off, then you may use the longitude value determined by GPE by selecting the other location option and clicking on the *Use GPE longitude* button.

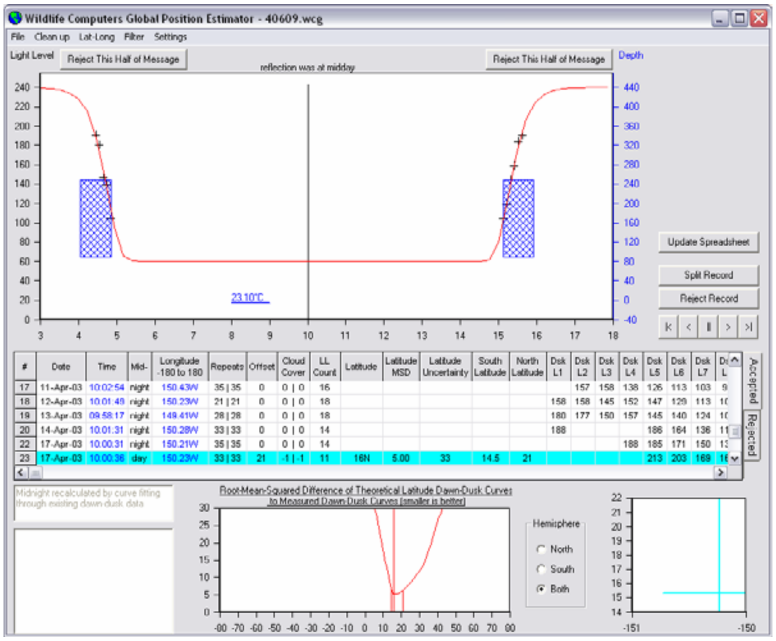
10) You may enter up to two additional days to be used for the latitude calibration. For example, if the tag was floating for a couple of days just prior to popoff, it is quite likely that those days had beautiful light-level curves. If you do not feel the PAT drifted significantly during that time prior to popoff , you can add those days in the *Mid 1* and *Mid 2* tabs.

11) Once you have entered all of the days you want to use for latitude calibration, click on the *Calibrate* button. You will be returned to the main form once WC-GPE completes the calibration. Now you may either right click on the selected blue color row and select the option to *Recalculate Latitude for all messages* from the *Lat-Long* menu, or hold down the <ctrl> + <shift> + <a> keys.



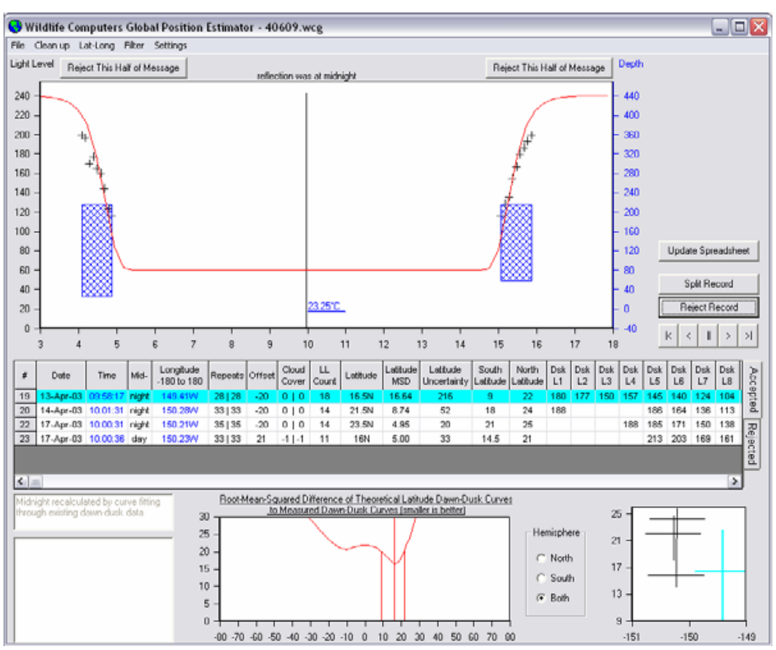
This is another good point to save your work.

12) Step through each day, looking for more outliers to reject. You can also check the Latitude graph in the Excel spreadsheet. Again, outliers are days where the movement is out of the realm of possibility for the animal. Keep in mind the error ranges before dismissing any points.



Note the "Root-Mean-Squared Difference" curve in the graph above. This gives you an idea about the quality of the latitude fit. The distance of the minimum of the curve above the origin indicates how well the actual light-level readings fit the theoretical light-level curve. The closer the minimum of the curve to the origin, the better the fit.

The "sharpness" of the curve indicates the range of latitudes whose theoretical light level curves share similar shapes. This aspect of the shape of the curve is dependent upon latitude/time-of year. "Sharper" curves generally yield better latitude (that is, the range of latitudes whose shapes are similar is small).



The above example shows where there are two “minimums” in the Root-Mean-Squared Difference curves, one as a northern hemisphere solution, the other as a southern hemisphere solution. WC-GPE will always choose the lowest “minimum”. You can, however, tell WC-GPE to select the best solution for a given hemisphere by clicking the appropriate button in the *Hemisphere* box.

Appendix A

The theory behind Geolocation by Light Level

The principle of determination of location is reasonably straightforward: Figure 1 shows the earth with the sun to the right. The bold circle (**A**) that encompasses the earth is the line between day and night. Note that this line does not pass through the north or south pole, night is shaded darker, and the earth has been made semi-transparent.

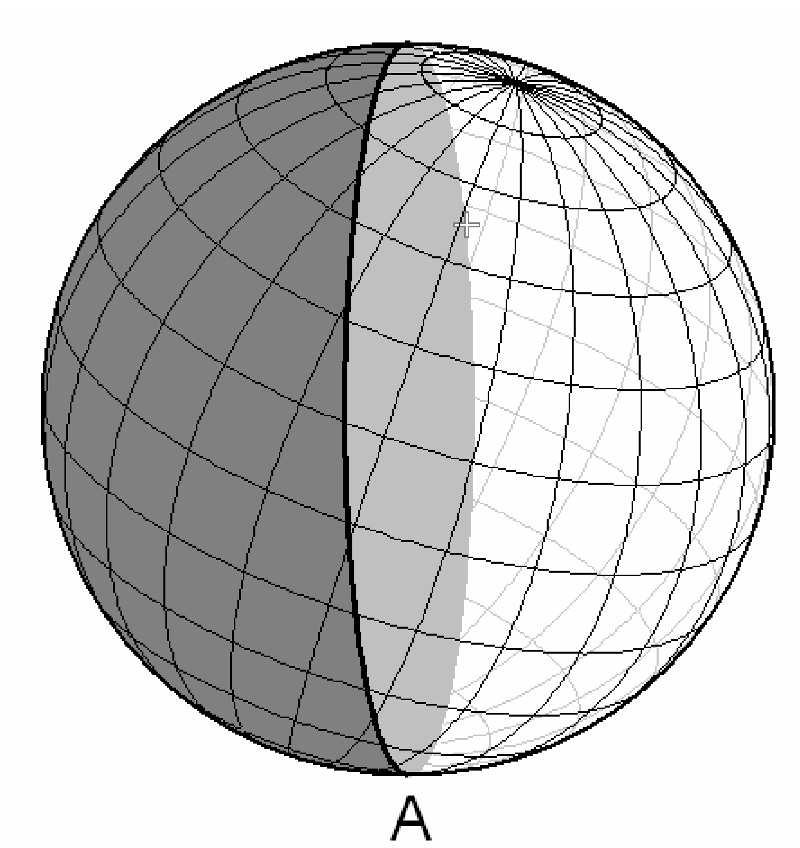


Figure 1

Figure 2 shows the earth 12.5 hours later. The sun is still to the right, but the earth has rotated a little over 180° and circle **A** from Figure 1 (together with its shadow) have rotated with it. Circle B is the line that currently divides day from night. If we consider a point on the earth for which the sun was rising in Figure 1 (on the back side of the globe) and is now experiencing a sunset, then the point must be on both circle **A** and circle **B**. Its location is therefore at the intersection of these two circles (marked on both figures with a ✢ symbol). Thus, if we know the times of dawn and dusk and the day of year (which affects the direction of the tilt of the earth with respect to the sun, and thus the position of the dawn-dusk circles), then we can theoretically calculate the location of the intersection of the dawn-dusk lines and, hence, our position.

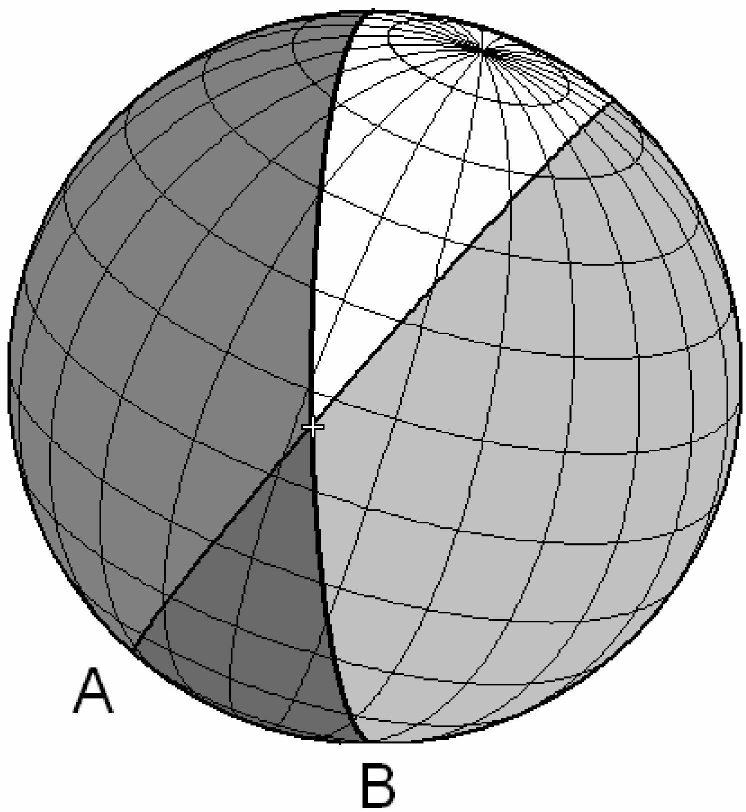


Figure 2

Sources of Error

Problems arise when we attempt to determine latitude near the vernal and autumnal equinoxes. In the “classic” description of the equinox (shown in Figure 3), the day and nights at every point on the earth are exactly 12-hours long, hence the name “equinox”. It is impossible to determine latitude under these circumstances. However, all is not lost. The reason that the dawn-dusk circles were coincident in Figure 3 was that they were both generated for a sun zenith angle of 90º (i.e. the sun was half above and half below the horizon). Figure 4 shows what happens if one uses a zenith angle of 95° (or 5° below the horizon) to calculate the dawn dusk circles. The “daylength” used here is 12.9 hours. Even with this crude figure, it is possible to see that not only can a latitude be calculated at the equinox, but that there may actually be two solutions: One in the northern hemisphere, and on in the southern hemisphere. You will commonly see this ambiguity when analyzing data near the equinoxes. Our ability to calculate latitude near the equinoxes is, however, limited to higher latitudes: There is no combination of zenith angle and daylength that will make the dawn and dusk circles non-parallel at the equator.

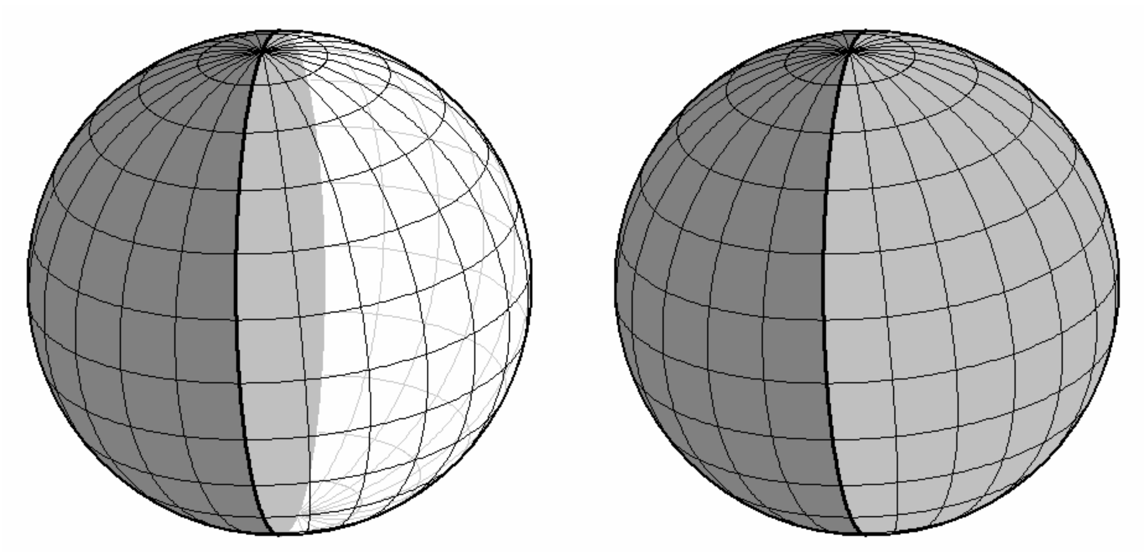


Figure 3.

Dawn and dusk on 14th March (spring equinox) using sun zenith angle of 90º. Earth is rotated by 12 hours.

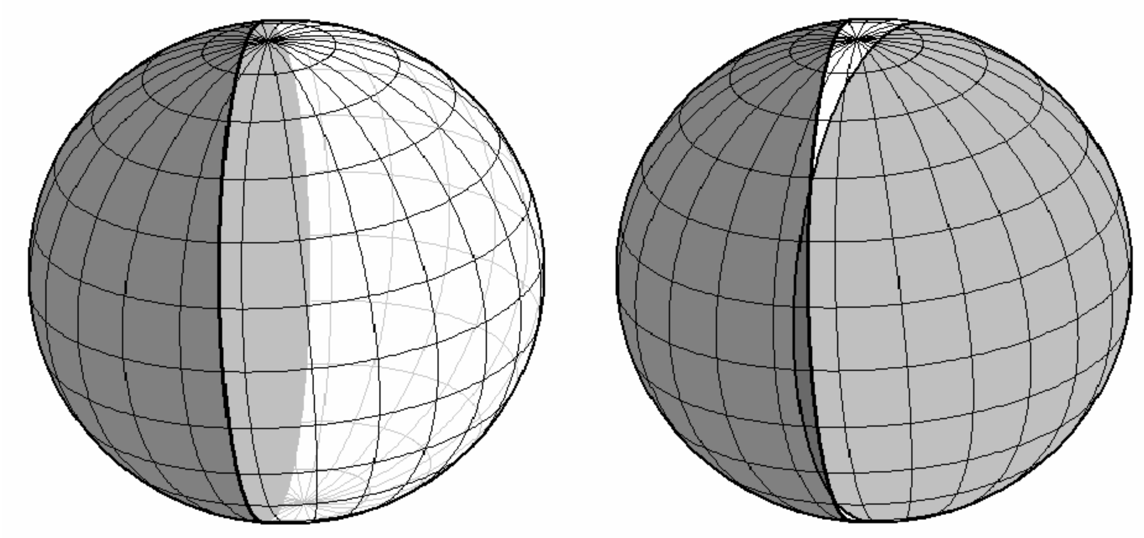


Figure 4.

Dawn and dusk on 14th March (spring equinox) using sun zenith angle of 95º. Earth is rotated by 12.9 hours.

Minimizing Error in Latitude Determination

The accuracy with which we can calculate latitude is effectively determined by the angle between the dawn and dusk circles. If they cross at right angles (as is possible at high latitudes near the solstices) then the accuracy will be greatest, if the circles overlay each other, then the accuracy will be very poor. Selection of appropriate zenith angles can help make the angle between the dawn and dusk circles as large as possible, but the best zenith angle to choose is not simple, and you need to know where you are to make the best selection! A better solution is to consider all zenith angles over a range from about 87º to 95º. The final location will effectively be determined from the zenith angle that created the largest angle between the dawn and dusk curves.

How do we implement this concept?

Revisiting Figures 3, note that the sun took 12 hours at all latitudes to go from dawn to dusk using a zenith angle of 90º to determine our dawn and dusk circles. Now, from Figure 4 we can see that the sun took 12.9 hours at about 40ºN latitude to go from dawn to dusk using a zenith angle of 95º. Furthermore at the equator it took less than 12.9 hours, and at latitudes north of 40ºN it will take longer. What does this mean? It means that although the sun passes a zenith of 90º at the same time regardless of latitude, the rate at which the sun is rising or setting varies with latitude. The sun rises and sets faster at the equator than at higher latitudes. In other words, the gradient of the dawn and dusk curves is steeper near the equator, and gentler nearer the poles, and we can use this information to tighten up our latitude estimate.

The GPE package implements this idea by determining the relationship between the sun's zenith angle and the tag's received light-level (corrected for any depth attenuation). This is done by selecting one (or more) days for which you know the tag's location, and for which you have good-looking dawn and/or dusk curves. Since we know where the tag is, we know the sun's zenith angle for each light-level reading taken (from standard astronomical equations). We can therefore determine an equation that relates the sun's zenith angle to the tag's received light-level over zenith angles in the range of interest. With this equation in-hand, we can analyze all the other days of the record: For any location we can use astronomical equations to determine what the sun's zenith angle was when our light-level readings were taken, and then convert those zenith angles to expected light-levels. Our best-guess position is when the expected light-level curves best match the measured light-level curves. This process effectively fits all the zenith angles from about 87º to 95º in one least-squares regression.