Georeferencing Calculator Manual

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Contents

Introduction

The Georeferencing Calculator (Wieczorek & Wieczorek 2019) described in this document is a tool created to aid in the georeferencing of descriptive localities such as those found in museum-based natural history collections. It was originally designed for the Mammal Networked Information System (MaNIS) and has been widely adopted in other large-scale collaborative georeferencing projects to supplement semi-automated georeferencing tools. The application makes calculations using the theory given in Georeferencing Best Practices (Chapman and Wieczorek 2019), derived from the earlier MaNIS/HerpNET/ORNIS Georeferencing Guidelines (Wieczorek 2001), and The point-radius method for georeferencing locality descriptions and calculating associated uncertainty (Wieczorek *et al*. 2004). Specific methods for calculating a wide variety of examples of the distinct Locality Types are given in Georeferencing Quick Reference Guide (Zermoglio *et al*. 2019).

Running the Calculator

The Georeferencing Calculator uses Javascript and runs in a browser. The latest version can be initiated from http://georeferencing.org/georefcalculator/gc.html, or it can be downloaded in a .zip or .tar.gz archive from the releases page on the Calculator GitHub repository (https://github.com/VertNet/georefcalculator/releases), unzipped to a convenient location and run in a browser by opening the file gc.html. Problems encountered with the Calculator should be entered as issues in the GitHub repository issue tracker at https://github.com/VertNet/georefcalculator/issues and should include the version identifier, which can be found in the lower right-hand corner of the Calculator (see Figure 1).When the **Calculator** is opened it should appear more or less as in Figure 1.

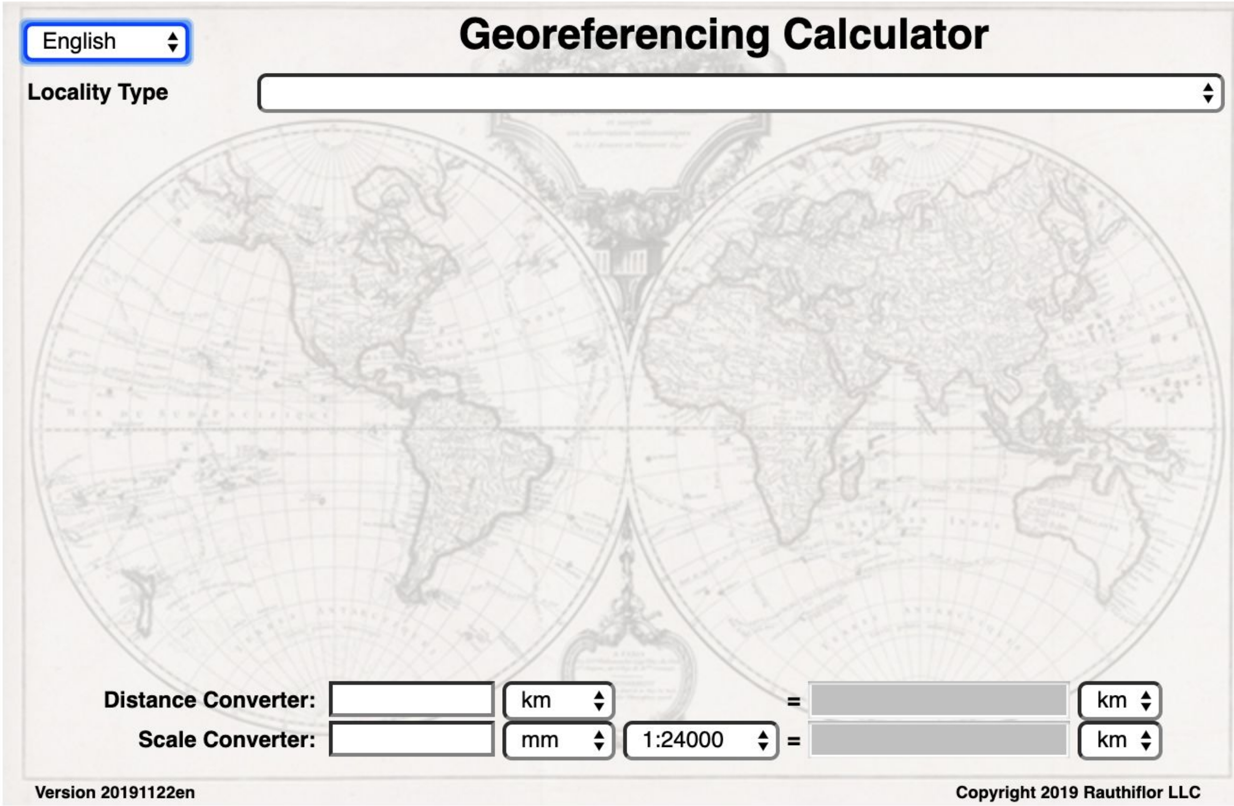

Figure 1. Screen image of the Georeferencing Calculator when it first opens, showing the language selection drop-down, the **Distance Converter**, the **Scale Converter**, and the **Locality Type** drop-down box to initiate a georeference calculation.

Basic Workflow

The calculator is designed to prompt the user only for what is needed to georeference based on the locality type selected. The steps in the basic workflow are:

1. Choose the language in which you would like to use the Calculator.
2. Select the locality type that best matches the descriptive locality you want to georeference. The interface will add all of the fields necessary to calculate the georeference.
3. Make selections and fill in all of the parameters shown Refer to the Glossary to get a description of what each parameter means.
4. Click on the Calculate button to calculate the results.
5. Enter the metadata for the person who is georeferencing and the protocol being used.
6. Click on the Copy button to put the results on the system clipboard.
7. Paste the results where the georeference will be stored.

8. Repeat for the next calculation. Note that the values for parameters chosen in one calculation will remain in the text and drop-down boxes and thus carry over to the next calculation whenever possible.

Detailed Workflow

Step 1: Choose a Language

Click on the drop-down in the upper left-hand corner of the Calculator to choose the language in which you would like to use the Calculator interface. Note that despite the language chosen, the number format always use the full stop '.' as the decimal indicator (*e.g.*, 2.5 for the number halfway between 2 and 3). When the list is expanded, the application should appear as in Figure 2, below.

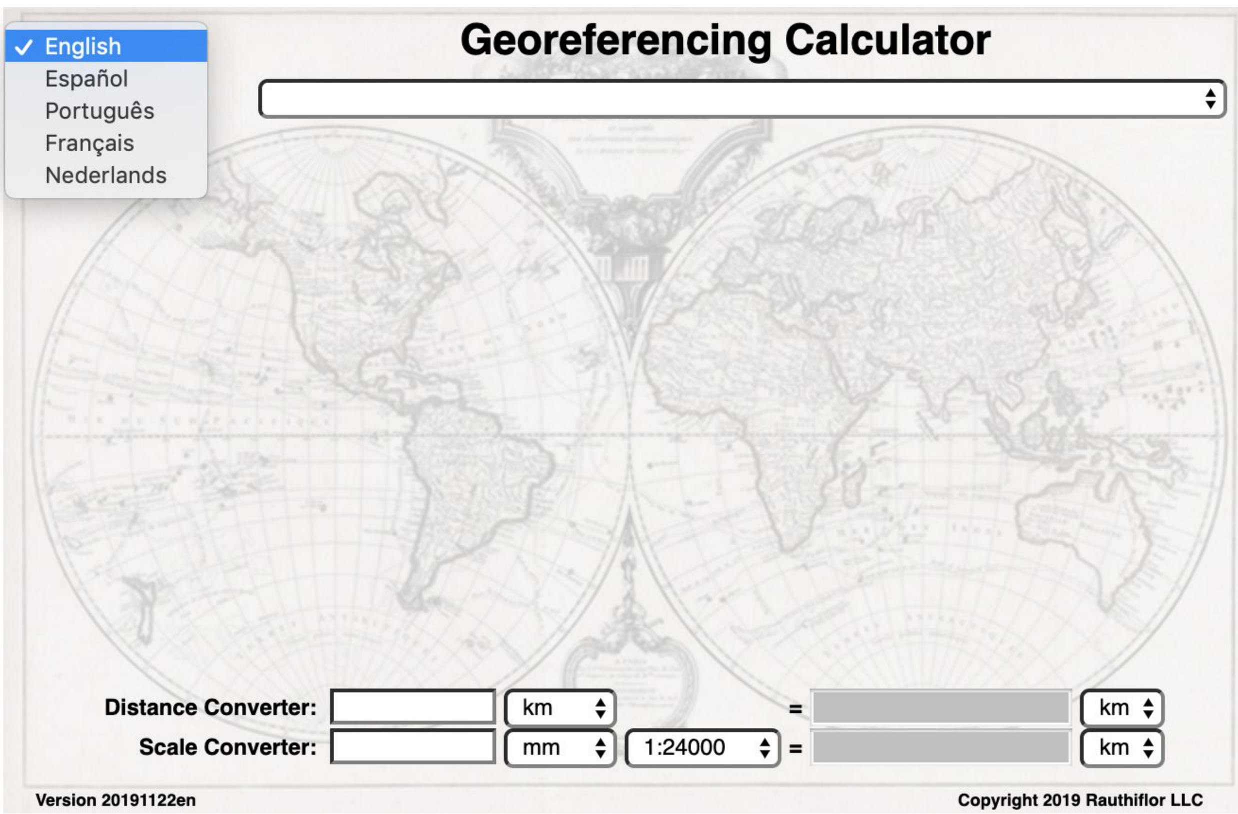

Figure 2. Step 1: Choose a Language. Calculator with the five language options showing after opening the Language drop-down list box.

Step 2: Choose a Locality Type

Click on the **Locality Type** drop-down to expand the list. When the list is expanded, the application should appear as in Figure 3, below.

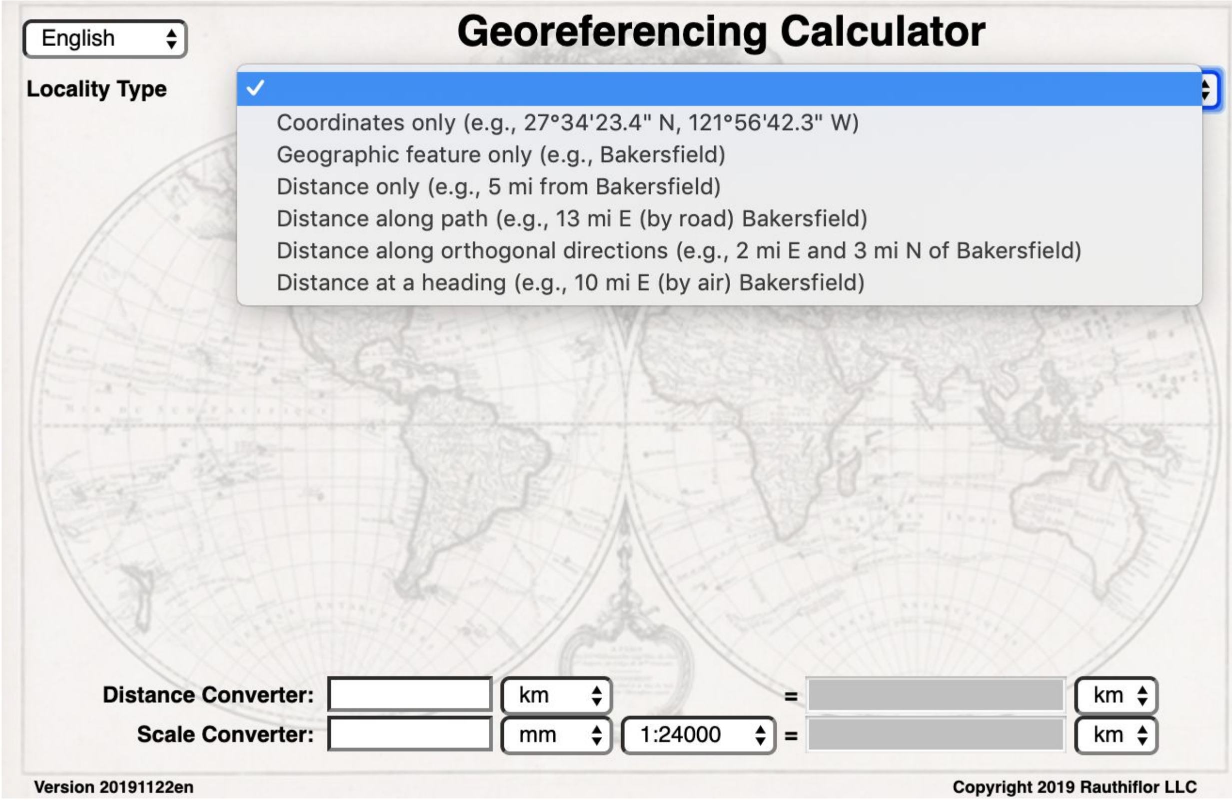

Figure 3. Step 2: Choose a locality type. Calculator with the six basic locality types showing after opening the **Locality Type** drop-down list.

Select the locality type that best matches the characteristics of the locality you want to georeference. Each locality type in the drop-down list shows an example to try to help you match your locality to a type. Locality types with many examples are given in the Georeferencing Quick Reference Guide.

Step 3: Enter Parameters

After selecting the locality type, a variety of text boxes, drop-down boxes, and buttons will appear on the Calculator (Figure 4). These text and drop-down boxes are those you need to fill and/or select values from to make the calculation of the locality type chosen.

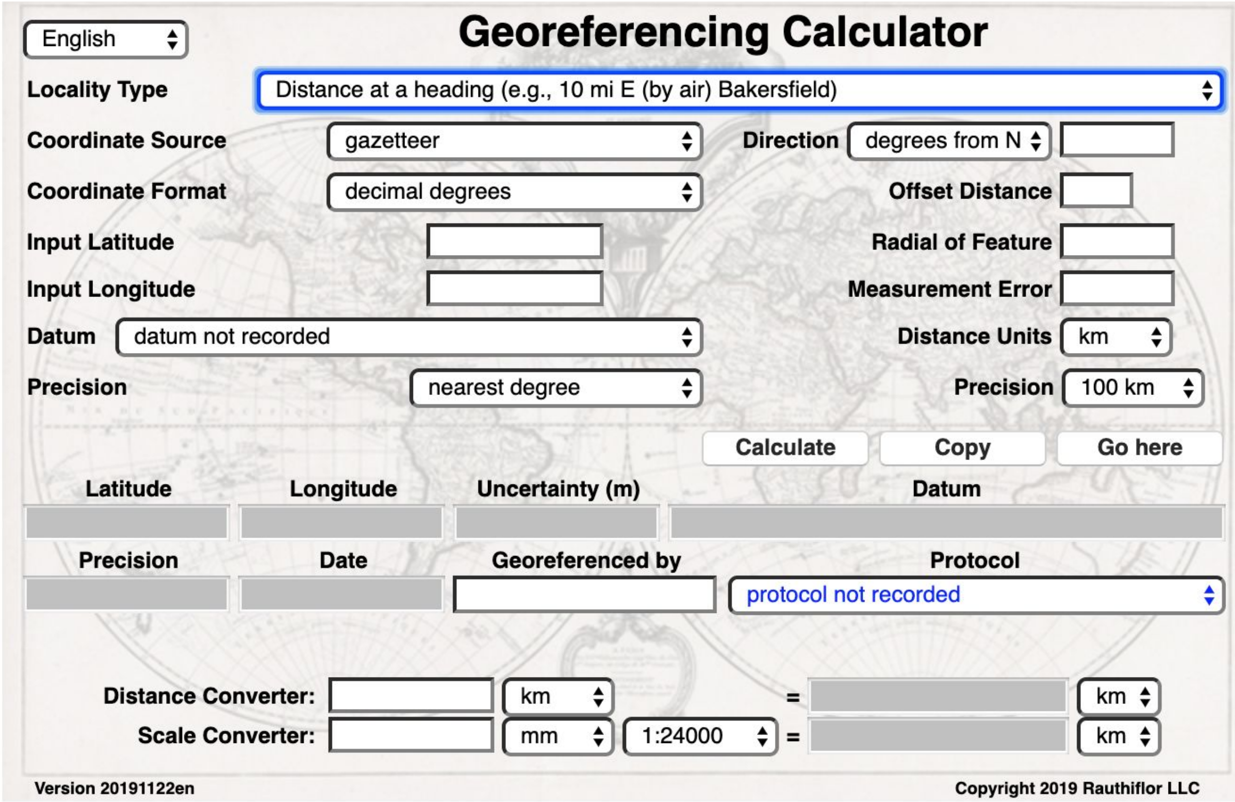

Figure 4. Step 3: Enter parameters. Calculator after selecting the "Distance at a heading" locality type, with all of the relevant text and drop-down boxes needed to be filled in or selected correctly in order to do a georeference calculation.

Step 4: Calculate

The **Calculate** button appears after a locality type is chosen. After all the parameters are correctly chosen or entered, click of the **Calculate** button. The calculated results will fill the text boxes with grey backgrounds in the middle of the Calculator, below the buttons and above the converters.

Calculation Example

Suppose the locality you are trying to georeference is "10 mi E (by air) Bakersfield" as shown in the example in selection box for the "Distance at a heading" locality type. Suppose you have obtained the coordinates for Bakersfield (35° 22' 24" N, 119° 1' 4" W) by determining the center of town to the nearest second using a USGS Gosford 1:24,000 Quad map.

To begin, select "USGS map: 1:24,000" from the **Coordinate Source** drop-down. Next, select “degrees minutes seconds” from the **Coordinate Format** drop-down. Next, enter the coordinates for Bakersfield in the **Input Latitude** and **Input Longitude** boxes that appear after selecting the **Coordinate Format**. Make certain to select the correct hemisphere from the drop-downs to the right of each coordinate fields. Note: For this example, the coordinate format 'degrees minutes seconds" was selected because the USGS map showed coordinates in degrees minutes seconds, thus the coordinates determined for the center of Bakersfield were described in the same way. In some cases, coordinates on a map, or other resource, may be represented in degrees decimal minutes (*e.g.*, 35° 22′ N, 119° 0′ W or 35° 22.4′ N, 119° 1.066667′ W) or as decimal degrees (*e.g.*, 35.3733333, -119.0177778). The coordinate format selected in the calculator MUST reflect the coordinate format used on the map or other resource.

The Gosford Quad map uses the North American 1927 horizontal datum, so select "North American Datum 1927" from the **Datum** drop-down list. In most cases you can find the datum printed on the map. Although sometimes an ellipsoid is listed instead. The Calculator also includes ellipsoids in the **Datum** drop-down list, so If you find a resource such as a map with a datum that in not listed in the Calculator, try to find the ellipsoid for that datum using online resources and then select the ellipsoid in the **Datum** drop-down list.

The coordinates in this example have been specified to the nearest second, so select "nearest second" from the **Coordinate Precision** drop-down list. The direction given in the locality description is E (east), so select "E" in the **Direction** drop-down list. The offset distance is 10 mi (miles), so type "10" into the **Offset Distance** text box.

Bakersfield is a large place and we don't know if the original locality means 10 miles from the center of town, 10 miles from the city limits, or something else entirely. Given that it is 3 miles from the specified coordinates to the furthest edge of town (as measured on the USGS map), the **Radial of Feature** should be 3 miles. Enter "3" into the **Radial of Feature** text field.

> TIP: ***If you had measured this distance in kilometers you can convert kilometers to miles using the Distance Converter at the bottom of the calculator and enter the converted number into the appropriate field (see the Distance and Scale Converters section to learn how to use the converters). All distance measurements MUST be in the same units as the locality description for the Calculator to return proper results.***

The determination of the coordinates for Bakersfield is only as accurate as the tools that you, the georeferencer, use; the map, the size of the units on the measurement tool, and the georeferencer's ability to discern their placement relative to items on the map. Any error associated with the map itself is accounted for in the **Coordinate Source** selection.

Error associated with the georeferencer's ability to measure on the map is accounted for in the **Measurement Error** field.

To complete the **Measurement Error** field, you must first determine or estimate the smallest distance that you can measure on the map reliably and repeatedly. Generally, people can distinguish features or locations to within about one (1) millimeter, given a ruler with millimeter divisions. If you use a ruler with English units, you may be able to distinguish to 1/16 of an inch. The quality of your measuring tool, eyesight, and technique may alter these suggested values.

Once you have determined the smallest distance at which you can measure consistently and reliably, enter that value and the units into the **Scale Converter** at the bottom of the calculator, select the scale of the map on which you made your measurement, and then select the unit of measure into which you want to convert. For example, if you used a digital measuring tool that was able to measure to the nearest 0.1 mm on a 1:24000 map and you need to convert to miles, enter "0.1" into the **Scale Converter**, then select "mm" from the units drop-down list. Next, choose the "1:24000" scale option in the map scale drop-down list. Finally, select "mi" in the second drop-down list. The value of 0.1 mm at 1:24000 converted into miles will be displayed in blue (0.00149 mi) within the grey text box on the right side of the **Scale Converter**. You can then type "0.00149" into the **Measurement Error** field, or move it from the **Scale Converter** using copy and paste keyboard combinations.

Next, make certain that "mi" is selected in the **Distance Units** drop-down, since the locality is described in miles ("10 mi E..."). The distance component in this locality is 10 mi, which is precise to the nearest 10 miles (see the discussion on this topic in the section **Uncertainty of Distance** in **Georeferencing Best Practices**). Select "10 mi" in the **Precisio**n drop-down.

Next, click the **Calculate** button. The calculated coordinates (always presented in decimal degrees) for the locality, "10 mi E (by air) Bakersfield" and the **Uncertainty** for the calculation (always in meters) will be given in the controls just above the distance and scale converters at the bottom of the calculator, as shown in Figure 5, below.

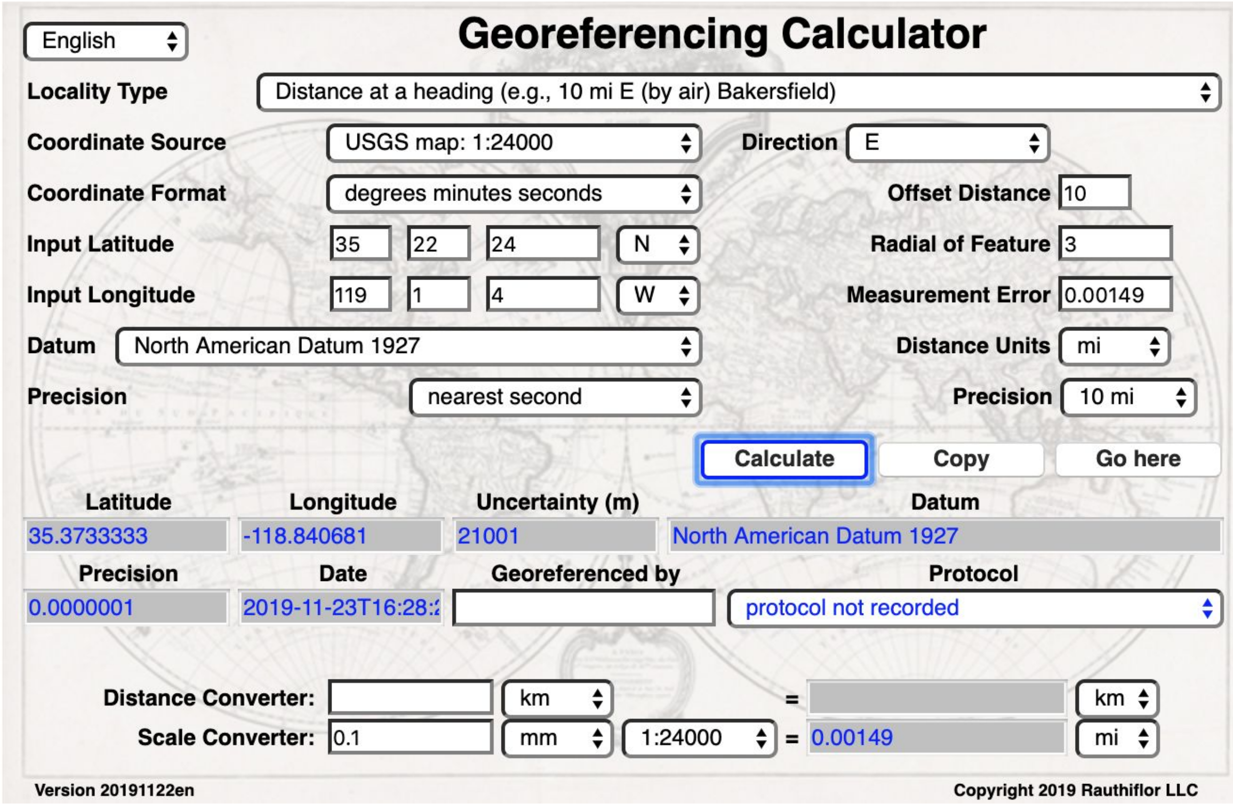

Figure 5. Step 4: Calculate. Calculator after clicking on the **Calculate** button, with all of the relevant text and drop-down boxes filled in or selected. Results appear in the grey text boxes in the middle section of the calculator below the **Calculate** button.

Step 5: Enter Metadata

After the results of the calculation have been presented, add the name of the georeferencer in the **Georeferenced by** text box. If there is more than one person, separate the names in the list by ' | '. Finally, select the appropriate georeferencing protocol. We recommend the use of the **Georeferencing Quick Referencing Guide** as the set of methods to follow. These methods are based on **Georeferencing Best Practices**. If you follow the **Georeferencing Best Practices** or the **Georeferencing Quick Reference Guide**, the protocol to choose is "Georeferencing Best Practices. 2019". Do not use this option if you altered the protocol in any way. People will rely on strict application of the protocol in order to be able to reproduce a georeference given the same input parameters. If you followed a distinct documented protocol, you will have to substitute the reference to the protocol documentation in your stored georeference records. If you follow a protocol that is not documented and publicly accessible, select "protocol not recorded". The example georeference from Figure 5, with the metadata filled in, is shown in Figure 6.

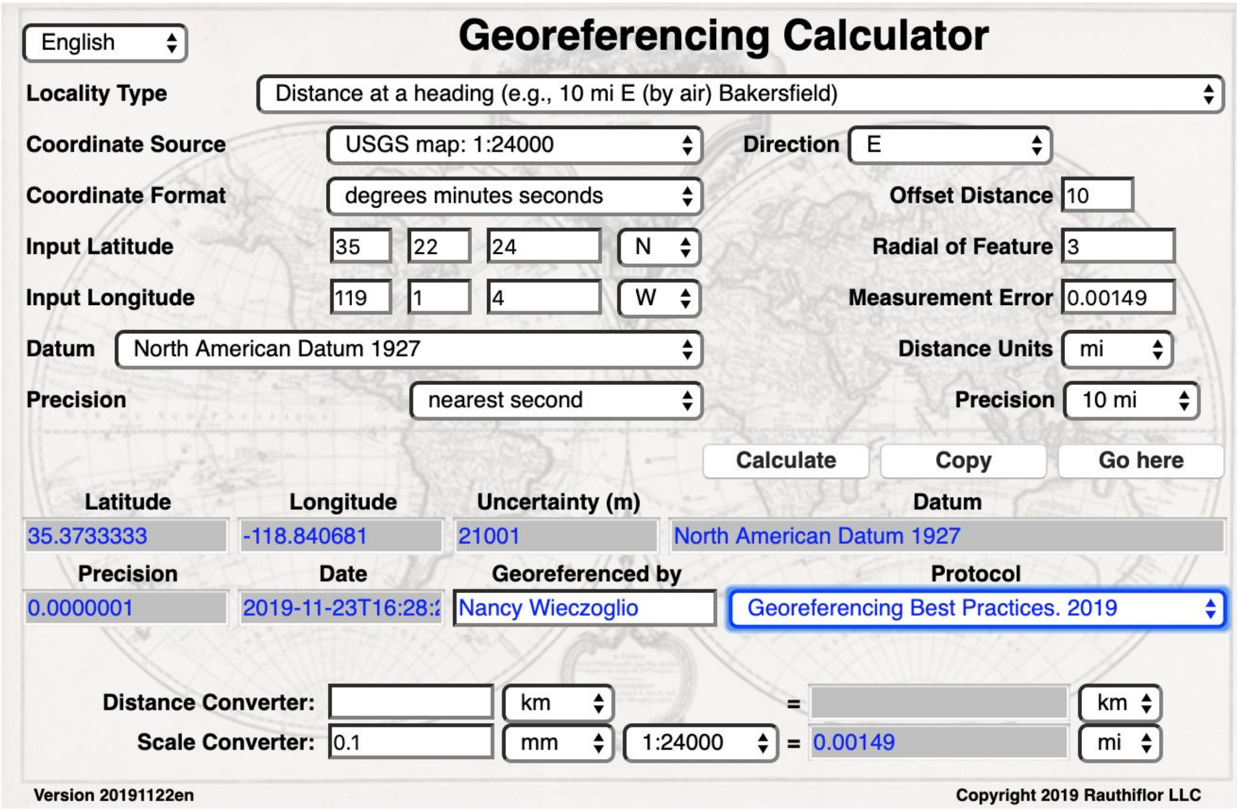

Figure 6. Step 5: Enter Metadata. Calculator after entering georeference metadata for the georeferencer and the georeferencing protocol used.

Step 6: Copy Results

The results (in blue in the middle section of the Calculator after clicking on the **Calculate** button), including the metadata, can be copied onto the system clipboard by clicking on the **Copy** button, after which a dialog box will appear displaying the content that has been copied, as shown in Figure 7. Note: This dialog box does not get translated based on the language chosen for the Calculator interface. To close the box, click the “OK” button. Once copied, the content can be transferred and pasted to a spreadsheet, database or text file as a tab-delimited record of the data for the current calculation.

This page says

Copied: 35.3733333 -118.840681 North American Datum 1927 21001 0.0000001 Nancy Wieczoglio 2019-11-22T02:57:39.045Z Georeferencing Best Practices. 2019

OK

Figure 7. Step 6: Copy Results. Pop-up dialog box after clicking on the **Copy** button, showing the tab-delimited results that have been copied to the system clipboard.

Step 7: Paste Results

The content on the system clipboard after clicking on the **Copy** button is tab-delimited. It can be pasted into a series of columns of a spreadsheet directly (this works in Excel as well as Google Sheets™). It also be pasted into a tab-delimited text file. When pasting the results, be certain that the order of the fields in the destination document matches the order of the fields in the results. Using Darwin Core (Wieczorek *et al*. 2012; http://rs.tdwg.org/dwc/terms/) term names, the order of the result fields is: decimalLatitude, decimalLongitude, geodeticDatum, coordinateUncertaintyInMeters, coordinatePrecision, georeferencedBy, georeferencedDate, and georeferenceProtocol. Figure 8 shows the results after being pasted into a cell in a Google Sheet™.

	A	B	C	D	E	F	G	H	I
1	decimalLatitude	decimalLongitude	geodeticDatum	coordinateUncerta	coordinatePre	georeferencedBy	georeferencedDa	georeferenceProtocol	
2	35.3733333	-118.840681	North American I	21001	0.0000001	Nancy Wieczoglio	2019-11-22T03:1	Georeferencing Best Practices. 2019	

Figure 8. Step 7: Paste Results. Part of a Google Sheet™ into which the results have been pasted. The column names reflecting Darwin Core terms were already in row 1 when the results were pasted into the cell A2.

Step 8: Start a New Calculation

A new calculation can be started simply by entering new parameter values and selecting new drop-down list values pertinent to the next calculation. If the locality type for the next calculation is different from the previous one, make a new selection on the **Locality Type** drop-down list. New parameters will appear that are relevant to the new Locality Type calculation. Previously entered and chosen values will remain in the text and drop-down boxes and thus carry over to the next calculation whenever possible. This can increase the efficiency of calculations if locality descriptions that include the same feature are georeferenced one after another. Note: Always check that all parameter values and choices are correct before accepting the results of a calculation.

Figure 9 shows the Calculator after selecting the locality type "Feature only" for a new georeference following the georeference calculation shown in Figure 6. Without doing anything further, the Calculator would be ready to calculate the georeference for the locality "Bakersfield" based on the previous entries. Note that the **Date** value will change automatically when the **Calculate** button is clicked.

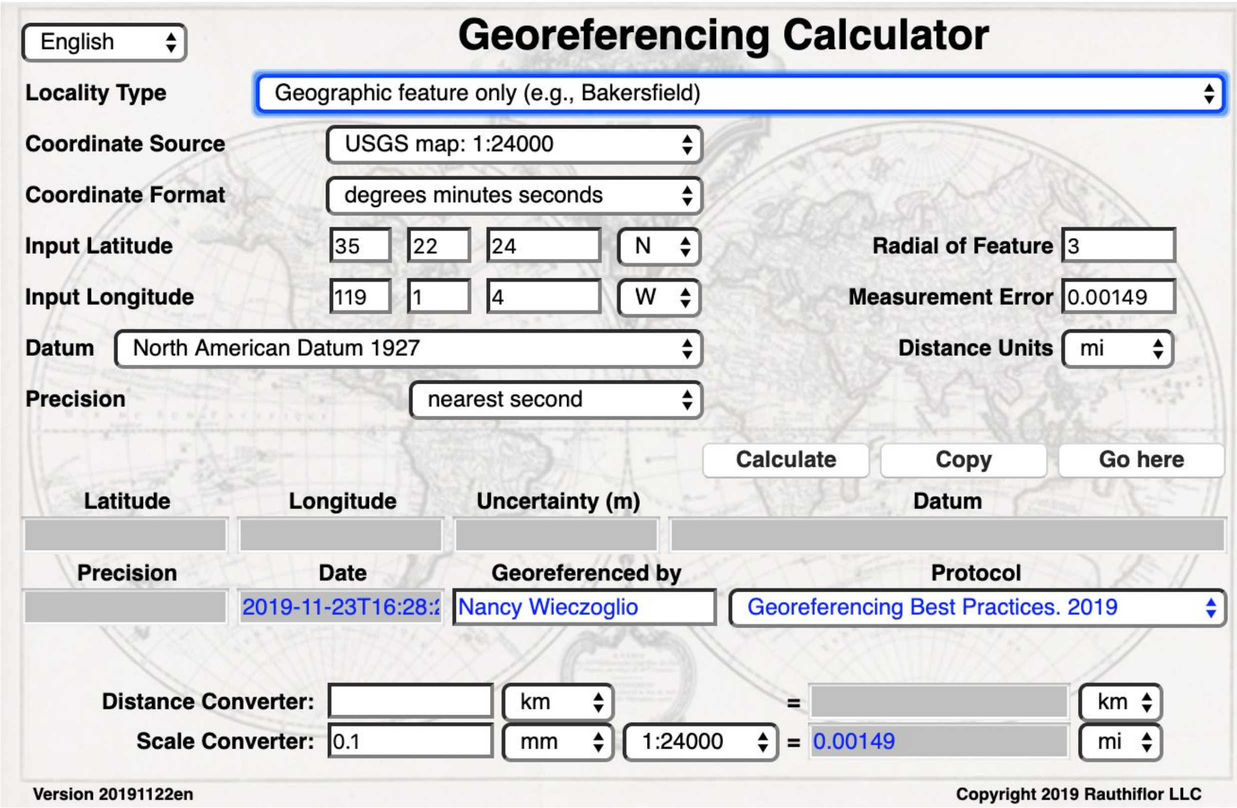

Figure 9. Step 8: Start a New Calculation. The Calculator after choosing a new locality type to start a new georeference calculation following the calculation from Figure 6. Note that there are fewer parameters to enter for this locality type, and that the parameter values that were in the previous calculation are preserved for this calculation.

Calculating Coordinates from a Map

Georeferences for every locality type require coordinates for the starting point. For all of the locality types except "Coordinates only", the coordinates of the reference feature are needed. In many cases these can be determined directly from a gazetteer or from an online tool such as Google Maps™. If the coordinates of a feature need to be determined from other reference points that have coordinates on a map (such as the corners), there is a nice little trick that can be done with the georeferencing Calculator to determine the coordinates of the feature easily. For example, to georeference the locality "10 mi E (by air) Bakersfield", it is first necessary to determine the coordinates for “Bakersfield”. Suppose your coordinate source is the USGS Gosford 1:24,000 Quad map. Once you have determined the point on the map you believe to be the center of Bakersfield, find a convenient point on the map having known coordinates, such as the nearest corner of the map. In this case, the northeast corner of the map is closest and marked with the known coordinates 35° 22” 30” N, 119° 00′ W.

To begin the calculation, select the **Locality Type** “Distance along orthogonal directions” (because you are going to measure due south and due west from the northeast corner of the map to the center of Bakersfield). Next, select and “degrees minutes seconds” as your **Coordinate Format**. Enter the coordinates of the known point (the northeast corner of the map, in this example) into the **Latitude** and **Longitude** fields (35° 22” 30” N, 119° 0” 0′ W - don’t neglect the hemisphere indicators). Select “(NAD27) North American 1927” as the **Datum** used by the map.

Now use your measuring tool to measure a) the distance between the northeast corner of the map and the line of latitude of the center of Bakersfield where it meets the east edge of the map, and b) the distance between the northeast corner of the map and the line of longitude of the center of Bakersfield where it meets the north edge of the map. These are your orthogonal distances to the S and W of the known point, the northeast corner of the map.

TIP*: *You will have to convert the measurements you make on the maps (mm, cm, or inches) into the distance unit provided in the locality (miles, in this example). You can use the Scale Converter, at the bottom of the Calculator, to do this calculation (see the section entitled Distance and Scale Converters).

The point we have determined to be the center of Bakersfield is 8 mm south of the 35° N line of latitude and 67 mm west of the 119° W line of longitude. After you have used the **Scale Converter** to convert millimeters to miles, cut and paste the values for miles into the Offset Distance text boxes on the right side of the calculator: 0.1193 should be pasted or typed into the **North or South Offset Distance** field, and the cardinal direction drop-down should be set to “S” (south); 0.99916 should be pasted or typed into the **East or West Offset Distance** field, and the cardinal direction drop-down should be set to “W” (west). The **Distance Units** drop-down should display “mi” (miles), since that is the unit described in the locality. The calculator now has all of the parameters necessary to complete the calculation and should appear as in Figure 10, below.

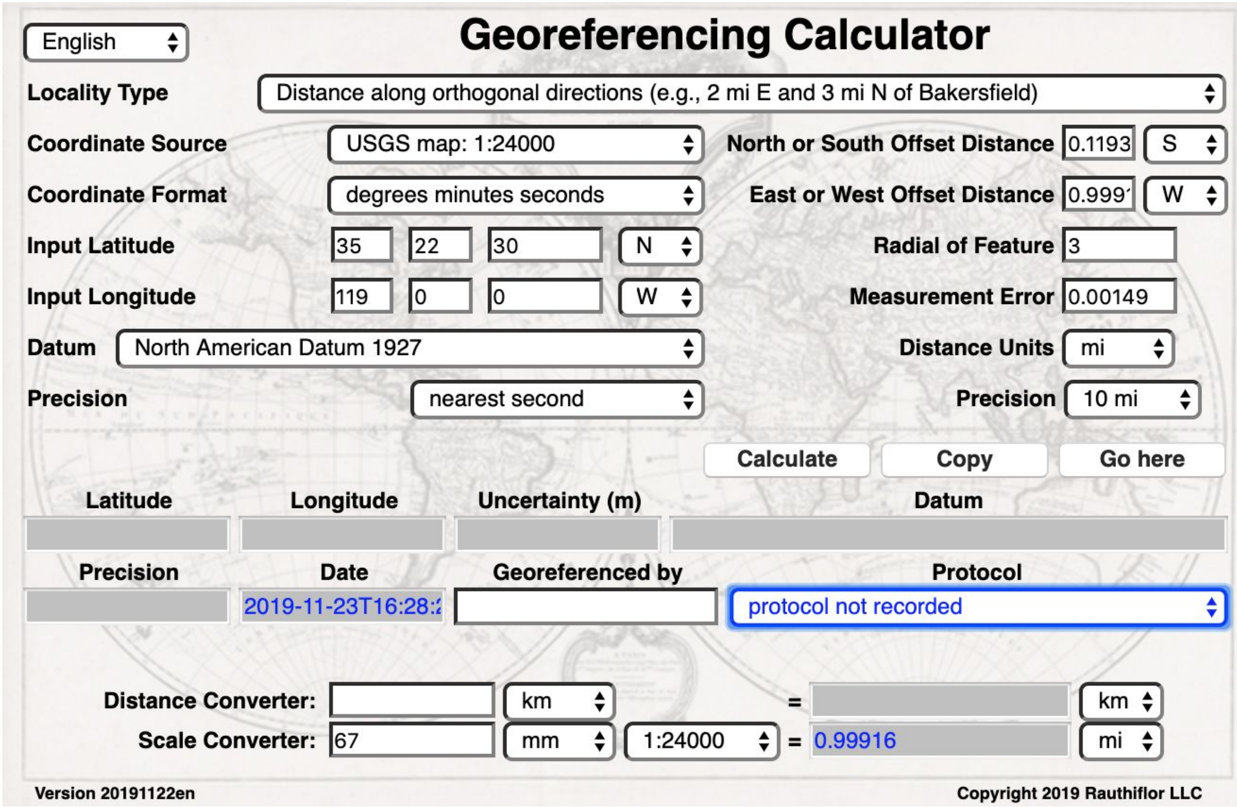

Figure 10. Calculating Coordinates from a Map: The Calculator after setting the parameters needed to calculate the coordinates of the center of Bakersfield by using measured offsets south and west of the northeast corner of the 1:24000 map, converted to miles.

Next, click the **Calculate** button. The calculated coordinates (always in decimal degrees) for the center point of Bakersfield are displayed in blue in the **Latitude** and **Longitude** fields in the results section of the Calculator, as shown in Figure 11. Note: This calculation was only to determine a new set of coordinates based on distances from a known set of coordinates. The parameters coordinate precision, radial of feature, measurement error, and distance precision were irrelevant to this calculation.

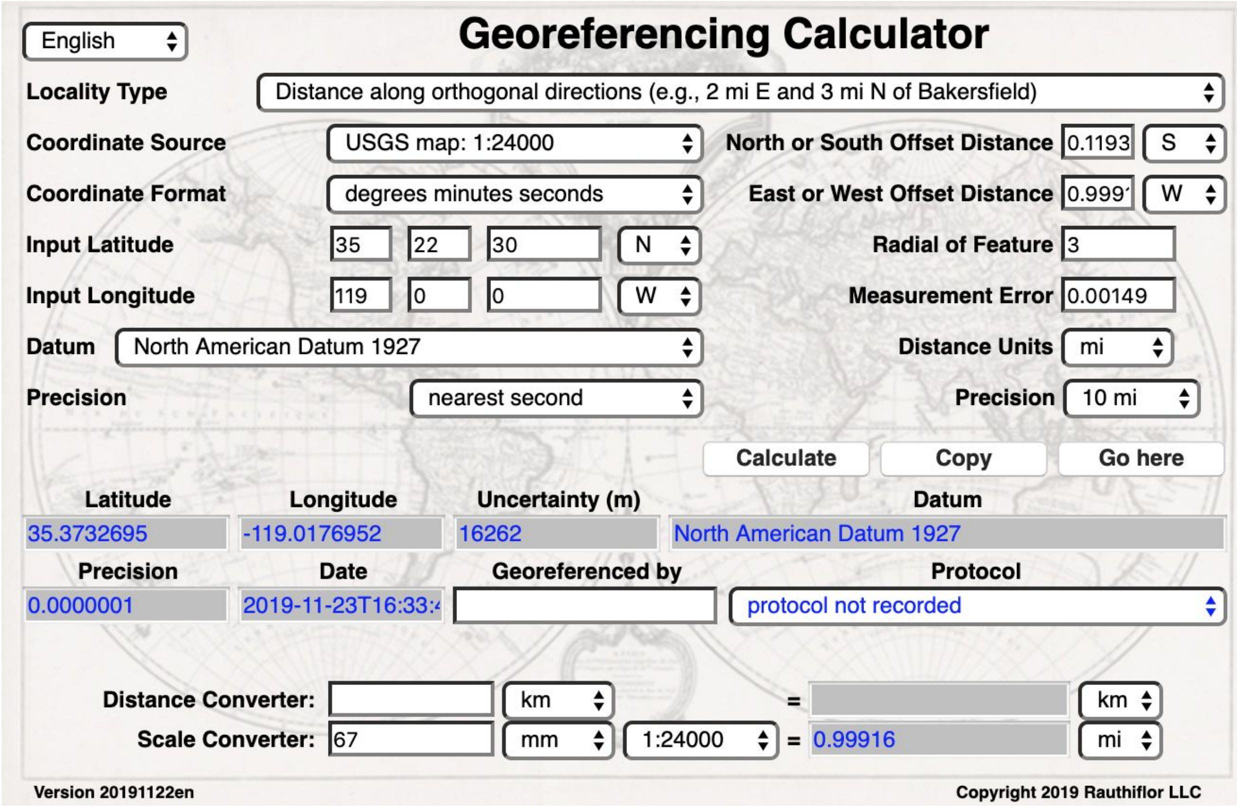

Figure 11. Calculated Coordinates from a Map. The Calculator after clicking on the **Calculate** button to determine the coordinates of Bakersfield by using measured offsets south and west of the northeast corner of the 1:24000 map, converted to miles.

"Going to" Calculated Coordinates

Now that you have calculated the starting coordinates for Bakersfield after measuring offsets on a map, you can use those coordinates to georeference subsequent locality descriptions that reference Bakersfield. Rather than copying and pasting (and possibly also converting) the coordinates into the various **Latitude** and **Longitude** fields, you can click the **Go Here** button to populate the starting coordinates with the coordinates you have just calculated. This process will automatically copy and convert the previous **Latitude** and **Longitude** from the results into the starting **Latitude** and **Longitude** fields in the **Coordinate Format** you are currently using (degrees minutes seconds in this example), as shown in Figure 12.

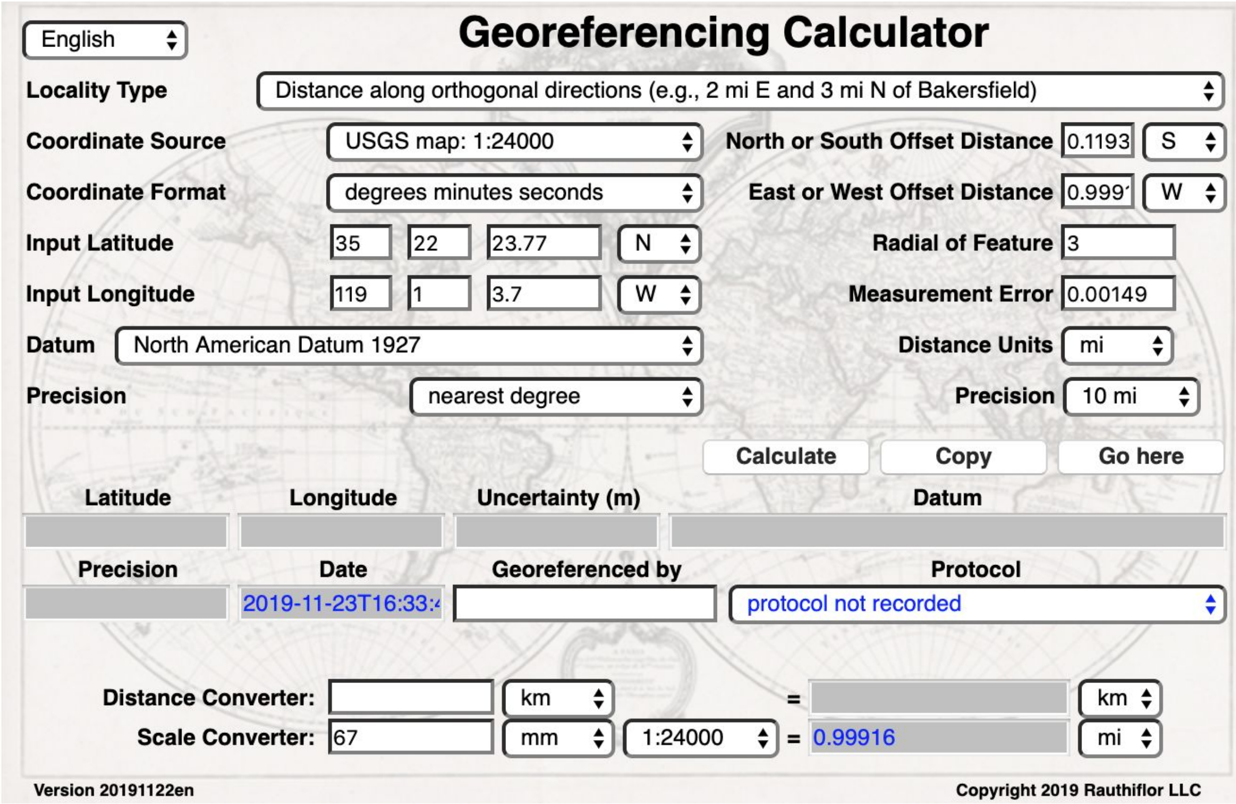

Figure 12. Calculated coordinates pushed to starting coordinates. The Calculator after clicking on the **Copy** button to move the coordinates in a previous result to the starting coordinates for a feature.

To complete a georeference using the new coordinates, follow the **Basic Workflow** starting at **Step 2 Choose a Locality Type**.

Coordinate, Distance, and Scale Converters

The Calculator has three converters built in to eliminate the need for additional tools during the georeferencing process. Built into the parameters section of the Calculator is a converter changes the format of coordinates between the three options decimal degrees, degrees decimal minutes, and degrees minutes seconds.

To convert between coordinate formats, simply select the desired format from the **Coordinate Format** drop-down list. The text and drop-down boxes for the **Input Latitude** and **Input Longitude** will change and be populated with the values in the new format.

Below the georeference calculation section of the Calculator is a **Distance Converter**. To convert a distance from one unit to another, put the value and units in the text and drop-down boxes in the **Distance Converter**, to the left of the "=". The value in the units of the drop-down box to the right of the "=" will appear in blue in the text box with the grey background on right side of the "=". For example, to converter 10 miles into kilometers, enter “10” in the first field of the **Distance Converter,** select “mi” from the left-hand unit drop-down list, and select “km” from the right-hand unit drop-down list. The result, 16.09344, automatically appears in the right-hand text box, from which you can copy the value to be placed in a distance field in the input area of the Calculator or elsewhere (see Figure 13).

Figure 13. Distance Conversion. The **Distance Converter** section of the Calculator showing a conversion of 10 miles into kilometers.

Below the **Distance Converter** is a **Scale Converter** designed to convert a measurement on a map of a given scale to a real-world distance in another unit. To convert a distance measured on a map with a known scale into a distance on the ground, put the distance value, distance units, and map scale in the text and drop-down boxes in the **Scale Converter**, to the left of the "=". The value in the units of the drop-down box to the right of the "=" will appear in blue in the text box with the grey background on right side of the "=". For example, to convert a map measurement of 8 centimeters on a 1:50000 map into miles on the ground, enter “8” in the first field of the **Scale Converter,** select “cm” from the left-hand unit drop-down list, select "1:50000" in the second drop-down list, containing scales, and select “mi” from the right-hand unit drop-down list. The result, 2.48548, automatically appears in the right-hand text box, from which you can copy the value to be placed in a distance field in the input area of the Calculator or elsewhere (see Figure 14).

Figure 14. Map Measurement Distance Conversion. The **Scale Converter** section of the Calculator showing a conversion of 8 centimeters on a map of 1:50000 scale to miles on the ground.

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Understanding Uncertainty Contributions

The Calculator is an excellent tool for investigating the contributions to uncertainty from distinct sources. For any given **Locality Type**, one can nullify all but one source of uncertainty to see what the contribution to overall uncertainty is from that source. For example, to see what the contribution to overall uncertainty is from unknown datum at a given location, choose the "Coordinate only" **Locality Type**, set the coordinates to the place you want to check, set the **Coordinate Source** to "gazetteer" or "locality description" (because neither of these choices contributes an uncertainty to the calculation), select "datum not recorded" from the **Datum** drop-down list, select "exact" from the **Coordinate Precision** drop-down list, set the **Measurement Error** to '0'. With these settings, the only source of uncertainty is the unknown datum. At the coordinate 0,0, the calculated uncertainty is 5030m, as shown in Figure 15. This large uncertainty reflects the maximum distance between the point 0,0 in any geographic coordinate reference system and the point 0,0 in the coordinate reference system WGS84. See the section **Coordinate Reference System** in **Georeferencing Best Practices** for further discussion on the subject.

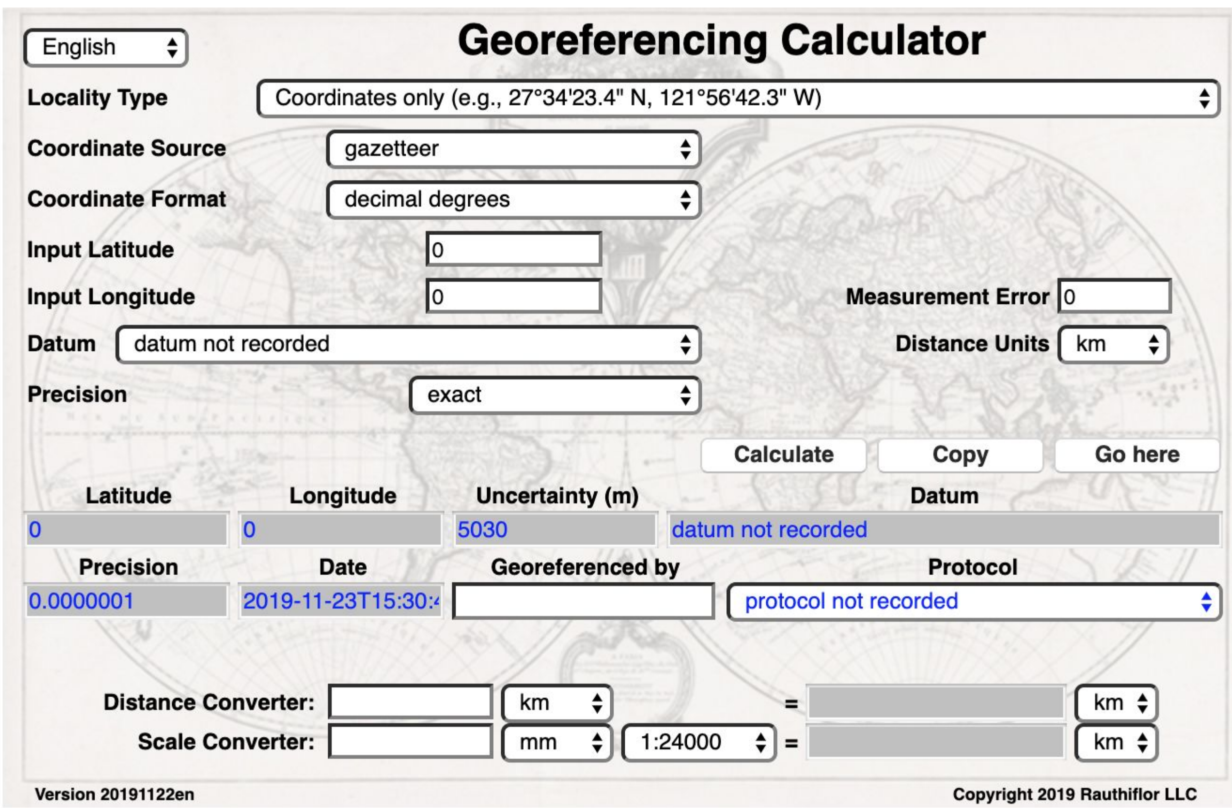

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Figure 15. Isolating uncertainty from an unknown datum. The Calculator showing setting that reveal the uncertainty due to an unknown datum at the coordinate 0,0. The choices nullify all other contributions to overall uncertainty.

Following are the sources of uncertainty and the values for the various input parameters that will nullify the uncertainty from that source.

Glossary

This glossary explains the user interface elements of the Calculator and how they relate to the underlying calculations.

Calculate - Button used to calculate coordinates and uncertainty using the point-radius method (Wieczorek *et al*. 2004) based on the values of parameters pertinent to the selected locality type. Clicking on the Calculate button fills in the results section of the Calculator with Darwin Core fields that need to be recorded for a georeference that follows **Georeferencing Best Practices**; decimalLatitude, decimalLongitude, geodeticDatum, coordinateUncertaintyInMeters, coordinatePrecision, georeferencedBy, georeferencedDate, and georeferenceProtocol. The calculation combines the sources of uncertainty using the algorithm appropriate to the locality type. The calculations account for uncertainties due to coordinate imprecision, unknown datum, data source, GPS error, measurement error, feature extent, distance imprecision, and heading imprecision.

Coordinate Format - Defines the original geographic coordinate format (decimal degrees, degrees minutes seconds, degrees decimal minutes) of the coordinate source. Equivalent to the Darwin Core term *verbatimCoordinateSystem*. Selecting the original coordinate format allows the coordinates to be entered in their native format and forces the calculator to present appropriate options for coordinate precision. Note that changing the coordinate format will reset the coordinate precision value to "nearest degree". Be sure to correct this for the actual coordinate precision. Behind the scenes, the Calculator stores coordinates in decimal degrees to seven decimal places. This is to preserve the correct coordinates in all formats regardless of how many transformations are done.

Coordinate Precision (input) - Labeled as "Precision" in the first column of input parameters, this drop-down list is populated with levels of precision in keeping with the **Coordinate Format** chosen for the verbatim original coordinates. This is similar to, but **NOT** the same as the Darwin Core term *coordinatePrecision*, which applies to the output coordinates. A value of “exact” is any level of precision higher than the otherwise highest precision given on a list. Sources may include paper or digital maps, digital imagery, GPS’s, gazetteers, or locality descriptions. Example: For 35° 22′ 24″, the Coordinate Precision would be "nearest second".

Coordinate Precision (output) - Labeled as "Precision" in the results, this text box is populated with precision of the output coordinates, and as such is equivalent to the Darwin Core term *coordinatePrecision*. The precision of the output is always 0.0000001, no matter how many digits appear to the right of the decimal indicator in the **Output Latitude** and **Output Longitude**.

Coordinate Source - The resources (map, GPS, gazetteer, locality description) from which the starting coordinates were derived. Related to, but **NOT** the same as the Darwin Core term *georeferenceSources*, which requires the specific resources used rather than their characteristics. Note that the uncertainties from the two sources "gazetteer" and "locality description" can not be anticipated universally, and therefore do not contribute to the uncertainty in the calculations. If the error characteristics of these sources are known, they can be added in the **Measurement Error** before calculating. If the source "GPS" is selected, the label for **Measurement Error** will change to **GPS Accuracy**, which is where accuracy distance of the GPS at the time the coordinates were taken should be entered. For details on **GPS Accuracy** see the section on **Using a GPS** in **Georeferencing Best Practices** (Chapman and Wieczorek 2019).

Datum - Defines the position of the origin and orientation of an ellipsoid upon which the coordinates are based for the given Coordinate Source. Equivalent to the Darwin Core term *geodeticDatum*. The Calculator includes ellipsoids on the **Datum** drop-down list, as sometimes that is all that coordinate source shows. The choice of datum has two important effects. The first is the contribution to uncertainty if the datum of the source coordinates is not known. If the datum and ellipsoid are not known, you must choose the option "datum not recorded". Uncertainty due to an unknown datum can be severe and varies geographically in a complex way, with a worst-case contribution of 5359 m (see the section **Coordinate Reference System** in **Georeferencing Best Practices**.

The second important effect of the datum selection is to provide the characteristics of the ellipsoid model of the earth, which the distance calculations depend on.

Ellipsoid - The shape and size of a 3-dimensional model of the earth. The ellipsoid information is used to do distance calculations.

Direction - The heading given in the locality description, either as a standard compass point (see http://en.wikipedia.org/wiki/Boxing_the_compass) or as a number of degrees in the clockwise direction from north. If "degrees from N" is selected, there will appear a text box to the right of it in which to enter the degree heading. Note: Some marine locality descriptions reference a direction (azimuth) to a landmark rather than a heading from the current location, for example, "327° to Nubble Lighthouse. If you want to make an offset at a heading calculation for such a locality description, use the compass point 180 degrees from the one given in the locality description (147° in the example above) as the **Direction**.

Distance Precision - Labeled as "Precision" in the second column of input parameters. Refers to the precision with which a distance was described in a locality (see the section **Uncertainty of Distance** in **Georeferencing Best Practices**). This drop-down list is populated in keeping with the **Distance Units** chosen and contains powers of ten and simple fractions to indicate the precision demonstrated in the verbatim original offset. Examples: select “1 mi” for "6 mi NE of Davis," select “1/10km” for “3.2 km SE of Lisbon”.

Distance Units - Denotes the real world units used in the locality description. It is important to select the original units as given in the description, because this is needed to properly incorporate the uncertainty from distance precision. Examples: select “mi” for "10 mi E (by air) Bakersfield," select “km” for “3.2 km SE of Lisbon”.

Go here - Button used to copy and potentially convert) the calculated coordinates from the **Output Latitude** and **Output Longitude** into the **Input Latitude** and **Input Longitude** fields in preparation for a new calculation based on the previous results, eliminating the need to copy manually or to use cut and paste keyboard combinations. Used when the calculated coordinates represent the coordinates of a named place in locality description.

GPS Accuracy - When “GPS” is selected from the **Coordinate Source** drop-down list, the label for the **Measurement Error** text box changes to **GPS Accuracy**. Enter the value given by the GPS at the time the coordinates were captured. If not known, enter 100 m for standard hand-held GPS coordinates taken before 1 May 2000 when Selective Availability was discontinued. After that, use 30 m as a default value.

Languages - The Calculator may be used in English, Spanish, Portuguese, French, or Dutch. The language can be changed using the language drop-down in the upper left-hand corner of the Calculator. Regardless of the language chosen, the Calculator always uses a period ('.') as the decimal separator.

Latitude (input) - The geographic coordinate north or south of the equator (where latitude is 0) for the verbatim original starting location in the locality description. Latitudes north of the equator are positive by convention, while latitudes to the south are negative. The Calculator supports degree-based geographic coordinate formats for latitude and longitude: degrees minutes seconds (*e.g.*, 35° 22′ 24″ N), decimal degrees (*e.g.*, 35.3733333), and degrees decimal minutes (*e.g.*, 35° 22.4 N).

Latitude (output) - The resulting latitude for a given calculation, in decimal degrees. Equivalent to the Darwin Core term *decimalLatitude*. See also, **Latitude** (input).

Locality Type - The pattern of the most specific part of a locality description to be georeferenced. The Calculator can compute georeferences for six locality types: **Coordinates only**, **Geographic feature only**, **Distance only**, **Distance along a path**, **Distance along orthogonal directions**, and **Distance at a heading**. Selecting a Locality Type will configure the Calculator to show all of the parameters that need to be set or chosen in order to do the georeference calculation. The **Quick Reference Guide** gives specific instructions for how to set the parameters for many different examples of each of the Locality Types.

Longitude (input) - The geographic coordinate east or west of the prime meridian (an arc between the north and south poles where longitude is 0) for the verbatim original starting location in the locality description. Longitudes east of the prime meridian are positive by convention, while longitudes to the west are negative. The Calculator supports degree-based geographic coordinate formats for latitude and longitude: degrees minutes seconds (105° 22′ 24″ W), decimal degrees (-105.3733333), and degrees decimal minutes (105° 22.4 W).

Longitude (output) - The resulting longitude for a given calculation in decimal degrees. Equivalent to the Darwin Core term *decimalLongitude*. See also, **Longitude** (input).

Measurement Error - Accounts for error associated with the ability to distinguish one point from another using any measuring tool, such as rulers on paper maps or the measuring tools on Google™ Maps or Google™ Earth. The units of the measurement must be the same as those for the locality description. The **Distance Converter** at the bottom of the Calculator is provided to aid in changing a measurement to the locality description units.

Offset Distance - The linear distance from a point of origin. Offsets are used for the **Locality Types Distance at a heading** and **Distance only**. If the **Locality Type** "Distance in orthogonal directions" is selected, there are two distinct offsets:

North or South Offset Distance - The distance to the north or south of the **Input Latitude**.

East or West Offset Distance - The distance to the east or west of the **Input Longitude**.

Radial of Feature - The feature is the place in the locality description that corresponds to the **Input Latitude** and **Input Longitude**. Types of features vary widely and include, for example, populated places, street addresses, junctions, crossings, lakes, mountains, parks, islands, etc. The radial of the feature is the distance from the **corrected center** of the feature to the furthest point on the geographic boundary of that feature (see the section **Extent of a Location** in **Georeferencing Best Practices**).

Uncertainty (m) - The resulting combination of all sources of uncertainty (coordinate precision, unknown datum, data source, GPS accuracy, measurement error, feature extent, distance precision, and heading precision) expressed as a linear distance - the radius in the point-radius method (Wieczorek *et al*. 2004). Along with the Output Latitude, Output Longitude, and Datum, the radius defines a circle containing all of the possible places a locality description could mean.

Version - Displayed in the bottom left-hand corner of the Calculator as yyyymmddll, where ll is the two-letter language code of the interface. Example: 20191122en is the English version created 22 November 2019.

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