Climate Distance Mapper: spatial decision-support tools for seed sourcing and collection efforts in the Desert Southwest

Tutorial

Daniel F. Shryock, Lesley A. DeFalco, and Todd C. Esque

U.S. Geological Survey
Western Ecological Research Center

USGS
science for a changing world
Contents
Overview ........................................................................................................................................... 4
Rationale and Methodology .................................................................................................................. 4
Tools provided in the Climate Distance Mapper .................................................................................. 5
Single Point Tools .............................................................................................................................. 6
Multipoint Tools ................................................................................................................................. 8
Cluster Tool ....................................................................................................................................... 9
Compare distance values at points ..................................................................................................... 10
Using Climate Distance Mapper ...................................................................................................... 11
Getting started with the stand-alone desktop version ...................................................................... 11
Required software ............................................................................................................................. 11
Required R packages ......................................................................................................................... 11
Download the application package ................................................................................................. 11
Opening Climate Distance Mapper from Rstudio ........................................................................... 12
Using the single point climate distance tool .................................................................................. 15
Forward projection ............................................................................................................................ 17
Backward projection .......................................................................................................................... 19
Constraining climate distances ......................................................................................................... 20
Climate distances with multiple points ............................................................................................. 21
Forward projection ............................................................................................................................ 22
Backward projection .......................................................................................................................... 23
Using the Cluster tool ......................................................................................................................... 24
Forward projection ............................................................................................................................ 25
Backward projection .......................................................................................................................... 26
Clusters with constrained climate distances ..................................................................................... 27
Comparing distances at points .......................................................................................................... 28
Tool citation ....................................................................................................................................... 29
Contacts ............................................................................................................................................ 29
References ........................................................................................................................................ 29
Climate Distance Mapper: Decision support tools for seed sourcing and collections
Overview

Climate Distance Mapper is a spatial decision-support tool designed to help land managers match seed sources with restoration sites based on climatic variation across the landscape. Plant populations are commonly adapted to local climatic gradients and frequently exhibit a home-site advantage (Leimu and Fischer 2008, Hereford 2009). For this reason, climate information may serve as an effective proxy for local adaptation in restoration designs (Shryock et al. 2017). Climate Distance Mapper allows users to rank the suitability of seed sources for restoration sites by displaying the multivariate climate distance (incorporating aspects of precipitation and temperature) from input points to the surrounding landscape. Results can be viewed in a zoomable map interface or downloaded. Currently, the application supports four regions in the desert southwest: the Mojave Desert, Sonoran Desert, Colorado Plateau, and Southern Great Basin. Users can perform calculations for either the current or future climates, facilitating climate-resilient restoration designs. Additionally, functions are available for users to map the degree to which multiple seed collections represent the diversity of climates across the landscape and to choose which seed sources are appropriate for different parts of the landscape.

Rationale and Methodology

Seed sourcing poses a considerable challenge in large-scale restoration. Local plant materials are often unavailable, leaving resource managers to choose from distant seed sources for planting at a given restoration site. However, low population fitness and poor restoration success may result when seeds are planted in environments to which they are not adapted. Hybridization between local and imported genotypes may further erode population fitness through time if introduced plant materials are maladapted (e.g., outbreeding depression; Hufford and Mazer 2003). Consequently, minimizing adaptive differences between local populations and introduced plant materials may improve restoration outcomes. For these reasons, the National Seed Strategy for Rehabilitation and Restoration (www.blm.gov/seedstrategy) defines ensuring “the reliable availability of genetically appropriate seed” and “developing tools that enable managers to make timely, informed seeding decisions” as major goals towards meeting future restoration needs.

Climate Distance Mapper is an interactive mapping application designed to facilitate informed seed sourcing decisions and to aid in directing broad-scale seed collections. Implemented as a Shiny web application (Chang et al. 2017; https://CRAN.R-project.org/package=shiny), Climate Distance Mapper can be opened in a web browser from RStudio (RStudio Team 2016; http://www.rstudio.com/) or R (R Foundation for Statistical Computing, Vienna, AT; www.R-project.org). The application is designed to guide restoration seed sourcing in the desert southwest by allowing users to interactively visualize climatic differences – in the form of multivariate distance values – from specific restoration sites to the surrounding landscape. Climatic distances are based on a combination of variables likely to influence patterns of local adaptation among plant populations, including: mean annual temperature, summer maximum temperature, winter minimum temperature, temperature...
seasonality, annual temperature range, mean annual precipitation, winter precipitation, precipitation seasonality, long-term winter precipitation variability, and long-term summer precipitation variability. The climate variables are first transformed into principal components to account for covariation among variables and to emphasize the natural groupings of sites. All climate data is obtained through ClimateNA (Wang et al. 2016), an application for dynamically downscaling PRISM climate data (Daly et al. 2008).

All of the tools in climate distance mapper support projections into future climate – either by comparing the current climate at input points with the future climate across the landscape (forward projection, from current climate forward to future climate), or by comparing the future climate at input points with the current climate across the landscape (backward projection, from future climate back to current climate). Future climate is defined as the predicted 30-year average for the 2040-2070 period using an ensemble average of three models from the Coupled Model Intercomparison Project phase 5 (CMIP5) database corresponding to the 5th IPCC Assessment Report for future projections (IPCC 2014). We selected the RCP8.5 (high emissions) scenario for projections. The future climate models included CCSM4 (Community Climate System Model, version 4.0), GFDL-CM3 (Geophysical Fluid Dynamics Laboratory Climate Model, version 3), and HadGEM2-ES (Hadley Centre Global Environmental Model, version 2 (Earth System). All future climate data were generated using ClimateNA.

Tools provided in the Climate Distance Mapper

The fundamental unit of measure in Climate Distance Mapper is the multivariate climate distance, which is defined as the Euclidean distance between climate variables at input points and climate variables at other grid cells spread throughout the chosen spatial extent. All distance calculations incorporate 5 principal components derived from an original set of 12 climate variables. The conversion to principal components accounts for covariation in climate variables and thereby emphasizes natural gradients that distinguish climatic regimes across landscapes. Within the application, a number of different tools are available (see Table 1 for detailed descriptions) to help restoration practitioners “put the right seed in the right place at the right time” (National Seed Strategy, www.blm.gov/seedstrategy).

Climate distance values are relativized to the 95th percentile of the maximum possible climate distance in the study extent (which may be set dynamically by the user), such that values correspond to a percentage of the total climate variability (Doherty et al. 2017). Using the 95th percentile of the maximum climate distance reduces the influence of outlier grid cells, but does result in some climate distance values greater than one. An additional option (Constrain Distances) allows users to constrain results to a specific level of climate similarity (e.g., 90% similar).

Note: for efficiency in display of raster layers on the zoomable map interface, Climate Distance Mapper reclassifies raster layers into 20 ordinal categories. However, raster layers with non-ordinal climate distances may be downloaded from the application.
Table 1. Spatial tools available in Climate Distance Mapper.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Definition</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single point tools</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single point distance</td>
<td>Multivariate climate distance from input point to all other grid cells</td>
<td>Local seed sourcing, assisted migration</td>
</tr>
<tr>
<td>Forward projection</td>
<td>Multivariate climate distance from input point in current climate forward to future climate at all other grid cells</td>
<td>Predictive seed sourcing, assisted migration</td>
</tr>
<tr>
<td>Backward projection</td>
<td>Multivariate climate distance from input point in future climate backward to current climate at all other grid cells</td>
<td>Predictive seed sourcing</td>
</tr>
<tr>
<td><strong>Multipoint tools</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multipoint distance</td>
<td>Minimum multivariate climate distance from grid cells to any input point</td>
<td>Planning seed collections, admixture seed sourcing</td>
</tr>
<tr>
<td>Forward projection</td>
<td>Minimum multivariate climate distance from future climate at grid cells to current climate of any input point</td>
<td>Planning seed collections, admixture seed sourcing</td>
</tr>
<tr>
<td>Backward projection</td>
<td>Minimum multivariate climate distance from current climate at grid cells to future climate of any input point</td>
<td>Planning seed collections, admixture seed sourcing</td>
</tr>
<tr>
<td><strong>Cluster tools</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cluster points</td>
<td>Partition grid cells into groups according to their most climatically similar input point</td>
<td>Local seed sourcing</td>
</tr>
<tr>
<td>Forward cluster</td>
<td>Partition grid cells in future climate into groups according to their most similar input point in the current climate</td>
<td>Predictive seed sourcing</td>
</tr>
<tr>
<td>Backward cluster</td>
<td>Partition grid cells in current climate into groups according to their most similar input point in the future climate</td>
<td>Planning seed collections, predictive seed sourcing</td>
</tr>
<tr>
<td><strong>Extract tool</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compare distances at points</td>
<td>Requires raster output from above tools. Extracts distance values (or cluster identity) at additional points provided in a file and adds these values to the map display as popup labels for each point.</td>
<td>Local seed sourcing, predictive seed sourcing, planning seed collections</td>
</tr>
</tbody>
</table>

**Single Point Tools**

For a given input point (e.g., a restoration site), the Single-Point Tools will calculate and map climate distances from the input point to all other grid cells across the chosen region at an 800 m² spatial resolution (Figure 1). These **climate distances** can be used to quantitatively rank alternative seed sources in terms of their predicted climatic suitability (where smaller distance values equate to lower risk of maladaptation at the input point / restoration site), or to guide seed sampling efforts by focusing collections in climatically suitable areas (areas with lower climate...
distance from a restoration site). If the input point is a seed collection, the tool will display areas that are climatically similar and to which the seeds may be best adapted. If the input point is a restoration site, the tool will display climatically similar areas from which seed could be collected.

Figure 1. Example of the single point climate distance calculated for an input point in Climate Distance Mapper. Blue colors indicate areas that are similar in climate to the input point, while red colors indicate areas with dissimilar climatic regimes.

The Single-Point Tools are meant to guide local or admixture seed sourcing strategies in native plant restoration.

- For local seed sourcing, we recommend choosing seed sources with low climate distance values from the restoration site.
- For admixture seed sourcing, we recommend choosing seed sources with low to moderate climate distance values that are geographically distributed across the landscape.

Calculations can be performed for either the current or future climate. Climate distance mapper supports two types of future climate projections:

- The forward projection is the climate distance from the current climate at an input point forward to the future climate across the landscape. This type of distance indicates where seeds collected from a particular input site may be planted for future climate resilience.
- The backward projection is the climate distance from the future climate at an input point backwards to the current climate across the landscape. This type of distance indicates where on the landscape to collect seeds that will be resilient to the future climate at an input site.
**Multipoint Tools**

An enduring challenge for restoration practitioners is to increase the supply of native seed collections such that they adequately represent the genetic diversity of a given region. For example, the Seeds of Success (SOS) program in the United States seeks to “collect, conserve, and develop native plant materials for stabilizing, rehabilitating and restoring lands” ([www.blm.gov/sos](http://www.blm.gov/sos)), and directs annual seed collections across a broad range of ecoregions (Haidet and Olwell 2015). Practitioners need interactive tools for planning seed collections to ensure that sufficient diversity is maintained both within and between ecoregions.

The *Multipoint Tools* are designed to allow users to visualize the extent to which a set of input points represents the climate diversity of the landscape as a whole. The multipoint climate distance is defined as the minimum climate distance from grid cells to one of multiple input points. For each grid cell in the chosen spatial extent, the climate distance to each input point is calculated, and the minimum distance value is retained in the final raster (Figure 2). The climate distance value for each grid cell indicates how climatically similar that cell is to an input point.

The multipoint distance tool can be used interactively to guide seed collections within a single region or across the full extent covered by Climate Distance Mapper. By inputting seed collection locations to the tool, users can visualize which parts of the landscape need additional sampling due to poor climatic representation, and which parts are already well represented. In this way, the tool can be used to develop a climatically (and, by extension, genetically) diverse sample of seed sources for future use in restoration projects.

![Figure 2. Example of the multipoint climate distance calculated for four input points in the Mojave Desert. The map visualizes the extent to which the input points represent the different climatic regimes present in the chosen spatial extent. Areas symbolized in blue are climatically similar to an input point, whereas areas symbolized in red are climatically dissimilar from all input points. In a seed collection context, this would mean that seed collections do not provide climatic coverage of the areas symbolized in yellow and red.](image-url)
Calculations with the multipoint tool can be performed for either the current or future climates. If the *forward* projection option is selected, the tool will display the minimum climate distance between the future climate at grid cells and the current climate at any input point. If the *backward* projection option is selected, the tool will display the minimum climate distance between the current climate at grid cells and the future climate at any input point. Forward multipoint climate projections can be used to visualize the extent to which existing seed collections represent the climatic conditions predicted for the future. Alternatively, if restoration sites are entered as input points, the backward multipoint projection can visualize parts of the landscape from which suitable collections may be obtained for future climates.

**Cluster Tool**

In planning large scale restoration projects, practitioners are often faced with choosing from among multiple, distant seed sources for application to specific restoration sites. The cluster tool is designed to quickly display which of the available seed sources are most suitable for different parts of the landscape, helping practitioners put the right seed in the right place. Users can provide input points representing different seed sources, and Climate Distance Mapper will partition a given region into clusters representing the most suitable areas for each seed collection to be planted (Figure 3). The clusters are determined by assigning each grid cell to the input point from which it has the lowest climate distance value. With the “Constrain output” option, users can also constrain clusters such that only areas with a certain level of climate similarity are included. For example, by selecting “90% similar climate,” the resulting clusters will include only grid cells that are at least 90% similar in climate to an input point.

The cluster tool can perform calculations for either the current or future climates. If the *forward* climate projection is selected, the tool will partition the landscape into clusters representing, for each input point, areas where the future climate will be most similar to the current climate at that location. Hence, the forward projection can be used to identify areas where existing seed sources may be most resilient to the future climate.

If the *backward* climate projection is selected, the tool will partition the landscape into clusters representing areas where the current climate is most similar to the predicted future climate at each input point. The backward projection can be used to select areas for seed collections where populations may be resilient to the future climate at planned restoration sites.
Figure 3. Example output of the Cluster tool for four input points in the Mojave Desert. The display shows which areas of the landscape are most climatically similar to each input point. There is one cluster per point. This tool can be used to quickly visualize which parts of the landscape are most appropriate for planting each available seed source.

Compare distance values at points

The tools described above all output a raster layer with climate distance values (single and multipoint distance; Figs. 1, 2) or cluster identities (cluster tool; Fig. 3). Once this raster is loaded in the display, Climate Distance Mapper allows users to compare distance values (or cluster identities) at an additional set of locations. For example, if you used a restoration site as input to the single point tool, you can then identify the climate distance values at a set of seed source locations provided as additional points. In this way, the seed sources can be ranked in terms of their climate similarity to a restoration site.

When additional points are provided, Climate Distance Mapper will add these points to the map display and generate a pop-up label for each point. Hovering the mouse over a point will trigger the pop-up label to display, providing the climate distance value at that point. These values will be automatically updated if the user performs a new climate distance calculation.
Using Climate Distance Mapper

Getting started with the stand-alone desktop version

The following instructions pertain only to the stand-alone desktop version of Climate Distance Mapper. If using the online version, you may skip ahead to “Using the single point climate distance tool.”

Required software

To use Climate Distance Mapper as a standalone desktop application, you will need to have recent versions of R and RStudio installed on your computer. R can be downloaded from the Comprehensive R Archive Network (https://cran.r-project.org/). Detailed installation instructions are provided on the CRAN website. RStudio can be downloaded from the following link: https://www.rstudio.com/. Both programs are open-source and will run on a variety of operating systems.

Required R packages

Many advanced features of R require the installation of “packages” which make additional functions available. Climate Distance Mapper requires several packages to be installed beyond those available with the base installation of R.

The required packages include: shiny, shinyjs, leaflet, raster, plyr, and RColorBrewer, as well as any dependencies.

To check if these packages are installed and to load, paste the following into an open R console:

```r
library(shiny)
library(shinyjs)
library(leaflet)
library(raster)
library(plyr)
library(RColorBrewer)
```

If any of the packages are missing, you will receive an error message. To install, select Packages > Install package(s) from the menu bar at the top of the R console. You will be directed to choose a CRAN mirror before the list of available packages will appear. Select any packages you are missing from the list and click OK. Any required dependencies will install automatically with the packages.

Download the application package
Download the Climate Distance Mapper zip file to the location on your computer where you would like to store output from the application. Next, simply unzip the file so that a new folder called “Climate_Distance_Mapper” appears in your workspace. You will now be able to open Climate Distance Mapper from RStudio. Do not alter, rename, or move any of the content within the application folder.

**Opening Climate Distance Mapper from Rstudio**

Once RStudio has been successfully installed, open the program by double clicking the desktop icon, or by using your computer’s Start menu.

With RStudio open, go to **Session > Set Working Directory > Choose Directory** and then navigate to the “Climate_Distance_Mapper” folder on your computer. Set this folder as the working directory.
Next, go to File > Open File and select the file named “app.R” from the Climate Distance Mapper folder.

Next, when the app file opens, click the “Run App” option at the upper right of the RStudio editor.
An RStudio window will pop up with the Climate Distance Mapper. Although Climate Distance Mapper can be run from this RStudio window, downloading output files will require running the application from a web browser. To do so, select the “Open in Browser” option at the top of the RStudio window. You are now ready to use Climate Distance Mapper from your web browser.
**Using the single point climate distance tool**

Single point climate distance is defined as the multivariate climate distance from an input point to all other grid cells across the chosen spatial extent. If the input point is a seed collection, the output indicates climatically similar areas to which the seeds may be well adapted. If the input point is a restoration site, the output indicates climatically similar areas from which suitable seeds could be collected.

To use the tool, first choose from among the available spatial extents. Options include the Mojave Desert, Sonoran Desert, Colorado Plateau, or Southern Great Basin ecoregions, as well as the full extent (combination of all ecoregions).

Next, select a time period for the calculations. Options include current climate (1981-2010 normal period), forward, or backward projection (2040-2070 predicted climate). For descriptions of these options, see the section *Single Point Tools* above.

Finally, select an input point from which climate distances will be calculated. Climate Distance Mapper provides three options for choosing input coordinates: coordinates can be entered into the X and Y fields directly, a point can be set by clicking the map, or a csv file containing X and Y coordinates can be uploaded. The CSV File should contain two columns labelled “X” and “Y” as follows:

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>-118.063</td>
<td>34.84988</td>
</tr>
</tbody>
</table>
If setting a point by clicking on the zoomable map, be sure to click the checkbox labelled “Set points by clicking map.” Previously clicked points may be cleared by clicking the “Clear points” button. All coordinates should be in the WGS 1984 projection (EPSG 4326).

Once the input point is added, make sure that “Distance values” are selected under “Output raster type”, and click **Calculate**. The output file will appear in the map display after a few moments.
Below, climate distances have been calculated from a single input point (the blue marker) in current climate. The layer can be toggled on or off by clicking the “Raster output” checkbox.

To download the results as a projected GeoTiff raster file, click the “Download raster file” button and navigate to the location on your computer where you would like to save the file. The downloaded raster file will contain original climate distance values rather than the ordinal classes used in the map display. Raster layers from Climate Distance Mapper can be opened in most popular GIS software packages, including ArcGIS, QGIS, and R.

Forward projection

The Single Point Distance tool can be used to perform a forward climate projection. This is defined as the climate distance from the current climate at the input point forward to the future climate across the surrounding landscape. The forward projection illustrates where to plant material from the input point for future climate resilience. Select “Forward 2050” under the Time Period options to perform this type of calculation.
In the forward projection shown below, we have calculated climate distances from the blue marker, which is in current climate, forward to the surrounding Mojave Desert landscape in future climate. Here, the future climate has shifted from the marker, such that the lowest climate distance values are now away from the point. These areas have a future climate that most resembles the current climate at the marker.
**Backward projection**

The Single Point Distance tool can also be used to perform a backward climate projection. In this calculation, the climate distance from the future climate at an input point backwards to the current climate across the surrounding landscape is displayed. This type of distance indicates where to collect plant material that will be resilient to the future climate at an input site.

In the backward projection shown above, blue areas with low climate distances have a climate that most resembles the predicted future climate at the input point (blue marker). Hence, these areas could serve as the basis for seed collections that may be resilient to the future climate at the input point.
**Constraining climate distances**

Optionally, Climate Distance Mapper can constrain output to a specified level of climate similarity. For example, a climate distance of 0.3 means that two sites are about 70% similar in climate. With the **Constrain output** dropdown menu, you can control how large of a climate distance is included in the results.

For example, you can constrain the output to show only areas that are at least 70% similar to the input point. In the graphic below, all of the climate distances are \( \leq 0.3 \), meaning that only areas with 70% climate similarity to the input point are displayed.
Climate distances with multiple points

Multipoint climate distance is defined as the minimum climate distance from grid cells to one of multiple input points. For each grid cell in the chosen region, the climate distance to each input point is calculated, and the minimum distance value is retained in the final raster. This type of calculation displays the degree to which a set of input points represents the range of variability in climate within the chosen spatial extent.

To calculate the multipoint climate distance, simply use the menu on the left to enter multiple input points. There is no need to specify a “multipoint” calculation – Climate Distance Mapper will calculate the multipoint distance anytime there are multiple input points and “Distance values” are selected under Output Options.

Multiple points can be supplied by clicking on the zoomable map display (an input point will be added with each click to the map), or by uploading a csv file with “X” and “Y” columns containing the coordinates in the WGS 1984 projection (latitude and longitude values). All points must be contained within the selected region.
In the display above, multipoint climate distance has been calculated for four input points. Here, the blue areas with low climate distances are climatically similar to an input point, while yellow to red areas with larger climate distances are climatically dissimilar from all input points.

**Forward projection**

The Multipoint tool can make a forward climate projection. This is defined as the minimum climate distance between the current climate at any input point and the future climate at grid cells across the chosen region. The forward projection is useful to display how well the input points represent the future climate in the spatial extent, i.e., which parts of the landscape will be most similar to the input points in the future.

To select this option, make sure the “Forward 2050” option is selected under Time Period and that “Distance Values” is selected for Output Options. Click the calculate button to perform the calculations. The output file will display in a few moments.

In the display above, a forward projection with the Multipoint distance tool has been calculated. The future climate is more dissimilar from the input points than the current climate of the previous figure, particularly in the Western Mojave.
**Backward projection**

The Multipoint tool can also make a backward climate projection. This is defined as the minimum climate distance between the future climate at any input point and the current climate at grid cells across the chosen region. The backward projection is useful to display areas of the landscape that are currently most similar to the future climate at the input points, which could help direct seed collections for future climate resilience.

To select this option, make sure the “Backward 2050” option is selected under Time Period and that “Distance Values” are selected for Output Options. Click the calculate button to perform the calculations. The output raster file will display in a few moments.

In the display above, a backward projection with the multipoint distance tool has been calculated. Here, only a small area of the current climate in the Northeast Mojave is similar to the future climate predicted at these input points.
Using the Cluster tool

The Cluster tool is used to partition the landscape into areas that are most climatically similar to each input point (one cluster per input point). The clusters are determined by assigning each grid cell to the input point from which it has the lowest climate distance. Use this tool to quickly determine which parts of the landscape are most climatically similar to each input point.

To use the Cluster tool, first select a region within which to perform calculations, and a time period for the analysis. Next, supply input points by clicking on the zoomable map display (an input point will be added with each click to the map), or by uploading a csv file with “X” and “Y” columns containing the coordinates in the WGS 1984 projection. All points must be within the chosen region.

Once the input points are loaded, make sure that “Clusters” is selected under Output Options, and click the “Calculate” button.

Above, a climate partition with the cluster tool is displayed. Hovering the mouse over a marker will display its cluster id (IDs are the order of points as they were input, and the numbers correspond to the colors in the map legend).
Forward projection

The Cluster Tool can make a forward climate projection. The forward projection is useful to display areas where the future climate will be most similar to the current climate at each input point.

To select this option, make sure the “Forward 2050” option is selected under Time Period and that “Clusters” is selected for Output Options. Click the calculate button to perform the calculations. The output file will display in a few moments.

Note that with the forward projection option, markers may no longer be geographically located within their assigned clusters, due to the shifting of climate through space. Hovering the mouse over a marker on the map display will cause a label to pop up, revealing the cluster number for the marker, which can be matched with the colors in the map legend.

In the display above, climate clusters have been identified where the future climate is most similar to each input point. Cluster 1 (red) no longer contains its marker in the Western Mojave because the future climate has shifted westward. The area contained within Cluster 2 (yellow) has greatly expanded, indicating that much of the future climate is more similar to this point.
**Backward projection**

The Cluster Tool can make a backward climate projection. The backward projection is useful to display areas where the current climate is most similar to the predicted future climate at each input point.

To select this option, make sure the “Backward 2050” option is selected under Time Period and that “Clusters” is selected for Output Options. Click the calculate button to perform the calculations. The output file will display in a few moments.

Note that with the backward projection option, markers may no longer be geographically located within their assigned clusters, due to the shifting of climate through space. Hovering the mouse over a marker on the map display will cause a label to pop up, revealing the cluster number for the marker, which can be matched with the colors in the map legend.

In the display above, climate clusters have been identified where the current climate is most similar to the future climate at each input point. Here, the vast majority of the region is most similar to the future climate at only 2 of the markers.
Clusters with constrained climate distances

Optionally, Climate Distance Mapper allows users to constrain output such that only areas below a certain climate distance value are included in the results. This feature is particularly useful with the Cluster option, as the area within each cluster can be restricted to a given climate similarity level with each input point.

In the following example, by selecting “70% similar climate” from the Constrain output menu, only areas that are at least 70% similar to each input point are included in the climate clusters.

In the above display, the climate has been partitioned into clusters that are at least 70% similar to each input point.
Comparing distances at points

This tool will extract climate distance values or cluster identities to an additional set of point locations provided by the user in a csv file. Raster output from one of the other tools (Single or Multipoint Distance, or Cluster tool) must first be present in the map display. Typically, the points used to compare climate distances will be different from the input points used to calculate climate distances or clusters. For example, if the input point was a restoration site, the user may wish to extract climate distance values at a number of additional seed source locations to rank their suitability for that restoration site.

To use this tool, use the file input option to load a csv file with coordinates (datum: WGS 84). This file should have two columns labelled “X” and “Y” as follows:

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>-118.063</td>
<td>34.84988</td>
</tr>
</tbody>
</table>

You may upload an unlimited number of points. As soon as the file is loaded, Climate Distance Mapper will add these points to the display. Hovering the mouse over a point will create a pop-up label with the climate distance value at that location. These values will update automatically if a new climate distance calculation is performed.
Tool citation


Contacts

Questions and comments regarding Climate Distance Mapper can be directed to dshryock@usgs.gov.

References


