

## Guide to using downscaled climate data

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Feb. 2023

### Content

This guide covers the following tasks for working with the WICCI downscaled climate data:

1. Formats for the downscaled data and details on attributes.
2. Extracting cloud raster data (CRF) from downloaded zip file.
3. Opening and viewing the CRF file in ArcGIS Pro.
4. Conducting simple analysis with a CRF file.
5. Conducting more advanced analysis with the CRF data.

*Note: This guide assumes basic knowledge of ESRI's ArcGIS Pro software and is not intended for those new to GIS software. ArcGIS Pro version 2.9.5 is used in this guide.*

### Overview

This dataset provides access to the downscaled climate modeling data used by the [WICCI](#) team for their [2021 Assessment Report](#) in a GIS-friendly raster format for users not familiar with raw modeled climate data. It allows users to replicate maps and analysis in the report and conduct more site-specific and theme-specific analysis for research, climate adaptation planning, hazard assessment, and other uses.

More information about the raw modeled climate data is available [here](#). Access to the original data and a review of the final product was provided by the WICCI [Climate Working Group](#).

In brief, this data is an aggregation of 22-24 global climate models (GCMs) that were statistically downscaled to a 0.1 x 0.1 degree (approximately 6 x 6 miles in Wisconsin) for two climate scenarios, RCP 4.5 and RCP 8.5 ([more details here](#)). In addition, there is historic climate data covering 1981-2010 for comparison. The aggregation was conducted monthly across 20-year time spans: 2021-2040, 2041-2060, 2061-2080, and 2081-2100. For each there are several temperature and precipitation metrics as detailed below. The Python

code used to generate these files is available in a GitHub repository (<https://github.com/TheGeographer/DownscaledClimateData>) if you'd like to review or modify the code.

These temperature and precipitation metrics allow for comparison between models, comparisons of future conditions to historic ones, and trend analysis through time.

## 1. File formats and attributes

The results of the aggregation, while easier to use than the raw data, are still fairly complex. They include multiple variables for multiple time frames with a raster data set for each. As such, they are stored in “multidimensional” or “mesh” raster data formats that may be unfamiliar to GIS practitioners. Both ESRI (“[multidimensional](#)” data) and QGIS (“[mesh](#)” data) have introductions and documentation for these types of data.

To allow for use within both ESRI and open source GIS packages, e.g. QGIS, the data is provided in two formats:

1. ESRI's proprietary [cloud raster format](#) (CRF): a format optimized for multidimensional raster data. Multiple rasters for multiple time frames are stored in a folder similar to a file geodatabase. These folders are zip compressed for download on the [GeoData@Wisconsin website](#).
2. [NetCDF](#): an open, scientific format for storing a variety of raster and vector data. These files are also zip compressed for download on GeoData@Wisconsin.

For both, the file names describe the data within with the name starting with the type of data – temperature or precipitation, the climate model, years covered, and temporal step. For example,

*temp\_rcp45\_2021-2040\_monthly.crf*

would hold temperature metrics using the RCP 4.5 climate scenario aggregated across the twenty years from 2021 to 2040 summarized monthly.

### *Attributes*

Each type of file – temperature and precipitation – include estimated metrics that are similar to those used in the WICCI 2021 Assessment Report and others useful for assessing potential hazards.

For temperature:

- **tmax\_mean** = mean daily maximum temperature per month
- **tmax\_std** = standard deviation of daily maximum temperature (across all climate model monthly averages)
- **tmax\_gt90** = number of days per month where the maximum temperature is above 90 F
- **tmax\_gt95** = number of days per month where the maximum temperature is above 95 F
- **tmax\_gt100** = number of days per month where the maximum temperature is above 100 F
- **tmax\_comfort** = number of days per month where the maximum temperature is between 70 and 85 F
- **tmin\_mean** = mean daily minimum temperature per month
- **tmin\_std** = standard deviation of daily minimum temperature (across all climate model monthly averages)
- **tmin\_gt70** = number of days per month where the minimum temperature is above 70 F
- **tmin\_lt32** = number of days per month where the minimum temperature is below 32 F
- **tmin\_lt0** = number of days per month where the minimum temperature is below 0 F

For precipitation:

- **prcp\_total** = total monthly precipitation (in inches)
- **prcp\_std** = standard deviation of total monthly precipitation (across all climate model monthly averages)
- **prcp\_gt1** = number of days per month where precipitation exceeds 1 inch
- **prcp\_gt2** = number of days per month where precipitation exceeds 2 inches
- **prcp\_gt3** = number of days per month where precipitation exceeds 3 inches
- **prcp\_norain** = number of days per month with no precipitation

Please see instructions below about how to view and analyze these variables.

## 2. Extracting CRF files

The zipped CRF files need to be extracted or decompressed before use. In Windows, the built-in extraction tool will, by default, create an additional folder (so, a folder in a folder) that should be removed before use. Like a file geodatabase, the files within this CRF folder are not meant to be modified and the folder should be copied and moved as a whole to maintain its integrity.

## 3. Viewing CRF files in ArcGIS Pro

After opening a blank project in ArcGIS Pro, CRF files are added as a layer to your map either through the **Add Data** button or by drag-and-drop from the Catalog view.

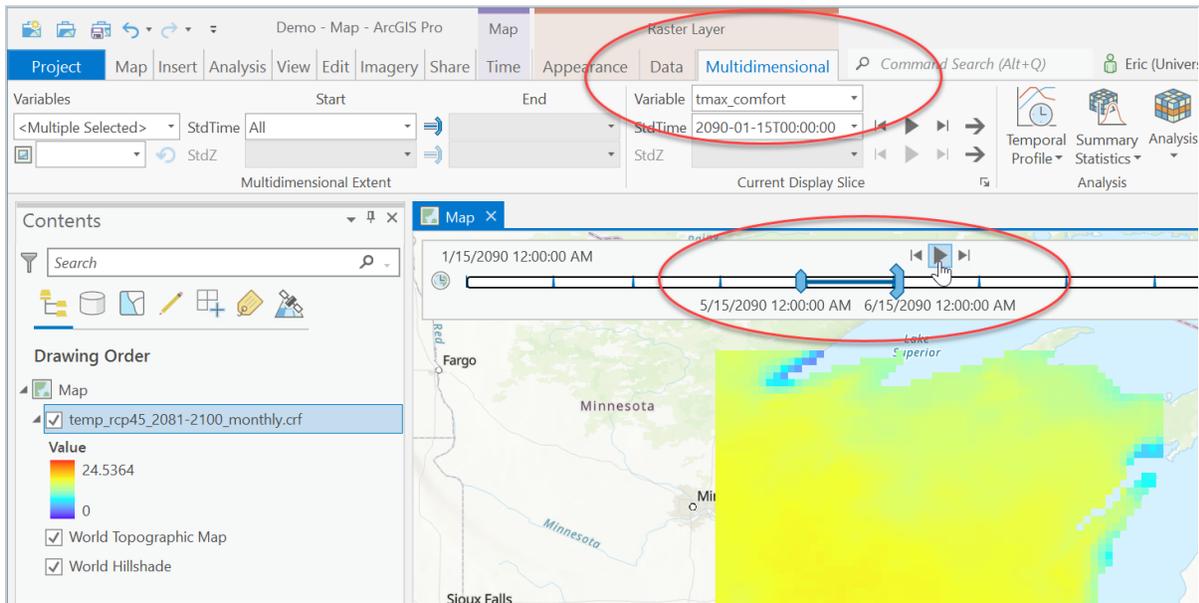
*Note: Don't use the **Add Data Multidimensional Raster Data** option (that will work for the netCDF file, though). In the examples, we'll use the "temp\_rcp45\_2081-2100\_monthly.crf" file.*

You'll notice several differences after this layer is added to the map.

First, the **Time Slider** is enabled. Since the time slider doesn't recognize aggregate time ranges, the dates will show up as the middle of the 20-year period and the middle of the month. So, for our "temp\_rcp45\_2081-2100\_monthly.crf" file, there will be twelve time frames starting at 1/15/2090 and running to 12/15/2090.

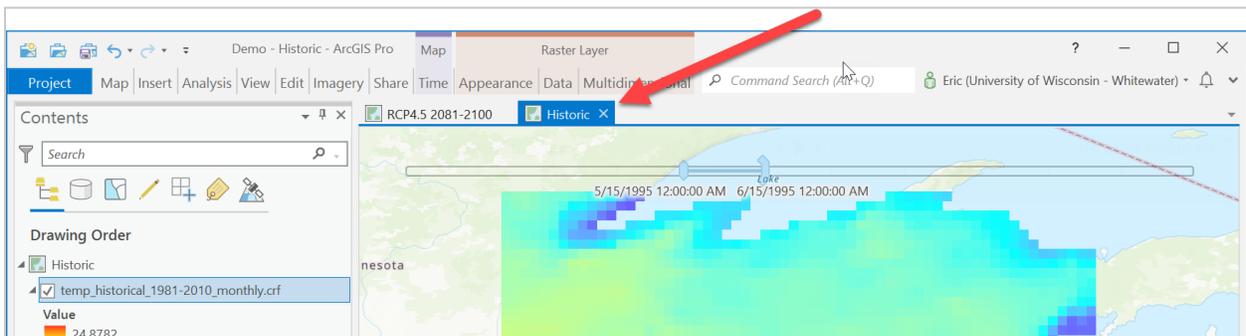
One of the advantages of the CRF file is that the legend takes into account the range of values across each time slice. Click the time slider "play" button to view the changing temperature metric across the twelve months (the default attribute for this dataset is *tmax\_comfort*).

Second, you'll see a new ribbon menu for the multidimensional raster layer which includes three ribbons specific to multidimensional data. The **Multidimensional** ribbon is shown below and is used to switch which variable is currently displayed, e.g. *tmax\_comfort*. Use the **Variable** option to switch between the temperature metrics in this data set.



When loading more than one CRF file from different time periods, it's recommended to open them in separate maps to retain useful settings in the **Time Slider**.

For example, to compare historic temperatures to this 2081-2100 projection, you'd add a new map and load the historic data within it:



#### 4. Conducting simple analysis with a CRF file

Another useful visualization of this time series data is to use the **Temporal profile chart** tool. It allows you to click on a location to see the annual change in one or more metrics.

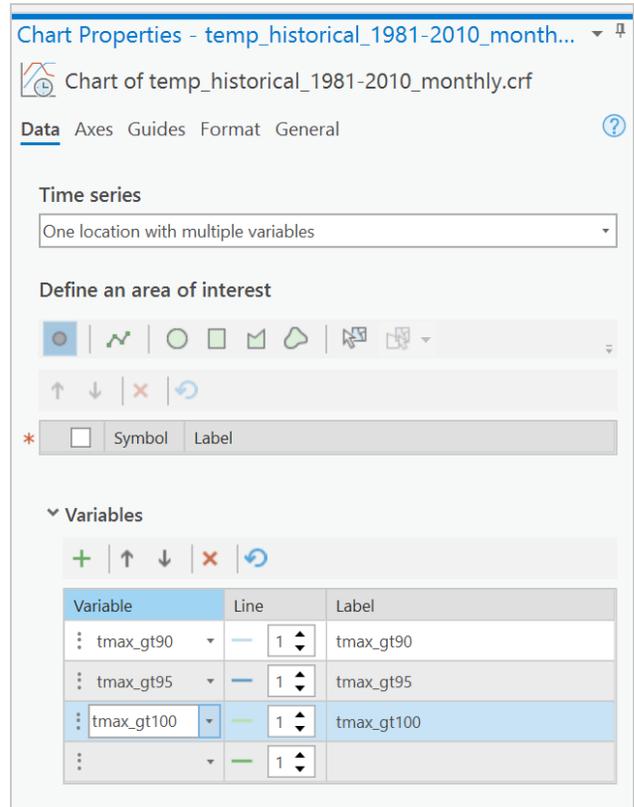
For example, we could compare the number of extreme temperature days that Janesville will experience in the 2081-2100 period in the RCP 4.5 scenario compared to historic data.

First, open the “Historic” map, click on the historical CRF file (to show the ribbons for this layer), and under the **Appearance** ribbon, change the transparency to 30% or so. This will allow us to see through the historical projection to the basemap to find Janesville.

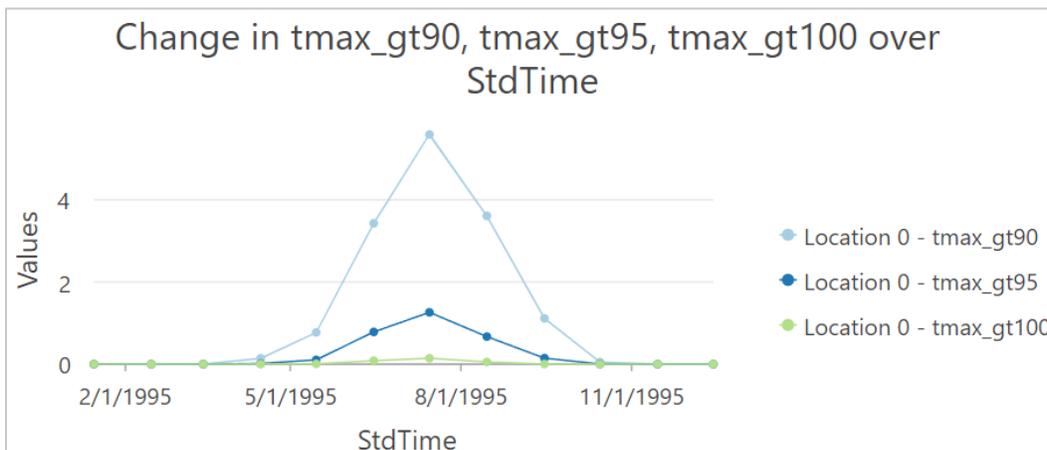
Next, open the Multidimensional ribbon, and click on the **Temporal Profile** tool. Make the following settings in the chart tool:

1. Switch **Time series** to **One location with multiple variables**
2. Under **Variables**, add tmax\_gt90, tmax\_gt95, and tmax\_gt100.
3. Change **Define an area of interest** to a point (far left option)

Finally, click on Janesville with your cursor (should be a red circle).

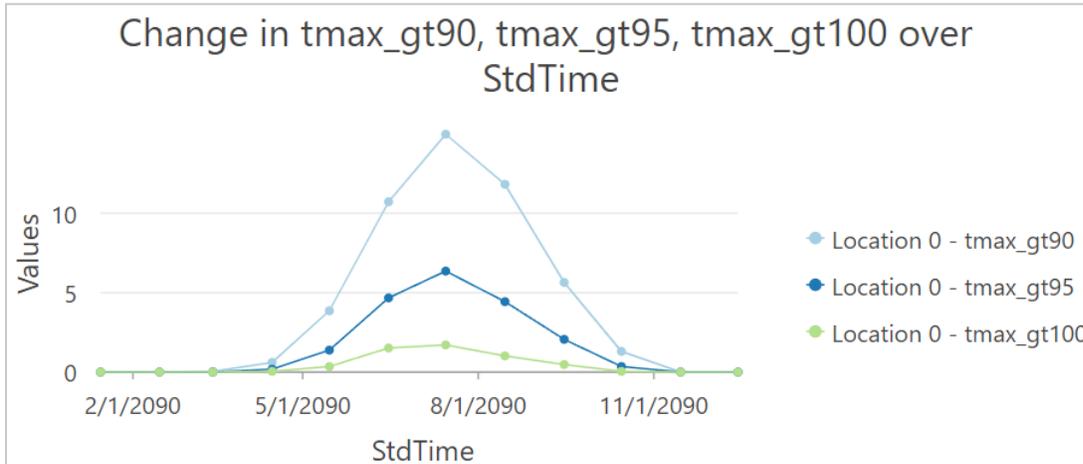


In your project, you’ll get a new pane showing the results of the time series, a month-by-month estimate of the number of days that exceed these temperature thresholds:



So, in July, we'd expect around 5.6 days of the month to be warmer than 90 F.

Next, switch to the RCP4.5 map and follow the same procedure for the 2081-2100 model. You should get something like the following:



In the late 21st century if the RCP4.5 scenario holds, we're likely to see 15.0 days above 90 F in Janesville, 6.4 days above 95 F, and 1.7 above 100 F. That's a 12x increase in the chance of 100 F days! Note also that the width of the distribution has changed with a longer summer season of higher temperatures. These results could help Janesville assess the need for adaptation measures for heat waves.

While not possible in ArcGIS Pro, a chart combining the two results can be produced by exporting the data for each as a table and importing into Excel or Google Spreadsheets.

## 5. Conducting more advanced analysis with the CRF data

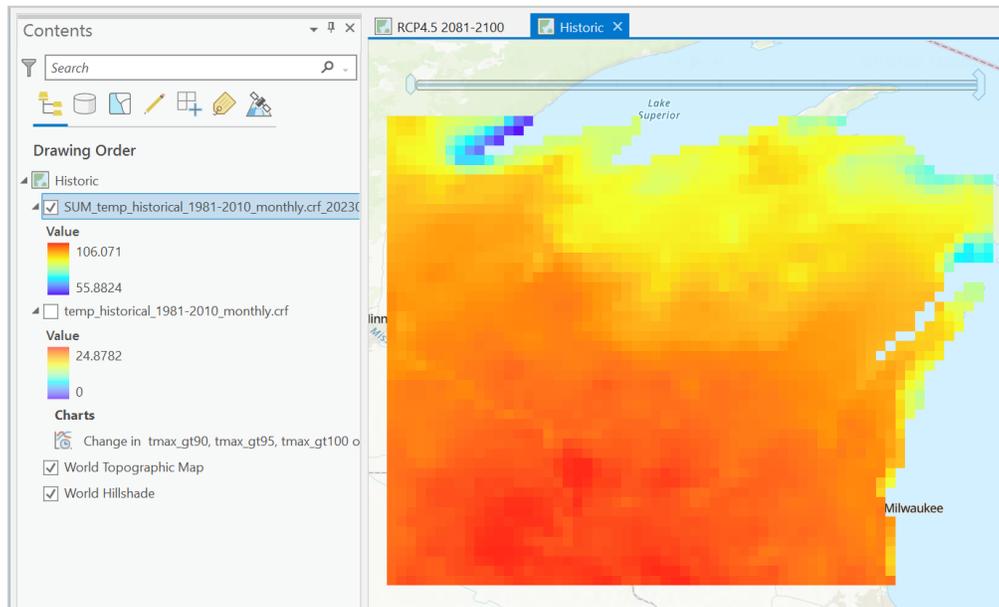
While a full discussion of all the ways that this data can be analyzed is beyond the scope of this document, let's look at two more – slightly more advanced – ways to use it. First, let's calculate the change in the annual number of “comfortable” days across the state.

### *Calculating a temporal change to a climate metric*

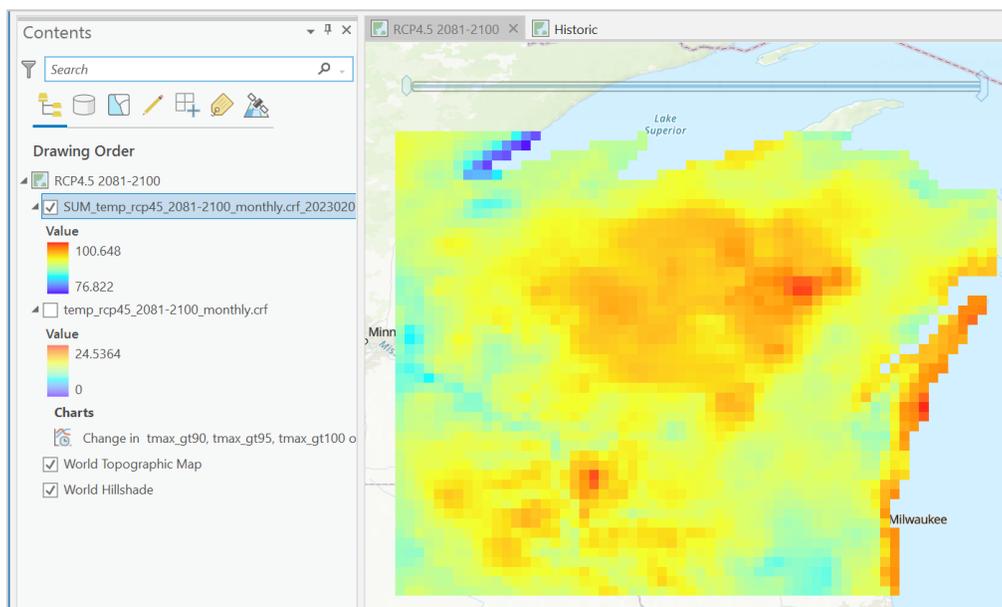
First, open the historic map and highlight the “temp\_historical\_1981-2010\_monthly.crf” file to enable the Multidimensional ribbon. Switch your variable to *tmax\_comfort* (number of days per month where the maximum temperature is between 70 and 85 F) and then click on **Summary Statistics** and choose **Sum**. This tool will “flatten” all twelve time frames and add up the values for each time slice to yield a new raster layer with the annual total.

*Note: You may need to disable the **Time Slider** and refresh your map to see this new layer (and you may need to reset your Symbology for this layer to see the correct and full range of values).*

Here's our annual map for historical comfort days (70 to 85 F):

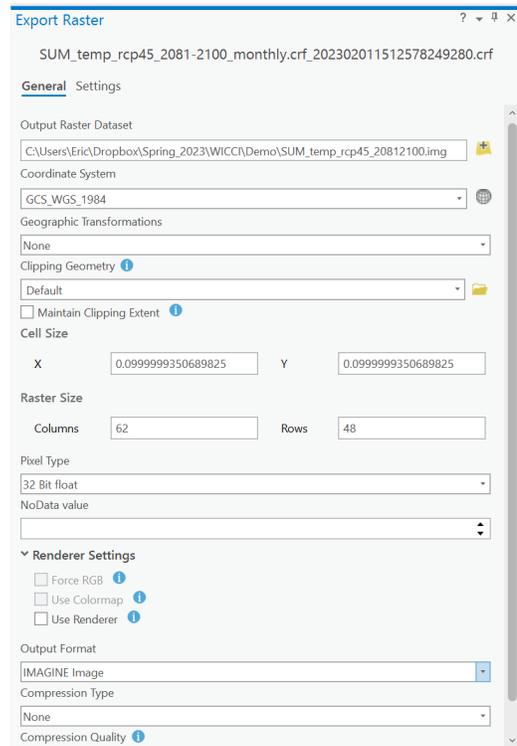


Doing the same for the RCP4.5 scenario for 2081-2100 yields a different spatial pattern:

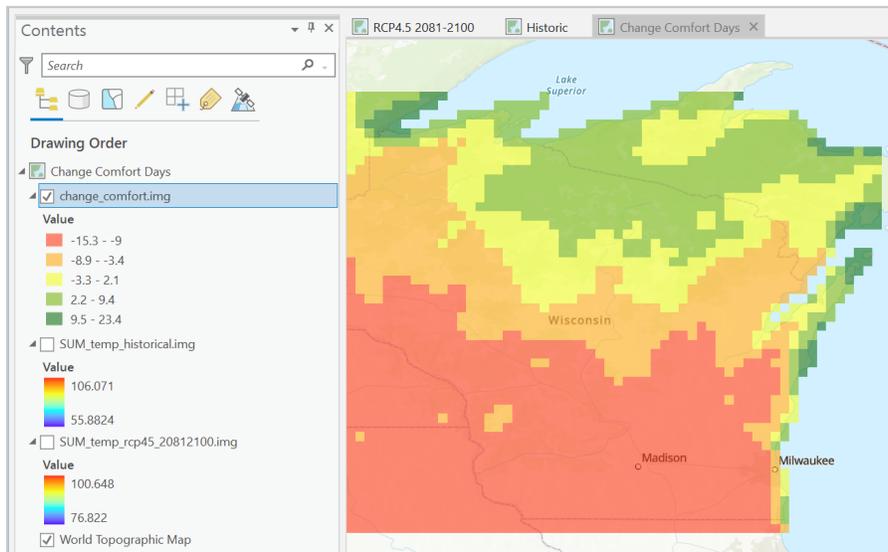


Northern Wisconsin and the Lake Michigan shoreline will see the highest number of comfortable days annually.

Finally, let's calculate the difference or change from the two time periods. For our "traditional" raster functions, ArcGIS Pro works better with non-CRF files, so let's first export our SUM datasets to ERDAS imagine files. Right-click on each, and choose **Data Export Raster** and use similar settings to export to an \*.img raster file for each.



Finally, use the **Raster Calculator** tool to subtract the historical count from the RCP4.5 scenario to yield our change raster:



Much of the southern portion of the state is projected to lose between one and two weeks of comfortable weather annually while some lake shore regions are expected to gain up to

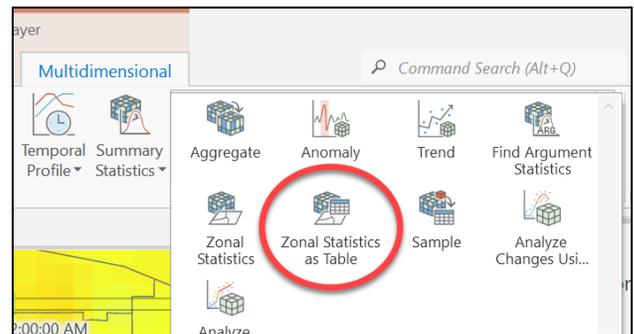
three weeks. *Where do you plan on building your summer cabin?*

### *Calculating area summaries of climate variables*

For our final “act,” we’ll summarize temperature data for a set of polygons – counties in this example. Note that the regions used could be any arbitrary set of polygons, e.g. watershed, assembly districts, etc., that cover Wisconsin.

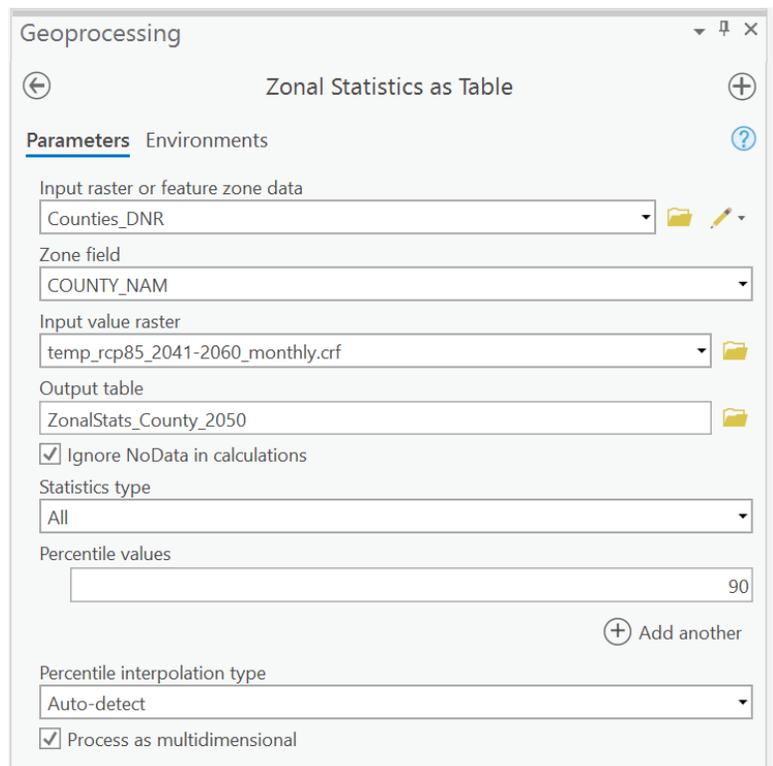
First, we’ll add the “*temp\_rcp45\_2041-2060\_monthly.crf*” to our map to look at county summaries for the 2041-2060 period. Next, we’ll add our polygon boundary file, a

Wisconsin county file (from the [Wisconsin DNR Open Data Portal](#)). Next, click on the CRF file to activate the Multidimensional tool ribbon and under the Analysis tool dropdown, choose **Zonal Statistics as Table**. This tool will calculate basic descriptive statistics for each county for each variable and time period in our temperature CRF file.



Here’s what your tool parameters will look like when setting up this tool:

Note that you’ll want to be careful about the **Zone field** that you choose. Here, we’re using the name of the county here, but if you needed to do table joins later, the FIPS code would be a better choice. Note also that the **Process as multidimensional** option is checked.

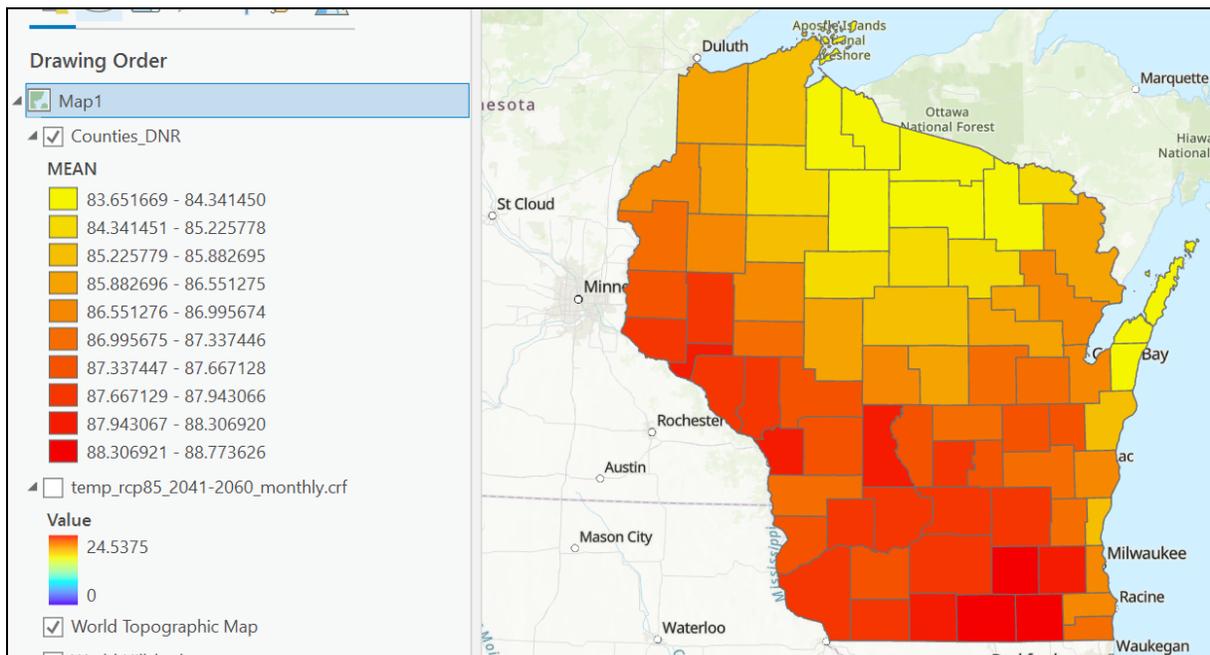


This tool will only generate a table (not a spatial layer) that will show up in the Contents pane. Right-clicking and choosing open will yield the detailed table to review:

	OBJECTID *	COUNTY_NAM	ZONE_CODE	COUNT	AREA	Variable	Dimensions	Standard Time	MIN	MAX	RANGE	MEAN	STD	S
3761	3761	Marathon	17	53	0.529999	tmax_mean	StdTime	5/15/2050	72.281754	74.1903	1.908546	73.22358	0.404762	3
3762	3762	Monroe	18	24	0.24	tmax_mean	StdTime	5/15/2050	74.824715	75.841789	1.017075	75.276419	0.305529	1
3763	3763	Pepin	19	8	0.08	tmax_mean	StdTime	5/15/2050	75.47583	76.110359	0.634529	75.739326	0.195046	1
3764	3764	Crawford	20	18	0.18	tmax_mean	StdTime	5/15/2050	74.659088	76.181511	1.522423	75.085292	0.367185	1
3765	3765	Dunn	21	30	0.3	tmax_mean	StdTime	5/15/2050	74.133644	76.171272	2.037628	75.19223	0.628803	2
3766	3766	Eau Claire	22	21	0.21	tmax_mean	StdTime	5/15/2050	73.735275	75.659279	1.924004	74.70564	0.529136	1
3767	3767	Chippewa	23	28	0.28	tmax_mean	StdTime	5/15/2050	73.24868	74.946594	1.697914	74.354371	0.410751	2

This table can be exported to Excel for further non-GIS analysis or used to create a join back to our original table to map one or more variables. To create the join and map, we'll need to first select a subset of this table to get a one-to-one cardinality join. The table contains every combination of variables in our CRF file and date, so in this case, 11 variables x 12 months x 72 counties yields 9,504 rows.

Here, we've used **Select by attribute** to select only the **tmax\_mean** variable for July. We then exported the data to a standalone table and joined it back to our county file. Symbolizing on the mean temperature yields this map:



Permutations of this workflow can be used to summarize by a particular set of months, seasons, or the whole year.<sup>1</sup>

Hopefully, these examples are sufficient to get you started on using these downscaled data for your climate and adaptation projects. If you do have additional questions, reach out and let us know.

### **Feedback**

If you have any comments or suggestions for improving this guide (or the data used within), please contact Dr. Eric Compas at [compase@uww.edu](mailto:compase@uww.edu) or 262-472-5126.

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<sup>1</sup> Note that averaging across multiple months of slightly different duration would end up slightly overweighting shorter months. While it would only lead to a minor difference in the result, a precise calculation would use a weighted average.