# U.S. DOT CMIP Climate Data Processing Tool
# **User's Guide**

March 2016

Prepared by ICF International for the U.S. Department of Transportation Center for Climate Change and Environmental Forecasting under *The Gulf Coast Study, Phase 2, Impacts of Climate Change and Variability on Transportation Systems and Infrastructure*.

# CONTENTS

# Acronyms

| | |
|---|---|
| BCCA | Bias-Correction Constructed Analogues |
| CMIP | Coupled Model Intercomparison Project |
| CMIP3 | Coupled Model Intercomparison Project phase 2 |
| CMIP5 | Coupled Model Intercomparison Project phase 5 |
| DCHP | Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections |
| IPCC | Intergovernmental Panel on Climate Change |
| NLDAS | North American Land-Data Assimilation System |
| SRES | Special Report on Emissions Scenarios |
| U.S. DOT | United States Department of Transportation |
| WCRP | World Climate Research Programme |

# Introduction

The **CMIP Climate Data Processing Tool consists of two different Excel files** – one to be applied if you are using CMIP3 data and one to be applied if you are using CMIP5 data. See the box on page 9 for information on the differences between the two datasets. Unless otherwise specified, the term "CMIP Climate Data Processing Tool" in this document refers to both versions.

The purpose of the U.S. DOT CMIP Climate Data Processing Tool is to process readily available downscaled climate data at the local level into relevant statistics for transportation planners. This tool is not appropriate for geographical areas significantly larger than 225 square miles.

This tool works with data from the U.S. Bureau of Reclamation's Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections (DCHP) website, available at http://gdo-dcp.ucllnl.org/downscaled_cmip_projections. This website houses climate model data from phase 3 (CMIP3) and phase 5 (CMIP5) of the World Climate Research Programme's (WCRP) Coupled Model Intercomparison Project (CMIP).

Use of the tool requires three primary steps:

1. **Downloading Data** – Determining the appropriate climate data to download from the DCHP website, including location, models, and emissions scenario(s)
2. **Processing Data** – Using the appropriate CMIP Climate Data Processing Tool Excel file to process data from the DCHP website into specific temperature and precipitation variables
3. **Interpreting Data** – Reviewing the results and properly applying them to decision-making

This User's Guide provides instructions within each of the three main steps.

Note: While using the tool, be careful not to add/remove columns or rows. Many areas of the tool have not been "protected" for purposes of functionality and transparency, but interacting with the sheets outside of instructed use may prevent the tool from working properly.

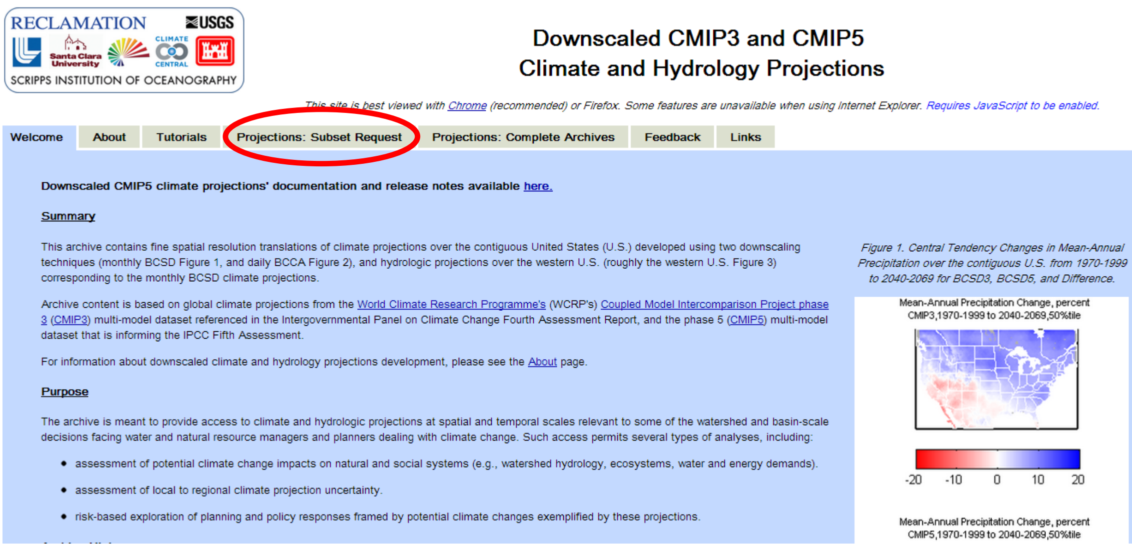
# 1. Downloading Data

## 1.1 Requesting Data

Note: The DCHP website has its own list of numbered steps to follow when downloading data. These instructions reference those step numbers (e.g., Step 1.1 through Step 3.10).

1. Go to: http://gdo-dcp.ucllnl.org/downscaled_cmip_projections. *The site is best viewed in Chrome or Firefox. You may experience some issues when using Internet Explorer.*

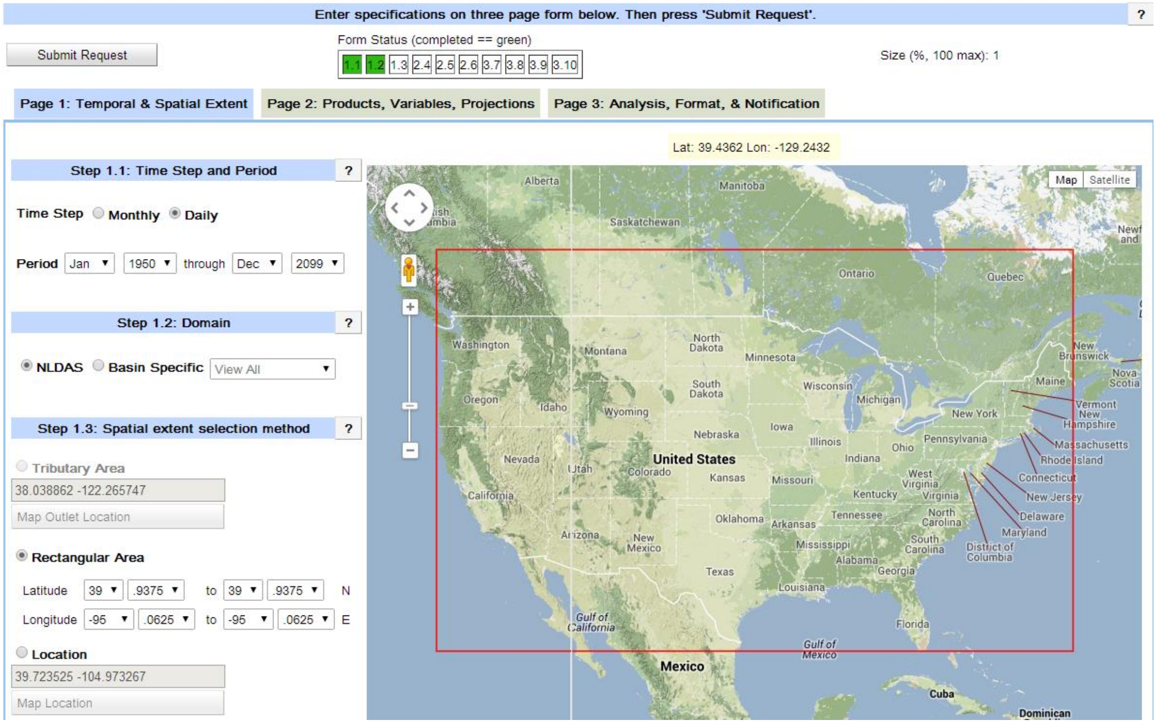
2. Click on the **"Projections: Subset Request"** tab.



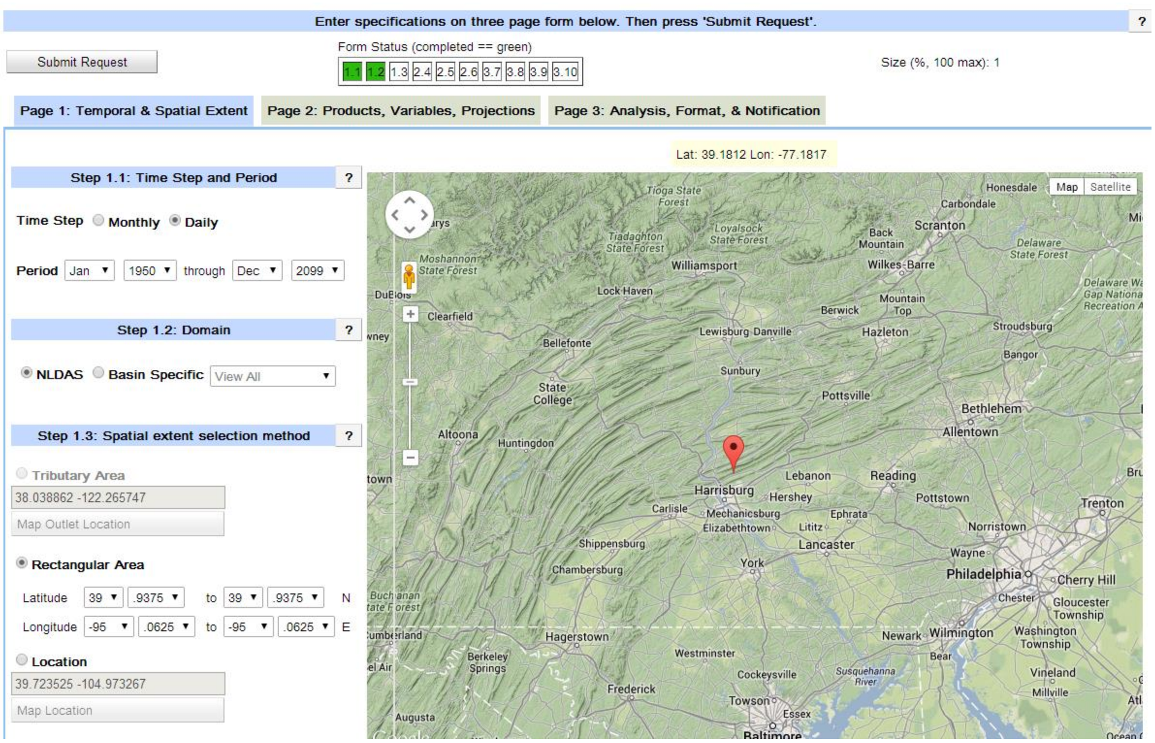

3. **Time Step and Period (Step 1.1)**
   a. Select **Daily**
   b. Select the full time period, **January 1950** through **December 2099**

4. **Domain (Step 1.2)**
   a. Select **NLDAS** (referring to North American Land-Data Assimilation System)

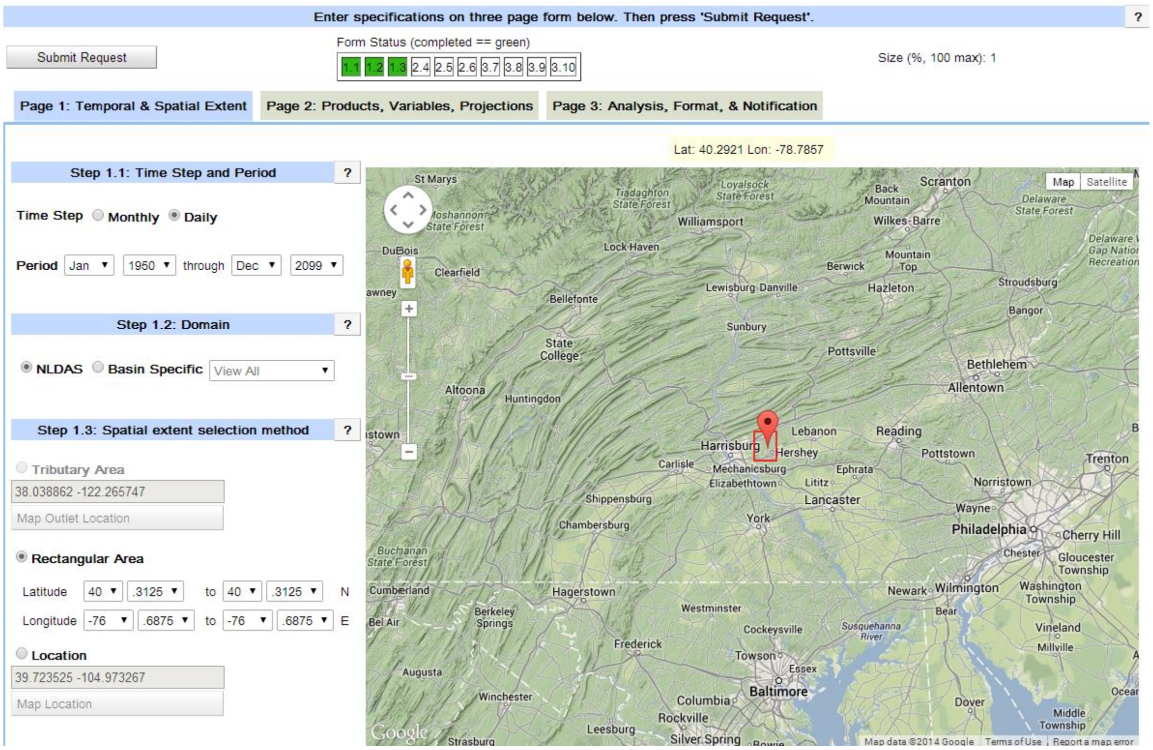
5. **Spatial extent selection method (Step 1.3)**



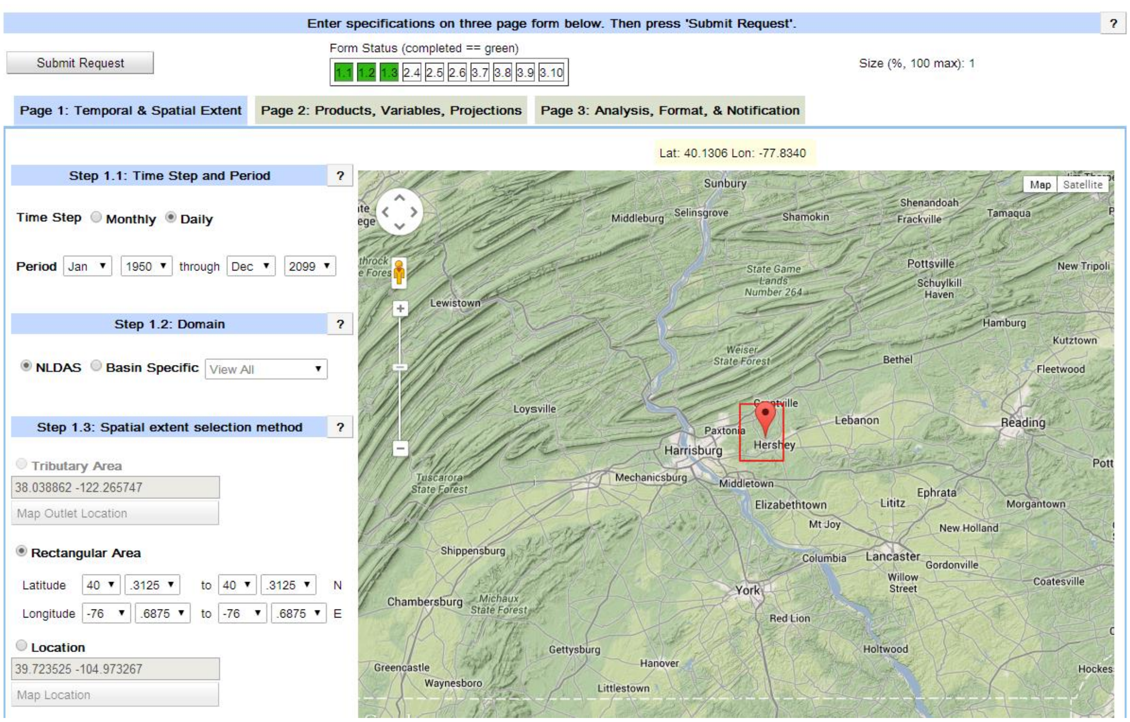

a. Using the zoom buttons in the top left corner of the map or your mouse's scroll button, zoom in and click your area of interest.



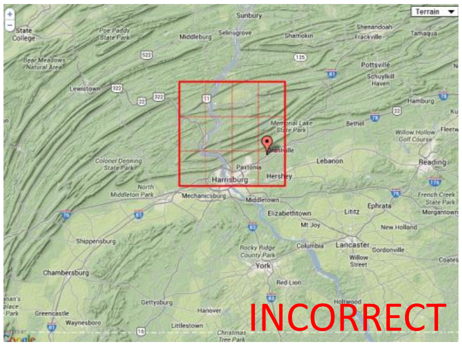
b. Click on the red marker and drag it over your area of interest. Do not drag out the box too much, as you only want to get information for one grid (each is 1/8 degree latitude by 1/8 degree longitude, or approximately 12 km by 12 km). See below. ***Be careful not to select a grid that is predominantly over water.***

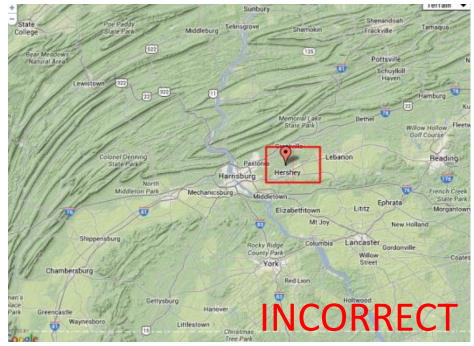


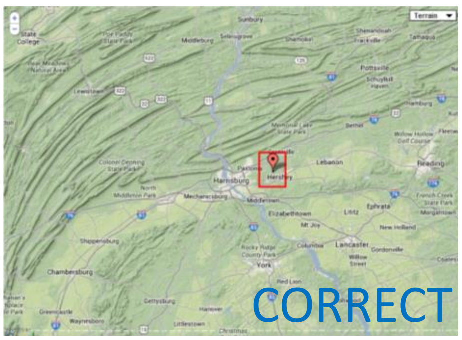

c. Confirm that one red grid cell has been selected



***Do not select more than one grid cell at a time***. *The DCHP website cannot generate daily climate information for more than one grid cell at a time in an Excel-compatible format. If you do, simply click again on your area of interest and drag the box again to cover a smaller area. Later in this process, you will have the opportunity to request data for up to three additional nearby grid cells.*




**Helpful Hint**: Keep track of the location you select! Perhaps take a screen shot of the map so that you can easily refer back to the location of the projections.

**Box: Choosing Grid Cells Over Water**

Be careful not to select a grid that is predominantly over water. Data may not be available for these grids, and the tool will generate an error when it tries to perform its calculations.

6. Click on the second tab at the top of the form, **Page 2: Products, Variables, Projections**.

7. **Select Projection Sets (Step 2.4)**
    a. Select either **BCCAv2-CMIP3-Climate-daily** or **BCCAv2-CMIP5-Climate-daily**, corresponding to CMIP3 and CMIP5 data, respectively. See the text box below for information on how to decide whether you want to use CMIP3 or CMIP5. The page will then show further steps to take.

**Box: Choosing between CMIP3 and CMIP5**

CMIP5, released in May 2013, is a more recent version than CMIP3. Whereas CMIP3 was used for the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) and uses the Special Report on Emissions Scenarios (SRES) family of emissions scenarios (B1, A1B, and A2), CMIP5 has been used for the IPCC Fifth Assessment Report (AR5). AR5 contains new emissions scenarios called Representative Concentration Pathways (RCPs), which are identified by their approximate total radiative forcing (watts per meter squared) in the year 2100 relative to 1750 and reflect a narrower range of potential emissions trajectories than AR4.

The climate science community has not yet determined whether CMIP5 is a more reliable source of climate projections than CMIP3 projections, largely because this more recent version has not been tested as thoroughly as CMIP3 has. Therefore, the World Climate Research Programme (WCRP) advises that CMIP5 projections should not replace existing CMIP3 projections but rather add to them. For this reason, if you do not have a preference for which version to use, consider using CMIP3 as the default option.

However, note that the DCHP CMIP3 data are only available for specific time periods: 1961-2000, 2046-2065 (mid-century), and 2081-2099 (end-of-century). The DCHP CMIP5 data are available for a continuous period from 1950-2099. **Users of the CMIP5 Climate Data Processing Tool can select their own time periods for baseline and two future time periods (such as near-term, mid-century, or end-of-century).**

For more information on choosing CMIP3 and CMIP5 data and understanding their differences, please visit http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/techmemo/downscaled_climate.pdf.

Key differences are also summarized in the table below.

| | CMIP3 | CMIP5 |
|---|---|---|
| Used in | IPCC Fourth Assessment Report (2007) | IPCC Fifth Assessment Report (2014) |
| Years available | 1961-2000; 2046-2065; 2081-2099 | 1950-2099 |
| Emissions scenarios | B1, A1B, A2 | RCP2.6, RCP4.5, RCP6.0, RCP8.5 |
| Number of available climate models | 9 | 21 |

8. **Products & Variables -- daily projections (Step 2.5)**
    a. Under **Products**, select **1/8 degree BCCA projections** and **1/8 degree Observed data (1950-1999)**
    b. Under **Variables**, select all three: **Precipitation Rate (mm/day)**, **Min Surface Air Temperature (deg C)**, and **Max Surface Air Temperature (deg C)**
9. **Emissions Scenarios, Climate Models and Runs (Step 2.6)**

**Box: Choosing Emissions Scenarios**

We recommend that you select models under one Emissions Path at a time. If you would like to compare projections under different Emissions Paths, you should run a separate version of the tool for each scenario and then compare the results.

If you choose to select multiple emissions paths, the tool will not treat them independently. The tool provides multi-model mean projections for each variable. The projections will average across all models, regardless of emissions scenario chosen.

Note that if you are concerned with **mid-century** projections, the emissions scenario(s) you choose will not greatly affect your results. Emissions scenarios do not differ much by mid-century. If you are focusing on **end-of-century** results, choosing and comparing emissions scenarios may be more important.

The tables below summarize the CMIP3 and CMIP5 emissions scenarios available through the DCHP website.

**CMIP3 Emissions Scenarios[1]**

| Scenario Name | Description | Global Surface Temp. Change by 2100 | Global Mean Sea Level Rise by 2100 |
|---|---|---|---|
| B1 | Low emissions. Declining global population after mid-century, transition to lower emission technologies and economies. | 0.54-1.62 °F (0.3-0.9 °C) | 0.59-1.25 ft (0.18-0.38 m) |
| A1B | Medium-High emissions. Rapid economic growth, declining global population after mid-century, more efficient technologies. | 3.06-7.92 °F (1.7-4.4 °C) | 0.69-1.57 ft (0.21-0.48 m) |
| A2 | Medium-High emissions. High population growth, regional economic development, slower technology change. | 3.6-9.72 °F (2.0-5.4 °C) | 0.75-1.67 ft (0.23-0.51 m) |

**CMIP5 Representative Concentration Pathways[2]**

| Scenario Name | Description | Concentrations (ppm $CO_2$ equiv.) by 2100 | Global Surface Temp. Change by 2100 | Global Mean Sea Level Rise by 2100 |
|---|---|---|---|---|
| RCP2.6 | Substantial and sustained emissions reductions | 475 | 0.5-3.0 °F (0.3-1.7 °C) | 0.85-1.8 ft (0.26-0.55m) |
| RCP4.5 | Stabilization | 630 | 2.0-4.7 °F (1.1-2.6 °C) | 1.0-2.1 ft (0.32-0.63m) |
| RCP6.0 | Stabilization | 800 | 2.5-5.6 °F (1.4-3.1 °C) | 1.1-2.1 ft (0.33-0.63m) |
| RCP8.5 | High emissions continue | 1313 | 4.7-8.6 °F (2.6-4.8 °C) | 1.5-2.7 ft (0.45-0.82m) |

[1] Source: UN IPCC Working Group I: The Scientific Basis (http://www.ipcc.ch/ipccreports/tar/wg1/029.htm)

[2] Source: UN IPCC, Climate Change 2013: The Physical Science Basis (https://www.ipcc.ch/report/ar5/wg1/)

**Box: Choosing Climate Models**

We recommend that unless you have strong reason to do otherwise, you should select all available climate models under your chosen emissions scenario and rely on the multi-model ensemble for your results. You may want to consult with your NOAA Regional Integrated Sciences and Assessments (RISA) team, local universities, state climatologist, or other experts if you are considering selecting specific models.

***For CMIP3:***

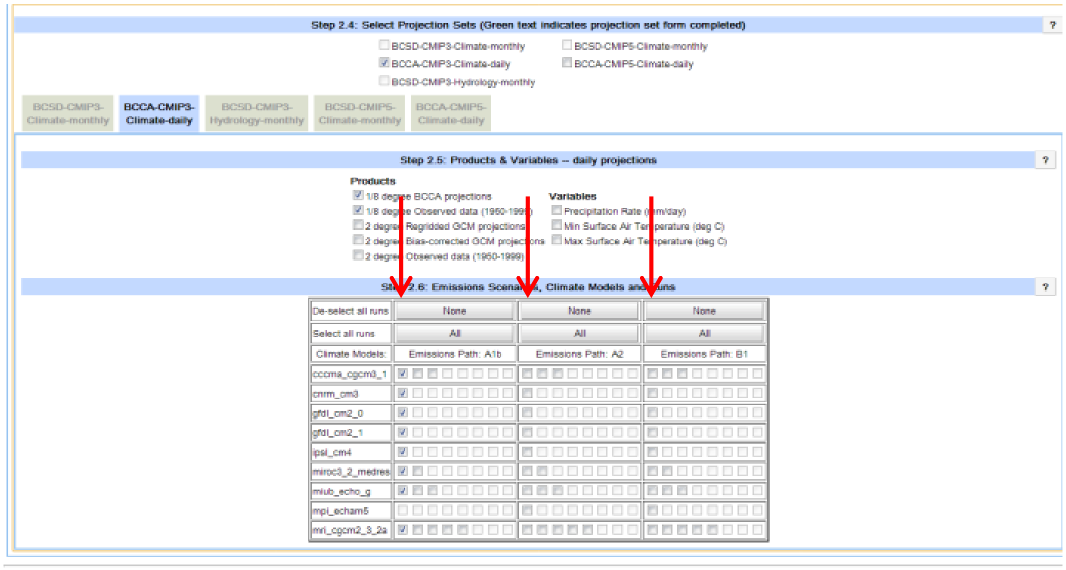
a. Check the box for **up to nine (9)** models under any Emissions Path (see boxes above). Roughly speaking, the B1 emissions path represents the lowest emissions, followed by A1B then A2. Detailed information on the emissions paths is available in the IPCC Special Report on Emissions Scenarios (SRES), particularly Chapter 4 at: http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=98.

***For CMIP5:***

a. Check the box for **up to twenty-one (21)** models under any Emissions Path (see boxes above). Roughly speaking, the emissions paths are listed in order from low to high (RCP2.6 is the lowest emissions path and RCP8.5 is the highest emissions path). Detailed information on the emissions paths is available in the IPCC Fifth Assessment Report at: https://www.ipcc.ch/report/ar5/wg1/.

***Both CMIP3 and CMIP5:***

b. When selecting your models, **check only one box per model**, as shown below (for CMIP3, A1B). *Each checkbox represents a different run of the model. Each run starts the model at a slightly different initial condition, which characterizes the current state of the atmosphere. By selecting only one run per model, you are avoiding weighting any one climate model over others. You can select any one run per model, since the variation within a model is smaller than the variation across different models.*



**Helpful Hint**: Keep track of the number of boxes you check and the emissions scenario(s) you chose. You will need this information later when you begin to use the tool spreadsheet.

10. Click on the third tab at the top of the form, **Page 3: Analysis, Format, & Notification**

11. **Analysis (Step 3.7)**
    a. Select **No Analysis (Extracting Time Series only)**

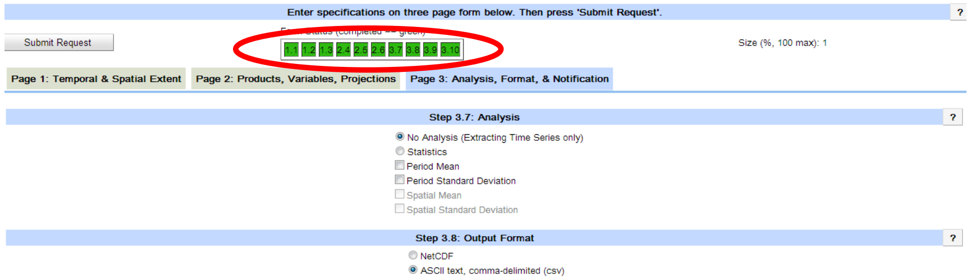
12. **Output Format (Step 3.8)**
    a. Select **ASCII text, comma-delimited (csv)**.
    *If this option is not available, you may have inadvertently selected multiple grid cells in Step 5 (DCHP site Step 1.3). Return to the Page 1 tab and make sure you have selected only one grid cell. See Step 5, part c.*

13. **Notification when Processing is Complete (Step 3.9)**
    a. Enter the email address where you would like to receive notification when the processing is complete.

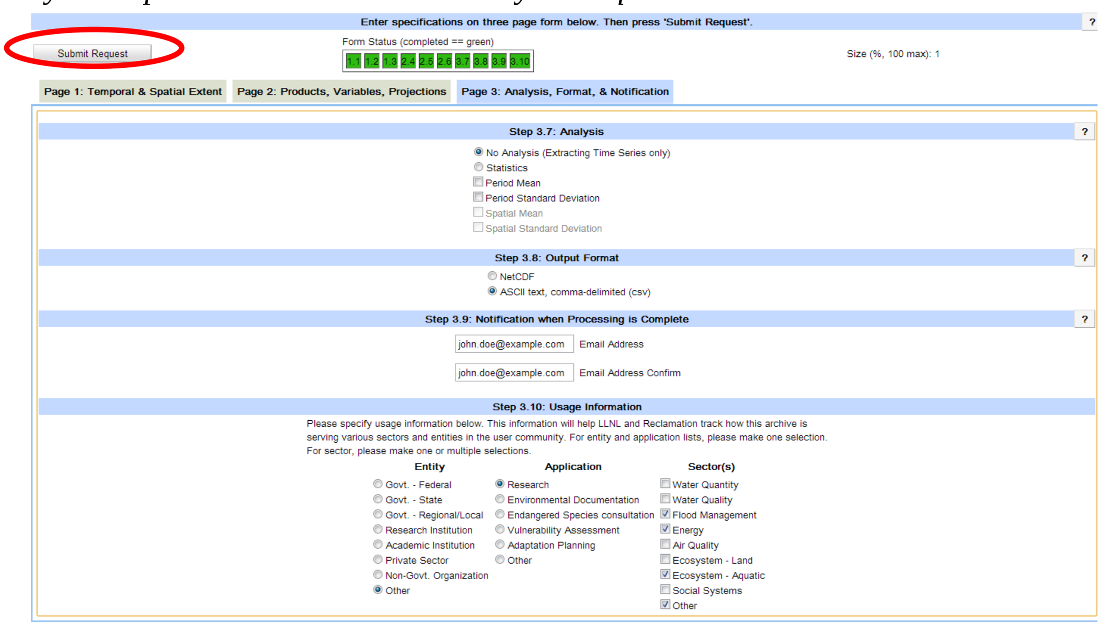
14. **Usage Information (Step 3.10)**
    a. Select the appropriate Entity, Application, and Sector(s) for your use.

15. When complete, scroll up the page to make sure that all boxes for steps 1.1-3.10 are colored green. If a box is white, click on that box, return to the appropriate step in these

instructions, and fill in the required information.




16. Once all information is entered, click on **Submit Request** at the top left corner of the form. A Summary of Requested Files will appear. Select **Submit** to send your request. *It may take up to several hours to receive your requested data*.




17. Note that the CMIP Climate Data Processing Tool accepts data from up to four grid cells, and will average across those grid cells as a first step in determining the climate projections for your location (see text box below). Including more grid cells makes the results more robust, as it can smooth out anomalies that may be associated with a single grid cell. If you only want data from one grid cell, then you have completed the data request step and can disregard Steps 18-21. If you want data from more than one grid cell, proceed to **Steps 18-21**.

**Box: Using Multiple Grid Cells**

A best practice when using climate model data is to average the data across multiple grid cells. The CMIP Climate Data Processing Tool can accept data from up to four grid cells. The tool will then average the data across all grid cells downloaded as the basis for the projections. The four grid cells should be close to one another – if not immediately adjacent, they should be no more than one or two cells apart.

18. With your browser window still open, click on the tab **Page 1: Temporal & Spatial Extent**.

19. On the map, select another grid cell, following the same rules as defined in **Step 5**. The grid cell should be close by, but does not have to be immediately adjacent to the grid(s) you already downloaded.

20. Click on the tab **Page 3: Analysis, Format, & Notification**.

21. Click on **Submit Request** at the top left corner of the form. A Summary of Requested Files will appear. Select **Submit** to send your request.

22. Repeat Steps 18-21 up to two more times to collect data for a total of four grid cells around your area.

## 1.2 Retrieving and Inputting Data

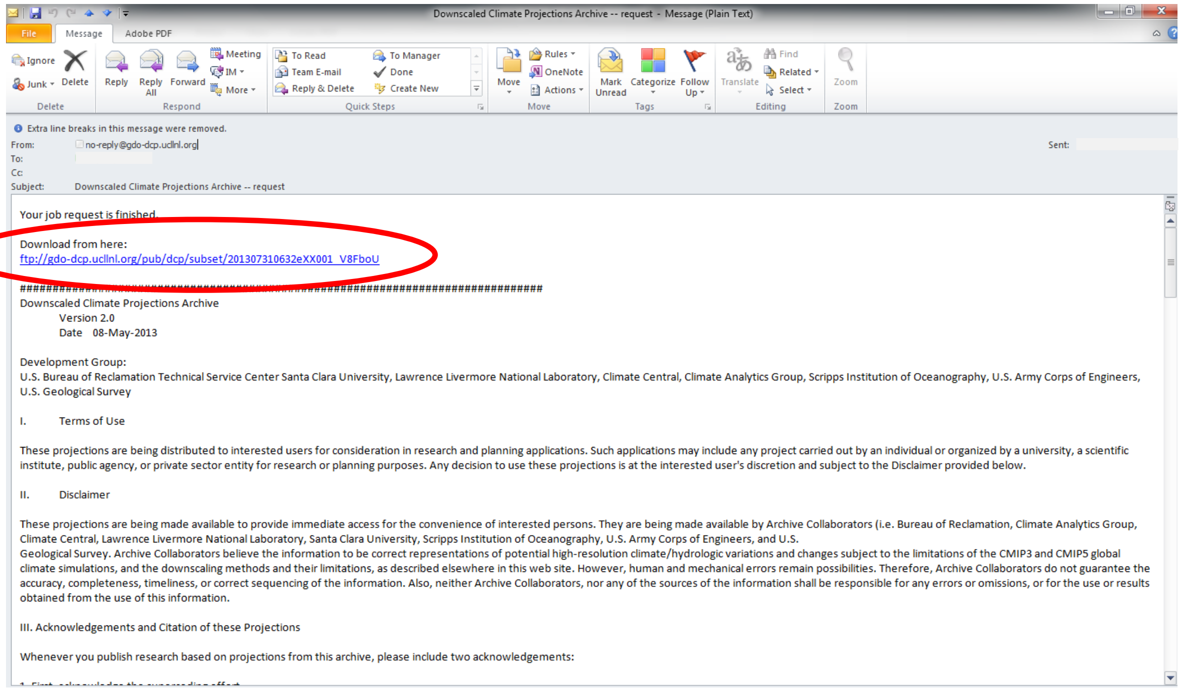
23. While you are waiting for your data, prepare your computer to accept the files. Create a new folder on your computer entitled "CMIP Climate Data Processing Tool".

24. Download the CMIP Climate Data Processing Tool Excel spreadsheet and save it into your created folder.

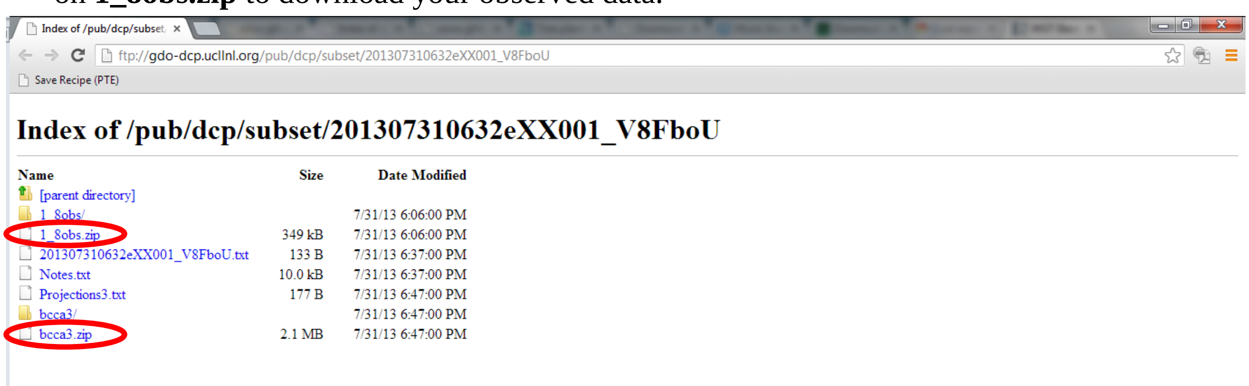
25. Within the "CMIP Climate Data Processing Tool" folder you just created, create a sub-folder for each grid cell that you requested in Step 22. Name the folders ***exactly*** as follows for each grid you need (note that there is a space between "Grid" and each number):
    - Grid 1
    - Grid 2
    - Grid 3
    - Grid 4

26. Keep this folder open, as you will be moving your projection data into these sub-folders.

27. When your data are available, you will receive a link to your request in an email. Open the message and click on the link provided.

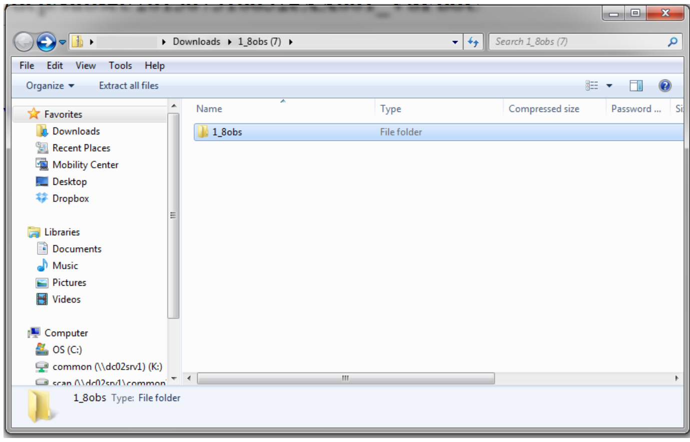



28. The link takes to you a webpage with links for downloading your requested data. Click on **1_8obs.zip** to download your observed data.



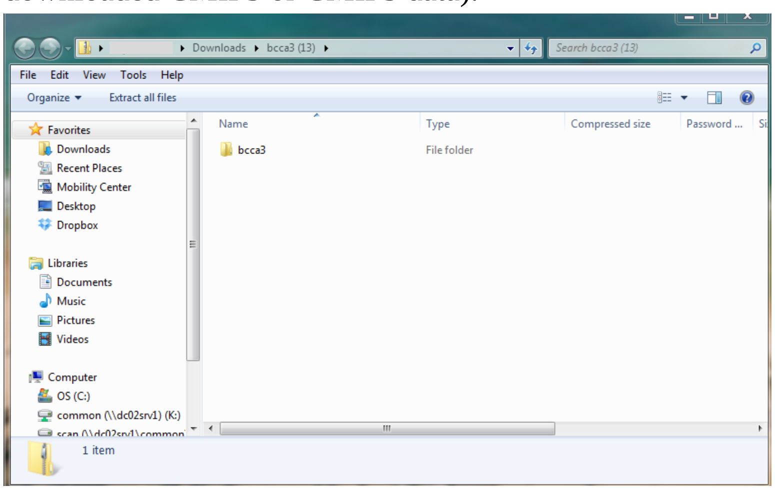

29. Click on **bcca3.zip** (or **bcca5.zip** if you downloaded CMIP5 projections) to download your downscaled climate model data.

30. Once downloaded, open the folder **1_8obs**.



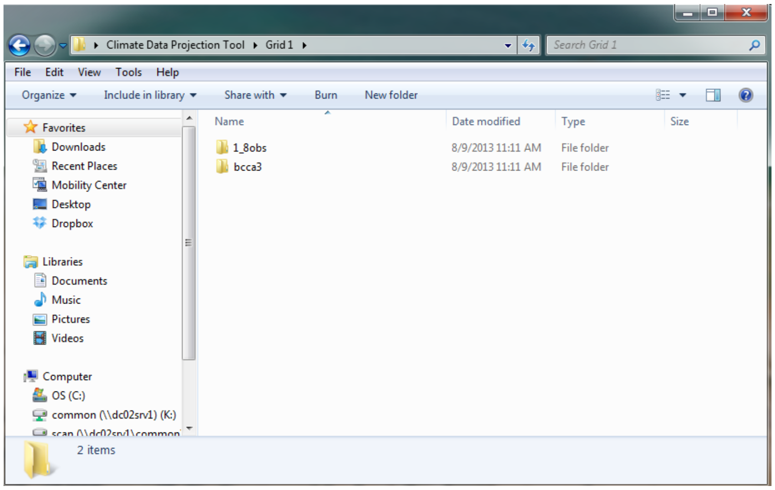

31. Drag the “1_8obs” folder into the **Grid 1** folder.

32. Once downloaded, open the **bcca3** or **bcca5** folder (depending on whether you downloaded CMIP3 or CMIP5 data).

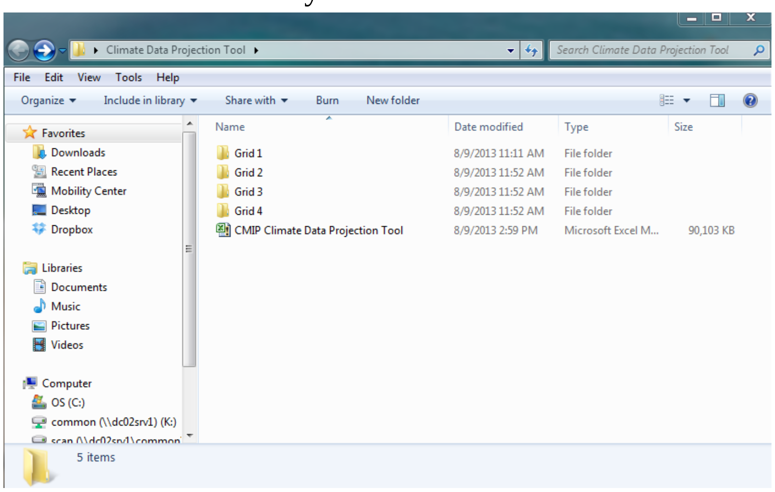



33. Drag the “bcca3” or “bcca5” folder into the **Grid 1** folder.

34. Your **Grid 1** folder should look like the following:




35. The main folder where you saved the tool should look like the following:




36. Repeat **Steps 24** through **30** for any additional grids you have selected. Once all data files have been placed into your desktop folder, open the CMIP Climate Data Projection Excel Tool and follow the directions there.

# 2. Processing Data

Based on your selection of CMIP3 or CMIP5 data in the previous section, open the corresponding CMIP3 or CMIP5 Excel file. The files open with an introductory page. When you are ready to move on, select the blue arrow in order select your parameters and process your data. Follow the instructions below based on which file you open.

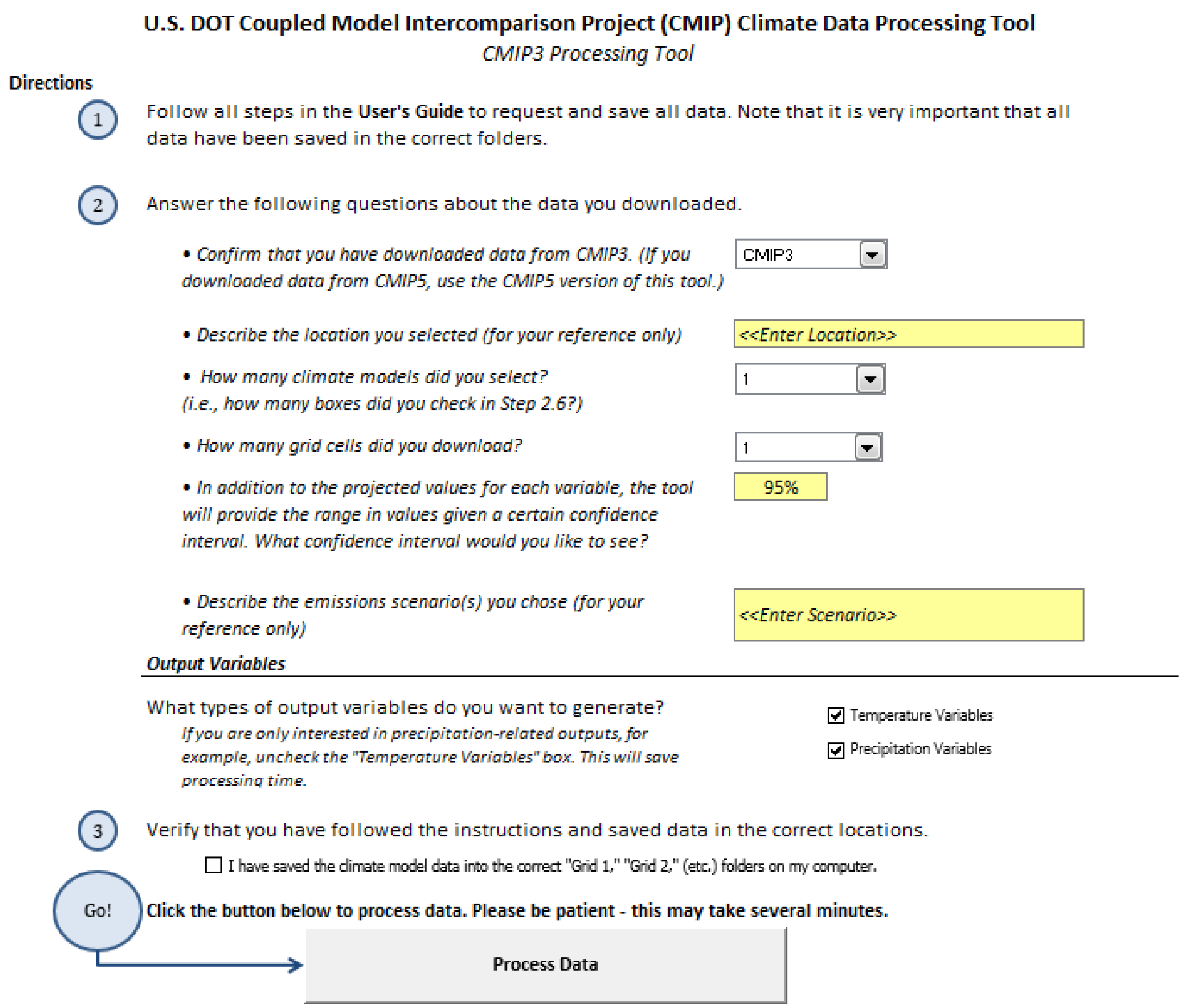
## 2.1 CMIP3 Tool

Follow the instructions on the "Home" tab of the CMIP3 Climate Data Processing Tool and answer the six questions about the data you downloaded.

- **CMIP3** – Confirm that you chose to download CMIP3 data (back in Step 7).
- **Location** – This field is optional, but recommended to help you keep track of what data are housed in the tool. Describe the location however it makes sense for your purpose (e.g., general city, site location, or lat/long coordinates). This will be especially helpful if you run the tool for multiple locations.
- **Climate models** – Use the drop-down menu to indicate the number of boxes you checked in Step 9 (DCHP website step 2.6).
- **Grid cells** – Use the drop-down menu to indicate the number of grid cell locations you downloaded data for in Steps 18-21.
- **Confidence interval** – Enter the confidence interval you would like to see for the projections. For all projections, you will see the "projected value" (based on the multi-model mean) and the range of projected values. The range displayed will be based on the confidence interval entered. The default is 95%. Entering a lower percentage will display a smaller range, and entering a higher percentage will display a larger range. To see the full range of model projections (what the lowest model says and what the highest model says), enter 99.99%. **You can adjust the confidence interval range at any time, even after you have processed the data.**
- **Emissions scenario** – This field is optional, but recommended to help you keep track of what data are housed in the tool. Enter the name of the emissions scenario you downloaded data for when you selected models. This will be especially helpful if you run the tool multiple times to compare results between emissions scenarios.
- **Output variables** – Select whether you would like to process variables for precipitation, temperature, or both.

**Once you have answered the questions, click the "Process Data" button**. This will run the calculations necessary to convert the raw data you downloaded into several specific temperature and/or precipitation variables.

The Process Data step may take several minutes, depending on your system's processor speed, amount of available memory, and what other operations are running, as well as the amount of data you downloaded. You may want to close any unnecessary programs to free up processing power. You will be unable to use Excel for other tasks during this time. Please be patient. When the program has completed running, a box will appear noting that processing is complete. Click the "Okay" button to be presented with your results.




## 2.2 CMIP5 Tool

Follow the instructions on the "Home" tab of the CMIP5 Climate Data Processing Tool and answer the five questions about the data you downloaded.

- **CMIP5** – Confirm that you chose to download CMIP5 data (back in Step 7).
- **Location** – This field is optional, but recommended to help you keep track of what data are housed in the tool. Describe the location however it makes sense for your purpose (e.g., general city, site location, or lat/long coordinates). This will be especially helpful if you run the tool for multiple locations.
- **Climate models** – Use the drop-down menu to indicate the number of boxes you checked in Step 9 (DCHP website step 2.6).

- **Grid cells** – Use the drop-down menu to indicate the number of grid cell locations you downloaded data for (in Steps 18-21).
- **Emissions scenario** – This field is optional, but recommended to help you keep track of what data are housed in the tool. Enter the name of the emissions scenario you downloaded data for when you selected models. This will be especially helpful if you run the tool multiple times to compare results between emissions scenarios.

Next, configure your preferences for certain tool outputs.

- **Baseline time period** – Indicate the desired start year and end year for the baseline time period, using the drop-down menus provided. This will be the time period that future changes in climate are compared against. The period must be between 1950 and 1999.
- **Future time periods (2)** – The tool allows you to calculate projections for two future time periods (if you want projections for more future time periods, you can run additional copies of the tool). For each time period, input the start year and end year. It is strongly recommended that all time periods be between 20 and 30 years long.[3] Also include a name for the future time periods (such as mid-century and end-of-century) to help you keep track of them later on in the tool.
- **Confidence interval** – Enter the confidence interval you would like to see for the projections. For all projections, you will see the "projected value" (based on the multi-model mean) and the range of projected values. The range displayed will be based on the confidence interval entered. The default is 95%. Entering a lower percentage will display a smaller range, and entering a higher percentage will display a larger range. To see the full range of model projections (what the lowest model says and what the highest model says), enter 99.99%. **You can adjust the confidence interval range at any time, even after you have processed the data.**
- **Output variables** – Select whether you would like to process variables for precipitation, temperature, or both.
- **Maximum Annual Precipitation** – Use the checkbox to indicate whether you would like the tool to provide a time series of highest 24-hour precipitation amount for each year between 1950 and 2099. This will add some additional processing time, and if you choose not to do it during the initial run, you will have the option to run that process it separately later. Doing so will create a new "CMIP5 1950-2099 Precipitation Data" Excel file with the calculations supporting these values.

[3] Climate model data are intended to be used to estimate long-term averages of future climate. "Climates" are defined as an average of 20-30 year observations (http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html#WHATARENORMALS). For that reason, to understand potential future climate in a single year (e.g., 2040), you should select a 20-30 year period around that year (e.g., 2030-2050). For example, the Intergovernmental Panel on Climate Change (IPCC) uses 20-year return values for various indicators in its Fifth Assessment Report of the IPCC (http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf).

## U.S. DOT Coupled Model Intercomparison Project (CMIP) Climate Data Processing Tool

*CMIP5 Processing Tool*

**Directions**

1 Follow all steps in the **User's Guide** to request and save all data. Note that it is very important that all data have been saved in the correct folders.

2 Answer the following five questions about the data you downloaded.

- *Confirm that you have downloaded data from CMIP5. (If you downloaded data from CMIP3, use the CMIP3 version of the tool.)* — CMIP5
- *Describe the location you selected (only for your reference)* — *<<Location>>*
- *How many climate models did you select? (i.e., how many boxes did you check in Step 2.6?)* — 1
- *How many grid cells did you download?* — 1
- *Describe the emissions scenario(s) you chose (only for your reference)* — *<< Scenarions>>*

3 **Set your output preferences**

Baseline time period (must end by 1999) (e.g., 1950-1999): Start: End

Future time period 1: Name: *<<e.g., mid-century>>* Start: End:

Future time period 2: Name: *<e.g., end-of-century>* Start: End:

***Output Variables***

What types of output variables do you want to generate?
*If you are only interested in precipitation-related outputs, for example, uncheck the "Temperature Variables" box. This will save processing time.*

☑ Temperature Variables
☑ Precipitation Variables

Would you like to generate a time series of maximum annual precipitation from 1950-2099?
*You can also choose to generate this information later. This will increase processing time.*

☐ Yes, generate time series of maximum annual precipitation from 1950-2099.

***Uncertainty***

In addition to the projected values for each variable, the tool will provide the range in values given a certain confidence interval. — 95%

4 **Verify that you have followed the instructions and saved data in the correct locations.**

☐ I have saved the climate model data into the correct "Grid 1," "Grid 2," (etc.) folders on my computer.

Go **Click the button below to process data. Please be patient - this may take several minutes.**

**Process Data**

**Once you have answered the questions, click the "Process Data" button**. This will run the calculations necessary to convert the raw data you downloaded into several specific temperature and/or precipitation variables.

The Process Data step may take several minutes, depending on your system's processor speed, amount of available memory, and what other operations are running, as well as the amount of data you downloaded. **It is recommended that you close any unnecessary programs to free up processing power**. You will be unable to use Excel for other tasks during this time. Please be patient. When the program has completed running, a box will appear noting that processing is complete. Click the "Okay" button to be presented with your results.

**Box: Exploring the Tool**

Once processing is complete, you will be taken to the Temperature Outputs sheet, which shows the projected changes in all temperature variables calculated by the tool. The tool contains three results sheets:

- **Temperature Outputs** – projected changes in temperature variables
- **Precipitation Outputs** – projected changes in precipitation variables
- **Precipitation Annual Maxima** – a time series of the annual maximum daily precipitation values in the observed and model datasets

Other Features:

- **Show/Hide Details** – clicking this button will show or hide additional projection information, such as the projected change from baseline, the percent change, and the uncertainty range across models
- **Show/Hide Supporting Raw Data Tabs** – on the Temperature and Precipitation outputs sheets, you can click this button to show or hide the raw climate model data from the DCHP website
- **How are these values calculated?** – This button will take you to the Technical Notes tab, which explains how all values are calculated (see also User's Guide section 3.2).
- **Export Results** – This button will create a separate excel file containing the three output tabs. This may be useful for working with the data as you move forward.

The bottom of the output sheets also provides a summary of the underlying data, including the grid locations, models and scenarios used, and data source.

# 3. Interpreting Data

The temperature and precipitation projected values should be used carefully. Be sure to understand what the numbers represent before applying them in decision-making.

These results can be used to provide information on the potential magnitude and range of changes in your location, which in turn can inform vulnerability assessments, adaptation, and long-term planning. These variables are **not** recommended to be plugged directly into design models for built infrastructure.

Please review the DCHP website for information on the underlying climate data and review the information below (also on the Technical Notes tab of the tool) for details on how specific variables were calculated and what each value represents.

## 3.1 Output

The tool provides three output sheets: temperature outputs, precipitation outputs, and precipitation annual maxima. The temperature and precipitation outputs sheets provide projected values for 59 total variables derived from the climate data. The third sheet provides a time series of the highest 24-hour precipitation value in each year of the dataset.

For each variable on the temperature and precipitation outputs tabs, the Outputs tabs show the following:

Baseline:

- **Observed Value** – Value calculated using the observed data downloaded from the DCHP website.[4] **You may also override this value with observed data from a local weather station, if desired. To do so, use the password "edit" to unlock the observed value cells.**
- **Modeled Value** – Value for the baseline time period calculated based on climate model data

Future Time Periods:

- **Projected Value** – Change from Baseline + Observed Value
- **Change from Baseline** – Change in value from modeled baseline to modeled future period *(Note: modeled future period value not shown on Output sheet)*
- **% Change from Observed** – Change from Baseline / Observed Value[5]
- **Model Uncertainty Range** – The confidence interval range for the projected value across all models, using a Student's T distribution for the user-specified confidence interval (e.g.,

*Time periods pre-set for CMIP3; user-defined for CMIP5

[4] The observed data come from gridded observed meteorological data. The website cites the source of the observed data as: Maurer, E.P., A.W. Wood, J.C. Adam, D.P. Lettenmaier, and B. Nijssen, 2002, A Long-Term Hydrologically-Based Data Set of Land Surface Fluxes and States for the Conterminous United States, J. Climate 15(22), 3237-3251.

[5] For percent changes in temperature, the change is shown in absolute temperature (Kelvin) rather than on the Fahrenheit scale

95%). The confidence interval is calculated for the projected *change* to determine the range of changes, which are then added to the observed value to show a range in projected values.

## 3.2 Processing Methodology

The raw data files from the downscaled CMIP3 and CMIP5 Climate and Hydrology Projections website contain daily maximum temperature (Tmax), minimum temperature (Tmin), and precipitation (Precip) values for each climate model. The DCHP website also provides observed daily maximum temperature, minimum temperature, and precipitation values for the same grid locations. The CMIP Climate Data Processing Tool converts that raw data into projected changes in 45 temperature variables and 13 precipitation variables using the processes described here.

Additional information on the raw observation or model projection data is available through the DCHP website at http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/#Welcome.

The raw data from the DCHP website provides daily Tmax, Tmin, and Precip for each climate model. This tool converts this raw data into projected changes in 45 temperature variables and 14 precipitation variables. All of these variables are calculated using the following general process. Specific processes for each variable are explained subsequently.

**Box: Definitions**

**Tmax** – The maximum surface air temperature on a given day

**Tmin** – The minimum surface air temperature on a given day

**Precip** – The amount of precipitation on a given day (24-hour period)

**Seasons** – In the CMIP Climate Data Processing Tool, the seasons are defined as including the following months:

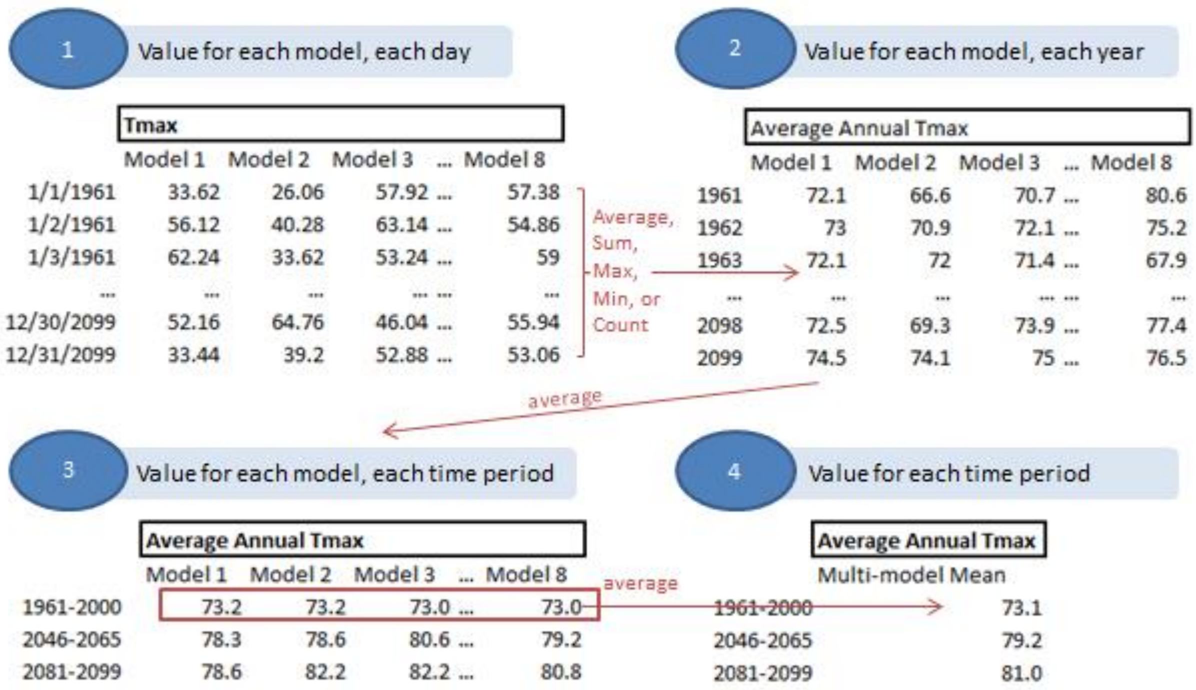
- ***Winter*** – December, January, February
- ***Spring*** – March, April, May
- ***Summer*** – June, July, August
- ***Fall*** – September, October, November

### Processes for All Variables

The projected values for all variables are calculated using the same general process:

1. First, **for each model**:
    a. Calculate daily Tmax, Tmin, and Precip by **averaging across all grid cells**
    b. Calculate variable for each year for each model, and then
    c. **Average across years** within each time period preset in CMIP3 (e.g., 1961-2000, 2046-2065, 2081-2099) or defined by the user in CMIP5
2. Calculate **multi-model ensemble average** projections for each time period by taking the average values from Step 1 across models
3. Calculate the change from baseline (modeled value minus modeled baseline) using the multi-model ensemble means
4. Finally, add the change in baseline to the baseline observed value to derive the "projected value" for each variable.

An example is shown in the figure below for the variable *Average Annual Maximum Temperature*. The tool starts with the Tmax for each model, each day. Then, it calculates[6] across each day in the year to get the average Tmax for each model, each year. Next, it averages across the years in each time period (for CMIP3, 1961-2000, 2046-2065, 2081-2099) to get the average annual Tmax for each model in each time period. Finally, it averages across models to get a single value for each time period. The changes in these values are calculated, and then combined with the observed average annual maximum temperature to derive the projected average annual maximum temperature for the future time periods.




## Processes for Each Variable

Listed below are the processing steps used to calculate each variable. These steps focus on how the tool arrives at Steps 1 (a value for each model, each day) and 2 (a value for each model, each year) from the figure above from the raw daily Tmax, Tmin, and Precip data. From the annual values, an average is calculated for the time period selected. The specific process for each variable is described below.

### Temperature Outputs

#### *Annual Averages*

- **Average Annual Mean Temperature**

[6] For the example shown, the tool averages across all days in the year to get the average annual Tmax. However, for some variables, the tool calculates the sum, maximum, or minimum value across all days in each year. Any variables that do not represent annual averages are specified within the "Processes for Each Variable" section.

- For each day, calculate the average across the Tmax and Tmin values
    - Calculate average value across all days in each year
- **Average Annual Maximum Temperature**
    - Calculate average daily Tmax value across all days in each year
- **Average Annual Minimum Temperature**
    - Calculate average daily Tmin value across all days in each year

### *Annual Extreme Heat*

- **Hottest Temperature of the Year**
    - For each year, find the maximum Tmax value
- **"Very Hot" Day Temperature**
    - For each time period, calculate the 95$^{th}$ percentile Tmax value (i.e., the threshold at which 95% of Tmax values for the entire time period are cooler). This is done using Excel's PERCENTILE function.
    - (Note that this variable is an exception to the general process, and is calculated based on all the daily values across the time period—this is the only step necessary to calculate the projected value for this variable for each time period)
- **"Extremely Hot" Day Temperature**
    - Similar to above, for each time period, calculate the 99$^{th}$ percentile Tmax value (i.e., the threshold at which 99% of Tmax values for the entire time period are cooler).
- **Average Number of Days per Year above Baseline "Very Hot" Temperature**
    - Count the number of days per year with Tmax greater than or equal to the baseline (e.g., 1961-2000) 95$^{th}$ percentile Tmax value
- **Average Number of Days per Year above Baseline "Extremely Hot" Temperature**
    - Count the number of days per year with Tmax greater than or equal to the baseline (e.g., 1961-2000) 99$^{th}$ percentile Tmax value
- **Average Number of Days above 95°F, 100°F, 105°F, 110°F per Year**
    - Count the number of days per year with Tmax greater than or equal to 95°F, 100°F, 105°F, and 110°F
- **Maximum Number of Consecutive Days per Year above Baseline "Very Hot" Temperature**
    - For each day, check whether that day is greater than or equal to the baseline (e.g., 1961-2000) 95$^{th}$ percentile Tmax value; if so, count how many consecutive days have been above that value (see example in table below, where the "Very Hot" temperature is 92°F)

| Date | Tmax (°F) | Consecutive Days > 92°F |
|---|---|---|
| 7/1/1961 | 90.0 | 0 |
| 7/2/1961 | 92.5 | 1 |
| 7/3/1961 | 92.0 | 2 |
| 7/4/1961 | 97.0 | 3 |

| | | |
|---|---|---|
| 7/5/1961 | 91.7 | 0 |

  - Calculate the maximum number of consecutive days above the threshold for each year
- **Maximum Number of Consecutive Days per Year above Baseline "Extremely Hot" Temperature**
  - Similar to above. Find the maximum number of consecutive days in each year with Tmax greater than or equal to the baseline (e.g., 1961-2000) 99$^{th}$ percentile Tmax value
- **Maximum Number of Consecutive Days per Year above 95°F, 100°F, 105°F, 110°F**
  - Similar to above. Find the maximum number of consecutive days in each year with Tmax greater than or equal to 95°F, 100°F, 105°F, and 110°F

### *Annual Extreme Heat*

- **Average Summer Temperatures**
  - For each day, calculate the average across the Tmax and Tmin values
  - For each year, average the above across all days in the summer (June 1 to August 31)
- **Highest 4-Day Average Summer High Temperatures**
  - For each day, calculate the running average Tmax across a four-day period consisting of that day and the three previous days (e.g., the 4-day average maximum temperature on July 4, 1961 equals the average of the Tmax values on July 1, 2, 3, and 4, 1961)
  - Find the maximum value of these four-day averages within the summer of each year
- **Highest 7-Day Average Summer High Temperatures**
  - Same as above, except first step takes the average across 7 days
- **Number of Days per Season above 95°F, 100°F, 105°F, 110°F**
  - For each season, count the number of days with Tmax values greater than or equal to 95°F, 100°F, 105°F, and 110°F

### *Extreme Cold*

- **Coldest Temperature of the Year**
  - Find the minimum Tmin value for each year
- **"Very Cold" Day Temperature**
  - Calculate the 5$^{th}$ percentile Tmin value (i.e., the threshold at which 5% of Tmin values for the entire year are cooler)
  - (Note that this variable is an exception to the general process, and is calculated based on all the daily values across the time period—this is the only step necessary to calculate the projected value for this variable for each time period)
- **"Extremely Cold" Day Temperature**
  - Similar to above, calculate the 1$^{st}$ percentile Tmin value (i.e., the threshold at which 1% of Tmin values for the entire year are cooler)
- **Average Number of Days per Year Below Freezing**

    - Count the number of days per year that have Tmin values less than or equal to 32°F
- **Average Number of Times per Year Low Temperatures Fluctuate around Freezing**
    - For each year, count the number of times Tmin values drop below and go above freezing temperatures. For example, as shown in the table below, if the Tmin on January 1 is 30°F and the Tmin on January 2, is 35°F, then that is considered one fluctuation around freezing. If on January 3, Tmin goes back down to 30°F, then that is considered another fluctuation.

| Date | Tmin (°F) | Fluctuation? |
|---|---|---|
| 1/1/1961 | 30.0 | |
| 1/2/1961 | 35.0 | **Yes** |
| 1/3/1961 | 30.0 | **Yes** |
| 1/4/1961 | 27.0 | No |

    - (Note this variable is intended to be a *rough proxy* for changes in freeze-thaw cycles)
- **Average Winter Temperatures**
    - For each day, calculate the average across the Tmax and Tmin values
    - For each year, average the above across all days in the winter
- **Lowest 4-Day Average Winter Low Temperatures**
    - For each day, calculate the running average Tmin across a four-day period consisting of that day and the three previous days (e.g., the 4-day average minimum temperature on January 4, 1961 equals the average of the Tmin values on January 1, 2, 3, and 4, 1961).
    - Find the minimum value of these four-day averages within the winter of each year.
- **Lowest 7-Day Average Winter Low Temperatures**
    - Same as 4-day average above, except first step takes the average across 7 days

## Precipitation Outputs

- **Average Total Annual Precipitation**
    - For each year, calculate the sum of all Precip values
- **"Very Heavy" 24-hr Precipitation Amount**
    - For each time period, calculate the $95^{th}$ percentile Precip value for days with nonzero precipitation (i.e., the threshold at which 95% of nonzero Precip values for the entire time period are less). This is done using Excel's PERCENTILE function.
    - (Note that this variable is an exception to the general process, and is calculated based on all the daily values across the time period – this is the only step necessary to calculate the projected value for this variable *for each time period*)
- **"Extremely Heavy" 24-hr Precipitation Amount**
    - Similar to above, for each time period, calculate the $99^{th}$ percentile Precip value within days with nonzero precipitation (i.e., the threshold at which 99% of nonzero Precip values for the entire time period are less)

- **Average Number of Baseline "Very Heavy" Precipitation Events per Year**
  - Count the number of days per year that have Precip values greater than or equal to the baseline (e.g., 1961-2000) 95$^{th}$ percentile Precip value
- **Average Number of Baseline "Extremely Heavy" Precipitation Events per Year**
  - Count the number of days per year that have Precip values greater than or equal to the baseline (e.g., 1961-2000) 99$^{th}$ percentile Precip value
- **Average Total Monthly Precipitation**
  - For each year, calculate the sum of all Precip values in each month
- **Average Total Seasonal Precipitation**
  - For each year, calculate the sum of all Precip values in each season
- **Largest 3-Day Precipitation Event per Season**
  - For each day, calculate the running total Precip across a three-day period consisting of that day and the two previous days (e.g., the 3-day total precipitation on January 3, 1961 equals the sum of Precip values on January 1, 2, and 3, 1961)
  - For each year, find the maximum value of these three-day averages within each season

### Precipitation Annual Maxima

The tool provides a summary of the precipitation annual 24-hour maxima time series from the observed dataset as well as the projections from each climate model. For each year in the dataset, the tool calculates the highest 24-hour precipitation amount in that year.

## 3.3 Clarification Notes

**1%, 5% Precipitation Events** – The 1st percentile precipitation amount is the threshold of precipitation above which only one percent of observations or projections are found in a given data set. The 5th percentile precipitation amount is the threshold of precipitation above which only five percent of observations or projections are found in a given data set. Note that because datasets may have covered only 20-, 30-, or 40-year time periods, 1% precipitation events is not equivalent to the 100-year storm. Rather, these values represent events with a 1% or 5% chance of occurring within the specified time period.