Weather Generator and Climate Change Scenario Generator for Climate Risk Assessment

(version 0.1.0 BETA)
August,2019

User's Manual

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PREFACE

This manual will explain the users how to use this tool - 'Weather Generator and Climate Change Scenario Generator (version 0.1.0 Beta)'. It will focus on explain step-wise processes to carry the weather generation and apply any shifts / changes to the weather variables in order to generate climate change scenarios.

This tool is developed in Python 3.7.

Please feel free to use the tool and send us email for queries, bugs or issues related to this tool.

Regards,

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Introduction

'Weather Generator and Climate Change Scenario Generator (version 0.1.0 Beta)' is a tool aiming to support climate risk assessments of water resources system. It is mainly designed to produce inputs for climate stress test and it provides an interfaces for weather generating process and enforcing changes in climatic means to produce climate change scenarios.

The tool is developed based on research papers by Apipattanavis et al (2007) and Steinschneider and Brown (2013). Users are requested to read those papers for details about the weather generation processes used in this tool.

This tool provides five major interfaces. Interface 'Annual Series Simulator' provides tools to generate annual precipitation series based on historic precipitation series by using ARMA method. It is diversion from wavelet based approach as described by Steinschneider and Brown (2013). Interfaces 'WG-CRA' and 'k-NN WG' are for weather generation. The former one is conditioned on annual precipitation series as described in Steinschneider and Brown (2013) whereas latter is not conditioned but simply weather generator as formulated in Apipattanavis et al (2007). Interface 'CC Scenario Generator' allows to enforce shifts or changes in distributional properties of weather variables by quantile mapping approach for precipitation and simple shifting approach for other variables and it is described in Steinschneider and Brown (2013). Finally, interface 'Result viewer' is for graphically viewing the results generated by mentioned interfaces.

References:

Apipattanavis, S., G. Podesta´, B. Rajagopalan, and R. W. Katz (2007), A semiparametric multivariate and multisite weather generator, Water Resour. Res., 43, W11401, doi:10.1029/2006WR005714

Steinschneider, S., and C. Brown (2013), A semiparametric multivariate, multisite weather generator with low-frequency variability for use in climate risk assessments, Water Resour. Res., 49, 7205–7220, doi:10.1002/wrcr.20528.

Installing and running the program

This chapter describes the recommended computer requirements for running the tool. Step wise process to run the program is also described.

Operating system requirement

The tool has developed in Python 3.7.3 in Windows 10 Pro (64-bit) with packages 'numpy', 'pandas', 'statsmodels', 'matplolib' and self-developed package called WGEN (with weather generating module). GUI interface is developed using 'wxpython' and is converted to stand alone application using 'pyinstaller'.

This program is available for Windows 10 Pro (64-bit operating system).

Hardware requirements: The tool will occupy about 920 MB of space when unzipped. The zipped file is about 250 MB.

Installation and running

Please use the following steps to download, install and run the program.

1. Obtain zipped folder by downloading from the following link:

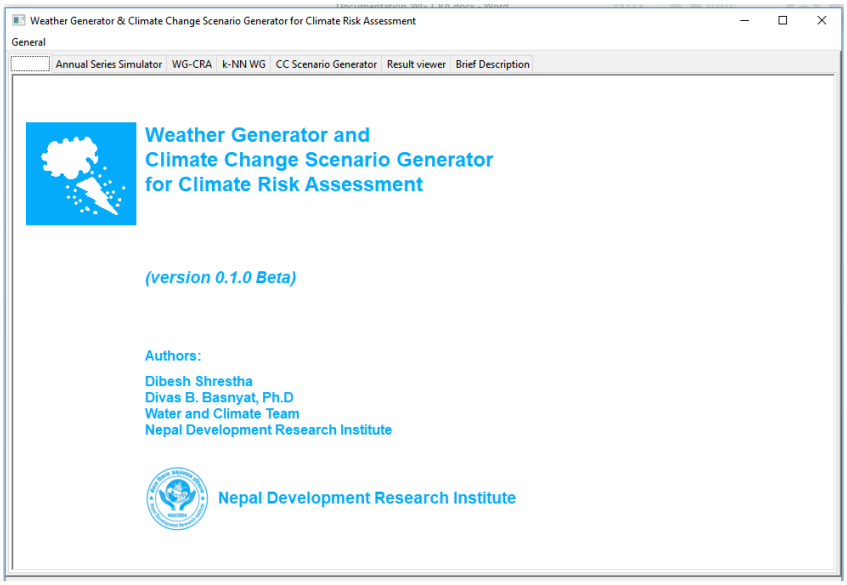
www.ndri.org.np

2. After you have obtained the zipped file named 'WG_CRA.rar ', unzip the folder into your working drive. You will get the folder WG_CRA.

3. Look for 'WG_CRA.exe' file (WG_CRA.exe) inside WG_CRA folder.

4. Double click the file to run the tool. Please wait for few seconds (depending upon your computer) to open the tool.

5. Once open, the following screen will appear and you are ready to run the tool.



Overview

This chapter describes basic information of the 'pages' (tabs) in the tool. Out of seven pages, two are information related to this tool. Each of remaining pages has its own independent functions (weather generation, climate change scenario generation, result viewing). They are briefly described as follows:

Pages	Brief description
(with blank tab)	It gives information on name, version and authors of the tool.
Annual Series Simulator	It is for simulating the annual precipitation series using ARMA method. Users can fit ARMA model with (p, q) parameters, simultaneously viewing autocorrelation and partial autocorrelation plots. Users can carry residual analysis and simulate annual series using the fitted ARMA model.
WG-CRA	Users can generate daily weather variables conditioned on annual precipitation values based on provided daily observed weather variables. Users have to supply observed and simulated annual precipitation series, observed areal averaged daily weather variables (can be single site or multisite) and declare which of the variable is precipitation. Users should provide the model parameters and initial conditions. Users can change the transition probability in case of enforcing climate change condition. Please refer to Steinschneider and Brown (2013) for technical details. Users can save the results.
k-NN WG	It is for simulating the weather based on provided daily observed weather variables but without conditioned on annual precipitation series. Users have to observed areal averaged daily weather variables (can be single site or multisite) and declare which of the variable is precipitation. Users should provide the model parameters and initial conditions. Users can change the transition probability in case of enforcing climate change condition. Results will be save in the output directory. Please refer to Apipattanavis et al (2007) for technical details.
CC Scenario Generator	It is for enforcing the long-term changes/ shifts in the simulated or observed climatic variables. For precipitation, users can enforce changes in mean and coefficient of variation of its distribution (which is modelled as gamma distribution). For other variables like temperature, users can shift mean. Users can save the output in desired location.
Result viewer	It is for graphically viewing the results and it is intended for basic viewing only. Users can view the generated daily series, annual / monthly sums and averages of generated series. Users can further use other advanced data analysis tools for further analysis.
Brief Description	It provides brief description of the tool including contact details of the developers.

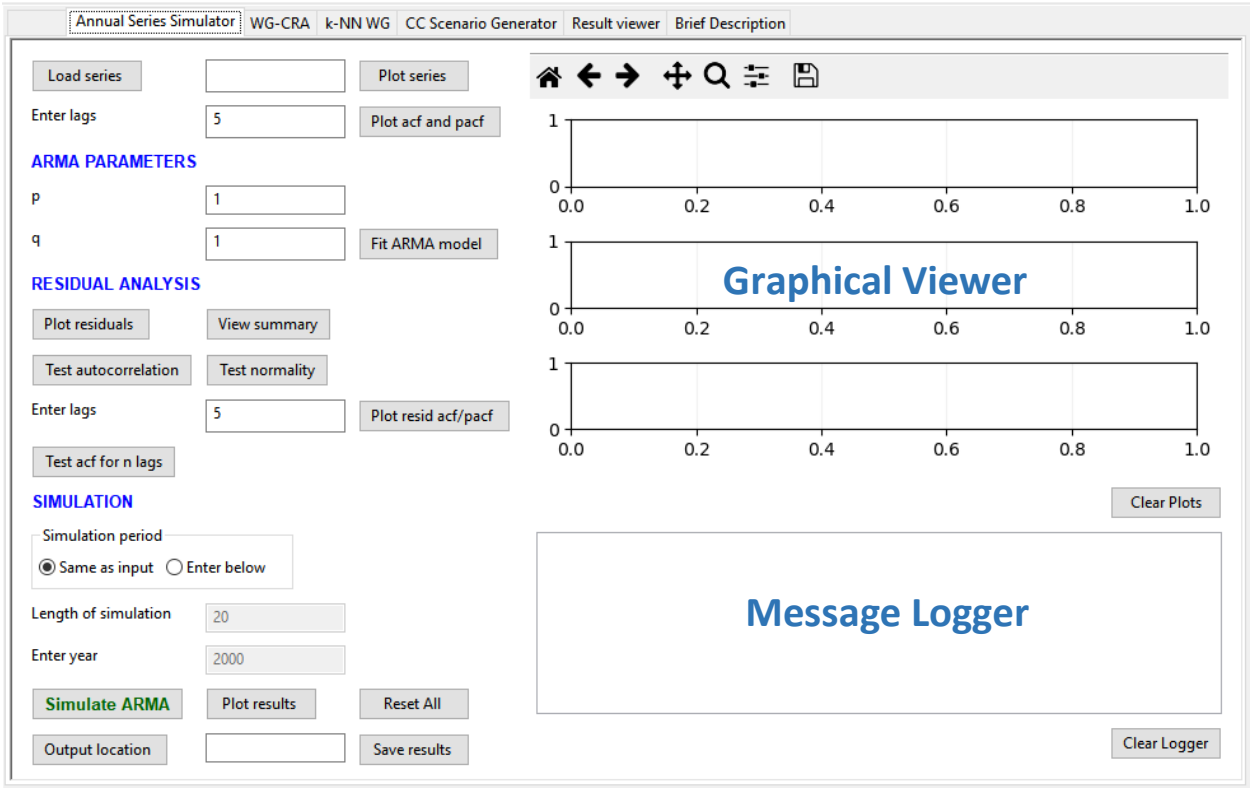
Annual Series Simulator

This chapter describes simulation of the annual precipitation using ARMA method using 'Annual Series Simulator'. Dataset used as example are provided in 'Example_Dataset' folder in the installation folder.

Terminologies and Abbreviations

Terms	Meanings
series	Annual precipitation series
lags	Lags in time steps in ARMA method
acf	Auto-correlation function
pacf	Partial Auto-correlation function
ARMA	Autoregressive Moving Average method for time series data analysis
p	Model order for Autoregressive component of ARMA model of order (p,q)
q	Model order for Moving-Average component of ARMA model of order (p,q)
residuals	Difference in the observations and modelled values
Test autocorrelation	Check for presence of autocorrelation in the residuals
Test normality	Check if the residuals follow normal distribution

Screen shot



This page consists of graphical viewer in order to view the inputs, acf/pacf, residuals, residuals acf/pacf and simulated series. The page also consists of message logger than provides information after an event occurs (like when button is pressed etc).

Steps

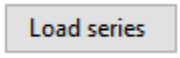
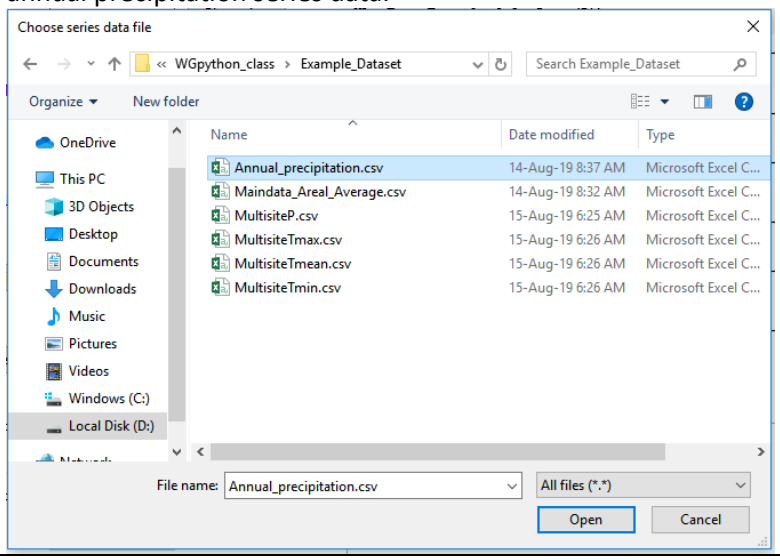
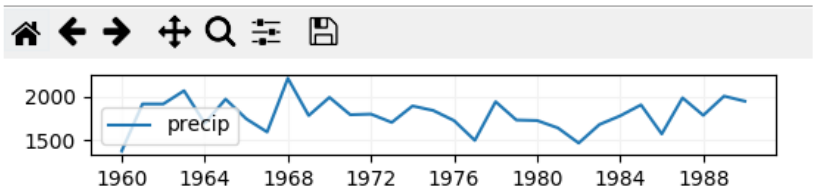
Followings are the steps to simulate the annual precipitation series:

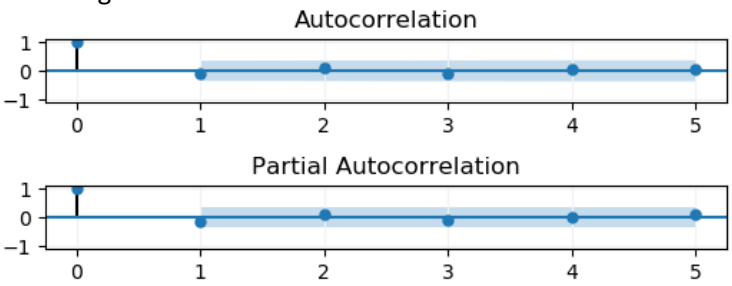
Important notes: Input data for this page is a file consisting of the observed annual precipitation series. It must be in Comma Separated Values (CSV) format. It must have 'Date' column followed by column with precipitation values. Dates in the file will read in 'dayfirst' format. Therefore, the format "dd-mm-yyyy" or "yyyy-mm-dd" for date values is recommended. Snapshot of the file format in Notepad ++ is given below:

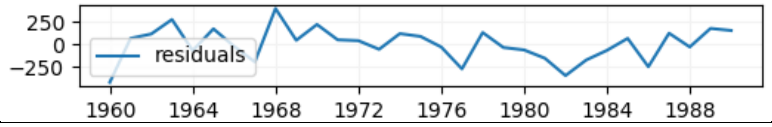
Annual_precipitation.csv

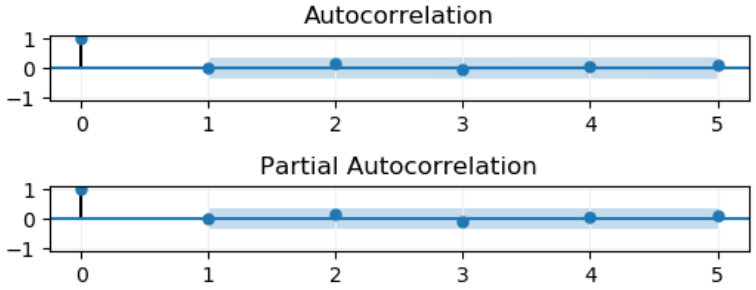
```
Date,precip
1960-01-01,1377
1961-01-01,1901
1962-01-01,1924
1963-01-01,2066
1964-01-01,1696
1965-01-01,1975
```

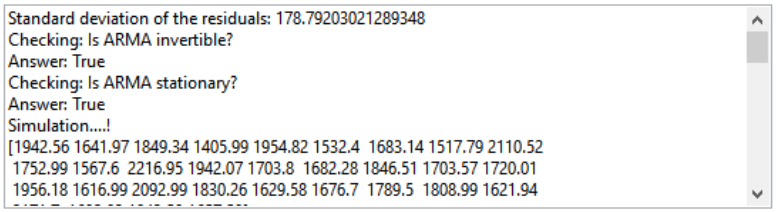
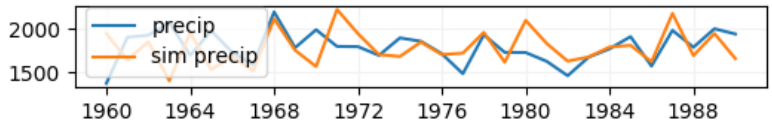
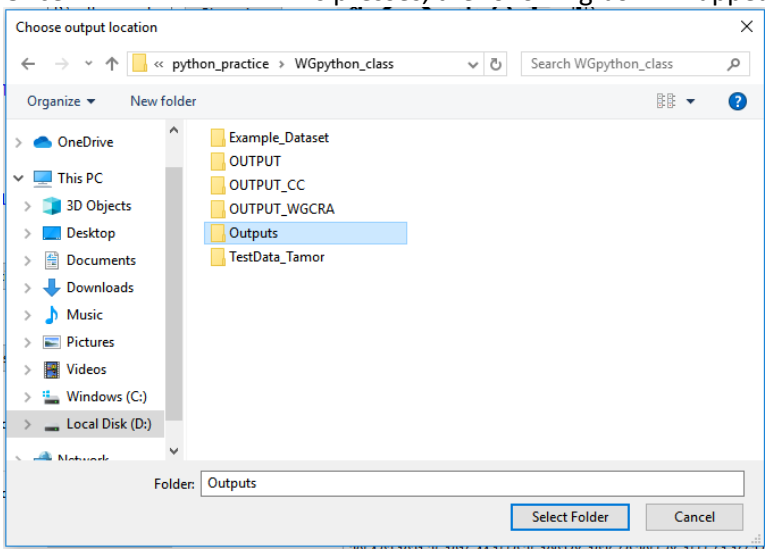
File 'Annual_precipitation.csv' is inside 'Example_Dataset' folder inside installation folder.

Steps	Description
A. Providing and viewing the inputs	
1. Press 'Load series' button 	It will prompt the following window to select the file consisting of annual precipitation series data. 
2. Select the data that consists of observed annual precipitation series and press 'Open' Eg: Annual_precipitation.csv	Once the data is loaded, it can be seen in the graphical viewer as:  The data can viewed in the message logger too as:

	Data loaded and convert into pandas dataframe! Its columns are: Index(['precip'], dtype='object') precip Date 1960-01-01 1377 1961-01-01 1901 1962-01-01 1924 1963-01-01 2066 1964-01-01 1696
	Users can clear the plots pressing [Clear Plots] button.
3. Enter the lags that you want to see the acf / pacf of the loaded series	Enter lags 5
4. To see the plots of acf/pacf, press [Plot acf and pacf] Button.	You will see the graph of acf and pacf in the graphical viewer as following:  Besides, logger will also show the acf / pacf values in the logger. pacf lags 0 1.000000 1 -0.090592 2 0.109933 3 -0.086127 4 0.024404 5 0.100263
B. Supplying the ARMA parameters and fitting the ARMA model	ARMA PARAMETERS
1. User can see ARMA PARAMETERS below which ARMA parameters are to be provided.	This is shown as: ARMA PARAMETERS p 1 q 1 Default values are p = 1 and q = 1
2. Fitting ARMA model by pressing [Fit ARMA model] button.	Once you press [Fit ARMA model] button, following message can appear in the message logger: A. Message A – 'The computed initial AR coefficients are not stationary' When user supply p= 1 and q = 1 using the example dataset, the following message is generated in the logger.

	p: 1 q: 1 ARMA model fit error. Try: 1.Load the data if not loaded 2.Check the data. Fill missing data if exists. 3.>> The computed initial AR coefficients are not stationary You should induce stationarity, choose a different model order, or you can pass your own start_params. This message is generated when the provided ARMA coefficients are inadequate to induce stationarity. So, user have to choose another ARMA parameters. B. Message B – 'SVD did not converge' When user supply p= 2 and q =1 using the example dataset, the following message is generated in the logger. p: 2 q: 1 ARMA model fit error. Try: 1.Load the data if not loaded 2.Check the data. Fill missing data if exists. 3.>> SVD did not converge This is an issue the developers are trying to solve currently and will fix in upcoming version. For now, try different p and q. C. Message C – ARMA results When user supply p= 3 and q = 1 using the example dataset, the following message is generated in the logger. q: 1 const 1786.991409 ar.L1.precip 0.851728 ar.L2.precip 0.202247 ar.L3.precip -0.212007 ma.L1.precip -1.000000 dtype: float64 ARMA Model Results ========== This message shows that ARMA with coefficients p = 3 and q = 1have been fitted to the data. Rest of the results described below are by fitting ARMA(3,1) model to the supplied input.
C. Analyzing the residuals	Users can see **RESIDUAL ANALYSIS** below which are buttons for analysis for residuals
1. Press Clear Plots button to clear the plots before residual analysis.	Plots will be cleared.
2. Press Plot residuals button	Residuals will be plotted as shown below: 
3. Press View summary to view the residuals and its summary in logger.	Residuals and its summary will appear in the logger as:

	Residuals Summary: count 31.000000 mean 7.878837 std 178.792030 min -409.991409 25% -92.490268 50% 31.953885 75% 131.642528 max 413.964140
4. Press [Test autocorrelation] to test presence of autocorrelation in the residuals.	Durbin-Watson statistic will be generated in the message logger as: dtype: float64 The Durbin-Watson statistic will always have a value between 0 and 4. A value of 2.0 means that there is no autocorrelation detected in the sample. Values from 0 to less than 2 indicate positive autocorrelation. Values from from 2 to 4 indicate negative autocorrelation. Durbin Watson statistic = 1.8229485696675585 User can decide if there is autocorrelation in the sample or not. If autocorrelation is present, users have to refit ARMA model with other parameters or use other methods to generate annual series.
5. Press [Test normality] to test normality for the residuals	Results from D'Agostino and Pearson's test for normality will be generated in the message logger. D'Agostino and Pearson's test for normality. Test whether a sample differs from a normal distribution. Null hypothesis that a sample comes from a normal distribution. If p < alpha: Null hypothesis can be rejected. If p >= alpha: Null hypothesis cannot be rejected. K^2 statistic = 1.3176615982257454 p value = 0.5174559909440481 User and decide for alpha (eg. 0.05) and decide for the normality of residuals.
6. Enter the lags that you want to see the acf / pacf of the residuals	Enter lags 5
7. Press [Plot resid acf/pacf] to plot the residual acf and pacf	Once you press the button, the following graphs will appear. 
D. Simulating	**SIMULATION**
1. Please select the options to simulate in the radio button Simulation period (•) Same as input ( ) Enter below	-Option 'Same as input' uses the same year and length of the input series to simulate annual precipitation series. -Option 'Enter below': When clicked the following boxes will activate. Users can supply length of the simulation (years) in 'Length of simulation' box and the starting year in 'Enter year' box. Length of simulation 20 Enter year 2000

<table>
<tr>
<td>2. Simulate new annual precipitation series by pressing Simulate ARMA button.</td>
<td>Once the button is pressed, the new series will be genrated and displayes in the message logger as follows:

</td>
</tr>
<tr>
<td>3.In order to view the simulated series in top of the observed series
Press Clear Plots to clear the plots, and press Plot series
button followed by Plot results button.</td>
<td>The following graphs will appear in the graph viewer

</td>
</tr>
<tr>
<td>4. In order to save the output, please provide the output directory by pressing Output location</td>
<td>Once Output location is presses, the following box will appear:


Please select the folder in which you want to save the results.
Once you press, ‘Select Floder’ the location will show as:
Output location D:\python_practice
Users can change the location in the box if required.</td>
</tr>
<tr>
<td>5. Press Save results to save the results.</td>
<td>File ‘ARMA_annual_series.csv’ will be created in the output directory and the following message will appear in the message logger.
File saved as D:\python_practice\WGpython_class\Outputs\ARMA_annual_series.csv.
Check inside the folder to view the file and its contents.
Example view of output in Notepad ++ is shown below:</td>
</tr>
</table>

	ARMA_annual_series.csv 1 Date,precip 2 1960-01-01,1942.56 3 1961-01-01,1641.97 4 1962-01-01,1849.34 5 1963-01-01,1405.99 6 1964-01-01,1954.82 7 1965-01-01,1532.4 Each time you press Simulate ARMA button new samples will be generated. (So, above results maynot match with what users generate)
6. Press Reset All to reset all the values and setting after the completion of process or anytime in the middle to redo.	It will clear all the values, setting and plots.

Notes:
(a) Outputs are in similar format as of the inputs with 'Date' and annual precipitation variable in csv format.
(b) Users can also simulate annual precipitation series using other methods external to this tool and supply as input for weather generation process in WG-CRA page.

WG-CRA

(Weather generator for Climate Risk Assessment)

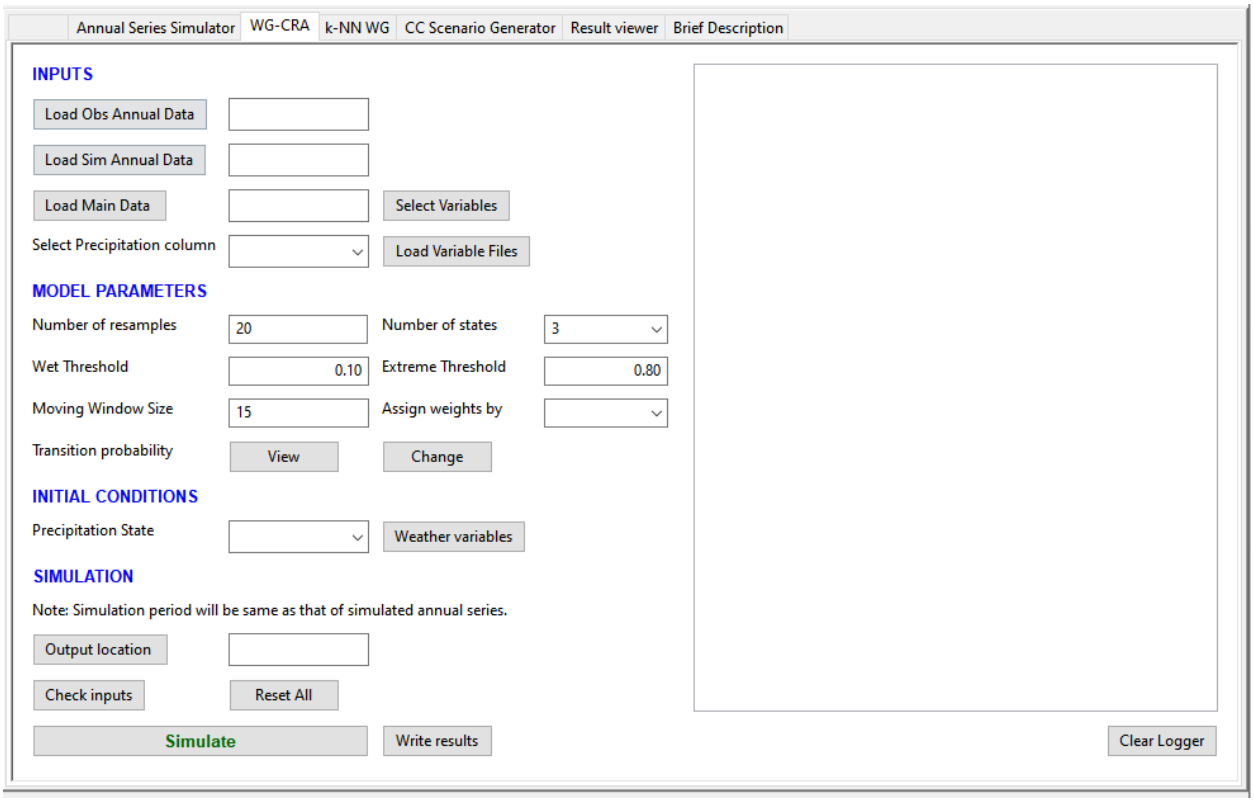
This chapter describes simulation of daily series method using Weather generator as described by Steinschneider and Brown (2013). Example files used in this users' manual are provided in in 'Example_Dataset' folder in the installation folder.

Terminologies and Abbreviations

Terms	Meanings
Obs Annual Data	Observed annual precipitation series
Sim Annual Date	Simulated annual precipitation series
Main Data	It is observed daily series of weather variables (areal average values in case of multisite generation)
Variable File	They are observed daily series files of weather variables. Each variable will have separate file but consists data for multiple stations. Variables are those weather variables that are considered for weather generation process.
Precipitation column	Precipitation column is the name of weather variables which represents 'precipitation' among different weather variables.
Number of resamples	If simulated annual precipitation value for a particular year is P, then its number of resamples made from k-nearest neighbors of P in observed annual series as described in Steinschneider and Brown (2013). Also, please refer section- 'Simulation of weather variables conditioned on annual precipitation series' in the technical documentation.
Number of States	It is number of precipitation states to be included in weather generation. Its either 2 or 3. If number of states is 2, then precipitation states are dry (0) and wet (1). If it is 3, then precipitation states are dry (0), wet (1) and extremely wet (2).
Wet Threshold	If it threshold in absolute value (eg – 0.1 mm) of precipitation to separate wet state from dry state.
Extreme Threshold	It is percentile threshold in fraction (Eg 0.8) to separate wet state from extremely wet state. Rainfall greater than or equal to given threshold percentile is considered to be in extremely wet state.
Moving Window Size	It is length of days (odd integer, minimum of 15) from which k- nearest neighbors are selected for daily weather generation. For example, for 8th of January, when moving window size is 15, its days from 1st January to 15th January from all the years.
Weights type	'Weights type' defines how weather variables are weighed during computation of distance metrics for selecting k-nearest neighbors. In this tool, there are three types (A) 'equal' where all the weather variables have equal weights (equal to 1) (b) 'user_defined' where user is asked to supply weights for each of the variables (c) 'inv_std' (inverse of standard deviation) where weights are inverse of standard deviation of weather variables within the moving window. Refer to Steinschneider and Brown (2013) for more details.
Transition probability	It is the probability with which precipitation state changes from one state into another. If number of states is 2, then there are four transition probabilities, namely, 'p00','p01','p10' and 'p11'. Here, 'p01' means the probability of occurring wet day (state 1) after dry day (state 0). If the number of states is 2,

	then there are nine probabilities, namely, ‘p00’,’p01’,p’02’,’p10’, ‘p11’,’p12’,’p20’,’p21’ and ‘p22’.
Change in transition probability	It is value between -1 and +1 that is applied to change the transition probability. This is to be supplied in case of climate change scenario.
Initial condition – precipitation state	It is the initial precipitation state to start the simulation. Its either 0,1 or 2.
Initial condition – weather variables	They are initial values of weather variables supplied to start the simulation. There units are same as of weather variables.
Multisite weather generation	It is weather generation process at multiple sites simultaneously. Here, ‘site’ means station at which climate data are measured.
Single site weather generation	It is weather generation process at single site only.

Screen shot



Steps

Important notes on inputs:
All the input files for weather variables must in Comma Separated Values (CSV) format. They must all have 'Date' column followed by variables. First line (row) of the file is header where 'Date' and name of variables are declared. Dates in the file will read in 'dayfirst' format. Therefore, the format "dd-mm-yyyy" or "yyyy-mm-dd" for date values is recommended. Values of weather variables are numeric (floats or integer) type. **It is very important that all observed input files must have same 'Date' description and must have same length of data.** Description with snapshots of different input files in Notepad ++ are shown below:

(a) Observed annual precipitation series: This file consists of observed annual precipitation series. Snapshot is shown below:

Annual_precipitation.csv

```
Date,precip
1960-01-01,1377
1961-01-01,1901
1962-01-01,1924
1963-01-01,2066
1964-01-01,1696
1965-01-01,1975
```

(b) Simulated annual precipitation series: This file consists of simulated annual precipitation series. Snapshot is shown below:

ARMA_annual_series.csv

```
Date,precip
1960-01-01,1942.56
1961-01-01,1641.97
1962-01-01,1849.34
1963-01-01,1405.99
1964-01-01,1954.82
1965-01-01,1532.4
```

(c) Main Data: This file consists of daily values of weather variables. In case of multisite weather generation, this file consists of areal average values of weather variables over the study area or basin. In case of single site generation, it consists of values of weather variables at given particular climate measurement station. In both cases, weather variables can be precipitation, temperature (max, min, mean), evapo-transipiration or more. Note that in case of multisite weather generation, values of weather variables for multiple sites are to be provided in separate files, each weather variable with each file. Snapshot of the Main Data file is shown below:

Maindata_Areal_Average.csv

```
Date,precip,tmax,tmin,tmean
1960-01-01,0.0,9.12,-1.34,3.89
1960-01-02,0.0,6.76,-2.32,2.22
1960-01-03,0.0,5.64,-3.47,1.09
1960-01-04,0.0,6.84,-4.61,1.12
1960-01-05,0.0,8.7,-3.04,2.83
1960-01-06,0.0,8.8,-1.76,3.52
```

Important notes on inputs (continued…):

(d) Variable files: These are applicable only in case of multisite weather generation. Data for each of the weather variables are supplied in separate CSV files. Inside the file, data for each of the sites are provided. Number of stations for different weather variables may or may not be same, for instance, there can be more precipitation stations than temperature stations in an area. Snapshot of input file for precipitation and 'Tmean' variables are show below:

Precipitation – Example file – 'MultisiteP.csv'

MultisiteP.csv

```
Date,P1,P2,P3,P4,P5,P6,P7,P8,P9
1960-01-01,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
1960-01-02,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
1960-01-03,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
1960-01-04,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
1960-01-05,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
1960-01-06,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
```

In above file, P1, P2, P3, P4, P5, P6, P7, P8 and P9 are precipitation stations.

Mean Temperature – Example file – 'MultisiteTmean.csv'

MultisiteTmean.csv

```
Date,T1,T3,T5,T6
1960-01-01,13.3,12.2,9.8,14.65
1960-01-02,11.47,10.37,8.22,12.82
1960-01-03,10.33,8.98,7.18,11.53
1960-01-04,10.5,9.0,7.2,11.55
1960-01-05,12.25,10.95,8.8,13.5
1960-01-06,12.91,11.71,9.46,14.26
```

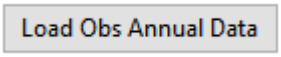
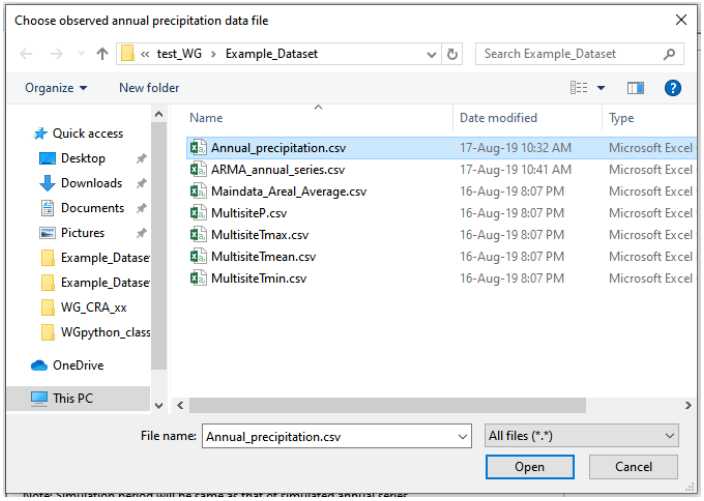
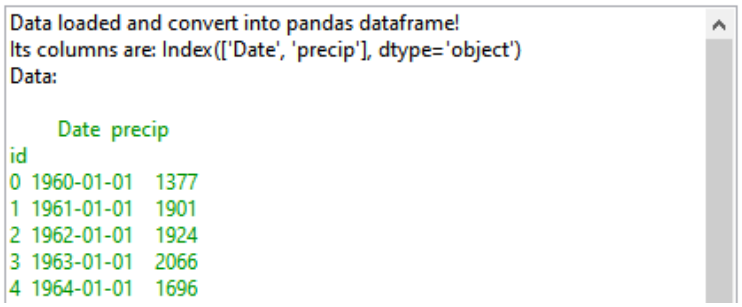
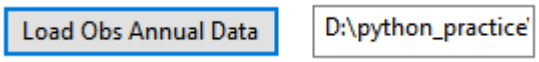
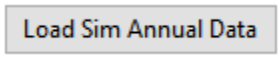
In above file, T1, T3, T5 and T6 are temperature stations.

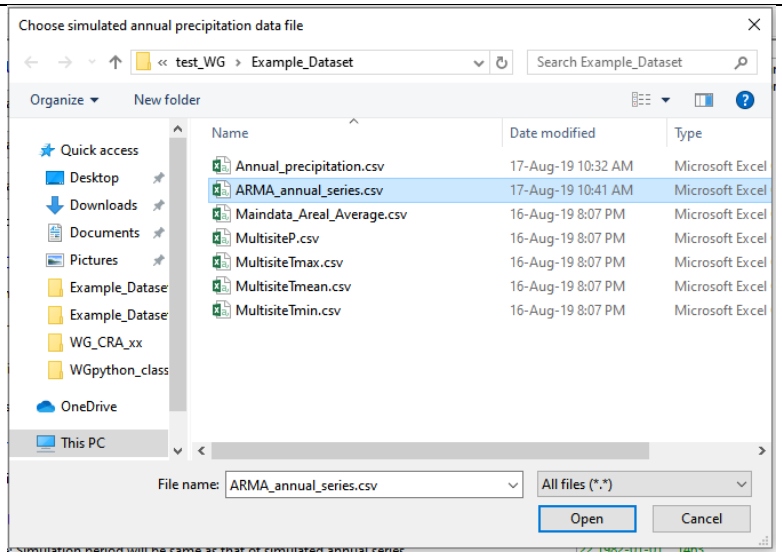
(e) Transition probability change file: This file contains changes to be made in transition probabilities. It must have 'month' column and columns for changes in transitional probabilities. When number of states is 3, the file look like:

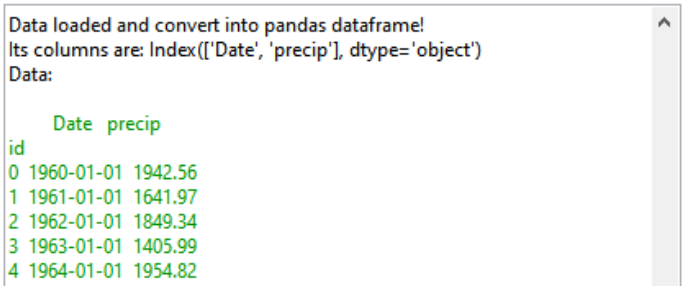
changes_TP.csv

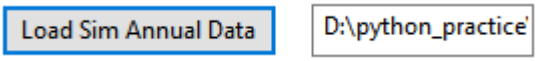
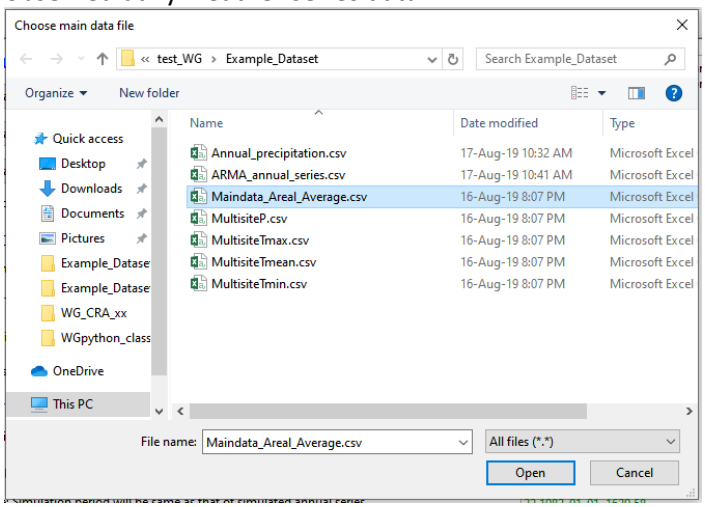
```
month,p00,p01,p02,p10,p11,p12,p20,p21,p22
1,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
2,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
3,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
4,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
5,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
6,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
7,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
8,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
9,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
10,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
11,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
12,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
```

Note: Sum of changes in probabilities for given predecessor state should be zero and individual changes in probability should be between -1 and +1. Also, it should be taken care beforehand that after applying changes, probabilities with should be between 0 and 1. If those criteria doesn't hold, it will revert to original transition probability.

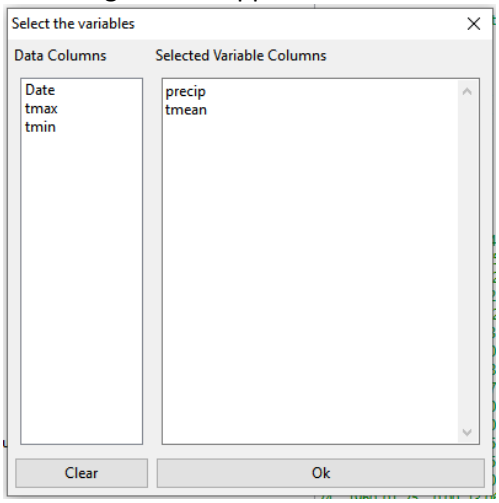
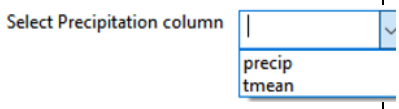
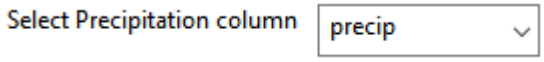
Steps	Description
A. Providing the inputs	**INPUTS**
1. Load the observed annual series by pressing 'Load Obs Annual Data' button 	It will prompt the following window to select the file consisting of observed annual precipitation series data.  Select the file and press 'Open'. Once it is pressed, it will be loaded and it can be seen in the message logger.  Besides, file location will be displayed as: 
2. Load simulated annual series by pressing 'Load Sim Annual Data' button 	It will prompt following window to select the file consisting of simulated annual precipitation series data.

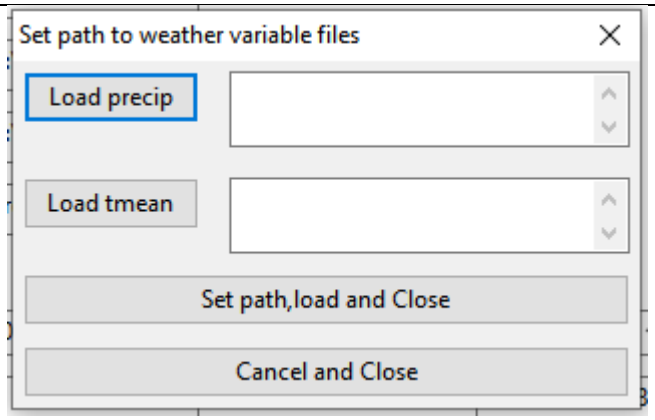
<table>
<tr>
<td></td>
<td> 

Select the file and press ‘Open’. Once it is pressed, it will be loaded and it can be seen in the message logger.
 

Besides, file location will be displayed as:
 
</td>
</tr>
<tr>
<td>3. Load daily weather series data by pressing ‘Load Main Data’ button
 
</td>
<td>It will prompt following window to select the file consisting of observed daily weather series data.
 

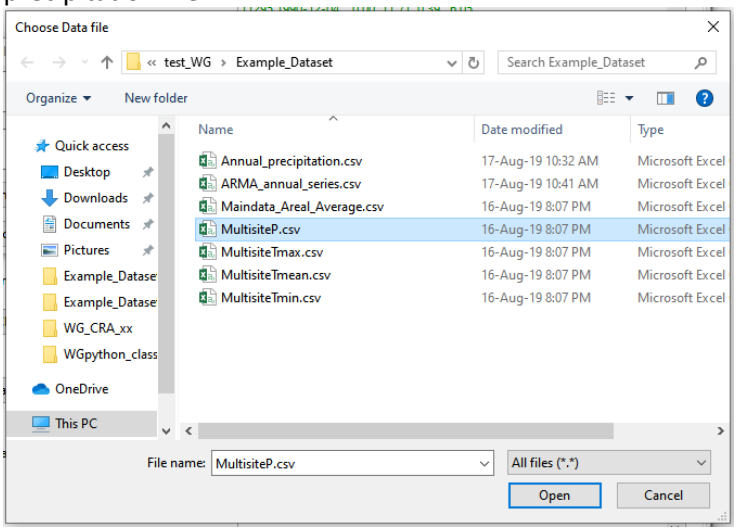
Select the file and press ‘Open’. Once it is pressed, it will be loaded and it can be seen in the message logger.</td>
</tr>
</table>

	Data loaded and convert into pandas dataframe! Its columns are: Index(['Date', 'precip', 'tmax', 'tmin', 'tmean'], dtype='object') Data: Date precip tmax tmin tmean id 0 1960-01-01 0.00 9.12 -1.34 3.89 1 1960-01-02 0.00 6.76 -2.32 2.22 2 1960-01-03 0.00 5.64 -3.47 1.09 3 1960-01-04 0.00 6.84 -4.61 1.12 4 1960-01-05 0.00 8.70 -3.04 2.83
4. Now select weather variables that you consider for weather generation by pressing Select Variables button.	Following box will appear and user can select the variables as follows:  After selecting variables, please select 'Ok' button. If there is mistake in selecting, user can press 'Clear' button and reselect again. For demonstration, 'precip' and 'tmean' is selected now. Following message will appear in message logger: Selected variables are: ['precip', 'tmean'] Note: Variables shown in 'Data Columns' are the data columns in Main Data File.
5. Declare the precipitation variable among the variables selected by from drop-down button.  	Select 'precip' in this example. Once selected, it will appear as below:  And following message will appear in the logger. precipitation_column is precip.
6. In case of multisite generation, provide the multisite weather data files by pressing Load Variable Files button.	Once pressed, the following box will be prompted for selection of the files.

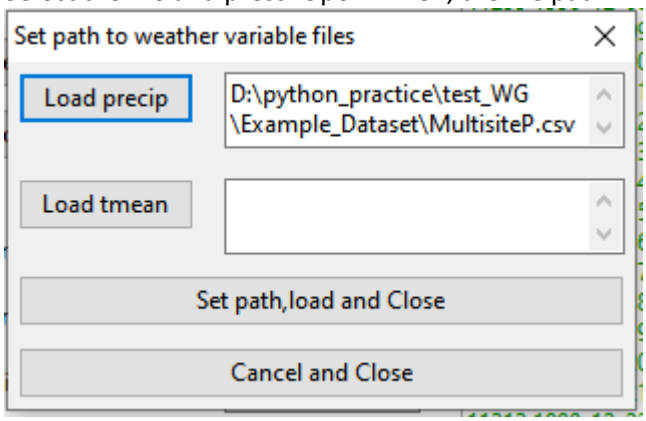


Press ‘Load precip’ to load precipitation file and ‘Load tmean’ to load ‘tmean file’. If more variables are selected before, then they will also appear in the list.

Once ‘Load precip’ is presses, following box will appear asking for the precipitation file:

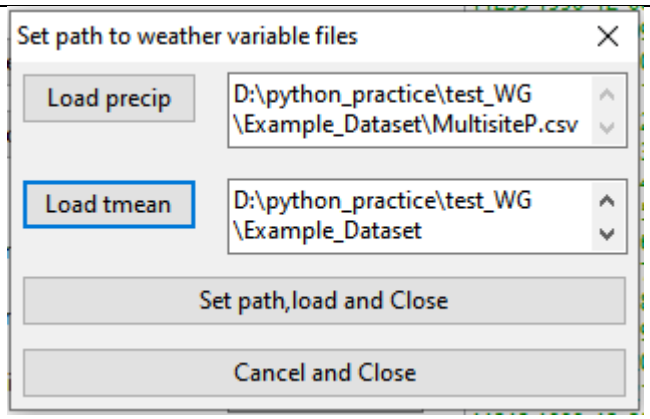
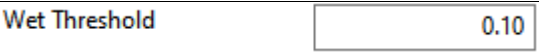
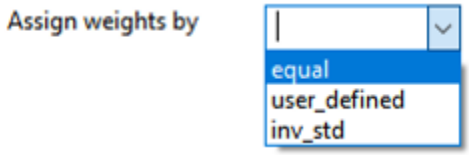


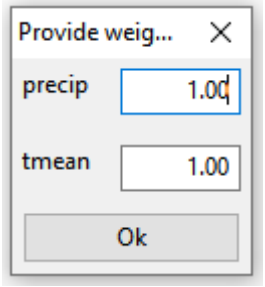
Select the file and press ‘Open’. Then, the file path will be loaded as

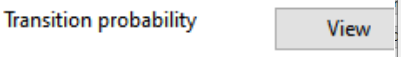


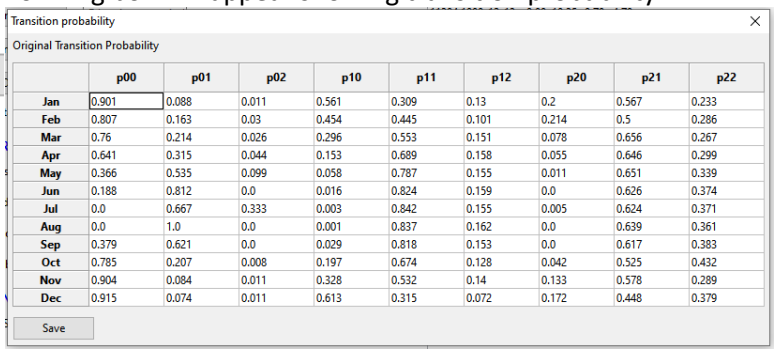
Repeat similar steps for loading other weather variable files, in this example for ‘tmean’.

Once, you load ‘tmean’, box will be seen as:

	 Press 'Set path, load and Close' button for loading purpose else press 'Cancel and Close' to cancel. Once you press 'Set path, load and Close' button, the files will read and loaded; and following message will appear in the message logger. Path of variable files are: {'precip': 'D:\\python_practice\\test_WG\\Example_Dataset \\MultisiteP.csv', 'tmean': 'D:\\python_practice\\test_WG \\Example_Dataset\\MultisiteTmean.csv'} File D:\python_practice\test_WG\Example_Dataset\MultisiteP.csv loaded as precip! File D:\python_practice\test_WG\Example_Dataset\MultisiteTmean.csv loaded as tmean! This will complete providing the input files and user now have to supply model parameters.
B. Providing model parameters	MODEL PARAMETERS
1. Enter Number of Resamples	 Default is 20. Users are recommeded not to go beyond 100 as it will increase computation burden.
2. Enter Number of States	 Default is 3. Users hs option to choose state-2 from dropdown button.
3. Provide Wet Threshold	 Default is 0.10 (mm). If the unit of precipitation is 'inch', it will imply 0.10 inch.
4. Provide Extreme Threshold	 Default is 0.80. This is in fraction and it represents percentile.
5. Provide Moving Window Size	 Default is 15. Users are recommeded not to use lower values as it will decrease the search space for finding k nearest neighbors.
6. Provide Weights type	 There are three options, namely, 'equal', 'user_defined' and 'inv_std'.

<table>
<tr>
<td></td>
<td>If ‘user_defined’ is selected, users are asked to enter user-defined weights as follows:
 

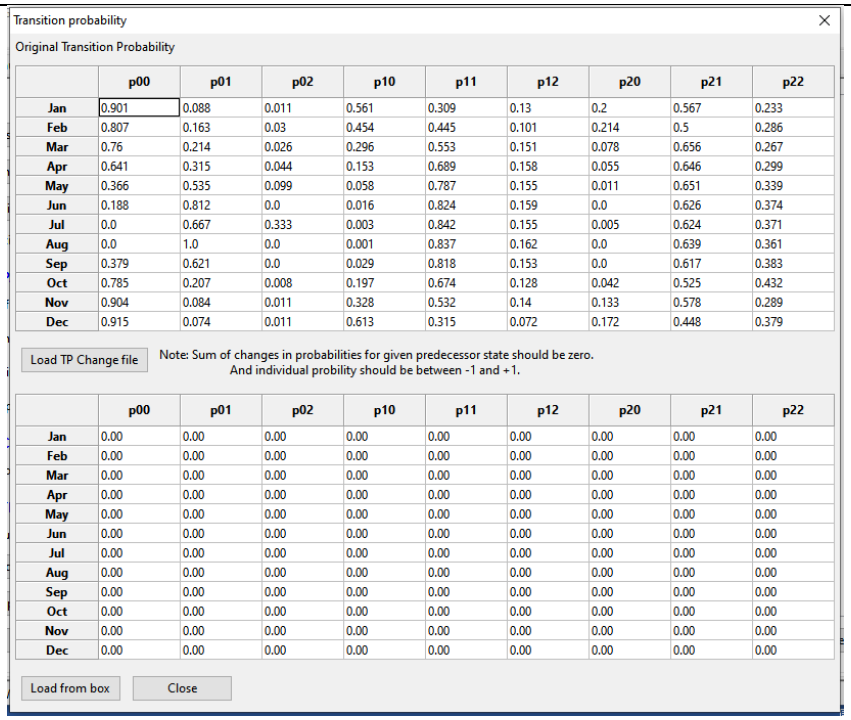
Provide the weights and press ‘Ok’.
Selection of any weights type will prompt the following message in the logger:
(a) in case of ‘equal’ weights type
Weighing method given to weigh the variables in k-NN is 'equal'.
(b) in case of ‘user_defined’
Weighing method given to weigh the variables in k-NN is 'user_defined'.
'user_defined' weights set to [1.0, 1.0]
(Default user defined weight to each of weatehr variable is 1.)
(c) inc ase of ‘inv_std’ weights type
Weighing method given to weigh the variables in k-NN is 'inv_std'.
(In this manual, it will continued with ‘equal’ weights type.)</td>
</tr>
<tr>
<td>7. Users can view transition probability by pressing
 

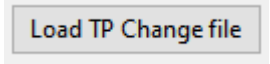
Button.</td>
<td>Follwing box will appear showing transition probability:
 

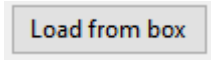
	p00	p01	p02	p10	p11	p12	p20	p21	p22
Jan	0.901	0.088	0.011	0.561	0.309	0.13	0.2	0.567	0.233
Feb	0.807	0.163	0.03	0.454	0.445	0.101	0.214	0.5	0.286
Mar	0.76	0.214	0.026	0.296	0.553	0.151	0.078	0.656	0.267
Apr	0.641	0.315	0.044	0.153	0.689	0.158	0.055	0.646	0.299
May	0.366	0.535	0.099	0.058	0.787	0.155	0.011	0.651	0.339
Jun	0.188	0.812	0.0	0.016	0.824	0.159	0.0	0.626	0.374
Jul	0.0	0.667	0.333	0.003	0.842	0.155	0.005	0.624	0.371
Aug	0.0	1.0	0.0	0.001	0.837	0.162	0.0	0.639	0.361
Sep	0.379	0.621	0.0	0.029	0.818	0.153	0.0	0.617	0.383
Oct	0.785	0.207	0.008	0.197	0.674	0.128	0.042	0.525	0.432
Nov	0.904	0.084	0.011	0.328	0.532	0.14	0.133	0.578	0.289
Dec	0.915	0.074	0.011	0.613	0.315	0.072	0.172	0.448	0.379

Users can save it by pressing ‘Save’ Button and cancel the view by pressing ‘X’ in top-right corner of the window.</td>
</tr>
<tr>
<td>8. Users can enforce changes in transition probability by pressing
 

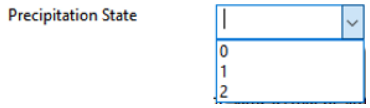
button.</td>
<td>Following window will appear.</td>
</tr>
</table>

<table>
<tr><td></td><td> 

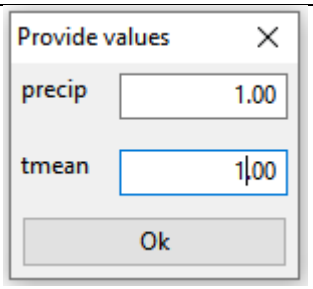
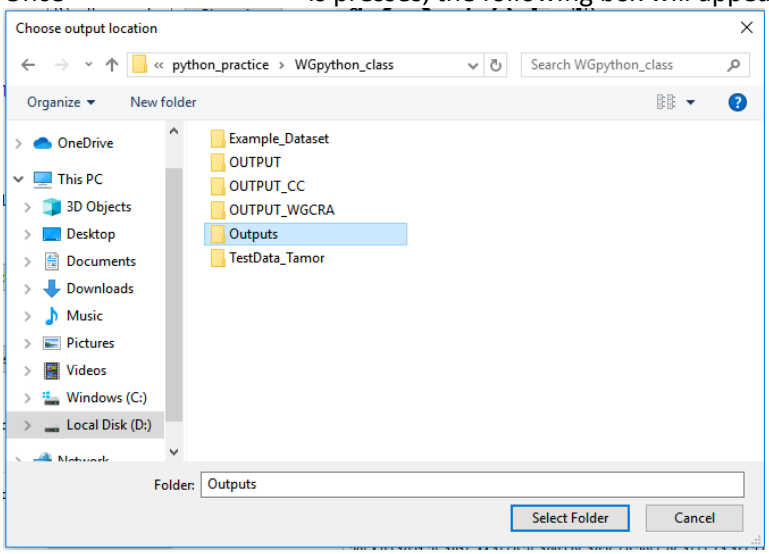
Users can load the changes that are to be enfored from file by pressing 

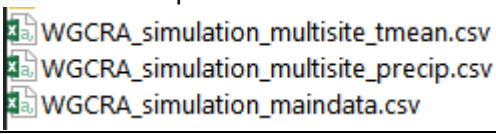
button.
Or, users can supply changes values in the box and press 

button.
It is important to note that sum of changes in probabilites for given predecessor state should be zero and individual changes in probability should be between -1 and +1. Also, it should be taken care beforehand that after applying changes, probabilities with should be between 0 and 1. If those criteria doesn't hold, it will revert to original transition probability.
Once window is cloased, the cahnges will load.
Note: If you are not changing transtion probability, please don't press this 

button.</td></tr>
<tr><td>C. Providing initial conditions</td><td>INITIAL CONDITIONS</td></tr>
<tr><td>1. Provide initial precipitation state for simulation by selection from drop-down options:
 
</td><td>Options are 0, 1 and 2. Once selected, it will appear as:
 

Message will also appear in message logger.
Initial precipitation state is 0.</td></tr>
<tr><td>2. Supply initial values of weather variables by pressing</td><td>The following box will appear for provinding values:</td></tr>
</table>

Weather variables button.	 Default value of weather variable is 1. However, users have to carefully supply the values. In this example, 'precip' value of 0 and 'tmean' value of 4 is supplied. The following message will appear in logger. Intial values of weather variables set to [0.0, 4.0]
D. Running Simulation	**SIMULATION** It is to be noted that simulation period will be same as simulated annual series.
1. In order to save the output, please provide the output directory by pressing Output location	Once Output location is presses, the following box will appear:  Please select the folder in which you want to save the results. Once you press, 'Select Floder' the location will show as: Output location D:\python_practice Users can change the location in the box if required.
2. Check if inputs are supplied correctly by pressing Check inputs	It will display all the inputs in the logger. If everything goes okay, then following message will appear in the logger. Ready to simulate!
3. Once Ready to simulate! message appears in the logger, press Simulate to simulate.	Message showing start of simualtion will appear as follows: Starting simulation... Simulating - Year: 1960, Annual precipitation: 1942.56 It will take few minutes to complete simulation. Time taken to simulate depends upon computer preformance. Once simulation is ended, the following messge will appear in the logger:

	Simulating - Year: 1990, Annual precipitation: 1657.59 Simulation ended! Besides, simulated data will also be displayed.
4. To save the results, press  button.	It will save the outputs inside provided location. All the outputs are saved inside OUTPUT_WGCRA folder. Message will appear in the logger similar as: File outputs will be created in: D:\python_practice\test_WG\Example_Dataset\OUTPUT_WGCRA Output files created! Please check inside the folder OUTPUT_WGCRA. You will find simulation output files similar as below: 
5. Press  to reset all the values and setting after the completion of process or anytime in the middle to redo.	It will clear all the values and settings.

k-NN WG

(k-Nearest Neighbor Weather Generator)

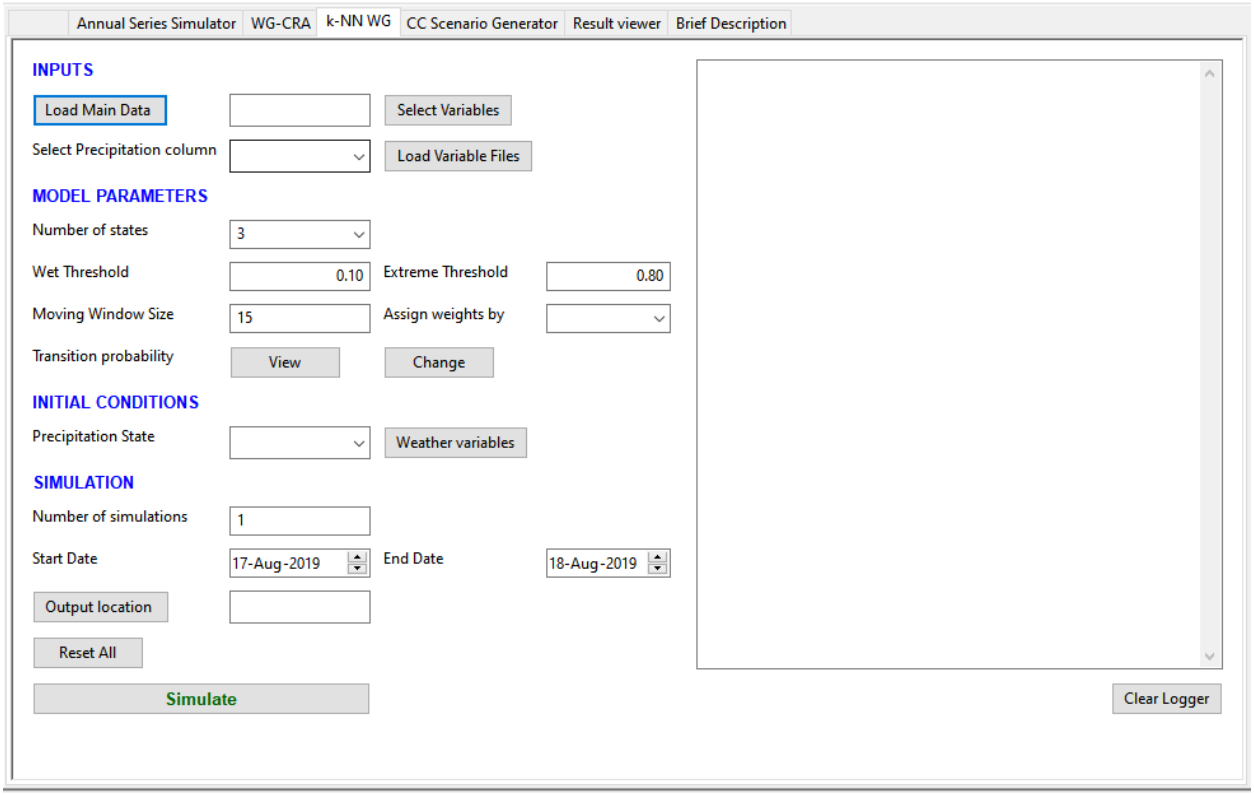
This chapter describes simulation of daily series method using weather generator as described by Apipattanavis et al (2007) and Steinschneider and Brown (2013). Example files used in this users' manual are provided in in 'Example_Dataset' folder in the installation folder.

Terminologies and Abbreviations

Terms	Meanings
Main Data	It is observed daily series of weather variables (areal average values in case of multisite generation)
Variable File	They are observed daily series files of weather variables. Each variable will have separate file but consists data for multiple stations. Variables are those weather variables that are considered for weather generation process.
Precipitation column	Precipitation column is the name of weather variables which represents 'precipitation' among different weather variables.
Number of resamples	If simulated annual precipitation value for a particular year is P, then its number of resamples made from k-nearest neighbors of P in observed annual series as described in Steinschneider and Brown (2013). Also, please refer section- 'Simulation of weather variables conditioned on annual precipitation series' in the technical documentation.
Number of States	It is number of precipitation states to be included in weather generation. Its either 2 or 3. If number of states is 2, then precipitation states are dry (0) and wet (1). If it is 3, then precipitation states are dry (0), wet (1) and extremely wet (2).
Wet Threshold	If it threshold in absolute value (eg – 0.1 mm) of precipitation to separate wet state from dry state.
Extreme Threshold	It is percentile threshold in fraction (Eg 0.8) to separate wet state from extremely wet state. Rainfall greater than or equal to given threshold percentile is considered to be in extremely wet state.
Moving Window Size	It is length of days (odd integer, minimum of 15) from which k- nearest neighbors are selected for daily weather generation. For example, for 8th of January, when moving window size is 15, its days from 1st January to 15th January from all the years.
Weights type	'Weights type' defines how weather variables are weighed during computation of distance metrics for selecting k-nearest neighbors. In this tool, there are three types (A) 'equal' where all the weather variables have equal weights (equal to 1) (b) 'user_defined' where user is asked to supply weights for each of the variables (c) 'inv_std' (inverse of standard deviation) where weights are inverse of standard deviation of weather variables within the moving window. Refer to Steinschneider and Brown (2013) for more details.
Transition probability	It is the probability with which precipitation state changes from one state into another. If number of states is 2, then there are four transition probabilities, namely, 'p00','p01','p10' and 'p11'. Here, 'p01' means the probability of occurring wet day (state 1) after dry day (state 0). If the number of states is 2, then there are nine probabilities, namely, 'p00','p01',p'02','p10', 'p11','p12','p20','p21' and 'p22'.

Change in transition probability	It is value between -1 and +1 that is applied to change the transition probability. This is to be supplied in case of climate change scenario.
Initial condition – precipitation state	It is the initial precipitation state to start the simulation. Its either 0,1 or 2.
Initial condition – weather variables	They are initial values of weather variables supplied to start the simulation. There units are same as of weather variables.
Multisite weather generation	It is weather generation process at multiple sites simultaneously. Here, 'site' means station at which climate data are measured.
Single site weather generation	It is weather generation process at single site only.

Screen shot



Steps

Important notes on inputs:
All the input files for weather variables must in Comma Separated Values (CSV) format. They must all have 'Date' column followed by variables. First line (row) of the file is header where 'Date' and name of variables are declared. Dates in the file will read in 'dayfirst' format. Therefore, the format "dd-mm-yyyy" or "yyyy-mm-dd" for date values is recommended. Values of weather variables are numeric (floats or integer) type. **It is very important that all observed input files must have same 'Date' description and must have same length of data.** Description with snapshots of different input files in Notepad ++ are shown below:

(a) Main Data: This file consists of daily values of weather variables. In case of multisite weather generation, this file consists of areal average values of weather variables over the study area or basin. In case of single site generation, it consists of values of weather variables at given particular climate measurement station. In both cases, weather variables can be precipitation, temperature (max, min, mean), evapo-transipiration or more. Note that in case of multisite weather generation, values of weather variables for multiple sites are to be provided in separate files, each weather variable with each file. Snapshot of the Main Data file is shown below:

Maindata_Areal_Average.csv

```
1  Date,precip,tmax,tmin,tmean
2  1960-01-01,0.0,9.12,-1.34,3.89
3  1960-01-02,0.0,6.76,-2.32,2.22
4  1960-01-03,0.0,5.64,-3.47,1.09
5  1960-01-04,0.0,6.84,-4.61,1.12
6  1960-01-05,0.0,8.7,-3.04,2.83
7  1960-01-06,0.0,8.8,-1.76,3.52
```

(b) Variable files: These are applicable only in case of multisite weather generation. Data for each of the weather variables are supplied in separate CSV files. Inside the file, data for each of the sites are provided. Number of stations for different weather variables may or may not be same, for instance, there can be more precipitation stations than temperature stations in an area. Snapshot of input file for precipitation and 'Tmean' variables are show below:
Precipitation – Example file – 'MultisiteP.csv'

MultisiteP.csv

```
1  Date,P1,P2,P3,P4,P5,P6,P7,P8,P9
2  1960-01-01,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
3  1960-01-02,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
4  1960-01-03,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
5  1960-01-04,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
6  1960-01-05,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
7  1960-01-06,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
```

In above file, P1, P2, P3, P4, P5, P6, P7, P8 and P9 are precipitation stations.

Important notes on inputs (continued…):

Mean Temperature – Example file – 'MultisiteTmean.csv'

MultisiteTmean.csv

```
Date,T1,T3,T5,T6
1960-01-01,13.3,12.2,9.8,14.65
1960-01-02,11.47,10.37,8.22,12.82
1960-01-03,10.33,8.98,7.18,11.53
1960-01-04,10.5,9.0,7.2,11.55
1960-01-05,12.25,10.95,8.8,13.5
1960-01-06,12.91,11.71,9.46,14.26
```

In above file, T1, T3, T5 and T6 are temperature stations.

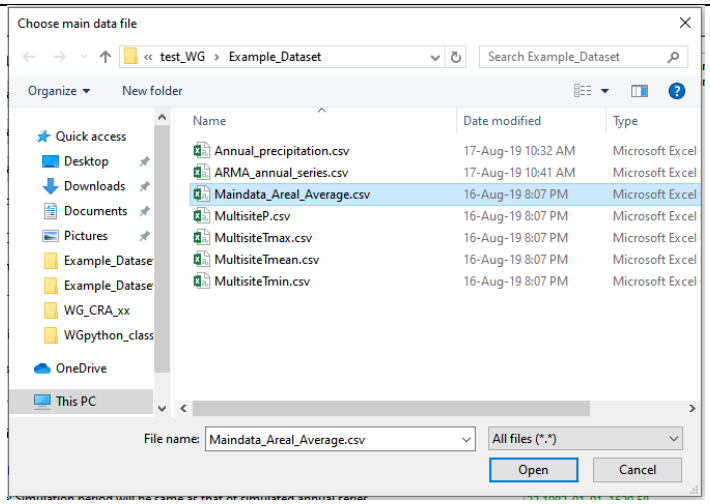
(c) Transition probability change file: This file contains changes to be made in transition probabilities. It must have 'month' column and columns for changes in transitional probabilities. When number of states is 3, the file look like:

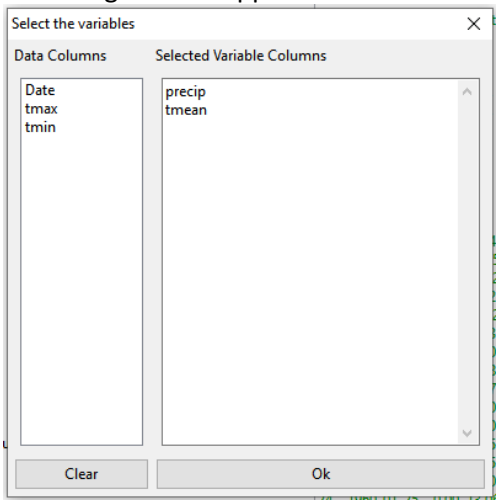
changes_TP.csv

```
month,p00,p01,p02,p10,p11,p12,p20,p21,p22
1,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
2,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
3,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
4,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
5,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
6,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
7,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
8,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
9,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
10,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
11,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
12,0.05,-0.05,0.0,0.0,0.0,0.0,0.0,0.0,0.0
```

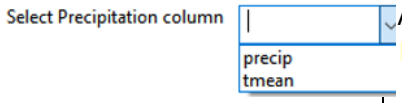
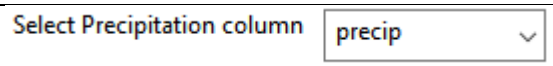
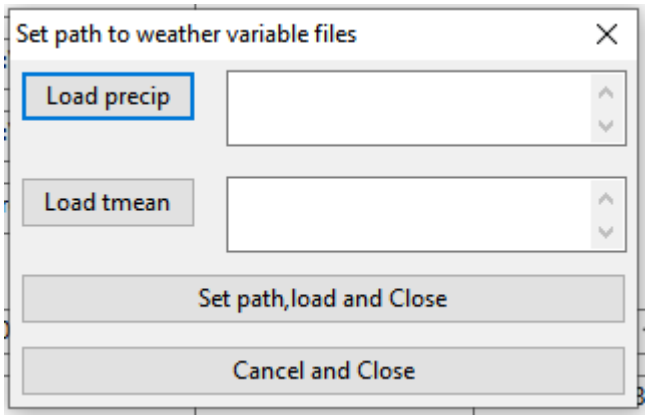
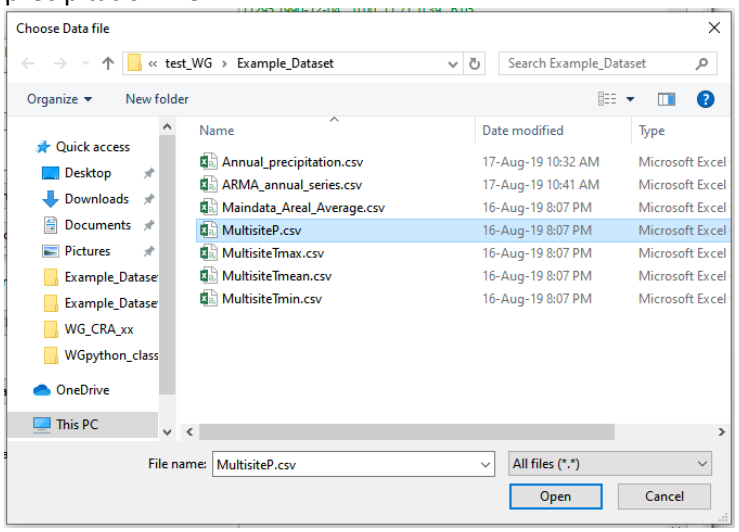
Note: Sum of changes in probabilities for given predecessor state should be zero and individual changes in probability should be between -1 and +1. Also, it should be taken care beforehand that after applying changes, probabilities with should be between 0 and 1. If those criteria doesn't hold, it will revert to original transition probability.

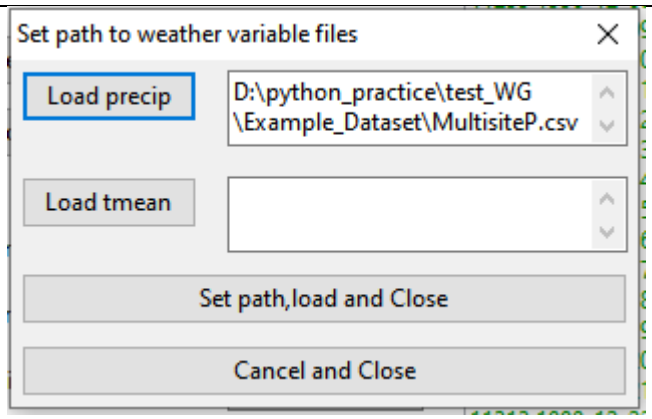
Steps	Description
A. Providing the inputs	**INPUTS**
1. Load daily weather series data by pressing 'Load Main Data' button 	It will prompt following window to select the file consisting of observed daily weather series data.

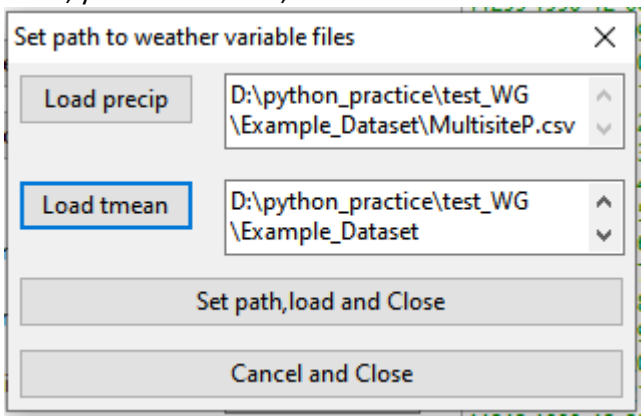
<table>
<tr><td></td><td> 

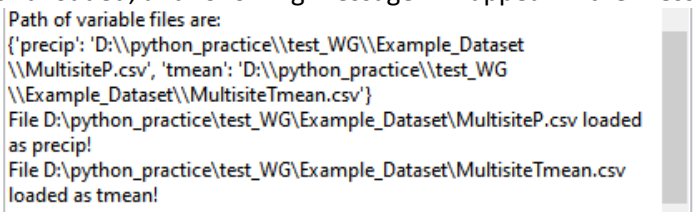
Select the file and press ‘Open’. Once it is pressed, it will be loaded and it can be seen in the message logger.
Data loaded and convert into pandas dataframe!
Its columns are: Index(['Date', 'precip', 'tmax', 'tmin', 'tmean'], dtype='object')
Data:
<table>
<tr><th></th><th>Date</th><th>precip</th><th>tmax</th><th>tmin</th><th>tmean</th></tr>
<tr><td>id</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>0</td><td>1960-01-01</td><td>0.00</td><td>9.12</td><td>-1.34</td><td>3.89</td></tr>
<tr><td>1</td><td>1960-01-02</td><td>0.00</td><td>6.76</td><td>-2.32</td><td>2.22</td></tr>
<tr><td>2</td><td>1960-01-03</td><td>0.00</td><td>5.64</td><td>-3.47</td><td>1.09</td></tr>
<tr><td>3</td><td>1960-01-04</td><td>0.00</td><td>6.84</td><td>-4.61</td><td>1.12</td></tr>
<tr><td>4</td><td>1960-01-05</td><td>0.00</td><td>8.70</td><td>-3.04</td><td>2.83</td></tr>
</table></td></tr>
<tr><td>2. Now select weather variables that you consider for weather generation by pressing
Select Variables button.</td><td>Following box will appear and user can select the variables as follows:
 

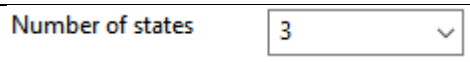
After selecting variables, please select ‘Ok’ button. If there is mistake in selecting, user can press ‘Clear’ button and reselect again.
For demonstration, ‘precip’ and ‘tmean’ is selected now.
Following message will appear in message logger:
Selected variables are: ['precip', 'tmean']
Note: Variables shown in ‘Data Columns’ are the data columns in Main Data File.</td></tr>
<tr><td>3. Declare the precipitation variable among the variables</td><td>Select ‘precip’ in this example. Once selected, it will appear as below:</td></tr>
</table>

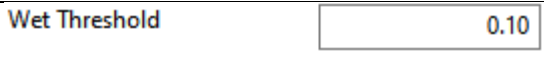
selected by from drop-down button. 	 And following message will appear in the logger. precipitation_column is precip.
4. In case of multisite generation, provide the multisite weather data files by pressing  button.	Once pressed, the following box will be prompted for selection of the files.  Press 'Load precip' to load precipitation file and 'Load tmean' to load 'tmean file'. If more variables are selected before, then they will also appear in the list. Once 'Load precip' is presses, following box will appear asking for the precipitation file:  Select the file and press 'Open'. Then, the file path will be loaded as

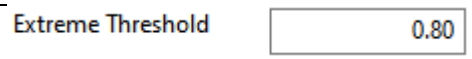
<table>
<tr><td></td><td> 

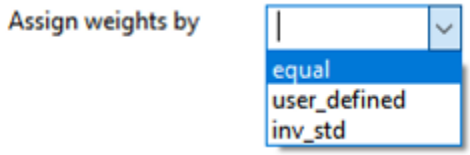
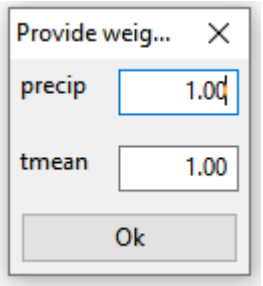
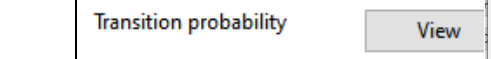
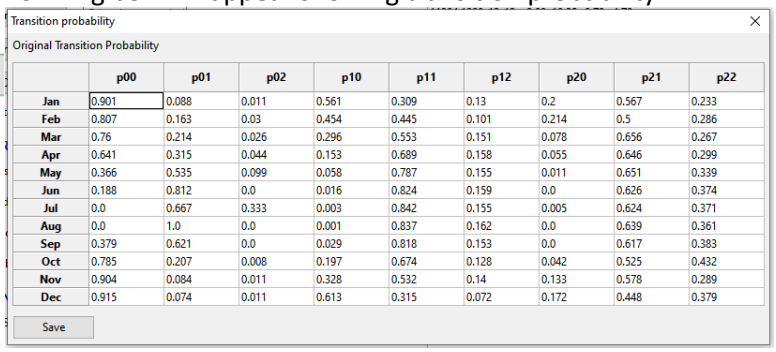
Repeat similar steps for loading other weather variable files, in this example for ‘tmean’.
Once, you load ‘tmean’, box will be seen as:
 

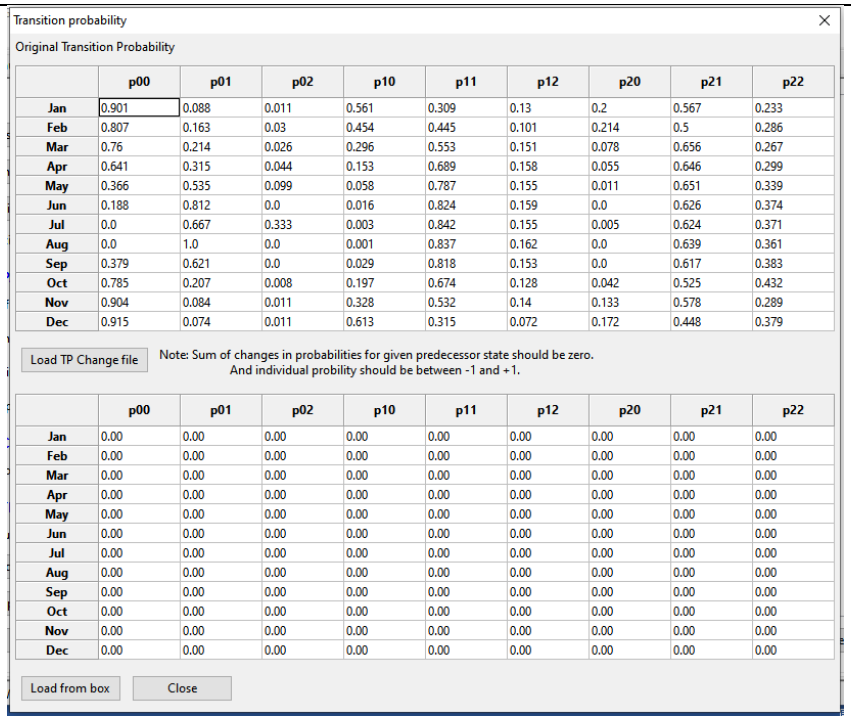
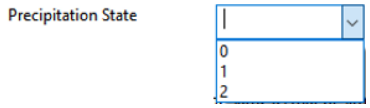
Press ‘Set path, load and Close’ button for loading purpose else press ‘Cancel and Close’ to cancel.
Once you press ‘Set path, load and Close’ button, the files will read and loaded; and following message will appear in the message logger.
 

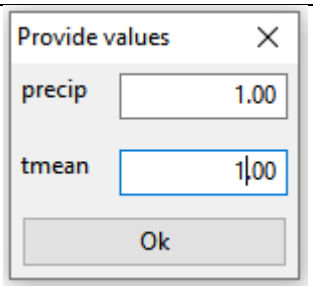
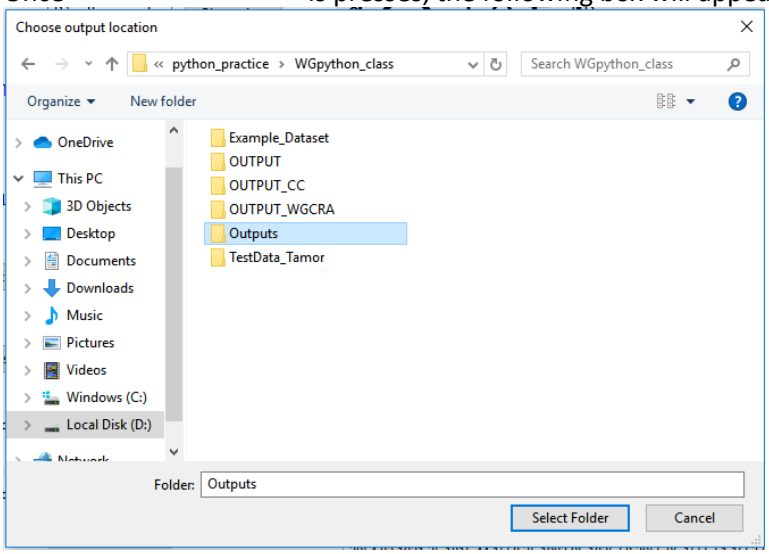
This will complete providing the input files and user now have to supply model parameters.</td></tr>
<tr><td>B. Providing model parameters</td><td>MODEL PARAMETERS</td></tr>
<tr><td>1. Enter Number of States</td><td> 

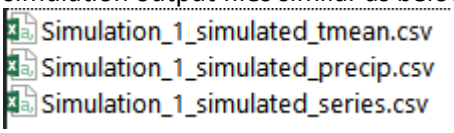
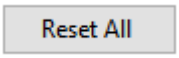
Default is 3. Users hs option to choose state-2 from dropdown button.</td></tr>
<tr><td>2. Provide Wet Threshold</td><td> 

Default is 0.10 (mm). If the unit of precipitation is ‘inch’, it will imply 0.10 inch.</td></tr>
<tr><td>3. Provide Extreme Threshold</td><td> 
</td></tr>
</table>

	Default is 0.80. This is in fraction and it represents percentile.
4. Provide Moving Window Size	 Default is 15. Users are recommeded not to use lower values as it will decrease the search space for finding k nearest neighbors.
5. Provide Weights type	 There are three options, namely, 'equal', 'user_defined' and 'inv_std'. If 'user_defined' is selected, users are asked to enter user-defined weights as follows:  Provide the weights and press 'Ok'. Selection of any weights type will prompt the following message in the logger: (a) in case of 'equal' weights type Weighing method given to weigh the variables in k-NN is 'equal'. (b) in case of 'user_defined' Weighing method given to weigh the variables in k-NN is 'user_defined'. 'user_defined' weights set to [1.0, 1.0] (Default user defined weight to each of weatehr variable is 1.) (c) inc ase of 'inv_std' weights type Weighing method given to weigh the variables in k-NN is 'inv_std'. (In this manual, it will continued with 'equal' weights type.)
6. Users can view transition probability by pressing  Button.	Follwing box will appear showing transition probability:  Users can save it by pressing 'Save' Button and cancel the view by pressing 'X' in top-right corner of the window.
7. Users can enforce changes in transition probability by pressing	Following window will appear.

Change button.	 Users can load the changes that are to be enfored from file by pressing Load TP Change file button. Or, users can supply changes values in the box and press Load from box button. It is important to note that sum of changes in probabilites for given predecessor state should be zero and individual changes in probability should be between -1 and +1. Also, it should be taken care beforehand that after applying changes, probabilities with should be between 0 and 1. If those criteria doesn't hold, it will revert to original transition probability. Once window is cloased, the cahnges will load. **Note: If you are not changing transtion probability, please don't press this Change button.**
C. Providing initial conditions	INITIAL CONDITIONS
1. Provide initial precipitation state for simulation by selection from drop-down options: 	Options are 0, 1 and 2. Once selected, it will appear as:  Message will also appear in message logger. Initial precipitation state is 0.
2. Supply initial values of weather variables by pressing	The following box will appear for provinding values:

Weather variables button.	 Default value of weather variable is 1. However, users have to carefully supply the values. In this example, 'precip' value of 0 and 'tmean' value of 4 is supplied. The following message will appear in logger. Intial values of weather variables set to [0.0, 4.0]
D. Running Simulation	**SIMULATION**
1. Provide number of simulations to carry out. Number of simulations 1	Default number of simulation is 1.
2. Provide start date of simulation	Start Date 17-Aug-2019
3. Provide end date of simulation	End Date 18-Aug-2019 Please note that start date should preceed end date.
4. In order to save the output, please provide the output directory by pressing Output location	Once Output location is presses, the following box will appear:  Please select the folder in which you want to save the results. Once you press, 'Select Floder' the location will show as: Output location D:\python_practice Users can change the location in the box if required.
3. Press Simulate to run simulation.	On pressing 'Simulate' button, at first, inputs provided are checked. It will appear in the message logger. If everything goes okay, then following message will appear Simulation started....! Otherwise, error message will be displayed in logger.

	It will take few minutes to complete simulation. Time taken to simulate depends upon computer preformance. Once simulation is ended, the following messge will appear in the logger: Simulation_1 completed. Besides, running simulation, outputs are also saved automatically in the provided output location. OUTPUT folder will be created in provided location and simulation files are saved inside it. You will find simulation output files similar as below:  Simulation_1_simulated_tmean.csv Simulation_1_simulated_precip.csv Simulation_1_simulated_series.csv In above example, 'Simulation_1_simulated_series.csv' is Main Data file while others are multisite weather files.
4. Press  to reset all the values and setting after the completion of process or anytime in the middle to redo the process.	It will clear all the values and settings.

CC Scenario Generator

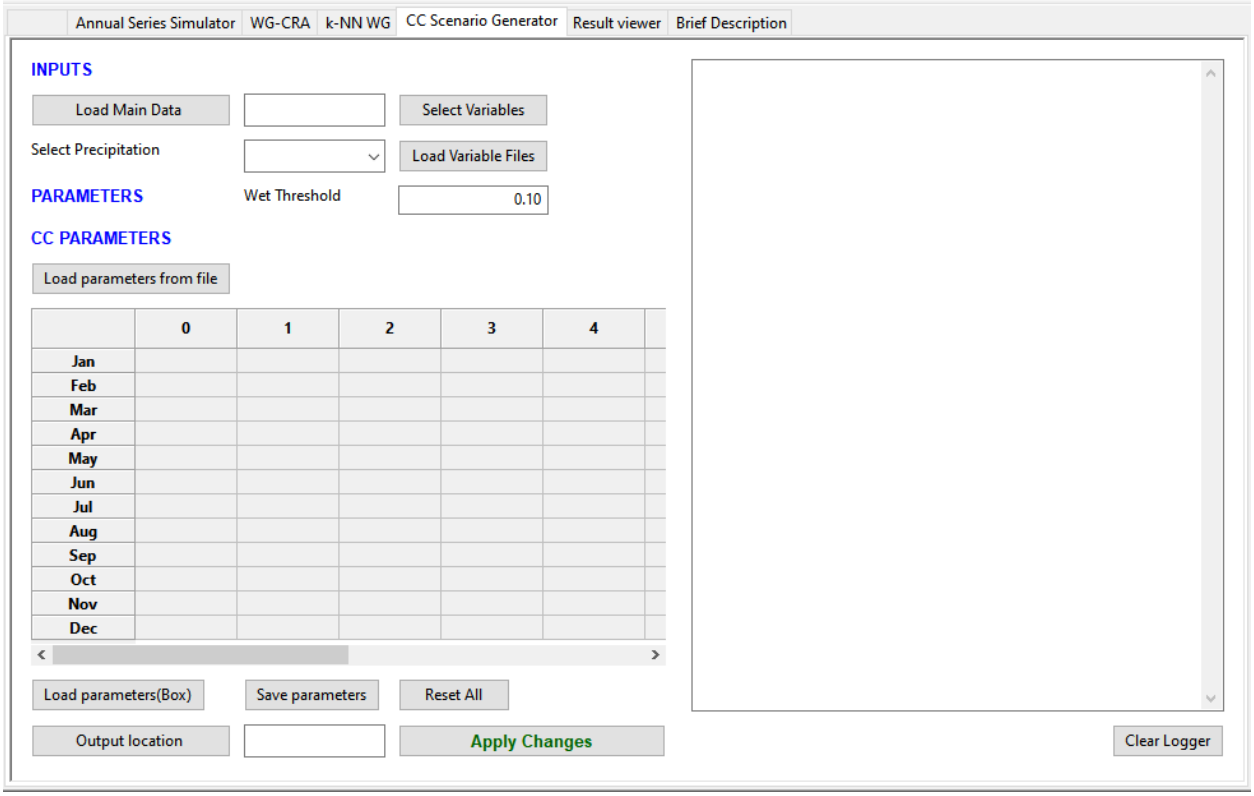
(Climate Change Scenario Generator)

This chapter describes how to enforce long terms shifts / changes in the weather variables as climate change scenarios. The process is described in Steinschneider and Brown (2013) as well as technical documentation of this tool. Example files used in this users' manual are provided in in 'Example_Dataset' folder in the installation folder.

Terminologies and Abbreviations

Terms	Meanings
Main Data	It is observed daily series of weather variables (areal average values in case of multisite generation)
Variable File	They are observed daily series files of weather variables. Each variable will have separate file but consists data for multiple stations. Variables are those weather variables that are considered for weather generation process.
Precipitation column	Precipitation column is the name of weather variables which represents 'precipitation' among different weather variables.
Wet Threshold	If it threshold in absolute value (eg – 0.1 mm) of precipitation to separate wet state from dry state.
Multisite weather generation	It is weather generation process at multiple sites simultaneously. Here, 'site' means station at which climate data are measured.
Single site weather generation	It is weather generation process at single site only.
Gamma distribution	To enforce changes, precipitation is modelled using gamma distribution. Parameters provided for enforcing changes are changes in mean and coefficient of variation of gamma distribution.

Screen shot



Steps

Notes:

Important notes on inputs:

All the input files for weather variables must in Comma Separated Values (CSV) format. They must all have 'Date' column followed by variables. First line (row) of the file is header where 'Date' and name of variables are declared. Dates in the file will read in 'dayfirst' format. Therefore, the format "dd-mm-yyyy" or "yyyy-mm-dd" for date values is recommended. Values of weather variables are numeric (floats or integer) type. **It is very important that all observed input files must have same 'Date' description and must have same length of data.** Description with snapshots of different input files in Notepad ++ are shown below:

(a) Main Data: This file consists of daily values of weather variables. In case of multisite weather generation, this file consists of areal average values of weather variables over the study area or basin. In case of single site generation, it consists of values of weather variables at given particular climate measurement station. In both cases, weather variables can be precipitation, temperature (max, min, mean), evapo-transipiration or more. Note that in case of multisite weather generation, values of weather variables for multiple sites are to be provided in separate files, each weather variable with each file. In case of single site too, users have to make separate files for each of weather variables. Snapshot of the Main Data file is shown below:

Maindata_Areal_Average.csv

```
Date,precip,tmax,tmin,tmean
1960-01-01,0.0,9.12,-1.34,3.89
1960-01-02,0.0,6.76,-2.32,2.22
1960-01-03,0.0,5.64,-3.47,1.09
1960-01-04,0.0,6.84,-4.61,1.12
1960-01-05,0.0,8.7,-3.04,2.83
1960-01-06,0.0,8.8,-1.76,3.52
```

(b) Variable files: Data for each of the weather variables are supplied in separate CSV files. Inside the file, data for each of the sites are provided. Number of stations for different weather variables may or may not be same, for instance, there can be more precipitation stations than temperature stations in an area. Snapshot of input file for precipitation and 'Tmean' variables are show below:

Precipitation – Example file – 'MultisiteP.csv'

MultisiteP.csv

```
Date,P1,P2,P3,P4,P5,P6,P7,P8,P9
1960-01-01,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
1960-01-02,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
1960-01-03,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
1960-01-04,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
1960-01-05,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
1960-01-06,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
```

In above file, P1, P2, P3, P4, P5, P6, P7, P8 and P9 are precipitation stations.

(c) Changes in weather variables (CC parameter files): They are files that contains values of changes that are to be enforced to the weather variables. Each of the weather variables must has its own changes file. Since changes in precipitation is made by quantile mapping following gamma distribution, changes in mean and coefficient of variation (CV) are provided. For other variables, like temperature, monthly mean changes in values are to be provided. Note that changes values for precipitation variable are in fraction (from 0 to 1) while changes in other variables are in their corresponding units (Example - °C for temperature). Each of the file must have 'month' column for months followed by changes. First row is a header. For example, change file for precipitation in Notepad ++ environment is shown below:

Ch_precip.csv

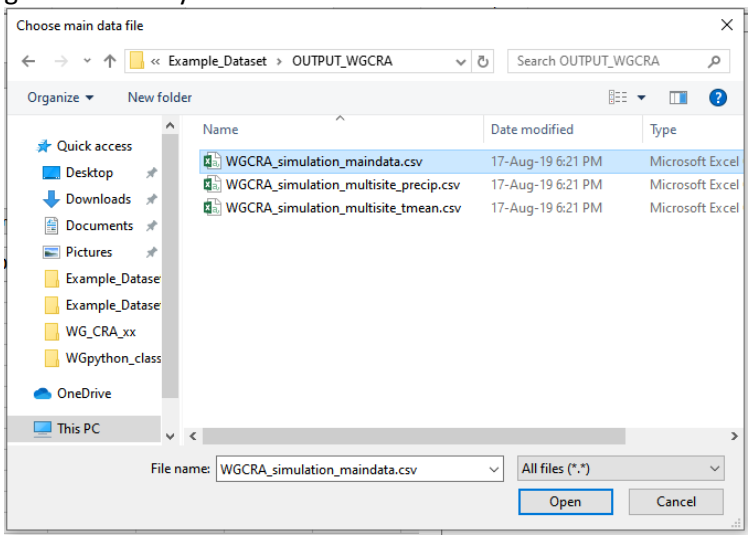
```
month,Mean_Ch,CV_Ch
Jan,0.1,0
Feb,0.1,0
Mar,0.1,0
Apr,0.1,0
May,0.1,0
Jun,0.15,0
Jul,0.15,0
Aug,0.15,0
Sep,0.15,0
Oct,0.1,0
Nov,0.1,0
Dec,0.1,0
```

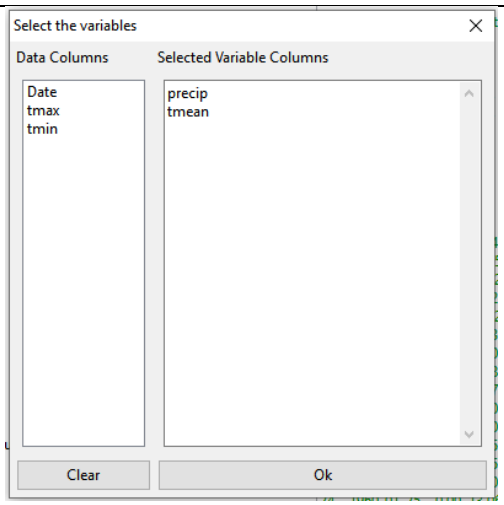
Here, Mean_Ch and CV_Ch are changes to be applied to mean and coefficient of variation of gamma distribution. Here values are in fraction. For eg, 0.1 means 10% increase. Likewise, example file for changes in temperature is shown below:

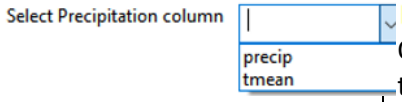
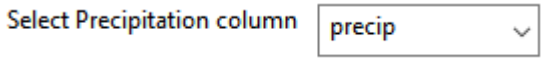
Ch_tmean.csv

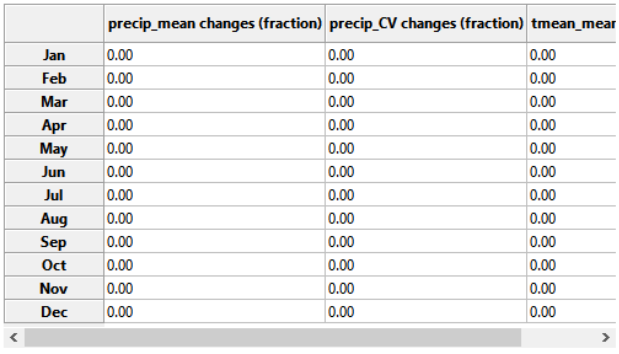
```
month,Mean_Ch
Jan,0.2
Feb,0.2
Mar,0.2
Apr,0.2
May,0.2
Jun,0.2
Jul,0.3
Aug,0.3
Sep,0.3
Oct,0.3
Nov,0.3
Dec,0.3
```

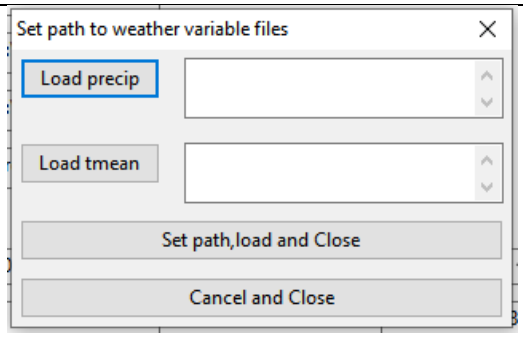
Here, Mean_Ch are mean changes to be applied in values of temperature. Here, 0.2 means 0.2°C increase in temperature.

Steps	Description
A. Providing the inputs	**INPUTS**
1. Load daily weather series data by pressing 'Load Main Data' button Load Main Data	It will prompt following window to select the file consisting of generated daily weather series data.  Select the file and press 'Open'. Once it is pressed, it will be loaded and it can be seen in the message logger. Data loaded and convert into pandas dataframe! Its columns are: Index(['Date', 'precip', 'tmax', 'tmin', 'tmean'], dtype='object')
2. Now select weather variables that you consider for weather generation by pressing Select Variables button.	Following box will appear and user can select the variables as follows:

<table>
<tr>
<td></td>
<td> 

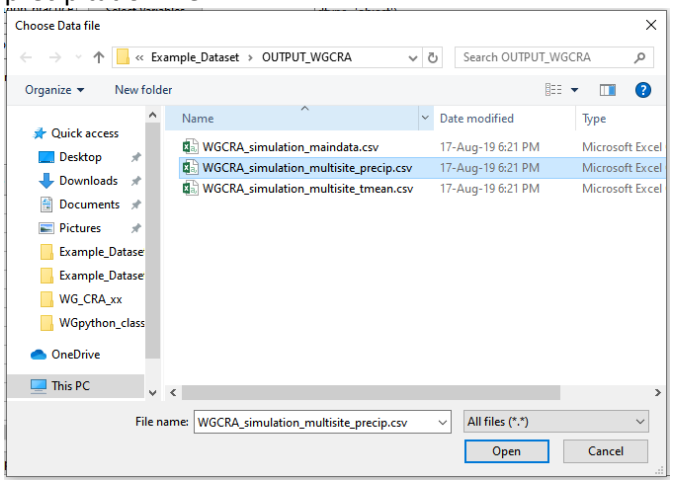
After selecting variables, please select ‘Ok’ button. If there is mistake in selecting, user can press ‘Clear’ button and reselect again.
For demonstration, ‘precip’ and ‘tmean’ is selected now.
Following message will appear in message logger:
Selected variables are: ['precip', 'tmean']
Note: Variables shown in ‘Data Columns’ are the data columns in Main Data File. Besides, there will be changes in the box for providing changes under ‘CC parameter’ section.</td>
</tr>
<tr>
<td>3. Declare the precipitation variable among the variables selected by from drop-down button.
 
</td>
<td>Select ‘precip’ in this example. Once selected, it will appear as below:
 

And following message will appear in the logger.
precipitation_column is precip.
Once, the precipitation variable is declared, there will be changes in the box under ‘CC parameter’ section and it will look as below:
 
</td>
</tr>
<tr>
<td>4. In case of multisite generation, provide the multisite weather data files by pressing 
 button.</td>
<td>Once pressed, the following box will be prompted for selection of the files.</td>
</tr>
</table>

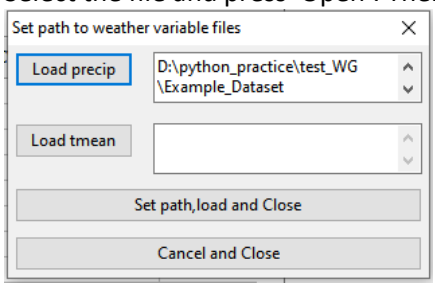


Press ‘Load precip’ to load precipitation file and ‘Load tmean’ to load ‘tmean file’. If more variables are selected before, then they will also appear in the list.

Once ‘Load precip’ is presses, following box will appear asking for the precipitation file:

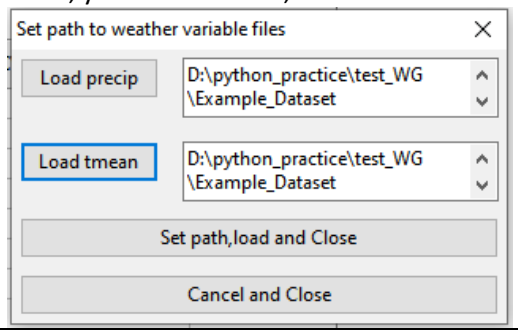


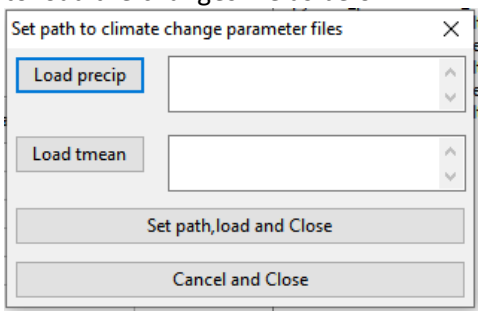
Select the file and press ‘Open’. Then, the file path will be loaded as

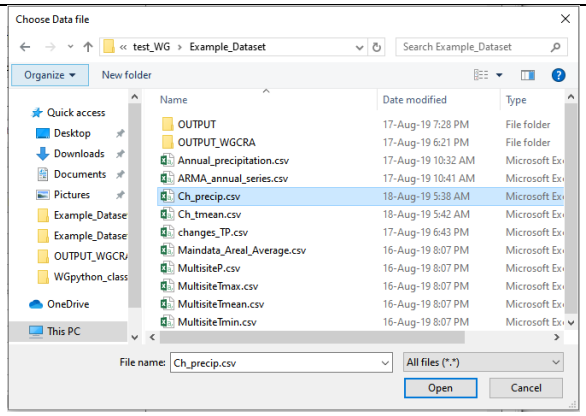


Repeat similar steps for loading other weather variable files, in this example for ‘tmean’.

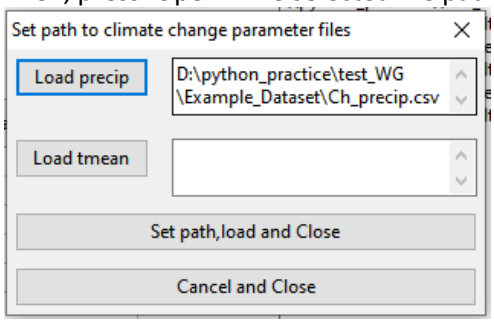
Once, you load ‘tmean’, box will be seen as:



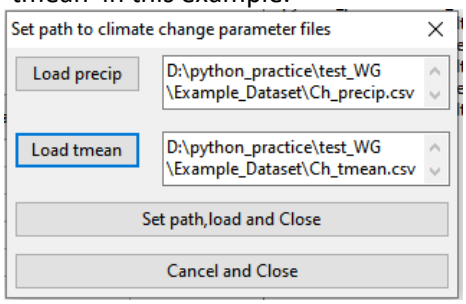
	Press 'Set path, load and Close' button for loading purpose else press 'Cancel and Close' to cancel. Once you press 'Set path, load and Close' button, the files will read and loaded; and following message will appear in the message logger. Path of variable files are: {'precip': 'D:\\python_practice\\test_WG\\Example_Dataset\\OUTPUT_WGCRA\\WGCRA_simulation_multisite_precip.csv', 'tmean': 'D:\\python_practice\\test_WG\\Example_Dataset\\OUTPUT_WGCRA\\WGCRA_simulation_multisite_tmean.csv'} File D:\python_practice\test_WG\Example_Dataset\OUTPUT_WGCRA\WGCRA_simulation_multisite_precip.csv loaded as precip! File D:\python_practice\test_WG\Example_Dataset\OUTPUT_WGCRA\WGCRA_simulation_multisite_tmean.csv loaded as tmean! This will complete providing the input files and user now have to supply model parameters.
B. Providing model parameters	MODEL PARAMETERS
1. Provide Wet Threshold	Wet Threshold 0.10 Default is 0.10 (mm). If the unit of precipitation is 'inch', it will imply 0.10 inch.
C. Providing climate change parameters	CC PARAMETERS
There are two ways to provide climate change parameters. One is to provide from the file and another is to type directly in the box and then, load from box.	
Option 1 1. Load climate change parameters from file by pressing Load parameters from file button.	Once, Load parameters from file button is pressed, user will be asked to load the changes file as below:  Press 'Load precip' button to load changes file for precipitation variable as follows:



Then, press 'Open'. The selected file path will be loaded as shown:



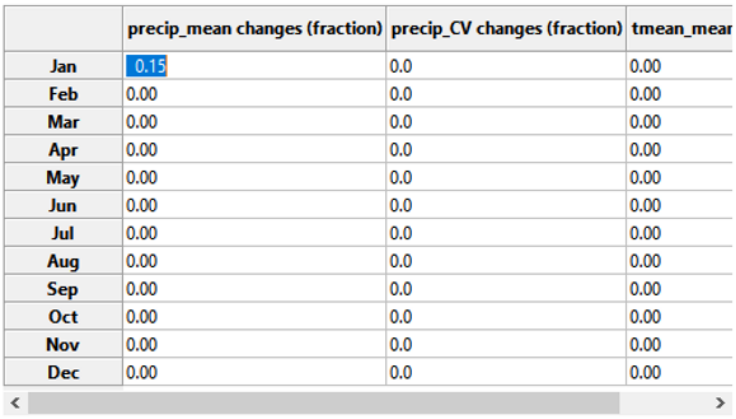
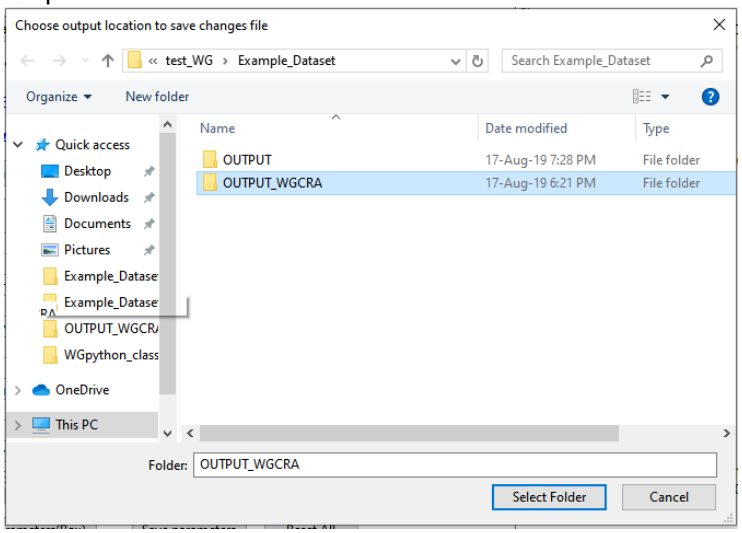
Repeat similar process to upload the changes for onther variables as 'tmean' in this example.

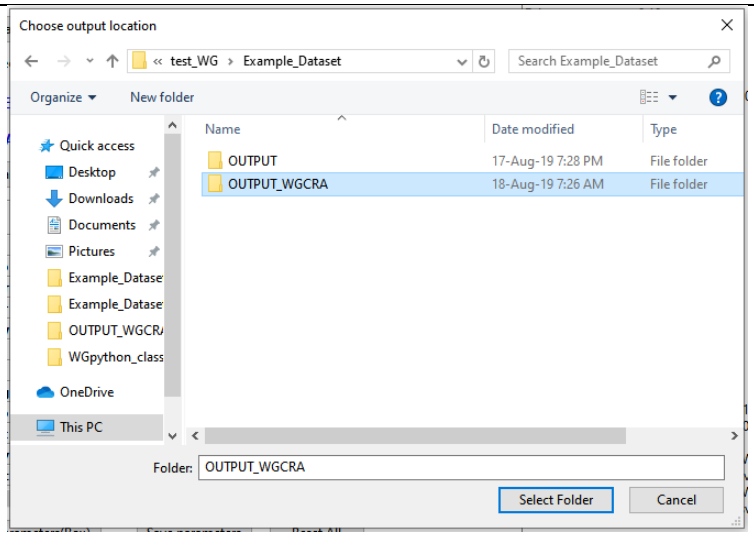


Then press 'Set path,load and Close' button. Once, it is pressed the files are loaded and the values can be seen under box as follows:

	precip_mean changes (fraction)	precip_CV changes (fraction)	tmean_mear
Jan	0.1	0.0	0.2
Feb	0.1	0.0	0.2
Mar	0.1	0.0	0.2
Apr	0.1	0.0	0.2
May	0.1	0.0	0.2
Jun	0.15	0.0	0.2
Jul	0.15	0.0	0.3
Aug	0.15	0.0	0.3
Sep	0.15	0.0	0.3
Oct	0.1	0.0	0.3
Nov	0.1	0.0	0.3
Dec	0.1	0.0	0.3

Besides, the messages will also appear in the message logger.
User can edit the values in the box if further changes are required.

	Once editing is finished, press Load parameters(Box) to load the parameters. Messages will apper in the logger.
Option 2: Typing changes directly in the box 2. Provide changes directly in the box by manual typing in the box	Place the cursor in the cell in the box which you want to type and then double-click the cell to edit its values as follows:  Once providing inputs and editing is finished, press Load parameters(Box) to load the parameters. Messages will appear in the message logger.
3. Users can save the changes by pressing Save parameters button.	The follwing box will appear asking to provide the output folder where output files are to be saved.  Select the folder and press 'Select Folder'. Save messages will appear in the logger similar to one below: File saved in D:\python_practice\test_WG\Example_Dataset \OUTPUT_WGCRA\Changes_precip.csv as Changes_precip.csv File saved in D:\python_practice\test_WG\Example_Dataset \OUTPUT_WGCRA\Changes_tmean.csv as Changes_tmean.csv
4. Provide output location to save data after applying changes by pressing	Select the folder which you want to save the outputs in the following box:

Output location button.	 And press 'Select Folder'.
5. Finally press Apply Changes button to apply the desired changes to the weather generated weather variables.	First, the input data are checked. Then, the following message will appear: Starting...! Once completed, Ended! message will appear in the logger. This process will take few minutes. Output folder will be created in the selected location as follows: OUTPUT_CC And the files will look like as follows: CC_tmean CC_precip
6. Press Reset All to reset all the values and setting after the completion of process or anytime in the middle to redo the process.	It will clear all the values and settings.

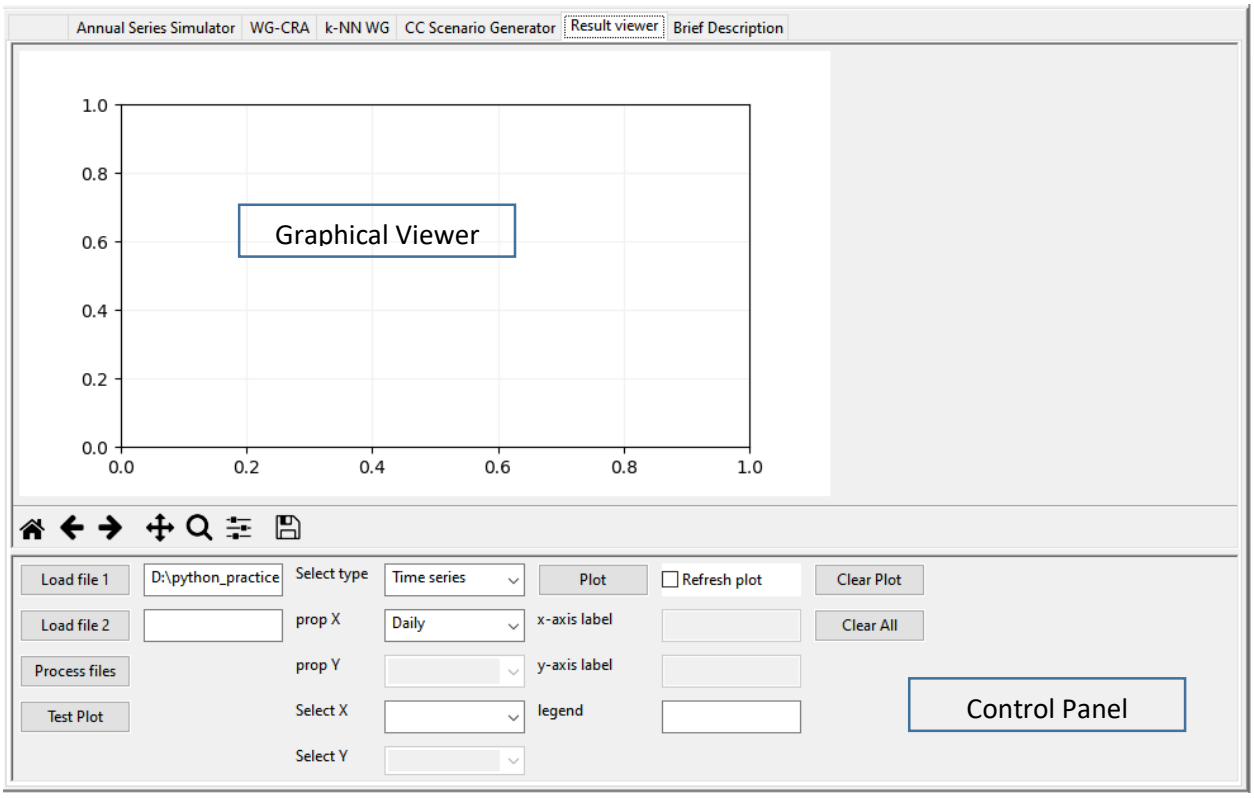
Result Viewer

This chapter describes how to view the results that we have generated in result viewer. It is a basic tool that allows to view simple 'time series' plot and 'x-y scatter' plots.

Terminologies and Abbreviations

Terms	Meanings
File 1	This is first file to be loaded. It can be observed series or simulated series; and can be of single site data or of multisite data.
File 2	This is the second file to be loaded. This is optional. It also can be observed series or simulated series; and can be of single site data or of multisite data. At least one between File 1 and File 2 should be present.
type	It is type of the graph to be displayed. It is either '**Time Series'** or '**Scatter X-Y'** **In case of 'Time Series', 'prop Y' and 'Select Y' will be disabled. Its enable only in case of 'Scatter X-Y'.**
Prop X	It is attribute of variables X (to be plotted in x-axis) that is to be plotted or viewed. Options are: (a) Daily: Daily time series of weather variables (if the data is annual, then it is annual series) (b) Annual Sum: Annual sum of weather variables, plotted as annual series. Example in case of precipitation (c) Annual Average: Annual average of weather variables, plotted as annual series. Example in case of temperature (d) Monthly sum: Monthly sum of weather variables, plotted as monthly series. Example in case of precipitation (e) Monthly average: Monthly average of weather variables, plotted as monthly series. Example in case of temperature (f) Average Monthly (sum): It is average of monthly sums of weather variables for all years, plotted as monthly values, Example in case of precipitation (g) Average Monthly (mean): It is mean of monthly average of weather variables for all years, plotted as monthly values, Example in case of temperature
Prop Y	It is attribute of variables Y (to be plotted in y-axis) that is to be plotted or viewed. Options are same as of X.
Select X	Variable to be plotted in x-axis. It will be displayed with 'file1_' or 'file2_' suffix depending upon which file it is from (File 1 or File 2).
Select Y	Variable to be plotted in y-axis. It will also be displayed with 'file1_' or 'file2_' suffix depending upon which file it is from (File 1 or File 2).

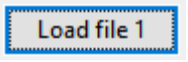
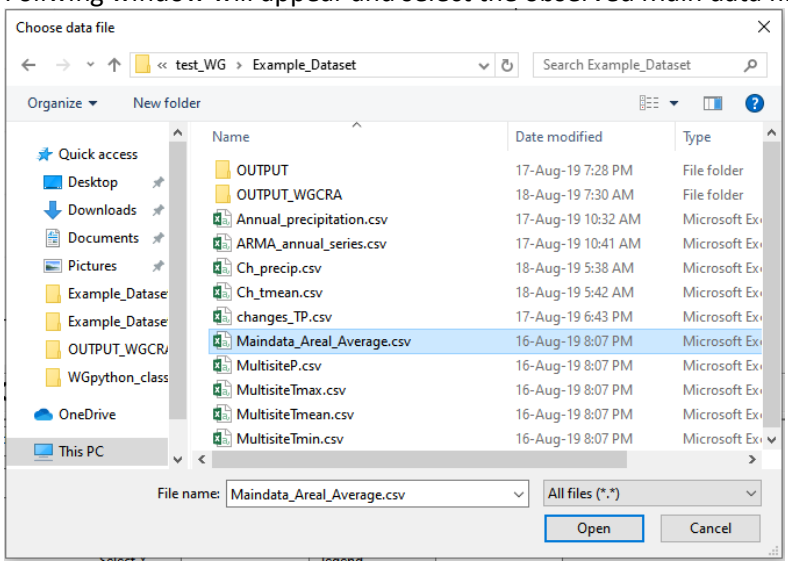
Screen shot

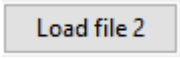
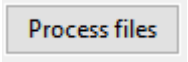
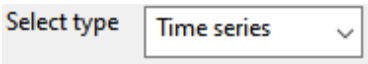
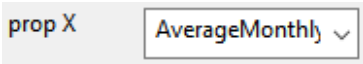
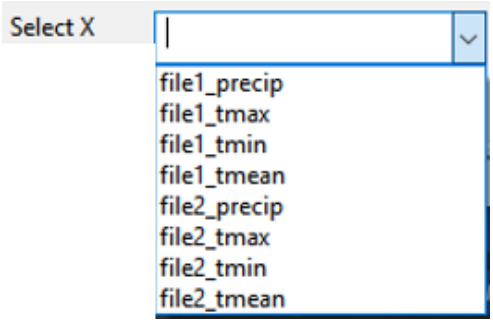
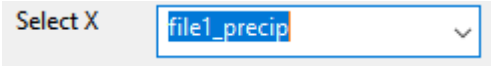
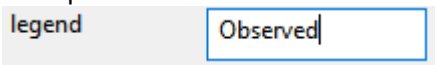
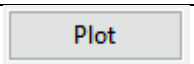


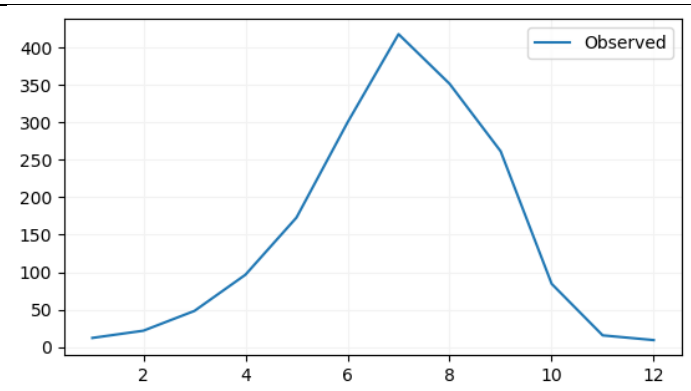
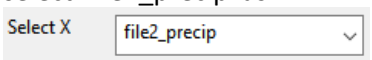
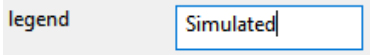
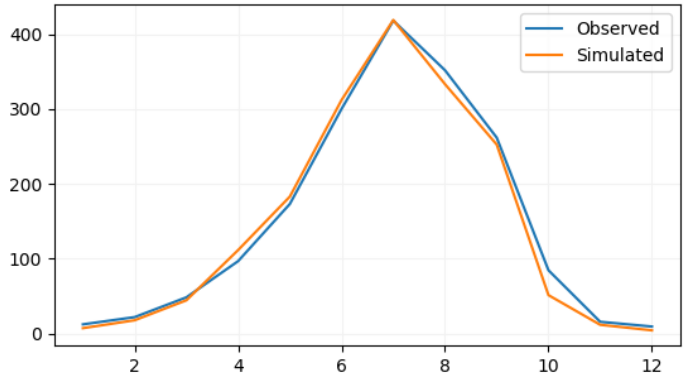
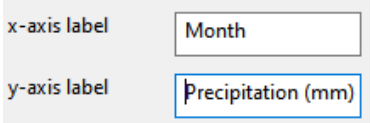
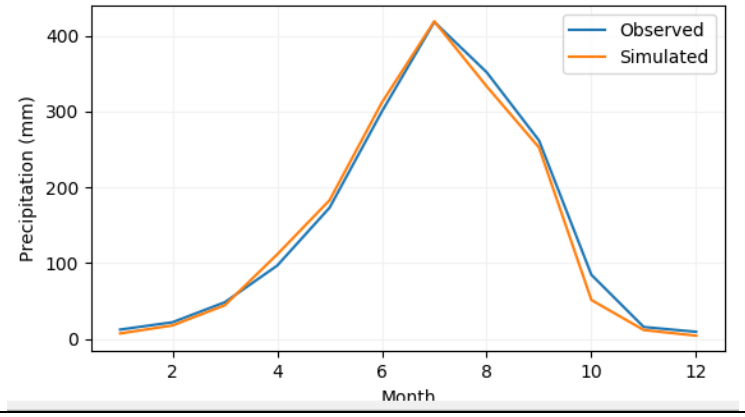
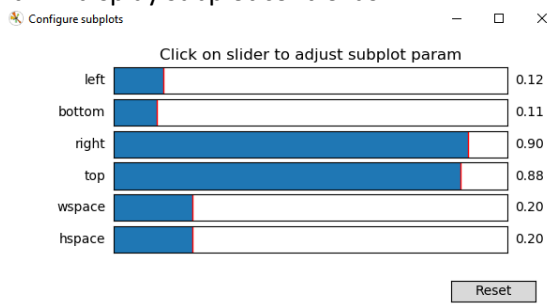
There are two subpanels (a) Graphical Viewer and (b) Control Panel

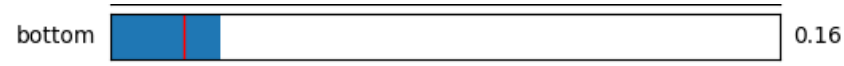
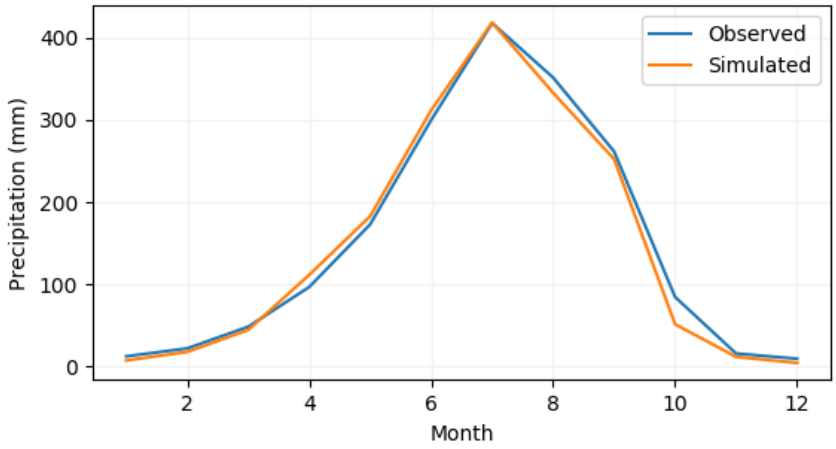
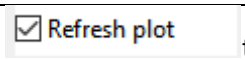
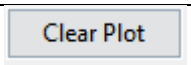
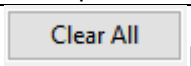
Steps by examples

Example A: To compare average monthly precipitation series of observed and weather generated (WG-CRA) series.

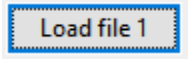
Steps	Description
1. Load observed daily weather series data by pressing  button.	Follwing window will appear and select the observed Main data file.  Press 'Open' after selecting the file.

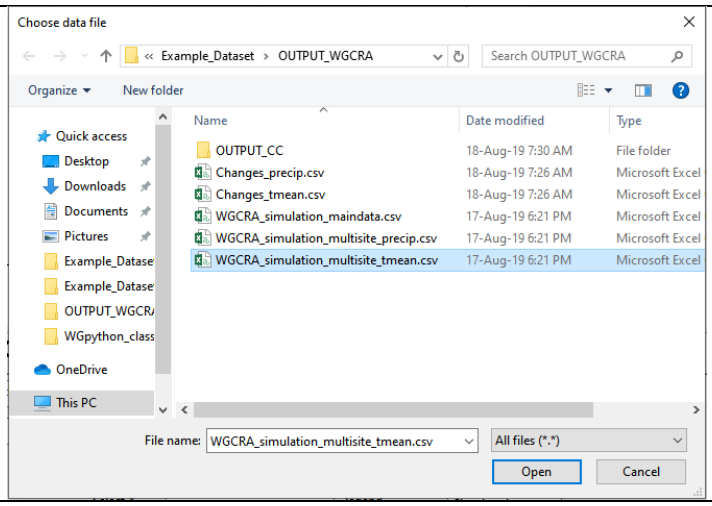
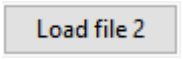
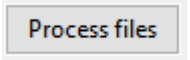
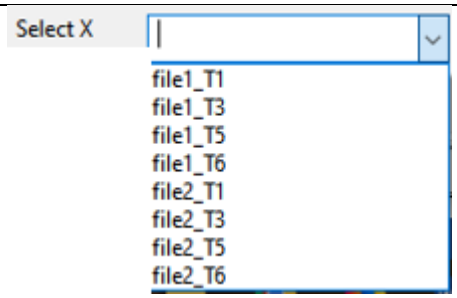
2. Load simulate daily weather series data by pressing  button.	Similar as above.
3. After loading the files, press  button.	This will load the data in the files for plotting.
4. Select 'Time Series' in 'Select type' drop-down button 	This will assign 'Time Series' to be plotted. When 'Time Series' is selected, 'prop Y' and 'Select Y' boxes are diabled.
5. Select 'AverageMonthly(sums)' in prop X drop-down options. 	This will assign Average Monhtly sum to be plotted.
6. Select variables by pressing 	It will display as follows:  Note: In this example, 'file1_precip' is observed precipitation data while 'file2_precip' is weather generated data. Select 'file1_precip'. 
7. Type the legend to this selected series in  box.	Example: 
8. Press  button to plot.	The following graph will appear in the graphical viewer.

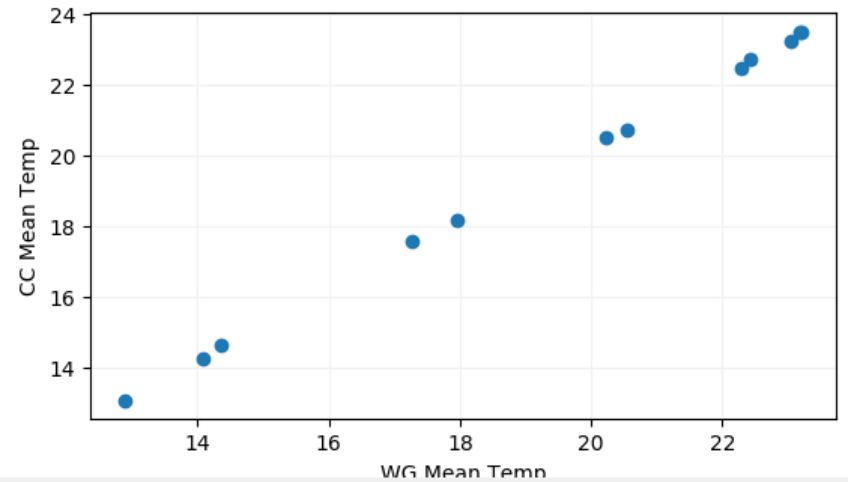
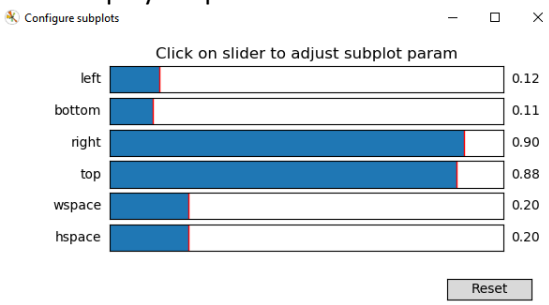
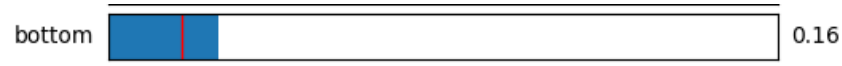
	 In order to plot, the weather gerneated series,
9. In order plot simulated weather generated series, select 'file2_precip' as  and also rewrite the legend as  and press  again.	The simulated series will appear in the above plot as 
10. Supply the axis labels as 	Now, the graph will look like: 
11. In order to adjust the figure, press  button.	It will display subplot control as: 

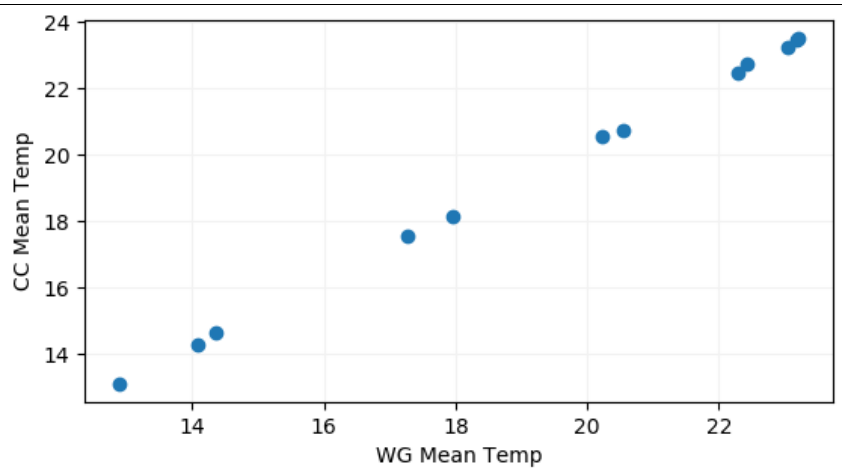
	Increase 'bottom' slider as shown below and close it.  Then,the plot will look like: 
12. Save the figure by pressing  button.	
Other buttons	
Check  to refresh the graphical viewer each time new graph is generated.	
Press  button to clear the plots.	
Press  button to clear the plots and all other settings and data loaded.	

Example B: To generate scatter plot between weather generated average monthly temperature series and climate change enforced average monthly temperature series by 0.2°C.

Steps	Description
1. Load generate daily temperature series (multisite) data by pressing  button.	Follwing window will appear and select the observed Main data file. Press 'Open' after selecting the file.

	
2. Load CC enforced daily weather series data by pressing  button.	Similar as above.
3. After loading the files, press  button.	This will load the data in the files for plotting.
4. Select ‘Scatter X-Y’ in ‘Select type’ drop-down button 	This will assign ‘Scatter X-Y’ to be plotted.
5. Select ‘AverageMonthly(means)’ in prop X drop-down options. 	This will assign ‘AverageMonthly(means)’ for X-variable.
6. . Select ‘AverageMonthly(means)’ in prop Y drop-down options. 	This will assign ‘AverageMonthly(means)’ for Y-variable.
7. Select the variable for X in 	 Here, for example, ‘file1_T1’ is selected. Note: ‘file1’ denotes weather generated multisite series for temperature and ‘file2’ denotes climate change enforced multisite series.

	Select X file1_T1
8. Likewise, select variable for Y in Select Y	As above, Select 'file2_T1'. Select Y file2_T1
9. Press Plot button to plot.	Following graph will appear in the graphical viewer.
10. Supply the axis labels as x-axis label: WG Mean Temp y-axis label: CC Mean Temp	Now the graph will look as: 
11. In order to adjust the figure, press button.	It will display subplot control as:  Increase 'bottom' slider as shown below and close it.  Then,the plot will look like:

	
12. Save the figure by pressing  button.	