

HYDROLOGY MODELLING CLIMATE CHANGE METHODOLOGY

Climate change resulting from anthropogenic CO₂ production can affect water security. This section outlines the approach taken for the incorporation of climate change into data for IQQM modelling. Figure 1 shows a general schematic of the process used to generate the climate change data from the historical data.

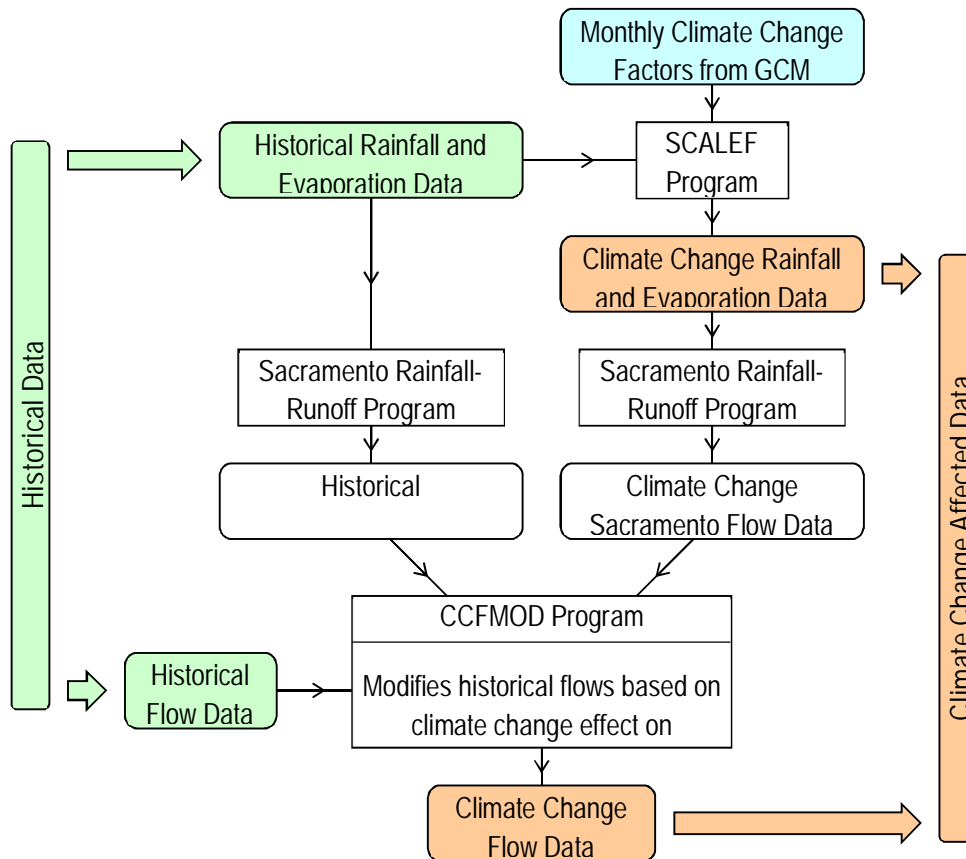


Figure 1 Schematic for Generation of Daily Climate Change Data for IQQM

D.1 Climate Change Model Selection

- Select climate change models which demonstrate 10th percentile, 90th percentile and median flow
 - The selection of these three models was based on the ranking of their weighted mean annual rainfall (rainfall is the predominant variable which impacts flows).
 - The monthly rainfall for the catchment should be multiplied by the monthly scaling percentages for each model and added together to determine the average annual rainfall expected based on each of the climate change models.
 - The mean annual rainfall associated with these climate change models should then be ranked and the 10th percentile, 90th percentile and median models selected.
 - See Table 1 below for an example of ranking and selection.

Table 1 Climate Change Model Ranking

Climate Change Model	Weighted Mean Annual Rainfall (mm)	
GFDL CM2.1	990	
UKMO HadGEM1	1,011	← 90 th Percentile
MPI ECHAM5	1,045	
UKMO HadCM3	1,047	
CSIRO Mark 3.5	1,048	
IAP FGOALS g1.0	1,064	← Median
CSIRO Mark 3.0	1,083	
NCAR CCSM 3.0	1,084	
MIROC 3.2 (hires)	1,100	
MIUB echo G	1,114	← 10 th Percentile
MIROC 3.2 (medres)	1,141	

D.2 Climate Change Model Percentage Changes

- Evaporation factors are omitted from a number of the climate change models. If this is the case for any of the 3 chosen models, evaporation factors are required to be generated before the models can be applied.
- Firstly, determine the relationship between annual percentage change in temperature and evaporation
 - For the models which include both temperature and evaporation, the factors for these two parameters should be applied to actual monthly data from the catchment to obtain weighted mean annual values.
 - Comparing the historical weighted mean annual parameter result with the factored mean annual parameter result, will give an annual percentage change for evaporation and temperature for the various climate change models.
 - The annual percentage change of temperature and evaporation can be plotted against each other for a relationship to be determined.
- Calculate the annual percentage change in evaporation for the models which do not included evaporation factors.
 - The annual percentage change in temperature for the models which do not include evaporation should then be calculated using the method described above.
 - The calculated annual temperature change should then be inputted into the relationship between temperature and evaporation; using this method the annual evaporation change for the incomplete models can be determined.
- Convert the yearly change in evaporation to monthly scaling percentages
 - Compare the annual percentage changes in evaporation for the complete and incomplete models; chose the complete model which has the closest annual percentage evaporation change for each incomplete model and calculate the ratio difference.
 - Use the monthly pattern of the aforementioned chosen model evaporation and multiply each monthly percentage change of evaporation by the calculated ratio. This will result in monthly percentage changes for each incomplete model.

D.3 Generation of Climate Change Evaporation and Rainfall

- Use SCALEF4 (Harding 2008) to scale each rainfall and evaporation series based on monthly climate change percentage variations for each of the three selected models
 - Write a SCALEF4 input file for each series of rainfall and evaporation (i.e. Scale_R1.in) which contains the name of the original rainfall/evaporation file, the name of the climate change output file, the 12 monthly percentage changes and the monthly seepage (only for some evaporation series).
 - Write a text file for each series of rainfall and evaporation (i.e. Rain_01.txt) which contains the name of the scalef4 input file (i.e. Scale_R1.in), the name of a monthly statistic output file and two “y’s” (this signifies to overwrite the files if they already exist in that directory).
 - Write a batch file which runs the SCALEF4 program for each series of rainfall and evaporation (i.e. Generate_CC_Rain_&_Evap.bat). The SCALEF4 program runs and inputs the text files which were previously created.
- The output of this process should be a climate change IQQM file for each series of rainfall and evaporation.

D.4 Generation of Climate Change Flows

- Run all the Sacramento files for the catchment using historical rainfall and evaporation data series
- Re-run all the Sacramento files for the catchment, this time using the appropriate climate change adjusted rainfall and evaporation files
- Modify the historical flows to generate climate change flows using the CCFMOD program (Harding 2008); the CCFMOD program looks at the relationship between the historically generated Sacramento flow and the climate change generated Sacramento flow and applies this relationship to the historically recorded flow.
 - Create an input file for CCFMOD which contains the number of files to be modified, the start and end dates, the name of the Sacramento flow file which was generated using historical rainfall and evaporation, the name of the Sacramento flow file generated using climate change rainfall and evaporation, the name of the historical file which is to be modified and the name of the output climate change flow file. If more than one file is to be modified, the name of the next historical file should then be written, followed by the name of its output climate change file and so forth.
- For each flow series, a climate change IQQM flow file should be generated as a result of this process.

D.5 Post-Processing of Flows

- **Generate periodic flows**
 - Periodic flows do not need to be modified in any way, so using NRW Process (Vitkovsky 2008) the pattern of the periodic flow can be obtained and then the length of data required can be generated from this pattern.

D.6 Discussion

There is a great deal of uncertainty in climate change modelling. Some of these are:

- Uncertainty in GCM – these are the 10th, 50th and 90th percentiles presented.
- Uncertainty in CO₂ projection – shown as the difference between A1B and A1FI scenarios.
- Uncertainty from initial conditions in GCM – Not considered.
- Uncertainty from calibration of GCM parameters – Not considered.
- Probably many other sources of uncertainty.

Climate change analysis is in its infancy and many GCMs and generation of data for IQQM are being refined.

Some ongoing work will potentially be incorporated in future analyses are:

- GCMs with improved replication of physical processes.
- GCMs that use a finer grid.
- Ensemble GCM output.
- Downscaling analysis (both statistical and dynamic).
- BOM to generate climate change affected rainfall and evaporation data.