# User's Guide for the Vatic Weather File Generator (VWFG v1.0.0)

Amir A. Aliabadi
Atmospheric Innovations Research (AIR) Laboratory
School of Engineering, University of Guelph, Guelph, Canada
http://www.aaa-scientists.com
aliabadi@uoguelph.ca

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## 1 The Vatic Weather File Generator (VWFG)

To combat climate change caused by cities, it is necessary to perform urban physics modeling to assess mitigation solutions suitable for future climates. A challenge is availability of reliable future weather files for investigation of future climate scenarios. The Vatic Weather File Generator (VWFG) uses the statistical downscaling approach to fill this gap. VWFG is novel by using a history of weather files over multiple years to downscale future climate model data utilizing 1) quantile-quantile bias corrections, 2) record matching by the Finkelstein-Schafer method, and 3) shifting-stretching corrections. This implementation of VWFG uses the CanRCM4 climate model (1980-2100) and the ERA5 reanalysis data product as weather files (1980-2020) for the Representative Concentration Pathway (RCP) scenario of 4.5 $\mathrm{W m^{-2}}$. VWFG is a simple, practical, and widely applicable tool for urban physics simulations of future climates, particularly in cases where reliable forcing data is lacking otherwise.

The output of VWFG can be used to force Urban Physics Models (UPMs). UPMs are often used to investigate urban development alternatives under different future climate scenarios [Pörtner et al., 2022]. The Vertical City Weather Generator (VCWG) is an example computationally-fast UPM that predicts temporal and vertical variation of meteorological variables in the urban environment, building envelope temperatures, and temporal variation of building performance metrics, such as indoor air temperature, indoor specific humidity, building thermal and electricity loads, and natural gas and electricity consumptions [Moradi et al., 2021, Aliabadi et al., 2021, Moradi et al., 2022]. UPMs often require weather files (for instance in EnergyPlus Weather (EPW) or International Weather for Energy Calculations (IWEC) formats) for each region with at least hourly time resolution. For instance VCWG takes weather files in the EPW format. This guide provides the step by step instructions to run VWFG.

VWFG v1.0.0 is shared under the GNU General Public License Version 3. The terms and conditions of the license are accessible via: https://www.gnu.org/licenses/gpl-3.0.en.html. Please do not distribute VWFG v1.0.0 to third parties. Instead, please refer interested groups to the Atmospheric Innovations Research (AIR) Laboratory to acquire a copy of VWFG v1.0.0 Please consider offering co-authorship to AIR lab members if VWFG v1.0.0 is used significantly toward the completion of a project.

## 2 Folder Structure

The main folder is "VWFG". The following folders are populated by data associated with application of VWFG for Toronto under RCP 4.5 $Wm^{-2}$. Under folder "CM" there should be free subfolders titled "CM-Historical", "CM-Validation", and "CM-Future". These contain the Climate Model (CM) files for the historical (1980-1999), validation (2007-2020), and future (2021-2100) preiods, respectively. These files should be named using a consistent file naming convention that only distinguishes the file names by year. That is, the files should by listed in sequential order from the oldest to newest by the operating system. For example the historical CM file names are given as:

"NAM-22_CCCma-CanESM2_historical_r1i1p1_CCCma-CanRCM4_r2_1980"
"NAM-22_CCCma-CanESM2_historical_r1i1p1_CCCma-CanRCM4_r2_1981"
...
"NAM-22_CCCma-CanESM2_historical_r1i1p1_CCCma-CanRCM4_r2_1999"

Under folder "EPW" there should be two subfolders titled "EPW-Historical" and "EPW-Validation". These contain the EPW files for the historical (1980-1999) and validation (2007-2020) preiods, respectively. Note that there are no EPW files for the future period. Again, these files should be named using a consistent file naming convention that only distinguishes the file names by year. That is, the files should by listed in sequential order from the oldest to newest by the operating system. For example the historical EPW file names are given as:

"ERA5-Toronto-1980"
"ERA5-Toronto-1981"
"..."
"ERA5-Toronto-1999"

The "Figures" folder should be existent but empy. Upon execution of plotting scripts, this folder will be populated with resulting figures.

The "Results" folder should contain the following subfolders: "EPW-Future-Not-Corrected", "EPW-Future-Corrected", "CM-Future-Bias-Corrected", and "CM-Validation-Bias-Corrected". Note that it is very important that these folders should all be empty of files. Upon execution of the calculation scripts, these folders will be populted with results.

# 3 Python Scripts and Input Variables

It is recommended to use a Python version that is at least 3. There are 5 analysis scripts titled "Analysis1.py", "Analysis2.py", ..., and "Analysis5.py", and there are three plotting scripts titled "Plots1.py", "Plots2.py", and "Plots3.py". These scripts should be run in sequential order for a successful completion of the VWFG process. In addition, there is a template EPW file in the main folder titled "EPW-Template-Toronto". This template will later by copied and manipulated by executing the scripts above.

"Analysis1.py" is meant to extract data from NetCDF files produced by a CM, in our case the CanRCM4 data. Depending on the source of the CM data, this analysis file may be modified. For CanRCM4 data, we must specify the following variables: "lat_rural = 43.649889", "lon_rural = 360 - 80.121909", and "NYears = 5", and a few directories, sub-directories, and file names. It takes the NetCDF files and batches of 5 and formats the data in the files mentioned already under the "CM" folders. For simplicity, this step of the process is not necessary to execute since the files in the CM folders have already been generated. The contents of the files in the CM folder follow this format, which list daily averages of dry bulb temperature, surface wind speed, surface pressure, and radiation flux:

```
# 0: Day of Year [-] 1: lat [deg] 2: lon [deg] 3: tas [K]
# 4: sfcWind [m s-1] 5: ps [Pa] 6: rad [W m-2]
0   41.678688   283.323761   265.603729   2.334936   98599.953125   277.086670
1   41.678688   283.323761   267.726898   1.530065   98223.648438   301.935883
2   41.678688   283.323761   263.530579   1.622525   98564.757812   291.135010
3   41.678688   283.323761   264.215393   3.314878   98840.726562   292.283752
4   41.678688   283.323761   268.024506   3.666362   98211.281250   267.137665
5   41.678688   283.323761   269.779297   2.717463   98287.382812   329.165802
```

"Analysis2.py" is meant to perform a few calculations:

- Quantile-Quantile analysis of EPW and CM to correct for bias
- Output bias of non-corrected CM vs EPW data for the historical period
- Output bias of non-corrected CM vs EPW data for the validation period
- Output bias of corrected CM vs EPW data for the validation period
- Output daily-averaged mean/std of EPW data for the past period
- Output daily-averaged mean/std of non-corrected CM data for the validation period
- Output daily-averaged mean/std of corrected CM data for the validation period

It will take a few directories, sub-directories, and file names. There are three key variables to set for specifying the year range for the historical, validation, and future periods. These are "NYearsPast = 20", "NYearsValid = 14", and "NYearsFuture = 80".

"Analysis3.py" is meant to perform a few calculations:

- Quantile-Quantile analysis of CM versus EPW data
- Output matching indices for year and month of past EPW data corresponding to CM for validation period
- Output matching indices for year and month of past EPW data corresponding to CM for future period

It will take a few directories, sub-directories, and file names. There are three key variables to set for specifying the year range for the historical, validation, and future periods. These are "NYearsPast = 20", "NYearsValid = 14", and "NYearsFuture = 80". In addition, the user must define weights for the F-S record matching method according to [Hosseini et al., 2021]. For Toronto, these weights are currently set as:

FSWeightsTdryb = [0.773, 0.912, 0.891, 0.884, 0.869, 0.887, 0.830, 0.868, 0.829, 0.831, 0.905, 0.922]
FSWeightsPressure = [0.086, 0.036, 0.041, 0.043, 0.052, 0.048, 0.064, 0.057, 0.068, 0.060, 0.039, 0.027]
FSWeightsRad = [0.078, 0.027, 0.036, 0.038, 0.043, 0.037, 0.057, 0.045, 0.054, 0.056, 0.031, 0.026]
FSWeightsWindS = [0.063, 0.026, 0.032, 0.036, 0.036, 0.028, 0.048, 0.030, 0.048, 0.053, 0.025, 0.026]

"Analysis4.py" is meant to perform a few calculations:

- Morph EPW files for the future period
- Output the files

It will take a few directories, sub-directories, and file names. There are three key variables to set for specifying the year range for the historical, validation, and future periods. These are "NYearsPast = 20", "NYearsValid = 14", and "NYearsFuture = 80". Further the EPW template filename should be specified as "EPWTemplateFile = "EPW-Template-Toronto.epw"".

"Analysis5.py" is meant to perform a few calculations:

- Shift/stretch weather variables for the morphed EPW files for validation and future periods
- Computing errors for the method before and after shifting/stretching for the validation period
- Updating the morphed EPW files by shifting and stretching
- Updating soil layer temperatures

It will take a few directories, sub-directories, and file names. There are three key variables to set for specifying the year range for the historical, validation, and future periods. These are "NYearsPast = 20", "NYearsValid = 14", and "NYearsFuture = 80". The "FirstFutureYear = 2021" should be specified. The scripts takes a few inputs to update the soil layer temperatures as well:

```
# Soil layers information in EPW file
```

```
SoilLayersN = 3
SoilTemperatureLineN = 4
SoilTemperatureStart = 6
SoilTemperatureJump = 16
```

In addition, a minimum wind speed is imposed when updating the future EPW files by setting "MinimumWindS = 0.1".

"Plots1.py" is meant to generate Quantile-Quantile plots for all historical records and a sample validation record. It will take a few directories, sub-directories, and file names. There are three key variables to set for specifying the year range for the historical and validation periods. These are "NYearsPast = 20" and "NYearsValid = 14". In addition, the same F-S weights should be specified as in "Analysis3.py"

"Plots2.py" is meant to generate color plots for matching months and future weather variables as well as time series of weather variables. It will take a few directories, sub-directories, and file names. There are three key variables to set for specifying the year range for the historical, validation, and future periods. These are "NYearsPast = 20", "NYearsValid = 14", and "NYearsFuture = 80". The "FirstFutureYear = 2021" should be specified.

"Plots3.py" is meant to plot Climate Model (CM) bias for the validation period before and after bias correction. It will take a few directories, sub-directories, and file names.

# References


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