User's Guide for the Vertical City Weather Generator (VCWG v1.4.5)

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1 About VCWG

The Vertical City Weather Generator (VCWG) is a software that predicts the urban micro-climate in relation to a nearby rural climate given the urban characteristics. VCWG predicts vertical profiles of temperature, wind speed, humidity, and turbulence kinetic energy as well as the building energy performance metrics in an urban area. More details on the model can be found at the Atmospheric Innovations Research (AIR) laboratory website at www.aaa-scientists.com and corresponding publications [Moradi et al., 2021, Aliabadi et al., 2021].

2 Setting the Climate Forcing Files

To run the VCWG, it is required to put the weather file (*.epw) of the region of interest in the directory e.g. "/resources/epw/ERA5_Guelph_2015.epw". This file can be downloaded from EnergyPlus (https://energyplus.net/) or prepared using alternative datasets. In the released version of the software it is prepared using the ERA5 data product from the European Centre for Medium-Range Weather Forecasts (ECMWF) (`https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5` and `https://www.shinyweatherdata.com/`).

3 Setting Input Parameters

VCWG can take input parameters from the files located in the directory "/resources/parameters/". These files contain the required parameters of the case study including urban characteristics, vegetation parameters, view factors, simulation parameters, and building renewable and alternative energy configurations. In the released version of the software there are 13 input parameter files. File "initialize_Guelph_0.uwg" is associated with a case with no renewable energy options, and it is set up to run the model for 31 days in January 2015. To exclude the renewable energy options from

the model, variable "Adv_ene_heat_mode" should be set to 2. For inclusion of renewable energy options, this variable should be set to 1 for heating mode and 0 for cooling mode of operation.

Files "initialize_Guelph_1.uwg" to "initialize_Guelph_12.uwg" are associated with the optimized case 8 of the study [Aliabadi et al., 2021], and they are set up to run for each month of the year 2015. Lines 230, 231, 232 contain the starting month, starting day, and the duration of the simulation in number of days. For each month, it is desired to start the simulation 3 days before the start of the month and then discard the first 3 days of data as spin up data. For example, to simulate Feburary, one can start from Month = 1 (January), Day = 29 (3 days before start of February), for nDay = 31 (28 days in February plus 3 days for spin up). The January simulation is an exception because the ERA5 dataset only contains data in 2015, so for January we cannot start 3 days earlier in 2014. The user is able to change the parameters to define and run a simulation of interest.

There are three more files in which input parameter specifications should be made. 1) To change the building envelop properties (e.g. resistance values) and HVAC equipment specification (e.g. coefficient of performance and thermal efficiency) the file "BLD6_LocationSummary" in directories "/resources/DOERefBuildings/BLD1" through "/resources/DOERefBuildings/BLD16" should be modified corresponding to building type. Note that in the released version of the software the appropriate folder is "/resources/DOERefBuildings/BLD6" for mid rise appartment, and the current settings correspond to the optimized case 8 of the study [Aliabadi et al., 2021]. Also note that only the last column of the spreadsheet is advised to be modified corresponding to custom values. i.e. the users are discouraged to change values in the other columns. 2) To change the ventilation and infiltration rates, the appropriate file "BLD6_ZoneSummary" in directories "/resources/DOERefBuildings/BLD1" through "/resources/DOERefBuildings/BLD16" should be modified corresponding to building type. Note that in the released version of the software the appropriate folder is specified for the mid rise apartment as "/resources/DOERefBuildings/BLD6", and the current settings correspond to the optimized case 8 of the study [Aliabadi et al., 2021]. 3) The corresponding thermal conductivity, volumetric heat capacity, and thickness for the building envelop should be specified in file "ReadDOE.py" in the directory "/UWG/". The envelop resistance, conductivity, heat capacity, and thickness should be consistent as they are specified throughout the model. e.g. if the user changes the resistance values, the user must also change the other input variables associated with the resistance values. The user is only advised to change values associated to building wall type "EPPWall" and roof type "EPPRoof". The user is discouraged to change values for other construction material.

If desired, new view factors can be obtained by running "/UWG/Run_RayTracing.py" and copy and paste the results from file e.g. "/UWG/ViewFactor_Guelph.txt" into the input file e.g. "/resources/parameters/initialize_Guelph_0.uwg" or other initialization files.

4 Running VCWG

There are two options for running VCWG v1.4.5: the single and serial modes. The single mode only runs the model given one set of input parameters, while the serial mode allows running the model for 12 consecutive months, requiring 12 initialization files. For the single mode, in the python file "/VCWG/VCWGv1.4.5.py" located in the main directory, the user is required to

change the name of weather file and the name of the initialization file to the ones located in the directories of "/resources/epw" and "/resources/parameters/", respectively. This run produces hourly results that are saved in directory "/Output/". For the serial mode, in the python file "/VCWG/VCWGv1.4.5Serial.py" located in the main directory, the user is required to specify 1 weather file and 12 input parameter files for each month of the year. In addition, the user should specify the 12 file names for the output files for building performance metrics for the entire month to be saved in directory "/Output/". In this mode, the detailed run output files, with the hourly resolution, are over written every time the main UWG function is called. So if detailed hourly results are required the model should be run under the single mode. In either simulation mode, it takes a few minutes to generate the output files located in the "/Output/" directory. It is recommended to discard the first 72 hours (3 days) of simulation for each month as spin-up period while considering results after this period.

"VCWGv1.4.5.py" and "VCWGv1.4.5Serial.py" are designed to run on Python 2.7.13. This version of Python can be downloaded from "https://www.python.org/downloads/release/python-2713/". For example, for a 64-bit Windows operating system the installation file will be "python-2.7.13.amd64". The following packages and versions can be used: numpy 1.14.3, scipy 1.1.0, matplotlib 2.2.2. Note that other packages may also work. "UWG/Run_RayTracing.py" is designed to run on Python 3.6.1. This version of Python can be downloaded from the following link "https://www.python.org/downloads/release/python-361/". For example for a 64-bit Windows operating system the installation file will be "python-3.6.1-amd64". The following packages and versions can be used: numpy 1.19.5, scipy 1.1.0, matplotlib 3.1.1. Note that other packages may also work.

References

[Aliabadi et al., 2021] Aliabadi, A. A., Moradi, M., McLeod, R. M., Calder, D., and Dernovsek, R. (2021). How Much Building Renewable Energy Is Enough? The Vertical City Weather Generator (VCWG v1.4.4). *Atmosphere*, 12(7):882.

[Moradi et al., 2021] Moradi, M., Dyer, B., Nazem, A., Nambiar, M. K., Nahian, M. R., Bueno, B., Mackey, C., Vasanthakumar, S., Nazarian, N., Krayenhoff, E. S., Norford, L. K., and Aliabadi, A. A. (2021). The Vertical City Weather Generator (VCWG v1.3.2). *Geosci. Model Dev.*, 14(2):961–984.