Assignment 8: Water balance and hydrological analysis using CWatM

Due: Wednesday 20 March, 14:30 of Week 9

Instructions

Please submit your report as a PDF file **individually** via Blackboard before the specified due date. To do this, navigate to the assignment, attach the PDF, and then click 'Submit'. If you encounter any difficulties in completing the assignment, first try to find solutions online (e.g., CWatM tutorials, documentation, and stack overflow), and then seek assistance from the instructor.

Background

Water balance analysis is important to verify the performance of a hydrological model and to evaluate the importance of different hydrological components under different hydrological conditions. It is the basis of management and policy making such as flood estimation, water allocation and use, wastewater management in urban areas, aquatic ecosystems management, water and virtual water trading. This week, we will use CWatM to analyze the water balance of your model simulation for the Rhine River Basin and look into different hydrological (i.e., flux and storage) components. In addition, one model parameter will be looked into more details on the flow routing process to understand how it impacts discharge and hydrograph.

Part 1: Configure a CWatM model run towards water balance analysis

1. Make a new copy of the settings file in Exercise 1 (CWatM\Tutorials\01_Turn-ON) into Exercise 6 (CWatM\Tutorials\06_Watercycle) and rename it to your liking (this will be simulation ***run2***).
2. Go to Exercise 6 and open the Watercycles.ipynb in Jupyter Notebook
    a. Open anaconda prompt
    b. Navigate to Exercise 6: CWatM\Tutorials\06_Watercycle
    c. Type jupyter notebook
    d. Click on the link and open the folder in a browser (or copy paste one of the URLs and open the folder in a browser)
    e. In the browser, click and open the ipython notebook file (i.e., Watercycles.ipynb)
    f. Check the comment on OUT_MAP_Daily for the condition when modflow_coupling = False in the first section of the notebook and copy all the variable names under OUT_MAP_Daily.
3. Edit the renamed settings file for a model run for water balance analysis

a. Paste all the variable names under OUT_MAP_Daily to the [OUTPUT] section of the new settings file you just created:

OUT_MAP_Daily = Rain, Snow, IceMelt, SnowMelt, snowEvap, iceEvap, act_nonpaddyConsumption, act_paddyConsumption, act_livConsumption, returnflowIrr, returnflowNonIrr, GW_Irrigation, Res_Irrigation, Lake_Irrigation, Channel_Irrigation, GW_Industry, GW_Livestock, GW_Domestic, Res_Industry, Res_Livestock, Res_Domestic, Lake_Industry, Lake_Livestock, Lake_Domestic, Channel_Domestic, Channel_Livestock, Channel_Industry, prefFlow_GW, perc3toGW_GW, lakeResInflowM, lakeResOutflowM, act_indConsumption, act_domConsumption, act_livConsumption, act_irrWithdrawal, act_nonIrrWithdrawal, act_domWithdrawal, act_indWithdrawal, act_livWithdrawal, snowEvap, capillar, baseflow, actTransTotal_forest, actTransTotal_grasslands, actTransTotal_paddy, actTransTotal_nonpaddy, unmet_lost, unmetDemand, pot_GroundwaterAbstract, storGroundwater, discharge, nonFossilGroundwaterAbs, Precipitation, totalET, EvapoChannel, EvapWaterBodyM, act_nonIrrConsumption, channelStorage, lakeResStorage, totalSto, sum_actTransTotal, sum_actBareSoilEvap, sum_interceptEvap, sum_openWaterEvap, addtoevapotrans, lakeResInflowM, act_bigLakeResAbst, sum_gwRecharge, sum_capRiseFromGW, act_totalIrrConsumption, sum_runoff, returnFlow, act_SurfaceWaterAbstract, dis_outlet, act_irrNonpaddyWithdrawal

b. Add a line in the [OUTPUT] section as per comment in the notebook:

OUT_MAP_TotalEnd = cellArea

c. Check the option of useSmallLakes and make sure it's turned off

useSmallLakes = False

d. Change the simulation period with at least 5 years of spin-up and at least 2 years of model simulation, e.g.,

StepStart = 1/1/1991

SpinUp = 1/1/1996

StepEnd = 31/12/1998

4. Change the output path to your liking and create a folder for storing the model output

   PathOut = ./output_run2

5. Be sure to add the discharge time series as output to plot the hydrograph to be used in Part 3.

   OUT_TSS_Daily = discharge

6. Run the model with the modified settings file (***run2***) following method of the last assignment

Part 2: Running the post processing tool to generate the water circle

1. Install python packages for running the notebook in anaconda prompt,

   conda install plotly

   conda install pandas

   conda install matplotlib

   conda install notebook

   conda install xlsxwriter

2. Make your own copy of the ipython notebook file and rename it (e.g., Watercycles_TT.ipynb)
    a. In the browser for jupyter notebook, go to file →save notebook as and save it under a different name. The new file should be open directly in the browser, or
    b. Copy and paste in Windows Explorer or Mac terminal, rename the new file, and open the file using the method described in Part 1.2
3. Change the file path to your model output path
   output_folder = r'C:\Users\TANGT0A\Documents\GitHub\CWatM\Tutorials\06_Watercycle\output_run2'
4. Change the location of simulation area to somewhere inside the Rhine basin area, e.g.,
   latitude = 48.75
   longitude = 7.75
5. Run the entire notebook using ⏩ or cell by cell using ▶
6. Explore the output figures, especially the water circle for different component (e.g., overall (for the whole system, groundwater, soil, lakes/reservoirs)
   Note: water circle for withdrawal and consumption will be empty in this case because the configuration file did not enable the water demand module (Line 37 of the settings file: includeWaterDemand = False)
7. Export and report the png files of water balance of soil, groundwater and the whole system. Please add text to explain 1) whether the water balance is closed, 2) what are the major water components.

For more information on the water cycle and post-processing tool, please check:
https://iopscience.iop.org/article/10.1088/1748-9326/ad18de

Part 3: Testing model sensitivity to manning roughness coefficient for channel flow

The manning's roughness coefficients (***n***) are used channel flow in the routing module in CWatM. Straight, clean and smooth channels typically have lower ***n*** values (in the order of 0.01) than meandering channel with stones, debris, and vegetation (up to 0.10). In CWatM, ***n*** is provided as an input map under the name chanMan. A calibration factor (variable name manningsN) is included in the model as a multiplier for model calibration. In this exercise, we will modify the manning's roughness coefficients for channel flow calculations and explore how this impacts flow response and hydrograph.

1. Make a new copy of the previous settings file and rename it (this will be simulation ***run3***)

2. Change the output path to your liking and create a folder for storing the model output
3. Be sure to add the daily discharge time series as output to plot the hydrograph.
4. Check the source code and understand meaning of chanMan and manningsN (Line 219 and L227 in CWatM\cwatm\hydrological_modules\ routing_reservoir\routing_kinematic.py)
5. Change the routing manningsN Factor within the physically possible range of [0.1-10.0], e.g.,
   manningsN = 3.72
6. Run the model with the modified settings file (***run3***)
7. Plot hydrographs of ***run2*** and ***run3*** in the same plot with legend and unit for at least one gauge station and compare/contrast them
8. Reflect on the physical meaning of manning's roughness coefficient and manningsN, and how it impacts the hydrographs

For your report this week, the final report should be in pdf format, including

- Your simulation period (including the spin-up period) and the coordinates of the added gauging station(s) used for ***run2*** and ***run3***
- Water balance of ***run2*** for soil, groundwater and the whole system as water circle plots with legend and unit with texts to explain 1) whether the water balance is closed, 2) what are the major water components.
- The plots of hydrographs with legend and unit with reflections on the physical meaning of manning's roughness coefficient and how it impacts the hydrograph.