User Guide: DRYP: a parsimonious model for DRYland regions water Partitioning.

March 7, 2021

1 INTRODUCTION TO RUNNING DRYP

1.1 Introduction

DRYP v1.0 has been tested in Python 3.7.4. and runs in windows and Linux.

The following python packages must be installed in order to use DRYP:

Landlab 2.0. (see https://landlab.readthedocs.io/en/master/index.html)
Numpy 1.16.4
Pandas 0.25.1

DRYP can run in previous versions of python that are compatible with packages listed above.

DRYP comes with an example (GW_1D) in addition to the following python scripts:

DRYP_Gen_Func.py
DRYP_groundwater_EFD.py
DRYP_infiltration.py
DRYP_io.py
DRYP_model_list.txt
DRYP_Modflow.py
DRYP_rainfall.py
DRYP_routing.py
DRYP_soil_layer.py
run_DRYP_v1_0.py
run_model.py
test_dryp.py

The folder GW_1D contains all files required to run a simple integrated 1D model. Inside this folder a folder called 'input' as well as two files 'input.dmp' and 'settings.dmp' required to run the model are provided.

To run DRYP:

1. Copy and paste the folder DRYP in a convenient location in your PC.
2. Open the file 'run_model.py' and change the name of the input file of the function 'run_DRYP(model_input_filename)'. This function will call DRYP and its components.
3. Open the command line or any IDLE available in your PC and run the file previously edited ('run_model.py')

Details about the input files, model parameter files as well as simulation setting are specified in the following sections.

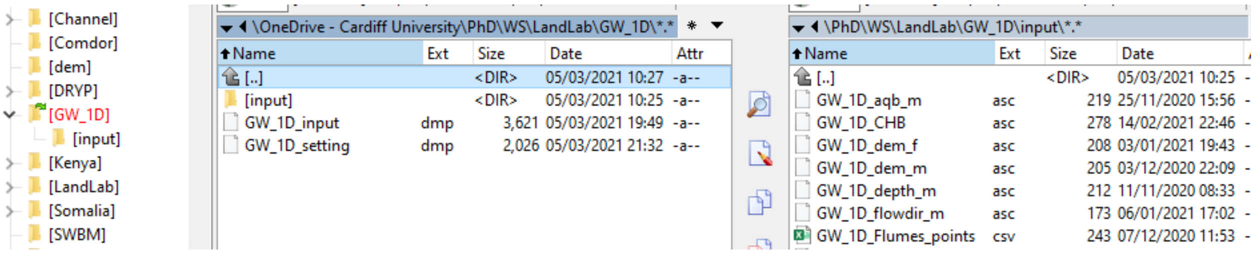

Figure 1: Location of the GW_1D example

For running the example copy and paste the folder GW_1D into the same directory of DRYP folder (see figure 1).

For model installation testing, run pytest command providing the location of the DRYP folder. A simple test file ('test_dryp.py') is provided in order to check the installation.

2 DATA INPUT FILE FORMAT

2.1 Forcing Data

The main driven variables of the model are the precipitation and evapotranspiration. Time variable parameters can be provided as gridded data in netcdf format or it can be provided as time series in '.csv' format. When provided as time series, the precipitation/evapotranspiration will be uniform for each time step.

The model will not interpolate/aggregate spatially or temporally any variable. Model grid size will depend entirely on datasets/maps provided as input files. The time step of precipitation/evapotranspiration has to be according to the time step specified in the model setting parameters.

For netcdf datasets, a variable representing time has to be specified with name 'time' Time has to be defined as numeric values but it should include a time units and the calendar. Names of variables must be specified as 'pre' for precipitation and 'pet' for evapotranspiration. The model will not recognise any other name specified for the last variables. The netCDF4 API for python can be used to create input files for the model. The following is an example of a variable defined created as netCDF4 file in python that can be read by DRYP:

```
dataset = Dataset(fname_out, 'w', format='NETCDF4_CLASSIC')
dataset.createDimension('time', None)
dataset.createDimension('lon', columns)
dataset.createDimension('lat', rows)
dataset.createDimension('grid', grid size)
lat = dataset.createVariable('lat', np.float64, ('lat',))
lon = dataset.createVariable('lon', np.float64, ('lon',))
time = dataset.createVariable('time', np.float64, ('time',))
pre = dataset.createVariable('pre', np.float32,('time','grid'))
time.units = 'hours since 1980-01-01 00:00:00'
time.calendar = 'gregorian'
```

For dataset provided as time series in csv files, columns must be label as 'Date' for time and 'pre' and 'ETo' for precipitation and evapotranspiration, respectively.

```
Date,pre,ETo
01/01/2000 00:00,0,0
01/01/2000 01:00,0,0
01/01/2000 02:00,0,0
01/01/2000 03:00,0,0
```

2.2 Model Parameters

A list of parameters required for each component is presented below:

Surface component:

- Digital elevation model (DEM), required
- River network (values greater than zero are considered as river), if not available all cells are considered rivers
- Flow direction in landlab format (ID of receiving node following landlab indexing), if no available, Landlab will automatically find the direction of flow based on the DEM.
- Drainage area, it can specified as the model domain for the catchment. Default value is 1.0.

subsurface component:

- Rooting depth in mm, default value 1000mm
- Wilting Point (θ_{wp}), default value 0.1
- field capacity (θ_{fc}), default value 0.15
- Porosity, n_e, default value 0.35
- Standard deviation of the saturated hydraulic conductivity, σ
- Infiltration at saturated conditions, (K_{sat}) in mm/h
- Water content at residual capacity, θ_r
- Exponent of the water retenction function, b default value 2.
- Suction head, ψ, default value 300mm

Groundwater component

- Aquifer saturated hydraulic conductivity, Ks_{GW}, default value 1 [m/h]
- Aquifer specific yield, Ks_{GW}, default value 0.01 [-]
- Groundwater model domain, optional, in case that groundwater catchment is different than surface catchment.
- Initial water table, default value is specified at 1 meter below the rooting depth.

Parameters can be provided as numerical values or as maps. When maps are provided, they must be raster files. An example of the raster format for a 3 x 3 grid size map is shown below.

```
ncols        3
nrows        3
xllcorner    574361
yllcorner    3502989
cellsize     1000
NODATA_value  -99999
825.233 860.3439 864.650
825.233 860.3439 864.650
825.233 860.3439 -99999
```

Filenames of parameters required for the model must be included in the input file. If a filename is not provided, default values will be considered. The input file must be a plain text file. This file must start with 'drylandmodel' in the first line (see example below), omitting the first line will stop the simulation.

Filenames provided in the input file must be written in each line specified in the the example, changes will result in simulation errors or wrong variables being read (e.g. if the file 'GW_1D_dem_m.asc' is written in line 5, python will raise an exception error).

input_file

```
drylandmodel
Model name --------------------------------------(3):
GW
=============== TERRAIN COMPONENTS =================
Topography (DEM)---------------------------------(6):
../GW_1D/input/GW_1D_dem_m.asc
Cell factor area --------------------------------(8):
../GW_1D/input/GW_1D_area_m.asc
Flow Direction (fd)-----------------------------(10):
../GW_1D/input/GW_1D_flowdir_m.asc
Boundary conditions (check CHB) ----------------(12):
../GW_1D/input/GW_1D_chb.asc
Basin Mask (catchment) -------------------------(14):
../GW_1D/input/GW_1D_mask_m.asc
River length -----------------------------------(16):
../GW_1D/input/GW_1D_riv_m.asc
River width ------------------------------------(18):
none
River bottom elevation -------------------------(20):
none
================ SURFACE COMPONENTS ===============
Vegetation type Kc -----------------------------(23):
none
Soil land use ----------------------------------(25):
none
Other ------------------------------------------(27):
none
========== SOIL AND SUBSURFACE PARAMETERS ==========
Soil porosity: porosity ------------------------(30):
../GW_1D/input/GW_1D_rawls_ne.txt
Theta residual ---------------------------------(32):
../GW_1D/input/GW_1D_rawls_theta_r.txt
Available Water content (AWC) ------------------(34):
../GW_1D/input/GW_1D_rawls_awc.txt
Wilting Point (wp) -----------------------------(36):
../GW_1D/input/GW_1D_rawls_wp.txt
Soil Depth (D) ---------------------------------(38):
../GW_1D/input/GW_1D_depth_m.asc
Soi particle distribution parameter (b) --------(40):
../GW_1D/input/GW_1D_rawls_n.txt
Soil suction head ------------------------------(42):
../GW_1D/input/GW_1D_rawls_phi.txt
Saturated hydraulic conductivity ---------------(44):
../GW_1D/input/GW_1D_rawls_ks.txt
sigma_Ksat -------------------------------------(46):
../GW_1D/input/GW_1D_rawls_sigma_ks.txt
Initial soil water content ---------------------(48):
none
Other ------------------------------------------(50):
none
=== GROUNDWATER PARAMETER AND BOUNDARY CONDITIONS ===
Groundwater Boundary condition (domain) --------(53):
../GW_1D/input/GW_1D_mask_m.asc
Aquifer Sat. Hydraulic Conductivity (Ksat_aq) --(55):
../GW_1D/input/GW_1D_rawls_ks1.txt
Specific Yield----------------------------------(57):
none
Initial Conditions Water table elevation -------(59):
..\Channel\GW_input_1D\GW_1D_wte_ini_4.asc
Flux Boundary Conditions -----------------------(61):
```

```
none
Head Boundary Conditions -----------------------(63):
../GW_1D/input/GW_1D_CHB.asc
Other-------------------------------------------(65):
../GW_1D/input/GW_1D_aqb_m12.asc
================ METEOROLOGICAL DATA ===============
Precipitation ----------------------------------(68):
../Channel/input/Pre_60m_00_05_sin.csv
Potential Evapotranspiration -------------------(70):
../Channel/input/Pre_60m_00_05_sin.csv
Other-------------------------------------------(72):
none
Other ------------------------------------------(74):
none
========= RESULTS AND OUTPUT DIRECTORIES ===========
Discharge point results ------------------------(77):
../GW_1D/input/GW_1D_Flumes_points.csv
Soil point results output ----------------------(79):
../GW_1D/input/GW_1D_SM_points.csv
Groundwater point results ----------------------(81):
../GW_1D/input/GW_1D_well_point_m.csv
Folder location results ------------------------(83):
../GW_1D/outputs
Other ------------------------------------------(85):
none
Other ------------------------------------------(87):
none
MODEL PARAMETER SETTINGS FILE ------------------(89):
../Channel/GW_1D_par_setting.dwapm
```

Additionally, a simulation settings file must also be provided. This file should contain parameters that control the simulations such as simulation period, format of input files as well as the activation of model components such as groundwater flow.

Simulation settings file is a plain text document file, which has to include in the first line the following text 'DWAPM_SET', as it is shown in the example below, omitting the first line will will stop the simulation. Lines with numerical values are allowed to change, but they can not be displaced by adding a new line. The change of position of lines will result in errors or will stop the simulation.

simulation_setting_file

```
DWAPM_SET
======== SIMULATION PERIOD AND TIME STEP =========
Initial date for simulation (YYYY MM DD) ........(4)
2000 1 1
Initial date for simulation (YYYY MM DD) ........(6)
2001 1 6
Activate SUBDAILY time step: 1 active 0 disable..(8)
0
OF Time step - dt_Pre (min) - (1440 for daily)..(10)
60
GW Time step -----------------------------------(12)
0
============ MODEL READING OPTIONS ================
Read Precipitation from NETCF file..............(15)
0
Read Evapotranspiration from NETCF file.........(17)
0
Other...........................................(19)
0
============== MODEL COMPONENTS ===================
Inf.- 0: Scheeke 1: Philips 2: Up_GA 3: Mod_GA..(22)
```

```
22 3
23 Run surface routing ----------------------------(24)
24 0
25 Run Groundwater Modflow ------------------------(26)
26 1
27 Run OF linear reservoir: 1 active 0 disable.....(28)
28 0
29 Run UZ linear reservoir: 1 active 0 disable.....(30)
30 0
31 ============== OUTPUT OPTIONS ===================
32 Show simulation times 1 active 0 disable .......(33)
33 0
34 Save OF and UZ maps as figures and netcf files..(35)
35 0
36 Save GW as figures and netcf files (daily)......(37)
37 0
38 Plot maps and the end of the period............(39)
39 0
40 Save maps as raster at the end of the period....(41)
41 0
42 Print daily maps................................(43)
43 0
44 Print simulation time...........................(45)
45 0
46 ============= MODEL PARAMETERS FACTORS ===========
47 Runoff partition parameter (kdt-Sheeke).........(48)
48 1.0
49 Soil Depth factor - kDroot (mm) ................(50)
50 1.0
51 Available Water Content factor - kAWC ..........(52)
52 1.0
53 Infiltration rate factor - kKsat ...............(54)
54 1.0
55 Heterogeneity factor - k_sigma - (Upscaled GA)..(56)
56 1.0
57 Transmission losses - Kch (m/h) ................(58)
58 1.52967
59 Decay discharge - T - (hours)...................(60)
60 0.1512967
61 Channel width parameter (pe-not activated)......(62)
62 1
63 Aquifer saturated hydraulic conductivity........(64)
64 5.0
65 Aquifer specific yield factor...................(66)
66 1.0
```

Information related to simulation period should be specified as the initial and final date of the simulation and must be on lines 4 and 6. Date must be specified as integers separated by spaces (e.g. 2001 1 9), zero on the left side is not allowed and will stop the simulation (e.g 2001 01 19, will raise an error).

Simulation time step of the surface component must be specified in line 10. Time has to be specified in minutes, with a maximum time step of one day. Time step must be an integer, and values must be rational fraction of the hour (e.g 20 min is allowed but 25 will stop the simulation) when sub-hourly time step is set. In case of hourly time steps, it must be a rational fraction of the day (e.g. 180 min (3h) is allowed but 300 min (5h) will result in errors).

For groundwater component, the simulation time step must be specified on line 12. Time step has to be an integer value, and should be specified in hours.

The format of precipitation/evapotranspiration files must be specified in lines 15 and 17, respectively, A value of 1 represent grids in netcdf format, whereas a value of zero represent comma-separated formats.

DRYP has four types of infiltration methods implemented which has to be specified in line 22. The following codes can be chosen in depending on the infiltration approach adopted:

0: Schaake model,
1: Philip's equation,
2: Upscaled Green and Ampt,
3: Modified Green and Ampt method.

The groundwater components can be activated or disabled in line 26, a value of 1 enable the groundwater component whereas a value of 0 disables it.

Lines 27 to 32 are currently disabled, in the future this options will be added to the model capabilities.

A set of parameters that globally modify the model parameters are also specified in the simulation settings file. Vales are scale factors of the following parameters:

line 48: kdt, for water partitioning of the Shaake infiltration approach,
line 50: kDroot, for rooting depth,
line 52: kAWC, for available water content,
line 54: kKsat for the saturated hydraulic conductivity of the soil,
line 56: kSigma, for the standard deviation of the saturated hydraulic conductivity of the Modified Green and Ampt approach,
line 58: kKch, for infiltration rates in the channel,
line 60: kT for decay parameter of discharge,
line 62: kKaq for aquifer saturated hydraulic conductivity,
line 64: kSy for aquifer specific yield factor,

3 DRYP RESULTS

Output variables for each model component are summarised below:

Surface component

- Runoff
- Infiltration rate
- Flow accumulation
- Transmission losses

Subsurface component:

- Water content (θ)
- Actual evapotranspiration (AET)
- Percolation

Groundwater component:

- Recharge (percolation + transmission losses)
- Water table elevation

By default, DRYP saves all results in the directory specified in the line 83 of the input parameter file (see section 2). Filename of the result files start with the name of the model (line 2, input files), followed by the following codes:

DRYP will automatically save the average fluxes and water content of model compartments. Results are saved at time steps specified for the surface component.

Table 1: Suffix of model result files stored by DRYP

Code	**Variable**
avg:	average results over the active model domain
SM:	oil moisture deficit [-]
PET:	Potential evapotranspiration [T L-1]
AETr:	Actual evapotranspiration for river [T L-1]
AET:	Actual evapotranspiration [T L-1]
INF:	Infiltration rate [T L-1]
EXS:	Infiltration excess [T L-1]
RCH:	Recharge [T L-1]
Dis:	Discharge [T L-1]
BFL:	Baseflow [T L-1]
wte:	Water table elevation [L]

Average results are saved in a comma separated file that can be opened in microsoft excel or any text editor. The document contains the following information which is specified by codes for each variable in the first line:

- pre: precipitation,
- rch: recharge,
- dis: discharge,
- aet: actual evapotranspiration,
- usz: soil water content,
- gws: groundwater storage,

Result at specific locations of each model component can be obtained by providing a list of coordinates. Coordinate files should be specified in a comma separated format (e.g. .csv) with column heads specified as `Nort` and `East` for the y and x, respectively. If a coordinate is not inside the model domain, the simulation will stop. Coordinate files must be specified in the following lines of the input file:

line 77: File of coordinates for surface component,
line 79: File of coordinates for unsaturated zone,
line 81: File of coordinates for saturated zone,

Point result files are named with the model name (see 2.2) as prefix followed by the codes specified in table 1. Point result files store a number of variables variables depending on the component. A list of model variables for each component is specified below:

Table 2: Variables stored in point result files and codes of each variable, for filename see table 1

code	**variable**
Surface component	
OF	Discharge
TL	Transmission losses
EXS	infiltration excess
Unsaturated zone	
SM	soil moisture
AET	actual evapotranspiration
RCH	recharge, diffuse and foccused recharge
Saturated zone	
WT	water table elevation

Point result files are time series with the first column specified as time with head 'Date'. The number of columns of result files depend on the number of points specified in the coordinate files defined above. Columns are label depending on the component and variable (see 2) followed by number starting by zero (e.g. for discharge, the file model_name_Dis.txt will contain the following columns, 'Date' for time and 'OF_0', 'OF_1', .. etc. for discharge values)