How to use GlobWat 1.0

1. Introduction

GlobWat is a soil water balance model to assess water use in irrigated agriculture, described in Hoogeveen et al., 2015. Usage is subject to mandatory citation (see Reference).

Input layers and parameters, output data, and model code are freely distributed through FAO GeoNetwork spatial data catalogue[1] and FAO AQUAmaps, spatial water data explorer[2]. The output data made available for distribution refer to global water use in irrigation around the year 2005 and are based on long term climatic averages.

This document provides additional information on how to run the model to assess water use in irrigated agriculture under different circumstances, including climate parameters, irrigation patterns, or any other user defined input.

2. Input data

Input data feeding the model -as it is configured in the distributed version- are listed in Table2. A comprehensive list of input and output files, including references and sources, is included in the package for download (Filenames-keys.xlxs). All input grids have the following characteristics:

Table 1: grid specification

File type	AAIGrid: Arc/Info ASCII Grid
Columns (X)	4320
Rows (Y)	2160
Pixel size	0.08333
No Data value	-9999
Data type	Float32
Reference System	GCS WGS84
Extent	-180; -90 : 180; 90

Table 2: list of input data

12 input grids with monthly precipitation	prc*01 to 12*wb.asc
12 input grids with reference evapo(transpi)ration[3]	eto*01 to 12*wb.asc

[1] http://www.fao.org/geonetwork/srv/en/metadata.show?id=42661
[2] http://www.fao.org/nr/water/aquamaps/
[3] The term "evaporation" as used in GlobWat and in this document includes and substitutes the term "evapotranspiration" defined in FAO Irrigation and Drainage Paper n. 56 "Crop evapotranspiration".

12 input grids with rainy days	wet*01 to 12*wb.asc
12 input grids with coefficient of variation of precipitation	cov*01 to 12*wb.asc
1 input grids with maximum soil moisture	hwsd-smax.asc
1 input grid with initial soil moisture	hwsd-sini.asc
1 input grid with maximum deep percolation flux	gwinfmx.asc
1 input grid with average effective rooting depth	rtdpth5m.asc
1 input grid with land use systems to be linked with kc-values	farmsys-final.asc
1 input grid with maximum soil moisture correction factor used for calibration	soil-corr22.asc
1 input grid with maximum percolation flux correction factor used for calibration	gw-corr.asc
1 grid with codes to be linked with irrigation kc-values and intensities	adm-ataq-5min.asc
1 irrigation density grid	gmia_v5_0_1_pct.asc
list with kc-values per land use class	farmsys-kc.prn
list with kc-values for irrigated areas per country	sum_kc_GMIA5.prn
list with irrigation intensities per country	sum_int_GMIA5.prn
1 grid with area in ha	ar-5mingr-ha.asc
1 grid with open water density	glwd-ow.asc
1 grid with kc-values for open water, wetlands and marshes	1_1-grid.asc
1 grid with wetlands and marshes density	glwd-wetl3.asc
1 grid with sub-basin codes	subbas-wrld-g.asc
list with names and flow direction codes for each sub-basin	subbas_flow.prn
1 grid with summary codes	admin2012-5mn.asc
list with summary codes	admin2012.prn

Grid data can be edited in any commonly used GIS software, including Q-GIS or ArcGIS, provided that grid specifications are maintained as per Table 1. PRN files can be edited in text editors such as Notepad ++ provided that columns spacing is maintained (or, alternatively, that changes are reflected in the first line of the file, for example "i4, 8x, a55, f9.4" means that the file structure uses, for each row, 4 spaces for integer values, then 8 empty spaces, followed by 55 spaces for text characters, followed by 9 spaces for floating numbers with 4 decimals).

3. Output data

Output files are listed in Table 3, but changing parameters in the configuration file will affect the names and numbers of output files.

Table 3: list of output files

1 output grid with soil moisture content at the end of the simulation	soil5m.asc
12 output grids with monthly generated precipitation	prcgen*jan to dec*.asc
12 output grids with monthly actual evaporation	etact*jan to dec*.asc
12 output grids with monthly deep percolation fluxes	gwflux*jan to dec*.asc

12 output grids with monthly drainage	runoff*jan to dec*.asc
12 output grids with monthly irrigation evaporation	etirr*jan to dec*.asc
1 output files with monthly water balances per sub-basin	subbas-month.out
1 output file with yearly water balance per sub-basin	subbas-yr.out
1 output file with yearly water balance per major basin	majbas-yr.out
1 output file with monthly water balance per summary code	country-month.out
output file with yearly water balance per summary code (country)	country-yr.out
12 output grids with monthly water balance grids	etact5m-ow-*month*.asc
1 output grid with yearly water balance (corrected for evaporation over water and wetlands)	etact5m-ow.asc
1 output grid with yearly incremental evaporation over irrigated areas	etinc5m-irr.asc
1 output grid with yearly incremental evaporation over open water	etinc5m-ow.asc
1 output grid with yearly incremental evaporation over wetlands	etinc5m-wet.asc
output file with flow accumulation per sub-basin	subbas_flow.out

Grid files can be imported in any commonly used GIS software, such as Q-GIS or ArcGIS. Files with ".out" extension can be imported in spread sheets as fixed width text files. Table 4 shows an example of subbas-yr.out imported in Excel, and Table 5 provides a description of field names.

Table 4: example of output file

Area	Precip.	ETo	Inc. flow	Gen Precip	ET act	ET open wat	ET wet lands	Gr water	Drain age	Area irrig.	ET irrig.	Outflow
842024	8959	9558	0	8976	5544	38.84	12.44	1142	2338	3541	8	3373
137409	1480	1608	0	1457	877	0	0	179	397	1431	3.65	577
448241	5005	5118	0	5236	3116	66.22	0	652	1483	1956	4.28	2049
441522	4839	5210	2626	4970	3008	29.23	0	590	1360	4894	11.08	4548
636555	7335	7736	7921	7435	4603	348.93	545.06	645	2208	6752	15.54	9843
433915	4882	5240	0	4591	2891	0	326.45	482	1229	4885	11.7	1362

"Area" and "Area irrig." are in hectares, while all other fields are in million cubic meters.

Table 5: output field names

Field name	Descritpion
Sub_Code	Identification number linked to subbas-wrld-g.asc
Name Sub-basin	Sub-basin names (read from subbas_flow.prn)
Maj_Code	ID code of major basin (read from subbas_flow.prn)
Name Major Basin	Name of major basin (read from subbas_flow.prn)
Area	Sub-basin area (ha)
Precip.	Average precipitation calculated from climatic input data

ETo	Reference E(T) calculated from climatic input data
Inc. flow	Incoming flow (based on routing specified in subbas_flow.prn)
Gen Precip	Generated precipitation, after rainfall daily distribution is applied
ET act	Rainfall dependent actual evaporation
ET open wat	Additional evaporation over open water
ET wetlands	Additional evaporation over wetlands
Groundwater	Recharge to groundwater
Drainage	Surface runoff
Area irrig.	Irrigated area (ha)
ET irrig.	Additional evaporation due to irrigation
Outflow	Sub-basin outflow

4. Configuration file

A configuration file is used to list names and location of input and output data, and to specify a few calculation options (for example, whether monthly output water balance are to be calculated or not). This file should have the same name of the executable file, but with ". inp" extension, and it can be edited in any text editor, such as Notepad ++. The structure of the file should not be changed and, in particular, no new row should be added, otherwise the program will not be able to recognize the position of input files.

Extract of the first 6 rows of globwat-1-0.inp:

```
! 0-scenario, with irrigation
! in- and output files, all in Arc-Info ASCII-grid format, (maximum length
! mask grid:
input\subbas-wrld-g2014.asc
! 12 input grids with precipitation
input\prc01wb.asc
```

5. Running the model

The model can be run using the bat file globwat.bat, or executing soilwatbal.exe, followed by flowwatbal.exe. However, it is sometimes necessary, depending on system configuration, to re-compile the code from Fortran as explained below.

The model's code, written in Fortran, is available in the file "soilwatbal-1-0.f". In order to run the model, the Fortran file needs to be compiled into an executable file (.exe, in Windows). Compilation can be done using GFortran, whose binaries are available at http://gcc.gnu.org/wiki/GFortranBinaries. One possible step-by-step procedure to run GlobWat is the following:

1. Download and install gfortran (http://gcc.gnu.org/wiki/GFortranBinaries);
2. open Command Prompt (Run cmd, or Accessories/Command Prompt);
3. change directory (command: cd) to the directory where the .f file is and write in Command Prompt:

```
gfortran filename.f -static⁴ -o filename.exe;
```

4. once the exe file is written, execute soilwatbal-1-0.exe from command prompt (type filename.exe) making sure you're in the right directory;
5. execute flowwatbal5m.exe

Additional useful resources on compiling Fortran code can be found at: http://fortranhelp.blogspot.it/ and, more in general on Fortran, at http://www.neng.usu.edu/cee/faculty/gurro/Fortran.html.

REFERENCES

J. Hoogeveen, J.-M. Faurès, L. Peiser, J. Burke, and N. van de Giesen, 2015, GlobWat – a global water balance model to assess water use in irrigated agriculture, Hydrol. Earth Syst. Sci., 19, 3829-3844, 2015. *doi:10.5194/hess-19-3829-2015*

[4] This option is only necessary if one wants to create an executable which runs without Fortran DLLs (without having GFortran installed), see http://gcc.gnu.org/wiki/GFortranGettingStarted.