Reducing The Uncertainty Of The BBH Water Balance Model Using The Budyko Framework

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Abstract

Time distribution of soil moisture is simulated by *BBH* model (ref. 5) on the daily timescale at the catchment's level for a three years period. Daily observations of climatic variables (sunshine duration, air temperature, air humidity, wind speed) are available. *BBH* model is adjusted assuming a one layer vertical column and it is coupled with the FAO Penman-Monteith approach (ref. 1) as well as with a rainfall-runoff transformation (SCS CN model (ref. 3) derived in (FAO 25)). In the lack of soil moisture observations to calibrate model parameters, intervals of variation for *BBH* parameters are derived in linkage with the literature and according to the soil and climate of the studied region. Moreover, a precipitation threshold is considered as lower limit to give rise to runoff occurrence. Thus, SCS model outputs are taken as basis to reduce the range of the *BBH* parameters. In fact, this lack of soil moisture observations introduces an important uncertainty about BBH model parameters. To take this uncertainty into account, an ensemble of twenty parameters sets is performed to simulate twenty different responses for the *BBH* model (ref.2). In the third stage, *BBH* outputs are evaluated in comparison to Generalized Hsuen Chun Model (ref. 4) using a dryness index, according to Budyko framework. a regional value of this model parameter is adopted to compare the results and reduce the uncertainty about *BBH* parameters.

Objectives

- Development of a coupled model (*BBH*-FAO Penman-Monteith) for estimating actual evapotranspiration.
- Apply Budyko approach to diminish the uncertainty about *BBH* parameters using dryness index (ratio precipitation to potential evapotranspiration).
- Sensitivity of *BBH* results on model timescales.

Case Study and Data

Case study:

Châal, is an olive field area (30690 ha) situated near Sfax (Tunisia), and belongs to an arid region (Fig.1). Dryness index is estimated to 4.68.

Climatic data:

Daily rainfall, air temperature, wind speed, air humidity and sunshine duration of Châal meteorological station are applied to *BBH* model for 3 years.

Daily and monthly rainfall and Piche evaporation (Fig.2) for 17 years are applied to *BBH* model and in the Budyko approach.

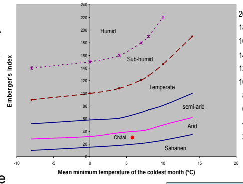

Fig.1 Emberger's pluviothermic index

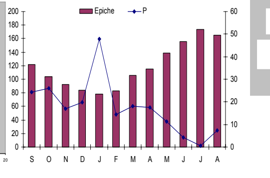

Fig.2 Mean monthly distribution of rainfall (P) and of Piche evaporation (Epiche) (1989-2006)

Models

BBH and FAO Penman Monteith models for estimating actual evapotranspiration (Fig.3)

Budyko approach (1)

$$ETR=[Rn\,P\,tnh(\frac{P}{Rn})(1-\cosh(\frac{Rn}{P})+\sinh(\frac{Rn}{P}))]^{\frac{1}{2}}$$

Generalized Hsuen Chun model (2) (ref.4)

$$ETR=ETP\left[\frac{(P/ETP)^K}{1+(P/ETP)^K}\right]^{\frac{1}{K}}$$

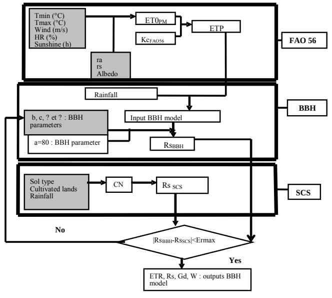

Fig.3 Coupling of BBH, FAO Penman Monteith and SCS CN models

Results

Results of BBH model

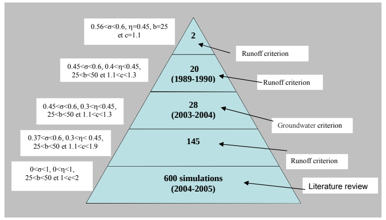

Fig.4 Hierarchical procedure for estimating parameters for BBH model

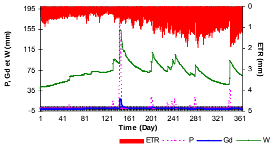

Fig.5 Daily Actual evapotranspiration (ETR), rainfall (P), soil moisture (W) and groundwater (Gd) for 1989-1990

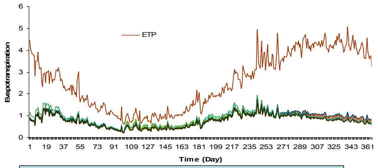

Fig.6 Estimation of 20 daily actual evapotranspiration (ETR) by BBH model for 1989-1990

Application of Budyko approach (GHS model)

Tab.1 Comparison of actual evapotranspiration with different models and timescales

Equation	ETR (mm)	Rn/P	ETR/P	ETP/P	K parameter
Budyko (1)	207	6,1	0,99	4,68	
Hsuen chun (2)	195	6.1	0.92	4.68	1.5
BBH (Daily) (ETR=P-Rs_{BBH}) (20 sets of parameters)	175 -189	6.1	0.84-0.91	4.68	
BBH (Daily) (ETR=P- Rs_{BBH}) (2 best sets of parameters)	189	6.1	0.91	4.68	
BBH (Decadal)	182-189	6.1	0.88-0.91	4.68	
BBH (Monthly)	183-189	6.1	0.88-0.91	4.68	

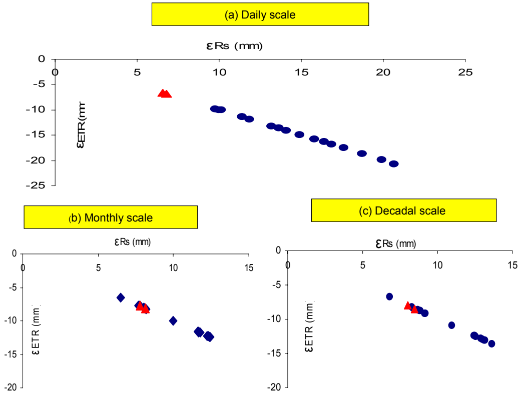

Fig.7 Annual values of actual evapotranspiration errors vs runoff errors for the twenty sets of BBH parameters (Error= BBH estimation – Budyko estimation)

Discussion and Conclusions

The hydrological year is considered (from 1 September to 30 August). The ET0 within the site was evaluated to 1325 mm (2004-2005) and 1368 mm (2003-2004). The ETP ranges between 909 and 938 mm. Among the sets of parameters, simulation of ETR varies between 246 and 283 mm during 2004-2005 and between 289 and 320 mm for 2003-2004. Using data of the extreme hydrological year 1989-1990 (precipitation =582 mm), allowed the reduction of uncertainty on the parameters (Fig. 4). Water budget variables are presented in Fig 5 for 1989-1990 . Simulated ETR for the most likely 20 parameters sets are presented in Fig 6 for the same year. They range from 289 to 303 mm. The application of the *BBH* model in monthly and decadal timescales for 17 years and with the 20 most reliable sets of parameters allows to verify the Budyko hypothesis (that deep losses of water are negligible and that the soil water content is identical at the beginning and at the end of the hydrological year while this hypothesis is not confirmed at daily timescale. The mean value of ETR estimated from radiative Budyko index (R_n/P) is 206 mm. A regional value of the k parameter of the generalized Hsuen Chun model witch constitute an approximation of the Budyko model (2), was derived using observed runoff from several catchments in Tunisia leading to *k=1,5 (ref.6).* For each of the twenty most likely *BBH* parameter sets, differences in ETR vs Rs with GHC with K=1,5 are presented in Fig. 7 for the three time scales. For ETR, they range from -6 to -20 mm/year meaning a systematic underestimation of about 10% for all time scales. This methodology may be adopted to estimate the actual evapotranspiration in ungauged basins.

References

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