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Helping Africa to Help Itself

Assessment of soil moisture budget using a water balance model and use of model results for drought early warning. Case of a moderate semi arid watershed northern Tunisia

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Motivation

- Drought is an adverse meteorological situation.
- Economical issues of drought have multiple faces such as deficit of the trade balance, food insecurity and loss of population incomes.
- For an agricultural country such as Tunisia, drought preparedness is an important task.
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- The purpose of this study is to build an early warning drought system on the basis of watershed water balance assessment.

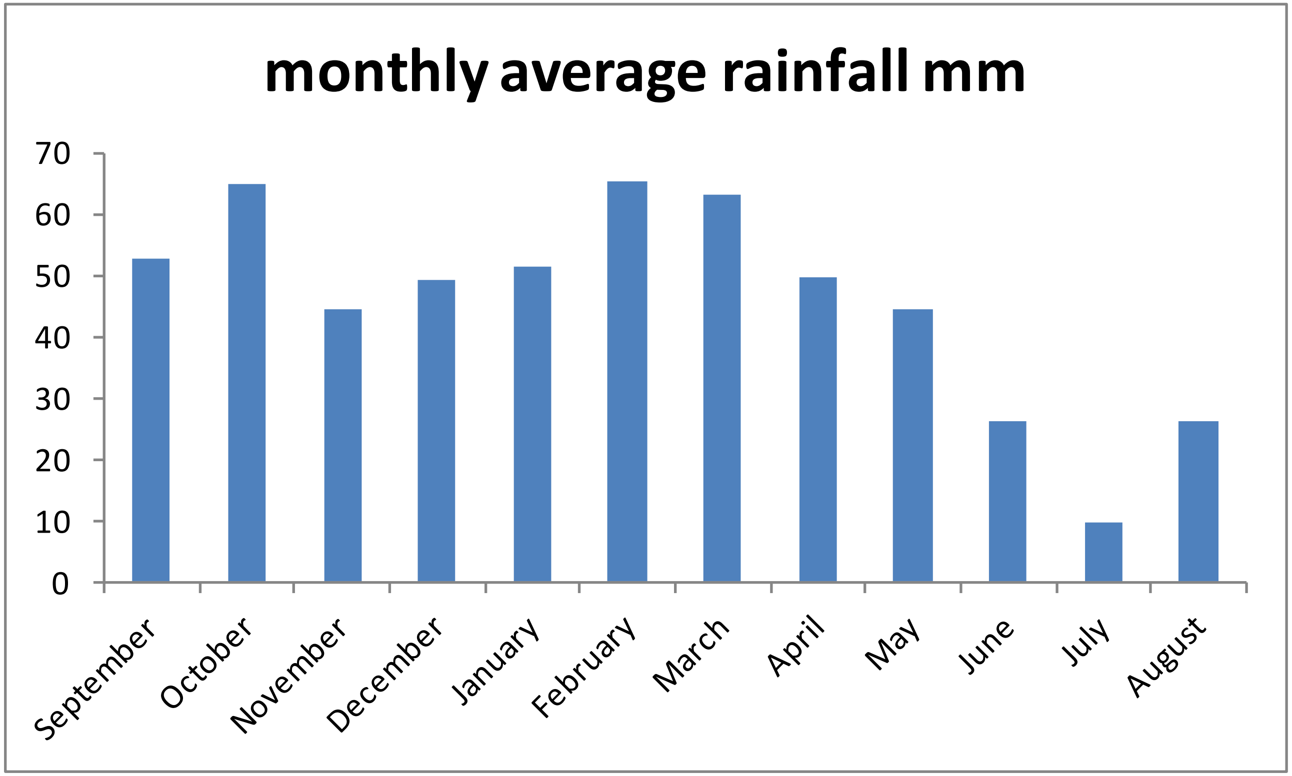
basin physiographic characteristics

- Oussafa watershed
- Semi arid climate conditions
- Area: 397 km²
- Maximum elevation: 1294 m
- minimum elevation: 508 m
- Concentration time: 16 h

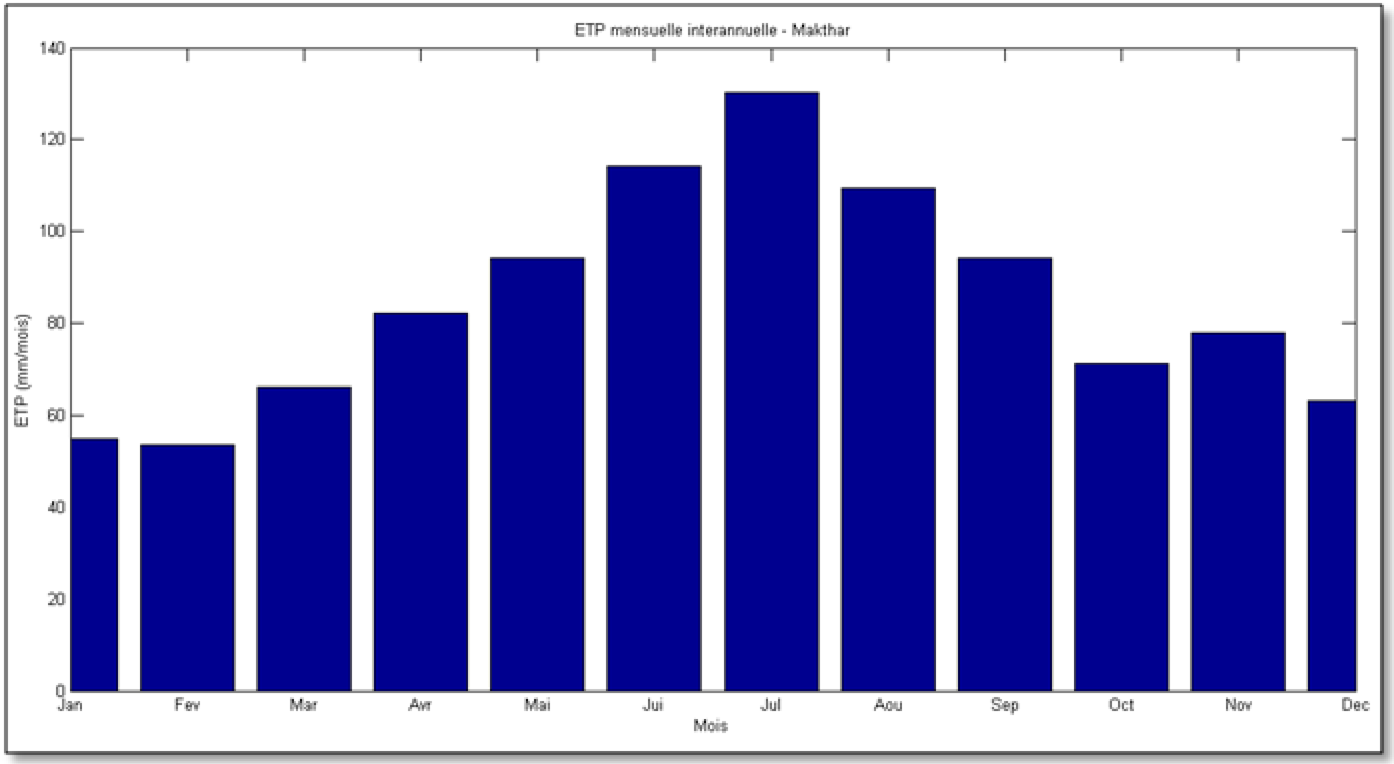
hydrometeorological Data

- Observed river discharge series cover three periods: 1928-1938; 1960-1963; 1966-1972;
- Observed daily rainfall series are available during the period 1928-1982.
- Monthly Piche evapotransporimeter data are available for 8 years and help estimating monthly averages.

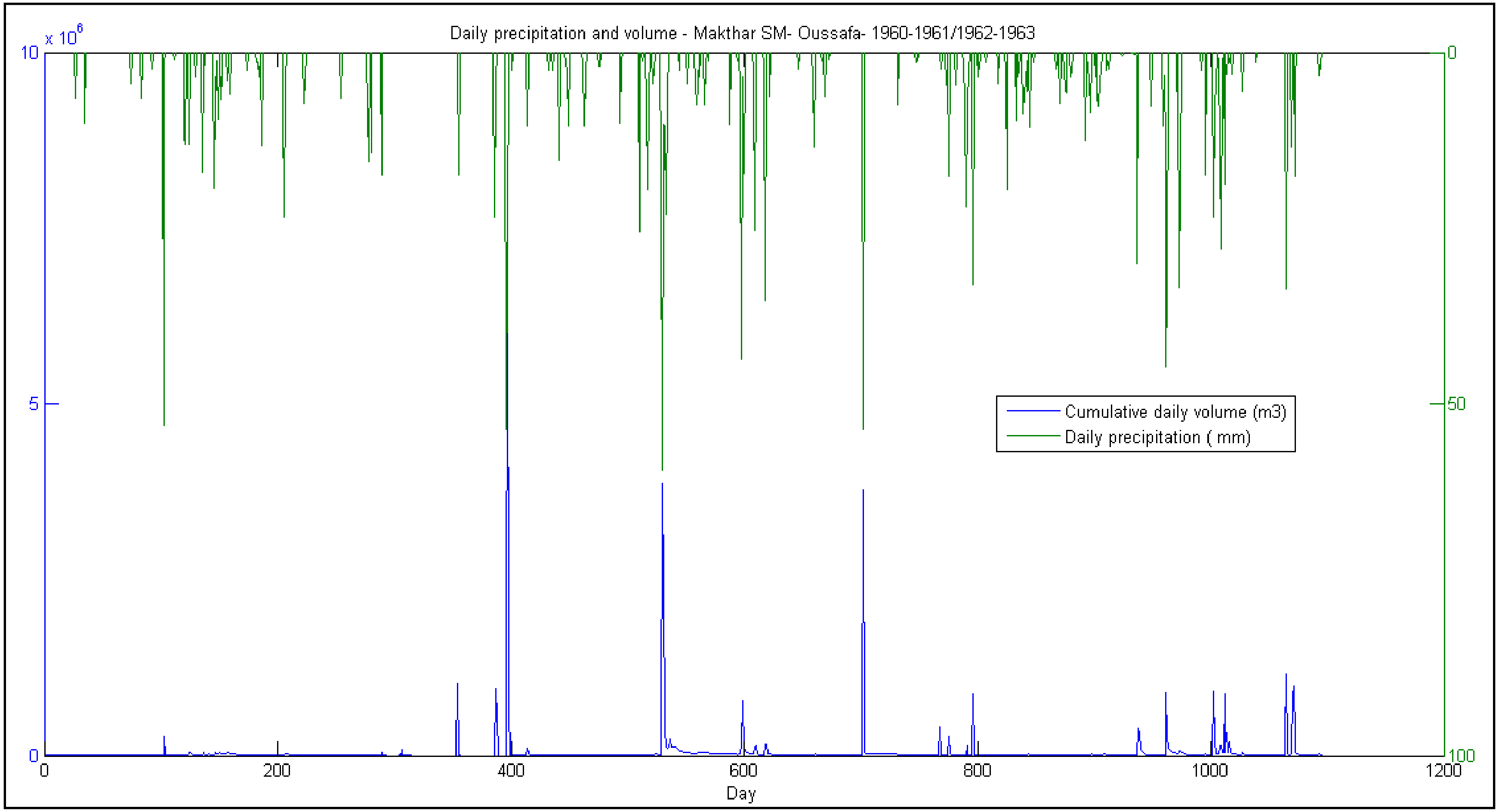
Average monthly precipitation mm



Average Monthly Piche evaporometer mm



Example of daily time series of rainfall and runoff volumes (1960-1961 / 1962-1963)



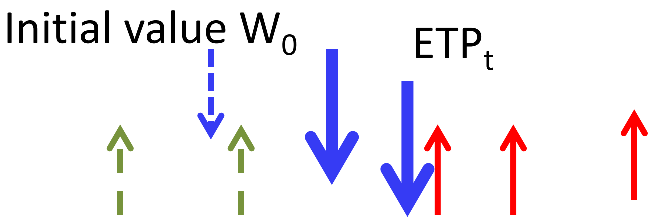
The model (BBH Bucket Buttom Hole)

- **The Kobayachi et al. (2001**) water balance model is adopted at daily time scale. It is a single soil bucket model.

- Model reparametization so as to limit the number of tuning parameters to three have been performed **(Bargaoui et Houcine, 2010)**. Remaining (four) parameters are estimated according to soil texture information.

- It represents at watershed scale the water flux exchanges between the atmosphere, the root zone as well as exchanges with deeper soil horizons (percolation and capillary rise).

  - W_t : soil water content (mm) at day t
  - P_t: precipitation (mm)
  - ETR_t : Actual evapotranspiration (mm)
  - R_{st} : Surface Runoff (mm)
  - Percolation (G_{dt} >0) (mm)
  - Capillary rise (G_{dt} <0) (mm)



$$W_{t+1} = W_t + P_t - ETR_t - Rs_t - Gd_t$$

The model calibration criteria

- The annual runoff bias < 20%,
- The Nash Sutcliffe coefficient > 0.4 for decadal and monthly time scales,
- The simulated vegetation relative productivity **(Eagleson, 1994)** representing the ratio Kv = ETR_{an}/ ETP_{an} (at annual scale) meets semi arid conditions of the watershed.

The model verification

- The model is calibrated using data from a given calibration period
- Sets of calibrated parameters are used to run the model and test its performance for other observation periods.
- The sets of parameters giving the best performance compromise with respect to both calibration and testing periods are retained.
- The average model output is assumed as model output (mean model).

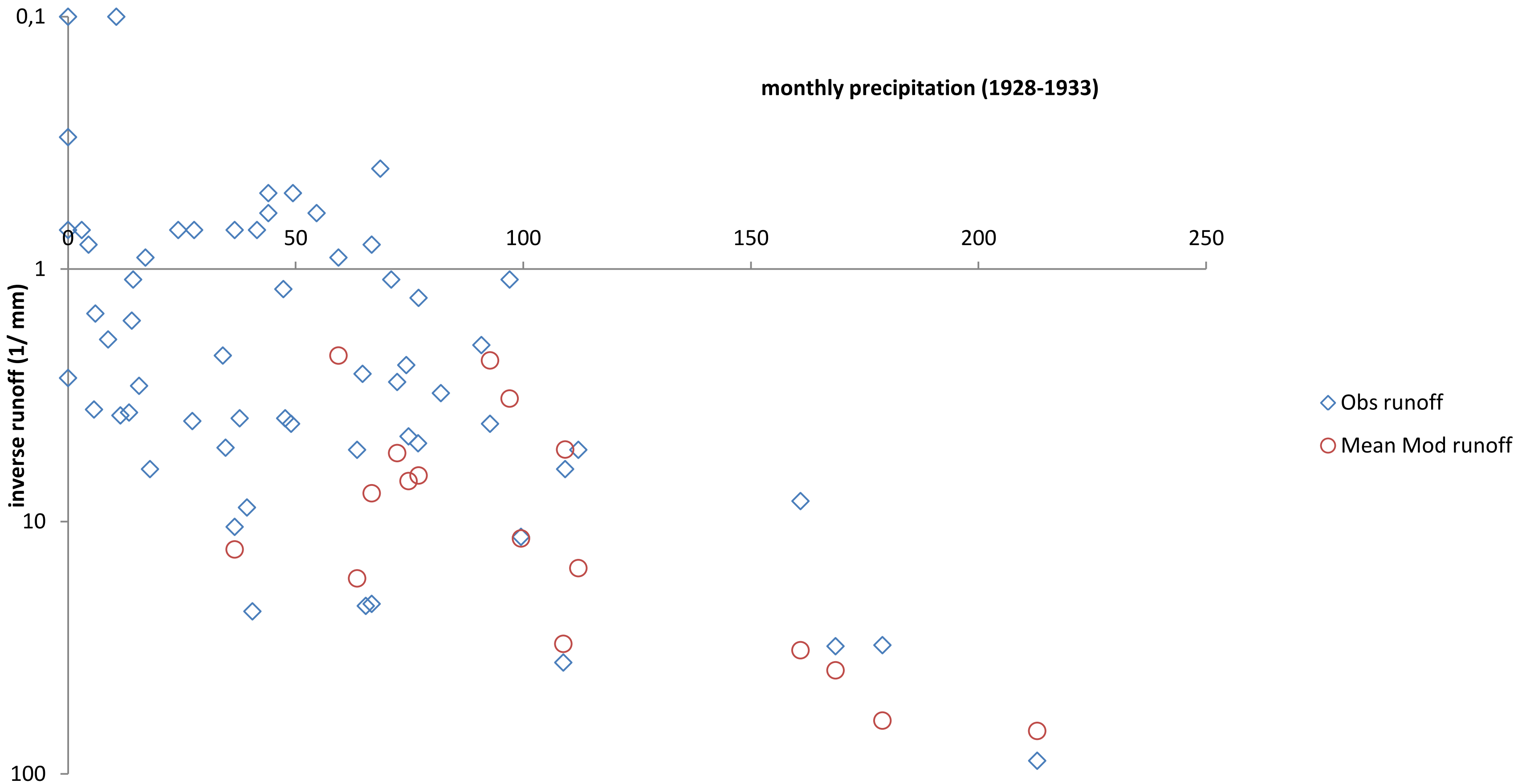
The soil water content analysis

- Monthly soil water content are computed for the simulated series
- Minimum and maximum monthly values are reported
- Monthly Percentiles are estimated
- A comparison to some fixed percentiles (0.15; 0.20; 0.30; 0.5) is completed.

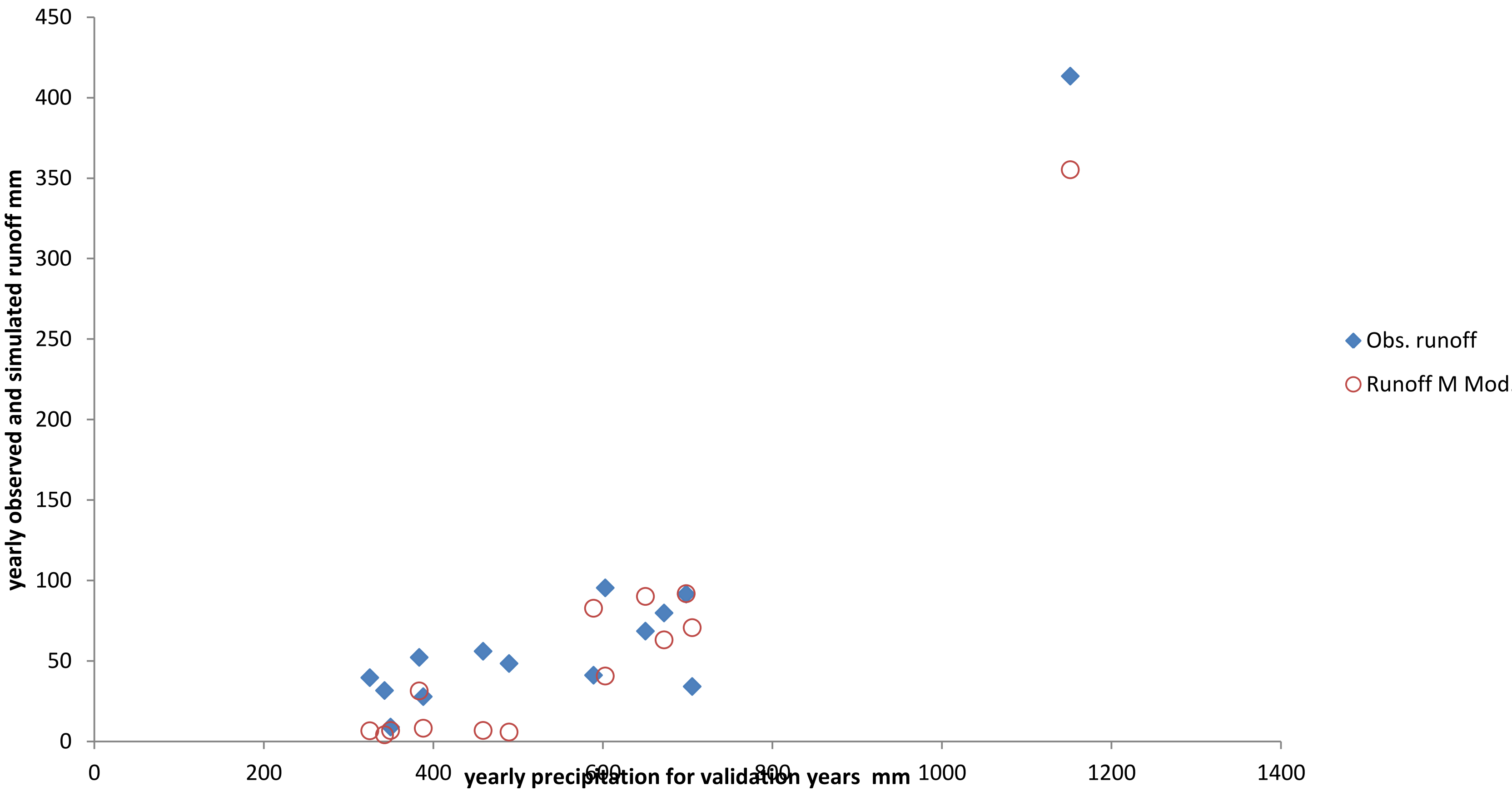
Results

- Simulated and observed runoff during the calibraton period (1928-1933) are reported versus precipitation inputs at
  - monthly and
  - yearly resolutions.
- They report acceptable matching for high and moderate runoff.
- However, the model underestimates small runoff values.
- The existence of springs upstream might explain this mismatching.

Simulated and observed runoff compared to precipitation inputs at monthly resolution



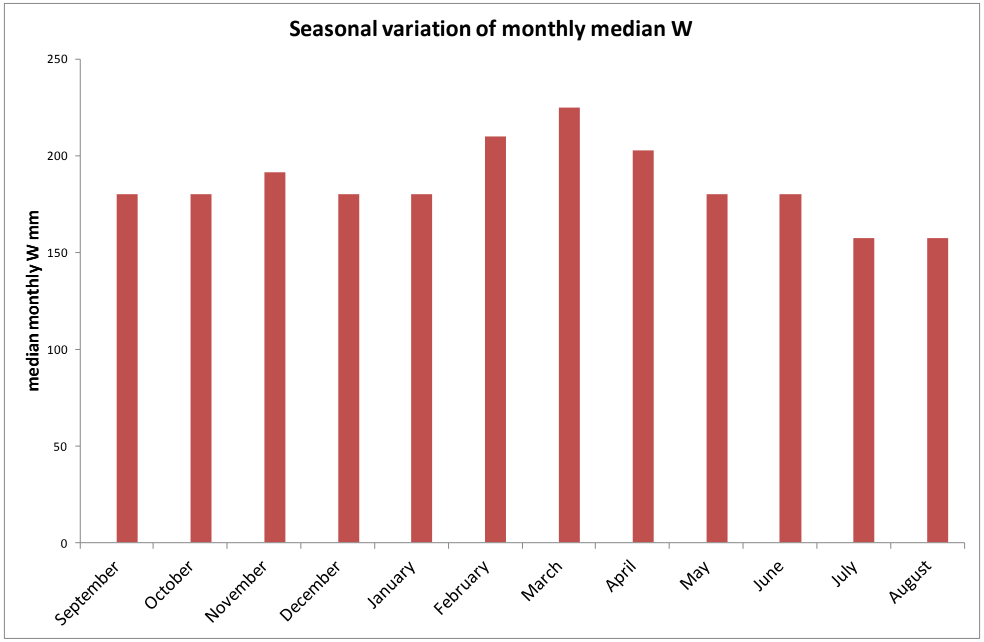
Simulated and observed runoff compared to precipitation inputs at annual resolution (test period 1972- 1982)

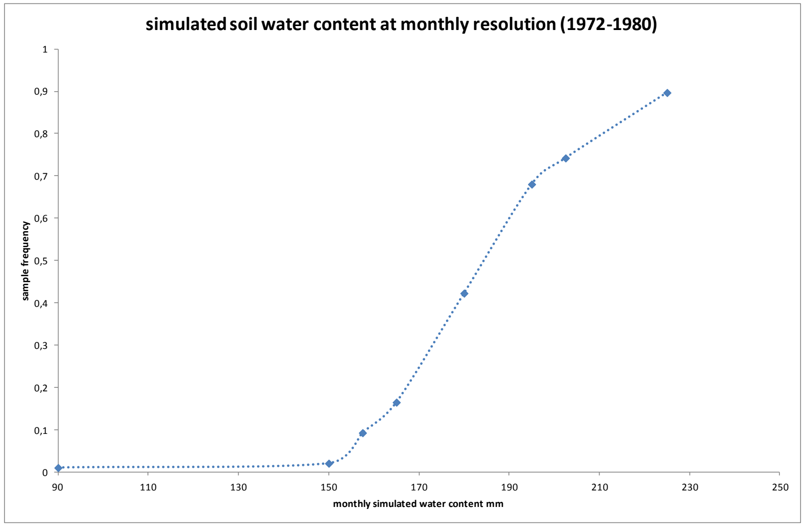


Inter annual and inter mensual Variability of simulated soil water content (sample distribution of monthly values)

November (fall) peak

March (spring) peak





Simulated monthly soil water content values compared to precipitation data (1972-1982)

Months that are important for crop yield are November, February, March, April.

Those for which the **0.15 percentile** is not exceeded are indicated in orange in the table

In the crop growing season, February 1977 and 1980, March 1977 and 1980 as well as April 1978 and 1980 are identified as drought months for the simulation period 1972-1980.

Months indicated « Orange » for soil water content are either « orange » for precipitation or in shortage (rainfall < 0.30 percentile) ot in deficit during preceeding months.

if they are not in situation of important rainfall deficit (<0.3 Percentile) for the actual month , they were in that case either in the precedent month or in the precedent two months.

If a month has a severe precipitation deficit but a surplus was in place during the precedent month, soil water content is not identified as « orange » (example of April 1973)

W Month mm	September	October	November	December	January	February	March	April	May	June	July	August
1972/1973	90	180	180	202,5	225	225	225	203	180	165	150	158
1973/1974	180	180	203	225	180	195	225	203	180	180	180	158
1974/1975	180	180	180	180	180	225	225	225	203	180	158	180
1975/1976	180	180	225	180	180	225	225	203	225	203	203	180
1976/1977	180	225	225	203	203	180	180	225	180	180	158	158
1977/1978	158	180	180	180	180	225	203	180	180	180	158	158
1978/1979	158	180	180	180	180	180	225	225	180	180	158	158
1979/1980	180	180	225	180	180	180	180	180	180	180	158	158
0,15 percentile	158	180	180	180	180	180	181	181	180	180	158	158
0,2 percentile	158	180	180	180	180	180	189	189	180	180	158	158

rainfall mm	September	October	November	December	January	February	March	April	May	June	July	August
1972-1973	60	134	12	53	157	61	193	14	1	4	1	33
1973-1974	3	64	18	105	10	68	31	60	18	7	30	0
1974-1975	41	25	15	21	13	138	55	64	31	2	0	70
1975-1976	46	18	91	19	48	48	67	25	83	87	39	21
1976-1977	43	84	88	26	32	14	79	39	49	0	0	7
1977-1978	29	18	43	11	18	84	33	35	34	0	0	15
1978-1979	0	34	33	18	16	67	51	62	33	29	0	22
1979-1980	86	35	136	2	15	24	33	25	32	13	0	17
mean	53	65	45	49	51	65	63	50	44	26	10	26
0,15 perc	7	18	10	18	13	25	27	25	18	0	0	5
0,20 perc	10	23	12	19	16	35	32	26	19	1	0	8
0,3 perc	19	34	16	24	29	48	35	32	30	3	0	12
0,5 perc	41	43	33	36	41	67	53	39	36	13	0	18

Conclusions

- A lumped water balance model at watershed scale is worth to assess drought occurrence at monthly scale provided that potential evapotranspiration, rainfall and river discharge data are available for its calibration and quality assessment.
- Drought identification using simulated soil water content analysis differ from identification using only rainfall data.
- Monthly shortages or deficits detected on the basis of soil water content come either from a rainfall deficit in the present month or in the two previous months.

Acknowledgments

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