Simulations of the soil moisture dynamics in the small scale forested catchment using mesoscale hydrological model

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INTRODUCTION

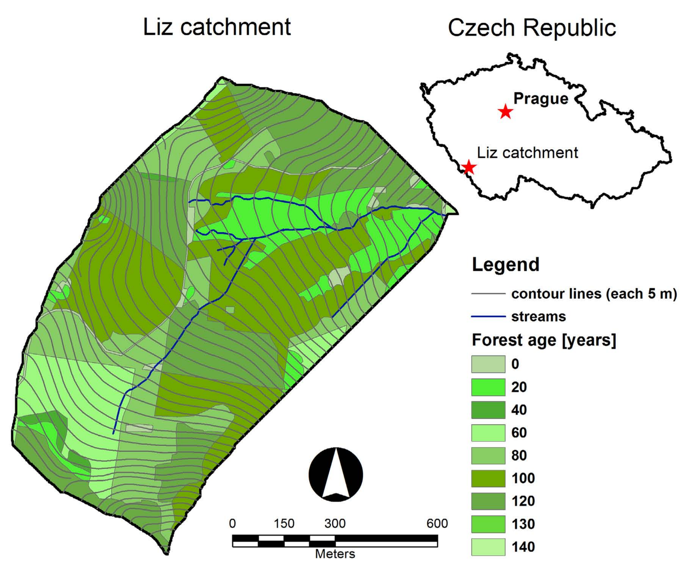
Soil moisture plays a key role in the hydrological cycle and also in the entire ecosystem. It controls the flux of water between soil, vegetation and atmosphere. Hence, understanding of soil moisture variability participates in the modelling of the climate system and improves eco-hydrological simulation. Meso- and macro-scale models usually use simplified equations for soil moisture content estimation, enabling an application of the larger scales. Well established SWAT (Arnold et al., 1993) and SWIM (Krysanova et al. 1998, 2005) models are representatives of this type of models. However, in spite of numerous applications of models of the SWAT/SWIM type, only a few contributions have dealt explicitly with soil moisture. Thus the aims of this study is to assess the ability of the SWIM model to simulate a hydrological cycle in micro-scale areas, where detailed measurements are available. The study is primarily focused on the soil moisture regime.

If we summarise the goals, the aims were:

- to assess the ability of the mesoscale SWIM model to simulate a hillslope scale watershed;
- to investigate the reliability of total soil water content simulations as a whole and with an emphasis on particular soil layers;
- to compare two different approaches (kinematic and exponential storage) of lateral flow estimation.

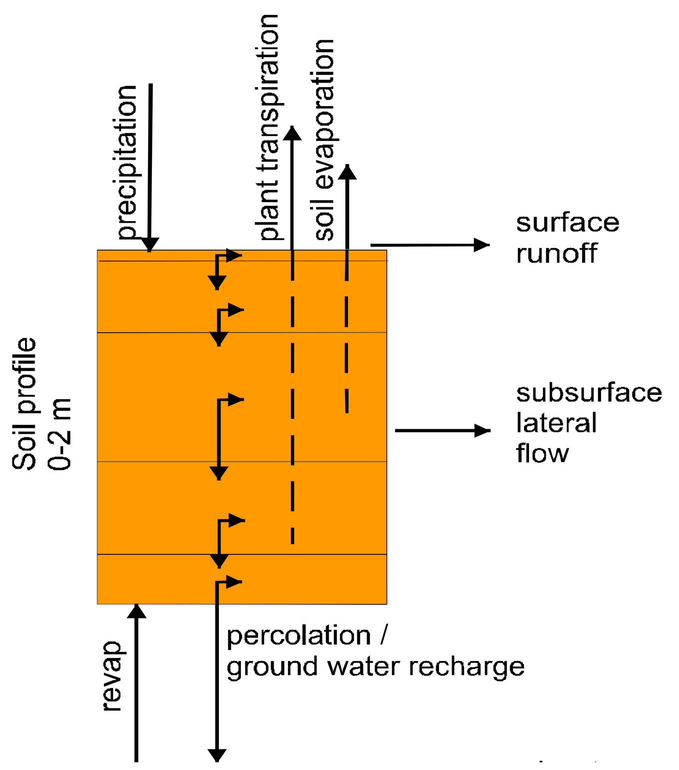
STUDY SITE

- The total catchment area is 99.7 ha
- The average altitude equals 941 m.a.s.l.
- The soil refers to sandy loam acidic podzol with three horizons: 0 – 17 cm, 17 – 60 cm, and 60 – 100 cm
- The saturated conductivity ranges from 200 to 350 mm/hr
- The mean monthly temperature varying from -3.4 °C in January to 13.6 °C in July and the average annual precipitation is 825 mm
- The entire catchment is covered by mixed forest
- The soil moisture data were gained from the set of tensiometers (UMS T8) at three depths (15 cm, 40 cm and 60 cm).



SOIL AND WATER INTEGRATED MODEL

- For the basins from 100 to 10000 km^2
- Calculates the values in the daily step
- For the climate change and also land cover/land use change
- Based on SWAT and MATSALU models
- Integrates hydrology, water quality, erosion, vegetation and nutrient dynamics at the watershed scale
- Precipitation, temperatures and solar radiation represent input datasets
- SOIL MOISTURE SIMULATION TECHNIQUES:
- Surface runoff – Soil Conservation Service – Curve Number
- Evapotranspiration - (Priestly-Taylor, 1972; Ritchie, 1972
- Percolation – storage routing technique (Arnold et al., 1990)
- Lateral Flow - storage routing technique or kinematic storage (Sloan and Moore, 1984)

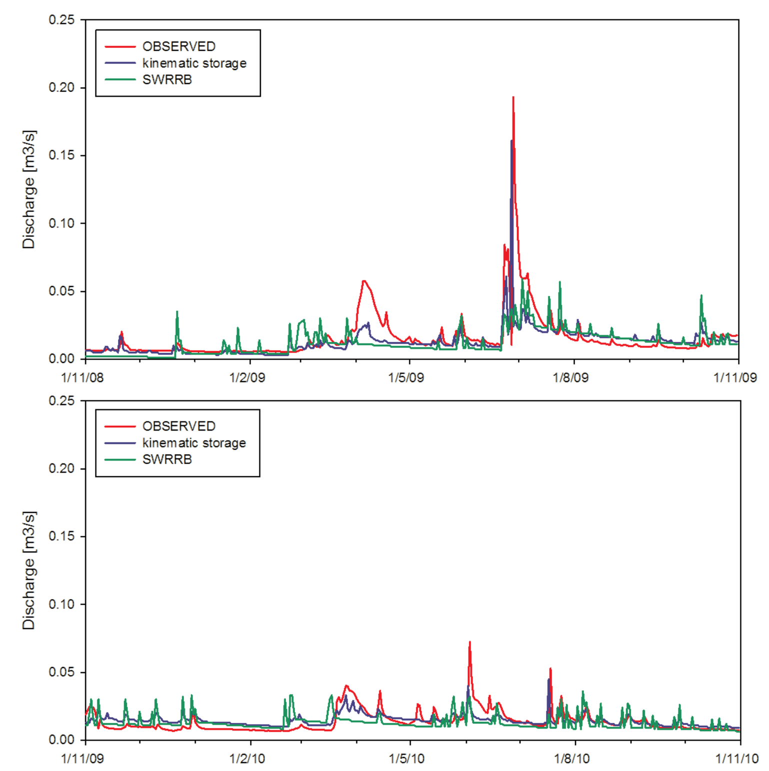


DISCHARGE SIMULATIONS

- Model was was calibrated in the daily time step using the period of hydrologic years 2007 and 2008
- Both methods for lateral flow calculation give generally similar results
- The application of the error measurement statistics proves better performance by the method based on the kinematic storage (Table I.)

	kinematic storage	SWRRB
NS	0,39	0,38
RMSE	0,0102	0,0104
RE	0,73	0,74
R²	0,24	0,25
B	-4,0%	-15,3%

Table I. The error statistics of the model performance concerning discharge simulation for the entire validation period (2007 - 2010)



SOIL MOISTURE SIMULATIONS

- The soil moisture simulation are generally more accurate during the warm periodm (April - August)
- In the winter period (September – March) the differences between observed and simulated data are significantly higher (Fig.2)
- The depth distribution of the moisture content is also simulated sufficiently in the warm period, only the top soil layer (represented by the tensiometer at the 15 cm depth) exhibits higher amplitude and generally higher moisture content than estimated (Fig.2)
- The total soil moisture content within the soil column corresponds most accurately to the tensiometer at 40 cm depth
- The more efficient technique for lateral flow calculation, considering total soil moisture content, is the kinematic storage model (Fig.3)

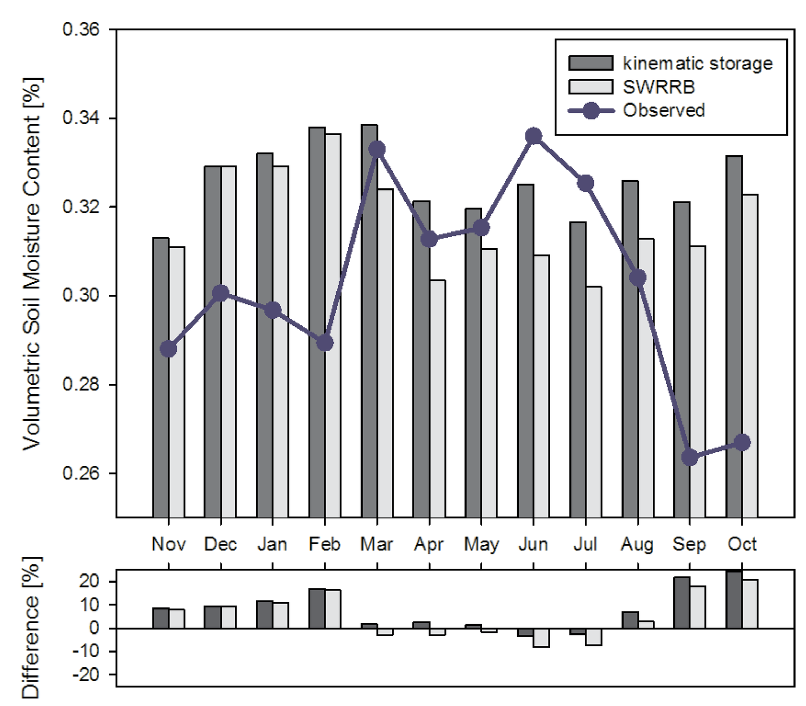


Figure 3. Comparison of the simulated and observed monthly average soil moisture content in the Liz catchment (2009-2010).

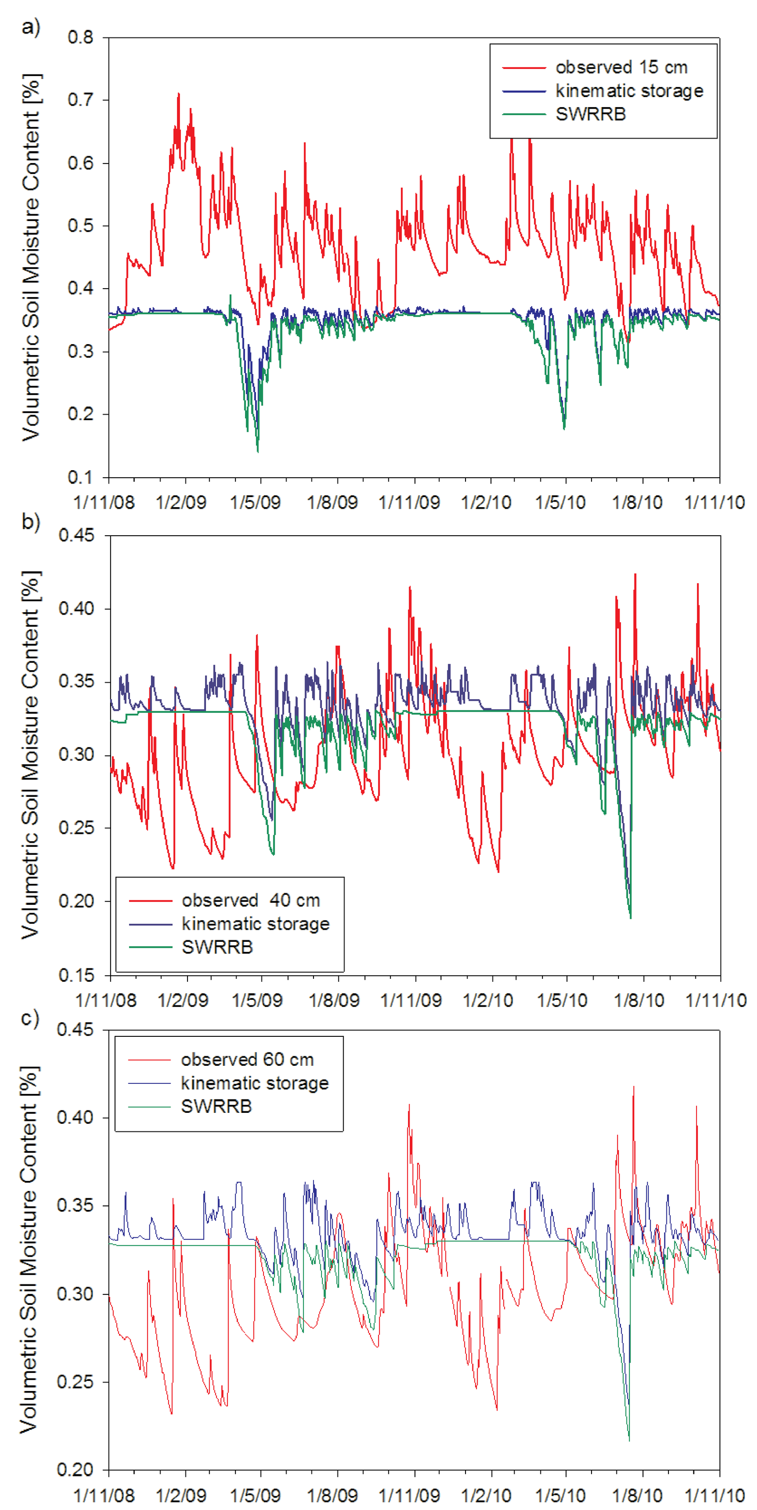


Figure 2. Simulated and observed soil moisture content at the depth of a) 15 cm, b) 40 cm, c) 60 cm

Warm period (1st April - 31th August)

- Total soil moisture content is simulated sufficiently
- Both the the fluctuations and their magnitudes are represented satisfactorily

Cold period (1st September - 31th March)

- The restricted ability to predict the soil moisture fluctuations
- The main difference is in the inability to simulate the depletion of the soil moisture content, caused probably by the gradual percolation to lower layers of the soil profile and groundwater

season	lateral flow	RMSE	Correl	B
cold 2009	kinematic storage	0,043	0,519	7,08%
	SWRRB	0,042	0,491	6,89%
warm 2009	kinematic storage	0,035	0,855	2,57%
	SWRRB	0,037	0,784	-2,47%
cold 2010	kinematic storage	0,049	0,750	10,82%
	SWRRB	0,046	0,542	8,13%
warm 2010	kinematic storage	0,020	0,689	-0,67%
	SWRRB	0,025	0,653	-4,48%

Table I. The seasonal error statistics of the soil moisture simulations

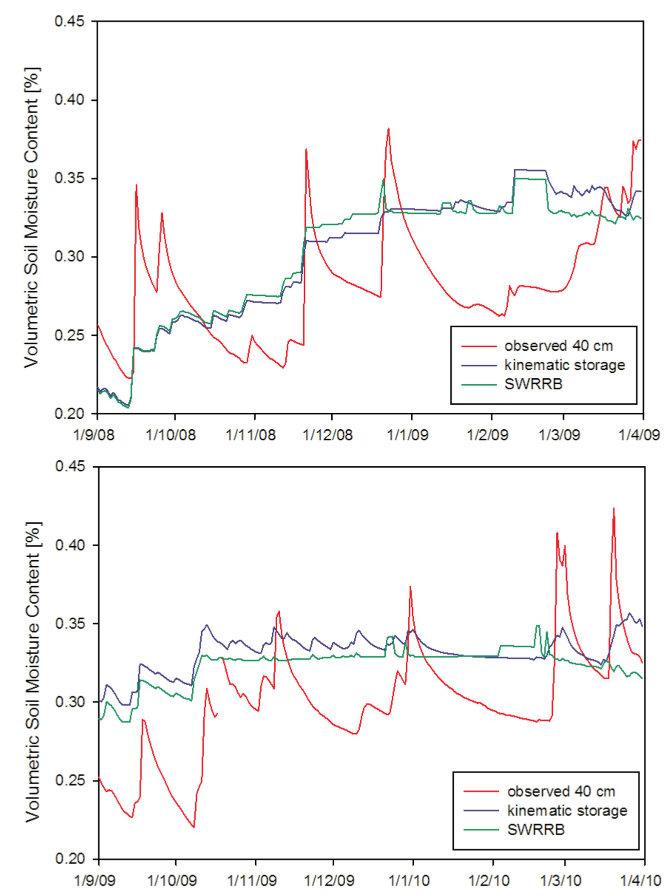


Figure 4. Model performance of total soil moisture content in the cold season (1st September - 31th March).

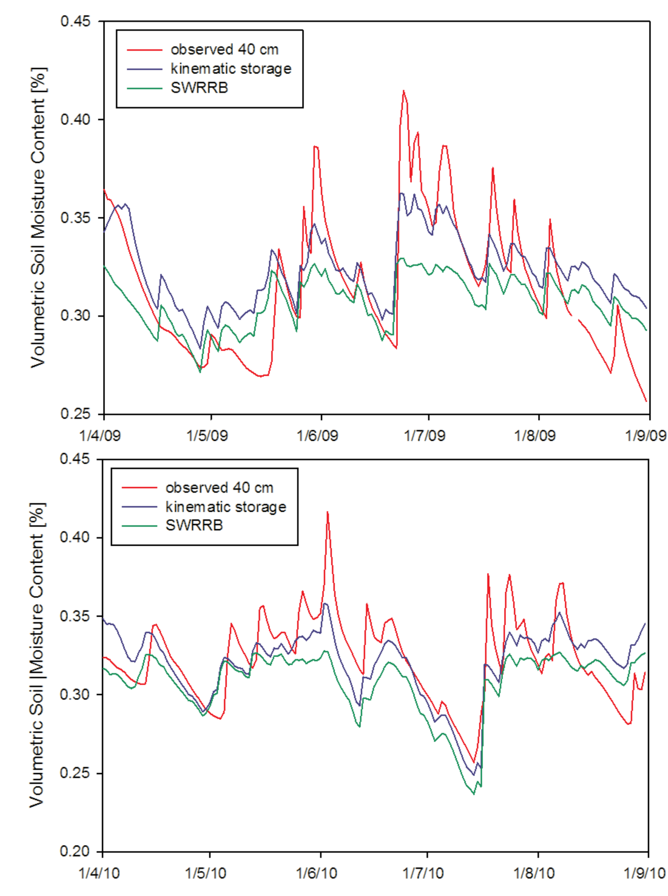


Figure 5. Model performance of total soil moisture content in the warm season (1st April – 31st August).

CONCLUSIONS

- The SWIM model is able to describe the fundamental dynamics of the runoff response from the forested single hillslope catchment. However, the drawbacks are in the area of the snowmelt routine and recession curve estimation.
- Comparing the two techniques of lateral flow estimation, using the small scale forested watershed, the kinematic storage technique reproduces the observed values of discharge and also soil moisture content more efficiently.
- The soil moisture simulations exhibit contrasting results
- Warm period (April – August) - the dynamics of soil moisture content is simulated quite accurately
- Cold period (September – March) – the simulations are less sufficient as the decreases in moisture content are either not evident at all (in the year 2009) or present only to a very limited extend (in 2010).

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The research is supported by the Czech Science Foundation (IAA300600901) and by the Institutional Research Plan AV0Z20600510. Contact: Václav Šípek, e-mail: sipek@ih.cas.cz, Institute of Hydrodynamics, Pod Paťankou 30/5, 166 12 Prague 6