

PARAMETERIZATION OF HYDROLOGICAL PROCESSES FOR APPLICATION TO REGIONAL AND MESOSCALE MODELING

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In this paper, the hydrological module of the biophysical scheme named LAPS (Land-Air Parameterization Scheme) is presented. LAPS is designed as a stand-alone one software package that can also be used as a component of a regional/mesoscale model. It includes three modules for parameterizing hydrological, bare soil and canopy transfer processes.

In the hydrological module, the direct loss of liquid water across the scheme domain boundaries is calculated taking into consideration mainly overland flow, sub-surface runoff and vertical drainage through the lower boundary. Moving from the top to the bottom of the soil, the water column has three layers, where the vertical water flow is calculated according to Darcy's law.

The physical background of the equations describing the above processes is presented. The performance of the hydrological module of the LAPS scheme has been tested by a one year integration of soil moisture content, over bare soil and a soybean field. The integration over bare soil in the so-called "no-evaporation" experiment, tested the quality of the runoff and drainage parameterization in the soil column, during the four month-period. During this test, the precipitation was specified as a heavy rain in the first half, and zero in the second part of the 120 days of integration, with the zero evaporation through out the whole period. The validity of the hydrological module of the LAPS scheme was also checked by comparing the simulated values of the bare soil water budget components with observations of the soil column extending to a depth of 1.6 m from data gathered during the HAPEX-MOBILHY experiment.

Keywords: Surface parameterization; atmospheric modeling; hydrological processes; soil moisture

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1. INTRODUCTION

In the last two decades, substantial effort of many modelers and modeling groups has been devoted to the study and simulation of atmospheric systems such as sea breezes (Mahrer and Pielke, 1977), frontal perturbations (Ross and Orlanski, 1982), tropical cyclones (Rosenthal, 1978), interaction between convective clouds and a vegetative surface (Garrett, 1982) and squall lines (Plantin, 1985) using mesoscale models. Such models have also been used to investigate the role of the mesoscale circulation in the dispersion of air pollutants, released from different types of sources (Kallos, 1989; Kallos, 1990; Kallos *et al.*, 1993; Pielke and Uliasz, 1993). The atmospheric numerical models used in these studies, as well as in climatic change scenarios and numerical weather prediction, require accurate boundary conditions over the continental surface (Rowntree, 1991). A large number of land-surface schemes, (providing the lower boundary conditions for them) have been designed during the last three decades. Main features and biophysical background can be found, for most of them, in comprehensive papers by Henderson-Sellers *et al.* (1993) and Shao *et al.* (1994).

The processes parameterized in land-surface schemes can broadly be divided into broad three categories: subsurface thermal and hydraulic processes, bare soil transfer processes, and vegetation processes. The conceptual difference between land-surface schemes is more clearly illustrated in the configuration of the soil layers and treatment of soil hydrological processes. Parameterization of surface hydrology in these schemes depends on the structure of the atmospheric, hydrological or ecological model where the scheme operates as a land-surface interface. However, regardless of the design of the hydrology in the boundary layer, it is important how well the scheme simulates the hydrological budget and the interactions between the components such as precipitation, evaporation, runoff plus drainage and soil moisture (Mihailovic *et al.*, 1995a). This is especially important when studying atmosphere-biosphere-hydrosphere interactions and feedback mechanisms that are relevant in a regional and/or mesoscale scale (Giorgi and Mearns, 1991). The corresponding partitioning of precipitation into water fluxes strongly depends on the soil characteristics and soil moisture content parameters which can vary substantially within a broad range of values. Consequently, incorrect parameterization of surface water fluxes and prescription of the soil parameters can result in erroneous partitioning of the surface energy into latent and sensible heat fluxes which may lead to an inaccurate mesoscale or larger scale circulation simulated by an atmospheric model.

Generally, the current state of parameterization of hydrology in land surface schemes used in different atmospheric models utilizes single or multi-layer methods for the treatment of soil moisture content. The single-layer method generally overestimates the near surface soil moisture content (Laval, 1988). To overcome this problem Deardorff (1977) proposed a two-layer scheme in which the "force-restore" concept is used. Multi-layer schemes have diffusion type exchanges between layers based on Darcy's law (Shao *et al.*, 1994). The hydrological modules in land-surface schemes, based on these concepts, have been significantly improved in the last decade. These improvements are mostly the result of available data sets such as HAPEX-MOBILHY (Hydrological Atmospheric Pilot Experiment) 86, FIFE (First Field Experiment) 87, EFEDA (European Field Experiment in Desertification-Threatened Area) 91, HAPEX-SAHEL 92 and BOREAS (Boreal Ecosystem-Atmosphere Study) 94, which provided land-surface schemes to be checked and calibrated.

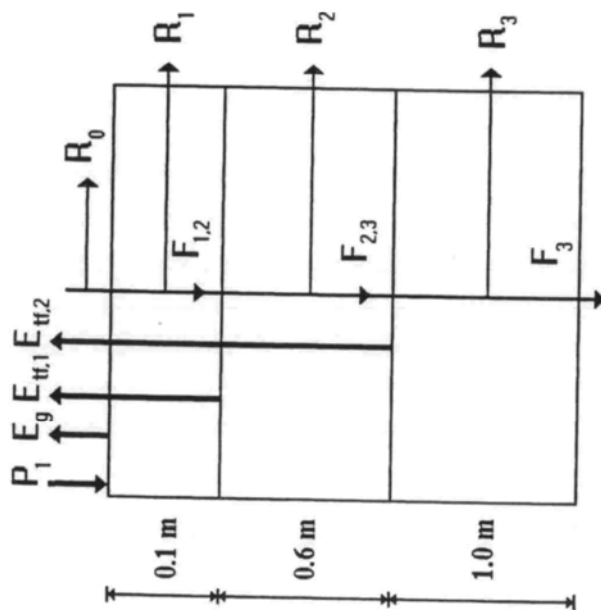
In this paper the hydrological module of the biophysical scheme LAPS which is designed for use in regional/mesoscale and other scale atmospheric models (Mihailovic *et al.*, 1993; Mihailovic and Ruml, 1996; Mihailovic, 1996; Mihailovic and Kallos, 1997) is evaluated. The physical background of the equations describing the vertical and horizontal movement of water through the soil is presented in Section 2. Data sets: i) a four-month water budget and ii) a one-year time series of soil moisture taken from HAPEX-MOBILHY data set (Goutorbe, 1991) used for the evaluation of the hydrological module are described, in Section 3. Finally, Section 4 provides an analysis of obtained results.

2. GOVERNING EQUATIONS

The schematic diagram of hydrology in the LAPS scheme is shown in Figure 1. The parameterization of the soil moisture content is based on the concept of the three-layer model that is described by Sellers *et al.* (1986) and Mihailovic *et al.* (1995c). The governing equations have the form

$$\frac{\partial w_1}{\partial t} = \frac{1}{D_1} \left[P_1 - F_{1,2} - \frac{E_g + E_{g,1}}{\rho_w} - R_0 - R_1 \right] \quad (1)$$

$$\frac{\partial w_2}{\partial t} = \frac{1}{D_2} [F_{1,2} - F_{2,3} - E_{g,2}/\rho_w - R_2] \quad (2)$$



- P_1 precipitation
 E_g evaporation rate from bare soil
 $E_{tf,i}$ canopy extraction of soil moisture by transpiration
 R_0 surface runoff
 R_1 subsurface runoff
 $F_{i,i+1}$ water flux between layers i and $i+1$
 F_3 gravitational drainage

FIGURE 1 Representation of hydrology for LAPS scheme.

$$\frac{\partial w_3}{\partial t} = \frac{1}{D_3} [F_{2,3} - F_3 - R_3] \quad (3)$$

where w_i is the volumetric soil moisture content in the i th layer, P_1 is the infiltration rate of precipitation into the upper soil moisture store, D_i is the thickness of the i th soil layer, ρ_w is the density of water, $F_{i,i+1}$ is the water flux between i and $i+1$ soil layer, F_3 is the gravitational drainage flux from recharge soil moisture store, E_g is the evaporation rate from bare soil, $E_{tf,i}$ and $E_{tf,2}$ are the canopy extraction of soil moisture by transpiration from the first and the second soil layer, respectively, R_0 is the surface runoff, and R_i is the subsurface runoff from the i th soil layer.

The governing equation for the water stored in the canopy, w_f , is:

$$\frac{\partial w_f}{\partial t} = P_f - D_f - \frac{E_{wf}}{\rho_w} \quad (4)$$

where P_f is the water amount retained on the canopy, D_f is the rate of drainage of water stored in the canopy and E_{wf} is the rate of evaporation from the wetted fraction of canopy.

The precipitation P_1 that infiltrates into the top soil layer is given by:

$$P_1 = \begin{cases} \min(P_0, K_s) & w_1 < w_s \\ 0 & w_1 = w_s \end{cases} \quad (5)$$

where K_s is the saturated hydraulic conductivity (assumed to be the same for all three layers), w_s is the volumetric soil moisture content at saturation, and P_0 is the effective precipitation rate on the soil surface given by:

$$P_0 = P - (P_f - D_f) \quad (6)$$

where P is the precipitation rate above the canopy. The rate of interception (inflow) for the canopy, P_f , is given by:

$$P_f = P(1 - e^{-\eta})\sigma_f \quad (7)$$

where η is a constant depending on the leaf area index and σ_f is the fractional cover of the ground by the vegetation. The rate of drainage of water stored in the vegetation, D_f , is given by:

$$D_f = \begin{cases} 0 & w_f < w_{max} \\ P_f & w_f = w_{max} \end{cases} \quad (8)$$

where w_f is the canopy interception store and w_{max} is the maximum amount of water held by the canopy parameterized according to Dickinson (1984).

The evaporation rate from bare soil E_g is parameterized as

$$E_g = \frac{\rho c_p}{\lambda \gamma r_A} [\alpha c_a (T_g) - e_r] \quad (9)$$

where λ is the latent heat of vaporization, ρ is the density of air, c_p is the specific heat of air at constant pressure, r_A is the aerodynamic resistance

between the ground surface and the reference level, $e_s(T_g)$ is the saturation vapor pressure at ground temperature T_g , e_r is the vapor pressure of the air at the reference level, γ is the psychrometric constant, and α is considered as a function of the volumetric soil moisture content of the top soil layer, ϑ_1 , and field capacity, ϑ_{fc} (Mihailovic *et al.*, 1995b) is given by:

$$\alpha = \begin{cases} 1 - [(\vartheta_{fc} - \vartheta_1)/\vartheta_{fc}]^2 & \vartheta_1 \leq \vartheta_{fc} \\ 1 & \vartheta_1 > \vartheta_{fc} \end{cases} \quad (10)$$

The aerodynamic resistance r_A in Eq. (9) under neutral condition was calculated using

$$r_A = \frac{1}{k u_r^2} \ln^2 \left[\frac{z_r}{z_g} \right] \quad (11)$$

where k is von Karman's constant (taken to be 0.41), z_g is the ground roughness length and u_r is the wind speed at the reference level. The effect of atmospheric stability due to aerodynamic resistance is determined according Mihailovic *et al.* (1993).

The rate of evaporation from the wetted fraction of canopy, E_{wf} , with wetted fraction denoted by w_w is calculated as

$$E_{wf} = \frac{[e_s(T_f) - e_a] w_w \rho c_p}{r_b \lambda \gamma} \quad (12)$$

where $e_s(T_g)$ is the saturation of vapor pressure at the canopy temperature T_f , e_a is the water vapor pressure at the temperature inside the canopy and r_b is the bulk boundary layer resistance of the canopy leaves calculated following Mihailovic and Kallos (1997). The fraction of the foliage that is wet, w_w , is parameterized according to Deardorff (1978) and Dickinson (1984).

The transpiration part E_{gf} is calculated by using the equation

$$E_{gf} = \frac{[e_s(T_f) - e_a] \rho c_p}{r_b + r_c \lambda \gamma} (1 - w_w) \quad (13)$$

where r_c is the bulk stomatal resistance of the canopy leaves parameterized according to Mihailovic (1996).

The vertical transfer of water is calculated according to Darcy's law which has the form

$$F = -K \nabla(\Psi + z) \quad (14)$$

where F is the water flux, K is the hydraulic conductivity, Ψ is the soil moisture potential, and z is the depth. The vertical component of this equation is

$$F = -K \left(\frac{d\Psi}{dz} + 1 \right) \quad (15)$$

The finite difference form of Darcy's law, used in the LAPS scheme is:

$$F_{i,i+1} = K_{ef} [2(\Psi_i - \Psi_{i+1}) / (D_i + D_{i+1}) + 1] \quad (16)$$

where $F_{i,i+1}$ is the water flux between i th and $i+1$ soil layer, Ψ_i is the soil moisture potential of the i th layer and K_{ef} is the effective hydraulic conductivity between soil layers. The soil moisture potential, Ψ_i , is parameterized (as it is usually done) according to Clapp and Hornberger (1978):

$$\Psi_i = \Psi_s \left(\frac{w_i}{w_s} \right)^{-B} \quad (17)$$

where Ψ_s is the soil moisture potential at saturation and B is the soil type constant.

K_{ef} is calculated as $(D_i K_i + D_{i+1} K_{i+1}) / (D_i + D_{i+1})$, where K_i is the hydraulic conductivity of the i th soil layer determined by the empirical formula

$$K_i = K_s \left(\frac{w_i}{w_s} \right)^{2B+3} \quad (18)$$

The gravitational drainage from the bottom of the soil layer is defined as

$$F_3 = K_s \left(\frac{w_3}{w_s} \right)^{2B+3} \sin x \quad (19)$$

where x is the mean slope angle (Abramopoulos *et al.*, 1988).

The surface runoff, R_0 , is computed as $R_0 = \min(P_0, K_3)$, while the subsurface runoff, R_b , for i th soil layer is calculated as $R_i = \min(F_{i,i+1}, K_3)$. At the end of the time step, Δt , the value Γ_i is calculated as

$$\Gamma_i = \frac{D_i}{\Delta t} [w_i^k + A_i \Delta t - w_{fc}] \quad (20)$$

where w_i^k is the volumetric soil moisture content at the beginning of time step, A_i represents the terms on the right-hand side of Eqs. (1)–(3), and w_{fc}

is the field capacity. If the condition $\Gamma_i > 0$ is satisfied then Γ_i becomes runoff which is added to the corresponding sub-surface runoff R_i . Consequently, at the end of the time step the calculated value of the volumetric soil moisture content w_i^{k+1} takes the value w_{fc} .

3. DESCRIPTION OF DATA SET USED IN TESTS

In this section the main features of the data set and land surface parameters derived from the HAPEX-MOBILHY program are described. This data set has been chosen because it includes a full year of atmospheric forcing and weekly soil moisture measurements up to 1.6 m depth at 0.1 m intervals. The HAPEX data set in its present form was prepared by Mahfouf and Noilhan (Shao *et al.*, 1994). The data were obtained from the HAPEX-MOBILHY experiment at Caumont (SAMER No. 3, 43° 41' N, 0° 06' W, mean altitude 113 m). Detailed information on the SAMER network and the site can be found in Goutorbe (1991) and Goutorbe and Tarrieu (1991). Most of the forcing data were taken from Caumont, particularly during the intensive observation period (May–July 1986). If data at Caumont were missing, measurements from neighboring meteorological stations were used. The atmospheric forcing data (downward short wave radiation, downward infrared radiation, precipitation, air temperature at 2 m, wind speed at 2 m, atmospheric pressure at 2 m and specific humidity at 2 m) were available every 30 minutes for one year continuously.

The location chosen was a soybean crop field. Soybean plants start to grow in May and are harvested at the end of September. Although the HAPEX data set was collected in a heterogeneous area, the immediate surroundings of Caumont can be considered as uniform on a scale of several hundred meters. Surface fluxes (for the HAPEX area) reveal the signature of two main ecotypes: coniferous forest and crops (SAMER No. 3 represents one of the crops). Analysis of soil moisture also splits soil textures in two broad categories: sand and loam. The soil type at Caumont is loam. The parameters used for characterizing the land surface are summarized in Table I.

Monthly leaf area index (LAI), fractional vegetation cover (σ_f), bare soil ground roughness length (z_g), canopy roughness length (z_c), zero displacement height (d), and the canopy height (h), used in one year integration, are presented in Table II. The monthly distribution of the soybean root system is listed in the same table. It is noted that the characterization of the root system is not based on the experience that the soybean plant has its roots concentrated in the first 0.5 m of soil. Crop height and zero plane

TABLE I Soil parameters for experimental site Caumont (France)

Parameter	Notation		Unit
	Soil type: loam (17% clay, 46% silt and 37% sand)		
Field capacity	w_{fc}		$0.32 \text{ m}^3 \text{ m}^{-3}$
Wilting soil water content	w_{wilt}		$0.20 \text{ m}^3 \text{ m}^{-3}$
Soil water potential at saturation	Ψ_s		-0.0471 m
Volumetric soil moisture water content at saturation	w_s		$0.449 \text{ m}^3 \text{ m}^{-3}$
Hydraulic conductivity at saturation	K_s		$5.1 \times 10^{-6} \text{ ms}^{-1}$
Clapp and Hornberger "B" parameter	B		5.25

TABLE II Monthly variations of leaf area index LAI, fraction vegetation cover σ_f , ground roughness length z_g , canopy roughness length z_c , zero plane displacement d , canopy height h and roots distribution used in one year integration by the LAPS scheme. In the roots distribution it was specified: (0)–no roots, (60)–60% roots in the top 0.1 m soil layer and remaining roots mainly in the top 0.5 m soil layer and (70)–70% roots in the top 0.1 m soil layer and remaining roots in the top 0.5 m soil layer

	J	F	M	A	M	J	J	A	S	O	N	D
LAI	0	0	0	0	1	3	3	3	3	0	0	0
σ_f	0	0	0	0	0.5	0.9	0.9	0.9	0.9	0	0	0
$z_g(m)$	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0
	1	1	1	1	5	5	5	5	5	1	1	1
$z_c(m)$	0	0	0	0	0.0	0.1	0.1	0.1	0.1	0	0	0
					9	7	7	7	7			
$d(m)$	0	0	0	0	0.2	0.6	0.6	0.6	0.6	0	0	0
					8	4	4	4	4			
$h(m)$	0	0	0	0	0.5	1.0	1.0	1.0	1.0	0	0	0
Roots	0	0	0	0	70	60	60	60	60	0	0	0

displacement have been estimated from the measurements. Albedo is based on radiative measurements which revealed a nearly constant value of 0.20 for the annual albedo. Other albedos and emissivities used in the radiative module of the LAPS are similar to those of Shao *et al.* (1994).

In the framework of this study observations of water balance components available from the HAPEX-MOBILHY program were used. The measurements of the soil moisture based on neutron sounding probes were available every week throughout the year at every 0.1 m from the ground down to a depth of 1.6 m. For the estimation of partitioning the land surface water simulated by LAPS another reference data set was used. It was an approximate water budget for the first four months (for days 0 to 120) which was

generated using the observed weekly root zone (1.6 m), soil moisture content, accumulative precipitation, and evaporation estimated by the Penman-Monteith formula (Shao *et al.*, 1994). Estimated evaporation was 149.6 mm for the period indicated. The total precipitation was 368.4 mm. The available observations from the first four months show very little changes in total soil moisture. The total root zone water content change was estimated at -22.3 mm while the generated runoff plus drainage was 241.1 mm during the four month period.

4. RESULTS AND COMMENTS

In order to test the performance of the hydrological module LAPS was run for a one year period with a time step of 1800 s. Atmospheric forcing data, validation data and parameters representing land surface properties were obtained from HAPEX-MOBILHY (discussed in previous section). In the numerical experiments, the soil column was extended from the ground to a depth of 1.6 m and was divided into three soil layers: $D_1 = 0-0.1$ m, $D_2 = 0.1-0.6$ m, and $D_3 = 0.6-1.6$ m. The system of partial differential Eqs. (1) - (4) was solved using an explicit time differencing scheme.

The run was initialized by setting the prognostic variables as follows: all water stores as saturated, canopy water as zero, snow mass as zero and all temperatures to 279.0 K. After initialization the scheme was run to equilibrium by looping through the one year forcing data. The equilibrium was reached when the conditions: $|\lambda E_m(n+1) - \lambda E_m(n)| < 0.1 \text{ W m}^{-2}$, $|\lambda E_{st}(n+1) - \lambda E_{st}(n)| < 0.1 \text{ W m}^{-2}$, $|H_m(n+1) - H_m(n)| < 0.1 \text{ W m}^{-2}$, and $|H_{st}(n+1) - H_{st}(n)| < 0.1 \text{ W m}^{-2}$ were satisfied. $\lambda E_m(n)$, $H_m(n)$, $\lambda E_{st}(n+1)$, $H_{st}(n+1)$ are the annual mean values of latent and sensible heat fluxes for year n and $n+1$, while $\lambda E_{st}(n)$, $H_{st}(n)$, $\lambda E_{st}(n+1)$, and $H_{st}(n+1)$ are the standard deviations for year n and $n+1$, respectively. LAPS was converging after three iterations. Additionally, LAPS was tested using "Milly criteria" which requires that the condition $|P_a - D_a - R_a - E_a| < 1$ mm has to be satisfied. Here, P_a , D_a , R_a and E_a denote annual cumulative values of precipitation, drainage, runoff and evapotranspiration respectively. The residual obtained by LAPS was 0.6 mm.

A comparison of the predicted total soil water with the HAPEX measurements is shown in Figure 2. There is general agreement between the simulation and the observations. Moreover, LAPS correctly describes the annual trend of soil moisture in a qualitative sense. As a result of the frequent rainfall and low amount of evaporation, the soil remains very wet for the

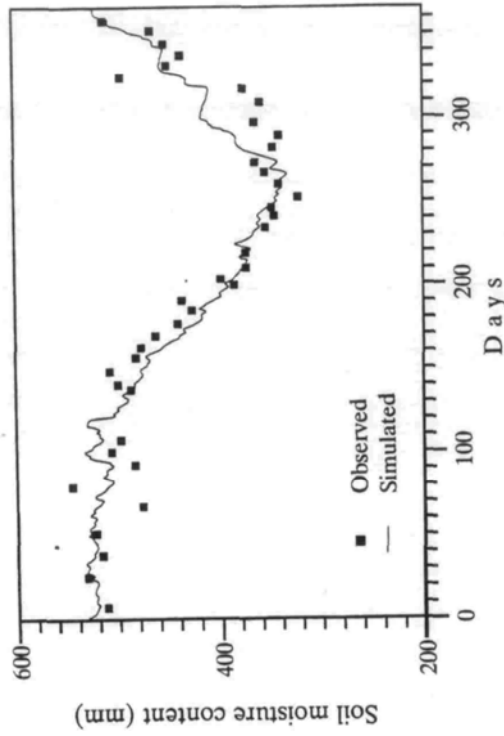


FIGURE 2 Daily averages of total soil moisture content (mm) over a depth of 1.6 m simulated by LAPS scheme and in comparison with HAPEX data (weekly measurements).

first four months of the year. Black squares indicating the observations are more concentrated above the field capacity of 512 mm during this period. The curve representing simulated values of the total soil moisture content through a depth of 1.6 m is very close to the observations. At the beginning of the growing season (early May) the soil was losing water intensively because of the prevailing process of evapotranspiration. The good agreement between the simulated and observed values is extended through the end of the year, except for one and a half months after the end of the growing season. In order to quantify these differences we calculated three simple statistical quantities: a) mean absolute value (MAE), b) root mean square error (RMSE), and c) factor of deviation (FOD) as in Mihailovic *et al.* (1993), using the value of the soil moisture content computed for the soil column extending from the ground surface to a depth of 1.6 m and the observed value. For the entire year the values for MAE, RMSE and FOD were: 19.9 mm ($0.01 \text{ m}^3 \text{ m}^{-3}$), 24.8 mm ($0.02 \text{ m}^3 \text{ m}^{-3}$) and $4.57 \cdot 10^{-2}$, respectively. These values indicate that the LAPS correctly simulates annual cycle of the soil moisture content.

The performance of the runoff and drainage segments of the LAPS hydrological module was evaluated using a simple "no evaporation" test

with the water balance components cumulated over 120 days for which the observed and estimated data were available (see Section 3). The cumulative values used in above test were obtained from the soil moisture budget equation derived from Eqs. (4)–(6) taking the form:

$$\frac{dM}{dt} = P_r - E - R - F_3 \quad (21)$$

where M is the mass of water in a soil column of unit area, P_r is the infiltration, E is the evapotranspiration or bare soil evaporation, $R = R_1 + R_2 + R_3$ is the runoff representing loss of soil water through horizontal flow, and F_3 is the drainage describing the loss of water in the vertical direction. Integration of this equation in the chosen time interval (0 to 120 days in this case) is a powerful method to test whether a scheme retains a water balance and how the soil moisture balance is fulfilled.

In the "no evaporation" test, the precipitation was specified to be ten times larger than the observed precipitation for the first 60 days and was set to zero from day 61 to day 120. For the entire 120 days period bare soil evaporation was set to zero, with an initial soil moisture content was set to $0.05 \text{ m}^3 \text{ m}^{-3}$, as in Shao *et al.* (1994). The outcome of the test is shown in Figure 3 in the form of integrated water balance components (cumulative values) and soil water changes. Inspection of this figure indicates that for the first 60 days, during a heavy rain period, the soil is filling with water. In the absence of evaporation, the water quickly exits from the soil column through sub-surface and drainage flows. However, the amount of precipitation reaching the ground surface is still large; thus a considerable part of water remains in the soil, whose soil moisture content (fine dashed line) increases to the point of exceeding the field capacity. In the second 60 days period there was no precipitation and consequently the only process by which the water exited horizontally and vertically are runoff and drainage. As expected, the soil moisture content approaches the field capacity (512 mm). This is reproduced by the LAPS simulation.

The validity of the hydrological module of the LAPS scheme was also checked by comparing the simulated values with observations of the bare soil water budget components, in the soil column extending from the ground to a depth of 1.6 m using a data set for the first four months. These components are shown in Figure 4. They are presented as the cumulative values (in units of mm) obtained from the integration 120-day. From this figure it can be seen that the simulated change in soil moisture is lower

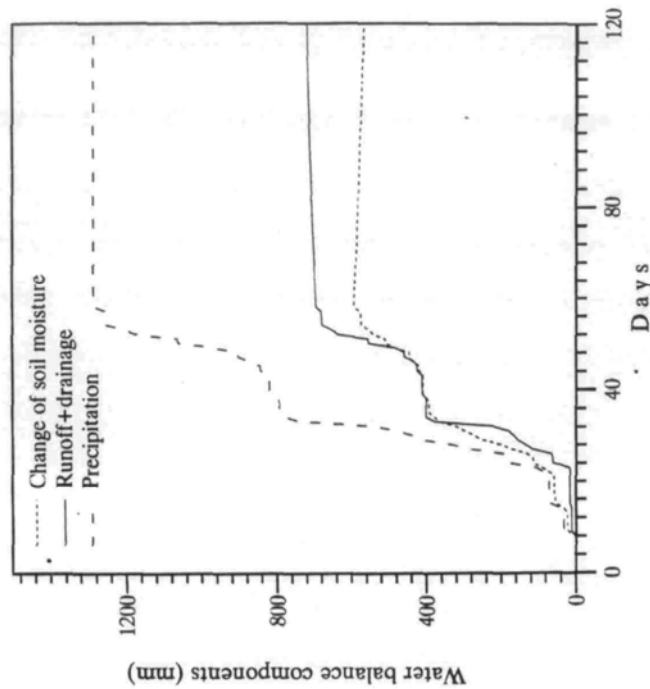


FIGURE 3 Integrated water balance components (cumulative values) and soil moisture content for the first 120 days of the year in "no evaporation" test.

(-17.8 mm) than was observed (-22.3 mm). Furthermore, the LAPS scheme drains roughly 237.6 mm of water, which is very close to the amount obtained from the observed soil water budget (241.1 mm). Apparently, the good agreement between the simulated and the observed runoff, drainage and soil water content components, reflects the fact that the simulated value of the cumulative bare soil evaporation (148.6 mm) practically coincides with the observed one (149.6 mm).

The previously described parameterization of hydrological processes and corresponding sensitivity tests indicate that the hydrological module of the LAPS scheme can be used as a reliable mathematical and computational tool in describing and analyzing the behavior of meteorological and hydrological systems at regional or mesoscales. Further development of this module should focus on more sophisticated physics and for incorporation of high resolution soil, vegetation and geographical data.

5. CONCLUSIONS

The parameterization of hydrological processes in the land-air parameterization scheme LAPS and its application to regional and mesoscale modeling was examined. The physical background of the hydrological module of this scheme was presented. Data sets of continuous micrometeorological measurements were extracted from the HAPEX-MOBILHY data set over a loam soil and a soybean field in Caumont, France. The conclusions can be summarized as follows:

- LAPS correctly describes the annual trend of soil moisture content during the one year of period integration. Comparing with observed annual variations of soil moisture content which were in the interval of 332–533 mm, it was found that the values of the mean absolute error (MAE), root mean square error (RMSE) and factor of deviation (FOD) were: 19.9 mm, 24.8 mm and $4.57 \cdot 10^{-2}$ respectively. Generally, the differences between observed and simulated values of the soil moisture content were apparent during the growing season. Thus, future efforts should be directed to the parameterization of stomatal resistance.
- In the “no evaporation” test (no evaporation during the simulation) the precipitation was specified as a heavy rain in the first half of the integration and zero in the second half. The soil hydrology module in LAPS demonstrated physically correct behavior since the soil moisture content approached field capacity.
- The LAPS scheme simulates quite well the bare soil water budget during the 120-day integration. The simulated change in soil moisture is lower (–17.8 mm) than it was observed (–22.3 mm) while the scheme drains around 237.6 mm of water which is very close to the observed amount obtained (241.1 mm). There is good agreement between simulated and observed runoff, drainage and soil moisture content components reflecting the fact that the simulated value of cumulative bare soil evaporation (148.6 mm) practically coincided with the observed value (149.6 mm).

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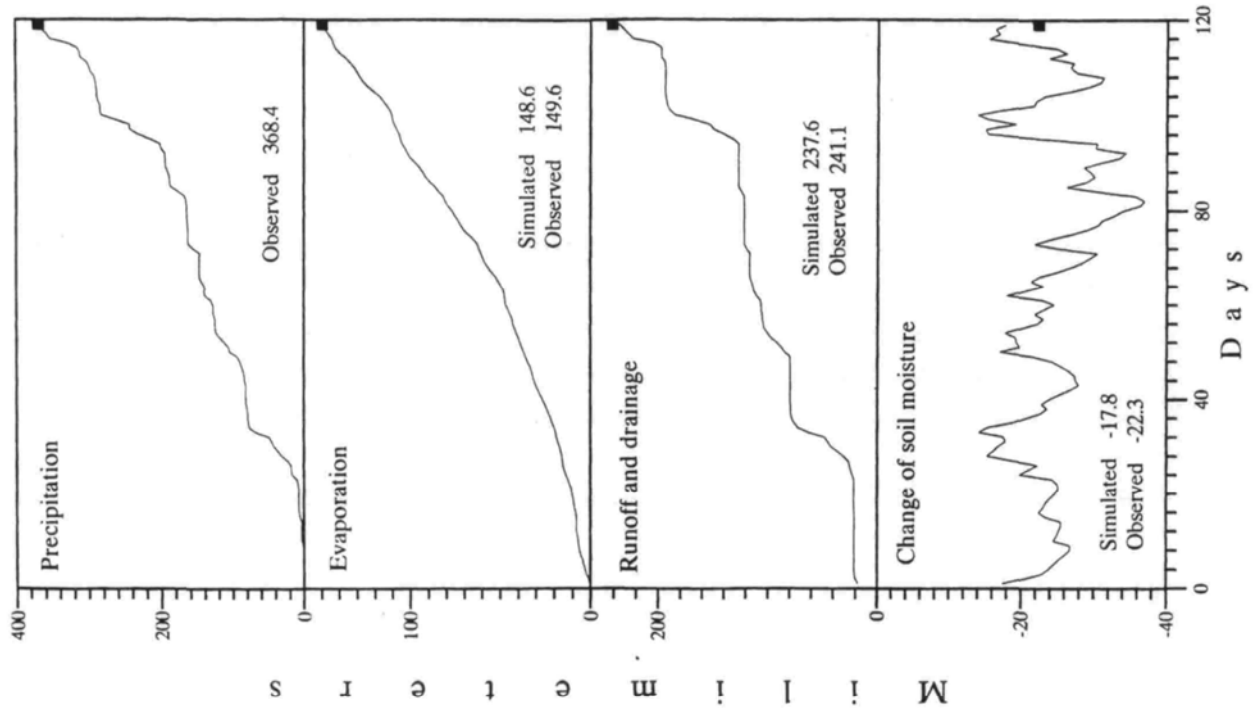


FIGURE 4 The water budget cumulative components for a loam soil at Caumont (France) simulated by the LAPS land surface scheme for the period 1 January–30 April 1986. The observed values are indicated by black squares.

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