Description of a land–air parameterization scheme (LAPS)

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Abstract

A land–air parameterization scheme (LAPS) describes mass, energy and momentum transfer between the land surface and the atmosphere. The scheme is designed as a software package, and can be run as part of an atmospheric model or as a stand-alone model. A single layer approach is chosen for the physical and biophysical scheme background. The scheme has seven prognostic variables: three temperature variables (the canopy vegetation, soil surface and deep soil), one interception storage variable, and three soil moisture storage variables. In the scheme upper boundary conditions are used: air temperature, water vapor pressure, wind speed, radiation and precipitation at a reference level within the atmospheric boundary layer. The sensible and latent heat are calculated using resistance representation. The evaporation from the bare soil is parameterized using an “α” scheme. The soil model part is designed as a three-layer model which is used to describe the vertical transfer of water in the soil.

1. Introduction

Recently, a large effort has been invested in coupling the land surface and the atmosphere in atmospheric, hydrological and ecological models. For that purpose a vast number of land surface parameterization scheme has been designed based on different concepts. Also, they have different level of complexity depending on the model where the scheme is incorporated. Comprehensive overviews of the achieved levels, future plans and recommendations in designing the land surface schemes can be found in Henderson-Sellers et al. (1993) and Shao et al. (1994).

This paper describes the biophysical scheme named LAPS (Land–Air Parameterization Scheme), developed through the joint efforts of the University of Novi Sad and University of Belgrade. The scheme is designed as a software package which can be run as a part of an atmospheric model or as a stand-alone model. The vegetation in the model is treated as a block of constant density porous material sand-
wiched between two constant stress layers with an upper boundary (the height of canopy top) and a lower boundary (the height of canopy bottom).

The design of the scheme is based on papers by Sellers et al. (1986); Dickinson et al. (1986); Mihailović (1990); Mihailović et al. (1993) and Mihailović and Jeftić (1994).

A detailed description and explanation of the scheme’s structure, governing equations, the representation of energy fluxes and radiation, the parameterization of aerodynamic canopy characteristics, resistances and model hydrology will be given in the following sections.

2. Scheme structure and basic equations

The LAPS scheme uses the morphological and physiological characteristics of the vegetation community for deriving the coefficients and resistances that govern all the fluxes between the surface and atmosphere.

The model has seven prognostic variables: three temperatures (canopy, soil surface and deep soil); interception store for canopy; and three soil moisture stores.

The prognostic equations for the canopy temperature, $T_f$, and the soil surface temperature, $T_g$ and deep soil temperature $T_d$, are

$$\frac{\partial T_f}{\partial t} = \frac{R_{net}}{C_f} - H_f - \lambda E_f$$

$$\frac{\partial T_g}{\partial t} = \frac{R_{net}}{C_g} - H_g - \lambda E_g - G$$

$$\frac{\partial T_d}{\partial t} = \frac{2C_g \left( R_{net} - H_g - \lambda E_g \right)}{\sqrt{365}}$$

where $C$ is the heat capacity, $R_{net}$ the absorbed short wave and long wave radiation, $H$ the sensible heat flux, $\lambda$ the latent heat of vaporization, $E$ the evapotranspiration rate and $G$ the soil heat flux. The subscript $f$ refers to the canopy, $g$ to the soil surface. The soil heat flux is parameterized using “force-store” method. The ground heat capacity $C_g$ is parameterized following Zhang and Anthes (1982).

The prognostic equations for the water stored on the canopy, $w_f$, is

$$\frac{\partial w_f}{\partial t} = P_f - E_{wf}/\rho_w$$

where $\rho_w$ is the density of water, $P_f$ the water amount retained on the canopy, $E_{wf}$ the evaporation of water from the wetted fraction of canopy. When the conditions for dew formation are satisfied, the condensed moisture is added to the interception store, $w_f$.

The parameterization of the soil moisture content is based on the concept of the three-layer model that was already supported by Sellers et al. (1986) and Mihailović (1991). The governing equations take the form:

$$\frac{\partial w_i}{\partial t} = \frac{1}{D_i} \left( P_i - F_{i+1} - \frac{E_{i} + E_{i+1}}{\rho_w} - R_0 - R_i \right)$$

$$\frac{\partial w_2}{\partial t} = \frac{1}{D_2} \left( F_{1.2} - F_{2.3} - E_{1.2}/\rho_w - R_2 \right)$$

$$\frac{\partial w_3}{\partial t} = \frac{1}{D_3} \left( F_{2.3} - F_3 - R_3 \right)$$

where $w_i$ is the volumetric soil moisture content in $i$th layer, $P_i$ the infiltration rate of precipitation into the upper soil moisture store, $D_i$ the thickness of the $i$th soil layer, $F_{i,i+1}$ the water flux between $i$ and $i+1$ soil layer, $F_3$ the gravitational drainage flux from recharge soil moisture store, $E_{1.2}$ and $E_{1.3}$ the canopy extraction of soil moisture by transpiration from the first and the second soil layer, respectively, $R_0$ the surface runoff and $R_i$ the subsurface runoff from the $i$th soil layer. Detailed description the foregoing terms will be given in the next sections.

Eq. (1)–(3) are solved by an implicit backward method, while Eq. (5)–(7) are solved using an explicit time scheme.

3. Representation of energy fluxes

Our treatment of the energy fluxes may be classified as the so-called “resistance” representation. This formulation is often used to describe the energy fluxes in an Ohm’s law analog form:

$$\text{flux} = \frac{\text{potential difference}}{\text{resistance}}$$

Potential difference for sensible and latent heat fluxes can be expressed in terms of chosen prognostic
Fig. 1. LAPS schematic diagram of transfer pathways for latent and sensible heat fluxes.

Variables, atmospheric boundary layer reference temperature and water vapor pressure in the canopy air space. Since resistances will be considered in the next section, here we will pay our attention to the physical background of the energy fluxes used in the model. The LAPS schematic diagram of transfer pathways for latent and sensible heat fluxes is shown in Fig. 1.

The latent heat flux from canopy vegetation to canopy air space is given by

\[ \lambda E_t = \left[ e_*(T_t) - e_a \right] \frac{w_w}{r_b} \frac{1 - w_w}{r_b + r_c} \frac{\rho c_p}{\gamma} \]

where \( e_*(T_t) \) is the saturation water vapor pressure at the canopy temperature \( T_t \), \( e_a \) the water vapor pressure of the air at the canopy source height, \( w_w \) the wetted fraction of canopy, \( r_b \) the bulk boundary layer resistance for the canopy leaves, \( r_c \) the bulk stomatal resistance of the canopy leaves, \( \rho \) the density of air, \( c_p \) the specific heat of air at constant pressure and \( \gamma \) the psychrometric constant.

The sensible heat flux from canopy vegetation to canopy air space is given by

\[ H_t = 2(T_t - T_a) \frac{\rho c_p}{r_b} \]

where \( T_a \) is the temperature of air at the canopy source height.

The latent and sensible heat fluxes from soil surface are parameterized as

\[ \lambda E_g = \frac{\rho c_p}{\gamma} \frac{\alpha e_*(T_g) - e_a}{r_b + r_c} \]

\[ H_g = \frac{\rho c_p}{r_d} \frac{T_g - T_a}{r_d} \]

where \( e_*(T_g) \) is the saturation water vapor pressure at the soil surface temperature \( T_g \), \( r_b \) is the bare soil surface resistance and \( r_d \) the aerodynamic resistance between the soil surface and the canopy source height. Parameter \( \alpha \) is calculated according to Mihailović et al. (1993), where \( \alpha \) is considered as a function of the volumetric soil moisture content of the top soil layer, \( w_t \), and field capacity, \( w_{fc} \),

\[ \alpha = \begin{cases} 
1 - \left[ \frac{(w_{fc} - w_t)}{w_{fc}} \right]^2 & w_t \leq w_{fc} \\
1 & w_t > w_{fc} 
\end{cases} \]

The flux \( \lambda E_{wf} \) from the wetted portion of foliage, with wetted fractions denoted by \( w_w \) according to Eq. (9) is

\[ \lambda E_{wf} = \left[ e_*(T_f) - e_a \right] \frac{w_w \rho c_p}{r_b} \frac{1 - w_w}{r_b + r_c} \frac{\gamma}{\gamma} \]

The fraction of the foliage that is wet, \( w_w \), is parameterized according to Deardorff (1978) and Dickinson (1984).

Transpiration occurs only from dry leaf and it is only outward. This physiological process is parameterized with the equation:

\[ \lambda E_{tr} = \left[ e_*(T_r) - e_a \right] \frac{1 - w_w}{r_b + r_c} \frac{\rho c_p}{\gamma} \]

where \( E_{tr} \) is the transpiration rate from foliage. Dew formation occurs when \( e_*(T_r) \leq e_a \). In that case the condensed moisture is added to the surface interception store, \( w_I \). The transpiration rate is zero under this condition.

Air within the canopy has negligible heat capacity, so the sensible heat flux from the canopy, \( H_t \), and from the soil surface, \( H_g \), must be balanced by the sensible heat flux to the atmosphere, \( H_I \),

\[ H_I = H_t + H_g = (T_t - T_a) \frac{\rho c_p}{r_a} \]
where $T_r$ is the air temperature at the reference level within the atmospheric boundary layer and $r_a$ the aerodynamic resistance between canopy air space and reference level. Similarly, the canopy air is assumed to have zero capacity for water storage so that the latent heat flux from canopy air space to reference level in atmospheric boundary layer, $\lambda E_t$, balances the latent heat flux from canopy vegetation to canopy air space, $\lambda E_f$, and the latent heat flux from soil surface to the canopy air space, $\lambda E_g$.

$$\lambda E_t = \lambda E_f + \lambda E_g \frac{(e_a - e_r) \rho c_p}{r_a}$$  \(17\)

where $e_r$ is the water vapor pressure of the air at the reference level within the atmospheric boundary layer.

Diagnostic variables $T_a$ and $e_a$ were calculated from Eq. (16) and (17), using corresponding expressions for $H_f$, $H_g$, $hE_f$ and $hE_g$.

4. Parameterization of radiation

The net radiation absorbed by the canopy, $R^m_{\text{rf}}$, and the soil surface, $R^m_{\text{rg}}$, is calculated as a sum of short and long wave radiative flux,

$$R^m_{\text{rf}} = R^s_{\text{rf}} + R^l_{\text{rf}}$$  \(18\)

and

$$R^m_{\text{rg}} = R^s_{\text{rg}} + R^l_{\text{rg}}$$  \(19\)

The short wave radiation absorbed by the canopy, $R^s_{\text{rf}}$, and the soil surface, $R^s_{\text{rg}}$, is:

$$R^s_{\text{rf}} = R^0_{\text{rf}} \left[ \alpha_f - \alpha_f \right] \left[ 1 + \left( 1 - \sigma_f \right) \alpha_g \right]$$  \(20\)

$$R^s_{\text{rg}} = R^0_{\text{rg}} \left( 1 - \sigma_f \right) \left( 1 - \alpha_g + \alpha_f \alpha_g \right)$$  \(21\)

where $R^0_{\text{rf}}$ is the incident downward directed short wave flux, assumed to be known as the forcing variable, $\alpha_g$ and $\alpha_f$ are the soil surface albedo and the foliage albedo, respectively, and $\sigma_f$ is the vegetation fraction cover. The variability of ground albedo with soil wetness is parameterized in accordance with Idso et al. (1975). There is no distinction between direct and diffuse radiation and it is assumed that albedo does not vary with zenith angle. Both short wave and long wave radiation are reflected once between the soil surface and canopy.

The long wave radiative fluxes absorbed by the canopy, $R^l_{\text{rf}}$, and the soil surface, $R^l_{\text{rg}}$, are

$$R^l_{\text{rf}} = R^0_{\text{rf}} \sigma_f e_f - 2 \sigma_f e_f \sigma_g T_r^4$$

$$+ \sigma_f e_f \left[ R^0_{\text{rf}} \left( 1 - \sigma_f \right) (1 - e_g) + \sigma_f e_f \left( 1 - e_g \right) \sigma_g T_r^4 + e_g \sigma_g T_r^4 \right]$$  \(22\)

$$R^l_{\text{rg}} = e_g \left[ R^0_{\text{rg}} \left( 1 - \sigma_f \right) + e_f \sigma_f \sigma_g T_r^4 + (1 - e_g) \sigma_g T_r^4 \right]$$

where $\sigma_g$ is the Stefan-Boltzman constant, $e_f$ and $e_g$ the emissivities of the foliage and the soil surface respectively, and $R^0_{\text{rf}}$ the incident downward long wave radiation prescribed as the forcing variable.

5. Aerodynamic canopy characteristics and resistances

In the model the vegetation is represented as a block of constant density porous material sandwiched between two constant stress layers, the height of the canopy top, $H$ and the height of the canopy bottom, $h$ (Fig. 1).

The shear stress $\tau$ above the canopy was calculated according to the Monin-Obuhov theory where it has the form:

$$\tau = \rho \left[ ku \left[ \ln \left( \frac{z - d}{z_o} \right) \right] + \Psi_M \right]^2$$  \(24\)

where $\rho$ is the air density, $u$, the wind speed at a reference height, $z_r$, within the atmospheric boundary layer, $k = 0.41$ the von Karman’s constant, $d$ the zero plane displacement height, $z_o$ the roughness length and $\Psi_M$ the stability adjustment function for momentum transport.

The shear stress within the canopy using the “K-theory” is expressed as

$$\tau = \rho K_m \frac{\partial u}{\partial z}$$  \(25\)

where $K_m$ is the momentum transfer coefficient which is parameterized as

$$K_m = \sigma u$$  \(26\)

where $\sigma$ is a constant and $u$ the wind speed within the canopy. The constant $\sigma$ is defined following Goudriaan (1977)

$$\sigma = \left[ \frac{4w_d}{\pi L_d} \right]^{1/2}$$  \(27\)
where $i_w$ is the relative turbulence intensity, $w_d$ is the width of the square leaves and $L_d$ the stem and leaf area density related to leaf area index, LAI, as $L_d = L_d (H - h)$.

The wind speed inside the canopy is given by

$$u = u_H \left[ \sinh(\beta z/H) / \sinh \beta \right]^{1/2}$$  \hspace{1cm} (28)

where $u_H$ is the wind speed at the canopy top. The extinction factor, $\beta$, depends on the plant morphology and is defined as

$$\beta = \left( \frac{C_d \text{LAI} H}{2 \alpha_s} \right)^{1/2}$$  \hspace{1cm} (29)

where $C_d$ is the leaf drag coefficient.

For the zero plane displacement height, $d$ and roughness length, $z_o$, we calculated according to Goudriaan (1977):

$$d = H - \frac{1}{k} \left( \frac{\alpha_s H}{\beta} \right)^{1/2}$$  \hspace{1cm} (30)

and

$$z_o = \left( H - d \right) \exp \left\{ - \frac{H}{\beta(H - d)} \right\}$$  \hspace{1cm} (31)

As we mentioned in Section 3 the fluxes in the model are calculated using aerodynamic and surfaces resistances. Corresponding electrical circuits with resistances are shown in Fig. 1. The resistances $r_a$, $r_b$, and $r_d$ are usually called aerodynamic resistances and they are equivalent to the integrals of inverse conductances over a specified length. In the case of the aerodynamic resistances, the conductances correspond to the turbulent transfer coefficient for heat and water vapor. Surface resistances $r_c$ and $r_f$ control water transfer through the plant–soil system.

The aerodynamic resistance $r_a$ represents the transfer of heat and moisture from the canopy to reference level, $z_r$, and is calculated as

$$r_a = \frac{1}{k u_*} \ln \frac{z_r - d}{H - d}$$  \hspace{1cm} (32)

where $u_*$ is the friction velocity.

The area-averaged bulk boundary layer resistance, $r_b$, is calculated as

$$r_b = \frac{1}{u_H^{1/2}} P_s C_f \beta (\sinh \beta)^{1/4} \int_{\alpha_w}^\beta (\sinh y)^{1/4} dy$$  \hspace{1cm} (33)

where $\alpha_w = h/H$, $y = \beta z/H$, $C_f$ is the transfer coefficient and $P_s$ is the leaf shelter factor.

In the model physics we considered $r_b$ as the total resistance, what implicitly includes an assumption that both forms free and forced convection equally contribute to convection over the whole unstable region.

The resistance to water vapour and heat flow from the soil surface to air space within the canopy is represented by an aerial resistance $r_d$, which is parameterized as

$$r_d = \int_{z_o}^h dz = \frac{1}{k^2 u_H} \left[ \frac{\sinh (\beta z)}{\sinh (\alpha_w \beta)} \right]^{1/2} \ln^2 \left( \frac{h}{h_o} \right)$$  \hspace{1cm} (34)

where $h_o$ is the effective roughness length. The aerodynamic resistances were modified taking into account the effect of non-neutrality (Businger et al., 1971).

In the LAPS scheme stomatal resistance, $r_s$, depends both upon the atmospheric factors and water stress. This dependence is given in the form:

$$r_s = r_{s\min} \Phi_1 \Phi_2^{-1} \Phi_3^{-1} \Phi_4^{-1}$$  \hspace{1cm} (35)

where $r_{s\min}$ is the minimum stomatal resistance.

The factor $\Phi_1$ gives the dependence on the solar radiation. We parameterized it using expression suggested by Dickinson (1984):

$$\Phi_1 = (1 + f)(f + r_{s\min}/r_{s\max})^{-1}$$  \hspace{1cm} (36)

where

$$f = 1.1 R_{sL} / (R_g l \text{LAI})$$  \hspace{1cm} (37)

where LAI is the leaf area index, $R_{sL}$ the incoming short wave radiation and $R_g l$ the limit value of 30 W m$^{-2}$ for a forest and 100 W m$^{-2}$ for crops. The value of 5000 s m$^{-1}$ for $r_{s\max}$ was used. The factors $\Phi_2$, $\Phi_3$ and $\Phi_4$ are limited to a range from 0 to 1.
The factor $\Phi_2$ takes into account the effect of the water stress on the stomatal resistance and it is parameterized in the following way:

$$
\Phi_2 = \begin{cases} 
1 & w_a > w_{fc} \\
1 - \left( \frac{w_{wil}}{w_a} \right)^{1.5} & w_{wil} \leq w_a \leq w_{fc} \\
0 & w_a < w_{wil}
\end{cases}
$$

where $w_a$ is the mean volumetric water content in the first and second soil layer, $w_{wil}$ the volumetric soil moisture content at wilting point and $w_{fc}$ volumetric soil moisture content at field capacity.

The factor $\Phi_3$ gives the dependence of stomatal resistance on the air temperature. According to Dickinson et al. (1986) this factor can be written in the form:

$$
\Phi_3 = 1.0 - 0.0016(298 - T_r)^2
$$

where $T_r$ is the air temperature at the reference level.

The factor $\Phi_4$ represents the effect of atmospheric water vapor pressure deficit. It is parameterized following Jarvis (1976) who suggested the following form

$$
\Phi_4 = 1 - \eta [e_*(T_r) - e_r]
$$

where $e_*(T_r)$ is the saturation water vapor pressure for canopy temperature $T_r$, $e_r$ the water vapor pressure at some reference level and $\eta$ the species-dependent empirical parameter that is equal to 0.025 h Pa$^{-1}$.

The bulk stomatal resistance, $r_c$, represents the effective stomatal resistance per unit ground surface area and it is given by

$$
r_c = r_s / \text{LAI}
$$

The leaf water potential $\Psi_l$ describing the water transfer pathway from root zone to leaf is calculated following Van der Honert (1948),

$$
\psi_l = \psi_r - z_i - E_{tr}(r_{\text{plant}} + r_{\text{soil}}) / \rho_w
$$

where $\Psi_r$ is the soil moisture potential in the root zone, $z_i$ the height of the transpiration source (equal to canopy source height, $h_a$). $E_{tr}$ the transpiration rate, $r_{\text{plant}}$ the plant resistance imposed by the plant vascular system prescribed as a variable, $r_{\text{soil}}$ the resistance of the soil and root system. The canopy source height, $h_a$, is defined as a center of action of bulk aerodynamic resistance within the canopy. An estimation for $h_a$ is suggested by Mihailović and Rajković (1993) in the following form:

$$
h_a = H\left[1 + 2/\beta \ln\left(0.5[1 + \exp(\beta(h/H - 1))]\right)\right]
$$

(43)

The soil water potential in the root zone, $\Psi_r$, is parameterized as an average term obtained by summing the weighted soil water potentials of the soil layers from the surface to the rooting depth, $z_d$.

$$
\psi_r = \sum_i \left( \psi_i D_i / z_d \right)
$$

(44)

where $\Psi_i$ is the soil water potential of the $i$th soil layer and $D_i$ the depth of the $i$th soil layer. The soil water potential, $\Psi_r$, is parameterized as it is usually done, after Clapp and Hornberger (1978),

$$
\psi_i = \psi_s \left( \frac{w_i}{w_{sat}} \right)^{-B}
$$

(45)

where $\psi_s$ is the soil water potential at saturation, $w_i$ and $w_{sat}$ are the volumetric soil moisture content of the $i$th soil layer and its value at saturation and $B$ the soil type constant.

The depth-averaged resistance $r_{\text{soil}}$ to water flow from soil to roots, is parameterized according to Federer (1979),

$$
r_{\text{soil}} = (R/D_d + \alpha_j/K_r) / z_d
$$

(46)

where

$$
\alpha_j = \left[ V_r - 3 - 2 \ln\left( V_r / (1 - V_r) \right) \right] / (8\pi D_d)
$$

(47)

and where $R$ is the resistance per unit root length, $D_d$ the root density, $V_r$ the volume of root per unit volume of soil and $K_r$ the mean soil hydraulic conductivity in the root zone expressed as function of $\Psi_r$:

$$
K_r = K_s (\psi_i / \psi_s)^{(2B+3)/B}
$$

(48)

where $K_s$ is the saturated hydraulic conductivity.

The bare soil surface resistance, $r_1$, governs moisture flux from the top soil layer into the atmosphere. This surface resistance is parameterized following the empirical expression given by Sun (1982),

$$
r_1 = \rho_1 + \rho_2 \left( \frac{w_1}{w_s} \right)^{-\rho_1}
$$

(49)
where \( p_1, p_2 \) and \( p_3 \) are empirical constants obtained from the data, equal to 30, 3.5 and 2.3, respectively (Sellers et al., 1989).

6. Hydrology parameterization

Moving from top to bottom of the soil water column the LAPS has the three layers (Fig. 1). The governing equations for the three volumetric soil moisture content are given by Eq. (5)-(7). The terms \( E_g, E_{tf,1} \) and \( E_{tf,2} \) in these equations are already defined by Eq. (11) and (15) thus, in this section we will define rest of terms in them.

The precipitation \( P_l \) that infiltrates into the top soil layer is given by

\[
P_l = \begin{cases} 
\min(P_0, K_s) & w_1 < w_s \\
0 & w_1 = w_s 
\end{cases}
\]  
(50)

where \( K_s \) is the saturated hydraulic conductivity and \( P_0 \) the effective precipitation rate on the soil surface given by

\[
P_0 = P - (P_f - D_f)
\]  
(51)

The rate of interception (inflow) for the canopy, \( P_f \), is given by

\[
P_f = P (1 - e^{-\alpha_f}) \sigma_f
\]  
(52)

where \( P \) is the precipitation rate above the canopy, \( \alpha_f \) a constant depending on the leaf area index. It is assumed that the interception of the rainfall can be considered via the expression describing the exponential attenuation (Sellers et al., 1986). The rate of drainage of water stored on the vegetation (outflow) for the canopy, \( D_f \), is given by

\[
D_f = \begin{cases} 
0 & w_f < w_{max} \\
P_f & w_f = w_{max} 
\end{cases}
\]  
(53)

The transfer of water between adjacent layers \( F_{i,i+1} \), is given by

\[
F_{i,i+1} = K_{ef} \left[ 2(\Psi_i - \Psi_l) / (D_l + D_{i+1}) + 1 \right]
\]  
(54)

where \( \Psi_i \) is the soil moisture potential of the \( i \)th layer, obtained by Eq. (45) and \( K_{ef} \) the effective hydraulic conductivity between soil layers given by

\[
K_{ef} = (D_l K_i + D_{i+1} K_{i+1}) / (D_l + D_{i+1})
\]  
(55)

where \( K_i \) is the hydraulic conductivity of the \( i \)th soil layer determined by the empirical formula

\[
K_i = K_{si} (w_i / w_s)^{2B+3}
\]  
(56)

where \( K_{si} \) is the hydraulic conductivity at saturation of the \( i \)th soil layer.

The gravitational drainage from the bottom soil layer is defined as

\[
F_3 = K_{si} (w_2 / w_s)^{2B+3} \sin x
\]  
(57)

where \( x \) is the mean slope angle (Sellers et al., 1986; Abramopoulos et al., 1988).

The schematic diagram representing the drainage and runoff in the LAPS is shown in Fig. 2. The surface runoff \( R_o \) is computed as

\[
R_o = P_1 - \min(P_1, K_s)
\]  
(58)

The subsurface runoff is calculated for each soil layer using the expressions

\[
R_1 = F_{1,2} - \min(F_{1,2}, K_s)
\]  
(59)

\[
R_2 = F_{2,3} - \min(F_{2,3}, K_s)
\]  
(60)

\[
R_3 = F_3 - \min(F_3, K_s)
\]  
(61)

At the end of time step, \( \Delta t \), the value \( \Gamma_i \) is calculated as

\[
\Gamma_i = \frac{D_i}{\Delta t} \left[ w_1^i + A_i \Delta t - w_c \right]
\]  
(62)
where $w_i^k$ is the volumetric soil moisture content at the beginning of $k$ time step while $A_i$ representing the terms on the right side of Eq. (5)–(7). If the condition $F_i > 0$ is satisfied then the $I_i$ becomes runoff which is added to corresponding subsurface 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 $w_i^{fc}$.

7. Summary and further plans

We have given a detailed description of a parameterization of land surface processes. In designing the scheme, we tried to find a compromise between an accurate description of the main physical processes and the restriction of the number of prescribed input parameters.

In this version the LAPS was evaluated using micrometeorological measurements over: maize, winter wheat and soya fields. The scheme accurately reproduced the observed values of the components of the surface energy balance with the parameterization which has been able to capture most of the main physical processes involved (Mihailović et al., 1993; Mihailović and Jefić, 1994 and Mihailović and Ruml, 1996).

In further development of the LAPS scheme, more attention has to be devoted to two fundamental points: energy partitioning (i.e. the partitioning of available energy between surface sensible and latent heat fluxes in the surface budget equation) and water partitioning (i.e. the partitioning of precipitation between evaporation and runoff–drainage in water budget equation). It will include reconsideration of some formulations in current parameterization of evapotranspiration and hydrology using more specific tests.

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