Supplemental Information

Simulating Surface and Subsurface Water Balance Changes Due to Burn Severity

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Pages: 5
Figures: 1
### SI.1 Surface and Subsurface Hydrologic Model Equations

Overland flow and groundwater-surface water is coupled by solving three-dimensional Richards equation for pressure head $\psi$ [L] for every domain cell:

$$ S_s \frac{\partial (\psi)}{\partial t} + \frac{\partial S_s}{\partial t} = \nabla \cdot \left[ K_s(x) k_r(y) \nabla (\psi) \right] + q_s $$

[1]

$S_s$ is specific storage [L$^{-1}$], $\phi$ is porosity [-], $t$ is time [T], $K_s(x)$ is saturated hydraulic conductivity [L T$^{-1}$], $k_r$ is relative permeability [-], $z$ is depth below the surface [L], and $q_s$ [T$^{-1}$] is a general source-sink term. $k_r$ along with $S(\psi)$, the degree of saturation [-], is a function of the van Genuchten model [Van Genuchten, 1980]. Surface pressures are a continuum of subsurface pressure head, $\psi$, and used as ponded depth in the kinematic wave equation:

$$ K_s(x) k_r(y) \nabla (\psi) = \frac{\partial \left[ \| \psi \| .0 \| \right]}{\partial t} \nabla \left( \nabla \cdot (\psi) .0 \right) + q_r(x) $$

[2]

$\vec{v}$ is the depth-averaged velocity vector of surface flow; $q_r$ is the rainfall rate [L T$^{-1}$]; and $\| \psi .0 \|$ indicates the greater of $\psi$ and 0. Surface water velocity in the lateral directions, $v_x$ and $v_y$ [L T$^{-1}$] is a function of the surface pressure head or ponded depth via Manning’s equation

$$ v_x = \frac{\sqrt{S_{f,x}}}{n} \; \frac{\gamma_3}{3} \; \text{and} \; v_y = \frac{\sqrt{S_{f,y}}}{n} \; \frac{\gamma_3}{3} . $$

[3]

$S_{f,x}$ and $S_{f,y}$ are the friction slopes in the x and y directions respectively, and $n$ is the Manning’s coefficient [T L$^{-1/3}$]. Implicitly solving surface and subsurface flow results in a full coupling between flow where runoff from any cell can contribute to infiltration downstream or leave the domain as discharge.
SI.2 CLM Land Surface Energy Budge Equations

Total evaporation ($E_{tot}$) is the sum of surface evaporation ($E_g$), transpiration ($E_{tr}$), and wet canopy evaporation ($E_w$). $E_g$ is calculated by:

$$E_g = \beta_r e_g e_a$$

[4]

$\beta$ is a linear function of soil saturation $\theta [-]$ and residual saturation $\theta_{res} [-]$:

$$\beta = \frac{\theta_{res}}{\theta_{res}}.$$  

[5]

$\rho_a$ is density at a given atmospheric pressure and temperature [kg m$^{-3}$], $r_d$ is the aerodynamic resistance term [s m$^{-1}$], and $e_g$ and $e_a$ are specific humidity at the soil surface and a specified height above the ground surface respectively. $E_{tr}$ is calculated as a fraction of the total evaporative potential $E_{f pot}$ from the dry portion of the canopy $L_d [-]$ by:

$$E_{tr} = L_d \frac{r_d}{r_d} E_{f pot}, \quad E_{f pot} = \frac{a}{r_d} (e_{f sat} - e_{ca})(LAI + SAI)$$

[6]

$LAI$ and $SAI$ are the leaf and stem area index respectively [-], $r_s$ is the stomatal resistance [-], and $e_{f sat}$ and $e_{ca}$ are the saturated specific humidity on the foliage and specific humidity of the air within the canopy as determined by meteorological conditions. Similarly, $E_w$ is calculated by:

$$E_w = \frac{1}{f} (LAI + SAI) \left[ 1 - \left( E_{f pot}^w \right) \left( 1 - L_w \right) \right] E_{f pot}$$

[7]

$\sigma_f$ is the fraction of foliage excluding the part buried by snow, $\zeta$ is the turbulent stability function, and $L_w$ is the wetted fraction of the canopy. $L_w$ is determined by:

$$L_w = \left( \frac{L_{cap}}{f} \times L_s \right)^{2/3}$$

[8]
\( I_{cap} \) is the maximum canopy storage, which is 0.1 [mm] times the LAI.  \( I_s \) is water stored in the canopy.  Interception is calculated as precipitation rate \( P \) [L T^{-1}] minus the through-fall rate \( I_{tr} \) [L T^{-1}] determined by:

\[
I_{tr} = \left( 1 - \exp\left( -0.5(LAI + SAI) \right) \right) P.
\]

[9]

The canopy drainage rate \( D_r \) [L T^{-1}] is:

\[
D_r = \frac{I_s}{I_{cap}}
\]

[10]

when \( I_s > I_{cap} \) and 0 when \( I_s \leq I_{cap} \).
Sl.3 Forcing conditions

Fig. S1. The plots show the 2013 and 2014 July and August meteorological data used to force the model. In addition to precipitation (Figure 4), meteorological data includes shortwave radiation, longwave radiation, air temperature, windspeed, atmospheric pressure, and specific humidity.