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A large scale hydrological model combining Budyko hypothesis and stochastic soil moisture model

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Based on the Budyko hypothesis, the actual evapotranspiration, E,is controlled by the water conditions and the energy conditions, which are represented by the amount of annual precipitation, P and potential evaporation, E_0, respectively. Some theoretical or empirical equations have been proposed to represent the Budyko curve. We here select Choudhury's equation to describe the Budyko curve (Mezentsev, 1954; Choudhury, 1999; Yang et al., 2008; Roderick and Farquhar, 2011).

$$\varepsilon = \left(1+\varphi^{-\alpha}\right)^{-1/\alpha}, \varepsilon = \frac{E}{P}, \varphi = \frac{E_0}{P}$$

Rodriguez-Iturbe et al. (1999) proposed a stochastic soil moisture model based on a Poisson distributed rainfall assumption. Porporato et al. (2004) described the average water balance based on stochastic soil moisture model as following,

$$\varepsilon = 1 - \frac{\varphi \cdot \gamma^{\frac{\gamma}{\varphi}} - 1 \cdot e^{-\gamma}}{\Gamma\left(\frac{\gamma}{\varphi}\right) - \Gamma\left(\frac{\gamma}{\varphi}, \gamma\right)}, \gamma = \frac{Zr}{h}$$

where, h means the average rainfall depth, Zr means basin water storage ability. Combining these two equation, we can get the relation between α and γ. Then we develop a large scale hydrological model to estimate annual runoff from P, E_0, h and Zr.

$$R = (1-\varepsilon) P, \varepsilon = \left(1+\varphi^{-\alpha}\right)^{-1/\alpha}, a = 0.7078\gamma^{0.5946}, \gamma = \frac{Zr}{h}$$

This method has good performance when it is applied to estimate annual runoff in the Yellow River Basin and the Yangtze River Basin. The impacts of climate changes (P, E0 and h) and human activities (Zr) are also discussed with this method.