IAHS2017-215
IAHS Scientific Assembly 2017

The Budyko Functions Under Non-steady State Conditions

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The Budyko framework has become a simple tool widely used within the hydrological community to estimate the evaporation ratio E/P at catchment scale (E is evaporation and P precipitation) as a function of the aridity index $\Phi = E_p/P$ (E_p is potential evaporation) for Predictions in ungauged basins. They are valid on long timescales under steady state conditions. A new physically based formulation (noted ML) is proposed to extend the Budyko framework under non-steady state conditions taking into account the change in soil water storage ΔS (Moussa and Lhomme, 2016). Under non-steady state conditions, either a given amount of water ΔS stored in the area at stake participates to the evaporation process (for instance, groundwater depletion for irrigation), or a given amount of the precipitation ΔS is stored in the area (soil water, ground water, reservoirs) following the water balance ($E = P - \Delta S - Q$). The variation in storage amount ΔS is taken as negative when withdrawn from the area at stake and used for evaporation and positive otherwise, when removed from the precipitation and stored in the area. The ML formulation introduces a dimensionless parameter $H_E = -\Delta S/E_p$ and can be applied with any Budyko function. It represents a generic framework, easy-to-use at various time steps (year, season or month), the only data required being E_p, P and ΔS. For the particular case where the Fu-Zhang equation is used, the ML formulation with $\Delta S \leq 0$ is similar to the analytical solution of Greve et al. (2016) in the standard Budyko space $(E_p/P, E/P)$, a simple relationship existing between their respective parameters. The ML formulation is extended to the space $[(E_p/(P-\Delta S), E/(P-\Delta S)]$ and compared to the formulations of Chen et al. (2013) and Du et al. (2016). The ML (or Greve et al.) feasible domain has similar upper limit to that of Chen et al. and Du et al., but its lower boundary is different. Moreover, the domain of variation of $E_p/(P-\Delta S)$ differs: for $\Delta S \leq 0$ it is bounded by an upper limit $1/H_E$ in the ML formulation, while it is only bounded by a lower limit in Chen et al.'s and Du et al.'s formulations. The ML formulation can also be conducted using the dimensionless parameter $H_P = -\Delta S/P$ instead of H_E, which yields another form of the equations. Applications are conducted to simulate the impact of land use change on water resources.

References

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