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Dynamic Snow Distribution Modeling using the Fokker-Planck Equation Approach

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The Fokker-Planck equation (FPE) describes the time evolution of the distribution function of fluctuating macroscopic variables. Although the FPE was originally derived for the Brownian motion, this framework can be applied to various physical processes. In this presentation, applications in the snow accumulation and thaw process, which attributes to considerable spatial and temporal variations, are discussed. It is well known that snow process is a major source of heterogeneity in hydrological systems in high altitude or latitude regions; therefore, better treatment of the snow sub-grid variability is desirable. The main advantage of the FPE approach is that it can dynamically compute the probability density function (PDF) governed by an advection-diffusion type FPE without a prescribed PDF.

First, a bivariate FPE was derived from point scale process-based governing equations (Ohara et al., 2008). This FPE can express the evolution of the PDF of snow depth and temperature within a finite space, possibly a computational cell or small basin, whose shape is irrelevant. This conceptual model was proven to be effective through comparing to the corresponding Monte-Carlo simulation. Then, the more realistic single variated FPE model for snow depth was implemented with the snow redistribution and snowmelt rate as the main sources of stochasticity. In this study, several realistic approximations were proposed to compute the time-space covariances describing effects induced by uneven snowmelt and snow redistribution.

Meanwhile, observed high-resolution snow depth data was analyzed using statistical methods to characterize the sub-grid variability of snow depth, which is essential to validate the FPE model for representing such sub-grid variability. Airborne light detection and ranging (Lidar) provided the snow depth measurements at 0.5 m resolution over two mountainous areas in southwestern Wyoming, Snowy Range and Laramie Range (He et al., 2019). It was found that PDFs of snow depth tend to be Gaussian distributions in the forest areas. However, due to the no-snow areas effect, mainly caused by snow redistribution and uneven snowmelt, the PDFs are eventually skewed as non-Gaussian distribution.

The simulated results of the FPE model were validated using the measured time series of snow depth at one site and the spatial distributions of snow depth measured by ground penetrating radar (GPR) and airborne Lidar. The modeled and observed time series of the mean snow depth agreed very well while the simulated PDFs of snow depth within the study area were comparable to the observed PDFs of snow depth by GPR and Lidar (He and Ohara, 2019). Accordingly, the FPE model is capable to capture the main characteristics of the snow sub-grid variability in the nature.

References

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