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On subsurface flow modeling for parsimonious models

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The description of subsurface flow in a hillslope is one of the main topic in hydrological modeling. The subsurface flow equations are the well-known Richards' equation whose proper treatment is data and computationally intensive. Recently, some authors simplify the complexity of Richards' Equation in order to have an analytical solution for practical applications. For instance, Iverson [2000] linearizes the equations and observes two different scales for vertical and lateral subsurface flows, their solution quickly provides dynamic profiles of soil water pressure head and the landslide triggering condition of a hillslope.

This work refers about a perturbation analysis of Richards' Equation which leads to the classical equations for infiltration and groundwater flow with different levels of approximation and complexity. This approach allows for simplifications and clarifies some of the mechanisms acting in water pressure redistribution at a hillslope scale, even without solving them. In particular, at the first approximation order, soil subsurface water flow is assumed to be slope-normal, whereas lateral flow occurs at the successive approximation orders. Boussinesq Equation for water-table dynamic is shown to be obtained by depth-integrating Richards' Equation on the soil thickness, and the variation of pressure head at the bottom, also due to vertical infiltration, provides the recharge of the water-table. Further integrations then lead to the hillslope-storage Boussinesq model (HsB) [Troch et al, 2003] and finally to the generalization of the O'Loughlin or TOPOG formula [O'Loughlin, 1986, Montgomery and Dietrich, 1994] for the slope-parallel long-term subsurface flow.

The physical meaning of the reported integration and the simplifications will be described and discussed.