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Sixty years of interest in flow and transport theories: Sources of inspiration and a few results

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By choosing to major in soil physics at Wageningen now exactly 60 years ago, I could combine my interest in exact sciences with my experience of growing up on a farm. I never regretted that choice. In the first twenty years, I profited much from close contacts with members of the immediate post-WW II generation of soil physicists (especially Jerry Bolt, Arnold Klute, Ed Miller, Champ Tanner, Wilford Gardner, John Philip, and Jan van Schilfgaarde), chemical engineers (especially at UW Madison the trio Bob Bird, Warren Stewart and Ed Lightfoot) and experts in continuum mechanics (especially at Johns Hopkins Clifford Truesdell and Jerald Ericksen). As graduate student at Illinois with Klute, to describe flow and transport theories in soil science I initially explored as possible framework thermodynamics of irreversible processes (TIP), but soon switched to the continuum theory of mixtures (CTM), initiated by Truesdell in 1957. In CTM, the balance of forces gave a rational basis for flux equations. CTM allowed me to deal with swelling/shrinkage, role of inertia, boundary conditions, and structured soils. Later, I did use TIP to deal with certain aspects of transfer of water and heat in soils and selective uptake of water and nutrients by plant roots. Recently, a variety of theories for upscaling from the pore scale to the Darcy scale have clarified the potential, limits and common ground of CTM and TIP.

A great advantage of CTM is that it provides geometric tools suited for kinematic aspects of flow, transport, and growth/decay processes. In particular, the concept of material coordinates of the solid phase that I used in my PhD thesis to cope with large deformation due to swelling/shrinkage of soils, later also turned to be useful to deal with simultaneous shrinkage and decay in peat soils and compost heaps, and the growth of plant tissues. Also, by focusing on the material coordinates for the water, it became possible to describe transport of solutes in unsaturated soils and selective uptake of water and solutes in saline soils and to explore the rational basis for residence time distribution functions and input-output relationships for flow regions. It turns out to be useful to classify flow patterns on the basis of the presence or absence of time dependence, of the geometry of the region and of the intrinsic nature of the flow pattern arising from the form of the flux equation. For example, the fact that the flux of a fluid with spatially variable density cannot be expressed as proportional to the gradient of a single potential, implies possible non-zero helicity of the flow pattern.

Generally, I enjoyed considerable freedom in the choice of theoretical and practical problems to study. Only quite late, I was faced with time consuming, overly strict accountability. I retired early, so as to live healthier and pursue freely my interest in our science and, especially, its history.