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From Engineering Hydrology to Earth System Science: Milestones in the Transformation of Hydrologic Science (Alfred Wegener Medal Lecture)

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Hydrologic science has undergone almost transformative changes over the past 50 years. Huge strides have been made in the transition from early empirical approaches to rigorous approaches based on the fluid mechanics of water movement on and below the land surface. However, further progress has been hampered by problems posed by the presence of heterogeneity, especially subsurface heterogeneity, at all scales. The inability to measure or map subsurface heterogeneity everywhere prevented further development of balance equations and associated closure relations at the scales of interest, and has led to the virtual impasse we are presently in, in terms of development of physically based models needed for hydrologic predictions. An alternative to the mapping of subsurface heterogeneity everywhere is a new earth system science view, which sees the heterogeneity as the end result of co-evolutionary hydrological, geomorphological, ecological and pedological processes, each operating at a different rate, which have helped to shape the landscapes that we see in nature, including the heterogeneity below that we do not see. The expectation is that instead of specifying exact details of the heterogeneity in our models, we can replace it, without loss of information, with the ecosystem function they perform. Guided by this new earth system science perspective, development of hydrologic science is now guided by altogether new questions and new approaches to address them, compared to the purely physical, fluid mechanics based approaches that we inherited from the past. In the emergent Anthropocene, the co-evolutionary view is expanded further to involve interactions and feedbacks with human-social processes as well. In this lecture, I will present key milestones in the transformation of hydrologic science from Engineering Hydrology to Earth System Science, and what this means for hydrologic observations, theory development and predictions.