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Hydrological states and fluxes in terrestrial systems: from observation to prediction (John Dalton Medal Lecture)

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Quantification and prediction of hydrological processes requires information on the spatial and temporal distribution of soil water fluxes and soil water content. The access to spatially and temporally highly resolved soil water content and fluxes is needed to adequately test hydrological hypotheses and to validate hydrological models. In this presentation we will discuss new developments for the determination of soil water content and quantification and prediction of hydrological fluxes based on hydrogeophysical measurement techniques and novel ground- and satellite based sensing platforms. At the field scale, ground penetrating radar and passive microwave methods are presently being developed which provide the possibility to map soil water content with a high spatial and temporal resolution, also in the subsurface environment. Recent developments show that the application of full wave form inversion methods is a unique technique to derive soil water and soil hydraulic parameters from on- and off-ground systems with high spatial resolution. At the small catchment scale, wireless sensor networks are presently being developed providing soil moisture content values with a high spatial and temporal resolution. Stochastic theories have been used to interpret the relationship between average soil water content and its standard deviation. Cosmic ray sensors are presently being deployed within the TERENO observatories. These sensors provide soil moisture content values with a high temporal resolution at a scale of one to two hundred meters, thereby bridging the gap between local scale measurements and remote sensing platforms. Cosmic ray probes are extremely valuable for the determination of soil water content in agriculturally managed soils. Data assimilation methods provide a unique approach to fully exploit the value of spatially and temporally highly resolved soil water content measurements and states of the terrestrial system for the prediction of hydrological fluxes. Recently, particle filter methods have been used to predict the evolution of soil water content and to estimate soil hydraulic parameters from soil moisture measurements. In addition, estimated drainage fluxes using particle filter methods were compared with directly measured fluxes obtained in lysimeter systems. Finally, a combination of hydrological and regional weather models in a data assimilation framework provides the opportunity to derive weekly forecasts of key hydrological fluxes and soil water content. Finally, we will address and outline some future challenges and perspectives in soil hydrology.