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New theories vs new measurement technologies: Which take precedence?

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Science never progresses smoothly or uniformly on all fronts. History of science tells us that progress cannot be meticulously planned, and elaborate plans do not always end up at their intended targets. Breakthroughs tend to happen by themselves through human ingenuity, which is unpredictable. New theories/ideas, or new measurements/data sources or new analysis techniques have alternated in generating vital breakthroughs. Hydrology is no exception. However, at this point in time it is not clear if hydrologic science is limited by data (and our ability to measure or monitor water cycle dynamics) or by theories or vital ideas that can help us understand how the hydrologic system works and will evolve. We can map the surface of Mars in search of the presence of water, but cannot close the water balance here on Earth. We have instruments that can help us observe pore scale processes in the laboratory, but still cannot predict how these will evolve in time in real places, at much larger scales. We are dealing with a complex adaptive system that evolves at all time and space scales. There is a great need for data to close the water balance, but there is an even greater need to understand and predict in all places in such a dynamic environment. It often happens that every time a new measurement technology or data analysis technique is introduced we get excited and pour all of resources on their development only to be disappointed that we have gone down a narrow alleyway. In spite of occasional breakthroughs in our measurement capability, the bigger challenge remains our inability to extrapolate beyond the measurement points to ungauged, unmapped and unmeasured points, in a rapidly changing environment. Which path should we therefore pursue? Should we be guided by deeper questions, and then use appropriate instruments that fit the task in a balanced way? Or should we follow the opportunistic path provided by the potential of new measurement technologies or new forms of data analysis, and then hope for the best? In this talk I will use a few examples taken from theory development, measurements and data, and model diagnostics to illustrate the interactions and feedback between theory and measurements, and to challenge both the theory and measurement communities to operate as part of a broad front, guided by deep abiding questions about water cycle dynamics at all scales.