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On the co-evolution of geodetic observations and Earth System Models

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While surface freshwater storage components are easily observable components of our landscapes, a major part of continental water resides and flow below ground in groundwater systems (GW) and is broadly inaccessible to direct observations. GW sustain ecosystems with high quality freshwater, support food security, however, they are hardly represented within global land models. The main difficulties lie in the long response time of GW and the complexity water flow within heterogeneous geological layers.
In this presentation, we show how geodesy, i.e. the study of the Earth's shape and gravity field, can support the implementation of GW within models. First, gravity observations from GRACE have revolutionized our vision of the water cycle, by its sensitivity to total water storage changes. Another fundamental processes lies in the physical interactions between water and rock: fluid pressure gradients is the engine for water flow, but also generate a deformation that is measurable at the surface with current geodetic tools (GPS). New opportunities also emerge with the development of seismic noise monitoring, highly sensitive water pressure changes. All these instruments provide valuable information on shallow and confined GW storage changes and contribution to water cycle, on a variety of spatial scales, from $\sim$10 km to 1000s km scales. Considering the development of dense international networks (GPS, seismic stations), and new satellite missions (InSAR from Sentinel, GRACE-FO), there is a wide opportunity to improve the representation of GW within global models.
We support the analysis with recent examples at all scales, and show the link between the current knowledge of water flow and geodetic analyses. While a goal of the geodesy is to provide independent measures of the water cycle, it is clear that an iterative analysis is the most effective. It is anticipated that global models will guide the formulation of geodetic water storage variation estimates as, in turn; geodetic estimates will contribute to global hydrological modeling.