1. The current generation of numerical weather and climate prediction models fall short of **reasonably forecasting the local surface hydrologic state** (e.g., soil moisture, evapotranspiration, and surface runoff). Higher-resolution modelling is thus required for accurate surface hydrologic prediction.
2. At present, our understanding of the **scaling (both up and down) of physical surface hydrologic processes** remains relatively unsophisticated. Land-surface and numerical weather prediction models are often used across a wide range of spatial scales (1-100 km) without modifications to the physical representations, even though component physical schemes may have been developed and tested at much smaller scales.
3. At the hillslope scale, for instance, preferential flow is observed, which cannot be explained by directly scaling up local hydrologic flow (Pierre Gentine et. al, 2012). A new paradigm is thus needed to systematically develop scaling laws in surface hydrology.
4. The **turbulent heat flux scaling laws** are fundamentally non-linear and their representativeness is not clear at larger scales. The surface can exhibit heterogeneity over a large range of spatial scales induced by the landscape, topography, and vegetation. In addition, atmospheric turbulence leads to horizontal variations in the properties of the boundary layer (depth, temperature, humidity) at scales of about 1 km, which can profoundly impact the surface heat fluxes in return. Considerable effort is thus required to represent turbulent heat fluxes with fidelity in land-surface and climate models.
5. One of the major challenges facing surface hydrology is the **discrepancy between the models and observations** against which validation occurs. The observational scales do not generally match the scales of the process modelling. For instance, soil moisture values from coupled (land-surface and atmospheric) numerical weather prediction and climate models are usually obtained at scales of 20-30 km and 100 km, respectively. By contrast, observations of soil moisture are usually obtained at a point using a gravimetric method or a probe, and multiple measurements must be performed to sample a larger area.
6. Many hydrological **transport processes are non-local in nature**. Thus, site-level, “point” measurements may provide an incomplete picture of the actual processes.
7. Another major problem is related to the **discrepancy between the temporal scales of the physical processes, the temporal resolution of the numerical models, and the observed scales.** The lack of long term data to estimate slow land-surface processes remains a major problem of the field. At this stage, stream flow and pan evaporation are the only data available on scales of decades.
8. The general form of Darcy’s law implies non-local transport over a wide range of scales (Paradisi et al. 2001). At the hillslope scale the larger-scale moisture transport process might be the dominant transport and cannot be explained by local observations and the calibration of local processes. This might partly explain why physically-based, spatially distributed hydrologic models outputs are still at odds with field observations.