Geophysical Research Abstracts
Vol. 16, EGU2014-13790, 2014
EGU General Assembly 2014

Emergent phase shift between diurnal transpiration maxima and stream flow minima during base flow as diagnostic of eco-hydrologic interactions in landscapes

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Diurnal oscillations in river base flow are frequently observed in hydrological datasets, yet have only been examined in a few, exploratory studies. In this work we focus on the oscillation shift between base flow and the forcing signal, which, in the case study at hand, is essentially dominated by the tree transpiration oscillation. This quantity characterizes the propagation time of the forcing throughout the river basin, and will be referred to as Eco-hydrological Phase Shift (EHPS). In principle, it is reasonable to hypothesize that EHPS depends on the combination of hillslope and channel characteristic transport times, however it is unclear whether and how its value varies over a range of spatial scales. This is the central question of the study. We analyzed base flow data collected between 2009 and 2012 in 8 stations within the Eel river basin (Mendocino county, CA), where the typical Mediterranean climate allows for long, undisturbed summer base flow recessions. The drainage areas relative to each gauging station span over four orders of magnitude, ranging from $\sim$10 km^2 to $\sim$10000 km^2. We found that, despite the wide range of spatial scales, EHPS by late summer tends to a remarkably narrow range of values, between 8 and 11 hours for all the stations considered. This implies that the timing of diurnal oscillations is dominated by hillslope rather than river network processes, even at large spatial scales. We then propose a simple, conceptual model to explore the hillslope controls on EHPS. The framework allows deriving analytical expressions for EHPS under different "behavioral assumptions" for vegetation water-use. Results show that, within this framework, a delay of 8-11 hours can only be observed if tree roots exclusively use water from the unsaturated zone and variations within that range are due to different signal propagation times in both the unsaturated and the saturated zone. This analysis demonstrates that EHPS represents a scale-invariant signature of river basins and can be used to further explore the eco-hydrological interactions between hillslopes and streams.