Geophysical Research Abstracts
Vol. 14, EGU2012-6827, 2012
EGU General Assembly 2012

Delays in fluvial systems

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Delays between generation in, deposition in, and yield from river catchments of sediment, carbon, nutrients and pollutants are fundamental properties of fluvial systems, and a fundamental feature of all system dynamics. In large catchments delays can be very long, creating significant challenges for identification of the causes of changes in loads and material properties, recorded in either gauged measurements or sedimentary archives, in downstream locations. In the case of conservative materials the major challenge lies in linking changes of deposition rates and loads downstream to causes of generation upstream. For non-conservative materials, such as carbon, significant material changes also occur with mixing of 'old' and 'young' carbon and loss by evasion. Despite the importance of delays in fluvial systems, both for fundamental understanding of fluvial dynamics and for management, current knowledge is poor except in a few well studied catchments. For example,estimates of delays vary by several orders of magnitude in the same catchment depending upon methods and assumptions. In this paper the various approaches to estimating delays will be reviewed along with the results, focussing on carbon and sediment. It is clear that the use of one approach to this problem is unlikely to be successful. Combining measurements of modern loads and their properties, analysis of sedimentary archives, modeling, and isotopic analyses to identify travel times and material sources appears to be the most useful way forward.