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Vanishing Point: A Savage Journey Into Heart of the Scale Hierarchy

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Scale linkage problems in geosciences are often associated with a hierarchy of functional units. Both dynamical systems perspectives and intuition show that processes or relationships operating at fundamentally different scales are independent with respect to influences on system dynamics. But how far apart is "fundamentally different?" And how do we reconcile that with the idea (again, supported by both theory and intuition) that we can work our way along scale hierarchies from microscale to planetary (and vice-versa)? Graph and network theory are employed here to address these questions. Many geoscience scale hierarchies have characteristics of connected caveman small-world or erase-with-a-trace networks. In these cases high overall connectivity but low algebraic connectivity lead to low levels of inferential synchronization. This explains the apparent paradox between scale independence and hierarchical linkages. Treating hierarchies as networks, incorporating more hierarchical levels results in an increase in complexity or entropy of the network as a whole, but at a nonlinear rate. complexity increases as a power α of the number of levels in the hierarchy, with $\alpha < 1$, and usually < 0.5. However, algebraic connectivity also decreases at approximately the same rate. Thus, the ability to infer one part of the hierarchical network from other level decays rapidly as more levels are added. These findings suggest a strategy of identifying and focusing on the most important or interesting scale levels, rather than attempting to identify the smallest or largest scale levels and work top-down or bottom-up from there. Examples are given from soil geomorphology, fluvial hydraulics, and karst flow networks.