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Coupling between solid-earth geodynamics, climate and surface processes: still searching for the peak

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The plate-tectonic revolution constitutes the major breakthrough in the Earth Sciences of the 20th century and may have led to a perception that (as stated in the session description) "we have now made all of the key geoscience breakthroughs" and have reached "Peak Geoscience". Here, I will argue that the Earth Systems approach developed over the last three decades represents a paradigm shift that is at least as fundamental as the plate-tectonic revolution, but still requires significant efforts in both theory development and gathering of observational evidence to arrive at the theory stage. I will focus on the multiple inferred couplings and feedbacks between solid-earth tectonics, climate and surface processes, which have potentially profound implications for the Earth's climatic evolution on geological timescales. The efficacy of this feedback system depends on the strengths of the couplings between (1) physical erosion and chemical weathering; (2) climate and both physical erosion and chemical weathering; (3) erosion and tectonics. Regarding (1), coupled earth-system models include simple relationships between erosion and weathering, leading to diverse outcomes in terms of coupling strength, but the available data suggest a much more complex and still incompletely understood coupling. As for (2), we currently lack a clear theoretical basis for the strength and (in part) even the direction of this coupling and models are often based on intuitive "truisms"; significantly more theoretical development supported by empirical data is required to advance our understanding of this coupling. Regarding (3), in contrast, we do have a fairly sound theoretical understanding of what the tectonic response to changes in erosional regime should be, but the available data have stubbornly refused to fit the theoretical predictions. Thus, I am arguing that despite three decades of intense research on this subject we have not yet made the scientific breakthroughs necessary to fully understand it. In a way, we are still searching for the peak to climb. This state of affairs provides a significant challenge to coupled earth-system models but also exciting and timely research opportunities in understanding specific parts of the system.