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Ice, Fire or Fizzle: The climate footprint of Earth's Supercontinental Cycles

Problems emerging in geodynamics, planetary science, volcanology, and geological fluid mechanics. My work typically involves experimental, theoretical and computational fluid dynamics as well as field- and laboratory-based observational studies.

Earth's climate variability over time scales greater than about one million years is modulated by a time-varying balance between volcanic sources for CO_2 and chemical weathering sinks. The characters and magnitudes of these sources and sinks depend on the continuously evolving planform of plate tectonics, as well as on the rate and extent of mantle convective overturning and thermal mixing. Although plate-driven lateral thermal mixing in the mantle is extensive over time scales of order 1 billion years, the intermittent formation and breakup of supercontinents can perturb this mixing and influence the major controls on Earth's long-term carbon cycle for a few hundred million years. In this talk I will develop a thought experiment to investigate quantitatively how and to what extent supercontinental cycles have modulated Earth's long-term climate change. I will show that the remarkably steady and arguably boring climate of the Precambrian Nuna supercontinental epoch (1.8-1.3 Ga), the extreme climate variability of the Neoproterozoic Rodinia episode (1-0.63 Ga), as well as the Jurassic cooling to Cretaceous warming characteristic of the Mesozoic Pangea cycle (0.3-0.05 Ga) may reflect an inherent tectonic control on the long-term dynamics of the surface Earth system through consequences for mantle convective thermal mixing. Combined with a one-dimensional radiative energy balance climate model, this tectonic control reliably predicts the Mesozoic climate evolution expressed in tropical sea-surface temperature and ice sheet proxy data, as well as a high likelihood for observed Ocean Anoxia Events. For the Neoproterozoic, we show that this tectonic control can drive Earth into, as well as out of, an intermittently pan-glacial climate, depending on the predominant mechanics of chemical weathering.