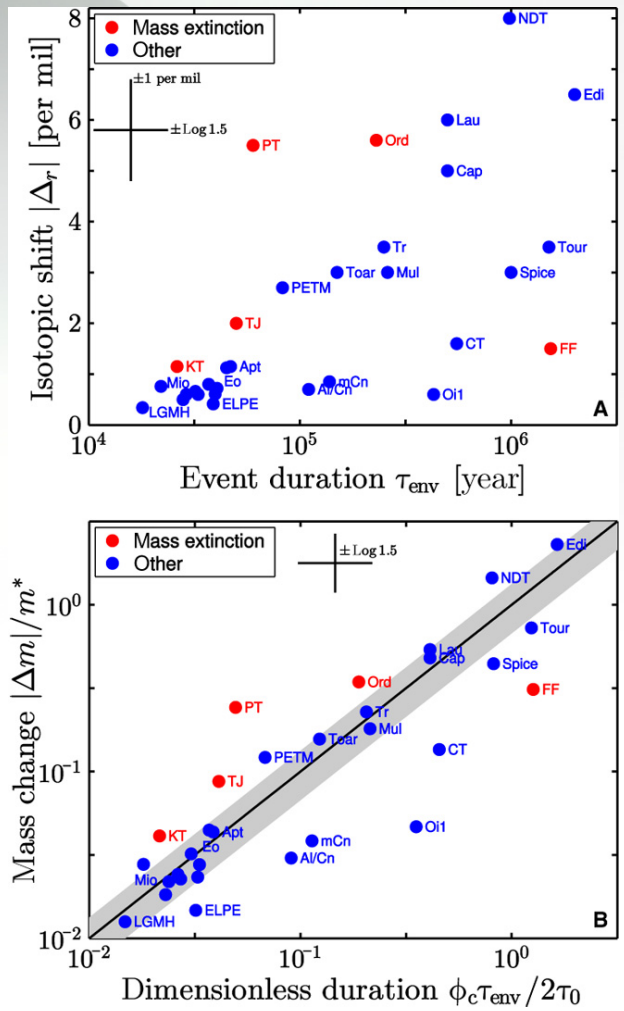
Thresholds of Catastrophe in the Earth System

BACKGROUND: The history of the Earth system is a story of change. Some changes are gradual and benign, but others, especially those associated with catastrophic mass extinction, are relatively abrupt and destructive. What sets one group apart from the other?

THE RESEARCH: Physical reasoning suggests that perturbations of Earth's carbon cycle lead to mass extinction if they exceed either a critical rate at long time scales or a critical size at short time scales. By analyzing 31 carbon isotopic events during the past 542 million years, this study identifies the critical rate with a limit imposed by Mass conservation. Further analysis identifies the crossover timescale separating fast from slow events with the timescale of the ocean's homeostatic response to a change in pH. The product of the critical rate and the crossover timescale then yields the critical size. The modern critical size for the marine carbon cycle is roughly similar to the mass of carbon that human activities will likely have added to the oceans by the year 2100.

TAKE-HOME: At geologic time scales, perturbations of the carbon cycle that exceed a critical rate are associated with instability and mass extinction. At human time scales, rates no longer matter; mass extinction is instead associated with perturbations that exceed a critical mass. The net uptake of carbon into the oceans due to human activities will likely have exceeded the critical mass by the end of the present century.



Daniel H. Rothman. **Thresholds of catastrophe in the Earth system.** *Science Advances* 20 Sep 2017: Vol. 3, no. 9, e1700906. DOI: 10.1126/sciadv.1700906