A holistic reconstruction of Earth's penultimate icehouse

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Earth's penultimate icehouse (340 to 290 Ma) was the time of invasion of animal life onto land, the radiation of the most expansive wetland tropical forests, and widespread continental glaciation in the Southern Hemisphere (Gondwana), all under unique atmospheric O_2:CO_2 conditions. The demise of this ancient glacial state is our only record of an icehouse-to-greenhouse transition on a planet populated by complex life. Studies of the Late Paleozoic over the past decade have revealed a more dynamic Earth system than suggested by long-standing paradigms — once characterized by glacial-interglacial cycles at a heirarchy of time-scales, varying atmospheric pCO_2, and major regional to global-scale hydroclimate changes.

Here, I present a holistic reconstruction of the late Paleozoic icehouse built using U-Pb calibrated and integrated proxy records and ecosystem- and earth system-modeling studies. Comparison of geologic, geochemical, and paleobotanical records with late Paleozoic simulations permits assessment of linkages between late Paleozoic climate processes and delineates the nature of latitudinal climate teleconnections in deep-time. Data-model comparisons further reveal counter-intuitive relationships that explain long-standing paradoxes such as the large-scale discrepancy between inferred magnitudes of glacioeustasy and hypothesized ice distribution, and the anomalous radiative forcing of the late Paleozoic.

High-resolution reconstruction of paleo-atmospheric pCO_2 reveal orbital-scale CO_2 fluctuations during the main phase of the icehouse that are linked to major changes in ice volume, sea level and climate as well as repeated restructuring of Pangaean tropical forests. Estimates of early Permian CO_2 concentrations indicate a greenhouse-gas forced demise of the penultimate icehouse. Process-based ecosystem modeling suggests Carboniferous tropical forests not only responded to climate but were capable of physiologically forcing it. Ultimately, comparison of the CO_2 and paleobotanical records with modeled vegetation shifts for the late Paleozoic indicate a more dynamic carbon sequestration history than previously considered and a major role for terrestrial vegetation-CO_2 feedbacks in driving climate cycles of Earth's penultimate icehouse.