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New Earth system modelling constraints on marine carbonate chemistry and $p\mathrm{CO_2}$ in the geologic past - *R. Berner Lecture*

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Earth's climate state both regulates and is regulated by the global biogeochemical cycling of calcium carbonate and the marine carbonate system. The carbonate system not only buffers ocean pH, but also exerts control on the exchange of carbon between the atmosphere, the ocean, and marine sediments. This means that proxies for the marine carbonate system, for example boron isotopes in marine carbonates or the seafloor carbonate preservation, can provide powerful constraints on past atmospheric CO_2 and global carbon cycling, given the tools to interpret them.

The links between climate, terrestrial weathering rates and the *global* carbonate compensation depth are complex and sometimes counterintuitive. Nonetheless, *spatial* patterns of carbonate preservation still contain powerful information about past marine carbonate chemistry. Here, taking the Early Eocene Climate Optimum as an example, we show how treating the spatial patterns of seafloor carbonate preservation and surface ocean pH as dual constraints in an Earth system modelling framework allows us to reconstruct past seawater alkalinity and atmospheric CO_2. However, such dual constraints are not always possible, e.g., in the early Mesozoic, which predates the advent of the pelagic carbonate pump and for which little deep ocean sediment is preserved. We show that even absent such constraints on background marine carbonate chemistry, it is nonetheless possible to place critical lower limits on the magnitude of past carbon emissions events using boron isotope records of pH change alone. As an example, we show that ocean acidification and $p\mathrm{CO_2}$ increase across the end-Triassic mass extinction interval was indeed severe and almost certainly deleterious. Lastly, we show how these Earth system modelling approaches can be extended to identify the source and strength of past carbon emissions and carbon cycle feedbacks in the geologic past.