



Exploring the Connections between Vegetation, Orbital Forcing, and Anoxia in the Devonian with a Hierarchical Model Framework

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The Devonian period (419–359 million years ago) was characterized by significant climatic changes, including Oceanic Anoxic Events (OAEs) and mass extinctions. A potential link between these events and long-term astronomical cycles influencing Earth's climate has been suggested, yet the mechanisms connecting these processes remain unclear.

To investigate this link, an emulator-based framework has been developed to simulate atmospheric conditions during the Devonian. The emulator, trained on an ensemble of snapshot simulations using HadSM3 (a General Circulation Model), captures the spatial effects of climatic precession, eccentricity, obliquity, and $p\text{CO}_2$ on runoff and temperature. This approach provides a computationally efficient alternative to traditional GCMs and has been integrated into the recent GEOCLIM7 model, which combines a geographically distributed model of vertical weathering profile with a biogeochemical ocean box model. Vegetation distribution is estimated using FLORA, a fast model accounting for temperature, runoff, and insolation to determine potential biomass. Steady-state oceanic circulation fields are provided by cGENIE, a model of intermediate complexity. Dynamic feedbacks are incorporated as $p\text{CO}_2$ levels are passed between the box model and the emulator, enabling the simulation of associated climate fields.

These results offer insights into the potential role of vegetation and astronomical cycles, such as eccentricity and precession in triggering oceanic anoxia, and allow for a critical evaluation of existing hypotheses on the mechanisms underlying these events.