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On understanding causal relationships within the Earth-life sciences

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Dolby, Greer

A goal common to several disciplines within earth and life sciences is to understand how earth processes and abiotic conditions shape the diversification and distribution of species on our planet. To develop a mechanistic and detailed understanding of these relationships across taxonomic-geographic settings should inform a set of boundary conditions that describe the geologic and climatic conditions under which new biodiversity is generated along with the organismal traits (e.g., generation time, dispersal ability) that govern why species vary in their evolutionary responses to the same external influences. However, earth and life sciences each encompass a set of highly complex and sometimes nested relationships. This presents a need for new ways to guide the integration of domain knowledge across these complex systems in a way that can generate new hypotheses, facilitate interdisciplinary collaboration, and shape earth-life theory moving forward. Here, I outline the use of causal structures, which are a set of tools to diagram cause-effect relationships at different levels of detail (specification) that include structural equation meta models (SEMMs), causal diagrams (CDs), and structural equation models (SEMs). I will give examples of how to use SEMMs and CDs to detail earth-life relationships, what we can learn from doing so, and pose a way for how we might quantify these relationships. I hope to demonstrate the usefulness and applicability of thinking about earth-life systems within a causal framework, and speculate about temporal dynamics and the potential for abiotic-to-biotic causal thresholds that may occur over time in different earth-life systems.

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