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Recurrence analysis of large-scale dynamical properties of terrestrial mammal evolution

Robertas Stankevič, Simona Bekeraitė, Andrej Spiridonov, and Ivona Juchnevičiūtė
Vilnius University, Department of Geology and Mineralogy, Faculty of Chemistry and Geosciences, Lithuania
(dunedimensia@gmail.com)

Contrary to ecology, biology and climate science, analysis of nonlinear dynamics in paleontological time series is still relatively uncommon. Palaeontology tend to focus on events such as mass extinctions or radiations over dynamical processes and relationships. However, all parts of the Earth system, including the biota, are interrelated at multiple scales, showing feedback relations and nonlinearity. Nonlinear analysis of global palaeodiversity dynamics and its coupling with abiotic variables could offer a fresh view into a long-running question of the relative importance of biotic and abiotic factors in macroevolution by identifying interactions and responses not amenable to classical methods of time series analysis.
As a part of our inquiry into causal explanation of the drivers of mammal evolution, we present our analysis of the dynamics of Cenozoic land mammal evolution, based on high resolution time series data and methods of recurrence plots and causal inference.
Using *PyRate*, a Bayesian palaeodiversity analysis framework, we estimate diversification parameters and individual taxon lifetimes of several extinct Paleogene mammal orders and several extant large bodied orders Carnivora, Proboscidea, Artiodactyla and Perissodactyla. We then use recurrence analysis tools developed by the author to investigate dynamics of the evolution of the aforementioned taxons, identifying regime transitions and regions of deterministic and chaotic regimes over multi-million year timescales.
Abrupt changes in species composition are indentified particularly in Perissodactyla recurrence plots. First and the most abrupt change occured at ca. 32 Ma, corresponding to Eocene-Oligocene extinction event. Another prominent change indentified at ca. 17 Ma, corresponding to Middle Miocene disruption. Both concide with changes in $\delta^{13}C$ and $\delta^{18}O$ isotopic record (Westerhold et al. 2020).
In search of signatures of general synchronisation, we performed joint-recurrence plot analysis between matrices of diversity composition, $\delta^{13}C$ isotopic record and $\delta^{18}O$-derived global temperature time series.
Our preliminary results shed light on diversification dynamics of the main terrestrial mammal orders and similarity over time and coupling with the climatic and carbon cycle dynamics of the Earth. We compare them with findings of causal analysis of climate and diversification time series, using the same datasets and transfer-entropy based causal inference tools. The relative degrees of herbivore and carnivore diversity couplings with climate is also discussed.