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Geochemistry of Carbon Cycles on Rocky Exoplanets

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The atmospheres of rocky exoplanets are secondary and regulated by geochemical volatile cycles. Earth scientists have studied in detail the long-term inorganic carbon cycle (also known as the carbonate-silicate cycle) acting on timescales of hundreds of thousands of years. This cycle provides essential negative feedback to maintain temperate climates on Earth. With the discovery of about a thousand rocky exoplanets and ongoing hunts for an Earth-twin, it is imperative to understand the factors affecting the stability of the carbon cycle. These factors could be dependent on the orbital and stellar parameters such as stellar radiation as well as planet-specific properties such as rock composition, land and ocean fractions. On Earth, continental silicate weathering and seafloor basalt weathering act as sinks for the atmospheric carbon dioxide. In this study, we develop a novel framework to unify both weathering processes. This is done by incorporating a set of silicate weathering reactions leading to the formation of carbonates. We focus on modeling the chemistry of rock-water interaction for different rock types (depending on the planet's surface composition), as well as pH, temperature and partial pressure of carbon dioxide. We quantify the effects of fresh rock availability for the continental weathering and landmass fractions and shallow and deep ocean fractions for the seafloor weathering. Other components of the carbon cycle such as subduction, ridge and arc volcanism are parameterized based on previous studies. The effects of planet size, redox states, and tidal locking are also investigated. Our study gives a strong control over the connection between atmospheric observables and the carbon cycle. The ultimate goal is to provide an abiotic library of geological false positives of biosignatures.