EGU21-4075
EGU General Assembly 2021

The role of hydrological processes on enhanced weathering for carbon sequestration in soils in tropical areas

Giuseppe Cipolla[1], Salvatore Calabrese[2], Leonardo Valerio Noto[1], and Amilcare Porporato[3]
[1]Dipartimento di Ingegneria, Università degli Studi di Palermo, Palermo, Italy
[2]Department of Biological and Agricultural Engineering, Texas A&M University, College Station, TX, USA
[3]Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ, USA

To mitigate global warming, a noticeable research effort is being devoted to NCS (Natural Climate Solutions) as means to reduce greenhouse gas emissions or sequester carbon within the oceans or terrestrial environments by exploiting natural processes. Enhanced weathering is a NCS that aims to increase the weathering reaction rates of silicate minerals, by amending soils with crushed reactive minerals. Various studies have shown that this technique is favored by hot and humid climates (i.e., tropical ecosystems), since weathering reactions are mostly effective under high temperature and soil moisture. Despite olivine dissolution dynamics in laboratory conditions are quite well known, understanding and modeling them in field is still a challenge. Indeed, apart from some pot experiments involving soils of agricultural fields, only few weathering models are available. Given the urgency of the problem, models play a very important role for extrapolating results of laboratory and field experiments in both time and space, as well as for quantifying the impact of hydroclimatic fluctuations on the involved biogeochemical processes.

The present study explores the role of hydrological processes on long-term Forsterite dissolution, a highly reactive silicate mineral also known as Mg-olivine or simply olivine. Toward this goal, we present a novel dynamic mass balance model coupling ecohydrological and biogeochemical dynamics, including mineral dissolution. Results under different climate scenarios highlight that hydrological fluctuations lead to hysteretic patterns of weathering rate with soil moisture, meaning that the process maintains a memory of past events (i.e., dry or wet periods). The model allows to explore the twofold role of organic matter on enhanced weathering; indeed, while its decomposition is a source of CO_2, organic matter also increases the soil CEC, thus buffering changes in soil pH. Carbon sequestration and nutrients availability due to enhanced weathering are quantified, in this study, as a function of MAP (Mean Annual Precipitation). Average CO_2 that reacts with olivine can exceed 40 t ha^{-1} y^{-1} for MAP higher than 2000 mm, condition that is always reached in the tropics. This CO_2 can be found as dissolved in soil water in the form of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions and will be leached away from the domain, eventually reaching the ocean. In presence of tropical climate olivine application also leads to an increase of soil pH and nutrients availability, especially calcium and magnesium, which in turn can enhance plant productivity. This study paves the way for a potential integration of enhanced weathering in agroecosystem management practices, especially in humid tropical regions since these are characterized by high MAP and temperature.