Geophysical Research Abstracts
Vol. 21, EGU2019-7778, 2019
EGU General Assembly 2019

Sea-level variations modulate magmatism and carbon emissions at mid-ocean ridges

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Glacial cycles transfer water between continental ice sheets and oceans; they have caused global sea-level (SL) variations up to 100 m during the Pleistocene, at rates of up to 1 cm/yr. These SL variations change the hydrostatic pressure at mid-ocean ridges (MORs), modifying the rate of mantle decompression and the depth at which melting begins beneath the ridge axis. SL variations may therefore induce changes in the flux and composition of magma at MORs, potentially affecting the flux of carbon into the climate system [Huybers and Langmuir 2009].

Published models predict up to 10% variation in carbon emission rates for absolute changes in SL of $\sim$100 m [Burley and Katz, 2015]. However, two major assumptions of those models are (1) that carbon is a passive, incompatible element, and (2) that the perturbations to melting rate do not affect the carbon concentration in the magma. As a result, in the models of Buley and Katz [2015] the perturbations in carbon concentration are only generated at the depth at which the mantle begins to melt and are transported upwards with liquid velocity. The authors predict lags (between a peak in SL and a peak in carbon emissions) of several tens of kyrs. Here, we present 1-D melting-column models in which carbon participates in the thermodynamics of melting, and in which SL variations affect the melting rate throughout the column. We revisit estimates of the impact of SL-changes on magmatism and carbon fluxes at MORs.

Our models predict variations in carbon emissions between 1% and 12% for forcing at the periods that dominate the reconstructed SL record of the late Pleistocene. We find that the perturbations to carbon flux near the surface are mainly driven by perturbations to the melting rate. Since these perturbations travel faster than the liquid, we predict lags smaller (<20 kyrs) than those obtained by previous models.