Habitability of an Early Stagnant-Lid Venus. D. Höning[1], P. Baumeister[2,3], J.L. Grenfell[2], N. Tosi[2], M.J. Way[4,5,6] [1]Potsdam-Institute for Climate Impact Research, Germany (dennis.hoening@pik-potsdam.de), [2]Institute of Planetary Research, DLR Berlin, Germany, [3]Department of Astronomy and Astrophysics, Institute of Technology Berlin, Germany, [4]NASA Goddard Institute for Space Studies, New York, USA, [5]GSFC Sellers Exoplanet Environments Collaboration, [6]Theoretical Astrophysics, Department of Physics and Astronomy, Uppsala University, Sweden.

Introduction: How long could ancient Venus have remained habitable? Small amounts of atmospheric CO_2 over long timescales are commonly associated with plate tectonics because of its ability to recycle carbon into the interior [1]. The tectonic state of ancient Venus is unknown, however. We model the coupled interior-atmosphere evolution of Venus as a planet without plate tectonics and investigate how long a modified carbon cycle consisting of weathering, carbonate burial, and crustal decarbonation would have allowed for liquid water on early Venus.

Model: We employ a parameterized thermal evolution model of the mantle [2] coupled to a model of CO_2 outgassing, silicate weathering, carbonate weathering, and metamorphic release [3]. Weathering is active as long as liquid water is present on the surface. We consider water vapor and CO_2 as greenhouse gases. As soon as all surface water has evaporated, weathering ceases. Model parameters that determine the outgassing rate are chosen in a way to obtain the atmospheric CO_2 that is observed on Venus today. For the obtained CO_2 in the early evolution, climate results are benchmarked with the ROCKE-3D GCM [4].

Results: We find that silicate weathering can keep the planet habitable for a period of 900 Myr (Figure 1), which is 500 Myr longer than obtained from a model that neglects weathering. Control runs from a 3D global climate model back up this finding. The habitable period is followed by rapid metamorphic release of CO_2 from the crust, causing an increase of the surface temperature. As a consequence, water evaporates, the crust becomes depleted in carbonates, and a thick, CO2-rich atmosphere as observed today builds up [5].

Conclusions: Even without plate tectonics, Venus might have remained habitable for the first 900 million years of its evolution. During this period, weathering ensures that outgassed carbon is stored in the crust. As soon as the water evaporates, the atmospheric CO_2 budget increases by more than one order of magnitude within 100 million years. For stagnant-lid exoplanets, we therefore predict a bimodal distribution of atmospheric CO_2, with high CO_2 indicating crustal carbonate depletion as a consequence of a runaway greenhouse and small CO_2 indicating active silicate weathering and therefore a habitable climate.

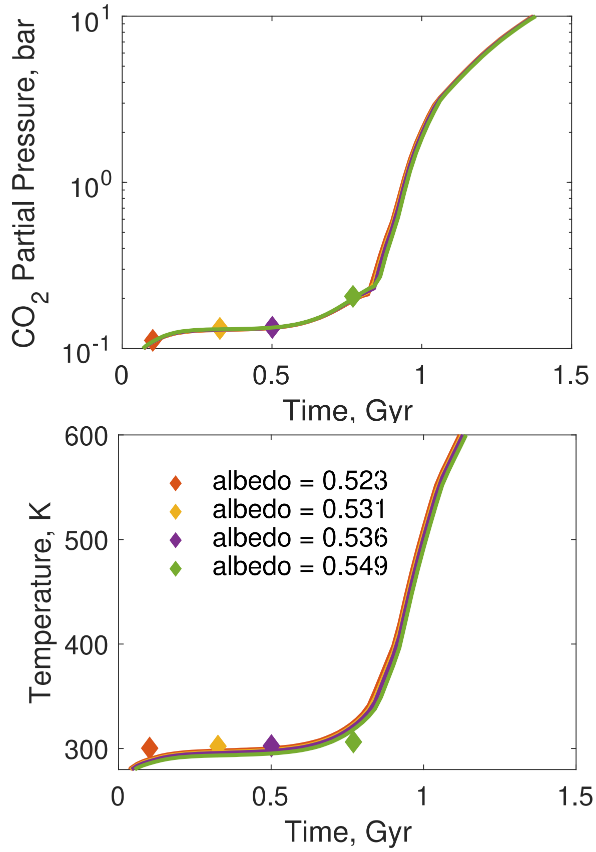

Figure 1. Early evolution results from the coupled interior-atmosphere model. Diamonds in the top panel depict parameter combinations of solar flux and atmospheric CO_2 that are used as an input for the ROCKE-3D GCM, and derived temperature and albedo are depicted in the bottom panel.

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