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Insensitivity of weathering behavior to planetary land fraction and effect on habitability

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It is likely that an increasing number of terrestrial planets of unknown water content will soon be discovered in the habitable zone of their stars. Planetary surface land fraction may, however, influence the functioning of the silicate weathering feedback, which buffers planetary surface climate against changes in stellar luminosity over a star's lifetime. It is therefore worthwhile to consider the effect of land fraction on the planetary carbon cycle and weathering behavior in a general sense. Here a low-order model of weathering and climate is developed that includes both continental silicate weathering and seafloor weathering. This model can be used to gain an intuitive sense of the behavior of terrestrial planets with different land fractions in the habitable zone of main-sequence stars as their star's insolation changes with time.

It is found that, as long as seafloor weathering is independent of surface temperature, there can be no weathering feedback on a waterworld. This means that the tenure of a waterworld in the habitable zone (before it undergoes a moist greenhouse) is likely to be much shorter than that of a planet with some land fraction. The silicate weathering feedback, however, is effective even at very low land fractions. A planet with a land fraction of 0.01 should remain in the habitable zone nearly as long as a planet with a land fraction of 0.3. Finally, by comparing the timescale for water loss to space to the weathering timescale, it is found that it is possible for a waterworld to draw down atmospheric CO_2 quickly enough as a moist greenhouse is in progress to prevent complete loss of all water. This would imply that waterworlds in the habitable zone of main sequence stars can go through a moist greenhouse stage and end up as planets like Earth with only partial ocean coverage and a habitable climate.