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Habitability of Super-Earth Planets around Main-Sequence Stars including Red Giant Branch Evolution: Models based on the Integrated System Approach

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In a previous study published in Astrobiology, we focused on the evolution of habitability of a 10 M_E super-Earth planet orbiting a star akin to the Sun. This study was based on a concept of planetary habitability in accordance to the integrated system approach that describes the photosynthetic biomass production taking into account a variety of climatological, biogeochemical, and geodynamical processes. In the present study, we pursue a significant augmentation of our previous work by considering stars with zero-age main sequence masses between 0.5 and 2.0 M_sun with special emphasis on models of 0.8, 0.9, 1.2 and 1.5 M_sun. Our models of habitability consider again geodynamical processes during the main-sequence stage of these stars as well as during their red giant branch evolution. Pertaining to the different types of stars, we identify so-called photosynthesis-sustaining habitable zones (pHZ) determined by the limits of biological productivity on the planetary surface. We obtain various sets of solutions consistent with the principal possibility of life. Considering that stars of relatively high masses depart from the main-sequence much earlier than low-mass stars, it is found that the biospheric life-span of super-Earth planets of stars with masses above approximately 1.5 M_sun is always limited by the increase in stellar luminosity. However, for stars with masses below 0.9 M_sun, the life-span of super-Earths is solely determined by the geodynamic time-scale. For central star masses between 0.9 and 1.5 M_sun, the possibility of life in the framework of our models depends on the relative continental area of the super-Earth planet.

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