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The Inner Boundary of the Habitable Zone: Loss Processes of Liquid Water from Terrestrial Planet Surfaces

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The question of habitability is very important in the context of terrestrial extrasolar planets. Generally, the Habitable Zone (HZ) is defined as the orbital region around a star, in which life-supporting (habitable) planets can exist. Taking into account that liquid water is a commonly accepted, fundamental requirement for the development of life - as we know it - the habitable region around a star is mainly determined by the stellar insolation of radiation, which is sufficient to maintain liquid water at the planetary surface.

This study focuses on different processes that can lead to the complete loss of a liquid water reservoir from the surface of a terrestrial planet to determine the inner boundary of the HZ. The investigated criteria are, for example, reaching the temperature of the critical point of water at the planetary surface, the runaway greenhouse effect and the diffusion-limited escape of water from the atmosphere, which could lead to the loss of the complete water reservoir within the lifetime of a planet.

We investigate these criteria, which determine the inner boundary of the HZ, with a one-dimensional radiative-convective model of a planetary atmosphere, which extends from the surface to the mid-mesosphere. Our modelling approach involves the step-by-step increase of the incoming stellar flux and the subsequent iterative calculation of resulting changes in the temperature profiles, the atmospheric water vapour content and the radiative properties. Therefore, this climate model had to be adapted to account for high temperatures and water mixing ratios. For example, the infrared radiative transfer scheme was improved to be suitable for such high temperature and pressure conditions.

Modelling results are presented determining the inner boundary of the HZ affected by these processes, which can result in no liquid water on the planetary surface. In this context, especially the role of the runaway greenhouse effect is discussed in detail.