The fate of the Earth oceans: a 3D perspective on runaway greenhouse processes

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Because the solar luminosity increases over geological timescales, Earth climate is expected to warm, increasing water evaporation which, in turn, enhances the atmospheric greenhouse effect. Above a certain critical insolation, this destabilizing greenhouse feedback can "runaway" until all the oceans are evaporated (the so-called runaway greenhouse instability). Through increases in stratospheric humidity, warming may also cause oceans to escape to space before the runaway greenhouse occurs. The critical insolation thresholds for these processes, however, remain uncertain because they have so far been evaluated with unidimensional models that cannot account for the dynamical and cloud feedback effects that are key stabilizing features of Earth's climate. With more than 1000 exoplanets discovered, the need to understand these processes goes beyond the boundaries of the Earth, as it is the main way to know which planet can harbor liquid water... with many implications.

Here, I will present results form a 3D global climate model specifically developed to describe hot, extremely moist atmospheres to quantify Earth like planets climate response to an increased insolation. In contrast with previous studies, we find that clouds have a destabilizing feedback on the long term warming. However, subsident, unsaturated regions created by the Hadley circulation have a stabilizing effect that is strong enough to defer the runaway greenhouse limit to higher insolation than inferred from 1D models. Because of these unsaturated regions, the stratosphere remains cold and dry enough to hamper atmospheric water escape, even at large fluxes.

Finally, I will discus the implications of these results for Venus early water history and the extent of the habitable zone around low mass stars when the rotation of the planet can be tidally synchronized.