The Runaway Greenhouse: Could it happen here?

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The water vapor runaway greenhouse is one of the prime determinants of the inner edge of the habitable zone, the other being the risk of irreversible atmosphere loss due to high EUV illumination in early stages of a star's lifetime (especially for M-dwarf stars). The conventional threshold for a runaway is phrased purely in terms of the absorbed stellar radiation, and is based on clear-sky radiative transfer. In the simplest formulation, the runaway threshold is based on the limiting outgoing longwave radiation (OLR) for a pure steam atmosphere, and is independent of the presence of other constituents in the atmosphere, notable CO_2. The *wet runaway*, in contrast, occurs in the presence of a liquid water ocean, and while it can support irreversible water loss, is sensitive to the presence of other greenhouse gases in the atmosphere.

In this talk, I will survey current thinking about the conditions which can support dry or wet runaway states. I will pay particular attention to dynamically influenced issues, including stratospheric water vapor, subsaturation and clouds. It has sometimes been suggested that anthropogenic increases in CO_2 could trigger a runaway on Earth in the near future. The plausibility of this is in part dependent on how close Earth's orbit really is to a runaway state, even given clear sky and saturated conditions. I will review current results pertinent to this question. Addition of a noncondensible greenhouse gas like CO_2 can only trigger a runaway if a planet is in a metastable non-runaway state such as sketched in the accompanying figure. The existence of a metastable state depends on an overshoot of the $OLR(T)$ curve. I will discuss various mechanisms that can lead to such an overshoot, which include presence of a transparent background gas like N_2, subsaturation, or clouds, and address the question of whether it is conceivable that the present Earth is in a metastable non-runaway state.

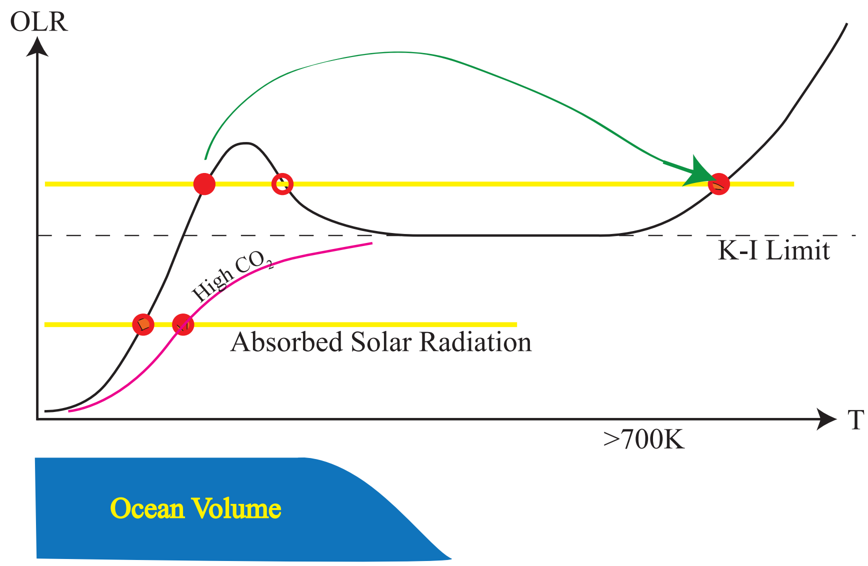

Figure 1: Sketch of the way a runaway state can be triggered by addition of CO_2.