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A new climate instability that triggers the runaway greenhouse in a 3-dimensional heterogeneous world.

ABE, Yutaka[1*] ; NITTA, Akira[1] ; ABE-OUCHI, Ayako[2] ; O'ISHI, Ryouta[2] ; TAKAO, Yuya[3]

[1]School of Science, University of Tokyo, [2]Atmosphere and Ocean Research Institute, University of Tokyo, [3]Center for Public Affairs and Communications, Tokyo Institute of Technology

The onset condition of the runaway greenhouse is considered that the atmosphere takes in more incoming solar radiation than a "runaway threshold." The runaway threshold is important because it defines the absolute inner limit of the habitable zone. Most of previous studies on the runaway threshold used one-dimensional radiative-convective equilibrium model and considered the atmospheric state where the ocean cannot exist in a equilibrium state. Such studies indicated that the runaway threshold is the "radiation limits," which is an asymptotic value or an upper limit of the planetary radiation (Nakajima et al., 1992,).

Recently, the runaway threshold of planets with heterogeneous surface water distribution has been investigated using 3 dimensional dynamic models (Abe et al., 2011; Leconte et al., 2013; Nitta et al., in preparation). The threshold strongly depends on the surface water distribution and it can be quite different from the radiation limit. Therefore, we have to understand the controlling mechanism of the runaway threshold in a 3-dimensional world.

Here, we report a new climate instability that triggers the runaway greenhouse based upon the analysis of GCM results and the linear stability analysis of a simplified model. The instability requires horizontal transport of heat and water vapor, thus it does not appear in one-dimensional world. On the other hand, surprising enough, this instability does not require the radiation limit. Namely, the instability is not directly related to the asymptotic value or the upper limit of the planetary radiation. This result suggests that the onset of the runaway greenhouse in 3-dimensional heterogeneous world may not be understood in terms of the simple radiation limit.

Keywords: runaway greenhouse, habitable zone, radiation limit, climate instability