Contribution ID: **17** Type: **Interactive presentation**

Transition to self-aggregation with enhanced variability for increasing CO2 concentration in radiative-convective equilibrium with a slab ocean

Thursday, 6 May 2021 16:00 (1h 45m)

In a general circulation model (ECHAM6) configured to represent radiative-convective equilibrium coupled to a slab ocean, we explore a wide range of CO_2 concentrations. We obtain reliable statistical quantities from thousand-year-long simulations, and we characterize the horizontal scale of ascending and subsiding regions by the so-called integral length scale of the vertical velocity field at a given atmospheric level, which is based on the horizontal autocorrelation function of that field. For moderate CO_2 concentrations, we find weak spatial organization, which comes along with unskewed temporal variations of 1–2 K in global mean surface temperature and an almost constant climate sensitivity of 2 K. At CO_2 concentrations beyond four times the preindustrial value, the climate sensitivity decreases to nearly zero as a result of episodic global cooling events as large as 10 K, in association with global-scale convective self-aggregation and relying on the appearance of a low-level stratiform cloud field in the subsiding region which constitutes the global complement of the self-aggregated ascending region. We qualitatively sketch a potential description in terms of the phenomenology of spatially extended dynamical systems for the transition between the weakly organized and the self-aggregated regime.

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Session Classification: RCE and Processes in Deep Convective Organization

Track Classification: RCE and Processes in Deep Convective Organization