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Analysis of tropical cyclone dynamics in two models of different complexity

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Tropical cyclone dynamics and its sensitivity to several climatological parameters is investigated within the axisymmetric high-resolution cloud model HURMOD on and by means of a conceptual tropical cyclone (TC) model. Within the conceptual model, the TC is divided into three regions, the eye, eyewall and ambient region. The conceptual model forms a low order dynamical system of three ordinary differential equations. These are based on entropy budget equations comprising processes of surface enthalpy transfer, entropy advection, convection and radiative cooling. For tropical ocean parameter settings, the system possesses four non-trivial steady state solutions when the sea surface temperature (SST) is above a critical value. Two steady states are unstable while the two remaining states are stable. Bifurcation diagrams provide an explanation why only finite-amplitude perturbations above a critical SST can transform into TCs. Besides SST, relative humidity of the ambient region forms an important model parameter as it highly affects the entrainment of low entropy air into the inflow region of the TC. The surfaces that describe equilibria as a function of SST and relative humidity reveal a cusp-catastrophe where the two non-trivial equilibria split into four. Within the model regime of four equilibria, cyclogenesis becomes very unlikely due to the repelling and attracting effects of the two additional equilibria. It is tested, whether the qualitative behaviour observed in the box-model simulations is reproducible in the axisymmetric cloud model HURMOD by variation of the initial vortex strength and climatological parameters in analogy to conceptual model experiments. It is shown that an attractor associated with a tropical cyclone exists in HURMOD when a warm-rain micro-physical scheme is applied. By varying SST, the reference temperature profile and relative humidity of the reference state, we find a tropical cyclone branch and a bifurcation in HURMOD similar to those detected in the low order box-model. The results evince the relevance of approaching the dynamics of tropical cyclone formation and its maximum potential intensity (MPI) using a hierarchy of models of different complexity.