The role and timescale of the moisture-entrainment-convection feedback in Spontaneous TC genesis

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Abstract

Tropical cyclones (TCs) are one of the most fascinating examples of organized convection. In idealized simulations of rotating radiative-convective equilibrium (RRCE), TCs can self-emerge without the need for a pre-existing disturbance. In a recent study, Ramírez Reyes and Yang (2021) showed that in contrast to prevailing knowledge (e.g., Muller and Romps (2018)), spontaneous TC genesis can occur without radiative and surface-flux feedbacks. Here we explore the hypothesis that under these conditions, the moisture-entrainment-convection (MEC) feedback is responsible for the spontaneous TC genesis. In the MEC feedback, a moister environment favors new deep convective events, and their associated large-scale circulations and detrainment processes further moisten the environment, leading to aggregation of deep convection. We examine the role of the MEC feedback in spontaneous TC genesis using RRCE simulations (Ramírez Reyes and Yang, 2021), in which we weaken the MEC feedback by relaxing the clear-sky specific humidity to its horizontal average throughout the entire column. TCs can still self-emerge when we weaken the MEC feedback, but TC intensity monotonically decreases as we reduce the relaxation time scale. TCs can no longer appear in the 100-day simulations when the relaxation time scale is reduced to 3 hours. We then relax the clear-sky specific humidity to its horizontal mean at individual vertical layers and find that weakening the MEC feedback below 7km significantly decreases TC intensity. However, nudging specific humidity above 7km has a much weaker impact. We will also present further analyses to test the hypothesis by using vorticity, the available potential energy (APE) budget and a vertically resolved moist static energy framework (Yao, Yang, Tan 2021). Ramírez Reyes, A., & Yang, D. (2020). Spontaneous Cyclogenesis without Radiative and Surface-Flux Feedbacks. arXiv preprint arXiv:2004.08662. Muller, C. J., & Romps, D. M. (2018). Acceleration of tropical cyclogenesis by self-aggregation feedbacks. Proceedings of the National Academy of Sciences, 115(12), 2930-2935. Yao, L., Yang, D., & Tan, Z. M. (2020). A Vertically Resolved MSE Framework Highlights the Role of the Boundary Layer in Convective Self-Aggregation. arXiv preprint arXiv:2008.10158

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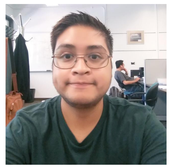

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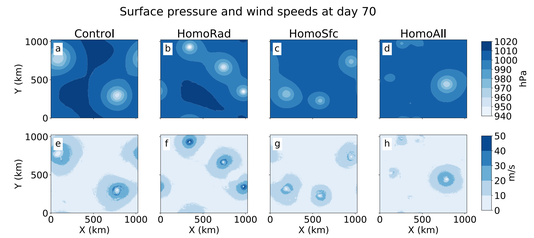
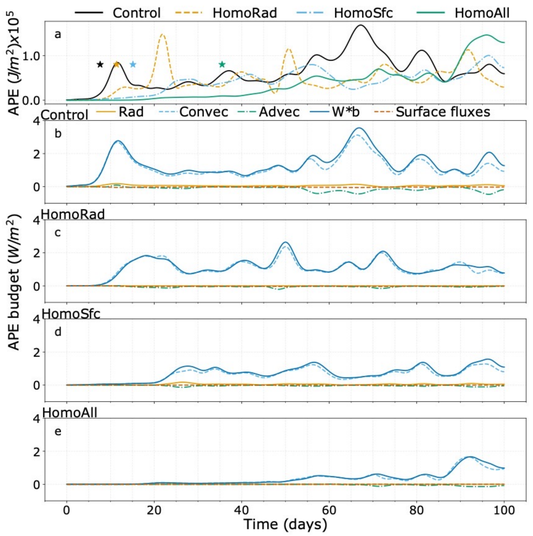


1. Mechanism denial experiments show that tropical cyclones can self-emerge in the absence of both, radiative and Surface-flux feedbacks*

2. Radiative and surface-flux feedbacks do affect the timing and intensity of the simulated tropical cyclones



3. Increases in available potential energy lead by convective heating anomalies coincide with the spontaneous genesis of tropical cyclones

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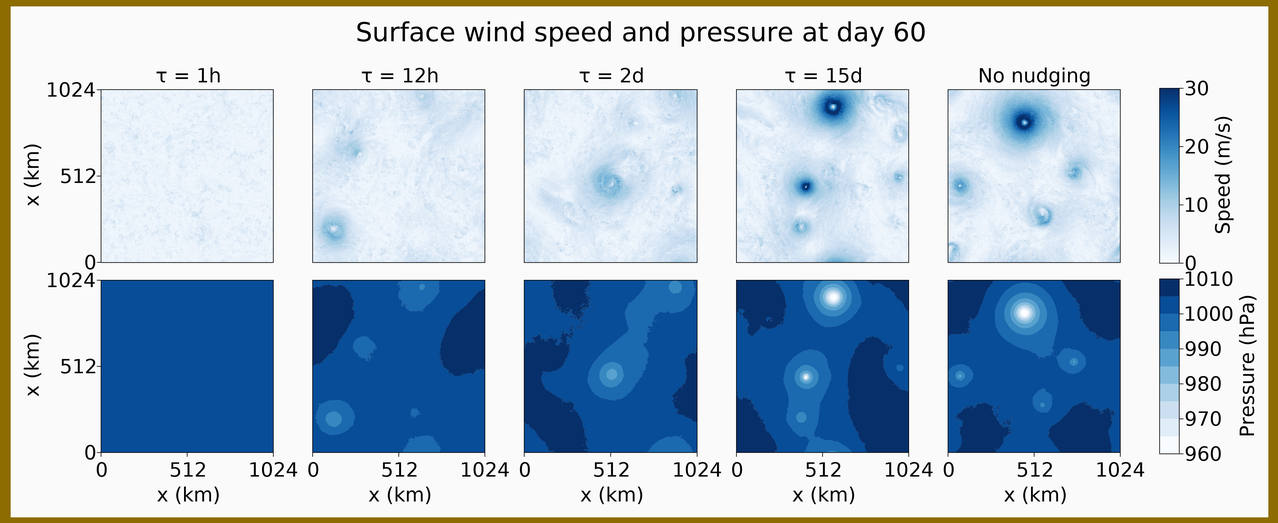
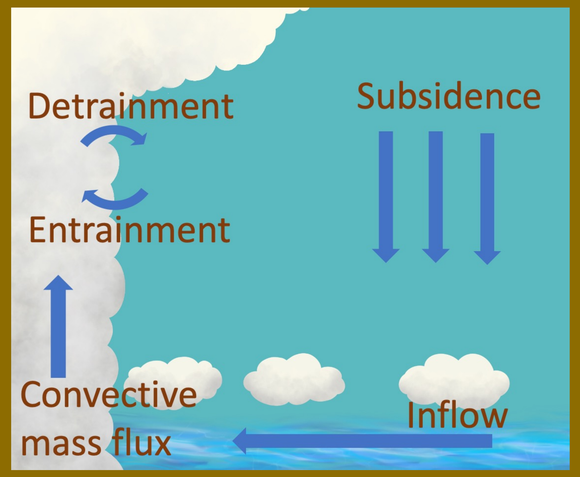
Spontaneous tropical cyclone genesis **does not need radiative or surface-flux feedbacks.** But in these conditions, tropical cyclones **require** feedbacks between moisture and convection to **emerge and intensify.**

Weakening moisture-entrainment-convection feedback



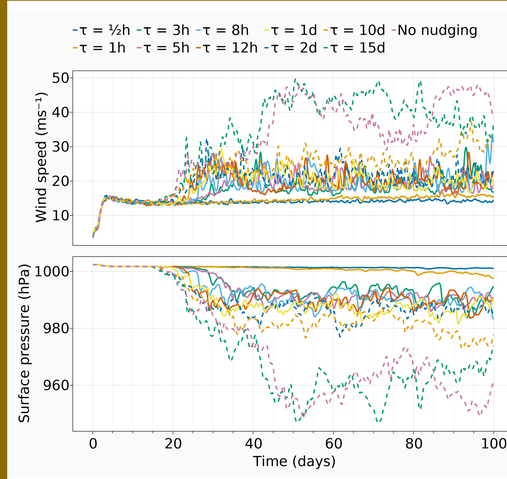


Two possible timescales may explain the impact in intensity and genesis:

$$\tau_1 = \frac{Length_{entrainment}}{Velocity_{convection}} \sim \frac{5km}{1\,{}^{m}/_{s}} \sim 1.5\ hours$$

$$\tau_2 = \frac{Length_{troposphere}}{Velocity_{subsidence}} \sim \frac{15km}{0.01\,{}^{m}/_{s}} \sim 17\ days$$

*Ramírez Reyes, A. ., & Yang, D. (2021). Spontaneous Cyclogenesis without Radiative and Surface-Flux Feedbacks, *Journal of the Atmospheric Sciences* (published online ahead of print 2021). Retrieved Dec 9, 2021, from https://journals.ametsoc.org/view/journals/atsc/aop/JAS-D-21-0098.1/JAS-D-21-0098.1.xml



4. When we weaken the coupling between moisture and locations of convection, weaken the storms and finally prevent them from appearing!