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The Critical Role of Cloud–Infrared Radiation Feedback in Tropical Cyclone Development

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The deep convective clouds of developing tropical cyclones (TCs) are highly effective at trapping the infrared (or longwave) radiation welling up from the surface. This “cloud greenhouse effect” locally warms the lower–mid-troposphere relative to the TC’s surroundings – an effect that manifests in all stages of the TC lifecycle. While idealized studies suggest the importance of this feedback for TC formation, this issue has remained unexplored for TCs in nature, where non-zero background flow, wind shear, and synoptic-scale variability are known to greatly constrain TC development.

To address this gap, we examine the potential role of this cloud–infrared (or longwave) radiation feedback in the context of two archetypal storms: Super Typhoon Haiyan (2013) and Hurricane Maria (2017). We conduct a set of numerical model experiments for both storms with a convection-resolving model (WRF-ARW) from the very early stages of TC development. We examine sensitivity experiments wherein this cloud–radiation feedback is removed at various lead-times prior to TC genesis and the onset of rapid intensification (RI). In both storms, removing this cloud–radiation feedback at a lead-time of ~1 day or less leads to delayed and/or weaker intensification than in the control case. When this feedback is removed with a lead-time of two days or longer, however, the storms altogether fail to development and intensify. This local cloud greenhouse effect strengthens the thermally direct transverse circulation of the incipient storm, in turn both promoting saturation within its core and accelerating the spin-up of its surface tangential circulation via angular momentum convergence. These findings indicate that the cloud greenhouse effect plays a critical role in accelerating and promoting TC development in nature. Progress in the prediction of TC formation and intensification has been very limited in recent decades. Cloud–radiation feedback represents a large source of uncertainty in models, which hence manifests as uncertainty in the prediction of TC development. Our findings highlight the

pressing need to better constrain this feedback in models. Doing so holds promise for advancing our ability to forecast TCs.