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Factors That Influence the Size of Tropical Cyclones

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Tropical cyclone (TC) size is an important feature setting the extent of coastal flooding, the size of storm surge and area threatened by landfall. The importance of TC size is demonstrated comparing Hurricanes Sandy in 2012 and Bret in 1999. As a Saffir-Simpson Hurricane Scale category-3 hurricane, the radius of gale-force wind of Hurricane Sandy exceeded 800 km prior to landfall, and the storm caused catastrophic storm surge into the New Jersey and New York coastlines, and damage up to an estimated total of $50 billion. Hurricane Bret, on the other hand, was a more intense category-4 hurricane with a radius of gale-force wind of only 140 km. Although Bret's intensity is considerable, damage was reported to be relatively light, totalling an estimated $60 million. The difference impacts are mainly caused by the difference in size.

Despite the fact that a wide range of observed TC sizes has been recognised, the underlying factors that control both individual storm size and the climatological size variation remain mysterious. Here an idealized full-physics numerical cyclone model and a modified hurricane steady-state model (λ model) for TC wind profile are used to investigate the influence of environmental temperature and initial vortex properties on TC size. In the simulation we find that a sea surface temperature increase, a temperature decrease in the upper troposphere, a large or strong initial vortex can lead to the extension of TC size. The numerical model simulations show a Gaussian distribution with width, λ, of the moist entropy in the boundary layer. The width, λ, has good linear relationship with the size changes caused by different factors. With regards to TC size and intensity, we find that, unlike the intensity prediction based on the maximum potential intensity theory, it seems that there is no upper limit for TC size providing there is sufficient latent heat flux. The increase of TC size at the steady stage also causes a slight drop in intensity. In addition, a weak relationship between TC size and intensity is confirmed in the simulations, and this relationship can be understood with the λ model. The λ model correctly depicts the tangential velocity profile at the top of boundary layer (TBL). Based on the λ model, the TC size is a function of the distribution of moist entropy at the TBL given by λ, the pressure drop from the ambient environment to the eye, and the Coriolis parameter. We establish that for the size the width of the entropy distribution close to the core is more important than the environmental entropy or the difference between the environment and the core entropy. One can predict TC size by understanding what sets the width, λ.