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An Absolute Angular Momentum Based Analytical Model for Tropical Cyclone Radial Wind Profiles

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The ability to construct radial wind profiles of tropical cyclones (TC) from limited observations is crucial to the initialization of TC simulations and predictions. A minimum requirement of constructing a reasonable radial wind profile is its high skill in estimating one of the four TC characteristic parameters, namely maximum wind speed (V_{max}), radius of maximum wind speed (r_{max}), 17 m/s wind speed (V_{17}), and radius of 17 m/s wind (r_{17}) from the other three. In this study, we put forward an absolute angular momentum (AAM) based analytical model for inferring the radial profile outside the r_{max} from observations of these four parameters. An AAM loss function L, defined as the ratio of the AAM at r_{17} to that at r_{max}, is introduced to represent the AAM loss during radially inward motions in a TC. This model allows us to construct radial profiles of TCs under four different configurations from observations of these four parameters. Specifically, we can use V_{max} and r_{max} as inputs for solving (a) the tangential velocity profile of a TC from r_{max} to r_{17} or (b) the TC's radius for a given tangential velocity from V_{max} to V_{17}. Alternatively, we can use V_{17} and r_{17} as inputs for solving (c) the tangential velocity profile of a TC from r_{17} to r_{max} or (d) the TC's radius for a given tangential velocity from V_{17} to V_{max}. This enables us to acquire radial wind profiles when one of four parameters is not available in observations. The degree of consistency of (a) versus (c) and (b) versus (d) is an indicator of the robustness of the model. We evaluate the skill of our model using 4491 records of 197 named TCs derived from the Extended Best Track Dataset for the period of 1998-2016, finding that mean errors in estimating V_{max}, r_{max}, V_{17}, and r_{17} are, respectively, 7 m/s, 27 km, 4 m/s, and 70 km. The proposed model has several advantages over widely recognized existing TC wind profile models. Most empirical models are designed to construct radial wind profiles in only one of the four configurations. The mean errors in estimating V_{max}, r_{max}, and r_{17} of other physically based models are larger by several factors. Furthermore, our model can yield physical solutions (meaning that $V_{max} > V_{17} > 0$ and $r_{17} > r_{max} > 0$) for all 4491 TC records, regardless of which of the four configurations is chosen. For more than 10% of the TC records, however, solutions of other physically based models either do not exist or are not physical under certain configurations.