EGU22-6728
https://doi.org/10.5194/egusphere-egu22-6728
EGU General Assembly 2022

African easterly wave evolution and tropical cyclogenesis in a pre-Helene (2006) hindcast using the Model for Prediction Across Scales (MPAS)

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Despite recent advancements in our understanding of tropical cyclogenesis (TCG), it remains an elusive research topic. Here, the Model for Prediction Across Scales (MPAS) is used to study the TCG case of the African easterly wave (AEW) that became Hurricane Helene (2006). This study has two main objectives: 1) evaluate MPAS high-resolution AEW hindcast capability by comparing MPAS simulations—initialized with data from both the Integrated Forecasting System (IFS) and the Global Forecast System (GFS)—with observations and, 2) analyze the role of moisture in the mechanisms that lead to Helene's TCG. Both 15-km horizontal grid resolution simulations developed a more intense wave and ultimately tropical depression compared to observations. However, the track, intensity, and rainfall of the simulated pre-Helene when initializing with IFS were more comparable to those of observations than the simulation initialized with GFS. The simulated pre-Helene initialized with GFS was more intense than the IFS-initialized pre-Helene, with the track of the wave deviating farther east of the observed track, especially as it reached the west coast of Africa. The more intense GFS-initialized pre-Helene is associated with larger moisture availability in the boundary layer (BL), and stronger West African monsoon southwesterly winds in the mean state when compared to the IFS simulation and observations. A moisture flux convergence budget centered on the wave trough shows that during the wave's lifetime the convergence term in the BL dominates and increases as the wave approaches TCG. However, TCG only happens when conditions are optimal—net moisture flux in the BL at the center of the wave increases in addition to increased mass convergence. These results could potentially be the link that explains the intersection between recent TCG theories. In the moisture-vortex instability (MVI), the wave-related flow advects moisture and temperature towards the synoptic-scale vortex, creating a favorable environment for convection near the vortex center, promoting TCG. The pre-genesis top-heavy profile to bottom-heavy profile during genesis, which provides vorticity convergence associated with TCG, could be a consequence of MVI attainment. It is the increase in wave-centered net moisture flux in combination with wave-centered mass flux convergence increase in the BL that ultimately could bring these theories together and help explain how TCG is achieved.