The vacillation cycles found in a simulation of Hurricane Katrina (2005) using the Australian Bureau of Meteorology model TCLAPS are studied further with high-resolution ensemble simulations of the same model. During a vacillation cycle, the inner core structure of the simulated tropical cyclone (TC) exhibits two distinct phases: the symmetric phase and the asymmetric phase. During the symmetric phase, the eyewall comprises elongated convective bands and the low-level potential vorticity (PV) exhibits a ring structure with the maximum at some radius from the vortex centre. In contrast, during the asymmetric phase, the eyewall is more polygonal with vortical hot towers (VHTs) located at the vertices and the low-level PV has a monopole structure with the maximum at the centre. The intensification rates of the mean tangential wind are higher during the symmetric phase than during the asymmetric phase. These two phases are similar to the two regimes found by Kossin and Eastin (2001) using the aircraft observations. The transition from the symmetric phase to the asymmetric phase is shown to be associated with the development of VHTs, which is the result of a cooperative combination of convective and barotropic instabilities.

From the ensemble simulations, it was found that stronger vacillation cycles tend to be associated with large vortices (with large radius of the outermost closed isobar) and the conditions of high sea surface temperature. The analysis of barotropic instability and convective instability are presented to explain the observed sensitivity of the vacillation cycles.