Ekman downwelling from the lower troposphere in the intense tropical cyclones

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The warm-core structure is one of the most important features of tropical cyclones (TCs). As the warm-core structure is related to the tangential wind field and the intensity of the TC, understanding the mechanism controlling the warm-core structure is a fundamental issue. Although the warm-core structures are observed in the troposphere in many studies, several cases of high-level warm core (HWC) located near the tropopause height have been reported in previous studies, particularly of intense TCs. A number of mechanism have been proposed to explain the formation of such HWCs, it seems that no consensus has been reached yet on the formation mechanism.

A mechanism by which the HWCs develop in the development early stage of TCs is proposed on the basis of sensitivity studies using a three-dimensional nonhydrostatic model. We hypothesize that the occurrence of downdraft from the lower stratosphere near the TC center which causes the warming can be explained based on the theory of Ekman layer. According to Ekman layer theory, the vertically integrated ageostrophic mass transport is determined from the stress at the layer boundaries, and the magnitudes of vertical flows which cross the boundaries are proportional to the curl of the stress at the boundaries. When considering a layer near the lower stratosphere, downward flow which crosses the lower boundary can be caused by the turbulent momentum flux through the lower boundary, because the primary circulation of the TC is always cyclonic and decays with height.

This hypothesis was examined by conducting idealized TC simulations which are similar to those examined in the study of Ohno and Satoh (2015, JAS). It was found that suppressing the vertical mixing of momentum above the upper troposphere caused significant impact for the formation of the HWCs. This is consistent with the proposed hypothesis. The present analysis suggests that TCs can be even stronger than those expected by theories in which TC structures are confined in the troposphere (i.e., Emanuel, 1986, JAS). In addition, it is expected that the dynamical processes occurring near the tropopause have impact on the intensification through the imbalance effect near the surface suggested by the previous studies (i.e., Syono and Yamasaki, 1966, JMSJ).

Keywords: Tropical Cyclone

