Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

AAS01-08 Room:101A Time:May 23 11:20-11:35

Structural Changes of a Tropical Cyclone Moving across the Oceanic Frontal Zone in the Southern East China Sea

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Many of the tropical cyclones (TCs) that reach in midlatitude baroclinic zones change their structure into that characteristic of extratropical cyclones. This process, called extratropical transition (ET), has been discussed in many studies with particular focus on structure changes of TCs that occur in deep baroclinic zones associated with midlatitude westerly jets. Possible influence on ET that can be exerted by strong SST gradient associated with a midlatitude oceanic frontal zone has been overlooked, despite the importance of a near-surface baroclinic zone anchored by an oceanic front for the development of extratropical cyclones, as pointed out recently. However, an oceanic frontal zone and a westerly jet are often collocated, which makes it difficult to distinguish their individual effects on structure changes of TCs. To overcome this difficulty, this study investigates a particular TC, typhoon Songda (T1102), that approached an early-summer oceanic frontal zone in the southern East China Sea far south of a westerly jet, with particular focus on the influence of its frontal SST gradient on the thermal structure of the TC within the planetary boundary layer (PBL). The investigation is based on the JMA meso-scale analysis (MANAL), in addition to, a control and two sensitivity experiments with modified SST gradient performed with a cloud-resolving model (CReSS). One of the sensitivity experiments was conducted with a particular SST distribution that had been obtained by applying meridional running mean with 10 degree width to the high-resolution SST distribution used for the control experiment, while the other uses another SST distribution that had been obtained by applying zonal averaging further to the smoothed distribution used for the former sensitivity experiment.

MANAL reveals that zonal asymmetry in thermal structure emerges first in PBL mainly within the western outer region of the TC in the vicinity of the oceanic frontal zone, which precedes the emergence of deeper asymmetric structure within the deep baroclinic zone associated with the westerly jet. The near-surface asymmetric structure is caused by cold advection with TC-associated northerlies acting on persistent air temperature gradient that is maintained through sensible heat exchanges with the underlying ocean. In the upper portion of PBL, the corresponding cold advection is contributed to also by air temperature gradient kept intensifying nonlinearly with the cold advection.

Although all the CReSS experiments well represent the TC approaching the oceanic frontal zone, the degree of the zonal asymmetry in thermal structure of the TC within PBL is found sensitive to the strength of the SST gradient prescribed at the model boundary. Specifically, the enhancement of near-surface air temperature gradient by stronger SST gradient in the control run yields stronger cold advection and thereby stronger cold anomaly in the western outer region of the TC than in the sensitivity experiments. The results of the present study indicate particular importance of SST distribution assigned to a numerical model in reproducing a TC.

Keywords: Extratropical transition, Oceanic frontal zone, East China Sea, Planetary boundary layer, Data analysis, Numerical experiment