Potential Changes in Typhoon Intensity in the Near Future

Background

The IPCC Fourth Assessment Report (AR4), published in 2007, states with certainty that warming of about 0.2℃ per decade is projected for near-future (~ 2030) climate change, irrespective of any variation in carbon dioxide emissions from now. The AR4, however, does not provide useful information about possible changes in the frequency and intensity of typhoons caused by global warming . It is generally difficult to distinguish global warming signals about typhoon frequency and intensity from relatively large fluctuations affected by natural variations of sea surface temperature and large-scale atmospheric circulation. Toward useful future projection, a need exists not only to improve numerical climate models but also to develop analysis methods to examine climate model output from various aspects relevant to typhoon changes.

Objectives

This study aims to quantify near-future potential changes in typhoon intensity around Japan in the western North Pacific based on thermodynamic aspects of results from climate model experiments for the 20th century and future projection. The experiments were conducted by CCSM3, one of the latest atmosphere-ocean coupled general circulation models.

Principal Results

1. Relationship between sea surface temperature and potential typhoon intensity

The upper limit of typhoon development (or the lower limit of central pressure)*[1], which is a measure of potential typhoon intensity, can be theoretically estimated from thermodynamic environment given by sea surface temperature and vertical profile of upper temperature (Fig. 1). This study compares the present (1980-1999 average) and near-future (2010-2029 average) climate regarding the potential intensity based on the CCSM3 experiments, resulting in the following.

(1) In typhoon development regions of the western North Pacific, the lower limit of central pressure decreases on average by 5-7 hPa for 0.6-0.7℃ warming of sea surface temperature during 30 years (Table 1). This change is equivalent to about 3 m/s increase in the maximum wind speed at the mature stage of a typhoon.

(2) The relationship between central pressure and sea surface temperature differs between the present and near-future climate. Possible typhoon intensification due to global warming is modest compared to intensity change inferred from sea surface temperature change alone (Fig. 2).

2. Impact of upper air temperature change

Influence of upper air temperature change on the potential typhoon intensity is found as follows.

(1) Typhoon development regions are characterized by the fact that upper troposphere (about 10 km) warming is about two times greater than sea surface warming (Fig. 3). Lowering central pressure at a typhoon center directly results from the above air warming relative to the environment. It is, therefore, understood that global-scale greater warming contributes to suppression of typhoon intensification.

(2) Relatively large changes in mid-latitude sea surface temperatures lead to a tendency of smaller meridional temperature gradient in the upper air. This environment change suggests an influence on keeping intensity and structural change of typhoons that approach or make landfall over Japan.

Future Developments

Potential typhoon intensity will be further improved with probabilistic information derived from multiple climate model projections including different biases and uncertainties. Surface wind models, used for strength design of infrastructure, will be also improved with the advanced information about typhoons approaching or making landfall over Japan.

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Reference

J. Tsutsui, 2008, "Maximum potential intensity of tropical cyclones derived from numerical experiments using the Community Climate System Model (CCSM3)", J. Disaster Research, vol.3, pp.25-32

*1 : The upper limit of typhoon intensity is theoretically calculated from upper-air temperature increase (density decrease) relative to the environment, leading to a central pressure drop.

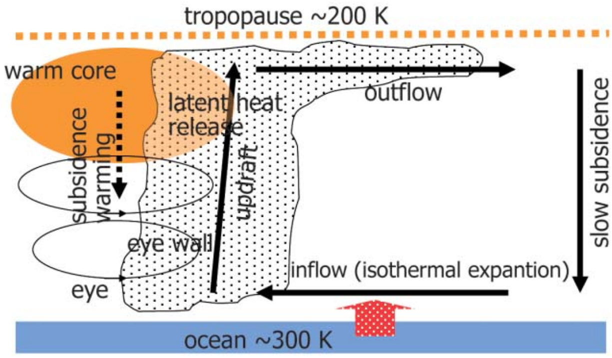

Fig.1 Conceptual model of a tropical cyclone (one side of vertical cross section at the center)

The air flow in a typhoon or hurricane features an axisymmetric intense vortex and transverse secondary circulation. Thermodynamic model for the secondary circulation gives a theoretical upper limit of cyclone intensity as minimum central pressure. This study uses a theoretical model formulated by Holland (1997, J. Atmos. Sci.).

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Table 1 Mean sea surface temperature (SST) and minimum central pressure (Pc) in the typhoon genesis region in the western North Pacific

Season	Latitude	Present		Near-future change	
		SST (ºC)	P_c (hPa)	SST (ºC)	P_c (hPa)
Jun-Jul	6.3-23.1N	28.5	926	0.64	5.1 (3.5-10.0)
Aug-Sep	6.3-25.9N	28.8	911	0.66	7.3 (5.3-10.8)
Oct-Nov	6.3-21.7N	28.5	925	0.73	7.2 (4.2-11.5)

Near-future (2010-2029) changes represent differences from the present (1980-1999) state, where positive numbers indicate an increase for sea surface temperature and a decrease for central pressure. 120-160E averages are shown. Numbers in parentheses indicate the min-max range over each latitude region.

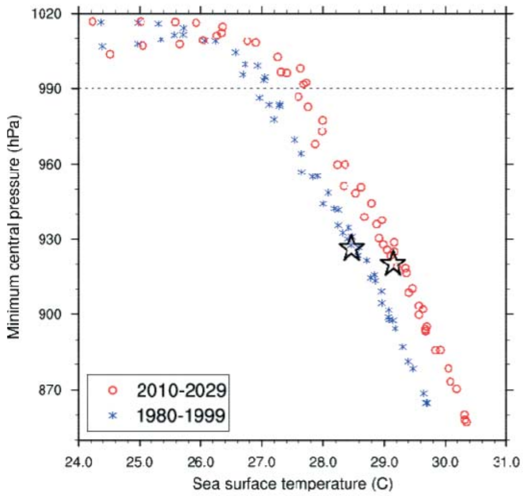

Fig.2 Relationship between minimum central pressure and sea surface temperature

Numerical values at each season and latitude for the present and near future are plotted by markers. Large stars indicate the average of points below 990 hPa, shown by dotted line, for each climate state. A curve representing the near-future relationship shifts from a similar curve for the present climate toward a higher temperature and slightly lower central pressure.

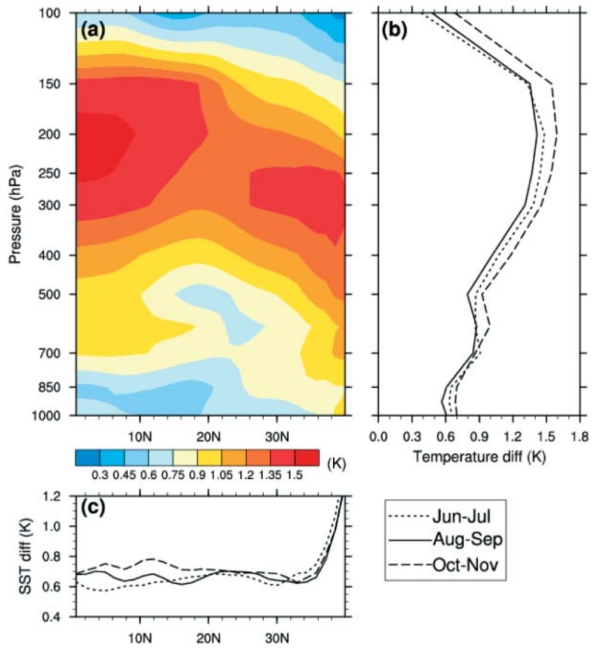

Fig.3 Near-future change in thermodynamic environment over the western North Pacific

Change in the near-future relative to the present state for (a) vertical cross section of air temperature, (b) its 5-25N average, and (c) sea surface temperature. Greater warming occurs in the tropical upper troposphere.