Effect of warm ocean current on the formation of low-level humid air causing a F3 tornado storm observed in middle Japan on 6 May 2012

Teruyuki KATO

Meteorological Research Institute, Tsukuba, Ibaraki, Japan
(E-mail: tkato@mri-jma.go.jp)

1. Introduction

On 6 May, 2012, a strong tornado with Fujita scale 3 (> 70 m/s) struct Tsukuba City, located Kanto Plain in the middle part of Japan (see Fig. 1a). The tornado occurred in a supercell storm that formed mainly due to the northward inflow of low-level humid air from the Pacific Ocean, as well as large temperature difference in the vertical between low and middle levels that maintained from the previous day.

The specific humidity at a height of 500 m became almost doubled from 6 g/kg during 12 hours when the low-level air traveled over the ocean south of the Japanese Islands (Figs. 2a and 2b). This humidified air flowed spotly into Kanto Plain to cause the storm just after 12 JST (= UTC + 9 hours) on 6 May. The increase of specific humidity could be mainly caused by updrafts associated with a low-level short trough travelling eastward (see dashed lines in Figs. 2a and 2b). The value of specific humidity at 06 JST 06 was, however, larger than that near the surface before 12 hours (Fig. 2c). This means that near-surface water vapor increased by latent heat flux from the sea surface, which is ascertained by the increase of about 2 g/kg at 06 JST 06 (Fig. 2d).

Japan Current, a warm ocean current, existed along the route where the near-surface air obtained latent heat flux from the sea surface. In this study, the effect of Japan Current on the formation of low-level humid air is examined using a Japan Meteorological Agency (JMA) nonhydrostatic model with a horizontal resolution of 5 km (Saito et al. 2007).

2. Experimental designs

Eighteen-hour forecasts from 18 JST 05 May 2012 are conducted using initial and boundary conditions produced from 3-hourly available JMA mesoscale analyses with a horizontal resolution of 5 km. Model domain, topography and given sea surface temperature (SST) are shown in Figs. 1a and 1b, and 50 stretched layers (6 of which are set below a height of 500 m) are set in the vertical. A bulk-type microphysics parameterization scheme in which two moments are treated only for ice hydrometeors (i.e., snow, graupel and cloud ice) is used for precipitation processes, and the Kain-Fritsch convection parameterization scheme is additionally used. The turbulence closure scheme is Mellor-Yamada-Nakanishi-Niino level-3 (Nakanishi and Niino 2006). The surface fluxes are calculated by a bulk method, in which the bulk coefficients are determined from the formula of Berjaars and

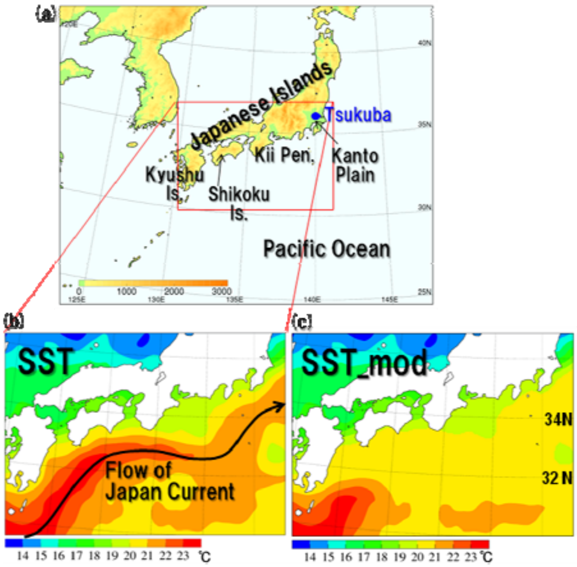

Fig. 1 (a) Model domain and topography of 5km-model and (b) distribution of sea surface temperature on 6 May 2012, depicted from JMA mesoscale analysis. (c) Same as (b), but the maximum sea surface temperature north of 32 °N is set under 20 degrees of Celsius.

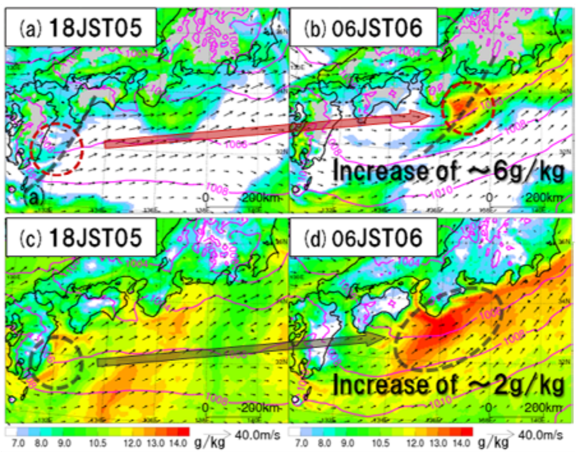

Fig. 2 Horizontal distributions of specific humidity (color), sea level pressure (contour) and horizontal wind vectors at a height of 500m at (a) 18 JST 05 May 2012 and (b) 06 JST 06, depicted from JMA mesoscale analysis. (c) and (d) same as (a) and (c), respectively, but near the surface.

Holtslag (1991) over both sea and land. The other specifications are almost the same as those in Saito et al . (2007).

To examine the effect of Japan Current on the formation of low-level humid air, a sensitivity experiment is also conducted using a modified distribution of SST in which the maximum sea surface temperature north of 32 °N is set under 20 degrees of Celsius (Fig. 1c). This modification eliminates Japan Current located south of the Japan Islands, and lowers the SST up to about 3 degrees (see pink contours in Fig. 4).

3. Results

The forecast accuracy is checked by the distribution of 500m-height specific humidity after 12 hour integration (Fig. 3a). A humid area with a horizontal scale of 100 ~ 200 km is successfully reproduced southeast of Kii Peninsula, although the maximum value is slightly smaller and the low-level short trough slightly travels faster than the analysis (Fig. 2b).

On the other hand, the sensitivity experiment shows that removal of high SST areas associated with Japan Current results into the reduction of low-level water vapor (Fig. 3b). The decrease of 2 g/kg at a height of 500 m corresponds to one-third for the increase of 6 g/kg during 12 hours (Figs. 2a and 2b). Such a decrease of 2 g/kg is also found near the sea surface (not shown). Therefore, additional increase of 2g/kg over Japan Current could be significant to the formation of the storm causing the Tsukuba tornado.

4. Effect of Japan Current on the accumulation processes of low-level water vapor

The effect of Japan Current on the accumulation processes of low-level water vapor with a depth of about 1 km are examined by the differences between the control and sensitivity experiments. Figure 4 shows the differences at 03 JST 6 May 2012, 3 hours later from Fig.3.

It is easy expected that high SST produces warm humid air in the lower layer due to large sensible and latent heat fluxes to induce the pressure drop. This drop is found over Japan Current, and consequently near-surface wind convergence is produced along the Current (Fig. 4a). The convergence intensifies updrafts around the low-level short trough that transports water vapor upward from the near sea surface (Fig. 4b). Noted that such a convergence is not found at a 334-m height. The pressure drop also accelerates near-surface winds (Fig. 4c), which further increases latent heat flux from the sea surface in addition to the increase due to high SST (Fig. 4d). The above-mentioned interaction between air and sea helps the formation of low-level humid air.

References

Beljaars, A.C.M. and A.A.M. Holtslag, 1991: Flux parameterization over land surfaces for atomospheric models. *J. Appl. Meteor.*, **30**, 327-341.

Nakanishi, M. and H. Niino, 2006: An improved Mellor-Yamada level-3 model: Its numerical stability and application to a regional prediction of advection fog. *Bound.-Layer Meteor.*, **119**, 397-407.

Saito, K., J. Ishida, K. Aranami, T. Hara, T. Segawa, M. Nareta, and Y. Honda, 2007: Nonhydrostatic atmospheric models and operational development at JMA. *J. Meteor. Soc. Japan*, **85B**, 271-304.

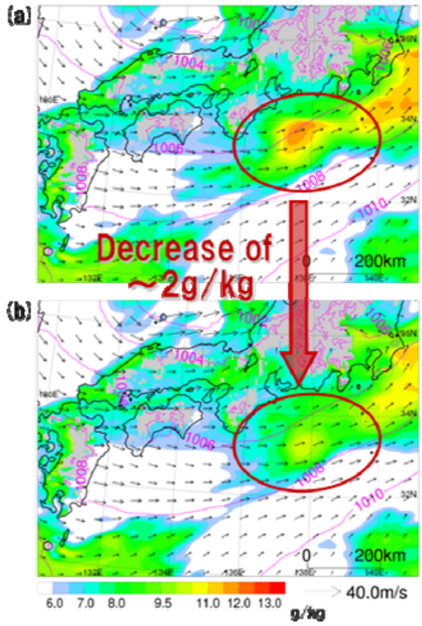

Fig.3 (a) Same as Fig. 2, but 12 hour forecasts of 5km model. (b) Same as (a), but the result of a sensitivity experiment in which SST is given by Fig. 1c.

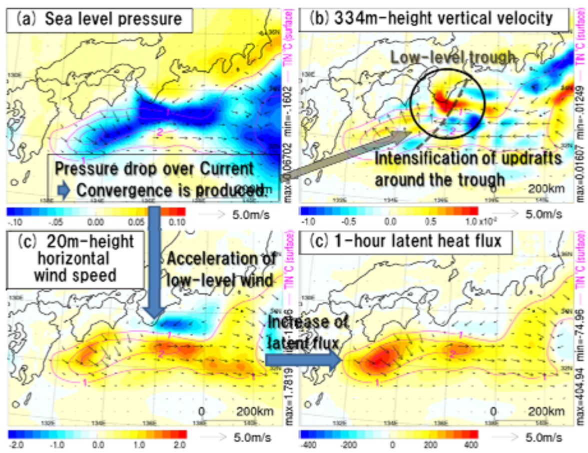

Fig. 4 Horizontal distribution of the differences between control and sensitivity experiments in (a) see level pressure (hPa), (b) 334m-height vertical velocity (m/s), (c) near-surface horizontal wind speed (m/s), and (d) one-hour accumulated latent heat flux (W) at 03 JST 06 May 2012. Pink contours and wind vectors denote the differences in given SST and horizontal winds, respectively.