8.3 IMPACT OF SEA SURFACE TEMPERATURE ON SEA AIR TEMPERATURE IN TOKYO BAY

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1. INTRODUCTION

It has been believed that Tokyo Bay will have more or less influence on atmospheric environmental issues such as the heat island phenomenon, heavy rainfall, and air pollution, through the land–sea breeze mechanism (e.g., Yoshikado, 1992; Fujibe, et al., 2002). However, little is known about the actual impact since there is previously no evidence to validate it. Moreover, the current model estimation of air–sea interaction is based on conventional sea surface parameters which were observed from ocean surfaces at considerably far distance from the shore.

In this study, to investigate the spatial and temporal variations of Sea Surface Temperature (SST) over Tokyo Bay, an observation network has been constructed. Water temperature gauges and thermometers have been installed at 14 observation sites (lighted buoy, light beacon, offshore structure) in Tokyo Bay since November 2006, thereby observing SST and Sea Air Temperature (SAT). The purposes of this study are to (1) evaluate the spatial and temporal variations SST and SAT in Tokyo Bay, and to (2) investigate the impact of SST on urban climate using the numerical modeling system, WRF, in which SST obtained from this observation is used.

2. OBSERVATIONS

2.1 *Site Description and Data Processing*

The study site, Tokyo Bay is located in the central part of the main island in Japan (Fig. 1). This area belongs to the monsoon region that the wind directions have the seasonal reversal. Wind blows from the south during summer and from the north during winter. The inside bay has an area about 960 km^2. Mean water depth is about 15m, and it is gradually deep from head to the mouth of bay, finally it reaches down 50m. The seacoast region is almost an industrial area which includes a food complex, steel and a petrochemical complex.

The measurements have been conducted at 14 observation sites (Fig. 2), such as existing lighted

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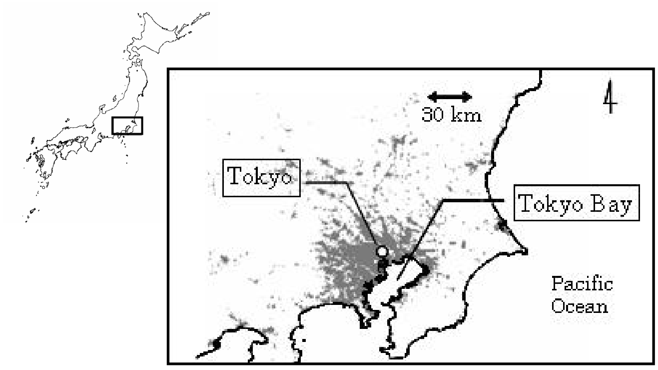

Fig.1 Environment of the study site. Location of Tokyo Bay in Japan. Gray area indicates built-up area where artificial structures occupy significant surfaces.

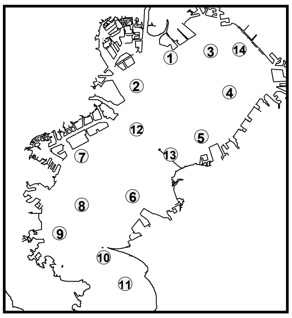

Fig.2 Observation sites.

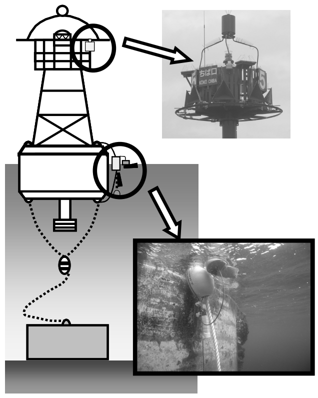

Fig.3 The installed instruments at lighted buoy.

Table 1 The list of the instruments

Items	Air temperature	Water temperature
Instruments	HOBO H8 Pro Temp	HOBO U22 Water Temp Pro v2
	(Onset Computer Corporation)	
Operation range	-30℃～+50℃	0℃～+50℃
Accuracy	±0.2℃ at 20℃	±0.2℃ over 0℃ to 50℃
Resolution	0.03℃ at 20℃	0.02℃ at 25℃
Response time	35 minutes still in air	5 minutes in water
Weight	105g	42g
Dimensions	102mmH×81mmW×51mm D	3cm max. diameter, 11.4cm length
Sampling	10minutes	10minutes

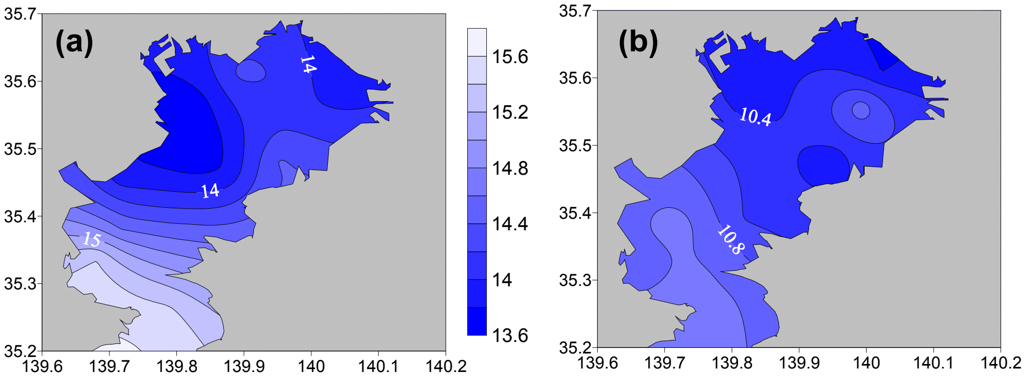

Fig.4 Spatial distribution of (a) SST and (b) SAT in Tokyo Bay at 1200 JST on December 10th, 2006.

buoy, light beacon, offshore structure since November 2006.

We measured SST and SAT at intervals of 10 minutes at 14 sites, and analyzed the 60 minutes mean value. For example, data of 1200 means an average of 1200 to 1300 Japan Standard Time (JST; GMT-0900). Table 1 shows the list of instruments which were installed, and Fig.3 shows the setting of the instruments each site.

2.2 *Spatial and Temporal variations SST and SAT in Tokyo Bay in Winter Season*

Figure 4 shows the spatial distribution of SST and SAT in Tokyo Bay at 1200 JST on December 10th , 2006. During winter, SST at the mouth of bay is warmer than that at the head of bay, because warm current (i.e., black current) from the surrounding sea cause the SST at the mouth of bay to be warmer, and cool water flow in the head of bay from rivers. The spatial distribution of SAT was also like that of SST. However, the spatial variation of SAT was smaller than that of SST. Figure 5 shows the diurnal variation of SST and SAT from January 19th to 25th, 2007. Standard deviation of SAT was 0.47 degC, whereas that of SST was 0.76 degC. As for diurnal range, SAT was larger than SST. Moreover, SAT was similar to that of the air above the Tokyo Metropolitan Area. These results indicate that SAT is considerably affected by air advection from the coastal land area. The impact of SST on SAT and urban air was not significant during this season due to the diurnal variation of SST is small (low radiative forcing and sea surface cooling) and wind blows from the north.

3. NUMERICAL SIMULATION

As mentioned in the introduction, the current model estimation of air–sea interaction is based on conventional sea surface parameters which were observed from ocean surfaces. However, Tokyo Bay has different SST from the outer sea. Therefore, we investigate the impact of SST on SAT and sensible heat flux, using numerical modeling system under

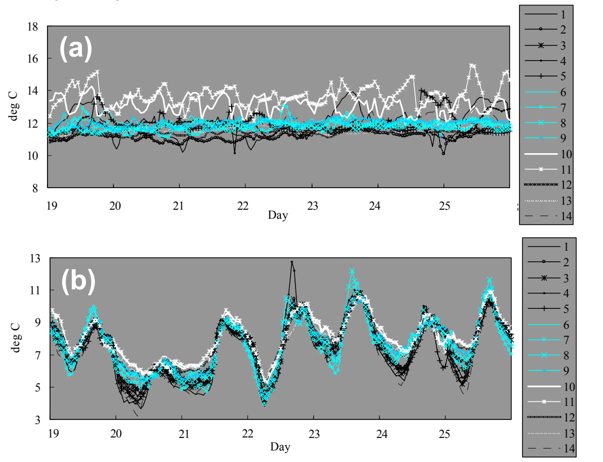

Fig.5 Diurnal variation of (a) SST and (b) SAT in Tokyo Bay from January 19th to 25th, 2007.

actual SST observed from this observation.

3.1 *Description of the Numerical Modeling System*

The Weather Research and Forecasting (WRF) model, which has been developed by collaboration among the National Center for Atmospheric Research (NCAR), the National Centers for Environmental Prediction (NCEP), the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, Oklahoma University, and the Federal Aviation Administration (FAA), is adopted as a tool to simulate the urban climate. The specifications of WRF numerical experiments used in this study are summarized in Table 2.

The model has two-way interactive multiple nested grid capability. A two-tier nested grid system is used in this study. The first domain (coarse grid) covers central Japan including the Japan Alps, the Sea of Japan and the Pacific Ocean. The second domain (fine grid) covers the Kanto area including Tokyo Bay and parts of the Pacific Ocean. Figure 6 shows each computational domain, and specification of that is summarized in Table 3.

Table 2 Specification of WRF used in the present numerical study.

Basic equations	Non-hydrostatic; compressible
Horizontal coordinates	Cartesian
Vertical coordinates	Mass-based terrain following
microphysics	WSM 3-class simple ice scheme
Surface layer	Monin-Obukhov scheme
Lower boundary	5-layer thermal diffusion scheme
Upper and Lateral boundary	PBL・・・YSU scheme, lateral・・・specified with relaxation zone
Radiation (short-wave)	Dudhia scheme
Radiation (long-wave)	rrtm scheme
Turbulence	Horizontal Smagorinsky first order closure Evaluate 2nd order diffusion term on coordinate surface

Table 3 Specification of computational domains

	Horizontal grid number (grid points)	Horizontal domain size (km)	Horizontal grid spacing (km)	Vertical grid number (grid points)	Time inclement (s)
Domain 1	80 x 88	400 x 440	5	28	30
Domain 2	140 x 145	140 x 145	1	28	6

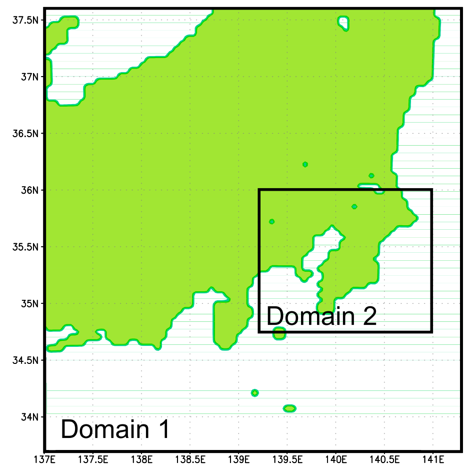

Fig.6 Computational domains. (a) Domain 1: central Japan; (b) Domain 2: Kanto area.

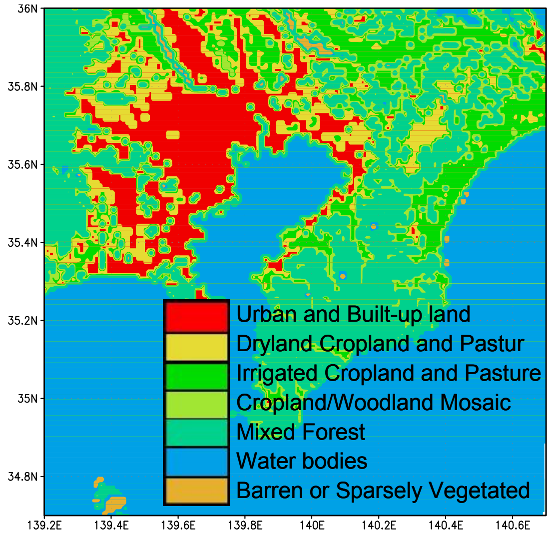

Fig.7 Land-cover map for Domain 2.

3.2 *Geographical and Meteorological Information*

Land use category and terrain height are based on land-cover data for 100m squares and topographic data for 50m squares, respectively, supplied by the Geographical Survey Institute of Japan. Land-cover map for Domain 2 is illustrated in Fig. 7. As for meteorological information, the model is initialized through the Grid Point Value (GPV) data set, which is prepared by the Japan Meteorological Agency (JMA). These are 0.05 x 0.0625 degree grids in surface data and 0.1 x 0.125 degree grids in pressure surface data, every 3 hours.

The feature of this study is that SST observed in Tokyo Bay (TBSST) and Anthropogenic Heat Flux (AHF) data are used in WRF.

The model was run for 11days from December 10th to 20th, 2006. The weather condition was fine on 10th, 11th and after 17th, and rainy or cloudy on the other days. Wind direction was almost from the north during this period.

3.3 *Results*

Figure 8 shows the comparison of simulated and observed (by weather station) diurnal variations of wind velocity, wind direction and air temperature at central Tokyo. NOSST, AHF_NOSST, AHF_TBSST means the case with updates of; 1) no outer SST and no AHF, 2) no outer SST and AHF, and 3) TBSST and AHF, respectively. Note that SST in outer sea is used the New Generation Sea Surface Temperature for Open Ocean (NGSST-O), which is based on an objective analysis of satellite SST, and supplied by NGSST development group. In Fig. 8(c), the impact of TBSST on air temperature over Tokyo Bay is not significant due to wind direction is from the north. However, AHF has a considerable impact on urban air, especially in calm condition. Air temperature increases about 1 degC. Senoo et al., (2004) pointed out that air temperature is increased about 0.5 degC due to AHF in central Tokyo in summer. It would be appeared that the reason of the difference between these different increase rate of air temperature is due to the radiative forcing is small and the influence of AHF is relatively large in winter (Ichinose et al., 1999).

At the center of Tokyo Bay, SAT also increases about 0.4 degC due to AHF. Moreover, SAT drops about 0.3 degC due to the replacement of outer SST (about 18 degC) with TBSST (about 14.5 degC) (Fig. 9). Positive sensible heat flux becomes small as SST drop (Fig.10). Figure 11 shows the relation between simulated sensible heat flux and wind velocity at the head of bay in the case of using TBSST, with the result from observed flux at No.14 site during December, 2004. The simulated sensible heat flux quantitatively agrees with those observed by an instrument. These results indicate that it is necessary to install the actual SST into the numerical

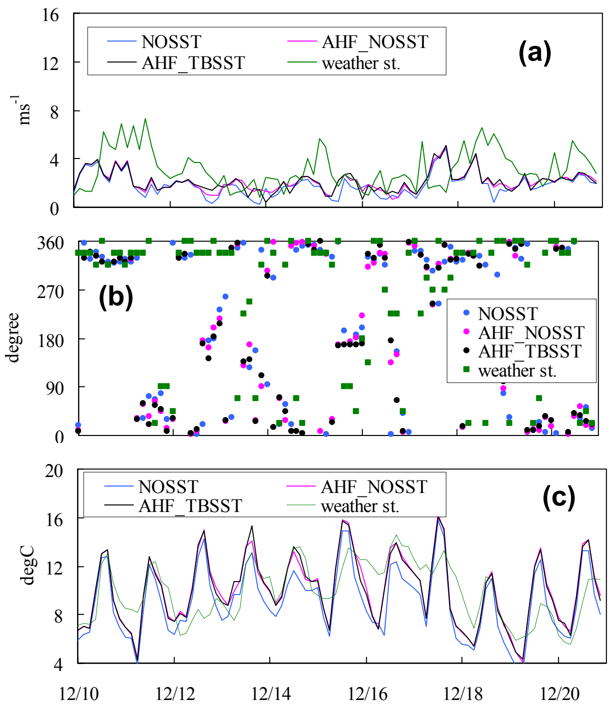

Fig.8 Diurnal variation of (a) wind velocity; (b) wind direction; (c) air temperature at Tokyo.

modeling system to estimate air-sea interaction in coastal region. In summer, the diurnal range of SST in Tokyo Bay become large and land-sea breeze circulation appears. Therefore, we need to successive monitoring for long-term evaluation.

4. CONCLUSIONS

The impact of Sea Surface Temperature (SST) on Sea Air Temperature (SAT) and urban climate in Tokyo Bay have been investigated through our observational and numerical study in winter. From observational study, there is no significant influence on SAT due to the diurnal variation of SST during this season. On the other hand, from numerical study, SAT drop and positive sensible heat flux agree with actual flux if the replacement of outer SST with TBSST. These results indicate that it is necessary to use the actual SST into the numerical modeling system to estimate air-sea interaction in coastal region.

ACKNOWLEDGEMENTS

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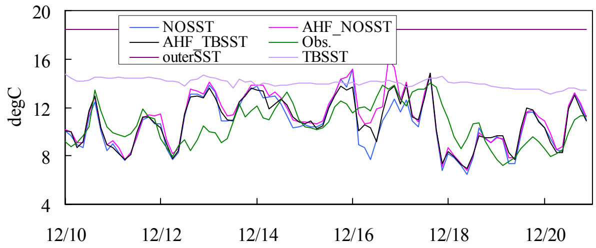

Fig.9 Diurnal variation of SST and SAT at the center of Tokyo Bay.

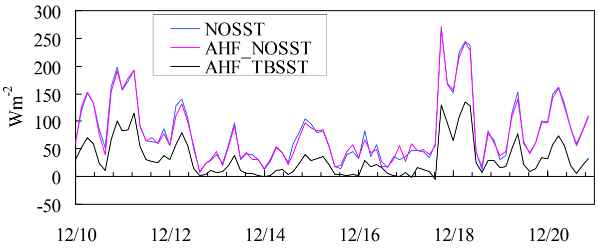

Fig.10 Diurnal variation of sensible heat flux at the head of Tokyo Bay.

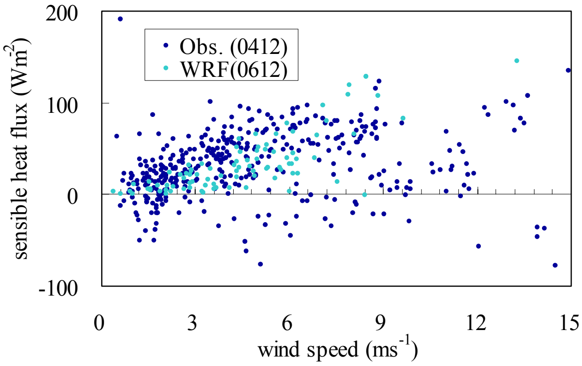

Fig.11 The relation between sensible heat flux and wind velocity in the head of Tokyo Bay.

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