A RELATIONSHIP BETWEEN THE CHARACTERISTICS OF SEA BREEZE AND LAND-USE IN FUKUOKA METROPOLITAN AREA

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Abstract

Numerical simulation was carried out by using mesoscale meteorological model "Weather Research and Forecasting" (WRF) to study about the relationship between the characteristics of sea breeze and land use in Fukuoka metropolitan area developed along the coast. The simulation was carried out under the conditions of present actual land use of Fukuoka plains and ancient Fukuoka plains. From the computations, following conclusions are obtained. The time that the sea breeze intrudes the Fukuoka Metropolitan area is earlier in the present condition due to the heat of the metropolitan area. The time that sea breeze intrudes inner land is earlier in the past condition. This difference is due to the change of the land roughness. Sea breeze velocity at each point is slower in the present. The temperature of the Fukuoka metropolitan area in the present condition is warmer.

Key words: heat island, land use, WRF

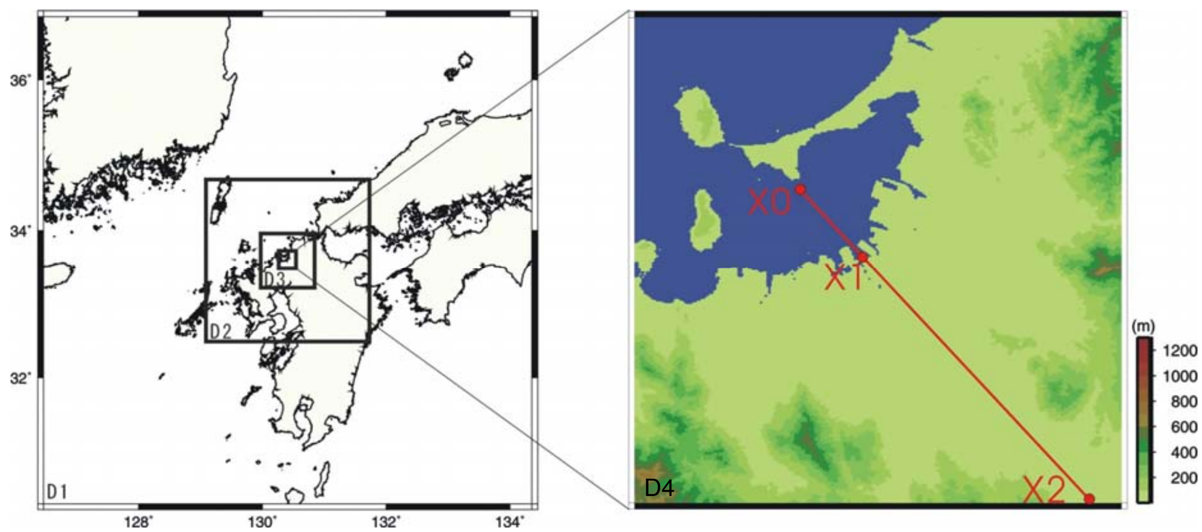
1. INTRODUCTION

In recent years, heat island effect has been observed in many cities. Cooling effects of sea breezes have attracted attention as a countermeasure; studies of them are in progress at various sites (Tonimura et al. 2003, Iwatani et al. 2003). Sea breezes that appear on the coast during the daytime on a sunny day are local winds that have been familiar to communities from ancient times. The Fukuoka plain, the target region of this study, is surrounded by Genkainada to the north, the Mt. Sefuri system to the southwest, and the Mt. Sangun system to the southeast. A sea breeze is therefore known to flow therein quite often all year (Fukuda et al. 2001). It is very important to solve the invasive property of sea breezes.

The mechanism by which sea breezes flow into Fukuoka metropolitan area and the effect of the city's geometrical configuration on that mechanism were investigated. WRF was applied to analyze two cases of differing land use. In the first case, the present actual land use of the city was considered. This case will be described hereinafter as "the realistic model". In the second case, the urban area was replaced by grassland in a case described hereinafter as "the grassland model". Analytical results obtained for the two cases were compared.

2. ANALYSES

Calculations for August 1, 2003 were performed. Calculation regions are shown in Figure 1. The solid line X0-X2 in Domain 4 is a cross-sectional line used to analysis, set up in the invasion direction of a sea breeze. Table 1 show the schematic of numerical simulation.



(a) domain1~4 (D1~D4) (b) Topography of domain4 (D4)

Fig. 1 Calculation regions

Analyses were made for the two cases described above. In the grassland model, the urban area was delineated based on the land-use database. The urban area replaced by grassland is presented in Fig. 2(b); this procedure has been done for domain 3 and domain 4 depicted in Fig. 1. In these two domains, when the grassland model was applied, the zones outside of the grassland were considered to have exactly the same land-use pattern set for the realistic model. The land-use patterns set for the two models are compared in Fig. 2 for domain 4.

3. RESULT AND DISCUSSION

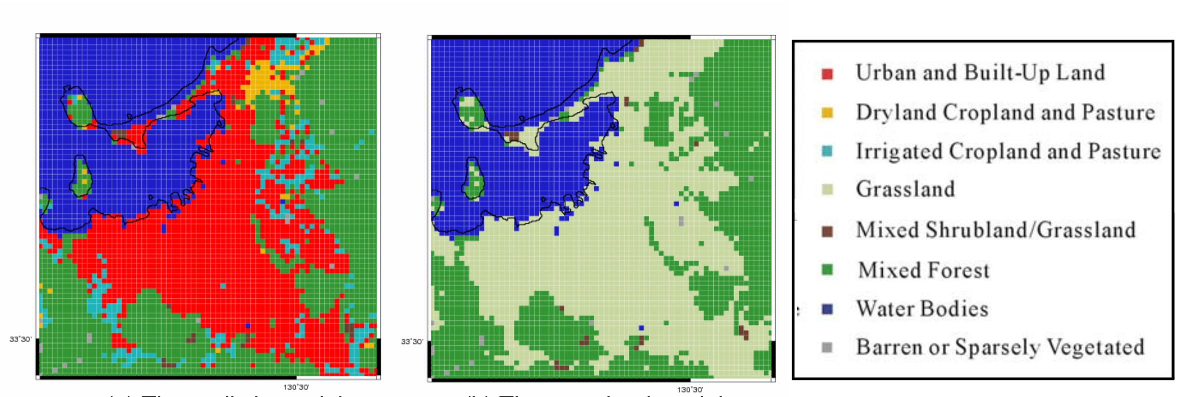
Figure 3 portrays the distribution of wind velocity in domain 4 for 1200 JST. In the figure, arrows show the direction of the horizontal wind velocity at 10 m altitude with a 4 mesh interval. Isograms depict the vertical velocity at 300 m altitude. In the isograms, colors close to the red end of the spectrum show increasingly higher velocities; those close to the blue end show descending velocities. This figure shows that the sea breeze, in the realistic model, flows some 20 km in from the coastline. It then produces a convergent ascending wind. In contrast, in the grassland model, the sea breeze runs all the way across the hypothetical grassland, sweeping it fully.

Figure 4 depicts distribution of temperature in domain 4 at 1200 JST. In both models, temperatures along the coastline are suppressed by the incoming cool sea breeze. However, hot zones form at the innermost part of the plain. The hot zone temperature is 34°C in the realistic model. However, using the grassland model, they are 32–33°C. The general features of these findings are quite understandable because the innermost part of the plain or city is warmed by sunshine and by heat from the ground surface. The coastal zone is cooled by the incoming sea breeze.

Figure 5 depicts wind velocities along the X0–X2 line presented in Fig. 1(b). The horizontal wind velocity is shown in the top figures and positive numerical values represent the direction of incoming sea breeze; reddish colors are assigned for that direction. In the bottom figures, positive numerical values show the ascending direction and reddish colors are assigned for that direction. The intensity of ascending wind by the realistic model is much stronger and is much more intense than that in the grassland model. This results from stronger ascending thermal convection driven by higher temperatures in the plain in the realistic model. The incoming velocity of the sea breeze in the realistic model is slower than that in the grassland model. In the realistic model, the incoming sea breeze is slowed first by rough surfaces of urban structures, which produce frictional resistance, and secondly by the ascending winds described above. These explain the slower incoming velocity of the sea breeze in this model.

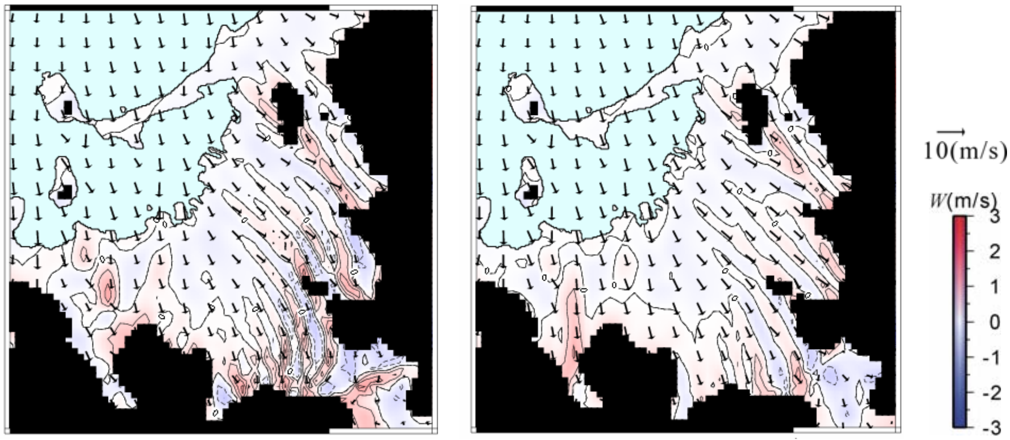
Table 1 Schematic of numerical simulation

Domain	1	2	3	4
Domain size (km)	931.5	310.5	103.5	34.5
Horizontal mesh size (km)	13.5	4.5	1.5	0.5
Number of mesh cell	69×69	69×69	69×69	69×69
Vertical levels	27			
Time step (s)	54	18	6	2
Land use data	2min	30s	100m	100m
Digital elevation data	2min	30s	50m	50m
	USGS		Geographical Survey Institute	



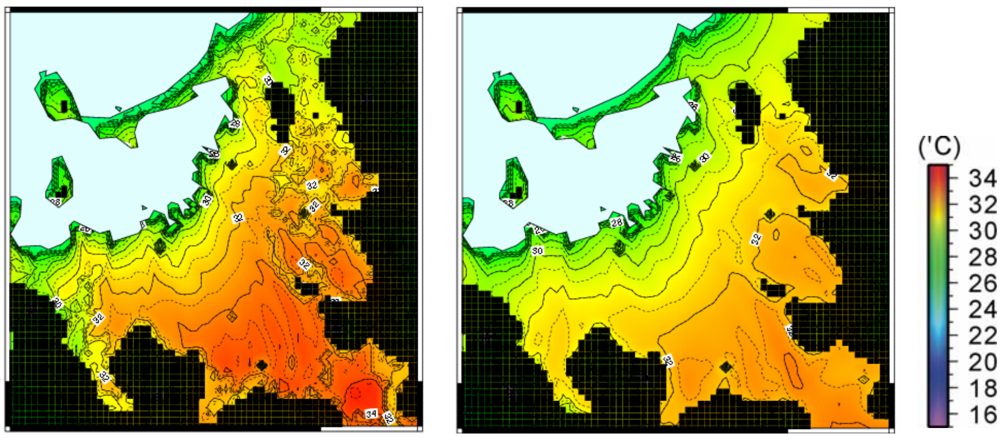
(a) The realistic model (b) The grassland model

Fig. 2 Land use of domain 4



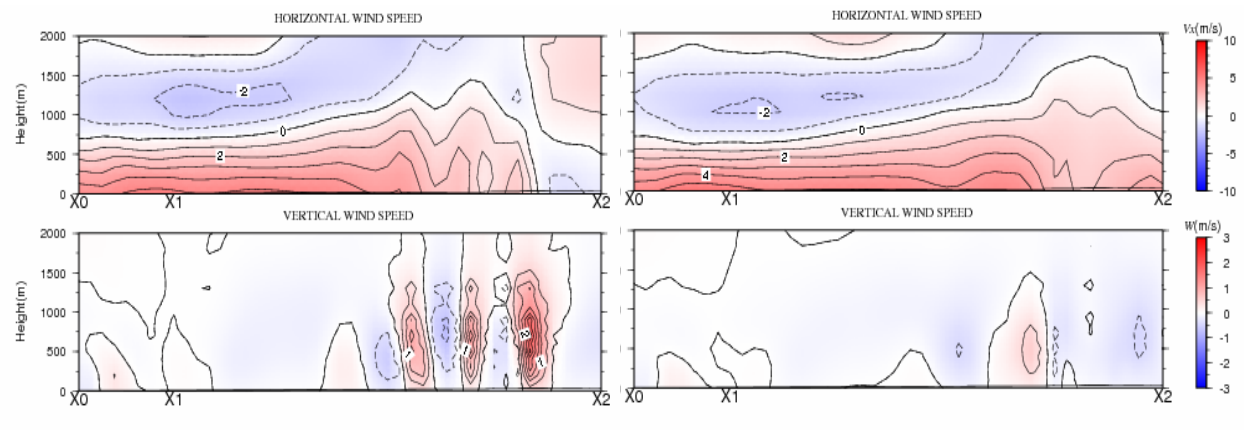
(a) The realistic model (b) The grassland model

Fig. 3 Distribution of wind velocity in domain 4 (12JST)



(a) The realistic model (b) The grassland model

Fig. 4 Distribution of temperature in domain 4 (12JST)



(a) The realistic model (b) The grassland model

Fig. 5 Wind velocities along X0-X2 line (12JST)

Figure 6 portrays the distance that the sea breeze traveled versus time along the X0–X2 line described above. The sea breeze arrives at point X1 at 0810 JST in the realistic model and at 0830 JST in the grassland model. However, it arrives at point X2 at 1310 JST in the realistic model and at 1150 JST in the grassland model. The earlier arrival of the sea breeze at point X2 in the realistic model might result from higher barometric gradient ascending winds produced at the urban area. That earlier arriving sea breeze, however, later becomes slowed by surface roughness and by ascending winds, as described above. According to the slopes of the two lines, the incoming velocity is estimated as 1.4 m/s for the realistic model and as 1.8 m/s for the grassland model.

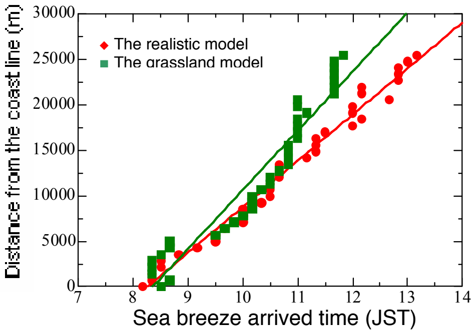


Fig. 6 Invasion speed of sea breeze

4. CONCLUSION

The analyses explained herein suggest that existence of a coastal urban area exerts strong influences on the characteristic of sea breeze generation and its flow into lands surrounding the urban area. A hot area generated at the coastal urban area might bring about a higher barometric gradient in early periods and thereby invite an intensive incoming velocity of the sea breeze. However, this does not work to moderate high temperatures of the innermost urban areas by incoming cool sea breezes. As described herein, the incoming sea breeze is slowed by the friction force of rough urban surfaces and by ascending winds.

References

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