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Dispersion of atmospheric aerosol at few thousands meter height in the presence of land and sea breeze-a numerical simulation

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1. Introduction

The transport of yellow sand originating from inland China across the national boundaries in East Asia is a well-known phenomenon. The dust particles in the atmosphere originate mainly from Taklamakan and Gobi Desert and are transported by atmospheric circulation. Yellow sand is often observed between February and May in Japan and approaches to Japanese islands in thousands of meters altitude. Numerical simulation play a role in the clarify of yellow sand transport process. However most of the researchers concern about the long-range effects of transport between Japan and China. It seems that no simulation has considered local weather on the descending process of the dust.

The land and sea breeze is one of the local weather phenomenon and occurs by the temperature difference between the land and sea surface in the afternoon and night. According to previous works, the thickness of the circulation layer reaches 1-2 km.

There is a possibility that yellow sand in few thousands of meters altitude falls by interference of land and sea breeze. The present work aims at investigating the deposition mechanism of yellow sand in few thousands of meters altitude by numerical simulation.

2. Numerical method

We use a two-dimensional primitive equations system and Mellor-Yamada model level 2.25 as turbulent closure model. The dispersion of aerosol is calculated by the advection-diffusion equation of the scalar concentration. Computed area and calculating conditions are shown schematically in Fig.1. Horizontal and vertical lengths of the computed area are 200 km and 3 km. Coordinates are taken such that x is mainstream direction and z is vertical direction, and the origin is the center of land surface. The land area is located in the center with 100km width, and sea area is in the both sides. The no-slip condition is used at the bottom. The temperature on the land surface is varied diurnally as a sine function around the constant sea temperature at 290K with amplitudes of $\Delta\theta$ [K]. Lateral boundaries are periodic. Line source of the scalar concentration is located at 1, 1.5, 2 and 2.5 km altitude. The atmospheric initial condition is windless state. Calculation starts at the daybreak (A.M 6:00), and Calculation period is two days. Calculating cases are shown in table 1. Brunt-Vaisala frequency N is calculated by equation (1) and is used as a parameter to indicate a magnitude of atmospheric stability. When N has a large value, the atmosphere is in a stable state. N and the amplitude of land temperature $\Delta\theta$ are varied as calculating

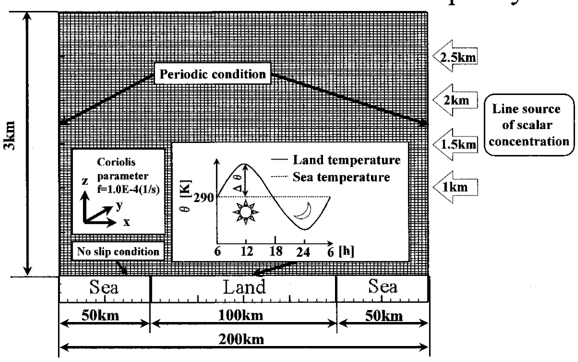

Fig.1 Schematic of computed area and calculating conditions

Table 1 Calculating cases

			$\Delta\theta$	
			10[K]	15[K]
more stable ↑	N	$0.0118[s^{-1}]$	Case A	Case C
less stable ↓		$0.0102[s^{-1}]$	Case B	Case D

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parameters to investigate the velocity field and the ground scalar concentration.

$$N = \sqrt{\frac{g}{\theta_{sea}} \frac{\partial \theta}{\partial z}} \quad (1)$$

θ_{sea} : Potential temperature of sea surface θ : Potential temperature g : Gravity acceleration

3. Result and discussion

Outline of the present calculating results are that sea breeze grows due to the increase of land surface temperature and becomes strongest at P.M 3:00. The sea breeze circulation ends at P.M 9:00 and the land breeze starts growing. The sea breeze circulation appears again at A.M 9:00. Similar results are obtained for all calculating cases. The streamlines of Case A and C at P.M 3:00 are shown in Fig.2 and 3. The circulation center of Case C is higher compared with that of Case A, and the penetrating length toward inland of Case C is larger compared with that of Case A. Horizontal velocity U of vertical distribution at P.M 3:00 at 9km from the coastline is shown in Fig.4. As N has a small value or $\Delta\theta$ is large, the sea breeze velocity and the thickness of the circulation layer become greater.

The scalar concentration contour line of Case C at P.M 3:00 is shown in Fig.5. Line source of scalar concentration is set at 1 km altitude. It was shown that the scalar concentration at 1 km altitude falls toward the ground by the return flow of sea breeze at upper layer. Time variations of the ground scalar concentration at 9 km from the coastline are shown in Fig.6 and 7. Line source of the scalar concentration is set at 1 and 1.5 km altitude respectively. The ground scalar concentration for the initial concentration at 1 km altitude is higher compared with that at 1.5 km altitude in early time. As N has a small value or $\Delta\theta$ is large, the ground scalar concentration becomes higher. It was shown that time variation of the ground scalar concentration is cyclic. On the other hand, the ground scalar concentrations of Case A and B after two-day calculation for the initial concentration at 1.5 km altitude are still low. It's because the land and sea breeze circulation layer thickness of Case A and B are lower than 1.5 km. All cases of the ground scalar concentration after two-day calculation for the initial concentration at 2 km and 2.5 km altitude are almost negligible.

4. Conclusion

As atmospheric stability increases or the amplitude of land temperature is large, the sea breeze velocity and the thickness of circulation layer become greater and the ground scalar concentration becomes higher.

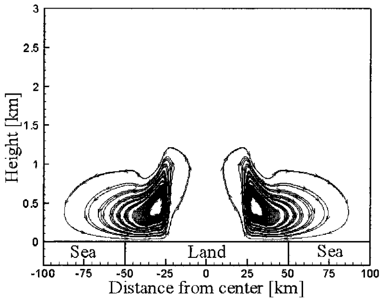

Fig.2 Stream line (Case A, P.M 3:00)

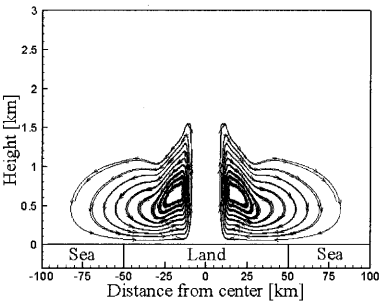

Fig.3 Stream line (Case C, P.M 3:00)

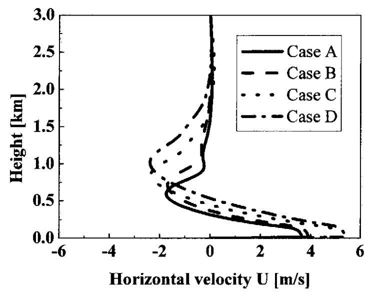

Fig.4 Horizontal velocity U at 9 km from the coastline (P.M 3:00)

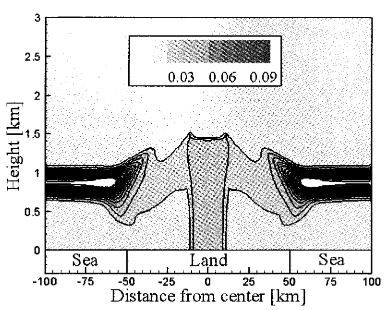

Fig.5 Contour line of scalar concentration (Initial concentration at 1 km altitude, Case C, P.M 3:00)

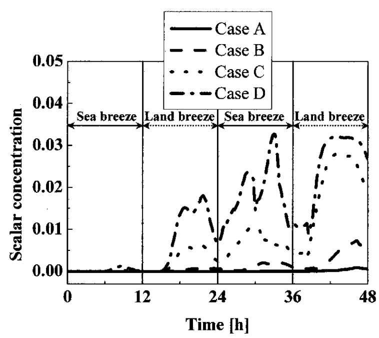

Fig.6 Ground scalar concentration at 9 km from the coastline (Initial concentration at 1 km altitude)

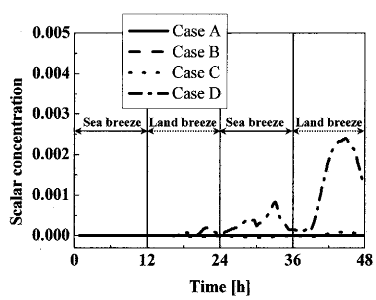

Fig.7 Ground scalar concentration at 9 km from the coastline (Initial concentration at 1.5 km altitude)