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Numerical Study on Trapped Mountain Waves and Their Effect on Aerosol Diffusion

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Abstract

Numerical modeling plays an important role in understanding the transport mechanism of aerosols such as Yellow Sand, for which many researchers have performed simulations for long-range transport from the Asian continent to Japan[1)]. There seem to be, however, no small-scale simulations that consider meteorological phenomena and topography in a range from several kilometers to several tens of kilometers. One example of such a small-scale meteorological phenomena is the mountain wave which occurs on the leeward side of a mountain when the atmosphere is stably stratified. Flows at high altitudes are drawn downward behind the mountain by mountain waves. Hence, there is a possibility that mountain waves affect the transport of aerosol by pulling it towards the ground. The main purpose of this study is to use numerical simulation to examine our hypothesis that mountain waves affect the deposition mechanism of aerosol.

Transient two-dimensional computations are performed using the commercial CFD software FLUENT. Under the Boussinesq approximation, the governing equations used were the continuity equation, the Navier-Stokes equation and a transport equation for the density disturbance[2)]. Turbulence is accounted for by using the k-ε turbulence model. In addition, there is a transport equation for a scalar concentration that is used to simulate the transport of aerosol. Figure 1 shows the computational domain and the boundary conditions. A bell-shaped mountain is set at ground level in the middle of the domain. The time step for the calculation is Δt = 1s. The Froude number, $Fr = U / Nh_0$, is employed as the atmospheric stability parameter, where U is the upstream uniform velocity, N is Brunt-Väisälä frequency and h_0 is the mountain height. To describe the atmosphere, we employ a two-layer model in which the density gradient changes at an altitude of 11 km.

Figures 2, 3, and 4 show the streamlines, the vertical velocity and the scalar concentration, respectively, for Fr = 0.5 at t = 5000 s. The release point of the scalar concentration is set at

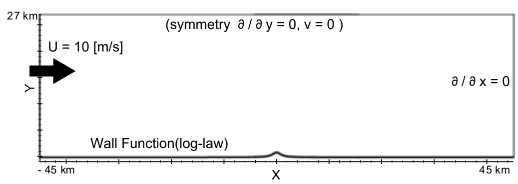

Figure 1 Calculation domain and boundary conditions

10 km upstream of the mountain and y = 1000 ~ 1200 m. Mountain waves propagate obliquely upward and reflect at the interface of the two layers, and then trapped mountain waves and rotors[1] are generated. The scalar concentration is transported along the downslope of the mountain. As *Fr* decreases, or in other words as the atmosphere becomes more stable, the scalar concentration contours behind the mountain are displaced downwards. Figure 5 shows the ground scalar concentration. The region with the high values corresponds to the rotor region and these concentrations increase as the atmosphere stabilizes. Therefore, there is a distinct possibility that aerosol at high altitudes may be pulled towards the ground and diffused at the rotor regions.

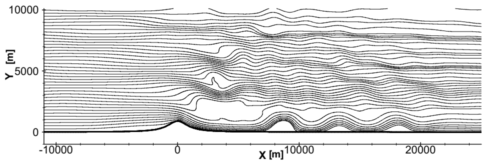

Figure 2 Streamlines for *Fr* = 0.5 at *t* = 5000 s

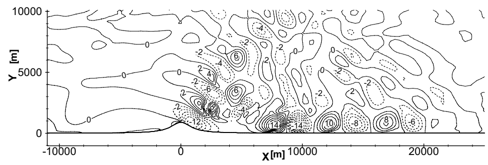

Figure 3 Vertical velocity for *Fr* = 0.5 at *t* = 5000 s

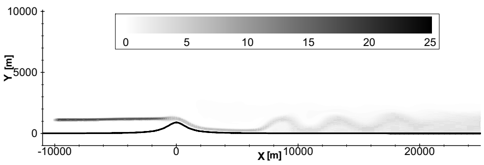

Figure 4 Scalar concentration for *Fr* = 0.5 at *t* = 5000 s

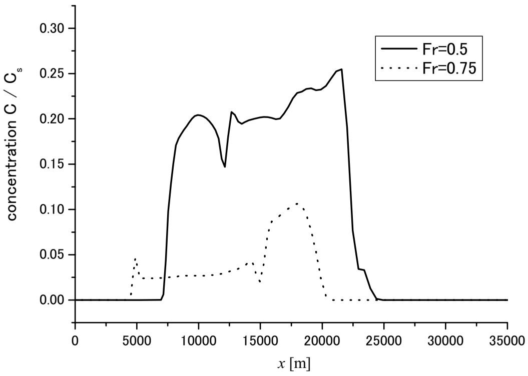

Figure 5 Ground scalar concentration for *Fr* = 0.5 and 0.75

References

1) I. Uno, H. Amano, S. Emori, K. Kinoshita, I. Matsui and N. Sugimoto, Trans-Pacific yellow sand transport observed in April 1998: A numerical simulation, *J. Geophy. Res.*, **106(D16)** (2001), 18,331-18,344.
2) Y. Utanohara, S. Kimura and T. Kiwata, Numerical study on Mountain Waves Generated by a Two-Dimensional Mountain and Their Effect on the Transport of Yellow Sand, *JSME Int. J.*, Ser. B, **49(3)** (2006), 576-582.
3) J. D. Doyle and D. R. Durran, Recent developments in the theory of atmospheric rotors, *Bull. Amer. Meteor. Soc.*, **85**(2004), 337-342.