A Varification of Propriety of the LCM and Application on the Atmospheric Circulation Over the Pusan Coastal Area

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1. Introduction

It is known that well designed numerical model is strongly required for the simulation of regional atmospheric circulation. The LCM, Local Circulation Model, has an ability of high resolution and is convenient for using and selection of the option.

Kimura (1986) investigated the formation of the Nocturnal Mesoscale Vortex in Kanto Plain in Japan using LCM. Kimura et al (1993) demonstrated the thermally induced wind system from Plain to Basin over a Mountain Range using LCM. Kuwagata et al (1997) simulated the daytime boundary layer evolution in a deep valley using LCM, too. Kang (1997), moreover, have contributed to the interpretation of Karman Vortex using LCM.

In this study, therefore, we would like to compare the results of the linear model with those of LCM using the simple topography for a verification of propriety of LCM and investigate Land/Sea Breeze around Pusan coastal area.

2. Numerical Model

LCM is based upon the three-dimensional Boussinesq equations which are written in a terrain-following coordinate system using the hydrostatic assumption. The model includes a turbulent closure model in the boundary layer and a prognostic equation for the surface temperature. The governing equations and numerical scheme of the model are the same as for the model development by Kikuchi et al. (1981) and modified by Kimura and Arakawa (1983).

Equation of Motion :

$$\frac{\partial hu}{\partial t} + \frac{\partial huu}{\partial x} + \frac{\partial huv}{\partial y} + \frac{\partial huw*}{\partial z*}$$

$$= -h\Theta\frac{\partial \Pi'}{\partial x} + h\frac{Z_T}{Z_T - Z_G}\frac{\partial Z_G}{\partial x}\frac{\partial \Pi'}{\partial z*} + \frac{\partial}{\partial x}(hK_H\frac{\partial u}{\partial x})$$

$$+ \frac{\partial}{\partial y}(hK_H\frac{\partial u}{\partial y}) + \frac{z_T^2}{h}\frac{\partial}{\partial z*}(K_v\frac{\partial u}{\partial z*})$$

$$\frac{\partial hv}{\partial t} + \frac{\partial hvu}{\partial x} + \frac{\partial hvv}{\partial y} + \frac{\partial hvw*}{\partial z*}$$

$$= -h\Theta\frac{\partial \Pi'}{\partial y} + h\frac{Z_T}{Z_T - Z_G}\frac{\partial Z_G}{\partial y}\frac{\partial \Pi'}{\partial z*} + \frac{\partial}{\partial x}(hK_H\frac{\partial v}{\partial x})$$

$$+ \frac{\partial}{\partial y}(hK_H\frac{\partial v}{\partial y}) + \frac{z_T^2}{h}\frac{\partial}{\partial z*}(K_v\frac{\partial v}{\partial z*})$$

Continuity equation :

$$\frac{\partial hu}{\partial x} + \frac{\partial hv}{\partial y} + \frac{\partial hw*}{\partial z*} = 0$$

Equation of Thermodynamics :

$$\frac{\partial h\theta'}{\partial t} + \frac{\partial h\theta' u}{\partial x} + \frac{\partial h\theta' v}{\partial y} + \frac{\partial h\theta' w*}{\partial z*}$$

$$= \frac{\partial}{\partial x}(hK_H\frac{\partial \theta'}{\partial x}) + \frac{\partial}{\partial y}(hK_H\frac{\partial \theta'}{\partial y}) + \frac{z_T^2}{h}\frac{\partial}{\partial z*}(K_v\frac{\partial \theta'}{\partial x})$$

Hydrostatic assumption :

$$\frac{\partial \Pi'}{\partial z*} = \frac{h}{z_T}\frac{g\theta'}{\Theta^2}$$

Here, $z*$ is the terrain-following vertical coordinate defined as

$$z* = z_T\frac{z - z_G}{h} \quad , \quad h = z_T - z_G$$

3. Result

The simulation result, vertical velocity(w), of LCM on the simple topography was compared with exact solution of a linear model for a verification of accuracy. From the comparison between the result of LCM and an exact solution, they have almost the same values. therefore, numerical simulation of the land/sea breeze circulation using LCM gave to us a reliance. It was described that the sea breeze at the daytime and land breeze at the nighttime were well developed over the Pusan coastal area.

In case of previous ordinary land/sea breeze model, when the horizontal grid interval reduced to 1 km, the result of calculation used to be unstable. but that of LCM was stable. the study, therefore, using LCM can be provide more accurate description of regional circulation and results for the prediction of dispersion problem around complex terrain area.

4. Reference

Kang, S. D., 1997 : A Numerical Study on the Mesoscale Disturbance in the Lee of an Isolated Mountain, Ph. D. dissertation., Tsukuba University

Kikuchi, Y., S. Arakawa, F. Kimura, K. Shirasaki, and Y. Nagano, 1981 : Numerical Study on the Effects of on the Land and Sea Breeze Circulation in the Kanto District. J. Meteor. Soc. Japan, 59, 723-738

Kimura, F., 1986 : Formation Mechanism of the Nocturnal Mesoscale Vortex in Kanto Plain. J. Meteor. Soc. Japan, 64, 857-869

Kimura, F., and S. Arakawa, 1983 : A Numerical Experiment of the Nocturnal Low level Jet over the Kanto Plain. J. Meteor. Soc. Japan, 61, 846-861

Kimura, F., and T. Kuwagata, 1993 : Thermally Induced Wind Passing from Plain to Basin over a Mountain range. J. Appl. Meteor., 32, 1538-1547

Kuwagata, T., and F. Kimura, 1997 : Daytime Boundary Layer Evolution in a Deep Valley. Part II : Numerical Simulation of the Cross-Valley Circulation. J. Appl. Meteor., 36, 883-895