Implementation of a non-local like PBL scheme in JMANHM

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The JMA non-hydrostatic model(JMANHM) is a community model which has been developed for use of both operational prediction and research. JMANHM is known to have several problems in the surface properties such as temperature and humidity:

Problem 1 The cold bias at the surface in case of the unstable conditions.

Problem 2 The wet bias at the surface.

The causes of the problems are the following points:

Cause 1 Too much the surface latent heat flux.

Cause 2 Too small the eddy diffusion coefficients.

The more the surface latent heat flux exists, the more surface cooling occurs. That is why the cold bias at the surface existed. Furthermore, because of the small turbulent mixing with the small eddy diffusion coefficients, the water vapor in the lower model level is accumulated too much. That is why the wet bias at the surface existed.

Kumagai[1] removed the Cause 1 and solved the Problem 1 by modifying the land surface processes, while the Problem 2 remained. To remove the Cause 2 and solve the Problem 2, the following modifications have been made.

1) Non-local like PBL scheme

The turbulent closure of JMANHM is 1.5-order TKE-based closure, and the eddy diffusion coefficients K_m, K_h are calculated as follows:

$$\frac{\partial E}{\partial t} = -ADV.E - \frac{gK_h}{\theta G^{\frac{1}{2}}}\frac{\partial \theta_l}{\partial z^*} - \sum_{i,j}\overline{u_i' u_j'}\frac{\partial u_i}{\partial x_j} - \frac{C_e E^{\frac{3}{2}}}{l} + DIF.E \ , \tag{1}$$

$$\overline{u_i' u_j'} = -K_m\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) + \frac{2}{3}\delta_{ij}E \ , \tag{2}$$

$$K_m = C_m l E^{\frac{1}{2}} \ , \qquad K_h = \frac{1}{Pr}K_m \ , \tag{3}$$

$$l_\infty = \begin{cases} \Delta s & N^2 \leqq 0 \\ \min(\Delta s, 0.76\frac{E^{\frac{1}{2}}}{N}) & N^2 > 0 \end{cases} \ , \tag{4}$$

$$\frac{1}{l} = \frac{1}{k(z - z_s)} + \frac{1}{l_\infty} \ . \tag{5}$$

Here Δs is the grid scale. Obviously, the eddy diffusion coefficients K_m, K_h in Eq. (3) are strongly dependent on the mixing length l.

The mixing length l is regarded as the maximum scale of turbulence. So, at most the grid scale turbulence are considered by using Eq. (4). Furthermore, the mixing length l is restricted to the product of Kármán constant k and the height $(z - z_s)$ by using Eq. (5). But, in a convective boundary layer, large eddies which have the scale of the PBL height exist and the atmosphere is mixed by these large eddies. To include the effect of the large eddies, a non-local like PBL scheme has been implemented into JMANHM following Sun and Chang[2]. The mixing length l below the PBL top is decided by using the PBL height h_{PBL} as follows:

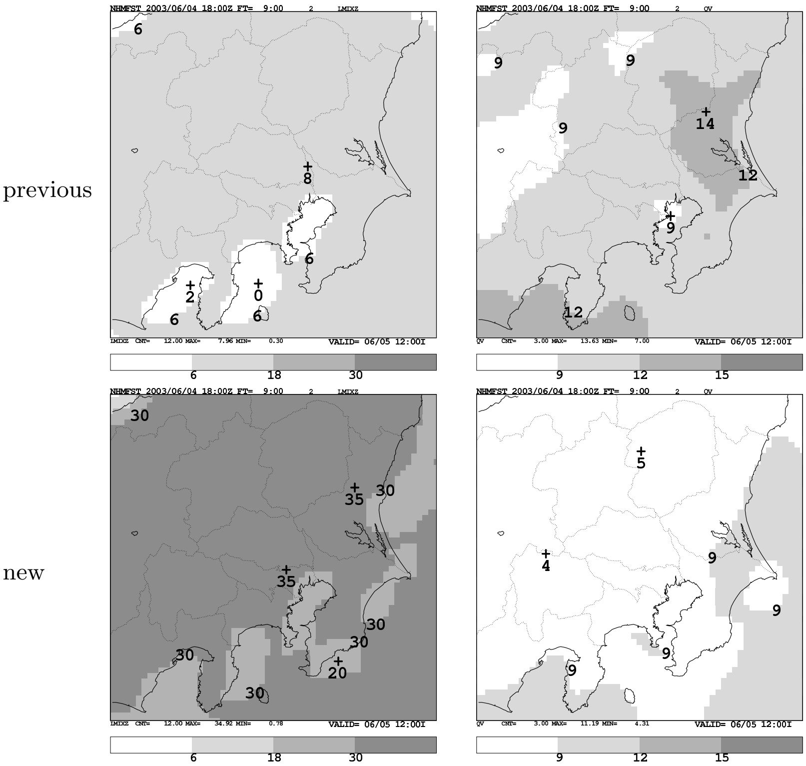
$$l = 0.25\left[1.8h_{\mathrm{PBL}}\left\{1 - \exp\left(-4\frac{z - z_s}{h_{\mathrm{PBL}}}\right) - 0.0003\exp\left(8\frac{z - z_s}{h_{\mathrm{PBL}}}\right)\right\}\right] \ . \tag{6}$$

By using Eq. (6) instead of Eqs. (4) and (5) below the PBL top, the mixing length l becomes larger. This leads to the increase of the eddy diffusion coefficients K_m, K_h through Eq. (3).

2) Anisotropy of turbulence

When the grid aspect ratio $\Delta x/\Delta z$ is much larger than the order of unity, the turbulence can not be isotropic. Since the mixing length l is regarded as the maximum scale of turbulence, the mixing length has to be different values for the horizontal and vertical directions. So, an option for anisotropy of turbulence has been added to JMANHM. If this option is selected, the mixing length of the horizontal direction is set to be equal to the horizontal grid size.

Figure 1 shows the comparison between the previous PBL scheme and the new one at 03 UTC (noon) June 5, 2003. The initial time of this experiment is 18 UTC June 4, 2003. By using the new PBL scheme, the mixing length at the lowest level is increased, and the mixing ratio of the water vapor at the lowest level is decreased. Figure 2 shows the time sequence of the temperature and dew-point temperature at 1.5 [m] at Kumagaya. As shown in Figure 2, the Problem 2 is also solved.



Mixing length at the lowest level [m]

Mixing ratio of the water vapor at the lowest level [g/kg]

Figure 1: The spatial distributions of the mixing length at the lowest level and the mixing ratio of the water vapor at the lowest level over the Kanto region at 03 UTC June 5, 2003.

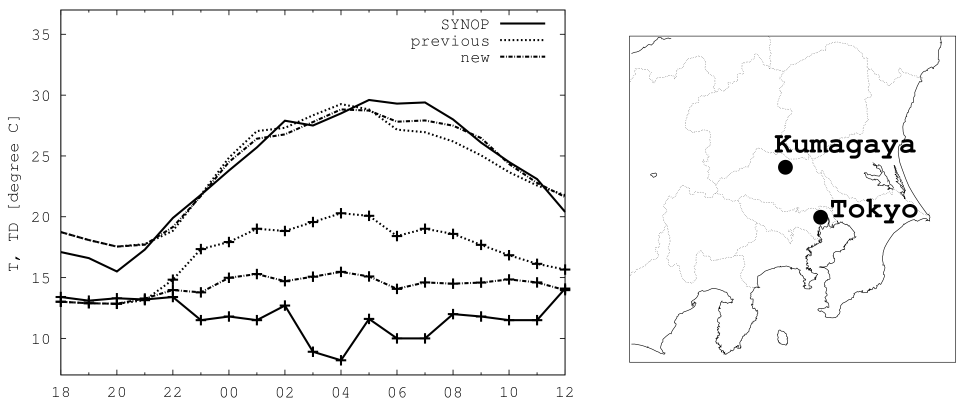


Figure 2: The time sequence of the temperature and dew-point temperature at 1.5 [m] at Kumagaya. The lines and lines with cross dots represent the temperature and dew-point temperature, respectively.

References

[1] Kumagai, Y., 2004 : "Improvement of the land surface processes in JMANHM", *CAS/JSC WGNE Research Activities in Atomospheric and Oceanic Modelling*, submitted.

[2] Sun, W. Y. and C. Z. Chang, 1986 : "Diffusion model for a convective layer. Part I: Numerical simulation of convective boundary layer", *J. Climate Appl. Meteor.*, **25**, 1445 - 1453.