5.8 IMPROVEMENT ON THE PARAMETERIZATION FOR ATMOSPHERIC BOUNDARY LAYERS IN THE JMA GLOBAL NWP MODEL

Hiroto Kitagawa *
Japan Meteorological Agency, Tokyo, Japan

1. INTRODUCTION

Atmospheric boundary layer (ABL) plays an important role in connecting the earth's atmosphere with the surfaces, and its representation is of large interest to the numerical weather prediction (NWP). Nevertheless, it is widely recognized that ABLs are not easy to be reproduced correctly in NWP model due to their large variations.

The Japan Meteorological Agency (JMA) global NWP model employs a first order turbulence closure scheme to handle effects of atmospheric turbulence. In the scheme vertical diffusivities both within and above ABL are determined in terms of the local Richardson number (hereafter, called "local scheme"). Such a local diffusion scheme, however, cannot treat explicitly "non-local mixings" due to large eddies driven in unstably stratified atmosphere. In order to avoid too weak mixing in unstable conditions, the current turbulence scheme in the JMA model limits a diffusion coefficient by a certain lower bounding value within ABLs regardless of their stratifications.

2. NON-LOCAL MIXING

In many NWP models, a so-called non-local approach has been often adopted to represent unstable ABLs. Application of a non-local diffusion scheme to the JMA global NWP model is examined on purpose to improve turbulent mixings under unstable condition. The non-local scheme introduced to the model is based on Lock et al. (2000). It includes not only representation of non-local mixings excited near the surface but also parameterizations for non-local mixings driven by a cloud-top radiative cooling and entrainment fluxes at the top of ABL.

Under unstable conditions, a non-local mixing may efficiently transport heat and moisture upward and make structures of ABL more vertically homogeneous. Fig.1 shows total cloudiness simulated by using the current local scheme and the non-local scheme, respectively, with the observation obtained from the ISCCP dataset (Rossow and Schiffer 1991). The non-local mixings transport more moisture upward compared to those by the local scheme within well-mixed ABLs. As a consequence of that, more low-level clouds form mainly in mid and high latitudes in the simulation using the non-local scheme.

Over ocean, ABL has a crucial role that transports large amount of moisture from the ocean surface to cumulus clouds existing above ABLs. Fig.2 shows total precipitation rates simulated by the local and non-local schemes respectively, with the observation from the CMAP database (Xie and Arkin 1997). The non-local scheme enhances precipitations over the convective region through an abundant supply of moisture to cumuli. However, precipitations with the non-local scheme are produced rather too much than the observation, e.g., over the Atlantic ITCZ.

3. MIXING IN STABLE ABL

3.1 *GABLS experiment*

As described in a previous section, non-local mixings may transport heat and moisture more efficiently within unstable ABLs. In a single-column model intercomparison experiment of the GEWEX Atmospheric boundary layer study (GABLS), however, the 1-dimensional version of JMA ABL scheme shows too strong turbulent mixing (Fig.3) for the stably stratified ABL case, which was derived from the large eddy simulation (LES) study presented by Kosovic and Curry (2000). The experiment also suggested that the excessive mixing in a stable condition mainly come from too large minimum value for diffusivity, which is introduced to complement insufficient mixing in unstable ABLs, and an overestimation of mixing lengths under stable situations.

According to the result of 1-dimensional simulation, the following modifications are tested; 1) a minimum for diffusivity is removed and 2) an asymptotic mixing length is reduced from 50m to 10m in stable conditions. These modifications may decrease mixing efficiency in the stable ABL and give a better simulation of ABL structure in the comparison with LES results (not shown).

* *Corresponding author address:* Hiroto Kitagawa, Japan Meteorological Agency, Numerical Prediction Div., 1-3-4, Ote-machi, Chiyoda-ku, Tokyo 100-8122, Japan; e-mail: kitagawa@naps.kishou.go.jp

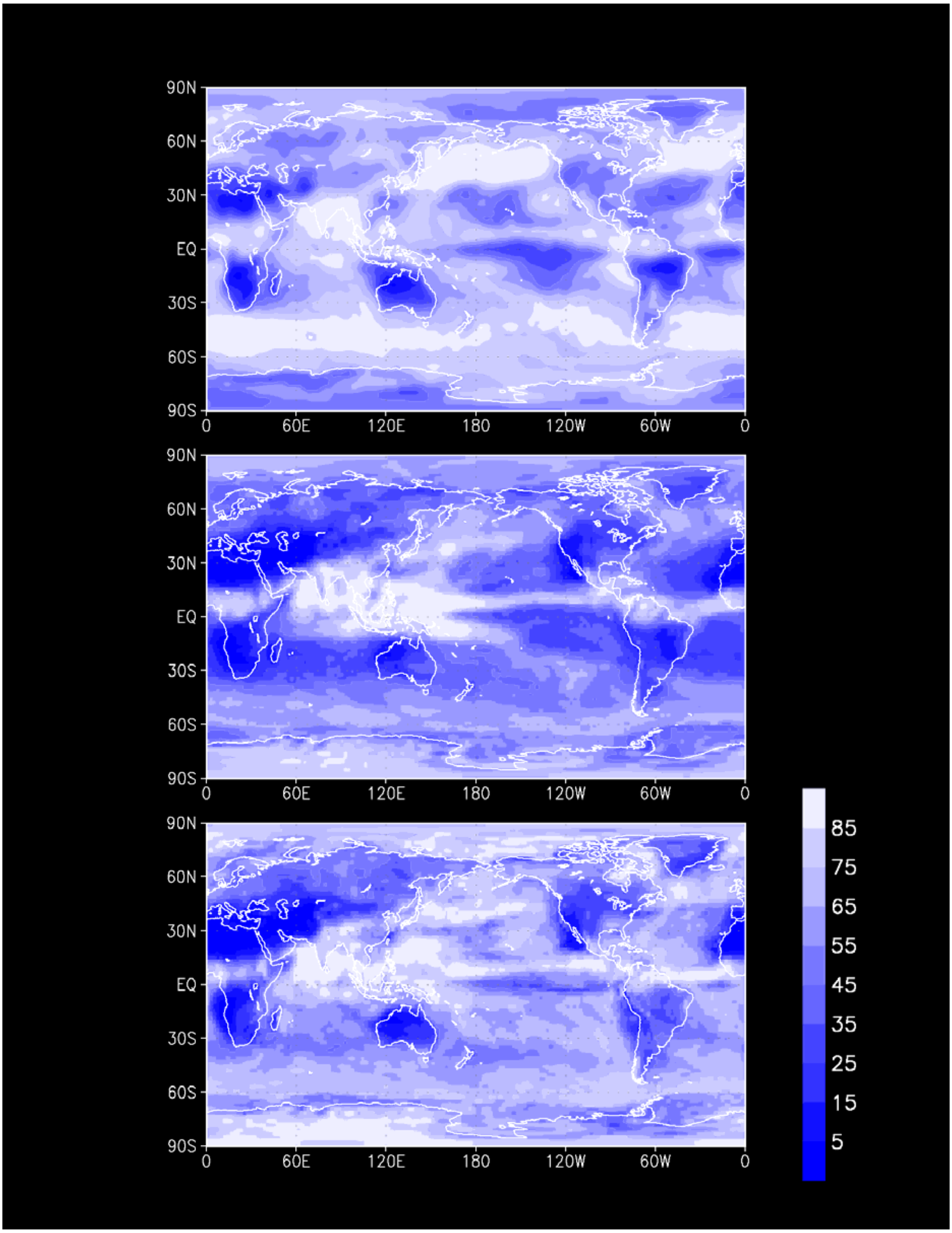

Fig.1 Monthly mean total cloudiness derived from the satellite observation and simulated by the models, for July 1988. Top: observation (ISCCP). Middle: simulation using the local ABL scheme. Bottom: simulation using the non-local scheme. Unit is in %.

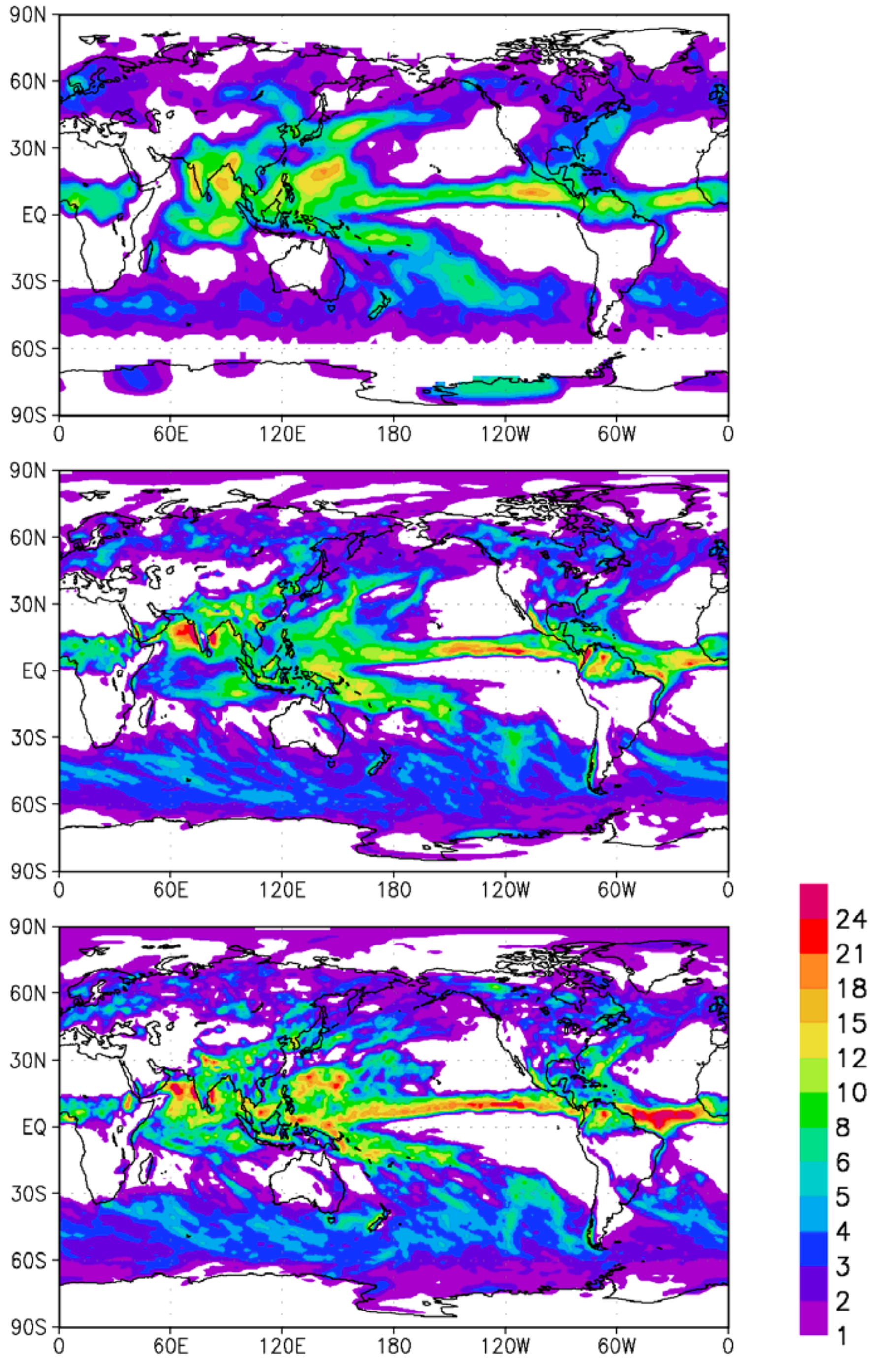

Fig.2 Monthly mean total precipitation rate derived from the observational dataset and simulated by the models, for July 1988. Top: observation (CMAP). Middle: simulation using the local ABL scheme. Bottom: simulation using the non-local scheme. Unit is in mm/day.

3.2 *Diurnal Cycles*

Fig.4 shows comparisons of diurnal variations of surface air temperature, humidity and wind speed between the observations and the model simulations over the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site. Observations are derived from the GEWEX Coordinated Enhanced Observing Period (CEOP) data archive, and both the observed and simulated values are averaged over 7 ARM/SGP stations (E4, E7, E8, E9, E15, E20, E25), respectively.

The non-local scheme produces more efficient mixing between near-surface and upper ABL air and represents relatively stronger daytime surface winds compared to those by the local mixing scheme. The impact of the non-local scheme on diurnal cycles simulation of the surface temperature shows similar characteristics and less extent to that of surface winds. On the humidity, the non-local scheme transports large amount of moisture upward and builds too dry surface layers. The modification to mixings in stable situations based on the GABLS experiment may reduce dry bias of surface layer in the nighttime and suppress nocturnal strong winds.

4. CONCLUSIONS

The current ABL scheme used in the JMA global NWP model cannot express any non-local mixings under unstable conditions. A lower bounding limit, therefore, is set to a diffusivity to avoid too weak mixing within ABLs. It came obvious from the GABLS experiment that the lower boundary of diffusivity may lead to significant over-mixing in the stable ABL case. Introductions of the non-local scheme and the modification to stable mixings bring improvements on the representation of ABL structure and moisture field and modify the simulations of diurnal cycles of surface layers.

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6. REFERENCES

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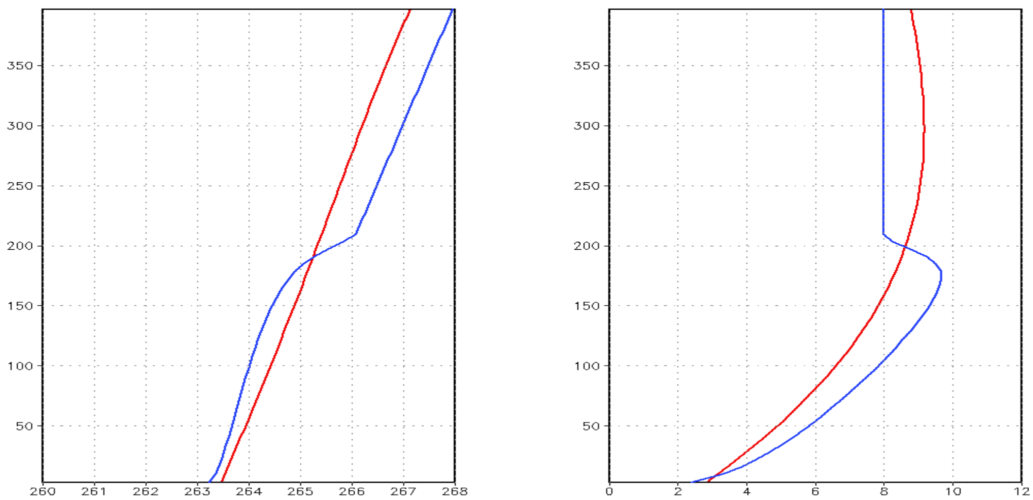

Fig.3 Simulations of the stably stratified ABL, same case as in the GABLS single-column model experiment. Vertical profiles of left) potential temperature (K) and right) wind speed (m/s) are shown. Red and blue lines denote results of the current and modified schemes, respectively.

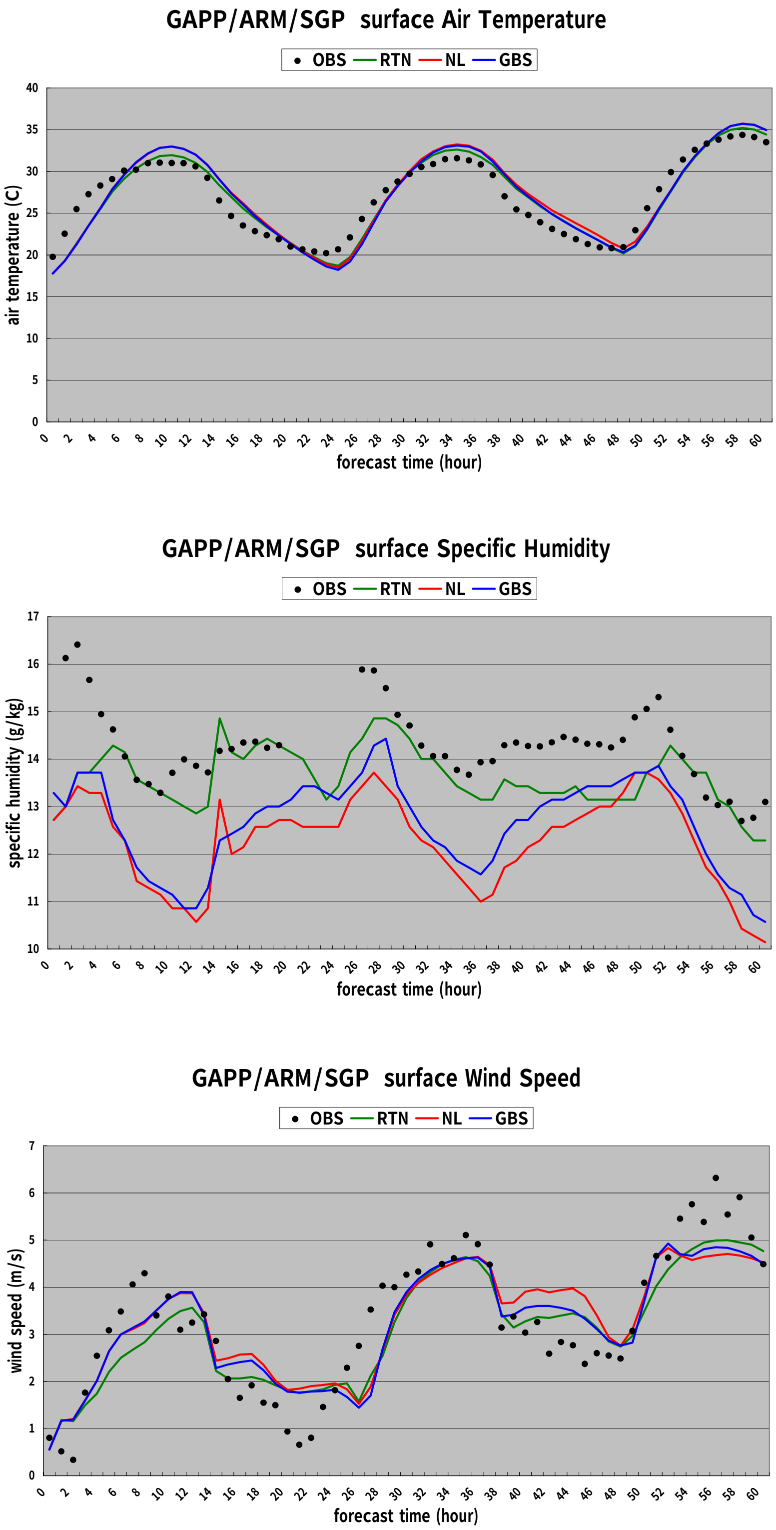

Fig.4 Diurnal variations of surface air temperature (K), humidity (g/kg) and wind speed (m/s) over the ARM SGP site, for the period from July 1, 00UTC to July 3, 12UTC, 2001. Black points denote hourly observations, and green, red and blue lines the simulations using the local, non-local and modified non-local schemes, respectively.