Interaction between stable boundary-layer and precipitation processes in atmospheric models

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1. Introduction

The Yonsei University (YSU) vertical diffusion package (Hong et al. 2006, hereafter HND06), which is a revised vertical diffusion package over the medium-range forecast (MRF) BL (Hong and Pan 1996) has been extensively applied to weather prediction and climate studies since its addition to the Weather Research and Forecasting model (WRF; Skamarock et al. 2008). It is reported that the YSU BL scheme produces a too-low nocturnal BL height over the continental valley in New Mexico (F. Zhang 2006, personal communication), in that the observed PBL height is as high as 500 m in observations, whereas the corresponding values from the YSU scheme stays at the height of the lowest model level. We presume that these behaviors are regarded to be mainly due to a deficiency in SBL mixing in the version of the YSUBPL, as of July 2007. In the HND06 algorithm, the local K profile method whose vertical mixing is determined by a local stability at a given level is applied to all the model levels above the mixed layer.

For the above reasons, we designed a revised SBL mixing in the WRF model. The new SBL scheme, based on the bulk Richardson number between the surface layer and the top of the boundary layer and implemented in the Yonsei University (YSU) boundary layer scheme, was evaluated against the local scheme in which the mixing coefficient is a function of the local Richardson number at a given model level. The role of SBL mixing on the monsoonal circulations over East Asia is investigated. A short-range simulation for one month is designed to investigate the immediate effect of the SBL mixing on the PBL structure. The interaction between the SBL mixing and precipitation processes embedded within the large-scale circulations is examined in a regional climate testbed for July 2006. This was a major summer monsoonal precipitation period in Korea and Japan. The 10-yr June-August (JJA) simulations from 1999-2008 are designed to evaluate the revised SBL processes for the simulated

monsoonal circulations over East Asia. Interaction between the boundary-layer mixing and the gravity wave drag will also be investigated.

2. The revised SBL parameterization

In the revised SBL parameterization, we keep the K-profile method as in the case of unstable situations. It is not only due to its computational efficiency, but also there is a general support for the use of K-profile similarity in parameterizations of SBL.

The major differences between the HND06 and revised SBL schemes includes i) the computation of PBL h using the bulk Ri greater than 0, and ii) the parabolic profile of the eddy diffusivity coefficients with heights. It is not deterministic whether the magnitude of the coefficients in the revised scheme is systematically larger than that in the HND06 since the definition is different. However, it is expected that h in the revised scheme is always greater than that from the HND06. It is noted that the revised scheme takes the mechanical mixing into account when winds are strong by reducing the computed local Ri , even if the surface buoyancy flux is negative.

3. Conclusions

A statistical evaluation of a series of short-range forecast confirms that the boundary layer structure is closer to the radiosonde observation when the new SBL scheme is used. In a regional climate framework, the results with the new SBL scheme in July 2006 demonstrate that modulating the subcloud structure with enhanced vertical mixing improves the simulated monsoon climatology by displacing the monsoonal precipitation southward. Together with the local effects of the enhanced SBL mixing that warms and dries the boundary layer, the dynamical feedbacks accompanying strengthened moisture convergence results in enhanced precipitation toward what was observed. A ten-member ensemble of three-month June-July-August (JJA) simulations for 1999-2008 exhibits that the revised SBL scheme improves the temperature and moisture profiles in the lower troposphere as well as the precipitation climatology. The interannual variation of seasonal precipitation is more realistic over both land and oceans. It was also found that the gravity wave drag induced by orography is very sensitive to the boundary layer structure when stable.

4. References: will be provided by the author at the request.