DEVELOPMENT AND TESTING OF A NEW ATMOSPHERIC BOUNDARY LAYER (ABL) SCHEME IN WRF

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Although the advent of high-performance parallel computing technology has made it easy for operational environmental prediction models to be run with finer and finer resolutions to meet the increased demand on detailed predictions, the parameterizations of the atmospheric boundary layer (ABL) in these models are still those designed and tuned for the models running with coarser resolutions. It will remain expensive in the next decade to explicitly simulate turbulent mixing and transport of momentum and enthalpy in operational models. In other words, turbulent processes within the ABL will have to be implicitly modeled in operational models through parameterization schemes. Due to the nature of parameterizing the complex, intertwined energy cascading and transfer occurring within the ABL, assumptions are needed to make the parameterization schemes mathematically close. Different assumptions lead to different parameterization schemes. Each assumption has an intrinsic limitation on its applicability for fine vertical and horizontal resolutions.

In this project, we intend to develop a new WRF ABL parameterization suitable for fine resolution modeling. This parameterization is based on the two-equation turbulence closure that involves two prognostic equations respectively for TKE and the master length scale. The use of the two-equation closure is motivated by the following physical consideration. The minimum description of turbulence requires two quantities for ABL modeling on fine scales in a mesoscale model: 1. the intensity of turbulence indicated by the kinetic energy of the turbulence fluctuations (i.e., TKE), and 2. the scale around which this energy is concentrated, represented by the peak in the turbulence spectrum (i.e., the master length scale). If one accepts this minimum-description approach as a currently available method that is feasible in mesoscale models, it is natural to ask what its strengths and weakness are, and how one can remedy the latter. In this sense, the question of the master length scale and how to model it properly have long been controversial, and still remain as outstanding issues in using a minimum-description approach in mesoscale models.

Recently, Kantha (2002) has demonstrated that several mainstream methods suggested and used in the past are equivalent, and the inconsistencies in the use of these methods arise from improper modeling of the diffusion term in the master length scale equation. Therefore, a general length scale equation that is devoid of the inconsistencies has been developed. Closure constants suitable for fine scale ABL modeling in mesoscale models have been derived. Therefore, it is our belief that the use of this new master length scale equation will be worthwhile in mesoscale models.

When implementing this new ABL parameterization in WRF, we will use the updated values for the second moment closure that occur in the stability functions of momentum and temperature so that hopefully some of the deficiencies in the surface flux calculation in the current ETA ABL scheme will be overcome. These deficiencies are rooted in the closure values suggested originally in Mellor and Yamada (1982), as pointed out by Cheng et al. (2002).

Currently, this new ABL parameterization has been fully tested in 1D mode, and is being calibrated with the observations available at ETL. Shortly, it will be implemented in MM5 to compare with four parameterization schemes for the ABL used in MM5: the Blackadar, the MRF, the ETA, and the Gayno-Seaman schemes. The reason for us to conduct this comparison study using MM5 is that we have a few case studies using MM5 that are very suitable for evaluating the performance of the new ABL parameterization. Moreover, the four schemes in MM5 were developed at different times, perhaps with different targeted applications in the developer's mind. Nowadays, they are not only widely used among MM5 users for various applications, from regional climate simulations, realtime weather forecasts, to air-quality predictions, but they also are representative of the ABL parameterization schemes commonly used in current major climate, weather and air-quality models. As a matter of fact, both the MRF and ETA schemes have been implemented in the WRF model. This comparison study is expected be accomplished by the end of 2002.

Starting at the beginning of 2003, after the performance of the new ABL parameterization in MM5 is fully evaluated, we will implement it into WRF. By implementing this new ABL parameterization into WRF, the WRF community will be able to have one more choice for ABL parameterization, one that takes into account the dynamical consistence of the three basic attributes of the ABL parameterization: the prediction of day-time ABL height, the surface flux forcing, and the vertical mixing.