Comment on "Spatial Switching between First-Order Closure Schemes in a Numerical Mesoscale Model"

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Pitts and Lyons (1987, henceforth PL) have evaluated the use of an optional procedure involved with the computation of boundary layer depth (as suggested originally by McNider and Pielke, 1981) during transitional periods between stable to convective boundary layers. In view of the evaluation by PL, the following comments are made in order to provide a general assessment of the applicability of the parameterization scheme during boundary layer transition.

1) The computation of a PBL height is required under stable conditions for continuity of computations in situations in which the domain includes grids which elsewhere have a convective PBL, or when a stable PBL is changed to a convective PBL, such as following sunrise. The convective PBL, capped by a temperature inversion, is nearly neutral above the superadiabatic surface layer and can easily be scaled as to its depth. The stable PBL depth, however, is not so straightforwardly computed because both longwave radiational cooling and mechanical turbulent mixing in a thermodynamically stable atmosphere determine its depth. Under steady conditions in which mechanically generated turbulence dominates, its depth, h, can be approximated at $\sim 0.3u_*/f$.

In most stable PBL cases associated with nocturnal surface inversions, u_* is relatively small, and therefore the corresponding PBL depth, h, is usually several hundred meters or less. During the unsteady period involved with the transition from a stable PBL to an unstable PBL, such as in the morning, the formulation for the surface layer based on similarity theory and the Deardorff (1974) formulation of convective PBL development as used in McNider and Pielke (1981) are conceptually inappropriate, and thus are providing at best only a general approximation during that period. An optional procedure for the computation of the PBL is described in PL. However, regardless of the poor approximation during the transition period, after the transition period the subsequent development of the mesoscale fields is little affected by the precise form of the boundary layer depth equation during the transition, as found also by PL.

2) Running the model while switching off thermal forcing (i.e., skipping the solution of the surface heat balance, for the surface temperature, T_s) is usually used over complex terrain in order to obtain a dynamic balance of the potential temperature and flow fields. This is required since the single synoptic profile of wind and temperature used as the initial condition in the model obviously represents only the site of the observation. Thus the dynamic initialization leads to spatially dependent flow and temperature fields which are then used as the initial conditions for the thermal forced circulations which subsequently develop when the surface heat balance is invoked.

In PL, in which a flat terrain and a horizontally uniform potential temperature field are assumed, there is no conceptual need for the dynamic initialization period. This situation is unlike that reported in Mizzi and Pielke (1984) in which the dynamic initialization is required because of the presence of irregular terrain.

In some recent simulations, we have activated the surface heat balance during the dynamic initialization. This provides more realistic initial conditions for the simulated period of interest. For example, such a procedure allows nocturnal drainage flows to be at least partially developed for a simulation over complex terrain beginning at sunrise.

3) Assuming $f = 10^{-4}$, $u_* \approx 0.2$ m s^{-1} in the PL application, the initial stable PBL is $h = 0.3u_*/f = 600$ m. This value should not change substantially during the integration to steady state. As indicated by the PL results, they obtained $h = 1600$ m by the end of the integration period. The PBL height change was caused, apparently, by deriving w_s (the synoptic-scale vertical motion needed to force the initially selected h to remain unchanged under the initial environmental conditions) according to the Deardorff PBL formulation, which leads to $w_s > 0$. Maintaining the value of h at its initial

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magnitude requires a determination of w_s based on the Smeda formulation when the PBL is stably stratified.

4) In the specific case of PL, their interest is in the morning transitional period. The procedure which should be adopted initially is that $h \rightarrow 0$ as long as $\theta_* > 0$ (i.e., a stable surface layer), with the Deardorff formulation used when θ_* becomes $\leqslant 0$.

We have recently experimented with a relaxation procedure for the boundary layer height under stable conditions in place of the Smeda (1979) formulation, i.e.

$$\frac{dh}{dt} = \begin{cases} -\dfrac{(h-\hat{h})}{\tau} & \theta^* > 0 \\ \text{Deardorff}\,(1974) & \theta^* \leqslant 0. \end{cases}$$

The relaxation time scale τ should be considerably shorter than the nocturnal period; perhaps a few hours is appropriate. Strictly speaking, $\hat{h} = 0$ when $\theta^* > 0$ as implied by the previous discussion, but this may produce numerical noise due to the imposition of a sharp gradient. We have used $\hat{h} = 200$ m, which approximates the lowest convective boundary layer height considered by Deardorff (1974).

5) The PBL depth evaluations in the model code during the morning transition period or along coastal areas should be modified in some cases according to the objective of the specific study as, for example, performed in Segal et al. (1985), or as applied by PL. In recent years a turbulence kinetic energy equation was introduced to the model code in order to specify the eddy exchange coefficients (Arritt, 1985). Using this approach eliminates possible continuity discrepancies during PBL stratification switching. The implementation of an integral closure technique for the convective boundary layer (e.g., Stull, 1984; Fiedler and Moeng, 1985) would need to address the switching problem, as such methods must be altered for the stably stratified case.

REFERENCES

Arritt, R. W., 1985: Numerical investigations of thermally and mechanically forced circulations over complex terrain. Ph.D. dissertation, Colorado State University, 201 pp.

Deardorff, J. W., 1974: "Three-dimensional study of the height and mean structure of the planetary boundary layer." *Bound.-Lay. Meteor.*, **7**, 81–106.

Fiedler, B. H., and C.-H. Moeng, 1985: A practical integral closure model for mean vertical transport of a scalar in a convective boundary layer. *J. Atmos. Sci.*, **42**, 359–363.

McNider, R. T., and R. A. Pielke, 1981: Diurnal boundary layer development over sloping terrain. *J. Atmos. Sci.*, **38**, 2198–2212.

Mizzi, A. P., and R. A. Pielke, 1984: A numerical study of the mesoscale atmospheric circulation observed during coastal upwelling event on 23 August 1972. Part I: Sensitivity studies. *Mon. Wea. Rev.*, **112**, 76–90.

Pitts, R. O., and T. J. Lyons, 1987: Spatial switching between first-order closure schemes in a numerical mesoscale model. *Mon. Wea. Rev.*, **115**, 3188–3199.

Segal, M. R., R. T. McNider and R. A. Pielke, 1985: Use of a mesoscale primitive equation model in the design of 1985 South Central Coast Cooperative Aerometric Monitoring Program (California). ASTER Report #1/85, ASTER Inc., Fort Collins, CO, 76 pp.

Smeda, M. S., 1979: Incorporation of planetary boundary layer processes into numerical forecasting models. *Bound.-Lay. Meteor.*, **16**, 115–129.

Stull, R. B., 1984: Transilient turbulence theory. Part I: The concept of eddy-mixing across finite distances. *J. Atmos. Sci.*, **41**, 3351–3367.