Vertical advection at the lower boundary in a non-hydrostatic mesoscale model

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Tapp and White (1976) have described a non-hydrostatic mesoscale model and compared its simulation of a sea-breeze over Florida with that of the hydrostatic model described by Pielke (1974). Tapp and White reported that "the effect of Lake Okeechobee is noticeably less strong than in Pielke's model", a discrepancy that is particularly marked after 8 hours of simulated time, i.e. at about 1330 local time. The discrepancy existed whether centred differences or upstream differences were used to calculate the advective terms in the non-hydrostatic model.

In the model as described by Tapp and White the vertical velocity \( w \) was made zero at the lowest level (i.e. at 75 m for the Florida sea-breeze simulations) so that, in particular, the vertical advection of potential temperature vanished there. In contrast, Pielke set the vertical velocity equal to zero at the ground \( (z=0) \). Several modifications to the non-hydrostatic model have now

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Figure 1. Horizontal winds at 75 m and vertical velocity at 1090 m obtained using the mesoscale model with \( w = 0 \) at 75 m.
been separately tested, each with the aim of discovering the importance of the lower boundary condition to the simulation of the Florida sea-breeze. The conclusion is that the effect of Lake Okeechobee on the simulated sea-breeze is very sensitive to the specification of the lower boundary.

If centred differences are used to calculate vertical derivatives there are two second-order accurate formulations of the vertical advection: Eqs. (1) and (2) give these two approximations for the lowest model level for potential temperature.

\[
\frac{\partial \theta}{\partial z} = \frac{2b_s}{b_1 + 2b_s} \left( \frac{\theta_2 - \theta_1}{b_1} \right) + O(b_1, b_2, b_s^2)
\]

(1)

\[
\frac{\partial \theta}{\partial z} = \left( \frac{2b_s}{b_1 + 2b_s} \right) \left( \frac{b_s}{b_1 + b_s} \right) \left( \frac{\theta_2 - \theta_1}{b_1} + \frac{b_1}{b_1 + b_s} \frac{\theta_3 - \theta_2}{b_s} \right) + O(b_1, b_2, b_s^2)
\]

(2)

where \( \theta_0 \) is potential temperature at ground level

\( \theta_1 \) and \( \theta_2 \) are potential temperature at the lowest and second model levels

\( b_s \) is the height of the lowest model level

\( b_1 \) is the separation between the lowest and second model levels

\( w_z \) is the vertical velocity midway between the lowest and second levels.

Both (1) and (2) increase the influence of the lake on the sea-breeze when comparison is made with \( w = 0 \) at the lowest level. However, formulation (2), which involves the surface temperature, gives the more marked lake effect.

The figures show fields at 8 hours taken from simulations in which upstream differencing was used to calculate the advective terms. Fig. 1 shows the original simulation reported by Tapp and White; Fig. 2 shows a more recent simulation in which the vertical velocity was made zero at ground level. In order to calculate the vertical derivatives in regions of ascent the horizontal wind was assumed to vanish at ground level and the hydrostatic relation was used to give the vertical gradient of pressure at ground level. The second simulation was designed to use a model as like that of Pielke as possible.

It has been demonstrated that the results given by the non-hydrostatic model are sensitive to the formulation of vertical advection at the lowest level. In order to obtain accurate forecasts using the model it may prove necessary to calculate vertical derivatives of velocity and temperature from theoretical profiles implied by the surface flux layer formulation rather than from numerical differences.

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NOTES AND CORRESPONDENCE

REFERENCES


551.521.3: 551.593.7

COMMENTS ON THE PAPER BY C. R. NAGARAJA RAO, T. TAKASHIMA AND R. B. TOOLIN "MEASUREMENTS AND INTERPRETATION OF THE POLARIZATION OF RADIATION EMERGING FROM THE ATMOSPHERE AT AN ALTITUDE OF 28 KM OVER SOUTHWESTERN NEW MEXICO (USA)"

By T. TAKASHIMA and C. R. NAGARAJA RAO

In the paper which we co-authored with Mr. Toolin (Rao, Takashima and Toolin 1973) and which will hereafter be referred to as I, we assumed that the state of polarization of the incident radiation remained unaltered on scattering by atmospheric aerosols in our computations of the degree of linear polarization of the radiation emerging from the top of a homogeneous model of a purely scattering plane parallel turbid atmosphere bound by a Lambert surface at the bottom and illuminated with unpolarized, parallel radiation from the sun at the top. We have since extended these computations to atmospheric models in which the polarizing properties of aerosols are taken into account in order to determine to what extent our earlier conclusions about atmospheric turbidity, drawn from a comparison between theory and experiment, could have been influenced by the simplifying assumption we made about aerosol scattering in I.

Atmospheric aerosols are usually modelled as polydispersions of homogeneous, spherical Mie-type scatterers in radiative transfer studies. The polarizing properties of such model representations can be deduced from a knowledge of the associated phase matrices (Deirmendjian 1969; Harris 1972; Takashima, unpublished). With the aerosol models we have used, it is observed that the elementary act of single scattering results in the following:

(i) when the incident radiation is unpolarized, the scattered radiation is partially linearly polarized at all angles other than the exact forward and backward directions, with its plane of polarization being either parallel or perpendicular to the scattering plane.

(ii) when the incident radiation is completely linearly polarized with its plane of polarization oriented at an angle other than 0° or 90° to the scattering plane, the scattered radiation is elliptically polarized at all angles other than the exact forward and backward directions; considerable depolarization is noticed at intermediate values of the scattering angle; if the plane of polarization of incident radiation is either perpendicular or parallel to the scattering plane, the state of polarization remains unaltered on scattering.

(iii) when the incident radiation is completely elliptically polarized, the scattered radiation is partially depolarized at all angles other than the exact forward and backward directions.

The nature of the scattered radiation when the incident radiation is partially polarized can be easily determined from the above by considering the incident beam as being made up of two beams, one of them being completely polarized while the other is neutral or unpolarized.

The above features are incorporated into the computational scheme by using the actual aerosol phase matrix \( P_\lambda^A(\theta) \) in the computation of \( P_\lambda^A(\theta) \), the phase matrix for single scattering in the initial atmospheric layer used in the doubing procedure, instead of using the product of a scalar function and the unit matrix in place of \( P_\lambda^A(\theta) \) as was done in I.

For reasons of economy, we have performed the present computations with only one of the two aerosol models used in I - the model L water haze (Deirmendjian). The size distribution function for this water haze is given by \( n(r) = 4.9757 \times 10^8 \times r^4 \times \exp (-15.1186r^4) \) where \( n(r) \) is the partial concentration of haze particles per cm\(^2\) per micrometer interval in radius \( r \) which lies between the limiting values of 0.005 and 2.9 \( \mu \text{m} \). The other atmospheric model parameters, namely