

Corrections and Modifications to the Reprint (2000) of "Fundamentals of Atmospheric Modeling"

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**These changes should also apply to the original
printing. A separate file contains additional
corrections and modifications to the original
printing that have been made in the reprinted
(2000) version**

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Chapter 2

P. 11. Following Equation 2.2 and throughout the text, the term “thermal velocity” should be replaced with “thermal speed.”

P. 11, Section 2.2. Clarification of temperature definition. From a Maxwellian distribution of molecular speeds, one can define the distribution’s average speed (thermal speed) (\bar{v}_a), root-mean-square speed (v_{rms}), and most probable speed (v_p) as

$$\bar{v}_a = \sqrt{\frac{8k_B T}{M}} \quad v_{rms} = \sqrt{\frac{3k_B T}{M}} \quad v_p = \sqrt{\frac{2k_B T}{M}}$$

respectively. From these equations, temperature can be defined as

$$\frac{4}{3} k_B T = \frac{1}{2} \bar{M} \bar{v}_a^2 \quad \frac{3}{2} k_B T = \frac{1}{2} \bar{M} v_{rms}^2 \quad k_B T = \frac{1}{2} \bar{M} v_p^2$$

respectively. When temperature is defined from the average speed equation, it is “proportional to the kinetic energy of an air molecule traveling at its average speed” rather than “proportional to the average kinetic energy of an air molecule,” as written in the text. The description written in the text (“proportional to the average kinetic energy of an air molecule”) is applicable to the equation that uses v_{rms} since v_{rms} is determined by summing the squares of all individual speeds then dividing by the total number of speeds.

P. 24. Paragraph prior to Equation 2.27. Clarification. Change

“Specific humidity is similar to the mass mixing ratio, except that it expresses the mass of water vapor per unit mass of moist air (dry air plus water vapor).”

to

The mass of any substance per unit mass of moist air (dry air plus water vapor) is the **moist-air mass mixing ratio** (q). Specific humidity is moist-air mass mixing ratio of water vapor (mass of water vapor per unit mass of moist air).

P. 42, Equation 2.86, change 0.859 to 0.856 in the exponential term.

Chapter 4

P. 78. Four lines from bottom. Change, “A reference frame that moves,..., is a **noninertial reference frame**,” to “A reference frame that accelerates or decelerates relative to an inertial reference frame,..., is a **noninertial reference frame**.”

P. 105. Change the right side of Equation 4.83 to $= -\mathbf{i}_R \frac{v^2}{R_c} = -\mathbf{i}_R a_R$

P. 110. Equation 4.94, change the a to p_a .

P. 112. Equation 4.99, change v_c to c four times.

P. 120. Two lines above Equation 4.126, change g to v_g .

Chapter 5

P. 146. Equation 5.99. Change second “=” to a “+”. Also, just above the equation, change “Substituting $s/z = -1/Z_t$ into (5.98) gives” to “Substituting $dz = -Z_t ds$ into the right side of (5.98) gives”

Chapter 6

P. 171, Equation 6.58. Change first term to $a_{i-1} = \frac{-(x_{i+1} - x_i)}{(x_i - x_{i-1})(x_{i+1} - x_{i-1})}$. (This correction is made in the replacement of Section 6.4.6 below).

P. 172, Equation 6.60. Change $N_{i,t+h}$ to $N_{i,t-h}$ and multiply entire right-hand-side of the equation by -1. (This correction is made in the replacement of Section 6.4.6 above).

P. 171-172. Improvement. Section 6.4.6 can be replaced with the following to obtain a more accurate solution to the diffusion term in the advection-diffusion equation.

6.4.6. Variable Grid Spacing and Eddy Diffusion Coefficients

The previous solutions to the advection-diffusion equation were obtained by assuming constant grid spacing and eddy diffusion coefficients. Here a solution that assumes variable grid spacing and diffusion coefficients is considered.

The west-east advection term in (6.1) can be discretized with (6.24) as

$$\frac{(uN)}{x} = a_{i-1}(uN)_{i-1} + a_i(uN)_i + a_{i+1}(uN)_{i+1} \quad (6.54)$$

When grid spacing is variable, the second-order central-difference approximation coefficients for this equation can be obtained by solving the matrix equation

$$\begin{matrix} 1 & 1 & 1 & a_{i-1} & 0 \\ -(x_i - x_{i-1}) & 0 & (x_{i+1} - x_i) & a_i & = & 1 \\ (x_i - x_{i-1})^2 & 0 & (x_{i+1} - x_i)^2 & a_{i+1} & 0 \end{matrix} \quad (6.55)$$

to yield

$$a_{i,i-1} = \frac{-(x_{i+1} - x_i)}{(x_i - x_{i-1})(x_{i+1} - x_{i-1})} \quad (6.56)$$

$$a_{i,i} = \frac{(x_{i+1} - x_i) - (x_i - x_{i-1})}{(x_{i+1} - x_i)(x_i - x_{i-1})}$$

$$a_{i,i+1} = \frac{x_i - x_{i-1}}{(x_{i+1} - x_i)(x_{i+1} - x_{i-1})}$$

The west-east diffusion term in (6.1) can be expanded then discretized as

$$\frac{a}{x} K \frac{N}{x} = \frac{K}{x} \frac{N}{x} + K \frac{2N}{x^2} \quad K_{i,i-1}N_{i-1} + K_{i,i}N_i + K_{i,i+1}N_{i+1} \quad (6.57)$$

where

$$K_{i,i-1} = \left(a_{i,i-1}K_{i-1} + a_{i,i}K_i + a_{i,i+1}K_{i+1} \right) a_{i,i-1} + K_i d_{i-1}$$

$$K_{i,i} = \left(a_{i,i-1}K_{i-1} + a_{i,i}K_i + a_{i,i+1}K_{i+1} \right) a_{i,i} + K_i d_i$$

$$K_{i,i+1} = \left(a_{i,i-1}K_{i-1} + a_{i,i}K_i + a_{i,i+1}K_{i+1} \right) a_{i,i+1} + K_i d_{i+1}$$

The right side of (6.57) was obtained by substituting the second-order central-difference approximations,

$$\frac{K}{x} \quad a_{i,i-1}K_{i-1} + a_{i,i}K_i + a_{i,i+1}K_{i+1} \quad (6.58)$$

$$\frac{N}{x} \quad a_{i,i-1}N_{i-1} + a_{i,i}N_i + a_{i,i+1}N_{i+1}$$

$$K \frac{2N}{x^2} \quad K_i \left(d_{i,i-1}N_{i-1} + d_{i,i}N_i + d_{i,i+1}N_{i+1} \right)$$

into the middle expression in (6.57). In (6.58), the a terms were given in (6.56) and

$$d_{i-1} = \frac{2}{(x_i - x_{i-1})(x_{i+1} - x_{i-1})} \quad (6.59)$$

$$d_i = \frac{-2}{(x_{i+1} - x_i)(x_i - x_{i-1})}$$

$$d_{i+1} = \frac{2}{(x_{i+1} - x_i)(x_{i+1} - x_{i-1})}$$

Applying (6.54) and (6.57) to the advection-diffusion equation, (6.1), gives a solution of second order in space that allows for variable grid spacing, wind speeds, and eddy diffusion coefficients. In Crank-Nicolson form, the resulting advection-diffusion equation is

$$\frac{N_{i,t} - N_{i,t-h}}{h} = -\mu_c \left\{ [(au - K)N]_{i-1} + [(au - K)N]_i + [(au - K)N]_{i+1} \right\}_t - (1 - \mu_c) \left\{ [(au - K)N]_{i-1} + [(au - K)N]_i + [(au - K)N]_{i+1} \right\}_{t-h} \quad (6.60)$$

This equation can be written in tridiagonal matrix form and solved.

Chapter 7

P. 201, Modeling Project, Part (e). Below is an alternate method of initializing surface pressure (this method should be used for periodic boundary conditions and either method can be used for limited-area boundary conditions).

“(e) Initialize surface pressure by creating a small hill of pressure in the center of the grid superimposed on background pressure. First, select a background surface pressure ($p_{a,base}$) of 1000 mb and a peak incremental surface pressure ($p_{a,peak}$) of 3 mb. Calculate the surface pressure at the horizontal center of each grid cell ij with the Gaussian distribution,

$$p_{a,surf,i,j} = p_{a,base} + p_{a,peak} \exp - \frac{R_e \cos \frac{i,j + c}{2} (i,j - c)^2}{2} - \frac{[R_e (i,j - c)]^2}{2}$$

where c and c are the longitude and latitude (radians), respectively, at the center of your grid. Calculate the initial column pressure at the horizontal center of each grid cell with $i,j - p_{a,surf,i,j} - p_{top}$.

Chapter 8

P. 207, Example 8.3. Units of a should be $\text{kg m}^{-1} \text{s}^{-1}$ and of a should be $\text{m}^2 \text{s}^{-1}$.

P. 216, Equation (8.34). Replace $\bar{v}_h(z_r)$ with $|\bar{v}_h(z_r)|$.

P. 224, Clarification following Equation 8.55. The equation holds if positive z is defined as downward. The original reference for this equation is Philip, J. R. (1957) Evaporation, moisture, and heat fields in the soil. *J. Meteorology*, **14**, 354-366.

Chapter 10

P. 252 - P. 254, Figures 10.4, 10.5, 10.6, and 10.7. Vertical axes should be divided by 10^4 .

P. 281, Equation 10.56. Change equation and description to

$$N_{JD} = 364.5 + (Y - 2001) \times 365 + D_L + D_J$$

where

$$D_L = \begin{cases} \text{INT}(Y - 2001)/4 & Y \geq 2001 \\ \text{INT}(Y - 2000)/4 - 1 & Y < 2001 \end{cases}$$

is the number of days from the beginning of Julian year 2000. In (10.56), Y is the current year, D_L is the number of leap days from the beginning of year Y and the beginning of 2001, and D_J is the **Julian day of the year**, which varies from 1 on January 1 to 365 (for nonleap years) or 366 (for leap years) on December 31.”

P. 295, 3 lines below Equation (10.114), h (Planck's constant) should be in units of J s, not J s⁻¹.

Chapter 11

P. 313, Figure 11.3, caption, change the last sentence to "The rate coefficient for HNO₃ decreases with increasing height near 400 mb, because the absorption cross section of HNO₃ decreases with decreasing temperature, and this factor becomes important at 400 mb."

Chapter 12

P. 339. Table 12.3. Total mobile source emissions of SO_x should be 62.26%, not 67.26%.

Chapter 16

P. 442, Equations (16.17) and (16.18), remove M/N from the terms on the top right side of both equations.

P. 445, Sixth line following Equation (16.25), change "... G_i approaches zero,..." to " G_i approaches unity..."

P. 446, Second line following Equation (16.27), change "...the kinetic energy of light

(small) particles..." to "the thermal speed of light (small) particles..."

P. 446, Equation (16.30), change subscript on all four occurrences of Re from i to j and on

both occurrences of Sc from j to i. Also, add "for $r_j \geq r_i$ " to the right of the equation.

P. 446, last paragraph to page 447. Replace the text starting with "A third coagulation

kernel...temperatures above 0°C)." With

A third coagulation kernel is that for gravitational collection (differential fall velocities). When two particles of different size fall, one may catch up with, collide with, and coalesce to the other. The **coagulation kernel for gravitational collection** accounts for these processes and is written as

$$\frac{GC}{i,j} = E_{coll,i,j} E_{coal,i,j} (r_i + r_j)^2 |V_{f,i} - V_{f,j}| \quad (16.32)$$

where $E_{coll,i,j}$ is a **collision efficiency**, $E_{coal,i,j}$ is a **coalescence efficiency**, and the product of the two is a **collection efficiency**. A parameterization of the collision efficiency is

$$E_{coll,i,j} = \frac{60 E_{V,i,j} + E_{A,i,j} Re_j}{60 + Re_j} \quad r_j \geq r_i \quad (16.33)$$

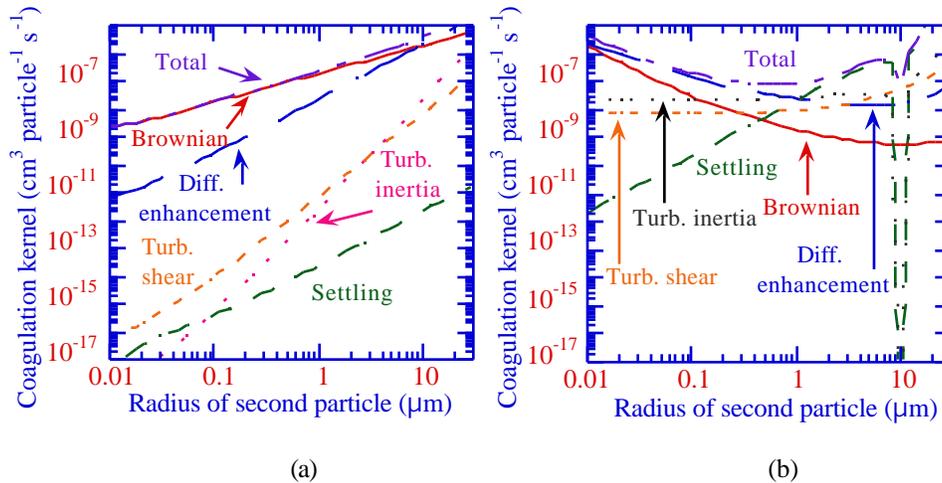
$$E_{V,i,j} = \begin{cases} 1 + \frac{0.75 \ln(2K_{i,j})}{K_{i,j} - 1.214} & K_{i,j} > 1.214 \\ 0 & K_{i,j} \leq 1.214 \end{cases} \quad E_{A,i,j} = \frac{K_{i,j}^2}{(K_{i,j} + 0.5)^2} \quad (16.34)$$

(Ludlum 1980) where $K_{i,j} = V_{f,i} |V_{f,j} - V_{f,i}| / r_j g$ (for $r_j \geq r_i$) is the dimensionless **Stokes number**. (16.33) simplifies to $E_{V,i,j}$ when $Re_j \ll 1$ and to $E_{A,i,j}$ when $Re_j \gg 1$. When one particle is $< 2 \mu\text{m}$ in radius, the coalescence efficiency is generally unity. When two larger particles collide, the kinetic energy of a collision is high, increasing the chance that a collision will result in a bounce-off rather than a coalescence. Some parameterizations for the coalescence efficiency can be found in Pruppacher and Klett (1997). Gravitational collection is the most important mechanism by which cloud drops form raindrops in warm clouds (clouds with temperatures above 0°C).

P. 447, Add "for $r_j \geq r_i$ " to the right of Equation (16.33) and to the right of the equation

$K_{i,j} = \dots$, which appears immediately below Equation (16.34).

P. 448. Modify Figures 16.4 (a) and (b) with



P. 449, Caption for Figure (16.5). Change 10⁷ to 10⁶ particles cm⁻³.

P. 450, Caption for Figure (16.6), Change “ $p=0.1 \mu\text{m}$ ” to “ $p=0.0005236 \mu\text{m}^3$ ”

Chapter 18

P. 497, Equation (18.81). Change " $Q_n = \max(\dots)$ " to " $Q_n = \min(\dots)$ "

Chapter 19

P. 523, in the line above Equation (19.46), change HO₂⁻(aq) to HO₂(aq) and O₂ to O₂⁻.

Chapter 21

P. 544, change paragraph immediately above Section 21.1.10 to the following:

“From Section 6.2, a time interval was defined as the period during which several time steps of a process are solved without interference by another process. For time-consuming processes in which the time step is constant (e.g., some aerosol processes), the time interval often equals the time step. For processes that require short time steps (e.g., dynamics) or variable time steps (e.g., chemistry), the time interval often exceeds the time step. In three-dimensional models, time intervals often range from 1 minute to 1 hour.”

Appendices

P. P.607 and 608, Footnotes to Table B.8. Remove the subscript "1" from " T_1 " in the first equation on the bottom of P. 607 and Equation (1) on P. 608.