Corrections and Modifications to the First Printing (1999) of "Fundamentals of Atmospheric Modeling"

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These Changes Have Been Implemented in the Second Printing (August, 2000)

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Chapter 2

P. 10, 6th line above Section 2.1.2.4, change 0.17 ppmv to 1.7 ppmv and change 0.08 ppmv to 0.8 ppmv.

P.12, Equation (2.3), change $(T - 273.16)$ to $(T - 273.15)$

P. 23, Example 2.5, change "Assume $T = 288$ K." to "Assume $T = 288$ K and $p_d = 1013$ mb."

P. 24, immediately above Example 2.7, change $q_v = \omega_v \rho_d / \rho_a$ to $q_v = \omega_v \rho_d / \rho_a = \omega_v / (1 + \omega_v)$

P. 24, change Equation (2.31) to $R_m = R' \dfrac{1 + \omega_v / \varepsilon}{1 + \omega_v} = R' \left(1 + \dfrac{1 - \varepsilon}{\varepsilon} q_v\right) = R'(1 + 0.608 q_v)$

P. 25, change Equation (2.32) to $T_v = T \dfrac{R_m}{R'} = T \dfrac{1 + \omega_v / \varepsilon}{1 + \omega_v} = T \left(1 + \dfrac{1 - \varepsilon}{\varepsilon} q_v\right) = T(1 + 0.608 q_v)$

P. 25, change Equation (2.33) to $m_a = \dfrac{m_d}{1 + 0.608 q_v}$

P. 25, Example 2.8, change ω_v to q_v twice, change "From (2.25)..." to "From (2.27)...",

change "$\omega_v = ...$" to "$q_v = 0.622$ x $10 / (1013 + 0.622$ x $10) = 0.0061$ kg kg^{-1}",

change "$m_a = ...$" to "$m_a = 28.966 / (1. + 0.608$ x $0.0061) = 28.86$ kg kg^{-1}",

change "$R_m = ...$" to "$R_m = 2.8704$ x $(1. + 0.608$ x $0.0061) = 2.8811$ m^3 mb^{-1} kg^{-1} K^{-1}"

change "$T_v = ...$" to "$T_v = 298$ x $(1. + 0.608$ x $0.0061) = 299.1$ K",

change "$\rho_a = ...$" to "$\rho_a = p_a / (R_m T) = 1023/(2.8811$ x $298) = 1.19$ kg m^{-3}"

P. 27, 4th line from top, change "...in a standard atmosphere..." to "...in a standard

troposphere..."

P. 27, Example 2.10, change Γ_e to Γ_s

P. 36, second line from the top, change "...before liquid water is depleted. ... in the cloud."

to "...before liquid water is depleted, resulting in less-than-optimal precipitation

from the cloud. When the ratio is between 100,000:1 and 1,000,000:1, each ice

crystal receives the liquid water from 100,000 to 1,000,000 droplets. These ice

crystals fall from the cloud, maximizing precipitation."

P. 39, change Equation (2.70) to
$$c_{v,m} = \left(\frac{\partial Q}{\partial T}\right)_{\alpha_a} = \frac{M_d c_{v,d} + M_v c_{v,V}}{M_d + M_v} = \frac{c_{v,d} + c_{v,V}\omega_v}{1 + \omega_v} = c_{v,d}(1 + 0.955q_v)$$

P. 40, top, add "where $q_v = \omega_v / (1 + \omega_v)$ and $0.955 = c_{v,V}/c_{v,d} - 1$." just prior to "Substituting..."

P. 40, change Equation (2.74) to $c_{p,m} = \left(\frac{dQ}{dT}\right)_{p_a} = \frac{M_d c_{p,d} + M_v c_{p,V}}{M_d + M_v} = \frac{c_{p,d} + c_{p,V}\omega_v}{1 + \omega_v} = c_{p,d}(1 + 0.856q$

P. 40, add "$q_v = \omega_v / (1 + \omega_v)$, and $0.856 = c_{p,V}/c_{p,d} - 1$," between "constant pressure," and

"where" in the second line past Equation (2.74).

P. 40, change $c_{v,m} \approx c_{v,d}(1 + 0.96\omega_v)$ to $c_{v,m} \approx c_{v,d}(1 + 0.955q_v)$ in third line after Equation

(2.75)

P. 40, change $R_m \approx R'(1 + 0.608\omega_v)$ to $R_m \approx R'(1 + 0.608q_v)$ in third line after Eqation (2.75)

P. 40, Second line before Equation (2.76), change "...can be written..." to "...can be approximated..."

P. 40, Equation (2.76) change the "dQ=" to "dQ≈"

P. 40, First line below Equation (2.76), change the "dU=" to "dU≈"

P. 40, last line, end of paragraph, add "The error of (2.76) is small."

P. 42, change ω_v to q_v three times in Equation (2.86), once in Equation (2.88), once immediately after Equation (2.88), and twice immediately after Equation (2.89).

P. 43, Example 2.20, change $\theta_p = 298.5$ K to $\theta_p = 287.8$ K.

P. 43, change ω_v to q_v once in Equation (2.90)

P. 44, change ω_v to q_v twice in Equation (2.91).

Chapter 3

P. 55, Equation (3.4), change $\dfrac{\partial N}{\partial t}\dfrac{\mathrm{d}x}{\mathrm{d}t}$ to $\dfrac{\partial N}{\partial x}\dfrac{\mathrm{d}x}{\mathrm{d}t}$

P. 61, 2nd line above Figure 3.3, change "flood layers" to "fluid layers"

P. 62, Equation (3.39), change $u'\overline{N}$ to $\overline{u'\overline{N}}$ in the third term after the first "=" sign

P. 62, Example 3.2, Solution, change "$\overline{u'N'}=...= 4\,\overline{u}\overline{N}$" to "$\overline{u'N'}=...= 4$"

P. 68, paragraph immediately before Section 3.3.5, change "...cubic centimeters of particles per cubic centimeter of air per second." to "...cubic centimeters of component q per cubic centimeter of air per second."

P. 72, Equation (3.76), change the T in the last term of the equation to T_v

Chapter 4

P. 77, Equation (4.5), change $\nabla \bullet v$ to $\nabla \bullet \mathbf{v}$ at the beginning of the equation

P. 82, Equation (4.25), change $\left(\mathbf{j}_\varphi \dfrac{\mathrm{d}v}{\mathrm{d}t} + v \dfrac{\mathrm{d}\mathbf{j}_\varphi}{\mathrm{d}t} \right)\left(\mathbf{k}_r \dfrac{\mathrm{d}w}{\mathrm{d}t} + w \dfrac{\mathrm{d}\mathbf{k}_r}{\mathrm{d}t} \right)$ to

$$\left(\mathbf{j}_\varphi \frac{\mathrm{d}v}{\mathrm{d}t} + v \frac{\mathrm{d}\mathbf{j}_\varphi}{\mathrm{d}t} \right) + \left(\mathbf{k}_r \frac{\mathrm{d}w}{\mathrm{d}t} + w \frac{\mathrm{d}\mathbf{k}_r}{\mathrm{d}t} \right)$$

P. 95, 4th line below the title for Section 4.2.6, change "creat" to "creates"

P. 96, line immediately above Equation (4.64), change "yeilds" to "yields"

P. 98, Example 4.12, change $K_m = 2.5 \times 10^3$ to $K_m = 100$. This changes the solution from

 -0.01 m s^{-2} to -0.0004 m s^{-2}.

P. 97, Change the the last paragraph, starting with "The eddy diffusion coefficients..." and

 ending with Equation (4.69) to

"The eddy diffusion coefficients in (4.67) can be written in tensor form as

$$\mathbf{K}_m = \begin{bmatrix} K_{m,xx} & 0 & 0 \\ 0 & K_{m,yx} & 0 \\ 0 & 0 & K_{m,zx} \end{bmatrix} \text{ for } u \quad \begin{bmatrix} K_{m,xy} & 0 & 0 \\ 0 & K_{m,yy} & 0 \\ 0 & 0 & K_{m,zy} \end{bmatrix} \text{ for } v \quad \begin{bmatrix} K_{m,xz} & 0 & 0 \\ 0 & K_{m,yz} & 0 \\ 0 & 0 & K_{m,zz} \end{bmatrix} \text{ for } w$$

(4.68)

where a different tensor is used depending on whether the u, v, or w momentum

equation is being solved. In vector and tensor notation, (4.67) simplifies to

$$\frac{\mathbf{F}_t}{M_a} = -\frac{1}{\rho_a}(\nabla \bullet \rho_a \mathbf{K}_m \nabla)\mathbf{v} \qquad\qquad (4.69)$$

where the choice of tensor K_m depends on whether the scalar in vector $\mathbf{v}$ is u, v, or w.

P. 98, Examples 4.11 and 4.12, change $\mathbf{F}_{t,zx}$ to $F_{t,zx}$

P. 99, Table 4.1, change range of values for horizontal turbulent flux divergence of

 momentum from 0-1 to 0-0.005.

P. 99, Example 4.13, change "$z \approx 10^6$ m" to "$x \approx 10^6$ m"

P. 108, line immediately below Equation (4.89), change $\left|\tilde{\mathbf{K}}\right| = \mathbf{i}\tilde{k} + \mathbf{j}\tilde{l} + \mathbf{k}\tilde{m}$ to $\tilde{\mathbf{K}} = \mathbf{i}\tilde{k} + \mathbf{j}\tilde{l} + \mathbf{k}\tilde{m}$

P. 112, 2nd line below Example 4.17, change "stable, stratification" to "stable stratification"

P. 119, Second line before Equation (4.121), change "...wind in nondivergent..." to "...wind is nondivergent..."

<h2 style="text-align:center; color:blue">Chapter 5</h2>

P. 130, Equation (5.18), change $\left(\partial p_a/\partial t\right)_z$ to $\left(\partial \rho_a/\partial t\right)_z$.

P. 130, Equation (5.19), change "-" to "+"

P. 133, line before Equation (5.36), change $+\mathbf{j}(\nabla \bullet \rho_a \mathbf{K}_h \nabla)v$ to $+\mathbf{j}(\nabla \bullet \rho_a \mathbf{K}_m \nabla)v$

P. 133, Equation (5.36), change $(\nabla \bullet \rho_a \mathbf{K}_h \nabla)u$ to $(\nabla \bullet \rho_a \mathbf{K}_m \nabla)u$

P. 138, after Equation (5.57), change $p_a = p_{top} + \pi_a \sigma$ to $p_a = p_{a,top} + \pi_a \sigma$.

P. 139, Equation (5.59). Change $\mathbf{v}_h \bullet \nabla_\sigma$ to $\left(\mathbf{v}_h \bullet \nabla_\sigma\right)$.

P. 140, 4th line from top, Change "In reality, $\dot{\sigma} \neq 0$ at the model top" to "In the real atmosphere, vertical velocities would not equal zero a the location of the model top."

P. 144, Equation (5.88), change $(\nabla \bullet \rho_a \mathbf{K}_h \nabla)u$ to $(\nabla \bullet \rho_a \mathbf{K}_m \nabla)u$

P. 144, line after Equation (5.88), change $(\nabla \bullet \rho_a \mathbf{K}_h \nabla)v$ to $(\nabla \bullet \rho_a \mathbf{K}_m \nabla)v$

<h2 style="text-align:center; color:blue">Chapter 6</h2>

P. 162., Equation (6.29), change $(x_1 - x_*)^q$ to $(x_q - x_*)^q$ to $(x_1 - x_*)^{q-1}...(x_q - x_*)^{q-1}$ in last row in left bracket of matrix equation.

P. 166, immediately after Equation (6.41), add "where R_i represents the right side of (6.39)."

P. 166, second line from bottom, change "The linear ODE was then solved..." to "The linear ODE was finite-differenced then solved..."

P. 174, line before Equation (6.65), change "the series expansion..." to "a series expansion..."

P. 174. Equation (6.65), change $N_i = \sum_j N_j e_j$ to $N_i \approx \mathbf{N}_i(x) = \sum_j N_j e_j(x)$

P. 174, following Equation (6.65), replace "which is a trial function.....the exact function." with "where $\mathbf{N}_i(x)$ is a **trial function**. Assume for now that u is constant. The set of j nodes over which the trial function is approximated is the **trial space**. The trial function is the sum, over each node in the trial space, of the true concentration, N_j, multiplied by a **basis function** $e_j(x)$. The difference between (6.64) when $\mathbf{N}_i(x)$ is used and that when N_j is used is the **residual**, $R_i(x)$. A residual is the difference between an approximate and an exact function."

P. 174, Change text before Equation (6.66) from "The sum, over... In other words." to "The sum, over the test space, of the residual multiplied by the weight is zero (e.g., Pepper et al. 1979; Celia and Gray 1992). Thus,"

P. 174, Equation (6.66) Change $\int_x R_i e_i dx = 0$ to $\int_x R_i(x) e_i(x) dx = 0$

P. 174. Change text following Equation (6.66) from "In this equation...trial space." to "The purpose of this constraint is to minimize $R_i(x)$ by forcing its weighted average over the domain to zero. With the Galerkin method, the weight function $e_i(x)$ and test

space in (6.66) are the same as the basis function $e_j(x)$ and trial space, respectively, in (6.65). For other methods, $e_i(x)$ and $e_j(x)$ may differ, and the test space may differ from the trial space. Methods in which the test and trial spaces differ are Petrov-Galerkin methods."

P. 175, top, change "The residual of (6.64) is" to "When u is constant, the residual of (6.64) is"

P. 175, change Equation (6.67) to

$$R_i(x) = \left[\frac{\partial \mathbf{N}_i(x)}{\partial t} + u \frac{\partial \mathbf{N}_i(x)}{\partial x} \right] - \left[\frac{\partial N_i}{\partial t} + u \frac{\partial N_i}{\partial x} \right] = \left[\frac{\partial \mathbf{N}_i(x)}{\partial t} + u \frac{\partial \mathbf{N}_i(x)}{\partial x} \right] - 0\backslash$$

P. 175, after Equation (6.67), change "...the approximated and the exact..." to "...the approximate and exact..."

P. 175, change Equation (6.68) to

$$\int_x \left[\frac{\partial \mathbf{N}_i(x)}{\partial t} + u \frac{\partial \mathbf{N}_i(x)}{\partial x} \right] e_i(x) dx$$

$$= \int_x \left[\frac{\partial}{\partial t} \left(\sum_j N_j e_j(x) \right) + u \frac{\partial}{\partial x} \left(\sum_j N_j e_j(x) \right) \right] e_i(x) dx$$

$$= \sum_j \left[\frac{\partial}{\partial t} \int_x e_j(x) e_i(x) dx \right] + u \sum_j \left[N_j \int_x \frac{\partial}{\partial x} e_i(x) dx \right] = 0$$

P. 175, after Equation (6.68), change "...over three nodes ($j = i - 1, ..., i + 1$), centered at i,..." to "... three nodes centered at i ($j = i - 1, ..., i + 1$),..."

P. 175, Equation (6.69), change all e_{i-1} to $e_{i-1}(x)$, change all e_i to $e_i(x)$, and change all e_{i+1} to $e_{i+1}(x)$

P. 175, after Equation (6.69) change ""...chapeau (hat) functions," to "...chapeau (hat) function,"

P. 175, Equation (6.70), change e_i to $e_i(x)$

P. 175, second line after Equation (6.,70), change e_j to $e_j(x)$

P. 175, Equation (6.71), change $e_{i-1}e_i$ to $e_{i-1}(x)e_i(x)$

P. 176, top line, change $\mathbf{U}_i = \sum_j u_j e_j$ to $\mathbf{U}_i(x) = \sum_j u_j e_j(x)$

Chapter 7

P. 185. Change the text between Equation (7.5) and (7.6) to the following: "Alternatively, the vertical midpoint can be defined in such a way that the finite difference expression for the hydrostatic equation, given in Section 7.6, becomes exact for an isentropic atmosphere (e.g., where potential virtual temperature increases monotonically with height, as shown in Fig. 2.13). In such a case, the midpoint is the pressure at which the mass-weighted mean of P, the potential temperature factor defined in (2.92), is located (Arakawa and Suarez 1983). The mass-weighed mean of P in layer k is"

P. 188, Equation (7.15) change $(uR_e\Delta\varphi)_{i+1/2,j,k}$ to $(uR_e\Delta\varphi)_{I+1/2,j,k}$

P. 190, Second line above Equation (7.22), change "interpolting" to "interpolating"

P. 190, 3rd line from bottom, change "Arakawa (1982)" to "Arakawa (1984)"

P. 191, Equation (7.25) change $\pi_{a,t}R_e^2\cos\varphi\Delta\lambda_e$ to $\pi_{a,t}R_e^2\cos\varphi\Delta\lambda_e\Delta\varphi$ in vertical velocity term.

P. 193, Equation (7.29) change the subscript "1+1/2,j" to "i+1/2,j"

P. 195, 4th line below Equation (7.41), change "Arakawa (1982)" to "Arakawa (1984)"

P. 196, Equation (7.43) change subscript on second S from "i+1,j+1" to "i+1/2,j+1"

P. 196, Equation (7.44), change

$$+\frac{1}{\Delta\sigma_k}\left(\pi_{a,t}\Delta A\dot\sigma_{k-1/2,t}u_{k-1/2,t-h} - \pi_{a,t}\Delta A\dot\sigma_{k+1/2,t}u_{k+1/2,t-h}\right)_{i,j+1/2} \text{ to}$$

$$+\frac{1}{\Delta\sigma_k}\left(\pi_{a,t}\Delta A\dot{\sigma}_{k-1/2,t}v_{k-1/2,t-h}-\pi_{a,t}\Delta A\dot{\sigma}_{k+1/2,t}v_{k+1/2,t-h}\right)_{i,j+1/2}$$

P. 202, following Modeling Project 7.12, part (r), add the following text. "(s) Instead of using horizontal limited-area boundary conditions as described in the text, it may be more convenient, for this project, to use periodic boundary conditions. To accomplish this, setup the limited-area model grid so that it is symmetric in the south-north direction about the Equator, allow flow out of the north boundary edge to enter the south boundary edge and vice-versa, and allow flow out of the east boundary edge to enter the west boundary edge and vice versa. For this example case, the Coriolis parameter, f, may be set to zero, otherwise it will have opposite signs on the North and South boundaries, which connect to each other. Allowing f to vary, however, does ensure enstrophy and energy conservation. Although not necessarily realistic, this setup will simplify the coding, and allow for useful sensitivities of the numerical properties of the code."

Chapter 8

P. 203, fifth line below Section 8.1 heading, change "Section 4.1.6" to "Section 4.2.6"

P. 207, Table 8.1, change "0.03-0.01" to "0.003-0.01" in "Short grass" row

P. 208, Example 8.4, change "P_d" to "p_d"

P. 210, line after Equation (8.12) change "(unitless)" to "(dimensionless)"

P. 212, Equation (8.18), change "netural" to "neutral"

P. 215, line immediately after Equation (8.30), change "...turbulence due to shear relative to that due to buoyancy." to "...turbulence due to buoyancy relative to that due to shear."

P. 215, 8th line below Equation (8.30), change "...the potential virtual temperature exceeds zero,..." to "...the potential virtual temperature gradient exceeds zero,..."

P. 220, 4th line from bottom, change "(8.50) is valid for..." to (8.50) is applicable when..."

P. 221, 8th line from bottom and 2nd line from bottom, change "Jacobson (1998c)" to "Jacobson (1999)" both times.

P. 224, 5th line below Equation (8.54), change, "In (8.54), the specific heat and mass density of air are neglected, since they are assumed to be much smaller than those of soil and water." to " In (8.54), the specific heat multiplied by mass density of air is neglected, since the mass density of air is much smaller than that of soil or water."

P. 225,line after Equation (8.61), change $q_{v,s}(T_g) = \varepsilon p_s/(p_d + \varepsilon p_s)$ to just $q_{v,s}(T_g)$

Chapter 9

P. 231, Line immediately above title of Section 9.2, change "Stratus clouds often..." to "Stratus clouds sometimes..."

P. 231, 8th line from bottom, change "...increases instability below that altitude..." to "...increases instability at and below that altitude..."

P. 231, 3rd line from bottom, change "...cooling by up to +4 K km^{-1}." to "cooling, typically by up to +4 km^{-1}, but by up to +8 K km^{-1} in the tropics."

P. 232, first line, change "Moist- and pseudoadiabatic ascent occur only within a cloud,..."

    to "Moist- and pseudoadiabatic approximations apply only to clouds,..."

P. 237, 9th line from top, change "...the cloud stops rising." to "...the cloud top

    decelerates."

P. 237, 12th line from top, change "...the cloud to stop rising." to "...the cloud-top to

    decelerate."

P. 237, 4th line after the title for Section 9.4, change "...entrainment can inhibit..." to

    "...entrainment inhibits..."

P. 237, 5th line after the title for Section 9.4, change "...is the opposite of entrainment,

    except that during detrainment..." to "...is the opposite of entrainment. During

    detrainment..."

P. 242, Problem 9.2, change "...in a parcel of air..." to "...in an unsaturated parcel of air..."

Chapter 10

P. 245, 1st line below Section 10.1, remove comma between "...photon, or

    electromagnetic..."

P. 247, 7th line from top, change "...it often condenses..." to "...it eventually condenses..."

P. 251, line immediately after Equation (10.11), change "Radiance usually propagates..." to

    "Radiation usually propagates..."

P. 251, 3rd line after Equation (10.12), change "...is the radiant energy propagating..." to

    "...is the vertical component of radiant energy propagating..."

P. 251, 8th line from top, change "de Arellana" to "de Arellano"

P. 252, 5th line below Equation (10.16), change "The center of the sun has a temperature of about 1.5×10^6 K and emits primarily X rays, as shown in Fig. 10.4." to "The center of the sun has temperatures of about 15 million K and emits primarily gamma and X rays, and shown in Figure 10.4"

P. 252, Replace Figure 10.4 with
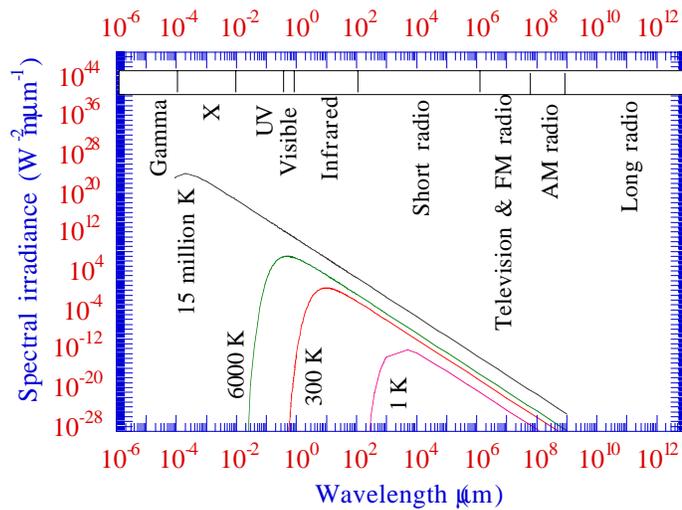

P. 253, Replace Figure 10.6 with
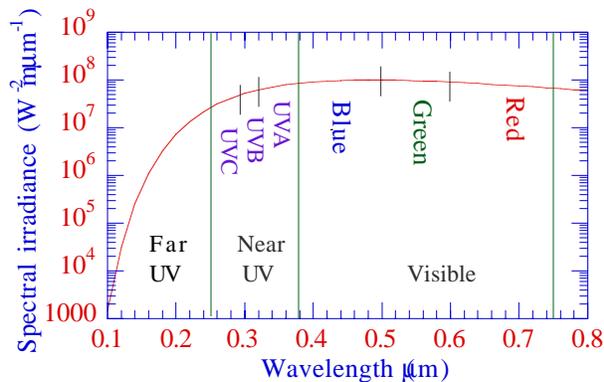
P. 255, 2nd line below Section 10.3, change "...reflection, refraction, scattering, and diffraction." to "...reflection, refraction, diffraction, and scattering."

P. 259, Figure 10.11 caption, change "E is refracted, reflected once, and refracted." to "E is refracted, reflected once, then refracted."

P. 259, 10th line from the bottom, change "When a wave refracts in the particle, it can refract out of the particle, reflect internally and then refract out, or reflect twice internally and then refract out. **Particle scattering** is the sum of the five processes discussed above, each of which is shown in Fig. 10.11." to "Once in the particle, the wave can be absorbed, transmit through the particle and refract out, or reflect internally one or more times and then refract out. Fig. 10.11 illustrates these processes, except for absorption. **Particle scattering** is the sum of the effects of reflection, refraction, and diffraction on a wavelength of energy"

P. 261, 3rd line below figure caption, change "...appears white at noon..." to "...usually appears whitish at noon..."

P. 263, 13th line from top, change, "...their mixing ratios are..." to "...their mixing ratios (except those of O_2 and O_3) are..."

P. 263, 3rd line below Section 10.4.1.2, change "...transparent to incoming solar radiation..." to "...transparent to incoming visible radiation..."

P. 263, 12th line from bottom, change, "...and certain wavelengths of outgoing infrared radiation cannot,..." to "...and no wavelengths of outgoing infrared radiation can,..."

P. 266, Table 10.6, change 10^{-8} cm^{-1} to 10^8 cm^{-1} in column heading under 0.25 ppmv NO_2.

P. 267, first line after title of Section 10.4.2, change "The only important gas-scattering..." to "The only gas-scattering..."

P. 268, Example 10.6, last line, change "visual range" to "meteorological range"

P. 270, 3rd line below Equation (10.32), change 11.5 to 10.

P. 274, replace Figure 10.19 with the following figure:
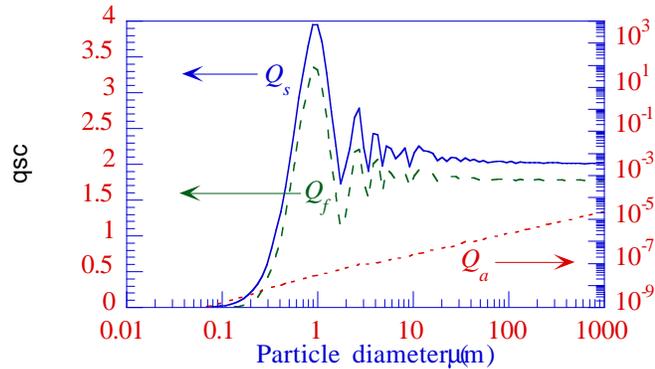
P. 274, Caption for Figure 10.19, change "(n_λ=1.34, κ_λ=0)" to "(n_λ=1.335, κ_λ=1.0x10^{-9})"

P. 275, just before Equation (10.41), change "...the scattering efficiency drops and then approaches another constant,..." to "...the scattering efficiency approaches another constant,..."

P. 275, Example 10.18, change "n_λ=1.34" to "n_λ=1.335."

P. 275, Example 10.18, Replace "Figure 10.19 shows....which is consistent with (10.41)." with "Hence, the scattering efficiency at $\lambda = 0.5$ μm, shown in Figure 10.19, decreases from 2 to 1.1 as the diameter approaches infinity. The absorption efficiency also approaches 1.1 at infinite diameter"

P. 275, 5th line from bottom, change "Figure 10.19 shows how...100 μm." to "Figure 10.19 shows how the absorption efficiency of water increases with increasing diameter when λ=0.5 μm, even though κ_λ=1.0 x 10^{-9} at this wavelength"

P. 277, Figure 10.21, Change caption to "Change of radiation intensity along a beam. A radiation beam originating from a dark object has intensity I_0=0 at point x_0=0. Over a distance dx, the beam's intensity increases due to scattering of background

light into the beam. This added intensity is diminished somewhat by absorption along the beam and scattering out of the beam. At point x, the net intensity of the beam has increased close to that of the background intensity."

P. 277, 12th line above Equation (10.43), change "...is the greatest visual range a person can see anywhere along a 180° horizontal arc." to "...is the greatest visual range a person can see anywhere along 180° of a horizontal arc around the horizon circle, but not necessarily in continuous sectors around the circle."

P. 279, 4th line from top, change "comparable to" to "comparable with"

Chapter 11

P. 298, 3rd line from top, change "Lightning and molecular collisions..." to "Lightning, changes in temperature, and molecular collisions..."

P. 300, 1st line below title for Section 11.1.1, change "...from volcanos and produced chemically..." to "...from volcanos, produced biologically, and produced chemically..."

P. 300, 1st line below title for Section 11.1.2, change "...has a typical mixing ratio of..." to "...has a mixing ratio of..."

P. 301, 8th line below Section 11.1.6 heading, change "...of NO_2 near sea level..." to "...of NO_2 just above sea level..."

P. 304, Equation (11.1), change $\lambda<410$ to $\lambda<420$

P. 304, 6th line after Equation (11.2), change "...of N_2, O_2, or N_2+O_2,..." to "...of N_2, O_2, N_2+O_2, or total air,..."

P. 308, immediately above Section 11.4.2, change "...and Pitts (1986))." to "...and Pitts 1986).

P. 309, 1st line after Equation (11.25), change "frequency factory" to "frequency factor"

P. 313, Figure 11.3, caption. Change the second occurrence of [a]HO_2NO_2 to [b]HO_2NO_2

P. 316, Example 11.4, change $\tau_{O(^1D)} = 1/k_r[M] = 2 \times 10^9 \, s$ to $\tau_{O(^1D)} = 1/k_r[M] = 2 \times 10^{-9} \, s$

P. 317, Problem 11.7, add $[N_2O] = 7.6 \times 10^{12}$ following $[HO_2\} = 1.0 \times 10^8$.

Chapter 12

P. 318, 6th line below title of Section 12.1, change "...isoprene and other high-molecular-weight terpenes..." to "...isoprene, a hemiterpene, and other terpenes..."

P. 319, 1st line below Equation (12.4), change "...compared to..." to "...compared with..."

P. 320, 10th line below title of Section 12.1.2, change "The OH concentration..." to "The daytime average OH concentration..."

P. 320, 1st line above Equation (12.9), change "The main free-tropospheric..." to "The primary free-tropospheric..."

P. 321, Table 12.1, change second occurrence of N_{OH} from $N_{OH} = 5 \times 10^6$ to $N_{OH} = 2 \times 10^6$

P. 321, Table 12.1 footnote, change "bisulfite" to "bisulfite radical"

P. 321, Table 12.1 footnote, change "CH_3COOH=methyl hydroperoxide" to "CH_3OOH=methyl hydroperoxide"

P. 322, 5th line past Equation (12.27), change "During the night, HONO is not produced chemically, since OH, required for its production, is absent at night." to "During the night, HONO is not produced from gas-phase reactions, since OH, required for its

production, is absent at night. HONO can be produced from gas-particle reactions during day or night."

P. 324, 3rd line below title of Section 12.1.7, change "...has enabled it to mix uniformly up to an altitude of 15-20 km." to "...has enabled it to mix uniformly up to the tropopause."

P. 324, 7th line below title of Section 12.1.7, change "...compared to..." to "...compared with..."

P. 325, 3rd line below title of Section 12.1.8, change "...these gases are 0-2.5 ppbv for ethane, 0-1.0 ppbv for propane, 0-1.0 ppbv for ethene, and 0-1.0 ppbv for propene..." to "...these gases are up to 2.5 ppbv for ethane, up to 1.0 ppbv for propane, up to 1.0 ppbv for ethene, and up to 1.0 ppbv for propene..."

P. 327, 1st line below title of Section 12.1.9, Change "...is a carcinogen and..." to "...is a carcinogen at high concentrations and..."

P. 330, 7th line before Equation (12.56), change "...removes a hydrogen atom..." to "...removes an atom..."

P. 333, 3rd line below Equation (12.64), change "...but often does not..." to "...but does not..."

P. 334, 3rd line from top, change "...have built up over..." to "...have increased over..."

P. 334, 5th line from top, change "...surface and 15-20 km..." to "...surface and tropopause..."

P. 337, last line, change "...95 percent was emitted as NO, and about 5 percent was..." to "...85 percent was emitted as NO, and about 15 percent was..."

P. 339, first line below footnotes to Table 12.3, change "...emitted ROGs in Los Angeles." to "...emitted organic gases in Los Angeles."

P. 341, Table 12.5, caption, change to "Estimated Lifetimes of Reactive Organic Gases Representing Alkanes, Alkenes, Alkynes, Aromatics, Terpenes, Aldehydes, and Ketones Against Photolysis..."

P. 341, Table 12.5, change "9.6" to "9.6 d" for lifetime of Acetone breakdown by OH in polluted urban air.

P. 343. Add an "M" over the first arrow in Reaction (12.91).

P. 344. Add an "M" over the first arrow in Reaction (12.94).

P. 347, 5th line from bottom, following "...and other terpenes.", add "Strictly speaking, **terpenes** are aromatic hydrocarbons that have the formula $C_{10}H_{16}$. Loosely speaking, terpenes include hemiterpenes, such as **isoprene** (C_5H_8), sesquiterpenes ($C_{15}H_{24}$), diterpenes ($C_{20}H_{32}$), etc.."

P. 347, last line, change "...some of its by-products do." to "...some of its byproducts last longer."

P. 348, last line, change "The isoprene-O_3 reaction proceeds along one of several pathways, including" to "When O_3 reacts with isoprene, it attacks isoprene at either end of either double bond:"

P. 351, first line past title of Section 12.2.7, change "In sum, photochemical..." to "Photochemical..."

P. 351, 4 lines after Section 12.2.7 heading, change "The radicals that break down..." to "The species that break down..."

P. 351, 6th line from bottom, change "Peak ozone mixing ratios in the stratosphere are usually greater..." to "Peak ozone mixing ratios in the stratosphere are always greater..."

P. 353, third line from top, change "Polluted urban regions are generally 0.5 to 1.5 km thick." to "Pollutants in urban regions generally mix to depths of 0.3 to 1.5 km."

P. 354, 2nd line from top, change "...from the troposphere or airplane emissions." to "from the troposphere."

P. 354, 3rd line from top, change "In the troposphere, N_2O is produced by lightning, emitted by bacteria in fertilizers, sewage, and the oceans, and emitted during combustion processes." to "In the troposphere, N_2O is emitted by bacteria in fertilizers, sewage, and the oceans, and emitted during biomass burning and automobile combustion."

P. 357, 3rd line above Equation (12.128), change "Non-CFCs have..." to "Non-CFCs, including HCFCs, have..."

P. 360, 3rd line below Equation (12.147), change "The presence..." to "It is believed that the presence..."

P. 364, 10th line from bottom, change "caled" to "called"

P. 365, 3rd line below Equation (12.152), change "When $ClONO_2$, N_2O_5, or HOCl, impinge..." to "When $ClONO_2$, N_2O_5, or HOCl impinges..."

P. 369, Equation (12.168) put the dots over O instead of over Cl in both occurrences of ClO.

P. 370, 2nd line from top, change "...to melt." to "...to melt and evaporate."

P. 371, Table 12.11, change "$\chi\chi_{O_3,m}$" to "$\chi_{O_3,m}$" in column label.

P. 371, Problem 12.3, change the question to "Write the rate expressions for the reactions (12.167) - (12.170), and write the first-derivative expressions for each species (except for O_2 and M) in the reactions (ignore the factor of two in the first reaction). Assume M is already included in the rate coefficients. What is the steady-state expression for the Cl concentration from the rate expression for Cl? If $T = 197$ K and $p_d = 25$ mb, calculate the rate coefficient of each of the kinetic reactions."

Chapter 13

P. 377, 2nd line from bottom, change "...expansion that..." to "expansion of a derivative that..."

P. 377, 2nd line from bottom, change "A first-order approximation of the explicit Taylor series expansion is the **forward Euler** solution, which is also explicit." to 'Dividing (13.7) by h and eliminating all terms of order h and higher gives a first-order approximation of an explicit Taylor series expansion called the **forward Euler**."

P. 381, 6th line from top, change "...similar to the backward Euler..." to "...similar to the linearized backward Euler..."

P. 388, 1st line above Equation (13.67), change "...matrix in (13.62)..." to "...matrix on the left side of (13.62)..."

P. 398, Table 13.4, change "CH_3CHO 1.6(10)" to "CH_3CHO ----   1.6(-10)"

P. 398, Table 13.4, add "----" to second column for HBr.

Chapter 14

P. 401, 7th line from bottom, change "Toon and Pollack (1976) quantified..." to "Toon and Pollack (1976) estimated..."

P. 402, 4th line from top, change "...similarly showed that sulfate particles with more than 5 percent elemental carbon cause a much larger cooling than sulfate particles with less than 5 percent..." to "...similarly found that sulfate particles with less than 5 percent elemental carbon caused a much larger cooling than did sulfate particles with more than 5 percent..."

P. 402, 6th line from top, change "...absorbing aerosols causes..." to "...absorbing aerosols cause..."

P. 403, 3rd line from top, change "...account for observed..." to "...account for excess..."

P. 403, last line, change "The most abundant..." to "At high relative humidities, the most abundant..."

P. 409, Equation 14.15, Change $v_{i,q}$ to $v_{q,i}$ twice in the equation.

P. 414, Table 14.2, change $\overline{D}_S$ to $\overline{D}_A$

P. 415, Equation (14.31), change Δd_i to Δr_i.

P. 415, Immediately after equation (14.31), change "where Δd_i is the diameter width..." to "where Δr_i is the radius width..."

P. 416, Table 14.3 column headings, change "Number Conc." to "Number conc."

P. 416, Table 14.3, change Liquid water content = 1.17 to 0.117 g cm^{-3} and Number conc. = 0.01 to 0.001 particles cm^{-3} for Light rain.

P. 416, Example 14.7, change "seze" to "size"

P. 416, Example 14.7, change "between 14 and 16 μm in diameter" to "between 14 and 16 μm in radius"

P. 416, Example 14.7, change "...and the diameter width of the bin is $\Delta d_i = 2$ μm." to "and the radius width of the bin is $\Delta r_i = 2$ μm."

P. 422, Problem 14.4, Table, reorder stage numbers from $j = 1...8$ to $j = 8...1$

P. 422, Problem 14.4, Table, change "between d_j and d_j-1" to "between d_j and d_j+1"

Chapter 15

P. 423, 9th line below title of Section 15.1, change "Over time, a layer..." to "A layer..."

P. 424, 22nd line from bottom, change "Ericksson" to "Eriksson"

P. 424, 22nd line from bottom, change "...in the drops decreases..." to "...in the drops sometimes decreases..."

P. 424, 21st line from bottom, change "...by dehydration or acidification..." to "...by acidification..."

P. 424, 20th line from bottom, change 9 lines of text between "Dehydration...of their chloride." to "**Acidification** occurs when acids, such as sulfuric and nitric acid, enter a drop. The anions from these acids (e.g., HSO_4^-, SO_4^{2-}, NO_3^-) decrease the solubility of chloride (Cl^-), forcing chloride to evaporate as HCl. Hitchcock et al. (1980) observed that some marine aerosols that react with nitric and sulfuric acid lose up to 100 percent of their chloride. The size of a sea-spray drop is also affected by dehydration. **Dehydration** occurs when water from a drop evaporates due to the decrease in relative humidity between the ocean surface and marine boundary layer. Dehydration increases the concentration of solute with the drops. If acidification occurs together with dehydration, gas-phase HCl rapidly becomes undersaturated at the drop surface and evaporates quickly. Sodium does not become undersaturated

at the drop surface because its saturation vapor pressure is much lower than that of HCl.

P. 431, 4th line above Equation (15.11), change $\left(N_x N_y\right)\exp\left(-\Delta G^*_{hom}/k_B T\right)$ to

$$\left(N_x + N_y\right)\exp\left(-\Delta G^*_{hom}/k_B T\right)$$

P. 433, 4th line below title of Section 15.2.3, change "...nucleation generally produces..." to "...nucleation events can produce..."

P. 434, Example 15.1, change the $J_{hom} = 2.6 \times 10^{-5}$ to $J_{hom} = 4.0 \times 10^{-3}$

P. 434, Example 15.1, change the $J_{hom} = 3.1 \times 10^{-5}$ to $J_{hom} = 3.1 \times 10^{5}$

P. 434, Example 15.1, second-to-last line, change, "...10 orders of magnitude." to "eight orders of magnitude..."

Chapter 16

P. 445, 2nd line from top, change "...in comparison to..." to "...in comparison with..."

P. 449, 1st line after Equation (16.38), change "...kernel." to "...kernel, derived from (16.23) and (16.24) assuming $r_i=r_j$ and $G_i=1$.

Chapter 17

P. 449, Equation (16.39), change $\exp\left(\upsilon_i/\upsilon_p\right)$ to $\exp\left(-\upsilon_i/\upsilon_p\right)$ in the equation.

P. 450, Figure 16.6 caption, change $n_{T,t-h}=10^6$ cm^{-3} to $n_{T,t-h}=10^5$ cm^{-3}.

P. 453, 2nd line before Equation (17.1), change "...**of diffusion**,..." to "...**of diffusion**, which applies to the continuum regime (Kn<<1),..."

P. 457, 3rd line below Equation (17.18), change "...**geometry** is a function..." to

"...**geometry** accounts for noncontinuum-regime growth and is required, since

(17.1) applies only to the continuum regime. The correction is a function..."

P. 464, 7th line from bottom, remove, ", and the ability of a particle to absorb depends on

its absorption efficiency"

P. 471, Footnote for Table 17.3, change "0.00833" to "0.000833"

Chapter 18

P. 477, 2nd line from top, change "...composition of the solution..." to "...composition or

temperature of the solution..."

P. 478, 5th line from bottom, change "H_2CO_3(aq),..." to "H_2CO_3(aq) [which originates

from CO_2(aq)],..."

P. 478, 3rd line from bottom, change "HCl(aq),..." to "At pHs>-1, HCl(aq),..."

P. 479, Second line below Equation (18.7), change "busulfate" to "bisulfate"

P. 480, last line, change "kilogarm" to "kilogram"

P. 484, 1st line from bottom, change "...with large..." to "...with moderate or large..."

P. 485, third line after Equation (18.39), change $\gamma_{HNO_3^-}$ to $\gamma_{NO_3^-}$

P. 487, 7th line from bottom, change "principals" to "principles"

Chapter 19

P. 512, 15th line from bottom, change "...change of mass of a particle..." to "...change of

concentration of a particle component..."

P. 513, Figure 19.1 caption, change "...comparison of gas concentrations..." to

"...comparison of aqueous-phase concentrations..."

P. 514, 8th line from top, change "...can absorb only..." to "...absorbs proportionately less

of all four components and absorbs only..."

P. 514, 14th line from the top, after "...respectively." add "Since oxidation of SO_2 by O_3

reduces pH, H_2O_2 often becomes the most important oxidant of SO_2 when the

initial pH > 6."

P. 514, 16th line from the top, change "Liang and Jacobson (1998)" to Liang and Jacobson

(1999).

P. 517, 1st line from top, change "...as Fe(III). Although Fe(II)..." to "...as Fe(III),

although these values depend highly on location. Whereas Fe(II)..."

P. 517, 3rd line from top, change "...does not readily catalyze..." to "...does not catalyze..."

P. 517, 5th line from top, remove ", or in the form of soluble sulfate and hydroxy

complexes, which do"

P. 517, 6th line from top, change "...is primarily in the form of..." to "...is mainly in the

form of..."

P. 517, 1st line after Equation (19.13) change "Carbonyl..." to "Slightly-soluble

carbonyl..."

P. 517, 2nd line after Equation (19.13) change "...also react with S(IV) in solution." to

"...also react in solution."

P. 519, 3rd line from top, change "Other soluble organics..." to "Other slightly-soluble

organics..."

Chapter 20

P. 529, Table 20.2, footnote, change "...in Fig. 20.3." to "...in Fig. 20.3, which were calculated for near-surface conditions."

P. 529, 14th line below Table 20.2, change "...1 km." to "...1 km for near-surface conditions."

P. 530, 11th line below Equation (20.10), change "...and air density." to "...air density, and atmospheric stability."

P. 532, Equation 20.15 add a power to the -1 so that the equation reads,

$$R_s = \left(\frac{1}{R_{stom} + R_{meso}} + \frac{1}{R_{cut}} + \frac{1}{R_{conv} + R_{exp}} + \frac{1}{R_{canp} + R_{soil}} \right)^{-1}$$

Chapter 21

P. 541, 10th line from top, change "...form during..." to "...form frequently during..."

P. 541, 16th line from top, change "...when volcanic aerosols or polar stratospheric clouds are present." to "...when polar stratospheric clouds or aerosols from recent volcanic eruptions are present."

Appendices

P. 579, Footnote to Table B.2., change "from $\lambda = 0.1475$ to 0.1575" to "from $\lambda = 0.1475$ to 0.1525"

P. 579, Footnote to Table B.2., change "$\overline{F}_{s,\lambda}, \Delta\lambda =$ "to "$\overline{F}_{s,\lambda} \Delta\lambda =$"

P. 579, Footnote to Table B.2., change "0.005 mm" to "0.005 μm"

P. 591, Table B.4, Reaction 12, change "(P) 0.85" to "(P) 0.55"

P. 592, Table B.4, Reaction 22, change 4.80×10^{11} to 4.80×10^{-11}

P. 592, Table B.4., Reaction 35, change $300/T^{3.2}$ to $(300/T)^{3.2}$

P. 592, Table B.4., Reaction 37, change $e^{2000/T}$ to $e^{-2000/T}$

P. 592, Table B.4., Reaction 38, change $300/T^{1.6}$ to $(300/T)^{1.6}$

P. 592, Table B.4., Reaction 41, change 9.00×10^{-31} to 9.00×10^{-32}

P. 592, Table B.4., Reaction 50, change 2.30×10^{-12} to 1.50×10^{-11}

P. 593, Table B.4., Reaction 51, change 3.90×10^{-12} to 2.30×10^{-12}

P. 593, Table B.4., Reaction 61, change 5.90×10^{-14} to 5.90×10^{-13}

P. 594, Table B.4., Reaction 106, change e^{-1550} to e^{-1600}

P. 597, Table B.4, Reaction 222, align footnote symbol "f"

P. 597, Table B.4, Add the heading "Chlorine Chemistry" above Reaction 244

P. 598, Table B.4, Align the rate coefficients for Reactions 249, 267, and 269

P. 598, Table B.4., Reaction 275, change $ClOO \to Cl+O_2$ to $ClOO+M \to Cl+O_2+M$

P. 599, Table B.4., Reaction 291, change $e^{-40/T}$ to $e^{40/T}$

P. 600, Footnote (a) to Table B.4., change "...for which the reaction rate is" to "...for which the reaction rate coefficient is"

P. 604, Table B.7, Reaction 48, change 1.38×10^{12} to 1.38×10^{2}

P. 605, Table B.7, Reaction 54, change 1.91 to -1.91

P. 610, Table B.10, change "NH_4HSO_4" to "$^D NH_4HSO_4$"

P. 611, Table B. 11, change "R_i" to "R_{min}" five times in left-most column

P. 611, Table B.11, footnote, change "(Wesely 1989)" to "Wesely (1989)"

P. 621, References, Change the reference for "Jacobson M. Z. (1998c)...*J. Appl. Meteorol.*, in press." to "Jacobson M. Z. (1999)...*J. Appl. Meteorol.* **38**, 607-616" (same title)

P. 624, References, Change the the reference for "Liang J. and Jacobson M. Z. (1998)...*J. Geophys. Res.*, in review" to "Liang J. and Jacobson M. Z. (1999)...*J. Geophys. Res*. **104**, 13,749-13,769**"** (same title)