Errata for: Global Atmospheric Circulations
by R. Grotjahn
dated version: 18 February 1999

Dear reader:

To make the book, I produced page proofs by TEX, then sent the publisher electronic TEX files rather than paper. While this has advantages, it can have disadvantages. My book had more than 60 files. Unfortunately, several incorrect files, mainly early drafts, were sent by mistake. This led to some sections of the final product having lots of errors. This errata is my best recourse unless the book is ever reprinted. I encourage you to inform other readers that this errata exists and that I distribute it for free. On one of my web sites, I offered earlier errata versions, but those are not as good as this copy (*the web files cannot duplicate specialized math symbols or Greek letters*).

The entire book has not yet been checked. This version considers about 4/5 the book. (Some of chapter 7 has not yet been checked.)

This document supercedes earlier errata sheets (dated July 1994, February 1995, April 1996 and July 1998). Please replace any earlier errata you may have with this version. This version is complete.

I maintain an internet home page for information related to my book. The URL is (as of 3/98):

http://www-atm.ucdavis.edu/~grotjahn/book/book.html

I also maintain web pages for the course I teach from the book. Readers may wish to examine the lecture outlines on the web. My lectures on book sections 4.2 and 6.5 are particularly improved over the book. A summary table of energy flow improves upon figure 4.33. And I have another on momentum. Instructors are encouraged to contact me if they are interested in seeing typed lecture notes. The URL (as of 5/98) is:

http://www-atm.ucdavis.edu/~grotjahn/course/atm240.html

Thank you for your patience,
-Richard Grotjahn

Page corrections, comments and clarifications

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ix preface date changed by publisher; it should be 9/91. no material after 8/91 was included in this book.

18 ASDAR has horizontal resolution placed in column for vertical resolution

19 table 2.1: middle 3 columns for dropsondes should be shifted right by 1 column.

26 middle of page: buoys are dropped, not balloons

40 C_1 and C_2 are not defined. Actually, I would redo this discussion to include Planck's, Boltzmann's, and the speed of light constants. I would also include discussion of other relevant expressions, such as Wien's law, etc. But, for the current printing:

$C_1 = \pi\ 1.19 \times 10^{-16}$ Wm^2 $C_2 = 1.44 \times 10^{-2}$ mK

E_i (perhaps call it E_λ since E_i in eqn 6.5 means something different) is MONOchromatic irradiance (from isotropic radiance in one hemisphere)

44 What do the "100 units" of fig. 3.4 equal? If the solar constant is 1368 W/m2, then the "100

units" equals 1368/4 = 342 Wm^{-2} . The factor of 4 is the ratio of the surface area to cross sectional area of the earth.
Also, recent references vary in their estimates, for example:
1380 — Wallace & Hobbs (1977); 1360 — Peixoto & Oort (1992);
1370 — James (1994) 1368 — Kiehl & Trenberth (BAMS, 2/97)
Also, some values in Fig. 3.4 differ significantly from corresponding values in Kiehl & Trenberth (1997). (And both of those from the 11/95 BAMS cover! etc.)

45-46 eqn (3.2) & fig 3.5 are not "wrong" but the "graybody" aspect can be done better. (I plan to redo it.) E of the ground might be E_a + 21. Note 2 typos: the summation in both cases should start at n=0; also, that summation = 3.333, not 3.28. Another explanation of the model is: 51 units absorbed by the ground, of which 51 units must be emitted in the net. The 21 (net) includes downward IR from the 20 units absorbed by clouds & clear air. From the 51 units 29.7 units come back down which the ground gains then looses soley as radiation. Thereafter 70% of ground emission comes back down each time (20.8, then 14.56, then 10.192, etc.)

66 (i) contour interval in fig 3.16b appears to be 1.0, but it's 0.5 in 3.16a.
(ii) the figure may be misleading -- if you use [v] to calculate a mass flux across 10N during DJF and assume that half that rate continues for 90 days (say) then the average N. Hemis. SLP change is ~100 mb! Clearly mass is not balanced.

67-69 Fig. 3.17 was intended to be a reproduction of Fig. 3.19 in Newell et al. (1972) which would be consistent with the eqns. (3.4) and (3.5). (Note sign error in Newell et al.'s corresponding formulae). Therefore my 3.17 would indeed show ψ, which Newell et al. plot as their fig. 3.19. ψ should have units mass/time from (3.4).
Unfortunately, I reproduceed the wrong figure from Newell et al. Notice the figure includes a "chi" label in the upper right corner which reveals that I inadvertently used fig. 4.13 from Newell et al. (1972). What is shown is a mass streamfunction, suitable for showing fluxes of momentum. It is also clear from the units of "chi" that it differs from ψ. We cannot deduce meridional or vertical motion directly from "chi" since "chi" includes various momentum fluxes which mix together the velocity components; to see this point, note the partitioning of momentum flux in (4.5) on p 92 of my book.
Having said that, one notices that the shapes in Newell et al. figs. 3.19 & 4.13 are quite similar. If one assumes the shapes to be the same, then a simple magnitude correction could be made to obtain the correct units, approximate amplitude, and roughly correct shape. (Newell et al. use cgs, I shall use mks units). Multiply the numbers in my fig 3.17 by A; where $A \sim 3.5 \times 10^{-17}$ (kg sec)/(gm cm^2) so that the "100" contour in my fig 3.17 becomes 3.5×10^{10} kg/s.

81 double maximum ICZ cloud cover

91 (i) continuity equation used to get (4.3). (ii) Also: lower case u in (4.1) And also:
(iii) Instead of calling M absolute "angular velocity" a more descriptive label might be that M be absolute angular momentum per unit mass. The new label has the correct units (= L*L/S). (Holton's 1992 text, p. 328, uses the suggested label.)

96 Fig 4.3: The units should have 10 raised to the 18th power.

97 in next two eqns AFTER (4.11): tanϕ term already included in second term.

100 in eqn (4.16b) delete "R"; in (4.17) insert "+" before "v/R" in term (A)

100-103 =0 should NOT be on the RHS of eqns: 4.16a, 4.16b, 4.19a, 4.19b, top of p. 102, and 4.20.

101 Eqn (4.18) needs "+" sign before v/R in term (B); 3rd integrand in eqn. (4.19a) should be: g [u $\partial z/\partial x$] dm; similarly, 3rd integrand in eqn. (4.19b) should be: g [v $\partial z/\partial y$] dm.

108-109 The discussion of fig. 4.12 could be more clear. First, a key term in the K_Z tendency eqn (4.16a) is the first part of the first integrand on the RHS. Expanding with the chain rule gives two parts which partly cancel on the poleward side of the jet and reinforce each other on the equatorward side. Though convergence in the figure is poleward of the jet, geometry increases zonal KE close to the jet. Second, eddy fluxes of heat oppose those eddy momentum convergences poleward of the jet leading to "Ferrel" circulations which both oppose building the jet further poleward and which limit the meridional extent of the Hadley circulation.

109 line 7: a word is missing: "to *be* more"

98, 100, 105, 110 Some additional comments regarding figs. 4.7 & 4.12, using the zonal mean KE eqn (4.16a): (i) The derivation of (4.16) relys upon (4.14) which may be reasonable when considering the vertically averaged information in fig. 4.7. As for fig. 4.12e & f, one is better off not using (4.14), but using the form where momentum fluxes are differentiated (similar to (4.12).
(ii) The [u]/R profile may differ strongly from [u] shown in fig. 4.12. Newton (1972, fig 9.8) shows the latitudinal profile of annual and vertical average [u]/R. It has a max near 43 N.
(iii) A further sense of the picture in fig. 4.12 might be gained by examining the contributions to zonal flow KE tendency, as might be deduced from (4.16a). One may focus on Northern Hemisphere, winter, 200 mb level conditions near the jet stream, using data tabulated in Oort and Peixoto (O&P, 1983). The calculation may be approximated by finite differences and the estimates suggest the following: that KE is gained by Hadley cell fluxes, but lost by eddy momentum flux divergence in the tropics. In middle latitudes the opposite: eddy momentum convergence creates KE while the Ferrel cell reduces it. Using O&P's vertical velocities, the eddy vertical momentum term is comparable in magnitude to the horizontal eddy momentum term.

110 Side note: there is greater seasonal change in the N. Hemis. so, the atmosphere has greater westerly momentum in DJF than in JJA. Since total angular momentum of the air, ocean & solid earth may be assumed conserved, greater atmospheric westerly momentum means less solid earth rotational momentum. Thus the length of day (LOD) during DJF is slightly longer than in JJA. (by only a few milliseconds! and it is observed!)

113-115 A motionless reference state is the simplest case, but not necessarily a "must". A reference state with motion may be possible: tilted surfaces of Θ & P imply horizontal velocities which may not be balanced (must avoid inertial oscillations).

120 γ in (4.25) should have a —σ overbar. Average in equation just before (4.25) is applied separately to P, Θ, and γ.

121 Table 4.1 uses data from a cross section at 75 W only. APE/unit area is found for 3 different domains. Since the calculation of A uses an average P value that is raised to a non-unity power, the "global" value will not necessarilly equal the average of the two hemispheric values. See p. 374 in D&J (1967). Also, the units should be: J/m^2

123 (i) "dp" should not be in boundary integral at top of page; (ii) in eqn (4.27) (Θ/P^{κ}_{oo}) term on last line should not be raised to a power; (iii) "}dPdS" missing before "+" on last line

124 (i) 3rd integral in (4.29) needs g/C_p out front and (Θ/P^{κ}_{oo}) term should not be raised to a power; (ii) delete second "-" sign in first line of "W" eqn.

128 delete sentence on line -8 (count from page bottom).

130 (i) fig. 4.17 includes $\partial Z/\partial\Theta$ term which should be mentioned in caption. (already in text)
(ii) The units in fig. 4.17 appear to be m/K. (D&J, 1967, do not state the units)

132 strong surface winds, not just T_A-T_S difference makes sfc fluxes (↑) in fig 4.19 large.

130 The units in fig. 4.17 appear to be m/K. (D&J, 1967, do not state the units)

133 The upper panel in Figure 4.19 has dashed contours of Θ, not "ϵ"

137 Note: divide “CKA” on this page by g (see eqn. 4.36) to obtain A_E to K_E conversion.

138 lines 14-15: shifting the mass up or down uniformly defines a new reference state.

139 no "ln" should appear in (4.43)

141 In discussion of fig 4.23d, Θ surfaces are distorted, not crossed by air motions.

141 (bottom) Terms C are more like divergences of energy due to motions: net transfer of heat or momentum out of the domain.

145 (i) eqn (4.70): each integral should have a "dM"; (ii) on second line of (4.70): first integral needs g added to integrand, last integral should have g removed.

149 Units in fig. 4.26: 10^5 J/m^2 for energy; W/m^2 for conversion, generation, & destruction terms

154 Caption of fig. 4.29 should refer to equation (4.70)

156 A general comment about fig. 4.31: the lower level max seems too far north in the N. Hemis. winter. Other figs. like 7.22c and 5.17a seem more consistent.

157 In fig. 4.32 the plotted values of CK have opposite sign to the CK def in (4.66).

167 "both" on line 10 may be too strong. The pattern is too weak to tell in S. Hemis.

176 Plate 1: the figs are reversed from caption: July is above, January is below

177 line -9: delete redundant phrase: "...in the subtropics."

183&185 The SPCZ is described as a NW-SE cloud band. But it may be more standard for the SPCZ label to include the western extension of this diagonal cloud band. The western extension is more zonally-aligned and extends west to roughly 130E and paralleling the equator. See Vincent, 1994, MWR, 122:1949-1970 for a review.

193 line 18: ...from Figures 5.7a and 5.9a...; line 20: note that the negative value is only on the west side of the tilted trough.

195 (line 6) In reference to fig 5.17c: note the large downstream maxima from semi-permanent lows. Since sfc (fig 5.3) and 700mb thermal troughs are further west (fig. 5.4) the persistent wind yield persistent heat fluxes.

198 caption should indicate $(\omega')''(T')''$ with an overbar

207 2-dimensional isotropic turbulence in the enstrophy-cascade range is expected to vary with wavenumber raised to the -3 power. (Not the -5/3 power stated in the book; which is presumed to apply to 3-dimensional turbulence.) Such a power law, when plotted on Fig. 5.21 is nearly parallel to the kinetic energy spectrum for $n > 12$. So, the spectrum **DOES** look similar to expectations for 2-dimensional turbulence. (To draw a -3 power law line, make it parallel to a line connecting the "n=10" point to a point 3 powers of 10 up from the bottom on energy scale, e.g. the top left corner of Fig. 5.21a, or the "10^1 " in Fig. 5.21b)

220 (i) In (6.3) "z" and "infinity" are limits of the integral. And (ii) First eqn with β ("beta") in it: should have a + ("plus" sign) in front of the I.

223 "tau" should have subscript "1" in eqn (6.19). Also: $\sigma = 5.67 \times 10^{-8}$ Wm^{-2} K^{-4} is not specified.

229 One might include a discussion of cloud feedback conceptual models, similar to Wielicki et al (1995, BAMS, p 2129-2131) here.

234 replace [ ] in eqn (6.26) with { } to avoid confusion in notation. In eqn (6.27) are these typos: 4 is missing, 10^{-4} should be just 1, friction loss integral should approximately equal 6.6×10^{-2} N-s per second (a rate of change). In next eqn AFTER (6.27) 2nd integral should be designated dArea dP. In (6.28): replace power 7 with power 5, replace 10^{-4} with 1, result should equal 4×10^{4} N-s.

236 line 1-3 delete last sentence of paragraph. Replace [ ] in (6.33) with ( )

237 line -7: ...is almost $\sqrt{2}$...

241 The Grotjahn et al. 1992 reference appeared in 1995. (See page 398 below)

244 (i) 4th line: g should not be in definition of DSE. (ii) Fig 3.16 shows moist static energy (MSE), removing the Lq part obtains DSE. DSE < MSE at lower levels but MSE and DSE are essentially the same at high levels. One might use MSE and compare the flux F with summing the latent and sensible values reported in fig. 3.9. Alternatively, MSE values at 20N could be used to estimate sensible heat flux since the latent heat flux is ~zero there. For a mass flux with [v]=0.5 (say) in the 400-100 mb layer and [v]=1 in the 1000-850 mb layer (for mass balance), F=3x10^15 W which compares favorably with 2.5x10^15 W in fig. 3.9.

254-255 the ellipticity can be estimated using fig 3.15.

271-275 Fig. 6.19a (@ 500mb) should be used in combination with 5.16a (a similar quantity, @ 200 mb) to deduce vertical derivative in the K-E eqn forcing. Hatched areas of fig 6.21 have $\partial\chi/\partial p > 0$ since $\chi<0$ @ 200 but $\chi>0$ @ 500 mb there.

281 in both (6.52) & (6.53) the $\tan\phi$ terms should be deleted

286-297 The CISK mechanism is not the only explanation. While the discussion in this chapter is intended to show how feedback between vorticity and heating results in the smallest scale (i.e. convection) being selected (i.e. most unstable), readers may want to examine another mechanism: CAPE. In CAPE parcels gain moisture as they move equatorward becoming progressively more convectively unstable.

301 (7.8) follows from (7.7) using (4.51)

318 replace p_0 in (7.27), (7.28) and (7.30) with RT_0. T_0 is surface temperature, R is gas constant

332 wrong sign for the 2nd term on RHS of (7.59) -d/dx(v'du/dx)

333 (i) wrong sign for the 5th term on RHS of (7.61) -d/dx(v'du'/dx) (ii) inline divergence equation on line 7 (between 7.61 and 7.62) needs a minus sign on either the RHS or LHS.

372 lines 20-21: a word is missing: ...jet *maximum* not changed...

385 line 5: some may argue about GCMs not forming hurricanes. Manabe et al (J.Atmos.Sci., **31**,43-83) find hurricane-like features which are broader & weaker than observed ones due to the grid resolution. Resolution is partly my point. It is unclear if such weak approximations move nonlinearly in a similar way to real typhoons.

398 (i) Grotjahn (1991b) reference missing journal: Geophys. Astrophys. Fluid Dyn. (ii) The Grotjahn et al "1992" reference appeared in 1995: Grotjahn, et al (same authors) 1995, J. Atmos. Sci., 52:754-763.

409 Rossow & Schiffer 1991 reference should have ISCCP

Items noticed by readers (Thank you!)

*Item noted in I. James review:

36 Ian says the rotation rate of Jupiter is 9.925 hrs. I thought it was unclear if Jupiter even has a “surface”, let alone figuring out how fast it rotates, hence my original wording...

*Items noted in M. Hantel’s review:

87-88 (note: my book manuscript was completed 8/91) more recent, and presumably more accurate moisture-related charts exist. For example, charts in Peixoto & Oort’s 1992 book differ slightly from mine:

My 3.28a — > P&O figs 7.25c & 7.27 & Table 7.1 (p. 168-170)
my 3.28b — > P&O figs. 12.12a (p. 292)
half of my 3.29a — > P&O fig 7.27 (p. 169)
half of my 3.29b — > P&O fig 7.25c (p. 168)
half of my 3.29c — > P&O fig 12.12a (p. 292)

109 Fig. 4.11 has N and S reversed.

386 As to why one might make the indicated partitionings, (i) existing maps and (ii) ease of depiction are mentioned here. One could remind the reader of the discussion on p. 37: (iii) observed zonal orientation of properties. Perhaps also point out (iv) how the mathematics simplifies by removing

(most) zonal derivatives from budget equations (mountain torque an exception).