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Donald Rapp

Assessing Climate Change

Temperatures, Solar Radiation
and Heat Balance

Third Edition

 Springer

PRAXIS 

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South Pasadena, CA
USA

Published in association with Praxis Publishing Chichester, UK

ISBN 978-3-319-00454-9 ISBN 978-3-319-00455-6 (eBook)
DOI 10.1007/978-3-319-00455-6

Library of Congress Control Number: 2014943407

Springer Cham Heidelberg New York Dordrecht London

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Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Contents

1. Long-term climate change	1
1.1 Weather and climate	1
1.2 Time scales to characterize climate	2
1.3 Factors that affect long-term climate	3
1.3.1 Variability of solar luminosity	3
1.3.2 Variations in reflected solar flux	4
1.3.3 Variations in the Earth's orbit	9
1.3.4 Effect of greenhouse gases on radiant emission by the Earth	10
1.4 Ancient climates and CO ₂ concentration	16
1.4.1 Summary	16
1.4.2 Introduction	17
1.4.3. The transition from the LGM to the pre-industrial era	21
1.4.4 Paleo climates and CO ₂	30
2. Temperatures during the past few millennia	39
2.1 Use of proxies to estimate historical temperatures	39
2.2 Proxies and climate	40
2.2.1 Processing proxy data	40
2.2.2 Challenges in using proxies	41
2.2.3 Combining multiple proxies	41
2.3 The Little Ice Age and the medieval warm period	43
2.3.1 Proxy evidence for the LIA and the MWP	43
2.3.2 Anecdotal inferences on the MWP and the LIA	49
2.3.3 Challenges to the notion of the LIA and MWP	51
2.4 Global and hemispheric average temperatures in recent millennia	57
2.4.1 The "MBH" model	57
2.4.2 Other related models	60
2.4.3 Fallacies in reconstruction of millennial temperatures	60
2.4.3.1 The fallacy of choosing the wrong mean	62

2.4.3.2	Hiding the decline	70
2.4.3.3	Sparse data set	75
2.4.3.4	Lack of uniqueness	75
2.4.3.5	Other criticisms	77
2.4.3.6	The Wegman Report	78
2.4.3.7	The <i>paleoclimatic cabal</i>	84
2.4.3.8	The <i>climate alarmism cabal</i>	89
2.4.4	Proxy analysis	95
2.4.5	Evidence for the MWP and the LIA	105
2.4.6	Asian climate records.	109
2.4.7	Regional approaches to the MWP and the LIA	114
2.4.8	Borehole measurements	117
2.4.9	Arctic environment change	120
2.4.10	How reliable are proxy methods?.	123
2.4.11	The <i>paleoclimatic cabal</i>	128
2.4.12	The blogs.	133
2.5	Conclusions on millennium temperature history	139
3.	Temperatures in the past century	143
3.1	Near-surface land measurements.	143
3.1.1	Introduction	143
3.1.2	Quality and reliability of land temperature measurement networks	145
3.1.3	Urban Heat Islands (UHI).	156
3.2	Ocean temperature measurements.	166
3.3	Troposphere temperature measurements.	172
3.4	Measured Earth, regional, and local surface temperatures.	174
3.4.1	U.S. surface temperature measurements.	174
3.4.2	Global and hemispheric surface temperatures.	179
3.4.3	Troposphere temperatures	191
3.4.3.1	Measured troposphere temperatures	191
3.4.3.2	Temperature plateau: 1998 through 2012.	192
3.4.3.3	Climate: El Niños and volcanic eruptions vs. CO ₂	197
3.4.3.4	Tropospheric and surface temperatures	199
3.4.4	20th century climate and El Niños.	205
3.4.5	The 1940–1978 temperature dip: effect of aerosols	214
3.5	Mountain glaciers as climate indicators	221
3.6	Antarctic and Arctic temperatures	229
3.6.1	Antarctic temperatures.	230
3.6.2	Arctic temperatures	235
3.7	Ocean temperatures	244
3.8	Utility of a single global temperature	248

4.	Global scores, subjective science, and climatologists	251
4.1	Global scores	251
4.2	Dealing with subjective science	254
4.2.1	Nature of subjective science—emergence of consensus	254
4.2.2	How consensus becomes orthodoxy	258
4.2.3	Counting adherents to the orthodoxy	259
4.2.4	Climate science and determinism	261
4.2.5	Implications of uncertainty and extreme events	265
4.3	Hyperbole on impacts of global warming	267
4.4	Spreading the gospel	269
4.5	Climatologists	273
4.6	The golden rule	281
4.7	The lunatic fringe	283
4.8	The role of Google	284
5.	Variability of the Sun	287
5.1	Solar irradiance	287
5.1.1	Introduction	287
5.1.2	Measurements of TSI in space since 1978	290
5.1.3	Short-term TSI models	291
5.1.4	Long-term TSI models	292
5.2	Aspects of solar variability	293
5.2.1	The solar cycle	293
5.2.2	Sunspots	293
5.2.3	Faculae	294
5.2.4	Sunspot indices	295
5.2.5	Estimation of sunspot activity from proxies	298
5.2.6	Diameter of the Sun	299
5.2.7	Indices of solar activity	300
5.2.8	Effect of the Sun–Earth distance	300
5.3	The Maunder Minimum: John Eddy’s study	301
5.3.1	Historical telescope observations of sunspots	301
5.3.2	Historical records of aurorae	302
5.3.3	Historical visual observations of sunspots	302
5.3.4	¹⁴ Carbon in tree rings	303
5.3.5	The solar corona	303
5.3.6	Beckman and Mahoney on Eddy’s work	304
5.3.7	Eddy’s conclusions	305
5.4	Historical sunspot levels and recent solar inactivity	305
5.5	Solar cycle duration	310
5.6	Reconstructing TSI in the past	313
5.6.1	Reconstructions based on sunspots, solar cycles, and solar activity	313
5.6.1.1	Introduction	313
5.6.1.2	Overview of Hoyt and Schatten	314

5.6.2	Constant quiet Sun models	316
5.6.2.1	CQSM based on sunspot number	316
5.6.2.2	CQSM based on sunspot area and cycle duration	321
5.6.3	The MM temperature model	324
5.6.4	Stellar Ca HK index models	327
5.6.5	Solar cycle duration model	337
5.6.5.1	The “Sun Melody”	337
5.6.5.2	Danish Meteorological Institute studies	339
5.6.5.3	Hoyt and Schatten model	343
5.6.6	Coronal source flux model	345
5.6.7	TSI reconstructions based on cosmogenic isotope proxies	347
5.6.7.1	Introduction	347
5.6.7.2	Reconstruction of TSI from cosmo-nuclide production proxies	349
5.6.7.3	Projections for the Holocene	351
5.6.8	Temperature changes driven by the Sun	356
5.6.8.1	Global climate models	356
5.6.8.2	Climate sensitivity parameter	358
5.6.8.3	Solar activity and climate change	363
5.7	Conclusions on TSI	363
5.8	Solar intensity at ground level	367
6.	The Earth’s heat balance and the greenhouse effect	369
6.1	The greenhouse effect	369
6.1.1	Terrestrial examples	369
6.1.2	Simplistic models of the Earth	371
6.1.3	More realistic description	373
6.1.4	Absorption by greenhouse gases	376
6.1.5	Carbon dioxide as a greenhouse gas	379
6.1.6	Methane as a greenhouse gas	380
6.1.7	Water vapor as a greenhouse gas	381
6.2	The Earth’s heat balance	392
6.2.1	Introduction	392
6.2.2	Kiehl and Trenberth analysis	392
6.2.3	Stephens <i>et al.</i> ’s model	398
6.2.4	Miskolczi’s model	400
6.2.5	Heat balance of the Earth from 1950 to 2005	401
6.2.6	Albedo and emissivity of the Earth	405
6.2.6.1	Albedo of the Earth	405
6.2.6.2	Ocean emissivity	407
6.2.7	Simple models	407
6.2.7.1	Lindzen’s adaptive infrared iris—cloud feedback	407
6.2.7.2	Willis Eschenbach’s thermostat model	410
6.2.7.3	Spencer and Braswell’s model	411

6.2.7.4	Trends in middle- and upper-level tropospheric humidity	416
6.2.8	Heat capacity, time constant, and sensitivity of the Earth's climate system	416
6.2.9	Heat content of the oceans	420
6.2.10	Influence of human activities	430
6.2.10.1	Differences between surface temperatures and tropospheric temperatures	430
6.2.10.2	Correlation of surface temperatures with CO ₂ sources	432
6.2.10.3	Urban heat islands	433
6.2.10.4	Heat generation by urbanization	433
6.2.10.5	Effects of land-use/land-clearing changes	434
6.3	Climate variability	437
6.3.1	El Niños and climate	437
6.3.2	Interruption of warming	437
6.3.3	North Atlantic climate variability and ocean oscillations	440
6.3.4	Volcanic eruptions	443
6.3.5	Cosmic rays as a source of climate change	450
6.4	Global climate models	454
6.4.1	Description of GCMs	454
6.4.2	The IPCC view of climate models	455
6.4.3	Uncertainties and limitations of GCMs	458
6.4.4	Effect of clouds	476
6.5	The relation between ancient climates and CO ₂ concentration	480
6.5.1	Background	480
6.5.2	The transition from the LGM to the pre-industrial era	485
6.5.3	The early Pliocene: three to five million years ago	496
6.5.4	The past ~20 million years	498
6.5.5	Initiation of Antarctic glaciation 34–33 million years ago	505
6.5.6	Peak warming around 40 million years ago	508
6.5.7	60 to 40 million years ago	508
6.5.8	100 to 300 million years ago	513
6.5.9	Estimates of climate sensitivity based on CO ₂ and climate in the Phanerozoic Eon	513
6.5.9.1	Introduction	513
6.5.9.2	Climate during the Phanerozoic Eon	513
6.5.9.3	CO ₂ variability during the Phanerozoic Eon	517
6.5.9.4	Comparison of Phanerozoic climate with CO ₂ concentrations	521
6.5.9.5	Climate sensitivity assuming “the force” is with CO ₂	524
6.5.9.6	Correlation with galactic cosmic rays	525
6.5.9.7	Oxygen in the Phanerozoic atmosphere	526
6.5.9.8	Phanerozoic summary	527

6.5.9.9	Concluding remarks	528
6.5.10	Relationship between sea level and climate forcing by CO ₂ on geological timescales	529
7.	Anthropogenic influences on climate change	533
7.1	CO ₂ concentration past and present	533
7.1.1	Introduction	533
7.1.2	Measurements and proxies	536
7.1.3	Carbon cycle: CO ₂ fluxes	542
7.1.4	CO ₂ variations in glacial–interglacial cycles	543
7.1.5	CO ₂ and global warming	554
7.2	Projections of future CO ₂ concentration by climatologists	557
7.2.1	CO ₂ emissions and build-up in the 21st century	557
7.2.2	Persistence of CO ₂ beyond the 21st century	565
7.2.3	Practicality of reducing CO ₂ build-up in the 21st century	567
7.2.4	Constraints on CO ₂ production imposed by the limits of fossil fuels	573
7.3	Black carbon as a source of 20th-century global warming	577
7.3.1	Warming early in the 20th century	577
7.3.2	Effect of carbon deposition on ice and snow	583
7.3.3	Rate of emission of carbon in the 20th century	585
7.3.4	Estimated role of BC in Arctic warming	586
7.3.5	Measurement of BC in Arctic ice cores	589
7.4	Role of sulfate aerosols	590
7.5	Land clearing and surface development	591
8.	Impacts of global warming	597
8.1	Alarmists and skeptics	597
8.2	Future increases in global temperature	601
8.3	Sea level rise, the ice sheets, and sea ice	604
8.3.1	Historical sea level rise since the LGM	604
8.3.2	Measurement of sea level	607
8.3.3	Measured sea level change in the 20th century	609
8.3.4	Recent sea level change	618
8.3.5	Global warming and future sea level change	626
8.3.6	Evidence from previous deglaciations	638
8.3.7	Impact of sea level rise	641
8.3.8	Sea ice extent	643
8.3.9	Summary	653
8.4	Changes in precipitation: floods, drought, and storms	654
8.4.1	Drought	654
8.4.2	Floods	656
8.4.3	Storms	656
8.4.3.1	Tropical hurricanes	656
8.4.3.2	Tornadoes	664

8.4.3.3	Extreme weather	665
8.5	Species extinction	667
8.6	Vegetation	671
8.7	Coral reefs	671
8.8	Food production	672
9.	Global climate change and public policy	675
9.1	U.S. government policy actions and inactions.	675
9.2	The Kyoto Protocol	679
9.2.1	Description of the Kyoto Protocol.	679
9.2.2	Commentary on the Kyoto Protocol	681
9.2.3	Future of the Kyoto Protocol	685
9.3	Economics: will it cost more to do nothing?	686
9.3.1	The Stern Report.	686
9.3.2	Nordhaus's review of the Stern Report	690
9.3.3	Other critiques of the Stern report.	692
9.3.4	Investment opportunities in climate change	697
9.4	Economic analyses	698
9.5	Renewable energy.	701
9.6	Pirilä's summary	705
10.	Final remarks	707
10.1	Conclusions	707
10.2	The nine questions	718
10.3	About climatology and climatologists.	721
10.4	Logical fallacies used in climate discussions	726
Appendix I:	Review of the film <i>An Inconvenient Truth</i>	729
Appendix II:	Warming of oceans by increases in greenhouse gas concentrations in the atmosphere.	737
A.2.1	Brief overview of the model	737
A.2.2	The initial response to forcing at the ocean surface.	738
A.2.3	Establishment of a new equilibrium.	741
A.2.4	Zero'th order model	741
A.2.5	First order model	744
A.2.6	Analyses by Ramanathan (1981)	746
A.2.7	Summary of models	748
A.2.8	Effective back radiation at the ocean surface.	749
References	755
Index	811

Figures

1.1. Estimate of global average temperature over the past ~500 million years	3
1.2. Solar Power Input to the Earth for the decade 2000–2010	5
1.3. Dependence of temperature on latitude for three hypothetical distributions of landmass.	7
1.4. Land area vs. latitude on the Earth.	8
1.5. Absorption for CO ₂ vs. wavelength.	10
1.6. Lindzen’s picture of how the greenhouse effect works	12
1.7. Lindzen’s picture of how the greenhouse effect works; part two	13
1.8. Estimated forcing of the climate due to changes in CO ₂	14
1.9. Hypothetical single curve relating T _G to CO ₂ concentration	18
1.10. Hypothetical curves relating T _G to CO ₂ concentration	18
1.11. Range of CO ₂ concentration for 21st century climate change	20
1.12. Variation of T _G with CO ₂ concentration	20
1.13. Variation of ΔT _G with latitude	23
1.14. Inclusion of LGM point in relationship between CO ₂ concentration and T _G	24
1.15. Smoothed data from Vostok ice core	27
1.16. Summary of estimates from LGM → pre-industrial period transitions.	30
1.17. Comparison of CO ₂ and temperature proxy across the Eocene–Oligocene boundary	33
1.18. Comparison of CO ₂ and temperature proxy across the Eocene–Oligocene boundary	34
2.1. Concept of calibration period for a proxy	40
2.2. Ice core records showing LIA and MWP	44
2.3. Mg/Ca analyses as a measure of sea-surface temperatures	45
2.4. Mean temperature anomaly for 18 non-tree-ring proxy series	45
2.5. Estimates of Historical Temperatures in Asia	46
2.6. Calibration curve for northern Scandinavian tree-ring data	46

2.7. Reconstruction of 2000-year history of Northern Scandinavian temperatures	47
2.8. Reconstruction of 2000-year history of Northern Scandinavian temperatures	48
2.9. Fifteen individual proxies from various locations	54
2.10. Derived NH temperature anomalies	55
2.11. Reconstructed temperatures since 1400	59
2.12. Temperature anomaly vs. year since AD 1000	59
2.13. Estimates of historical temperatures by Mann <i>et al.</i> (2008) and others . . .	61
2.14. Hypothetical set of proxies where all proxies except one are flat and only one rises	63
2.15. Two tree-ring temperature anomaly series from the MBH data set	64
2.16. Some of the proxies used by Mann <i>et al.</i> (2008)	66
2.17. “Spaghetti chart” of individual proxies	69
2.18. Simple average of proxy data	69
2.19. Temperature anomalies from MBH.	70
2.20. Eight reconstructions of historical northern non-tropical summer temperatures	71
2.21. Comparison of reconstructions	72
2.22. “Trick” of replacing tree-ring proxy by measured temperature	73
2.23. Temperature reconstructions	76
2.24. The <i>hockey stick</i> is shown to be an artifice	80
2.25. Comparison of temperature reconstructions	95
2.26. Rendition of individual proxies	96
2.27. Simple average of proxy data	97
2.28. Retreat of the Swiss Alps over the last 3,000 years	106
2.29. Tree-ring density reconstruction of NH	108
2.30. Basic data for the calibration period for South China	110
2.31. Longer term data for South China	111
2.32. Estimated temperature profiles for all China	111
2.33. Two-thousand-year histories of average temperature for Chinese and vicinity areas	112
2.34. Comparison of several temperature reconstructions for China	113
2.35. Comparison of several temperature reconstructions for China and the Northern Hemisphere	114
2.36. Annual mean temperature reconstructions.	117
2.37. Temperature reconstructions for the NH using the “trick” to hide the discrepancy between measured temperatures and proxies in the late 20th century	117
2.38. Borehole estimate of global average surface temperature over the past 2,000 years.	119
2.39. Borehole estimate of global average surface temperature over the past 20,000 years	120
2.40a (left) Standardized 400-year proxy climate records of surface air temperature.	121

2.40b (right) Same as 2.43a but for sites in Canada east to Greenland 121

2.41. Ten-year running average Iceland temperatures 123

2.42. Comparison of tree-ring density with temperature for NH 126

2.43. Comparison of tree-ring width with temperature for NH. 126

3.1. Locations of GHCN mean temperature station locations 148

3.2. Locations of GHCN maximum/minimum temperature station locations . 149

3.3. World temperature measurement stations 150

3.4. Distribution of temperature stations in the U. S. Stations by rank 151

3.5 The United States at night 157

3.6. Comparison of annual average temperatures in rural New York State with the center of New York City 162

3.7. Adjustment of raw temperature data at Tokyo, Japan for urban heating 163

3.8. Smoothed monthly temperatures for the two hemispheres 169

3.9. Global smoothed monthly sea-surface temperatures 170

3.10. U.S. mean temperature anomalies 175

3.11. Historical variation of U.S. heat wave index 175

3.12. Historical variation of U.S. cold wave index 176

3.13. Number of daily high U.S. T_{\max} records (1895–2011) 177

3.14. Number of daily U. S. T_{\max} and T_{\min} records (1895–2011) 177

3.15. Fraction of monitored area that exceeds 3σ threshold 178

3.16. Global temperatures based on a combination of land and sea data 179

3.17. Global mean temperatures for the two hemispheres. 180

3.18. Global mean temperature anomalies after 1997 180

3.19. Global temperature anomalies for three latitude ranges 181

3.20. Mean temperature anomalies as a function of latitude and time period . . 182

3.21. Area-weighted mean observed surface temperatures over latitude bands . 183

3.22. The relative amplification of air temperature as a function of latitude . . . 185

3.23. BEST ten-year moving average of global land temperatures 188

3.24. BEST 10-year average data showing major volcanic eruptions. 189

3.25. BEST yearly land temperature data compared to volcanic eruptions 189

3.26. Tropospheric temperature over three decades 191

3.27. Satellite-based temperature of the lower atmosphere 192

3.28. Satellite-based temperature of the lower atmosphere 192

3.29. Comparison of tropospheric temperature data with Santer model 194

3.30. S/N estimates 194

3.31. Trend of TT vs. start year for ten-year durations 195

3.32. Tropospheric temperatures compared to Nino 3.4 Index 198

3.33. Global temperature compared to Nino 3.4 index 199

3.34. Forcing due to doubling CO_2 as a function of altitude 200

3.35. Long-term SOI index 208

3.36. SOI Index since 1950. 208

3.37. Integral of SOI anomaly since 1950. 209

3.38. Integral of Douglass’ modified El Niño index 213

3.39. Comparison of El Niño index and its integral with temperature 214

3.40. Estimate of sulfur emissions 1850–2000	216
3.41. Estimate of sulfur emissions 1850–2000	217
3.42. Global sulfur dioxide emissions	218
3.43. Sulfur dioxide emissions by region	218
3.44. Retreat of two glaciers in Glacier National Park	223
3.45. Retreat of two glaciers in the European Alps	224
3.46. Changes in glacier volume	225
3.47. Reconstruction of “extension” of three alpine glaciers in the Alps	226
3.48. The Aletsch glacier in 1856 and 2001	227
3.49. Retreat of Aletsch glacier compared to build-up of CO ₂	228
3.50. Advance and retreat of Aletsch glacier reconstructed over twomillennia	228
3.51. Extent of Glacier Bay Alaska glaciers at several time periods	229
3.52. Arctic and Antarctic temperatures over the past 30 years	230
3.53. Stations in Antarctica	231
3.54. Change in air temperature in the Antarctic from isotopic composition of ice cores	234
3.55. Change in Antarctic temperature from any starting date to 2002	234
3.56. December–January temperature anomaly and ONDJ melting anomaly for Antarctica	235
3.57. Changes in mean annual air temperature in the 70°–85°N zone	240
3.58. Temperature anomalies for Arctic and Antarctic regions since 1967	241
3.59. Standardized melting index for Greenland	243
3.60. Snowfall and modeled run-off and surface mass balance for Greenland	243
4.1. Cartoon showing several random patterns and their average	264
4.2. Measured cloud feedback vs Earth surface temperature	279
4.3. Cloud feedback plot with four-month time lap	280
5.1. Overlapping satellite TSI measurements since late 1978	289
5.2. Composite of TSI measurements	290
5.3. Comparison of calculated TSI with measured values	292
5.4. Sunspots on the Sun and close-up of sunspot	294
5.5. Sunspot groups	294
5.6. Sunspots and faculae	295
5.7. Estimated group sunspot numbers since ~1600	296
5.8. Estimated group sunspot numbers from 1728 to 1799	297
5.9. Estimated group sunspot numbers	297
5.10. Comparison of R _G and R _Z series	298
5.11. Comparison of 25-year moving averages of R _G and R _Z series	298
5.12. Sunspot number reconstructed from ¹⁰ Be concentrations in ice cores	299
5.13. Historical record of sunspot activity	306
5.14. Comparison of end of Solar Cycle 23 with previous Cycles 20–22 and 14–16	307
5.15. Comparison of end of Solar Cycle 23 with previous cycles	308
5.16. Comparison of end of Solar Cycles 22 and 23 with previous cycles	308
5.17. Measured sunspot numbers for solar cycle 23 and predicted sunspot numbers for Solar Cycle 24	309

5.18. Comparison of Alps temperatures with sunspot number and solar cycle length 310

5.19. Variability of solar cycle length since 1860 based on minima 311

5.20. Length of “11 yr” sunspot cycle from Cycle 1 To Cycle 23 311

5.21. Comparison of estimates of smoothed solar cycle duration 312

5.22. Modeled TSI through the MM up to the present 318

5.23. Relationship between TSI and sunspot number 319

5.24. Relationship between TSI and sunspot number 320

5.25. Reconstructed TSI since 1880 322

5.26. Reconstructed TSI based on sunspot number or cycle duration 323

5.27. Estimates of $\Delta(QS)$ (W/m^2) based on sunspot number or cycle duration 323

5.28. Reconstruction of TSI using two models for the “quiet Sun contribution” 324

5.29. Reid’s 15-year moving average of group sunspot variations 326

5.30. Dependence of long-term TSI on 15-year filtered sunspot number 326

5.31. Modification of Reid’s estimate of variation of TSI over four centuries . . 327

5.32. TSI data vs. Ca II H and K indices 333

5.33. Estimated TSI for the 20th century 335

5.34. Global annual mean surface temperature anomalies for the 20th century 335

5.35. Modeled TSI and temperature variations since 1600 337

5.36. “Sun Melody” estimate of TSI based on variable duration of solar cycle 338

5.37. Comparison of solar cycle duration with temperature 339

5.38. Sunspot number and cycle duration 340

5.39. NH temperature compared to sunspot cycle duration 341

5.40. Comparison of sunspot cycle duration with frequency of aurora occurrence 341

5.41. Dependence of NH temperature variance on solar cycle duration 342

5.42. Reconstruction of TSI using cycle duration or sunspot indices 343

5.43. Modeled total solar irradiance based on sunspot decay rates 344

5.44. Comparison of NH temperature with modeled TSI 345

5.45. Variation of measured TSI and calculated F_s since 1978 346

5.46. Comparison of the predicted TSI (from F_s) with the actual TSI 347

5.47. Cosmo-nuclide production as percent of present production based on ^{10}Be in polar ice and ^{14}C in tree rings 350

5.48. Modeled TSI during the period 850 to the present 350

5.49. Atmospheric radiocarbon level ^{14}C derived from tree-ring chronologies . . 351

5.50. Comparison between measured group sunspot number (GSN) and SN reconstructed from different cosmogenic isotopes 353

5.51. Reconstructed sunspot numbers and observed sunspot numbers 354

5.52. Reconstructions of TSI based on ^{10}Be proxy 356

5.53. Estimated historical variation of TSI for three assumed differences between TSI at the MM vs. TSI today 357

5.54. Estimated historical variation of temperature for three assumed differences between TSI at the MM vs. TSI today.	358
5.55. Estimated temperature anomaly for the last millennium	359
6.1. Radiant heat balance for a hypothetical Earth with no atmosphere.	371
6.2. Simplistic model of effect of greenhouse gases on Earth temperature.	372
6.3. Absorption factor for CO ₂ vs. wavelength.	374
6.4. Lindzen's picture of how the greenhouse effect works	375
6.5. Lindzen's picture of how the greenhouse effect works; part two	376
6.6. Comparison of spectral distribution of upward irradiance from the surface with that at the top of the atmosphere	377
6.7. Downward radiant forcing	378
6.8. Estimated forcing of the climate due to changes in CO ₂ concentration	379
6.9. Atmospheric methane concentrations	381
6.10. Calculated outgoing long-wave radiation (OLR) as a function of global average temperature, for various relative humidity	386
6.11. Global oceanic integrated water vapor variations	391
6.12. Power fluxes between the Earth's surface, the atmosphere, and space	393
6.13. Distribution of clouds showing coverage and emissivity of each layer	396
6.14. Heat flows in the Earth-atmosphere system during average cloudiness during 1985–9.	397
6.15. Heat flows in the Earth's atmosphere during 2000–2004	397
6.16. Factors contributing to heat balance of the Earth.	402
6.17. Comparison of net forcing due to greenhouse gases with increase in ocean heat content	403
6.18. Comparison of several estimates of Earth albedo	406
6.19. Relative atmospheric humidity (%) at three different altitudes in the lower part of the atmosphere	409
6.20. Cloud cover vs. temperature since 1983.	410
6.21. Changes in global ocean heat content to 700 m depth.	423
6.22. Ocean heat content	425
6.23. Percent of world ocean volume below any depth.	426
6.24. Yearly changes in heat content of the oceans	430
6.25. Trend of TT vs. start year for ten-year durations	438
6.26. Winter index of the NAO from 1864 through 2000	442
6.27. Change in direct and indirect insolation following volcanoes.	445
6.28. Modeled global temperature change after Toba eruption.	446
6.29. Aerosol optical depth following the 1991 Pinatubo eruption	446
6.30. The relationship between major volcanic eruptions and hemispheric temperature variations.	449
6.31. Comparison of radionuclide fluxes with relative amount of ice-rafted debris over the past 12,000 years.	452
6.32. Comparison of lower troposphere cloud cover anomaly with cosmic ray anomaly over the past two sunspot cycles	453
6.33. GISS estimates of forcings for the period 1880–2003.	466
6.34. Overlay of Spencer's estimate for PDO forcing on the GISS model.	467

6.35. Model used by Roe and Baker	473
6.36. Dependence of ΔT on f	474
6.36a. Predictions by the MET Office.	476
6.37. Deep-sea temperature over the past 60 million years	486
6.38. Dependence of global average temperature on CO_2 concentration.	489
6.39. Smoothed data from Vostok ice core	490
6.40. Summary of estimates from LGM \rightarrow pre-industrial period transitions.	494
6.41. Range of values for Earth System Sensitivity.	499
6.42. CO_2 concentration and Bethic $\Delta^{18}\text{O}$ over the past 25 million years	500
6.43. Dependence of ΔT_{NH} on CO_2	501
6.44. Estimates of CO_2 concentration over the past 20 million years	501
6.45. Dependence of (ΔT_{NH}) on CO_2 concentration.	502
6.46. Comparison of $\Delta^{18}\text{O}$ with CO_2 concentration over 25 million years.	503
6.47. Estimated CO_2 vs. temperature over 20 million years	504
6.48. Comparison of CO_2 and temperature proxy across the Eocene– Oligocene boundary	506
6.49. Comparison of CO_2 and temperature proxy across the Eocene– Oligocene boundary	507
6.50. Estimates of CO_2 over the past 65 million years	508
6.51. CO_2 concentration and Bethic $\Delta^{18}\text{O}$ over the past 60 million years	509
6.52. CO_2 concentration and Bethic $\Delta^{18}\text{O}$ over the past 60 million years	510
6.53. CO_2 concentration and Bethic $\Delta^{18}\text{O}$ over the past 60 million years	511
6.54. Estimated variations of tropical seawater temperatures during the Phanerozoic eon	514
6.55. Corrected changes in tropical sea temperatures due to change in pH from changing CO_2 concentration.	515
6.56. Estimate of average global temperature during the Phanerozoic eon	516
6.57. Temperatures derived from $\Delta^{18}\text{O}$ values of calcitic shells for the Phanerozoic.	517
6.58. Estimate of global average temperature for the Phanerozoic	517
6.59. The short-term carbon cycle	518
6.60. Plot of $R(\text{CO}_2)$ versus time based on geological models.	519
6.61. Plot of $R(\text{CO}_2)$ versus time based on proxies, compared with geological models	520
6.62. $R(\text{CO}_2)$ estimated by Rothman	520
6.63. Comparison of $R(\text{CO}_2)$ with temperature changes during the Phanerozoic	522
6.64. Royer’s 2006 estimate of the net forcing due to CO_2 variability.	523
6.65. Comparison of estimates of CO_2 history with tropical sea temperature in the Phanerozoic	525
6.66. Comparison of $R(\text{CO}_2)$ and climatic effect of cosmic rays with estimated tropical sea-surface temperature anomalies	526
6.67. CO_2 and tropical sea-surface temperatures	529
6.68. Comparison of estimated CO_2 and sea level over two geologic time periods	531

7.1. Rough estimates of carbon storage and annual carbon fluxes as of about year 2000	535
7.2. Measured CO ₂ concentration at Mauna Loa	536
7.3. Annual and long-term variation of CO ₂ concentration	537
7.4. CO ₂ emissions and concentration and Niño index	537
7.4a CO ₂ emissions by country	538
7.5. Atmospheric CO ₂ concentration over the past 2,000 years	540
7.6. Variation of CO ₂ concentration since the LGM	541
7.7. CO ₂ concentration during Holocene from ice cores	541
7.8. Historical variation of CO ₂ concentration during the past four hundred thousand years	542
7.9. Reconstruction of paleo-atmospheric CO ₂ levels	554
7.10. Range of projected future annual CO ₂ emissions from various models . .	558
7.11. Various models for future CO ₂ concentration in the 21st century	558
7.12. Energy mix for generation of electric power assumed by IS92a projection	559
7.13. Carbon factor assumed by IS92a projection	559
7.14. MIT estimates of carbon emissions for various levels of control	560
7.15. MIT estimates of all greenhouse emissions stated as CO ₂ equivalent for various levels of control	560
7.16. Airborne fraction of CO ₂	561
7.17. Carbon emissions per year needed to stabilize CO ₂ concentration at various levels.	562
7.18. Annual emissions of carbon for five future scenarios in the 21st century .	563
7.19. Buildup of CO ₂ in the atmosphere corresponding to five scenarios	564
7.20. Range of future CO ₂ emissions corresponding to each range of ultimate CO ₂ concentration in year 2100.	565
7.21. Projection of world population made by IS92a	568
7.22. Comparison of BAU emissions with target for putative 2°C temperature rise by 2100	572
7.23. Held's projection of world energy supply to year 2100	573
7.24. Estimated cumulative production of hydrocarbons and coal to date, and projected ultimate production.	574
7.25. Estimated annual production of hydrocarbons and coal to date, and projected ultimate production by 2100.	575
7.26. Comparison of cumulative CO ₂ emissions based on fossil fuel constraints with the range of IPCC projections for future CO ₂	575
7.27. Estimated world production of oil, gas and coal showing peak years. . . .	576
7.28. Annual emissions of carbon for five future scenarios in the 21st century compared with a fossil fuel limited scenario	576
7.29. Build-up of CO ₂ in the atmosphere corresponding to six scenarios	577
7.30. Reconstructed sea-surface temperatures (SSTs)	578
7.31. Measured summer and winter temperatures at Spitsbergen	579
7.32. Reconstructed near-surface air temperatures over Greenland.	581
7.33. Effect of various concentrations of soot (ppm) on snow	584

7.34. Estimates of reduction of albedo by deposition of BC 584

7.35. Snow-albedo reduction attributed to BC 585

7.36. History of BC emissions by region 586

7.37. Annual average BC concentrations 589

7.38. Estimated surface radiative forcing for a seasonal snow cover 590

7.39. Deforested area shown as time-varying isolines for 10 latitude bands . . . 592

7.40. Estimate of deforestation. 592

7.41. Cumulative area of land cleared by latitude and year 593

7.42. Modeled NH temperatures based on all forcings, or only deforestation. . 594

8.1. Rise in sea level since the LGM 604

8.2. Modeled extent of Greenland ice at previous interglacial, last glacial maximum and present. 606

8.3. Modeled extent of Antarctica ice at previous interglacial, last glacial maximum and present. 607

8.4. Reconstruction of relative sea level since 1700. 610

8.5. Reconstruction of rate of sea level rise since 1700 610

8.6. Rate of sea level rise 612

8.7. The mean sea level record from the nine tide gauges over the period 1904–2003. 613

8.8. Decadal variation of sea level 613

8.9. Comparison of estimates of sea level rise for the 20th century. 615

8.10. Calibration curve for sea level model based on salt-marsh sediments. . . . 617

8.11. Ice sheet mass balance by surface mass balance and GRACE methods . . 622

8.12. Projection of future contribution to sea level rise from ground water . . . 624

8.13. Global mean sea level from altimetry from 1992 to 2012. 625

8.14. Projections of future sea level rise 629

8.15. A stream of snow melt cascades down a moulin on the Greenland ice sheet 632

8.16. Record of atmospheric CO₂, CH₄, and temperature extracted from an Antarctic ice core 633

8.17. Relative temperatures of the last four interglacials. 636

8.18. Variation of sea level near previous interglacial relative to present sea level 637

8.19. Sea level subsequent to the LGM 637

8.20. Global sea ice extent since 1980 646

8.21. Northern Hemisphere seasonal sea ice extent. 647

8.22. Six-year running mean of sum of changes in sea ice extent in four Arctic seas. 649

8.23. Six-year running mean of fast sea ice thickness in five Arctic locations . . 649

8.24. Variability of the total ice extent in the Greenland, Barents, and Kara Seas for the period 1900–2003. 650

8.25. Variability of total ice extent in the Laptev, East Siberian, and Chukchi Seas 651

8.25a Variation of extent of Arctic sea ice during the year since 2005 653

8.26. Scaled smoothed curves for August–October SST and storm lifetime maximum PDI for the North Atlantic	658
9.1 Distribution of sources of world energy use in 2008	703
10.1. Cartoon showing derivation of trend line from noisy data	724
10.2. Measured cloud feedback vs. Earth surface temperature	725
10.3. Cloud feedback plot with four-month time lag	726
A2.1. Schematic temperature profile in a tropical ocean	738
A2.2. Schematic temperature profile in a tropical ocean	738
A2.3. Effective back radiation from the sea surface to a clear sky as a function of sea-surface temperature and relative humidity of the air	750

Tables

Table 1.1.	Parameters used by C&L	26
Table 1.2.	Parameters for analyzing LGM – pre-industrial transitions	29
Table 2.1.	Number of proxies vs. earliest date	58
Table 2.2.	Space–time matrix of temperature data	123
Table 3.1.	Clear sky forcing at various altitudes for various changes in greenhouse gas	201
Table 3.2.	Clear sky forcing at various altitudes for various changes in greenhouse gas	201
Table 3.3.	Rate of heat absorption for the 0–700 m ocean layer (W/m^2) per unit area of the Earth.	246
Table 3.4.	Heat gains by time period and ocean layer.	246
Table 3.5.	Total temperature rise ($^{\circ}C$) by time period and ocean layer	247
Table 3.6.	Rate of heat absorption by time period and layer per unit area of ocean.	247
Table 4.1.	Personality Traits	273
Table 4.2.	Comparison of Personality Traits of Climate Scientists with those of the general public.	274
Table 5.1.	Estimated TSI contribution to global warming.	335
Table 6.1.	Measured temperatures in and around a car parked in sunshine.	370
Table 6.2.	Percentage of downward forcing due to each absorber	378
Table 6.3.	Global power balance for 1985–1989 and 2000–2004	394
Table 6.4.	Surface components of the annual mean power budget for the globe, global land, and global ocean for 1985–1989 and 2000–2004	395
Table 6.5.	Solar power balance comparison	399
Table 6.6.	Surface power balance comparison.	400
Table 6.7.	Comparison of Miskolczi’s data with other models	401
Table 6.8.	Comparison of alternative parameters for cloud feedback	408
Table 6.9.	Estimated components of the Earth’s heat balance. Data from Levitus, Antonov, and Boyer (2005).	424

Table 6.10.	Rate of heat absorption for the 0–700 m ocean layer per unit area of the Earth for two time periods	428
Table 6.11.	Heat gains by time period and ocean layer	428
Table 6.12.	Total temperature rise by time period and ocean layer	428
Table 6.13.	Rate of heat absorption by time period and layer per unit area of ocean	428
Table 6.14.	Calculated temperature change from 1983 to 1992 due to deforestation and CO ₂ greenhouse effect	436
Table 6.15.	The <i>volcano explosivity index</i> (VEI)	443
Table 6.16.	The largest volcanoes of the past 250 years	444
Table 6.17.	List of volcanoes used in Figure 6.30	449
Table 6.18.	Parameters used by C&L	490
Table 6.19.	Parameters for analyzing LGM – pre-industrial transitions	493
Table 7.1.	Exchange of CO ₂ Between Biosphere, Atmosphere and Oceans	543
Table 7.2.	Estimated temperature change in the NH due to CO ₂ and land clearing	594
Table 8.1.	Impacts of global warming according to IPCC (2001)	598
Table 8.2.	Historical dependence of sea level on CO ₂ concentration	605
Table 8.3.	Estimates of acceleration of the of sea level rise	616
Table 8.4.	Projected rise in sea level (cm)	627
Table 8.5.	Predicted rise (cm) in sea level by 2100.	628
Table 9.1.	Emissions and socio-economic quantities as national percentages of world total.	684
Table 9.2.	National emissions as ratios of various national socio-economic quantities.	684
Table A.2.1	Change in total heat loss of T_s	743
Table A.2.2	Change in total heat loss as a function of T_s	745
Table A.2.3	Clear sky formulas for back radiation	752
Table A.2.4	Simple formulas for back radiation including clouds	753

Acronyms and abbreviations

ABL	Atmospheric Boundary Layer
ACRIM	Active Cavity Radiometer Irradiance Monitor
AE	Auroral Electrojet (index)
AIT	<i>An Inconvenient Truth</i>
AOGCM	Atmosphere–Ocean General Circulation Model
BC	Black Carbon
BP	Before the Present
C&L	Chylek and Lohmann (2008)
CCN	Cloud Condensation Nuclei
CCPI	Climate Change Performance Index
CET	Central England Temperature
CFI	Comprehensive Flare Index
CFR	Climate Field Reconstruction
CME	Coronal Mass Ejection
CNES	Centre National d’Etudes Spatiales
CO _{2e}	Equivalent CO ₂ concentration to produce the equivalent effect of all greenhouse gases
CPS	Composite Plus Scaling
CQSM	Constant Quiet Sun Model
DIC	Dissolved Inorganic Carbon
DTR	Diurnal Temperature Range
EA	East Antarctica
EAIS	East Antarctica Ice Sheet
ECS	Esper, Cook, and Schweingruber (2002)
ELA	Equilibrium-Line Altitude
ENSO	El Nino/Southern Oscillation
EOS	Earth Observing System
EPA	Environmental Protection Agency
ERB	Earth Radiation Budget
ERBS/ERBE	Earth Radiation Budget Satellite/Earth Radiation Budget Experiment

EOF	Empirical Orthogonal Function
EPICA	European Project for Ice Coring in Antarctica
GCM	Global Climate Model
GDP	Gross Domestic Product
GHG	GreenHouse Gas
GICC	Glacial–Interglacial CO ₂ Cycles
GIS	Greenland Ice Sheet
GISS	Goddard Institute for Space Studies (NASA)
GMST	Global Mean Surface Temperature
GNP	Gross Domestic Product
GRACE	Gravity Recovery And Climate Experiment
GSL	Global Sea Level
GSLR	Global Sea Level Rise
GSN	Group Sunspot Number
GST	Ground Surface Temperature
H&A	Hargreaves and Annan (2009)
HadCM3	Hadley Climate Model 3
HFC	HydroFluoroCarbon
IJC	International Journal of Climatology
IMF	Interplanetary Magnetic Field
IPCC	Inter-government Panel on Climate Change
IR	InfraRed
JGR	Journal of Geophysical Research
LFO	Low Frequency Oscillation
LGM	Last Glacial Maximum
LIA	<i>Little Ice Age</i>
LULC	Land Use/Land Clearing
M&M	McIntyre and McKittrick
M&W	McShane and Wyner (2010)
MBH	Mann, Bradley, and Hughes
MDI	Michelson Doppler Imager
MIROC3.2	Model for Interdisciplinary Research on Climate
MM	Maunder Minimum
MOC	Meridional Overturning Circulation (Atlantic)
MPH	Mobile Polar High
MSU	Microwave Sounding Unit
MWP	Medieval Warm Period
NADW	North Atlantic Deep Water
NAO	North Atlantic Oscillation
NCEP–NCAR	National Centers for Environmental Protection/National Center for Atmospheric Research
NDVI	Normalized Difference Vegetation Index
NH	Northern Hemisphere
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation

OHCA	Ocean Heat Content Anomaly
OLR	Outgoing Long-wave Radiation
OPEC	Organization of Petroleum Exporting Countries
PC	Principal Component; Politically Correct
PCA	Principal Component Analysis
PDI	Power Dissipation Index
PFC	PerFluorohydroCarbon
ppmv	parts per million by volume
RE	Radiative Effectiveness
RSL	Relative Sea Level
SAT	Surface Air Temperature
SD	Standard Deviation
SEAS	NOAA's XBT program
SETI	Search for Extraterrestrial Intelligence
SH	Southern Hemisphere
SMAX	Sunspot MAXimum
SMIN	Sunspot MINimum
SMM	Solar Maximum Mission
SN	Sunspot Number
SO	Southern Oscillation
SOHO	SOLar Heliospheric Observer
SOI	Southern Oscillation Index
SORCE	Solar Radiation and Climate Experiment
SST	Sea-Surface Temperature
TAV	Tropical Atlantic Variability
TIM	Total Irradiance Monitor
TMN	Temperature Measurement Network
TOA	Top Of Atmosphere
TOPEX	Poseidon Ocean Topography Experiment
TSI	Total Solar Irradiance
UAH LT	University of Alabama in Huntsville Lower Troposphere
UARS	Upper Atmosphere Research Satellite
UHI	Urban Heat Island
UNFCCC	U.N. Framework Convention on Climate Change
U/P	Umbra/Penumbra
USHCN	U.S. Historical Climate Network
UT	Upper Troposphere
VEI	Volcano Explosivity Index
VIRGO	Variability of solar IRradiance and Gravity Oscillations
WA	West Antarctica
WAIS	West Antarctica Ice Sheet
XBT	eXpendable BathyThermographs
YBP	years before the present

Preface

THE GLOBAL-WARMING DEBATE

The Earth has gone through incredibly wide climate changes over hundreds of millions of years. A number of factors contributed to this, including a gradually strengthening Sun, drift of continents, incidence of volcanism, etc. But it is widely believed that the Earth's thermostat was mainly controlled by prevailing CO₂ concentrations in the tug of war between CO₂ emissions and CO₂ burial. Thus, the "accepted paradigm" is that, over geological time, variability of CO₂ was the main controller of the Earth's climate (Foster *et al.*, 2009). For example, 500 million years ago, the CO₂ concentration was much higher (possibly 20 times) than it is today and the Earth was very balmy. There is little doubt that, if we again increased CO₂ to 20 times the pre-industrial value, the Earth would become considerably more tropical. The question before us now is how the Earth's climate will respond to a much smaller increase in CO₂: a mere doubling from 280 ppm to 560 ppm? There is little doubt that some temperature rise will result from this. Alarmists believe that the temperature rise will be sufficiently great to cause great harm to humanity. Skeptics think we can take in stride the relatively modest temperature rise that ensues. In between, there are so-called "lukewarmers" who are unsure. Perhaps the biggest worry is that, if the alarmists are right, we would require immediate draconian reductions in carbon emissions in which we would ramp down use of fossil fuels by 80% (or more) in a few decades. With world population growing and future energy demand projected sharply upward, how would we provide the world with needed energy while eliminating fossil fuels? There does not seem to be an answer.

Global-warming alarmists (aka "warmists") believe that human production of greenhouse gases, particularly carbon dioxide, with its concomitant water vapor feedback mechanism, has begun to add to the natural greenhouse effect, thereby raising global temperatures inordinately during the 20th century, with predictions of further increases in the 21st century that they claim would be catastrophic.

James E. Hansen, a leading spokesman for the alarmists, said that "Ignoring the

climate problem at this time, for even another decade, would serve to lock in future catastrophic climatic change and impacts that will unfold during the remainder of this century and beyond". The Earth "is close to dangerous climate change, to tipping points of the system with the potential for irreversible deleterious effects. . . . The planet is on the verge of dramatic climate change". We "are forced to find a way to limit atmospheric CO₂ more stringently than has generally been assumed. . . . We cannot shrink from our moral responsibilities . . . to preserve the planet for future generations".

Al Gore's film *An Inconvenient Truth* has carried the message to many millions of people. This has spawned a growing world movement that is seeking controls on greenhouse gas emissions. Because such controls would have serious economic consequences and, furthermore, attempts to apply controls have been unbalanced relative to developed countries vs. developing countries, there has been strong resistance to such moves by skeptics.

The majority of research climatologists at universities are alarmists to some degree. In today's political environment, it is necessary to be an alarmist (or at least to appear to be one) in order to obtain research funding. Some university and government agency alarmists have banded together in an informal association to (1) exert pressure on journal editors to prevent contrary views from being published, (2) to very quickly publish rebuttals to those few contrarian papers that slip through their net, and (3) immediately produce nasty, vicious attacks on contrarian papers on their blogs. These alarmists pompously refer to their interpretations as "*climate science*", implying that any contrary views are not *climate science*. Yet, most of the work published by these university climatologists is based on sparse, noisy, short-term data and their results typically are based on drawing a dollar's worth of conclusions from a penny's worth of data.

Skeptics span a wide range of viewpoints ranging from uncertainty regarding how much of recent global warming was primarily induced by rising CO₂ levels, to outright denial that there is any connection between rising CO₂ and global warming. Skeptics maintain blogs and circulate reports, but have only occasionally penetrated the peer-reviewed scientific literature that is dominated by alarmist publications. Alarmists provide the impression of scientific integrity through peer-reviewed publications, while skeptics often (but certainly not always) lack the credentials of alarmists. The alarmist position is often "sold" on the basis of the number and importance of climatologists and institutions that subscribe to this persuasion. But the important thing is data, not credentials and number of adherents.

Both sides have argued like trial lawyers with a case to be made, by craftily selecting ("cherry picking") bits and pieces of data to support their preconceived viewpoints. Fact, supposition, speculation, and pseudo-science have been mixed together in a brew that is confusing and difficult to resolve. I recently checked *amazon.com* books to see what's available in the way of climate books. There seemed to be about 100 new books in the last two years. All of those written by establishment climatologists present the alarmist view. All of those written by anti-establishment writers present the skeptical view. Both sides are absolutely sure they are right. Neither side has any doubt that I can discern. One thing the world does not

need is another high-level book arguing with assurance on one side of the question or the other, with little actual data content, manipulated to achieve an apparent conclusion based on specious arguments and cunningly selected references.

In this book, I have investigated a large body of technical data relevant to global climate change, approaching each element with necessary (but hopefully neutral) scientific skepticism. As Einstein said: “The goal is to be as simple as possible, but not simpler.” Thus, by necessity, this book is quite technical, but hopefully still quite readable.

The essential questions are:

- (1) How well has the world monitored near-surface temperatures of the 30% land and 70% ocean areas on the Earth during the past 120 years or more, and how well can we characterize the changes in climate over that time span?
- (2) What are the utility and significance of a single global average temperature?
- (3) How has the Earth’s climate varied over the past Ice Ages, the Holocene, the last millennium, and the past century, and what can we infer about “natural” variability of the climate prior to industrialization by humankind?
- (4) How reliable are proxies for historical temperatures? What do we really know about past temperature variations? Is the *hockey stick* version of millennium temperatures credible, in which temperatures were relatively flat for 2,000 years prior to a sudden rise in the 20th century?
- (5) How does the current global-warming trend compare with past fluctuations in the Earth’s climate, and what is the likelihood that the warming trend we are experiencing now is primarily just another in a series of natural climate fluctuations as opposed to a direct result of human production of greenhouse gases?
- (6) How credible are the global climate models that claim that greenhouse gases produced most of the temperature rise of the 20th century, and forecast much greater impacts in the 21st century?
- (7) How good were the “good old days”? Was the climate of the *Little Ice Age* ideal, should we abhor warming from that baseline, and do we want to return to the climate of the early 19th century?
- (8) How will limits on fossil energy supplies constrain future CO₂ production and climate change, even if the climate models are accurate?
- (9) How can the world provide itself with energy needed for a burgeoning population that will demand more and more energy in the future, considering the finite limits on fossil fuel resources?

According to Beckman and Mahoney (1998):

“The vested interests on both sides of the argument between the ‘greenhouse’ party and the ‘solar warming’ party are obvious. Scientifically, the meteorologists, climatologists, and atmospheric physicists, who were responsible for ‘discovering’ the human contribution to the terrestrial greenhouse effect, have been the most consistent champions of its importance, while the solar physics community, and especially those interested in solar–terrestrial relations, have

increasingly stressed the possible importance of the long-term variations of the solar constant as the chief cause of climate change. Both communities tend to take the change for granted, and to neglect any purely statistical or chaotic effects which could lead to excursions of the Earth's surface temperature during periods of a couple of decades, without requiring a secular change either in the solar constant or in atmospheric transparency. In addition, the debate is conditioned by more powerful vested interest groups. The oil industry in all its guises would obviously like to believe, and would like the public to believe, that greenhouse warming has been greatly exaggerated, and exploits any genuine scientific differences to undermine the credibility of the climatologists."

Unfortunately, many global-warming alarmists have weakened their cases by building them around models and analyses of dubious veracity and, in the case of the infamous *hockey stick* temperature profile, mathematically incorrect manipulations of past temperature data from proxies. From this, they have concluded improperly that the late 20th century is far warmer than any time in the distant past, and made other elaborate claims regarding recent warming trends and dire predictions for the near future that are unsupported by the evidence. Furthermore, the network for monitoring the Earth's temperatures is inadequate to precisely characterize the trends in climate for the past 100 years, and the utility of a single global average temperature in defining the state of the climate is limited.

Projections for the 21st century are typically far out of line with realistic expectations. The credibility attributed to global climate models belies their inherent fragility. This has provided the skeptics with plenty of ammunition with which to debunk these exaggerated claims. On the other hand, most of the skeptics made up their minds *a priori* that global warming in the 21st century due to CO₂ emissions is not a potential problem, and their arguments are often vague and hardly convincing.

A major problem in discussing climate change is that we lack a time period that we can objectively define as a base for comparison. As Anon. (N) emphasized, temperatures near the end of the 20th century were generally higher than those of the preceding four centuries. Taken at face value, this seems to imply that the preceding temperatures were normal, while the relatively higher temperatures at the end of the 20th century are comparatively abnormal. However, the preceding four centuries extended across the *Little Ice Age*, and therefore one might state the proposition differently: temperatures during the preceding four centuries were colder than they were at the end of the 20th century. Stated this way, the abnormality is attributed to the *Little Ice Age*. Perhaps the most accurate statement is that there is no normal climate, and the climate of the Earth has always varied widely, and continues to do so to this day. As Balling, Vose, and Weber (1998) said:

"... it is entirely possible that the warming in the record of the past century has been caused by an unusually cool period 100 years ago as opposed to an unusually warm period in recent decades."

By carefully sifting through the evidence, we find that there are no ironclad answers to major questions on global climate change. Our temperature data for the

past are fragmentary and sparse, both spatially and temporally. Urban heat islands and land clearing have affected measured temperatures. Past variations in solar irradiance can only be estimated with speculations. Proxies used to estimate the temperature history of the Earth over past millennia are noisy and inconsistent, leaving us with uncertain indications of the past. Climate models do not deal realistically with water vapor, aerosols, and clouds, resulting in wide variations from model to model.

The thesis of this book is that our data and models are presently inadequate to reach credible conclusions regarding how much global warming is likely to take place in the 21st century. We have emerged from the *Little Ice Age* in the latter half of the 19th century and the Earth has warmed, but the connection to greenhouse gases is uncertain. Estimates for the future depend on climate models that cannot yet properly account for changes in humidity, aerosols, and cloud cover as greenhouse gas concentrations increase.

Scientists (and the public) abhor a vacuum. They can't seem to shrug their shoulders and admit that we just don't know the answers to important questions. They introduce explanations, however speculative. Thus, we are besieged with models purporting to describe the past millennium's history of the Earth's climate, and making firm predictions about the future, none of which stands up to detailed review. The *alarmist cabal* that controls the paleo-climatological literature has a political agenda to promote public concern about greenhouse gases and, in many cases they have lost objectivity. We have ended up with two opposing camps: the alarmists and the skeptics, each 100% convinced they are right, and each firmly for or against a global-warming catastrophe, each seemingly more concerned with furthering their agendas than with discovering truth. What seems to be missing in all this is a little bit of humility. Speculation is rife. Data are lacking. Use of complex models obscures the fact that the data are limited and, in many cases, untrustworthy. Meanwhile, there is much to be gained on a personal basis from the international preoccupation with climate change. Grants and contracts are awarded, often to the most strident voices supporting the orthodoxy. Blogs have evolved like religious factions, swearing allegiance to their orthodoxies, and twisting the facts to fit their preconceived notions. Any moron can have his say—and does.

The world will face a crisis sometime around or after 2030. But that crisis will not be calamitous global warming. While global warming might become a significant problem late in the 21st century, the greater, and nearer-term crisis will be that, with oil, gas, and coal production going at full bore, the world will not be able to supply the energy that is demanded by a growing world population intent on using energy at higher rates. This could lead to significantly higher energy costs, resulting in worldwide economic recession or depression. However, on the positive side, it will provide great incentive to develop renewable energy that will then become more competitive. Whether renewable energy can be developed and expanded rapidly enough to stave off economic collapse remains to be seen. The same people who are of the climate alarmist persuasion also seem to be unduly optimistic about the prospects for renewable energy to supplant fossil fuels.

SUMMARY

There is a good deal more that we don't understand about climate variability than we do understand. As Wunsch (1999) emphasized:

“Sometimes there is no alternative to uncertainty except to await the arrival of more and better data.”

The warming of the 20th century represents emergence from the *Little Ice Age*. The quantitative role of greenhouse gases in this warming remains uncertain. We need better data and better models; there are too many speculations that have hardened into beliefs.

Scientists have studied past climates using proxies. Proxies are residual data from processes that occurred in the past, when the processes were dependent on local temperatures at the times they took place, and the evidence is preserved in the present in an accessible form.

Chapter 1 deals with long-term climate change.

Chapter 2 examines what we have learned from proxies about major climate changes that have occurred over the past two millennia. A detailed study of proxy evidence for climate fluctuations in the last millennium or two has led to a controversy. Some climatologists claim that temperature variability in the last millennium or two was small prior to the 20th century, leading to a *hockey stick* graph of temperature vs. time with an unprecedented sudden rise in the 20th century. Alternatively, there is considerable evidence that temperatures varied significantly during the past few millennia, with a warm period about 1,200 years ago and a cold period from about 1600 to about 1850—the so-called *Little Ice Age*. This controversy is examined in considerable detail. Is the temperature rise of the 20th century unique, and must it be attributed mainly to increased CO₂?

Chapter 3 analyzes the measurements of Earth surface temperature that were made in the past century or so and discusses the limitations of the measurement network. Temperature data are reviewed in considerable detail. The primary trend during the 20th century has been upward from the base of the *Little Ice Age*, but this temperature rise has not been uniform, either geographically or in time. The limitations of attempting to describe the Earth with a single global average temperature are emphasized.

Chapter 4 provides a discussion of generic global scares. It also discusses subjective science: the science of inference when we cannot go back in time to validate our hypotheses of what might have taken place in the past. It then goes on to discuss the alarmist movement and the ways that climatologists think.

Chapter 5 provides an in-depth review of solar irradiance: historical observations, recent measurements, theories, and models, and use of proxies to estimate past irradiance. Reliable measurements only exist for the past 30 years. There remains considerable uncertainty as to how solar irradiance varies over time periods of centuries. There are a number of models that attempt to estimate solar intensity in the past, but each of these is based on assumptions that are impossible to validate.

In Chapter 6, the Earth's heat balance and the greenhouse effect are discussed. Recent estimates of energy transfer within the Earth system are reviewed. The Earth's current energy balance is discussed with emphasis on the heat content of the oceans—which represent most of the heat capacity of the Earth's surface. Climate variability due to volcanoes and El Niños are reviewed. The concept of climate sensitivity is introduced. Finally, the relationship of CO₂ concentration to climate over 500 million years is reviewed.

Chapter 7 deals with anthropogenic influences on climate change. While most studies have focused exclusively on the putative effects of greenhouse gases, other important effects include the deposition of Arctic black carbon snow and ice, land modification, and generation of sulfate aerosols. The major challenge of the 21st century is not global warming, but rather providing the people of the world with energy. Problems due to climate change must be discussed as a subsidiary element of energy production and consumption.

Chapter 8 deals with the potential impacts of future global warming by contrasting the views of alarmists and skeptics. While alarmists have exaggerated many risks, a significant concern is the potential future rise in sea level. Other threats of global warming have been exaggerated by alarmists.

Chapter 9 deals with climate change and public policy. Governments are rushing to judgment on the putative role of CO₂ and enacting policies that will cost trillions, and may induce economic disaster. Economists have invaded the field of climate change and as with all aspects of climate change, there are opposite viewpoints expressed with great certainty based on flimsy foundations.

Chapter 10 provides a summary and conclusions. The Earth's climate is very complex. There is more that we don't know than we do know about climate change. Past temperatures; long-term variation of solar irradiance; variations in ocean circulation; reaction of cloud cover, humidity, and aerosols to rising greenhouse gas concentrations; heat exchange between the Earth and the atmosphere all remain (like most analyses of climate) speculative, conjectural, and unproven. Nevertheless, the predictions of alarmists can be treated as worst-case possibilities and these are a cause for concern. The bigger problem, however, is an increasing population with growing need for energy.

Appendix I reviews the widely viewed Al Gore film *An Inconvenient Truth*, for which he received a Nobel Prize. This glossy, glib presentation has little actual content, and much of it is wrong. Appendix II provides a model for warming of the oceans as greenhouse gas concentrations increase. While some websites claim that increased greenhouse gas concentrations do not warm the ocean, we show that in fact they do.

In this Third Edition, I have added more than 285 new references, over 180 manuscript pages of new text, and more than 80 new figures. Particularly notable are the following additions:

- Additional data and discussion related to the Medieval Warm Period and the Little Ice Age.
- Information and discussion of so-called “climategate” revelations

- Further revelations on manipulations of proxy data and the “*hockey stick*”
- Expanded coverage of the connection of climate to El Niños
- Updated data on global and regional temperatures
- Data and discussion of weather extremes
- Expanded data and discussion of mountain glacier retreat
- Greatly expanded treatment of Earth heat balance
- Greatly expanded treatment of global warming due to CO₂
- Expanded discussion of humidity and cloudiness effects
- Inclusion of Spencer and Eschenbach models
- Extensive discussion of estimates of climate sensitivity from paleo geological data
- Updates on heat content of the oceans
- Greatly expanded treatment of climate forcings
- Expanded discussion of models for future emissions
- Expanded discussion of the role of black carbon
- Greatly expanded treatment of sea level change
- Greatly expanded treatment of sea ice extent
- Comparison of Holocene to previous deglaciations
- Expanded discussion of “Stern Report” and other economic analysis of remediation of climate change
- Discussion of ocean warming due to increased greenhouse gas concentrations