

Index

Figures in *italic*, Tables in **bold**; B after page number signifies Box; n after page number signifies material in notes.

- acid rain 51, 117, 172
- adaptation 167, 188
  - cost of 270–1, 237
  - ecosystems and human communities 144
  - and mitigation, climate change 10–12, 11
  - potential to reduce climate change cost to agriculture 164–9
  - to climate change 178, **179**, 179
  - to crops and agricultural practices 189
- adaptive capacity 144B, 145
  - in growth of food crops 164
- aerosols 48, 50, 95, 260
  - influence on climate change 127–8
  - smaller emissions in SRES scenarios 122
  - sulphate 266n
- afforestation
  - can change Earth’s albedo 251–2
  - effects on atmospheric carbon dioxide 250–1
- Africa
  - damage in disasters not realised in economic terms 180
  - forecasting for the Sahel 87B, 87
  - prolonged droughts 5, 160
- agriculture
  - adaptation, potential to reduce climate change cost 164–9
  - and food supply, impact of climate change 164–9
    - carbon dioxide fertilisation effect 165–6B
    - effect of temperature changes 165
    - likely to affect countries differently 168–9
    - matching crops to new climatic conditions 164–5
    - sensitivity of major crops during the 21st century 166, 166–8B
    - and vulnerability of water supplies 157–8, 165
  - reducing methane emissions 254
  - water use 155, 156
- aid agencies, to prepare for more frequent and intense disasters 325
- air transport 285
  - greenhouse gas emissions 48, 283
- Amazonian forest
  - dieback and carbon release 173B
  - drastic effect of loss 173B
- Annan, Kofi, on competing futures 329
- Antarctica 99B, 124, 149
  - ice sheet in west vulnerable to disintegration 150, **186**
  - ozone hole over 46, 229
- Arctic 124
  - Greenland ice cores 71, 72, 74
  - Greenland ice sheet 149–50
- Arrhenius, Svante 17B
- Asia
  - hydrological study under climate change 158
  - increased intensity of drought and floods 160
  - southeast, monsoon region, vulnerable to floods and droughts 161, 162
- atmosphere
  - 20th century changes in 61, **62–3**, 63
  - composition of 16, **16**
  - heat transfer by convection 18, 19
  - movement of carbon in and out 30, 30
  - a partially chaotic system 83, 84–5B
  - particles in 48–52
  - radiation budget 20–1, 21
  - transfer of radiation 18, 19, 20
- atmosphere–ocean coupled models 88B, 97–98, 97
- atmospheric models
  - initialising data 82B
  - numerical, setting up 80–2B
  - parameters and physical processes involved 78–79, 79
- atmospheric particles 117
  - sources 48–9
- Australia, changing precipitation 127, 128
- back to nature, not practical 199
- Bangladesh 4
  - impact of sea level rise 150–4
  - loss of agricultural land 150–1

- possible responses 152
- salt water intrusion affecting more agricultural land 151–2
- vulnerability to storm surges 4, 151
- BedZED, a Zero Emission (fossil fuel) Development 283B
- biodiversity loss 250
- biofuels 285B
- biogas
  - from wet wastes 297
  - from wood plantations 297–8
  - integrated systems, China 295B
- biological pump 34–5, 35–6B
- biomass
  - forest, carbon dioxide from 251
  - from wood plantations 297
  - as a fuel 293–8
    - modern 292
    - traditional 293–4
  - a genuinely renewable resource 294
  - growth for energy in industrialised countries **292**, 298
  - reducing fuel wood demand 294
- biomass burning
  - aerosols from 50
  - cut if deforestation reduced 253
  - in homes, causes serious health problems 294
- biomes 167, 169
  - climate a dominant factor in distribution 169, 171
- A Brief History of Time*, Hawking, Stephen 208
- Broecke, Professor Wallace 74
- Browne, Lord John
  - on carbon dioxide stabilisation 261
  - on constructive action 329
  - on planning for the long term 310–11
- Bruntland Commission, *Our Common Future* 226B
- buildings
  - energy conservation and efficiency in 280–5
  - passive solar gain 301B
  - solar energy in design 301B
  - passive solar design 300
- Callendar, G.S. 17B
- Canada, tree die-back 172
- carbon cycle
  - and carbon dioxide 29–40, 41
  - possible effects of climate feedbacks 40B, 41
- carbon dioxide 28
  - anthropogenic, transfer to oceans 34
  - atmospheric, increase in 8–9
  - capture and storage 287–92
    - options for disposal/sequestration 287
    - potential for underground storage 290
  - and the carbon cycle 29–40, 41
  - choice of stabilisation levels 258–9
  - doubled 17B, 23, **120**, 118–9, 122
    - cost of damage due to 185, 191
  - fertilisation effect 39, 40B, 166B
  - from deforestation **33**, 251
  - increase since the Industrial Revolution 23
- carbon dioxide concentrations 68, 69, 227
  - atmospheric 32, 32
  - contributions to 31, 33, **33**, 34
  - stabilisation of 254–8, 272–3
- carbon dioxide emissions 227
  - action essential for 21st century reductions 315
  - costs per tonne of carbon 232–3
    - considering incremental damage cost 233
    - sensitive to discount rate 233
  - from cars, reduction technologies 285B
  - future 41–2
    - need to fall 255
  - increasing, ecosystems unable to cope 217
  - per capita 257–8, 258
  - reductions 264
    - by large companies 329
  - substantial savings possible, petrochemical industry 286
  - total emissions, 2001–2100, SRES and stabilisation scenarios 255, **257**
    - omit effect of climate feedbacks 255, 257
- carbon emissions, anthropogenic, distribution among carbon reservoirs 30–1
- carbon intensity 272B
- carbon isotopes 36–7B
- carbon monoxide 48
- carbon tax 307
- carbonates, in ocean bottom sediments 67B
- Carson, Rachel, *Silent Spring* 197–8
- CFCs *see* chlorofluorocarbons
- change, human vulnerability to 8–9
- chaotic systems 84–5B
- Charles, Prince of Wales 326, 326B
- China
  - flooding 4–5
  - losses from natural disasters (1989–1996) 182
  - Three Gorges project 293
  - Yunnan, integrated biogas systems 295B
- chlorofluorocarbons 45–8, 263
  - controlled under the Montreal protocol 245–6
  - destruction of ozone 45–6
  - greenhouse effect 46
  - replacement by other halocarbons 47

- Christianity, caring for the Earth 205
- Clark, Professor William, on the conception and conduct of environmental research 328–9
- Clean Development Mechanism, Kyoto protocol 249B
- climate
  - acted on by oceans 92–5
  - is it chaotic? 106
  - monitoring of parameters 222
  - natural variability 127
  - past 56–76
    - past stability 71–5
  - simulations compared with observations 102–6
- climate change 199
  - action to slow and stabilise 242–67
  - adaptation to 178–80
    - costs 231–2, 238
  - anthropogenic 239
    - an integrated view 10–12, 11
    - costs 231–2, 238
    - a near certainty 229
  - complex network of changes 142–4
  - detection and attribution studies 104–5, 105
  - effects of ‘no regrets’ proposals 227–8
  - a global and long-term problem 325
  - important role for communicators and educators 325
  - likely to affect countries differently 166–7
  - longer-term 135–6
  - mitigation of 11, 231, 234–5, 235, 239
  - modelling the impact on world food supply 168B
  - need for better and clearer information 323–4
  - other possible influential factors 137–40
  - past 1–2
  - predicted rate of change is rapid 10
  - regional patterns 124–8
  - see also* climate extremes
- Climate Change Convention xxxi, 221, 225–6, 242–4, 261, 324
  - extracts 243B
  - objectives, short and long-term 242–3
  - Precautionary Principle 228
- climate change impacts 143–196
  - on agriculture and food supply 164–9
  - cannot be quantified in monetary cost alone 187–8
  - components included in projection of 218, 224
  - costing the total impacts 182–6
  - costs, extreme events 178–82
  - on ecosystems 167–74, 195
  - on fresh water resources 157–64
    - on human health 176–8
  - increasing human use of fresh water resources 155–7
  - overall impact of global warming 186–90
  - positive 143–4
  - possible 227
  - sea level rise 144–54
- Climate Convention Objective
  - action essential to reduce carbon dioxide emissions 314–15
  - guidance on stabilisation levels 244, 258
  - realisation of 261–3
  - stabilisation of atmospheric carbon dioxide concentrations 272–3
- climate extremes
  - changes in 128–33
    - vulnerability of human populations to 64–5
  - and human health 176–7, 177B
  - late 20th century 2–7
- climate modelling 77–114
  - future of 109–10
  - modelling the weather 77–85
  - of regional anomalies 101–2
  - regional modelling 107–109
- climate models 222
  - regional 133, 135, 162
  - simple 121B
    - simple upwelling-diffusion model 121B, 121
- climate prediction models 95–198
  - comparison with observations 102–6
  - model validation 100–4
  - use for predicting future climate change 105
- climate sensitivity 95, 124
  - best estimate for (IPPC) 120
  - cloud radiation feedback and uncertainty 222–3
- climate system 88–9
  - feedbacks in 89–94
  - oceans redistribute heat throughout 92–3
  - space observation of 223, 226B
  - unexpected changes 135–6
- climatic niches, for trees 170, 171, 172
- climatic variability 57, 60–1
- clouds
  - cloud radiative forcing 92B, 92
  - interfere with transfer of radiation 90–1
  - layer and convective 95
  - see also* feedbacks, cloud-radiation
- co-generation, of heat and power 286
- coal *see* fossil fuels
- coastal wetlands, loss of 154
- coral atolls

- important marine ecosystems in 176
- and sea-level rise 153
- corals 67B
- crop wastes, fuel from 294
- crops, use as fuels 297
- Daisyworld 205
  - and life on early Earth 203B
- Dansgaard-Oeschger events 73
- Danube, River, shared water resource 157–8
- deforestation 37, 39, 115–16, 250B, 253
  - can lead to changes in rainfall 161
  - carbon dioxide from 33, 251
  - and climate change 173B
  - effects on climate in region of change 173B
  - reduction in will slow greenhouse gas increase 251
  - tropical, carbon released into the atmosphere 173
  - in tropical regions 37, 39
- delta regions, vulnerable to sea level rise 150–3
- Denmark, energy from wind power 299
- desertification 162, 163B
  - progress in drylands will increase with more droughts 163B
- developed countries 225
  - Climate Convention, short term objective 245
  - food surpluses likely under climate change 166
- developing countries 225
  - agriculture likely to decline with climate change 167
  - biomass projects in rural areas 295B
  - less adaptive capacity 145
  - loss of agricultural employment will lead to migration 167
  - reliance on traditional biomass 294
  - technical advances in agriculture needed 167
  - urgent need for large scale provision of simple stoves 294
  - will be very disadvantaged by global warming 185–6
- discount accounting 233–4
- diseases, increased spreading in a warmer world 175–6
- drought 4, 5, 160
  - Africa 5, 160
  - in the Sahel 173B
  - damage due to seriously under estimated 182
  - due to drop in summer rainfall 127, 131
- drylands 163, 163B
- Earth 205
  - feedback and self-regulation 202–3
  - orbital variations 69, 69, 70–2, 101, 106, 138–9
  - stewards of 208–10
  - unity of 201–6
  - warming processes 14–16
  - see also* Daisyworld
- Earth in the Balance*, Al Gore 197, 208
- Earth Radiative Budget Experiment (ERBE) 94
- Earth's orbit, variations in 70–2, 69
- eccentricity, of Earth's orbit 70, 71
- economists, new challenges for 325
- ecosystems 143, 217
  - impact of climate change 174–6, 192
    - loss of species and biodiversity 173
    - on natural forests 170–3
    - will become unmatched to their environments 169
  - marine 174
  - and their environments (Lovelock) 202
  - unable to respond fast to global warming 167, 169
  - wetland and mangrove, vulnerable to sea level rise 153–4
- Einstein, Albert, comment on the universe 205
- El Niño, associated droughts and floods 6–7, 7
- El Niño events 5–7, 13n, 127
  - adaptation of Peruvian farmers to 163
  - coral bleaching events 174
  - disease epidemics associated with 175
  - large variation in ocean temperature 87, 87
  - predictions up to a year ahead 87, 101
  - short-term variations of atmospheric carbon dioxide 40B
  - simple model 89B
- El Niño oscillation 89B
- emission scenarios 42, 115–17
  - see also* Intergovernmental Panel on Climate Change (ipcc); World Energy Council
- emissions trading 248–9, 248B
- energy
  - disparity in amounts used 269
  - from solar cells *see* photovoltaic (PV) cells
  - from the Sun 300–5
  - future projections 272–8
  - renewable 290–306
    - financial incentives 307
    - some sources competitive 307
    - support and finance 306–10
  - traditional sources 269, 269
  - use of 270
- energy balance models 121, 121B
- Energy in a Changing Climate*, Royal Commission on Environmental Pollution (RCEP) 313B
- energy conservation and efficiency in buildings 278–83
- improvement of insulation 279, 280B, **280**
- improving efficiency of appliances 280B
- thermodynamic efficiencies 278B

- energy conservation (*cont.*)
  - use of integrated building design 282–3
    - BedZED a Zero Emission (fossil fuel) Development 283B
    - low energy buildings 282–3
- energy generation
  - efficiency improvement possible 234
  - proven recoverable reserves of fossil fuels 270, 271
- energy intensity 274, 276B
  - and carbon intensity 272B
- energy intensity index 272B
- Energy Review*, Policy and Innovation Unit (PIU), UK Cabinet Office 313B
- energy savings
  - in industry 286–7
  - in transport 283–5
- energy sector, significant policy initiatives required 309
- England, eastern, Norfolk coast in need of protection 153
- environmental degradation 186, 322
- environmental problems
  - human-induced, impacts now 142
  - long-term and potentially irreversible 225
  - and our will to act 210–11
- environmental refugees 167, 327
  - destabilising international order **186**
- environmental research, conception and conduct 327–8
- environmental science xxxi–xxxii
- environmental stewardship, goal of 328–30
- environmental values 206–08
  - assessment and development of appropriate attitudes 210–11
- equations, in a numerical atmospheric model 80B
- equity, principle of, international and intergenerational 226, 231B, 261
- ethane 40
- ethanol 308
- EU, proposed limit for global average temperature rise 261
- Europe, heatwaves 177B
- exploitation 198–9
  - of Earth’s biological resources 198–9
  - of Earth’s mineral resources 198
- extreme events 2, 3
  - changes in frequency/intensity of 188, **189**, 189
  - costing climate change impacts 179–84
  - disasters causing largest losses **183**
  - likely future costs 184–5
  - weather-related disasters (1990s), fatalities, economic and insured losses 183, **183**, 186
  - and disasters, adaptation to 179, 180
  - future incidence 133, **134**
  - storms in Europe, 1980s and 1990s 2, 3
  - see also* climate extremes; drought; hurricanes/cyclones/typhoons; temperature extremes
- Fair Isle 299B, 307
- feedbacks 120, 173B, 202, 260
  - biological 36B, 39, 72
  - in the biosphere 39–40B, 173, 255, 257
  - on the carbon cycle 118, 121, 135, **186**
  - in the climate system 89–93
  - and climate variation 71–2
  - cloud-radiation 90–1, 95, 222–3
  - hydrological cycle-deep ocean circulation 99, 99B
  - ice-albedo 94, 99
  - incorporated into climate prediction models 99
  - lapse rate 112
  - ocean-circulation 91–4, 95–6
  - positive and negative 39–40
  - water vapour 90, 111n
- financial incentives 306–8
  - for renewables 307
  - must be applied to solid, liquid or gaseous fuels 307–8
  - needed in area of research and development (R & D) 308
- floods/flooding 4–5, 160, 161, 162, 163–4
- forest dieback 40B, 174, 173B
- forest fires 3, 6
- forest plantations, growth in 250B
- forests
  - deforestation 250B
    - and climate change 173B
  - impact of climate change 173–4
    - decline in health noticed 174
  - and projected rates of climate change 164–5
  - represent large store of carbon 175
  - as sources and sinks of carbon 250–3
  - trees cannot respond quickly to climate change 170–1
  - tropical, destroyed 198
- fossil fuel reserves 135
  - proven recoverable reserves 270, 272
- fossil fuels 198, 199, 268
  - burning in northern hemisphere 34
  - global impact of burning 323
  - increased burning 31, 33, **33**
  - rise in global emissions 245
  - ultimately recoverable 270
- Fourier, Jean-Baptiste 17B
- France, La Rance tidal barrage 306
- fresh water resources

- impact of climate change 157–64
- increasing human use 155–8
  - see also* water; water supplies
- fuel cell technology 331, 311B, 312
- sources of hydrogen 312
- future generations, our responsibility to 200–1
- Gaia hypothesis 201–3
  - Earth seen as central 206–7
  - Earth’s feedbacks and self-regulation 202–3
- galactic cosmic ray flux 139
- Ganges–Bramaputra, River, shared water resource 156–7
- gas turbine technology, efficient 286
- geoengineering 229
- geothermal energy 305–6
- glacier retreat, and rising sea level 146–7
- global average temperature
  - change in 10, 57–8, 135
  - projections of 121–4
- Global Climate Observing System (GCOS) 222
- Global Commons Institute (GCI), Contraction and Convergence proposal 261–3, 262
- global economics 231–39
  - cost–benefit analysis 232, 233
  - costs of mitigation and adaptation 231–2, 234–5, 235, 238–9
  - debate on application of discount accounting 233–4
- global food production 189
  - rise in 164
  - see also* agriculture
- global village 322–32
- global warming
  - 20th century, not uniform 60–1
  - arguments for action concerning 228–9
  - business-as-usual scenario 115, 116, 188
  - challenges of 322–5
    - and deforestation 251–3
  - estimates of costs of damage 189, 232
  - impact will not fall uniformly 323
  - implications 237–8
  - not the only problem 326–7
  - overall balance sheet 238–9
  - overall impact 188–92
  - the problem 9–10
  - trends in 8–9
  - what the individual can do 329–30
- global warming potential (GWP) 52, 55n
- global water cycle 155–6, 155
- Gore, Al, *Earth in the Balance* 197, 208
- Green Revolution 164
- greenhouse effect 16–21
  - basic science well known 16–17, 17–18B, 216
  - complicated by feedbacks and regional variations 216–17
  - enhanced effect 16, 23–5
  - gases with an indirect effect 48
  - natural effect 16, 23
  - runaway effect 22–3
- greenhouse gas concentrations 117, 119
- greenhouse gas emissions
  - controlled by Kyoto protocol 247, 247
  - from transport 283–4
  - stabilisation 245
- greenhouse gases 16, 16, 26–7n, 28–9, 65, 139, 235
  - conversion to carbon dioxide equivalents 120, 122, 141n
    - a useful tool 260
  - estimates in SRES scenarios 33, 115–16
  - gases other than carbon dioxide 259–60
  - generation from waste incineration 297
  - Kyoto Protocol 52, 247
  - longer-term impacts of growth 185
  - stabilisation target level 260
  - to be returned to 1990 levels 245
  - see also* emission scenarios
- Greenland ice cores
  - showing Younger Dryas event 74
  - variations in Arctic temperature 72, 73
- Greenland ice sheet, vulnerable to future melting 149–50
- groundwater
  - use and replenishment 160
  - withdrawal by large cities causing subsidence 153
- Hawking, Stephen, *A Brief History of Time* 205
- heat pumps 280B
- heat stress 176–7, 189
- heat transfer, by radiation or convection 17, 18
- Heinrich events 75
- Hinduism 204
- Holocene, long stable period 72
- Honduras, losses due to Hurricane Mitch 181
- honesty, humility and holism, in research 328
- human behaviour and activities, studies of 223
- human health
  - impact of climate change 176–8
  - problems from biomass burning 294
- human–environment relationship 198
- humans
  - as gardeners caring for the Earth 208–10, 328
  - profligate in use of world’s resources 228
  - a special place in the universe 211

- Hurricane Andrew 4
  - a huge weather-related loss 181B
- Hurricane George 179
- Hurricane Gilbert 4
- Hurricane Mitch 4, 179, 181
  - most damaging hurricane known so far 183
- hurricanes/cyclones/typhoons 4–6, 131
  - mid-latitude storms, increased intensity expected 132–3
  - severe storm, England (October 1987) 85B
- Huxley, Thomas ‘humility before the facts’ 211
- hydro-power/hydro-electric schemes 290, 291–3, **292**
  - pumped storage 293
- hydrogen
  - for fuel cells 311B, 312
  - storage problems 213
- hydrological cycle, becoming more intense 128, 129, 130–1
- hydroxyl radicals (OHs) 48
- ice ages 53, 70
  - data over four cycles 69
  - and the greenhouse effect 17B
  - periods of greater marine biological activity 35–6B
- ice caps 64, 67
- ice cores 67
  - evidence for the biological pump 35
  - information sources 67–70
  - show series of rapid temperature oscillations 73–5, 74
- Iceland, development of a hydrogen economy 314
- ice-sheets, and sea level rise 145–6, 149–50
- India 302
  - heatwaves 177B
  - northwest, water availability seriously reduced in
    - simulations 161
  - rural power production 295B
- industrial haze 48
- industry
  - energy savings in 284–5
  - estimates of potential greenhouse gas reductions **286–7**
  - responsibilities of 324–5
- insurance industry
  - and climate change 5, 183B, **182**
  - costs of weather-related disasters 4, 5
  - losses due to extreme events 179
  - recent disasters 4
- Integrated Assessment and Evaluation 145, 237B, 260
- integrated assessment models 109, 237, 237B
- Intergovernmental Panel on Climate Change (IPCC)
  - xxviii–xxix, 42
  - 1990 report xxix, 76n, 104, 120
  - 1995 report 104, 120, 123, 218
    - review of four cost studies 184
  - 2001 report 105, 120, 123
  - assessments 218–19
  - description of scientific uncertainty 217B, 218
  - IS 92a scenario (business-as-usual) 115, 118, 192
  - SRES scenarios 51–2, 116, 116, 117B
    - estimates of human-related methane emissions 44, **44**
  - working groups
    - contributions widely based 221–2
    - reports xxix–xxx, 219
    - Science Assessment Working Group 219–20
- international action, principles for 230
- irrigation 164
  - improvements in availability and management of water
    - needed 167
  - micro-irrigation techniques 163
  - MINK region, groundwater resource non-renewable 160
  - wasteful of water 162
- Islam 205
- isotopes
  - carbon 36–7B
  - palaeoclimate reconstruction from data 67B
- Japan, rooftop solar installations 303
- Joint Implementation, Kyoto protocol 248B
- Judaean-Christian tradition 213–14n
  - stewardship 208–9
- Judaism, caring for the Earth 205
- Kelvin wave 89B, 89B
- Kyoto protocol 244, 246–7
  - emissions targets for greenhouse gases 246, **246**
  - likely implementation costs 248–9
  - mechanisms 248B
    - allow offsetting of domestic emission obligations 246–7
- land-use change
  - can affect amount of rainfall 173B
  - carbon dioxide emissions from 31, 33, **33**
  - deforestation in tropical regions 37, 39
- landfill sites, cut in methane produced 253–4
- light emitting diodes (LEDs) 279B
- Little Ice Age 65, 138B
- Lorenz, Edward 82
- Lovelock, James E.
  - Daisyworld 202, 203B
  - Gaia, the Practical Science of Planetary Medicine* 203
  - quoted on Gaia 203

- malaria and dengue fever 178
- Maldives, Indian Ocean, vulnerable to sea-level rise 153
- marine biological activity
  - greater during the ice ages 35–6B
  - past variations in, control on atmospheric carbon dioxide concentrations 69, 173–4
- Mars, atmosphere 21, 25
- Marshall Islands, Pacific Ocean, vulnerable to sea-level rise 152
- Maunder Minimum 67
- Medieval Warm Period 65
- Mendeleev, Dmitri 16
- methane 29, 42–4, 55n, 294
  - changes in concentration 42–3, 43
  - a more effective greenhouse gas 297
  - reduction in sources of 253–4
  - removal from atmosphere 43
  - sources and sinks 43, 44
- methane hydrates 40, 270
- Microwave Sounding Unit (MSU), remote temperature observations 59–60B
- Milankovitch theory/cycles 70–2
  - correlation with cycles of climatic change 69, 102, 106
- minerals, and the Industrial Revolution 198, 199
- MINK region (USA) study 160B
  - decline and die-back of forests 172
- mitigation of climate change 11, 231, 232–3, 235, 239
  - see also Kyoto protocol
- mitigation energy scenarios 277, 277
  - see also World Energy Council, detailed energy scenarios
- models
  - atmospheric 79–80, 79, 80B
  - climate models, regional and simple 121B, 121, 133, 135, 162, 222
  - climate prediction models 95–8
  - coupled models 87B, 96–9, 97
  - limitations give rise to uncertainty 217, 217B
  - for ocean–atmosphere carbon exchange 33, 33, 36
  - Regional Climate Models (RCMs) 107, 108, 132, 133, 135, 162, 181
  - weather-forecasting 80, 81, 82, 84
  - see also Daisyworld
- monitoring
  - of climate parameters 222–3
  - of major oceans 223
- Montreal Protocol 46, 245–6, 260, 264, 326
- Mozambique 5
- multicriteria analysis 260
- Native Americans 204
- natural capital 238
- natural disasters, involving water 160
- natural gas see fossil fuels
- natural gas pipelines, reduction of leakage 254
- The Netherlands, protected coastal lowlands 153
- Nile Delta, Egypt, affected by sea level rise 152
- Nile, River, shared water resource 157–8
- nitrogen 16, 16
- nitrogen oxides (*NO* and *NO*<sub>2</sub>) 48, 245–6
  - emitted from aircraft 48
- nitrous oxide 29, 45, 260
- ‘no-regrets’ proposals 227–8, 287
- North Atlantic
  - GCMs show less warming in 126, 136
  - northern 124
  - ocean circulation 75, 101B, 102
- North Atlantic Oscillation (NAO) 130
- nuclear energy 274, 316
  - uranium reserves 276
- nuclear fission 316
- ocean circulation
  - North Atlantic 75, 99B, 99
  - see also thermohaline circulation
- ocean currents, tidal streams and ocean waves, energy present 306
- ocean–atmosphere GCMs 126
  - model projections 118–19, 121
  - show weakening of the THC 136, 137
  - see also atmosphere–ocean coupled models
- ocean–atmosphere interface, exchange of heat, water and momentum 96
- oceans
  - inadequately monitored 223
  - recent work relating to warming of 105–6
  - thermal expansion 64, 146, 146B, 148
- oil see fossil fuels
- orbital variation 69, 69, 70–2, 101, 106, 138–9
- Our Common Future*, Bruntland Commission 226B
- oxygen isotopes 74
  - in palaeoclimatic reconstruction 67B
- ozone
  - complex effect from depletion 47
  - destroyed by CFCs 45–6, 323
  - a greenhouse gas 46
  - levels beginning to recover 229
  - tropospheric 260, 267n
  - can become a health hazard 47–8
- ozone hole, Antarctica 46, 229



- Pacific, tropical, surface temperature more El Niño-like **62–4**, 127
- Pacific–North Atlantic Anomaly (PNA) 127
- Pakistan, northwest, water availability in simulations 162
- palaeoclimatic data 67B, 69–70, 100
- palaeoclimate reconstruction, from isotope data 67B
- Pan American Health Organisation (PAHO), policies to reduce effects of hurricanes 179
- Patmos Principles 214n
- perfluorocarbons 47
- perihelion 70, 71, 101, 101
- Peru, adaptation to changing climate 166
- Philippines, biomass power generation and coconut oil pressing 296B
- photosynthesis 37
- photovoltaic (PV) cells 293, 300B, 302, 304, 312–13
  - building-integrated-PV sector 303
  - costs competitive 303–4
  - provision of local electricity sources in rural areas 303–4
- Pinatubo, Mount, eruption 1991 40B
  - dust from 8, 49, 101, 102, 139
- plankton multiplier 36B, 40B
- plant species, constraints imposed by dispersal process 169
- Polluter Pays Principle 226B, 231B, 249, **247**, 261, 262, 328, 326
  - financial incentives for renewables 307
- pollution, a danger to human health 176
- pollution issues xxxviii
  - see also* acid rain; global warming; ozone
- population growth
  - demands of 326
  - and poverty 326B
- poverty 326
  - and population growth 326B
- power stations
  - increased efficiency possible 286
  - use of low-grade heat 286
- Precautionary Principle 226B, 228–9, 231B, 261
- precipitation
  - change with a warming Earth 126–7
  - and climate change 157
  - increased, leading to more flooding 163–4
  - with a more intense hydrological cycle 128, 129, 130–1
- primary energy, proportion of wasted 278
- pumped storage 293
- radiation, absorption and reflection 18, 20
- radiation balance, Earth 14, 15–16, 15
- radiation budget 20–1, 21
- radiative forcing 29, 46, 54n, 105
- cloud 92B, 94
  - direct and indirect, caused by aerosols 49, 50, 51
  - of doubled carbon dioxide 123–4
  - estimates 50, 52–3
  - from emission profiles 117, **120**, 122
  - possible effects of aviation 50, 53
  - significant effects of tropospheric ozone and sulphate aerosols 267n
- Regional Climate Models (RCMs) 107, 108, 131, 133, 135, 162, 218
- regional modelling techniques 107, 108, 109
- religion
  - and science, seen to be complimentary 208
  - and the scientific outlook 207
  - and the will to act 210
- renewable energy 268, 290–306
  - current status, future potential costs **292**
  - support and financing of 306–8
- resource consumption, contributing to global warming 326
- respiration 37, 40B
- Revelle, Roger 17–18B
- Richardson, Lewis Fry 77–8
- Rio Declaration 198, 231, 231B, 323
  - Precautionary Principle 228
- river systems, regulated and unregulated, sensitivity to climate change 164
- road transport
  - freight transport 284
  - greenhouse gas emissions 283
  - growth in motor vehicle population 284, 285
  - motor transport, actions to curb energy use 284
  - use of fuel cells 285B, 311, 312
- Rossby waves 89B, 89B
- Royal Commission on Environmental Pollution (RCEP), *Energy in a Changing Climate* 313B
- runoff, sensitive to changes in climate 157–8
- Sahel region, Africa, seasonal weather forecasting 87B, 87
- satellite observations 58–9
  - of atmospheric temperature 59–60B
  - of the climate system, instruments for 223B
- satellites, geostationary and polar orbiting 224B
- science, and religion, seen to be complementary 209–10
- Science Assessment Working Group (IPCC) 219–21
  - reports contain Summary for Policy Makers 222
- scientific uncertainty 216–18
  - reasons for 217B
- scientists, and Theories of Everything 207
- sea level, changes in 145

- melting or growth of ice-sheets 145–6, 149
- thermal expansion of ocean waters 146, 146B
- sea level rise 237B
- 21st century
  - changes from ice-sheets will be small 149
  - melting of glaciers 146–7
  - not uniform over the globe 147, 149
  - SRES scenarios 147, 148
  - through thermal expansion of ocean waters 146
- by how much? 145–50
- impacts of 150–5
- indirect consequences 237B
- sea surface temperatures
  - anomalies persistent 85
  - changes in 58
  - and El Niño events 5–6
  - forecast of aids seasonal forecasting 85–6
  - tropics, atmosphere sensitive to 84
- seasonal forecasting 83–8
  - Sahel region, Africa 87B, 87
- security, threatened by climate change impacts 326–7
- sediments, oceanic, palaeoclimatic data contained in 69–70
- semi-arid regions, loss of vegetation, can lead to changes in rainfall 163
- sensitivity 144B, 145
  - of different systems, variation in 143
  - to climate change in 21st century of major crops 164, 163B
- sequential decision making 260
- Silent Spring*, Rachel Carson 197–8
- singular (irreversible) events 232
  - effects 185, **186**
  - need to guard against 228–9
- snowmelt, as runoff, affected by climate change 159
- soil degradation 164
- soil moisture, loss of in continental areas 159, 163
- solar cookers 294, 300
- solar energy 308
  - concentration with mirrors 290
  - efficiency of conversion to electrical energy 302
- solar (energy) systems, growth potential 304
- solar heat, used in the generation of electricity 391–2
- Solar Home Systems 304, 304
- solar lanterns 304
- solar output
  - reduction in and ‘Little Ice Age’ 138B
  - variation in 66–7
  - very constant 138B
- solar radiation 79, 92, 101
  - and orbital changes 138–9
  - reflection by ice/snow 95
  - varies over time 100
- solar variability 50, 52–3
- solar wall 301B, 301
- solar water heating 300B, 300
- solubility pump 34
- Sri Lanka, small hospitals benefit from solar arrays 304
- stabilisation
  - of carbon dioxide concentrations 254–8, 272–3
    - Contraction and Convergence proposal 261–2, 262, 264
  - choice of stabilisation levels 258–9
- of greenhouse gas emissions 245
- Statistical Downscaling 107, 109
- stewardship, of the earth xxxii, 208–10, 211
- storm surges 4, 151, 237B
- stratosphere, lower, cooling in 59, 61
- Suess, Hans 17–18B
- sugar cane
  - alcohol for fuel produced from 297
  - as biomass 295B, 296
- sulphate particles 49, 49, 50, 117
- sulphur dioxide
  - emissions likely to rise less rapidly 51, 117
  - from volcanic eruptions 7–8
- sulphur hexafluoride 47
- summers, drier 157
- Sun
  - energy from 301–5
  - indirect mechanisms to alter Earth’s climate 139
  - possibility of change in output 138B
  - radiant energy from 14–15, 15
- sunspot activity 138B
- surprises *see* singular (irreversible) events
- sustainability analysis 260
- sustainable consumption 326
- sustainable development 198, 225–6, 231B, 261
  - definitions 226B
  - and the environment 235
- Sustainable Development Commission (UN) 324
- Sweden, Uppsala, comprehensive district heating system 297
- Tambora (volcano) 66
- technical fixes 229–30
  - neither balanced nor sustainable 201
- technology
  - for the longer term 311–14
  - necessary, already available 327

- temperature
  - global, increase in leads to climate change 9–10
  - millennial northern hemisphere record 65, 66, 67
  - minima increased more than maxima 61
  - rate of change since last glacial maximum 72–3
- temperature change, atmospheric 124–6
- temperature extremes 7–8, 177B
- Thatcher, Baroness Margaret xxix, 225
- THC *see* thermohaline circulation
- thermal expansion (oceans) 146, 146B, 148
- thermal radiation 15–16, 26n, 78, 94
  - in the infrared region 18, 19, 20
- thermodynamic efficiencies 277B
- thermohaline circulation 99B, 99, **186**
  - changes in 135, 137
  - cut off, effects of 136, 137
  - effects of increased precipitation 136
  - link with melting ice 74
- This Common Inheritance*, UK White Paper 226B
- tidal energy 306
- tracers, modelling of in the ocean 102B
- tradeable permits 307
  - see also* emissions trading
- transport, energy savings in 283–5
- tritium, as a tracer 102, 102
- Tyndall, John 17B
- UK
  - Policy and Innovation Unit (PIU), Cabinet Office, *Energy Review* 313B
  - potential of Severn estuary 306
  - White Paper, *This Common Inheritance* 226B
- UN Conference on Environment and Development (UNCED) (Rio:1992) xxix, 198, 210, 221
- UN Framework Convention on Climate Change *see* Climate Change Convention
- uncertainty 120, 216–41
  - carbon dioxide concentration scenarios 117, 121B
  - and future innovation 235–6
  - mitigating responses 12
  - of model predictions 109–10
  - narrowing of 222–4
  - over size of warming 10
  - regarding cloud-radiation feedback 95
- uranium 270
- USA
  - the Dust Bowl 161
  - energy use in buildings 279
    - identification of electricity savings to be made 280–2, 282
  - Mississippi delta, lacks sediment inputs 152–3
  - Sacramento Basin, runoff, simulations 158–9, 158
  - study of MINK region 160B, 172
  - withdrawal from Kyoto protocol 247
- values
  - environmental 205–7
  - shared values 205–6
  - related to science 206
  - and religion 207
- Venezuela 5
- Venus, atmosphere 21–2, 25
- volcanic dust, Mount Pinatubo 8, 49, 102, 102
- volcanic eruptions 66, 102
  - and climatic variability 60, 139
  - effect on temperature extremes 7–8
- Vostok ice core 67, 72
- data on temperature and carbon dioxide concentrations 68, 69
- vulnerability 144B, 145
  - of some watersheds to climate change 159–60
  - to extreme events and disasters 178, 179
  - to sea level rise
    - Bangladesh 150–2, 154
    - cities in coastal regions 153, 154
    - low-lying Pacific and Indian Ocean islands 153
    - Nile Delta 152–3
    - The Netherlands 153, 154
    - wetland and mangrove ecosystems 153–4
- war
  - over oil 326
  - threatened by loss of water supplies 326–7
- waste, incineration for power generation 199–200
- water
  - growth in worldwide use 156, 158
  - a key substance for human 156
  - vulnerability arising from shared resources 157–8
- water supplies
  - loss of and threat of conflict 326–7
  - vulnerable to climate change 158–65
- water vapour 91
  - in climate models 79
- water-stressed countries 156
- watershed, vulnerable to climate change, identification of 160
- weather, variations in 2
- weather forecasting
  - data sources for UK Meteorological Office model 82
  - ensemble forecasting 74
  - models for 79, 81

- improvement in 81, 83
- potential improvements in forecasting skill 82–5, 83
- and uncertainty 220
- weather-related disasters (1990s), fatalities, economic and insured losses 179, **182**, 183
- wetlands, and mangrove swamps, can adjust to slow levels of sea level rise 154
- will to act 209–10
  - lack seen as a spiritual problem 210
- wind energy 298–300, 308
  - suitable for isolated sites 300
  - wind power on Fair Isle 299B, 307
- wind farms, public concerns 298
- wind turbines 298, 300
- winter cold, several deaths during 175
- wood fuel, recycling of carbon from 253
- World Climate Conference (Geneva:1990) xxix
- World Energy Council
  - contributions from ‘new’ renewables 291, **291**
  - detailed energy scenarios 42, 273–7, 274, 276B
    - recognise importance of nuclear energy 310
  - ecologically driven scenario (Scenario C) 263, 273, 273, **277**, 275, 277B
    - energy demand reduced 278–9
  - Report, *Energy for Tomorrow’s World* 141n
- world energy demand and supply 268–72
- world religions, close relationship between humans and the Earth 204–5
- Younger Dryas event 73, 74, 75