

Index

- A Brief History of Time* (Hawking, 1989), 225
- acid rain pollution, 54, 164
- action. *See* climate change action; Framework Convention on Climate Change (FCCC)
- adaptation to climate change, 10, 201–5
- costs, 252–8
- adaptive capacity
- and climate change, 164
- definition, 163
- aerosols (atmospheric particles)
- contribution to the greenhouse effect, 53–9
- equivalent carbon dioxide (CO₂e) conversions, 142
- future contribution to radiative forcing, 137, 148
- Africa
- climate change impacts, 202
- vulnerability to droughts, 7–9
- agriculture and food supply
- carbon dioxide fertilisation effect, 185
- efficient irrigation techniques, 182
- impacts of climate change, 184–7
- increasing demand for fresh water, 176–7
- intrusion of salt water into the land, 172
- modelling impacts on food supply, 188
- soil loss and impoverishment, 164
- aid agencies
- challenges facing, 353
- air transport emissions
- aviation-induced cloudiness, 57
- contribution to radiative forcing, 53
- contribution to the greenhouse effect, 57
- albedo of the land surface
- effects of afforestation, 275–6
- ice-albedo feedback, 112
- influence on radiative forcing, 61
- Amazonia, 195
- Antarctic ice-sheet
- effects of climate change, 167–8
- ice core data, 46, 80
- rate of melting, 76
- Antarctica
- ozone hole over, 250
- anthropic principle, 225
- anthropogenic climate change
- integrated framework, 10
- appliances
- efficiency of, 304
- Arrhenius, Svante August, 22
- Atlantic Meridional Overturning Circulation (AMOC), 117, 155–7
- atmosphere
- composition of, 19–30
- heat transfer by convection, 20–3
- atmospheric circulation
- coupling with ocean circulation, 99–104, 114–16
- atmospheric particles. *See* aerosols
- ‘back to nature’ solution for environmental problems, 220–1
- Ban Ki-moon, 355–6
- Bangladesh
- floods of 1998, 5
- local energy provision, 328
- vulnerability to sea level rise, 170–2
- vulnerability to storm surges, 3
- biodiversity loss, 197
- biofuels, 320–1
- biological pump in the oceans, 38, 41
- biomass energy, 316–19
- projects in rural areas of the developing world, 318–19
- Bolin, Bert, 12, 241
- Boulding, Kenneth, 348
- Boutros-Ghali, Boutros, 178
- Brazil
- production and use of biofuels, 320
- Broecker, Wallace, 86–7, 283
- Brown, Gordon, 248–9, 300
- Browne, Lord John, 332
- buildings
- energy conservation and efficiency, 300–7
- insulation of, 305
- integrated building design, 302
- solar energy in building design, 324
- ZEDs (Zero Emission Developments), 306
- Burke, Edmund, 354
- Bush Snr, President George, 243
- Callendar, G.S., 22
- carbon capture and storage (CCS), 312–13
- carbon cycle, 33–44
- carbon dioxide
- and the carbon cycle, 33–44
- Contraction and Convergence proposal, 285–6
- contribution to anthropogenic radiative forcing, 44
- contribution to the greenhouse effect, 33
- equivalent carbon dioxide (CO₂e) conversions, 142
- estimates of future emissions, 44–6
- reducing emissions from industry, 310–11
- reducing emissions from motor vehicles, 310
- reducing emissions from transport, 307–10
- role in global warming, 9–10
- stabilisation of CO₂ concentrations, 281–3
- carbon dioxide fertilisation effect, 43, 185

- carbon dioxide levels
 - association with global warming, 22
 - effects of burning fossil fuels, 22
 - feedbacks in the biosphere, 45–6
 - first concerns about climate change, 22
 - routine measurement of, 22
- carbon-free energy supply
 - biofuels, 320–1
 - biomass energy, 316–19
 - carbon capture and storage (CCS), 312–13
 - carbon intensity reduction, 312
 - energy efficiency improvements, 311–12
 - fuel cell technology, 335
 - geothermal energy, 328
 - hydrogen energy economy, 332–6
 - hydropower, 315–16
 - new technologies, 332–6
 - nuclear energy, 313–14
 - nuclear fusion, 336
 - policy instruments, 331
 - power generation from waste, 316–19
 - renewable energies, 314–29
 - research and development (R&D) effort, 331–2
 - solar energy, 322–8
 - support and financing, 329–32
 - technologies of the future, 332–6
 - tidal energy, 328–9
 - wave energy, 329
 - wind energy, 321–2
 - zero carbon future, 336–9
- carbon intensity of energy supply, 296–7, 312
- carbon isotopes
 - identifying the source of carbon dioxide, 42
- carbon monoxide
 - indirect greenhouse effect, 53
- carbon trading, 271
- Carson, Rachel, 219
- cement manufacture
 - carbon dioxide emissions from, 36
- CFCs. *See* chlorofluorocarbons
- chaos
 - features of chaotic systems, 99–100
 - in climate systems, 125
 - in weather systems, 99–100
- Charney, Jules, 195
- China
 - devastating floods of the 1990s, 5
 - emissions related to exports, 286
 - integrated biogas systems (Yunnan), 319
 - vulnerability to sea level rise, 173
- chlorofluorocarbons (CFCs), 19
 - as greenhouse gases, 50, 52
 - destruction of ozone, 50–1
 - Montreal Protocol, 266–7
 - sources of, 50
- Christianity
 - relationship with the Earth, 225, 228–30
- Clean Air Acts, 347
- climate/carbon-cycle feedbacks, 43
- climate change
 - and variations in the weather, 2–3
 - extreme events in the last 40 years, 2–8
 - first concerns about greenhouse gases, 22
 - influence on El Niño events, 101–2
 - integrated framework, 10
- climate change action
 - adaptation to climate change, 201–5, 252–8
 - carbon trading, 271
 - choice of greenhouse gas target levels, 279–81
 - damage from climate change and its cost, 252–8
 - Durban Platform for enhanced action, 279–80
 - Integrated Assessment and Evaluation, 253–4
 - Kyoto Protocol, 267–72
 - mitigation of causes of climate change, 252–8
 - mitigation role of forests, 272–6
 - Montreal Protocol, 266–7
 - Precautionary Principle, 250–1
 - Principles for international action, 251–2
 - realising the Climate Convention Objective, 283–7
 - recent reports from some world bodies, 280
 - reduction in non-CO₂ greenhouse gases, 276–8
- stabilisation of CO₂ concentrations, 281–3
- stabilisation of emissions, 266
- sustainable development, 247–9
- the wait-and-see approach, 258–9
- the will to act, 231–2
- use of discounting, 258–9
- See also* Framework Convention on Climate Change (FCCC).
- Climate Change Committee (UK), 337
- climate change impacts
 - adaptation to climate change, 201–5
 - agriculture and food supply, 184–7
 - carbon dioxide fertilisation effect, 185
 - coastal area impacts, 169–75
 - coastal protection in the Netherlands, 173–4
 - complex network of changes, 163–5
 - coral reefs, 197–9
 - costs of, 205–12
 - desertification, 183
 - ecosystem effects, 187–99
 - forests, 184, 190–5
 - fresh water resources, 178–82
 - heatwaves, 200
 - human demand for fresh water resources, 175–8
 - human health impacts, 199–201
 - impacts on Africa, 202
 - insurance industry, 207
 - low-lying small islands, 174
 - melting of the Antarctic ice-sheet, 167–8
 - melting of the Greenland ice-sheet, 167–8
 - modelling impact on world food supply, 188
 - sea level rise, 164–9
 - spreading of diseases, 201
 - summary of extreme weather and climate impacts, 212
 - thermal expansion of the oceans, 167
 - vulnerability of large river delta areas, 170–3
- climate change in the future
 - amount and distribution of precipitation, 143–8
 - Atlantic Meridional Overturning Circulation (AMOC), 155–7

- climate change in the future (cont.)
 - changes in the deep ocean (thermohaline) circulation, 155–7
 - changes in the Sun's energy output, 157–8
 - climate sensitivity estimations, 137–8
 - droughts, 149–50
 - effects of Earth's orbital variations, 157
 - emission scenarios, 134–7
 - equivalent carbon dioxide (CO₂e), 142
 - extreme weather and climate events, 149–53
 - floods, 149–50
 - global average temperature projections, 138–42
 - heatwaves, 149
 - influence of volcanic eruptions, 157–9
 - longer-term climate change, 155
 - model projections, 137–8
 - non-uniformity of changes, 143–8
 - possibility of surprises, 155
 - precipitation amount and distribution, 149–50
 - radiative forcing effects of aerosols, 137, 148
 - radiative forcing effects of greenhouse gases, 137, 148
 - regional climate models, 153–5
 - regional patterns of climate change, 143–8
 - Representative Concentration Pathways (RCPs), 135–7
 - simple climate models, 138–9
 - Special Report on Emissions Scenarios (SRES), 134–6
 - storms, 153
 - tropical cyclone frequency and intensity, 150–3
 - uncertainty in prediction, 14
 - See also* models for climate prediction.
- climate change in the past. *See* past climates
- Climate Convention. *See* Framework Convention on Climate Change (FCCC)
- climate sensitivity, 114
 - definition of sensitivity, 163
 - estimations, 137–8
- cloud properties
 - incorporation into climate models, 113–14
- cloud-radiation feedback, 107–9
- cloud radiative forcing (CRF), 110–11
- clouds
 - influence of aerosols on, 60
- communicators
 - challenges facing, 353
- computers
 - development of data analysis and modelling, 11
 - used to run models of the weather, 91–2
- concentrating solar power (CSP) systems, 324–5
- concerns. *See* environmental concerns
- convection in the atmosphere, 20–3
- coral reefs
 - climate change impacts, 197–9
- costs
 - adaptation to climate change, 252–8
 - damage related to climate change, 252–8
 - extreme weather events, 4–6
 - mitigation of causes of climate change, 252–8
 - of climate change impacts, 205–12
- coupling of ocean and atmospheric circulations, 99–104, 114–16
- Croll, James, 84
- Daisyworld, 224
- damage from climate change and its cost, 252–8
- Dansgaard-Oeschger events, 85
- Dasgupta, Partha, 258
- deaths
 - caused by droughts, 7–9
 - caused by floods, 5–7
 - caused by storm surges, 3, 171–2
 - related to heatwaves, 2, 200
- deep ocean circulation, 117
 - possible future changes, 155–7
- deforestation
 - contribution to atmospheric carbon dioxide, 36
 - rates of, 273
- deltas
 - vulnerability to sea level rise, 170–3
- dengue infections, 201
- desertification
 - impact of climate change, 183
- developing world
 - biomass energy projects in rural areas, 318–19
- diarists and writers
 - records of weather and climate, 77
- diseases
 - spreading related to climate change, 201
- Dobson, Gordon, 229
- droughts
 - associated with El Niño events, 101
 - deaths caused by, 7–9
 - desertification, 183
 - future projections, 149–50
 - intense and prolonged droughts in Africa, 7–9
 - Sahel region, Africa, 105
- Dryas octopetala*, 85
- drylands
 - process of desertification, 183
- Durban Platform for enhanced action, 279–80
- Earth
 - balances in the environment, 219
 - effects of orbital variations, 157
 - enhanced greenhouse effect, 27–9
 - exploitation by humans, 219–20
 - Gaia hypothesis, 221–6
 - how it keeps warm, 17–19
 - orbital cycles, 125
 - orbital cycles in the past, 81–4
 - radiation balance, 17–24
 - stewardship by humans, 228–30
- Earth in the Balance* (Gore, 1992), 219, 227
- Earth Summit. *See* UN Conference on Environment and Development (1992)
- Ecological Footprint, 348
- economists
 - challenges facing, 352
- ecosystems
 - impacts of climate change, 187–99
- educators
 - challenges facing, 353

- Einstein, Albert, 226
- El Niño events
 adaptation by crop growers, 184–5
 features of, 101–5
 influence of climate change, 148
 variation in cycles, 77
- El Niño Southern Oscillation (ENSO),
 69, 117
 influence of climate change, 101–2
 modelling, 102–3
- emission scenarios, 134–7
- emissions
 action strategy for stabilisation,
 266
- energy and CO₂ savings
 industry, 310–11
 reducing CO₂ emissions from motor
 vehicles, 310
 transport, 307–9
- energy balance models, 137
- energy conservation and efficiency
 appliances, 304
 buildings, 300–7
 insulation of buildings, 305
 integrated building design, 302
 lighting, 301, 304
 thermodynamic efficiencies, 303
 ZEDs (Zero Emission Developments),
 306
- energy demand and supply worldwide
 carbon intensity of energy supply,
 296–7
 energy investment projections,
 298–300
 future energy projections, 293–9
 future scenarios to 2050, 294–5
 levels of energy use, 291–3
 levels of reserves, 291–3
 long-term energy strategy, 300
 See also carbon-free energy supply.
- energy efficiency improvements,
 311–12
- energy intensity
 and carbon intensity, 296–7
- energy storage technologies, 335
- energy strategy
 components, 301
 long-term strategy, 300
- Energy Technology Perspectives*
 World Energy Outlook 2014
 (International Energy Agency),
 294–5, 297, 338–9
- England
 October 1987 storm, 2
 enhanced greenhouse effect, 27–9
 ensemble forecasting, 97, 99–100
 environmental concerns
 anthropic principle, 225
 assumption that there will be a
 ‘technical fix’, 221
 ‘back to nature’ viewpoint,
 220–1
 balances of nature, 219
 environmental values, 226–8
 equity, 229–31
 exploitation of the Earth’s resources,
 219–20
 Gaia hypothesis, 221–6
 interdependencies, 221–6
 intergenerational equity, 229–31
 international equity, 229–31
 religious views of relationship with
 the Earth, 225, 228–30
 stewardship of the Earth, 228–30
 the will to act, 231–2
 environmental stewardship goal,
 354–6
 environmental values, 226–8
 equity
 intergenerational and international,
 229–31, 252
 Principle of Equity, 252
 equivalent carbon dioxide (CO₂e),
 142–3
- Europe
 heatwave in 2003, 2, 200
 extinctions, 221
 extreme weather and climate events,
 2–3
 costs of, 4–6
 future projections, 149–53
 in the last 40 years, 2–8
 summary of impacts, 212
- Fair Isle
 wind power, 322
- Farman, Joe, 51
- FCCC. *See* Framework Convention on
 Climate Change
- feedback parameters, 113
- feedbacks
 biological pump in the oceans, 41
 carbon dioxide fertilisation, 43
 climate/carbon cycle feedbacks, 43
 cloud-radiation feedback, 107–9
 cloud radiative forcing (CRF),
 110–11
 comparison of feedback parameters,
 113
 effects of climate change stress on
 forests, 45
 greenhouse gases from forest fires, 45
 ice-albedo feedback, 112
 in the biosphere, 45–6
 in the climate system, 105–13
 microbial carbon dioxide emissions
 and temperature, 45
 ocean-circulation feedback, 109–12
 plankton growth, 41
 release of methane from hydrates, 45
 release of methane from wetlands, 45
 total feedback parameter, 113
 water vapour feedback, 107
- floods
 caused by storm surges, 175
 deaths caused by, 5–7
 future projections, 149–50
 monsoons, 181–2
- food supply. *See* agriculture and food
 supply
- forecasting
 Sahel region, Africa, 105
- forest–climate interactions and
 feedbacks, 195
- forests
 effects of climate change stress, 45
 effects of deforestation, 36
 greenhouse gases from forest fires, 45
 impacts of climate change, 184,
 190–5
 increase in forest fires, 45
 rates of deforestation, 273
 role in mitigating global warming,
 272–6
- fossil fuel burning
 association with global warming, 22
 contribution to atmospheric carbon
 dioxide, 34–9
- Fourier, Jean-Baptiste, 22
- fracking, 278, 293

- Framework Convention on Climate Change (FCCC), 13, 231, 243, 250, 259
 choice of greenhouse gas target levels, 279–81
 establishment of, 264–6
 extracts from, 264–5
 Paris meeting (December 2015), 259
 realising the Climate Convention Objective, 283–7
 reduction in non-CO₂ greenhouse gases, 276–8
 stabilisation of CO₂ concentrations, 281–3
 stabilisation of emissions, 266
 fuel cell technology, 335
- Gaia hypothesis, 221–6
 Gardiner, Brian, 51
 general circulation models (GCMs), 138
 geoengineering, 251
 geothermal energy, 328
 glaciers
 advance and retreat, 77
 loss of ice, 133
 Global Atmospheric Research Programme (GARP), 11
 global average temperature
 predicted rate of change, 9–10
 projections for the future, 138–42
 global challenges
 for aid agencies, 353
 for all sections of the community, 351–4
 for communicators, 353
 for economists, 352
 for educators, 353
 for industry, 352
 for politicians, 352
 for social scientists, 352
 for the scientific community, 351–2
 global pollution, 347
 global security issues, 349–50
 goal of environmental stewardship, 354–6
 importance of individual contributions, 354
 increasing wealth disparity, 349
 population growth, 349
 sustainability issues, 347–8
- sustainable consumption of resources, 349
 technological challenges, 352
 transfer of technology, 352
 global circulation models (GCMs), 125
 Global Climate Observing System (GCOS), 244
 Global Commons Institute (GCI)
 Contraction and Convergence proposal, 285–6
 global warming
 association with burning fossil fuels, 22
 association with carbon dioxide levels, 22
 current scientific understanding, 9–10
 global warming potentials (GWPs) of greenhouse gases, 59
 global water cycle, 175–6
 Gore, Al, 219, 227
 award of the Nobel Peace Prize (2007), 244
 Goudzwaard, Bob, 354
 Grameen Shakti, 328
 Green Revolution (1960s), 184
 greenhouse effect
 and ice ages, 22
 contribution of aircraft, 57
 contribution of atmospheric particles, 53–9
 contribution of carbon dioxide, 33
 early pioneers, 22
 enhanced greenhouse effect, 27–9
 how the Earth keeps warm, 17–19
 natural greenhouse effect, 19–24
 on Mars, 24–6
 on Venus, 24–7
 radiation balance of the Earth, 17–24
 runaway greenhouse effect, 26–7
 greenhouse gases
 association with global warming, 22
 chlorofluorocarbons (CFCs), 52
 choice of target levels, 279–81
 composition of the atmosphere, 19–20
 definition, 32
 equivalent carbon dioxide (CO₂e) conversions, 142–3
 estimates of radiative forcing over time, 60
- first concerns about climate change, 22
 future radiative forcing effects, 137, 148
 gases with an indirect greenhouse effect, 53
 global warming potentials (GWPs), 59
 halocarbons, 276, 278
 hydrochlorofluorocarbons (HCFCs), 52
 hydrofluorocarbons (HFCs), 52
 methane, 46–9, 276–8
 most important in relation to climate change, 33
 nitrous oxide, 50, 276, 278
 ozone, 52
 perfluorocarbons, 52
 radiative forcing, 33
 reduction in non-CO₂ greenhouse gases, 276–8
 sulphur hexafluoride, 52
 types of, 32
See also carbon dioxide.
- Greenland ice-sheet
 effects of climate change, 167–8
 ice core data, 46, 80
 rate of melting, 76
- halocarbons, 276
 reduction of emissions, 278
 Hansen, James, 138, 283, 338
 Hawking, Stephen, 225
 heatwaves, 149
 Europe in 2003, 2, 200
 India in 2003, 200
 Russia in 2010, 2
 Heinrich events, 86
 Hindu view of the Earth, 225
 human health
 impacts of climate change, 199–201
 impacts of dietary changes, 187
 Hurricane Andrew (1992), 3, 207
 Hurricane George (1950), 205
 Hurricane Gilbert (1988), 3
 Hurricane Katrina (2005), 3, 207
 Hurricane Mitch (1998), 4, 205–6
 hurricanes. *See* tropical cyclones
 hydrochlorofluorocarbons (HCFCs), 52, 267
 hydrofluorocarbons (HFCs), 52, 267
 hydrogen energy economy, 332–6

- hydrogen-oxygen fuel cell technology, 335
- hydropower, 315–16
- ice ages
 - future projections, 157
 - influence of Earth's orbital variations, 81–4, 157
 - role of the greenhouse effect, 22
- ice-albedo feedback, 112
- ice core analysis, 77
 - information on past climates, 80
 - methane concentration in the atmosphere, 46
- icebergs
 - Heinrich events, 86
- India
 - heatwave in 2003, 200
 - rural power production, 318–19
 - vulnerability to storm surges, 4
- industrial haze, 53
- Industrial Revolution, 292
 - contribution to atmospheric carbon dioxide, 34–9
- industry
 - challenges facing, 352
 - energy and CO₂ savings, 310–11
- insulation of buildings, 305
- insurance industry
 - costs of catastrophic weather events, 4–6
 - impacts of climate change, 207
- Integrated Assessment and Evaluation, 253–4
- Integrated Assessment Models (IAMs), 254
- Integrated Assessment process, 164
- integrated water management, 182
- intergenerational equity, 229–31
- Intergovernmental Panel on Climate Change. *See* IPCC
- international cooperation in climate science, 10–14
- International Council of Scientific Unions (ICSU), 11
 - Scientific Committee on Problems of the Environment (SCOPE), 12
- International Energy Agency
 - energy investment projections, 298–300
- Energy Technology Perspectives World Energy Outlook* 2014, 294–5, 297, 338–9
- international equity, 229–31
- IPCC (Intergovernmental Panel on Climate Change), 232, 259
 - assessments, 240–4
 - award of the Nobel Peace Prize (2007), 244
 - establishment of, 13–14
 - Physical Science Assessment Working Group, 241–4
 - reasons for scientific uncertainty, 240
 - reports on anthropogenic climate change, 122–4
 - Representative Concentration Pathways (RCPs), 134–6
 - series of reports, xv, 13–14
 - Special Report on Emissions Scenarios (SRES), 135–7
 - Synthesis Report 2014, 355–6
- Islam
 - relationship with the Earth, 225
- isotope analysis
 - information on past climates, 81
- isotopes of carbon, 42
- Judaism
 - relationship with the Earth, 225, 228–30
- Kaya Identity, 296–343
- Kelvin wave, 102
- Kyoto Protocol, 232, 266–72, 279–81, 287, 330
 - carbon trading, 271
 - greenhouse gases covered by, 60
 - mechanisms, 270
- La Niña cycles, 77
- Lake Chad, 180
- lake level data, 77
- land use changes
 - contribution to atmospheric carbon dioxide, 36
- landslides
 - Venezuela (1999), 5
- lighting
 - energy efficiency, 301, 304
- Little Ice Age, 78, 158
- Lomborg, Bjorn, 356
- longer-term climate change, 155
- longwave atmospheric window, 52
- Lorenz, Edward, 99
- Lovelock, James
 - Daisyworld, 224
 - Gaia hypothesis, 222–3
- malaria, 201
- Mars
 - greenhouse effect, 24–6
- Maunder Minimum, 79, 158
- media
 - role of, 353
- Medieval Warm Period, 78
- methane
 - as a greenhouse gas, 46–9
 - identifying the sources, 42
 - increase in the atmosphere, 9
 - isotopic measurements, 42
 - reduction of emissions, 276–8
 - release from wetlands, 45
 - sinks, 60
 - sources of, 46–9, 60
- methane hydrates
 - potential contribution to global warming, 45
- microbial carbon dioxide emissions
 - influence of temperature, 45
- Milankovitch, Milutin, 84
- Milankovitch forcing, 125
- Milankovitch theory, 84
- Miscanthus* (elephant grass), 319–20
- Mississippi and Missouri river floods (1993), 5, 7
- Mississippi delta
 - vulnerability to sea level rise, 173
- mitigation of causes of climate change, 10, 252–8
- modelling the climate
 - carbon exchange between atmosphere and ocean, 38–9
 - cloud radiative forcing (CRF), 110–11
 - cloud-radiation feedback, 107–9
 - comparison of feedback parameters, 113
 - components of the climate system, 104–6
 - Daisyworld, 224

- modelling the climate (cont.)
 - feedbacks in the climate system, 105–13
 - forecasting in the Sahel region, Africa, 105
 - ice-albedo feedback, 112
 - ocean-circulation feedback, 109–12
 - water vapour feedback, 107
- modelling the weather
 - chaos in weather systems, 99–100
 - coupling of atmospheric and ocean circulations, 99–104
 - data to initialise the model, 95–6
 - early work of Lewis Fry Richardson, 91
 - El Niño events, 102–3
 - ensemble forecasting, 97
 - limit of future forecast skill, 95–7
 - numerical models, 90–9
 - seasonal forecasting, 99–105
 - setting up a numerical atmospheric model, 93–4
 - use of computers to run models, 91–2
- models for climate prediction
 - chaos in climate systems, 125
 - comparison with observations, 120–5
 - components of models, 112–16
 - deep ocean circulation, 117
 - future developments, 126–8
 - impact on world food supply, 188
 - incorporation of cloud properties, 113–14
 - IPCC reports on anthropogenic climate change, 122–4
 - land surface interactions, 116
 - modelling of chemical tracers in the ocean, 121–2
 - regional climate models, 125–6, 153–5
 - representation of the ocean circulation, 114–16
 - simple climate models, 138–9
 - validation of climate models, 116–22
 - See also* climate change in the future.
- Monet, Claude, 346
- monsoon flooding events, 181–2
- Montreal Protocol, 51, 266–7, 347
- Morel, Pierre, 12
- motor vehicles
 - reducing CO₂ emissions, 310
- Mozambique
 - floods in 2000–1, 5
- National Aeronautics and Space Administration (NASA)
 - atmospheric temperature measurements from space, 11
- National Oceanic and Atmospheric Administration (NOAA), 68
- Native American view of the Earth, 223
- natural greenhouse effect, 19–24
- natural resources
 - exploitation of, 219–20
- Netherlands
 - vulnerability to sea level rise, 173–4
- Nile Delta
 - vulnerability to sea level rise, 172
- nitrogen oxides (NO and NO₂)
 - indirect greenhouse effects, 53
- nitrous oxide, 276, 278
 - as a greenhouse gas, 50
 - sources and sink, 50
- Nobel Peace Prize (2007)
 - Al Gore and IPCC, 244
- North Atlantic Oscillation (NAO), 69, 148
- Northcott, Michael, 223
- northern annular mode (NAM), 117
- nuclear energy, 313–14
- nuclear fusion, 336
- ocean circulation
 - coupling with atmospheric circulation, 99–104, 114–16
 - representation in climate models, 114–16
- ocean-circulation feedback, 109–12
- ocean sediments
 - information on past climates, 81
- oceans
 - biological pump, 38, 41
 - deep ocean circulation, 117
 - functions in the carbon cycle, 36–41
 - modelling of chemical tracers, 121–2
 - thermal expansion and sea level rise, 167
 - warming in the last hundred years, 73–5
 - wave energy, 329
- Oswald, Sir Julian, 350–8
- ozone
 - as a greenhouse gas, 52
 - destruction by CFCs, 50–1
 - hole over Antarctica, 51, 250
 - sources of, 52
- Pacific islands
 - vulnerability to sea level rise, 174
- Pacific–North Atlantic Anomaly (PNA), 148
- Pakistan
 - extreme floods in 2010, 5
- palaeoclimate reconstruction from isotope data, 81
- past climates (last hundred years)
 - changes in sea level, 76
 - detection and attribution of climate change, 66–77
 - extreme weather in the last 40 years, 2–8
 - upper atmosphere temperature from satellites, 68–9
 - warming of the oceans, 73–5
- past climates (last thousand years)
 - direct and indirect evidence, 77–9
- past climates (past million years), 80–7
 - ice ages, 81–4
 - information from ice core analysis, 80
 - information from isotope analysis, 81
 - information from ocean sediments, 81
 - large and relatively rapid climate changes, 84–7
 - level of stability in the past, 84–7
 - Milankovitch theory, 84
 - orbital cycles of the Earth, 81–4
 - palaeoclimate reconstruction from isotope data, 81
- perfluorocarbons as greenhouse gases, 52
- pesticides
 - effects on the environment, 219
- Philippines
 - biomass power generation from coconut waste, 319
- photosynthesis
 - and the carbon cycle, 33
- photovoltaic (PV) solar cells, 324–6
- Pinatubo eruption (1991), 54, 119–21, 157–9

- plankton growth
 - biological pump in the oceans, 41
- Polanyi, Michael, 226
- politicians
 - challenges facing, 352
- pollen record in lake sediments, 77
- Polluter-Pays Principle, 252
- pollution
 - global challenge, 347
- population growth
 - global challenge, 349
- poverty, 202, 231, 252, 265, 285, 349
- Precautionary Principle, 250–1
- precipitation
 - changes in amount and distribution, 149–50
 - future changes in amount and distribution, 143–8
- Principle of Equity
 - international and intergenerational, 252
- Principle of Sustainable Development, 247–9, 251
- Principles for international action, 251–2

- radiation balance of the Earth, 17–24
- radiative forcing, 33
 - aerosols (atmospheric particles), 55–7
 - cloud radiative forcing (CRF), 110–11
 - contribution of aircraft emissions, 53
 - contribution of carbon dioxide, 44
 - estimates over time for greenhouse gases, 60
 - future effects of aerosols, 148
 - future effects of greenhouse gases, 148
- regional climate models, 125–6, 153–5
- regional patterns of climate change
 - future projections, 143–8
- renewable energies, 314–29
- Representative Concentration Pathways (RCPs), 135–7
- respiration
 - and the carbon cycle, 33
- Revelle, Roger, 22
- Richardson, Lewis Fry, 91
- Rio Declaration (1992), 219, 251–2
- Rolston, Holmes, 227
- Rossby wave, 102

- runaway greenhouse effect
 - on Venus, 26–7
- Russia
 - heatwave of 2010, 2
- Sahel region, Africa, 108, 195
 - forecasting, 105
- satellite observations
 - beginning of, 10–12
 - upper atmosphere temperature, 68–9
- scientific community
 - challenges facing, 351–2
- scientific prediction of climate change
 - current understanding of global warming, 9–10
- scientific uncertainty
 - reasons for, 240
 - related to climate change, 239–41
- sea level change
 - in the last hundred years, 76
 - information from isotope analysis, 81
- sea level rise
 - estimates for the future, 164–9
 - future impacts on coastal areas, 169–75
 - thermal expansion of the oceans, 167
 - vulnerability of Bangladesh, 170–2
 - vulnerability of coastal areas of China, 173
 - vulnerability of delta areas, 170–3
 - vulnerability of low-lying small islands, 174
 - vulnerability of the Mississippi delta, 173
 - vulnerability of the Netherlands, 173–4
 - vulnerability of the Nile Delta, 172
- seasonal forecasting, 99–105
- security
 - global security issues, 349–50
- sensitivity
 - definition, 163
 - to climate change, 164
- Shanklin, Jonathan, 51
- Silent Spring* (Carson, 1962), 219
- social scientists
 - challenges facing, 352
- soil loss and impoverishment, 164
- solar energy, 322–8
 - concentrating solar power, 324–5
 - in building design, 324
 - photovoltaic (PV) solar cells, 324–6
 - solar photovoltaics (PV), 326–8
 - water heating, 323
- solar output
 - and sunspot activity, 158
 - effects of changes in, 157–8
- solar radiation
 - variation in distribution in the last millennium, 81–4
 - variation in the last millennium, 79
- solubility pump
 - carbon dioxide in the oceans, 37
- southern annular mode (SAM), 117
- space observations of the climate system, 245–6
- Spaceship Earth metaphor for sustainability, 347–8
- Special Report on Emissions Scenarios (SRES), 135–7
- Sputnik satellite launch (1957), 10–12
- statistical downscaling technique, 126
- Stern Review, 258, 273
- stewardship of the Earth, 228–30
- storm front Lothar (1999), 99–101
- storm surges
 - deaths caused by, 3, 171–2
 - flooding caused by, 175
- storms
 - future intensity and frequency, 153
 - October 1987 (southern England and western Europe), 2
 - superstorm Sandy (2013), 3
 - See also* tropical cyclones.
- Suess, Hans, 22
- sulphate aerosols, 54
- sulphur emissions
 - and acid rain pollutions, 54
- sulphur hexafluoride as a greenhouse gas, 52
- sunspot activity and solar output, 158
- superstorm Sandy (2013), 3
- sustainability
 - global challenge, 347–8
- sustainable consumption of resources, 349
- sustainable development, 247–9
 - definitions, 248

- Sweden
 Uppsala district heating system, 317
- Tambora eruption, Indonesia (1815), 78
- technology
 assumption that there will be a 'technical fix', 221
 global challenges, 352
 technology transfer, 352
- Temple, William, 225
- Thatcher, Margaret, xv, 230, 247
- thermodynamic efficiencies, 303
- thermohaline circulation (THC), 117
 possible future changes, 155–7
- Tickell, Sir Crispin, 231, 352
- tidal energy, 328–9
- transport
 energy and CO₂ savings, 307–9
 reducing CO₂ emissions from motor vehicles, 310
- tree ring data, 77
- tropical cyclones, 2–3
 economic and insured costs, 4–6
 future frequency and intensity, 150–3
 Hurricane Andrew (1992), 3, 207
 Hurricane George (1950), 205
 Hurricane Gilbert (1988), 3
 Hurricane Katrina (2005), 3, 207
 Hurricane Mitch (1998), 4, 205–6
 storm surges, 3
 Typhoon Haiyan (2013), 3, 169, 206
 Typhoon Mireille (1991), 3
- Tropical Oceans Global Atmosphere (TOGA) experiment, 12
- tropopause
 increase in height of, 69
- troposphere, 21
- Tyndall, John, 22
- Typhoon Haiyan (2013), 3, 169, 206
- Typhoon Mireille (1991), 3
- typhoons. *See* tropical cyclones
- UN Conference on Environment and Development (1992), 13, 231–2, 243
- Principles for international action, 251–2
- Rio Declaration (1992), 219, 251–2
- UN Environment Programme (UNEP), 13, 241
- UN Framework Convention on Climate Change. *See* Framework Convention on Climate Change (FCCC)
- uncertainty related to climate change
 damage from climate change and its cost, 252–8
 influence on response, 14
 Integrated Assessment and Evaluation, 253–4
 IPCC assessments, 240–4
 narrowing the uncertainty, 244–6
 Precautionary Principle, 250–1
 reasons for scientific uncertainty, 240
 role of sustainable development, 247–9
 scientific uncertainty, 239–41
 space observations of the climate system, 245–6
 the wait-and-see approach, 258–9
- United States
 Mississippi and Missouri river floods (1993), 5, 7
 superstorm Sandy (2013), 3
- upper atmosphere temperature
 observation from satellites, 68–9
- values
 environmental values, 226–8
- Venezuela
 floods and landslide (1999), 5
- Venus
 greenhouse effect, 24–6
 runaway greenhouse effect, 26–7
- viral encephalitides, 201
- volcanic eruptions
 influence on future climate change, 157–9
 Pinatubo (1991), 54, 119–21, 157–9
 source of particles in the atmosphere, 54
 Tambora, Indonesia (1815), 78
- vulnerability
 definition, 174
 to climate change, 164
- water resources
 efficient irrigation techniques, 182
 global water cycle, 175–6
 impacts of climate change, 178–82
 increasing human demand for, 175–8
 integrated water management, 182
 intrusion of salt water, 172
 over-extraction of groundwater, 164
 potential conflicts over, 177
 sources of demand, 176–7
 water-stressed countries, 177–8
- water vapour feedback, 107
- water vapour in the atmosphere, 9
- wave energy, 329
- wealth disparity, 349
- weather
 day-to-day variations, 2–3
- weather forecasting
 and chaos, 99–100
 ensemble forecasting, 99–100
 modelling the weather, 90–9
 seasonal forecasting, 99–105
- wetlands
 release of methane from, 45
- wind energy, 321–2
- wind power on Fair Isle, 322
- wind turbines, 321
- Wirth, Tim, 248
- World Climate Research Programme (WCRP), 12
- World Meteorological Organization (WMO), 11, 13, 240
- World Ocean Circulation experiment (WOCE), 12
- yellow fever, 201
- Younger Dryas event, 85–7
- Yunus, Professor, 328
- ZEDs (Zero Emission Developments), 306
- zero carbon future, 336–9