

Index

Locators in bold refer to glossary entries.

500 hPa height field 250
 absolute humidity 85, 88, **280**
 absolute zero 4
 absorption 63–65, 68
 see also selective absorption
 accretion (ice crystals) 134
 acid rain 137, 257, **280**
 adiabatic cooling 102, **280**
 adiabatic expansion 103
 adiabatic lapse rate 103, 105, **280**
 adiabatic processes 96, 100–102, **280**
 in the atmosphere 102–103
 dry adiabatic lapse rate 103–104, 116,
 128
 moist adiabatic lapse rate 105–106,
 116, 128
 relative humidity 104–105
 Skew-T, Log-P diagram 127–129
 adiabatic warming 102, **280**
 advection 61, **280**
 advection fog 101, **280**
 aerosols 48, **280**
 atmospheric composition 48
 as condensation nuclei 100, 259
 African Sahel 172–174
 aggregation 134, **280**
 air density 53
 air masses 24, **280**
 adiabatic processes 100–102
 classification of 186–187
 conduction 60
 convection 60–61
 fronts 187–191
 midlatitude cyclone development
 186, 191–204
 see also cloud formation; global wind
 systems
 air parcel 2, **280**
 air pollution 256
 dispersion, wind and stability 259–262
 large-scale patterns 262–263

pollutants 256–259
 topography 263
 air quality 258
 Air Quality Index (AQI) 258
 albedo 65, **280**
 feedback loop 73
 at the poles 75
 surface types 66
 Aleutian Low 167, **280**
 altocumulus clouds 124, **280**
 altostratus clouds 124, **280**
 ammonia (NH_3) 257, 259
 Anderson, Charles E. 6
 anemometers 12, 16
 aneroid barometer 10, **280**
 angular momentum 217, **280**, **282**
 Antarctic ice sheet 273–274
 Antarctica
 ozone hole 54
 wind systems 172
 anticyclonic weather 262, **280**
 air pollution 262
 thunderstorms 215
 wind 151
 Archimedes' principle 61, 112,
 281
 Area Forecast Discussion 251
 aspect, the atmosphere 46
 assimilation (data) 255, **281**
 the atmosphere 46, xiii
 aspect 46
 the averaged atmosphere 162
 changing composition 269
 climate projections 271
 composition 46–48
 conservation laws xiv
 dynamic equilibrium 58
 future evolution 51–53
 general circulation 161, **284**
 origin and evolution 48–51
 vertical structure 53–56
 vertical temperature profile 57

atmospheric pressure 8, 11, **281**
 atmospheric stability 111–120, 114, 260
 atmospheric window 70, **281**
 Automated Surface Observing Systems
 (ASOS) 15
 Automated Weather Observing
 Systems (AWOS) 15
 average environmental lapse rate 55
 Azores High 167, **281**

 Bacon-Bercey, June 33
 bar 11, **281**
 barometers 10, 11, 19, **281**
 Beaufort wind scale 13, 14, **281**
 Bergen school 192, 208
 Bergeron process 133, **281**
 Bergeron, Tor 133, 208
 Bermuda High 167, 172, **281**
 bias 249
 Bjerknes, Jacob 192, 208
 Bjerknes, Vilhelm 208
 blackbody 64–65, 68, **281**
 black ice 136, **281**
 blizzards 137, **281**
 Boltzmann, Ludwig 64–65
 Brill, Yvonne 33
 buoyancy 61, 112, 156, **281**
 see also convection
 buoys *see* weather buoys
 Buys Ballot, C. H. D. 160

 carbon cycle 50, **281**
 carbon dioxide (CO_2) 47, **281**
 atmospheric composition 47, 51
 feedback loops 73, 268
 geological history of Earth 48
 global trends 267–268, 269
 as greenhouse gas 256
 carbon monoxide (CO) 257, 259
 carbonation 49
 Celsius, Anders 19
 Celsius temperature scale 4, **281**

Centigrade *see* Celsius temperature scale
 centrifugal force 37, 149, **281**
 chaos theory, and weather forecasting 247–248
 Chapman Reactions 51
 chemical weathering 48
 chinook 109, 155, **281**
 chlorofluorocarbons (CFCs) 53, 256, **282**
 cirrocumulus clouds 124, 125, **282**
 cirrostratus clouds 124, 125, **282**
 cirrus clouds 124, 131, **282**
 Clapeyron, Benoît 89
 Clausius–Clapeyron relationship 88, 89, 270
 Clausius, Rudolph 89
 climate change
 an altered water cycle 270–272
 beyond weather 273–274
 changing composition 269
 changing global wind systems 272–273
 cyclones 273
 feedback loops 73
 forecasting 274–275
 greenhouse gases 72
 past and future 267–268
 a warmer world 269–270
 and weather 266–267
 see also global warming
 climate, distinction from weather xiii
 climate projections 269–270, 271, 274–275, 277–278
 cloud condensation nuclei 100
 cloud cover 21, 35
 cloud formation 99–100
 adiabatic processes 100–102
 adiabatic processes in the atmosphere 102–103
 atmospheric stability 111–120
 dry adiabatic lapse rate 103–104
 frontal lifting 111
 lifting by convergence 110
 moist adiabatic lapse rate 105–106
 orographic lifting 106–110
 relative humidity during adiabatic processes 104–105

cloud sequence 125
 cloud signatures 44–45
 clouds **282**
 classification of 123
 solar radiation 78
 warm vs. cold 130–131
 coalescence 131–134
 cold fronts 188, **282**
 cloud signatures 44–45
 midlatitude cyclone development 188
 cold occlusion 190
 cold pools (thunderstorm development) 211
 cold tongue (equatorial) 176, 177, **282**
 cold vs. warm clouds 130–131
 collision 131–134
 commercial aircraft 15
 condensation 89, **282**
 humidity and temperature 89–91
 orographic lifting 106–110
 relative humidity 86–87
 and saturation 84–85
 water cycle 84
 condensation nuclei 100, 259, **282**
 conditional instability 118–120, **282**
 conduction 3, 60–61, **282**
 conservation laws xiv
 angular momentum 185, **282**
 energy 2, 63, 100, **282**
 mass 7, **282**
 momentum 12
 temperature 1–2
 weather forecasting 241–244
 continental air masses (c) 186–187
 convection 60–61, 111–120, **282**
 convergence (air masses) 192, 193–194
 convergence (cloud formation) 110
 Coriolis force 144–146, **282**
 southern hemisphere cyclones 207
 cumulonimbus clouds 118, **282**
 classification of clouds 123
 conditional instability 118–120
 Hurricane Katrina 229
 temperature distribution 131
 thunderstorm development 210
 thunderstorms 209
 tropical cyclone structure 239
 cumulus clouds 115, **282**
 classification of clouds 123
 cloud formation 115–118
 thunderstorm development 210
 tropical cyclone structure 239
 as warm clouds 131
 cumulus congestus 123, **282**
 cyclogenesis 197–204
 cyclones **282**
 climate change 273
 cloud signatures 44–45
 February 2014 case study 195–197
 heat imbalance 75
 large-scale influences 190–191
 midlatitude 186, 191–204
 midlatitude air masses 186–187
 midlatitude formation 197–204
 midlatitude fronts 187–191
 midlatitude life cycle 191–192
 midlatitude vertical structure 192–195
 satellite imagery 33, 35, 39, 41
 surface maps 92
 tropical 226
 tropical cyclone conditions 236
 tropical cyclone development 233–235
 tropical cyclone hazards 226, 235–236
 tropical cyclone structure 228–232, 239
 upper-level maps 30
 weather forecasting 244–247
 cyclonic weather systems 151
 Dalton, John 86
 Dalton's law 86
 dart leader 214
 data *see* spatial representation of data
 day length 76
 de Coriolis, Gaspard-Gustave 145, 160
 decaying cyclone 192, 202, 234–235
 deepening cyclone 192, 198
 density 7, **283**
 deposition (water) 84, 133, **283**
 Descartes, René xiv
 deterministic forecasts 242, **283**
 see also weather forecasting
 dew 47, **283**
 dew point depression 91, **283**

dew point temperature 91–92, **283**
 applications of 92–96
 visual analysis 98
 diabatic process 96
 digital thermometers 3
 diurnal cycle 76–78, **283**
 humidity and temperature 89–91
 meteograms 94
 diurnal variations 98
 divergence (air masses) 192,
 193–194
 Doppler radar 32, 221, **283**
 drizzle 135, **283**
 dry adiabatic lapse rate 103–104, 116,
 128
 dry line 220, 221, **283**
 dynamic equilibrium 58, 76, **283**
see also radiative equilibrium

the Earth
 geological history 48–51
 modeling the climate 278
 past and future 267–268
 planetary comparisons 49, 57
 significance of water 83
see also climate change; global wind
 systems
 Earth's orbit 267–268
 El Niño 176
 El Niño/Southern Oscillation (ENSO)
 178–180, **283**
 discovery of 185
 weather forecasting 247, 252
 El Niño/Southern Oscillation (ENSO)
 index
 178, 179
 electromagnetic radiation 61–62
 electromagnetic waves 69, **283**
 electronic transition 69
 emission spectrum of Earth 68, **283**
 energy conservation 2, 63, 100, **282**
 energy transfer 59
 conduction 60, 61
 convection 60–61
 feedback loops 73
 land–ocean contrasts 78–80
 radiation 61–63
 radiation and weather 73–80
 radiative interactions 63–72

ensemble forecasting 244–247, **283**
 entrainment 118, **283**
 cloud formation 118
 thunderstorms 210
 environmental lapse rate 55, **283**
 environmental lapse rates 55, 103, 116
 Environmental Protection Agency
 (EPA) 258
 environmental temperature profiles
 113
 equator, geostationary satellites 39
 evaporation **283**
 latent heat 86
 relative humidity 86–87
 and saturation 84–85
 thunderstorm development 211
 water cycle 83–84
 evaporation fog 96, 101, **283**
 extratropical cyclone 186, **283**
see also midlatitude cyclones
 extratropics 39, **283**
 eye 229, **283**
 eyewall 229, **283**

Fahrenheit, Gabriel 19
 Fahrenheit temperature scale 4, **283**
 fair-weather cumulus clouds 115–118,
 123
 feedback loops
 greenhouse effect 73, 268
 water vapor 73, 271
 Ferrel cell (air circulation) 171, **284**
 Ferrel, William 185
 Findeisen, Walter 133
 foehn 109, **284**
 fog **284**
 advection fog 101
 evaporation fog 96, 101
 formation 101
 humidity and temperature 91
 radiation fog 96, 101
 smog 101, 257–259
 valley fog 156
 force, and pressure 7–8
 forced variability of the climate system
 268
 forecast calibration 249
 forecasting *see* weather forecasting
 fragmentation 134, **284**

freezing 84
 freezing nucleus (cloud droplets) 132,
284
 freezing rain 136, **284**
 friction 152–155, **284**
 frontal lifting (cloud formation) 111
 frontal squall line 212
 fronts 24, **284**
 classification of 187–191
 cold 44–45, 188
 midlatitude cyclone development
 187
 warm 44–45, 188
 Fujita scale 218, **284**
 Fujita, Tetsuya 218
 funnel clouds 217, 219, **284**
 funnels (rain gauges) 15

Galileo 19
 general circulation 161, **284**
 geological history of Earth 48–51
 Geostationary Operational
 Environmental Satellite (GOES)
 37, **284**
 geostationary orbit 37
 geostationary satellites 36–39, **284**
 geostrophic balance 147, 148, **284**
 geostrophic wind 146–149, **284**
 glacial periods (history of Earth's
 climate) 267–268
 glaciated clouds 131
 global images, geostationary satellites
 38, 39
 Global Precipitation Measurement
 (GPM) 32
 global warming 51, **284**
 atmospheric composition 51
 feedback loops 73
 future evolution of the atmosphere
 51–53
 greenhouse effect 71–72
 greenhouse gases 72
 weather forecasting 247
see also climate change
 global wind systems 161
 the averaged atmosphere 162
 contemporary changes and trends
 272–273
 historical context 184, 185

- global wind systems (cont.)
 large-scale circulations 171–181
 the single-cell model 169–170
 the three-cell model 170–171
 gradient wind 149–150, **284**
 gradients 24, 25
 graupel 134, 136, **284**
 greenhouse effect 71–72, 268, **284**
 feedback loops 73
 see also global warming
 greenhouse gases
 changing composition 269
 effect of 72
 as pollutants 256
 projected changes 269–270
 Greenland ice sheet 273–274
 gust front 211, **284**
- Hadley cell (air circulation) **284**
 changing global wind systems 272–273
 climate projections 272
 single-cell model 169, 170
 three-cell model 171
 Hadley, George 169, 185
 hail 134, **285**
 hailstones 136
 Halley, Edmond 185
 halo (optical phenomena) 124,
 139–140, **285**
 haze 21, **285**
 heat 2–3, **285**
 see also temperature
 heat capacity 79, **285**
 heat imbalance 73–75
 heat transfer 59
 adiabatic processes 100–102
 conduction 60, 61
 convection 60–61
 feedback loops 73
 land–ocean contrasts 78–80
 radiation 61–63
 radiation and weather 73–80
 radiative interactions 63–72
 hectopascal 86, **285**
 helium (He) 48
 heterogeneous nucleation 100, **285**
 historical context
 climate change 267–268
 geological history of Earth 48–51
- global wind systems 184, 185
 laws of motion 160
 plate tectonics theory 133
 scientific instruments 19
 thermodynamics 89
 homogeneous nucleation 100, **285**
 Hooke, Robert 19
 humidity 85–86
 absolute 85, 88
 altered water cycle 270–272
 dew point temperature 91–92
 meteograms 92–94
 relative 86–87, 88, 95–96
 specific 86
 and temperature 87–91
 Hurricane Andrew 226
 Hurricane Fred 233
 Hurricane Katrina 229, 231–232
 Hurricane Mitch 226, 236
 hurricanes 227
 see also tropical cyclones
 Huygens, Christiaan 19
 hydrofluorocarbons (HFCs) 53
 hydrogen bonds 79
 hydrogen (H) 48
 hydrostatic equilibrium 112, **285**
 hygrometers 85, **285**
- ice-albedo effect 73, 75, **280**
 ice cores 267
 ice-crystal growth 135
 ice-crystal types 136
 ice fragmentation 134
 ice nuclei 132, 134, **285**
 ice storms 136
 Icelandic low 167, **285**
 ideal gas law 8, 60, **285**
 ideal radiator 64–65, 68
 incipient wave 195, 196
 Indian monsoons 175, 181, **285**
 Industrial Revolution 47, 51, 268
 infrared radiation **285**
 detection 62
 heat imbalance 73–75
 Kirchhoff's law 68
 satellite imagery 34, 36
 uniformity 74
 infrared satellite images 33–36, 250
 infrared thermometers 3, 65
- infrared transmission spectrum 71
 infrared window 70–71, **285**
 initial conditions 243, **285**
 insolation 76
 Intergovernmental Panel on Climate
 Change (IPCC) 269
 Intertropical Convergence Zone
 (ITCZ) 169, **285**
 see also changing global wind systems
 272–273
 climate projections 272
 the Sahel 172–174
 single-cell model 169
 three-cell model 171
 tropical cyclone development 233
 weather associated with 173–176
 inversion *see* temperature inversion
 ionosphere 56, **285**
 isobars 24–25, **285**
 isotherms 23–24, **285**
- jet streams 164, **286**
 El Niño and La Niña 180
 global wind systems 163–167
 midlatitude cyclone development
 190–191, 197–204
 pollutant transport 260
 Rossby waves 208
- Kalnay, Eugenia 255
 katabatic winds 157–158, 172–173,
 286
 Kelvin, Lord 19
 Kelvin temperature scale 4, **286**
 kinetic energy 2, **286**
 Kirchhoff, Gustav 64–65
 Kirchhoff's law 64–65, 68
 knots 13, **286**
- La Niña 178, 179–180, **286**
 land breeze 143–144, **286**
 land–ocean contrasts 78–80
 lapse rate 55, **286**
 see also environmental lapse rate
 latent heat 84, **286**
 dew point temperature 92
 evaporation 86
 latent state 84
 lenticular clouds 126, **286**

- level of free convection (LFC) 119, 120, **286**
- lifting condensation level (LCL) 106, 116, 209, **286**
- lightning 213–215, **286**
- liquid-in-glass thermometers 3
- long-range weather forecasting 251–252
- machine learning 249
- Madden–Julian Oscillation 180–181, 182
- Magellan’s expedition (1519–1522) 184
- mammatus clouds 211, 212, **286**
- maritime air masses (m) 186–187
- Mars 49, 51
- mass
 - conservation of 7, **282**
 - ideal gas law 8
- mature stage cyclone 192, 200, 202
- mean sea level 27, **286**
- medium-range forecasts 252, **286**
- medium-range weather forecasting 251–252
- mercury barometer 10, **286**
- mesocyclone 215, 216–219
- mesopause 56, **286**
- mesoscale convective system (MCS) 212
- mesosphere 55, 56, **286**
- meteograms 77, 82, 92–94, **286**
- meteorological sunrise 77
- meteorological sunset 77
- methane 47, **286**
 - atmospheric composition 47, 51
 - as greenhouse gas 256
- microbursts (thunderstorm development) 212, **286**
- midlatitude cyclones 186
 - climate change 273
 - cold fronts 188
 - cyclical rotation 187
 - development 191–204
 - extratropics 39, **283**
 - February 2014 case study 195–197
 - formation origins 197–204
 - heat imbalance 75
 - large-scale influences 190–191
 - life cycle 191–192
- midlatitude geostationary satellites 39
- midlatitudes 39, **286**
- Milankovitch, Milutin 267
- millibars 11, **287**
- mixed layer, atmosphere 262
- mixed-phase clouds 131
- mixing ratio 86, **287**
- model output statistics (MOS) 249, 251
- moist adiabatic lapse rate 105–106, 116, 128
- momentum, conservation of 12, **282**, **287**
- monsoon rains 175, **287**
- Montreal Protocol 53, 54
- motion, laws of 141–142, 160
- mountain breeze 155–157
- mountains
 - cloud formation 106–110
 - cyclone development 201
- National Data Buoy Center (NDBC) 231, 232
- natural variability of the climate system 268
- neutral stability 114, **287**
- neutral temperature profile 114
- Newton, Isaac 141–142, 160, 241–244
- newton (unit) 11
- nimbostratus clouds 124, **287**
- nitric acid (HNO_3) 257
- nitric oxide (NO) 257, **287**
- nitrogen 48, **287**
- nitrogen dioxide (NO_2) 257, **287**
- nitrous oxide 48, 256, 259, **287**
- Norwegian cyclone model 191, 192
- nowcasts 249
- occluded fronts 189–190, **287**
- occluded stage cyclone 192
- ocean circulations 274
- ocean–land contrasts 78–80
- ocean upwelling 176
- Oklahoma tornado (1999) 221, 223–224
- optical effects (sunlight) 139–140
- orbital cycles 267
- ordinary storms 210–211
- ordinary thunderstorms 209, 210–211
- orographic lifting (cloud formation) 106–110
- orographic precipitation 106–110, **287**
- overrunning 111, **287**
- oxygen 46, **287**
- oxygen, geological history of Earth 49
- ozone 47, **287**
 - atmospheric composition 47, 51
 - Chapman Reactions 51
 - chlorofluorocarbons as pollutants 256
- photochemical smog 257, 258–259
- tropospheric (O_3) 257
- ozone hole 54, **287**
- ozone layer 49, 53, **287**
- Pacific High 167, 172, **287**
- Pacific Ocean
 - El Niño 176
 - Madden–Julian Oscillation 180–181
 - Pacific warm pool 177, **287**
- parameterization 244, **287**
- particulate matter (PM) 257–258, 259
- Pascal, Blaise 19
- pascal (unit) 11
- permafrost 274
- permanent gases 47, 51, 269, **287**
- phase 84, **287**
- photochemical smog 257, 258–259, 262–263
- photosynthesis 47, 50, **287**
- Planck feedback loop 73
- Planck, Max 64–65
- Planck’s law 63, 64–65
- planetary boundary layer 153
- plate tectonics 133
- point source pollution 259
- polar air masses (P) 186–187
- polar cell (air circulation) 171, **287**
- polar front 162, **287**
- polar-orbiting satellites 39–42, **287**
- pollution *see* air pollution
- ppm 51, **288**
- precipitation 130, **288**
 - acid rain 257
 - the averaged atmosphere 167–169
 - climate projections 271
 - collision and coalescence 131–134

precipitation (cont.)
 definition 15
 ice-crystal growth 132
 measurements 15
 orographic lifting 106–110
 radar 30–32
 types 135–137
 warm vs. cold clouds 130–131
 weather forecasting 241, 251
 precipitation symbols 15
 pressure 6–12, **288**
 adjustment to mean sea level 27
 atmospheric 8, 11
 and force 7–8
 surface 167
 and temperature 7
 upper-level maps 28–30
 useful numbers 11–12
 vertical distribution 8–9
 vertical structure of the atmosphere
 53
 weather forecasting 250
 pressure gradient 142
 pressure gradient force (PGF)
 142–143, 144–146, **288**
 pressure maps
 highs, lows, ridges, and troughs 24
 isobars 24–25
 pressure units 11
 primary pollutants 257–258
 see also air pollution
 probabilities 241
 see also weather forecasting
 prognostic equations 241–244, **288**
 radar 30–32, **288**
 radar images 251
 radiation 61, **288**
 heat and energy transfer 61–63
 infrared satellite images 33–36
 and temperature 62–63, 68
 and weather 73–80
 radiation fog 96, 101, **288**
 radiation laws 64–65, 68
 radiative equilibrium 66–68, 72–75, **288**
 radiative interactions 63–72
 absorption 63–65
 diurnal variations 76–78
 feedback loops 73

greenhouse effect 71–72
 heat imbalance 73–75
 influence of clouds 78
 land–ocean contrasts 78–80
 reflection 65
 scattering 66, 67
 seasonal variations 75–76
 selective absorbers 68–70
 visible and infrared windows 70–71
 radiosonde profiles 5–6, 94–95, 251
 radiosondes 18, **288**
 rain 135, **288**
 see also precipitation
 rain gauges 15, **288**
 rainbows 139–140
 reflection 65, **288**
 relative humidity 86–87, **288**
 vs. absolute 88
 adiabatic processes 104–105
 in an air parcel 95–96
 visual analysis 98
 representative concentration pathways
 (RCPs) 269
 respiration **288**
 return stroke 213
 ridge (pressure) 24, **288**
 riming 134, **288**
 Rossby, Carl-Gustaf 208
 Rossby waves 208
 rotation 69–70
 Saffir–Simpson hurricane intensity
 scale 227, 228, **288**
 the Sahel 172–174
 satellites
 cloud signatures 44–45
 geostationary satellites 36–39
 infrared satellite images 33–36
 polar-orbiting satellites 39–42
 spatial representation of data 32–42
 visible satellite images 33
 water vapor images 36
 weather forecasting 250
 wind information 15
 saturated adiabatic lapse rate *see* moist
 adiabatic lapse rate
 saturation 84–85, **288**
 dew point temperature 91–92
 humidity and temperature 89–91

orographic lifting 106–110
 relative humidity 86–87
 Skew-T, Log-P diagram 127–129
 supersaturation 87
 saturation water vapor pressure 88,
 89–91, 134, 270–272, **288**
 scattering 66, **288**
 scattering (radiation) 66, 67
 science
 birth of modern science 19
 women in meteorological science 33
 scientific instruments, historical
 context 19
 sea breeze 143–144, 169, **288**
 sea breeze circulation 144
 sea level
 adjustment of pressure to mean 27
 rise due to climate change 273–274
 seasonal variations 75, **288**
 solar radiation 75–76
 weather forecasting 252
 Second World War 6
 secondary pollutants 257–258
 see also air pollution
 selective absorption 68–70, **288**
 Shaefer, Vincent 135
 shelf clouds 212, 213, **288**
 showers 135
 Simpson, Joanne 239
 Skew-T, Log-P diagram 127–129
 sleet 136, **289**
 smog 101, 257–259, **289**
 snow 137, **289**
 see also ice-albedo effect
 solar radiation 49
 absorption by gases 70
 diurnal variations 76–78
 energy transfer 59
 heat imbalance 73–75
 influence of clouds 78
 land–ocean contrasts 78–80
 poles vs. tropics 74
 seasonal variations 75–76
 Solomon, Susan 54
 southern hemisphere cyclones
 207
 spatial representation of data 20
 radar 30–32
 satellites 32–42

station model 20–23
 surface maps 23–28
 upper-level maps 28–30
 specific heat capacity 79, **289**
 specific humidity 86, **289**
 spectrophotometer 69
 squall lines 209, **289**
 stability, atmospheric 111–120, 260,
 289
 see also unstable air
 stable air 112
 station model 20–23, **289**
 stationary fronts 188, **289**
 statistical post-processing 249
 Stefan–Boltzmann law 64–65
 Stefan, Jožef 64–65
 stepped leader 213
 storm clouds 120, 125
 storm surge 235–236
 storm tracks 200, **289**
 storms *see* thunderstorms; tropical
 storms
 stratocumulus clouds 125, 126, **289**
 stratopause 56, **289**
 stratosphere 56, **289**
 ozone hole 54
 ozone layer 49, 53
 vertical structure of the atmosphere
 54, 56
 stratus clouds 123, 124–125, **289**
 string jets 191
 subgeostrophic wind 149, 233, **289**
 sublimation 84, **289**
 subpolar lows 167, **289**
 subsidence (air masses) 193, **289**
 subtropical geostationary satellites
 39
 subtropical highs 167, **289**
 subtropics 39, **289**
 sulfur dioxide (SO_2) 257, 259
 sulfuric acid (H_2SO_4) 257
 sunlight refraction 139–140
 supercell storms 209, 215–217, **289**
 supercooled clouds 131, **289**
 supergeostrophic wind 149, 150, **289**
 supersaturation 87, 134, **289**
 surface friction 152–155, **289**
 surface maps 23–28, 43, 92
 surface pressure 167

surface temperature 162–163
 surface winds 150–152
 sustained wind 14, **290**
 synoptic scale 260, **290**
 T-bone model (cyclones) 190–191
 teleconnections 179, **290**
 Television Infrared Observation
 Satellite (TIROS) 32
 temperature 1–6, 53, **290**
 adiabatic processes 104–105
 the averaged atmosphere 162–163
 conservation laws 1–2
 cyclone development 206
 dew point 91–92
 diurnal variations 76–78
 global trends 269–270
 and heat 2–3
 historical context 19
 and humidity 87–91
 measurements 4
 past and future 267–268
 and pressure 7
 and radiation 62–63, 68
 radiosonde profiles 5–6
 scales 4–5
 seasonal variations 75–76
 at the surface 162–163
 surface maps 23–24
 thermometers 3–4
 weather forecasting 250
 see also climate change
 temperature fronts 24–25
 temperature inversion 56, **285**
 air pollution 261
 diurnal cycle 78
 stability 116
 stratosphere 56
 visual analysis 18
 temperature profiles
 air pollution 261, 265
 cumulonimbus clouds 119
 stability 114, 117
 stable air 113
 unstable air 113
 visual analysis 57
 thermal expansion 60
 thermals 61, 113, 115, **290**
 thermocline 176, **290**
 thermodynamics
 birth of 89
 first law of 102, 105
 warm to cold air flow 59
 see also energy transfer; heat transfer
 thermograph 3
 thermometers 3–4, 19, **290**
 thermosphere 56, **290**
 thunder 213–215, **290**
 thunderstorms 210, **290**
 cloud formation 120
 lightning and thunder 213–215
 ordinary 209, 210–211
 severe 211–212
 supercells 209, 215–217
 tropical cyclones 229
 tropical easterly wave 233
 weather conditions 209
 Tibetan Plateau 175
 time series, weather variables 17
 tipping buckets 15
 topography
 air pollution 263
 and wind 155–158
 Tornado Alley 220–222, **290**
 tornado family 219
 tornadoes **290**
 description 217
 development 217–219
 supercell storms 216, 217
 weather conditions 209
 Torricelli, Evangelista 10
 trade winds 169, **290**
 discovery of 185
 thunderstorms 233
 triple point (cyclone development)
 195
 tropical air masses (T) 186–187
 tropical cyclones 226, **290**
 climate change 273
 conditions for 236
 development 233–235
 facts and figures 227–228
 hazards 226, 235–236
 intensity scale 227, 228
 structure 228–232, 239
 tropical depression (TD) 233–234, **290**
 tropical disturbance 227, **290**
 tropical easterly wave 233, **290**

Tropical Rainfall Measuring Mission (TRMM) 32, 239
 tropical storms (TS) 234, 290
 tropics 74, 290
 tropopause 6, 290
 definition 6
 tropical cyclones 230
 vertical structure of the atmosphere 55
 troposphere 12, 290
 definition 6
 useful numbers 12
 vertical structure of the atmosphere 55
 water vapor images 36
 tropospheric ozone (O_3) 257
 trough (pressure) 24, 27, 290
 turbulence
 cloud formation 118
 pollutant dispersion 260, 262
 thunderstorms 210–211
 wind gusts 13
 typhoons 226, 227, 290
 see also cyclones

ultraviolet (UV) radiation 49, 62, 290
 uncertainty 290
 climate projections 274–275
 weather forecasting 241, 244

United States
 climate projections 277
 reference map 279
 Tornado Alley 220–222
 tornadoes by state and season 218
 west coast vs. east coast 171–172

Universal Time Coordinates (UTC) 5
 unstable air 113–115, 291
 upper-level maps 28–30
 upwelling (ocean) 176, 291

valley breeze 155–157, 291
 valley fog 156, 291
 van Straten, Florence 6
 variable gases 256, 269, 291
 Venus 49, 57
 vertical profile of the atmosphere 18
 vertical wind shear 273
 vibration 69–70
 virga 124, 291

visible light 62
 visible satellite images 33
 visible window (absorption spectrum) 70–71
 volatile organic compounds (VOCs) 257, 259
 Vonnegut, Bernard 135

Walker circulation 177, 291
 Walker, Sir Gilbert 185
 wall clouds 217, 291
 warm fronts 44–45, 291
 midlatitude cyclone development 188, 189
 warm occlusion 190
 warm sectors 189, 291
 warm vs. cold clouds 130–131
 Washington, Warren 278
 water
 land–ocean contrasts 78–80
 phases of 83–84
 significance to the Earth 83
 see also cloud formation; precipitation
 water cycle 83–84
 and climate change 270–272
 water vapor 291
 altered water cycle 270–272
 atmospheric composition 47
 average environmental lapse rate 55
 dew point temperature 91–92
 dew point temperature applications 92–96
 feedback loops 73, 271
 geological history of Earth 48
 greenhouse effect 71–72
 humidity 85–86
 humidity and temperature 87–91
 relative humidity 86–87
 saturation 84–85
 water vapor feedback 73
 water vapor images 36, 37
 water vapor pressure 86, 88, 291
 wave cyclone 192
 wave frequency 62
 wavelength 62, 71, 291
 weather
 the atmosphere xiii
 conservation laws xiv

distinction from climate xiii
 radiative interactions 73–80
 weather balloons 18
 weather buoys 16
 weather forecasting 240–241
 chaos 247–248
 climate change 274–275
 ensemble forecasting 244–247
 from forecast grids to reliable forecast values 248–250, 255
 medium- to long-range 251–252
 prognostic equations 241–244
 seasonal outlook 252
 tools used 250–251
 uncertainty 241, 244
 see also climate projections
 weather maps 18
 weather modification 135
 weather stations 15–16, 250, 291
 see also station model
 weather symbols 21
 see also spatial representation of data
 weather variables 1
 precipitation 15
 pressure 6–12
 temperature 1–6
 wind 12–15
 Wegener, Alfred 133
 Wien, Wilhelm 64–65
 Wien's displacement law 64–65
 wind 12–15
 additional sources of information 14
 air pollution 259–262
 Coriolis force 144–146
 diagnostic and prognostic approach 141
 force and acceleration 141–142
 friction 152–155
 geostrophic wind 146–149
 gradient wind 149–150
 measuring 12–13
 pressure gradient force 142–143
 reporting 13–14
 sea breeze and land breeze 143–144
 surface winds 150–152
 topography 155–158
 see also global wind systems

wind direction
Coriolis force 145, 146
geostrophic balance 148
gradient wind 149–150
measuring 12
surface maps 23
surface winds 150–152
symbols 22
visual representation 13
wind gusts 13, **291**

wind shear **291**
supercells 215, 221
thunderstorms 209
tornadoes 219
tropical cyclones 179, 232, 234,
 236
wind speed
the averaged atmosphere
 163–167
Beaufort wind scale 14

convergence (cloud formation)
 110
cyclone development 206
measuring 12, 13
meteograms 92–94
symbols 22
wind vanes 12, **291**
wind velocity 12
women in meteorological science and
engineering 33