

# Index

- Accretion 130, 173  
 Africa 7  
 Age dating 84, 149–50  
 Alaska 92  
 Albedo 15, 16  
   Maps of Mercury 34,  
   40, 41, 42–3  
   Pluto and Charon  
   157, 159  
   South Polar Cap of  
   Triton 161  
 Alps 21  
 Antarctica 14, 18, 21,  
   22, 26, 29, 32, 80,  
   92, 108  
 Antarctic ice sheet 6,  
   11, 120, formation  
   12–14 million years  
   ago 9, 13, 17, 18,  
   32, 83  
 Apollo (program) 51  
 Arecibo Observatory 38  
   Radar observations  
   of Mercury 41, 42,  
   44  
   Radar observations  
   of polar regions on  
   the Moon 52  
 Arctic ice sheets 32  
 Ariel (satellite of  
   Uranus) 120, 134,  
   136, 137  
 Arizona, University of  
   74  
 Asteroid 137, 139, 140,  
   142, 168, 180  
 Asteroid Belt 110, 118  
 Atmospheres 62, 64,  
   67, comets as  
   major source of  
   atmospheres of  
   inner planets 67,  
   72, affect of  
   impact erosion on  
   a. of Mars 74, 75,  
   76, 178  
 Pluto 140, bound  
   atmosphere on  
   Pluto 141, 155, 156,  
   158, 159, 161, 162,  
   will Pluto's  
   atmosphere  
   disappear? 163  
 Martian atmosphere  
   80, 81, 85, 89, 92,  
   93, 104  
 Titan 115, 130,  
   131–2  
 Triton 112, 151, 152,  
   153, 154, 161  
 Australia 7  
 Bar-Nun, Akiva 68, 75,  
   76  
 Basal sliding 26  
 BepiColombo (mission)  
   58, 59  
 Bernstein, Max 176  
 Big Bang 173  
 Blue ice 31  
 Borelly (comet)  
   188  
 Callisto (satellite of  
   Jupiter) 110,  
   115–16, 117, 120,  
   liquid water ocean  
   may lie beneath  
   several hundred  
   kilometers of icy  
   crust 121, Galileo  
   mission findings  
   129–30, surface  
   very heavily  
   cratered 150  
 Canada 18, 92, 113  
 Canali (martian canals  
   or channels) 79  
 Cantaloupe terrain  
   (on Triton) 133  
 Carbonaceous  
   chondrites 118  
 Cassini, Giovanni  
   Domenico, Italian  
   astronomer  
   1625–1712 117  
 Cassini (mission) 110,  
   117, 132, 135,  
   138  
 Centaur 186, 187  
 Ceres (largest known  
   asteroid, diameter  
   912 km) 141  
 Chao Meng-Fu (crater  
   on Mercury) 15  
 Chaotic terrain  
   (on Mars) 95  
   (on Europa) 123  
 Chapman, Clark 34

## Index

191

- Charon (satellite of Pluto) 115, largest satellite in solar system relative to its primary 141, in 3:2 resonance with Neptune 144, discovered 1978 156, 157, 185
- Christy, James 156
- CHON 181, 187
- Churyumov/Gerasimenko (comet) 76, 78, 189
- Circumplanetary nebula 117
- Clementine (mission) 53, 54, 57
- Climate change 21–2, 83, 96–7, 103, 108
- Climatic events  
 Cooling of Earth 2.3 billion years ago 8, 15, 33, seasonal changes on Mars 86, 89, current climate on Mars 92, clues to martian climate history 104
- Coded Long Pulse technique 38
- Coherent backscatter (radar reflectivity) 41
- Comet  
 Short period comets (Mercury-crossing comets) 48, 56, major source of atmospheres of the inner planets 60, 71, D/H ratio 60, bombardment of Earth 74, 75, 76, 114, 116, 117, 137, Oort Cloud, source of long-period comets 142, 168, delivered volatiles and stuff of life to Earth in first half billion years of the planet 168, 170, 172, 173, 174, 177, formation at exceedingly low temperatures characteristic of interstellar medium 177, 178, 179, comets delivered about 15% of Earth's water 179, 180, 181, 182, 183, Kuiper Belt, source of short period comets 184, 187, 188, 189
- Comet coma 170, 174, 175, 178, 180, 187
- Comet dust 180, 181
- Comet showers 184
- Comet tail 170, 178, 180, 187
- Cometary nucleus 68  
 Temperature of formation of ice grains in 68, 78, 170
- Whipple recognized typical nucleus is very small; 1–2 km in diameter 170, 174, 175
- Continental shelf 11
- Corona (on Miranda) 136, 137
- Cosmic rays 33, 93, 177
- Cratered terrain (on Mars) 82
- Crevasses 26
- Cryosphere 17, 92, 106
- Cryptoendolithic lichens 108
- Deep Impact (mission) 189
- Deep Space 1 (mission) 188
- Deep Space Network 37, 54
- Diagenetic zones 23
- Diapirs 124, 133
- Dione (satellite of Saturn) Evidence of past volcanism 21, 118, interactions with Enceladus 137, 138
- Dirty snowballs (Whipple concept of comets, 1950) 170, 176
- Discovery program 54
- Drumlins 29
- Dust storms (on Mars) 84, 90

- Early bombardment 74
- Earth 6, 7, the “water planet” 8, lack of evidence for ice during early history of 8, percentage of water currently frozen 9, present climate on 9, orbit 12, climate change on 21, 26, 29,30, comparisons with Mercury 33, 34, 36, 38, 41, 43, 46, 50, 57, origin of atmosphere and oceans 60, Atmosphere 61, 62, 64, and origin of life 61, 64, 65–6, 67, cometary contribution to atmosphere 67, 69, 71, 75, 76, 43, composition of water 73–4, 78, presence of meteorites from Mars 74, comparisons with Mars 79, 83, 85, 86, 91, 92, 94, 100, 103, 104, 105, clues to origin of life on Earth from Mars 109, 114, 119, 122, 125, 127, Titan compared to early Earth 130, 147, 149, 159, comets brought matter of life and means to extinguish life to Earth 168, extinction of dinosaurs caused by comet or asteroid impact 168, 178, about 15% of Earth’s water could have come from comets 179, next return of Comet Halley to Earth 2061 184
- Earth-based observations 58
- Of Mars 79
- Earth–Moon system 57
- Edgeworth, Kenneth 140, 184
- Edgeworth–Kuiper Belt 139
- Elias 18 (star) 177
- Eskers 29
- Enceladus (satellite of Saturn) Possible ongoing volcanic activity 118, 120, 134, 135, 137
- Europa (satellite of Jupiter) 110, surface covered by water layer 113, 116, salty ocean beneath icy crust 116, possible ongoing volcanic activity 110, 119, liquid water layer up to 100 km thick may lie just a few kilometers below icy surface 111, 121, 122–3, 124, 125, 140, young surface the result of orbital resonance with Jupiter 150
- Europe 9, 12
- European Space Agency (ESA) 58, 76, 189
- Exosphere On Mercury 34 Planetary 60
- Extrasolar giant planets 36
- Facies 23, 24
- Firn 21
- Flagstaff, Arizona 79
- Flowstripes 26
- Frost (on Mars) 80, 85, 86, (on Triton) 133–4
- Frozen in time (outer solar system bodies offer opportunity to study primitive environments) 64
- Galileo Galilei, Italian astronomer 1564–1642 110

## Index

193

- Galileo (mission) 110, 111, 116  
 NIMS infrared instrument 116  
 Magnetometer data 121  
 Europa liquid water ocean data 123, 124, 127  
 Galileo entry probe 69–71  
 Galilean satellites (Io, Europa, Ganymede, Callisto) 112, abundant water ice on surfaces of all but Io 113, tidal heating and geologic history 119, 121, density decreases moving out from Jupiter and water content increases 121, geological complexity increases toward Jupiter 121  
 Ganymede (satellite of Jupiter) 114, 115, 116, 117, evidence of past volcanism 118, 119–20, liquid ocean may lie beneath several hundred kilometers of icy crust 157, relatively inactive geologically; composed more than 50% of water 121, Galileo mission findings 126–9, 150  
 Gamma ray spectrometer On Lunar Prospector spacecraft 54  
 On Messenger and BepiColombo spacecraft 58  
 On Mars Odyssey spacecraft 93  
 Gas giant planets 61, 62, 64, 70, 71, 140, 145  
 Geysers (in the outer solar system) 115, (on Triton), 138  
 Giotto (mission) 73, 181  
 Glacial periods 9, 11, 13, last on Earth 6, 11, 12  
 Glacial valleys 29  
 Glaciation event (first on Earth) 8  
 Gondwanaland 9  
 Gravitational field Role in composition of planetary atmospheres 60, 61  
 Greenland 18, 21, 26, 41  
 Greenland ice sheet 6  
 Ice cores from 11, 83  
 Greenhouse effect 8, 64, 89  
 Greenhouse gases 7, 8, 64, 108  
 Hale-Bopp (comet) 73, 78, 142, 170, 173, 174, 176, 178, 179, 180, 183, 187  
 Halley (comet) 68, 73, 78, 168, 170, 176, 178, 181, 184, 189  
 Hayakutake (comet) 73, 78, 179, 183  
 Himalayas 41  
 Hubble Space Telescope 132  
 Human exploration 109  
 Human habitation On Mercury 36  
 On the Moon 57  
 On Mars 81, 105, 107–8  
 Iapetus (satellite of Saturn) 117, 137, 138  
 Ice Age, the last on Earth 29, 104, 118  
 Iceberg 11, 24, 29  
 Ice-cores, in Antarctica 21, 22, 50, 94  
 Ice sheets (on Earth) 7, 9, 11, 13, 14, 15, 17, 18, 20, 22, 23, 24, 26, 28, 29, 30, 31, 32  
 Comparison of ice sheets on Earth with ice deposits on Mars 83

- Ice lenses 94
- Ice rise 29
- Ice rumples 29
- Icy planetesimals 67, 69, 72
- Impact craters 67, 74, 79, 84, 90, lobate craters give appearance of meteor striking mud 116, 118, 124, on Callisto 129, on Triton 133, 149, on Iapetus 138, ubiquitous feature on most solid surfaced bodies in the solar system 149, cosmic impacts implicated in mass extinction of species on Earth 250 million years ago 168, extinction of the dinosaurs 65 mya 168
- Impact erosion 74
- Indonesia 7
- Inner solar system 36, early collisional environment 36, 62, 180, 183
- Interglacials (on Earth) 9, 11, 12, 13
- Interplanetary Dust Particles (IDPs) 180
- Interstellar matter 171, interstellar clouds contain main constituents of comets 172, interstellar gas 173, interstellar ices 176, interstellar gases identified in comets Hyakutake and Hale-Bopp 184, deuterium content of comets confirms they consist of material frozen initially in the interstellar cloud 179, 187
- Interstellar medium 52, 172, 178, study of comets Halley and Hale-Bopp consistent with formation in the interstellar medium 178
- Institute of Space and Astronautical Science, Japan (ISAS) 58
- Io (satellite of Jupiter) Discovery of volcanoes by Voyager spacecraft 110, 119, only galilean satellite with no detected water ice 110, sulfurous volcanic activity 116, ongoing geologic activity 118, 119, 122, youngest surface amongst outer solar system satellites 150, young surface the result of orbital resonance with Jupiter 150
- Isochrones 23
- Jet Propulsion Laboratory 37
- Jewitt, David 180, 185
- Jokobshavn Isbrae 26
- Jovian satellites Complexities revealed by Galileo mission 111 Tidal configurations 130 Smaller moons display heavily cratered, ancient surfaces 150 Large moons display variety of crater densities 150 Jupiter 41, atmosphere 60, 61, formation 69–70, 71, 103, arrival of Voyager spacecraft 1979 110, 111, radiation belts 116, 138, 142, 167, 184, 185–6 Jovian satellites (moons of Jupiter) Complexities revealed by Galileo mission 111, 130

## Index

195

- Jovian satellites (*cont.*)  
 smaller moons  
 display heavily  
 cratered, ancient  
 surfaces 139, 150
- Jupiter Moons Orbiter  
 (hypothetical  
 mission) 126
- Kasting, Jim 64
- Keck Observatory 186
- Kuiper Airborne  
 Observatory 155
- Kuiper Belt (also  
 referred to as the  
 Kuiper Disk) 71,  
 78, 139, 184, 185,  
 contains 70,000  
 bodies larger than  
 100 km diameter  
 in nearest parts  
 185, 186
- Kuiper Belt Objects  
 (KBOs) 132, 152,  
 composed mostly  
 of water ice 152,  
 185, 186, what  
 distinguishes them  
 from comets? 187
- Gerard Kuiper  
 (Dutch-American  
 astronomer,  
 1905–1973) 130,  
 140, 184
- Lake Ontario 22
- Laplace Resonance 119
- Laser altimeter,  
 (on Messenger  
 mission) 59
- Leads 16
- Lecluse, Dominique 73
- Lewis, John 113
- Life, establishment on  
 Earth 8, role in  
 composition of  
 atmosphere on  
 Earth 60, 63, 64  
 On Mars 81, 108, 109  
 Outer solar system  
 satellites 112,  
 Europa 124, 125,  
 Titan 130, Comets  
 and 168, stuff of  
 life delivered to  
 Earth by comets in  
 first half billion  
 years of planet's  
 existence 168, 189
- Life support systems  
 106
- Living organisms 63
- Little Ice Age 12
- Low-melting-point ices  
 120
- Lowell Observatory 156
- Lowell, Percival 79, 81,  
 109
- Lunar-A (mission) 58
- Lunar Prospector  
 (mission) 33, 58
- Luu, Jane 185
- McEwen, Alfred 123
- McKinnon, Bill 132
- Magellan (mission) 33,  
 49
- Magnetic field  
 On Mercury 36  
 On Europa
- Maria (lunar) 34, 149
- Mariner (program) 79
- Mariner 10 (mission)  
 33, 34, 36, 42, 49,  
 58
- Mars  
 Meteorites from  
 18, 32, 33, 41, 43,  
 carbon dioxide  
 dominated  
 atmosphere 60, 62,  
 63, 64, cometary  
 contribution to  
 atmosphere 67, 69,  
 72, composition of  
 water 73, 74, 76,  
 best location to  
 detect origin of  
 planetary water on  
 terrestrial planets  
 78, 79, 80, surface  
 frost 80, 85, 86,  
 clouds 80, 90, 93,  
 water and CO<sub>2</sub> ice  
 89, 90, 91,  
 orographic clouds  
 82, 90, polar ice  
 deposits 83, 84,  
 surface age 85,  
 surface  
 dramatically  
 different at each  
 of the poles 86, ice  
 fog 89, 90,  
 geothermal heat  
 92, 95, permafrost  
 92, current climate  
 92, 93, abundant  
 geological evidence  
 for water 94,

- valley networks 94,  
 outflow channels  
 94, 95, 96,  
 shorelines 94, lake  
 deposits 94, role of  
 ice in evolution of  
 martian landscape  
 95, incised  
 channels 95,  
 evidence for liquid  
 water on the  
 surface 95, CO<sub>2</sub>  
 rather than water  
 could be erosive  
 agent 95, valley  
 networks on oldest  
 terrain suggest  
 earlier abundant  
 liquid water 96,  
 gullies (recent) 96,  
 lobate termini 99,  
 100, 101, 102, 104,  
 106, 107, 108, 109,  
 life and dramatic  
 climate change  
 108,  
 109, 112, 150,  
 178
- Mars Global Surveyor  
 (program) 79,  
 polygonal patterns  
 imaged on Mars  
 101
- Mars Odyssey  
 (program) 79, 93
- Marsquakes 95
- Mars Sample Return  
 (mission) 78
- Martian channels 75,  
 79
- Martian climate 81
- Martian moons 79
- Martian seasons 79, 81,  
 85
- Matthews, Henry 180
- Mauna Kea, Hawaii  
 186
- Melosh, Jay 74
- Melt-water 23, 24,  
 81
- Mercury  
 Possibility of water  
 ice on 33, 34,  
 Mariner 10 flybys  
 in 1974 and 1975  
 34, 36, radar  
 experiments 37,  
 40, polar features  
 43, thin  
 atmosphere 43, 60,  
 floors of polar  
 craters coldest  
 places on the  
 planet 43, possible  
 large deposits of  
 ice in polar craters  
 43, 44, 49, surface  
 area covered by  
 volatile deposits  
 44, how can ice  
 exist in polar  
 craters? 45,  
 temperatures in  
 polar craters 46,  
 47, 48, 49, 50,  
 polar crater  
 comparison with  
 the Moon 52,  
 similar polar  
 inversion signal  
 detected on the  
 Moon 54, 56, 58
- Messenger (mission)  
 58–9
- Metamorphism 20, 21,  
 23
- Meteorites 30, 31, 48,  
 50, 51, 66–7, 69,  
 From Mars 72, 74,  
 76, 79, 116, 118,  
 179, 180
- Meteorite  
 bombardment 33,  
 43, 45, 46, 50, 65,  
 85, 111, 135,  
 177
- Meteor (shooting star)  
 180
- Milky Way Galaxy 183
- Mimas (satellite of  
 Saturn) 135
- Minnesota, University  
 of 76
- Miranda (satellite of  
 Uranus)  
 Evidence of past  
 volcanism 118,  
 120, 134,  
 complexity  
 discovered by  
 Voyager mission  
 135, proximity to  
 Uranus may result  
 in heavy asteroid  
 and cometary  
 bombardment  
 136, may have  
 started to turn  
 inside out through  
 volcanism 137

- Miranda (*cont.*)  
 possibly locked in  
 transient orbital  
 resonances with  
 Umbriel or  
 another outer  
 satellite in the past  
 137, slightly tilted  
 orbit (remnant of  
 earlier orbital  
 resonance?) 137
- Moon  
 Meteorites from  
 32, possible  
 existence of water  
 ice 33, surface  
 characteristics  
 compared with  
 Mercury 34, 36,  
 radar signature in  
 cold polar craters  
 differs from that  
 for Mercury 43, 50,  
 Apollo data  
 suggested no ice at  
 lunar poles 51,  
 case for water ice  
 deposits in lunar  
 polar craters 52,  
 53, 54, Lunar  
 Prospector 54, 56,  
 57, use of  
 Earth-based  
 observations for  
 future study of  
 polar deposits 58,  
 atmosphere 60, 61,  
 138, 148, 149
- Moonquakes 119
- Moraines 29
- Mt. Fuji 120
- M-type giant stars 180
- Mumma, Michael 176,  
 178
- National Aeronautics  
 and Space  
 Administration  
 (NASA) 37, 54, 58,  
 155, 167
- National Radio  
 Astronomy  
 Observatory 37
- National Space  
 Development  
 Agency, Japan  
 (NASDA) 58
- Natural History  
 Museum, Paris 73
- Natural resources 50
- Neptune 37, 112, 114,  
 115, 132, 139
- Not formed in  
 present orbit 141,  
 142–3
- Orbital migration  
 143
- Orbital resonance  
 with Pluto 143
- Orbital resonance  
 with Triton 139,  
 145, 147
- Characteristics of  
 Neptune's regular  
 satellites  
 consistent with  
 disruption of an  
 early, more typical  
 system of moons  
 145, 147, 150,  
 1951 Kuiper  
 suggests source  
 region for short  
 period comets just  
 beyond Neptune  
 184
- Gravitational action of  
 Neptune extracts  
 comets from the  
 Kuiper Disk 184
- Neutron spectrometer  
 On Lunar Prospector  
 spacecraft 54,  
 identifies  
 signature for water  
 ice in lunar polar  
 craters 55
- On Messenger and  
 BepiColombo 58
- On Mars Odyssey  
 spacecraft 93
- New Horizons (mission)  
 167
- New Mexico 37
- Noble gases 66, 72, 75,  
 76
- Non-protic ices 168, 176
- North America 9
- Northern Hemisphere  
 (Earth) 17, 18
- Northern Hemisphere  
 ice sheets 13
- Oceanic circulation 9
- Olympus Mons 120
- Oort Cloud 78, 142,  
 182, 183, 184, 185,  
 186
- Oort, Jan 182
- Ortho water 178



- Outer solar system  
 Most abundant gases  
 60, 63, 110  
 Much more dynamic  
 than previously  
 believed 110  
 Possible  
 environments  
 conducive to  
 formation of basic  
 elements of life  
 112, 114, 118  
 Water and ice  
 abundant 117, 141  
 Owen, Toby 7, 178  
 Paleoclimate 9, 22  
 Para water 178  
 Pathfinder (mission) 79  
 Pangea 9  
 Peale, Stan 119  
 Pennsylvania,  
 University of 64  
 Pepin, Robert 76  
 Permafrost (on Mars)  
 92  
 (on Earth) 94, 95,  
 104, 106, ice-laden  
 99, ice-cemented  
 100, 104, 106, 107,  
 108  
 Permian Period 168  
 Phoebe (satellite of  
 Saturn) 138  
 5145 Pholus (centaur)  
 186, 187  
 Photosynthetic plants  
 62  
 Pine Island Glacier 26  
 Pingo 94  
 Planetesimals 142, 143,  
 172, 173, 185, 186  
 Planet formation 67  
 Pluto 60, 63, 64, 115,  
 117, atmosphere so  
 thin it wasn't  
 detected until  
 1989 140, 141, has  
 a bound  
 atmosphere 141,  
 orbital resonance  
 with Neptune 143,  
 orbit transformed  
 by resonance with  
 Neptune 143, 147,  
 density difference  
 between Pluto and  
 Triton key to  
 different  
 formation histories  
 151, impact that  
 formed Charon  
 melted all the ice  
 in Pluto 151, 152,  
 155, research from  
 2002 occultations  
 show a very  
 different  
 atmosphere from  
 that observed in  
 1989 consistent  
 with idea of strong  
 seasonal variation  
 156, 157, 158, 159,  
 complex  
 ice-atmosphere  
 system 159, 160,  
 161, 162,  
 atmosphere may  
 be ephemeral 161,  
 162, will Pluto's  
 atmosphere  
 disappear? 163,  
 166–7, new  
 Horizons mission  
 167, 185  
 Polar caps (on Mars) 81  
 Northern 82, 86  
 Southern 82, 84,  
 87  
 Frost caps (on  
 Ganymede) 127  
 Polar cold traps (on  
 Mercury) 48, polar  
 deposits (on Mars)  
 81, 83, 84, 85, 88,  
 105, 106, consist of  
 buried CO<sub>2</sub> 89,  
 layered deposits  
 83, 85, 104, water  
 abundant at north  
 polar deposit 105,  
 (on Earth) 19,  
 Antarctic 23  
 Polar hood 91  
 Polar layered terrain  
 (on Mars) 81  
 Polar winter (on Earth)  
 16  
 Polarization inversion  
 40, 42–3, 44, 54  
 Poynting, John Henry  
 79  
 Protic ices 176  
 Proto-planetary disk  
 140, 141, 143, 145,  
 147  
 Protoplanets 117  
 Proto-solar nebula 139,  
 140

## Index

199

- Protostar W33A 176  
 Proxima Centauri (star)  
   182  
 Quaoar (largest known  
   Trans-Neptunian  
   object) est.  
   diameter 1,100 km  
   141  
 Race to the Moon 52  
 Raging fifties 18  
 Rampart craters 101,  
   103  
 Regolith 33, 46, 48,  
   55  
 Resonant orbit  
   Mercury in 3:2  
     resonance with  
     the Sun 34  
   Pluto in 3:2  
     resonance with  
     Neptune 143, 144  
   Trans-Neptunian  
   Objects in  
   resonant orbit  
   with Neptune 144  
   Triton in 1:1  
     resonance with  
     Neptune 145  
   Young surfaces on Io  
   and Europa due to  
   resonances with  
   Jupiter 150  
 Rhea (satellite of  
   Saturn) 110, 138  
 Roaring forties 18  
 Robert, Francois 73  
 Robot explorers 111  
 Rock glacier 99  
 Rosetta (mission) 76,  
   189  
 Sahara 9  
 Saturn 112, 117, 185  
 Saturnian satellites  
   Water ice detected  
     on major satellites  
     by 1984 114, 115,  
     117, 121, 135, 150  
   Saturn's rings 110,  
     135  
 Scandinavia 113  
 Schenk, Paul 123  
 Schiaparelli 79  
 Sea level 9, 13, 15, 26,  
   29  
 Selene (mission) 58  
 Shackleton crater (on  
   the Moon) 54  
 Siberia 92  
   Viable 3 million year  
   old bacteria in  
   Siberian  
   permafrost 109  
 Side Aperture Radar  
   (SAR) 38  
 Smart-1 (mission) 58  
 Snow cover blanket,  
   global 17  
 Snowflakes 6, 20  
 Snow pack 24  
 Solar Composition Icy  
   Planetesimals  
   (SCIPS) 69, 71, 72  
 Solar nebula 36, 61, 65,  
   68, 69, 70, 71, 73,  
   78, 114–15, 117,  
   151, 172, 173, 178,  
   179, 186  
   *See also proto-solar  
   nebula*  
 Solar radiation 31, 46,  
   47  
 Solar system formation  
   36, 111, 143  
 Solar wind 56, 60, 74,  
   140  
 South Africa 7  
 South Polar Basin  
   (on Mars) 82  
 South Polar Cap (SPC)  
   (on Triton) 161–2  
 South Pole (Earth) 17,  
   18  
 Southern Hemisphere  
   (Earth) 17  
 Space age 110, 112  
 Stardust (mission) 181,  
   188  
 Sublimation 46, 80, 81,  
   84, 86, 87, 90, 94,  
   102, 104, 106, 107,  
   157, 158, 159, 160,  
   161, 162–3  
 Sun 7, 8, 13, 32, 33,  
   Distance to  
   Mercury 33, 37, 45,  
   46, 47, 64, 65, 68,  
   and martian  
   seasons 79, 114,  
   139, 162, 163, 168,  
   170, 172, 184  
 Surface lander  
   (on BepiColombo  
   mission) 59  
 Tectonic plates  
   (on Earth) 8, 9  
 Tectonic processes 73

## 200

## Index

- Tel Aviv, University of  
68
- Tempel 1 (comet) 189
- Thermal IR mapping 49
- Thermal radiation 46
- Thermokarst 95
- Tholins 116, 187
- Tidal heating (in the  
outer solar system)  
119, 130, 132, 150,  
151
- Titan 60, 112  
Atmosphere 63, 64,  
72, 115, 117,  
130
- Trans Alaskan Pipeline  
108
- Trans-Neptunian  
Kuiper-Edgeworth  
Belt 111
- Trans-Neptunian  
Objects 139  
Typically diameter  
more than 100 km  
145, water rich,  
146
- Classical TNOs 144
- Scattered TNOs 144,  
147, New Horizons  
mission 167
- Triton 60, 112  
Atmosphere 63, 64,  
117, 118, 120
- Retrograde inclined  
orbit 132, 139, 145
- KBO captured by  
Neptune 132
- Surface possibly less  
than 100 million  
years old 133
- Most geologically  
complex of the icy  
satellites 133
- Cantaloupe terrain  
133
- Geysers 133
- Geologically active  
80
- Water could  
constitute 30% of  
interior 133
- Similar in size to  
Pluto 139
- Formed in solar  
orbit, not present  
orbit 141
- In 1:1 resonance  
with Neptune 145,  
146, 147, 150,  
151
- Formed in a circular  
orbit around the  
Sun 147, 148
- Almost complete  
lack of impact  
craters indicates  
surface is very  
young 149, 150
- Density difference  
from Pluto key to  
different  
formation history  
151
- Constant change  
ongoing in  
seasonal cycles  
and surface-  
atmosphere system  
152, 153, 154,  
157
- Nitrogen-dominated  
atmosphere 153,  
154
- Surface/atmosphere  
interaction 158, 159
- Complex  
ice-atmosphere  
system 159, 160,  
161, 162
- Umbriel (satellite of  
Uranus) 137
- United States 18, 113
- U.S. Naval Observatory,  
W. 156
- Uranus 112, 136, 141,  
142, 185
- Uranian satellites  
Water ice detected  
on major satellites  
by 1984 114, 115,  
117, 121, 136, 137,  
150
- U-shaped valley 11
- Vega (mission) 181
- Venus  
Bulk density similar  
to Earth and  
Mercury 33
- Magellan mapping  
mission 39, 43
- Carbon dioxide  
dominated  
atmosphere 60, 62,  
63, 64
- Cometary  
contribution to  
atmosphere 60, 67,  
72, 178

## Index

201

- Very Large Array (VLA)  
 37, 39
- Vesta (asteroid) 32
- Vickery, Ann 74
- Viking (program) 79  
 Landers 100,  
 101
- Volcanism 110, 113,  
 122, 125, 129, 130,  
 131, 133, 135, 137,  
 138, 149, 150
- Vonnegut, Kurt 163
- Vostok Station  
 (Russia's, in  
 Antarctica) 22, 32
- Voyager (missions) 37,  
 110, 111, 117, 119,  
 122, 123, 126, 133,  
 134, 135, 148, 154,  
 159, 161
- Water, percentage  
 currently frozen  
 on Earth 9, 11,  
 percentage  
 contained in ice  
 sheets on Earth  
 during last glacial  
 period 11, 17, 20,  
 in lunar polar soil  
 33, 41, 48, 50,  
 volume of water  
 on Moon implied  
 by Lunar  
 Prospector data 55,  
 58, 63, 72–3, 78,  
 (on Mars) interior  
 rocky water  
 reservoir on Mars  
 74, D/H in  
 water-containing  
 minerals in  
 Martian meteorites  
 74, 80, abundant  
 reservoir on Mars  
 81, 82, 89, 90, 94,  
 where is the  
 martian water  
 today? 85, 94, 95,  
 97, 102,  
 underground  
 reservoirs on Mars  
 97, 103, 106–7, 108,  
 109, (outer solar  
 system) 110, liquid  
 water layers  
 discovered on  
 some ice-rich  
 satellites in the  
 outer solar system  
 112, 113, 120, 121,  
 123, Europa 128,  
 Titan, Ganymede  
 and Callisto could  
 have deep water  
 oceans 132, 137,  
 objects beyond  
 Jupiter rich in  
 water (primarily as  
 water ice) 140, 146,  
 170, abundant  
 water 168, 172,  
 first water in  
 comets positively  
 identified 1985  
 176, 177
- Water ice, on Earth 6  
 (on Mercury and  
 the Moon) 33,  
 possible presence  
 at lunar poles 33,  
 50, 52,  
 Mechanisms for  
 delivery to  
 terrestrial planets  
 36, possible  
 presence at poles  
 of Mercury 37, 48,  
 49, 50,  
 Reexamination of  
 case for water ice  
 on the Moon 52,  
 Clementine  
 spacecraft attempt  
 to detect water ice  
 on the Moon 54,  
 Lunar Prospector  
 55, 56, 57, (on  
 Mars) Northern  
 residual ice cap on  
 Mars 86, 88, 86,  
 89, 90, 91, in  
 permafrost 92,  
 104, (in outer solar  
 system) abundant  
 on Callisto, Europa  
 and Ganymede  
 113, outer solar  
 system satellites  
 composed mostly  
 of water (and  
 other) ices 114,  
 115–16, 120, 133,  
 147, Pluto and  
 Triton have outer  
 layers of water ice  
 approx 300 km  
 thick 147, 148,  
 Water ice  
 identified on the

- surfaces of 2 KBOs  
152, (in comets)  
Water ice a  
dominant ice in  
comets 175,  
Whipple predicted  
water ice would be  
most abundant ice  
in comets. This
- positively detected  
35 years after his  
1950 prediction  
176, 177, 178, 188,  
Water ice found  
on centaur 5145  
Pholus 186  
Water planet 6, 8  
Waterworld (Earth) 110
- Weidenschilling, Stuart  
173  
Whipple, Fred 170,  
175–6  
Wild 2 (comet) 181  
Wind patterns 84  
1993 SC (KBO) 186  
1996 TO<sub>66</sub> (KBO) 186