

# Index

**This index should be cited as:**

IPCC, 2019: Index. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 739–755.

Note: An asterisk (\*) indicates the term also appears in the Glossary. Bold page numbers indicate main discussion of topics. Italicised page numbers denote tables, figures and boxed material.

## A

- Ablation (of glaciers, ice sheets, or snow cover)\***, 139–140
- Abrupt changes**, 67–69, 76, 591–593, **618–623**  
cross-system assessment and examples, 595–596  
decision making for, 629–630  
definitions, 594–595  
examples of, 592  
FAQ, 632  
framework for, 594, 594  
governance and, 629–631  
impacts, 595–596  
knowledge gaps, 633  
ocean circulation, 618–623  
permafrost thaw, 249  
projections, 592, 595–596  
thresholds for, 45, 69  
tipping point and, 45, 81, 82, 626
- Abrupt climate change\***, 591–593, 594, 618–623  
definition of, 594  
framework for, 594
- Accommodation**, 329, 385, 386, **393–396**
- Active layer\***, 145, 146
- Adaptation\***, 92, 94  
barriers and limits, 29, 67, 69, 88, 325, 398–399, 455  
challenges, 29, 45, 76, 325, 407–410, 629  
community based, 67, 402, 406, 408  
enabling conditions, 33, 34–35, 49, 407–410  
ethical challenges of, 629  
implementing responses, 29–35  
political nature of, 408  
risk reduction and, 87–89  
scenarios, 382  
societal challenges of, 666  
socioinstitutional, 66–67, 454, 525  
transformative governance and, 630–631
- Adaptation limits\***, 29, 46, 57–58, 67, 69, 88, 325, **658**  
reaching/exceedence of, 27, 68, 69, 592, 658, 668
- Adaptation options\***, 27, 30–34, 76, **92–94**, 93  
coastal adaptation, 31–32, 323–325, **385–410**, 451, 664, **665–667**  
integrated responses, 31, 49, 69, 325, 329, 593  
mitigation and, 115  
ocean-based adaptation, 454–455, **525–540**, 526–527  
strengthening, 30–34
- Adaptation pathways\***, 666–667  
adaptation pathway analysis, 325, 327
- Adaptation planning**, 49, 89–90, 326–327, 330, 408  
spatial planning, 400–401, 407
- Adaptive capacity\***, 29, 75, 88  
capacity-building, 34, 35, 67, 69, 454, 593, 631  
enhancing, 93  
indicators of, 271, 272  
in low- versus high-emission scenarios, 24, 34
- Adaptive decision-making**, 33, 88, 325, 405
- Adaptive evolution**, 94
- Adaptive governance**. See Governance
- Aerosols\***, 139–140
- Agriculture**  
coasts and low-lying islands, 55, 328, **380**, 383–384, 663–664  
high mountain areas, 47, 48, 133, 134, 154–155, 156, 164  
in Ladakh, India, 156  
observed impacts, 14, 15, 133
- Albedo\***, 212, 241, 247, 253  
sea ice albedo feedback, 213, 215, 224
- Algal blooms**. See Harmful algal blooms (HABs)
- Alien (non-native) species\***, 258
- AMOC**. See Atlantic Meridional Overturning Circulation
- Antarctic Bottom Water**, 220–222, 242, 463–464
- Antarctic Circumpolar Current (ACC)**, 212, 217, 220, 221, 466
- Antarctic Ice Sheets**, 53, 79, 206, **236–237**, 244–246  
abrupt changes, 592, 596  
bedrock topography, 330, 333, 346, 347  
deep uncertainty and, 108–109  
irreversibility potential for some changes, 10, 53, 206, 632  
mass change, 53, 236–238, 236, 237  
observed changes, 6, 7, 53, 84, 111, 206, 323  
projected changes, 7, 17, 56, 68, 111, 324  
sea level rise contribution, 10, 17, 20, 53, 55, 56, 75, 80, 108–109, 206, 323–324, **330**, 333, 336, 337, **346–350**, 351  
tipping point, 626, 632  
West Antarctic Ice Sheet (WAIS), 6, 53, 68, 206, 236, **236–238**, 240, 245, 362, 592, 596, 626, 632
- Antarctic krill**, 22, 207, 230, 231, 233, 234–235  
fishery management, 234
- Antarctic region**, 51–54, **203–320**  
climate trends, 212, 213  
glaciers, 53, 241, 242, 245, 347, 348  
key features and mechanisms, 210  
map and place names, 211  
observed changes, 6, 51–53, 75, 205–206, 212–219, **236–242**, **246–250**  
ozone depletion, 212  
polar species and ecosystems, 207  
polynyas, 224, 243, 464  
projected changes, 7–8, 22, 53–54, 206–207, 213, 214, **222–236**, **242–246**, **250–261**  
sea ice, 52, 205–206, 214, 223  
temperatures, 212  
Thwaites glacier, 347, 348  
tourism, 264, 267  
See also Polar regions; Southern Ocean
- Antarctic Treaty System**, 269, 270
- Anthropogenic\***  
confidence/likelihood statements, 42, 81  
detection and attribution, 81, 82
- Anthropogenic subsidence\***, 55, 323, 324, 327, **342–343**  
observed regional impacts, 14  
relative sea level change and, 20, 55, 326
- Aquaculture**, 453, 506, 506–507, 515, 532–533  
adaption in, 536  
harmful algal blooms and, 511  
seaweed aquaculture, 454, 524  
Sri Lankan shrimp aquaculture, 536
- Aragonite saturation**, 205, 218, 225, 453, 469–470, 491, 492
- Aragonite shell-forming species**, 19
- Arctic ocean**, 50–51, 205, 207  
acidification, 52, 207, 225–226  
marine ecosystems, 53–54, 226–230, 228  
productivity, 207  
salinity, 225  
sea surface temperature, 213  
stratification, 225  
temperature, 52, 205, **216–218**, 217, 224–225  
wave heights, 67, 591
- Arctic region**, 51–54, **203–320**  
adaptive capacity, 29  
adaptive management, 207, 262  
Alaska Eskimo Whaling Commission, 103  
albedo, 212  
amplified warming/changes, 51, 84, 112, 114, 205, 212, 604  
Arctic 5 (states), 262  
Arctic Council, 269–270  
biodiversity, 54, 207, 256–258  
Canadian coast adaptation, 406  
climate extremes, 212  
climate trends, 212, 213  
coasts/coastal communities, 259, 265, 268, 405, 664  
economy/livelihoods, **260**, **262–265**  
Exclusive Economic Zones (EEZs), 262–263  
extractive industries, 210, 264–265, 268  
fire, 54, 206, 207, 248, 249, 251, 254  
fish and fisheries, 228–229, 228, **234**, 256, 256–257  
food and water security, 52–53, 259, 268  
glaciers, 53, 206, 210, 240–242, 241  
governance, 54, 269–271, 518

- human communities in, 5, 15, 27, 54, 259–260, 384
- human health and well-being, 15, 260, 266–267, 268
- human population in, 5, 75, 77, 112, 259
- hydrology/water cycle, 52–53, 54, 207
- ice sheers, 210
- Indigenous and local knowledge, 54, 103–105, 208, 259–260
- Indigenous peoples, 5, 15, 54, 103, 259–260
- infrastructure, 15, 25, 54, 91, 207, 260–261, 265–266, 265, 268
- Inuit Circumpolar Council, 105
- key features and mechanisms, 210
- land ecosystems, 21
- landfast ice, 215
- land surface components, 248
- livelihoods in, 15, 25, 52–53, 91, 223, 260
- local community engagement, 208
- map and place names, 211
- marine ecosystems, 2, 53–54, 210, 226–230, 228
- marine heatwaves, 19, 592
- Marine Resources Act, 262
- mid-latitude weather linkages, 52, 67, 216, 591, 604
- near-surface permafrost, 54, 207
- observed changes, 6, 14, 15, 51–53, 75, 205–206, 212–219, 236–242, 246–250
- planned relocation and, 15, 625
- polynyas, 223
- primary production in, 12, 22, 52, 226–227
- projected changes, 7–8, 17–18, 21, 22, 53–54, 206–207, 212, 213, 222–223, 222–236, 242–246, 250–261
- rapid change in, 84, 112, 114, 205, 212
- resource management, 54, 208
- sea level rise and, 32, 98, 324–325, 328, 328, 382, 384
- snow and frozen ground, 53, 54, 246–248, 248, 250–251
- social-ecological systems, 234–236, 259–261
- subsistence systems, 53, 262–263, 267
- surface air temperature, 51, 205, 212, 247
- tipping points, 91
- tourism, 235, 264, 267
- transportation and shipping, 52, 91, 206, 228, 235–236, 261, 266, 268, 276
- urbanisation trend, 265
- vulnerability, 92
- winter roads/ice roads, 261
- See also Indigenous Peoples; Polar regions
- Arctic sea ice**, 52, 206, 212, 213, 213, 213–216, 591
- freeze-up timing, 212, 214
- observed changes, 6, 7, 14, 75, 84, 111
- projections, 7, 18, 53, 111, 222–223
- summer extent of, 212, 213, 217, 223, 235, 518
- Areas Beyond National Jurisdiction (ABNJ)**, 455, 540
- Assisted evolution**, 521, 529
- Atlantic Meridional Overturning Circulation (AMOC)**, 239, 340, 591, 595, 618–623
- collapse of (potential), 19, 68, 69, 81, 83, 593, 619, 621–622
- Greenland Ice Sheet melting and, 620–621
- heat transport in, 618–619, 622–623
- impacts, 621–623, 622, 632
- methane production and, 623
- observed changes, 10, 68, 75, 591, 619
- paleoclimate reconstructions, 83, 618
- prediction of, 623
- projections, 18, 19, 68, 592, 595, 619
- reversibility of, 621
- risk management and adaptation, 623
- Southern Ocean and, 219
- subpolar gyre (SPG) and, 619, 621
- teleconnections, 622, 622
- temperature change and, 619–620, 620
- tipping point, 626, 632
- weakening of, 68, 591, 592, 618, 620–621
- Atmosphere\***
- carbon dioxide (CO<sub>2</sub>) concentration in, 83, 450
- feedbacks in polar regions, 210
- moisture content, 139–140, 142
- Atolls (urban atoll islands)**, 27, 328, 383, 663
- Attribution**. See Detection and attribution
- Avalanches\***
- ice avalanches, 159
- rock avalanches, 158, 162
- snow avalanches, 133, 134, 159–161, 160
- B**
- Baseline**, 85–86
- Benthos\***
- benthic communities, 227–228, 228, 231
- polar regions, 227–228, 228, 231
- Biochar**, 93
- Biodiversity\***
- alien species and, 258
- Arctic region, 54, 207, 256–258
- coastal ecosystems, 61, 65, 453, 495, 514–515
- Convention on Biological Diversity (CBD), 541, 542
- deep sea, 453
- high mountain areas, 166, 596
- loss of, 514
- observed impacts, 13
- oceans, 453
- polar regions, 256–258
- projected risks, 21, 23, 24, 54, 453
- spatial planning for, 271, 274
- Biogeochemistry**, 80
- oceans, 456–476
- polar regions, 242–243
- Biogeography of marine organisms**, 61, 450–451
- Biological (carbon) pump\***, 65, 484, 485, 486–487, 520
- Biomass\***
- marine animals, 22, 65, 452–453, 484
- ocean/marine ecosystems, 65, 452–453, 481–484, 483, 492
- plankton, 481–483
- projections, 22, 453, 481–484, 483
- Black carbon (BC)\***, 93, 139, 236, 247
- Blocking events**, 603–604
- Blue carbon\***, 30, 66, 454, 494, 508, 520–524
- cost effectiveness, 523
- Built environment adaptation**, 525
- C**
- Calcium carbonate**, 65, 207, 218, 225, 452
- calcifying species, 24, 53, 65, 207, 487, 501
- Calving (of glaciers or ice sheets)\***, 143, 239, 241, 245, 331, 332
- Cape Town, South Africa**, 98–99
- Carbon**
- cost of carbon emissions, 68–69, 592
- dissolved inorganic carbon, 80, 113, 467, 470
- ocean carbon chemistry, 469–470
- ocean carbon fluxes, 65, 467–469
- in oceans, 65, 248–249, 254, 467–470, 468, 487, 487
- Carbonate**, 450, 452, 453, 469–470, 477
- Carbon cycle\***, 80, 252–253
- polar regions, 248–249, 252–253, 254
- Carbon dioxide (CO<sub>2</sub>)\***
- atmospheric concentration in 2016, 83
- capture and storage, 93, 93
- release from permafrost, 18, 52, 84, 108, 207, 596
- taken up by oceans, 53, 59, 205, 218, 450
- Carbon dioxide removal (CDR)\***, 93, 542
- Carbon price\***, 592
- cost of carbon emissions, 68–69, 592
- Carbon sequestration**. See Sink
- Carbon sink**. See Sink
- Cascading impacts\***, 11, 12, 67, 69, 77–78, 81, 82, 591, 594, 624–626
- case studies, 626–628
- compound events and, 591, 624–626, 626–628
- coral reefs, 624–625
- deep uncertainty and, 109
- definition of, 595
- governance and, 625
- in high mountain areas, 134, 162
- impacts on ecosystems, 624–625

- impacts on social systems, **625**
- multiple hazards/stressors and, **67, 624, 626–628**
- risk management and adaptation, **625–626**
- sea level rise, **375, 624**
- sustainable and resilient pathways and, **625–626**
- Climate\***, **83**
- Climate change\***
  - committed and unavoidable, **49, 69, 83, 328, 658**
  - escalation of, **77–78**
  - key indicators of, **86**
  - people's engagement with, **102–103**
  - summaries, **3–69**
- Climate change insurance**, **630**
- Climate extreme\***. *See* Extremes; Extreme weather/ climate event
- Climate feedbacks\***, **55**
  - biogeomorphic, **508**
  - in mountain cryosphere, **148**
  - in polar regions, **210**
- Climate governance**. *See* Governance
- Climate literacy**, **34, 35, 47, 76, 102**
- Climate models\***, **47, 76, 331, 344, 602**
- Climate-resilient development pathways (CRDPs)\***, **34, 35, 58, 69, 90, 410, 592–593, 631**
  - factors promoting, **45–47, 593**
- Climate sensitivity\***, **108**
- Climate system\***, **5, 83**
  - feedbacks, **55**
- Climate variability\***, **83**
- CMIP**. *See* Coupled Model Intercomparison Project
- Coast\***, **78**
- Coastal and low-lying areas**, **55–58, 657–674**
  - adaptation limits, **69, 658, 668**
  - adaptive capacity, **29**
  - agriculture, **55, 328, 380, 383–384, 663–664, 664**
  - anthropogenic drivers, **55, 326, 662, 667**
  - aquifers and groundwater, **378**
  - blue carbon, **30, 66, 454, 494, 508, 520–524**
  - case studies of hazard and response, **363–367**
  - climate-related drivers and hazards, **326, 659, 660–661, 667**
  - deltas, **342, 383–384, 659, 663–664**
  - erosion, **371–373, 377–378, 531, 591, 660, 663**
  - estuaries, **64, 65, 453, 493–494, 501**
  - exposure and vulnerability, **43, 56, 92, 323, 324, 328, 367–375, 659–662**
  - flooding and submergence, **56, 61, 364–366, 372, 376–377, 661, 664**
  - flood protection, **27**
  - freshwater inputs, **661**
  - GDP in, **658**
  - global distribution (map), **659**
  - hazards in, **16, 20, 21, 43, 91, 112, 326, 363–367, 375, 659, 660–661**
  - human population, **5, 75, 77, 92, 112, 371, 658**
  - impacts and risks, **29, 32, 324–325, 375–385, 657–674, 667**
  - infrastructure, **16, 55, 324, 534, 665**
  - observed changes and impacts, **16–17, 75, 323, 658, 660–661, 662–665**
  - physical changes, **465**
  - projections, **25–27, 324–325, 662–665**
  - Reasons for concern (RFC), **381–385, 667–668**
  - responses to sea level rise, **17, 385–386, 385–410, 665–667**
  - risk in, **55, 323, 324–325, 328, 328, 381–385, 658, 659–668**
  - sea level change and, **321–445**
  - sediment and, **65, 371–373**
  - soils, **378–379**
  - summary, **657–674, 667**
  - surface water, **378**
  - synthesis, **543–544, 543**
  - tides, **62, 68, 328, 330, 332, 342, 357, 452, 465**
  - tourism, **380–381, 516–517, 536, 665**
  - See also* Low-Lying Islands and Coasts
- Coastal adaptation**, **16–17, 31–32, 55, 323–325, 385–410, 451, 530–537, 664, 665–667, 667**
  - accommodation, **329, 385, 386, 393–396**
  - adaptive capacity, **29**
  - advance, **16–17, 31, 33, 323, 329, 385, 386, 392–393**
  - benefits, **66, 384–385**
  - case studies, **363–367, 406**
  - choosing and implementing, **325, 329–330**
  - costs and benefits, **377, 388, 388, 390, 664**
  - costs and limits, **538–540**
  - early warning systems, **31, 35, 163, 323, 663**
  - ecosystem-based adaptation, **30, 323, 329, 386, 390–392, 530–531, 665–666**
  - governance and, **385, 389, 392, 393, 398, 535**
  - hard protections, **323, 329, 385, 386, 387–390, 665**
  - human systems, **531–537**
  - integrated coastal management, **535**
  - migration and relocation, **31, 33, 385, 386, 665, 666**
  - options and challenges, **329–330, 531–537**
  - protection, **385, 386**
  - retreat, **17, 31, 33, 323–324, 329, 385, 386, 396–398, 666**
  - risk reduction with, **56, 384–385**
  - sediment-based protections, **387–390, 531**
  - summary, **16–17, 31–32, 323–325, 532–533**
  - See also* Coastal responses
- Coastal advance**, **16–17, 31, 33, 323, 329, 385, 386, 392–393**
- Coastal communities**, **16–17, 323, 382–383, 531, 659, 662**
  - adaptation benefits, **66, 384–385**
  - adaptation responses, **31–32, 323–324, 534**
  - early warning systems, **31, 35, 163, 323**
  - exposure and vulnerability, **43, 56, 323, 324, 328, 370–374, 659–662**
  - extreme sea level events and, **17, 20, 27, 55, 56, 342, 591, 660**
  - governance for sea level rise, **98–99**
  - hazards, **75, 112**
  - impacts and risks, **328, 382–383, 662**
  - integrated adaptation responses, **31, 325, 329**
  - livelihoods, **55, 664–665**
  - megacities, **659, 662**
  - planned relocation, **31, 33, 265, 396–398, 666**
  - in polar regions, **259, 265, 268**
  - resource-rich cities, **382–383**
  - responses to sea level rise, **17, 31–32, 665–667, 667**
  - risks, **328, 328, 382–383**
  - settlement trends, **371, 407**
  - social values, **381, 513–515**
- Coastal ecosystems**, **55, 329, 367–370, 379–380, 493–502, 662**
  - biodiversity, **61, 65, 453, 495, 513–514**
  - biogeomorphic climate feedbacks, **508**
  - changes in exposure, **369–370**
  - changes in vulnerability, **370**
  - coastal protection by, **380, 451**
  - conservation of, **521, 522–524**
  - coral reefs, **497–498**
  - dune systems, **55, 323, 369, 385, 531**
  - ecosystem services, **30, 379–380, 385, 451, 662, 665**
  - estuaries, **64, 65, 453, 493–494, 501**
  - exposure to hazards, **43, 55, 90–91, 328, 367–370**
  - extreme sea level events and, **17, 20, 27, 55, 342, 591, 660**
  - fisheries, **381, 664–665**
  - kelp forests, **61, 65, 453, 499–500, 501**
  - mangroves, **23, 30, 55, 61–62, 64, 324, 451, 453, 454, 496, 501, 665**
  - marine heatwaves and, **610**
  - multiple stressors, **61, 451**
  - near-shore, **493**
  - observed changes, **13, 16–17, 61–62, 451**
  - ocean acidification and, **24, 498–499, 661**
  - oxygen-depleted dead zones, **61, 65, 494**
  - projected changes and risks, **24–25, 65, 324, 328, 453**
  - regulatory services, **508, 519**
  - restoration of, **30, 66, 93, 521, 522–524, 530–531, 665**
  - risk assessment, **55, 65, 500–502, 501, 509**
  - rocky shores, **61, 64, 65, 451, 453, 498–499, 501**
  - salinisation, **13, 25, 27, 56, 61, 65, 324, 328, 378, 451, 494, 531**
  - salt marshes, **55, 62, 64, 65, 451, 453, 454, 494, 501**

- sandy beaches, 55, 62, 64, 65, 453,  
496–497, 501
- sea level rise, exposure, 367–370
- sea level rise, impacts, 13, 324, 328, 328,  
379–380
- wetlands, 494–496
- Coastal impacts and risks**, 55, 375–385, 658,  
659–665, 660–661
- floods, 56, 61, 324, 364–366, 372, 376–377,  
661, 664
- impacts from sea level rise, 13, 21, 32, 324–325,  
328, 328, 375–381
- Coastal responses**, 16–17, 31–32, 65, 323–324,  
329–330, 385–386, 385–410, 664,  
665–667, 667
- case studies, 363–367
- Nadi, Fiji, 363–364, 365
- New York City, 364–366
- Nile Delta regions (Egypt), 366–367
- planning and decision making, 326–327, 330,  
402–405
- protection, 385, 386
- Shanghai, 364–366
- See also Coastal adaptation
- Coastal retreat**, 17, 31, 33, 323–324, 385, 386,  
396–398, 606, 666
- Coastal seas**, 493
- Coastal squeeze**, 372, 662
- Co-benefits\***, 30, 69, 454, 592, 665
- responses to sea level rise, 33
- Community-based adaptation**, 67, 402, 406, 408
- Community-based monitoring**, 271, 272
- Compound events**, 68, 81, 624–626
- case studies, 626–628
- definition of, 595
- multiple hazards, 68, 594, 624
- tipping points and, 624
- Compound hazards**, 68, 591
- Compound risks\***, 69, 109, 594
- Compound weather/climate events\***, 68, 81,  
624–626
- case studies, 626–628
- Confidence\***, 4, 42, 81, 83, 106, 106–107
- deep uncertainty and, 106, 107, 107–109
- Conflicts**, 66, 329, 400, 409, 666
- conflict resolution, 330, 401–402, 409
- over resource utilisation, 66, 515
- Copepods**, 227, 229, 610
- Coral/coral reefs\***, 497–498, 545, 545
- adaptation, 528, 529–530
- adaptation limits, 325
- algal-dominated reefs, shift to, 61
- biodiversity, 497
- bleaching events, 451, 545, 608, 610, 612,  
627, 661
- as breakwaters, 665
- cascading impacts, 624–625, 627–628, 665
- cold water corals, 22, 23, 64, 453, 489, 489,  
490–491, 501
- compound events, 627–628
- Coral Reef Watch, 611–612
- Coral Triangle (case study), 627–628
- critical thresholds, 65, 69, 545, 592
- ecosystem services, 26, 65, 379, 453, 529
- extinction risk, 25, 610
- gardening/farming, 455, 528, 529, 665
- marine heatwaves and, 591, 608, 610, 611–612
- multiple hazards/stressors, 65, 497
- observed impacts, 13, 14, 61, 529, 545, 627
- ocean acidification and, 13, 455, 545, 627
- projections, 22, 23, 24, 25, 27, 29, 64, 65, 379,  
453, 497–498, 501
- relocation, 521
- restoration, 30, 33, 455, 521, 528, 529–530, 665
- risk management, 627–628
- risks, 64, 65, 453, 627–628, 665
- tourism, 665
- vulnerable human communities, 27
- warm-water corals, 23, 24, 25, 64, 455, 501,  
529–530, 545
- Coral Triangle**, 627–628
- Cordillera Blanca, Peru, 164
- Cost-benefit analysis\***, 15, 35, 93, 324
- costs of delay in responses, 35, 77
- decision analysis methods, 93, 402
- of disaster risk reduction, 630
- Total Economic Value method, 93
- Cost-effectiveness\***, 27, 35, 69, 593
- blue carbon, 523
- coastal adaptation, 31, 324, 377, 388, 388,  
390, 664
- ecosystem-based adaptation (EbA), 31, 391–392,  
391, 454, 531
- ocean adaptation responses, 538–540
- Coupled Model Intercomparison Project  
(CMIP)\***, 75, 85
- CMIP5, 85, 86, 331, 457–460
- Cryosphere\***, 78–79, 83–84
- abrupt and irreversible changes, 596
- changes in, 43–47, 44, 67
- climate change commitment, 49
- climate regulation and, 77, 78–79, 80
- components of, 43, 78–79
- importance for people, 5, 43, 75, 77–78
- interconnectedness with ocean, 79, 80, 81
- newly emergent characteristics of change, 43, 83
- observed changes, 6, 11, 14, 44, 84, 591
- projections, 7–8, 17–18, 21, 44–45, 68, 84, 592
- role in Earth system, 75, 80
- roles and functions of, 75, 77, 80
- scale and cross-boundary dimensions, 45–47,  
76, 78
- summary, 3–69, 205–208, 274–275
- surface area, 5
- See also Polar regions
- Cultural assets**, 49, 134
- Cultural services**. See Ecosystem services
- Cultural values**, 49, 66, 171–172, 513–515, 519
- D**
- DDT (dichlorodiphenyl-trichloroethane)**,  
152, 153
- Decision analysis**, 58, 93, 325, 330, 402–405, 629
- Decision making**, 402–405, 629–630
- for abrupt change and extreme events, 629–630
- adapting decisions over time, 403
- adaptive, 33, 88, 325, 405
- community-based, 666
- in deep uncertainty, 58, 325, 327, 402–403, 629
- evidence-based, 537
- linking knowledge with, 271, 272–273, 325
- participatory, 535–536
- shared, 35, 97
- steps in, 60
- structured (SDM), 271, 273–274
- Deep uncertainty\***, 106, 107, 107–109
- compound events and cascading impacts, 624
- decision making and, 58, 325, 327,  
402–403, 629
- Deltas**, 328, 342, 383–384, 659, 663–664
- Dutch Delta Programme, 410
- Nile Delta, Egypt, 366–367
- Detection and attribution\***, 45, 50–51, 75,  
81, 82, 591
- climate warming, 45, 83, 591
- confidence and likelihood statements, 42, 81
- event attribution, 82
- ocean impacts, 45, 50–51, 58, 450, 457, 591
- sea ice loss, 52, 205, 213
- sea level change, 343–344
- Development pathways\***. See Climate-resilient  
development pathways
- Dinoflagellates**, 479, 481, 510
- Disaster\***
- cascades of, 625
- Catastrophe Bonds, 616
- high mountain areas, 162–163, 174
- projected risks, 25
- Disaster risk management (DRM)\***, 69, 592–593,  
630–631
- cost-benefit analysis, 630
- coupling with adaptation, 631
- governance and, 135, 593
- in high mountain areas, 163–164
- integration with adaptation, 593
- investments in, 69, 592–593, 630
- Sendai Framework, 49, 174, 631
- transformative governance and, 630–631
- See also Risk management

**Disease**

- foodborne, 260
- polar regions, 260
- waterborne, 15, 260, 509–510

**Displacement.** See Internal displacement

(of humans); Migration (of humans)

**Dissolved inorganic carbon\***, 80, 113, 467, 470

- polar oceans, 218–219

**Dissolved organic carbon (DOC)**, 22, 486**Dutch Delta Programme**, 410**E****Early warning systems (EWS)\***, 31, 35, 69, 163, 323, 592, 663

- for floods, 630
- for marine heatwaves, 69, 592
- for tropical cyclones, 592, 606

**Earthquakes**, 162**Earth system**, role of ocean and cryosphere in, 75, 79, 80**Earth system models (ESMs)\***, 63, 452, 457**Eastern Boundary Upwelling Systems (EBUS)**, 451, 453, 506–507

- observed changes, 12, 14, 50–51, 62, 451
- projections, 19, 65–66, 453, 501

**Eco-engineering**, 524, 536**Ecosystems\***, 50–51, 87

- adaptive ecosystem governance, 271, 274
- cascading impacts on, 624–625
- critical thresholds for, 592
- ecosystem stewardship, 271, 273–274
- networks of protected areas, 30, 54, 208
- observed impacts, 11–13, 14, 16, 50–51
- projected changes and risks, 21–25, 23–24, 134
- See also *specific ecosystems*

**Ecosystem-based adaptation (EbA)\***, 30, 66, 323, 329, 386, 390–392, 528–531, 665–666

- combining knowledge and culture sources, 451
- cost-effectiveness, 31, 391–392, 391, 454, 531
- limits of, 325

**Ecosystem management**, 30**Ecosystem services\***, 5, 30, 87

- adaptation options, 30–31
- coastal ecosystems, 30, 379–380, 451, 662, 665
- coral reefs, 26, 65, 379, 453, 529
- cultural services, 509
- high mountain areas, 15–16, 50–51, 167–168
- linking with human livelihoods, 271, 274
- marine ecosystems, 30, 502–520, 519, 545
- observed impacts, 14, 15–17, 50–51
- polar regions, 50–51, 253–254
- projected impacts and risks, 22, 25–27, 28
- provisioning services, 502–506, 519
- regulating services, 507–508, 519
- supporting services, 508–509, 519

**Education**, 34, 35, 47, 76, 102, 514

- role in adaptation, 538

**Elevation-dependent warming (EDW)\***, 138**El Niño-Southern Oscillation (ENSO)\***, 239, 331, 591–593, 612–616

- adaptation limits and, 592
- extreme events, 67, 68, 591, 592, 612–616, 613
- impacts of, 593, 614–615, 627
- La Niña, 591, 592
- losses and damages, 592
- monitoring and forecasting, 69, 593, 615–616
- observations, 67, 591
- projections, 18, 19, 68, 592
- risk management and adaptation, 615–616
- teleconnections, 611, 614–615, 615
- tipping point, 626

**Emission scenarios\***

- comparison of projected futures under, 7, 44, 45, 46, 57, 62, 68, 86, 592–593
- See also Representative Concentration Pathways (RCPs)

**Emissions**

- atmospheric CO<sub>2</sub> in 2016, 83
- cost of carbon emissions, 68–69, 592
- rapid reduction in, 66, 454, 632
- See also Representative Concentration Pathways (RCPs)

**Enabling conditions**, 33, 34–35, 49, 60, 406, 407–410

- education, 34, 35
- governance, 49
- long-term perspective, 35

**Enhanced weathering\***, 93, 454, 521, 524**Ensemble.** See (Model) Ensemble**Equality\***. See Equity**Equity\***, 35, 325, 329, 399, 408

- gender\*, 373

**Estuaries**, 64, 65, 453, 493–494, 501**Evidence\***, 42, 42, 75, 76**Evolutionary adaptation\***, 94**Evolution, assisted**, 521, 529**Exposure\***, 29, 45, 46, 88, 91–92

- coastal and low-lying areas, 43, 90–91, 323, 324, 328, 367–375
- drivers of, 31, 374–375
- high mountain areas, 47, 133, 162
- methodological advances in assessment, 368–369
- projections of future exposure, 368
- to sea level rise (SLR), 55, 367–375, 659–662

**Extinction risk**

- in coastal ecosystems, 24
- in coral reefs, 25, 610
- in high-mountain ecosystems, 11, 48–49, 134, 167

**Extratropical cyclones (ETCs)\***, 360–361, 592, 603–604, 660

## blocking events and, 603–604

- early warning systems for, 592
- investments in risk reduction, 69, 592
- losses and damages, 592
- Superstorm Sandy (2012), 606

**Extremes**, 67–69, 589–655

- cascading impacts and, 67, 591, 624–626, 626–628
  - case studies, 626–628
  - compound events, 68, 591, 624–626, 626–628
  - costs of recovery, 593
  - critical thresholds and, 592
  - decision making for, 629–630
  - definitions, 594–595
  - ENSO events, 68, 591–593, 612–616, 613
  - framework for, 594, 594
  - governance, 629–631
  - inter-ocean exchanges, 616–618
  - knowledge gaps, 633
  - marine heatwaves (MHWs), 67, 68, 591, 592, 606–612
  - multiple extreme events, 67, 68, 591
  - multiple hazards, 68, 591, 624, 626–628
  - recent events, regions, and causes, 596, 597–601
  - responses, SDGs, and CRDPs, 68–69, 592–593
  - risk management, 69, 592–593
  - risks, 591–593
  - summary, 591–593
  - transformative governance and, 593, 629, 630–631
  - tropical and extratropical cyclones, 68, 591, 592, 601–606
  - wave heights, 67, 68, 591, 592, 604–605
- Extreme sea level (ESL) events**, 11, 17, 20, 28, 324, 342, 343, 357–361, 660
- amplification factors, 359–360, 359
  - changes in, 357–361
  - coastal communities and, 17, 20, 27, 342, 343, 660
  - compounding effects of, 624
  - defined, 357
  - exposure and vulnerability, 55
  - historical centennial events (HCEs), 20, 28, 57, 359, 359–360
  - hydrodynamic models, 357
  - observations, 67, 357–359, 358, 591, 604
  - projections, 56, 324, 660
  - regional sea level rise and, 57
  - return period, 357–359, 358
  - storm surge and tides, 604–605
  - tide gauge records, 357–360, 358
  - tropical cyclones and, 592
  - See also Storm surge
- Extreme weather/climate event\***, 81, 589–655
- case studies, 626–628
  - compound events, 81, 591, 624–626, 626–628
  - definition of, 595

early warning systems and, 31, 35, 163, 323  
 El Niño/La Niña events, 18, 19, 67, 592,  
 612–616  
 recent events, regions, and causes, 596, 597–601  
*See also* Extremes

## F

**Fairness\***, 35, 325  
**FAQs.** *See* Frequently Asked Questions (FAQs)  
**Feedback.** *See* Climate feedbacks  
**Fiji**, coastal hazard and response in, 363–364, 365  
**Fires.** *See* Wildfire  
**Firn\***, 239, 241  
**Fish and fisheries**, 61, 228–229, 451, 483–484, 502–506, 545  
 adaption in, 534–536  
 adaptive management, 207, 262  
 Antarctic region, 231–232, 234–235  
 Arctic fish: spatial distribution, 256–257  
 Arctic region, 228–229, 228, 234, 256, 261–262  
 bycatch, 232  
 coastal areas and islands, 381, 664–665  
 commercial fisheries, 261–262, 267, 505–506  
 conflicts over, 66, 515  
 deep ocean, 505–506  
 dependent human communities, 26  
 economy and, 517–518  
 ensemble model, 483  
 food security and, 16  
 freshwater, high mountain areas, 167  
 freshwater, polar regions, 256  
 global catch, 502, 503, 514  
 governance, 16, 26, 66, 450, 535, 540, 541  
 management of, 30, 61, 234, 451, 535  
 mariculture, 506  
 marine fisheries, 22, 26, 61, 64, 228–229, 234–235, 451, 664–665  
 marine heatwaves and, 611  
 maximum catch potential, 65, 504, 505, 513  
 maximum sustainable yield, 504  
 observed impacts, 12, 14, 16, 61, 451  
 polar regions, 52, 207, 228–229, 228, 231–232, 233, 234–235, 256–257, 276, 546  
 productivity, 61, 451, 546  
 projections, 22, 23, 26, 64, 65, 452, 483–484  
 provisioning service of, 502–506, 519  
 range shifts of species, 53, 256–257, 535, 546  
 rebuilding fisheries, 30  
 seafood safety, 26, 66, 611  
 spatial distribution of fish, 61, 66, 256–257, 451, 480  
 species composition, 12, 22, 451  
 sustainable practices, 504, 535  
 vulnerability, 536  
 wealth generated, 515–516

**Floods\***  
 case studies of adaptation, 364–366  
 coastal and low-lying areas, 56, 61, 324, 372, 376–377, 661, 664  
 coastal protections and, 27, 377  
 compound events, 624  
 costs of, 324  
 early warning systems, 630  
 extreme sea level (ESL) events and, 357  
 flood index, 624  
 high mountain areas, 160, 161–162  
 investments in flood management, 69, 592, 630  
 observed regional impacts, 14  
 rain-on-snow, 47, 48, 134, 161–162  
*See also* Glacial lake outburst flood (GLOF)  
**Food safety**, 26, 66, 454, 510, 611  
**Food security\***  
 Arctic region, 52–53, 259, 268  
 observed impacts, 15, 16, 206  
 projections, 453  
 seafood, 512–513  
**Foodwebs**  
 pelagic, 233–234  
 projected changes, 22  
**Foraminifera**, 479, 482, 488, 492  
**Forcing\***, 81  
**Forests\***, 50–51, 165, 248, 254  
 fire and, 249, 251, 254  
 observed changes, 206  
 observed regional impacts, 14, 50–51  
 projections, 21, 251, 254  
**Frequently Asked Questions (FAQs)**  
 1.1 How do changes in the ocean and cryosphere affect our life on planet Earth?, 112–113  
 1.2 How will changes in the ocean and cryosphere affect meeting the Sustainable Development Goals?, 114–115, 115  
 2.1 How does glacier shrinkage affect river runoff further downhill?, 151, 152  
 3.1 How do changes in the Polar Regions affect other parts of the world?, 276  
 4.1 What challenges does the inevitability of sea level rise present to coastal communities and how can communities adapt?, 411  
 5.1 How is life in the sea affected by climate change?, 545–546, 545  
 6.1 How can risks of abrupt changes in the ocean and cryosphere related to climate change be addressed?, 632  
**Freshwater ecosystems**  
 high mountain areas, 48, 133–134, 165, 165, 167  
 observed impacts, 11, 133  
 polar areas, 210, 249–250, 251–252, 255–256  
 projected changes and risks, 21, 251–252

**Freshwater ice**, 250  
**Frozen ground\***, 53, 54, 210, 246–249, 248, 250–251

## G

**Gender inequality**, 373  
**General circulation model.** *See* Climate model  
**Gilgit-Baltistan, Pakistan**, 98  
**Glacial-isostatic adjustment (GIS)**, 245–246, 664, 668  
**Glaciers\***, 47, 53, 79, 141–144, 240–242, 596  
 Antarctic, 53, 241, 242, 245  
 disappearance of, 17, 143  
 ENSO and, 239  
 floods, 161  
 glacier collapses, 159  
 glacier flow, 142–143  
 glacier-related disasters, 164  
 glacier surges, 159  
 mass budgets, 141, 142, 199, 199–202  
 mass changes, 133, 141, 142, 143–144, 206, 240–242, 241  
 modelling, 143  
 observed changes, 6, 7, 15, 47, 53, 84, 111, 133, 142, 240–242, 241  
 outlet glaciers, 6, 53, 206, 239, 246  
 in polar regions, 53, 143–144, 206, 210, 240–242, 241  
 projections, 7, 17, 48, 53, 111, 134, 143–144, 596  
 Randolph Glacier Inventory (RGI), 136, 199  
 regional summary statistics, 136  
 rock glaciers, 145–146, 158  
 runoff, glacier shrinkage and (FAQ), 151, 152  
 sea level rise contribution, 6, 7, 10, 17, 53, 79, 143, 206, 323, 331, 337, 352, 354  
 tourism and, 134  
 water quality and, 48, 152–153  
**Glacial lake outburst floods (GLOF)/Glacier lake outburst\***, 18, 91, 133, 161, 162, 596  
**Global climate model.** *See* Climate model  
**Global mean surface temperature (GMST)\***, 86  
 past and future changes, 7, 86  
 RCP scenarios and, 8, 86  
**Global warming\***, 34, 83  
 limiting, benefits of, 592  
**Governance\***, 29, 95, 95–99, 268–271  
 abrupt changes and extreme events, 629–631  
 accountability and, 593  
 adaptation response, 536–537  
 adaptive ecosystem governance, 271, 274  
 adaptive governance, 29, 271, 274  
 Antarctic Treaty System, 269, 270  
 Arctic Council, 269–270

- Areas Beyond National Jurisdiction (ABNJ), 455, 540
- cascading impacts and, 625
- case examples, 98–99
- challenges, 329–330, 406, 407–410
- climate governance, 95–98, 541
- complexity, 67, 98, 409–410, 455
- cooperation and coordination in, 34–35, 49, 135
- fisheries, 16, 26, 66, 450, 535, 540, 541
- high mountain areas, 98, 135, 173–174
- The High Seas, 96, 262
- Indigenous and local knowledge in, 54, 104–105, 268
- informal actors, 270–271
- informal arrangements, 270
- international climate governance, 173–174, 269
- levels of, 97, 268–269
- multi-level, 98
- ocean acidification and, 542
- ocean governance, 67, 96, 97–98, 455, 540–542, 541
- Polar Code, 266, 269
- polar regions, 54, 208, 210, 268–271, 630
- sea level rise and, 58, 325, 326, 329–330, 398–400, 406, 407–410
- sovereignty and sovereign rights, 96
- transboundary, 35, 49, 76, 96
- transformative, 27, 47, 76, 593, 629, 630–631
- United Nations Convention on the Law of the Sea (UNCLOS), 97, 98, 269, 541
- vulnerability and, 92
- Gravity Recovery And Climate Experiment (GRACE)\***, 199, 199–202, 334, 337
- Great Barrier Reef**, 514
- coral bleaching, 610
- marine heatwave events, 610
- Green infrastructure\***, 665
- Greenhouse gases (GHG)\***, 83
- reductions, and projected climate impacts, 17
- Greenland Ice Sheet**, 79, 238–239, 246
- abrupt changes, potential for, 68, 592, 596
- AMOC and, 620–621
- bedrock topography, 346, 346
- observed changes, 6, 7, 53, 84, 206, 238–239
- projected changes, 7, 17, 68, 111
- sea level rise contribution, 10, 17, 53, 55, 80, 206, 238, 332, 336, 337–338, 344–346, 345, 352
- tipping point, 626
- Gross domestic product (GDP)\***, 27
- coastal and low-lying areas, 658
- decrease per degree C of warming, 625
- small islands, 663
- Ground ice**, 247–248, 248
- Grounding line\***, 79, 237–238, 246, 351
- H**
- Habitability\***
- extreme weather events and, 625
- high mountain areas, 173
- loss of, 91, 546
- small islands, 27, 663
- thresholds, 27
- Habitat**
- displacement, 90
- expansion of, 48, 134
- fragmentation, 30
- reduction in, 65, 90, 133, 134, 166, 256
- restoration, 30, 665
- shifts in, 53
- Harmful algal blooms (HABs)**, 16, 26, 62, 451, 510–511, 611
- Hazards\***, 46, 88, 90–91
- cascading events and, 162, 375
- coastal areas, 16, 20, 21, 43, 75, 91, 326, 328, 375, 591
- combined, 162
- compound, 68, 591
- compound events and, 68, 594, 624
- direct vs. indirect, 91
- high mountain areas, 48, 49–51, 133, 134, 158–164
- multiple, 68, 91, 109, 369, 453, 456, 591, 596, 624
- recent severe hazards (with locations), 597–601
- Health adaptation**, 266–267
- Heatwaves**. See Marine heatwaves (MHWs)
- Heavy metals**, 48, 134, 152, 153
- High mountain areas**, 47–51, 131–202
- adaptation measures, 134, 135, 163–164, 170, 175
- adaptation planning, 49
- adaptive capacity, 29
- aerosols, 139–140
- agriculture, 47, 133, 134, 154–155, 156, 164
- atmospheric moisture content, 139–140, 142
- atmospheric radiation, 139, 142
- biodiversity, 166, 596
- camouflage mismatch (of species), 166
- cascading impacts, 134, 162
- climate feedbacks, 148
- cold-adapted species, 133–134
- combined hazards, 162
- common features in, 136
- Cordillera Blanca, Peru, 164
- cultural assets, 49, 134
- cultural values and human well-being, 171–172
- disaster risk, 25, 133, 174
- disaster risk reduction, 163–164
- disasters, 162–163
- drinking water, 48, 157
- ecosystems, 11, 14, 21, 48–49, 50–51, 134, 165, 165–168
- ecosystem services, 15–16, 50–51, 167–168
- elevation-dependent warming, 138
- elevations, distribution of, 136
- enablers and response options, 49, 135
- enabling conditions, 49
- exposure, 47, 133, 162
- extinction risk, 11, 134
- floods, 160, 161–162
- glacier mass change estimates, 199, 199–202
- glaciers, 47, 48, 133, 134, 141, 141–144
- global distribution of, 136
- governance, 98, 135, 173–174
- habitability, 173
- hazards, 48, 49–51, 133, 134, 158–164, 160
- human population in, 5, 75, 77, 112, 133, 136
- humans and ecosystem services in, 15–16
- impacts, 49–51
- Indigenous populations in, 5, 15
- infrastructure, 14, 133, 168
- key impacts and vulnerability, 153–158
- knowledge gaps, 174–175
- lake and river ice, 147
- landslides, 158, 162
- livelihoods, 163, 172–173
- migration (of humans), 172–173
- mining, 168
- mountain-specific research, 135
- observed changes, 6, 11, 14, 47–48, 50–51, 133–134, 137–143, 165
- permafrost, 48, 145–146, 146–147
- projections, 7, 17–18, 21, 48–49, 134, 134–135, 138–139
- rain and snowfall, 138–139, 139
- rain-on-snow floods, 47, 48, 134, 161–162
- regional summary statistics, 50–51, 136
- rock glaciers, 145–146, 158
- runoff and, 47, 48, 133, 134, 147–151, 152
- SDGs and, 49, 135
- slope instability, 6, 18, 91–92, 133, 134, 158–159, 160
- snow avalanches, 133, 134, 159–161, 160
- snow cover, 47, 48, 133, 134, 140
- social-ecological systems, impacts, risks, and human responses, 148–173
- species composition and abundance, 48, 133–134
- summary, 47–51, 49–51, 133–135
- surface air temperature, 137–138, 137, 139
- sustainable development (SD), 173–174
- tourism and recreation, 48, 133, 134, 162, 168–171
- UNESCO World Heritage sites, 49, 134, 171
- vulnerability, 153–158, 163, 164
- water governance, 157–158
- water management, 98, 135, 157–158



- water quality, 48, 152–153  
 water resources, 47–48, 133, **148–158**  
 wildfires, 133, 168  
 wind, 140
- Holocene\***, 216, 242
- Human health**  
 foodborne disease, 260  
 food safety, 26, 66, 454, 510, 611  
 harmful algal blooms (HABs), 16, 26, 62, 451, **510–511**  
 health adaptation, 266–267  
 marine-dependent communities, 509–512  
 polar regions, 260, 266–267, 268  
 waterborne diseases, 15, 62, 260, **509–510**
- Human mobility\***. See Migration (of humans)
- Human rights\***. See Equity
- Human systems\***, 50–51, 87  
 cultural values and well-being, 171–172, **513–515, 519**  
 marine-dependent communities, 26, 453, **509–520**  
 observed impacts, 14, 15–17  
 ocean-based adaptation, 525, **531–537**  
 projected impacts and risks, 25–27, 28  
 socioinstitutional adaptation, 66–67, 454, 525  
 synthesis, 50–51, 543–544, 543  
 vulnerability and exposure, 29, 75, **91–92**
- Hurricanes**, 91, 628  
 Hurricane Harvey (2017), 628  
 Hurricane Katrina (2005), 625  
 Hurricane Sandy (2012), 364–365, 606  
 severe Atlantic hurricanes of 2017, 628
- Hydrological cycle\***, 80, 332  
 observed changes, 14, 206  
 polar regions, 52–53, 54, 206, 207, 210  
 projected changes, 21
- Hydropower**, 25, 48, 133, 134, **153–154**
- I**
- Iceberg\***, 242–243, 243, 259  
**Iceberg calving\***, 242, 244  
**Ice cliffs**, 245–246  
**Ice sheets\***, 79, 210, **236–240**, 242–246, 330–331, 344–350  
 abrupt changes and irreversibility, 10, 53, 592, 596, 632  
 Antarctic, mass change, 53, 236–238, 236  
 calving, 239, 331, 332  
 consequences and impacts, 242–244  
 drivers of mass change, 239–240, 330–331  
 Greenland, mass change, 53, 238–239  
 grounding line, 79, 237–238, 246, 351  
 marine ice sheet instability (MISI)\*, 81, 206, 245, 348–349  
 modelling, 348–350
- nutrient and carbon release, 242–243, 243  
 observed changes, 6, 7, 53, 75, 84, 111, 206, 236–237, 237, 337, 344  
 projected changes, 7, 17, 111, **344–350**, 361–363  
 sea level rise contribution, 7, 10, 17, 20, 53, 55, 75, 79, 80, 83, 108–109, 111, 206, 276, 323, 324, **330–331**, 332, 336, **337–338**, **344–350**, 351, 354, 361–363  
 stability, sea level change and, 244–246  
 tipping point, 626
- Ice shelves\***, 79, 237, 244, 324, 331, 362  
 buttressing of ice sheets, 239
- Ice stupas**, 156
- Impacts (consequences, outcomes)\***, 87  
 greenhouse gas reductions and, 8, 18  
 implementing responses to, 29–35  
 observed impacts on ecosystems, 11–13, 14  
 observed regional impacts, 14  
 time scales of, 29, 81  
 See also *specific topics*
- Indian Ocean**, 50–51, 67–68, 592, **613–614**, 615, 616–617  
 Indonesian Throughflow (ITF) and, 68, 591, **616**  
 water transport, 67–68, 591, **616–617**
- Indian Ocean Dipole events**, 19, 68, **613–614**
- Indigenous knowledge (IK)\***, 15, 30, 35, 47, 76, **102, 103–105**, 208, **513–514**  
 Alaska Eskimo Whaling Commission, 103  
 confidence in, 260  
 glacier retreat and, 171  
 in governance, 54, 104–105, 268  
 importance of, 102, 209  
 loss of, 260, 373–374, 662  
 transmission of, **513–514**
- Indigenous Peoples**  
 in Arctic, 5, 15, 54, 103, **259–260**  
 coastal communities, 26, 259, **513**  
 connection with nature, 259  
 culture and knowledge, 54, **259–260**  
 diversity of, 261  
 engagement in decision making, 35  
 food production/harvesting, 52–53, 262–264  
 in high mountain areas, 5  
 livelihoods, 53, 66, 453–454  
 responses to climate change, 261  
 subsistence systems, 262–263  
 wildfood harvesting, 262–264
- Indonesian Throughflow (ITF)**, 68, 591, **616**
- Industrial revolution\***, 83
- Infrastructure**  
 adaptation, 66, 525, **534**  
 Arctic region, 15, 25, 54, 91, 207, **260–261**, 265, 268  
 cascading impacts, 625  
 coastal areas, 16, 55, 324, 534, 665
- damages from climate change, 265–266, 265, 268  
 exposure to hazards, 47  
 high mountain areas, 14, 133, **168**  
 observed regional impacts, 14, 15  
 polar regions, 15, 47, 54, 207, **260–261**, 265, 268  
 projected risks, 25
- Institutions\***, 45–47, 67  
 institutional capacity, 631  
 socioinstitutional adaptation, 66–67, 454, 525
- Insurance**, 69, 593, 616  
 climate change insurance, 630
- Integrated assessment\***, 76
- Internal Displacement (of humans)\***, 385, 386  
 See also Migration (of humans)
- International climate governance**, 173–174, 269
- International cooperation**, 35, 49, 76, 96, 135  
 polar regions, 210, 269
- Invasive species\***, 15, 236, 258
- Irreversibility\***, 76, 77, 90, 591, 595–596, 629, 632  
 Antarctic ice sheet losses, 10, 53, 206, 632  
 committed changes and, 81  
 cross-system assessment and examples, 595–596  
 definition of, 595  
 framework for, 594, 594  
 impacts, 595–596  
 knowledge gaps, 633  
 projections, 595–596  
 thresholds, 45
- J**
- Justice\***, 408, 629  
 climate justice, 629  
 procedural justice, 398
- K**
- Kelp forests**, 61, 453, **499–500**  
 marine heatwaves and, 591  
 projections, 23, 24, 64, 65, 453, 500, 501
- Knowledge systems**, 35, 47, **99–103**, 325, 409  
 adaptation and, 527, 533, **538**  
 co-production, 103–104, 208, 271, **271–272**  
 Indigenous knowledge (IK), 15, 30, 35, 47, 76, **102, 103–105**, 208, 325  
 linking with decision making, 271, 272–273, 325  
 local knowledge (LK), 30, 47, 76, **102, 103–105**, 208, 325, 538  
 model simulation data, 100  
 palaeoclimate data, 100  
 role in adaptation, 538

role of in people's responses to changes, 102–103  
 scientific knowledge, 47, 99–100, 101, 629  
 trust in, 629  
**Krill (Antarctic)**, 22, 207, 230, 231, 233, 234–235

## L

**Labile dissolved organic carbon (LDOC)**.  
 See Dissolved organic carbon (DOC)  
 and particulate organic carbon (POC)  
**Ladakh, India**, 156  
**Lahars**, 162  
**Lake and river ice**, 147  
**La Niña**. See El Niño-Southern Oscillation (ENSO)  
**Landfast ice**, 215  
**Land-sea eco-engineering**, 524  
**Landslides**, 158, 162, 596  
**Land use\***, 58, 400–401, 630  
**Last Interglacial (LIG)**, 55, 323  
**Law of the Sea**, 97, 98  
**Likelihood\***, 42, 81, 106, 107  
**Livelihoods\***  
 Arctic region, 15, 25, 52–53, 91, 260, 262–265  
 high mountain areas, 163  
 linking with ecosystem services, 271, 274  
 low-lying islands and coasts, 55, 534, 664–665  
 observed impacts, 15  
 oceans changes and, 65, 66, 112, 453–454, 534  
 polar regions, 260, 262–265  
 projected changes, 25, 26  
 subsistence systems, 262–263, 267  
**LLIC**. See Low-Lying Islands and Coasts (LLIC)  
**Lobsters**, 611  
**Local knowledge (LK)\***, 30, 47, 76, 102, 103–105, 208, 513–514  
 importance of, 102, 209  
 loss of, 373–374, 662  
 role in adaptation, 538  
**Loss and Damage, and losses and damages\***, 69, 88–89, 629–630  
 early warning systems and, 592  
 extreme events and, 68, 592  
 in high mountain areas, 49, 173–174  
 property losses, 605–606  
 risk reduction investments and, 592, 593  
 tropical cyclones, 69, 592, 605–606  
 Warsaw International Mechanism, 629  
**Low elevation coastal zone (LE CZ)**, 659, 662, 664–665  
**Low-Lying Islands and Coasts (LLIC)**, 69, 657–674, 667  
 adaptation limits, 69, 658, 668  
 adaptation/responses, 665–667, 667  
 anthropogenic drivers, 55, 662  
 Arctic coasts, 664

climate-related drivers and hazards, 659, 660–661  
 deltas, 342, 383–384, 659, 663–664  
 exposure and vulnerability, 55, 323, 324, 367–375, 658, 659–662  
 extreme sea level (ESLs) events, 55, 56, 660  
 GDP in, 658  
 global distribution (map), 659  
 human population, 658  
 impacts on sectors and livelihoods, 55, 664–665  
 migration options, 665, 666  
 observed and projected impacts, 660–661, 662–665  
 Reasons for concern (RFC), 381–385, 667–668  
 risks, 324–325, 658  
 small islands, 659, 662–663  
 tourism, 380–381, 665

## M

**Mangroves**, 30, 55, 61–62, 324, 451, 454, 496, 665  
 adaptation, 530–531  
 mitigation potential, 66, 522  
 projections, 23, 64, 324, 453, 501  
 restoration, 530–531  
**Marine-dependent human communities**, 26, 65, 453, 509–520  
 human health, 509–512  
**Marine ecosystems**, 12, 16, 53–54, 112–113, 478–492, 502–520, 545  
 Arctic Large Marine Ecosystems, 211  
 Arctic region, 226–230, 228  
 bathyal ecosystems, 488–489  
 benthic communities, 227–228, 228, 231  
 biomass, 65, 452–453, 481–484, 483, 492  
 calcifying shell-producing organisms, 53, 207, 218, 225, 501  
 carbon sequestration, 507–508  
 chemosynthetic ecosystems, 490  
 community structure, 61, 65, 452–453  
 contaminants, 454, 511–512, 512  
 cultural dimensions, 26, 65, 513–515, 519  
 deep seafloor, 65, 486–490, 487, 489, 492, 507  
 distribution of species, 478–480, 480  
 Eastern Boundary Upwelling Systems (EBUS), 62, 65–66, 451, 453, 506–507  
 ecosystem services, 30, 502–520, 519, 545  
 epipelagic, 64, 451, 478–485, 485, 501  
 fisheries and production, 22, 26, 61, 64, 228–229, 234–235, 451, 452–453, 664  
 habitat and species, 22, 23, 26, 52, 61, 64, 65–66  
 key drivers of, 228, 233  
 livelihoods and, 65, 66, 112, 453–454, 534  
 marine heatwaves and, 67, 610–611  
 mitigation options, 454–455  
 multiple hazards/stressors, 90, 480, 481  
 observed changes, 12, 14, 16, 50–51, 52, 450–451, 469  
 open ocean, risk assessment for, 491–492  
 pelagic ecosystems, 478–486, 485, 492  
 pelagic foodwebs and, 233–234  
 plankton, 226–227, 450–451, 479, 481–482, 485  
 polar regions, 22, 53–54, 210, 226–234, 228  
 primary production, 12, 19, 22, 23, 52, 61, 226–227, 452, 470, 474, 474–476, 476  
 projections, 19, 22, 23, 26, 53–54, 62, 64, 65, 65–66, 452–453, 469–470  
 provisioning services, 502–506, 519  
 regulating services, 507–508, 519  
 sea level rise, 55, 56, 323, 324, 367–385, 659–662  
 Southern Ocean, 230–234, 233  
 supporting services, 508–509, 519  
 Sustainable Development Goals (SDGs) and, 518–520, 519  
 synthesis, 543–544, 543  
 time of emergence for changes, 19, 477–478  
 See also Fish and fisheries  
**Marine heatwaves (MHWs)\***, 68, 79, 83, 113, 595, 606–612  
 coastal effects of, 661  
 critical thresholds, 69  
 detection and attribution, 607–609  
 drivers of, 607  
 early warning systems for, 592  
 forecasts of, 69, 592  
 impacts of, 591, 608, 610–612  
 intensity of, 19, 24, 68, 592, 608  
 locations of recent, 608  
 observations, 9, 67, 111, 591, 607, 661  
 projections, 7, 18, 19, 24, 68, 111, 592, 595, 609, 609–610, 661  
 risk management and adaptation, 69, 611–612  
**Marine ice cliff instability (MICI)\***, 245–246, 349–350, 351, 351  
**Marine ice sheet instability (MISI)\***, 81, 206, 245, 347, 348–349  
**Marine mammals**, 61, 228, 233, 256, 450, 480  
 marine heatwaves and, 610  
 polar regions, 229–230, 232–233, 256  
**Marine protected areas (MPAs)**, 454, 521, 535  
**Marine renewable energy**, 30, 518, 521  
**Marine Resources Act**, 262  
**Mercury**  
 methylmercury, 511  
 ocean contamination, 454, 511  
 released from glaciers, 153  
 release from permafrost, 15, 134  
 seafood contamination, 26  
**Meridional Overturning Circulation (MOC)\***, 239, 340, 591, 618–623  
 observed changes, 10, 75, 591

projections, 18, 19  
 See also Atlantic Meridional Overturning Circulation (AMOC)

**Methane (CH<sub>4</sub>)\***, 252–253, 596  
 AMOC and, 623  
 from permafrost thaw, 18, 52, 84, 108, 596  
 removal by deep sea ecosystems, 507

**Methodologies**, 106

**Microbial carbon pump\***, 520, 524

**Microbiome**, 528  
 coral, 529  
 sponges, 491

**Mid-latitude weather**, 52, 67, 216, 591, 604

**Mid-Pliocene Warm Period (mPWP)**, 55, 323

**Migration (of humans)\***  
 climate refugees, 630  
 coasts and low-lying islands, 385, 386, 396–398, 665, 666  
 conflict escalation, 666  
 costs, 397  
 governance and, 398  
 high mountain areas, 172–173  
 observed regional impacts, 14  
 pastoralism, 172  
 wage labour migration, 172–173  
 See also Planned relocation

**Mining**, 168, 261

**Mitigation (of climate change)\***, 76, 90, 92–94  
 benefits of, 32–34, 115  
 ethical challenges of, 629  
 ocean-based mitigation, 454–455, 520–525, 521  
 See also Responses, under specific topics

**Mitigation options\***, 92–93, 93

**Mobility**. See Human mobility

**(Model) Ensemble\***, 457, 458–460, 459, 483  
 uncertainties and, 465–466

**Monsoons**, 615

**Multiple extreme events**, 67, 68, 591

**Multiple hazards/stressors**, 61, 65, 68, 453, 456, 480, 481, 543, 591, 624  
 cascading impacts and, 624–626, 626–628  
 case studies, 626–628  
 compound events and, 68, 594, 624  
 compound hazards, 68, 591  
 vulnerability to, 369

**N**

**Nationally determined contributions (NDCs)\***, 391

**Nature's contributions to people (NCP)\***, 87

**Near-term interval**, 85

**Negative emissions\***, 542

**Nepal**, 91

**New York City**, coastal flood adaptation, 364–366

**New Zealand**, 407  
 Hawkes Bay Coastal Hazards Strategy, 406

**Nile Delta regions, Egypt**, climate change adaptation, 366–367

**North Atlantic Deep Water (NADW)**, 463, 536

**North Atlantic Oscillation (NAO)**, 240, 340, 463

**O**

**Observed changes**, 6–17, 7–8, 14–15, 44, 75, 83–84  
 impacts on ecosystems, 11–13, 14–15  
 impacts on human systems, 14–15, 15–17  
 physical changes, 6–11, 14–15, 50–51  
 summary, 7–8, 111  
 See also specific regions and systems

**Ocean\***, 58–67, 78, 83–84, 447–587  
 abrupt and irreversible changes, 595  
 abyssal plains, 64, 453, 486–488, 492, 501  
 anthropogenic climate changes in, 457, 460–465  
 biogeochemical properties, 456–476  
 biogeography of organisms, 61, 450–451  
 biological (carbon) pump, 65, 484, 485, 486–487, 520  
 biomass, 65, 452–453, 481–484, 483, 484, 492  
 carbon, changes in, 467–470, 468, 487, 487  
 as carbon sink, 219, 225–226, 450, 467–469  
 changes in, 43–47, 44, 67, 456–493, 591  
 chemosynthetic ecosystems, 490  
 climate regulation and, 77, 78, 79, 80  
 CO<sub>2</sub> removal from atmosphere, 52, 53, 59, 205, 218, 450, 468  
 cultural services, 66, 509, 509, 513–515, 519  
 deep ocean, 62, 485, 485–486, 492, 505–506  
 deep seafloor systems, 65, 486–490, 487, 489, 492, 507  
 depth of, 78  
 ecosystem services, 502–520  
 epipelagic, 64, 478–485, 485, 501  
 FAQ, 545–546, 545  
 governance, 67, 96, 97–98, 455, 540–542, 541  
 heat transport, 67–68, 591  
 heat uptake, 457–460, 458, 459  
 The High Seas, 96, 262  
 human communities dependent on, 26, 65, 453, 509–520  
 impacts under emissions scenarios, 50–51, 451–452, 543, 545  
 importance for people, 5, 43, 58, 75, 77–78, 112, 456  
 interconnectedness with cryosphere, 79, 80, 81  
 inter-ocean exchanges, 616–618  
 livelihood impacts, 65, 66, 453–454, 534  
 major components of, 43, 78, 79  
 multiple hazards/stressors, 453, 456, 480, 481, 543

new ocean states projected, 62, 63, 83, 452

nitrate concentrations, 63, 452, 470, 473–474, 474

nutrient cycles/fluxes, 61, 63, 450, 452, 464–465, 473–474, 474

observed changes, 9–10, 14, 44, 58–62, 75, 83, 101, 111, 450–451, 456–493, 543

open ocean, 450, 456–457, 491–492, 501, 520, 525

oxygen levels, 46, 59–61, 62, 470, 471–473, 472, 473

physical changes, 50–51, 456–476, 543

polar regions, 205, 216–219, 224–226

pollutants, 66, 454, 511–512, 512, 521

primary production, 12, 19, 22, 23, 52, 61, 63, 63, 226–227, 452, 470, 474–476, 476, 525

projections, 7–8, 18–20, 23–24, 44–45, 62–66, 68, 83, 101, 111, 451–454, 592–593

regional hazards and impacts, 49–51

response options, 66–67, 454–455

risk assessment, 64, 491–492, 501

role in Earth system, 75, 80

roles and functions of, 75, 77, 80, 112–113

scale and cross-boundary dimensions of changes, 45–47, 76, 78

scenario projections, 451–452

scientific observations, 99–100, 101

summary, 3–69, 49–51, 58–67, 450–455, 543–544, 543

surface area, 5

Sustainable Development Goals (SDGs) and, 518–520, 519

synthesis, 543–544, 543

thermal expansion, 10, 55–56, 324, 331, 3 35–337, 336, 352, 354, 363, 457

time scales of changes, 18, 81, 82

turbulent mixing, 465–467, 466

uncertainties and knowledge gaps, 544

water-mass properties, 461  
 See also Sea level change; specific oceans, e.g., Arctic Ocean, Southern Ocean

**Ocean acidification (OA)\***, 83, 113, 469–470, 545, 661  
 aragonite shell-forming species, 19, 205, 207  
 ecosystem effects, 22  
 governance and, 542  
 observations, 9, 14, 59, 75, 83, 111, 450, 661  
 pH, 7, 46, 62, 83, 86, 111, 218, 452, 469, 470  
 polar oceans, 52, 205, 207, 218–219, 225–226  
 projections, 18, 19, 83, 111, 207, 452, 595, 661

**Ocean alkalisation**, 454, 521

**Ocean-based responses**, 66–67, 454–455, 520–542, 521  
 adaptation, 454–455, 525–540, 526–527, 532–533  
 adaptation barriers and limits, 67, 455

adaptation costs and limits, 538–540  
 adaptation frameworks, 536–537  
 assisted evolution, 521, 529  
 blue carbon, 66, 454, 508, 520–524  
 built infrastructure, 66, 525, 534  
 coral reefs, 455, 521  
 eco-engineering, 524, 536  
 ecological options, 526, 532  
 economic options, 527, 533  
 ecosystem-based adaptation (EbA), 66, 454, 525, 528–531  
 education and knowledge systems, 538  
 eliminating over-exploitation, 521  
 enhanced weathering, 454, 521, 524  
 fisheries and aquaculture, 506, 506–507, 532–533, 534–536  
 governance, 455, 527, 533, 536–537  
 human systems, 525, 526–527, 531–537  
 knowledge and, 527, 533, 538  
 marine protected areas, 454, 521  
 marine renewable energy, 518, 521  
 mitigation, 454–455, 520–525, 521  
 nutrient management, 524, 525  
 ocean fertilisation, 66, 454, 521, 525, 542  
 physical processes, 526, 532  
 productivity, adding nutrients for, 525  
 reducing pollution, 521  
 relocation & restoration (reef systems), 521  
 restoring coastal systems, 66, 521, 522–524  
 restoring hydrological regimes, 521  
 sediment disturbance, control of, 524  
 social options, 526–527, 532–533  
 socioinstitutional adaptation, 66–67, 454, 525  
 summary, 454–455, 526–527, 532–533, 540  
 upwelling, increasing, 525  
 See also Coastal adaptation

**Ocean circulation**, 79, 80, 462–464, 591, 592, 618–623  
 extreme changes in, 591, 592, 593  
 polar oceans, 210, 219, 220–222, 450  
 risk of abrupt change, 618–623  
 See also Atlantic Meridional Overturning Circulation (AMOC)

**Ocean deoxygenation\***, 452, 470, 471–473, 545, 595  
 ecosystem effects, 22  
 observed changes, 10, 14, 59–61, 83, 111, 470, 472, 545  
 projections, 7, 18–19, 62, 83, 86, 111, 452, 470, 472–473, 473, 595

**Ocean-dependent communities**. See Marine-dependent human communities

**Ocean economy**, 517–518

**Ocean ecosystems**. See Marine ecosystems

**Ocean fertilisation**, 66, 454, 521, 525, 542

**Ocean renewable energy**, 30, 518, 521

**Ocean salinity**, 456, 457, 460, 461, 462, 485

polar oceans, 218, 242

**Ocean stratification\***, 78, 450, 464, 464–465  
 nutrient fluxes and, 473  
 observations, 9, 59, 450, 464, 464  
 projections, 18, 62, 452, 453, 464

**Ocean temperature**, 7, 83, 111, 450, 457–460, 458, 459, 463–464, 606–607  
 attribution to anthropogenic changes, 58, 457, 461, 545, 591  
 deep ocean, 463  
 heat content, 7, 78, 91, 111, 205, 217, 458, 458  
 heat uptake, 457–460, 458, 459  
 marine heatwaves, 7, 9, 18, 19, 24, 67, 79, 83, 591, 595, 606–612  
 observations, 9, 58, 83, 111, 450, 457–458, 458, 545, 591, 606–607  
 polar oceans, 52, 205, 207, 216–218, 217, 224–225  
 projections, 18, 19, 22, 62, 86, 111, 452, 458, 458–460, 459, 463, 606  
 regional patterns, 14, 461–462  
 time scales of warming, 18  
 warming trend, long-term, 58, 462, 463, 607

**Opportunities**, 84, 90–91, 164

**Outburst flood**. See Glacial lake outburst flood (GLOF)

**Ozone (O<sub>3</sub>)\***, 212, 214, 217

## P

**Pacific Ocean**, 50–51, 67–68, 592, 616–617  
 Indonesian Throughflow (ITF) and, 68, 591

**Pacific trade winds**, 67–68, 591, 592, 616–617, 617

**Palaeooclimate data**, 44, 83, 100, 322–323  
 Last Interglacial (LIG), 55, 323  
 mid-Pliocene Warm Period (mPWP), 55, 323

**Paris Agreement\***, 49, 77  
 temperature goal of, 92

**Particulate organic carbon (POC)\***, 484, 487

**Pathways\***, 84–86  
 adaptation pathways, 666–667  
 baseline and reference periods, 85–86  
 Climate Resilient Development Pathways, 34, 35, 58, 69, 90, 410, 592–593, 631  
 oceans pathway, 92  
 Representative Concentration Pathways (RCPs), 8, 55–56, 75, 84–85, 457  
 shared socioeconomic pathways (SSPs), 85  
 sustainable development pathways (SDPs), 625–626  
 See also Representative Concentration Pathways (RCPs)

**PCBs (polychlorinated biphenyls)**, 152–153, 511

**Pelagic\* ecosystems**, 478–486, 485, 492

**Pelagic\* fish**, 229

**Pelagic\* foodwebs**, 233–234

**Pelagic\* primary production**, 207, 230–231

**Penguins, Antarctic**, 232, 233, 258

**Permafrost\***, 47, 48, 52, 79, 145–146, 247–249  
 active layer thickness, 145, 146  
 carbon dioxide release from, 18, 52, 84, 108, 207, 596  
 carbon in, 248–249, 252, 254  
 deep uncertainty and, 108  
 methane release from, 18, 52, 84, 108, 596  
 near-surface, 54, 207, 248, 251  
 observed changes, 6, 7, 11, 47, 52, 75, 84, 111, 133, 145–146, 146  
 permafrost area, 133, 145, 146  
 in polar regions, 206, 207, 247–249  
 projections, 7, 18, 21, 48, 54, 111, 134, 248, 251  
 regional summary statistics, 136

**Permafrost degradation\***, 91, 134, 145–146

**Permafrost temperature**, 6, 47, 52, 79, 84, 133, 145–146, 146, 247  
 mean annual ground temperature and, 146, 147  
 in polar regions, 52, 54, 206, 247, 248

**Permafrost thaw\***, 54, 79, 134, 145–146  
 abrupt, 18, 249  
 drivers of, 145  
 greenhouse gases released from, 18, 84  
 ground subsidence from, 21, 25, 207, 265  
 mercury released from, 15  
 observed changes, 6, 11, 15  
 projected changes and risks, 7, 18, 21, 54, 207

**Persistent organic pollutants (POPs)**, 152–153, 454, 511

**pH\* of ocean**, 218, 469, 470  
 past and future changes, 7, 83, 111  
 projections, 7, 19, 46, 62, 86, 111, 452  
 thresholds, 542

**Phenology**, 229, 478–480, 480  
 primary production and, 227

**Phytoplankton**, 61, 223–224, 226–227, 228, 230, 231, 233, 450–451  
 dinoflagellates, 479, 481, 510  
 harmful algal blooms (HABs), 16, 26, 62, 451, 510–511  
 projections, 481–482, 485

**Plankton**, 226–227, 230–231, 450–451, 479, 485  
 dinoflagellates, 479, 481, 510  
 distribution shift, 479  
 harmful algal blooms (HABs), 16, 26, 62, 451, 510–511  
 phytoplankton, 61, 223–224, 226–227, 228, 230, 231, 233, 481–482, 485  
 zooplankton, 227, 228, 233, 482–483, 485

**Planned relocation (of humans)\***, 15, 625  
 Arctic region, 15, 625  
 climate refugee, 630  
 coastal areas, 31, 33, 386, 396–398, 666  
 costs of, 397

- Plastic pollution**, 113, 511–512
- Plasticity\***, 48–49, 528
- Polar amplification**, 51, 84, 112, 114, 205, 212, 333, 604
- Polar bears**, 228, 230, 256
- Polar Code**, 266, 269
- Polar regions**, 51–54, 203–320
- adaptation, 53, 206, 207–208
  - adaptation challenges, 206–207
  - adaptive management, 262
  - Antarctic Circumpolar Current (ACC), 212, 217, 220, 221, 466
  - atmospheric feedbacks, 210
  - biodiversity, range shifts, and species invasions, 53–54, 236, 256–258
  - biogeochemistry, 242–243
  - carbon, 248–249, 254
  - carbon cycle, 252–253
  - climate resilient pathways, 271, 271–274
  - climate trends, 212, 213
  - commercial activity, 210
  - commercial fisheries, 261–262, 267
  - economy and livelihoods, 260, 262–265
  - ecosystem impacts, 50–51, 207, 226–234, 244, 253–255
  - enabling conditions, 208
  - fish/fisheries, 207, 228–229, 228, 231–232, 234–235, 261–262, 267
  - freshwater systems, 48, 210, 249–250, 251–252, 255–256
  - glaciers, 53, 143–144, 206, 210, 240–242, 241
  - governance, 54, 208, 210, 268–271, 630
  - human health and well-being, 260, 266–267, 268
  - human responses to climate change, 207–208, 261–268, 267–268
  - hydrology, 52–53, 54, 206, 207, 210
  - ice sheets, 206, 210, 236–240, 242–244
  - infrastructure, 54, 207, 260–261, 265–266, 265, 268
  - interactions with rest of world, 209, 210, 276
  - international cooperation, 210
  - key features and mechanisms, 210, 276
  - knowledge gaps and uncertainties, 275–276
  - local community engagement, 208
  - map and place names, 211
  - marine ecosystems, 22, 53–54, 210, 226–234
  - mid-latitude weather, influence on, 52, 67, 216, 276, 591, 604
  - mitigation, 53, 207
  - multiple perspectives and diversity, 209, 261
  - networks of protected areas, 54, 208
  - nutrient fluxes, 242–244, 243
  - observed changes, 6, 51–53, 75, 205–206, 212–219, 236–242, 246–250
  - observed regional impacts, 14
  - ocean acidification, 52, 205, 207, 218–219, 225–226
  - ocean circulation, 210, 219, 220–222
  - oceans, 52, 205, 216–219, 224–226, 242, 545
  - ocean temperature/heat content, 52, 205, 216–218, 217
  - permafrost, 52, 206, 207, 247–249, 251
  - polar species, 207
  - primary productivity, 22, 52, 207, 226–227
  - projected changes, 7–8, 22, 53–54, 206–207, 213, 214, 222–236, 242–246, 250–261
  - resource extraction, 210, 264–265, 268
  - resource management, 54, 208
  - runoff, 47–48, 248, 250
  - seabirds and marine mammals, 228, 229–230, 232–233, 233, 256
  - sea ice, 205–206, 210, 212–216, 213, 222–223
  - sea level and, 242
  - sea surface temperature, 213
  - snow and frozen ground, 53, 54, 210, 246–249, 248, 250–251
  - social-ecological systems, 234–236, 259–261
  - spatial footprints, 209, 211
  - summary, 51–54, 205–208, 274–275
  - surface air temperature, 51, 205, 212, 247
  - terrestrial ecosystems, 210
  - tourism, 235, 264, 267
  - transportation and shipping, 52, 210, 235–236, 266, 268, 276
  - wildlife, 43, 206, 207, 248, 249, 251, 255
  - See also Antarctic region; Arctic region
- Polar vortex**, 212, 216
- Polychlorinated biphenyls (PCBs)**, 152–153, 511
- Polynyas**, 223–224, 243, 464
- Poverty\***, 49
- cascading impacts and, 667
  - mountain communities, 154, 164
  - vulnerability and, 135, 164
- Poverty eradication\***, 90, 93, 114
- Precipitation**
- in high mountain areas, 138–139, 139, 140
  - observed changes, 11, 67, 591
  - projections, 20
- Pre-industrial\***, 85, 101
- past climates warmer than, 323
- Primary production\***
- high mountain areas, 167
  - limiting resources (ocean), 474
  - marine ecosystems, 12, 19, 22, 23, 26, 226–227
  - net primary production (NPP)\*, 12, 19, 22, 63, 63, 226–227, 470, 474–476, 476, 525
  - observed changes, 11–12
  - oceans, 12, 19, 22, 23, 52, 61, 63, 63, 226–227, 452, 470, 474, 474–476, 476, 525
  - pelagic, 207, 230–231
  - phenology and, 227
  - plankton and, 226–227, 230–231, 525
  - polar regions, 22, 52, 207, 226–227
  - projections, 19, 22, 23, 63, 452
- Private costs\***, 263
- Productivity**. See Primary production
- Projections\***, 7–8, 17–28, 44, 83–84, 86
- ecosystems, 21–25, 23–24
  - humans and ecosystem services, 25–27, 28
  - key indicators, 86
  - physical changes, 7–8, 17–21, 86, 101
  - summary, 7–8, 111
  - See also specific regions and systems
- Property losses**, 605–606
- Property values**, 517
- Pteropods**, 227, 228, 233
- ## R
- Radiative forcing\***, 75
- Rain-on-snow floods**, 47, 48, 134, 161–162
- Range shifts (of species)**, 11, 12, 16, 21, 22, 53, 61, 90, 92, 134, 207, 256–258, 535
- RCPs**. See Representative Concentration Pathways
- Reasons for concern (RFC)\***, 381–385, 667–668
- Reference periods\***, 85–86
- Regime shifts**, understanding, 271, 272
- Regions\***
- observed regional impacts, 14–15, 50–51
  - recent extreme events, 596, 597–601
  - regional hazards and impacts, 49–51
  - regional sea level change, 10, 20, 56, 57, 324, 340–341, 341, 354–355, 660
- Reindeer**, 206, 255
- reindeer herding, 263–264, 267
- Relative sea level\***, 10, 17, 20, 56, 326, 354–355
- Relocation**. See Planned relocation
- Renewable energy**, 93
- ocean renewable energy, 30, 518, 521
- Representative Concentration Pathways (RCPs)\***, 8, 55–56, 75, 84–85, 457
- comparison of projections under, 7, 44, 45, 46, 57, 62, 68, 86, 592–593
  - RCP1.9, 85
  - RCP2.6 (low emissions), 8, 85
  - RCP4.5 and 6.0, 8, 85
  - RCP8.5 (high emissions), 8, 85
- Resettlement**. See Planned relocation
- Residual risk\***, 88–89
- Resilience\***, 89–90
- adaptive ecosystem governance, 271, 274
  - biodiversity, spatial planning for, 271, 274
  - building, 69, 89–90, 207–208, 271, 454
  - Climate Resilient Development Pathways, 34, 35, 58, 69, 90, 410, 592–593, 631
  - community-based monitoring, 271, 272
  - ecosystem stewardship, 271, 273–274
  - enabling conditions, 34–35

- general strategies, 89  
 indicators of, 271, 272  
 linking ecosystem services with human livelihoods, 271, 274  
 ocean-related responses for, 454–455  
 participatory scenario analysis, 271, 273  
 in polar regions, 271–274, 271  
 regime shifts, understanding, 271, 272  
 structured decision making, 271, 273–274
- Responses to changes**  
 dynamic response of systems, 82  
 implementing, 29–35  
 polar regions, 261–268  
 role of knowledge, 102–103  
 strengthening, 30–34, 68–69, 592–593  
 time scales and thresholds, 81, 82  
 tipping points, 82  
 See also Coastal responses; Ocean-based responses; Sea level rise: Responses
- Restoration\***, 521  
 coastal ecosystems, 30, 66, 93, 521, 522–524, 530–531, 665  
 coral reefs\*, 30, 33, 455, 521, 528, 529–530, 665
- Risk\***, 29, 46, 59, 87–92, 326, 381–382  
 adaptation and, 87–89  
 coastal and low-lying areas, 55, 323, 324–325, 328, 328, 375–385, 658  
 compound risks, 69, 109, 594  
 exposure and vulnerability, 29, 91–92, 323, 324, 367–375, 659–662  
 extremes and abrupt changes, 591–593  
 future risks (from SLR), 56, 382–384  
 greenhouse gas emissions and, 113  
 hazards and, 90–91, 594  
 key concepts, 46, 87–90  
 projected, 7, 17–28  
 risk framework, 326, 381–382  
 risks considered, 382
- Risk assessment\***, 47, 84, 87  
 confidence statements and, 107  
 Millennium Ecosystem Assessment (MEA), 87  
 open ocean ecosystems, 491–492
- Risk management\***, 25, 67–69, 589–655  
 buyout programs, 606  
 cascading impacts, 625–626  
 collective, 409  
 early warning systems, 592, 606  
 FAQ on, 632  
 investments in, 69, 592, 630  
 managed retreat, 606  
 marine heatwaves (MHWs), 69, 611–612  
 tropical cyclones (TCs), 69, 606, 631  
 See also Disaster risk management
- Risk perception\***, 374
- Risk reduction**, 46, 520–542, 592–593  
 adaptation and, 87–89, 384–385  
 coastal adaptation, 56, 384–385  
 investments in, 69, 592, 593  
 ocean-related responses, 520–552  
 reducing carbon emission and, 592  
 responses to sea level rise, 32, 58
- Risk tolerance**, 32, 327
- Risk transfer**, 616
- Rock avalanches**, 158, 162
- Rock glaciers**, 145–146, 158
- Runoff\***  
 glacier shrinkage and, 151, 152  
 high mountain areas, 47, 133, 134, 147–151, 152  
 observed changes, 15–16, 47–48, 133, 148–149  
 polar regions, 47–48, 248, 250  
 projections, 18, 48, 134, 149, 248  
 sea level change and, 331, 332  
 seasonality of, 48, 148–149  
 timing of peak water, 150
- S**
- Salmon**, 229, 506
- Salt marshes**, 55, 62, 64, 65, 451, 453, 454, 494, 501  
 mitigation potential, 66, 522
- Scenarios\***, 8, 84–86  
 baseline and reference period, 85–86  
 high emissions (RCP8.5), 8, 85  
 low emissions (RCP2.6), 8, 85  
 participatory scenario analysis, 271, 273  
 participatory scenario building, 666–667  
 RCPs, 8, 84–85  
 See also Representative Concentration Pathways (RCPs)
- Seabirds**, 480, 480  
 marine heatwaves and, 610, 611  
 polar regions, 229–230, 232
- Seagrasses**, 30, 61, 380, 454, 494, 665  
 marine heatwaves and, 591, 610  
 mitigation potential, 66, 522  
 projections, 23, 24, 64, 65, 380, 501
- Sea ice\***, 52, 79, 205–206, 212, 212–216, 591  
 age and thickness, 214  
 Antarctic, 52, 205–206, 214, 223, 324  
 Arctic, 52, 205, 206, 212, 213–216, 222–223, 518  
 differences of Antarctic vs. Arctic, 212  
 drivers for loss, 213–214  
 ecosystem effects, 22  
 formation of, 80  
 freeze-up timing, 212, 214  
 landfast ice, 215  
 mid-latitude weather and, 52, 67, 216, 591  
 motion/drift, 215  
 observed changes, 6, 14, 52, 75, 84, 111, 212, 212–216, 661  
 polar regions, 205–206, 210, 212–216, 213, 222–223  
 projections, 7, 18, 22, 53, 111, 222–223, 223, 661  
 seasonality, 215, 216  
 shipping activity and, 206, 235–236, 518  
 snow on ice, 215–216  
 thickness, 84, 222
- Sea level change\***, 10–11, 55–58, 83, 321–445  
 adaptation options, 326, 385–386, 658, 665–667  
 attribution of, 55, 343–344  
 benefits of responses to, 32  
 commitment to (long-term), 27, 69, 83, 328, 658  
 drivers of, 7, 10, 55, 323–324, 326, 330–332, 335–338, 344–350  
 enabling conditions for responses, 60, 406, 407–410  
 exposure, vulnerability, impacts, and risk, 55, 56, 323, 324, 367–385, 659–662  
 extreme sea level (ESL) events, 11, 17, 20, 28, 55, 56, 324, 357–361, 660  
 global mean sea level (GMSL), 7–8, 10, 17, 20, 55, 79, 323, 327, 332, 333–335, 336, 352, 660  
 GMSL change, budget for, 338–340  
 governance and, 58, 95, 97, 98–99, 325, 398–400, 406, 407–410  
 interconnection of processes, 326  
 local, 20, 342–343  
 measurement of, 55, 323, 334–335, 357–360  
 observed changes, 7–8, 10–11, 14, 75, 83, 323, 328, 332–344, 339, 660  
 palaeoclimate reconstructions, 44, 55, 83, 100, 322–323  
 physical basis for, 330–363  
 probabilistic projections, 353–356, 355, 356  
 processes of, 330–332  
 projections, 7–8, 17, 20–21, 55–57, 77, 324–327, 327, 328, 338–340, 339, 344–363, 660–661  
 rate of change, 17, 20, 56, 83, 327  
 regional, 10, 20, 56, 57, 324, 340–341, 341, 354–355, 660  
 satellite altimetry measurements, 323, 335  
 scenarios, 324, 327–328, 327, 352, 353, 404  
 scenarios, divergence of, 404  
 scenarios, long-term, 361–363  
 steric, 7–8  
 summary, 10–11, 55–58, 323–330  
 tide gauge measurements, 323, 334, 357–360, 358, 660  
 time scales, 324, 329, 399, 407  
 See also Extreme sea level events
- Sea level equivalent (SLE)\***, 7, 17, 332
- Sea level rise (SLR)\***, 10–11, 55–58, 79, 321–445

- adaptation limits and, 88, 325, 658, 668  
 adaptation to, 16–17, 31–32, 94, 323–325, 385–386, 385–410, 664, 665–667  
 cascading impacts, 375  
 commitment to, long-term, 27, 69, 83, 328, 658  
 exposure and vulnerability, 55, 56, 323, 324, 367–375, 659–662  
 FAQ on, 411  
 future risks, 59, 382–384  
 Indigenous knowledge and, 102, 373–374, 662  
 long-term scenarios, 361–363  
 observed changes, 10–11, 14, 55, 75, 83, 323, 328, 332–344, 660  
 palaeo data/reconstructions, 100, 238, 322–323  
 projections, 7, 17, 20–21, 27, 55–56, 77, 83, 324–327, 327, 328, 344–363, 352, 660  
 rate of rise, 10, 20, 56, 83, 327  
 RCP scenarios, 55–56, 324, 327–328, 327, 352, 353  
 regional differences in, 10, 56, 57, 324, 340–341, 341, 354–355, 660  
 relative sea level (RSL) and, 10, 17, 20, 56, 326, 354–355  
 scenario divergence, 404  
 scenarios, 361–363, 382, 404  
 summary, 10–11, 55–58, 323–330  
 synthesis, 326–330  
 uncertainties about, 20, 31, 58, 108–109, 325
- Sea level rise: Drivers and Contributions**, 7, 53, 55, 83, 323–324, 326, 330–332, 332, 335–338, 336, 354, 361–363  
 budget for GMSL change, 338–340, 339  
 extreme sea level events, 332, 342, 343  
 geodynamic processes, 331–332  
 glaciers, 6, 7, 10, 17, 79, 143, 206, 276, 323, 331, 336, 337, 352, 354  
 ice sheets, 6, 7, 10, 17, 53, 55, 79, 206, 276, 323, 324, 330–331, 336, 337–338, 344–350, 351, 354, 361–363  
 non-climatic anthropogenic drivers, 55, 56, 323, 324, 326  
 ocean thermal expansion, 10, 55–56, 324, 331, 335–337, 336, 352, 354, 363, 457  
 summary, 7, 10–11, 17, 20, 44, 111, 323–324  
 terrestrial reservoirs, 331, 336, 338, 354  
 vertical land movements (VLM), 324, 331–332, 355
- Sea level rise: Impacts and Risks**, 55, 59, 324–325, 328, 328, 328, 367–385, 658, 659–665  
 cascading impacts, 375, 624  
 coastal areas, 13, 16, 21, 27, 323, 324–325, 375–381, 660–661, 662–665  
 direct impacts (summary), 375  
 exposure and vulnerability, 56, 323, 324, 367–375, 659–662  
 human communities, 27, 32, 328, 370, 372, 373–374, 375, 382–383, 662  
 observed impacts, 375–381  
 risks, 27, 32–34, 55, 367–385, 658, 659–665  
 risks from future rise, 59, 382–384
- Sea level rise: Responses**, 17, 31–32, 32–34, 55, 57–58, 60–61, 325, 326, 329–330, 385–386, 385–410, 658, 665–667  
 accommodation, 329, 385, 386, 393–396  
 adaptation limits, 57–58, 69, 325  
 adaptation planning, 326–327, 330, 408  
 advance, 16–17, 31, 33, 323, 329, 385, 386, 392–393  
 choosing and implementing, 57–58, 325, 326  
 continuum of responses, 667  
 decision analysis and, 58, 325, 330, 402–405  
 early warning systems, 31, 35, 163, 323, 663  
 economic and social barriers, 325  
 ecosystem-based adaptation, 30, 323, 329, 386, 390–392, 665–666  
 equity and fairness, 325, 329  
 future sea level rise and, 326–328, 327  
 governance and, 58, 325, 326, 329–330, 385, 389, 392, 393, 398, 398–400  
 hard protections, 323, 325, 329, 387–390, 665  
 integrated and sequenced, 325, 329  
 knowledge systems and, 325  
 limits to, 57–58  
 long-term perspective, 325, 407  
 migration and relocation, 31, 33, 386, 665, 666  
 options and challenges, 329–330  
 public participation in, 58, 325, 330, 401, 407  
 retreat, 17, 31, 33, 323–324, 329, 385, 386, 396–398  
 sediment-based protections, 387–390  
 SLR impacts and, 328, 328  
 Sustainable Development Goals and, 325  
 synergism and, 57  
 types of responses, 386–387  
 See also Coastal adaptation
- Seals**, 229–230, 232–233
- Seasonal activities**  
 observed changes, 11, 12  
 phenology, 227, 229, 478–480, 480  
 plants and animals, 11, 12  
 projected changes, 17  
 runoff, 48, 148–149  
 sea ice, 215, 216
- Sea surface temperature (SST)\***, 7, 46, 63, 111, 591, 615, 661  
 forecasts, 612  
 Indo-Pacific SST variability, 616, 617–618
- Seaweeds**, 524  
 seaweed aquaculture, 454, 524
- Sendai Framework for Disaster Risk Reduction\***, 49, 174, 631
- Shanghai**, coastal flood adaptation, 364–366
- Shared socioeconomic pathways (SSPs)\***, 85
- Shelf seas\***, 340, 357, 451, 493  
 See also Coastal ecosystems
- Shipping**. See Transportation/shipping
- Short-lived climate forcers (SLCF)\***, 139–140
- Sink\***  
 coastal ecosystems, 66  
 marine ecosystems, 507–508  
 ocean as, 219, 225–226, 450, 467–469  
 permafrost as, 18
- Skiing**, 134, 169
- Ski tourism**, 25, 48
- Small Island Developing States (SIDS)\***, 27, 69, 658, 659, 663  
 adaptation, 631, 665–666  
 atoll islands, 27, 328, 383, 663, 666  
 habitability, 27, 663  
 human migration, 663, 666  
 human population in, 77, 663  
 impacts and risks in, 29, 69, 328  
 SDGs and, 114
- Small islands**, 69, 328, 659, 662–663, 666
- Snow avalanches**, 133, 134, 159–161, 160
- Snow cover**, 47, 53, 78, 79, 140, 246–247, 248  
 high mountain regions, 47, 48, 133–134, 140  
 observed changes, 6, 7, 15, 47, 75, 84, 111, 133, 246  
 polar regions, 53, 210, 246–247, 248, 250–251  
 projections, 7, 17, 48, 54, 111, 134, 140, 250–251
- Snow on ice**, 215–216
- Social capital**, 374
- Social conflict**, 66, 329, 400, 409, 666  
 conflict resolution, 58, 330, 401–402, 409
- Social costs**. See Private costs
- Social learning\***, 35, 263, 325, 408
- Social vulnerability**, 329, 399, 408
- Socioinstitutional adaptation**, 66–67, 454, 525
- Solar radiation modification (SRM)\***, 93
- Southern Annular Mode (SAM)**, 212, 239–240
- Southern Ocean\***  
 acidification, 52, 207, 218–219, 276  
 Antarctic Bottom Water, 220–222, 242, 463  
 Antarctic krill, 22, 207, 230, 231, 233, 234  
 benthic communities, 231  
 carbon uptake and storage, 219, 225–226, 450  
 circulation, 219, 220–222  
 CO<sub>2</sub> removal from atmosphere, 52, 205  
 fish and fisheries, 231–232, 234–235  
 heat content, 205, 212, 217, 217  
 marine ecosystem, 230–234, 233  
 observed changes, 9, 50–51  
 plankton and primary production, 230–231  
 projections, 222  
 salinity, 218, 242  
 sea ice, 210  
 stratification, 242

temperature/heat content, 52, 205,  
216–218, 217

wave height projections, 21, 68, 592

**Sovereignty and sovereign rights**, 96

**Species**

- alien (non-native) species, 258
- cold-adapted, 48, 53, 133–134, 226, 546
- habitat management, 30
- high mountain areas, 48, 48–49, 133–134,  
165–166
- invasive species, 15, 236, 258
- keystone/foundation, 66, 591
- marine species, 12, 16, 22
- polar regions, 53, 207, 229, 255, 256–258, 546
- poleward migrations, 12, 90
- range expansions, 52, 61, 257–258
- range shifts, 11, 12, 16, 21, 22, 53, 61, 90, 92,  
134, 207, 229, 256–258, 535
- relocation, 30
- spatial distribution of, 66, 256–257,  
478–480, 480
- upslope migration, 21, 48, 133
- See also Extinction risk

**Sponges**, 490–491

**Storm surge**\*, 342, 660

- extreme, 592
- modelling, 604–605
- observed trends, 342, 660
- projections, 21, 660
- warnings, 606

**Storyline of this report**, 110

**Storytelling**, 409

**Stratification**\*. See Ocean stratification

**Structured decision making**, 271, 273–274

**Subsidence**

- anthropogenic, 14, 20, 55, 323, 324, 327,  
342–343
- observed impacts, 14, 158
- permafrost thaw and, 21, 25, 207, 265

**Superstorm Sandy (2012)**, 364–365, 606

**Sustainable development (SD)**\*, 43, 75

- enabling conditions, 34–35, 49
- fairness and equity, 35

**Sustainable Development Goals (SDGs)**\*, 58, 77,  
114–115, 115, 325

- connection with ocean and cryosphere (FAQ), 77,  
114–115, 115
- global responses and, 592–593
- high mountain areas, 49, 135
- ocean changes and, 518–520, 519
- SDG 13 (Climate Action), 114, 115

**Sustainable development pathways (SDPs)**\*,  
625–626

## T

**Tasmania's Summer of 2015–2016**, 626–627

**Teleconnections**\*, 611, 614–615, 615

- AMOC, 622, 622

**Terrestrial ecosystems**

- high mountain areas, 133–134, 165,  
165–166, 167
- observed impacts, 11
- polar regions, 210
- projected risks, 21

**Thermokarst**\*, 249, 250, 255

**Thresholds**, 45, 81, 82, 369

- abrupt changes, 45, 69, 592
- coral reefs, 65, 69, 545, 592
- critical, 69, 592
- habitability, 27
- irreversibility, 45
- marine heatwaves, 69
- ocean pH, 542

**Tides**, 62, 68, 328–330, 332, 342, 357, 452, 465

- modelling, 604–605
- tide gauge records, 323, 334, 357–360, 358, 660

**Time of Emergence (ToE)**\*, 19, 81, 82, 477–478

**Time scales**, 29, 81, 82, 329

- committed changes, 27, 81, 328, 658
- governance and, 407
- irreversibility and, 77, 81
- of ocean warming, 18

**Tipping point**\*, 81, 82, 595, 626, 632

- in Arctic regions, 91
- compound events and, 624
- definition of, 595
- examples of, 81, 626
- pH-associated, 542

**Tourism**

- adaptation in, 536
- Antarctic region, 264, 267
- Arctic region, 235, 264, 267
- coastal areas, 380–381, 516–517, 536, 665
- coral reefs, 665
- glaciers, 134
- high mountain areas, 48, 133, 134, 162,  
168–171
- increased exposure and, 162
- low-lying islands and coasts, 665
- observed impacts, 14, 15, 50–51
- opportunities, 91
- polar regions, 235, 264, 267
- projected impacts, 25
- ski tourism, 25, 48
- wealth generated from, 516–517

**Trade-offs**, 93, 329

**Trade winds**, 67–68, 69, 591, 592, 593,  
616–617, 617

**Transboundary cooperation**, 35, 49, 76, 96

- in high mountain areas, 49, 158, 174
- in water management, 158

**Transboundary river basins**, 49, 135

**Transformation**\*, 34, 76, 90

- transformative change, 27

**Transformational adaptation**\*, 90, 94, 629, 630

**Transformative governance**, 27, 47, 76, 593, 629,  
630–631

**Transportation/shipping**, 52, 91

- Arctic region, 52, 206, 228, 235–236, 261, 266,  
268, 276, 518
- commercial activity, 210
- infrastructure, 25
- International Maritime Organization (IMO), 266
- observed impacts, 14, 15
- Polar Code, 266, 269
- in polar regions, 210, 228, 235–236, 266, 268
- sea ice extent and, 52, 206, 518
- winter roads/ice roads, 261

**Tropical cyclones (TCs)**\*, 68, 360–361, 601–603

- abrupt changes and tipping points, 605
- adaptation limits and, 592
- cascading impacts, 625
- Category 4 and 5 storms, 68, 591, 592
- damages from, 361
- early warning systems for, 592, 606
- ENSO and, 614
- extreme events, 592
- frequency of, 11, 601–602
- impacts, 605–606
- intensity of, 20, 21, 592, 602–603
- investments in risk reduction, 69, 592
- losses and damages, 592, 605–606
- observed changes, 11, 67, 660
- poleward migration of, 591, 603
- projections, 20, 21, 68, 592, 603, 660
- rapid intensification of, 602
- risk management, 69, 606, 631
- Typhoon Winnie (1997), 364–365

**Tsunamis**, 162

**Turtles, marine**, 479, 480

**Typhoon Winnie (1997)**, 364–365

## U

**Uncertainty**\*, 84, 106, 106

- deep uncertainty, 106, 107, 107–109
- See also Confidence; Likelihood

**UNESCO World Heritage sites**, 49, 134, 171

**United Nations Convention on the Law of the  
Sea (UNCLOS)**, 97, 98, 269, 541

**United Nations Environment Programme  
(UNEP)**, 542



**United Nations Framework Convention on Climate Change (UNFCCC)\***, 92, 541, 542, 629

**Upwelling**, 80

EBUS, 451, 453, 506–507  
increasing, as mitigation, 525  
observed changes, 12, 14  
projections, 19, 22, 453, 501

## V

**Variability**, 69, 81, 82, 83

decadal scale, 472, 479, 506  
Earth System Models and, 63, 452, 461  
ENSO, 67, 471

**Vibrio pathogens**, 26, 62, 451, 509–510

*Vibrio cholerae*, 509

**Volcanoes**, 162

**Vulnerability\***, 27, 29, 46, 88, 92

Arctic region, 92, 328  
coastal and low-lying areas, 56, 323, 328, 658, 659–665  
drivers of, 31, 374–375  
dynamic assessment, 368–369  
empowerment of vulnerable groups, 69, 593  
functions, 369  
governance and, 92  
high mountain areas, 153–158, 163  
methodological advances in assessment, 368–369  
to multiple hazards, 369  
to sea level rise (SLR), 55, 56, 323, 324, 367–375, 659–662  
social vulnerability, 329, 399, 408  
socio-ecological assessment, 369

## W

**Walker circulation**, 616

**Walrus**, 228, 229

**Water availability**

drinking water, 48, 157  
migration of humans and, 172  
observed regional impacts, 14  
projected changes, 25

**Waterborne diseases**, 15, 260, 509–510

**Water cycle**. See Hydrological cycle

**Water governance**, 157–158

**Water management**

in Gilgit-Baltistan, Pakistan, 98  
in high mountain areas, 98, 135, 157–158  
ice stupas, 156  
integrated water management, 30–31, 135, 157–158  
transboundary cooperation, 158

**Water quality**

high mountain areas, 48, 152–153, 167  
observed impacts, 15  
polar regions, 255–256  
pollutants, 152  
projected impacts, 134

**Water resources**, 77, 92

high mountain areas, 47–48, 133, 148–158  
hydropower, 25, 133, 134  
projected changes, 25

**Water security**, 14, 15

Arctic region, 52, 259

**Waves**, 360, 604–605

austral winter swell waves, 605  
Coordinated Ocean Wave Climate Project (COWCLIP), 360  
extreme heights, 11, 67, 68, 591, 592, 604–605

Rossby waves, 465

wave climate, 604

wave heights, 11, 20–21, 68, 604–605, 660, 661

**Wealth**

generated from coastal/marine tourism, 516–517  
generated from fisheries, 515–516  
monetary and material, 515–520

**Well-being\***

climate change and, 514–515  
coastal and ocean communities, 509–520  
high mountain areas, 171–172  
polar regions, 260, 266–267

**Wetlands**, 494–496, 630

observed changes, 13, 14  
projected changes, 24  
restoration, 33, 665

**Whales**, 228, 233

**Wildfire**

Arctic region, 54, 206, 207, 248, 249, 251, 254  
high mountain areas, 133, 168  
observed changes, 11  
polar regions, 43, 206, 207, 248, 249, 251, 255  
projected changes and risks, 21

**Winds**, 62, 67, 69

EBUS, 62

high mountain areas, 140

trade wind system, 67–68, 69, 591, 592, 593, 616–617, 617

wind stress trend, 617

**World Heritage sites (UNESCO)**, 49, 134, 171

## Z

**Zooplankton**, 227, 228, 233, 482–483, 485

