

Index

This index should be cited as:

IPCC, 2021: Index. In: *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 2339–2391.

Note: * indicates the term also appears in the Glossary (Annex VII).

A

Abrupt climate change*. *See also* **Tipping points*/elements***

Atlantic Meridional Overturning Circulation collapse, 1148, 1214
biogeochemical cycle, 739
definition of, 202, 739
Earth system model projections, 741
forest dieback, 740
from solar radiation modification, 1059
from water cycle change, 1148
greening of Sahara and Sahel amplification, 1150
in Earth's history, 202
in water cycle, 1059, 1148, 1148–1151, 1151
potential irreversibility of, 633
simulation of, 979, 983, 1010
tipping point thresholds, 106, 630
water cycle changes, 1059

Absolute global forcing potential (AGFP), 1012

Absolute global temperature change potential (AGTP), 1013, 1015

Abundances. *See* **Atmospheric concentrations (abundances)**

Added value*, 1990

AerChemMIP multi-model ensemble

black carbon interaction adjustments, 950
climate–biogenic volatile organic compound feedback, 859
dimethyl sulphide feedback estimate, 858
global OH increase, 850
interactive gas and aerosol chemistry analysis, 852
lightning feedback parameter estimation, 859
nitrate aerosol inclusion in, 854
non-CO₂ parameter estimates, 860
perturbation lifetime for CH₄, 836
projections of atmosphere composition, 878
radiative forcing from emissions (1750–2019), 853
seasaltclimate feedback estimates, 858
surface ozone and particulate matter analysis, 861
 α estimation, 858

Aerosol–cloud interactions* (ERFaci)

alteration of cloud radiative properties, 951
AR5 assessment of, 825, 953
cirrus cloud thinning effects, 861
cooking and heating emissions effect, 866
direct interactions of, 852
effective radiative forcing (1750–2014), 926
effects on water clouds, 950
historical estimates of, 321–322
model-based evidence for, 953
observation-based evidence for, 951
overall assessment of, 953
quantification of forcing from, 951
satellite-based estimates of, 953
sea-spray feedback effects, 858
seeding and cloud-thinning effects, 860
sulphur dioxide emissions in, 820, 855

sulphur emissions from shipping, 872

Aerosol Comparison between Observations and Models project (AeroCom)

atmospheric short-lived climate forcers, 835
black carbon concentration estimates, 848
non-CO₂ parameter estimates, 860
present-day aerosol optical depth estimation, 844

Aerosol effective radiative forcing (ERFari+aci).

See also **Effective radiative forcing (ERF)**
direct and indirect components of, 852
distribution of (1850–2014), 852, 853
evolution of 20-year means of regional, 852
geographical variations in, 855
shortwave and longwave components of, 852
South–North gradient of, 819

Aerosol index (AI), 951

Aerosol optical depth (AOD)

changes in global mean, 845
change with anthropogenic emissions, 939
forcing of aerosol–radiation interactions, 844
global mean trend in (1850–2015), 844
industrial-era change in, 949
over mid-latitudes since 2000, 290
satellite-derived trends of, 309
simulation of regional trends, 844
spatially resolved trends of, 309
sub-micrometre aerosol contribution to, 290
trends in (2000–2009), 308

Aerosol–radiation interactions* (ERFari)

contribution to total forcing from, 926
direct and indirect effects of, 852
marine cloud brightening effects, 860
model-based evidence, 950
top-of-atmosphere adjustments, 948

Aerosols*. *See also* **Particulate matter (PM)**;

Secondary organic aerosols (SOA)

agricultural sources of, 866
ammonia reactions in, 842
AR5 findings for, 844
atmospheric effects of light-absorbing, 1078
carbonaceous, 847–848
chemistry and microphysical processes, 833
composition of, 823
contribution to sea level change, 481
effective radiative forcing (1750–2014), 926
effective radiative forcing (1995–2014), 852
effects in SSP scenarios, 30
effects of decrease in, 1557
for solar radiation modification, 860
from sea spray, 858
historical effective radiative forcing of, 819
in dimming and brightening, 939
indirect effects in forcing, 948
instantaneous and radiation interactions, 950–956
interactions with radiation, 949
mineral dust abundance in, 858
net effect on radiation budget, 311
ocean heat uptake effects of, 1229
particle size in anthropogenic, 309
particulate matter in, 844
precursor sulphur gases in formation of, 845
proxy records of, 308
radiative forcing effects of, 823

regional emissions of, 1373
response to humidity in clouds, 952
sea-salt aerosol interactions, 478
short-lived climate forcers in atmosphere, 819
surface air temperature response (1995–2014), 856
total aerosol effective radiative forcing, 954
water cycle changes from anthropogenic, 1076–1078

Afforestation*/reforestation*. *See also*

Deforestation*

biogenic volatile organic compound emissions, 831
for CO₂ removal, 621, 698, 762
for negative emissions, 1528
freshwater requirements of, 699
in temperate regions, 310
precipitation effects in tropics, 698
regional water cycle alteration with, 1076
surface albedo effects of, 956

Africa

2°C warming effects on, 135
air pollution sources in, 869
assessment of projections, 1969–1970
Atlas, 1967–1971
attribution for trends in, 1968–1969
carbon monoxide burden in, 841
climate features and previous findings, 1967
climatic features in variability in, 1967
climatic impact-driver change in, 1791–1797
climatic impact-driver indices change, 1792
coastal and ocean related hazards, 1796
coastal erosion changes, 1796
confidence in climatic impact-driver changes, 1797
drought changes and human contribution, 1624
drought duration projections, 1120
extreme daily precipitation in, 1558
findings in AR5 and SR1.5 assessments, 1968–1969
glacier, snow and ice changes in, 135
global runoff projections, 1119
groundwater projections in South-western Africa, 1123
heat and cold changes in, 1791–1792
heat stress threshold projections, 1793
heavy precipitation and flooding in, 135
heavy precipitation changes by warming level, 1619
heavy precipitation projections, 1565
hot and cold extreme projections, 1556
model performance assessment, 1969
oceanic influences on climate, 1971
particulate matter emission sources, 821
precipitation and temperature change (1961–2015), 1971
precipitation projections for, 1795
projections for warming, 613
rainfall projections through 21st century, 1971
regional precipitation changes for, 135
regional solar radiation projections, 1791
regional wind projections, 135
sea level changes in, 135
snow and ice projections for, 1795
summary of changes, 122, 135, 1971
surface ozone and particulate matter projections, 882

- temperature and heat extremes in, 135
 temperature and precipitation changes, 1970
 temperature and precipitation changes for, 1967–1973
 temperature changes in, 1971
 temperature extremes in, 1548
 temperature increase projections, 1971
 tropospheric NO₂ levels over, 839
 warming level projections for temperature, 1613
 wet and dry conditions in, 1793–1794
 wind changes in, 135
 wind speed, severe wind and dust storm changes, 1795–1797
- African Easterly Waves (AEWs)**, 2198
- African Multidisciplinary Monsoon Analysis Model Intercomparison Project (AMMA-MIP)**, 2198
- Agricultural and ecological drought***
 African changes, 1624, 1794
 Asian changes, 1644, 1801
 attribution and projections for, 1518
 Australasian projections, 1662, 1809
 Central and South American changes, 1675, 1816
 European changes, 1686, 1823
 human contribution to, 8
 indices used for, 1783
 North American changes, 141, 1701, 1831
 projections for drying regions, 18
 regional observations of, 1575
 Small Islands changes, 1838
- Agriculture**
 atmospheric ammonia from, 828, 842
 greenhouse gas emissions from, 866
 heat and cold impact on, 1780
 heavy precipitation impact on, 1783
 methane production from, 821
 nitrogen cycle perturbation by, 708
 soil carbon loss with, 763
 solar radiation modification effects, 768
 surface effects of atmospheric CO₂, 1787
- Agriculture, Forestry and Other Land Use (AFOLU), emissions from**, 188, 866
- Airborne fraction of CO₂* (AF)**
 constraint of carbon-climate feedbacks, 681
 in CO₂ removal, 760
 ocean and land sinks determination of, 744
 perturbation of, 760
- Air pollution***. *See* **Air quality–climate interaction**
- Air quality–climate interaction**
 anthropogenically driven climatic impact-driver effects on, 1787
 AR5 and AR6 assessment of, 41, 825
 assessment of future air pollution change, 892
 capture by CMIP6 simulations, 835
 climate response to policies on, 872
 cooking and heating emissions in, 866
 decarbonization strategies, 875
 decarbonization strategies for, 822
 dedicated policy for air quality, 889, 890, 891
 effects on short-lived climate forcer warming, 892
 extreme pollution criteria, 863
 future emissions policy for control of, 1790
- implications of COVID-19 for, 875–878, 876
 links to climate change limitation, 896
 meteorology change effects on, 861
 precursor emissions driving of, 820
 projections for effects of, 103
 regional source attribution for, 869
 response to mitigation, 864
 response to short-lived climate forcers in SSPs, 103
 scenarios for air quality control, 820
 short-lived climate forcer patterns, 829
 sulphate aerosol effects on, 845
- Air–sea CO₂ flux**
 atmospheric CO₂ effects on (1960–2018), 691
 ocean circulation shaping of, 745
 predictability of, 742
- Air–sea fluxes**
 assessment approach for, 692
 biases in modelling of, 1225
 observations and inference of, 1224
 ocean circulation effects on, 745
 regional ocean storage for CO₂, 693
 air–sea heat flux
 Atlantic Meridional Mode driving by, 2168
 effects in subantarctic mode water, 1235
 estimates of net air–sea flux, 1224–1225
 patterns of, 1224
- Albedo***
 carbon dioxide removal effects on, 100
 enhancement of surface albedo, 624
 feedback contribution to Greenland Ice Sheet melt, 1257
 land cover change effects on, 188, 310
 surface-albedo feedback, 971
 surface-based solar radiation modification, 629
- Alcohols, emissions of**, 831
- Aldehydes, emissions of**, 831
- Aleutian Low**
 Arctic Oscillation and, 2156
 El Niño–Southern Oscillation effects on, 2164
 Pacific Decadal Oscillation and, 2171
 Pacific Decadal Variability effects and, 2174
 proxy reconstructions of, 2174
- Alkanes, C₂–C₃ and C₂–C₅ trends**, 841
- Alkenes, emissions of**, 831
- Alkenone δ¹³C proxies**, 299
- Aluminium oxide (Al₂O₃), stratospheric injection***, 627
- Amazon region**
 climate features of, 1994
 deforestation and drying in, 1149
 dry-season length trends, 1995
 fire weather projections for, 1817
 impact of forest dieback, 740
 meteorological drought projections, 1119
 Pacific Decadal Variability effects on, 2174
 seasonal change of water cycle in, 1058
 warming projections for basin, 1997
 warming trend in, 1995
- Ammonia (NH₃)**
 estimated radiative forcing from, 854
 indirect climate forcing by, 823
 sources and trends in atmosphere, 842
- Ammonium (NH₄⁺)**
 aerosol formation by, 846
 in sulphate partitioning, 845
- Ammonium nitrate (NH₃) aerosols**
 concentration patterns of, 846
 particulate evaporation warming, 863
- Ammonium sulphate aerosols**
 formation, 846–847
- Amundsen-Bellinghousen Seas**, 1236
- Amundsen Sea Embayment (ASE)**, 1265
- Amundsen Sea Low**, 1240
- Amur River region**, 1977
- Andes**
 frost line height for, 1850
 glacier mass change in, 1122, 1275
 historical snow cover studies in, 1817
 permafrost thawing in, 140
 warming projections for, 1997
 warming trends in, 1995
- Anomalies***
 air temperatures in CMIP models and observations, 441
 around Labrador Sea, 2176
 concurrent global-scale case study, 1601
 definition and use of, 189–191
 in equatorial Indian Ocean, 2167
 land CO₂ sink and air temperature (1980–2019), 696
 precipitation relative to average (1995–2014), 574
 surface air temperature in CMIP models, 572
 time series for temperature, 1523
 wet and dry region tropical precipitation, 454
 with El Niño–Southern Oscillation, 2162, 2174
 zonal average annual mean precipitation, 455
- Anoxia/anoxic zones (of ocean)**. *See* **Ocean deoxygenation***
- Antarctic**
 assessment and synthesis of projections, 2021
 Circumpolar Deep Water shoaling and warming, 1236
 climatic features of, 2016
 heat and cold extremes in, 1308, 1844, 1847
 ice-shelf melt in, 1214, 1268
 model performance assessment, 2019
 models used in intercomparison studies, 2110
 observations, trends and attribution, 2017
 pCO₂ rise at the onset of last deglacial transition, 686
 previous IPCC assessments, 2017
 sea ice area (1979–2017), 469
 sea ice coverage, 1251–1252
 summary of changes, 127, 142, 2025
 temperature and precipitation changes in, 2016
 upwelling around, 1222
 warming compared to Arctic, 927
 warming of, 1844, 2022
- Antarctic abyssal ventilation, effects on oceanic heat budget**, 1233
- Antarctica ISMIP6**, 2108
- Antarctic Bottom Waters (AABW)**
 changes in volume and temperature, 1235
 in Circumpolar Deep Water formation, 1236

- ventilation in last deglacial transition, 715
- warming projections for, 1230, 1233
- Antarctic Circumpolar Current (ACC)**
 - sensitivity to winds, 1239
 - Southern Hemisphere atmospheric jet effects, 1240
 - Southern Ocean circulation and, 485, 1235
- Antarctic Ice Sheet* (AIS)**
 - anthropogenic effects on, 472, 1266
 - carbon–climate feedback information from, 684
 - changes in extent of, 468
 - CMIP5 and CMIP6 modelling of, 467
 - confidence level for projections, 1252, 1253
 - contribution to sea level change, 1220, 1270, 1271, 1270–1273, 1298
 - cumulative emissions effects on, 21
 - drivers of future change, 1267–1272
 - during Last Interglacial period, 1294
 - evaluation of model simulations, 1266–1268
 - feedbacks associated with, 977
 - historical development and retreat of, 294, 1269
 - historical record and CMIP projections, 1252
 - ice-sheet instability, 1269
 - ice-shelf disintegration, 1268
 - ice-shelf melt rates and projections for, 1267
 - low confidence ice-sheet projections, 1299
 - mass change and change rate for, 1255
 - mass change and sea level contribution, 1264
 - mass loss (1992–2020), 1215
 - mass loss and change rate for, 77, 187, 188
 - projections to 2100 and beyond, 1272–1273
 - recent observed changes, 1263–1265
 - response in emissions scenarios, 1270
 - snowfall and glacier flow in mass change, 1264
 - Southern Annular Mode modulation of, 2159
 - sub-shelf melting, 1268
 - sulphate records from, 298
 - trends and interannual variability, 1215
 - uncertainties in sea level and cryosphere change, 1314
- Antarctic intermediate water (AAIW)**
 - formation of, 1235
 - warming projections for, 1233
- Antarctic Oscillation* (AAO)**, 2159. *See also*
 - Southern Annular Mode* (SAM)**
- Antarctic Peninsula (AP)**
 - calcium carbonate undersaturation, 721
 - Circumpolar Deep Water effects on, 1236
- Anthropocene* geological epoch**, 161
- Anthropogenic aerosols**
 - Atlantic Multi-decadal Variability index, 427
 - effects on cloud properties, 952
 - global monsoon land precipitation effects, 426, 463
 - large-scale water cycle changes with, 1057
 - radiative effects on precipitation, 1076
 - regional patterns of emission, 1373, 1374
 - surface solar radiation changes with, 939
- Anthropogenic carbon dioxide (CO₂)**
 - airborne fraction growth, 681
 - airborne fractions, 690
 - atmospheric accumulation of, 690
 - climate impacts on ocean uptake of, 728
 - invasion of depth, 717
 - land and ocean uptake scenarios, 20
 - ocean absorption of, 693, 714
 - ocean acidification effects, 608
 - ocean and land sink driving by, 681
 - removal for net zero emissions, 29
 - sea–air CO₂ flux and storage, 693
 - sources of, 687–689
- Anthropogenic forcing**
 - agents contributing to, 956
 - atmospheric aerosol concentration changes, 676
 - attribution of, 438–445
 - CO atmospheric burden, 841
 - cooking and heating emissions, 866
 - cooling trend in Northern Hemisphere, 438
 - estimates for 1850–1900, 193
 - evapotranspiration projections, 1117
 - global and regional trends (1850–2000), 827
 - greenhouse gases in, 712, 1414
 - in emerging signal detection, 1853
 - in hydrological deficits, 1578
 - land-based transportation contribution to, 868
 - land water storage changes, 1288
 - large-scale precipitation changes, 456, 1563
 - local effects on temperature variability, 438
 - ocean effects on Earth system, 1841
 - ocean heat content gains (since 1970s), 1228
 - ocean heat content increase from, 714
 - of atmospheric modes of variability, 1374
 - of regional temperature extremes, 1553
 - over industrial era (1750–2019), 926
 - ozone-depleting substances in, 445
 - regional response to warming level, 1543
 - regional temperature change (since 1950), 1423
 - short-lived climate forcers in, 827, 829
 - signal emergence in oceanic regions, 1855
 - since pre-industrial era, 948
 - soil moisture drying effects of, 1578
 - solar radiation modification effects on, 679
 - sulphur dioxide transport to stratosphere, 845
 - surface melting in Greenland from, 1258
 - surface warming trend (1998–2012), 425
 - top-of-atmosphere budget imbalance, 933
 - tropical cyclone effects of, 1588
 - warming contribution in scenarios, 13
 - warming over uninhabited continents, 441
 - water cycle changes from, 1057
 - western boundary currents and gyre shifts, 1241
 - wind stress changes with, 1214
- Anthropogenic signal emergence**
 - at regional scale, 1423, 1424
 - internal variability delay of emergence, 1427
 - in the Combined Extreme Index (CEI), 1552
 - time of emergence for, 1853
- Approximate Partial Radiation Perturbation technique, quantification of ERF_{ari}**, 950
- Arabian basins, tropical cyclone activity in**, 1589
- Arabian Peninsula (ARP)**, trends and projections for, 1983–1986
- Aragonite saturation state (Ω_{arag}) change**
 - in Arctic Ocean and Southern Ocean, 720
 - in Atlantic Ocean, 721
 - in Pacific Ocean, 717, 721
 - in subpolar and polar ocean zones, 717
 - undersaturation at high latitudes, 634
- Arctic**
 - areas included in, 2022
 - assessment and synthesis of projections, 2024
 - black carbon model estimates for, 848
 - climate change signal for sea ice in, 1855
 - climatic features of, 2022
 - CMIP models estimation of warming, 431
 - extreme heat and cold events in, 1550, 1847
 - high-warming storylines for, 637
 - influence on mid-latitude climate, 1379
 - model performance assessment, 2023
 - observations, trends and attribution for, 2023
 - previous IPCC assessments, 2022
 - seasonal duration changes in, 1847
 - summary of changes, 127, 142, 2022
 - surface warming projections, 556
 - temperature and precipitation changes in, 2016
 - warming changes in, 596
 - warming compared to Antarctic, 927
 - warming compared to global rate, 15, 856, 1844, 2025
- Arctic amplification***
 - compared to global level of warming, 613
 - mechanisms contributing to, 596
 - mid-latitude climate effects, 1380
 - Southern and Northern Hemisphere gradient, 982
 - uncertainty in projections, 596
- Arctic cloud feedback**, 974
- Arctic Ocean (ARO)**. *See also* **Polar regions**
 - carbonate chemistry measurements in, 717
 - deepening of the mixed-layer, 1226
 - dynamic sea level change in, 1247
 - in polar climate regions, 2016
 - liquid freshwater column projections for, 1842
 - marine heatwave frequency projections, 1227
 - ocean acidification in, 720, 722
 - ocean heat content changes in, 1231
 - sea ice change in, 1251
 - sea ice projections (2081–2100), 557
 - sea ice projections at 1.5°C to 2°C warming, 1217
 - sea surface temperature change, 1222
 - stratification changes in, 1226
 - surface salinity projections, 1842
- Arctic Oscillation* (AO)**, 489, 2156. *See also*
 - Northern Annular Mode* (NAM)**
- Arctic sea ice**
 - abrupt and seasonal changes in, 634
 - Atlantic Multi-decadal Variability effects on, 2177
 - current coverage and projections, 76, 291, 586
 - detection and attribution studies on, 466
 - historical records and CMIP6 projections, 1248
 - human influence on, 466–468
 - indication of climate change, 574, 1247–1251
 - internal variability role in models, 467
 - lack of tipping point for loss, 1251
 - main driver for loss of, 426
 - model mean and trend for (1979–2017), 467
 - scenario extension (to 2300), 633
 - scenario projections for, 586

- sea ice volume and thickness, 1251
simulations in Earth system models, 575
temperature threshold for loss, 1249
volume change (since 2003), 1251
- Argo program**, 1234
- Aridity* and desertification**
African changes, 1794
Asian changes, 1800
Australasian changes, 1808
biodiversity effects from, 1849
Central and South American changes, 1816
changes with 2°C global warming, 143
climatic drivers of, 1073, 1849
emergence of signals for, 1854
European changes, 1823
indices used for tracking, 1783
model projections for, 1119
North American changes, 1831
polar terrestrial region changes in, 1844
poleward shift of dryland areas, 1849
Small Islands changes, 1838
temperature increase in semi-arid regions, 15
- Asia**
aerosol optical depth trends, 845
agricultural and ecological droughts in, 1801
air quality/pollution in, 822
air temperature and precipitation changes (1995–2014), 1972
ammonia transport in monsoon region, 842
climatic impact-driver changes with 2°C warming, 138
climatic impact-driver indices projections, 1798
climatic impact-drivers change projections, 1804, 1799–1807
coastal/oceanic related projections for, 1812
cold-day/warm-day trends in, 1973
drought changes with warming levels, 1644
extreme precipitation with warming levels, 1565
heat and cold changes with 2°C warming, 138
heat and cold events, 1799–1801
High Mountain glacier mass loss estimates, 1275
hot and cold extreme projections, 1548, 1556
NH₃ emissions drivers in, 829
NO₂ increases in (1996–2011), 839
particulate pollution and winter conditions in, 864
precipitation and river flood changes in, 1801
precipitation and temperature projections, 1971
precipitation links to Southern Annular Mode, 2161
regional monsoon projections, 19
regional snow and ice changes, 139
regional solar radiation projections, 1791
regional temperature and precipitation changes, 1971–1988
regional temperature extreme studies, 1552
regional wet and dry projections, 138
regional wind changes in, 139
regional wind speed changes, 138
relative sea level changes for, 139
shoreline retreat and progradation in, 139
short-lived climate forcer emissions, 829
snowfall/snow melt trends in, 1973
- sub-continental areas of assessment, 1971
sulphate aerosol concentrations in, 846
sulphur dioxide trends in, 843
summary of changes, 123, 138, 1986
surface air temperature and precipitation changes, 1989
surface air temperature projections, 1978
surface air temperature simulations for, 1978
temperature extreme trends and projections for warming level, 1631
warm/cool days trends in, 1978
- Atlantic Equatorial Mode***, 501. *See also* **Atlantic Zonal Mode* (AZM)**
- Atlantic Inter-tropical Convergence Zone**, 1967
- Atlantic Meridional Mode* (AMM)**
air–sea heat fluxes driving of, 2168
AR5 findings for, 375
boreal summertime, 2170
climate variability and, 2156
CMIP simulations of, 501
proxy-based reconstruction of, 2171
sustained changes to variability, 375
tropical Atlantic climate variability, 2168
- Atlantic Meridional Overturning Circulation* (AMOC)**
21st century projections for, 1214
change relative to 1850–1900, 1237
deep ocean ventilation in last deglacial transition, 715
Gulf stream and, 1321
heat and carbon storage in North Atlantic, 745
heat transport in climate system, 483, 1232
in ice ages, 160
in South and North Atlantic oceans, 1236–1240
likelihood of weakening and abrupt collapse, 427
links to Atlantic Multi-decadal Variability, 2174
mean state, variability and long-term trends, 484
North Atlantic Oscillation fluctuations and, 2159
ocean heat content change, 1232
precipitation response to collapse, 1149
projections for weakening with CMIP simulations, 576
RAPID Array measurements, 1238
response to anthropogenic forcing, 485
response to stabilization of warming, 106
strength and sensitivity to resolution and forcing, 1238
water cycle response to collapse of, 1148
water cycle shifts in paleoclimate records, 1059
weakening and abrupt collapse likelihood, 611, 1149, 1239
- Atlantic Multi-decadal Oscillation* (AMO)**
definition of, 2176
influence in Russian Far East climate, 1976
influence on European climate, 1998
- Atlantic Multi-decadal Variability* (AMV)**
aerosol contribution to, 427, 1237
Atlantic Inter-tropical Convergence Zone shift and, 2177
Atlantic Niños modulation by, 589
based on index (1900–2014), 2175
changes in indices, 376
climate driver for South America, 1994
climate variability and, 2156
CMIP simulations, 504–506, 590
contribution to precipitation in Caribbean, 1991
definition of mode, 2174
drivers of regional climate change, 1374
external forcing on, 505
Mediterranean and North Africa climate effects, 1968
model evaluation of, 505
North Atlantic anomalous warming, 2174
North Atlantic Oscillation connection, 2159
phases of timeseries, 2176
precipitation changes in regional climates, 2177
projections for, 612
sub-polar branch near-term predictions and projections, 557
teleconnections and regional influence of, 2176
temporal evolution of, 2176
- Atlantic Niño***, 501. *See also* **Atlantic Zonal Mode* (AZM)**
El Niño–Southern Oscillation relationship, 2164
- Atlantic Ocean**
eutrophication effects in, 721
hurricane activity, 1588–1589
North and South Atlantic salinity projections, 1842
projections for salinity change in, 1844
regional acidification in, 717, 721
- Atlantic Warm Pool**, 1991
- Atlantic Zonal Mode* (AZM)**
Atlantic Niño, 375, 2168
CMIP model simulations of, 501
Indian summer monsoon rainfall, 2171
link with El Niño–Southern Oscillation, 2171
proxy-based reconstruction of, 2171
sea surface temperature anomalies, 2169
sustained changes to variability, 375
tropical Atlantic climate variability, 2168
wind field over the equatorial Atlantic, 2168
- Atmosphere***
annual mean temperature of, 598
assessment of CMIP simulations by scenario, 571–573
atmospheric water budget projections, 1108
indicators of changes in climate systems, 312
in physical climate system, 157
lifetime of regional aerosols in, 1373
mid-, near- to long-term global change in, 583, 595–608
ocean buffering of volcanic eruption response, 1232
oxidizing capacity of, 848
simulations of indicators for change, 570, 571–573
thermodynamic constraints on moisture fluxes in, 1067
upper air temperature/circulation changes, 70
water exchange in, 158
- Atmosphere–land CO₂ fluxes**
changes in terrestrial cycle, 486
- Atmosphere–ocean coupling**
CO₂ release into atmosphere, 744
in tropical cyclone evolution, 1588

- in tropical oceans, 1241
 - regional sea surface temperature effects, 1223
 - regional temperature variations, 1222
 - Atmosphere–ocean–ice model systems in Baltic area, 2001**
 - Atmospheric-based drought indices, 1572, 1578, 1582**
 - Atmospheric chemical composition**
 - chemical adjustments by short-lived climate forcers, 825
 - in situ and remotely sensed observations of, 833
 - short-lived climate forcer sources and sinks, 825
 - Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP) models, 830, 851**
 - Atmospheric CO₂ concentrations**
 - after cessation of CO₂ emissions, 631
 - and natural carbon sinks, 771
 - anthropogenic effects on seasonal cycle, 487
 - changes at surface, 1791
 - changes in deep past and next 300 years, 44
 - changes in remote locations, 689
 - characteristics of last 50 Myr, 684
 - concentration by reference period, 299
 - during last deglacial transition, 715
 - evolution through last 450 million years, 300
 - geological carbon sources for, 686
 - geological versus current comparison, 300
 - glacial–interglacial fluctuations, 300
 - human activities role in growth, 689
 - increase in all SSPs, 135
 - in paleoclimate reconstructions, 159
 - isotope proxy reconstructions of, 298
 - land and ocean sinks regulation of, 680
 - land carbon storage effects of, 677
 - last millennium (1000–1750), 299
 - leaf-level photosynthesis effects, 697, 722
 - levels in recent times, 8
 - mid-Pliocene and Early Eocene, 683
 - ocean and land carbon sink effectiveness with accumulation, 19–20
 - paleoclimate mixing ratios, 299
 - paleo period reference ranges, 1292
 - past growth rates and projections, 683
 - photosynthetic response to, 486
 - plant growth effects of, 722, 1787
 - pre-industrial regulation of, 684
 - present-day concentrations of, 290
 - reconstruction over past 800 kyr, 160
 - response to CO₂ emissions and removals, 761
 - seasonal cycle of, 427, 487
 - seawater pH changes with, 716
 - simulated changes in climate indices, 617
 - solar radiation modification effects, 679
 - terrestrial cycle changes and, 486
 - threshold for regional ice-sheet development, 684
 - Atmospheric concentrations (abundances)**
 - carbonaceous aerosols reliance on models, 848
 - carbon cycle and indirect contributions, 1013
 - carbon from peat soils, 725
 - CO₂, CH₄ and N₂O in ice cores, 685
 - CO₂, CH₄ and N₂O projections in SSPs, 2144
 - CO₂ concentrations by reference periods, 299
 - evolution of short-lived climate forcers, 819, 833–835
 - geographical distribution of emissions, 819
 - historical abundances and forcing of halons, 2143
 - historical abundances and forcing of NF₃, SF₆ and perfluorocarbons, 2141
 - historical CO₂, CH₄ and N₂O abundances and forcing, 2141
 - historical hydrofluorocarbons and forcing, 2143
 - hydrofluorocarbons historical abundance and forcing, 2142
 - implications of COVID-19 restrictions for, 875
 - methane growth rates, 701
 - metrics for evaluation of emissions, 1011
 - N₂O and isotope composition (since 1940), 709
 - N₂O in troposphere, 708
 - regional emissions of greenhouse gas, 713
 - short-lived climate forcer projections, 878
 - Atmospheric energy balance, forcing response, 1065**
 - Atmospheric evaporative demand (AED)**
 - continental increases in, 1575
 - effects of warming over land, 1057
 - in drought events, 1570, 1571
 - intensification of drought events, 1573
 - projections for, 1580
 - Atmospheric global climate models (AGCMs), 1389**
 - Atmospheric Infrared Sounder (AIRS), 209, 327**
 - Atmospheric Model Intercomparison Project (AMIP), 459, 1551**
 - Atmospheric oxidizing capacity, 848–851**
 - Atmospheric rivers* (ARs)**
 - definition of, 1103
 - in water cycle, 1133
 - moisture transport by, 1103
 - rain rates with warming, 1519
 - warming effects on, 1058
 - Atmospheric simulation chambers, 833**
 - Atmospheric Tomography Mission (ATom), 209**
 - Attribution*, 431. See also Detection* and attribution***
 - Australasia**
 - agricultural and ecological droughts, 1809
 - assessment and synthesis of projections, 1989–1990
 - Atlas, 1986–1989
 - changes in climatic impact-driver indices, 1806, 1813
 - climate features and sub-regions, 1986
 - climate model performance assessment, 1989
 - climatic impact-driver assessment for, 1805–1812
 - climatic impact-driver changes with 2°C warming, 139
 - coastal and oceanic climatic impact-driver changes, 1811
 - coastal and ocean related hazards, 1812
 - drought trends and projections by warming level, 1662
 - findings from previous IPCC assessments, 1986
 - global warming trends for, 1987
 - greenhouse gas emissions for, 713
 - hazards from human-induced change, 1987
 - heat hazards in, 1807
 - heavy precipitation changes, 1559, 1565, 1659
 - marine heatwaves, 140, 1812
 - observations, trends and attribution, 1987
 - projections for hot and cold extremes, 1556
 - summary of changes, 124, 139, 1990
 - temperature and precipitation change, 1989
 - temperature changes in, 1549
 - temperature extremes and warming levels, 1655
 - trends in mean annual temperature, 1988
 - warming over the last century, 1987
 - Australian-Maritime Continent monsoon* (AusMCM)**
 - anthropogenic aerosol forcing in simulation, 1131
 - austral summer occurrence of, 2199
 - characteristics of, 2199
 - observed variability and changes in, 1099
 - Aviation**
 - assessment of climate forcing by, 867
 - contrail production by, 956
 - Aviation-specific absolute global temperature change potential (AGTP), 867**
 - Azores High, 2156, 2159**
- ## B
- Baltic Sea**
 - hypoxia in, 722
 - projections for freshening in, 2002
 - Barents-Kara Sea, 1976**
 - Barotropic stream function simulation, 1242**
 - Barystatic* sea level change, 1220**
 - Baseline and reference periods***
 - alternative recent baselines (1986–2005), 192
 - approximate pre-industrial (1850–1900), 299
 - AR5 20-year baseline (1986–2005), 1935
 - AR6 20-year baseline period (1995–2014), 1935
 - climate normal period (1981–2010), 1935
 - comparing observations and model simulations, 190
 - Early Eocene Climatic Optimum, 299
 - for future time slice and global warming levels, 1935
 - future periods (AR6), 192
 - historical (1961–1990), 1935
 - last 100 years (1919–2019), 299
 - Last Deglacial Transition, 299
 - Last Glacial Maximum, 299
 - Last Interglacial, 299
 - last millennium (1000–1750), 299
 - long-term (2081–2100) projections, 1936
 - Mid-Holocene, 299
 - mid-Pliocene Warm Period (KM5c), 299
 - mid-term (2041–2060) climate, 1936
 - modern (1995–2014), 299
 - near-term (2021–2040) projections, 1936
 - Paleocene–Eocene Thermal Maximum, 299
 - paleoclimate, 45, 295
 - paleoclimate and recent periods, 45

- pre-industrial (1750) greenhouse gases, 676
pre-industrial (1851–1900), 1936
recent decades (2010–2020), 1936
recent past (1986–2005) for AR5, 1935
recent past (1995–2014), 1935
since 2014 (last historical simulations), 1935
surface temperature, CO₂ concentration, and sea level ranges, 1292
warming comparisons (1850–1900), 612, 1935
World Meteorological Organization 30-year climate normal, 1935
- Baseline Surface Radiation Network**, 939
- Bayesian model averaging**, 430
- Bay of Bengal (BOB)**, 1978
- Bering Sea/Strait**, 1243, 2174
- Bias adjustments**
at top-of-atmosphere for climate drivers, 943
climate model simulations, 1945
cold bias in some Regional Climate Models, 1982
definition used in AR6, 941
dynamical methods for, 1415
for downscaling, 1412
for snow water equivalent uncertainty, 1284
in regional climate modelling, 1391
model biases with dynamic models, 1394
observational uncertainty and internal variability, 1413
rainfall biases in climate simulation, 1982
relevance and limitations of, 1411–1415
systematic biases identified, 428
to stratosphere aerosol optical depth, 958
to top-of-atmosphere CO₂ forcing, 945
tropospheric effects on effective radiative forcing, 925
- Bifurcation tipping***, 202
- Biochar production**, 763
- Biodiversity* hotspots**
AR6 definition of, 1848
deserts and semi-arid areas, 1849
hotspot change with 2°C warming, 143
tropical forests, 1850
- Bioenergy with carbon capture and storage* (BECCS)**, 698, 763, 1528
- Biogenic/microbial processes**
anaerobic ammonium oxidation, 719
methane uptake by soil, 704
nitrification/denitrification of soil, 830
- Biogenic nitrification processes**, 830
- Biogenic volatile organic compounds* (BVOCs)**
contribution to land use forcing, 956
emissions from forests, 825
environmental change effects on, 831
plant emission rates, 831
production of, 859
sources and effects of, 825
temperature effect on emissions, 863
vegetation emissions of, 831
- Biogeochemical/biogeophysical feedbacks**
assessment for emissions reduction, 857
changes of surface temperature in, 967
CO₂ and non-CO₂, 739
developments for future assessments, 769
from CH₄ and N₂O sources and sinks, 737
links to physical climate variables, 975
on climate change, 722
vegetation change effects in, 976
- Biogeochemical cycles**
abrupt change and tipping points in, 741
alteration by short-lived climate forcings, 824
AR6 Working Group I (WGI) assessment, 153
carbon dioxide removal termination, 679
effects of CO₂ removal methods, 678, 762
effects of solar radiation modification, 769
human activity effects on, 676
in Earth system processes, 154
response to perturbations, 678
short-lived climate forcings effects on, 819
tipping points and change impacts, 739
- Biological carbon dioxide removal methods**, 762–763
- Biological carbon pump* (BCP)**
carbon sink for anthropogenic carbon, 744
climate feedback from alterations of, 729
during Last Glacial Maximum, 715
during past ice ages, 685
for long-term CO₂ storage, 729
in biogeochemical feedback on climate change, 770
in mid-Pliocene Warm Period, 684
- Biomass* burning emissions. See also Wildfires/ biomass burning**
biochar effects on soil carbon, 763
carbonaceous aerosols from, 825
contribution to air pollution, 869
emissions from tropical forest fires, 832
patterns of carbon monoxide from, 841
percentages of global emissions, 832
regional ammonia in, 842
short-lived climate forcer emissions (1850–2100), 879
trends in emissions from, 832
uncertainty in effects of, 833
- Biosphere***
global changes in terrestrial, 292
human influence on, 427, 485–489
in physical climate system, 157
large-scale indicator of change, 314
large-scale warming in, 82
observational capability improvements, 210
- Bipolar seesaw***, 160
- Bjerknes feedback**, 476, 589, 2167, 2168
- Black carbon* (BC)**
changes in Northern Hemisphere, 819
contribution to aerosol–cloud interactions, 949
deposition on snow, 893, 957
diesel versus gasoline vehicle emissions, 868
effective radiative forcing by, 847
emissions trends for, 828
emissions with fossil fuel use, 829
in regional warming patterns, 1373
interaction with aviation cirrus, 867
lower atmosphere effects of, 1077
model simulations of burdens, 848
reduction effects on warming, 825
- Blocking***. See **Storm tracks* and blocking***
- Bølling/Allerød (B/A) warm interval**, 685
- Boreal summer intra-seasonal oscillation (BSISO)**, 2177
- Boron isotope (δ¹¹B)**
decrease in sea-surface pH, 715
proxy analysis for, 298
ratio reconstruction from coral, 715–716
- Bottom-up (BU) estimation, global methane sink**, 835
- Brewer–Dobson circulation***
climate-ozone feedback, 858
projections for strengthening of, 599
transport of volcanic aerosols, 1373
- Brightening (solar radiation*)**. See also **Solar radiation modification* (SRM)**
decadal variation in observations, 1791
in Europe and Mediterranean region, 1999
multi-decadal solar radiation changes, 938
- Bromine**, 843
- Bromoethane (CH₃Br) abundance and forcing**, 2143
- Brown carbon (BrC) aerosol**, 847
- Buffering capacity of the ocean**, 744
- Buoyancy fluxes**, 2159
- ## C
- calcite (CaCO₃) for stratospheric injection**, 627
- Calibrated language**. 169 See also **Uncertainty***
- Calibrated simple climate models comparisons**, 965
- CanESM2 large ensembles**, 222
- Cape Town drought (case study)**
anthropogenic and natural drivers, 1441
global simulations, 1442
historical and projections for rainfall, 1440
historical simulation and attribution, 1442
information distilled from multiple lines of evidence, 1443
motivation and regional context, 1439
observational issues, 1441
regional climate information construction, 1439
regional downscaling, 1442
storyline approaches, 1442
- Carbonaceous aerosols**
atmospheric distribution of, 848
black carbon and organic aerosols, 825
components of, 847–848
effective radiative forcing from, 847
emissions trends for, 828
impact from residential burning, 866
trends at background observation sites, 847
- Carbonate chemistry (in seawater)**
basis for the carbon–heat nexus, 746
biological processes and drivers, 720
CO₂ spread into ocean interior, 717
excess CO₂ effects on, 723
processes involved in, 714
projections for changes in, 745
shoaling effects on, 717
- Carbon budget***. See also **Remaining carbon budget***
CMIP scenario simulations for uptake and storage, 587

- factors affecting remaining value of, 678
 - for climate stabilization, 678
 - for limiting global warming, 676
 - global budget (2010–2019), 700
 - historical emissions and remaining budget, 29
 - ocean storage of, 473
- Carbon–climate feedbacks***
 - carbon-concentration and feedbacks map, 735
 - compartments, processes and pathways in, 682
 - decomposition rate changes, 725
 - estimates of fire-driven effects, 725
 - in nutrient limited ecosystems, 725
 - modelling estimates of wildfire effects on, 724
 - partitioning of CO₂ airborne fraction, 681
 - physical and biogeochemical processes in, 681
 - projections of effects on climate change, 677
 - warming effect on fire carbon emissions, 724
- Carbon cycle***
 - biological carbon pump effects, 729
 - carbon reservoirs in paleoclimate, 47
 - climate change effects of feedback from, 677
 - CMIP6 Earth system model properties, 730
 - CO₂ removal processes in, 756
 - constraints in Earth system models, 736
 - Earth system model projections, 730
 - feedback interactions in, 682
 - fluxes in climate system, 758
 - historical simulations of (1850–2014), 486
 - human-induced changes in, 79–83
 - interaction with water cycle, 697
 - land-use change influence on, 485
 - long-term extension scenarios, 741
 - long-term response of, 741
 - outgassing of CO₂ from sinks, 757
 - ozone–vegetation interactions in, 857
 - processes and projections for, 81
 - removal and emission relationships, 678
 - response to CO₂ removal, 758, 759
 - response to emissions and removal, 761
 - response to indirect contributions, 1013
 - response to instantaneous CO₂ removal, 759
 - scenario-dependent feedbacks, 95
 - shifts during Cenozoic period, 294
 - short-lived climate forcers effects, 820, 857
 - sink response with net CO₂ removal, 760
 - solar radiation modification effects, 768
 - terrestrial cycle change indicators, 485–487
 - trajectory dynamics beyond 2100, 741
 - tropospheric aerosol effect on climate, 857
- Carbon-cycle feedbacks**
 - physical and biogeochemical processes in feedback, 681–698
- Carbon dioxide (CO₂)**
 - airborne fraction of, 676
 - anthropogenic and biomass burning emissions (1850–2100), 879
 - anthropogenic fraction of, 676
 - anthropogenic sources of, 687
 - atmospheric change in last century, 686
 - atmospheric concentration and growth of, 683
 - climate change and, 150
 - concentrations (2019), 290
 - concentrations in ambient air, 690
 - cumulative emissions and temperature relationship, 624
 - direct effect on land carbon uptake, 722
 - direct effects on ocean carbon uptake, 723
 - during 450 Ma to 800 ka, 298
 - during Carboniferous and Permian periods, 299
 - early Holocene period concentrations, 687
 - effective radiative forcing and, 312
 - effective radiative forcing by, 944
 - effective radiative forcing estimates, 853
 - effective radiative forcing for 2×CO₂, 945
 - effects oceanic heat budgets, 1233
 - effects of net negative CO₂ emissions, 242
 - equilibrium warming pattern under forcing, 989
 - forcing of polar amplification, 987
 - fraction of well-mixed greenhouse gases, 303
 - from human activities, 180, 676
 - future abundances for SSPs (2020–2500), 2144
 - global anthropogenic emissions, 688
 - historical abundances and radiative forcing, 2141
 - historical and future concentrations, 682
 - historical emissions and remaining carbon budget, 29
 - indirect and direct carbon dioxide forcing, 857
 - initiation of carbon dioxide removal, 621
 - land use, land-use change and forestry emissions, 689
 - last glacial and deglacial transition, 300
 - limiting warming to below 2°C, 189
 - long-term temperature effects, 821
 - ocean acidification by absorption, 714
 - ocean storage trends and variability, 1573
 - partial pressure in detection and attribution, 489
 - permafrost thawing, 677
 - polar amplifications with, 985
 - probability distribution of effective radiative forcing with doubling, 994
 - proxy records for estimates of, 299
 - quantifying past accumulation rate, 683
 - radiative efficiency change, 947
 - remineralized CO₂ storage in ocean, 685
 - seasonal cycles in high-latitude regions, 726
 - sensitivity to climate, 686
 - solar radiation modification effects on sinks, 679
 - stratospheric-temperature-adjusted radiative forcing revision, 944
 - surface CO₂ mixing ratio trends, 303
 - temperature change with cessation, 618
 - trends, variability and budget, 687
 - tropospheric adjustments effect on effective radiative forcing, 925
 - variability in uptake, 487
- Carbon dioxide (CO₂) budget**
 - estimates of flux components in, 699
 - industrial era accumulation, 699
 - proxy estimates accumulation rates, 299
 - sources and sinks, 699, 700
- Carbon dioxide (CO₂) fertilization***
 - nutrient availability limitation of, 723
 - photosynthesis effects of, 768
 - projections for land carbon uptake (1869–2100), 723
- Carbon dioxide (CO₂) sink**
 - anomalies of net land sink and air temperature (1980–2019), 696
 - drought effects on terrestrial, 697
 - ocean and land transition to source, 677
 - restoration of peatlands for sequestration, 763
- Carbon dioxide removal* (CDR)**
 - afforestation/reforestation for, 698
 - anthropogenic activities, 755
 - assessments of feasibility for, 770
 - biogeochemical implications of, 678
 - biogeochemical responses to, 755
 - characteristics of methods for, 756
 - chemical methods for, 765
 - climate response to mitigation, 619, 621
 - decadal mean for the global ocean sink, 692
 - delayed climate response to net-negative emissions, 623
 - effectiveness of, 760
 - effects of land-based biological removal methods, 762
 - effects on land and ocean stores of CO₂, 678
 - effects on water cycle, 698
 - for net zero CO₂ emissions, 99–100
 - geochemical methods for, 764
 - impact for climate mitigation, 681
 - methods and carbon storage time scale, 766
 - net negative CO₂ emissions from, 622
 - ocean-based biological methods for, 764
 - overshoot effects, 618
 - perturbation airborne fraction metric for, 760
 - ramp-up, ramp-down simulations for, 633
 - removal effectiveness, 761
 - removal of anthropogenic CO₂, 29
 - reversal of ocean acidification by, 720
 - side-effects of methods for, 678
- Carbon Dioxide Removal Model Intercomparison Project (CDRMIP)**, 633, 757
- Carbon fluxes**
 - 10-, 20- and 30-year trends (2021–2040), 587
 - Air–sea fluxes and storage, 691
 - Atmosphere–land CO₂ fluxes, 486
 - from land-use change, 688
 - land–atmosphere CO₂ exchange, 694
 - ocean flux mitigation and driving effects, 587
- Carboniferous periods, CO₂ proxy estimates for**, 299
- Carbon monoxide (CO) budget**
 - changes in abundance of, 819
 - current trends since 2000, 841
 - global mean burden of, 841
 - global trends, 840
 - indirect climate forcing by, 823
 - model simulation comparisons, 841
 - sources of atmospheric burden of, 841
 - trends in burden of (1850–2000), 841
- Carbon sinks***
 - anthropogenic CO₂ emissions effects on, 681
 - anthropogenic warming effects on, 726
 - growth of oceanic and terrestrial, 677
 - imbalance of sources and sinks, 303
 - increased CO₂ emissions effects, 19, 42
 - land and ocean change with overshoot, 677

- land an ocean sink evolution (1850–2100), 734
 latitudinal distribution of simulated, 732
 linear feedback analysis, 735
 model simulation of land and ocean, 485
 near-term prediction of ocean and land, 742
 net land CO₂ sink, 695
 oceanic and terrestrial growth, 733
 ocean response in high emissions scenarios, 676
 reactive nitrogen deposition effects on, 857
 response to CO₂ concentrations, 690
 response to CO₂ removal, 760
 response to stratospheric SO₂ injection, 767
 response with net CO₂ removal, 100
 terrestrial cycle sink to source reversal, 741
 warming effects on effectiveness, 20
 zonal distribution and atmospheric inversion (2000–2009), 733
 zonal distribution of, 732
- Carbon tetrachloride (CCl₄) historical abundance and forcing**, 2143
- Carbon Tracker 2017**, 732
- Carbon uptake and storage**
 amplitude of the seasonal cycle, 488
 CMIP scenario flux simulations, 587
 CMIP scenario uptake simulations, 576
 coastal wetlands and seagrass meadows for, 764
 ocean air–sea fluxes in, 692
 projections through 21st century, 557
 regional forcing of global variability in ocean, 693
- Carbonyl sulphide (OCS)**, 845
- Caribbean (CAR) region**
 anthropogenic influence in (1950–2016), 2010
 areas included in, 1991
 assessment and projections, 1993
 Atlantic Multi-decadal Variability effects in, 2177
 Caribbean low-level jet effects in, 1991
 climate change assessment for, 2010
 climate features of, 1991
 drought projections for, 1994
 drying projections for, 1993
 model performance assessment, 1993, 2010
 observations, trends and attribution, 1991
 precipitation trends in, 2009
 previous IPCC assessments, 1991
 rainfall projections for, 2012, 2015
 regional climate model simulations, 2010
 regional warming 1.5°C in, 1991
 temperature projections for, 1993
 temperature trends for, 1993
 warming trends and projections, 1994, 2009
- Caribbean low-level jet (CLLJ)**, 1991, 2010, 2012
- Cenozoic period**
 CO₂ estimates by proxies, 299
 Earth's mean temperature during, 294
 proxy CO₂ record, 683
- Central Africa (CAF)**
 greenhouse gas emissions for, 713
 precipitation changes in, 1968
 regional climate features, 1967
- Central America**
 climate extreme projections, 1994
 climate variability and extreme events in, 1991
 climatic impact-driver changes, 1812
 climatic impact-driver changes with 2°C warming, 140
 drought duration expected in, 1119
 drought trends and warming level projections, 1675
 extreme precipitation changes and projections, 1559, 1565
 heatwave projections for, 1994
 heavy precipitation trends and warming level projections, 1672
 hot and cold extreme projections, 1556
 model performance assessment, 1993
 observations, trends and attribution, 1991
 observed hot extremes in, 1549
 precipitation changes with warming, 1993
 precipitation projections for, 1994
 precipitation regional and seasonal trends, 1991
 previous IPCC assessments, 1991
 regional climate features in, 1991
 regional precipitation and drought projections, 140
 regional relative sea level projections, 141
 regional surface air temperature and precipitation, 1992
 regional temperature projections with warming, 1993
 relative sea level rise in, 1820
 runoff projections for, 1119
 scenario-based warming projections, 1993
 summer rainfall projections for, 2012
 temperature extreme trends and warming level projections, 1665
 temperature projections for, 1991
 temperature trends over, 1991
 warming projections for, 1994
 warming trends in, 1994
- Central and South America. See also Latin America**
 agricultural and ecological droughts in, 1816
 Atlas, 1991–1999
 changes in climatic impact-drivers, 1812–1819
 coastal and oceanic changes in, 1818–1819
 coastal and oceanic projections, 140
 heat and cold event projections for, 1812
 regional climate model performance, 1993
 regional precipitation projections, 1817
 regional surface air temperature changes, 1992
 snow and ice changes in, 140, 1817
 summary of changes, 125, 140, 1991
 solar radiation projections for, 1791
 tropical cyclone projections for, 1991
 wet and dry condition changes in, 1815–1818
 wind power potential, 140, 1817
- Central Australia (CAU), climatic features**, 1986
- Central North America (CAN), climatic features of**, 2004
- Central-range projections (for sea level)**, 576
- Centre National de la Recherche Météorologique (CNRM) models, variability in**, 438
- Chemical abbreviations (Kyoto and Montreal Protocols)**, 2140
- Chemical CO₂ removal methods**, 765
- Chemistry–Climate Modelling Initiative (CCMI)**, 835
- Chemistry-climate models (CCMs)**
 aerosol impacts and bias reduction, 851
 ammonia simulations by, 842
 assessment of skill of, 834
 estimation of chemical methane sink, 835
 global three-dimensional models, 834
 ozone concentration projections, 858
 short-lived climate forcers in, 833
- Chlorine**, 843
 abundance (2011–2019), 843
- Chlorofluorocarbons* (CFCs)**
 changes in, 304
 emissions from human activity, 180
 historical abundances and radiative forcing, 2143
 tropospheric adjustment effects on radiative forcing, 925
- Chloroform (CHCl₃) abundance and forcing**, 2143
- Chlorophyll concentration, in phytoplankton**, 292
- Chukchi Peninsula**, 1978
- Circumpolar Deep Water (CDW)**
 Antarctic basal melting from, 1268
 formation of, 1236
- Cirrus cloud thinning (CCT)**
 effective radiative forcing modification with, 624, 861
 initiation of ice crystal formation, 951
 modelled aerosol-cloud interactions, 861
 solar radiation modification by, 628
- Cities and settlements. See Urbanization*/urban climate**
- Clathrates, methane release from**, 740
- Clausius–Clapeyron (C–C) relationship***
 extreme precipitation and thermodynamic change, 1557
 for tropical cyclone projections, 1592
 global scale water vapour content, 969
 heavy precipitation and pluvial flood increase, 1851
 low-altitude specific humidity increase with warming, 1065
 precipitation and mean surface temperature, 1523
 temperature lapse rate and specific humidity feedback, 969
 warming effects on atmospheric water-holding capacity, 1557
 water vapour content change with temperature, 1526
- Climate–atmospheric chemistry feedback**, 858
- Climate–carbon cycle**
 century-scale of response to CO₂ removal, 678
 emergent constraints for projections, 736
 feedback with high CO₂ emissions levels, 20
 projections, 733
 response to removal and emissions of CO₂, 761
 role of ocean in climate response, 744
 time scale of processes in feedbacks, 681

Climate change*. *See also* **Committed climate change**; **Abrupt climate change***

abrupt and irreversible potentials, 633
 air-quality interactions with, 820, 895
 altered climatic impact-driver profiles, 1770
 assessment at regional scale, 1435
 assessment of distillation of information, 1433
 barriers to distillation of information, 1432
 black carbon and methane reduction effects, 825
 carbon feedbacks effects, 677
 cause-effect chain, 53
 changes across global system, 63
 characteristics of assessment, 39–40
 communication of scientific information, 151
 current status of climate, 4–13, 157
 cycles before industrialization, 160
 dimensions of integration for, 227
 effects on surface ozone, 861
 effects without mitigation, 621
 emergence of signals for, 157, 193, 194
 following zero emissions commitment, 630
 global and regional signs of, 246
 global, regional, and local scale of, 50
 historical estimates of regional short-lived climate forcing, 851
 human influence, 41, 430–552
 impact on extreme pollution, 863
 impact on particulate matter, 863
 information construction for, 1431
 information for decision-making, 1366, 1431
 information for risk assessment, 1774
 key indicators of change, 160
 knowledge synthesis, 227–230
 large-scale indicators for, 312, 313
 large-scale indicators of, 486
 lightning nitrogen oxide emissions perturbation by, 830
 limiting future change, 27–31
 low-likelihood, high-impact events with, 1520
 media coverage of, 173
 milestones in science, 174
 motivated reasoning in acceptance of, 1430
 multivariate attribution of, 506
 natural change, 150
 observations of, 187
 overshoot effects in scenarios, 741
 possible futures of, 12–26, 88, 182–184
 regional impact and risk assessment, 1770, 1767–1926
 regional manifestations of global change, 1366
 representation of change in projections, 565
 risk assessment and regional adaptation, 23–26
 scenarios for future assessment, 52–56
 scenarios, models and projections for, 12–16, 52–56, 118, 562
 scientific evidence and projections for, 43
 short-lived climate forcers effect on, 819
 SRCCL assessment of drivers, 188
 storylines with impact of concern, 1434
 synthesis of projections for changes in extremes, 1533
 temperature and precipitation signals for, 1944
 uncertainty and calibrated language for, 169

uncertainty from natural variability of, 1059
 uncertainty levels for projections, 198
 user context for, 1431, 1432, 1863

Climate change commitment*. *See* **Committed climate change****Climate change signals**

emergence in seawater carbonate chemistry, 721
 emergence of, 157, 1853
 emergence of impact-relevant changes, 1770
 estimation of time-varying signals, 430
 first realization (r_1) in simulations, 570
 mitigation effects on emergence of, 591
 progression of changes in, 158
 projection for ocean acidification emergence, 720
 reference period for emergence, 1853
 signal-to-noise ratio in emergence, 1853, 1950
 signatures of, 2002
 Type I versus Type II errors in identification of, 1946
 variability and emergence of, 193–194

Climate drivers

changes in natural and anthropogenic, 296
 solar and orbital forcing, 296–297
 volcanic aerosol forcing, 298

Climate–dust feedback, radiative forcing due to, 858**Climate emulators**. *See* **Climate model emulators****Climate feedbacks***

assessment methods, 967–968
 assessment of parameters for (α_x), 968
 biogeochemical feedback, 737
 biogeophysical and non-CO₂ biogeochemical feedbacks, 975, 976
 climate–biogenic volatile organic compound feedback, 859
 climate–fire, 859
 climate–lightning–NO_x feedback, 859
 climate–ozone feedback, 858
 components of, 967
 defined, 967
 dependence on climate mean state, 979
 dimethyl sulphide, 858
 direct and indirect influence of sea spray, 858
 dust aerosol feedback in abrupt climate events, 1151
 effective radiative forcing probability with CO₂ doubling, 994
 effects rate of greenhouse gas accumulation on, 680
 equilibrium climate sensitivity to, 926
 forcing-feedback framework, 932
 for non-CO₂ biogeochemical processes, 858
 from CH₄ and N₂O, 737
 from change in atmospheric composition, 857
 from galactic cosmic rays, 297
 from thawing of permafrost, 677
 global carbon and biogeochemical cycles, 683
 in abrupt 4xCO₂ simulations, 979
 in Earth system models, 978
 methane lifetime feedback, 859
 mineral dust, 858
 net cloud feedback, 974–975
 net feedback parameter estimate confidence, 981

non-linearities in land surface processes and feedbacks, 1146–1148
 observational capacity expansion for, 209
 Paleocene–Eocene Thermal Maximum recovery, 714
 physical and biogeochemical, 96
 projections for climate system effects, 681
 radiative feedbacks from ice sheets, 977
 radiative forcings and, 967
 relationship to temperature patterns, 981
 short-lived climate forcer effects on, 820
 surface-albedo feedback, 970
 synthesis assessment for, 978
 uncertainty range for, 977
 warming in the Arctic from, 187
 water-vapour and temperature lapse-rate feedbacks, 969

Climate–fire feedback, 859**Climate forcers, effective radiative forcing for**, 2139–2152**Climate hazards and consequences**

assessment according to global warming levels, 1857
 associated with tropical cyclones, 1784
 changes in climatic impact-drivers and, 132
 climate impacts and consequences, 1773
 coastal/oceanic related for 2°C global warming, 2009
 compound events and multiple hazards, 1314
 extremes in Tasmania (case study), 1987
 hazard profile components, 1875
 infrastructure hazards with permafrost thaw, 1785
 magnitude or intensity of, 1875
 of sea level changes, 1786
 regional hazard profile, 1876
 regional impact of warming, 152
 risk from landslides, 1783
 risks and reasons for concern by warming level, 1857
 sand and dust storm impact, 1784
 summary of climatic impact-driver hazards, 1858
 tropical cyclones in Central/South America, 1991
 vulnerable zones and hotspots, 1847–1856
 with extreme water levels, 1786

Climate index time series*, 2155**Climate indicators***

key set of, 312
 recent changes in, 157
 simulated changes in, 194

Climate indices

derivation of, 2207
 extreme indices selection, 2207, 2208
 for characterization and quantification, 2207

Climate–methane lifetime feedback, 859**Climate metrics* use**, 931 *See also* **Emissions metrics****Climate model emulators**, 962

approximation of large-scale climate responses, 962
 comparison of RCPs and SSPs, 619
 constrained ensemble use, 1956
 emulator value compared to best estimate, 966

- equilibrium climate sensitivity and transient response emulation, 994
- estimates of equilibrium climate sensitivity and transient climate response based on, 997
- global surface air temperature attribution from, 962
- idealized energy balance models, 1011
- non-CO₂ emissions impact on remaining carbon budget, 751
- performance compared to physical climate assessment, 936
- relationship of ocean heat content and thermosteric sea level, 1245
- scenario classification in WGIII, 964
- simple climate model versus, 219
- understanding generations of scenarios, 618
- use in AR6, 963
- use with ISMIP6 and GlacierMIP projections, 1263
- Climate model evaluation**
- Africa, 1967–1971
- Asia, 1971–1986
- atmospheric-based drought indices, 1576
- atmospheric convection simulation, 1137
- atmospheric evaporative demand, 1575
- Australasia, 1989–1990
- bias adjustment methods, 1403
- bias corrections for, 563
- biases in simulations, 1395
- carbon cycle in concentration-driven runs, 730
- Central and South America, 1990–1997
- centred pattern correlations between models and observations (1980–1999), 510
- changes in for mean austral summer precipitation, 1409
- changes in Hadley and Walker circulations, 460
- CMIP5, CMIP6 and Earth system models for benchmarks/datasets, 731
- CMIP model simulation warming biases, 444
- CMIP reproduction of surface temperature patterns, 438
- coastal winds and lake effects, 1399
- control simulations, 1393
- convection including tropical cyclones, 1398
- correlations patterns between models and variables, 520
- detection and attribution of surface temperatures, 431–438
- diagnostics for, 1395
- El Niño–Southern Oscillation teleconnections, 1397
- ensemble evaluation and weighting, 568
- Europe, 1998–2003
- evaluation of downscaling methods, 1393
- extratropical cyclones, 1592
- extratropical cyclones and storm track simulations, 463
- fitness-for-purpose and poorly constrained key processes, 1137–1139
- flooding even simulations, 1568
- for drought simulations, 1577
- for regional climate projections, 1393
- for simulated temperature extremes, 1550–1552
- fronts, 1400
- glacier mass projection evaluations, 1278–1279
- global monsoon domain, intensity, and circulation, 462
- historical carbon cycle simulations (concentration-driven), 732
- historical period, 2100
- hydrological deficits, 1576
- improvements in CMIP6, 48–49
- in AR5 and AR6, 154
- mapping between global warming level- and scenario-based responses, 1544
- methods for, 429
- mid-to-high latitude atmospheric variability phenomena, 1396
- Model Intercomparison Projects, 561
- model response uncertainty, 197
- mountain wind systems, 1399
- multivariate model evaluation, 508
- multivariate models, 508–512
- North America, 2004–2008
- of Atlantic Multi-decadal Variability, 505
- of El Niño–Southern Oscillation teleconnections, 498
- of North Annular Mode, North Atlantic Oscillation and Southern Annular Mode in boreal winter, 491
- of Pacific Decadal Variability, 503
- of permafrost in climate models, 1281–1283
- paleoclimate records for, 449
- perfect prognosis methods, 1402
- performance evaluation for regional climate projections, 1366
- performance of weather generators, 1404
- Polar regions, 2016–2025
- precipitation and temperature trends for North Asia, 1977
- precipitation deficits, 1575
- process representation in model classes, 512–514
- relative space–time root-mean-square deviation for CMIP simulations, 509
- seasonal snow in, 1285
- severe convective storms, 1595
- simulating historical regional climate changes, 1404
- simulating regional drivers of climate, 1401
- simulating regional feedbacks, 1400
- simulating regional phenomena and processes, 1398
- simulation of current trends, 433
- simulation of heavy precipitation extremes, 1561–1562
- Small Islands, 2009–2012
- snow cover simulation by, 470
- soil moisture deficits, 1575
- statistical downscaling, bias adjustment and weather generation, 1402
- statistical methods for representing local weather, 1403
- temperature extreme reproduction by, 1552
- tropical cyclone, 1587–1590
- unforced variability in models, 438
- updated observation comparison with simulations, 446
- user-defined or user-relevant diagnostics for, 1395
- Climate modelling techniques**
- added value of increased resolution, 1139
- advantages of multi-model use, 561
- aerosol and cloud size distributions, 851
- aerosol–cloud interactions evidence, 953
- aerosol effects on clouds and precipitation, 1138
- Antarctic model intercomparison studies, 2110
- atmospheric blocking, 607
- atmospheric sulphur loading (1990–2015) estimates, 846
- bias adjustments for, 1945
- biomass burning emissions estimates, 832
- centres contributing to CMIP and CORDEX, 218
- changes in ocean N₂O emissions, 719
- cloud seeding, 860
- CMIP5 models use in downscaling, 2098
- CMIP6 structures, 223, 2111
- common types of model ensembles, 222
- dedicated climate change assessment programmes, 1957
- developments since AR5, 2100
- emergent constraints in, 225
- ensemble modelling technique, 221
- European climates, 1998
- fine-mode nitrate trends, 846
- fitness-for-purpose, 221, 566
- forecast quality assessment, 564
- GlacierMIP2 model intercomparison, 2111
- global ammonium burden, 846
- global spatial distribution of carbon monoxide, 841
- global to regional models, 218
- high-resolution and variable resolution models, 1389
- high-resolution global climate models, 1140
- high resolution improvements, 1315
- ice-sheet and glacier intercomparison studies, 2108
- improvements since AR5, 151
- initialized versus uninitialized systems for predictions, 564
- irradiance models, 297
- land surface processes, 1138
- model evaluation tools, 224
- model grids and resolution improvements, 215
- model performance evaluations for skill, 563–564, 564
- models of lower complexity, 219–220
- models participating in HighResMIP, 2108
- multi-model mean and pattern-scaled response, 637
- observational constraints for projections, 555
- observation-constrained methods, 563
- ocean dynamic/thermosteric response (1961–2005), 1290
- ocean simulation in, 473
- of forced changes in climate system, 151
- paleoclimate models and reconstructions, 45
- performance assessments, 221–224

- permafrost carbon dynamics in, 727
- principle of emergent constraints, 225
- process-based models against observations, 225
- regional climate and convective permitting models, 1140
- resolution of atmospheric and oceanic components, 216
- sea surface temperature biases in, 473, 1223
- single-model initial-condition large ensembles in, 566
- sources of uncertainty in simulations, 196–197
- state-dependence of feedback, 980
- surface temperature reproductions, 431
- temperature and precipitation response to CO₂ forcing, 626
- Tropical Atlantic Variability, 611
- tuning and adjustment of, 217
- types and characteristics, 215
- uncertainties for water cycle, 1136
- uncertainty from future volcanic activity, 592
- uncertainty sources in, 559
- upper-stratospheric ozone increase, 838
- urban modules in, 1454
- weighting techniques for model comparisons, 226
- year-to-year temperature variability, 598
- Climate–ozone feedback, 859**
- Climate risk and adaptation assessment (CRA)**
 - approaches for information construction, 1431
 - low-likelihood, high-impact events in, 151, 198
 - Reasons for Concern in AR5 WGII, 199
 - risk framing for decision-making, 151
- Climate science, history of 174**
- Climate services***
 - adaptation, mitigation and risk management, 1862
 - climate change information in climate services, 1862–1864
 - climate information for decision-making, 1865
 - climate risk and adaptation assessment, 1868
 - Climate Risk Narrative infographic, 1868
 - climate services and climate change information (case studies), 1866–1869
 - decision-making assistance from, 111
 - defined, 1433
 - El Niño-induced drought in Vietnam (case study), 1869
 - focused relationships (case study), 1868
 - framing for user-relevant information, 1429
 - history and advances in, 1862
 - interactive group activities (case study), 1867
 - practice and products related to climate change information, 1863
 - practices and products for, 1771
 - types of, 1864
 - user engagement with, 1863, 1866
 - websites and tools (case study), 1867
- Climate Services Information System (CSIS), 1864**
- Climate stabilization**
 - committed climate change, 630
 - net zero emissions for, 30, 97–98, 242, 630, 631
 - remaining carbon budgets to, 678, 681, 770
 - reversibility of climate response, 106
 - zero emissions commitment, 630
- Climate system response***
 - change in drivers of, 67–68
 - changes in modes of variability, 292
 - changes in short-lived climate forcers, 884
 - changes occurring in, 158
 - changing state of, 287–422
 - continuous warming of, 425
 - drivers of Earth's energy balance, 290
 - effects of inertia on modifications of drivers, 865
 - emergence with mitigation, 619
 - forcing due to aerosols, 851
 - human-forced air temperature change (1750–2019), 927
 - human influences on, 39, 423–552
 - implications for limiting warming, 90–98
 - international climate governance efforts, 157
 - key indicators of change in, 290
 - ocean role in, 473
 - ozone–vegetation interaction influence on, 857
 - physical changes since AR5, 157
 - reduction of uncertainty in AR6, 41
 - scale of recent change in, 8
 - scientific understanding of processes in, 174
 - short-lived climate forcers interaction with, 823
 - temporal coverage of, 176
 - to COVID-19 restrictions, 877
 - to past air quality policies, 872
 - to solar radiation modification, 629
 - to strong mitigation, 557
 - to termination of solar radiation modification, 629
 - uncertainty in, 197
 - understanding features of, 150
 - warming effects on, 15
- Climate (topological) regions**
 - Africa, 1967
 - AR6 WGI reference regions, 1937
 - Asia, 1799
 - Australasia, 1805
 - Central and South America, 1812
 - Europe, 1820
 - land grid boxes AR6, CMIP5 and CMIP6, 1938
 - North American sub-regions, 1828
 - polar region subdivisions, 2016
 - principles used in definition of, 1936
 - Small Island regions, 1836
 - spatial domains and socio-economic regions, 1938
 - subcontinental regions defined in SREX, 1936
 - typological and socio-economic, 1939
 - used in AR5 and AR6, 206–208, 1937
- Climate variability***
 - Atlantic Multi-decadal Variability index, 2176
 - documentation and description of, 2155
 - driver interactions with regional changes, 117, 117–118
 - extratropical modes, 1135
 - from sea surface temperature (1950–2019), 374
 - indices defined by AR5, 2155
 - influence on trends over short periods, 193
 - Madden–Julian Oscillation index, 2177
 - main modes assessed in AR6, 2156
 - natural changes in, 160
 - ocean basin scale processes driving, 312
 - regional teleconnections and, 1134
 - regional water cycle consequences of, 1134
 - sea surface temperature (1854–2019), 376
 - simulations of indicators for change, 570
- Climate zone shifts, 82. See also Seasonal change**
- Climatic impact-drivers* (CIDs)**
 - African changes, 1971–1799
 - Asian changes, 1799–1805
 - additional factors interacting with, 1777
 - air pollution weather, 1787
 - assessment method and tables, 1788
 - association with modes of variability, 2155
 - atmospheric carbon dioxide at surface, 1787
 - Australasian changes, 1805–1812
 - categories and associated risks, 1775
 - categories of, 1776
 - Central and South American changes, 1812–1820
 - changes for polar regions, 1846
 - changes from oceanic drivers, 1848
 - characterization by indices, 2207
 - coastal sea level hazards, 1786
 - common regional changes, 132–135
 - concurrent changes and variables with, 135
 - confidence for changes in, 122–127
 - confidence for projected direction and mitigation efforts, 1771
 - crop response to temperature thresholds, 1874
 - dangerous hazard combinations of, 1788
 - defined and used in AR6, 201, 1773
 - defined in AR6, 1871
 - ecosystems and society effects of, 1872
 - effects on biodiversity hotspots, 1848
 - emergence across time and scenarios, 1853–1854
 - European changes, 1820–1828
 - evolution of effective radiative forcing, 311
 - extreme conditions as, 1521
 - extremes, 2205–2214
 - geographical distribution of change, 131
 - global scale change in, 1851–1854
 - graduating thresholds affecting hazards, 1782
 - heat and cold, 1780
 - heat and cold hazard for natural systems, 1782
 - impact of the residential sector, 866
 - impact on human or ecological systems, 40
 - index definitions and projections, 1869
 - indices and thresholds for vulnerability, 1773
 - low greenhouse gas emissions scenarios, 31
 - main types and assessment of impacts, 1774–1776
 - North American changes, 1828–1836
 - oceanic changes and impacts, 1786
 - open and deep ocean changes, 1841–1844
 - polar terrestrial region changes, 1844–1847
 - projected regional changes in, 26
 - projections for changes by 2050 (2041–2060), 1852
 - projections for changes for selected indices, 1789

- regional impact for risk assessment, 1777
 regional impacts and risks assessment, 1770
 regional indices, 2209, 2212
 regional vulnerability and adaptation/mitigation, 1775
 region-by-region changes in, 135–141
 region-specific change relative to recent past, 1770
 relevance for sectoral assets, 1778
 selection of indices, 2209
 Small Islands changes, 1836–1841
 solar and volcanic forcing (2.5 kyr), 297
 summary of hazards, 1858
 surface solar and longwave radiation fluxes, 1787
 temperature changes, 1851
 time of emergence for, 1856
 wet and dry, 1782
 wind change effects, 1784
 with global warming 2°C, 135
- Climatic Research Unit gridded global historical near-surface air temperature dataset (CRUTEM4)**, 1385
- Cloud condensation nuclei* (CCN)**
 anthropogenic aerosol particles in, 950
 dimethyl sulphide in formation of, 858
 from marine aerosols, 832
 in aerosol cloud interactions, 948
 in climate–sea-spray feedback, 858
 microphysical effects of aerosols, 1078
 mineral dust in formation of, 858
- Cloud drop effective radius (re)**, 950
- Cloud drop number concentration (Nd)**, 950
- Cloud feedbacks***
 Arctic cloud feedback, 974
 extratropical cloud optical depth feedback, 974
 feedback processes in individual regimes, 974
 high-cloud altitude feedback, 972
 land cloud feedback, 973
 marine low-cloud feedback, 974
 mid-latitude cloud amount feedback, 973
 sign and confidence levels for feedback from, 975
 subtropical marine low-cloud feedback, 973
 tropical high-cloud amount feedback, 972
 uncertainty for transient warming projections, 1011
- Cloud fraction (Cf)**
 adjustment for aerosol–cloud interactions, 953
 response to emissions/aerosols, 952
 response to ship emissions, 952
 sea surface temperature effects, 972
- Cloud radiative effect* (CRE)**, 579, 971
- Clouds**
 aerosol index and microphysical properties, 951
 decomposition into regimes, 971–973
 effects of aerosols on radiation, 311
 effects of seeding on, 860
 microphysical processes in, 1078, 1373
 pH changes in cloudwater, 845
 radiative feedbacks from, 926
 response to warming, 926, 971
- Clouds and the Earth's Radiant Energy System (CERES)**, 935, 1225
- Cloud-top temperature and aerosol optical depth/AI**, 952
- Coarse-mode nitrate, in global nitrate budget**, 846
- Coastal and oceanic changes**
 changes in climatic impact-drivers, 134
 changes with 2°C global warming for polar regions, 142
 climatic impact-driver changes for Africa, 1796
 climatic impact-driver changes for Asia, 1803
 estimated total water level around Australia, 140
 polar terrestrial changes in, 1847
 regional responses to acidification, 721
- Coastal cities and settlements**, 1848
- Coastal erosion**, 1820
 African changes, 1796
 Arctic changes, 1847
 Asian changes, 1805
 Australasian changes, 1811
 Central and South American changes, 1818
 ecosystem and infrastructure impacts, 1786
 European changes, 1826
 index, derivation of, 2211
 North American changes, 1836
 polar terrestrial changes, 1847
 projections for shoreline retreat, 1853
 Small Islands changes, 1841
- Coastal flooding**
 1-in-100-year extreme total water level as index for, 2211
 African changes, 1796
 Asian changes, 1803
 Arctic changes, 1847
 Australasia changes, 1811
 Central and South American changes, 1818
 European changes, 1826
 North American changes, 1834
 polar terrestrial changes in, 1847
 Small Islands changes, 1839
- Coastal systems and marginal seas**, 1244, 1786
- Cold extremes**
 agricultural, ecosystem and health relevance, 1781
 human influence on probability of, 1553
 projections for, 1518, 1851
- Cold spells and frost**
 African changes, 1793
 agricultural impact, 1781
 Asian changes, 1799
 Australasian changes, 1807
 Central and South American changes, 1815
 European changes, 1822
 frost impact, 1781
 index for climatic impact-drivers, 2210
 magnitude of cold spells, 1781
 North American changes in, 1830
- Cold tongue estimates**, 989
- Combined Extreme Index (CEI)**, 1552
- Combined global temperature change potential (CGTP), metrics for**, 927
- Committed climate change**
 after forcing stabilization, 630
 Arctic sea ice (to 2300), 633
 beyond 2100, 629
 defined, 39
 emissions from infrastructure, 630
 for slow-to-respond processes, 106
 from greenhouse gas emissions, 21
 global land precipitation (to 2300), 633
 global sea level rise, 21, 1307
 global surface air temperature (to 2300), 632
 in ocean warming, 21
 ocean carbon–heat nexus and, 743
 response to zero emissions, 630
 sea level change with scenarios, 1305
 zero CO₂ emissions commitment, 557
- Common Information Model concepts and standards**, 2100
- Community Earth System Model (CESM2.1)**, 431
- Community Earth System Model decadal prediction large ensemble (CESM-DPLE)**, 591
- Community Emissions Data System (CEDS)**, 827
- Compound extreme events***
 change in probability of, 25, 1519
 concurrent droughts and heatwaves, 1600
 concurrent extremes in coastal and estuarine regions, 1599
 concurrent global-scale temperature and precipitation extremes (case study), 1603–1605
 definition and overview, 1598
 flooding, 1519, 1848
 global-scale concurrent climate anomalies, 1601
 human activity effects on, 9
 impact from, 1522
 multiple hazards in, 1314
 regional concurrent changes and adaptation, 1770
- Concurrent events**. *See* **Compound extreme events**
- Concurrent extremes**, 1519
- Confidence* levels**
 calibrated language for, 169
 use in AR6, 38
- Consecutive dry days (CDD)**, 1572
- Continental Regions**, 208
- Contrails (condensation trails)**
 assessed effective radiative forcing from, 956
 assessment of aviation climate forcing, 867
 effective radiative forcing predictor for, 956
 formation of cirrus clouds, 866
- Control simulations**, 1393
- Convection-permitting regional climate models***
 advances in regional modelling, 2008
 downscaling of global simulations, 1140
 over alpine domain, 2001
 severe convective storm analysis, 1596
- Convective available potential energy (CAPE)**, 1594
- Cooling degree days (CD)**, 2209, 2210
- Cooling, in Cenozoic period**, 294

- Coordinated Regional Downscaling Experiment (CORDEX).** *See* CORDEX (Coordinated Regional Downscaling Experiment)
- Copernicus Atmosphere Monitoring Service (CAM5),** 213, 732
- Copernicus Climate Change Service (C3S),** 1382, 1867
- CORDEX (Coordinated Regional Downscaling Experiment)**
 Africa, 1792, 1970
 Asia, 1798, 1972
 Australasia, 1806, 1989
 Central and South America, 1814, 1992
 climate modelling/simulation, 224
 CORDEX-CA, 1977
 CORDEX-CORE, 1944
 CORDEX-EA, 1974, 1975, 1977
 curvilinear domain boundaries in, 1942
 domains and resolutions, 2089
 domains used in Interactive Atlas, 1943
 Europe, 1821, 2003
 extreme rainfall event capture, 1562
 Flagship Pilot Study (FPS), 1393
 heat index calculation and bias adjustment, 2210
 high-resolution historical and future climate projections, 1390
 high-resolution regional projections, 1945
 historical reference (1970–2005) in Atlas, 1944
 inter-model comparison experiment, 151
 NA-CORDEX, 2006
 North America, 1829, 2007
 regional downscaling activities, 2089
 regional simulations, 2099
 regional simulations by, 1942
 simulation of regional extremes, 1551
- Coupled atmosphere–land–river–ocean models,** 2001
- Coupled atmosphere–ocean general circulation models (GCMs),** 1389
- Coupled Model Intercomparison Project* (CMIP)**
 20-year mean precipitation changes, 1136
 aerosol–cloud interactions, 851, 950
 aerosol optical depth simulation, 844, 845
 Africa, 1792, 1969–1970
 air pollutant simulation, 861
 Annular Mode index change (hPa) (1995–2014 to 2021–2040), 588
 Antarctic sea ice loss simulation, 468
 anthropogenic signal emergence, 1427
 Arctic sea ice projections, 575, 586–587
 Asia, 1798, 1971–1972
 Atlantic Meridional Mode simulations, 501
 Atlantic Meridional Overturning Circulation changes, 484, 576, 1236
 Atlantic Multi-decadal Variability simulations, 504
 Atlantic Zonal Mode simulations, 501
 atmospheric ammonia trend estimation, 828
 attributable warming estimates, 439
 Australasia, 1806, 1989
 backward comparability of scenarios, 562
 biogenic volatile organic compound projections, 831
 biogeochemical model performance, 488
 boreal wintertime Annular Mode indices, 578
 cascade of uncertainties in projections, 198
 Central and South America, 1814, 1991–1992
 change in Hadley circulation, 459
 climate change signals, 1945
 CMIP3 studies assessed in AR5, 1989
 CMIP5 and CMIP6 global model (Atlas), 1941–1942
 concentration-driven experiments in, 561
 concentration-driven projections, 681
 concentration-driven simulations (1850–2014), 732
 control simulations with external forcings, 1393
 coupled models participating in CMIP6 DECK, 2101
 cyclone and blocking simulations, 463
 datasets used in report, 2111
 DECK for assessment and projections in AR6, 224
 derived global monsoon changes from, 586
 detection and attribution of warming, 425, 428
 El Niño–Southern Oscillation, 495–499, 610
 equatorial sea surface temperature biases, 474
 equilibrium climate sensitivity and transient response estimates, 12, 93, 927, 1008, 1009
 estimates of Arctic warming in the mid-Holocene, 431
 Europe, 1821, 2001–2003
 feedbacks in CMIP5 and CMIP6, 979
 fractional changes with warming, 1527
 global land monsoon precipitation, 603
 global mean sea level rise, 575, 1245
 global surface air temperature, 555
 global surface-albedo feedback (α_A), 970
 Hadley circulation changes, 1125
 heat index calculation for, 2210
 heavy precipitation simulation, 1561
 historical and scenario precipitation changes, 574
 historical carbon uptake and scenarios, 577
 historical simulations, 12, 447, 462, 477, 570, 1234, 1562
 improvements in simulations, 48
 Indian Ocean Basin and Dipole modes simulations, 499–500
 Indian summer monsoon simulations, 1979
 Indo-Pacific climate assessment, 1989
 intercomparisons of chemistry–climate models, 835
 Inter-tropical Convergence Zone shift detection, 452
 large-scale indicators of climate change, 425
 long-term surface warming scenarios, 572
 lower stratospheric temperatures, 445
 Madden–Julian Oscillation simulations, 2179
 model intercomparisons used for AR6, 151, 223
 models for regional simulations, 2098
 models used for simulations, 2089
 near-surface air temperatures anomalies, 441
 near-surface humidity projections, 601
 near-term Southern Annular Mode trend, 588
 North America, 1829, 1978, 2006–2007
 Northern Annular Mode/North Atlantic Oscillation, 489–492, 578, 609
 Northern Hemisphere blocking, 1397
 Northern Hemisphere snow cover extent, 471
 North Pacific storm track simulations, 464
 observed natural variability estimates in, 444
 ocean acidification, 608
 ocean carbon and heat storage, 745
 ocean dynamic sea level projections, 1247
 ocean heat content, 1232
 ocean mixed layer projections, 1226
 ocean salinity detection and attribution, 479
 ocean temperature biases in, 473, 474
 output availability, 2089
 ozone concentration simulations, 836, 838
 Pacific Decadal Variability simulations, 502–504
 precipitation anomalies (1995–2014), 574
 precipitation change at 2°C warming, 1544
 precipitation increase with warming, 616
 precipitation over land by scenario, 574
 projections for deoxygenation rate, 718
 regional seasonal precipitation, 601
 reproduction of precipitation changes in paleo reference periods, 451
 reproductions of overturning circulations representation in, 427
 scenario sets used in, 236, 618, 2090
 sea level change evaluation, 481
 sea surface temperature biases in, 1223
 sea surface temperature pattern representation, 1223
 Shared Socio-economic Pathways used, 555
 short-lived climate forcer emissions, 591, 827
 simulated and observed snow cover extent, 1286
 simulation of global monsoon variability, 452
 simulation of rainfall patterns, 452
 Small Islands, 2012
 snow cover extent biases in, 470
 sources of uncertainty in, 567
 Southern and Northern Annular Mode reproduction comparisons, 427
 Southern Annular Mode projections, 609
 Southern Ocean circulation characteristics, 1239
 Southern Ocean fresh bias in, 479
 sudden stratospheric warmings/vortex splits biases, 466
 surface air temperature anomalies, 572
 temperature and salinity biases, 475
 temperature bias distribution in, 431
 temperature estimations for Europe, 2001
 temporal simulation of ice-sheet changes, 471
 top-of-atmosphere flux anomalies in, 936
 total ozone column change, 838
 tropical Atlantic Ocean evaluation, 476
 Tropical Atlantic Variability changes, 590
 tropical circulation projection, 1124
 tropical Indian Ocean evaluation, 476
 tropical Pacific Ocean evaluation, 476
 tropical volcanic eruptions effect on, 452
 troposphere warming simulations, 599
 upper ocean salinity biases in, 479

- wind stress projections, 1225
- Coupled ocean–atmospheric modes of variability**, 1223
- COVID-19 pandemic**
- implication of restrictions for climate, 875–878
 - implications for emissions, air quality and climate, 822
 - observational capacity and continuity threat, 151, 212
 - temporary emissions reductions with, 42, 875–878
- CryoSat-2 period**, 1251
- Cryosphere***
- biodiversity hotspots in, 1848
 - changes at specific warming levels, 1217
 - changes in, 158, 1932
 - cryosphere–atmosphere coupling, 2158
 - human influence on the, 426, 466–491
 - indicators of changes in terrestrial, 291
 - in physical climate system, 157
 - observational capacity improvement, 210
 - sea ice and glacier changes in, 76–77
 - shrinking of components, 187
- Cryosphere, ocean and biosphere**
- abrupt and irreversible change, 633
 - change beyond 2100, 630
 - changes for warming levels, 612
 - changes with 2°C and 3°C warming, 1217
 - climate indices changes, 570
 - low-likelihood, high-warming storylines, 635
 - mid- to long-term global changes, 595–603
 - modes of variability, 587–590
 - overshoot and pathways, 617
 - response to mitigation, 619–626
 - simulations for indicators of change, 574–576
 - volcanic eruption effects, 593
- Cumulative carbon dioxide (CO₂) emissions**
- defined, 39
 - for information integration, 227
 - near-linear relation to warming, 240
 - relationship to global surface temperature, 28, 152
 - relationship to temperature, 678
 - relation to global warming levels, 55
 - temperature effects of removal, 557
- Cumulative carbon dioxide (CO₂) equivalent emissions**
- estimated for methane, 1016
 - new emissions metrics for, 927
- D**
- Decadal Climate Prediction Project (DCPP)**, initialized prediction use in, 569
- Decarbonization strategies**, 822
- Deep uncertainty***, 202
- Deforestation***. *See also* **Afforestation*/reforestation***
- biome shifts and die-back changes, 724
 - contribution to hot extremes, 1553
 - contribution to warming, 1547
 - effects in Amazon, 1149
 - effects in mid-latitudes, 310, 1552
 - forest dieback effects, 740
 - in tropical regions, 171
 - precipitation changes from, 1076
 - surface albedo effects of, 956
- Denitrification/nitrification processes in soil**, 830
- Desert and semi-arid areas**, 143. *See also* **Aridity* and desertification**
- Detection and attribution***
- AR5 assessment of regional-scale, 206
 - attributable regional climate change, 109
 - changes in ocean circulation, 483–492
 - current warming attribution, 60
 - drought conditions, 1577–1581, 1606
 - extratropical cyclones, 1593
 - extreme changes and contribution to, 1525
 - extreme storm events, 1588, 1596
 - for extratropical modes, 1105
 - for mitigation response, 559
 - for water cycle changes, 1152
 - global study of streamflow trends, 1086
 - heavy precipitation events, 1562
 - historical model reproductions for, 425
 - human-induced change, 8
 - human influence on ocean, 473–478
 - human influence on surges and waves, 1310
 - internal variability effects on, 449
 - methods for attribution, 429–430
 - methods used for near-term projections, 563
 - of temperature extremes, 1552–1553
 - optimal fingerprint regression-based methods, 1414
 - precipitation changes with global monsoons, 463
 - regional climate attribution examples, 1416–1422
 - regional climate change, 11, 1414
 - regional patterns of biogeochemical change, 488–490
 - regional-scale extremes, 1540
 - regional sea level change, 1290
 - regional temperature change, 1367
 - removing model biases for, 1416
 - simulation and observed change integration, 429
 - streamflow use for terrestrial water cycle, 456
 - studies on flood events, 1569
 - studies on Greenland Ice Sheet, 472
 - studies on ocean heat content, 478
- Detection and Attribution Model Intercomparison Project (DAMIP)**, 435
- Developing Pacific region, surface O₃ and particulate matter projections**, 882
- Diabatic heating**, 2164
- Diagnostic, Evaluation and Characterization of Klima (DECK)**, 224, 2100
- Dichloromethane (CH₂Cl₂)**, 843
- Dimensions of integration***
- across Working Groups, 227
 - comparison of CO₂ and greenhouse gases, 241
 - cumulative CO₂ emissions, 240
 - global warming levels as, 239, 1543
 - history of scenarios in IPCC, 237
 - reference scenarios and storylines, 238
 - scenario generation process, 236
- Dimethyl sulphide (DMS)**, 832, 858
- Dimming (solar radiation)**. *See also* **Solar radiation modification* (SRM)**
- decadal variations in past, 1791
 - observational records, 925
 - over Northern Hemisphere, 1077
 - solar radiation decline (1950s–1980s), 938
- Direct air carbon capture with carbon storage (DACCS)**, 757, 765
- Dissolved inorganic carbon* (DIC)**, 723, 742
- Dissolved oxygen**, 1787, 1842. *See also* **Ocean deoxygenation***
- Distillation of climate information**, 40, 1375
- Droughts*** *See also* **Agricultural and Ecological Drought and Hydrological Drought**
- agricultural and ecological indices for, 1783
 - agricultural and hydrological characteristics, 1851
 - amplification by dust, 1150
 - assessed variables and metrics for, 1572
 - assessment for drought projections, 1606
 - atmospheric-based indices for, 493, 1572
 - atmospheric evaporative demand, 1571
 - attribution of types of, 1579
 - Australasian trends, 1987
 - carbon and water cycle interactions, 697–699
 - climatic drivers of, 1074
 - common metrics, types, and indices, 1760
 - concurrent heatwaves and, 1600
 - consecutive dry days (1960–2018) trend, 1574
 - consecutive dry days, soil moisture with warming levels, 1584
 - continental atlases for, 330
 - definition and types of, 1518, 1570
 - detection and attribution of, 1577, 1577–1580
 - drivers of, 1073
 - effects of warming over land on, 1057
 - elevated CO₂ effects on, 697
 - emergence of signals for, 1854
 - hydrological deficits, 1572, 1574
 - impact in semi-arid regions, 1849
 - intensity and frequency with warming levels, 1581
 - map of drought areas, 1158
 - mechanisms and drivers, 1570–1573
 - meteorological changes, 1119
 - model evaluation for, 1575–1577
 - observed trends, 1573–1575
 - precipitation deficits, 1570
 - processes affecting, 1527–1529
 - projections for, 1579–1584
 - regional atmospheric-based drought indices, 1574
 - regional drought projections, 1583, 1605
 - regional occurrence of, 1575
 - risk projection for southern Australia, 1987
 - soil moisture deficits, 1571
 - terrestrial CO₂ sink effects of, 697
 - water management use of indices, 1783
- Dry deposition**
- CO removal from atmosphere, 841
 - of sulphur dioxide, 845

sulphate removal from atmosphere, 845

Dust particles

climate change effects on, 863
land emissions of, 831

Dynamic global vegetation models* (DGVMs), 689, 694

Dynamic sea level change, 1221, 1244

E

Early Eocene Climatic Optimum* (EECO)

atmospheric CO₂ estimates during, 299
global mean surface temperature estimate for, 292
polar amplifications in, 986
reference period, 295

Earth gravity, changes in, 1221

Earth models of intermediate complexity* (EMIC), 219, 686

Earth's energy budget*

aerosol emissions in, 948
changes for surface energy budget, 938–939
changes in, 935
changes in inventory, 937
changes through time, 933
constraints on total aerosol effective radiative forcing, 954
cryospheric component assessment, 937
direct aerosol–radiation interactions, 948
sea level budget, 1291–1296
Earth's surface energy budget, 938
effective radiative forcing in, 925
estimated energy imbalance for, 935
forcing and response, 931
forcing-feedback framework for, 932
global energy inventory, 938
global energy inventory changes, 937
global energy inventory increase, 925
global mean with/without cloud effects, 934
global water cycle change, 1057
heat redistribution in climate system, 447
imbalance from perturbations, 931
imbalance in 2000s, 447
increase in global energy inventory, 925
internal energy flow in, 933
latent and sensible heat fluxes, 939
measure of global climate change, 925
net cumulative energy change (1971–2018), 90
observed energy increase in the Earth system (1971–2018), 925
ocean heat content change contribution to, 937
ocean heat storage in, 476
ocean uptake of imbalance, 313
ocean warming effects on (1971–2010), 1228
present-day (early 21st century), 933
present state of knowledge of, 925
quantification of energy imbalance in, 93
surface radiation components in, 935
the imbalance in, 39, 937

Earth system

accumulation of energy in, 925
feedback amplification of climate forcing, 94–95

impacts of carbon dioxide removal methods, 764
multivariate attribution of change in components, 506
multivariate model evaluation, 508–511
ocean circulation role in, 483–487
perturbation effects on, 857
response to solar radiation modification, 104–105
rotation effects in, 1221
total energy accumulation in, 929
understanding of components and processes, 154

Earth System Documentation (ES-DOC) project, 2100

Earth System Grid Federation (ESGF)

distributed data platform use, 224
metadata for simulations, 1944
regional climate data dissemination, 2089
shared model datasets, 2100

Earth System Model Evaluation Tool (ESMValTool), 224, 429

Earth system models* (ESM)

aerosol–cloud interactions in, 851
aerosol–radiation interactions estimates, 949
biogeochemistry representation in, 217
bottom-up models for methane life assessment, 835
carbon cycle projections, 730
climate feedback in, 978
climate forcer data sets for SSPs, 234
climate projections, 2100
CO₂ composition experiments, 943
drought variables, 1577
emissions- versus concentration-driven runs, 730
evolution of ocean carbon sink, 427
feedback parameter (α) quantification, 858
increased complexity of, 681
instantaneous removal of anthropogenic or fossil fuel-related emissions, 865
interactive ozone-vegetation damage in, 857
land and ocean carbon sinks simulation, 485
land carbon sinks simulation, 487
methane lifetime estimates, 835
non-CO₂ biogeochemical feedback estimation, 820
ocean acidification projections, 719
ocean deoxygenation projections, 677
participating in the CMIP6 DECK, 2101
physical and chemical processes representation, 216
precipitation deficits and trend identification, 1575
regional climate modelling, 1389
removal-caused net negative CO₂ emissions, 622
reproduction of dimming and brightening, 939
scenario classification and integration, 962
short-lived climate forcer future concentration estimates, 887
tipping point detection, 202
top-of-atmosphere flux estimates, 935
types of, 215
zero emissions commitment, 631

East Africa

aerosol optical depth, 290

aerosol trends over, 310
drying in recent decades, 449
extreme total water levels, 135
precipitation projections for, 1971
rainfall changes, 1968–1969
rainfall projections, 1971
snow and glacier projections, 1795
temperature changes, 1968
tropical cyclone projections, 135
warming projections for, 1969

East Antarctica (EAN), 2016

East Antarctic Ice Sheet*

mass loss in, 1263
new projections for, 1270
tipping/critical thresholds for, 1272

East Asia (EAS)

aerosol effective radiative forcing, 852
air pollution in, 869
atmospheric sulphate changes, 846
atmospheric sulphur dioxide levels, 842
distribution of short-lived climate forcers, 819
global warming level 2°C, 1974
greenhouse gas emissions, 713
non-methane volatile organic compound emissions, 828
observations, trends and attribution, 1973
particulate matter emissions sources, 821
precipitation and temperature projections, 1974
precipitation projections for, 1973
precipitation trends over, 1973
regional climate features and AR5 findings, 1973
regional snowfall changes, 139
short-lived climate forcers, CO₂, and NO₂ emissions, 821
short-lived climate forcer effects, 888
summer monsoon projections, 1973
surface ozone and particulate matter, 869, 882
temperature projections for, 1973
trends and projections summary, 1975
warming trends in, 1973

East Asian monsoon* (EAsiam)

AR5 findings for summer and winter circulations, 1973
boreal summer manifestation, 2196
decadal variations in winter, 1973
projections for, 1096, 1973, 1975
seasonality and large-scale features, 2197

Eastern Africa *see* East Africa

Eastern Asia *see* East Asia

Eastern Australia (EAU), climatic features of, 1986

Eastern boundary upwelling systems* (EBUS)

large-scale wind intensification in, 1243
productivity in food chain, 1243–1244
sea surface temperature trends, 1223

Eastern Europe (EEU)

climatic features of, 1998
winter temperature trends in, 1999

Eastern North America (ENA)

climatic features of, 2004
precipitation projections for, 2007

East Siberia (ESB)

aridification trend (1976–2016), 1976

- climate features of, 1975
- warming trends in, 1976, 1978
- wildfire risk in, 1976
- East Southern Africa (ESAF)**
 - climatic features, 1967
 - tropical cyclone projections, 135, 1795
- Ecological drought.** *See* **Agricultural and ecological droughts***
- Economic sectors/stakeholders**
 - climate services for, 1433
 - physical and cultural diversity of, 1461
 - prioritizing metrics for use by, 172
 - spatial and temporal scales of, 1431
 - transdisciplinary approaches to interactions, 1432
 - useful regional information, 1461
- Ecosystems*, large-scale indicator of change,** 314
- Eddy**
 - exchanges between gyres, 1234, 2156
 - large eddy simulation, 972
 - transient activity of, 2158
- Effective feedback parameter,** 933
- Effective radiative forcing* (ERF).** *See* **Aerosol effective radiative forcing* (ERFari+aci); aerosol–radiation interactions* (ERFari)**
 - 2100 level in scenarios, 555
 - aerosol changes (1850 and recent-past), 852
 - aerosol–radiation interaction effects on, 948, 950
 - aerosols in historical period, 819
 - altitude of ozone changes, 306
 - assessment in AR5, 941
 - assessment summary, 959
 - attributable to emissions versus short-lived climate forcers, 853
 - aviation contribution to, 867
 - changes with COVID-19, 876
 - climate forcers (1750–2019), 2144
 - climate forcers assessed in AR6, 2140
 - climate outcomes with overshoot, 617
 - cloud seeding effects on, 860
 - component emissions and global surface temperature, 92
 - contribution of CO₂, N₂O, and halogenated, 713
 - distribution of net aerosol forcing (1850–2014), 819
 - emissions- versus abundance-based, 853–855
 - estimates from biophysical processes, 310
 - evidence for net aerosol forcing, 955
 - forcing agents (1750 to 2019), 959
 - for CO₂ doubling, 925
 - for industrial era (1750–2019), 926
 - for stratospheric water vapour, 947
 - from component emissions (1750–2019), 854
 - from solar activity (since late 19th century), 298
 - historical timeseries of (1750–2019), 962
 - instantaneous and cloud water content adjustments, 948
 - land-use change effects, 290, 310
 - linear and cirrus contrails, 867
 - natural versus anthropogenic drivers (since 1750), 290
 - net effect from climate drivers, 312
 - net energy flux of the Earth system, 931
 - of assessed climate drivers, 310
 - of black carbon, 847
 - of climate drivers, 290
 - quantification and representation in models, 941–942
 - quantification following perturbation, 941–953
 - quantification of perturbations, 925
 - short-lived gases association with, 290
 - solar radiation modification by aerosols, 860
 - specific forcing agents, 942–944
 - stratospheric aerosol injection effects, 860
 - summary by time period and driver, 960
 - temporal evolution of, 311
 - time evolution of 20-year mean averages, 853
 - time series for SSP1-1.9, 2145
 - time series for SSP1-2.6, 2146
 - time series for SSP2-4.5, 2146
 - time series for SSP3-7.0, 2147
 - time series for SSP5-8.5, 2147
 - time series of halogen components, 2148
 - total solar irradiance change, 297
 - versus stratospheric-temperature-adjusted radiative forcing, 944
- Ekman pumping,** 1227
- El Chichon (1982) eruption,** 327
- Elevation-dependent warming (EDW),** 1849
- El Niño–Southern Oscillation* (ENSO)**
 - 2015–2016 boreal spring and summer, 1601
 - activity on multi-decadal to centennial time scales, 371
 - amplitude changes in, 1104
 - AR5 conclusions on, 371
 - Australasia teleconnections, 1986
 - Australian-Maritime Continent monsoon, 2199
 - boreal wintertime mode, 2163
 - Central America and Caribbean teleconnections, 1991
 - changes in amplitude of variability, 580
 - climate variability and, 2156
 - CMIP projections for, 589
 - CMIP simulations of, 495–499
 - decadal variability in, 2172
 - diagnostics for feedbacks in, 1395
 - dominant mode of interannual variability, 610
 - East Asian winter monsoon effects, 1973
 - eastern and central Pacific events with, 2162
 - eastern and southern African effects, 1967
 - effect on interannual ocean heat transport variability, 1231
 - effects on Aleutian Low, 2164
 - effects on surface moisture levels (2015–2016), 330
 - events related to 2015–2016 extreme, 1602
 - Indian Ocean Basin mode, 2167
 - Indian summer monsoon connection, 2171
 - indices for monitoring, 2162
 - influences on extreme still water levels, 1309
 - in interannual variability projections, 557
 - interannual time scale of variability, 579
 - links to modes of variability, 2164
 - model evaluation of teleconnections, 498
 - mode of tropical variability, 2162
 - multi-decadal to centennial time scale activity, 2172
 - observations and historical simulations, 496
 - precipitation influence of, 1528
 - projections for rainfall variability with, 19
 - proxy-based reconstructions of, 2164
 - reconstructed and historical variance ratio of, 372
 - revisions to observed tropical Pacific sea surface temperature data, 372
 - Russian Far East influence, 1976
 - seasonality observations and historical simulations, 497
 - sea surface temperatures with, 2162
 - Small Islands extreme events, 2013
 - South American influence, 1994
 - South East Asia temperature influences, 1981
 - South West Asia influences, 1983
 - sporadic evidence of presence, 371
 - SROCC projections for, 188
 - trans-Pacific coherent variability, 2155
 - tropical climate impacts, 2164
 - water cycle changes, 2164
 - West Central Asia effects, 1983
- Emergence (of climate variable),** 39
- Emergent constraints***
 - cloud feedbacks and present-day climate, 1004
 - defined, 225
 - equilibrium climate sensitivity assessment, 1005
 - global or near-global surface temperature change, 1003
 - observational data and simulations, 968
- Emissions-based radiative forcing**
 - for methane, 855
 - for organic carbon aerosols, 854
 - from black carbon, 854
- Emissions metrics.** *See also* **Climate metrics***
 - applications of, 1018
 - definition and physical description of, 1012–1017
 - effects of forcing agents, 931
 - for selected compounds, 1017
 - for selected species, 1017
 - physical consideration in choice, 1017–1018
 - physical indicators for radiative forcing, 1012
 - radiative properties and lifetimes in, 1012
 - relation of emissions to climate system change, 1011
 - short-lived greenhouse gases, 1015
- Emissions***
 - benefits of reductions, 643
 - climate-driven changes in, 859
- Empirical orthogonal function (EOF) analysis,** 2155, 2158, 2159, 2167, 2168, 2171, 2195
- Energy imbalance.** *See* **Earth's energy budget***
- Enhanced weathering (EW), for carbon dioxide removal,** 764
- Ensemble* empirical mode decomposition method,** 1415
- Eocene–Oligocene transition, carbon dioxide levels,** 684
- Epistemic (knowledge-related) values of science,** 171

Equatorial Indian Ocean (EIO), rapid warming signal for, 1979**Equatorial warm pool**

- convective cloud system formation, 971
- sea surface temperature gradient, 989
- top-of atmosphere radiative flux co-variation with, 991

Equator-to-pole temperature gradient (polar amplification), 988**Equilibrium climate sensitivity* (ECS)**

- AR5 WGI assessment, 182
- AR6 estimate of, 93
- assessed uncertainty range for, 932
- assessment from instrumental records, 999
- assessment of, 1298
- CMIP Last Glacial Maximum simulation, 431
- CMIP model range for, 197
- combined assessment of transient climate response, 1005
- defined, 933
- emergent constraint studies used in assessment, 1005
- estimates based on emergent constraints, 1003, 1004
- estimates based on global energy budget, 995–1004
- estimates based on process understanding, 993
- estimates from paleo radiative forcing and temperature, 1001
- estimates from pre-Quaternary warm periods, 1000
- estimates of, 183, 926, 992
- evolution of assessments of, 94
- from paleoclimate proxy reconstructions, 1001, 999–1003
- in CMIP6 models, 618
- in global climate models and role in assessment, 1007
- likely* range of, 11
- low-likelihood outcome relation to, 199
- measures of response to forcing, 925
- paleoclimate estimates of, 46
- reduction of uncertainty range for, 41
- response to cumulative CO₂ emissions, 93
- response to different lines of evidence, 1006
- response to greenhouse gases, 49
- statistical approaches for linking with observed changes, 1024
- summary of assessment, 1007
- translation of past climate change to equilibrium climate sensitivity, 1003
- warming level effects on, 635

ERA5 models, 431, 1941, 1980**Essential Climate Variables (ECVs)**

- climatic impact-driver characterization, 2207
- Global Climate Observing System definition, 312
- satellite products for, 1382

Estimates of equilibrium climate sensitivity and transient climate response, 992–1002**Ethane, geologic source of, 842****Eurasia**

- air pollution sources, 869
- mean snow depth (1966–2012), 1999

- snow and ice trends for, 1802, 1999
- surface ozone concentration changes, 882

Eurasian Ice Sheet, 1294**Europe**

- aerosol effective radiative forcing, 852
- aerosol forcing of climate in, 2001
- agricultural and ecological droughts, 1823
- air pollution in, 869
- ammonia trends, 842
- anthropogenic aerosol effects, 2000
- anthropogenic aerosol trends in, 2003
- AR5 assessment, 1998
- assessment and synthesis of projections, 2001
- Atlantic Multi-decadal Variability effects, 2176
- Atlantic storm track effects on, 1998
- Atlantic Zonal Mode effects, 2171
- atmospheric sulphur dioxide reduction (1990–2000), 843
- black carbon model estimates, 848
- carbonaceous aerosol emissions in, 828
- climatic impact-driver change projections, 140, 1821, 1827
- climatic reference regions, 1998
- coastal and ocean climatic impact-driver changes, 141, 1826, 1828
- compound events observations and projections, 1828
- drought observed trends and warming level projections, 1686
- extratropical cyclones projections, 1998
- extreme precipitation increase (since 1950s), 1559
- extreme precipitation projections, 1566
- fossil fuel emissions, 829
- glacier mass change projections, 1825
- glacier mass loss estimates for Alps, 1275
- glacier mass loss projections, 1998
- greenhouse gas emissions for, 713
- heat and cold changes, 141, 1820
- heavy precipitation trends and warming level projections, 1684
- hot and cold extremes projections, 1556
- large-scale patterns of precipitation, 1999
- maximum temperature and heatwave changes, 1549
- model estimates of temperature trends, 2001
- model performance assessment, 2001
- NO₂ decreases, 839
- observations, trends and attribution synthesis, 1998
- ozone-induced gross-primary productivity losses, 857
- particulate matter emissions sources in, 821
- present day 1-in-100-year extreme total water level and projections, 1826
- recent precipitation trends in, 1999
- regional climate and main hazard assessment, 1820–1829
- regional climate features, 1998
- regional model performance for, 2001
- regional precipitation trends, 1999, 2003
- regional solar radiation projections, 1791
- regional surface air temperature change over land, 2003

- regional temperature and rainfall changes, 1998
- regional temperature extreme studies for, 1552
- regional temperature projections for, 2003
- regional wind projections, 141
- river floods changes, 1824
- seasonal signal and precipitation gradient, 2002
- short-lived climate forcer effects in, 888
- short-lived climate forcers distribution, 819
- snow and ice changes, 141, 1825
- snow cover extent projections, 1825, 1998
- snow depth and snow water equivalent changes, 1825
- snowfall/snow melt trends and projections, 1999, 2003
- snow projections for, 2002
- solar radiation changes in, 938
- sulphate aerosol concentrations, 846
- sulphate aerosols in, 845
- sulphur dioxide emissions over, 844
- sulphur dioxide reductions in, 842
- sulphur trends (1990–2015), 846
- summary of changes, 126, 140, 2003
- surface air temperature trends (1980–2015), 2000
- surface ozone concentration changes, 882
- surface shortwave radiation trends, 1999
- temperature and precipitation projections, 2003
- temperature and precipitation trends (1980–2015), 1999
- temperature extreme trends and warming level projections, 1680
- temperature trends in subdomains, 1999
- warming level projections, 1998
- wet and dry climate impact-driver changes, 1822
- wind changes, 1824
- wind speed changes, 1824

European Centre for Medium-Range Weather Forecasts (ECMWF), 431**European Space Agency Climate Change Initiative (ESA CCI), 1382****Eutrophication***

- anthropogenic mechanisms, 721
- carbonate chemistry effects, 720
- exacerbation of coastal ocean acidification, 721
- from inadvertent fertilization, 857
- in Baltic Sea, 722
- in coastal tropical waters, 721

Evaluation diagnostics (for models), 1395**Evaporation* minus precipitation (E–P) patterns, 1225****Evapotranspiration* (ET)**

- atmospheric water demand effects, 1058
- change in terrestrial (since 1980), 1084
- changes in, 1084
- drivers of change in, 1116
- in regional droughts, 1575
- linear trends in annual means, 1085
- projections for, 1116
- quantification of, 1571

Exposure* in risk assessment, 201**External forcing, effects on variability and teleconnections, 2155****Extratropical cloud optical depth feedback, 974**

- Extratropical cyclones* (ETCs)**
 annual anomalies in numbers, 1102
 changes in intensity, 1101
 detection and attribution, 1593
 extreme sea level events, 1310
 future projections for, 606
 model evaluation, 1396, 1592
 observed trends, 1592
 precipitation changes with warming, 1058
 precipitation with, 1132
 rain rate changes, 1519
 uncertainties in projections, 1133
 wind speed changes, 1519
- Extratropical jets* and cyclone tracks**
 effects of, 463
 shift in tracks of, 464
 storm tracks, and blocking, 338
- Extratropical modes, 1105**
- Extreme Coastal Water Level* (ECWL)**
 contribution to sea level change, 1221
 impacts of, 1786
 swash contribution to extreme sea level, 1310
- Extreme heat**
 African regional changes, 1791
 Asian regional changes, 1799
 Australasian changes, 1807
 Central and South American changes, 1815
 European changes for, 1820
 global projections for, 1851
 health and agricultural impact and risks, 1780
 hot temperature threshold changes, 1793
 impact in polar regions, 1844
 North American changes, 1828
 projections for, 1518, 1555
 scenarios in arid and semi-arid regions, 1849
 signal emergence in land regions, 1854
 Small Islands changes, 1837
 societies, health, and habitability impact, 1849
 thresholds crossing projections for, 1851
- Extreme precipitation. *See also* Heavy Precipitation**
 attribution of anthropogenic influence, 457, 1563
 changes with warming levels, 1564
 from orographic effects in mountains, 1850
 human influence attribution, 457
 increase in (since 1950s), 1558
 observed and simulated changes, 458
 projections with warming levels, 1531
 temperature increase effects on, 1526
 thermodynamic and dynamic processes, 1557
- Extreme river flow trends, 1569**
- Extreme sea level* (ESL)**
 defined, 1221
 factors contributing to, 2211
 localized storm surge processes, 1310
 methods and projections for, 1312
 modelled trends in, 1309
 past changes in, 1309
 regional projections, 1853
 sea level and atmospherically forced drivers, 1314
 signal link and emergence, 1310
- tidal constituent effects on, 1309
 tides, surges and waves, 1309
- Extreme still water level* (ESWL)**
 causes of changes in, 1309
 historical occurrences of extreme, 1311
 in sea level change, 1221
 observed trends in, 1309
 projections of amplification factors, 1313
- Extreme storms**
 quantifying effects of climate change, 1583–1599
 rain rates with, 1519
 severe wind storms, 1784
 tropical cyclones, 1519
- Extreme total water level* (ETWL)**
 components of, 1310
 defined, 1221
 frequency projections, 1852
 hazards associated with, 1786
 index for episodic coastal flooding, 2211
- Extreme weather events***
 AR6 use of "extreme", 201
 as climatic impact-drivers, 201, 1521
 attribution of, 1523
 attribution to human influence in AR6, 42
 confidence in changes, 1517
 definition of, 1522
 incremental warming effects on, 15
 indices for, 2208
 indices selection for, 2207
 maps for extreme conditions, 1609
 modes of variability influence on, 1962
- Extreme winds**
 climatic impact-drivers, 1784
 definition of, 1597
 in extreme storm characteristics, 1598
 observed intensity changes in, 1598
- F**
- FalRv1.6.2, emissions-based emulator, 964**
- False alarms (for hazards), 172**
- Feedback parameter**
 biogeochemical climate feedback parameter, 738
 change in net energy flux, 932
 climate–biogenic volatile organic compound feedback, 859
 climate–lightning NO_x feedback estimate, 859
 climate–ozone feedback, 859
 diagnosed parameters on 4xCO₂ runs, 735
 estimates of overall climate effects, 859
 estimation in global climate models, 968
 for CO₂, 739
 for mineral dust, 858
 for short-lived climate forcers, 820
 in surface temperature changes, 967
 net feedback assessment, 95
 non-CO₂ biogeochemical feedback estimates, 860
 quantification in Earth system models, 858
 relative to pre-industrial, 981
 temperature effects on, 980
- Fertilization**
 atmospheric CO₂ effect on land storage, 677
 mineral nitrogen application, 828
 perturbation of nitrogen cycle by, 708
 reactive nitrogen deposition in forests, 857
 seasonal cycle of atmospheric CO₂, 427
- Fifth Assessment Report (AR5)**
 20-year baseline (1986–2005), 1935
 advances in assessment on uncertainty since, 559
 air quality–climate interaction, 825
 anthropogenic effects on Arctic sea ice, 466–467
 Arctic sea ice coverage projections with RCPs, 574, 586
 assessed magnitude of aerosol–cloud interaction, 926
 assessment of warming potential of human emissions, 180
 assessment on climate system warming, 157
 carbon-cycle response for non-CO₂ gases, 1017
 carbon-cycle response in 21st century, 741
 changes in circulation features, 1101
 changes in tropospheric and stratospheric temperatures, 327
 climate change effects on land carbon uptake, 724
 climate-DMS feedback parameter estimation, 858
 climate driver changes over industrial period, 310
 climate–fire feedback assessment, 859
 cloud microphysical properties in, 951
 CMIP5 models of sea surface temperature biases, 1223
 confidence of model reproductions of temperature, 433
 contribution of anthropogenic forcings to warming, 443
 contribution of internal variability to warming (1951–2010), 443
 correlation between Northern Hemisphere snow cover extent (SCE), 470
 cumulative emissions of CO₂ and warming, 742
 decadal climate predictions from observed climate state, 563
 deep ocean warming, 1228
 determining carbon budgets, 749
 Earth system components susceptible to abrupt change/tipping, 634
 effective radiative forcing estimates, 925
 effective radiative forcing introduction, 931
 effects of air pollution reduction on warming, 591
 effects of ozone on plant physiology and carbon storage, 857
 El Niño–Southern Oscillation climate effects, 589
 equilibrium climate sensitivity range, 1006
 evidence for human influence, 425
 factors in marine aerosol formation, 832
 feedback of cloud regimes in, 972
 glacier change assessment, 1273
 global energy inventory increase, 937
 global warming potential and global temperature change potential estimates of, 927

- Hadley cell widening in Southern Hemisphere, 459
- historical trends in atmospheric CO₂ concentrations, 683
- human influence on surface temperature (1951–2010), 428
- Inter-tropical Convergence Zone changes, 1093
- introduction of climate services, 1862
- large-scale aerosol optical depth trends (2000–2009), 308
- long-term global monsoon changes, 603
- mapping of uncertainty/robustness, 1946
- methane emissions reporting in, 704
- non-CO₂ biogeochemical feedbacks estimation, 858
- observations of air–sea fluxes, 1224
- observed temperature trends in Central America, 1991
- ocean salinity assessment, 1234
- predictions of near-term Pacific Decadal Variability, 590
- radiative forcing assessment of short-lived gases, 825
- radiative forcing from contrails, 866
- reference periods/baselines used in, 1935
- regional downscaling for South Asia, 1978
- regional downscaling methods, 1377
- representation of aerosol processes in CMIP5, 851
- representation of change in (traditional methodology), 565
- Representative Concentration Pathways and simulations used in, 562
- role for anthropogenic forcing in driving warming, 441
- sea surface temperature change in, 1221
- short-lived climate forcers treatment in, 825
- solar radiation changes, 938
- solar variability assessment in, 296
- Southern Annular Mode assessment, 588
- spatial patterns of aerosol and ozone forcing, 852
- subcontinental reference regions for, 1936
- sulphate aerosols over USA and Europe, 845
- surface downward thermal radiation increase, 939
- temperature effects in polluted areas, 864
- terrestrial paleo hydroclimate indicators, 329
- top-of-atmosphere radiation budget quantification, 935
- tropical forest loss due to climate change, 724
- tropospheric ozone burden assessment, 836
- uncertainty quantification in, 568
- upper-ocean stratification assessment, 1225
- volcanic aerosol forcing, 298
- water cycle change assessment, 1062–1064
- water cycle change summary from, 1062
- water vapour and temperature effects on surface ozone, 861, 862
- zonal mean precipitation projections, 584
- Findable, Accessible, Interoperable, and Reusable (FAIR) principles**, 38, 171, 1935, 1954
- Fine-mode NO₃ burden simulations**, 846
- Fingerprinting methods**
- for Northern Hemisphere snow cover, 2005
 - pattern similarity use, 430
 - regional anthropogenic and natural forcings, 113
 - spatial expressions of multivariate fingerprints, 1088
- Fire weather***
- African changes, 1794
 - Asian changes, 1801
 - Australasian changes, 1809
 - Central and South American changes, 1817
 - changes in, 725
 - drought and heatwave associations, 1600
 - emergence of signals for, 1854
 - European changes, 1823
 - global projections, 1852
 - in compound events, 1519
 - indices and metrics for impact, 1784
 - North American changes, 1832
 - polar terrestrial regions changes, 1844
 - Small Islands changes, 1838
 - tropical forest projections, 1851
 - warming effects on, 833
- First Assessment Report (FAR)**
- global warming prediction, 186
 - human emissions assessment in, 180
 - importance of regional climates, 206
 - projections for temperature change (1990–2030), 186
 - structure of assessment, 153
- First realization (r1) from CMIP modelling**, 570
- Fixed-sea surface temperature (fSST) method**, 942
- Floods***
- agricultural and infrastructure effects, 1783
 - classification of, 1567–1571
 - coastal flooding impact, 1786
 - compound surge and river flow, 1848
 - continental and regional scale projections, 1569
 - extreme precipitation and, 1518
 - large-scale circulation effects on, 1528
 - long-term attribution for, 1569
 - mechanisms and drives, 1567
 - model evaluation, 1568
 - observed trends for, 1568
 - projections for, 1569
 - projections for changes in, 1119
 - river floods, 1518
- Fluvial flood**, 1851. *See also* **River (fluvial) flood**
- Forcing agents**
- natural versus anthropogenic, 425
 - relations between agents, 101
 - solar irradiance, 957
- Forecast quality assessment**, 564. *See also* **Climate modelling techniques**
- Forest-based methods for CO₂ removal**, 762
- Formaldehyde (HCHO)**
- proxy for tropospheric OH estimates, 850
 - regional distribution trends, 842
- Fossil fuel combustion**
- anthropogenic CO₂ from, 150, 687
 - atmospheric concentration from burning, 708
 - atmospheric concentration of ¹⁴C versus ¹²C, 180
 - carbonaceous aerosols from, 825
 - carbon release by combustion (1750–2019), 680
 - emissions during COVID-19, 822
 - industrial era growth of CO₂ emissions, 687
 - methane emissions from, 821
 - short-lived climate forcers with, 829
- Fram Strait, sea ice thinning signal**, 1251
- Free-atmosphere* temperature assessments**, 327
- Freezing Level Height (FLH), elevation-warming and**, 1850
- Frequently Asked Questions (FAQs)**
- Are climate models improving?, 519
 - At a given level of global warming, what are the spatial patterns of climate change?, 644
 - Atlantic Meridional Overturning Circulation, 1321
 - Can continued melting of the Greenland and Antarctic ice sheets be reversed?, 1316
 - Can thawing permafrost substantially increase global warming?, 773, 774
 - Clouds – What is the role in a warming climate?, 1022, 1023
 - Could climate change be reversed by removing carbon dioxide from the atmosphere?, 775
 - Did climate change cause that recent extreme event in my country?, 1610, 1611
 - Do we understand climate change better now compared to when the IPCC started?, 244
 - How can we provide useful climate information for regional stakeholders?, 1460
 - How do changes in climate extremes compare with changes in climate averages?, 1608
 - How does land use change alter the water cycle?, 1153, 1154
 - How do we know humans are responsible for climate change?, 515
 - How is the current warming any different?, 378
 - How much will sea level rise in the next few decades?, 1318
 - How quickly would we see the effects of reducing carbon dioxide emissions?, 642
 - How will climate change affect the regional characteristics of a climate hazard?, 1875
 - How will the climate change over the next twenty years?, 640
 - Is the natural removal of carbon from the atmosphere weakening?, 771
 - The Earth's temperature has varied before. How is the current warming any different?, 378
 - What are carbon budgets?, 777
 - What are climatic thresholds and why are they important?, 1873
 - What are short-lived climate forcers and how do they affect the climate?, 893
 - What are the links between limiting climate change and improving air quality?, 895
 - What can past climate teach us about the future?, 248, 249
 - What causes droughts, and will climate change make them worse?, 1157
 - What is a climatic impact-driver (CID)?, 1871

- What is equilibrium climate sensitivity and how does it relate to future warming?, 1024, 1025
- What is natural variability and how has it influenced recent climate changes?, 517
- What is the Earth's energy budget, and what does it tell us about climate change?, 1020, 1021
- What is the evidence for climate change?, 380, 381
- What is the role of clouds in a warming climate? 1022
- Where is climate change most apparent?, 246, 247
- Why are cities hotspots of global warming?, 1462, 1463
- Will floods become more severe or more frequent as a result of climate change?, 1155
- Will the Gulf Stream shut down?, 1320
- Will unprecedented extremes occur as a result of human-induced climate change?, 1610
- Freshening**
- in Baltic, 2002
 - Pacific and Southern Ocean projections, 143
 - Southern Hemisphere subtropics, 1235
- Freshwater reservoirs**
- changes in, 1089–1092
 - Greenland and Antarctic ice sheets as, 1220
 - groundwater, 1123
 - in sea level change, 1220
 - methane from wetlands, 704
 - terrestrial water storage trends, 1092
 - wetlands and lakes, 1123
- Frost**, 1793. *See also* **Cold spells and frost**
- Frost days (FD) index**, 2210
- Future Resilience for African CiTies And Lands (FRACTAL) project**, 1867
- G**
- Galactic cosmic rays (GCR)**
- climate feedbacks from, 297
 - new particle formation, 958
- Gas exchange coefficient calculation**, 729
- Gas-to-particle reactions (ammonium aerosols)**, 846
- GCOS Reference Upper Air Network data (RS92-GDP)**, 327
- General circulation/global climate models* (GCMs)**
- for climate projections, 2100
 - in the CMIP6 DECK, 2101
- Geocentric sea level change***, 1220
- Geoengineering Intercomparison Project (GeoMIP)**, 860
- Geostationary Earth-orbit (GEO) satellites**, 1382
- Glacial-interglacial cycles**, 160, 1000
- Glacial Isostatic Adjustment (GIA)**, 1221, 1300
- Glacier mass balance loss/retreat**
- Asian glacier and snowpack projections, 1803
 - Asian regional scenario projections, 1802
 - Central and South American changes, 1817
 - changes for Europe, 1825
 - Greenland Ice Sheet, 472
 - Hindu Kush Himalaya region, 1456
 - human influence on, 5
 - in Northern Hemisphere systems, 471
 - in the Andes Cordillera, 140
 - meltwater dispersion from, 1220
 - New Zealand, 1987
 - North American regional changes, 1833
 - polar and high mountain ecosystems, 1785
 - South Asia, 1978, 1979
- GlacierMIP Project**
- contribution to sea level rise, 1263
 - emulations used for projections, 1299
 - loss projected in South America, 1818
 - model intercomparisons, 2108, 2111
 - modelling for retreat, 471
- Glacier response time**, 1220
- Glaciers* and ice sheets***
- anthropogenic influence on, 471
 - attribution of large-scale changes, 471–474
 - bathymetry requirements for projections, 1257
 - committed changes in, 21
 - drivers of change in, 1276
 - extent and mass change, 1273–1274
 - GlacierMIP projections, 1299
 - global and regional mass change rate (1960–2019), 1274
 - global and regional mass evolution (1901–2100), 1277
 - global changes in, 1273, 1275
 - global mass loss projections, 1122, 1215, 1852
 - ice loss projections for, 42
 - mass loss of, 158
 - model evaluation, 1278
 - model intercomparison studies, 2108
 - New Zealand projections, 1811
 - ocean temperatures and calving rate, 1257
 - polar region changes, 1847
 - polar terrestrial changes, 1845
 - projections for, 1122
 - projections for global glacier mass, 1278
 - regional changes in, 1275–1277
 - sea level change contribution, 482, 1089, 1220, 1279
 - simulations of mass changes, 471
 - West Antarctic Ice Sheet, 1265
- Global budgets of organic aerosols**, 831
- Global Carbon Project (GCP)**, 695, 699
- Global climate change projections**
- assessment of air temperature projections, 580–581
 - atmospheric blocking, 607
 - attribution and projections for extremes, 1529
 - climate policy implications, 612
 - CMIP6 Annular Mode index change, 610
 - CMIP6 global surface air temperature simulations, 570
 - CMIP scenario simulations for precipitation, 584
 - commitment and change (beyond 2100), 557, 630
 - confidence in climatic impact-drivers change, 1853
 - cryosphere, ocean, and biosphere, 574, 586
 - El Niño–Southern Oscillation variability, 579
 - ensemble evaluation and weighting, 568
 - global mean sea level projections (2081–2100), 576
 - global monsoon projections, 585, 603
 - historical land-cover change in, 310
 - historical simulations, 570
 - Indian Ocean Basin and Dipole Modes, 611
 - indicators of change, 22
 - indicators of change from simulations, 571
 - initialized predictions (2019–2028), 569
 - key indicators for, 290
 - large-scale circulation and modes of variability, 556
 - linking global to regional change, 1363–1365
 - mid- to long-term change, 595–614
 - mitigation response, 557
 - model agreement and spread display, 567
 - models used for, 561
 - modes of variability, 609
 - modes of variability in assessment, 578–579
 - near-surface relative humidity, 600
 - near-term changes, 583
 - near-term information sources, 563
 - Northern and Southern Annular Modes, 609
 - ocean, 608
 - ocean and cryosphere, 557
 - ocean and land carbon flux projections, 587
 - ocean and land carbon uptake (RCP/SSP), 576
 - Pacific Decadal Variability, 611
 - past regional evaluations, 186
 - pattern scaling, 565
 - precipitation projections, 556, 601
 - projected global climate indices changes (21st century), 570
 - projections specific warming levels, 612
 - response to mitigation, 619
 - sea ice extent and external drivers, 575
 - seasonal warming patterns, 597–601
 - simulations for two indicators (1995–2040), 641
 - solar radiation modification response, 619
 - SSP scenarios, 232, 555
 - temperature patterns for warming levels, 614
 - temperature variability projections, 597
 - time-shift method for representation, 565
 - uncertainty quantification, 566
- Global climate models (GCMs)**
- atmospheric global climate models, 1389
 - climate change projections for Europe, 2002
 - equilibrium climate sensitivity and transient climate response in, 1007
 - feedback parameter in estimations, 968
 - regional climate models, 1389
 - water cycle projections, 1058
- Global Climate Observing System (GCOS) program**, 312, 1382
- Global energy budget**. *See* Earth's energy budget*
- Global energy budget and inventory**
- and sea level budget, 1291–1293
 - assessed changes in, 937, 938
 - change in, 937
 - components of, 938
 - energy change (1971–2018), 939, 940
 - equilibrium climate sensitivity estimates, 995–1004

- trends in, 925
- Global energy inventory.** *See* Earth's energy budget*
- Global Extreme Sea Level Analysis (GESLA) tide gauge database,** 1309
- Global Framework for Climate Services (GFCS),** 172, 1862, 1864
- Global Historical Climatology Network,** 455, 1385
- Global hydrological cycle.** *See also* **Water (hydrological) cycle***
 - global precipitation, 332
 - limitations on reconstructions of, 329
 - paleo perspective of, 329
 - precipitation minus evaporation, 333
 - streamflow, 335
 - surface humidity, 330
 - total column water vapour, 330
- Global Land 30,** 1382
- Global land precipitation.** *See* **Land precipitation**
- Global land temperature, Callendar's estimates of variations,** 179
- Global legislation, short-lived climate forcer relevant,** 872
- Global mean sea level* (GMSL)**
 - acceleration of rise, 187
 - climate system heating effects on, 11
 - commitment and peak global surface air temperature, 1307
 - commitment sensitivity to warming, 1306
 - definition of change in, 1220
 - evaluation of budget for, 1287–1289, 1288
 - glacial-interglacial cycle reconstructions, 160
 - human influence driving of, 427, 482
 - ice-sheet mass loss contribution, 1288
 - in climate change assessment, 575
 - likely magnitude of rise, 21
 - observations and projections, 42, 77–80
 - observations and projections for rise, 1319
 - observed budget for, 1292
 - observed contributions to change and time periods, 1289
 - paleoclimate reconstructions, 160
 - projections (beyond 2100), 1217
 - projections for (1995–2014 and 2300), 1306
 - projections for (2081–2100), 557, 576
 - projections for drivers of change, 1297
 - projections for rise, 188
 - projections for rise (through 2100), 1216
 - rate of change (1993–2015 and 2006–2015), 1288
 - rate of change in, 291
 - rate of rise in 20th century, 1216
 - rate of rise (since 1900), 8
 - RCP-based projections, 1295, 2009
 - reconstruction (past 800kyr), 160
 - response time for, 47
 - rise from low-confidence process, 1302
 - rise in (1901–2018), 5
 - rise with high emissions scenarios, 1304
 - scenario projections for (RCP/SSP), 1296, 1299
 - sea level projection categories, 576
 - SSP-based projections, 1302–1304
 - thermoelectric and halosteric changes, 1220
 - threshold exceedance projections, 1304, 1305
 - time scales and scenario changes, 78
- Global mean surface temperature* (GMST)**
 - anomalies in simulations and observations, 1009
 - anthropogenic influence attribution, 442
 - attributable to human influence (1951–2010), 428
 - climate system warming indicator, 157
 - compared to global surface air temperature, 291
 - cumulative CO₂ emissions and remaining carbon budget, 97
 - current interglacial period estimates, 317
 - effects on sea level, 160
 - five-year trend (2016–2020), 426
 - history and key findings, 316
 - Holocene prior to industrialization, 315
 - human activity effects (2006–2015), 187
 - improved estimation of, 325
 - in situ data products considered in AR6, 325
 - Last Glacial Maximum reconstructions, 315
 - long-term context of anthropogenic effects, 159
 - long-term effects of CO₂ emissions, 160
 - observed increase in, 326
 - paleoclimate reference periods, 294–296
 - past 60 million years, 296
 - rate of increase, 290
 - rate of increase (1998–2012), 447
 - rate of increase (1998–2012 versus 1951–2012), 425
 - reconstruction (past 800 kyr), 160
 - reconstructions for last millennium, 317
 - response to mitigation, 621
 - updates to observational dataset, 446
- Global mean thermoelectric sea level (GMTSL)**
 - anthropogenic forcings, 481
 - change in, 1220
 - from ocean heat content increase, 1244
- Global monsoon* (GM)** *See also* **Regional Monsoon**
 - AR5 report on, 337, 1094
 - CMIP projections for, 585
 - global and regional areas of, 2195
 - global and regional trends and projections, 119, 1094, 1127
 - history of concept, 2195
 - human influence on, 461
 - identification of, 2195
 - land–ocean heat contrast effects on, 1528
 - land precipitation changes and projections, 118–121
 - land precipitation changes in, 9
 - land precipitation projections, 1127
 - mean water cycle projections for mid- and long-term, 1128
 - onset and precipitation projections, 19
 - paleoclimate records and projections, 118
 - rationale and definition of regional, 2195
 - summer precipitation changes in, 462
 - volcanic eruption effects on, 24
 - wet season changes with warming, 1114
- Global Monsoon Model Intercomparison Project (GMMIP),** 2195
- Global Navigation Satellite System (GNSS)-RO datasets,** 327
- Global ocean biogeochemical models (GOBMs),** 691
- Global ocean data analysis project for carbon (GLODAPv2),** 743
- Global Ocean Data Analysis Project (GLODAP),** 691
- Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP),** 380, 1230
- Global precipitation**
 - averaged trend estimates over land, 332
 - observed changes in precipitation, 333
 - response to radiative forcing, 1065
- Global precipitation change potential,** 220
- Global Precipitation Climatology Centre (GPCC),** 1385
- Global-scale Concurrent Climate Anomalies,** 1601–1604
- Global stocktake**
 - AR6 contribution and relevance to, 162, 163
 - every 5-years for Paris Agreement, 150
- Global surface air temperature* (GSAT)**
 - 20-year averaged change in, 582
 - 50 years after cessation of emissions, 631
 - AR5 and SR1.5 data conversion for comparisons, 580
 - assessed historical and future ranges of, 927
 - attributable change (1750–2019), 962
 - attributable trends for (2010–2019), 440
 - attribution to anthropogenic activities, 157
 - change without mitigation, 621
 - concentration- and emissions-driven simulations, 573
 - contribution of forcing agents to change, 960–962
 - emissions-based radiative forcing effects, 853, 855
 - emissions-driven versus concentration-driven simulations (1995–2014), 573
 - emissions contribution to (1750–2019), 92
 - emissions levels and mitigation effects on, 557
 - emulator match with assessed ranges, 964, 966
 - estimates of change (1850–2019), 995
 - estimation of remaining carbon budget, 751
 - evidence long-term change by scenario, 581
 - forcing of sea level change by, 1298
 - for defining warming levels, 1936
 - high-warming storylines in, 555
 - historical and forced scenario simulations, 569
 - human-induced warming (2010–2019), 425
 - influence of unforced variations, 937
 - internal decadal variability change with warming, 448
 - metrics for response to doubling of CO₂, 931
 - metrics for response to forcing, 992
 - near-term change in, 555, 583
 - observational constraints and scenario-based projections, 555
 - observed and simulated anomalies, 435
 - precipitation pattern and rate change, 601

- projections with CMIP scenario simulations, 580–582
- quantification of surface temperature change, 929
- rate of increase (1998–2012), 447
- recent increases in, 5
- regional emissions of short-lived climate forcers, 887
- relationship to carbon dioxide emissions, 678
- relation to global mean surface temperature, 291
- response at 10 and 100 years after pulse, 870
- response to abrupt emissions reduction, 865
- response to mitigation, 621, 865
- response to perturbations, 931
- response to pulse of current emissions, 868
- response to short-lived climate forcers, 820
- scenario-based projections for, 571
- scenario-dependence of, 632
- seasonal contrast and regional differences, 556
- short-lived climate forcers and hydrofluorocarbons, 886
- simulated internal variability versus observed change, 437
- spatial patterns of surface warming, 583
- threshold crossing time for, 582
- total human-forced change (1750–2019), 927
- variance and skewness changes, 597
- warming attributable to human influence, 442
- Global surface temperature***
 - 10 and 100 years after pulse, 102
 - 15-year trends, 448
 - 20-year averaged change, 63
 - annual, decadal and multi-decadal variations, 518
 - anthropogenic factors in warming, 150
 - AR5 limitation of datasets, 324
 - AR6-assessed range and model-simulated, 45
 - assessment of global surface air temperature* (GSAT) and global mean surface temperature (GMST), 317
 - confidence in change, 430
 - deep past (65 Ma to 8 ka), 314
 - during the instrumental period, 323
 - effects on regional water cycle, 1071
 - estimated from proxy records and models, 46
 - future changes, 60–62
 - historical changes in, 60
 - history and future with key findings, 61
 - human influence on, 430–443
 - human influence on current warming, 60
 - land domain, 324
 - marine domain, 323
 - mid- and long-term change, 595
 - model evaluation, 431–438
 - near-term change in, 584
 - past, current and future changes, 59–64
 - post-glacial period (past 7000 years), 315
 - rate of increase since 1970, 8
 - response for forcers with short lifetimes, 819
 - scenario projections for, 14
 - seasonal warming pattern changes, 597
- Global surface warming (early 21st century), 445**
 - regional effects of increase in, 24–25
 - remaining carbon budget and, 751
 - sectors contributing most to, 821
 - short-lived climate forcers contribution to, 885
 - surface warming for land and ocean, 556
 - temperature signal emergence over land, 150
 - temporary slowing (1998–2012), 447
 - warming since mid-20th century, 438
 - water vapour and lapse rate feedback, 95
- Global warming level 1.5°C**
 - Atlas presentation of, 1936
 - austral-winter rainfall projections, 615
 - greenhouse gas emissions levels, 15
 - precipitation projections, 573
 - threshold-crossing time, 42, 582
- Global warming level 2°C**
 - Atlas presentation of, 1936
 - biodiversity hotspots change, 143
 - climatic impact-driver changes, 24–25
 - confidence in changes and projections, 1529
 - greenhouse gas scenarios, 14
 - precipitation changes with, 1544
 - projection with high emissions, 582
 - regional change projections, 135
 - tropical cyclone projections for, 2009
- Global warming levels (GWLs)**
 - 20-year periods at specific warming levels, 2210
 - agriculture contribution to, 866
 - analysis framework for, 967
 - as dimension of integration, 55
 - assessing past projections, 185
 - assessments based on warming levels, 1546
 - basin-scale runoff with increases in, 1147
 - calculation of, 1936
 - climate extremes projections, 1541
 - CMIP model scenario simulations for global surface air temperature, 572
 - constraints on projections, 1008
 - contrast of wet and dry seasons with, 1114
 - cryosphere and sea level rise (1.5°C and 2°C warming), 1217
 - cryospheric change (2°C, 3°C and 5°C), 1217
 - drought frequency, 1519
 - effects of first versus second 2 degrees on precipitation, 1145
 - emissions scenarios, regional climate response, and impacts, 1543
 - expectations with CO₂ emissions levels, 618
 - extended scenarios (to 2300), 558
 - extreme change projections, 1533
 - extreme changes with, 1522
 - extreme precipitation projections, 1531
 - for information integration, 227
 - hazard assessment for, 1857
 - heavy precipitation changes with, 1566
 - hot and cold extremes with, 1518
 - human-caused warming (to 2017), 187
 - information for end users, 1542
 - land-related changes as function of level, 83
 - land versus ocean and latitude differences, 613
 - levels used in report, 1936
 - low-likelihood, high-impact extreme changes, 1535
- Global temperature change (1750–1850), 192–193**
- Global temperature change potential (GTP), 220, 927**
- Global Terrestrial Network for Glaciers, 210**
- Global Terrestrial Network for Permafrost, 210**
- Global Tide and Surge Reanalysis (GTSR), 1309**
- Global total column water vapour content change, 291**
- Global warming***
 - 21st century projections, 1931
 - air pollution control in mitigation, 821
 - amplification of greenhouse gas-induced changes, 1059
 - assessed human influence on, 440
 - atmospheric moisture and precipitation effects, 1057
 - attribution of, 7, 438
 - changes in regional climate variability, 1960
 - changes in year-to-year variability, 598
 - climatic impact-driver evolution with warming, 1777
 - cumulative emissions and mean warming, 240
 - defined, 39
 - effective radiative forcing values with, 290
 - effects of CO₂ and short-lived climate forcers, 821
 - effects of methane emissions, 821
 - emissions pathways to limit warming, 189
 - equator-to-pole amplification of, 1554
 - estimated warming to date, 323
 - estimate of human-induced, 425
 - first versus second 2°C of warming, 1145
 - history and temperature change, 6
 - impact on climatic impact-drivers, 1771
 - incremental warming effects, 15
 - Kigali Amendment enforcement, 873
 - land-use change effects, 310
 - loss of frozen water stores, 1072
 - low oxygen zone changes with, 1842
 - mid-19th century beginning, 161
 - modes of variability in projections, 1557
 - N₂O response to, 677
 - Nationally Determined Contribution submissions, 150
 - net zero anthropogenic emissions to halt, 678
 - new estimates and implications, 317
 - nitrogen fixation in non-agricultural ecosystems, 830
 - observed warming (1850–2019), 516
 - observed warming to date, 41
 - ocean warming contribution, 938
 - offset by cessation of emissions, 630
 - overshooting global warming levels, 558
 - over the instrumental period, 191
 - precipitation and evaporation increase with, 1057
 - precipitation changes with, 616
 - projected transient warming, 1010
 - projections and observations on, 150
 - projections for short-lived climate forcer emissions, 820
 - rate in early 21st century, 447

- mean fractional changes with warming, 1527
 - metrics used for, 192
 - non-linearities across, 1144
 - observed changes in extremes and projections, 67
 - patterns of climate change, 612
 - precipitation, 2007
 - projections for extreme precipitation events, 1564
 - projections for extreme temperatures, 1555
 - regional impact and hazards associated, 152
 - sampling approach for timing and response, 1545
 - scenarios and patterns of change, 56
 - scientific and socio-economic relevance, 239–240
 - sea level commitment/exceedance for warming levels, 1305
 - sea level projections (to 2100), 1304
 - spatial patterns of extreme precipitation events, 1564
 - summary of extreme condition assessments, 1761
 - surface warming in early 21st Century, 445–447
 - uncertainty in response to forcing, 1009
 - warming of at least 4°C with high emissions, 132
 - Global warming potential* (GWP)**, 220, 927
 - Gravitational, rotational and deformational (GRD) effects***, 1221, 1300
 - Gravity Recovery and Climate Experiment* (GRACE)**, 209, 1263, 1288
 - Greenhouse gases* (GHGs)**
 - aerosol masking of warming effect of, 819
 - AR5 assessment in tropospheric warming, 444
 - Arctic sea ice loss driver, 426
 - attribution of Arctic sea ice loss, 468
 - attribution of contemporary trends in, 769
 - attribution of contribution to warming, 425
 - attribution of temperature extremes, 1552
 - attribution of warming to, 439
 - climate response to reduction of emissions, 619
 - CO₂, CH₄, N₂O driving of radiative balance, 712
 - CO₂ uptake and storage (SSPs), 20
 - concentration changes in, 158, 676
 - contemporary trends and attribution, 769
 - cumulative emissions effects, 202
 - driver of hot and cold extremes, 426
 - driver of warming, 1547
 - effective radiative forcing (1750–2019), 926, 947
 - effects of local forcing, 1553
 - effects with continued warming, 1146
 - forcing of extreme conditions, 1522
 - forcing of hot and cold extremes, 1517
 - glacial-interglacial records of, 684
 - global annual mean mixing ratios (2011–2019), 302
 - global land monsoon precipitation effects, 463
 - global precipitation changes, 1113
 - heavy precipitation changes, 1518
 - historical and projections for changes in, 2140
 - historical trends, variability and budgets for, 687
 - influence of anthropogenic, 1552
 - influence on Brazil water shortage, 1996
 - in sea level change, 481
 - instrumental mixing ratios, 2140
 - irreversible changes with, 21
 - land monsoon precipitation changes, 9
 - land precipitation scenario projections, 19
 - lifetimes, radiative efficiencies and metrics for, 833
 - likelihood of 2°C warming, 14
 - long-lived versus short-lived, 1014
 - natural emissions in ocean-climate feedback, 719
 - net zero emissions for, 30, 101, 928
 - paleoclimate concentration measurement, 684
 - projections for concentrations, 2140
 - radiative perturbations due to, 944
 - regional distribution of CO₂, CH₄, N₂O (net fluxes), 713
 - relation to cumulative CO₂ emissions, 240
 - release from permafrost thaw (21st century), 740
 - scenarios for projections, 12
 - simulated temperature response, 445
 - temperature change with low emissions, 15
 - Greenhouse Gases Observing Satellite (GOSAT)**, 209, 689
 - Greening**
 - CMIP model simulations of, 1150
 - CO₂ radiative forcing of, 1150
 - evapotranspiration trends and, 1084
 - land surface and precipitation feedbacks, 1150
 - of the Sahara and the Sahel region, 1150
 - Greenland and Iceland (GIC)**
 - contribution to sea level (in 2300), 1260
 - glacier mass loss estimates, 1275
 - ice core data on atmospheric sulphur, 846
 - in Arctic region, 2022
 - in polar climate regions, 2016
 - models used for intercomparison studies, 2108
 - Greenland Blocking Index**, 1257
 - Greenland Ice Sheet* (GRIS)**
 - anthropogenic contribution to melting, 472–552
 - contribution to sea level (in 2100), 1259–1261
 - contribution to sea level rise, 1220
 - cumulative emissions effects, 21
 - feedback associated with, 977
 - high-end warming scenarios, 1308
 - human influence on melting, 5
 - Last Interglacial period response, 1294
 - low confidence projections, 1299
 - mass change and change rate for, 1255
 - mass change and sea level contribution, 1256
 - mass loss (1992–2020), 1215
 - mass loss from, 187, 1260
 - mass loss (since 2000), 291
 - mass loss through 21st century, 188
 - model evaluation for, 1258–1259
 - projected contribution to sea level (by 2100), 1260
 - projections (beyond 2100), 1260–1261
 - recent observed changes, 1254–1257
 - response to stabilization of warming, 106
 - sea level change drivers, 1298
 - sulphate records from, 298
 - surface mass balance loss in, 1254
 - thresholds and tipping points, 1261
 - time series of annual surface mass balance rate, 2020
 - uncertainties in future change, 1314
 - Gridding for dataset production**, 1386
 - Gross primary productivity* (GPP)**
 - effects of solar radiation modification, 768
 - ozone induced losses, 857
 - Groundwater**, 1091–1092, 1221
 - Guatemala Pacific coastal region temperature projections**, 1993
 - Guidelines for National Greenhouse Gas Inventories**, 153
 - Gulf of Mexico, eutrophication of**, 721
 - Gulf Stream**, 1320
 - Gyre* circulations**, 1241, 1242, 1243, 2159
 - Gyres, western boundary currents, and inter-basin exchanges**, 1241–1244
- ## H
- Hadley circulation* (HC)**
 - AR5 report on trends in strength, 335
 - effects on tropical cyclones, 1528
 - extent and intensity trends, 336
 - human influence on, 459, 461
 - Northern and Southern hemisphere changes, 459
 - poleward expansion of, 426, 606, 1528
 - poleward shift of dryland areas, 1849
 - stratospheric ozone depletion effects (1981–2000), 459, 1124, 1373
 - strength and widening, 1093
 - Hail**
 - Asian changes, 1803
 - European changes, 1825
 - frequency and distribution changes, 1771, 1785
 - North American change, 1834
 - Halogenated greenhouse gases**
 - effective radiative efficiencies, 946
 - effective radiative forcing increase, 947
 - natural sources, 304
 - ozone-depleting substances in, 304
 - summary of changes in, 305
 - types and current status of, 304
 - Halons, historical abundances forcing**, 843, 2143
 - Halosteric sea level change* defined**, 1220
 - Hazards***. *See also* **Climate hazards and consequences**
 - characteristics of, 1875
 - defined for AR6, 201
 - Heat extremes**. *See* **Extreme heat**
 - Heat index* (HI)**
 - calculation of, 2209
 - definition of, 2207
 - mapping threshold exceedances, 2210
 - threshold relation to emissions levels, 132
 - Heating degree days (HD)**, 2210
 - Heat stress* and Heatwaves***
 - African regional changes, 1613, 1791
 - Asian regional changes, 1631, 1799
 - Australasian changes, 1655, 1807
 - Central and South American changes, 1665, 1815
 - European changes for, 1680, 1820
 - expected increase in, 1851
 - extreme ozone and pollution effects, 864
 - in Antarctica, 1844

- increases in, 864
- intensity and duration (1950–2011), 1550
- North American changes, 1693, 1828
- projections for, 1554
- Small Islands changes, 1837
- Heavy precipitation and pluvial floods.** *See also*
 - Extreme precipitation**
 - African changes, 1619, 1794
 - agricultural and infrastructure impact, 1783
 - anthropogenic forcing contribution, 1562
 - Asian changes, 1638, 1800
 - Australasian changes, 1659, 1808
 - Central and South American changes, 1672, 1816
 - changes since 1950s, 8
 - changes with warming, 1518
 - daily precipitation change with warming, 1566
 - daily precipitation trends (1950–2018), 1560
 - detection and event attribution, 1562–1564
 - European changes, 1684, 1822
 - extreme hourly precipitation, 1564
 - factors in heavy precipitation/flooding change, 1156
 - global scale frequency and intensity, 1560
 - increased warming effects on, 16
 - mechanism and drivers for, 1557
 - model evaluation, 519, 1561–1562
 - multi-model mean bias in daily precipitation (1979–2014), 1561
 - North American changes, 1697, 1831
 - observed trends, 1557–1560
 - polar terrestrial changes, 1844
 - processes determining, 1072–1073
 - projections for, 1518, 1563–1565
 - projections for regional changes, 1853
 - projections from AR5, 1563
 - regional climate information, 1605
 - signal emergence, 1854
 - Small Islands changes, 1838
 - trends in sub-daily extremes, 1558
- Heavy snowfall and ice storms**
- Asian changes, 1803
- energy infrastructure and transportation impacts, 1785
- European changes, 1825
- North American changes, 1834
- polar terrestrial changes, 1847
- High-cloud altitude feedback,** 972
- High-latitude climates**
- carbon release from permafrost, 632
- high-warming storylines for, 637
- Northern Hemisphere cooling trend reversal, 438
- Northern Hemisphere land precipitation changes, 426
- Northern Hemisphere precipitation (1966–2005), 455
- Northern Hemisphere temperature change, 613
- observed extreme winds in, 1598
- ocean freshening and warming effects, 478
- precipitation projections for, 615
- snow water equivalent changes in, 134
- Southern Hemisphere changes, 426
- Southern Hemisphere wetting, 456
- surface freshening of ocean in, 1214
- temperature variability in, 598
- warming compared to low latitudes, 613
- High Mountain Asia,** 1275, 1984
- High-resolution cloud resolving models (CRMs),** 972
- High-Resolution Model Intercomparison Project (HighResMIP),** 431
- High spectral resolution radiative transfer models,** 944
- High-warming storylines**
- annual mean precipitation change with, 638
- changes in annual mean temperature, 636
- Hindu Kush Himalaya (HKH) region**
- annual precipitation change in, 1973
- climate change over, 1456–1459
- glacier melting in, 1979
- glacier projections for, 1122
- glacier trends in, 1458
- historical surface air temperature linear trend, 1457
- landslides in, 1800
- precipitation trends, 1458
- projections for change, 1458
- snow cover reduction in, 139
- temperature trends, 1456
- westerly disturbance interactions with, 1978
- Historical period simulations.** *See also*
 - Paleoclimate (proxy*) reconstructions**
 - aerosol effective radiative forcing changes, 857
 - CMIP reproduction of large-scale surface temperature patterns, 431
 - greenhouse gas effects, 819
 - marine heatwave definition by, 1227
 - models participating in CMIP6 DECK, 2101
 - net effect on globally averaged surface temperature, 188
 - Paleoclimate Model Intercomparison Project Phase 4 (PMIP4), 957
 - Paleoclimate Modelling Intercomparison Project Phase III (PMIP3), 298
 - pre-satellite dataset for biomass burning emissions, 832
 - short-lived climate forcer emissions, 885
 - use in model scenarios, 1936
- Holocene period**
- global mean sea level during, 1294
- greenhouse gas concentrations, 687
- thermokarst processes in, 727
- wetting trend, 329
- Homogenization of data,** 1384
- Horn of Africa,** 1968, 1970, 1971
- Human-induced climate change**
- Antarctic mass balance assessment, 473
- AR5 assessments of effects on water cycle, 1063
- atmosphere, ocean and land warming, 4
- atmospheric circulation, 459
- atmospheric oxidizing capacity, 848
- atmospheric water vapour changes, 451
- attribution of change to, 51
- carbon and geochemical cycles, 676
- carbon dioxide as driver of, 158
- cause–effect chain, 1012
- changes (1750–1850), 192
- climatic impact-driver index changes, 1853
- cold, hot and wet extremes, 1525
- compound event probability with warming, 1519
- compound extreme event changes, 9
- cryosphere, 466–491
- detection and attribution methods, 429
- distribution of aerosol effective radiative forcing, 852
- dry season water availability, 1579
- eastern boundary water upwelling, 1243
- effects on modes climate variability, 427
- evolution from theory to fact, 150
- extratropical atmospheric circulation, 606
- extratropical jets, storm tracks and blocking, 463–464
- extreme sea level events, 1310
- from land use forcing, 956
- global mean surface air temperature (2010–2019), 425
- global monsoon, 461
- global scale flooding, 1569
- global warming from, 187
- global water cycle changes with, 1057
- greenhouse gas level effects in scenarios, 31
- increased CO₂, CH₄, and N₂O in atmosphere, 676
- in current observed warming, 60
- large-scale precipitation changes, 426
- large-scale temperature and precipitation changes, 457
- last 2000 years, 161
- limiting cumulative CO₂ emissions for, 27–28
- local and regional streamflow change, 456
- long-term context for, 159
- natural climate variability masking, 150
- natural drivers and internal variability modulation of, 23
- natural versus human-induced changes, 202
- Northern Hemisphere snow cover, 426
- observed change and human contribution, 1532
- ocean acidification, 677
- ocean heat content increase, 1228
- ocean salinity changes, 1234
- on cryosphere, 426
- precipitation, humidity and streamflow, 449–453
- primary causes and consequences, 153
- probabilistic approaches to, 430
- radiative forcing effects, 11
- regional meteorological droughts, 1577
- since the mid-20th century, 161
- snow cover, 471–552
- SROCC assessment, 188
- stabilization of global temperature increase, 97–102
- stratospheric temperatures, 445
- strengthened evidence for, 428
- sudden stratospheric warmings, 466
- surface temperature, 430
- tropospheric temperature, 443–446
- upper air temperature, 443–445
- upper air temperatures and atmospheric circulation, 70–72
- upper troposphere moistening (since 1979), 451

- warming since pre-industrial times, 425
 weather and climate extreme effects, 8
 wet and dry zone precipitation contrast, 426
- Human influence on climate system***
 annual-mean precipitation rate (1995–2014), 453
 anomalies in zonal annual precipitation, 455
 assessed contribution to warming, 439, 440
 assessment of, 428
 Atlantic Meridional Overturning Circulation trends, 484
 Atlantic Multi-decadal Variability model evaluation, 505
 atmospheric tropical mean temperature trends, 444
 attribution of seasonal trends in annular modes, 492
 El Niño–Southern Oscillation life cycle, 496
 El Niño–Southern Oscillation seasonality, 497
 evaluation of global monsoon changes, 462
 Executive Summary, 425–429
 global mean thermal sea level change, 482
 global ocean heat content observations and simulations, 477
 global ocean temperature and salinity biases, 475
 global surface temperature anomalies, 435
 global surface temperature changes, 442
 global surface temperature internal variability, 437
 halosteric and thermosteric sea level trends, 480
 Handley and Walker circulation changes, 460
 historical emissions-driven simulations (1850–2014), 486
 instantaneous Northern Hemisphere blocking, 465
 large-scale indicator changes, 507
 model evaluation of modes of variability, 491
 near-surface air temperature (1995–2014), 434
 near-surface air temperature anomalies, 441
 near-surface salinity trends, 479
 Northern Hemisphere seasonal snow cover extent, 470
 Pacific Decadal Variability (PDV model evaluation), 503
 precipitation change simulations and reconstructions, 449
 seasonal Arctic and Antarctic sea ice area, 467, 469
 seasonal cycle of land carbon uptake (1961–2014), 488
 sea surface temperature and near-surface salinity, 474
 sea surface temperature model biases, 474
 Southern Annular Mode indices, 494
 Southern Hemisphere zonal wind trends (1985–2014), 465
 surface temperature in paleoclimates, 432
 total column water vapour trends (1998–2019), 450
 wet and dry tropical annual precipitation anomalies, 454
 zonal-mean near-surface air temperature, 436
- Hurricanes Florence, Harvey, Sandy**, 1589
- Hydrochlorofluorocarbons (HCFCs)**
 atmospheric lifetime of, 823
- direct radiative forcing effects of, 823
 historical abundances and effective radiative forcing, 2142
 rates of increase, 304
 total chlorine from, 843
- Hydrofluorocarbons* (HFCs)**
 atmospheric lifetime of, 823
 changes in abundances of, 819
 contribution to warming in scenarios (2019–2040), 885
 direct radiative forcing effects of, 823
 effects on global surface air temperature, 886
 emissions (1990–2100), 879
 historical abundances and effective radiative forcing, 2142
 increases in, 304
 scenario projections for, 882
 significant increases in, 843
 warming effects by scenario, 889
- Hydrological drought***
 African changes, 1624, 1794
 Asia changes, 1644, 1801
 Australasian changes, 1662, 1809
 Central and South America changes, 1675, 1816
 European changes, 1686, 1823
 incremental warming effects on, 15
 North American changes, 1701, 1831
 regional occurrence of, 1575
 Small Islands changes, 1838
 water management use of indices, 1783
- Hydrological models, flooding consideration in**, 1569
- Hydrological sensitivity***, 1066–1067
- Hydroxyl (OH) radical**
 atmospheric oxidising capacity and, 848
 biogenic volatile organic compounds estimations, 831
 global mean trend of (1950–1980), 851
 global OH trends and interannual variability, 849
 interannual variations in global mean, 849
 lifetime of, 849
 lightning impact on, 830
 primary methane sink in troposphere, 835
 response to climate change and variability, 849
 sink for short-lived climate forcers, 825
 source of tropospheric OH, 848
 tropospheric concentration evolution, 850
 tropospheric concentration trends, 819
- Hypoxic* areas (of ocean)**, 1844
- I**
- Ice**. See **Snow and ice**
- Ice (cirrus) clouds**, 951. See also **Cirrus cloud thinning* (CCT)**
- Ice core* proxies**
 atmospheric concentrations of CO₂, CH₄ and N₂O, 685
 decadal trends in atmospheric sulphur loading, 846
 for Atlantic Multi-decadal Variability reconstructions, 2177
 mid- and high-latitude aerosol deposition, 308
- Icelandic Low**, 2156
- Ice nucleating particles (INPs)**
 aerosols serving as, 951
 climate sea-spray feedback and, 858
 from marine aerosols, 832
 in aerosol cloud interactions, 949
 mineral dust and formation of, 858
 relationship to cloud properties, 952
- Ice-sheet extent**
 Antarctic ice sheet, 1263–1275
 anthropogenic contribution to loss, 472–473
 attribution of large-scale changes in, 471
 changes in Greenland and Antarctic regions, 1255
 Greenland and Antarctic changes, 1215
 Greenland Ice Sheet, 1254–1259
 growth and decay of, 1317
 mass loss in scenarios, 1215
 models used in intercomparison studies, 2108
 past and future changes, 75
 polar terrestrial changes, 1845
 relevance to ecosystems, 1785
 sea level budget contribution, 1288
 volume fluctuations in, 1220
- Ice sheet Mass Balance Inter-comparison Exercise (IMBIE)**, 1263
- Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6)**, 471, 1259, 1298
- Ice-sheet models**, 2100
- Ice-shelf disintegration/melting**
 annual surface melt threshold for, 1262
 Antarctic shelves, 1236
 basal melt rates and projections, 1267
 high-end storyline for sea level rise (2100), 1308
 in Antarctic Peninsula, 1265
 thresholds for, 1270
 West Antarctic Ice Sheet outlet glaciers, 1264
- Ice storms**. See **Snow and ice**
- Idealized energy balance models/emulators**, 1011
- Image transformation techniques in attribution approaches**, 1416
- Indian Ocean**. See also **Equatorial Indian Ocean**
 freshening projections, 1844
 surface salinity projections, 1842
 warming rate of, 143, 1222
 warming trends, 2010
- Indian Ocean Basin*/Indian Ocean Dipole* (IOB/IOD)**
 anthropogenic forcing effects on, 1104
 AR5 assessment, 373
 associated with climate anomalies, 2167
 Australasian teleconnections with, 1986
 boreal autumn sea surface temperature, 2166
 climate variability and, 2156
 climatic effects in Africa, 1968
 CMIP simulations of, 499–500, 589
 coral reconstructions of, 2168
 decadal mode of, 2167
 effects on East Asian winter monsoon, 1973
 El Niño–Southern Oscillation association, 2167
 extreme event association in Small Islands, 2013
 global climate change projections, 611

- influence on South American climate, 1994
interannual climate variability, 2164
multi-decadal variability trend, 374
Pacific Decadal Variation in driving of variability, 2174
sea surface temperature anomalies, 2165
signature of, 2167
South East Asia climatic effects of, 1981
- Indian summer monsoon (ISM)** *See also South and South East Asian monsoon*
anthropogenic and natural drivers, 1444
Atlantic Zonal Mode effects on, 2171
changes in historical and future periods, 1446
climate projections from regional downscaling, 1447
future climate projections from global simulations, 1445
model assessment for rainfall (ISMR), 1980
motivation and regional context, 1443
observational issues for India, 1443
rainfall simulation for, 1979
regional climate information distillation, 1448
regional climate of India, 1443
simulation and attribution of drying over the historical period, 1444
- Indirect aerosol effects* (ERFacI)**, 823, 857
- Indirect forcing, compared to direct carbon dioxide forcing**, 857
- Indonesian Throughflow (ITF)**
effects on ocean heat content change, 1232
increase in, 1243
ocean warming and, 1222
Pacific and Indian ocean connections, 1241
- Industrial era (since 1750)**
aerosol contribution in industrial era, 926
anthropogenic effective radiative forcing, 926
climate driver changes in, 310
estimates of aerosol optical depth absorption in, 949
total anthropogenic effective radiative forcing, 960
- Industry, global warming contribution of**, 821
- Initial condition ensemble* (ICE) technique**, 222, 563, 588
- Initial state intercomparison projects (initMIP)**
projections for Antarctic ice sheet, 1270
sea level rise projections, 1305
- Initialized predictions/projections**
assimilation of observed information into model, 563
contribution to near-term climate change, 564
skill for temperature projections over the North Atlantic, 590
- In-service Aircraft for a Global Observing System (IAGOS) effort**, 209
- Instrumental period observations**
Atlantic Multi-decadal Variability evolution, 2176
combined with paleoclimate reconstructions, 157
equilibrium climate sensitivity and transient climate response, 995, 999
formaldehyde over industrial regions, 842
global warming over, 191
- Pacific Decadal Variability evolution, 2174
- Integrated assessment models* (IAMs), urbanization assessment**, 230, 878
- Integrated Carbon Observation System (ICOS)**, 209
- Interactive Multisensor Snow and Ice Mapping System (IMS)**, 1980
- Interannual variability**
El Niño–Southern Oscillation in, 557, 589, 610
global OH trends, 849
in detection of change signals, 1853
in land–atmosphere CO₂ exchange, 695
- Inter-basin exchange**
Agulhas leakage, 1243–1246
Atlantic to Arctic transport, 1243
Atlantic Water inflow, 1243
Bering Strait transport, 1243
- Inter-decadal Pacific Oscillation* (IPO)**, 590, 2172. *See also Pacific Decadal Variability* (PDV)*
- Intergovernmental Panel on Climate Change (IPCC) WGI**
formal Principles Governing IPCC Work, 171
historical overview of major conclusions, 281
international policy context changes, 150
role and structure for assessments, 153
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)**, 161
- Interhemispheric cross-equatorial sea surface temperature gradients**, 375
- Internal variability***
approaches to study of, 1392
control simulations for assessing, 1393
influence on dynamic sea level change, 1246
influence on signal emergence, 1427
in identification of forced climate signals, 561
in models compared with observational estimates, 438
in multi-model mean and pattern-scaled responses, 637
in regional climate projections, 1408
in water cycle projections, 1141
large ensembles for evaluation of, 193
masking of mitigation response by, 620
model estimation of decadal and multi-decadal, 436
model simulations for understanding of, 151
modulation of human-caused changes, 23
quantification for water cycle, 1141–1143
temperature fluctuation (1998–2012), 446
- International Comprehensive Ocean–Atmosphere Dataset (ICOADS)**, 323
- Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP)**, 1945
- Inter-tropical Convergence Zone (ITCZ)**
bias in CMIP simulation, 452
bias in simulation, 452
Central America and Caribbean precipitation effects, 1991
convective cloud system formation over, 971
effects of migration, 1981, 1994
global monsoon variability and change in, 2195
- influence on midsummer drought, 1991
large-scale and regional variability changes, 1124
model biases in simulations, 2010
northward migration of, 2171
observed variations in tropical belt, 1093
paleo reconstruction data, 335
projections for position of, 1124
Southern Central American precipitation effects, 1991
- Irreversible change**
after removing forcing, 630
defined, 202
Earth system components susceptible to tipping point/abrupt change, 634
ocean's thermohaline circulation, 202
tipping points in Earth system components, 106
- Irrigation**
contribution to land-use forcing, 956
driving changes in water cycle, 1076
local and regional water cycle responses to, 1057
local effects of, 1374
- Isoprene**
decline since pre-industrial period, 831
driver for production of, 831
effect of oxidation on OH recycling, 849
historical emissions of, 831
vegetation emission of, 831
- Isotope* analyses**
anthropogenic forcing of ocean acidification, 715
atmospheric CO₂ changes in geological periods, 298
deglacial increase in N₂O emissions, 715
for methane sources, 706
greenhouse gases from ice cores, 684
methane from fossil fuels, 705
methane in Antarctic ice cores, 727
ocean pH time series, 715
ocean pH time series reconstruction, 715
soil ¹⁴C responses to atmospheric changes, 725
sources of methane growth, 708
- ## J
- JAXA ALOS-2**, 1382
- Joint UK Land Environment Simulator (JULES)**, 471
- JRA-55, global reanalysis products**, 1980
- ## K
- Karakoram Anomaly**, 1979, 1980
- Kelvin wave propagation**, 2168
- Ketones, emissions of**, 831
- Kigali Amendment**, 821, 872
- Köppen–Geiger classification**, 2004
- Kuroshio–Oyashio extension**, 2172, 2174
- Kyoto and Montreal Protocols, chemical abbreviations and symbols**, 2140

L

Land–atmosphere feedback, 2155

Land-based biological CO₂ removal methods, 762

Land carbon uptake

- climate effect on, 724
- direct effect of CO₂ on, 722
- droughts effects on terrestrial sink, 697
- fire and other disturbances, 724
- land CO₂ sink, 677
- net land CO₂ sink trends, 695
- plant physiology, 724
- soil carbon stocks in, 725

Land CO₂ fluxes

- historical and contemporary trends, 694
- interannual variability in, 695

Land ice evolution intercomparison projects

- comparison for Greenland and Antarctic, 1262
- GlacierMIP projections, 1263
- Greenland and Antarctic ice sheet projections, 1262–1264
- regional forcing for, 1261

Land precipitation

- 21st century global projections, 556
- changes in 20th century, 454
- in low-emissions and high-emissions scenarios, 556
- link with Atlantic Multi-decadal Variability, 591
- long-term (2081–2100) climate projections, 556
- monsoon changes with warming, 556
- projections for 1.5°C warming, 573
- societal relevance of, 573

Land precipitation–evaporation (P–E), 312, 1067, 1106

Landslides

- African changes, 1794
- Asian changes, 1800
- Australasian changes, 1808
- Central and South American changes, 1816
- European changes, 1823
- hazards and risk from, 1783
- North American changes, 1831
- polar terrestrial changes, 1844
- Small Islands changes, 1838

Land surface changes

- abrupt water cycle response to, 1149
- assessment of land heating, 937
- biophysical effects of cover change, 310
- differential warming of, 82–84
- dust particle emissions from, 831
- emissions effects on sinks, 19–20
- forcing representation in models, 1552
- global change in precipitation over, 291
- integration of biosphere and cryosphere, 157
- land biosphere changes, 6
- modification during the Holocene, 310
- natural methane sources, 704
- non-linearity in water cycle response, 1146–1148
- partitioning of surface radiation, 1138
- rate of temperature increase over, 290
- short-lived climate driver emissions from, 825
- temperature projections for surface, 1851

- terrestrial latent heat flux estimation, 939
- urbanization effects on temperature, 1374
- warming compared to ocean surface, 15

Land-use change*

- anthropogenic CO₂ emissions, 676, 687
- carbon fluxes from, 688
- driving changes in water cycle, 1076
- effective radiative forcing from, 310
- effects on Earth's albedo, 310
- effects on Indian summer monsoon, 1979
- estimates of CO₂ flux from, 688–689
- forcing from, 1528
- forcing from surface property changes, 956
- heavy precipitation effects of, 1557
- local and regional water cycle responses to, 1057
- local climate effects of, 1374
- local use effects on heavy precipitation, 1557
- over the industrial period, 312
- projections for human-caused changes due to, 1119
- reconstruction from pollen data, 310

Land-water storage* (LWS)

- in sea level budget, 1288
- method and projections for, 1299
- processes and changes in, 1220

Lapse rate* (LR) feedback

- contribution to warming, 95
- quantification of radiative flux, 969
- upper-level temperature gradient, 579

Large eddy simulations (LES), 972

Large-scale atmospheric circulation

- Atlantic Zonal Mode effects over Europe, 2171
- changes and impacts on regional water cycle, 1126
- change since the mid-20th century, 291
- continued warming effects on, 1146
- convection changes in, 2164
- drivers for local and regional extremes, 1528
- effects on extreme conditions, 1528
- Hadley and Walker circulations, 335, 459
- impact of biases on regional climate projections, 1411
- model projections for, 616
- non-linearities in, 1144–1146
- North Atlantic Oscillation variability, 2156
- short-lived climate forcer alteration of, 893
- short-term change in Greenland Ice Sheet, 1256
- teleconnections and regional variability, 1092

Large-scale climate change

- atmospheric indicators for, 312
- biospheric indicators for, 314
- changes in indicators (1995–2014), 64
- CMIP reproduction of temperature patterns, 431
- cryospheric indicators for, 313
- forcing and internal variability in, 312
- global to continental or ocean-basin scales of, 153
- human influence on temperature and precipitation extremes, 457–459
- indicators of, 312
- main modes of variability, 2155
- marine biosphere changes with warming, 292
- modes of variability in, 314–316
- observations and projections for, 63–67

oceanic indicators for, 313

past changes of, 293

projections for water cycle changes in, 1124

short-lived climate forcer emissions effects on, 820

simulated and observed change in indicators, 507

spatial distribution of precipitation extremes, 1562

terrestrial biosphere changes with, 292

Large-scale modes of variability

- AR5 assessment of, 2155
- circulation effects on, 556
- effects of circulation on water cycle, 1092
- precipitation extremes modulation by, 1557

Last deglacial transition* (LDT)

- atmospheric CO₂ during, 299, 300, 686
- changes in ocean pH during, 715
- climate state in, 295
- global mean sea level during, 1294
- methane release during, 727
- reconstructions for global mean surface temperature, 315

Last Glacial Maximum* (LGM)

- atmospheric CO₂ concentration, 299
- climate state in, 295
- equilibrium climate sensitivity estimates from, 1000
- global mean sea level during, 1294
- global mean surface temperature reconstructions for, 315
- hydroxyl radical estimations, 850
- polar amplification in, 986
- terrestrial moisture changes during, 450
- Walker circulation trends, 336
- wetland methane emissions, 684

Last Interglacial* (LIG) period

- Antarctic ice sheet retreat in, 1269
- atmospheric CO₂ concentration, 299
- climate state during, 295
- global mean sea level in, 1293
- temperatures in, 292

Latin America. See also Central and South America

- biomass burning emissions in, 869
- particulate matter emissions sources in, 821
- tropospheric NO₂ levels over, 839

Leaf area index, in terrestrial carbon cycle, 486

Leaf-level CO₂ fertilization, 722

Least-squares approach (for attribution), 1415

Length of frost-free period (LFFP), 2155

Lesser Antilles

- Inter-tropical Convergence Zone effects on rainfall, 1991
- precipitation projections for, 2012
- projections for warming over land, 2012
- reference region for, 1991

Levant, prolonged dry spells in, 449

Light-absorbing particles* (LAPs) on snow and ice, 956

Lightning, contribution to emissions, 830, 859

Likelihood*

- statement of confidence and uncertainty, 169–171
- use in AR6, 38

- Linear Antarctic Response Model**
Intercomparison Project (LARMIP-2)
 basal melt sensitivities, 1268
 in ice-sheet and glacier model intercomparison studies, 2108
 new projections for Antarctic ice sheet, 1270
 sea level rise projections, 1305
 uncertainty estimation and probabilistic inferences in, 1314
- Linear detrending**, 2176
- Linear energy budget equation**, 931
- Linear pattern scaling**, 1543
- Liquid water path (LWP)**, 951–953
- Livestock**, 828. *See also* **Agriculture**
- Long-lived greenhouse gases* (LLGHGs)**
 contribution to warming, 751
 forcing mechanisms for, 851
 reduction for mitigation, 864
 regional climate response, 865
 spatial influence of, 855
- Long-term (2081–2100) climate projections**
 AR6 reference period for projections, 192
 carbon cycle dynamics for models, 741
 change of annual and zonal mean atmospheric temperature, 599
 change of annual and zonal ocean pH, 609
 change of zonal-mean, zonal wind, 605
 changes in seasonal mean relative humidity, 600
 CMIP6 Annular Mode index change, 610
 effects on N₂O release from ecosystems, 737
 evidence for global surface air temperature changes, 581
 first realization in modelling, 570
 global land precipitation for, 556
 heat stress quantification, 2210
 mid-latitude jet shift in Southern Hemisphere, 556
 monsoon projections for, 19
 monsoon water cycle projections, 1128
 ocean salinity change, 478
 response of carbon cycle (past 2100), 741
 seasonal mean precipitation, 602
 seasonal mean sea level pressure, 604
 spatial pattern of monsoon precipitation, 556
 warming due to short-lived climate forcers, 821
 water cycle projections, 1064, 1107
- Long-term commitment**, 39. *See also* **Committed climate change***
- Long-term temperature goal (LTTG)**, 162
- Longwave (LW) radiation***
 cirrus cloud thinning for increase in, 624
 expected increase in upward radiation, 939
 forcing from, 852
 from vertically uniform warming, 968
- Low Earth orbit (LEO) satellites**, 1382
- Low-frequency component analysis**, 1415
- Low-likelihood, high-impact (LLHI) scenarios***
 changes in extremes, 1534–1536
 changes with warming levels, 1535
 climate extremes association, 1520
 defined, 40
 for systematic risk framing, 151
 high-warming and high-impact scenarios, 198
 high-warming storylines for, 72–74
 in risk assessments, 27
 potential impacts of, 202
 risk level associated with, 198
 scenarios for, 199
- Low oxygen zones. *See* Ocean deoxygenation***
- ## M
- Madagascar (MDG)**
 key climatic features, 1967
 tropical cyclones projections, 135, 1795
- Madden–Julian Oscillation* (MJO)**
 climate variability and, 2156
 climatic effects in Africa, 1967
 diagnostics for characteristics of, 1395
 evaluation in climate models, 2179
 global impacts through teleconnections, 2179
 influence on South American Monsoon variability, 1994
 intra-seasonal East Asian monsoon variability and, 2197
 intra-seasonal variability influence of, 1981
 rainfall variability in northern Australia, 1986
 real-time multivariate index, 2177
 regions of influence of, 2178
 tropical intra-seasonal variability time scale, 2177
 water cycle effects of, 1104
- MAGICC6 emulator**, 963
- MAGICC7 emissions-based emulator**, 964
- Marine aerosols**, 832
- Marine biosphere/ecosystem**
 carbon dioxide removal effects, 100
 changes in, 292
 marine heatwave impacts on, 1227
- Marine cloud brightening* (MCB), for solar radiation modification**, 624, 628, 860
- Marine heatwaves* (MHWs)**
 African changes, 1796
 Asian changes, 1805
 Australasian changes, 1812
 Central and South American changes, 1818
 changes with 2°C warming, 143
 definition and impact of, 1227
 ecosystem and economic impacts of, 1787
 European changes, 1826
 frequency changes, 1214, 1842
 global ocean projections for, 1844
 in tropical ocean and Arctic, 15
 North American changes, 1836
 polar terrestrial changes, 1847
 projections, 188
 regional probability ratio of, 1228
 scenario-based projections, 1227
 signal emergence, 1855
 Small Islands changes, 1841
 trends with future warming, 1227
- Marine ice cliff instability* (MICI)**
 effects on global mean sea level, 1217
 in Antarctic mass loss, 1269
 incorporation into projections, 1305
- Marine ice sheet instability* (MISI)**
 effects on global mean sea level, 1217
 glaciers in the Amundsen Seay Embayment, 1265
 in Antarctic mass loss, 1269
 modelling since AR5, 1269
 unmitigated calving in, 1269
- Marine Isotope Stage* 11 (MIS 11), Greenland Ice Sheet in**, 1293
- Marine low-cloud feedback**, 974
- Marine organisms/marine biota**
 effects of warming, acidification and deoxygenation on, 714
 influences on ocean acidification, 717
 shifts in ranges of, 292
- Marine sediment proxies**, 686
- Mauna Loa Observatory (MLO), atmospheric CO₂ measurements from**, 689
- Maunder Minimum (1645–1715)**, 296, 297
- Mean air temperature**
 African changes, 1791
 agricultural, infrastructure and health relevance, 1780
 Asian changes, 1799
 Australasian changes, 1805
 Central and South American changes, 1812
 emergence of signal for warming, 1854
 European changes, 1820
 North American changes, 1828–1837
 polar region changes, 1844
 Small Islands changes, 1837
- Mean precipitation**
 African changes, 1793
 Asian changes, 1800
 Australasian changes, 1807
 Central and South American regional changes, 1815
 emergence of increasing precipitation, 1854
 European changes, 1822
 North American changes, 1830
 Small Islands changes, 1837
 terrestrial polar region changes, 1844
- Mediterranean (MED) region. *See also* North Africa**
 Atlantic Multi-decadal Variability effects in, 2177
 climatic features of, 1998
 drought duration expected in, 1119
 drought projections, 1437
 global runoff projections, 1119
 groundwater changes in, 1123
 hydrological drought observations in, 135
 hydrological drought projections for, 1794
 marine heatwave projections, 2002
 mean wind speed changes, 1795, 1824
 rainfall projections, 1971
 temperature trends in, 1999
 water cycle projections for, 1058
 wind projections for, 135
- Mediterranean summer warming**
 anthropogenic and natural drivers, 1449
 aspects of, 1451
 information from global simulations, 1450
 information from regional downscaling, 1452
 lines of evidence for climate information, 1453

- observational issues, 1449
 over the historical period, 1449
 projections for, 1452
 regional climate, 1449
 regional context, 1449
 storyline approaches, 1453
- Meltwater**
 bottom water density effects of, 1240
 climate feedback from, 1270
 driving of hydrofracturing, 1309
 effects on Atlantic Meridional Overturning Circulation, 1320
 flow from glacier to ocean, 1220
 from Antarctic Ice Sheet, 1239
 from glaciers and ice sheets, 1220
 from Greenland Ice Sheet surface (1960–2014), 1257
 Greenland meltwater effects on ocean salinity, 1234
 in ice-shelf disintegration/melting, 1264, 1269
 Meltwater pulse 1A, 1294
 production and ice-cliff collapse, 1270
 pulses during Holocene, 1294–1295
 surface mass balance decrease for Greenland, 1260
- Meltwater pulse 1A* (MWP-1A), global mean sea level during**, 1294
- Meridional overturning circulation* (MOC), warming and wind stress effects on**, 728
- MERRA-2, global reanalysis products**, 1980
- Mesoscale convective systems (MCSs)**, 1594, 1595, 2198
- Meteorological conditions**
 climate change influence on, 864
 effects on air pollution, 864
- Meteorological (precipitation-based) drought***
 human-induced contribution to, 1577
 incremental warming effects on, 15
 regional evidence for, 1575
 regional projection scenarios, 1119
- Methane* (CH₄)**
 annual emissions contribution to warming, 751
 anomalies in global and regional emissions (1988–2017), 707
 anthropogenic emissions sources, 702
 atmospheric concentration growth rate, 42
 atmospheric growth rate of, 835
 atmospheric lifetime and perturbation time, 835
 benefits of atmospheric reduction in, 874, 875
 biochar effects on soil emissions of, 763
 bottom-up global emissions estimates of, 828
 burden/imbalance increase, 705
 carbon dioxide removal effects on, 100
 chemical destruction by OH, 707
 concentrations, growth and isotopic composition time series, 701
 concentrations in chemistry–climate models, 834
 concentrations of (2019), 290
 concentrations (past 110 kyr), 301
 cumulative CO₂ equivalent emissions estimate for, 1016
 direct radiative forcing effects of, 823
 drivers of atmospheric changes (1980–2019), 706–708
 effective radiative forcing effects, 819, 853, 945
 emissions from permafrost regions, 726
 emissions from wetlands and landfills, 737
 emissions- versus abundance-based forcing effects, 855
 estimation of global chemical sink, 835
 estimations of emissions and sinks (2008–2017), 705
 feedback sources for, 737
 from human activity, 180
 from permafrost thaw (21st century), 740
 from wildfires, 737
 future abundances projections for, 2144
 global budget, 703, 705
 global warming and temperature-change potentials for, 927
 growth rate changes, 303, 676, 701
 historical abundances and effective radiative forcing, 2141
 in current short-lived climate forcer emissions, 821
 land biospheric sources and sinks, 704
 lifetime assessment of, 823, 835, 836
 lightning effects on lifetime of, 830
 methane perturbation lifetime, 836
 methods for removal from atmosphere, 765
 modelled wetland emissions anomalies, 707
 ocean and inland water emissions and sinks, 704
 pre-industrial sources for, 684
 pulsed geologic release of, 686
 radiative efficiency change (since 2011), 947
 rate of atmospheric change in last century, 686
 recent concentrations of, 8
 reduction of emissions for mitigation, 825
 regional warming projections for, 888
 release from clathrates, 740
 response to future warming, 677
 role in feedback processes, 677
 sources and sinks, 706
 trees and wetland forests contribution to, 704
 trends, variability and budget, 700
 tropospheric adjustment effects on effective radiative forcing, 925
 tropospheric OH estimates from paleo time scales, 850
 uptake from soil, 835
 wetland emissions of, 684
- Methyl chloroform (MCF)**
 constraint of methane lifetime assessment, 835
 in estimation of global OH abundance, 849
- Microbial/biogenic processes**
 anaerobic ammonium oxidation, 719
 methane uptake by soil, 704
 nitrification/denitrification of soil, 830
- Middle East. See also Arabian Peninsula and West Central Asia**
 Atlantic Multi-decadal Variability effects in, 2177
 natural sources of surface ozone in, 869
 NO₂ trends over, 839
 particulate matter emissions sources in, 821
 surface ozone and particulate matter projections, 882
- Mid-Holocene* (MH), atmospheric CO₂ concentrations**, 299
- Mid-latitude climates**
 aerosol emissions trends for northern, 310
 Arctic influence on, 1379, 1380
 Arctic link hypotheses, 1380
 deforestation contribution to hot extremes, 1553
 drivers affecting variability in, 1381
 drying in Southern Hemisphere, 456
 extreme precipitation event projections, 1563
 high-warming storylines for northern, 637
 jet response to forcing, 606, 616
 land precipitation in Northern Hemisphere, 426
 marine heatwave frequency projections, 1227
 Northern Hemisphere specific and relative humidity trends, 330
 observed extreme winds in, 1598
 polar warming effects on Siberia, 1976
 precipitation changes in Southern Hemisphere, 426
 reversal of Northern Hemisphere cooling trend in, 438
 storm track response to anthropogenic forcing, 578
 storm tracks shifts in, 5
 surface humidity changes in Northern Hemisphere, 451
 temperature increases in, 15
- Mid-latitude westerlies**, 2158
- Mid-Pliocene period, 23rd century temperature comparisons to**, 633
- Mid-Pliocene Warm Period* (MPWP)**
 Antarctic ice sheet retreat in, 1269
 atmospheric CO₂ levels in, 299, 684
 atmospheric CO₂ mixing ratio estimates, 300
 climate during, 1293
 climate in, 295
 CO₂ and temperature in, 292
 global mean sea level in, 291, 1293
 global mean surface temperature estimate for, 292
 polar amplification in, 986
 sea surface temperature gradient change, 988
- Midsummer drought (MSD)**, 1991, 1993
- Mid-term (2041–2060) climate projections**
 air quality–climate interaction in, 821
 AR6 reference period for, 192
 first realization in modelling, 570
 heat stress projections, 2210
 likelihood of 2°C warming, 14, 582
 monsoon projections for, 19
 monsoon water cycle projections, 1128
 water cycle projections, 1064, 1107
- Mineral dust**
 direction of change in, 825
 impacts on water cycle, 1150
 longwave and shortwave radiation interactions, 858
- Miocene Climatic Optimum (MCO)**
 climate in, 295
 global mean surface temperature estimate for, 292
 temperature comparison with 23rd century, 633
- Missed warnings (Type II research errors)**, 172
- Mitigation* (of climate change)**
 air quality–climate interactions and feedbacks, 864
 benefits emergence in scenarios, 621

- carbon budget use for, 97
 - commitment and change beyond 2100, 557
 - emergence of climate response to, 619
 - for short-lived climate forcer emissions, 821–822
 - global climate response to, 619
 - internal variability masking response to, 620
 - projections for strong measures, 557
 - quantification expected response to, 620
 - requirements for limiting warming, 678
 - response to solar radiation modification, 624
 - scenarios for pathways for mitigation, 238
 - short-lived climate forcings response to, 591
 - strategies for short-lived climate forcings, 873–874
 - sustainable development goals opportunities, 874–875
 - uncertainty in assessment of benefits, 559
 - WGII assessment of options, 153
 - Model for Interdisciplinary Research on Climate Atmospheric Transport Model (MIROC-ATM4)**, 732
 - Model Intercomparison Projects (MIPs)**, 213, 223, 561
 - Model response uncertainty**, 197
 - MODerate Resolution Imaging Spectroradiometer (MODIS)**, 309, 1980
 - Modern-Era Retrospective Analysis for Research and Applications (MERRA)**, 213
 - Modern period (1995–2014)**
 - annual mean surface air temperature for, 434
 - atmospheric CO₂ mixing ratios, 299
 - baseline for AR6 calculations, 191
 - CMIP6 Annular Mode index change (2021–2040), 588
 - CMIP6 Annular Mode index change (2081–2100), 610
 - heat stress quantification, 2210
 - projections for global surface air temperature, 555
 - surface temperature response to aerosol changes, 856
 - Modes of climate variability***
 - annular modes, 370
 - assessments and teleconnections for, 115
 - changes in, 370
 - climate change projections, 609
 - climate fluctuations with, 197
 - definition of, 2155
 - historical identification of, 2155
 - human influence on, 427, 489–505
 - in assessment of climate change, 578–579
 - in climate, 314
 - Indian Ocean Basin and Dipole modes, 2164
 - influence on regional extreme events, 1962
 - in North Atlantic Oscillation, 2155
 - interannual and longer time scales, 370
 - internal climate processes in, 2155
 - in warming projections, 1557
 - near-term evolution of large-scale modes, 587–589
 - Northern and Southern Annular Mode scenario simulations, 578–579
 - over North Atlantic–Europe region, 2156
 - regional teleconnections, 1104
 - selection of indicators of, 314
 - tropical modes, 1104
 - Zonal modes, 2156
 - Modoki events**, 2162
 - Moisture transport**
 - flux enhancement with warming, 601
 - into weather systems with warmer climate, 1057
 - surface air temperature and relative humidity coupling, 596
 - Monoterpenes**
 - direct CO₂ inhibition of, 831
 - driver for production of, 831
 - emissions of, 831
 - Monsoon***. *See* **Global monsoon* (GM) and Regional monsoons**
 - Monte Carlo approach/analysis**, 747, 867, 954
 - Montreal Protocol* on Substances that Deplete the Ozone Layer**, 304, 821
 - Mortality-related heat stress**, 1793. *See also* **Heat stress***
 - Mountainous regions**
 - Central Asian precipitation projections, 1984
 - changes in climatic impact-drivers for, 1849
 - changes with 2°C global warming, 143
 - committed glacier changes in, 21
 - elevation-dependent warming in, 1849
 - glacier surface mass balance relevance to, 1785
 - influence of climatic impact-drivers, 1850
 - orographic effects on convection and precipitation, 1850
 - projections for changes in, 1853
 - regional climate observations for, 1386
 - snow depth and snow water equivalent, 1284, 1285
 - snow water equivalent trends in, 1284
 - SROCC report on climate change in, 1849
 - Mount Pinatubo eruption**, 444, 445
 - MPI Grand Ensemble**, 222
 - Multi-Angle Imaging Spectroradiometer (MISR)**, 309
 - Multi-hazard resilience assessment**, 1962
 - Multi-model ensembles* (MMEs)**, 221
 - MultIRCM Ensemble Downscaling (MRED)**, 2005
- ## N
- National Center for Atmospheric Research (NCAR) Climate Variability Diagnostic Package (CVDP)**, 429
 - Nationally Determined Contribution (NDC)**
 - insufficiency for temperature goals, 161
 - Paris Agreement party submission of, 150
 - National Oceanic and Atmospheric Administration (NOAA)**
 - heat index calculation, 2209
 - heat warnings issued by, 2207
 - Natural aerosols, regional variation in**, 1373
 - Natural forcing and variability***
 - change attributable to, 425
 - natural aerosol variations, 1373
 - short-lived climate forcer emissions, 823, 830
 - volcanic aerosol drivers, 298
 - Near-surface air temperature**
 - patterns of change by scenario, 595
 - projections for spatial patterns of change in, 614
 - Near-term (2021–2040) climate projections**
 - AR5 assessment of forcings for, 825
 - AR6 reference period for projections, 192
 - Atlantic Multi-decadal Variability in, 2177
 - change of seasonal mean precipitation, 585
 - change of seasonal mean surface temperature, 584
 - effects of mitigation on surface, 557
 - first realization in modelling, 570
 - large-scale global climate change, 583–592
 - likelihood of exceeding 1.5°C warming, 555
 - mitigation effects for, 557
 - near-term climate predictability, 742
 - ocean and land carbon flux trends, 587
 - precipitation change projections, 556
 - projections for 1.5°C warming, 15, 555, 582
 - volcanic forcing effects on, 1144
 - warming from short-lived climate forcings, 820
 - water cycle projections, 1059, 1064, 1119, 1141
 - Net negative CO₂ emissions scenarios**
 - carbon dioxide removal to achieve, 623
 - land and ocean transitions to net source, 677
 - Net primary production (NPP), solar modification effects on**, 768
 - Net zero CO₂ emissions***
 - definition, 39, 242, 751
 - effect on anthropogenic global warming, 188, 752
 - limiting human-induced warming, 27–29
 - stabilization of surface temperature, 30, 752
 - Net zero emissions**
 - for greenhouse gases, 242
 - ocean warming after, 1233
 - relationship of CO₂ and greenhouse gases, 242, 752
 - Structured Expert Dialogue on timing of, 162
 - temperature and carbon dioxide removal relationship, 242
 - New Zealand (NZ)**
 - climatic features of, 1986
 - glacier retreat in, 1987
 - glacier volume decrease in, 140
 - mean sea levels trends in, 1987
 - precipitation projections for, 139, 1810, 1990
 - rainfall changes in, 1987
 - seasonal changes in, 1987
 - snow and ice projections for, 140
 - temperature and precipitation trends, 1988
 - warming projections for, 1990
 - wet and dry changes with 2°C global warming, 139
 - wet and dry conditions, 139
 - Nitrate aerosols, lightning NO_x emissions effects on**, 859
 - Nitrate burden, radiative effect of**, 846
 - Nitric acid (HNO₃), formation in atmosphere**, 846
 - Nitrification/denitrification processes in soil**, 830, 842
 - Nitrogen cycle**
 - carbon–climate feedback in Earth system models, 725

- dynamics over land in CMIP4–CMIP6, 723
- human perturbation of, 708
- in water column (ocean), 719
- physical and biogeochemical processes, 676
- reactive nitrogen deposition effects, 857
- Nitrogen dioxide (NO₂)**
 - geographic changes in tropospheric columns of, 819
 - mean and time evolution in troposphere, 839
- Nitrogen fixation, in non-agricultural ecosystems**, 830
- Nitrogen oxides (NO_x)**
 - anthropogenic driving of tropospheric OH change, 851
 - anthropogenic sources, 839
 - effective radiative forcing by, 854
 - effective radiative forcing of (1750–2019), 819
 - from aviation, 866
 - global emissions of, 827
 - high emissions scenario projections for, 881
 - in diesel versus gasoline vehicle emissions, 868
 - indirect climate forcing by, 823
 - lightning release of, 830
 - net global emissions-based forcing of, 855
 - nitric acid formation, 846
 - secondary OH production control by, 849
 - soil emissions effects on surface ozone, 863
 - soil emissions, 830
 - tropospheric distribution and processing, 839
- Nitrogen trifluoride (NF₃), historical abundances and effective radiative forcing**, 2141
- Nitrous oxide* (N₂O)**
 - anthropogenic emissions, 709
 - assessment of global budget, 708
 - atmospheric concentration growth rate, 676
 - atmospheric lifetime of, 708
 - calculated tropospheric adjustments to, 946
 - carbon dioxide removal effects on, 100
 - changes in atmosphere and isotopic composition (since 1940), 709
 - changes with COVID-19, 822
 - concentrations (2019), 290
 - cumulative contribution to warming, 751
 - decadal mean nitrous oxide emissions (2007–2016), 710
 - effects of peatland restoration on, 763
 - effects of soil carbon sequestration on, 763
 - emissions after biochar addition to soil, 763
 - emissions from human activity, 180
 - estimates of warming and temperature change potential, 927
 - future abundances for scenarios (2020–2500), 2144
 - glacial-interglacial transition concentrations, 301
 - global budget decadal averages, 712
 - global nitrous oxide budget (2007–2016), 711
 - global source estimate (2007–2016), 711
 - global surface annual mean trend, 303
 - historical abundances and forcing, 2141
 - lightning release in troposphere, 830
 - net effective radiative forcing of, 853
 - non-agricultural anthropogenic sources, 709
 - non-agricultural land emissions and sinks, 711
 - ocean, inland water body and estuary emissions, 710
 - primary natural production of, 708
 - production in the ocean, 737
 - projected trends for oceanic emissions, 719
 - radiative efficiency changes (since 2011), 947
 - recent concentrations of, 8
 - response of future warming, 677
 - terrestrial ecosystems release of, 737
 - tropospheric adjustment effects on forcing, 925
- N-limited forests and grasslands, reactive nitrogen deposition in, 857
- NOAA National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) reanalysis**, 213
- Noise-induced tipping**, 202
- Non-CO₂ biogeochemical feedbacks**, 975
- Non-CO₂ greenhouse gases**
 - biogeochemical feedbacks, 857, 860, 975
 - emissions from agriculture, 866
 - estimates from Earth system models, 820
- Non-methane volatile organic compounds* (NMVOCs)**
 - anthropogenic emissions sources, 828
 - anthropogenic light alkanes (C₂–C₅) trend, 841
 - effective radiative forcing effects (1750–2019), 819
 - indirect climate forcing by, 823
 - net global emissions-based effective radiative forcing of, 855
- North Africa. *See also* Mediterranean (MED) region.**
 - anthropogenic climate forcing in, 1969
 - Atlantic Multi-decadal Variability effects in, 2177
 - drought duration and intensity, 1119
 - precipitation changes over, 1968, 1971
 - temperature projections for, 1971
 - wind projections for, 135
- North America**
 - aerosol effective radiative forcing over, 852
 - agricultural and ecological droughts, 1831
 - air temperature and precipitation for subregions of, 1943
 - annual maximum snow depth for cold-season periods, 2005
 - annual mean surface air temperature change (2070–2099), 2008
 - annual precipitation trends, 2004
 - anthropogenic emissions effects in, 2004
 - anthropogenic signal detection over, 2004
 - assessment and synthesis of projections, 2006
 - assessment, observations, trends, and attribution, 2004
 - Atlas, 2004–2014
 - atmospheric sulphur dioxide reduction (2000–2015), 843
 - biomass burning emissions in, 869
 - black carbon estimates of, 848
 - carbonaceous aerosol emissions in, 828
 - climate changes, 141, 1828, 1830
 - climatic reference regions, 2004
 - coastal and oceanic climatic impact-driver indices change, 1834
 - confidence in climatic impact-driver projections for, 1835
 - current short-lived climate forcers, CO₂, and NO₂ emissions, 821
 - distribution of short-lived climate forcers over, 819
 - drought trends and projections for changes by warming levels, 1701
 - emissions with fossil fuel use, 829
 - extreme precipitation changes, 1560, 1566
 - fire weather exposure and vulnerability, 1832
 - global surface temperature trends and projections for, 2008
 - greenhouse gas emissions for, 713
 - hail changes for, 1834
 - heat and cold changes for, 141
 - heat stress indicators in, 1830
 - heavy precipitation trends and projections by warming levels, 1697
 - lake-effect snowstorms projections for, 2008
 - mean surface air temperature and precipitation changes, 2007
 - model performance assessment, 2005
 - NO₂ decreases, 839
 - non-methane volatile organic compound trends in, 828, 842
 - Pacific Decadal Variability effects on, 2174
 - particulate matter emissions sources in, 821
 - pattern of changes in climatic impact-drivers, 1832
 - precipitation changes with Atlantic Multi-decadal Variability, 2177
 - precipitation trends and projections for, 2008
 - previous IPCC assessments, 2004
 - projections for hot and cold extremes for, 1556
 - projections for in climatic impact-driver indices, 1829
 - rain-on-snow event evolution in 21st century, 2008
 - regional climate features in, 2004
 - regional climate model testing in, 2005
 - regional relative sea level projections, 141, 1834
 - regional sea level and shoreline retreat, 141
 - regional surface air temperature signal emergence, 2004
 - regional wind changes (2°C warming), 141
 - sand and dust storm shift toward extremes, 1833
 - shoreline progradation in, 142
 - short-lived climate forcer effects in, 888
 - snow and ice changes, 141, 1833–1834
 - snowfall transition zone shift in, 2008
 - snow mass trends for, 2005
 - snow-related projections for, 2008
 - snow water equivalent projections for high-latitude climates, 2009
 - solar radiation projections for, 1791
 - south-western drought attribution to anthropogenic forcing, 1421
 - subregional precipitation projections, 2007
 - subregion reanalysis/historical simulations, 1943
 - sulphate aerosol trends, 846–846

- summary of changes, 126, 141, 2008
 surface ozone concentration changes in, 882
 temperature changes in, 1550
 temperature extreme trends and projections by warming levels, 1693
 trends in coastal climatic impact-drivers, 1836
 wet and dry regional changes in, 141
 wind changes, 141, 1832
- North American monsoon* (NAmerM)**
 changes in, 1098, 1130
 Gulf of California low-level jet effects on, 2198
 history and definition of, 2198
 seasonal climate influence of, 1991
 warming trends in, 1994
- North American Regional Climate Change Assessment Program (NARCCAP), 2005**
- North Asia**
 assessment and synthesis of projections, 1977
 changes with 2°C global warming, 138
 greenhouse gas emissions for, 713
 model performance assessment, 1977
 observations, trends and attribution, 1976
 precipitation and temperature summary, 1978
 previous assessment findings, 1976
 reference regions in, 1975, 1976
 regional climate and findings, 1975
 seasonal snow duration and extent in, 139
 snow season trends (1980–2015), 1976
 temperature change (2080–2099), 1978
 temperature reanalysis (1976–2010), 1977
- North Atlantic Deep Water (NADW)**
 freshening trends and decadal variability in, 1235
 in Circumpolar Deep Water formation, 1236
 internal variability in, 1230
 warming projections for, 1233
- North Atlantic Ocean (NAO)**
 acidification in subtropical and equatorial regions, 489
 biases in model simulation of storm tracks, 464
 jet stream changes, 2158
 mode of large-scale variability, 2156
 redistribution of ocean heat in basin, 1231
 regional mean relative sea level change in, 1826
 salinity projections for, 1842
 sea level change signal in, 1290
 shift in blocking anticyclones, 1101
 subpolar gyre warming projections, 1223
 subpolar warming in, 1222, 1229
 subtropical gyre, 1320
 thermohaline circulation in, 202
 tripole pattern, 2176
 wind stress changes in, 1225
- North Atlantic Oscillation*/Northern Annular Mode* (NAO/NAM)**
 Arabian Peninsula climate influence by, 1983
 boreal wintertime modes, 2157
 climate variability and, 2156
 CMIP scenario simulations for, 578
 correlation with Northern Annular Mode, 489
 cryosphere–atmosphere coupling and variability in, 2158
 drivers of, 2156
- European climate influence of, 1998
 evaluation of forced component of, 2158
 hemispheric-scale mode of variability, 2156
 impact on climate trends (2016–2045), 1142
 importance in large-scale climate, 370
 index reconstruction of, 2159
 influence on Siberian climate, 1976
 influences on extreme still water levels, 1309
 jet stream and storm track associations, 2158
 modes of variability in, 2155
 ocean heat content patterns and variability in, 1231
 ocean responses to fluctuations in, 2159
 proxy-based reconstruction from sea level pressure, 2159
 reconstruction of winter patterns, 2159
 sea level pressure, 2158
 sea surface temperature anomalies affecting, 2158
 seasonal asymmetry of teleconnection patterns, 2159
 solar cycle and near-term predictability, 1373, 2158
 South American climate influence of, 1994
 variability in the North Atlantic basin, 2156
 West Central Asia climate influence by, 1983
- North Atlantic Subtropical High (NASH)**
 climate effects in Small Islands, 2013
 influence on midsummer drought, 1991
 projections for intensification of, 2012
- North Eastern Africa (NEAF)**
 key climatic features, 1967
 precipitation changes over, 1971
- North-Eastern North America (NEN)**
 climatic features of, 2004
 land uplift and sea level rise in, 1847
 precipitation projections for, 2007
 warming trends for, 2006
- North-Eastern South America (NES), climatic features and drivers, 1994**
- Northern Annular Mode (NAM). See also North Atlantic Oscillation*/Northern Annular Mode* (NAO/NAM)**
 attribution of observed seasonal trends to forcing, 492
 boreal winter mode of, 2157
 boreal wintertime surface projections for, 609
 CMIP simulations of, 587
 defined, 489
 fixed latitude-based zonal estimations, 2158
 in Northern Hemisphere extratropical atmosphere, 578
 model reproduction of spatial features, 427
 physical mechanisms of changes in, 578
 relevance as mode of variability, 2156
 scenario-projections for boreal wintertime changes, 556
- Northern Australia (NAU), climatic features of, 1986**
- Northern Central America (NCA)**
 areas included in, 1991
 climatic features of, 1991, 2004
- El Niño–Southern Oscillation and Pacific Decadal Variability effects in, 1991
 precipitation projections for, 1991, 2007
 temperature projections for, 1993
 warming projections for, 2006
 wet and dry changes in, 141
- Northern Europe (NEU)**
 annual precipitation in, 1998
 climatic features of, 1998
 decrease in meteorological droughts, 1577
 high-latitude climate warming in, 1998
 snow trends in, 1999
 warming trends in, 1999
- Northern Hemisphere (NH)**
 aerosol effective radiative forcing over, 852
 aerosol optical depth in mid-latitudes, 290
 average annual temperatures (1983–2012), 315
 CMIP6 models for storm tracks, 606
 dichloromethane concentrations in, 843
 extratropical cyclone projections for, 1133
 global land monsoon precipitation projections, 556
 high-latitude precipitation change from human activity, 455
 human influence on snow cover in, 1284, 2005
 instantaneous blocking frequency (1979–2000), 465
 methane concentrations over past 110 years, 301
 mid- to high-latitude land precipitation increase, 426
 observed snow cover reductions in, 426
 poleward shift in storm tracks, 1101
 precipitation changes in high-latitude climates, 85
 seasonal snow cover changes in, 1123, 1216, 1283
 subtropical mode waters changes in, 1235
 surface downward radiation and precipitation anomalies, 1077
 temperature changes with global warming, 613
 trends in non-methane volatile organic compounds, 842
 tropospheric ozone changes, 290
- Northern South America (NSA), climatic features and drivers, 1994**
- North Pacific Ocean (NPA)**
 loss of oxygen in subsurface waters, 488
 poleward shift of storm tracks, 1058
 subpolar gyre changes, 1241
 wind stress changes in, 1225
- North-Western North America (NWN)**
 climatic features of, 2004
 precipitation projections for, 2007
- North-Western South America (NWS), climatic features and drivers, 1994**
- O**
- Observational data and constraints**
 assimilation into models for initial conditions, 563
 changes in capacity for, 151
 emergence of temperature change signal, 50

- evidence of warming from, 290
 for atmosphere, land and hydrological cycle, 209
 historical simulations, 41
 ship-based sampling for ocean temperatures, 1230
 sources of uncertainty in, 293
 threats to capacity or continuity, 212
 use in modelling to improve projections, 563
 use in simulations and scenarios, 446, 819, 2062
- Ocean***
- absorption of anthropogenic CO₂ emissions, 714
 - acidification and deoxygenation of, 677
 - acidification of, 161
 - biogeochemical changes in, 488
 - brominated and iodinated species from, 843
 - carbon uptake and mitigation levels, 723
 - changes in geochemistry, 292
 - changes in heat and salinity, 1228–1234
 - climatic impact-driver indices for open and deep ocean, 1841
 - continued warming of, 447
 - dynamic sea level, 1246, 1247, 1300
 - ecosystem impacts of temperature shift, 1786
 - expansion of observations, 209
 - human influence on, 426, 473–516
 - initialized predictions/projections for, 563
 - in physical system, 157
 - integration of paleo-oceanographic data with modelling, 47
 - interior change in, 717
 - manifestation of deep warming in, 1233
 - mean fluxes with high emissions, 1224
 - mean temperature shifts, 1786
 - model development since AR5, 473
 - N₂O emissions from ocean, 737
 - observational capacity for, 151
 - ocean-related quantities for climate change, 1966
 - oxygen concentration changes, 488
 - paleo-evidence and recently observed changes in, 74–76
 - past and future changes, 75
 - projected N₂O emissions trends, 719
 - projection of stressors, 488–489
 - projections for ocean warming (by 2100), 1232
 - properties for prediction of variability, 563, 564
 - reanalyses improvements, 214
 - recent global changes in, 291
 - sea surface temperature increase signal, 1855
 - Southern Hemisphere subsurface temperature increase, 1235
 - SROCC warming assessment, 187, 188
 - storage and transport of heat, carbon, and freshwater, 473
 - surface changes, 1221–1234
 - surface-intensified warming, 1214
 - temperature in model evaluation, 473
 - upper ocean historical trends and spatial characteristics, 715
 - upper ocean warming, 5
 - uptake of anthropogenic CO₂ with RCPs, 576
 - warming of, 158
- Ocean acidification***
- African changes, 1797
 - anthropogenic CO₂ driving of, 427, 489, 677, 714–718
 - Asian changes, 1804
 - Australasian changes, 1813
 - biological processes in, 720
 - carbon dioxide removal effects on, 29, 100
 - Central and South American changes, 1819
 - changes with 2°C global warming, 143
 - CO₂ emissions driving of, 5
 - continued growth of, 720
 - effects of ventilation processes, 717
 - European changes, 1827
 - eutrophication effects on, 721
 - extent in ocean interior, 717
 - future projections for, 719, 1790
 - global average surface ocean pH, 577
 - heterogeneity in coastal ocean and shoreline, 720
 - long-term change of annual and zonal ocean pH, 609
 - marine ecosystem effects of, 1787
 - metabolic CO₂ release in intermediate waters, 717
 - model-simulated long-term trend of, 608
 - multi-decadal pH trends in surface layer, 716
 - North American changes, 1835
 - observations in recent decades, 716
 - of ocean surface waters with increased atmospheric CO₂, 717
 - paleoclimate and pre-industrial, 714
 - pH in scenarios, 135
 - pH time series reconstruction, 715
 - pre-industrial spread from surface to interior, 718
 - projections for signal emergence, 1855
 - reconstructed centennial trends in, 715
 - reconstructions of paleo ocean pH, 211
 - regional coastal response to, 721
 - regional mean surface pH change, 1842
 - regional signal emergence, 1855
 - reversal by CO₂ removal, 720
 - Small Islands changes, 1840
 - solar radiation modification effects on, 679, 768
 - spatial and temporal variability in surface processes, 720
 - subpolar and polar zone changes, 716
 - subtropical ocean changes in pH, 716
 - surface ocean pH simulations (RCP/ SSP), 577
- Ocean alkalization*, for carbon sequestration,** 764
- Ocean–atmosphere–land biosphere system,** 684
- Ocean carbon fluxes**
- 10-, 20- and 30-year trends (2021–2040), 587
 - CO₂ storage in ocean, 691–694
 - multi-decadal trends in, 691
 - regional and global variability, 693
- Ocean carbon–heat nexus**
- changes and impact of ocean processes on, 745
 - climate change commitment and, 743
 - drivers and change in, 744
- Ocean carbon uptake and storage**
- biological drivers of future uptake, 729
 - biological processes in CMIP5 and CMIP6, 729
 - climate effects on future uptake, 728
 - drivers of weakening CO₂ uptake, 723
 - emissions scenario dependence of, 677
 - growth of sink stops (2050), 723
 - increasing CO₂ emissions effects on, 19
 - near-term changes with high emissions, 587
 - ocean carbon flux scenario projections, 587
 - response to the growing ocean sink, 676
- Ocean circulation/currents.** *See also* **Atlantic Meridional Overturning Circulation* (AMOC)**
- Antarctic Circumpolar Current, 485, 1239, 1240
 - Atlantic Meridional Overturning Circulation, 483, 1214, 1236, 1321
 - coastal systems and marginal seas, 1244
 - Eastern boundary upwelling systems, 1214, 1243–1244
 - eddy exchanges, 1234
 - effects on air–sea fluxes, 745
 - Gulf Stream, 1320
 - gyres, western boundary currents, and inter-basin exchange, 1241–1243
 - in heat and freshwater transport, 483–487
 - pattern of carbon dioxide uptake/storage, 744
 - Southern Ocean, 485, 1239–1240
 - tropical oceans, 1241
 - western boundary currents, 143, 1222, 1241
- Ocean–climate feedback,** 719
- Ocean CO₂ sink (S_{ocean})**
- modelled evolution of (1850–2100), 734
 - multi-decadal trends for, 692
 - pCO₂-based reconstructions (1960–2019), 691
 - scenario trajectories for, 677
 - solar radiation modification effects on, 679
- Ocean deoxygenation***
- anthropogenic CO₂ absorption, 714–718
 - areas of signal emergence for, 1855
 - changes with 2°C warming, 143
 - drivers of, 714, 720
 - effects on N₂O flux to atmosphere, 719
 - heterogeneity in coastal ocean and shoreline, 720, 722
 - implications for greenhouse gases, 717
 - in tropical oceans, 719
 - in upper ocean regions, 5
 - low oxygen zone expansion, 143
 - marine ecosystem effects of, 1787
 - oxygen concentration projections with high emissions, 1842
 - paleoclimate and pre-industrial, 714
 - projections of subsurface oxygen loss, 42
 - projection with ocean warming, 677
 - reduction of anthropogenic nutrient inputs, 722
 - spatial and temporal variability in surface processes, 720
 - spatial characteristics of response to atmospheric CO₂, 721
 - total N₂O production in ocean, 719
- Ocean dynamic sea level change***
- contribution to relative sea level change, 1304
 - detectable signal for, 1290
- Ocean fluxes, projections with high emissions,** 1224
- Ocean heat content (OHC)**
- air–sea flux inferred from, 1225

- as metric for global climate change, 937
- attribution of change, 426, 476–477
- change on patterns of heat transport, 1231
- change relative to Last Glacial Maximum, 1233
- changes with time, 1229
- continued increase in slower surface warming period, 447
- contribution to Earth system imbalance, 925
- contribution to heating in climate system, 11
- decomposition and northward heat transport simulation, 1231
- global energy inventory (1971–2010), 937, 1228
- global uptake rate (1971–2014), 477
- heat storage by, 473
- human-induced upper ocean warming, 5
- human influence driving of increase, 1228
- increase in (1998–2012), 425
- in global energy inventory, 937
- large-scale change indicator, 313
- long-term commitment of, 47
- long-term trends of surface temperature, 1233
- observed changes for full-depth ocean temperature, 1230
- partitioning of heat between atmosphere and ocean, 744
- processes driving patterns of, 1230
- projections for increase over 21st century, 1214
- regional patterns in, 1233
- response to stabilization of warming, 106
- Southern Ocean system modulation of, 1239
- thermosteric sea level change from, 1244
- warming impact on ocean structure, 1786
- warming rate of, 8
- zonal-mean potential temperature and rate of change, 1230
- Ocean heat transport (OHT), 1231**
- Ocean memory**
 - acidification in ocean interior, 717
 - predictability of the ocean carbon sink, 742
- Ocean Reanalyses Intercomparison project, 214**
- Ocean salinity**
 - air–sea flux inferred from, 1225
 - changes in, 1842
 - changes with 2°C warming, 143
 - circulation change effects on, 1234
 - detection and attribution of change in, 479–481
 - global changes in patterns of, 456
 - halosteric and thermosteric sea level in models and observations, 480
 - human contribution to changes in, 5
 - human influence contribution to, 426
 - long-term change and variability, 478
 - multi-decadal salinity trends for the near-surface ocean, 479
 - multi-model-mean biases in, 479
 - North and South Atlantic salinity projections, 1842
 - projections for changes in, 1235
 - regional contrast in, 1234
 - sea level change with, 1220
 - sea surface and depth-profile evaluation, 478
 - signal emergence in, 1855
 - structure and ecosystem impact, 1787
 - surface and subsurface salinity changes, 1234
- Ocean stratification***
 - 21st century trend for upper ocean, 1226
 - changes in oxygen minimum zones, 715
 - changes in stability of, 1214
 - CO₂ effects on mixed layer, 728
 - increases in, 42
 - mechanism and projections for, 1226
 - mixed layer depth in winter and summer, 1226
 - projected, 1844
 - salinity changes and, 478
 - seasonal change in, 1226
 - upper and deep layer warming in, 1228
 - upper ocean and surface mixed layers, 1225–1226
- Ocean warming**
 - hemispheric asymmetry of, 1230
 - large-scale change indicator, 313
 - regional variation in rate of, 1229
 - surface increase (1850–2020), 1214
 - time course of, 1228
 - variation with depth, 1228
- Oil production-distribution and transport sector, emissions from, 828**
- Optimal fingerprint regression-based methods, 1414**
- Orbiting Carbon Observatory satellites (OCO-2 and OCO-3), 209**
- Organic aerosols* (OA)**
 - components of, 847
 - model estimates of surface concentrations, 848
 - model lifetime estimates of, 848
 - simulated burdens of, 848
 - sources of, 823
- Organic compounds (OC)**
 - association with fossil fuel use, 829
 - trends in aerosol emissions, 828
 - vegetation emissions of, 831
- OSNAP observing system, 1237**
- Outgoing longwave radiation* (OLR), convective activity and zonal winds in troposphere, 2177**
- Overcompensating (climate change), 629**
- Overshoot trajectories**
 - risks and impacts with, 617
 - ocean and land response to CO₂ concentrations in, 677
 - with solar radiation modification, 625, 629
- Oxidant levels in global climate models, 845**
- Oxygen minimum zone* (OMZ). See also Ocean deoxygenation***
 - climate variability effects on oxygen loss in, 718
 - during Last Glacial Maximum, 715
 - effects on remineralization of POC, 729
 - N₂O response to oxygen loss in, 770
 - NO₂ emissions from, 714
 - rate of oxygen decrease, 719
 - vertical and lateral expansion of, 714
- Ozone (O₃) concentrations**
 - assessed tropospheric radiative forcing for, 946
 - climate change effects on surface, 861, 863
 - decadal trends (since 1994), 838
 - decreases in tropospheric, 290
 - depletion driving upper stratospheric cooling, 445
 - depletion effects on extratropical jet in Southern Hemisphere, 464
 - direct radiative forcing effects of, 823
 - effective radiative forcing from, 311
 - effective radiative forcing from precursors, 830
 - effect of dedicated air pollution or climate policy on, 891
 - effects of precursor emissions abatement, 883
 - effects of solar radiation modification on surface, 769
 - effects on carbon dioxide uptake and methane emissions, 857
 - effects on photosynthesis and plant growth, 857
 - energy and land transportation sector contribution to, 821
 - estimates of tropospheric burden of, 838
 - evolution of surface concentrations of, 882
 - forcing effects on Southern Annular Mode, 427
 - global mean tropospheric burden (1850–2100), 837
 - global pre-industrial abundance of, 837
 - global tropospheric budget for, 837
 - impact of lightning on, 830
 - loss in stratosphere, 307
 - meteorology driven feedbacks on climate, 859
 - methane mitigation effects of surface, 875
 - photo-oxidation of biogenic volatile organic compound emissions in budget, 831
 - precursor emissions in SSPs, 30
 - production of tropospheric, 848
 - projections for surface change (2015–2100), 883
 - recovery and greenhouse gas effects on Southern Annular Mode, 609
 - regional surface concentrations from natural surfaces, 869
 - stratosphere depletion of, 5
 - stratospheric levels, 306, 838
 - surface and tropospheric trends, 308
 - surface concentration change with warming, 862
 - temperature effects in polluted areas, 864
 - total tropospheric column, 836
 - transportation contribution to surface, 868
 - tropospheric, 307–308, 836
 - tropospheric production with methane, 946
 - vapour abundances and temperature effects on, 861
- Ozone-depleting substances* (ODS)**
 - atmospheric mixing ratios of, 304
 - decline (late 1990s), 838
 - halogenated greenhouse gases, 304
 - in anthropogenic forcing, 445
 - in lower stratosphere cooling, 445
 - stratospheric halogen loading by, 843
 - transition away from use of, 843
 - ultraviolet radiation changes, 853
- Ozone hole/ozone layer***
 - air transportation effects on, 180
 - recovery effects on stratospheric temperature, 599
 - recovery effects on westerly wind jets, 1240
 - surprise event, 203
 - trends in Southern Annular Mode, 588

Ozone-induced gross-primary productivity (GPP) losses, 857

P

Pacific Decadal Oscillation* (PDO)

CMIP simulation for, 590
drivers of, 2171
Pacific Decadal Variability and teleconnections of, 502

Pacific Decadal Variability* (PDV)

African climate effects of, 1967
association with global air surface temperature fluctuations, 446
characteristics of, 2172
climate variability and, 2156
CMIP simulations for, 502–504, 590
drivers of regional climate change, 1374
East Asia climatic effects of, 1973
effects in tropics, 2174
El Niño–Southern Oscillation decadal effects on, 2172
external forcing versus internal generation of, 590
in CMIP6 trends (1998–2012), 425
model evaluation of, 503
model reproductions of, 2172
modulation of surface temperature, 2172
projections for future change in, 611
proxy evidence for existence, 375
Russian Far East influence of, 1976
sea surface temperature anomaly patterns, 2174
South American influence of, 1994
temporal evolution of, 2174
tripole index (1900–2014), 2173

Pacific-North American* (PNA) pattern, 2164, 2174

Pacific Ocean

changes in tropical cyclone activity, 1589
marine heatwave frequency projections for western tropical, 1227
oxygen loss in equatorial and North, 1842
oxygen minimum zone in Eastern Pacific, 488
projections for freshening of, 1844
regional intermediate water acidification in, 717
regional projections for changes in pH, 721
sea level rise in Eastern Pacific, 1216
sea surface east–west gradient in, 988
statistical modes for variability description, 2171
warming projections for equatorial, 1224
warming rate in western equatorial, 143
warming rate of, 1222

Pacific-South American (PSA) pattern, 2164, 2174

Palaeosol carbonates, terrestrial CO₂ proxy, 299

Paleocene–Eocene Thermal Maximum* (PETM)

atmospheric CO₂ concentration comparison to present, 683
carbon dioxide change in, 299
climate during, 295
global mean surface temperature during, 294
global warming in, 202, 714
ocean deoxygenation during, 714

Paleoclimate Modelling Intercomparison

Project Phase 4 (PMIP4), 957

Paleoclimate Modelling Intercomparison

Project Phase III (PMIP3), 298

Paleoclimate (proxy) reconstructions. *See also*

Historical period simulations

advances since AR5, 211
Atlantic Multi-decadal Variability-related signal reconstructions, 2177
avalanche in the Indian Himalayas, 1803
Cenozoic CO₂ record from marine sediment, 683
centennial- to millennial-scale variations, 160
CH₄ and N₂O emissions under glacial climate conditions, 685
climate system evidence from, 45
context for drought projections, 1120
cooling in the Northern Hemisphere, 161
drought reconstruction and models, 1121
equatorial warm pool gradient, 989
equilibrium climate sensitivity estimates, 11, 999, 1001
equilibrium sea surface temperature patterns, 1223
estimates of OH in last glacial maximum, 850
feedbacks between climate and carbon cycle, 683
fluctuations of Indian Ocean Basin/Indian Ocean Dipole, 2167
for Paleocene–Eocene Thermal Maximum, 714
global hydrological cycle perspectives, 329
global mean sea level over 20th century, 1287
global mean surface temperature estimation, 294
global monsoon variations with forcing, 461
global surface air temperature extension to 2300, 633
greening of the Sahara and Sahel, 1150
ice core proxies for carbon–climate feedbacks, 684
impacts of eruptions on contemporary society, 593
improvements in radiocarbon calibration datasets, 211
in AR5 and AR6, 154
Indian Ocean Dipole and Indian Ocean basin, 2168
isotope analysis of continental and marine sediments, 298
key indicators for, 159
longitudinal sea surface temperature gradient changes in, 988
millennial rates of CO₂ concentration change, 686
non-methane volatile organic compounds, 842
North Atlantic Oscillation index, 2159
ocean heat content, 1233
ocean pH change with atmospheric CO₂ concentrations, 715
of Atlantic Meridional Mode and Atlantic Zonal Mode, 2171
of El Niño–Southern Oscillation, 2164
of ice-sheet mass response, 47
Pacific Decadal Variability reconstructions, 2174

paleo reference period assessment, 314
past climate comparisons with projections, 292
past space-time changes, 2155
precipitation, humidity and streamflow, 449–451
rate of changes in key indicators, 160
reconstruction efforts completed since AR, 211–212
reconstruction from archived materials, 158
reconstructions of carbon monoxide concentrations, 841
reference periods for, 294, 295
sea level change/rise, 1292–1298
solar irradiance reconstruction for 9kyr, 297
Southern Annular Mode regional influence, 2161
state-dependence of feedbacks in, 980
synopsis of paleoclimate model results compared to observational references, 511
tree ring evidence for dry spells, 449
tree ring records of Southern Annular Mode, 2161
tropospheric OH estimates in paleo time scales, 850
updated evidence for AR6, 41
volcanic eruption frequency, 593

Paleoclimate reference periods, 295–296

Paleoreconstruction efforts. *See* Paleoclimate (proxy) reconstructions

Palmer Drought Severity Index (PDSI), 1572, 2009

Paris Agreement goals

1.5°C or 2°C warming limitation goal, 189
balance between emissions and removals, 242
emissions metrics for, 1018, 1542
for NO_x emissions, 881
framing of report for climate policy, 172
global stocktake for, 162
limiting global temperature increases, 192
limiting of global average temperature increase, 161
mitigation scenarios for, 680
net zero emissions meaning, 1018
reductions in non-CO₂ emissions for, 864
scenario approximations for, 228
scenarios compliant with, 881
stocktake requirements of, 150

Partial pressure of CO₂ (pCO₂)

Antarctic rise at last deglacial transition onset, 686
feedback effects on gradients, 681
governing of ocean carbon uptake/storage, 732
North Atlantic subtropical and equatorial biomes, 489
ocean warming effects on, 728
seasonal cycle of surface ocean, 775

Particulate matter (PM). *See also* Aerosols

agricultural contribution to, 866
carbonaceous aerosols in, 847
change in chemical composition of, 863
changes in regional 5-year mean (2015–2100), 884
contribution of nitrate to, 846
dedicated air pollution or climate policy effects on, 890

- distribution of major aerosol components, 844
 effects of climate change on, 863
 emissions source-sector attribution of regional population, 871
 evolution of surface concentrations of, 882
 in air pollution/quality simulation, 861
 in future air quality, 820
 in nitrate formation, 846
 regional changes in surface concentrations, 883
 residential and commercial sector contribution, 821
 typical atmospheric lifetime of, 863
 warming effects on concentrations, 863
 wet deposition of, 863
- Particulate organic carbon (POC), 729**
- Passive microwave satellite observations, 1980**
- Pathway independence, 743**
- Pattern scaling**
 climate change representation, 565
 mid-latitude atmospheric circulation and global surface air temperature, 616
 observational constraints on the magnitude, 991
 radiation changes affected by, 990
- Peatland restoration, 763**
- Perfect-prognosis models, 1391**
- Perfluorocarbons (PFCs), 304, 2141**
- Permafrost***
 Asian changes, 138, 1802, 1979
 biogenic emissions with thaw, 740
 carbon accumulation after thawing of, 727
 carbon content of Arctic and boreal, 188
 carbon feedback projections to 2100–2300, 728
 carbon feedbacks to climate, 726–730
 carbon release from thawing, 677
 Central and South American changes, 1818
 CH₄-climate feedback estimation, 728
 change from sink to source of CO₂, 727
 East Siberia changes, 1976
 European changes, 1825
 expectations of emissions with thawing, 727
 infrastructure hazards with thaw, 1785
 in remaining carbon budgets, 747
 methane release from thaw, 728
 model evaluation, 1281–1283
 near-surface volume loss of, 1216
 North America changes, 1833
 observed and reconstructed changes for, 1280–1281
 observed versus simulated extent of by warming level, 1282
 polar regions changes, 1845–1847
 projections for changes in, 727, 1282
 time scales of irreversibility in thawing, 21
 uncertainty in scaling carbon feedback with warming, 728
 warming effects on, 16
- Permian era, CO₂ proxy estimates for, 299**
- Peroxy radical recycling, 848**
- Perturbation lifetime (τ_{pert}), 836**
- Perturbed-parameter ensemble (PPE) modelling, 222, 562**
- Perturbed-physics ensembles for regional-scale attribution, 1416**
- Phosphorus availability, effects on carbon storage response in plants, 723**
- Photosynthesis***
 acclimation to long-term CO₂ exposure, 722
 control of land CO₂ sink, 694
 effects of solar radiation modification on, 768
 feedback on anthropogenic climate change, 723
 ozone effects on, 857
 radiation fluxes effects on, 1787
- Photosynthetically active radiation (PAR), 1788**
- Physical emulators and simple climate models, 219**
- Phytoplankton, 292, 729**
- Pinatubo (1991) volcanic eruption, 327, 629**
- Planck response (P), 95, 926, 932, 967, 968**
- Planetary albedo, 970**
- Plant physiology**
 atmospheric CO₂ effects on, 1580
 CO₂ uptake relation to water loss, 722
 effects of climate variability and warming on, 724
 effects of elevated CO₂ on, 722
 phosphorus and nitrogen limitation effects, 723
 temperature versus vapour pressure deficit effects on, 724
- Pliocene Model Intercomparison Project Phase 1 (PlioMIP1) models, 989**
- Pluvial floods, 1783. See also Heavy precipitation and pluvial floods**
- Polar amplification***
 Arctic versus global average for warming, 596
 changes with 2°C warming, 142
 CO₂ emissions and, 985
 confidence in occurrence of, 987
 critical processes driving, 982–984
 driving processes for, 982
 in paleo proxies and models, 986
 mid-Pliocene Warm Period, 1293
 overall assessment, 987
 paleoclimate model simulation of, 985
 projections for Arctic heat extremes, 1844
 Southern and Northern Hemisphere projections, 597
- Polar regions. See also Antarctic; Arctic**
 Arctic Oscillation/North Annular Mode and strength of vortex, 2156
 Atlas, 2016–2028
 changes for, 1932
 climatic impact-driver changes (2°C warming), 142
 heat and cold changes (2°C warming), 142
 heat and cold changes in, 1844
 projections for, 2016–2058
 recent and future climatic changes, 1844
 regional annual mean surface air temperature and precipitation changes, 2016
 regional subdivisions of, 2016
 relative sea level changes, 1847
 remote effects of vortex collapse, 2158
 surface warming amplification of, 927
 temperature, precipitation and mass balance in, 2016–2018
 terrestrial snow and ice changes, 1845
 wet and dry projections for, 1844
- Policy-making decisions**
 climate services, 111, 172
 effect of dedicated policy for air pollution, 889
 effects of dedicated policy on air pollution, 890
 framing of report for climate policy relevance, 172
 international policy context changes since AR5, 150
 policy and governance context of AR6, 161
 practitioner's dilemma, 1429
 prioritizing mitigation of specific anthropogenic sources, 864
 relevance of signal emergence for, 1853
 spatial and temporal resolution in relation to, 1430
 Summary for Policymakers, 3–32
 support for regional decision-making, 1773
 use of climate metrics for, 931
- Potential added value, 1990**
- Precipitation**
 agricultural and infrastructure impact of change, 1782–1784
 amount, frequency and intensity changes, 1081–1084
 amount, frequency and intensity projections, 1109
 annual maximum one-day (Rx1 day) changes, 1523
 annual mean change in, 17
 annual mean rate (1995–2014), 453
 area fraction of change with warming, 616
 around eye of Typhoon Haiyan, 1399
 Atlantic Multi-decadal Variability association with changes, 2177
 changes with surface air temperature rise, 615
 CMIP model simulations for land, 573
 continental scale of changes, 1518
 continued warming effects on, 1146
 extratropical storm precipitation with warming, 1133
 extreme precipitation with extratropical cyclones, 607
 geographical patterns of projections, 1109
 global changes over land, 291
 global climate change projections, 601
 global pattern and rate of increase, 5
 greenhouse gas forcing effects on, 1057
 greenhouse gas masking of changes, 1084
 high emissions projections (2081–2100), 556
 high-warming storyline projections, 637
 human influence contribution to changes over land, 452
 increase and extremes with surface warming, 1068
 Inter-tropical Convergence Zone migration effects, 2171
 land and ocean contrast in projections, 602
 linear trends (1901–1984 and 1985–2014), 1083
 long-term change of seasonal mean, 602
 long-term relative changes in daily statistics, 1111
 long-term relative changes in seasonal mean, 1110

- long-term seasonality changes, 1115
 - Madden–Julian Oscillation simulated changes and, 1105
 - model skill for multi-year/decadal forecasts, 564
 - near-term change of seasonal mean, 585
 - near-term projections for changes in, 556
 - non-linearities in, 1144–1146
 - Northern Hemisphere high-latitudes change (1966–2005), 455
 - Northern Hemisphere temperate land regions, 158
 - observed and simulated trends over land, 455
 - precipitation and precipitation–evapotranspiration indices (1951–2016), 1574
 - projections for increases by scenarios, 573
 - projections for seasonal patterns of, 584
 - reconstruction Mid-Holocene trends, 449
 - regional detection of changes, 1414
 - regions with recorded deficits, 1573
 - scale of change emergence, 1542
 - scenario-based projections and near-term information, 556
 - seasonality change projections for, 1058
 - signal emergence for increase, 1855
 - spatial patterns of change with warming, 615
 - tropical mean annual anomalies, 454
 - uncertainties in regional changes, 1124
 - volcanic eruption effects on, 1144
 - wet removal efficiency for pollutants, 861
 - with tropical cyclones, 1132
 - Precipitation deficits**
 - detection and attribution of deficits, 1577
 - projections for, 1579
 - regional observations of, 1575
 - Precipitation Driver Response Model Intercomparison Project (PDRMIP) models**, 950
 - Precipitation, humidity and streamflow**, 449–453
 - Precipitation minus evaporation (P-E)**
 - changes in, 334
 - changes over land, 1079
 - changes with warming, 1057
 - confirmation of changes with warming, 1068
 - trends in, 333
 - zonally averaged annual mean changes, 1069
 - Precursor gases***, 839
 - Predictability* (of climate)**
 - atmospheric CO₂ growth-rate, 742
 - CMIP role in investigation of, 2100
 - modes of variability in, 2155
 - Pre-industrial control (piControl) simulations**, 1393
 - Pre-industrial era baseline (1851–1900)**
 - atmospheric CO₂ concentration, 299
 - climate change signal emergence, 1853
 - for projections, 1936
 - Primary organic aerosols (POA)**
 - in marine aerosol composition, 832
 - model predictions of, 848
 - origin of, 847
 - sea-spray aerosol interactions, 858
 - Primary production* (PP) of carbon**
 - in climate–carbon feedbacks, 681, 729
 - nitrogen-limitation in oxygen-depleted waters, 719
 - organic carbon fixed by, 729
 - removal of dissolved CO₂ from ocean surface, 720
 - Primary sea spray particles**, 832
 - Principal component analysis (PCA)**, 2155
 - Probabilistic projections**, 169, 576
 - Proxy-based reconstructions. See Paleoclimate (proxy) reconstructions**
- Q**
- Quadripolar anomaly pattern**, 2158
 - Quality control (QC) process, for observational datasets**, 1384
 - Quantile delta mapping (QDM)**, 2210
 - Quaternary***, 202, 329
- R**
- Radiative forcing* (RF)**
 - anthropogenic sulphur dioxide emissions impact on, 845
 - assessment by IPCC reports, 180
 - as uncertainty source, 196
 - aviation climate forcing and, 867
 - by volcanic activity, 958
 - CMIP models for, 2100
 - combined effects of all, 926
 - direct forcing by short-lived climate forcers, 823
 - efficiencies of background compounds, 1012
 - energy accumulation in Earth system, 90–93
 - equilibrium climate sensitivity estimation, 11
 - evolution with CO₂ concentration increase, 995
 - forcing from solar and volcanic activity (1750–1900), 150
 - from contrails, 866
 - historical and *abrupt4xCO₂* relationships in models, 992
 - implications of COVID-19 restrictions, 876
 - labels on Shared Socio-economic Pathways and RCP, 618
 - major changes in forcing since AR5, 959
 - RCP and SSP comparisons of, 562
 - solar irradiance (1750–2011), 296
 - Radioactive fallout**, 180
 - Radiocarbon (¹⁴C) studies, attribution of increasing CO₂ levels**, 180
 - Radio occultation (RO)**, 327
 - Rainfall. See Precipitation**
 - Randolph Glacier Inventory (RGI)**, 1273
 - RAPID Array measurements**, 1236, 1238
 - RAPID-MOCHA array**, 483
 - Reactive nitrogen (Nr) deposition**
 - effects of, 857
 - effects on natural CO₂ sinks, 857
 - in N-limited forests and grasslands, 857
 - Realised added value**, 1990
 - Real-time multivariate Madden–Julian Oscillation (RMM) index**, 2177
 - Reanalysis***
 - applications of, 215
 - as evidence in assessments, 151
 - atmospheric, 213
 - intercomparison of models, 213
 - model output constrained by observations, 212
 - ocean, 214
 - of pre-instrumental era, 214
 - precipitation minus evaporation, 334
 - sparse input of instrumental era, 214
 - Reasons for Concern* (RFCs)**
 - AR6 WGII assessment of hazards, 1771
 - ecosystem impact in Siberia, 1976
 - risk with climate change consequences, 1857
 - risk with low-likelihood outcomes, 199
 - Reduced-complexity climate model, 962. See Climate model emulators**
 - Reduced Complexity Model Intercomparison Project (RCMIP)**, 963
 - Reference Land and Ocean Regions**, 208
 - Reforestation*. See Afforestation*/reforestation***
 - Regional climate**
 - abrupt changes with anthropogenic perturbations, 678
 - actor and community values in, 1430
 - aerosol forcing effects on, 1528
 - anthropogenic change and internal variability interplay, 1413
 - anthropogenic signal robustness and emergence, 1423–1426
 - assessing response to external forcing, 1414
 - assessment of, 172, 1435
 - Atlantic Multi-decadal Variability influence, 2176
 - attribution approaches for, 1415
 - attribution examples for, 1416–1422
 - attribution of precipitation and temperature changes, 1422
 - challenges for assessment, 1384
 - challenges in information construction, 1459
 - changes in climate extremes in, 1517
 - classes used in AR6, 208
 - combining approaches for constructing, 1427–1429
 - commonly used indices and thresholds for impact drivers, 1788–1792
 - confidence assessment of information, 1436
 - conflicting information from different sources, 1428
 - constructing user-relevant information, 1429
 - data scarcity, 1385
 - definition of regions, 1371
 - derived gridded datasets for, 1386
 - derived observational product use, 1383
 - distillation and synthesis of independent assessments, 1436
 - distillation of information for, 1375
 - drivers of variability and change, 113–116
 - droughts, 1605
 - El Niño–Southern Oscillation impact on, 2167
 - extreme event interactions, 1529
 - extreme precipitation modulation, 1557
 - fitness for purpose of information, 1436

- flood event projections, 1518
 forcings controlling, 1373–1374
 framing for user-relevant information, 1429
 future anthropogenic signal emergence, 1426
 generation from multiple lines of evidence, 112
 heavy precipitation extremes, 1605
 hourly accumulated precipitation profiles (Typhoon Haiyan), 1399
 human influence and internal variability in, 1367
 impact and risk assessment, 1767–1926
 improving observational data for, 1388
 inconsistency in dynamical downscaling, 1375
 information from AR5 and Special Reports, 1377, 1377–1381
 information from models and observations, 1366–1368
 information sources for, 1370, 1427
 in situ (surface) observations, 1382
 internal drivers of variability, 1374
 land-use and aerosol forcing effects, 1529
 land-use forcing of extremes, 1528
 Madden–Julian Oscillation influence on, 2177, 2179
 methodologies for attribution, 1414
 model improvement and added value, 1395
 modelling progress since AR5, 1942
 model projections of warming to 1.5°C, 188
 model types and chains used in, 1388–1395
 modes of variability and teleconnections, 113–114
 new knowledge on, 154
 observations in mountain areas, 1386
 observations used for constructing, 1382
 open biomass burning emissions differences, 832
 overview of observed trends and projections, 1931
 Pacific Decadal Variability effects on, 2172
 paleoclimate data assimilation for, 1387
 projections from global models, 1366
 quality control processes for assessment, 1384
 reanalyses use for information, 1366
 regional feedback effects on extremes, 1529
 regional scale observation use, 1387
 remote-sensing data for, 1382
 robustness and scalability of anthropogenic signals, 1424
 severe convective storm trends, 1595
 sources of variability and change in, 1372
 spatial and temporal homogenization of data, 1384
 storylines for constructing and communicating, 1433–1438
 structural uncertainty in data, 1387
 teleconnection influence on, 2164
 temperature and precipitation changes, 645
 temperature extremes, 1605
 temperature variations (since 1850), 247
 time-evolving contribution of different mechanisms in, 1425
 treatment in WGI report, 1376
 types of model experiments, 1392–1395
 typological regions for, 208
 uncertainty and confidence in, 1374
- using models for constructing, 1388
 weather and climate prediction framework, 1372
- Regional Climate Centres (RCCs)**, 1862
- Regional climate change**
- Africa, summary of changes, 122, 135, 1971
 agricultural and ecological droughts, 1519
 Antarctic, summary of changes, 127, 142, 2025
 anthropogenic and biomass burning emissions (1850–2100), 880
 Arctic, summary of changes, 127, 142, 2022
 Asia, summary of changes, 123, 138, 1986
 assessing change and Interactive Atlas, 111–112
 attribution of observed changes in, 11
 Australasia, summary of changes, 124, 139, 1990
 Central and South America, summary of changes, 125, 140, 1991
 changes daily maximum temperature for land area by scenarios, 1524
 climate information for risk assessment, 40
 climatic impact-driver indices for, 2155, 2212
 data integration in Atlas, 1934
 defined, 1370
 direct anthropogenic influence on water cycle, 1075
 distillation and climate services, 110
 effects of further warming on, 24–25
 emergence of extreme changes, 1542
 Europe, summary of changes, 126, 140, 2003
 generation and communication of information, 107
 impact and risk assessment, 57–59
 implications for extremes and climatic impact-drivers, 120–124
 information for, 1369
 information on extremes, 1604–1607
 large-scale teleconnection and anomalies in, 2155
 linking global to regional climate change, 1363–1512
 mean relative sea level rise through 21st century, 25
 methods for attribution of, 1414
 North America, summary of changes, 126, 141, 2008
 observational data and reanalyses used in, 1938–1941
 observed and attributable changes, 109
 precipitation amount, frequency, and intensity changes, 1081–1083
 projections for water cycle changes, 1124
 regional and local processes in cryosphere, 1221
 remote influences on, 2155
 responses to short-lived climate forcer mitigation, 885
 short-lived climate forcer emissions effects on, 887
 Small Islands, summary of changes, 127, 142, 2012
 spatial and temporal scales for, 1371–1372
 temperature at year 100 of *abrupt4xCO₂* simulations, 983
 tipping points and abrupt changes in, 202
- warming effects on hot and cold climatic impact-drivers, 24
- Regional climate change impact and risk**, 1773–1926
- aerosol and greenhouse gas forcing in, 1854
 changes in climatic impact-drivers, 1853
 climate change information in climate services, 1862–1864
 climate services and climate change information (case studies), 1866–1869
 climatic impact-driver changes in indices and thresholds, 1788–1863
 climatic impact-drivers for sectors, 1777–1790
 climatic impact-driver trends and thresholds, 1788
 drought/aridity or fire weather increases, 1853
 global perspective on climatic impact-drivers, 1851–1864
 impact and risk assessment, 1773
 key risks and reasons for concern assessments, 1857–1862
 methodological approach, 1774–1775
 regional changes in climatic impact-drivers, 1770
 societal and environmental impacts of change, 1773–1774
 solar radiation variation projections, 1791
 spatial pattern of atmospheric circulation change, 1851
 summary of climatic impact-driver hazards, 1858
- Regional climate models* (RCM)**
- anthropogenic signal emergence, 1367
 assessment of projection uncertainties, 1367
 assumptions for simulations, 1389
 atmosphere-only general circulation models for, 1389, 1397
 components of, 1390
 contributing to CORDEX experiment, 2090
 detection and attribution studies and observed emergence analysis, 1367
 ensemble use to assess uncertainty, 1410
 extreme rainfall event capture by, 1562
 fitness of climate models for projections, 1367, 1405
 for downscaling global simulation, 1140
 general circulation models for, 1396
 global climate model use for, 1389
 horizontal resolution for, 1389–1390
 improving the representation of regional climate, 1367
 observation types used in, 1382
 participating in CORDEX, 2089
 performance for climate and change simulations, 1406
 projections for change in summer precipitation, 1405
 projections for temperature-related extremes in, 1555
 regional responses to El Niño–Southern Oscillation, 1398
 simulating large-scale phenomena and teleconnections, 1396
 simulation of climatology extremes, 1551
 simulations and models used in CORDEX, 2099

- simulations using, 1942
- statistical downscaling, bias adjustment and weather generators in, 1367
- uncertainty of long-term temperature and precipitation estimates, 1366
- Regional climate projections**
 - internal variability role in, 1408
 - managing uncertainties in, 1407
 - regional precipitation differences, 556
 - relationship of emissions scenario, global warming levels, and impacts, 1543
 - statistical approaches to generation, 1390
- Regional monsoons, *See also* Global Monsoon (GM)**
 - Australian-Maritime Continent monsoon, 2199
 - definition used in AR5 and AR6, 2195
 - East Asian monsoon, 2196–2197
 - North American monsoon, 2198
 - paleoclimate reconstructions and projections, 118–122
 - South American monsoon, 2198
 - South and South East Asian monsoon, 2196
 - West African monsoon, 2197
- Regression-based methods**, 429, 1391
- Relative humidity* (RH)**
 - change over land, 291
 - coupling with surface air temperature, 596
 - decrease over land (since 2000), 330
 - long-term changes in seasonal mean change, 600
 - modulation of water cycle by change in, 600
 - near-surface changes over land and ocean, 600
 - nitrate production and, 846
 - spatial trends in patterns, 330
- Relative sea level (RSL) change***
 - African changes, 1796
 - Asian changes, 1803
 - Australasian changes, 1811
 - Central and South American changes, 1818
 - driver of change in estimated total water level, 1309
 - emergence of climate change signal for, 1855
 - European changes, 1826
 - glacial isostatic adjustment contribution to change in, 1300
 - global projections for, 1852
 - gravitational, rotational and deformational effects, 1300
 - land-ice mass contribution to spatial patterns, 1304
 - land uplift effects with, 1847
 - measurement of, 1220
 - median global and regional projections in SSPs, 1301
 - non-polar regions with a coastline, 1853
 - North American changes, 1834
 - ocean dynamic sea level contribution to, 1300
 - Small Islands changes, 1839
 - with relative sea level change, 1786
- Remaining carbon budget***. *See also* Carbon budget*
 - adjustments for Earth system feedbacks, 752
- AR5 and AR6 definitions and estimates of, 42, 749
- assessed budget and uncertainties in, 753
- components contributing to, 750, 751
- cumulative CO₂ emissions relationship to surface air temperature increase, 750
- developments for climate stabilization, 770
- estimate of CO₂ levels for warming stabilization, 97–99, 189, 681, 742
- estimates and uncertainties, 98, 752
- framework and approaches for, 749
- historical warming in assessment of, 751
- importance of permafrost in, 747
- methodological advancements for estimation, 754
- non-CO₂ contribution to warming, 751
- threshold exceedance estimates, 750
- Representative Concentration Pathway* (RCP) scenarios**
 - acronyms used with, 231
 - anthropogenic forced signal emergence, 1855
 - assessing future climate change, 229
 - assumptions used for emissions trajectories, 878
 - biodiversity hotspot projections, 1848
 - comparison with Shared Socio-economic Pathways, 618
 - emulator estimation of scenario differences, 619
 - extratropical storm projections with, 1593
 - for model simulations, 561
 - in projections using CORDEX-EA models, 1975
 - ocean particulate organic carbon flux projections, 729
 - ocean salinity projections, 1842
 - projections for climate changes in AR5, 184
 - relative sea level, coastal flood and coastal erosion signals, 1855
 - use in scenario-based projections, 555
- Representative Key Risks (RKR)**
 - categories of concern, 1857
 - hazards assessed by AR6 WGII, 1771
- Revelle Factor**, 744
- Reversibility (of transient climate response to cumulative CO₂ emissions)**, 747
- Risk assessment*/framework***. *See also* Climate risk and adaptation assessment (CRA)
 - AR6 framing and assessment of, 200
 - assessment of changes in climatic impact-drivers, 1857
 - climate information for regional use, 23
 - hazard versus risk use in AR6, 201
 - impacts, vulnerability and adaptation, 153
 - in communication to decision makers, 40
 - low-likelihood, high-impact outcomes in, 202
 - low-likelihood, high-warming storylines for, 635
 - methodological approach and rationale for, 1774–1777
 - relevance of signal emergence for, 1853
 - risk modelling and historical climate data for, 1773
 - Sendai Framework for Disaster Risk Reduction, 167
- River (fluvial) flood**
 - African changes, 1793
 - Asian changes, 1800
 - Australasian changes, 1808
 - calculation of index, 2210
 - Central and South American changes, 1815
 - European regional changes, 1822
 - extreme river flow trends, 1569
 - index of, 2210
 - infrastructure and agricultural impact of, 1783
 - North American changes, 141, 1830
 - projections for, 1518
 - regional projections for, 1853
 - Small Islands changes, 1837
 - spatial variability in changes, 1851
- Robustness/uncertainty***
 - analysing climate change signals &, 1953
 - climate change display in maps, 1948
 - display and quantification for models, 567
 - display in maps, 1945–1950
 - map representation of projections, 1949
 - multi-model ensembles for assessment, 561, 568
 - of regional anthropogenic signals, 1423
 - tropospheric temperature change, 599
- Rossby Centre Regional Climate Model (RCA4)**, 1993
- Rossby waves**
 - Arctic amplification effects on, 1380
 - extratropical influence of Madden–Julian Oscillation, 2179
 - large-scale, 2164
 - mechanism, 2158
 - tropical-extratropical teleconnections, 2164
 - Walker circulation alteration and, 2174
 - zonal temperature anomalies and, 2172
- Runoff*, streamflow and flooding**
 - Atlantic Multi-decadal Variability regional effects on, 2177
 - changes in, 1086
 - from glaciers, 1122
 - projections for, 1117
 - seasonal mean runoff projections, 1118
 - with increased warming, 1119
- Russian Arctic (RAR)**, 1971, 2016, 2022
- Russian Far East (RFE)**
 - climate features of, 1975
 - El Niño–Southern Oscillation influence, 1976
 - Pacific Decadal Variability influence, 1976
 - precipitation trends in, 1976
 - snow depth trends in, 1977
 - warming trends in (1976–2014), 1976, 1978

S

- Saharan Heat Low**, 1969
- Sahel (SAH)/Sahara and Sahel (SAH)**
 - anthropogenic influence on rainfall in, 1971
 - Atlantic Multi-decadal Variation effects on, 2177
 - Atlantic Zonal Mode effects on, 1968, 2171
 - attribution of drying in, 1969
 - droughts over, 2198
 - effects of South Atlantic sea surface temperature increase, 1971
 - greening of, 1150
 - monsoon drought and recovery, 1416–1418

- precipitation changes, 1417, 1971
- rainfall changes in, 1968
- rainfall projections for, 1971
- reference region, 208
- sub-region defined for Africa, 1967
- West African monsoon in, 2197
- Samalas eruption (1257)**, 593
- Sand and dust storms**
 - African regional projections, 1795
 - Asian regional changes, 1802
 - Australasian changes, 1810
 - hazards associated with, 1784
 - impact in deserts and semi-arid areas, 1849
 - North America changes, 1833
- Satellite Application Facility on Climate Monitoring (CM SAF)**, 938
- Satellite-based observations**
 - essential climate variables from, 1382
 - sea ice thickness estimation in, 1251
 - spatial allocation of emissions activity, 830
- Scenario-based climate projections (RCP/SSP)**
 - AR5 and AR6 use of, 227
 - Asian regional change, 1799
 - baseline and temporal scales for, 1935
 - carbon dioxide emissions levels and outcomes, 618
 - change under overshoot trajectories, 617
 - climate goals, overshoot, and path-dependence, 617
 - climatic impact projections for Asia, 1799–1806
 - extreme heat for North America, 1830
 - for Africa and subregions, 1793–1800
 - for modes of variability, 2155
 - for North Asia, 1978
 - for ocean salinity, 1842
 - greenhouse gas concentrations, 2140
 - Greenland Ice Sheet sea level contribution (by 2100), 1260
 - land and ocean transition from sink to source of carbon, 677
 - long-term increase Northern Annular Mode, 556
 - methodology used, 561
 - ocean acidification, 608
 - ocean heat uptake in scenarios, 1232
 - ocean sink change with medium emissions, 676
 - overview and scope of, 227, 929
 - probabilistic statements of outcomes, 559
 - projection analysis across scenarios, 1935
 - projections for Southern Annular Mode, 609
 - regional solar radiation projections, 1791
 - Representative Concentration Pathways use in, 184
 - ScenarioMIP simulations in, 562, 2101
 - sea surface temperature changes, 1223
 - South and South East Asian monsoon, 1127
 - Southern Annular Mode change projections, 556
 - temperature projections for Australasia, 1989
 - translating regional information for end users, 1542–1544
 - uncertainty in, 196
 - use for climate projections, 562
 - warming in the Arctic, 596
- Science–society linking**
 - climate change understanding, communication and uncertainties, 168
 - communication of climate information, 171
 - constructing regional climate information, 1427–1434
 - context for use in decision-making, 172
 - information, co-production, and climate services, 172
- Scientific evidence**
 - identifying natural and human driver, 178–180
 - instrumental observations, 174–177
 - paleoclimate, 177–178
 - understanding and attributing climate change, 181–182
- Sea ice area* (SIA)**
 - additional warming effects on Arctic, 16
 - Arctic and Antarctic seasonal evolution (1979–2017), 469
 - Arctic Ocean and Antarctic changes, 1215
 - Arctic Ocean projections, 557
 - Arctic sea ice coverage, 1247, 1843
 - changes in Arctic and Antarctic, 143
 - changes in polar regions, 1845, 1847
 - glacier retreat since 1950s, 8
 - human influence driving decrease in, 5
 - human influence on, 466
 - model differences for loss, 467
 - North Atlantic Oscillation coupling assessment, 2158
 - regional seasonal changes in, 1247–1250
 - seasonal change in, 1250
 - signal emergence in Arctic and Antarctic, 1855
 - thinning signal for, 1251
- Sea level budget, components of, 1287–1288.**
See also **Global mean sea level* (GMSL)**
- Sea level change***
 - anthropogenic forcing of, 481
 - at specific warming levels, 1217
 - basin scale rise (1993–2018), 1216
 - change due to thermal expansion, 482
 - CMIP6 projections for contributions to, 1246
 - costal sea level effects of wind, 1221
 - drivers of projected changes, 1297
 - dynamic changes in, 1221
 - emergence and attribution of regional change, 1290–1292
 - emergence of near-coast relative sea level rise, 1855
 - estimates during interglacial periods, 160
 - extreme sea level event projections, 188
 - frozen freshwater reservoir contribution to, 1220
 - global mean thermosteric rise, 1298
 - Greenland contribution to, 1260
 - high-end storyline of 21st century, 1308
 - historical emissions and commitment, 1305
 - identification of drivers for high-end rise, 1309
 - in estimated total water level index, 2211
 - metric for the equilibrium sea level response, 1306
 - model evaluation, 481
 - multi-century and multi-millennial projections, 1305
 - paleoclimate proxy reconstructions of, 1292–1296
 - paleo context of global and regional changes, 865
 - paleo records of change, 1292–1296
 - processes driving change, 1220–1222
 - projections for future changes, 1295–1303
 - projections for glacier contribution (RCP/SSP), 1279
 - projections for thermosteric contributions, 1245
 - regional anthropogenic signal emergence, 1216
 - regional change effects, 1216
 - regional change in satellite era, 1289–1290
 - sea level projections with emissions levels, 1305
 - signal emergence for regional change, 1291
 - sources of uncertainty in budget for, 1314
 - steric and dynamic changes, 1244
 - thermosteric rise and emissions levels, 1232
 - vertical land movement in local variability, 1290
- Sea level pressure (SLP)**
 - global climate change projections, 603
 - in description of climate variability, 2155
 - in North Atlantic Oscillation definition and estimate of, 2158
 - long-term change of seasonal mean, 604
 - seesaw variations in, 2156
- Sea-salt–climate feedback, uncertainty in, 858**
- Seasonal change**
 - atmospheric CO₂ cycles, 427
 - attribution of trends in annular forcing, 492
 - boreal summertime Atlantic Meridional Mode, 2170
 - boreal summertime Atlantic Zonal Mode, 2169
 - boreal wintertime El Niño–Southern Oscillation mode, 2163
 - climatic impact-driver evolution with warming, 1775–1777
 - contrast between wet and dry with warming, 1114
 - flooding changes in, 1568
 - freeze–thaw cycles, 1782
 - in Arctic sea ice cover, 1248
 - in El Niño–Southern Oscillation, 497
 - in Madden–Julian Oscillation, 2177, 2179
 - in ocean stratification, 1226
 - in partial pressure of CO₂, 775
 - in warming patterns, 597
 - North Atlantic Oscillation/North Annular Mode teleconnections, 2158
 - Northern Annular Mode projections for, 556
 - of Atlantic Multi-decadal Variability teleconnections, 2176
 - of East Asian monsoon, 2197
 - of Indian Ocean Basin/Indian Ocean Dipole modes, 2167
 - of North Atlantic Oscillation variability, 2156
 - precipitation mean change from models, 601
 - projections by CMIP simulations, 584
 - snow cover extent, 1283–1285
 - South and South East Asian monsoon, 2196
 - West African monsoon precipitation changes, 1130
- Sea surface salinity (SSS), indirect radiative feedbacks to atmosphere, 478**
- Sea surface temperature* (SST)**
 - and mean ocean temperature evaluation, 473–475

- and near-surface salinity, multi-model biases, 474
- anomalies over tropical North and South Atlantic, 2168
- anomalies with El Niño–Southern Oscillation, 2162
- change in gradients with warming, 988
- change in Pacific ocean (1870 to recent times), 988
- changes with 2°C warming, 143
- changes with El Niño–Southern Oscillation, 589
- changes with time, 1222
- effects of CO₂ forcing on Pacific gradients, 989
- emissions scenario projections for, 1223
- evaluations for tropical oceans, 476
- exceedance of hazard thresholds, 1843
- future spatial pattern of change in, 1223
- gradient change (since 1870), 460
- in Atlantic Multi-decadal Variability interpretation, 2176
- increase in (2011–2020), 1841
- increase since beginning of 20th century, 1221
- in description of climate variability, 2155
- interhemispheric gradient of, 375
- long-term trends of ocean heat content and, 1233
- Madden–Julian Oscillation sensitivity to, 1105
- marine proxy data for, 315
- meridional gradient in, 1967
- mid-Pliocene Warm Period estimates, 315
- migration of Inter-tropical Convergence Zone, 2171
- processes determining tropical Pacific gradients, 988–989
- proxy-based reconstructions of equilibrium patterns, 1223
- regional changes in, 134
- regional warming projections (by 2050), 1223
- revised gradient estimate since AR5, 989
- simulated and observed trends in, 473
- spatial pattern changes (since 1870), 990
- top-of-atmosphere radiative fluxes and, 991
- tripole index locations, 2172
- tropical Atlantic Ocean model biases, 476
- tropical Pacific gradients, 987
- tropical Pacific Ocean evaluation, 476
- variations in tropical Indian Ocean, 2167
- with marine heatwaves (1982–2016), 1227
- Sea-to-air fluxes, N₂O and CH₄ enhancement with deoxygenation, 721**
- Secondary organic aerosols (SOA). *See also* Aerosols***
 - evaluating formation of, 833
 - formation of, 825, 847, 859
 - in marine aerosol composition, 832
 - temperature effects on, 863
 - uncertainty in simulation of production rates, 848
- Second Assessment Report (1995), human influence on global climate, 425**
- Semi-empirical projections (for sea level), 576**
- Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR), 167, 1773**
- Sequestration* (of carbon dioxide), 762**
- Sesquiterpene emissions, 831**
- Severe convective storms**
 - detection and attribution, 1596
 - mechanisms and drivers, 1594–1595
 - model evaluation, 1595
 - observed trends, 1595–1596
 - societal impacts of, 1583
- Severe wind storms**
 - African regional changes, 1795
 - Asian regional changes, 1801
 - Australasian changes, 1810
 - Central and South American changes, 1817
 - European changes, 1824
 - North American changes, 1832
 - Small Island changes, 1839
- SGMIP coordinated effort for regional climate modelling, 1390**
- Shared Socio-economic Pathway* (SSP) scenarios**
 - abrupt human-caused water cycle changes, 1059
 - acronyms used with, 231
 - air pollution levels and precursor emissions trajectories, 883
 - air quality projections, 820
 - anthropogenic and natural effective radiative forcing, 2147–2148
 - Arctic Ocean sea ice changes in, 1215
 - Arctic sea ice projections, 1843
 - Arctic surface warming projections, 596
 - assumptions on pollution control policies for, 879
 - Atlantic Meridional Overturning Circulation projections, 745, 1214
 - carbon cycle responses over time with CO₂ removal, 759
 - categorization and use of, 230
 - changes in short-lived climate forcers on climate response, 884–885
 - climate response to short-lived climate forcers in, 878
 - committed ocean warming with, 21
 - comparison of paleo temperatures and projected (2080–2100), 294
 - comparison of RCPs and SSPs, 52, 235
 - core scenarios, 228, 230, 233
 - core scenarios and storylines, 232
 - coupled climate–carbon cycle projections, 733
 - emissions-driven simulations, 561
 - extension to 2300, 631
 - for information integration, 227
 - future abundances of forcers, 2144
 - future global climate projections, 553–672
 - future trajectories of ocean CO₂ sink, 677
 - generation process, 236
 - glacial mass loss variations between scenarios, 1279
 - glacier mass loss in, 1215
 - global carbonaceous aerosol projections, 881
 - global land monsoon precipitation index projections, 586
 - global mean and relative sea levels, 1301
 - global mean sea level projections for, 21, 576, 1296, 1302–1305
 - global surface temperature projections, 43, 228
 - global surface temperature beyond 2300, 632
 - global warming levels, regional climate response and impacts, 1543
 - greenhouse gas levels in, 30–31
 - heat thresholds and mitigation, 1830
 - high-warming storylines for high emissions, 637
 - historical and projected concentrations of CO₂, CH₄ and N₂O and temperatures, 229
 - history of scenarios within IPCC, 237
 - hydrofluorocarbon projections for, 882
 - ice-sheet mass loss projections, 1215
 - idealized scenario experiments, 230
 - integration across Working Groups, 151
 - integration in scientific communities and across time scales, 230
 - key climate forcer datasets used, 234
 - long-term extensions and overshoot, 741
 - maps of net carbon changes under scenarios, 734
 - marine heatwave projections for, 1227
 - mean sea level pressure projections, 603
 - near-surface air temperature projections, 595
 - near-term warming effects of short-lived climate forcers, 820
 - numeric designations of, 555
 - observed, simulated and projected key indicator changes (1995–2014), 66
 - ocean heat content projections for, 1232
 - precipitation change at 2°C global warming level, 1544
 - projections beyond 2100, 558
 - projection scenarios for Asian regions, 1969
 - projections for changes with CMIP5 and CMIP6, 576
 - projections for short-lived climate forcers, 879
 - quantification of urbanization for, 878
 - RCP and SSP comparison of fossil fuel and industrial CO₂ emissions, 237
 - RCP and SSP run with single emulator, 619
 - RCP comparison, 572, 618
 - regional annual mean surface ozone projections (2015–2100), 883
 - ‘regional rivalry’ storyline in, 889
 - regional sea level change for 2100, 1303
 - regional surface ozone and particulate matter projections, 882
 - results and evidence presentation for, 562
 - scenario generation process, 236
 - scenarios used for AR6, 12–14
 - sea level projections based on warming levels, 1304
 - sea level projections for, 1302
 - short-lived climate forcer mitigation effects, 591, 888–892
 - short-lived climate forcer projections, 825
 - short-lived climate forcer ranges in, 820
 - short-lived climate forcers and hydrofluorocarbons effects on warming, 889
 - simulated climate changes to 2300, 632

- simultaneous changes in CH₄, aerosol, and ozone precursors, 30
- South Asia projections, 1981
- temperature effects of regional emissions of short-lived climate forcers, 887
- time evolution of short-lived climate forcers and hydrofluorocarbons, 886
- time series for all climate forcers for SSP1-1.9, 2145
- uncertainty of emissions representation in, 566
- used in WGI, 232
- use with models, 224
- warming levels and patterns of change with, 56
- warming with stringent mitigation policy, 821
- zonal wind and westerly jet projections, 604
- Shoreline progradation**, 135, 139, 142
- Shoreline retreat**, 139, 141, 1853. *See also Coastal erosion*
- Short-lived climate forcers* (SLCFs)**
- air pollution control for reduction of, 864
- air quality responses in Shared Socio-economic Pathways, 103
- anthropogenic and natural sources of, 825
- anthropogenic regional and sectoral contributions to, 829
- aviation emissions of, 866
- biofuel and fossil fuel contributions, 866
- chapter roadmap for, 826
- climate evolution in response to emissions of, 884
- climate response to, 591–592, 851, 855
- consequences for air quality and climate system, 893
- contrails and cirrus cloud formation, 866
- contribution to warming, 751
- current yearly emissions compared to CO₂ emissions, 821
- direct and indirect forcing by, 823
- effective radiative effects of ozone, 311
- effect on global warming in future, 42
- effects compared to CO₂, 101
- effects of future changes in, 821
- effects of strong abatement for emissions, 881
- effects on effective radiative forcing, 855
- effects on global surface temperature and air pollution, 104
- emissions changes (1750–2019), 819
- emissions and abundances projections, 878
- emissions by natural systems, 830
- emissions from wildfires, 859
- evolution and abundances of emissions, 819
- evolution of effects on air temperature in scenarios, 886
- extension of effects on radiative forcing in AR6, 41
- global and regional temporal evolution of emissions, 827
- global anthropogenic and biomass burning emission (1850–2100), 879
- global climate system effects of, 592
- heterogenous forcing effects of, 865
- ice-core analyses of, 892
- importance for climate and air quality, 823
- indirect radiative forcing by, 857
- induced warming rate scenario, 820
- influence on projected global surface air temperature change, 591
- laboratory studies, observations and climate models for, 834
- mechanism of climate effects, 825
- methane and ammonia from agriculture, 866
- mitigation effects of signal emergence, 591
- mitigation strategies and opportunities, 873
- models for projections, 827
- near-term effects on global air surface temperature, 887
- near-term warming from, 820
- non-methane volatile organic compounds, 828
- of short-lived climate forcers burden and distribution, 833
- overview of characteristics of, 824
- previous assessments of, 825
- process level studies and global chemistry–climate models, 833
- projections and climate response in SSPs, 878
- projections for air pollution management, 820
- projections for effects on global surface air temperature, 820
- projections of future abundances of, 882
- pulse emission decay rate of, 821
- radiative forcing and climate effects, 825
- reduction policies and mitigation opportunities, 871
- reductions of methane and black carbon for mitigation, 825
- reduction to curb climate change, 864
- regional anthropogenic and biomass burning emissions (1850–2100), 880
- regional contribution to temperature change, 887
- regional emissions effects on temperature, 887
- regional scale of effects, 824
- residential and commercial cooking, heating, 866
- scenario experiments with, 591, 825
- sea level commitment association, 1245
- sources and processes for atmospheric burden, 823
- sources, lifetime and contribution to warming (1750–2019), 894
- sources on land, 825
- spatial and temporal emission patterns of, 829
- surface temperature response to change in, 865
- targeted reduction policies for, 864
- temperature effects in scenarios (2019–2040), 885
- temperature response to high emissions, 821
- time course of mitigation efforts, 865
- values in chemistry–climate models, 834
- warming and cooling gases and aerosols, 893
- warming effects by scenario, 889
- warming in core SSSP scenarios, 892
- Short-lived climate pollutants* (SLCPs)**, 864. *See also Short-lived climate forcers (SLCFs)*
- Short-lived halogenated species, sources of**, 843
- Shortwave (SW) radiation***
- mineral dust interactions with, 858
- regional projections for, 1791
- short-lived climate forcers effect on, 852
- solar radiation modification effects on, 860
- tropospheric aerosols influence on, 857
- Signal-to-noise ratio (S/N)**
- detection and attribution of regional sea level change, 1290
- in signal emergence, 1853
- methods for improving, 429
- Simple climate model* (SCM)**, 219, 965
- Single-model initial-condition large ensembles (SMILEs)**
- anthropogenic signal delay, 1367
- ensemble size for robust use of, 1409
- internal variability and lack/late anthropogenic signal emergence, 1427
- investigation of uncertainty with, 222
- realistic representation of internal variability, 1409
- regional-scale forced response to external forcing, 1409
- separation of model uncertainty and internal variability in projections, 1367, 1410
- south-eastern South America summer wetting attribution, 1420
- Sixth Assessment Report (AR6)**
- 20-year baseline (1995–2014), 1935
- abrupt changes and tipping point assessment, 741
- advances since AR5 and SROCC, 691
- AR5 and AR6 report chapter relations, 155
- AR6 Working Group I (WGI), 153
- assessment of recent warming, 41
- baselines, reference periods and anomalies, 189–191
- baseline use for (1995–2014), 191
- boron isotope and ice core agreement, 299
- calculation of contrail cirrus forcing in, 867
- climate regions used in, 206–208
- climate risk framework in, 151
- climate services advances, 172
- constraining variability of carbon sources and sinks, 680
- context of WGI assessment, 156
- contributions to, 4
- core concepts of, 39
- data, tools and methods used, 151
- defining Reference Sets of Land Regions, 208
- Earth's energy budget closure in, 937
- emissions metrics in, 220
- estimates of gross and net fluxes, 688
- foundations and concepts for WGI, 189
- future changes assessed in AR6, 12
- global warming levels for dimension of integration, 1304
- improved complex climate models, 151
- information on the input data used, 154
- integration with Working Groups II and III, 156
- Interactive atlas (WGI), 1934
- key findings on water cycle, 1063
- land and open ocean reference regions for AR6 WGI, 1938
- major developments since AR5, 208

- modes of variability assessed in, 2156–2192
 net zero emissions definitions in, 242
 new coordinated model results, 428
 new results/updates since AR5, 41–43
 new techniques for attribution, 151
 observational products used in, 2062
 policy and governance context, 161
 quantification of energy in Earth system, 925
 rationale for structure and relation to AR5 WGI report, 154
 reanalysis as lines of evidence, 151
 regional climate information in, 1375
 regional information emphasis in, 172
 regional monsoon definition, 2195
 revision of ocean heat content change, 937
 scientific evidence for climate change, 150
 separation between forcing and feedbacks, 944
 special reports in cycle, 40
 SSPs and CMIP6 simulations in, 562
 structure of, 153
 themes in AR6 WGI, 154
 uncertainty/robustness display in maps, 1947
 use of emulators in, 963
 water cycle effects on water availability, 1064
 WGI finding and relevance for global stocktake, 163
 Working Groups and report from, 153
- Skill assessment of models.** *See* **Climate modelling techniques**
- Sliding law, model variations due to, 1269**
- Small Islands**
 agricultural and ecological droughts, 1838
 AR5 findings for, 2009, 2013
 Atlas, 2009
 climate hazards and consequences, 2009
 climatic impact-driver changes (2°C warming), 142
 climatic impact-driver projections, 1840
 climatic impact-drivers affecting, 1836
 coastal and oceanic hazards, 1841
 coastal and oceanic impact-driver projections, 1839
 cryosphere changes in, 1932
 difficulty in assessing climate change in, 2010
 global mean sea level projections for, 2009
 heat and cold changes for, 142, 1837
 heat stress projections for, 1837
 heavy precipitation changes, 1560, 1838
 model performance assessment, 2010
 observations, trends and attribution, 2009, 2012, 2013–2015, 2015
 observed trends for, 2014
 precipitation projections for (2081–2100), 2012
 previous IPCC assessments, 2009
 projection assessment and synthesis, 2011
 rainfall and sea level projections for, 2015
 regional climate features, 2009
 regional context of, 2013
 regional rainfall and drying trends, 142
 scenario-based projections, 2013
 summary of changes, 127, 142, 2012
 temperature, precipitation and sea level changes, 2011
- temperature projections for, 2011
 warming changes for, 19, 142, 1839, 1932, 2012
 water resources for, 2012
 water stress in, 1838
 wet and dry conditions in, 1837
 wind projections for, 142
- Snow and ice**
 African climatic impact-driver changes, 1795
 Asian climatic impact-driver changes, 1802–1804, 1976
 Australasian climatic impact-driver changes, 1810, 1987, 1990
 Central and South American changes, 1817
 climatic impact-drivers and indices for, 1784–1785
 effects of light-absorbing particles on, 956
 emergence of change signal, 1855
 European climatic impact-driver changes, 1825
 lake, river and sea ice ecosystem effects of, 1785
 local hydrological processes related to, 1071
 low elevation projections, 1850
 North American climatic impact-driver changes, 1833
 polar region changes (2°C warming), 142
 polar terrestrial changes, 1845
 regional changes in climatic impact-drivers, 134
 seasonal change in snowmelt and runoff, 1071
 snow season length, 2211
 societal impact and risks with, 1784
- Snow avalanche**
 Asian changes, 1802
 European changes, 1825
 North American changes, 1834
 polar terrestrial changes, 1844
 transportation and tourism impacts, 1785
- Snow cover extent* (SCE)**
 changes in, 1122
 changes with warming, 1216
 CMIP5, CMIP6 and observations, 470
 CMIP6 simulated and observed, 1286
 correlation between mean surface temperature and, 470
 Eurasian seasonal changes, 1802
 European changes, 1825
 global projections for, 1852
 in Northern Hemisphere and Southern Hemisphere, 1283
 model evaluation of seasonal snow, 1285
 North American changes, 1833
 North America projections for, 2008
 observed changes of seasonal snow cover, 1283
 observed Northern Hemisphere trends and anomalies, 1285
 projections for amount and seasonal duration, 1123
 projections for changes in, 1287
 regional projections for, 1853
 variables in terrestrial snow cover, 1283
 warming effects on, 16
- Snowfall/snowmelt**
 Australasian changes for, 1810
 indices used to track changes, 1785
- projections for precipitation falling as snow, 2008
 projections in snow-dominated regions, 1119
 snow water equivalent for defining snow season, 2211
- Snow, glacier and ice-sheet indices, 1785**
- Snow season length (SWE100), 2211**
- Snow water equivalent* (SWE)**
 continental-scale trends (1980–2018), 1285
 importance of greenhouse gases in change of, 2005
 in defining snow season length, 2211
 mountainous regions, 1285
 North American projections for, 2008
 regional climate model simulation, 2006
 seasonal changes in, 1283
 trends in mountain areas, 1284
- Social media platforms, 173**
- Societal and environmental impacts**
 heat and cold events, 1780–1783
 in framing climate science information, 172
 interaction of scientific information with values, 151
 of climate change, 1773
- Soil**
 biochar effects on soil carbon, 763
 carbon recovery and prevention of loss, 763
 carbon response to climate change, 725
 methane uptake and lifetime assessment, 835
 nitrogen oxides emissions from, 830
 soil NOx emissions, 830, 863
- Soil Moisture Active Passive (SMAP) satellite retrievals, 209, 1234**
- Soil Moisture and Ocean Salinity (SMOS), 209, 1234**
- Soil Moisture Ocean Salinity Earth Explorer (SMOS) mission, 1382**
- Soil moisture* (SM)**
 and vapour pressure deficit changes, 1120
 changes in Africa, 1794
 changes in annual mean, 17
 deficit projections for, 1581
 deficits, 1571
 detection and attribution of deficits, 1578
 during Last Glacial Maximum, 450
 evapotranspiration effects on, 1571
 increased evapotranspiration effects on, 1058
 index computation for, 2211
 observational studies on deficits, 1573
 plant water stress and, 1571
 uncertainty in projections for topsoil layer, 1119
- Soil nitrogen oxides (SNOx) emissions, 830**
- Solar and orbital forcing**
 changes in, 296
 CMIP6 trends (1998–2012), 425
 of North Atlantic Oscillation, 2158
 solar cycle effects on atmospheric circulation, 1373
- Solar radiation**
 changes under cloud-free conditions, 938
 decadal trends for surface, 938
 dimming and brightening (1950s–1980s), 925, 938

- dimming and brightening with aerosol changes, 1791
insolation cycle relation to monsoons, 2195
variation from Earth's orbit, 297
- Solar Radiation and Climate Experiment (SORCE)**, 935
- Solar radiation modification* (SRM)**
abrupt water cycle responses to, 1059, 1151
approaches to, 624
AR5 assessed the climate response to, 624
biogeochemical responses to, 767
carbon cycle effects of, 768
carbon dioxide removal implications for, 678
cirrus cloud thinning for, 628
climate response to, 619, 629
consequences and termination effects, 768
defined, 755
Earth system response to, 104–105
effective radiative forcing by aerosols in, 860
effects on anthropogenic warming, 557
effects on land and ocean sinks, 679
equatorial sulphate injection modelling studies, 627
feasibility assessments for, 770
impact for climate mitigation, 681
large-scale consequences of, 676
marine cloud brightening, 628
stratospheric aerosol injections for, 627, 860
surface-based albedo modification, 629
techniques for, 624
- South America**
annual mean temperature projections, 1997
AR5 precipitation and temperature trends in, 1995
assessment and synthesis of projections, 1997
Atlantic and Pacific basins effect on, 2171
barrier to study of climate change in, 1996
carbon monoxide from biomass burning, 841
changes in climatic impact-drivers, 1812, 1814
climate extremes projections, 1994
climatic impact-driver changes (2°C warming), 140
continued relative sea level rise, 1820
drought duration projections, 1119
drought trends and projected changes by warming levels, 1675
extreme events projections for, 1996
extreme precipitation changes, 1559, 1565
glacier loss projections for, 1818
global runoff projections for, 1119
global warming projections, 1997
greenhouse gas emissions (tropical), 713
heatwave projections for, 1994
hot and cold extremes projections, 1556
influence of Pacific Decadal Variability in, 1994
model performance assessment, 1996
observations, trends, and attribution synthesis, 1995
observed hot extremes in, 1549
Pacific Decadal Variability effects in, 2174
precipitation projections for, 1993, 1994
reference regions for, 1994
regional climate features and drivers for, 1994
regional climate model simulations for, 1996
regional extreme heat conditions, 1437
regional precipitation and drought projections, 140
regional precipitation projections for, 1997
regional surface air temperature and precipitation, 1992
seasonal change projections for, 1997
summary, 1997
temperature extreme trends and projected changes by warming levels, 1665
temperature extreme trends in, 1995
temperature projections for, 613, 1991, 1994, 1997
- South American monsoon* (SAmerM)**
changes in, 1099
climatic features and drivers, 1994
Inter-tropical Convergence Zone migration effects on, 1994
precipitation changes for, 1130
projections for, 1997
regional circulation system characteristics, 2198
regional rate of warming in, 15
- South and South East Asian monsoon* (SAsiaM)**, *See also* **Indian summer monsoon**
characteristics of, 2196
climatological onset of, 2196
regional climate model for monsoon and hydrological processes, 1980
scenario-based precipitation projections, 1127
- South Asia (SAS)**
aerosol effective radiative forcing, 852
aerosol observations for, 310
aerosol optical depth over, 290
air pollution in, 869
assessment and synthesis of projections, 1980
changes with 2°C global warming, 138
climate changes in, 1981
glacier mass balance loss/retreat trends in, 1979
greenhouse gas emissions for, 713
heat stress thresholds in, 1799
key regional climate features, 1978
model performance assessment, 1979
observations, trends and attribution, 1979
particulate matter emission sources in, 821
precipitation projections, 1978, 1980
precipitation trends in, 1978, 1980
previous IPCC findings for, 1978
river flow projections, 1981
short-lived climate forcings distribution, 819
snow cover extent trends in (1960–2010), 1979
snowfall/snowmelt projections for, 1979
sulphur dioxide emissions in, 845
summer monsoon precipitation projections, 1981
surface ozone and particulate matter projections, 882
surface ozone sources in, 869
temperature changes in, 1978
tropospheric NO₂ level growth, 839
warming level projections, 1981
- South Atlantic Convergence Zone (SACZ) formation**, 2199
- South Atlantic Ocean (SAO), salinity projections for**, 1842
- South Atlantic Subtropical Dipole mode, El Niño–Southern Oscillation influence on**, 2164
- Southern Central America (SCA)**. *See also* **Central America**
climatic features of, 1991
midsummer drought projections for, 1994
precipitation projections for, 1991
projections for drying in, 1993
temperature projections for, 1993
- South East Asia (SEA)**
assessment of observations, trends and attribution, 1981
assessment of temperature and precipitation projections, 1982
biomass burning emissions in, 869
carbon monoxide from biomass burning, 841
changes with 2°C global warming, 138
climate model evaluation, 1983
El Niño–Southern Oscillation climatic effects, 1981
El Niño–Southern Oscillation influence on temperature, 1981
findings from previous IPCC assessments, 1981
greenhouse gas emissions for, 713
Indian Ocean Basin/Indian Ocean Dipole effects in, 1981
mean and extreme temperature projections for, 1981
natural sources of surface ozone in, 869
Pacific Decadal Variability effects on, 2174
precipitation projections for, 1983
regional climate features, 1981
regional climate model precipitation projections, 1983
subsidence projections for, 1983
summary of trends and projections, 1983
surface ozone and particulate matter projections, 882
warming trends in, 1982
- South Eastern Africa (SEAF)**
key climatic features, 1967
rainfall change projections, 1971
shoreline progradation, 135
tropical cyclone projections for, 1795
- South-Eastern South America (SES)**
annual rainfall change in, 1996
attribution example, 1418, 1418–1420
climatic features and drivers, 1995
mean precipitation trend and drivers (1951–2014), 1419
stratospheric ozone depletion attribution, 1420
- Southern Africa**
greenhouse gas emissions for, 713
Indian Ocean warming effects, 1971
rainfall changes in, 1969
rainfall projections for, 1971
temperature changes in, 1968
warming projections for, 1969, 1971
wind projections for, 135
- Southern Annular Mode* (SAM)**

- Antarctic Oscillation, 2159
 austral summertime, 2160
 barotropic structure of and quantification of, 2159
 changes with volcanic activity, 594
 climate projections for, 609
 climate variability and, 2156
 definition of, 2159
 drivers of, 2161
 effects in New Zealand and Southern Australia, 1986
 empirical orthogonal function-based index of, 2161
 forced changes in, 556
 historical and projections for Cape Town rainfall, 1440
 historical station-based reconstructions, 371
 human influence on trend (2000–2019), 427
 indices in the last millennium, 494
 influence in southern extratropics, 579
 influence on South American climate, 1994
 influence on Southern Hemisphere extratropics, 2161
 near-term projections for, 1135
 ozone hole effects on, 588
 proxy-based reconstruction of influence, 2161
 RCP and SSP projections for, 588
 reconstruction over the last millennium, 371
 strengthening trend in (1970–1990), 1105, 1373
 strengthening trend since 1980s, 464
 systematic changes in, 292
 teleconnection links to Asian precipitation, 2161
 trends during instrumental period, 370
- Southern Asia.** *See* **South Asia**
- Southern Australia (SAU), climatic features of,** 1986
- Southern Hemisphere Mode Waters,** 1231
- Southern Hemisphere (SH)**
 aerosol optical depth over, 290
 blocking regions in, 464
 dichloromethane concentrations in, 843
 extratropical cyclone projections for, 607
 extratropical influence of Southern Annular Mode, 2161
 extratropical jet changes, 427
 Hadley Cell poleward expansion, 426
 human influence on austral summer, 464
 large-scale atmospheric circulation variability, 2159
 methane concentration (past 110 kyr), 301
 mid-latitude jet projections, 556
 model placement of storm tracks, 464
 observed rainfall changes in extratropics, 456
 pattern of warming over, 613
 stationary wave association with ozone depletion, 1101
 storm tracks and precipitation shifts, 1058
 storm track shift and intensification in, 19
 storm track shifts in, 1133
 subtropical mode waters change in, 1235
 westerly wind jet strength changes, 1240
- Southern Ocean (SOO)**
 Antarctic ice-shelf cavity changes, 1214
 anthropogenic CO₂ sink, 729
 anthropogenic forcing of warming, 1229
 atmospheric forcing of, 1240
 circulation influence on the global climate, 1239
 connections between ocean basins, 485
 deep ocean warming in, 1228, 1230
 heat uptake in (1870–1995), 1229
 marine heatwave frequency projections, 1227
 meltwater from Antarctic Ice Shelf in, 1240
 partial pressure of CO₂ trends in, 489
 projections for freshening, 1844
 temperature changes in, 1222
 uncertainty in modelling circulation, 485
 upper overturning cell change (since 1990s), 427
 uptake of anthropogenic CO₂ and heat, 745
 warming projections for, 1224
 zonal increase in wind stress, 1225
- Southern South America (SSA), climatic features and drivers,** 1995
- South Pacific Decadal Oscillation (SPDO), drivers of,** 2172
- South Pacific Ocean (SPO), subtropical gyre changes,** 1241
- South Pole Observatory (SPO), atmospheric CO₂ measurements from,** 689
- South West Asia**
 assessment and synthesis of projections, 1985
 changes with 2°C warming, 138
 findings from previous IPCC assessments, 1983
 model performance assessment, 1985
 observations, trends and attribution, 1984
 permafrost degradation in, 139
 regional climate and sub-regions, 1983
- South-Western North America drought (case study),** 1420–1422
- South-Western South America (SWS),** 1577, 1995
- Spatial patterns of surface warming,** 565, 989
- Special Report on Climate Change and Land (SRCLL)**
 anthropogenic contribution to, 188
 aridification of climate in East Asia, 1976
 changes for water cycle, 1062–1064
 global vegetation photosynthetic activity change, 485
 in assessment cycle, 187
 land temperatures increases, 596
 land use assessment, 1374
 land-use change in China (1871–2007), 1973
 regional and global climate links in, 1378
 short-lived climate forcers on land, 825
 source of greenhouse gases, 866
 wildfire changes, 724
- Special Report on Emissions Scenarios (SRES), scenarios used,** 237
- Special Report on Global Warming of 1.5°C (SR1.5)**
 changes in global monsoons with warming, 615
 emission pathways to limit warming, 189
 framing for climate policy relevance, 172
 global and regional climate links, 1378
 global warming levels above 1850–1900, 1936
 methane and sulphur dioxide emissions and limiting warming, 825
 permafrost importance in remaining carbon budget, 747
 projected years to reach 1.5°C, 188
 range for human-induced warming rate, 443
 reductions in methane emissions for mitigation, 825
 remaining carbon budgets compatible warming goals, 189
 Sixth Assessment Cycle reports, 153
 to achieve Paris Agreement goals, 864
 warming attributed to human influence, 442
- Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)**
 anthropogenic influences on temperatures, 1552
 assessment of extreme changes and adaptation for, 1521
 confidence for changes on global scale, 1568
 confidence in long-term trends in tropical cyclones, 1583
 extreme temperatures, 1546
 first definition of compound events, 1598
 heavy precipitation assessment in, 1557
 heavy precipitation events over land, 1557
 low-likelihood, high-impact changes in extremes, 1534
 projections of increased drought severity in some regions, 1579
 subcontinental regions for projections of change, 1936
 trends in number of warm and cold days, 1548
- Special Report on Oceans and Cryosphere in a Changing Climate (SROCC)**
 Antarctic Bottom Water volume changes, 1235
 Antarctic sea ice coverage, 1251–1253
 anthropogenic effects on Antarctic Ice Sheet, 472
 anthropogenic forcing in mean sea level rise, 481
 Arctic sea ice thinning estimates, 1251
 Atlantic Meridional Overturning Circulation changes, 1237, 1238
 black carbon deposition on snow melt, 825
 carbonate chemistry changes seawater, 716
 change in ocean acidification, 681
 changes and impacts of, 1786
 changes for water cycle changes, 1062–1064
 climate change in mountains, 1849
 climatic impact-driver changes for Arctic coastal settlement, 1849
 compound events and multiple hazards, 1314
 deep ocean layer warming, 1228
 driver of short-term change for Greenland Ice Sheet, 1256
 Earth system components susceptible to tipping/ abrupt change, 634
 extent, frequency and duration of marine heatwaves, 1227
 global acidification in response to CO₂ uptake, 716
 global and regional climate links in, 1378
 global ocean pH emergence, 1855
 local storm surge processes in extreme sea level trends, 1310
 mean sea level trends and projections, 2013

- modelling of Greenland Ice Sheet, 1258–1259
 observations on air–sea fluxes, 1224
 ocean density stratification change rate, 1225
 ocean deoxygenation, 714
 ocean deoxygenation projections, 677
 ocean heat content reconstructions, 1288
 ocean oxygen minimum zone expansion, 488
 ocean warming pattern, 1231
 primary driver of glacier recession, 472
 projections for effects of warming, 188
 projections for loss of permafrost carbon, 728
 projections for precipitation changes, 1973
 regional dissolved oxygen loss in upper ocean, 717
 sea surface temperature trends in recent decades, 1223
 snow cover and glacier extent changes, 1998
 snow cover and glacier retreat in Australasia (1983–2008), 1987
 stratification change in ocean, 478
 terrestrial carbon cycle changes, 428
 thinning of West Antarctic Ice Sheet outlet glaciers, 1264
 time course of warming of deep ocean, 1233
 treatment of situations with deep uncertainty, 202
 trends and projections for oceans, 2009
 under-observed methane fluxes, 726
 upper ocean stratification trend in 21st century, 1226
- Special Sensor Microwave/Imagers (SSM/I)**, 451, 1597
- Specific humidity* (WV)**
 change in levels (1973–2019), 330
 feedback, 969
 near surface changes over land and oceans, 291
 observed changes in, 330
- Spectral solar irradiance (SSI)**, 297
- Stability iris effect**, 972
- Standardized Precipitation Evapotranspiration Index (SPEI)**, 1572, 1851
- Standardized Precipitation Index (SPI)**, 1572, 2211
- Standard optimal fingerprinting methods**, 1415
- STAR dataset**, 327
- Stationary waves**
 amplitude changes, 1100
 defined, 1100
 possible influence on water cycle, 1132
 seasonal and shorter-term anomalies with, 1100
- Station-based North Atlantic Oscillation index**, 2158
- Statistical downscaling, using bias adjustment for**, 1411
- Steric sea level change**, 1220, 1244–1247, 1246.
See also **Thermosteric* change (in ocean)**
- Stochastic physics approach for internal variability**, 562
- Storm surges***, 1310, 2211
- Storm tracks* and blocking**
 atmospheric blocking with climate change, 607
 biases in model simulation of storm tracks, 464
 by Siberian High, 1976
 definition, 1101
 definition of, 463
 extratropical jets and cyclone tracks, 338
 extratropical storm track density changes, 607
 global climate change projections, 604, 606, 607
 hemispheric biases in, 464
 human-caused extratropical jets, storm tracks and blocking, 463–464
 instantaneous Northern Hemisphere frequency (1979–2000), 465
 model performance in simulations, 1396
 model simulations and projections for, 1132
 model simulations of atmospheric blocking, 607
 observed trends in, 1101
 poleward shift effects on wind speeds, 1519
 projections for dynamical intensity, 606
 projections for wintertime frequencies, 608
 shift in anticyclone blocking in North Atlantic, 1101
 simulation of cyclones and blocking, 463
 simulation of storm tracks and blocking, 1977
 with North Atlantic Oscillation/North Annular Mode, 2158
- Storyline approach***
 21st-century seal level rise, 1308
 changes in temperature in high-warming, 636
 constructing and communicating climate information, 1433
 defined, 40
 explaining and exploring, 199
 for communication of relevance, 1957
 for consideration of risk, 151
 high-warming, 555
 low-likelihood, high-warming, 635
 precipitation changes with high warming, 638
- Stratosphere***
 aerosol-induced heating and surface climate change, 627
 aerosol injection for solar modification, 860
 assessment of methane lifetime, 835
 effects of sudden warmings in, 2156
 factors determining temperature trends, 599
 global mean temperature through depth of, 425
 halogen loading of, 843
 lifetime of ozone in, 838
 lower warming and upper cooling of, 327
 lower warming over Antarctic pole, 599
 model simulations of temperatures in, 445–446
 projections for end of 21st century, 556
 sudden warming effects on teleconnections, 2179
 temperature changes in, 291
 temperature changes in lower and upper, 445
 temperature response to greenhouse gases and ozone depletion, 445
 tropopause height relation to temperature in, 328
 water vapour and ozone contribution to forcing, 926
- Stratosphere–troposphere coupling**, 2164
- Stratosphere–troposphere exchange* (STE)**
 air pollutant effects on, 861
 effects on surface ozone, 863
 NH₃ transport in, 842
 tropospheric ozone budget control by, 837
- Stratospheric aerosol injection (SAI)**
 aerosol particles used for, 627
 effects on carbon cycle, 768
 possible effects of, 861
 solar radiation modification by, 624
 uncertainty in stratospheric response to, 627
- Stratospheric aerosol optical depth (SAOD)**
 adjustments from model simulations, 958
 reconstructions of, 298
- Stratospheric ozone**
 annual mean total column ozone from 1964–2019, 306
 depletion effects on Hadley circulation (1981–2000), 459, 1373
 effects of recovery in, 556
 human-induced depletion of, 425
 Southern Annular Mode trends with depletion, 579
- Stratospheric-temperature-adjusted radiative forcing (SARF)**
 2×CO₂ adjustments, 945
 comparison to effective radiative forcing for measurement of driving, 941
 definition used in AR6 versus AR5, 941
 estimation of climate response to forcing, 932
 for fixed-sea surface temperatures experiments, 943
 from methane-induced stratospheric water vapour changes, 947
 halogenated species revision for AR6, 946
 re-evaluation of radiative efficiencies, 1012
 revision for CO₂ emissions, 944
 SSP and RCP comparison of, 231
 updates for methane, 945
- Stratospheric water vapour (SWV)**. *See also* **water vapour**
 direct anthropogenic effects on, 947
 seasonal and interannual variability in data, 305
- Streamflow***
 anthropogenic influence on middle- and high-latitude regions, 456
 attribution to anthropogenic forcing, 1086
 detection and attribution analysis for terrestrial water cycle, 456
 in droughts, 1572
 regional anthropogenic influence alterations, 456
- Structured Expert Dialogue (SED)**, 162
- Subantarctic mode water (SAMW), formation of**, 1235
- Subarctic basin (Greenland/Norwegian/Barents Sea)**, 2156
- Subsidiary Body for Implementation (SBI)**, 162
- Subsidiary Body for Scientific and Technological Advice (SBSTA)**, 162
- Subtropical marine low-cloud feedback**, 973
- Subtropical mode waters (STMW), circulation time scales in**, 1235
- Sudden stratospheric warming* (SSW)**, 466, 2156, 2158
- Sulphate (SO₄²⁻) aerosols**
 climate forcing effects of, 845
 dimethyl sulphide in formation of, 858

- from aviation, 867
 - in near-term warming, 820
 - interaction with aviation cirrus, 867
 - lightning NO_x emissions effects on, 859
 - pH effects on radiative forcing, 845
 - precursor sulphur gases for, 845
 - production pathways for, 845
 - removal from the atmosphere, 845
 - shipping contribution to, 872
 - tropospheric burden of (1850–2005), 846
 - Sulphur, decadal trends in atmospheric loading,** 846
 - Sulphur dioxide (SO₂)**
 - anthropogenic emissions of, 844
 - conversion to secondary sulphate aerosols, 845
 - effective radiative forcing by, 854
 - effective radiative forcing effects (1750–2019), 819
 - geographic changes in tropospheric columns, 819
 - global emission inventories for, 827
 - in stratosphere aerosol layer, 845
 - precursor of direct forcers, 823
 - radiative forcing associated with, 958
 - regional variation in atmospheric abundance, 843
 - sulphuric acid formation in atmosphere, 846
 - summary of changes in atmospheric abundance, 843
 - trends in abundances of, 842
 - Sulphur hexafluoride* (SF₆)**
 - historical abundances and effective radiative forcing, 2141
 - increases in, 305
 - radiative importance, 304
 - Sulphuric acid (H₂SO₄) formation in atmosphere,** 846
 - Surface air temperature* (SAT).** *See also* **global mean surface temperature* (GMST) and global surface air temperature* (GSAT)**
 - annual mean near-surface (1995–2014), 434
 - anomalies in CMIP6 models and observations, 441
 - CMIP projections by scenarios, 571–572
 - coupling of relative humidity over land and temperature, 596
 - land temperature changes, 82
 - net negative CO₂ emissions effect on, 30
 - observed and simulated change in, 17
 - response to aerosol changes, 856
 - standard deviation of averaged zonal-mean, 436
 - Surface albedo**
 - enhancement of, 624
 - estimates of feedback, 970
 - factors determining, 970
 - Surface-albedo feedback,** 970, 971
 - Surface humidity**
 - atmospheric climate indicator, 312
 - CMIP projections for, 601
 - monitoring, 330
 - trends in, 331
 - Surface mass balance* (SMB)**
 - Greenland Ice Sheet loss, 1254
 - loss rate for Greenland Ice Sheet, 2020
 - relevance to polar and high mountain ecosystems, 1785
 - sea level contribution of Antarctic Ice Sheet loss, 1267
 - simulations of Antarctic changes, 1266
 - Surface Ocean CO₂ atlas (SOCAT),** 691
 - Surface ocean pH,** 577
 - Surface ozone**
 - future air quality and, 820
 - natural sources in South Asia, 869
 - nitrogen oxides effects on, 863
 - trends in, 308
 - Surface solar radiation,** 938, 939
 - Surface water, deficits in droughts,** 1572
 - Surprises* (risk class),** 203
 - Sustainable Development Goals (SDGs)**
 - environmental problems and development, 167
 - feasibility of CH₄ and black carbon reductions, 825
 - opportunities for, 874–875
 - short-lived climate forcer reduction with implementation, 822
 - short-lived climate forcers mitigation, 864
 - Sustainable socio-economic development, climate change and,** 168
 - Swash*, in extreme coastal water level,** 1221
 - SYNOP/CLIMAT networks,** 1385
 - Synoptic-scale monsoon systems,** 1981
- T**
- Tambora eruption (1815),** 593
 - Task Force on National Greenhouse Gas Inventories (TFI),** 892
 - Teleconnections***
 - Arctic warming and mid-latitude circulation, 1101
 - association with Pacific Decadal Variability, 2174
 - atmospheric convection changes and, 2164
 - Australasia with remote drivers, 1986
 - circum-global pattern of, 2171
 - control simulations for assessment, 1393
 - effects over South Asia, 1978
 - El Niño–Southern Oscillation, 2164
 - El Niño–Southern Oscillation and Central America and Caribbean, 1991
 - El Niño–Southern Oscillation eastern or central Pacific location, 2162
 - Indian Ocean Basin and El Niño–Southern Oscillation regional influence, 2167
 - in tropical Atlantic and Pacific variability, 2171
 - Madden–Julian Oscillation with tropics, 1104
 - model evaluation of El Niño–Southern Oscillation teleconnection, 498
 - of Atlantic Multi-decadal Variability, 2176
 - of Pacific Decadal Variability, 2172
 - principal tropical modes of interannual climate variability, 427
 - regional influence of, 2161
 - regional influence of Atlantic variability, 2171
 - regional influence of Madden–Julian Oscillation, 2179
 - regional influence of North Atlantic Oscillation/North Annular Mode, 2158
 - remote effects of modes of variability, 2155
 - Southern Annular Mode links to Asian precipitation, 2161
 - teleconnection association with modes of variability, 1962
 - tropical Atlantic–El Niño–Southern Oscillation, 611
 - Temperature change**
 - 1.5°C warming effects, 613
 - annual mean surface temperature, 17
 - assessment of trends, 327
 - atmosphere and surface in deep past, 314
 - attribution of to human influence, 431
 - change in variability of, 597
 - contribution of forcing agents (2019 relative to 1750), 961
 - dataset developments for, 327
 - Earth's surface temperature, history and key findings, 316
 - effects of emissions, 866
 - effects on water vapour content, 1526
 - emergence of change over historical period, 51
 - for post-glacial period, 315
 - free atmosphere during instrumental period, 327
 - global scale hot and cold extremes since 1950, 1517
 - global warming implications for, 613
 - growing and cooling degree day projections, 1851
 - index for climatic impact-drivers, 2209
 - key characteristics in change pattern, 595
 - land–ocean warming contrast, 596
 - land surface temperature projections, 1851
 - long-term change of annual and zonal mean atmospheric, 599
 - magnitude of response to CO₂ removal, 761
 - model skill for initialized predictions of near-surface temperature, 564
 - observed and simulated temperature trends in tropical atmosphere, 444
 - observed emergence of, 195
 - paleoclimate proxy reconstructions for model evaluation, 431
 - percentage change in interannual variability, 598
 - projections for change (1990–2030), 186
 - projections for days in exceedance of 35°C, 134
 - quantification of net zero greenhouse gas emissions, 928
 - reconstructions for Early Eocene Climatic Optimum, 314
 - regional projections for increases, 15
 - response to aerosol radiative forcing, 819
 - response to short-lived climate forcers, 103, 821
 - scenario-based projections and near-term information, 555–556
 - seawater CO₂ storage effects of, 744
 - teleconnection effects on, 2164
 - time period of signal emergence, 133
 - time series observed anomalies, 1523

- trends in the upper air, 328
- upper-tropospheric equator-to-pole meridional gradient, 606
- variance and skewness changes in, 597
- Temperature extremes**
 - attribution of human influence on, 457, 1553
 - attribution of short duration temperature extremes, 1553
 - comparison of global observed and simulated changes, 458
 - concurrent precipitation seasonality (2018), 1603
 - constraints for projections, 1554
 - effects of modifying weather patterns, 1526
 - exceeding threshold for hot and cold events, 1555
 - globally averaged annual daily maximum and minimum, 1548
 - global projections for, 1851
 - global projections for heat extremes, 1556
 - linear scaling with global warming, 1554
 - maximum/minimum projections for changes with warming levels, 1554
 - mechanisms and drivers, 1546–1549
 - multi-model bias (1979–2014), 1551
 - observed trends for warm and cold days, 1548–1551
 - percentage land area affected by, 1601
 - probability of occurrence, 1553
 - projected change over land, 18
 - projected intensity changes with warming levels, 1555
 - projections for warming levels, 1530
 - projections in continental regions, 1555
 - regional changes in daily maximum temperatures for land areas, 1524
 - regional climate, 1605
 - similarity of observed and simulated, 1550
 - studies since AR5 on, 1552
 - thermodynamic responses and feedbacks with, 1526
- Temperature patterns**
 - dependence of feedbacks on, 989
 - relationship between feedbacks and, 981
- Terrestrial carbon cycle**, 485–487, 741, 768
- Terrestrial cryosphere**. *See also Cryosphere**
 - indicators of changes in, 291
- Terrestrial snow cover**. *See Snow cover extent* (SCE)*
- Terrestrial vegetation**. *See Vegetation*
- Thermal expansion***, 1220
- Thermal radiation, changes since 1970s**, 939
- Thermodynamic response to warming**
 - enhanced moisture flux with warming, 601
 - global monsoon precipitation enhancement, 603
- Thermosteric* change (in ocean)**. *See also Steric sea level change**
 - anthropogenic forcing of, 481
 - contribution to steric sea level change, 1220
 - global mean sea level changes with, 1298
 - in upper 700 m (1970–2005), 1290
 - ranges of sea level change from, 1245
- Thermosteric* sea level rise**
 - global mean change, 1244–1245
- human influence driving of, 427
- projections for, 1232
- Third Assessment Report (TAR), equilibrium climate sensitivity and transient climate response derivation in**, 1007
- Threshold avoidance budgets (TAB)**, 749
- Threshold exceedance budgets (TEB)**, 749
- Thresholds for climatic impact-drivers**. *See also Tipping points*/elements**
 - criteria for emergence of climate change signal, 1853
 - defined, 1773
 - for heat indices, 1851
 - probability of exceeding hot extreme, 1555
- Tibetan Plateau (TIB)**
 - frequency and intensity of snowfall in, 139
 - glacier retreat trends in, 1979
 - precipitation projections, 1981
 - snow and snow water equivalent projections, 1980
 - snow depth and cover reanalyses, 1980
 - solar radiation change in, 938
 - surface temperature projections, 1981
 - topographical mechanical effect on moisture, 1978
 - warming projections for, 1974
- Tide gauge network**, 134
- Tides, surges and waves, amplitude changes in 21st century**, 1312
- Time scale separation methods (for attribution)**, 1415
- Tipping points/elements***. *See also Abrupt climate change**
 - abrupt change with, 202, 739
 - assessment of biogeochemical, 740
 - bifurcation tipping, 202
 - changes in forcing with, 202
 - climate effects of, 202
 - components susceptible to tipping points/abrupt change, 634
 - defined, 739
 - for vulnerability, exposure for risk or opportunity, 1773
 - illustration of types, 203
 - irreversibility and abrupt changes with, 106
 - loss of Arctic summer sea ice, 1215
 - narrow regions of parameter space, 202
 - noise-induced, 202
 - paleoclimate evidence for, 106
 - seasonal change role in, 634
 - thresholds for climatic impact-drivers, 1777
 - West and East Antarctic ice sheets as tipping elements, 1272
- Titanium dioxide (TiO₂) for stratospheric injection**, 627
- Top-down (inverse) observational constraints**, 954
- Top-down observational inversion methods (TD)**, 835
- Top-of-the-atmosphere (TOA) energy budget**
 - adjustments to carbon dioxide forcing in, 945
 - anomalies in fluxes, 936
 - calculation of flux changes, 942
 - changes following a perturbation, 91
 - changes in, 935
 - cloud effects on, 971
 - effective radiative forcing driving of, 941
 - estimates of equilibrium climate sensitivity based on variability, 998
 - imbalance with anthropogenic forcing, 933
 - instantaneous radiative forcing from aerosol–cloud interactions, 948
 - mechanism of anthropogenic effects on climate, 925
 - monitoring methods for, 929
 - net energy flux of Earth system, 931
 - radiative adjustments for climate drivers, 943
 - radiative flux evaluation, 968
 - reconstruction of variations, 937
 - response to spatial pattern of warming, 989
- Tornadoes**
 - association with extratropical cyclones, 1594
 - convective systems with, 1594–1600
 - spatial and temporal scales of, 1522
- Total aerosol effective radiative forcing, assessment of**, 954
- Total alkalinity* (of ocean)**, 742
- Total column ozone (TCO), in stratosphere**, 838
- Total column water vapour (TCWV)**
 - changes since 1970s, 330
 - effects of increase in, 85
 - indicator of water cycle changes, 312
 - timeseries of annual anomalies, 331
- Total ozone column (TCO)**
 - change from (1850 to 1960), 838
 - CMIP estimates of, 838
- Total solar irradiance* (TSI)**
 - change (1986–2008), 297
 - changes since 1900, 297
 - fluctuations in, 296
 - natural external forcing from, 957
- Trade winds**, 2158
- Transient climate response* (TCR)**
 - assessment based on instrumental record, 999
 - assessment of, 1298
 - best estimate of, 927
 - combined assessment of equilibrium climate sensitivity, 94, 1005
 - defined, 933
 - estimate based on emergent constraints, 1003–1004
 - estimate based on process understanding, 993
 - estimates based on global energy budget, 995–1004
 - estimates of, 183, 992
 - for estimation of response to greenhouse gases, 49
 - in global climate models and role in assessment, 1007
 - measure of response to forcing, 925
 - reduction of uncertainty range for, 41
 - response to cumulative CO₂ emissions, 93
 - response to different lines of evidence, 1006
 - summary of assessment, 1007
 - use to inform mitigation policies, 931

Transient climate response to cumulative CO₂ emissions* (TCRE)

- comparison of studies on, 749
- defined, 933
- effects on global surface air temperature, 184, 678
- estimate of, 747
- in assessment of remaining carbon budget(s), 742, 751
- metrics for, 931
- pathway independence of, 743
- physical processes and theoretical frameworks, 742
- response to cumulative CO₂ emissions, 748
- reversibility and Earth system feedbacks, 747
- sensitivity to cumulative CO₂ emissions, 746
- sensitivity to rate of CO₂ emissions, 746

Transient simulations and time-slice experiments, 1392**Trans-Pacific coherent variability, atmospheric and oceanic conditions, 2155****Transportation**

- aerosols from ship exhaust emissions, 952
- air transportation effects on ozone layer, 180
- attribution of temperature and pollution changes, 866
- energy infrastructure concerns with heavy snow and ice, 1785
- forcing from land-based transportation, 868
- international shipping emissions regulation, 872
- land transportation impact on climate, 868
- shipping effects on climate, 867
- short-lived climate forcer co-emission with CO₂, 825

Tree ring* proxy data

- introduction to, 178, 211
- for aridity and drought, 1086, 1578
- for extremes, 1538
- for Southern Annular Mode, 2161
- of Pacific Decadal Variability, 2174

Triassic period, atmospheric CO₂ proxy estimates, 299**Trichloroethane (CH₃CCl₃) abundance and forcing, 2143****Tripole index (TPI), 2172****Tropical Atlantic–El Niño–Southern Oscillation teleconnection, 611****Tropical Atlantic Variability* (TAV)**

- modes of, 589
- projections for changes in, 611
- teleconnections with climate variability, 2171

Tropical circulation, weakening of, 1124**Tropical cyclones* (TCs)**

- African regional changes, 1795
- anthropogenic forcing effects on, 1100
- Asian changes, 1801
- Australasian changes, 1810
- boreal summer intra-seasonal oscillation effects on, 2177
- Central and South American changes, 1817
- change in global proportion of Category 3–5, 132
- changes and effects on water cycle, 1131

- detection and attribution, event attribution, 1588–1590
- global changes in Category 4–5 storms, 1839
- hazards associated with, 1784
- increased warming effects on, 16
- intensity and frequency in warmer climate, 1313
- intensity and latitude shifts in, 9
- intensity and precipitation projections, 2009
- landfall on eastern Australia, 1987
- mechanisms and drivers of, 1585
- model evaluation, 1587–1590
- North American changes, 1832
- observed trends in, 1585
- Pacific Decadal Variability effects on formation, 2174
- past and projections for change summary, 1586
- projections for, 1590–1592
- projections for global change in, 1852
- rain rates with warming, 1519
- sea-salt aerosol interaction effects on, 478
- Small Islands changes, 1839
- storm-surge driven extreme sea level events, 1310
- wind speed changes with warming, 1519

Tropical forests

- biodiversity in, 1850
- changes with 2°C warming, 143
- climatic impact-driver changes of importance, 1850
- potential for dieback due to drought, 634
- projections for carbon accumulation in, 740

Tropical high-cloud amount feedback, 972**Tropical Pacific Decadal Variability (TPDV), 2172****Tropical Pacific Ocean**

- regional pH changes in, 716
- sea surface temperature gradients in, 987
- surface temperature biases in CMIP5 and CMIP6, 2010

Tropical regions

- Pacific temperature gradients in past high-CO₂ climates, 988
- precipitation projections, 615
- rain forest dieback in climate change, 740
- regional precipitation anomalies, 454
- sea surface temperature evaluation, 476
- signal emergence for tropical regions, 1854
- tropical rain belt changes, 1093, 1124

Tropopause*, rise in height (1981–2015), 328**Troposphere***

- abundance of NO₂, 708
- adjustment for effective radiative forcing, 925
- aerosol effects on ecosystem productivity, 857
- atmospheric ozone in, 836
- chlorine trends, 843
- concentrations of hydrofluorocarbons in, 843
- effects of fluctuations of midlatitude westerly jet stream, 2156
- evolution of ozone burden (1850–2100), 837
- extratropical jets in, 463
- formation of sulphate particles in, 845
- global hydroxyl trend in (1980–2014), 851
- global ozone budget for, 837
- greenhouse gas contribution to warming, 5

- greenhouse gas forced warming, 444, 445
- halogen loss, 835
- human-induced warming (since 1979), 425
- hydroxyl (OH) radical trends in, 819
- hydroxyl radical change in (1850–2000), 851
- lightning NO_x release in, 830
- lower warming trend, 327
- mean NO₂ and time evolution of, 839
- model estimation of nitrate burden, 846
- moistening in the upper troposphere, 451
- moistening in upper, 426
- Northern Hemisphere mid-latitudes aerosol concentrations, 290
- NO_x abundance (1850–2015), 839
- observed change in free atmospheric temperatures, 329
- OH abundance and short-lived climate forcer emissions, 849
- ozone changes in, 858
- process-level studies to chemistry–climate models, 833
- projections for long-term temperature changes, 599
- projections for pattern for end of 21st century, 598
- propagation of geopotential height anomalies, 2156
- sulphate burden trends (1850–2005), 846
- temperature changes in, 291
- temperature response to sea surface temperature, 990
- upper warming in tropics, 556
- warming biases in models, 443
- warming projection scenarios, 599
- warming since the mid-20th century, 328
- water vapour and temperature lapse rate in feedback analysis, 969
- water vapour changes in, 451

Tropospheric ozone*

- control of budget for, 837
- emissions from human activity, 180
- lightning NO_x emission effects, 859
- present-day estimates of burden, 838
- trends in, 308

Twomey effect, 860**Type I and Type II errors, 172****Typhoon Haiyan, 1589****Typological Regions, 208****U****Uncertainty***

- and calibrated uncertainty language in AR6, 169
- AR5 characterisation of, 566, 568
- assessment of aviation climate effects, 867
- cascade of uncertainties in CMIP6 projections, 198
- clear communication and consistent treatment for, 170
- climate model investigation of, 222
- deep uncertainty in communication of risk, 202
- display in maps, 1945–1950

- equilibrium climate sensitivity and transient climate response values, 927
- estimates of feedback parameters, 859
- estimation with models, 151
- evaluation and assessment of findings, 170
- future sea level and cryosphere change, 1314
- in assessment of observational evidence, 293
- in climate scenario projections, 197
- in CO₂ estimates from proxy records, 299
- in estimation of emergence of climatic impact-drivers, 1853
- in historical effective radiative forcing timeseries, 855
- in projections for warming to 2100, 1011
- in regional climate projections, 1407
- internal variability as source of, 567
- model-based future regional climate information, 1374
- multi-model ensembles for estimation of, 1408
- natural and internal climate variations in, 197
- of model response, 197
- process for assessing, 169
- propagation and potential accumulation of, 1408
- quantification of, 170, 197
- quantifying sources of, 566–567
- radiative forcing uncertainty, 196
- range of the net climate feedback, 977
- regional climate assessment, 1372
- regional climate information, 1374
- sources for projections, 559
- sources in model projections, 566
- statistical inference framework to account for, 430
- variability and radiative forcing interaction, 197
- Unexpected biological epidemics**, 203
- United Nations Framework Convention on Climate Change* (UNFCCC)**, 150, 161, 688, 1018, 1773
- Univariate detection method, regional-scale attribution**, 1415
- Unknown unknowns**, 203
- Upper troposphere and lower stratosphere (UTLS)**, 842
- Urbanization*/urban climate**
- anthropogenic eutrophication by, 721
 - climate projections for, 1456
 - climatic impact-driver changes (with 2°C warming), 144
 - climatic impact-drivers effects on coastal areas, 1849
 - coastal flood and erosion impacts on, 1786
 - coastal hazard risks for, 1848
 - effects on short-lived climate forcers, 878
 - effects on solar radiation trends, 938
 - heavy snowfall and ice storm impacts, 1785
 - in coastal areas, 1849
 - observed trends in, 1455
 - processes and trends, 1454–1456
 - simulation trends of radiation and energy exchanges, 1368
 - urban heat island in coastal cities, 1848
 - urban modules in climate modules, 1454
 - urban warming compared global greenhouse-induced warming, 1455
 - warming or cooling in urban areas, 1463
 - warming trend in South Korea and Tokyo, 1973
- UVic ESCM model**, 761
- V**
- VALUE initiative, statistical downscaling assessment**, 1393
- Vapour pressure deficit**, 1120
- Variable resolution global models**, 1390
- Vegetation**
- biome composition effects of climate change, 724
 - climate-driven carbon loss from soil, 725
 - CO₂ effect of land carbon uptake, 723
 - compounds emitted from, 831
 - effects of short-lived climate forcers on, 820
 - in biogeophysical feedbacks, 976
 - net land CO₂ sink observations (1980–2019), 695
 - ozone-vegetation interaction effects, 857
 - photosynthesis control of land CO₂ sink, 694
 - reactive nitrogen, ozone and aerosol effects on, 857
 - vegetated coastal ecosystems in CO₂ removal, 764
- Vertical land motion* (VLM)**
- defined, 1221
 - glacial isostatic adjustment and other drivers of, 1300
 - sources for, 1300
- Very short-lived halogenated species* (VSLs)**, 843
- Viscoelastic solid Earth deformation.**
See **Gravitational, rotational and deformational* (GRD) effects**
- Voeikov Main Geophysical Observatory (MGO) regional climate model**, 1978
- Volatile organic compounds* (VOCs).** *See* **Biogenic volatile organic compounds* (BVOCs)**
- Volcanic forcing/eruptions**
- 21st century projections for, 556
 - alteration of near-term projections by, 592
 - anthropogenic warming offset by, 425
 - as surprises/events, 203
 - Atlantic Multi-decadal Variability index and, 427
 - atmospheric effects of, 1373
 - changes in forcing, 298
 - climate effects of, 593–595
 - climate response to, 591–592
 - effects on ocean heat content, 1231
 - effects on water cycle, 1144
 - equilibrium climate sensitivity estimates from, 999
 - implications for 21st century projections, 594
 - in climate models, 444
 - in pre-industrial air temperature driving, 592
 - in projections for water cycle changes, 1141
 - model reproduction of response to, 433
 - North Atlantic Oscillation forcing by, 2158
 - Northern Hemisphere cooling, 161
 - oceanic buffering of atmospheric response, 1232
 - past climate response to, 593
 - potential impact on temperature change, 594
 - radiative forcing for stratospheric aerosols, 958
 - radiative forcing from, 958
 - simulation of effects of, 851
 - stratospheric aerosol injection analogue, 627
 - stratospheric sulphate loading, 845
 - upper stratospheric temperature change, 445
- Volcanic gas-phase sulphur emissions, direct observation of**, 298
- Vortex splits**, 466
- Vulnerability* in risk assessment**, 201
- W**
- Walker circulation* (WC)**
- AR5 trends in strength of, 335
 - changes in strength of, 459
 - connection of Pacific and Indian oceans, 1241
 - easterly equatorial Pacific winds strengthening, 1225
 - El Niño–Southern Oscillation effects on, 2164, 2167
 - Last Glacial Maximum trends, 336
 - ocean warming and trends in, 1222
 - Pacific Decadal Variation and, 2174
 - projections for, 1094, 1125
 - trends since 1980, 337
- Warming hole (North Atlantic)**, 1229
- Waste management, methane production by**, 821
- Water cycle and climate change, 1060–1210**
- anthropogenic aerosols in, 1076–1077
 - changes in seasonality, 1113–1115
 - Executive Summary, 1057–1060
 - Frequently Asked Questions, 1153–1157
 - global and regional constraints on, 1065–1079
 - importance for societies and ecosystems, 1060–1063
 - limits for projections, 1135–1147
 - observed changes, 1079–1108
 - potential for abrupt change, 1148–1151
 - projected water cycle and climate change, 1106–1138
 - visual guide to, 1064
- Water Efficiency Improvement in Drought-Affected Provinces (WEIDAP) project**, 1869
- Water (hydrological) cycle*.** *See also* **Global hydrological cycle**
- abrupt changes with solar radiation modification, 1151
 - abrupt change with rapid implementation or termination of solar modification, 1059
 - annual mean water cycle projections, 1107
 - anthropogenic aerosols in changes of, 1076–1078
 - AR6 key findings of special reports, 1063
 - aridity and drought, 1086–1088
 - assessment of deficits in droughts, 1572
 - attribution of changes in, 1079–1080

- attribution studies for, 1578
 - carbon cycle interaction under drought conditions, 697–699
 - carbon dioxide removal effects on, 100
 - causes of observed changes, 1057
 - change from AR5 and special reports, 1062–1064
 - changes across warming levels, 1112
 - changes for in seasonality of, 1113
 - changes in Madden–Julian Oscillation implications for, 2179
 - changes in polar regions, 142, 1847
 - changes since 1980, 85
 - changes with high-warming storylines, 637
 - chapter structure and content, 2176
 - constraints on regional, 1067
 - depiction of present day, 1061
 - detectable effects since AR5, 42
 - direct anthropogenic influence on regional, 1075
 - effects of continued warming, 19
 - expectations for future, 1065
 - freshwater reservoirs, 1089–1092, 1122
 - future change projections, 1058
 - global changes in, 158, 291
 - groundwater, 1091
 - high-warming storyline manifestations, 637
 - human-caused changes in, 85
 - importance for human societies and ecosystems, 1060
 - Indian Ocean Basin and Indian Ocean Dipole, 2168
 - intensity and P–E over land and oceans projection, 1106
 - land surface responses and feedbacks effects in, 1146
 - large-scale changes in, 1057
 - large-scale responses in atmospheric circulation patterns, 1069
 - limits for projections, 1135
 - local processes related to ice and snow, 1071
 - local/regional effects of land-use change and irrigation, 1057
 - local-scale physical processes affecting, 1071
 - modulation by relative humidity change, 600
 - nonlinear at the regional scale, 1148
 - observational capacity expansion, 209
 - observed changes in, 1079
 - overview of climate system and, 1060
 - ozone–vegetation interaction effects, 857
 - Pacific Decadal Variability implications for, 2174
 - physical basis for change in, 1057
 - potential for abrupt human-caused changes in, 1059
 - precipitation minus evaporation, 333
 - precipitation minus evaporation over land and oceans, 1079
 - projected changes, 1106
 - projected water cycle changes, 87
 - projections for deficits, 1582
 - projections for trends in near-term, 1144
 - reconstructions and model-data comparisons, 46
 - region-specific changes with 2°C warming, 135
 - responses to a collapse of Atlantic Meridional Overturning Circulation, 1148
 - river and pluvial flood event projections, 1518
 - runoff, streamflow and flooding, 1086
 - seasonal snow cover, 1090
 - solar modification effects on, 1059
 - streamflow and surface water deficits, 1572
 - streamflow observations for detection and attribution, 456
 - streamflow record evidence for deficits, 1574
 - tropical forest effects of, 1851
 - variability and extremes in, 1058
 - wetlands and lakes, 1090
- Water management**
- effects on land surface hydrology, 1143
 - heavy precipitation and flood impacts on, 1783
 - snow, glacier and ice-sheet indices use in, 1785
 - snowpack changes and storage, 1221
 - use of drought indices in, 1783
- Water masses***
- entry into glacial fjords, 1257
 - formation in marginal sea areas, 1244
 - heat storage in Southern and North Atlantic, 1214, 1225
 - ice shelf penetration by, 1268
 - ocean heat uptake circulation by, 1235
 - redistribution of, 1246
 - salinity changes and rate of formation, 1234
 - salinity changes in, 1235
 - subduction in Southern Hemisphere Mode Waters, 1231
 - variability on Antarctic continental shelf, 1240
 - warming in subduction regions, 1232
- Water-use efficiency (WUE), 697, 722**
- Water vapour**
- and temperature lapse-rate feedbacks, 969
 - attribution of tropospheric changes in, 451
 - CMIP6 projections for, 1107
 - contribution to global warming, 95
 - increased atmospheric content of, 1526
 - stratospheric increase with methane, 946
 - transport of, 1080
 - trends (1998–2019), 450
- Wave-mean flow interaction, 2156**
- Waves**
- contribution to extreme sea level, 1310
 - response to surface conditions, 1313
 - wind-generated, 1221
- Weather and climate extreme events in a changing climate**
- attribution of extremes, 1525, 1532, 1540
 - changes in low-likelihood, high-impact extremes, 1534–1536
 - compound events, 1598–1604
 - concurrent meteorological conditions (July 2018), 1603
 - confidence for changes at 2°C, 1529
 - data and methods, 1536–1543
 - data sources for studies of, 1537
 - definition of extremes, 1536
 - detection and attribution, 1552–1553
 - droughts, 1518, 1570–1587
 - extratropical storms, 1592–1594
 - extreme El Niño in 2015–2016, 1601–1602
 - extreme precipitation changes, 1531
 - extreme storms, 1583–1599
 - extreme winds, 1597
 - extremes in paleoclimate and instrumental records, 1538–1540
 - floods, 1567–1571
 - global and regional-scale emergence of changes, 1542
 - global warming levels versus scenarios for end users, 1542–1545
 - greenhouse gases and external forcing effects, 1522
 - heavy precipitation and pluvial floods, 1518
 - heavy precipitation events, 1557–1568
 - hot and cold extremes projections, 1518
 - impact of concomitant extremes, 1522
 - large-scale circulation on changes, 1528
 - low-likelihood, high-impact extremes, 1534–1535
 - magnitude and probability changes, 1611
 - mean fractional changes with warming, 1527
 - Northern Annular Mode links with, 1105
 - paleoclimate compared to instrumental records, 1538–1540
 - projections for changes in extremes, 1533
 - regional information on extremes, 1604–1607
 - regional-scale processes and feedbacks in, 1528
 - spatial and temporal scales of, 1522
 - temperature and precipitation extremes (2018), 1603
 - temperature anomalies time series, 1523
 - temperature extremes, 1530, 1546–1558
 - thermodynamic and dynamic changes in, 1526
 - tropical cyclones, 1585
 - warming effects on, 1761
- Weather generators, 1391**
- Well-mixed greenhouse gases* (WMGHGs)**
- atmospheric burdens (2005–2011), 298
 - atmospheric concentrations from ice cores, 301
 - changes from pre-industrial levels, 676
 - CO₂ trend (since 1958), 303
 - concentration and effective radiative forcing changes, 68
 - concentration changes (since 1850), 290
 - concentrations in geological periods, 298–301
 - forcing offset by aerosols, 310
 - from human activities, 4
 - glacial-interglacial fluctuations, 300
 - growth rates, 303
 - in human-induced climate change, 680
 - methane concentrations (past 110 kyr), 301
 - methane mixing ratio (2019), 303
 - modern measurements of, 301
 - N₂O fluctuations at glacial-interglacial transition, 301
 - N₂O global surface mean trends, 303
 - ozone and aerosol chemistry effects, 944
 - plant function effects of, 1787
 - pre-instrumental and instrumental mixing ratios, 2140
 - present-day mole fractions for, 948
 - summary of changes in, 303

- West Africa.** *See* **Western Africa**
- West African Monsoon Modelling and Evaluation (WAMME),** 2198
- West African monsoon* (W AfrIM)**
anthropogenic forcing of, 1097
Atlantic Multi-decadal Variability effects, 2177
Atlantic Zonal Mode influence, 1968
Atlantic Zonal Mode link between, 2171
CORDEX climate models, 1969
domain and characteristics of, 2197–2198
drivers of variability in, 2198
projections, 1130
variability time scales, 2198
- West Antarctica (WAN),** 2016
- West Antarctic Ice Sheet* (WAIS)**
contribution to recent ice loss, 473
ice-sheet instability effects on, 1269
ongoing grounding line retreat in, 1265
response to stabilization of warming, 106
thinning of outlet glaciers in, 1264
threshold instability/tipping, 1269, 1273
- West Central Asia (WCA)**
glacier projections, 1122
global warming level projections, 1985
influence on regional climate, 1983
precipitation changes, 1983–1986
snow cover extent projections, 1984
surface air temperature trend, 1984
- Westerly winds at midlatitudes,** 2158
- Western Africa (WAF),**
climate features of, 1967
climate simulation, 2198
droughts over, 2198
extreme changes in, 1613, 1619, 1624
rainfall changes in, 1968, 1971
temperature changes in, 1968, 1969
wind projections for, 135
- Western and Central Europe (WCE),** 1998, 1999
- Western boundary currents (WBCs),** 143, 1222, 1242
- Western North America (WNA)**
climatic features, 2004
wind power projections, 1833
- Western Pacific**
rainfall and streamflow trends in, 2010
sea level rise in, 1216
temperature trends in, 2009
- West Siberia (WSB)**
climate features of, 1975
snow depth trends, 1977
- West Southern Africa (SWAF)**
extreme total water level, 135
key climatic features, 1967
rainfall projections, 1971
- Wet and dry conditions**
Asia regional changes, 1800–1802
Australasia changes, 1807–1811
intensification of zonal mean patterns, 452
North American changes in, 1830
polar region changes (2°C warming), 142
regional changes in climatic impact-drivers, 132
terrestrial polar region changes, 1844
- Wet-gets-wetter, dry-gets-drier paradigm,** 456, 584, 601
- Wetland CH₄-climate feedback,** 737
- Wetlands* and lakes**
lake and river ice projections, 1123, 1847
mechanisms of climate impact, 1090
projections for changes for extent, 1123
SRCC and SROCC discussion of, 1123
- Wet scavenging,** 845, 848
- Wet tropics–dry subtropics contrast,** 456
- Wildfire Decision Support System (WFDES)**
calculation for wildfire/biomass burning, 2210
data for atlas, 1941
- Wildfires/biomass burning**
bias adjusted heat index calculation, 2210
climate–fire feedback, 859
effects of climate change on, 724
effects on surface ozone, 863
increase in fire weather, 1852
Pacific Decadal Variability effects, 2174
- Wind.** *See* **Wind Speed**
- Wind-generated waves,** 1221
- Wind power potential**
Africa, 135
Australasia, 1810
Europe, 1824
North America, 1832, 1833
projections for augmentation of, 1817
renewable energy impact wind changes, 1784
Southern Africa, 135
Western North America, 141
- Wind speed.** *See also* **Severe wind storms**
African changes, 1795
Asian changes, 1801–1803
Australasian changes, 1810
Central and South American changes, 1817
European changes, 1824
impact of changes in, 1784
North American changes, 1832
observed mean surface wind speed trends, 1855
polar terrestrial region changes, 142, 1845
projections for changes in, 1519
regional changes in climatic impact-drivers, 132
sea-spray particle emission rate, 832
Small Islands changes, 1839
Southern Hemisphere westerlies strengthening, 1240
Southern Hemisphere zonal mean Dec–Jan–Feb (1985–2014), 465
surface wind speed changes, 1802
transportation of Circumpolar Deep Water heat by, 1236
tropical cyclone projections, 1592
- Wind stress**
Atlantic Meridional Mode fluctuations and anomalies, 2168
North Atlantic Oscillation fluctuations and anomalies, 2159
ocean current change in response to, 1214
- Windward Islands, precipitation trends for,** 2009
- World Climate Research Programme (WCRP)**
coordinated model results from, 428
- Coupled Model Intercomparison Project, 12
Work Group on Climate Modelling, 2100
- World Data Centre of the Russian Institute for Hydrometeorological Information (RIHMI-WDC), trends for snow (1980–2015),** 1976
- World Meteorological Organization Expert Team on Sector-Specific Climate Indices (ET-SCI),** 1777
- World Meteorological Organization (WMO)**
30-year long-term climate normal as a baseline, 1935
climate normal period (1981–2010 baseline), 192
definition of climate normals, 191
development of Regional Climate Centres, 1862
Global Framework for Climate Services, 172
standards for change assessments, 1935
- World Ocean Circulation Experiment (WOCE),** 1230
- Y**
- Younger Dryas* event,** 1096, 1148
- Z**
- Zero emissions commitment* (ZEC)**
adjustments due to, 752
climate change following, 630
CO₂ and temperature changes, 630
- Zonal wind and westerly jets**
long-term change of, 605
projections for, 604

