Disastrous and Catastrophic Adverse Global Climate Change Impacts on the Oceans from the IPCC 2019 Special Report Oceans & cryosphere

By Peter Carter, 29 Sept 2019

Oceans extracts

World media

The Associated Press, September 25, 2019

‘We’re all in big trouble’: UN climate report says oceans rising, ice melting faster

UPI, SEPT. 25, 2019

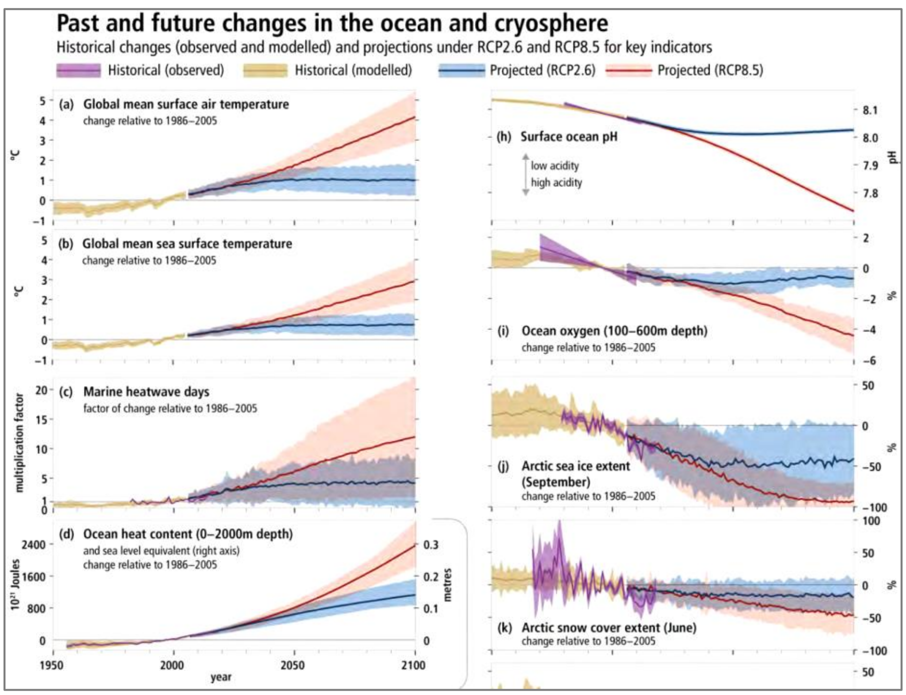
Climate report: 1 billion will face water, food shortages by 2050

BBC 25 September 2019 **Climate change: UN panel signals red alert on 'Blue Planet' Climate change is devastating our seas and frozen regions as never before, a major new United Nations report warns.**

Note: The condensed summary for policy makers SPM (from the full IPCC scientists report) has been approved by all world governments. Bolding of text added.

“Human communities in close connection with coastal environments, small islands (including Small Island Developing States, SIDS), are particularly exposed to ocean and extreme weather events. The low-lying coastal zones is currently home to around 680 million people (nearly 10% of the 2010 global population), projected to reach more than one billion by 2050. SIDS are home to 65 million people.

All people on Earth depend directly or indirectly on the ocean. The global ocean covers 71% of the Earth surface and contains about 97% of the Earth’s water. **The projected responses of the ocean to past and current human-induced greenhouse gas emissions and ongoing global warming include changes over decades to millennia that cannot be avoided, thresholds of abrupt change, and** irreversibility.



PH is the indicator for ocean acidification. Acidification is inverse of PH

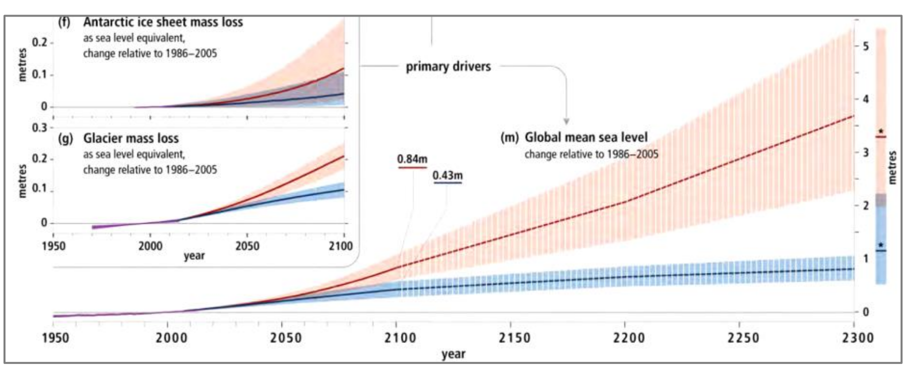


Figure SPM.1: Observed and modelled historical changes in the ocean since 1950, and projected future changes under low (RCP2.6) and high (RCP8.5) greenhouse gas emissions scenarios.

Table SPM.1: Projected global mean surface temperature change relative to 1850–1900 for two time periods under four RCPs[16].

	Near-term: 2031–2050		End-of-century: 2081–2100	
Scenario	Mean (°C)	*likely* range (°C)	Mean (°C)	*likely* range (°C)
RCP2.6	1.6	1.1 to 2.0	1.6	0.9 to 2.4
RCP8.5	2.0	1.5 to 2.4	4.3	3.2 to 5.4

A2.1. **The ocean warming** trend documented in the IPCC Fifth Assessment Report (AR5) has continued. Since 1993 the **rate of ocean warming and thus heat uptake has more than doubled** from 3.22 Zetajoules/year (0– 700 m depth) and 0.97 ZJ /year (700–2000 meters) between 1969 and 1993, to 6.28 ZJ/yr(0–700 m) and 3.86 ZJ/yr (700–2000m) between 1993 and 2017, and is attributed to anthropogenic forcing The Southern Ocean accounted for 35–43% of the total heat gain in the upper 2000 m global ocean between 1970 and 2017. Its share increased to 45–62% between 2005 and 2017. The deep ocean below 2000m has warmed since 1992, especially in the Southern Ocean.

A2.3 Globally, **marine heat related events have increased**; marine heatwaves, defined when the daily sea surface temperature exceeds the 99th percentile over the period 1982 to 2016, have doubled in frequency and have become longer-lasting, more intense and more extensive. It is very likely that between 84–90% of marine heatwaves that occurred between 2006 and 2015 are attributable to the anthropogenic temperature increase.

A2.4 Density stratification has increased in the upper 200 m of the ocean since 1970. Observed surface ocean warming and high latitude addition of freshwater are making the surface ocean less dense relative to deeper parts of the ocean and **inhibiting mixing between surface and deeper waters**. The mean stratification of the upper 200 m has increased by 2.3% from the 1971–1990 average to the 1998–2017 average.

A2.6 Datasets spanning 1970–2010 show that **the open ocean has lost oxygen** by a very likely range of 0.5–3.3% over the upper 1000 m, alongside a likely expansion of the volume of oxygen minimum zones by 3–8%. Oxygen loss is primarily due to increasing ocean stratification, changing ventilation and biogeochemistry

A2.5 The ocean has taken up between 20–30% of total anthropogenic CO2 emissions since the 1980s causing further **ocean acidification**. Open ocean surface pH has declined by a very likely range of 0.017–0.027 pH units per decade since the late 1980s, with the decline in surface ocean pH very likely to have already emerged from background natural variability for more than 95% of the ocean surface area.

A3. **Global mean sea level (GMSL) is rising, with acceleration in recent decades** due to increasing rates of ice loss from the Greenland and Antarctic ice sheets, as well as continued glacier mass loss and ocean thermal expansion. Increases in tropical cyclone winds and rainfall, and increases in extreme waves, combined with relative sea level rise, exacerbate extreme sea level events and coastal hazards

A3.2 **Sea-level rise has accelerated due to the combined increased ice loss from the Greenland and Antarctic ice sheets** . Mass loss from the Antarctic ice sheet over the period 2007– 2016 tripled relative to 1997–2006. For Greenland, mass loss doubled over the same period

A3.3 **Acceleration of ice flow and retreat in Antarctica**, which has the potential to lead to sea-level rise of several metres within a few centuries, is observed in the Amundsen Sea Embayment of **West Antarctica** and in Wilkes Land, East Antarctica. **These changes may be the onset of an irreversible ice sheet instability**

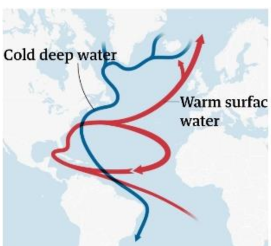
A3.6 **Anthropogenic climate change has increased observed precipitation, winds, and extreme sea level events associated with some tropical cyclones, which has increased intensity of multiple extreme events and associated cascading impacts**. There is emerging evidence for an **increase in annual global proportion of Category 4 or 5 tropical cyclones in recent decades** (SPM-11)

A6. Coastal ecosystems are affected by ocean warming, including intensified marine heatwaves, acidification, loss of oxygen, salinity intrusion and sea level rise, in combination with adverse effects from human activities on ocean and land. Impacts are already observed on habitat area and biodiversity, as well as ecosystem functioning and services (SPM-13)

A6.1 Vegetated coastal ecosystems protect the coastline from storms and erosion and help buffer the impacts of sea level rise**. Nearly 50% of coastal wetlands have been lost over the last 100 years, as a result of the combined effects of localised human pressures, sea level rise, warming and extreme climate events. Vegetated coastal ecosystems are important carbon stores; their loss is responsible for the current release of 0.04–1.46 GtC yr–1** (SPM-13)

A6.4 Warm-water coral reefs and rocky shores dominated by immobile, calcifying (e.g., shell and skeleton producing) organisms such as corals, barnacles and mussels, are currently impacted by extreme temperatures and ocean acidification. **Marine heatwaves have already resulted in large-scale coral bleaching events at increasing frequency causing worldwide reef degradation** since 1997,

B2. OCEAN Over the 21st century, the ocean is projected to transition to unprecedented conditions with increased temperatures , greater upper ocean stratification, further acidification, oxygen decline, and altered net primary production. Marine heatwaves and extreme El Niño and La Niña events are projected to become more frequent. The Atlantic Meridional Overturning Circulation (AMOC) is projected to weaken.



AMOC image added

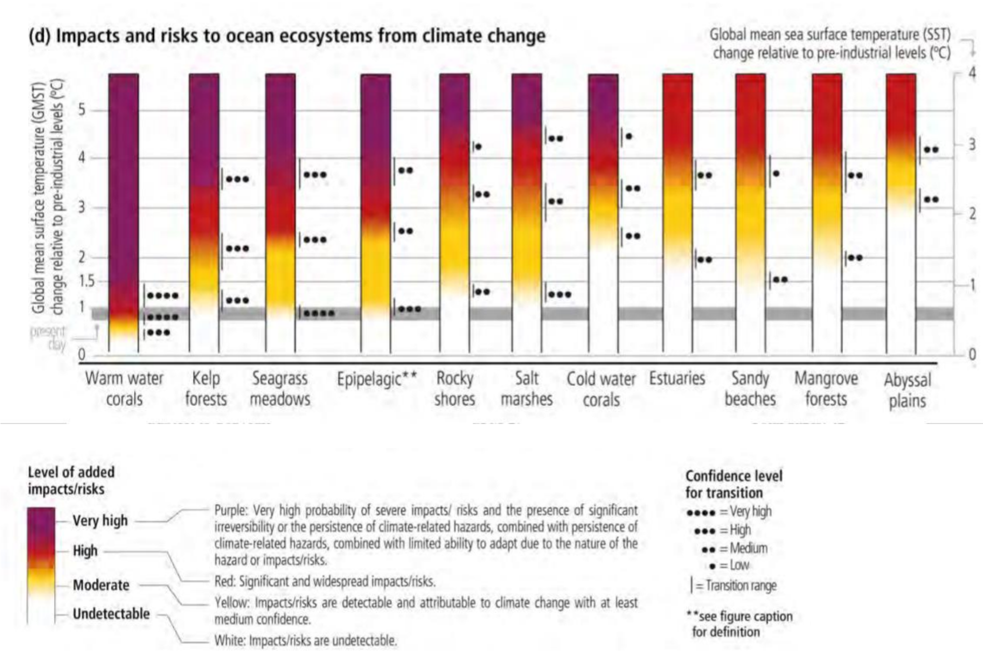


Figure SPM.3: Projected changes, impacts and risks for ocean regions and ecosystems

B2.2 By 2081–2100 under RCP8.5, ocean oxygen content, upper ocean nitrate content, net primary production and carbon export are projected to decline globally by very likely ranges of 3–4%, 9–14%, 4–11% and 9-16% respectively, relative to 2006– 2015.

B2.3 **Continued carbon uptake by the ocean by 2100 is virtually certain to exacerbate ocean acidification.**

B2.4 **Climate conditions, unprecedented since the preindustrial period, are developing in the ocean**, elevating risks for open ocean ecosystems. Surface acidification and warming have already emerged in the historical period. Oxygen loss between 100 and 600 m depth is projected to emerge over 59–80% of the ocean area by 2031– 2050 under RCP8.5. The projected time of emergence for five primary drivers of marine ecosystem change (surface warming and acidification, oxygen loss, nitrate content and net primary production change) are all prior to 2100 for over 60% of the ocean area under RCP8.5 and over 30% under RCP2.6

B2.5 **Marine heatwaves are projected to further increase in frequency, duration, spatial extent and intensity** (maximum temperature). Climate models project increases in the frequency of marine heatwaves by 2081–2100, relative to 1850–1900, by approximately 50 times under RCP8.5 and 20 times under RCP2.6. The largest increases in frequency are projected for the Arctic and the tropical oceans. **The intensity of marine heatwaves is projected to increase about 10-fold under RCP8.5 by 2081–2100, relative to 1850–1900**

B2.6 **Extreme El Niño and La Niña events are projected to likely increase in frequency in the 21st century and to likely intensify existing hazards, with drier or wetter responses in several regions across the globe**. **Extreme El Niño events are projected to occur about as twice as often under both RCP2.6 and RCP8.5 in the 21st century when compared to the 20th century.**

B2.7 **The AMOC (deep ocean conveyer current) is projected to weaken in the 21st century under all RCPs,** although a collapse is very unlikely. Based on CMIP5 model projections, by 2300, an AMOC collapse is as likely as not for high emissions scenarios. Any substantial weakening of the AMOC is projected to cause a decrease in marine productivity in the North Atlantic, more storms in Northern Europe, less Sahelian summer rainfall and South Asian summer rainfall, and an increase in regional sea level along the northeast coast of North America. Such changes would be in addition to the global warming signal.

B3.1 **The global mean sea level (GMSL) rise** .. For RCP8.5, the GMSL rise is 0.71 m for 2081–2100 and 0.84 m in 2100. Mean sea level rise projections are higher by 0.1 m compared to AR5 under RCP8.5 in 2100, and the likely range extends beyond 1 m in 2100 due to a larger projected ice loss from the Antarctic Ice Sheet. The uncertainty at the end of the century is mainly determined by the ice sheets, especially in Antarctica

B3.4 **Global mean sea level rise will cause the frequency of extreme sea level events at most locations to increase. Local sea levels that historically occurred once per century (historical centennial events) are projected to occur at least annually at most locations by 2100 under all RCP scenarios.** Many low-lying megacities and small islands (including SIDS) are projected to experience historical centennial events at least annually by 2050 under RCP2.6, RCP4.5 and RCP8.5 (all scenarios). The year when the historical centennial event becomes an annual event in the mid-latitudes occurs soonest in RCP8.5, next in RCP4.5 and latest in RCP2.6. The increasing frequency of high water levels can have severe impacts in many locations depending on the level of exposure

B3.5 **Significant wave heights** (the average height from trough to crest of the highest one-third of waves) are projected to increase across the Southern Ocean and tropical eastern Pacific and Baltic Sea…under RCP8.5

B3.6 **The average intensity of tropical cyclones, the proportion of Category 4 and 5 tropical cyclones and the associated average precipitation rates are projected to increase for a 2°C global temperature** rise above any baseline period. Rising mean sea levels will contribute to higher extreme sea levels associated with tropical cyclones. Coastal hazards will be exacerbated by an increase in the average intensity, magnitude of storm surge and precipitation rates of tropical cyclones. There are greater increases projected under RCP8.5 than under RCP2.6 from around mid-century to 2100

B5.1 **Ocean warming and changes in net primary production alter biomass, production and community structure of marine Projected ecosystems.** The global-scale biomass of marine animals across the foodweb is projected to decrease by 15.0% and the maximum catch potential of fisheries by 20.5–24.1% by the end of the 21st century relative to 1986–2005 under RCP8.5. These changes are projected to be very likely three to four times larger under RCP8.5 than RCP2.6

B5.2 Under enhanced stratification reduced nutrient supply is projected to cause tropical ocean net primary production to decline by 7–16% for RCP8.5 by 2081–2100. In tropical regions, marine animal biomass and production are projected to decrease more than the global average under all emissions scenarios in the 21st century . … Globally, the sinking flux of organic matter from the upper ocean is projected to decrease, linked largely due to changes in net primary production. As a result, 95% or more of the deep sea (3000–6000 **m depth) seafloor area and cold-water coral ecosystems are projected to experience declines in benthic (very deep sea) biomass under RCP8.5**

B5.4 Ocean warming, oxygen loss, acidification and a decrease in flux of organic carbon from the surface to the deep ocean are projected to harm habitat-forming **cold-water corals**, which support high biodiversity, partly through decreased calcification, increased dissolution of skeletons, and bioerosion. Vulnerability and risks are highest where and when temperature and oxygen conditions both reach values outside species' tolerance ranges

B6.1 **All coastal ecosystems assessed are projected to face increasing risk level, from moderate to high risk under RCP2.6 to high to very high risk under RCP8.5 by 2100.** Intertidal rocky shore ecosystems are projected to be at very high risk by 2100 under RCP8.5 due to exposure to warming, especially during marine heatwaves, as well as to acidification, sea level rise, loss of calcifying species and biodiversity. Ocean acidification challenges these ecosystems and further limits their habitat suitability by inhibiting recovery through reduced calcification and enhanced bioerosion. **The decline of kelp forests is projected to continue in temperate regions due to warming**, particularly under the projected intensification of marine heatwaves, with high risk of local extinctions under RCP8.5

B6.2 **Seagrass meadows and saltmarshes and associated carbon stores are at moderate risk at 1.5°C global warming and increase with further warming. Globally, 20–90% of current coastal wetlands are projected to be lost by 2100**, depending on projected sea level rise, regional differences and wetland types

B6.3 Ocean warming, sea level rise and tidal changes are projected to **expand salinization and hypoxia in estuaries** with high risks for some biota leading to migration, reduced survival, and local extinction under high emission scenarios. These impacts are projected to be more pronounced in more vulnerable eutrophic and shallow estuaries with low tidal range in temperate and high latitude regions

B6.4 **Almost all warm-water coral reefs** are projected to suffer significant losses of area and local extinctions, even if global warming is limited to 1.5°C

B8. Future shifts in **fish distribution and decreases in their abundance** and fisheries catch potential due to climate change are projected to affect income, livelihoods, and food security of marine resource-dependent communities. Long-term loss and degradation of marine ecosystems compromises the ocean's role in cultural, recreational, and intrinsic values important for human identity and well-being

B8.2 The decline in warm water coral reefs is projected to greatly compromise the services they provide to society, such as food provision , coastal protection and tourism . Increases in the risks for seafood security associated with decreases in seafood availability are projected to elevate the risk to nutritional health in some communities highly dependent on seafood, such as those in the Arctic, West Africa, and Small Island Developing States. Such impacts compound any risks from other shifts in diets and food systems caused by social and economic changes and climate change over land

B8.3 **Global warming compromises seafood safety** through human exposure to elevated bioaccumulation of persistent organic pollutants and mercury in marine plants and animals , increasing prevalence of waterborne Vibrio pathogens, and heightened likelihood of harmful algal blooms. These risks are projected to be particularly large for human communities with high consumption of seafood, including coastal Indigenous communities

B8.4 Climate change impacts on marine ecosystems and their services put key cultural dimensions of lives and livelihoods at risk, including through shifts in the distribution or abundance of harvested species and diminished access to fishing or hunting areas. **This includes potentially rapid and irreversible loss of culture and local knowledge and Indigenous knowledge, and negative impacts on traditional diets and food security**, aesthetic aspects, and marine recreational activities

B9. Increased mean and extreme sea level, alongside ocean warming and acidification, are projected to exacerbate risks for human communities in **low-lying coastal areas**. **Under a high emissions scenario (RCP8.5), delta regions and resource rich coastal cities are projected to experience moderate to high risk levels after 2050**

B9.**1 In the absence of more ambitious adaptation efforts compared to today, and under current trends of increasing exposure and vulnerability of coastal communities, risks, such as erosion and land loss, flooding, salinization, and cascading impacts due to mean sea level rise and extreme events are projected to significantly increase throughout this century under all greenhouse gas emissions scenarios. Under the same assumptions, annual coastal flood damages are projected to increase by 2–3 orders of magnitude by 2100 compared to today**

B9.2 High to very high risks are approached for **vulnerable communities** in coral reef environments, urban atoll islands and low-lying Arctic locations from sea level rise well before the end of this century in case of high emissions scenarios Some island nations are likely to become uninhabitable due to climate related ocean and cryosphere change

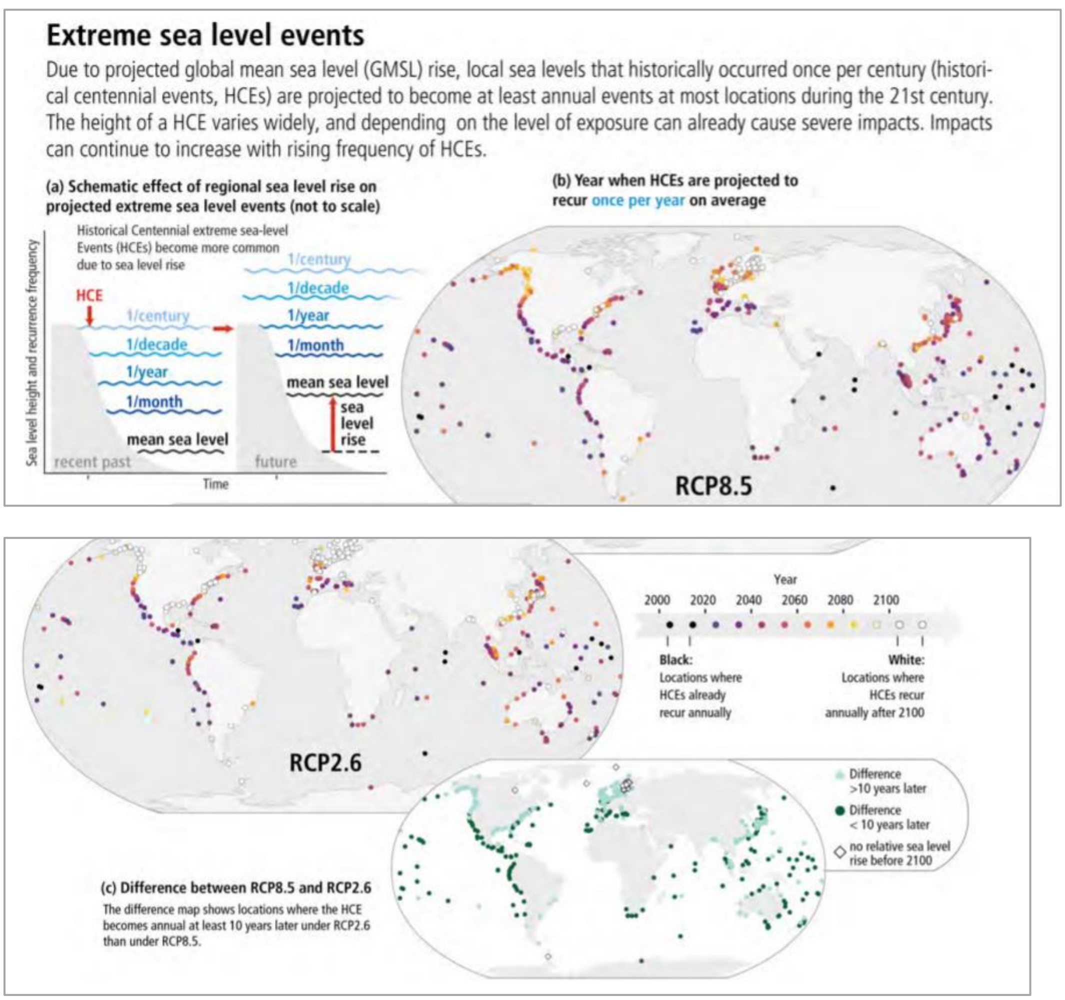


Figure SPM.4: The effect of regional sea-level rise on extreme sea level events at coastal locations

Science Chapter 1

Characteristics of ocean change include thresholds of abrupt change, long-term changes that cannot be avoided, and irreversibility. Ocean warming, acidification and deoxygenation are expected to be irreversible on time scales relevant to human societies and ecosystems. Long response times of decades to millennia mean that the ocean … committed to long-term change even after atmospheric greenhouse gas concentrations and radiative forcing stabilise.

Chapter 6 Extremes, Abrupt Changes

Satellite observations reveal that **marine heatwaves** have *very likely* doubled in frequency between 1982 and 2016, and that they have also become longer-lasting, more intense and extensive.

Marine heatwaves will further increase in frequency, duration, spatial extent and intensity under future global warming pushing some marine organisms, fisheries and ecosystems beyond the limits of their resilience, with cascading impacts on economies and societies. Globally, the frequency of marine heatwaves is *very likely* to increase by a factor of 46- 55 by 2081-2100 under the RCP8.5 scenario and by a factor of 16-24 under the RCP2.6 scenario, relative to the 1850-1900 reference period.

Extreme El Niño and La Niña events are *likely* to occur more frequently with global warming and are *likely* to intensify existing impacts, with drier or wetter responses in several regions across the globe, even at relatively low levels of future global warming

The AMOC will *very likely* weaken over the 21st century, although a collapse is *very unlikely*. Nevertheless, a substantial weakening of the AMOC remains a physically plausible scenario. Such a weakening would strongly impact natural and human systems, leading to a decrease in marine productivity in the North Atlantic, more winter storms in Europe, a reduction in Sahelian and South Asian summer rainfall, a decrease in the number of tropical cyclones in the Atlantic, and an increase in regional sea-level around the Atlantic especially along the northeast coast of North America. Such impacts would be superimposed on the global warming signal

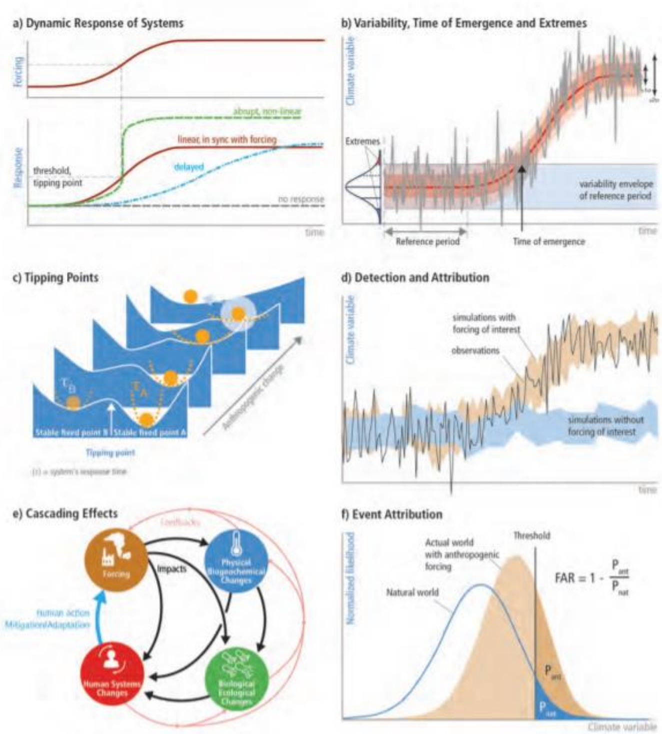


Figure 1.1: Schematic of key concepts associated with changes in the ocean and cryosphere. (a) Differing responses of systems to gradual forcing (e.g., linear, delayed, abrupt, non-linear). (b) Evolution of a dynamical system in time,