Frequently Asked Questions

FAQ

Frequently Asked Questions

These Frequently Asked Questions have been extracted from the chapters of the underlying report and are compiled here. When referencing specific FAQs, please reference the corresponding chapter in the report from where the FAQ originated (e.g., FAQ 3.1 is part of Chapter 3).

Table of contents

FAQ 1.1 | How do changes in the ocean and cryosphere affect our life on planet Earth?

The ocean and cryosphere regulate the climate and weather on Earth, provide food and water, support economies, trade and transportation, shape cultures and influence our well-being. Many of the recent changes in Earth's ocean and cryosphere are the result of human activities and have consequences on everyone's life. Deep cuts in greenhouse gas emissions will reduce negative impacts on billions of people and help them adapt to changes in their environment. Improving education and combining scientific knowledge with Indigenous knowledge and local knowledge helps communities to further address the challenges ahead.

The ocean and cryosphere – a collective name for the frozen parts of the Earth – are essential to the climate and life giving processes on our planet.

Changes in the ocean and cryosphere occur naturally, but the speed, magnitude, and pervasiveness of the global changes happening right now have not been observed for millennia or longer. Evidence shows that the majority of ocean and cryosphere changes observed in the past few decades are the result of human influences on Earth's climate.

Every one of us benefits from the role of the ocean and cryosphere in regulating climate and weather. The ocean has absorbed about a third of the carbon dioxide humans have emitted from the burning of fossil fuels since the Industrial Revolution, and the majority (more than 90%) of the extra heat within the Earth system. In this way, the ocean has slowed the warming humans and ecosystems have experienced on land. The reflective surface of snow and ice reduce the amount of the sun's energy that is absorbed on Earth. This effect diminishes as snow and ice melts, contributing to amplified temperature rise across the Arctic. The ocean and cryosphere also sustain life giving water resources, by rain and snow that come from the ocean, and by melt water from snow and glaciers in mountain and polar regions.

Nearly two billion people live near the coast, and around 800 million on land less than 10 m above sea level. The ocean directly supports the food, economies, cultures and well-being of coastal populations (see FAQ 1.2). The livelihoods of many more are tied closely to the ocean through food, trade, and transportation. Fish and shellfish contribute about 17% of the non-grain protein in human diets and shipping transports at least 80% of international imports and exports. But the ocean also brings hazards to coastal populations and infrastructure, and particularly to low-lying coasts. These populations are increasingly exposed to tropical cyclones, marine heat waves, sea level rise, coastal flooding and saltwater incursion into groundwater resources.

In high mountains and the Arctic, around 700 million people live in close contact with the cryosphere. These people, including many Indigenous Peoples, depend on snow, glaciers and sea ice for their livelihoods, food and water security, travel and transport, and cultures (see FAQ 1.2). They are also exposed to hazards as the cryosphere changes, including flood outbursts, landslides and coastal erosion. Changes in the polar and high mountain regions also have far-reaching consequences for people in other parts of the world (see FAQ 3.1).

Warming of the climate system leads to sea level rise. Melt from glaciers and ice sheets is adding to the amount of water in the ocean, and the heat being absorbed by the ocean is causing it to expand and take up more space. Today's sea level is already about 20 cm higher than in 1900. Sea level will continue to rise for centuries to millennia because the ocean system reacts slowly. Even if global warming were to be halted, it would take centuries or more to halt ice sheet melt and ocean warming.

Enhanced warming in the Arctic and in high mountains is causing rapid surface melt of glaciers and the Greenland ice sheet. Thawing of permafrost is destabilising soils, human infrastructure, and Arctic coasts, and has the potential to release vast quantities of methane and carbon dioxide into the atmosphere that will further exacerbate climate change. Widespread loss of sea ice in the Arctic is opening up new routes for shipping, but at the same time is reducing habitats for key species and affecting the livelihoods of Indigenous cultures. In Antarctica, glacier and ice sheet loss is occurring particularly quickly in places where ice is in direct contact with warm ocean water, further contributing to sea level rise.

Ocean ecosystems are threatened globally by three major climate change-induced stressors: warming, loss of oxygen and acidification. Marine heat waves are occurring everywhere across the surface ocean, and are becoming more frequent and more intense as the ocean warms. These are causing disease and mass-mortality that put, for example, coral reefs and fish populations at risk. Marine heat waves last much longer than the heat waves experienced on land, and are particularly harmful for organisms that cannot move away from areas of warm water.

Warming of the ocean reduces not only the amount of oxygen it can hold, but also tend to stratify it. As a result, less oxygen is transported to depth, where it is needed to support ocean life. Dissolved carbon dioxide that has been taken up by the ocean reacts with water molecules to increase the acidity of seawater. This makes the water more corrosive for marine organisms that build their shells and structures out of mineral carbonates, such as corals, shellfish and plankton. These climate-change stressors occur alongside other human-driven impacts, such as overfishing, excessive nutrient loads (eutrophication), and plastic pollution. If human impacts on the ocean continue unabated, declines in ocean health and services are projected to cost the global economy 428 billion USD yr^{-1} by 2050, and 1.979 trillion USD yr^{-1} by 2100.

The speed and intensity of the future risks and impacts from ocean and cryosphere change depend critically on future greenhouse gas emissions. The more these emissions can be curbed, the more the changes in the ocean and cryosphere can be slowed and limited, reducing future risks and impacts. But humankind is also exposed to the effects of changes triggered by past emissions, including sea level rise that will continue for centuries to come. Improving education and using scientific knowledge alongside local knowledge and Indigenous knowledge can support the development of context-specific options that help communities to adapt to inevitable changes and respond to challenges ahead.

FAQ 1.2 | How will changes in the ocean and cryosphere affect meeting the Sustainable Development Goals?

Ocean and cryosphere change affect our ability to meet the United Nations Sustainable Development Goals (SDGs). Progress on the SDGs support climate action that will reduce future ocean and cryosphere change, and as well as the adaptation responses to unavoidable changes. There are also trade-offs between SDGs and measures that help communities to adjust to their changing environment, but limiting greenhouse gas emissions opens more options for effective adaptation and sustainable development.

The SDGs were adopted by the United Nations in 2015 to support action for people, planet and prosperity (FAQ 1.2, Figure 1). The 17 goals and their 169 targets strive to end poverty and hunger, protect the planet and reduce gender, social and economic inequities by 2030.

SDG 13 (Climate Action) explicitly recognises that changing climatic conditions are a global concern. Climate change is already causing pervasive changes in Earth's ocean and cryosphere (FAQ 1.1). These changes are impacting food, water and health securities, with consequences for achieving SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-Being), SDG 6 (Clean Water and Sanitation), and SDG 1 (No Poverty). Climate change impacts on Earth's ocean and cryosphere also affect the environmental goals for SDG 14 (Life below Water) and SDG 15 (Life on Land), with additional implications for many of the other SDGs.

SDG 6 (Clean Water and Sanitation) will be affected by ocean and cryosphere changes. Melting mountain glaciers bring an initial increase in water, but as glaciers continue to shrink so too will the essential water they provide to millions of mountain dwellers, downstream communities, and cities. These populations also depend on water flow from the high mountains for drinking, sanitation, and irrigation, and for SDG 7 (Affordable and Clean Energy). Water security is also threatened by changes in the magnitude and seasonality of rainfall, driven by rising ocean temperatures, which increases the risk of severe storms and flooding in some regions, or the risk of more severe or more frequent droughts in other regions. Among other effects, ongoing sea level rise is allowing salt water to intrude further inland, contaminating drinking water and irrigation sources for some coastal populations. Actions to address these threats will likely require new infrastructure to manage rain, melt water, and river flow, in order to make water supplies more reliable. These actions would also benefit SDG 3 (Good Health and Well-Being) by reducing the risk of flooding and negative health outcomes posed by extreme rainfall and outbursts of glacial melt.

Climate change impacts on the ocean and cryosphere also have many implications for progress on food security that is addressed in SDG 2 (Zero Hunger). Changes in rainfall patterns caused by ocean warming will increase aridity in some areas and bring more (or more intense) rainfall to others. In mountain regions, these changes bring varying challenges for maintaining reliable crops and livestock production. Some adaptation opportunities might be found in developing strains of crops and livestock better adapted to the future climate conditions, but this response option is also challenged by the rapid rate of climate change. In the Arctic, very rapidly warming temperatures, diminishing sea ice, reduced snow cover and degradation of permafrost are restricting the habitats and migration patterns of important food sources (SDG 2 Zero Hunger), including reindeer and several marine mammals (SDG 15 Life on Land; SDG 14 Life below Water), resulting in reduced hunting opportunities for staple foods that many northern Indigenous communities depend upon.

Rising temperatures, and changes in ocean nutrients, acidity and salinity are altering SDG 14 (Life Below Water). The productivity and distributions of some fish species are changing in ways that alter availability of fish to long-established fisheries, whereas the range of fish populations may move to become available in some new coastal and open ocean areas.

Ocean changes are of concern for small island developing states and coastal cities and communities. Beyond possible reductions in marine food supply and related risks for SDG 2 (Zero Hunger), their lives, livelihoods and well-being are also threatened in ways that are linked to several SDGs, including SDG 3 (Good Health and Wellbeing), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 11 (Sustainable Cities and Communities). For example, sea level rise and warming oceans can cause inundation of coastal homes and infrastructure, more powerful tropical storms, declines in established economies such as tourism and losses of cultural heritage and identity. Improved community and coastal infrastructure can help to adapt to these changes, and more effective and faster disaster responses from health sectors and other emergency services can assist the populations who experience these impacts. In some situations, the most appropriate responses may involve relocation of critical services and, in some cases, communities; and for some populations, migration away from their homeland may become the only viable response.

FAQ 1.2, Figure 1 | The United Nations 2030 Sustainable Development Goals (SDGs).

Without transformative adaptation and mitigation, climate change could undermine progress towards achieving the 2030 SDGs, and make it more difficult to implement CRDPs in the longer term. Reducing global warming (mitigation) provides the best possibility to limit the speed and extent of ocean and cryosphere change and give more options for effective adaptation and sustainable development. Progress on SDG 4 (Quality Education), SDG 5 (Gender Equality) and SDG 10 (Reduced Inequalities) can moderate the vulnerabilities that shape people's risk to ocean and cryosphere change, while SDG 12 (Responsible Consumption and Production), SDG 16 (Peace, Justice and Institutions) and SDG 17 (Partnerships for the Goals) will help to facilitate the scales of adaptation and mitigation responses required to achieve sustainable development. Investment in social and physical infrastructure that supports adaptation to inevitable ocean and cryosphere changes will enable people to participate in initiatives to achieve the SDGs. Current and past IPCC efforts have focused on identifying CRDPs. Such adaptation and mitigation strategies, supported by adequate investments, and understanding the potential for SDG initiatives to increase the exposure or vulnerability of the activities to climate change hazards, could also constitute pathways for progress on the SDGs.

FAQ

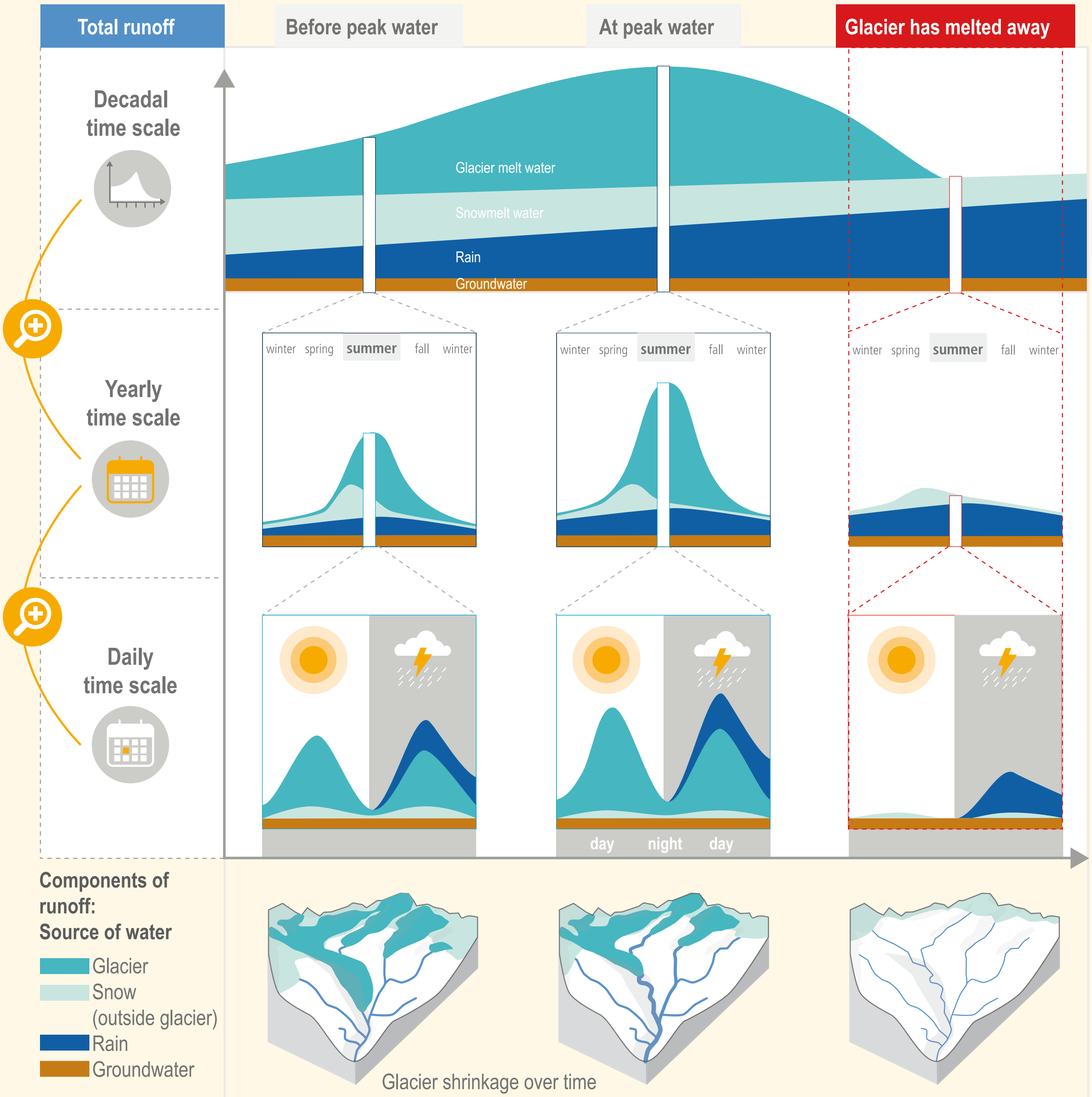
FAQ 2.1 | How does glacier shrinkage affect river runoff further downhill?

Glaciers supply water that supports human communities both close to the glacier and far away from the glacier, for example for agriculture or drinking water. Rising temperatures cause mountain glaciers to melt and change the water availability. At first, as the glacier melts, more water runs downhill away from the glacier. However, as the glacier shrinks, the water supply will diminish and farms, villages and cities might lose a valuable water source.

Melting glaciers can affect river runoff, and thus freshwater resources available to human communities, not only close to the glacier but also far from mountain areas. As glaciers shrink in response to a warmer climate, water is released from long-term glacial storage. At first, glacier runoff increases because the glacier melts faster and more water flows downhill from the glacier. However, there will be a turning point after several years or decades, often called 'peak water', after which glacier runoff and hence its contribution to river flow downstream will decline (FAQ 2.1; Figure 1). Peak water runoff from glaciers can exceed the amount of initial yearly runoff by 50% or more. This excess water can be used in different ways, such as for hydropower or irrigation. After the turning point, this additional water decreases steadily as the glacier continues to shrink, and eventually stops when the glacier has disappeared, or retreated to higher elevations where it is still cold enough for the glacier to survive. As a result, communities downstream lose this valuable additional source of water. Total amounts of river runoff will then depend mainly on rainfall, snowmelt, ground water and evaporation.

Furthermore, glacier decline can change the timing in the year and day when the most water is available in rivers that collect water from glaciers. In mid- or high latitudes, glacier runoff is greatest in the summer, when the glacier ice continues to melt after the winter snow has disappeared, and greatest during the day when air temperature and solar radiation are at their highest (FAQ 2.1, Figure 1). As peak water occurs, more intense glacier melt rates also increase these daily runoff maxima significantly. In tropical areas, such as parts of the Andes, seasonal air temperature variations are small, and alternating wet and dry seasons are the main control on the amount and timing of glacier runoff throughout the year.

The effects of glaciers on river runoff further downhill depend on the distance from the glacier. Close to the glaciers (e.g., within several kilometres), initial increases in yearly glacier runoff until peak water followed by decreases can affect water supply considerably, and larger peaks in daily runoff from the glaciers can cause floods. Further away from the glaciers the impact of glacier shrinkage on total river runoff tends to become small or negligible. However, the melt water from glaciers in the mountains can be an important source of water in hot and dry years or seasons when river runoff would otherwise be low, and thereby also reducing variability in total river runoff from year to year, even hundreds of kilometres away from the glaciers. Other components of the water cycle such as rainfall, evaporation, groundwater and snowmelt can compensate or strengthen the effects of changes in glacier runoff as the climate changes.



FAQ 2.1, Figure 1 | A simplified overview of changes in runoff from a river basin with large (e.g., >50%) glacier cover as the glaciers shrink, showing the relative amounts of water from different sources – glaciers, snow (outside the glacier), rain and groundwater. Three different time scales are shown: annual runoff from the entire basin (upper panel); runoff variations over one year (middle panel) and variations during a sunny then a rainy summer day (lower panel). Note that seasonal and daily runoff variations are different before, during and after peak flow. The glacier's initial negative annual mass budget becomes more negative over time until eventually the glacier has melted away. This is a simplified figure so permafrost is not addressed specifically and the exact partitioning between the different sources of water will vary between river basins.

FAQ

FAQ 3.1 | How do changes in the Polar Regions affect other parts of the world?

Climate change in the Arctic and Antarctic affect people outside of the polar regions in two key ways. First, physical and ecosystem changes in the polar regions have socioeconomic impacts that extend across the globe. Second, physical changes in the Arctic and Antarctic influence processes that are important for global climate and sea level.

Among the risks to societies and economies, aspects of food provision, transport and access to non-renewable resources are of great importance. Fisheries in the polar oceans support regional and global food security and are important for the economies of many countries around the world, but climate change alters Arctic and Antarctic marine habitats, and affects the ability of polar species and ecosystems to withstand or adapt to physical changes. This has consequences for where, when, and how many fish can be captured. Impacts will vary between regions, depending on the degree of climate change and the effectiveness of human responses. While management in some polar fisheries is among the most developed, scientists are exploring modifications to existing precautionary, ecosystem-based management approaches to increase the scope for adaptation to climate change impacts on marine ecosystems and fisheries.

New shipping routes through the Arctic offer cost savings because they are shorter than traditional passages via the Suez or Panama Canals. Ship traffic has already increased and is projected to become more feasible in the coming decades as further reductions in sea ice cover make Arctic routes more accessible. Increased Arctic shipping has significant socioeconomic and political implications for global trade, northern nations and economies strongly linked to traditional shipping corridors, while also increasing environmental risk in the Arctic. Reduced Arctic sea ice cover allows greater access to offshore petroleum resources and ports supporting resource extraction on land.

The polar regions influence the global climate through a number of processes. As spring snow and summer sea ice cover decrease, more heat is absorbed at the surface. There is growing evidence that ongoing changes in the Arctic, primarily sea ice loss, can potentially influence mid-latitude weather. As temperatures increase in the Arctic, permafrost soils in northern regions store less carbon. The release of carbon dioxide and methane from the land to the atmosphere further contributes to global warming.

Melting ice sheets and glaciers in the polar regions cause sea levels to rise, affecting coastal regions and their large populations and economies. At present, the Greenland Ice Sheet (GIS) and polar glaciers are contributing more to sea level rise than the Antarctic Ice Sheet (AIS). However, ice loss from the AIS has continued to accelerate, driven primarily by increased melting of the underside of floating ice shelves, which has caused glaciers to flow faster. Even though it remains difficult to project the amount of ice loss from Antarctica after the second half of the 21st century, it is expected to contribute significantly to future sea level rise.

The Southern Ocean that surrounds Antarctica is the main region globally where waters at depth rise to the surface. Here, they become transformed into cold, dense waters that sink back to the deep ocean, storing significant amounts of human-produced heat and dissolved carbon for decades to centuries or longer, and helping to slow the rate of global warming in the atmosphere. Future changes in the strength of this ocean circulation can so far only be projected with limited certainty.

FAQ 4.1 | What challenges does the inevitability of sea level rise present to coastal communities and how can communities adapt?

As the global climate changes, rising sea levels, combined with high tides, storms and flooding, put coastal and island communities increasingly at risk. Protection can be achieved by building dikes or seawalls and by maintaining natural features like mangroves or coral reefs. Communities can also adjust by reclaiming land from the sea and adapting buildings to cope with floods. However, all measures have their limits, and once these are reached people may ultimately have to retreat. Choices made today influence how coastal ecosystems and communities can respond to sea level rise (SLR) in the future. Reducing greenhouse gas (GHG) emissions would not just reduce risks, but also open up more adaptation options.

Global Mean Sea Level (GMSL) is rising and it will continue to do so for centuries. Sustainable development aspirations are at risk because many people, assets and vital resources are concentrated along low-lying coasts around the world. Many coastal communities have started to consider the implications of SLR. Measures are being taken to address coastal hazards exacerbated by rising sea level, such as coastal flooding due to extreme events (e.g. storm surges, tropical cyclones, coastal erosion and salinisation). However, many coastal communities are still not sufficiently adapted to today's ESLs.

Scientific evidence about SLR is clear: GMSL rose by 1.5 mm yr^{-1} during the period 1901–1990, accelerating to 3.6 mm yr^{-1} during the period 2005–2015. It is likely to rise 0.61–1.10 m by 2100 if global GHG emissions are not mitigated (RCP8.5). However, a rise of two or more metres cannot be ruled out. It could rise to more than 3 m by 2300, depending on the level of GHG emissions and the response of the AIS, which are both highly uncertain. Even if efforts to mitigate emissions are very effective, ESL events that were rare over the last century will become common before 2100, and even by 2050 in many locations. Without ambitious adaptation, the combined impact of hazards like coastal storms and very high tides will drastically increase the frequency and severity of flooding on low-lying coasts.

SLR, as well as the context for adaptation, will vary regionally and locally, thus action to reduce risks related to SLR takes different forms depending on the local circumstances. 'Hard protection', like dikes and seawalls, can effectively reduce risk under two or more metres of SLR but it is inevitable that limits will be reached. Such protection produces benefits that exceed its costs in low-lying coastal areas that are densely populated, as is the case for many coastal cities and some small islands, but in general, poorer regions will not be able to afford hard protection. Maintaining healthy coastal ecosystems, like mangroves, seagrass beds or coral reefs, can provide 'soft protection' and other benefits. SLR can also be 'accommodated' by raising buildings on the shoreline, for example. Land can be reclaimed from the sea by building outwards and upwards. In coastal locations where the risk is very high and cannot be effectively reduced, 'retreat' from the shoreline is the only way to eliminate such risk. Avoiding new development commitments in areas exposed to coastal hazards and SLR also avoids additional risk.

For those unable to afford protection, accommodation or advance measures, or when such measures are no longer viable or effective, retreat becomes inevitable. Millions of people living on low-lying islands face this prospect, including inhabitants of Small Island Developing States (SIDS), of some densely populated but less intensively developed deltas, of rural coastal villages and towns, and of Arctic communities who already face melting sea ice and unprecedented changes in weather. The resultant impacts on distinctive cultures and ways of life could be devastating. Difficult trade-offs are therefore inevitable when making social choices about rising sea level. Institutionalising processes that lead to fair and just outcomes is challenging, but vitally important.

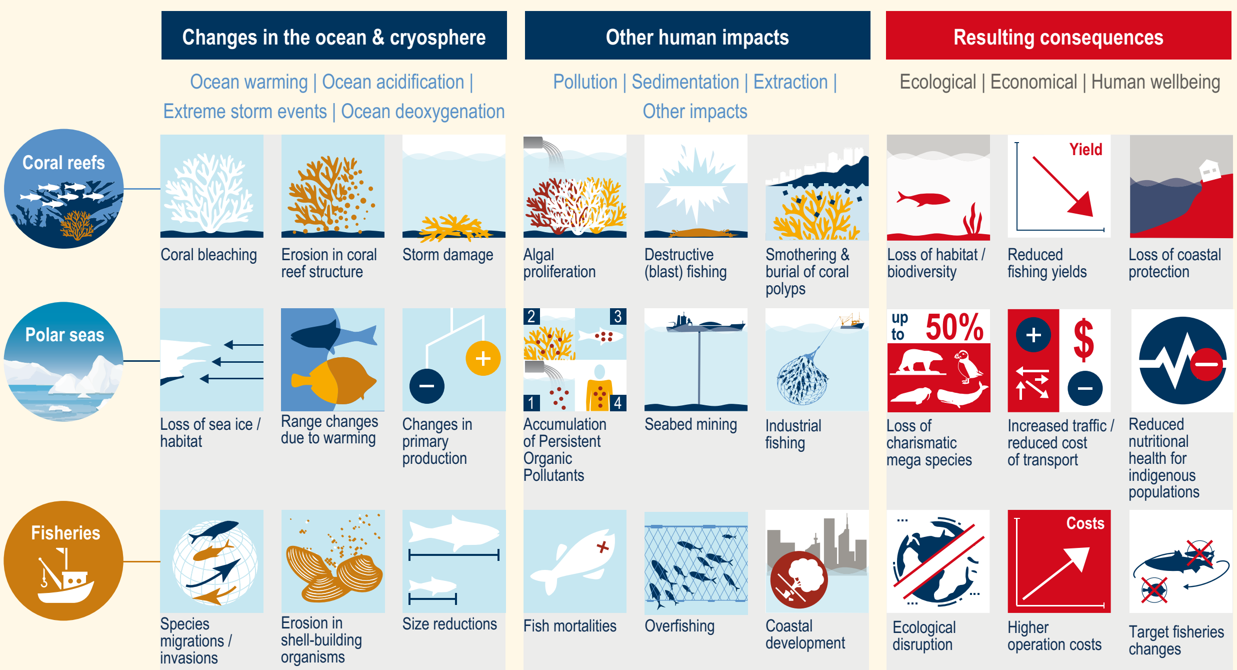
Choices being made now about how to respond to SLR profoundly influence the trajectory of future exposure and vulnerability to SLR. If concerted emissions mitigation is delayed, risks will progressively increase as SLR accelerates. Prospects for global climate-resilience and sustainable development therefore depend in large part on coastal nations, cities and communities taking urgent and sustained locally-appropriate action to mitigate GHG emissions and adapt to SLR.

FAQ 5.1 | How is life in the sea affected by climate change?

Climate change poses a serious threat to life in our seas, including coral reefs and fisheries, with impacts on marine ecosystems, economies and societies, especially those most dependent upon natural resources. The risk posed by climate change can be reduced by limiting global warming to no more than 1.5°C.

Life in most of the global ocean, from pole to pole and from sea surface to the abyssal depths, is already experiencing higher temperatures due to human-driven climate change. In many places, that increase may be barely measurable. In others, particularly in near-surface waters, warming has already had dramatic impacts on marine animals, plants and microbes. Due to closely linked changes in seawater chemistry, less oxygen remains available (in a process called ocean deoxygenation). Seawater contains more dissolved carbon dioxide, causing ocean acidification. Non-climatic effects of human activities are also ubiquitous, including over-fishing and pollution. Whilst these stressors and their combined effects are likely to be harmful to almost all marine organisms, food-webs and ecosystems, some are at greater risk (FAQ5.1, Figure 1). The consequences for human society can be serious unless sufficient action is taken to constrain future climate change.

Warm water coral reefs host a wide variety of marine life and are very important for tropical fisheries and other marine and human systems. They are particularly vulnerable, since they can suffer high mortalities when water temperatures persist above a threshold of between 1°C–2°C above the normal range. Such conditions occurred in many tropical seas between 2015 and 2017 and resulted in extensive coral bleaching, when the coral animal hosts ejected the algal partners upon which they depend. After mass coral mortalities due to bleaching, reef recovery typically takes at least 10–15 years. Other impacts of climate change include SLR, acidification and reef erosion. Whilst some coral species are more resilient than others, and impacts vary between regions, further reef degradation due to future climate change now seems inevitable, with serious consequences for other marine and coastal ecosystems, like loss of coastal protection for many islands and low-lying areas and loss of the high biodiversity these reefs host. Coral habitats can also occur in deeper waters and cooler seas, and more research is needed to understand impacts in these reefs. Although these cold water corals are not at risk from bleaching, due to their cooler environment, they may weaken or dissolve under ocean acidification, and other ocean changes.



FAQ5.1, Figure 1 | Summary schematic of the impacts and resulting consequences of climate change (warming, acidification, storminess and deoxygenation) and other human impacts, on coral reefs, polar seas and fisheries, discussed in this FAQ.

FAQ

Mobile species, such as fish, may respond to climate change by moving to more favorable regions, with populations shifting poleward or to deeper water, to find their preferred range of water temperatures or oxygen levels. As a result, projections of total future fishery yields under different climate change scenarios only show a moderate decrease of around 4% (~3.4 million tonnes) per degree Celsius warming. However, there are dramatic regional variations. With high levels of climate change, fisheries in tropical regions could lose up to half of their current catch levels by the end of this century. Polar catch levels may increase slightly, although the extent of such gains is uncertain, because fish populations that are currently depleted by overfishing and subject to other stressors may not be capable of migrating to polar regions, as assumed in models.

In polar seas, species adapted to life on or under sea ice are directly threatened by habitat loss due to climate change. The Arctic and Southern Oceans are home to a rich diversity of life, from tiny plankton to fish, krill and seafloor invertebrates to whales, seals, polar bears or penguins. Their complex interactions may be altered if new warmer-water species extend their ranges as sea temperatures rise. The effects of acidification on shelled organisms, as well as increased human activities (e.g., shipping) in ice-free waters, can amplify these disruptions.

Whilst some climate change impacts (like possible increased catch levels in polar regions) may benefit humans, most will be disruptive for ecosystems, economies and societies, especially those that are highly dependent upon natural resources. However, the impacts of climate change can be much reduced if the world as a whole, through inter-governmental interventions, manages to limit global warming to no more than 1.5°C.

FAQ 6.1 | How can risks of abrupt changes in the ocean and cryosphere related to climate change be addressed?

Reducing greenhouse gas (GHG) emissions will reduce the occurrence of extreme events and the likelihood of abrupt changes. Abrupt changes can be irreversible on human time scales and, as tipping points, bring natural systems to novel conditions. To reduce risks that emerge from these impacts of climate change, communities can protect themselves or accommodate to the new environment. In the last resort, they may retreat from exposed areas. Governance that builds on diverse expertise and considers a variety of actions is best equipped to manage remaining risks.

Climate change is projected to influence extreme events and to potentially cause abrupt changes in the ocean and the cryosphere. Both these phenomena can add to the other, slow-onset impacts of climate change, such as a global warming or sea level rise (SLR). In addition, abrupt changes can be tipping points, bringing the ocean, cryosphere, as well as their ecosystems, or the whole climate system, to new conditions instead or going back to the ones prevailing before the abrupt change.

In the ocean, a possible abrupt change is associated with an interruption of the Atlantic Meridional Overturning Circulation (AMOC), an important component of global ocean circulation. A slowdown of the AMOC could have consequences around the world: rainfall in the Sahel region could reduce, hampering crop production; the summer monsoon in Asia could weaken; regional SLR could increase around the Atlantic, and there might be more winter storms in Europe. The collapse of the West Antarctic Ice Sheet (WAIS) is considered to be one of the tipping points for the global climate. Such an event can be triggered when ice shelves break and ice flows towards the ocean. While, in general, it is difficult to assess the probability of occurrence of abrupt climate events they are physically plausible events that could cause large impacts on ecosystems and societies and may be irreversible.

Reducing GHG emissions is the main action to limit global warming to acceptable levels and reduce the occurrence of extreme events and abrupt changes. However, in addition to mitigation, a variety of measures and risk management strategies supports adaptation to future risks. Future risks linked to abrupt changes are strongly influenced by local conditions and different characteristics of the events themselves and evolve differently depending on the circumstances. One major factor for adaptation is whether the extreme events will simply amplify the known impacts or whether they will cause completely new conditions, which may be related to a tipping point. Another essential factor is whether an extreme event or abrupt change will happen in isolation or in conjunction with other events, in a chain of cascading impacts or as part of a compound risk where several events happen at the same time so that impacts can multiply each other. Also, impacts are heavily aggravated by increasing exposure and changes in vulnerability, for example reducing the availability of food, water and energy supply, and not just the occurrence of extremes themselves.

Successful management of extreme events and abrupt changes in the ocean and cryosphere involves all available resources and governance approaches, including among others land-use and spatial planning, indigenous knowledge and local knowledge. The management of the risks to ecosystems include their preservation, the sustainable use of resources and the recognition of the value of ecosystem services. There are three general approaches that, alone or in combination, can enable communities to adapt to these events: retreat from the area, accommodation to new conditions and protection. All have advantages and limitations and their success will depend on the specific circumstances and the community's level of adaptability. But only transformative governance that integrates a variety of strategies and benefits from institutional change helps to address larger risks posed by compound events. Integrating risk-reduction approaches into institutional practices and inclusive decision making that builds on the respective competences of different government agencies and other stakeholders can support management of these extremes. A change of lifestyles and livelihoods might further support the adaptation to new conditions.