Climate information relevant for Marine Ecosystems, Fisheries and Aquaculture

Marine ecosystems encompass coastal land; intertidal and upwelling zones; coastal, shelf and polar seas; the open ocean; and deep seas. {WG II, Chapter 3} The fisheries and aquaculture systems include food, fibre and other ecosystem products, and refer to industrial and artisanal fishing, harvesting wild fish and other aquatic organisms, and the farming of aquatic organisms. {WG II, Chapter 5} This fact sheet is focused on the marine environment, and information for freshwater systems is provided in the fact sheet for terrestrial and freshwater ecosystems.

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***Impacts and adaptation options** for marine ecosystems, fisheries and aquaculture are assessed in the WGII Report Chapters 3 and 5 {3.2, 3.3, 3.5, 3.6 CCB; 5.8 CCB}, and their mitigation options are assessed in WGIII Report Chapters 4, 7, 11, and 12. {SPM C11.1; TS 5.7; 4.4.2; 7.4.2; 11.4.4; 12.3.1; 12.4.1; 12.4.3}*

Types of climatic impact-drivers (CIDs) that are of high relevance for the sectors addressed in this fact sheet are: Heat and Cold, Snow and Ice, and Coastal and Oceanic. Oceanic CIDs can have implications for marine ecosystems from coral bleaching; changes in phytoplankton blooms; and migration, growth, reproduction and survival of marine and aquatic organisms; with implications for fisheries and aquaculture. {WGI: Chapter 5 ES; 5.3.5; Chapter 9, Box 9.2; 12.3.6.1; 12.3.6.3} Coastal CIDs can affect coastal ecosystems, fisheries, aquaculture and tourism. {WG1: 12.3.5.2; WGII: Chapter 3, 3.6, Chapter 5, 5.8; 5.9} Heat and cold CIDs can affect freshwater species ranges, ecosystem health and aquaculture suitability {WGI: 12.3.1.1; WGII: Chapter 5, 5.9}.

COASTAL CIDs with high relevance for marine ecosystems include relative sea level, coastal flooding and coastal erosion. Coastal flooding in coastal land and intertidal zones is also highly relevant for fisheries and aquaculture systems.

- Uncertainty in the timing of reaching different levels of global mean sea level rise is an important consideration for adaptation planning. {9.6.3}
- It is *very likely* to *virtually certain* that regional mean relative sea level rise will continue throughout the 21st century, except in a few regions with substantial geologic land uplift rates. Due to relative sea level rise, extreme sea level events that occurred once per century in the recent past are projected to occur at least annually at more than half of all tide gauge locations by 2100 (*high confidence*). {SPM C.2.5}

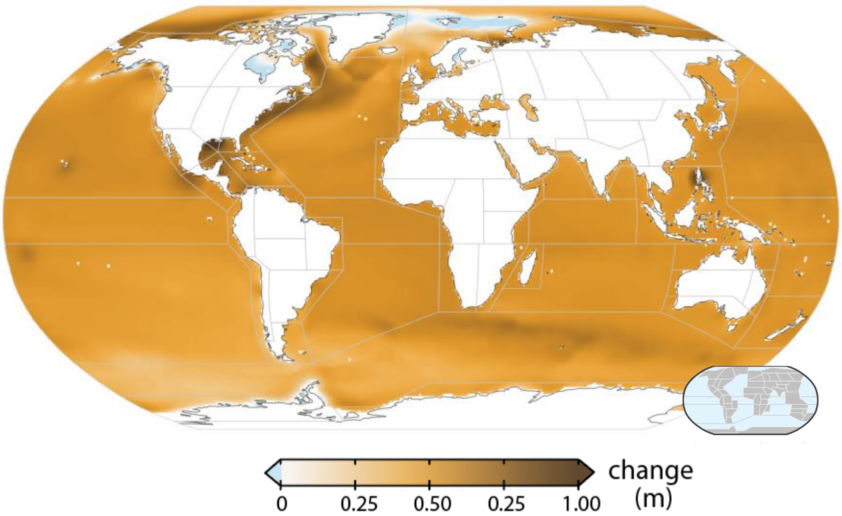
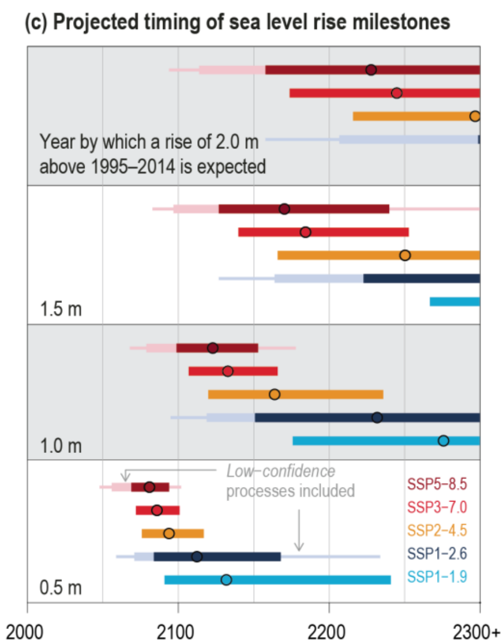


Figure 1: CMIP6 – Projected sea level rise for 2081–2100 (relative to 1995–2014) for intermediate (SSP2-4.5) emissions scenario {Interactive Atlas}.

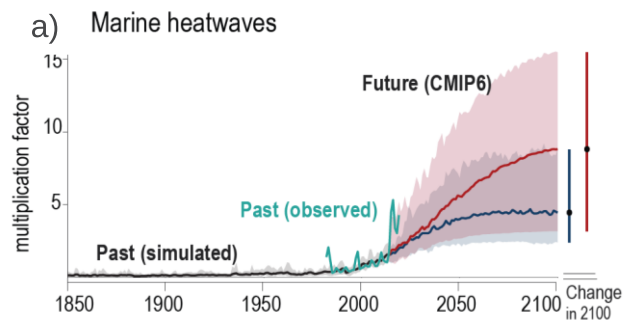


- Relative sea level rise contributes to increases in the frequency and severity of coastal flooding in low-lying areas and to coastal erosion along most sandy coasts (*high confidence*). A vast majority of the world's regions are projected to experience an increase in coastal flooding throughout the 21st century (*high confidence*). {SPM C.2.5; Table TS.5, 12.4}

Figure 2: Timing of exceedance of global mean sea level thresholds of 0.5, 1.0, 1.5 and 2.0 m, under different SSPs. Lightly shaded thick/thin bars show 17th–83rd/5th–95th percentile *low confidence* ranges for SSP1-2.6 and SSP5-8.5. {TS Box 4, Figure 1} {4.3.2, 9.6.1, 9.6.2, 9.6.3, Box 9.4}

OCEANIC CIDs with high relevance for all parts of marine ecosystems include ocean temperature, marine heatwaves, and ocean acidification and can be relevant for fisheries and aquaculture systems. Dissolved oxygen is of high relevance for coastal and shelf seas and upwelling zones.

- It is *virtually certain* that the global upper ocean (0–700 m) has warmed since the 1970s. Marine heatwaves have approximately doubled in frequency since the 1980s (*high confidence*), and their frequency will continue to increase (*high confidence*) {SPM A.3.1; SPM A.1.6; SPM B.2.3}
- It is *virtually certain* that surface sea water pH has declined globally over the last 40 years, which is one of the major processes indicating ocean acidification takes place. There is *high confidence* that oxygen levels have dropped in many upper ocean regions since the mid-20th century {SPM A.1.6; TS.2.4}
- Past greenhouse gas emissions since 1750 have committed the global ocean to future warming (*high confidence*), and ocean acidification (*virtually certain*) and ocean deoxygenation (*high confidence*) will continue to increase in the 21st century at rates dependent on future emissions. Changes are irreversible at centennial to millennial time scales in global ocean temperature (*very high confidence*), deep ocean acidification (*very high confidence*) and deoxygenation (*medium confidence*). {SPM B.5.1}



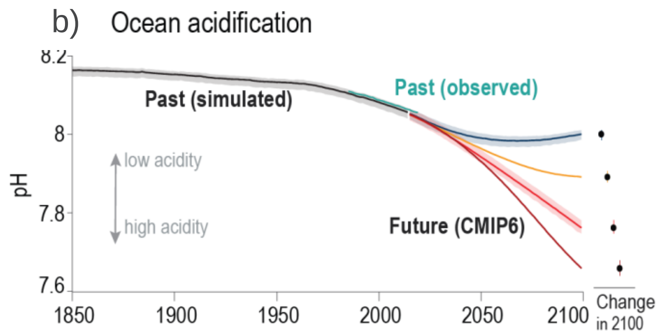


Figure 3: Past and future change in a) marine heatwave days and b) ocean surface pH under varying greenhouse gas emissions scenarios {Figure TS.11}

SNOW and ICE CIDs with potential relevance for marine ecosystems include sea ice in polar seas.

- In 2011–2020, annual average Arctic sea ice area reached its lowest level since at least 1850 (*high confidence*). Since the late 1970s, Arctic sea ice area and thickness have decreased in both summer and winter, with sea ice becoming younger, thinner and more dynamic (*very high confidence*). {SPM A.2.3; TS.2.5}
- The Arctic is likely to be practically sea ice free in September at least once before 2050 under the five illustrative scenarios considered, with more frequent occurrences for higher warming levels. There is *low confidence* in the projected decrease of Antarctic sea ice. {SPM B.2.5}

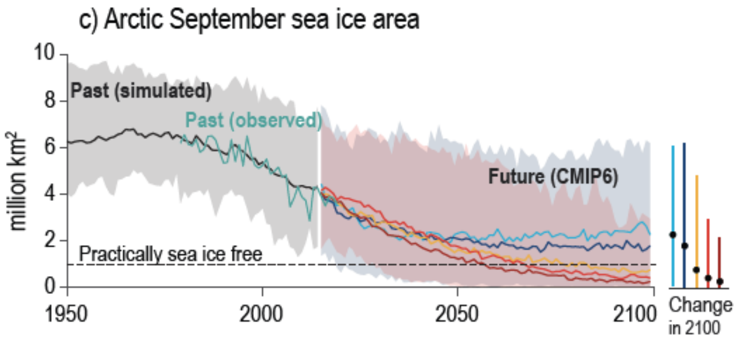


Figure 4: Past and future change in September Arctic sea ice area under varying greenhouse gas emissions scenarios {Figure TS.8}.

HEAT and COLD CIDs with high potential relevance for marine ecosystems include surface temperature for coastal land and intertidal zones.

- Compared to 1850–1900, global surface temperature was 1.1°C higher in 2011–2020 and will *very likely* be higher in 2081–2100, for example by 2.1°C–3.5°C in the intermediate scenario (SSP2-4.5). {SPM A.1.2, SPM B.1.1}
- It is *virtually certain* that hot extremes have become more frequent and more intense across most land regions since the 1950s, and vice versa for cold extremes. Some mid-latitude and semi-arid regions, and the South American Monsoon region, are projected to see the highest increase in the temperature of the hottest days (*high confidence*), and the Arctic is projected to experience the highest increase in the temperature of the coldest days (*high confidence*). {SPM A.3.1, SPM B.2.3}