Summary report on the SBSTA–IPCC special event: Unpacking the new scientific knowledge and key findings in the IPCC Special Report on the Ocean and Cryosphere

Madrid, Spain, 5 December 2019

Note by the Chairs of the SBSTA and the IPCC

20 May 2020

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I. Introduction

A. Background

1. The Intergovernmental Panel on Climate Change (IPCC) adopted a special report on the Ocean and Cryosphere in a Changing Climate (SROCC) and the SROCC's Summary for Policymakers (SPM) at the Second Joint Session of Working Groups I and II of the IPCC held on 20–23 September 2019, Principality of Monaco. The SROCC's Summary for Policymakers (SPM) was accepted by the IPCC at its 51st Session on the 24th September 2019.[1]

2. The decision to prepare the SROCC was taken at the IPCC's 43rd Session (Nairobi, April 2016), as part of the Sixth Assessment cycle. The SROCC was prepared under the joint scientific leadership of Working Group I and Working Group II, with operational support from the Working Group II Technical Support Unit. In line with the approved outline, mitigation options are not assessed with the exception of the mitigation potential of blue carbon (coastal ecosystems).

3. The SROCC was the result of substantial effort by the IPCC, entailing the collaborative work of 104 authors and review editors from 36 countries, 19 of which were from developing countries or economies in transition. The drafts of the report received 31,176 comments from 80 countries and the EU. The final draft of the report references 6,891 publications.

4. The SROCC assesses the latest scientific knowledge about the physical science basis and impacts of climate change on ocean, coastal, polar and mountain ecosystems, and the human communities that depend on them. Their vulnerabilities as well as adaptation capacities are also evaluated. Options for achieving climate-resilient development pathways are presented as well.

B. General objective and approach for the special event

5. The joint SBSTA-IPCC special event on the SROCC[2] was organized by Mr. Paul Watkinson, the Chair of the Subsidiary Body for Scientific and Technological Advice (SBSTA), and Mr. Hoesung Lee, the Chair of the IPCC. The event was organized to generate a better understanding of the key scientific findings of the SROCC through an open exchange of views between Parties and IPCC experts by unpacking the new scientific concepts and definitions used in the special report. It was also an opportunity to identify research gaps and clarify uncertainties associated with specific findings. In return, it was expected that the special event would assist the IPCC and the scientific community in identifying areas of interest to policymakers to be further developed in future publications and IPCC products.

6. In the lead up to the special event, the Chairs of the SBSTA and the IPCC issued an information note[3] which provided background information on the SRCCL and proposed an approach for the special event, including guiding questions for participants and presenters to consider when preparing for the event.

7. The agenda of the special event, following an introduction and welcome section, was focused on four aspects to unpack the new scientific knowledge and key findings:

(a) Hazards from Changes in High Mountains and Permafrost;

(b) Hazards from Changes in the Cryosphere and the Ocean from Sea Level Rise;

(c) From Risk Assessment to Adaptation and Nature-based Solution Options: Ecosystems and Human Societies;

(d) From Response Options to Governance and Policies.

1 See https://www.ipcc.ch/event/second-joint-session-of-ipcc-working-groups-i-and-ii-and-ipcc-51/.
2 See https://unfccc.int/event/srocc-special-event.
3 Available at https://unfccc.int/sites/default/files/resource/SROCC_InfoNote_SBSTA_IPCC_6Nov2019.pdf.

II. Summary of the special event

8. The special event was held during SBSTA 51 in Madrid, Spain, on the 5 December 2019 from 15:00 to 18:00 in Plenary Loa.[4] The event was open to all attendees at COP 25, and webcast.[5] The event was jointly chaired by the SBSTA and IPCC Chairs. The SBSTA rapporteur, Stella Gama (Malawi) took over chairing from the Chair of SBSTA for the latter part of the event.

A. Opening

9. The Chair of the SBSTA, Mr. Paul Watkinson, welcomed all participants to the special event.

10. The IPCC trailer on the SROCC was presented at the opening of the session.[6]

11. Mr. Watkinson congratulated the IPCC on the release of the SROCC and introduced the IPCC Co-Chairs Mr. Panmao Zhai and Ms. Valerie Masson Delmotte of Working Group I, and Mr Hans-Otto Pörtner and Ms. Debra Roberts of Working Group II. Mr. Watkinson conveyed his gratitude on behalf of the SBSTA to Mr. Lee and the IPCC for their continuing work as trusted providers and assessors of the best available science. He recalled that the IPCC has delivered two Special Reports in 2019: the SROCC and the Special Report on Climate Change and Land[7] and continues work on the Sixth Assessment Report (AR6).

12. Mr. Watkinson introduced Mr. Andrés Couve, the Minister for Science, Technology, Knowledge and Innovation of Chile, and Mr. Ovais Sarmad, UNFCCC Deputy Executive Secretary, who gave opening statements.

13. Mr. Couve noted that while observed changes described in the SROCC are worrying, the projected changes are more worrying still. He emphasised that this should not paralyze us and that now is not the time for apocalyptic visions, but for building the opportunities based on science, technology and innovation. From the joint work of scientists and policy-makers, governments can better achieve their social, economic, and environmental goals by promoting science and a broad range of technologies through mission-driven innovation and policies. He outlined that the ocean is a large part of the Chilean identity and that the Chilean presidency has followed its own 'Time for Action' call. This includes launching the Platform for Ocean Based Solutions; convening a virtual meeting of Science Ministers from eighteen countries during COP 25; updating the Chilean NDC to include the ocean as an integrated pillar of mitigation and adaptation action; and building long-term planning with the United Kingdom of Great Britain and Northern Ireland, Monaco, and other governments to include the oceans as a central aspect of discussions and actions.

14. Mr. Sarmad emphasised that the IPCC provides the scientific basis on which the efforts of the UNFCCC process, including at COP, are built. He highlighted that the oceans are part of the climate system, and the protection of oceans in the context of climate change is included in the Convention, the Cancun Agreement and the Paris Agreement. COP25 is being held at a crucial time for the oceans. Global attention is turning to the impacts of climate change on the services that the oceans provide. With Parties working on their revised NDCs for 2020, this Report provides evidence to help Parties to increase their ambition including action for the ocean.

15. Mr. Lee concluded the opening session by providing a short summary of the topics of SROCC, the implications of its findings for human society within the natural world and how these findings inform action.

16. Mr. Lee reflected that, with the publication of the Special Report on Global Warming of 1.5° C, the Special Report on Climate Change and Land, the SROCC and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, this marks the most intensive and ambitious period in the IPCC's 31-year history.

17. Together with the Special Report on Climate Change and Land, SROCC complements the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) Global Assessment Report on Biodiversity and Ecosystem Services.

18. The chapter structure of the Report follows water in all its states from glacier and high-mountain sources the ice sheets in the polar regions and to the deep ocean. The Report addresses sea level rise and how this impacts coastal and island communities. Mr. Lee highlighted that for the first time the IPCC has produced an in-depth report examining the farthest corners of the Earth, from the highest mountains to remote polar regions and to the deep oceans. Even, and especially, in these places, human-caused climate change is evident. The Summary for

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[4] See https://unfccc.int/event/srocc-special-event.
[5] The webcast can be viewed at https://unfccc-cop25.streamworld.de/webcast/joint-sbsta-ipcc-special-event-special-report-on-t.
[6] Available at https://www.youtube.com/watch?v=CU3_NDklRVM.
[7] See https://www.ipcc.ch/srccl/.

Policymakers (SPM) covers the observed changes and impacts to the projected changes and risks and considers the response options (figure 1). He conveyed that the structure of the SPM shaped the agenda of the special event.

19. Mr. Lee concluded the opening by stating that the SROCC reports on the melting of high mountain glaciers and polar ice sheets, which contain the fresh water for our cultures and future. The report documents the thawing of permafrost, the frozen foundation of Northern communities. It highlights coastal and low-lying areas where the impacts of sea level rise threaten the livelihoods and lives of large segments of the population. It documents the ways in which for decades the ocean has absorbed CO_2 from the atmosphere to regulate the global temperature but can no longer keep up. In sum, this shows the ocean and cryosphere have been ‘taking the heat’ for decades. The consequences for nature and humanity are severe.

20. The report highlights the urgent need for timely, ambitious, and enduring action. It outlines that the health of ecosystems, of wildlife, and of the world we leave our children is at stake. The ocean and cryosphere might feel remote, but they impact us all, be that for climate, food and water, energy, trade and transport, health and wellbeing, or for culture and identity. The ocean and cryosphere are critical to all life on Earth. This report shows that if greenhouse gases continue to increase, **global warming will drastically alter the ocean and cryosphere**. If emissions are sharply reduced, consequences for people and their livelihoods will still prove challenging but will be potentially more manageable for those who are more vulnerable. There are benefits of ambitious and effective adaptation for development. Conversely, there are risks associated with delayed action.

Figure 1
The front and back covers of the Summary for Policymakers.

Source: Slide 5 of the full presentation by the IPCC during the special event.

B. Presentations by experts to unpack the new scientific knowledge and key findings

1. Hazards from changes in high mountains and permafrost

21. Mr. Panmao Zhai, Co-Chair of the IPCC Working Group I, opened by providing some background information for the presentation, highlighting that the two emission scenarios used in the presentation were RCP 2.6 and RCP 8.5, although the underlying report covers more scenarios reflecting the available literature. RCP 2.6 is a low greenhouse gas (GHG) emission, high mitigation scenario that in five simulations indicated a two in three chance of limiting global warming to below 2° C by 2100. In contrast, RCP 8.5 is a high GHG scenario that does not incorporate policies to combat climate change and leads to continued and sustained growth in atmospheric GHG concentrations.

22. Mr. Zhai presented on the **observed and projected effects of climate change on mountain cryosphere**. Mountain glaciers snow and ice and the thawing permafrost are very visible symbols of climate change. A total of 670 million people in high mountain regions and hundreds of millions more elsewhere are dependent on water from the mountain cryosphere. These people are increasingly exposed to hazards, including changes in water availability, due to changes in the mountain cryosphere.

23. Ice mass loss of glaciers in all mountain regions was about 123 gigatonnes (Gt) per year from 2006 to 2015. In nearly all high mountain regions the depth, extent and duration of snow cover has declined over recent decades, particularly in lower elevation areas. Permafrost temperatures averaged across polar and high mountain regions have increased to record high levels from the 1980s to the present.

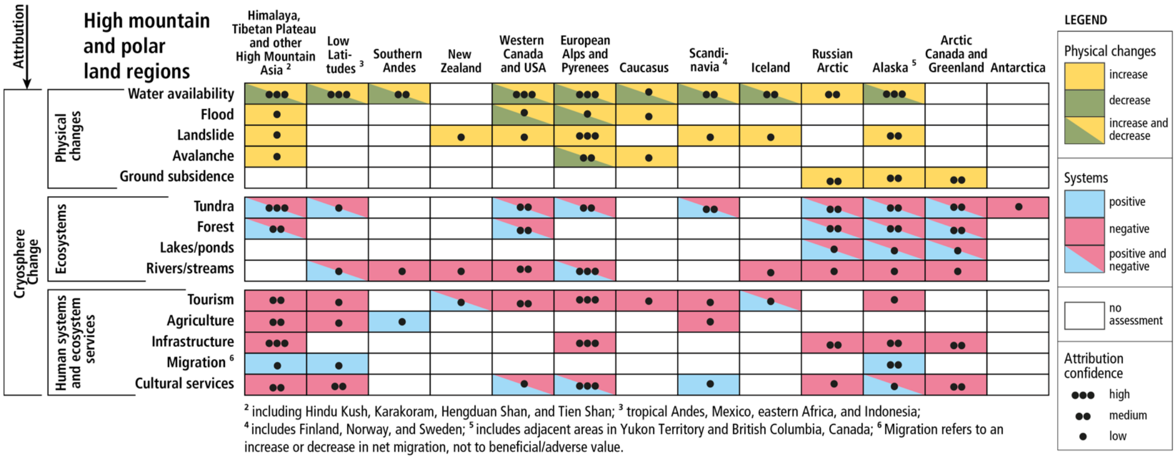
24. Consequently, glacier snow and permafrost decline has **altered the frequency, magnitude, and location of most related natural hazards** such as landslides, avalanches, floods, ground subsidence and wildfires in many high mountains regions (figure 2, physical changes).

25. At the same time, the exposure of people and infrastructure to natural hazards has increased due to increased populations, tourism and socioeconomic development. Some disasters have been linked to changes in the mountain cryosphere in, for example, the Andes' high mountain glaciers, the Caucuses and the Europeans Alps. Impacts have also been observed on ecosystems such as the tundra, and on forests, lakes, rivers and on human systems such as tourism, agriculture, infrastructure, migration, cultural services and ecosystem services.

Section 1. Source: Slide 5 of the full presentation by the IPCC during the special event. *Photo*: Yungdrung Tsewang.

26. The reduction in glaciers, permafrost and snow cover alters the land and the freshwater habitats of mountain vegetation and wildlife. Lower elevation vegetation and wildlife have extended upslope and become established in new areas. Cold and snow adapted species have decreased in abundance (figure 2, ecosystems). Glacial retreat and snow cover reduction have contributed to declines in tourism in many regions and to agricultural yields in some regions including the Hindu-Kush Himalaya and the tropical Andes (figure 2, human systems and ecosystem services).

Figure 2
Synthesis of observed regional hazards and impacts in high mountain and polar land regions

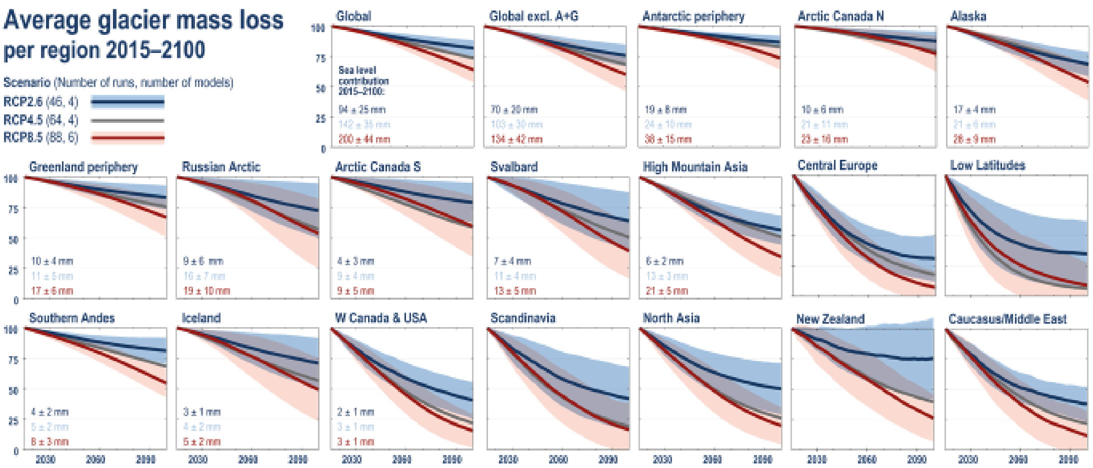


Source: Slide 7 of the full presentation by the IPCC during the special event.

IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (SPM figure 2, lower panel). Synthesis of observed regional hazards and impacts in high mountain and polar land regions assessed in the SROCC.

27. In the future, glaciers, snow cover and the permafrost are projected to continue to decline in most mountain regions. Regions with smaller glaciers are projected to lose more than 80% of their ice mass by 2100 under RCP 8.5. In most regions, glaciers are projected to disappear regardless of the emission scenario (figure 3). Projected low elevation winter snow depths compared to 1986–2005 are likely to decrease by 10–40% in 2031–2050 regardless of the emission scenario. For 2081–2100 the projected decrease is likely to rise to 50–90% under RCP 8.5. Widespread permafrost thaw is projected for this century and beyond. By 2100 projected near surface permafrost area will decrease by 24% under RCP 2.6 and by 96% for RCP 8.5.

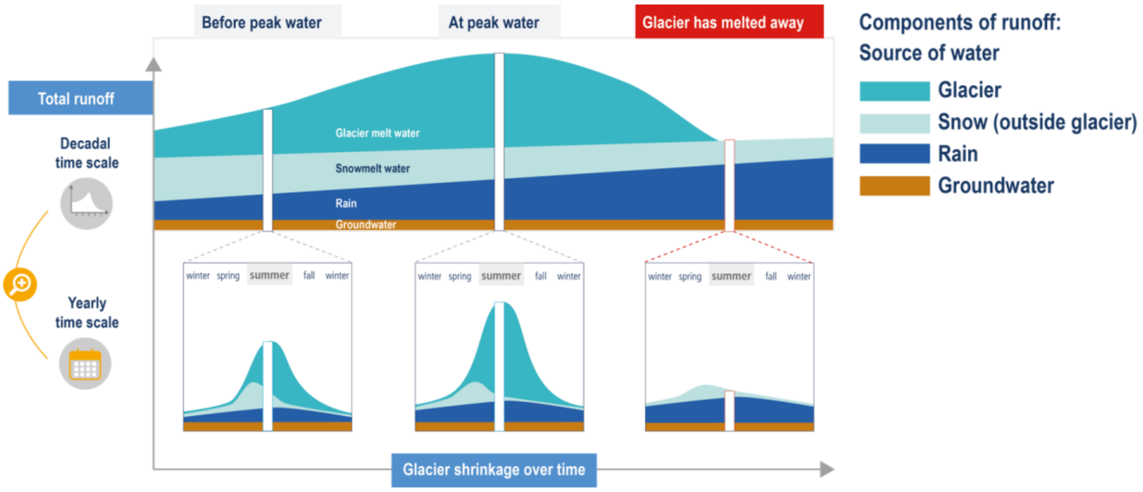
Figure 3
Average glacier mass loss



Source: Slide 8 of the full presentation by the IPCC during the special event.
IPCC, 2019: The IPCC Special Report on the Ocean and Cryosphere (Cross-Chapter Box 6, figure CB6.1). Projected glacier mass evolution between 2015 and 2100 relative to each region's glacier mass in 2015 (100%) based on three RCP emission scenarios. Thick lines show the averages of 46 to 88 model projections based on four to six glacier models for the same RCP, and the shading marks ± 1 standard deviation (not shown for RCP4.5 for better readability).

28. **Hazards are projected** to occur in new locations and different seasons. In many high-mountain areas glacial retreat and permafrost thaw are projected to further decrease the stability of slopes. The number and area of glacial lakes will continue to increase. Floods due to glacial lake outbursts or rain and snow, landslides, and avalanches are projected to occur in new locations and in different seasons (figure 4).

Figure 4
Changes in runoff from a river basin with large glacier cover as the glacier shrinks



Source: Slide 9 of the full presentation by the IPCC during the special event.
IPCC, 2019: The IPCC Special Report on the Ocean and Cryosphere (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. Two different time scales are shown: annual runoff from the entire basin (upper panel); and runoff variations over one year (middle panel).

29. Future cryosphere changes are projected to further affect water resources. River run off in snow dominated or glacier fed high mountain basins is projected to change with increases in winter runoff and earlier spring peaks. Runoff from glaciers is projected to reach peak at or before the end of the 21st century, followed by a decline in glacial runoff. Projected decline in glacial runoff in 2100 under RCP 8.5 can reduce basin runoff by 10% or more in at least one month each year or in one season each year in several large river basins, especially in high mountain Asia during dry seasons.

30. Mr. Zhai continued by describing the **projected risks** posed by climate change for high mountain ecosystems. Permafrost thaw and the decrease in snow will affect mountain hydrology and wildfires, and impact vegetation and wildlife. Future cryosphere change will continue to alter terrestrial and fresh-water **ecosystems** in high mountain areas. This will cause major shifts in species distribution resulting in ecosystem changes, changes in the structure and functioning of globally unique biodiversity, and the eventual loss of this biodiversity. Plant and animal species already adapted to warmer conditions will migrate upslope, while other species already adapted to cold and snow conditions will decrease and eventually face extinction, especially without conservation.

31. There are also many **risks for people**. Glacial retreat and permafrost thaw will further decrease the stability of slopes and the number and area of glacial lakes will continue to increase. Hazards for people from landslides, avalanches or floods will increase. The retreat of the cryosphere will continue to adversely affect recreational activities, tourism and cultural assets. Disaster risks to human settlements and livelihoods are expected to increase. Changing water availability and quality affects the people in their regions and beyond. Limiting warming will help people to adjust to changes in their water supply and limit risks related to mountain hazards.

32. Significant risk reduction and adaptation strategies will help to avoid the impacts from mountain floods and landslide hazards. Integrated water management and transboundary cooperation provide opportunities to reduce the impacts of climate-related cryospheric changes in water resources.

2. Hazards from changes in the cryosphere and the ocean from sea level rise

33. Ms. Valerie Masson-Delmotte continued the presentation with a discussion of the **observed and projected effects of climate change on the polar regions**.

34. The polar regions are losing ice and the polar oceans are changing rapidly. The consequences of this transition extend to the whole planet and are affecting people in multiple ways. Polar regions encompass 20% of the ocean surface, contain more than 90% of permafrost, 70% of the total glacier area and the Greenland and Antarctic ice sheets.

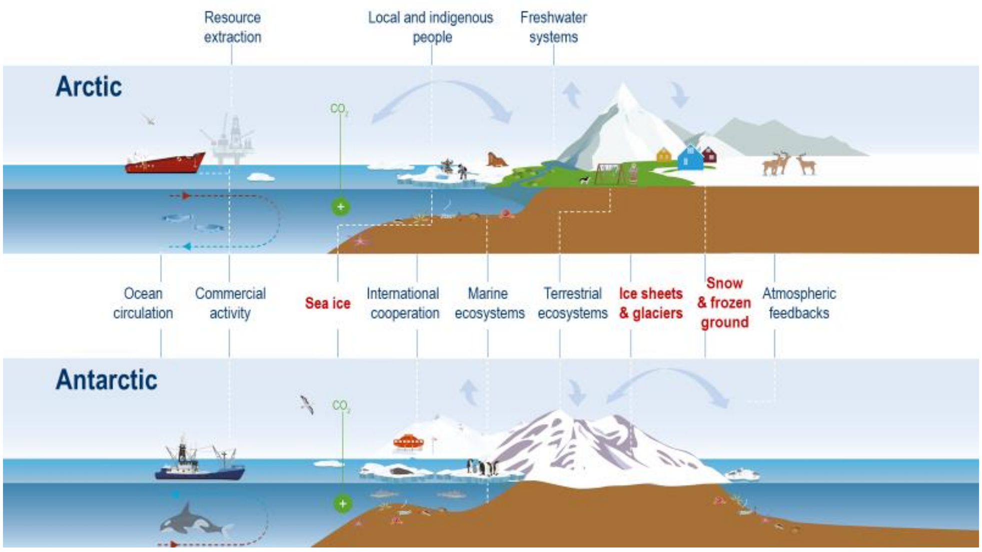
35. There are multiple and diverse perspectives with respect to the polar regions – they are a source of resources, a key part of the climate system, a place for preserving marine and terrestrial ecosystems and unique biodiversity, a place for international cooperation, and a homeland. Figure 5 illustrates some of the key features and mechanisms assessed in the SROCC, and by which the cryosphere and ocean in the polar regions influence climate, ecological and social systems in the regions and across the globe. Around 4 million people live in the Arctic and 10% of these people are indigenous. The SROCC incorporated published indigenous knowledge and local knowledge for assessing climate change impacts and responses.

36. Over the last decade global warming has led to the widespread shrinking of the cryosphere with mass loss from glaciers and ice sheets, reductions in Arctic snow cover, increased permafrost temperature and reduced Arctic sea ice extent (figure 6). **Arctic sea ice extent** has decreased for all months of the year. The amount of Arctic sea ice in September has decreased by 30% each decade since 1979. These changes are unprecedented for at least 1000 years. Arctic sea ice has thinned and is getting younger. Changes in Arctic sea ice have the potential to influence weather at mid latitudes, but there is low confidence in the detection of this influence for specific weather types.

Section 1. Source: IPCC, 2019: Slide 23 of the full presentation by the IPCC during the special event. *Photo:* Jess Melbourne Thomas.

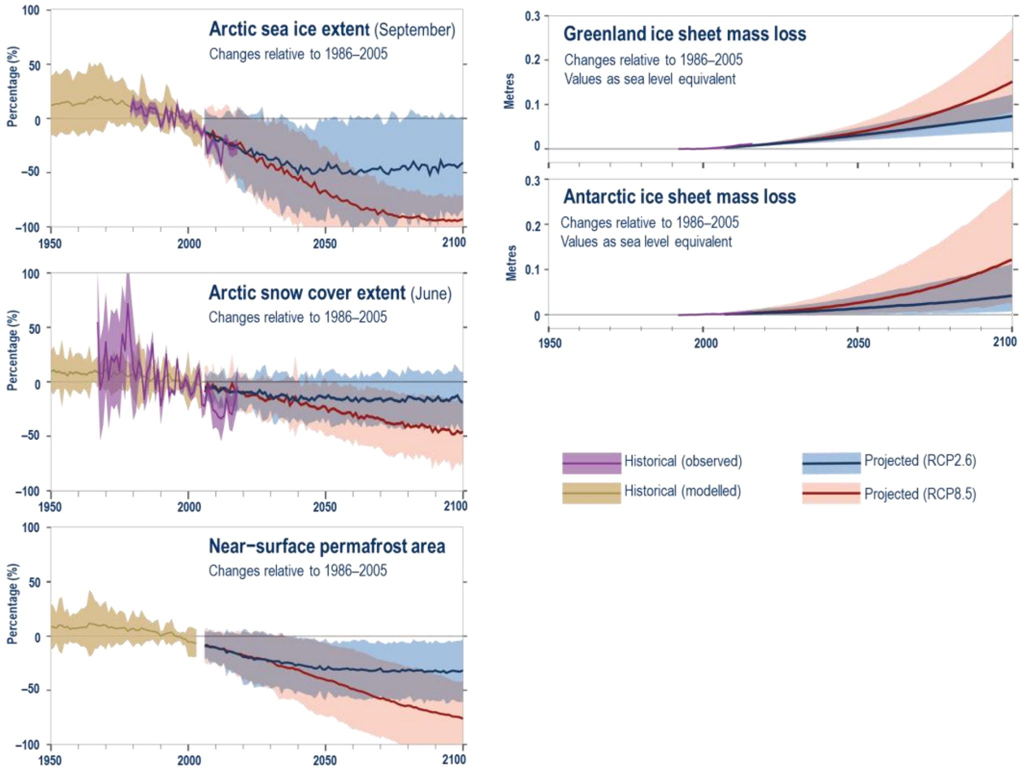
37. **Summer Arctic ship-based transportation**, including tourism, has increased over the past two decades, concurrent with sea ice reductions. This has implications for global trade and economies dependant on traditional shipping corridors and poses risks to Arctic marine ecosystems and coastal communities from, for example, invasive species and local pollution.

Figure 5
Key features and mechanisms relevant to the ocean and cryosphere.



Source: Slide 12 of the full presentation by the IPCC during the special event.
IPCC, 2019: The IPCC Special Report on the Ocean and Cryosphere (figure 3.1). Schematic of some of the key features and mechanisms assessed in the report, and by which the cryosphere and ocean in the polar regions influence climate, ecological and social systems in the regions and across the globe.

Figure 6
Observed and modelled historical changes in the cryosphere and projected future changes



Source: Slide 13 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.1). Observed and modelled historical changes in the cryosphere since 1950,[8] and projected future changes under low (RCP2.6) and high (RCP8.5) greenhouse gas emissions scenarios. Changes are shown for: Arctic sea ice extent change for September 13 (top left; Arctic snow cover change for June (land areas north of 60°N) (bottom left); change in near-surface (within 3–4 m) permafrost area in the Northern Hemisphere (top right); and contributions to sea level rise from Greenland (middle right) and Antarctic (bottom right) ice sheet mass loss.

38. **Arctic sea ice loss** is projected to continue through to the mid-century with differences thereafter depending on the magnitude of global warming. For global warming of 1.5° C, the Arctic ocean would only be ice-free in September once in 100 years. For just half a degree more, at 2° C, this would occur one year in ten to one year in three with implications for the dependent marine life.

39. **Antarctic sea ice** exhibits no significant trend over the period of satellite observations. There is currently limited evidence and low agreement concerning causes of the strong recent decreases since 2016 and low confidence for projections concerning the Antarctic sea ice.

40. **Permafrost** temperatures in the Arctic have continued to increase by about 0.4° C in the last decade and have reached record high levels. Widespread permafrost thaw is projected for this century. Even if global warming is limited to well below 2° C, around a quarter of the near-surface permafrost area will thaw by the end of the century. For high emission scenarios, around 70% of that surface could be lost. Arctic and boreal permafrost contain approximately 1,500 billion tonnes of organic carbon, almost twice the amount of carbon in the atmosphere. There is currently medium evidence and low agreement as to whether northern permafrost regions are currently releasing additional net methane and carbon dioxide due to thaw.

41. In the future, increased plant growth in northern permafrost regions is projected to replenish soil carbon in part, but it will not match releases over the long term and it is clear that lower emission scenarios dampen the response of carbon emissions from the permafrost region.

42. In the **Arctic**, snow cover in June has declined by around 30% per decade since the 1960s over an area of approximately 2.5 million square kilometres due to warming. Feedbacks from the loss of summer sea ice and spring snow cover on land have contributed to amplified warming in the Arctic. The surface air temperature has increased to more than double the average over the last two decades. Arctic autumn and spring snow cover are

[8] Source: *IPCC, 2019:* The Summary for Policymakers of the IPCC Special Report on *the Ocean and Cryosphere (*figure *SPM.1*). This does not imply that the changes started in 1950. Changes in some variables have occurred since the pre-industrial period.

projected to decrease by 5–10% relative to the period from 1986 to 2005 in the near term followed by no further losses under a low emission pathway. However, an additional 15–25% loss by the end of the century is projected to occur under increasing and high emission scenarios.

43. Permafrost thaw and the decrease in snow in the **Arctic** affects hydrology, wildfires, ecosystems, human activities and infrastructure. Lake ice cover has declined. Runoff into the Arctic ocean has increased. Increased wildfires and abrupt permafrost thaw as well as changes in hydrology have caused ecosystem disturbances. There has been an overall greening of the tundra, but also a browning in some regions and changes in the abundance and distribution of some animals, such as reindeer and salmon.

44. Together these **observed changes impact** access and food availability linked to herding, hunting and fishing, affecting the livelihood, health and cultural identity of residents, including indigenous peoples. These people have adjusted the timing of their activities to respond to changes in the seasonality and the safety of land ice and of snow travel conditions. Communities are beginning to address infrastructural failures associated with flooding and thawing permafrost and some coastal communities have planned for relocation. Limited funding, skills, capacity and institutional support have challenged this adaptation.

45. Ms. Masson-Delmotte continued with an outline of the **projected changes in the polar regions**.

46. Even if the overall water cycle intensifies in these regions, projected decreases in the cryosphere may lead to soil drying with consequences for ecosystem productivity. Fire is projected to increase across most tundra and boreal regions. A loss of globally unique biodiversity is projected in the Arctic as limited refuges exist for some high Arctic species which are outcompeted by temperate species.

47. Woody shrubs and trees are projected to expand to cover a quarter to a half of today’s tundra area by 2050. About 20% of the Arctic land permafrost is vulnerable to abrupt thawing and ground subsidence. Disaster risks to settlements and livelihoods are expected to increase due to future changes in hazards such as unreliable ice and snow conditions, and increased exposure of people and infrastructure. Today the majority of Arctic infrastructure is located in regions where permafrost thaw is projected to intensify by mid-century. Retrofitting and redesigning infrastructure can halve the costs arising from permafrost thaw and related impacts.

48. In the last decade the **Greenland ice sheet** has lost mass at an average rate of around 280 billion tonnes of ice per year. This accounts for around 0.8 millimetres per year of global sea level rise due to surface melting. At the same time, the Antarctic ice sheet has lost mass of 155 billion tonnes per year, accounting for around 0.4 millimetres per year of global sea level rise. This is mostly due to the rapid thinning and retreat of outlet glaciers draining the west Antarctic ice sheet. In the last decade the mass loss from the Antarctic ice sheet has tripled compared to the previous decade. The mass loss from Greenland has doubled over the same period.

49. Acceleration of **ice flow and retreat in Antarctica**, which has the potential to lead to sea level rise of several metres over several centuries, is observed in several sectors. These changes may be the onset of irreversible ice sheet instability, but there is uncertainty related to the detection of this process due to limited observations and understanding.

50. In sum, the polar regions have changed and will be profoundly different in the future compared to today. This will strongly depend on the level of future global warming. This will challenge adaptation and responses regionally as well as worldwide, especially for sea level rise. Small island developing states are home to 65 million people and 80 million people live in low-lying coastal zones today. They are exposed to sea level rise and coastal extreme events.

51. Ms. Masson-Delmotte then addresses the **observed changes in sea level**.

Section 2. Source: IPCC, 2019: Slide 31 of the full presentation by the IPCC during the special event. *Photo:* Glenn R. Specht.

52. **Global mean sea level** is rising and accelerating in recent decades due to mass loss from the Greenland and Antarctic ice sheets as well as continued glacial mass loss and thermal expansion of the ocean (figure 7). The current rate of sea level rise is 3.6 millimetres per year. It is unprecedented over the last century and about 2.5 times the average rate of the 20th century.

53. The cryospheric contribution of melt-water is now the dominant driver of sea level rise, slightly exceeding the effect of thermal expansion of water. The dominant cause of global mean sea level rise since the 1970s is the emission of anthropogenic GHGs.

54. Sea level rise is not uniform globally. **Regional differences** up to 30% result from land ice loss and variations in ocean warming and circulation. Differences can be greater in areas of rapid vertical land movement, including from local human activities such as the extraction of ground water. Extreme wave heights contribute to extreme sea level events, coastal erosion, and flooding, and have increased in the southern and northern Atlantic oceans by around a centimetre per year since the 1980s. Sea ice loss in the Arctic has also increased wave height.

55. Finally, the report shows that anthropogenic climate change has increased **observed precipitation, winds and extreme sea level events** associated with some tropical cyclones. This has increased the intensity of multiple extreme events and associated cascading impacts. There is emerging evidence for an increase in the annual global proportion of category 4 and 5 tropical cyclones in recent decades.

56. Ms. Masson-Delmotte continued with an outline of the **projected future rise in sea level**.

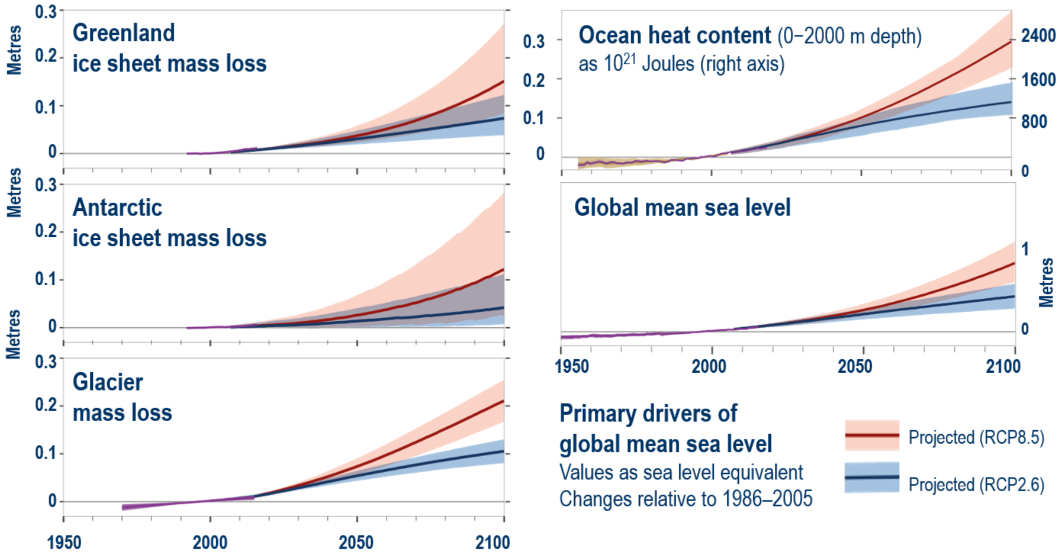
57. **Sea level** is projected to continue to rise at an accelerating rate (figure 8). The global mean sea level rise projected in 2100 under a low emission scenario is around 43 centimetres above the mean sea level over the period from 1986 to 2005. For a high emission scenario, the corresponding rise is 0.84 metres and the likely range extends to 1.10 metres in 2100. **This upper range is higher compared to the Fifth Assessment Report (AR5)**[9] **due to larger projected losses from the Antarctic ice sheet**. Sea level projections show different regional levels. Processes not driven by climate change such as natural and anthropogenic subsidence are important for relative sea level changes and need to be considered.

58. A key point is that the sea level rise range that must be considered for planning and implementing coastal responses must take into account the **risk tolerance of stakeholders**. Those with a higher risk tolerance can use the likely range, but those with a lower risk tolerance, for example for critical infrastructure, must also consider global and local mean sea level rise at the upper end of the likely range and draw from lower confidence methods such as expert elicitation.

59. Sea level rise is projected to continue after the **end of this century**. The main uncertainty associated with this is that of the ice sheets, especially in Antarctica. At the end of the century the rate of global mean sea level rise is projected to reach around 15 millimetres per year in a high emission scenario and exceed that rate in the 22nd century. Rates are lower with lower emissions. Model studies indicate, with low confidence, a multi-metre rise in sea level by 2100 for high emission scenarios. This indicates the importance of reduced emissions for limiting sea level rise in the long term.

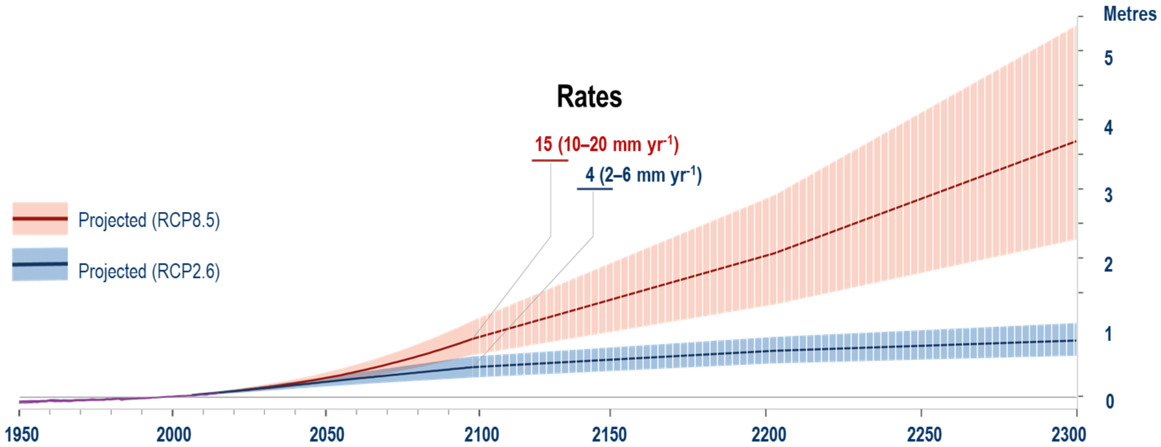
[9] Available at https://www.ipcc.ch/assessment-report/ar5/, and the synthesis report at https://www.ipcc.ch/report/ar5/syr/.

Figure 7
Observed and modelled historical changes in the ocean and cryosphere and projected future changes



Source: Slide 17 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.1). Observed and modelled historical changes in the ocean and cryosphere since 1950,[10] and projected future changes under low (RCP2.6) and high (RCP8.5) greenhouse gas emissions scenarios. Changes are shown for ocean-related changes with very likely ranges for: global ocean heat content change (0–2000 m depth) (top right). An approximate steric sea level equivalent is shown with the right axis by multiplying the ocean heat content by the global-mean thermal expansion coefficient ($\varepsilon \approx 0.125$ m per 1024 Joules)12 for observed warming since 1970; global mean sea level change (middle right); components from Greenland (top left) and Antarctic (middle left) ice sheet mass loss; and glacier mass loss (bottom left).

Figure 8
Observed and modelled historical changes in the global mean sea level, and projected future changes



Source: Slide 17 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.1). Observed and modelled historical changes in the global mean sea level since 1950,[11] and projected future changes under low (RCP2.6) and high (RCP8.5) greenhouse gas emissions scenarios. Hashed shading reflects low confidence in sea level projections beyond 2100 and bars at 2300 reflect expert elicitation on the range of possible sea level change.

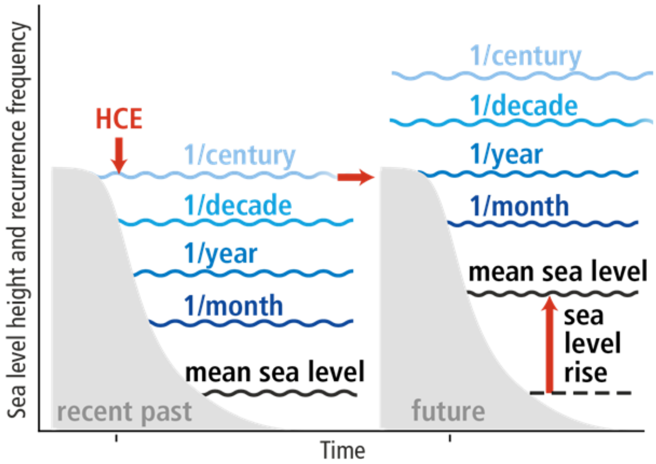
[10] Source: IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.1). This does not imply that the changes started in 1950. Changes in some variables have occurred since the pre-industrial period.

[11] Source: IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.1). This does not imply that the changes started in 1950. Changes in some variables have occurred since the pre-industrial period.

60. Beyond 2100 a growing contribution from Antarctica has important consequences for the pace of sea level rise in the Northern Hemisphere. Processes controlling the pace of future ice shelf loss and the extent of ice sheet instabilities could increase the Antarctic contribution to sea level rise to values substantially higher than the likely range on centennial and longer timescales, with low confidence. Considering the consequences of sea level rise that a collapse of part of the Antarctic ice sheet entails, this high impact risk merits attention.

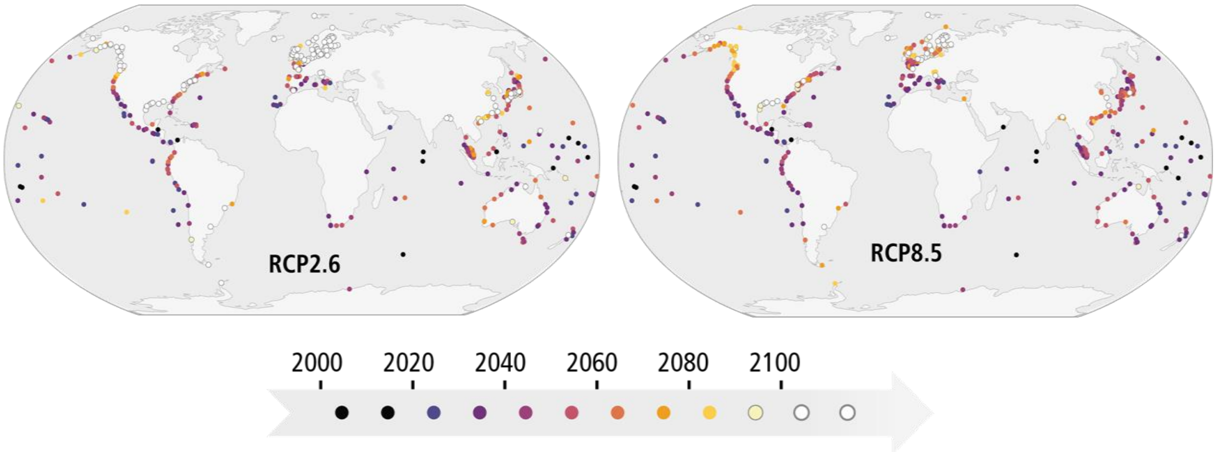
61. The rise in global mean sea level will cause the **frequency of extreme sea level events** to increase. As a result, events that were historically rare, for example once per century in the case of major storm surges, will occur much more frequently each year (figure 9a). Many low-lying cities and small islands are projected to experience historical centennial events at least annually by 2050 under all emission scenarios (figure 9b).

Figure 9a
The effect of regional sea-level rise on extreme sea level events at coastal locations



Source: Slide 18 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.4). a) Schematic illustration of extreme sea level events and their average recurrence in the recent past (1986–2005) and the future. As a consequence of mean sea level rise, local sea levels that historically occurred once per century (historical centennial events, HCEs) are projected to recur more frequently in the future.

Figure 9b
The effect of regional sea-level rise on extreme sea level events at coastal locations



Source: Slide 18 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.4). The year in which HCEs (historical centennial events) are expected to recur once per year on average under RCP8.5 and RCP2.6, at the 439 individual coastal locations where the observational record is sufficient. The absence of a circle indicates an inability to perform an assessment due to a lack of data but does not indicate absence of exposure and risk. The darker the circle, the earlier this transition is expected. The likely range is ±10 years for locations where this transition is expected before 2100. White circles (33% of locations under RCP2.6 and 10% under RCP8.5) indicate that HCEs are not expected to recur once per year before 2100.

62. The year when the historical centennial event becomes an annual event in the mid latitudes occurs sooner in high emission scenarios than in low emission scenarios. The increasing frequency of high-water levels can have severe impacts in many locations depending on the level of exposure and adaptation. This assessment assumes that the variability of sea level remains unchanged. However projected changes in waves and tides due to changes in weather patterns and sea level rise can locally modulate coastal hazards. Extreme sea level and coastal hazards will be exacerbated by projected increases in the average intensity and magnitude of storm surges, the precipitation rates of tropical cyclones, and the proportion of category 4 and 5 tropical cyclones. There are greater increases projected under RCP 8.5 than under low emission pathways from around 2050 to 2100.

63. Ms. Masson-Delmotte then presented the findings of the SROCC related to the **deep oceans** (figure 10).

64. Due to emissions of GHGs from human activities the global ocean has warmed and taken up more than 90% of the excess heat in the climate system, making climate change irreversible. Ocean warming also contributes to sea level rise, as shown above. In the last decade at least half of the total accumulation in the global ocean has occurred in the Southern Ocean which plays a disproportionate and increasing role in regulating the Earth's climate.

65. Due to warming, **marine heatwaves** have doubled in frequency since the 1980s and are increasing in intensity. Surface ocean warming is also making the surface ocean less dense relative to deeper parts of the ocean, and this inhibits the mixing and exchange of heat, carbon, nutrients and oxygen.

66. The **loss of oxygen** has occurred from the surface to 1,000 metres deep. The ocean has also taken up 20–30% of total human CO_2 emissions since the 1980s, causing further ocean acidification. The decline in surface ocean pH has already emerged for more than 95% of the ocean area compared to background variability. Over the 21st century the ocean is expected to transition to unprecedented conditions with further increases in temperature stratification, acidification and oxygen decline.

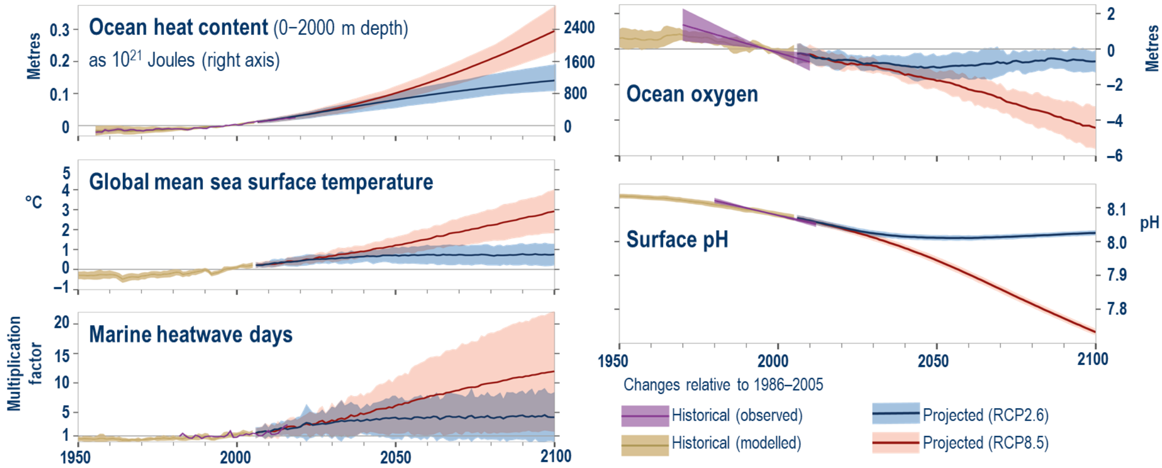
67. If global warming is limited to 2° C, the ocean will absorb two to four times more heat than between the 1970s and today by the end of the century, and up to five and seven times more for higher emissions. Marine heatwaves are projected to increase in frequency duration, extent and intensity with the largest increases in the Arctic and in tropical oceans.

Section 3. Source: IPCC, 2019: Slide 37 of the full presentation by the IPCC during the special event.

68. Continued carbon uptake by the ocean is virtually certain to exacerbate ocean acidification. Polar oceans will be increasingly affected by this carbon uptake which, under high emission conditions, will cause the corrosion of calcium carbonate in the shells of marine organisms. These conditions would be avoided for low emission scenarios.

69. In a warmer world, extreme El Niño and La Niña events are also projected to increase in frequency in the 21st century and to intensify existing hazards. The Atlantic Meridional Overturning Current is projected to weaken, but the scale, rate and magnitude of ocean changes will be smaller under scenarios with low GHG emissions.

Figure 10
Observed and projected changes in the ocean



Source: Slide 19 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.1). Observed and modelled historical changes in the ocean since 1950,[12] and projected future changes under low (RCP2.6) and high (RCP8.5) greenhouse gas emissions scenarios. Changes are shown for: global mean sea surface temperature change (middle left); change factor in surface ocean marine heatwave days (bottom left); global ocean heat content change (0–2000 m depth) (top left). An approximate steric sea level equivalent is shown with the right axis by multiplying the ocean heat content by the global-mean thermal expansion coefficient ($\varepsilon \approx 0.125$ m per 1024 Joules) for observed warming since 1970; and global mean surface pH (on the total scale) (middle right). Assessed observational trends are compiled from open ocean time series sites longer than 15 years; and global mean ocean oxygen change (100–600 m depth) (top right). Assessed observational trends span 1970–2010 centered on 1996.

3. Summary of discussions

70. An IPCC expert responded to a question on the **projected substantial permafrost thaw given the low certainty of the subsequent release of methane and other GHGs.** A huge amount of carbon is located in global permafrost and 95% of permafrost is in the Arctic. The rate of release of carbon emissions from permafrost thaw is projected to increase. There is limited confidence in the exact projected amount of emissions over the coming century, however there is certainty about the cumulative carbon emissions from permafrost thaw over this period, which is in the range of tens to hundreds of gigatonnes of carbon over this century. In this regard, it is worth noting that approximately 11 gigatonnes of carbon was emitted in anthropogenic emissions annually over the last decade. There is limited knowledge on when exactly these emissions will occur in the coming decades as well as on the amount of carbon released as CO_2 versus as methane. Considering the difference in radiative forcing between CO_2 and methane, it is not possible to elaborate on the degree of warming related to emissions from permafrost. However, these GHGs are being emitted over a critical time period where the earth is struggling with an increase in atmospheric carbon.

71. In responding to a question asking for **further detail on the role of marine ice sheet instability on sea level rise**, an IPCC expert identified that is high confidence of the continued expansion of the ocean and continued loss of ice from the Greenland and Antarctic ice sheets beyond 2100. The complete loss of the Greenland ice sheet, contributing about 7 metres to sea level over 1000 years or more, would occur with sustained global warming between 1° C (low confidence) and 4° C (medium confidence) above preindustrial levels. There are deep uncertainties regarding the processes that could trigger a major retreat in Antarctica and low confidence in the estimates of the contribution of the Antarctic ice sheet after the end of this century. The estimates in SROCC project that by 2300 for a high emission scenario sea level will rise by 2.3 to 5.4 metres. These estimates are considerably higher than presumed in the Fifth Assessment Report. It is also clear that high emission scenarios over several centuries lead to rates of sea level rise as high as several metres per century in the long term. Low emission scenarios lead to limited contribution over low century time scales. It is not possible to discriminate between 1.5° C and 2° C scenarios in terms of long term sea level change due to limited evidence in the literature. In conclusion sea level rise on 1000-year time scale is strongly dependant on emission scenario. Due to the lack of predictability of tipping points, it flags the importance of emission mitigation for minimising the risk to low lying coastlines and islands, even if no tipping points are passed.

[12] Source: IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.1). This does not imply that the changes started in 1950. Changes in some variables have occurred since the pre-industrial period.

72. In regards to a further question on the **temperature range at which ice sheet retreat is irreversible, particularly on the upper boundary of that temperature range**, the IPCC expert responded that the SROCC contains the latest knowledge on both ice sheet instability and ice cliff instability from the literature, and an assessment of the level of understanding based on today's limited observations based on the representation of processes related to marine ice sheet instability in current models and knowledge from the past climate. It is not impossible that irreversible ice sheet loss is already at play. The ability of models to simulate the processes controlling marine ice sheet instability has improved but significant discrepancies in projections remain. The SROCC contains the findings of the Special Report on Global Warming of 1.5° C on the temperature ranges of possible irreversible ice sheet response and will be revisited based on the latest modelling of ice sheets and shelves in the main WGI report. This is also the first time that the IPCC report reflects the state of the literature related to event attribution, especially related to tropical cyclone characteristics, intensity of rainfall, winds and storm surges. Time responses of the ocean and cryosphere are connected to committed changes in the next decade and this highlights the need for adaptation and cooperation around adaptation.

73. A question was asked on whether **diseases in the equator and subtropics are moving to the poles as marine species move**. The IPCC experts responded that in regards to the poleward expansion of vibrio (pathogenic bacteria), there is some discussion in SROCC Chapter 5, section 5.2.1.1, where evidence is presented of increased vibrio abundance in the north Atlantic. In the literature, there is also some evidence of poleward expansion in general of vibrio pathogens attributed to climate change. With respect to the occurrence of harmful algal blooms, the ongoing changes in the ocean parameters such as warming, oxygen loss and acidification are hypothesised to stimulate the occurrence of harmful algal blooms and associated toxicity events. This is also exacerbating the challenges to human health.

74. The IPCC experts were asked to **clarify the most pressing short-term risks that high mountain areas could address in their planning?** Regarding the major risks in these regions, impacts have already been seen. One is related to the water resources, another linked more to the influence of the infrastructure and preparedness for hazards as mentioned above (see paragraphs 29–33). The SROCC focuses on cryosphere driven impacts, but these are also climate driven impacts, for example, precipitation pattern change or the direct impact of warming. In report, Chapter 2, table 2.8 lists the publications available for the assessment. There will be an opportunity to revisit the impacts on high mountains in the AR6 WGII report which has specific sections focussing on high mountain regions.

75. **In responding to the increasing availability of natural resources in the Arctic and how using these resources could address problems posed by climate change instead of just being used for profit**, an IPCC expert highlighted that increases in shipping in the Arctic is concomitant to the loss of sea ice but is not only linked to that. Increases in shipping have beneficiaries, but also negative impacts on communities. Economies will grow as a result of the increased shipping, but those stakeholders interested in the classical routes that are used are forecasted to be negatively impacted by the increases in Arctic shipping. More importantly, Arctic shipping regulations are not keeping up in terms of marine shipping governance, so the local communities that are dependent on marine resources and coastal ice are vulnerable, as these conditions will be disturbed by increased shipping in the region. Improvements in marine shipping governance will determine whether these risks become impacts.

76. A number of queries were related to knowledge and information sharing. In regards to **how the IPCC can contribute to closing research gaps, particularly in terms of weather, climate and water in high mountains areas, so that future reports can support climate adaptation and resilience building of vulnerable communities in high mountain regions**, an IPCC expert responded that SROCC mentions monitoring, forecasting and sharing information, data and knowledge as crucial to adapting to changes in the mountain regions. After the report was concluded, the WMO held the high mountain summit, in which many IPCC authors participated, and which included the establishment of the observation network, forecasting, climate, weather and water services for high mountain regions. This WMO effort contributed to identifying gaps and the establishment of the monitoring system in high mountain areas.

77. **In regards to the literature assessed on the Himalayas**, the IPCC is glad to have a dedicated chapter on the mountain cryosphere in this report. The authors attempted to incorporate information from many different mountainous regions. Their work uncovered gaps in knowledge, as is visible in the table (see Figure 2 above). In the Himalayan and European mountain regions more literature is available than in other regions. The report attempted to reflect the information of all mountainous regions and does not focus on one specific region. However, there is still lack of some knowledge and understanding in these regions. The high population in the Himalayan region makes it important to increase the research in that region for the IPCC's work in the future. It was noted that WG II will produce regional chapters for the AR6 report, with regional authors.

78. In regards to **grey literature and its use on IPCC Assessment Reports**, an IPCC expert identified that whilst there is an emphasis on peer-reviewed literature, if there is well documented grey literature available in any region it would be considered by the authors and this is being done regularly.

79. **In regards to the weaving of indigenous knowledge and Western science in the coproduction of reports**, an IPCC expert identified that indigenous knowledge is acknowledged particularly in the polar section of the report but also contributes to the coastal and high mountain region sections. The Summary for Policymakers section C44 describes specific activities including the utilisation of multiple model systems and regional climate systems into decision making, engagement of local communities and local stakeholders in adaptive governance arrangements, and planning frameworks. The IPCC have assessed the promotion of climate literacy and identify that learning about specific local risks and responses potentially contributes to more effective adaptation and increased sustainability of natural renewable resources. Such investments can develop and transform existing institutions and is, in several cases, dependant on the transformation of these institutions to enable informed interactive and adaptive governance arrangements.

80. A reference was made to a paper on ocean heat uptake that had been withdrawn from the literature, and the IPCC assured the speaker that this paper was not used in the SROCC assessment.

4. From risk assessment to adaptation and nature-based solution options: ecosystems and human societies

Section 4. Source: IPCC, 2019: Slide 39 of the full presentation by the IPCC during the special event. *Photo*: Mr. JK.

81. Mr. Pörtner continued the presentation presenting on risk assessment, adaptation and nature-based solutions in the context of ecosystems and human societies.

82. Marine life is already being affected by climate change. The key drivers of this are ocean warming, oxygen loss and acidification which act individually but also in combinations. This has consequences for the people who depend on the natural resources of the ocean.

83. We have seen the global development of hazards. These signals are already developing strongly in different marine regions ranging from the Arctic upwelling systems to the North Atlantic, South Atlantic, South Pacific, Southern Ocean, temperate Indian Ocean, tropical Atlantic, tropical Indian Ocean and tropical Pacific. The strongest signal visible in all of these is ocean acidification (figure 11).

84. Temperature is rising in most of these systems and there is also a declining trend in oxygen content. In the Arctic there is a loss of sea ice coverage and in all sea systems there is an increase in sea level.

85. Some **ecosystems** from the upper water column such as coral, coastal wetlands, kelp forests, rocky shores, deep sea, polar benthos and sea ice associated ecosystems are responding positively, partly due to the stimulation of productivity, but most, with different levels of confidence, are responding negatively.

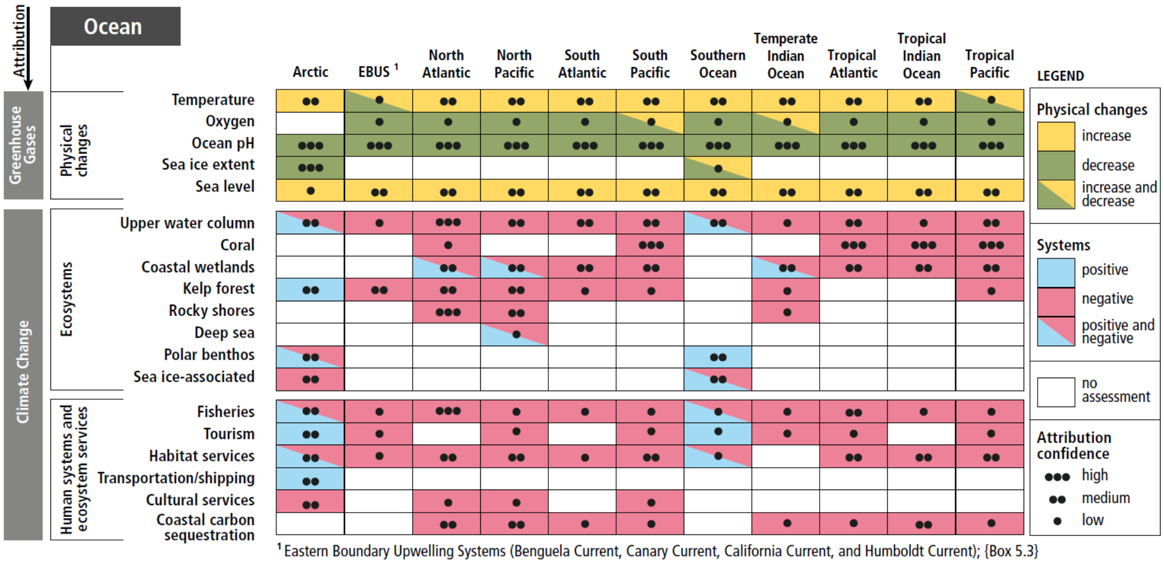
86. **Human systems** depending on these ecosystem services are also responding relatively strongly for fisheries, tourism, habitat services, transportation, shipping cultural services, and coastal carbon sequestration. These are mostly responding negatively.

87. Mr. Pörtner highlighted the **projected changes** in the future from the point of view of risk assessment.

88. One of the most vulnerable marine ecosystems is the warm water coral reefs, where marine heatwaves have already resulted in large scale coral bleaching causing worldwide reef degradation. Reports of the vulnerability of this ecosystem started in AR 4 and continued in AR 5. The vulnerability of warm water corals was further emphasised in the Special Report on Global Warming of 1.5° C and now in SROCC (figure 12).

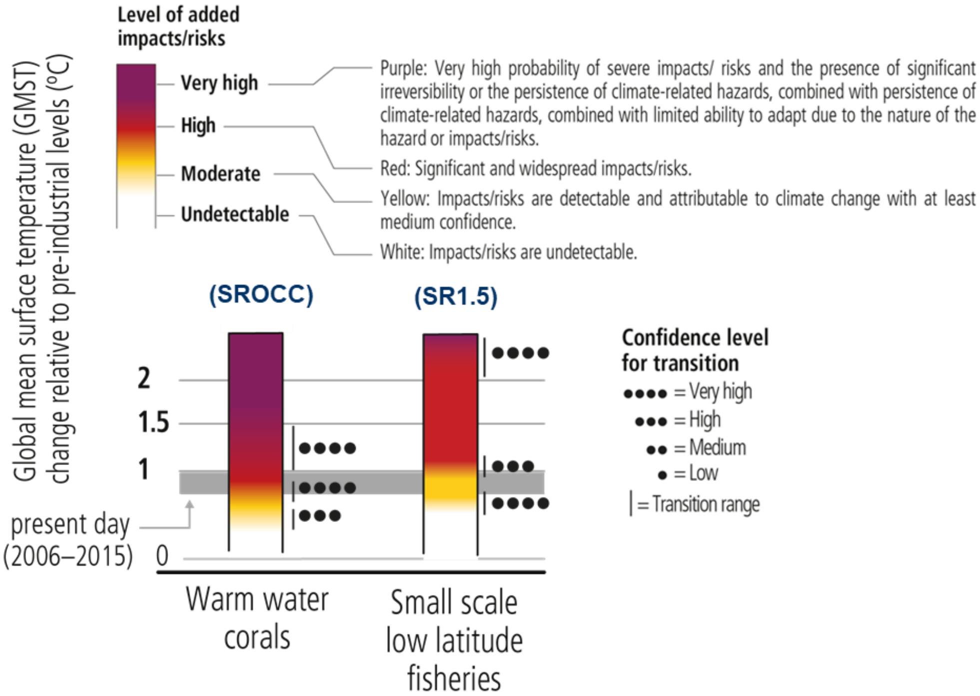
89. The risk assessment indicates that under the current degree of warming, we are already in a high-risk situation, reflecting that healthy reefs, dependant on their unicellular algal powerplants living in the coral, are being challenged by high temperatures. These algae are being released, resulting in the starvation of the corals. The large-scale ejection of these algae, known as **coral bleaching**, occurs if a marine heatwave lasts too long. The animals die and the ecosystem is lost and turns into something completely different, overgrown by algae.

Figure 11
Synthesis of observed regional hazards and impacts in the ocean assessed in SROCC



Source: Slide 21 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.2, upper panel). For each region, physical changes, impacts on key ecosystems, and impacts on human systems and ecosystem function and services are shown. For physical changes, yellow/green refers to an increase/decrease, respectively, in amount or frequency of the measured variable. For impacts on ecosystems, human systems and ecosystems services, blue or red depicts whether an observed impact is positive (beneficial) or negative (adverse), respectively, to the given system or service. Cells assigned 'increase and decrease' indicate that within that region, both increase and decrease of physical changes are found, but are not necessarily equal; the same holds for cells showing 'positive and negative' attributable impacts. The confidence level refers to the confidence in attributing observed changes to changes in greenhouse gas forcing for physical changes and to climate change for ecosystem, human systems, and ecosystem services. No assessment means: not applicable, not assessed at regional scale, or the evidence is insufficient for assessment.
[1] EBUS = Eastern boundary upwelling systems.

Figure 12
Assessing risk of global warming to warm water corals

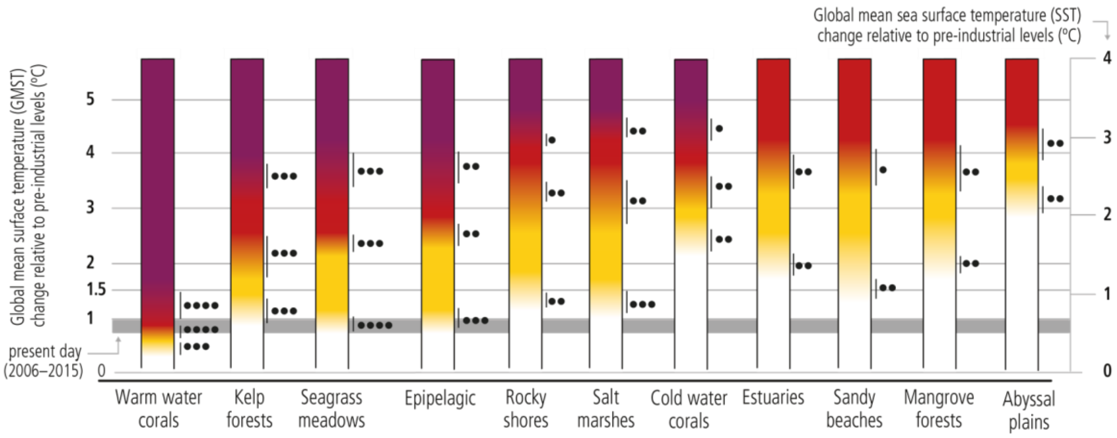


Source: Slide 22 of the full presentation by the IPCC during the special event.
IPCC, 2019: Slide 43 of the full presentation by the IPCC during the special event and the Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.3). A comparison of the difference in risk assessed for warm water corals reflecting the increased understanding between the Special Report on Global Warming of 1.5°C (SR1.5) and the Special Report on the Ocean and Cryosphere (SROCC).

90. These processes are already happening, and we have passed the tipping point for tropical coral, with high confidence. At global warming of 1.5° C there is a high risk of losing 70–90% of coral reefs and the associated services to humans. More will be lost at 2° C.

91. However, for many other ecosystems the risk transitions do not occur at similarly low temperatures as that for tropical coral reefs. If countries can limit global warming to within the temperature range described by the Paris Agreement, none of these other systems will transition to a high-risk situation. These ecosystems would benefit from high ambition mitigation. Nevertheless, projected ecosystem responses include the losses of species' habitat, of diversity and the degradation of ecosystem functions (figure 13).

Figure 13
Impacts and risks for coastal and open ocean ecosystems.



Source: Slide 22 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.3). See above figure for explanation of risk levels. Assessment of risks for coastal and open ocean ecosystems based on observed and projected climate impacts on ecosystem structure, functioning and biodiversity. Impacts and risks are shown in relation to changes in Global Mean Surface Temperature (GMST) relative to pre-industrial level. Since assessments of risks and impacts are based on global mean Sea Surface Temperature (SST), the corresponding SST levels are shown. The figure indicates assessed risks at approximate warming levels and increasing climate-related hazards in the ocean: ocean warming, acidification, deoxygenation, increased density stratification, changes in carbon fluxes, sea level rise, and increased frequency and/or intensity of extreme events. The assessment considers the natural adaptive capacity of the ecosystems, their exposure and vulnerability. Impact and risk levels do not consider risk reduction strategies such as human interventions, or future changes in non-climatic drivers. Risks for ecosystems were assessed by considering biological, biogeochemical, geomorphological and physical aspects. Higher risks associated with compound effects of climate hazards include habitat and biodiversity loss, changes in species composition and distribution ranges, and impacts/risks on ecosystem structure and functioning, including changes in animal/plant biomass and density, productivity, carbon fluxes, and sediment transport.

92. In all parts of the ocean we see the impacts of climate change (figure 14). Warm water corals are at high risk today. Most coastal ecosystems are also at risk, including seagrass meadows and kelp forests which are at moderate to high risk at 1.5° C and at more risk at 2° C. Ecosystems overall would benefit from keeping warming at or below 1.5° C.

93. In the open ocean, the physical and biogeochemical changes projected affect **primary production**, the base of the oceanic food web. They also affect marine animals indirectly through the food webs, but also directly. Animals are among the most vulnerable organisms in the ocean and are directly and indirectly affected by the biotic and abiotic changes in in the ocean.[13]

94. Concerning future changes to primary production - the models are not fully able to depict the current trends. There is some disagreement especially for the high emission reduction scenario, RCP 2.6, but the RCP 8.5 signal is stronger and shows an increase in production in the high latitudes, especially in the Arctic, whereas there is a decline in the lower latitudes, especially in the tropical areas.

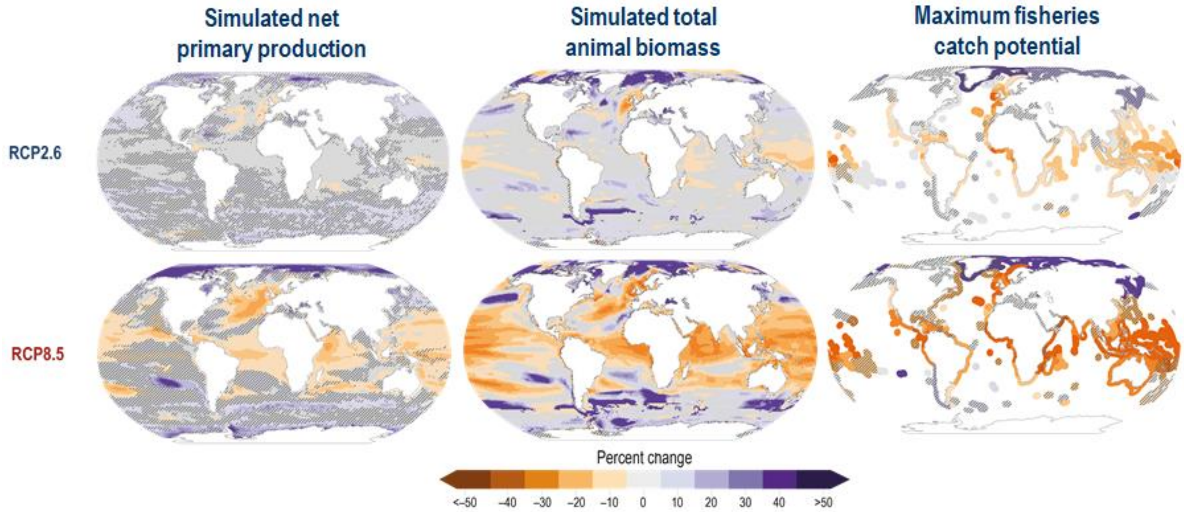
[13] Abiotic factors are the non-living parts of an environment. These include things such as sunlight, temperature, wind, water, soil and naturally occurring events such as storms, fires and volcanic eruptions. Biotic factors are the living parts of an environment, such as plants, animals and micro-organisms.

95. In summary, ocean warming alters the biomass production and structure of marine ecosystems. In recent decades, **Arctic net primary production** has increased in ice-free waters and is projected to further increase. There are cascading effects based on these processes on polar zooplankton, which are affected by the food web structure and function and b fisheries. In the Antarctic, the habitat of Antarctic krill, a key prey species for penguin, seals and whales, is projected to contract South. Under high emission **scenarios Net Primary Productivity in tropical oceans** will decline by 7–16% by 2100.

96. Changes in production have implications for changes in animal biomass including fish and invertebrates, but there are also strong direct effects of different climate change parameters on individual animal species. Under an ambitious emission reduction scenario, the current trend of polar displacement of species would still occur, enriching the higher latitudes and depleting to some extent the biomass in lower latitudes and in some other areas where warming and warming velocity plays a role. These trends are emphasised where global warming, based on the principal effects of warming on these organisms, causes a clearance in biodiversity and animal species in the lower latitudes in similar ways as it has during past mass extinctions. There is a moderate shift with some strengthening of animal biomass towards the high latitudes. It is to be emphasised that these models may have limited value in high latitudes as they do not fully reflect the different environmental conditions in those places.

97. As a consequence of these processes, there is **pressure coming from the invasion of the polar areas by species from lower latitudes**. The different drivers of ocean change such as acidification, stratification and warming also range to some extent into the polar areas. There is a loss of habitat and foraging success observed in polar regions for ice-associated marine mammals and seabirds, and there is also an accompanying retreat of sea ice cover. There is an expansion of subarctic fish communities that is projected to occur further into the future. Therefore, for indigenous peoples and those living in the Arctic there is disrupted access for hunting and fishing areas.

Figure 14
Projected changes, impacts and risks for ocean regions and ecosystems



Source: Slide 23 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.3). Depth integrated net primary production (left), total animal biomass (middle), and maximum fisheries catch potential (right). The panels represent projected changes (%) by 2081–2100 relative to recent past under low (RCP2.6) and high (RCP8.5) greenhouse gas emissions scenario respectively. Total animal biomass in the recent past represents the projected total animal biomass by each spatial pixel relative to the global average. Average observed fisheries catch in the recent past displays projected changes in maximum fisheries catch potential in shelf seas based on the average outputs from two fisheries and marine ecosystem models. To indicate areas of model inconsistency, shaded areas represent regions where models disagree in the direction of change for more than: (left and middle panels) 3 out of 10 model projections, and (right) one out of two models. Although unshaded, the projected change in the Arctic and Antarctic regions in total animal biomass and fisheries catch potential have low confidence due to uncertainties associated with modelling multiple interacting drivers and ecosystem responses. Projections presented in biomass and fisheries catch are driven by changes in ocean physical and biogeochemical conditions e.g., temperature, oxygen level, and net primary production projected from CMIP5 Earth system models.

98. Mr. Pörtner explained the implications of these trends for the **maximum fisheries catch potential**, building on the biological changes and responses to climate change in the ocean. This is emphasised for the shelf areas and mirrors the trends emphasised previously for animal biomass. Even with ambitious emission reduction there is some loss of catch potential, especially in low latitudes and where it affects the small artisanal fisheries, especially of developing countries, and challenges food security. Especially in high latitudes we are seeing an expansion of fisheries activity following the expansion of subarctic fish species into polar and subpolar waters. There, trends

will be emphasised under the unabated emission scenario RCP 8.5 in which there will be an even stronger decline of fish species in the lower latitudes.

99. Building on the changes in marine species distribution and production, a key consideration is that there are limited temperature ranges and the current rate of climate change is too fast for many species to adapt to the ongoing warming trend, which is faster than the past climate changes of the last 50 million, if not 300 million, years. Change in the ocean causes shifts in fish populations and catch potential and these have positive and negative impacts on catch, economic benefit and the livelihoods of the local communities depending on the region.

100. Global warming and biogeochemical changes have already reduced fisheries catch in many regions and communities. Communities in the Arctic and in Small Island Developing States that depend on seafood may face risks to nutritional health and food security.

101. Mr. Pörtner continued by describing the difference in the development of **risk due to sea level rise** in different illustrative geographies. The most at risk are the atolls and Arctic communities, to some extent the risks and challenges are less for the large agricultural tropical deltas, depending on sea level rise. Resource rich coastal cities can mobilise resources to cope with the challenges of sea level rise and respond toward the end of the century.

Section 5. Source: IPCC, 2019: Slide 55 of the full presentation by the IPCC during the special event. *Photo*: Glenn R. Specht.

102. **Adaptive capacity**, **resilience** and **adaptation limits** differ between locations and regions. If there is an adaptive capacity in-situ, citizens do not need to move. With less adaptative capacity, planned relocation may occur to respond to challenges imposed by sea level rise. When limits are reached with respect to alternative responses, planned relocation may have to occur, and may already be occurring, especially in Arctic communities and in urban atoll islands if adaptation efforts are not enough to reduce risk level in-situ.

103. **Adaptation responses to sea level rise** are already being implemented worldwide including hard protection, sediment-based protection, ecosystem-based adaptation based on corals and wetlands, coastal advance, coastal accommodation and retreat (figure 15). Some of these systems, for example the use of the service of warm water corals, are already under pressure and will not be able to be explored further if global warming is unabated.

104. In developing countries people with the highest exposure and vulnerability often have the lowest capacity to respond. For each of the above-mentioned adaptation measure, SROCC assesses effectiveness, advantages of their uses, co-benefits, drawbacks, economic efficiency and governance challenges.

105. **Hard protection** is especially useful for resource-rich cities and can be used to respond to multiple metres of sea level rise and effectively reduce risk levels. The protection provides predictable levels of safety and, depending on the system used, there may be multifunctional dykes that strengthen recreational activities and other land uses. On the downside hard protection may destroy natural habitats and ecosystems. Economic efficiency can be high if the value of protecting assets is high, but these measures are often unaffordable for poor areas.

106. **Coastal advance** can also be used in resource rich places. It would be effective in the event of multiple metres of sea level rise; would reach predictable levels of safety; and has the co-benefit of generating land and land sale revenues. The drawbacks include salinization and enhanced erosion and loss of ecosystems and habitats. The economic efficiency is high if land prices are high. It is, however, often unaffordable in poorer areas.

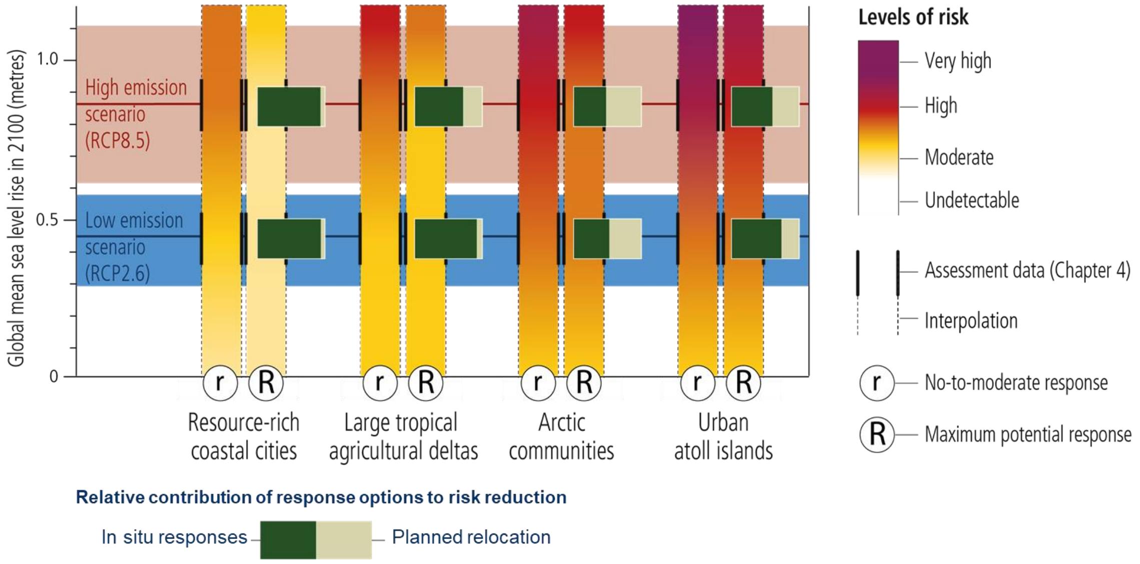
107. **Ecosystem-based adaptation** includes coral and wetland conservation or restoration measures. It provides dynamic measures which are effective and may be able to respond and cover up to 0.5 to 1 centimetre per year of sea level rise. There is an opportunity for community involvement. Co-benefits include habitat gain and biodiversity gain. The drawbacks are vulnerability of corals to climate change, so effectiveness depends on ocean warming, acidification and emission scenarios. For wetlands the safety levels are less predictable. There is limited evidence on benefit-cost ratios and there are governance challenges involved as there is a lot of land required. Permits are difficult to obtain and there is a lack of finance and enforcement of conservation policies.

108. There is also a **time dimension** to be considered in risk reduction, as benefits of adaptation measures may be time limited (figure 16). The projected risk can be compared across places and across emission scenarios, taking into account the adaptation and mitigation efforts. The combination of adaptation and mitigation efforts would lead to the maximum degree of risk reduction. Nonetheless, the amount of reduction and delay depends on sea

level rise and the response scenario, which varies between contexts and localities. While some places may be able to reduce risk levels long term, in others risk levels may creep up and reach unacceptable levels. The time gained is maximised under combined emission reduction and mitigation with maximum adaptation efforts considering that risk thresholds may be reached over time in some places.

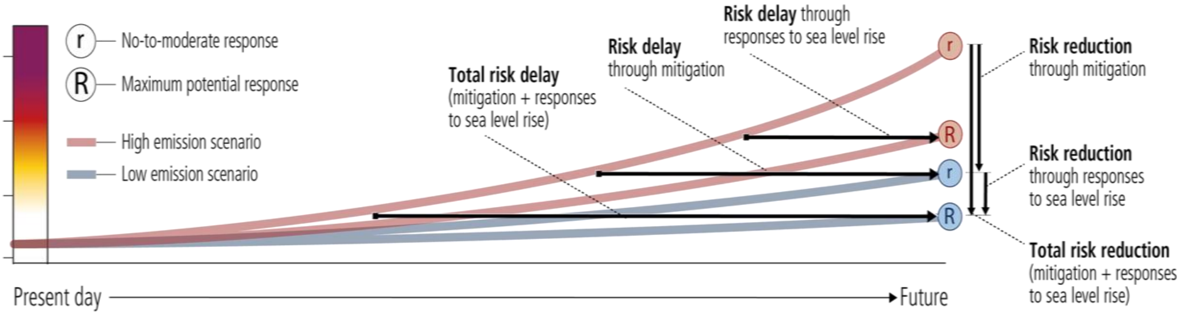
109. Considering the benefits of responses to sea level rise and mitigation, risks may continue to increase at different rates as exemplified by sea level rise. Risk levels also depend on the capacity of responses, for example, local adaptive capacity and or retreat may and depend on mitigation effort. Risk reduction through adaptation may therefore be time limited, which emphasises the urgency of enough action on the adaptation and mitigation fronts.

Figure 15
Sea level rise risks and responses



Source: Slide 29 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.5). The term response is used here instead of adaptation because some responses, such as retreat, may or may not be considered to be adaptation. Shown is the combined risk of coastal flooding, erosion and salinization for illustrative geographies in 2100, due to changing mean and extreme sea levels under RCP2.6 and RCP8.5 and under two response scenarios. Risks under RCPs 4.5 and 6.0 were not assessed due to a lack of literature for the assessed geographies. The assessment does not account for changes in extreme sea level beyond those directly induced by mean sea level rise; risk levels could increase if other changes in extreme sea levels were considered (e.g., due to changes in cyclone intensity). A socioeconomic scenario is considered with relatively stable coastal population density over the century. Risks to illustrative geographies have been assessed based on relative sea-level changes projected for a set of specific examples: New York City, Shanghai and Rotterdam for resource-rich coastal cities covering a wide range of response experiences; South Tarawa, Fongafale and Male' for urban atoll islands; Mekong and Ganges-Brahmaputra-Meghna for large tropical agricultural deltas; and Bykovskiy, Shishmaref, Kivalina, Tuktoyaktuk and Shingle Point for Arctic communities located in regions remote from rapid glacio-isostatic adjustment. The assessment distinguishes between two contrasting response scenarios. "No-to-moderate response" describes efforts as of today (i.e., no further significant action or new types of actions). "Maximum potential response" represents a combination of responses implemented to their full extent and thus significant additional efforts compared to today, assuming minimal financial, social and political barriers. The assessment has been conducted for each sea level rise and response scenario, as indicated by the burning embers in the figure; in-between risk levels are interpolated. The assessment criteria include exposure and vulnerability (density of assets, level of degradation of terrestrial and marine buffer ecosystems), coastal hazards (flooding, shoreline erosion, salinization), in-situ responses (hard engineered coastal defences, ecosystem restoration or creation of new natural buffers areas, and subsidence management) and planned relocation. Planned relocation refers to managed retreat or resettlement, i.e., proactive and local-scale measures to reduce risk by relocating people, assets and infrastructure. Forced displacement is not considered in this assessment. Also highlighted is the relative contributions of in-situ responses and planned relocation to the total risk reduction.

Figure 16
Sea level rise risks and responses – Risk reduction and delay



Source: Slide 32 of the full presentation by the IPCC during the special event.
IPCC, 2019: The Summary for Policymakers of the IPCC Special Report on the Ocean and Cryosphere (figure SPM.5). The risk reduction (vertical arrows) and risk delay (horizontal arrows) through mitigation and/or responses to sea level rise.

5. From response options to governance and policies

110. Ms. Debra Roberts, Co-Chair of IPCC WGII, continued the presentation by describing SROCC's findings concerning governance and policy.

111. The emphasis on action and consideration of best response to these complex systemic challenges is necessary given the urgency of the messages of the report. An important triumvirate that facilitates action is the **interaction between governance, policies, and institutions**. The role of these three important tools is to reduce risk to society and to the important natural ecosystems on which we are dependant.

112. The IPCC describes risk as the product of the interaction between climate hazards and the levels of exposure and vulnerability that we see in the impacted natural and human systems. In terms of policy, governance and the ability to reduce risk, adaptation offers the possibility to act on the three components of risk (figure 17).

113. In terms of **hazards**, adaptation provides the ability to reduce hazards, as has been underscored in terms of ecosystem-based adaptation for example with the use of mangroves to alleviate coastal storm energy. We have also heard from delegates the impacts of climate change on coastal environments. There are opportunities to reduce **vulnerability and exposure**, for example regulations requiring hazard proof housing, infrastructure and smart planning, and risk sensitive land use planning to reduce the exposure of human communities and infrastructures to specific risks, such as storm surges.

Section 6. Source: IPCC, 2019: Slide 55 of the full presentation by the IPCC during the special event. *Photo*: Kelly-Marie Davidson, PML.

114. It is important to underscore that there are **limits to adaptation**. Adaptation is not a silver bullet. We cannot adapt our way out of the problems outlined in the context of ocean and cryosphere systems. Limitations to adaptation can be broad ranging: physical - not enough space to move; ecological; technological; economic - a lack of resources with poorer communities having more difficulty adapting; political - lack of political will - a significant hurdle; institutional; psychological; social; and cultural - a lock of willingness to change behaviours that put human societies at risk.

Figure 17
Option for risk reduction through adaptation

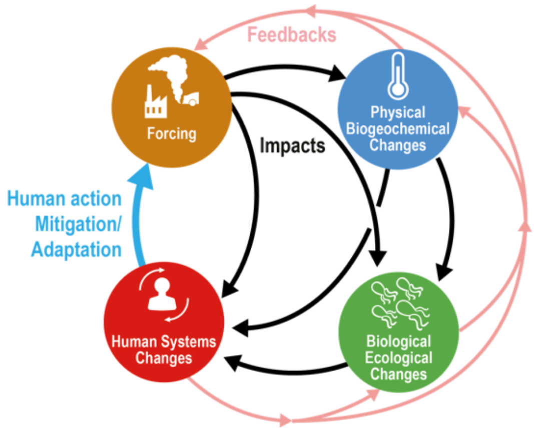
Source: Slide 34 of the full presentation by the IPCC during the special event.
IPCC, 2019: The IPCC Special Report on the Ocean and Cryosphere (figure CB2.1). There are options for risk reduction through adaptation. Adaptation can reduce risk by addressing one or more of the three risk factors: vulnerability, exposure, and/or hazard. The reduction of vulnerability, exposure, and/or hazard potential can be achieved through different policy and action choices over time until limits to adaptation might be reached. The figure builds on the conceptual framework of risk used in AR5 (Oppenheimer et al., 2014).

115. Adaptation limits also include the **temporal scales** of climate change impacts and the significant societal consequences. These impacts happen on time horizons that are much longer than the governance arrangements that are in place to respond to them. Sea level rise will cause enduring and unprecedented changes over many centuries. Thus, impacts and changes will continue during planning cycles, decisions cycles and finance planning which typically happen over three to five years. The SROCC highlights **changes will continue for over 300 years**. So, there is disjuncture created in responding to these very significant challenges.

116. Impacts caused by climate-related changes in the ocean and cryosphere challenge our existing **governance** efforts to respond to them. Adaptation responses can enable us to reduce risk at all scales, ranging from the individual to the global. The level of the impacts is large and the long term and systemic and the impacts range from the top of the mountains to the depths of the oceans. They are extensive and it is unsurprising that the report calls out that governance systems will be pushed to their limits. Governance systems are already being challenged and overwhelmed, such as in the Bahamas following Hurricane Dorian in 2019.

117. While governance systems are at risk given the kinds of impacts that we are observing and are projected going forward, Ms. Roberts stressed that, in many cases the governance arrangements for ocean and cryosphere systems are simply too fragmented across administrative boundaries and sectors. This impedes the facilitation of the integrated responses that are required to the systemic changes and the cascading risks from the climate related changes (figure 18). The SROCC underscores that the governance systems that provide us with our key tools of response are not up to the challenge that the changes in these two major global systems are posing.

Figure 18
The interconnectedness of the ocean and cryosphere and the cascading effects of changes in the two systems



Source: Slide 36 of the full presentation by the IPCC during the special event.
IPCC, 2019: The IPCC Special Report on the Ocean and Cryosphere (figure 1.1). Cascading effects, where changes in one part of a system inevitably affect the state in another, and so forth, ultimately affecting the state of the entire system. These cascading effects can also trigger feedbacks, altering the forcing.

118. The SROCC highlights that **adaptive capacity** is not uniform across the world. Often people with the highest exposure and vulnerability to existing and projected hazards from ocean and cryosphere systems are often those with the lowest response capacity such as due to limits to adaptation, timelines being unsynchronised and fragmented governance systems.

119. One important response that SROCC highlights is to **reduce other non-climatic stressors**, for example, pollution and habitat modification. By addressing these kinds of non-climate impacts, we give species the ability to adjust to changes in their environment. The report also calls out, as underscored in the SPM, the importance of **integrating policy frameworks** in order to increase opportunities for adaptation in both human societies and natural societies, ensuring that policy frameworks where there are similarities between systems and natural synergies provide co-benefits. For example, ensuring water management, fisheries, and networks of protected areas are aligned and coordinated not only together but across scales so that we see vertical and horizontal integration.

120. **Nature-based adaptation** is something that has been called out in all three of the special reports, but SROCC underscores that nature-based adaptation can be effective locally as many of these global changes in these large systems have serious local impacts. Those nature-based interventions can be made most effective when they are supported by local communities and this underscores the importance of engaging with local communities, and the importance of science-based interventions that also draw on local knowledge and indigenous knowledge to inform action.

121. Approaches that reduce non-climate stressors involve the engagement of nature-based solutions and increasing the capacity of people to adapt. These allow us to ensure that interventions not only address climate-related challenges but give multiple benefits across a range of developmentally important issues such as biodiversity, human development and, importantly, climate mitigation.

122. Other opportunities for improving our effective responses to the challenges posed by the changes in these two global systems (figure 19), echoing messaging from the land report, are **intensified cooperation and coordination across all scales and jurisdictions, sectors, policy domains and planning horizons**.

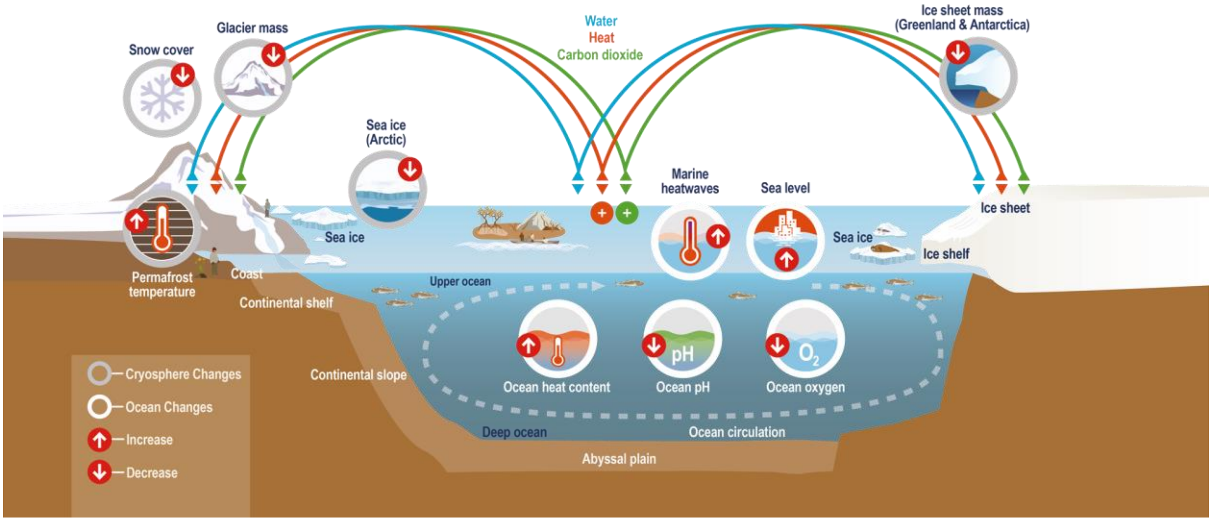
123. Engagement at all levels is important. On a global level, **climate change conferences** provide the global platform for ensuring cooperation between stakeholders at the global level. Important in that cooperation is the sharing of data and information that comes from long term monitoring and forecasting which are important enablers in responding to the changes and challenges in these systems. **Regional and transboundary cooperation** can be facilitated through the judicious use and coordination of treaties and conventions, investments in education, and capacity building, including engagements with local and indigenous peoples. The role of **local stakeholders** is critical, but we must look to ensuring investments in education and capacity building that allow them to bring all of their strengths to the table in this important debate.

124. Another important message across all reports is that we cannot only act on the climate-related challenges linked to the oceans and cryosphere. All actions must occur within a broader developmental framework linked to our broader aspirations as a global society of sustainable development. Key to tackling the issues of sustainable development are the needs to address the importance of social vulnerability and equity.

125. Ultimately the SROCC identifies the benefits of ambitious mitigation and effective adaptation for sustainable development. Climate is not seen as separate from the broader development agenda, and conversely there are escalating costs and risks to us and the natural systems on which we are reliant if we delay action in that regard.

126. The SROCC underscores the scale of the challenge we face, and, in many ways, the report brings to us as human society the biggest challenge we face as these two global systems cover 80% of the Earth’s surface. They are life sustaining systems, there is no single person who is not impacted by these two systems in some part of our lives. Ms. Roberts emphasised the enduring and unprecedented nature of the changes in these major global systems that will impact our lives and the lives of generations to come.

Figure 19
Key components and changes of the ocean and cryosphere



Source: Slide 38 of the full presentation by the IPCC during the special event.
IPCC, 2019: The IPCC Special Report on the Ocean and Cryosphere (box 1.1, figure 1). Schematic illustration of key components and changes of the ocean and cryosphere, and their linkages in the Earth system through the movement of heat, water, and carbon. Climate change-related effects in the ocean include sea level rise, increasing ocean heat content and marine heat waves, ocean deoxygenation, and ocean acidification. Changes in the cryosphere include the decline of Arctic sea ice extent, Antarctic and Greenland ice sheet mass loss, glacier mass loss, permafrost thaw, and decreasing snow cover extent. For illustration purposes, a few examples of where humans directly interact with ocean and cryosphere are shown.

127. The SROCC provides an assessment of the challenges and enables consideration of the options that are available to society to respond to these widespread and enduring changes. The most important message as underscored in every special report, is the sense of urgency of timely, near-term, ambitions action that is coordinated between various parties at all scales from individual to international in order to deal with these widespread and enduring changes. The report also underscores the important factors of protecting and restoring the ecosystems on which our development depends and the careful management of these natural resources in order to reduce risks that we experience from the changes in these two systems that bring us multiple societal benefits.

128. It underscores the importance of our people, communities and governments in tackling these unprecedented changes, the need for a variety of stakeholders in the **unprecedented transitions** that are important for society to consider in responding to these significant changes. The call for the unprecedented systemic transitions identified in the Special Report on Global Warming of 1.5° C are echoed in the Special Report on Climate Change and Land and are reinforced in the SROCC.

129. The SROCC also provides us with the evidence, combining different forms of knowledge, combining scientific knowledge with important local and indigenous knowledge. It focusses for the first time on the importance of education and climate literacy in increasing our capacity to respond to these challenges.

130. The more decisively and earlier we act, the more able we will be to address unavoidable changes, manage risks, improve our lives and achieve sustainability of ecosystems and people around the world today and in future.

131. The ocean and the cryosphere systems sustain us, but they are under pressure, their changes affect all our lives, the time for action is now.

6. Summary of discussions

132. In response to a question asking **which scenario would limit sea level rise to below 1 centimetre by 2100**, an IPCC expert highlighted that for a mean projected warming of around 1.6° C by 2100 under RCP 2.6 the projected rate of sea level rise is about 4 millimetres per year, close to today's value. The upper likely range goes to 6 millimetres, twice today's value. For the mean projected warming of 2.5° C by 2100 under RCP 4.5, the median value for the projected rate of sea level rise is 7 millimetres, around twice today's value, and the upper likely range is 9. The current evidence suggests that the level of warming linked to limiting the rate of sea level rise to less than 1 centimetre per year is less than 2.5° C.

133. In regards to providing **insights as to how investments could be mobilised for the purpose of establishing coastal protection to reduce flood risk, keeping in mind the financial limitation of many vulnerable regions**, an IPCC expert highlighted that the IPCC Special Report on Global Warming of 1.5° C identified the major systemic transition required to achieve a 1.5-degree future and broadly identified that current

flows of investment would have to be redistributed and altered. There is ongoing work in the context of AR6 WGII to assess the transition required on a regional level.

134. A question was asked in regards to **what extent it is possible to restore vegetated coastal ecosystems and what kind of benefits are related to such restoration in terms of adaptation and other measures.** An IPCC expert responded that this depends on the coastline available and the political will to restore those systems as well as the degree of global warming. Vegetated coastal ecosystems are highly specialised to a limited range of temperatures and will not be able to colonise places that are warmed beyond their heat limits. The warmest places in the ocean are already going beyond the heat tolerances of some of those systems, especially sea grasses and kelp forests. Any effort to restore coral reefs will be hampered once global warming exceeds the temperature thresholds for these highly complex systems and any experimental efforts to shift the thermal limits of those systems have so far not been able to provide a positive perspective, although such research continues. The SROCC identifies that restoration of vegetable coastal ecosystems, for example mangroves, tidal marshes and seagrass meadows, could provide climate change mitigation through increased carbon uptake and storage of around 0.5% of current emissions, which shows the limits of this as a mitigation method. However, there are many co-benefits: coastal protection from erosion, improving water quality, benefiting biodiversity, and fisheries. This accounts to a relatively low mitigation efficiency compared to the global carbon emissions, but a lot of co-benefits.

135. It was highlighted that **the changes of the cryosphere and oceans, as presented in the SROCC could result in future generations not knowing what a glacier or warm water coral is or understanding the beauty of these living species. Responding to how these systems can be conserved and how to tell future generations of their future as changed by the actions of previous generations**, the IPCC experts responded that it is important to note that reference to the IPCC reports must be factual and must not be extrapolated to the extreme. There will be a marginalisation of the large-scale coral reefs and their services, but not a complete loss of the respective coral species. However, they will not be found where they currently exist or be able to support large scale reefs. There is no report yet of the extinction of a marine species under climate change. Species go through different stages of abundance, loss, reproduction, and loss and shifts in biogeographical distribution so we must be careful in phrasing such statements. The engagement and investment of the public, particularly the youth is important in keeping science at the heart of forward planning. The Youth have caused huge mobilisation of people following the publication of the Special Report on Global Warming of 1.5° C, and this is an important element in implementing the right policies.

136. In regards to making the findings of the IPCC report more accessible and bridging the **gap between the dense Summary for Policymakers and the descriptive text of the main report to make the findings of the report more accessible**, the IPCC experts highlighted that the IPCC is working towards improving communication of its reports, although it is a compliment received for the first time that the chapters of the SROCC are easier to read than the Summary for Policy-Makers.

137. An issue was identified that had not been assessed in SROCC. This was **the movement of the sediments from the Amazon, which support the mudbanks on which mangroves grow in Suriname, and how these movements would** be **affected by sea level rise and how the ecosystem could adapt to these changes.** The IPCC expert encouraged Parties to join the review of the regional chapters for the AR6, which address issues such as this, and identify as part of the review the importance of processes such as this in order that the literature available can be assessed.

C. Summary of the general discussion and interventions from Parties

138. A total of 19 Parties and five Observers posed questions and/or provided comments. Overall, participants expressed their gratitude to the IPCC for their continued work, welcomed the report and thanked the SBSTA and IPCC for organising the event, which was deemed a useful opportunity to discuss the report's findings. Parties acknowledged also the importance of the content of the report to the upcoming negotiations, particularly to enhancing mitigation efforts in preventing the exceedance of the 1.5° C target.

139. Several participants expressed their concern that their regions are already experiencing some of the effects described in the report and requested clarification on region-specific findings. Some participants also sought clarification on what can be expected in these regions in the future, given their already exposed condition. The co-chairs responded with reference to the upcoming regional Chapters of the AR6, and invited Parties to become involved in the draft review process of the Assessment.

140. Participants also expressed the need for the observed and predicted effects identified in the findings of the report to have their interlinkages made clearer, for example, the effect of tropical cyclones on the weather conditions in a region's interior.

141. One participant praised the comprehensiveness of the report in covering the entire values chain from science to policy and assisting in bridging the gap between them. The ability of the report to assist in developing science-based solutions and to help to reduce the impacts on the ocean, marine ecosystems and human subsistence and well-being was also highlighted.

142. The Decade of Ocean Science for Sustainable Development was highlighted in terms of participant's hopes that it will support transformative solutions to the problems presented in the report.

143. One participant highlighted the important role of indigenous people in sharing their knowledge of adaptation and mitigation techniques and emphasised the value of indigenous knowledge to strengthening response options. The importance of the co-production of knowledge and the opportunity presented by the reports to do so was underlined.

144. On behalf of the FAO, one participant highlighted the value of the report to ocean food production and socioeconomic implications. The participant noted that the importance and vulnerability of fisheries is also highlighted in FAO technical paper 627.[14] The governance challenges and opportunities related to the redistribution of fish stocks is emphasised, especially in terms of the opportunity to implement sustainable fisheries practices. The participant underscored the importance of ecosystem-based adaptation, traditional knowledge and participatory decision making as advocated for by the FAO and included among a broad set of adaptation methods and tools in the FAO adaptation toolbox that are relevant to different scales and contexts.

D. Closing remarks

145. In his closing remarks, the IPCC Chair thanked the speakers from the two Working Groups and the participants. He briefly summarised the key conclusions of the presentation and discussion:

(a) Immediate action is necessary to reduce climate impacts on the ocean and cryosphere;

(b) There were many questions around region-specific information such as risks, adaptation options potential, limits to adaptation and enabling conditions;

(c) Research is still needed to address the uncertainty in particular sectors and expand the literature base and data sources.

146. The IPCC Chair expressed his appreciation for the participants' questions and comments and indicated that they will be considered in the ongoing work on the IPCC's Sixth Assessment Report.

147. Finally, Ms. Gama, the SBSTA rapporteur, noted the rich discussions of the event and made participants aware of the production of the summary report ahead of SBSTA 52. She expressed her gratitude to the IPCC Chair, and to all presenters and participants.

[14] Available at http://www.fao.org/policy-support/resources/resources-details/en/c/1152846/.