Assessment Report on Climate Change Impacts in Japan

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Ministry of the Environment, Japan

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Key Points of this Report

This report is an assessment, based on scientific findings, of the kinds of impacts climate change could have on Japan, in a total of 71 categories in seven sectors, from the perspective of magnitude and likelihood (significance), timing of occurrence, adaptation measures and critical decision-making (urgency), and certainty of information (confidence). It is expected that this report will find various uses as input for an update of Japan's Climate Change Adaptation Plan, planned for fiscal year 2021, and for local governments and businesses to grasp the impacts of climate change and consider adaptation plans, etc.

1. Increased Findings and Improved Confidence

A total of 1,261 items of reference literature were cited as a basis for this report, approximately 2.5 times the number used for the previous assessment (2015). As a result, the confidence level of 31 categories increased, with 55 categories (77%) now rated medium or higher. This shows that the impacts of climate change are now being assessed with a higher level of confidence. Also, many of the categories that could not be assessed in terms of urgency or significance in the previous review could actually be assessed this time (9 of 11 categories for significance, 5 of 7 categories for urgency). In terms of significance, more accurate assessments were conducted this time, including assessments in 8 categories for each climate scenario.

Nevertheless, some categories are still assessed at a low confidence level, particularly in sectors such as natural ecosystems and industrial/economic activities, making further research necessary.

2. Categories Assessed at a High Level of Significance, Urgency, and Confidence

The current assessment shows that the impacts of climate change are significant and urgent. Among 71 categories in 7 sectors, 49 categories (69%) were "recognized as having particularly significant impacts" and 38 categories (54%) as "high urgency." Also, 33 categories (46%) were found to have a high level of both significance and urgency. In addition, 3 new categories were assessed this time as "recognized as having particularly significant impacts" and 8 as "high urgency of response."

A selection of these is introduced below. In addition to these, there are impacts that merit careful attention, including categories that as in the previous assessment continue to be assessed as high in terms of significance, urgency, and confidence, and categories newly added this time and assessed as high in terms of significance and urgency; more details are available in Table 3-6 (assessment summary table) and in the Climate Change Impact Assessment Report (Detailed Report) (current status and future impacts are described for each category).

Categories with increased confidence levels among those assessed high in significance, urgency, and confidence

(Categories are listed that increased in confidence in this assessment (from "low" or "medium" to "high"). For "Heat illness, etc." there was no change in confidence, but it is the only item in the "Human Health" sector assessed as high for each of significance, urgency and confidence, so it is listed here.)

[Agriculture] Water, land and agricultural infrastructure

<Current status> Water shortages, etc., due to increase in rainless days, decrease in winter snow fall

<Projected future impacts> Reduction in available water volume, impacts on farmland due to frequent slope disasters, etc.

[Water resources] Water supply (surface water)

<Current status> Droughts, etc., due to increase in rainless days, etc.

<Projected future impacts> Problems with water intake in river estuaries due to seawater (saltwater) ingress as a result of sea-level rise

[Natural ecosystems (coastal ecosystems)] Subtropics

<Current status> Extensive coral bleaching thought to be due to high water temperature in summer, mangrove die-off due to sea-level rise, etc.

<Projected future impacts> Decrease in suitable habitat for coral reefs in subtropical zones, etc.

[Natural disasters] Inland waters

<Current status> Costs of water damage from inland flooding account for approximately 40% of total water damage nationwide (average for 2005 to 2012), even higher in urban areas

<Projected future impacts> River flooding and inundation, etc., due to heavy rainfall and rise in sea level

[Natural disasters (mountain areas)] Debris flows, landslides, and other disasters

<Current status> Simultaneous multiple slope failures collapses in watersheds and atypical large-scale sediment disasters caused by debris flows, etc.

<Projected future impacts> Increased frequency of heavy rainfall events, increased frequency of sediment disasters and extent of area affected, increased scale of impacts, etc.

[Human health (Heat stress)] Heat illness, etc.

<Current status> Nationwide increase in number of heat illness patients transported by ambulance, and mortalities related to heat illness, etc.

<Projected future impacts> Shorter in outdoor working hours, increased risk from heat-related illness, etc.

[Life of citizenry, urban life (urban infrastructure, critical services)] Water supply, transportation, and the others

<Current status / Projected future impacts> Impacts on infrastructure and critical services due to increased frequency of heavy rainfall events and droughts, and more intense tropical cyclones, etc.

Examples of items newly assessed "recognized as having particularly significant impacts," and current status

[Water resources (water supply)] Groundwater

Impacts occurring include excessive groundwater pumping and decreased groundwater levels, etc., due to drought.

[Human health] Impacts on vulnerable populations

Health impacts on the elderly have occurred due to heat stress, and they are expected to increase in the future.

*This category is newly added in this assessment.

[Industrial / economic activities] Construction

Buildings have been affected by tropical cyclones, tornadoes, and heavy snowfalls, etc., and the need to update design criteria and standards for wind loads and air conditioning loads, etc., is being reviewed.

* This category is also newly assessed as "urgency of countermeasures is high."

Examples of items newly assessed as "high urgency of response," and

current status

(List includes items also assessed as having high significance.)

[Agriculture] Livestock farming

Impacts occurring include declines in productive capacity and reproductive functions of livestock.

[Natural ecosystems (terrestrial ecosystems)] Natural forests, secondary forests

New current impacts have been confirmed, including changes in forest constituent species near vegetation zone boundaries.

[Natural ecosystems (terrestrial ecosystems) Planted forests

Japanese cedar (*sugi*) forests are declining in some areas due to increases in water stress.

[Natural disasters] Strong winds, etc.

New current impacts have been confirmed including changes in the spatial position of maximum tropical cyclones intensity, and tornado damage, etc.

[Human health] Vector-borne diseases

It has been confirmed and projected that mosquito vectors of infectious diseases (e.g., Asian tiger mosquito (*Aedes (Stegomyia) albopictus*), a vector of the dengue virus) will have expanded habitat and longer active periods.

3. Climate Change Impacts on Meteorological Disasters

In recent years, Japan has experienced many severe meteorological disasters including the Heavy Rain Event of July 2018, Typhoon Jebi (T1821), Typhoon Faxai (T1915), and Typhoon Hagibis (T1919). With insurance payments for wind and water damage exceeding a trillion yen two years in a row, in fiscal 2018 and 2019, the impacts of meteorological disasters on citizen life, industrial activities and more, are resulting in a growing interest about how climate change is affecting meteorological disasters. In June 2020, then-Minister of State for Disaster Management Ryota Takeda and Minister of the Environment Shinjiro Koizumi issued a joint message as a strategy for drastic disaster risk reduction measures based on climate change risks. The message states that when recovering from disasters, we must respond to them conveying the idea of "Adaptive Recovery" by implementing resilient measures including the control of land use where communities can ensure adaptation to climate change.

There has been limited research into the effects of climate change on the tropical cyclones and heavy rains experienced to date, but it has been reported that, for example, climate change causes changes in the spatial position of the maximum intensity of tropical cyclones and changes in tropical cyclones tracks. In addition, in the Heavy Rain Event of July 2018, record heavy rainfall was observed for extended periods over a wide region of Japan, and there are reports that an increase in the amount of water vapor due to global warming contributed to the series of rainfall events. Regarding future impacts, although trends differ from region to region, wind and tropical cyclones intensity are projected to increase with temperature increases toward the latter part of the 21st century. Heavy rainfall events causing floods are also projected to increase significantly at the end of this century relative to today in major Japanese river basins.

4. Impacts of Complex Disasters

In the Heavy Rain Event of July 2017 in northern Kyushu and the Heavy Rain Event of July 2018, sediment disasters and floods occurred simultaneously, and their mutual effects reportedly exacerbated the extent of the damage. Although the impacts of climate change on past disasters are not entirely clear, considering projections that climate change will increase the frequency of heavy rainfall events with large total rainfall and intense tropical cyclones, this report describes current impacts with a focus on the impacts of complex disasters that increase the scale and extent of damage over extensive areas compared to isolated impacts that occur alone.

Impacts of Recent Complex Disasters

(The Heavy Rain Event of July 2017 in northern Kyushu)

- Extensive slope failures and debris flows were the direct cause of disasters; in addition, large sediment flows downstream raised riverbeds and caused rivers to overflow, resulting in significant flooding.
- Damage further downstream was exacerbated by the large volume of wood debris from slope failures, combined with wood debris washed down from trees along streams and river banks.

(The Heavy Rain Event of July 2018)

- Besides record rainfall over extended periods, intense rainfall events with a short duration also occurred over a wide area, resulting in both river flooding and inland flooding.
- Continuous rainfall drove a large amount of sediment from sediment disasters upstream into rivers, and the its accumulated further downstream where the flow velocity was slower, resulting in raised riverbeds, sediment overflows, and combined sediment and river flooding.

5. Inter-sectoral Impact Linkages

It has been stated that to deal properly with the impacts of climate change, it will be important to not only ascertain and project the impacts in each sector, but also to pay attention to the inter-linkages of impacts across multiple sectors and categories. For example, in recent weather-related disasters it has been confirmed that there were also major socioeconomic impacts of infrastructure damage and disruptions to critical services. This report therefore uses the term “inter-sectoral impact linkages” to define the linkages among impacts due to a given impact triggering impacts in other categories or sectors, and events that exacerbate impacts due to the inter-linkages in other categories or sectors; the report provides examples and discusses impacts of concern. Because the driving mechanisms are complex, findings are currently limited, and assessments have not been implemented, scientific findings need to be further augmented in the future.

Examples of Impacts Linked Across Sectors

- Expanded distribution of Asian tiger mosquito (*Aedes (Stegomyia) albopictus*) due to warmer temperatures ==> Increase in risk of a-borne infectious diseases
- Loss of sandy beaches due to sea-level rise and lack of snow depth due to reduced snowfall ==> Impacts on leisure and tourism industries
- Earlier blossoming of cherry and plum blossoms due to increased temperatures ==> Impacts on timing of traditional ceremonies and festivals

6. Importance of Promoting Measures for Both Adaptation and Mitigation

In response to the types of climate impacts described above, in a variety of areas such as flood control and agricultural, forestry and fisheries industries, adaptation strategies are being planned and implemented based on future projections of the impacts of climate change. In the future, improved detail and accuracy of impact assessments is expected to enable the planning and implementation of more coherent and efficient measures. Meanwhile, the global average temperature has increased by approximately 1°C so far relative to pre-industrial levels, and it has been projected that there is a high likelihood that the temperature will increase by 1.5°C between 2030 and 2052 if global warming continues at the current pace. Also, it has been pointed out that there are tipping points that result in irreversible changes and impacts if exceeded, so it is important to steadily implement mitigation efforts to reduce and avoid significant climate change impacts by limiting the temperature increase to well below 2°C, and pursue efforts to limit the warming to 1.5°C.

Chapter 1 Background and Purpose

1.1 Background

(1) International Trends relating to Climate Change

At the twenty-first session of the Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC), held in 2015 in Paris, France, the Paris Agreement was adopted to be an equitable and practical legal framework for all members, whether they were developed or developing countries, to address climate change from 2020 onward. The Paris Agreement calls for global efforts to keep the increase in the global average temperature to well below 2°C above pre-industrial levels, and pursue efforts to limit the increase to 1.5°C.

With the decision of COP21, the Intergovernmental Panel on Climate Change (IPCC) was invited to prepare a special report on the impacts of global warming of 1.5°C and greenhouse gas (GHG) emission pathways to limit warming to that level. In response, in October 2018, the IPCC released the "Special Report on Global Warming of 1.5ºC" (An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty); this was its special report providing the latest scientific knowledge relating to climate change. In August 2019, the IPCC released the "Special Report on Climate Change and Land" (IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems), and in September 2019, the "Special Report on the Ocean and Cryosphere" (IPCC Special Report on the Ocean and Cryosphere in a Changing Climate).

The "Special Report on Global Warming of 1.5ºC" states that the global average temperature increase due to human activities had reached approximately 1.0ºC by 2017, and that if the current rate of warming continues at the same pace, 1.5ºC may be reached between 2030 and 2052.

The "Special Report on Climate Change and Land" states that climate change creates additional stresses on land and has impacts on people and ecosystems, exacerbates existing risks to food systems, and affects the price of grains and other products.

The "Special Report on the Ocean and Cryosphere" reported that changes and impacts already observed include receding of the extent of the cryosphere and a degradation in the quality and quantity of ice sheets and glaciers, a reduction of snow cover and the extent and thickness of Arctic sea ice, and warmer temperatures in the permafrost.

Also, the Sustainable Development Goals (SDGs) were at the core of the 2030 Agenda for Sustainable Development, which was adopted by the United Nations General Assembly in 2015. The SDGs aim for integrated solutions to issues relating to the environment, economy, and society, consisting of 17 goals and 169 targets, shared in common by developing and developed countries, with the aim of creating a sustainable society. The goals and targets are inter-connected, and climate change falls under Goal 13. In Japan, the SDGs Promotion Headquarters were established by the government in May 2016, and the relevant ministries and agencies are working together to mainstream the SDGs.

Further, based on the potential for enormous damage to occur from meteorological disasters intensified by climate change, in recent years there has been a growing recognition of the economic and financial risks of climate change. From concerns about impacts of climate change on financial systems, the Financial Stability Board (FSB), an international organization, has established the Task Force on Climate-related Financial Disclosures (TCFD). The TCFD has discussed the development of a framework for appropriate information disclosure relating to climate change risks and opportunities for companies, and calls upon them to disclose climate-related information such as strategies and risk management that can have financial impacts on the companies. Many companies in Japan have endorsed the TCFD recommendations, so we have now entered an era in which the impacts of climate change will have a significant impact on corporate activities and investor behavior.

(2) Developments in Japan relating to Climate Change Impact Assessments

Within Japan, long-term changes that have been observed include warmer average temperatures and increased frequency of heavy rain events, and many impacts of these changes have been reported. In recent years in particular, there has been a significant amount of damage from weather-related disasters, including the Heavy Rain Event of July 2018, Typhoon Faxai (T1915), Typhoon Hagibis (T1919), and the Heavy Rain Event of July 2020; also, record high temperatures occurred in the summer of 2018, with new national records broken for the number of patients transported by ambulance due to heat-related illness. Because risks of extreme high temperatures and heavy rains are projected to increase in the future due to the advance of climate change, climate change impact assessments in various sectors are becoming increasingly important.

In March 2015, the "Report on Assessment of Impacts of Climate Change in Japan and Future Challenges" was published as a comment submission to the Minister of the Environment from the Central Environment Council of the Ministry of the Environment. Based on the scientific findings presented therein, a Cabinet decision was made in November that year to adopt the Adaptation Plan for the Impacts of Climate Change. Subsequently, the Climate Change Adaptation Act was passed in June 2018 (entry into force December 1, 2018), and Article 10 of the Act stipulates that the Minister of the Environment shall prepare and publish a Climate Change Impact Assessment Report approximately every five years. Prior to the Act's entry into force, the Climate Change Adaptation Plan was adopted by Cabinet decision in November 2018, based on Article 7 of the Act.

Climate Change Adaptation Act, Article 10

Based on the most recent scientific knowledge on climate change and various other fields in the observation, monitoring, projection and assessment of climate change impacts, the Minister of the Environment shall receive the opinions of the Central Environment Council approximately every 5 years and make and publicize a report on the comprehensive assessment of climate change impacts. This, however, may be done after a shorter period if it is found to be necessary to do so, due to the improvement of scientific knowledge or other circumstances.

(2) Before preparing a draft as prescribed in paragraph (1) of the preceding Article, the Minister of Environment shall make a draft in advance and consult with the heads of the related administrative agencies.

Since the first Impact Assessment was published, significant progress has been made with research and studies relating to climate change assessments and adaptation. With the "Program for Risk Information on Climate Change" and "Social Implementation Program on Climate Change Adaptation Technology" (SI-CAT) under the Ministry of Education, Culture, Sports, Science and Technology, ensemble climate projection datasets have been developed based on future climate conditions of global average temperatures at 4ºC and 2ºC above pre-industrial levels (d4PDF, d2PDF), enabling stochastic and highly accurate assessments of future changes relating to extreme events such as tropical cyclones and intense heavy rainfall events. Examples of how these datasets can be utilized include research using methodologies for quantitative assessment of the impacts of climate change on individual extreme events (known as event attribution).

Furthermore, with initiatives such as SI-CAT and the Climate Change Regional Adaptation Consortium Program (a joint initiative of the Ministry of the Environment, Ministry of Agriculture, Forestry and Fisheries, and Ministry of Land, Infrastructure, Transport and Tourism), progress was made in the development of climate change impact assessments and adaptation strategies, at not only the national but also prefectural and municipal scales. In addition, the findings of the project Strategic Research on Global Mitigation and Local Adaptation to Climate Change (Environment Research and Technology Development Fund, Theme S-14) under the Ministry of the Environment are also reflected in this report.

Furthermore, in order to promote adaptation by various actors, including the central government, local governments, the private sector and individuals, a number of information platforms have been developed, including the Climate Change Adaptation Information Platform (A-PLAT) and the Data Integration and Analysis System (DIAS).

Going forward, led by the Center for Climate Change Adaptation established within the National Institute for Environmental Studies in April 2019 based on the Climate Change Adaptation Act, information on climate change impacts and adaptation is being consolidated in collaboration with local research institutes, government bodies and universities, etc., and significant further progress is expected in the efforts of each of these bodies.

Table 1-1. International and domestic developments relating to climate change since the previous impact assessment (2015)

Year	International developments		Developments in Japan	
2015	September	**2030 Agenda for Sustainable Development** [United Nations]	March	**Report on Assessment of Impacts of Climate Change in Japan and Future Challenges (Comment Submission) from Central Environment Council** [Ministry of the Environment]
	December	**COP21 of UN Framework Convention on Climate Change: Paris Agreement adopted** [UNFCCC]	November	**Adaptation Plan for the Impacts of Climate Change** [Ministry of the Environment]
2016			May	**SDGs Promotion Headquarters established** [Ministry of Foreign Affairs]
	November	**Paris Agreement enters into force** [UNFCCC]	August	**Climate Change Adaptation Information Platform (A-PLAT) launched** [Ministry of the Environment]
2017	June	**Task Force on Climate-related Financial Disclosures (TCFD) Recommendations published** [Financial Stability Board]	July	**High Level Meeting on ESG Finance** [Ministry of the Environment]
			December	**SDGs Action Plan 2018** (subsequently updated annually)[Ministry of Foreign Affairs]
2018	October	**Special Report on Global Warming of 1.5ºC** [IPCC]	November	**Climate Change Adaptation Plan** [Ministry of the Environment]
			December	**Climate Change Adaptation Act entered into force** [Ministry of the Environment]
2019			March	**Policy for Strategic Observation and Monitoring of Climate Change Impacts** [Ministry of the Environment]
	August	**Special Report on Climate Change and Land** [IPCC]	June	**Long-term Strategy under the Paris Agreement**
	September	**Special Report on the Ocean and Cryosphere** [IPCC]		**Asia-Pacific Adaptation Information Platform (AP-PLAT) launched** [Ministry of the Environment]

Year	International developments		Developments in Japan	
2020			December	**Report on Climate Change in Japan 2020** [Ministry of Education, Culture, Sports, Science and Technology, Japan Meteorological Agency] **Climate Change Impact Assessment Report (this report)** [Ministry of the Environment]

* The responsible ministries in Japan are shown in brackets.

1.2 Purpose

This report (Climate Change Impact Assessment Report) is the report of a comprehensive assessment of climate change impacts, prepared by the Minister of the Environment under Article 10 of the Climate Change Adaptation Act, having received the opinions of the Central Environment Council and consulted with the heads of the related administrative agencies, based on the most recent scientific knowledge relating to the observation, monitoring, projection and assessment of climate change and the impacts of climate change in many sectors. It is the second Climate Change Impact Assessment Report, five years after the Comment Submission from the Central Environment Council in 2015, and it is the first to be based on Japan's Climate Change Adaptation Act.

In order to prepare this report, the Expert Committee on Climate Change Impact Assessment (hereinafter "Expert Committee"), under the Global Environment Committee of the Central Environment Council, compiled future projections of climate change based on existing research, and assessments of the impacts of climate change on nature and human society in Japan (hereinafter "impacts") and discussed the impacts of climate change on Japan.

The Climate Change Impact Assessment Report consists of two volumes, a "Detailed Report" providing detailed information on impact assessments, and a "Summary Report" providing a summary of the detailed report plus a summary of climate change in Japan, as well as current efforts, challenges, and future prospects relating to impact assessments.

The Climate Change Impact Assessment Report (Detailed Report) is a compilation of the results of discussions that were held by the Expert Committee and its sectoral working groups in order to provide information for the Climate Change Impact Assessment Report (Summary Report) relating to assessments of the impacts of climate change on Japan.

The main purpose of this report is to enable efficient access to information on climate change impacts and countermeasures, by sector and by category, for the central government to develop "Climate Change Adaptation Plans" and for local governments, companies and other actors to develop adaptation plans, by summarizing from the scientific perspective the kinds of impacts that may occur due to climate change in Japan as well as the magnitude and likelihood of those impacts (significance), the timing of impacts and necessary adaptation measures as well as critical decision-making (urgency), and the certainty of projections (confidence).

1.3 Process for Considering This Report

For the preparation of this report, the March 2017 meeting of the Expert Committee on Climate Change Impact Assessment (hereinafter "Expert Committee") of the Global Environment Committee, Central Environment Council, reviewed "Guidelines for Initiatives relating to Scientific Knowledge and Climate Risk Information for Promoting Climate Change Adaptation Measures (Interim Report)." Regarding the topic of "Regular Climate Change Impact Assessments" in that report, in order to work toward a climate change impact assessment in 2020 it was deemed appropriate for the Expert Committee to proceed with the ongoing collection and compilation of scientific knowledge through annual plans and with the cooperation of various experts; and as with the 2015 climate change impact assessment, it was decided to establish expert sector-by-sector working groups (hereinafter “Sectoral Working Groups”) and have them begin detailed work after they provide schedules and guidelines for the collection and compilation of literature and data.

Accordingly, it was decided to establish five Sectoral Working Groups and for them to engage in detailed discussions relating to climate change impacts in each sector (namely, Agriculture, Forestry, and Fisheries; Water Environment/Water Resources and Natural Disasters/Coastal Areas; Natural Ecosystems; Human Health; and Industrial/Economic Activities and Life of Citizenry and Urban Life).

In addition, a meeting of Sectoral Working Group chairs was convened to decide on basic guidelines to deal with topics shared across all sectors for this impact assessment, including significance, urgency, and confidence, etc. Literature was gathered and organized in accordance with the basic guidelines, the Sectoral Working Groups each met five times between 2017 and 2020, compiled information on the impacts of climate change in terms of “current status” and “projected impacts” from the scientific perspective based on the literature gathered, and made assessments in terms of significance, urgency, and confidence. As a result of the assessment, the meeting of working group chairs confirmed matters on the cross-sectoral perspective and discussed how to deal with impacts that span two or more sectors (inter-sectoral impact linkages, etc.).

In parallel, the Expert Committee met four times between 2019 and 2020 to examine the content of assessments in terms of work progress and draft reports at each stage and discuss overarching topics such as report structure and future issues to address. A meeting in December 2020 of the Global Environment Committee (Central Environment Council) approved the “Climate Change Impact Assessment Report (Summary Report)” and “Climate Change Impact Assessment Report (Detailed Report).”

The preparation of this report involved the collection of peer-reviewed papers and other literature, particularly in relation to climate change impacts on Japan, including the findings of IPCC’s Fifth Assessment Report, Special Report on Global Warming of 1.5ºC, and Special Report on the Ocean and Cryosphere, and through the work of Sectoral Working Groups, 1,261 documents were ultimately cited.

Chapter 2 Overview of Climate Change in Japan

2.1 Major Efforts for Observation and Projection of Climate Change Impacts

(1) Observation of Climate Change

Observation has been conducted by the Japan Meteorological Agency, Ministry of Education, Culture, Sports, Science and Technology, Ministry of the Environment, and other bodies via ground-based and ship-based observations, and the use of Argo floats, and in recent years by satellite as well. For greenhouse gases (GHGs), besides aircraft-based observation, column-averaged concentrations of gases such as CO_2 and methane are also being monitored by the Greenhouse gases Observing SATellite "IBUKI 2" (GOSAT-2). Continuous monitoring climate change is being done in a variety of ways, such as satellite monitoring of vapor, sea surface temperatures, soil moisture, snow and ice, etc., using GCOM-W (Global Change Observing Mission - Water "SHIZUKU"), and physical parameters (vegetation, clouds, aerosols, etc.) using GCOM-C (Global Change Observing Mission - Climate "SHIKISAI"). Furthermore, some of the important initiatives cited under the "Ten Year Implementation Policy for Earth Observation by Japan" (Council for Science and Technology Policy, 2015) include the elucidation of human-caused global environmental change, elucidation of the effectiveness of climate change countermeasures, and improvements in the accuracy of climate change projections. These efforts are being advanced through collaboration among ministries and agencies.

(2) Future Projections of Climate Change

Regarding projections of climate change, since FY 1996 the Japan Meteorological Agency has been periodically publishing the results of numerical model simulations as "Global Warming Projection" reports, with the latest edition published in March 2017 ("Global Warming Projection Vol. 9"), in order to provide information to contribute to discussions about mitigation and adaptation. Using that data, local changes in the climate are being assessed and published.

The Ministry of the Environment, Ministry of Agriculture, Forestry and Fisheries, and Ministry of Land, Infrastructure, Transport and Tourism, collaborated and cooperated on the "Regional Adaptation Consortium Program" over a three-year period, from FY 2017 to FY 2019. Under this program, wide-area councils were created in six regional blocks nationwide with the participation of local branch bureaus and departments of the central government, local governments, and research institutes of universities, etc., to exchange information on their adaptation initiatives and conduct climate change impact studies responding to regional needs.

In addition, the Ministry of Education, Culture, Sports, Science and Technology implemented the "Social Implementation Program on Climate Change Adaptation Technology" (SI-CAT) from FY 2015 to FY 2019, and after a needs survey done in collaboration with model local governments and other participants, "d2PDF," a large-scale ensemble climate projection dataset, was developed as a nationwide database with 20 km resolution for near-future climate projections, in collaboration with the Ministry of Education, Culture, Sports, Science and Technology's "Program for Risk Information on Climate Change"; it was used to simulate the world in about 2030 to 2050 using the RCP8.5 scenario with a global average increase of 2°C relative to pre-industrial temperatures, provided to model local governments and others in the Program, and used to predict the impact of climate change at the regional level.

Moreover, in order to better understand the mechanisms of climate change, improve climate prediction models, study the hazards of climate change, and develop more advanced climate projection datasets, the Ministry of Education, Culture, Sports, Science and Technology implemented the "Integrated Research Program for Advancing Climate Models" starting in FY 2017 and conducted future change projections that included model improvements and higher resolution for physical processes such as clouds expressed by climate models, improved data assimilation technology needed for near-future climate prediction, and assessed the frequency and maximum level of intensity of hazards associated with extreme events such as tropical cyclones and heavy rains.

2.2 Observation Results and Future Projections of Climate Change

The results of climate change observations provided below are based mainly on observational data from the Japan Meteorological Agency. In addition, the future projections of climate change provided below are based mainly on the following projection data.

i) Atmospheric Projections

The future climate projections for Japan are principally based on the result of future projection calculations performed using a global atmospheric model (MRI-AGCM: Mizuta et al., 2012) with a 20 km horizontal resolution, and a non-hydrostatic regional climate model (NHRCM05: Sasaki et al., 2011) with a 5 km horizontal resolution, both developed by the Meteorological Research Institute (Japan Meteorological Agency).

ii) Ocean Projections

Future projections of sea surface temperatures, sea levels, sea ice, and ocean circulation are based on the SI-CAT Ocean Dataset. The SI-CAT ocean dataset is a near-future projection database for the sea around Japan created by Japan Agency for Marine-Earth Science and Technology under the Social Implementation Program on Climate Change Adaptation Technology (SI-CAT) of the Ministry of Education, Culture, Sports, Science and Technology; it was calculated by using the ocean model MRI.COM (Tsujino et al., 2017) developed by the Meteorological Research Institute.

iii) Ocean Acidification Projections

For future projections of ocean acidification, projection results from Earth system models in the Coupled Model Intercomparison Project - Phase 5 (CMIP5) were utilized, as well as the results of applying future changes from Earth system models to multiple regression models developed based on long-term ocean observation.

iv) Extreme Event Projections

Regarding changes in the frequency of extreme events that do not occur frequently (e.g., once in every few decades), under the Program for Risk Information on Climate Change of the Ministry of Education, Culture, Sports, Science and Technology, assessments were done based on an ensemble climate projection database (d4PDF: database for Policy Decision making for Future climate change)[1] created by conducting multi-member ensemble experiments (maximum 100 members).

Moreover, climate change projections are calculated by using climate models that are based on scenarios of how atmospheric concentrations of greenhouse gases, aerosols, and other substances change; those future projections involve a certain degree of uncertainty due to factors such as the uncertainty of the scenarios, imperfections in the models, and internal variability of climate systems.

Also, in day-to-day weather and seasonal variations, there can be high or low temperature events, heavy rainfall, heavy snowfall, or other events that diverge significantly from the long-term trends. Thus, it is important to have a long-term perspective spanning several decades in order to ascertain the impacts of global warming.

[1] http://www.miroc-gcm.jp/~pub/d4PDF/

(1) Current Greenhouse Gas Concentrations

- Anthropogenic emissions of GHGs have increased since the pre-industrial era (mid-18th century). The increase in atmospheric GHG concentrations is extremely likely the dominant cause of the global warming observed in the latter half of the 20th century. The representative GHGs that have a major impact on global warming--carbon dioxide, methane, and nitrous oxide--have increased to concentrations unprecedented in at least the past 800,000 years, and their average rates of increase of concentrations over the past 100 years are unprecedented in the past 22,000 years (very high confidence) (IPCC, 2013).
- The global average concentration of carbon dioxide in the atmosphere in 2019 was 410.5 ppm,[2] approximately 1.5 times the pre-industrial level (WMO, 2020). The concentration increased an average of 2.4 ppm per year during the decade up to 2019, approximately 1.5 times the average rate of increase of 1.5 ppm per year during the 1990s.
- Global average concentrations of methane in the atmosphere reached 1,877 ppb (approximately 2.6 times the pre-industrial level) in 2019 (WMO, 2020). The increase of methane in the atmosphere since pre-industrial times is due to human activity (very high confidence) (IPCC, 2013).
- Global average concentrations of nitrous oxide in the atmosphere have continued to increase due to human activities, reaching 332.0 ppb in 2019 (approximately 1.2 times the pre-industrial level) (WMO, 2020). About 60% of the nitrous oxide emitted into the atmosphere is from natural sources (oceans, soil, etc.) and about 40% is from anthropogenic sources (biomass burning, fertilizer, industrial processes, etc.) (IPCC, 2013).
- Many halocarbons[3] are powerful greenhouse gases, and their atmospheric concentrations have increased rapidly since the latter half of the 20th century due to artificial production. These include chlorofluorocarbons (CFCs), which have declined in atmospheric concentrations since about the 1990s after restrictions were placed on their production and use because they are also ozone-depleting substances; however, atmospheric concentrations of many hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) are increasing (WMO, 2020), which makes it important to continue monitoring.
- Atmospheric concentrations of carbon dioxide, methane and nitrous oxide continue to increase at monitoring stations in Japan. Atmospheric carbon dioxide concentrations in 2019 at Ryori, Minamitorishima, and Yonagunijima were 414.0 ppm, 412.2 ppm, and 414.8 ppm, respectively (preliminary estimations), and all of these were higher than the global average. Atmospheric concentrations of methane observed at the same monitoring stations in 2019 were 1,954 ppb, 1,902 ppb, and 1,928 ppb, respectively (preliminary figures), and all of these were higher than the global average. Atmospheric concentrations of nitrous oxide observed at Ryori also continue to increase. The annual mean concentration in 2019 was 333.8 ppb (preliminary estimations), higher than the global average, and reflecting the fact that the major sources are in the northern hemisphere (Japan Meteorological Agency, 2020).

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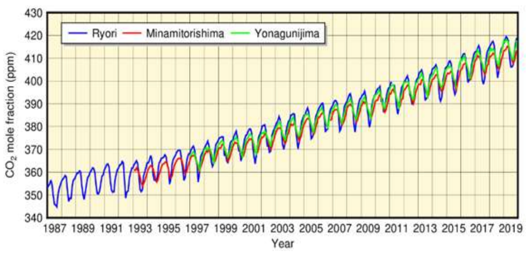
[2] ppm and ppb are ratios of a target substance present in the atmosphere. ppm (parts per million) is 10^{-6} (one molecule per million in dry air) ppb (parts per billion) is 10^{-9} (one molecule per billion).

[3] A general term for carbon compounds containing a halogen such as chlorine and bromine.

(a) Carbon dioxide



(b) Methane

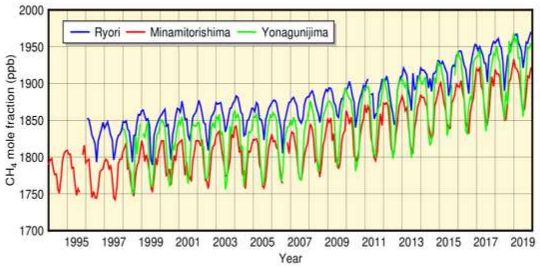


Figure 2-1. Monthly mean atmospheric concentrations of carbon dioxide and methane at Ryori, Minamitorishima, and Yonagunijima

Monthly mean near-surface atmospheric concentrations of (a) carbon dioxide and (b) methane, from three Japan Meteorological Agency stations in Japan: Ryori (Ofunato, Iwate Prefecture), Minamitorishima (Ogasawara, Tokyo), and Yonagunijima (Yonaguni, Okinawa Prefecture).

(2) Air Temperature

i) Observation Results

Past trends in average temperature

- The global average near-surface air temperature is increasing relative to the pre-industrial level (very high confidence: IPCC, 2013)
- The annual average air temperature[4] in Japan has increased from 1898 to 2019, with fluctuations, at a rate of 1.24°C per century (statistically significant at a confidence level of 99%) (Figure 2-2).
- By season, the rate of warming per century was 1.13°C for winter (previous December to current year February), 1.47°C for spring (March to May), 1.11°C for summer (June to August), and 1.23°C for autumn (September to November) (all statistically significant at a confidence level of 99%).
- The rate of temperature increase in Japan is larger than the global average rate of increase (0.74°C per century, by Japan Meteorological Agency analysis).[5] This reflects the fact that the rate of temperature increase due to global warming is relatively larger in Japan, located at middle latitudes in the northern hemisphere.[6]
- Besides the impacts of climate change, a long-term warming trend is evident in large cities due to urbanization. Comparing the rate of temperature changes from 1927 to 2019 at observation stations in large Japanese cities (Sapporo, Sendai, Niigata, Tokyo, Yokohama, Nagoya, Kyoto, Osaka, Hiroshima, Fukuoka, Kagoshima) that can provide consistent data over long periods of time with 15 observation stations[4] where the effects of urbanization are considered to be relatively small, the increase in the large cities is greater; also, while there are differences depending on the location, the annual average temperatures of the large cities are about 0.4°C to 1.7°C higher than the average of the 15 stations.

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[4] This is the average of 15 meteorological stations relatively less affected by urbanization and where the observational data is consistent over a long period of time (Abashiri, Nemuro, Suttsu, Yamagata, Ishinomaki, Fushiki, Iida, Choshi, Sakai, Hamada, Hikone, Tadotsu, Miyazaki, Naze, and Ishigakijima). For Iida and Miyazaki, the data are corrected for the effects of relocation during the statistical period. However, even these observation stations are not entirely unaffected by urbanization.

[5] To make it easier to compare with the average temperature in Japan, the analysis by the Japan Meteorological Agency is shown as the result of analysis for the same period. Although the data and analytical methodology used are different from the information contained in IPCC reports, there is no significant difference in the results.

[6] The increase in greenhouse gases in the atmosphere alters the Earth's radiation budget, raising the surface temperature as a result of the increase in downward long-wave radiation from the atmosphere. This increased energy not only raises air temperature and seawater temperature, but also evaporates moisture from the ground surface. Due to the limited amount of water on land, the energy used for evaporation is less than in ocean areas. This is believed to be a major factor to explain why temperature increases due to global warming tend to be larger over land than the oceans (Sutton et al., 2007). This difference between land and ocean is believed to be contributing to the larger temperature increase in middle and higher latitudes in the northern hemisphere where land accounts for a greater ratio of the surface area.

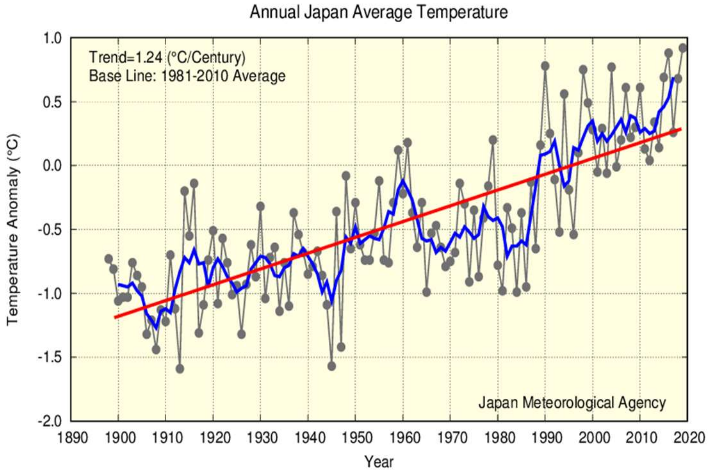


Figure 2-2. Annual surface temperature anomalies in Japan (1898 to 2019)

The thin line (black) indicates the surface temperature anomaly from the baseline each year at 15 observation stations in Japan. The thick line (blue) indicates the 5-year running mean of the anomaly, and the straight line (red) shows the long-term trend (averaged over the period). The baseline is the 30-year average for the years 1981 to 2010.

Past trends in extreme high and low temperatures

- Analysis of observed values at 13 Japan Meteorological Agency sites[7] where the effects of urbanization are considered to be relatively small shows that during the statistical period from 1910 to 2019 the number of days with a daily maximum temperature of 30°C or above and 35°C or above both have statistically significant increases (confidence level of 99% or higher). In particular, the number of days with a maximum temperature of 35°C or above has shown a large increase since the mid-1990s (Figure 2-3). Meanwhile, the number of days with a daily minimum temperature below 0°C decreased during the same period, and the number of days with a daily minimum temperature of 25°C or above increased (both statistically significant at a confidence level of 99%) (Figure 2-4).

(a) Annual number of days with a maximum temperature of 30°C or above

(b) Annual number of days with a maximum temperature of 35°C or above

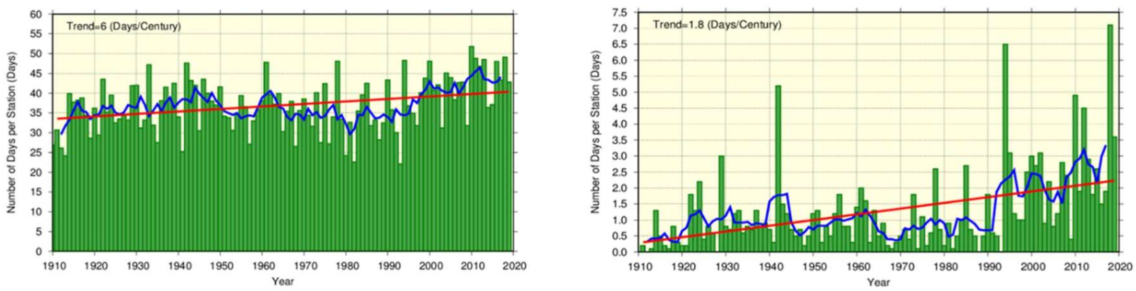


Figure 2-3. Annual number of days with a maximum temperature of 30°C or above and 35°C or above (1910 to 2019)

Number of days per year with a daily maximum temperature of (a) 30°C or above and (b) 35°C or above, based on observations at 13 Japan Meteorological Agency sites nationwide where the effects of urbanization are considered to be relatively small. Bars (green) show the value of total annual days each year divided by the total number of valid sites (annual number of days per site). The thick line (blue) shows the 5-year running mean and the straight line (red) shows the long-term

[7] Among the 15 sites indicated in 4, the sites remaining after excluding Miyazaki and Iida, where the effects of site relocation are difficult to remove.

trend (average change over the statistical period).

(a) Annual number of days with a minimum temperature below 0°C

(b) Annual number of days with a minimum temperature 25°C or above

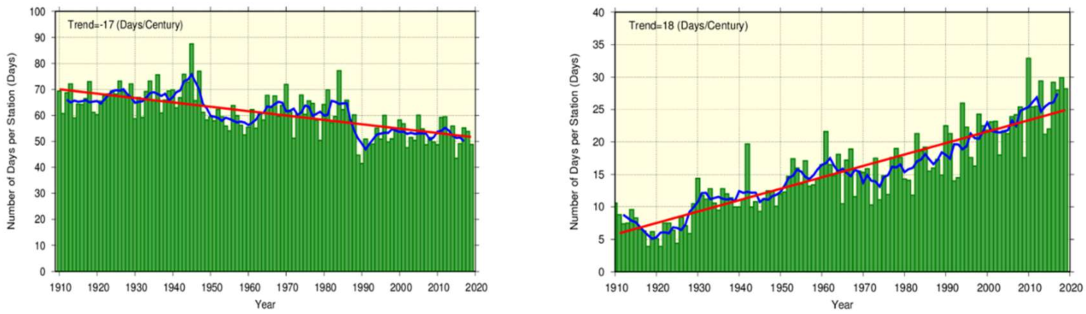


Figure 2-4. Annual number of days with a minimum temperature below 0°C and 25 °C or above (1910 to 2019)

Number of days per year with (a) a daily minimum temperature below 0°C and (b) 25°C or above, based on observations at 13 Japan Meteorological Agency sites nationwide where the effects of urbanization are considered to be relatively small. Bars (green) show the value of total annual days each year divided by the total number of valid sites (annual number of days per site). The thick line (blue) shows the 5-year running mean and the straight line (red) shows the long-term trend (average change over the statistical period).

ii） Future Projections

Future prospects for average temperatures

- The annual mean temperature in Japan at the end of the 21st century is expected to be significantly higher nationwide relative to the end of the 20th century (high confidence). The national mean temperature increase is 4.5°C under the RCP8.5 scenario and 1.4°C under the RCP2.6 scenario.
- Projections in the IPCC Fifth Assessment Report (for changes in mean temperature from 2081 to 2100 relative to the average from 1986 to 2005) show the average annual temperature increase globally by about 3.7°C in the RCP8.5 scenario and 1.0°C in the RCP2.6 scenario, and the temperature increase in the vicinity of Japan by 1.2 to 1.4 times the global average. This ratio is nearly the same as the warming observed to date, and the factors are thought to be the same (see Section “i) Observation Results”).
- Looking at the distribution of temperature changes in the vicinity of Japan, the increase is greater in both the annual mean temperature and the seasonal mean temperatures at higher latitudes, and the temperature increase is greater in winter than in summer (Figure 2-5).
- As with the annual mean temperature, the annual mean maximum and minimum temperatures also rise significantly nationwide, and geographically, the higher the latitude the greater the increase. Also, the increase in minimum temperatures is greater than the increase in the mean and maximum temperatures.

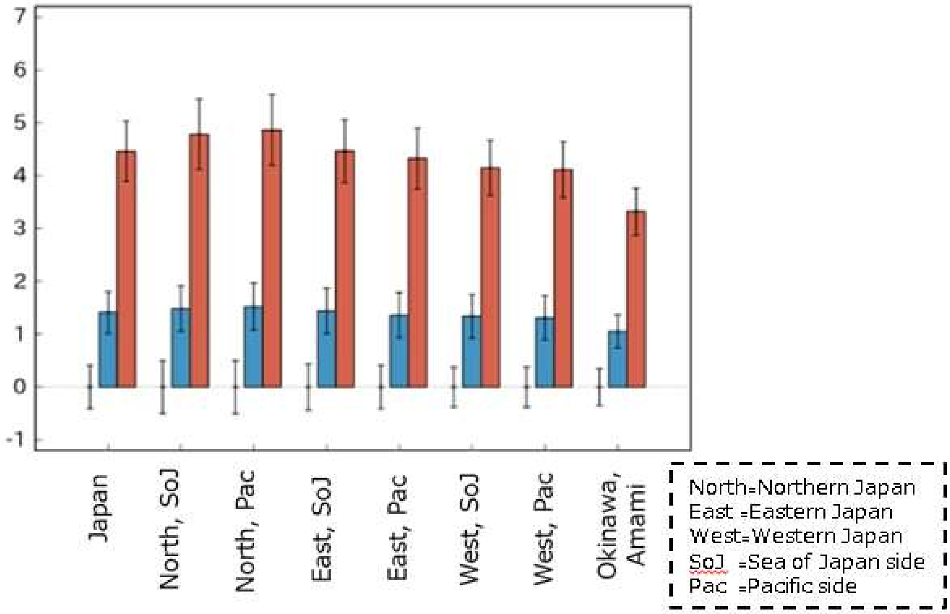


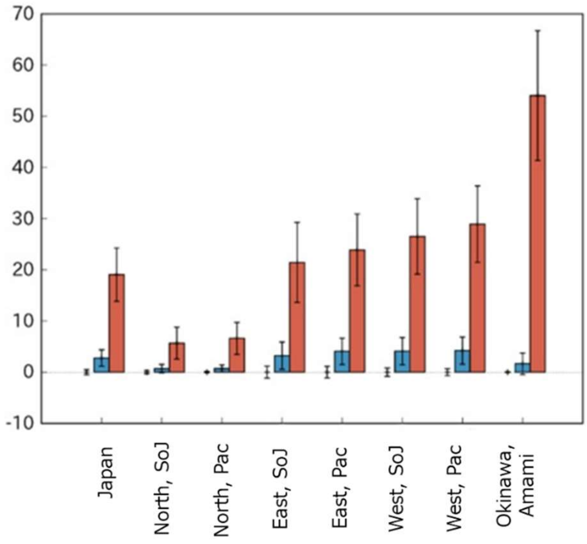
Figure 2-5. Future trends in annual mean temperatures as projected by the Japan Meteorological Agency (°C)

The bar graph shows the future changes at the end of 21st century (average for 2076-2095) relative to the end of the 20th century (average for 1980-1999), with the thin vertical lines indicating the range of interannual variability. For the color of the bars, red corresponds to the RCP8.5 scenario and blue to the RCP2.6 scenario. Thin vertical lines where there is no bar represent the range of interannual variability at the end of the 20th century. (Projection results for the RCP8.5 scenario are from the Japan Meteorological Agency (2017)).

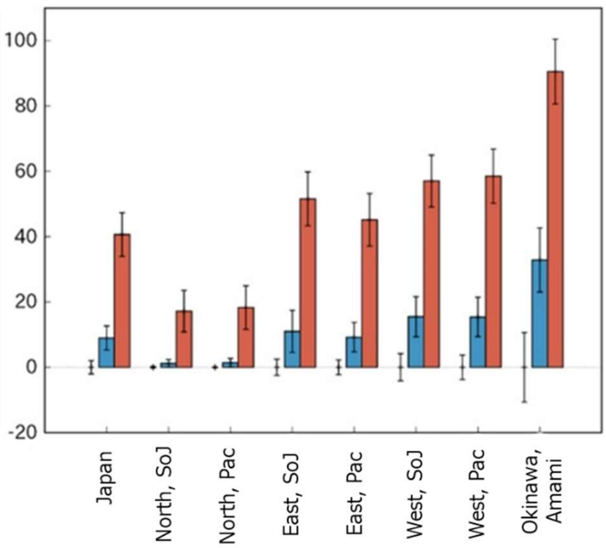
Future prospects for extreme high and low temperatures

- Under the RCP8.5 scenario, the annual number of days with a maximum temperature of 35°C or above is projected to increase significantly nationwide at the end of the 21st century (average for 2076-2095) relative to the end of the 20th century (average for 1980-1999). This can be interpreted as accompanying the significant temperature increases being projected, and since it is consistent with the global-level projections by the IPCC as well as actual observations indicated in Section “i) Observation Results”, the level of confidence is high. They are projected to increase mainly in summer in northern Japan, and from summer to autumn from eastern Japan westwards (Figure 2-6). Similarly, the annual number of days with a maximum temperature of 30°C or above is projected to increase significantly nationwide, by about 30 days on the Pacific side of northern Japan, and about 88 days in Okinawa and Amami.
- The annual number of days with a minimum temperature of 25°C or above is projected to increase significantly nationwide. They are projected to become more frequent in coastal and other low-lying areas, which is a simlar projected trend tothe number of days with a maximum tempearture of 35°C or above.
- It is projected that the decrease in the annual number of days with a minimum temperature below 0°C will be statistically significant, with the exception of Okinawa and Amami where they almost never occur under the current climate (high confidence, for reasons similar to the number of days with a maximum tempearture of 35°C or above). Daily minimum temperatures in Hokkaido winters rise relative to the end of the 20th century, but there are many days below 0°C, and the decrease in number of days is less than in the Tohoku region, etc.

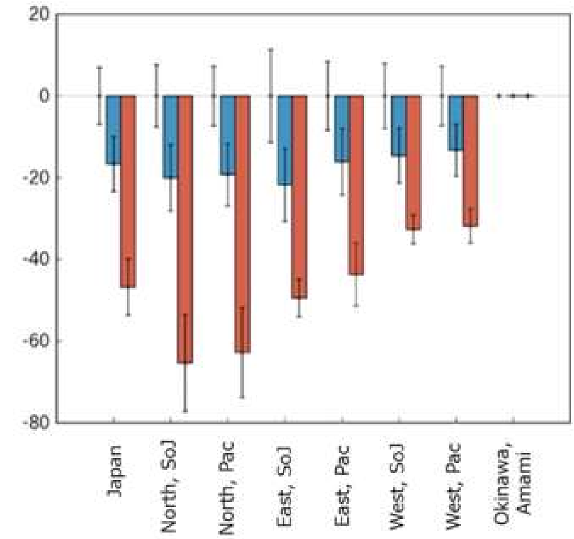
(a) Maximum temperature of 35°C or above



(b) Minimum temperature of 25°C or above



(c) Minimum temperature below 0°C



North=Northern Japan
East =Eastern Japan
West=Western Japan
SoJ =Sea of Japan side
Pac =Pacific side

Figure 2-6. Future trends in annual number of days with an extreme maximum or minimum temperature as projected by the Japan Meteorological Agency (days)

The bar graph shows the future change at the end of 21st century (average for 2076-2095) relative to the end of the 20th century (average for 1980-1999), with the thin vertical lines indicating the range of interannual variability. For the color of the bars, red corresponds to the RCP8.5 scenario and blue to the RCP2.6 scenario. Thin vertical lines where there is no bar represent the range of interannual variability at the end of the 20th century. Okinawa and Amami are not shown in the panel (c), as number of days they occur is zero at both the end of the 20th century and the end of the 21st century. (Projection results for the RCP8.5 scenario are from the Japan Meteorological Agency (2017)).

(3) Precipitation

i) Observation Results

Past long-term trends in precipitation

- No statistically significant long-term trend is evident during the period 1898 to 2019 in terms of annual precipitation (Figure 2-7) and seasonal precipitation calculated from precipitation data observed nationwide at 51 observation stations[8] of the Japan Meteorological Agency. No significant

[8] List of 51 Japan Meteorological Agency observation stations with long-term, consistent observational data: Asahikawa, Abashiri, Sapporo,

long-term trend is evident in terms of the amounts of annual precipitation averaged by region.

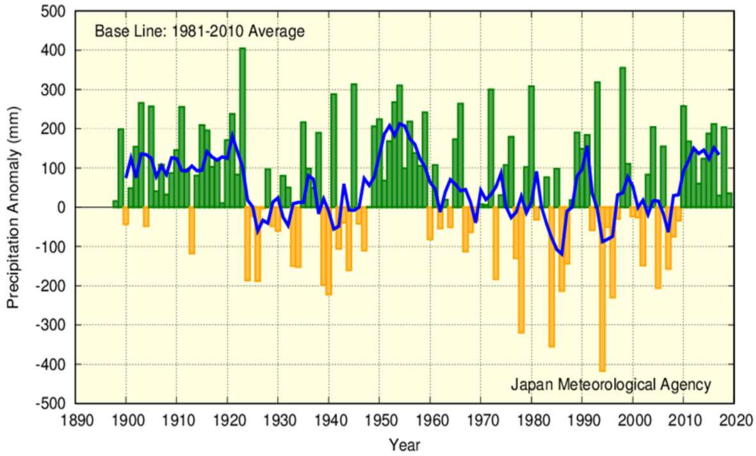


Figure 2-7. Annual anomalies in precipitation in Japan (1898 to 2019)

The bars indicate the average anomaly in the amount of precipitation each year from the baseline at 51 observation stations in Japan. Green bars indicate a value greater than, and yellow bars less than, the baseline. The thick line (blue) shows the 5-year running mean of the anomalies. The baseline is the 30-year average for the years 1981 to 2010.

Past long-term trends in rainfall patterns

- There is an increasing number of days with heavy rainfall of 100 mm or more per day, and 200 mm or more per day, calculated from precipitation data as observed at 51 Japan Meteorological Agency observation stations nationwide for the period 1901 to 2019 (statistically significant at a confidence level of 99%) (Figure 2-8). The rate of increase per site is 0.29 days per century and 0.05 days per century, respectively.
- The annual frequency of rainfall events with precipitation of 50 mm or more per hour, and 80 mm or more per hour, is increasing, calculated from precipitation data from about 1,300 Japan Meteorological Agency AMeDAS stations nationwide for the period 1976 to 2019 (statistically significant at a confidence level of 99%) (Figure 2-9). The rate of increase in annual occurrences per 1,300 stations is 28.9 times per decade and 2.7 times per decade, respectively.
- The annual number of days with heavy rainfall at 200 mm or more per day, and 400 mm or more per day, is on an increasing trend (statistically significant at a confidence level of 95%). However, the range of interannual variability in the number of extreme rainfall events is large, and the observational period for AMeDAS is relatively short, so further data collection will be needed to verify any long-term trends.
- The ratio of annual maximum daily precipitation relative to the baseline (1981 to 2010) is showing an increasing trend for AMeDAS sites nationwide that have had continuous observation over the period 1976 to 2019 (640 sites) (statistically significant at a confidence level of 95%) (Figure 2-10). The rate of increase is 3.9% per decade.
- The number of days per year with precipitation of 1.0 mm or more decreased during the period 1901 to 2019, according to precipitation data observed at 51 Japan Meteorological Agency observation sites nationwide (statistically significant at a confidence level of 99%). The rate of decrease is 9.5 days per century (Figure 2-11).

Obihiro, Nemuro, Suttsu, Akita, Miyako, Yamagata, Ishinomaki, Fukushima, Fushiki, Nagano, Utsunomiya, Fukui, Takayama, Matsumoto, Maebashi, Kumagaya, Mito, Tsuruga, Gifu, Nagoya, Iida, Kofu, Tsu, Hamamatsu, Tokyo, Yokohama, Sakai, Hamada, Kyoto, Hikone, Shimonoseki, Kure, Kobe, Osaka, Wakayama, Fukuoka, Oita, Nagasaki, Kumamoto, Kagoshima, Miyazaki, Matsuyama, Tadotsu, Kochi, Tokushima, Naze, Ishigakijima, Naha.

(a) Precipitation of 100 mm or more per day (b) Precipitation of 200 mm or more per day

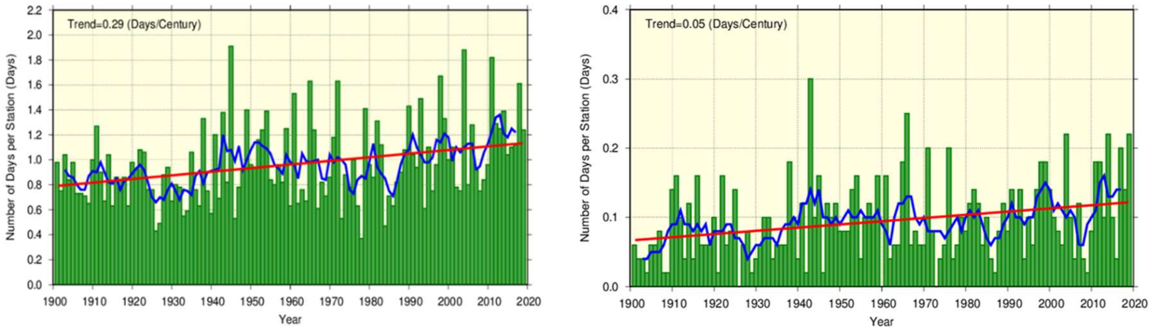


Figure 2-8. Annual number of days with precipitation of 100 mm or more and 200 mm or more (1901 to 2019)

Annual number of days with daily precipitation of (a) 100 mm or more and (b) 200 mm or more, based on observations at 51 stations nationwide with long-term, consistent observational data. Bars (green) show the value of total days each year divided by the total number of valid sites (annual number of days per site). The thick blue line shows the 5-year running mean, and the straight red line shows the long-term trend (average trend over the period).

(a) Precipitation of 50 mm or more per hour (b) Precipitation of 80 mm or more per hour

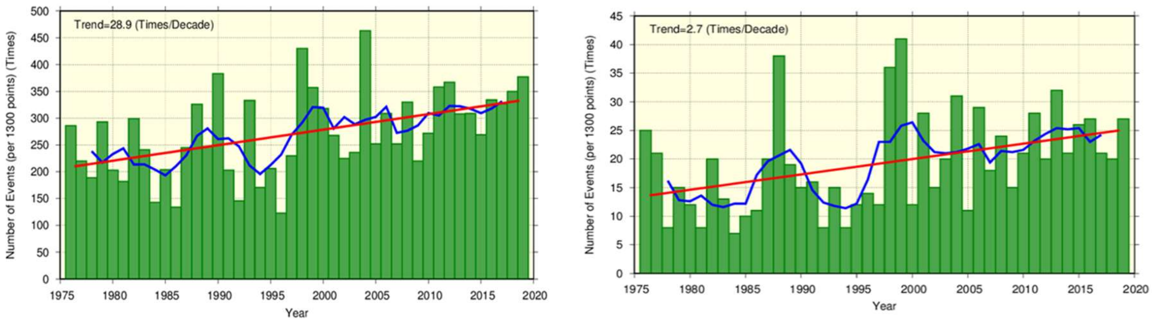


Figure 2-9. Annual number of events of hourly precipitation of 50 mm or more and 80 mm or more (1976 to 2019)

Annual number of occurrences of hourly precipitation of (a) 50 mm or more and (b) 80 mm or more. The bars (green) show the number of occurrences each year (values converted per 1,300 sites from observed values of the AMeDAS system nationwide), and the straight red line shows the long-term trend (average change over the period). The bars (green) show the number of occurrences each year (values converted per 1,300 sites from observed values of the AMeDAS system nationwide), and the straight line (red) shows the long-term trend (average trend over the period).

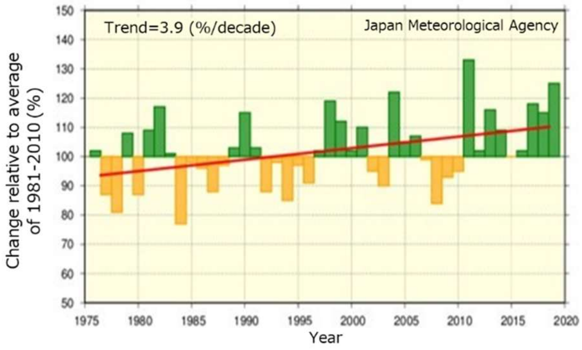


Figure 2-10. Annual maximum daily precipitation over Japan relative to baseline (1976 to 2019)

The bars indicate the average ratio for each year relative to baseline for stations with continuous observation over the period 1976 to 2019 (640 stations) among the AMeDAS stations nationwide. The straight red line indicates the long-term trend (average trend over the period). The baseline is the average for the years 1981 to 2010.

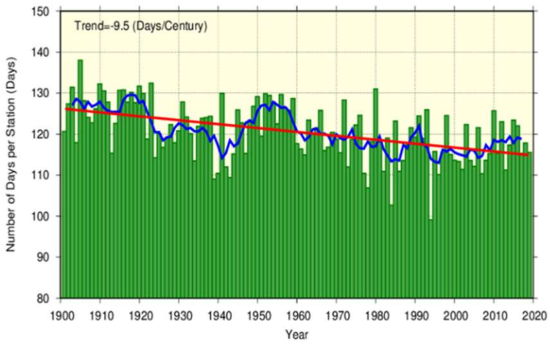


Figure 2-11. Annual number of days with daily precipitation of 1.0 mm or more (1901 to 2019)

Interpretation of this figure is same as with Figure 2-8.

ii) Future Projections

Future prospects for precipitation

- **RCP8.5 Scenario**

・ Under the RCP8.5 scenario, no significant trend is evident in national annual average precipitation from the end of the 20th century (average of 1980-1999) to the end of the 21st century (average of 2076-2095). Projections by global models of annual precipitation over Japan are included in the range of projections of the CMIP5 model, but the range that can be assessed for precipitation over Japan with the resolution of global models is limited. As a result, the fact that no significant trend is evident from nationally-averaged future projections of annual precipitation is consistent with actual observations, but the level of confidence is medium. (Figure 2-12, Figure 2-13)

・ Analyzed by region and season, there is an increase in summer on the Sea of Japan side of northern Japan, a decrease in the annual average and in winter on the Sea of Japan side of eastern Japan, a decrease in winter on the Sea of Japan side of western Japan, and a decrease in spring on the Pacific side of eastern Japan, and each change is statistically significant. However, there is a large difference in the projection results among the members and there not enough research has been done, so there is a high level of uncertainty in projections of precipitation at the regional level.

- **RCP2.6 Scenario**

・ Under the RCP2.6 scenario as well, no significant trend is evident in the national average (medium confidence; Figure 2-12, Figure 2-13)

・ By region and by season, a significant increase is evident for Okinawa and Amami in the yearly average, in summer, and in autumn, and the changes are projected to be larger than under the RCP8.5 scenario. However, projections at the regional level have a high level of uncertainty.

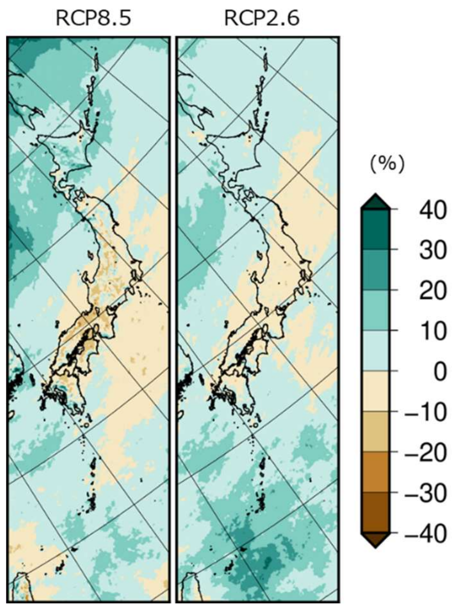


Figure 2-12. Future changes in annual precipitation based on Japan Meteorological Agency projections (%)

Projections for the RCP8.5 scenario are on the left, and RCP2.6 on the right. The figures indicate the percent of change from the end of the 20th century (average of 1980 to 1999) relative to the end of the 21st century (average of 2076 to 2095).

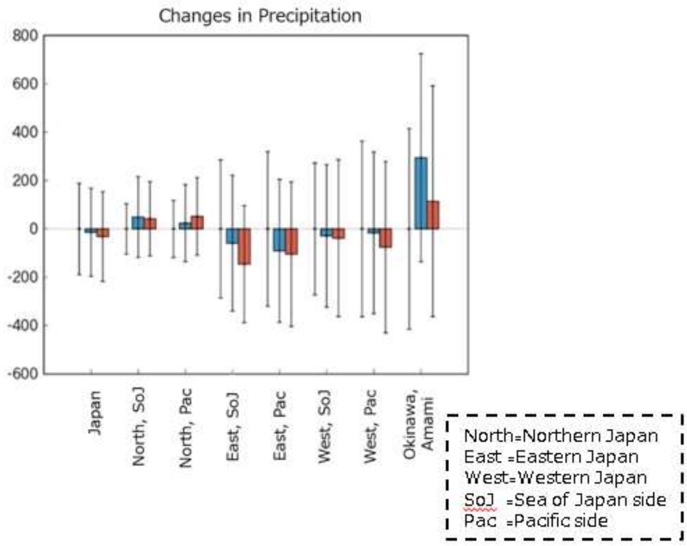


Figure 2-13. Future changes in precipitation, national and by region, based on Japan Meteorological Agency projections (mm)

The bar graph shows the future change at the end of 21st century (average for 2076-2095) relative to the end of the 20th century (average for 1980-1999), with the thin vertical lines indicating the range of interannual variability. Red bars correspond to the RCP8.5 scenario, blue bars to RCP2.6, each indicating projected future changes. Thin vertical lines where there is no bar represent the range of interannual variability at the end of the 20th century.

Future prospects for changes in rainfall patterns

● Heavy Rainfall (daily precipitation of 100 mm or more and 200 mm or more)

- Under the RCP8.5 scenario, the number of days with heavy rainfall of 100 mm or more and 200 mm or more increases significantly nationwide at the end of the 21st century (average of 2076 to 2095) relative to the end of the 20th century (average of 1980 to 1999). This is consistent with CMIP5 projections that heavy rainfall events will become more frequent in East Asia, including Japan, and also with the long-term increase observed to date, so the level of confidence is high.
- Although the range of increase varies by region, the national average number of days with heavy rainfall of 100 mm or more per day increases by a factor of 1.4, and heavy rainfall of 200 mm or more per day by a factor of 2.3.
- Under the RCP2.6 scenario, the national averages and many regions are projected to have a significant increase (high confidence). The range of increase is generally smaller than under the RCP8.5 scenario. The national average number of days with heavy rainfall of 100 mm or more per day increases by a factor of 1.2, and heavy rainfall of 200 mm or more per day by a factor of 1.5.
- Projections that rainfall patterns will become more extreme as global warming progresses are consistent with projection results of other research institutions inside and outside of Japan, and with trends that have been observed to date, so the level of confidence is high. The extent of increase tends to be larger for the RCP8.5 scenario than the RCP2.6 scenario, but projections on a regional scale such as the Pacific side of northern Japan and at the prefectural level have a high level of uncertainty.

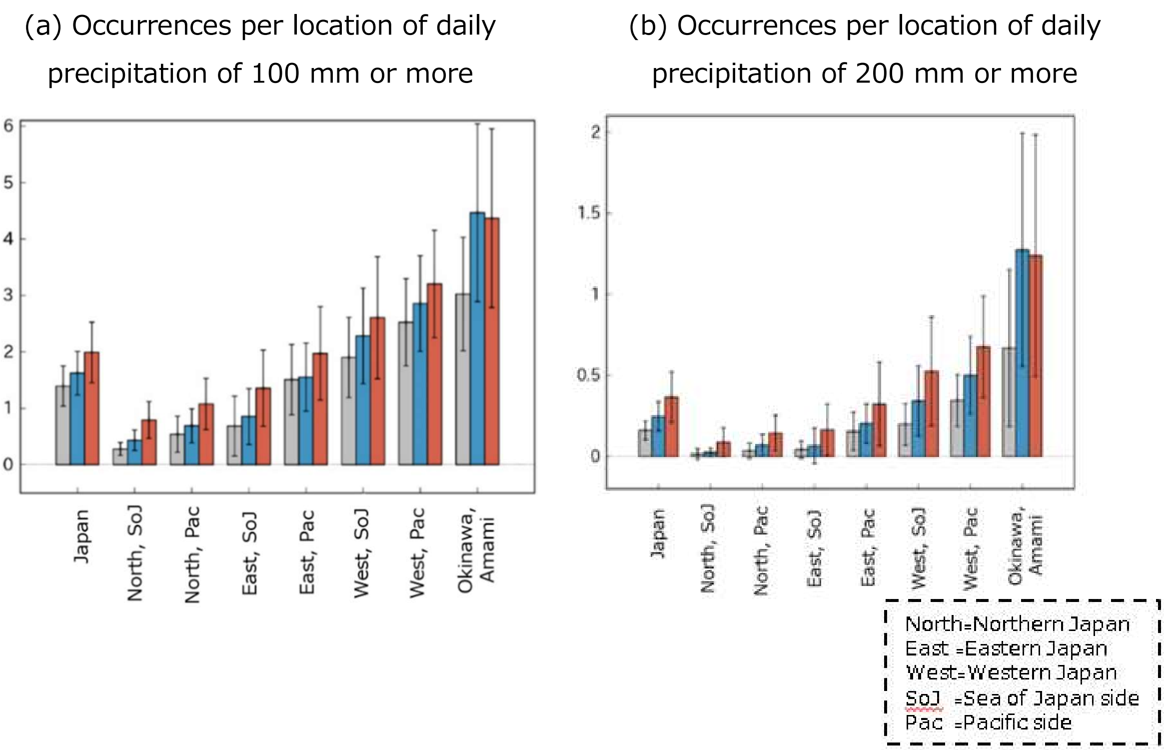


Figure 2-14. Occurrences per location of daily precipitation of 100 mm or more and 200 mm or more, nationwide and by region (days/year)

(a) is annual occurrences of precipitation of 100 mm or more per day, and (b) is 200 mm or more per day. Both graphs are based on projections by the Japan Meteorological Agency. The bars indicate the frequency of occurrence of heavy rainfall for each, and the thin vertical lines indicate the range of interannual variability. For the color of the bars, gray corresponds to the end of the 20th century (1980-1999), red to the RCP8.5 scenario, and blue to the RCP2.6 scenario at the end of the 21st century (2076-2095). However, it is important to note that although bias correction has been done for the values for the end of the 20th century, the bias has not been completely removed, and values are different from the observed values.

- **Rainfall events wih precipitation of 30 mm or more per hour, and 50 mm or more per hour**

- According to projections by the Japan Meteorological Agency, under the RCP8.5 scenario, the number of rainfall of 30 mm or more per hour and 50 mm or more per hour increases significantly nationwide at the end of the 21st century (average of 2076 to 2095) relative to the end of the 20th century (average of 1980 to 1999) (Figure 2-15). As with heavy rainfall, this is consistent with CMIP5 projections for East Asia and also with the observed long-term trends, so the level of confidence is high. Although the range of increase varies by region, the national average number of rainfall of 30 mm or more per hour increases by a factor of 1.7, and 50 mm or more per hour by a factor of 2.3.
- Under the RCP2.6 scenario, a significant increase is projected nationwide (high confidence). The range of increase is generally smaller than under the RCP8.5 scenario. The national average number of rainfall of 30 mm or more per hour increases by a factor of 1.3, and 50 mm or more per hour by a factor of 1.6.
- The uncertainty is high for projections of the rate of increase of these rainfall events, particularly at the regional level.

(a) Change in occurrences of hourly precipitation of 30 mm or more, per station

(b) Change in occurrences of daily precipitation of 50 mm or more, per station

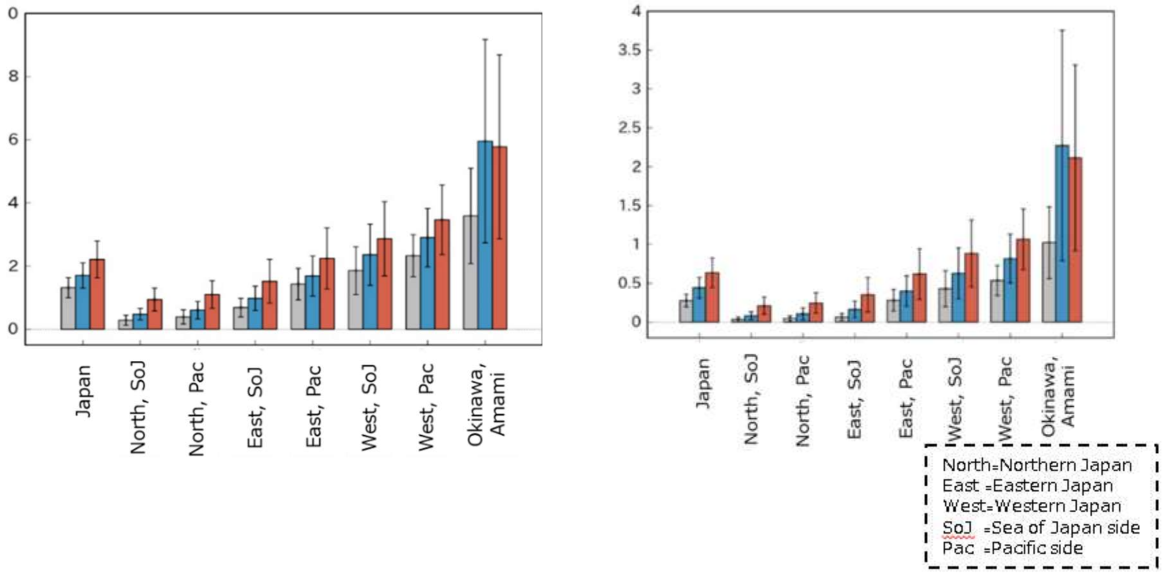


Figure 2-15. Occurrences per location of precipitation of 30 mm or more per hour and 50 mm or more per hour, nationwide and by region (days/year)

(a) is Annual number of occurrences of precipitation of 30 mm or more per hour, and (b) is 50 mm or more per hour Both graphs are based on projection by the Japan Meteorological Agency. Interpretation of this figure is same as with Figure 2-14.

- **Number of dry Days**

- According to projections by the Japan Meteorological Agency, under the RCP8.5 scenario, the number of dry days (days with less than 1.0 mm of precipitation) increases significantly nationwide at the end of the 21st century (average of 2076 to 2095) relative to the end of the 20th century (average of 1980 to 1999). CMIP5 projections show an increasing trend around Japan, and this is consistent with observational data showing a significant decreasing trend in the number of days with precipitation, so the projected increasing trend in dry days has a high level of confidence.
- Under the RCP2.6 scenario, no significant changes are projected in the national averages and in many regions (low confidence).

(4) Snow Depth / Snowfall

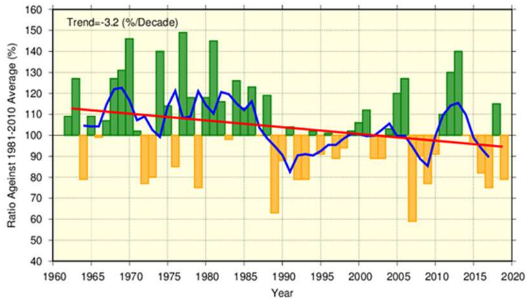
i) Observation Results

Past trends in annual maximum snow depth

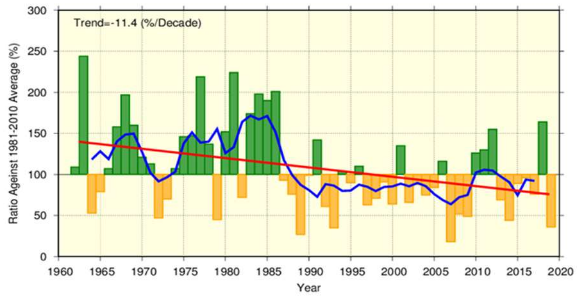
- The annual maximum snow depth ratio relative to the baseline (average of the 30 years from 1981 to 2010) in each region has decreased by 3.2% per decade on the Sea of Japan side of northern Japan (statistically significant at a confidence level of 90%), 11.4% per decade on the Sea of Japan side of eastern Japan (statistically significant at a confidence level of 95%), and 13.5% per decade on the Sea of Japan side of western Japan (statistically significant at a confidence level of 95%) (Figure 2-16). In all regions, it peaked in the early 1980s and then decreased significantly until the early 1990s, and subsequently has remained lower than the years prior to 1980 on the Sea of Japan side of eastern Japan and the Sea of Japan side of western Japan. It should be noted that the interannual variability in annual maximum snow depth is large, and the statistical period is relatively short, so further data collection will be needed to confirm the long-term trends.

- Besides observations by the Japan Meteorological Agency, universities and research institutes are also conducting their own observartions or numerical experiments about snow cover, and there are reports that a significant decreasing trend is evident in annual cumulative snowfall and annual maximum snow depth in the plains and coastal areas of the Hokuriku region, but that changes in snow cover in high-altitude mountain areas are small (Suzuki 2010, Kawase et al. 2012).

(a) Sea of Japan side of northern Japan



(b) Sea of Japan side of eastern Japan



(c) Sea of Japan side of western Japan

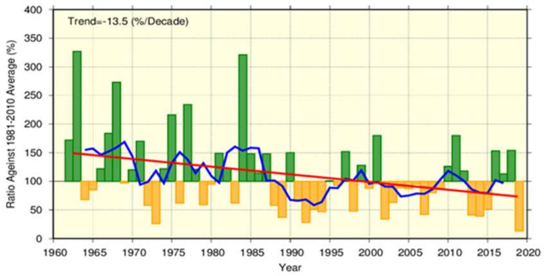


Figure 2-16. Annual maximum snow depth ratio in Japan relative to baseline (1962 to 2019)

Annual maximum snow depth ratio relative to baseline at observation sites on Sea of Japan side of (a) northern Japan, (b) eastern Japan, (c) western Japan (Table 2-1). The green bars indicate a value greater than the baseline, yellow bars less than the baseline. The thick blue line indicates the 5-year running mean, and the straight red line the long-term trend (average trend over the period). The baseline is the 30-year average for the years 1981 to 2010.

Table 2-1. Observation stations whose data are used to calculate snow depth ratios in Japan

Region	Observation stations
Sea of Japan side of northern Japan	Wakkanai, Rumoi, Asahikawa, Sapporo, Iwamizawa, Suttsu, Esashi, Kutchan, Wakamatsu, Aomori, Akita, Yamagata
Sea of Japan side of eastern Japan	Wajima, Aikawa, Niigata, Toyama, Takada, Fukui, Tsuruga
Sea of Japan side of western Japan	Saigo, Matsue, Yonago, Tottori, Toyooka, Hikone, Shimonoseki, Fukuoka, Oita, Nagasaki, Kumamoto

Past trends in heavy snowfall

- Data from observations since 1962 show a decrease in the annual number of days with a daily snowfall of 20 cm or more in each region along the Sea of Japan, at the rate of 0.5 days per decade in northern Japan, 0.6 days in eastern Japan, and 0.2 days in western Japan (all statistically significant at a confidence level of 99%) (Figure 2-17).
- Since there are large differences in snowfall patterns, depending on regional characteristics, the threshold values shown here may not be suitable as an indicator of extreme snowfall at some sites. However, because these are events that do not occur frequently, if the target area is narrowed further, the sample size will be too small, making assessment more difficult. Considering the fact that the statistical period is currently less than 60 years, more data needs to be collected in order to properly assess the long-term

trends in extreme snowfall events associated with global warming.

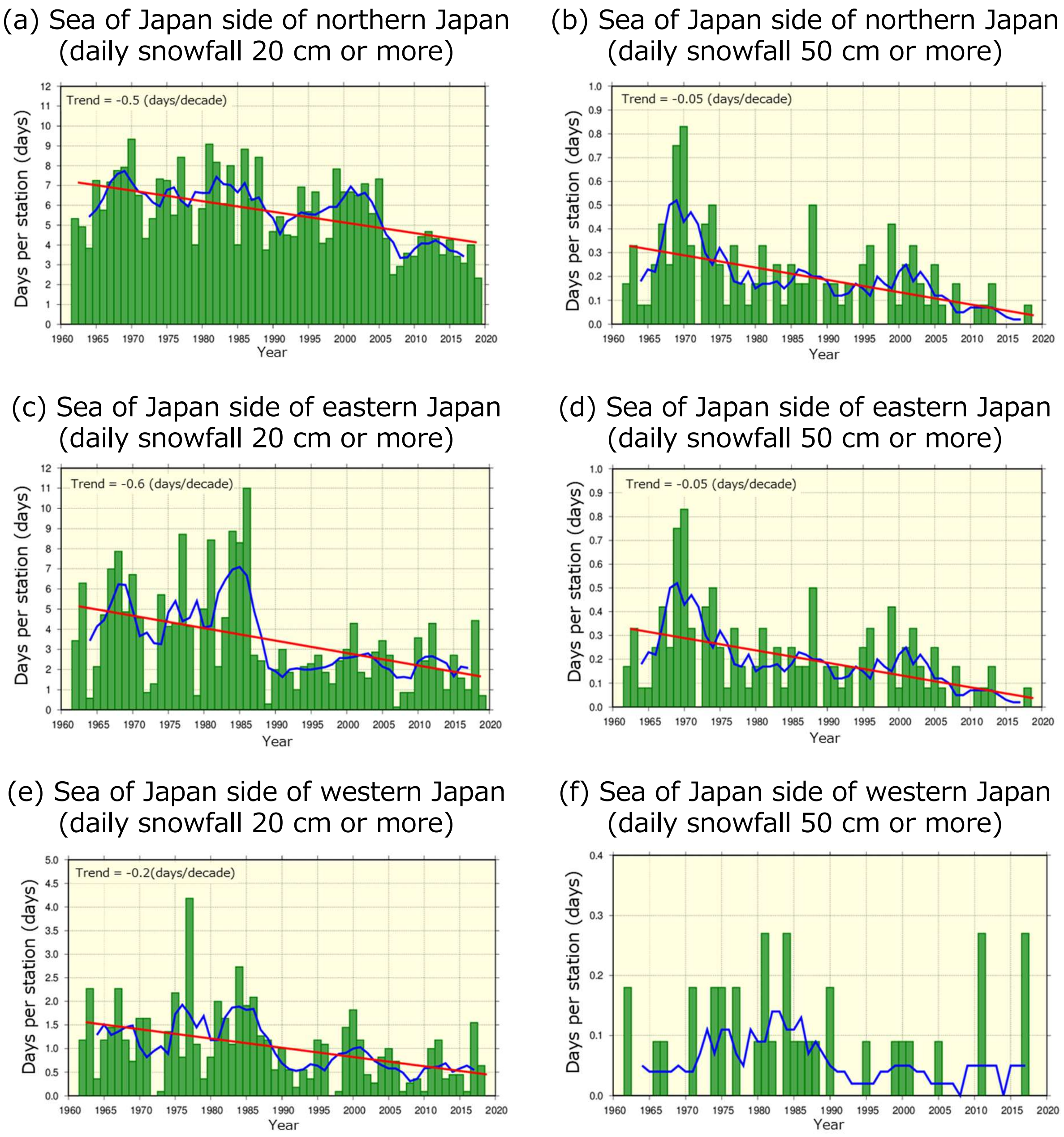


Figure 2-17. Annual number of days with daily snowfall of 20 cm or more and 50 cm or more in regions along Sea of Japan (1962 to 2019)

From top, northern Japan, eastern Japan, and western Japan on Sea of Japan side,with the graphs on the left (a, c, e) indicating days with 20 cm or more of snowfall, and graphs on right (b, d, f) indicating 50 cm or more. The green bars indicate the average days per year at the observation sites in each region (Table 2-1). The thick blue line indicates the 5-year running mean, and the straight red lines indicate the long-term trend (average trend over this period).

ii) Future Projections

- Under the RCP8.5 scenario, annual maximum snow depth and amount of snowfall in Japan are projected to decrease significantly nationwide at the end of the 21st century (average of 2076 to 2095) relative to the end of the 20th century (average of 1980 to 1999) (high confidence; Figure 2-18, Figure 2-19). Under the RCP2.6 scenario, they are projected to decrease significantly in most regions in Honshu and southward, but the trend in Hokkaido is not clear. Under both scenarios, the broad downward trend is believed to reflect the fact that as the temperatures increases, when precipitation falls it will fall as rain rather than snow; this is consistent with observed downward trends, so the level of confidence is high.
- In some inland areas of Hokkaido (under both scenarios) and in mountainous areas on the Sea of Japan side of eastern Japan (under th RCP2.6 scenario only), the amount of snowfall and maximum snow depth in winter is projected to increase. Such an increase is thought to occur in areas that are sufficiently cold even if warming progresses (to the extent that snow does not melt) as a result of increased precipitation associated with increased water vapor due to increased temperatures; however, considering the uncertainty of regional-scale projections of precipitation, the level of confidence is low.
- Findings from future projection research using large-scale ensembles (Kawase et al. (2016), Sasai et al. (2019), Kawase et al. (2020)) suggest that even if average snowfalls decrease as temperatures rise, the risk of infrequent but heavy snowfalls will not necessarily decrease.

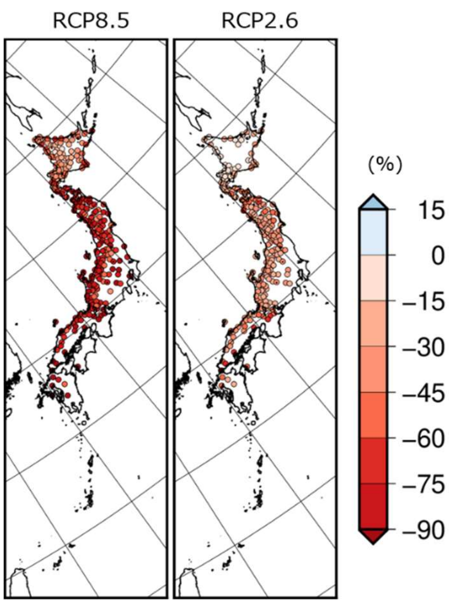


Figure 2-18. Future changes in annual maximum snow depth based on Japan Meteorological Agency projections (%)

Projections under the RCP8.5 scenario are on the left, and the RCP2.6 on the right. The figures indicate the percent change from the end of the 21st century (average of 2076 to 2095) relative to the end of the 20th century (average of 1980 to 1999), using bias-corrected projection data for each site. Due to the high level of uncertainty in projections, the percentage change is not shown for areas where the increase or decrease is not consistent among four members.

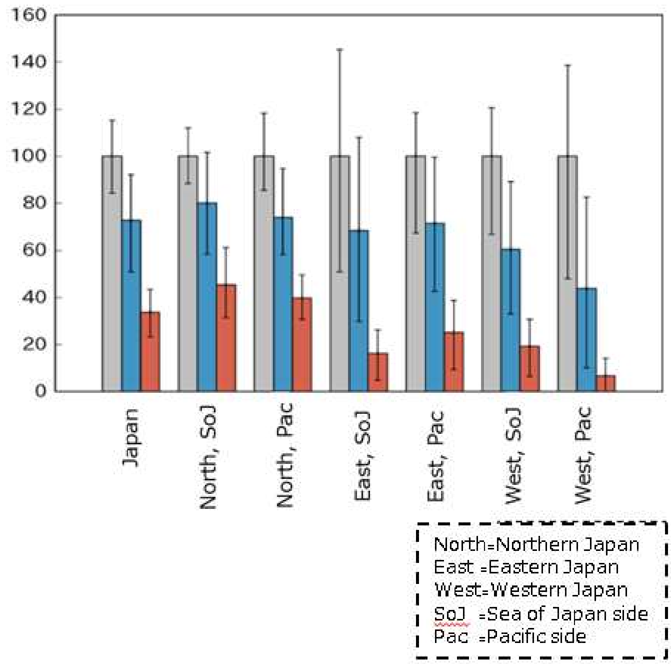


Figure 2-19. Future changes in annual maximum snow depth, nationwide and by region, based on Japan Meteorological Agency projections (%)

The bars indicate the ratio of annual maximum snow depth at the end of the 21st century (average of 2076 to 2095) relative to the end of the 20th century (average of 1980 to 1999), using bias-corrected projection data for each site, and the thin vertical lines indicate the range of interannual variability. For the colors of the bars, gray is for the end of the 20th century, red for projected future changes under the RCP8.5 scenario, and blue for the RCP2.6.

(5) Oceans

A. Seawater Temperatures

i) Observation Results

- The annual mean of the global average sea surface temperature is on a long-term rising trend, increasing at a rate of +0.55°C per century (statistically significant at a confidence level of 99% for the statistical period 1891 to 2019). The global average seawater temperatures to a depth of 2,000 m are also on a long-term rising trend.
- The long-term trend of annual mean sea surface temperatures averaged for 13 areas around Japan is shown in Figure 2-20. The average rate of increase in the 13 regions over the statistical period from 1900 to 2019 was +1.14°C per century, (statistically significant at a confidence level of 99%), which is more than the average rate of increase in the North Pacific overall (+0.53°C per century), and about the same as the rate of increase in air temperatures in Japan (+1.24°C per century) (high confidence). The rate of increase is not constant and decadal variability is remarkable in addition to the long-term temperature increase.
- In terms of regional differences, rather than rising the same way in each sea area, the rates of increase in the average sea surface temperature in the areas of the Yellow Sea, the East China Sea, the southwestern part of the Sea of Japan, off the coast of Shikoku and Tokai, and off the coast of Kushiro, are about the same as Japan's rate of increase in air temperature; in areas off the coast of Sanriku, the eastern part off the coast of Kanto, the southern part off the coast of Kanto, the eastern part of Okinawa and the sea around the Sakishima Islands, they are less than Japan's rate of increase in air temperature; and in the central part of the Sea of Japan, it is greater than Japan's rate of increase in air temperature (high confidence) (Figure 2-21). Seasonally, the rate of temperature increase is generally greater in winter.

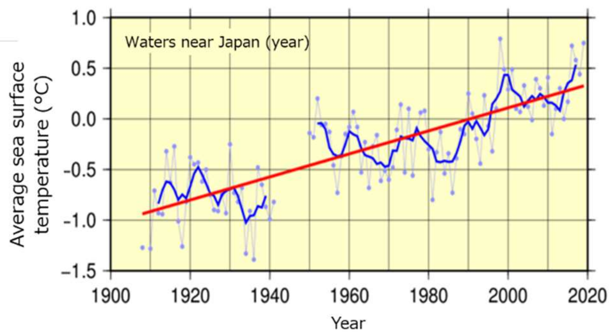


Figure 2-20. Sea surface temperature anomaly for waters near Japan (yearly average)

The blue plots in the figure indicate the yearly anomaly from normal, the thick blue lines indicate the 5-year running mean, and the thick red line indicates the long-term trend. Normal temperature is the 30-year average for the years 1981 to 2010.

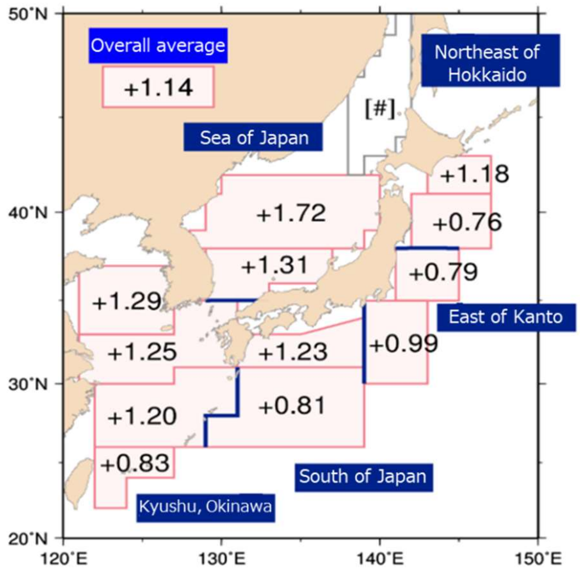


Figure 2-21. Rate of increase of area-averaged annual average sea surface temperatures in waters near Japan (°C per century)

The figures represent the rate of increase for the years 1900 to 2019. The figures for rate of increase show a significant trend, with a statistically significant confidence level of 99% or more. The area with symbol # is where no clear trend could be discerned for a 100 year period.

ii) Future Projections

- According to the IPCC Special Report on the Ocean and Cryosphere, it is verturally certain that the global average sea surface temperature will increase during the 21st century (high confidence). Under the RCP2.6 scenario, the global average sea surface temperature is projected to increase by 0.73°C (90% confidence interval is 0.60°C to 0.87°C) at the end of the 21st century (average for 2081 to 2100) relative to the end of the 20th century (average for 1986 to 2005) , and under the RCP8.5 scenario to increase by 2.58°C (90% confidence interval is 2.34°C to 2.82°C).
- Accoding to the ocean model of SI-CAT[9], the average sea surface temperature in the waters near Japan will increase during the 21st century (high confidence, Figure 2-22). Under the RCP2.6 scenario, the projected increase is 1.1±0.6°C at the end of the 21st century (average for 2081 to 2100) relative to the end of the 20th century (average for 1986 to 2005), and under the RCP8.5 scenario, 3.6±1.3°C (the range of uncertainty is a 90% confidence interval). These estimates are higher than the global average.
- The increase in sea surface temperatures in the waters around Japan is not uniform, and the extent of increase is higher in the central part of the Sea of Japan under the RCP2.6 scenario, and off the coast of Kushiro and Sanriku under the RCP8.5 scenario.

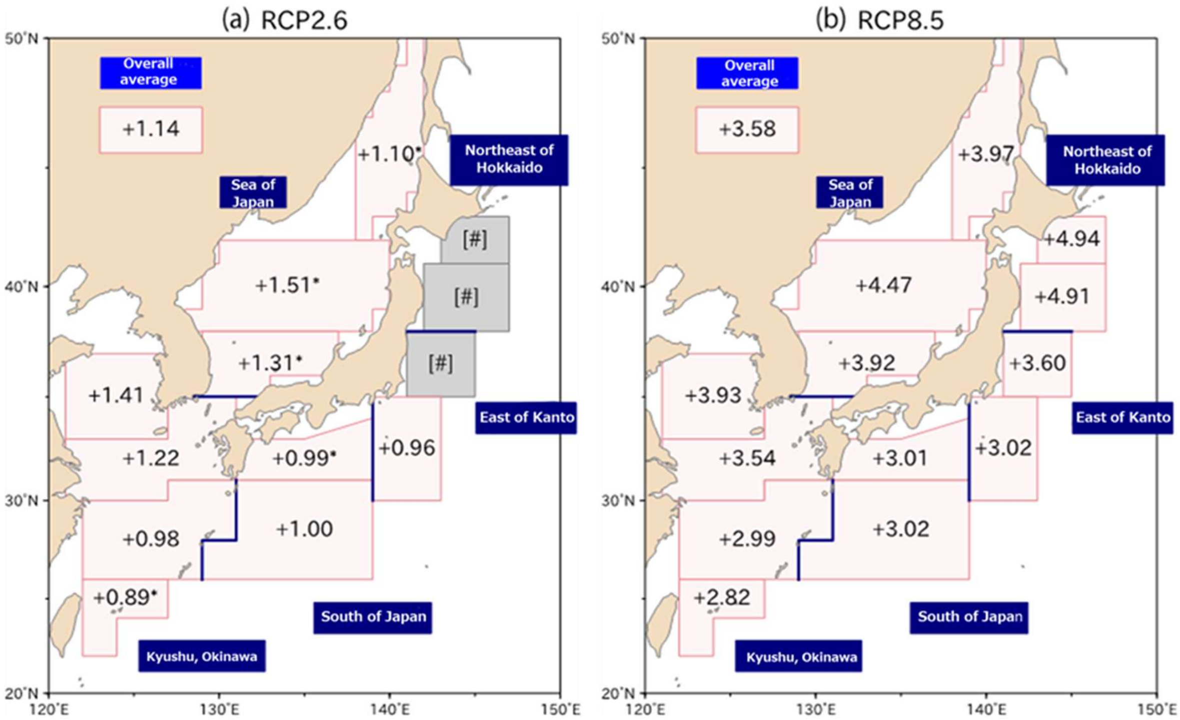


Figure 2-22Range of increases in average sea surface temperatures in waters near Japan at end of 21st century relative to end of 20th century, based on SI-CAT model data[9] (°C)

Estimates under (a) the RCP2.6 scenario, and (b) the RCP8.5 scenario. Values with no asterisk are statistically significant with a confidence level of 99% or more, while values with an asterisk (*) are significant with a confidence level of 95% or more. The areas with the # symbol are where no statistically significant long-term trend could be discerned.

[9]This refers to an ocean future projection dataset, developed by the Japan Agency for Marine-Earth Science and Technology under the Social Implementation Program on Climate Change Adaptation Technology (SI-CAT) of the Ministry of Education, Culture, Sports, Science and Technology to contribute to the development of climate change adaptation measures by local governments.

B. Sea Ice[10]

i) Observation Results

- The maximum sea ice extent[11] in the Sea of Okhotsk shows large interannual variasions, as it is strongly affected by variations in regional air temperatures, winds, and seawater temperatures, but the long-term trend for 1971 to 2020 is a decrease at a rate of 61,000 km^2 per decade (5.3% of normal years). (Statistically significant at a confidence level of 99%.) (Figure 2-23)
- As for Wakkanai, Abashiri, and Kushiro, where sea ice along the coast of the Sea of Okhotsk has been observed and data collected since 1956, the amount of drift ice in sight (sea ice that drifts in the sea and does not attach to the coastline) has decreased significantly since the latter half of the 1980s.
- In Abashiri, where drift ice is most frequently observed along the Hokkaido coast, the amount of drift ice in sight has decreased significantly since 1989. In addition, the last date of drift ice in sightis coming gradually earlier at a rate of 3.5 days per decade (statistically significant at a confidence level of 99%) and the first date of drift ice in sight is coming gradually later at a rate of 1.4 days per decade (statistically significant at a confidence level of 95%).

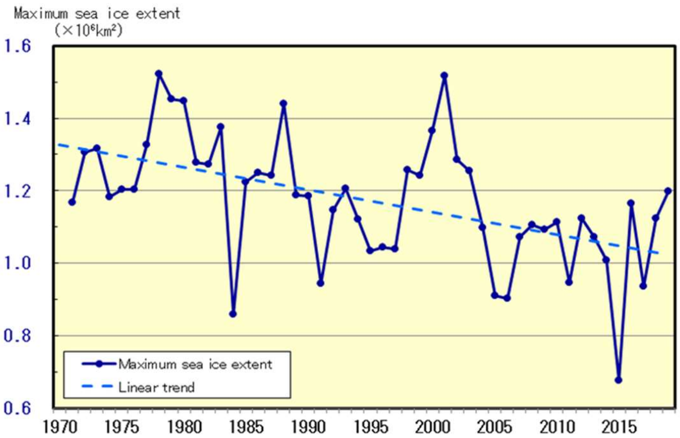


Figure 2-23. Maximum sea ice extent in the Sea of Okhotsk (1971 to 2020)

The solid line indicates the maximum sea ice extent, and the dashed line indicates the long-term trend.

ii) Future Projections

- The Sea of Okhotsk is a seasonal sea ice zone. Projections of the sea ice area in March, the month of annual maximum sea ice area by the SI-CAT model (reffered in footnote 9) show it decreasing from the end of the 20th century to the end of the 21st century (high confidence). This result is consistent with observed trends, as well as model projections by the Coupled Model Intercomparison Project - Phase 5 (CMIP5) for air temperature and sea water temperature.
- The rate of decrease under the RCP2.6 scenario is 28±34% and under the RCP8.5 scenario it is 70±22%. However, the extent of decrease under the RCP2.6 scenario is within the range of interannual variability of the current climate. Under the RCP8.5 scenario, there is a significant decrease relative to the uncertainty of projections (including interannual variability and model uncertainty), so it is believed that the year will come when the area of sea ice will be less than anything that has been experienced in the current climate.
- The amount of drift ice reaching the coast of Hokkaido is projected to decrease as a result of the decrease in sea ice formation along the coast of Siberia. Sea ice concentration (the fraction of ocean covered by

[10]Sea ice: Ice that is formed when seawater freezes. Sea ice cover is characterized by higher reflection of sunlight (albedo) compared to sea water. Therefore, if sea ice decreases due to global warming, more solar radiation is absorbed by the sea surface, and this is thought to accelerate global warming. In addition, the highly-salinity water discharged when sea ice is formed is believed to be a driver of deep-ocean circulation, so changes in sea ice also affects deep-ocean circulation.

[11]Maximum sea-ice extent: The extent of sea ice for the five-day period when the sea ice extent was at its maximum for the year.

ice) in March along the coast of Hokkaido is projected to decrease from 0.5 to 0.7 at the end of the 20th century to 0.2 to 0.5 at the end of the 21st century under the RCP2.6 scenario and to 0.1 or lower under the RCP8.5 scenario. (Figure 2-24)

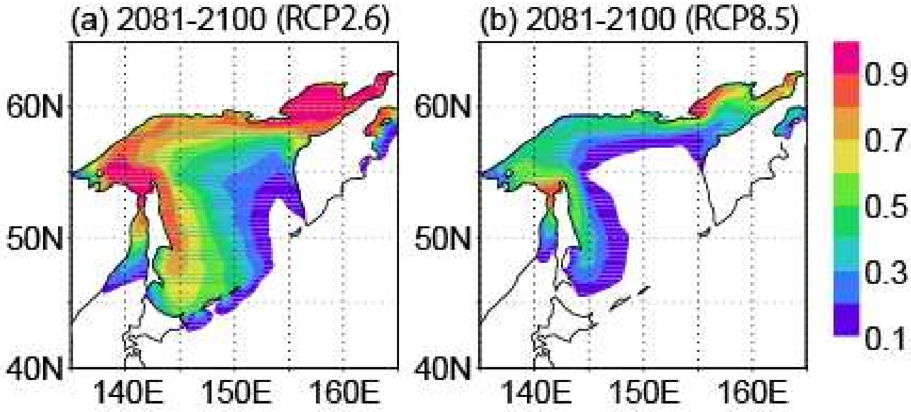


Figure 2-24. Distribution of sea ice concentration in March at end of 21st century based on SI-CAT Ocean Model

Projection results of (a) RCP2.6 scenario and (b) RCP8.5 scenario.

C. Ocean Circulation

i) Observation Results

- The Kuroshio[12] net flow rate near the southern coast of Japan has not shown a significant long-term trend since 1970. In the deep water of the Sea of Japan, an increase in water temperatures and a decrease in oxygen have been identified as long-term trends, and they are thought to be due to a decrease in deep-water formation as a result of a weakening cooling at the sea surface.

- There is a prominent variation of Kuroshio flow rate near the southern coast of Japan on a multi-decadal scale. There has been a slight downward trend since the 1990s, but no significant trend is evident since the 1970s. This is roughly consistent with the flow rate as determined from wind stress in the North Pacific based on the theory of ocean general circulation. It has been reported that Kuroshio flow rate is decreasing in the southern areas of the North Pacific subtropical gyre, such as in the region of Taiwan and Okinawa (Wang et al., 2015).

- Based on long-term observations by the Japan Meteorological Agency, long-term trends are evident in the Japan Basin and Yamato Basin at a depth of 2000 m, with an increase in water temperature of 0.02°C per decade and a decrease in dissolved oxygen of 7-9 μmol/kg per decade (Figure 2-25).

[12]The Kuroshio is a very strong current that runs through the western part of subtropical gyre that flows from the Philippines past the east side of Taiwan, reaching the southern coast of Japan. The Japan Meteorological Agency takes measurements along a 137°E line to the equator twice a year, and uses this data to estimate the Kuroshio flow rate passing the southern coast of Japan at 137°E.

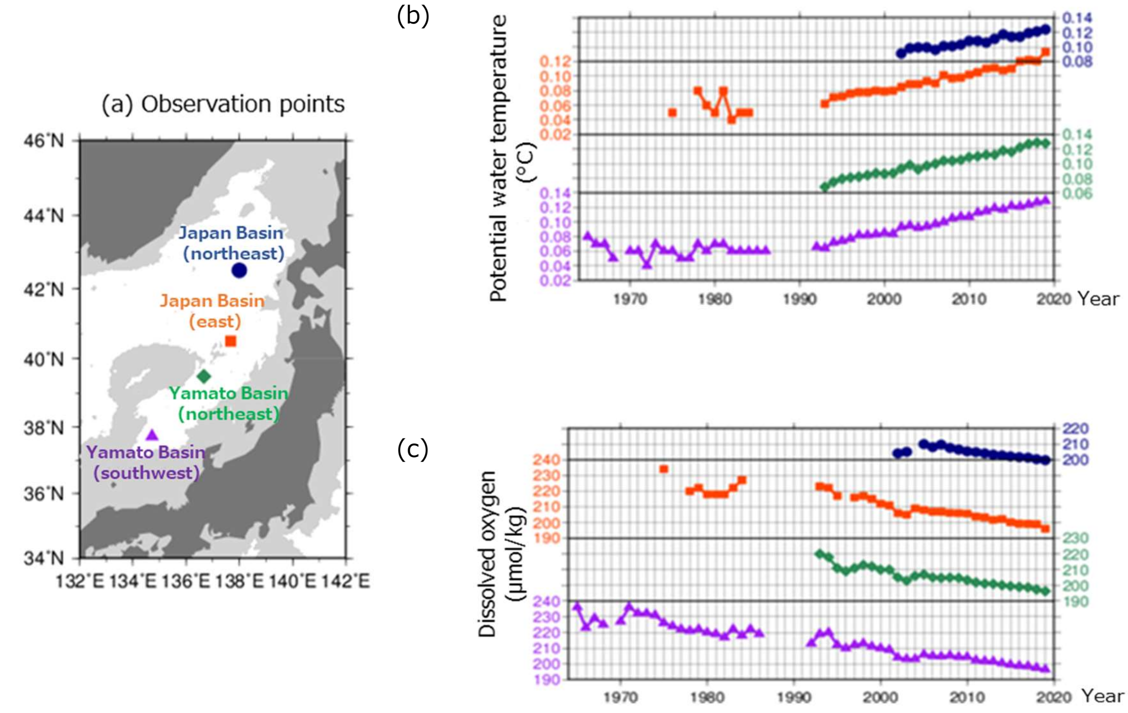


Figure 2-25. Observation points, temperature and dissolved oxygen of Japan Sea Proper Water[13] at a depth of 2000 m

In the figure, (a) is observation points, (b) is water temperature[14] and (c) is dissolved oxygen concentration. In figure (a), the light gray shade indicates sea areas less than 2,000 m in depth.

ii) Future Projections

- Under the RCP8.5 scenario, the average flow rate at the end of the 21st century relative to the end of the 20th century is projected to decrease by about 3 Sv (1 Sv = 106 m^3/s), but this is within the range of variability under the current climate. Under the RCP2.6 scenario, no clear change trend is evident in flow rates. In terms of the details of uncertainty of projections, the differences between models are large. Considering the range of uncertainty of projections, the changes in Kuroshio flow rate are not significant (low confidence).
- At the end of the 21st century relative to the end of the 20th century, the Kuroshio flow rate is projected to shift 0.2° northward under the RCP8.5 scenario and about 0.2° southward under the RCP2.6 scenario, but both of these are within the range of variability under the current climate.

[13]The Sea of Japan connects to the East China Sea and Pacific Ocean through relatively shallow straits, so seawater exchange is limited to the surface layer, and most of the seawater at depths of about 300 m and more (referred to as Japan Sea Proper Water) is nearly uniform in temperature and oxygen concentration.

[14]Potential water temperature: When a parcel seawater is moved deeper without exchanging heat with its surroundings, its temperature rises above what it was initially, due to compression. The potential water temperature (also referred to as potential temperature) is the temperature at which seawater is brought from an existing depth to the surface without heat exchange (i.e., the temperature of the water excluding the temperature increase associated with water pressure). This parameter is used to compare water temperatures at different depths of deep oceans with high water pressure, and to study the vertical distribution of water temperatures, etc.

D. Ocean Acidification

i) Observation Results

- The world's oceans are acidifying. The hydrogen ion exponent (pH) of surface seawater is declining at an average rate of about 0.02 per decade in the oceans. In the western North Pacific region south of Japan, a clear declining trend is evident at all latitudes with slightly smaller variations at low latitudes (Figure 2-26).
- According to analyses based on annual data provided by the National Institute for Environmental Studies on water quality in public waters (Ishuzu et. al, 2019), Japan's coastal seawaters have on average acidified, accompanying variasions due to influences from rivers and land, even though some areas are showing no acidification. Averaged for the period from 1978 to 2009, the rate of decrease in pH was 0.014 per decade for the annual minimum (summer) and 0.024 for the annual maximum (winter), which are similar to the observed values in the open ocean.

(a) 137°E line (b) 165°E line (c)

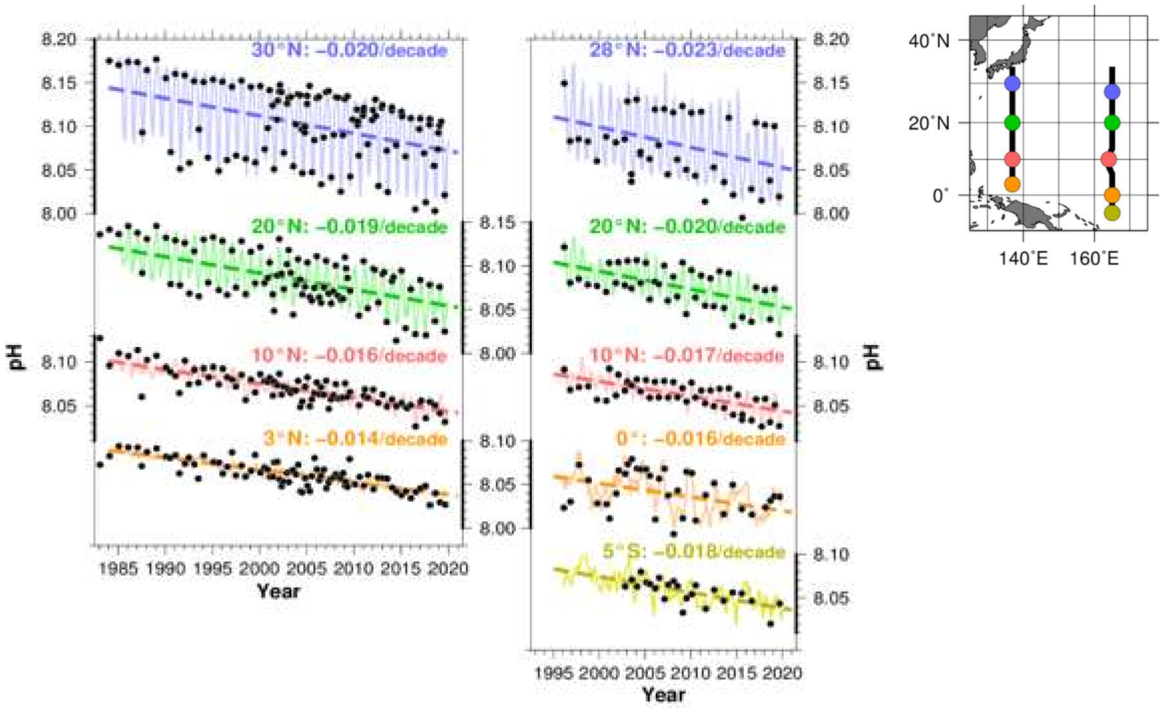


Figure 2-26. Long-term pH trends in surface seawater at 137°E and 165°E lines

In (a) and (b), black plots indicate pH calculated from observed values of partial pressure of carbon dioxide in surface seawater, lightly colored lines are the pH values obtained by analysis, dashed lines indicate the long-term trends, and numbers in the graphs indicate the rate of change (decrease) per decade. Locations of observation points are indicated in (c).

ii) Future Projections

- The decline in pH levels of surface seawater in the world's oceans is projected to continue in the future under the RCP8.5 scenario, but to stop by about 2050 under RCP2.6 scenario and be limited after that (high confidence, Figure 2-27). Comparing the conditions at the end of the 21st century (average of 2081 to 2100) relative to the end of the 20th century (average of 1986 to 2005), the average pH level of surface seawater in the world's oceans is projected to decrease by 0.31 (0.30-0.32) under the RCP8.5 scenario and 0.065 (0.06-0.07) under the RCP2.6 scenario (high confidence), and in the western North Pacific region south of Japan, to decrease by about 0.3 under the RCP8.5 scenario, which is about the same as the global average, and about 0.04 under the RCP2.6 scenario, which is slightly less than the global average (medium confidence).

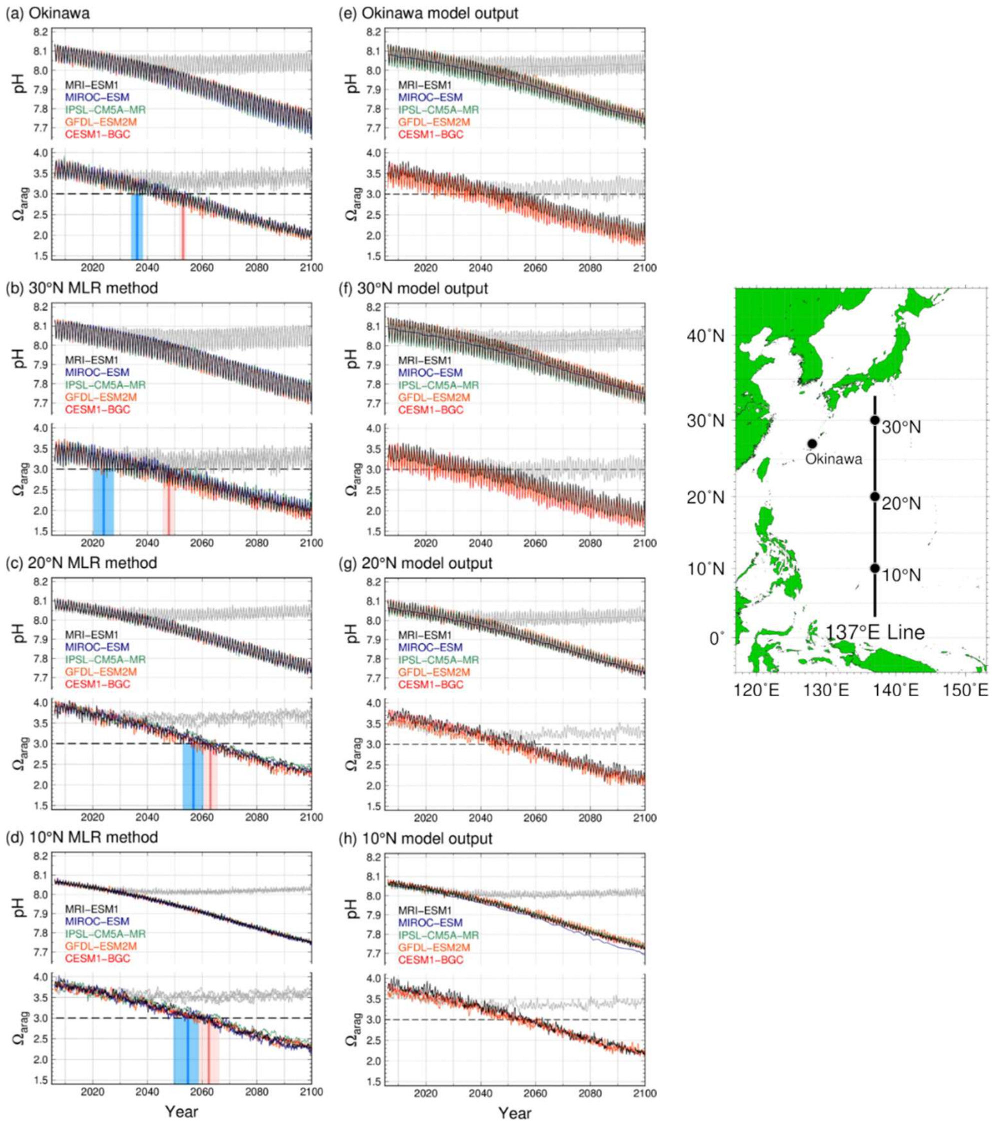


Figure 2-27. Surface seawater pH and Ω_{arag} under the RCP8.5 and RCP2.6 scenarios

Projections are based on five CMIP5 Earth system models. Panels (a) to (h) show projections for pH and Ω_{arag} in the seawaters; near Okinawa (a, e) and the 137°E at 30°N (b, f), 20°N (c, g), and 10°N (d, f). Locations are indicated in (i). The left column (a) to (d) indicates results of observation-based multiple linear regressions to which future changes were applied, and the right column (e) to (h) indicates output of Earth system model. In the panels (a) to (h), RCP8.5 and RCP2.6 scenario projections for changes in surface seawater pH and Ω_{arag} are indicated by dark and gray solid lines, respectively. The results of RCP8.5 scenario are color-differentiated for the five models and those of RCP2.6 scenario are all shown in gray for the three models, GFDL, IPSL, and MIROC. In (a) to (d), the blue vertical lines indicate the time when Ω_{arag} begins to fall below 3 seasonally, and the red ones indicate the time when it falls below 3 throughout the year.

(6) Tropical Cyclones

i) Observation Results

- An increase in the number of named tropical cyclones was observed in the mid-1960s, early 1990s, and mid-2010s, and their annual occurrences were below normal from the late 1990s to the early 2010s. For the entire period from 1951 to 2019, fluctuations on multi-decadal and year-to-year scales are clearly evident, but no long-term trend is evident (Figure2-28, top line).

- The numbers of approaches to Japan are on a trend similar to changes in the number of occurrences, and no long-term trends are evident. Similarly, no long-term trend is evident in the number of named tropical cyclones making landfall in Japan (Figure2-28, middle and lower lines).

- In many years, about 10 to 20 named tropical cyclones per year are classified as "Typhoon"[15] or stronger during their formation and dissipation; both the number of occurrences and ratio of intense tropical cyclones increased slightly from the late 1980s to the early 1990s and during the mid-2000s, and decreased slightly in the late 1990s and early 2010s. In addition, year-to-year fluctuations are large, and no long-term trends are evident (Figure 2-29).

- There is a relatively clear trend in the low latitudes of the western North Pacific for the latitudes where named tropical cyclones reach their lifetime peak intensity to be shifting poleward (Kossin et al., 2016), with the long-term trend having low to medium confidence (IPCC 2019, Knutson et al., 2019

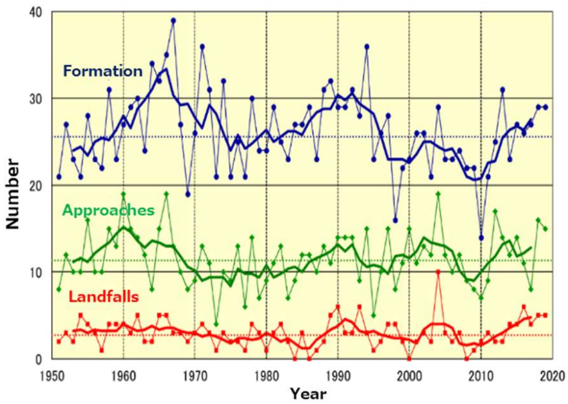


Figure2-28. Formations, approaches, and landfalls of named tropical cyclones

The dots connected by a thin solid line indicate numbers for each year, the thick line is the 5-year running mean, and the thin dotted line is the average from 1981 to 2010.

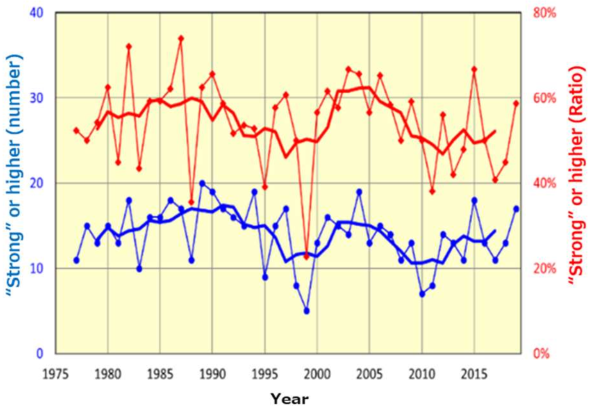


Figure 2-29. Occurrences and ratios of named tropical cyclones rated "Typhoon"or stronger

The thin blue line is the number of tropical cyclones rated as "Typhoon" or stronger above (33 m/s or more), and the thin red line is the ratio of tropical cyclones rated a "Typhoon" or stronger to the annual number of named tropical cyclones. The thick line is the 5-year running mean.

ii) Future Projections

- Future projection experiments based on greenhouse gas emission scenarios and pseudo global warming experiments that recreate past named tropical cyclones under global warming conditions project an increase in tropical cyclone intensity in the vicinity of Japan in the future (medium confidence). Experiments by Tsuboki et al. (2015) using the SRES A1B scenario project that the maximum intensity of so-called "super typhoons"[16] will increase at the end of the 21st century and reach Japan at the super typhoon intensity.

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[15]The Japan Meteorological Agency classifies tropical cyclones since 1977 based on the maximum sustained winds averaged over 10 minutes, with 33 m/s or more as "Typhoon," 44 m/s or more as "Typhoon (very strong)," and 54 m/s or more as "Typhoon (violent)."

[16]A super typhoon is the maximum intensity class defined by the Joint Typhoon Warning Center (JTWC) of the United States, as an average maximum ground wind speed per minute of 130 knots (about 67 m/s) or more.

- Some studies have examined the effects of global warming on named tropical cyclones by conducting pseudo global warming experiments looking at examples of individual named tropical cyclones, and many of them result in intense tropical cyclones in the vicinity of Japan. The studies listed below conduceted pseudo global warming experiments applying sea surface temperatures and air temperatures at the end of the 21st century under the RCP8.5 scenario.
  - Kanada et al. (2017) conducted comparative experiments on Typhoon Vera (T5915), also known as Isewan Typhoon, using four types of regional climate models with 5-km grid spacing. They obtained high confidence results in all models showing increased intensity of the Isewan Typhoon under global warming conditions. The study points out that the driver of greater intensity is an increase in water vapor in the lower troposphere due to global warming, resulting in a significant updraft and latent heat release inside the wall cloud.
  - Takemi et al. (2016) conducted a pseudo global warming experiment examining Typhoon Mireille (T9119), and Ito et al. (2016) examined Typhoon Songda (T0418), and found that under global warming conditions, the strength of the typhoons increased during their mature phase.
- Regarding precipitation associated with named tropical cyclones, the amount of rainfall of individual named tropical cyclones is projected to increase in the future (medium confidence). However, there is no change in the total annual precipitation from named tropical cyclones. According to Watanabe et al. (2019), there will be a decrease in the number of named tropical cyclones approaching Japan, but the precipitation intensity of individual named tropical cyclones will increase. Since these effects cancel each other out, there is no significant change in the total annual amount of precipitation associated with named tropical cyclones. In addition, the frequency of extremely heavy precipitation events associated with named tropical cyclones will increase. The reason is that the effects of increased precipitation intensity of individual named tropical cyclones are greater than the effects of a decrease in the number of named tropical cyclones approaching Japan.

iii) Pseudo Global Warming Experiment of Typhoon Hagibis (T1919)

・ Considering the fact that named tropical cyclones resulting in enormous damage have occurred frequently in recent years--including Typhoon Jebi (T1821), Typhoon Faxai (T1915), and Typhoon Hagibis (T1919), and more--in order to gain a better understanding of the impacts of climate change on named tropical cyclones, under the "Impact Assessment Program on Disaster Intensification Due to Climate Change,"[17] the Ministry of the Environment is currently (FY 2020) studying the possible impacts in the event a named tropical cyclones were to follow the same track as Typhoon Hagibis under a global warming scenario. The following is a summary of the interim findings.

・ Prior to impact assessment, a preliminary analysis[18] of precipitation associated with named tropical cyclones found that the amount of precipitation over all of Honshu would increase in all cases calculated under a scenario of a global average temperature increase of 4°C. Under a 2°C scenario, there was an increasing trend in most except for a few cases.

・ Current calculation results show that there are issues with recreating the development status of named tropical cyclones (central pressure) and tracks. Among the future projection calculations, in cases where precipitation decreased, the major cause of decrease was that the tropical cyclone track track diverged further than that calculated by recreating current conditions and moved away from Tohoku and Kanto regions, and in cases where it increased, the amount of increase varied greatly depending on the route. As a result, to project impacts for a specific region, it will be necessary to raise the reproducibility of tropical cyclone tracks, etc., using spatially-detailed data prepared by the Japan Meteorology Agency's Global Spectral Model (GSM) as initial and external forcing conditions.

・ Going forward, as ongoing work continues to address the above concerns, there are also plans to conduct simulations using multiple climate models, and also, to conduct simulations using discharge/flood models and storm surge models to assess impacts on river flows, flood levels, and tide levels, etc.

[17] This program is utilizing the outcomes of the Integrated Research Program for Advancing Climate Models, under the Ministry of Education, Culture, Sports, Science and Technology. For an outline of the program please refer to p. 90.

[18] Using the NHRCM regional climate model by the Meteorological Research Institute, an estimate of future changes was made by comparing the outcomes of calculations to recreate current conditions using JRA-55 reanalysis data as boundary conditions, and future projection calculations using six types of warming patterns for sea surface temperatures (SST) from d4PDF/d2PDF.

Chapter 2 References

- IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.
- IPCC, 2019: Extremes, Abrupt Changes and Managing Risks. In: The Ocean and Cryosphere in a Changing Climate. An IPCC Special Report on the ocean and cryosphere in a changing climate.
- Ishizu, M., Miyazawa, Y., Tsunoda, T., and Ono, T.: Long-term trends in pH in Japanese coastal seawater, Biogeosciences, 16, 4747–4763, https://4850 doi.org/10.5194/bg-16-4747-2019, 2019
- Ito, R., T. Takemi, and O. Arakawa, 2016: A possible reduction in the severity of typhoon wind in the northern part of Japan under global warming: A case study. SOLA, 2016, 12, 100−105.
- Kanada, S., T. Takemi, M. Kato, S. Yamasaki, H. Fudeyasu, K. Tsuboki, O. Arakawa, and I. Takayabu, 2017: A multimodel intercomparison of an intense typhoon in future, warmer climate by four 5-km-2611 mesh models. J. Climate, 30, 6017–6036.
- Kawase, H., T. Yoshikane, M. Hara, M. Fujita, N. Ishizaki, H. Hatsushika and F. Kimura, 2012: Downscaling of snow cover changes in the late 20th Century using a past climate simulation method over Central Japan. SOLA, 8, 61 – 64.
- Kawase, H., A. Murata, R. Mizuta, H. Sasaki, M. Nosaka, M. Ishii and I. Takayabu, 2016: Enhancement of heavy daily snowfall in central Japan due to global warming as projected by large ensemble of regional climate simulations. Climatic Change, 139, 265 – 278, https://doi.org/10.1007/s10584-016-1781-3.
- Kawase, H., T. Yamazaki, S. Sugimoto, T. Sasai, R. Ito, T. Hamada M. Kuribayashi, M. Fujita, A. Murata, M. Nosaka and H. Sasaki, 2020: Changes in extremely heavy and light snow-cover winters due to global warming over high mountainous areas in central Japan. PEPS, accepted.
- Kossin, J.P., K. A. Emanuel and S. J. Camargo, 2016: Past and projected changes in western North Pacific tropical cyclone exposure. J. Climate, 29, 5725–5739.
- Knutson, T., S. J. Camargo, J. C-L. Chan, K. Emanuel, C.-H. Ho, J. Kossin, M. Mohapatra, M. Satoh, M. Sugi, K. Walsh and L. Wu, 2019: Tropical cyclones and climate change assessment: Part I. Detection and attribution. Bull. Amer. Meteor. Soc., DOI: 10.1175/BAMS-D-18-0189.1
- Mizuta, R., H. Yoshimura, H. Murakami, M. Matsueda, H. Endo, T. Ose, K. Kamiguchi, M. Hosaka, M. Sugi, S. Yukimoto, S. Kusunoki and A. Kitoh, 2012: Climate simulations using MRI-AGCM3.2 with 20-km grid. J. Meteor. Soc. Japan, 90A, 233 – 258, doi:10.2151/jmsj.2012-A12.
- Osakada, Y., and E. Nakakita 2018. Future Change of Occurrence Frequency of Baiu Heavy Rainfall and Its Linked Atmospheric Patterns by Multiscale Analysis. SOLA. 14. 79-85, doi:10.2151/sola.2018-014.
- Sasai, T., H. Kawase, Y. Kanno, J. Yamaguchi, S. Sugimoto, T. Yamazaki, H. Sasaki, M. Fujita and T. Iwasaki, 2019: Future Projection of Extreme Heavy Snowfall Events With a 5-km Large Ensemble Regional Climate Simulation. Journal of Geophysical Research: Atmospheres, 124, https://doi.org/10.1029/2019JD030781.
- Sasaki, H., A. Murata, M. Hanafusa, M. Oh'izumi, and K. Kurihara 2011. Reproducibility of present climate in a non-hydrostatic regional climate model nested within an atmosphere general circulation model. SOLA, 7, 173−176, doi:10.2151/sola.2011-044.
- Sutton, R. T., B. W. Dong and J.M. Gregory, 2007: Land/Sea warming ratio in response to climate change: IPCC AR4 modelresults and comparison with observations, Geophys. Res. Lett., 34, L02701, https://doi.org/10.1029/2006GL028164.
- Takemi, T., R. Ito, and O. Arakawa, 2016: Effects of global warming on the impacts of Typhoon Mireille (1991) in the Kyushu and Tohoku regions. Hydrological Research Letters 10, 81–87.
- Tsuboki, K., M. K. Yoshioka, T. Shinoda, M. Kato, S. Kanada, and A. Kitoh, 2015: Future increase of supertyphoon intensity associated with climate change. Geophys. Res. Lett., 42, 646–652.
- Tsujino H., H. Nakano, K. Sakamoto, S. Urakawa, M. Hirabara, H. Ishizaki, G. Yamanaka, 2017: Reference manual for the Meteorological Research Institute Community Ocean Model version 4 (MRI.COMv4). Tech Rep 80, Meteorological Research Institute, Japan.
- Wang, G., S-P. Xie, R. Huang, C. Chen, 2015: Robust Warming Pattern of Global Subtropical Oceans and its Mechanism, J. Climate, 28, 8574-8584.
- Watanabe, S. I., A. Murata, H. Sasaki, H. Kawase, and M. Nosaka, 2019: Future projection of tropical cyclone precipitation over Japan with a high-resolution regional climate model, J. Meteor. Soc. Japan, 97, 805–820.
- WMO, 2020: WMO Greenhouse Gas Bulletin, No. 16.
- Japan Meteorological Agency, 2017: Global Warming Projection Vol. 9 (in Japanese).
- Japan Meteorological Agency, 2020: Climate Change Monitoring Report 2019 (in Japanese).
- Suzuki, H, 2010: Snowfall trends for 1927-2005 in and around Niigata Prefecture: Analysis using snowfall data observed at open spaces in railway stations (in Japanese). Tenki, 57, 289-303 (in Japanese).

Chapter 3 Overview of Climate Change Impacts in Japan

3.1 Climate Change Impact Assessment Methodologies

For the current report, assessment methodologies that were used in the previous Climate Change Impact Assessment (2015) were revised based on improvements in scientific findings, and on current circumstances. More specifically, the assessment was done as described below, referring to approaches used in the IPCC Fifth Assessment Report to identify major risks, and approaches used in other countries to evaluate risks (e.g., the U.K.'s Climate Change Risk Assessment, hereinafter referred to as "UK-CCRA").

● Organization Arrangements for This Review

Assessments were done from the perspective of "significance," "urgency," and "confidence" for seven sectors (Agriculture, Forest/Forestry, Fisheries; Water Environment, Water Resources; Natural Ecosystems; Natural Disasters, Coastal Areas; Human Health; Industrial/Economic Activities; Life of Citizenry, Urban Life), with the sub-categories for each sector shown in Table **3-1**. In addition, though no assessment was conducted, besides the seven sectors mentioned, climate change impact assessments were also summarized for "Inter-sectoral Impact Linkages." It is difficult to mechanically and quantitatively establish assessment criteria across the board due to the unique characteristics of each sector. As a result, it was decided to use expert judgment based on scientific findings in each Working Group, while employing common metrics in each sector for "significance," "urgency," and "confidence." In addition, the Expert Committee on Climate Change Impact Assessment, Global Environment Committee, Central Environment Council held comprehensive discussions for the current report based on the results of the discussions in each Working Group.

● Criteria for Assessment

Significance--Assess in terms of three criteria: social, economic, and environmental. See page 41 for details.

Urgency--Assess in terms of two criteria: Timing of occurrence of impacts, and timing required to initiate adaptation measures and critical decision-making. See page 43 for details.

Confidence--To some extent, applying the approaches to confidence used in the IPCC Fifth Assessment Report, assess in terms of two criteria: Type of research/report (e.g., quantitative projection based on model simulation; projection using an index for degree of increase in temperature; qualitative analysis or estimates); and degree of agreement. Where the number of research/reports is rather limited (e.g., only one or two), judgement is used to determine whether the contents are reasonable. See page 45 for details.

● Method of Summarization

For each sector and sub-category, a table format is used to summarize the assessment results for significance, urgency, and confidence. See page 46 for details.

Table 3-1 Classification system for sectors and sub-categories

Sectors	Categories	Sub-categories	Working Group
Agriculture, Forest/Forestry, Fisheries	Agriculture	Paddy field rice	Agriculture, Forest/Forestry, Fisheries Working Group
		Vegetables, etc.	
		Fruit trees	
		Barley/wheat, soybean, feed crops, other crops	
		Livestock farming	
		Plant pests, weeds, etc.	
		Water, land and agricultural infrastructure	
		Food supply and demand	
	Forest/Forestry	Timber production (e.g., planted forests)	
		Non-timber forest products (e.g., mushrooms)	
	Fisheries	Migratory fish stocks (ecology of fishes)	
		Propagation and aquaculture	
		Fishery environments in coastal areas and inland waters, etc.	
Water Environment, Water Resources	Water environment	Lakes, marshes, dams (reservoirs)	Water Environment / Water Resources and Natural Disasters / Coastal Areas Working Group
		Rivers	
		Coastal zones and closed sea areas	
	Water resources	Water supply (surface water)	
		Water supply (groundwater)	
		Water demand	
Natural Ecosystems	Terrestrial ecosystems	Alpine/subalpine zone	Natural Ecosystems Working Group
		Natural forests, secondary forests	
		Countryside-landscape ("satochi-satoyama")	
		Planted forests	
		Damage from wildlife	
		Material balance	
	Freshwater ecosystems	Lakes, marshes	
		Rivers	
		Marshlands	
	Coastal ecosystems	Subtropics	
		Temperate, subarctic	
	Marine ecosystems		
	Others	Phenology	
		Shifts in distribution and populations	
	Ecosystem services		
Natural Disasters, Coastal Areas	Rivers	Floods	Water Environment / Water Resources and
		Inland waters	
	Coastal areas	Sea-level rise	
		Storm surges, high waves	

Sectors	**Categories**	**Sub-categories**	**Working Group**
		Coastal erosion	Natural Disasters / Coastal Areas Working Group
	Mountain areas	Debris flows, landslides, and other disasters	
	Others	Strong winds, etc.	
	Impacts of complex disasters		
Human Health	Winter warming	Mortality in winter season	Human Health Working Group
	Heat stress	Risk of mortality, etc.	
		Heat illness, etc.	
	Infectious diseases	Water- and food-borne diseases	
		Vector-borne infectious diseases	
		Other infectious diseases	
	Others	Complex impacts of warming and air pollution	
		Impacts on vulnerable populations (elderly, children, persons with underlying health conditions, etc.)	
		Other health impacts	
Industrial / Economic Activities	Manufacture		Industrial / Economic Activities and Life of Citizenry and Urban Life Working Group
	Energy	Energy supply and demand	
	Commerce		
	Finance, insurance		
	Tourism	Leisure	
	Construction		
	Medical		
	Others	Overseas impacts	
		Others	
Life of Citizenry, Urban life	Urban infrastructure, critical services, etc.	Water supply, transportation, and others	
	Life with sense of culture and history	Phenology, traditional events/ local industry	
	Others	Impacts on life due to heat stress, etc.	
Inter-sectoral Impact Linkages	Impacts of disruptions of urban infrastructure and critical services		

* Red font indicates newly added or more detailed categories/sub-categories in this report.

(1) Approach for Assessment of Significance

The assessment of significance of impacts is based on three criteria (social, economic, and environmental) and with reference to criteria used in the IPCC Fifth Assessment Report as a basis to identify key risks (below), as well as the UK-CCRA approach.

- **Criteria used in the IPCC Fifth Assessment Report as a basis to identify key risks**

・ Magnitude

・ Probability

・ Irreversibility of impacts

・ Timing (of impacts)

・ Persistent vulnerability or exposure contributing to risks

・ Limited potential to reduce risks through adaptation or mitigation

However, among these criteria, "timing" is used to assess urgency, rather than significance. In addition, "limited potential to reduce risks through adaptation or mitigation" is not used directly to assess significance, but rather is incorporated into the assessment of mitigation and adaptation, as follows.

Mitigation

For some categories/sub-categories, it was decided to indicate the effects of mitigation by assessing significance with two scenarios, namely "RCP2.6 and the equivalent of 2°C of warming" and "RCP8.5 and 4°C of warming," based on considerations that include underlying emissions scenarios (RCP2.6, RCP8.5, etc.), time frames for projections (mid-21st century, end of 21st century, etc.), and the ranges of temperature increase since preindustrial levels, etc. In addition, where there is a finding based on multiple scenarios but it is difficult to distinguish between scenarios in terms of assessments of significance, it was decided to describe the differences in impact only in words, to the extent possible. Although such an approach was not considered for the previous impact assessment, advances in knowledge have made it possible to reflect this in the current assessment.

Adaptation

Since there is currently only limited literature on climate change impacts considering the effects of the implementation of adaptation measures, it was decided not to reflect the impacts of future additional adaptation measures in the assessment of significance. However, as adaptation measures have already been taken to some extent in some sectors, such as in flood control, agriculture, forest/forestry and fisheries, in assessing the significance of current impacts it was decided to take into account the effects of the adaptation measures that have already been implemented.

For the assessment of significance, the designation as "Recognized as having particularly significant impacts" or "Recognized as having impacts" is, in principle, determined based on science, including the findings described in research papers and other literature, as well as expert judgment, following the approach shown in Table 3-2. The term "N/A (currently cannot be assessed)" is used to indicate cases where assessment is currently difficult.

Table 3-2 Approach for assessment of significance

<table>
<tr><th rowspan="2">Criteria for Assessment</th><th colspan="2">Metrics for Assessment (Approach)</th><th rowspan="2">Means of Indicating Final Assessment</th></tr>
<tr><th>Recognized as having particularly significant impacts</th><th>Recognized as having impacts</th></tr>
<tr><td></td><td colspan="2">Assess significance in terms of social, economic, environmental impacts based on the following criteria:
● Magnitude of impacts (area, duration)
● Likelihood of occurrence of impacts
● Irreversibility of impacts (difficulty of restoring original conditions)
● Persistent vulnerability or exposure contributing to the impacts of concern</td><td rowspan="4">Indicate the degree of significance, and where “recognized as having particularly significant impacts,” indicate the criteria.</td></tr>
<tr><td>1. Social</td><td>At least one of the following applies:
● Involves the loss of human life, or on the health dimension, the extent of impacts and likelihood of occurrence are particularly high (abbreviated as “extent” below).
e.g.: Hazards (disasters) could result in the loss of human life
Health impacts for large numbers of people
● Magnitude of impacts on local society and community is particularly high
e.g.: Impacts are nationwide
Impacts are not nationwide, but are serious locally
● Magnitude of impacts on cultural assets and community services is particularly high
E.g., Irreversible impacts on cultural assets
Serious impacts on citizens’ livelihoods</td><td>An assessment of “Recognized as having particularly significant impacts” does not apply</td></tr>
<tr><td>2. Economic</td><td>The following applies:
● Magnitude of economic losses is particularly high
e.g., Large-scale losses occur to assets and infrastructure
Loss of employment opportunities for a large number of citizens
Large-scale disruptions of transportation networks over a large area</td><td>An assessment of “Recognized as having particularly significant impacts” does not apply</td></tr>
<tr><td>3. Environment</td><td>The following applies:
● Magnitude of losses to environmental and ecosystem functions is particularly high
e.g., Large-scale loss of important species, habitats, and landscapes
For ecosystems, significant deterioration in quality of places that are important internationally and nationally
Significant decline in land/water/atmospheric/ecological functions over a broad area</td><td>An assessment of “recognized as having particularly significant impacts” does not apply</td></tr>
</table>

(2) Approach for Assessment of Urgency

For criteria corresponding to urgency, reference was given to the IPCC Fifth Assessment Report "timing of impacts" and U.K. CCRA "timing of impacts" and "urgency with which adaptation decisions need to be taken." These are different concepts, but for this report it was decided to consider both perspectives and apply whichever concept has the highest level of urgency. It should be noted that because adaptation includes measures that need to be implemented in the long term and on an ongoing basis, for the "timing of impacts" and "urgency with which adaptation decisions need to be taken" it is necessary to consider the amount of time required to implement measures.

Approach for timing of appearance of impacts:

In the previous assessment, impacts were deemed to have medium urgency if there was a high likelihood that they would occur by about 2030 based on projections for the near term (from the present to about 2030). However, five years have elapsed since the previous assessment and considering of the time required to consider and implement adaptation measures, the 2030 time frame may not always be appropriate. In addition, since the previous assessment, there have been advances in the expertise required to make projections to the middle of the 21st century (about 2040 to 2060), which allows for better discretion regarding urgency based on whether an impact has a high likelihood of occurring by mid-century. As a result, the metrics for medium urgency have been changed from the "high likelihood that impacts will occur by about 2030" in the previous assessment to "high likelihood that impacts will occur by the middle of the 21st century" in the current assessment (Table 3-3).

Approach for timing required to initiate adaptation measures and make critical decisions:

Because adaptation includes actions that must be implemented over the long term and/or continuously and actions whose effects take time to appear, it is important to properly consider the amount of time required for adaptation and until adaptation effects appear, and to initiate measures and make critical decisions as early as possible. In terms of the time scale that can ensure a certain degree of effectiveness of measures by governments and other actors, considering a time frame of about ten years from the present (about 2020) as being reasonable, the metric for medium urgency in this assessment is "major decisions need to be made before about 2030," which is the same as in the previous assessment

The term "N/A (cannot currently be assessed)" is indicated in cases where assessment is currently difficult.

Table 3-3 Approach for assessment of urgency

Criteria for Assessment	Assessment Measure			Means of Indicating Final Assessment
	High urgency	**Medium urgency**	**Low urgency**	
1. Timing of impacts	Impacts are already evident	High likelihood that impacts will occur by mid-21st century	High likelihood that impacts will occur after mid-21st century or level of uncertainty is extremely high	The level of urgency is to be indicated for each sub-category as one of three levels, with both 1 and 2 considered
1. Timing needed to initiate adaptation measures and make critical decisions.	**High urgency**	**Medium urgency**	**Low urgency**	
	Decisions need to be made as soon as possible.	Major decisions need to be made within about 10 years (by about 2030)	The need is low to make major decisions within about 10 years (by about 2030)	

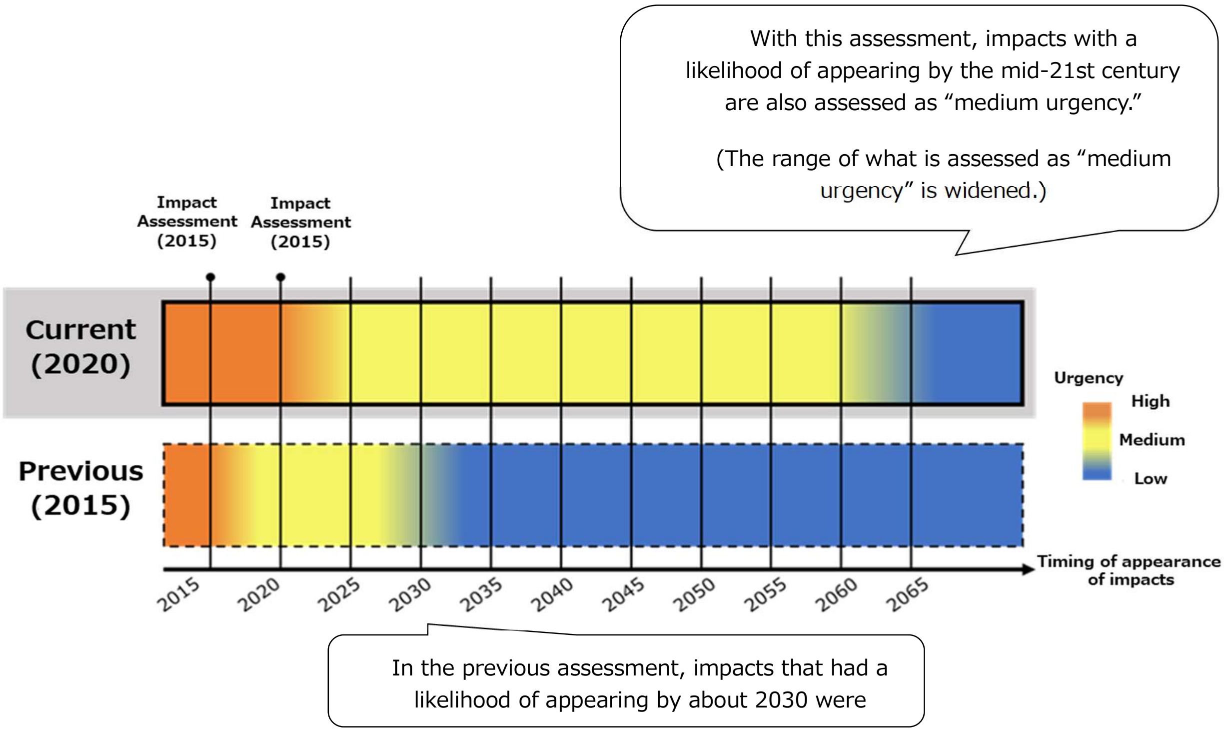

Figure 3-1 Comparison of assessments of urgency between the previous (2015) and current (2020) impact assessment

(3) Approach for Assessment of Confidence

The assessment of confidence is conducted, in principle, based on the IPCC Fifth Assessment Report's "type, amount, quality, and consistency of evidence," and "degree of agreement," and assessment is expressed with five terms: very high, high, medium, low, and very low.

- Types of evidence: Measurement/observation to date, models, experiments, paleoclimatic analogues, etc.
- Quantity of evidence: Numbers of research and reports
- Quality of evidence: Qualitative content of research and reports (ask whether assumptions are reasonable, etc.)
- Consistency of evidence: Consistency of research and reports (e.g., consistency of scientific mechanisms)
- Agreement of opinion: Agreement of opinion among research/reports

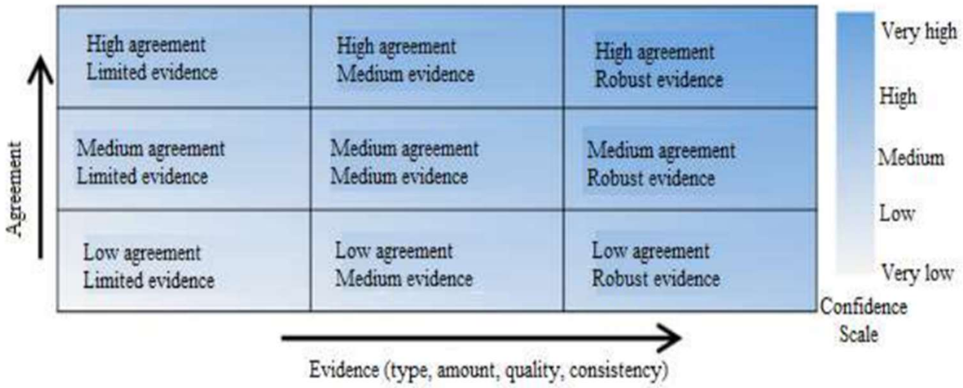

Figure 3-2 Evidence and agreement statements and their relationship to confidence

Confidence increases toward the top right corner. Generally, evidence is most robust when there are multiple, consistent, independent lines of high-quality evidence.

Source: Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties (2010, IPCC)

Here, the same two metrics were utilized as in the IPCC Fifth Assessment Report: "type, amount, quality, and consistency of evidence," and "degree of agreement." Regarding "type, amount, quality, and consistency of evidence," integrated judgment is to be used, but because in some cases the quantity of available research and reports containing projections of future impacts in Japan is less than in IPCC discussions, one of the key metrics for determining the approach is whether or not research and reports with quantitative analysis are available.

Regarding the assessment levels, it may not be possible to obtain a sufficient amount of literature, so just three options were used: high, medium, and low. When assessing confidence, the assessment was also based on the degree of certainty of projections, such as the amount of precipitation obtained from climate projection models being used. Also, the term "N/A (cannot currently be assessed)" is use in cases where assessment is currently difficult.

Table 3-4. Approach for assessment of confidence

Considerations for assessment	Levels of assessment (approach)			Means of Indicating Final Assessment
	High Confidence	**Medium Confidence**	**Low Confidence**	
IPCC Assessment of Confidence ○ Type, amount, quality, and consistency of research/reports ○ Agreement of opinion among research/reports	Corresponds to IPCC confidence rating of "high" and above	Corresponds to IPCC confidence rating of "medium"	Corresponds to IPCC confidence rating of "low" and below	Using the IPCC's confidence level, indicate the confidence level for each sub-category using one of three levels

(4) Format for Presentation of Outcomes

In the Climate Change Impact Assessment Report (Detailed Report), for each sub-category by sector, the final assessments of significance, urgency, and confidence are reported in the format indicated in the following table, together with an overview of the current situation and projected future impacts.

Table 3-5 Assessment of climate change impacts (summary table) (Example)

Sector	Category	Sub-categories	Current status	Projected impacts	Significance			Urgency	Confidence	Note
						Criteria	Rationale			
Agriculture, Forestry, Fisheries	Agriculture	Paddy field rice	● Deterioration in quality has already been confirmed nationwide due to warmer temperatures.	● Projections by RPC2.6 scenario indicate nationwide... ● Projections by d2PDF indicate...	◆	Social/Economic	Scope of impacts of changes in rice yields and quality...	●	●	
				● Projections by RPC8.5 scenario indicate nationwide... ● Projections by SRESA2 scenario indicate ... ● Projections by d4PDF indicate...	●	Social/Economic	Scope of impacts of changes in rice yields and quality...			

In the "Current Situation" column, indicate clearly any phenomena that could be considered to be an impact of climate change--not only observed impacts but also other phenomena--even if it cannot be stated with certainty that they are caused by climate change.

In this column indicate projected future impacts of climate change. To the extent possible, descriptions regarding impacts should clearly include assumptions (assumed temperature increase, etc.), timing, place, details, extent, and likelihood of occurring, followed by the level of confidence. For some sub-categories, the same "Overview of impacts" may be noted multiple times.
Note that the overview of impacts is to include not only negative but also positive impacts.

Where assessed "Recognized as having particularly significant impacts," indicate the rationale.

Indicate rationale for assessment of

In the "Notes" column, to the extent possible indicate the rationale for the assessment of urgency, confidence, etc., plus information as necessary such as the potential for adaptation, relationship with other sectors/sub-categories, etc.

Legend for Significance

● Recognized as having particularly significant impacts ◆ Recognized as having impacts

— N/A (cannot currently be assessed)

Legend for Urgency

● High ▲ Medium ■ Low — N/A (cannot currently be assessed)

Legend for Confidence

● High ▲ Medium ■ Low — N/A (cannot currently be assessed)

3.2 Climate Change Impact Assessment - Comments and Summary Table

Impacts that may be associated with climate change have already been observed in areas such as agriculture and ecosystems, and it has been pointed out there may be a relationship between climate change and more frequent occurrences of heat illnesses due to extreme high temperatures, floods due to intense heavy rainfall, and damage from sediment disasters. The following section provides a summary of the "current situation" and "projected impacts" in each sector covered in the "Climate Change Impact Assessment Report (Detailed Report)"as discussed and summarized by each Working Group and the Expert Committee on Climate Change Impact Assessment, Global Environment Committee, Central Environment Council, Ministry of the Environment. For more detailed information, please refer to the Climate Change Impact Assessment Report (Detailed Report) (in Japanese). Table 3-6 is a summary of assessment results of climate change impacts in the current report, with page numbers indicating where each assessment category is covered in the Climate Change Impact Assessment Report (Detailed Report).

For this initiative, an effort was made to cover the impacts of climate change to the greatest extent possible, but this is not a complete list of all impacts. Further and ongoing information collection as well as analysis of long-term terms is necessary.

Also, when referring to this report and considering the current situation as well as projected impacts, it is important to keep the following points in mind.

- For the climate change impacts in each sector, to the greatest extent possible, assessments in this report are done by relying on existing scientific literature, and where necessary, on expert judgment. It should also be noted that impacts of a nature and/or scale may appear in the future that cannot be fully assessed based on existing literature.
- The impacts described in this report are mainly impacts affecting Japan. However, impacts that arise overseas but have ripple effects in Japan are also described in this report, along with mention of the relationship with Japan.
- Climate change projections (e.g., temperature increases and changes in precipitation) vary in the range of magnitudes of projected changes and involve some uncertainty, due to differences in the greenhouse gas emission scenarios and climate models utilized. Differences in projected impacts also arise due to differences in assumptions for climate projections. Also, extreme events such as short-term intense rainfall have a high degree of spatial uncertainty in terms of the location of their occurrence.
- Impacts in each sector are not all necessarily caused only by climate change. Almost all phenomena are affected by a variety of factors other than climate change.[19]
  - Regarding the descriptions of the current situation, there is not a direct correlation with climate change in every single case, although examples are introduced where there are suggested possible impacts of climate change.
  - It is also important to remember that it can be difficult to investigate the contribution to climate change impacts of events associated with climate change that already affect human society or that could affect human society in the future.
  - On the other hand, it is also important to recognize that natural disasters and other damage or impacts would not all necessarily disappear in the absence of climate change.
  - The ways in which impacts are manifested can vary significantly depending on the characteristics of the hazards. Disaster risk depends not only on the intensity of meteorological events or phenomena but also the exposure and vulnerability of the sectors subjected to the impacts. Thus, future decisions of society can influence the ways in which impacts are manifested.

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[19] The IPCC Fifth Assessment Report states that warming of the climate system is unequivocal and that anthropogenic impacts on the climate system are clear. On the other hand, climate change is ultimately caused by a combination of factors, including cyclical changes in the tilt of the Earth's axis and the behavior of the Earth, variations in the solar cycle, and volcanic activity, and anthropogenic global warming (as defined by Japan's Act on the Promotion of Global Warming Countermeasures) caused by greenhouse gas emission associated with human activities. Furthermore, for individual events such as intense tropical cyclones or intense heavy rainfall events, it is difficult to ascertain the relative contribution to each event, whether it was due to global warming arising from anthropogenic greenhouse gas emissions or from natural variability such as the El Niño effect.

Table 3-6 Results of climate change impact assessment - Summary table

Significance (previous assessment)	Significance (current assessment)	Urgency, Confidence
● Particularly high	● Recognized as having particularly significant impacts	● High
◆ Not particularly high	◆ Recognized as having impacts	▲ Medium
— N/A (currently cannot be assessed)	— N/A (currently cannot be assessed)	■ Low
		— N/A (currently cannot be assessed)

Red font indicates items newly added since the previous impact assessment

Numbers in parentheses below the sector name indicate the change in number of items of literature from previous to the current assessment (numbers do not include 65 items cited in multiple sectors)

Sector	Category	No.	Sub-categories	Previous (2015) Significance	Previous (2015) Urgency	Previous (2015) Confidence	Current assessment (2020) Significance	Current assessment (2020) Urgency	Current assessment (2020) Confidence
Agriculture, Forest/Forestry, Fisheries (117→339)	Agriculture	111	Paddy field rice	●	●	●	● / ●	●	●
		112	Vegetables, etc.	—	▲	▲	◆	●	▲
		113	Fruit trees	●	●	●	● / ●	●	●
		114	Barley/wheat, soybean, feed crops, other crops	●	▲	▲	●	▲	▲
		115	Livestock farming	●	▲	▲	●	●	▲
		116	Plant pests, weeds, etc.	●	●	●	●	●	●
		117	Water, land and agricultural infrastructure	●	●	▲	●	●	●
		118	Food supply and demand				◆	▲	●
	Forest/Forestry	121	Timber production (e.g., planted forests)	●	●	■	●	●	▲
		122	Non-timber forest products (e.g., mushrooms)	●	●	■	●	●	▲
	Fisheries	131	Migratory fish stocks (ecology of fishes)	●	●	▲	●	●	▲
		132	Propagation and aquaculture	●	●	■	●	●	▲
		133	Fishery environments in coastal areas and inland waters, etc.				● / ●	●	▲
Water Environment, Water Resources (26→88)	Water environment	211	Lakes, marshes, dams (reservoirs)	●	▲	▲	◆ / ●	▲	▲
		212	Rivers	◆	■	■	◆	▲	■
		213	Coastal zones and closed sea areas	◆	▲	■	◆	▲	▲
	Water resources	221	Water supply (surface water)	●	●	▲	● / ●	●	●
		222	Water supply (groundwater)	◆	▲	■	●	▲	▲
		223	Water demand	◆	▲	▲	◆	▲	▲

Note. BD: Biodiversity, ES: Ecosystem services

Sector	Category	No.	Sub-categories	Previous Significance BD	Previous Significance ES	Previous Urgency BD	Previous Urgency ES	Previous Confidence BD	Previous Confidence ES	Current Significance	Current Urgency	Current Confidence
Natural ecosystems (127→252)	Terrestrial ecosystems	311	Alpine/subalpine zone	●	—	●	—	▲	—	●	●	▲
		312	Natural forests, secondary forests	●	—	▲	—	●	—	◆ / ●	●	●
		313	Countryside-landscape (“satochi-satoyama”)	◆	—	▲	—	■	—	◆	●	■
		314	Planted forests	●	—	▲	—	▲	—	●	●	▲
		315	Damage from wildlife	●	—	●	—	—	—	●	●	■
		316	Material balance	●	—	▲	—	▲	—	●	▲	▲
	Freshwater ecosystems	321	Lakes, marshes	●	—	▲	—	■	—	●	▲	■
		322	Rivers	●	—	▲	—	■	—	●	▲	■
		323	Marshlands	●	—	▲	—	■	—	●	▲	■
	Coastal ecosystems	331	Subtropics	●	—	●	—	▲	—	● / ●	●	●
		332	Temperate, subarctic	●	—	●	—	▲	—	●	●	▲
	Marine ecosystems	341	Marine ecosystems	●	●	▲	—	■	■	●	▲	■
	Others	351	Phenology	◆	—	●	—	●	—	◆	●	●
		361	Shifts in distribution and populations	●	—	●	—	●	—	●	●	●
				●		●		▲		●	●	▲

Sector	Category	No.	Sub-categories	Previous (2015)			Current assessment (2020)		
				Significance	Urgency	Confidence	Significance	Urgency	Confidence
	Ecosystem services	371	—				●	—	—
			Nutrient and turbid material retention functions in watersheds				●	▲	■
			Supply of fisheries resources by coastal seagrass ecosystems				●	●	▲
			Eco-DRR functions of coral reefs				●	●	●
			Recreational functions related to natural ecosystems				●	▲	■
Natural Disasters, Coastal Areas (88→136)	Rivers	411	Floods	●	●	●	● / ●	●	●
		412	Inland waters	●	●	▲	●	●	●
	Coastal areas	421	Sea-level rise	●	▲	●	●	▲	●
		422	Storm surges, high waves	●	●	●	●	●	●
		423	Coastal erosion	●	▲	▲	● / ●	▲	●
	Mountain areas	431	Debris flows, landslides, and other disasters	●	●	▲	●	●	●
	Others	441	strong winds	●	▲	▲	●	●	▲
	Impacts of complex disasters	451	—						
Human health (35→178)	Winter warming	511	Mortality in winter season	◆	■	■	◆	▲	▲
	Heat stress	521	Risk of mortality	●	●	●	●	●	●
		522	Heat illness	●	●	●	●	●	●
	Infectious diseases	531	Water- and food-borne diseases	—	—	■	◆	▲	▲
		532	Arthropod-borne infectious diseases	●	▲	▲	●	●	▲
		533	Other infectious diseases	—	—	—	◆	■	■
	Others	541	Complex impacts of warming and air pollution	—	▲	▲	◆	▲	▲
		542	Impacts on vulnerable populations (elderly, children, persons with underlying health conditions, etc.)	—	●	■	●	●	▲
		543	Other health impacts				◆	▲	▲
Industrial /Economic Activities (37→ 104)	Manufacture	611	—	◆	■	■	◆	■	■
	Food manufacturing industry						●	▲	▲
	Energy	621	Energy supply and demand	◆	■	▲	◆	■	▲
	Commerce	631	—	—	—	■	◆	■	■
	Retail industry			—	—	■	◆	▲	▲
	Finance, insurance	641	—	●	▲	▲	●	▲	▲
	Tourism	651	Leisure	●	▲	●	◆	▲	●
	Leisure industry based on natural resources						●	▲	●
	Construction	661	—	—	—	—	●	●	■
	Medical	671	—	—	—	—	◆	▲	■
	Others	681	Overseas impacts	—	—	■	◆	■	▲
		682	Others				—	—	—
Life of Citizenry, Urban Life (36→99)	Urban infrastructure, critical services, etc.	711	Water supply, transportation, and others	●	●	■	●	●	●
	Life with sense of culture and history	721	Phenology, traditional events	◆	●	●	◆	●	●
			Local industry, etc.	—	●	■	—	●	▲
	Others	731	Impacts on life due to heat stress, etc.	●	●	●	●	●	●

3.3 Overview of Impacts of Climate Change in Each Sector

(1) Agriculture, Forest/Forestry, Fisheries

Overviews of climate change impacts in the agriculture, forest/forestry, and fisheries sectors are provided in Figure 3-3 and Figure 3-4. Climate change has impacts on the supply of many items, such as food and timber, as well as the incomes and production methods of people in the agriculture, forest/forestry and fisheries sectors, by affecting crop growth and suitable growing areas, expanding the scale of outbreaks and distribution of pests and weeds, and having impacts on livestock growth and breeding, the growth of planted forests, and marine resource distribution and survival. Impacts such as results from the direct impacts of climate change such as increased air and water temperatures and CO_2 concentrations, and indirect impacts such as changes in water resource volumes and natural ecosystems. There are also enormous impacts on economic activities due to the ripple effects of climate change on commerce, distribution, and international trade in the agricultural, forest/forestry and fisheries sectors.

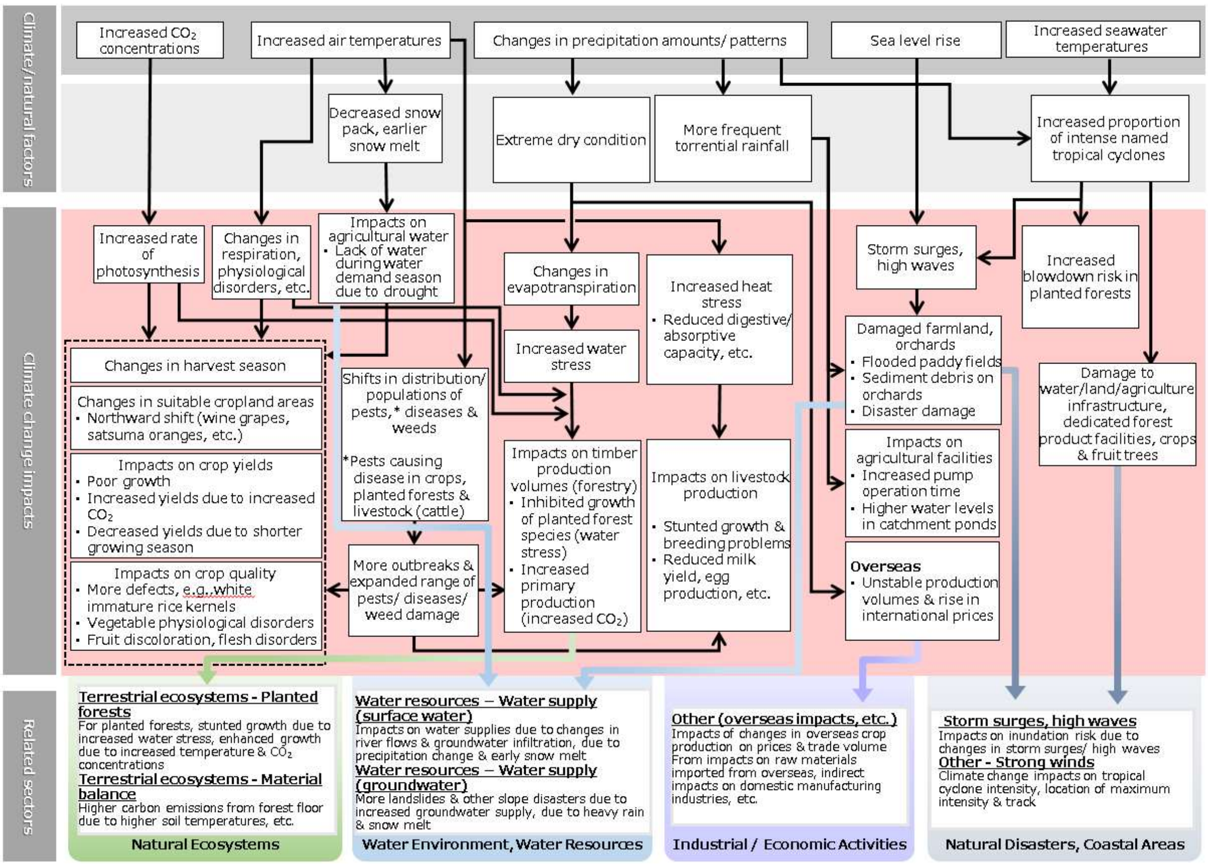

Figure 3-3. Schematic of projected impacts of climate change (agriculture, forest/forestry, fisheries: agriculture and forest/forestry) [20]

[20] This figure is a schematic of anticipated key impacts in the agriculture, forest/forestry and fisheries sectors in Japan, selected from the scientific findings cited in this report; it shows the linkages with expected climate and natural factors (hazards), as well as impacts in other sectors. Therefore, it should be noted that the figure does not completely cover all impacts in each sector and relationships between categories. "Climate / Natural Factors" (top row in the figure) is divided into two levels: the direct impacts of climate change (dark gray), and the hazards that directly affect the agriculture and forest/forestry sectors (light gray). To avoid making the figure overly complicated, the causal relationships between the boxes for the direct impacts of climate change (dark gray) are not shown.

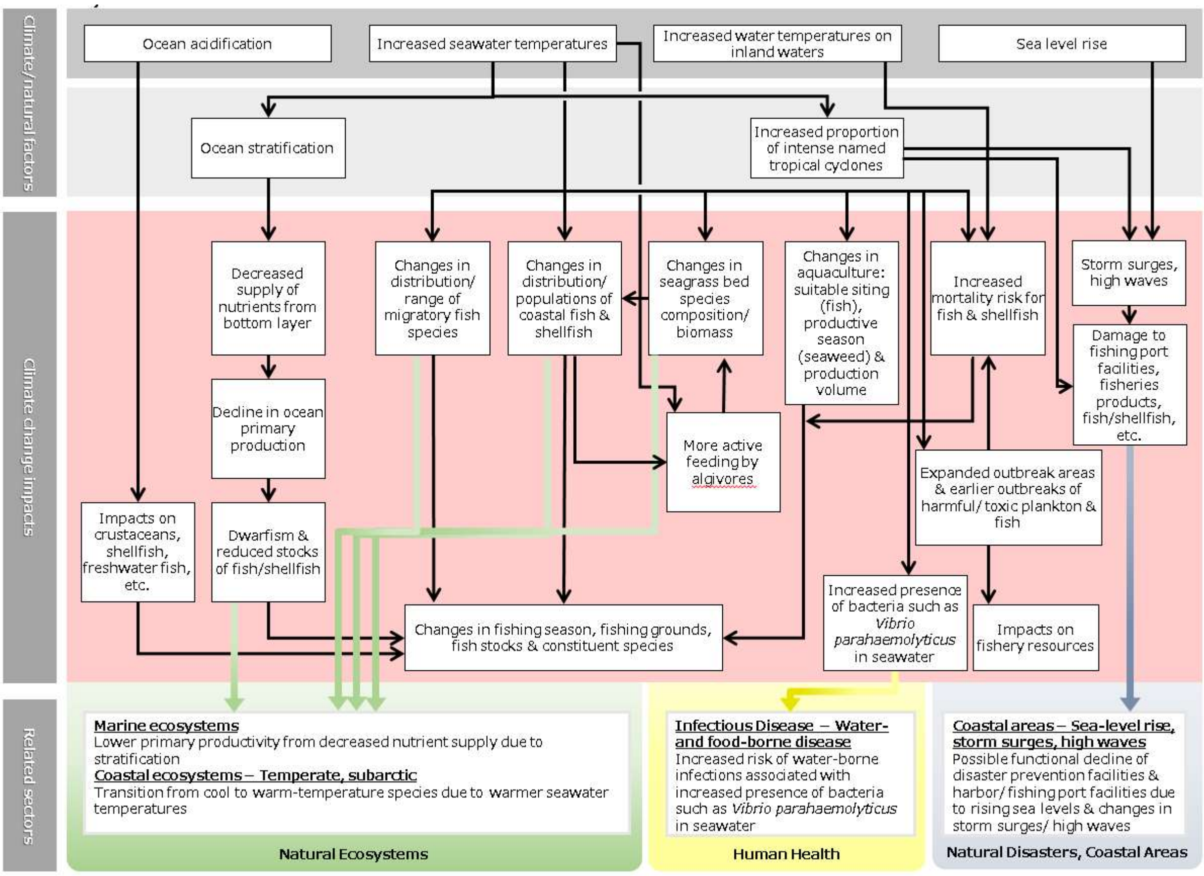

Figure 3-4 Schematic of projected impacts of climate change (agriculture, forestry, fisheries: fisheries)[21]

● Changes in Citation Numbers, Categories, etc.

For the current impact assessment, 339 documents (188 current impacts, 149 future impacts, 2 both current and future impacts) were cited in total (excluding literature citing multiple sectors) for agriculture, forest/forestry, and fisheries sectors overall, of which 243 were newly added since the previous impact assessment. In terms of categories, the number of citations has increased particularly in the “Paddy field rice,” “Plant pests, weeds, etc.”, and “Fisheries” categories.

As a category change from the previous impact assessment, the new sub-category of “Food supply and demand” has been added under the “Agriculture” category, in recognition of the possibility that climate change impacts on grain production overseas will affect Japan. In addition, since many more findings have been accumulated in the “Fisheries” category it has been reorganized into three sub-categories of “Migratory fish stocks (ecology of fishes),” “Propagation and aquaculture,” and “Fishery environments in coastal areas and inland waters, etc.” Furthermore, since it was decided to include flowers with vegetables, and mycotoxins with plant pests and weeds, the names of sub-categories were changed to “Vegetables, etc.” (“Vegetables” in the previous assessment) and “Plant pests and weeds, etc.” (“Plant pests and weeds” in previous assessment).

[21] This figure is a schematic of anticipated key impacts in the fisheries sector in Japan, selected from the scientific findingscited in this report; it shows the linkages with expected climate and natural factors (hazards), as well as impacts in other sectors. Therefore, it should be noted that the figure does not completely cover all impacts in each sector and relationships between items. “Climate / Natural Factors” (top row in the figure) is divided into two levels: the direct impacts of climate change (dark gray), and the hazards that directly affect fisheries sector (light gray). To avoid making the figure overly complicated, the causal relationships between the boxes for the direct impacts of climate change (dark gray) are not shown.

- **Overview of Climate Change Impacts**

Current Status

In agriculture, the quality and yields of many crops have seen declines nationwide in Japan due to changes such as increased temperatures and changes in temporal and spatial distribution of precipitation, with decreases in the ratio of first-class rice produced, poor growth of vegetables, and physiological disorders of fruit trees; the effects of heat stress are also becoming increasingly evident in the livestock sector. Crop damage is occurring due to the expanded distribution and increased outbreaks of pests and diseases. In water, land and agricultural infrastructure, the lack of rain and other factors are leading to shortages in agricultural water and impacts on agricultural water supply facilities. In forest/forestry, disease outbreaks in shiitake mushroom log cultivation are affecting larger areas. In fisheries, there have been changes in the distribution of migratory species such as the Japanese common squid and Pacific saury (*samma in Japanese*), with resultant impacts on processing and distribution industries, as well as fish and shellfish mortality in aquaculture and inland fisheries, and decreased yields in seaweed production. There is also a serious decline in seagrass beds, believed to be due to increased seawater temperatures. Conversely, there have been reports of increased yields of crops such as feed corn in some areas, expansion of areas suitable for fruit tree cultivation (e.g., wine grapes), and increased fish catches (e.g., Japanese amberjack (*buri*), and Japanese Spanish mackerel (*sawara*). In addition, some reports have described impacts on production methods to respond to climate change especially in agriculture, with adaptation measures already being implemented for certain crops, such as growing heat-tolerant cultivars and making modifications to growing seasons.

Projected impacts

A variety of approaches are being used for future projections, including research using greenhouse gas emission and concentration scenarios, research that takes uncertainty into account using multiple climate prediction models, field experiments, and research that reflects cultivation test results in plant growth models, etc. In sub-categories such as “Paddy field rice,” “Fruit trees,” and “Fishery environments in coastal areas and inland waters, etc.” new findings have been reported relating to future projections using RCP2.6 and RCP8.5 scenarios. In agriculture, it has been suggested that yields will decrease for paddy rice, fruit and vegetables, fall wheat, soybean in warm regions, and tea, etc.; it has been predicted that a greater ratio of paddy rice will become more susceptible to high temperature risk; for fruit trees, there are projections for a deterioration of grape coloration and changes in suitable growing areas for fruit such as satsuma mandarin oranges and apples. In addition, decreases are predicted in livestock growth, increases in pest outbreaks and habitat area, and increases in damage resulting from disease. For water, land and agricultural infrastructure, a lack of agricultural water is predicted for some areas due to a decrease in snowmelt runoff during the wet-ploughing (*shirokaki*) season for paddy rice cultivation, and an increased risk of damage to low-lying paddy fields due to heavy rainfall. In forestry, research is underway to estimate the net primary production of Japanese cedar (*sugi*) planted forests; for *shiitake* log cultivation it is predicted that pests will appear earlier in the season and the number of days of occurrence will increase. In fisheries, in the waters around Japan, the distribution is predicted to shift and expand for tuna species, Japanese sardine (also known as pilchard; *maiwashi*), Japanese amberjack, and Pacific saury, while salmon and trout habitat is expected to decrease, and the larger marine areas are expected to see lower distribution densities of Japanese common squid. In aquaculture, some areas that produce fish and shellfish are expected to become unsuitable for production due to increased water temperatures in summer. For seaweed, the habitat for kelp (*kombu*) is expected to move significantly northward, the harvest season for *wakame* seaweed to be shortened, the start of seedling raising for *nori* seaweed growing to be delayed, and the variety of seaweed types in seaweed beds along the coast of Japan to decrease.

- **Summary of Assessments for Significance, Urgency, and Confidence**

In the agriculture, forest/forestry, and fisheries sectors there is a strong tendency for the assessments of significance to be "Recognized as having particularly significant impacts" and assessments of urgency to be "High," because they are very much affected by the weather, and because significant impacts of climate change are already occurring. In addition, since many projection studies using climate scenarios and experiments based on global warming are underway, assessments of confidence have been revised upwards in many categories.

For three categories where significance was assessed based on climate scenarios ("Paddy field rice," "Fruit trees," and "Fishery environments in coastal areas and inland waters, etc."), the assessments under both the RCP2.6 and the RCP8.5 scenario were "Recognized as having particularly significant impacts." Significant impacts are already evident for these categories. In particular, categories such as "Fruit trees" and "Fishery environments in coastal areas and inland waters, etc." have low adaptability to climate change.

In the agriculture, forest/forestry and fisheries sectors, there are limits to the extent to which impacts can be reduced by adaptation measures alone, and this indicates the importance of linking adaptation with mitigation measures.

(2) Water Environment, Water Resources

A summary of climate change impacts in the water environment and water resources sectors is provided in Figure 3-5.

Water Environment Sector

Increased temperatures due to climate change could increase water temperatures and affect the water quality of lakes/marshes, dam reservoirs, rivers, coastal areas, and closed sea areas. There are also concerns that changes in rainfall patterns due to climate change could increase sediment flows into dam reservoirs and rivers, and in coastal areas and closed sea areas there could be an increased influx of contaminants from rivers.

Water Resources Sector

Changes in rainfall patterns due to climate change could also cause increases or other changes in the number of rainless days, reduce snow pack, reduce river flows due to an increase in evapotranspiration, and reduce groundwater levels. Due to increased temperatures, water demand for agricultural and urban uses is expected to increase, as well as individual water usage, and there are concerns that water supplies may not be available when they are needed due to increases in rainfall events in winter, as well as decreases in the snow pack and earlier snow melt. In addition, sea-level rise can increase seawater (saltwater) intrusion into river estuaries and groundwater, resulting in salinization.

These impacts can also affect other sectors, such as water, land and agricultural infrastructure, natural ecosystems, and the life of citizenry, etc.

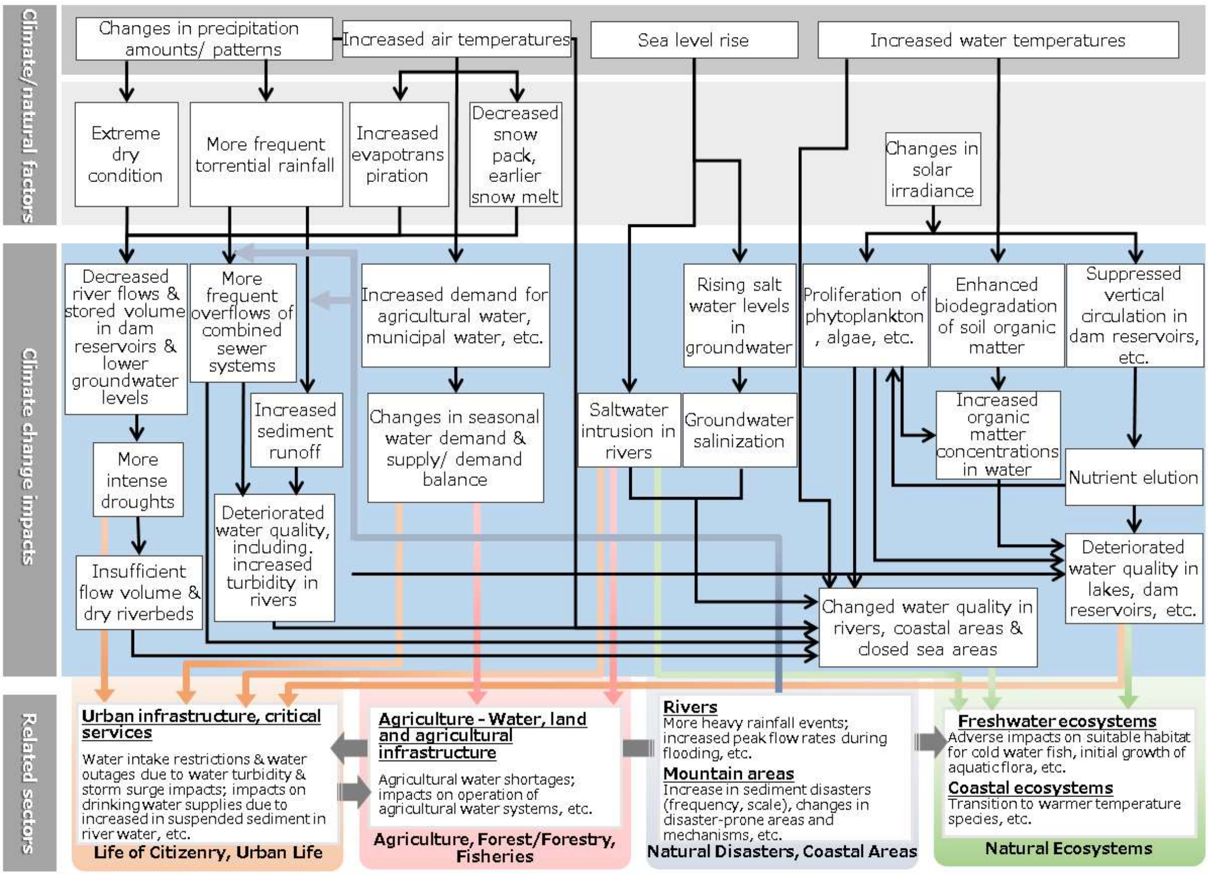

Figure 3-5. Schematic of projected impacts of climate change (water

environment, water resources)[22]

- **Changes in Citation Numbers, Categories, etc.**

For the current impact assessment, 88 documents (39 current impacts, 48 future impacts, 1 both current and future impacts) were cited in total (excluding literature citing multiple sectors) for the water environment and water resources sectors overall, of which 73 were newly added since the previous impact assessment. In terms of sub-categories, the number of documents has increased particularly in the "Water environment (lake, marshes and dams (reservoirs))," "Water environment (rivers)" and "Water resources (water supply (surface water))" and "Water resources (water supply (groundwater))" sub-categories. There have been no changes in categories from the previous impact assessment.

- **Overview of Climate Change Impacts**

Current status

In the water environment sector, newly observed impacts include increases in water temperatures already occurring in public waters (lake, marshes, rivers, seas) all over Japan, including a warming trend in water temperatures at 76% (summer) and 94% (winter) of 265 monitoring sites nationwide, and associated changes in water quality, as well as increases in the temperature of water, as well as increased temperatures of springwater in spring-fed ponds. In the water resources sector, there have been reports of impacts such as water restrictions being imposed due to water shortages associated with the absence or lack of rain, the lack of irrigation water in spring due to an increase in snow melt during winter, and increased agricultural and urban water demand. In terms of newly reported impacts, some examples include saltwater intrusion in coastal aquifers and the contraction of small island freshwater lenses.

Projected impacts

Projected impacts in the water environment sector include more reservoirs being classified as being eutrophic water bodies, increased water temperatures and salinity concentrations in Lake Shinji and Nakaumi (brackish lakes in Shimane and Tottori Prefectures), increased aquifer temperatures on the Sendai plain, increased water temperature in the Seto Inland Sea and Ise Bay, and longer periods of turbid water discharge due to increases in suspended particulates associated with higher inflows into four reservoirs in the Tohoku region.[23] Projected impacts in the water resources sector include more severe droughts due to an increase in rainless days, increased river flows in winter due to a shift from snowfall to rain, decreased river flows in spring due to decreased snow melt, decrease in river flow during demand periods due to early snow melt, impacts on domestic water use by citizens in Sapporo due to future decreases in water resources, a mismatch between supply and demand for agricultural water due to dropping groundwater levels, etc.; saltwater intrusion extending further upstream due to sea level rise, and due to that, impacts of the utilization of river water; a growing tendency for polarization of drought risk and flood risk; and the occurrence of landslides and other slope disasters due to increased groundwater supply as a result of heavy rainfall and snow melt.

- **Summary of Assessments for Significance, Urgency, and Confidence**

[22] This figure is a schematic of anticipated key impacts on the water environment and water resources in Japan, selected from the scientific findings cited in this report; it shows the linkages with expected climate and natural factors (hazards), as well as impacts in other sectors. Therefore, it should be noted that the figure does not completely cover all impacts in each sector and relationships between items. "Climate / Natural Factors" (top row in the figure) is divided into two levels: the direct impacts of climate change (dark gray), and the hazards that directly affect water environment and water resources sectors (light gray). To avoid making the figure overly complicated, the causal relationships between the boxes for the direct impacts of climate change (dark gray) are not shown.

[23] The description here mentions areas where fndings have been obtained on future climate change impacts, and this by no means suggests that areas not mentioned will not have future climate change impacts.

In the water environment and water resources sectors, there is a tendency to assess the significance as "Recognized as having impacts" because the impacts are deemed to be limited in terms of magnitude and scope. However, based on literature compiled this time, the assessment of urgency for "Water environment (rivers)" was revised upward due to considerations such as the fact that impacts have been confirmed to be already occurring. In addition, since some quantitative projections using climate projection models are underway, while limited in number, assessments of confidence have been revised upwards in the two sub-categories of "Water environment (coastal zones and closed sea areas)," and "Water resources (water supply (groundwater))."

(3) Natural Ecosystems

A summary of climate change impacts in the natural ecosystems sector is provided in Figure 3-6.

Climate change affects ecosystem structure and processes through changes in suitable habitat range and phenology, as well as interactions between them. In addition, one feature of climate change impacts on natural ecosystems is that there are also ripple effects from ecosystems to the benefits humans receive from them, that is, through ecosystem services,[24] resulting in impacts on sectors including agriculture, forest/forestry, fisheries, life of citizenry, and industrial/ecomic activities sectors. Human societies rely on the diverse ecosystem services provided by ecosystems, such as food and raw material inputs, mitigation of damage from extreme weather events, improvement of water and air quality, and cultural and aesthetic values, etc. If the ecosystems that provide them cease to function effectively due to the impacts of climate change, etc., the ecosystem services provided may deteriorate or be lost.

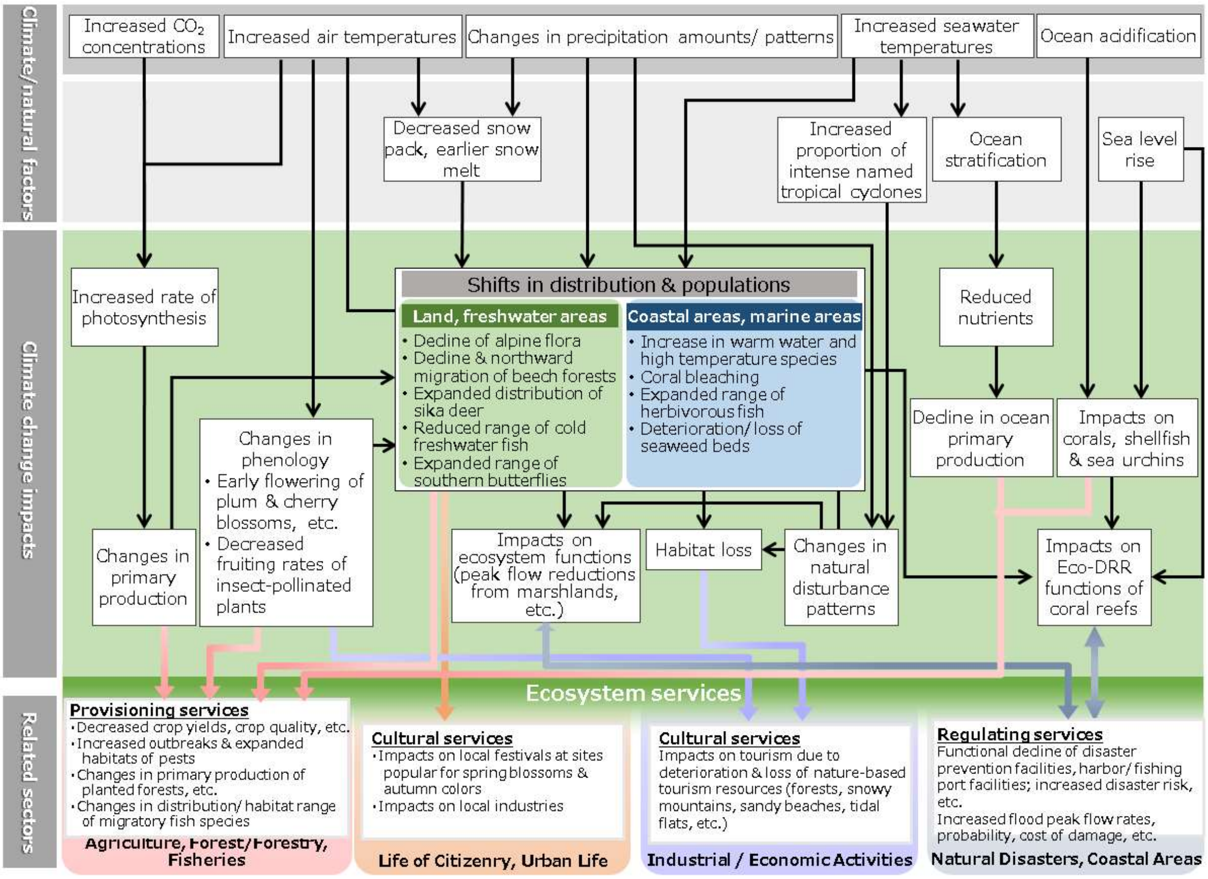

Figure 3-6. Schematic of projected impacts of climate change (natural ecosystems)[25]

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[24]Ecosystem services: Benefits (e.g., food, water, climate stabilization) that humanity obtains from the diversity of biota in ecosystems. The Millennium Ecosystem Assessment (2005) conducted under the auspices of the United Nations provides four categories: “provisioning services” (e.g., the provision of food and water, timber, fiber, and medicinal resources), “regulating services” (e.g., water purification, climate regulation, natural disaster prevention and damage mitigation, disease/pest suppression by the existence of natural predators), “cultural services” (e.g., the provision of spiritual and religious values, aesthetic values such as natural landscapes, and recreational places, etc.), and “supporting services” (e.g., nutrient cycling, soil formation, the supply of oxygen through photosynthesis).

[25] This figure is a schematic of projected key impacts on natural ecosystems in Japan, selected from the scientificfindings cited in this report; it shows the relationships with expected climate and natural factors (hazards), as well as impacts on other sectors. Therefore, it should be noted that the figure does not completely cover all impacts in each sector and relationships between items. “Climate / Natural Factors” (top row) in the figure is divided into two levels: the direct impacts of climate change (dark gray), and the hazards that directly affect natural ecosystems (light gray). To avoid making the figure overly complicated, the causal relationships between the boxes for the direct impacts of climate change (dark gray) are not shown.

Changes in Citation Numbers, Categories, etc.

For the current impact assessment, 252 documents (135 current impacts, 116 future impacts, 1 both current and future impacts) were cited in total (excluding literature citing multiple sectors) for natural ecosystems overall, of which 161 were newly added since the previous impact assessment. In terms of sub-categories, the number of documents has increased particularly relating to “Alpine/subalpine zones (terrestrial ecosystems)”, “Natural forests, secondary forests (terrestrial ecosystems)”, and “Subtropics (coastal ecosystems)”, “Temperate, subarctic (coastal ecosystems)”.

In terms of category changes from the previous impact assessment, “Ecosystem Services” have been added as a category, and “Phenology” and “Shifts in distribution and populations” have been newly created as sub-categories under the category of “Others,” and it was decided to use these new sub-categories to cover impacts on species that use multiple ecosystems and are distributed over a wide area, where it is not appropriate to cover them in the other sub-categories.

Overview of Climate Change Impacts

Current Status

Impacts already occurring that have been reported around the country include long-term changes in species composition in forests near alpine and vegetation transition zones, seasonal mismatches between plant flowering seasons and pollinators, nationwide increases in *sika* deer habitat, and northward movement of the distribution of southern species in river and coastal ecosystems. Newly appearing impacts include expansion near the northern limit of distribution of *moso* bamboo and Japanese timber bamboo over the past 30 years, decline of seagrass bed ecosystems and transition to coral reef communities in coastal areas, and further ocean acidification and oxygen depletion nationwide.

Projected Impacts

Projected impacts include the nationwide reduction or local disappearance of suitable habitat for species such as alpine ptarmigan and cold-water fish such as char, shifts in the distribution and growth of forest constituent tree species, expanded distribution of *sika* deer and bamboo species to higher latitudes and elevations, reduction or disappearance of suitable areas for the distribution of coral reefs in subtropical zones, transition from seagrass bed ecosystems to coral reefs in temperate zones, and decreases in suitable habitat for species of coral, sea urchin and shellfish due to further ocean acidification. In sub-categories such as “Natural forests, secondary forests”, and “Subtropics (coastal ecosystems)” new findings have been reported relating to future projections using RCP2.6 and RCP8.5 scenarios.

Other changes being predicted include negative socioeconomic ripple effects due to impacts on ecosystem services, such as the reduced supply of fisheries resources due to reductions in the nutrient and turbid material retention functions in watersheds and the deterioration and disappearance of seagrass bed ecosystems in coastal areas, reductions in ecosystem-based disaster risk reduction (Eco-DRR) functions due to the deterioration and disappearance of coral reefs, and reduced recreational functions associated with natural ecosystems.

Summary of Assessments for Significance, Urgency, and Confidence

For natural ecosystems, although impacts may be discovered early in many cases, there may be limits to what can be done in terms of adaptation, so in some cases the only response may be to try to limit climate change itself (i.e., mitigation). In such cases, it is difficult to assess the urgency from the perspective of “urgency with which adaptation decisions need to be taken,” so assessment is only done from the perspective of “timing of impacts.”

For natural ecosystems there is a strong tendency for the significance of impacts to be assessed as "Recognized as having particularly significant impacts," because changes in natural ecosystems can have significant impacts on important species and habitats, and through ecosystem services these changes can have ripple effects on the culture and economy of local communities.

However, natural ecosystems have also been exposed to threats from factors other than climate change, such as development activities and the lack of proper management due to population decline (i.e., labor shortage), and there are complex interactions between living things and changes in weather conditions, making it more difficult to detect the direct impacts of climate change; as a result, there was a tendency here to assess the level of confidence lower than in other sectors. Among them, the confidence levels have been revised upward for the two sub-categories "Damage from wildlife" and "Subtropics (coastal ecosystems)" based on the literature compiled for this assessment. Also, because impacts are already confirmed to have occurred, the assessments of urgency have been revised upward for the three sub-categories of "Natural forests, secondary forests," "Countryside-landscape (satochi-satoyama)," and "Planted forests."

Regarding "Ecosystem services" newly assessed for the current impact assessment, only a limited amount of literature addresses direct impacts of climate change. However, some literature has been compiled regarding impacts on ecosystem components that underpin ecosystem services, such as the deterioration of coral reefs and seagrass bed ecosystems and changes in the phenology of sakura cherry, maple, and other trees. Thus, services that are closely related to these ecosystems are assessed individually as sub-categories. The result is that for four sub-categories ("Nutrient and turbid material retention functions in watersheds," "Supply of fisheries resources by coastal seagrass ecosystems," "Eco-DRR functions of coral reefs," and "Recreational functions related to natural ecosystems") the significance of impacts was assessed as "Recognized as having particularly significant impacts."

According to assessments for various climate scenarios on the significance of impacts on "Natural forests, secondary forests" and "Subtropical (coastal ecosystems)," keeping the temperature increase to about 2°C will help to reduce impacts on "Natural forests, secondary forests," but coral reefs covered under "Subtropical (coastal ecosystems)" will experience significant impacts if temperatures increase by the equivalent of 2°C. Therefore, particularly in "Subtropical (coastal ecosystems)," there are limits to degree to which impacts can be reduced by adaptation measures alone, and this indicates the importance of linking adaptation with mitigation measures.

(4) Natural Disasters, Coastal Areas

A summary of climate change impacts in the natural disasters, coastal areas sector is provided in Figure 3-7.

Climate and natural factors such as sea level rise, increased frequency and intensity of extreme weather events, and increases in intense named tropical cyclones due to climate change, can affect each other in complex ways to cause river flooding and inundation, increase the frequency of sediment disasters, and cause increased frequency and intensity of storm surges and high waves. Also, changes in wave characteristics will drive beach accumulation and erosion. These impacts can also have ripple effects in other areas, including various industries and economic activities, and the life of citizenry, etc.

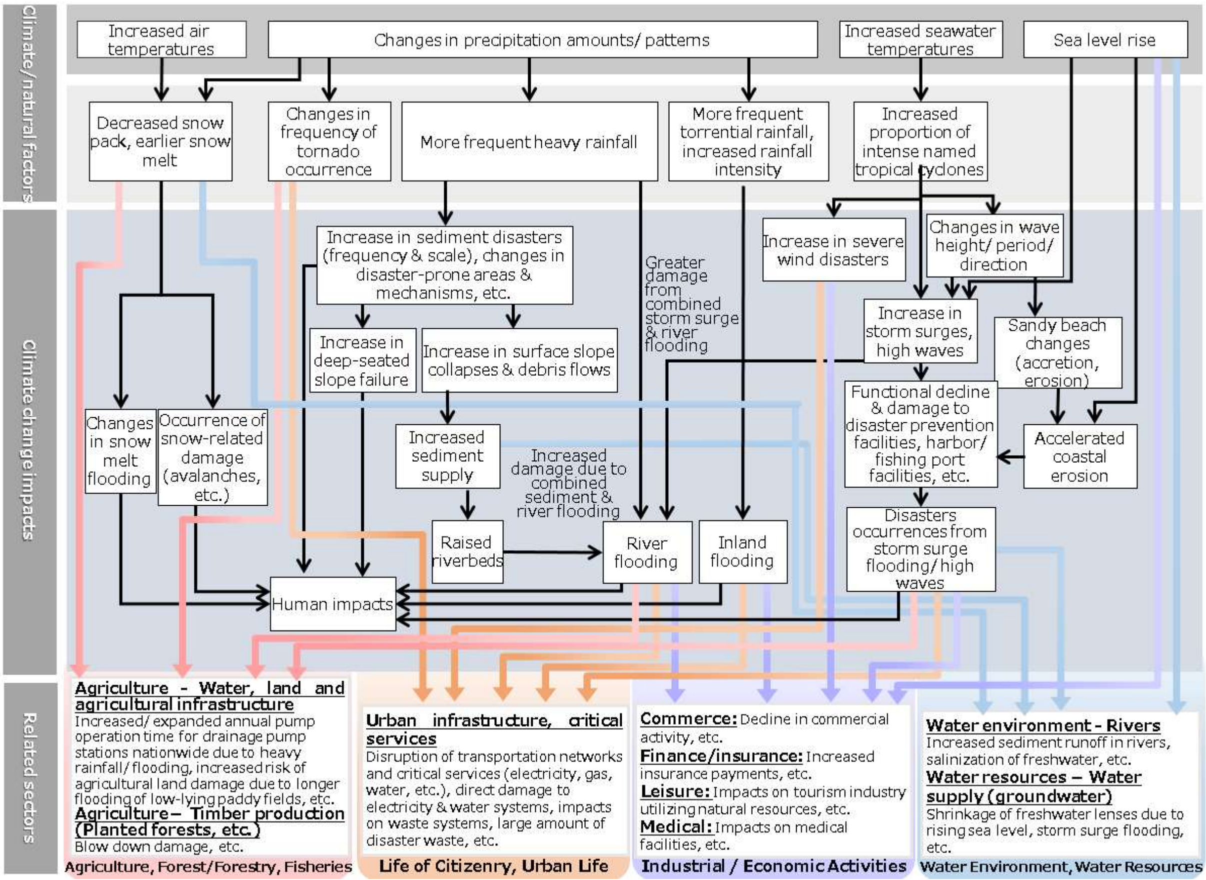

Figure 3-7. Schematic of projected impacts of climate change (natural disasters, coastal areas)[26]

- **Hazards Affecting Natural Disasters**

In terms of heavy rainfall events, examples include the Heavy Rain Event of July 2017 in Northern Kyushu when heavy rains continued falling in the same area due to a band-shaped precipitation system, and the Heavy Rain Event of July 2018 that brought continuous heavy rains to a wide area. In addition, damage was reported as a result of Typhoon Hagibis (T1919), which produced record heavy rainfall over a wide region from eastern

[26] This figure is a schematic of anticipated key impacts on natural disasters and coastal areas in Japan, selected from the scientific findings cited in this report; it shows the linkages with expected climate and natural factors (hazards), as well as impacts in other sectors. Therefore, it should be noted that the figure does not completely cover all impacts in each sector and relationships between items. "Climate / Natural Factors" (top row) in the figure is divided into two levels: the direct impacts of climate change (dark gray), and the hazards that directly affect natural disasters and coastal areas (light gray). To avoid making the figure overly complicated, the causal relationships between the boxes for the direct impacts of climate change (dark gray) are not shown.

Japan to the Tohoku region and set new records since observations began for rainfall over 3, 6, 12, and 24 hours at many locations in Shizuoka and Niigata Prefectures, and Kanto-Koshin, and Tohoku regions. Regarding tropical cyclone-related storm surge disasters and wind-related damage, disasters reported include Typhoon Jebi (T1821), which set new records for highest-recorded tide levels in Osaka Bay that surpassed even Typhoon Nancy (T6118), as well as Typhoon Faxai (T1915) which mainly struck Chiba Prefecture with a record storm that at many locations produced the highest-recorded maximum wind speeds and instantaneous wind speeds at many locations.

An event attribution methodology used to study the impact of global warming on the Heavy Rain Event of July 2018 showed that recent years' warming may have increased the amount of precipitation by about 6.5% during the Heavy Rain Event of July 2018

A study to project the future frequency of heavy rainfall events occurring during the Baiu rainy season showed heavy rainfall increasing in early July, and a study to project where it would occur showed heavy rainfall occurring not only in western Japan in the future but also in northern Japan. Although there is no significant increase in heavy rainfall during the Baiu season on the Pacific side of eastern Japan, there are many patterns in the current climate in which low-pressure disturbances such as named tropical cyclones contribute to heavy rainfall there, but projections showed a future with changes in causative factors of heavy rainfall during the Baiu season, such as heavy rainfall occurring only in the marginal flows of Pacific high-pressure systems. In addition, although atmospheric conditions similar to the Heavy Rain Event of July 2018 will not necessarily increase in the future climate, if heavy rainfall is falling from a similar stationary air mass in the future, projections show that the total amount of rainfall may increase as a result of a greater amount of atmospheric water vapor.

As for named tropical cyclones, there are projections that intense tropical cyclones will increase due to climate change toward the latter half of the 21st century.

- **Changes in Citation Numbers, Categories, etc.**

For the current impact assessment, 136 documents (53 current impacts, 78 future impacts, 5 for both current and future impacts) were cited in total (excluding literature that cites multiple sectors) for the natural disasters and coastal areas sector overall, of which 95 were newly added since the previous impact assessment. In terms of sub-categories, the number of documents has increased particularly for "Coastal areas (storm surges, high waves)" and "Others (strong winds, etc.)" categories.

In terms of structural changes from the previous impact assessment, "Impacts of complex disasters" was added as a new category. Based on the actual situations of recent torrential rainfall events and other disasters, this category is used to summarize the impacts of more widespread and significant damage compared to what occurs in single events; it covers events when multiple factors interact, such as sediment disasters combined with river flooding, storm surges combined with river flooding, etc.

- **Overview of Climate Change Impacts**

Current Status

There are reports on the occurrence of the following: vertical ground movement, a rising sea level trend that has been analyzed with corrections for air pressure and tides; extreme storm surge due to tropical cyclones; multiple deep-seated slope failures and simultaneous multiple surface slope failures; large-scale complex disasters, such as combined sediment and river flooding, as well as serious sediment disasters and catastrophic landslides on relatively gentle slopes in the Tohoku and Hokkaido regions where in the past there were few sediment disasters, due to changes in the locations where heavy rains fall; changes in tropical cyclone intensity and tracks; increases in insurance payments from natural disasters; and reductions in the maximum number of years of fire insurance contracts due to the findings of climate change research. In addition, the use of event attribution and other methodologies is further clarifying the contribution of climate change to disasters, such as river flooding and inundation.

Projected Impacts

Projected impacts include increased heavy rain events that can cause floods, increased flood peak flow and probability of floods occurring, and increased cost of damage; increased population likely to be affected by inundation due to inland flooding; increased expected costs of damage from surface water flood disasters; a rising sea level trend and associated impacts on water intake facilities on rivers and coastal disaster prevention facilities as well as port and fishing port facilities, etc.; increased storm surge anomalies due to changes in scales and tracks of named tropical cyclones, and increased risk of high waves; disappearance of sandy beaches due to sea-level rise; increased frequency of combined sediment and river flooding and increased damage from woody debris due to severe rainfall conditions; and increased strong winds and intense tropical cyclones and increased frequency of strong tornadoes. There are also concerns about the impacts of increased frequency of combined sediment and river flooding and increased damage from woody debris under severe rainfall conditions; as well as the impacts of increased frequency of strong tornadoes.

● Summary of Assessments for Significance, Urgency, and Confidence

In the Natural Disasters, Coastal Areas sectors, there is a strong tendency for the assessment of significance to be "Recognized as having particularly significant impacts," as the scope of impacts is nationwide, impacts have a high likelihood of appearing, and the scale and frequency of social, economic and environmental impacts is increasing.

Until now it has been difficult to determine whether or not climate change intensified the damages caused by disasters, but with recent advances in event attribution methodologies it is now possible to assess whether or not global warming contributed to specific extreme events. The confidence levels have been revised upward for the three sub-categories "Rivers (floods)," "Coastal areas (Coastal erosion)," and "Mountain areas (Debris flows, landslides, and other disasters)," based on literature compiled for this assessment. Also, the assessment of urgency has been revised upward for the sub-category of "Others (strong winds, etc.)," because impacts have already been confirmed to be occurring.

According to assessments for various climate scenarios on the significance of impacts on "Rivers (floods)" and "Coastal areas (coastal erosion)" major impacts are projected even with global warming of 2°C.

【Impacts of complex disasters】[27]

In the Natural Disasters, Coastal Areas sector, impacts have been organized into three categories ("Rivers," "Coastal areas," "Mountain areas"), but the Heavy Rain Event of July 2017 in Northern Kyushu and the Heavy Rain Event of July 2018 caused serious impacts and damage from both sediment disasters and river flooding, in both the "River" and "Mountain areas" categories.

A complex disaster is generally a disaster in which a given hazard is intensified by additional factors or where a given disaster countermeasure ceases to function properly due to additional factors. Those other factors could be an earthquake, infectious disease, or volcanic activity, etc. With a particular emphasis on the cause-and-effect relationship with climate change, this report defines the impacts of complex disasters as "**impacts that result in more widespread and extensive damage compared to an isolated disaster due to the mutual interactions of multiple factors, such as a sediment disaster combined with river flooding or a storm surge combined with river flooding, etc.**" Disaster hazards such as heavy rainfall events with high total rainfall and intense tropical cyclones are expected to increase in frequency due to climate change. Example of the impacts of complex disasters are shown below.

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[27] To see the basis for the description of this item, refer to the document numbers and list of references in the text starting on p. 214 of the Climate Change Impact Assessment Report (Detailed Report) (in Japanese).

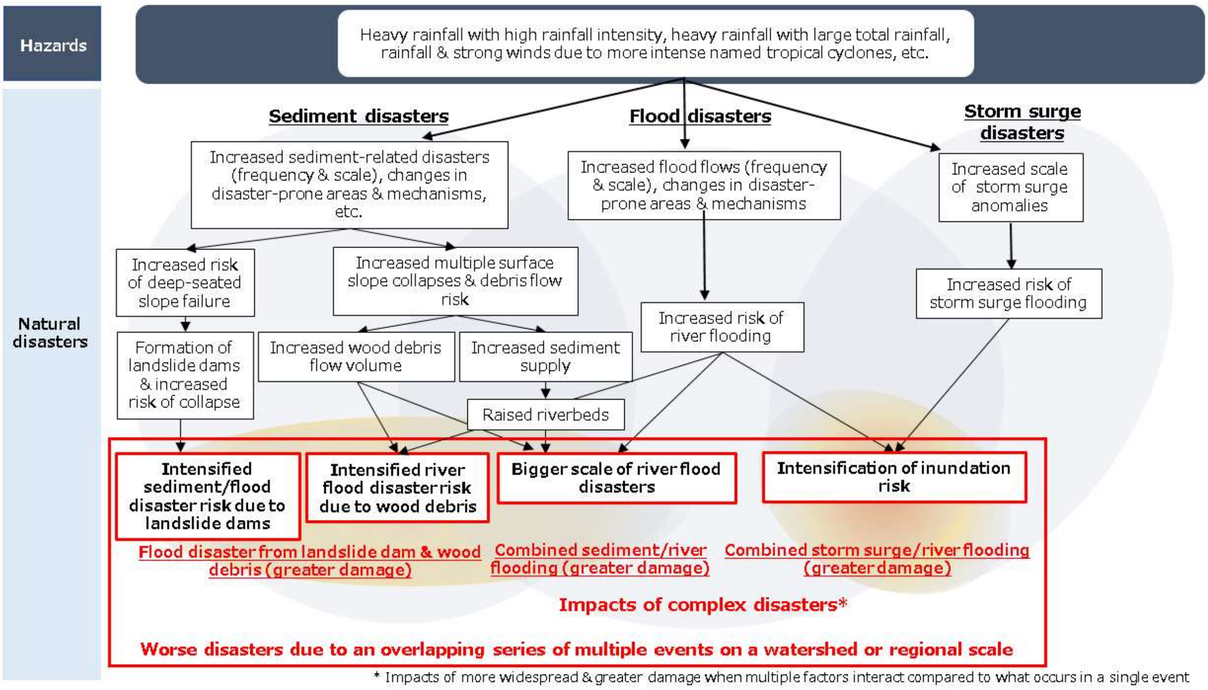

Figure 3-8. Examples of impacts of complex disasters

Section 3.4 covers "Inter-sectoral impact linkages," which refers to situations where impacts are exacerbated due to a series of impacts in other categories or sectors, or a chain of given impacts triggering other impacts in other categories or sectors and events, such as the impacts of infrastructure damage and critical service disruptions caused by natural disasters.

Current Status

The Heavy Rain Event of July 2017 in northern Kyushu was the direct cause of disasters such as extensive slope failure and debris flows that washed large sediment flows further downstream, raising riverbeds to the point of filling them with sediment, which was the cause that exacerbated the extent of river flooding. This kind of river flooding disaster caused by slope failures and debris flows is one form of sediment disaster that occurs on a watershed scale. The large volume of wood debris from slope failures combined with more wood debris washed down from trees along streams and river banks increased the extent of damage further downstream.

A special feature of the Heavy Rain Event of July 2018 was that compared to past major events associated with weather fronts and named tropical cyclones, for two to three days (48 to 72 hours) precipitation records were broken in a large region from western Japan to the Tokai region, including areas such as the Seto Inland Sea side of the Chugoku and Shikoku regions (which typical have lower rainfall), and Heavy Rain Emergency Warnings were issued in 11 prefectures, and the event became the first weather-related disaster designated as Specified Extraordinary Disasters. An increase in water vapor in the atmosphere due to global warming has been described as a contributing factor to this torrential rainfall. In addition to a record rainfall duration, river flooding and inland flooding occurred simultaneously in many places due to the widespread occurrence of heavy rainfall, and damage occurred mainly in western Japan. During this torrential rainfall event, continuous rain washed into rivers a large amount of sediment from sediment disasters upstream, and it accumulated further downstream where the river flow velocity was slower, raising riverbeds, causing sediment to overflow downstream, and resulting in combined sediment and river flooding.

In the case of heavy rainfall caused by Typhoon Hagibis (T1919) in 2019, combined sediment and river flooding resulted in inundation on low-lying land along the Uchikawa, Gofukutani, and Shinkawa rivers in Marumori Town, Miyagi Prefecture. This was most noticeable on the Gofukutani River, where it was confirmed that the riverbed had been raised and driftwood had piled up against a bridge.[28] In addition, debris flows occurred on flat valley topography in the Mawarikura area. In the Takumi district of Tomioka City, Gunma Prefecture, slope failures and landslides occurred on relatively gentle slopes of 15 to 25 degrees where there was a weathered pumice layer deposit along the slope (dip slope containing a weak layer), with the upper portion described geologically as a weathered pumice layer of highly permeable pumice and sandy volcanic ash soil, and the lower portion being low-permeability clay.[29]

On the other hand, in terms of impacts related to both “River” and “Coastal” categories, simultaneous river flooding and storm surge flooding could have impacts and cause damage; for example, Typhoon Jebi (T2118) caused such a situation at the mouth of the Yodo River, although no actual reports of such impact damage have been confirmed to date.

More than one trillion yen in insurance claims were paid out after Typhoon Jebi,[30] and the General Insurance Rating Organization of Japan, whose members include insurance companies, has reported that as a result of rising insurance payouts due to natural disasters and based on climate research, the maximum term of fire insurance policies has been reduced from 35 years to 10 years.

Projected Impacts

Research findings mention the future potential and projections for an increase in combined sediment and river flooding (complex disasters consisting of sediment disasters and flooding) and deep-seated landslide.

A rising trend is evident in the frequency of heavy rainfall events with large total rainfall and also high rainfall intensity lasting several hours, and such patterns of heavy rainfall are expected to intensify sediment disasters in the future. There are also concerns about changes in the actual mechanisms and conditions involved in sediment disasters. For example, sediment disasters have occurred in Japan in the past but most often they have been caused by surface-layer slope failure rather than deep-seated landslide. However, if deep-seated landslide occur more frequently in the future as heavy rainfall events occur more frequently, besides the damage from massive slope failures, the resulting river blockages will form landslide dams (natural dams), and if they break, even greater damage will result from sediment and debris flows, while raised riverbeds will also cause enormous flood damage further downstream. In addition, simultaneous surface-layer failures and debris flows over wide areas are expected to occur more frequently. The large volumes of sediment supplied by these collapses can raise riverbeds and cause combined sediment and river flooding, triggering secondary disasters and accelerating the sedimentation of reservoirs further downstream. Moreover, the amount of wood debris could increase with more frequent deep-seated and surface slope failures and debris flows, causing damage directly to housing and structures, with the debris buildup and blockage of bridges and structures becoming an additional cause of river flooding.

Studies assessing the number of potential sediment disastars in the future project that slope failures will increase by 20% and deep-seated landslides by 30% at the end of the 21st century relative to today.

There have also been research findings on the future likelihoods and projections for complex disaster impacts from river flooding and storm surge flooding.

Climate change is expected to increase the frequency of intense tropical cyclones, and greater rainfall amounts will increase the scale of future flood control programs by an estimated factor of 1.1 to 1.15 times, while damage will be further increased if storm surges and flooding occur at the same time.

In addition, for complex disasters with flooding and storm surges occurring in the same year or on the same day, the projected annual costs of complex disasters under future climate conditions rise to about 1.1 to

[28] Combined sediment and river flooding, etc. in Marumori Town, Miyagi Prefecture, October 2019 (https://www.mlit.go.jp/river/sabo/committee_kikohendo/200108/04shiryo2.pdf)

[29] Slope collapse and landslide in Takumi district, Tomioka City, Gunma Prefecture, October 2019.

[30] Insurance payments for wind and water damage, etc. (https://www.sonpo.or.jp/report/statistics/disaster/ctuevu000000530r-att/c_fusuigai.pdf).

1.2 trillion yen in 2050 and about 1.2 to 1.4 trillion yen in 2100. These costs are 1.4 to 1.5 and 1.5 to 1.8 times current levels, respectively, which shows that the costs of damage from complex disasters are expected to increase significantly in the future.

Based on the current situation and above-stated findings relating to future projections, in the natural disasters sector here is a summary of the likelihood of impacts from complex disasters of sediment disasters, river flooding, and storm surge flooding.

Extreme heavy rainfall events (heavy total rainfall, high rainfall intensity lasting several hours, or rainfall due to a band-shaped precipitation system) cause slope failures and debris flows in watersheds, raising riverbed, and leading to combined sediment and river flooding and a greater volume of wood debris. Besides slope failures, deep-seated landslides are also expected, leading to the formation of landslide dams. Events such as these would further exacerbate river flooding downstream. Moreover, if these events occur simultaneously, the impacts and damage will increase further.

Meanwhile, there have been studies to predict the damage from river flooding if it occurs simultaneously with storm surge flooding, but there have been no reports of studies on actual cases to date. However, such impacts and damage cannot be ruled out, so these topics require further attention in the future. Furthermore, in some areas it may be necessary to consider the potential for a sediment disaster, river flood, and storm surge to all occur at the same time, depending on geographical conditions.

(5) Human Health

A summary of climate change impacts in the human health sector is provided in Figure 3-9.

Increased temperatures due to climate change increase heat stress, leading to increased risks of heat illness and heat-related mortality as well as respiratory and a variety of other illnesses. The impacts are especially significant for elderly people, who are highly vulnerable to heat. Increased temperatures can also alter the distribution, population density, and activity of arthropods causing infectious diseases, affecting endemic areas and the number of cases of such diseases. In addition, changes in outdoor air temperatures can change the pattern of outbreaks of water-borne and food-borne infectious diseases, as well as infectious diseases such as influenza. In addition, a natural disaster occurring due to an increase in extreme weather events such as intense heat, intense tropical cyclones, and heavy rain, may increase heat risk and the risk of infectious diseases and mental illness for victims.

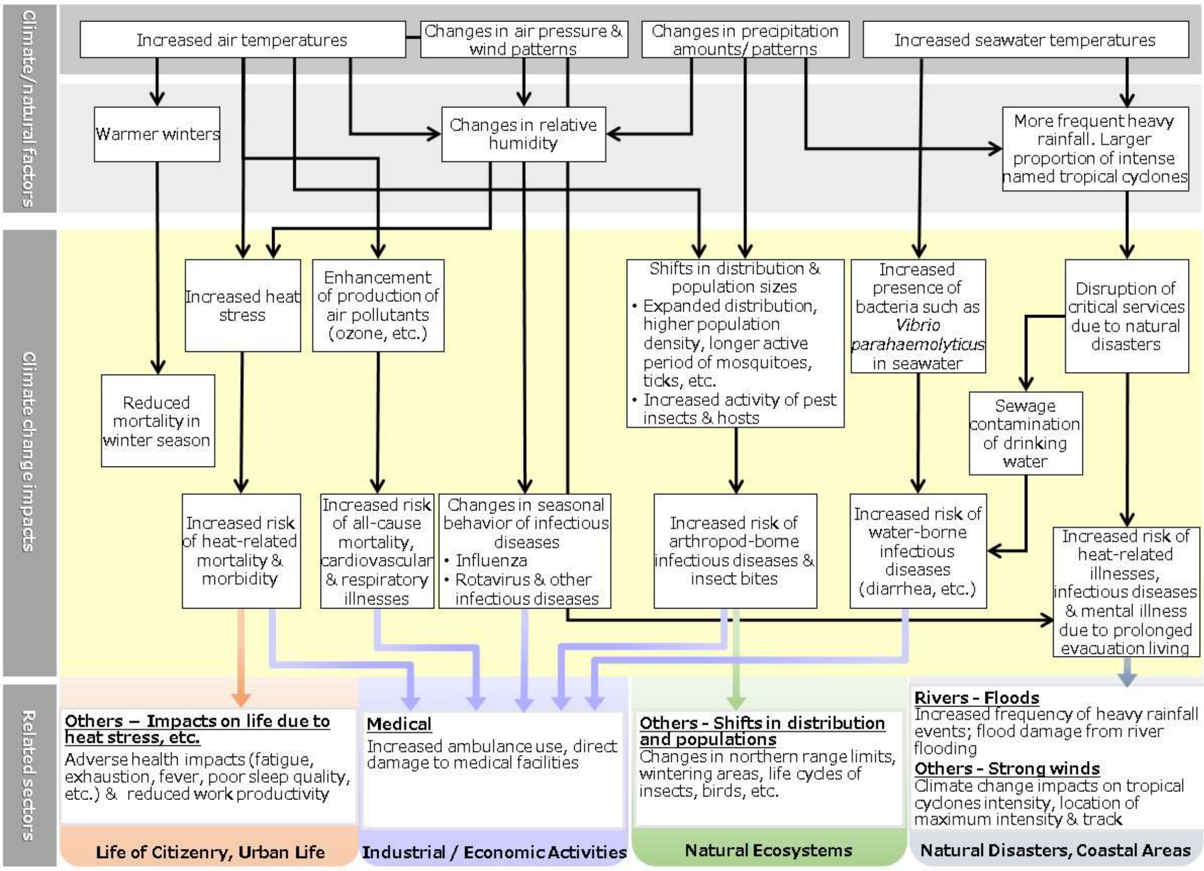

Figure 3-9. Schematic of projected impacts of climate change (human health)[31]

- **Changes in Citation Numbers, Categories, etc.**

For the current impact assessment, 178 documents (135 current impacts, 42 future impacts, 1 for both current and future impacts) were cited in total (excluding literature that cite multiple sectors) for the human health sector overall, of which 170 were newly added since the previous impact assessment. There has been

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[31] This figure is a schematic of projected key impacts on human health in Japan, selected from the scientific findings cited in this report; it shows the relationships with projected climate and natural factors (hazards), as well as impacts on other sectors. Therefore, it should be noted that the figure does not completely cover all impacts in each sector and relationships between items. The "Climate / Natural Factors" (top row) in the figure is divided into two levels: the direct impacts of climate change (dark gray), and the hazards that directly affect the human health sector (light gray). To avoid making the figure overly complicated, the causal relationships between the boxes for the direct impacts of climate change (dark gray) are not shown.

an increase in literature for all sub-categories.

The main category changes from the previous impact assessment are due to the larger findings base in the "Others" category, with three new sub-categories created: "Complex impacts of warming and air pollution," "Impacts on vulnerable populations (elderly, children, persons with underlying health conditions, etc.)," and "Other health impacts."

- **Overview of Climate Change Impacts**

Current Status

It has been reported that excess mortality due to heat stress is on the rise, especially among the elderly. Regarding heat illness, the numbers of patients transported by ambulance, medical consultations, and mortalities related to heat illness are all on the rise, although the numbers vary from year to year. In 2018, the number of heat illness patients transported by ambulance exceeded 95,000, a record high since studies began. There were more than 1,500 deaths due to heat illness that year, more than 80% of them being elderly persons. Although the impacts on the elderly are significant, the risk of heat illness for young people during outdoor activities is also increasing with the rising trend in the numbers of hot and extremely hot days. The effects of extreme heat also have health impacts, such as sleep quality deterioration, fatigue and tiredness, exhaustion, and other signs of physical function deterioration, as well as mental and physical stress.

In addition, there have been new reports that changes in outdoor air temperatures can change the risks and pattern of outbreaks of water-borne and food-borne infectious diseases such as infectious gastrointestinal disease, rotavirus, and diarrhea, and other infectious diseases, such as influenza and hand, foot and mouth disease. As for vector-borne infectious diseases, there are concerns that increases temperatures will change the distribution, population density, and active period of arthropods, and combined with the movement of infected people within the country will cause a chain of infections.

Projected Impacts

Heat stress is expected to increase due to the increase in temperature, and the risk of heat illness is expected to increase, especially for the elderly. With regard to water-borne and food-borne infectious diseases, the morbidity of diarrhea is expected to decrease particularly in winter throughout Japan toward the end of the 21st century as the temperature increases. It has been indicated that the Asian tiger mosquito (*hitosujishimaka*, or *Aedes (Stegomyia) albopictus*) may expand as far as north as southern Hokkaido, where it has not yet reached or become established, and the distribution of alien mosquitoes that transmit the Japanese encephalitis virus may expand north of Kagoshima Prefecture. In addition, tick species that prefer warmer regions have been reported in the Tohoku region, and ticks brought in from overseas may also become established in Japan. In the short term to the 2030s, the number of excess mortalities due to increases in pollutants such as photochemical oxidants and ozone are projected to increase as a result of warmer temperatures, but to decrease thereafter.

- **Summary of Assessments for Significance, Urgency, and Confidence**

Many of the impacts on human health tend to have the potential to extend nationwide, such as heat-illness patients and excess mortalities due to heat, and outbreaks of infectious diseases, etc. For sub-categories with significant impacts on society or where impacts could lead to the loss of human life, the significance was assessed as "Recognized as having particularly significant impacts" and the urgency as "High."

"Water-borne and food-borne infectious diseases" and "Other infectious diseases" were deemed as "Cannot currently be assessed" for the previous impact assessment, but with larger findings base the assessments for significance, urgency, and confidence have been revised upward. However, there have still only been limited studies focused on infectious diseases, so none have yet been assigned the significance level of "Recognized as having particularly significant impacts."

It is important to note that even if the significance is not assessed as "Recognized as having particularly significant impacts" or urgency as "Medium," socioeconomic losses could be significantly larger if there are any delays in tacking action.

* Human health is affected not only by climate change but also by a wide range of other factors, including the massive movement of goods and people due to globalization and major transformations in the natural environment due to land development. When assessing the impacts of climate change, it is crucial to do so based on an understanding that there are many other factors involved.

(6) Industrial / Economic Activities

A summary of climate change impacts in the Industrial / Economic Activities sector is provided in Figure 3-10.

Climate change causes changes in temperature and the intensity and frequency of natural disasters, etc., and can affect overseas supply chains and other corporate activities. However, industrial and economic activities are intrinsically diverse, and the mechanisms of impacts in manufacturing, commerce, health and overseas impacts are not yet well understood. In addition, although research in Europe, the United States and other countries suggests that climate change may have impacts on natural security, related research is still limited in Japan.

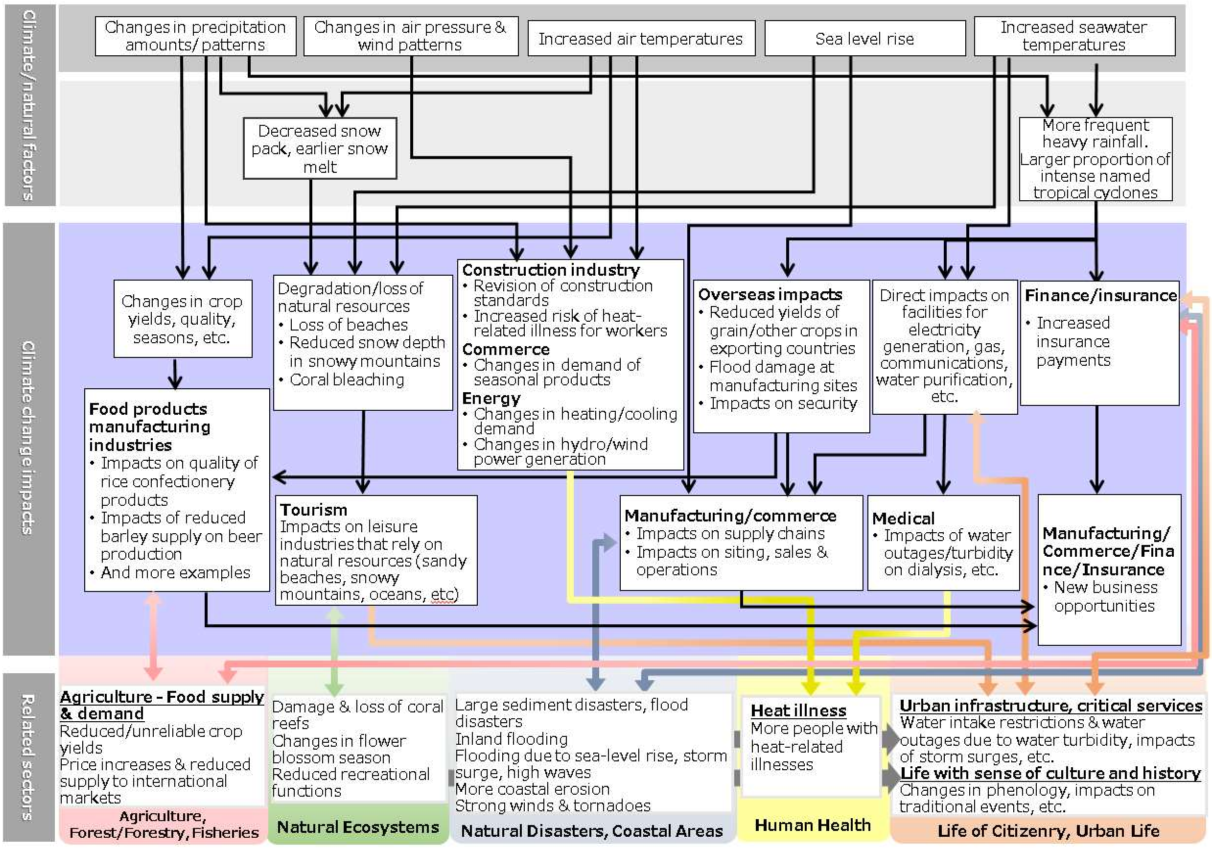

Figure 3-10. Schematic of projected impacts of climate change (industrial/ economic activities)[32]

- **Changes in Citation Numbers, Categories, etc.**

For the current impact assessment, 104 documents (56 current impacts, 48 future impacts) were cited in total (excluding literature that cites multiple sectors) for the industry and economic activities sector overall, of which 76 were newly added since the previous impact assessment. In terms of main categories, there has been an increase in literature on manufacturing, energy, and construction industries, but there is still a limited amount of literature on the current situation and future impact projections for these categories compared to other sectors overall.

In terms of category changes "Other (others)" has been added as a new sub-category, to address impacts

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[32] This figure is a schematic of expected key impacts on industry and economic activities in Japan, selected from the scientific findings cited in this report; it shows the relationships with expected climate and natural factors (hazards), as well as impacts on other sectors. Therefore, it should be noted that the figure does not completely cover all impacts in each sector and relationships between items. The "Climate / Natural Factors" (top row) in the figure is divided into two levels: the direct impacts of climate change (dark gray), and the hazards that directly affect industry and economic activities (light gray). To avoid making the figure overly complicated, the causal relationships between the boxes for the direct impacts of climate change (dark gray) are not shown.

that are not appropriate in other sub-categories.

Overview of Climate Change Impacts

Current Status

New cases of climate change impacts on Japanese companies have come to light, including impacts on the quality of products made from agricultural commodities (e.g., rice crackers and confectionery products), energy supply instability and decline in commercial activities due to impacts of intense tropical cyclones and other natural disasters, increases in insured losses, growth in ESG (environment/social/governance) investments, impacts on skiing and other tourism industries that rely on natural resources, increased heat-related mortality and morbidity rates at construction sites, revisions of standards in the construction industry, impacts on medical/health facilities due to floods and water supply disruptions, and impacts on overseas supply chains. In addition, new reports and literature on climate security have been confirmed.

Projected Impacts

Companies are recognizing climate change risks such as increased physical risks to production capacity due to natural disasters, changes in the supply and demand of seasonal products, and increases in insured losses, and it has also been suggested that companies also need to look at risks as new business opportunities, to develop products to meet new demand. In the tourism industry, changes in snowfall are expected to have either positive or negative impacts depending on which tourism resources they rely on. Overseas impacts of climate change are expected to have impacts such increasing or decreasing Japan's grain imports and affect the prices of related products.

Summary of Assessment of Significance, Urgency, and Confidence

Industrial and economic activities can be found everywhere in Japan and take various forms, and the impacts of climate change vary by region and by industry. There are still not many examples of research in this sector compared to other sectors, so assessments of significance tend to be mostly "Recognized as having impacts." The same can be said for urgency and confidence assessments, which tend to be lower than in other sectors.

However, some impacts are becoming clearer and have had their significance assessed as "High," such as degradation of quality of raw material inputs for food products manufacturing, increased non-life insurance payouts, negative impacts on leisure industries that use natural resources, and increased heat-related mortality and morbidity rates at construction sites. In the construction industry, measures to address heat-related illness were assessed as having high urgency. There were also multiple examples of projections of negative impacts on leisure industries that utilize natural resources, so the confidence levels were assessed as high.

Regarding the "Others" sub-category newly included in this impact assessment, literature mainly indicated climate change impacts on national security. Since there is still a limited amount of literature examining climate impacts on Japan relating to this topic, this report deemed that the significance, urgency, and confidence of impacts cannot be assessed at present, although a significant body of literature in Europe and the United States suggests that the risks may also apply to Japan.

(7) Life of Citizenry, Urban Life

A summary of climate change impacts on the life of citizenry and urban life is provided in Figure 3-11.

An increase in the occurrence of heavy rainfall events, droughts, and intense tropical cyclones, etc., due to climate change can have negative impacts on a variety of infrastructure and critical services such as transportation, electricity, communications, water supply, and waste treatment, all of which are key components of daily life, as well as traditional events, tourism, and local industries, etc. In addition, changes in phenology due to increased temperatures could have impacts on tourism and citizens' appreciation of the seasons, and traditional events at popular locations for viewing cherry blossoms and autumn colors. In urban areas, the combined impacts of increased temperature due to climate change and the heat island effect are increasing heat stress and affecting the comfort of urban life in the form of reduced sleep quality, and increased fatigue and exhaustion.

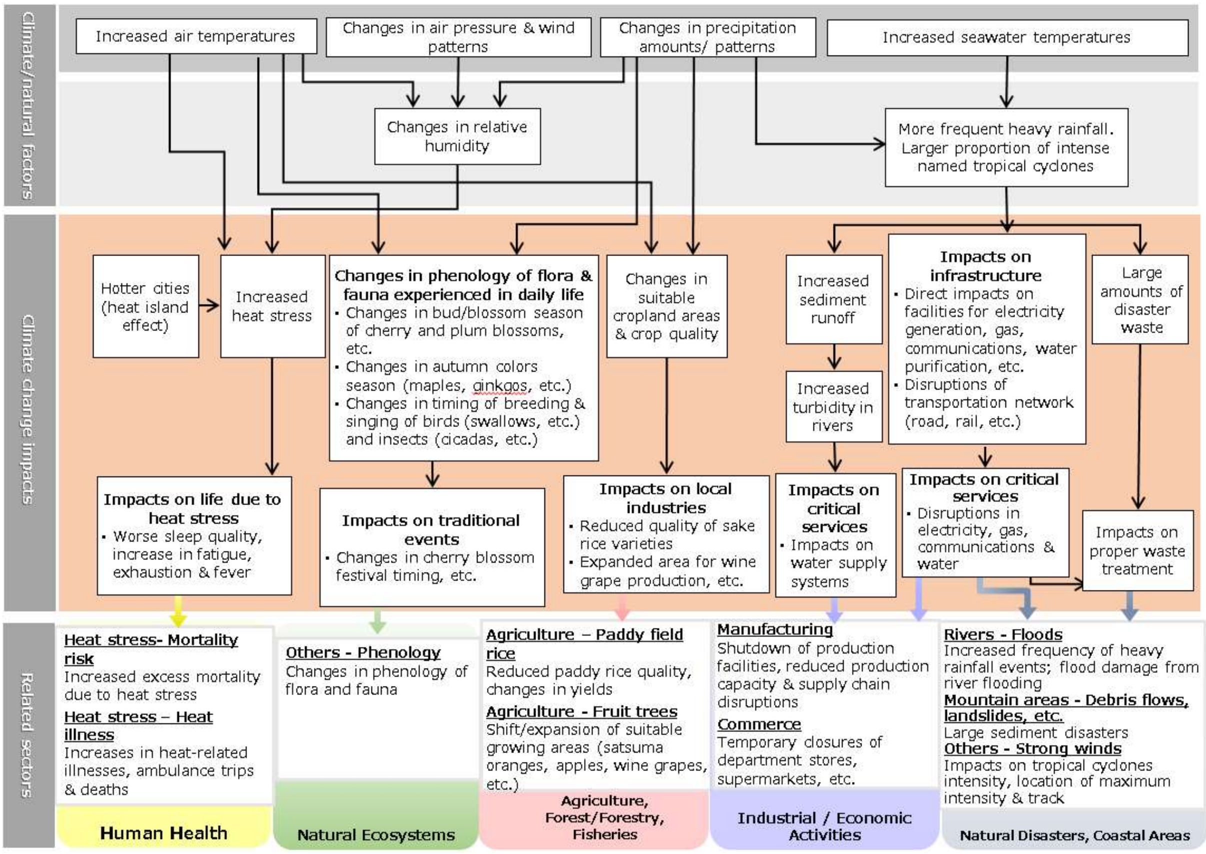

Figure 3-11. Schematic of projected impacts of climate change (life of citizenry, urban life)[33]

- **Changes in Citation Numbers, Categories, etc.**

For the current impact assessment, 99 documents (78 current impacts, 21 future impacts) were cited in total (excluding literature citing multiple sectors) for the life of citizenry and urban life overall, of which 74 documents were newly added since the previous impact assessment.

[33] This figure is a schematic of expected key impacts on the life of citizenry and urban life in Japan, selected from the scientific findings cited in this report; it shows the relationships with expected climate and natural factors (hazards), as well as impacts on other sectors. Therefore, it should be noted that the figure does not completely cover all impacts in each sector and relationships between items. The "Climate / Natural Factors" (top row) in the figure is divided into two levels: the direct impacts of climate change (dark gray), and the hazards that directly affect the life of citizenry and urban life (light gray). To avoid making the figure overly complicated, the causal relationships between the boxes for the direct impacts of climate change (dark gray) are not shown.

There have been no changes in categories from the previous impact assessment.

- **Overview of Climate Change Impacts**

Current Status

In recent years, the impacts of events such as heavy rains, named tropical cyclones, and droughts on infrastructure and critical services have been increasingly evident in many places in Japan. Besides causing direct damage to facilities such as power generation, water purification, and waste treatment, these weather events also are caused major disruptions to the lives of citizens by disrupting critical services such as electricity, gas, and water, and isolating communities due to road collapses.

Changes have been confirmed in the phenology of flora and fauna that have an important place in the lives of the people, such as cherry blossoms, ginkgo trees, cicadas, and wild birds; in terms of local industries, there have been reports of deterioration in the quality of sake rice varieties due to warmer temperatures, as well as expanded production areas for wine-making grape varieties in Hokkaido.

In urban areas, the combined impacts of temperature rise due to climate change and the heat island effect are increasing heat stress and the risks of heat-related illnesses, and also affecting the quality of life by causing fever, nausea, weakness, and deterioration in the quality of sleep.

Projected Impacts

There are concerns that future extreme weather events will have impacts on a variety of infrastructure and critical services such as electricity, water supply, transportation, communications, and waste treatment. In terms of phenology, the start of the cherry blossom season and full bloom are expected to change due to the increase in temperatures, and that will have impacts on areas that rely on this season as a tourism resource.

The combined effects of climate change and the heat island effect are likely to keep temperatures increasing in urban areas, leading to concerns that the deterioration of the thermal environment in cities may have major impacts on urban life.

- **Summary of Assessment of Significance, Urgency, and Confidence**

Regarding “Urban infrastructure, critical services, etc.” even now there are new reports of direct damage to electrical and water infrastructure from extreme weather events such as heavy rains and named tropical cyclones, as well as disruptions of transportation networks, and critical services of electricity, gas, and water supplies; as well, various impacts are expected to occur in the future, and the socioeconomic impacts from damage and injury are enormous, so significance was assessed here as “Recognized as having particularly significant impacts” and urgency as “High.”

Regarding “Phenology,” shifts are already evident in the phenology of cherry blossoms and more, and since shifts are expected nationwide in the future, the urgency was assessed as “High,” but since literature is still limited regarding the impacts of shifts in phenology on tourism and local economies, the significance was assessed as “Recognized as having impacts.” Regarding “Traditional events, local industry, etc.,” urgency was assessed as “High” due to the fact that socioeconomic impacts on some local industries are already evident, but because the degree of impact varies with the specific situation and it is difficult to make one standard assessment nationwide, significance was deemed to be “Cannot currently be assessed.”

Regarding “Impacts on life due to heat stress,” the increase in heat stress has a large impact on urban life due to the increased risk of heat illness and loss of comfort, and economic losses can also be large, so significance was assessed as “Recognized as having particularly significant impacts” and urgency as “High.”

3.4 Inter-sectoral Impact Linkages

The previous sections emphasized the individual impacts identified and/or projected in each category and in each sector.

Meanwhile, it has been pointed out that climate impacts are interlinked and transcend sectors and categories, because natural ecosystems and the activities of human society upon which they are based are built upon a multitude of complex interdependencies and mutual influences. For example, it is known that changes in rainfall patterns and temperature rise due to climate change can alter the distribution, populations, and phenology of living organisms, and are linked through ecosystem services to other sectors such as agriculture, forestry, and fisheries.

Due to the complexity of the factors causing impacts, it may not be clear whether some phenomena are due to climate change, but there are discussions among experts about the importance of paying attention to the linkages among impacts across sectors and categories.

This section therefore **defines "Inter-sectoral impact linkages" as the linkages among impacts due to a given impact triggering other impacts in other categories or sectors and events that exacerbate the impacts due to the inter-linkages among impacts in other categories or sectors**, and summarizes the linkages of impacts from the cross-sectoral perspective (Figure 3-12).

If the linkages are summarized with a focus on their end points, the linkages between impacts can be broadly classified as impacts on human health, impacts on agriculture, forestry and fisheries, impacts on industry and economic activities, impacts on the life of citizenry, and impacts due to infrastructure damage and critical services disruptions.

The impacts on human health can be caused by linkages with impacts from other sectors; for example, increase in the risk of vector-borne infectioud disease (expanded distribution of the Asian tiger mosquito (*Aedes (Stegomyia) albopictus*), etc. due to increased temperatures (Natural ecosystems)), increase in the risk of water-borne infectious disease (water quality deterioration and surface flooding as well as contact with sewage, etc. due to increased temperature (Water environment, water resources)), increase in the number of patients transported by ambulance due to heat illness as a result of extended power outages and extreme heat (Life of citizenry, urban life), etc.

The agriculture, forest/forestry, and fisheries sectors benefit directly from the provision of one or more ecosystem services (natural ecosystems). Therefore, if climate change results in changes such as in the suitable habitat for flora and fauna, phenology and ocean primary production, the primary industries that were benefiting from those ecosystems may be affected. In addition, there have been reports of cases of the very basis of production being damaged due to slope failures or other impacts caused by extreme events.

In the industrial and economic activities sector, the tourism industry benefits from the cultural services of ecosystem services (Natural ecosystems), for example, when utilizing nature as a place for recreation such as skiing, and using the natural landscape itself as a tourism resource. Loss of sandy beaches due to sea-level rise and lack of snow depth due to reduced snowfall in winter can have significant impacts on leisure and tourism industries that rely on nature.

In terms of impacts on the life of citizenry, as in the example of the early flowering of cherry and plum blossoms, increased temperatures result in shifts in phenology (Natural ecosystems), and as a result those impacts are linked to impacts on the timing of traditional events and festivals planned around the viewing of nature. In addition, if torrential rainfall results in the deterioration of river water quality, water supply systems that draw water from the rivers will be affected, with impacts on the life of the citizenry.

The impacts of infrastructure damage and critical services disruptions will directly affect other sectors through disasters such as sediment disasters, floods, storm surges and high waves. In particular, disruptions of electrical power systems will have major impacts on the agriculture, forest/forestry and fisheries sectors, as well as industrial and economic activities. In addition, disruptions in communication systems, water and sewage systems, and waste treatment systems, etc., will affect not only the industry and economic sectors but also the life of the citizenry. In fact, enormous impacts on a wide range of sectors, including natural ecosystems, agriculture, forest/forestry and fisheries, industry and economic activities, human health, and the life of citizenry, were confirmed as a result of the Heavy Rain Event of July 2017 in northern Kyushu, Typhoon Jebi (T1821), heavy rainfall from a weather front in August 2019, and Typhoon Faxai (T1915) and Typhoon Hagibis (T1919).

Since the impacts of infrastructure damage and disruptions of critical services have had such large socioeconomic impacts in recent years, this section summarizes the meteorological conditions and damage caused by recent disasters.

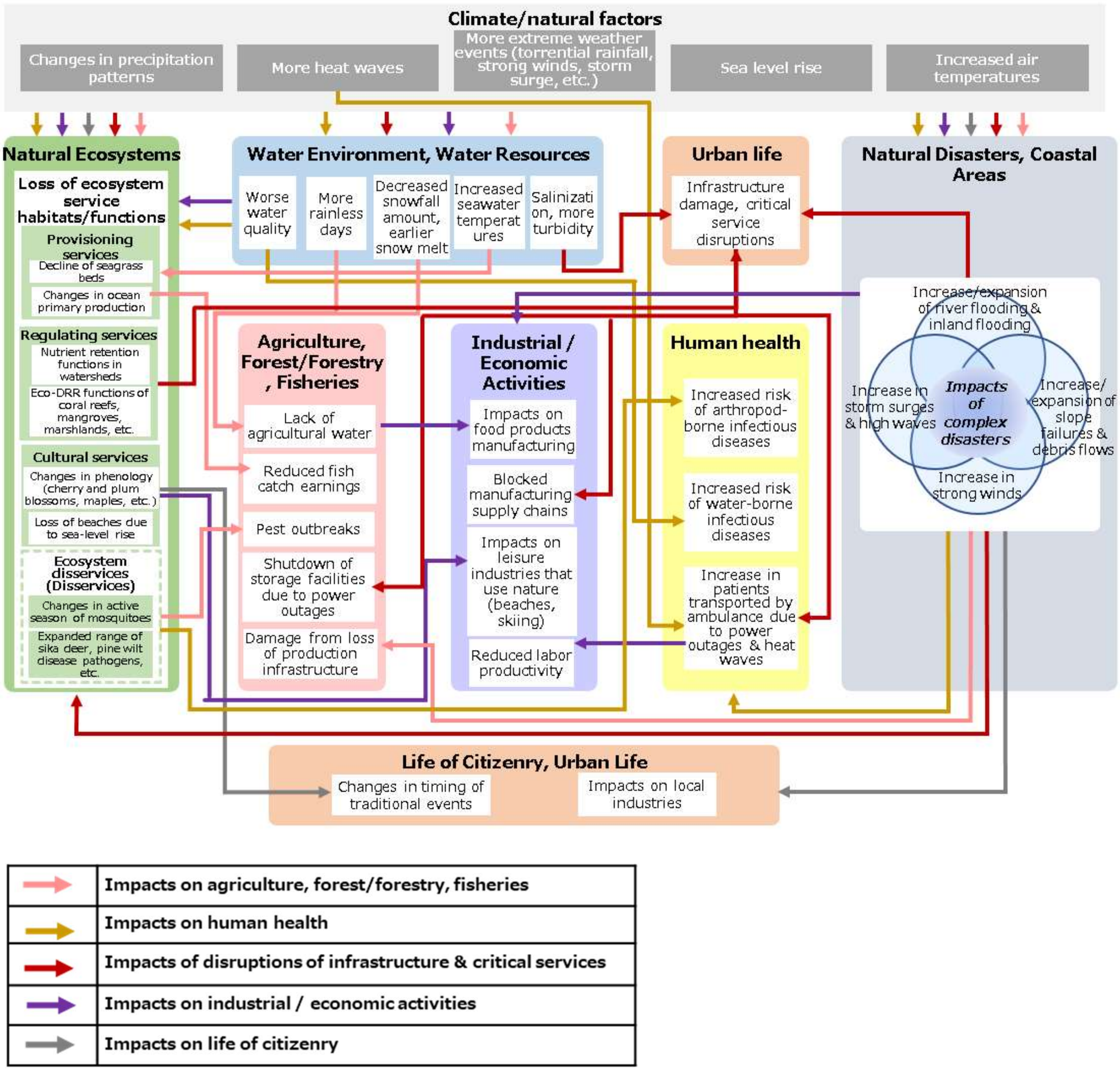

Figure 3-12. Examples of linkages of impacts among sectors[34]

[34]The white boxes in the figure show examples of the impacts summarized in this report. The colored areas around squares indicate the seven sectors covered by this impact assessment.
The arrows in the figure indicate the direction of impacts and are color-coded according to the endpoints of the impacts.
The "Examples of linkages of impacts among sectors" shown in this figure are selected based on the findings cited in this report, so it should be noted that the figure does not completely cover all impacts in every sector and linkages among sectors and categories.
Regarding "Life of Citizenry, Urban Life," the "Infrastructure damage and critical services disruptions" upstream in the chain of impacts includes "Timing of traditional events and ceremonies" and "Impacts on local industries" further downstream; to indicate them in the figure, the former is classified as "Urban Life" and the latter as "Life of Citizenry."
Details of "Impacts of infrastructure damage and critical service disruptions" are shown in Figure 3-13.

【Impacts of infrastructure damage and critical service disruptions】

It has been confirmed that one type of damage or impact can expand the scale of another impact, as in the cases of the Heavy Rain Event of July 2017 in northern Kyushu, when a sediment disaster caused by record heavy rainfall exacerbated flooding further downstream, and the Heavy Rain Event of July 2018 when besides the rain, sediment was washed downstream along the main channel of the river, causing flooding downstream. In addition, in Typhoon Faxai (T1915) and Typhoon Hagibis (T1919), strong winds and heavy rains driven from named tropical cyclones caused direct damage such as the loss of life, flooding of buildings, damage to agriculture, forestry and fisheries industries, and damage to factories and commercial facilities, as well as disruptions to infrastructure and critical services such as electricity, communications, water and sewer systems, transportation, and waste treatment systems; people still have fresh memories of the enormous knock-on effects on people's lives and business activities.

Research has clarified whether or not changes in the hazards driving some of these impacts are due to climate change, while others are still difficult to determine. However, even if it is not currently clear whether these impacts were due to climate change, increases in the frequency of extreme rainfall events and intense tropical cyclones are being predicted with a certain degree of certainty, and if the hazards change as shown hypothetically in projections, one can safely say that similar damage and impacts will increase in the future.

Based on the above, the figure summarizes the impacts of infrastructure and critical services disruptions resulting from extreme rainfall events and named tropical cyclones, based mainly on actual current examples of tropical cyclone damage and complemented by expert input (Figure 3-13).

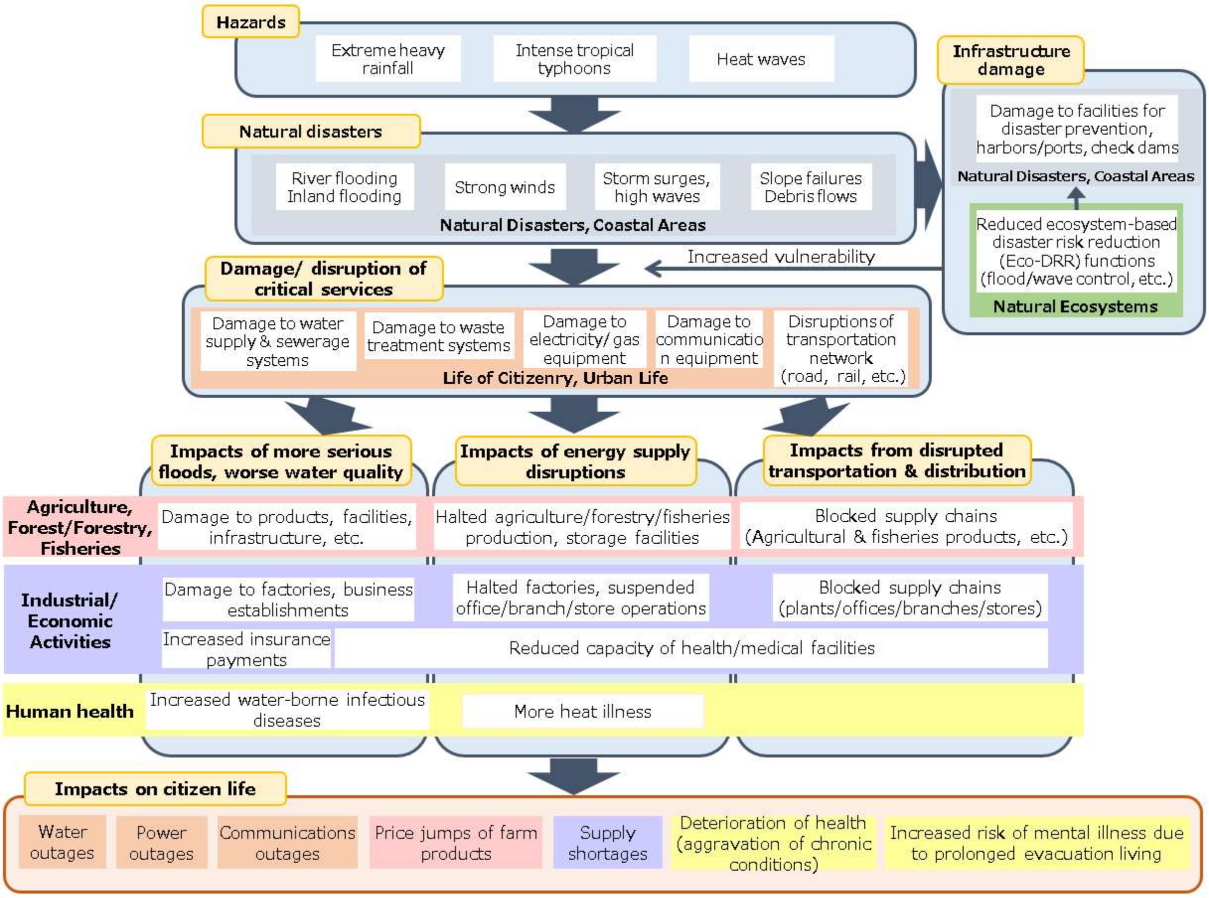

Figure 3-13. Examples of impacts of disruptions of infrastructure and critical services

Current Status

● Heavy Rain Event of July 2017 in northern Kyushu (from investigative report by Ecology and Civil Engineering Society)

This disaster filled some rivers with sediment and debris and the fish that lived there have been wiped out, so it is no exaggeration to say that the ecosystems of such rivers have been reset. ... It will be important to have a process of long-term ecosystem restoration and conduct continued, long-term monitoring. (Excerpt)

● Typhoon Jebi (T1821)

Jebi maintained very strong intensity when it landed in southern Tokushima Prefecture on September 4, 2018, and then landed again near Kobe City, Hyogo Prefecture, and brought a record storm to Shikoku and the Kinki region. Jebi also resulted in record high tides. The tide level rose sharply in the coastal areas of the Kinki region and Shikoku as Jebi approached and landed, and in Osaka, the tide level temporarily exceeded records set during Typhoon Nancy (T6118). Jebi's active rain clouds also reached the Shikoku, Kinki, and Hokuriku regions. The storm caused extensive damage, including fallen trees, roofs blown off buildings, damage to homes including inundation above and below floor boards, trucks overturned, scaffolding and cranes overturned at construction sites, and even gantry cranes overturned at port facilities, and there were also large-scale power outages. Along the coastline of Osaka Bay, the storm caused major damage to public infrastructure and civil engineering structures, with storm surge damage caused by strong winds, and flooding at Kansai Airport, as well as damage to an airport access bridge when a drifting tanker collided with it.[35] The cost of flood damage (cost of direct physical damage to buildings, etc.) from the disaster was approximately 41 billion yen,[36] and insurance payments reached approximately 969.8 billion yen.[37]

● Typhoon Faxai (T1915) (from damage report by Cabinet Office)

(Meteorological Conditions)

Intense wind and rain from Faxi struck mainly the Izu Islands and southern Kanto region. It was a record-breaking storm with the highest maximum wind speed and maximum instantaneous wind speed ever recorded at many observation points; for example, a maximum wind speed of 35.9 m/s and a maximum wind gust speed of 57.5 m/s were measured in Chiba City.

(Damage)

✓ Human losses (1 fatality), building damage (342,391 houses completely destroyed, 4,204 half-destroyed, more than 70,000 partially damaged, etc.)

✓ River-related damage (damaged embankments on 10 rivers managed by the central government, inundation/flooding along 4 rivers managed by prefectural governments)

✓ 77 sediment disasters

✓ Damage to greenhouses, crops, livestock facilities, agricultural facilities, livestock, and trees

✓ Damage to forest land, forest road facilities, and dedicated forest products facilities

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35 Disaster Investigation Report: Strong winds and storm surges caused by Typhoon Jebi in 2018 (Annual Report No. 62 of the Disaster Prevention Research Institute, Kyoto University)

36 Flood Damage Costs in 2018 (confirmed amounts) (Ministry of Land, Infrastructure and Transport and Tourism)

37 Report on number of claims and value of payments of non-life insurance claims (including anticipated claims) related to Typhoon Jebi (T1821) and Typhoon Trami (T1824)

- ✓ Damage to fishing gear warehouses, fishing gear, fishing boats, etc.
- ✓ Total damage related to agriculture, forestry and fisheries amounted to about 81.5 billion yen (as of December 5, 2019).
- ✓ Collapse of cooling tower at the Oarai Research and Development Institute, Japan Atomic Energy Agency
- ✓ Collapse of flaring tower at oil refinery in Kimitsu City (Kimitsu Steel Works of Nippon Steel Corp.)
- ✓ Power outages due to extensive fallen trees and landslides, etc., water outages due to power outages, communication failures due to power outages and damage to base stations
- ✓ Limited access to airports due to shutdown of transportation network, including suspension of train operations and closure of highways
- ✓ Temporary suspension of manufacturing and shipping of pharmaceutical products due to power outages
- ✓ Partial ocean release of dilute hydrochloric acid from an industrial complex
- ✓ Large amounts of disaster waste due to flooding, etc.
- ✓ Mainly at Port of Yokohama, damage to seawalls due to unexpectedly high waves, flooding inland, vessels, colliding with harbor road bridges due to dragging anchor and scattering containers

● Typhoon Hagibis (T1919) (from damage report by Cabinet Office)

(Meteorological Conditions)

Record heavy rainfall fell over a wide area, mainly in Shizuoka and Niigata prefectures, and Kanto-Koshin, and Tohoku regions due to rain clouds of Hagibis and the effects of moist air around Hagibis. Total rainfall after October 10 reached 1,000 mm in Hakone Town, Kanagawa Prefecture, and exceeded 500 mm at 17 observation stations in the Kanto-Koshin region and Shizuoka Prefecture. Due to this record heavy rainfall, heavy rain emergency warnings were issued at 15:30 on October 12 in Shizuoka Prefecture, Kanagawa Prefecture, Tokyo, Saitama Prefecture, Gunma Prefecture, Yamanashi Prefecture, and Nagano Prefecture; at 19:50 on October 12 in Ibaraki Prefecture, Tochigi Prefecture, Niigata Prefecture, Fukushima Prefecture, and Miyagi Prefecture; and at 00:40 on October 13 in Iwate Prefecture.

At the shoreline of Edogawa Ward in Tokyo, a maximum wind gust speed of 43.8 m/s was measured, the highest reading ever recorded there, maximum wind gust speeds exceeding 40 m/s were observed at seven observation stations in the Kanto region, and extremely strong winds were observed over a wide area from eastern to northern Japan. In addition, on October 12, there were gusts believed to have been a tornado in Ichihara City, Chiba Prefecture. The cost of flood damage (cost of direct physical damage to buildings, etc.) from this disaster came to approximately 1.86 trillion yen, the highest since statistics began. [38]

(Damage)

- ✓ Human losses (104 fatalities)
- ✓ River-related damage (levee failure on 14 rivers managed by the central government and 128 rivers managed by prefectural governments), 952 sediment disasters
- ✓ Damage caused by collapse of or damage to disaster prevention ponds and other catchment ponds
- ✓ Damage to agricultural facilities, agricultural land, crops, agricultural/livestock equipment, greenhouses, etc.
- ✓ Damage to forest lands, as well as damage to forest road facilities, wood processing and distribution

[38] Flood Damage Costs in 2019 (provisional figures) (Ministry of Land, Infrastructure and Transport and Tourism)

facilities, erosion control structures, dedicated forest products facilities, etc.

- ✓ Damage to fishing port facilities, multipurpose facilities, marine products, fishing gear, etc., damage caused by flotsam drift from overseas
- ✓ Total damage related to agriculture, forestry and fisheries came to approximately 344.6 billion yen (as of April 10, 2020)
- ✓ Power outages caused by fallen trees and flying debris, etc., due to the storm having damaged power distribution equipment
- ✓ Water outages due to water pipe breakage due to road collapse, water outages due to turbid water inflow at water treatment plants, water outages due to submersion at water treatment plants and pumping stations due to heightened river levels, water outages due to power outages, leaks from bridge-mounted water pipes
- ✓ Stoppage of sewage treatment operations due to flooding of water treatment center
- ✓ Suspension of train operations due to flooding of Hokuriku Shinkansen trains parked at Nagano Shinkansen train yard
- ✓ Physical damage to national treasures and important cultural properties
- ✓ Financial institution branch and post office closures due to flooding, etc.
- ✓ Damage to seawalls and flooding of wharves due to high waves at the Port of Yokohama, sinking of vessels and oil spills from vessels moored near the Port of Kawasaki

Projected Impacts

Strong winds and heavy rainfall from extreme rainfall events and intense tropical cyclones are expected to cause natural disasters such as flooding, storm surges, sediment disastars, and strong wind damage, leading to loss of life and direct damage to buildings, etc. These natural disasters are also significant because they have simultaneous impacts in multiple sectors. For example, these disasters may cause changes to the physical natural environment, such as the water environment and water resources (groundwater, water circulation, etc.), and may cause direct damage to natural ecosystems by affecting the growth of living things and loss of habitat. In agriculture, forestry, and fisheries sectors, there is direct damage to products themselves such as crops, forested land, and marine products, as well as various production facilities, equipment, and infrastructure; in addition, there is also direct damage as a result of flooding, damage and disruptions affecting industrial facilities such as factories and commercial facilities, as well as direct damage to infrastructure and critical services such as electricity, communications, water and sewer systems, transportation, and waste treatment.

The ripple effects are also enormous as a result of impacts and damage to infrastructure and critical services, which are the basis of people's lives and business activities, with power and water outages interfering with people's daily lives and potentially having serious impacts on business activities such as manufacturing, distribution, and sales. Impacts and damage to infrastructure and critical services may also have ripple effects on primary industries such as agriculture, forest/forestry, and fisheries due to power outages, water outages, and distribution disruptions.

Natural disasters can result in not only the loss of human life but also affect the health of the people. For example, the longer people live under evacuation conditions the more one can expect to see a worsening of chronic illnesses and the onset of infectious diseases. The Baiu rainy season and typhoon season in Japan can also coincide with extremely hot weather. In fact, the day after the passage of Typhoon Faxai (T1915), the number of heat illness patients transported by ambulance in Chiba Prefecture, which was affected by a massive power outage, was reportedly much higher than in Tokyo, where temperatures were similar. Thus, a major natural disaster from the Baiu rainy season or a tropical cyclone occurring while temperatures are high may lead to the additional loss of life. Thus, in the future it will be important to consider such scenarios when developing disaster response plans.

The potential for the above chain of events to occur is based not only on research-based findings but also in part on expert judgment and discussion. Going forward, in preparing for the impacts of climate change it will be important to include the potential for these kinds of impacts and risks, and to include them in scenarios. It should be noted that this section focused mainly on damage caused by extreme events and did not include damage resulting from gradual changes (e.g., the increase in annual average temperatures, sea-level rise, etc.).

3.5 Challenges and Prospects for Climate Change Impact Assessment Methodologies

(1) Climate Change Impact Assessment Methodologies of Significance, etc.

This report, following the methodology used in the previous assessment (2015), assesses the significance of each assessment category with either of two levels; “Recognized as having particularly significant impacts” or “Recognized as having impacts.” As a result, based on advances in scientific knowledge, the assessment of significance in nine categories (13%) was revised upwards compared to the previous time, with 49 of 71 categories (60%) assessed as “Recognized as having particularly significant impacts.”

If the current assessment levels were to continue being used for an assessment every five years, the ratio of categories deemed to be “Recognized as having particularly significant impacts” would increase as scientific findings improve. As a result, it could become more difficult to discern the differences in significance level between categories. Thus, it will be necessary to consider how assessment methodologies can better reflect the actual situation of each category at the time of the assessment. For example, effective approaches may be to make improvements in assessment methodologies to assess the magnitude of impacts relative to a scenario with no climate change, or to develop indicators that can represent the speed of change of impacts.

Other important topics include how to consider impact assessments and ways to represent the assessment results in order to better ascertain what impacts are significant for society as a whole and for each actor, in order to develop more effective adaptation strategies. For example, assessments could consider for whom the impacts are significant and urgent, on what scale or magnitude the impacts could occur, and what segments of the population are most vulnerable to the impacts.

Also, compared to the previous assessment, this time the confidence was revised upwards for 31 categories (44% of the total), but there are still categories assessed with low confidence, particularly in sectors such as natural ecosystems and industrial/economic activities; it is necessary to promote further research and studies to address this. In particular, the indirect impacts on Japan from climate change impacts overseas and climate security (new in this report) are relatively new topics, so the volume of existing research and studies is limited; however, they are very important in terms of developing climate actions internationally, so further advances in findings are needed. Also, in sectors such as industrial and economic activities, while they are not academic papers, reports by companies and organizations may provide relevant descriptions of current climate change impacts, so it will be important to reconsider the approaches used to compile literature and to assess confidence, keeping in mind the question of how to utilize these kinds of materials in impact assessment reports.

(2) Assessment Methodologies based on Mitigation and Adaptation Effects

In this report, in 8 (11%) of 71 assessment categories, different assessment results were produced for different levels of mitigation, by assessing the significance of impacts (plus confidence and urgency) separately for scenarios of global average temperature increase of 2°C and 4°C above preindustrial levels.

However, only a limited volume of existing literature on climate change impacts considers the effects of adaptation measures; thus, the current report followed the approach of the previous report, with assessments of significance, etc., of future climate change impacts done without any assumptions being made about the effectiveness of future additional adaptation measures. However, as some adaptation measures have already been taken in some sectors, such as changes in cropping seasons and development of temperature resistant cultivars in the agricultural sector, in assessing the significance, etc., of current impacts it was decided to take into account the effects of the adaptation measures.

Projects such as Strategic Research on Global Mitigation and Local Adaptation to Climate Change (Environment Research and Technology Development Fund, Project S-18) and the Climate Change Adaptation Research Program of the National Institute for Environmental Studies are expected to significantly increase findings about adaptation measures, so it may be possible in the near future to reflect the level of adaptation in impact assessments. Going forward, it will be important to further expand the knowledge base and consider assessment methodologies that consider multiple levels of both mitigation and adaptation.

In addition, when actors develop their own adaptation measures, they need to make decisions by taking into account the impacts in the case of not doing adaptation measures, as well as the costs of adaptation measures, the effectiveness[39] of each adaptation measure, and findings about trade-offs and synergies with mitigation measures. However, this information can become voluminous and complex,[40] so will be necessary to consider the option of handling all of this separately from impact assessment reports.

(3) Assessment Methodologies that Consider Changing Socioeconomic Conditions

The magnitude of projected climate change impacts in many cases depends on the socioeconomic context. The type and magnitude of feasible mitigation and adaptation measures also depend on socioeconomic context. In this report, it is suggested that socioeconomic conditions may increase ecosystem and human vulnerability to climate change, but there is only limited literature about projections of climate change impacts considering changes in socioeconomic status, so this topic has not been adequately assessed at present.

The Sixth Assessment Report of the Intergovernmental Panel (IPCC) is expected to use the Shared Socioeconomic Pathways (SSP) approach to consider future climate projections, impact assessments, mitigation and adaptation measures. SSP scenarios consist of quantitative and qualitative parameters for population, governance, equity, socioeconomic development, technology, and environment, etc., which represent the many shared aspects of a society.

In line with the SSP rationale, Japanese-style socioeconomic scenarios are being developed for use in consideration of prefectural-level impact assessments and mitigation and adaptation measures that take into account future projections for Japan (Environment Research and Technology Development Fund, Project 2-1805). It will be necessary to consider assessment methodologies that consider changes in socioeconomic context, based on findings about climate change impacts using these scenarios.

(4) Assessment Methodologies for Inter-sectoral Impact Linkages

There have been many reports where the impacts of record torrential rainfall and tropical cyclones in Japan in recent years, such as Typhoon Faxai (T1915) and Typhoon Hagibis (T1919), have affected multiple sectors and had many interacting ripple effects going well beyond the framework of sectors and categories used in this report. The cross-sectoral dimension of impacts has been covered in this report as “Inter-sectoral impact linkages.” However, no assessments of significance, etc., were done for this category, because the linkage mechanisms of impacts for these phenomena are complex and the causal relationships with climate change are not always well understood.

Because adaptation measures in a given sector may affect trade-offs and synergies in other sectors, it is important to have an understanding of the linkage mechanisms of impacts in order to develop effective adaptation measures. Also, data on the value of losses is published by sector for economic losses from weather-related disasters such as torrential rainfall and tropical cyclones, but with data comparability and other factors it is not clear whether it is feasible to compile data across all sectors and calculate the value of losses. Information about the total value of economic losses is important for policy decisions, so it is also necessary to consider existing information and elucidate the impact linkage mechanisms in order to utilize

[39] As one example of cost-benefit analysis of adaptation, in a study implemented in Jakarta, Indonesia, under Strategic Research on Global Mitigation and Local Adaptation to Climate Change (Environment Research and Technology Development Fund, Project S-14) on the case of efficient air conditioners, the benefits of using them to mitigate heat-related illnesses and sleep discomfort were estimated to be greater than the negative impacts of their use contributing to global warming and air pollution.
While this kind of analysis is important, it is also necessary to note that damage cannot always be converted into monetary values, particularly for natural ecosystems.

[40] For example, it is necessary to consider the time it takes for measures to have effect, and for that it is not always possible to respond on the time scales covered in this report Section 3.3.1(2), so there are concerns that this could complicate the information.

this information effectively. Also, improvements in documentation about impact linkages will help in determining whether or not events are likely to occur in each region. Based on these points, in the future it will be important to make further advances in scientific findings about impact linkages, and to further discuss methodologies for assessments of significance, etc., for “Inter-sectoral Impact Linkages.”

Chapter 4 Current Initiatives and Future Prospects for Climate Change Impact Assessments

To properly address the impacts of climate change, the consideration and implementation of adaptation measures need to be based upon a solid grasp of current conditions and future projections, so the government must make an effort to consider and develop frameworks to do comprehensive and strategic assessments of impacts and continue assessing those impacts on an ongoing basis. This report is the first Climate Change Impact Assessment Report prepared based on Article 10 of the Climate Change Adaptation Act, which was enacted in 2018 (in 2015, the Climate Change Impact Assessment was published as a Comment Submission from the Central Environment Council). Based on Article 8 of the Act, there are plans to update the national Climate Change Adaptation Plan in FY 2021, reflecting the contents of this report. In addition, based on Article 10 of the Act, there are plans to conduct the next climate change impact assessment in about five years (planned for 2025). With those plans in mind, this chapter examines issues that were identified in the preparation of this report, as well as the direction of efforts that should be promoted going forward.

4.1 Cross-sectoral Efforts on Climate Change Impact Assessments and Adaptation Planning

（1） Promotion of the Monitoring and Observation of Climate Change Impacts

Regarding the impacts of climate change, in order to consider adaptation measures that are based on scientific findings, it is necessary to have ongoing monitoring and observation of climate change and its impacts, and it is also necessary to systematically organize efforts for the monitoring and observation of impacts and consider efforts strategically (from the Interim Report of the Central Environment Council, March 2017)

The Study Team to Promote Climate Change Impact Monitoring and Observation was established in 2017 to enable the Ministry of the Environment and the National Institute for Environmental Studies to collaborate with the aim of systematically organizing efforts for the monitoring and observation of climate change and its impacts, and to strategically promote long-term monitoring and observation (data collection as basic information). The Team has been working to ascertain the status of major monitoring and observation initiatives on climate change impacts, identify common themes, and discuss priority levels for the implementation and expansion of monitoring and observation. Common issues pointed out across all sectors include low data usability (for example, data not being published, data not being digitized, burdensome procedures to use data, etc.), lack of continuity, low spatial and temporal resolution, and narrow scope, etc. It was also noted that there are categories/items where impacts of climate change are predicted to occur, but systematic monitoring and observation are not being conducted. High priority items for monitoring and observation will differ depending on the sector of climate change impacts, but for example, there is a high priority for advances and long-term continuity with respect to meteorological items that are required in common for impact assessments in a wide range of sectors. Also, for categories where especially major impacts are predicted even with a temperature increase of 2°C (alpine ecosystems, coastal ecosystems, etc.), there are concerns about irreversible changes occurring within a number of years, so their level of urgency is extremely high and priority monitoring will be necessary for some time.

Going forward, based on collaborative arrangements that go beyond jurisdictions of relevant government ministries and research institutions, it is necessary to conduct regular status updates and information sharing about the monitoring and observation efforts; to continue monitoring and observation of monitoring and observation items effectively and efficiently; and to promote improved usability of data obtained from various actors in order to promote the effective utilization of observation and monitoring results by diverse actors (standardization of monitoring, using open source formats, etc.). Also, in each sector, it is necessary to assign priorities for monitoring and observation based on the priority of monitoring and observation. This Study Team is planning to summarize the issues for the next impact assessment and publish a report at the end of FY 2020.

（2） Cross-sectoral Research on Climate Change Impacts and Adaptation

Uniform methodologies are not yet well established to broadly assess climate change impacts in Japan, so it is crucial to develop methodologies for enriching scientific findings relating to climate change impacts, and the government is promoting such research. Regarding climate change impacts and adaptation, the major cross-sectoral research implemented by the government since the previous Climate Change Impact Assessment (2015) is summarized in Table 4-1.

With participation from local governments (model local governments), the Ministry of Education, Culture, Sports, Science and Technology's Social Implementation Program on Climate Change Adaptation Technology (SI-CAT) developed near-future super high resolution climate change projection information and climate change impact assessment models based on actual needs. Its outputs have been provided to local governments and others and were used to develop and promote concrete adaptation measures relating to disaster prevention and agriculture, etc. It resulted in examples of model local governments making use of SI-CAT outputs, enhancing collaborative arrangements between researchers and governments, promoting the use of impact assessment results in adaptation measures for agriculture and disaster prevention, and establishing Local Climate Change Adaptation Centers.

The Climate Change Regional Adaptation Consortium Program (a joint initiative of the Ministry of the Environment, Ministry of Agriculture, Forestry and Fisheries, and Ministry of Land, Infrastructure, Transport and Tourism) conducted 35 studies and discussed adaptation options relating to climate change impacts at the local level, responding to local government needs, relating to diverse sectors including agriculture, fisheries, water resources, disaster prevention, disaster reduction, heat illness, etc. ; it also conducted impact projections nationally relating to agriculture (rice, fruit trees) and natural ecosystems sectors, and created climate change impact information to contribute to the implementation of adaptation measures by local governments. In order to share the outcomes of this project with local governments around the country, the detailed study results and study methodologies were published on A-PLAT, and it is anticipated that in the future they will be used in developing effective adaptation strategies, local climate change adaptation plans, and Local Climate Change Adaptation Centers, etc.

Table 4-1. Major Cross-sectoral and Integrated Research by Government since 2015

Project Name	Lead by	Years
SI-CAT Social Implementation Program on Climate Change Adaptation Technology	MEXT	2015-2019
TOUGOU Integrated Research Program for Advancing Climate Models	MEXT	2017-2021
Climate Change Regional Adaptation Consortium Program	MOE	2017-2019
S-14 Strategic Research on Global Mitigation and Local Adaptation to Climate Change	MOE	2015-2019
S-18 Comprehensive Research on Projection of Climate Change Impacts and Evaluation of Adaptation	MOE	2020-2024
2-1708 Development of Multivariate Vulnerability Assessment Method Considering Regional Environment for Adaptation Planning Support	MOE	2017-2019
2-1805 Shared Socioeconomic Pathways for Climate Change Impact and Adaptation Assessment in Japan	MOE	2018-2020
2-1904 Study to Apply Storylines of Extreme Weather in Japan caused by Global Warming with Impact Assessment and Adaptation Research	MOE	2019-2021
Research on Information Design to Promote Climate Change Adaptation	MOE	2019-2021
Climate Change Adaptation Research Program	National Institute for Environmental Studies	2019-2021

* MEXT: Ministry of Education, Culture, Sports, Science and Technology, MOE: Ministry of the Environment

In addition, the Integrated Research Program for Advancing Climate Models (TOUGOU) under the Ministry of Education, Culture, Sports, Science and Technology is developing and improving original

Japanese climate models as a basis for all climate change countermeasures, creating needs-based high-precision projection information for the region around Japan, and creating hazard projection information for tropical cyclones and floods, etc., which are expected to intensify due to global warming. Such information is being applied in various ways, including in recommendations by the Ministry of Land, Infrastructure, Transport and Tourism on “Flood Control Planning in the Context of Climate Change.”

Under the Environment Research and Technology Development Fund, a project entitled Strategic Research on Global Mitigation and Local Adaptation to Climate Change (Environment Research and Technology Development Fund, Theme S-14) examined global-scale climate change impacts and the costs and benefits of adaptation strategies considered feasible, to provide basic quantitative material with a focus on the four major themes of water-related disasters, grain production, human health, and coastal areas. It resulted in a published assessment linking life cycle assessments (LCA) to concrete and easy-to introduce adaptation measures in the area of urban health (which had largely been overlooked previously), a path forward to future research for the design of rational adaptation measures, and a variety of lead-edge research. This research was also incorporated in an integrated way and quantitatively into assessments of mitigation and adaptation measures, and estimates were conducted of costs of mitigation measures, impacts, and adaptation measures aligned with global GHG emissions. In addition, in FY 2020 the Ministry of the Environment began Comprehensive Research on Projection of Climate Change Impacts and Evaluation of Adaptation (Environment Research and Technology Development Fund, Theme S-18) to lead to the creation of more detailed climate change impact information and economic assessments of climate change impacts and adaptation measures, in order to develop scientific knowledge for the next Climate Change Impact Assessment Report (2025).

(3) Consideration of Adaptation Measures based on Climate Change Impacts

Based on seven basic strategies, the current Climate Change Adaptation Plan (adopted by Cabinet decision in November 2018), sets out basic directions, sector-by-sector strategies, and fundamental strategies to promote climate change adaptation through collaboration among diverse stakeholders. The seven basic strategies are as follows: incorporating climate change adaptation into all related measures and policies; promoting climate change adaptation based on scientific findings; consolidating knowledge from research institutions and developing information infrastructure; promoting climate change adaptation in ways that respond to local circumstances; deepening public understanding and promoting the adaptation business by companies; contributing to improved adaptive capacity in developing countries; and securing close collaborative arrangements with the relevant government bodies.

There are plans to update the national Climate Change Adaptation Plan in FY 2021, based on the climate change impact assessment results described in this report. Efforts are also under way to develop methodologies to ascertain and assess the effectiveness and progress of adaptation measures.

As for local governments, by August 2020, 44 of them had formulated local climate change adaptation plans based on the Climate Change Adaptation Act, and 25 had established a Local Climate Change Adaptation Center. Regarding the formulation of local climate change adaptation plans, progress has been made in the use of the latest scientific findings on climate change impacts at the local level, such as the outputs of the Climate Change Regional Adaptation Consortium Program and the Social Implementation Program on Climate Change Adaptation Technology (SI-CAT), and the proactive use of such findings is expected to result in improvements in local climate change adaptation plans and adaptation strategies.

The Local Climate Change Adaptation Centers reinforce the local information infrastructure relating to local climate change impacts and adaptation, collaborate with government departments and divisions across multiple sectors, and provide information to stakeholders including businesses and residents in their local region (regarding impacts at the local level on paddy rice, fruit trees, heat stress, etc.). In addition, the Ministry of the Environment has been implementing the “Commissioned Program on Climate Change Information Collection and Analysis based on Public Participation” since 2019 in order to support the activities of the Local Climate Change Adaptation Centers.

Since the details and scale of climate change impacts vary significantly with local climatic, geographical, and socio-economic conditions and other local characteristics, local governments need to take the lead in developing policies and measures that respond to the actual local conditions. The Ministry of the Environment, in collaboration with the Center for Climate Change Adaptation at the National Institute for Environmental Studies, has also been supporting the development of local government climate change adaptation plans and efforts to open Local Climate Change Adaptation Centers. Going forward, it will be necessary to bolster that support and to support the development of concrete adaptation measures from the perspective of promoting region-wide climate change adaptation, through efforts, including committee activities of the Regional Councils on Climate Change Adaptation (7 blocks nationwide) referred to in the Climate Change Adaptation Act, to strengthen cooperation arrangements among members to address locally-specific climate change impacts as well as common regional adaptation challenges.

Depending on the business sector, various climate change impacts affect private companies and other actors, and there are concerns about major impacts of climate change that will affect the activities of businesses via their supply chains, not only in Japan but overseas as well. Meanwhile, in recent years, investors and other stakeholders have been expecting companies to disclose their climate change risks, so companies are being called upon to ascertain the climate change impacts on their business activities, and to take appropriate actions to address them. As a result, in FY 2018, the Ministry of the Environment prepared and published the “Climate Change Adaptation Guide for the Private Sector: Preparing for and Surviving Climate Risk,” in order to promote a better understanding in the private sector about climate change impacts and adaptation.

In addition, recognizing that developing countries have significant needs and opportunities related to climate adaptation, and the related business market is expected to grow, the Ministry of Economy, Trade and Industry has continued since FY 2016 compiling and publishing good practices case studies about adaptation, and promoting the business of adaptation to global warming.

4.2 Sectoral Initiatives for Climate Change Impact Assessment and Adaptation Planning

This section covers major governmental initiatives relating to climate change impact assessments in each sector, as well as efforts to ascertain impacts, and efforts to develop plans, conduct technical development, and verification and demonstration relating to adaptation. However, initiatives related to the implementation and deployment of individual adaptation measures are not covered here, as they are already reflected in the current Climate Change Adaptation Plan or will be reflected in the 2021 update.

（1） Agriculture, Forest/Forestry, Fisheries

In project research commissioned for implementation between FY 2013 and 2017, the Ministry of Agriculture, Forestry and Fisheries developed a climate change impact analysis model and assessed impacts on crops (including paddy rice, wheat, soybeans, fruit trees, vegetables, and feed crops, etc.), and also used impact analysis model projections relating to forest monitoring and increases in extreme events to assess the impacts of climate change on the vulnerability of agricultural water resources, land resources and forests.

Furthermore, to contribute to measures to address damage from the expanded range of wildlife due to climate change, starting in FY 2016, commissioned project research has been clarifying changing trends in sika deer and wild boar individuals and populations due to environmental changes; work is under way utilizing the findings to develop maps of range expansion and damage projections from the medium- to long-term perspective.

In addition, the Ministry prepared the Ministry of Agriculture, Forestry and Fisheries Climate Change Adaptation Plan in August 2015 to promote adaptation measures in a systematic way, and updated it in November 2018 to align with the entry into force of the Climate Change Adaptation Act. This plan summarizes the efforts that are necessary over the next 10 years, by sector and by category, and based on them, promotes studies on topics such as the status of pest outbreaks, changes in the growth of sugi cedar planted forests, and studies on marine environments that are spawning areas and fishing areas of major fish species, as well as research and technical development for disaster-resistant forest management techniques in mountain areas, breeding techniques for sugi cedar trees adapted to climate change, trial introduction of subtropical and tropical fruit trees, breeding of heat-tolerant varieties of major aquaculture species, techniques for predicting red tide outbreaks that are expected to increase with global warming, and techniques for preventing and reducing damage from wood debris in rivers due to increased heavy rainfall. In addition, regarding the deployment of adaptation strategies at the local level based on future projections, by providing information analyzed and organized to be easy to understand for each local area, the Ministry is practicing and promoting adaptation strategies through local decision-making and choices in production areas, and supporting initiatives to prepare for future impacts.

(2) Water Environment, Water Resources

[Water Environment]

Since FY 2013, the Ministry of the Environment has been examining projections of future impacts on water quality and ecosystems specifically in lakes and marshes, as well as the necessary adaptation measures. From FY 2015 to FY 2019, it carefully reviewed analyses on model lakes and marshes based on the latest knowledge, and conducted climate change impact assessments on lakes and marshes nationwide, based on the impact assessments of model lakes and marshes. It also identified and considered adaptation strategies for lakes and marshes nationwide.

[Water Resources]

By offering guidance and advice via on-site inspections of water utilities and discussing matters with the operators, the Ministry of Health, Labour and Welfare has been promoting measures to deal with droughts and encouraging each water utility to prepare manuals for drought countermeasures.

In 2012 the Ministry of Land, Infrastructure, Transport and Tourism established the “Study Group on Adaptation Measures for Climate Change in the Water Resources Sector” (name changed in 2014 from “Study Group on Impact of Climate Change on Water Resources”) in order to reflect the latest findings from experts and scientifically get a grasp on the scale and frequency of future droughts due to climate change and consider the orientation for adaptation, and to consider measures to address the depletion of water resources and risk of having “zero water” (a drought crisis) causing serious and significant problems for people’s lives and socio-economic activities.

(3) Natural Ecosystems

The Ministry of the Environment is conducting ongoing monitoring of ecosystems such as alpine ecosystems and coral that are especially susceptible to the impacts of climate change, and assessed the impacts of climate change on biodiversity (extent of current damage, etc.) in the “Report of Comprehensive Assessment of Biodiversity and Ecosystem Services in Japan” (Japan Biodiversity Outlook 2, or JBO2) published in FY 2015. A program known as “Predicting and Assessing Natural Capital and Ecosystem Services” (PANCES) (Environment Research and Technology Development Fund, Theme S-15) examined 11 major species of *kombu* seaweed that grow in northern Japan, estimated the distribution of each species in the 1980s before significant warming occurred, and predicted future changes in distribution based on global warming scenarios.

Also, to support the development of adaptation strategies based on climate change impact assessments for national parks and other protected areas that contain many areas particularly vulnerable to climate change, in FY 2018, the Ministry prepared and published the “Handbook for Considering Climate Change Adaptation Measures in National Parks and Other Protected Areas.” In addition, research began in FY 2019 as part of the Climate Change Adaptation Research Program of the National Institute for Environmental Studies, with a major focus on natural ecosystems.

(4) Natural Disasters, Coastal Areas

In October 2019, the Ministry of Agriculture, Forestry and Fisheries, and the Ministry of Land, Infrastructure, Transport and Tourism established the "Study Group on Coastal Protection in the Context of Climate Change," which considered climate change impacts on coastal areas, such as sea level rise and intense named tropical cyclones, as well as climate change adaptation strategies, such as the future of coastal protection, and coastal protection with hazards considered, as well as approaches to make improvements in the context of climate change; its recommendations were released in July 2020 as "Coastal Protection in the Context of Climate Change." Based on the recommendations, the Ministry of Agriculture, Forestry and Fisheries, and the Ministry of Land, Infrastructure, Transport and Tourism are working to quantify climate change impacts on coastal areas and to revise technical standards for the design of coastal protection structures.

In addition, in October 2019 the Ministry of Land, Infrastructure, Transport and Tourism established the "Study Group on Countermeasures for Storm Surges, High Waves, and Windstorms Exceeding Design Parameters for Ports," which considered integrated disaster prevention and risk reduction strategies that combine self-help, mutual help, and public help to be effective in reducing damage even in the event of high waves, storm surges and windstorms that exceed design parameters; a final report was published in May 2020. In addition, since November 2019, regarding "future integrated disaster prevention and reduction countermeasures using both hard and soft port and harbor infrastructure," the Disaster Prevention Subcommittee of the Ports Committee of the Council for Transport Policy has been discussing concrete policy directions to respond to intensifying hazards caused by climate change, such as maintaining port functions in the future, reflecting this in structural designs, maintaining continuous monitoring, and conducting technical development to respond to intensifying hazards.

Furthermore, the "Technical Study Group on Flood Control Planning in the Context of Climate Change" was established in 2018, and it made projections of changes in rainfall due to climate change based on d4PDF and other large scale ensemble calculation results, and assessed the impacts on river flow volumes and frequency of flooding; the findings were released in October 2019 as recommendations on "Flood Control Planning in the Context of Climate Change."

Regarding countermeasures for urban flooding from sewer systems, heavy rainfall events are becoming more frequent due to climate change and there are growing risks of inland flooding, so the "Study Group on Urban Flooding Countermeasures in the Context of Climate Change," was established in December 2019 to discuss methodologies for establishing hazard assumptions for sewer systems plan in the context of climate change and consider measures to prevent flooding from sewer systems; the recommendations were released in June 2020 as "Promoting Countermeasures for Urban Flooding from Sewer Systems in the Context of Climate Change."

As for sediment disasters, the "Study Group on Erosion Control Techniques in the Context of Climate Change" was established with experts as members, to consider adaptation strategies to deal with sediment disasters, which are expected to increase in frequency and prominence due to changes in rainfall patterns in the context of climate change.

Based on the discussions of these groups, a meeting of the "Subcommittee on Water Disaster Countermeasures in the Context of Climate Change" was held in November 2019, and the outcomes were summarized as a report, entitled the "Water Disaster Countermeasures in the Context of Climate Change: Shifting to Sustainable Watershed-based Flood Control by All Stakeholders."

The Ministry of the Environment established the "Impact Assessment Program on Disaster Intensification Due to Climate Change" in FY 2020, and has been studying possible impacts in the event an actual historical named tropical cyclone that caused significant damage, such as Typhoon Hagibis (T1919), were to follow a similar path in a warmer climate in the future. The numerical calculations for tropical cyclone impact projections in this program are being done using outputs from the Integrated Research Program for Advancing Climate Models of the Ministry of Education, Culture, Sports, Science and Technology, as well as climate models from the Japan Meteorological Agency, and supercomputers of the National Institute for Environmental Studies. Moreover, a study group has been established comprised of members from the

Meteorological Research Institute (Japan Meteorological Agency), National Institute for Environmental Studies, Kyoto University, Hokkaido University, Nagoya University, and Ibaraki University, and in addition, with cooperation from the Ministry of Land, Infrastructure, Transport and Tourism, studies are in progress based on expertise from a broad range of perspectives.

Also, in recent years weather-related disasters have exceeded expectations in many places, and the frequency of events such as heavy rainfall and flooding is expected to increase in the future. To deal with such disasters, it is necessary to implement drastic disaster risk reduction measures based on climate change risk; in June 2020, then-Minister of State for Disaster Management Ryota Takeda and Minister of the Environment Shinjiro Koizumi issued a joint message called the “Strategy for Enhancing the Synergy between Climate Action and Disaster Risk Reduction in the Era of Climate Crisis.” The strategy calls for: mainstreaming the synergy between climate action and disaster risk reduction; promoting comprehensive measures for a decarbonized and highly disaster-resilient society; transforming awareness and facilitating behavior change among citizens, businesses, and communities; and promoting international cooperation. The strategy also sets out that when recovering from disasters, we must respond to them conveying the idea of “Adaptive Recovery” by implementing resilient measures including the control of land use where communities can ensure adaptation to climate change.

(5) Human Health

[Heat Stress]

Heat stress is an issue spanning many government ministries and agencies, so the Inter-Ministerial Liaison Committee on Heat Illness was established in 2017 to promote close collaboration among them, and it is discussing and implementing strategies to address heat illnesses (ministries and agencies involved include the Fire and Disaster Management Agency; Ministry of Education, Culture, Sports, Science and Technology; Ministry of Health, Labour and Welfare; Ministry of Agriculture, Forestry and Fisheries; Ministry of Economy, Trade and Industry; Ministry of Land, Infrastructure, Transport and Tourism; Japan Tourism Agency; Japan Meteorological Agency; Ministry of the Environment).

To provide information on the incidences of heat illnesses, the Ministry of Health, Labour and Welfare, has been posting annual mortality numbers due to heat illnesses based on demographic statistics on its website since FY 2015 (using 2014 survey results). It is also notifying private sector organizations about priority countermeasures together with information about of the previous year’s statistics for heat-related illnesses in the workplace each year.

In addition, the Ministry of the Environment and Japan Meteorological Agency decided to implement a new heatstroke alert system on a trial basis in FY 2020 to raise public awareness about heat risks. This system sends out alerts when the weather is expected to create high risk conditions for heat illnesses, with the aim of encouraging people to take effective actions to prevent heat illnesses; the new system was implemented first in FY 2020 in the trial region (Tokyo and eight prefectures in the Kanto-Koshin region), with plans a national expansion in FY 2021.

[Infectious Diseases]

Regarding countermeasures for mosquito-borne infectious diseases, the Ministry of Health, Labour and Welfare has implemented measures in prefectures, such as local continuous fixed-point monitoring in areas where outbreaks of mosquito-borne infectious diseases occur; awareness-raising about larvae source prevention, adult mosquito extermination, and mosquito prevention; and monitoring of trends in infectious disease outbreaks (based on the “Guidelines for the Prevention of Specified Infectious Diseases relating to Mosquito-borne Infectious Diseases,” Ministry of Health, Labour and Welfare, Notification No. 260 in 2015). Going forward, the guidelines will be revised as necessary, after enough new information on mosquito-borne infectious diseases has been compiled.

（6） Industrial / Economic Activities

The Ministry of the Environment has been implementing a "Study on Risks Arising from Global Climate Change on Socio-economic Activities in Japan" since FY 2018, and is promoting research about the impacts of climate change on overseas food production and supply chains, as well as national security, etc. (Environment Research and Technology Development Fund, No. 2-1801).

（7） Life of Citizenry, Urban Life

【Urban Infrastructure, Critical Services】

To promote infrastructure improvements to reinforce water supply systems, the Ministry of Health, Labour and Welfare is promoting seismic upgrades to pipes that can also withstand natural disasters such as flooding, and offers financial assistance to water utilities to subsidize a portion of costs of the upgrades (subsidies for seismic upgrades of community infrastructure, etc.). In 2019, the amended Water Supply Act entered into force, with changes that include the requirement for water utilities to endeavor to systematically upgrade their water supply facilities.

To establish systems to facilitate timely and appropriate emergency responses and restoration, the Ministry provided forums including the National Water Utilities Officials' Council with information such as "Guidelines for Preparation of Crisis Management Response Manuals" (which includes storm and flood damage countermeasures) and the "Emergency Response Handbook for Earthquakes, etc." (by the Japan Water Works Association), and encouraged utilities to develop crisis management and response manuals and put systems in place to provide emergency water supplies and emergency restoration in the event of storms or floods. During site visits, inspectors check on the status of manuals and systems, and where necessary, provide guidance and advice to the utilities.

For proper water quality management, the Ministry has been providing information to utilities since 2008 to encourage them to develop water safety plans to achieve source-to-faucet integrated water quality management, such as "Guidelines for the Development of Water Safety Plans" and "Simplified Tools to Support Water Safety Plan Development." During site visits, inspectors check on the status of plans, and where necessary, provide guidance and advice to the utilities.

[Life with Sense of Culture and History]

To identify trends in seasons starting earlier or later, as well as overall meteorological conditions such as climatic differences and changes, the Japan Meteorological Agency monitors phenological indicators, such as the opening of *sakura* cherry blossoms and the change of maple leaves to autumn colors; every year the Agency publishes a "Climate Change Monitoring Report," which includes information on changes in dates of blossoming and the start of autumn colors.

[Others (Impacts on Life Due to Heat Stress, etc.)]

The Japan Meteorological Agency summarizes monitoring results and analysis of key factors of the heat island effect, to contribute to heat island countermeasures and the scientific understanding of the heat island effect; the findings are published on the Agency's website.

In FY 2008, the Ministry of the Environment began studying the impacts on comfort levels of rising temperatures particularly in urban areas (including the heat island effect), and in FY 2016, developed and published "Guidelines to Fight the Heat in the City" to promote the introduction of effective adaptation measures to deal with the heat island effect.

4.3 Strengthening Cooperation in Climate Change Projection, Impact Assessment, Adaptation Planning and Implementation

(1) Current Issues and Future Prospects

To promote climate change adaptation by all actors, it is necessary to strengthen collaboration on climate change prediction research and impact assessment research, and to provide information to citizens in an understandable format regarding the outcomes of both types of research (from the Interim Report of the Central Environment Council, March 2017)

Since FY 2018, the Ministry of Education, Culture, Sports, Science and Technology and the Japan Meteorological Agency have been holding meetings of the expert "Advisory Panel on Climate Change," promoting discussions about the current state of climate change in Japan as well as future projections, and compiling "Climate Change in Japan 2020" and "Climate Projection Dataset 2022" reports, which are needed for climate change impact assessments. It is expected that they will be prepared approximately every five years, and that they will be used starting with the next Climate Change Impact Assessment and Climate Change Adaptation Plan and related researches.

Also, to facilitate collaboration and cooperative arrangements with the relevant research institutions, the "Climate Change Research Institution Liaison Committee" was established, consisting of national governmental institutes and incorporated administrative agencies. The National Institute for Environmental Studies is responsible for secretariat functions, and as necessary, it reports to the "Climate Change Adaptation Promotion Committee" which was established based on the national Climate Change Adaptation Plan.

In this context, the Ministry of the Environment and the National Institute for Environmental Studies jointly established the "Study Team on Climate Change Projection and Impact Assessment Collaboration Promotion" in FY 2017 with the aim of promoting collaboration on climate change projection research and impact assessment research; it identified five topics requiring collaboration and summarized the topics and proposed approaches. The five topics were "Integration of climate scenarios," "Development of guidelines for climate model selection," "Need for shared infrastructure for climate models," "Wait times for outputs of projection calculations and impact assessments," and "Reflecting user needs into scenario development." The Study Team also summarized current issues and the desired status of climate projections, impact assessments and information utilization. (Figure 4-1.)

Going forward, based on the understanding that (1) future climate projection results made from models will always involve uncertainty, so there is also uncertainty in impact assessments based on future projections, (2) there is a need to develop methodologies and prepare data for climate scenarios and impact assessments that include uncertainty, but (3) developers and implementers of adaptation strategies (governments, businesses, etc.) have a strong desire for the highest level of certainty in projections and for worst-case impact assessments to be identified. Thus, it is necessary to continue with research and development of methodologies to increase the accuracy of future projections and impact assessments. It is also necessary to develop manuals and guidelines for issues such as the development of adaptation strategies, the selection of implementing bodies, and the grounds or criteria for decision-making to address questions such as how to deal with uncertainty, and which projections and assessment results should be selected to develop and implement adaptation strategies. Through these kinds of activities, it will be important to fill the gaps between climate change projection research and impact assessment research, and gaps in awareness, understanding and demands between planners and implementers, and to promote collaborative creation.

Backcasting

Backcasting based on desired future outcomes: An examination from the user's perspective (local government, etc.) of what actions are needed, and when, for climate projections and impact projections

		Dataset 2022 Impact Assessment 2025	Dataset 2027 Impact Assessment 2030	Subsequent Goals	Other Points
Climate projections	Resolution	* 2-1 km (dynamic, stochastic)	* 1 km (dynamic, stochastic)	* Below 1 km (dynamic, stochastic)	• High past reproducibility of climate variables • Balance between, or option to choose, improved resolution/accuracy vs more ensembles • Balance between many projections covering uncertainty, few projections with high probability, and extreme projections with probabilistic info. How to adequately cover uncertainty with few projections • Enhancing info to contribute to projections for ecosystems and many other areas • Improving impact assessments, user convenience
	Experiments	* Time slice experiments * Multi-ensemble experiments * Combined CMIP5/6	* Continuous 21st century experiments (mainly CMIP6) * Experiments adequately reflecting uncertainty * Improve atmosphere/ocean/land integration	* Seasonal forecasts * Decadal variability projections * Integrate long-term projections * Ongoing event analysis (EA) for extreme events	
	Content	* Mainly temperature, precipitation * Start providing ocean data	* Improve content/parameters besides temperature, precipitation * Improve ocean data	* Provide content/parameters related to individual/company activities	
	Provision	* Commentary * Expand user support	* Upgrade data centers * Improve research efficiency with cloud computing	* Reduce time lags between climate projections, impact projections, utilization	
Impact Projections	Projections	* Projections considering adaptation measures, social change * Multi-model, multi-scenario projections	* Expanded impact observation/monitoring info * 21st century continuous experiments * Improve facilities and infrastructure info * Improve atmosphere/ocean/land integration	* Projections that include adaptation, complex disasters, social change * Achieve high past reproducibility	• Expanding info on adaptation options and effects • Role of impact projections in connecting users with climate projections • Reducing time lags between climate projections and impact projections • Consistency among socioeconomic scenarios
	Content	* Major risk info * Limited economic transition	* Expand risk-related content/parameters * Improve research efficiency with cloud computing	* Adequate risk coverage * Broad economic transition	
	Provision	* Provide basis for projections * Use in educational settings	* Indicate confidence levels * Info for flexible adaptation	* Provision of relevant info for individual/ company/ local government activities	
Users	Needs	○ Government Needs * High-resolution projections that can specify individual municipalities * Projections for aspects besides temperature, precipitation * A small number of high-probability projections * Worst-case projections for disaster prevention, infrastructure planning * Impact assessments for special local products, scenic spots * Guidance on what projection info to use or not to use	○ Government Needs (continued) * Guidelines on adaptation measures * Assessments of effects of adaptation measures * Economic assessments to help prioritize policies ○ Practical Needs of Users * Causal analysis of past events * Seasonal projections * Decadal projections * Projections for extreme events, including probability info * Easy-to-understand indicators, rather than scientific measures		• Challenges arising due to timing of required actions (difficulty in knowing actions required long term) • Challenges arising because specs are not announced in advance for next climate projections & impact assessments (e.g., in 5 years) (one reason there is no time sequence in left column) • Challenges arising from frequent changes in key personnel

Differences among Actors

○ Differences in Info Needs
* Need for seasonal & decadal projections (desired by users) vs long-term projections (with signal robustness)
* Spatial resolution vs accuracy
* Spatial resolution vs number of ensembles
* High probability vs coverage of uncertainty (worst-case scenarios). Is it possible to indicate uncertainty using a small number of storylines?

○ Info Provision Issues
* Disjointed info provision on climate/ impacts/ adaptation measures
* Mismatches in timing of info provision on climate projections/ impact projections, info use

○ Info Use Issues
* Different industries/departments have different interests
* Different levels of urgency for different content/parameters
* Different knowledge levels between info providers & users

Issues for Co-Creation

○ Building Shared Awareness
* Regular/ongoing communication
* Opportunities to collaborate on climate projections/ impact projections/ info use frontlines
* Communicating researchers' R&D plans to users
* Reverse info flows from users to researchers

○ Info Sharing
* Publishing/ open data/ using cloud services for projection-related info
* Publicizing innovative cases

○ Promoting Utilization of Info
* Strengthening cooperation between government ministries and departments
* Involving civil society, youth, NPOs, NGOs, industry
* Promoting environmental consulting & ventures to interpret climate projections, assess local impacts
* Expanding environmental education programs

Figure 4-1. Current issues and desired status of climate projections, impact assessments and information utilization

The "Subsequent Goals" column indicates the goals for climate projections and impact assessments. The items listed in the "Dataset 2022/Impact Assessment 2025" column are major items expected to be addressed in large-scale projects and initiatives. The "Dataset 2027/Impact Assessment 2030" column, based also on "Subsequent goals," indicates items that should be newly addressed in the next large-scale projects and initiatives. The "Users" row indicates the needs relating to climate projection and impact projection information, from the perspective of planning and implementing of adaptation measures, mainly by the national and local governments. The "Points" column indicates items that are essential but difficult to include in the matrix.

The "Gaps Between Actors" box is a compilation of "contradictions" or gaps that were identified mainly in the vertical direction in the table. "Gaps in Information Needs" are gaps between the information provided by climate projections / impact projections and the needs of users. "Information Provider Issues" are issues related to information provision based on climate projections and impact projections. "Information User Issues" are issues related to the use of information by users.

The "Issues for Co-creation" box is a compilation of issues for the desired use of climate projection and impact projection information and improving measures through collaborative creation among actors. "Awareness Sharing" includes items relating to sharing levels of awareness, which is the basis of cooperation among actors. "Information Sharing" includes items relating to the understanding and sharing of information, which is the basis for understanding and utilizing climate projections and impact projections. "Expanding Information Use" includes items relating to expanding the quality and quantity of human resources that can utilize the information and have it lead to measures and actions.

(2) Improving the Information Infrastructure

In order to promote initiatives relating to climate change adaptation, scientific information relating to current and future climate change impacts is essential. The Climate Change Adaptation Act stipulates that the National Institute for Environmental Studies has the role to collect, organize, analyze, and provide information regarding climate change impacts and climate change adaptation, and to give technical advice and other assistance on initiatives relating to climate change adaptation to prefectures, municipalities and Local Climate Change Adaptation Centers.

Prior to the entry into force of the Climate Change Adaptation Act, the Climate Change Adaptation Information Platform (A-PLAT) was established in August 2016, with the purpose of supporting its users' activities to consider adaptation measures. Later, the Center for Climate Change Adaptation was established at the National Institute for Environmental Studies in accordance with the Act, and through A-PLAT, by promoting information collection, organization, analysis and research relating to climate change impacts and adaptation and broadly disseminating the outcomes, has been contributing to initiatives relating to climate change adaptation by all actors including businesses and individuals, such as the formulation of plans relating to climate change adaptation by governments, prefectures, and municipalities, and the implementation of adaptation measures.

In addition, the Ministry of Education, Culture, Sports, Science and Technology(MEXT) has been developing and operating the Data Integration and Analysis System (DIAS)[41] which accumulates, integrates and analyzes big data on the global environment (including observation data, and climate change projection information), as an information system to contribute to solving global environmental issues, including climate change. Through DIAS, by broadly publishing climate change projection information and collaborating with A-PLAT and others, MEXT is contributing to the development of climate change impact assessments and adaptation measures by the central government, prefectures and municipalities.

4.4 International Cooperation for Climate Change Impact Assessment and Adaptation

Previous climate change impact assessments have suggested that the impacts of climate change occurring in other parts of the world may also directly affect Japanese society through the globalization of corporate activities, etc. Also, there is a need in developing countries of the Asia-Pacific region to develop projects with a high adaptation component, but few developing countries have the governmental and human resources to implement national impact assessments in all sectors.

Due to differences in regional characteristics and development-related government capacity, cases that Japan's domestic impact assessment expertise can be applied through international technical cooperation are limited. However, to make policy decisions that are based on scientific findings, develop adaptation measures that are based on local and practical knowledge, and attract funding assistance for the development of project proposals, there is a need to adjust the impact assessment models and expertise built up in Japan, and to promote the development of tools that can be put into practical use in international cooperation.

Climate disasters such as droughts and floods have intensified in recent years in countries of the Asia-Pacific region that are vulnerable to climate change, particularly least developed, inland, and small island state developing countries, and while various sectors have a strong need for adaptation measures, little progress has been made in terms of gathering scientific findings and improving a variety of data. Also, developing countries generally have the potential to utilize external fund sources, such as official development funding and climate change funding, so there is a need to use technical cooperation to train personnel who are able to procure and manage external funding.

In that context, through the Asia Pacific Climate Change Adaptation Information Platform (AP-PLAT) created in 2019, the Ministry of the Environment has been promoting efforts to make improvements in risk information relating to climate change impacts so that developing countries utilize the information. Through

41 DIAS: Data Integration & Analysis System

AP-PLAT, there is a need to promote capacity-building of local personnel within central and local governments so that they are able to guide the development of impact assessment and adaptation measures projects/programs that use the tools.

At the same time, through technical cooperation to develop tools and build capacity, the implementation of various adaptation projects in each country and region is likely to promote the use of the exceptional adaptation technologies and services available from Japanese companies, and this is expected to expand the adaptation business.

To date, the Ministry of the Environment has been deploying technical cooperation for the development of adaptation plans in ten countries in the Asia-Pacific region since 2015, in the form of bilateral international cooperation related to climate change adaptation, and this has included the implementation of pilot impact assessments. Major examples include impact assessment models for paddy rice production, the development of risk information on flood hazards for important transportation infrastructure based on remote sensing technologies, the application of pseudo global warming downscaling services, the development of adaptation-related learning materials for local government personnel, and project/program development using climate change funding. Besides the above-noted outcomes of cooperation, since FY 2020, the Ministry has been efficiently deploying technical cooperation to countries that are vulnerable to climate change, by promoting refinements in expertise, tools, and methodologies for impact assessments that have been implemented in Japan, combined with local capacity building for personnel.

Through the intergovernmental Group on Earth Observations (GEO), which links the global observation systems of countries around the world and promotes contributions to solve climate change and other societal issues, MEXTis providing Earth observation satellite data to other countries and contributing to impact assessments using that data (crop forecasting, etc.).

In addition, the Global Environment Information Platform Development Promotion Program of MEXTis contributing to flood risk assessments in countries such as Sri Lanka and Myanmar, by effectively merging monitoring data and hydrological models into the Data Integration and Analysis System (DIAS) and developing flood prediction systems. Moreover, the Integrated Research Program for Advancing Climate Models, under the Ministry of Education, Culture, Sports, Science and Technology, is utilizing detailed projection data for Southeast Asian countries and collaborating with researchers in Thailand, Vietnam, Indonesia, and the Philippines, etc., to assess changes in hazards due to climate change and promote advances in scientific knowledge.

In terms of institutional development for adaptation strategies overseas, the Ministry of Agriculture, Forestry and Fisheries is developing methodologies to apply Japanese erosion control techniques in developing countries for the purpose of forest disaster prevention and capacity building in disaster reduction. In addition, in terms of international cooperation and technical cooperation, the Ministry is engaged international joint research and the provision of scientific expertise, as well as contributions to international organizations.

The Ministry of Foreign Affairs is contributing to the appropriate promotion and mainstreaming of climate change adaptation measures in developing countries. It is applying expertise developing countries in Asia and Oceania relating to impact assessments and adaptation developed in Japan, and promoting assistance relate to climate change adaptation. Specifically, in Indonesia it supported improvements in monitoring, evaluation, and reporting (MER) and measurement, reporting, and verification (MRV) systems for the National Action Plan for Green House Gas Emission Reduction (RAN-GRK), as well as the Local Action Plan for Greenhouse Gas Emission Reduction (RAD-GRK), as well as promotion of implementation of the National Action Plan on Climate Change Adaptation (RAN-API) at the regional level, and system development of monitoring and evaluation (M&E). In Samoa, the Ministry contributed to improved resilience to climate change in Oceania by working to develop training functions at the Pacific Center for Climate Change (PCCC, completed in 2019) in the area of climate change in Oceania (mitigation, adaptation, access to funding), through improvement in climate change adaptation, access to climate finance, and implementation of trainings relating to climate change mitigation.

In addition, since 2017, the Ministry of Foreign Affairs has been holding conferences relating to climate change and vulnerability. In 2019, an international meeting was held relating to climate change and vulnerability in the Asia and Oceania region on the theme of oceans, with participants from a variety of backgrounds presenting the latest scientific findings and initiatives relating to climate change. The meeting promoted stronger international cooperation by sharing knowledge about climate change and vulnerability risk.

Appendix A: Overview of Scenarios Being Used for Climate Projections

1. RCP Scenarios

The IPCC "Special Report on Emissions Scenarios" (SRES, see further below) had various limitations, such as not taking into account policy-directed measures to reduce emissions. As a result, representative scenarios were developed by selecting scenarios from among a number of pathways that could lead to stabilized future GHG levels based on the implementation of policy-based GHG mitigation measures. These are referred to as the Representative Concentration Pathway (RCP) scenarios.[42]

The RCPs are characterized by the magnitude of impacts of radiative forcing from atmospheric greenhouse gas concentrations. They are referred to as RCP8.5 (high reference scenario), RCP6.0 (high stabilization scenario), RCP4.5 (medium stabilization scenario), and RCP2.6 (low stabilization scenario), and correspond to approximate radiative forcing relative to pre-industrial levels, at the end of the 21st century, as 8.5 W/m^2, 6.0 W/m^2, 4.5 W/m^2, and 2.6 W/m^2, respectively (see Table below).[43]

Summary of RCP Scenarios

Scenario	Estimate of radiative forcing compared to pre-industrial era	GHG concentrations (all gases) in 2100 (CO_2 equivalent)	Trend for concentrations
RCP8.5 (high reference scenario)	Exceeds 8.5 W/m^2 in 2100	Exceeds approx. 1,370 ppm	Continued increase
RCP6.0 (high stabilization scenario)	Stabilized at approx. 6.0 W/m^2 after 2100	Approx. 850 ppm (stabilizes after 2100)	Stabilization
RCP4.5 (medium stabilization scenario)	Stabilized at approx. 4.5 W/m^2 after 2100	Approx. 650 ppm (stabilizes after 2100)	Stabilization
RCP2.6 (low stabilization scenario)	Peaks at 3W/m^2 prior to 2100, then declines. Approx. 2.6W/m^2 in 2100	Peaks at approx. 490 ppm prior to 2100, then declines	Peaks then declines

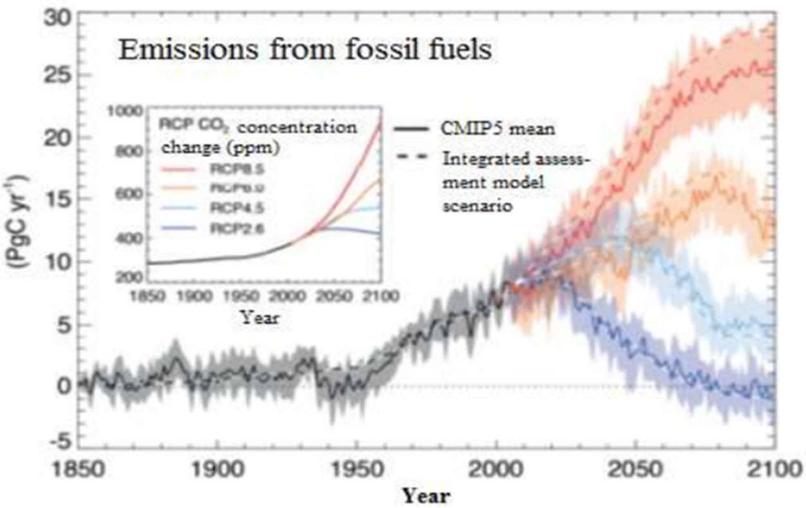

Figure A-1. Changes in carbon dioxide concentrations based on RCP scenarios (inset), and carbon dioxide emissions from fossil fuels corresponding to the RCP scenarios (main figure, showing results of reverse calculation by Earth system models, with thin lines showing results of each model and thick lines the average of multiple models). PgC is one billion tons (10^{15} g) in carbon equivalent.

[42] Statement relating to the release of Working Group II Report (Impacts, Adaptation, Vulnerability), Fifth Assessment Report, Intergovernmental Panel on Climate Change (Ministry of Education, Culture, Sports, Science and Technology, Ministry of Economy, Trade and Industry, Japan Meteorological Agency, Ministry of the Environment, 2014) (in Japanese).

[43] Text and figures are excerpted from "Synthesis Report on Climate Change Observation, Prediction and Impact Assessment," Climate Change and Its Impacts in Japan" (2012 edition) (Ministry of Education, Culture, Sports, Science, Japan Meteorological Agency, Ministry of the Environment, 2013) (in Japanese).

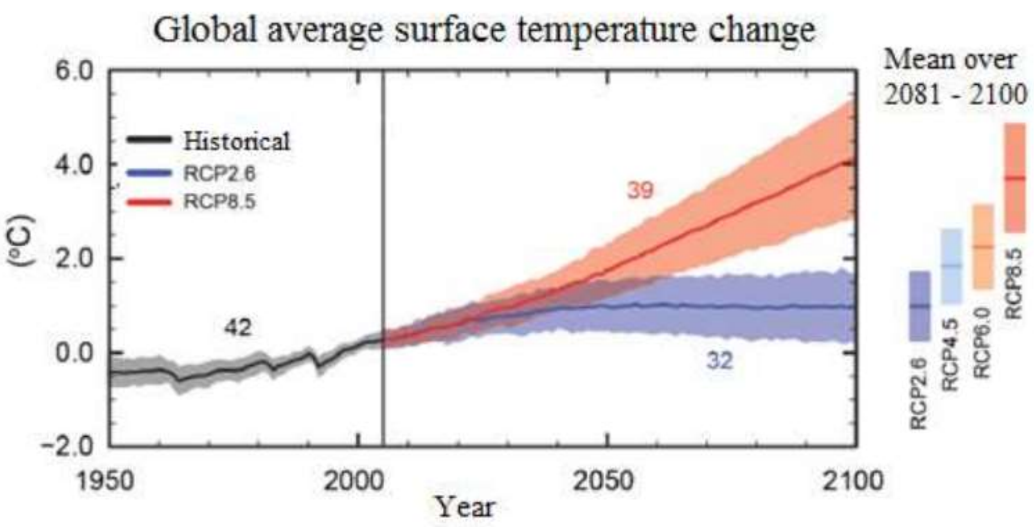

Figure A-2. Change in global mean surface temperature relative to 1986-2005 simulated using multiple CMIP5 models (1950-2100). Projections and uncertainties (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). Black (with gray shading) is the modelled historical evolution using reconstructed historical forcings. The mean and associated uncertainties averaged over 2081-2100 are given for all RCP scenarios as colored vertical bars. The numbers of CMIP5 models used to calculate the multi-model mean are indicated.

(Source: IPCC Fifth Assessment Report, Working Group I Report, Summary for Policymakers, Figure SPM.7(a))

Table A-1. Projected changes in global mean surface temperature and changes in global mean sea level, by scenario

Concentration Scenario	Temperature change (°C)		Sea-level rise (m)	
	Medium term (2046–2065)	Long term (2081–2100)	Medium term (2046–2065)	Long term (2081–2100)
RCP 2.6	0.4–1.6 (1.0)	0.3–1.7 (1.0)	0.17–0.32 (0.24)	0.26–0.55 (0.40)
4.5	0.9–2.0 (1.4)	1.1–2.6 (1.8)	0.19–0.33 (0.26)	0.32–0.63 (0.47)
6.0	0.8–1.8 (1.3)	1.4–3.1 (2.2)	0.18–0.32 (0.25)	0.33–0.63 (0.48)
8.5	1.4–2.6 (2.0)	2.6–4.8 (3.7)	0.22–0.38 (0.30)	0.45–0.82 (0.63)

・Projections indicate the change from the mean relative to 1986-2005.
・Numbers in parentheses indicate the mean value of projections.

Prepared from the following sources:

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Note

* Climate projections based on the SRES scenarios are from the Fourth Assessment Report, while climate projections based on RCP scenarios from the Fifth Assessment Report, and they differ not only in terms of emission scenarios but also methodology for climate projections.

2. SRES Scenarios

These are emission scenarios used as common scenarios in climate projection experiments assessed for the IPCC's Fourth Assessment Report, and are classified as A1 scenario (rapid economic growth), A2 scenario (heterogeneous society), B1 scenario (sustainable development society), and B2 (local coexistence society). The A1 scenario is further classified as A1FI (emphasis on fossil energy sources), A1T (emphasis on non-fossil energy sources), and A1B (emphasis on balance of energy sources).

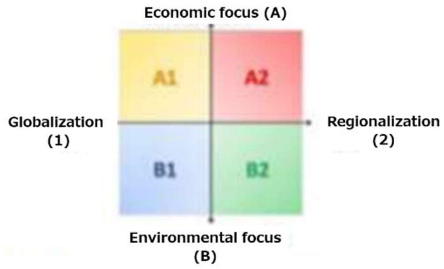

Figure A-3. Four SRES scenario families
The A1 scenario is further classified as A1B, A1T, and A1FI. The A1B scenario is frequently used (high-growth society with emphasis on balanced use of energy sources).
Source: Prepared from National Institute for Environmental Studies materials, 2001.

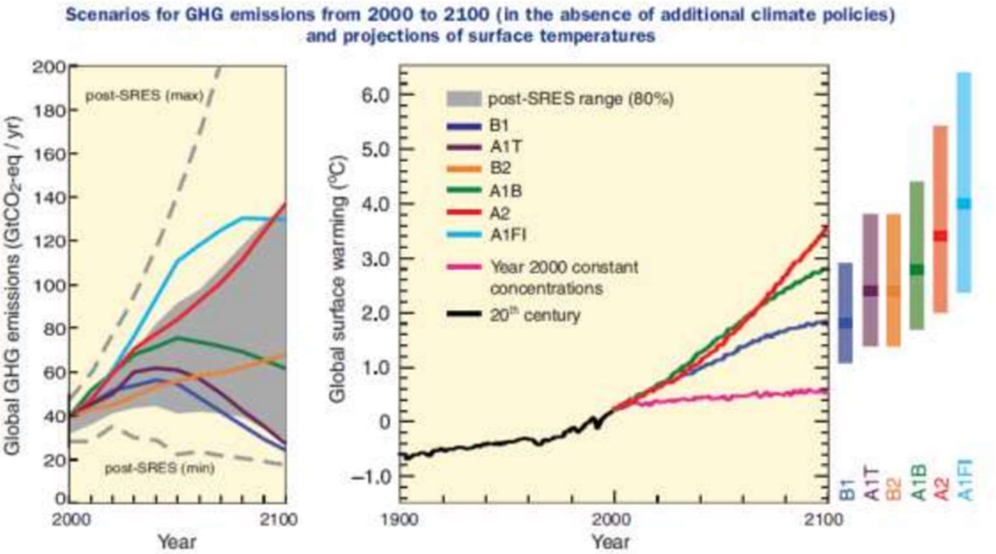

Figure A-4. Left Panel: Global GHG emissions (in $GtCO_2^{-eq}$) in the absence of additional climate policies: six illustrative SRES marker scenarios (coloured lines) and the 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases.

Right Panel: Solid lines are multi-model global averages of surface warming for scenarios A2, A1B and B1, shown as continuations of the 20th-century simulations. These projections also take into account emissions of short-lived GHGs and aerosols. The pink line is not a scenario, but is for Atmosphere-Ocean General Circulation Model (AOGCM) simulations where atmospheric concentrations are held constant at year 2000 values. The bars at the right of the figure indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios at 2090-2099. All temperatures are relative to the period 1980-1999.

(Source: IPCC Fourth Assessment Report, Synthesis Report, Summary for Policymakers, Figure SPM.5)

Table A-2. Projected changes in global mean surface tempearture and changes in global mean sea level, by scenario

Emissions Scenario	Temperature change (℃)	Sea level rise (m)
	Long term (2090–2099)	Long term (2090–2099)
SRES B1	1.1–2.9 (1.8)	0.18–0.38
A1T	1.4–3.8 (2.4)	0.20–0.45
B2	1.4–3.8 (2.4)	0.20–0.43
A1B	1.7–4.4 (2.8)	0.21–0.48
A2	2.0–5.4 (3.4)	0.23–0.51
A1F1	2.4–6.4 (4.0)	0.26–0.59

・Projections indicate the change from the mean over the base period 1980–1999.
・( ) Numbers in parentheses indicate best estimate.

Addendum: Correlation between SRES Scenarios and RCP Scenarios

Regarding the correlations between SRES, RCP and SSP scenarios, studies have been done to compare the SRES and SSP socio-economic development scenarios and the SRES and RCP radiative forcing and climate characteristics, and they have shown the suitable combinations of RCPs and SSPs that correspond to the SRES scenarios. While these are general tendencies, the studies have indicated the correlations shown in the following table.

Table A-3. Relation between RCP Scenarios and SRES Scenarios

RCP Scenarios	SRES Scenarios
RCP8.5 and SSP5	SRES A1FI
RCP8.5 and SSP3	SRES A2
RCP6.0 and SSP2	SRES B2 and A1B
RCP4.5 and SSP1	SRES B1
RCP2.6	No corresponding SRES scenario

The SSP scenarios were developed based on quantitative and qualitative components that represent common features of society, such as population, governance, equity, socioeconomic development, technology, and environment, etc., and provide a basis for climate change impact assessments as well as analysis of mitigation and adaptation strategies. (SSP1 sustainability, SSP2 middle of the road, SSP3 regional rivalry, SSP5 fossil-fueled development)

Source: Detlef P. van Vuuren & Timothy R. Carter (2014) Climate and socio-economic scenarios for climate change research and assessment: reconciling the new with the old. Climate Change 122: pp 415-429. DOI 10.1007/s10584-013-0974-2.

Table A-4. Projected changes in global mean surface temperature and global mean sea level, by RCP concentration scenario

Concentration Scenario	Temperature change (°C)		Sea level rise (m)	
	Medium term (2046–2065)	Long term (2081–2100)	Medium term (2046–2065)	Long term (2081–2100)
RCP 2.6	0.4–1.6 (1.0)	0.3–1.7 (1.0)	0.17–0.32 (0.24)	0.26–0.55 (0.40)
4.5	0.9–2.0 (1.4)	1.1–2.6 (1.8)	0.19–0.33 (0.26)	0.32–0.63 (0.47)
6.0	0.8–1.8 (1.3)	1.4–3.1 (2.2)	0.18–0.32 (0.25)	0.33–0.63 (0.48)
8.5	1.4–2.6 (2.0)	2.6–4.8 (3.7)	0.22–0.38 (0.30)	0.45–0.82 (0.63)

・Projections indicate the change from the mean over the base period 1986–2005.
・Numbers in parentheses indicate the mean value of projections.

Prepared from the following sources:
IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.
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3. Database for Policy Decision making for Future climate change (d4PDF, d2PDF)

Using high-resolution global atmospheric models and high-resolution regional climate models for an unprecedented number of ensemble experiments, the “Program for Risk Information on Climate Change” and “Social Implementation Program on Climate Change Adaptation Technology”(SI-CAT) under the Ministry of Education, Culture, Sports, Science and Technology have developed the database for Policy Decision making for Future climate change (d4PDF and d2PDF), which can be useful for extensive discussions about recreating events and changes of extreme weather that are the tails of probability density distributions.

With d4PDF and d2PDF, which consist of stochastic climate projection data, it is possible to use ensemble experiments to assess future changes in extreme phenomena such as tropical cyclones and torrential rains, probabilistically and with high accuracy.

Appendix B: Organization for this Review

(1) Expert Committee on Climate Change Impact Assessment, Global Environment Committee, Central Environment Council, Ministry of the Environment, Japan

(In Japanese spelling order, family name first, with honorific titles omitted)

Role	Name	Position and Affiliation
Expert	Akiba Michihiro	Department Director, Department of Environmental Health, National Institute of Public Health
Expert	Akimoto Keigo	Group Leader and Chief Researcher, Systems Analysis Group, Research Institute of Innovative Technology for the Earth
Ad hoc	Asano Naoto	Professor Emeritus, Fukuoka University
Expert	Ishikawa Yoichi	Japan Agency for Marine-Earth Science and Technology Director, Information Engineering Program
Expert	Isobe Masahiko	President, Kochi University of Technology
Ad hoc	Emori Seita	Deputy Director, Center for Global Environmental Research, National Institute for Environmental Studies
Expert	Oki Taikan	Senior Vice-Rector, United Nations University; Assistant Secretary-General, United Nations; Special Advisor to President, The University of Tokyo
Expert	Kitoh Akio	Researcher, Research Promotion Department, Japan Meteorological Business Support Center
Expert	Kidokoro Hideaki	Specially Appointed Director, Administration Department, Fisheries Resources Research Institute, Japan Fisheries Research and Education Agency (FRA)
Expert	Kimoto Hideaki	Professor, Atmosphere and Ocean Research Institute (AORI), The University of Tokyo
Expert	Saijo Masayuki	Director, Department of Virology 1, National Institute of Infectious Diseases
Expert	Sasaki Takashi	Research Coordinator for River Structures, River Department, National Institute for Land and Infrastructure Management (NILIM), Ministry of Land, Infrastructure, Transport and Tourism
Expert	Shirato Yasuhito	Global Warming Research Supervisor, Agricultural and Environmental Change Research Center, National Agriculture and Food Research Organization
Ad hoc	## Sumi Akimasa	Professor Emeritus, The University of Tokyo Project Professor, Institute for Future Initiatives, The University of Tokyo
Expert	Takahashi Kiyoshi	Deputy Director, Center for Social and Environmental Systems Research, National Institute for Environmental Studies
Regular	Takamura Yukari	Professor, Institute for Future Initiatives, The University of Tokyo
Expert	Takayabu Izuru	Senior Researcher, First laboratory, Department of Climate and Geochemistry Research, Meteorological Research Institute, Japan Meteorological Agency

Role	Name	Position and Affiliation
Ad hoc	Tanaka Mitsuru	Professor, Department of Policy Science on Society, Faculty of Social Sciences, Hosei University
Expert	Nakakita Eiichi	Professor, Hydrometeorological Disasters Research Section, Research Division of Atmospheric and Hydrospheric Disasters, Disaster Prevention Research Institute, Kyoto University
Expert	Nojiri Yukihiro	Professor, Faculty of Science and Technology, Hirosaki University
Expert	Hashizume Masahiro	Professor, Department of Global Health Policy, Graduate School of Medicine, The University of Tokyo
Expert	Hijioka Yasuaki	Deputy Director, Center for Climate Change Adaptation (CCCA), National Institute for Environmental Studies
Expert	Hirata Yasumasu	Research Director, Forestry and Forest Products Research Institute, Forest Research and Management Organization
Expert	Fukami Kazuhiko	Supervisor of Research Planning, Planning Department, Public Works Research Institute
Ad hoc	Furumai Hiroaki	Professor, Department of Civil Engineering, The University of Tokyo Professor
Ad hoc	Masui Toshihiko	Head, Integrated Environment and Economy Section, Center for Social and Environmental Systems Research, National Institute for Environmental Studies
Expert	Matsui Tetsuya	Head, Climate Change Laboratory, Center for International Partnerships and Research on Climate Change, Forestry and Forest Products Research Institute, Forest Research and Management Organization
Expert	Mikami Masao	Deputy Director, Research Promotion Department, and Director, International Affairs Division, Japan Meteorological Business Support Center
Regular	Mimura Nobuo	Project Professor, Global and Local Environment Co-creation Institute, Ibaraki University
Expert	Yasuoka Yoshifumi	Professor Emeritus, The University of Tokyo
Expert	Yamada Tadashi	Professor, Department of Civil and Environmental Engineering, Faculty of Science and Engineering, Chuo University
Expert	Yamano Hiroya	Director, Center for Environmental Biology and Ecosystem Studies, National Institute for Environmental Studies

Chair of Committee

(2) Sectoral Working Groups concerning Climate Change Impacts (Ministry of the Environment, Japan Commissioned Study Groups)

1) Agriculture, Forest/Forestry, Fisheries Working Group

(In Japanese spelling order, family name first, with honorific titles omitted)

Name	Position and Affiliation
Andoh Tadashi	Senior Researcher, Biological Functions Group, Aquaculture Division, Fisheries Technology Research Institute, Japan Fisheries Research and Education Agency
Iizumi Toshichika	Senior Researcher, Impact Projection Unit, Climate Change Response Research Domain, Agricultural and Environmental Change Research Center, National Agriculture and Food Research Organization
Okada Kunihiko	Department Director, Department of Vegetable and Floriculture Science, National Agriculture and Food Research Organization
Kidokoro Hideaki	Specially Appointed Director, Administration Department, Fisheries Resources Research Institute, Japan Fisheries Research and Education Agency (FRA)
Kojima Kamitsu	Professor, Biological Resources Development Division, Asian Natural Environmental Science Center, The University of Tokyo
# Shirato Yasuhito	Global Warming Research Supervisor, Agricultural and Environmental Change Research Center, National Agriculture and Food Research Organization
Sugiura Toshihiko	Unit Leader, Garden Environment Unit, Division of Production and Distribution Research, Fruit and Tea Research Division, National Agriculture and Food Research Organization
Nonaka Itoko	Unit Leader, Micronutrient Management Unit, Livestock Metabolism Nutrient Research Domain, Livestock Research Department, National Agriculture and Food Research Organization
Hasegawa Toshihiro	Leader, Agricultural Meteorology Group, Division of Agro-Environment Research, Tohoku Agricultural Research Center, National Agriculture and Food Research Organization
Hirata Yasumasa	Research Director, Forestry and Forest Products Research Institute, Forest Research and Management Organization
Masumoto Takao	Professor, Faculty of Bioresource Science, Akita Prefectural University
Matsumura Masaya	Division Head, Insect and Pest Damage Research Division, Central Regional Agricultural Research Center, National Agriculture and Food Research Organization
Miyata Akira	National Agriculture and Food Research Organization, Division Head, Climate Change Response Research Division, former Agricultural and Environmental Change Research Center
Yoshida Goro	Group Head, Seaweed Production Group, Resources and Environment Department, Seto Inland Sea National Fisheries Research Institute, Japan Fisheries Research and Education Agency

Chair of Working Group

2) Water Environment / Water Resources and Natural Disasters / Coastal Areas Working Group

(In Japanese spelling order, family name first, with honorific titles omitted)

Name	Position and Affiliation
Akiba Michihiro	Department Director, Department of Environmental Health, National Institute of Public Health
Isobe Masahiko	President, Kochi University of Technology
Emori Seita	Deputy Director, Center for Global Environmental Research, National Institute for Environmental Studies
Kuriyama Yoshiaki	President, National Institute of Maritime, Port and Aviation Technology
Sasaki Takashi	Research Coordinator for River Structures, River Department, National Institute for Land and Infrastructure Management (NILIM), Ministry of Land, Infrastructure, Transport and Tourism
Daimaru Hiromu	Research Director (Land Conservation and Water Resources Research), Forestry and Forest Products Research Institute, Forest Research and Management Organization
Takewaka Satoshi	Professor, Information and Systems, University of Tsukuba
Nagai Yoshiki	Director, Sediment Disaster Prevention, Sabo Department , National Institute for Land and Infrastructure Management (NILIM), Ministry of Land, Infrastructure, Transport and Tourism
Nakaegawa Toshiyuki	Head, Second Lab, Department of Applied Meteorology Research, Meteorological Research Institute, Japan Meteorological Agency
# Nakakita Eiichi	Professor, Hydrometeorological Disasters Research Section, Research Division of Atmospheric and Hydrospheric Disasters, Disaster Prevention Research Institute, Kyoto University
Fukami Kazuhiko	Supervisor of Research Planning, Planning Department, Public Works Research Institute
Fujita Masaharu	Professor, Research Center for Fluvial and Coastal Disasters, Disaster Prevention Research Institute, Kyoto University
Furumai Hiroaki	Professor, Department of Civil Engineering, The University of Tokyo
Masumoto Takao	Professor, Faculty of Bioresource Science, Akita Prefectural University
Yagi Hiroshi	Professor, Department of Civil and Environmental Engineering, School of Systems Engineering, National Defense Academy of Japan
Yamada Tadashi	Professor, Department of Civil and Environmental Engineering, Faculty of Science and Engineering, Chuo University

Chair of Working Group

3) Natural Ecosystems Working Group

(In Japanese spelling order, family name first, with honorific titles omitted)

Name	Position and Affiliation
Ono Tsuneo	Head, International Resources and Environment Group, Oceanic Resources Division, Fisheries Resources Research Institute, Japan Fisheries Research and Education Agency
Wada Naoya	Professor, Center for Far Eastern Studies, University of Toyama
Nakamura Futoshi	Professor, Division of Fundamental Agriscience Research, Graduate School of Agriculture, Hokkaido University
Nishihiro Jun	Director, Climate Change Impacts Observation and Monitoring Lab, Center for Environmental Biology and Ecosystem Studies, National Institute for Environmental Studies
Nojiri Yukihiro	Professor, Faculty of Science and Technology, Hirosaki University
Matsui Tetsuya	Head, Climate Change Laboratory, Center for International Partnerships and Research on Climate Change, Forestry and Forest Products Research Institute, Forest Research and Management Organization
Maruyama Yutaka	Professor, Department of Forest Science and Resources, College of Bioresource Sciences, Nihon University
# Yamano Hiroya	Director, Center for Environmental Biology and Ecosystem Studies, National Institute for Environmental Studies

Chair of Working Group

4) Human Health Working Group

(In Japanese spelling order, family name first, with honorific titles omitted)

Name	Position and Affiliation
Ueda Kayo	Associate Professor, Graduate School of Global Environmental Studies, Kyoto University
Ohmae Hiroshi	Project Professor, Dokkyo Medical University
Ono Masaji	Visiting Researcher, National Institute for Environmental Studies
Saijo Masayuki	Director, Department of Virology 1, National Institute of Infectious Diseases
Sawabe Kyoko	Senior Researcher, Department of Medical Entomology, National Institute of Infectious Diseases
# Hashizume Masahiro	Professor, Department of Global Health Policy, Graduate School of Medicine, The University of Tokyo
Honda Yasushi	Visiting Researcher, National Institute for Environmental Studies

Chair of Working Group

5) Industrial / Economic Activities and Life of Citizenry and Urban Life Working Group

(In Japanese spelling order, family name first, with honorific titles omitted)

Name	Position and Affiliation
Akimoto Keigo	Group Leader and Chief Researcher, Systems Analysis Group, Research Institute of Innovative Technology for the Earth
Kameyama Yasuko	Director, Center for Social and Environmental Systems Research, National Institute for Environmental Studies
Takamura Yukari	Professor, Institute for Future Initiatives, The University of Tokyo
Tanaka Mitsuru	Professor, Department of Policy Science on Society, Faculty of Social Sciences, Hosei University
Nakano Katsuyuki	Associate Professor, College of Policy Science, Graduate School of Policy Science, Ritsumeikan University
Nansai Keisuke	Head, International Material Cycles Section, Center for Material Cycles and Waste Management Research, National Institute for Environmental Studies
Fujibe Fumiaki	Project Professor, Urban Environmental Sciences, Tokyo Metropolitan University
# Masui Toshihiko	Head, Integrated Environment and Economy Section, Center for Social and Environmental Systems Research, National Institute for Environmental Studies
Misaka Ikusei	Professor, Department of Architecture, Faculty of Architecture, Nippon Institute of Technology
Murata Akihiko	Head, First Lab, Department of Applied Meteorology Research, Meteorological Research Institute, Japan Meteorological Agency

Chair of Working Group