Climate Change in Japan 2025

Report on Assessment of Observed/Projected Climate Change Relating to the Atmosphere, Land and Oceans

March 2025

Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Japan Meteorological Agency (JMA)

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The original version of Climate Change in Japan 2025 is Japanese, and this document is its English translation.

Climate Change in Japan 2025

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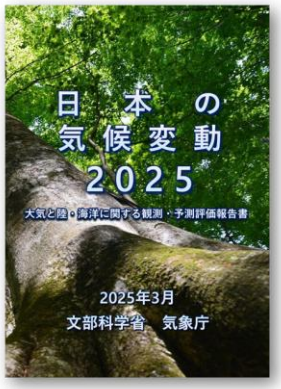
- Climate change progressing globally and regionally. ➡ Paris Agreement (2℃ goal)
- Climate Change Adaptation Act (Act No. 50, 13 June 2018)

  ➡ Climate Change Adaptation Plan (Cabinet Decree, 27 November 2018)

  Climate change actions to be promoted based on scientific findings.
- MEXT & JMA published Climate Change in Japan (2020) summarizing a physical science basis to serve as essential information for climate change action by the public, commercial enterprises and local/national government bodies.

  ➡ Utilized in the Assessment Report on Climate Change Impacts in Japan and other publications.
- In March 2025, MEXT & JMA published Climate Change in Japan 2025, incorporating recent findings and outcomes.
- **The main publication** provides an overview of observed/projected climate change. Related content (in Japanese) includes:
  - **Details:** More detailed information (including evidence and references) intended for use by researchers and experts considering countermeasures in individual fields
  - **Summary (this document):** Simplified slides of the main publication intended for use as-is in study sessions, presentations and other work
  - **Leaflets by prefecture:** Double-page leaflets providing overviews of observed/projected climate change for individual regions



- Others (in Japanese)
  - **Public page:** https://www.data.jma.go.jp/cpdinfo/ccj/index.html
  - **HTML version:** https://www.data.jma.go.jp/cpdinfo/ccj/2025/html_honpen/cc2025_honpen_index.html
  - **Introductory video:**

    Learn more about climate change from dialogue between weather forecasters and JMA officials.

    https://www.data.jma.go.jp/cpdinfo/ccj/movie/index.html
  - **Copyright:** https://www.data.jma.go.jp/cpdinfo/ccj/2025/html_honpen/cc2025_honpen_13.html#source

1. Introduction
2. Observed/Projected Climate Variables
3. Summary

Global Warming and Climate Change

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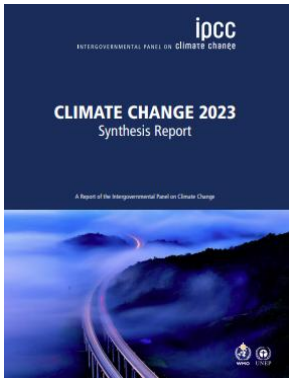
- Climate Change in Japan 2025 – Glossary
  - **Global warming:** A phenomenon in which the average temperature of the earth's surface rises due to the effects of greenhouse gases generated from human activities (as per the Act on Promotion of Global Warming Countermeasures)
  - **Climate change:** Changes in temperature, precipitation and other climate variables due to natural variability and global warming

- The IPCC*1 Sixth Assessment Report*2 states, "**It is unequivocal that human influence has warmed the atmosphere, ocean and land.**"*3
- It has also been reported that due to human-induced climate change, **the frequency and intensity of extremes such as heatwaves and heavy precipitation are increasing**, and that **unless further strengthened measures are taken, the changes will become even larger**.



IPCC Sixth Assessment Report (2023)

*1 Intergovernmental Panel on Climate Change. With the collaboration of scientists from around the world, the Panel regularly produces reports assessing recent scientific findings on climate change.

*2 This consists of the Working Group I report (The Physical Science Basis, released August 2021), the Working Group II report (Impacts, Adaptation and Vulnerability, released February 2022), the Working Group III report (Mitigation of Climate Change, released April 2022) and the Synthesis Report (released March 2023).

*3 The Fifth Assessment Report (2013 – 2014) concluded, "Warming of the climate system is unequivocal" and "It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century."

Climate Change and Changes in Atmospheric/Oceanic Variables

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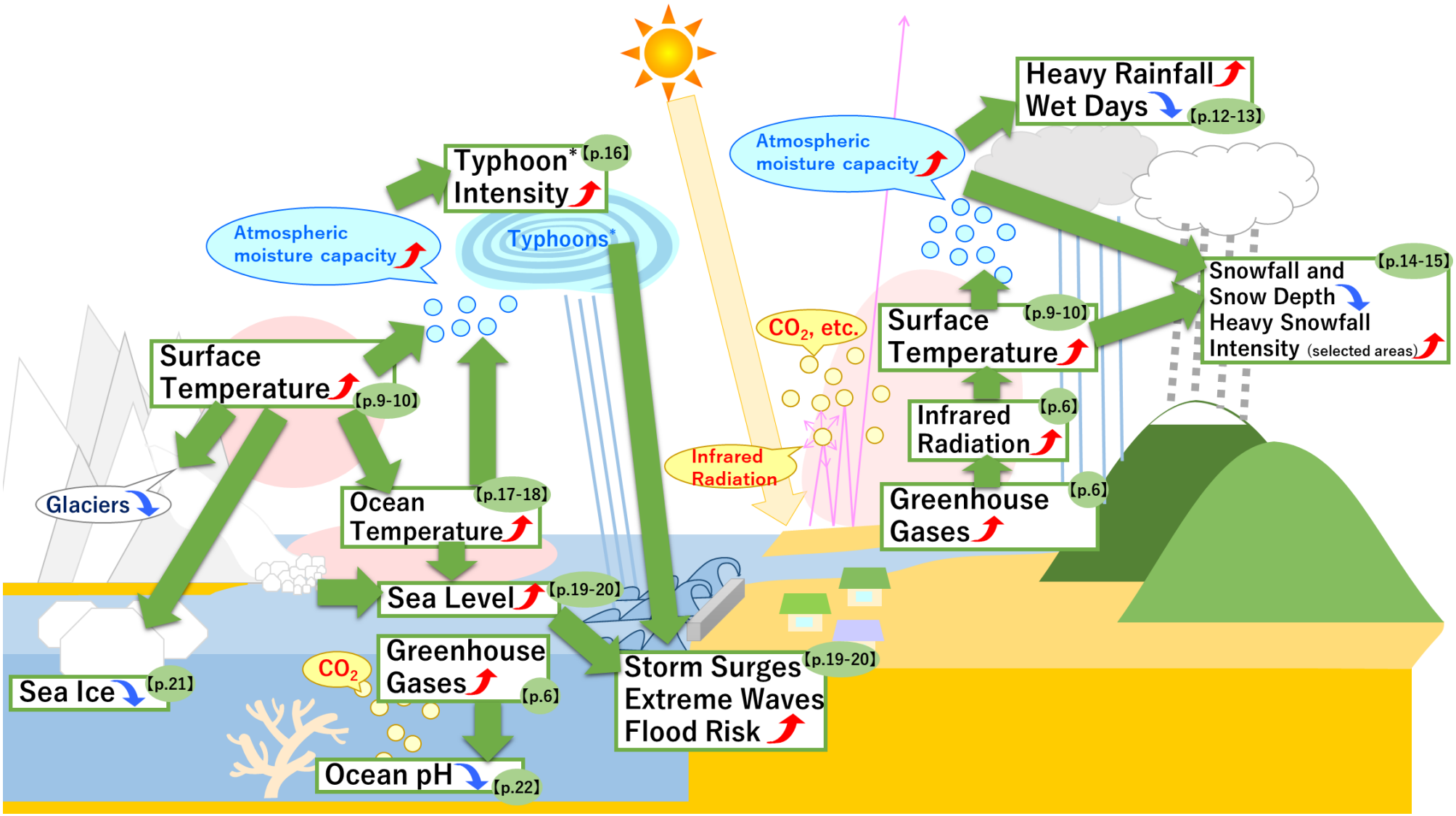
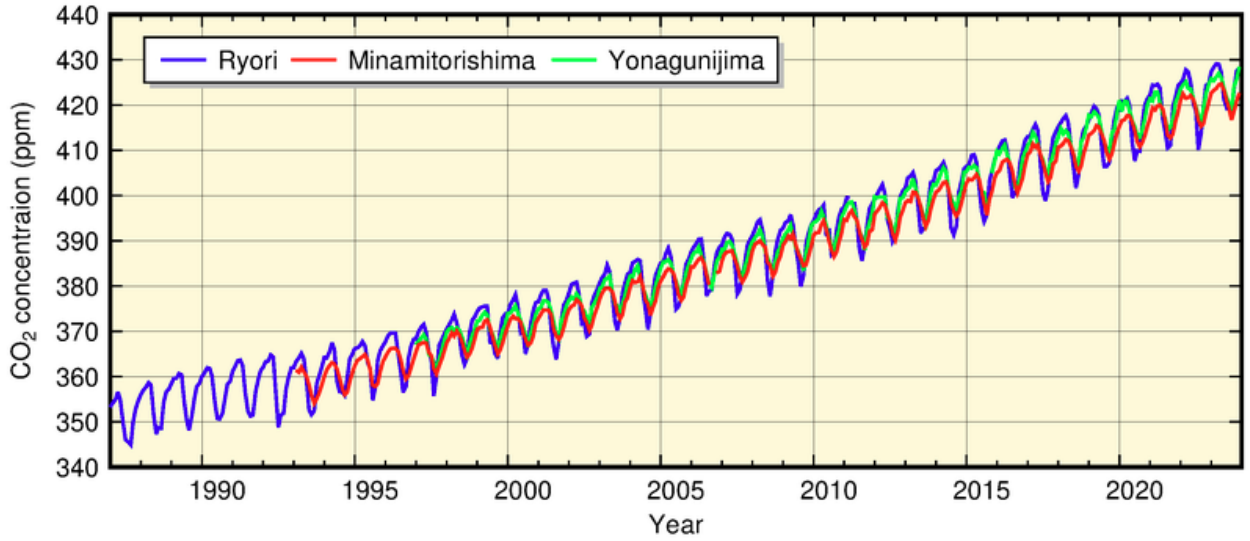


* The term "typhoon" here refers to tropical cyclones with maximum wind speeds of ≥ 34 kt forming over the western North Pacific and the South China Sea.

Atmospheric GHGs

- Atmospheric concentrations of the major greenhouse gases CO_2, CH_4 and N_2O have been higher than at any time in at least 800,000 years (IPCC, 2021).
  - The global mean atmospheric concentrations of CO_2, CH_4 and N_2O in 2023 were around 1.5, 2.7 and 1.2 times higher, respectively, than pre-industrial levels (around 1750) (WMO, 2024).
  - Atmospheric concentrations of CO_2, CH_4 and N_2O observed in Japan also continue to increase.
- Downward infrared radiation from the atmosphere is increasing.

This corresponds to the intensity of the Greenhouse Effect.
The earth's surface becomes warmer, and global warming progresses.



Monthly mean concentrations of atmospheric CO_2 (in Japan)

References

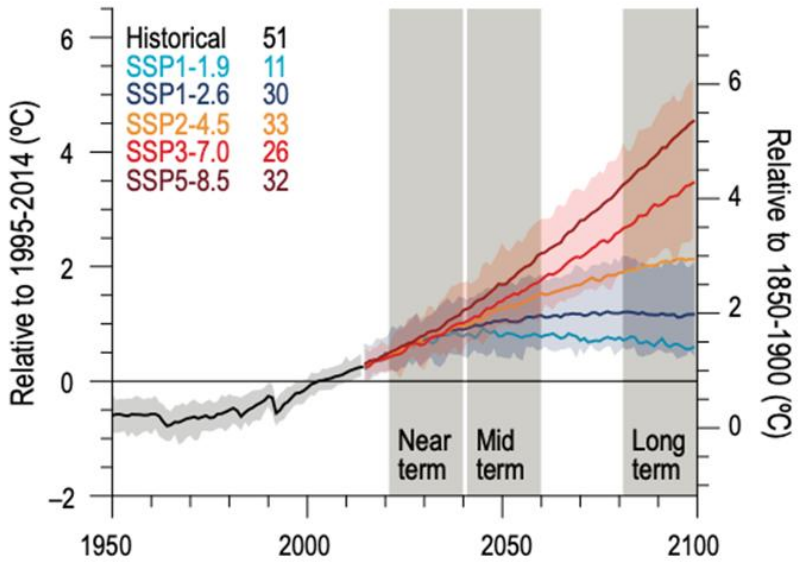
IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to theSixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P.Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger,N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M.Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews,T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp., https://doi.org/10.1017/9781009157896.

WMO, 2024: WMO Greenhouse Gas Bulletin, No. 20, https://library.wmo.int/idurl/4/69057.

2/4℃ Warming Scenarios

- Here, climate projections are based on the **2**/**4**℃ Warming Scenarios (**RCP2.6** and **RCP8.5**, respectively) used in the IPCC Fifth Assessment Report.*1
  - The **2℃ Warming Scenario** corresponds to potential climatic conditions **with achievement of the Paris Agreement's 2℃ goal**.
  - The **4℃ Warming Scenario** corresponds to potential climatic conditions **with no future additional mitigation measures**.

SSP1-2.6 is similar to RCP2.6, and SSP5-8.5 is similar to RCP8.5.*1



2℃ and 4℃ are global average temperature rises compared to pre-industrial levels*2.

Global surface air temperature changes from historical and scenario simulations
Curves: Averages over climate model simulations
Shading around SSP1-2.6 and SSP3-7.0 curves: 5 – 95% ranges
*The numbers near the top show the number of model simulations used.
(Based on IPCC (2021))

*1 Projections in the main publication of Climate Change in Japan 2025 are based on the Shared Socio-economic Pathway (SSP) scenarios used in the IPCC Sixth Assessment Report as far as possible. However, for areas around Japan, projections based on the RCP scenarios used in the IPCC Fifth Assessment Report are generally used, as these have many referenceable research results. As this summary mainly contains information for areas around Japan, projections are based on the RCP scenarios unless otherwise specified.

*2 Although large-scale industrial activity began around 1750, the IPCC defines "pre-industrial" as 1850 – 1900, the earliest period of sufficiently globally complete observations allowing estimation of global surface temperature.

References

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp., https://doi.org/10.1017/9781009157896.

1. Introduction

2. Observed/Projected Climate Variables

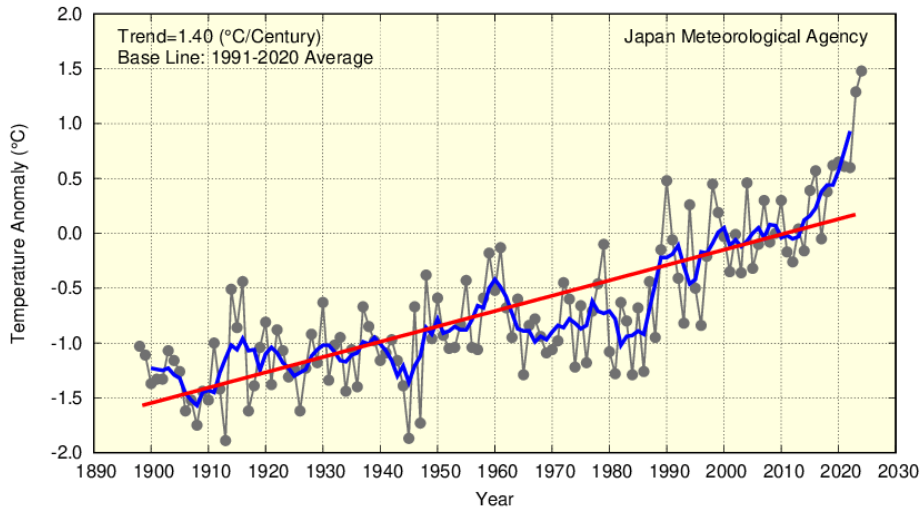
3. Summary

New ! : This section highlights new analysis and other work conducted since the publication of Climate Change in Japan (2020).

! : This section highlights matters (other than observed/projected climate variables) that could pose risks to humanity and ecosystems.

Surface Temperature [Observations]

- **Annual surface temperature*:** Virtually certain to have risen at a rate of 1.40℃ per century between 1898 and 2024.
  - ➢ Average temperatures at urban stations (e.g., Tokyo) have increased at a higher rate than the national average due to the heat island effect stemming from urbanization.
- **Extreme temperature events:** It is virtually certain that since 1910 (since 1929 for days with minimum temperatures (T_{min}) of ≥ 25℃), the annual numbers of days with maximum temperatures (T_{max}) of ≥ 30℃ and ≥ 35℃ and T_{min} of ≥ 25℃ have increased, while the number of T_{min} < 0℃ days has decreased.



● : Surface temperature anomaly for each year (anomalies: deviations from the 1991 – 2020 average)
— : Five-year running mean
— : Long-term linear trend

Annual Japan average temperature anomalies (1898 – 2024)

New !

Global warming effects in recent extreme temperature events

- Event attribution shows that some recent extreme temperature events, such as the July 2018 high temperatures and the July 2023 high temperatures, would not have occurred without global warming.

Event attribution assesses how global warming affects the frequency and intensity of extreme events via simulations under real conditions and conditions with no global warming.

* Based on data from 15 observation stations considered to be relatively uninfluenced by urbanization

Surface Temperature [Projections]

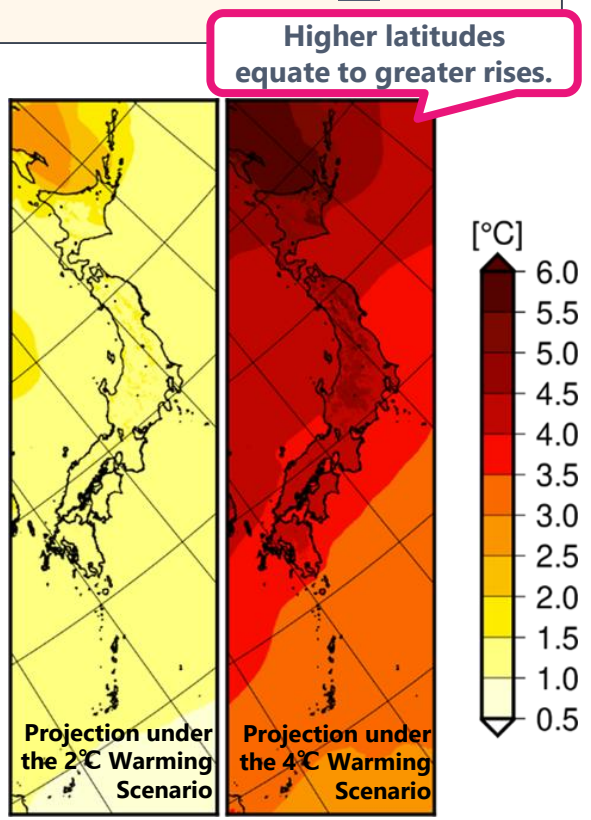
- **Annual surface temperature:** Projected to rise under both scenarios.
  - The temperature rise is larger under the 4℃ Warming Scenario than under the 2℃ Warming Scenario.
  - Under the same scenarios, higher latitudes correspond to larger increases in temperature. Values are also higher in winter than in summer.
- **Extreme temperature events:** Under both scenarios, more T_{max} ≥ 35℃ / T_{min} ≥ 25℃ days and fewer T_{min} < 0℃ days are projected in many regions.

	2℃ Warming Scenario Potential conditions with achievement of the Paris Agreement's 2℃ goal	**4℃ Warming Scenario** Potential conditions with no future additional mitigation measures
Annual surface temperature	Approx. +1.4℃	Approx. +4.5℃
Annual global average surface temperature*(IPCC, 2021)	(Approx. +1.1℃)	(Approx. +3.7℃)
T_{max} ≥ 35℃ days per year	Approx. +2.9 days	Approx. +17.5 days
T_{min} ≥ 25℃ days per year	Approx. +8.2 days	Approx. +38.0 days
T_{min} < 0℃ days per year	Approx. -16.6 days	Approx. -46.2 days

New !

Projected changes in centennial extreme temperatures

- Centennial extreme temperatures with pre-industrial conditions are projected to occur approximately 99 times with a 4℃ rise.
- Those in conditions with a 4℃ rise are projected to be approximately 5.9℃ higher than centennial values with pre-industrial conditions.



Changes in annual surface temperature at the end of the 21st century relative to the end of the 20th century

* Projections based on SSP scenarios, comparing the average for 2081 – 2100 to that for 1986 – 2005.

References

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to theSixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P.Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger,N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M.Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews,T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp., https://doi.org/10.1017/9781009157896.

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What does a 1℃ rise in average temperature mean?

- The term "more than a 1℃ rise in average temperature compared to pre-industrial times" refers to the average change in temperature from the past to the present; daily temperature variations will be **biased higher over the long term**.

Specifically, the term does not mean "a temporary increase of 1℃ above normal in a day"; rather, it is an average increase of 1℃ in overall temperature variation.

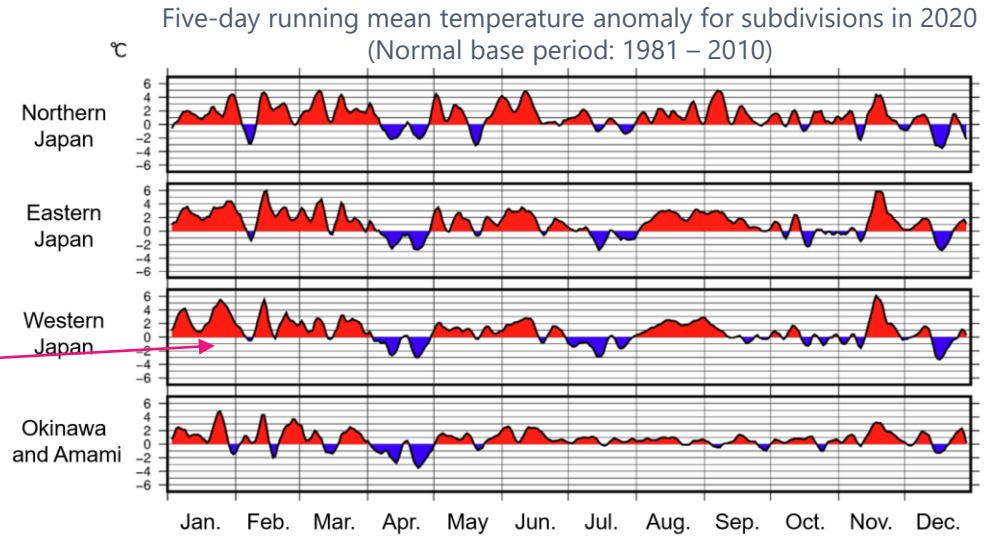
- Temperature increases due to global warming also **vary by region, season and other factors**.

For simplicity, here "temperature rise due to global warming" is replaced with "temperature anomaly in a single year."

The average temperature anomaly throughout 2020 was generally around +1℃ in each region.

However, temperatures are not uniformly high in all regions and periods; values vary, with some values being nearly 6℃ above normal.

Some areas and periods exhibit lower-than-normal temperatures, but the general bias is toward the warmer end of the spectrum.



➡ **The actual daily and regional temperature increase due to global warming does not remain at 1℃; hotter days and regions will emerge.**

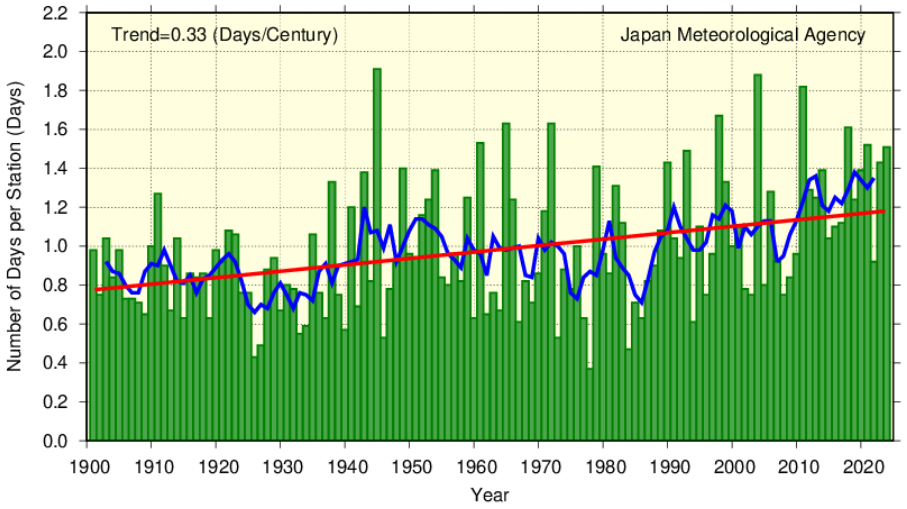
- These changes also affect the occurrence of **extreme temperature events**.
- **The effects of global warming are not limited to temperature. Precipitation, sea water temperature and sea level are also affected** (see p. 5).

Precipitation [Observations]

- **Heavy rainfall events:** Frequency has risen, with heavier rainfall equating to a higher rate of increase.
  - It is extremely likely that annual maximum daily precipitation has increased.
  - It is virtually certain that the annual number of days with precipitation of < 1.0 mm has also increased.

These observations indicate clear rainfall extremes at both ends of the scale.

- **Annual precipitation:** No discernible long-term trend is observed over the past period of approximately 130 years.



■: Annual number of days for each year (number of days per year per station calculated by dividing the total number of days per year from 51 observation stations nationwide by the total number of valid observation stations)
−: Five-year running mean
−: Long-term linear trend

Annual number of days with precipitation ≥ 100 mm (1901 – 2024)

New !

Global warming effects in recent extreme precipitation events

- Event attribution shows that the occurrence rate and intensity of recent extreme precipitation events were increased by global warming.
- Examples include the Heavy Rain Event of July 2018 (June 28 – July 8).
  - Global warming has caused an increase in the occurrence rate of extreme three-day precipitation levels observed only once every 50 years in the Seto Inland Sea region by a factor of approximately 3.3.
  - Due to warming in Japan over the past 40 years, total precipitation in western Japan has risen by approximately 6.7%.

Precipitation [Projections]

- **Heavy rainfall events:** Under both scenarios, the national average frequency is projected to increase.
  - ➢ Annual maximum daily precipitation is also projected to increase.

This means that extreme rainfall is projected to increase in both frequency and intensity.

- **Annual precipitation:** No statistically significant change is projected.
- The Baiu rain band is projected to intensify in early summer (June).

	2℃ Warming Scenario Potential conditions with achievement of the Paris Agreement's 2℃ goal	**4℃ Warming Scenario** Potential conditions with no future additional mitigation measures
Annual number of events with precipitation ≥ 50 mm/h	Approx. x1.8 increase	Approx. x3.0 increase
Annual number of days with precipitation ≥ 100 mm	Approx. x1.2 increase	Approx. x1.4 increase
Annual maximum daily precipitation	Approx. +12% (+13 mm)	Approx. +27% (+28 mm)
Annual number of days with precipitation < 1.0 mm	No statistically significant change	Approx. +9.1 days

New !

Projected changes in centennial extreme precipitation*

- Centennial extreme precipitation (daily) with pre-industrial conditions is projected to occur approximately 5.3 times in conditions with a 4℃ rise.
- Centennial daily precipitation amounts with a 4℃ rise are projected to increase by approximately 32% compared to that with pre-industrial conditions.

* Calculations here are based on daily precipitation.

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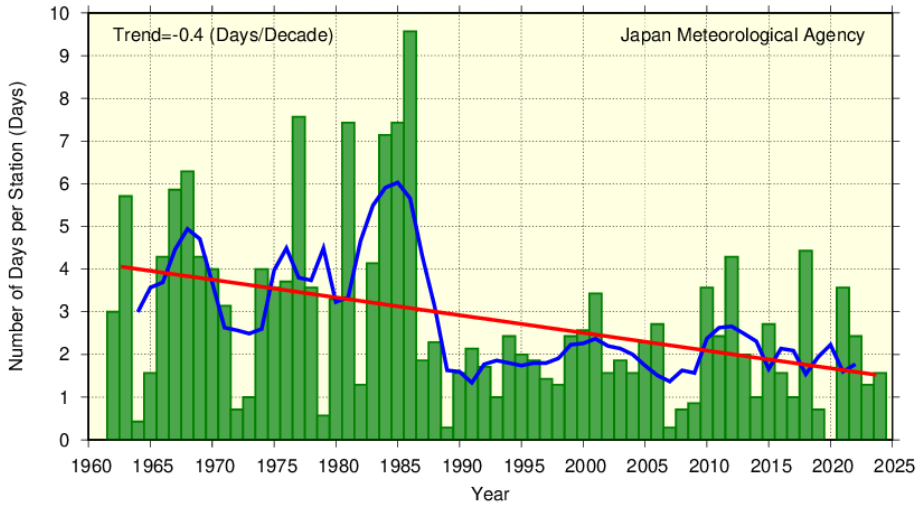
Snow [Observations]

- **Annual maximum snow depth:** Extremely likely to have decreased in each region* on the Sea of Japan side since 1962.
  - ➢ However, it is particularly difficult to capture long-term trends because of large interannual variations in annual maximum snow depth and the relatively short observation period.
- It is virtually certain that the annual number of heavy snowfall events (such as ≥ 20 cm per day) has decreased for the Sea of Japan side of eastern and western Japan*.



■: Annual numbers of days averaged for each year at observation stations* on the Sea of Japan side of eastern Japan (days per station)
—: Five-year running mean
—: Long-term linear trend

[The Sea of Japan side of eastern Japan] Annual number of days with snowfall ≥ 20 cm (1962 – 2024)

New !

Effects of global warming in recent extreme snowfall events

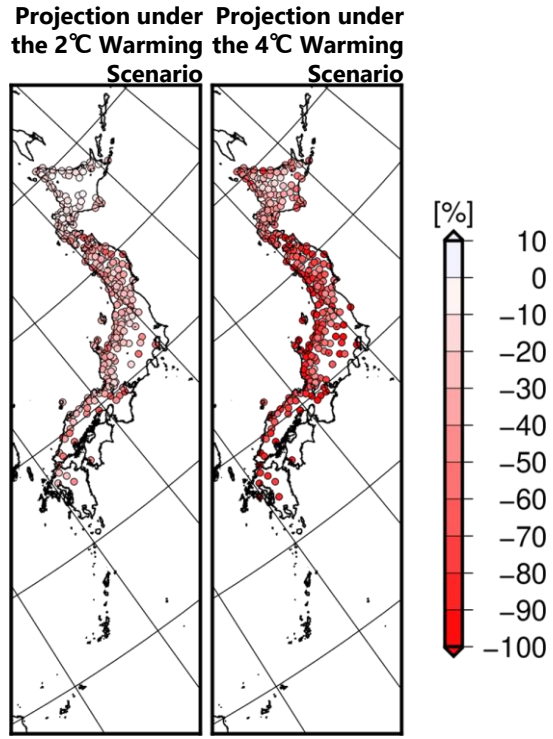
- In recent years, temporary heavy snowfall has continued to cause incidents with significant social impacts, including the heavy snowfall events of January/February 2018 and in December 2020.
- Event attribution shows that global warming caused increased snowfall in some cases.

* See Figure 1.4.3 and Table 6.2.1 in Climate Change in Japan 2025 "Details" for observation sites.

Snow [Projections]

- **Annual maximum snow depth and snowfall:** Projected to decrease for all of Japan under the 4℃ Warming Scenario (Honshu and southward: 2℃ Warming Scenario).
  - ➢ Even if average snowfall decreases, actual snowfall may increase during extreme events in some areas, such as mountainous regions of Honshu.
- **Snowfall period:** Projected to be shorter under the 4℃ Warming Scenario (delayed start, early end).

	2℃ Warming Scenario Potential conditions with achievement of the Paris Agreement's 2℃ goal	**4℃ Warming Scenario** Potential conditions with no future additional mitigation measures
Annual maximum snow depth and snowfall	Approx. -30% (Changes in Hokkaido are expected to be small, and are difficult to project.)	Approx. -60%
Snowfall period	(Change unclear)	Shorter (Delayed start, early end)



Percentage changes in annual maximum snow depth at the end of the 21st century relative to the end of the 20th century

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Tropical Cyclones (Typhoons*, etc.) [Observations/Projections]

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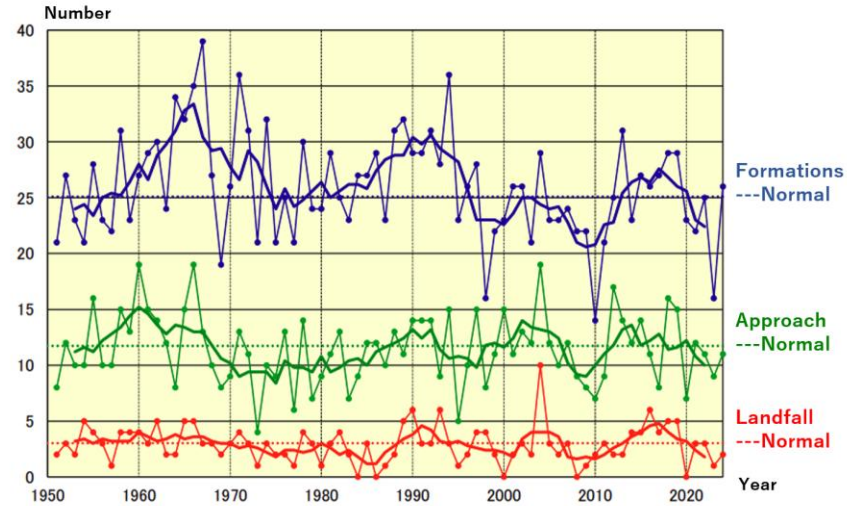
[Observations]

- No significant long-term trend is observed in the number of typhoons formed and the number approaching in Japan.
  - The number of typhoons approaching the Pacific side of Japan has increased over the last 40 years (Yamaguchi and Maeda, 2020).
- The latitude at which tropical cyclones in the western North Pacific reach peak intensity has shifted northward (IPCC, 2021).



Time-series representation of the number of typhoons approaching Japan and making landfall there (1951 – 2024).
Thin and thick lines represent annual and five-year running means, respectively.

[Projections]

Intensity and size differ.
It is not yet clear whether size will increase.

- Individual typhoons near Japan are projected to intensify.
  - This is thought to be due to the effects of increased water vapor and rising sea temperatures associated with global warming.
- Precipitation associated with typhoons is also projected to increase.

! Extreme weather events such as lightning strikes, hail and tornadoes are often linked to well-developed cumulonimbus clouds associated with typhoons.

! While assessment of individual future changes is challenging, the risk of their occurrence may increase with typhoon intensity.

* The term "typhoon" here refers to tropical cyclones with maximum wind speeds of ≥ 34 kt forming over the western North Pacific and the South China Sea.

References

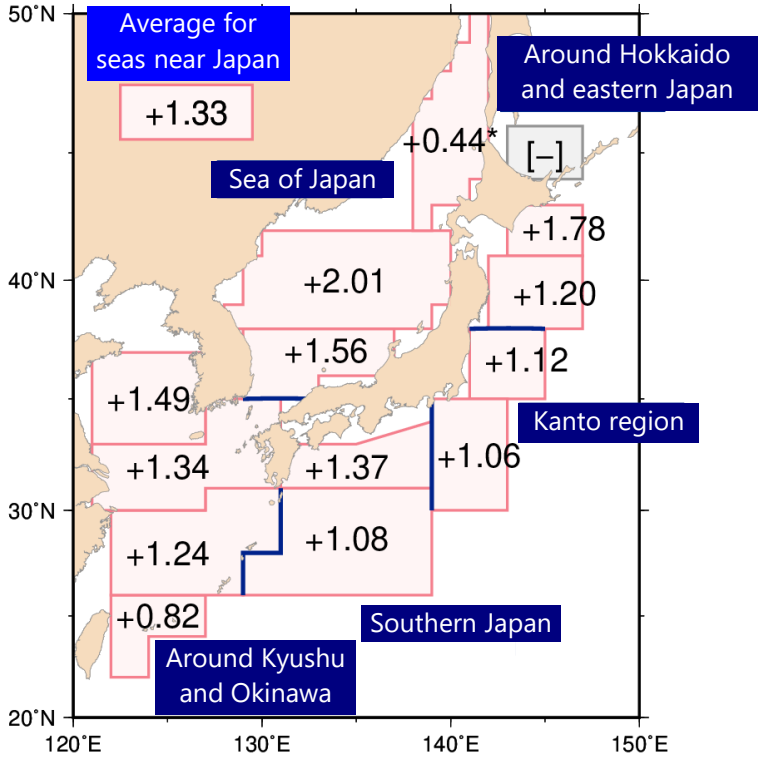
Yamaguchi, M. and S. Maeda, 2020: Increase in the Number of Tropical Cyclones Approaching Tokyo since 1980. Journal of the Meteorological Society of Japan, 98(4), 775 – 786, https://doi.org/10.2151/jmsj.2020-039.

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to theSixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P.Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger,N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M.Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews,T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp., https://doi.org/10.1017/9781009157896.

The projections on this slide are based on various research efforts involving analysis of typhoon changes associated with global warming.

Sea Surface Temperature [Observations]

- **Average sea surface temperature (SST) around Japan:** Virtually certain to have risen by +1.33℃ per century until 2024.
  - The rate of increase is more than twice the global average. Values are thought to be higher around Japan due to the influences of land warming up readily and the Kuroshio, a warm current.
  - The rate of increase depends on seasonal change and sea areas.

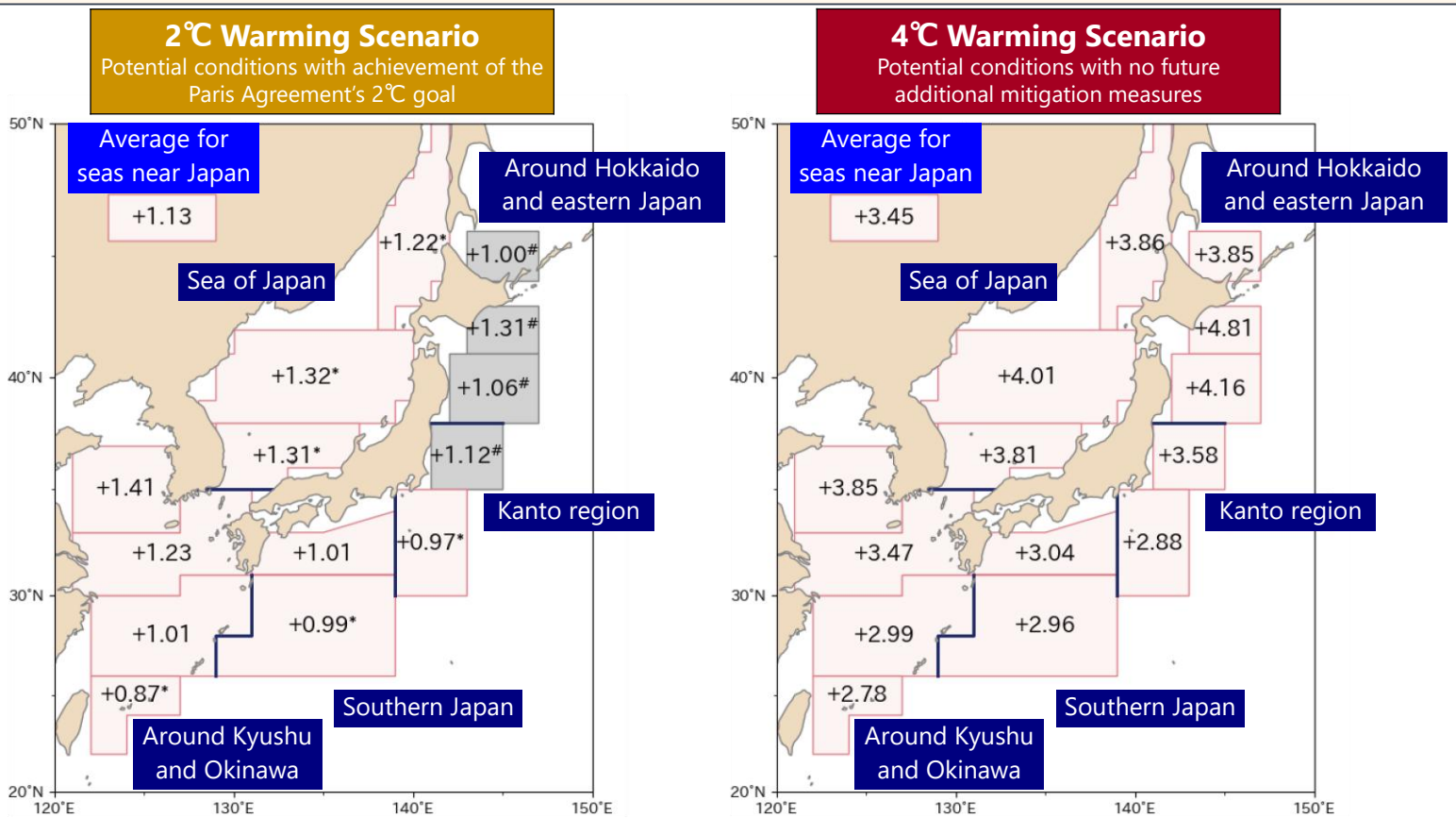


Increase rates of area-averaged annual mean SSTs around Japan from 1900 to 2024 **(℃/century)**

Areas with no symbols and those marked with [*] have virtually certain and extremely likely trends, respectively. As data from before the 1960s for the sea off Abashiri are scarce, no analysis of long-term trends has been conducted, and the rate of increase is shown as [-].

Sea Surface Temperature [Projections]

- **SSTs around Japan:** Projected to <u>increase</u> under both scenarios.
  - The projected increase exceeds the global average.
  - The projected increase is not uniform, with larger changes in the Yellow Sea under the 2℃ Warming Scenario and in the sea off Kushiro/Sanriku under the 4℃ Warming Scenario.



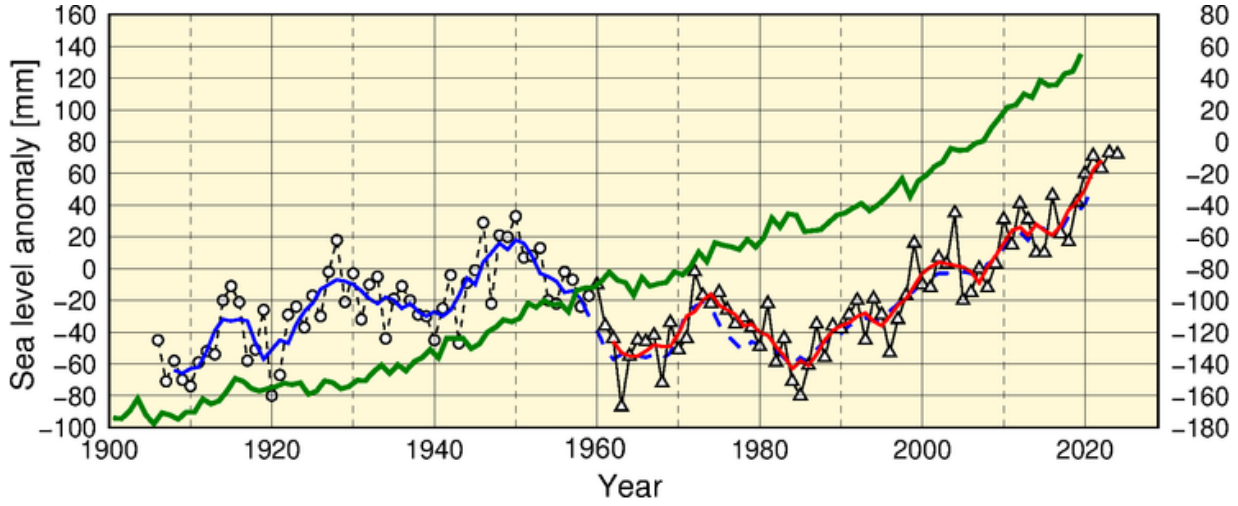
Projected **<u>changes</u>** in area-averaged SSTs around Japan at the end of the 21st century compared to the end of the 20th century **<u>(℃/century)</u>**

Areas with no symbols, those marked with [*], and those marked with [#] have virtually certain trends, extremely likely trends, and no discernible trend, respectively.

Unless otherwise specified, the term "projections" on this slide refers to those for all of Japan at the end of the 21st century compared to the end of the 20th century.

Sea Level, Storm Surges and Extreme Waves [Observations]

- **Mean sea level (MSL):** It is extremely likely that a trend of rise has occurred since the1980s along the coast of Japan, although some long-period variability (assumed to be natural variability) is predominant over the whole period.
- **Storm surges:** No discernible long-term trend is observed in frequency/intensity along the coast of Japan.
  - Assessment is challenging due to influences such as typhoon intensity/landfall numbers and port structures.
- **Extreme waves:** An increasing tendency in heights around Japan has been reported.
  - However, there is no agreement on whether this is due to global warming or natural variability.



Time-series representation of annual MSL around Japan (1906 – 2024)

○: Annual MSL anomalies averaged over four stations —: Five-year running mean
△: The same for 16 stations —: Five-year running mean
* For both dots, the scale is on the left of the figure (anomaly from the 1991 – 2020 average).

—: Global MSL
* The scale is on the right of the figure (anomaly from the 1991 – 2020 average).
* Global average analysis from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Climate Science Centre

Sea Level, Storm Surges and Extreme Waves [Projections]

- **MSL:** Projected to continue rising during the 21st century along the coast of Japan.
- **Storm surges:** Projected to increase in intensity in Tokyo Bay, Osaka Bay and Ise Bay.
  - ➢ This is because multiple projections often result in an increased number of strong typhoons.
- **Extreme waves:** While the average height of waves is projected to decrease along the coast of Japan, the height of extreme waves caused by typhoons is projected to increase in many sea areas.
  - ➢ Projection is challenging due to uncertainty in typhoon path projection and large amounts of natural variability.

	2℃ Warming Scenario Potential conditions with achievement of the Paris Agreement's 2℃ goal	**4℃ Warming Scenario** Potential conditions with no future additional mitigation measures
Mean sea level along the coast of Japan*	Approx. +0.40 m	Approx. +0.68 m
Global mean sea level* (IPCC, 2021)	(Approx. +0.44 m)	(Approx. +0.77 m)

* Projections based on the SSP scenario
"Mean sea level along the coast of Japan" is derived from projections comparing the average for 2081 – 2100 to the average for 1986 – 2005.
"Global mean sea level" is derived from projections comparing the 2100 value to the average for 1995 – 2014.

! Long-term mean sea level rise is projected to exacerbate flood risk due to a bottoming out of impacts from storm surges and extreme waves.

References
IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to theSixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P.Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger,N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M.Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews,T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp., https://doi.org/10.1017/9781009157896.

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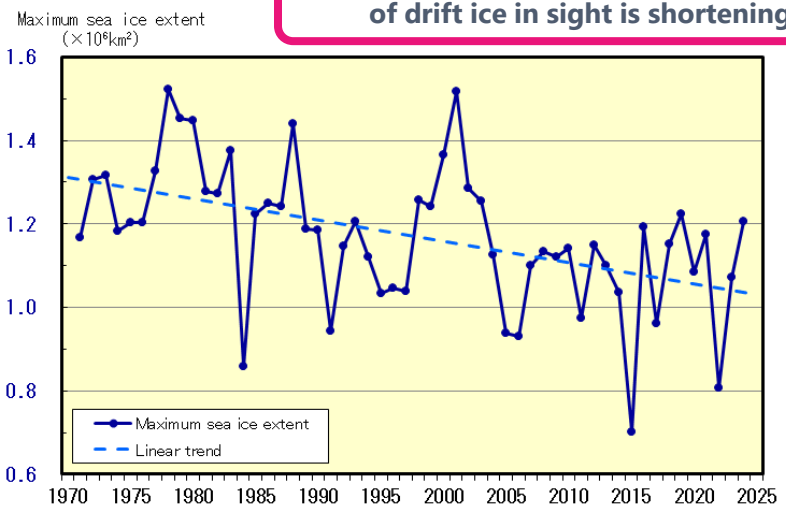
Sea Ice [Observations/Projections]

[Observations]

- **Sea ice extent:** It is virtually certain that the maximum sea ice extent in the Sea of Okhotsk exhibits a long-term trend of decrease.
  - The maximum extent has decreased by 0.051 × 10^6 km^2 per decade (approximately the same area as Kyushu and Shikoku combined).
- At Abashiri, it is extremely likely that the first date of drift ice in sight has become 1.3 days later per decade and the last date of drift ice in sight has become 3.6 days earlier per decade.

The period between the first and last dates of drift ice in sight is shortening.



Time-series representations of maximum sea ice extent for the Sea of Okhotsk (1971 – 2024)

[Projections]

- **Sea ice extent:** In March, when the sea ice extent in the Sea of Okhotsk is at its maximum, the value is projected to decrease under both scenarios.
  - The amount of sea ice drifting toward the coast of Hokkaido is expected to decrease along with reduced sea ice formation along the Siberian coast.
- Under the 4℃ Warming Scenario and the intermediate GHG emissions scenario, the Arctic Ocean is likely to be practically sea ice-free in late summer before the mid-21st century and is projected to become practically sea ice-free in late summer by the end of the 21st century (IPCC, 2021).

	2℃ Warming Scenario Potential conditions with achievement of the Paris Agreement's 2℃ goal	**4℃ Warming Scenario** Potential conditions with no future additional mitigation measures
Sea ice extent in the Sea of Okhotsk in March	Approx. -32% (Within the range of variability in the present climate)	Approx. -78%

References

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to theSixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P.Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger,N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M.Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews,T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp., https://doi.org/10.1017/9781009157896.

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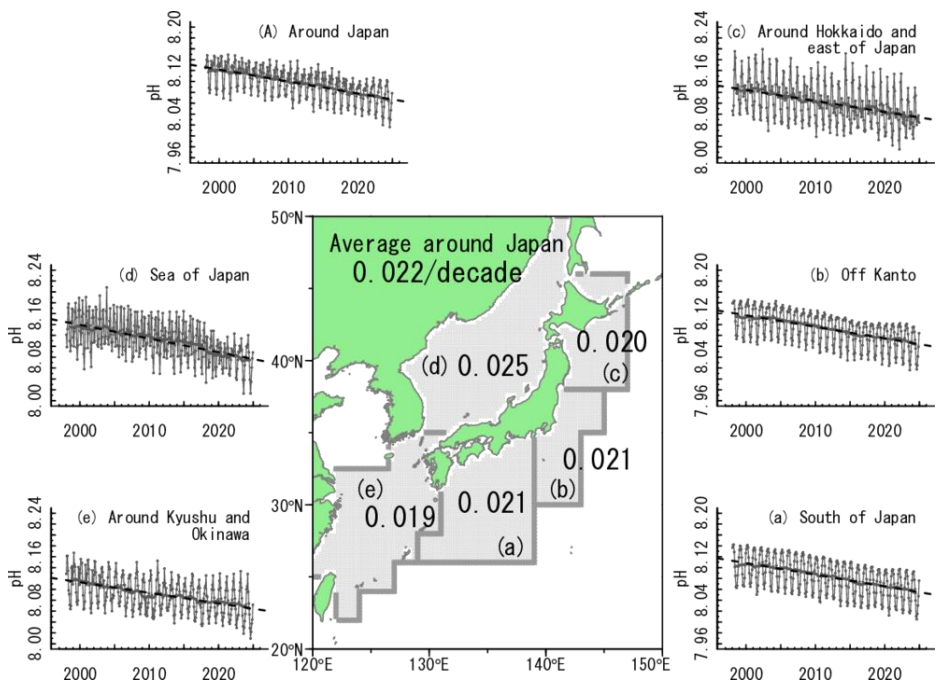
Ocean Acidification [Observations/Projections]

[Observations]

- The average trend of pH decrease in sea areas around Japan was 0.022 per decade for the period 1998 – 2024 (similar to the global average).



Long-term trends of pH decrease in sea areas around Japan (/decade)

Black points with lines, bold lines and dashed lines indicate monthly average pH values, 13-month running means and long-term trends in areas (a) to (e), and the average around Japan, respectively.

[Projections]

- Progressing ocean acidification in sea areas around Japan is projected at a rate similar to the global average.
- Under the 4℃ Warming Scenario, aragonite saturation (Ω_A)* is projected to begin to fall below 3 seasonally in the 2030s around Kyushu and Okinawa and in the south of Japan, and to fall below 3 throughout the year in the 2060s.
  - For the Sea of Japan and around Hokkaido and east of Japan, some project that aragonite will become seasonally unsaturated (Ω_A < 1) by the end of the 21st century.

	2℃ Warming Scenario Potential conditions with achievement of the Paris Agreement's 2℃ goal	4℃ Warming Scenario Potential conditions with no future additional mitigation measures
Surface seawater pH in sea areas around Japan	-0.06 – -0.09 (Ocean acidification is projected to stop by around 2060.)	-0.29 – -0.36

! There are concerns that ocean acidification may affect marine ecosystems because of its adverse influence on the ability of coral and shellfish to form skeletons and shells.

* A measure of the effect of ocean acidification on organisms with skeletons formed primarily of the mineral aragonite (principally calcium carbonate), such as coral.
When Ω_A is below 1, organisms have difficulty forming aragonite skeletons.
Even if Ω_A is above 1, a decrease will adversely affect growth rates. In this report, Ω_A = 3 was used as the threshold at which coral growth begins to be affected.

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Deoxygenation [Observations/Projections]

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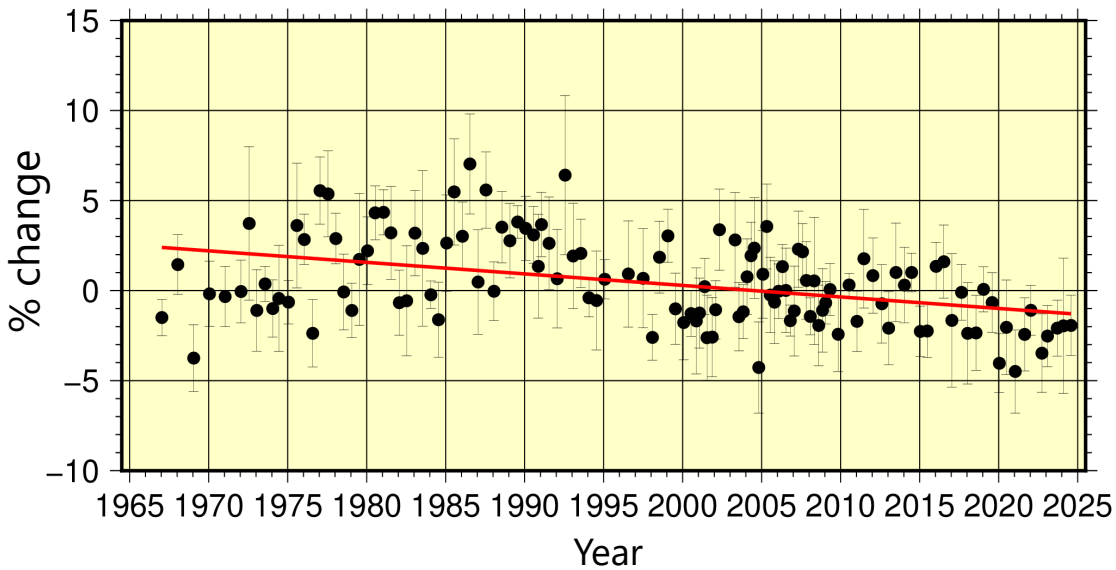
気象庁 Japan Meteorological Agency

[Observations]

- It is virtually certain that oxygen content in the upper 1,000 m of the ocean has decreased over southern Japan.
- The rate of progress in deoxygenation is similar to the global average.

[Projections]

- Oxygen content in the upper 1,000 m of the ocean is projected to continue its decrease during the 21st century over southern Japan under both scenarios.
- The progress of deoxygenation is projected at a rate similar to the global average.



●: Oxygen content anomaly in the upper 1,000 m of the ocean averaged for 20 – 25°N along 137°E for each cruise (anomalies: deviations from the 1991 – 2020 average). Error bars represent standard deviations from latitudinal averages for each cruise.
−: Long-term linear trend

Time-series representation of oxygen content in the upper 1,000 m of the ocean over southern Japan (1967 – 2024)

! There are concerns that deoxygenation may affect marine ecosystems, such as habitat shifts.

Unless otherwise specified, the term "projections" on this slide refers to those for all of Japan at the end of the 21st century compared to the end of the 20th century.

1. Introduction
2. Observed/Projected Climate Variables
3. Summary

Projection Summary

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気象庁 Japan Meteorological Agency

Projected climatic conditions for areas in and around Japan for the end of the 21st century relative to the end of the 20th century or present:

Yellow and red figures represent the 2℃ and 4℃ Warming Scenarios.

Annual surface temperature rise:

Approx. 1.4/4.5℃

With more T_{max} ≥ 35℃ days
more T_{min} ≥ 25℃ days
fewer T_{min} < 0℃ days

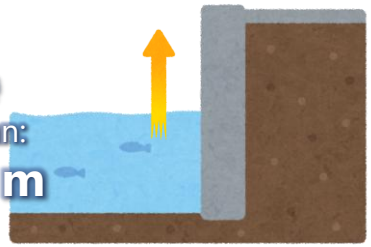
Sea surface temperature rise:

Approx. 1.13/3.45℃

The degree of rise exceeds the global average.

Sea level rise

along the coast of Japan:
Approx. 0.40/0.68 m



Snowfall and snow depth: Decrease

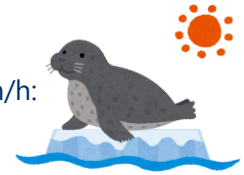
Rainfall rather than snow
Ongoing risk of heavy snow

Heavy rainfall events: More frequent

Annual maximum daily precipitation:
Approx. +12% (13 mm)/+27% (28 mm)
Annual number of events with precipitation ≥ 50 mm/h:
Approx. x1.8/x3.0 increase

Sea ice extent in the Sea of Okhotsk in March:

Approx. -32/-78%



Under the 4℃ Warming Scenario, the Arctic Ocean is projected to become practically sea ice-free in summer by the end of the 21st century (IPCC, 2021).

Typhoons*: Intensification

Precipitation associated with typhoons: Increase

Ocean acidification in sea areas around Japan: Progress at a rate similar to the global average

* The term "typhoon" here refers to tropical cyclones with maximum wind speeds of ≥ 34 kt forming over the western North Pacific and the South China Sea.

References

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to theSixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P.Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger,N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M.Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews,T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp., https://doi.org/10.1017/9781009157896.