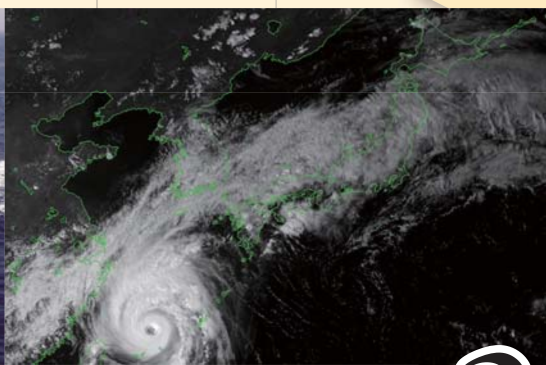
Climate Change Present and Future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Japan Meteorological Agency




Preface

The Intergovernmental Panel on Climate Change (IPCC) released its Fourth Assessment Report last year summarizing the newest scientific understanding of global warming. The report says that warming of the climate system is unequivocal, and that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas (GHG) concentrations. In addition to mitigation to reduce GHG emissions, the report points out the importance of adapting to the inevitable effects and risks of global warming.

The Japan Meteorological Agency (JMA) provides information based on operational earth observation and monitoring (including long-term air and sea-surface temperature changes) as well as the results of climate projections in reports such as Global Warming Projection in order to provide a basis for adaptation planning against global warming. Through the timely provision of weather warnings and advisories, it also supports adaptation to the increased occurrence of extreme weather events (such as heavy rainfall) expected as a result of global warming. JMA also contributes to the enrichment of scientific knowledge to support future mitigation planning by providing basic data and information on the emission/absorption of carbon dioxide through GHG measurements and the operation of the World Data Centre for Greenhouse Gases (WDCGG).

This brochure describes the current status of climate change and future global warming projection, and introduces JMA's activities in regard to climate observation, monitoring and projection.

Contents

back cover right-side picture : courtesy of Japan Center for Climate Change Actions (http://www.jccca.org/)

Part I Current State of Climate Change

Chapter 1. Current State of Greenhouse Gases

1 Atmospheric Greenhouse Gas Concentrations - Highest level on record -

Greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) contribute significantly to global warming. According to analyses of CO_2 from 1983 and N_2O from 1980, the global average of the annual mean atmospheric CO_2 and N_2O concentrations for 2006 reached record highs. Although growth rates of global mean CH_4 concentration have been close to zero in recent years, the global mean CH_4 concentration for 2006 remained at its highest level.

CO_2 is the most significant contributor to global warming of all the human-induced gases. Global mean atmospheric CO2 concentrations (Figure 1.1.1) have been increasing year by year because of human activities such as fossil fuel consumption. Growth rates of CO_2 have also increased in recent years.

Figure 1.1.2 shows the estimated distribution of CO_2 concentrations, which change seasonally due mostly to the influence of vegetation activities. In winter, CO_2 concentrations over continents are higher than those over the ocean due to inactive plant photosynthesis, and vice versa in summer.

These facts are ascertained through the analysis of greenhouse gas data observed around the world and reported to the WMO World Data Center for Greenhouse Gases (WDCGG) located at the Japan Meteorological Agency (JMA) (see Chapter 2 of Part III).

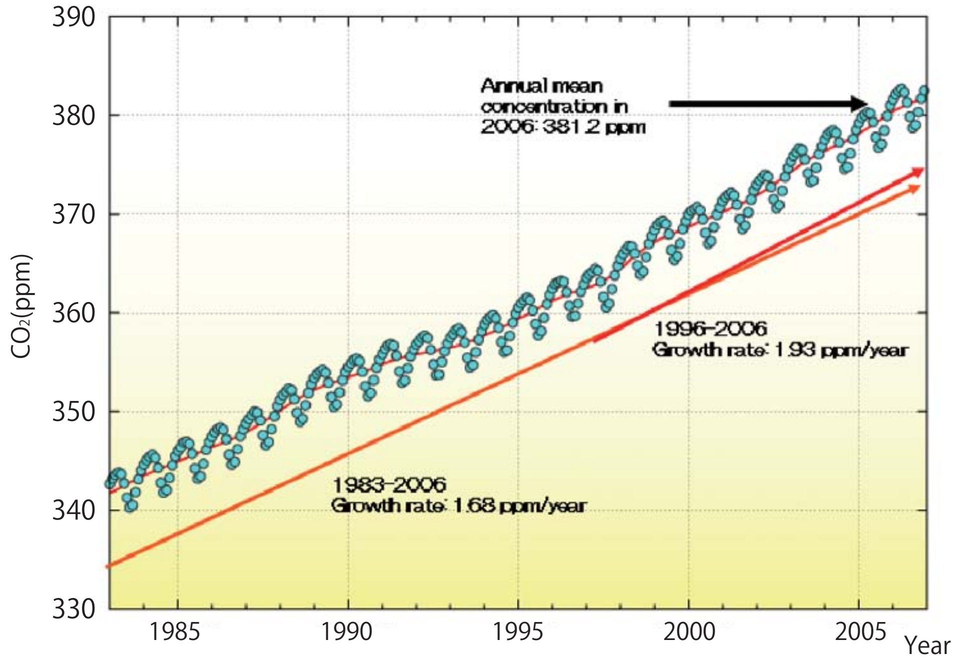


Figure 1.1.1 Time-series of global mean CO_2 concentrations
Blue dots: monthly concentration Thin red line: deseasonalized concentration

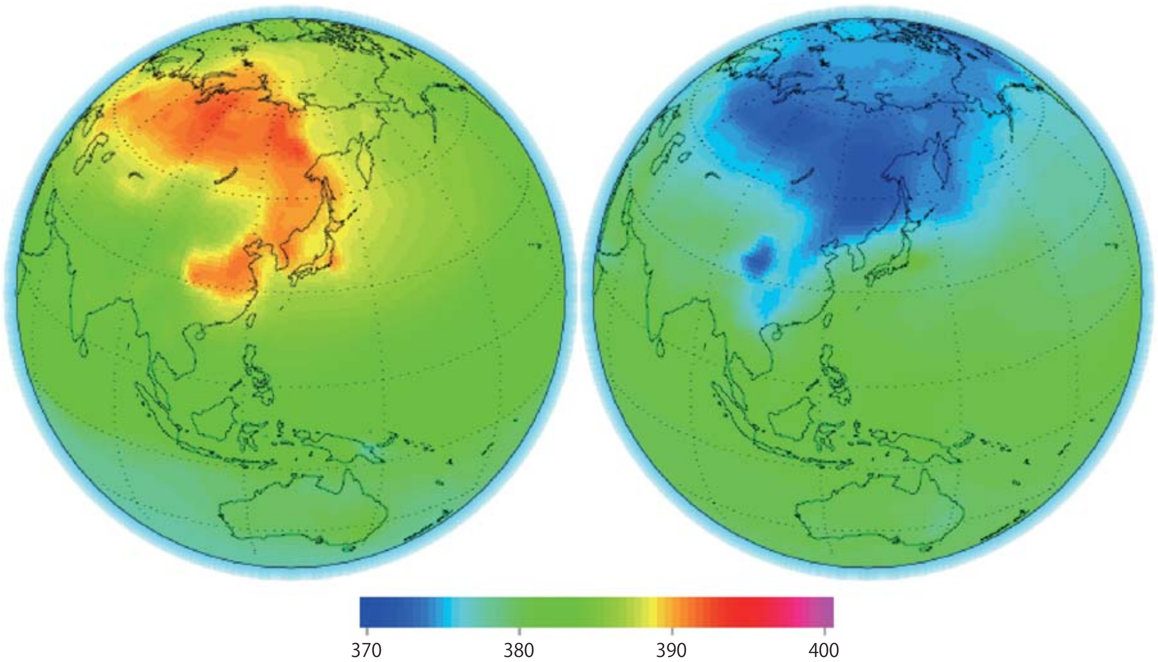


Figure 1.1.2 Estimated distribution of CO_2 concentrations
Left: February 2006 Right: August 2006

Figure 1.1.3 shows a time series of atmospheric CO_2 concentrations at three stations (Ryori, Minamitorishima and Yonagunijima) where JMA has carried out long-term monitoring. Concentrations in 2007 were the highest ever at all these stations, as also observed generally worldwide.

Moreover, the N_2O and CH_4 concentrations observed at these stations in 2007 were among the highest on record.

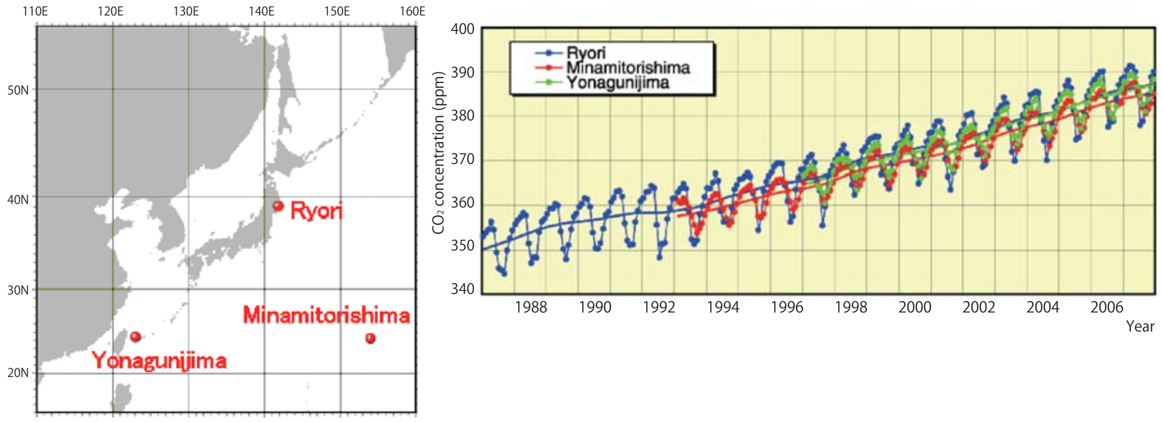


Figure 1.1.3 Left: JMA's three observational stations for greenhouse gases; Right: Time-series of monthly-mean atmospheric CO_2 concentrations (lines with dots) and deseasonalized concentrations (thin lines) at Ryori, Minamitorishima and Yonagunijima.

2 Oceanic Greenhouse Gas Concentrations - The western North Pacific is absorbing CO_2 -

The IPCC Fourth Assessment Report (AR4) shows that the ocean has so far absorbed about one third of net anthropogenic CO_2 emissions. In order to predict future atmospheric CO_2 concentration and global warming, it is very important to evaluate the amount of CO_2 taken up by the ocean. On a regional scale, the amount of oceanic CO_2 absorption changes from place to place and from season to season. These geographical and seasonal non-uniformities make it difficult to estimate global oceanic CO_2 uptake. In order to reduce the uncertainty of estimations, JMA conducts marine CO_2 observations in the air and seawater of the western North Pacific using research vessels.

Figure 1.1.4 shows a time-series graph of oceanic and atmospheric CO_2 concentrations along 137°E in winter. The oceanic CO_2 concentration rose by 40 ppm between 1984 and 2007. The growth rate in oceanic CO_2 is comparable to that in atmospheric CO_2. These data suggest that the western North Pacific is acting as a sink for atmospheric CO_2, and that there has been no appreciable change in the capacity for CO_2 uptake by the ocean in this region over the past 20 years.

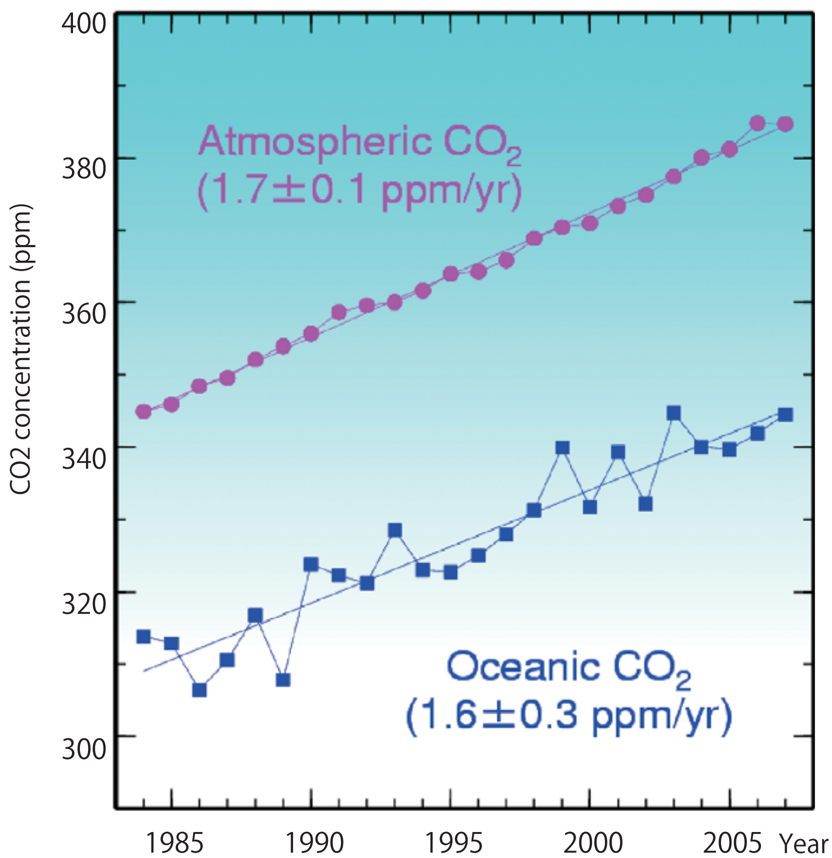


Figure 1.1.4 Time series of oceanic (blue lines) and atmospheric (pink lines) CO_2 concentrations averaged between 7°N and 33°N along 137°E in winter from 1984 to 2007.

Chapter 2. Long-term Trends of Climate Change

1 Global Surface Temperature and Precipitation - The global temperature is rising -

JMA operationally analyzes global surface temperatures and precipitation to monitor global warming.

Figure 1.2.1 shows annual anomalies of global average surface temperature (the average of the near-surface air temperature over land and the SST). The annual mean surface temperature has varied along different time scales ranging from a few years to several decades. On a longer time scale, global average surface temperatures analyzed by JMA have been rising at a rate of 0.67°C per century since 1891. The trend of the warming can be explained by fluctuations on different time scales ranging from several years to decades superimposed on global warming caused by the increase of greenhouse gases such as CO_2. According to the IPCC AR4, most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

Figure 1.2.2 shows a time series of annual precipitation ratios from 1880 to 2007 over the globe (for land areas only). There has not been any remarkable trend.

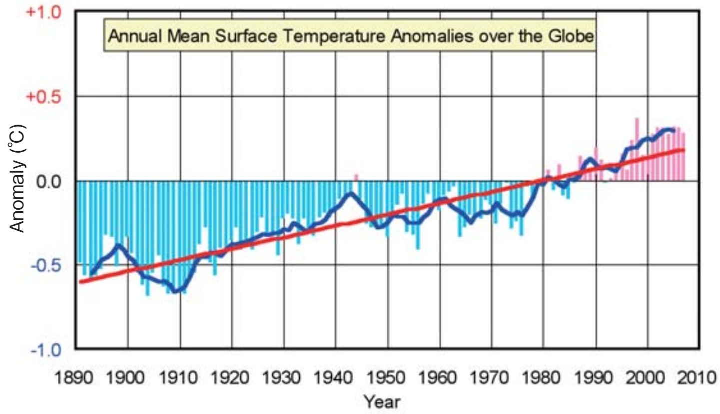


Figure 1.2.1 Annual anomalies in surface temperature (i.e. the average of the near-surface air temperature over land and the SST) from 1891 to 2007. Anomalies are deviations from the normal (i.e. the 1971-2000 average). The bars indicate anomalies in surface temperature for each year. The blue line indicates the five-year running mean, and the red line indicates the long-term linear trend.

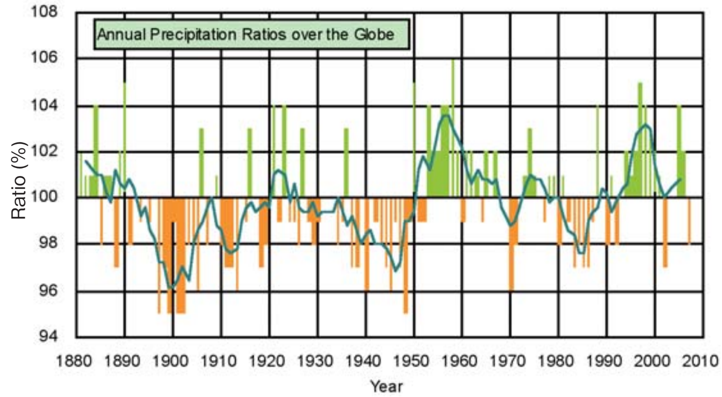


Figure 1.2.2 Annual precipitation ratios (land only) from 1880 to 2007. The bars indicate the ratios of annual precipitation to the normal (i.e. the 1971-2000 average). The green line indicates the five-year running mean.

2 Surface Temperature and Precipitation in Japan - Japan's air temperature is also rising -

In order to monitor long-term changes in surface temperature and precipitation, JMA has analyzed observations at its stations since 1898.

Figure 1.2.3 shows annual anomalies of average surface temperatures from 1898 to 2007 in Japan. The anomalies have been rising at a rate of 1.10°C per century since 1898. Surface temperatures in Japan have been rising at a faster rate than over the globe.

Figure 1.2.4 shows a time series of annual precipitation ratios from 1898 to 2007 in Japan. No long-term trend is detected in the nationwide annual precipitation ratios. Meanwhile, the fluctuations seem to have gradually increased for the last few decades.

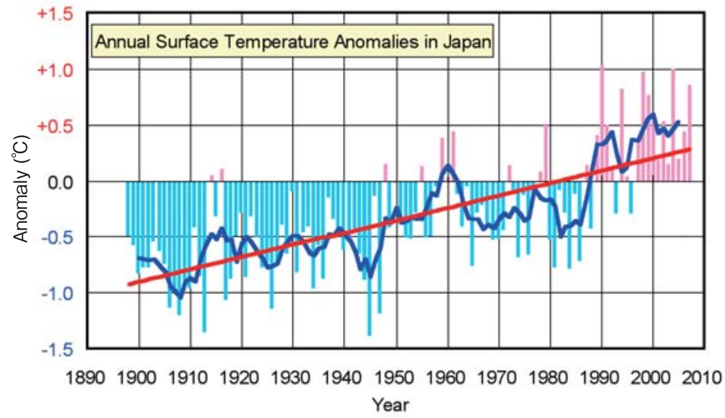


Figure 1.2.3 Annual surface temperature anomalies from 1898 to 2007 in Japan. The bars indicate anomalies from the normal (i.e. the 1971-2000 average of the 17 stations that have not been highly influenced by urbanization and have continuous long-term records). The blue line indicates the five-year running mean, while the red line indicates the long-term trend.

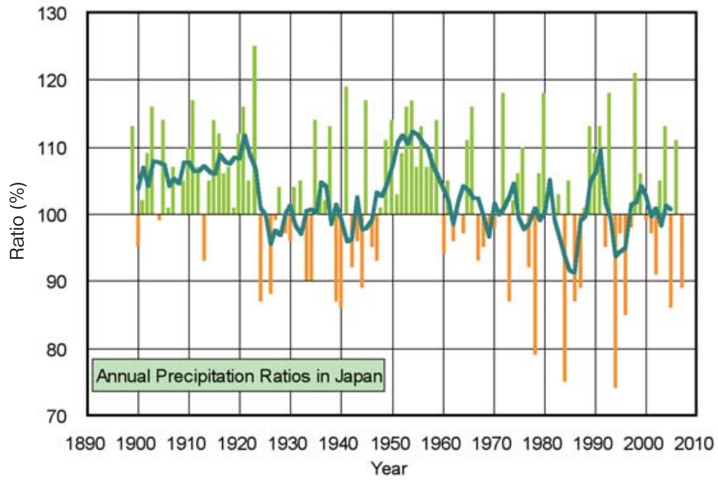


Figure 1.2.4 Annual precipitation ratios from 1898 to 2007 in Japan. The bars indicate annual precipitation ratios to the normal (i.e. the 1971-2000 average of the 51 stations). The green line indicates the five-year running mean.

3 Sea Surface Temperature and Sea Level around Japan

- The rate of SST rise around Japan is higher than the global average -

According to the IPCC AR4, long-term trends of regional average surface temperatures (the average of the near-surface air temperature over land and the sea surface temperature (SST) of the region) differ significantly from place to place.

According to JMA's investigation, the global average SST has risen by 0.5°C over the last 100 years, while SSTs have risen by 0.7°C to 1.7°C per century around Kyushu and Okinawa, the central and southern Sea of Japan, and the seas south of Japan (Figure 1.2.5). The rate of SST rise around Japan is higher than that of the global ocean.

According to the AR4, the total 20th-century increase in the global average sea level is estimated to be 0.12 to 0.22 m, and the sea level change is not geographically uniform. JMA's analysis over the last 100 years shows that there is no clear long-term trend in sea levels along the Japanese coast, but an approximate 20-year (bidecadal) variation is dominant (Figure 1.2.6). The extent to which global warming affects sea levels along the Japanese coast is unclear. However, since 1985, the average sea level has risen at a rate of 3.2 mm/year. (Figure 1.2.6).

Figure 1.2.5 Rates of mean SST rise around Japan by area from 1900 to 2007 (°C/100 years). Areas marked '*' are those where no significant value is estimated due to large SST variability such as decadal oscillation.

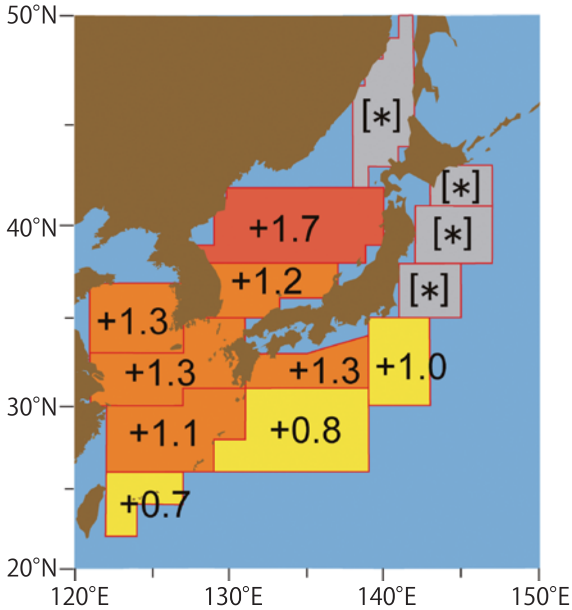


Figure 1.2.5 Rates of mean SST rise around Japan by area from 1900 to 2007 (°C/100 years). Areas marked '*' are those where no significant value is estimated due to large SST variability such as decadal oscillation.

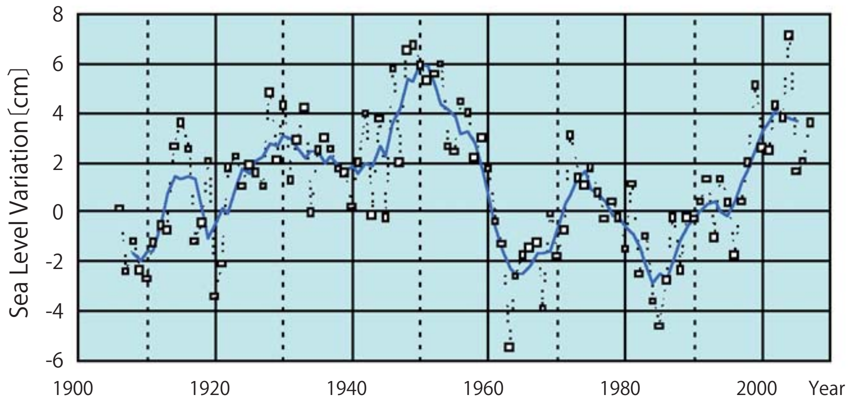


Figure 1.2.6 Variations in sea level along the Japanese coast. The open circles and blue line represent mean sea level anomalies at the tidal stations along the Japan coast and their five-year running mean respectively. The normal is the 1971-2000 average.

4 Sea Ice Extents in the Arctic Sea and in the Sea of Okhotsk - Sea ice extents are decreasing -

According to satellite observation data since 1978, an overall downward trend in the extent of Arctic sea ice is found, especially in summer, as shown in Figure 1.2.7 from the IPCC AR4. In September 2007, the extent of Arctic sea ice was the lowest on record.

Sea ice reflects most of the sunlight that reaches it back into space, and acts as a kind of lid that prevents heat exchange between the ocean and atmosphere. The melting of sea ice reduces the reflection of sunlight, which causes further warming. Reduced sea ice can therefore accelerate global warming.

In the IPCC AR4, sea ice is projected to shrink both in the Arctic and in the Antarctic. Some projections suggest that arctic sea ice in late summer will disappear almost entirely by the latter half of the 21st century. In winter, sea ice is formed in the Sea of Okhotsk, which is one of the lowest-latitude seas where sea ice is observed. The sea ice extent in the Sea of Okhotsk may also be affected by global warming. JMA monitors sea ice conditions in the Sea of Okhotsk as well as in the Arctic and Antarctic seas to analyze variations in sea ice extent due to global warming.

Although the sea ice extent in the Sea of Okhotsk has large interannual variations, a downward trend for the period from 1971 to 2007 is seen (Figure 1.2.8). The estimated rate of decline in the maximum sea ice extent is -5.52 × 104 km^2 every 10 years, corresponding to a 15% decrease over about 40 years. From December 2005 to May 2006, the accumulated sea ice extent in the Sea of Okhotsk was the lowest since 1971, and the seasonal maximum was the second lowest since 1971 (Figures 1.2.8 and 1.2.9).

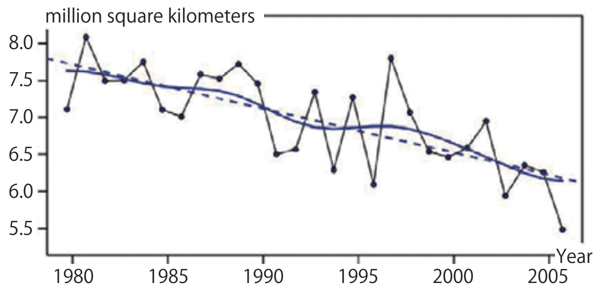


Figure 1.2.7 Minimum arctic sea ice extent from 1979 to 2005 in summer. The dots indicate annual mean values, while the smooth blue line shows decadal variations (IPCC AR4).

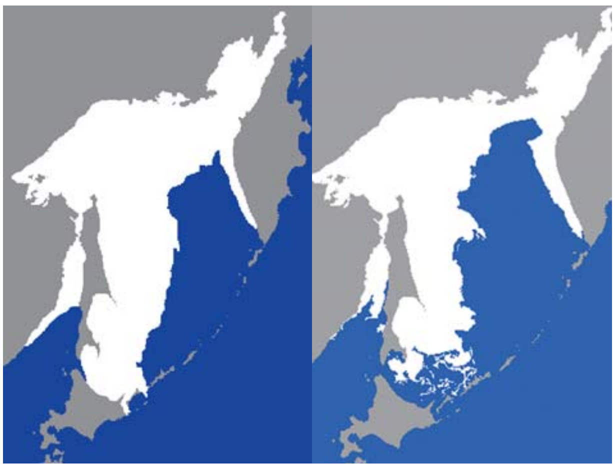


Figure 1.2.9 Sea ice extent in the Sea of Okhotsk (10 March). Left: Climatological distribution (1971-2000 average). Right: Distribution in 2006 (maximum sea ice extent recorded on 10 March 2006).

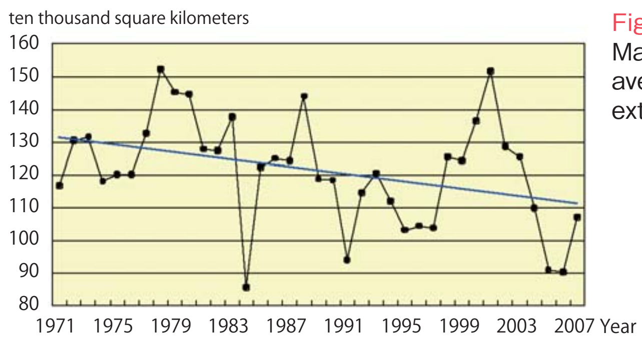


Figure 1.2.8 Maximum sea ice extent in the Sea of Okhotsk

5 Phenological Events in Japan - Cherry blossom blooming dates are becoming earlier -

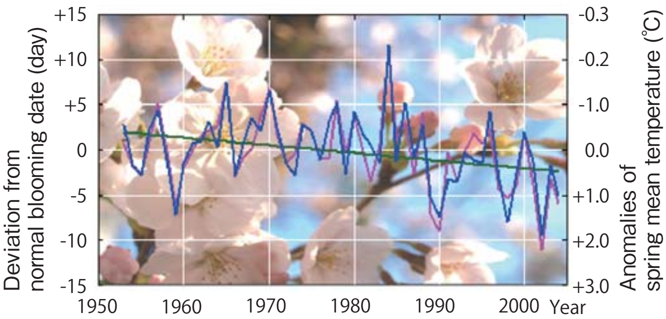
JMA has observed botanical, zoological and entomological events (blooming, first sighting and birdsong) since 1953. This practice is known as phenological observation.

Over the last five decades, the cherry blossom blooming date has become 4.2 days earlier, and the date of autumnal tints of the Japanese maple has become 15.6 days later (Figure 1.2.10).

Figure 1.2.11 shows the long-term change in the cherry blossom blooming front as of 1st April. This figure indicates that the front has shifted about 100 kilometers north on average over the last four decades.

It is well known that cherry blossom blooming and autumnal tints are closely related to air temperature.

It is suggested that the long-term trends seen in these phenomena are due to global warming and/or urbanization.



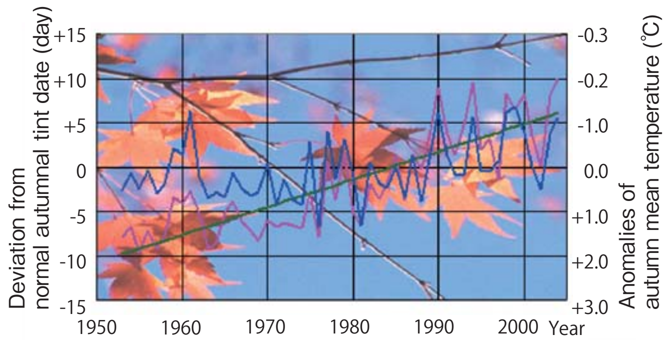


Figure. 1.2.10 (a) Deviations from the normal blooming dates (pink line) and anomalies of mean temperature in February/March/April (blue line) – both of which are averaged over Japan – and the linear trend of blooming dates (green line).
(b) Deviations from the normal of autumnal tint dates (red line) and anomalies of mean temperature in September/October/November (blue line) – both of which are averaged over Japan – and the linear trend of autumnal tint dates (green line). The normals are the average values for 1971-2000.

Picture 1.2.1 Many people enjoy viewing cherry blossoms in full bloom in Tokyo.

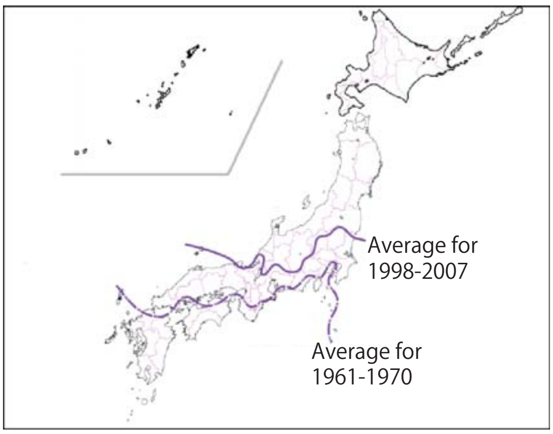


Figure 1.2.11 Geographical change in the cherry blossom blooming front as of April 1st showing the blooming date isolines. The bold and dotted lines represent the average blooming dates for 1998-2007 and 1961-1970 respectively.

6 Number of Tropical Cyclones Formed in the western North Pacific - No significant trends are found -

The IPCC AR4 shows that there is observational evidence suggesting an increase in intense tropical cyclone activity in the North Atlantic since about 1970.

There is no upward/downward trend in the number of tropical cyclones formed in the western North Pacific, those that approached Japan, or those that hit Japan in the period 1951-2007 (Figure 1.2.12).

Focusing on recent years, the number of approaching tropical cyclones has been above normal, while the number forming has been below normal.

The number and ratio of tropical cyclones forming with maximum winds of 64 knots or higher also shows no significant trend for the period 1977-2007 (Figure 1.2.13).

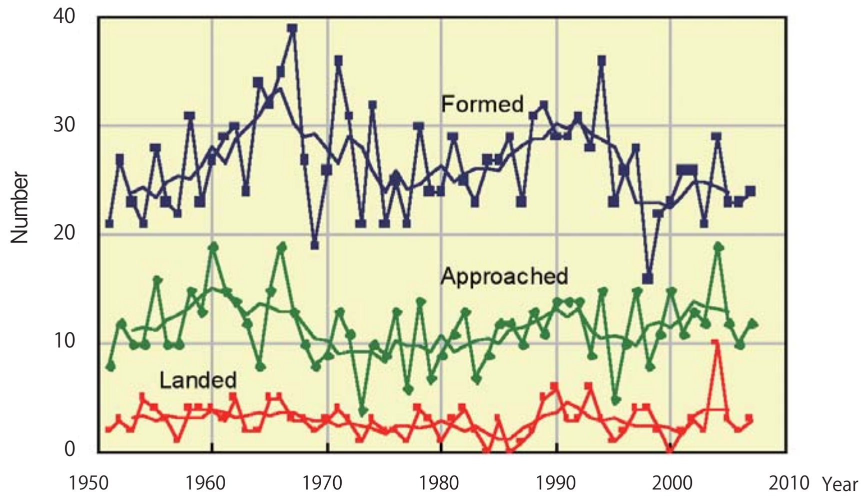


Figure 1.2.12 Number of tropical cyclones (34 knots or higher) that formed in the western North Pacific (top), those that approached Japan (middle) and those that hit Japan (bottom). The thin, thick and dashed lines represent the annual values, five-year running means and normal values (1971–2000 average) respectively.

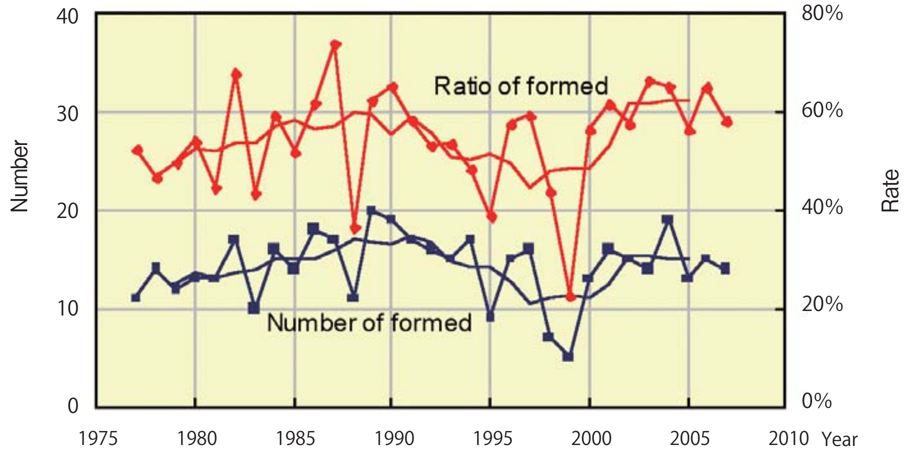


Figure 1.2.13 Number (bottom) and ratio (top) of tropical cyclone formations with maximum winds of 64 knots or higher. The thin and thick lines represent annual values and five-year running means respectively.

Chapter 3. Surface Climate and Extreme Events in Recent Years

1 Major Extreme Events in Japan and around the World - Extreme high temperature events are frequently observed -

Extreme climatic events have caused disasters across the world. Extremely high temperatures have frequently been observed in East Asia, Europe and the tropics since 2003 (Figure 1.3.1). In particular, heat waves in Europe in summer 2003 caused more than 70,000 fatalities.

In Australia, extremely light precipitation amounts have been observed continuously since 2003, causing severe agricultural damage (Figure 1.3.2).

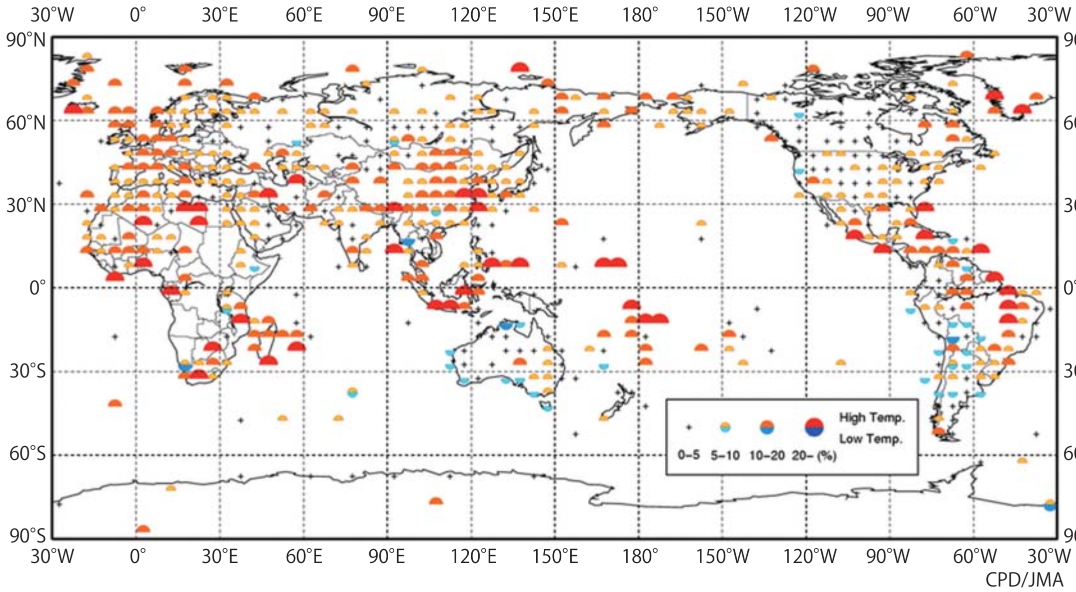


Figure 1.3.1 Frequencies of extremely high/low temperature in 2003-2007 are marked with upper/lower red/blue semicircles. The size of the semicircles illustrates the ratios of extremely high/low temperature occurrence based on monthly observation for the year in each 5° × 5° grid box.

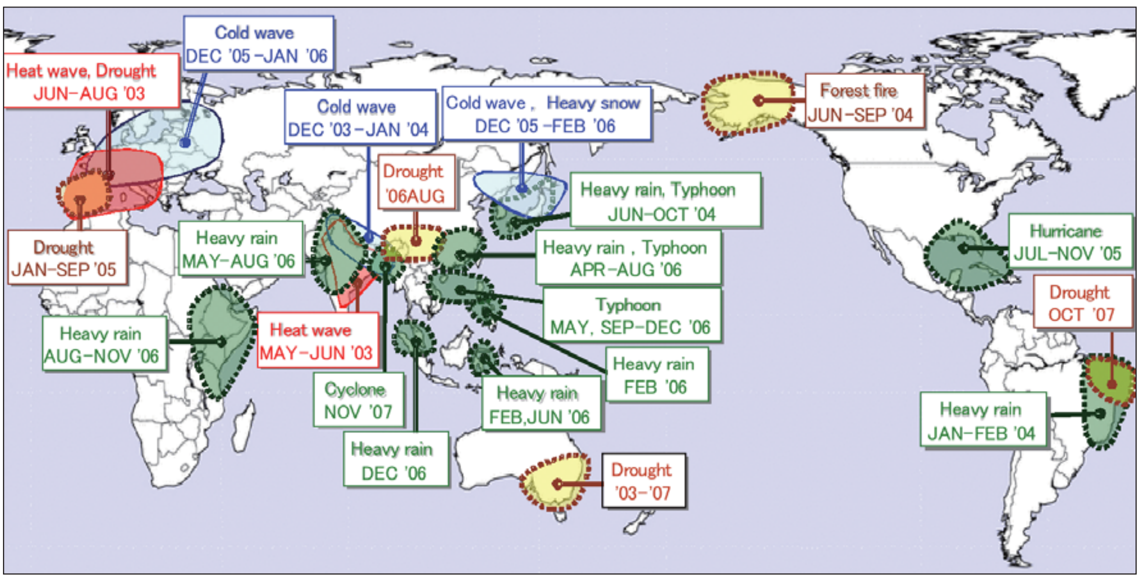


Figure 1.3.2 Major weather-related disasters worldwide in 2003-2007

In Japan, the number of fatalities and individuals unaccounted for as a result of weather-related disasters is decreasing. However, there have been several exceptions over the last five years. The number in 2004 exceeded 300 people for the first time since 1993, mainly due the record total of ten typhoons that hit Japan. The number exceeded 200 people for successive years in 2005 and 2006 (Figure 1.3.3, Table 1.3.1).

The figures related to human damage (such as heatstroke and death from intense heat) as well as agricultural and marine product damage due to extreme high temperatures show an increasing trend, especially those for heatstroke (Figure 1.3.4). In 1994 when a record-breaking hot summer was experienced, the figures for such heat-induced damage were the highest so far.

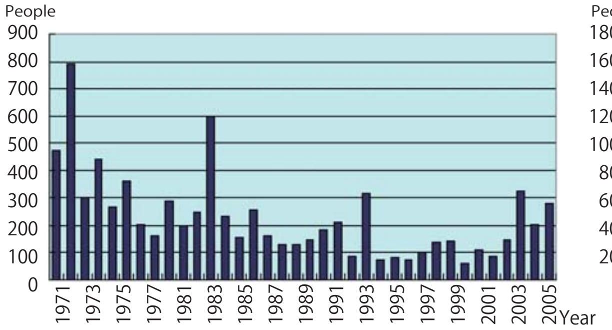


Figure 1.3.3 Number of fatalities and individuals unaccounted for as a result of weather-related disasters

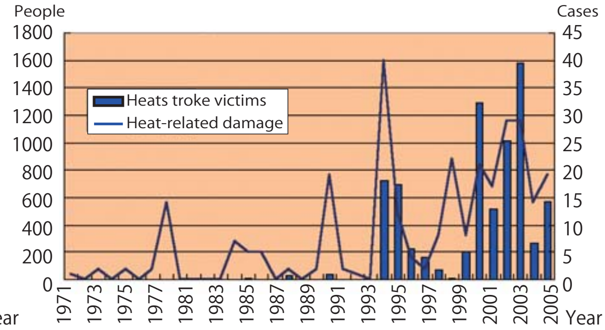


Figure 1.3.4 Number of cases of heat-related damage (thin line) and heatstroke victims (bars)

* These figures are based on reports by prefectural governments in Japan

Table 1.3.1 Major weather-related disasters in Japan over the last five years

2007		
Typhoon (MAN-YI) and Baiu front	July	Heavy rains in many districts across Okinawa to southern Tohoku; gales in Okinawa, the Pacific side of western Japan and the Izu Islands
2006		
Low pressure development	October	Gales and heavy rains from Kinki to Hokkaido; wrecks and alpine accidents in many districts
Baiu front	July	Heavy rains in Kyushu, San-in, Kinki, Hokuriku, especially in Nagano and Kagoshima prefectures
2005		
Strong winter monsoon	December 2005 to March 2006	Heavy snow from December to early January, causing many fatalities from accidents in snow-removal
Typhoon (NABI) and stationary front	September	Gales, heavy rains and high waves continued for many hours in Kyushu, Shikoku and Chugoku; extremely heavy rains exceeding 100 mm/hour in parts of Tokyo and Saitama prefectures
2004		
Typhoon (TOKAGE) and stationary front	October	Heavy rains in many districts; massive damage from landslides and floods
Typhoon (MEARI) and stationary front	September	Extremely heavy rains exceeding 130 mm/hour in Mie Prefecture; Daily precipitation of 740.5 mm in Owase
Typhoon (SONGDA)	September	Gales and gusts from Okinawa to Hokkaido; maximum wind speeds of 60.2 m/s in Hiroshima, 50.2 m/s in Sapporo
Baiu front	July	Heavy rains in Gifu and Fukui prefectures; daily precipitation exceeding the average monthly total in Miyama, Fukui Prefecture
Baiu front	July	Record-breaking heavy rains in Niigata and Fukushima prefectures
2003		
Baiu front	July	Extremely heavy rains exceeding 50 mm/hour in northern Kyushu

2 Long-term trend of extreme events in Japan - Extremely high temperature events are increasing -

The occurrence of extremely high monthly temperatures* in Japan increased significantly in the period from 1901 to 2006, while that of extremely low monthly temperatures decreased. The occurrence of extremely high temperatures increased remarkably in the 1980s, and the average for the most recent 30 years (1977-2006) reached five times the level seen at the beginning of the 20th century (1901-1930) (Figure 1.3.5).

The occurrence of extremely light monthly precipitation amounts increased significantly in the period from 1901 to 2006. Both extremely heavy and light precipitation amounts increased after the 1980s; the variability of precipitation amounts increased (i.e. both extremely heavy and light monthly precipitation amounts have appeared frequently) (Figure 1.3.6).

The IPCC AR4 shows that heat waves, heavy rains and droughts are very likely to increase in most areas across the world in the late 20th century.

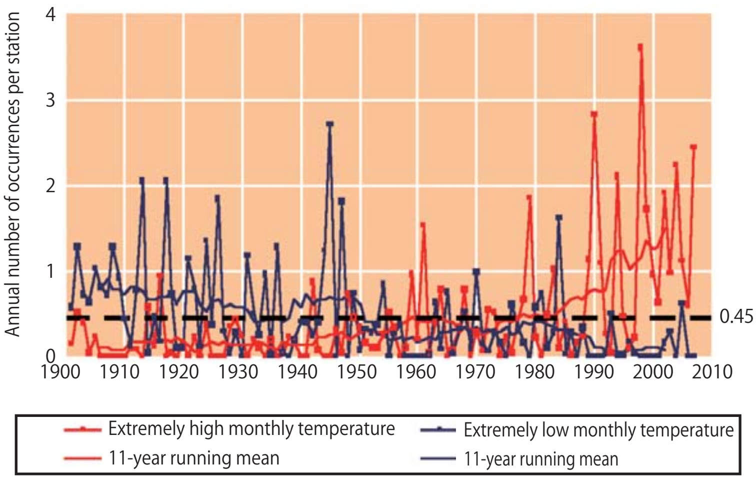


Figure 1.3.5 Annual number of occurrences of extremely high/low monthly mean temperatures in Japan

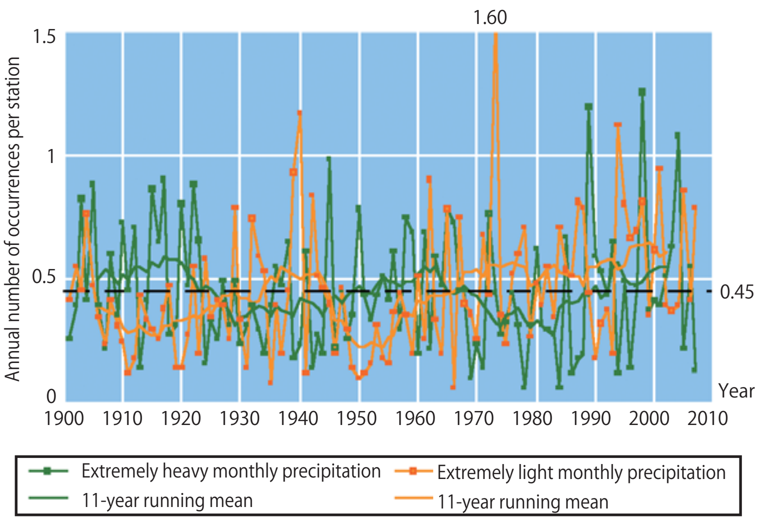


Figure 1.3.6 Annual number of occurrences of extremely heavy/light monthly precipitation amounts in Japan

* The threshold of extremely high/low temperature or heavy/light precipitation is defined as the fourth-highest/lowest value for the month over the period from 1901 to 2006.

In Japan, the number of extremely hot days (the annual number of days with a maximum temperature (Tmax) of ≥ 35ºC) increased significantly in the 1980s (Figure 1.3.7). Extremely hot nights (the annual number of days with a minimum temperature (Tmin) of ≥ 25ºC) also increased significantly (Figure 1.3.8), while cold nights (the annual number of days with Tmin of < 0ºC) decreased significantly over the period from 1931 to 2006 (Figure 1.3.9).

The annual number of days with daily precipitation of ≥ 200 mm increased significantly over the period from 1901 to 2006 (Figure 1.3.10).

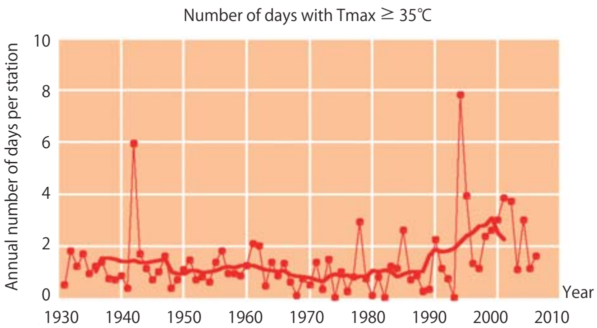


Figure 1.3.7 Annual number of days with maximum temperatures of ≥ 35°C (annual number of days per station). The thin line indicates the values for each year, and the thick line indicates the 11-year running mean value.

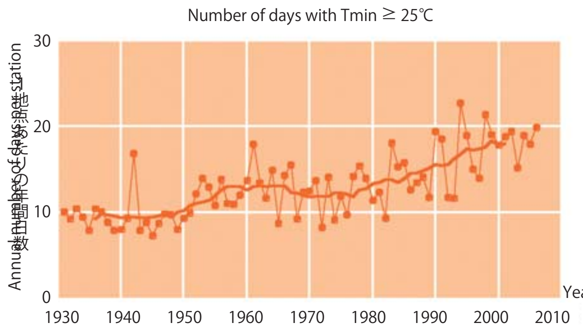


Figure 1.3.8 Annual number of days with minimum temperatures of ≥ 25°C. The same as Figure 1.3.7, but for a minimum temperature of ≥ 25°C

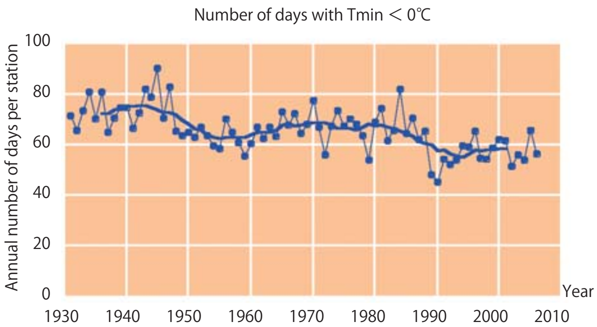


Figure 1.3.9 Annual number of days with minimum temperatures of < 0°C. The same as Figure 1.3.7, but for a minimum temperature of < 0°C

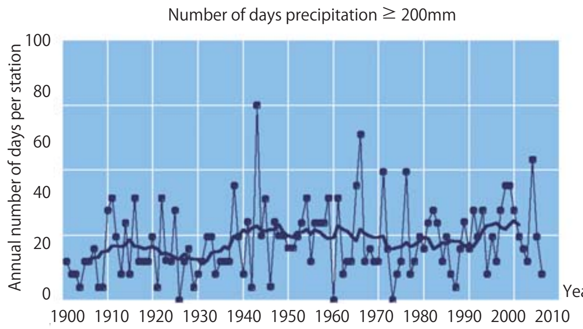


Figure 1.3.10 Annual number of days with precipitation of ≥ 200 mm. The same as Figure 1.3.7, but for precipitation of ≥ 200 mm.

Part II Global Warming Projections

Chapter 1. Global Projections (based on IPCC AR4)

Many climate model results were made available at the time of the IPCC AR4, which enabled us to create best estimates and uncertainty ranges for climate projections. There is high agreement and much evidence to suggest that, with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century. For the next two decades, warming of about 0.2°C per decade is projected for a range of cases in the Special Report on Emissions Scenarios (SRES). Even if the concentrations of all GHGs and aerosols were kept constant at the levels seen in 2000, further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emission scenarios (Figure 2.1.1). The best estimate and likely range for global average surface air warming is 1.8 [1.1-2.9]°C for the low scenario (B1), 2.8 [2.0-5.4]°C for the middle scenario (A1B), and 4.0 [2.4-6.4]°C for the high scenario (A1FI).

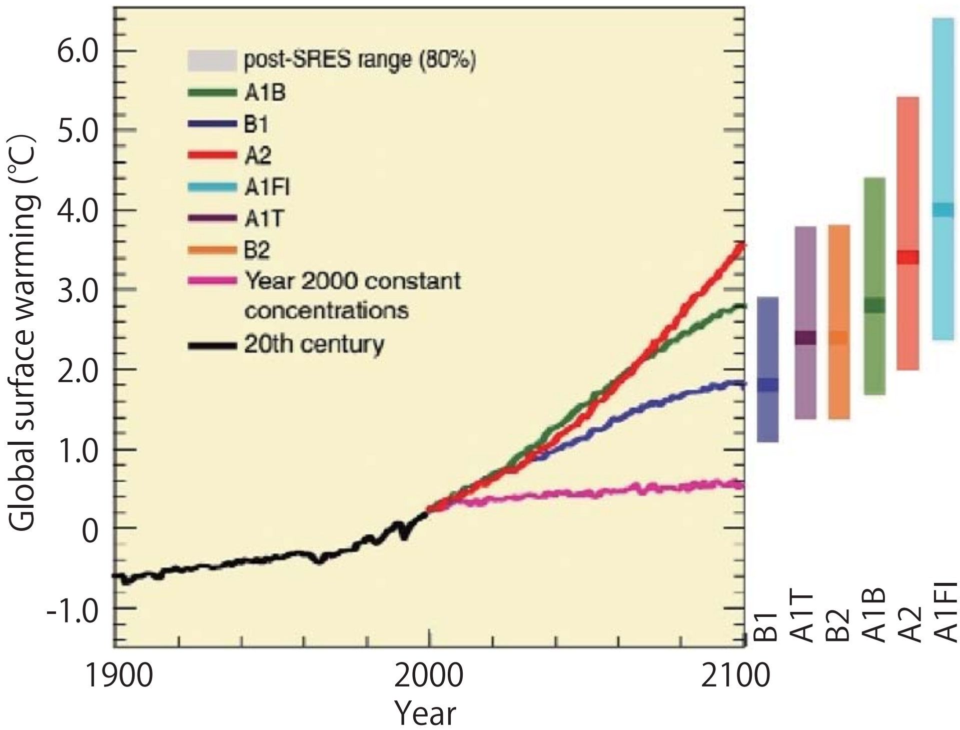


Figure 2.1.1 The solid lines represent multi-model global averages of surface warming for scenarios A2, A1B and B1. The bars to the right of the figure indicate best estimates (the solid line within each bar) and the likely range assessed for the six SRES marker scenarios at 2090-2099. All temperatures are relative to the period 1980-1999.

Projected regional-scale changes include: greater warming over land and in most northern high latitudes, and lesser warming over the Southern Ocean and parts of the North Atlantic Ocean (Figure 2.1.2), continuing recent observed trends; contraction of snow cover area, increased thaw depth over most permafrost regions, and reduced sea ice extent; a very likely increase in the frequency of hot extremes, heat waves and heavy precipitation; a likely increase in tropical cyclone intensity, poleward shift of extra-tropical storm tracks with consequent changes in winds, precipitation and temperature patterns; a very likely increase in precipitation in the high latitudes, and a likely decrease in most subtropical land regions (Figure 2.1.3). By the mid-21st century, annual river runoff and water availability is projected to increase in the high latitudes (and in some tropical wet areas) and decrease in some dry regions in the mid-latitudes and tropics. There is also high confidence that many semi-arid areas (e.g. the Mediterranean basin, the western United States, southern Africa and northern Brazil) will suffer a decrease in water resources due to climate change.

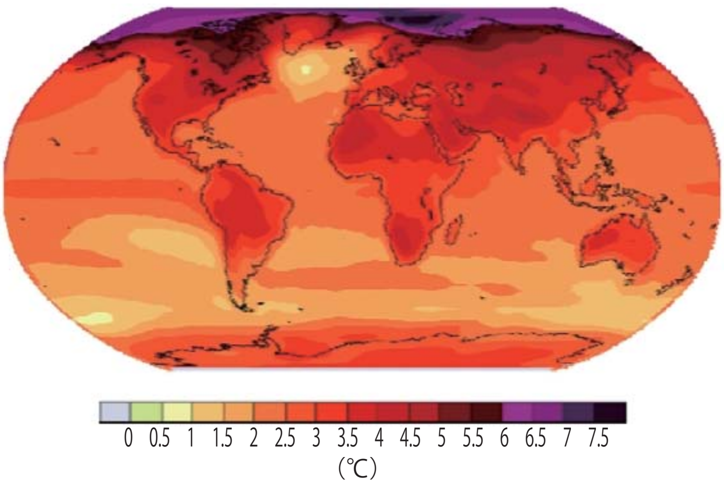


Figure 2.1.2 Projected surface temperature changes in 2090-2099 relative to 1980-1999 for the SRES A1B scenario.

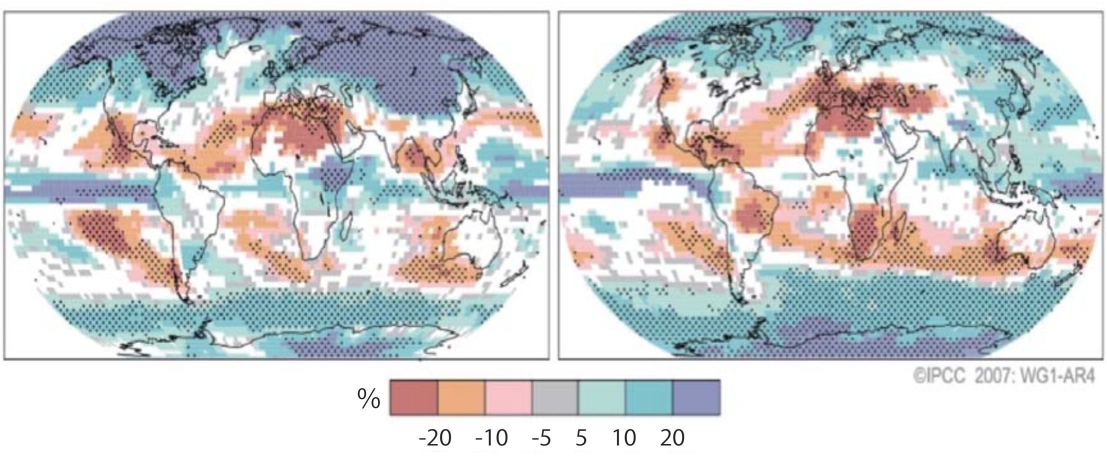


Figure 2.1.3 Relative changes in precipitation for the period 2090-2099 relative to 1980-1999, based on the SRES A1B scenario for December to February (left) and June to August (right).

Chapter 2. Projection around Japan

How will the climate of Japan change as a result of global warming? To develop adaptation measures for such warming, regional climate projection is essential. In Japan, climate conditions vary regionally due to the country's unique topographical characteristics and various atmospheric phenomena including monsoons, cyclones and typhoons. JMA's Meteorological Research Institute developed the Coupled Atmosphere-Ocean Regional Climate Model (CRCM) to project the climate peculiar to Japan, and conducted climatic projection at the end of the 21st century for the IPCC A1B and B1 scenarios (see Chapter 1 of Part II).

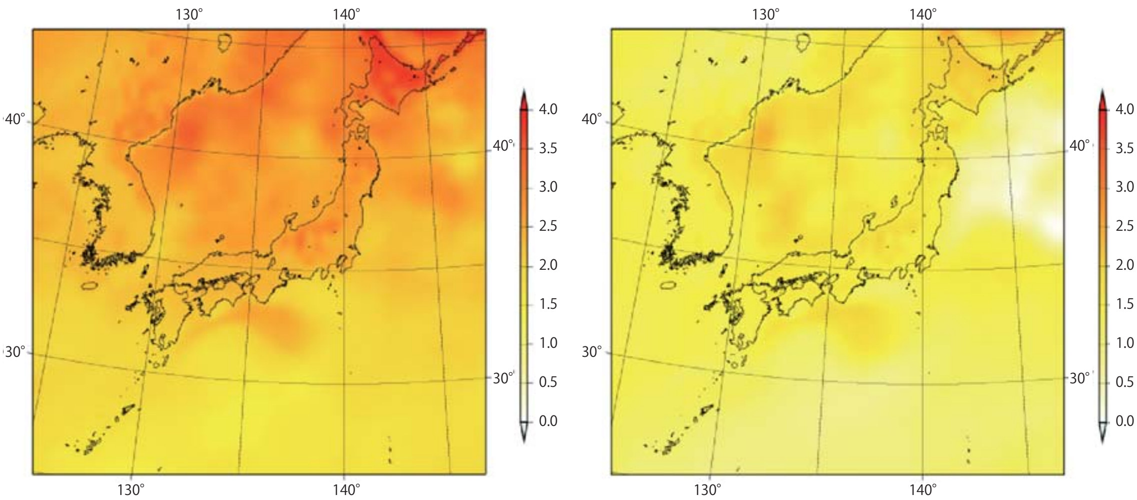


Figure 2.2.1 Projected surface temperature changes (°C) in winter (December to March) for the period 2081-2100 relative to 1981-2000 for the A1B scenario (left) and B1 (right).

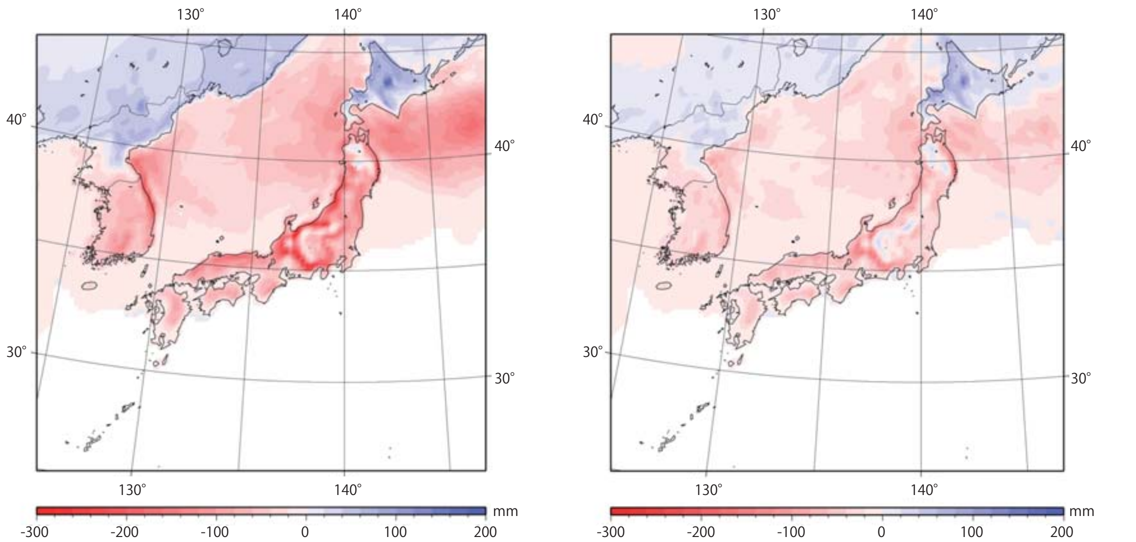


Figure 2.2.2 Projected snowfall changes converted to precipitation (mm) in winter (December to March) for the period 2081-2100 relative to 1981-2000 for the A1B scenario (left) and B1 (right).

Projections of average temperature and snowfall in winter (December to March) are shown in Figures 2.2.1 and 2.2.2.

Temperatures at the end of the 21st century relative to the present are projected to increase by 1.5 to 3°C for the A1B scenario and by 1 to 2°C for the B1 scenario. Warming is expected to be the greatest at higher latitudes.

Snowfall in the Tohoku district (the northern part of Japan's main island) is projected to decrease, while rainfall is expected to increase because of warming. In contrast, snowfall in Hokkaido (the island to the north of the main island) is projected to rise due to increased water vapor in the atmosphere.

A projection of sea surface temperatures around Japan is shown in Figure 2.2.3. In the Sea of Japan, warming is expected to be higher than that in any other area. Figure 2.2.4 shows how much the sea level is projected to rise.

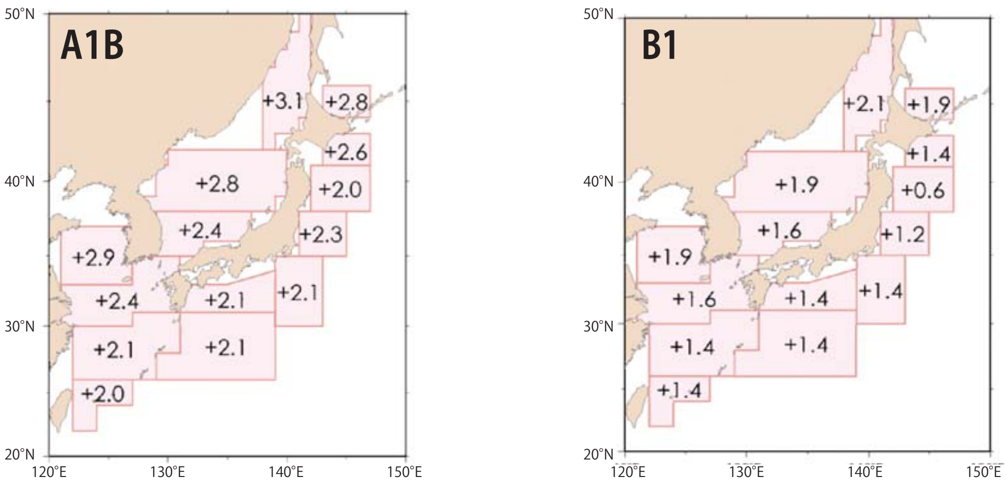


Figure 2.2.3 Projected linear trends of annual sea surface temperatures (°C per century) from 1981 to 2100 for the A1B scenario (left) and B1 (right).

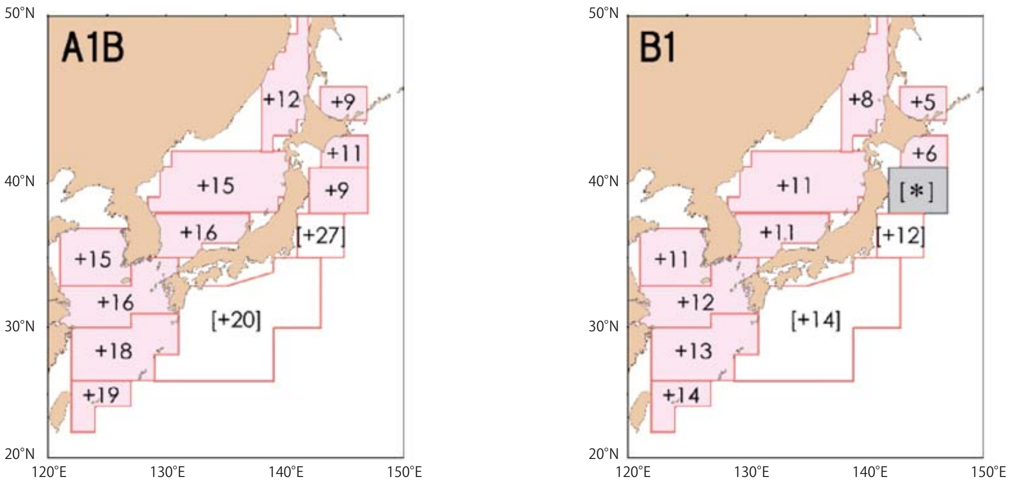


Figure 2.2.4 Projected linear trends of annual sea level rises (cm per century) from 1981 to 2100 for the A1B scenario (left) and B1 (right). [*] denotes that the value is not significant, while the uncertainty of values marked with [ ] is large. Contributions from melting glaciers and ice caps are not included in this projection.

Part III JMA's Efforts for Monitoring

Chapter 1. Ocean Observation and the Argo Project

The ocean plays an important role in climate variability and change by releasing and absorbing large amounts of heat and carbon. In order to monitor ocean and climate changes, JMA conducts oceanographic observations using research vessels, profiling floats, tidal stations, voluntary observing ships and earth-observing satellites.

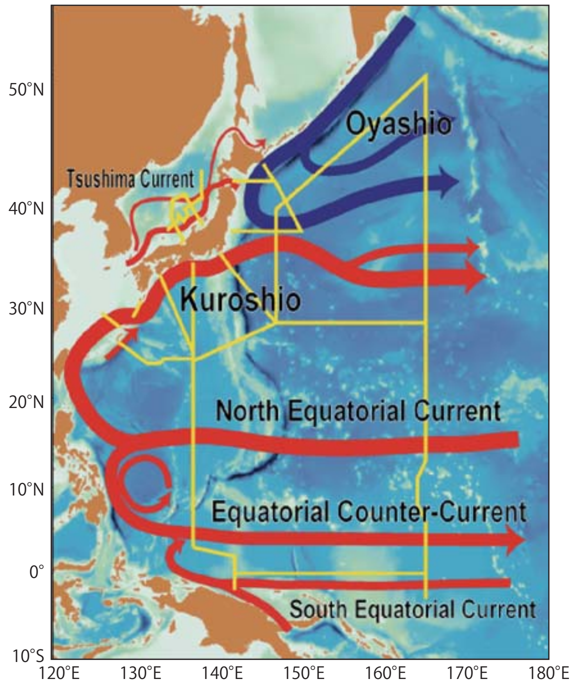


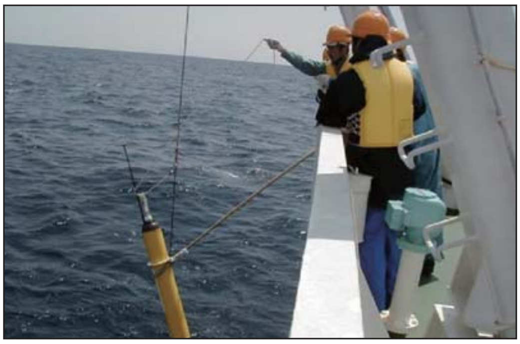
Figure 3.1.1 Map of major surface currents (red and blue lines with arrows) and routine observation lines of JMA research vessels (yellow lines)

Five JMA research vessels operate in the western North Pacific including the seas in the vicinity of Japan. These vessels mainly monitor large-scale, long-term oceanic variations such as seawater temperature, salinity, ocean currents and biogeochemical components. They also observe elements relevant to the marine environment, such as heavy metals, pollutants, concentration of CO_2 and other greenhouse gases both in seawater and in the air over the ocean.

JMA participates in the Argo project, which is conducted through an international cooperation of meteorological and oceanographic organizations. In this project, profiling units called *Argo floats* are deployed to observe water temperature and salinity from the sea surface to a depth of 2,000 meters. JMA operates the Japan Argo Data Assembly Center to collect and distribute the data for international exchange.

JMA observes sea levels at tidal stations located along the Japanese coast to monitor sea level rises related to global warming.

Picture 3.1.1
JMA's Ryofu Maru research vessel



Picture 3.1.2
Ryofu Maru crew members deploy an Argo float.

Chapter 2. World Data Centre for Greenhouse Gases (WDCGG)

JMA operates the World Data Centre for Greenhouse Gases (WDCGG) under the WMO's programme on the monitoring of greenhouse gases. The WDCGG gathers and archives measurement data on greenhouse gases from all over the world (Figure 3.2.1), and provides analyses using these data. The analyses of the WDCGG are adopted as basic materials in WMO Greenhouse Gas Bulletins (Figure 3.2.2), and are also used in the IPCC AR4.

One of the analyses of the WDCGG is a three-dimensional representation of annual variations in zonally averaged latitudinal distribution of atmospheric CO_2 concentrations (Figure 3.2.3). It shows that concentrations in mid- and high latitudes in the Northern Hemisphere increase faster than those in the Southern Hemisphere because of large CO_2 emissions from human activities in the Northern Hemisphere. It also indicates that seasonal variations in CO_2 concentrations are larger in the Northern Hemisphere than in the Southern Hemisphere because of the large influence of absorption by forests in the north.

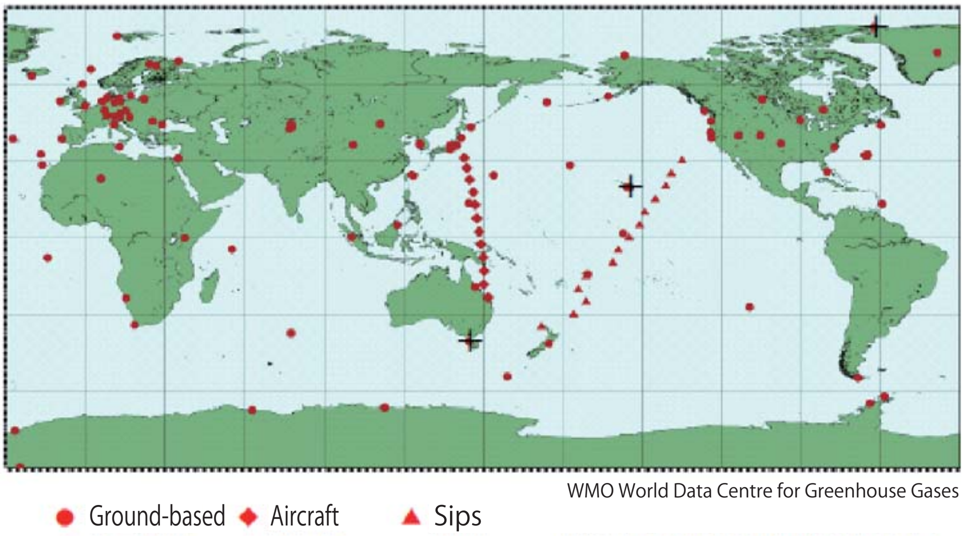


Figure 3.2.1 The WMO's CO_2 monitoring network

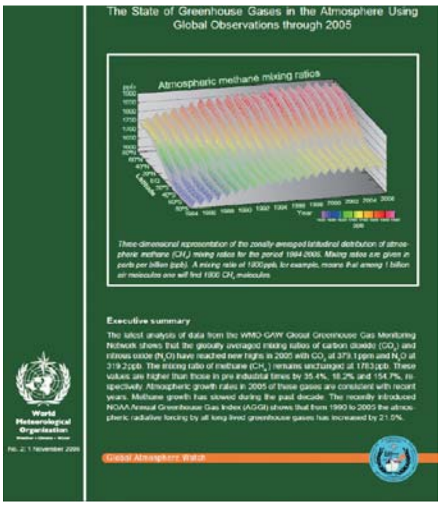


Figure 3.2.2 WMO Greenhouse Gas Bulletin

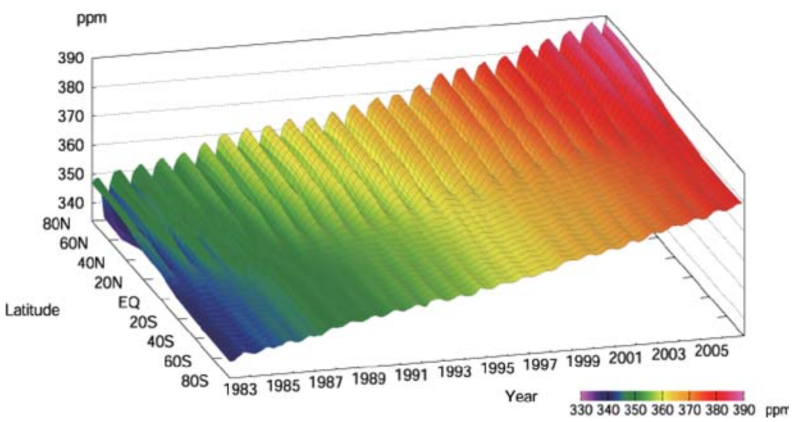


Figure 3.2.3 Three-dimensional representation of annual variations in zonally averaged atmospheric CO_2 distribution. This analysis was performed using data archived by the WDCGG.

Chapter 3 Asia's First Long-Term Atmospheric Reanalysis

Reanalysis is the process of analyzing the state of past weather using all observational data possible with the latest technology. The Japan Meteorological Agency and the Central Research Institute of Electric Power Industry jointly executed the Japanese 25-year Reanalysis (JRA-25) project, the first of its kind in Asia.

The JRA-25 covers the 26-year period from 1979 to 2004, and archives more than 100 meteorological variables (such as air temperature and wind) with consistent and high quality.

JRA-25 data and products are widely used for research on meteorology and climatology, as well as for operational climate monitoring and seasonal forecasting.

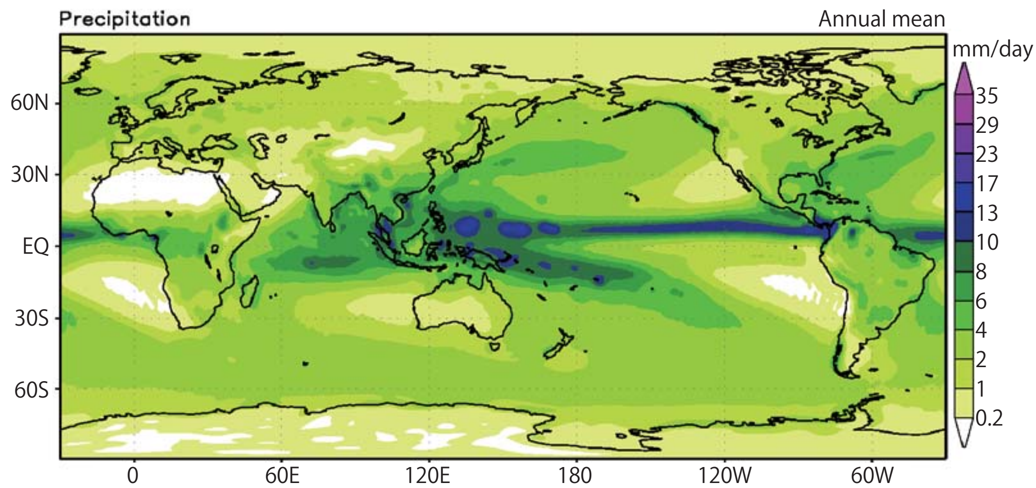


Figure 3.3.1 Distribution of annually averaged daily precipitation (mm/day)

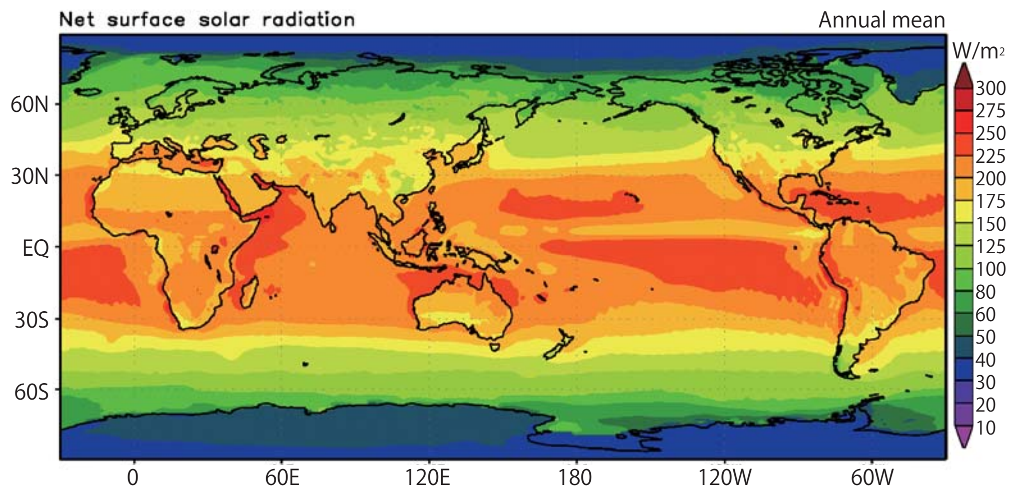


Figure 3.3.2 Distribution of annually averaged net surface solar radiation (W/m^2).
This distribution is expected to be used in identifying appropriate regions for solar power generation.

Chapter 4. Establishment of an Advisory Panel on Extreme Climate Events

Based on operational climate system monitoring, JMA has provided information on extreme climate events, such as the heat waves of 2004 and heavy snow in 2005/06.

In order to improve such information by enhancing cooperation with the research community and utilizing the outcome of recent research on extreme climate events, JMA established the Advisory Panel on Extreme Climate Events, consisting of 10 prominent experts from universities and research institutes, in June 2007.

The missions of the panel are as follows:

1) Climatological analysis and research on extreme climate events
2) Advice on information that JMA prepares in regard to extreme climate events, including their causes and mechanisms
3) Recommendations on the application of results from climatological research on extreme climate events to JMA's services and activities

When an extreme climate event occurs or is likely to occur, the panel immediately initiates analysis and examination of the event's causes to provide scientific advice to JMA. Based on the advice of the panel and other relevant information, JMA issues statements including the causes of and outlook for such events. These statements are provided to decision makers in various sectors as well as to the general public to help them avoid or minimize the adverse effects of extreme climate events.

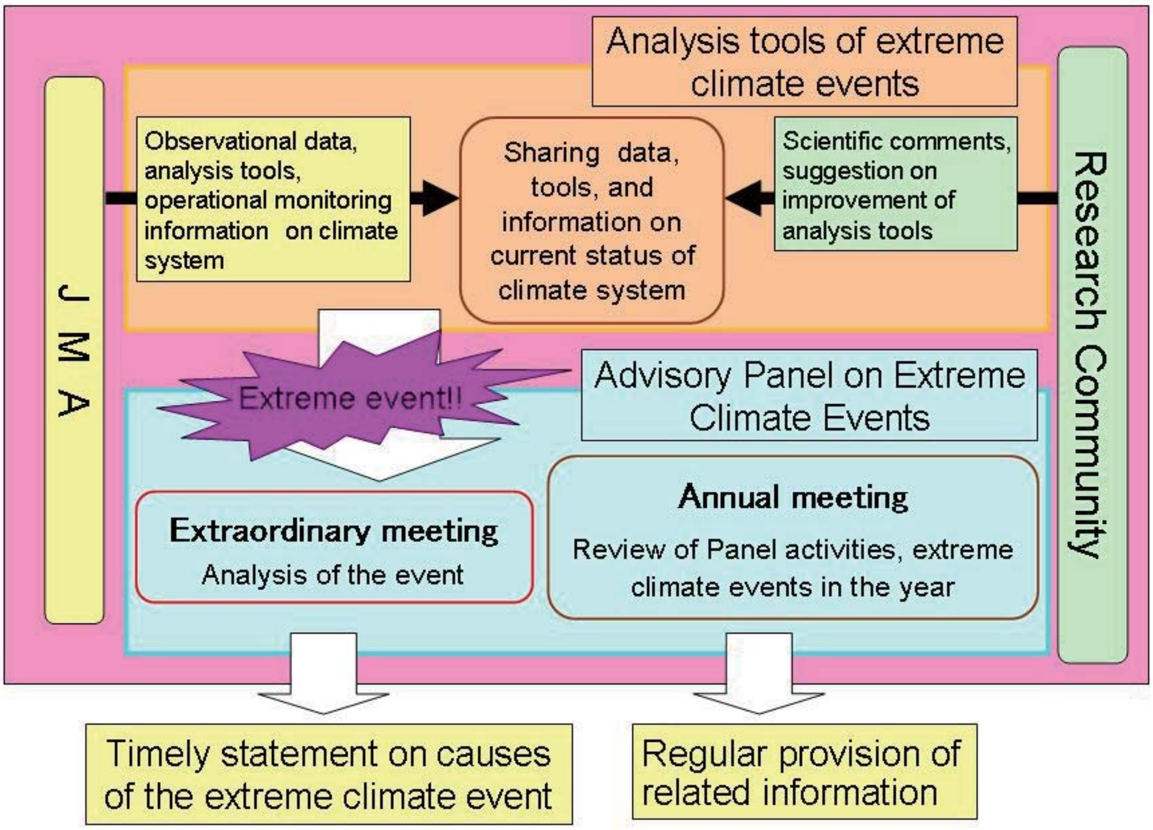


Figure 3.4.1 Activities related to the Advisory Panel on Extreme Climate Events

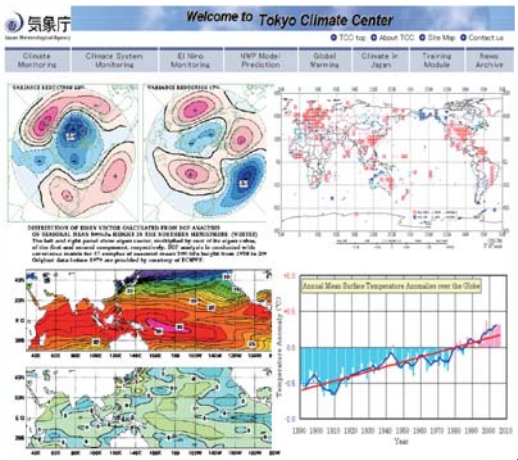
Chapter 5. Tokyo Climate Center (TCC)

JMA established the Tokyo Climate Center (TCC) in April 2002 with the main purpose of promoting the application of climate information in the mitigation of disasters due to extreme climate events, as well as the planning of agricultural production and water resource management in Asia and the Pacific region. TCC mainly provides National Meteorological and Hydrological Services (NMHSs) in Asia and the Pacific region with information on global extreme climate events, atmospheric and oceanic conditions, numerical prediction data for seasonal forecasts, El Niño monitoring and prediction, and global warming projection.

The center also places focus on technical transfer and capacity-building activities. As part of such services, TCC has conducted training sessions on the application of climate information for prospective NMHS staff members through the Japan International Cooperation Agency (JICA). Over the last 5 years, 42 participants from 34 countries have attended the training. On-site technical training in seasonal forecasting is also conducted by TCC.

These activities are in line with the Regional Climate Center (RCC)'s concept, which is in the process of formal approval by WMO.

Provision of Information on Climate Monitoring and Prediction



Workshops and International Meetings

● **TCC homepage**
http://ds.data.jma.go.jp/tcc/tcc/index.html

Tokyo Climate Center

Provision of climate information
- ·Data for seasonal forecasts
- ·El Niño monitoring and prediction
- ·Global extreme climate monitoring
- ·Global climate system monitoring
- ·Global warming projection

Capacity building
- ·Training on application of climate information in NMHSs

- Assistance in climate services in each country
- Promotion of application of climate information

NMHSs in Asia and the Pacific region
Preparation and provision of climate information

Application of climate information in each country
- Mitigation of disasters related to extreme climate events
- Planning of agricultural production
- Water resource management

Figure 3.5.1 TCC's activities at a glance.

Chapter 6. Research and Development for Global Warming Projection Information

The Meteorological Research Institute (MRI) carried out climate change projection using the MRI global climate model with a mesh of about 280 km. The results made an important contribution to the IPCC AR4, and were also utilized to drive the MRI regional climate model (RCM) with a 20-km mesh to project climate change in Japan. Information on regional climate changes in Japan for temperature, precipitation, etc. are presented for several climatological regions (such as North Japan, East Japan and West Japan), each of which is subdivided into the Sea of Japan side and the Pacific side as appropriate.

Since global warming is now unequivocal, more detailed and accurate projection is demanded from various sectors such as those dealing with water resources, disaster prevention, agriculture, forestry and human health, for the purpose of promoting adaptation and mitigation measures. To respond to these requests, MRI launched a five-year research project called Comprehensive Projection of Climate Change around Japan due to the Global Warming (Figure 3.6.1) in FY 2005.

In this research project, MRI develops a cloud-resolving regional climate model that explicitly treats clouds with a 4-km mesh, and can reflect Japan's detailed orography in projecting small-scale phenomena such as heavy rainfall and the frequency of extreme events.

MRI is developing the MRI Earth System Model (MRI-ESM) with the aim of reducing the uncertainty of global warming projection. Based on a state-of-the-art global climate model, carbon cycle processes on land and in oceans, sources and transport of aerosols, and chemical reactions of trace gases including ozone are modeled and integrated into the earth system model. The model also deals with changes in ice sheets, an important factor affecting sea level variations.

This project is expected to contribute to promoting adaptation to and mitigation of global warming in Japan. It will do so by providing more detailed and reliable climate change information as a sophisticated regional climate model that uses projection by the earth system model as its boundary conditions.

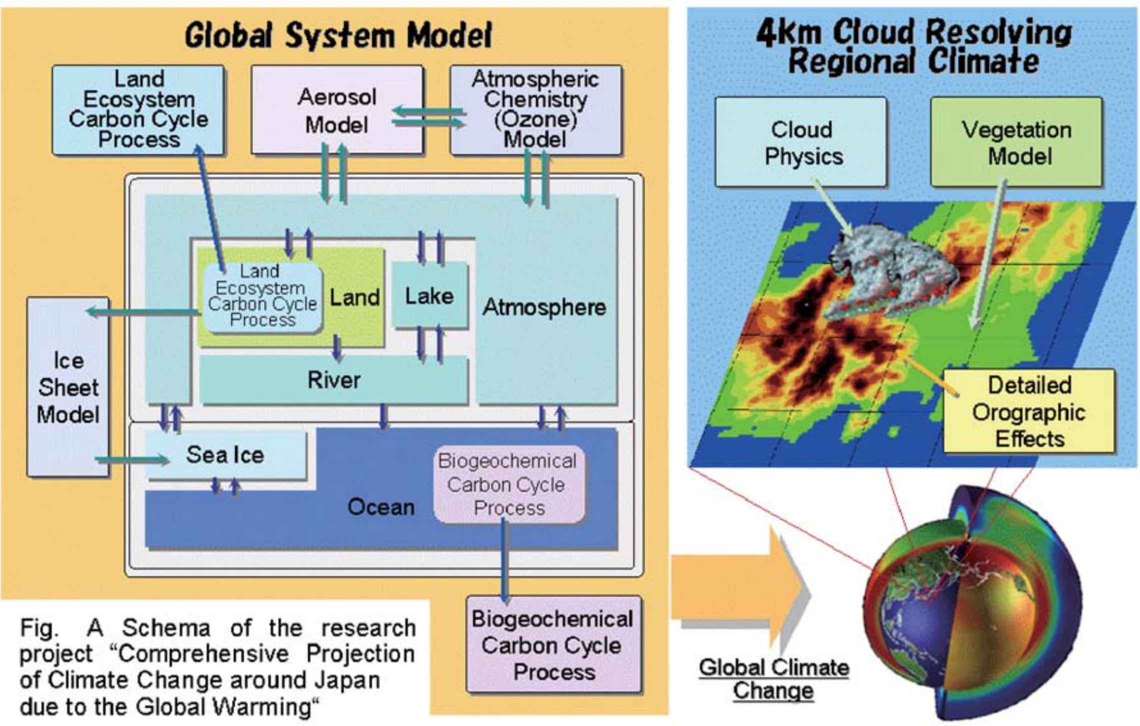


Figure 3.6.1 Schematic chart of the Comprehensive Projection of Climate Change around Japan due to the Global Warming research project

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