Consolidated Report on Observations, Projections and Impact Assessments of Climate Change

Climate Change and Its Impacts in Japan

FY2012

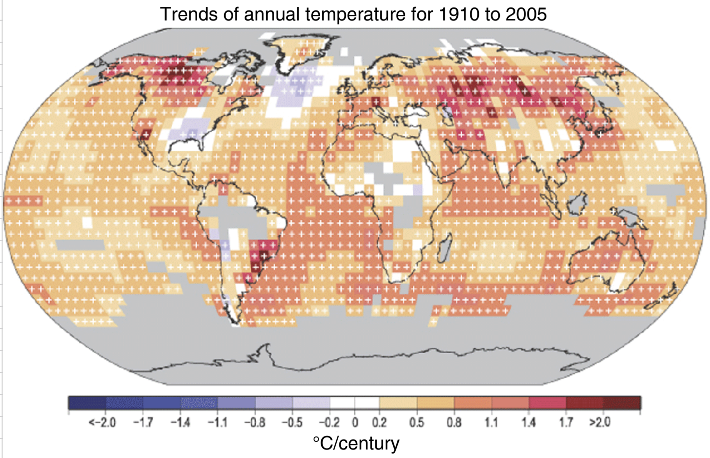
Observations and Projections of Climate Change: World

Historical Observations

The Earth is Warming

The global average temperature has been increasing over the long term, and since 1891, it has risen at a rate of 0.68°C per 100 years. The temperature increase is particularly significant at the high latitudes in the Northern Hemisphere. The sea level is on the rise due to the thermal expansion of the oceans and increased runoff from melting glaciers and ice sheets, and ocean temperatures are also increasing. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change ("IPCC AR4") has concluded from these observations that "warming of the climate system is unequivocal."

Source: Ref. 1

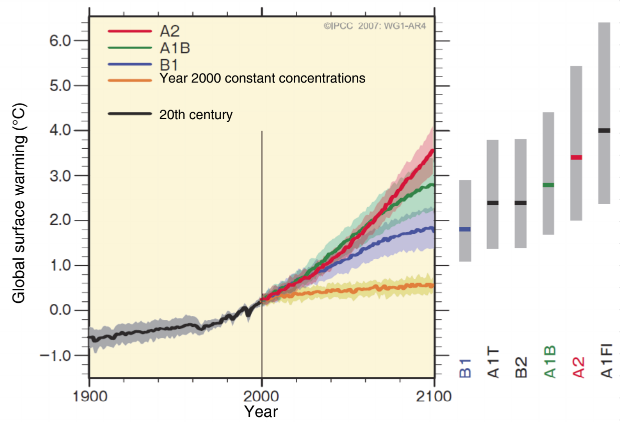


Global spatial trend patterns of annual surface temperature

Reconstruction based on historical observations. Linear trend of annual temperatures for 1901 to 2005 (°C per century). Gray areas represent regions with insufficient data.

Source: Ref. 1

Projections



Global Average Temperature Projections (relative to 1980-1999)

Solid lines are multi-model global averages of surface warming for the SRES scenarios A2 (red), A1B (green) and B1 (blue). The orange line is for the experiment where concentrations were held constant at year 2000 values. Shading denotes the ±1 standard deviation range of individual model annual averages

Source: AR4 WG1 SPM Figure SPM.5

The Earth will Continue Warming in the 21st Century

If greenhouse gas emissions caused primarily by the burning of fossil fuels continue, the global average temperature at the end of the 21st century compared to that at the end of the 20th century (1980-1999 average) is projected to be 1.8°C higher under Scenario B1, 2.8°C higher under Scenario A1B and 3.4°C higher under Scenario A2.

Continued warming would induce many changes to the global climate system in the 21st century that would likely be larger than those observed in the 20th century.

Source: Ref. 1

Drivers of Global Warming

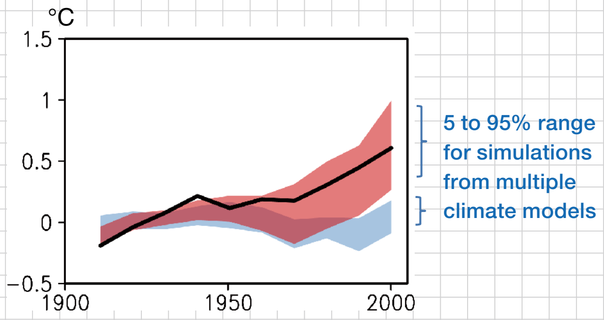
Carbon dioxide (CO_2) and other greenhouse gases continue to accumulate in the atmosphere. The global atmospheric concentration of CO_2 has increased 40% from a pre-industrial value of about 280ppm to 390.9ppm in 2011, and the rate of increase became larger, reaching 2ppm per year in recent years.

Source: Ref. 1, 2

The IPCC AR4 clearly states: "Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations."

Using the multi-model approach, observed changes in the global average surface temperature in the 20th century have been simulated only when the increase in anthropogenic forcings has been taken into account, and not when they have not; that means that temperature increases in the second half of the 20th century cannot be explained without considering anthropogenic influence.

Source: Ref. 1



Global Surface Temperature Change (Deviation from 1901 - 1950 average)
Comparison of observed values (black line) with results simulated by climate models

Blue: 15 models using only natural forcings
Red: 35 Models using both natural and anthropogenic forcings

Created by: Meteorological Research Institute

Scenarios Used in Climate Change Projections

Climate change projections are calculated using climate models based on scenarios of how atmospheric concentrations of greenhouse gas and aerosols may change in the future. The IPCC Special Report on Emissions Scenarios ("SRES") depicts the future world in six possible scenarios (B1 - A1F1), and provides a possible future pathway of CO_2 and other GHG emissions. Each projects CO_2 and other GHG emissions based on assumed socio-economic development. Scenarios B1, A1B and A2 are frequently used, and among them A2 represents the highest concentration of CO_2 by the year 2100, followed by A1B and B2.

Source: Ref. 3

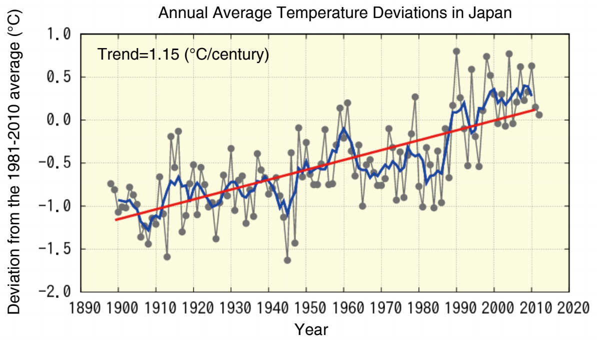
Observations and Projections of Climate Change: Japan

Historical Observations

Temperatures are Rising and Heavy Rains are More Frequent

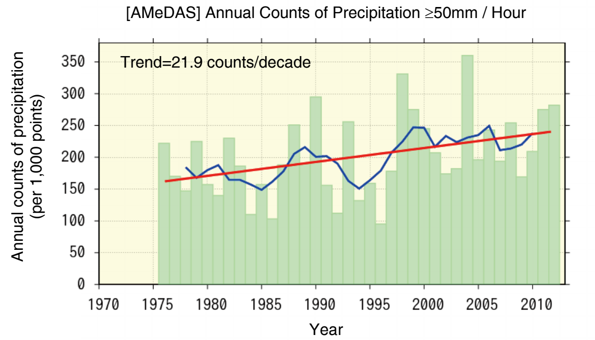
Japan's average temperature varies widely from year to year, but over the long term, it has been on an upward trend, rising at a rate of 1.15°C per 100 years, which is higher than the global average of 0.68°C per 100 years. Both the number of extremely hot days with maximum temperature of 35°C and higher and tropical nights with minimum temperatures of 25°C and higher appear to be on the rise. Changes in precipitation are also evident, with the number of days with rainfall of 1mm or more declining while the number of days with rainfall of 100 mm or more is on the rise. According to the Automated Meteorological Data Acquisition System (AMeDAS) observations, the frequency of hourly heavy rains of 50mm or more is extremely likely to have increased, although more data needs to be collected before reaching a conclusion whether there is any causal link between the trend and global warming.

Source: Ref. 4



Japan's Annual Average Temperature Change
(Deviation from 1981 - 2010 average)

Based on data from 17 locations where the effect of urbanization is considered negligible. The thin black line indicates the surface temperature anomaly for each year, the blue line indicates the five-year running mean and the red line indicates the long-term linear trend. Source: Ref. 4

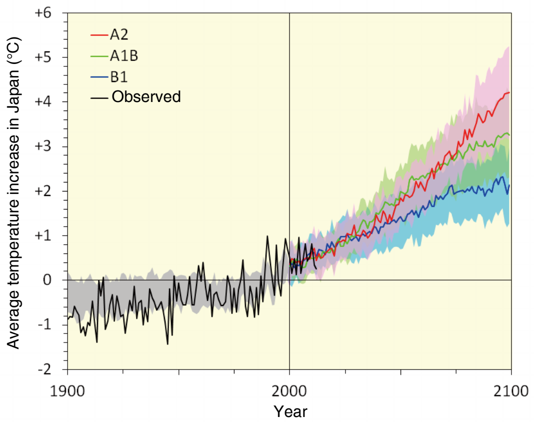


Changes in Annual Counts of Precipitation ≥50mm / Hour per 1,000 AMeDAS Station

Bars indicate annual values (1976-2012). The blue line indicates the five-year running mean, and the red line indicates the linear trend over time.

Source: Ref. 4

Projections



Temperature Projections for Japan (Deviation from the 1980-1999 average)

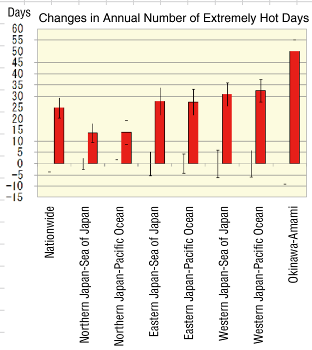
Solid lines are multi-model area averages of surface warming for the SRES scenarios A2 (red), A1B (green) and B1 (blue). The shaded area reflects the range of uncertainty. (± standard deviation)

Created by: Japan Meteorological Agency

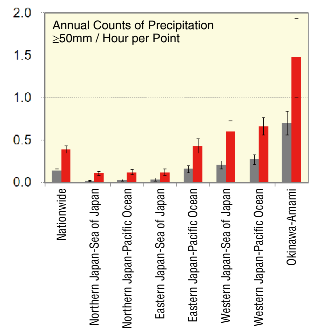
Temperatures will Continue Rising and Heavy Rains will Become More Frequent

If CO_2 concentrations increase in line with Scenarios B1, A1B and A2, Japan's average temperature is projected to increase by 2.1 - 4.0°C, which exceeds the global average of 1.8 - 3.4°C. Based on climate change model projections, temperature increases will be larger in Northern Japan, while the number of extremely hot days and tropical nights will increase significantly in Okinawa and Amami, Western Japan, and Eastern Japan. Meanwhile, the number of cold and extremely cold days will decline primarily in Northern Japan.

Furthermore, the frequency of hourly heavy rains will increase in all regions, while the number of dry days with daily precipitation less than 1mm is expected to increase in almost every region. Source: Ref. 5



Changes in Number of Extremely Hot Days by Region



Changes in Annual Counts of Precipitation ≥50mm / Hour by Region

Left: Deviation between the 1980-1999 average and the 2076-2095 average. Right: Comparison of the 1980-1999 average (gray) and the 2076-2095 average (red). Both graphs were created using a regional climate model with a resolution of 5 km. Based on Emissions Scenario A1B. Source: Ref. 5

Other Projections

- Excluding Hokkaido and parts of the Honshu interior, snowfall and snow depth is expected to decrease.
- Studies indicate that the probability of typhoon strikes will decline but that typhoons with low central pressure will approach Japan more frequently.
- Sea surface temperature in the waters around Japan in expected to increase over the long term.
- Sea levels are expected to rise over the long term. Excluding eastern Hokkaido, sea levels around Japan are projected to rise 5 - 10 cm more than the global average; the impact of noticeable 20-year variations must be taken into account.

Source: Ref. 1, 5, 6, 7

Impacts of Climate Change (1)

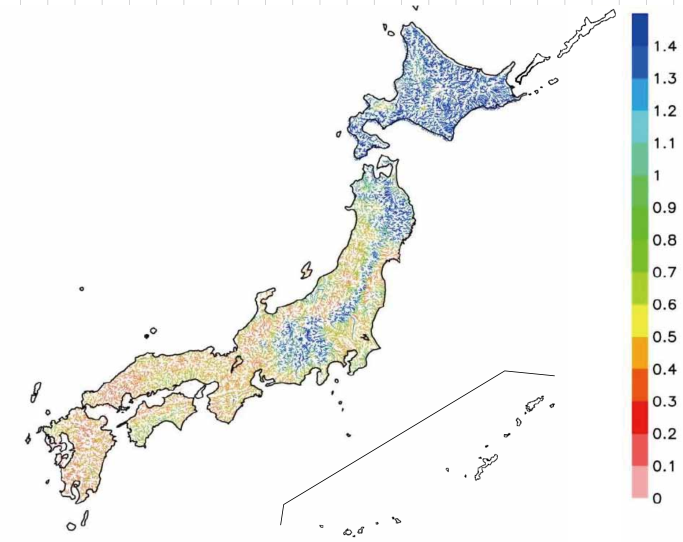
Impacts due to Average Temperature Increase

Phenomena thought to be the result of climate change have already started to occur in Japan, and these impacts are expected to expand across many areas.

Water resources and water-related disasters **The Impacts of Climate Change**

Increase Risk of Drought

Due to climate change, some regions are expected to see an increase in the number of days without rain as well as increased occurrences of drought due to decreased snowfall. Except for northern Japan and the central mountainous region, there is a risk that river discharge will decrease, leading to severe drought. In regions where snowmelt water is used, maximum river discharge may fall during the snowmelt period and its peak may occur earlier than usual, thereby leading to the possibility of decreased river discharge when water is most in demand.



10-year return period Drought-time change (End of the 21st Century)

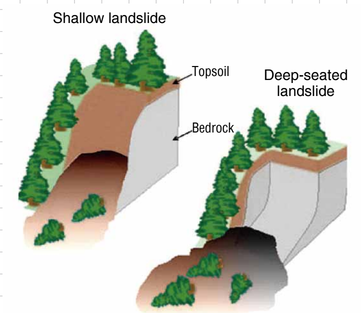
Based on MRI Global Climate Model (MRI-AGCM 20km) under SRES Scenario A1B. The figure shows the ratio of change for the end of the 21st century (2075-2099) compared to the current climate (1979-2003). Source: Ref. 8

Potential Changes in Water Quality

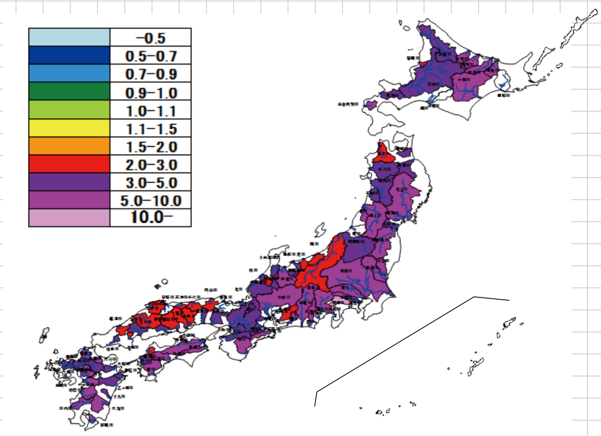
The impact of climate change on water temperature and water quality and their interaction is very complex. In rivers and lakes, water quality may deteriorate due to less water circulation and the increase in phytoplankton caused by rising water temperatures. In outlying islands, there is also a possibility that the rise in sea level could lead to increased salt water intrusion into the groundwater.

Increasing Risk of Heavy-Rain Induced Disasters

In addition to the increase in drought risk, the risk of disaster due to heavy rain could also increase. One study of class A rivers throughout the country predicts the probability of floods exceeding the rivers' prescribed target flood safety levels to be 1.8 to 4.4 times the current value. In addition, there is a possibility that the risk of mass movement in mountainous areas will also increase. Some slopes in hilly and mountainous areas have experienced considerably large deep-seated landslides, which are landslides in which the underlying bedrock collapses along with the topsoil, and the risk of these landslides may increase.



Credit: Ministry of Land, Infrastructure, Transport and Tourism



Flooding Magnification Factors by River Basin

Based on SRES Scenario A1B. Magnification factors are median values of the probability of floods in future climates (2075-2099) divided by the probability of floods in the current climate (1979-2003). Source: Ref. 9

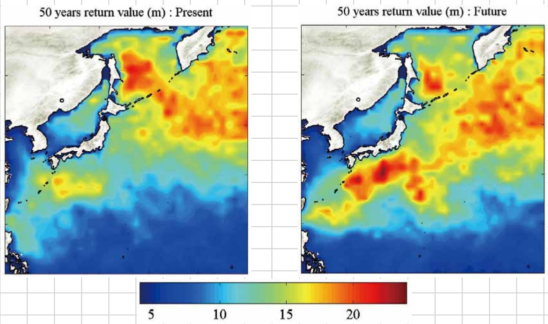
Flooding of the Kumano River (Kiho Town, Minamimuro District, Mie Prefecture) caused by Typhoon No. 12 in 2011

Credit: Ministry of Land, Infrastructure, Transport and Tourism

Increased Risk of High Waves and Storm Surges

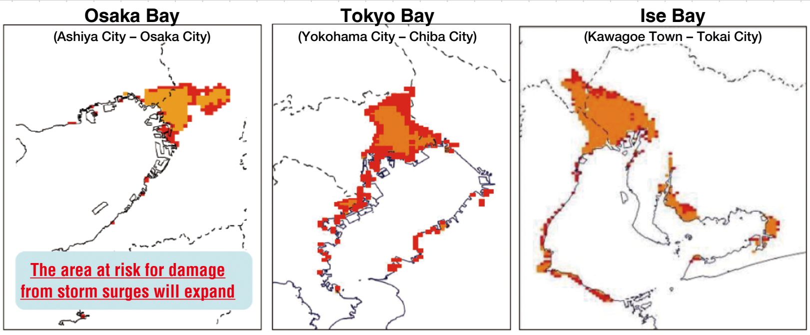
There is a large area of land at 0m above sea level along Japan's three major bays (Tokyo Bay, Ise Bay and Osaka Bay), but assuming a sea level rise of 60cm, the area of land at 0m above sea level and the population in those zones would both increase by as much as 50%; therefore, future sea level rise has the potential to cause serious problems. Furthermore, changes in the course and intensity of typhoons could lead to an increased risk of high waves in coastal areas along the Pacific Ocean.

When a phenomenon is said to have an "annual exceedance probability of 1 in 100," this does not mean that phenomena like it occur once every 100 years, it means that there is a 1% probability that a phenomenon of a certain size will occur in any given year. Therefore, "once in a hundred year" phenomena can occur multiple times in one year, and conversely, they may not occur for more than 100 years.



Wave Heights with Annual Exceedance Probabilities of 1 in 50 in Japan's Surrounding Waters

Projected heights of waves in Japan's surrounding waters with annual exceedance probabilities of 1 in 50 (m) (Left: Current climate; Right: Future climate)
Based on MRI Global Climate Model (MRI-AGCM 20km) and SRES Scenario A1B. Current climate corresponds to 1979-2003; future climate corresponds to 2075-2099
Source: Ref. 10



Now
After sea level rise (60cm)

	Current	After sea level rise	Magnification
Area (km²)	559	861	1.5
Population (10,000s)	388	576	1.5

* Created by Land and Water Bureau based on digital national land information
* Graphical representation of areas whose three-dimensional mesh (1km×1km) altitude is below tidal level; aggregate calculation of the area and population made using the three-dimensional mesh data.
* Water surface area of rivers and lakes/marshes is not included.
* Increase in area and population calculated at 60% in the event of 1m sea level rise.

Expansion of Areas Subject to Storm Surge Risk in Japan's Three Major Bays

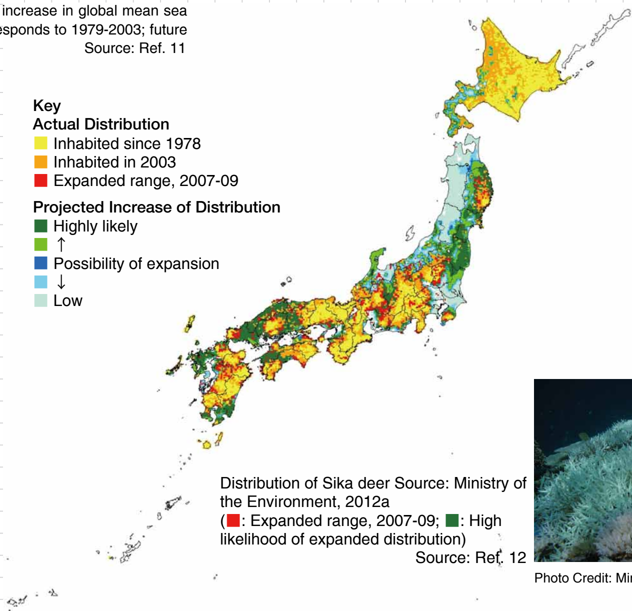
In AR4, a sea level rise of about 60cm corresponds to the upper end of the forecast increase in global mean sea level expected at the end of 21 century (Scenario A1F1: 59cm). Current climate corresponds to 1979-2003; future climate corresponds to 2075-2099.
Source: Ref. 11

Natural ecosystems Northward expansion of flora and fauna habitats

The impacts of climate change on flora are already evident. Changes in vegetation, an increase in wild mammals and an expansion of their range, the northerly expansion of some insects, coral bleaching and changes in animal herds have all been confirmed. In the future, these impacts are expected to continue expanding.

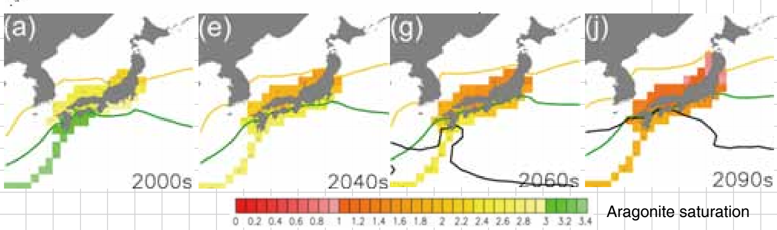
In recent years, damage to crops by wild boar, Sika deer and other animals has spread, and the potential impact of the Sika deer feeding damage on trees and forest ecosystems has also been pointed out. The distributions of wild boar and Sika deer appear to be expanding, and possible causes for this include an increase of abandoned farmland, a declining number of hunters, changes in snow conditions due to rising temperatures, reduced amounts of snowfall and shortened periods of snow cover. Aside from mammals, northerly expansion and widened distributions have been observed and reported for Great Mormon butterflies, Indian Fritillary butterflies and *Ictinogomphus pertina* dragonflies.
As for flora, researchers have found that the elevation where Maries' firs can grow is gradually getting higher and that the distribution of broad-leaved evergreens like the Japanese evergreen oak is expanding.

It is thought that the distribution range of coral along Japan's coasts will be affected by rising sea temperatures and acidification. Projections show that while the areas with water temperatures suitable for coral distribution will advance northward, they will be encroached upon by zones of increased bleaching and zones unfit for coral skeleton formation. For this reason, the waters along Japan's coasts that are suited for the distribution of tropical and subtropical coral are projected to shrink by half by 2020 - 2030 and to disappear by 2030 - 2040.



Distribution of Sika deer Source: Ministry of the Environment, 2012a
(■: Expanded range, 2007-09; ■: High likelihood of expanded distribution)
Source: Ref. 12

Photo Credit: Ministry of the Environment



Changes in the Northern Limit of Coral Reefs: Present Day (2000) and Future (2040, 2060, 2090)

Based on SRES Scenario A2. Figures are the average values from four climate models (IPSL, MPIM, NCAR CSM1.4 and NCAR CCSM3). Green line: Northern limit of tropical / sub-tropical coral reefs; Yellow line: Northern limit of temperate coral.
Black line: 30 °C water that is unsuitable for coral habitats. Mesh: The aragonite saturation, an indicator of acidification (see scale bar for aragonite saturation), decreases as CO_2 dissolves in sea water. Aragonite dissolves completely when its saturation level falls under 1.
Source: Ref. 13

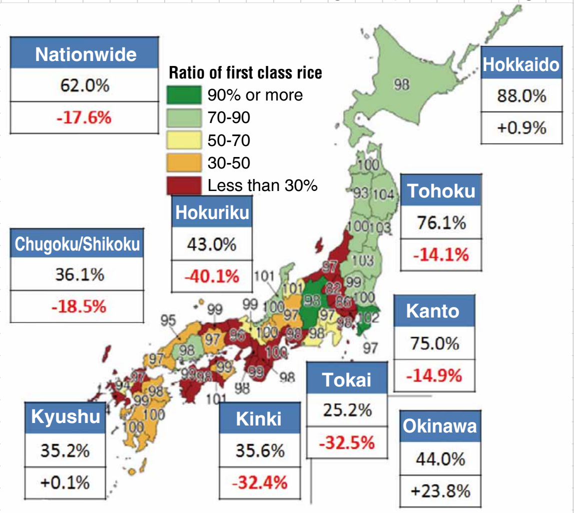
Impacts of Climate Change (2)

Agriculture

Wet Rice Yields will Increase, but Quality will Decline

Researchers already know that the temperature after heading has a significant impact on the quality of wet rice. In the record heat of 2010, many regions experienced average temperatures of 28 – 29°C during the ripening period, and there were many occurrences of white immature grains with partly milky-white kernels. In every region except Hokkaido, the quality of rice deteriorated remarkably.

In a rice cultivation experiment conducted with CO_2 levels set at 200ppm higher than current levels, rice yields increased, but a large ratio of white immature kernels were produced. This marked the first time that elevated CO_2 levels were shown to exacerbate high temperature damage.



2010 Wet Rice Harvest Conditions and Quality

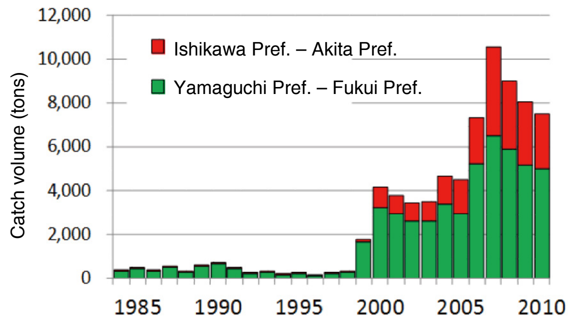
The map shows prefectural harvest condition indicators (numbers in each prefecture) and ratios of first grade rice (colors of each prefecture). The figures in boxes for each region indicate the first grade rice ratios in 2010 (top line) and the deviation from the annual average for the past five years (bottom line). Created based on Ministry of Agriculture, Forestry and Fisheries materials. Source: Ref. 14

Fisheries

Spanish Mackerel Have Increased, while Japanese Common Squid Have Decreased

Over the long term, sea surface temperature in the waters around Japan have been increasing, and the high rate of increase in the central Sea of Japan (1.73°C per 100 years) has impacted fisheries resources. Spanish mackerel (a species of mackerel found in warm seas) have been caught primarily in the Seto Inland Sea and the East China Sea, but since the late 1990s, the summer to autumn water temperature of the Sea of Japan has increased, so the catch volume from the Sea of Japan has surged. Since 2006, catches landed along the coast of Wakasa Bay in Fukui and Kyoto prefectures now account for most of Japan's Spanish mackerel catch volume.

On the other hand, the distribution of Japanese common squid that hatch in an area between the southwestern Sea of Japan and the East China Sea from September to December and move north as they grow (i.e., the autumn spawning group), has shifted northward due to the rise in the water temperature of the Sea of Japan, which now makes it difficult for fishing grounds to form along the Honshu coast from summer to autumn when water temperatures are high. As a result, there are some areas were catches have declined dramatically since the late 1990s.



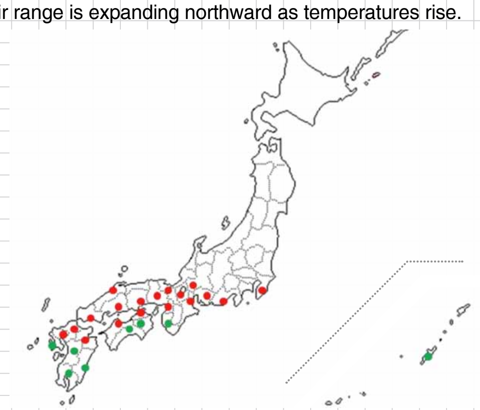
Changes in Spanish Mackerel Catches in the Sea of Japan

Source: Ref. 15

Agricultural Pests

Distributions of Agricultural Pests that can Harm Crops are Expanding

The southern green stink bug is a pest that lives on rice, wheat and soybean plants, and its distribution in the 1960s was limited to warm areas along the Pacific Ocean in southwestern Japan. Now, however, it has spread to western Japan and parts of eastern Japan. Stink bugs live in regions where the average temperature in January is 5°C or higher, and there are reports that their range is expanding northward as temperatures rise.



Southern Green Stink Bug Distribution

●: Distribution in the 1960s ●: Prefectures with confirmed sightings since 2001

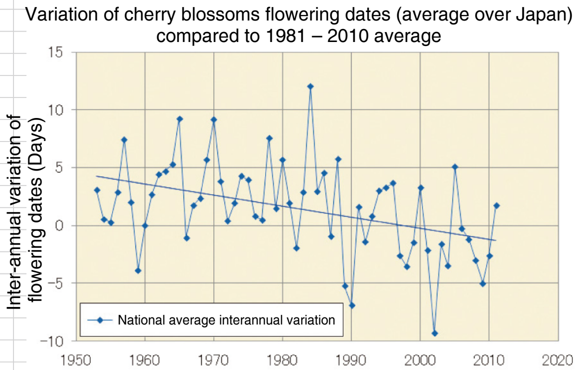
Created based on the Ministry of Agriculture, Forestry, and Fisheries' "Special Report on Forecast of Pest Occurrence"

Source: Kazuyuki Yagi, National Institute for Agro-Environmental Sciences

Phenology

Cherry Blossoms have been Flowering Earlier and Acer Leaves have been Changing Color Later

Cherry blossoms have been flowering earlier in the year, while Acer leaves have been changing color later. Meanwhile, animals are being seen and heard earlier. For example, the first warbler's call is being heard earlier in the year, which shows that climate change is causing shifts in the natural phenomena that have traditionally heralded the seasons in Japan.



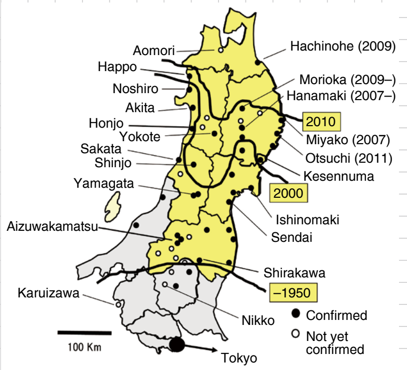
Changes in Cherry Tree Flowering Dates Source: Ref. 4

Health Risks are on the Increase

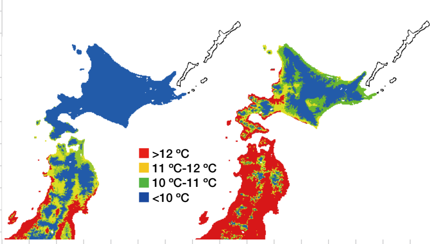
Health

Habitats of Infectious Disease-bearing Mosquitoes are Expanding

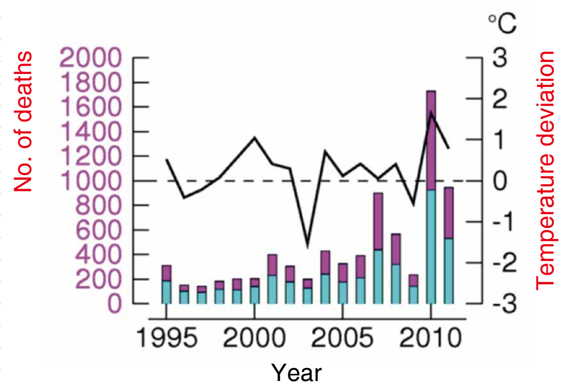
The distribution of the tiger mosquito, potential vector of dengue fever, is almost the same as the area where the annual average temperature is 11°C or higher. Since 1950, the this range has been gradually expanding northward into the Tohoku region. In a study aimed at projecting the future distribution of the tiger mosquito, the suitable habitat is predicted to reach the northern tip of Honshu by 2035 (figure on left, shown in red) and expand into Hokkaido by 2100. The expansion of the tiger mosquito's distribution itself does not directly lead to the transmission of dengue fever, but it indicates that the size of the area where there is a potential risk of dengue fever pandemic is expanding.



Tiger Mosquito Distribution
Created by: Dr. Mutsuo Kobayashi, National Institute of Infectious Diseases



Projected Potential Ranges (Red, Yellow) of the Tiger Mosquito
Left: 2035; Right: 2100
Created by: Dr. Mutsuo Kobayashi, National Institute of Infectious Diseases



Annual Number of Deaths from Heatstroke
●: Female, ●: Male. Overlaid with summer temperatures (average deviation at 17 sites in July and August).
Created by: Meteorological Research Institute

Instances of Heat Stroke are Increasing

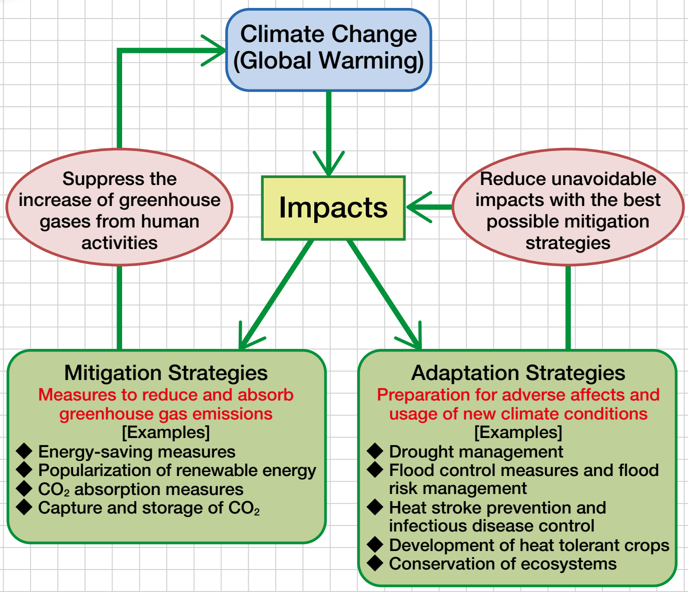
Heat stroke is a direct effect of heat and is thought to be strongly correlated with climate change. The number of annual deaths from heat stroke since 1995 has been trending upward over time. In 2010, especially, a record heat wave yielded a record number of fatalities. The incidence of heat stroke tends to increase as maximum daytime temperatures rise. One report indicates that when temperatures exceed 35° C, there is higher incidence of heat stroke among people aged 65 years or older.

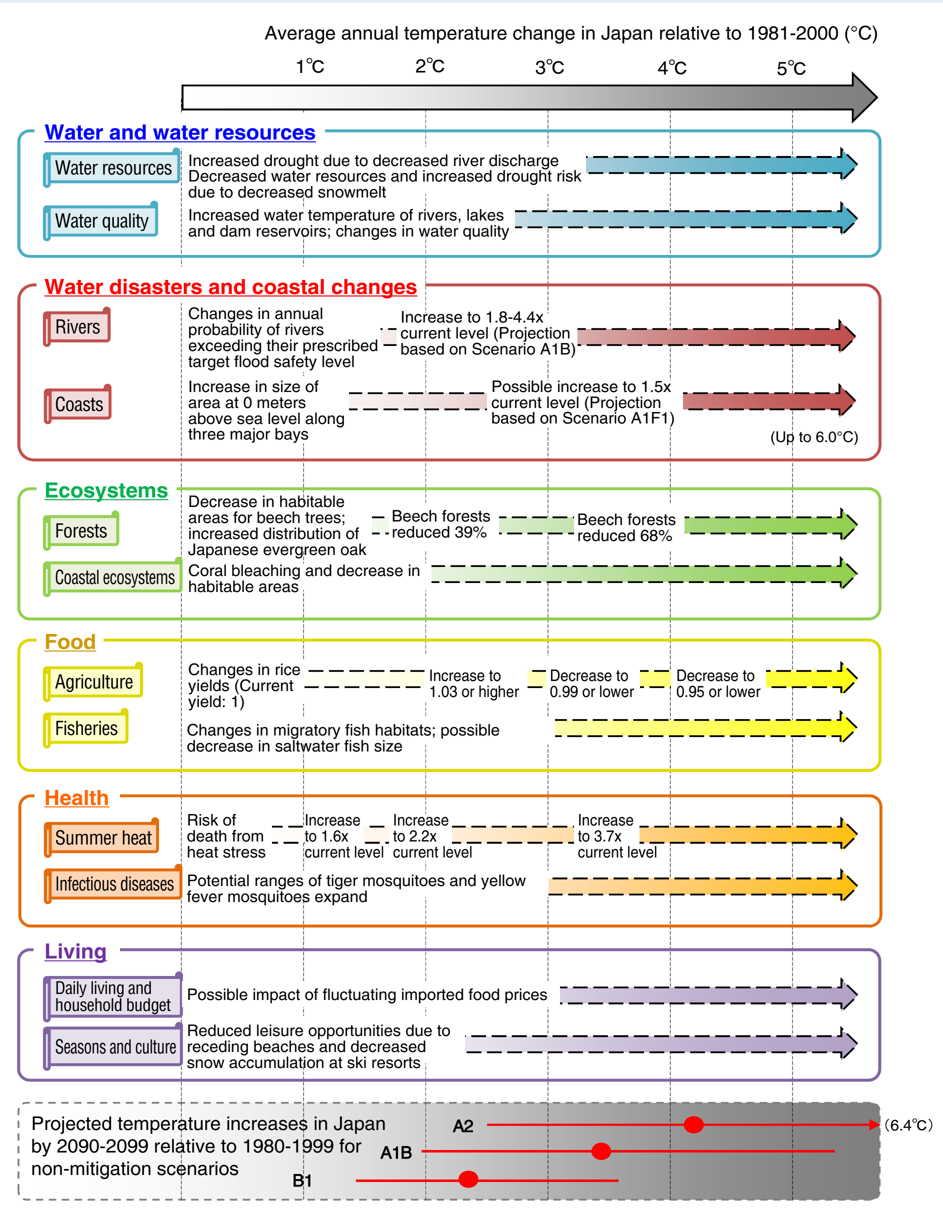
Measures to Prevent the Impacts of Climate Change

Balancing Mitigation and Adaptation Strategies

The IPCC AR4 states: "There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change."

From the standpoint of managing climate change risk, mitigation includes efforts to reduce greenhouse gases, the root cause of climate change, while adaptation refers to ways to handle the unavoidable impacts of climate change that may occur even if mitigation strategies are adopted. In addition to the impacts of climate change that are already evident, Japan will likely experience many other impacts even if it adopts mitigation strategies under the auspices of an international agreement. To adapt to unavoidable impacts that climate change will have on various fields over the long term, Japan will have to evaluate impacts and promote adaptation strategies in a well-planned manner. Initiatives toward the formulation of a government-wide Adaptation Program were launched in FY2012 with the cooperation of relevant ministries. This report is also part of these efforts.





Examples of Impacts Associated with Average Temperature Change in Japan.

Arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left-hand side of text indicates the approximate level of warming that is associated with the onset of a given impact. Source: modified from Ref. 16

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http://www.env.go.jp/earth/ondanka/knowledge.html