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

**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

**Drivers of Global Warming**

Carbon dioxide (CO₂) and other greenhouse gases continue to accumulate in the atmosphere. The global atmospheric concentration of CO₂ 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.

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

**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 CO₂ and other GHG emissions. Each projects CO₂ 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 CO₂ by the year 2100, followed by A1B and B2.

Source: Ref. 3
If CO₂ 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

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 is 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

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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

Projections

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 is 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

Observations and Projections of Climate Change: Japan
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.

**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.

### 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.

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**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 years” phenomena can occur multiple times in one year, and conversely, they may not occur for more than 100 years.

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.

Projected heights of waves in Japan’s surrounding waters with annual exceedance probabilities of 1 in 50 (m): Left: Current climate; Right: Future climate.

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

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

**Expanded Areas Subject to Storm Surge Risk in Japan’s Three Major Bays**

In APR, 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 (SRES A1F1: 50cm). Current climate corresponds to 1979-2003; future climate corresponds to 2075-2099.

**Natural ecosystems**

**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, MRI, NCAR CS1M 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 (scale bar for aragonite saturation), decreases as CO2 dissolves in sea water. Aragonite dissolves completely when its saturation level falls under 1.

Source: Ref. 15

**Distribution of Sika deer**

Source: Ministry of the Environment, 2012a

* 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
* Total surface area of land and habitable marine is not included.
* Created by Land and Water Bureau based on digital national land information
Impacts of Climate Change (2)

**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 CO₂ levels set at 200 ppm higher than current levels, rice yields increased, but a large ratio of white immature kernels were produced. This marked the first time that elevated CO₂ levels were shown to exacerbate high temperature damage.

**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.

**Fisheries**

**Agriculture**

**Phenology**

**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. 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.

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

Cherry blossoms have been blooming 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.

**Southern Green Stink Bug Distribution**

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

**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

**Changes in Spanish Mackerel Catches in the Sea of Japan**

Source: Ref. 15

**Variation of cherry blossoms flowering dates (average over Japan) compared to 1981 – 2010 average**

Source: Ref. 4

**Inter-annual variation of flowering dates (Days)**

Source: Ref. 4
Health Risks are on the Increase

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.

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.
### Average annual temperature change in Japan relative to 1981-2000 (°C)

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<th>Temperature (°C)</th>
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<td>Increased water temperature of rivers, lakes and dam reservoirs; changes in water quality</td>
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<td>Increase in size of area at 0 meters above sea level along three major bays</td>
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<td>Decrease in habitable areas for beach trees; reduced distribution of Japanese evergreen oak</td>
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<td>Coral bleaching and decrease in habitable areas</td>
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<td>Reduced leisure opportunities due to receding beaches and decreased snow accumulation at ski resorts</td>
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<td><strong>Projected temperature increases in Japan by 2090-2099 relative to 1980-1999 for non-mitigation scenarios</strong></td>
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| **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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