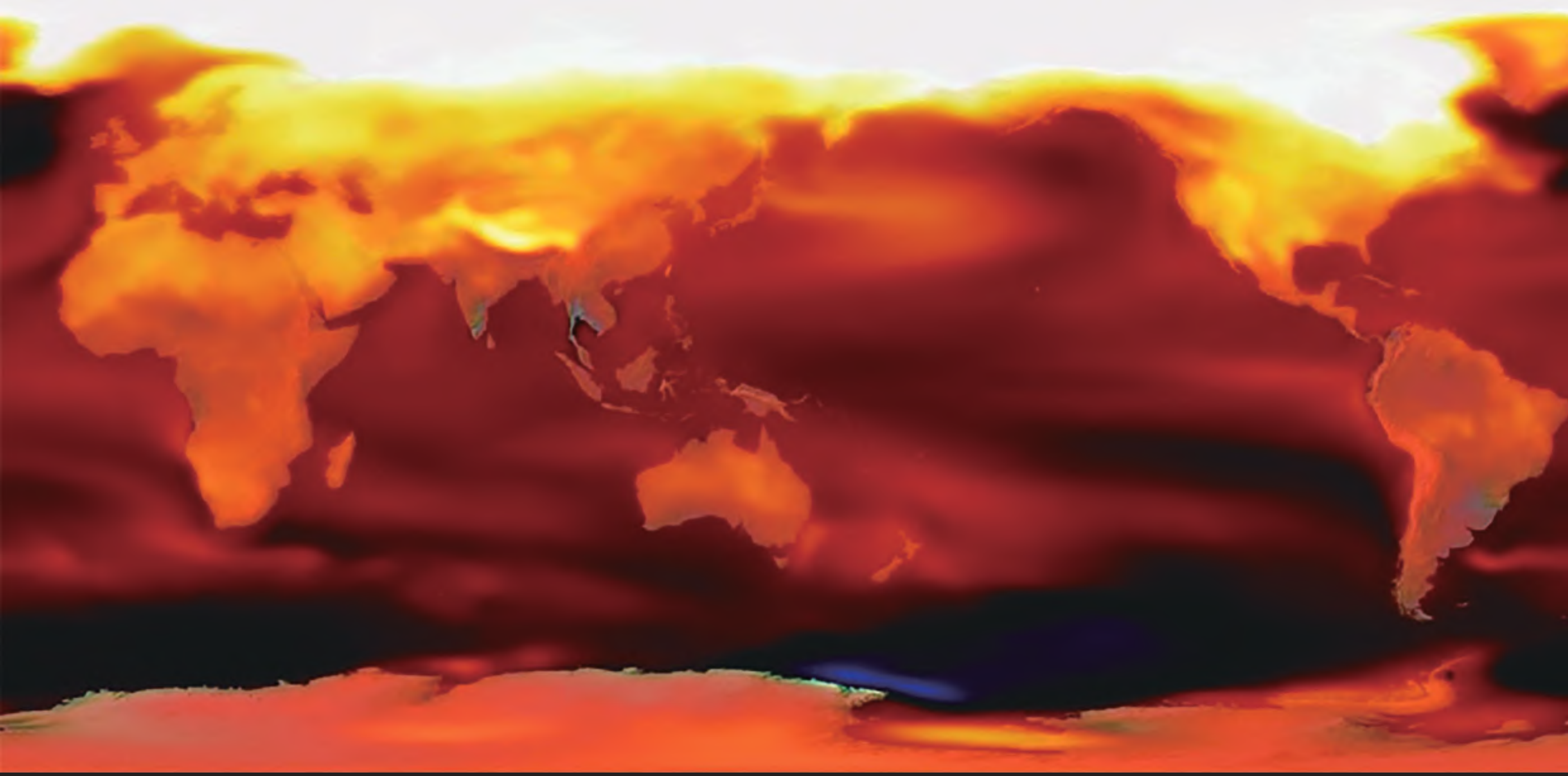


2100
2m temperature change
MIROC5 / RCP8.5

-12℃ -6℃ 0℃ +6℃ +12℃

AORI / NIES / JAMSTEC / MEXT

STOP GLOBAL WARMING

2017

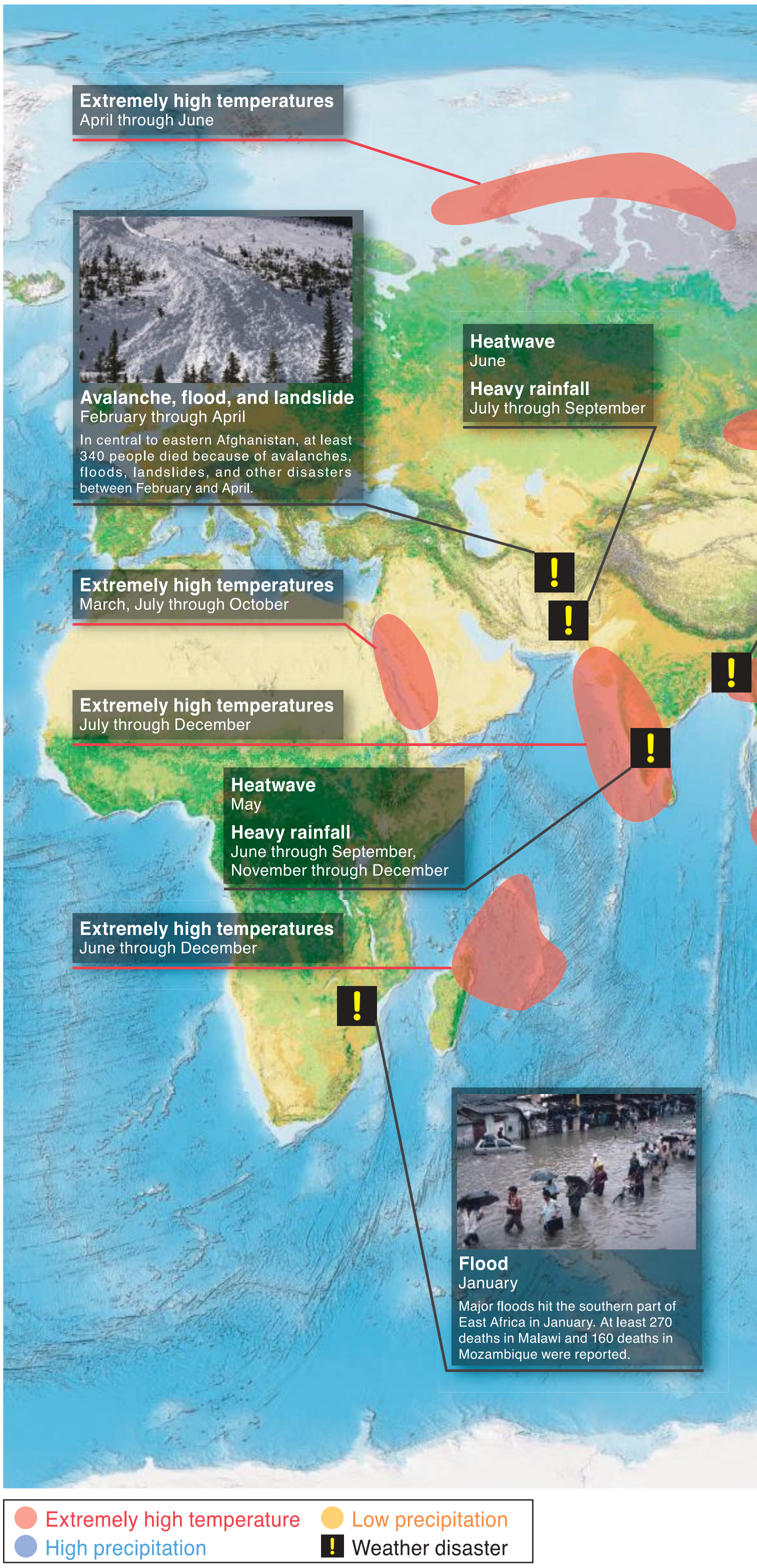
Ministry of the Environment

Chapter 1 Worldwide extreme weather events

CONTENTS

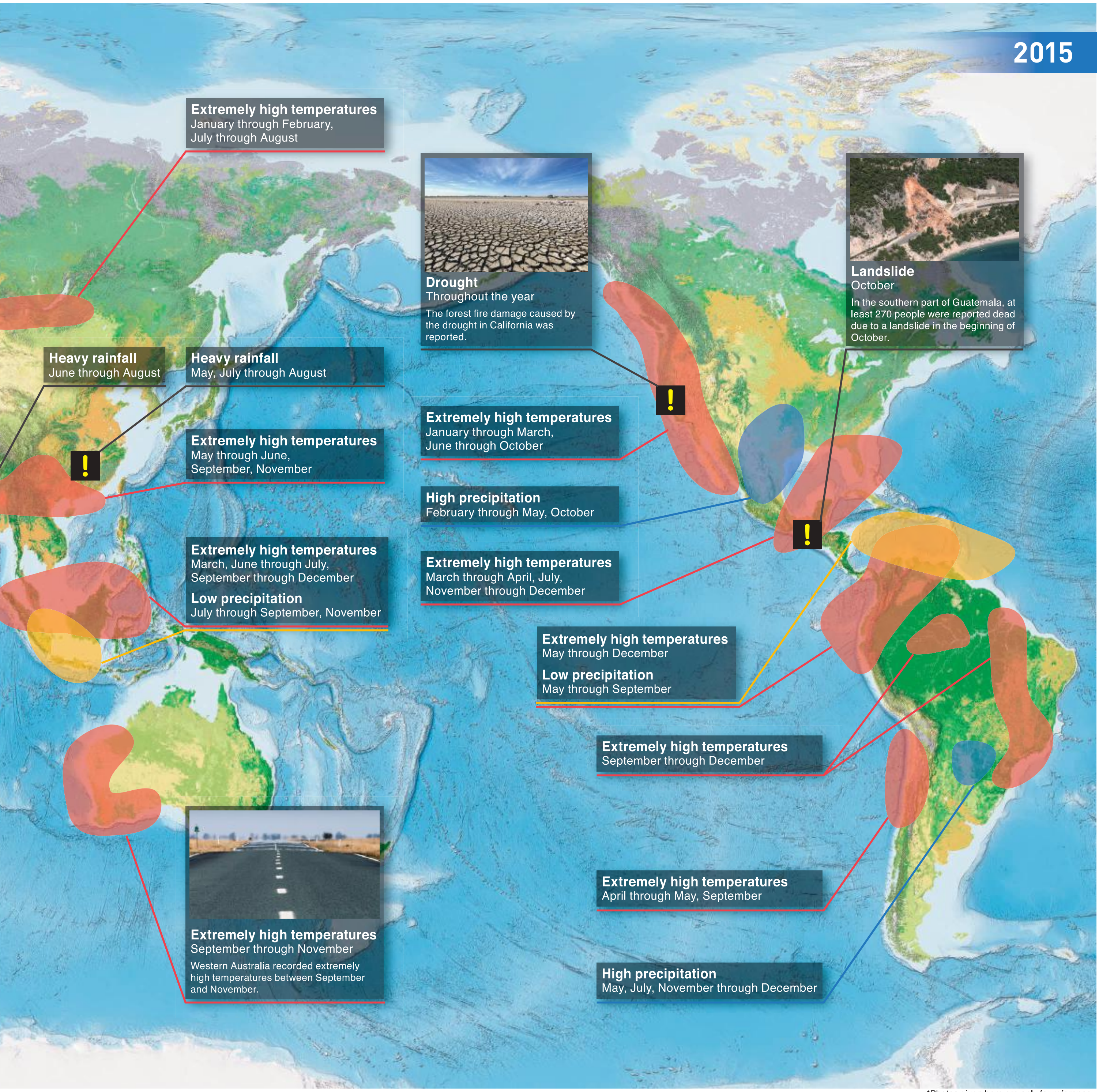
STOP GLOBAL WARMING 2017

World map of major extreme weather events in 2015.



In recent years, extreme weather events have been observed globally. Extreme weather events such as intense typhoons, hurricanes, torrential rains, droughts and heat waves have caused disasters in many areas, causing significant loss of life and serious crop damage. Such incidents are reported almost every year.
In 2015, a heatwave caused a catastrophic damages--in India, at least 2,000 people were reported dead in May and in Pakistan, the reported death toll was at least 1,200 in June.
In the case of Japan, three typhoons hit Hokkaido in summer 2016, and another typhoon hit the Pacific coast of the Tohoku region. These events were observed for the first time since the Meteorological Agency began keeping statistics in 1951. Because of damage caused by these typhoons, the eastern and northern part of Japan suffered from downpours and storm. Particularly in Hokkaido and Iwate prefectures, the extensive damage from record-breaking precipitation is still fresh in people's minds.
According to the Intergovernmental Panel on Climate Change(IPCC)'s Fifth Assessment Report (AR5), it is virtually certain that as global mean temperatures increase, there will be more frequent hot temperature extremes, and it is very likely that there will be more frequent extreme precipitation in the tropics and mid-latitude regions.

(From Source 1, 2)

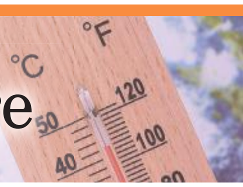


*Photos given here are only for reference.

The map above shows approximate locations and times of extreme weather events and weather disaster that were particularly severe in 2015.
The "extremely high temperatures" , "low temperature" , "high precipitation" , and "low precipitation" indicators in the map show extreme weather events compared to monthly mean temperatures and monthly average precipitation, while others show weather disaster.

(Created based on Source 1)

Chapter 2 Global warming--Past and future



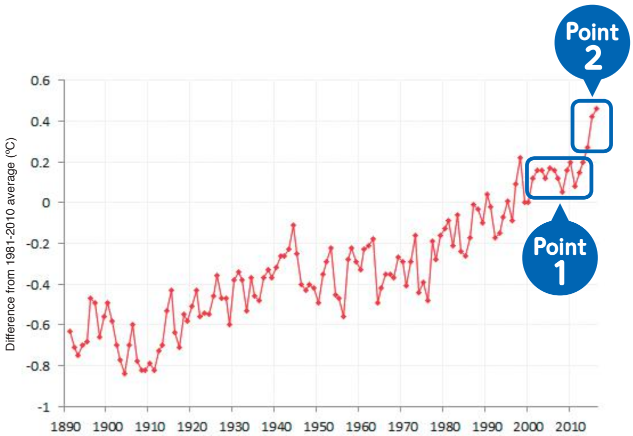
2-1 Climate change

Climate change of the world in the past (global warming)

Temperature increase is continuing

The global annual mean temperature is continuously increasing The Fifth Assessment Report (AR5) published by the Intergovernmental Panel on Climate Change (IPCC) indicated 0.85ºC temperature increase in the period of 132 years. A stagnant condition of global warming (hiatus) (Point (1)) can be seen during the 2000-2012 period. The major factors for this are considered as: heat absorption by the deep ocean, low solar activities, and volcanic activities. However, the mean average has continuously increased since 2014, making 2016 as the hottest year in recorded history (Point (2)).

▶ Change in global annual mean temperature compared to the 1981-2010 average

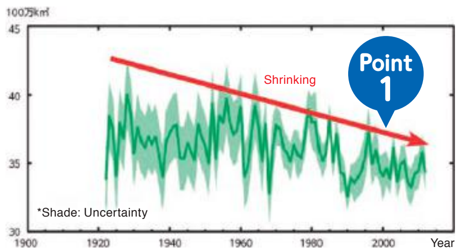


(Created based on Source 3)

Decreasing snow and ice

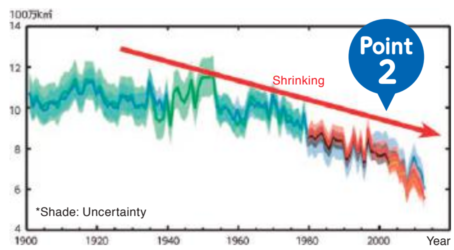
March-April (spring) average snow cover in the Northern Hemisphere has been shrinking(Point (1)). In the Arctic sea, extent of ice has been significantly shrinking since the second half of the 1970s. The figure indicates the sea ice shrinking trend in average July-September (summer with minimum sea ice) (Point (2)). The range of sea ice decrease in 1979-2012 was 0.73 to 1.07 million km² (approximately 9 to 13 times as large as Hokkaido) per decade. The area is rapidly shrinking.

▶ Northern Hemisphere spring snow cover



(From Source 4)

▶ Arctic summer sea ice extent

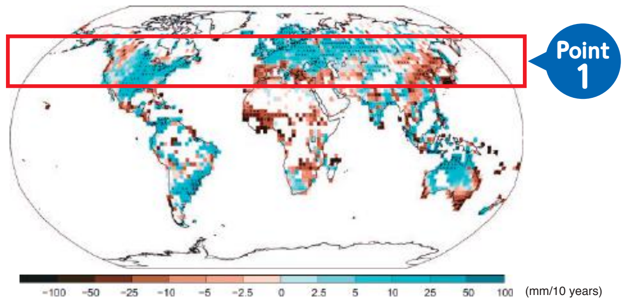


(From Source 4)

The gap between areas with heavy and low rainfall is expanding

Looking at the observed changes in annual global precipitation, since 1951, precipitation has increased in the mid-latitude land areas of the Northern Hemisphere (Point (1)). The frequency of heavy precipitation events has increased in North America and Europe. In contrast, precipitation has decreased in West Africa and Southeastern Australia.

▶ Observed change in annual precipitation over land (1951-2010)

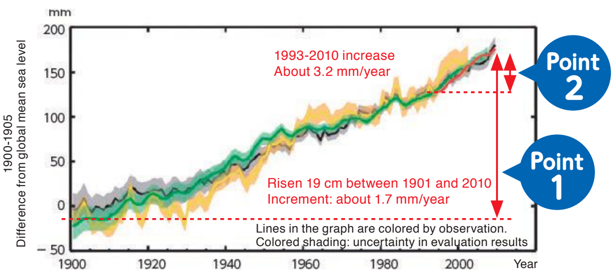


(From Source 4)

Rising sea levels

The mean rate of global average sea level rise was approximately 1.7 mm per year between 1901 and 2010 (Point (1)). It has risen particularly rapidly between 1993 and 2010, at around 3.2 mm per year (Point (2)). The biggest factor for this is thermal expansion in the ocean, but a decrease in glaciers and the ice sheets in Greenland and Antarctica are also thought to be factors. All of these are thought to be caused by global warming.

▶ Global average sea level change

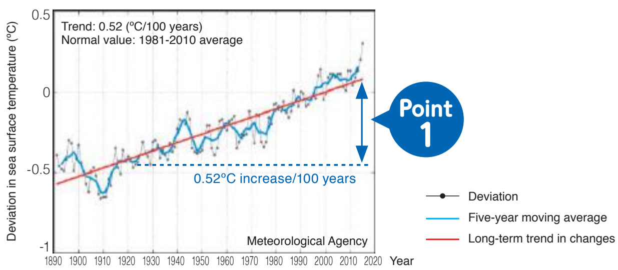


(From Source 4)

Increasing sea surface temperatures

Global mean sea surface temperatures change according to multiple factors including ocean/atmosphere fluctuation and global warming over time scales ranging from a few years to several decades. As a long-term trend, the centennial increase is 0.52ºC (Point (1)). (From Source 4)

▶ Long-term variation in global mean sea surface temperatures



(From Source 5)

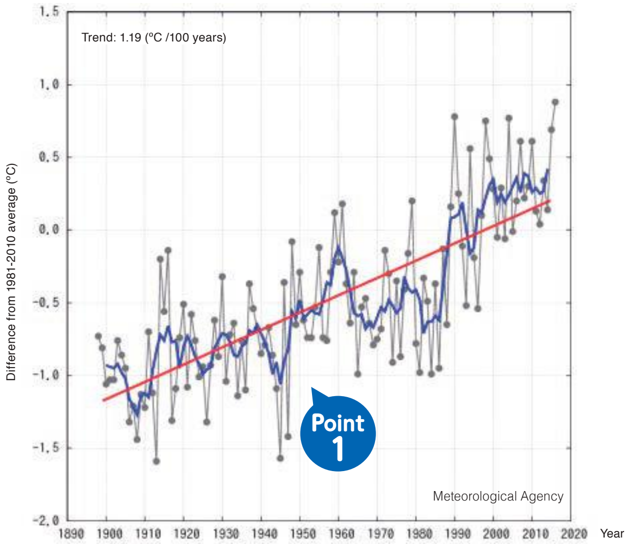
Climate change of Japan in the past (global warming)

Temperature is increasing in Japan, too

As a long-term, annual mean temperature is constantly increasing at a rate of about 1.19ºC per centennial in Japan (Point (1)). When compared to observation results presented in the IPCC AR5, this can be considered a high rate of increase. The report says that global temperature increased by 0.85ºC over a 132 year period.

(From Source 5)

▶ Difference between Japanese annual mean temperature and normal value



(From Source 6)

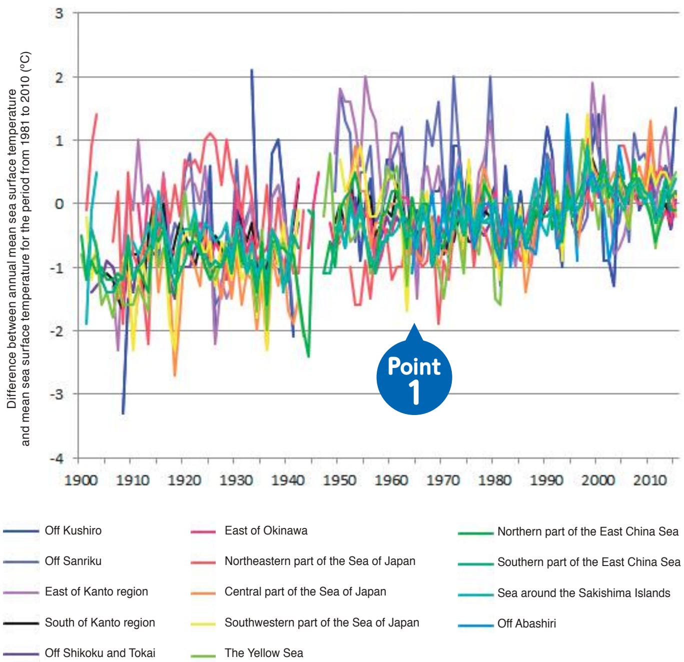
Increasing sea surface temperature near Japan

The sea surface temperature near Japan has been constantly increasing*statistically significant long-term trends can be observed (Point (1)). Annual average sea surface temperature in the sea near Japan (average) up to 2015 is increasing at +1.07ºC/100 years. The rate is higher than the global mean sea surface temperature (+0.52ºC/100 years), and almost equivalent to Japan's rate of mean temperature increase (+1.19ºC/100 years).

*Excludes the northeastern part of the Sea of Japan and the area off the coast of Abashiri, where the rate of increase rate has not been calculated.

(From Source 7)

▶ Change in sea surface temperature near Japan



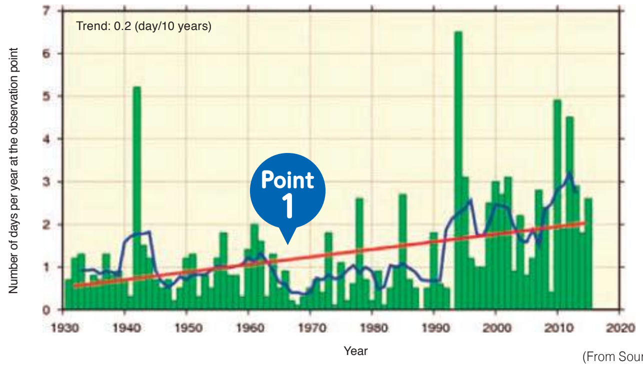
(Created based on Source 8)

The number of extremely hot days is increasing

Trends in the number of days with a maximum temperature over 35ºC (extremely hot days) clearly indicates an increase over the sample period between 1931 and 2015 of time (Point (1)) The number of days with a minimum temperature under 0ºC (extremely cold days) has decreased, and the number of days with a minimum temperature over 25ºC (hot nights) increased in the same period.

(From Source 1)

▶ Number of days with a maximum temperature over 35ºC (extremely hot days) in a year



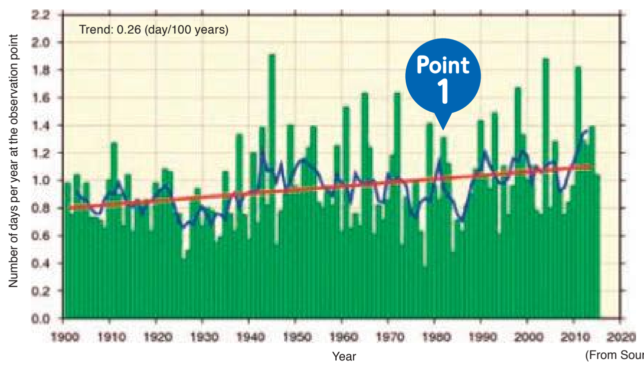
(From Source 1)

The number of days with heavy rain is increasing

No long-term trends have been observed in Japanese annual precipitation. On the other hand, the number of days in a year with 100 mm precipitation per day increased in the 115 years between 1901 and 2015 (Point (1)). The same trend is observed for the number of days in a year with 200 mm or more precipitation per day. The graph also shows that the number of days in a year with 1.0 mm or more precipitation is decreasing, as the frequency of heavy rain increases. However, the graph also suggests that the number of days with precipitation (including light rain) has decreased (Point (2)).

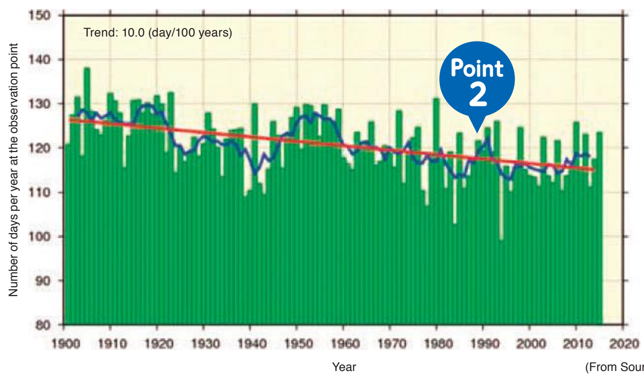
(From Source 1)

▶ The number of days with 100 mm or more precipitation per day in a year



(From Source 1)

▶ Number of days with 1.0mm or more precipitation per day in a year



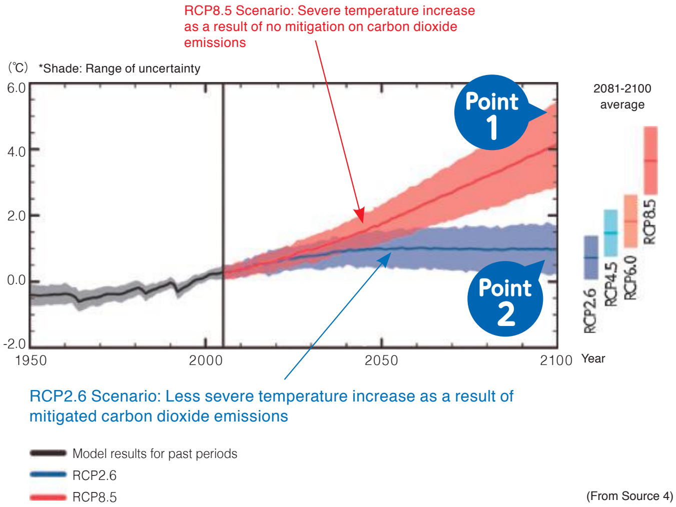
(From Source 1)

Climate change of the world in the future (global warming)

Further temperature increases are projected

According to the IPCC AR5, the global surface temperature for the period from 2081 to 2100 is projected to increase somewhere between 0.3ºC (minimum) and 4.8ºC (maximum) compared to the 1986-2005 average. In the RCP8.5 scenario, which projects the most rapid global warming when emitting GHGs at their current level (with more than double emissions at the end of the 21st century), projects 2.6-4.8ºC temperature increase (Point (1)). In the RCP2.6 scenario, where most GHG emissions are almost eliminated at the end of the 21st century (the least severe global warming), the projected temperature range increase is 0.3-1.7ºC (Point (2)).

▶ **Change in global annual mean surface temperature relative to 1986–2005**

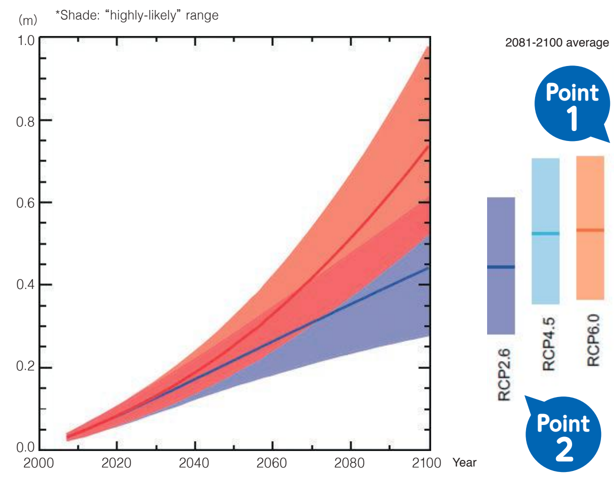


(From Source 4)

Further rise in sea water level is projected

When continuously emitting GHGs at current level, global averaged sea level is highly likely to increase by 45 - 82cm at the end of 21st century (Point (1)). However, even in a case that the most of the GHG emissions are almost eliminated at the end of the 21st century, projected rise in sea level is 26-55cm (Point (2)).

▶ **Projections of global mean sea level rise over the 21st century**

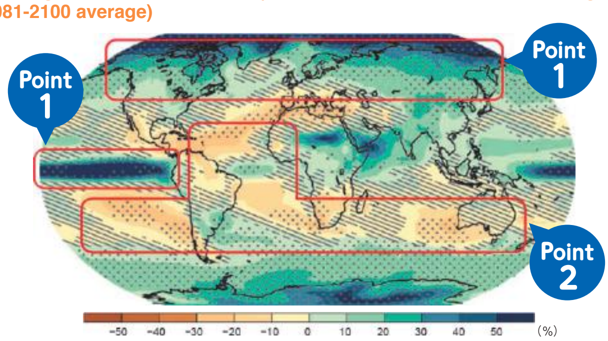


(From Source 4)

Increasing gap in precipitation between humid and dry regions is projected

By the end of 21st century, the gap in precipitation of humid and dry regions will be expanded. If we continuously emit GHGs at current level, precipitation in humid parts of high-latitude, equatorial, and mid-latitude regions are highly likely to increase by the end of the 21st century (Point (1)). On the other hand, precipitation is likely to decrease in many of the dry parts of the mid-latitude and subtropical regions (Point (2)).

▶ **Average percent change in annual mean precipitation when continuously emitting GHGs at current level (Difference between 1986-2005 average and 2081-2100 average)**



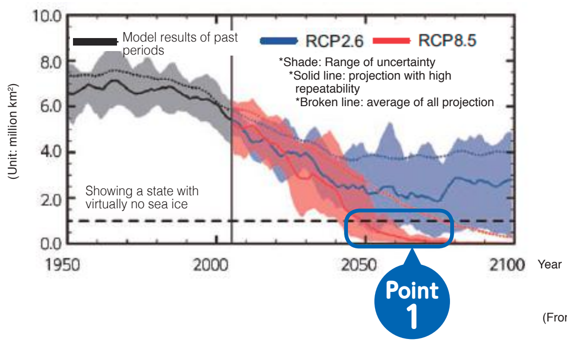
* Shaded area have smaller variation than internal variations of the earth.
Dotted areas have larger variation than internal variations, thus most of the models demonstrate similar patterns of change.

(From Source 4)

Sea ice reduction is accelerated

According to the IPCC AR5, Arctic sea ice cover is projected to shrink and get thinner during the 21st century. When continuously emitting GHGs at current level, sea ice in the north polar region is likely to disappear almost completely during Septembers by the middle of the 21st century (Point (1)).

▶ **Northern Hemisphere September sea ice extent**

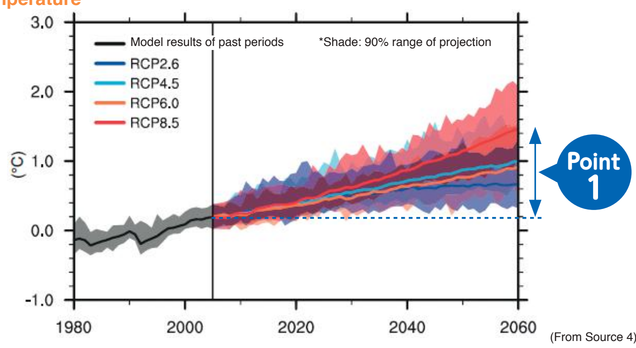


(From Source 4)

Sea surface temperature is constantly increasing

Future global mean sea surface temperature is projected to keep rising. Around 2060, global mean sea surface temperature is projected to increase about 1.4ºC from current level, if we continue to emit GHGs at current rate. Even if most GHG emissions are eliminated by the end of the 21st century, increase in the temperature is projected at about 0.6ºC (Point (1)). Regional variations are projected in the level of sea surface temperature increase due to the impact of oceanic circulation and heated surface.

▶ **Projected changes in annual averaged, globally averaged, sea surface temperature**



(From Source 4)

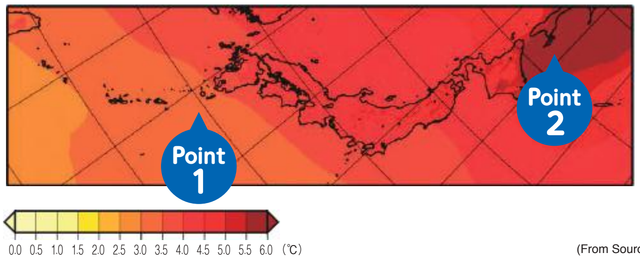
Climate change of Japan in the future (global warming)

Japan is projected to be hotter

Annual mean temperature at the end of the 21st century is projected to increase throughout Japan. At the end of 21st century, mean Japanese temperature is projected to increase by 3.3-4.9°C from present level, if we continue to emit GHGs as currently do. Note that high-latitude regions (Point (2)) have severer temperature increase compared to low-latitude regions (Point (1)).

(From Source 9)

▶ **Change in annual mean temperature when continuously emitting GHGs at current level.**



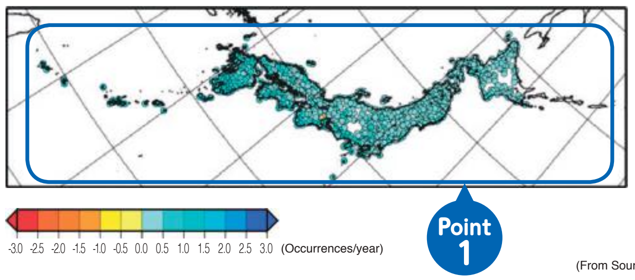
(From Source 9)

Frequency of heavy precipitation is projected to increase

Frequency of heavy rain falling in torrents (50 mm or more per hour) at the end of 21st century is projected to increase throughout Japan (Point (1)). It would be more than doubled for national average , if we continue to emit GHGs as currently do.

(From Source 9)

▶ **Change in frequency of heavy precipitation when continuously emitting GHGs at current level.**



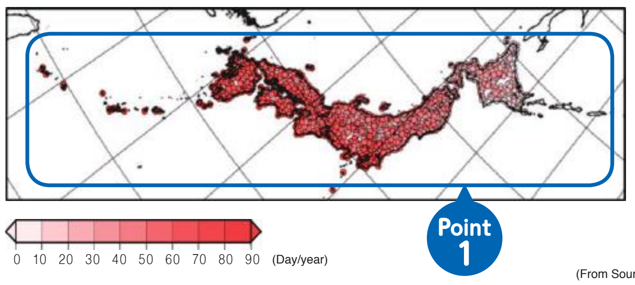
(From Source 9)

Number of hot days are projected to increase

Number of days with the temperature above 30°C at the end of 21st century is projected to increase throughout Japan (Point (1)). The number of days (national average) is projected to increase by 49 day or so from present level, if we continue to emit GHGs as currently do.

(From Source 9)

▶ **Increase of days where the temperature goes above 30°C when continuously emitting GHGs at current level.**



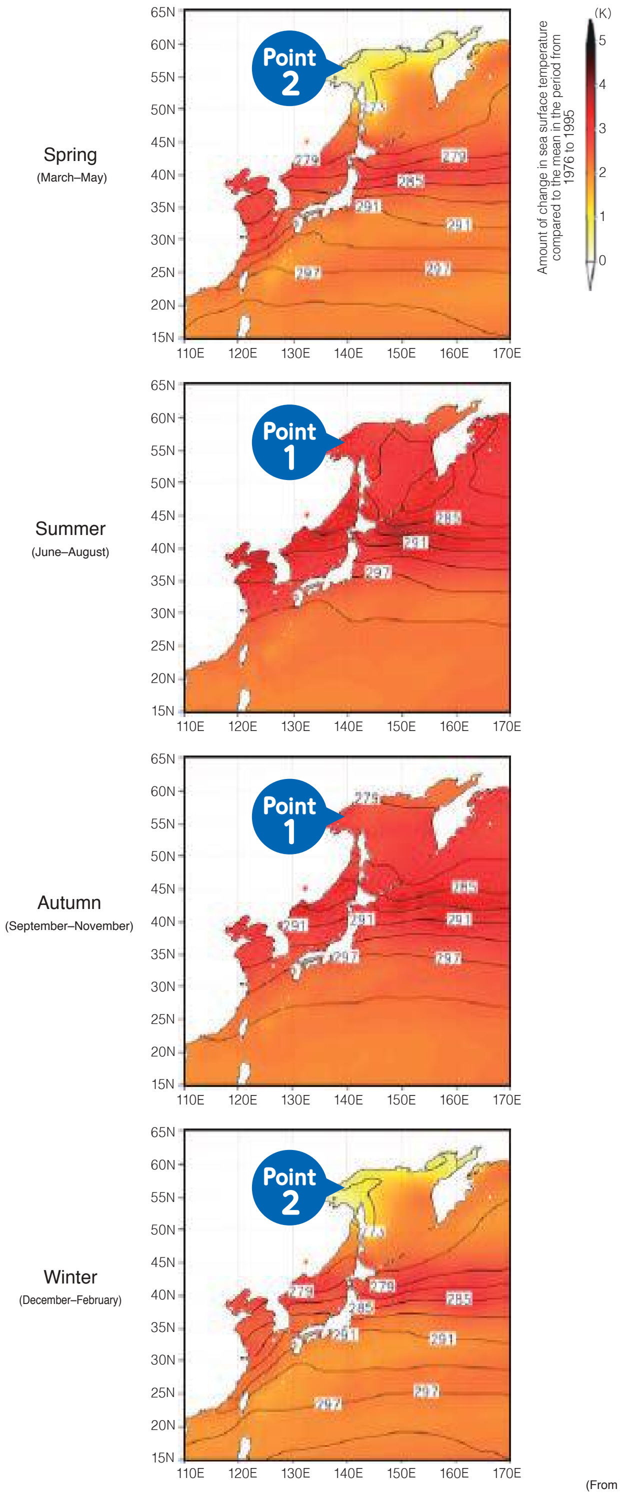
(From Source 9)

Sea surface temperature is projected to increase in most sea area

The sea surface temperatures near Japan are projected to increase from their present level in most areas, if we continue to emit GHGs at the current level*in the future (2076-2095 average). In the Sea of Okhotsk, the temperature is increasing almost uniformly throughout the region in the summer and autumn (Point (1)). Contrastingly, in spring and winter, the increase is relatively small, particularly for a coastal area of the Eurasian Continent (Point (2)). The difference in increment by sea area may be caused by the volume of sea ice covering the Sea of Okhotsk. In other words, the temperature of the Sea of Okhotsk increases in line with increasing temperatures in summer and autumn , when there is less sea ice coverage (similar to other sea areas), however, in spring and winter, the increase in temperature is smaller in areas with a large amount of sea ice.

*Here, the SRES A2 scenario is used instead of RCP8.5.
(From Source 10)

▶ **Future changes in sea surface temperature**



(From Source 10)

2-2 | Food (agriculture, forestry, and fishery industries)

IMPACT PROJECTION ADAPTATION

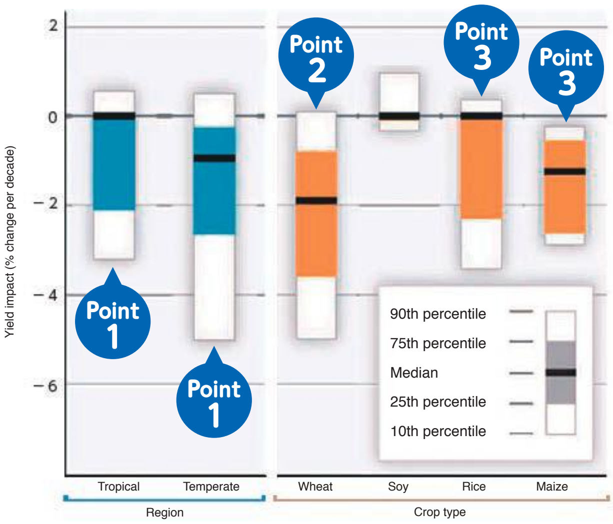
Impact of global warming in the past (Food: agriculture, forestry, and fishery industries)

Yield of major grains is declining in the world

Climate change is also closely related to food production. The figure on the lower provides a summary of the estimated impact of observed climate change on yields between 1960–2013 for four major crops (wheat, soy, rice, and maize) in temperate and tropical regions. In both regions, the negative impacts of climate change on crop yields have been more common than the positive impacts (Point (1)). Looking at yields of the four major crops, wheat yield is most severely impacted by climate change, suffering a significant negative impact (Point (2)). Yields of rice and maize also show negative impact (Point (3)).

However, there are a smaller number of studies showing positive impacts of climate change. They relate mainly to yields in high-latitude regions with lower mean temperature.

▶ **Summary of estimated impacts of observed climate changes on yields over 1960–2013 for four major crops in temperate and tropical regions**



Severity of impact of climate change observed between 1960 and 2013 on yields of four major crops in tropical and temperate regions

(From Source 11)

Domestic animals are also impacted

The following have been reported in dairy cattle: reduced milk volume and deteriorated milk composition, lower fecundity, and increased deaths due to high temperatures in summer. Weight loss, deteriorated meat quality, and death are reported for pigs and broiler chickens as well as for cows.

(From Source 12)

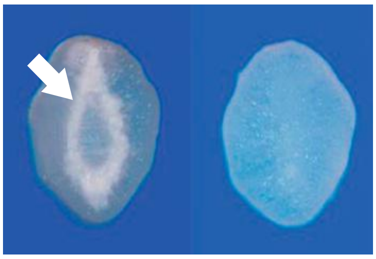
Paddy rice and fruit trees demonstrate quality deterioration

For rice, white immature grains and cracked grains due to high temperature are reported.

For example, rice grains are exposed to high temperature during the period when the fertilized rice cells are dividing and accumulating starch. The high temperature terminate development and maturation before the cells fully accumulate starch, causing white immature grains. The negative impacts of the high temperature causes reduce yields and lowers quality.

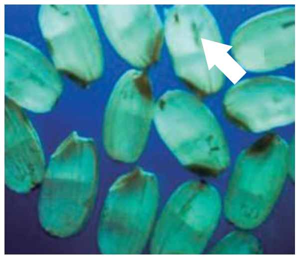
(From Source 12, 13)

▶ **Cross-section of white immature grains (left) and normal grains (right)**



Whitish rice grain due to insufficient starch accumulation (From Source 12)

▶ **Cracked grains**



Rice grain with cracked endosperm (From Source 12)

Fruit trees, including grape vines and apple trees, are demonstrating poor or delayed coloration and discoloration from sunlight. The negative impact of these changes includes deterioration in quality.

(From Source 11, 13)

▶ **Poor coloration of grapes**

Fruit with normal coloration

Fruits with poor coloration

(From Source 14)

▶ **Discoloration from sunlight on a Fuji apple**

(From Source 12)

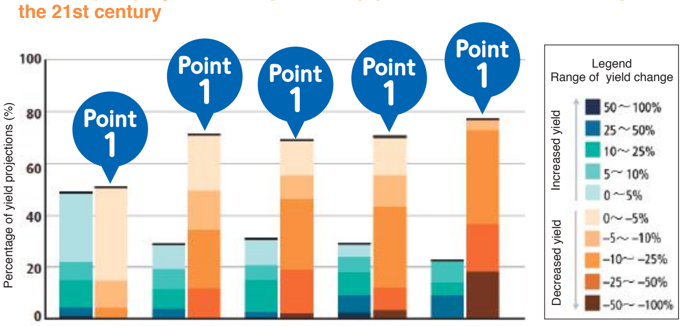
IMPACT PROJECTION ADAPTATION

Impact of global warming in the future (Food : agriculture, forestry, and fishery industries)

Reduction in grain yields is projected

Food demand will surge if population growth continues in the future.
However, if the mean temperature of a region increases by 2ºC compared to the latter part of the 20th century, the yield of crops grown in tropical and temperate regions (wheat, rice, and maize) will be reduced compared to normal figures if no adaptation measures are put in place. If mean temperature increases by 4ºC or more, the risk to food security will increase dramatically.
Projections summarized in the figure on the lower include cases with and without putting adaptation measures in place based on different emission scenarios for tropical and temperate regions. The change in yield in compared to those in latter part of the 20th century show increasing evidence of diminished yield as time goes by (Point (1)).

▶ Summary of projected changes in crop yields, due to climate change over the 21st century



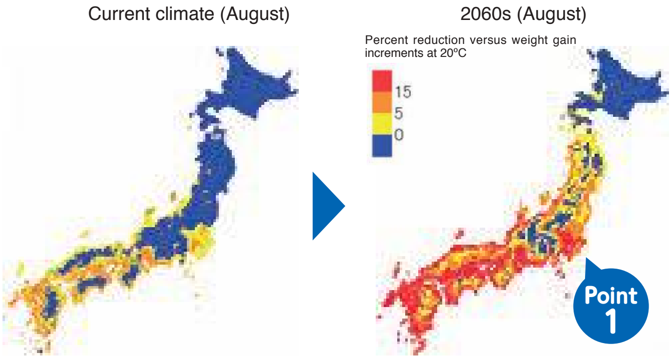
(From Source 11)

Cows are also impacted

The daily weight gain of cows is projected to decrease due to increasing temperatures in summer.
This would cause larger areas to experience deceleration of weight gain in summer due to global warming (Point (1)).
A similar trend has been observed for fattening hogs and broiler chickens.

(From Source 18)

▶ Projected decrease in daily weight gain of cows in summer



(From Source 18)

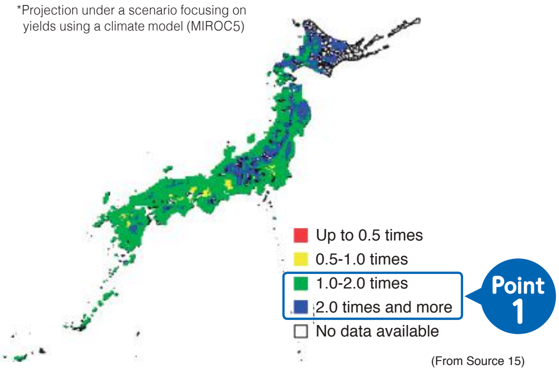
The quality of paddy rice would further deteriorate, while areas suitable for growing fruit trees would shift

If we continue to emit GHGs at current levels, projected rice yield at the end of the 21st century* will stay at the same level as it is currently or would be increased in most areas of Japan (Point (1)). There is another projection possible increased risk of quality deterioration due to high temperatures (Point (2)).

(From Source 14, 15)

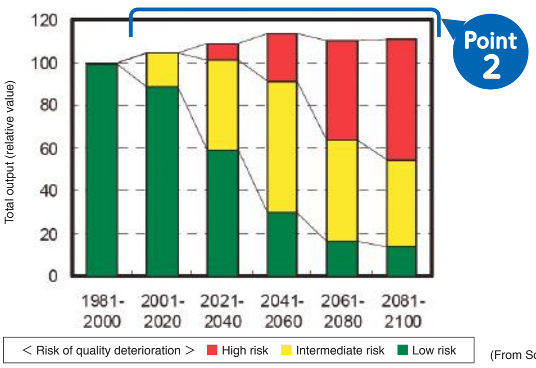
▶ Change in rice yield at the end of the 21st century versus present levels*

*Projection under a scenario focusing on yields using a climate model (MIROC5)



(From Source 15)

▶ Total production over a 20-year period

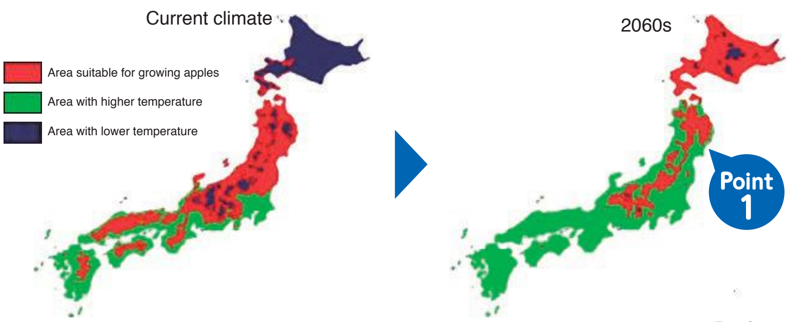


(From Source 16)

There is a suggested future possibility that the areas not suitable for growing apples will expand to the plain areas of the central Tohoku region. Areas suitable for growing citrus unshiu are moving north.
In the 2060s, under the scenario where the annual mean temperature increase is set at 3ºC from present levels, the plain areas in the northern Tohoku region (now a major production center of apples) will no longer be suitable for apple cultivation (Point (1)).
Research under a scenario with continued emission of GHGs at current levels projects that areas with higher temperatures than are suitable for citrus unshiu cultivation would gradually move to the north. This would halve the area suitable for citrus unshiu cultivation in part of the Kyushu region in the mid 21st century, and at the end of 21st century, most of the prefectures located in the western part of Japan facing the Pacific Ocean that produces the fruit at present (Point (2)).

(From Source 16, 17)

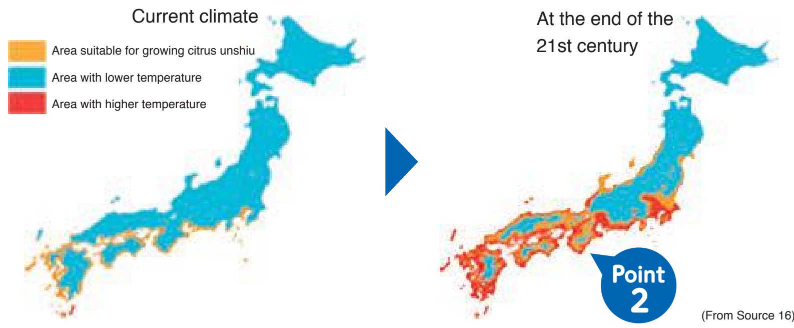
▶ Projection of change in areas suitable for growing apples



(From Source 17)

▶ Projection of change in areas suitable to grow citrus unshiu*

* Projection under a scenario using a climate model (MIROC5)



(From Source 16)

IMPACT PROJECTION ADAPTATION

Adaptation measure (Food: agriculture, forestry, and fishery industries)

Introducing recommended paddy rice varieties resistant to ripening under high temperature

The Hiroshima prefectural government selected "Koinoyokan" brand rice as a recommended variety for its superior features, including resistance to ripening under high temperature. This is a part of measures responding to emerging quality deterioration in "Hinohikari" brand rice grown in southern low-altitude areas, due to recent high temperature in summer. At this moment, "Hinohikari" is being gradually replaced with "Koinoyokan" rice, starting with areas suffering from severer quality deterioration.

*"Koinoyokan" brand rice: A variety developed by Kinki Chugoku Shikoku Agricultural Research Center (now NARO Western Region Agricultural Research Center) in 2014. Compared to "Hinohikari", it has low plant height and improved yield.

(From Source 12)

▶ Variety resistant to ripening under high temperature: "Koinoyokan" brand rice

(From Source 12)

Measures to prevent quality deterioration of fruit trees

Discoloration of fruit from sunlight can be reduced by shielding them from strong sunlight. Specifically, placing shading nets on apple orchards and covering grapes with paper are considered to be effective.

Measures have taken to prevent poor coloration of grapes, such as promoting girdling skins for grapes to accelerate coloration and switching to whiter varieties (e.g. Shine Muscat), which are free from coloration concerns.

Meanwhile, people in the islands and coastal areas of Matsuyama City, Ehime Prefecture who are producing citrus fruits (e.g. citrus unshiu and iyokan orange) have already launched new efforts to adapt to global warming. Specifically, they started growing avocados in 2008.

(From Source 12)

▶ Placing shading nets on apple orchards

(From Source 12)

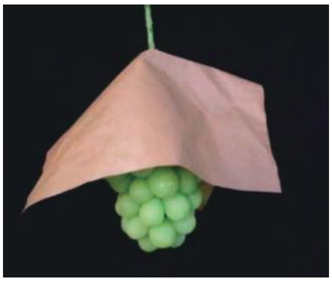
▶ Introducing Shine Muscat

(From Source 14)

▶ Girdling skins for grapes

(From Source 14)

▶ Covering grapes with paper



(From Source 12)

▶ Converting citrus fruit cultivation to avocado (Ehime Prefecture)

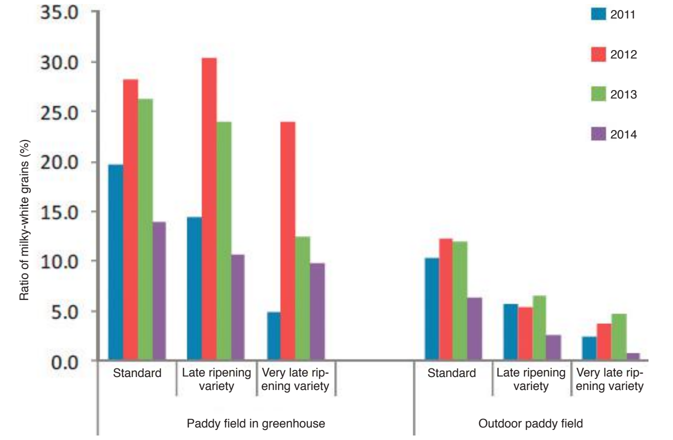
(From Source 12)

Technology to reduce white immature grains

The Nagano prefectural government is testing technology to reduce white immature grains in "Koshihikari" brand rice. The prefecture conducted an examination to clarify the relationship between soil fertilization management and white immature grains and verified the effect of reducing white immature grains by delaying the timing of topdressing. They also conducted another examination to establish water management technologies that effectively reduce white immature grains and verified the effect of reducing white immature grains through constant-flow irrigation (night time) for around 20 days after ear emergence.

(From Source 12)

▶ Timing to add fertilizers and ratio to have milky-white grains



(From Source 12)

Measures to mitigate excess heat for domestic animals

Mist generators and tunnel ventilation systems are installed in milk cowsheds to mitigate high temperatures. Measures to mitigate heat include: spraying water or lime on the roof using sprinklers or sprayers.

(From Source 12, 19)

▶ Mist fan for cowshed

(From Source 12)

▶ Fans installed on the walls of cowsheds

(From Source 12)

▶ Applying lime on the roof of cowshed

(From Source 19)

2-3 | Natural ecosystem

IMPACT PROJECTION ADAPTATION

Impact of global warming in the past (Natural ecosystem)

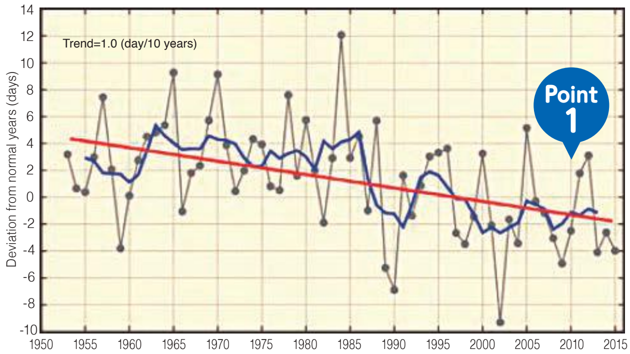
Earlier flowering date for cherry blossoms

Since 1953, the flowering date of cherry blossoms has been accelerated at a rate of 1.0 day per decade (Point (1)). The flowering date of cherry blossoms is thought to be related to the average temperature before blooming. Therefore, the impact of long-term temperature increase is considered to be a factor in earlier flowering of cherry blossoms.

Observation points (58 locations throughout Japan) indicated in the figure on the right include large cities such as Sapporo, Sendai, Tokyo, Osaka, and Fukuoka.

(From Source 1)

▶ National average: deviation from normal years in flowering dates of cherry blossoms



(From Source 1)

Declining beech forests

Beech is a variety of deciduous broadleaf tree, commonly found in cooler temperature zones ranging from Hokkaido to Kagoshima. Many beech forests are preserved as virgin forests. Therefore, a great variety of animals and plants that are unique to this kind of forest live there, while people enjoy the benefits of nature, including a stable water supply. This means that a decline in beech forests would have a significant impact on not only animals and plants, but also on human lives.

The area around Mt. Hirugatake, located in the Tanzawa Mountains (Kanagawa Prefecture), was covered in beech trees in the 1970s. However, the place is now covered with grasses in 2000s (Point (1)).

Another example of declining beech forests can be found at Mt. Tsukuba (Ibaraki Prefecture). Evergreen broadleaf trees have increased at all altitudes over the three decades from 1975 to 2005, taking over beech forests.

(From Source 20, 21)

▶ Aerial photograph in the vicinity of Mt. Hirugatake(Top: 1970s, bottom: 2000s)

1970s

2000s

(From Source 21)

Coral bleaching

It is reported that one-third of warm-water corals are in danger of extinction. Since the 1980s, coral bleaching has become more apparent and it is thought that global warming largely influences this phenomenon.

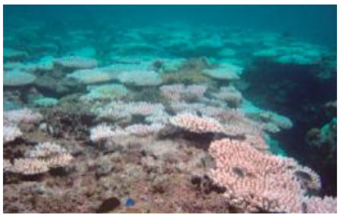
Coral bleaching occurs when the coral loses algae, called zooxanthella. When this occurs, the coral's white skeleton becomes visible. The reasons for coral bleaching are water temperature changes, strong sunlight, ultraviolet light and lower salinity. Water temperature changes significantly affect coral in particular. If the temperature is 30ºC or higher for a prolonged period, the zooxanthella algae is damaged, causing coral bleaching, and if the high temperature continues for a longer period, the coral dies.

In 2016, severe coral bleaching was confirmed in Sekisei Lagoon and other locations in Iriomote-Ishigaki National Park, where high temperatures of over 30ºC were maintained in summer.

(From Source 22, 23)

▶ Coral bleaching

Before



After

Photo: MOE

Concerns over decline of grouse population

The decline of the grouse population has become a concern due to the intrusion of Japanese deer in alpine zones, increased predators, changes in the status of dwarf stone pines ,as their nesting place, and alpine plants that they feed on . According to recent studies, it is shown that the grouse population in the northern part of the Minami Alps (a mountain range that extends from Mt. Kitadake and Mt. Ainotake to Mt. Noutoridake) has been shrinking severely. An alpine belt that extends from Mt. Chausudake to Mt. Izarugadake in the southern part of the Minami Alps is the world's southern limit of the grouse habitation range.

(From Source 24)

Photo: MOE

IMPACT PROJECTION ADAPTATION

Impact of global warming in the future (Natural ecosystem)

Change in flowering date of cherry blossoms

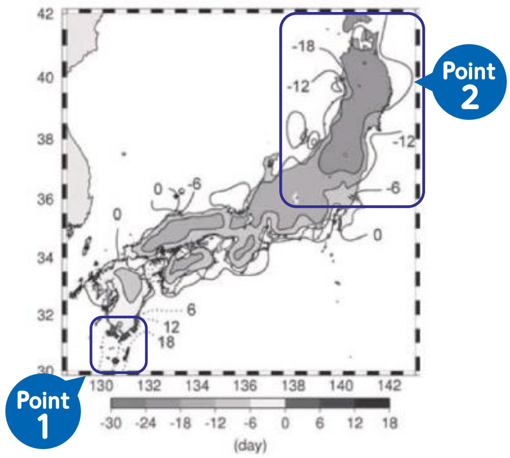
The flowering dates of cherry blossoms are projected to change as the temperature increases. If GHG emissions continue at the current levels*, at the end of the 21st century (2082-2100), the flowering date would be decelerated in southern areas of Kyushu (Point (1)) and the coastal areas of the Pacific Ocean, while it would be accelerated in Tohoku (Point (2)), on the Sea of Japan coast, and high altitude areas.

Cherry trees finish their winter dormancy after being exposed to low temperatures (dormancy breaking), and bloom their flowers after developing floral buds as temperature increases.

In the area where flowering is delayed, the trees cannot be exposed to low temperature in winter due to global warming, flowering is decelerated because time to break dormancy would be prolonged. There is a possibility that the cherry blossoms may not even bloom some years. On the other hand, in areas with early flowering, cherry trees can be exposed to low temperature in winter even in winters affected by global warming, and thanks to global warming, the tree can also be exposed to sufficiently high temperatures earlier for developing floral buds after breaking dormancy. As a result, flowering is accelerated.

*Here, SRES A2 scenario is used instead of RCP8.5.
(From Source 25)

▶ Change in flowering dates of cherry blossoms at the end of 21st century



Accelerated ← Difference in average flowering date (day) → Decelerated
(From Source 25)

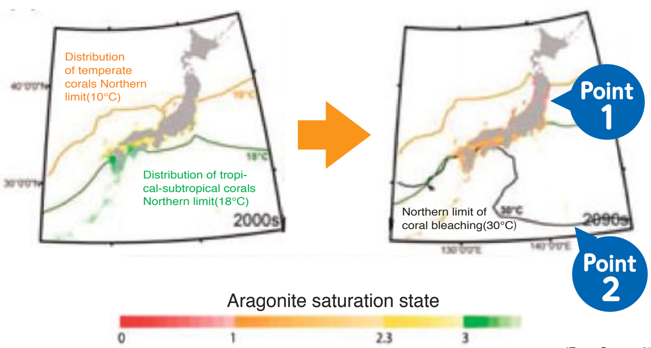
Coral

If the carbon dioxide concentration in the atmosphere increases, more carbon dioxide will be absorbed by seawater, leading to ocean acidification. This is projected to interrupt the skeleton formation process of coral.

If GHG emissions continue at the current levels*, the possible coral distribution range will move north due to temperature increase. This means that the habitat range of coral with optimal water temperature and ocean acidity will be caught between the northern sea areas not suitable for coral skeleton formation (Point (1)) due to ocean acidification and the southern sea areas where coral bleaching is taking place due to increased seawater temperature (Point (2)). Accordingly, 90% of the total areas suitable for the corals distributed in temperate area in the 2000s will disappear in the 2050s, and bleaching will occur in about half of the total areas where tropical-subtropical and temperate coals can be distributed.

*SRES A2 scenario is used instead of RCP8.5.
(From Source 27)

▶ Shift in the areas suitable for coral in the future



(From Source 27)

Beech trees

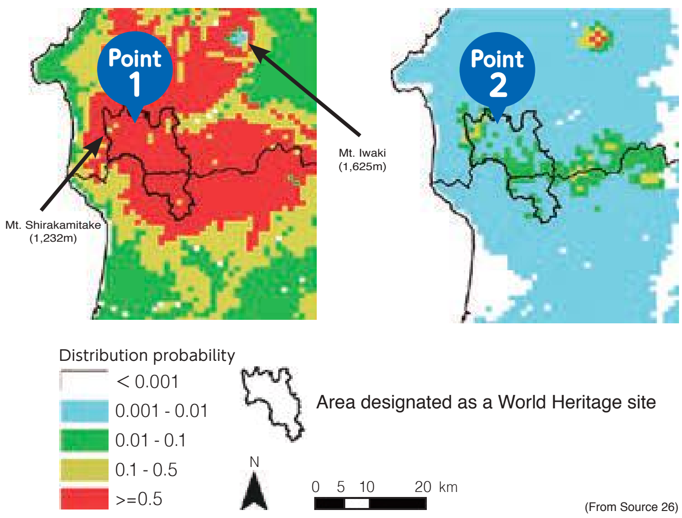
In the Shirakami Mountains (a World Heritage site) that extend over Aomori and Akita Prefectures, 95% of the area designated as a World Heritage site is suitable for beech trees under present*1 climate conditions (Point (1)).

However, if GHG emissions continue at the current levels*2, the area will shrink during the end of 21st century (2081-2100) due to temperature increase (Point (2)). Some research suggests that the area suitable for beech trees will completely disappear.

*1 average values between 1953 and 1982
*2 SRES A2 scenario is used instead of RCP8.5.
(From Source 26)

▶ Change in the areas suitable for beech forests around the Shirakami Mountains

Photo: MOE



(From Source 26)

Grouse

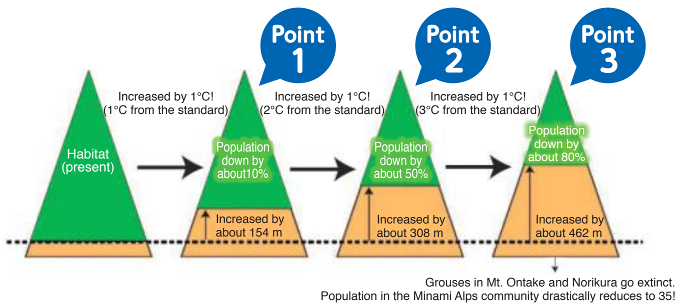
The habitat range of the grouse is considered to be shrinking with the decreases in the alpine plants to feed on due to global warming.

When the annual mean temperature increases by 1ºC, the projected population number is reduced by about 10% (Point (1)). A 2ºC increase reduces the number by about half (Point (2)), and a 3ºC increase by about 80% (Point (3)).

If the temperature increases by 3ºC, grouse nesting in Mt. Ontake and Mt. Norikura are projected to become extinct, and the population nesting in Minami Alps is also projected to decrease down to 35 becoming almost extinct.

(From Source 28)

▶ Change in grouse habitat range due to global warming



(From Source 28)

IMPACT | PROJECTION | ADAPTATION

Adaptation measure (Natural ecosystem)

Beech trees: Study and research through monitoring

The Shirakami-Sanchi World Heritage Conservation Center is carrying out ongoing monitoring studies every year to understand the long-term changes in the natural environment in the area designated as a World Heritage site. The monitoring study aims to understand the natural ecosystem with a focus on beech forests in the Shirakami Mountains and the changes. Through this, the basic data will be accumulated, which can be used for finding out the causes and taking appropriate measures to address any changes that may occur. The center has recently conducted research and studies to define the forest structure and dynamics from a broader perspective applying laser measurement technology and the satellite images. The center also has carried out a phenology study using fixed-point cameras.

(From Source 29)

▶ Phenology study using fixed-point cameras

Photo: MOE

Coral: Transplant and increase at artificial reefs

MOE carries out coral reef investigations known as Monitoring Site 1000. The purpose of this study is to understand the current condition of Japan's coral reef ecosystem and collect information that helps to conserve the nation's natural resources. In addition, the adaptation measure may include coral transplant and increase at artificial reefs, aiming to restore degraded corals. There are some ways to nurse plants for transplant. For example, MOE transplants coral by helping their nidation through installing nidation tools using immature corals.

(From Source 30, 31, 32)

▶ Settlement Device

(From Source 32)

▶ Corals grew while attached to the settlement device

(From Source 32)

Grouse: Monitoring the habitat status

In March 2009, the Nagano prefectural government formulated a project plan for protecting and restoring grouses.
As a part of the project, monitoring grouse habitat status is prioritized as an urgent issue. The Nagano Prefecture Environment Conservation Research Center conducts monitoring studies on grouse habitat status at two sites in the Prefecture.
One takes place in the alpine belt that includes the area around Mt. Izarugadake extending to Mt. Chausudake and Mt. Kamikouchitake. At this point, nearly a decade of ongoing research has taken place, led by the Shizuoka Grouse Study Group. The Center conducts joint research with this group. The other monitoring point is around Mt. Jiigatake, where the eight grouse habitat status researches have taken place. The Center is conducting a joint study with the Omachi Alpine Museum, owned by the town of Omachi.

(From Source 33)

Column

Response to changes in cherry blossom flowering dates

Hirosaki Park in Hirosaki City, Aomori Prefecture is one of the most popular places for cherry blossoms. Every year, a Cherry Blossom Festival takes place approximately from April 23 to May 5. A unique characteristics of the Hirosaki Cherry Blossom Festival is its schedule. Because the festival week overlaps with Japan's holiday season, called Golden Week (April 29 through May 5), this festival is ranked high in the number of visitors every year, among other tourist sites in this period.
According to a paper published by Sakurai and Kobori (2012), global warming correlates to the flowering dates for cherry blossoms, suggesting that the number of visitors would be severely affected by this phenomenon. As a part of their study, the two researchers conducted interviews with the organizers of cherry blossom festivals on how they view the correlation and how they are responding. It was revealed that many festival organizers recognize global warming, and are aware that the phenomenon affects the timing of the flowering. The advantage of the Hirosaki Festival is that it overlaps with Golden Week, something that no similar festival can offer. Therefore, if the flowering date of the cherry blossoms is accelerated due to global warming, the festival will no longer be held during Golden Week, resulting in falling visitors and profits. Despite these concern, the Hirosaki people may overcome the challenge by focusing on new tourist attractions in the city. For example, they have an idea to offer visitors a chance to look at apple flowers regardless of the blooming of cherry blossoms, since the area is the best in Japan for its apple flowers. Hirosaki City is also trying to become a major tourist destination throughout the year by holding Aomori's famous Neputa Festival in summer, an autumn festival for viewing the changing leaves, and a lantern festival in winter. If the flowering date of the cherry blossoms is accelerated, they can still use other local resources, holding another festival using the apple flowers that bloom after the cherry blossoms.

(From Source 34)

2-4 | Natural disaster/coastal area

IMPACT PROJECTION ADAPTATION

Damage in the past (Natural disaster/coastal area)

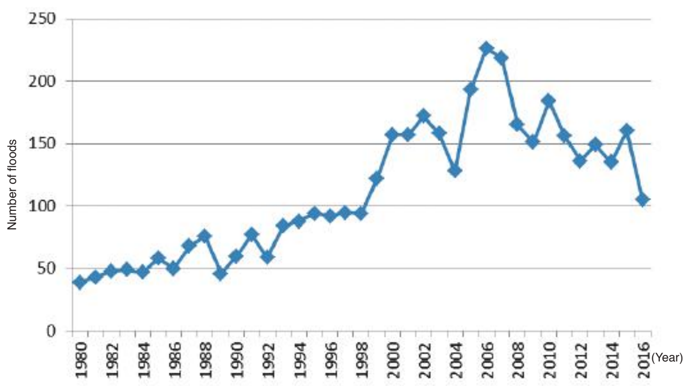
Flood damage in the world

Floods are one of the most common types of disasters, accounting for 47% of all disasters between 2006 and 2015, increasing from 40% in the 1996-2005 period. The figure on the lower left shows the number of floods occurring in the world between 1980 and 2016. It shows the number of floods is likely to increase as the annual average number of floods is increasing from 52 in the 1980s , 87 in the 1990s to 162 after 2000.

Floods typically occur throughout Asia, particularly southern China and northeastern India (see the figure on the lower right).

(From Source 35, 36)

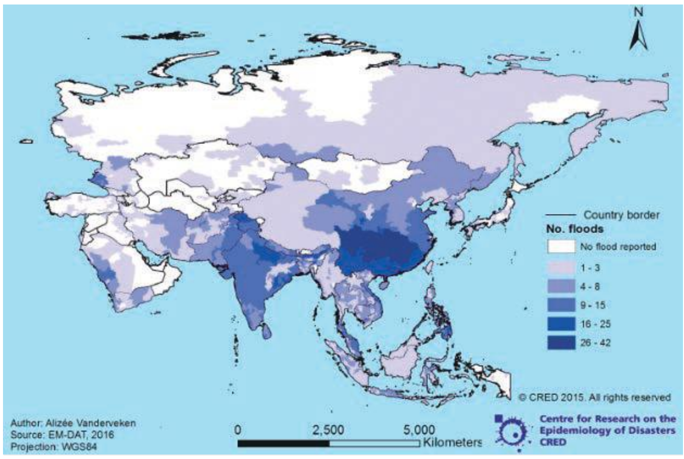
▶ The *Number of floods in the world(1980-2016)



*Floods involving either 10 or more deaths, 100 or more victims, a state of emergency, or calls for international aid

(Created based on Source 37)

▶ The number of floods in Asia by province between 2000 and 2015.



(From Source 36)

Flood and landslide disasters in Japan

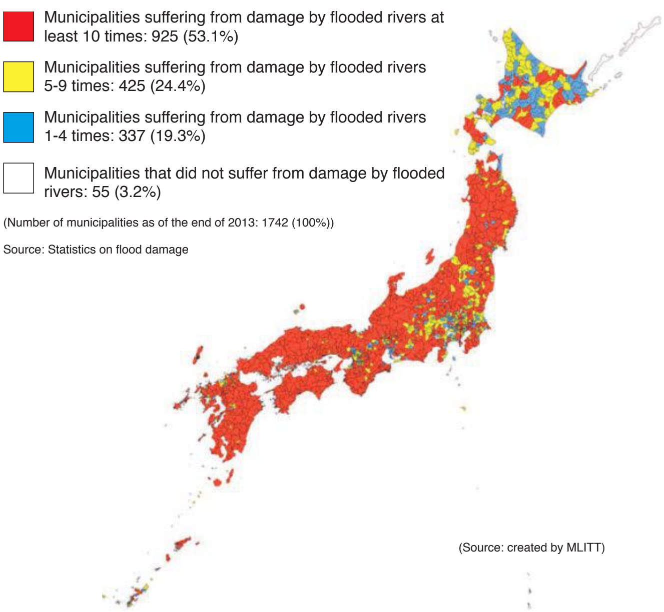
More frequent and severer inundations (flood, inland water, and high tide), landslide disasters, and droughts due to climate change triggered by global warming are major concerns. Every year, enormous flood damage and landslide disasters occur across the country.

Among Japan's 1,742 municipalities (as of the end of 2013), only 55 (3.2%) escaped inundation events, such as flooded rivers, in the decade between 2004 and 2013. The rest of the 1,687 municipalities (96.8%) experienced at least one inundation event that decade. Among them, 925 municipalities (53.1%) experienced at least 10 inundation events that decade (see the figure on the lower left). The data show that inundations are a common disaster in Japan.

Also, landslide disasters (including landslip and debris flows) are dreadful calamities that can ruin numerous lives and property in a second through the tremendous destructive power of soil and earth. Since Japan has many steep mountains and frequent natural disasters such as typhoons, heavy rains, and earthquakes, it is likely to experience many landslide disasters with its topographic and meteorological features. Looking at the landslide disasters in the previous decade (2006-2015), around 1,000 occurred per year on average. The figure on the lower right shows the number of landslide disasters in the last decade by prefecture. The data show that no Japanese prefecture escaped landslide disasters in Japan. In Japan, there are about 530,000 spots that are vulnerable to landslides.

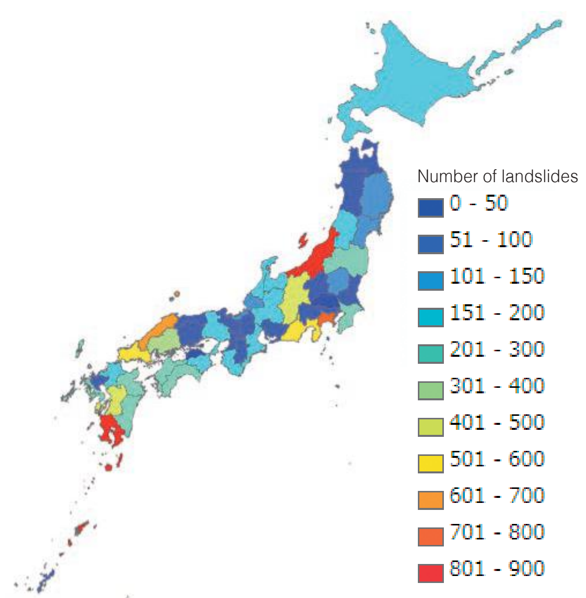
(From Source 38, 39)

▶ Number of floods (river) in 2004-2013



(From Source 38)

▶ Number of landslide disasters in 2006-2015 by prefecture



(Created based on Source 40)

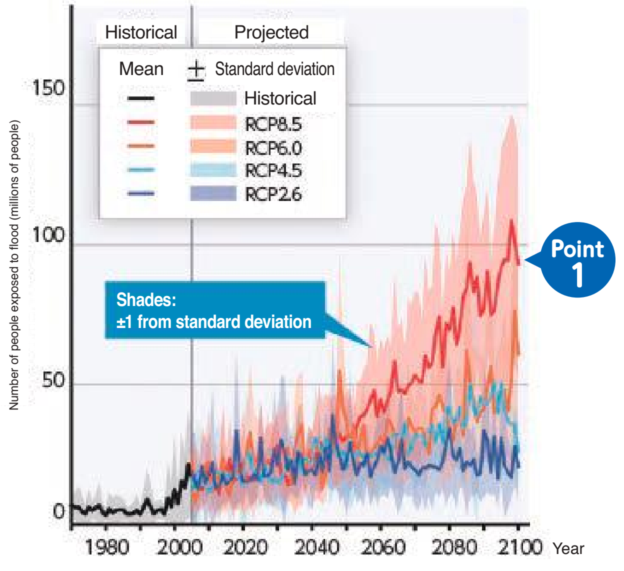
IMPACT | **PROJECTION** | ADAPTATION

Impact of global warming in the future (Natural disaster/coastal area)

About 100 million people are suffering from flood damage in the world

The figure shows the projected number of people exposed to large-scale floods (occurring once every 100 years during the 20th century) up to 2100. If GHG emissions continue at current levels, where global warming continues to advance rapidly, about 100 million people (about five times larger than the current number) per annum are projected to suffer from such large-scale floods around 2100 (Point (1)).

▶ World population exposed to flooding–Projection

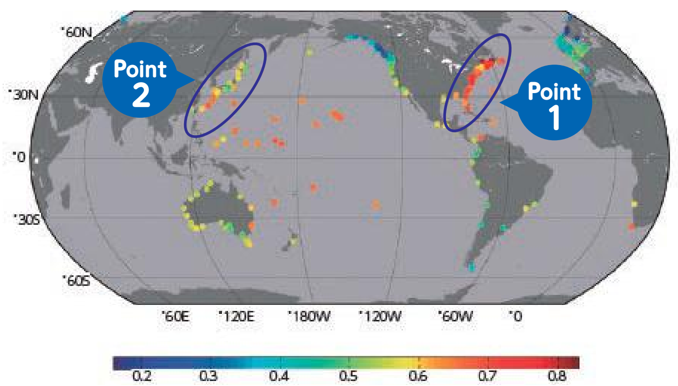


(From Source 11)

Projected increase in the number of areas which needs higher flood protection

The rise in sea level caused by global warning poses an enormous threat to the lives of people living in coastal areas, low and/or flat lands, and small islands. These areas will be affected more severely by high tides and inundation caused by typhoons, floods in coastal areas, and damage of coastal erosion. The figure below shows the projected required increase in height (m) for flood protection structures in the 2081–2100 period to keep the same frequency of flooding as the one for the 1986–2005 period, based on sea level rise projections under a Representative Concentration Pathway 4.5 (RCP4.5) scenario. This means that in some East Coast areas of the USA, flood protection structures must be raised more than 70 cm. In Japan, some coastal areas need to raise flood protection structures 50–70 cm (Point (2)).

▶ The estimated increase in height that flood protection structures would need to be raised in the future (allowance height)



(Unit: m)

(From Source 11)

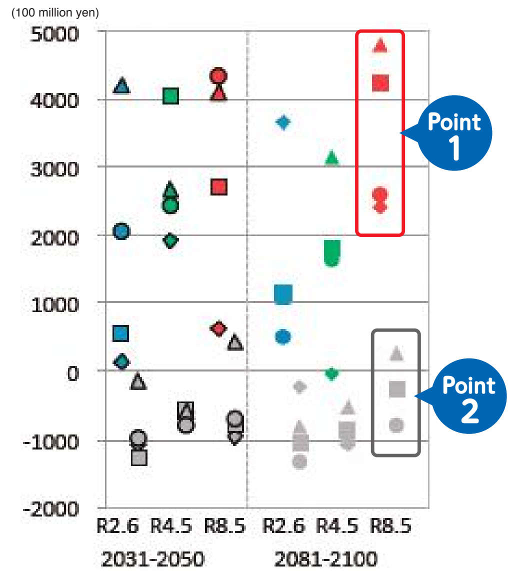
Increasing damage caused by floods

At the end of 21st century (2081-2100), the damage caused by flood would increase by 240-480 billion yen per year than now in Japan, if GHG emissions continue at the current level (Point (1)). Annual mean damage caused by floods is about 200 billion yen at present. In the worst-case scenario, the flood damage would jump up to the level that is three times higher than the current level.

If there are any applicable adaptation measures in place, the damage could be mitigated compared to the current level (Point (2)). However, improving flood risk management across the country would require a long time and enormous amount of investment.

(From Source 16)

▶ Amount of flood damage by nation, period, and scenario



R2.6: RCP2.6 (blue), R4.5: RCP4.5 (green), R8.5: RCP8.5 (red)
MIROC5: ◆ , MRI-CGCM3.0: ■
GFDL CM3: ▲ , HadGEM2-ES: ●
Adaptation measures formulated (grey)

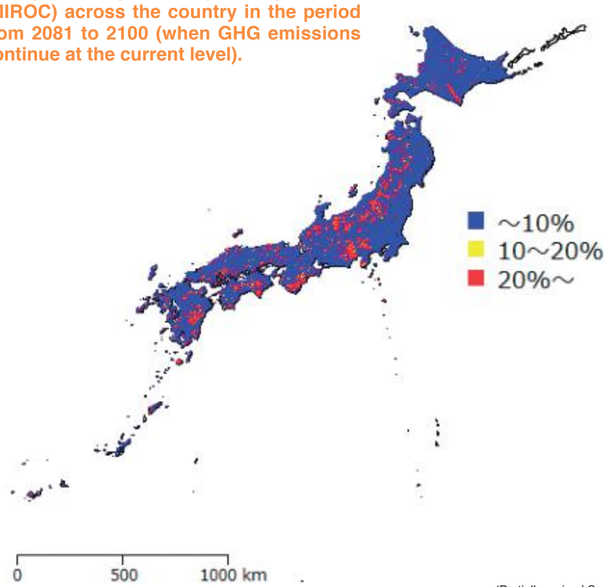
(From Source 16)

Increasing slope failures

The probability of slope failures is projected to increase in Japan at the end of 21st century (2081-2100), if GHG emission continues at the current level. This is because the frequency of heavy rains would increase due to global warming. The frequency is likely to increase across the country except the Kanto region.

(From Source 16)

▶ Change in the probability of slope failure (MIROC) across the country in the period from 2081 to 2100 (when GHG emissions continue at the current level).



(Partially revised Source 41)

IMPACT PROJECTION ADAPTATION

Adaptation measure(Natural disaster/coastal area)

Tide embankment in UK

The UK launched an adaptation programs in 2012, and has been taking adaptation measures with a focus on flood risk management, water resources and freshwater ecosystem. In the project for the facilities improvement at the River Thames Estuary, the tide embankment, with the length of 18 km, was built for protecting the land under the sea level from flooding. The flood damages caused by storm surges, which take place 10 times per year, are prevented by closing the gates 'Themes Barriers'.

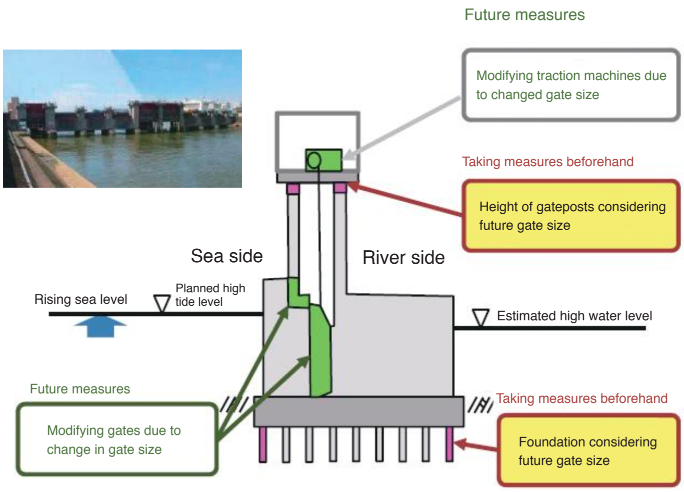
On the river mouth, the Thames Barrier is designed to protect inland areas from storm surges until 2030, even if sea level rises 8 mm per year.

Photo: Koichiro Aitani

Designing facilities that can endure the change in future sea level

For example, designing tide embankments to prevent damage from high tide requires a plan for which sea level should be considered. However, the level of these mitigation measures may change the degree of climate change, such as temperature and sea level increases. Therefore, MLIT decided to design tide embankments that allow for extensions to cope with the increased sea levels projected in the future with the most simple modifications possible. For gateposts and foundations that are less flexible for modification, measures will be taken at the design stage to ensure that the embankments will have replaceable gates and machines when they are updated.

(From Source 43)



(From Source 43)

Raising public awareness and anti-disaster education

From the perspective of policies to promote collaborative efforts between local governments, business operators, and residents, multiple scenarios are being formulated beforehand for how and when to take measures according to the severity of impact of climate change.

The central government also provide assistance, including announcements of the impact of climate change and effective measure to residents, showing practical examples of anti-disaster measures and environment-related issues.

(From Source 43)

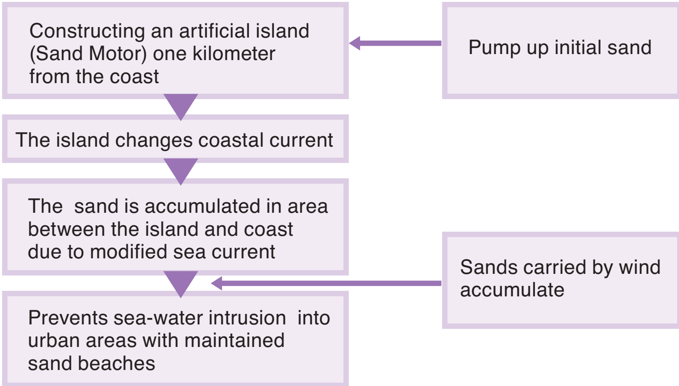
Anti-disaster education	Having residents' associations create hazard maps
	

(From Source 43)

Sand Motor installed in coastal areas of the Netherlands

The sand beaches along the coasts of the Netherlands are losing sand due to ocean currents. The loss of sand beaches may lead to sea-water intrusion into urban areas located at sea level. The Sand Motor, artificial island, is designed to prevent such damages due to sea level rise.

(From Source 42)



(prepared based on Source 42)

▶ Sand Motor

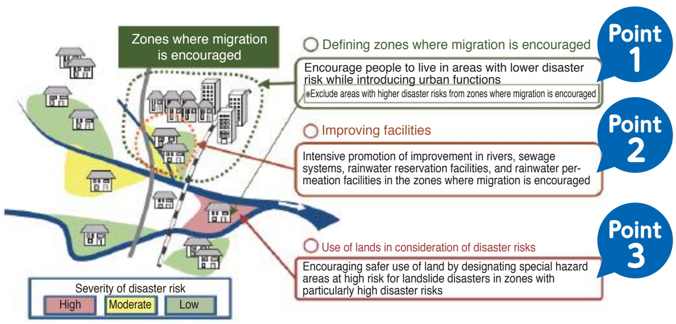
Source: ©https://beeldbank.rws.nl, Rijkswaterstaat

Promoting land use and residential areas in consideration of disaster risks

In Japan, relocating to areas with lower disaster risks and introducing urban functions have been promoted by informing the areas highly vulnerable to disasters such as the areas frequently damaged by landslides or inundation above floor level).

In the vulnerable areas especially with high risks involving human lives due to the depth of inundation, such possible risks are informed to promote safer use of land. Practical measures include: "defining zones where migration is encouraged (Point (1))", "Improving facilities (Point (2)), and "use of lands considering disaster risks (Point (3))".

(From Source 43)



(From Source 43)

2-5 | Human health

IMPACT PROJECTION ADAPTATION

Impact of global warming in the past (Human health)

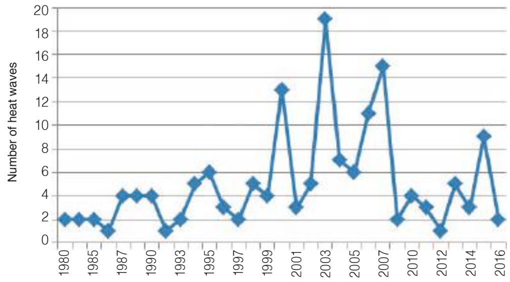
Number of heat waves in the world

Heat wave is defined as a phenomenon causing excessively hot weather for a prolonged period (four to five consecutive days, or even more) over an extended area, and typically occurs in summer in areas with anticyclone.
Major damage caused by heat waves in recent years include a 2003 event in Europe. The reported deaths for the disaster were at least 22,000. Another heatwave occurred over an extended area in India in 2015 with temperatures as high as 42ºC, causing at least 2,000 deaths.

(From Source 44, 45, 46, 47)

▶ The number of heat waves* in the world* (1980-2016)

*Heat waves involved either one of 10 or more deaths, 100 or more victims, state of emergency, and call for international aids



(Created based on Source 37)

Deaths caused by heatstroke in Japan

In environments with high temperature, high humidity, stagnant air, and strong source of radiation (objects generating heat), the risk of heatstroke is increased due to poor heat dissipation and sweating functions of the human body. In recent years, there have been an increasing number of deaths caused by heatstroke, which is a direct result of excessive heat.

(From Source 48)

▶ Conditions required to trigger heatstroke

〈Environment〉
- High temperature
- High humidity
- Weak wind
- Strong sunlight
- Tightly closed indoor space
- No air-conditioning
- Days with temperature surges
- Coming of heatwave

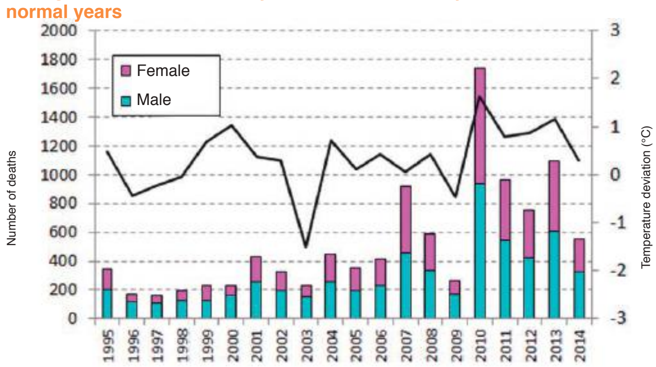
〈Body condition〉
- Elderly, infants, obese
- Chronic diseases (e.g. diabetes, cardiac disease, and psychiatric disorders)
- Undernutrition
- Dehydration (e.g. diarrhea or flu)
- Physical deconditioning (e.g. hangover, insufficient sleep)

〈Action〉
- Vigorous exercise
- Unfamiliar exercise
- Prolonged outdoor activities
- Difficult to get enough water

Possibility of heatstroke

(Partially revised source 48)

▶ Change in deaths caused by heatstroke and temperature deviation from normal years



(Created based on Source 49, 50)

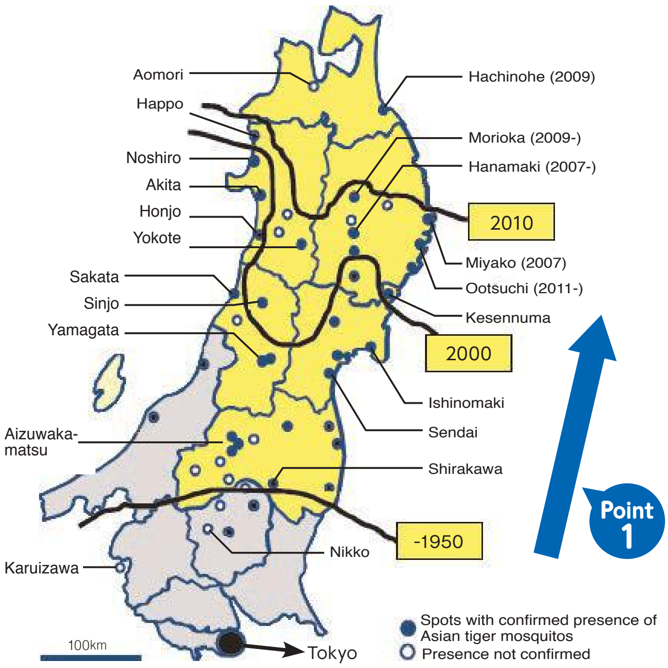
Growing habitat range of mosquitoes transmitting infectious diseases

Asian tiger mosquitoes (Aedes albopictus) are considered a critical transmitter of mosquito-borne viral infectious diseases. They carry both dengue fever and chikungunya fever. They typically inhabit areas where the annual mean temperature is 11ºC or higher. The research on the correlation between the distribution range of the Asian tiger mosquito and temperature has revealed that the northern limit of this kind of mosquito habitat is currently the northern part of the Tohoku region, and has been gradually moving further north since 1950 (Point (1)). This suggests that once the dengue fever virus is brought from overseas, the possibility to spread dengue fever may be increased.

(From Source 16)

▶ Expanding Asian tiger mosquito (Aedes albopictus) distribution range

(From Source 52)



Asian tiger mosquitoes constantly inhabit areas where the annual mean temperature is 11ºC or higher, and its distribution range is moving north due to global warming.

(From Source 16)

IMPACT PROJECTION ADAPTATION

Impact of global warming in the future (Human health)

More heat waves causing more deaths due to excessive heat

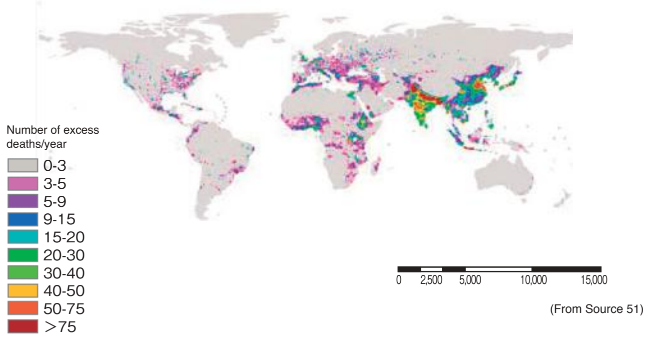
According to the IPCC AR5, the number of heat waves is very likely to increase by the end of 21st century (90% or higher). This suggests that the impact on health due to heat waves is likely to increase.

According to the estimates on the number of excess deaths* due to heat stress for people aged 65 or older around the world (2050), South Asian, East Asian, and Southeast Asian countries will have more deaths than other countries.

*Note: Deaths due to excessive heat (e.g. heatstroke) are called "deaths due to heat stress". The number of deaths due to excessive heat increases when the temperature increase higher than standard temperatures, where the number of deaths is minimal.

(From Source 51)

▶ Projecting the number of excess deaths due to heat stress in the world



(From Source 51)

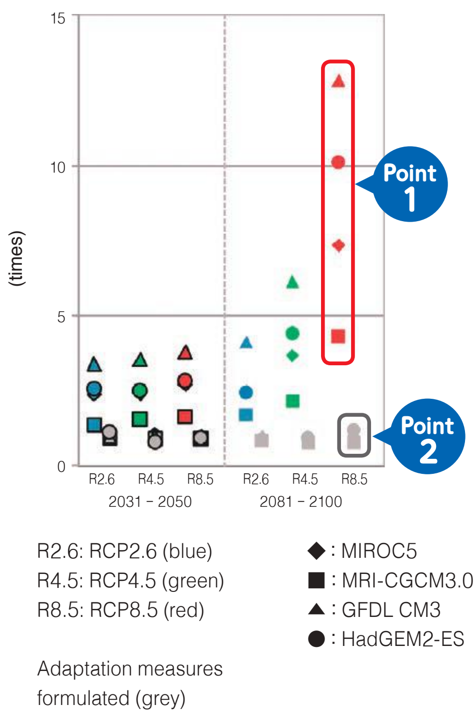
Increasing number of deaths due to heat stress

If GHG emissions continue at the current levels, at the end of 21st century, the number of deaths due to heat stress across the country may jump to the level that is four to thirteen times greater than at present (Point (1)).

If people can acclimate to the increasing temperatures (physiological adaptation), the increase in the number of deaths may be less than double (Point (2)). However, physiological adaptation takes time, so projections give an idea of the lower limit of the impact.

(From Source 16)

▶ Projecting the number of excess deaths due to heat stress in Japan



(From Source 16)

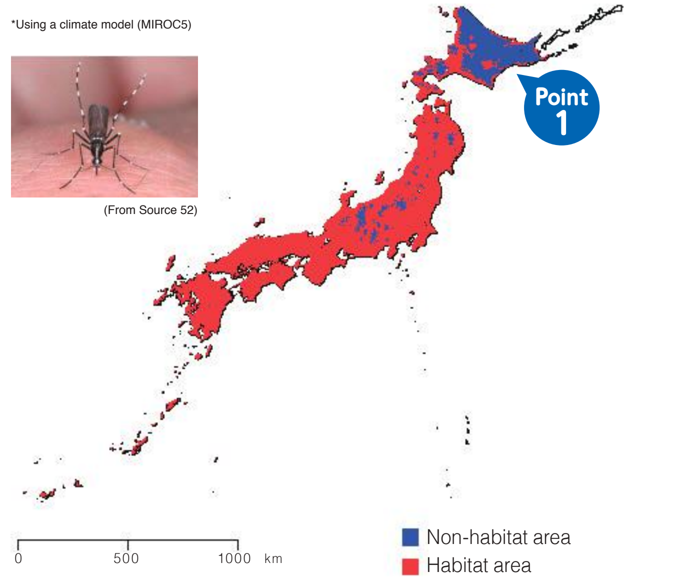
Increasing risk of various infectious diseases due to global warming

・Dengue fever and chikungunya fever (Asian tiger mosquito)

If GHG emissions continue at the current levels, the Asian tiger mosquito may survive in most of Japan except eastern Hokkaido and high latitudes by the end of the 21st century (Point (1)). This is because the temperature in the areas where annual mean temperature is currently less than 11ºC will increase, meaning that the mosquito can survive in these areas. Therefore, the infectious risk of mosquito-transmitted diseases is likely to become higher. In addition to the Asian tiger mosquito, there are other kinds of mosquitoes that transmit diseases (e.g. Culex tritaeniorhynchus transmits the Japanese encephalitis virus, and Aedes aegypti transmits dengue fever). These species also are experiencing an expanding distribution range and increasing habitat density.

(From Source 16)

▶ Projected* distribution area of the Asian tiger mosquito at the end of the 21st century



(From Source 53)

▶ Projected impact of infectious diseases

Waterborne diseases	• Vibrio vulnificus infection spreads to Hokkaido region
Mosquito-borne viral infectious diseases	• Distribution area of Asian tiger mosquitoes is moving north, beginning intrusion and constant habitation in the Hokkaido region • Japanese encephalitis infection spreads to Hokkaido region • Increasing habitat density of Culex tritaeniorhynchus in the Tohoku region • Intrusion of Aedes aegypti (Shikoku and southern regions) and constant habitation (Kyushu and Okinawa regions) • Increasing density of mosquitos in urban areas (Kanto and Chubu regions) • Epidemic of dengue fever in areas extending from the Tohoku and Chugoku regions, pandemic in Shikoku and southern regions

(From Source 54)

IMPACT PROJECTION ADAPTATION

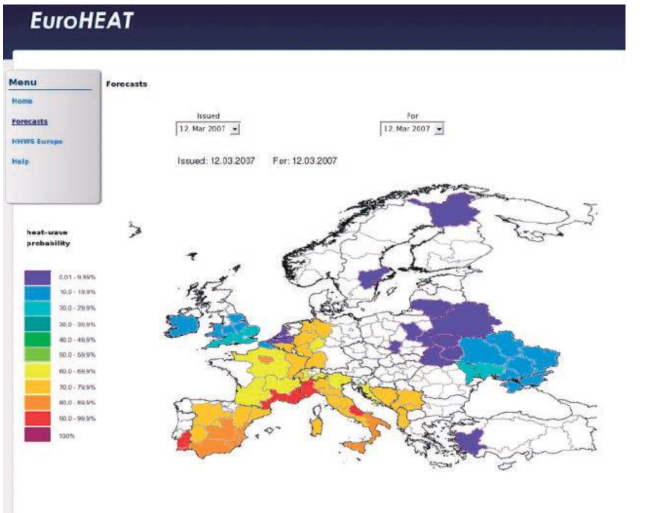
Adaptation measure (Human health)

Online heatwave forecast

The EuroHEAT project aims to improve public health services related to extreme weather, particularly heatwaves. The project was coordinated by the European arm of WHO between 2005 and 2007, with co-investment from DG SANCO, European Commission (EC). Online heatwave forecasts are one of the achievements of this project. The EuroHEAT project indicates daily forecasts of the probability of heatwaves (0-100%) for the next ten days, with map colored according to each European region. The maps can be accessed online (figure on the lower). The probability of heatwaves is calculated based on projections from fifty different sites (ensemble forecast).

(From Source 55)

▶ EuroHEAT screen



(From Source 56)

Adaptation measure to prevent infectious diseases

Adaptation measures for infectious diseases can be classified into those promoted by the government and those promoted by individuals. The former includes infectious disease surveillance (investigation and monitoring), improving drinking water and sewage process systems, vaccination programs, educational activities, measures against mosquitoes transmitting infectious diseases, infestation investigations of mosquitoes transmitting infectious diseases in various regions, cultivation of human resources who can formulate preventative measures for mosquitoes transmitting infectious diseases, and continuous investigation of animals transmitting infectious diseases and the number of bacteria in the sea in various areas. The latter includes measures to prevent contact with mosquitoes transmitting infectious diseases, eliminating infestation of mosquitoes transmitting infectious diseases, preventing mosquito larva, and paying attention to sanitary conditions when eating raw seafood.

To prevent infectious diseases transmitted by mosquitoes, surveillance is being carried out throughout Japan on these insects. For example, the Tokyo Metropolitan Government has been carrying out "region-wide surveillance" activities since 2004. In 2015, the government launched "priority surveillance" activities at nine facilities that have a large number of visitors and where many events take place.

(From Source 60)

▶ Mosquito trap

(From Source 60)

▶ Region-wide surveillance and priority surveillance

	Region-wide surveillance	Priority surveillance
Locations	16 facilities (16 locations)	9 facilities (50 locations)
Pathogens to be examined	■ West Nile virus ■ Dengue fever virus ■ Chikungunya virus ■ Zika virus ■ Malarial parasites	■ Dengue fever virus ■ Chikungunya virus ■ Zika virus
Investigation period	June-October	April-November
Number of investigations per year	Ten times total	Fourteen times total

(Created based on Source 60)

Adaptation measure for heatstroke

Ministry of the Environment, Japan (MOE) released a website posting information to prevent heatstroke. The Yokohama municipal government promotes measures focusing on "human-ware" (human movements) as an adaptation measure to cope with the increasing frequency of heatstroke.

The MOE is also taking measures to mitigate damages from heatstroke by providing information related to heatstroke severity level on a special website, as well as publishing a Heatstroke Environmental Health Manual, and Guidelines for Preventing Heatstroke at Summer Events.

(From Source 48, 57, 58, 59)

▶ Yokohama City's adaptation measure to prevent heatstroke

Classification	Adaptation measure (draft)
Increasing heatstroke frequency	■ Establishing a system of early detection in communities ■ Informing people on days with a minimum temperature higher than 25°C (hot nights) and extremely hot days ■ Providing basic knowledge on heatstroke, measures to be taken, and preventative measures ■ Promoting introduction/installation of green curtains at home ■ Promoting rooftop/wall greening and providing information

(From Source 58)

(From Source 48)

(From Source 57)

(From Source 59)

Chapter 3 Factors contributing to global warming/ change in emission

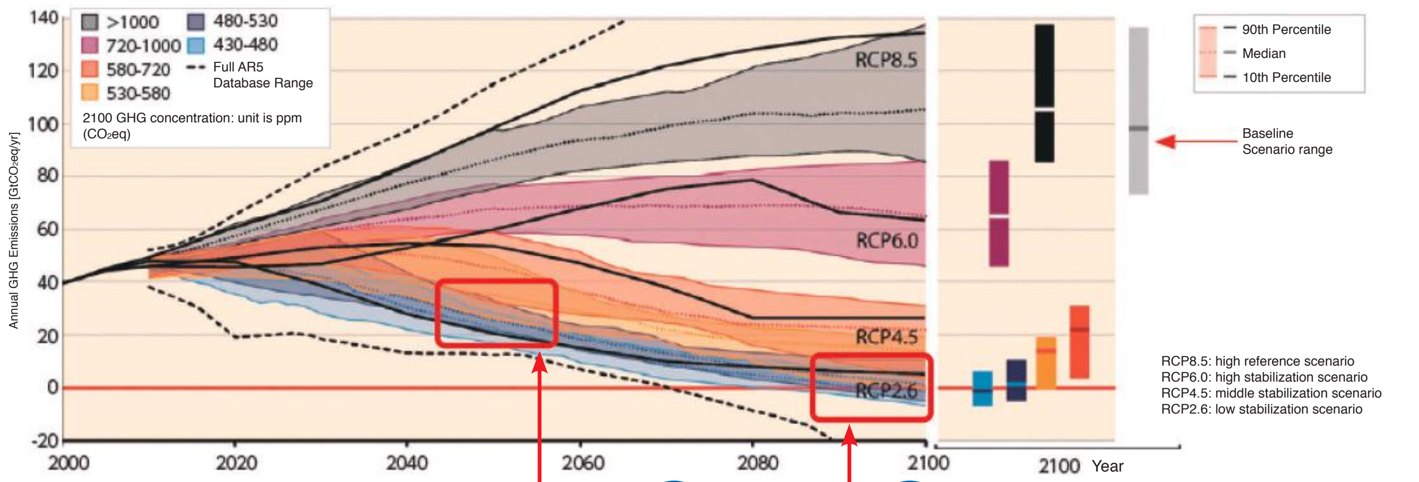
3-1 | Factors contributing to global warming

GHG Emission pathways

Reducing carbon dioxide emissions as a major cause of global warming to zero (net base)

Human activities have been deeply related to changes in the climate system since the pre-industrial era, and it is known that the largest contribution to global warming is caused by the increase in the atmospheric concentration of carbon dioxide (CO_2). The IPCC AR5 reviews multiple scenarios for changes in Greenhouse Gases(GHG) emissions and projects atmospheric concentrations and temperature increases in 2100. There are two types of scenarios: "Baseline Scenarios", which assume no additional efforts (mitigation measures) to constrain emissions of anthropogenic GHGs, and the "Mitigation Scenarios", which involve additional efforts. Also, some mitigation scenarios involve "overshoot" in which the concentration temporarily exceeds a certain threshold before 2100. RCP2.6 leading GHG concentrations in 2100 in range for the 430 ppm to 480 ppm carbon dioxide-eq is the only scenario that is likely to stay below 2ºC over the course of the 21st century relative to pre-industrial levels within four RCPs. Other RCPs (RCP4.5, 6.0, 8.5) in which concentration in 2100 ranges from 580 ppm to more than 1000 ppm are "more unlikely than likely or unlikely" or "unlikely" to stay below 2ºC over the 21st century relative to pre-industrial levels. RCP2.6 is characterized by 40% to 70% global anthropogenic GHG emissions reductions by 2050 compared to 2010 (Point (1)), and emissions levels near zero or below in 2100 (Point (2)). And it is also characterized by changing land use (such as afforestation and deforestation control), plus more rapid improvements in energy efficiency. Compared to 2010, it will be triple to nearly a quadruple the share of zero- and low-carbon energy supply, such as renewable energy (e.g. PV solar power and wind energy), fossil fuel energy with carbon dioxide capture and storage (CCS) and bioenergy with CCS (BECCS) by 2050. If introduction of such key technologies is delayed, mitigation costs can increase substantially, while the achievement of RCP2.6 will become harder.

▶ GHG emission pathways 2000-2100: All AR5 and RCP scenarios



(From Source 61)

▶ Key characteristics of the scenarios collected and assessed for WGIII AR5.

CO_2eq Concentrations in 2100 [ppm CO_2eq] Category label (concentration range)	Subcategories	Relative position of the RCPs	Cumulative CO_2 emissions [$GtCO_2$] 2011–2050	Cumulative CO_2 emissions [$GtCO_2$] 2011–2100	Change in CO_2eq emissions compared to 2010 in [%] 2050	Change in CO_2eq emissions compared to 2010 in [%] 2100	Temperature change (relative to 1850–1900): 2100 Temperature change [°C]	Likelihood of staying below temperature level over the 21st century: 1.5 °C	2.0 °C	3.0 °C	4.0 °C
< 430	Only a limited number of individual model studies have explored levels below 430 ppm CO_2eq										
450 (430–480)	Total range	RCP2.6	550–1300	630–1180	−72 to −41	−118 to −78	1.5–1.7 (1.0–2.8)	More unlikely than likely	Likely	Likely	Likely
500 (480–530)	No overshoot of 530 ppm CO_2eq		860–1180	960–1430	−57 to −42	−107 to −73	1.7–1.9 (1.2–2.9)	Unlikely	More likely than not		
	Overshoot of 530 ppm CO_2eq		1130–1530	990–1550	−55 to −25	−114 to −90	1.8–2.0 (1.2–3.3)		About as likely as not		
550 (530–580)	No overshoot of 580 ppm CO_2eq		1070–1460	1240–2240	−47 to −19	−81 to −59	2.0–2.2 (1.4–3.6)		More unlikely than likely[12]		
	Overshoot of 580 ppm CO_2eq		1420–1750	1170–2100	−16 to 7	−183 to −86	2.1–2.3 (1.4–3.6)				
(580–650)	Total range	RCP4.5	1260–1640	1870–2440	−38 to 24	−134 to −50	2.3–2.6 (1.5–4.2)				
(650–720)	Total range		1310–1750	2570–3340	−11 to 17	−54 to −21	2.6–2.9 (1.8–4.5)		Unlikely	More likely than not	
(720–1000)	Total range	RCP6.0	1570–1940	3620–4990	18 to 54	−7 to 72	3.1–3.7 (2.1–5.8)	Unlikely		More unlikely than likely	
>1000	Total range	RCP8.5	1840–2310	5350–7010	52 to 95	74 to 178	4.1–4.8 (2.8–7.8)		Unlikely	Unlikely	More unlikely than likely

(From Source 62)

3-2 | Change in GHG emissions

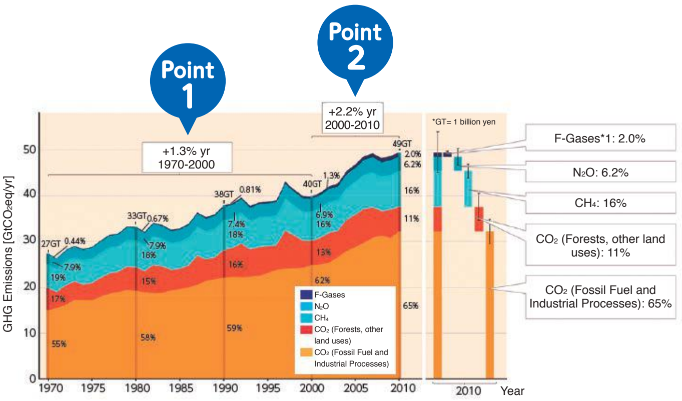
Change in global GHG emissions

GHG emissions had continued to increase

Global anthropogenic GHG emissions have continued to increase during 1970–2010. In particular, annual GHG emissions have grown on average by 2.2% per year from 2000 to 2010 (Point (2)) compared to 1.3% per year from 1970 to 2000 (Point (1)). The anthropogenic GHG for which emissions have increased significantly is been the carbon dioxide emitted by fuel combustions and industrial processes. Among anthropogenic GHG emissions, carbon dioxide emissions from fossil fuel combustion and industrial processes contributed about 76% of the total GHG emissions increase during 1970-2010. It is thought that the half of cumulative anthropogenic carbon dioxide emissions during 1750-2010 (after the Industrial Revolution) have been emitted in the past 40 years. Furthermore, if we look at the cumulative carbon dioxide emissions from fossil fuel combustion, cement production and flaring during 1750-2010, the amount has tripled over the past 40 years. In contrast, world carbon dioxide emissions have stayed almost flat since 2013 despite the global economy, which had been a driver of carbon dioxide emissions, has been grown in this period. This may be possibly caused by increase of renewable energy that does not emit carbon dioxide. Besides, changes in atmospheric carbon dioxide concentration can be observed by a satellite called Ibuki, which monitors GHGs in the total atmosphere* (Point (3)).

*Greenhouse gas Observing Satellite (GOSAT)

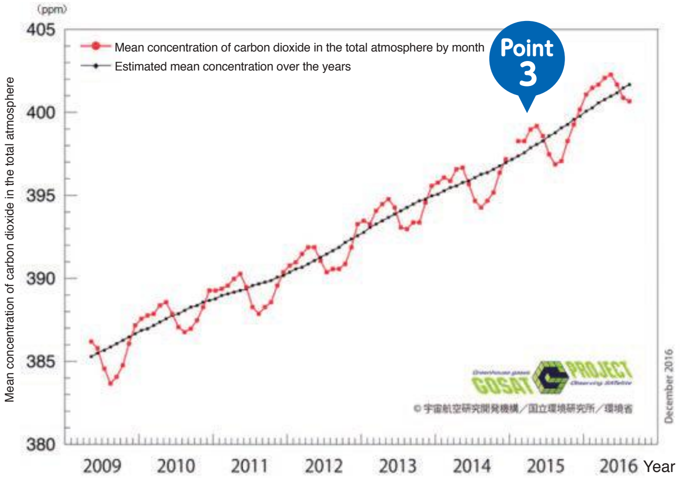
▶ Anthropogenic GHG emissions



*1 Gases designated by the Kyoto Protocol
*2 Converted to carbon dioxide based on GWP (global warming coefficient, 100 years)

(From Source 62)

▶ Changes in whole-atmospheric carbon dioxide concentration observed by GOSAT



(From Source 63)

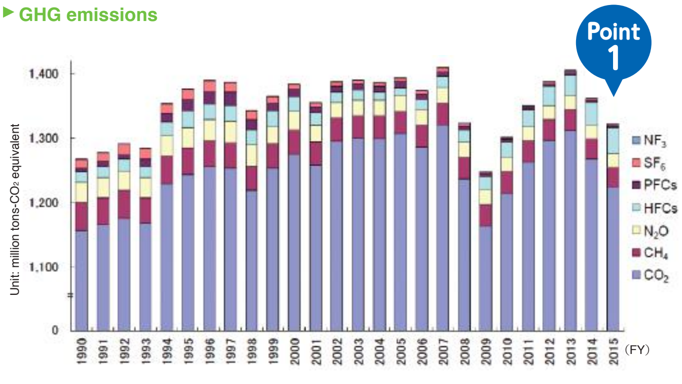
Change in GHG emissions in Japan

GHG emissions slightly reduce

The total volume of greenhouse gas (GHG) emissions in 2015 was 1.321 billion tons, a decrease of 3.0% from the previous year and a decrease of 6.0% from 2013 Point (1)). One of the possible causes for the reduction of GHG emissions from the previous year and 2013 is reduction of energy-related carbon dioxide emissions due to reduced electricity demand and improvement of carbon dioxide emission intensity of electricity. The reasons for the reduction in emissions compared to 2005 results include decreased energy-related carbon dioxide emissions in the industry and transportation sectors while hydrofluorocarbon (HFCs) emissions in the refrigerant sector are increased as an alternative to ozone-depleting substances.

(From Source 64)

▶ GHG emissions



(From Source 64)

The household sector accounts for 20% of carbon dioxide emissions as a whole

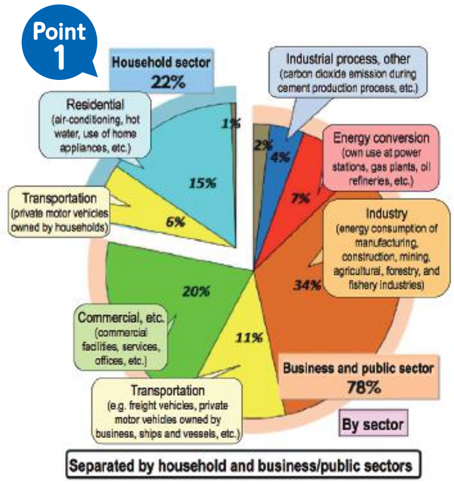
About 94% of carbon dioxide excluding industrial processes and waste is emitted in relation to energy consumption.

Household emissions, including private cars and municipal waste, account for about 20% of the carbon dioxide emissions as a whole (Point (1)), and a resting 80% is emitted from the business and public sectors.

Note that "power-derived" means emissions derived from power and heat purchased from electric companies and the like, and does not include autoproducers.

(From Source 64)

▶ Breakdown of carbon dioxide emissions in Japan (2015)



(From Source 64)

Chapter 4 Global warming measures

4-1 | Addressing global warming around the world

Sustainable Development Goals (SDGs)

The 2030 Agenda for Sustainable Development adopted in September 2015 is an international target for a period from 2016 to 2030, focusing on sustainable development goals (SDGs:17 goals and 169 targets). The greatest feature of the agenda is a universality that allows it to be adopted by all countries, regardless their development level. Many of the goals are related to the environment. Japan is committed to implementing the agenda at domestic and international locations focusing on the climate change, energy, and sustainable consumption and production fields. Through implementing the Paris Agreement (discussed later), countries around the world came to agree to take necessary measures to mitigate climate change. These measures play an important role in the achievement of the SDGs.

(From Source 65)

(From Source 65)

Intended Nationally Determined Contribution (INDC)

Previous to the 21st Session of the Conference of the Parties to the United Nations (UN) Framework Convention on Climate Change (COP21), countries submitted a greenhouse gas emission reduction target after 2020 (Intended Nationally Determined Contribution (INDC)). One hundred ninety-two countries and regions (including European countries) submitted, covering around 99% of the GHGs emitted by the signatory nations. The table on the right shows the INDCs of major countries.

(From Source 65)

Developed countries (Annex I Parties)	
US	-26% through -28% in 2025 (from 2005). Make maximum efforts to achieve 28% reduction.
EU	At least 40% reduction in 2030 (from 1990)
Russia	-25 to -30% in 2030 (from 1990) may be a long-term goal
Japan	-26.0% in 2030 (from 2013, -25.4% if compared to 2005)
Canada	-30% in 2030 (from 2005)
Australia	-26 to 28% by 2030 (from 2005)
Switzerland	-50% in 2030 (from 1990)
Norway	At least -40% in 2030 (from 1990)
New Zealand	-30% in 2030 (from 2005)

Developing countries (Non-Annex I Parties)	
China	-60 through -65% reduction of emission per GDP by 2030. Carbon dioxide emission would peak around 2030.
India	Achieve -33% through -35% emission per GDP by 2030 (from 2005)
Indonesia	-29% (from BAU) by 2030
Brazil	• -37% by 2025 (from 2005) (-43% by 2030 (from 2005))
Korea	-37% by 2030 (from BAU)
South Africa	• Emission peak sometime between 2020 and 2025. Expected emissions pathway: turn to decrease after staying flat for a decade or so. • 398-614 million ton in 2025 and 2030 (convert to carbon dioxide) (reference: 2010 emission was 487 million ton (IEA estimation))

(From Source 65)

Paris Agreement (PA)

The Paris Agreement was ratified at the COP21 held in Paris from the end of November through December 2015. This is the first legal framework ever to have a GHG emission reduction target (contributions) shared by all ratified countries including major emitting countries and developing countries.

The features and significance of the PA can be roughly divided into four categories. The climate agreement is “applicable to all”, “comprehensive”, “durable” and “progressive” manner. This indicates that the Agreement represents a turning point and a new start for global measures against climate change. The PA came into force in November 4, 2016. Japan completed the ratification process of the agreement on November 8, 2016.

The PA’s aim includes keeping the global temperature increase in this century well below 2ºC above pre-industrial levels, pursuing efforts to limit the temperature increase even further to 1.5ºC, strengthen the ability of countries to deal with the impacts of climate change, and providing appropriate financial flow to adapt a roadmap towards development resistant to climate change.

(From Source 65)

Features and significance of the Paris Agreement

Applicable to all

Improve adaptation of the principle of “equity and common but differentiated responsibilities and respective capabilities” beyond previous dualism

- Many provisions are adaptable to all countries (No specific definition is indicated despite of partial segregation of “developed countries” and “developing countries”.)

Comprehensive

Use well-balanced factors such as mitigation (emission reduction), adaptation, finance, technology, capacity building, and transparency.

- Define three purposes related to mitigation, adaptation, and finance.

Durable

A permanent framework pursuing longer term beyond 2025/2030.

- Defines long-term goals (e.g. 2°C goals, “emission and sink balance at the latter half of this century” as legal agreements for the first time
- Formulates a long-term low-emission development strategy

Progressive

Improve with PDCA cycle reviewing each country’s goals, report/review, check overall progress.

- Based on global progress check (long-term goals), the countries shall submit and update their contributions every five years
  Make progress beyond previous targets
- Report and review efforts taken by the member countries

Turning point and new launch of tackling global warming

(From Source 65)

Essential elements of the PA

- As a long-term common temperature goal, the agreement established the target to keep the global temperature increase in this century well below 2°C above pre-industrial levels (2°C target). In addition, the agreement states that the member states should pursue efforts to limit the temperature increase even further to 1.5°C.
- The Agreement requires all parties including all major emitters to formulate, submit, and maintain reduction goals, as well as put forward their best efforts through national adaptation efforts. The agreement also prescribes that parties shall submit and update their NDCs every 5 years.
- All parties that should formulate a long-term low emission development strategy while keeping low GHG emission shall report the status of implementation and be reviewed in a common and flexible manner.
- Establish a long-term goal on adaptation, implement domestic adaptation planning processes and actions, and submit adaptation reports and periodic updates.
- Definition of significance of innovation
- A mechanism to review global implementation status every five years (global stocktaking)
- Developed countries should continue providing financial aid, while rest of the parties voluntarily provide financial aids.
- Define the effective use of market mechanisms, including the Joint Crediting Mechanism/Bilateral Offset Credit Mechanism (JCM/BOCM))
- Making the effectuation requirements double; not only for the number of member states but also the amount of emissions.

(From Source 65)

4-2 | Addressing global warming in Japan

The Plan for global warming countermeasures

The Plan for global warming countermeasures is Japan's only comprehensive plan related to global warming that the central government has formulated based on the Act on Promotion of Global Warming Countermeasures. It aims to promote comprehensive and systematic efforts towards global warming measures. The plan describes GHG emission control and sink targets, basic items related to measures that should be taken by business operators and residents, and measures that should be taken by central and local governments to achieve goals.

(From Source 66, 67)

Actions to achieve mid-term target (reduction target by FY2030)

- Japan takes steady steps to achieve the mid-term target of 26.0% reduction by FY2030 compared to FY2013 (25.4% compared to FY2005) through domestic emission reductions and removals assumed to be obtained.

Actions toward global GHG reduction

- A key to maintain compatibility between the global warming countermeasures and the economic growth is the development of innovative technology.
- The Government promotes development and demonstration of technologies based on, inter alia, "Environmental and Energy Technology Innovation Plan", and also enhances R&D of innovative technologies based on "National Energy and Environment Strategy for Technological Innovation towards 2050". Also, Japan makes full contribution to global reduction of GHG emissions utilizing its leading technologies.

Strategic actions towards long-term goal

- Based on the Paris Agreement, under a fair and effective international framework applicable to all major Parties, Japan leads international community so that major emitters undertake emission reduction in accordance with their capacities, and, aims to reduce greenhouse gas emissions by 80% by 2050 as its long-term goal, while pursuing the global warming countermeasures and the economic growth at the same time.
- Such a deep cut in emissions is difficult to achieve through the extension of existing measures so far. Therefore, Japan pursues solution through innovation such as development and deployment of innovative technologies which enables drastic emission reductions, and, while promoting domestic investment, enhancing the international competitiveness, and asking citizens for their opinion, aims to achieve a deep cut in emissions through long-term, strategic actions, and contributes to global GHG emission reductions.

(Created based on Source 67)

National Plan for Adaptation to the Impacts of Climate Change

In order to comprehensively and systematically make efforts consistent throughout the government and applicable to a variety of impacts due to climate change, the National Plan for Adaptation to the Impacts of Climate Change (draft) was formulated at the third session of the Inter-Ministry Meeting for Climate Change Adaptation held on November 25, 2015. Thereafter, the cabinet approved the National Plan for Adaptation to the Impacts of Climate Change on November 27, 2015. (From Source 68)

Basic concept

Vision of society

- By promoting adaptation measures to climate change impacts, to build a secure, safe and sustainable society that is able to minimizing and avoiding damage for life of citizens, properties, economics, and natural environment due to its impacts, and to be resilient against damage..

Basic strategy

(1) Mainstreaming adaptation into government policy
(2) Enhancement of scientific findings
(3) Promotion of understanding and cooperation through sharing and providing information about climate-related risks
(4) Promotion of adaptation in region
(5) Promotion of international cooperation and contribution

Period

- Considered with long-term perspective till the end of 21st century,showing the basic direction in about coming 10 years.

Basic approach

- Adaptation will be promoted by using an adaptive approach that involves a repeated cycle of conducting ongoing observation, monitoring, and projection of climate change and its impacts, implementing regular assessments of impacts, considering and implementing adaptation measures, monitoring the state of progress, and making revisions as required.
- An assessment of climate change impacts is to be implemented and formulated approximately every five years, and the Plan is to be revised as required.

Sectoral measures

- Agriculture, forests/forestry, fisheries
- Water environment/water resource
- Natural ecosystems
- Natural disasters/Coastal areas
- Human health
- Industrial/ economic activity
- Life of citizens and urban life

Basic international measures

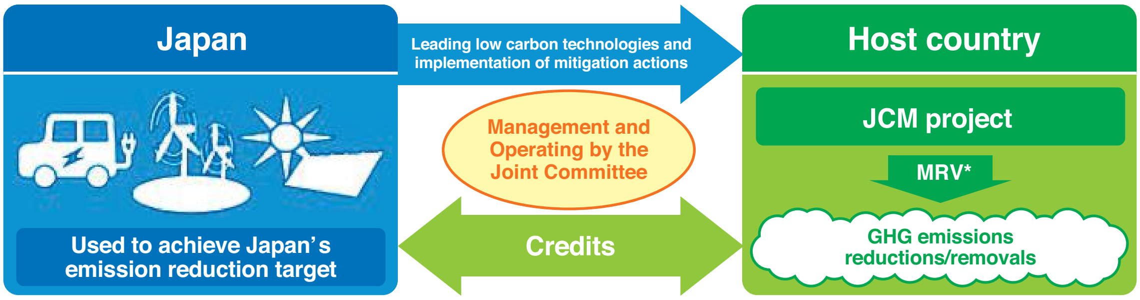
- Observation and monitoring, research and studies
- Sharing and providing information related to climate risk
- Promote of adaptation in region
- International measures

(Created based on Source 68)

Joint Crediting Mechanism (JCM)

The JCM is established to facilitate diffusion of leading low carbon technologies through which the Government of Japan acquires the credits to be used to achieve its emission reduction targets and contribute to global actions for GHG emission reductions. There are seventeen JCM partner countries: Mongolia, Bangladesh, Ethiopia, Kenya, the Maldives, Vietnam, Laos, Indonesia, Costa Rica, Palau, Cambodia, Mexico, Saudi Arabia, Chile, Myanmar, Thailand, and the Philippines (as of the end of January 2017). Ninety-three emission reduction or removal projects are currently being implemented through the JCM financing scheme by the Ministry of the Environment (MOE).

(From Source 66)



* Measurement, report, verification

(From Source 66)

Monitoring GHGs from space

Greenhouse gases–Observing SATellite (GOSAT), aka "IBUKI" was launched on January 23, 2009 to monitor GHGs (mainly carbon dioxide and methane) from space. GOSAT provides information on carbon dioxide and methane (including geographical distribution and seasonal and interannual variations), and therefore helps deepen our scientific understanding about climate change. GOSAT also contributes to future climate change projection and planning measures to reduce GHG emissions. There are plans to launch GOSAT-2 (the successor of GOSAT) in FY2018.

▶ GOSAT outer view

@JAXA

Disclosing information

Climate change adaptation platform

The climate change adaptation platform serves as the basis of activities of various parties, such as local governments, business operators, and residents, by providing information that matches users' needs, developing and providing tools supporting adaptation activities, collecting, organizing, and providing superior cases, while cooperating with government agencies involved. This is a portal site to centrally provide information related to adaptation to the impacts of climate change. The site is designed to collect and organize the necessary scientific knowledge (observation data, climate forecasts, and impact projections) and related information to support review measures to cope with climate change (adaptation measures).

(From Source 70)

▶ Screen showing climate change adaptation information platform

(From Source 70)

COOL CHOICE

COOL CHOICE, a national movement encouraging smart selection
"COOL CHOICE" is a people's movement for making all kinds of "smart choices" that contribute to anti-global measures (e.g. low-carbon products, services, and lifestyles), aiming to achieve a 26% emission reduction in 2030 (40% reduction for residential and commercial).

(From Source 71)

▶ COOL CHOICE symbol

COOL CHOICE
賢い選択

(From Source 71)

▶ COOL CHOICE video

(From Source 71)

Implementing local global warming countermeasures through public-private partnerships

Community-based global warming countermeasures through public-private partnerships are implemented not only to achieve a low-carbon society, but also to utilize the activities to vitalize local economies and strengthen anti-disaster capacity.

(From Source 65)

Local production for local consumption of energy

Higashi-matsushima City, Miyagi Prefecture, A Smart, Disaster-proof, Eco-friendly Town

Achieved Smart Town status based on local consumption of locally-produced solar power, accumulators, and privately-owned power grids, instead of relying on Feed-in tariff.

- 30% reduction in carbon dioxide emissions in the area per year
- Can supply power for three days, even during a power failure

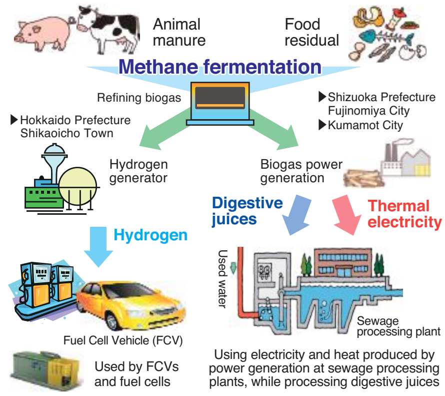
Achieve low-carbon society in remote islands

Assisting with equipment introduction, such as renewable energy generators and accumulators in 16 cases in 12 islands throughout Japan
*23 islands (36 cases) if project-forming investigations are included

Project to promote low-carbon society in remote islands (Introducing equipment, accumulator demonstrations)

Case study:
Hateruma Island, Okinawa Prefecture
Share of renewable energy doubled.
18% ➡ 40%

Using biogas



(From Source 65)

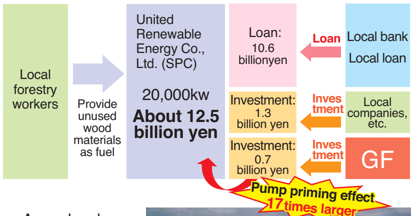
Green Fund

Assistance using investment through the Green Fund is promoted to infuse private funds into projects promoting low-carbon society.

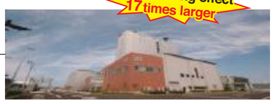
(From Source 65)

Revitalize local economy

Woody biomass power generation project in Akita Prefecture



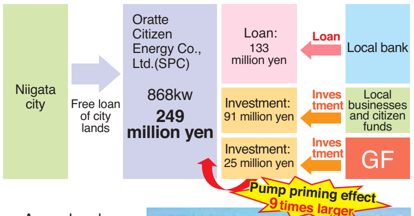
Annual carbon dioxide reduction: about 78,000 tons



Collaborated with local forestry workers to make contributions to achieve appropriate forest management, revitalize the local forestry business, and create jobs.

Strengthen anti-disaster capacity

Photovoltaic power generation project in Niigata Prefecture

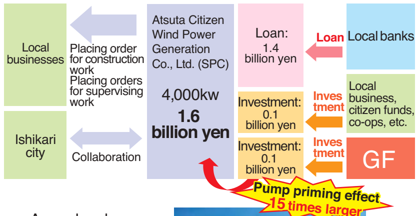


Annual carbon dioxide reduction: about 502 tons

Supplying power free of charge to facilities in Niigata Prefecture when power failures occur due to disasters

Collaboration with local governments

Wind power generation project in Hokkaido Prefecture



Annual carbon dioxide reduction: about 3,854 tons

Collaborated and cooperated with Ishikari City and used a part of the profits to conserve the local environment.

(From Source 65)

Floating wind turbine power generation

Offshore wind power is a stable and effective power generation method with the largest potential quantity among other renewal energy sources. Floating wind turbines that can be used in deeper sea areas (50 m or deeper) have more advantages in Japan, which has few shallow sea areas. Lately, Japan has succeeded in demonstrating practical utilization of commercial-grade (2MW) spar-type floating offshore wind power. Now, ongoing efforts are being made to achieve lower carbon emission and more effective construction methods.

(From Source 65)

Construction, installation, operation, and evaluation of Japan's first 2MW floating offshore wind turbine power station was implemented (off Goto City, Nagasaki Prefecture)

Demonstrator (2 MW)

100 kW Tester

Schedule	2011	2012	2014	2014	2015
Compact-size tester (100 kW)	Design, Construction	Building	Installed in June 2012, started operation in August of that year (Japan's first grid connection)		
Demonstrator (2MW)	Reflecting results of 100-kW machine	Design, Construction, Building	Installed and started operation in October 2013		

*A Feasibility Study was implemented in 2010 and a demonstration sea area and floating structure were selecte

Results and knowledge obtained

- ▶**Developed the world's first hybrid spar-type offshore wind turbine** ········ Drastically cut costs by using concrete for the submerged part of the floating body
- ▶**Effective power generation** ······· Over 30% capacity factor (20% for average land wind turbine) *A 2-MW wind turbine can generate power for 1,800 households
- ▶**Verified superior durability** ········ Resisted a direct hit from the largest typhoon in the postwar period with 53 m/s wind velocity and 17 m wave height
- ▶**Helping fishermen understand the project** ····· Verified that many fish gather around the floating body Less impact on marine environment

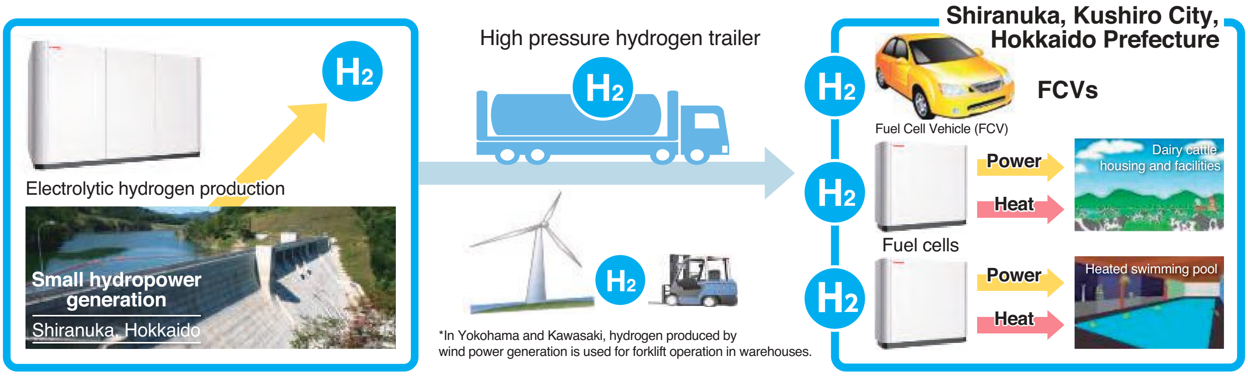
(From Source 65)

Promotion of low-carbon hydrogen

Hydrogen is considered to be a important global warming countermeasure, since it emits no carbon dioxide in end-use and can be used for storing renewable and other energies. To promote more use of hydrogen, demonstration projects using hydrogen converted from renewable energy and locally consuming them have been taking place throughout Japan.

(From Source 65)

Example of efforts made by MOE: demonstration project in Hokkaido

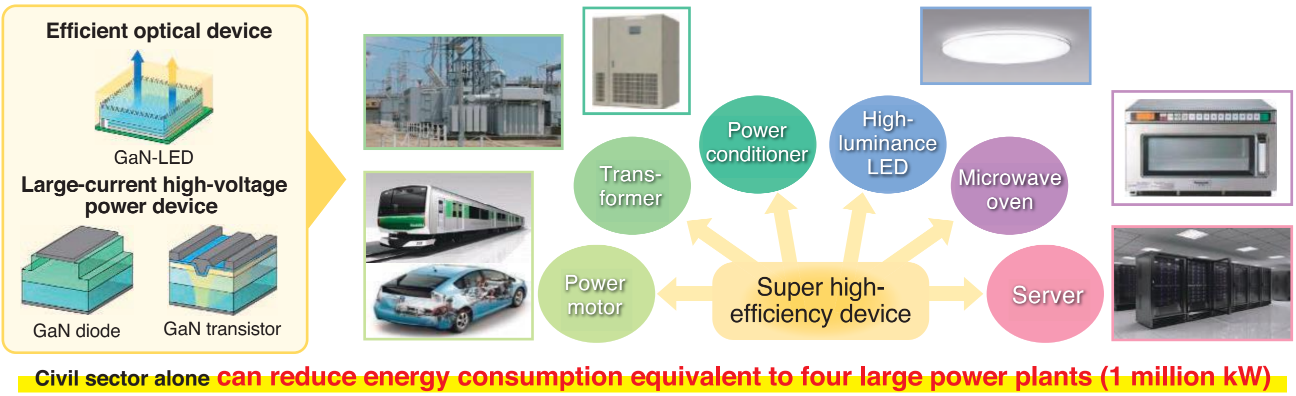


(From Source 65)

Technology development using gallium nitride (GaN), and the like

There is an ongoing effort to maximize efficiency in all kinds of electric devices (e.g. semiconductors) using gallium nitride (GaN), alloy nanocryhstals, and the like (example: cutting energy loss to 1/6 that of conventional materials). The MOE launched technical development in 2014. It plans to launch full-fledged demonstration and verification of emission reduction after 2017 by mounting developed GaN optical and power devices on instruments.

(From Source 65)

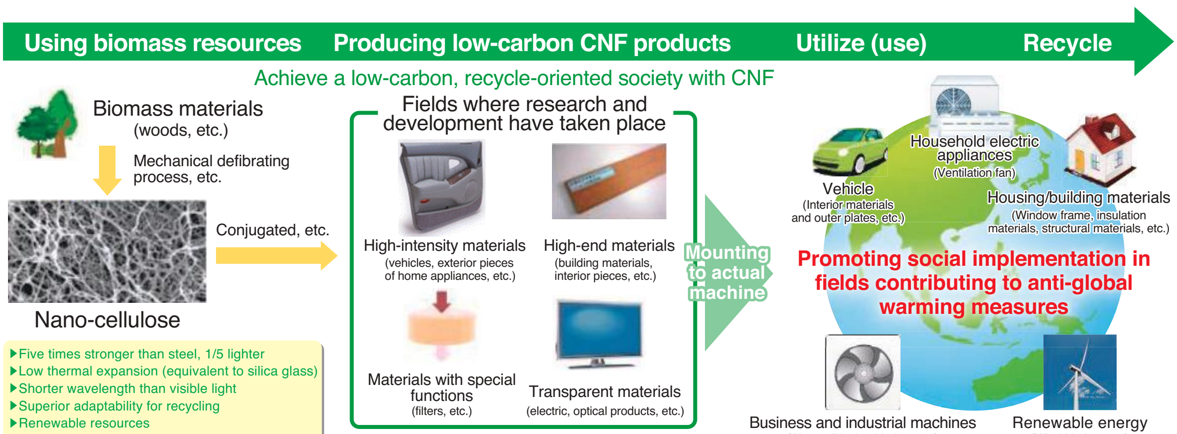


(From Source 65)

Cellulose nano-fiber (CNF)

CNF is five times stronger than steel, even though it is just a fifth of the weight Therefore, if CNF is used for vehicle bodies, it will result in a 10% weight reduction. The MOE is carrying out a project to encourage use of next-generation materials such as cellulose nano-fiber (3.3 billion yen in 2016).

(From Source 65)



(Figure: Nona Cellulose Forum)

(From Source 65)

Chapter 5

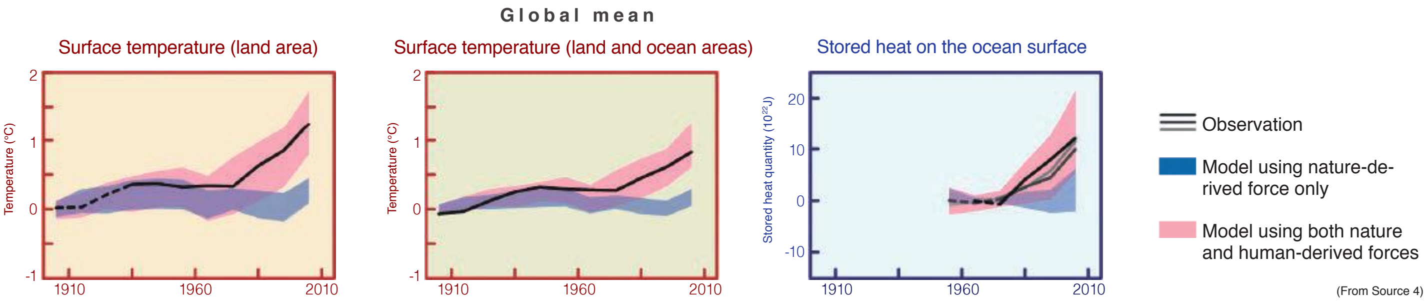
FAQ Let's learn more about global warming

Q. Isn't global warming a result of solar activity?

A. The temperature increases cannot be fully explained by the impact of naturally-occurring phenomena such as solar activities.

This graph shows a comparison between three data: (1) black line: observed annual mean temperature over the last 100 years as published in the IPCC AR5, (2) Blue line: simulation results considering only the impact caused by natural phenomena (e.g. solar and volcanic activities); and (3) red line: another simulation result adding the impact of human activities (carbon dioxide emission due to industrial activities). The three graphs suggest that the observed results (black line) are consistent with the simulation results considering both nature-derived and human activity-derived impacts (red line). In other words, the simulation results (blue line) only considering nature-derived impacts (solar, volcanic, and similar activities only), excluding human activities-derived impacts, is inconsistent with observed data. In other words, the increase in global mean temperature in the 20th century can be explained by the increase of GHGs due to human activities, and the explanation would not be sufficient without considering human activities. It is clear that global warming is caused by human activities, since the temperature keep increasing despite weakened solar activities in recent years.

▶ **Comparisons with climate change produced by observation and simulations**



(From Source 4)

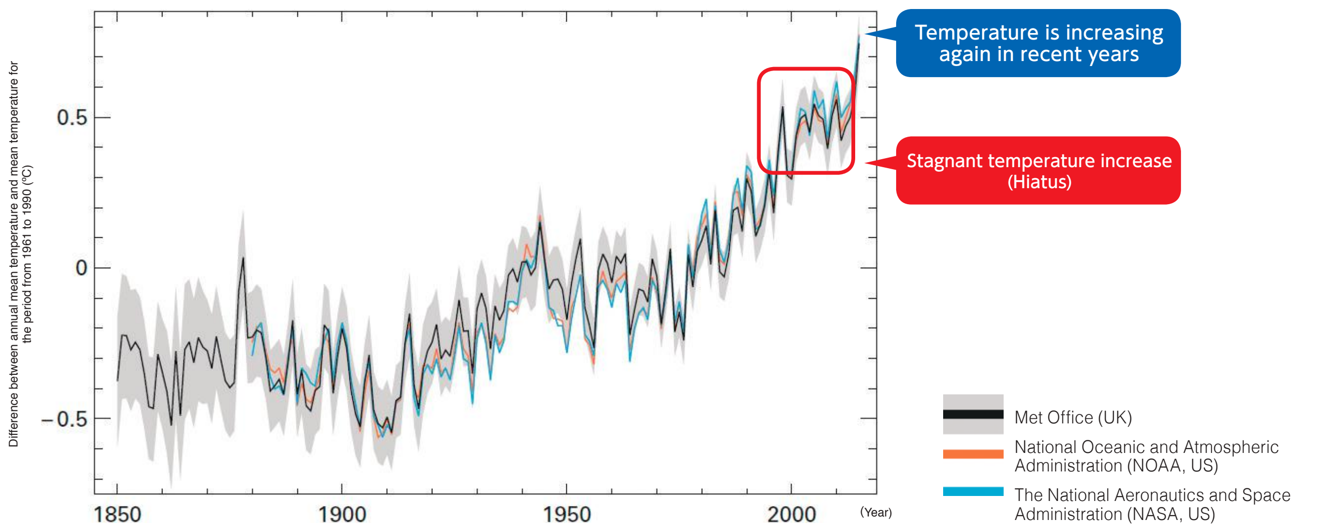
Q. Hasn't temperature increase stagnated in recent years?

A. This is a phenomenon called Hiatus. In the past few years, the temperature has been increasing.

In the period between around 2000 and 2012, the rate of increase of global mean temperature remained at the same level. This stagnant condition of global warming is called a hiatus. Temperature varies not only with natural mechanisms such as El Niño, but also external factors, including impacts due to volcanic activities and carbon dioxide. These factors are complexly intertwined. Therefore, even in the process of ongoing global warming, the temperature does not always simply increase as time goes by. Alternating between periods of moderate and radical temperature increases, the global temperature is increasing from a long-term perspective.

According to the IPCC AR5, the temperature increase was stagnant in the period from around 2000 through 2012. The major causes of the Hiatus includes heat sunk into the deep ocean shores, inactivated solar activities, and impact of volcanic activities. In addition, the temperature has again drastically increased recently, setting new world records of annual mean temperature for three consecutive years since 2014.

▶ **Change in difference of global annual mean temperature compared to the 1961-1990 average**



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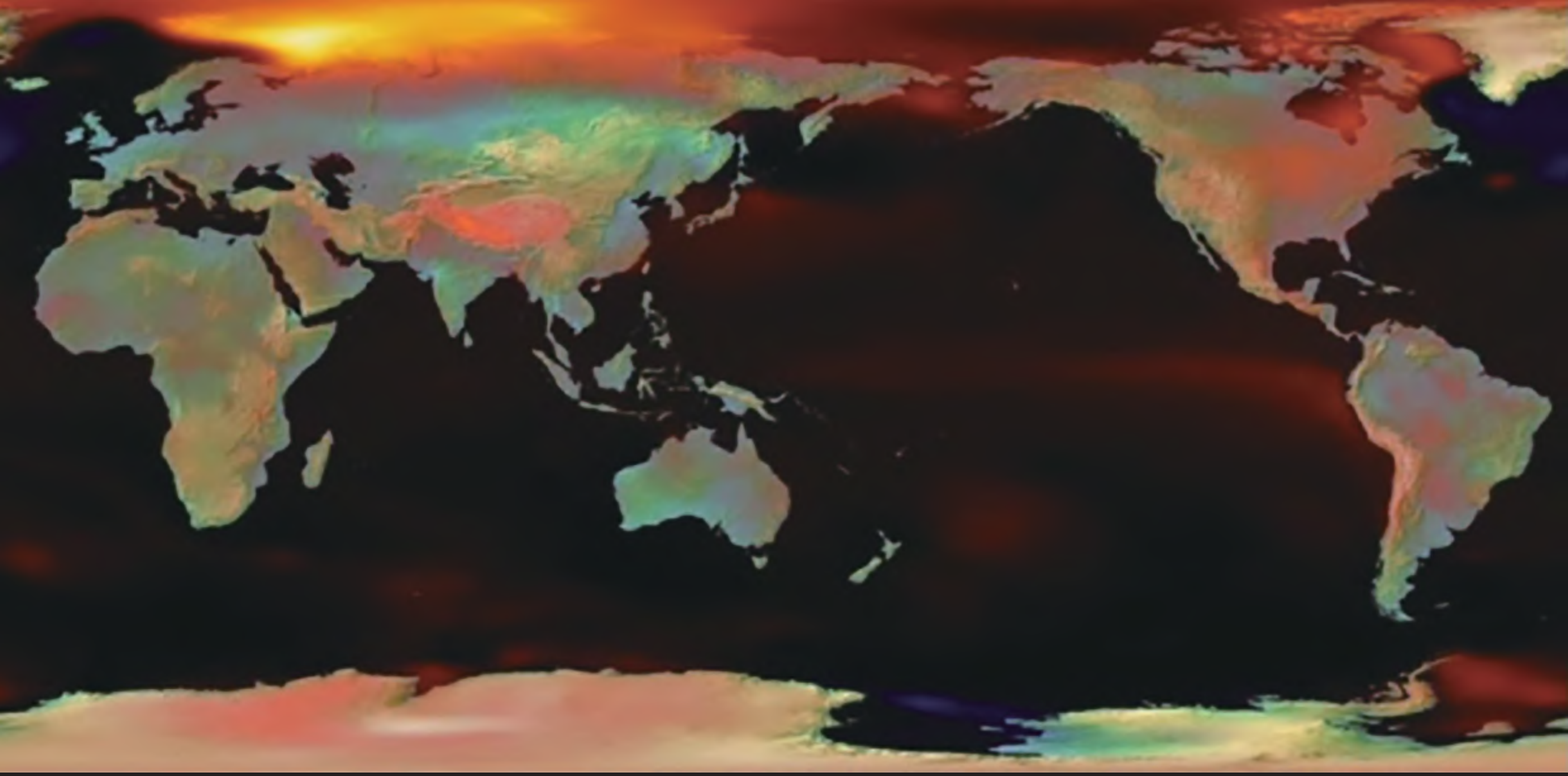

2100

2m temperature change
MIROC5 / RCP2.6

AORI / NIES / JAMSTEC / MEXT

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Front cover: World distribution of temperature deviation of RCP8.5 at 2100 calculated under MIROC5 from annual mean temperature between 1986 and 2005
Back cover: World distribution of temperature deviation of RCP2.6 at 2100 calculated under MIROC5 from annual mean temperature between 1986 and 2005

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