Proceedings of ICEMGD 2025 Symposium: Innovating in Management and Economic Development
DOI: 10.54254/2754-1169/2025.LH27721

Analysis of Frequency Surface Temperature Change Trends and Their Impacts in Japan

Yang Zhai

Chengdu Foreign Language School, Chengdu, China
746287131@qq.com

Abstract. This study analyzes Japan's environmental parameters, focusing on rainfall patterns, surface temperature dynamics, vegetation distribution, forest cover, snow cover extent, and water resource availability. Using a qualitative analytical approach, the research addresses Japan's geographical diversity, complex socio-institutional frameworks, and specific policy contexts. The primary emphasis is on surface temperature trends, examined through publicly available meteorological datasets and policy analysis. Results reveals two major patterns: (1) long-term warming since the 20th century (Greater Tokyo Area up 3°C in 100 years, driven by urban heat islands); and (2) spatial disparities (e.g., more summer extreme heat in subtropical Kyushu, shortened cold seasons in Hokkaido). Ecological impacts include altered temperate forest phenology (e.g., earlier beech flowering), reduced alpine snow affecting meltwater-dependent rivers, and higher forest fire risks in drought-prone areas. Policy gaps are evident: inadequate regional differentiation in national climate policies (e.g., uniform emission targets ignoring urban-rural thermal gaps); poor integration of meteorological data into micro-ecosystem protection (e.g., neglecting heat-induced agricultural pests); and insufficient urban planning regulations for heat island mitigation (e.g., limited green infrastructure mandates).

Keywords: Surface temperature, Japan, environmental parameters, qualitive analysis

1. Introduction

Japan, an island nation in East Asia, is located in the northwestern Pacific Ocean. It lies east of the Korean Peninsula and China, separated by the Sea of Japan, and stretches from the Sea of Okhotsk in the north to the East China Sea and Taiwan in the south. Due to its long north-south span, Japan exhibits significant climate diversity. Northern areas (e.g., Hokkaido) exhibit a cool temperate climate with long, snowy winters and mild summers, while most central and southern regions, including Honshu, Shikoku, and Kyushu, feature a temperate maritime climate with four distinct seasons—warm, humid summers (often with typhoons), cool winters with cherry blossoms and spring being a iconic seasonal highlight. Japan has a population of around 125 million, with a high concentration in urban areas. The Greater Tokyo Area, with over 37 million residents, is one of the most densely populated metropolitan regions in the world. Other major urban zones include Osaka-Kobe-Kyoto and Nagoya. In contrast, rural and mountainous areas are facing population decline and aging.

DOI: 10.54254/2754-1169/2025.LH27721

This study aims to 1) analyze the spatiotemporal patterns of surface temperature change in Japan, integrating urban and rural disparities; 2) assess the ecological consequences of these trends, particularly on vegetation, water resources, and forest ecosystems; 3) identify limitations in current climate policies and propose targeted recommendations.Given Japan’s vulnerability to climate change due to its long north-south span and high urbanization, this research contributes to refining region-specific adaptation strategies, enhancing the resilience of ecological systems, and improving policy alignment with on-the-ground thermal dynamics.

2. Surface temperature change trends in Japan

The Tokyo Metropolis consists of 23 districts under its jurisdiction and is home to Japan's national government. Its administrative area includes the Tama region, the Izu Islands, and the Ogasawara Islands. The Greater Tokyo Area covers the main urban area of the Tokyo Metropolis and the surrounding prefectures such as Kanagawa, Chiba, Saitama, Gunma, Tochigi, and Ibaraki, with a population of 37 million, making it the most populous metropolitan area in the world [1, 2]. In such a place with a high concentration of population, resources, capital, and information, such a large city has unique conveniences compared to small cities. Unfortunately, this excessive concentration of population and resources can damage the urban environment. The urban heat island effect is a good example: in the 20th century. Since 1900, urban areas of Japan have experienced significant warming: data from the Japan Meteorological Agency (JMA) shows that the average temperature in Tokyo has risen by 1°C, while the entire Greater Tokyo Area has seen a 3°C increase over the past 100 years, largely attributed to the urban heat island effect. Data from the Japan Meteorological Agency (JMA) shows that the average temperature in Tokyo has risen by 1 degree Celsius, while the average temperature in the entire Greater Tokyo Area has risen by a full 3 degrees Celsius. According to the IPCC Sixth Assessment Report, by 2050, approximately 70% of the global population will reside in cities, exacerbating urban thermal issues similar to those observed in Tokyo. By 2050, about 70% of the world's population will live in cities. In newly developed urban areas, problems similar to those in existing cities are likely to occur. Taking Tokyo as a case study, obvious indirect issues such as the increase in convective precipitation caused by the deterioration of the thermal environment can provide important data references for cities to formulate corresponding strategies.

3. Environmental variable analysis based on public data in Japan

3.1. Rainfall pattern and frequency

Japan has relatively abundant precipitation on a global scale. However, due to the influence of climatic factors, the amount of precipitation varies in different seasons. For instance, during the summer months (June to July), Japan experiences a distinct rainy season known as plum rain. In a few specific regions such as Okinawa and Amami, this season starts earlier from May to June. Rainfall during this period increases significantly. Sometimes, typhoons may approach Japan, bringing a large amount of precipitation. In winter, according to JMA, the areas on the Sea of Japan side receive a large amount of water vapor due to the Siberian High and the Tsushima Warm Current. Accompanied by a large amount of snow, it is another form of precipitation.

DOI: 10.54254/2754-1169/2025.LH27721

3.2. Surface temperature

The spatial differentiation of Japan's climate is remarkable, resulting in significant differences in surface temperatures. The Hokkaido region has a cool and short summer, and a long and frigid winter. In contrast, the southern Kyushu Island and Ryukyu Islands have a subtropical climate, with hot summers and warm winters. The average temperature in January ranges from -6°C in the north to 16°C in the south; in July, it increases from 17°C in the north to 28°C in the south [3].

In addition, the urban heat island effect exacerbates local warming. For example, the surface temperature in Fukuoka during the day in summer is significantly higher than that in the surrounding rural areas [4-6].

3.3. Vegetation

Affected by factors such as climate and terrain, the vegetation types in Japan show a trend of diversification. In areas with a humid climate and suitable temperature, forest vegetation thrives and contains a variety of temperate and subtropical plant species. For example, beech is the core tree species of the temperate deciduous broad-leaved forest in Japan. Its wood is hard and is often used in furniture and construction. The camphor tree is a symbolic tree species of the subtropical evergreen broad-leaved forest. Its wood is fragrant and can be used to make furniture and spices.

In mountainous areas, coniferous forests and broad-leaved forests are dominant, such as coniferous trees like Cryptomeria japonica, Chamaecyparis obtusa, and larch, as well as broad-leaved trees like Quercus autism and beech. Japan is long and narrow from north to south, with a climate changing from subtropical to sub-frigid zone, and its terrain is mainly mountainous, providing a diverse habitat for different plants [7].

3.4. Forest coverage

As of the end of March 1995, the forest coverage rate of Japan reached 67%, and the forest area was 25.15 million hectares. Among forest resources, planted forests accounted for 41.4% with an area of 10.4 million hectares; natural forests accounted for 53.2% with an area of 13.38 million hectares. Planted forests are mainly coniferous forests, while natural forests are mainly broad-leaved trees. The forest coverage rates vary in different regions. The forest coverage rate in mountainous areas is relatively high, playing a crucial role in maintaining ecological balance and conserving soil and water.

3.5. Snow coverage

In Japan, snow cover is mainly concentrated in winter, and the snowfall amounts vary in different regions. For example, Hokkaido has a long and cold winter with a long snow-accumulation period and a relatively large snowfall amount. In winter, the region on the Sea of Japan side of Honshu Island is affected by the Siberian high pressure, with northwest winds blowing. Coupled with moisture-laden air masses interacting with orography, heavy snowstorms often occur, resulting in extensive and deep snow cover. In contrast, the region on the Pacific side has relatively less snowfall in winter.

3.6. Water resource

As an island country, Japan is rich in water resources. Most of its rivers originate from the central mountains and flow into the Pacific Ocean and the Sea of Japan on the east and west sides. Due to the narrow terrain and steep mountains, the rivers are short and rapid. During the plum rain and typhoon seasons, the river water volume increases, and it is prone to flooding. Japan has built a large number of dikes and reservoirs for flood control, and the river water is widely used for domestic water, agricultural and industrial water, and hydropower generation. In addition, Japan has few lakes. The largest lake is Lake Biwa, with an area of 672.8 square kilometers, which plays a certain role in water resource regulation and other aspects. Water resource availability in Japan is increasingly vulnerable to temperature-driven precipitation variability. Rising surface temperatures intensify evaporation, exacerbating droughts in regions like the Seto Inland Sea. Conversely, extreme rainfall events during typhoons (amplified by warmer ocean temperatures) lead to more frequent river flooding, straining flood control infrastructure. This volatility threatens both agricultural water supply and the stability of aquatic habitats, such as Lake Biwa's fish populations during low-water periods.

4. Data analysis

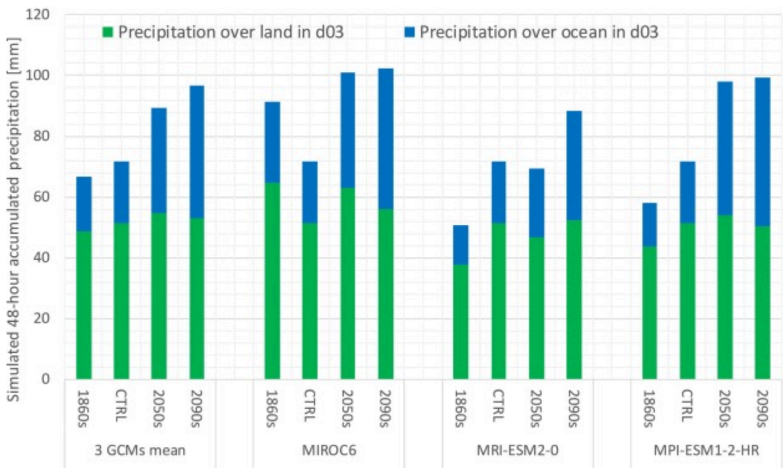

Figure 1. Simulated 48-hour cumulative precipitation under different time periods (1860s, 2050s, 2090s) and climate models (3 GCMs mean, MIROC6, MRI-ESM2-0, MPI-ESM1-2-HR)

Figure 1 presents the simulated 48-hour cumulative precipitation under different time periods and climate models, especially the 1860s (representing the past), the 2050s (representing the mid-term future), and the 2090s (representing the long-term future). Here, green represents the precipitation on land, and blue represents the precipitation over the ocean.

Across all time periods and climate models, the precipitation over the ocean is generally higher than that on land. In the 2050s and 2090s, the precipitation is significantly higher than that in the 1860s, which may reflect the increase in precipitation caused by climate change. There are certain differences in the simulation results of precipitation by different climate models. For example, the MIROC6 model simulates the highest ocean precipitation in the 2090s, approaching 100mm. The results of the 3 GCMs mean model are relatively stable, showing the average value of multiple models, which may be more representative. These variations demonstrate the projected intensification of precipitation under global warming, particularly over marine regions. Overall, the future precipitation may increase, and the increase in precipitation over the ocean is more significant. The differences among different climate models also suggest the uncertainty of climate prediction.

Japan has relatively abundant precipitation, and its surface temperature has been on the rise due to factors such as global warming [8]. Both have exerted numerous impacts on its human society in terms of economy, daily life, and environment, as detailed below:

(1) Precipitation conditions: Most areas of Japan are located in the Asian monsoon zone, with an annual precipitation of about 1,700mm, approximately twice the world average, making it a region with relatively heavy precipitation. In addition to the four seasons of spring, summer, autumn, and winter, there are two rainy seasons between spring and summer (the plum rain season) and between autumn and winter (the autumn rain season), both of which see relatively heavy rainfall. However, precipitation is unevenly distributed: the Sea of Japan coast receives heavy snowfall in winter and is a "heavy snow zone"; the Kyushu region is prone to heavy rains during the plum rain season and droughts; the Seto Inland Sea area has little precipitation and is sunny all year round with good weather; and the Pacific coast has abundant precipitation and a warm climate.

(2) Impacts on human society: Heavy rains may trigger disasters such as floods and mudslides, causing significant casualties and property losses. For example, the "July 23 Nagasaki Flood" in 1982 resulted in 299 deaths, 805 injuries, and direct economic losses as high as 315.3 billion yen. However, abundant precipitation also provides conditions for hydropower generation, facilitating the economy. The Sea of Japan coast can utilize snow resources to develop ski resorts and boost tourism. In addition, reduced precipitation will lead to a drop in lake water levels, affecting the habitat of fish, as well as water supply and fisheries. For instance, Lake Biwa, Japan’s largest freshwater lake, once saw a significant drop in water levels due to scarce rainfall, threatening the survival of endemic species such as the Biwa trout (Oncorhynchus masou rhodurus) and disrupting municipal water supplies for nearby cities like Kyoto and Osaka.

5. Suggestions for mitigating the urban heat island effect

Addressing the urban heat island phenomenon involves a range of strategies, from enhancing urban ecosystems and refining building designs to modifying human behaviors [9]. Below are some key steps:

(1) Boosting urban green cover: Enlarge parks and green areas. Plants cool the surroundings through transpiration, and they also absorb heat and help retain moisture. Encourage rooftop gardens and vertical greenery (like wall-climbing plants). This cuts down on heat absorbed by buildings, making local areas cooler.

(2) Improving urban surface materials: Swap heat-absorbing, impermeable materials such as asphalt and concrete with permeable options like porous bricks and permeable concrete. These aid rainwater absorption, which in turn lowers surface temperatures. Apply light-colored paints to roads and building exteriors. These reflect sunlight rather than soaking it up, reducing heat buildup.

(3) Planning urban layouts wisely: Keep ventilation channels clear to let natural winds circulate and carry away heat, avoiding overly dense buildings that block air flow. Slow down urban sprawl and protect nearby farmland, wetlands, and other natural areas, as they help regulate the climate.

(4) Cutting down on human-caused heat: Promote electric vehicles and limit the use of high-emission cars to reduce heat and pollution from transportation. Upgrade industrial processes to use energy more efficiently, thus reducing excess heat released by factories.

By improving how cities absorb and release heat, these actions can ease the urban heat island effect and make cities more pleasant to live in [10].

DOI: 10.54254/2754-1169/2025.LH27721

6. Conclusion

The study investigates the changing pattern and surface temperature in Japan, alongside their societal and environmental impacts, with particular emphasis on the urban heat island effect and its mitigation strategies. The main conclusions are as follows: Simulations of 48-hour accumulated precipitation under different time periods and climate models show that precipitation over oceans is generally higher than that over land. Precipitation in the future (2050s, 2090s) shows an increasing trend compared with the past (1860s), and the increase in precipitation over oceans is more significant. There are differences in the results of different climate models, reflecting the uncertainty of climate prediction. Among them, the 3 GCMs mean model may be more referential as it represents the average of multiple models. Japan has abundant but unevenly distributed precipitation. Affected by this, it is prone to disasters such as floods and mudslides, causing losses, but it also provides conditions for the development of hydropower, tourism, etc. Abnormal precipitation will also affect ecology and industries. At the same time, surface temperature has risen due to global warming, and both have exerted multiple impacts on Japan's society in terms of economy, life, environment, etc. Regarding the urban heat island phenomenon, suggestions are put forward to the government, such as increasing urban greening, improving surface materials, rationally planning urban layout, and reducing man-made heat generation, so as to alleviate the heat island effect and enhance urban livability. Future research could focus on: 1) Long-term monitoring of thermal impacts on specific ecosystems (e.g., alpine snowmelt-dependent rivers); 2) Quantitative analysis of policy effectiveness (e.g., evaluating green infrastructure in Fukuoka’s urban heat mitigation); 3) Integrating socioeconomic factors (e.g., rural depopulation) into thermal trend models to better predict regional vulnerabilities.

References

[1] Sato, Yousuke, et al. (2016). Regional Variability in the Impacts of Future Land Use on Summertime Temperatures in Kanto Region, the Japanese Megacity. Urban Forestry & Urban Greening, 20, 43–55, https: //doi.org/10.1016/j.ufug.2016.07.012.
[2] Kawamoto, Y. (2017). Effect of land-use change on the urban heat island in the Fukuoka–Kitakyushu metropolitan area, Japan. Sustainability, 9(9), 1521.
[3] Friedlingstein, P., et al. (2020). Global Carbon Budget 2020. Earth System Science Data, 12(4), 3269–3340. https: //doi.org/10.5194/essd-12-3269-2020.
[4] Yasunaka, S., and Hanawa, K. (2010). Intercomparison of Historical Sea Surface Temperature Datasets. International Journal of Climatology, 31(7), 1056–1073, https: //doi.org/10.1002/joc.2104.
[5] Fujibe, F. (2011). Urban warming in Japanese cities and its relation to climate change monitoring. International Journal of Climatology, 31(2), 162-173. DOI: 10.1002/joc.2104
[6] Peng, W., et al. (2021). Assessment of Urban Cooling Effect Based on Downscaled Land Surface Temperature: A Case Study for Fukuoka, Japan. Urban Climate, 36, 100790. https: //doi.org/10.1016/j.uclim.2021.100790.
[7] Ma, J, et al. (2006). Flora of Japan. Taxon, 55(4), 1072. https: //doi.org/10.2307/25065724.
[8] Tomlinson, C. J., Chapman, L., Thornes, J. E., & Baker, C. (2011). Remote sensing land surface temperature for meteorology and climatology: A review. Meteorological Applications, 18(3), 296-306.
[9] Sugiyama, N., and Takeuchi, T. (2008). Local Policies for Climate Change in Japan. The Journal of Environment & Development, 17(4), 424–441, https: //doi.org/10.1177/1070496508326128.
[10] Liu, F., Hou, H., & Murayama, Y. (2021). Spatial interconnections of land surface temperatures with land cover/use: A case study of Tokyo. Remote Sensing, 13(4), 610.