Weather and Climate

The distribution of climates in Korea is determined by key climate factors such as latitude, elevation, geographical location, land/sea heating properties, ocean currents, the East Asian Monsoon system, and air masses. During the summer, it is hot and humid, but during the winter, it is cold and dry in response to the East Asian Monsoon.

Due to its north-south orientation and length, the Korean Peninsula experiences distinct differences in temperature as well as length of daylight and amount of solar energy received between its northern and southern points. The difference in annual mean temperature between Seogwipo (16.6°C), located at the southernmost tip of South Korea (33° 14' N), and Cheorwon (10.2°C), located at the northernmost tip (38° 08' N) of South Korea, demonstrates a wide variation in temperature with latitude.

Climate features vary greatly depending on elevation. The annual mean temperature at Daegwallyeong (773 m), the highest located observation station in South Korea, is 6.6°C, which is 3.7°C lower than that at Hongcheon (10.3°C), which is at 141 m and located at a similar latitude. The difference in the mean temperature is also found in the southern area between Imsil (248 m) and Jeongeup (45 m), with 11.2°C and 13.1°C, respectively.

The geographical location also makes a difference in the climate. The Taebaeksanmaek acts as a barrier to the flow of air and brings a marked difference in climate between the Yeongseo area (windward side) and Yeongdong area (leeward side). When a cold northwesterly wind dominates over the Korean Peninsula during the winter, the temperature at Chuncheon, located in the Yeongseo area, is low. Whereas in Sokcho, located in the Yeongdong area, the temperature increases. The average temperature for the warmest month, August, in Chuncheon (24.6°C) is higher than that in Sokcho (23.7°C), while the average temperature for the coldest month, January, in Chuncheon (-4.6°C) is much lower than that in Sokcho (-0.3°C). However, as a northeasterly wind blows over the Taebaeksanmaek, Chuncheon becomes warmer while Sokcho becomes colder. Also, when the northeasterly wind crosses the East Sea with its warm current flows and is forced to rise over the mountain barrier, heavy snow occasionally falls in the Yeongdong area as a result.

Korea is largely characterized by a continental climate due to the effects of the Eurasian continent. However, the climate of the coastal areas, which is mostly governed by the ocean, differs from that of the inland areas. The annual mean temperature range for Daejeon is only 0.3°C greater than that of Boryeong, which is adjacent to the coast. The average temperature during the summer (months of June, July, and August) in Daejeon is approximately 1.3°C higher than that in Boryeong.

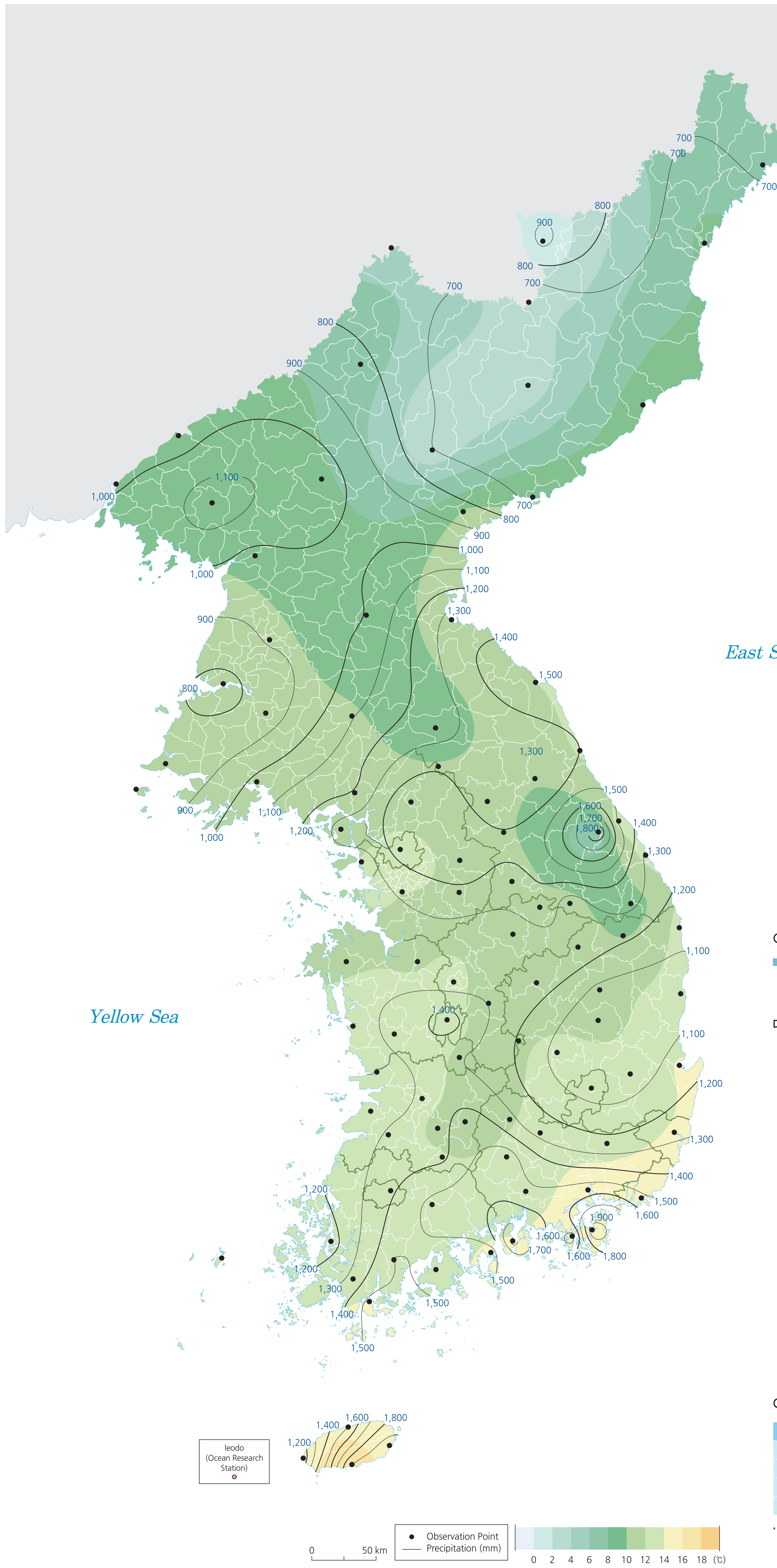
The following ocean currents also affect the climate of Korea: the East Korean Warm Current and North Korean Cold Current in the East Sea, and the Yellow Sea Warm Current in the Yellow Sea. The East Korean Warm Current, diverging from the Tsushima Current at the eastern end of the Korea Strait, flows along the eastern coast of Korea and provides warm ocean water up to the latitude of 37°–38° N. Part of the current flows north up to the coast of Goseong, Gangwon-do, and affects the climate of the surrounding area. The North Korean Cold Current, a part of the Primorye (Liman) Cold Current flowing from the Sea of Okhotsk, flows southward along the coast of Hamgyeong-do and reaches down to the southern region of Gangwon-do during the winter. The Yellow Sea Warm Current, a tributary of the Tsushima Current, flows from the western waters of Jejudo to the southern part of the Yellow Sea and occasionally exerts influence on the climate of the west coast.

The northward movement of the Yellow Sea Warm Current weakens during the winter, while the inflow becomes stronger during the summer. The Asian monsoon system over East Asia (including Korea, China, and Japan) is formed due to the land-sea distribution and the associated difference in heating properties. While cold, dry wind blows into the Korean Peninsula in the winter due to the continental effect, hot and humid wind blows into Korea during the summer due to the effect of the North Pacific. The climate of Korea is also under the influence of various air masses such as the Siberian air mass, the North Pacific air mass, the Okhotsk Sea air mass, and the equatorial air mass.

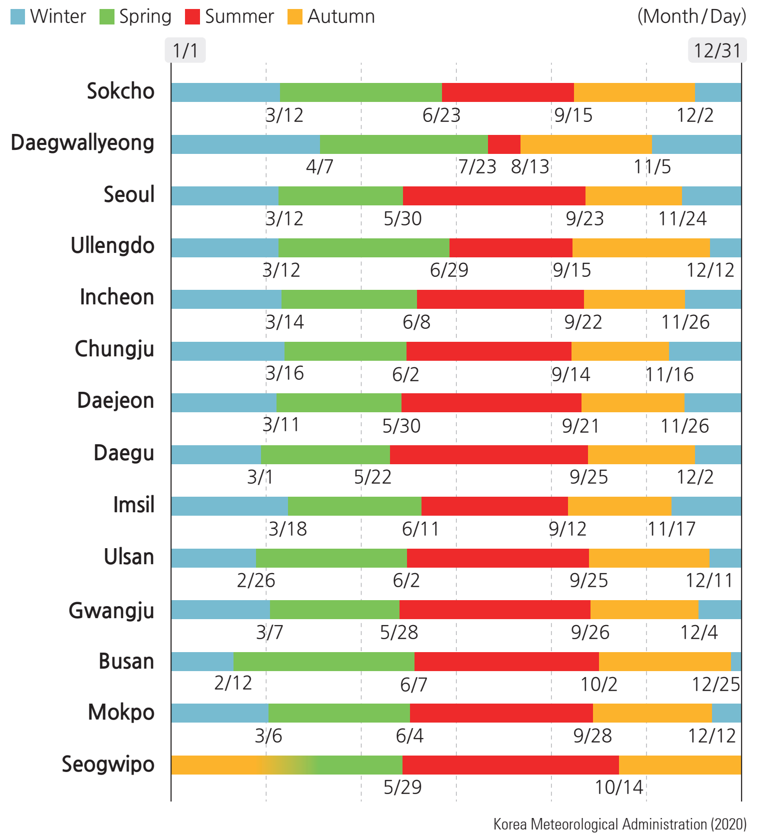
The classification of natural seasons based on the criteria of daily mean temperature results in regional differences in beginning date and number of days for each season. Except for Seogwipo, spring comes the earliest in Busan (February 12), while it comes the latest in Daegwallyeong (April 7). Except for Daegwallyeong (July 23), Ulleungdo (June 29), and Sokcho (June 23), summer mostly begins between late May and early June, lasting about 90–120 days. Except for Daegwallyeong (August 13), autumn starts around the middle of September, with a shorter duration (60–90 days) than spring and summer. Winter generally commences around late November, lasting about 50–150 days.

Climate Overview

Annual Mean Temperature and Precipitation



Classification of Natural Seasons by Region



Korea Meteorological Administration (2020)

Criteria for Classification of Natural Seasons

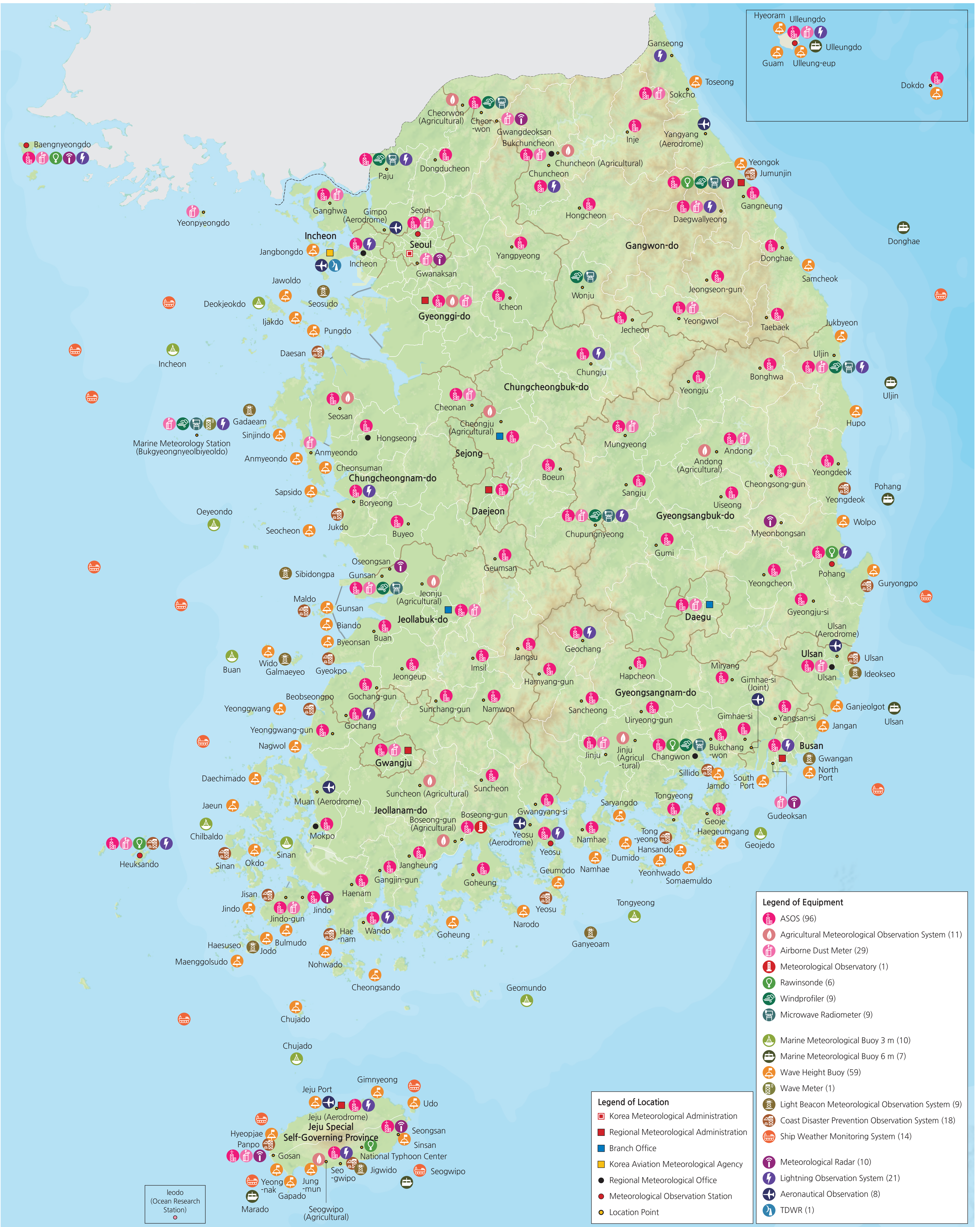
Season	Standard
Spring	The first date with daily mean temperature above 5°C
Summer	The first date with daily mean temperature above 20°C
Autumn	The first date with daily mean temperature below 20°C
Winter	The first date with daily mean temperature below 5°C

* The daily average temperature is a 9-day moving average of the daily average temperature for 30 years (1981-2010).

Korea Meteorological Administration (2020)

Meteorological Observations

Spatial Distribution of Weather Stations

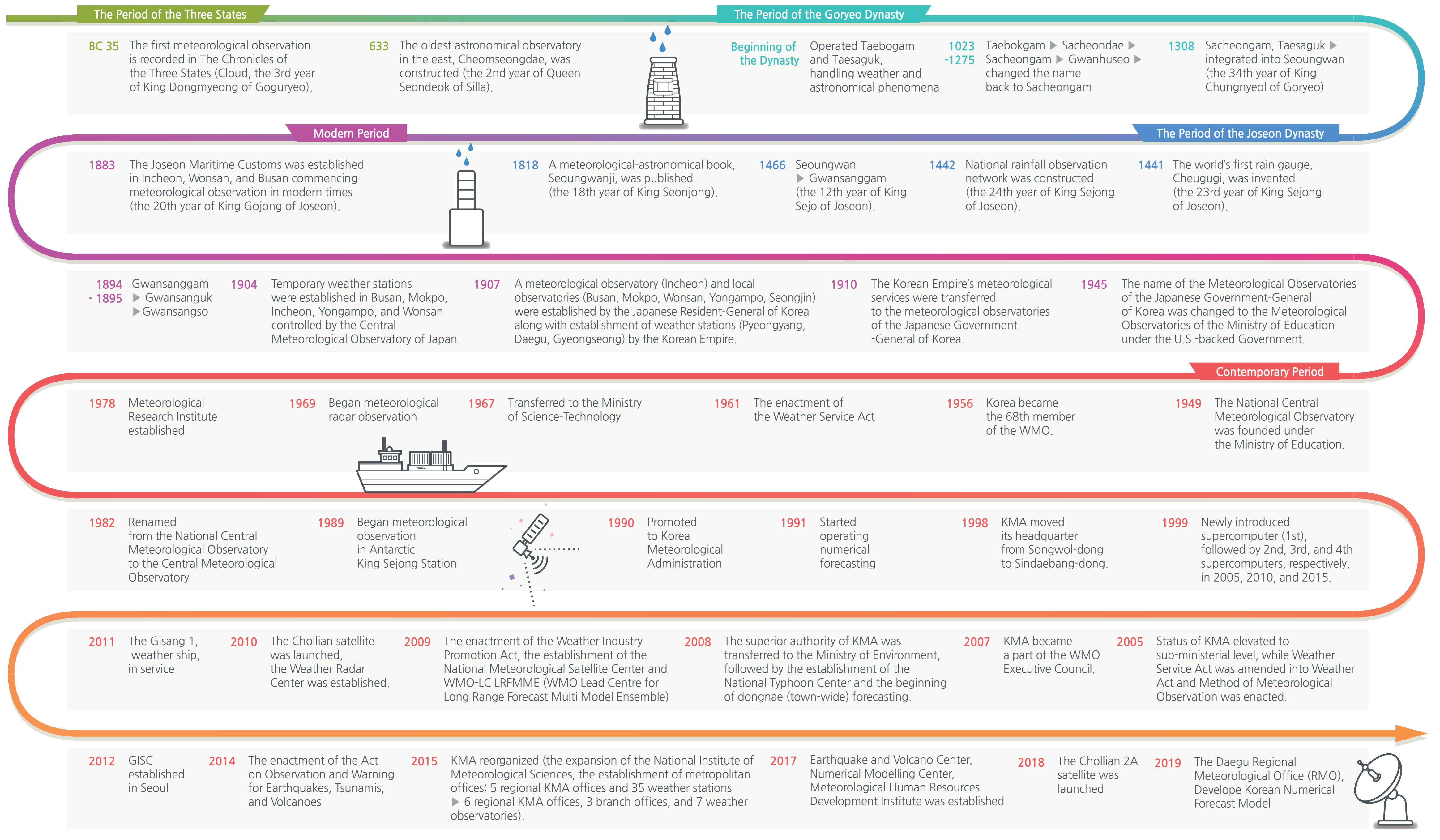


Korea Meteorological Administration (2019)

The Korean Meteorological Administration (KMA) conducts surface weather observations and other weather-related observations by categorization, including upper-air, marine, radar, aviation, and earthquake observations. The surface weather observation network consists of 96 automated surface observing systems (ASOS) and 494 automatic weather stations (AWS). Six rawinsonde units and nine wind profilers and microwave radiometers are operating for upper-air observation. Marine weather observations consist of 17 ocean data buoys, 59 coastal wave buoys, 9 light house automatic weather stations, 14 ship weather monitoring systems, 18 coastal long wave monitoring systems, 1 wave radar, and 1 marine weather observation vessel. In addition, KMA operates 10 weather radars, 21 lightning network (LINET) sensors, 8 aerodrome meteorological observation systems (AMOS), and 156 seismometer units.

History of Meteorology in Korea

History



Korea Meteorological Administration (2020)

According to *Samguk yusa*, Korea's meteorological history began with Hwanung, the legendary founder of Gojoseon, who descended from heaven with 3,000 followers to Sindansu in Taebaeksan to rule the world, along with his ministers of cloud, rain, and wind, who were capable of controlling the basic weather elements. Since the period of the Three Kingdoms, there have been numerous meteorological observation records. During the Goryeo dynasty, Seoungwan was established and operated as a government office dealing with weather and astronomical phenomena. During the Joseon dynasty, great progress was made in meteorological observations. The world's first rain gauge, Cheugugi, was invented (1441), and a rainfall observation network was built on a national scale. The instruments for measuring the water level of the Cheonggyecheon and the Hangang were invented. There were also instruments for observing wind direction.

In the 19th century, meteorological observation was modernized when P. G. Von Moellendorf, a German appointed as the Inspector General of Marine Customs by King Gojong, the Emperor of the Joseon dynasty, installed meteorological instruments at Incheon Port and Wonsan Port in 1884, and another at Busan Port in 1887.

Beginning in 1904, five temporary weather stations were established in Busan, Mokpo, Incheon, Yongampo, and Wonsan, followed by stations at Seongjin and Jinnampo. These stations formed a meteorological network that laid the foundation for the modern weather service. In 1907, eight weather stations were established in Gyeongseong (currently Seoul), Pyeongyang, Yongampo, Daegu, Busan, Mokpo, Wonsan, and Seongjin. These stations began forecasting the weather as soon as standards for forecasting and storm warnings were established. Additional weather stations were installed in Gangneung (1911) and Unggi/Junggangjin (1914).

In 1949, the Central Meteorological Office was founded. The period from 1949 until the 1960s saw the organization of laws and improvement in Meteorological Communication (METCOM), which enabled the establishment of an immediate exchange system for meteorological observations and data analysis. All these efforts paved the way for international cooperation.

In 1970s, the contemporary meteorological administration and technology system, including digitalization, satellite, and radar-related observation, were built. During the 1980s, Korea's weather service expanded the meteorological network, modernized equipment, implemented local forecasting, objectified forecast data, digitalized the weather service, and provided climate data and industrial meteorological information.

In 1990s, the Korean Meteorological Administration (KMA) established the foundation for advanced meteorological observations. KMA established an automatic weather station (AWS) network and a weather radar network, secured a supercomputer, released a weekly forecast every day, implemented a six-hour forecast system, established KMA certified programs at colleges, and operated a weather forecaster training curriculum for foreigners.

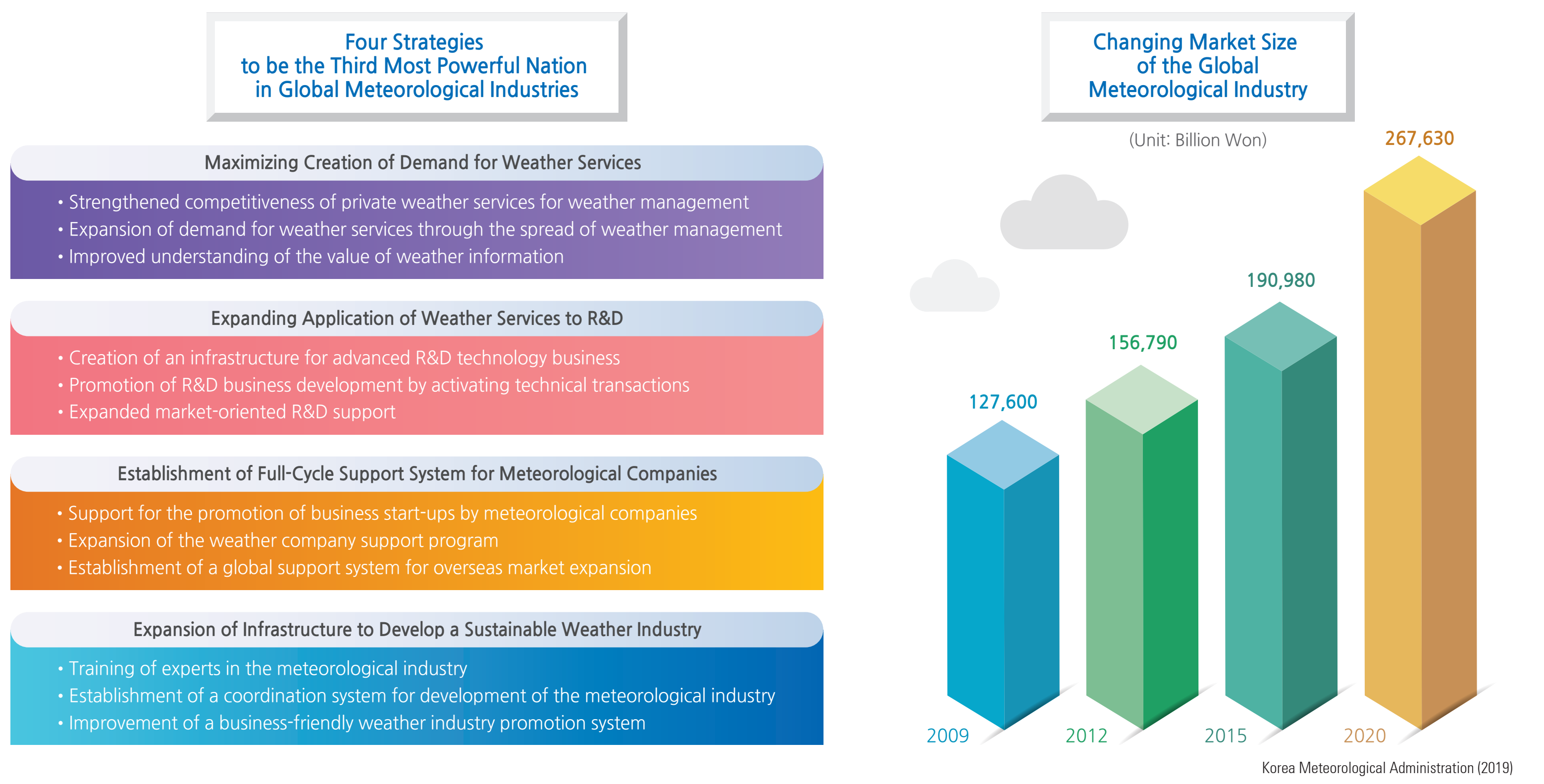
In the 21st century, Korea has developed forecasting technologies, expanded meteorological monitoring systems, strengthened meteorological services, established a nation-wide automatic weather system, strengthened the foundation for meteorological technical innovation, expanded weather-related research and development, and promoted weather-related cooperation with foreign countries. In 2001, Korea established a long-term vision (MT Vision 2025) to create an institutional basis for promoting the development of meteorological technology. This long-term vision presented a national vision for meteorological technology and set the basis for meteorological policy to realize the vision.

The market size of Korea's weather industry is growing steadily and was valued at 480 billion won in 2018. The weather industry has become a new growth engine for the country. Demand for the weather industry has increased. The KMA has established a life-cycle support system to strengthen the capabilities of weather enterprises and promotes various policies to revitalize the weather industry, such as supporting the expansion of domestic and foreign markets and expanding research and development for commercialization of market-oriented weather services.

The Weather Industry Promotion Act aims to support and foster the weather industry to lay the foundation for the development of the weather industry and strengthen its competitiveness, thereby contributing to the development of the national economy. The KMA formulates and implements a master plan for the advancement of the weather industry every five years to achieve the purposes of this Act in a systematic and efficient manner.

After the completion of the first plan for the promotion of the weather industry (2011–2015), Korea entered the growth phase of the weather industry through support and the establishment of a foundation for its activation. The second plan (2016–2020) is devoted to spreading the value of the weather industry by strengthening the capabilities of weather companies to become a global weather industry powerhouse.

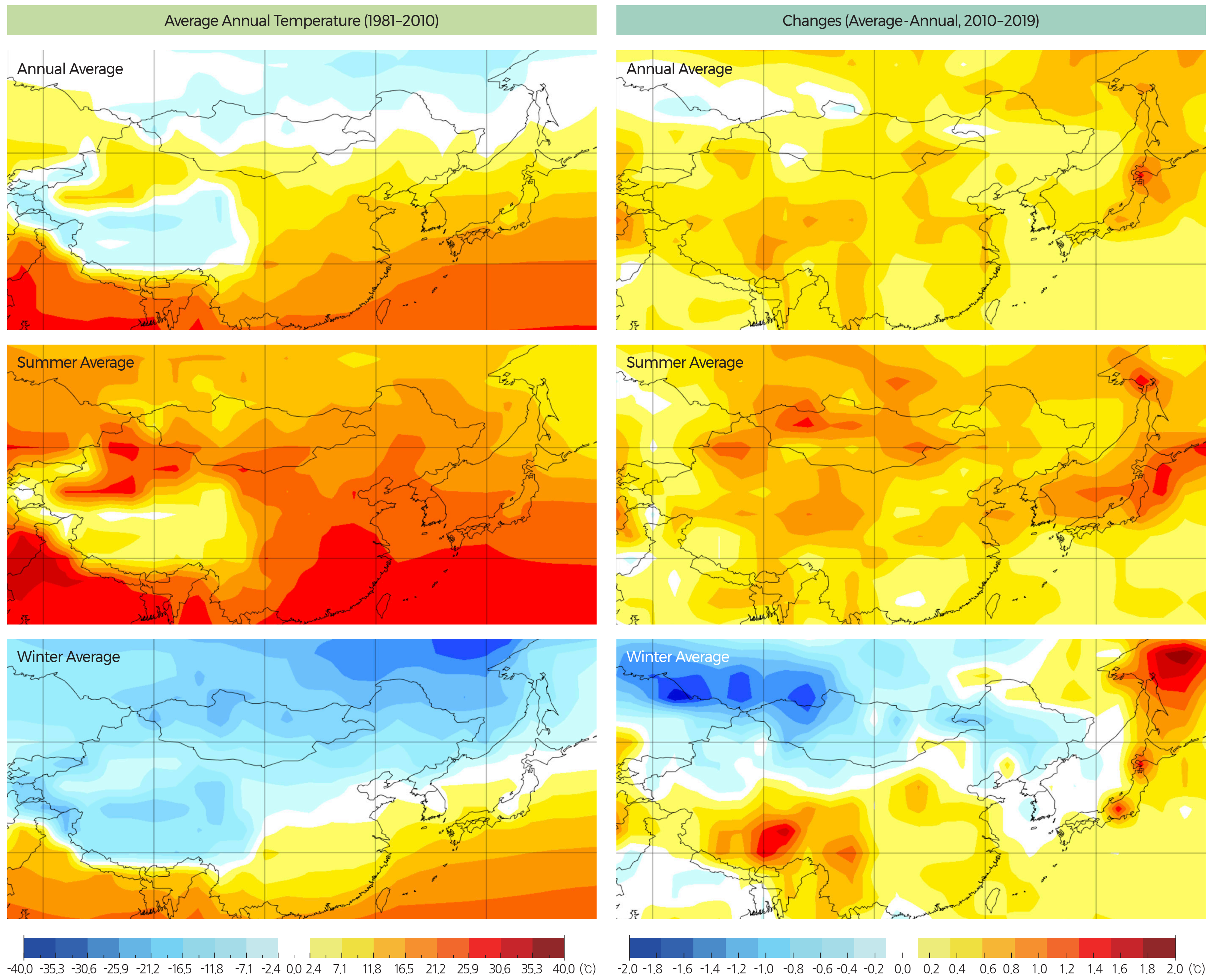
Scale of the Weather Industry in Sales



Korea Meteorological Administration (2019)

Climate Change in Northeast Asia

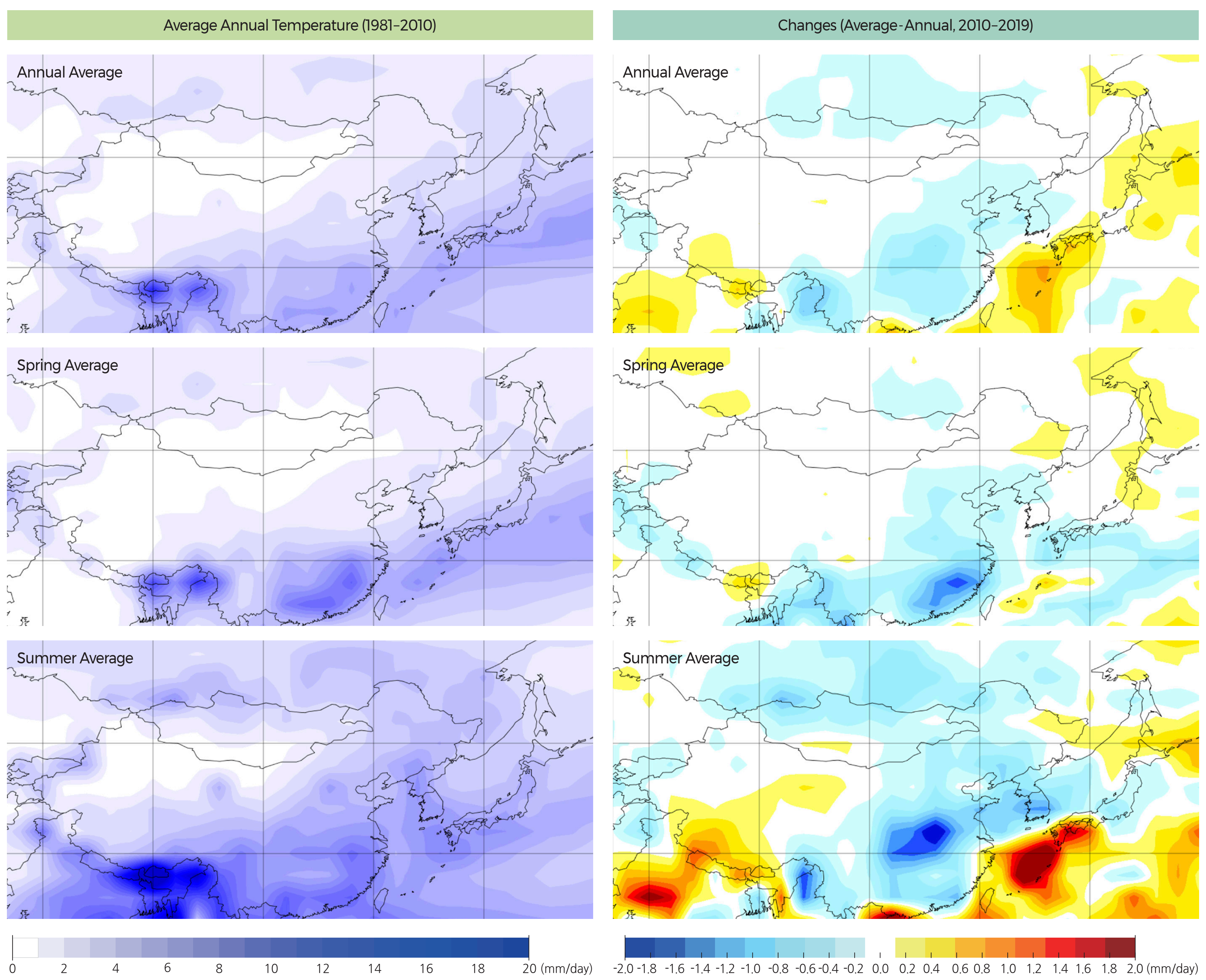
The Change in the Average Annual Temperature for the Last 10 Years



The average annual temperature for 10 years (2010–2019) has risen by about 0.2–0.8°C compared to the long-term average annual temperature (1981–2010). It increased in all seasons except winter, and the temperature increase in spring and summer was larger than in other seasons. On the other hand, the winter temperature in the northern interior of East Asia was lower than the long-term average annual temperature. On the Korean Peninsula, the average annual temperature of the past 10 years has the largest increase in summer (0.6–1.1°C) compared to the long-term average annual temperature. The temperature change in winter has not been as large as in summer.

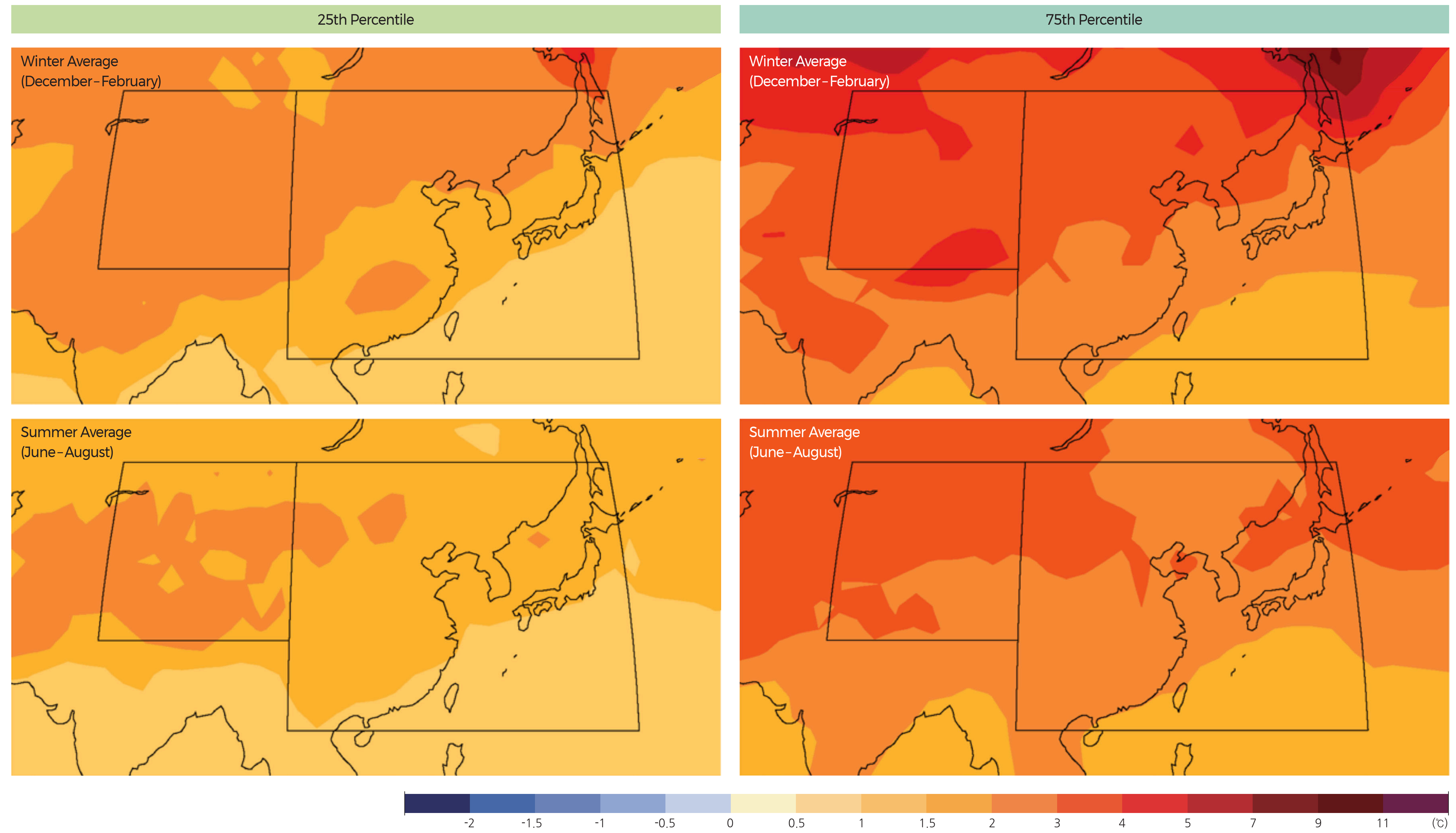
* ERA5 (ERA5, 2019: DOI: 10.24381/cds.f17050d7), Panoply Data Viewer (Panoply 4.11.5, NASA Goddard Institute for Space Studies)

The Change in the Average Annual Precipitation for the Last 10 Years



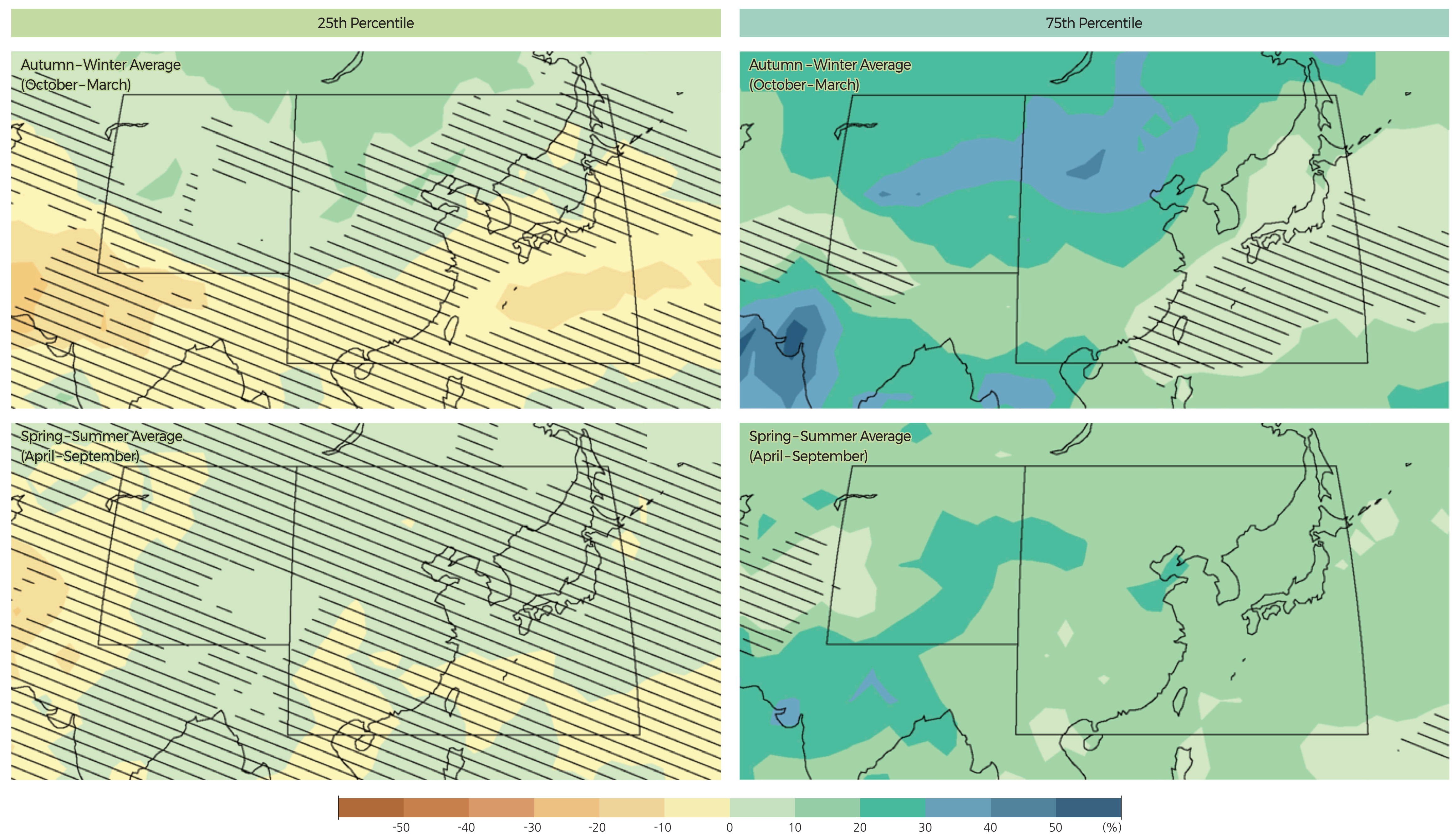
The change in the average annual precipitation for the last 10 years (2010–2019) appeared differently on land and in the ocean. Precipitation on land has decreased, but precipitation on the ocean has increased. The difference in the change in precipitation between land and ocean is evident during the summer months. The decrease of precipitation on land starts in winter and lasts through spring and summer, contributing to water shortages in East Asia in spring. The average annual precipitation on the Korean Peninsula for the last 10 years (2010–2019) has declined compared to the long-term average precipitation (1981–2010) due to the decrease in summer precipitation.

East Asia Seasonal Average Temperature Forecast



IPCC AR5/WG1/Annexes Figures A1.56, 57

East Asia Seasonal Average Precipitation Forecast



IPCC AR5/WG1/Annexes Figures A1.58, 59

* The difference in the seasonal average precipitation between 1986–2005 and 2081–2100 according to the RCP 4.5 scenario

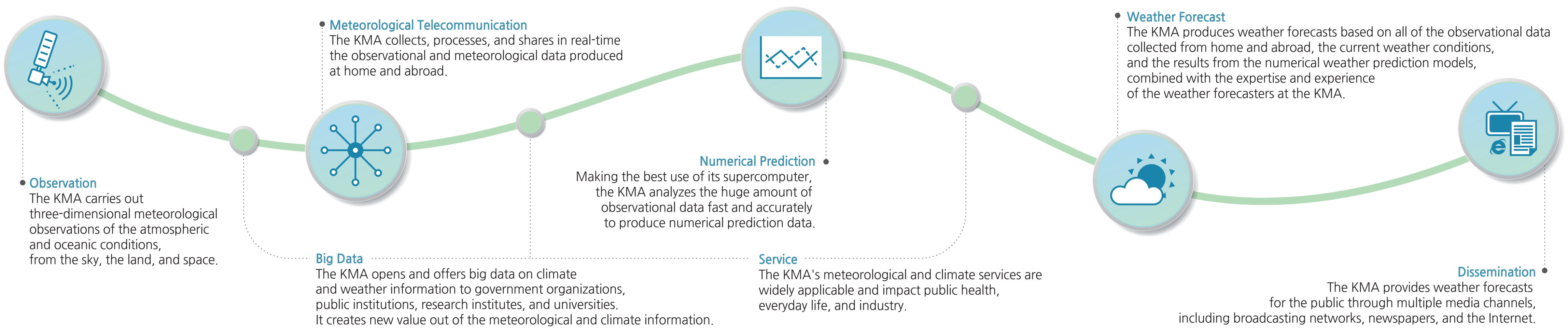
** The 25th percentile and 75th percentile represent the bottom 25% and top 25% of the seasonal average precipitation between 2081 and 2100, which is predicted by the Coupled Model Intercomparison Project-Phase 5 (CMIP5). In the shaded areas, the seasonal average precipitation in 2081–2100 is less than that in 1986–2005.

Compared to the average temperature for the period of 1986–2005, the RCP4.5 scenario predicts that the average temperature is likely to rise by more than 1.5°C in both winter and summer at the end of the 21st century (2081–2100). The scenario also predicts that the 75th percentile of the average temperatures in winter and summer projected by the climate models used in this scenario could be 3°C warmer.

Changes in precipitation vary by region. The climate models used in the scenario predict that the 25th percentile of the annual precipitation will decrease in the subtropical regions in southern East Asia, while it will increase in the northern inland region. Compared to the average temperature for the period of 1986–2005, the 75th percentile of annual precipitation is likely to increase across East Asia.

Weather Forecasting

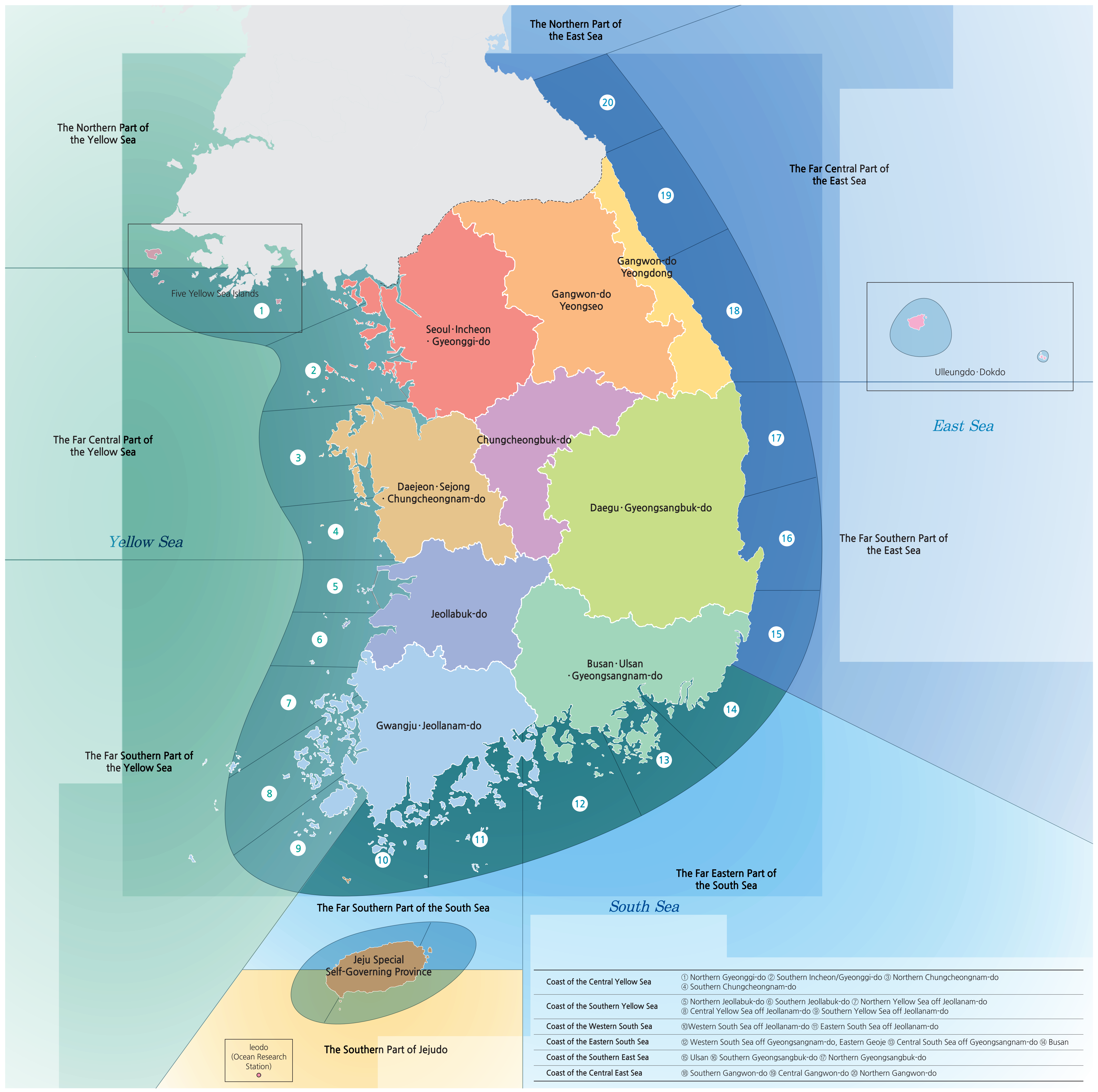
Process of Meteorological Service Weather Forecasting



Korea Meteorological Administration (2019)

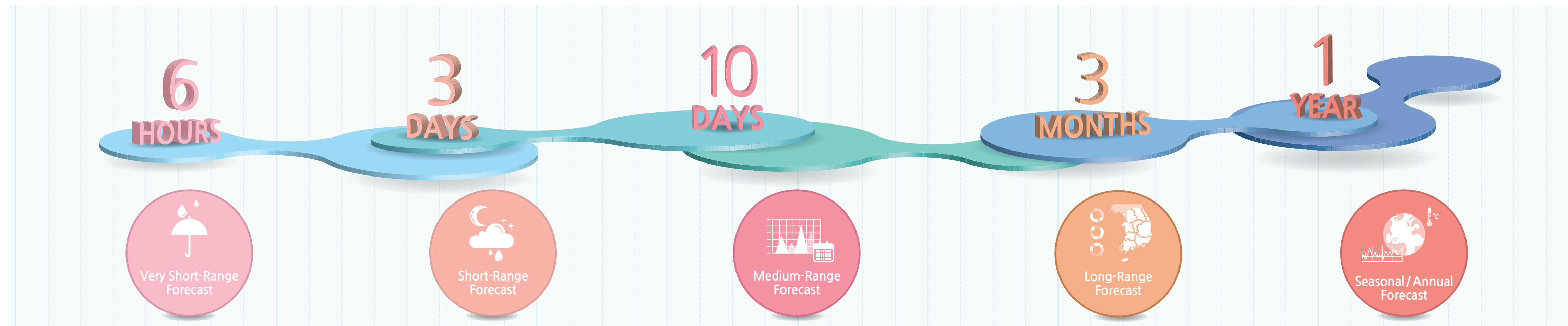
National weather data are collected in a central server of supercomputers and shared with member nations of the World Meteorological Organization (WMO) in real-time. These data are assimilated for the production of various numerical models through supercomputers. Then, trained forecasters with expertise and experience examine current atmospheric conditions based on the observations and analyze the numerical weather prediction models comprehensively. Finally, forecasters across the country consult and exchange opinions via videoconference to make a final forecast decision. The land forecast zone is divided into 12 wide-area forecast zones, 170 local forecast zones, 18 detailed special weather report zones, and neighborhood forecast zones for over 3,500 towns. The marine forecasting zone is divided into nine marine forecasting zones, which are further divided into 19 marine wide-area forecasting zones, such as the far sea and offshore. The marine local forecasting zone is divided into 25 offshore zones.

Terrestrial·Marine Weather Forecast Area Map



Coast of the Central Yellow Sea	① Northern Gyeonggi-do ② Southern Incheon/Gyeonggi-do ③ Northern Chungcheongnam-do ④ Southern Chungcheongnam-do
Coast of the Southern Yellow Sea	⑤ Northern Jeollabuk-do ⑥ Southern Jeollabuk-do ⑦ Northern Yellow Sea off Jeollanam-do ⑧ Central Yellow Sea off Jeollanam-do ⑨ Southern Yellow Sea off Jeollanam-do
Coast of the Western South Sea	⑩Western South Sea off Jeollanam-do ⑪ Eastern South Sea off Jeollanam-do
Coast of the Eastern South Sea	⑫ Western South Sea off Gyeongsangnam-do, Eastern Geoje ⑬ Central South Sea off Gyeongsangnam-do ⑭ Busan
Coast of the Southern East Sea	⑮ Ulsan ⑯ Southern Gyeongsangbuk-do ⑰ Northern Gyeongsangbuk-do
Coast of the Central East Sea	⑱ Southern Gangwon-do ⑲ Central Gangwon-do ⑳ Northern Gangwon-do

Type of Meteorological Forecasting



Reports weather elements including temperature, precipitation, and lightning for the upcoming 6 hours at 1-hour intervals. (10-minute intervals since June, 2020)

Reports 12 weather elements including temperature, precipitation, and sky conditions for the next 3 days at 3-hour intervals. (1-hour intervals since September, 2020)

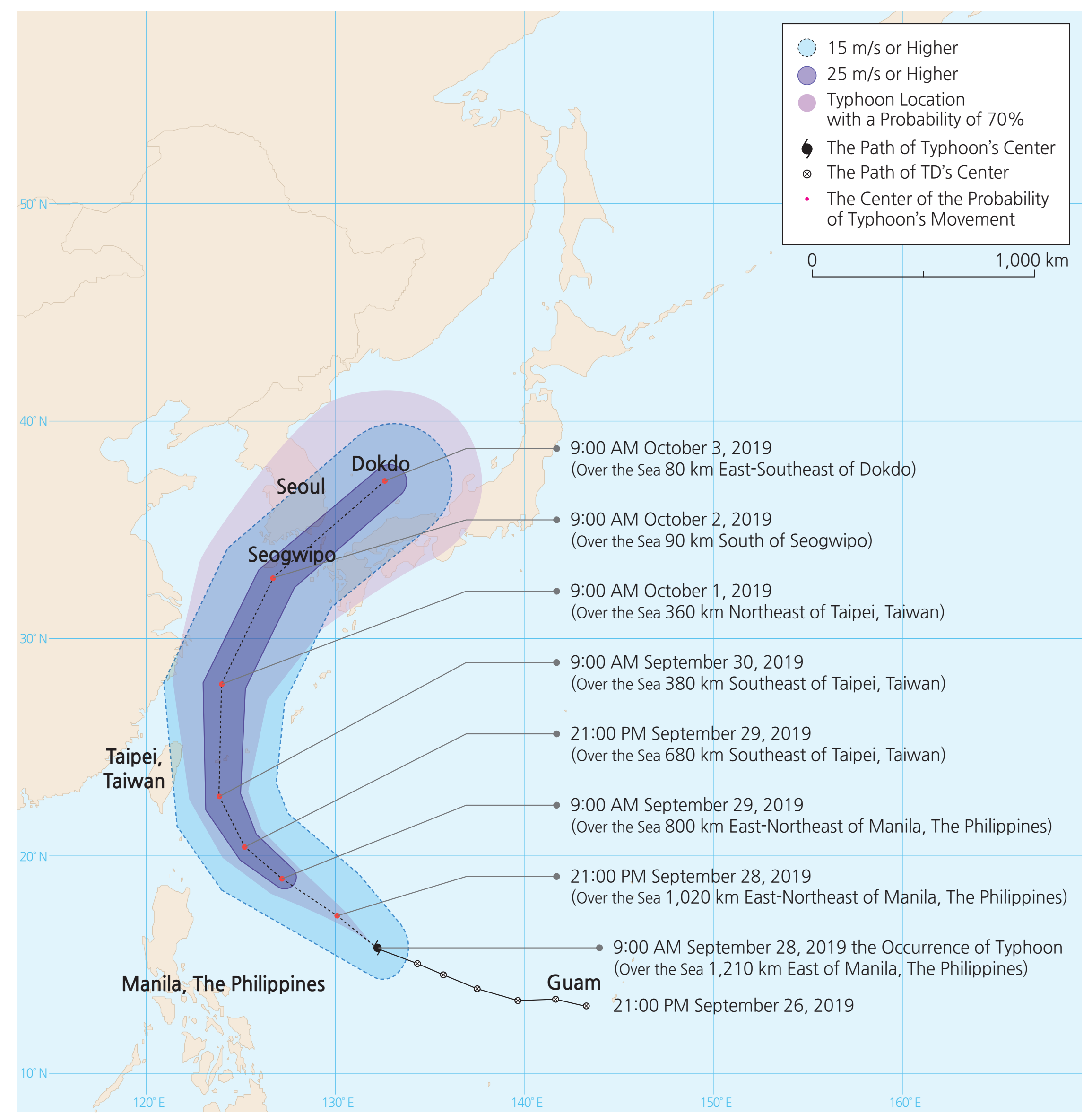
Reports weather for the next 10 days and reliability (High, Moderate, Low) 2 times a day (Morning, Afternoon).

A 1-month outlook, composed of each week's temperature and precipitation, is reported once a week, while a 3-month outlook of mean temperature and precipitation is reported every month.

Seasonal climate outlook, comprised of temperature, precipitation, El Niño/La Niña for upcoming season, is reported four times a year, while annual climate outlook is reported once a year regarding the upcoming year's outlook for temperature, precipitation, El Niño/La Niña.

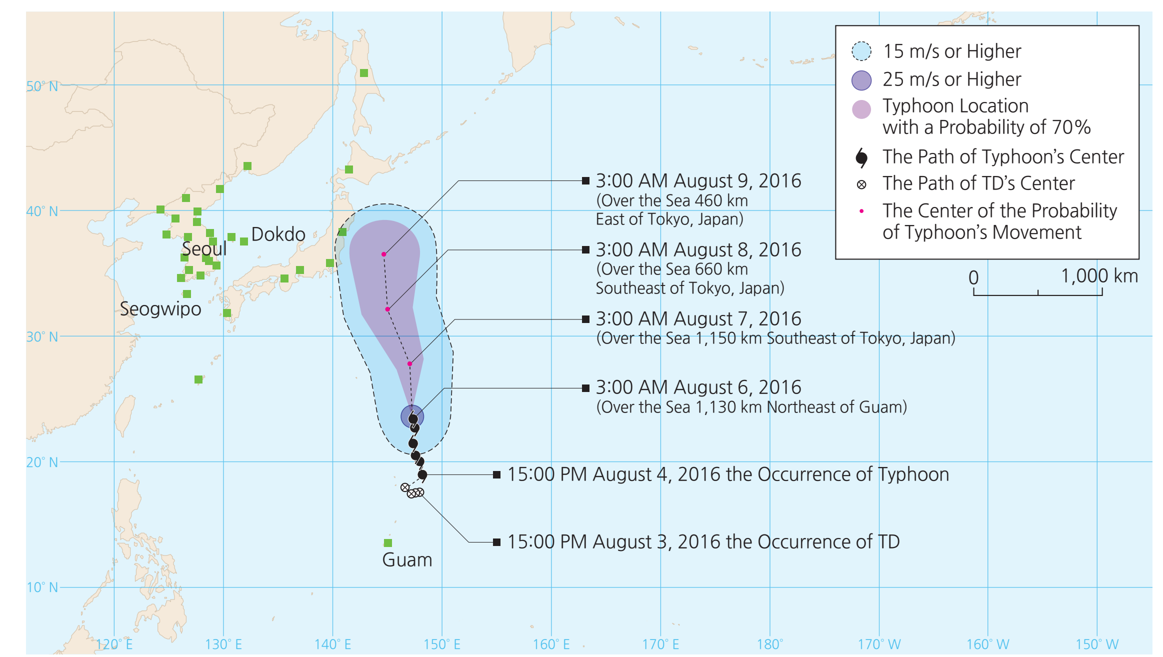
Korea Meteorological Administration (2019)

Forecast of Typoon MITAG (No. 18, 2019)



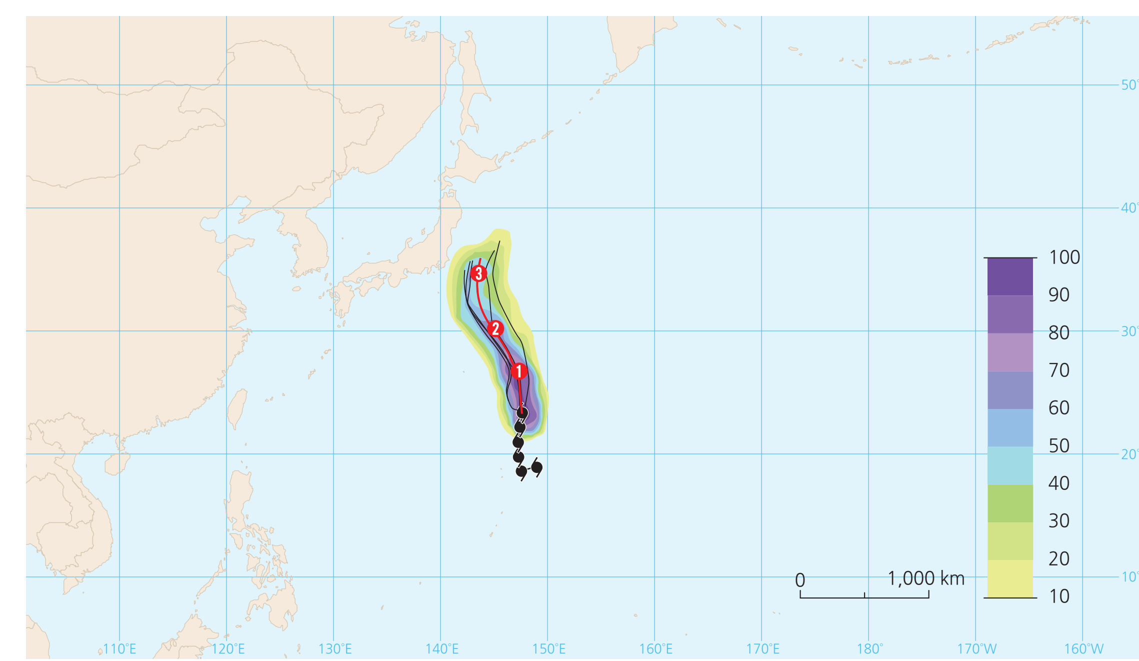
Korea Meteorological Administration (2020)

Typhoon Forecast



Korea Meteorological Administration (2016)

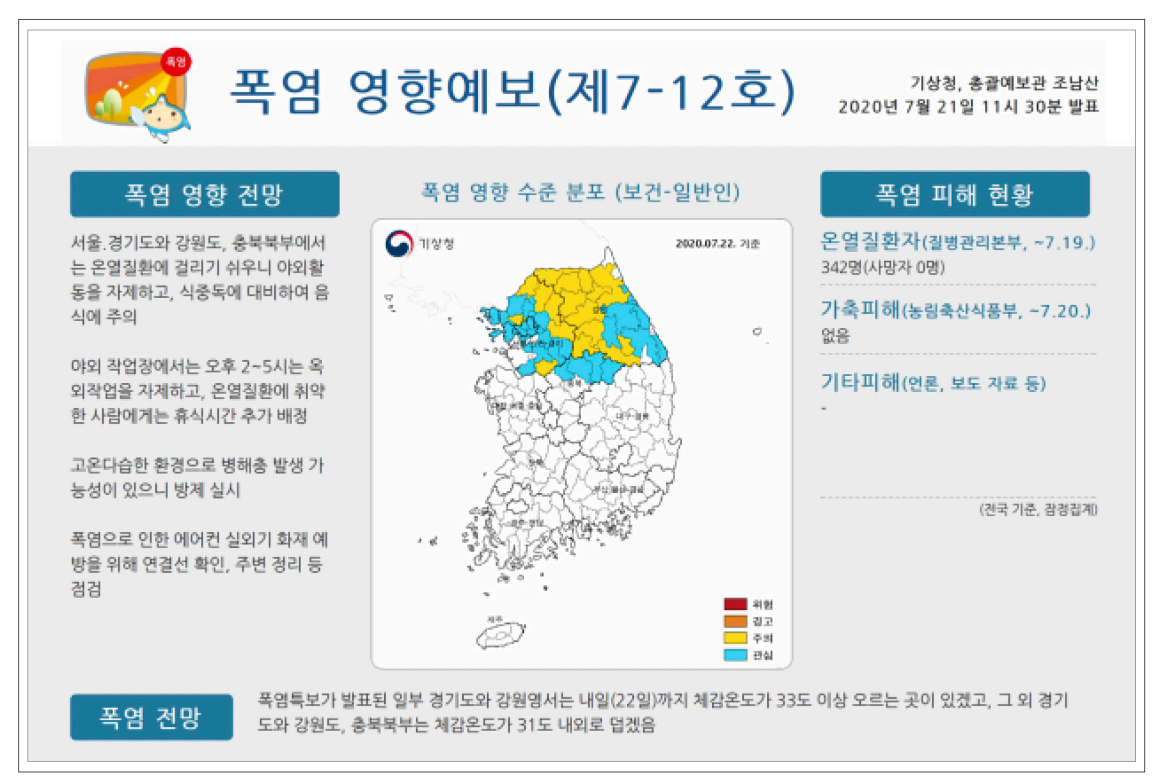
Typhoon Path Forecast



Korea Meteorological Administration (2016)

Special weather reports are issued as weather advisories for possible natural disasters. A report is issued as either a watch or a warning, depending on the risk level of the following 11 natural disasters: heavy rainfall, heavy snowfall, storm surge, tsunami, typhoon, strong winds, high seas, Asian dust, drought, cold wave, and heat wave. A preliminary weather advisory is issued ahead of a special weather report to help people prepare for meteorological disasters.

Heat Wave Impact Forecasting (July 21, 2020)



Korea Meteorological Administration (2020)

https://www.weather.go.kr

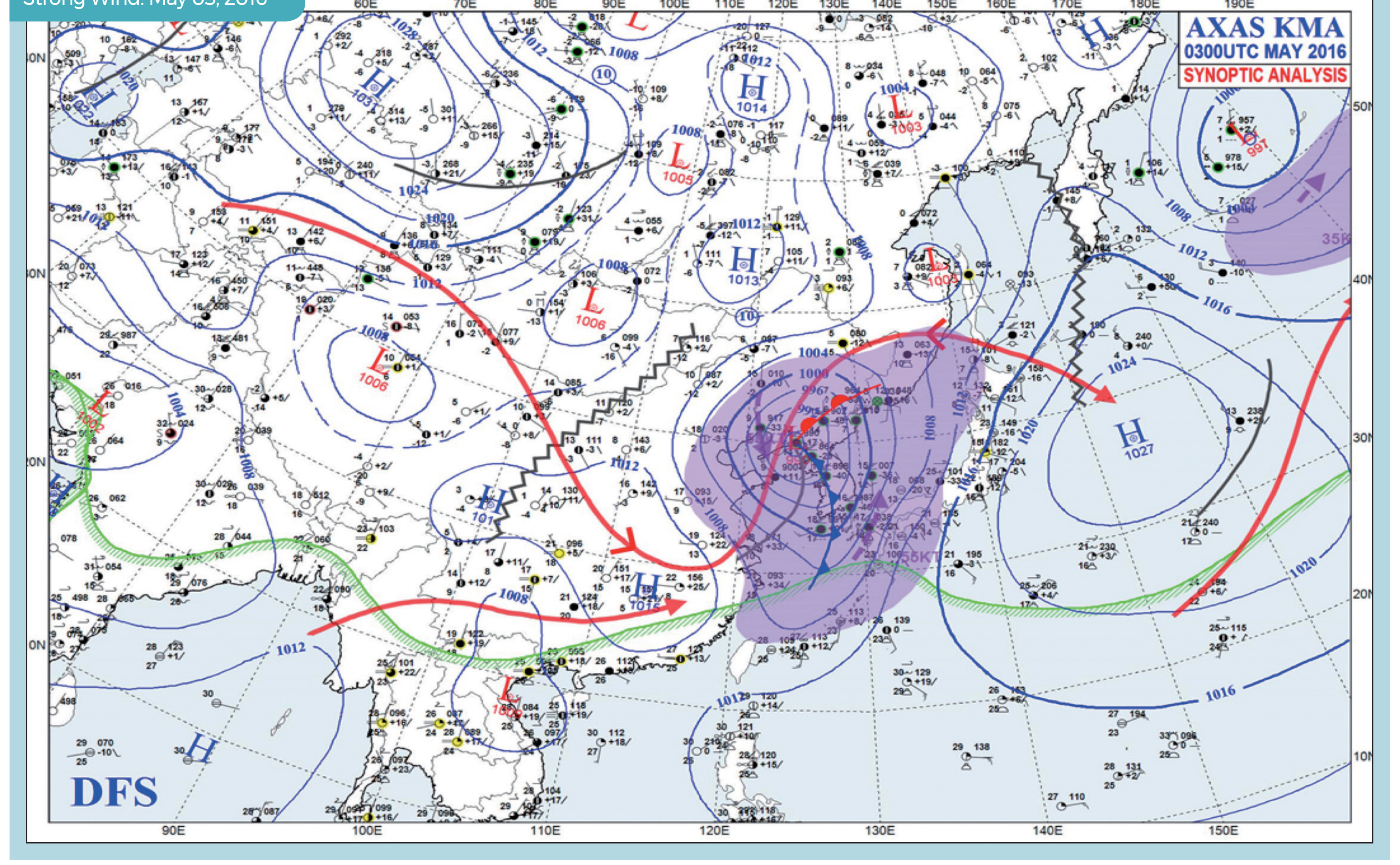
Cold Wave Impact Forecasting

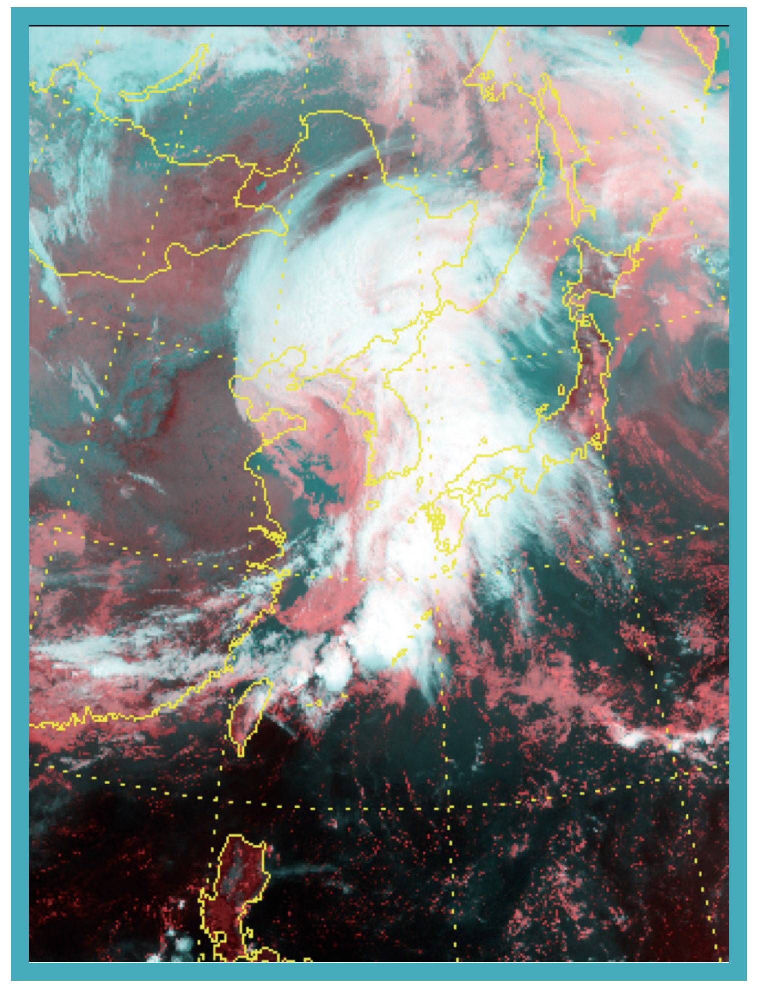
A heat wave impact forecasting system provides information on the heat waves and countermeasures by detailed field (health, industry, livestock, agriculture, aquaculture, and other) by risk level. This system supports disaster prevention work by providing practical information to reduce heat wave-related damage and aims to realize a better weather forecast service centered on the people by providing information that takes into account the social and economic impact caused by heat waves. This forecast is announced once a day (11:30 pm the day before) in specific areas (by si- and gun-units, but mountainous areas and some island areas are designated separately) when heat waves above the watch level are expected.

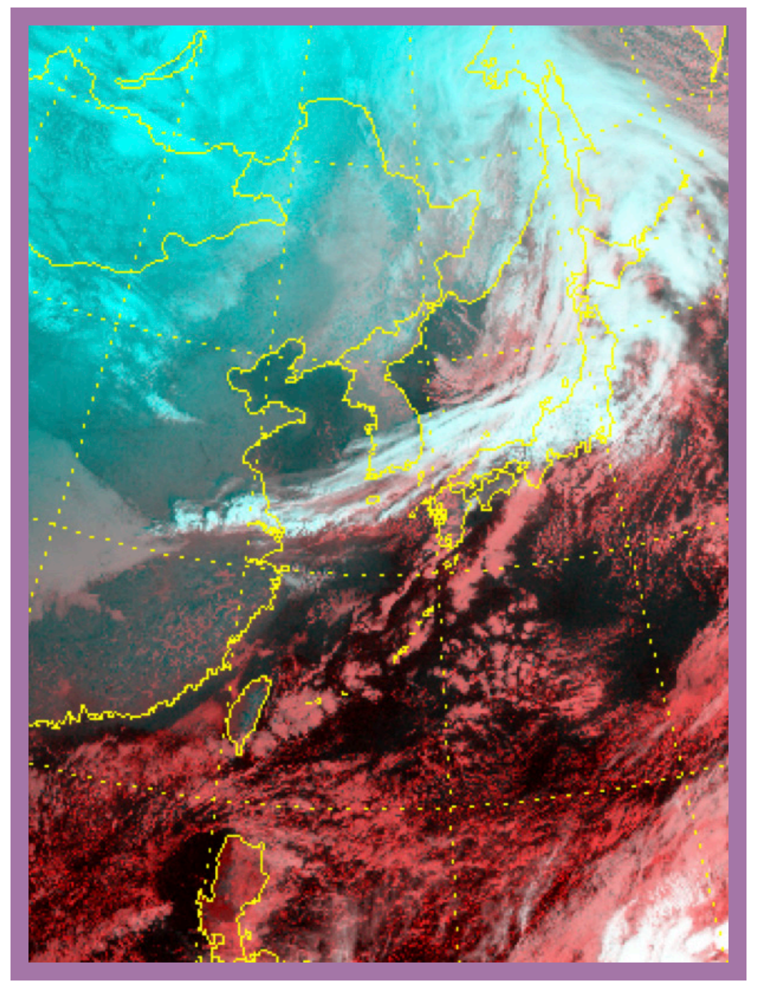
Surface Weather Chart

Surface Weather Chart and Chollian Satellite Image

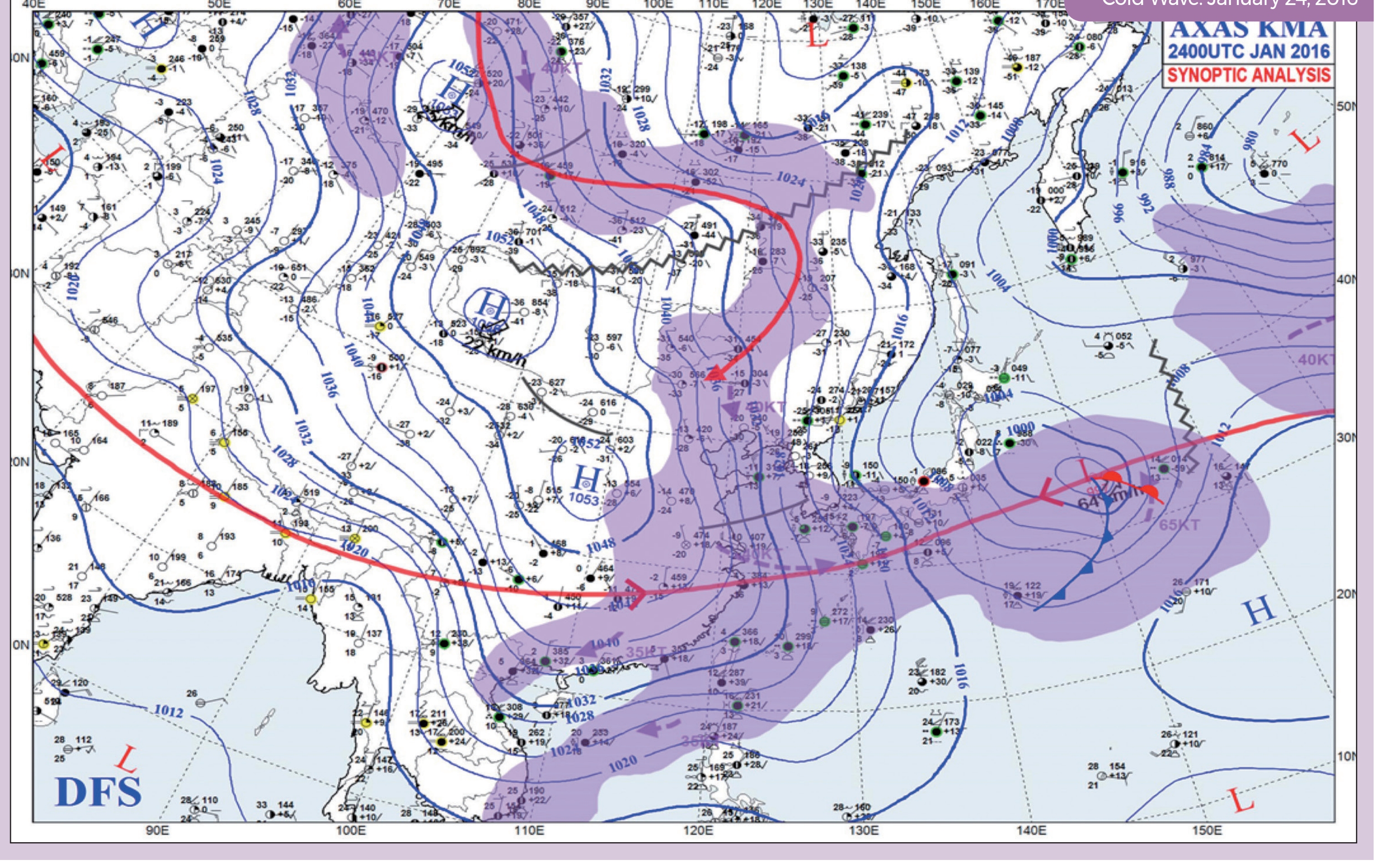
Strong Wind: May 03, 2016



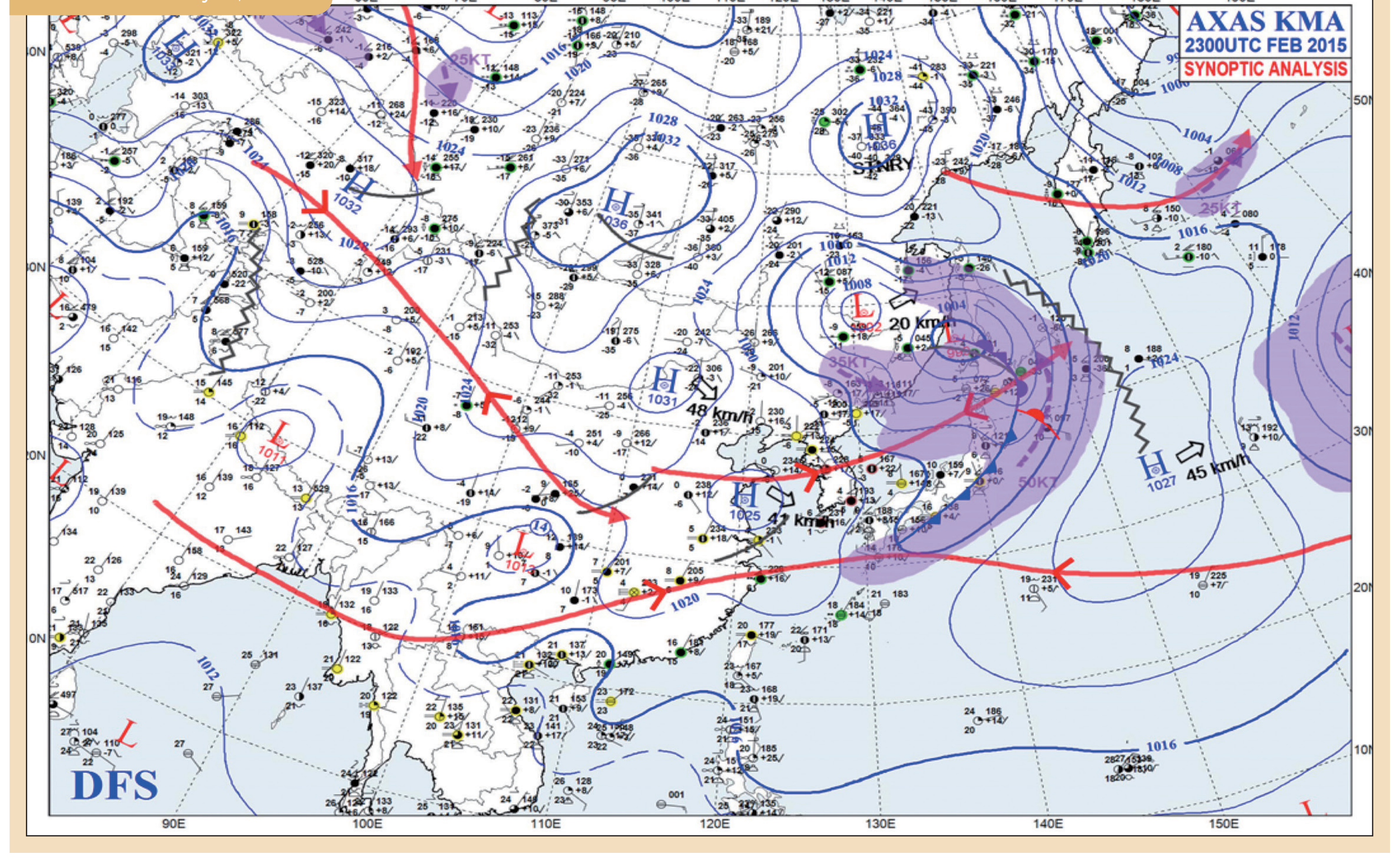


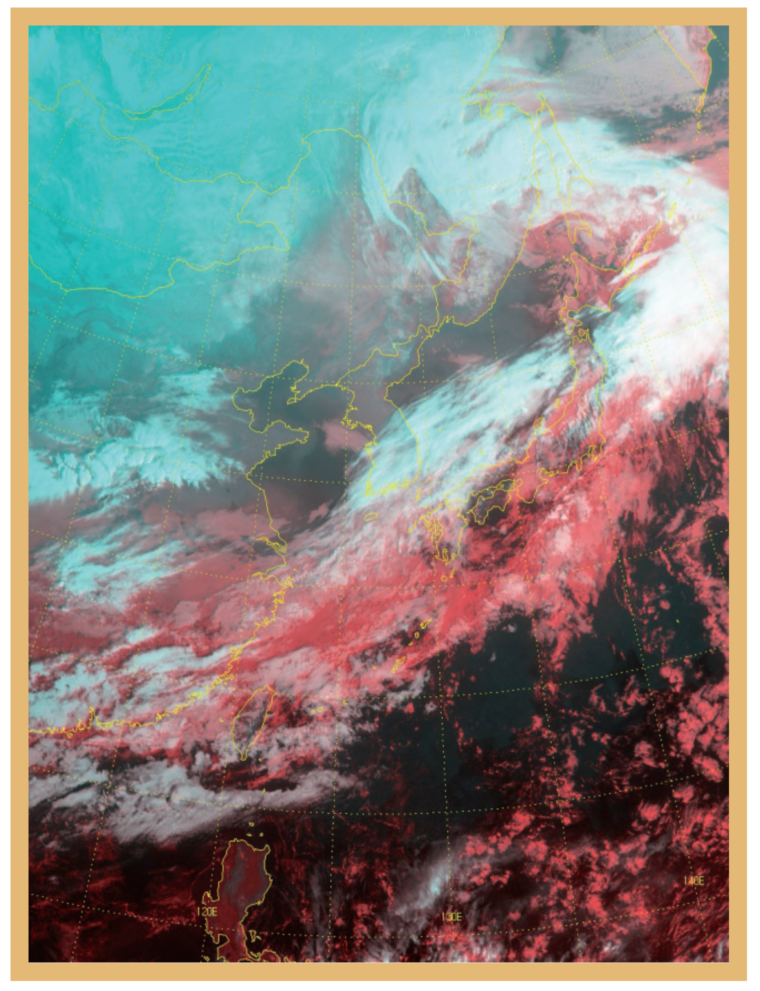


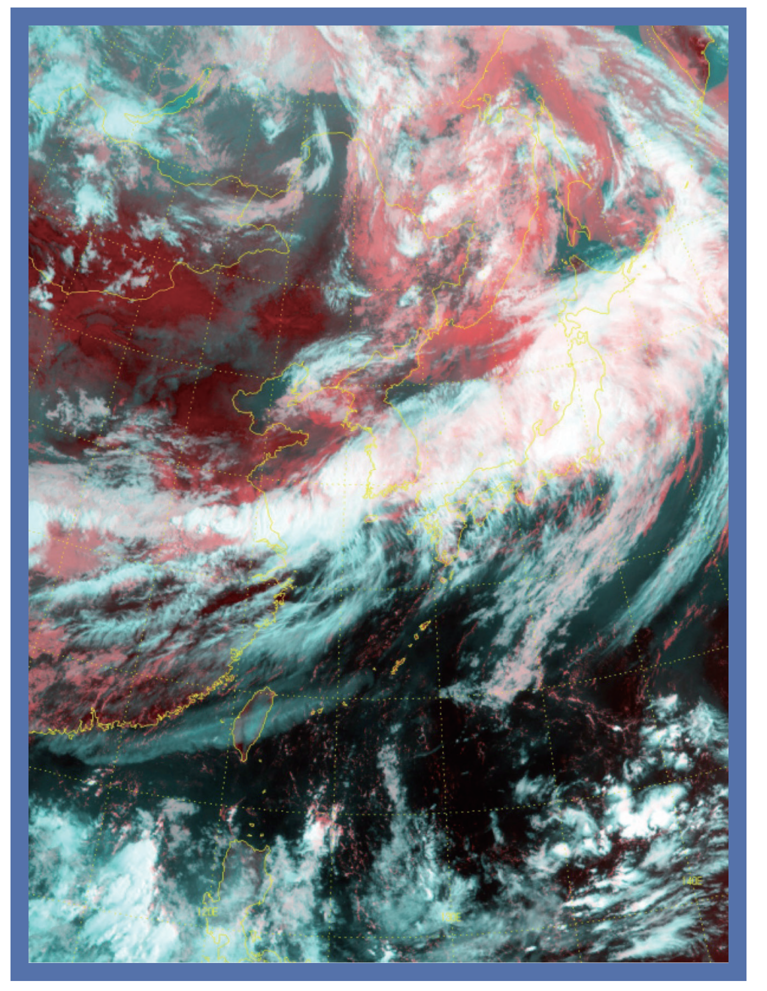
Cold Wave: January 24, 2016



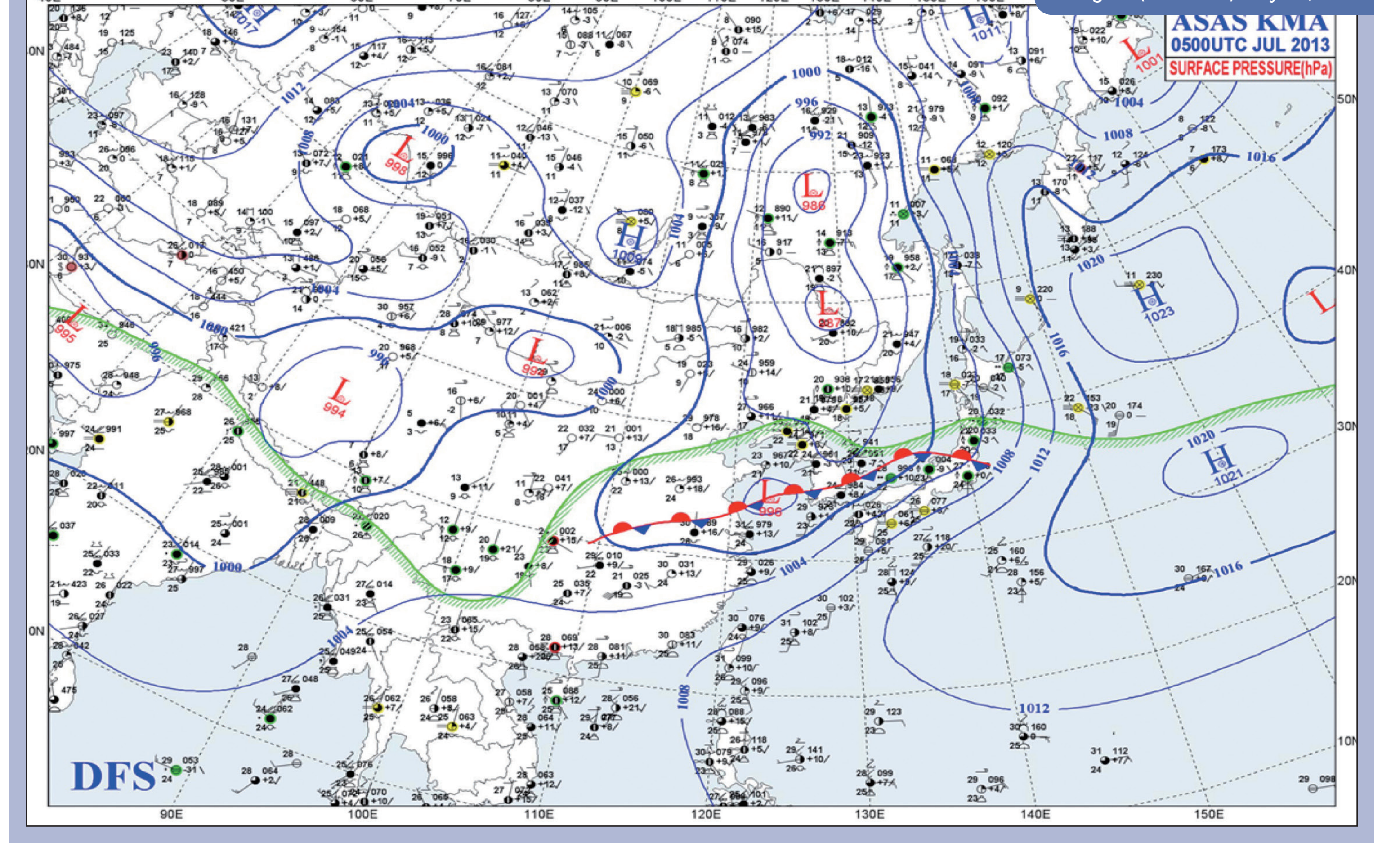
Asian Dust: February 23, 2015







Jangma (Monsoon): July 05, 2013



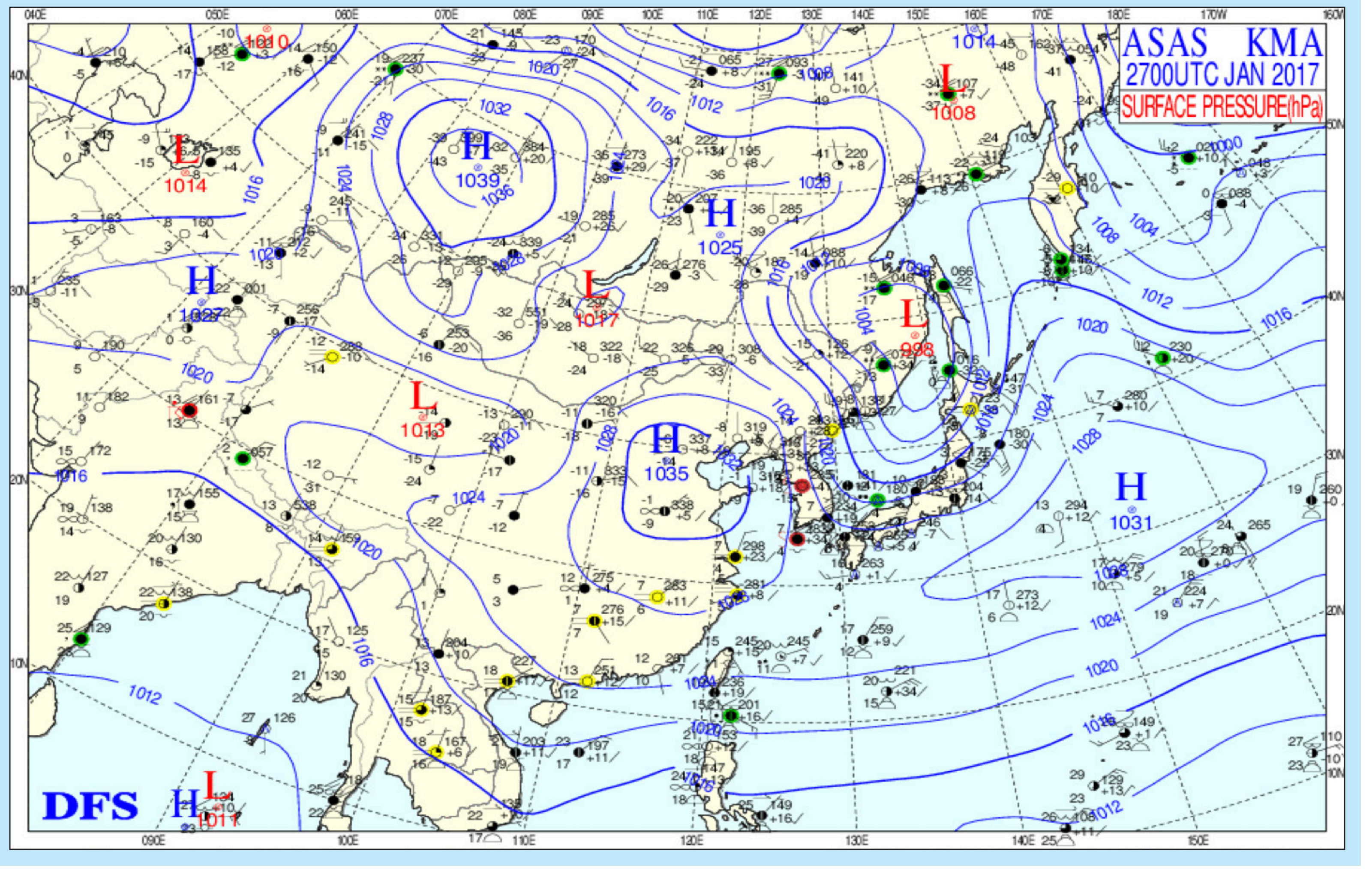
Korea Meteorological Administration (2016)

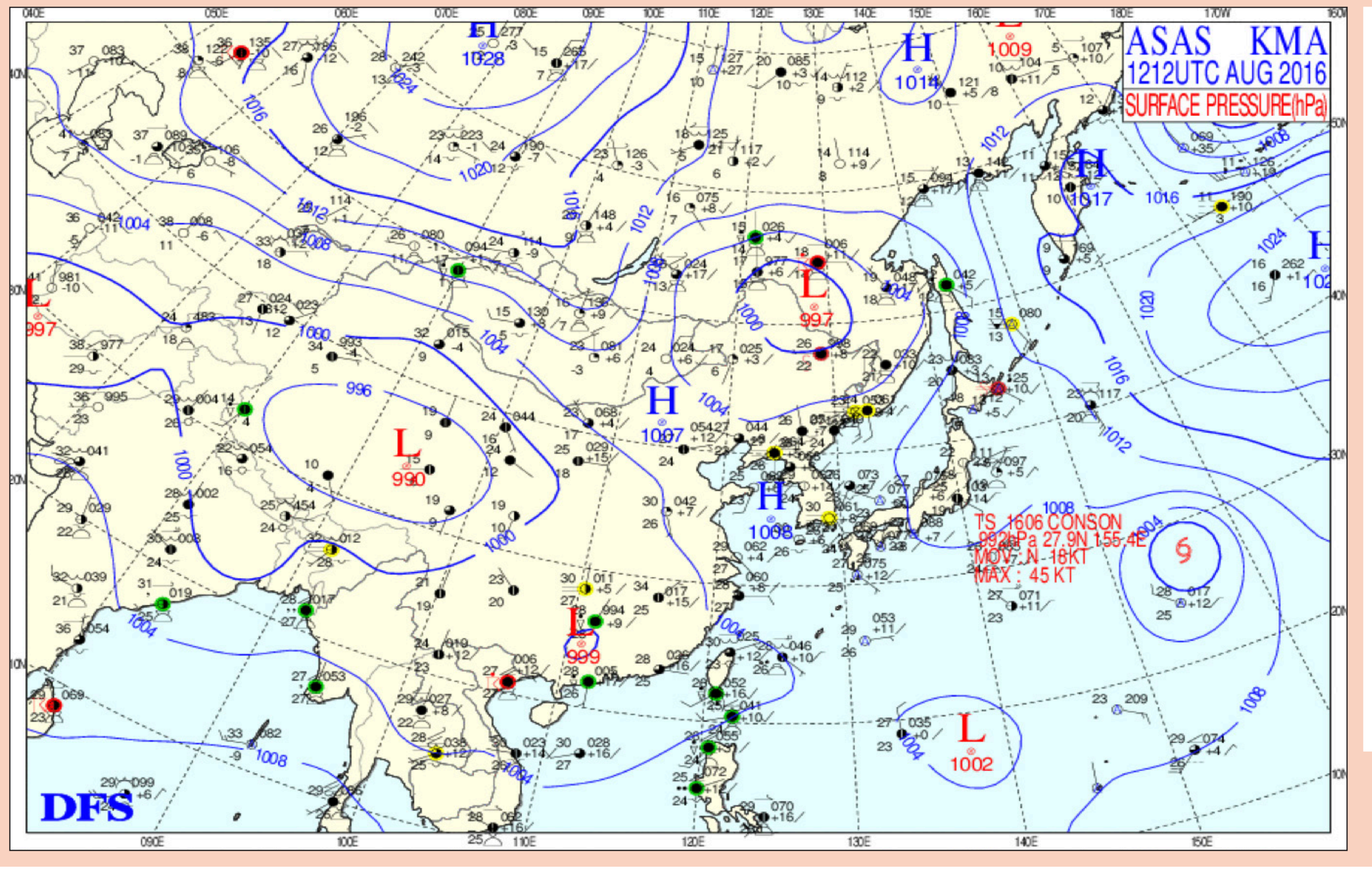
Korea Meteorological Administration (2016)

Weather Map: Cold Wave and Heat Wave

Cold Wave Weather Map
09:00 KST on January 27, 2017

The Korean Meteorological Administration produces surface weather maps. This surface weather map clearly shows the asymmetrical distribution of pressure around the Korean Peninsula, higher pressure to the west and lower pressure to the east, which is the cause of the cold wave that occurred in Korea on January 27, 2017. The cold and dry winds blowing down from the Siberian high pressure located in the northwest of the Korean Peninsula are a major cause of cold waves in Korea.





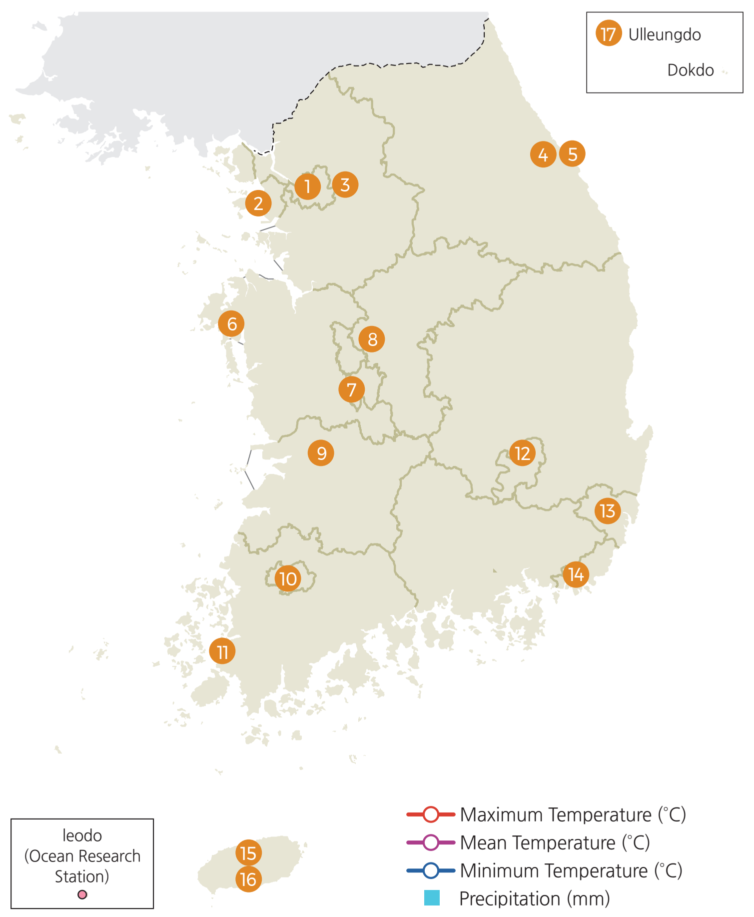
Heat Wave Weather Map
21:00 KST on August 12, 2016

This surface map shows that cyclones are located in the west and northeast of the Korean Peninsula, and Korea is affected by the stationary anticyclone placed between two cyclones. A stationary anticyclone can cause heat waves by increasing insolation.

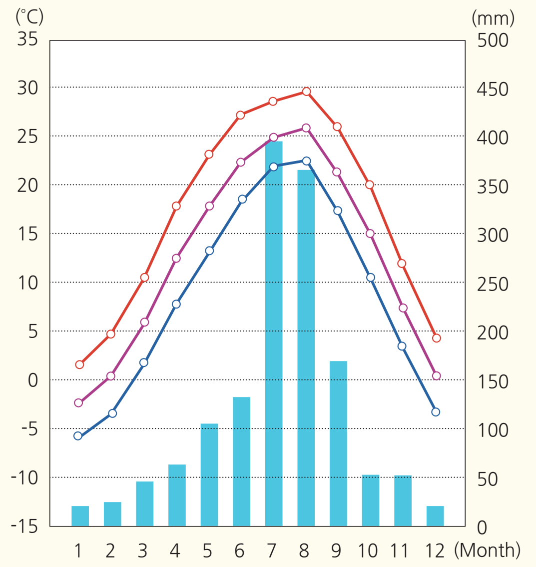
Korea Meteorological Administration (2020)

Korea Meteorological Administration (2020)

Climate of South Korea

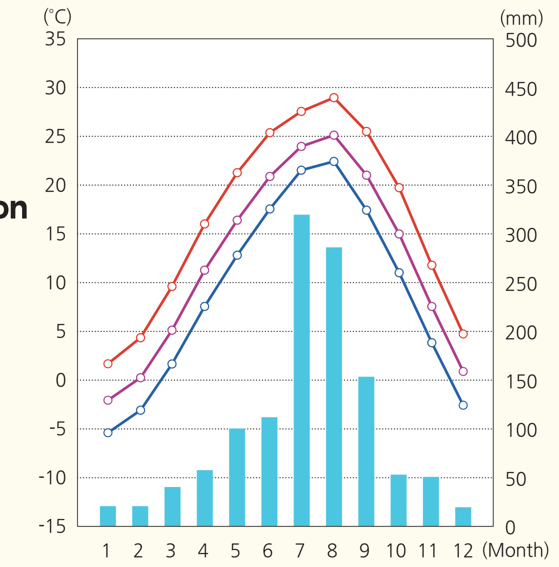


1 Seoul



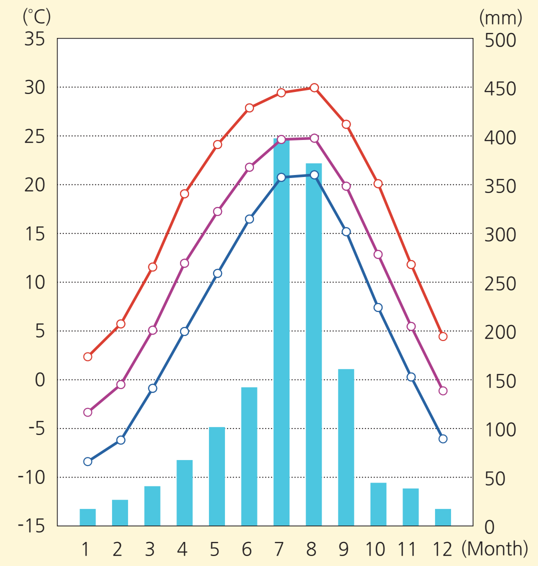
Seoul has an annual mean temperature of 12.5℃. The mean temperature of the coldest month, January, is -2.4℃, while that of the warmest month, August, is 25.7℃, creating a wide annual mean temperature range. Seoul receives 1,450.5 mm of precipitation annually. While summer precipitation (months of June, July, and August) is 892.1 mm (61% of the annual precipitation), winter precipitation (months of December, January, and February) is only 67.3 mm (5% of the annual precipitation).

2 Incheon



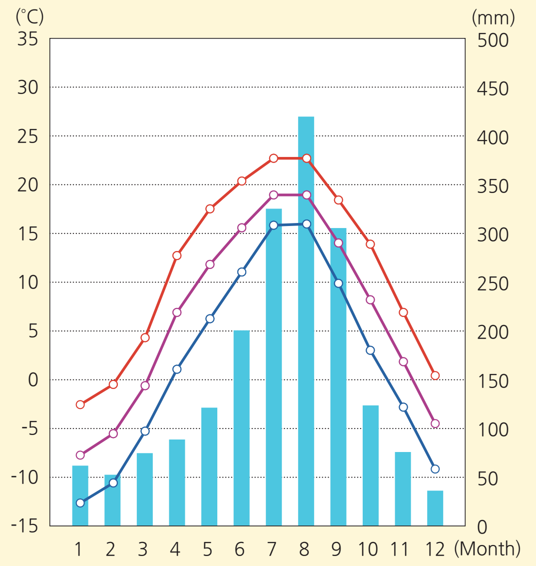
Incheon has an annual mean temperature of 12.1℃. Mean temperatures in January and August are -2.1℃ and 25.2℃, respectively, making a large annual mean temperature range of 27.3℃. Incheon receives relatively low precipitation (1,234.4 mm) annually. Incheon receives more precipitation in July than in August, epitomizing the monthly precipitation patterns of Korea. Summer precipitation (months of June, July, and August) is 717.4 mm, accounting for about 58% of the annual precipitation.

3 Yang-pyeong



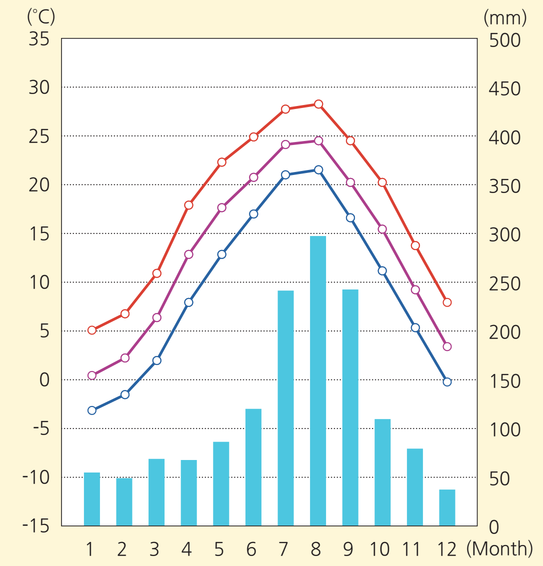
Yangpyeong has a larger annual mean temperature range (28.1℃) because it is geographically located in a basin. The minimum temperature in winter drops as low as -8.5℃. The annual mean temperature is 11.5℃, which is lower than that of cities located at similar latitudes, such as Incheon and Seoul. The average temperature in January is -3.4℃ and that in August is 24.7℃. Yangpyeong has an annual precipitation of 1,438.2 mm. Precipitation from June to August makes up 64% of the total amount, whereas that from December to February only accounts for 4%.

4 Daegwal-lyeong



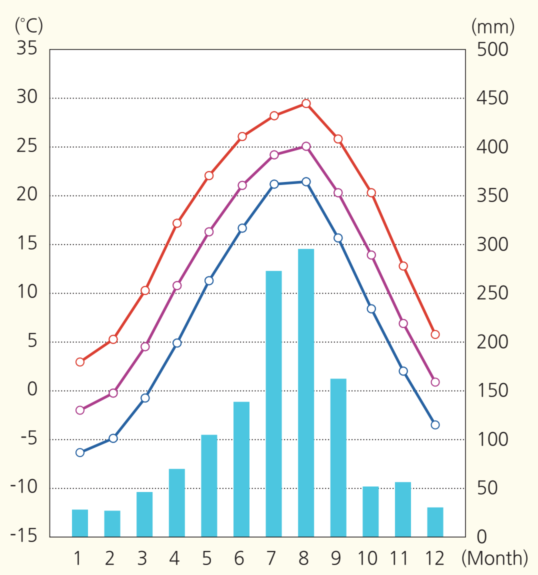
Daegwallyeong has the highest located weather station in Korea with an elevation of 773 m. Due to the elevation, the annual mean temperature (6.6℃) is the lowest in Korea. Daegwallyeong also has the lowest monthly mean temperatures in January (-7.7℃) and August (19.1℃). There's no single month in the year with an average temperature higher than 20℃. Daegwallyeong receives the highest annual precipitation (1,898.0 mm) due to the effect of the Taebaeksanmaek. Daegwallyeong has an August precipitation of 420.9 mm on average, which is 326.7 mm more than its average July precipitation.

5 Gang-neung



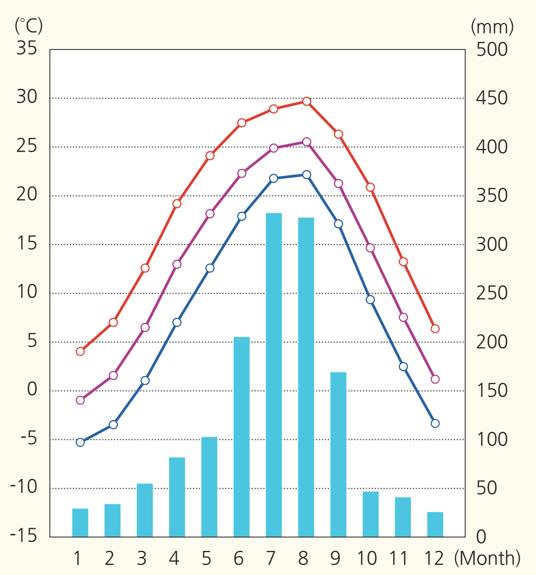
Since Gangneung is located on the eastern coast, its climate is largely influenced by the ocean. It has an annual mean temperature of 13.1℃, which is high, considering its latitude. Gangneung shows milder temperatures than the western coastal regions at the same latitude because of the effects of the Taebaeksanmaek blocking the northwesterly in winter, and the warm current flowing in the East Sea. Gangneung has an annual precipitation of 1,464.5 mm with relatively heavy precipitation in winter and spring. The city receives more precipitation in August (298.9 mm) than in July. It receives its lowest monthly precipitation (38.3 mm) in December.

6 Seosan



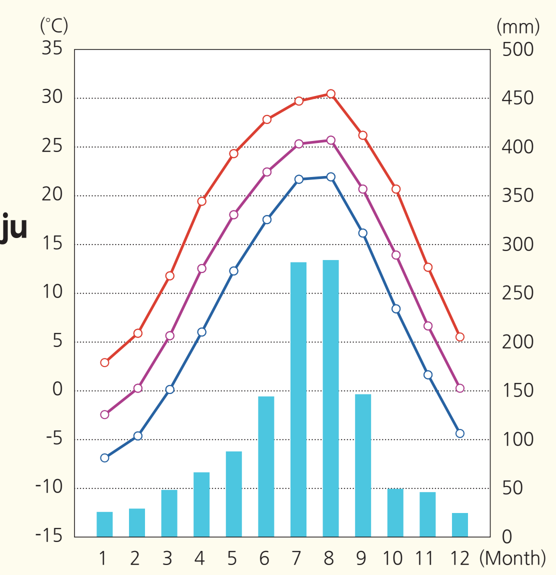
Since Seosan is located on the western coast of Korea, its climate is influenced by the ocean. It has an annual mean temperature of 11.9℃. Mean temperatures in January and August are -2.0℃ and 25.1℃, respectively, making Seosan's annual mean temperature range 27.1℃. Annual precipitation in Seosan is 1,285.7 mm; 55% of it falls in summer (mostly in August; 295.9 mm), while only 17%, 21%, and 17% of it fall in spring, autumn, and winter, respectively.

7 Daejeon



Because of its geographical location inland, Daejeon is characterized by a continental climate. Annual mean temperature in Daejeon is 13.0℃. The August mean temperature is 25.6℃, while January mean temperature is -1.0℃, having an annual mean temperature range of 26.6℃. While the highest monthly temperature (29.8℃) in Daejeon is similar to that of surrounding regions, its lowest monthly temperature (-5.4℃) is 2-4℃ higher than its surroundings. Daejeon has an annual precipitation of 1,458.7 mm with about 60% of it falling in summer. Spring, autumn, and winter precipitation make up only 16%, 18%, and 6% of the annual precipitation, respectively.

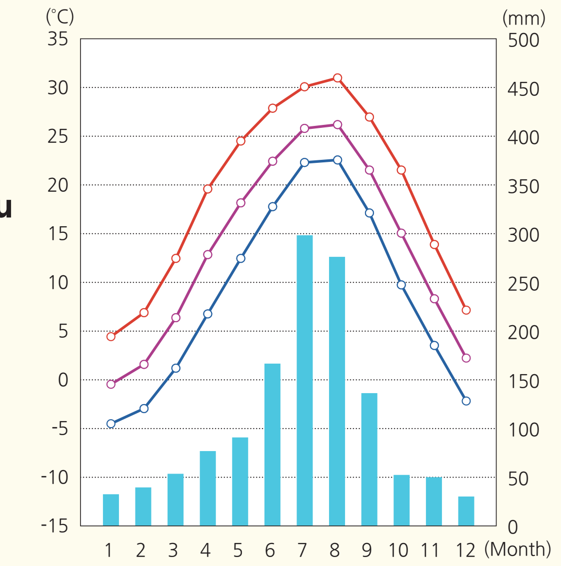
8 Cheongju



Cheongju, located in the central inland region of Korea, is characterized by a continental climate. Cheongju has an annual mean temperature of 12.5℃ with a wide annual mean temperature range (28.2℃). This is because of the big difference in average temperature between the coldest month, January (-2.4℃), and the warmest month, August (25.8℃). Cheongju has an annual precipitation of 1,239.7 mm. Cheongju receives 58% of its annual precipitation in summer, while it receives 16% of its precipitation in spring, 20% in autumn, and 6% in winter.

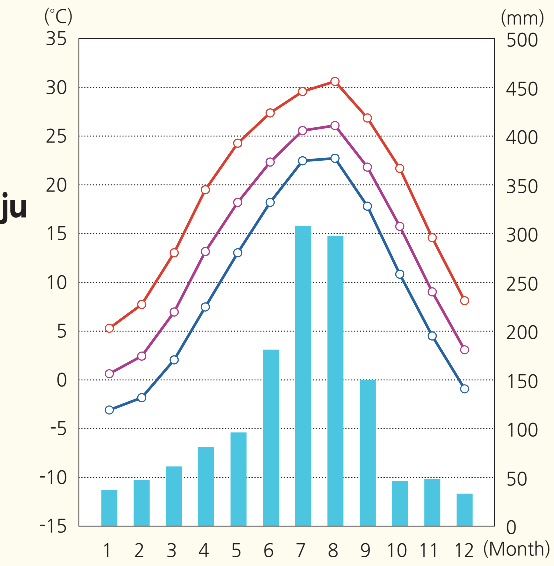
Korea Meteorological Administration (2011)

9 Jeonju



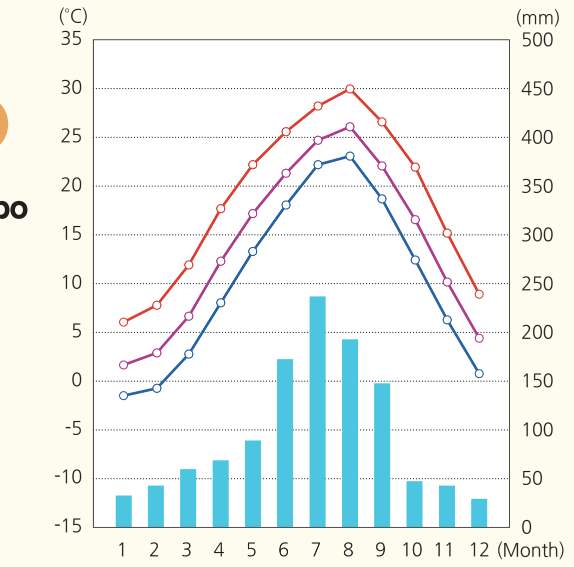
Jeonju, an inland city, shows an annual mean temperature of 13.3℃, with the highest August mean temperature (26.2℃) in the Honam area along with Jeongeup. Jeonju has a January average temperature of -0.5℃ and annual temperature range of 26.7℃. Annual precipitation for Jeonju is 1,313.1 mm. Summer precipitation makes up 57% of the annual total, whereas spring, autumn, and winter precipitation make up 17%, 18%, and 8%, respectively.

10 Gwangju



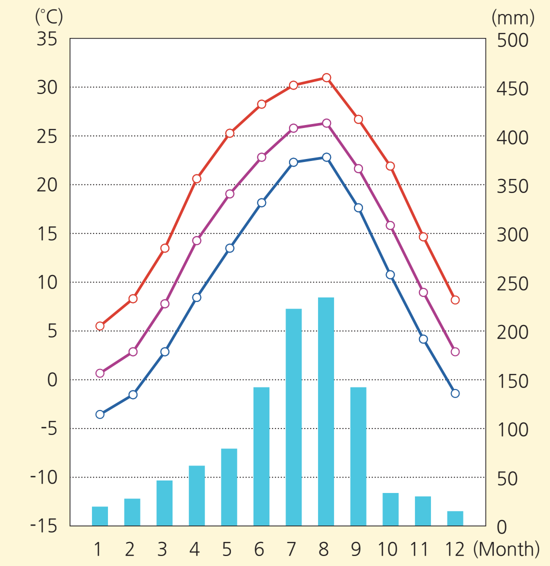
Gwangju, a southern inland city, has an annual mean temperature of 13.8℃. Its August average temperature is 26.6℃ and its January average temperature is 0.6℃, resulting in an annual mean temperature range of 25.6℃. Gwangju is characterized by a continental climate with an annual temperature range that is larger than the surrounding regions (Mokpo, Goheung, and Haenam). Annual precipitation in Gwangju is 1,391.0 mm. While about 57% of the annual precipitation falls in summer, only 17%, 18%, and 8% fall in spring, autumn, and winter, respectively.

11 Mokpo



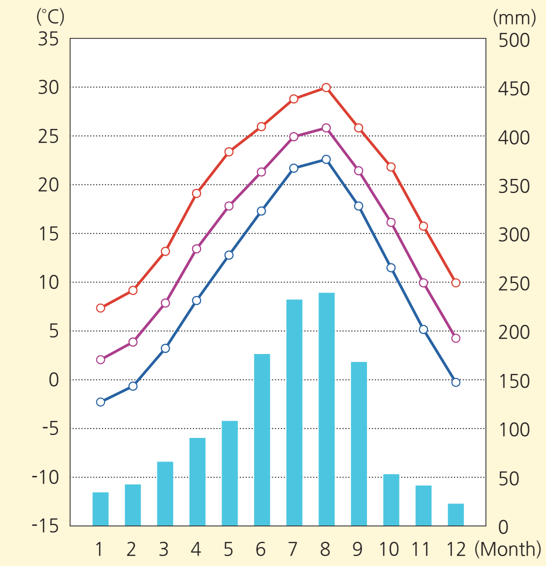
Mokpo has a relatively high annual mean temperature of 13.9℃. Due to the ocean effect, the January mean temperature is 1.7℃ and there is no month with a mean temperature below zero. The August mean temperature is 26.1℃ and the annual mean temperature range is 24.4℃. Mokpo receives low annual precipitation (1,163.6 mm) relative to the rest of Korea, and more precipitation falls in July than in August. Summer precipitation accounts for about 52%, whereas spring, autumn, and winter precipitation account for 19%, 20% and 9%, respectively.

12 Daegu



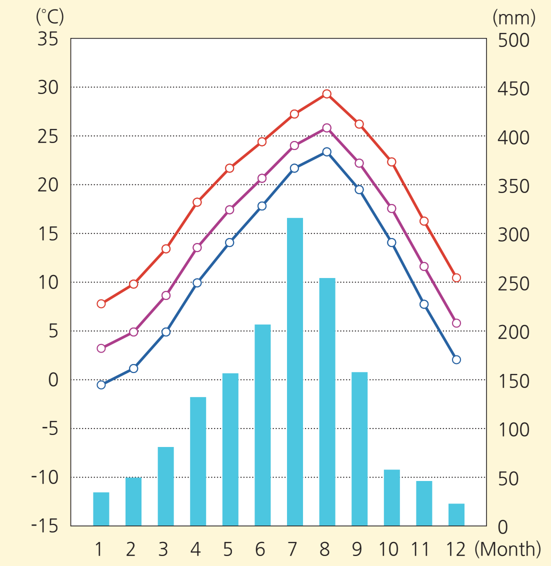
Daegu, a southeastern inland city, has a January mean temperature of 0.6℃ and an August mean temperature of 26.4℃, resulting in an annual mean temperature range of 25.8℃. Daegu (31.0℃) has one of the highest August mean temperatures, along with Jeongeup, Miryang, and Jeonju, since an air current passes through the Taebaek and Sobaek Mountains and blows into the basin as dry air. Owing to its location on the leeward side, Daegu receives the fourth least amount of precipitation (1,064.4 mm) after Baengnyeongdo, Uiseong, and Yeongcheon.

13 Ulsan



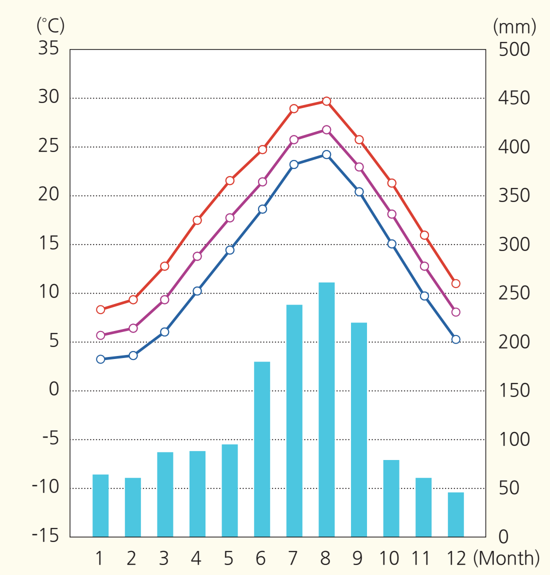
Ulsan, located on the southeastern coast, has an annual mean temperature of 14.1℃ and an annual mean temperature range of 23.9℃. The range is smaller than that for regions located at the same latitude owing to the influence of the adjoining ocean. Ulsan has an annual precipitation of 1,277.1 mm. The average amounts in July (232.3 mm) and August (240.3 mm) are similar due to the effects of typhoons.

14 Busan



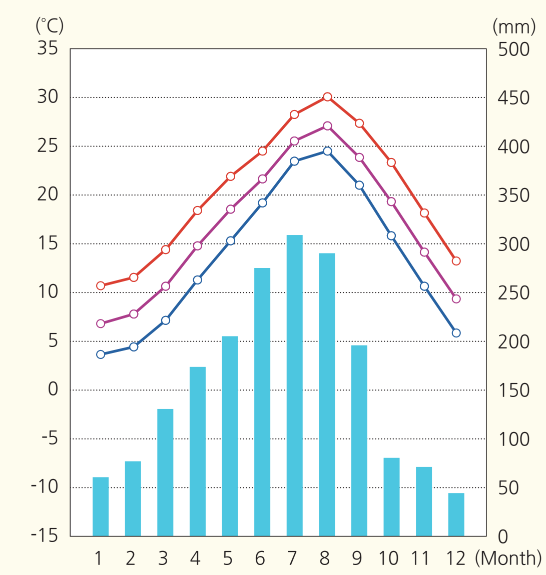
Busan, a low-latitude coastal city, has a high annual mean temperature (14.7℃) and a small annual mean temperature range (22.7℃). The city experiences relatively mild winters compared to the rest of the Korean Peninsula. For example, Gwangju, located at the same latitude, has a January mean temperature 2.6℃ lower than Busan. Annual precipitation (1,519.1 mm) in Busan is high. Rainfall amount from March to May totals 370.8 mm, which is the sixth largest amount after Geoje, Seogwipo, Seongsan, Namhae, and Tongyeong.

15 Jeju



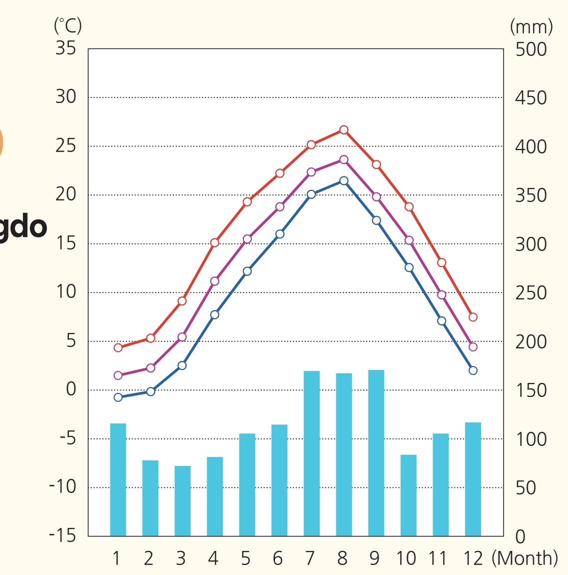
Jeju has the second highest annual mean temperature (15.8℃), with a relatively small annual mean temperature range of 21.1℃. Also, Jeju is warm throughout the year because its monthly average temperature is no lower than 5℃. Jeju has an annual precipitation of 1,497.6 mm. While summer precipitation makes up 46% of the total amount, spring, autumn, and winter precipitation account for 18%, 24%, and 12%, respectively.

16 Seo-gwipo



Seogwipo has the highest annual mean temperature (16.6℃) in Korea. The annual mean temperature range in Seogwipo is only 20.3℃. Seogwipo remains warm throughout the year because monthly mean temperatures are above 5℃. Annual precipitation in Seogwipo is 1,923.0 mm, the third highest after Geoje (2,007.3 mm) and Seongsan (1,966.8 mm). Seogwipo receives 46% of its annual precipitation in summer, while it receives 27% of its precipitation in spring, 18% in autumn, and 9% in winter.

17 Ulleungdo

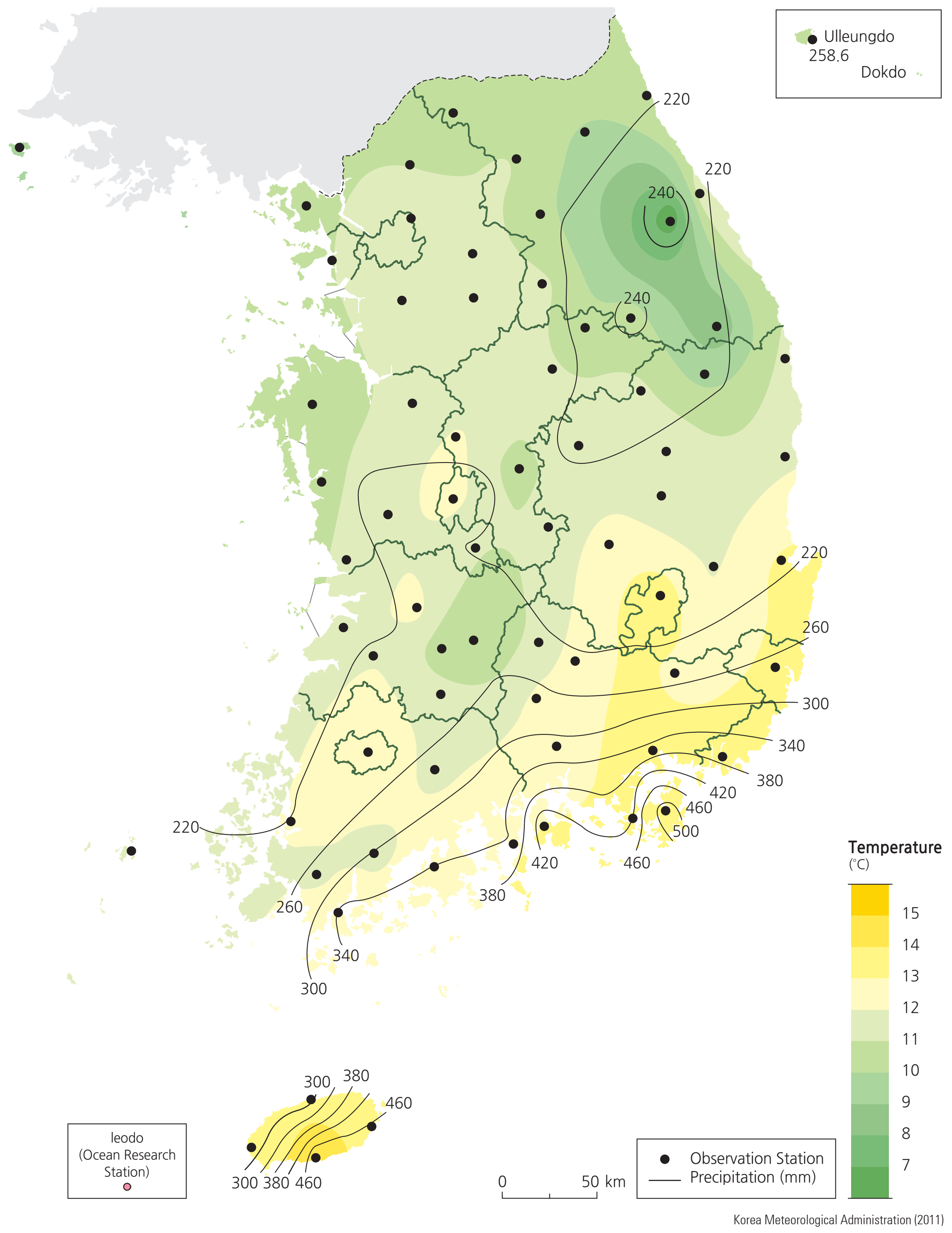


Ulleungdo is largely affected by the East Korea Warm Current. Monthly mean temperatures in January and August are 1.4℃ and 23.6℃, respectively, resulting in a small annual mean temperature range of 22.2℃. Also, Ulleungdo is characterized by a relatively mild climate compared to regions at the same latitude, such as Seoul and Incheon. Ulleungdo has an annual precipitation of 1,383.4 mm. It is a region of abundant snowfall during winter, which accounts for 22% of its annual precipitation. There is no big difference in the mean annual total for each season: spring (19%), summer (33%), autumn (26%), and winter (22%).

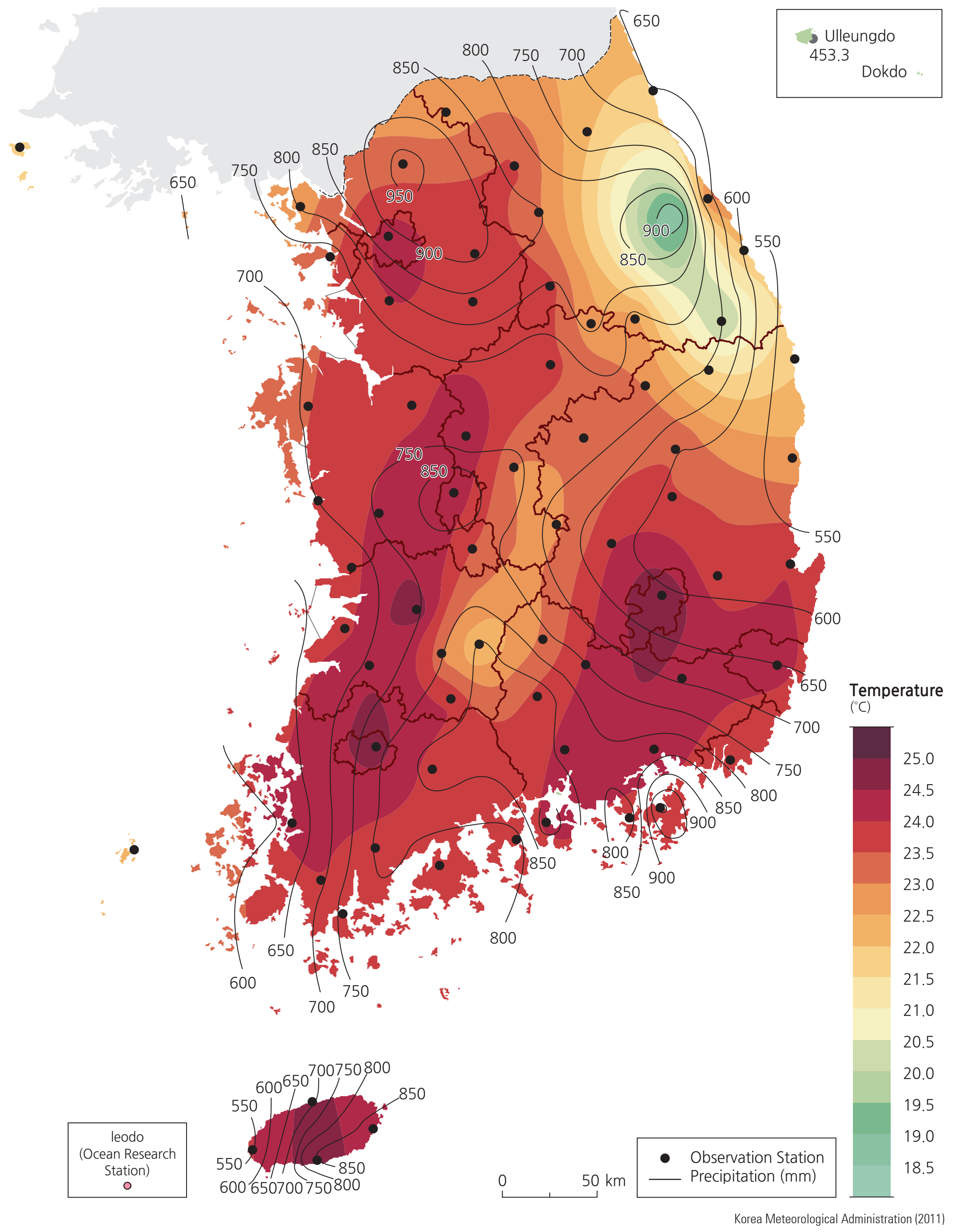
Korea Meteorological Administration (2011)

Climate Elements and Number of Days with Weather Phenomena

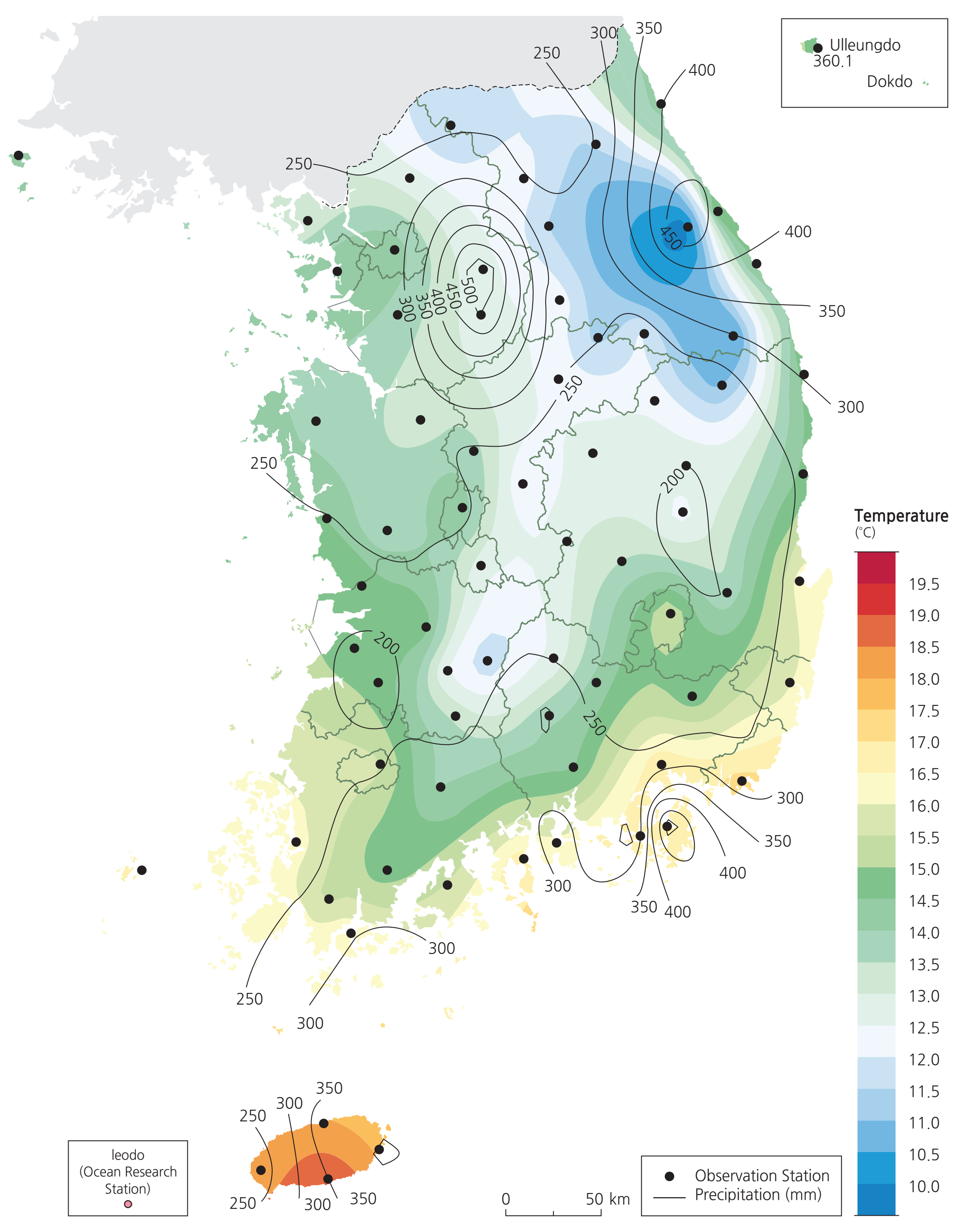
Spring Mean Temperature and Precipitation (1981–2010)



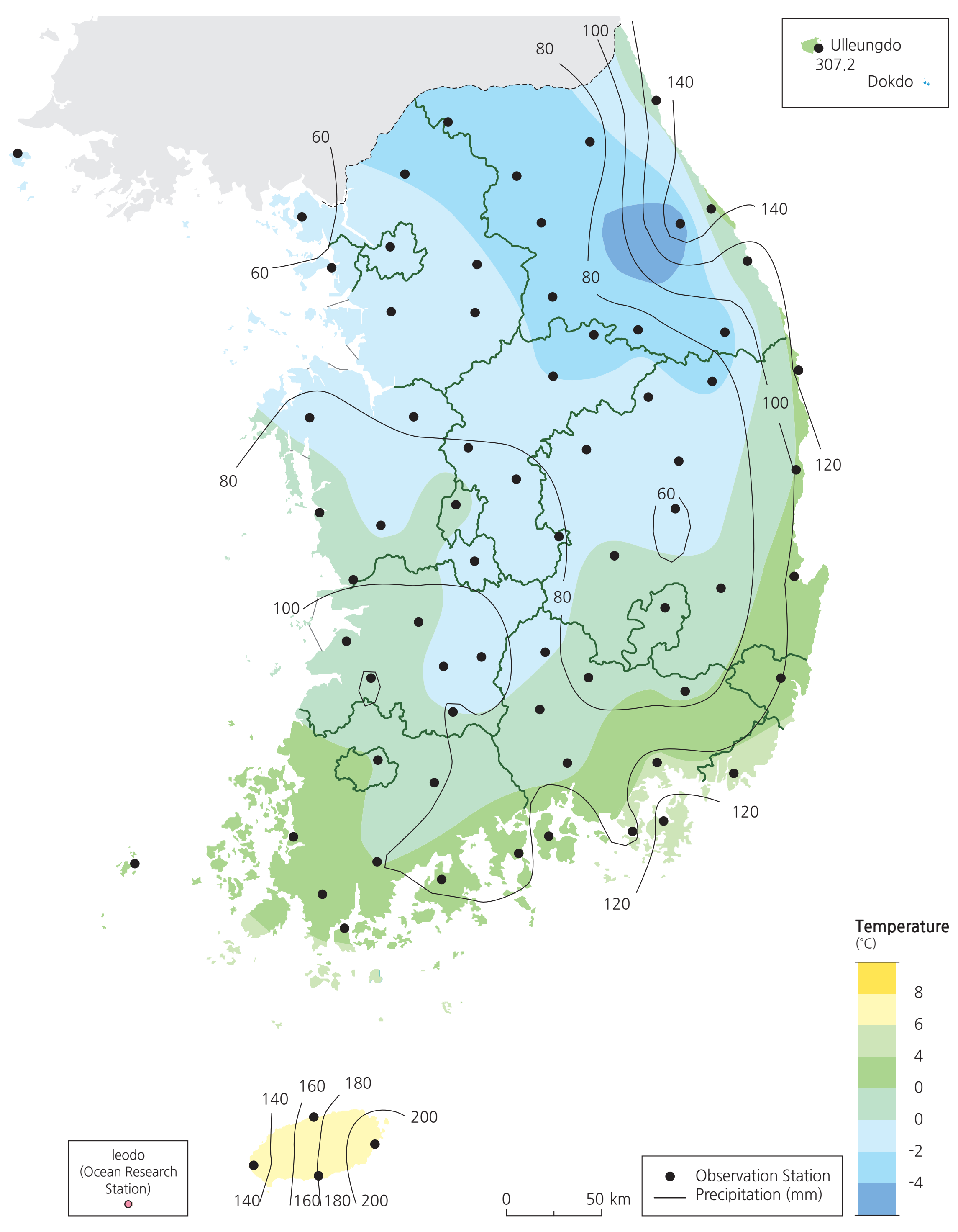
Summer Mean Temperature and Precipitation (1981–2010)



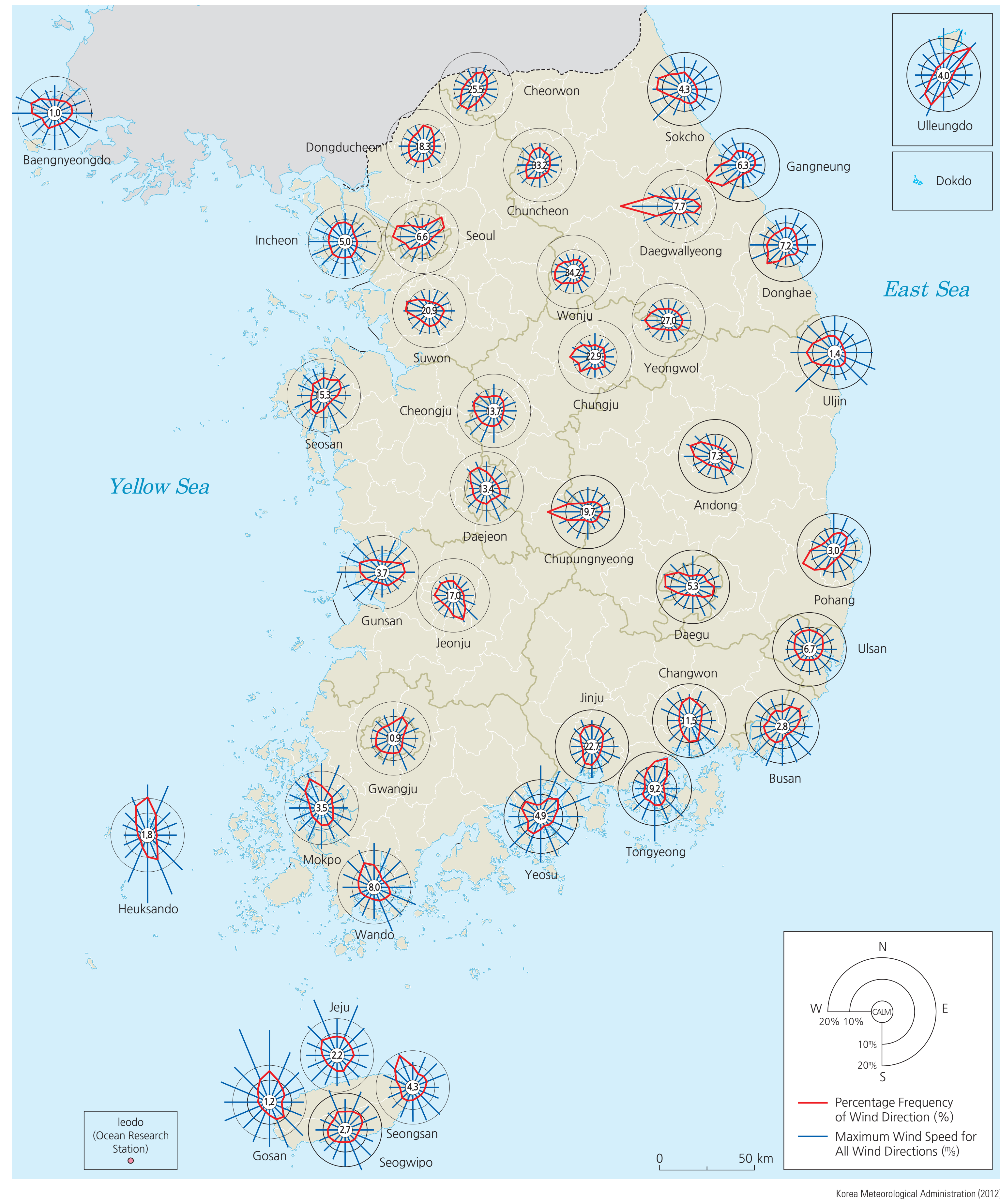
Autumn Mean Temperature and Precipitation (1981–2010)



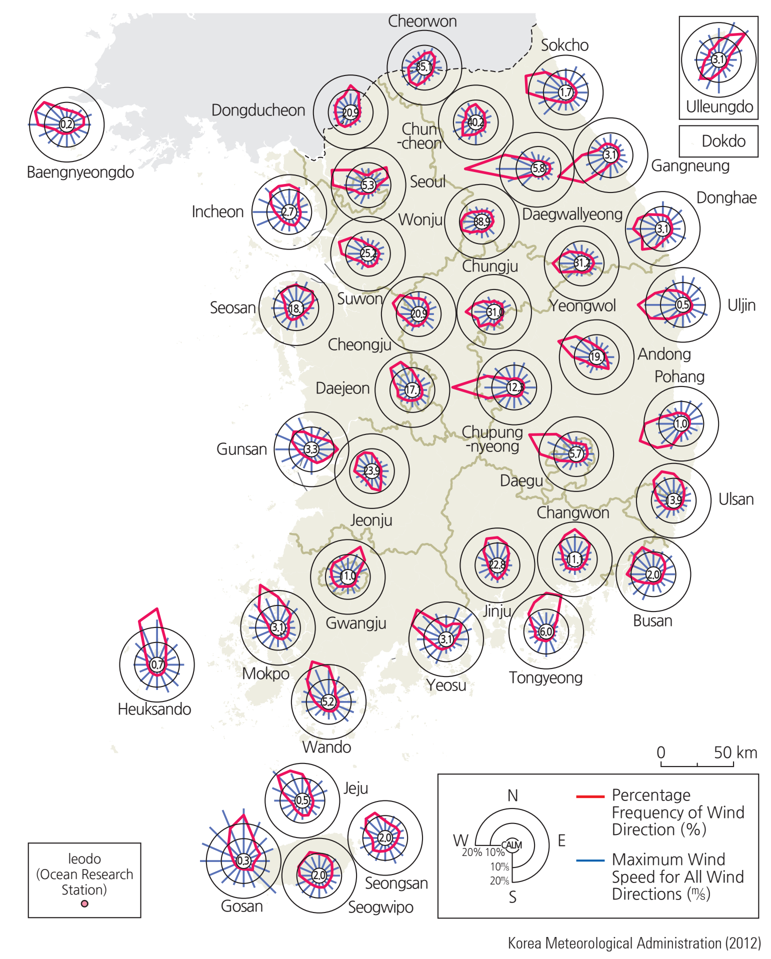
Winter Mean Temperature and Precipitation (1981–2010)



Annual Mean Wind Rose at Selected Stations (1981–2010)



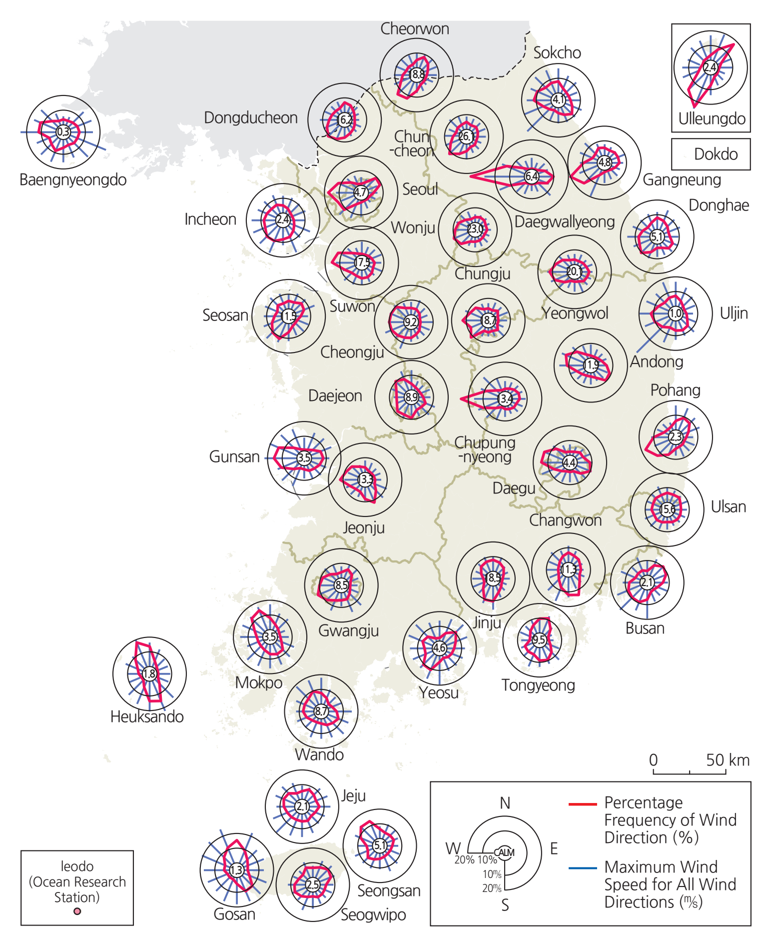
January Mean Wind Rose (1981–2010)



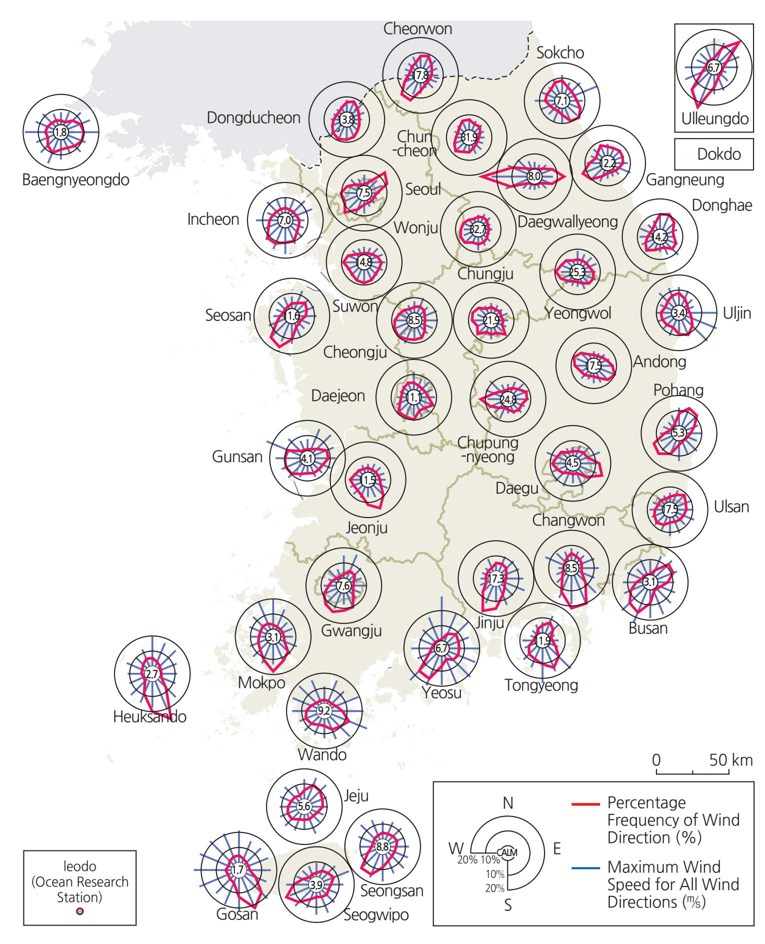
Korea, located in the mid-latitudes, is largely affected by the westerlies and the East Asian monsoon system. Thus, the northerly and the westerly are dominant during winter, especially in January, while the southwesterly, the southerly, and the southeasterly prevail in summer, especially in August. However, the wind direction in summer is not as prevalent as in winter. Although there is no prevailing wind in spring (April) and autumn (October), the northeasterly often blows into the east coast areas. However, the wind direction can vary on a local scale with the geographical location of weather stations and their surrounding topography.

Wind speed is generally much greater in coastal areas than in inland areas. The highest daily maximum wind speed was recorded in Gosan (51.1 m/s) on September 12, 2003, and the highest daily maximum instantaneous wind speed was recorded in Sokcho (63.7 m/s) on October 23, 2006.

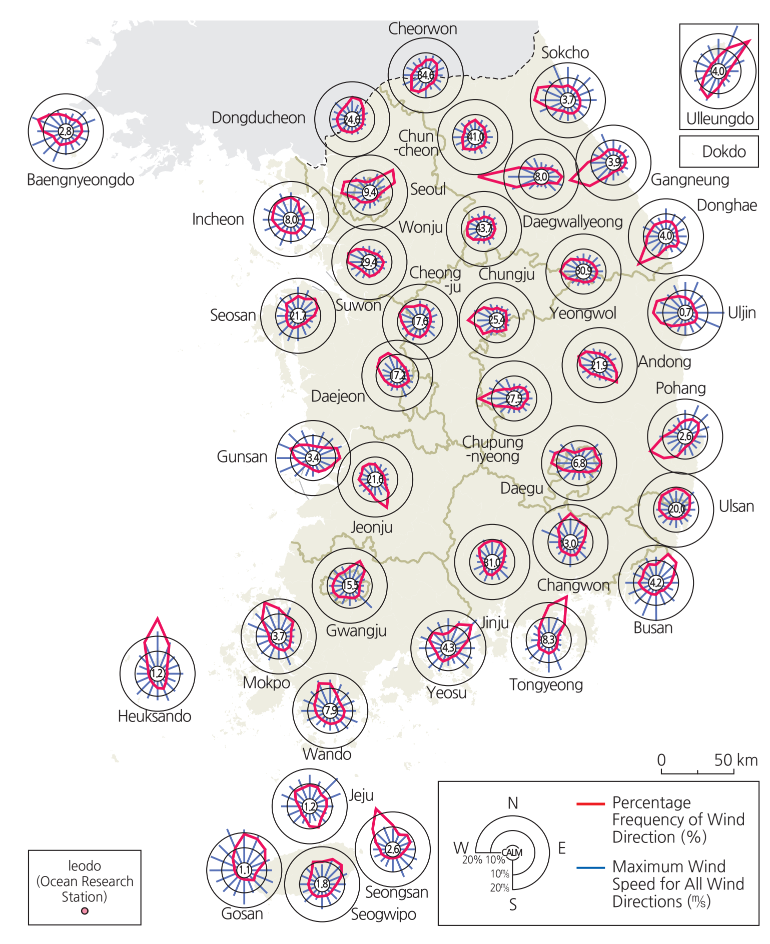
April Mean Wind Rose (1981–2010)



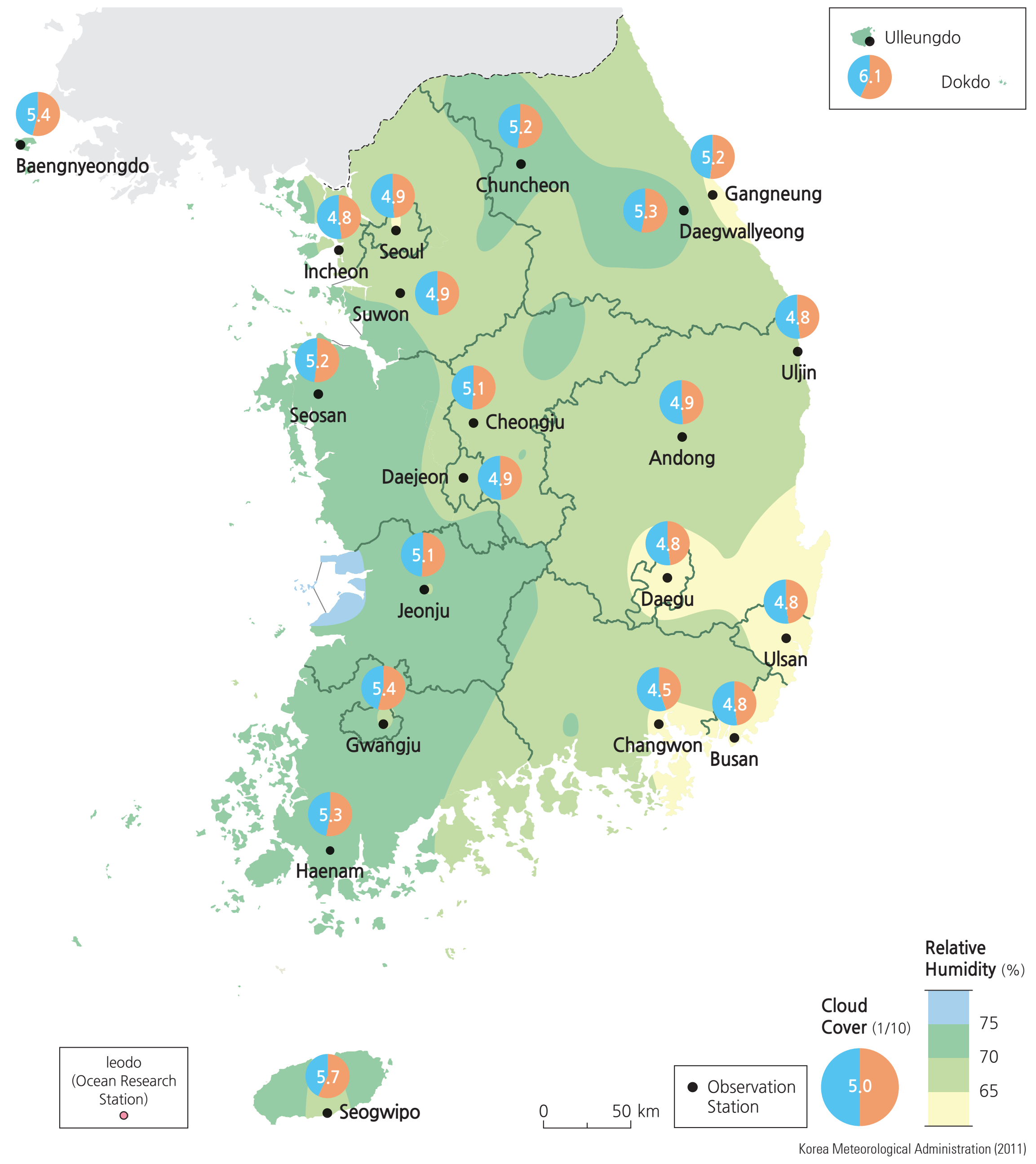
July Mean Wind Rose (1981–2010)



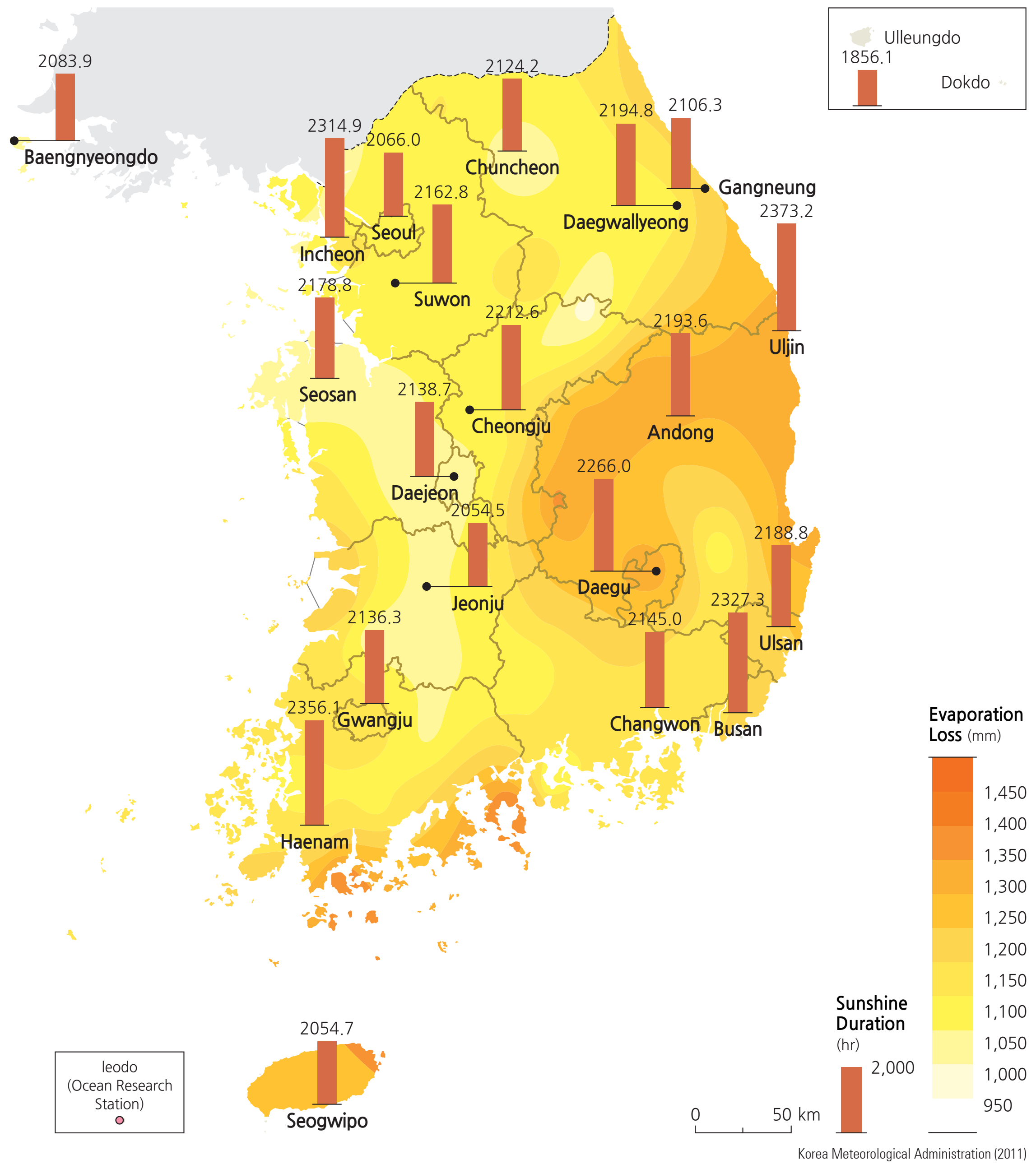
October Mean Wind Rose (1981–2010)



Annual Mean Cloud Cover and Relative Humidity (1981-2010)



Annual Sunshine Duration and Annual Mean Amount of Evaporation (1981-2010)



The annual mean sunshine duration is short in island areas such as Seogwipo (2,054.7 hrs), Ulleungdo (1,856.1 hrs), and Baengnyeongdo (2,083.9 hrs). On the other hand, the annual mean sunshine duration is long in the Yeongnam inland areas, the southeastern coastal areas, and the southernmost parts of the Taebaeksanmaek. Uljin (2,373.2 hrs) has the longest annual mean sunshine duration, followed by Haenam (2,356.1 hrs), Busan (2,372.3 hrs), Daegu (2,260.0 hrs), and Andong (2,193.6 hrs). In terms of the amount of evaporation loss, Yeosu (1377.6 mm) has the largest while Ganghwa (956.8 mm) has the lowest.

Annual mean cloud cover in Korea varies from 4.5% to 6.1%. Gosan, Jeju, and Ulleungdo have the highest cloud cover, with 6.1%. Changwon and Ganghwa have the lowest cloud cover at 4.5%.

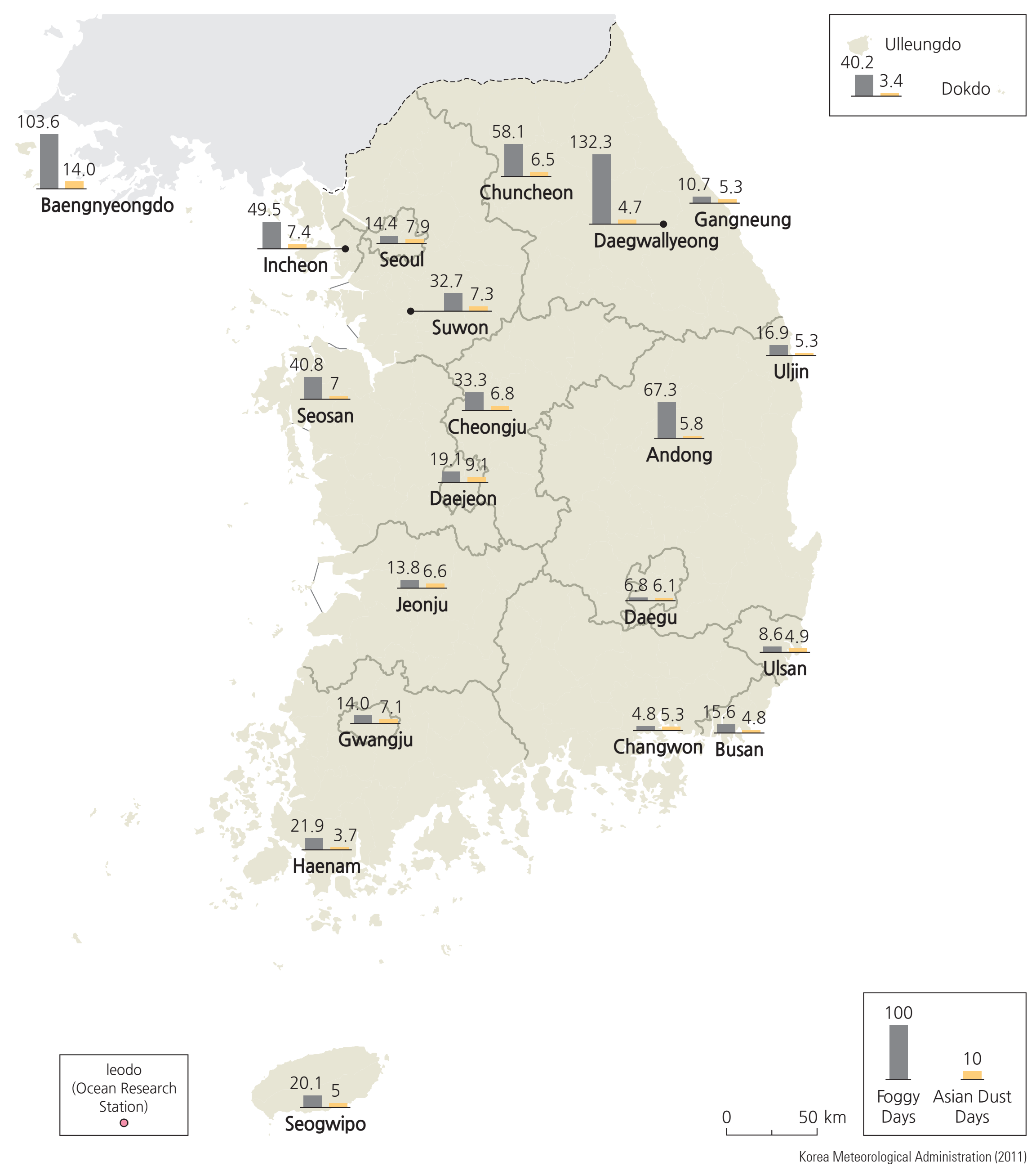
Annual mean relative humidity varies from 61.4% to 77.4%. The highest relative humidity appears in Heuksando (77.4%). Buan, Gunsan, and Ulleungdo also have high relative humidity. The lowest relative humidity appears in Gangneung (61.4%).

Daegwallyeong experiences the highest annual mean number of days with fog (132.3 days) due to high altitude. On average, the eastern coast has more foggy days than the western coast. Low numbers of fog days are found in Changwon (4.8 days) and Daegu (6.8 days).

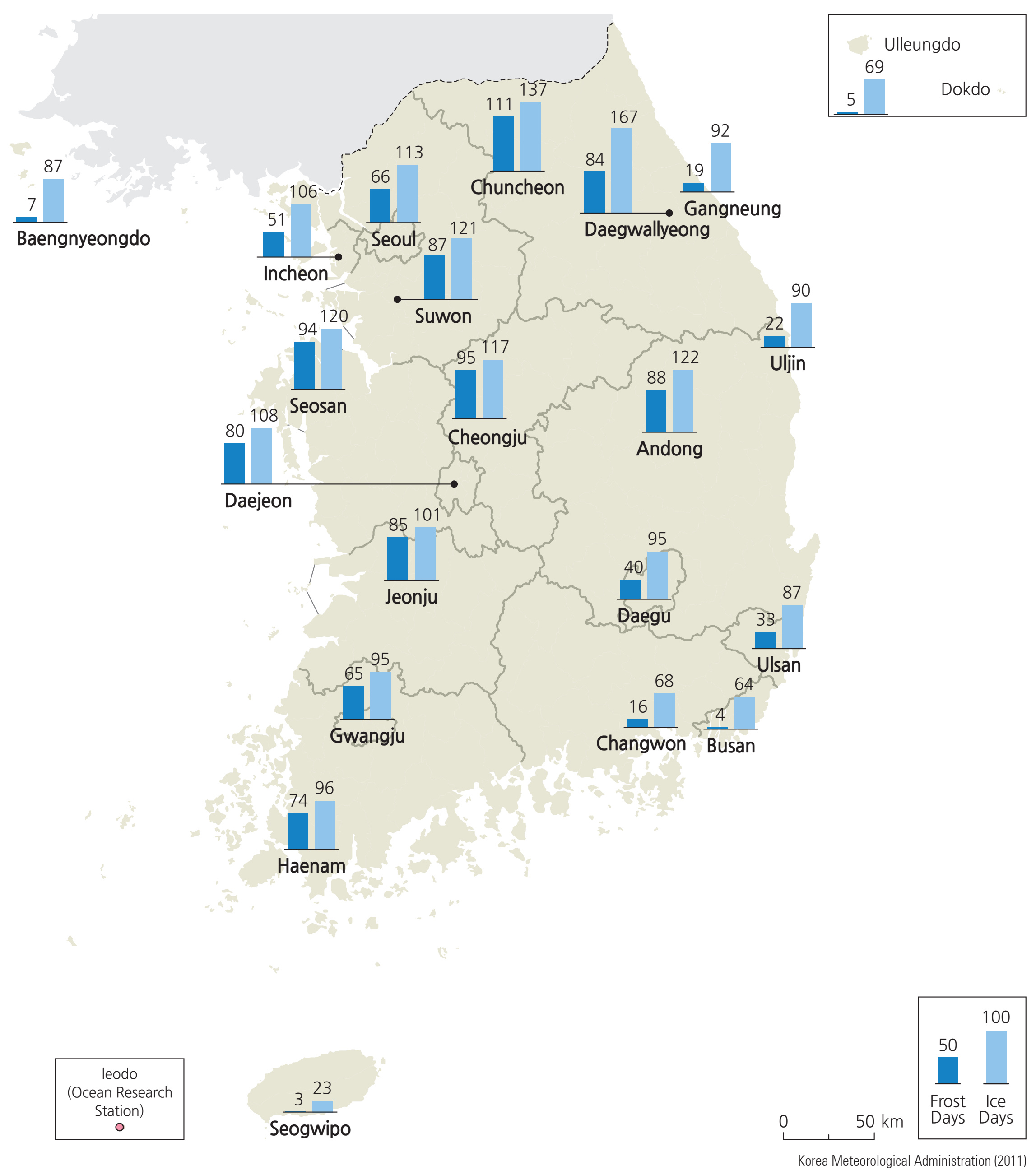
The annual mean number of Asian dust days varies from 3.4 to 14 days. The number of Asian dust days decreases from the west coast to the east coast because Asian dust moves along with the westerlies. Baengnyeongdo has the greatest number of days (14.0 days) while Ulleungdo has the fewest (3.4 days).

The greatest annual mean number of days with frost occurs in Chuncheon (111 days). The areas on the east coast experience more frost days than those on the west coast. For instance, Gangneung (19 days) and Uljin (22 days) have fewer frost days than Incheon (51 days) and Seosan (94 days). The least annual mean number of days with frost appears in Seoguipo (3 days). The largest annual mean number of days with ice occurs in Daegwallyeong (167 days). The annual mean number of ice days in the central region varies from 23 to 167 days, with the number of days decreasing from north to south. There is a relatively small difference in the annual mean

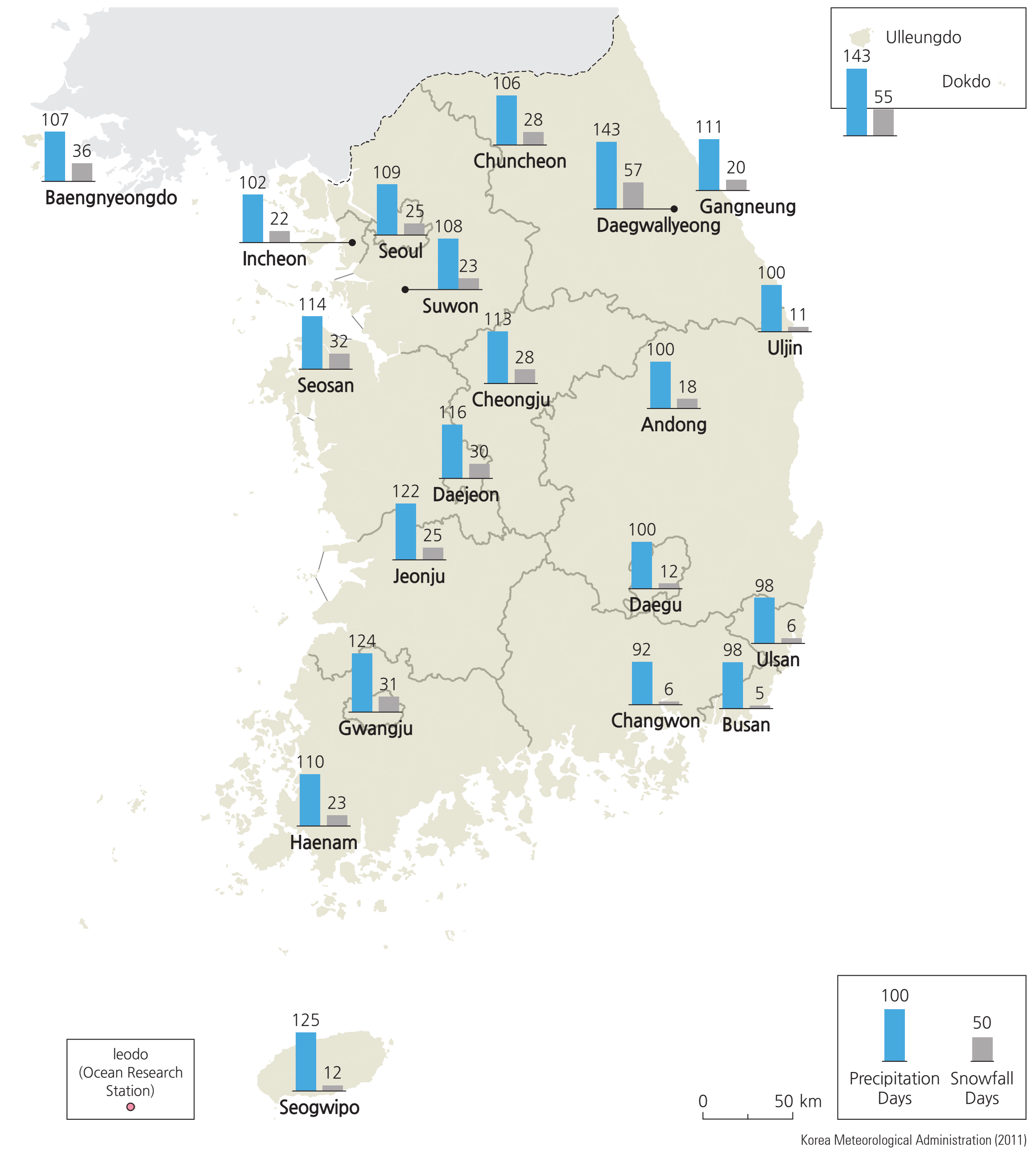
Annual Mean Number of Foggy Days and Asian Dust Days (1981-2010)



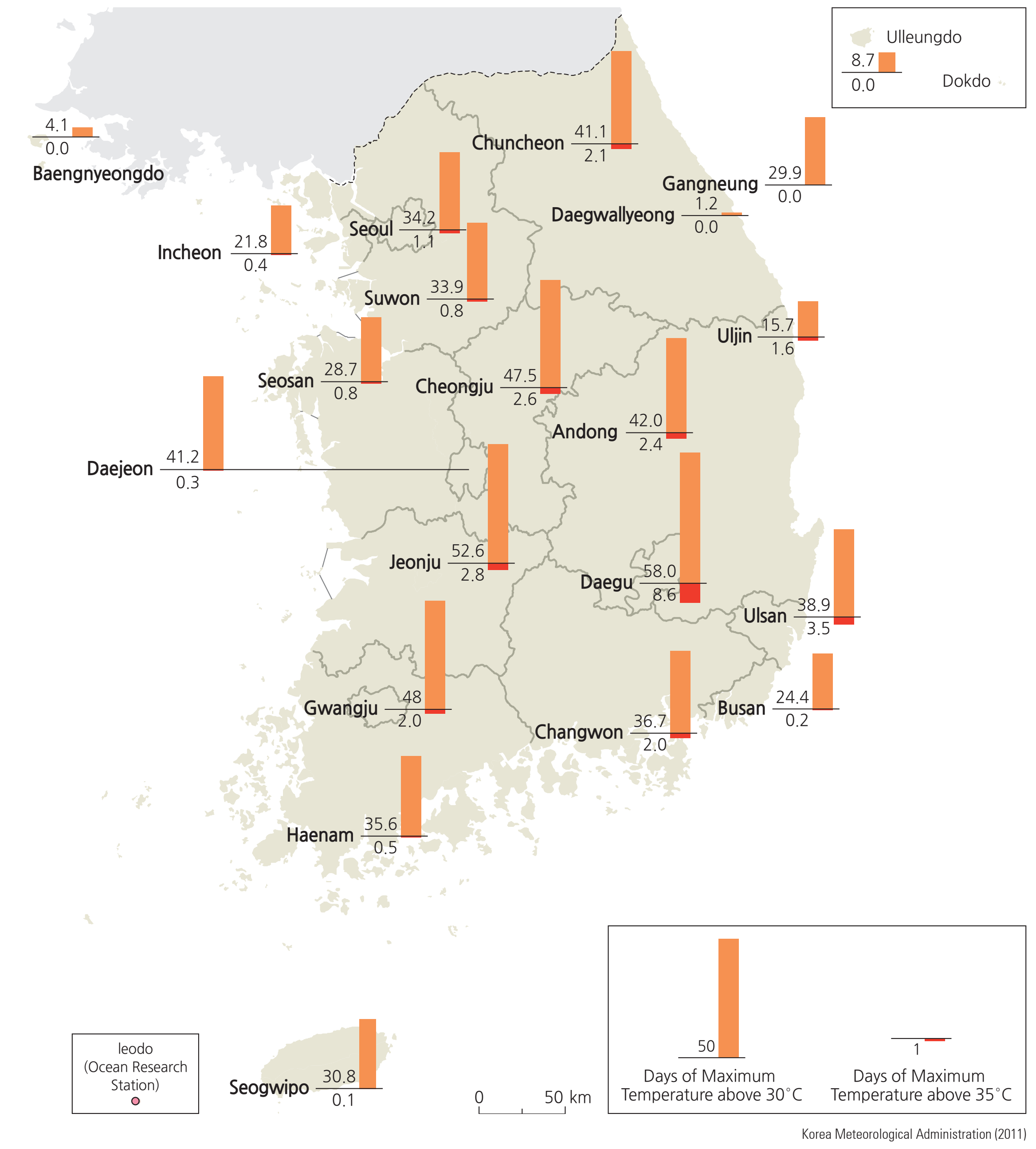
Annual Mean Number of Frost Days and Ice Days (1981-2010)



Annual Mean Number of Precipitation Days and Snowfall Days (1981-2010)



Annual Mean Number of Days with Daily Maximum Temperature above 30˚C and above 35˚C (1981-2010)



number of ice days and frost days between the western coastal areas and the eastern coastal areas. The least number of ice days appears in Seoguipo (23 days).

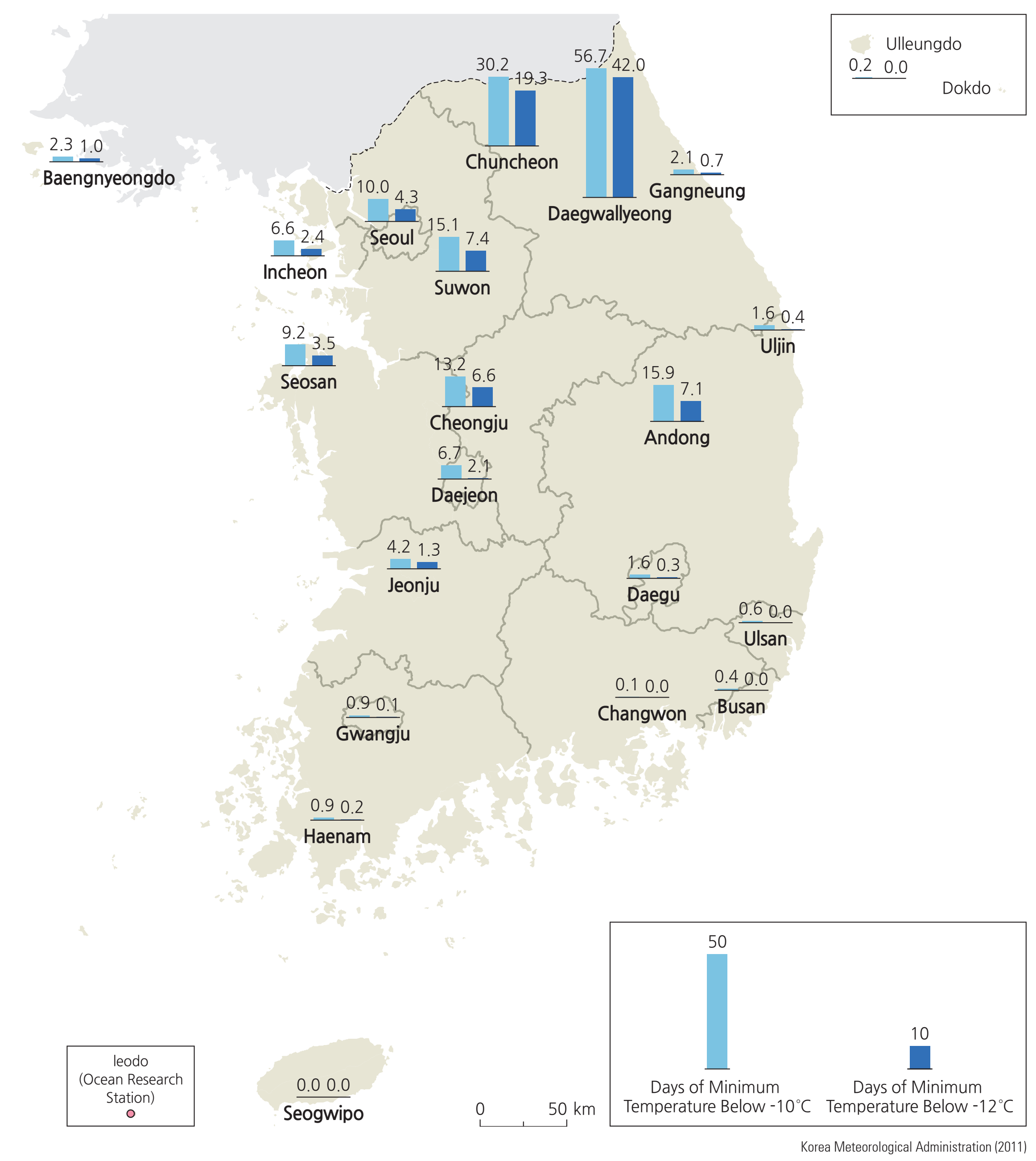
The annual mean number of days with daily precipitation over 0.1 mm in the central region and the southern region is about 110 days. Daegwallyeong and Ulleungdo (143 days) have about 30 more precipitation days than the average for the central region. There is a big difference in the annual mean number of snowfall days between the central (30 days) and the southern region (14 days). Due to its high elevation, the highest number of snowfall days occurs in Daegwallyeong (57 days), which is 37 days more than its neighboring city, Gangneung (20 days). Also, Ulleungdo experiences many snowfall days owing to the effects of the northeasterly. The regions with few annual snowfall days are Busan, Ulsan, and Changwon, with 5-6 days.

The annual mean number of days with a maximum temperature above 30°C increases from coastal areas to inland areas. Daegu (58.0 days) experiences the greatest number of days with a maximum temperature over 30°C, while Daegwallyeong (1.2 days) experiences the fewest. Daegu (8.6 days) also has the most number of days with a maximum temperature over 35°C, while Daegwallyeong, Gangneung, Baengnyeongdo, and Ulleungdo (all 0.0 days) have the fewest.

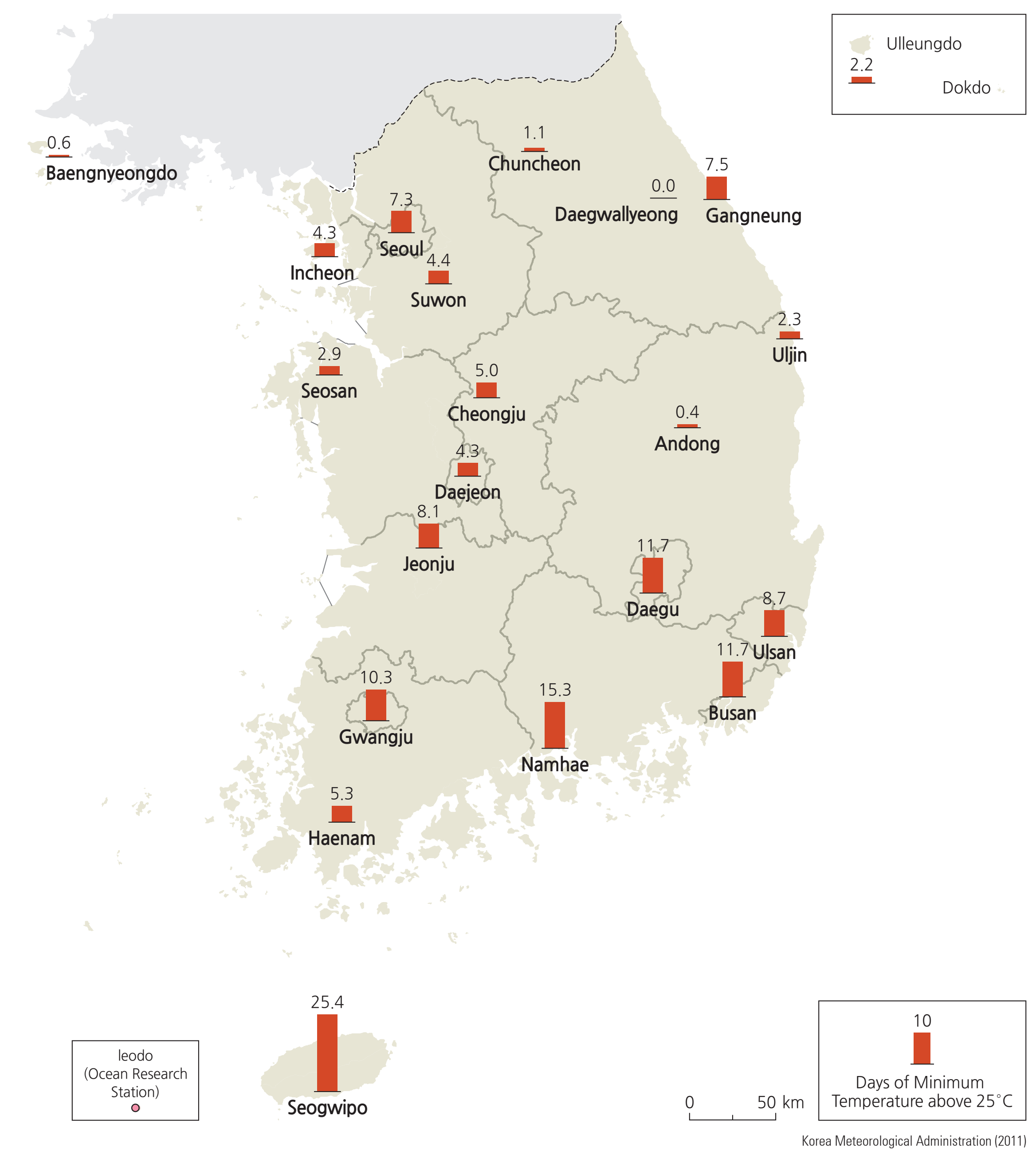
The annual mean number of days with a minimum temperature below-10°C and -12°C decreases from north to south, but increases from coastal areas to inland areas, as well as with altitude. The maximum number of days with a daily minimum temperature below -10°C occurs in Daegwallyeong (56.7 days) while the fewest number of days is found in Seogwipo (0.0 days). The most number of days with a daily minimum temperature below -12°C occurs in Daegwallyeong (42.0 days) while the fewest number of days is found in Changwon, Ulleungdo, Busan, Ulsan, and Seogwipo (all 0.0 days).

The daily minimum temperature above 25°C usually occurs from July to September. Seogwipo (25.4 days) has the most number of days with a minimum temperature above 25°C while Daegwallyeong (0.0 days) has the fewest.

Annual Mean Number of Days with a Minimum Temperature below -10˚C and -12˚C (1981-2010)

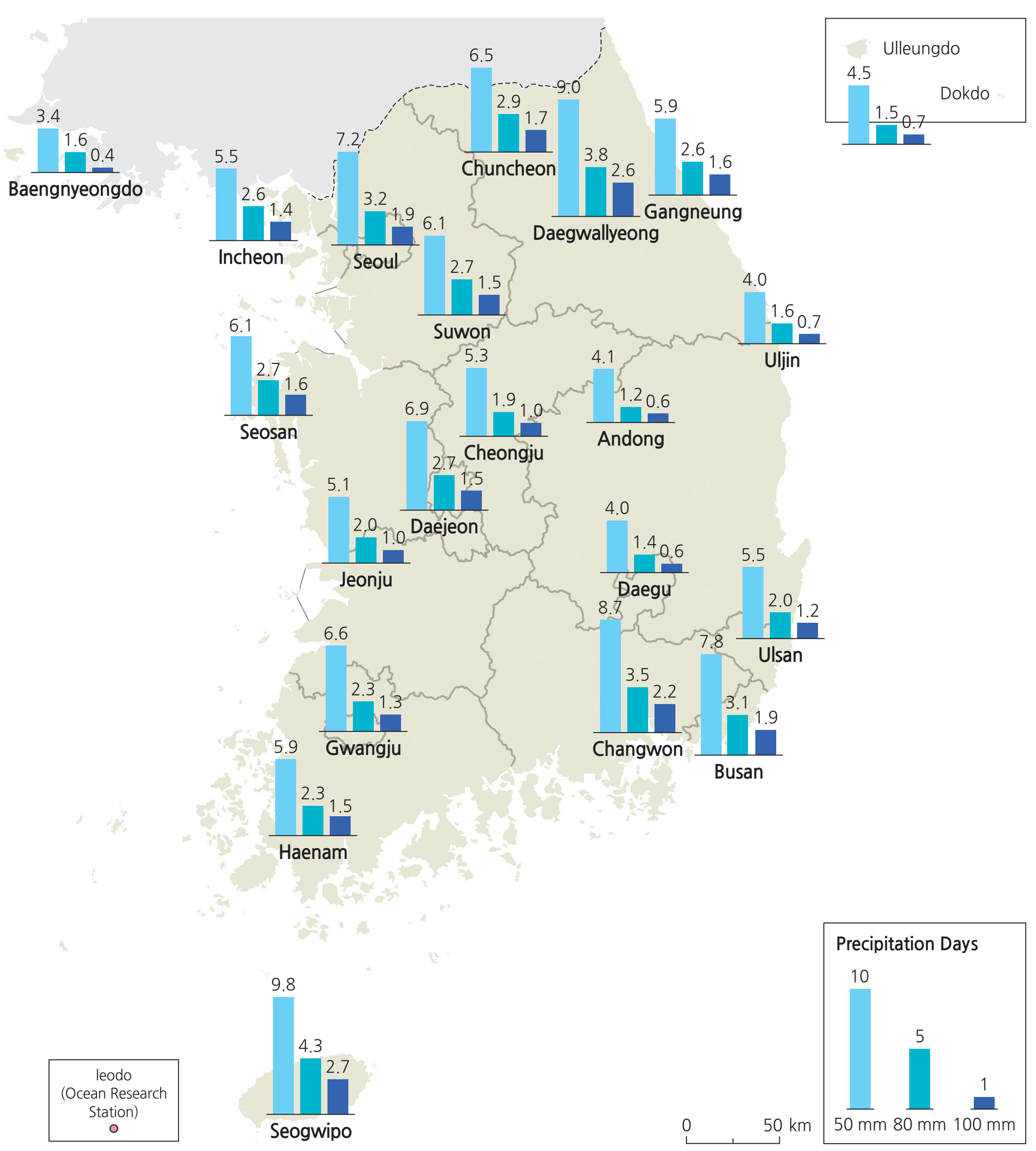


Annual Mean Number of Days with a Daily Minimum Temperature above 25˚C (1981-2010)

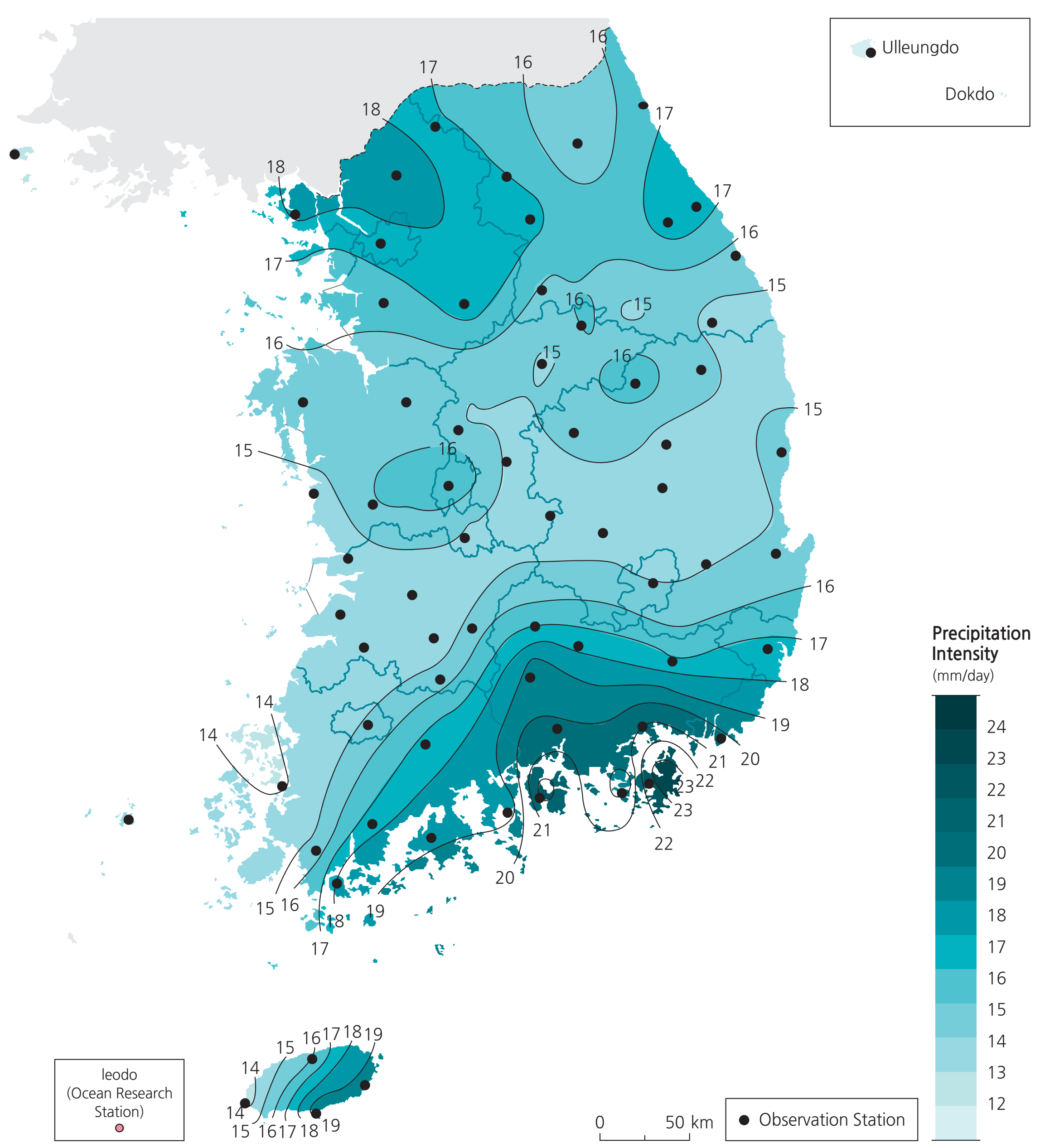


Extreme Climate Events

Annual Mean Numbers of Days with Daily Precipitation above 50 mm, 80 mm, and 100 mm (1981–2010)



Annual Precipitation Intensity (1981–2010)



The highest 1-hour maximum precipitation on record was measured in Suncheon (145.0 mm) on July 31, 1998. It is attributed to localized heavy rain resulting from a strong ascending air current formed by the combination of the North Pacific High and low pressure associated with the southerly on the windward side of Jirisan. The second highest 1-hour maximum precipitation was recorded in Ganghwa (123.5 mm) on August 6, 1998.

The highest maximum daily precipitation on record occurred in Gangneung (870.5 mm) on August 31, 2002, in the aftermath of Typhoon Rusa, followed by Daegwallyeong (712.5 mm) on the same day; Jangheung (547.4 mm) on September 2, 1981, in the aftermath of Typhoon Agnes; and Pohang (516.4 mm) on September 30, 1998, due to Typhoon Yanni.

The annual mean number of days with daily precipitation greater than 50 mm is largest in Seogwipo (9.8 days). Baengnyeongdo (3.4 days) has the fewest. Seogwipo (4.3 days) also has the largest annual mean number of days with daily precipitation exceeding 80 mm. Andong (1.2 days) has the fewest days. The annual mean number of days with daily precipitation greater than 100 mm is largest in Seogwipo (2.7 days. Baengnyeongdo (0.4 days) has the fewest.

Annual precipitation intensity is a climate index, calculated by dividing annual precipitation by the annual mean number of precipitation days. The precipitation intensity appears relatively strong in the southern region, including Jejudo and the northern part of Gyeonggi-do. For instance, the southern coastal region has a precipitation intensity greater than 20 mm/day in general. The precipitation intensity appears relatively weak in the inland areas of Gyeongsangbuk-do, the western coastal areas of Jeollanam-do and Jeollabuk-do, and Ulleungdo.

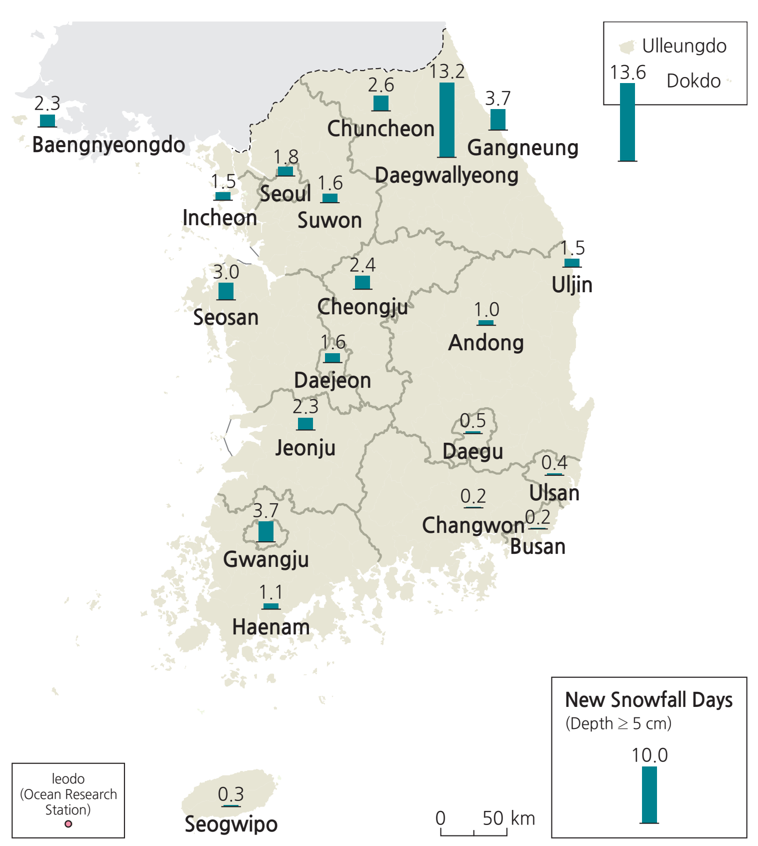
Annual mean maximum number of consecutive dry days (with daily precipitation below 1.0 mm) is a climate index indicating the severity of dryness. The number is small in Jejudo, Daegwallyeong, and Jeollabuk-do, while the number is large in inland and eastern coastal areas of Gyeongsangbuk-do. Baengnyeongdo (40.9 days) has the longest average stretch of consecutive dry days, whereas Ulleungdo (20.1 days) has the shortest average stretch of consecutive dry days.

The annual mean number of days with new snowfall (depth of snowfall ≥ 5 cm) varies from 0.2 to 13.6 days across regions. Ulleungdo (13.6 days) has the largest annual mean number of days with new snowfall due to effects of the northwest monsoon and northeasterly, followed by Daegwallyeong (13.2 days), which is located at a high elevation. In Gangneung (3.7 days) and Gwangju (3.7 days), the annual number of days with new snowfall is lower than 4 days. Busan (0.2 days) and Changwon (0.2 days) have the fewest annual mean number of days with new snowfall.

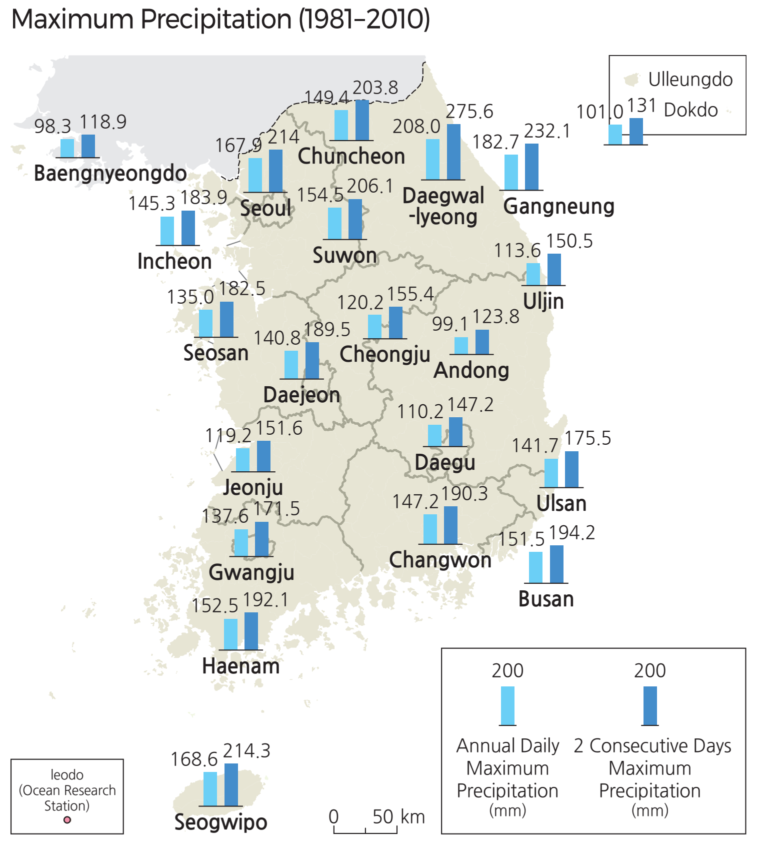
Extreme Climate Events	Rank	Location	Date (yyyy/mm/dd)	Value
Maximum Daily Precipitation (mm)	1	Gangneung	2002/08/31	870.5
	2	Daegwallyeong	2002/08/31	712.5
	3	Jangheung	1981/09/02	547.4
	4	Buyeo	1987/07/22	517.6
	5	Pohang	1998/09/30	516.4
1-Hour Maximum Precipitation (mm)	1	Juam	1998/07/31	145.0
	2	Gangwha	1998/08/06	123.5
	3	Seoul	1942/08/05	118.6
	4	Buyeo	1999/09/10	116.0
		Seoul	1964/09/13	116.0
Amount of Snowfall at One Time (cm)	1	Ulleungdo	1955/01/20	150.9
	2	Ulleungdo	1967/02/12	118.4
	3	Ulleungdo	1954/01/25	94.1
	4	Daegwallyeong	1992/01/31	92.0
	5	Daegwallyeong	198702/03	90.3
Snow Accumulation (cm)	1	Ulleungdo	1962/01/31	293.6
	2	Ulleungdo	1962/01/30	291.6
	3	Ulleungdo	1962/01/28	290.1
	4	Ulleungdo	1962/01/27	288.9
	5	Ulleungdo	1962/02/01	287.9

Korea Meteorological Administration (2012)

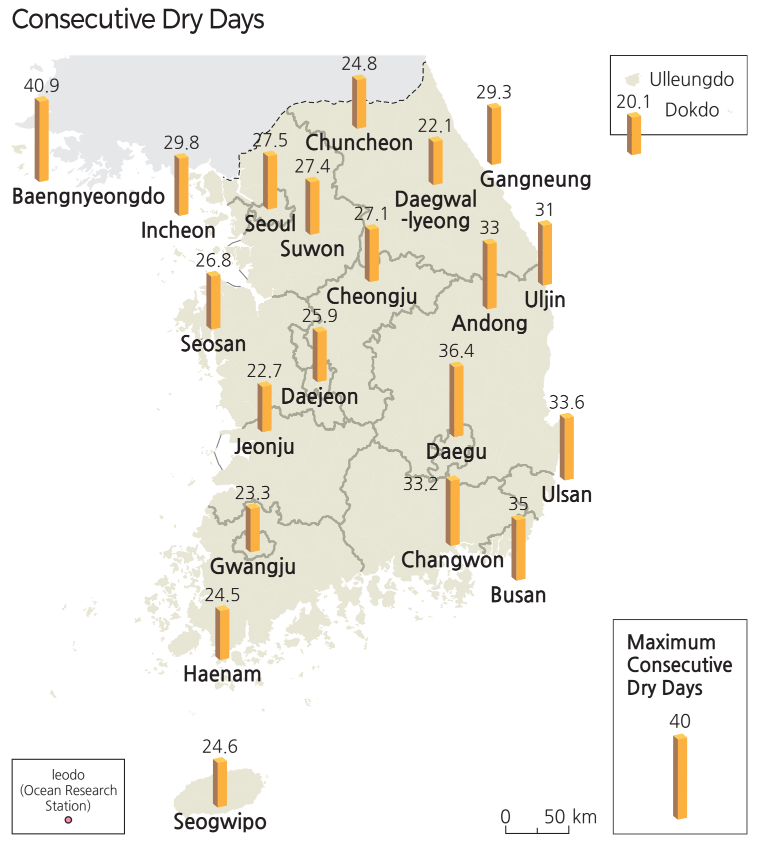
Annual Mean Number of Days with New Snowfall (1981–2010)



Annual Daily and 2 Consecutive Days Maximum Precipitation (1981–2010)

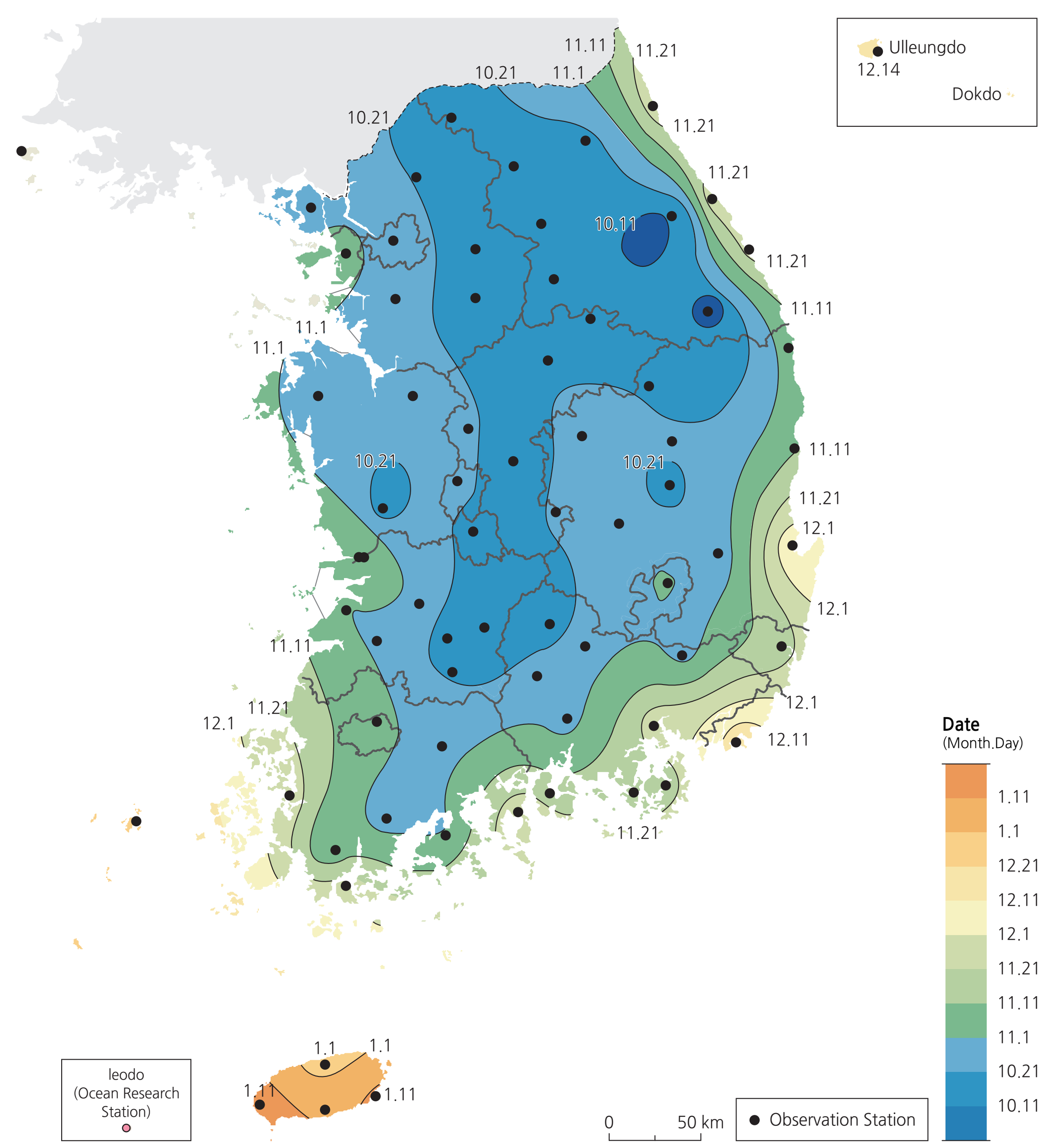


Annual Mean Maximum Number of Consecutive Dry Days

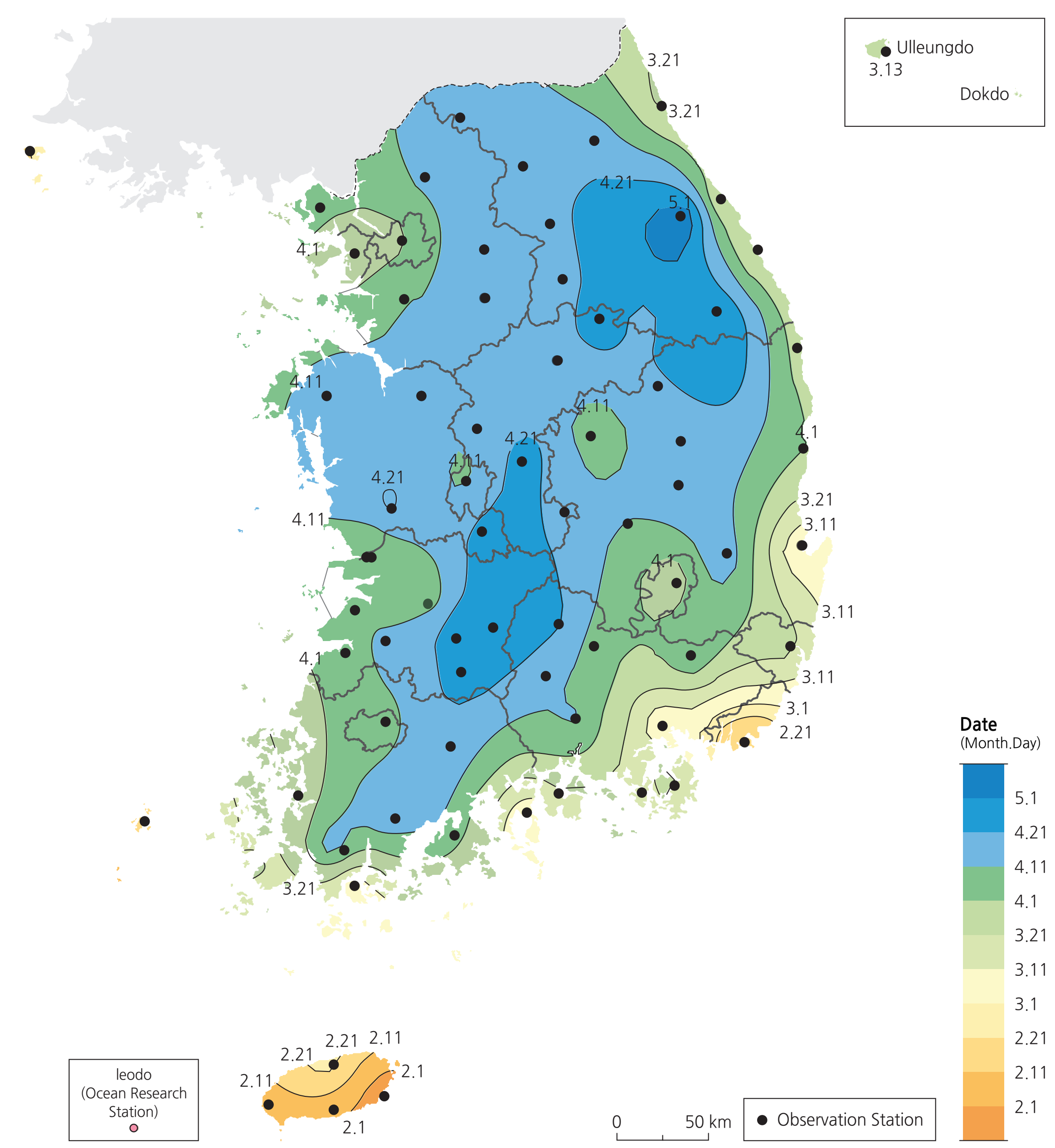


First and Last Days of Seasonal Climatic Events

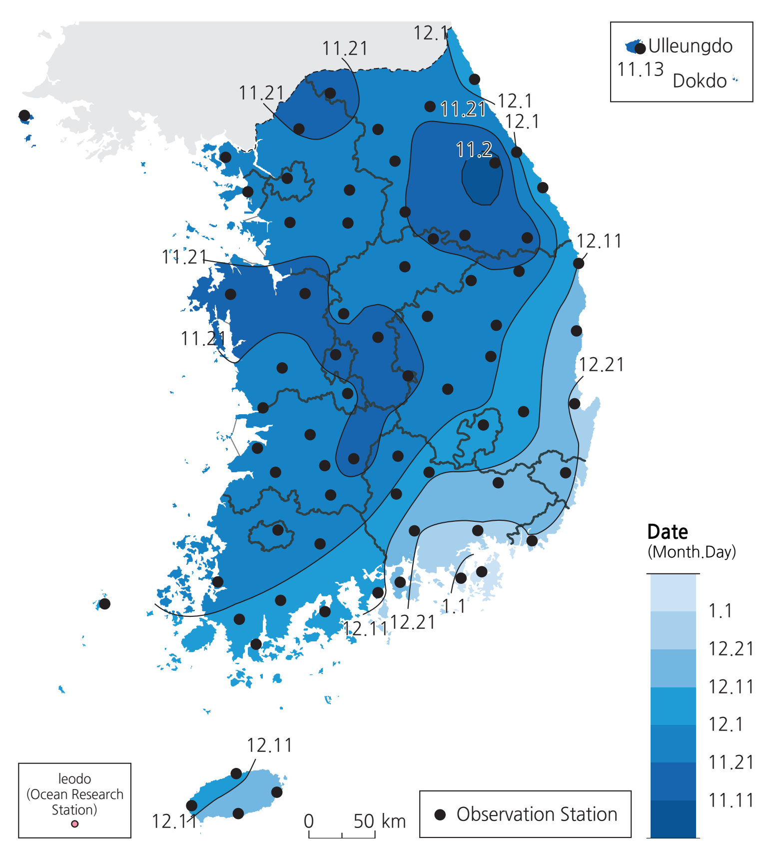
Mean First Day with Frost (1981–2010)



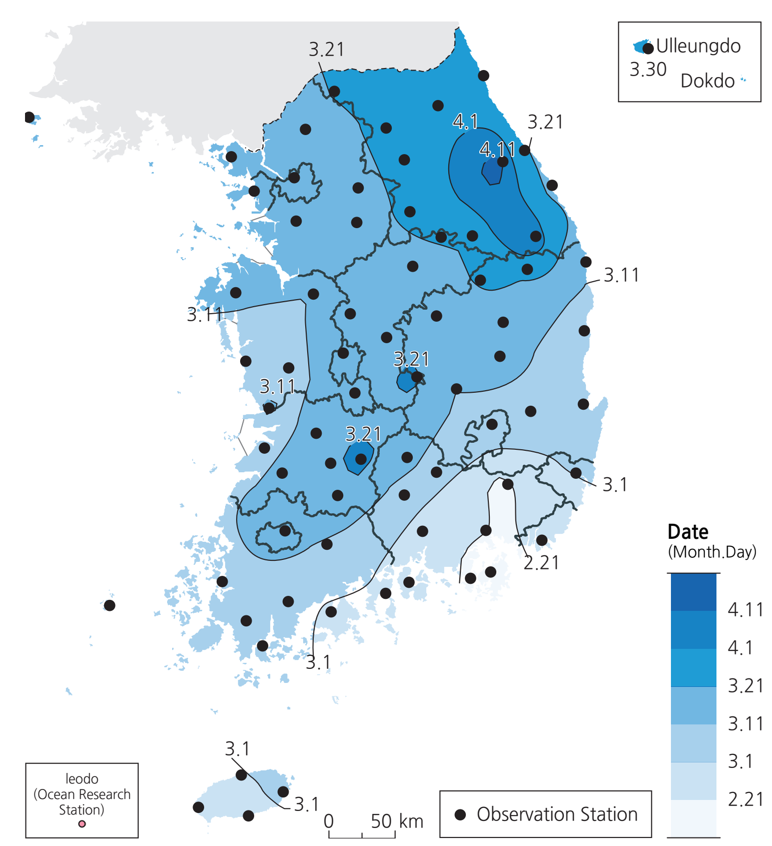
Mean Last Day with Frost (1981–2010)



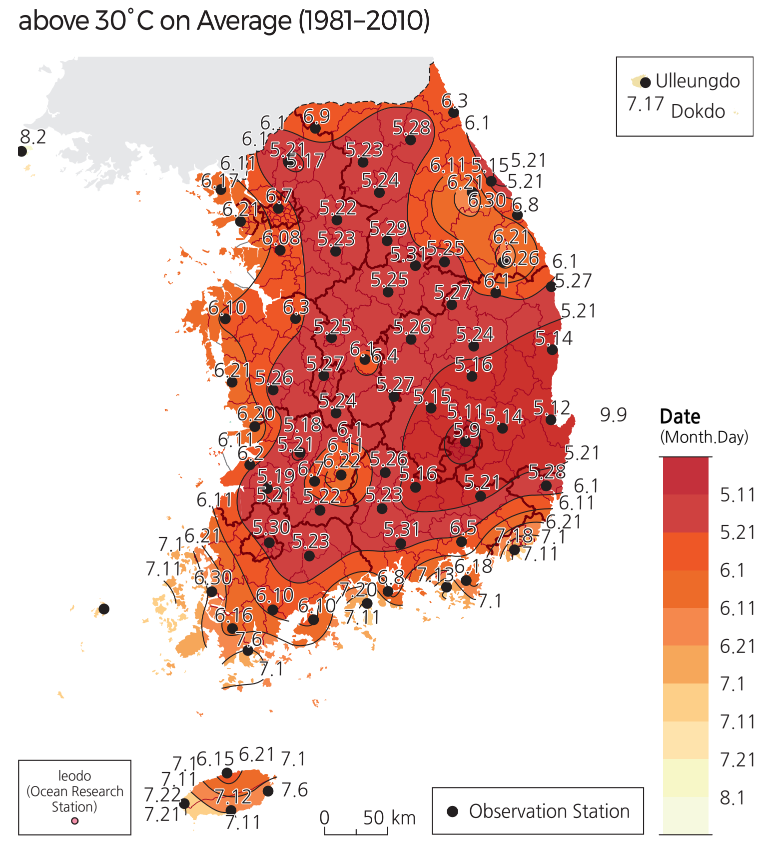
Mean First Day with Snowfall (1981–2010)



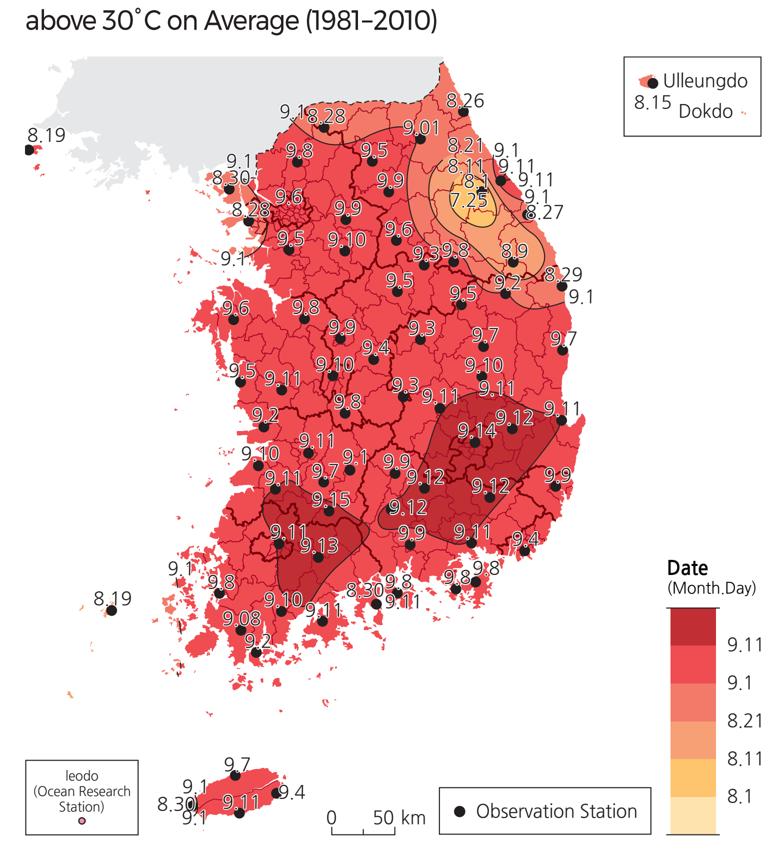
Mean Last Day with Snowfall (1981–2010)



Mean First Day with Maximum Temperature above 30°C on Average (1981–2010)



Mean Last Day with Maximum Temperature above 30°C on Average (1981–2010)



The first frost of the season occurs during October in most parts of the Korean Peninsula. However, some parts of the coastal areas and the southern region experience frost between November and December, with Jejudo, the last, in January. The last frost occurs during April in most places. In general, the later the frost begins, the earlier the frost stops forming. For instance, the earliest days with the last frost occur around January 27 in Seongsan, followed by Seogwipo (February 2), Gosan (February 5), and Busan (February 8). The latest frost occurs in Daegwallyeong around May 9, followed by Bonghwa, Jangsu, and Taebaek (all April 30).

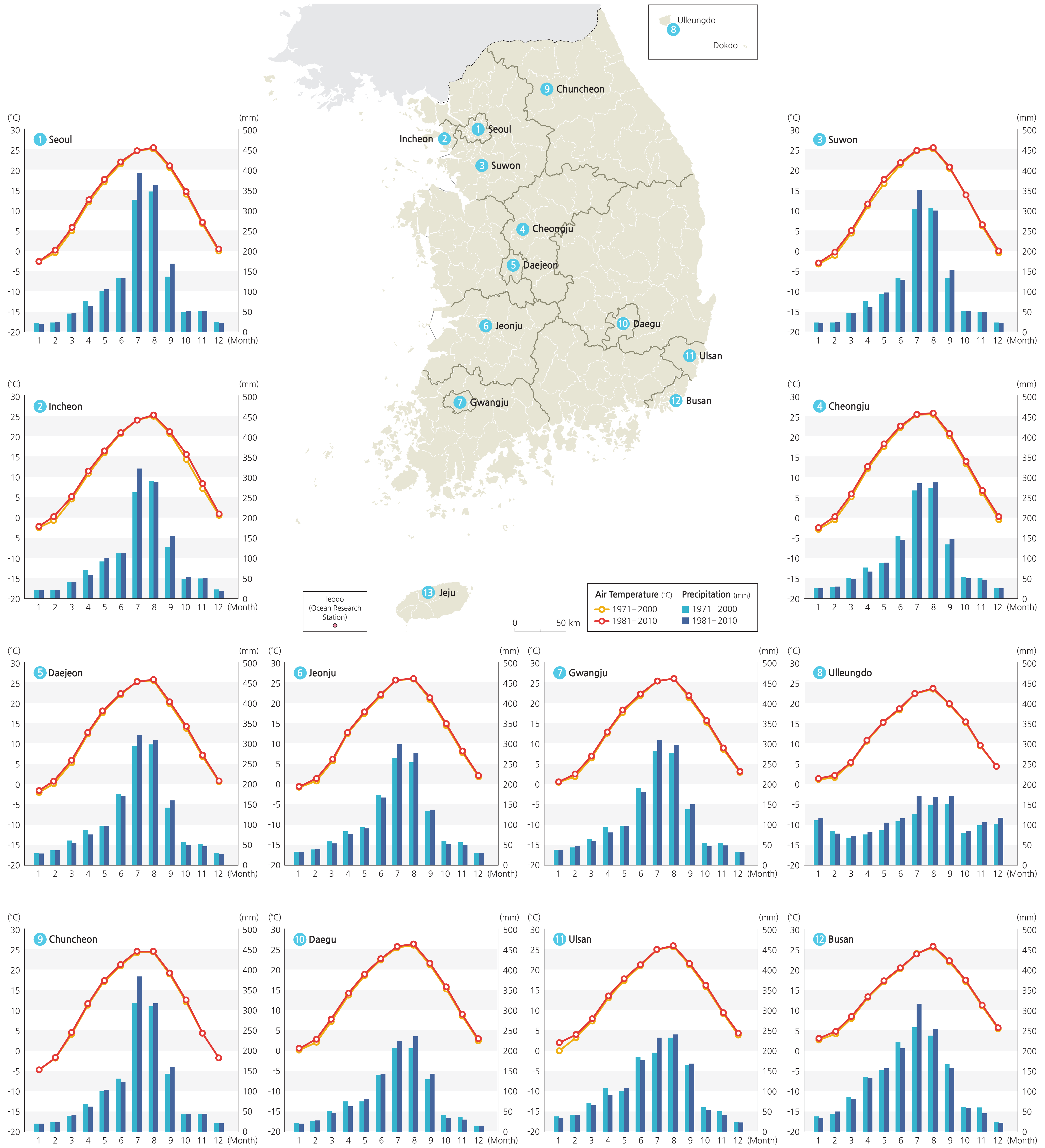
The first snow of the season falls around November on average in most parts of the Korean Peninsula. On average, the first snowfall occurs in Daegwallyeong (November 2), followed by Taebaek (November 11), Ulleungdo (November 13), and Baengnyeongdo (November 16). The latest first snow occurs in Geoje (January 9), followed by other southern regions, Tongyeong (January 3), Pohang (December 23), and Changwon (December 22). In most areas, the last snow of the season is seen around March. The earliest day with the last snow occurs in Geoje (February 16), followed by Miryang (February 19), Tongyeong (February 21), and Changwon (February 22). Daegwallyeong experiences snow until April 17 on average.

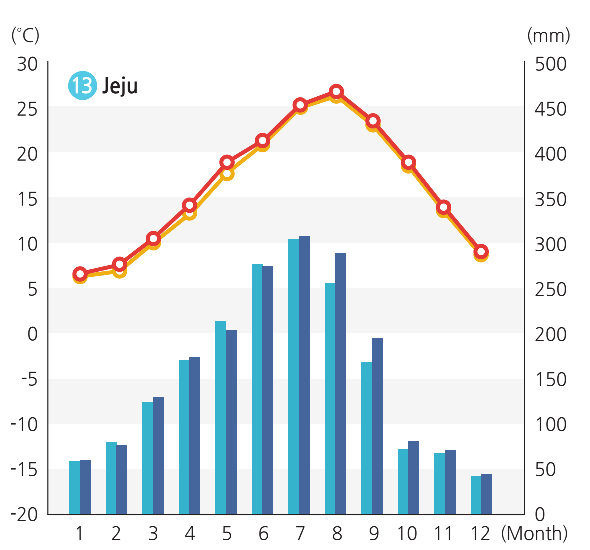
The first date with maximum temperature exceeding 30°C occurs in May or June in most regions. The regional difference in the first date with maximum temperature exceeding 30°C is greater than that in the first date with maximum temperature above 25°C. Daegu (May 9) experiences it the earliest, followed by Pohang (May 12), the southern inland areas such as Yeongcheon and Yeongdeok (May 14), and the eastern coastal areas. The latest mean first date with maximum temperature greater than 30°C occurs in Baengnyeondo (August 2), followed by the southern coastal areas such as Heuksando (August 1), Seongsan (July 22), and Yeosu (July 20). The mean first date of maximum temperature above 30°C is earlier in coastal areas than in inland areas.

The last date of maximum temperature above 30°C occurs around September in most areas. The earliest last date occurs in Daegwallyeong (July 25), followed by Taebaek (August 9) and Ulleungdo (August 15). The latest date for a maximum temperature greater than 30°C occurs in Namwon (September 15), followed by the southern inland areas such as Daegu (September 14) and Suncheon (September 11).

Climate Change

Changes in Climographs at Selected Stations





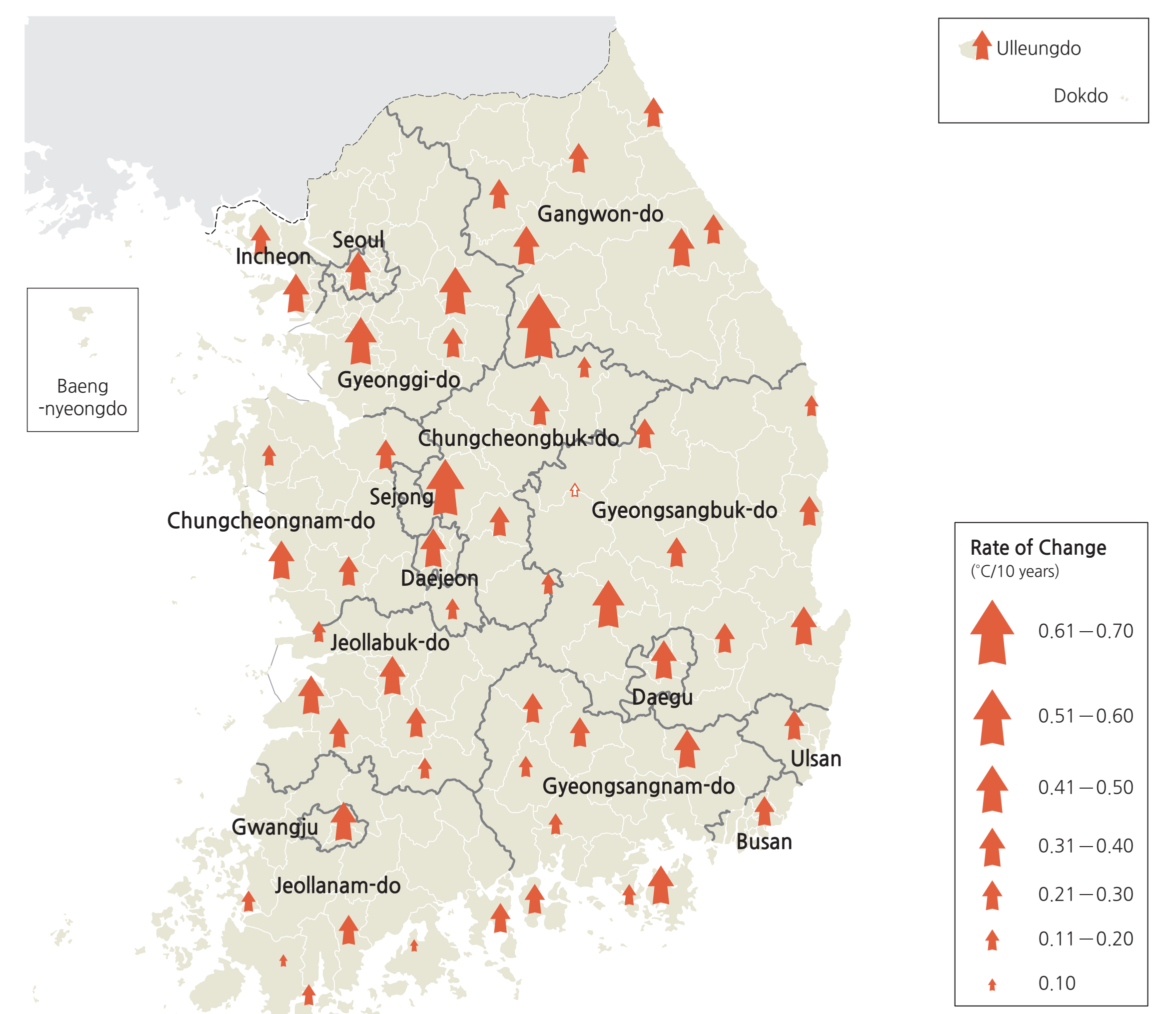
Korea Meteorological Administration (2011)

There has been an increasing trend in temperature over the past 30 years. According to the climographs, the average monthly temperature of the recent 30 years (1981–2010) is greater than the past 30 years (1971–2000), except for July.

The annual precipitation of the Korean Peninsula experienced a slight increase by around 50 mm on average in the last 30 years (1981–2010). The annual precipitation recorded at 13 observation stations increased by about 3.9% on average compared to the past (1971–2000), while Ulleungdo experienced an 11% increase in precipitation. In most areas, summer precipitation has increased, while precipitation in spring and autumn has decreased.

The rate of change in annual mean temperature, 0.27˚C/10 years, clearly shows a warming trend in Korea. All the areas except Mungyeong have experienced a rise in annual mean temperature between 0.10˚C and 0.61˚C for every 10 years. Wonju has experienced the greatest increase in temperature at 0.61˚C for every 10 years. The annual mean temperature increases at a greater rate in metropolitan areas than the national average rate of change. The highest rate of change in annual mean temperature occurs in Daejeon (0.39˚C/10 years). Winters (0.34˚C/10 years) have experienced the greatest increase in temperature, while summers (0.23˚C/10 years) have experienced the lowest temperature increase.

Rate of Change in Annual Mean Temperature (1973–2019)



Ieodo (Ocean Research Station)

Jeju Special Self-Governing Province

Rate of Change in Annual and Seasonal Mean Temperature (1973–2019)

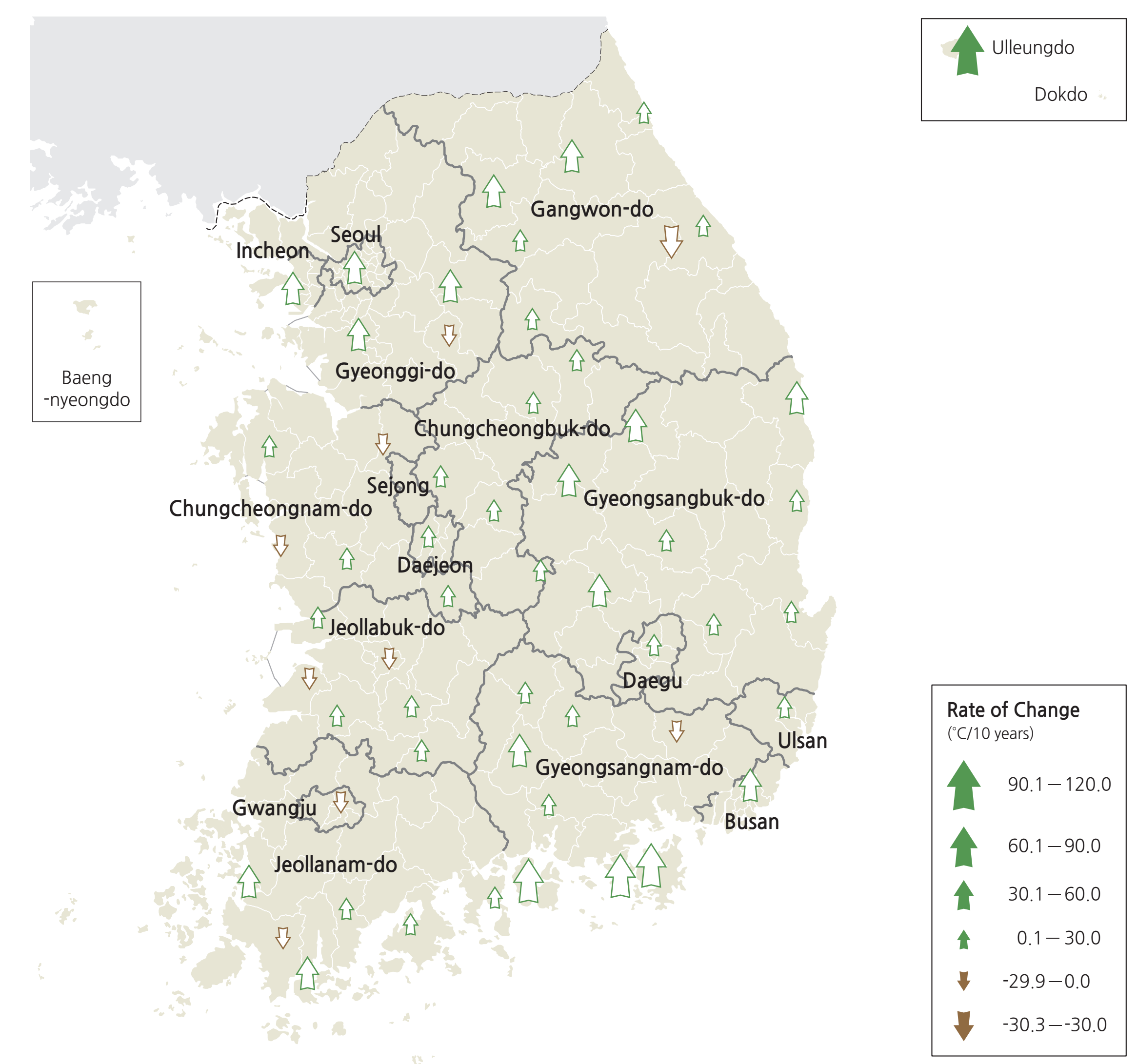
Unit (˚C/10 years)

Classification	Annual	Spring	Summer	Autumn	Winter
Mean Temperature	0.27 **	0.31 **	0.23 **	0.29 **	0.34 **
Maximum Temperature	0.25 **	0.35 **	0.23 *	0.20 *	0.28 *
Minimum Temeperature	0.31 **	0.30 **	0.29 **	0.39 **	0.34 *

* Significant at α = 0.05 / ** Significant at α = 0.01

Korea Meteorological Administration (2019)

Rate of Change in Annual Mean Precipitation (1973–2019)



Ieodo (Ocean Research Station)

Jeju Special Self-Governing Province

Rate of Change in Annual and Seasonal Mean Precipitation (1973–2019)

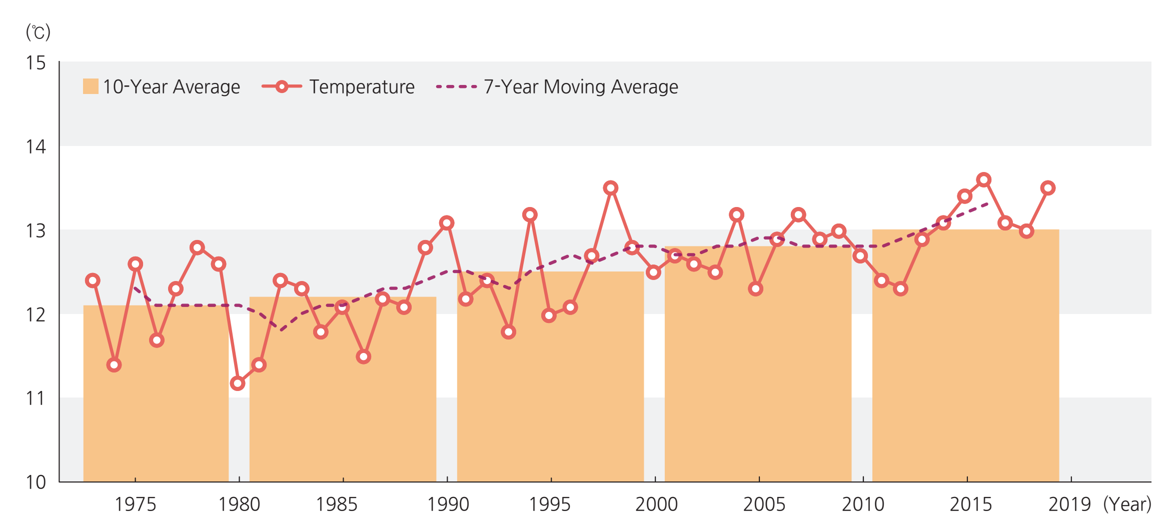
Unit (˚C/10 years)

Classification	Annual	Spring	Summer	Autumn	Winter
Precipitation	55.45	-5.75	55.20 *	6.89	0.15

* Significant at α = 0.05 / ** Significant at α = 0.01

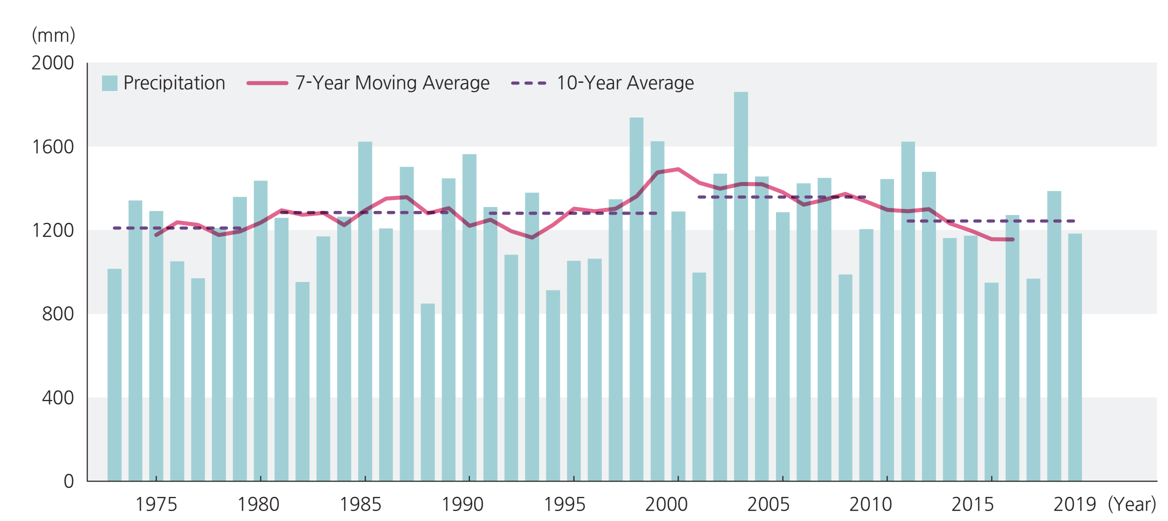
Korea Meteorological Administration (2019)

Change in Annual Mean Temperature (1973–2019)



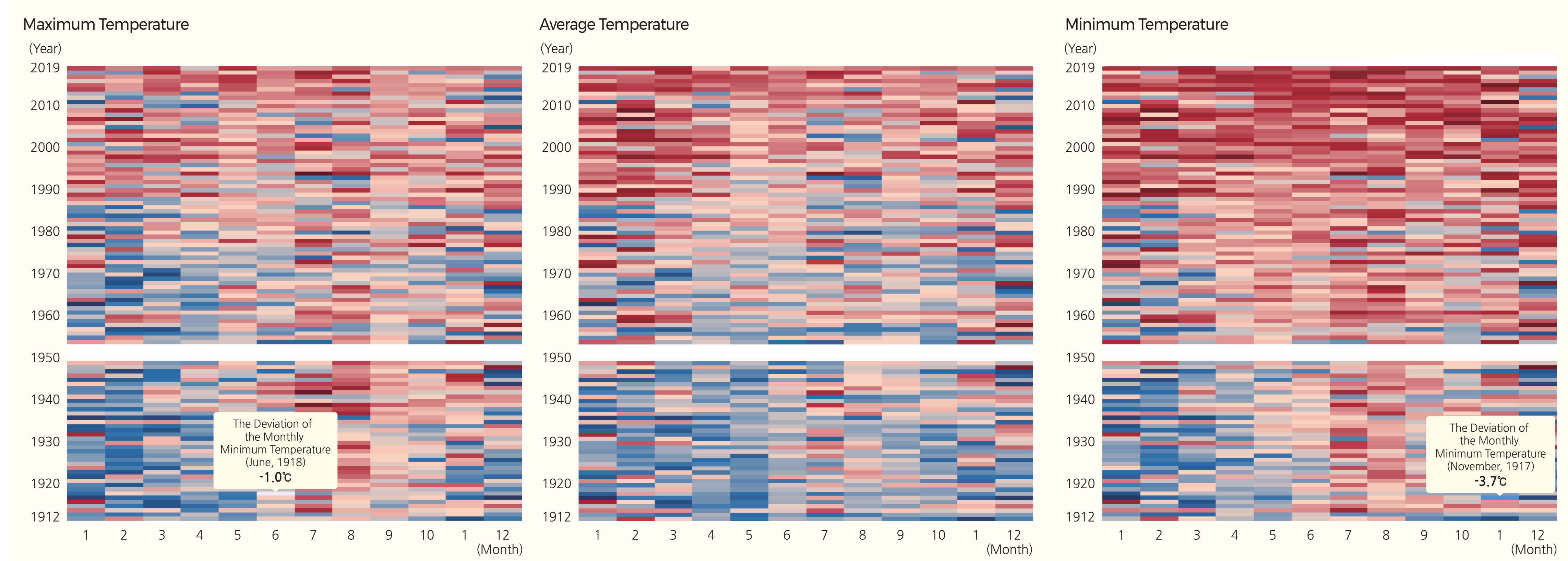
Korea Meteorological Administration (2019)

Change in Annual Mean Precipitation (1973–2019)



Korea Meteorological Administration (2019)

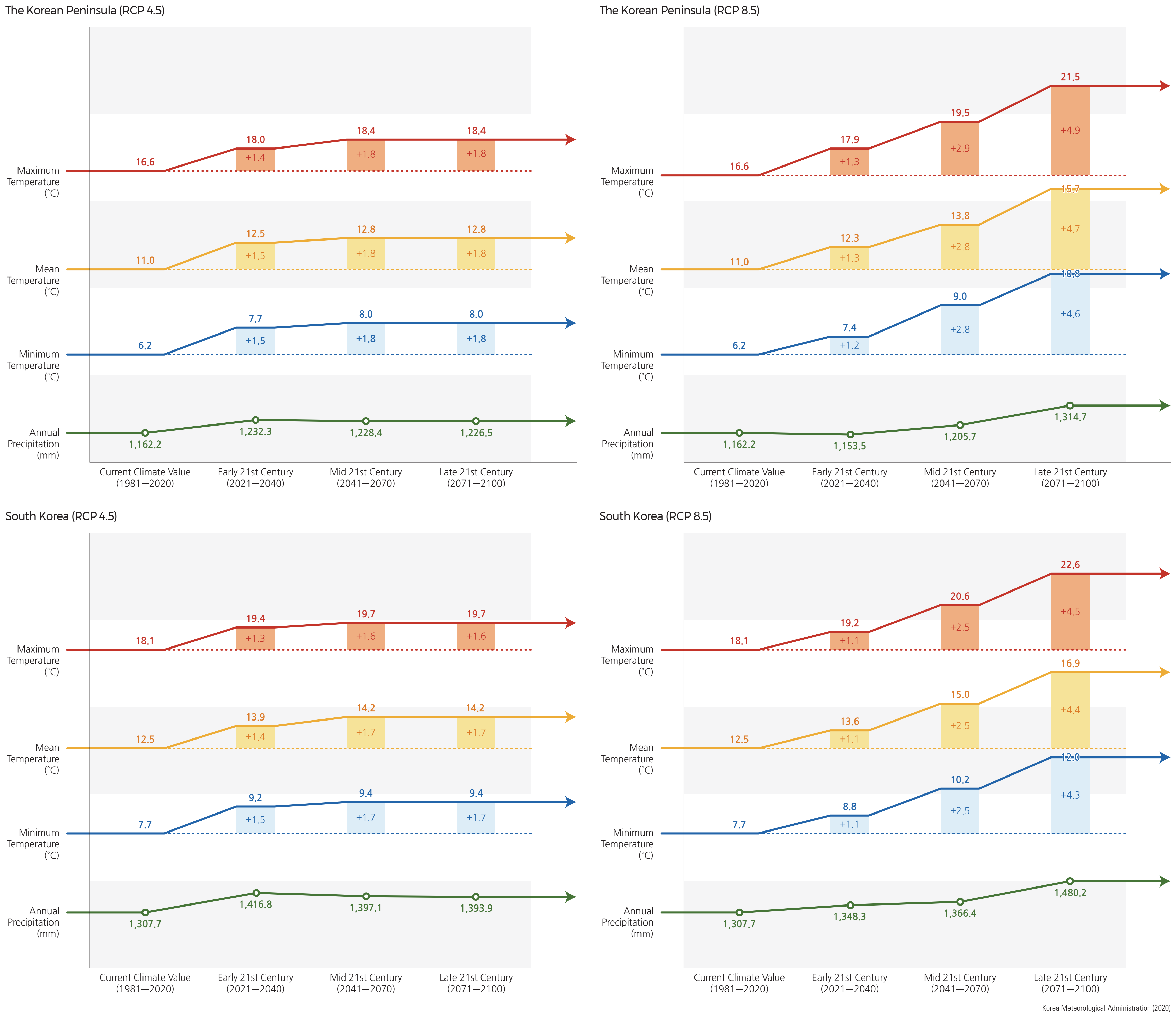
Changes in the Deviation of the Monthly Maximum, Average, and Minimum Temperature in Korea (1912–2019)



* The deviation is the difference between the average for each month and the average of the same month for 108 years (1912–2019). Since 2011, the deviations of the maximum, average, and minimum temperature for each month are larger than those of the 1981–2010 period. The increase in the deviation of the minimum temperature is remarkable as the cooling effect at night weakens.

Korea Meteorological Administration (2019)

Projection of the 21st Century Temperature and Precipitation over the Korean Peninsula under RCP Scenarios



The annual mean temperature of the Korean Peninsula is expected to rise steadily throughout the 21st century. According to the Representative Concentration Pathways (RCP) 2.6 scenario, the increasing trend projected from the current mean temperature (11˚C) in the early 21st century is similar to that in the RCP 8.5 scenario. However, the increasing rate is expected to slow down during the mid-21st century. The annual mean temperature in the late 21st century is projected to be 12.8˚C in the RCP 4.5 scenario, corresponding to the current average temperature in the southeastern coastal region.

According to the RCP 8.5 scenario, the magnitude of the increase in annual mean temperature gets greater after the second half of the 21st century. The annual mean temperature in the late 21st century is projected to be 15.7˚C, corresponding to the current average temperature of Jejudo (15.8˚C).

According to the RCP 2.6 scenario, the increasing rates of the maximum and minimum temperatures are projected to decrease toward the second half of the 21st century. These temperatures will remain the same in the middle and second half of the 21st century. According to the RCP 8.5 scenario, the increasing trends for the maximum and minimum temperatures accelerate toward the late 21st century. The diurnal temperature range will increase as the maximum temperature rises faster than the minimum temperature.

The annual precipitation for the Korean Peninsula is projected to rise until the late 21st century. The RCP 2.6 scenario and the RCP 8.5 scenario expect the annual precipitation in the late 21st century to be 1,226.5 mm and 1,314.7 mm, respectively, corresponding to the current annual precipitation in the interior Chungcheongbuk-do and the western coastal region of the Peninsula.

The annual mean temperature of the Korean Peninsula is projected to continue to increase. According to the RCP 2.6 scenario, the increasing trend in the early 21st century will have a rate similar to that of the RCP 8.5 scenario, but it will slow down over time. The annual mean temperature will remain the same in the middle and second half of the 21st century. The annual mean temperature in the late 21st century is predicted to be 14.2˚C, corresponding to the current value of Geoje. According to the RCP 8.5 scenario, the increasing trend for temperature accelerates from the mid-21st century to the late 21st century. In the scenario, the annual mean temperature in the late 21st century is projected to be 16.9˚C, which exceeds the current annual mean temperature of Seogwipo (16.6˚C). The annual mean maximum and minimum temperatures are also expected to increase steadily until the late 21st century.

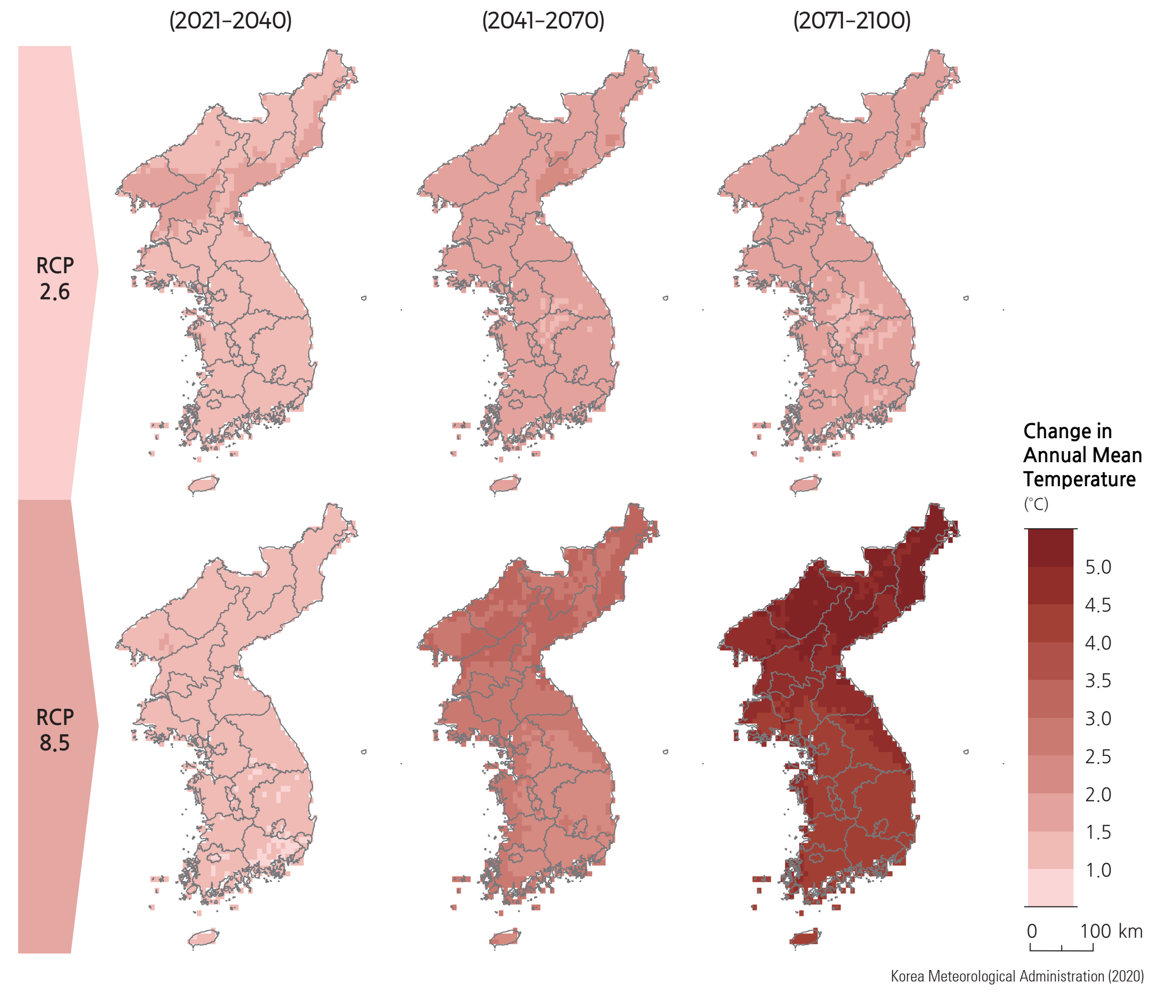
Annual mean precipitation in South Korea in the late 21st century projected in the RCP 2.6 and RCP 8.5 scenarios are 1,393.9 mm and 1,480.2 mm, respectively, which correspond to the current annual precipitation in the interior Jeollanam-do and Gyeongsangnam-do, respectively. The RCP 2.6 scenario shows a greater increasing rate in the annual mean precipitation during the early 21st century than the RCP 8.5 scenario. But the annual mean precipitation will decrease slightly from the mid-21st century. According to the RCP 8.5 scenario, the annual mean precipitation will slightly increase during the early and mid-21st century. Then, the annual mean precipitation appears to increase largely right after the mid-21st century.

According to the Trewartha climate classification, the southern coast of the Korean Peninsula, including Jejudo, is classified as a humid subtropical climate region. As global warming accelerates, the boundary of the subtropical climate region is projected to move gradually to the north. According to the RCP 2.6 scenario, in the late 21st century, Jeollanam-do, Jeollabuk-do, the west coast of Chungcheongnam-do, the west coast of Gyeonggi-do, and Gyeongsangnam-do are expected to belong to subtropical climate regions. The RCP 8.5 scenario predicts South Korea except for the mountainous region in Gangwon-do to be classified as subtropical climate regions in the late 21st century.

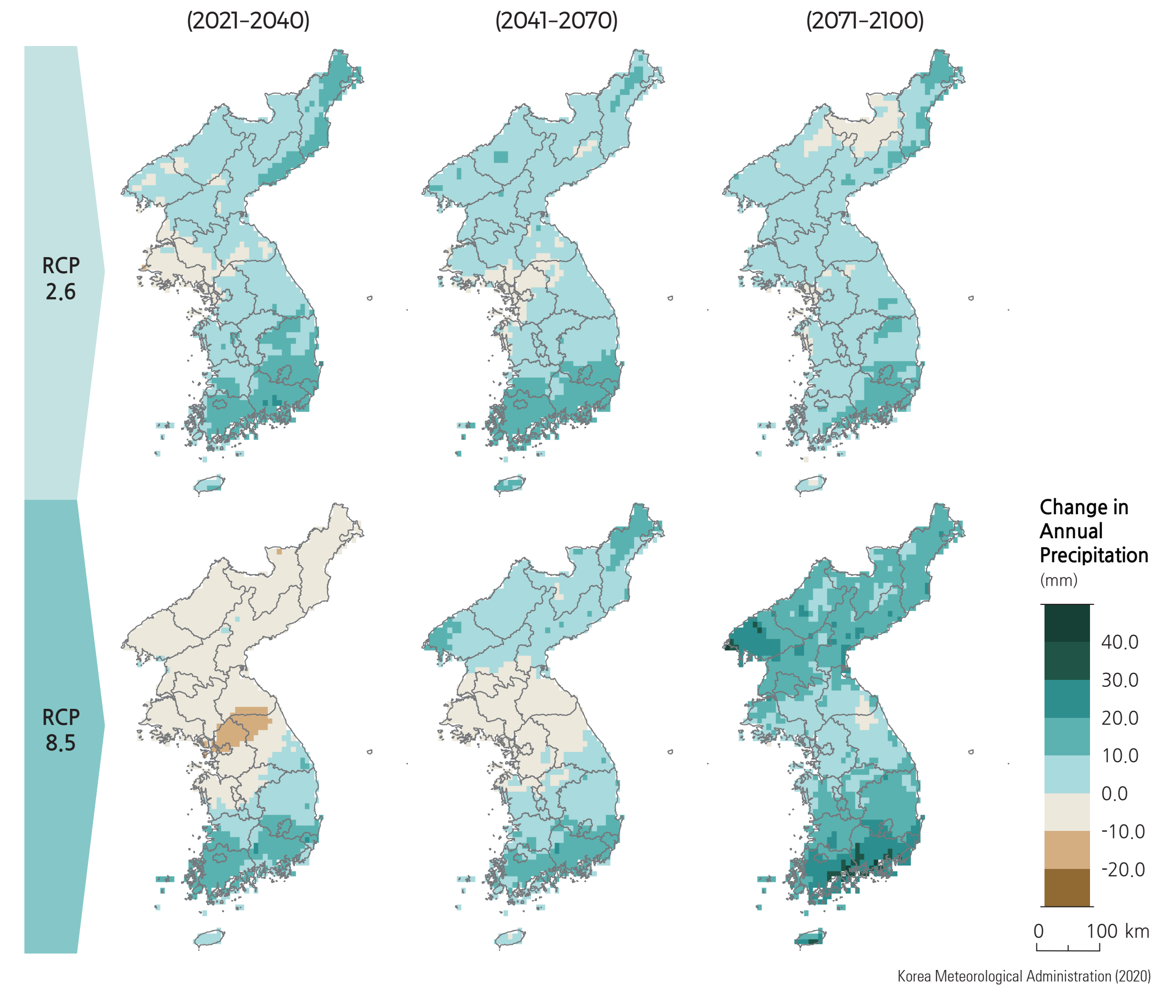
The annual mean number of tropical nights increases substantially in the late 21st century. According to the RCP 2.6 scenario, the annual mean number of tropical nights will increase during the mid-21st century but will slightly decrease in the late 21st century. The RCP 8.5 scenario predicts that most areas of the Peninsula except some major mountain highlands will have a much greater annual number of tropical nights than today in the late 21st century. Afterward, as climate change becomes more intensified, it is anticipated that areas with tropical nights will expand to the mountain highlands.

According to the RCP 2.6 and 8.5 scenarios, the increase in heat wave days will be greatly accelerated in the lowlands. Compared to the RCP 2.6 scenario, the annual number of heat wave days will be further accelerated in the RCP 8.5 scenario. The number of heavy precipitation days is projected to increase in most regions with wide variations depending on time, region, and scenario.

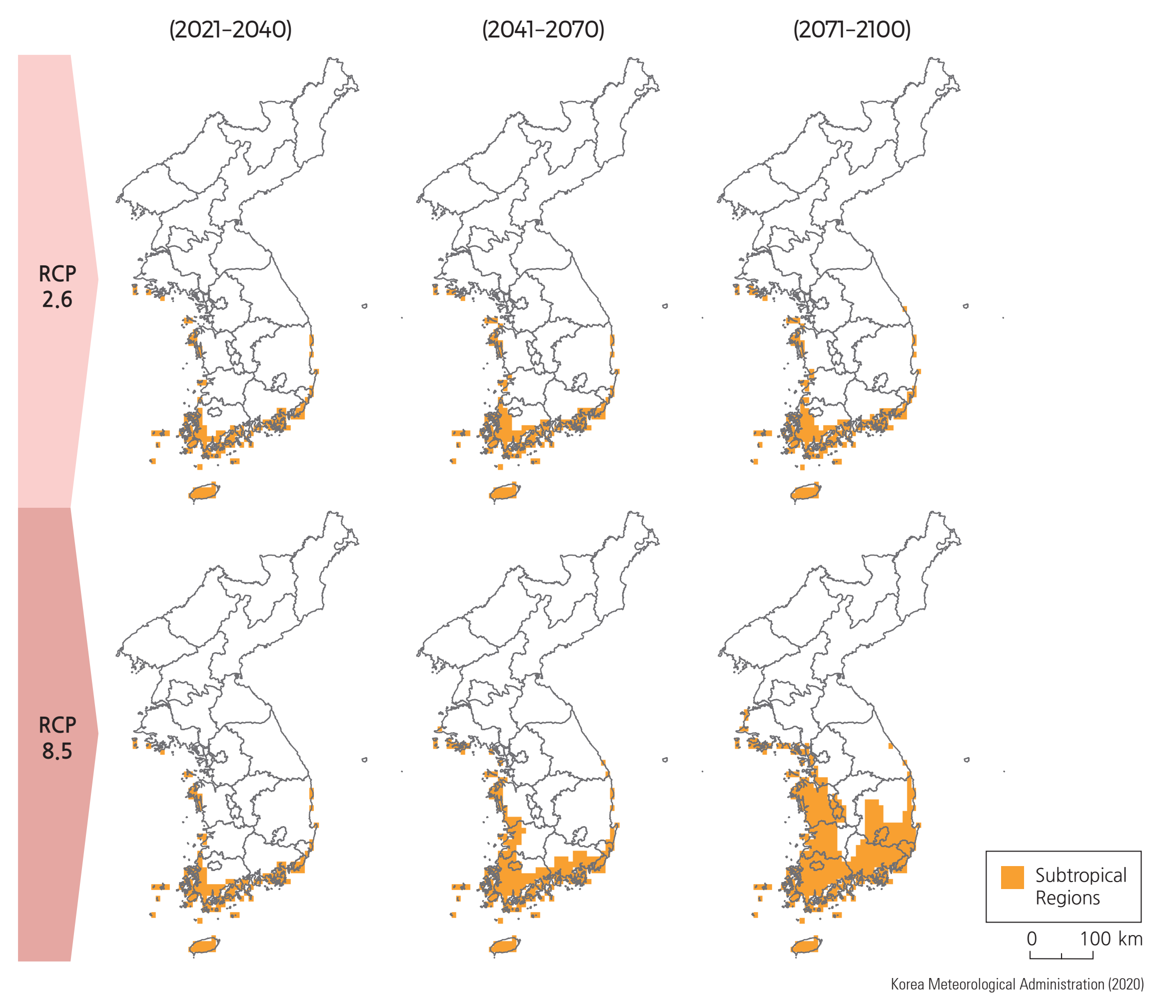
Projection of Temperature over the Korean Peninsula under RCP 2.6/8.5 Scenario



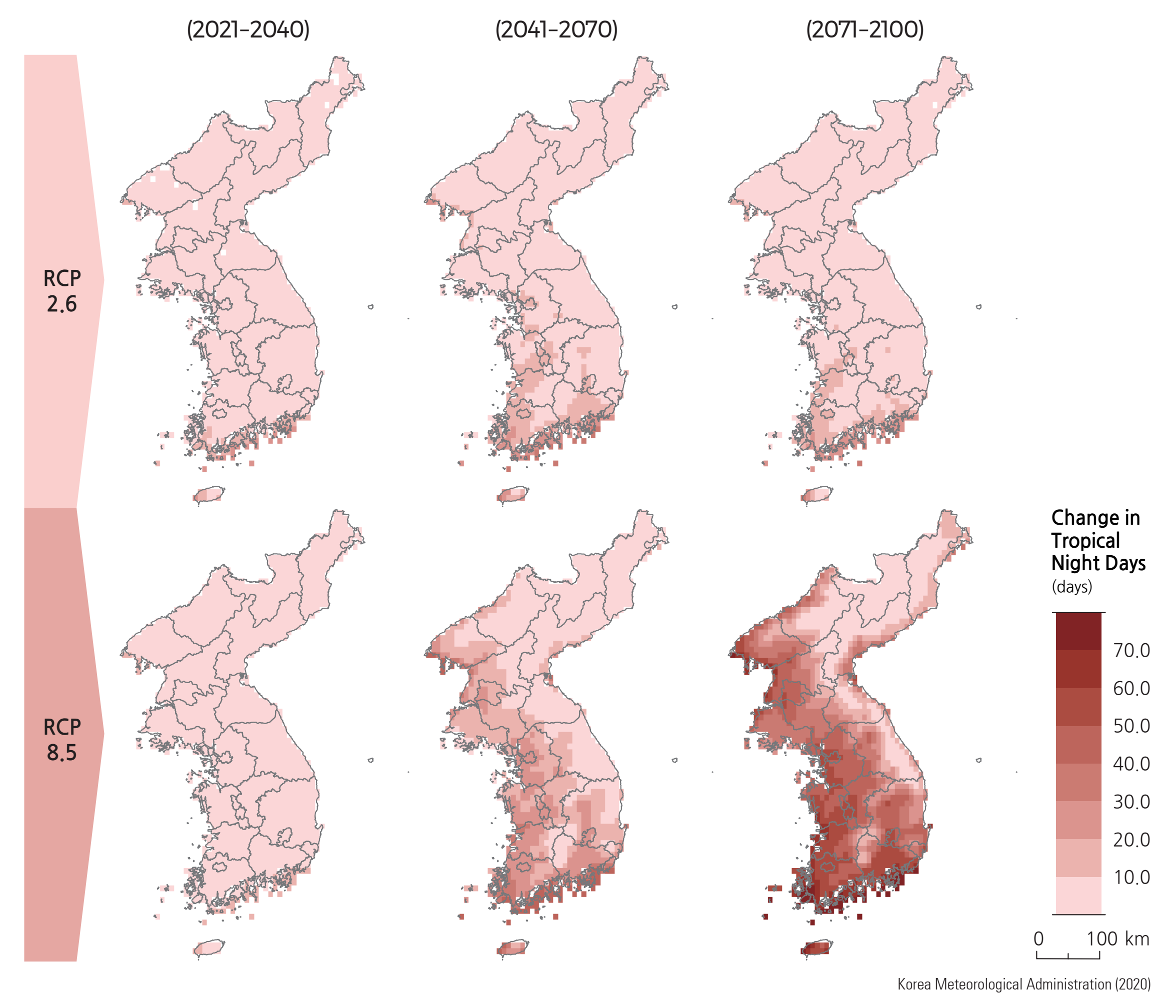
Projection of Precipitation over the Korean Peninsula under RCP 2.6/8.5 Scenario



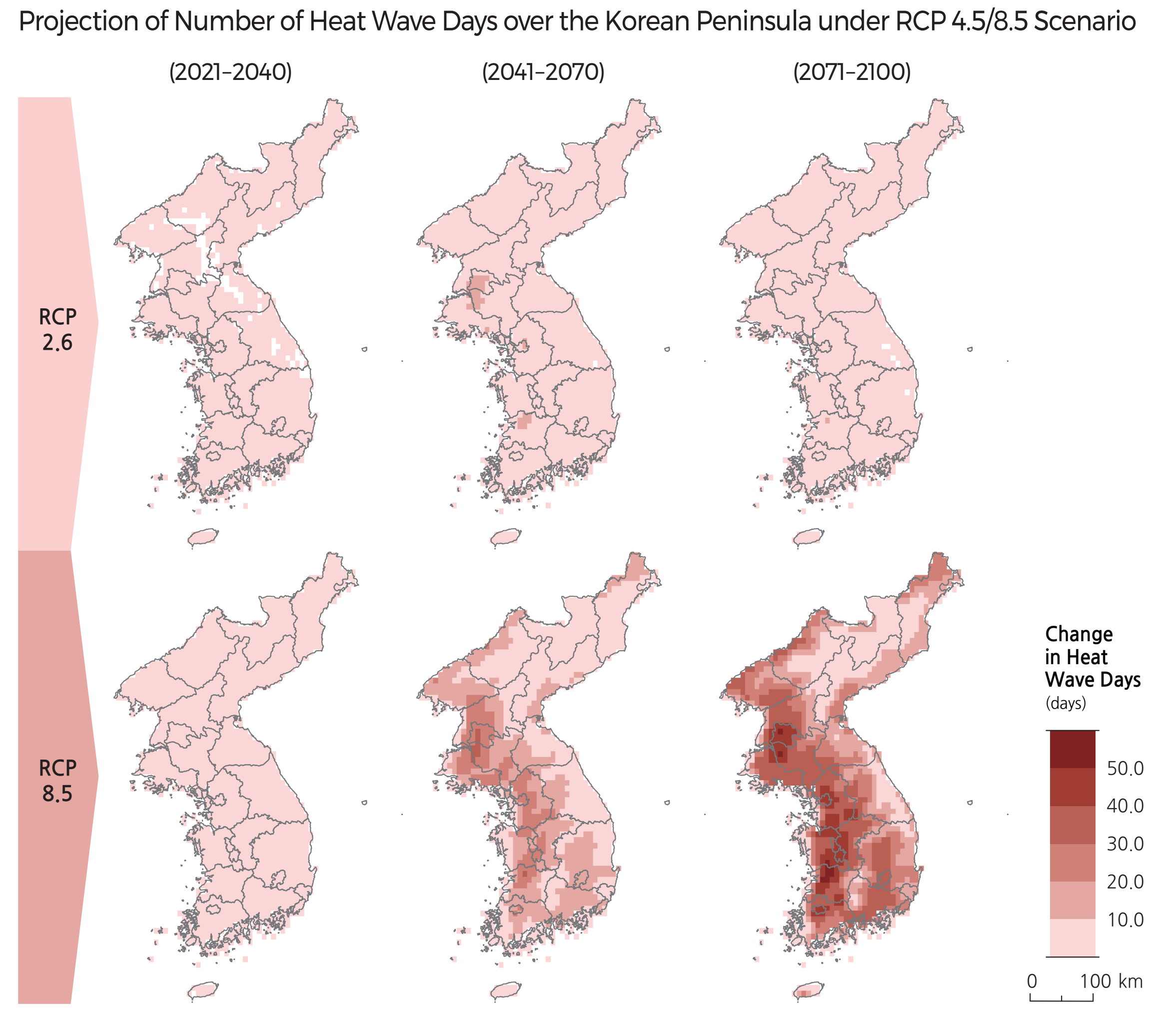
Projection of Subtropical Regions over the Korean Peninsula under RCP 2.6/8.5 Scenario



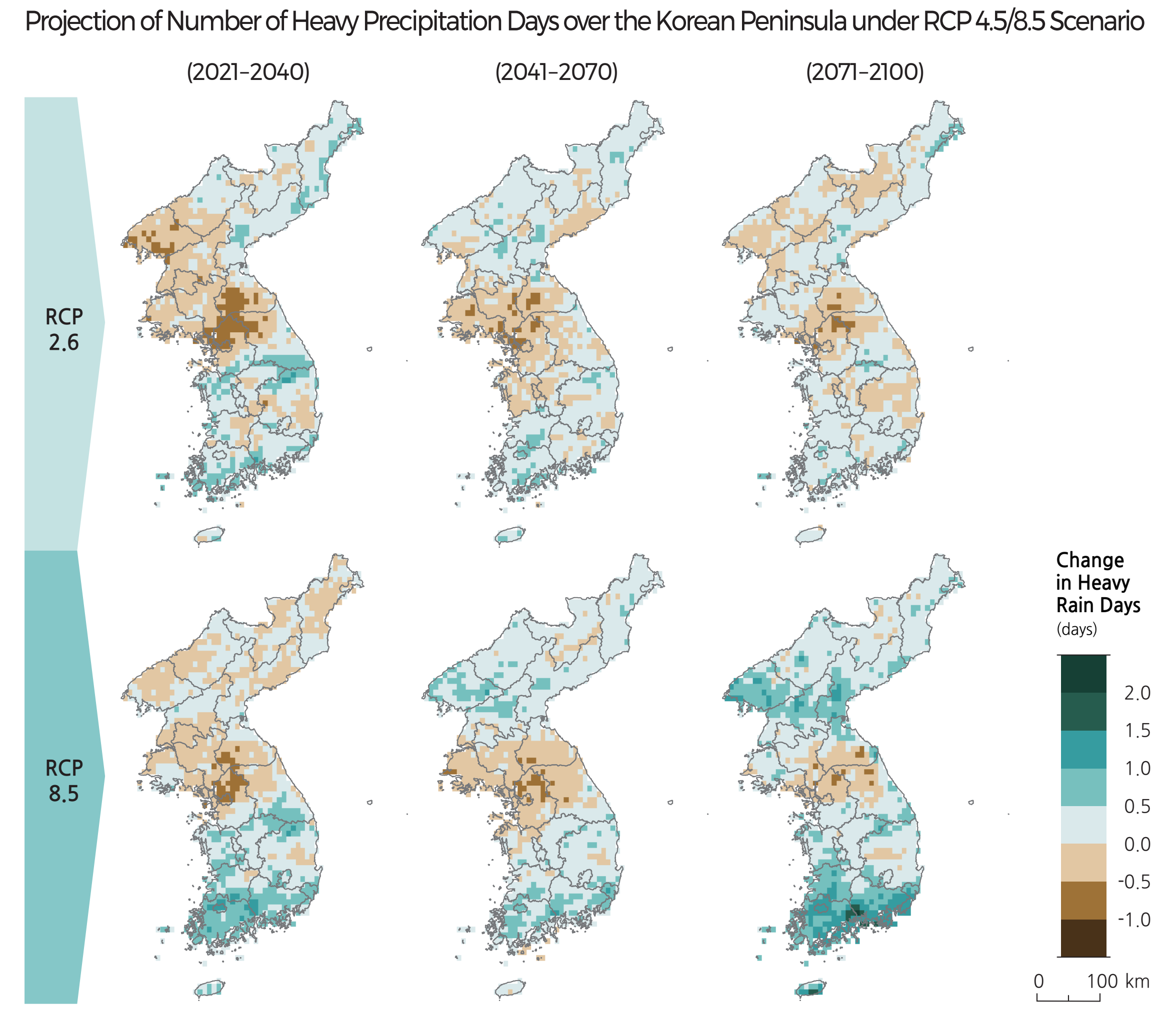
Projection of Number of Tropical Nights over the Korean Peninsula under RCP 2.6/8.5 Scenario



Projection of Number of Heat Wave Days over the Korean Peninsula under RCP 4.5/8.5 Scenario



Projection of Number of Heavy Precipitation Days over the Korean Peninsula under RCP 4.5/8.5 Scenario



International Cooperation on Climate

Korea Meteorological Administration (2019)

Korea carries out multilateral cooperation through international organizations, including the World Meteorological Organization (WMO). WMO is one of the UN agencies specialized in the meteorological field, with international authority over issues regarding atmospheric flow, the interaction between atmosphere and ocean, and climate-hydrology. After the founding of the WMO in 1950, its membership has grown to a total of 191 countries, including Korea, which joined as the 68th country in 1956.

The Korea Meteorological Administration (KMA) has been keeping its status as an executive council member of the WMO since 2007. The executive council is a core executive agency of the WMO, taking charge of supervising main policies such as the coordination of scientific technology and budget allocation. It is composed of head administrators from 37 member countries. The election of KMA's head administrator as an executive council member at the 17th World Meteorological Congress, in Geneva, Switzerland, 2015 was a great achievement for Korea as it raised the nation's status to a third term executive council member country. This could not have been possible without Korea's active participation in diverse international activities in meteorological field, headed by the WMO. As of 2016, the percentage of Korea's financial contribution to the WMO is 2.01%, which ranks Korea as 13th among member countries. The KMA is expected to strengthen its contribution as a part of a leading international meteorological community group.

Also, the KMA was officially designated as a WMO Regional Training Center (RTC) at the 17th World Meteorological Congress due to its international reputation for outstanding performance on education-training sections. Since then, the KMA has been equipped with an enhanced system, enabling Korea to share its long-accumulated expertise, technology, and experience with other members of the WMO. With the system, the KMA is planning to make specialized educational courses in accordance with the WMO education policy to lay a foundation for the RTC operation base.

Another noticeable accomplishment is the election of the first Korean chairman of the IPCC (Intergovernmental Panel on Climate Change), which has unparalleled authority over global climate change negotiations. The IPCC is an agency established jointly by the WMO and the United Nations Environment Programme (UNEP) in 1988 to handle climate change issues. The election of a Korean chairman of the IPCC in 2015 demonstrates the nation's international renown for coping with climate change. The KMA continues to fortify its position and influence in the international meteorological community by actively participating in international activities and training domestic experts.

In 1994, a memorandum of understanding (MOU) on bilateral cooperation in the field of meteorology between the KMA and the China Meteorological Administration (CMA) was made. Since then, MOUs on bilateral cooperation in meteorology were made with the Australian Bureau of Meteorology in 1996, the Russian Federal Service for Hydrometeorology and Environment Monitoring in 1999, and the U.S. National Weather Service in 2000. Also, MOUs with Qatar and Saudi Arabia were made respectively in 2013 and 2015, not only extending KMA's meteorological cooperation with the Middle East countries but also paving the way for expanding the Korean weather industry around the world. As a result, up until 2016, a total of 17 countries and 5 international agencies have made agreements on bilateral cooperation with the KMA.

The KMA has been keeping a strong reciprocal relationship with its partners by holding bilateral cooperation convention in every 2 to 3 years, operating working groups, and dispatching experts. In addition, the KMA is promoting cooperation with developed countries, including the US and the UK, to acquire state-of-the-art technologies such as next-generation meteorological satellite technology, the introduction of the Unified Model, and operational technology. Moreover, the KMA promotes a cooperation system with developing countries such as Vietnam and Mongolia, with the ODA program and capacity development program operation as the central figures.

The capacity of ODA began to develop in 1998 through the educational programs of the KMA and KOICA. Since then, there have been training courses such as a weather forecast training course for about 700 meteorological trainees from 69 countries. These courses contribute greatly to the development of the capability to predict meteorological disasters in developing countries by cultivating staff for meteorological administration with abilities to utilize radar, acquire the advanced technique of weather forecasting, and understand and utilize numerical forecasting.

The KMA actively participates in the technical committees of the World Meteorological Organization (WMO), which plan and discuss weather-related technologies and policies. The KMA held the Commission for Basic Systems (CBS) in 2007, Commission for Atmospheric Sciences (CAS) in 2009, the World Meteorological Organization/Intergovernmental Oceanographic Commission (WMO/IOC) Commission for Oceanography and Oceanography and the Oceanography and Marine Meteorology (JCOMM) during the Yeosu Expo in 2012, and the general meeting of the Commission for Agricultural Meteorology (CAgM) in 2018 in Korea. The KMA operates WMO's Global Information System Center (GISC-Seoul), Lead Center for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME), The Subseasonal-to-Seasonal Prediction Project International Coordination Office (S2S-ICO), and Regional Training Center (RTC-Korea) in Korea. Through these engagements, the KMA actively participates in sharing climate forecast information and real-time collection and exchange of weather data around the world and leads the capacity development of WMO member countries, centering on the Asian Pacific region.

The KMA, as a governing body of the Intergovernmental Panel on Climate Change (IPCC), has formed a government delegation composed of related ministries and has attended the IPCC General Meeting 2-3 times a year from the 11th IPCC General Meeting in 1995 to the present. The KMA leads Korea's participation in the IPCC by holding the 48th IPCC General Meeting in October 2018 in Incheon, Korea, and by supporting many domestic experts in the IPCC activities. A Korean, Dr. Hoesung Lee, was first elected as a chair of the IPCC at the 42nd IPCC General Assembly in October 2015. He leads the IPCC until 2023, when the 6th Assessment Report (AR6) is finalized. In addition, the KMA is jointly participating with relevant government ministries in intergovernmental negotiations of the United Nations Framework Convention on Climate Change (UNFCCC) to stabilize greenhouse gas concentrations to the level that can prevent changes in the climate system caused by greenhouse gases. The KMA also promotes the following projects for developing countries: the construction project of an automatic weather station system, the construction project of a system for receiving and analyzing satellite signals of the Cheonlian Satellite 2A, and the construction project of an integrated platform for monitoring and forecasting typhoons.

- The construction project of an automatic weather station system aims to improve forecast accuracy, respond to climate change, and reduce meteorological disasters through real-time weather observation data collection by constructing an automatic weather observation system in an unobserved area within the recipient country. The project was completed in Vietnam (2014–2016), Mongolia (2017–2019), and Myanmar (2017–2019), and is currently in progress in Cambodia (2019–2022).
- The construction project of a system for receiving and analyzing satellite signals of the Cheonlian Satellite 2A aims to build the Cheonlian Satellite 2A reception and analysis system in the recipient countries and to strengthen their abilities to operate the system and to utilize satellite data. The KMA dispatches experts to support related technology. This project is currently in progress in Bangladesh (2019–2021) and Cambodia (2020–2023). The KMA expects these countries to use high-definition satellite images to alleviate meteorological disasters and strengthen their capabilities to respond to meteorological disasters.
- The construction project of an integrated platform for monitoring and forecasting typhoons aims to improve the accuracy of typhoon forecasts and to prevent typhoon-related disasters by establishing the Cheonlian Satellite 2A reception and analysis system and field operation of the Typhoon Operation System (TOS). This project is currently in progress in Laos (2020–2030).

Building the capacity of ODA began in 2003 in cooperation with the KOICA and WMO. So far, about 20 programs, including modernizing the Mongolian aviation weather, constructing the early warning system to mitigate the disasters in the Philippines, advancing the Vietnamese meteorological disaster monitoring system, and establishing a master plan for the advancement in meteorological technology of Myanmar, have been completed. Supporting developing countries in their effort to advance in meteorological technology through the installation of large-scale systems helps promote domestic meteorological technology. It has contributed to increasing the export of Korea's meteorological brands and domestic meteorological enterprises.

World Friend Senior Expert Dispatch Program, conducted by the Ministry of Science, ICT and Future Planning and carried out by the National IT Industry Promotion Agency, is a program dispatching senior experts to developing countries to support and provide advice regarding meteorological technology. Teams of meteorological advisors have been sent 19 times to countries such as Vietnam, Mongolia, Kenya, and Uzbekistan from 2010 to 2016. With their efforts, the KMA was able to identify demand in meteorological technology in those countries and has consolidated its international status.

Establishing Global Leadership

- Korean candidate elected member of the WMO Executive Council
- KMA approved by the WMO to establish the WMO Lead Center for Long-Range Forecast Multi-Model Ensemble in Korea
- KMA approved by the WMO to establish the Global Information System Center (GISC) in Seoul
- KMA appointed government department representing Korea for the Intergovernmental Panel on Climate Change (IPCC)
- KMA approved by the WMO to establish the Global Atmosphere Watch (GAW) World Calibration Center for SF6 (Sulfur Hexafluoride)
- Korean candidate elected to the vice-presidency of the WMO Commission for Atmospheric Sciences (CAS)
- KMA has implemented joint research projects with the international community.

Infrastructure Support Program for Developing Countries

- The Construction of Korea-China Joint Observation Network (2003–2008)
- The Construction of Sri Lanka Meteorological Administration PC Cluster Numerical Forecasting System (2005)
- The Construction of the Philippines' Disaster Prevention Early Warning System
- The Modernization of Mongolian Meteorological Administration Climate Data Restoration and Management (2008–2009)
- The Establishment of East Africa Region Climate Center (East Africa Climate Prediction Application Center 2009–2012)
- The Construction of Vietnam Typhoon Analysis and Forecast System (2010–2012)
- The Construction of Sri Lanka Satellite Data Reception System (2010–2012)
- The Modernization of Vietnam Meteorological Disaster Monitoring System (2014–2016)
- The Establishment of Myanmar Meteorological Advancement Master Plan (2015–2016)

Numerical Forecasting Data Support

- The Atmospheric Pressure 500 hPa Geopotential Height Field, 200 hPa Isotach, and Other; Forecast Weather Chart
- 30 Countries/358 Cities Prediction Data for Temperature, Wind, and Precipitation

Supporting Developing Countries Projects and Invitation & Training Programs

- Education Program for Foreign Forecasters (1998–2005, 2014–)
- Education Program for the Operation of the Weather Radar and Data Utilization (2012–)
- KMA built the Korea-China Joint SDS (Sand & Dust Storm) Monitoring Network (2003–2006, 2006–2008, 2014–2018)
- KMA worked out the master plan for the advancement of the national meteorological system in Myanmar (2015–2016)
- KMA modernized the meteorological disaster monitoring system of Myanmar (2017–2019)
- KMA modernized the meteorological disaster monitoring system of Vietnam (2014–2016)
- KMA established the automatic weather observation system of Mongolia (2017–2019)

Educational Training Program for Developing Countries

- Foreigner Forecaster Course (1998–)
- Korea ASEAN Training Workshop (2002–2011)
- Meteorological Service Enhancement Course using Information Communication Technology (ICT) (2006–)
- Climate Prediction Experts Ability Cultivation Course (2006–2008)
- Numerical Forecast Training (2007–)
- COMS Satellite Data Analysis Training Course (2007–)
- Africa Disaster Management Ability Cultivation Course (2009–2012)
- Korea-China Asian Dust Joint Observation Network Operator Education (2010–)
- Weather Radar Operation and Data Utility Course (2012–)

Memorandum of Understanding (MOU) Signing

- As of August 2016, MOU signed with 17 Countries and Five International Agencies.
- Numerical Forecasting, Experts Exchange, Education Enhancement, Earthquake, Asian Dust, Satellite, and Other

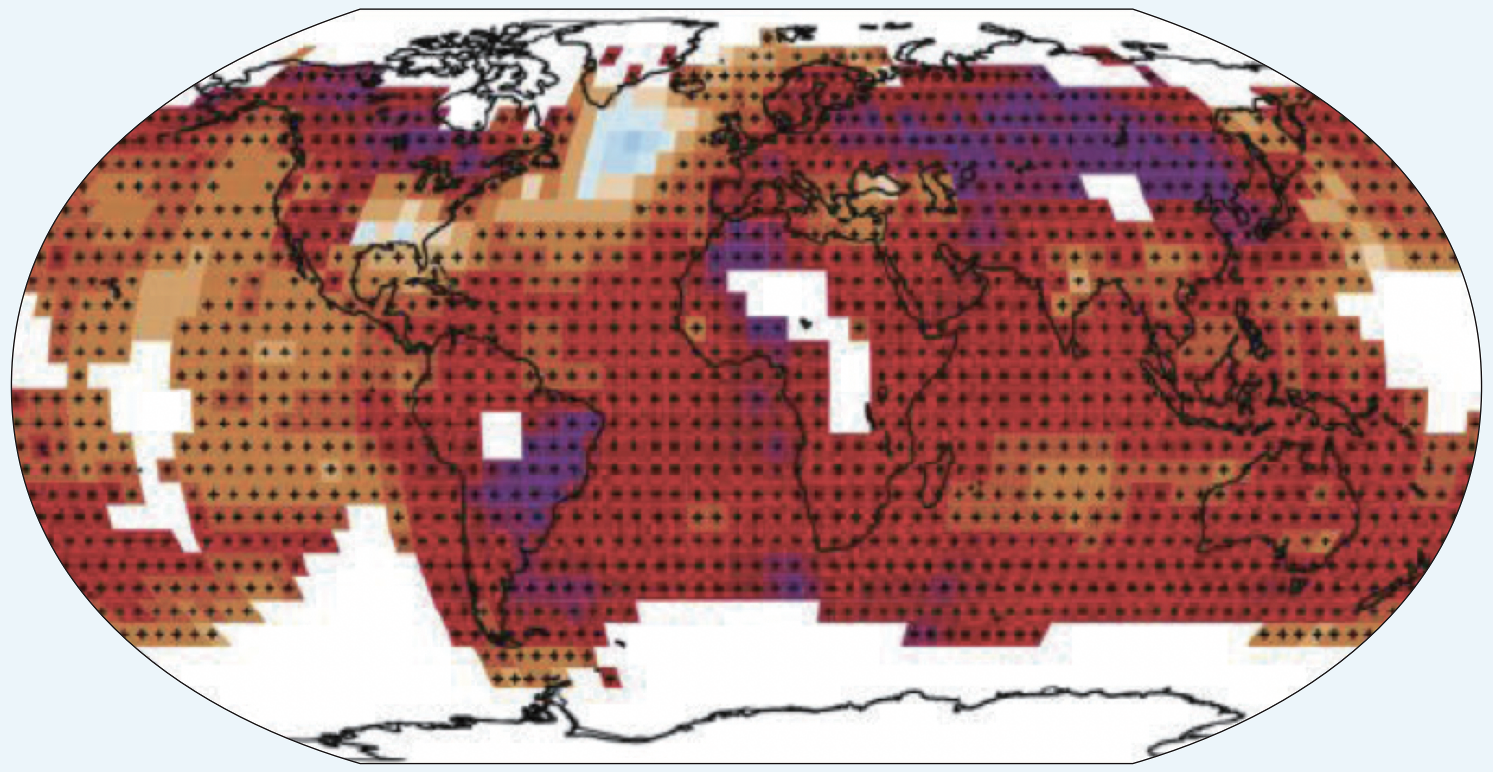
Overseas Dispatch

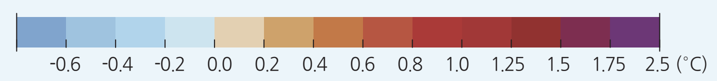
- Switzerland WMO Asia Southwestern Pacific Region Office
- King Sejong Station, Antarctica
- Qatar Meteorological Administration
- Meteorological Advisor Dispatch: Kenya, Mongolia, Vietnam, Malaysia, Senegal, Uzbekistan, Rwanda

Current Status of Global Climate Change

Changes of the Global Temperature and Precipitation

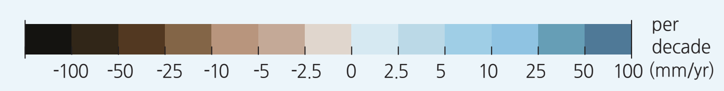
Observed Change of the Global Surface Temperature (1901–2012)



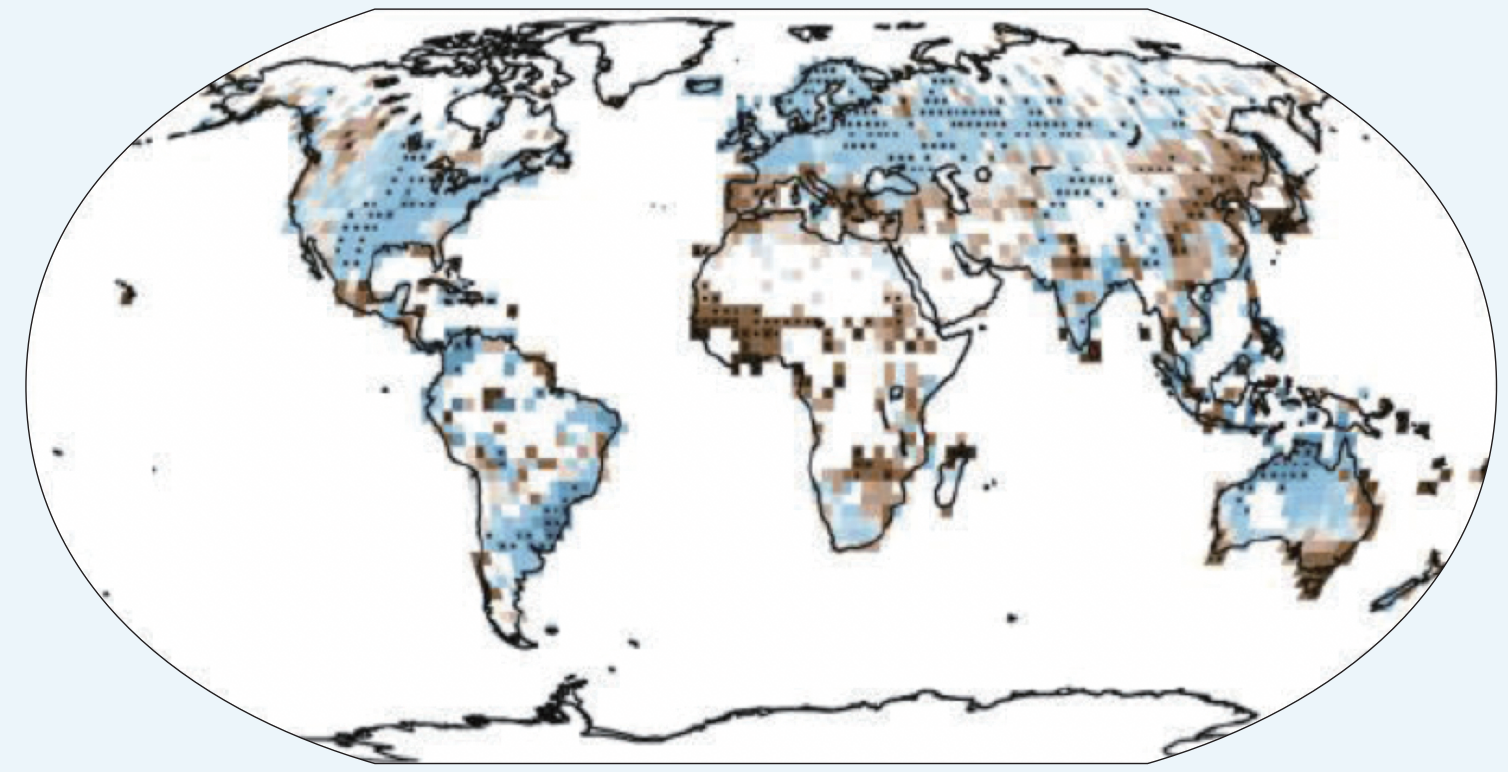


The warming of all climate systems is obvious. The atmosphere and ocean have warmed, the amount of snow and glaciers has decreased, sea levels have risen, and greenhouse gas concentrations have increased. Many of the changes observed since 1950 have been unprecedented. The global average temperature has risen noticeably over the past 130 years (1880–2012) at a rate of change of 0.062±0.012°C/10 years. The warming trend includes several natural variabilities at various time scales, so the rate of temperature change varies with time period. The observed global average temperature over the 10 years of 2006–2015 is 0.87°C (0.75–0.99°C) higher than the average between 1850 and 1900, and the rate of temperature change has increased recently. The average temperature in Korea has risen noticeably at a rate of 0.18°C /10 years, based on the average of the six locations (Seoul, Incheon, Gangneung, Daegu, Busan, and Mokpo) where observation data existed for 106 years (1912–2017). The rate of change in the global average temperature (land) based during the same period was 0.14°C/10 years, showing a higher rate of temperature increase in Korea than the global average. The temperature rise is common throughout the Korean Peninsula but is more pronounced in the metropolitan area and inland areas.

It is difficult to identify trends in precipitation because it is highly volatile. Global precipitation on land increased from 1901 to 2008. However, the precipitation data show different precipitation patterns from 1951 to 2008, and the trend of increase is unclear. On the other hand, all precipitation data reveal an increase in precipitation in the mid-latitude (30–60°N) of the northern hemisphere, where Korea is located, during the periods 1901–2008 and 1951–2008. The increase in precipitation in the 1973–2012 period is relatively large compared to the 1913–2012 period. At other latitudes, the trend of long-term changes in precipitation is not clear.



Observed Change of the Annual Precipitation on Land (1951–2010)

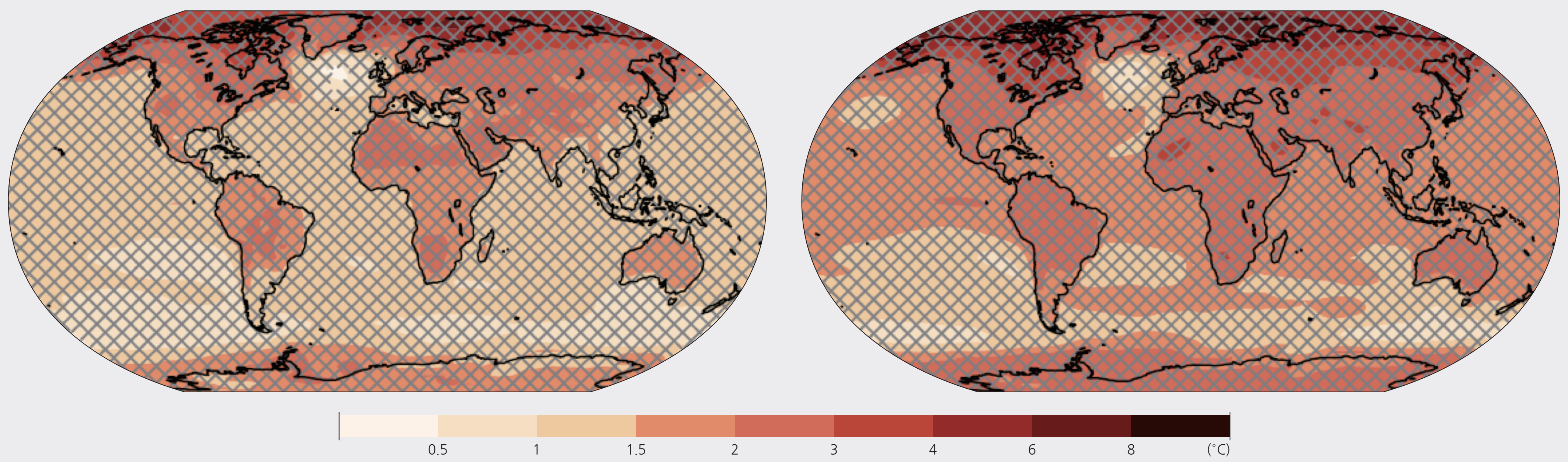


IPCC AR5 (2013)

Forecasts of the Global Temperature and Precipitation

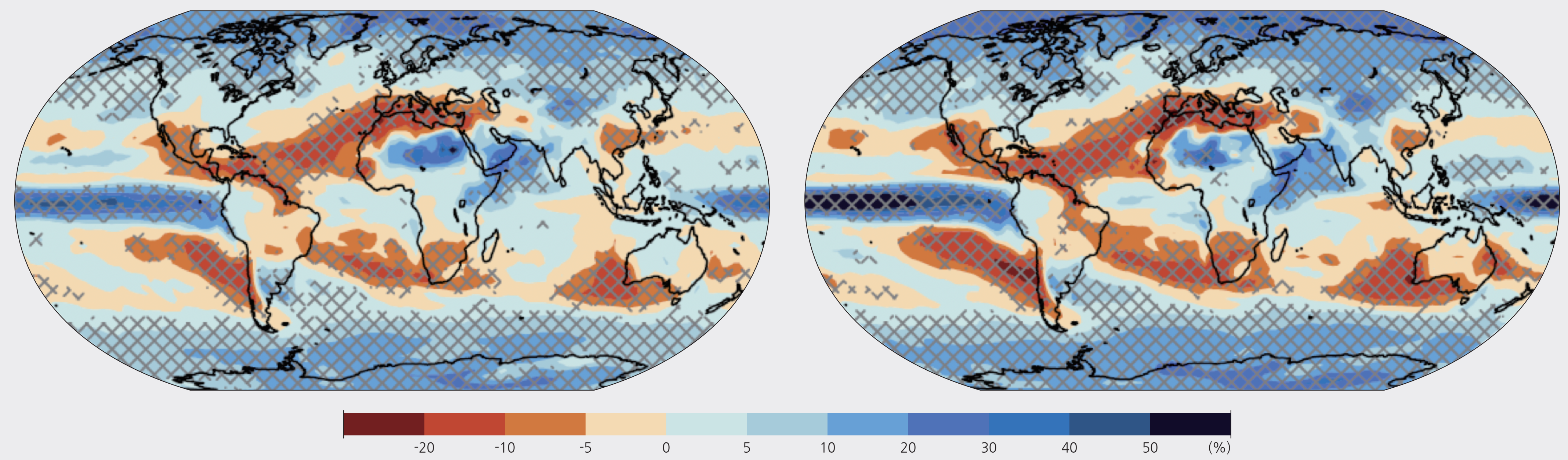
Mean Temperature Change at 1.5°C GMST Warming

Mean Temperature Change at 2.0°C GMST Warming



Mean Precipitation Change at 1.5°C GMST Warming

Mean Precipitation Change at 2.0°C GMST Warming

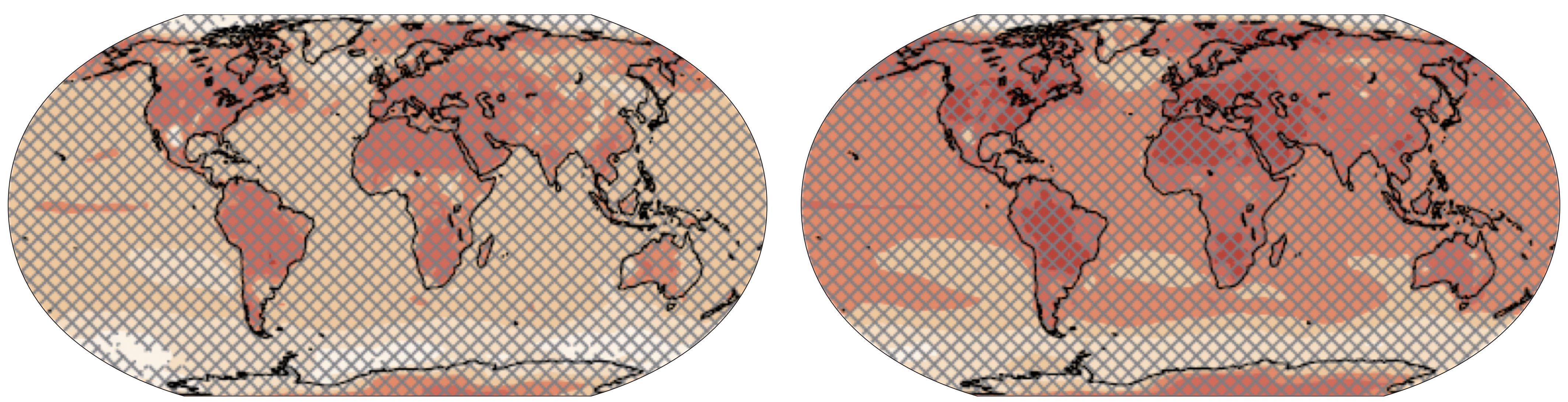


IPCC AR5 (2013)

Forecasts of the Global Hottest Days and Coldest Nights

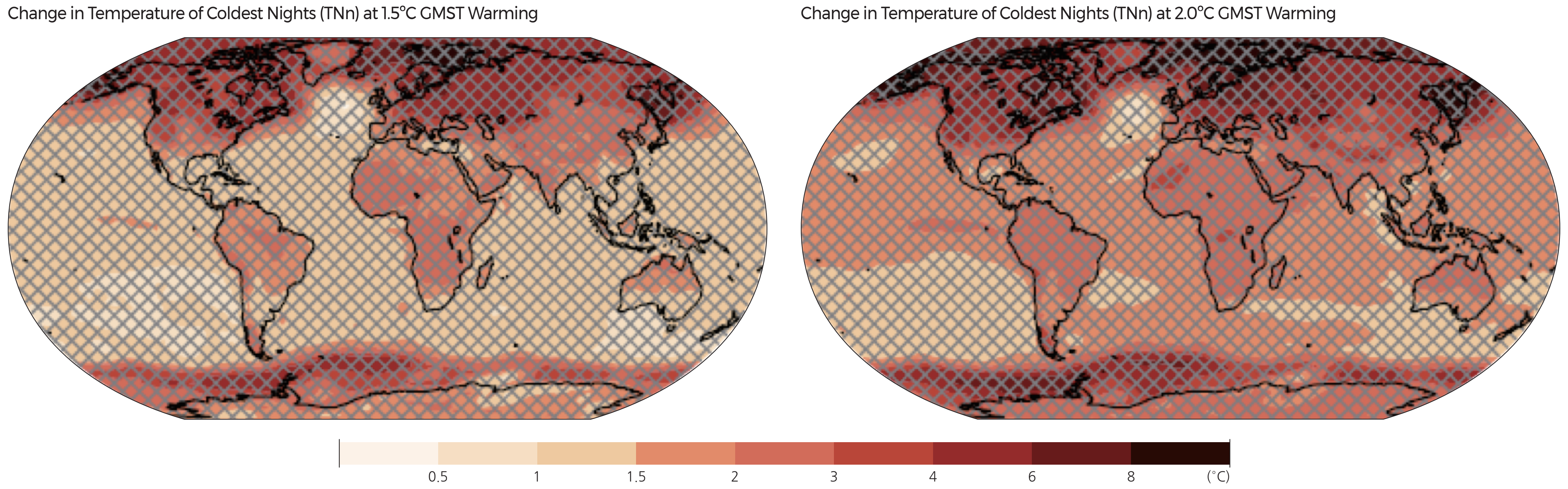
Change in Temperature of Hottest Days (TXx) at 1.5°C GMST Warming

Change in Temperature of Hottest Days (TXx) at 2.0°C GMST Warming



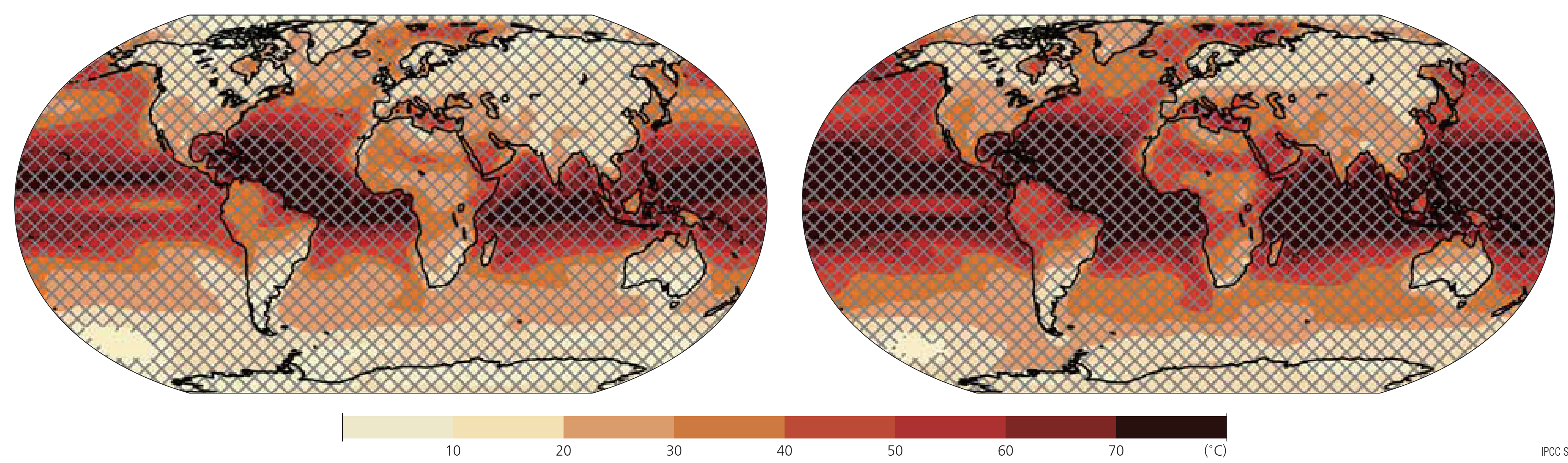
Change in Temperature of Coldest Nights (TNn) at 1.5°C GMST Warming

Change in Temperature of Coldest Nights (TNn) at 2.0°C GMST Warming



Change in Number of Hot Days (NHD) at 1.5°C GMST Warming

Change in Number of Hot Days (NHD) at 2.0°C GMST Warming



IPCC SR15 (2018)

When the global temperature rises by 1.5°C or 2.0°C compared to the pre-industrial period, the average temperature increases in most regions. On the other hand, the frequency and intensity of heavy rainfall and precipitation increase in some regions, while the frequency and intensity of drought also increase in other regions. Compared to the 1.5°C rises in the global temperature, the average temperature is expected to be higher in most continental regions, including East Asia, and 2–3 times higher than the global surface temperature in some regions, when the global temperature rises by 2.0°C.

Compared to the 1.5°C rises in the global temperature, the global precipitation is projected to increase further, and the risk from drought and lack of precipitation in some regions is projected to be higher, when the global temperature rises by 2.0°C. If the global average temperature rises by 1.5°C compared to the pre-industrial period (1861–1880), the monthly average, maximum, and minimum temperatures are expected to rise by 0.8°C (±0.11), 0.89°C (±0.16), and 0.91°C (±0.12), respectively, compared to the current period (2006–2015). These changes in temperatures in Korea are similar to the changes in global temperature. The increase in precipitation in Korea is expected to be slightly higher than the increase in global precipitation, resulting in an increase of 62.26 mm (±27.09).

If the global average temperature rises by 1.5°C compared to the pre-industrial period (1861–1880), it is predicted that the frequency of extreme, high temperatures will increase in most regions due to temperature rise, and the frequency of heavy rain and drought will increase in some regions. Such an increase in abnormal climate is expected to intensify as the global average temperature increases.

The frequency of extreme temperatures is projected to increase more than the global average. When the global average temperature rises by 1.5°C or 2.0°C, extreme high temperatures in mid-latitudes, including the Korean Peninsula and East Asia, are expected to rise from 3°C to 4°C, respectively, and extreme low temperatures at high latitudes are expected to increase from 4.5°C to 6.9°C, respectively. The frequency of extreme hot days increases in most land areas and is projected to increase significantly in the tropics.