Climate Characteristics of Japan's Warmest-ever Winter

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https://ds.data.jma.go.jp/tcc/tcc

Summary

- Winter 2019/20 (December to February) was the warmest on record for Japan, with an average temperature anomaly of 1.66°C above normal.
- The Japan Meteorological Agency and its Advisory Panel on Extreme Climatic Events[1] attributed this extreme to a persistent northward meandering of the subtropical jet stream over and around Japan. The Arctic Oscillation in its positive phase also dominated atmospheric circulation over the Northern Hemisphere from January onward, resulting in a lower incidence of typical surface pressure patterns associated with the East Asian Winter Monsoon in Japan and weaker-than-normal southward cold-air flow over the country. Global warming may also have contributed to these exceptionally warm winter conditions.

1. Climate conditions

In winter 2019/20, there were fewer days with typical East Asian Winter Monsoon (EAWM) pressure patterns around Japan (featuring the Siberian High and the Aleutian Low), and southward cold-air flow over Japan was weaker than normal. These conditions led to significantly above-normal temperatures all over Japan (Figures 1 and 2). The nation's seasonal mean temperature anomaly for the winter period was 1.66°C above normal (i.e., above the 30-year average from 1981 to 2010), making it the warmest since winter 1897/98 (December to February) (Figure 3 (a) and Table 1). In particular, seasonal mean temperature anomalies for eastern and western Japan were +2.2 and +2.0°C, respectively, which were the highest since winter 1946/47 (December to February) (Table 2). A total of 111 among 153 meteorological stations nationwide reported record-high mean temperatures for the season.

Japan also experienced significantly lower snowfall than usual in winter 2019/20 (Figures 4, 5). On the Sea of Japan side of northern and eastern parts of the country in particular, cumulative snowfall amounts were the lowest for the season since winter 1961/62 (December to February) at 44% and 7% of the normal, respectively (Table 3).

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[1] The JMA Advisory Panel, consisting of prominent experts on climate science from universities and research institutes, was established in June 2007 by JMA to investigate extreme climate events based on up-to-date information and findings. The current chair is Prof. Hisashi Nakamura from the University of Tokyo. See TCC News No. 56 for more details on the outline and the framework of the Panel.

Temperatures remained above normal in March 2020, with the highest national average for the month since 1898. Cumulative snowfall on the Sea of Japan side was exceptionally low.

Many areas of world, such as Europe, Russia and the southeastern part of North America, also saw above-normal temperatures for the season (Figure 6). The global average surface temperature anomaly was the second-highest for the season since winter 1891/92 at +0.57°C (December to February) (Figure 3 (b) and Table 1).

2. Characteristics of atmospheric circulation associated with the mild winter conditions

The record-warm winter climate conditions observed are primarily attributed to a weaker-than-normal Siberian High and Aleutian Low throughout the season, bringing fewer days with typical EAWM pressure patterns over and around Japan and consequent weaker-than-normal southward cold-air flow over the country.

Characteristics of associated atmospheric circulation (Figure 7):

- The subtropical jet stream meandered northward over and around Japan. This may be attributable to southward meandering of the jet stream over southern China (upstream of Japan) in response to suppressed convective activity over and around the Maritime Continent (Figure 8).
    - Subtropical jet stream meandering was also seen throughout Eurasia. The jet stream was shifted northward over the Arabian Peninsula due to enhanced convective activity over the western part of the Indian Ocean, reflecting higher-than-normal sea surface temperatures (SSTs) in the region. From January 2020 onward, the meander partly originated from the northward meandering of the jet stream over Europe.
        - The higher-than normal SSTs in the western Indian Ocean were likely associated with a positive Indian Ocean Dipole (Saji, 1999) that persisted from summer to December 2019.
    - The suppressed convection observed over the Maritime continent is considered to be linked to active convection around the equatorial date line, where SSTs were higher than normal.
- From January 2020 onward, the positive phase of the Arctic Oscillation (AO) pattern (Thompson and Wallace, 1998) was dominant in the Northern Hemisphere (Figure 9). In association, the polar-front jet stream was clear in northern Eurasia in such a way that the polar air mass was confined to within the high latitudes, which is linked with weak cold-air mass accumulation over a broad area from Europe to eastern Siberia. These conditions are considered to have been favorable for weakening southward cold-air intrusion from Siberia to Japan.
- In addition to the above effects from meandering jet streams and a positive AO, a

long-term trend of surface air temperature increase due to global warming and exceptionally higher-than-normal tropospheric temperatures throughout the mid-latitudes in the Northern Hemisphere are also considered to have contributed to these extremely warm winter conditions.

  - On a longer time scale, the annual average surface temperature over the globe and Japan has been rising at rates of about 0.79 and 1.19°C per century, respectively.
  - The high tropospheric temperatures observed throughout the mid-latitudes in the Northern Hemisphere are partly attributed to the presence of a clear polar front jet stream associated with the positive AO, which helped to keep the cold-air mass within the polar region.

- Most extratropical cyclones in and around Japan during this winter period took a course over or to the south of the Japanese mainland with little or no influence over the northern part of the country. This led to less snowfall than usual on the nation's Sea of Japan side, especially to the north.
- The persistent positive AO observed around March 2020 is considered a factor in the record-high temperatures recorded for the month in Japan.

Reference

Saji, N. H. et al., 1999: A dipole mode in the tropical Indian Ocean. *Nature* **401** (6751), 360–3. doi:10.1038/43854.

Thompson, D. W. J, and J. M. Wallace, 1998: The Arctic Oscillation signature in the wintertime geopotential height and temperature fields. *Geophys. Res. Lett.*, **25**, 1297-1300.

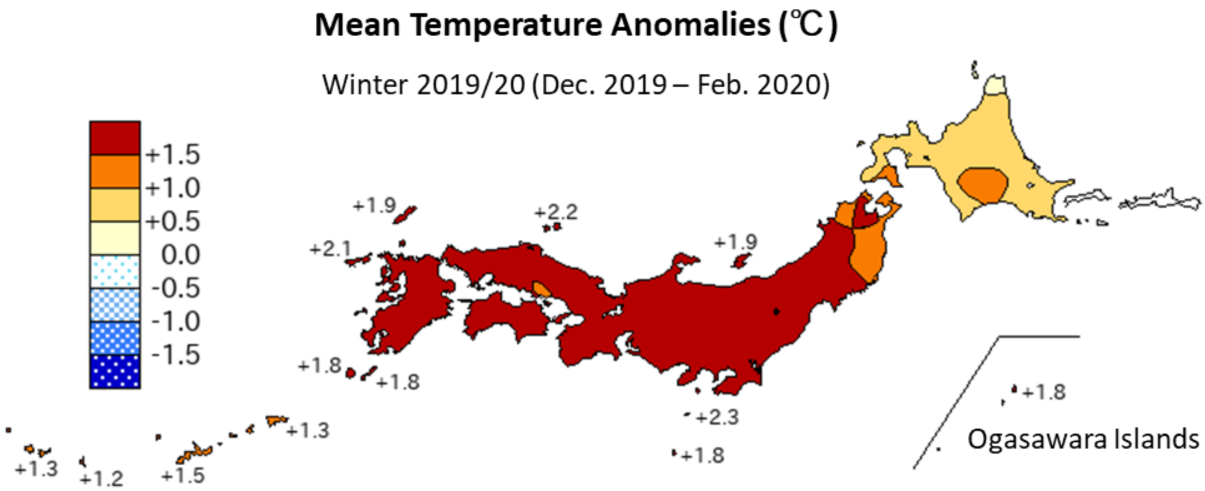

Figure 1. Mean temperature anomalies in winter 2019/20

The base period for the normal is 1981 – 2010.

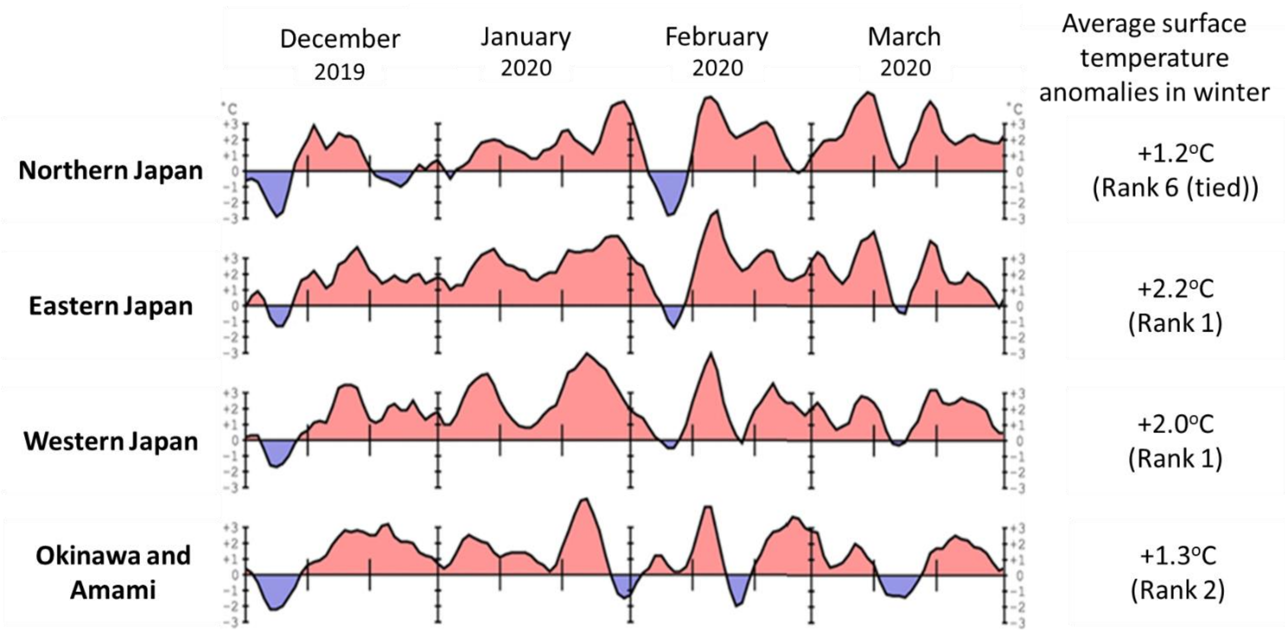

Figure 2. Time-series representations of 5-day running mean temperature anomalies from December 2019 to March 2020

The base period for the normal is 1981 – 2010.

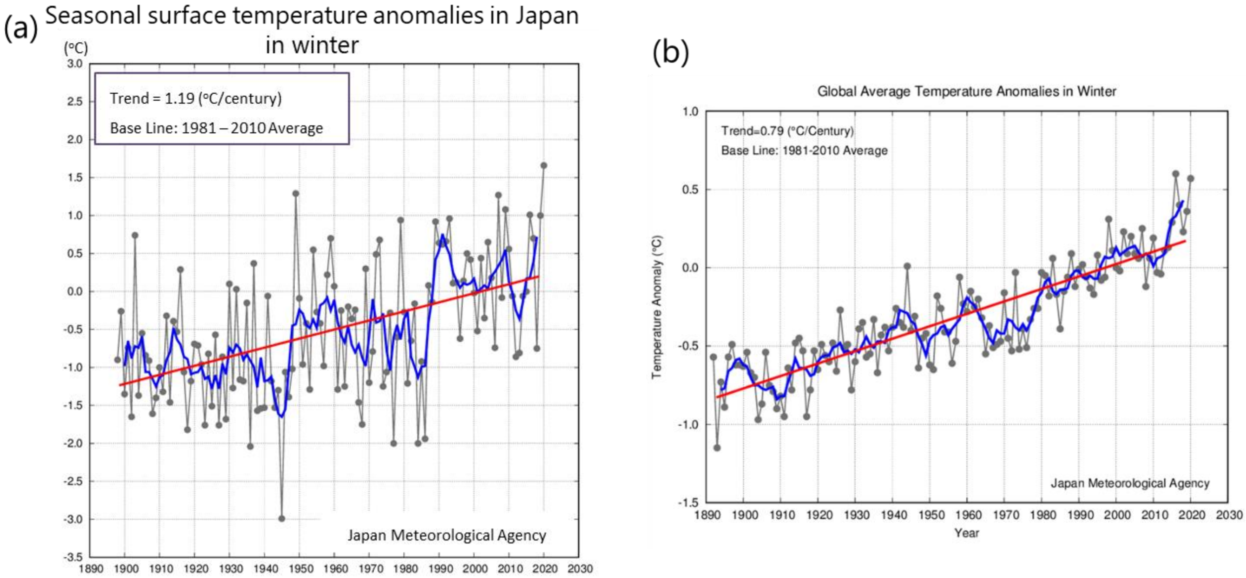

Figure 3. Seasonal surface temperature anomalies for winter in Japan (a) and in the world (b)
The thin black line with dots indicates seasonal surface temperature anomaly averaged over observation stations for each year. The blue line indicates the five-year running mean, and the red line indicates the long-term linear trend (statistically significant at a confidence level of 99%). Anomalies are deviations from the baseline (the 1981 - 2010 average).
Note that the scales are not the same for (a) and (b).

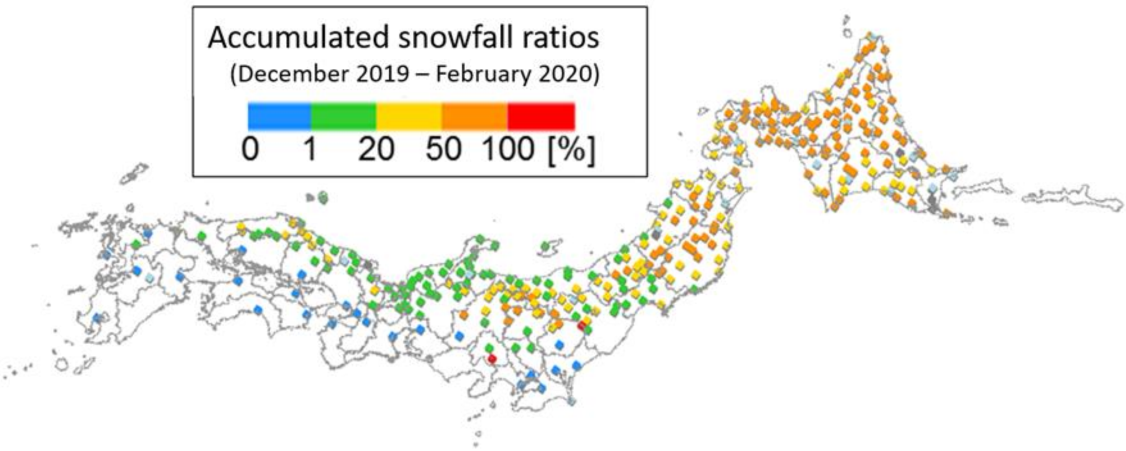

Figure 4. Cumulative snowfall ratios for winter 2019/20
The base period for the normal is 1981 – 2010. Station colors are as per the legend, with gray stations representing points where observation data for statistics is not sufficient.

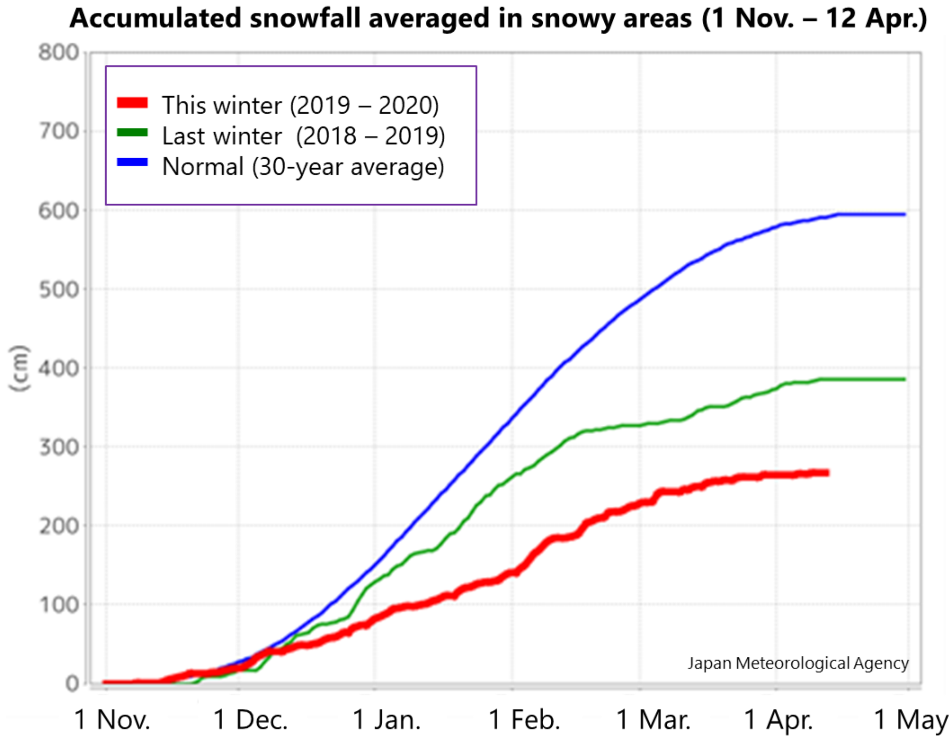

Figure 5. Cumulative snowfall averaged over snowy areas from 1 November (as of 12 April 2020)

The red line shows a cumulative time-series representation of snowfall for winter 2019/20, while the green line shows the same for the winters of 2018/19. The blue line represents the 30-year normal (1981 – 2010). Figures are based on Automated Meteorological Data Acquisition System (AMeDAS) observations in snowy areas as designated under the Act on Special Measures for Heavy Snowfall Areas. The number of weather stations varies from year to year, with 261 stations for the normal and 277 for winter 2019/20 as examples.

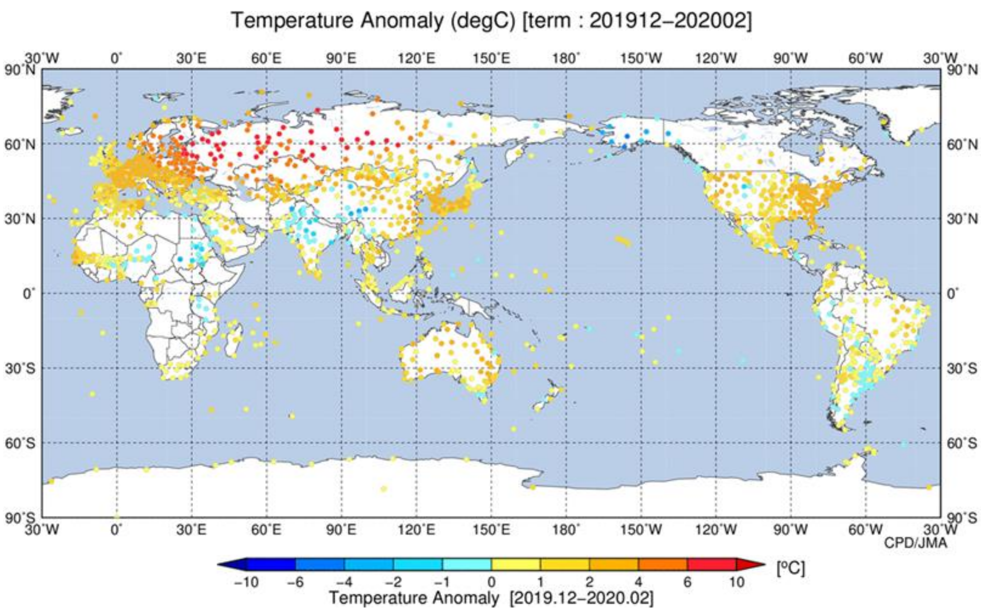

Figure 6. Seasonal mean temperature anomalies in winter 2019/20

The base period for the normal is 1981 – 2010.

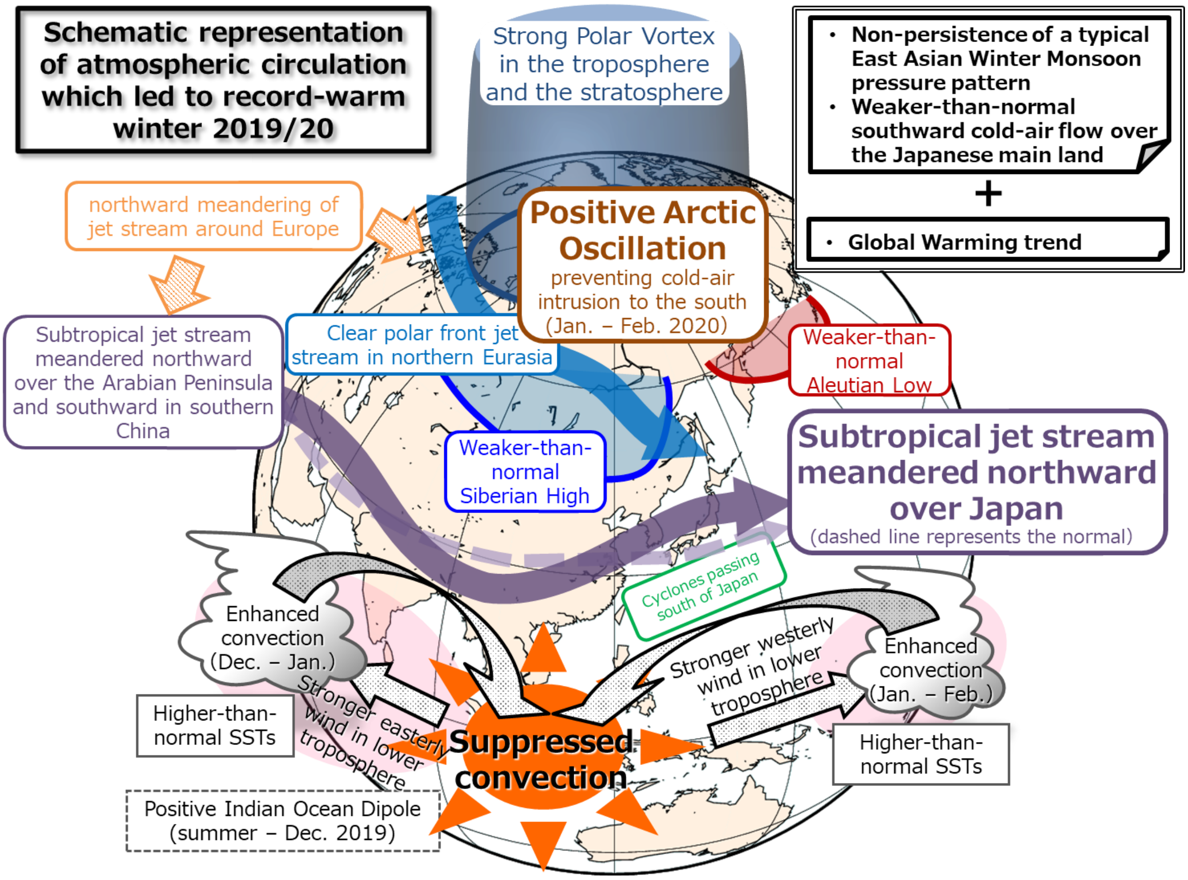

Figure 7. Atmospheric circulation conditions associated with the climate extremes observed in winter 2019/20

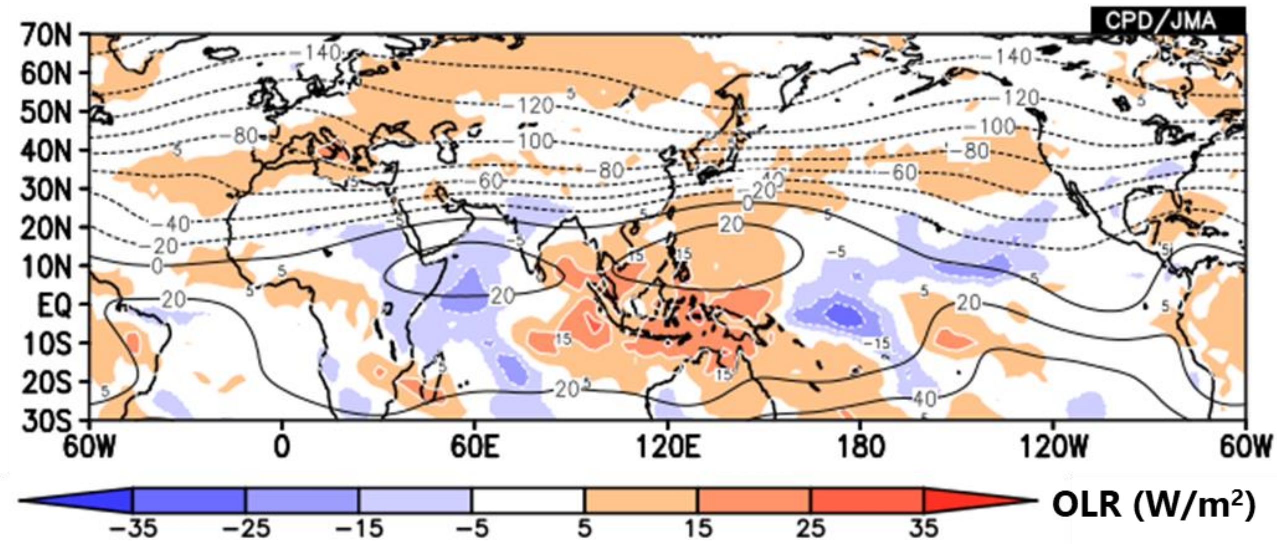

Figure 8. Three-month mean outgoing longwave radiation (OLR) anomalies and 200hPa stream function in winter 2019/2020

The contours show the stream function at intervals of 20x10^{6}m^2/s. The shading indicates OLR anomalies and they are deviations from the 1981 – 2010 average. Original data provided by the National Oceanic and Atmospheric Administration of the USA.

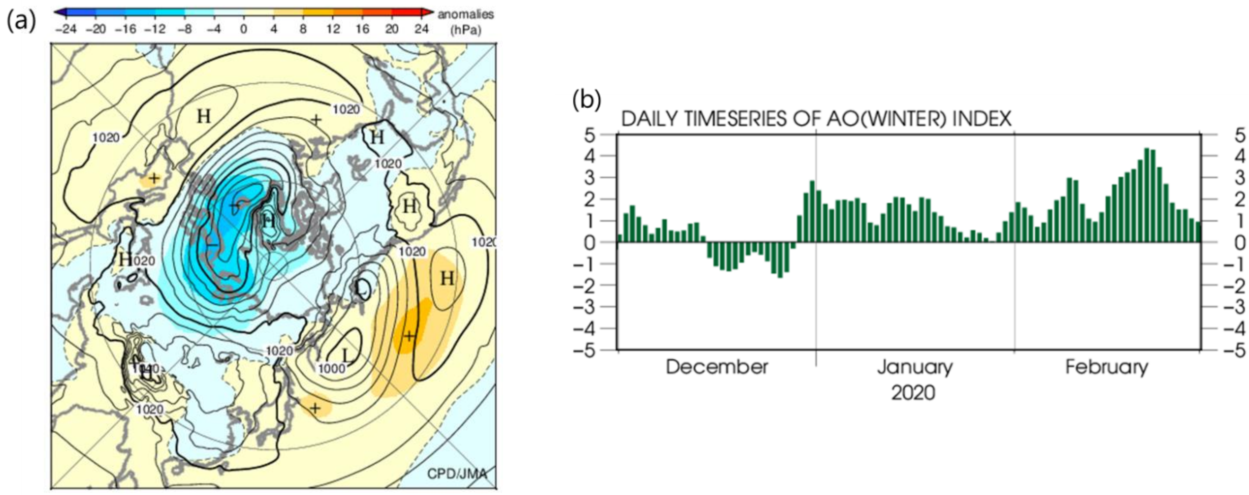

Figure 9. (a) Three-month mean Sea Level Pressure (SLP) and anomaly in the Northern Hemisphere and (b) Time-series representation of the daily AO-index in winter 2019/20.

(a) The contours show SLP at intervals of 4hPa. The shading indicates SLP anomalies and they are deviation from the 1981 – 2010 average.

(b) Daily AO-index scores are calculated by projecting daily SLP anomalies onto the spatial pattern of the AO, which was defined as the leading empirical orthogonal function (EOF) of wintertime (December, January and February) monthly SLP poleward of 20°N during 1958-2012. The spatial pattern was normalized for the base period of the climatological normal (1981-2010). .

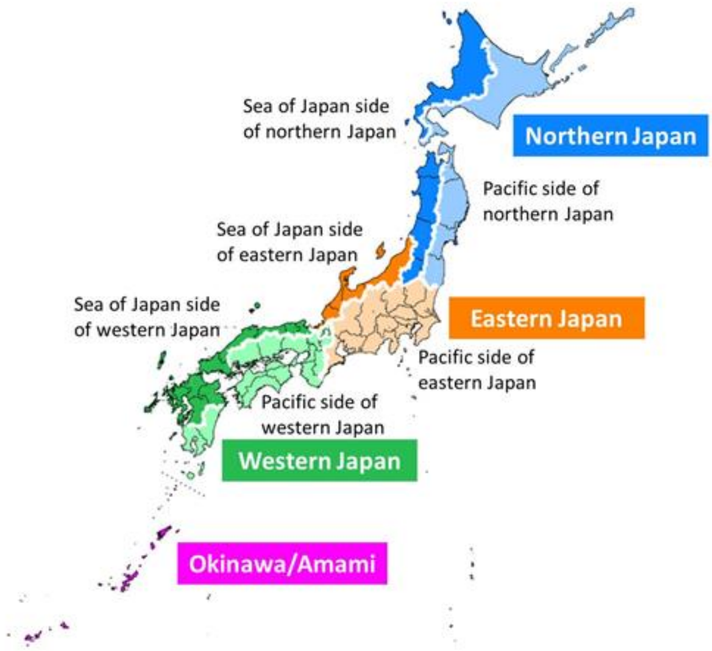

Figure 10. Climatological regions of Japan

The country has four divisions (northern, eastern, western Japan and Okinawa/Amami).

Table 1. Mean temperature anomalies in winter 2019/20 for Japan and the world, and their ranks on record

Averaged over	Winter 2019/20		Rank 1		Rank 2	
Japan	**+1.66℃**	**Rank 1**	**+1.66℃**	**(2019/20)**	+1.29℃	(1948/49)
World	**+0.57℃**	**Rank 2**	+0.60℃	(2015/16)	**+0.57℃**	**(2019/20)**

Table 2. Mean temperature anomalies in winter 2019/20 for climatological regions of Japan, and their ranks on record

Averaged over	Winter 2019/20		Rank 1		Rank 2	
Northern Japan	+1.2℃	Rank 6 (tied)	+1.8℃	(1948/49)	+1.6℃	(1990/91)
Eastern Japan	**+2.2℃**	**Rank 1**	**+2.2℃**	**(2019/20)**	+1.5℃	(2006/07)
Western Japan	**+2.0℃**	**Rank 1**	**+2.0℃**	**(2019/20)**	+1.4℃	(2006/07)
Okinawa and Amami	**+1.3℃**	**Rank 2**	+1.8	(2018/19)	**+1.3℃**	**(2019/20)**

Table 3. Cumulative snowfall ratios for winter 2019/20 averaged over climatological regions of Japan

Averaged over	Winter 2019/20		Rank 1		Rank 2	
Sea of Japan side of northern Japan	**44%**	**Rank 1**	**44%**	**(2019/20)**	57%	(2006/07)
Sea of Japan side of eastern Japan	**7%**	**Rank 1**	**7%**	**(2019/20)**	10%	(2006/07)
Sea of Japan side of western Japan	**11%**	**Rank 2**	7%	(2018/19)	**11%**	**(2019/20)**

Anomalies are deviations from the baseline (the 1981 – 2010 average). Here, cumulative snowfall is the sum of daily snowfall for the targeted periods. Ranking is based on snowfall records stretching back to when related statistical collection began in winter 1961/62.