2. Annual summaries of the climate system in 2015

2.1 Climate in Japan

- Annual mean temperatures were above normal all over Japan. However, western Japan experienced its second consecutive cool summer.

- Annual precipitation amounts were above normal in eastern and western Japan and significantly above normal on the Pacific side of western Japan. Unprecedentedly heavy rain was observed over the Kanto and Tohoku regions in September.

- Annual sunshine durations were above normal in northern Japan and on the Sea of Japan side of eastern Japan, and were below normal in western Japan.

2.1.1 Average surface temperature

The annual anomaly of the average surface temperature over Japan (i.e., that averaged over 15 observatories confirmed as being relatively unaffected by urbanization) for 2015 was +0.69°C above the 1981 – 2010 average, making it the fourth highest since 1898.

2.1.2 Annual features

Annual mean temperatures were above normal all over Japan, especially in northern parts and in Okinawa/Amami (Fig. 2.1.2). Record-breaking high monthly mean temperatures were observed in March in northern Japan, in May in northern and eastern Japan, in June and November in Okinawa/Amami, and in December in eastern Japan (Table 2.1.2, Fig. 2.1.3). In western Japan, although annual mean temperatures were above normal, temperatures were below normal from summer to autumn, resulting in the country’s second consecutive cool summer.

In western Japan, annual sunshine durations were below normal and annual precipitation amounts were above normal especially on the Pacific side due to weak expansion of the north Pacific high and a frequently active front line in summer. On the Pacific side of eastern Japan, annual precipitation amounts were above normal and record-breaking heavy rain was observed in September. Annual sunshine durations were above normal in northern Japan and on the Sea of Japan side of eastern Japan due to the frequent passage of migratory high-pressure systems in late spring and mid-autumn.

2.1.3 Seasonal characteristics

(a) Winter (December 2014 – February 2015, Fig. 2.1.4 (a))

Seasonal mean temperatures were above normal in northern Japan and below normal in other regions. Temperatures were below normal all over Japan in December 2014 and above normal thereafter, especially in northern Japan.

Seasonal snowfall depths on the Sea of Japan side were below normal, and were significantly below normal in northern Japan. Due to a tendency for low-pressure systems to develop around northern Japan, snowfall depths in mountainous regions of northern and eastern Japan were above normal, and severe blizzards occasionally hit the Hokkaido region.

(b) Spring (March – May, Fig. 2.1.4 (b))

Seasonal mean temperatures were above normal all over Japan due to the frequent passage of low-pressure systems north of the country and warm air flows from the south. Mean temperatures in northern Japan were the highest on record for spring since 1946.

Seasonal sunshine durations were above normal in northern and eastern Japan due to dominant migratory high-pressure systems. Wet southerly winds caused low levels of sunshine on the Pacific side of eastern and western Japan from early to mid-April.

(c) Summer (June – August, Fig. 2.1.4 (c))

In western Japan, seasonal precipitation amounts were above normal and seasonal sunshine durations were below normal especially on the Pacific side due to the significant influence of the Baiu front (Fig. 2.1.4 (c)).
2.1.3), typhoons and southerly wet flows. Seasonal mean temperatures were below normal, resulting in the country’s second consecutive cool summer.

In Okinawa/Amami, although seasonal precipitation amounts were above normal and seasonal sunshine durations were below normal, seasonal mean temperatures were significantly above normal due to record-breaking high temperatures in June.

In northern Japan, the north Pacific high increased in intensity and covered the region, causing significantly above-normal temperatures from mid-July to early August and above-normal seasonal mean temperatures. On the Sea of Japan side of eastern Japan, seasonal precipitation amounts were significantly below normal due to the low influence of the Baiu front (Table 2.1.3).

After mid-August, low temperatures and cloudy/rainy conditions continued due to fronts that tended to stagnate around the mainland and to the presence of the Okhotsk High, which caused cool wet northeastern flows on the Pacific side of northern and eastern Japan.

(d) Autumn (September – November, Fig. 2.1.4 (d))

In early September, the low temperatures and cloudy/rainy conditions observed from mid-August onward continued. Due to the approach of typhoons Kilo and Etau, the Kanto and Tohoku regions experienced record-breaking heavy rain that caused river overflows and other severely adverse conditions.

From mid-September to October, sunshine durations were significantly above normal due to dominant migratory high-pressure systems.

In November, the frequent passage of low-pressure systems and a tendency for warm air flows from the south caused above-normal temperatures all over Japan and below-normal sunshine durations on the Pacific side and in western parts of the country in particular.

Seasonal mean temperatures in Okinawa/Amami were significantly above normal, and record-breaking high temperatures were recorded in November. Seasonal precipitation amounts were significantly below normal due to a low impact from typhoons and low-pressure systems (with the exception of Typhoon Dujuan).
Fig. 2.1.1 Long-term change in the annual anomaly of average surface temperature over Japan

Anomalies are deviations from the baseline (i.e., the 1981 – 2010 average). The black line indicates the annual anomalies of the average surface temperature for each year. The blue line indicates the five-year running mean, and the red line indicates the long-term linear trend.

Table 2.1.1 Regional average and rank of annual mean temperature anomaly, annual precipitation ratio, and annual sunshine duration ratio for divisions and subdivisions (2015)

| REGIONAL AVERAGES AND THEIR RANKS OF MONTHLY MEAN TEMPERATURE ANOMALY, MONTHLY PRECIPITATION RATIO, AND MONTHLY SUNSHINE DURATION RATIO FOR SUBDIVISIONS (2015) |
|---|---|---|---|---|---|---|---|---|---|
| NORTHERN JAPAN | TEMPERATURE ANOMALY °C (RANK) | PRECIPITATION RATIO % (RANK) | SUNSHINE DURATION RATIO % (RANK) | HOKKAIDO | TEMPERATURE ANOMALY °C (RANK) | PRECIPITATION RATIO % (RANK) | SUNSHINE DURATION RATIO % (RANK) |
| 1.1 (+)* | 107 (1) | 102 (0) | (J) 110 (+) | (O) 111 (+) | (P) 103 (0) | (P) 104 (+) | (J) 102 (0) | (O) 97 (+) | (P) 104 (+) |
| 0.7 (+) | 109 (+) | 106 (+) | (J) 88 (+) | (J) 109 (+) | (P) 99 (0) | (P) 107 (0) | (J) 108 (+) | (J) 109 (+) | (P) 104 (+) |
| 0.4 (+) | 119 (+)* | 97 (+) | (J) 98 (+) | (P) 95 (+) | (J) 109 (+) | (P) 128 (+)* | (J) 123 (+)* | (J) 103 (0) | (P) 128 (+)* |
| 0.5 (+)* | 102 (0) | 100 (0) | (J) 108 (+) | (J) 109 (+) | (P) 103 (0) | (P) 104 (+) | (J) 109 (+) | (J) 109 (+) | (P) 104 (+) |
| OKINAWA AND AMAMI | 0.6 (+)* | 98 (0) | 102 (0) | 102 (0) | 102 (0) | 102 (0) | 102 (0) | 102 (0) | 102 (0) |

*: above normal
*: significantly below normal or significantly above normal

Table Representation:
(J): Sea of Japan side  (O): Sea of Okhotsk side  (Y): Sea of Japan
(K): Kyushu island  (A): Amami islands
(P): Pacific side
Table 2.1.2 Number of observatories reporting record monthly mean temperatures, precipitation amounts and sunshine durations (2015)

From 154 surface meteorological stations across Japan.

<table>
<thead>
<tr>
<th></th>
<th>Temperature</th>
<th>Precipitation amount</th>
<th>Sunshine duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Highest</td>
<td>Lowest</td>
<td>Heaviest</td>
</tr>
<tr>
<td>January</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>February</td>
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<td></td>
</tr>
<tr>
<td>March</td>
<td>20</td>
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<td>6</td>
</tr>
<tr>
<td>April</td>
<td>1</td>
<td></td>
<td>2</td>
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<tr>
<td>May</td>
<td>55</td>
<td></td>
<td>3</td>
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<tr>
<td>June</td>
<td>5</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>July</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>August</td>
<td>2</td>
<td></td>
<td>1</td>
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<tr>
<td>September</td>
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<td></td>
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<tr>
<td>October</td>
<td>1</td>
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</tr>
<tr>
<td>November</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>19</td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

Table 2.1.3 Onset/end of the Baiu (Japan’s rainy season) for individual subdivisions (2015)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Okinawa</td>
<td>20 May</td>
<td>9 May</td>
<td>8 June</td>
<td>23 June</td>
<td>73</td>
</tr>
<tr>
<td>Amami</td>
<td>19 May</td>
<td>11 May</td>
<td>6 July</td>
<td>29 June</td>
<td>141</td>
</tr>
<tr>
<td>Southern Kyushu</td>
<td>2 June</td>
<td>31 May</td>
<td>14 July</td>
<td>14 July</td>
<td>209</td>
</tr>
<tr>
<td>Northern Kyushu</td>
<td>2 June</td>
<td>5 June</td>
<td>29 July</td>
<td>19 July</td>
<td>102</td>
</tr>
<tr>
<td>Shikoku</td>
<td>2 June</td>
<td>5 June</td>
<td>24 July</td>
<td>18 July</td>
<td>142</td>
</tr>
<tr>
<td>Chugoku</td>
<td>2 June</td>
<td>7 June</td>
<td>24 July</td>
<td>21 July</td>
<td>78</td>
</tr>
<tr>
<td>Kinki</td>
<td>3 June</td>
<td>7 June</td>
<td>24 July</td>
<td>21 July</td>
<td>144</td>
</tr>
<tr>
<td>Tokai</td>
<td>3 June</td>
<td>8 June</td>
<td>24 July</td>
<td>21 July</td>
<td>135</td>
</tr>
<tr>
<td>Kanto-Koushin</td>
<td>3 June</td>
<td>8 June</td>
<td>10 July</td>
<td>21 July</td>
<td>128</td>
</tr>
<tr>
<td>Hokuriku</td>
<td>19 June</td>
<td>12 June</td>
<td>25 July</td>
<td>24 July</td>
<td>68</td>
</tr>
<tr>
<td>Southern Tohoku</td>
<td>26 June</td>
<td>12 June</td>
<td>26 July</td>
<td>25 July</td>
<td>66</td>
</tr>
<tr>
<td>Northern Tohoku</td>
<td>26 June</td>
<td>14 June</td>
<td>29 July</td>
<td>28 July</td>
<td>87</td>
</tr>
</tbody>
</table>

* The onset/end of the rainy season normally has a transitional period of about five days. The dates shown in the table denote the middle day of this period.
Fig. 2.1.2 Five-day running mean temperature anomaly for divisions (January – December 2015)

Fig. 2.1.3 Annual climate anomaly/ratio for Japan in 2015
Fig. 2.1.4 Seasonal anomalies/ratios for Japan in 2015
(a) Winter (December 2014 to February 2015), (b) spring (March to May), (c) summer (June to August), (d) autumn (September to November).
2.2 Climate around the world

2.2.1 Global average surface temperature

The annual anomaly of the global average surface temperature for 2015 was +0.42 ± 0.14°C above the 1981 – 2010 average. This was the warmest year since records began in 1891, surpassing the previous record of 2014 (+0.27°C). On a longer time scale, global average surface temperatures have risen at a rate of about +0.71°C per century since 1891 (Fig. 2.2.1).

In 2015, monthly average air temperatures for January, March, May, June, July, August, September, October, November and December, and seasonal average air temperatures for boreal spring, summer and autumn were also the highest on record since 1891.

High temperature deviations were seen over wide areas of Eurasia, the Indian Ocean and the North and Eastern Tropical Pacific (Fig. 2.2.2).

The high temperatures observed in recent years are thought to be associated with a global warming trend caused by increased atmospheric concentrations of carbon dioxide and other anthropogenic greenhouse gases. The global temperature is also affected by inter-annual to decadal-scale natural fluctuations intrinsic to the earth’s climate. The record-high temperatures of 2015 are partially attributed to an El Niño event that has continued since boreal summer 2014 and to global warming.

2.2.2 Regional climate

Annual mean temperatures were above normal in many parts of the world, and were below normal in eastern Canada and on the coast of Antarctica (Fig. 2.2.3). Extremely high temperatures were frequently observed in some parts of Siberia, on the western coast of North America and in various places at low latitudes (Fig. 2.2.4).

Annual precipitation amounts were above normal from western Japan to southeastern China, in northern China, from the western part of Central Siberia to northern India, in northern Europe, in and around the southern USA, in coastal areas from Ecuador to northern Chile, in and around Paraguay and in northern Australia, and were below normal from central to western Indonesia, on the southern Arabian Peninsula, in South Africa, around the southern Caribbean Sea, in eastern Brazil and in northeastern Australia (Fig. 2.2.5). Extremely high precipitation amounts were frequently observed from the southern USA to central Mexico and in and around Paraguay, and extremely low precipitation amounts were frequently observed in and around western Indonesia and in the northern part of South America (Fig. 2.2.6).

Major extreme climatic events and weather-related disasters occurring in 2015 are listed below (Fig. 2.2.9).

1. High temperatures in the southern part of Central Siberia (January – February, July – August)
2. Torrential rain in southern China (May, July, August)
3. High temperatures in and around the northern Indochina Peninsula (May – June, September, November)
4. High temperatures (June – July, September – December) and light precipitation (July, September – November) in and around western Indonesia
5. Torrential rain in Myanmar (June – August)
6. Heatwave (May) and torrential rain (June – September, November – December) in India
7. High temperatures in India (July – December)
8. Heatwave (June) and torrential rain (July – September) in Pakistan
9. Avalanches, floods and landslides in
Afghanistan (February – April)
(10) High temperatures in and around the northern part of Western Siberia (April – June)
(11) High temperatures around the Red Sea (March, July – October)
(12) High temperatures in and around Mauritius (June – December)
(13) Floods in the southern part of Eastern Africa (January)
(14) High temperatures in and around the western USA (January – March, June – October)
(15) Drought in California (all year round)
(16) Heavy precipitation from the southern USA to central Mexico (February – May, October)
(17) High temperatures from the southeastern USA to southeastern Mexico (March – April, July, November – December)
(18) Landslide in southern Guatemala (October)
(19) High temperatures (May – December) and light precipitation (May – September) in the northern part of South America
(20) High temperatures in eastern and northwestern Brazil (September – December)
(21) Heavy precipitation in and around Paraguay (May, July, November – December)
(22) High temperatures in northern Chile (April – May, September)
(23) High temperatures in western Australia (September – November)
Fig. 2.2.1 Long-term change in the annual anomaly of global average surface temperature
Anomalies are deviations from the baseline (i.e., the 1981 – 2010 average). The black dots indicate annual anomalies of the global average surface temperature for each year. The error bars indicate 90% confidence intervals. The blue line indicates the five-year running mean, and the red line indicates the long-term linear trend.

Fig. 2.2.2 Annual mean temperature anomalies in 2015
The circles indicate temperature anomalies from 1981-2010 baseline averaged in 5° x 5° grid boxes.

Fig. 2.2.2 Annual mean temperature anomalies in 2015
The circles indicate anomalies of surface temperature averaged in 5° x 5° grid boxes. Anomalies are deviations from the 1981 – 2010 average.
Fig. 2.2.3 Annual mean temperature anomalies for 2015
Categories are defined by the annual mean temperature anomaly against the normal divided by its standard deviation and averaged in 5° × 5° grid boxes. The thresholds of each category are -1.28, -0.44, 0, +0.44 and +1.28. The normal values and standard deviations were calculated from 1981 – 2010 statistics. Areas over land without graphical marks are those where observation data are insufficient or where normal data are unavailable.

Fig. 2.2.4 Frequencies of extreme high/low temperature for 2015 shown as upper/lower red/blue semicircles
The size of each semicircle represents the ratio of extremely high/low temperature based on monthly observation for the year in each 5° × 5° grid box. As the frequency of extreme high/low temperature is expected to be about 3% on average, occurrence is considered to be above normal for values of 10 – 20% or more.
Fig. 2.2.5 Annual total precipitation amount ratios for 2015
Categories are defined by the annual precipitation ratio to the normal averaged in 5° × 5° grid boxes. The thresholds of each category are 70, 100 and 120%. Areas over land without graphical marks are those where observation data are insufficient or where normal data are unavailable.

Fig. 2.2.6 Frequencies of extreme heavy/light precipitation amounts for 2015
As per Fig. 2.2.4, but for monthly values of extremely heavy/light precipitation.
Fig. 2.2.7 Seasonal mean temperature anomalies for (a) winter (December 2014 – February 2015), (b) spring (March – May), (c) summer (June – August) and (d) autumn (September – November)
As per Fig. 2.2.3, but for seasonal mean temperature anomaly.

Fig. 2.2.8 Seasonal total precipitation amount ratios for (a) winter (December 2014 – February 2015), (b) spring (March – May), (c) summer (June – August) and (d) autumn (September – November)
As per Fig. 2.2.5, but for seasonal total precipitation amount ratios.
Fig. 2.2.9 Extreme events and weather-related disasters observed in 2015
Schematic representation of major extreme climatic events and weather-related disasters occurring during the year.
2.3 Extratropical circulation

This section outlines the seasonal mean characteristics of atmospheric circulation observed in the extra-tropics of the Northern Hemisphere.

2.3.1 Zonal mean temperature anomaly calculated from thickness in the troposphere

Zonal mean temperature anomalies calculated from thickness in the troposphere are shown in Fig. 2.3.1. In the tropical troposphere, temperature anomalies prominently increased during spring to autumn, and remained above +0.5K after July. Temperatures in both the global troposphere and the extratropical troposphere remained above normal throughout the year.

In the zonal mean zonal wind of the Northern Hemisphere (Fig. 2.3.2, top), the subtropical jet stream shifted northward of its normal position in July. The westerly jet stream over Japan shifted northward in April and southward in summer from its normal position (Fig 2.3.2, bottom).

![Fig. 2.3.1 Time-series representation of zonal mean temperature anomaly calculated from thickness in the troposphere (January 2005 – December 2015)](image)
The thin and thick lines show monthly and five-month running mean values, respectively (unit: K).

![Fig. 2.3.2 Time-latitude cross section of five-day running mean 200-hPa zonal wind (December 2014 – December 2015)](image)
The top panel shows zonal mean zonal wind, and the bottom panel shows zonal wind averaged for the 120 – 150°E area. The black lines and shading show zonal wind at intervals of (top) 10 and (bottom) 15 m/s, respectively. The green lines indicate the normal at intervals of (top) 10 and (bottom) 15 m/s, respectively.
2.3.2 Winter (December 2014 – February 2015)

In the 500-hPa height field (Fig. 2.3.3), the polar vortex was stronger than normal and shifted toward the Atlantic. Positive anomalies were seen over western North America, the Atlantic and from Eastern Siberia to Alaska. Clear negative anomalies were observed over and around Japan in December (Fig. 2.3.7). In the sea level pressure field (Fig. 2.3.4), the Icelandic Low and the Azores High were both enhanced. The Aleutian Low was stronger than normal over the southeastern part of its normal extent. In December, the Aleutian Low and the Siberian High were both enhanced (Fig. 2.3.8). In the lower troposphere, temperatures were above normal over wide areas of Eurasia and western North America, and were below normal over eastern North America (Fig. 2.3.5). In the upper troposphere, the jet stream shifted southward of its normal position over the area from Japan to the sea east of the country (Fig. 2.3.6).
2.3.3 Spring (March – May 2015)
In the 500-hPa height field (Fig. 2.3.9), positive anomalies were seen over wide areas in the mid-latitudes and negative anomalies were seen over Greenland and Eastern Siberia. Clear positive anomalies were observed over the sea east of Japan. In the sea level pressure field (Fig. 2.3.10), negative anomalies were seen in the polar region and the Icelandic Low was stronger than normal. In the lower troposphere, temperatures were above normal over Alaska, the area from Western Russia to Western Siberia and around Japan, and were below normal over the area from northeastern Canada to Greenland. In the upper troposphere, the jet stream shifted northward of its normal position. The jet stream over the area from the eastern Pacific to eastern North America was stronger than normal (Fig. 2.3.12).

Fig. 2.3.9 Three-month mean 500-hPa height and anomaly in the Northern Hemisphere (March – May 2015)
As per Fig. 2.3.3, but for March – May 2015.

Fig. 2.3.10 Three-month mean sea level pressure and anomaly in the Northern Hemisphere (March – May 2015)
As per Fig. 2.3.4, but for March – May 2015.

Fig. 2.3.11 Three-month mean 850-hPa temperature and anomaly in the Northern Hemisphere (March – May 2015)
As per Fig. 2.3.5, but for March – May 2015 and with contour intervals of 3°C.

Fig. 2.3.12 Three-month mean 200-hPa wind speed and vectors in the Northern Hemisphere (March – May 2015)
The black lines show wind speed at intervals of 10 m/s, and the purple lines show its normal at intervals of 20 m/s.
2.3.4 Summer (June – August 2015)

In the 500-hPa height field (Fig. 2.3.13), the polar vortex was weaker than normal. Zonally elongated positive anomalies were seen over the area from central Europe to Caspian Sea, from the southern part of Central Siberia to Eastern Siberia, and from the Bering Sea to the northwestern USA, and negative anomalies were seen over the sea west of the UK and over the area from Western Russia to Western Siberia. Clear negative anomalies were observed over the area from eastern China to the sea east of Japan in August (Fig. 2.3.17). In the sea level pressure field (Fig. 2.3.14), positive anomalies were seen over the area from the polar region to Greenland, and negative anomalies were seen over the sea west of the UK and over the area from Western Russia to Central Siberia. The northwestward extension of the Pacific High was weaker than normal, and the Okhotsk high appeared in late August. In the lower troposphere, temperatures were above normal over wide areas of the Northern Hemisphere (Fig. 2.3.15). In the upper troposphere, the jet stream shifted southward of its normal position over the area from eastern China to the central Pacific (Fig. 2.3.16).

Fig. 2.3.13 Three-month mean 500-hPa height and anomaly in the Northern Hemisphere (June – August 2015)
As per Fig. 2.3.3, but for June – August 2015.

Fig. 2.3.14 Three-month mean sea level pressure and anomaly in the Northern Hemisphere (June – August 2015)
As per Fig. 2.3.4, but for June – August 2015.

Fig. 2.3.15 Three-month mean 850-hPa temperature and anomaly in the Northern Hemisphere (June – August 2015)
As per Fig. 2.3.11, but for June – August 2015.

Fig. 2.3.16 Three-month mean 200-hPa wind speed and vectors in the Northern Hemisphere (June – August 2015)
As per Fig. 2.3.12, but for June – August 2015.

Fig. 2.3.17 Monthly mean 500-hPa height and anomaly in the Northern Hemisphere (August 2015)
As per Fig. 2.3.7, but for August 2015.
2.3.5 Autumn (September – November 2015)

In the 500-hPa height field (Fig. 2.3.18), positive anomalies were seen over wide areas of the Northern Hemisphere. Clear positive anomalies were observed over the northern Pacific in November (Fig. 2.3.22). In the sea level pressure field (Fig. 2.3.19), positive anomalies were seen over Central Siberia, the northern Pacific and the area from the southern Atlantic to northern Europe, and negative anomalies were seen over the Arctic Ocean. In the lower troposphere, temperatures were above normal over wide areas of the Northern Hemisphere (Fig. 2.3.20). In the upper troposphere, the jet stream shifted southward of its normal position over and around Japan (Fig. 2.3.21).

Fig. 2.3.18 Three-month mean 500-hPa height and anomaly in the Northern Hemisphere (September – November 2015)
As per Fig. 2.3.3, but for September – November 2015.

Fig. 2.3.19 Three-month mean sea level pressure and anomaly in the Northern Hemisphere (September – November 2015)
As per Fig. 2.3.4, but for September – November 2015.

Fig. 2.3.20 Three-month mean 850-hPa temperature and anomaly in the Northern Hemisphere (September – November 2015)
As per Fig. 2.3.11, but for September – November 2015.

Fig. 2.3.21 Three-month mean 200-hPa wind speed and vectors in the Northern Hemisphere (September – November 2015)
The black lines show wind speed at intervals of 15 m/s, and the purple lines show its normal at intervals of 30 m/s.

Fig. 2.3.22 Monthly mean 500-hPa height and anomaly in the Northern Hemisphere (November 2015)
As per Fig. 2.3.7, but for November 2015.
2.4 Tropical circulation and convective activity

The El Niño event that began in the Northern Hemisphere summer 2014 developed from spring 2015 onward. The characteristics of tropical circulation and indices resembled those observed in past El Niño events, especially in the latter half of the year.

This section briefly outlines tropical atmospheric circulation and convection observed in 2015.

2.4.1 Tropical indices

Outgoing longwave radiation (OLR) indices and equatorial zonal wind indices are shown in Table 2.4.1 and Fig. 2.4.1 (see Section 1.4.3 for related definitions).

The Southern Oscillation Index (SOI) remained negative (indicating weaker-than-normal trade winds) except in February and April, with significantly negative values during the period from summer to autumn.

OLR-PH (for the area around the Philippines) and OLR-MC (for the area around Indonesia) generally remained negative (indicating convective inactivity), and OLR-DL (for the area near the dateline) remained positive (indicating convective activity).

U200-CP (for the central Pacific in the upper troposphere) remained negative (indicating easterly wind anomalies) except in March. U850-WP (for the western Pacific in the lower troposphere) and U850-CP (for the central Pacific in the lower troposphere) remained positive (indicating westerly wind anomalies) throughout the year.

OLR indices and equatorial zonal wind indices were significantly large in the latter half of the year.

Table 2.4.1 Tropical atmospheric and oceanographic indices (December 2014 – December 2015)
The base period for the normal is 1981 – 2010.
Fig. 2.4.1 Time-series representation of tropical atmospheric and oceanographic indices for the period from 2005 to 2015
Thin and thick lines indicate monthly and five-month running mean values, respectively.
Fig. 2.4.2 Longitude-time cross section of five-day running mean 200-hPa velocity potential averaged over 5°S – 5°N (December 2014 – December 2015)
The contour interval is $4 \times 10^6$ m$^2$/s. The blue (red) shading indicates areas of divergence that are stronger (weaker) than normal.

Fig. 2.4.3 Longitude-time cross section of five-day mean 850-hPa zonal wind averaged over 5°S – 5°N (December 2014 – December 2015)
The contour interval is 2 m/s. The blue (red) shading shows easterly (westerly) wind anomalies.
2.4.2 Winter (December 2014 – February 2015)

Convective activity was enhanced over the western Pacific and the eastern part of the North Pacific, and was suppressed over the equatorial Indian Ocean and the central Pacific (Fig. 2.4.4). In the upper troposphere, anticyclonic circulation anomalies were seen over the area from the Bay of Bengal to the central Pacific, and cyclonic circulation anomalies were seen over the eastern Pacific and the Atlantic (Fig. 2.4.5). In December, clear anticyclonic and cyclonic circulation anomalies were seen over southern China and Japan, respectively (Fig. 2.4.7). In the lower troposphere, anticyclonic (cyclonic) circulation anomalies straddling the equator were seen over the eastern Pacific (the Indian Ocean and the western-to-central Pacific) (Fig. 2.4.6). Clear eastward propagation of the Madden-Julian Oscillation (MJO) was seen from the Indian Ocean to the Pacific during the period from mid-December to mid-January (Fig. 2.4.2).

Fig. 2.4.4 Three-month mean outgoing longwave radiation (OLR) anomalies (December 2014 – February 2015)
Original data provided by NOAA.

Fig. 2.4.5 Three-month mean 200-hPa stream function and anomalies (December 2014 – February 2015)
The contours show the stream function at intervals of $10^6 \text{ m}^2/\text{s}$, and the shading shows its anomalies.

Fig. 2.4.6 Three-month mean 850-hPa stream function and anomalies (December 2014 – February 2015)
The contours show the stream function at intervals of $2.5 \times 10^6 \text{ m}^2/\text{s}$, and the shading shows its anomalies.

Fig. 2.4.7 200-hPa stream function and anomalies for December 2014
As per Fig. 2.4.5, but for monthly mean in December 2014.
2.4.3 Spring (March – May 2015)

Convective activity was enhanced over the area east of 150°E in the western Pacific and the central-to-eastern North Pacific, and was suppressed over the area from the South China Sea to north of New Guinea (Fig. 2.4.8). In the upper troposphere (Fig. 2.4.9), clear anticyclonic circulation anomalies straddling the equator were seen over the western-to-central Pacific, especially in May (Fig. 2.4.11). In the lower troposphere, clear cyclonic circulation anomalies were seen over the western-to-central Pacific (Fig. 2.4.10). Clear eastward propagation of the MJO was seen from the Pacific to the Indian Ocean during the period from early March to early April (Fig. 2.4.2).
2.4.4 Summer (June – August 2015)

Convective activity was enhanced over the equatorial Pacific, and was suppressed over southern India, the sea east of the Philippines and around Indonesia (Fig. 2.4.12). In the upper troposphere, anticyclonic (cyclonic) circulation anomalies straddling the equator were seen over the western-to-central Pacific (the area from South America to the Atlantic and the Indian Ocean). The Tibetan High was weaker than normal (Fig. 2.4.13). In the lower troposphere, clear cyclonic circulation anomalies straddling the equator were seen over the Pacific. Anticyclonic circulation over the North Pacific and monsoon circulation over the Indian Ocean were weaker than normal (Fig. 2.4.14). Clear eastward propagation of the MJO was seen from Africa to the Pacific during the period from June to the first half of July, and became obscure afterward (Fig. 2.4.2). In the sea level pressure field (Fig. 2.4.15), positive (negative) anomalies were seen over the area from the Indian Ocean to the western Pacific (the central-to-eastern Pacific) in association with negative SOI (Fig. 2.4.1).

Fig. 2.4.12 Three-month mean outgoing longwave radiation (OLR) anomalies (June – August 2015)
As per Fig. 2.4.4, but for June – August 2015.

Fig. 2.4.13 Three-month mean 200-hPa stream function and anomalies (June – August 2015)
As per Fig. 2.4.5, but for June – August 2015.

Fig. 2.4.14 Three-month mean 850-hPa stream function and anomalies (June – August 2015)
As per Fig. 2.4.6, but for June – August 2015.

Fig. 2.4.15 Three-month mean sea level pressure anomalies and surface wind anomalies (June – August 2015)
The contours and shading show the sea level pressure anomalies, and the vectors denote the surface wind anomalies (units: m/s).
2.4.5 Autumn (September – November 2015)

Convective activity was enhanced over the equatorial Pacific, and was suppressed over the area from the eastern Indian Ocean to Indonesia (Fig. 2.4.16). In the upper troposphere, clear anticyclonic circulation anomalies straddling the equator were seen over the Pacific (Fig. 2.4.17). In the lower troposphere (Fig. 2.4.18), anticyclonic (cyclonic) circulation anomalies straddling the equator were seen over the area from the eastern Indian Ocean to Indonesia (the Pacific) (Fig. 2.4.18). Eastward propagation of the MJO was observed from the Indian Ocean to Indonesia during the period from late October to early November, and from Indonesia to the central Pacific in late November. The active phase of the MJO was obscure from September to mid-October and in mid-November (Fig. 2.4.2). In the sea level pressure field (Fig. 2.4.19), positive anomalies were seen over the area from the eastern Indian Ocean to the western Pacific, and negative anomalies were seen over the central-to-eastern Pacific. Westerly wind anomalies were seen along and around the equatorial dateline.

Fig. 2.4.16 Three-month mean outgoing longwave radiation (OLR) anomalies (September – November 2015)
As per Fig. 2.4.4, but for September – November 2015.

Fig. 2.4.17 Three-month mean 200-hPa stream function and anomalies (September – November 2015)
As per Fig. 2.4.5, but for September – November 2015.

Fig. 2.4.18 Three-month mean 850-hPa stream function and anomalies (September – November 2015)
As per Fig. 2.4.6, but for September – November 2015.

Fig. 2.4.19 Three-month mean sea level pressure anomalies and surface wind anomalies (September – November 2015)
As per Fig. 2.4.15, but for September – November 2015.
2.4.6 Tropical cyclones over the western North Pacific

In 2015, the number of tropical cyclones (TCs) with maximum wind speeds of 17.2 m/s or higher forming over the western North Pacific was 27 (Table 2.4.2), which was near the normal of 25.6 (1981 – 2010 average). The average TC formation longitude in 2015 was 149.7°E (against a normal of 136.7°E), which was the easternmost since 1951. The average TC formation latitude in 2015 was 13.4°N, which was south of the normal (16.3°N).

Based on statistics for the period from 1951 to 2005, the position of TC formations in past El Niño events tended to be southward and eastward of those observed during non-El Niño/La Niña periods. As the positional shift of TC formations in 2015 coincided with this tendency, it was considered to be influenced by the El Niño event that began in summer 2014. In addition, the 12 TC formations observed from July to September 2015 (against a normal of 14.3) coincided with the tendency seen with El Niño events from 1951 to 2005.

A total of 14 of these TCs came within 300 km of the Japanese archipelago (against a normal of 11.4).

Four TCs made landfall on Japan (against a normal of 2.7). The tracks of tropical cyclones generated in 2015 are shown in Fig. 2.4.20.

Table 2.4.2 Tropical cyclones forming over the western North Pacific in 2015
Based on information from the RSMC Tokyo-Typhoon Center

<table>
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<th>Number ID</th>
<th>Name</th>
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<th>Category</th>
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<td>Higos</td>
<td>2/7 – 2/11</td>
<td>TS</td>
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<td>Bavi</td>
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<td>TS</td>
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<td>10/2 – 10/7</td>
<td>STS</td>
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<td>11/17 – 11/26</td>
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<td>Melor</td>
<td>12/11 – 12/16</td>
<td>TY</td>
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</tr>
</tbody>
</table>

1) Intensity classification for tropical cyclones (range of maximum wind speed)
   TS: Tropical Storm (34 – 47 knots)
   STS: Severe Tropical Storm (48 – 63 knots)
   TY: Typhoon (64 knots – )

2) Estimated maximum 10-minute mean wind speed
Fig. 2.4.20 Tracks of tropical cyclones in 2015
The lines indicate the tracks of tropical cyclones with maximum wind speeds of 17.2 m/s or higher. The numbers in circles indicate points where maximum wind speeds exceeded this value, and those in squares indicate points where they fell below it.
2.5 Oceanographic conditions

Throughout 2015, the global average sea surface temperature (SST) was much higher than normal, especially from summer onward. SST increased in the tropical Pacific and the Indian Ocean in association with the El Niño event that began in summer 2014. The annual mean anomaly was +0.30°C, which was much higher than the previous highest value of 0.20°C observed in 2014, and was the highest since 1891.

Positive SST anomalies were observed in most of the equatorial Pacific especially near the date line during winter 2014/2015 (Fig. 2.5.1 (a) (b)). Positive anomalies were enhanced from central to eastern parts in summer 2015 (Fig. 2.5.1 (c)) and were maintained during autumn (Fig. 2.5.1 (d)).

The SST deviation from the reference value (climatological mean based on a sliding 30-year period) averaged for the NINO.3 region decreased to +0.2°C in February and March 2015 before continuously increasing for the rest of the year and reaching +3.0°C in December. The five-month running mean of the deviation remained at +0.5°C or more from June 2014 onward. The El Niño event continued and developed remarkably from spring to autumn. Southern Oscillation Index (SOI) values remained negative except in February and April, and remained below -1.5 from July to October.

Positive ocean heat content (OHC) anomalies propagated eastward intermittently from the area near the date line to the eastern part of the equatorial Pacific. Negative OHC anomalies were observed in the western part from spring onward (Fig. 2.5.3).

Remarkably positive SST anomalies were observed near the western coast of North America and from the central to the eastern part of the tropical region in the North Pacific. Pacific Decadal Oscillation (PDO) ¹ index values were positive throughout the year. In the South Pacific, negative SST anomalies observed from the area near the western coast of South America to central parts of the tropical region weakened and remarkably positive anomalies were observed off the coast of Peru from summer onward. Positive anomalies observed in the western part of the tropical region during winter weakened and negative anomalies were observed from summer to autumn. In the Indian Ocean, positive SST anomalies were observed over a large area throughout the year. In the North Atlantic, a tripole pattern with positive SST anomalies to the east of the USA and negative anomalies to the north and south of the positive anomalies was observed from winter to spring. From summer onward, remarkably negative SST anomalies were observed south of Greenland and remarkably positive anomalies were observed to the south of the negative anomalies (Fig. 2.5.1).

¹ For details, see the Pacific Decadal Oscillation (PDO) index information on the TCC website.

Fig. 2.5.1 Seasonal mean sea surface temperature anomalies (2015)
(a) Winter (Dec. 2014 – Feb. 2015), (b) Spring (Mar. – May), (c) Summer (Jun. – Aug.), (d) Autumn (Sep. – Nov.).
The contour interval is 0.5°C. Maximum sea ice coverage areas are shaded in gray.

Fig. 2.5.2 Monthly values (thin lines) and five-month running means (thick lines) of the El Niño monitoring index (top: NINO.3 SST deviation from a sliding 30-year mean) and the Southern Oscillation Index (bottom)
The shading indicates El Niño (red) and La Niña (blue) events.
Fig. 2.5.3 Time-longitude cross sections of SST (left) and ocean heat content anomalies (right: vertically averaged temperature over the top 300 m) along the equator in the Pacific Ocean from 2013 to 2015
2.6 Stratospheric circulation in boreal winter

In winter 2014/2015, the polar vortex was stronger than normal. Two minor stratospheric sudden warming (SSW) events occurred during this period in association with enhanced anticyclonic activity in the mid-latitudes, but did not reach the criteria for categorization as major. This section reports on the characteristics of stratospheric circulation seen during winter 2014/2015, including the period of the minor SSW events.

SSW is a phenomenon in which a rapid stratospheric temperature increase of several tens of Kelvin is observed over a period of a few days in the polar region during winter, and was identified by Richard Scherhag at the Free University of Berlin in 1952. It is caused by enhanced propagation of energy from the troposphere due to planetary-scale wave action (Matsuno 1971). According to the World Meteorological Organization (WMO) definition (WMO 1978), a minor SSW occurs when polar temperatures increase by 25 K or more within a week at any stratospheric level. In addition to this criterion, if the zonal mean temperature increases in the poleward direction and net zonal mean zonal winds become easterly north of 60°N at 10-hPa or below, the event is classified as a major SSW.

2.6.1 Characteristics of stratospheric circulation

In the three-month mean 30-hPa height field from December 2014 to February 2015 (Fig. 2.6.1), negative anomalies were seen in the polar region in association with a stronger-than-normal polar vortex. Positive anomalies were observed over the area from Eastern Siberia to western North America and from the North Atlantic to Europe. The Aleutian anticyclone was enhanced to the south of Alaska.

In the monthly mean 30-hPa height field, clear negative anomalies were seen over the polar region in February, indicating enhancement of the polar vortex (Fig. 2.6.3(c)). In January, the Aleutian anticyclone was enhanced and the polar vortex was shifted toward Siberia (Fig. 2.6.3 (b)), with positive height anomalies over the polar region in association with the two SSW events that occurred during the period from the end of December to early January and in late January (Fig. 2.6.2).
2.6.2 SSW from the end of December to early January

In the five-day mean 30-hPa field (Fig. 2.6.4), the polar vortex was stronger than normal and below-normal temperatures over the North Pole persisted until the first half of late December (Fig. 2.6.2, Fig. 2.6.4 (a)). During the period from the end of December to the first half of January, clear positive anomalies were seen over the East Siberian Sea and the Norwegian Sea with northward extension of the Aleutian High, and the polar vortex split into two (Fig. 2.6.4 (b) and (c)). 30-hPa temperatures over the North Pole increased by 25 K or more within a week (Fig. 2.6.2) and a minor SSW event occurred. A time-series representation of 100-hPa Eliassen-Palm (E-P) flux\(^1\) shows enhanced upward propagation of planetary waves with zonal wavenumber 2 during the period from the end of December to early January (shown by blue lines in Fig. 2.6.5 (b)), contributing to deceleration of the stratospheric polar-night jet (Fig. 2.6.5 (a) and Fig. 2.6.6 (b)).

The polar vortex was centered over and around northern Canada in mid-January (Fig. 2.6.4 (d) – (f)), and temperatures over the North Pole decreased to near normal (Fig. 2.6.2).

2.6.3 SSW in late January

In late January the stratospheric polar vortex shifted toward Siberia and clear positive height anomalies at the 30-hPa level were seen over Greenland (Fig. 2.6.4 (g) and (h)). 30-hPa temperatures over the North Pole rapidly increased (Fig. 2.6.2), and a second minor SSW event occurred. Enhanced upward propagation of planetary waves with zonal wavenumber 1 was observed during the period (shown by red lines in Fig. 2.6.5 (b)), contributing to deceleration of the stratospheric polar-night jet (Fig. 2.6.5 (a) and Fig. 2.6.6 (d)).

In late January, upward propagation of planetary waves was enhanced over and around Siberia in association with a westward tilt with the height of troughs (Fig. 2.6.6 (c)). It can be presumed that upward wave packets contributed to positive height anomalies over and around Greenland in the stratosphere (Fig. 2.6.4 (h)). In the upper troposphere, ridges over Europe and upward propagation of

\(^1\) E-P flux provides a useful framework for diagnosing interaction between eddies and mean flow in the Transformed Eulerian Mean (TEM) equation system. The convergence (divergence) of E-P flux corresponds to the deceleration (acceleration) of westerly winds in the zonal mean field.
planetary waves to the east of the ridges were observed (Fig. 2.6.7), indicating the possibility that the ridges were a source of the planetary wave packets.

Temperatures over the North Pole decreased at the end of January (Fig. 2.6.2), and the polar vortex strengthened in the polar region during the period from early to mid-February (Fig. 2.6.4 (j) and (k)).

References

(a) 22 – 26 Dec.  
(b) 27 – 31 Dec.  
(c) 1 – 5 Jan.

(d) 6 – 10 Jan.  
(e) 11 – 15 Jan.  
(f) 16 – 20 Jan.

Fig. 2.6.4 Five-day mean 30-hPa height and anomaly in the Northern Hemisphere for (a) 22 – 26 December, (b) 27 – 31 December 2014, (c) 1 – 5 January, (d) 6 – 10 January, (e) 11 – 15 January, (f) 16 – 20 January, (g) 21 – 25 January, (h) 26 – 30 January, (i) 31 January – 4 February, (j) 5 – 9 February and (k) 10 – 14 February 2015
The contours show 30-hPa height at intervals of 120 m, and the shading indicates height anomalies.
Fig. 2.6.5 (a) Time-height cross sections of zonal mean zonal wind averaged over 60°N – 90°N, and (b) time-series representation of vertical components of E-P flux (unit: m²/s²) averaged over 30°N – 90°N at the 100-hPa level from 1 November 2014 to 31 March 2015.

In (a), positive (negative) values denote westerly (easterly) winds. The gray shading in (b) denotes the vertical component of E-P flux for whole zonal wavenumbers, and the red, blue and green lines denote the vertical components of E-P flux for zonal wavenumbers 1, 2 and 3, respectively.
Fig. 2.6.6 Left: longitude-height cross section of height anomalies from the zonal mean and wave activity flux averaged over 60 – 80°N; right: latitude-height cross section of zonal mean zonal wind, E-P flux and zonal wind tendency in line with the divergence/convergence of the E-P flux for 29 December 2014 – 5 January 2015 (a, b) and 20 – 31 January 2015 (c, d).

In the panels on the left, the contours show height anomalies at intervals of 100 m and the vectors denote wave activity flux with reference to Plumb (1985) (units: m²/s² (horizontal); Pa m/s² (vertical)). In the panels on the right, the contours show zonal mean zonal wind at intervals of 10 m/s, the shading indicates zonal wind tendency at intervals of 5 m/s/day (yellow: acceleration; green: deceleration) and the vectors denote E-P flux (units: 10⁶ m³/s² (horizontal); m²/s² (vertical)) scaled using the square root of pressure.

Fig. 2.6.7 300-hPa height and 100-hPa wave activity flux (Plumb 1985) with zonal wavenumber 0 – 3 for 21 – 25 January 2015.

The contours show 300-hPa height at intervals of 200 m. The vectors and shading denote horizontal (unit: m²/s²) and vertical (unit: Pa m/s²) components of wave activity flux with reference to Plumb (1985), respectively. The warm and cold shading indicates upward and downward propagation, respectively.
2.7 Summary of the Asian summer monsoon

Asian summer monsoon monitoring is very important because related fluctuations in convective activity and atmospheric circulation can influence the summer climate in Asia, including that of Japan. This section summarizes the characteristics of the Asian summer monsoon in 2015.

2.7.1 Temperature and precipitation

Four-month mean temperatures based on CLIMAT reports covering the monsoon season (June – September) were more than 1°C above normal from the southern part of Central Siberia to northern Mongolia, on the central Korean Peninsula, on the northern part of the Indochina Peninsula, and in central and southwestern India, and were more than 1°C below normal around the middle Yangtze River basin (Fig. 2.7.1).

Four-month total precipitation amounts for the same period were more than 140% of the normal on the Pacific side of eastern to western Japan, in eastern and southern China, from southern Mongolia to northwestern China, and in and around Pakistan. The corresponding figures were less than 40% of the normal on and around the western Korean Peninsula and in southern-to-western Indonesia (Fig. 2.7.2). These amounts were mostly consistent with the distribution of outgoing longwave radiation (OLR) anomalies (Fig. 2.7.3).

Extremely heavy precipitation (based on monthly data) was seen from the Kyushu region of Japan to central China in June. In contrast, extremely light precipitation was seen in Mongolia in August (figures not shown).

Floods hit various districts of India, mostly in July and August. Monsoon-season fatalities exceeded 850 in India according to the country’s government. Monthly precipitation in July at Kolkata/Alipore in eastern India was 674 mm (1981 – 2010 average: 409.4 mm), and that in August at Jodhpur in northwestern India was 232 mm (1981 – 2010 average: 114.1 mm).

Floods and landslides hit northern and eastern Pakistan from mid-July to mid-August. Monsoon-season fatalities exceeded 230 in Pakistan according to the country’s government. Monthly precipitation in July at Lahore in northeastern Pakistan was 329 mm (1981 – 2010 average: 171.7 mm), including more than 160 mm from 18 to 21 July. Monthly precipitation in August at Parachinar in northern Pakistan was 196 mm (1981 – 2010 average: 109.4 mm), including more than 100 mm from 12 to 15 August.

Floods in various districts of Myanmar mostly in July and August caused more than 120 fatalities.
according to the country’s government. Monthly precipitation in July at Sittwe in western Myanmar was 1745 mm (1981 – 2010 average: 878.6 mm).

A severe heatwave in southern Pakistan in the latter half of June reportedly caused more than 1200 fatalities (EM-DAT). At Karachi Airport in southern Pakistan, daily minimum temperatures were 30°C or more from 18 to 28 June and daily maximum temperatures exceeded 40°C from 19 to 23 June.

2.7.2 Typhoons

During the monsoon season, 14 tropical cyclones (TCs) of tropical storm (TS) intensity or higher formed over the western North Pacific (Table 2.4.2). This was lower than the normal (1981 – 2010 average) of 16.0. The average position of TC formations in 2015 was south and east of the normal. Four TCs hit the main islands of Japan, which was above the normal of 2.7.

Fatalities from Typhoon Soudelor exceeded 20 in China, and those from Typhoon Goni exceeded 30 in the Philippines according to the respective national governments.

2.7.3 Convective activity and atmospheric circulation

Convective activity (inferred from OLR) averaged for June – September 2015 was enhanced from eastern China to eastern Japan, and was suppressed over large parts of the Asian summer monsoon region, especially over the area around the Maritime Continent and east of the Philippines (Fig. 2.7.3). OLR index data (Table 2.7.1) indicate that the overall activity of the Asian summer monsoon (represented by the SAMOI (A) index) was below normal throughout the summer monsoon season, especially in August. The active convection area was located west of its normal position (see the SAMOI (W) index.).

In the upper troposphere, the Tibetan High was generally weaker than normal (Fig. 2.7.4 (a)) in association with the subtropical jet stream flowing southward of its normal position. In the lower troposphere, monsoon circulation over the Indian Ocean was weaker than normal and the Somali Jet was weaker than normal (Fig. 2.7.4 (b)). Zonal wind shear between the upper and lower troposphere over the North Indian Ocean and southern Asia (Fig. 2.7.5) remained weaker than normal after July. The northwestward extension of the Pacific High was weaker than normal, contributing to cool wet summer conditions around western Japan (see Section 3.2 for details).

In the second half of mid-June, the overall activity of the Asian summer monsoon temporarily shifted into an enhanced phase (Fig. 2.7.6). The active phase of the MJO was seen over the eastern Indian Ocean in the second half of mid-June (Fig. 2.4.2). The time-latitude section for OLR anomalies averaged over the area between 80° and 140ºE (Fig. 2.7.7) also indicates that an enhanced convection phase, which started to propagate northward at the end of May, reached the area around 10°N at about the same time.

Reference

Fig. 2.7.3 Four-month mean outgoing longwave radiation (OLR) and related anomaly for June – September 2015
The contours indicate OLR at intervals of 10 W/m², and the colored shading denotes OLR anomalies from the normal. Negative (cold color) and positive (warm color) OLR anomalies show enhanced and suppressed convection compared to the normal, respectively. Original data provided by NOAA.

Table 2.7.1 Summer Asian Monsoon OLR Index (SAMOI) values observed from May to October 2015
SAMOI is described in 1.4.3.

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<td>2.0</td>
</tr>
<tr>
<td>Jun. 2015</td>
<td>-1.2</td>
<td>-1.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Jul. 2015</td>
<td>-0.7</td>
<td>2.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Aug. 2015</td>
<td>-1.9</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Sep. 2015</td>
<td>-1.0</td>
<td>-0.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Oct. 2015</td>
<td>-1.4</td>
<td>1.8</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Fig. 2.7.4 Four-month mean stream function and related anomaly for June – September 2015
(a) The contours indicate the 200-hPa stream function at intervals of $10 \times 10^6$ m²/s, and the colored shading indicates 200-hPa stream function anomalies from the normal. (b) The contours indicate the 850-hPa stream function at intervals of $4 \times 10^6$ m²/s, and the colored shading indicates 850-hPa stream function anomalies from the normal. Warm (cold) shading denotes anticyclonic (cyclonic) circulation anomalies in the Northern Hemisphere and vice-versa in the Southern Hemisphere.
Fig. 2.7.5 Time-series representation of the zonal wind shear index between 200 hPa and 850 hPa averaged over the North Indian Ocean and southern Asia (pink rectangle in the right figure: equator – 20ºN, 40ºE – 110ºE)

The zonal wind shear index is calculated after Webster and Yang (1992). The thick and thin pink lines indicate seven-day running mean and daily mean values, respectively. The black line denotes the normal, and the gray shading shows the range of the standard deviation calculated for the time period of the normal.

Fig. 2.7.6 Time-series representation of the Summer Asian Monsoon OLR Index (SAMOI-A) indicating monsoon activity.

The thick and thin green lines indicate seven-day running mean and daily mean values, respectively. See Subsection 1.4.3 for details of SAMOI-A.

Fig. 2.7.7 Time-latitude section for OLR anomalies averaged over the area from 80 to 140ºE for 1 May to 31 October 2015.

Negative (cold colors) and positive (warm colors) OLR anomalies show enhanced and suppressed convection compared to the normal, respectively.
2.8 Arctic sea ice conditions

The sea ice extent in the Arctic Ocean has recently shown a decreasing tendency that has been particularly marked in terms of the annual minimum extent (Fig. 2.8.1). The monitoring of Arctic sea ice conditions has become more significant because of their possible influence on the climate as a result of related changes in the radiation budget and heat exchange between the Arctic Ocean and the atmosphere. This section outlines the characteristics of the Arctic sea ice extent seen in 2015 along with those of atmospheric circulation.

2.8.1 Presence of sea ice in the Arctic in 2015

The Arctic sea ice extent\(^1\) in 2015 was below normal throughout the year. It reached its annual maximum on 25 February at 14.64 million square kilometers (the smallest since 1979; Fig. 2.8.2) and its annual minimum on 7 September at 4.48 million square kilometers (a preliminary value and the fourth smallest since 1979; Fig. 2.8.3).

2.8.2 Arctic atmospheric circulation and melting of sea ice

In July and August 2015, a high-pressure system over the Arctic region (Fig. 2.8.4) brought warm and sunny conditions compared to the normal, contributing to sea ice convergence and a smaller sea ice extent (NSIDC\(^2\)). In the lower troposphere, above-normal temperatures in the Arctic region in July and September (Fig. 2.8.5) supported a reduction of the sea ice extent.

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\(^1\) The sea ice extent is defined as the area in which ice concentration (i.e., the ratio of ice cover in a particular reference area) is 15 – 100%.

\(^2\) http://nsidc.org/arcticseaicenews/2015/09/
Fig. 2.8.4 Monthly mean sea level pressure over the Arctic region in July (left), August (middle) and September (right) 2015
The contours show sea level pressure at intervals of 4 hPa, and the shading indicates related anomalies.

Fig. 2.8.5 Monthly mean 925-hPa temperature over the Arctic region in July (left), August (middle) and September (right) 2015
The contours show 925-hPa temperature at intervals of 3°C, and the shading indicates related anomalies.
2.9 Snow cover in the Northern Hemisphere

Snow cover has a close and mutual association with climatic conditions. The albedo of snow-covered ground (i.e., the ratio of solar radiation reflected by the surface) is higher than that of snow-free ground. As a result, the variability of snow cover has an impact on the earth’s surface energy budget and radiation balance. In addition, snow absorbs heat from its surroundings and melts, thereby providing soil moisture. The variability of atmospheric circulation and oceanographic conditions affects the amount of snow cover. This section outlines the characteristics of snow cover in 2015 as well as its long-term variability and related trends.

2.9.1 Related characteristics in 2015

In winter (December – February) 2014/2015, there were fewer days of snow cover than normal in the northern USA, Europe and the northern part of East Asia in December, and fewer than normal in many parts of the Northern Hemisphere in January. Meanwhile, there were more days of snow cover than normal in the eastern part of North America and western Europe in February (Fig. 2.9.1 (a)). This higher-than-normal trend continued in North America until April (figures not shown). There were also more days of snow cover than normal in Eastern Siberia and northeastern Canada in May (Fig. 2.9.1 (b)). In November 2015, there were more days of snow cover than normal in Western Siberia and northeastern Canada, and fewer in eastern Europe, western China and southern Canada (Fig. 2.9.1 (c)).
2.9.2 Interannual variability and related trends

Figure 2.9.2 shows interannual variations in the total area of monthly snow cover in the Northern Hemisphere and Eurasia over the 28-year period from 1988 to 2015.

The Northern Hemisphere exhibits a decreasing trend (with a 95% confidence level) for May, June and the period from September to December, while no trend

(with a 95% confidence level) is seen for the period from January to April.

In Eurasia there is a decreasing trend for May, June, November and December, while no trend is seen for the period from January to April or for September and October.

Fig. 2.9.2 Interannual variations in the total area of monthly snow cover ($10^6 \text{ km}^2$) in the Northern Hemisphere (north of 30°N; left) and Eurasia (30°N – 80°N, 0 – 180°E; right) for February ((a) and (d)), May ((b) and (e)), and November ((c) and (f)) from 1988 to 2015.

The blue lines indicate total snow cover area for each year, the red lines show five-year running means, and the black lines show linear trends (95% confidence level).