Summary of the 2016 Asian Summer Monsoon

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This report summarizes the characteristics of the surface climate and atmospheric/oceanographic considerations related to the Asian Sinter monsoon for 2016.

Note: Japanese 55-year Reanalysis (JRA-55; http://jra.kishou.go.jp/JRA-55/index_en.html; Kobayashi et al. 2015) atmospheric circulation data and COBE-SST (Ishii et al. 2005) sea surface temperature (SST) data were used for this investigation. The outgoing longwave radiation (OLR) data referenced to infer tropical convective activity were originally provided by NOAA. The base period for the normal is 1981 –2010. The term “anomaly” as used in this report refers to deviation from the normal.

1. <u>Precipitation and temperature</u>

Four-month total precipitation amounts based on CLIMAT reports for the monsoon season (June – September) were more than 140% of the normal in the Hokkaido region of Japan, in eastern China, in southern Mongolia, in the area from northern Lao PDR to northern Myanmar, in and around northern Pakistan and in central Indonesia. Conversely, the corresponding figures were less than 60% of the normal on the Korean Peninsula, in northeastern and central China, in and around southern India and in southwestern Pakistan (Figure 1). Remarkably high precipitation was seen over the mid- to downstream basin of the Yangtze River in China from June to August and in Hokkaido in August.

Four-month mean temperatures for the same period were more than 1°C above normal in many parts of East Asia, especially north of 30°N, and were slightly below normal in parts of South Asia and Myanmar (Figure 2).

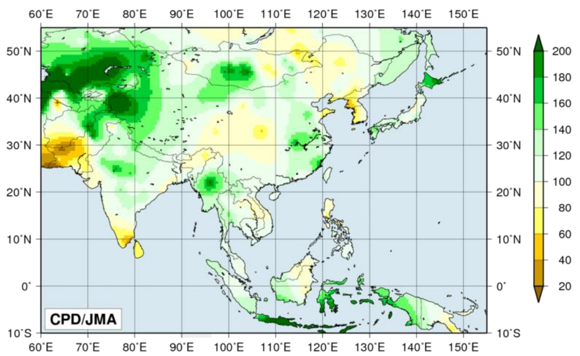


Figure 1 Four-month precipitation ratios (%) from June to September 2016

The base period for normal is 1981 – 2010. Note that the data in Vietnam, Thailand and Cambodia are interpolated due to the lack of CLIMAT report or climatological normal.

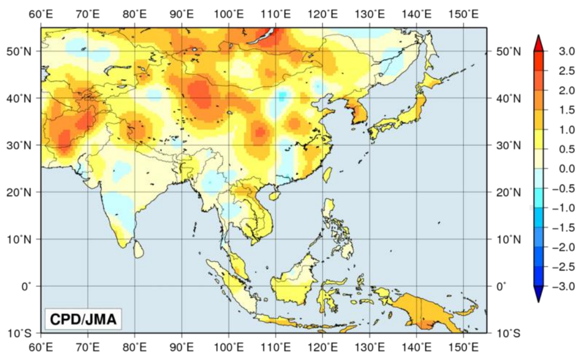


Figure 2 Four-month mean temperature anomalies (°C) from June to September 2016

The base period for normal is 1981 – 2010. Note that the data in Vietnam, Thailand and Cambodia are interpolated due to the lack of CLIMAT report or climatological normal.

2. Tropical cyclones

The first named tropical cyclone (TC) of 2016 formed over the western North Pacific on July 3, making it the second-latest on record since 1951. Subsequently, however, the number of TC formations approached the normal. As of the end of September, there had been 18 TCs (Table 1) against a normal of 18.4. Six of these made landfall on Japan, which is the joint-second-highest number on record (after the 10 recorded in 2004).

TC activity and tracks in August were especially notable. A total of seven TCs formed, with six approaching or making landfall on East Asia and five approaching or making landfall on mainland Japan (climatological normal: 1.7). Some of these TCs formed to the southeast of Japan and moved northward toward the country. This was unusual for the time of year, when most TCs in the region move westward along the southern edge of the North Pacific Subtropical High. These unusual track characteristics resulted in three TC landfalls on Hokkaido for the first time since 1951.

Table 1 Tropical cyclones forming over the western North Pacific from June to September 2016

Number ID	Name	Date (UTC)	Category[1]	Maxumum wind[2] (knots)
T1601	Nepartak	7/3-7/9	TY	110
T1602	Lupit	7/23-7/24	TS	40
T1603	Mirinae	7/26-7/28	STS	55
T1604	Nida	7/30-8/2	STS	60
T1605	Omais	8/4-8/9	STS	60
T1606	Conson	8/9-8/14	TS	45
T1607	Chanthu	8/13-8/17	STS	55
T1608	Dianmu	8/17-8/19	TS	40
T1609	Mindulle	8/19-8/23	TY	65
T1610	Lionrock	8/21-8/30	TY	90
T1611	Kompasu	8/20-8/21	TS	35
T1612	Namtheun	9/1-9/4	TY	70
T1613	Malou	9/6	TS	40
T1614	Meranti	9/10-9/15	TY	120
T1615	Rai	9/12-9/13	TS	35
T1616	Malakas	9/12-9/20	TY	95
T1617	Megi	9/23-9/28	TY	85
T1618	Chaba	9/29-10/5	TY	115

Note: Based on information from the RSMC Tokyo-Typhoon Center.

1) Intensity classification for tropical cyclones

TS: tropical storm, STS: severe tropical storm, TY: typhoon

2) Estimated maximum 10-minute mean wind

3. Monsoon activity and atmospheric circulation

Convective activity (inferred from OLR) averaged for June – September 2016 was enhanced from the eastern Indian Ocean to the Maritime Continent, over the area from the Bay of Bengal to the southwestern Indochina Peninsula and from southern China to the seas northeast of the Philippines, and was suppressed over the western part of the equatorial Pacific (Fig. 3). OLR index data (Table 2) indicate that the overall activity of the Asian summer monsoon (represented by the SAMOI (A) index) was near normal until August and above normal in September. The most-active convection area was shifted westward of its normal position until July (see the SAMOI (W) index.).

In the upper troposphere, the Tibetan High was stronger than normal over its northeastern part (Fig. 4 (a)). In the upper troposphere, the Tibetan High was stronger than normal over its northeastern part. In the lower troposphere, monsoon circulation over the Indian Ocean was stronger than normal and cyclonic circulation anomalies straddling the equator were seen over the area from the Indian Ocean to the Maritime Continent (Fig. 4 (b)). Zonal wind shear between the upper and lower troposphere over the North Indian Ocean and southern Asia (Fig. 5) remained above normal, indicating stronger-than-normal monsoon circulation from mid-May onward (except in the second half of July and the first half of late August).

Convective activity over the Maritime Continent was enhanced throughout the summer monsoon season, while to the east of the Philippines it was suppressed in the first half of the season and enhanced in the second half (Fig. 6). In the lower troposphere, cyclonic circulation associated with a deep monsoon trough was clearly seen over the seas to the southeast of Japan in August in association with enhanced convective activity over the western North Pacific.

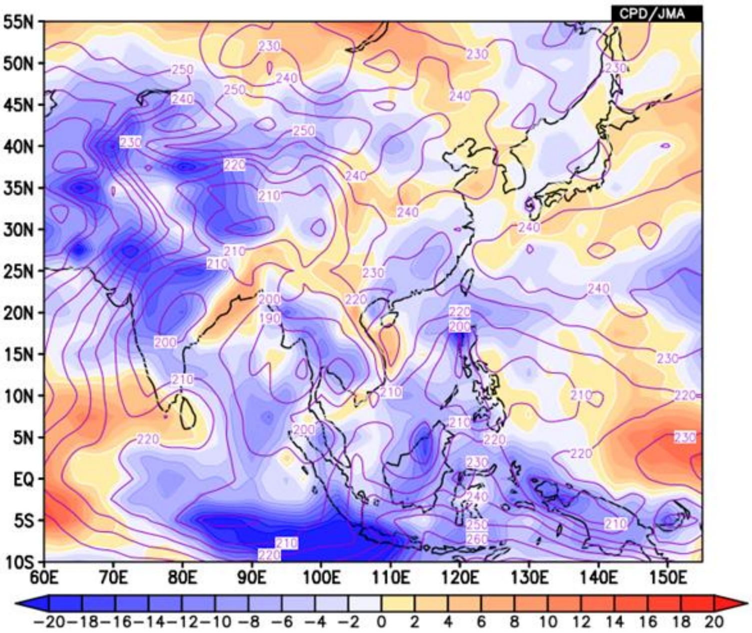


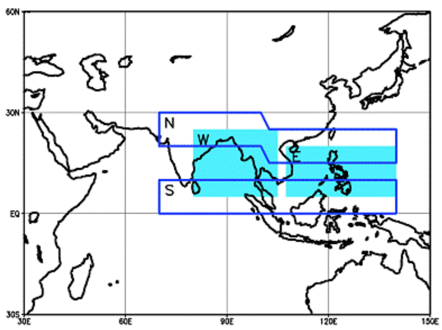
Figure 3 Four-month mean OLR and its anomaly for June–September 2016

The contours indicate OLR at intervals of 10 W/m^2, and the color shading denotes OLR anomalies from the normal (i.e., the 1981–2010 average). Negative (cold color) and positive (warm color) OLR anomalies show enhanced and suppressed convection compared to the normal, respectively. Original data are provided by NOAA.

Table 2 Summer Asian Monsoon OLR Index (SAMOI) values observed from May to October 2016

Asian summer monsoon OLR indices (SAMOI) are derived from OLR anomalies from May to October. SAMOI (A), (N) and (W) indicate the overall activity of the Asian summer monsoon, its northward shift and its westward shift, respectively. SAMOI definitions are as follows: SAMOI (A) = (-1) × (W + E); SAMOI (N) = S – N; SAMOI (W) = E – W. W, E, N and S indicate area-averaged OLR anomalies for the respective regions shown in the figure on the right normalized by their standard deviations.

	Summer Asian Monsoon OLR Index (SAMOI)		
	SAMOI (A): Activity	SAMOI (N): Northward-shift	SAMOI (W): Westward-shift
May 2016	0.4	-0.8	1.2
Jun. 2016	0.3	-0.5	1.0
Jul. 2016	-0.4	0.1	1.2
Aug. 2016	0.5	0.3	-0.9
Sep. 2016	1.6	0.8	0.0
Oct. 2016	1.1	-0.9	-0.5



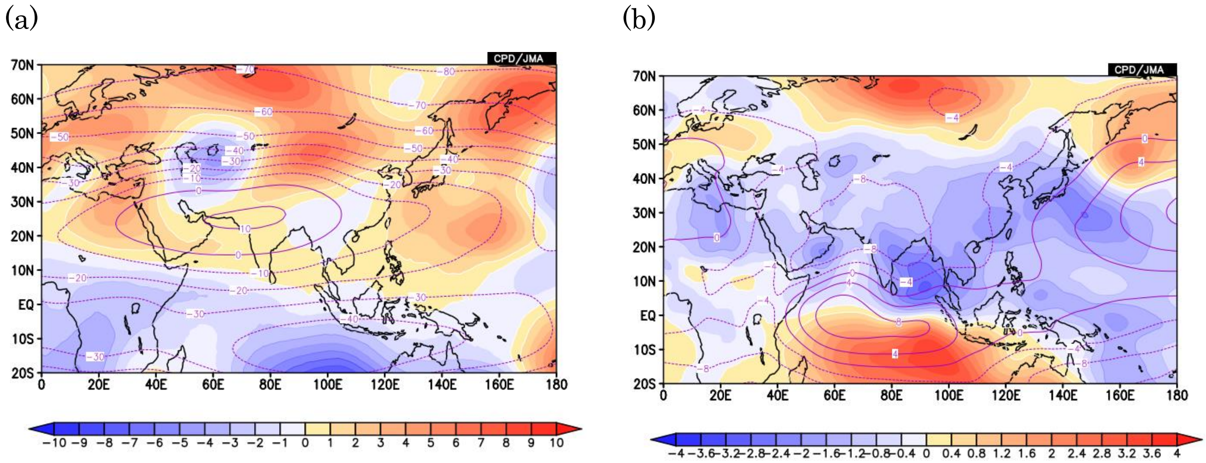
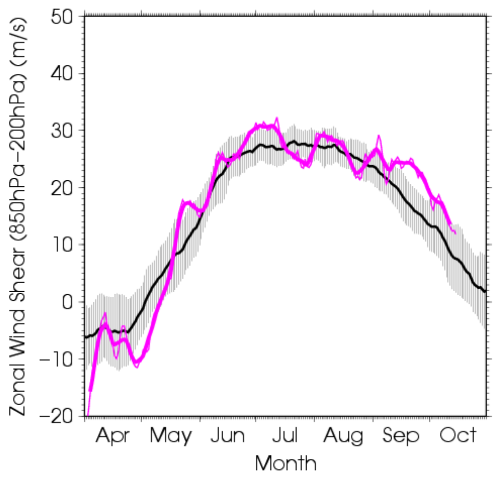


Figure 4 Four-month mean stream function and its anomaly for June – September 2016

(a) The contours indicate the 200-hPa stream function at intervals of 10 × 10^6 m^2/s, and the color shading indicates 200-hPa stream function anomalies from the normal. (b) The contours indicate the 850-hPa stream function at intervals of 4 × 10^6 m^2/s, and the color shading indicates 850-hPa stream function anomalies from the normal. The base period for the normal is 1981 – 2010. Warm (cold) shading denotes anticyclonic (cyclonic) circulation anomalies in the Northern Hemisphere, and vice-versa in the Southern Hemisphere.



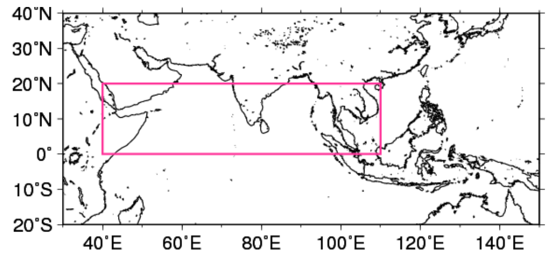


Figure 5 Time-series representation of the zonal wind shear index between 200-hPa and 850-hPa averaged over the North Indian Ocean and southern Asia (the region enclosed by the pink rectangle in the right figure: equator – 20°N, 40°E – 110°E)

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 (i.e., the 1981 – 2010 average), and the gray shading shows the range of the standard deviation calculated for the time period of the normal.

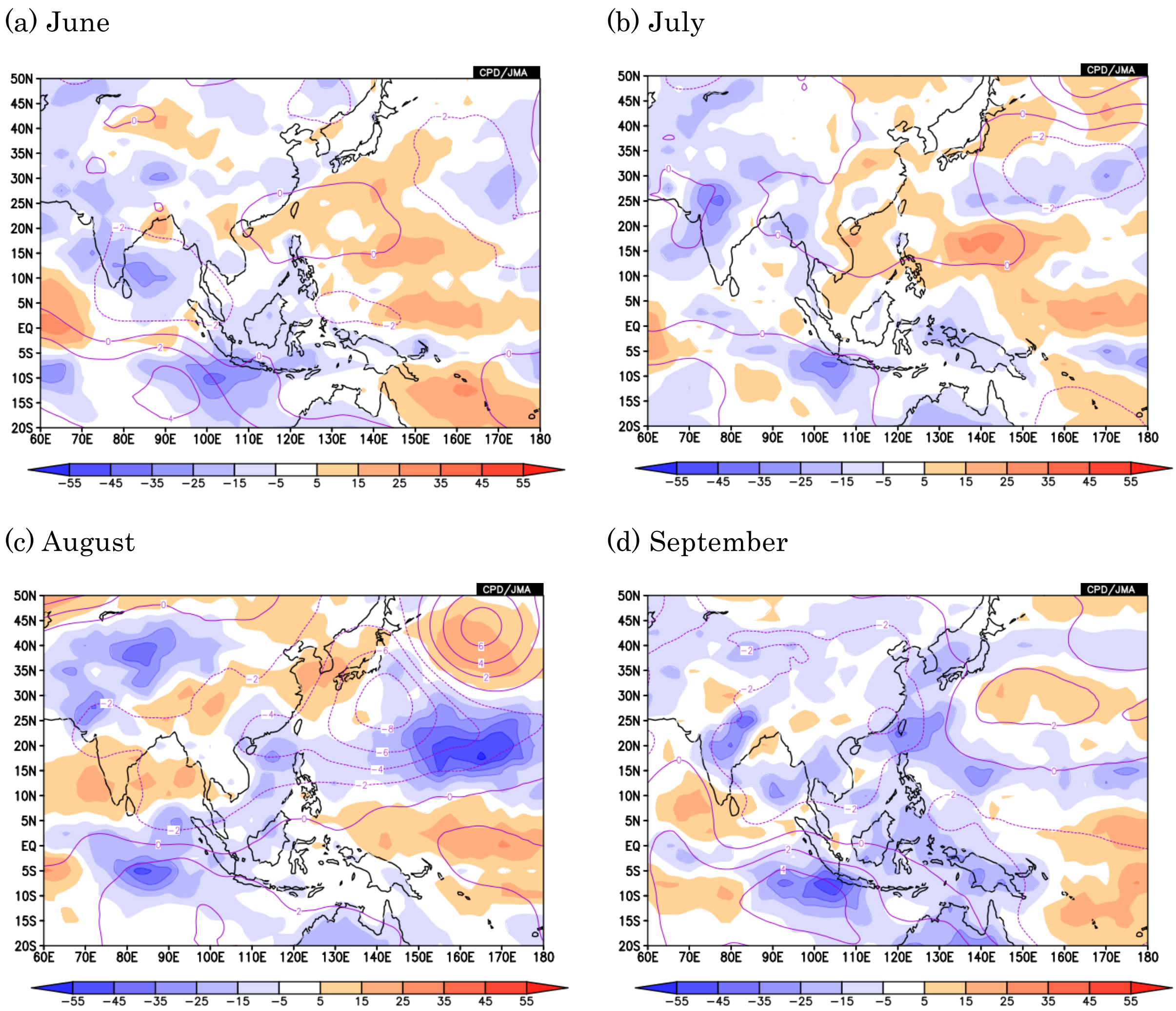


Figure 6 Monthly mean anomalies of OLR (shading at intervals of 10 W/m^2) and 850-hPa stream function (contour at intervals of 2×10^6 m^2/s) for (a) June, (b) July, (c) August and (d) September 2016

References

Webster, P. J. and S. Yang, 1992: Monsoon and ENSO: Selectively interactive systems. *Quart. J. Roy. Meteor. Soc.*, **118**, 877 – 926.

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