Primary Factors of Extremely Hot Summer 2010 in Japan

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Photo by K.Honda

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- Advisory Panel on Extreme Climate Events
- Temperature for summer 2010 in Japan
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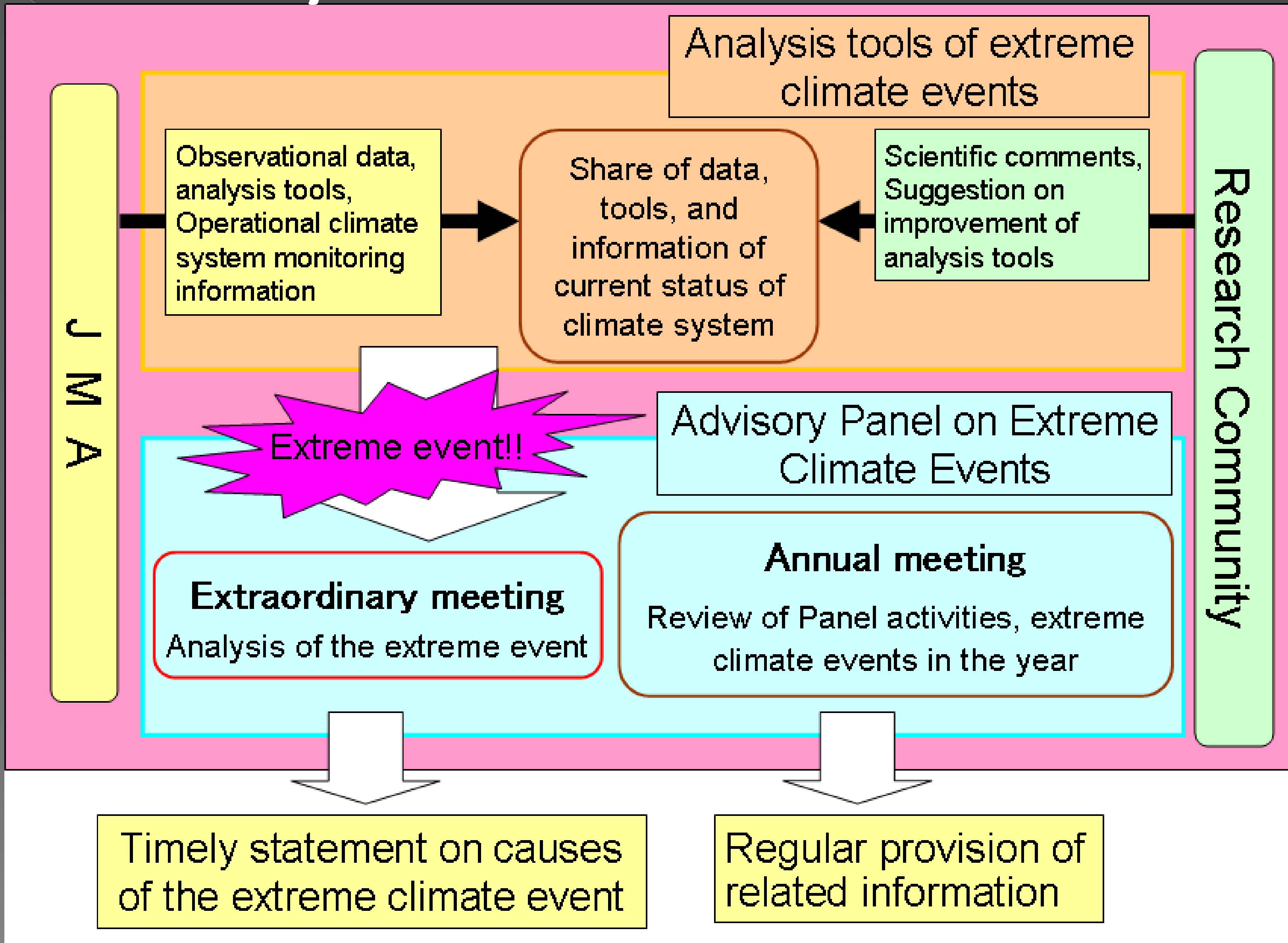
Advisory Panel on Extreme Climate Events



Flow of analysis in Advisory Panel on Extreme Climate Events

Extraordinary meeting (a web meeting)


JMA issued a press release to the public

http://www.jma.go.jp/jma/press/1009/03a/100903extreme.html
http://www.jma.go.jp/jma/press/1009/03a/extreme100903.pdf
(in Japanese)

http://ds.data.jma.go.jp/tcc/tcc/news/press_20100916.pdf
(in English)

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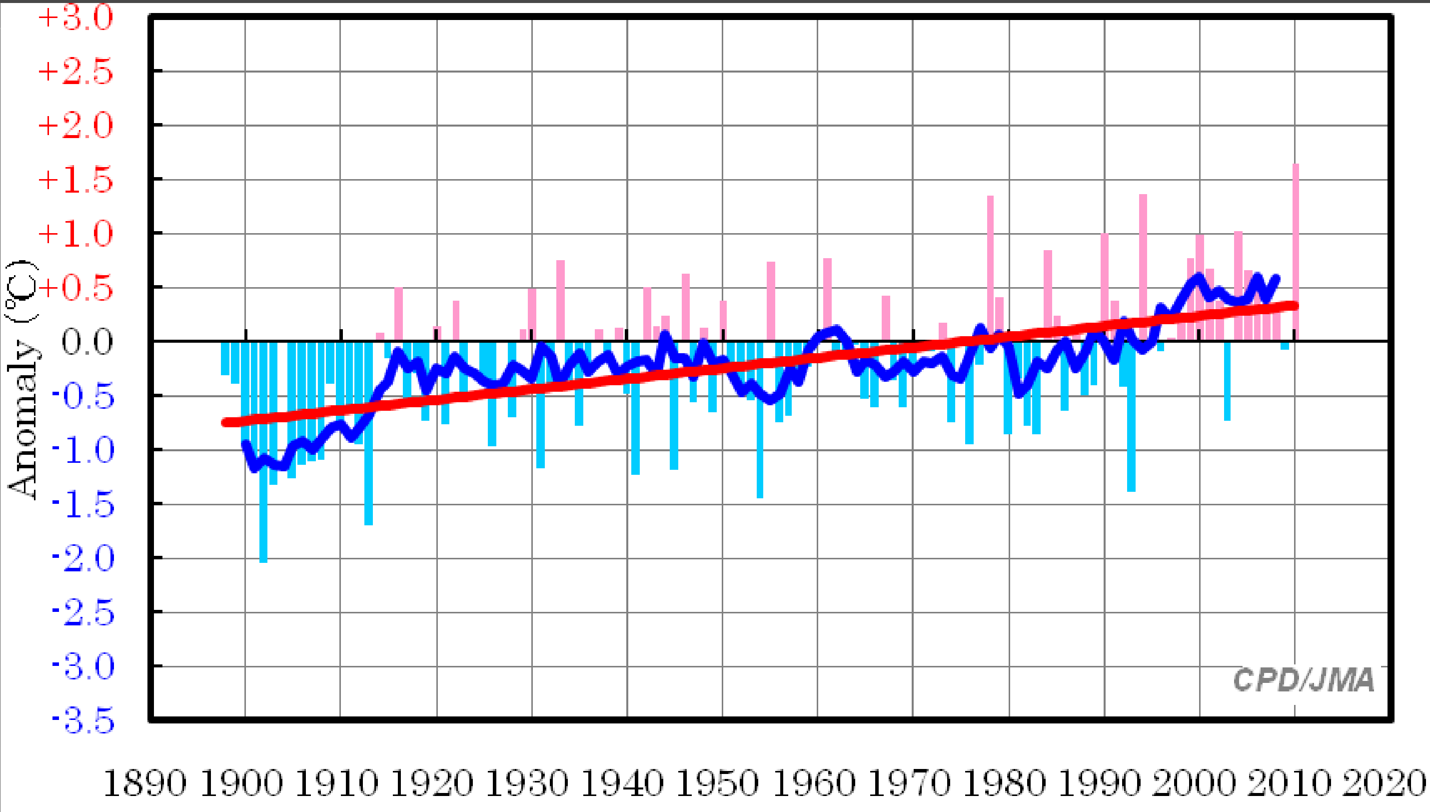
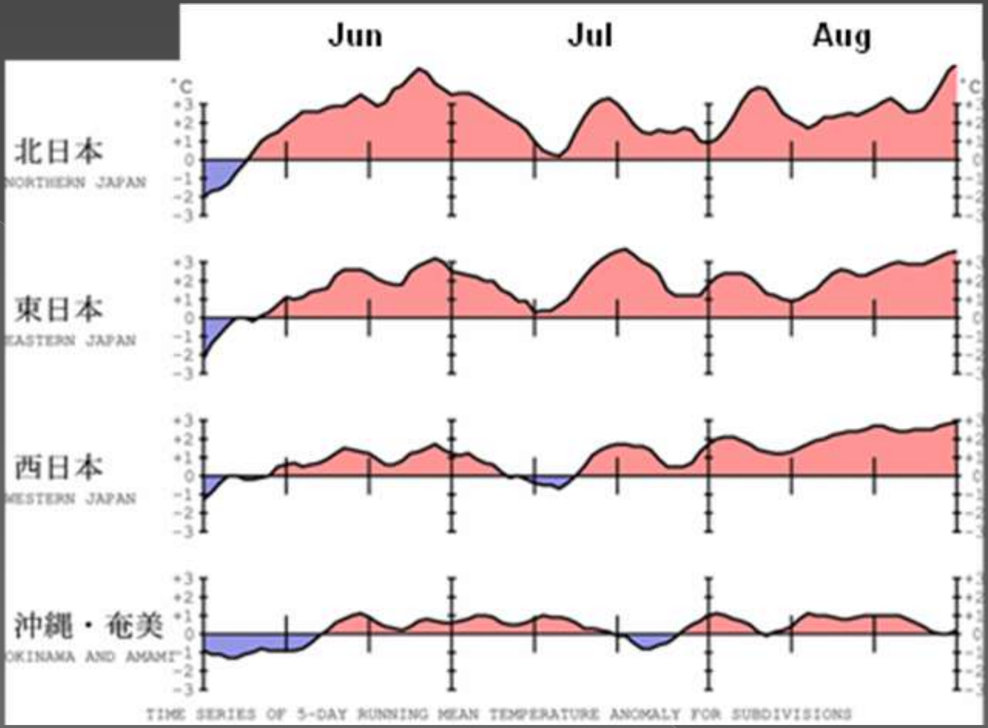


Long-term change in seasonal temperature anomalies for summer (June – August) in Japan.

Anomalies are calculated as the average of temperature deviations from the 1971 – 2000 normal at the 17 observation stations[2]. The bars indicate anomalies of temperature for each summer. The blue line indicates 5-year running mean, and the red line a long-term linear trend.



Time series of 5-day running mean temperature anomalies for regions in Japan (June – August 2010). Base period for the normal is 1971-2000.

- Three-month mean temperature for June – August in Japan was the highest on record since 1898;
- Three-month mean temperatures for June – August in Northern and Eastern Japan were the highest on record since 1946; and,
- Monthly mean temperatures for August in Northern, Eastern and Western Japan were the highest on record since 1946.

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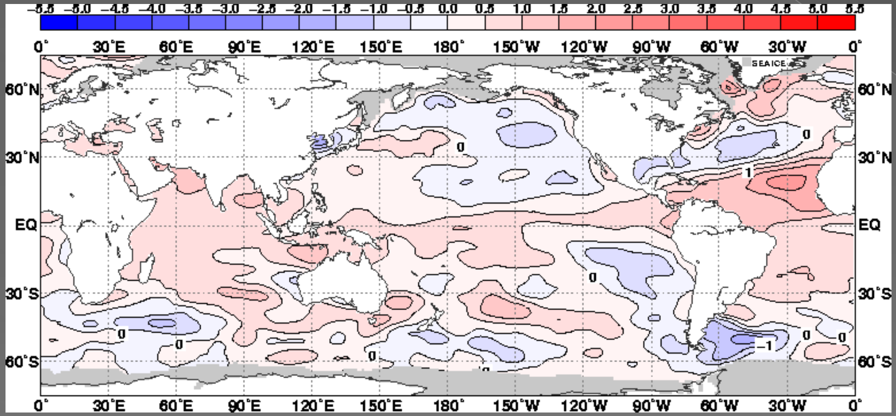
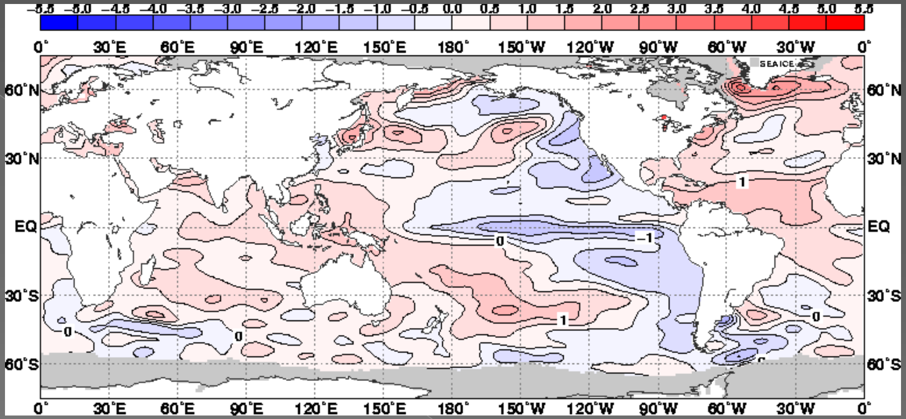
In summer (June – August) 2010, a La Niña event occurred after an El Niño event, which took place in summer 2009, ended spring (March – May) 2010

<u>Mar. – May 2010</u>

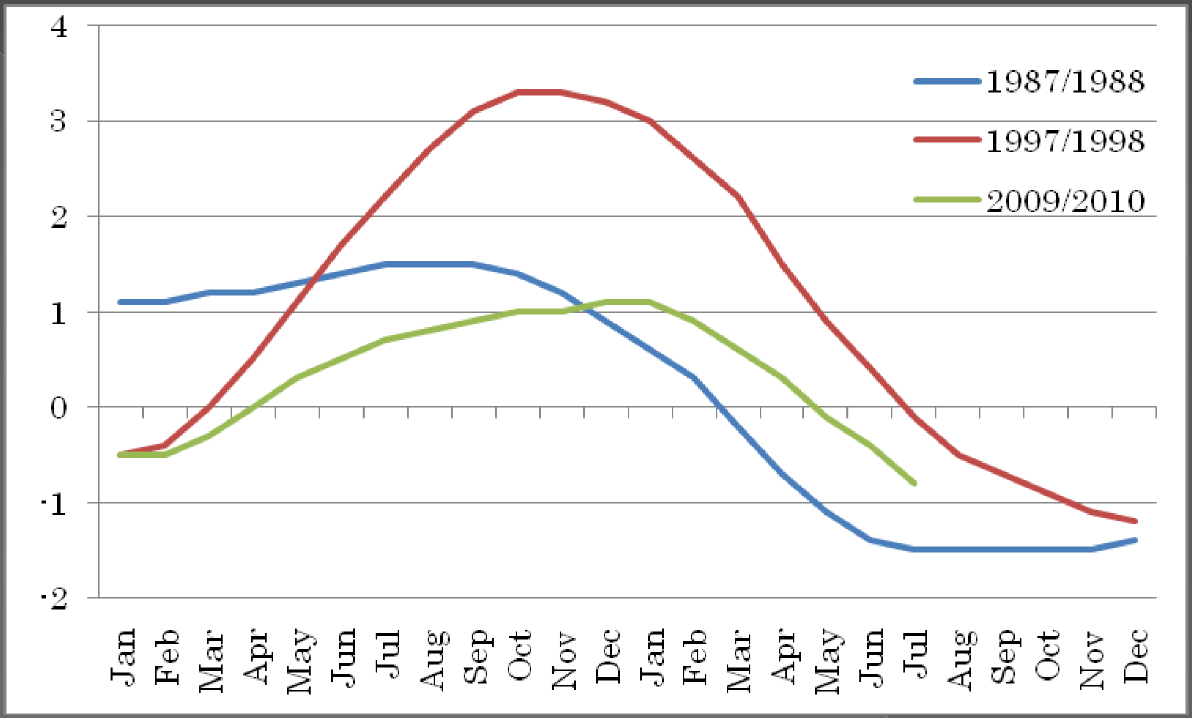


<u>Jun. – Aug. 2010</u>

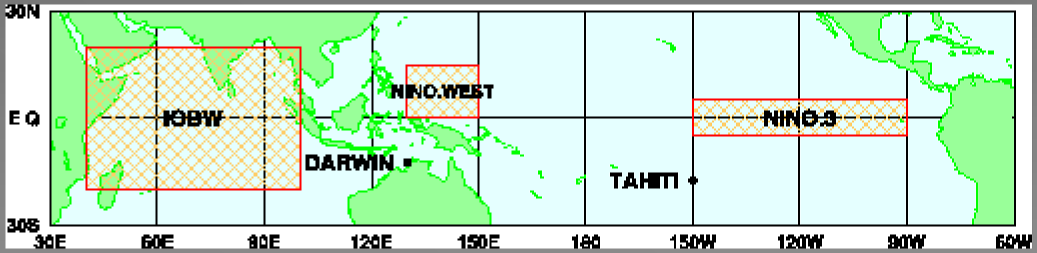


Three-month mean sea surface temperature anomalies. Normal is the 1971 – 2000 average. Analysis data are COBE-SST.

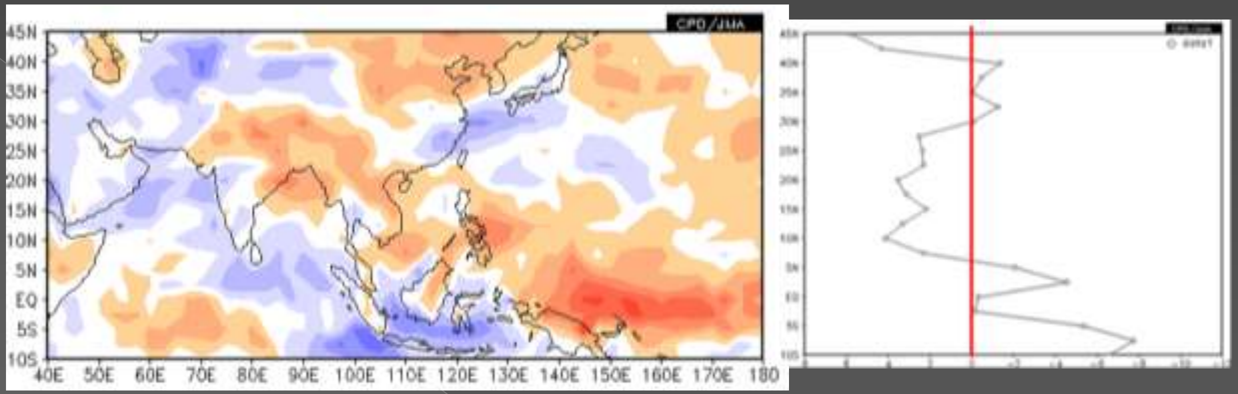
Comparison among three La Niña events rapidly occurred in spring and summer



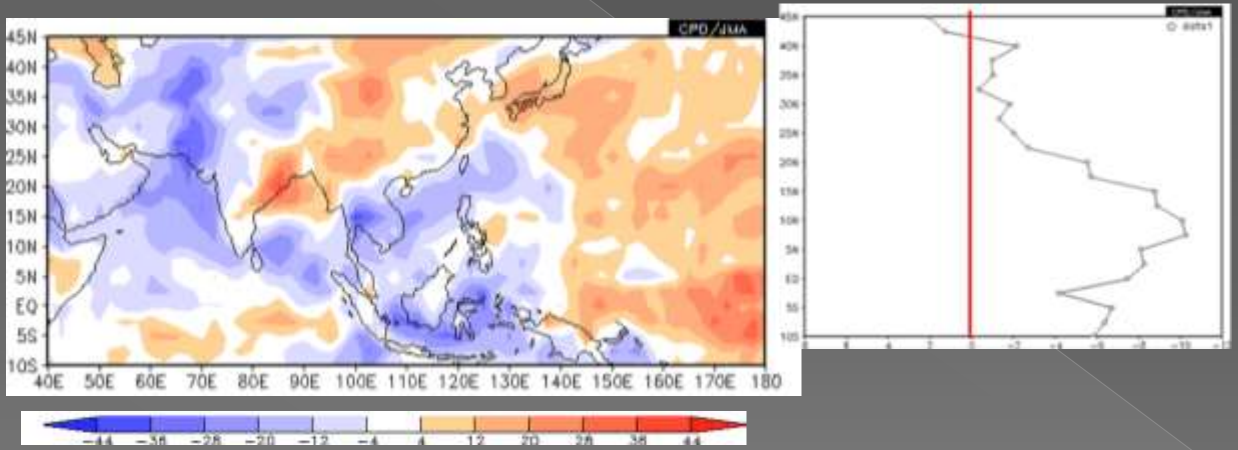
Time series of five-month running mean sea surface temperature deviations from the climatological mean based on a sliding 30-year period for NINO.3 (5˚S – 5˚N, 150˚W – 90˚W).



1 Jun. – 15 Jul. 2010



16 Jul. – 31 Aug. 2010



Outgoing Longwave Radiation (OLR) anomalies (unit: W/m^2). Left panels: cold- and warm-colored shading indicates enhanced and suppressed convective activities in comparison with normal (i.e. the 1979 – 2004 average), respectively. Right panels: values indicate zonal-averaged (60˚E – 140˚E) OLR anomalies in the corresponding left panels. Original data are provided by NOAA.

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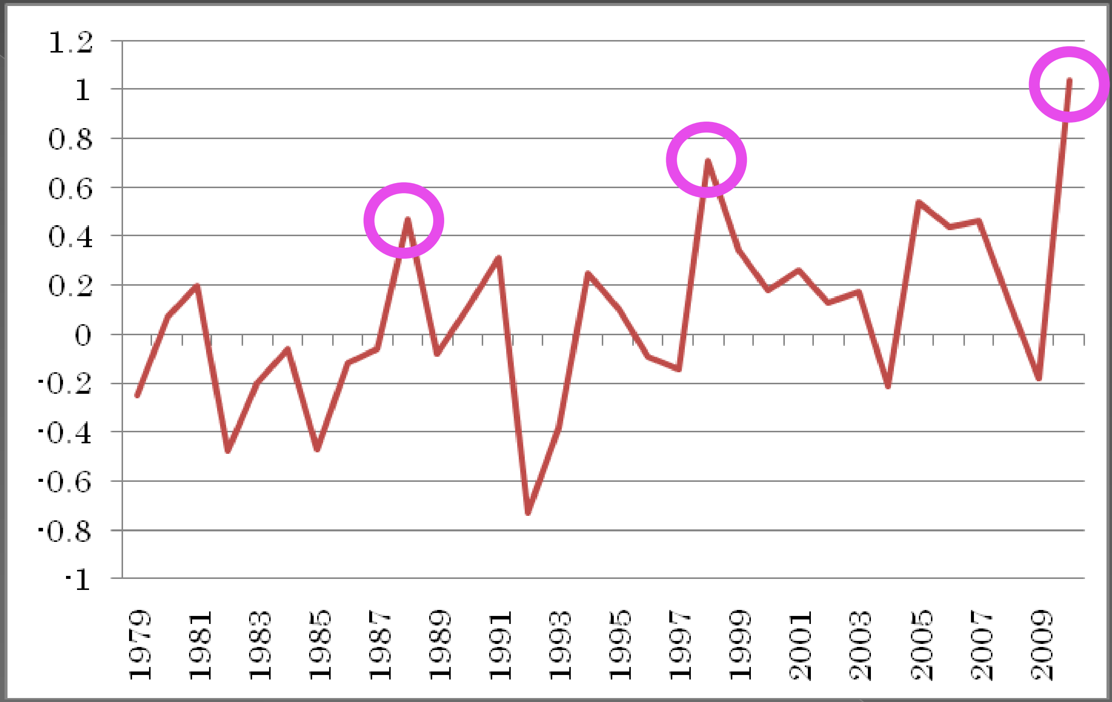
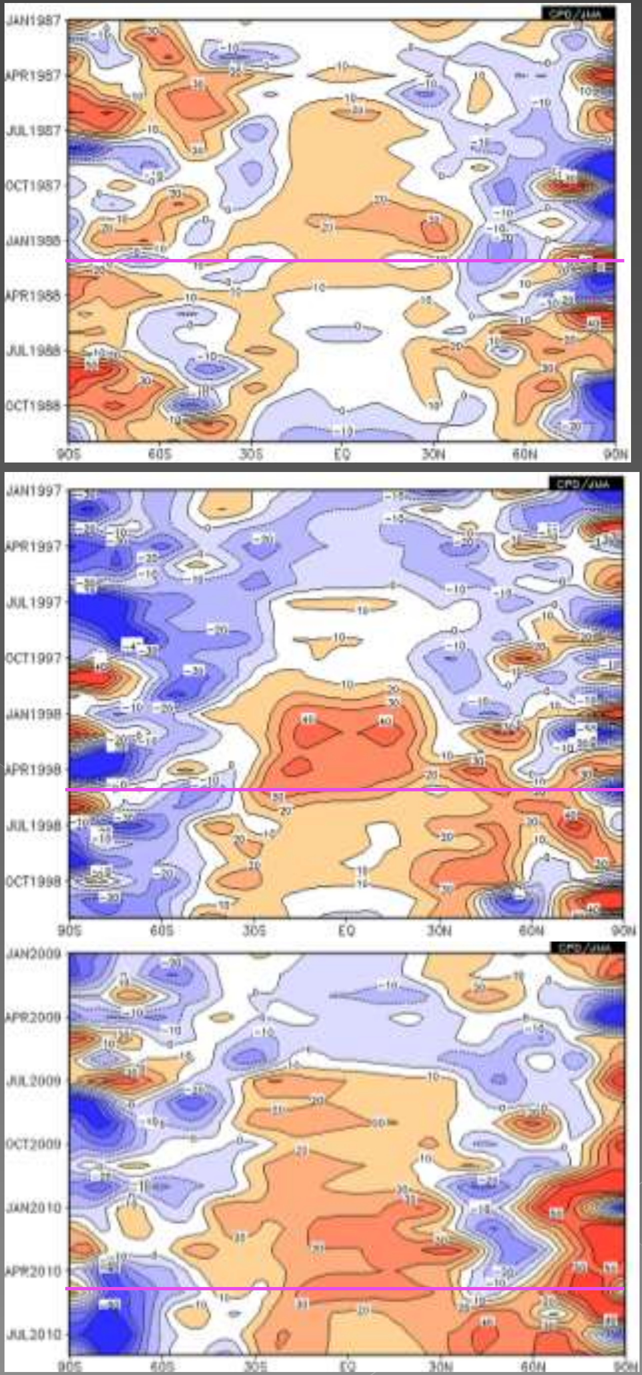
(1) Zonally-averaged tropospheric air temperature



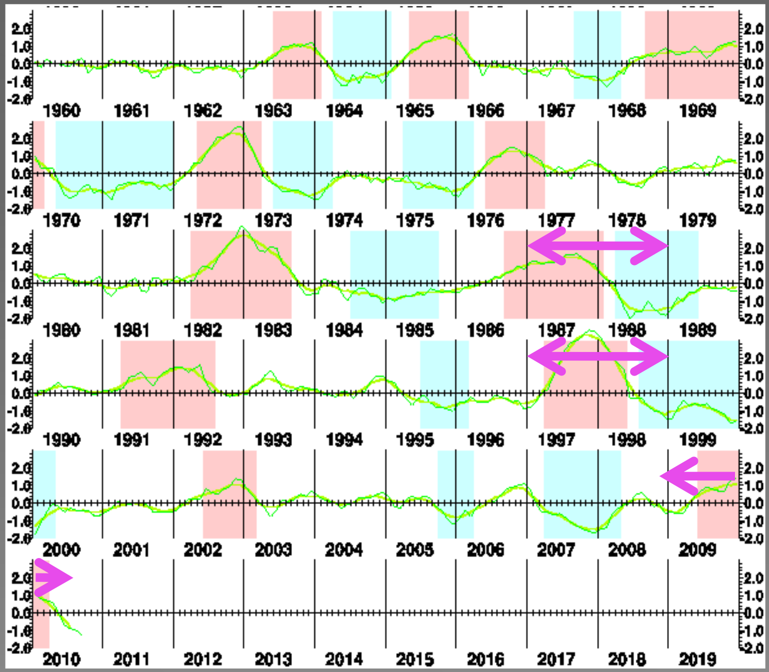
Time series of three-month (June – August) averaged zonal-mean temperature anomaly (unit: K) in the middle latitudes (30˚N – 60˚N) of the Northern Hemisphere calculated from thickness (850 – 300 hPa). Base period for normal is 1979-2004. Analysis data are JRA-25/JCDAS.

It can be identified that the zonally-averaged tropospheric air temperature in the mid-latitudes of the Northern Hemisphere has a warming trend . There is a possibility that the warming trend is associated with global warming due to the buildup of anthropogenic greenhouse gases.

Time-latitude cross section of monthly averaged zonal-mean thickness anomaly (unit: m). Base period for normal is 1979-2004. Analysis data are JRA-25/JCDAS.

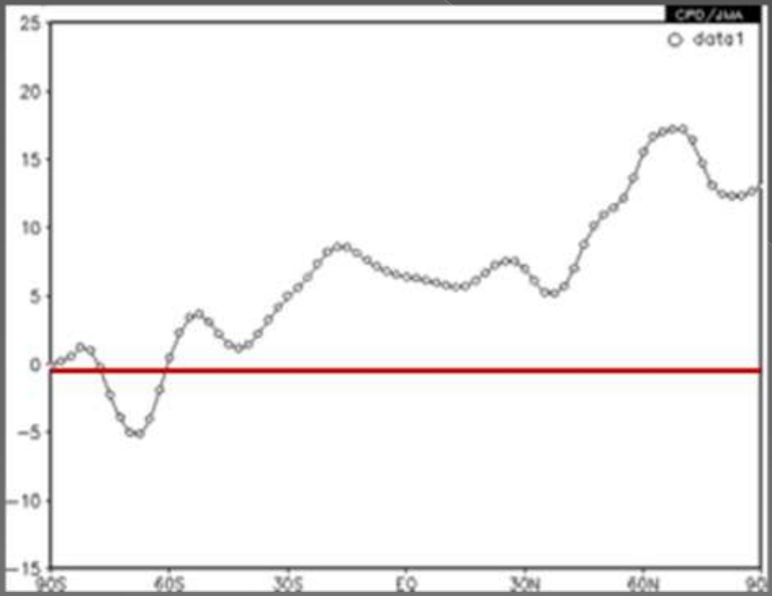


SST Anomaly at NONO.3(5S-5N,150W-90W)

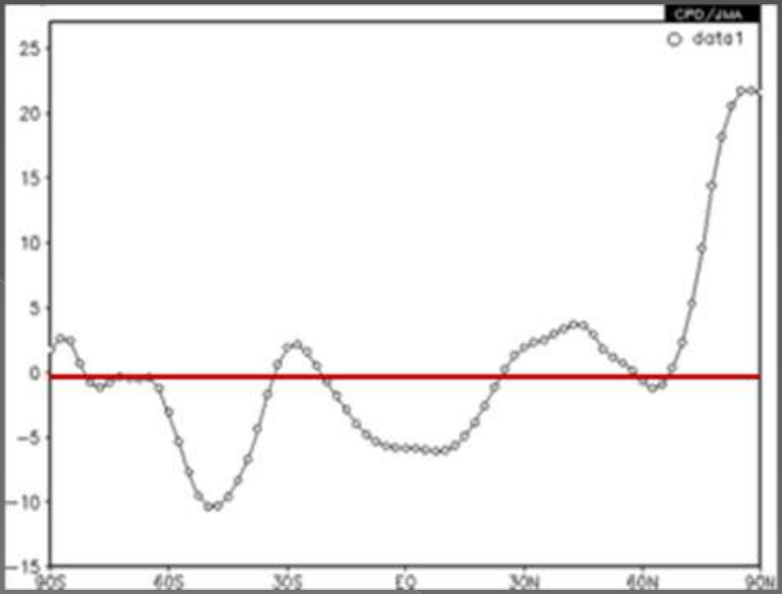


Composite of three-month (June – August) averaged zonal-mean tropospheric thickness

Post El Niño



La Niña



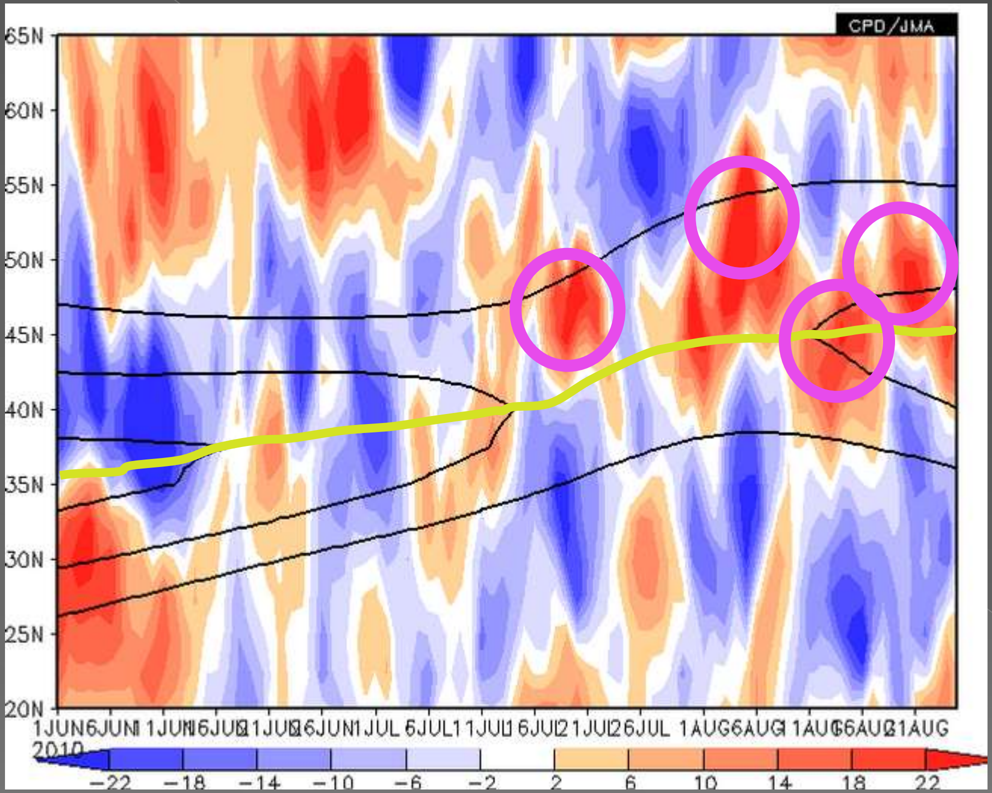
(1983, 1988, 1998 and 2003)

(1984, 1985, 1995, 1999 and 2007)

Base period for normal is 1979-2004. Analysis data are JRA-25/JCDAS.

(2) Remarkably strong anticyclone over Japan

Subtropical jet stream in the vicinity of Japan (125˚E – 145˚E)

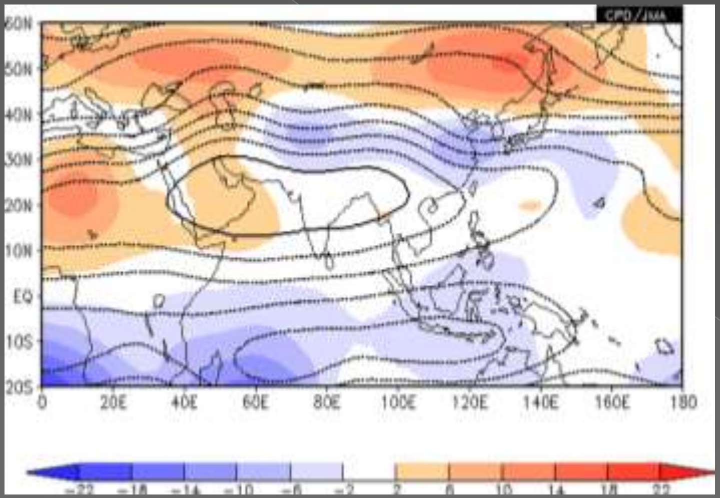


latitude-time cross section of normal (black lines) and anomalies (colored shading) of the 200-hPa zonal wind speed averaged in the area. Base period for normal is 1979-2004. Analysis data are JRA-25/JCDAS.

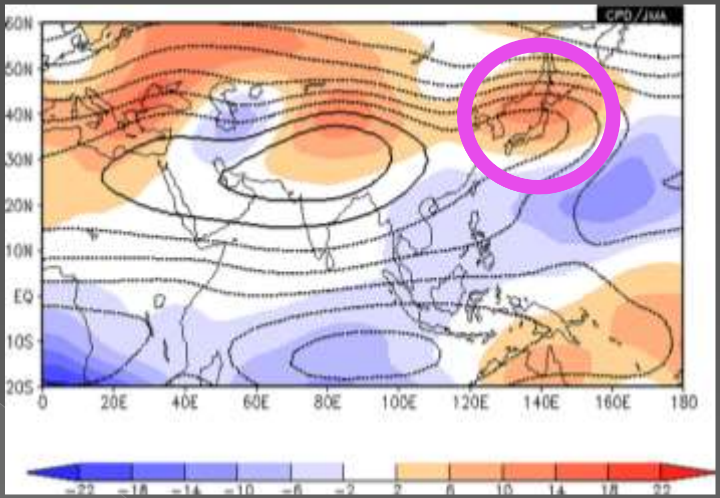
The subtropical jet stream in the vicinity of Japan tended to shift southward from its normal position in the first half of summer 2010, while the jet stream shifted northward from its normal position with a frequent northward meander (ridge of high pressure) in the second half of the summer.

Monthly-mean 200-hPa stream function and anomaly.

June 2010



August 2010

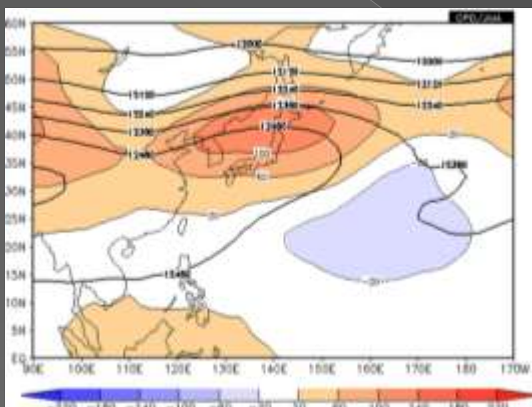


The contours show the stream function at intervals of 1 X 10^7 m^2/s, and the shading indicates stream function anomalies. In the Northern (Southern) Hemisphere, warm (cold) colored shading denotes anticyclonic (cyclonic) circulation anomalies. Base period for normal is 1979-2004. Analysis data are JRA-25/JCDAS.

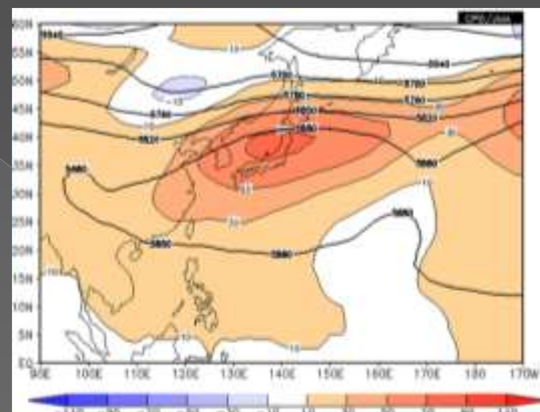
Corresponding to the features of the subtropical jet stream, extension of the Tibetan High to Japan was weaker than normal in the first half of summer 2010, while the extension was stronger than normal and equivalent-barotropic highs developed and persisted over Japan in the second half of the summer

Monthly-mean atmospheric circulation around Japan (August 2010).

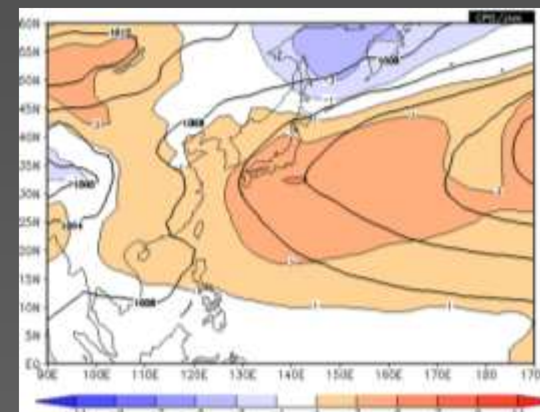
200-hPa height and anomaly



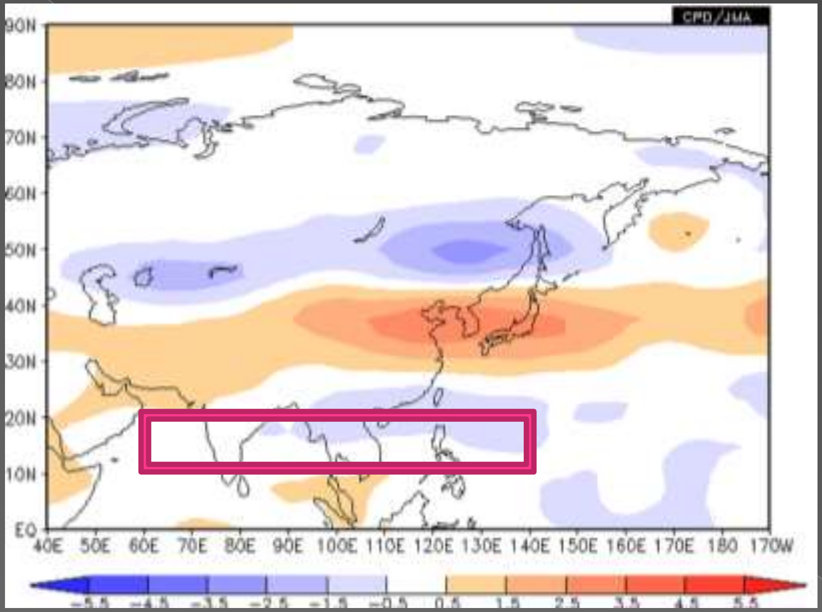
500-hPa height and anomaly

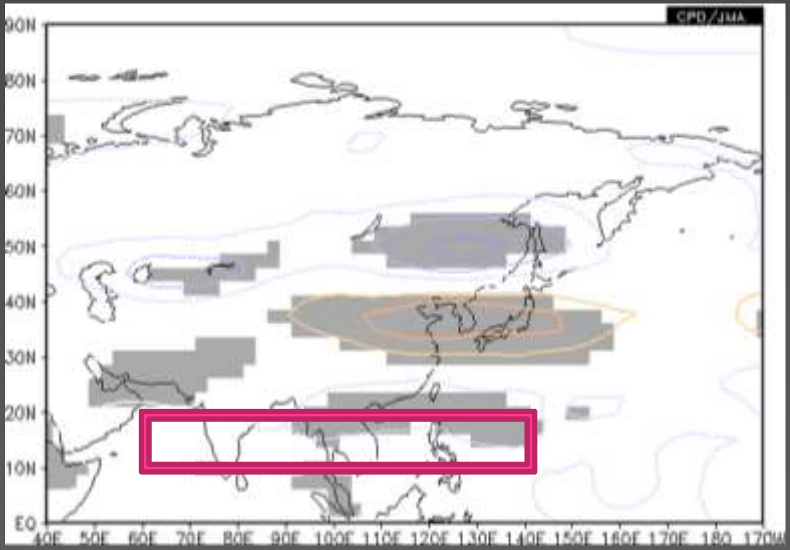


Sea level pressure and anomaly



Left panel: the contours indicate 200-hPa height at intervals of 120 m. Central panel: the contours indicate 500-hPa height at intervals of 60 m. Right panel: the contours indicate sea level pressure at intervals of 4-hPa. The shading shows their anomalies. Base period for normal is 1979-2004. Analysis data are JRA-25/JCDAS.





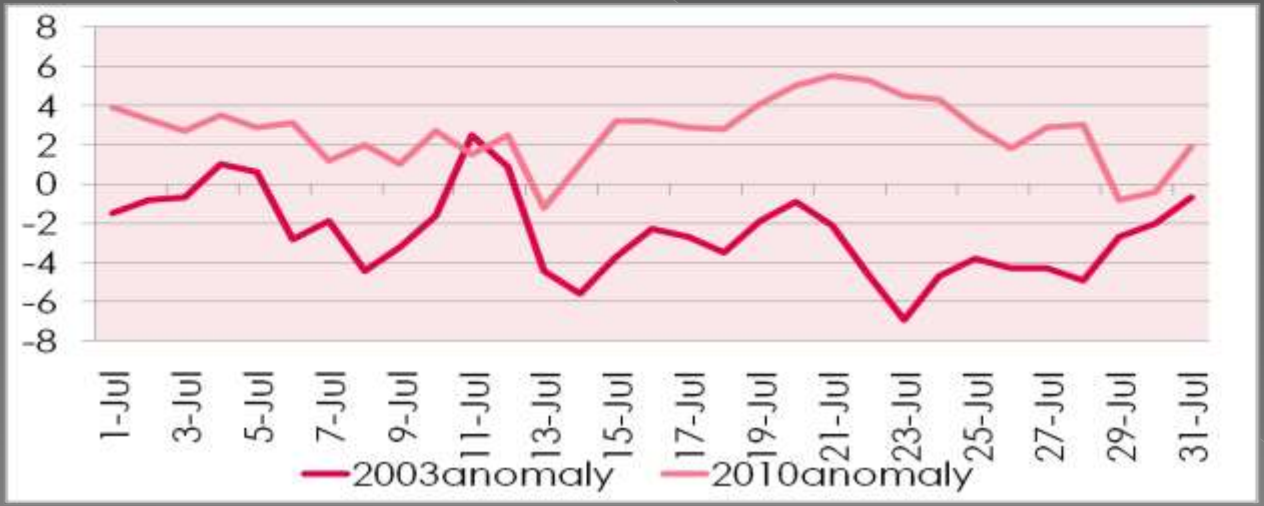
Linear regression coefficient of 200-hPa zonal wind speed onto area-averaged convective activity (OLR) over the region from the northern Indian Ocean to the northeast to the Philippines (10˚N – 20˚N, 60˚E – 140˚E) for July and August. Left panel indicates that when convective activity is enhanced (suppressed) over the region, the subtropical jet stream was stronger (weaker) than normal in the cold (warm) colored shading. Right panel: the shading shows a 95% confidence level based on F-test. The base period for statistics is 1979 – 2009. Analysis data are JRA-25/JCDAS.

When convective activity is enhanced (suppressed) over the region from the northern Indian Ocean to the northeast to the Philippines (10˚N – 20˚N, 60˚E – 140˚E), the subtropical jet stream near Japan tends to shift northward (southward) from its normal position (e.g., Krishnan and Sugi, 2001; Enomoto, 2004).

(3) Okhotsk High

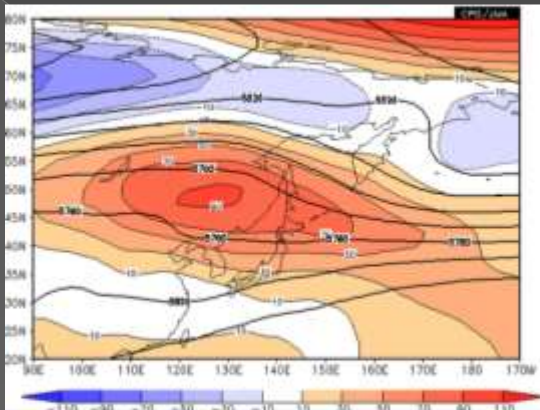
The Okhotsk High that is a cool semi-stationary anticyclone often develops around the Sea of Okhotsk from spring to autumn and occasionally brings cool air to the Pacific side of Northern and Eastern Japan, resulting in cool summer.

Blocking high in the upper troposphere over the Sea of Okhotsk plays an integral role for the formation of the Okhotsk High (Nakamura and Fukamachi, 2004).

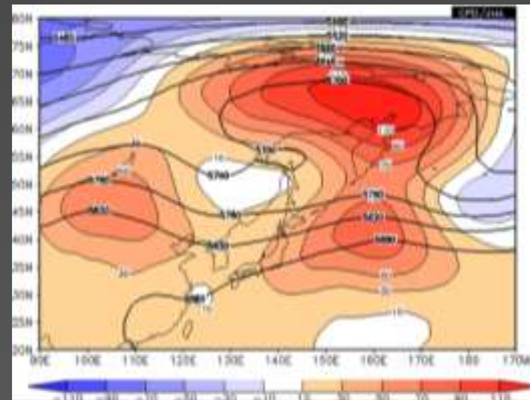


Time series of daily mean temperature anomalies at Tokyo station

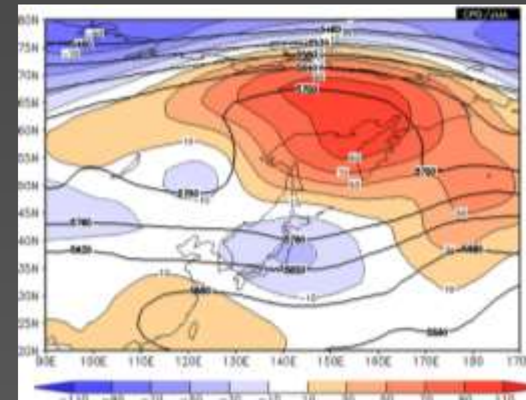
Z500 (June 2010)



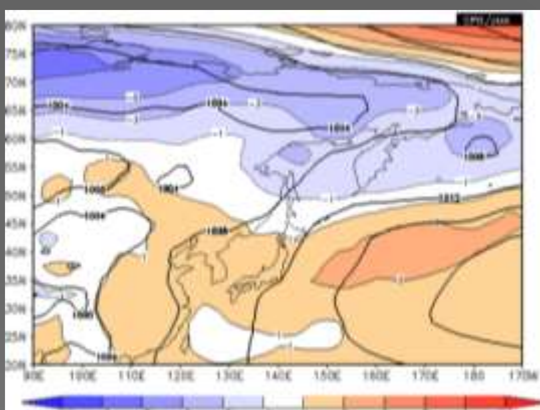
Z500 (July 2010)



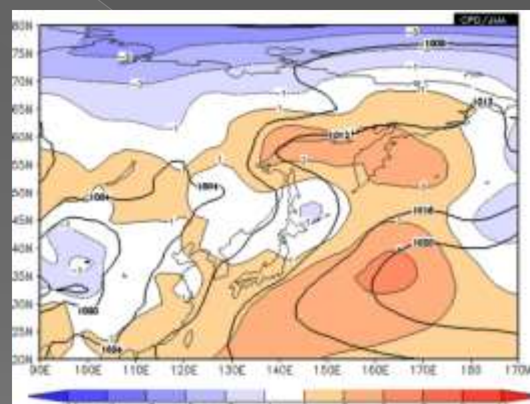
Z500 (July 2003)



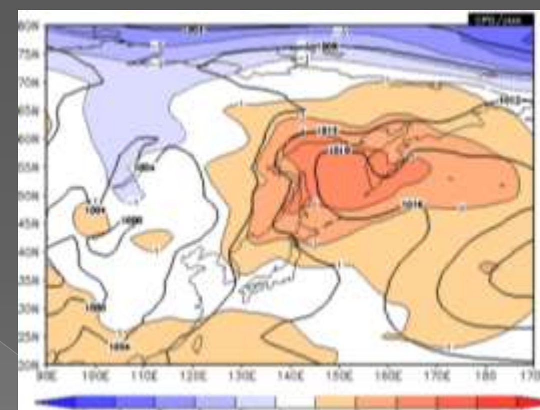
SLP (June 2010)



SLP (July 2010)



SLP (July 2003)



In July 2003, in association with the development of upper-level blocking high over the Sea of Okhotsk, the Okhotsk High appeared and persisted throughout the month, bringing about significantly below normal temperature in Northern and Eastern Japan (right panels).

In June 2010, warm anticyclones frequently covered Japan, particularly its northern parts (left panels). In the second half of July, the Okhotsk High temporarily took place, but Japan experienced little influence of the Okhotsk High due to northward shift of the subtropical jet near Japan and the strong Pacific High to the east of Japan (central panels).

Conclusion and discussion

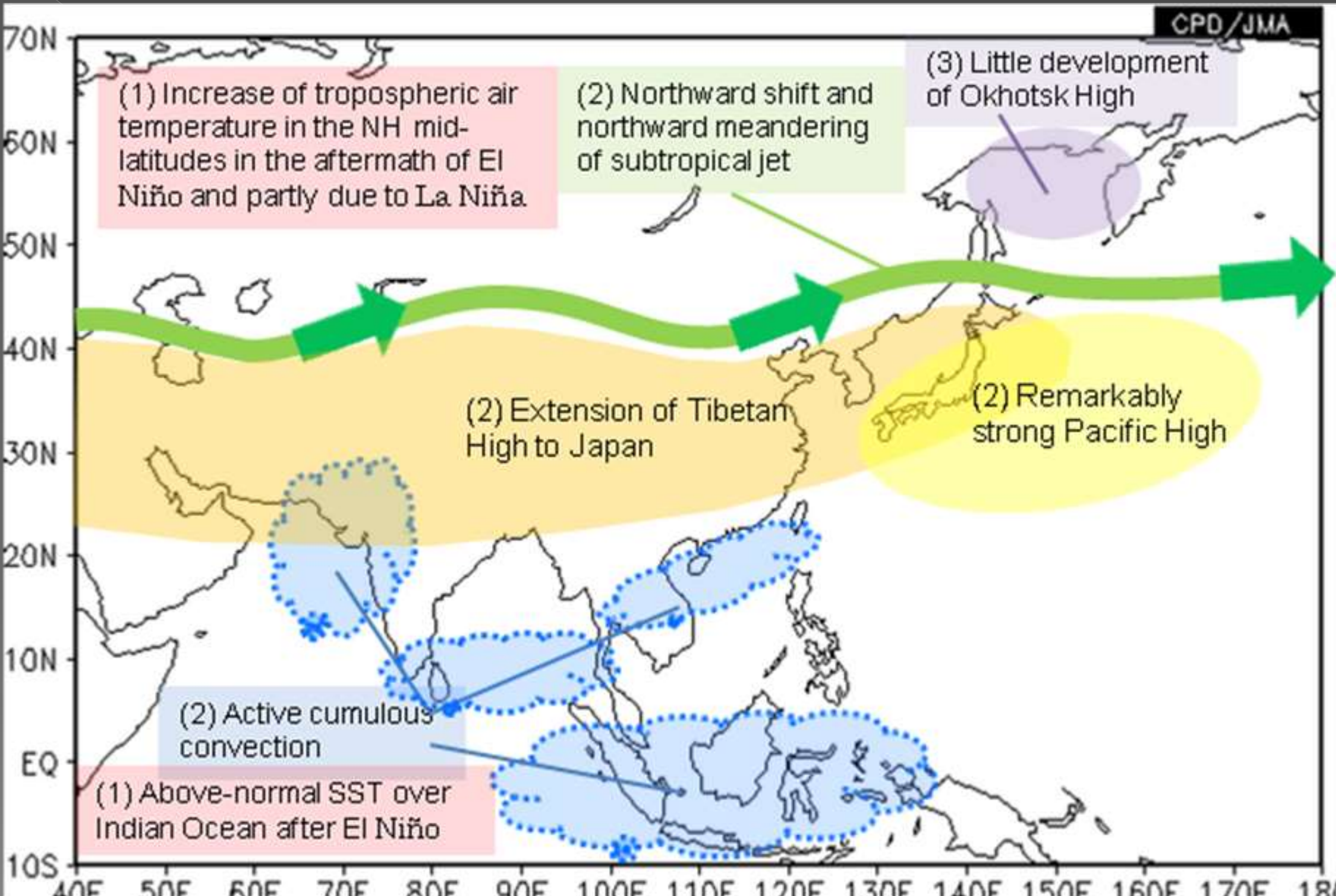
The *Advisory Panel on Extreme Climate Events* identified three atmospheric circulation features related to the extremely hot summer 2010 in Japan as follows:

(1) zonally-averaged tropospheric air temperature in the mid-latitudes of the Northern Hemisphere was the highest for June – August since 1979;

(2) remarkably strong anticyclone persisted over Japan; and

(3) Japan experienced less-than-usual influence of the Okhotsk High (a cool stationary anticyclone).

These atmospheric features and their possible factors can be illustrated in next Figure. The above-mentioned primary factors of the extremely hot summer in Japan are supported by statistical analyses and researches so far, but those can’t completely explain this extreme event. In order to further understand the extreme event and reveal its dynamical mechanism, it is necessary to investigate other possible factors and perform numerical model experiments.



CPD/JMA
(1) Increase of tropospheric air temperature in the NH mid-latitudes in the aftermath of El Niño and partly due to La Niña
(2) Northward shift and northward meandering of subtropical jet
(3) Little development of Okhotsk High
(2) Extension of Tibetan High to Japan
(2) Remarkably strong Pacific High
(2) Active cumulous convection
(1) Above-normal SST over Indian Ocean after El Niño
70N
60N
50N
40N
30N
20N
10N
EQ
10S
40E 50E 60E 70E 80E 90E 100E 110E 120E 130E 140E 150E 160E 170E 180

Thank you for your attention!