Climate analysis information
- Examples of analysis of past extreme events -

1. Influences of the El Nino event in 2014-2016 on the global climate
2. The Heavy Rain Event of July 2018 and the persistent heatwave of summer 2018 in Japan

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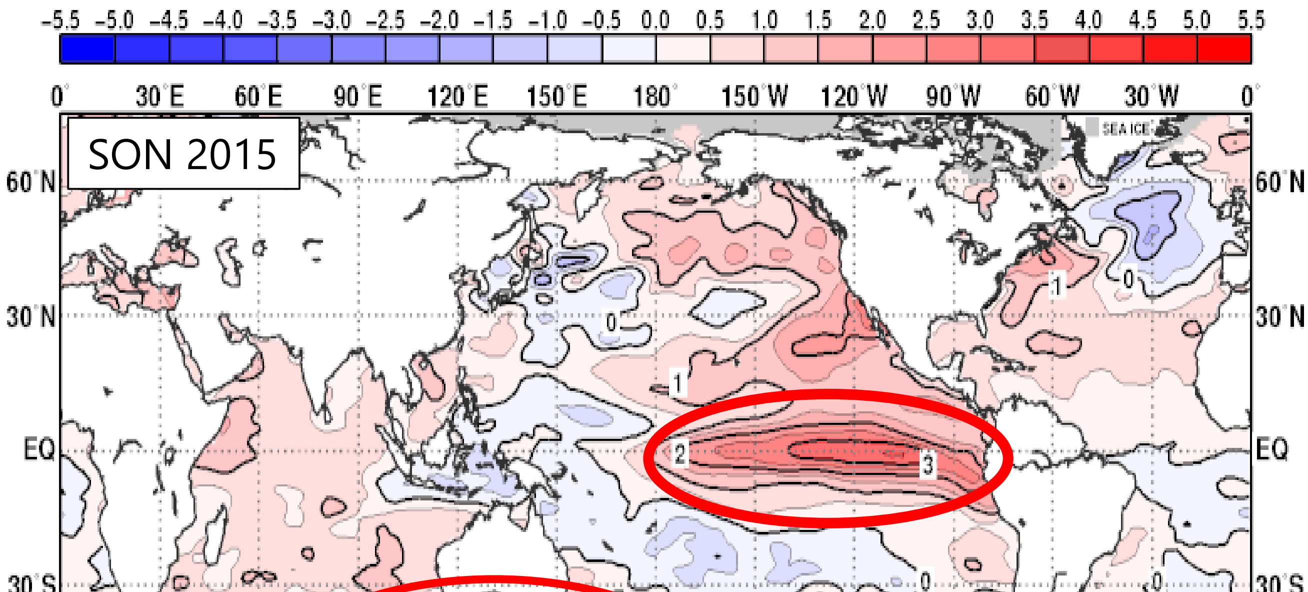
1. INFLUENCE OF THE EL NIÑO EVENT IN 2014-2016 ON THE GLOBAL CLIMATE

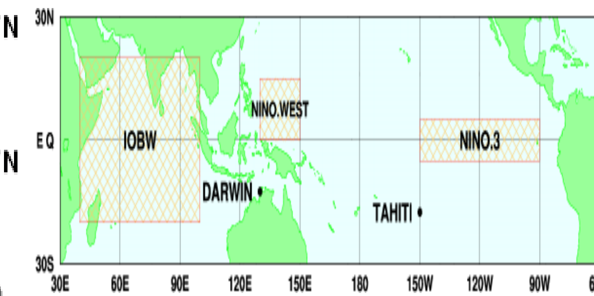
Introduction

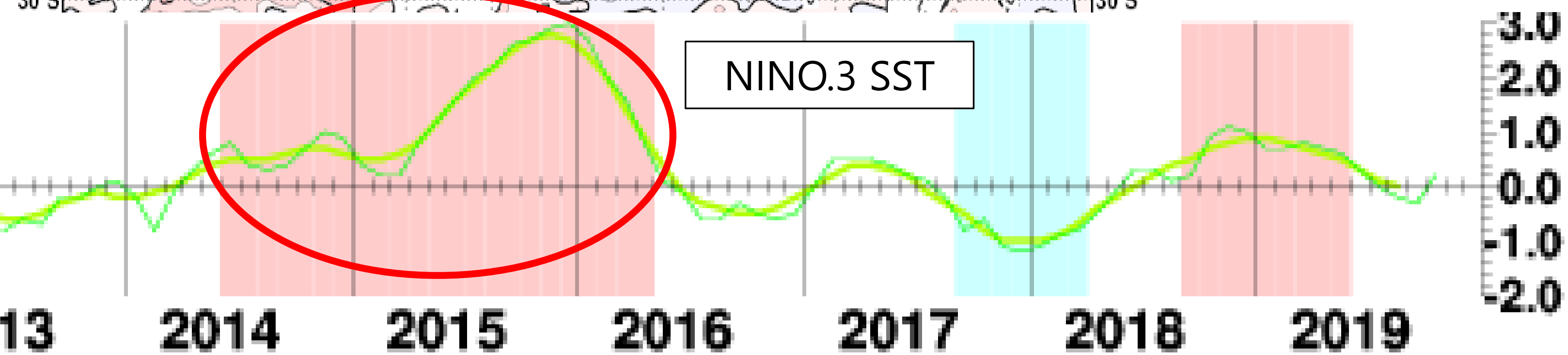
- An El Niño event started in summer 2014, peaked in winter 2015/2016 and ended in spring 2016. Sea surface temperatures (SSTs) in the Indian Ocean trailed the event by a couple of months and remained above normal toward spring/summer 2016.
- Influences from the resulting SST anomalies were extensively felt across the globe, with effects including dry conditions in Southeast Asia, extremely heavy precipitation along the Yangtze River basin.

ENSO and oceanic conditions

- The NINO.3 index turned positive around spring 2014 and began to increase rapidly in spring 2015. Values began to decline after peaking in winter 2015/2016, returned to near-normal in spring 2016, and turned negative in summer 2016.
- The IOBW index surged on the heels of NINO.3, peaking in spring 2016 before declining throughout summer.





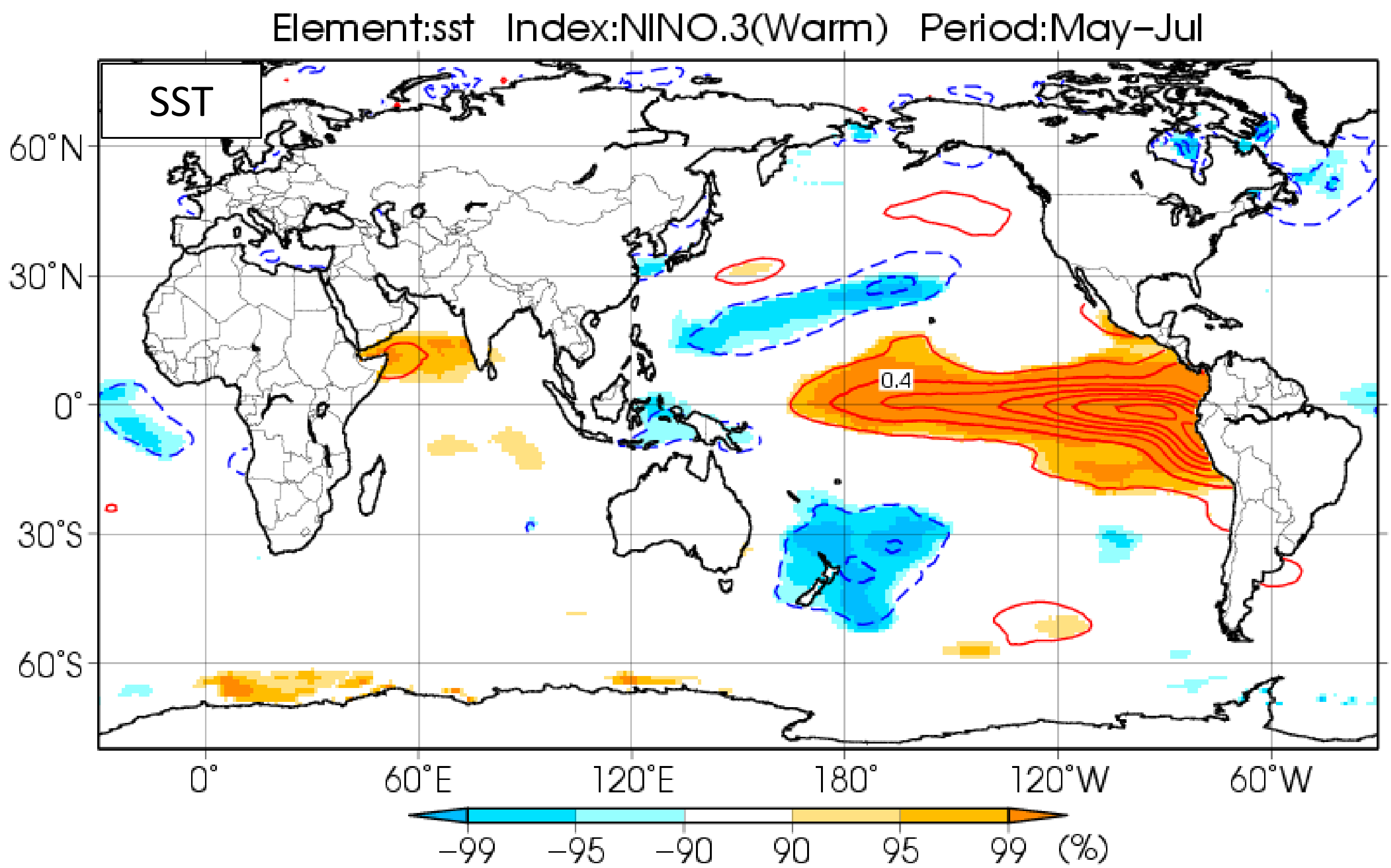


Composite analysis

- Composite analysis is a useful tool to understand characteristics of the targeted event and its influences on or relationship with circulations in statistical views.

Composite map for El Niño / La Niña events

https://ds.data.jma.go.jp/tcc/tcc/products/clisys/enso_statistics/index.html



May-July (early Asian summer monsoon)

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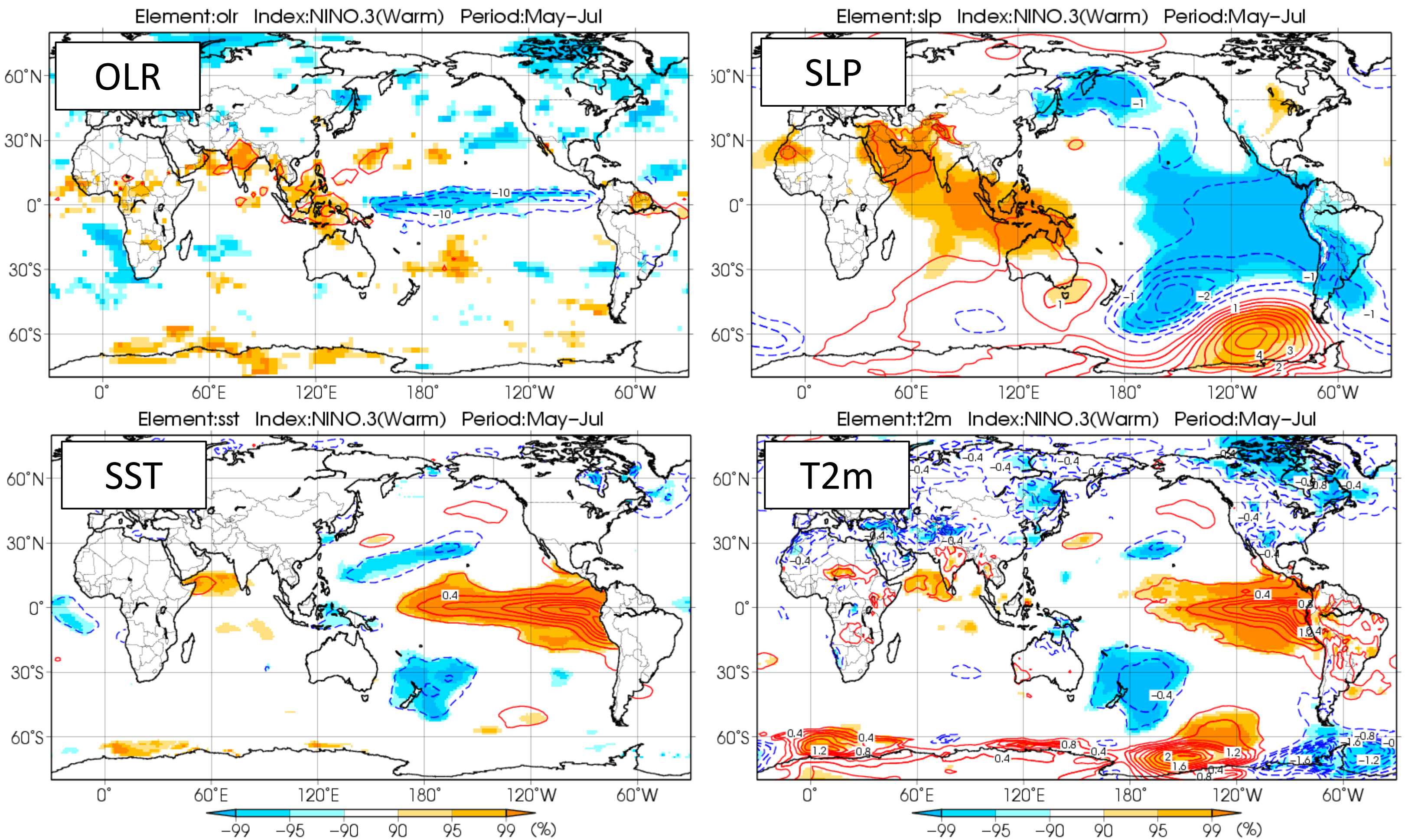

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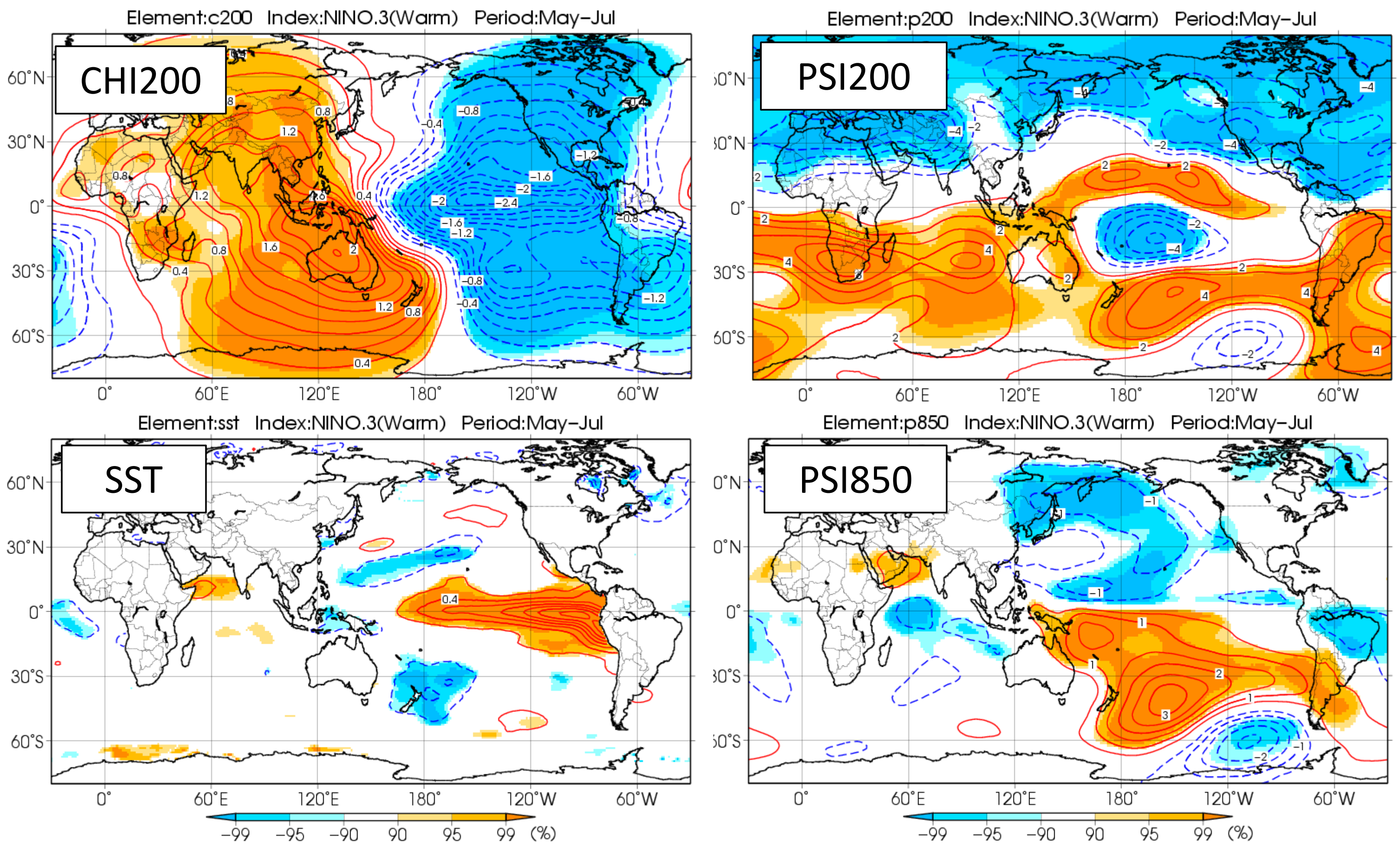

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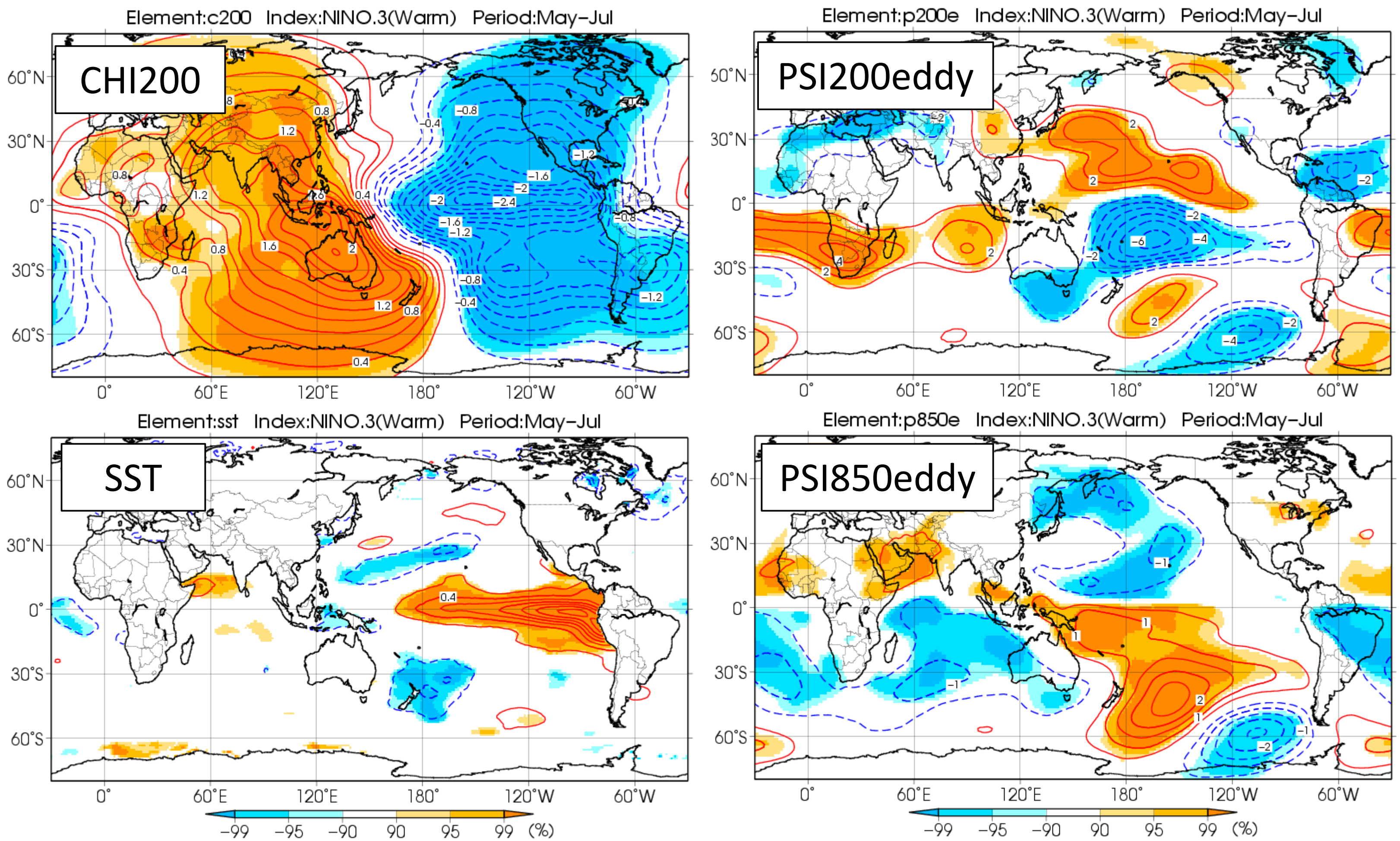


May-July (early Asian summer monsoon)

(Exercise) Composite analysis

- Composite analysis is a useful tool to understand characteristics of the targeted event and its influences on or relationship with circulations in statistical views.

Composite map for El Niño / La Niña events

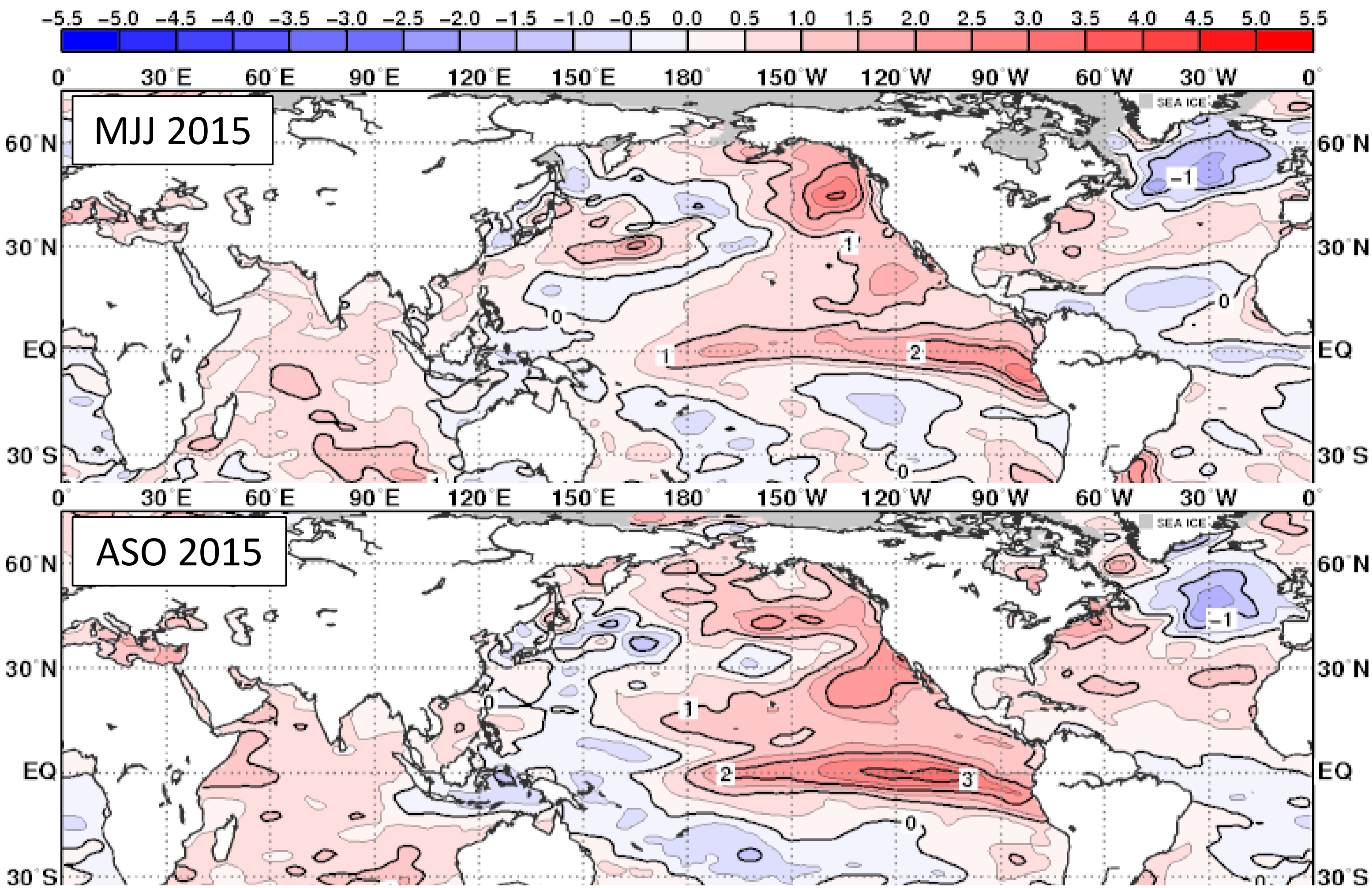
https://ds.data.jma.go.jp/tcc/tcc/products/clisys/enso_statistics/index.html

- Please take a look at the website above.

- Select “Elements”
- Select “ENSO Index”: NINO.3, NINO.WEST, IOBW
- Select “Phase”: positive / negative (ex. Positice for NINO.3 -> El Nino)
- Select “Month” and Time Mean: (ex. Month=6 and Time Mean=3-month mean -> May-July)

May-October 2015

- The circulation pattern of this period is characterized by cyclonic circulation anomalies over the Pacific and anticyclonic circulation anomalies centered over Indochina, which is quite similar to the situation of anomalies observed in past El Niño summers.



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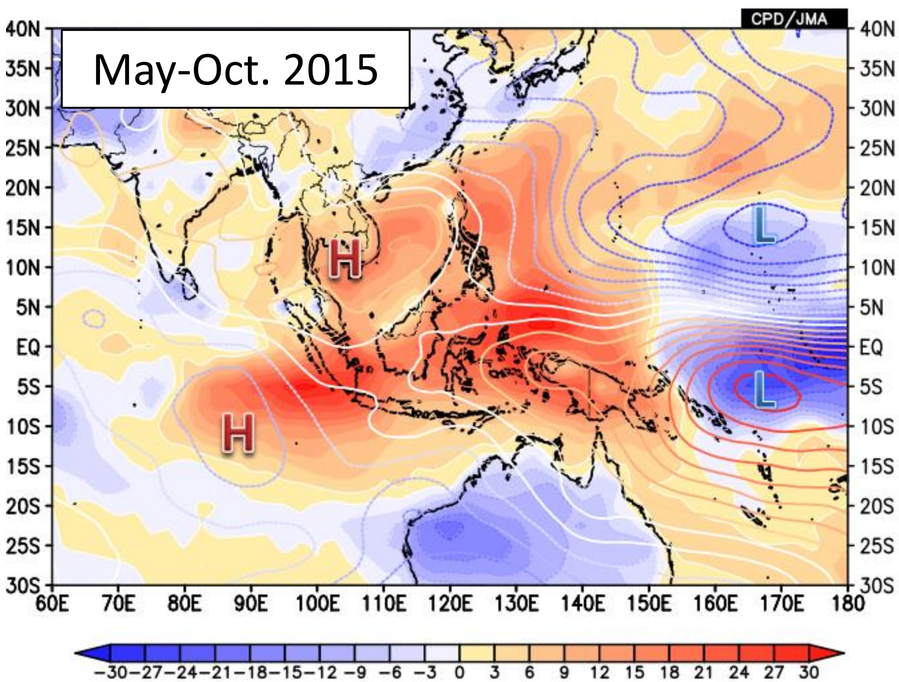
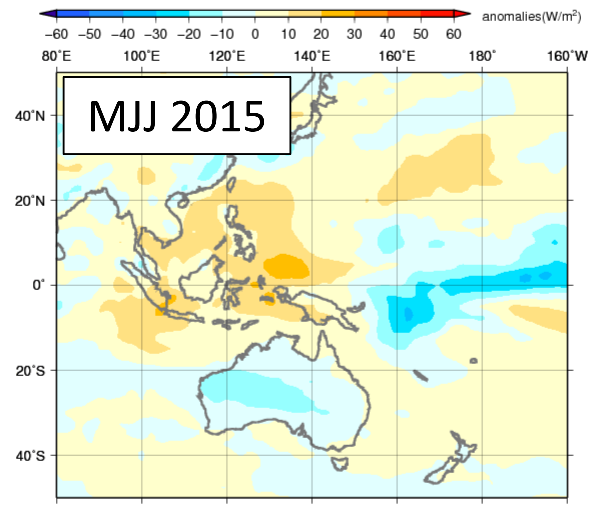
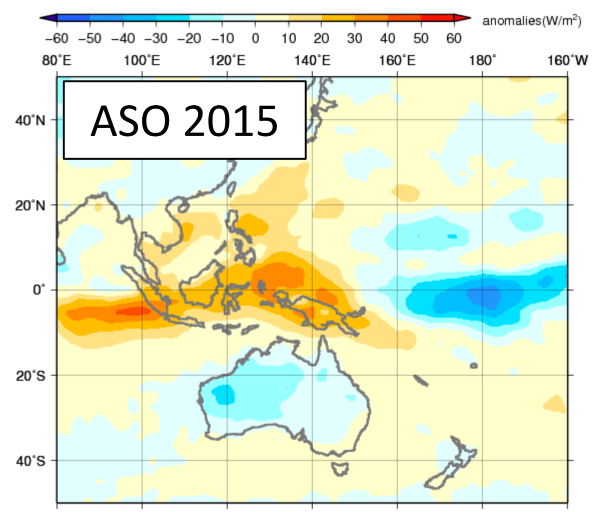


(S)OLRanom [W/m²] and (c)PSI850 [10^6 m²/s]
H and L denote anticyclonic and cyclonic circulation anomalies, respectively.
Contours are at intervals of 0.5 x 10^6 m²/s.





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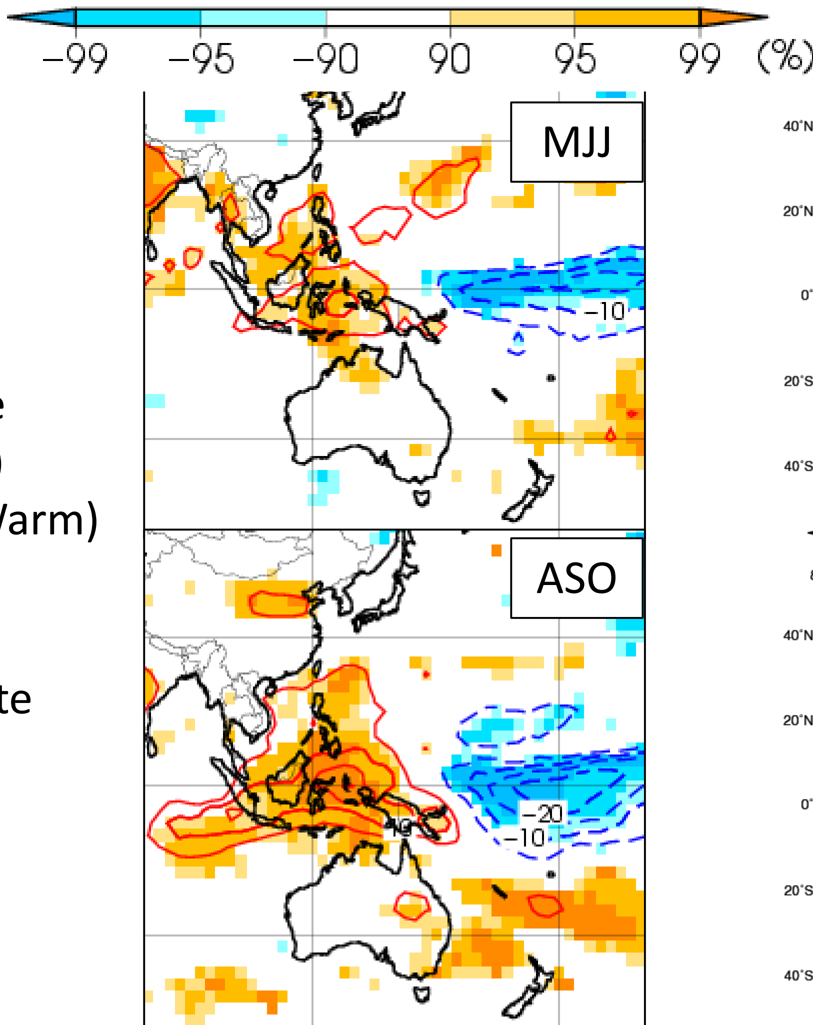
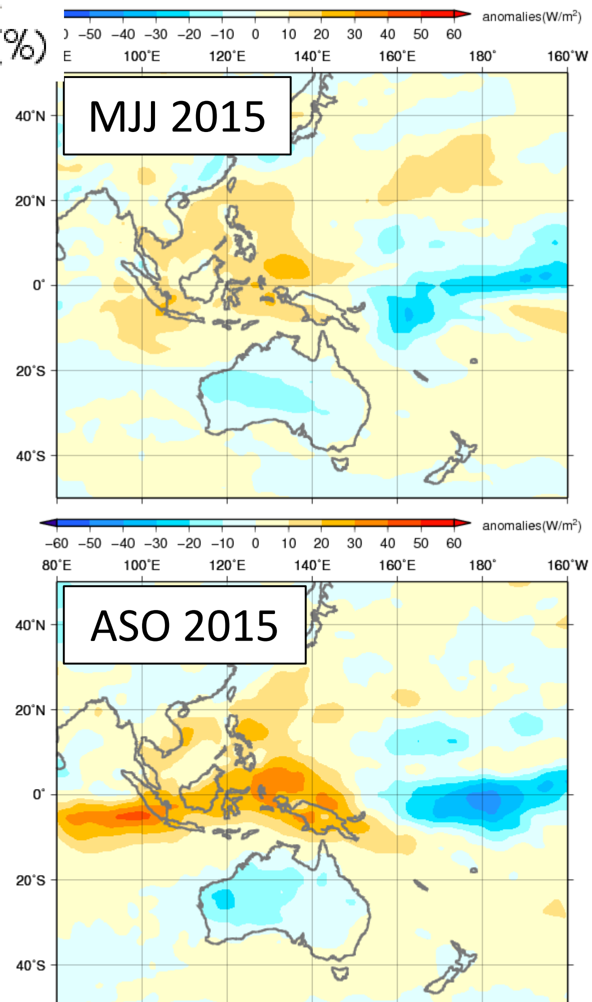
Composite Map (OLR) (NINO.3;Warm)

(Composite maps are produced using 1979/80-2012/13)





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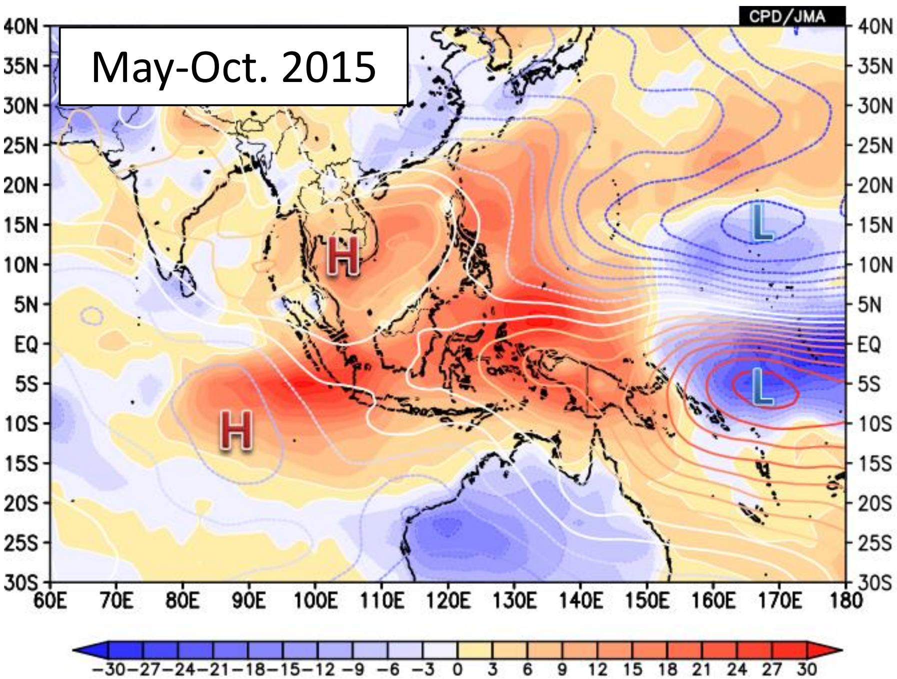

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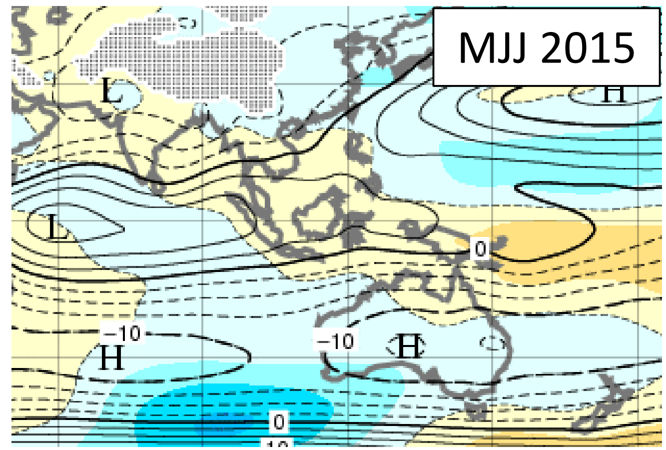

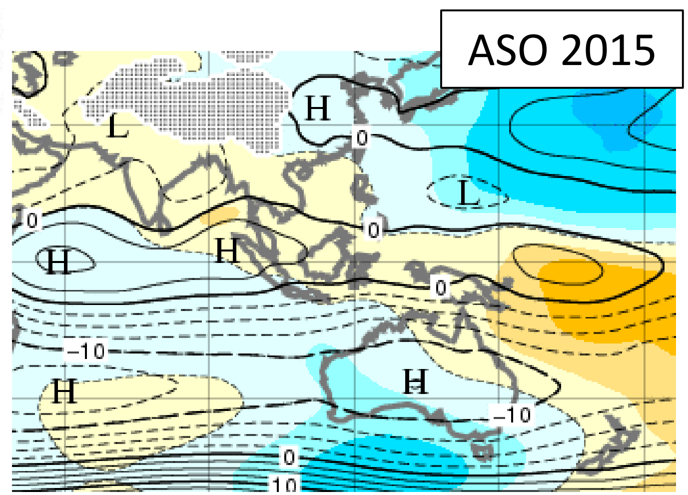

(S)PSI850 anom [10^6 m²/s]

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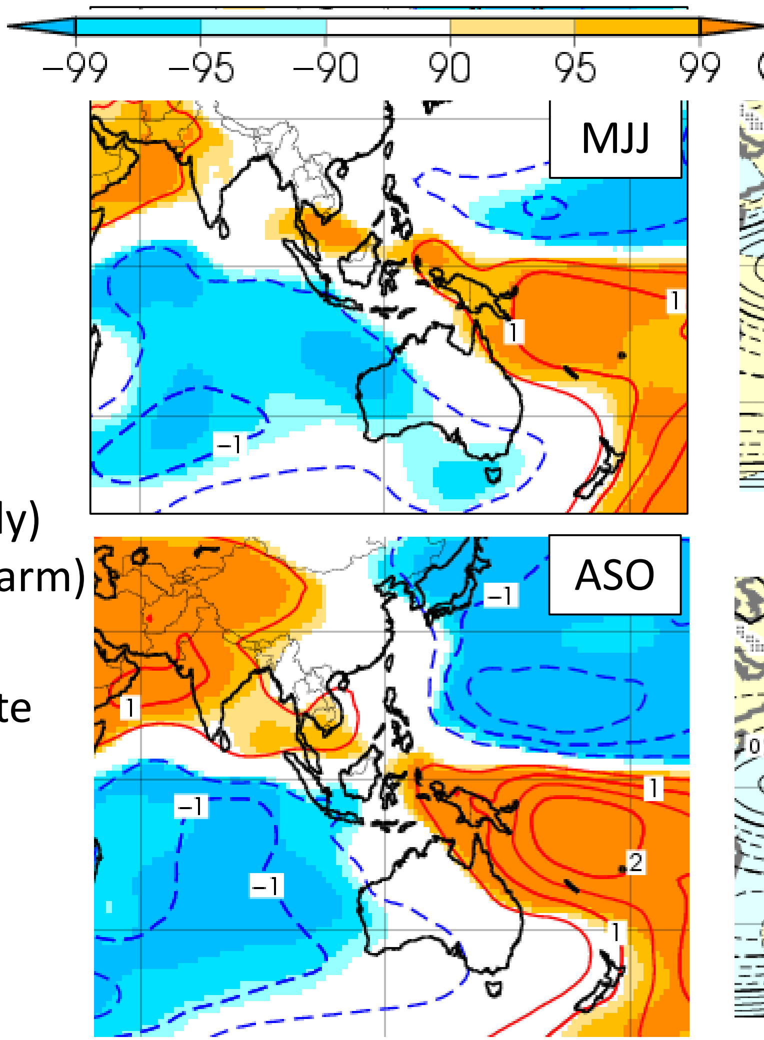
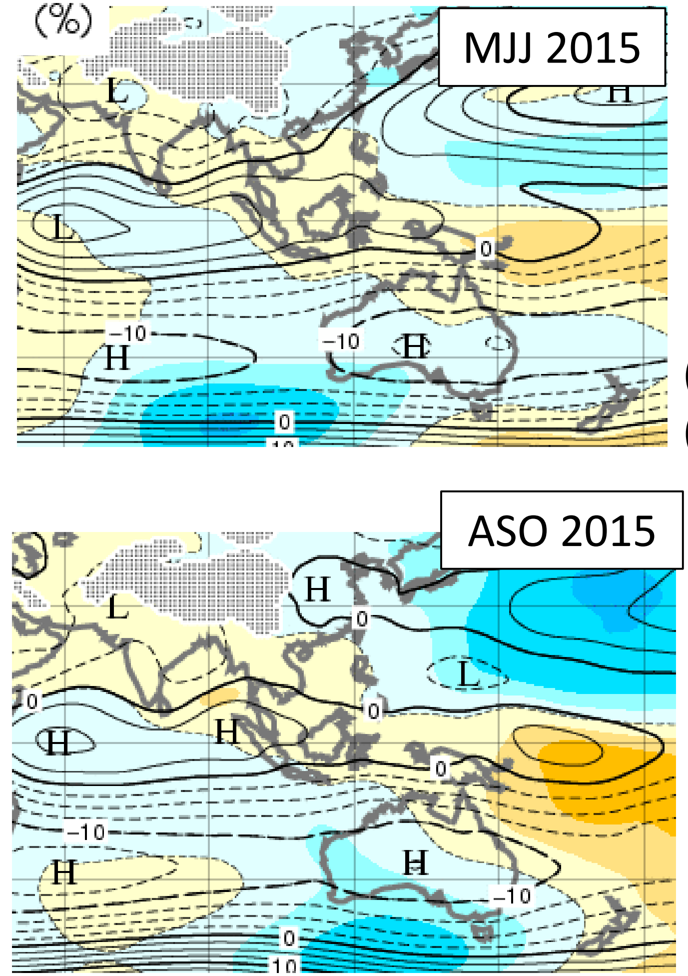


Composite Map (PSI850eddy) (NINO.3;Warm)

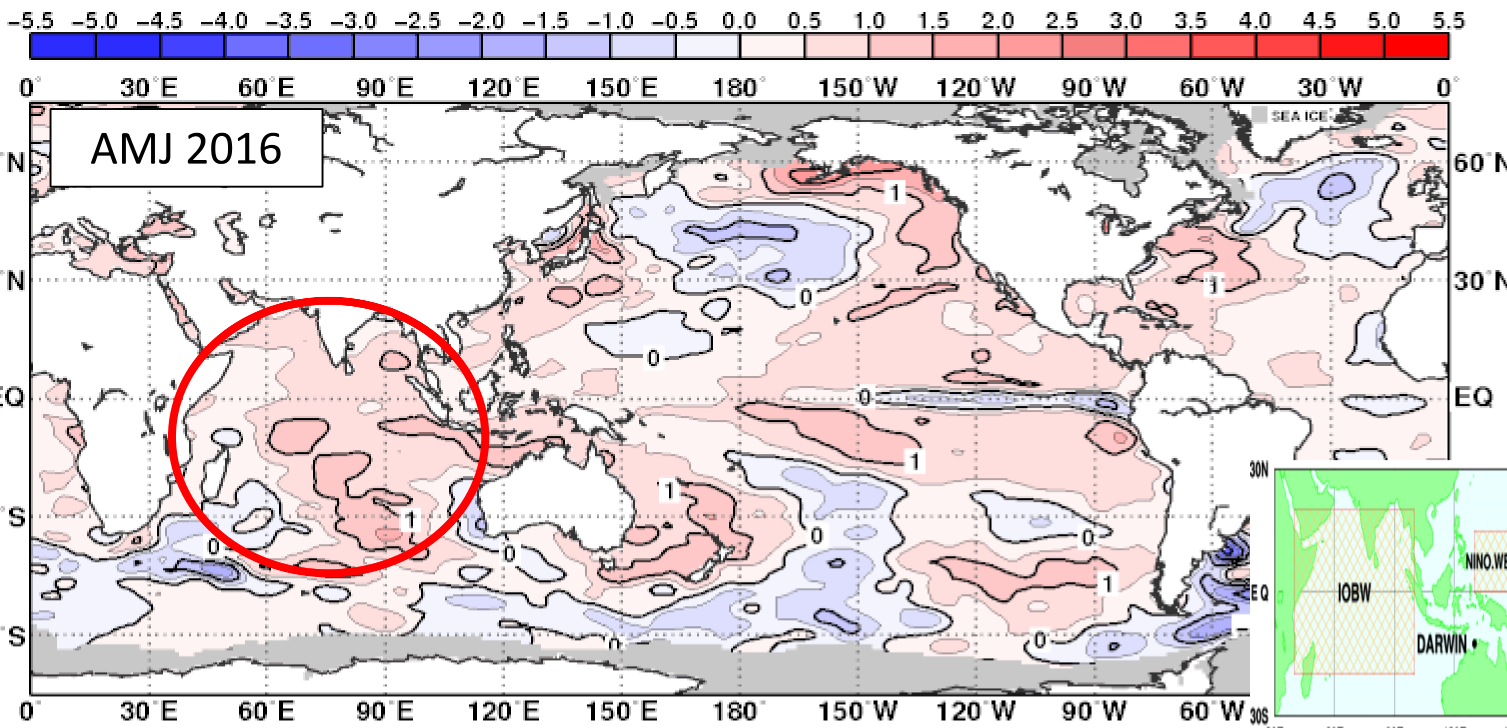
(Composite maps are produced using 1958/59-2012/13)

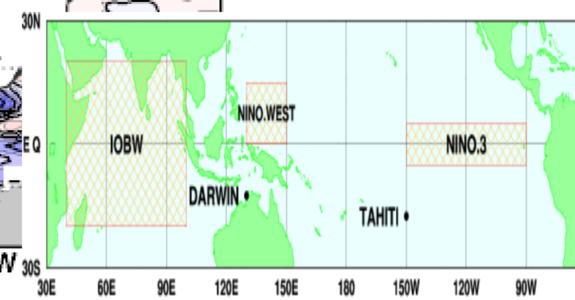


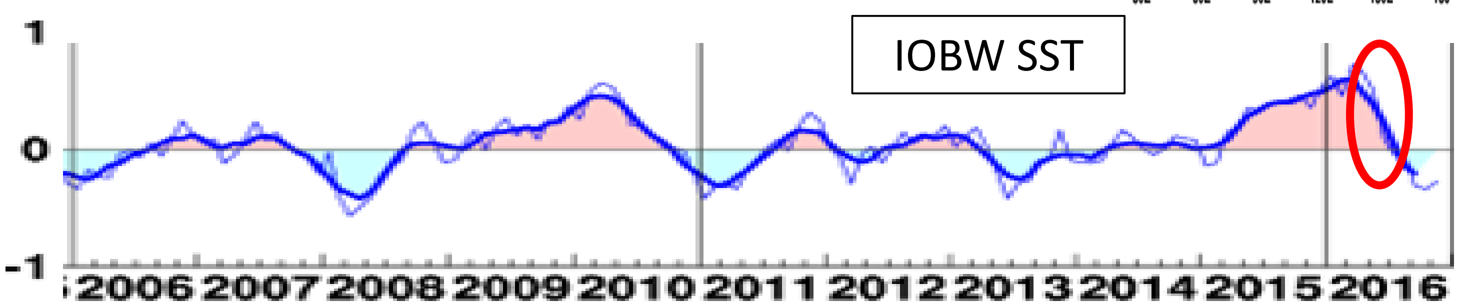
(C)PSI850
(S)PSI850 anom [10^6 m^2/s]

April-June 2016

- The anomaly pattern closely resembles that for the positive IOBW, with cyclonic circulation anomalies in the Indian Ocean and anticyclonic anomalies and suppressed convection over the area from Indochina to the western tropical North Pacific.







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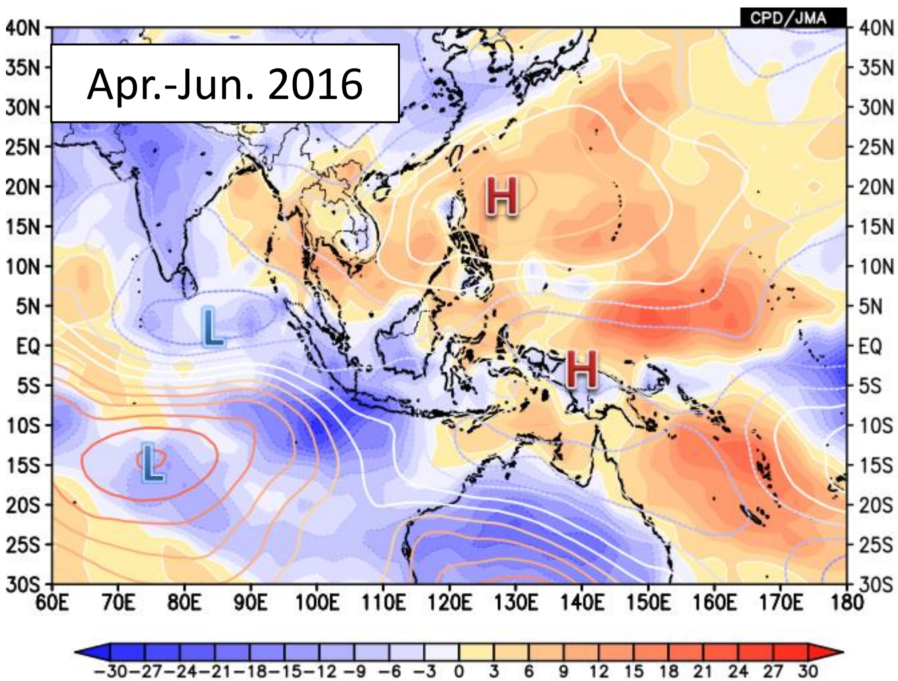

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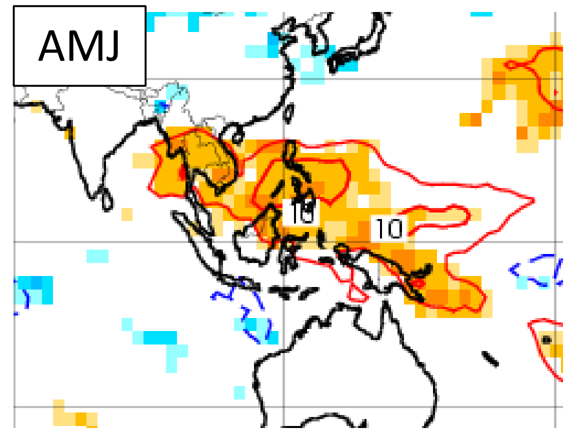
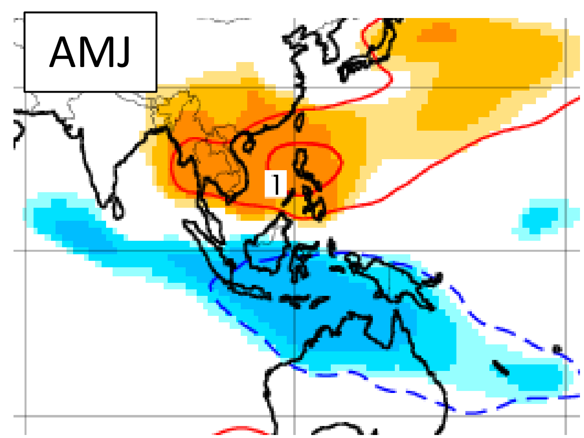


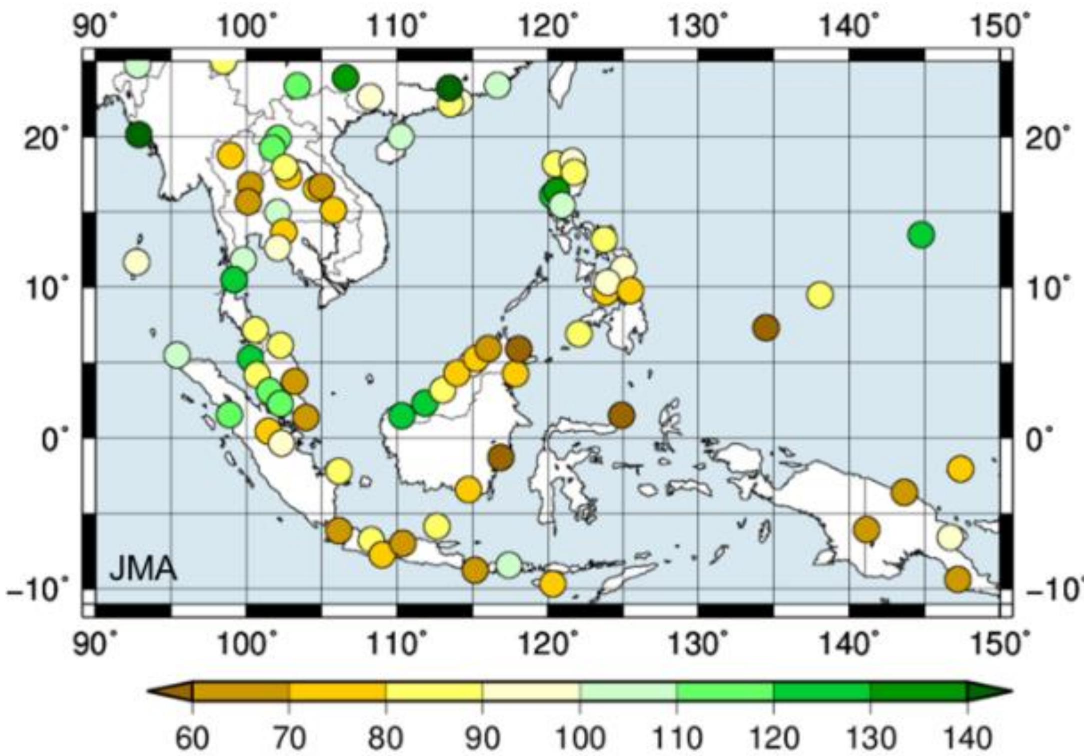
Composite Map (OLR) (IOBW;Warm)



Composite Map (PSI850eddy) (IOBW;Warm)

Suppressed precipitation over Southeast Asia

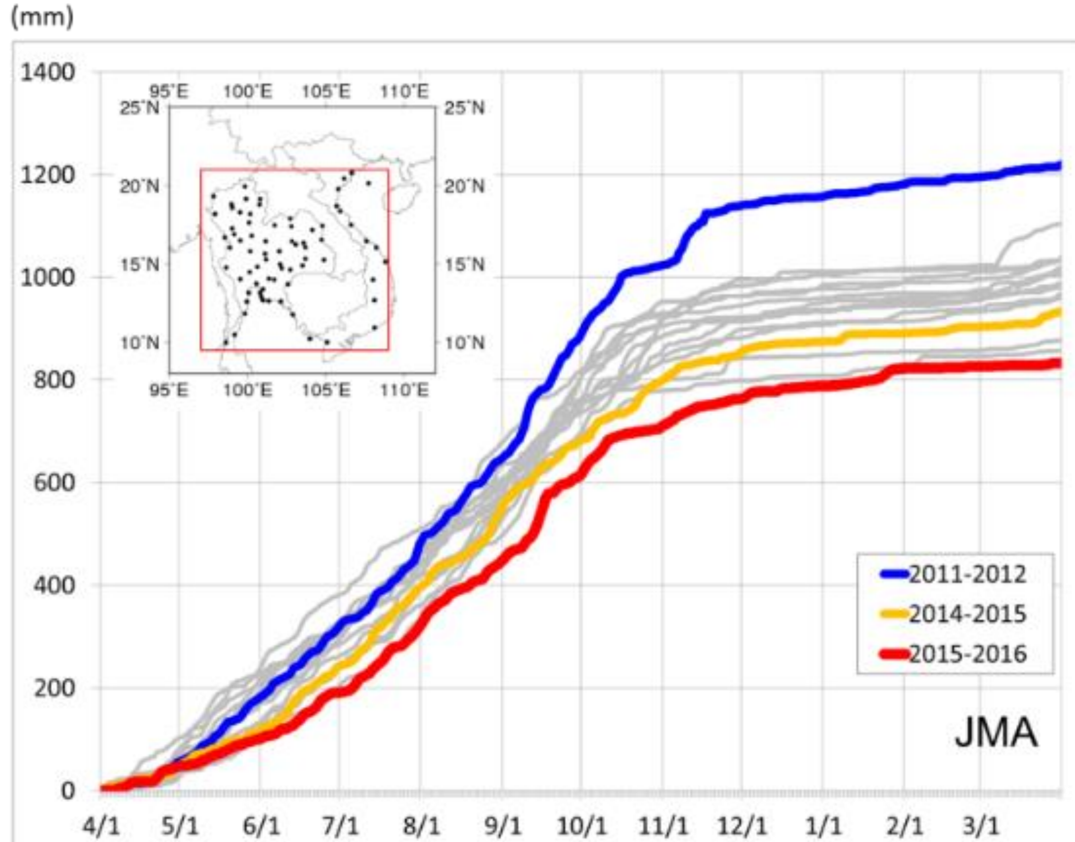
- Southeast Asia experienced below-normal precipitation from spring 2015 to spring 2016, which adversely affected water resource management and agriculture. In addition to the worst drought conditions for 90 years in Viet Nam (United Nations Food and Agriculture Organization), a state of emergency was declared for the Mekong Delta in relation to damage caused by sea water running up the water-deprived river (Unite Nations Country Team Viet Nam). Wildfires were frequently reported in Indonesia and Malaysia (United States National Aeronautic and Space Administration).



12-month precipitation anomalies for April 2015 to March 2016
Anomalies are based on CLIMAT reports and represented as ratios against the normal.

Suppressed precipitation over Southeast Asia

- In 2015, precipitation remained below normal from around May, and cumulative precipitation for the 12-month period ending March 2016 was the lowest since 2000 at that time.



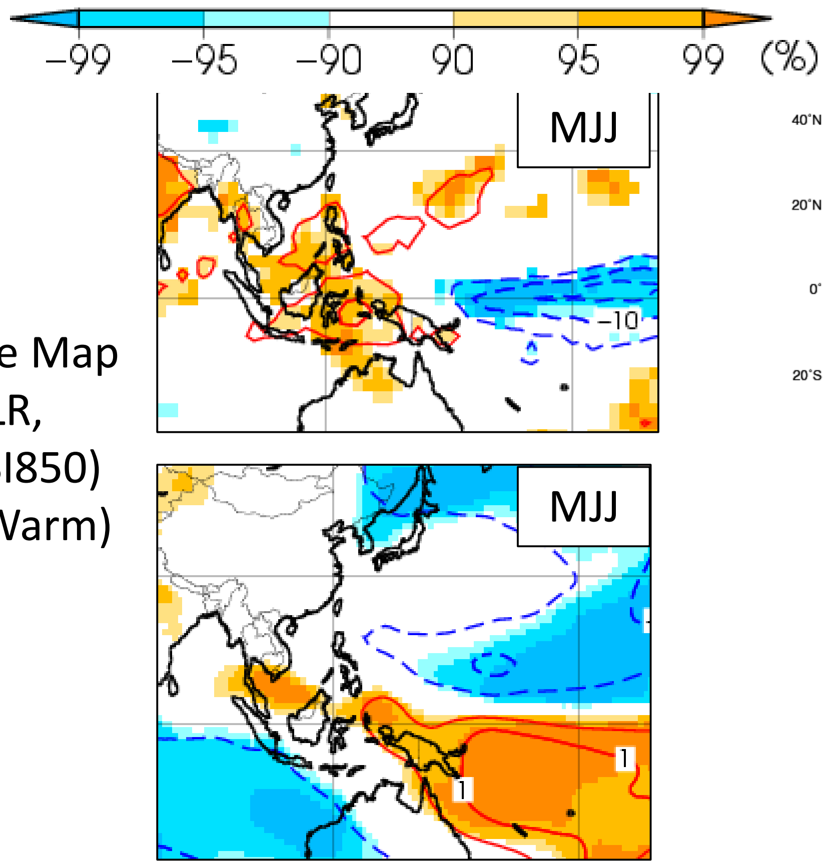
Apr.2015
- Mar. 2016

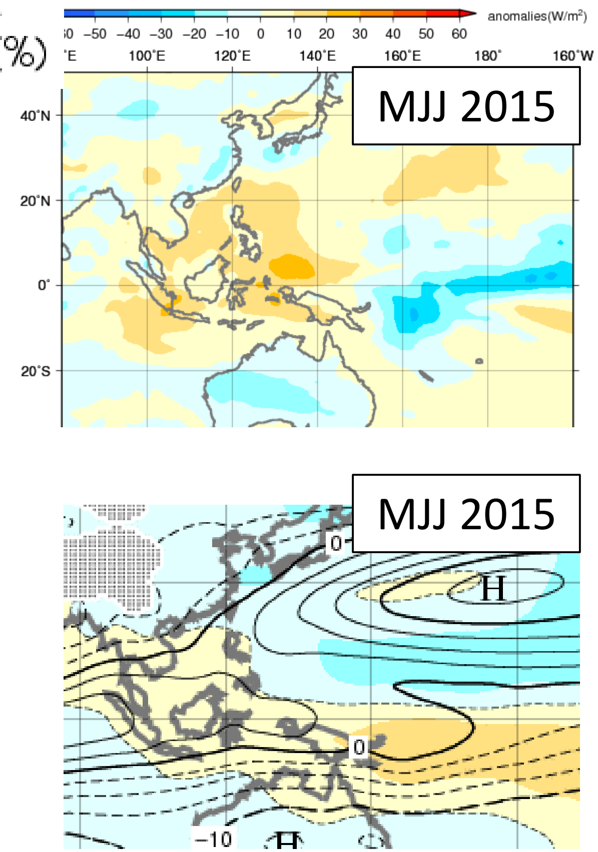
Cumulative precipitation averaged over stations in Indochina
Observation stations are shown on the inset map. The red, yellow and blue lines indicate cumulative precipitation for 12-month periods starting April 2015, April 2014 and April 2011, respectively. Grey lines indicate other years after 2000. All data are from SYNOP.

Suppressed precipitation over Southeast Asia

- southwest summer monsoon activity in Southeast Asia tends to be weak during El Niño events. The anticyclonic anomalies in the lower troposphere centered over Indochina, which are considered to be responses to the weak monsoon and similar to atmospheric characteristics seen in past El Niño events, were a factor behind below-normal precipitation from 2015 to 2016.

Composite Map
(upper;OLR,
lower; PSI850)
(NINO.3;Warm)



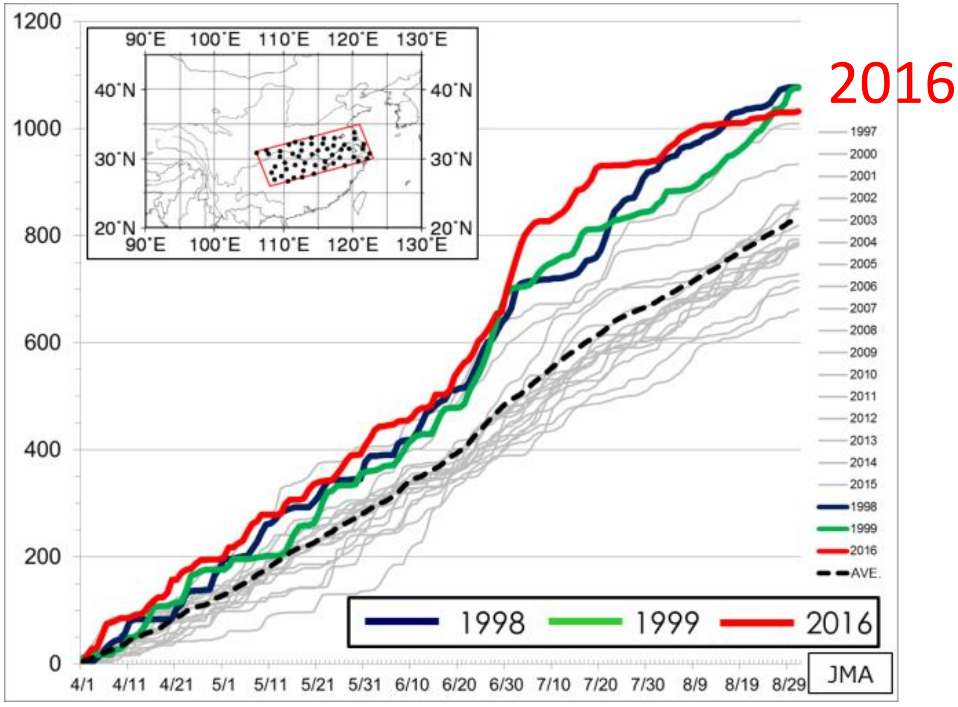


(S)OLRanom
[W/m^2]

(C)PSI850
(S)PSI850
anom
[10^6 m^2/s]

Heavy precipitation in the Yangtze River basin

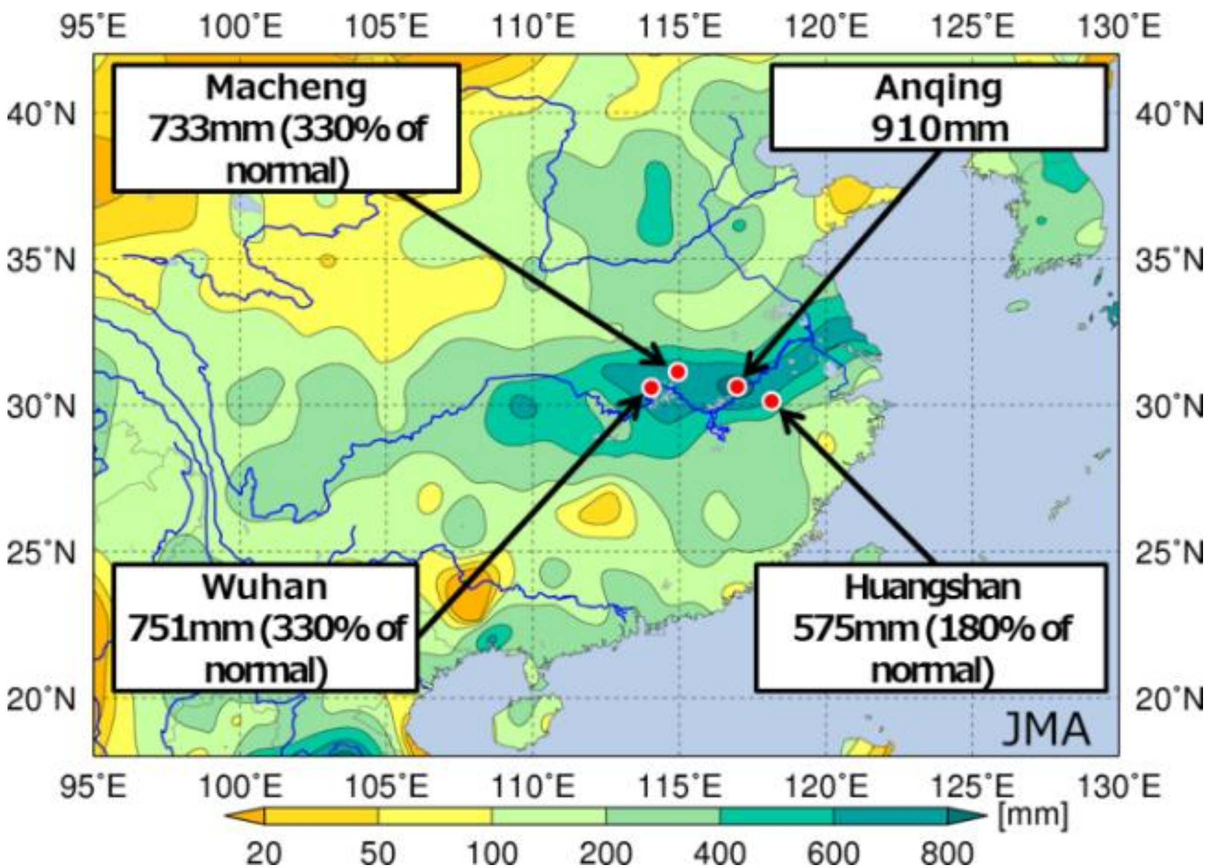
- Areas along the middle and lower Yangtze River experienced above-normal precipitation from April to July 2016. Cumulative precipitation from April 1 to the end of July averaged over the stations in the basin was the highest since 1997 at that time.



Cumulative precipitation averaged over stations in the middle and lower Yangtze River basin
Observation stations are shown on the inset map. The red, blue and green lines indicate cumulative precipitation for the periods starting on April 1 of 2016, 1998 and 1999, and grey lines indicate the same period for all other years since 1997. The dashed black line indicates the average over the 19 years from 1997 to 2015.

Heavy precipitation in the Yangtze River basin

- Amounts soared from late June onward in particular, with the highest cumulative 30-day precipitation among the stations for June 21 to July 20 exceeding 900 mm. More than 200 fatalities were reported in relation to heavy rainfall and landslides from late June to early July, according to the government of China.

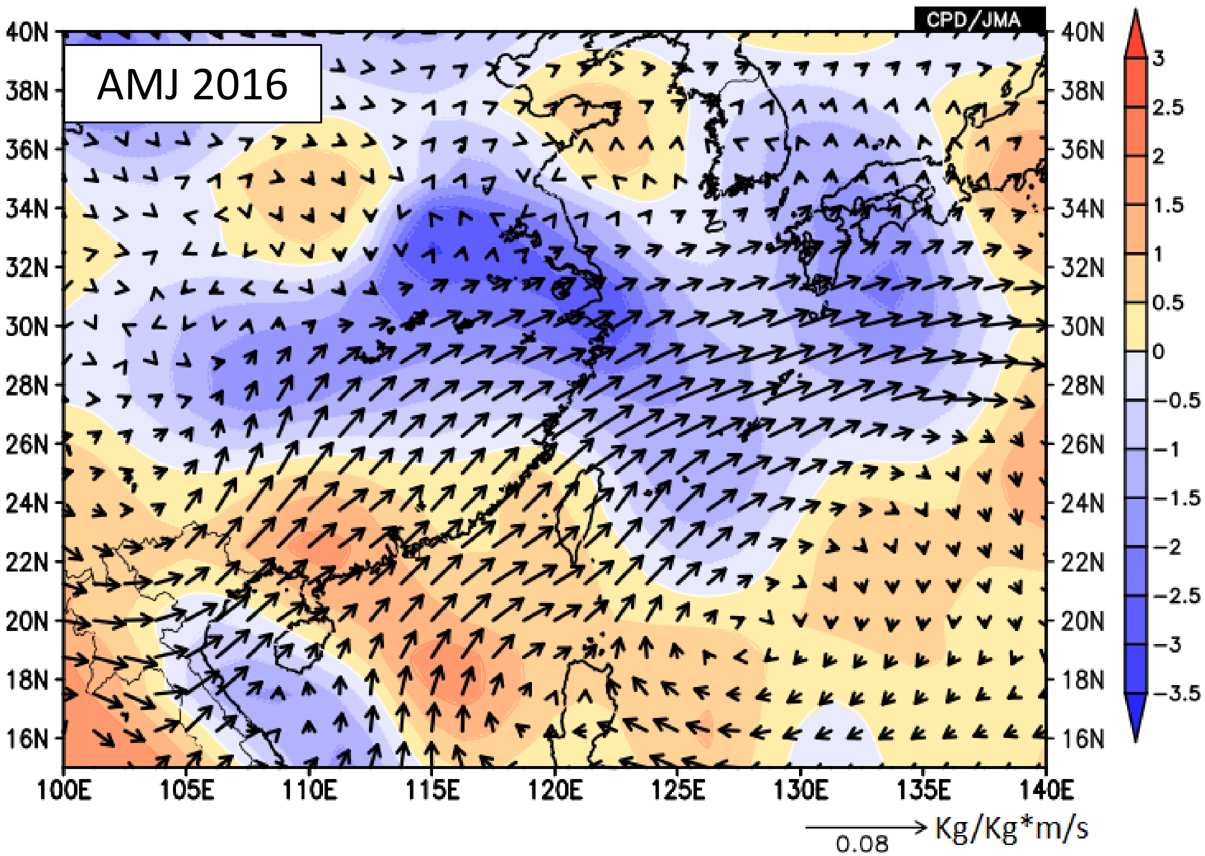


30-day precipitation in the middle and lower Yangtze River basin

The map indicates 30-day precipitation for June 21 to July 20, 2016, when particularly heavy rainfall was recorded. Red dots denote stations recording the three highest precipitation amounts for the 30-day period (Anqing, Wuhan and Macheng) and the highest amount for April 1 to July 24 (Huangshan).

Heavy precipitation in the Yangtze River basin

- Such an extended period of extremely heavy precipitation was caused by strong convergence of moist air flow from the South China Sea over the Yangtze River (Fig. 9). This was induced by anticyclonic circulation anomalies over the western tropical North Pacific associated with the high SSTs in the Indian Ocean.

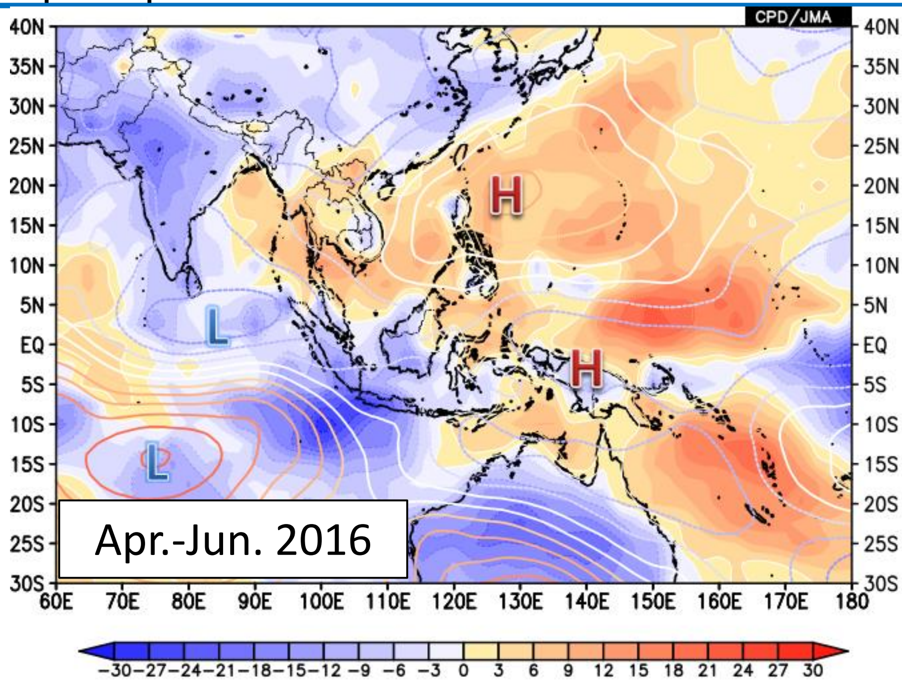


Water vapor flux (arrows) and normalized divergence (shading) anomalies at 850 hPa for April to June 2016

Warm and cool colors indicate divergence and convergence anomalies, respectively.

Heavy precipitation in the Yangtze River basin

- This pattern of high SSTs in the Indian Ocean, the anticyclonic circulation anomalies over the western tropical North Pacific, moist air intrusion from the South China Sea and water vapor convergence over southern China resembled the conditions seen in 1998 – another year when the Yangtze River basin was hit by heavy precipitation.



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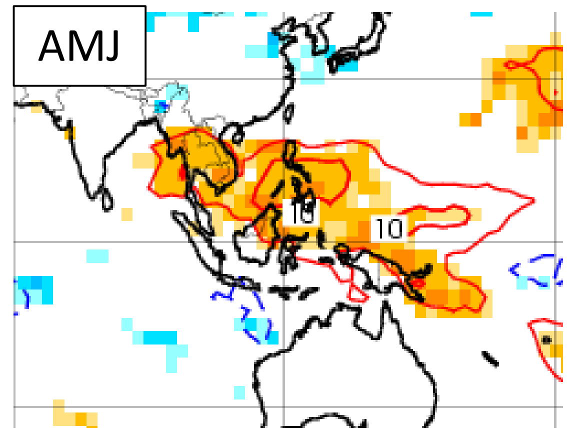
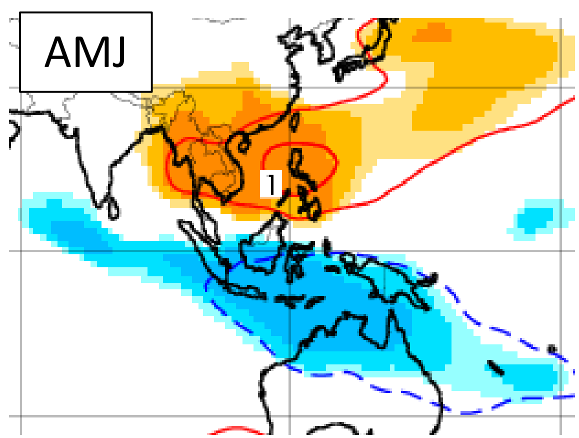


Composite Map (OLR) (IOBW;Warm)



Composite Map (PSI850eddy) (IOBW;Warm)

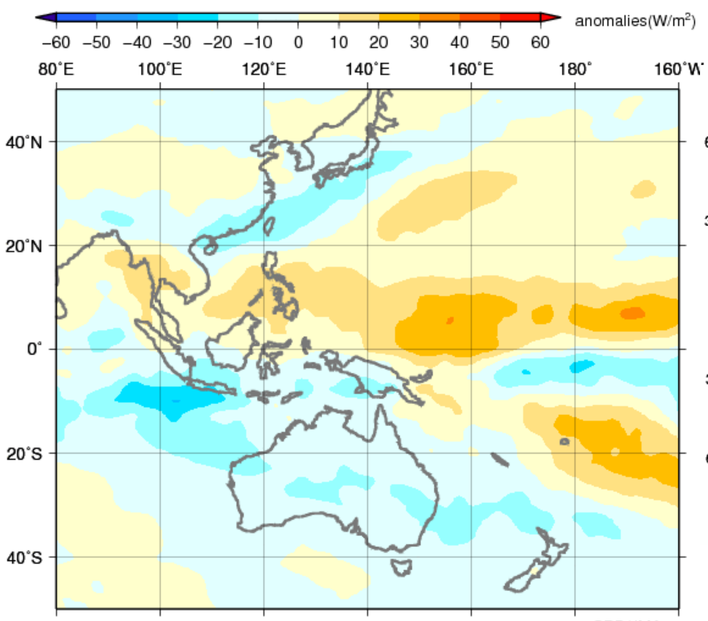
(Exercise) Case of April-June 1998

Global circulation maps

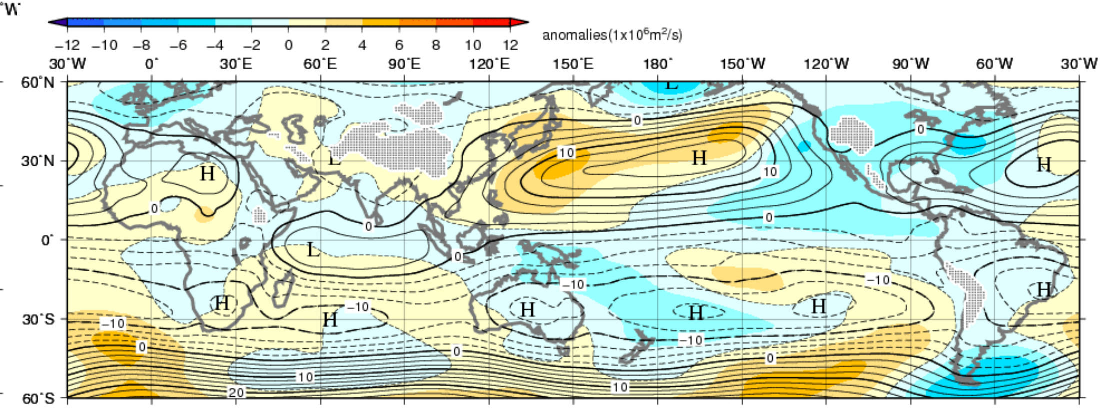
https://ds.data.jma.go.jp/tcc/tcc/products/clisys/figures/db_hist_3mon_tcc.html

- Please take a look at the website above.

- Select “Field”: Tropics
- Select “Element”: OLR/OLRanom, PSI850/PSI850anom, etc.
- Select “Year” and “Month”: Year=1998, Month=Apr.-Jun.



Three month mean outgoing longwave radiation (OLR) anomaly in the western Pacific (Apr.1998–Jun.1998)
Anomalies are deviations from the 1981–2010 average. Original data provided by NOAA.



Three month mean 850 hPa stream function and anomaly (Apr.1998–Jun.1998)
The contours show the stream function at intervals of 2.5×10^6 m^2/s, and the shading shows stream function anomalies.
Anomalies are deviations from the 1981–2010 average.

2. THE HEAVY RAIN EVENT OF JULY 2018 AND THE PERSISTENT HEATWAVE OF SUMMER 2018 IN JAPAN

Outline

- Introduction
- The Heavy Rain Event of July 2018 in Japan
  - Climatic conditions
  - Atmospheric circulation
  - Influence of global warming
- Heat wave in boreal summer 2018 in Japan
  - Climatic conditions
  - Atmospheric circulation
- Summary

(Data)

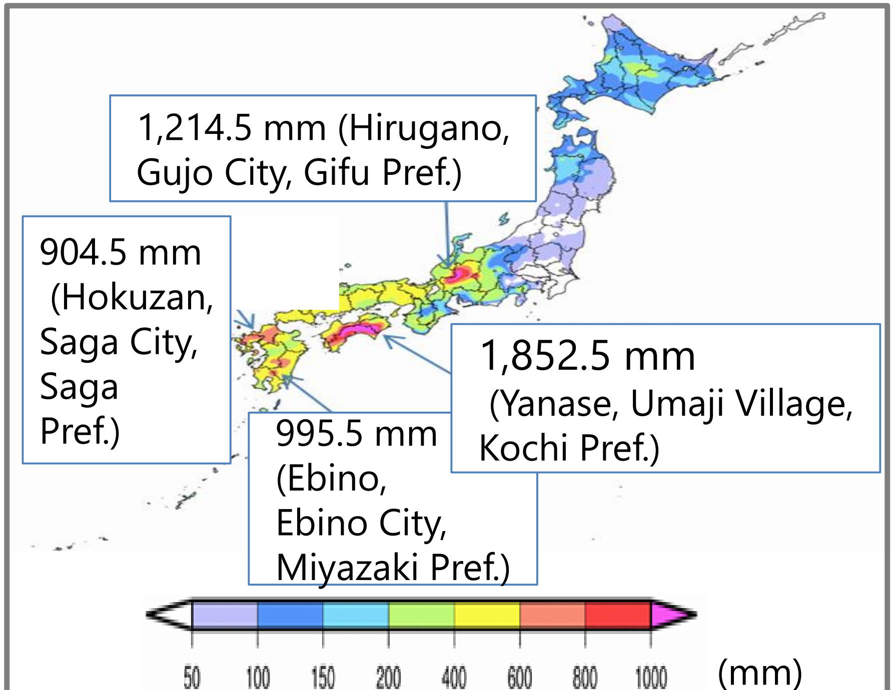
- JRA-55 (Kobayashi et al. 2015), NOAA OLR, COBE-SST
- AMeDAS observation, Radiosonde observation
- Climate normal: 1981-2010 (30 years) average
  - Anomaly is a deviation from climate normal

Introduction

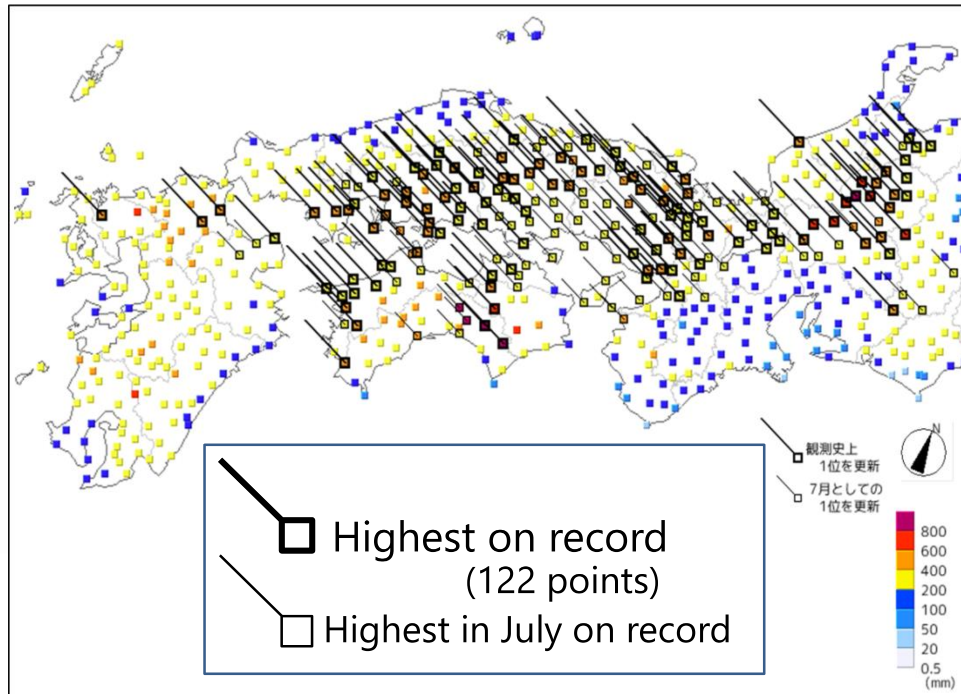
- Japan experienced significant rainfall particularly from western Japan to the Tokai region mainly in early July (The Heavy Rain Event of July 2018), which caused widespread havoc nationwide.
- After that, extremely high temperatures subsequently persisted throughout most of Japan from mid-July to the end of August.
- In this context, the Japan Meteorological Agency (JMA), investigated atmospheric and oceanic conditions considered to have contributed to such climate extremes and summarizes related primary factors, with the help of the JMA Advisory Panel on Extreme Climatic Events.

Climatic conditions: Heavy rainfall

- AMeDAS observation stations in the Shikoku regions of Japan recorded more than 1,800 mm during the period (28th June – 8th July, 2018).
- Some areas experienced two to four times the precipitation of the monthly climatological normal for July.
- A prominent characteristic is that areas with record precipitation, particularly within 48 to 72 hours, were widely observed over western Japan and the Tokai region.



Total precipitation amounts for the Heavy Rain Event of July 2018 (28th June – 8th July)

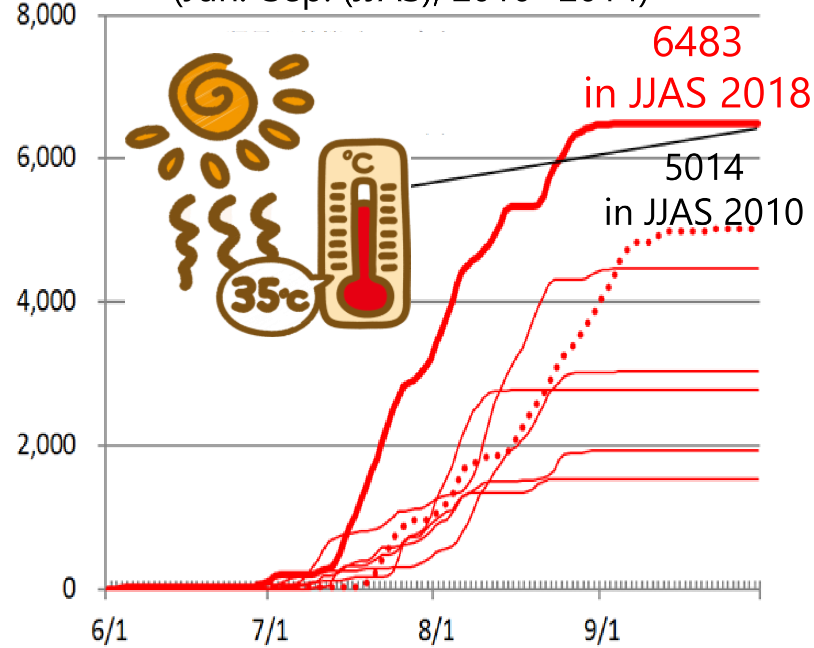


Maximum 72-hour precipitation amounts during the event (from 28th June to 8th July) from western Japan to the Tokai region

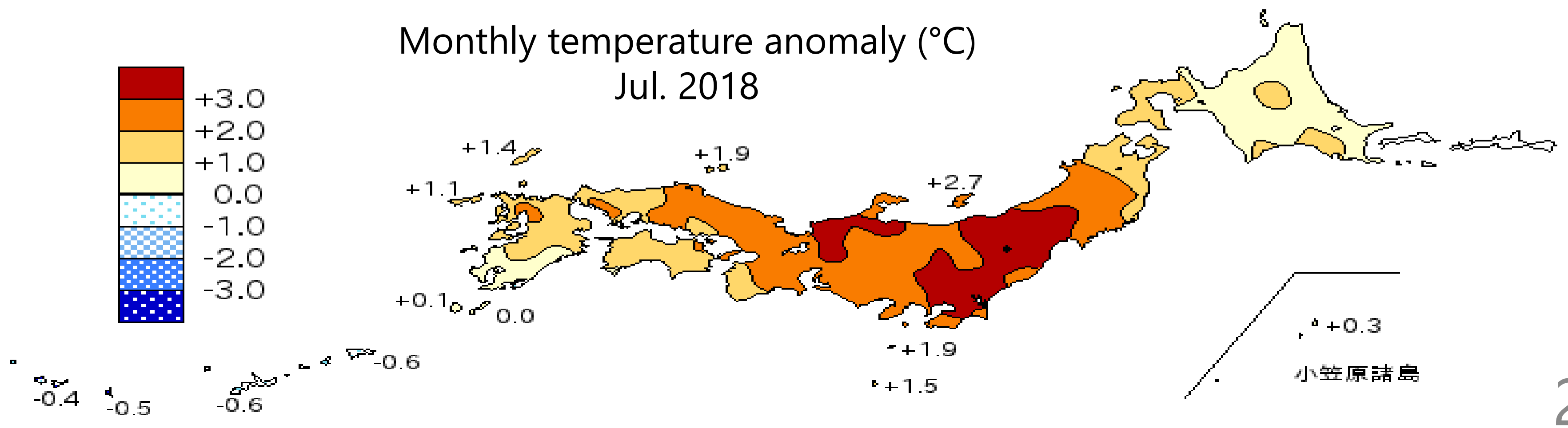
Climatic conditions: Heat wave

- The monthly mean temperature anomalies for July 2018 (+2.8°C) and JJA 2018 (+1.7°C) in eastern Japan were the highest on record for July and JJA since 1946, respectively.
- On 23rd July a new national record maximum temperature of 41.1°C was recorded in the Kumagaya city (Saitama Pref.).
- Cumulative number with daily temperatures of 35°C or more from June to September was the highest since 2010.

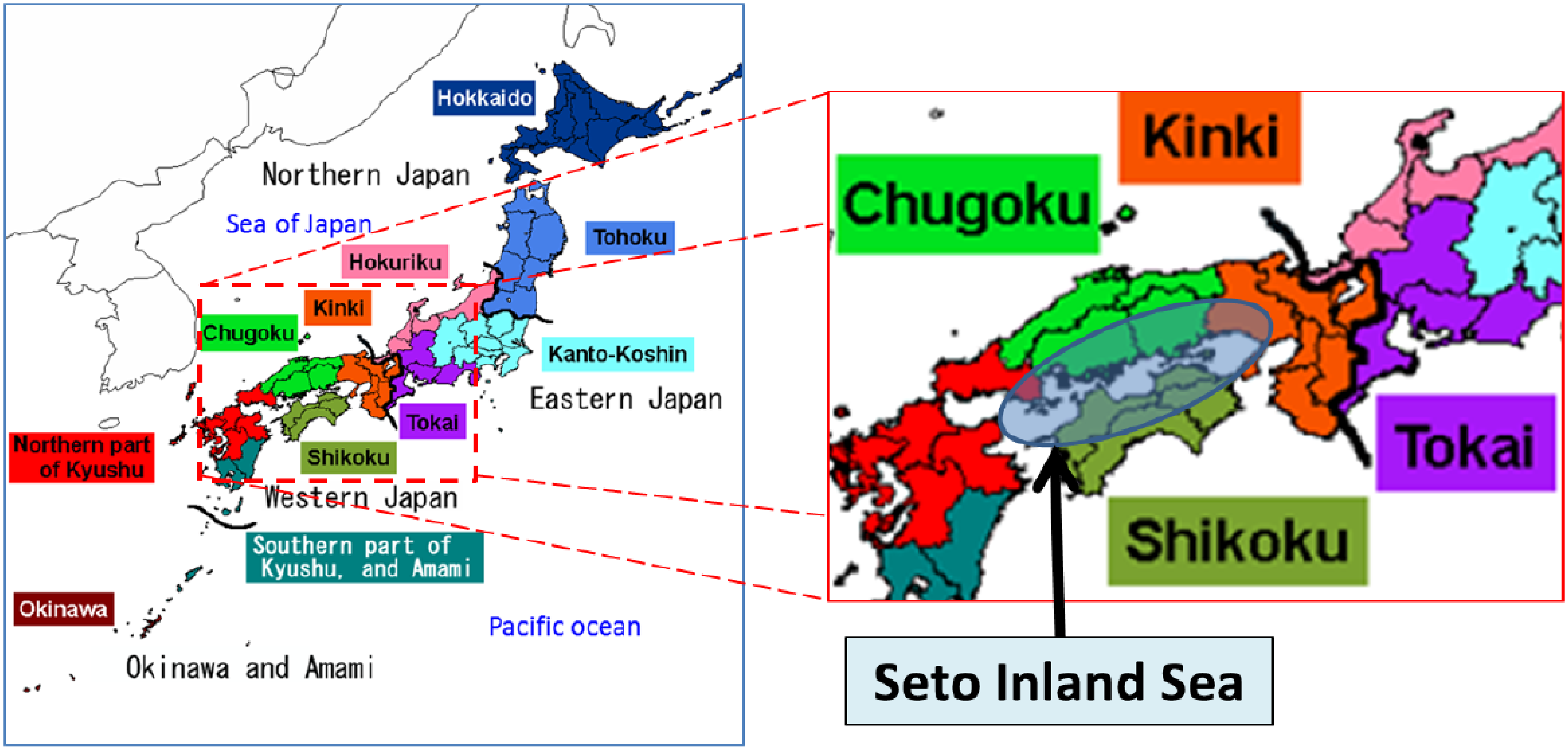
Cumulative No. of AMeDAS stations with daily maximum temperatures of 35°C or more (Jun.-Sep. (JJAS); 2010~2014)



Monthly temperature anomaly (°C)
Jul. 2018



Climatological regions of Japan



Climatological regions of Japan

The country has four divisions (Northern, Eastern, Western Japan and Okinawa/Amami) and eleven subdivisions (Hokkaido, Tohoku, Kanto-Koshin, Hokuriku, Tokai, Kinki, Chugoku, Shikoku, northern Kyushu, southern Kyushu and Okinawa).

HEAVY RAIN EVENT OF JULY 2018 IN JAPAN

Climatic conditions

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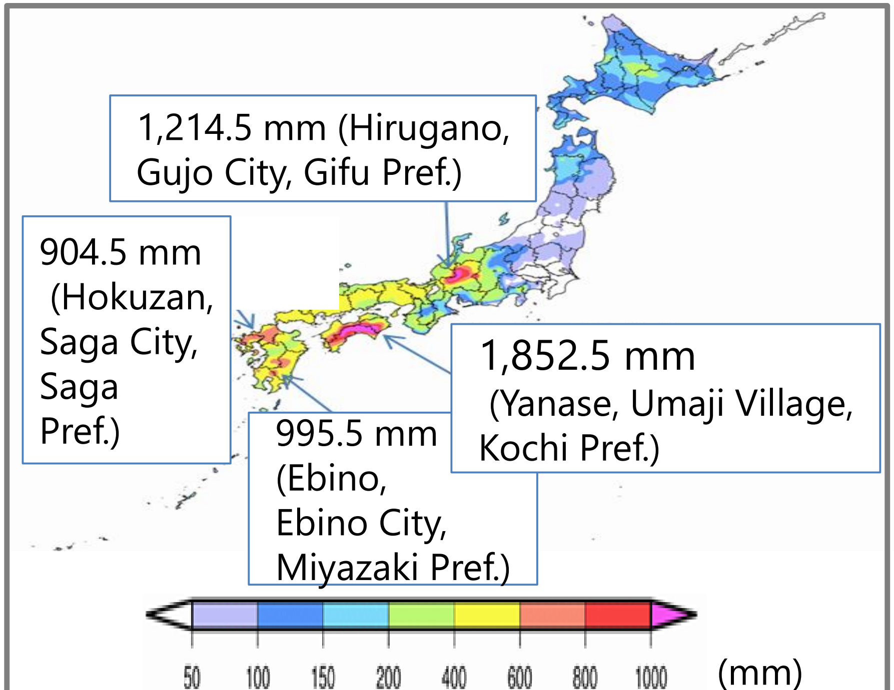
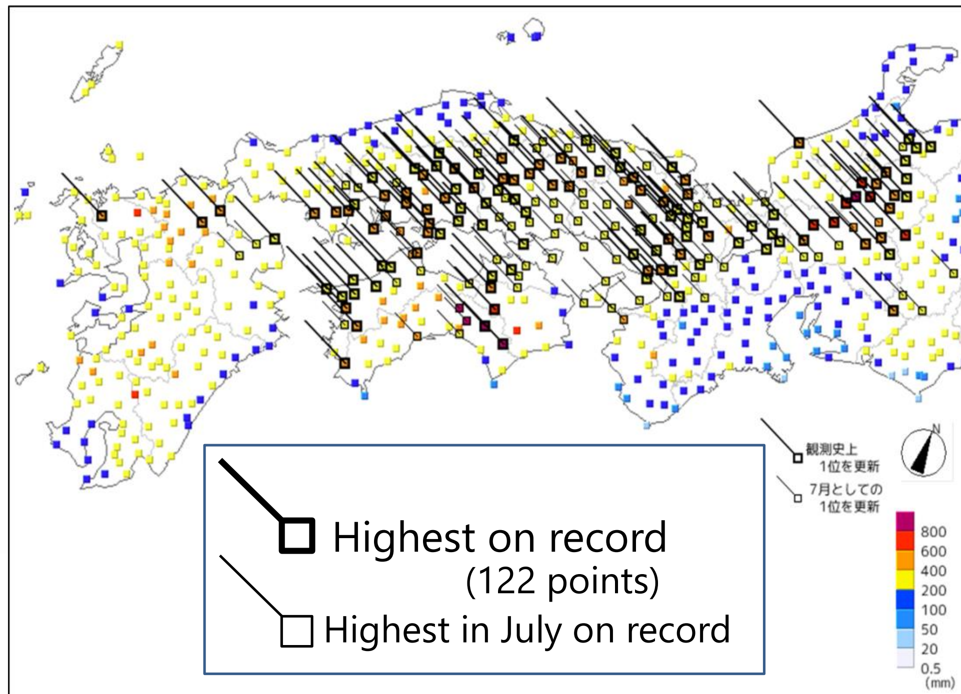


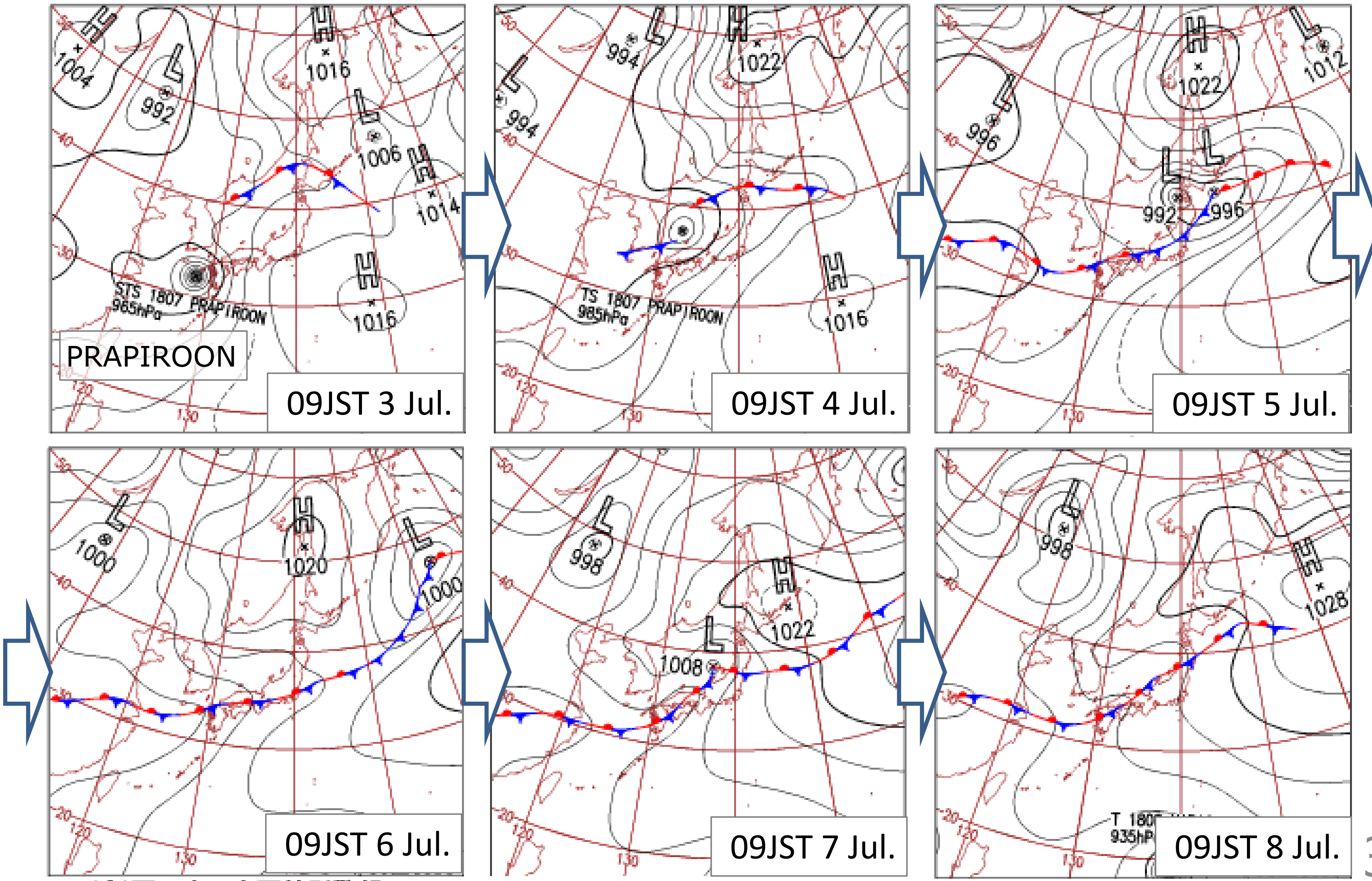
Total precipitation amounts for the Heavy Rain Event of July 2018 (28th June – 8th July)



Maximum 72-hour precipitation amounts during the event (from 28th June to 8th July) from western Japan to the Tokai region

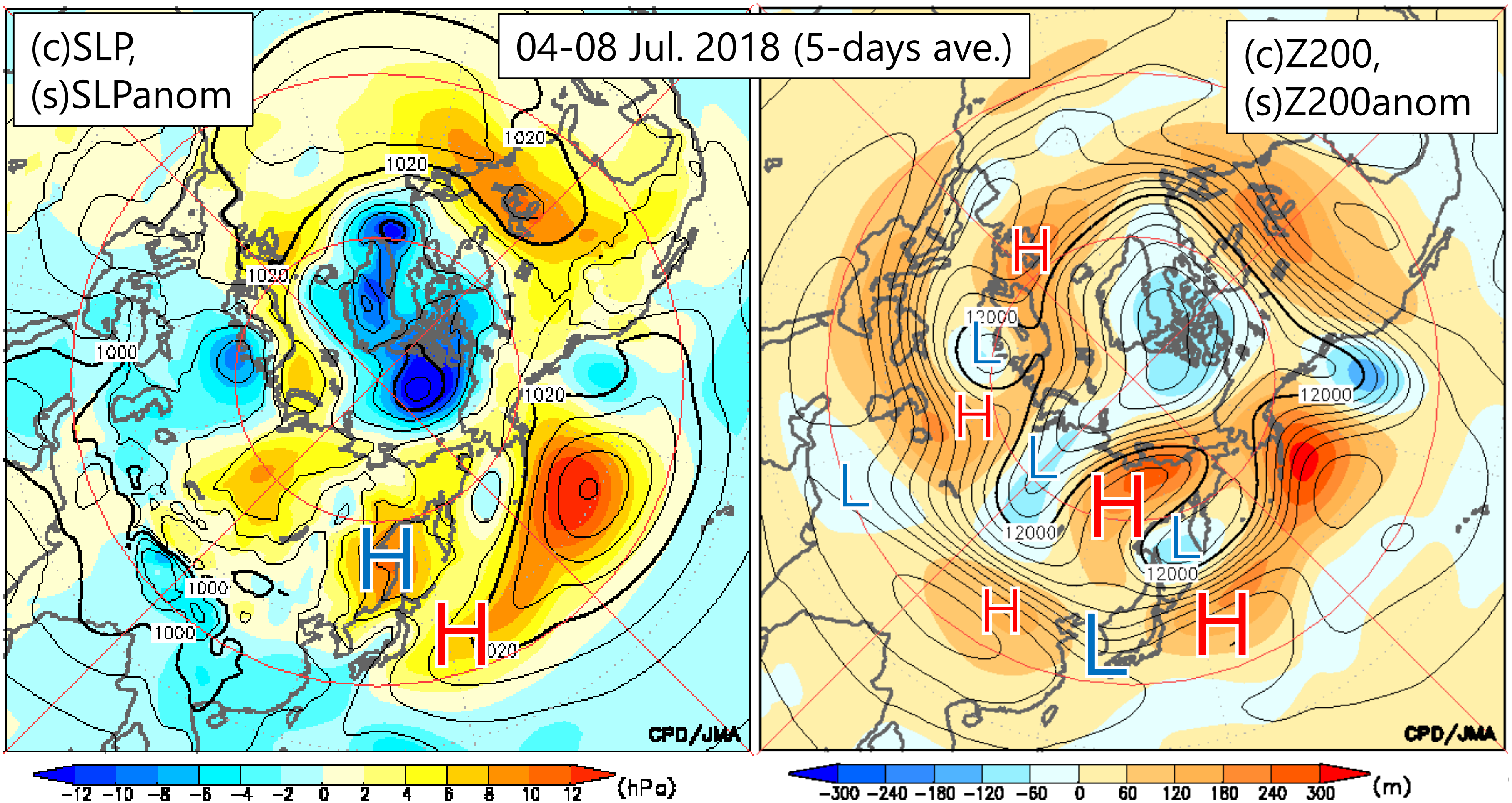
Weather maps

- 5～8 Jul., 2018 : Stationary Baiu front was seen around western Japan.



Atmospheric Circulation

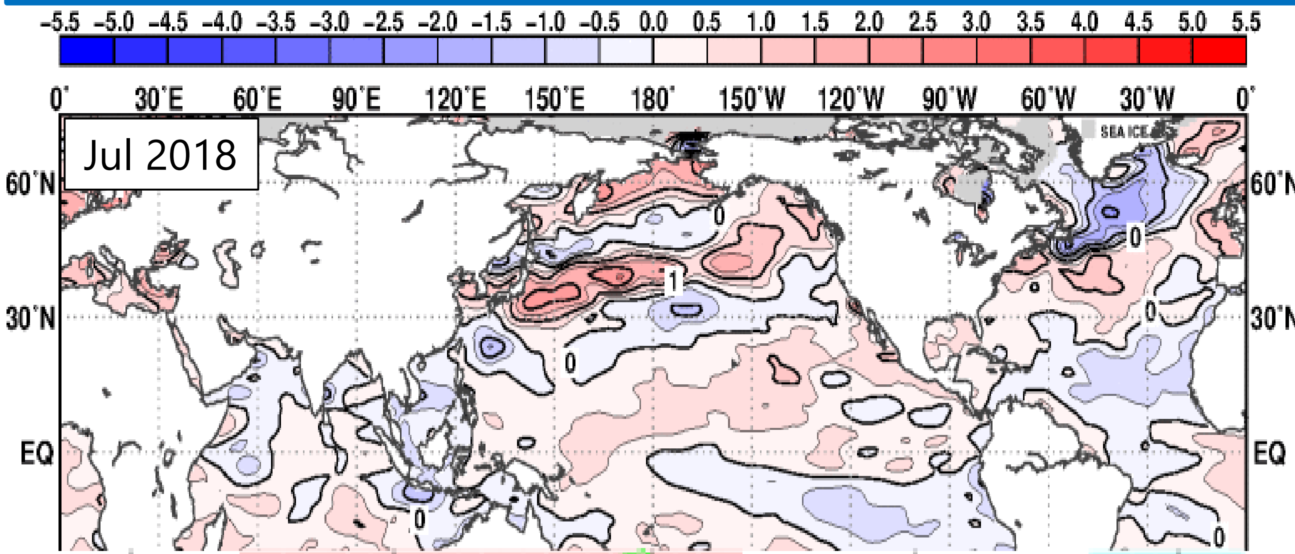
- The persistent meandering of the subtropical jet stream (STJ) and the polar front jet stream (PFJ) affected the positions and strength of the North Pacific Subtropical High (NPSH) ,the Okhotsk High, and the upper-level trough around the Korean Peninsula.
- The Baiu front remained stagnant over western Japan during the event.

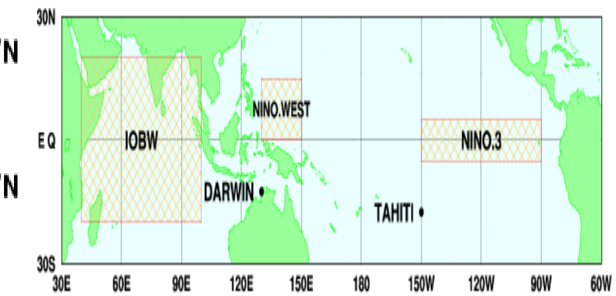


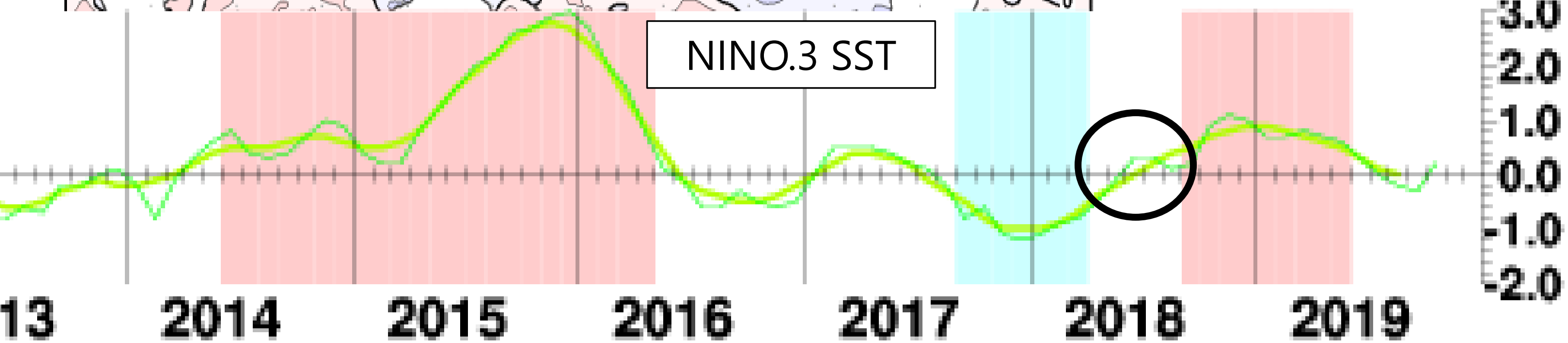
ENSO and oceanic conditions

- In summer 2018, ENSO was neutral and IOBW was near normal.
- La Nina continued from autumn 2017 to spring 2018, so that summer 2018 can be considered as post La Nina.

-> For the analysis of heat wave in summer 2018, we focused on the positive anomalies over the tropical North Pacific (to be shown later).

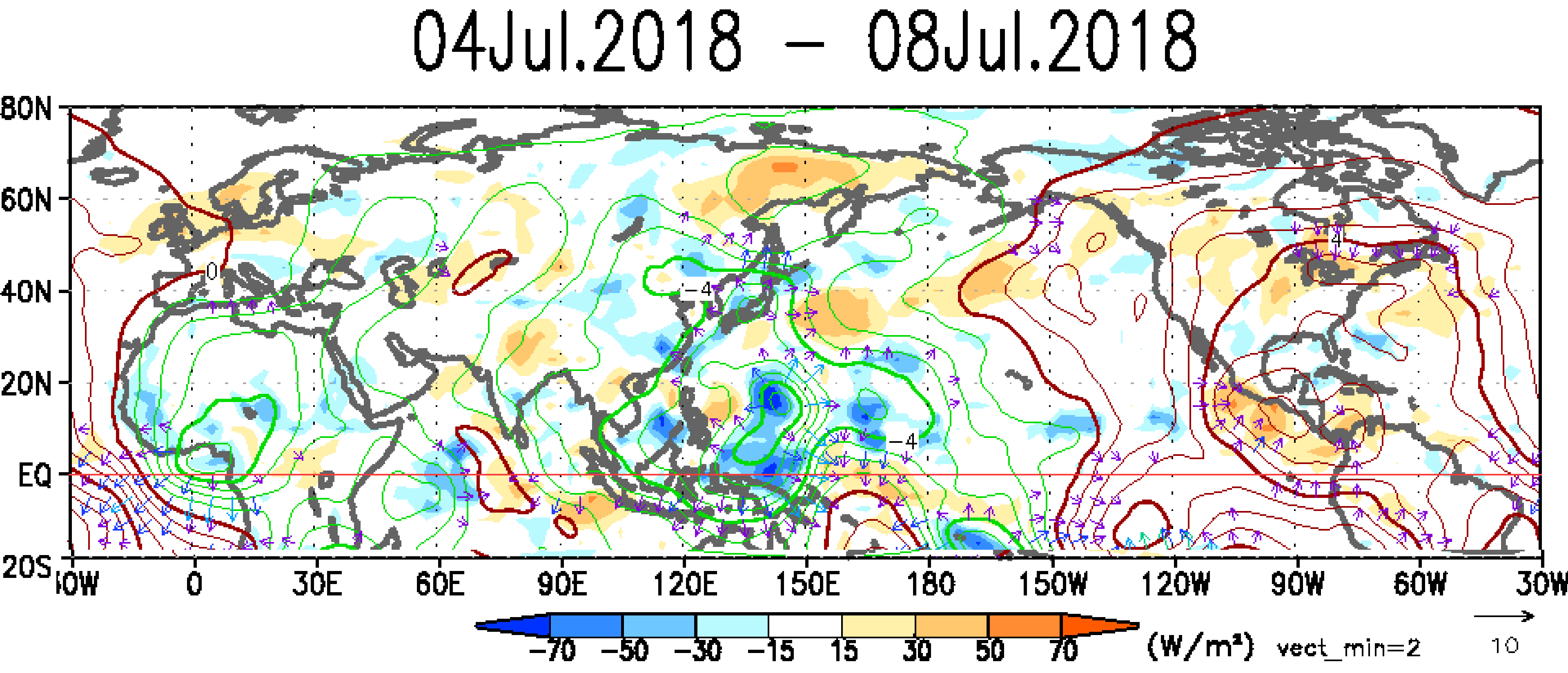




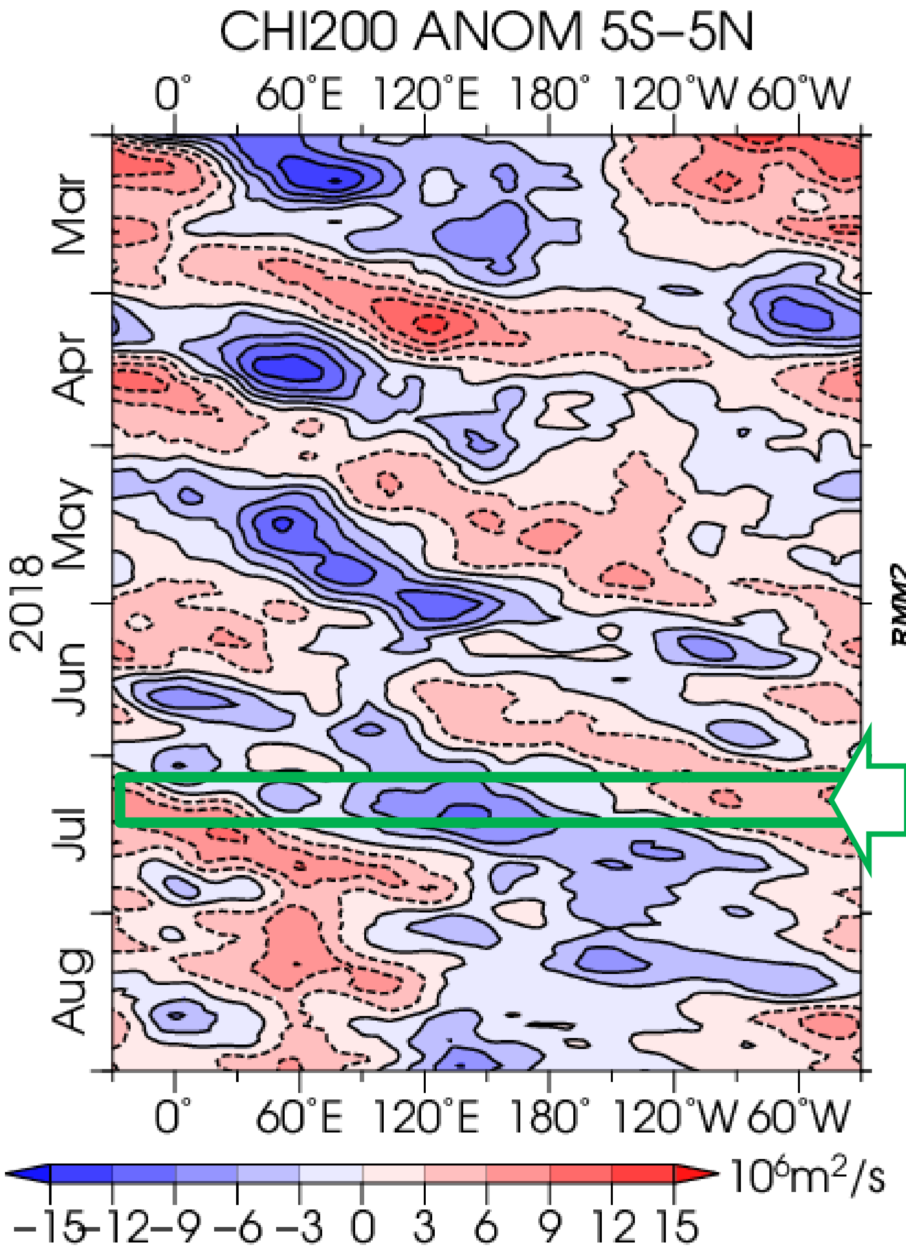


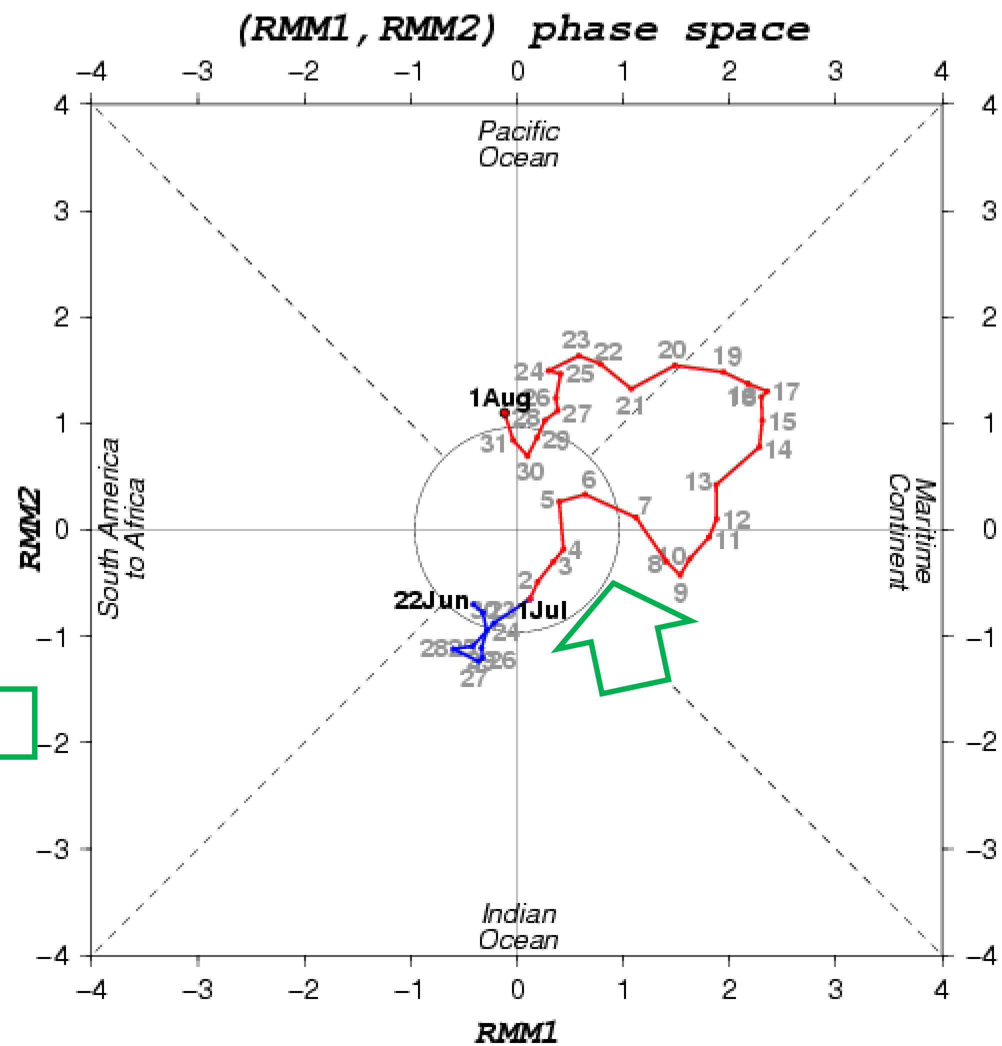
Atmospheric Circulation

- The persistent meandering of the subtropical jet stream (STJ) and the polar front jet stream (PFJ) affected the positions and strength of the North Pacific Subtropical High (NPSH) ,the Okhotsk High, and the upper-level trough around the Korean Peninsula.



Atmospheric Circulation



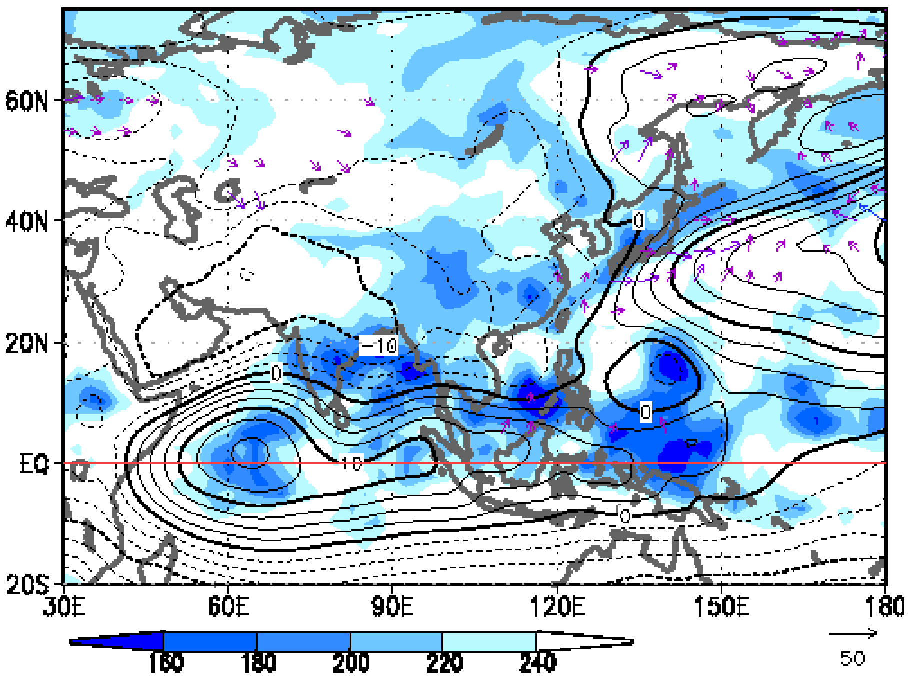


Atmospheric circulation

- Enhanced convective activity was seen over the East China See.
- Considering influence of convective activity in tropics, especially western tropical North Pacific, we need more investigation.

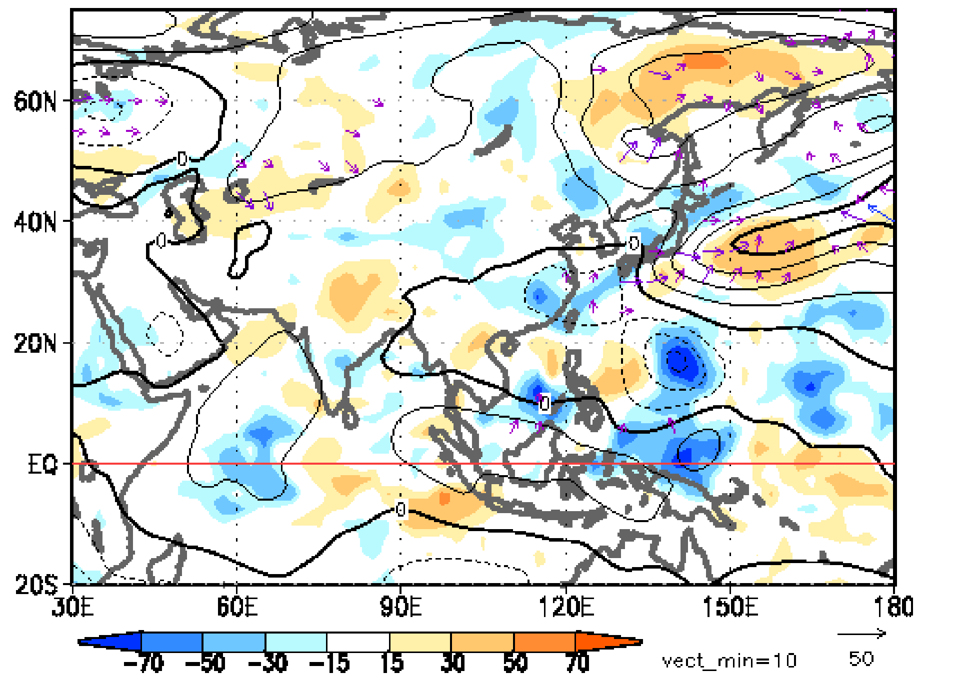
04-08 Jul. 2018(5-days ave.)

(c)PSI850 [$10^6 m^2/s$], (s)OLR [W/m^2]



<- Active convection

(c)PSI850anom [$10^6 m^2/s$], (s)OLRanom [W/m^2]

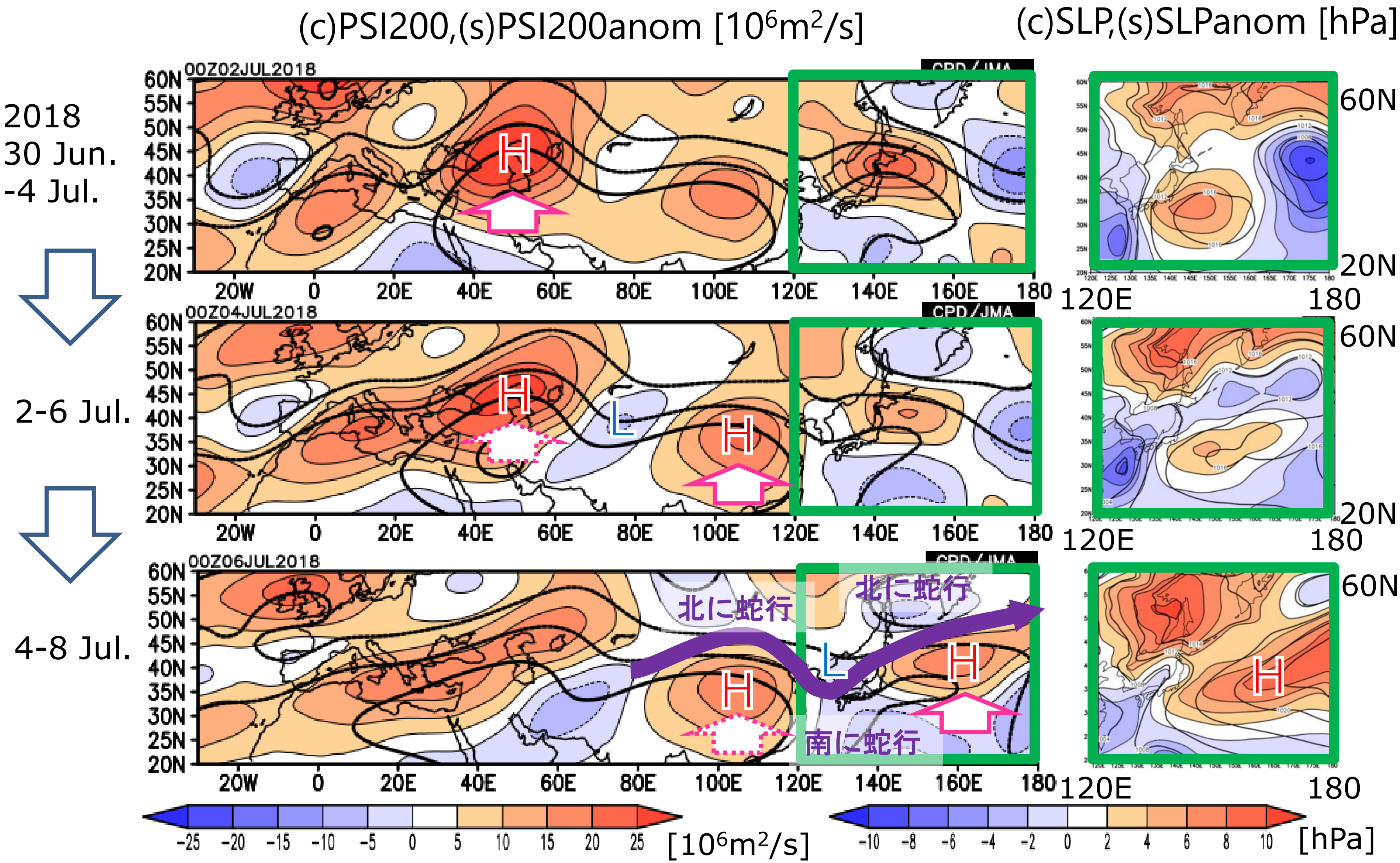


<- Active convection

Inactive -> convection

Atmospheric circulation

- Rossby wave propagation was seen over the Subtropical Jet (STJ).
- Expansion of the NPSH were associated with northward meanders of the STJ over the east of Japan.

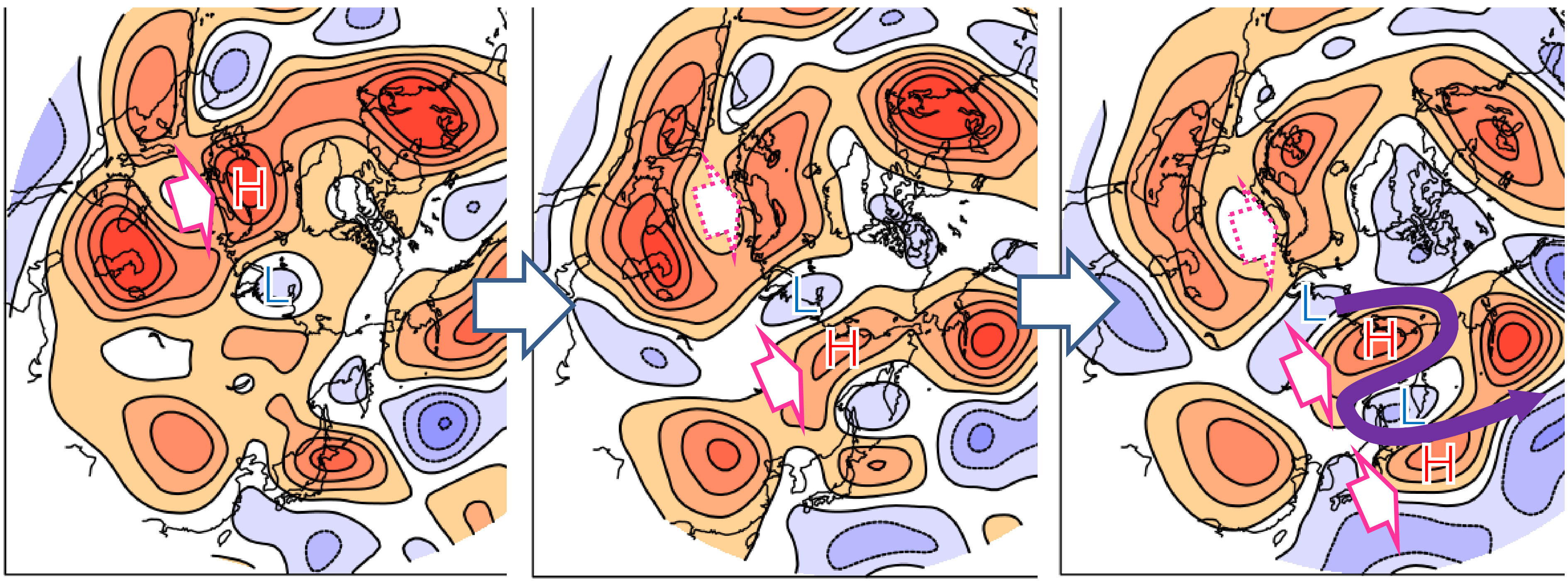


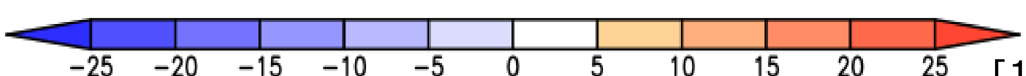
Atmospheric circulation

- Rossby wave propagation was seen over the Polar-front Jet (PFJ).
- Expansion of the NPSH were associated with northward meanders of the PFJ over the east of Japan.

(c)PSI200,(s)PSI200anom [$10^6 m^2/s$]

30 Jun.-4 Jul., 2018 | 2-6 Jul. | 4-8 Jul.

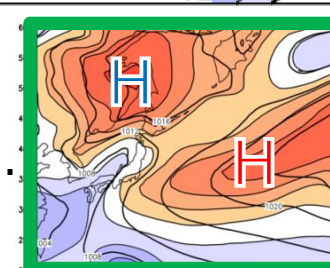




[$10^6 m^2/s$]

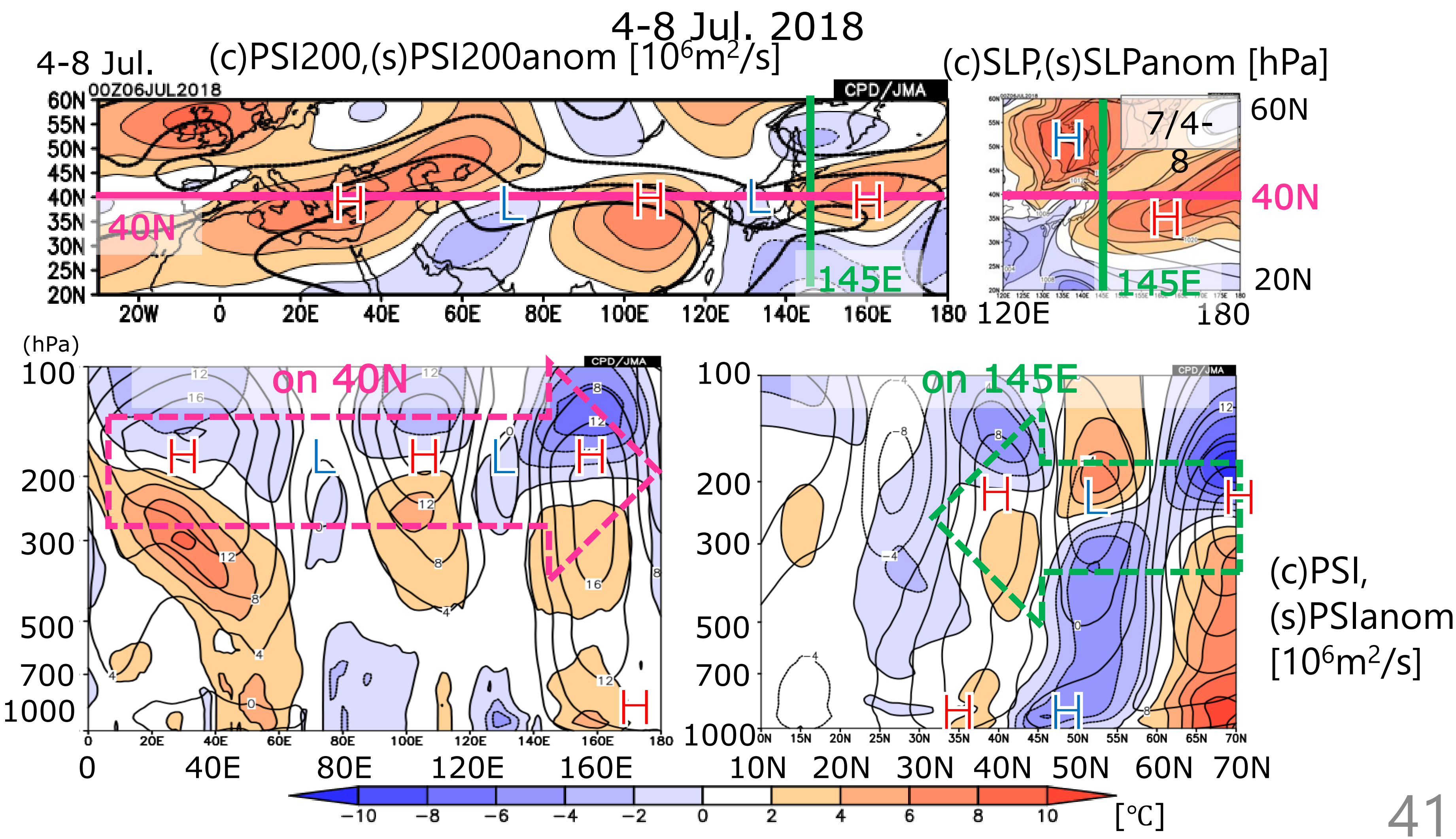
4-8 Jul.

(c)SLP,(s)SLPanom [hPa]



Atmospheric circulation

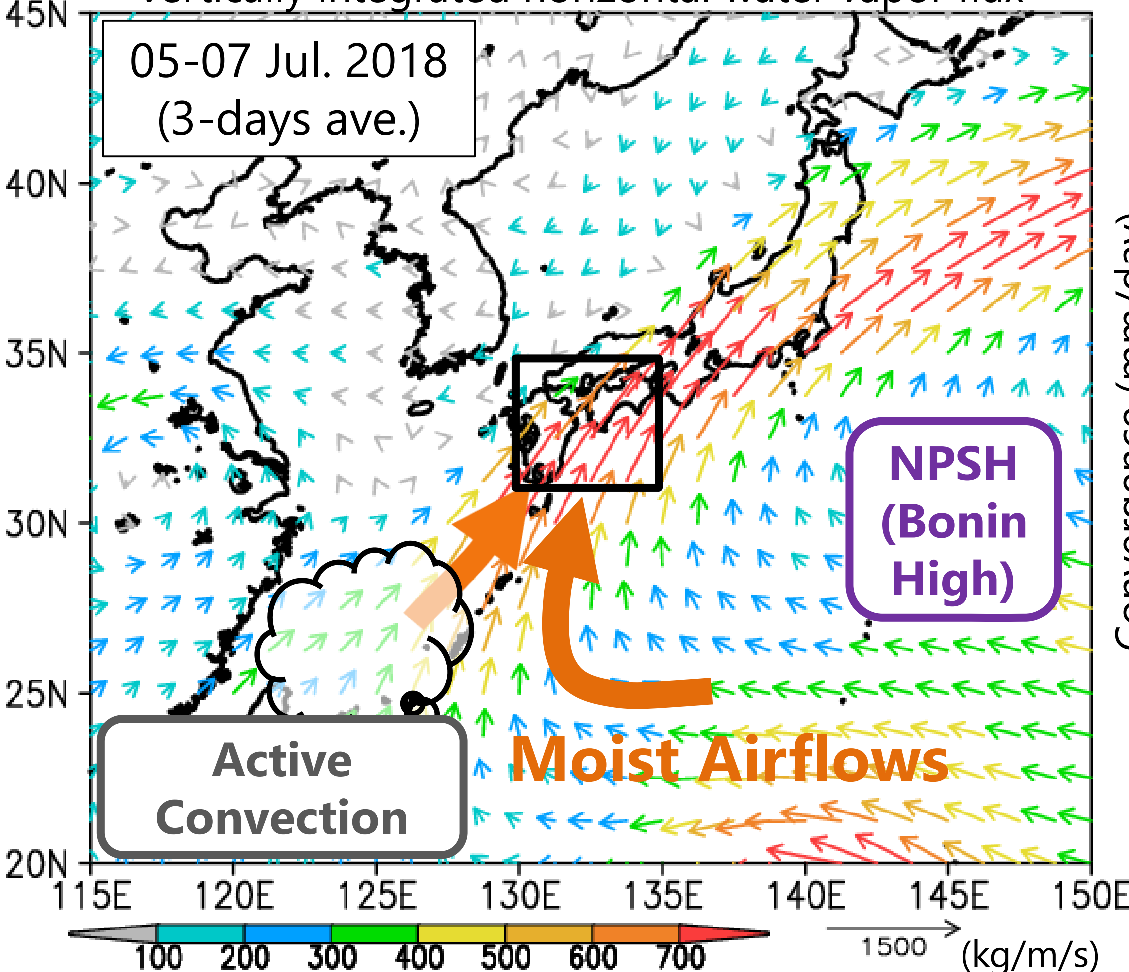
- Equivalent barotropic conditions were seen, so that these waves over STJ and SPJ, so that the Okhotsk High and NPSH could be maintained and the stationary Baiu front could be seen around the western Japan.



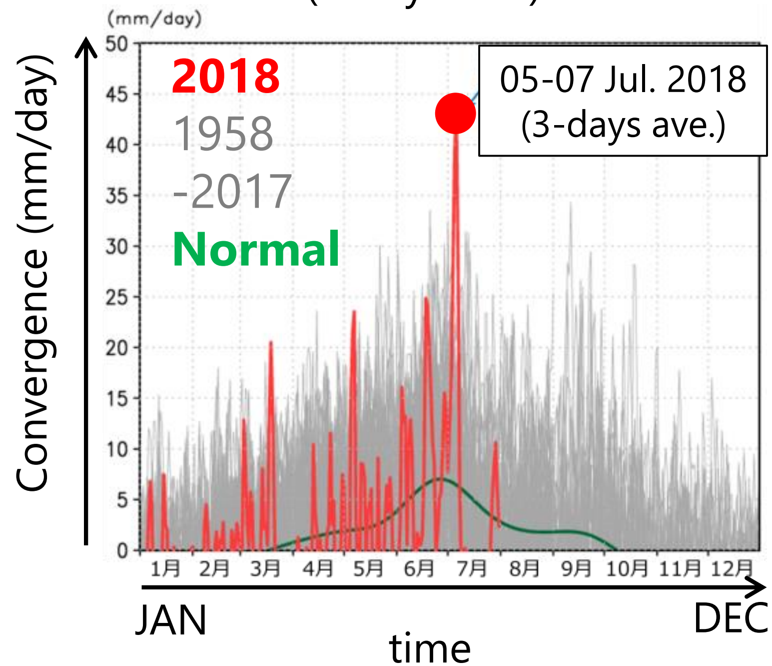
Concentration of moist airflows

- Two moist airflows (from East China Sea and along the periphery of the NPSH) brought significant amounts of water vapor to western Japan.
- Unprecedented amounts of water vapor were concentrated in and around western Japan from 5th to 7th July 2018 since 1958, based on the estimation using JRA-55

Vertically integrated horizontal water vapor flux

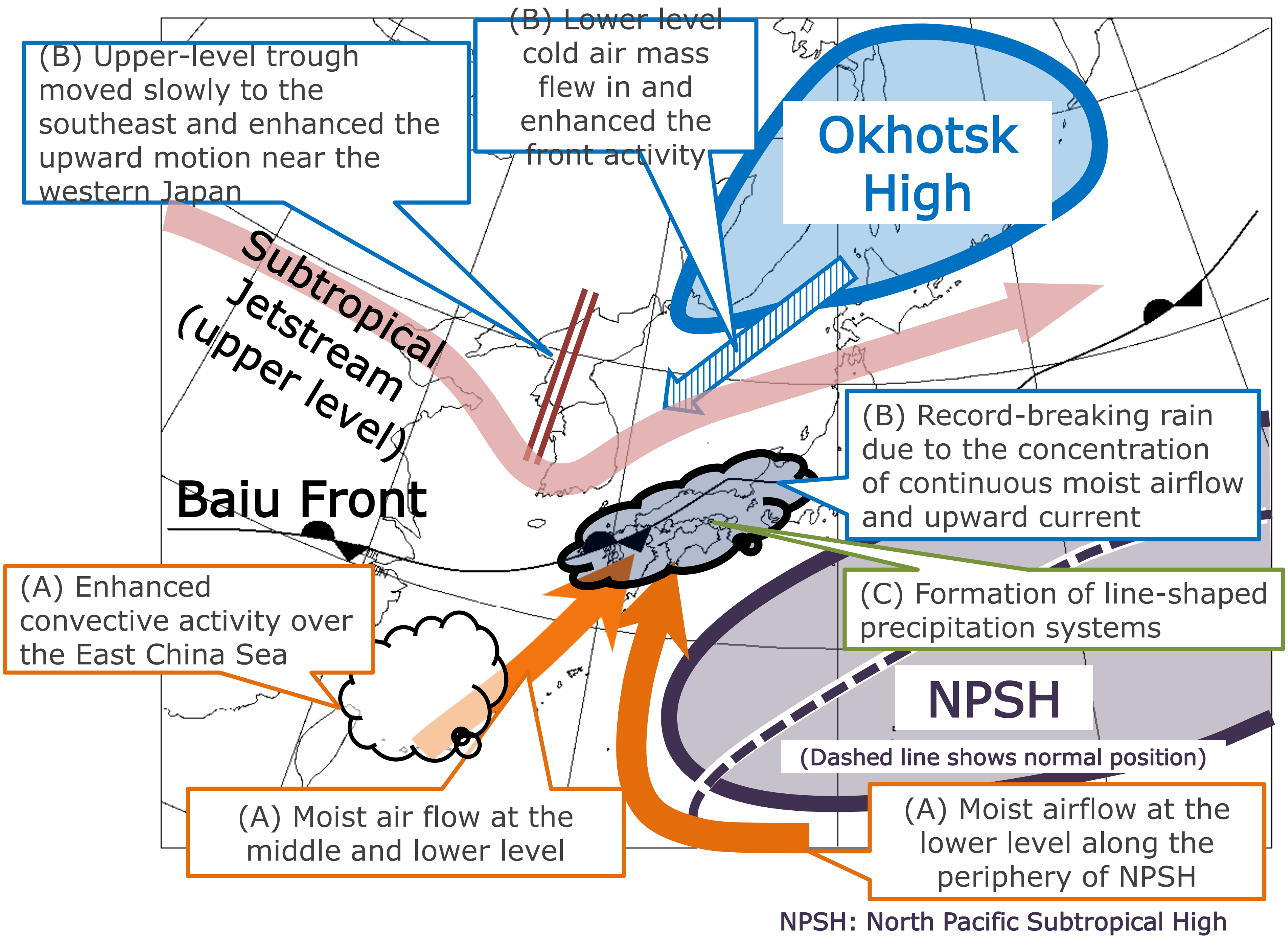


Time-series of vertically integrated horizontal water vapor flux in（31.25-35N, 130-135E）(3-days ave.)

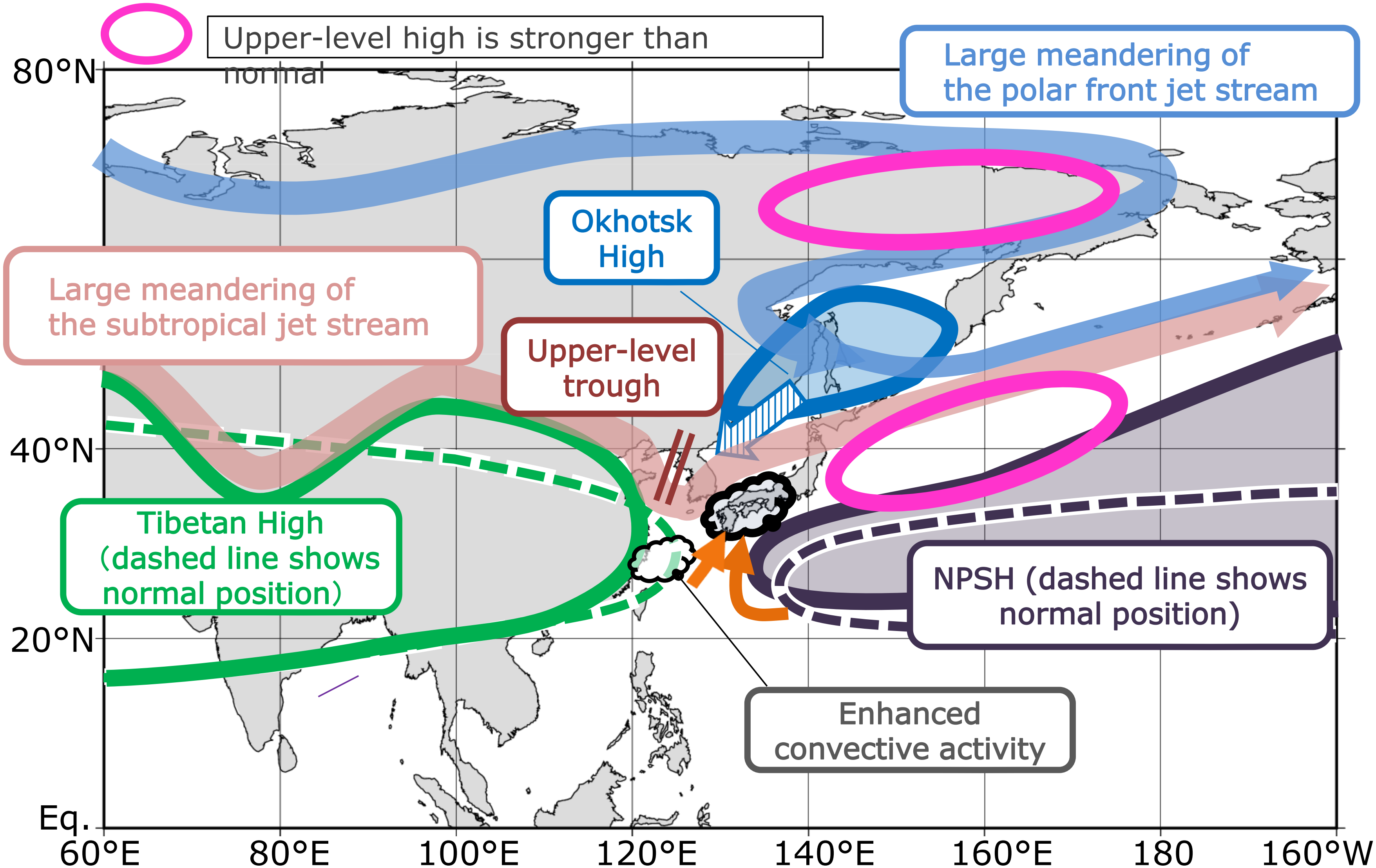


(The flux was integrated from surface to 300hPa.)

Primary synoptic-scale motion factors behind record rainfall from western Japan to the Tokai region from 5th to 8th July 2018



Primary factors behind the unprecedentedly heavy rain affecting areas from western Japan to the country’s Tokai region from 5th to 8th July 2018

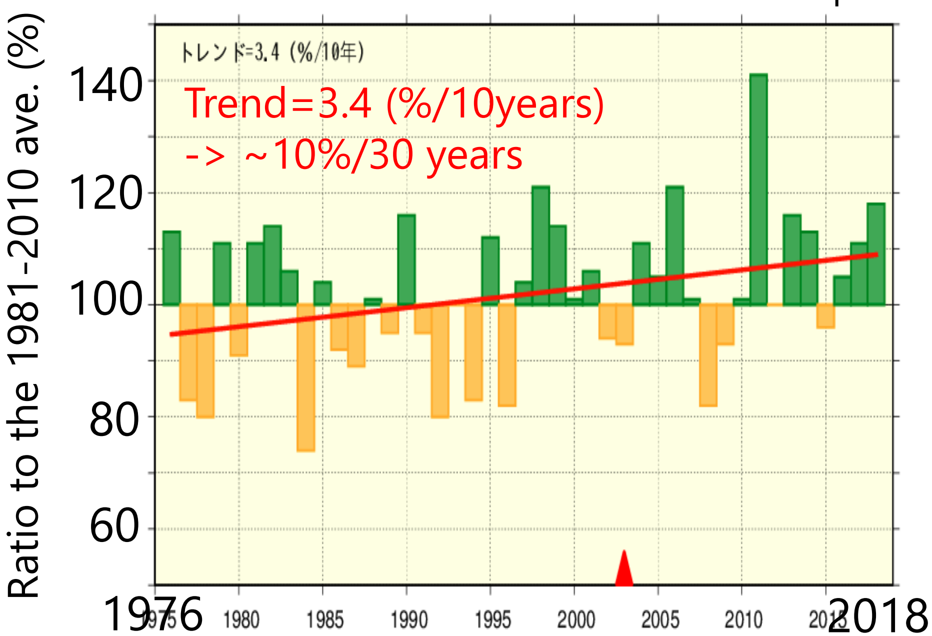


NPSH: North Pacific Subtropical High

Influence of global warming

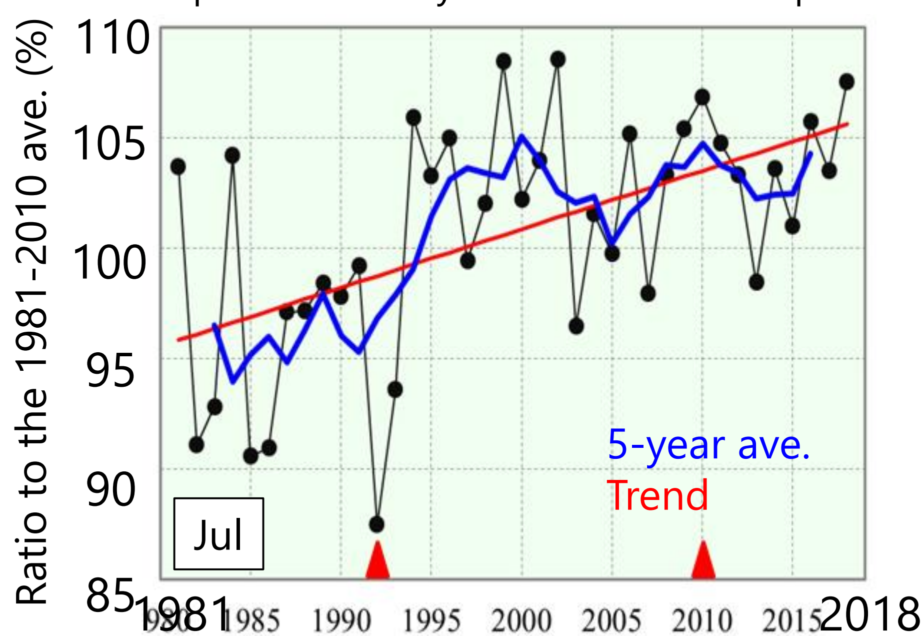
- On a longer time scale, a trend of increased intensity in extreme precipitation events in Japan is observed.
- Based on AMeDAS observation, nationwide averages of the ratio of annual 72-hour maximum precipitation have increased by about 10% over the past 30 years.
- This is associated with a long-term trend of surface air temperature increase due to global warming and a similar increasing trend in water vapor in the air over Japan.

Annual maximum Prec. Ratio in 72h in Japan



Based on 685 AMeDAS stations. The red line indicates the long-term linear trend (statistically significant at a confidence level of 90%). The value for 2018 is preliminary as of 1st of August.
▲ marks the timing of a change in the observation method for precipitation (observed every hour before 2003 and every 10 minutes thereafter).

Specific humidity ratio at 850hPa in Japan



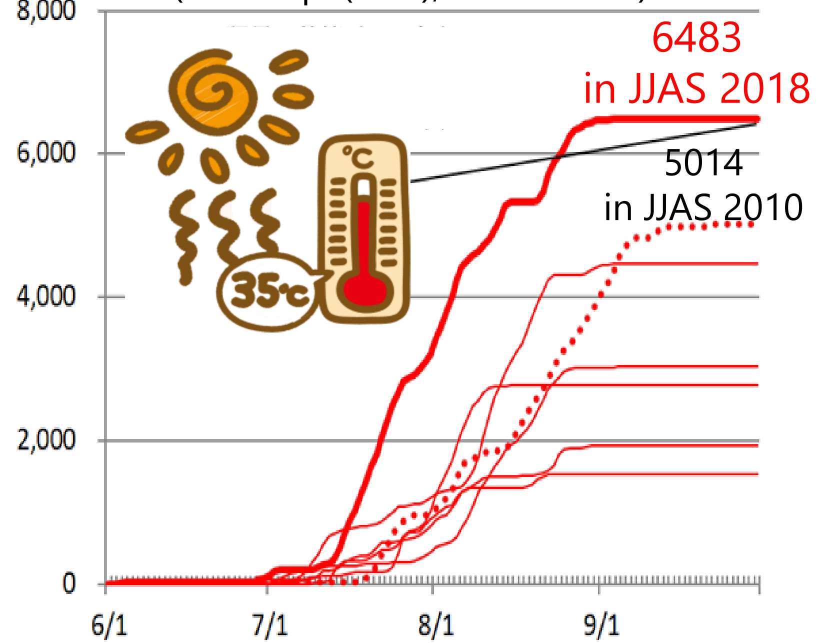
Based on 13 upper-air observation stations in Japan.
The dots show the averages of the data for the 13 stations.
The red line indicates the long-term linear trend (statistically significant at a confidence level of 99%).
Data from the period marked by ▲ may include biases due to instrument changes.

HEAT WAVE IN BOREAL SUMMER 2018

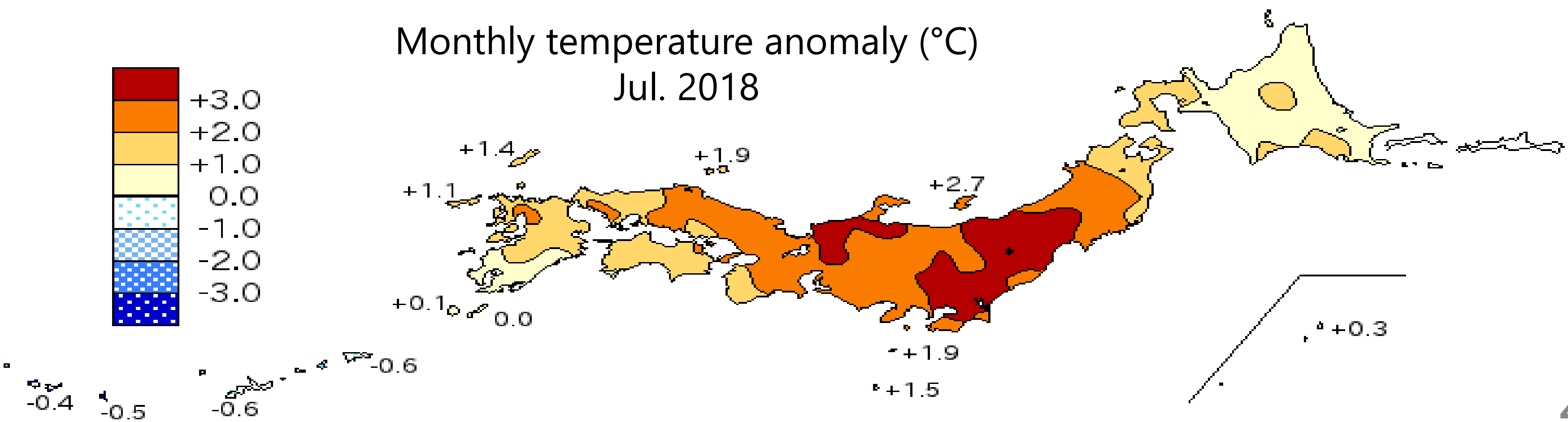
Climatic conditions

- The monthly mean temperature anomalies for July 2018 (+2.8°C) and JJA 2018 (+1.7°C) in eastern Japan were the highest on record for July and JJA since 1946, respectively.
- On 23rd July a new national record maximum temperature of 41.1°C was recorded in the Kumagaya city (Saitama Pref.).
- Cumulative number with daily temperatures of 35°C or more from June to September was the highest since 2010.

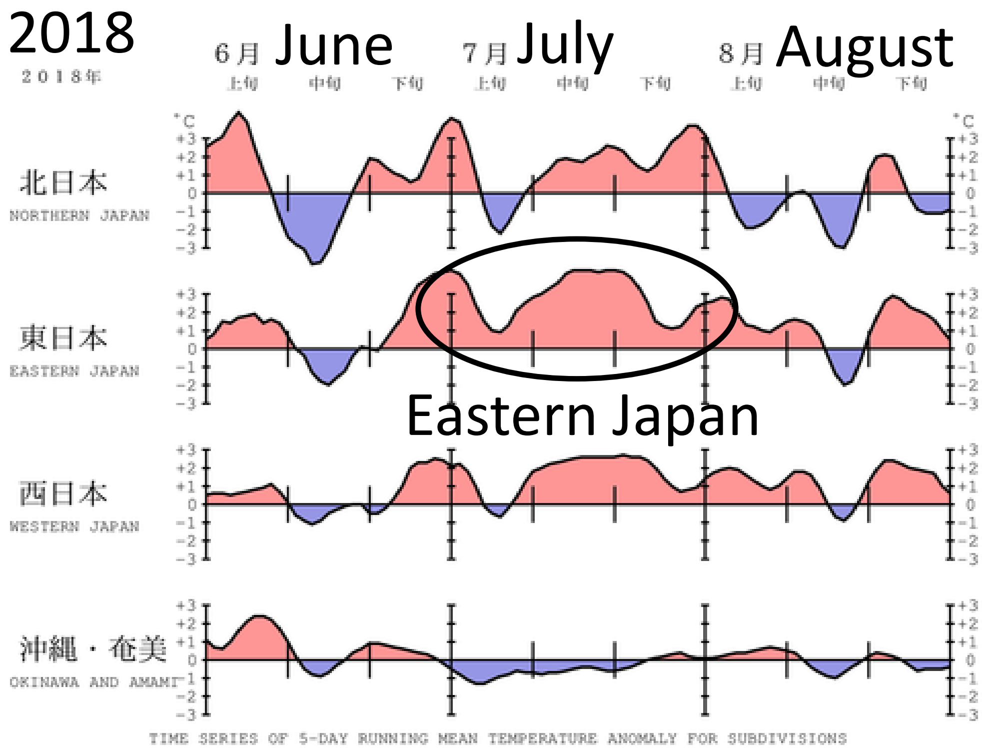
Cumulative No. of AMeDAS stations with daily maximum temperatures of 35°C or more (Jun.-Sep. (JJAS); 2010~2014)

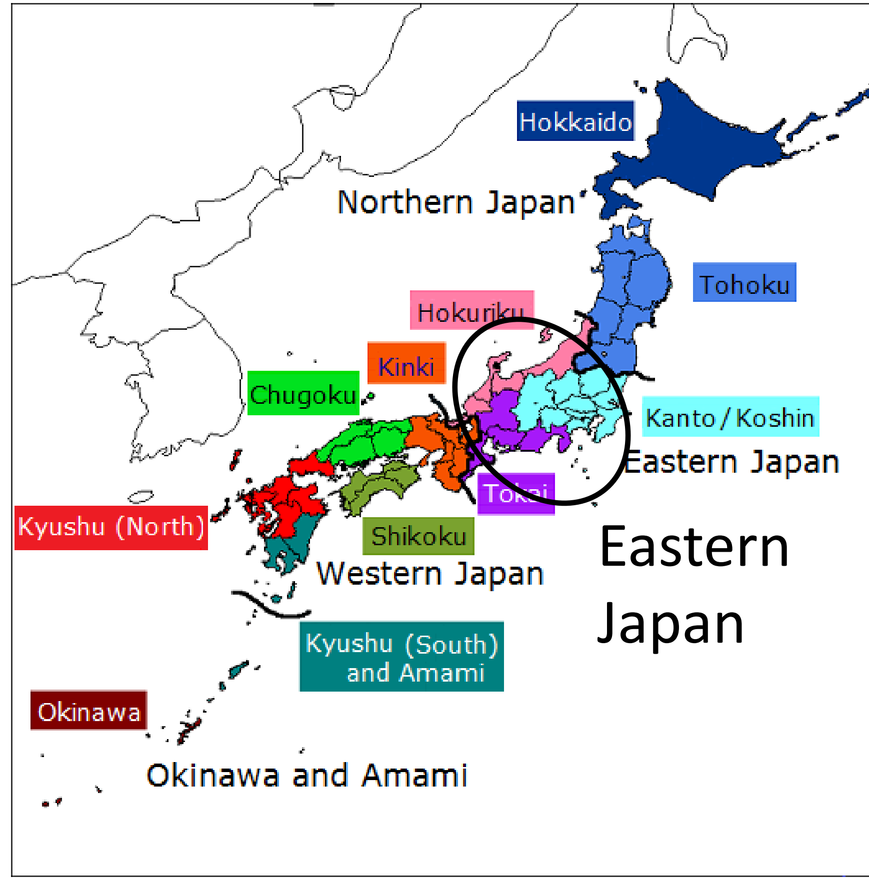


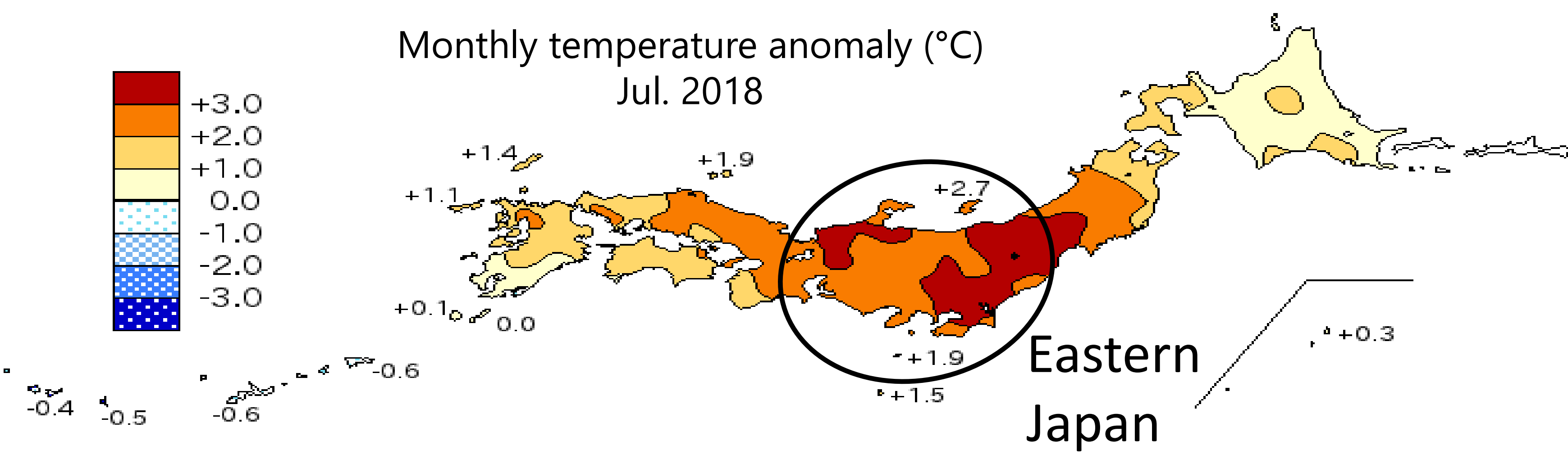
Monthly temperature anomaly (°C)
Jul. 2018



Climatic conditions

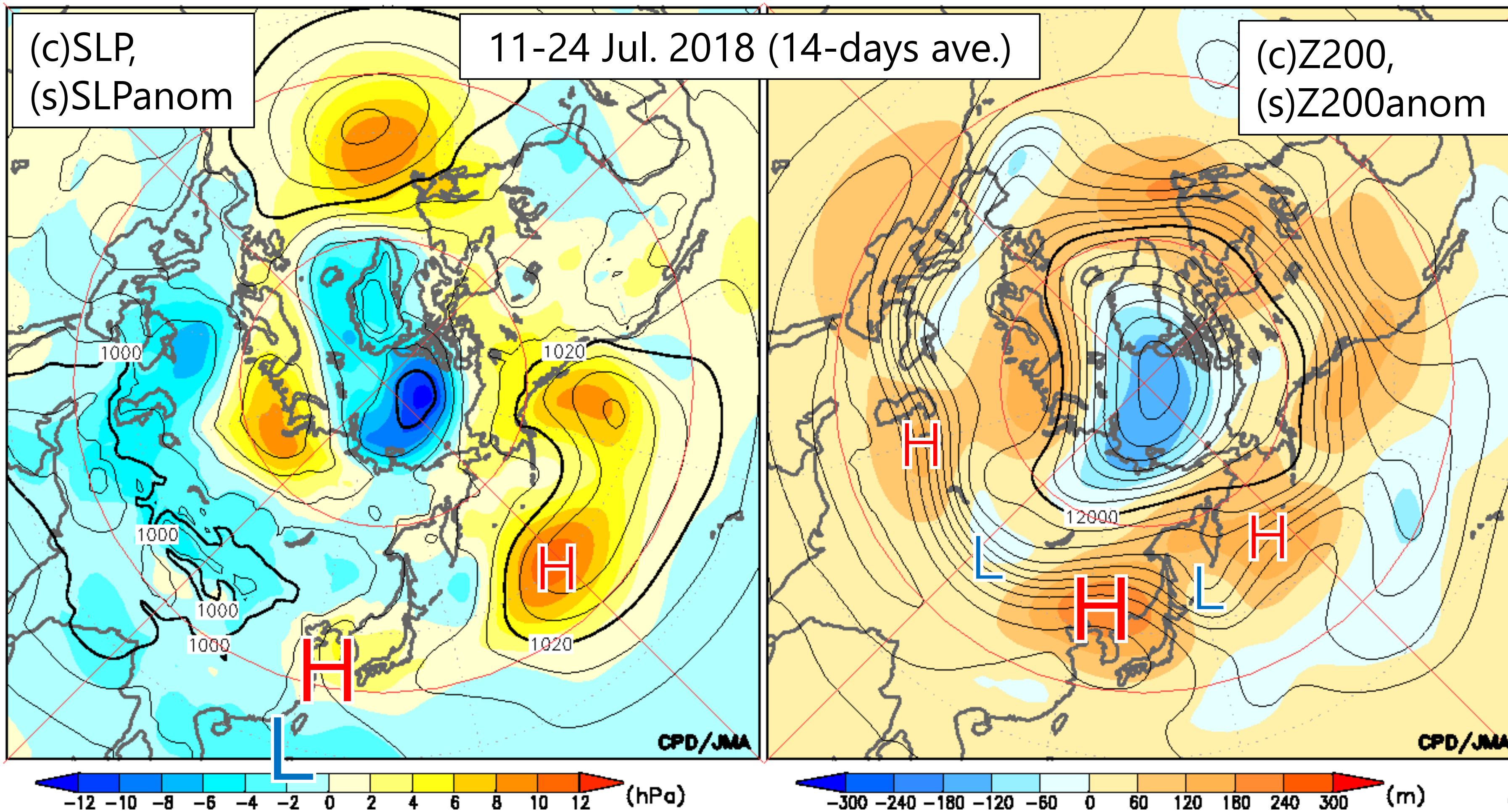




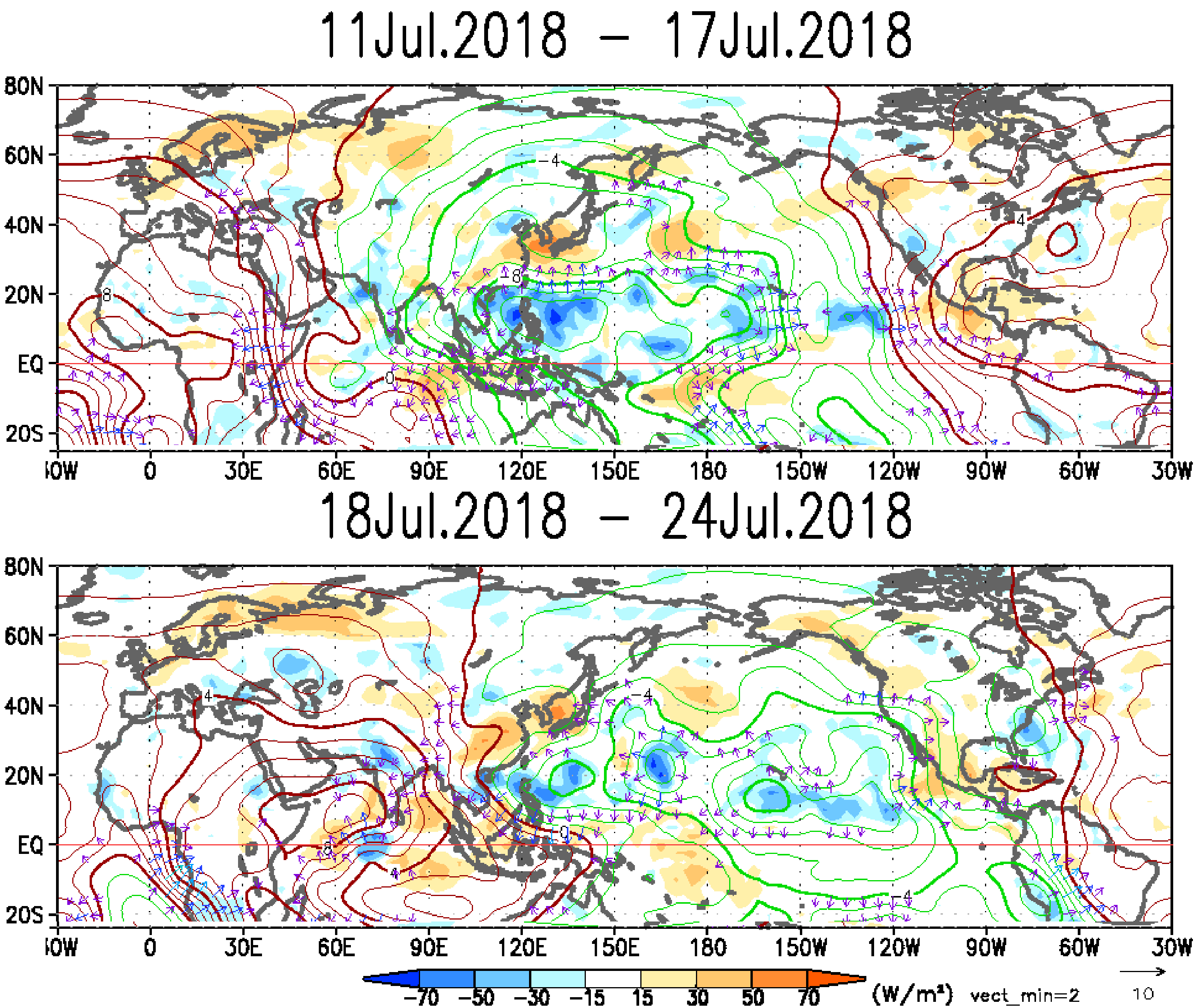


Atmospheric circulation

- Both the NPSH and the Tibetan High expanded to the main islands of the country and persisted. Surface temperatures in Japan increased due mainly to high-pressure systems with warmer-than-normal air covering these islands, predominant sunny conditions and downward flow associated with these pressure systems, influenced by northward meandering of the STJ in the vicinity of Japan.

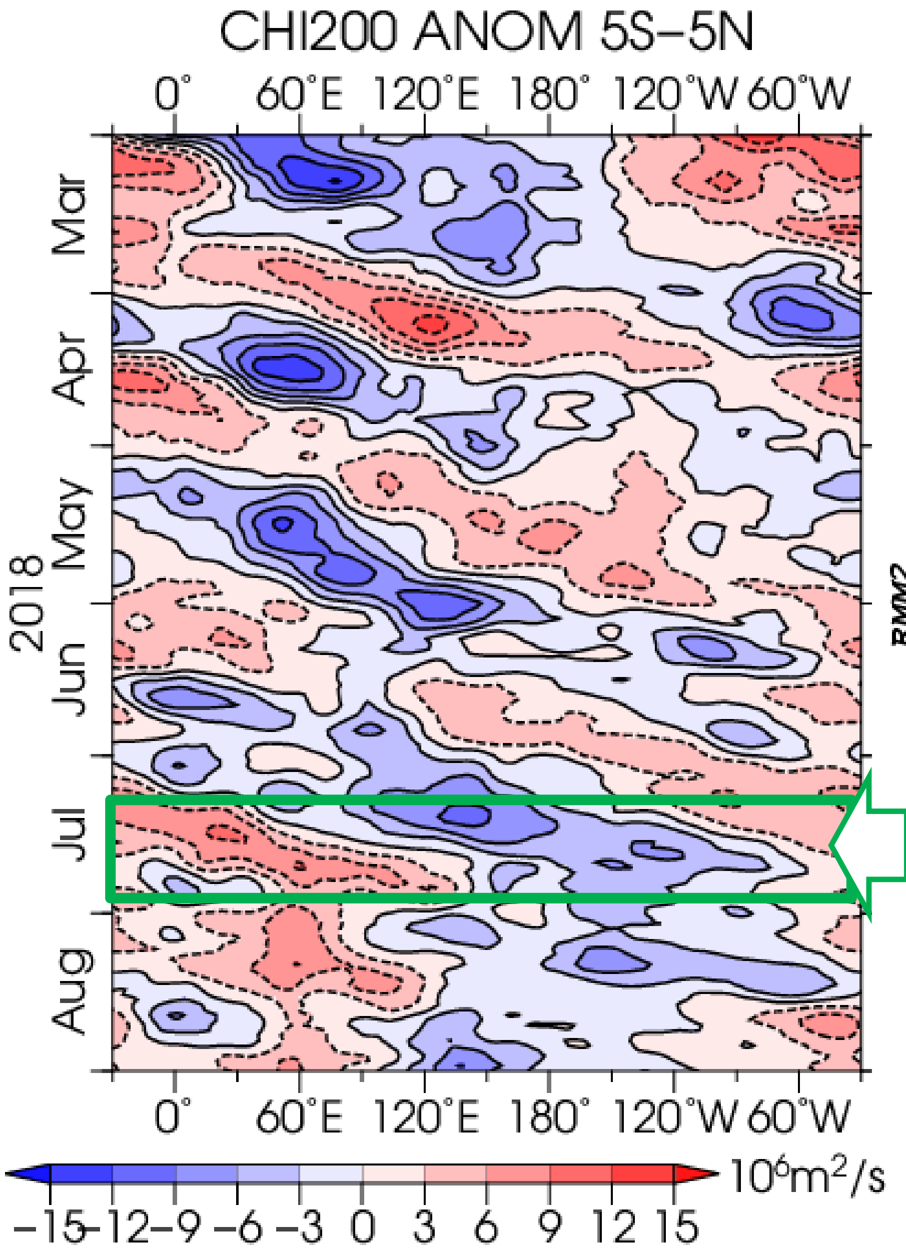


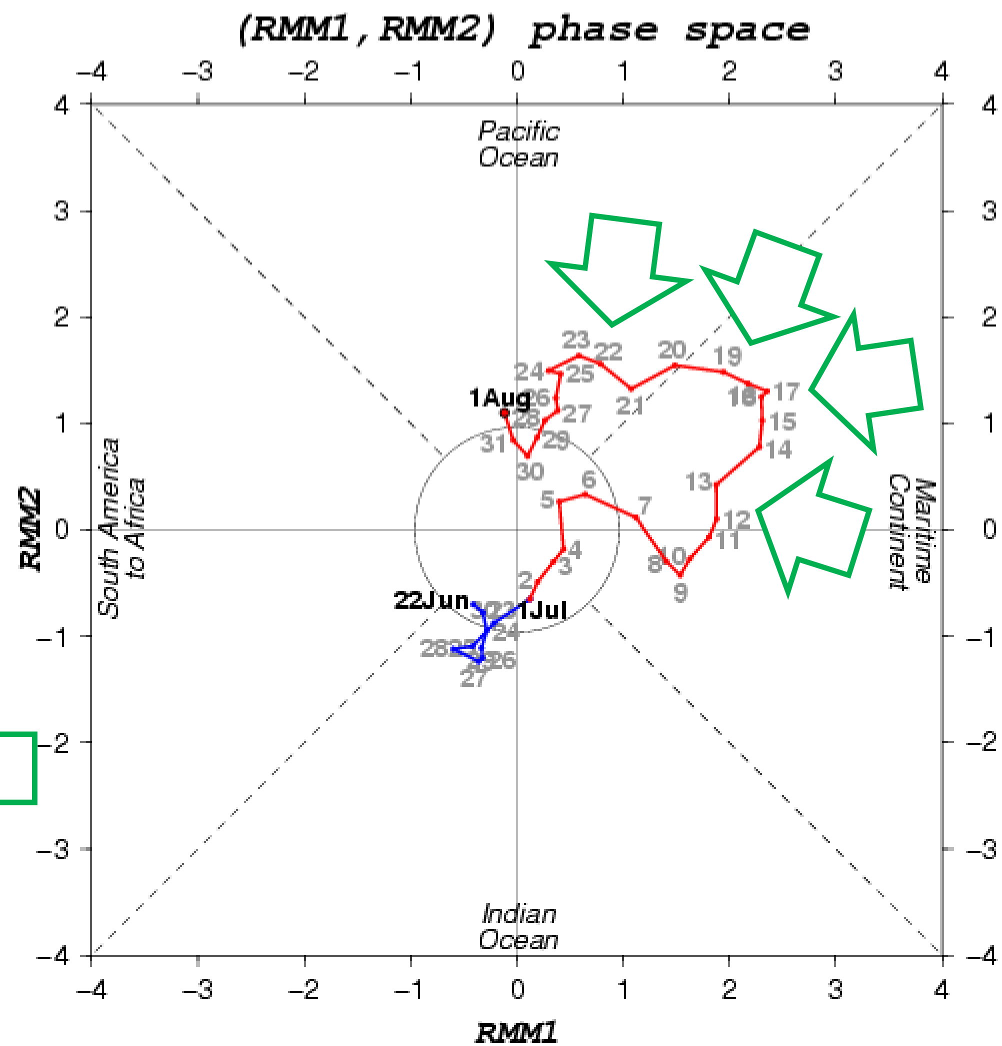
Atmospheric Circulation



(c)CHI200anom [$10^6 m^2/s$]
(s)OLRanom [W/m^2]
(v)200hPa divergent wind [m/s]

Atmospheric Circulation



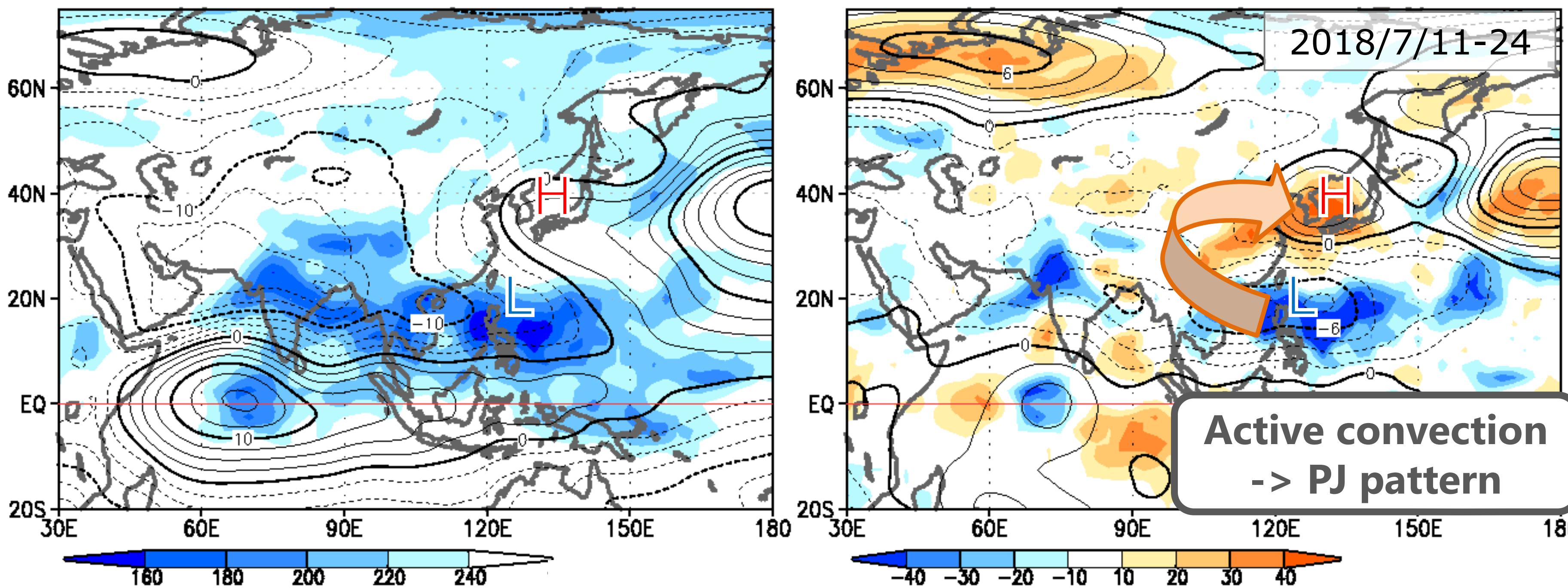


Atmospheric circulation

- The expansion of the NPSH in the vicinity of Japan appears attributable to enhanced convective activity over and around the Philippines with stronger-than-normal large-scale lower-level cyclonic circulation over the area from Southeast Asia to the Philippines (the Pacific-Japan (PJ) pattern (Nitta 1987; Kosaka and Nakamura 2010)).

11-24 Jul. 2018(14-days ave.)

(c)PSI850 [$10^6 m^2/s$], (s)OLR [W/m^2]　　(c)PSI850anom [$10^6 m^2/s$], (s)OLRanom [W/m^2]



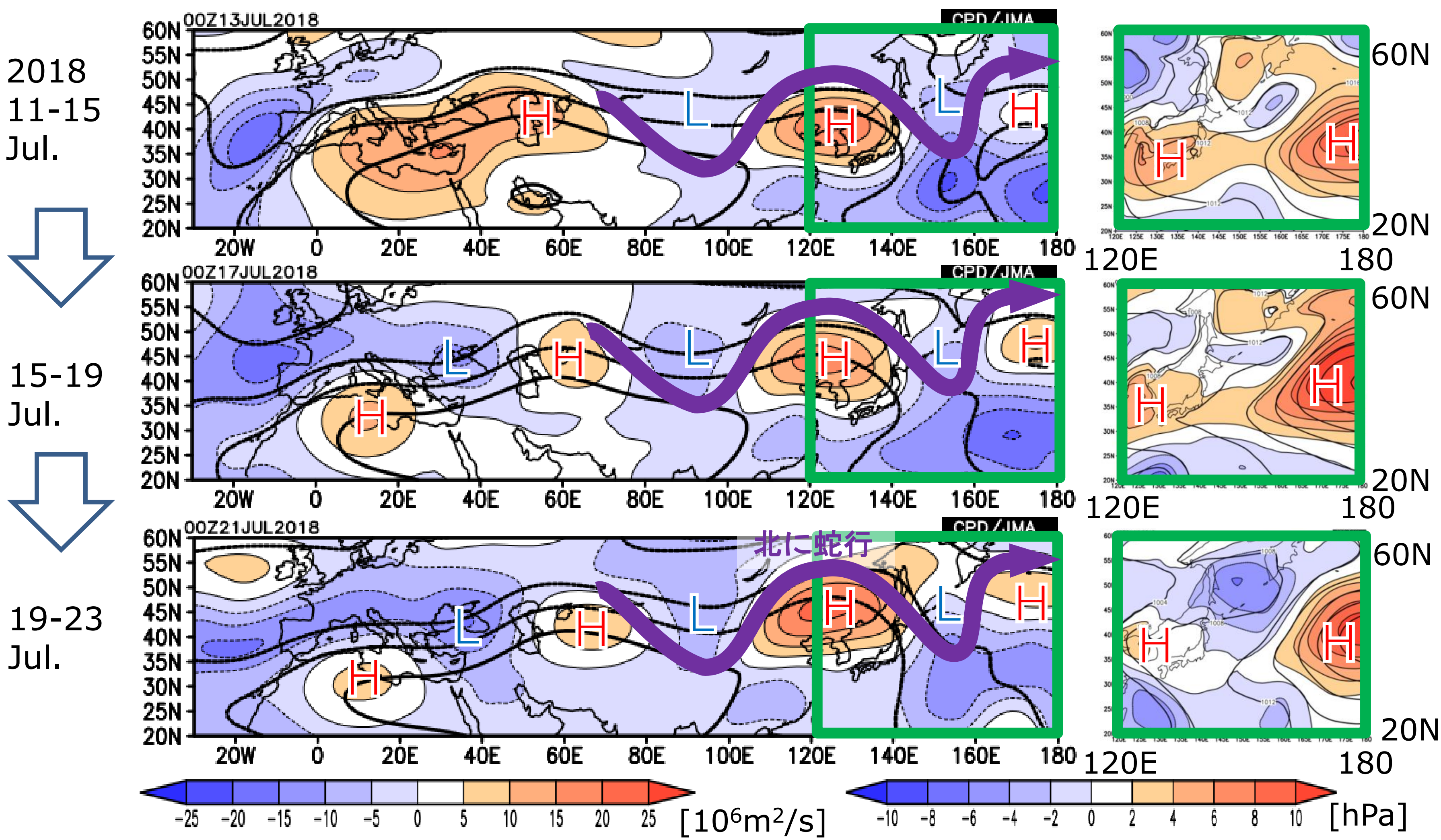
<- Active convection

<- Active convection　　Inactive -> convection

Atmospheric circulation

- Rossby wave propagation was seen over the Subtropical Jet (STJ).
- Expansion of the Tibetan High to Japan was attributable to the northward meanders of the STJ in the vicinity of Japan.

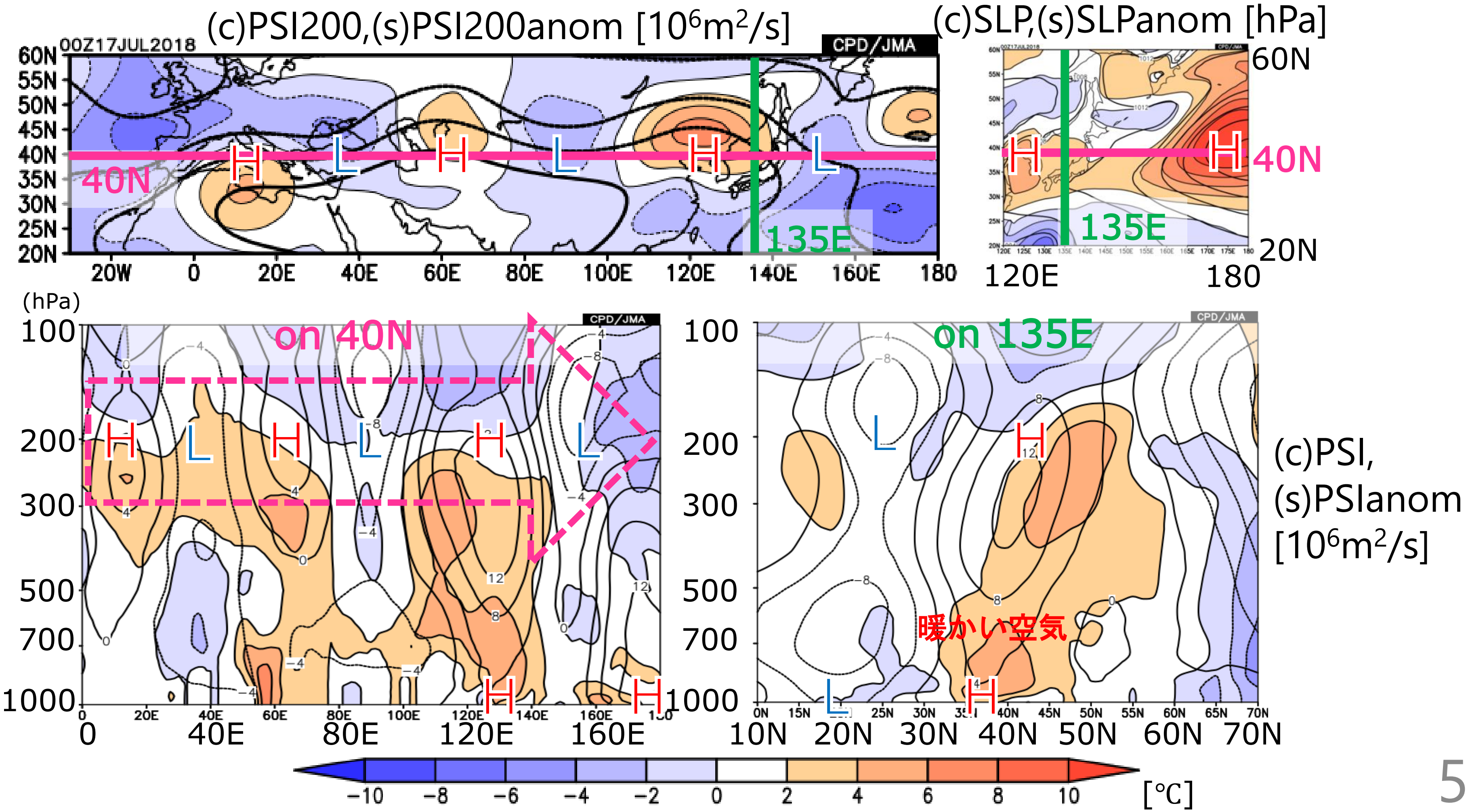
(c)PSI200,(s)PSI200anom [$10^6 m^2/s$] (c)SLP,(s)SLPanom [hPa]



Atmospheric circulation

- Equivalent barotropic conditions were seen, so that these waves over STJ, so that the extension of the Tibetan High could be maintained around Japan..

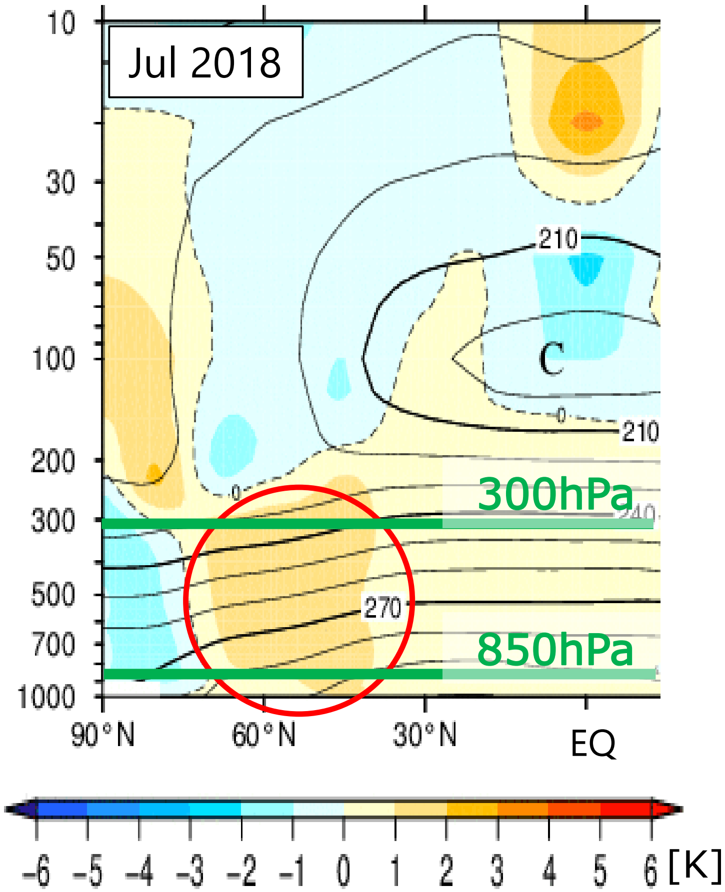
15-19 Jul. 2018



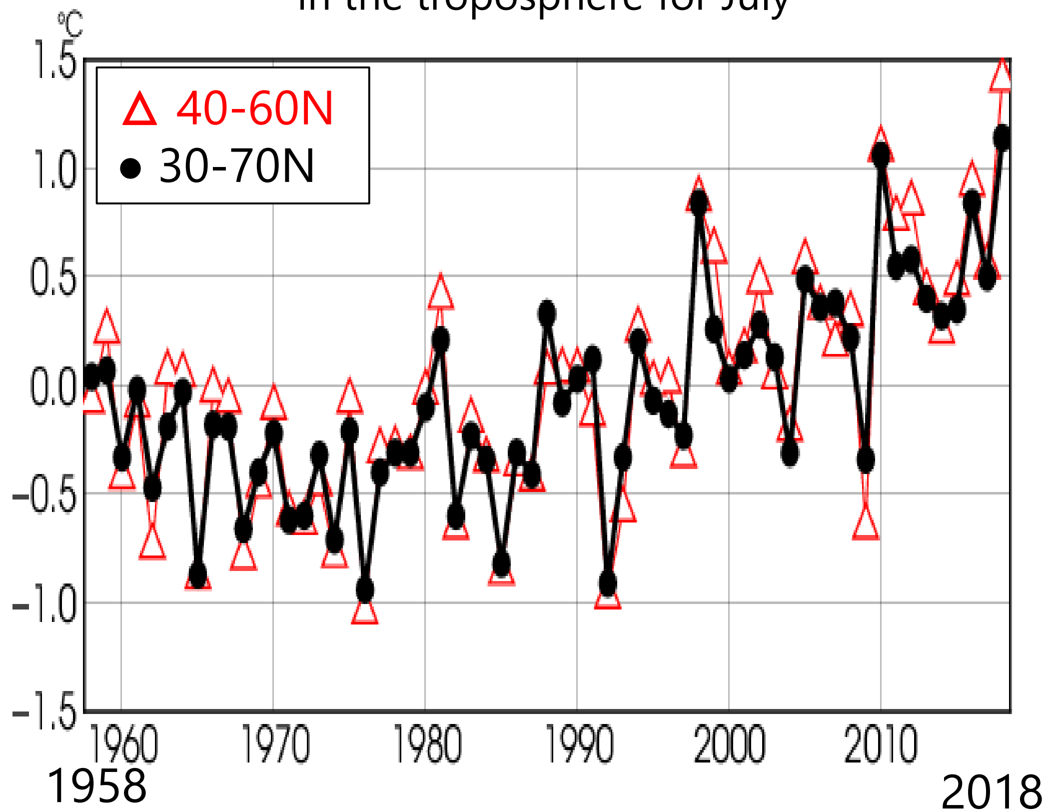
High temperature in NH mid-latitude

- Zonally averaged tropospheric air temperatures in the mid-latitudes of the Northern Hemisphere (NH; e.g., 40 – 60°N) had been high since boreal spring 2018, and the value for July 2018 was the highest for July since 1958.

(c) Zonal mean temperature [K],
(s) Zonal mean temperature anom. [K]



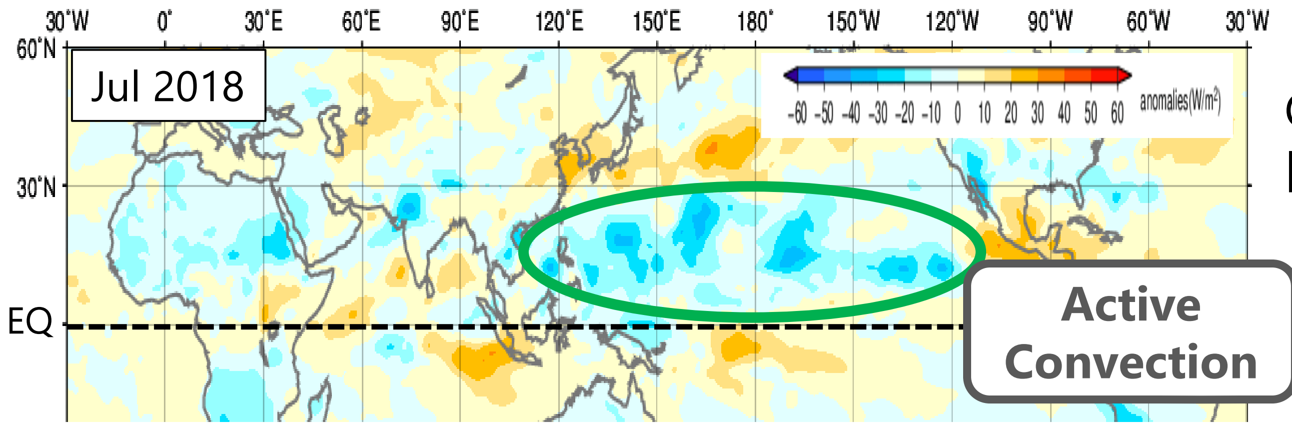
Thickness temperature anomaly
in the troposphere for July



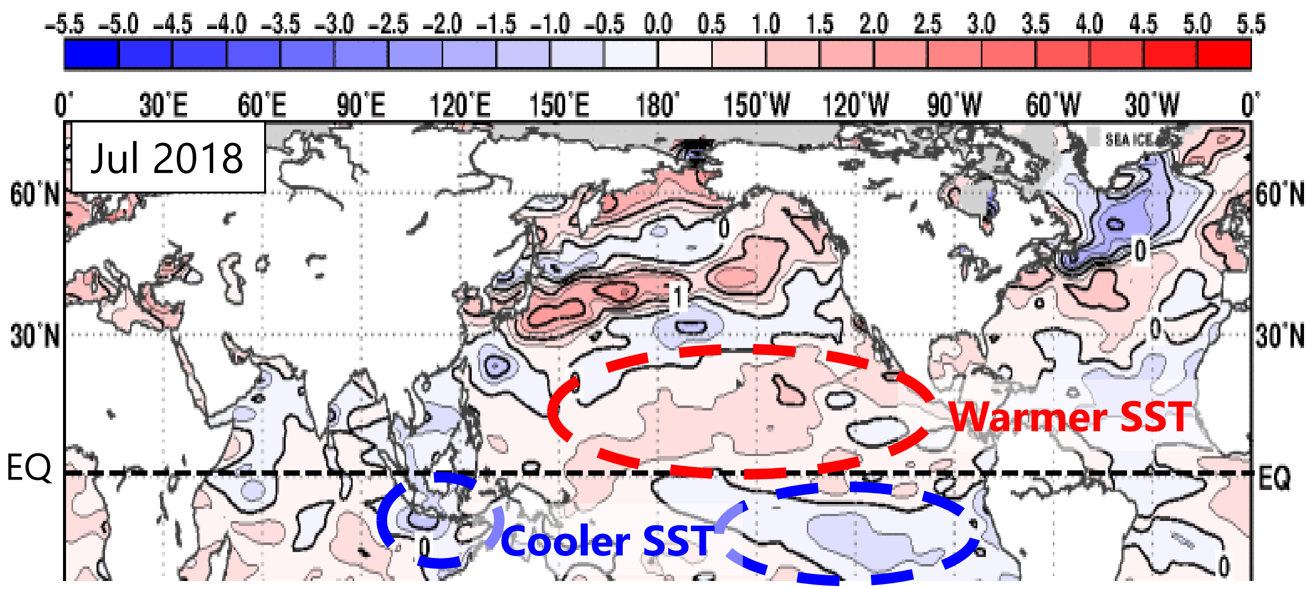
(Thickness temperature is estimated between 300hPa and 850hPa.)

High temperature in NH mid-latitude

- This high temperature of zonally averaged tropospheric air temperatures in the mid-latitudes of the NH was attributable to enhanced convective activity over a wide area of the NH in association with higher (lower)-than-normal SSTs over the tropics in NH (SH).

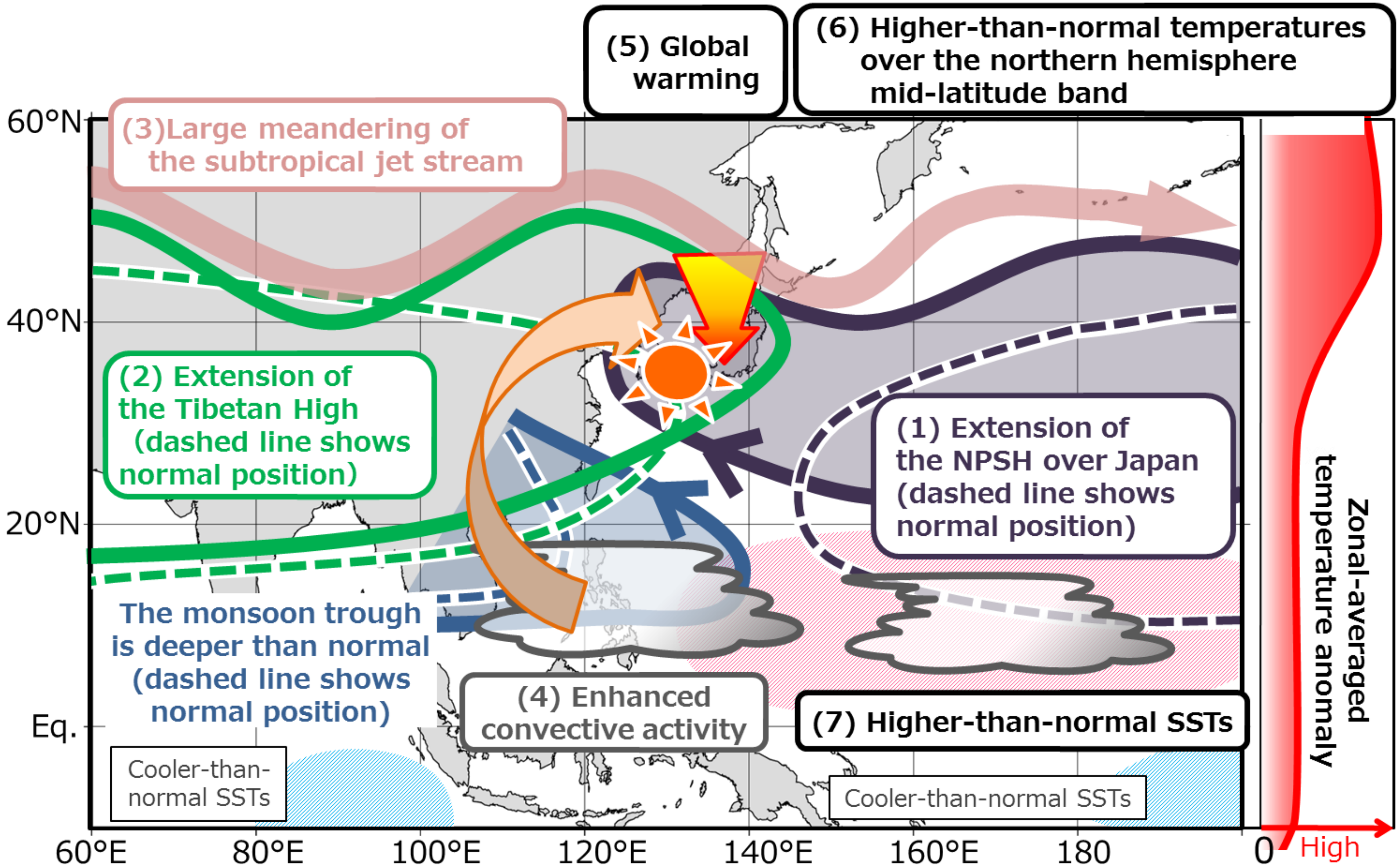


OLR anom [W/m^2]



SST anom [°C]

Primary factors behind the unprecedentedly hot conditions observed in boreal summer 2018



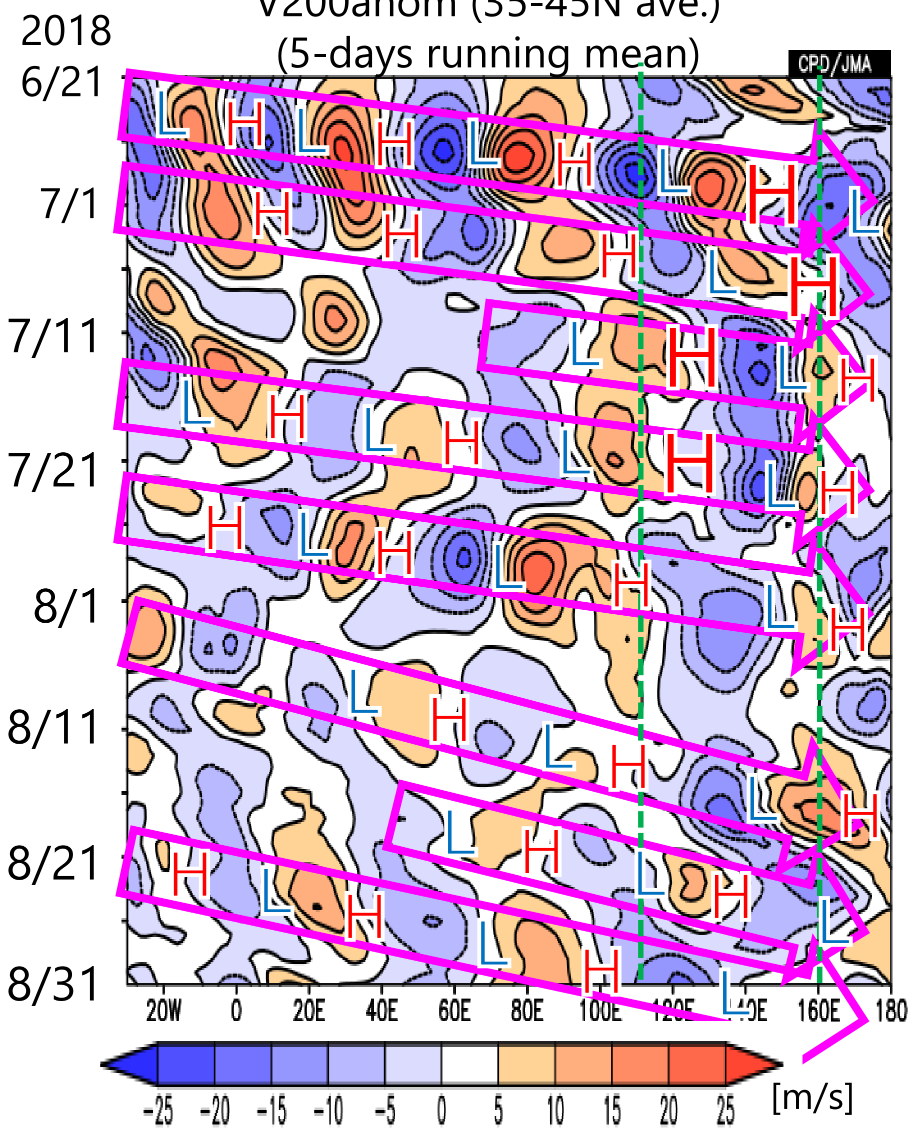
Extension of the North Pacific Subtropical High (NPSH) and the Tibetan High over Japan brought extreme high temperatures there through strengthening downward air flow and above-normal sunshine duration.

CHARACTERISTICS IN SUMMER 2018

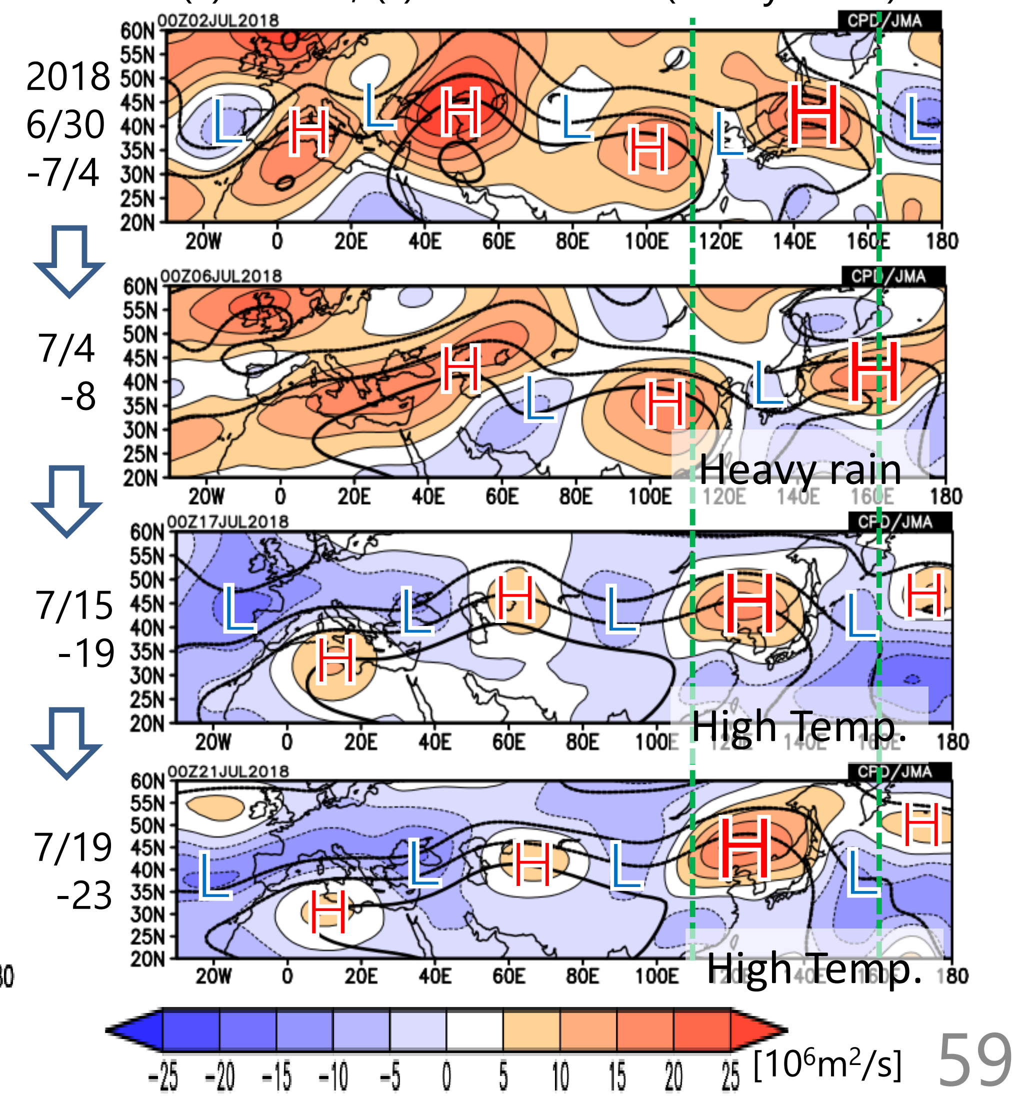
Persistent meandering of STJ in summer 2018

- The serial occurrence of extreme climate events in summer 2018 was caused by significant and persistent meandering of the subtropical jet stream (STJ).

V200anom (35-45N ave.)
(5-days running mean)



(c)PSI200, (s)PSI200anom (5-days ave.)



Global extreme climate events in July 2018

- Extremely high temperatures in many regions of the world in July 2018 were attributable to significantly warmer-than-normal tropospheric atmospheric air in the mid-latitudes as well as global warming, in addition to increased surface temperatures caused by the northward shift and significant meandering of the STJ and PFJ.