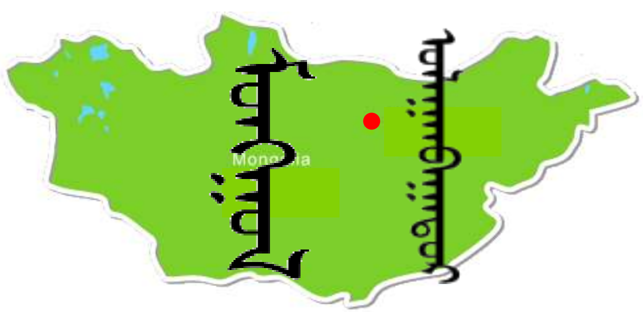
Tenth Joint Meeting of Seasonal Prediction on the East Asian Winter Monsoon
3-5 November 2009

The atmospheric characteristics of extremely wet July 2009 around Japan



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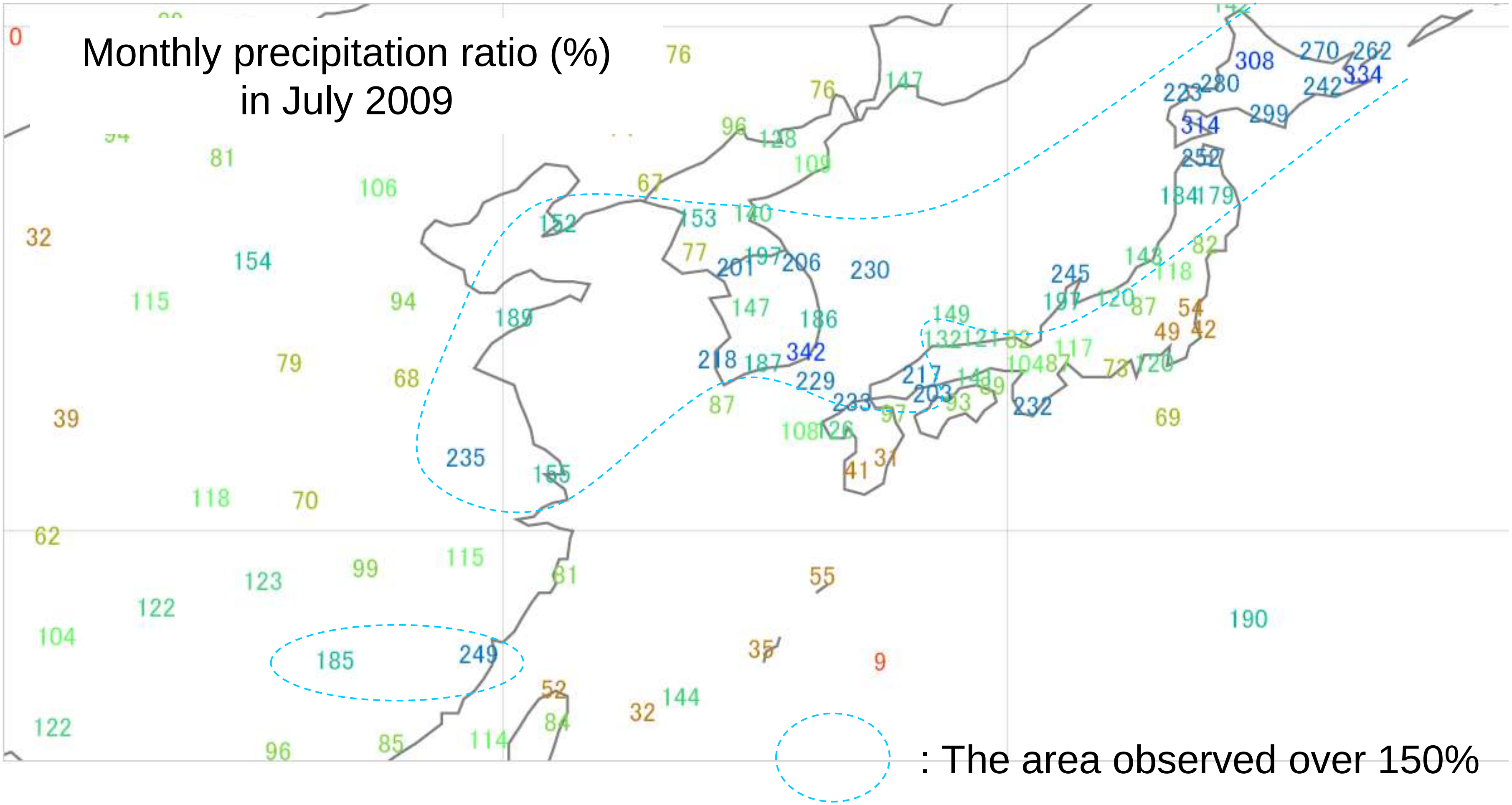
Contents

Extremely wet July around Japan

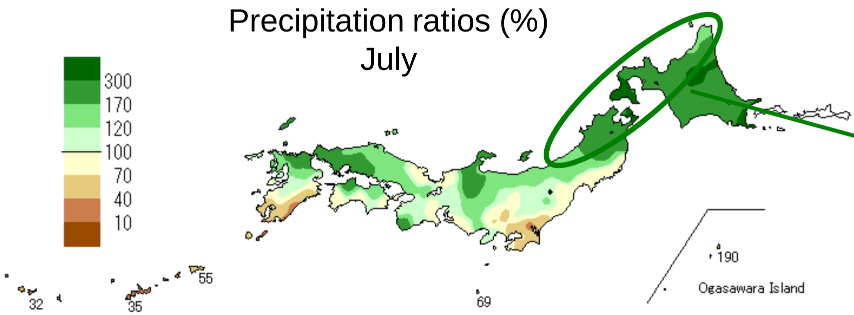
1. Distribution of weather around Japan
2. Influence of the extreme weather
3. Atmospheric condition
4. Discussion
5. Summary

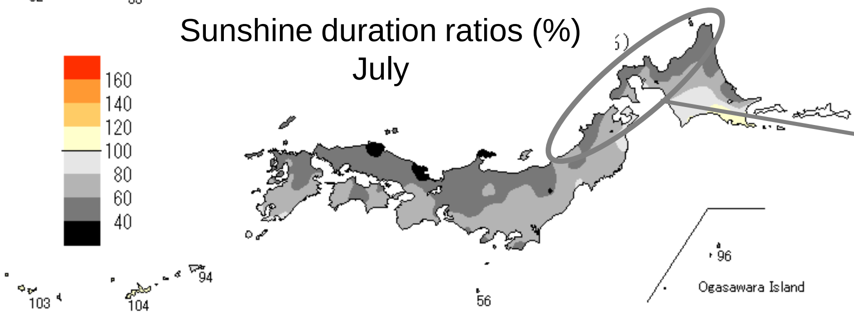
Extremely wet July around Japan



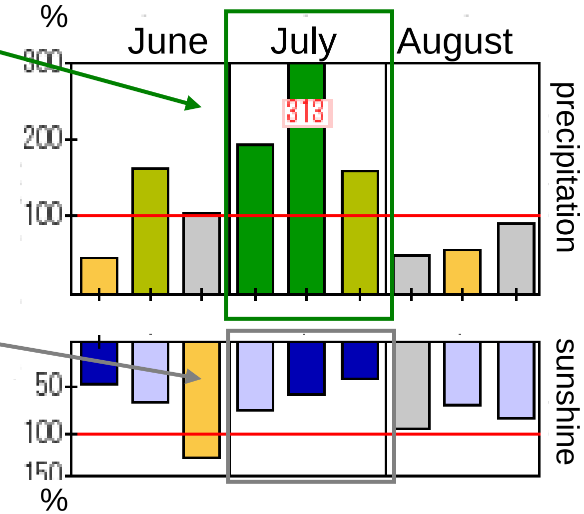
- Very wet from eastern coast of China to northern Japan
- Some stations observed more than 200% of the normal precipitation

Extremely wet and cloudy weather





Northern Japan
(Sea of Japan side)



The day of the end of rainy season (Baiu)

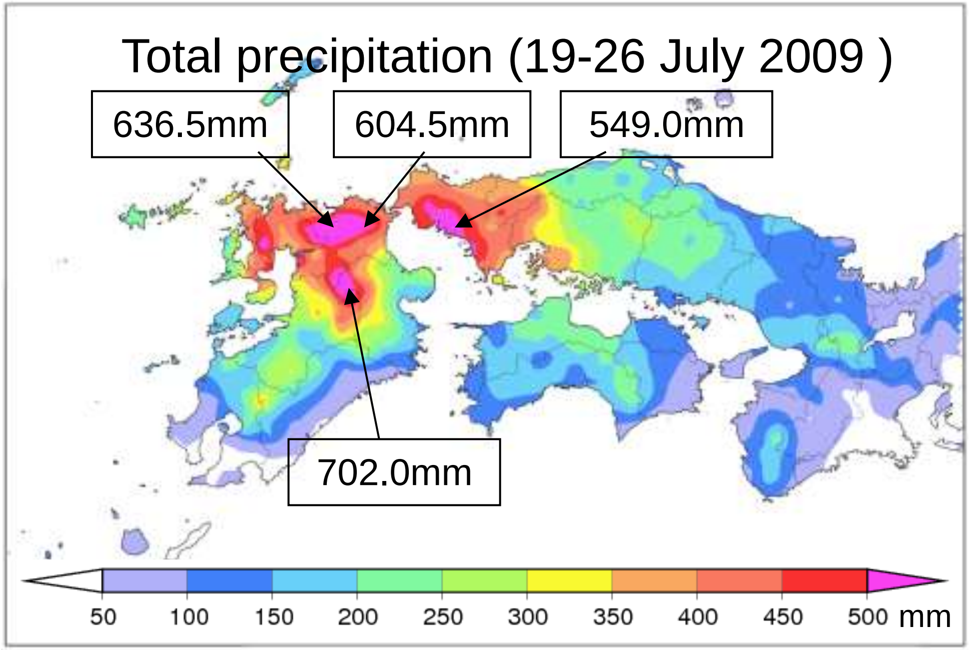
Area	normal	2009
Northern Japan	23 July	Not specified
Eastern Japan	20 July	3 August
Western Japan	17 July	30 July

- Extremely wet in northern Japan and part of western Japan
- Record breaking cloudy weather in the Sea of Japan side
- The end of rainy season (Baiu) was delayed (around two weeks) or not specified.

The statistical record began in 1946.

Influence of the extreme condition in Japan

Courtesy of JAXA



We suffered severe damages …

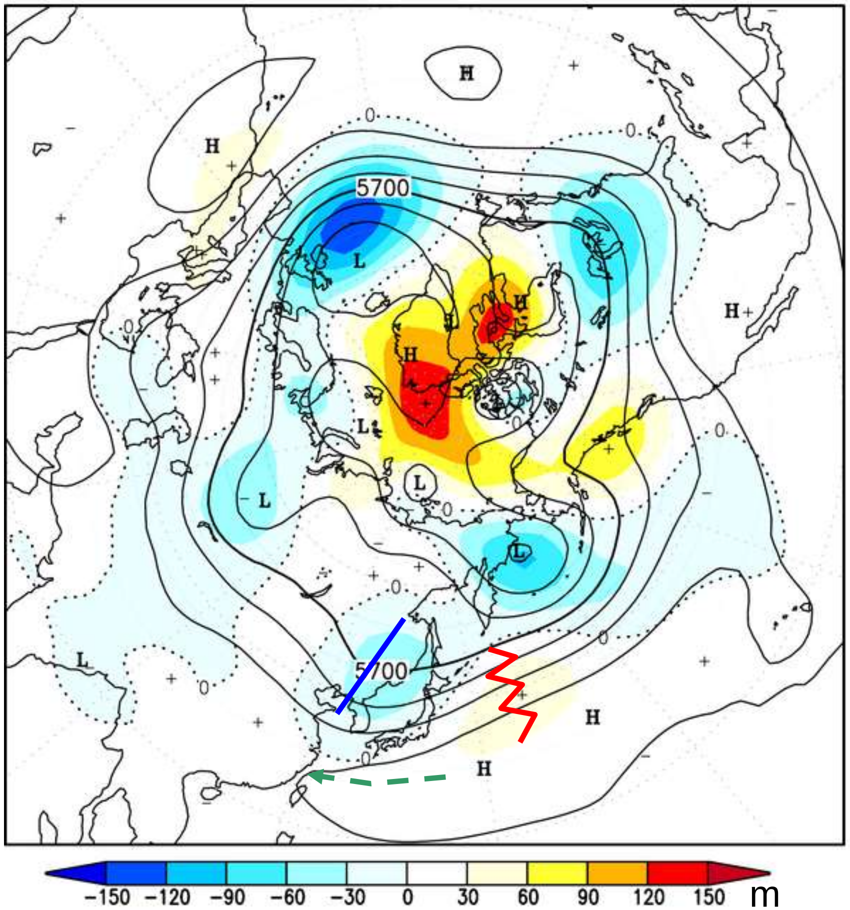
On the last half of July, western Japan experienced heavy rain.

Total precipitation amounts in one week exceeded 600 mm : double the monthly precipitation.

- 31 persons were dead because of mainly mudslides or flush floods.
- More than 11,000 houses were flooded.

Prolonged wet cloudy weather affected growth of rice crops, wheat or vegetables. Agricultural losses in Hokkaido (northern Japan) amounted to 60 billion yen.

Circulation field in the Northern Hemisphere
- 500 hPa height field -



Monthly mean 500hPa height (contours) and its anomaly (shadings) in July 2009

Circulation fields leading these extreme weather …

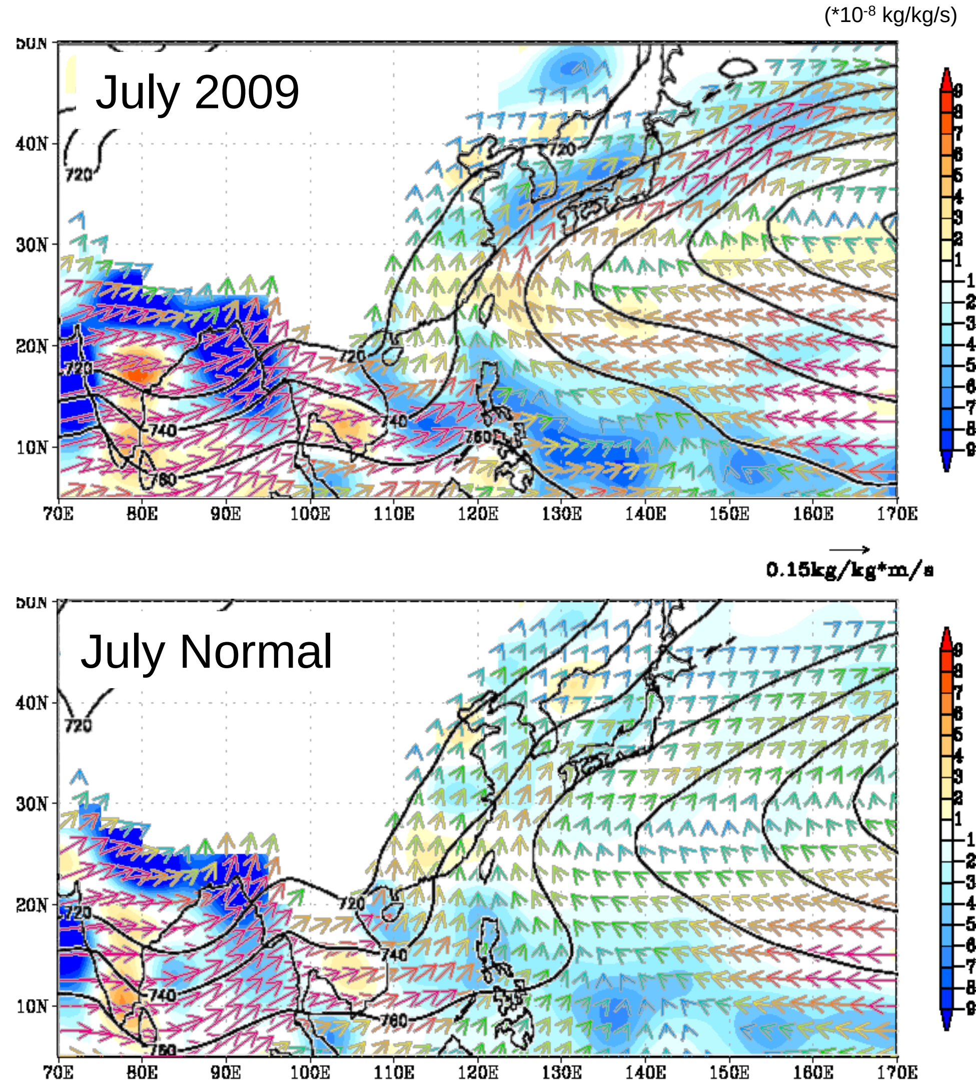
- In the 500hPa height field, positive and negative anomalies persisted in the high and the middle latitudes, respectively.

- The developed and persistent trough over north-eastern China and ridge to the east of Japan was observed.

- Subtropical high was stronger than normal most of subtropics.

- It extended westward but not northward in the south of Japan.

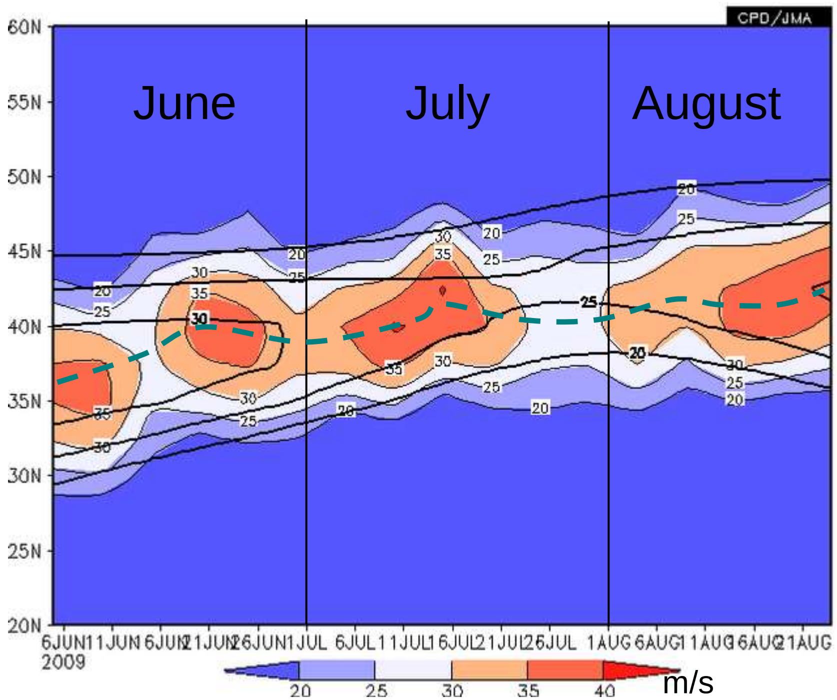
Water vapor flux in the lower troposphere



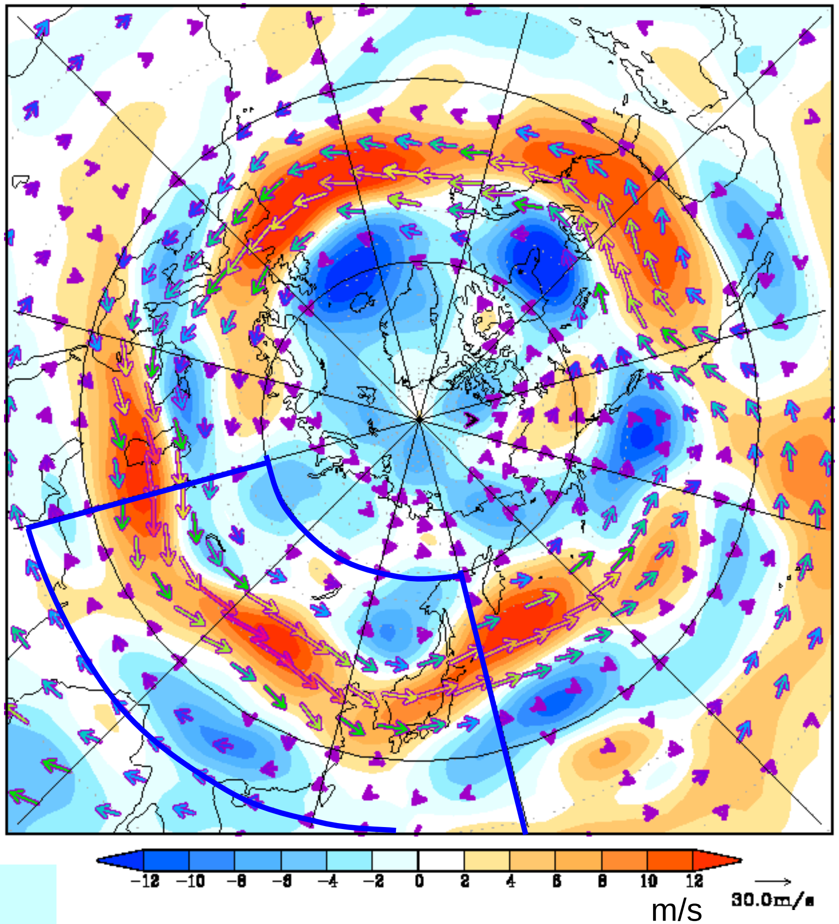
925hPa water vapor flux (vectors), horizontal divergence (shadings), height (contours) <contour interval is 20m>

- Strong subtropical high in the south of Japan and high baroclinity at the northern edge of the subtropical high contributed to transport strong water vapor and its convergence around Japan.

Subtropical jet stream around Asia



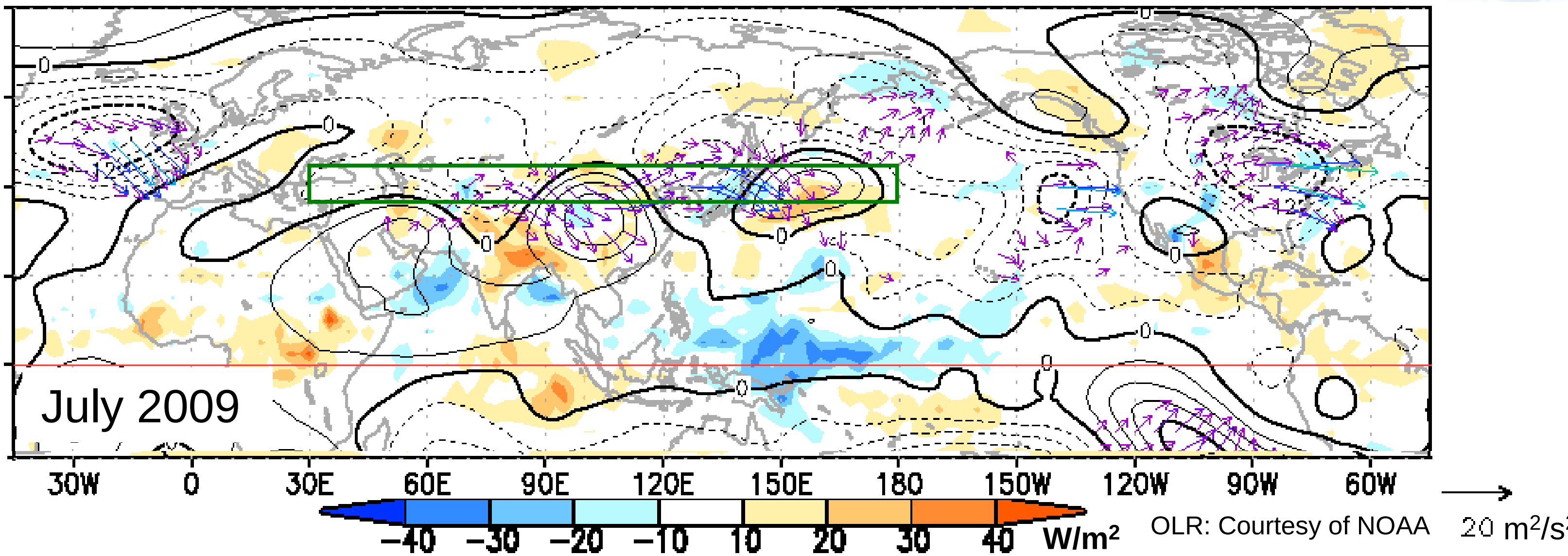
60-150N mean 200hPa zonal wind (Jun. – Aug. 2009)
shadings : 2009 contours : Normal
broken line : center of the Jet stream



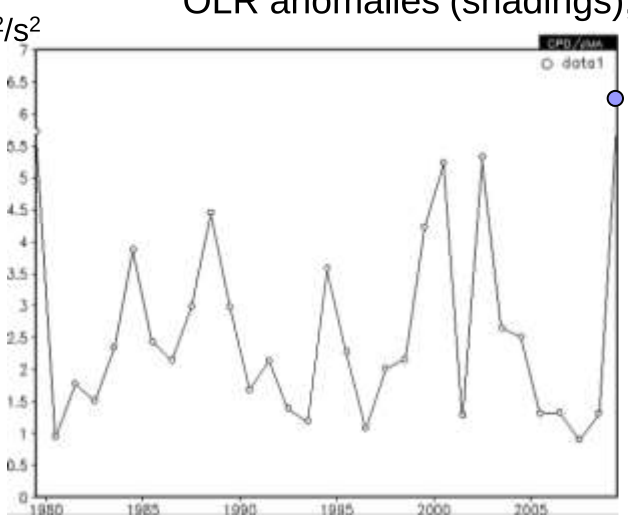
200hPa wind vector and zonal wind anomaly in July 2009

- Jet stream in Asia was stronger than normal and shifted southward with largely meandering
- Southward shift became prominent in second half of July.

Wave activity flux along subtropical jet



OLR anomalies (shadings), 200hPa stream function anomalies (contours unit:$10^6 m^2/s$), wave activity flux (vectors) by Takaya and Nakamura (2001)



Time series of zonal component of wave activity flux averaged over Asian jet (35-45N, 30-180E) (July)

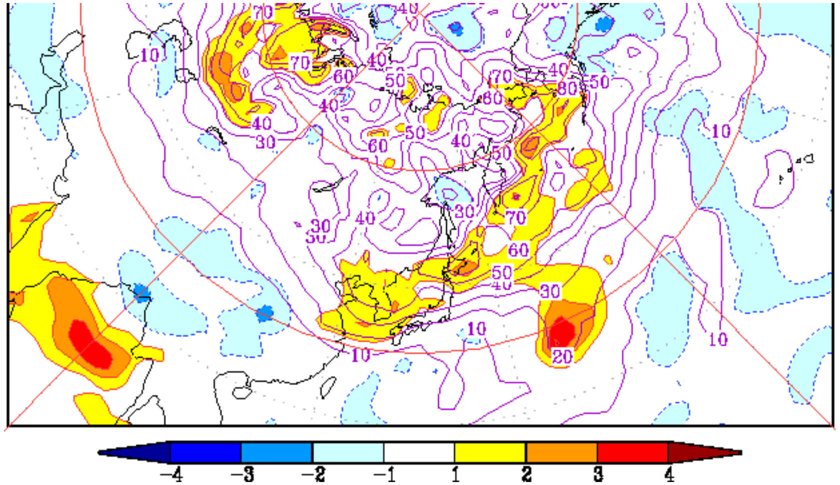
- Rossby wave packets frequently propagated from Europe to the Pacific along the subtropical jet.

- Wave activity flux along subtropical jet over Asia was the strongest for July since 1979.

- In accordance with very active propagation of the Rossby wave packets, the subtropical jet stream meandered largely.

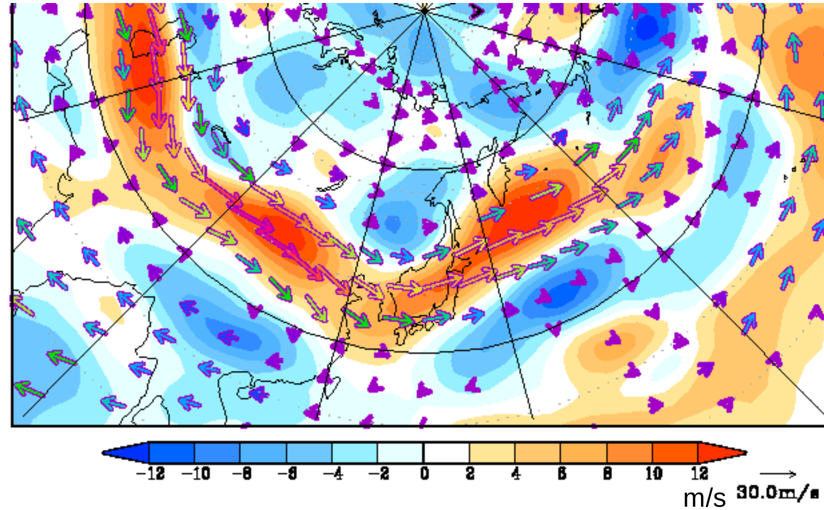
Wave activity flux is proportional to the Rossby wave energy with parallel to the direction of the group velocity.

High frequency disturbances



300-hPa kinetic energy of high-frequency variation in July 2009.

Contours show kinetic energy of high-frequency variation in an interval of 10 m^2/s^2. Shadings show kinetic energy standardized anomalies. It is defined as root mean square of 2-8-day band-pass-filtered zonal and meridional wind speed.



200hPa wind vector and zonal wind anomaly in July 2009

- High frequency disturbances were more active than their normal in East Asia in accordance with strong subtropical jet stream.
- The passage of active high frequency disturbances around Japan was one of the main reason of the wet condition in Japan.

Conclusion (1)

Extremely wet and cloudy condition in Japan was brought under the following atmospheric circulation :

- The subtropical jet stream was stronger than normal in Asia and shifted southward in late July.

- The subtropical jet stream meandered in accordance with very active propagation of the Rossby wave packets.

- They formed a trough over north-eastern China and a ridge to the east of Japan.

- Warm humid air flowed into Japan along the northern edge of the stronger subtropical high which contributed to transport stronger water vapor and its convergence around Japan.

- In accordance with strong jet stream, high frequency disturbances were more active than their normal (A synoptic scale low sometimes developed around Japan and brought heavy rain).

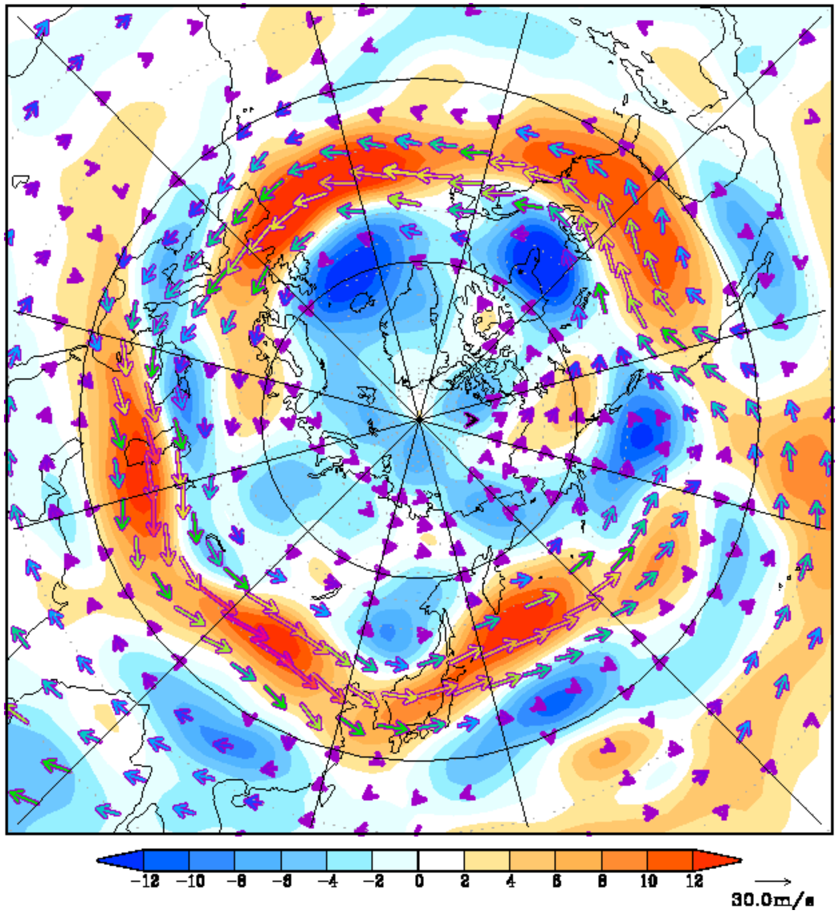
Discussion

- Why subtropical jet was stronger than normal?

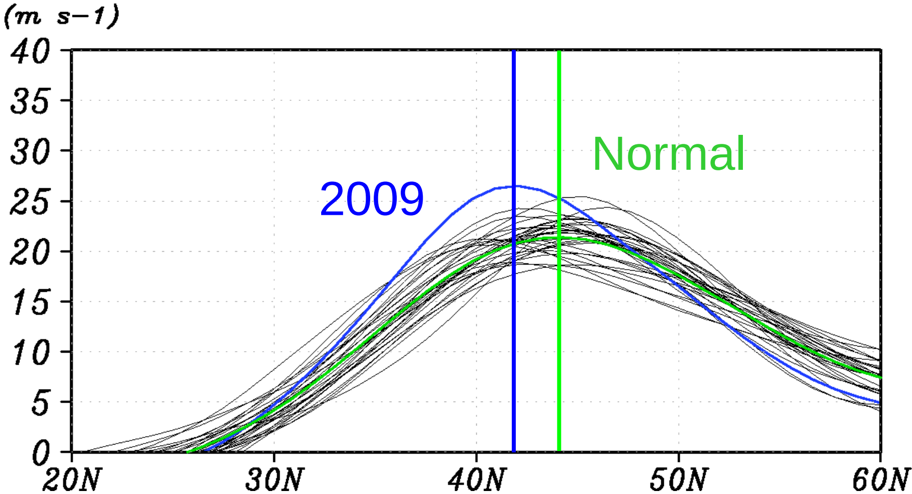
- Why the phase of the troughs and ridges were locked over Asia?

Why subtropical jet was stronger than normal?

Subtropical Jet in July 2009



200hPa wind vector and zonal wind anomaly in July 2009



200hPa zonal mean wind in July
(Each year from 1979 to 2009)

- Subtropical jet was very strong not only over Asia but also worldwide.

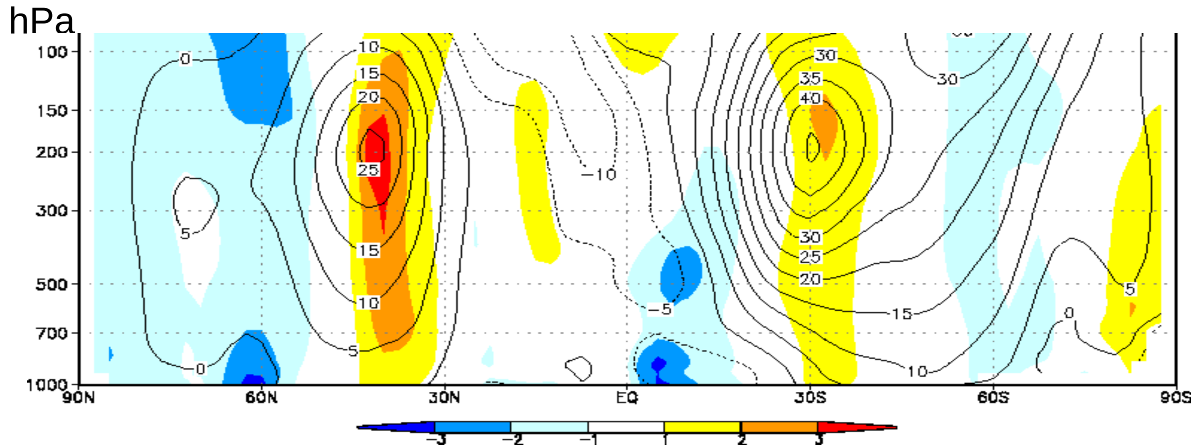
- Zonal mean wind was the strongest since 1979.

Zonal mean field (wind and temperature)

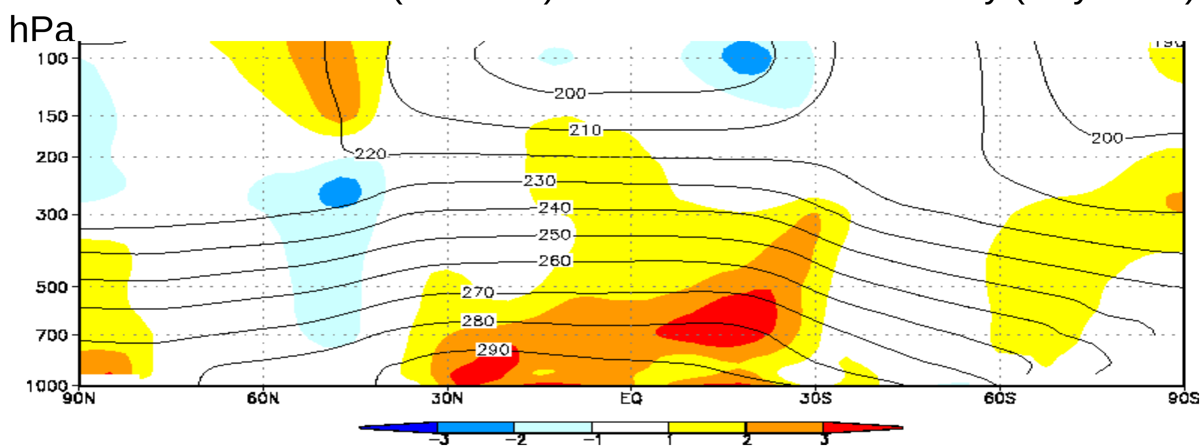
Subtropical jet in NH was very strong (exceed 3 sigma) and slightly shifted southward.

Tropospheric temperature was very warm in the tropics, whereas cooler in the mid-latitude (40-50N)

The contrast of the tropospheric temperature was consistent with strong subtropical jet.

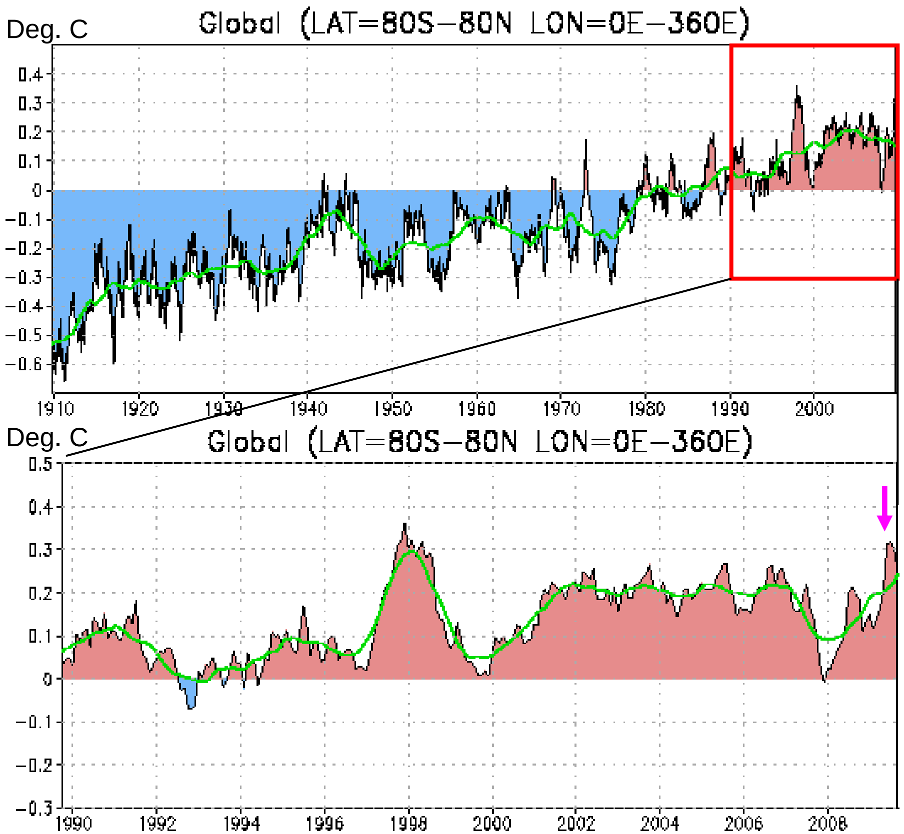


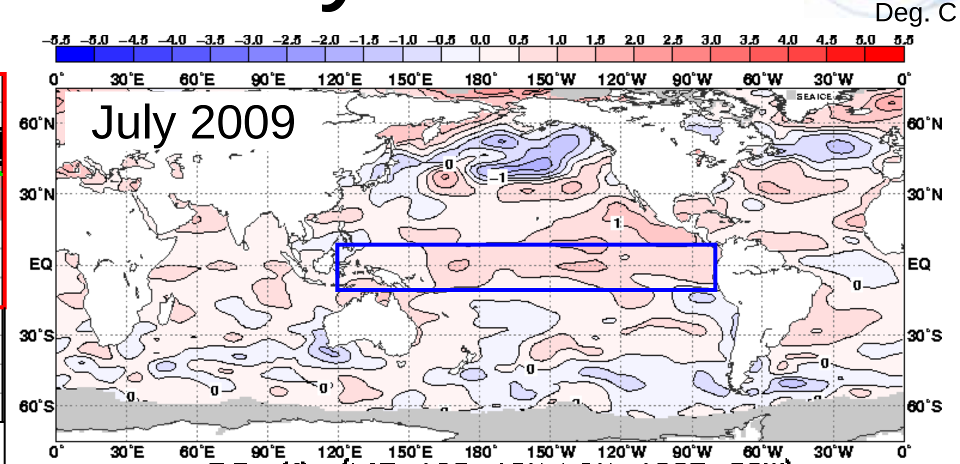
Zonal mean wind (unit: m/s) and standardized anomaly (July 2009)

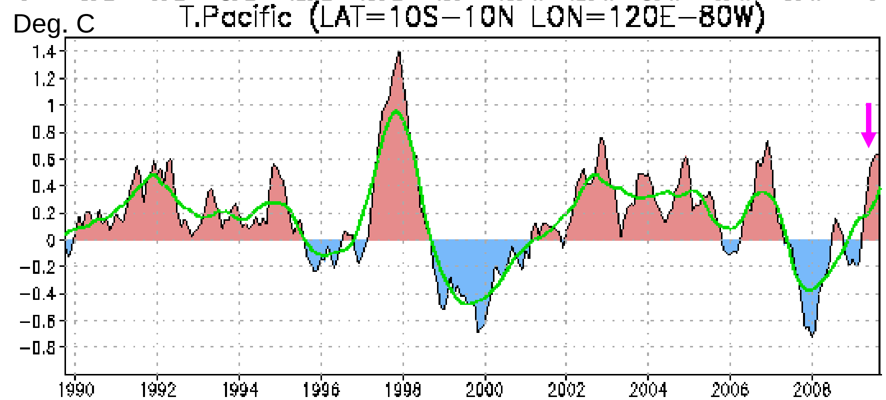


Zonal mean temperature (unit: K) and standardized anomaly (July 2009)

SST anomaly



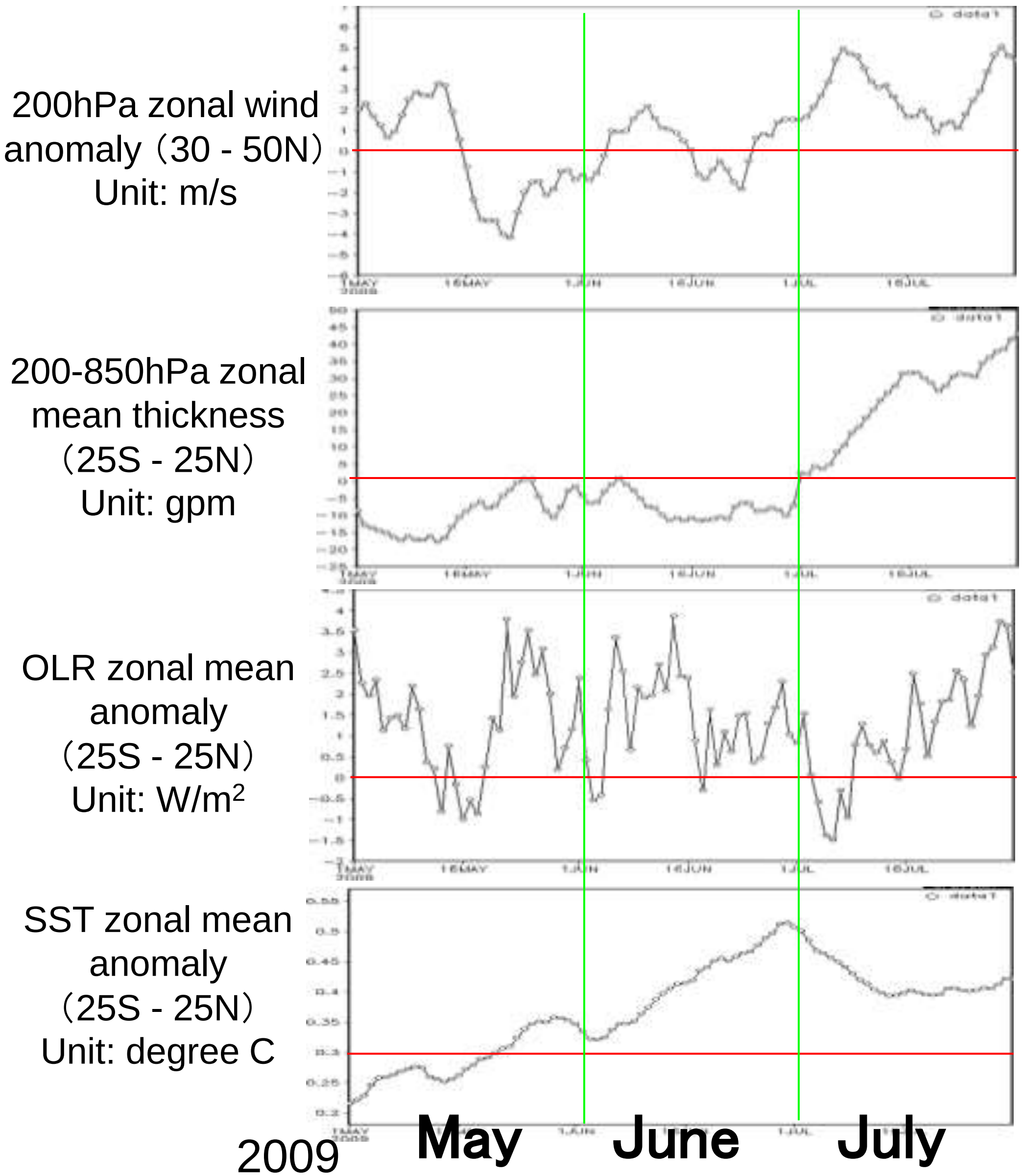




- Warm SST was observed from central to eastern equatorial Pacific
- El Nino conditions prevailed
- Global SST in July 2009 was the warmest for the month on record
- Tropical SST was also extremely warm

The record began in 1891.

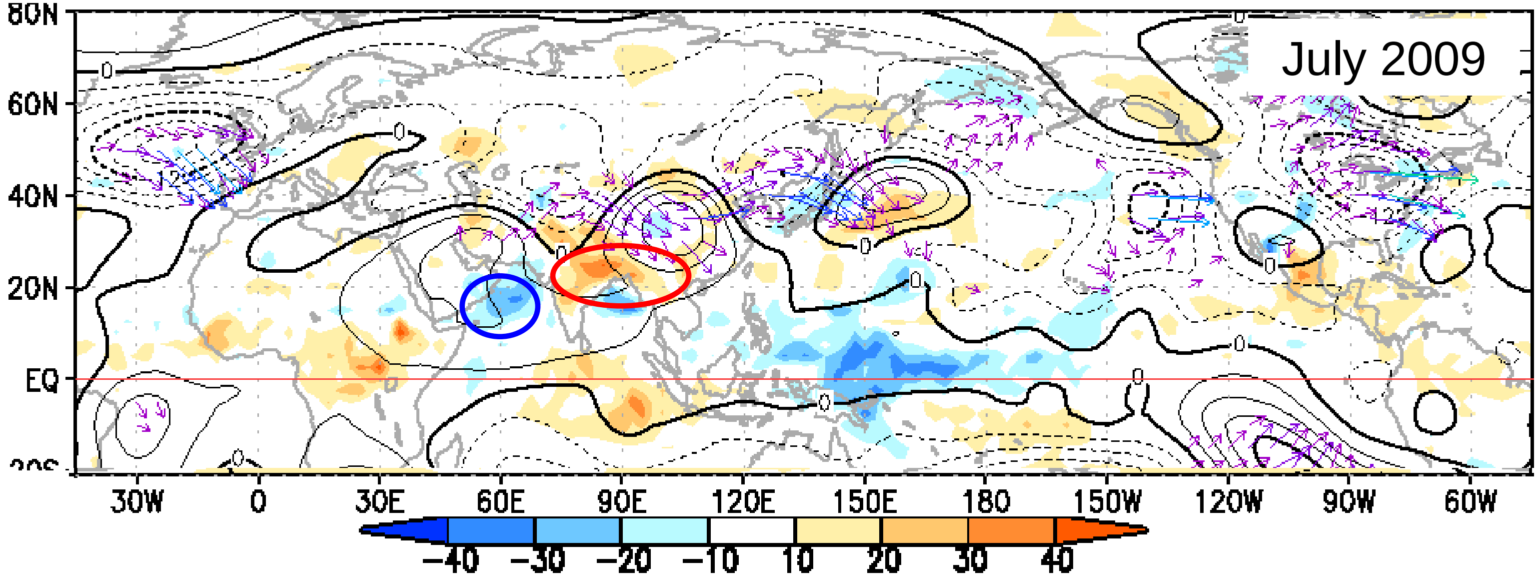
Strengthen of subtropical jet and tropospheric warming



- SST anomaly in the tropics rapidly rose during June.
- OLR anomaly changed negative (convection was enhanced) in first July behind the SST warm-up
- In the wake of enhanced convection, tropospheric temperature in the tropics rapidly rose.
- Coincident with the rise of tropospheric temperature, subtropical jet was strengthened.
- These change suggests SST warming may contribute enhanced subtropical jet stream.

Why the phase of the troughs and ridges over Asia were locked?

Influence of convective activities



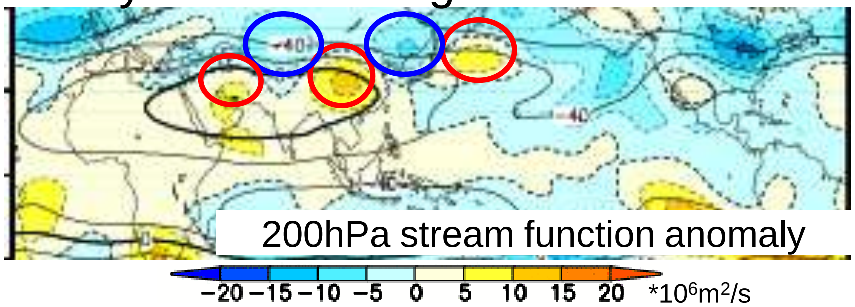
OLR anomalies (shadings), 200hPa stream function anomalies (contours), wave activity flux (vectors)

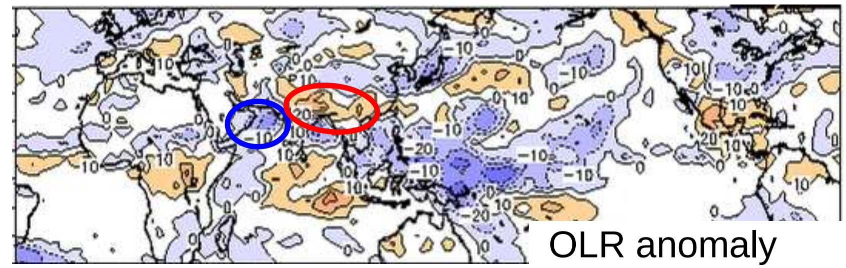
- Convective activities were suppressed from India to the Indo-China Peninsula and enhanced over the Arabian Sea.

- Enhanced convection over the Arabian Sea and suppressed convection around India might contribute to form the ridge over the Arabian Peninsula and the trough over central Asia.

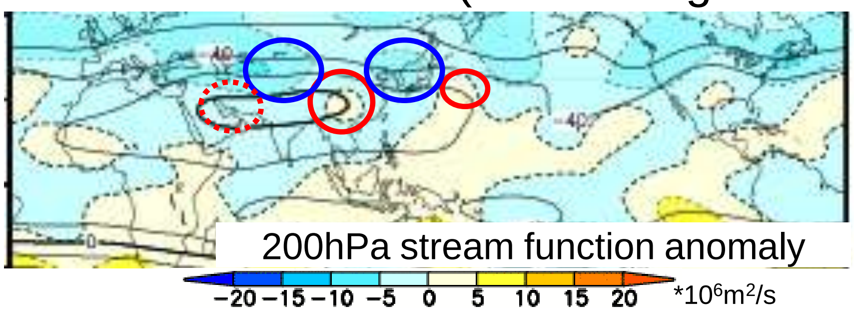
Results of operational AGCM

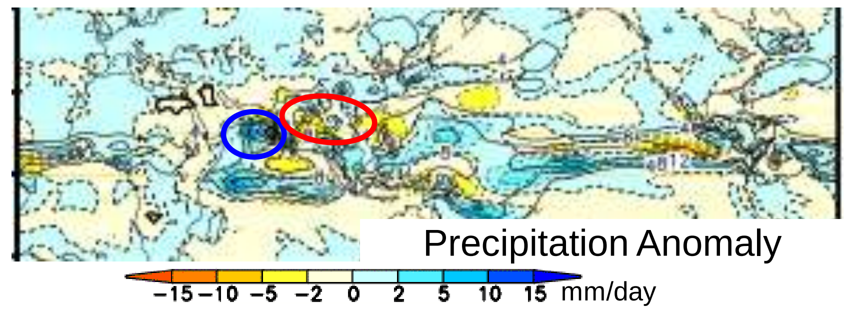
Analysis Jul. 4 - Aug. 1 2009





Model Init: 2009.7.2 (Jul. 4 - Aug. 1 2009)





- Operational AGCM for 1 month forecast predicted meandering of the subtropical jet over Asia.
- The phase of the meandering is almost the same as the analysis.
- The convective activities over South Asia are also well predicted.
- Although further investigation is needed, these convective activities might contribute to lock the phase.

Conclusion (2)

- The subtropical jet stream was stronger than normal in Asia.

  - Strengthened jet stream was mainly brought by tropospheric warming in the tropics through the record-breaking SST warming.

- Meandering subtropical jet stream formed a trough over north-eastern China and a ridge to the east of Japan.
  - Enhanced convection over the Arabian Sea and suppressed convection around India might contribute to form this phase.

Thank you
for your attention!

'HARERUN'
JMA's mascot

バヤルˮル, ラ~.
コマプスムニダ
シェーシェー

Tenth Joint Meeting of Seasonal Prediction on the East Asian Winter Monsoon
3-5 November 2009, Ulaanbaatar, Mongolia

East Asian summer monsoon 2009

- Focusing on the extremely wet July around Japan -

Hiroshi Nakamigawa
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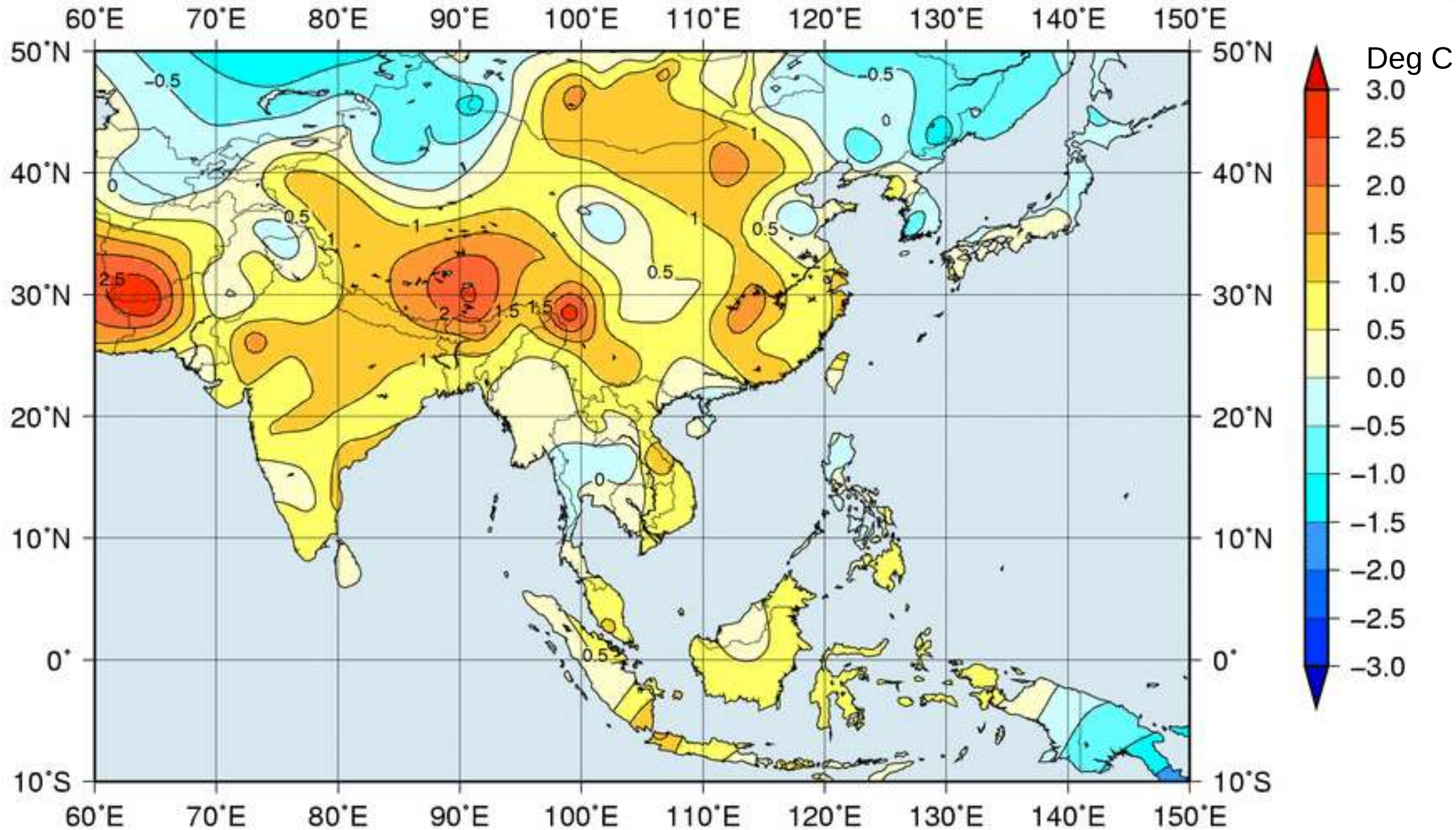
Contents

East Asian summer monsoon 2009

- Focusing on the extremely wet July around Japan -

1. East Asian summer monsoon
   - Precipitation, temperature and extreme events in East Asia
   - Monsoon activities and atmospheric circulation
2. Extremely wet July around Japan
   - Distribution of climate in Japan
   - Influence of the extreme condition
   - Oceanographic and atmospheric condition
   - Discussion
   - Summary

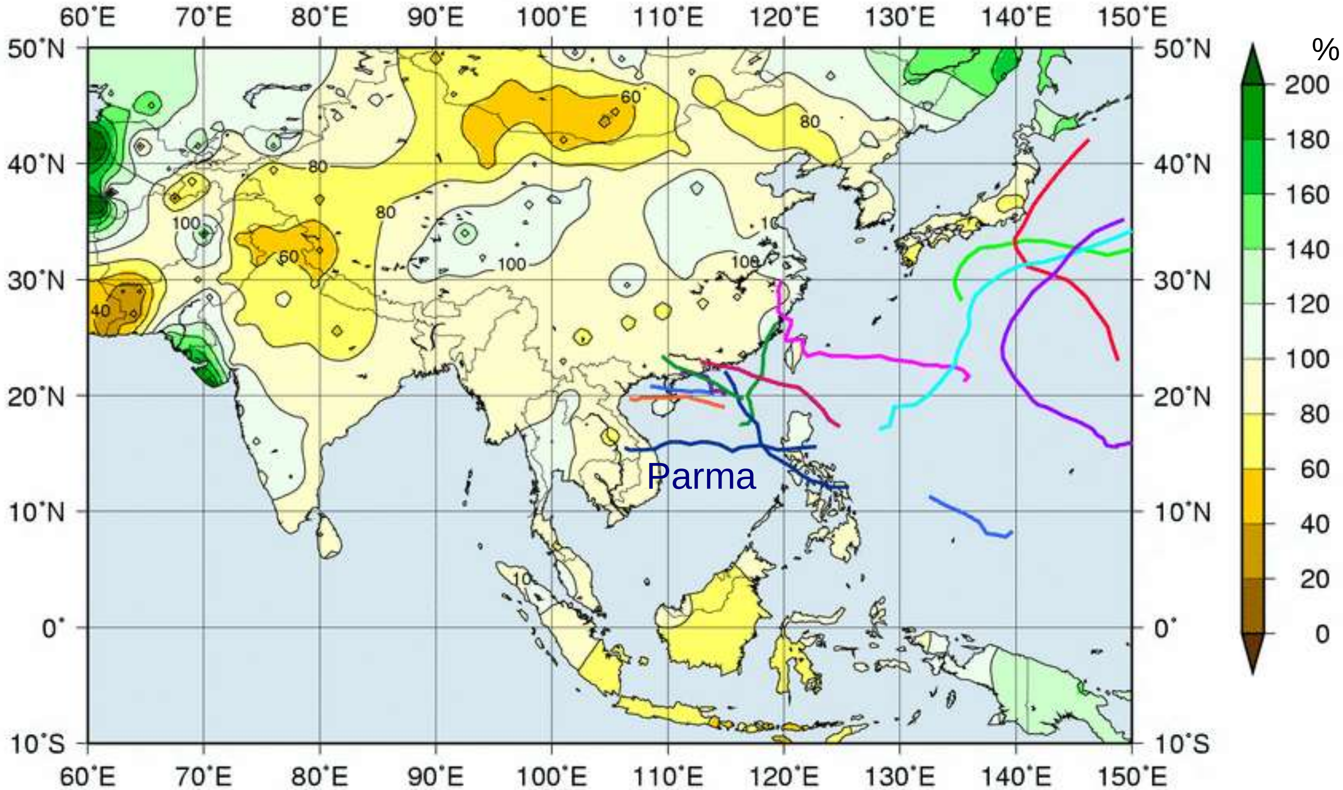
Summer Temperature in East Asia



Four-month mean temperature anomaly (deg C) from June to September 2009

- Summer (JJAS) temperature anomalies were positive in most of East Asia except northern part.

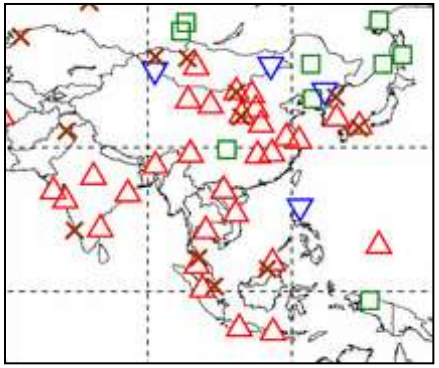
Summer Precipitation in East Asia



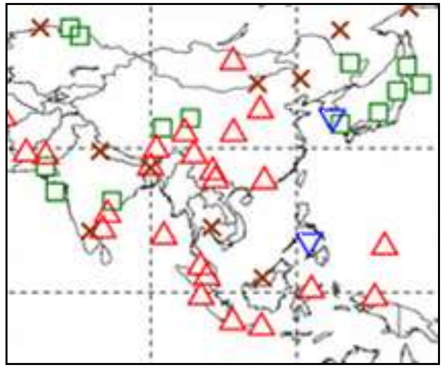
Four-month precipitation ratio (%) and tropical cyclone tracks in the northwestern Pacific from June to September 2009

- Summer precipitation amounts were below normal in most of East Asia
- 16 tropical cyclones formed, almost the same as the normal of 16.3
- Typhoon Parma brought enormous rain in the Philippines caused around 300 fatalities in late September.

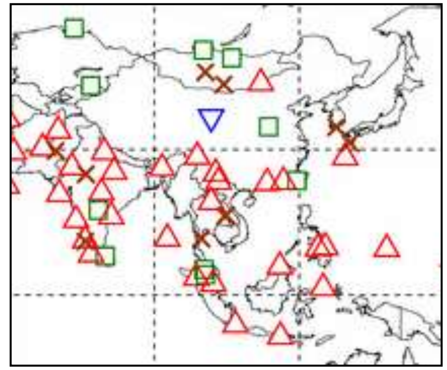
Extreme events in East Asia



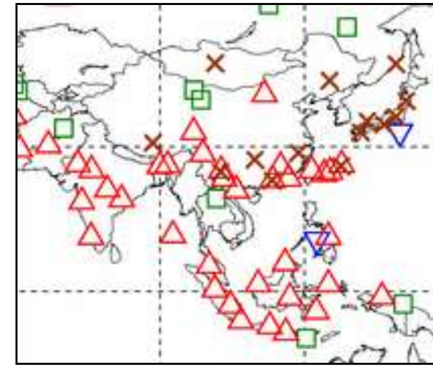
June 2009



July 2009



August 2009



September 2009

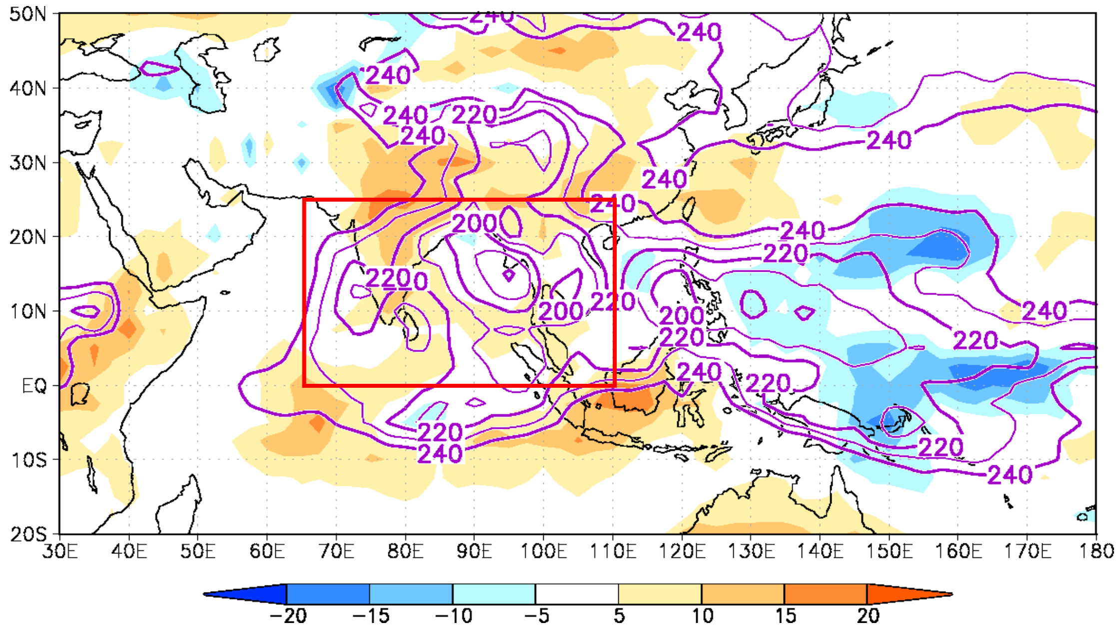
△ Extremely high temperature (ΔT/SD≧ 1.83)
▽ Extremely low temperature (ΔT/SD≦ −1.83)
□ Extremely heavy precipitation (Rd=6)
× Extremely light precipitation (Rd=0)

ΔT: Monthly temperature anomaly SD: Standard deviation
Rd: Quintile Rd=0,6 : (Less) greater monthly precipitation amounts than any values during the period of 1971-2000

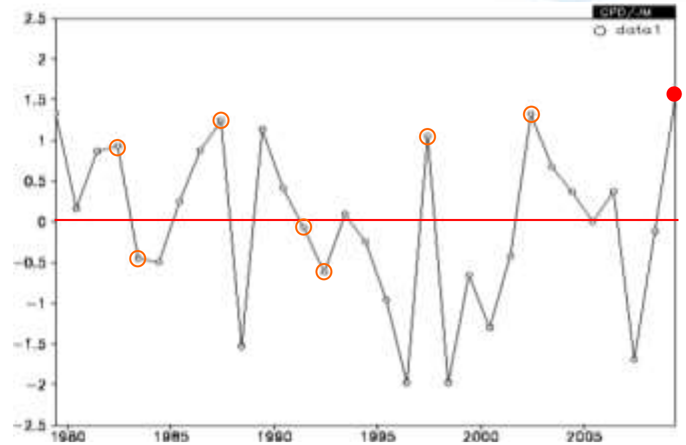
- Extremely high temperatures were continuously observed in the wide areas of the tropics and sub-tropics

- Japan experienced extremely wet July and dry September.

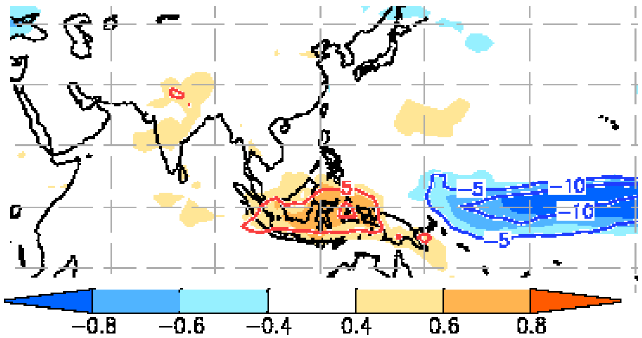
Convective activity in East Asia



Four-month mean OLR and its anomaly in June – September 2009
Solid lines indicate OLR (W/m^2) with a contour interval of 10 W/m^2, and color shadings indicate OLR anomalies.



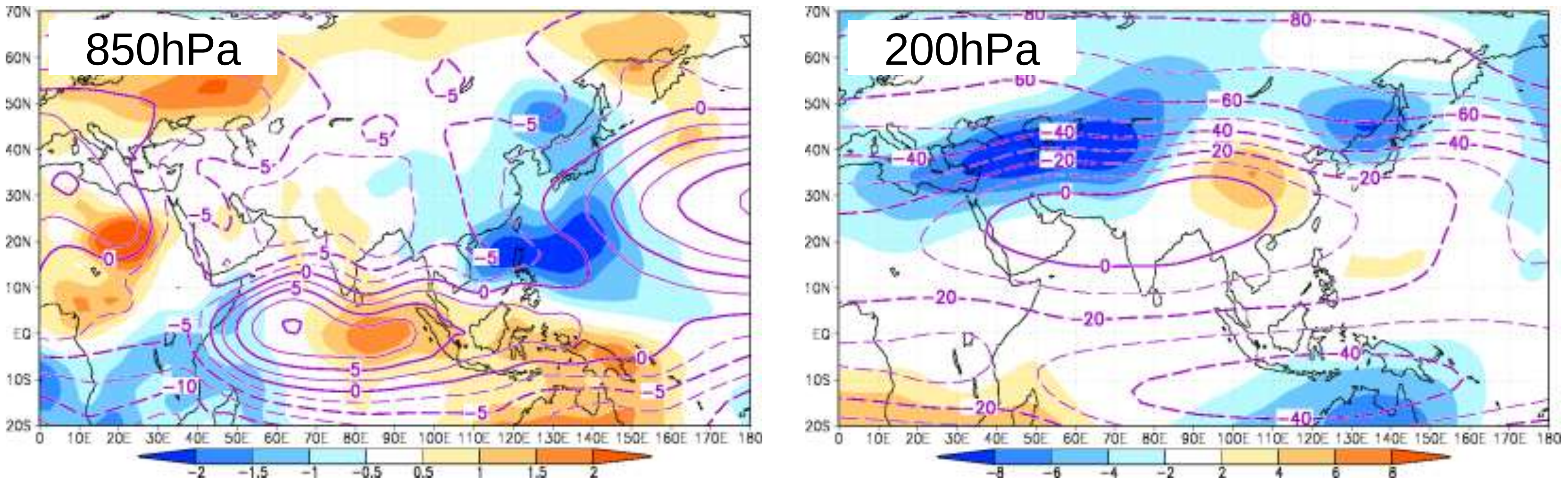
Time series of four-month mean OLR standardized anomaly averaged over 0-25 N, 60- 110 E from 1979 to 2009
○ **: El Nino year**



Regression and correlation coefficients between NINO.3 and OLR in JJA.
Contours show OLR when normalized indices are +1.0.
Red (blue) contours show positive (negative) anomalies.
Shadings show correlation coefficients.

- Asian summer monsoon activities were generally suppressed throughout the season except for the West North Pacific Monsoon (WNPM) region.
- Over South Asia, they were most suppressed for 31 years.
- These characteristics except for WNPM looks like ones during El Nino events.

Atmospheric circulation in East Asia

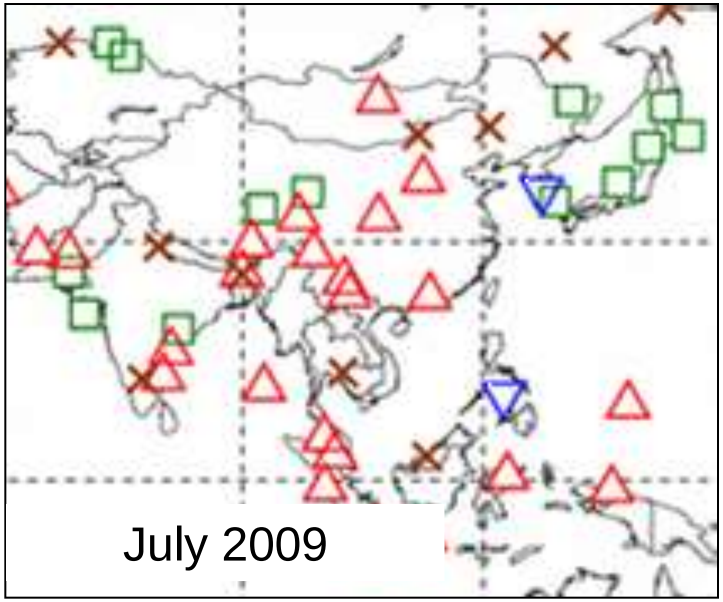


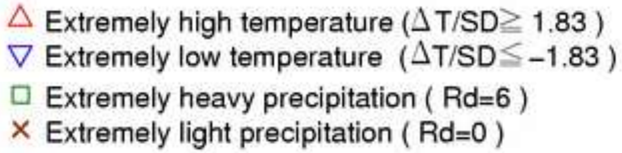
Four-month mean stream function and its anomaly in June – September 2009

Contours indicate stream function (m^2/s) and color shading indicates its anomalies (m^2/s)

- In the lower troposphere, the monsoon circulation was stronger than normal over the eastern Indian Ocean, while Somali jet was weaker than normal.
- Cyclonic circulation anomalies were observed around the Philippines, indicating that the monsoon trough was stronger than normal.
- In the upper troposphere, the Tibetan High shifted southward from its normal position from the Arabian Peninsula to India, corresponding to the suppressed convections over India.
- Anti-cyclonic and cyclonic anomalies were dominant along the subtropical jet stream over Eastern Asia.

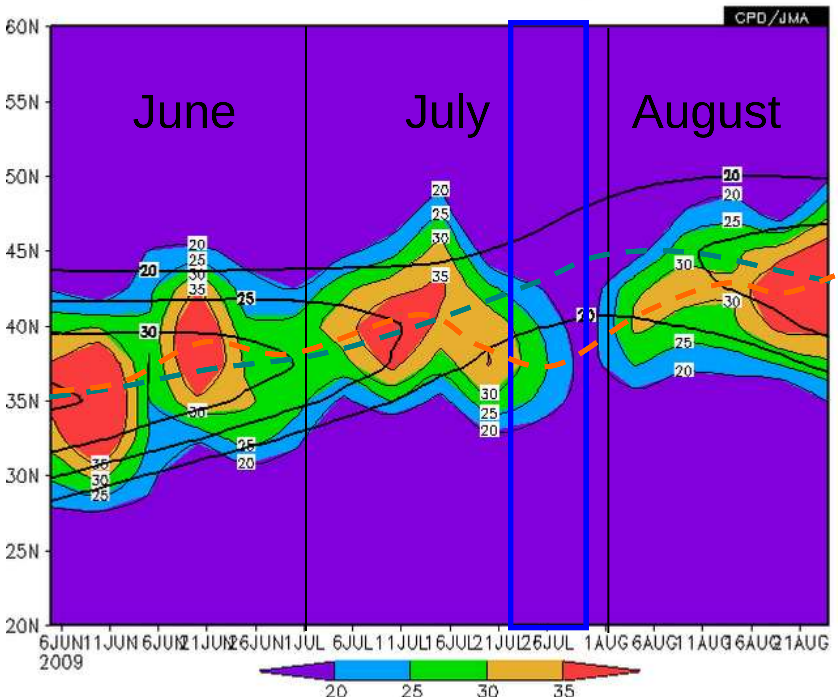
Extremely wet July around Japan



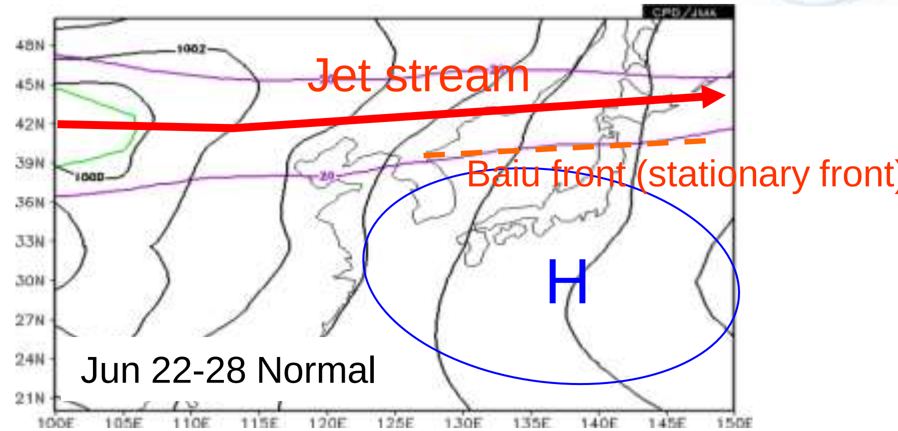


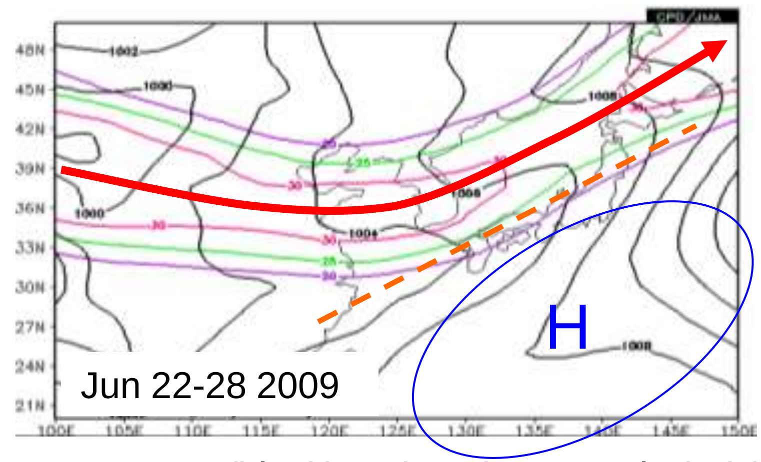
ΔT: Monthly temperature anomaly
SD: Standard deviation
Rd: Quintile Rd=0,6 : (Less) greater monthly precipitation amounts than any values during the period of 1971-2000

Jet stream around Asia



200hPa zonal wind (July – August) 120-140N mean
shaded : 2009 contour : Normal
green (orange) broken line : center of the Jet stream in normal (2009)

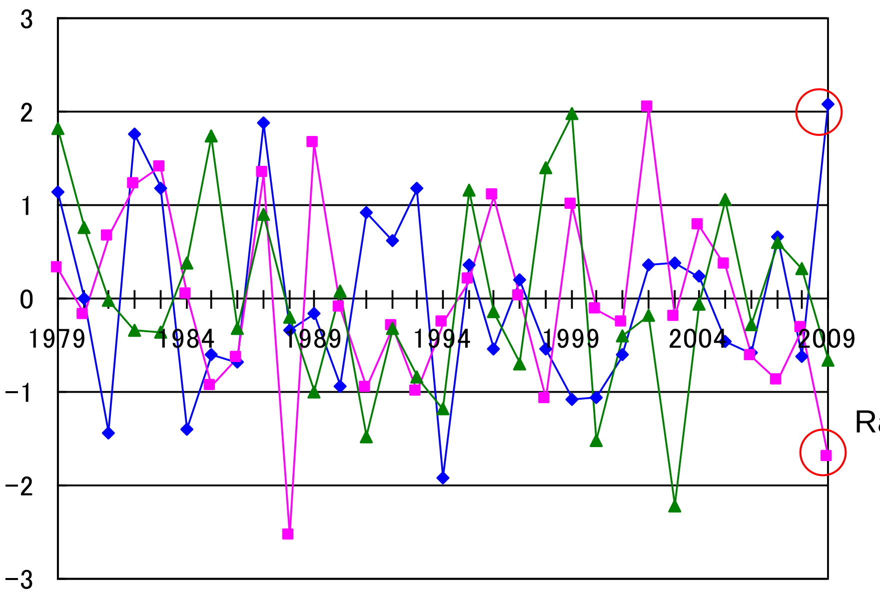




Sea surface pressure (black) and 200hPa zonal wind (color)

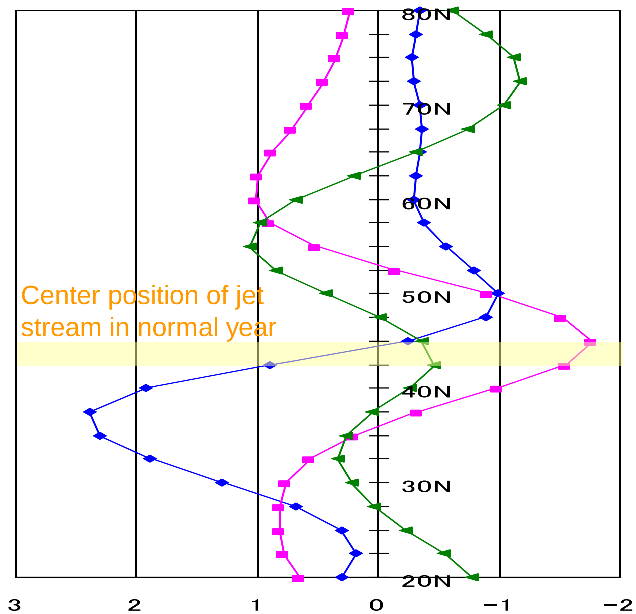
- Usually, by late July, rainy season ends most of Japan by northward shift of the jet stream with northward extension of subtropical high over Japan.
- In late July 2009, the jet stream shifted southward without northward extension of the high which brought delay of the end of rainy season.

EOF analysis of 200-hPa zonal mean flow



EOF scores of 200-hPa zonal mean flow (July)

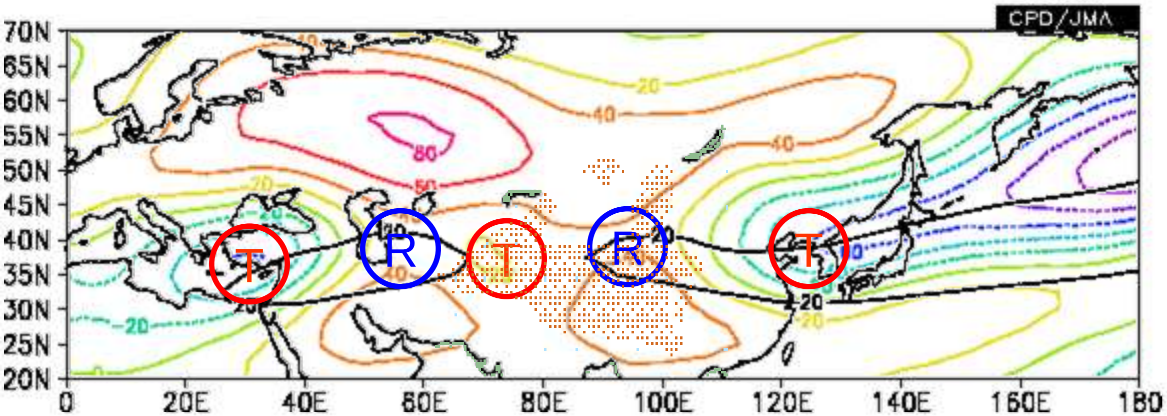
Rate of contribution
EOF1: 36.9%
EOF2: 26.6%
EOF3: 15.5%



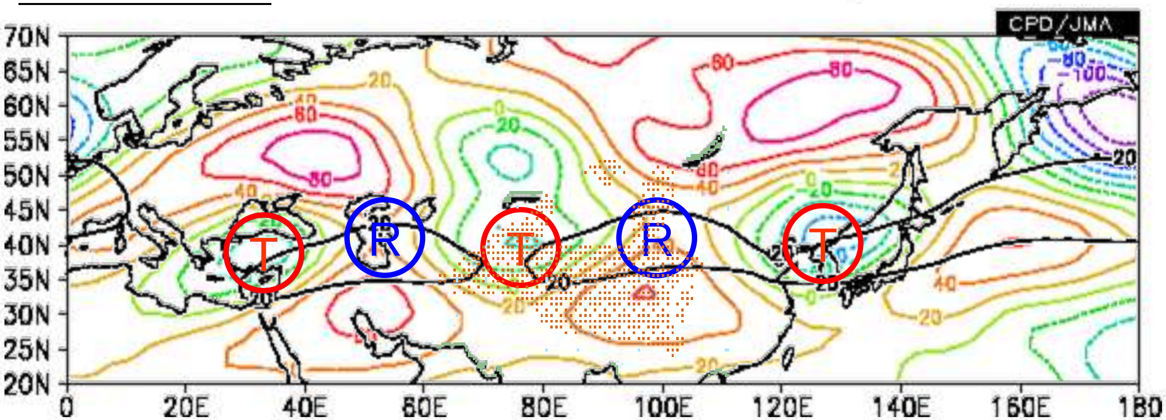
Distribution of eigen vector calculated from EOF analysis of 200-hPa zonal mean wind (July)

- Positive score of EOF1 relates to the southward shift of jet stream.
- Negative score of EOF2 relates to the strength of center of jet stream.
- In 2009, score of EOF1(2) was the most positive (2nd negative) score.
- It means the jet stream extremely shifted southward and was extraordinarily strong.

Effect of strong jet stream on the phase



200hPa geopotential height subtracting zonal mean (color) and zonal wind (black) Hatch indicates areas at an altitude of > 3,000m
Normal of June



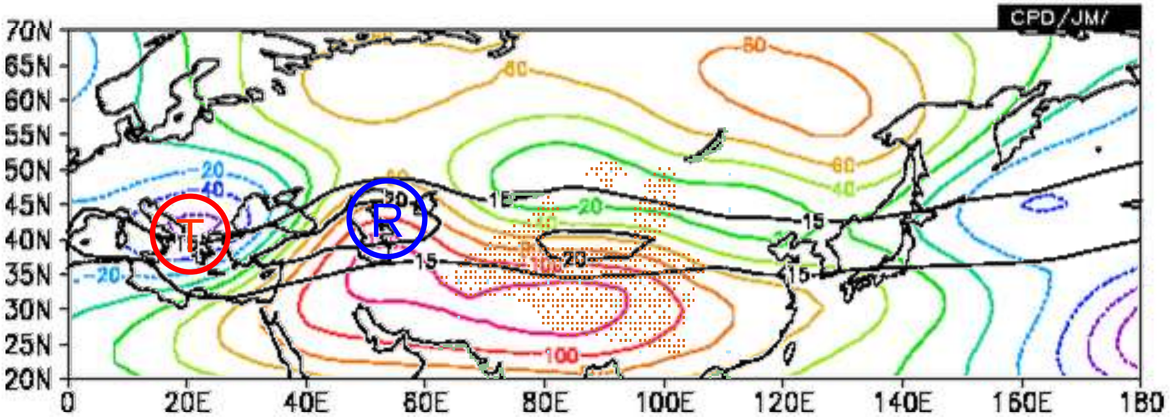
The same as the above figure, except for 2009 July

- Climatologically, in June, a ridge and a trough is formed in 90E and 130E, respectively partly due to orographical influence of Tibetan Plateau.

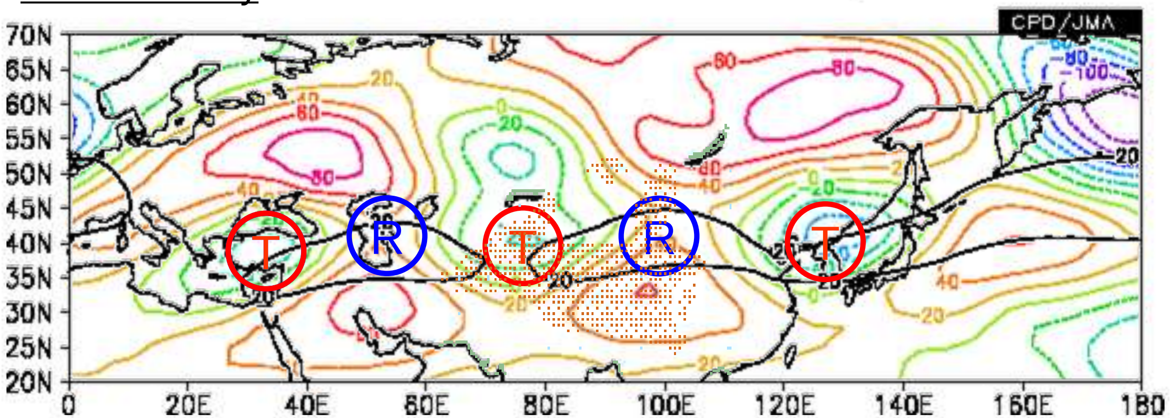
- The position and strength of the jet stream in July 2009 were almost the same as ones in normal year of June.

- The phase of the troughs and ridges might be influenced by Tibetan Plateau under the condition of the jet stream like normal year of June.

200hPa height and wind in normal and 2009 of July



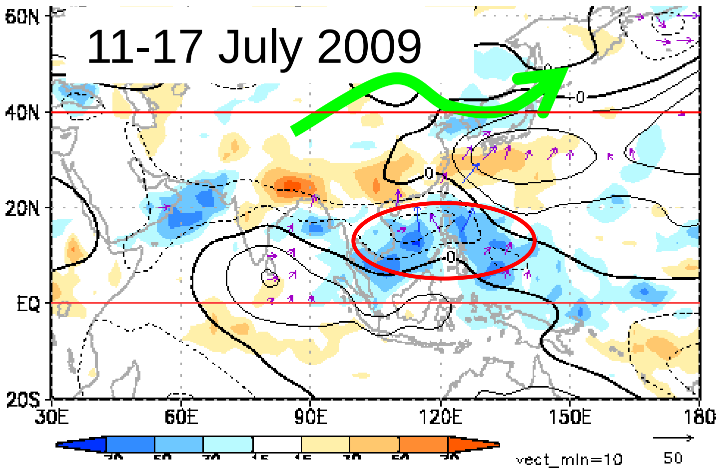
200hPa geopotential height subtracting zonal mean (color) and zonal wind (black) Hatch indicates areas at an altitude of > 3,000m
Normal of July

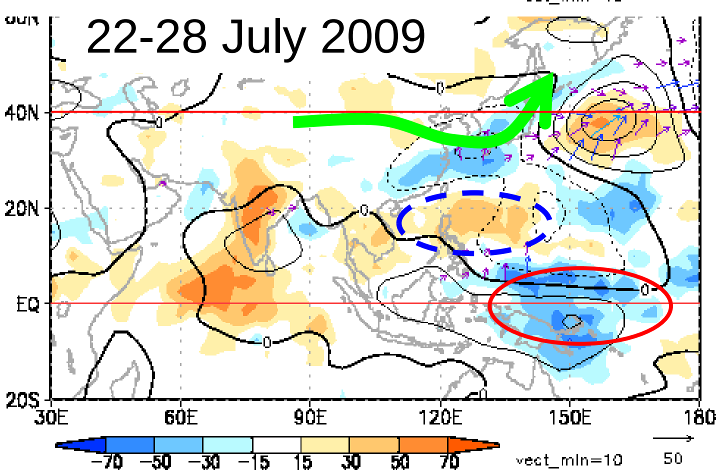


The same as the above figure, except for 2009 July

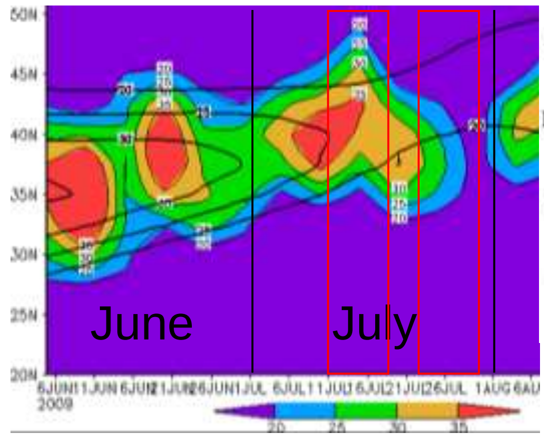
Why northward extension of subtropical high was weak over Japan even in late July when usually it shifts northward and brings the end of rainy season?

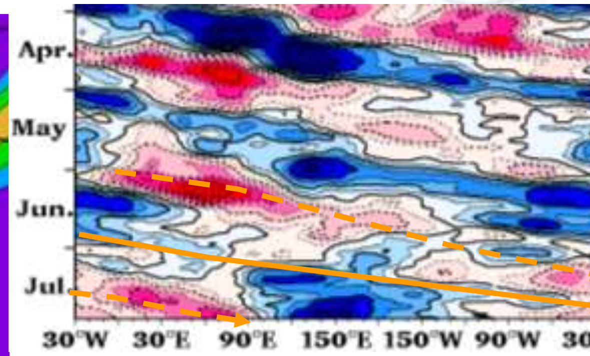
Convective activities around the Philippines





850hPa stream function (contour) and OLR anomalies (shade)
green arrow: subtropical jet





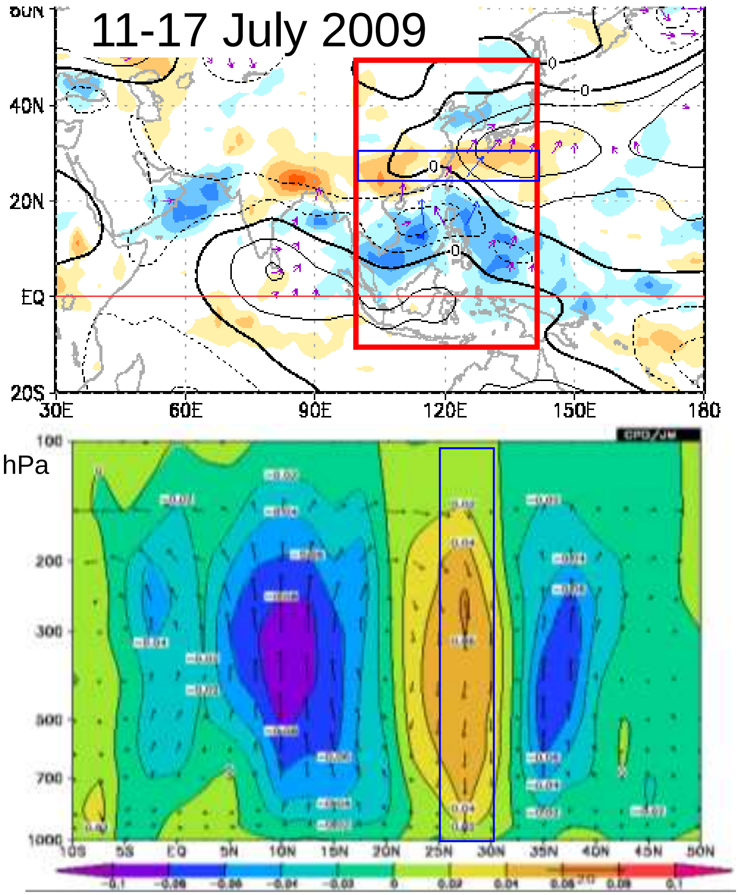
200hPa Velocity potential anomaly along 5S-5N (Apr. – Jul. 2009)

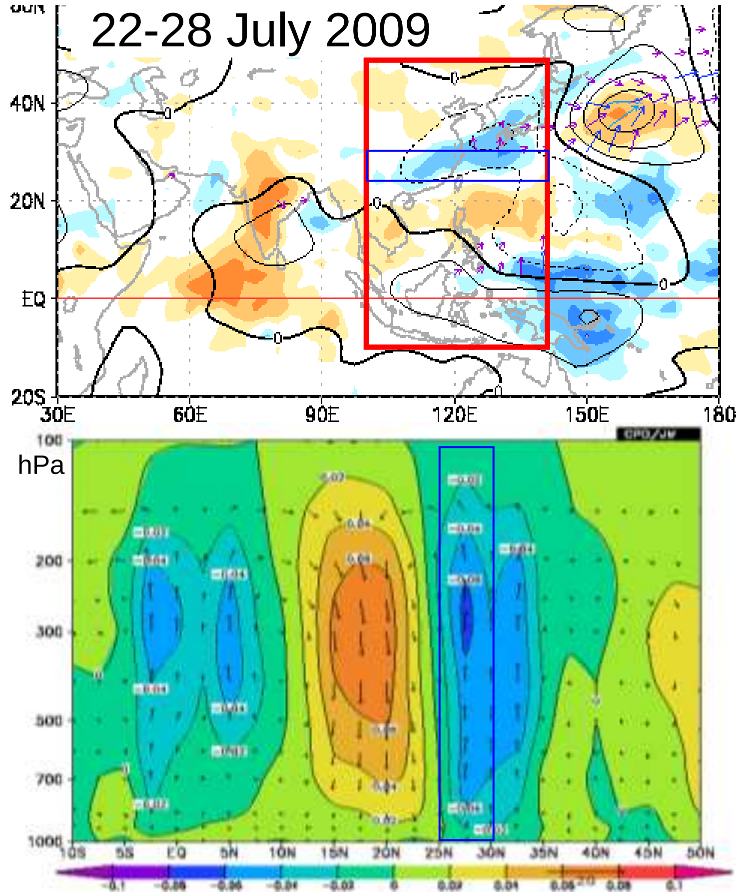
- In mid July, convective activities were enhanced over around the Philippines.
- The convection strengthened barotropic high just south of Japan (Pacific Japan (PJ) pattern, Nitta, 1987)

- In late July, they were suppressed around the Philippines, whereas enhanced around the western equatorial Pacific in accordance with MJO propagation.

- The convection weakened barotropic high and the jet shifted southward.

Vertical circulation around the Philippines





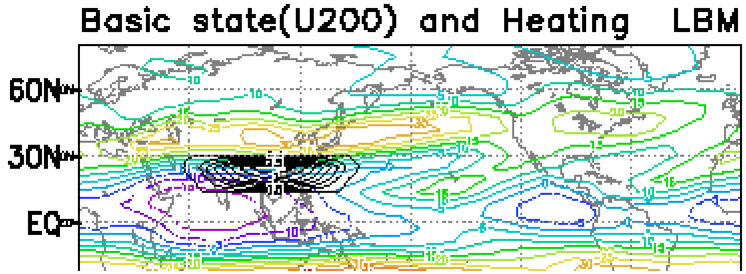
850hPa stream function (contour) and OLR anomalies (shade)

Pressure vertical velocity anomalies (shade), and meridional wind divergence (horizontal vector) and pressure vertical velocity (vertical vector) anomalies

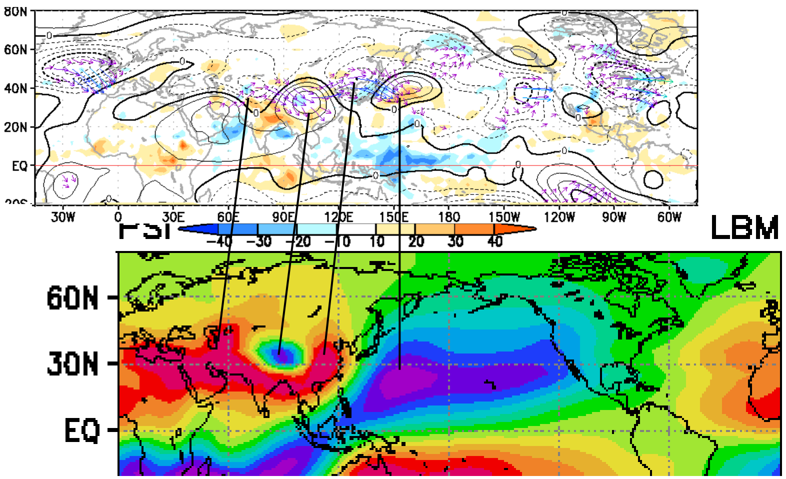
- Enhanced convective activities around the Philippines enhanced local Hadley circulation and strengthened barotropic high just south of Japan in mid-July.

- Vise versa in late-July.

The result of LBM



Black contour: Vertical-integrated diabatic heating anomalies (K/day) around 400 hPa
Color contour: 200hPa zonal wind in July 2009.



200hPa stream function anomaly responding the heating over India to southern China

- The atmospheric response to the diabatic heating from the southern China to India is…

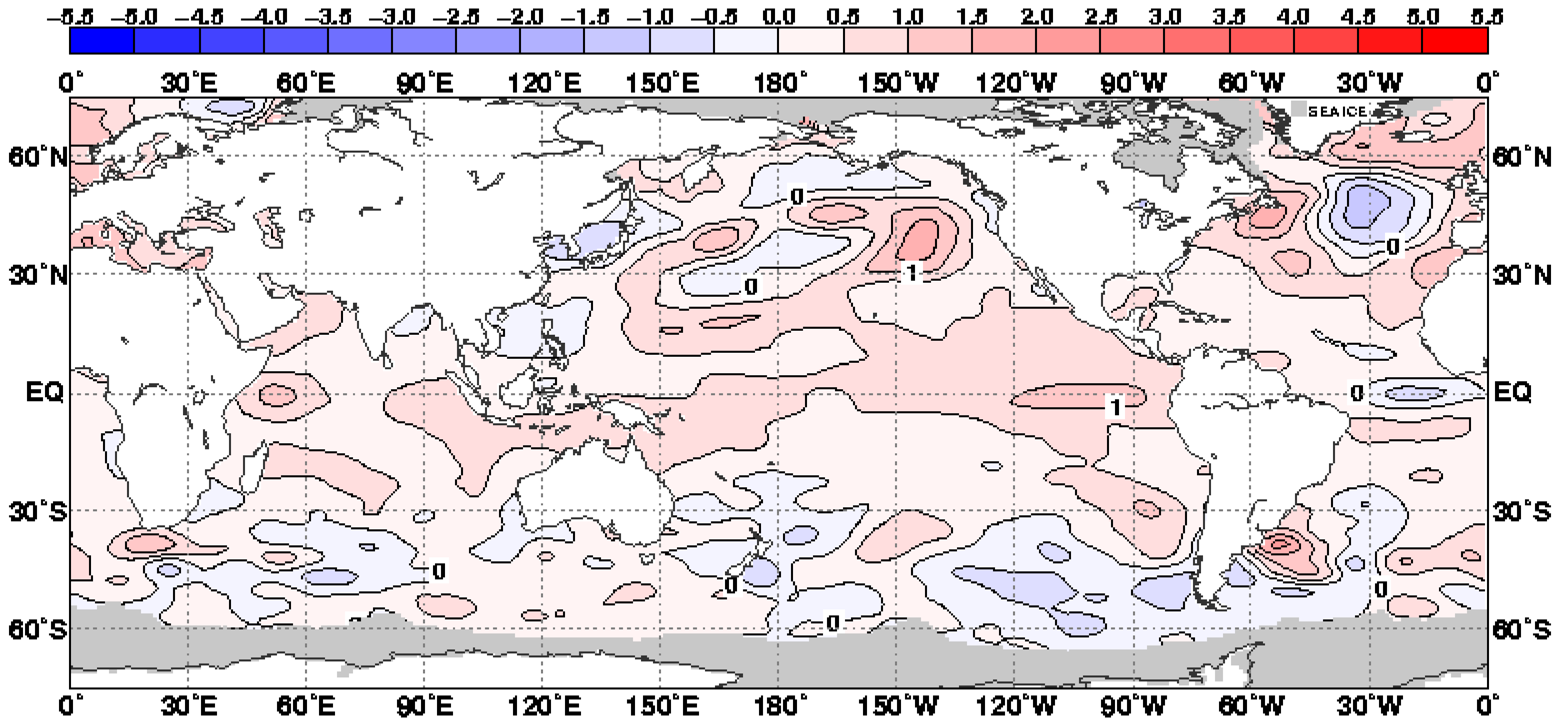
- Anticyclonic and cyclonic anomalies are found along the Asian jet.
- The wave length is consistent with observed one except over east of Japan.
- The phase of anomalies shift 20 degree westward.
- These suggest the convection over south Asia is the formation of the observed atmospheric anomalies over East Asia in some degree.

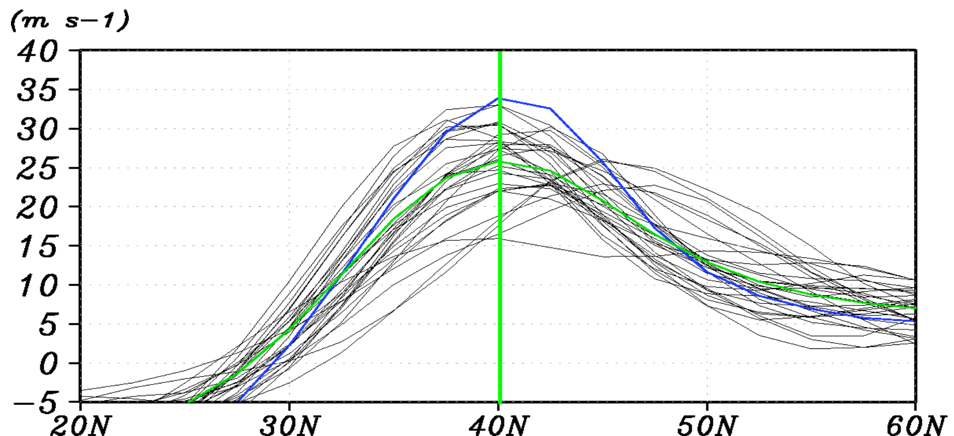
- LBM: Linear baroclinic model developed by Watanabe and Kimoto (2000)

- Global, time-dependent, primitive equation model linearized about the observed climatology

- Resolution : T21L5

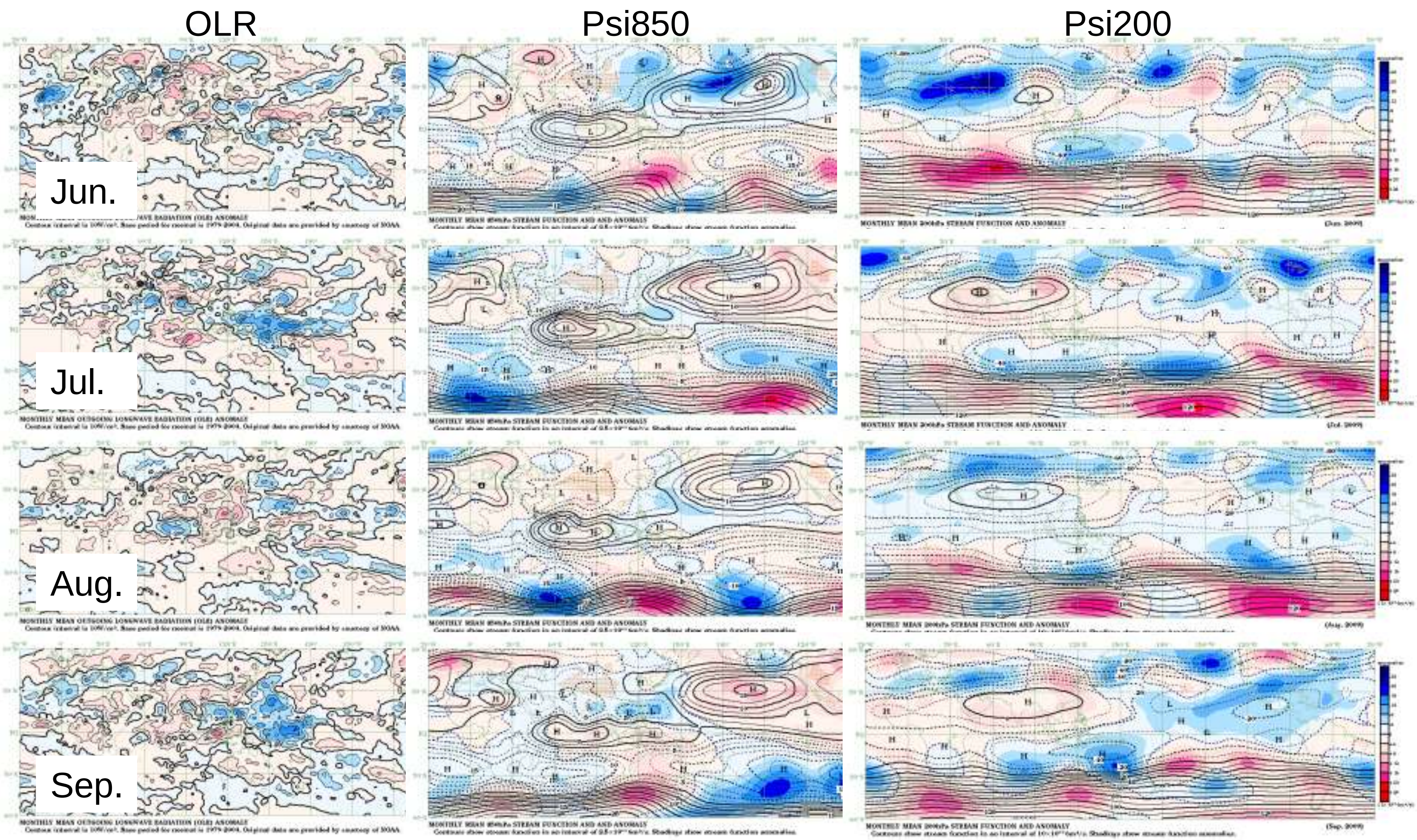
SST in JJA 2009



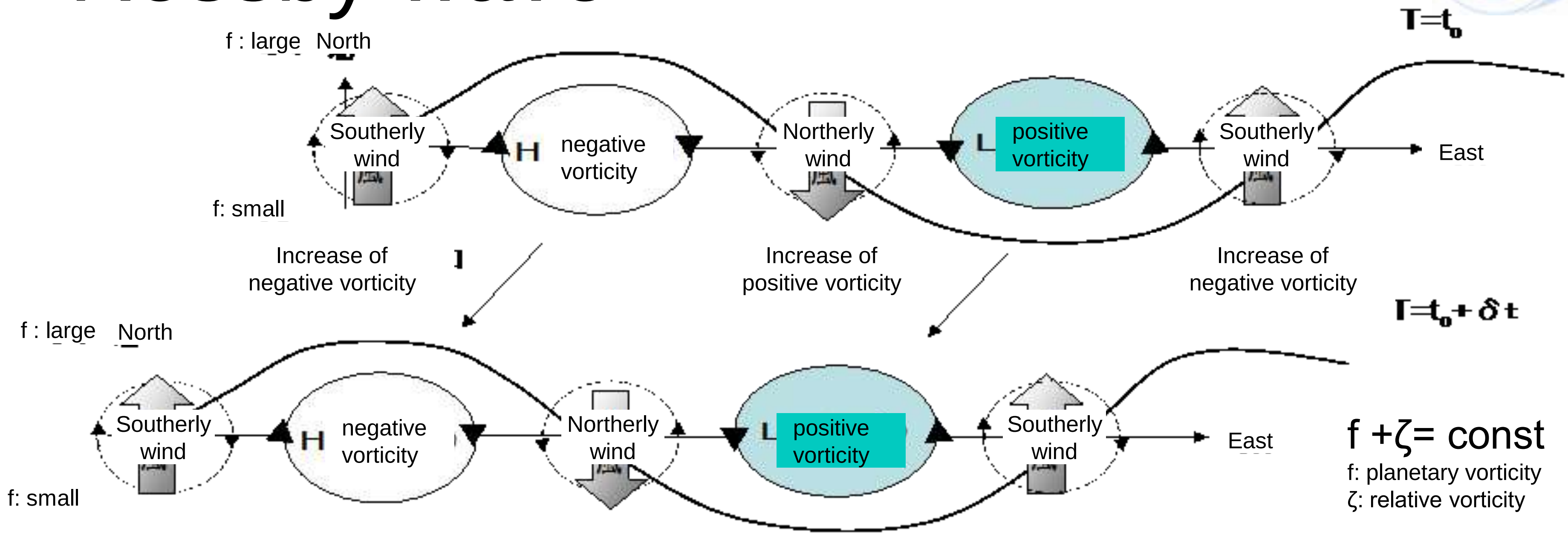


200hPa zonal wind in July averaged over 90E-150E

Monthly anomalies in the tropics



Rossby wave



- A wave on a uniform current in a two-dimensional nondivergent fluid system, rotating with varying angular speed about the local vertical (beta plane).
- A large, slow-moving, planetary-scale wave generated in the troposphere by ocean-land temperature contrasts and topographic forcing (winds flowing over mountains), diabatic heating in the tropics
- In planetary atmospheres, the emergence of Rossby wave is due to the variation in the Coriolis effect with latitude.
- Since absolute vorticity was conserved, when air mass move northward, cyclonic rotation (positive relative vorticity) increases due to reducing the effect of rotation of the earth
- $c = U - \beta/k^2$ c: wave speed U: the mean westerly flow, **β**: the Rossby parameter(the meridional gradient of the Coriolis parameter) K^2 : the total wavenumber squared