# Cool summer over Japan in 2003
# -- the summer following the 2002/03 El-Nino event --

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## 1. Introduction

In summer 2003, Japan experienced unusual low temperature and deficient sunshine since 1993. After 1980s, Japan tends to suffer from cool weather in the summer following the El-Nino reaches its mature phases (Fig. 1). And also, recent several researchers indicated that the Western North Pacific Monsoon and the East Asian Summer Monsoon behave with large anomaly in the summer following the El-Nino (Kawamura (1998), Y. Wang et al. (2001), B. Wang et al. (2001)). So, the cause of the cool summer 2003 was explored from a viewpoint of the summer following the 2002/03 El-Nino event.

## 2. Overview of summer 2003

Fig.2 shows climate anomalies in June-July-August (JJA) 2003. The data used are the CDAS-2 by NCEP, OLR by CDC/NOAA, GLBSST by JMA and CLIMAT report.

SST anomalies in the tropics were positive over the Indian Ocean and the central Pacific, while negative off the west coast of Peru. The 2002/03 El-Nino event ended in boreal winter 2002/03 (according to the definition of JMA).

Convective activities estimated from OLR were active over the western Indian Ocean and over the African Sahel, while in-active over the eastern Indian Ocean and the western Pacific region. In the upper-level troposphere, divergence anomalies were found from the western Indian Ocean to Africa, while convergence anomalies were found over the western Pacific. These are consistent with the convective anomalies.

The upper-level atmospheric circulation featured weak Tibetan High especially in its northern part. The lower-level atmospheric circulation featured weak monsoon jet from the Bay of Bengal to the east of the Philippines and westward extension and of the Western Pacific Subtropical High (WPSH) instead of its extension over Japan. Moreover, the Okhotsk high developed in July and persisted through about a month although it couldn't be clear in the seasonal mean field.

Observed temperature showed negative anomaly around the 40N over Eurasia including Japan.

## 3. Composite analysis for the summers following the El-Nino events

The method to choose the summer following the El-Nino events is as follows. The El-Nino events having its peak in autumn or winter were chosen based on the definition by JMA, then the year preceding its peak is defined as year (0) and the year following its peak is defined as year (+1). According to this definition, 10 years (1958, 64, 66, 70, 73, 77, 83, 88, 92, 98) were picked up as year (+1) from late 1950s to 1990s, then the composite maps were made separately two periods (late 1950s-70s and 1980s-90s) respectively. The data used in this analysis are the ERA-40 by ECMWF, OLR by CDC/NOAA and GLBSST by JMA. Departures from the different average in each period were used in order to reduce the effect of long term trend.

The composite maps in boreal summer for year (+1) for late 1950s-70s showed no large anomalies (not shown), whereas remarkable anomalies were seen in that for 1980s-90s (Fig. 3). Also, the latter were similar to the features of summer 2003 especially around Asia. However, those by ERA-40 are shown here because the composite maps for year (+1) during 1980s-90s by ERA-40 were almost same as those by CDAS-2.

Common characteristics between the 2003 summer and the composites for 1980s-90s were: (1) positive SST over the Indian Ocean, (2) enhanced convection over the Indian Ocean, while suppressed convection over the western Pacific, (3) westward extension of the WPSH instead of its extension over Japan, (4) weak low-level monsoon jet, (5) strong Okhotsk high and (6) weak Tibetan high especially over its northern pars (but not statistically significant).

## 4. Delayed effect of the El-Nino on Asian summer

The mechanisms of delayed impact of the El-Nino through tropical route on Asian summer were indicated by Kawamura (1998) and Wang et al. (2000). According to Kawamura (1998), an equatorially asymmetric mode over the Indian Ocean excited by the El-Nino in boreal spring bridges between the El-Nino and Asian summer monsoon. While according to Wang et al. (2000), the anomalous anti-cyclonic circulation in the lower troposphere established around late autumn during the El-Nino affects East Asian climate until the following spring or early summer. But the anomalies in spring 2003 weren’t similar to the feature shown by them (figure omitted).

Fig. 4 shows lagged correlations between Nino.3 SST in October-November-December (OND) and Nino.3 SST and Indian Ocean SST over each periods. It can be recognized that the Indian Ocean becomes warm about one to two seasons behinds El-Nino peaks. In 1980s-90s the Indian Ocean warming peaked at spring, then the condition persisted until summer. Similarly, from spring to summer 2003, Indian Ocean SST remained considerable positive anomaly. So, basin scale Indian Ocean warming after boreal winter related to the El-Nino is noticed as a possible forcing which caused delayed impact on Asian summer climate. Nitta (1990) also pointed that above-normal SST over the Indian Ocean affected Asian summer monsoon, resulting in unusual summer over Japan in 1988.

As Kawamura et al. (2001a, 2001b) pointed out that surface latent heat flux anomalies are dominant in SST change from boreal spring to summer over the Indian Ocean, it is considered that the examination of simultaneous relationship between SST anomalies and atmospheric anomalies is not appropriate for considering the cause-result relationship. Therefore, the statistical relationships between Indian Ocean SST in spring and Asian summer climate anomalies in the following summer were investigated.

Although the results were roughly similar to the composite map in year (+1) for 1980s-90s because of high correlation between the El-Nino and Indian Ocean SST in the following spring, some features became clear. Fig.5 indicates precipitation and westerly wind speed in summer averaged over 45-150E regressed with Indian Ocean SST anomaly in the preceding spring. This figure suggests that there is the statistically significant linkage between Indian Ocean SST warming in the spring and weak Asian monsoon and southward shift of Asian jet in the following summer. This speculation is also supported by the facts that the anomalies in summer 2003 were close to those of the regression pattern with slight northward shift.

## 5. Summary

In 2003, Japan experienced cool summer since 1993. Japan tends to suffer from cool weather in the summer of year(+1) after the El Nino reaches its mature phases in year(0). Therefore, the cause of the cool summer in 2003 was explored by considering the summer following the 2002/03 El-Nino event.

The obtained conclusions are following:

1) The large-scale anomalies around Asia in summer 2003 are also similar to those of composite in year (+1) for 1980s-90s.
2) The analysis for sprint 2003 indicates that it is difficult to explain the anomalies in summer 2003 using the mechanism by Kawamura (1998) and Wang et al. (2000).
3) The statistical analysis shown in this paper indicates that basin-scale Indian Ocean warming associated with the El-Nino affect Asian summer climate through convective activity over the Indian Ocean and meridional shift of the Asian jet, as the same as summer 2003.

The seasonal progresses of anomalies around Asian region from the peak of El-Nino to the following summer are schematically summarized in Fig.6 based on the statistical analysis here. Indian Ocean SST anomaly rises around boreal winter associated with El-Nino, then persist until the following summer. In the summer, convection is enhanced over the Indian Ocean, while over Asian monsoon region convection is suppressed and low-level monsoon wind is weakened. It is speculated that these convection and wind anomalies act to keep positive SST anomaly over the Indian Ocean, that is, occurring atmosphere-ocean positive feedback. Moreover, the associated anomalies also appear over mid-latitude. The Asian jet shift southward over wide area and westerly winds over 50-60N are weakened. Over the Far East, the WPSH does not extend over Japan and the Okhotsk high tends to appear. These global scale anomalies cause the cool summer over Japan.

It is also noticeable that westerly winds are reduced around 50-60N over southern part of Siberia in the summer following the Indian Ocean warming because the evolution of blocking ridge over the Far East, which relate to the developing of the surface Okhotsk high, prefers this condition (Nakamura and Fukamachi, 2004).

The mechanism obtained through this research needs to be confirmed by numerical model study.

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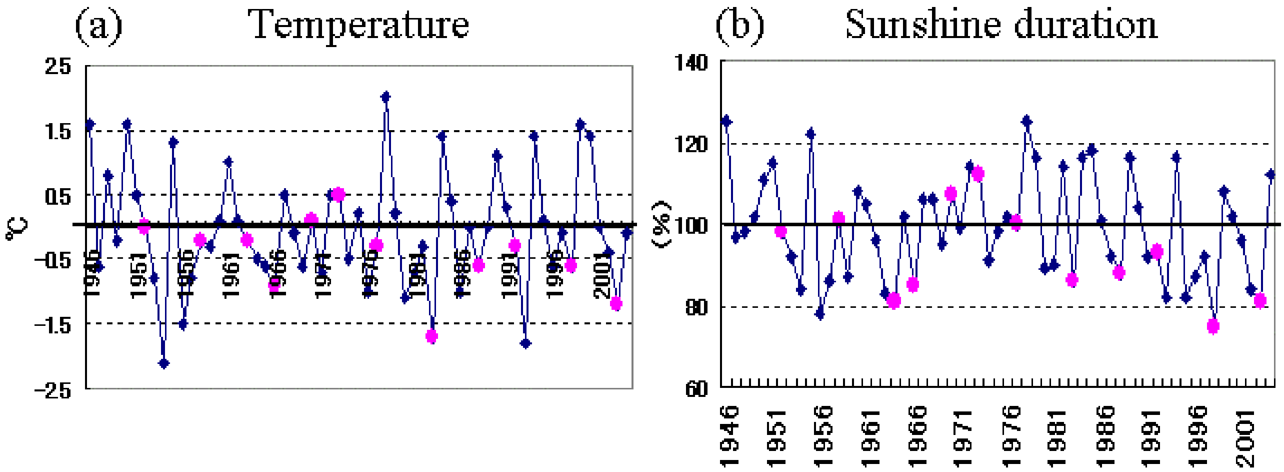


Fig.1 June-July-August (JJA) mean (a) surface temperature anomaly and (b) sunshine duration ratio in the Northern Japan in the period 1946-2004. Anomalies are the departures from the 1971-2000 average. Larger dots show the year (+1).

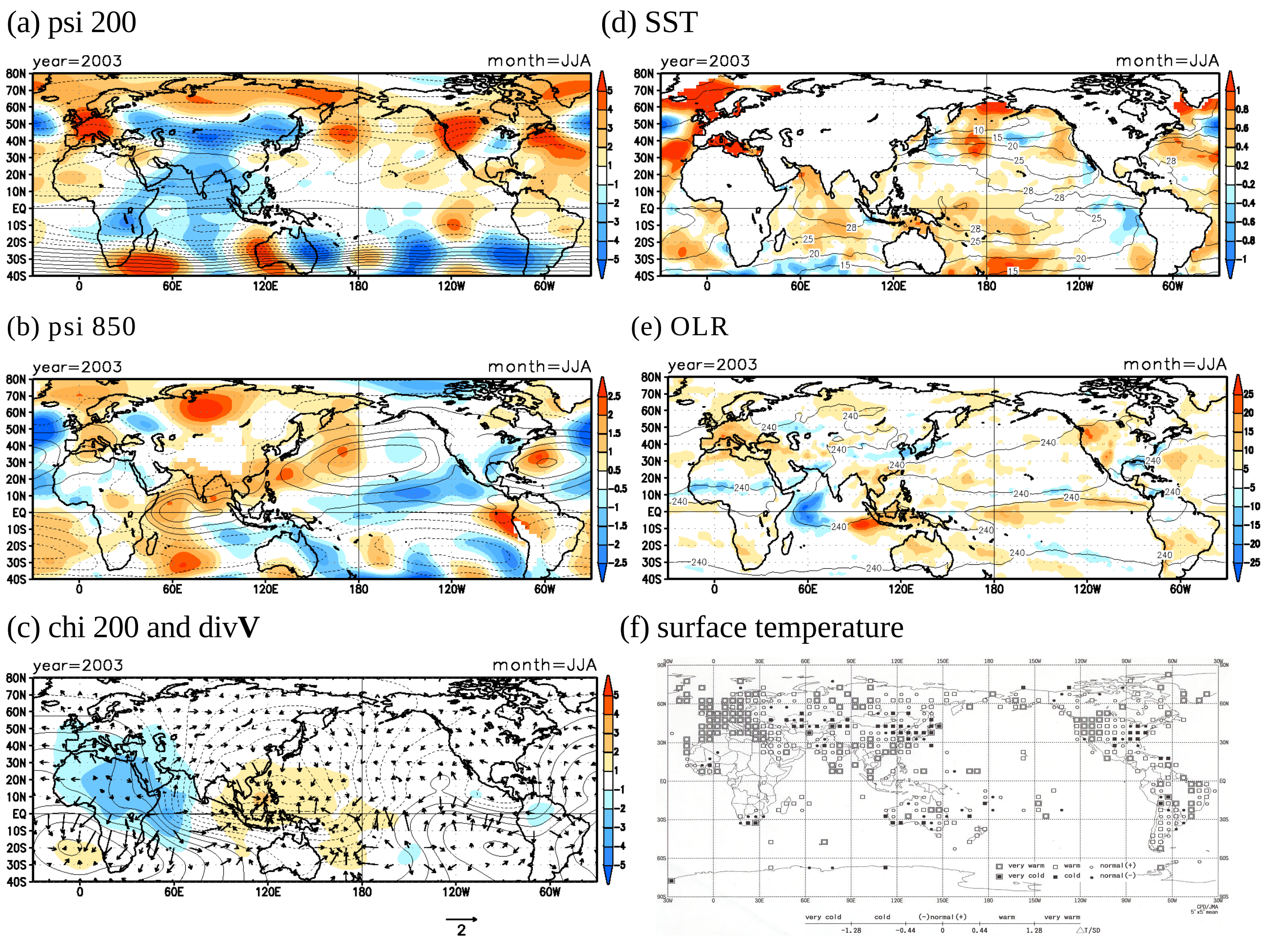


Fig. 2 JJA 2003 mean (a) stream function at 200hPa, (b) stream function at 850hPa, (c) velocity potential at 200hPa, (d) sea surface temperature, (e) OLR and (f) surface temperature anomaly (from JMA, 2003). Positive (negative) values are indicated by solid (dashed) line except in (f). Positive (negative) anomalies are shown by blue (red) shades except in (f). (f) is based on CLIMAT reports. Anomalies in (a)-(e) (in (f)) are departures from the 1979-2000 (1971-2000) base period.

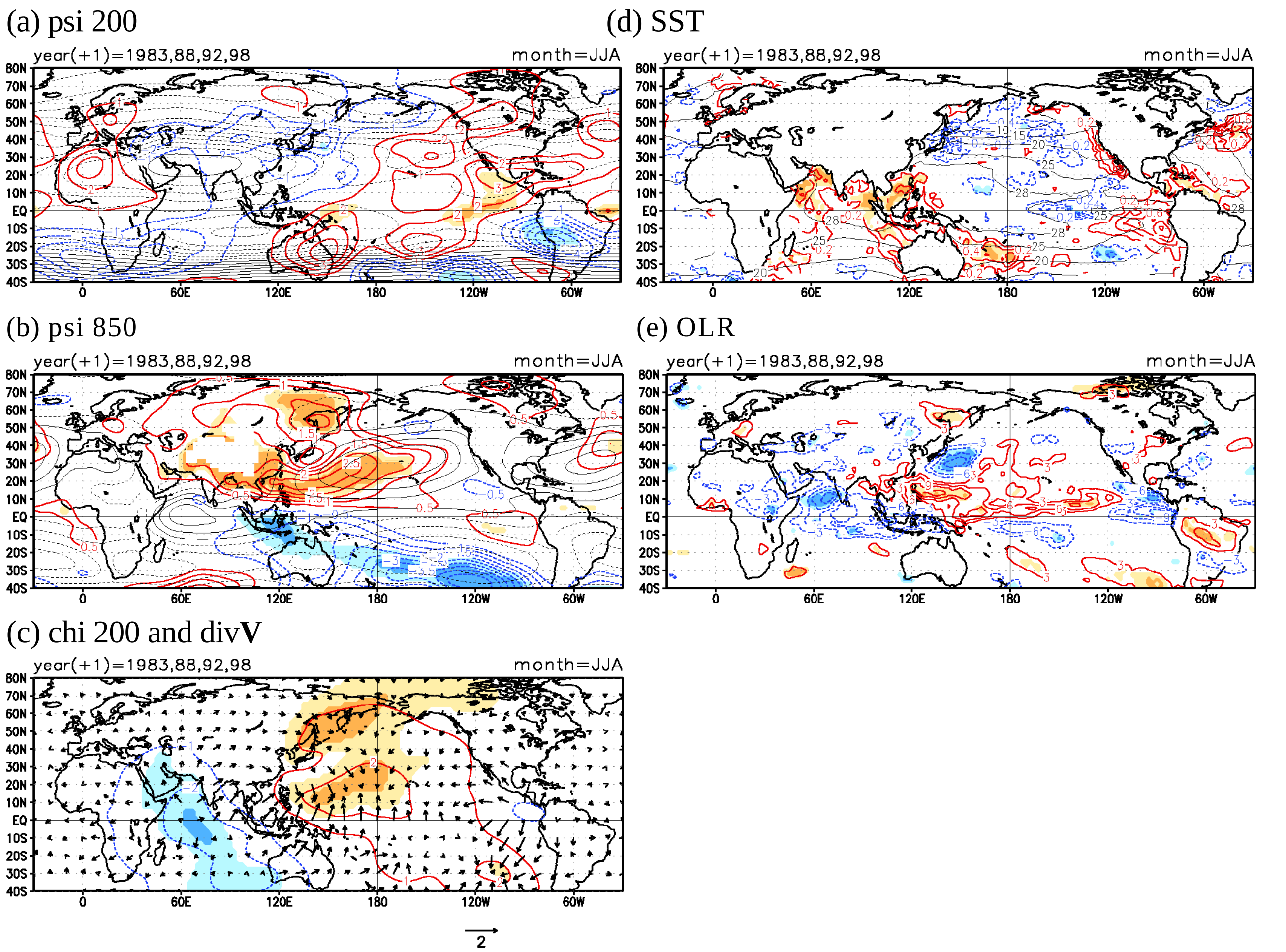


Fig. 3 Same as Fig. 2 except composite maps in the JJA of year(+1) during 1980s-90s. Red (blue) contour shows positive (negative) anomalies. Dark (light) shades denote statistical significance larger than 95% (90%).

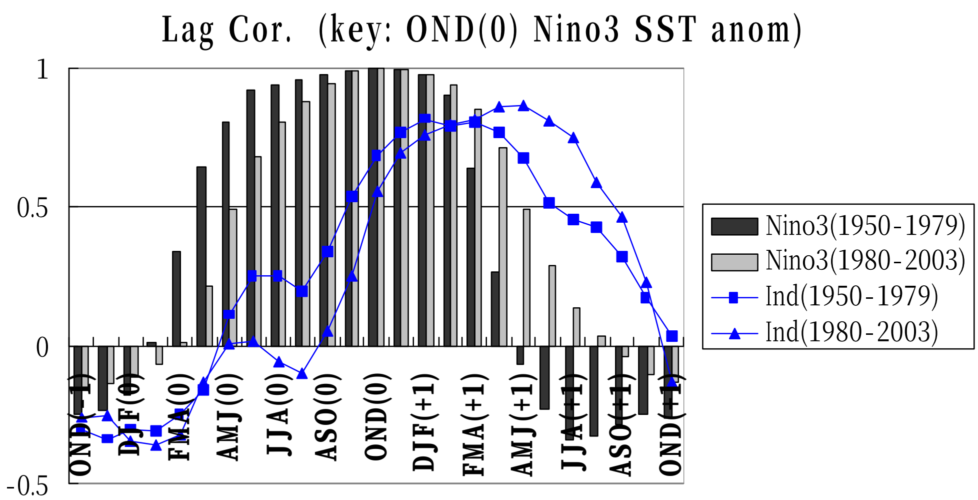


Fig. 4 Lag correlation coefficients of the Nino.3 SST anomalies (bars) and the Indian Ocean SST anomalies (line) with reference to the Nino.3 SST anomalies in Oct.-Dec. for the period of 1950-1979 and 1980-2003. The Indian Ocean is defined as the region enclosed by 50-120E and 20S-20N. Long tern trends are removed by linear regression in respective periods.

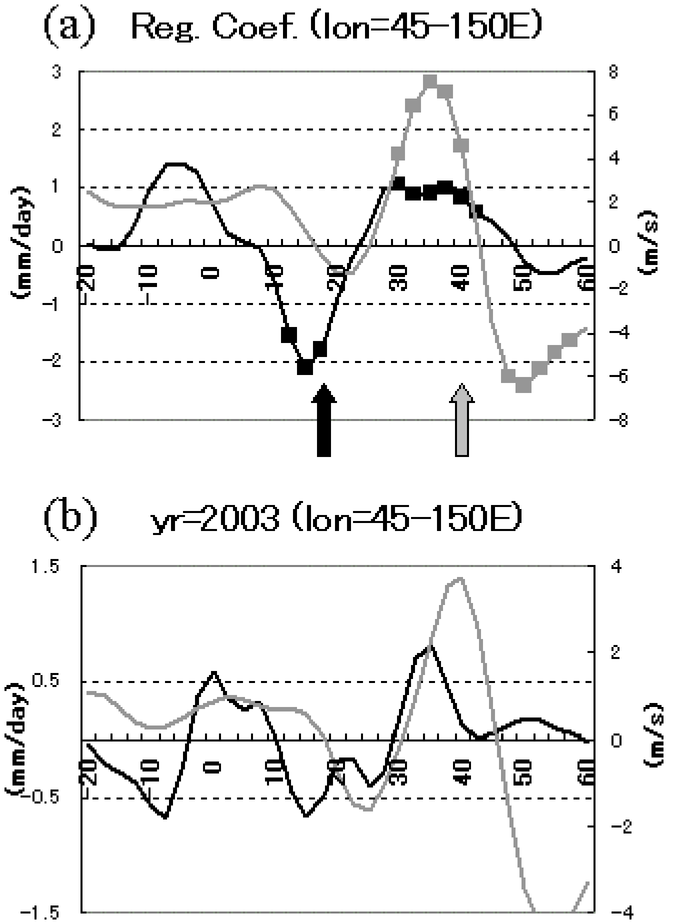


Fig. 5 (a) Regression pattern of westerly wind at 200hPa (dark line) and precipitation (light line) in JJA with respect to the Indian Ocean SST anomaly in the previous spring. Precipitation data come from CMAP (Xie and Arkin, 1997). Statistically significant values are marked by filled square. The latitudinal location of climatological peak of precipitation (westerly wind) is showed by black (gray) arrow. Long tern trends are removed by linear regression. (b) JJA 2003 mean westerly wind anomalies at 200hPa (dark line) and precipitation anomalies (light line).

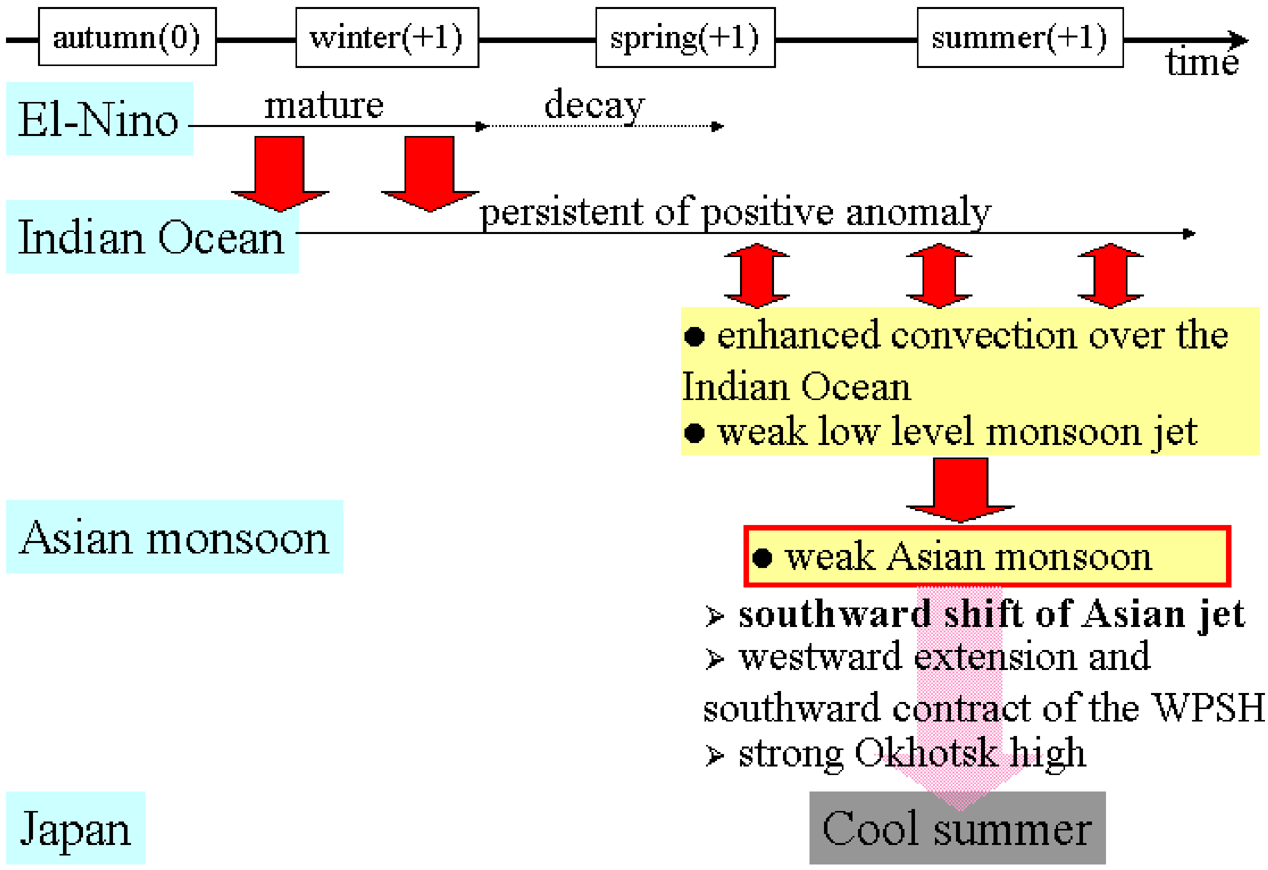


Fig. 6 Schematic diagram of the seasonal progress of anomalies around Asian region from the peak of El-Nino to the following summer.