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Possible Causes for the Persistence Barrier of SSTA in the South China Sea and the Vicinity of Indonesia

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ABSTRACT

The persistence barrier refers to the lag correlation of sea surface temperature anomalies (SSTA) showing a rapid and significant decline in a specific season, regardless of the starting month. This implies that there is a decrease in forecast skill for SSTA in this specific season. This paper investigates the possible causes for the persistence barrier of SSTA in the South China Sea (SCS) and its adjacent regions from the perspective of interannual-interdecadal time scales. The results show that the persistence barrier of SSTA exists not only in the SCS, but also in the vicinity of Indonesia south of the equator. The SCS barrier occurs around October–November, while the occurrence of the barrier in the Indonesia region is around November–December. For these two regions, the occurrence of the persistence barrier is closely associated with the interdecadal variability of SSTA, as well as the interannual variability. The persistence barriers in the SCS and the Indonesia region do not exist alone if the interdecadal variability is not considered, because SSTA have a short memory of less than 4 months, regardless of the starting month. Moreover, the influence of the interdecadal variability of SSTA on the persistence barrier of SSTA in the SCS and the Indonesia region may be associated with SSTA in the Indian Ocean and the western Pacific, but is not closely associated with the Pacific Decadal Oscillation. However, compared with the spring persistence barrier (SPB) of ENSO, the close relationship between the persistence barriers in the SCS and the Indonesia region and the interdecadal variability is unique, since the ENSO SPB is not significantly affected by such variability. In addition, although the persistence barriers in both the SCS and the Indonesia region are quite obvious in strong ENSO cases, the interdecadal variability of SSTA also plays a non-negligible role in this relationship.

Key words: South China Sea, sea surface temperature, persistence barrier, interannual-interdecadal variability of SSTA

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1. Introduction

The presence of the spring persistence barrier (SPB) in ENSO anomalies is well known. The persistence in numerous ENSO indices shows a rapid decline in boreal spring regardless of the starting month (Troup, 1965; Wright, 1979; Webster and Yang, 1992; Xue et al., 1994; Lau and Yang, 1996; Torrence and Webster, 1998; Clarke and Van Gorder, 1999; Zhou and Zeng, 2001; Yu, 2005).

In addition to the central and eastern equatorial Pacific, sea surface temperature anomalies (SSTA) in other regions are also subject to persistence barriers. Chen et al. (2007) found a fall persistence barrier (FPB) of SSTA in the South China Sea (SCS), and the SCS FPB is well-recognized in the developing phase of strong ENSO cases, but becomes vague in weak ENSO and non-ENSO cases. The SCS is located in the well-known East Asian monsoon region, and variability of the ocean-atmosphere in the SCS region can have a

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noticeable impact on the East Asian climate (e. g., Huang and Sun, 1992; Shen and Lau, 1995; Tomita and Yasunari, 1996; Ose et al., 1997; Wang and Fan, 1999; Wang et al., 2001; Bueh et al., 2001). Therefore, a better understanding of the seasonal and geographical dependence of the SSTA persistence in the SCS and its adjacent regions should be helpful for studying the SCS monsoon and the climate of East Asia.

In this study, possible causes for the persistence barrier of SSTA in the SCS and its adjacent regions are examined from a new perspective. We focus on investigating the relationship between the occurrence of the FPB and the interannual-interdecadal variability of SSTA in the SCS and it adjacent regions, and comparing them with the ENSO SPB. It is well known that ENSO is a strong signal on interannual time scales. Lau and Yang (1996) pointed out that the ENSO SPB is associated with the phase-locking of interannual anomalies to the annual cycle variation of the tropical ocean-atmosphere. Obviously, interannual variability is closely associated with the occurrence of the ENSO SPB. We consider whether there are any regional differences in the causes of the SCS FPB and the ENSO SPB, and what the relationship is between the SCS FPB and the interannual-interdecadal variability of SSTA. Comparing the persistence characteristics of the SCS SSTA and ENSO on different time scales will provide a clear understanding of these questions. Since Chen et al. (2007) found that the SCS FPB is well-recognized in the developing phase of strong ENSO cases, it is necessary to further analyze the role of the interannual-interdecadal variability of SSTA in this relationship. Further analyses over different time scales, on the basis of the work of Chen et al. (2007), should contribute to a better understanding of the causes and physical processes of the persistence barrier in the SCS, especially for detecting regional differences between the SCS FPB and the ENSO SPB.

In addition, Chen et al. (2007) only investigated the persistence barrier in the SCS in terms of correlations of a region-mean SST index in the domain 10°–20°N, 110°–120°E. Does the persistence barrier also exist in regions adjacent to the SCS, or is it just found in the SCS? This question is also examined in the present study, and may help identify similarities and discrepancies between persistence characteristics in the SCS and its adjacent regions.

2. Data and methodology

The SST data used in this paper are taken from the Improved Extended Reconstruction Sea Surface Temperature (IERSST) (Smith and Reynolds, 2004) for 1950–2004 on a 2°×2° grid. The annual cycle of data was removed by subtracting the mean monthly values. The Pacific Decadal Oscillation (PDO) index (1950–2004) is from the Joint Institute for the Study of Atmosphere and Ocean (JISAO).

Persistence is defined in terms of lag correlation coefficients and the extent to which these coefficients remain at the 95% confidence level for lag times. The lag correlation is defined as the correlation of SSTA for the starting month m (all years) with a lag month k. For example, for the starting month m=2 (February) and $k = 10$, the correlation is between the February SSTA and the December SSTA. The persistence indicates how long the memory of the system sustains, and hints at the potential predictability of the system.

In order to analyze the influences of different time scales of SSTA variability on the persistence, we apply a high-pass filter to the original data. By taking into account the effect of the filtering on the degree of freedom and significance test, the effective degrees of freedom are expediently evaluated. Davis (1976) and Chen (1982) presented a method for estimating the effective degrees of freedom, N, as: $N = n/T$, where,

$$T = \sum_{\tau=0}^{K} C_{xx}(\tau)C_{yy}(\tau) .$$

$C_{xx}(\tau)$ and $C_{yy}(\tau)$ are the autocorrelation coefficients of x_i $(i = 1, \cdots, n)$ and y_i $(i = 1, \cdots, n)$, respectively, with a lagged scale τ. The maximum of the integer K corresponds to $n/2$.

3. Results

3.1 *Persistence barriers in the SCS and its adjacent regions and SSTA variation*

In order to efficiently determine the spatial extent of the persistence barrier of SSTA, we analyze the persistence characteristic at each grid point within a larger region including the SCS and its adjacent regions. The shading in Fig. 1 indicates that the SSTA lag correlations drop to insignificant levels during October–December, for the January to December starting months. It is obvious that, as for the SCS, SSTA in the vicinity of Indonesia also experience a rapid decline in October–December for most of the starting months. This indicates that the persistence barrier of SSTA also exists in the vicinity of Indonesia, as well as in the SCS. These two regions are situated on the north and south sides of the equator, respectively. As shown in Fig. 1, the spatial extent of persistence barriers in the SCS and the vicinity of Indonesia undergoes obvious change from season to season. For the SCS, the spatial extent is smallest in May–June, while smallest in November–December for the vicinity of Indonesia.

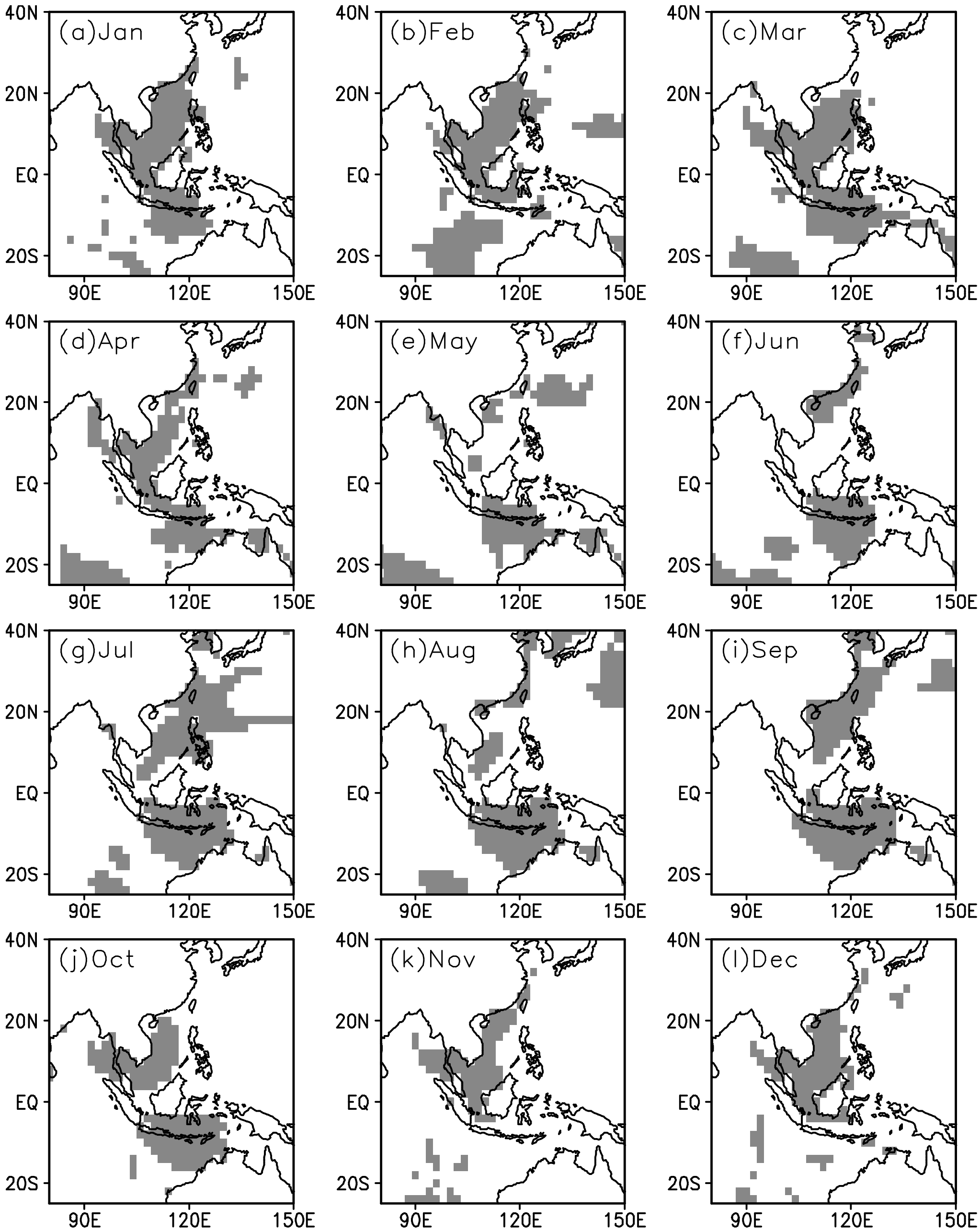

Fig. 1. Shading indicates where the SSTA lag correlation drops to the insignificant levels during October–December. (a)–(l) are for the starting months of January to December, respectively.

In order to clearly show the behavior of lag correlation coefficients, we define these two persistence barrier regions as follows: the SCS (5°–20°N, 105°–115°E) and the Indonesia region (5°–15°S, 110°–125°E). For ease of comparison, we also give the result for the Niño-3 region (5°S–5°N, 150°–90°W). Figure 2 shows their average lag correlations; the left panels and the right panels display the same information in different forms. The left panels clearly show the SSTA persistence for every starting month, while the right panels clearly show the timing of the occurrence of the persistence barrier. As we know, there is a March–April persistence barrier in the Niño-3 region (Figs. 2e–f), while persistence barriers of SSTA in the SCS (Figs. 2a–b) and the Indonesia region (Figs. 2c–d) exist around October–December. Although the persistence barriers in the SCS and the Indonesia region are similar, there are some discrepancies. From the left panels, it can be seen that SSTA persistence in the SCS and the Indonesia region exhibits obvious seasonal variation.

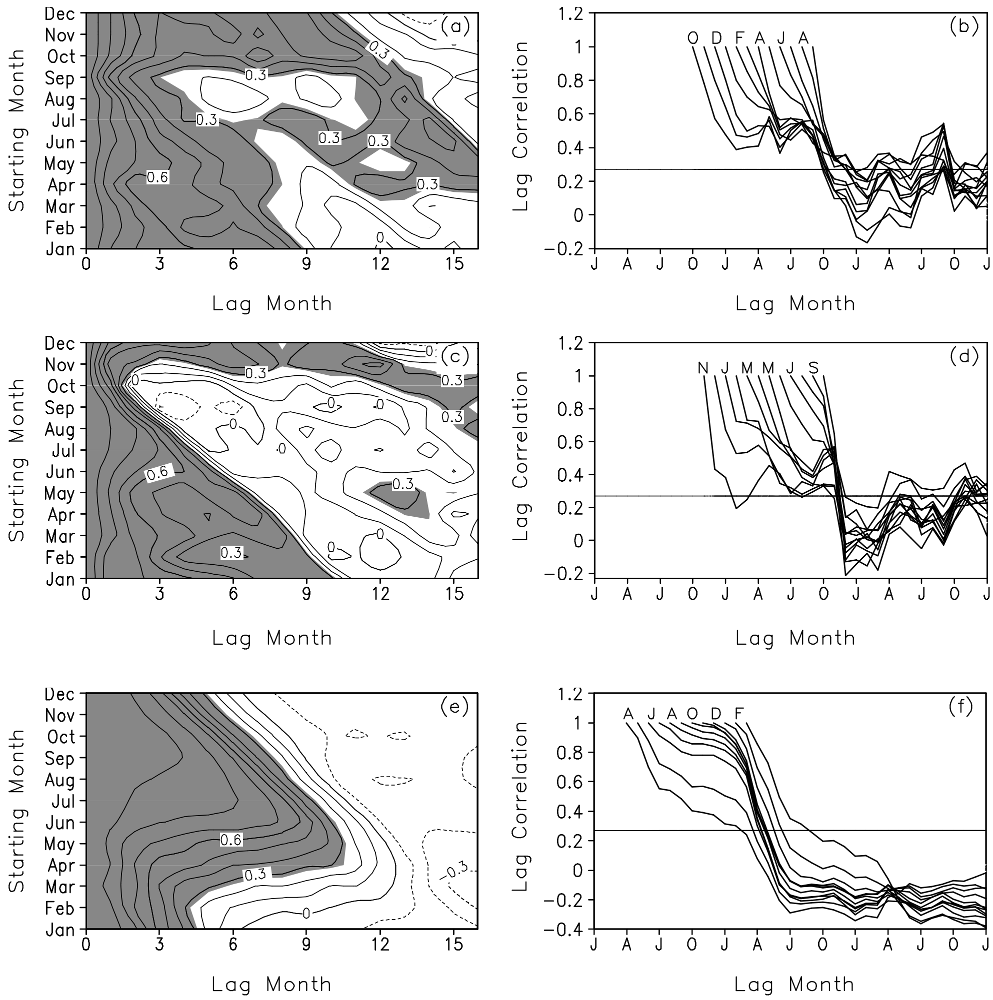

Fig. 2. (a) Lag correlation of the SCS SSTA as a function of the starting month (ordinate) and lag month (abscissa). The counter interval is 0.1, and correlation values greater than the 95% confidence level are shaded. (b) same as (a) but viewed as persistence curves as a function of the calendar months. Each curve is shifted to line up the starting month (letters at the top) with the corresponding lag month (x-axis). The solid line indicates the 95% confidence level. (c) and (e) same as (a) but for SSTA in the Indonesia region and the Niño-3 region. (d) and (f) same as (b) but for SSTA in the Indonesia region and the Niño-3 region.

For the SCS (Fig. 2a), the SSTA persistence is longest for the October–November starting months and shortest for September. For the Indonesia region (Fig. 2c), the SSTA persistence is longest for the January–February starting months and shortest for October. From the right panels, it can be seen that the lag correlations of these two regions show a significant decrease in October–December for most of the starting months. The SCS barrier is around October–November (Fig. 2b), but the occurrence of the barrier in the Indonesia region is around November–December (Fig. 2d), which is about one month later than that in the SCS. Therefore, the SCS barrier is the fall barrier, while it is more precise to refer to the barrier in the Indonesia region as the early winter barrier.

According to the hypothesis put forward by Torrence and Webster (1998), the ENSO SPB is related to the phase locking of ENSO to the annual cycle. To examine the phase locking, we show in Fig. 3 the standard deviation of SSTA in the Niño-3 region, the SCS, and the Indonesia region as a function of calendar moth. The ENSO variation is minimum in spring and maximum in winter (Fig. 3c). The variation of the SCS SSTA is minimum in May and maximum in January–March (Fig. 3a). This indicates that the SSTA variation in fall (October–November), when the SCS FPB occurs, is not the minimum. In contrast to the seasonal cycle of the SCS SSTA, the variation in

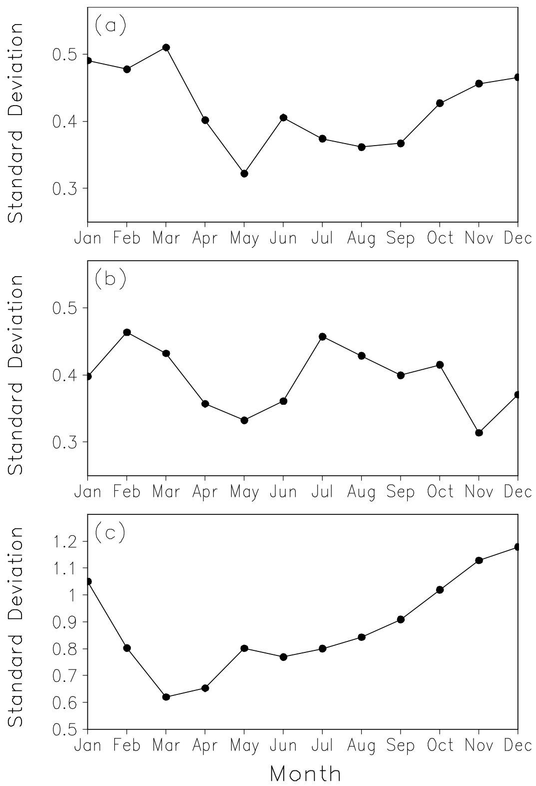

Fig. 3. Standard deviation of SST over (a) the SCS region, (b) the Indonesia region, and (c) the Niño-3 region as a function of the calendar month.

the Indonesia region shows two peaks, and the minima are in May and November (Fig. 3b). The persistence barrier just occurs in November–December in the Indonesia region.

3.2 *The relationship between the persistence barrier and the interannual-interdecadal variability of SSTA*

From variance analysis, it is known that the ratio of interdecadal variance to the total variance of SSTA in the Niño-3 region is about 10%, while the ratio for the SCS and the Indonesia region is about 25%. What is the influence of this difference on the persistence characteristic between Niño-3 SSTA and the SCS (the Indonesia region) SSTA? Are there any regional differences between the ENSO SPB and the SCS (the Indonesia region) persistence barriers? In this section, the relationship between the persistence barriers and the interannual-interdecadal variability of SSTA in the SCS and the Indonesia region is investigated. The results are compared with those of the ENSO SPB. In order to analyze the influence of different time scales of SSTA variability, we apply a 7-year high-pass filter to the original data. The 7-year low-pass filtered time series are generated using a Gaussian-type filter, and the corresponding high-pass filtered series are formed by subtracting the low-pass filtered time series from the original series. The lag correlation analysis is performed on the high-pass filtered SSTA data. By taking into account the effect of the filtering on the degree of freedom and significance test, the effective degrees of freedom are evaluated.

Figure 4 gives the lag correlation of SSTA in the Niño-3 region, the SCS, and the Indonesia region as a function of the starting month and lag month, using the 7-year high-pass filtered data. When the interdecadal variability of SSTA is filtered out, the SSTA persistence in Niño-3 region (Fig. 4c) still shows the obvious SPB. In contrast, persistence barriers of SSTA in the SCS (Fig. 4a) and the Indonesia region (Fig. 4b) do not exist, because SSTA have a short memory of less than 4 months for all starting months, and the

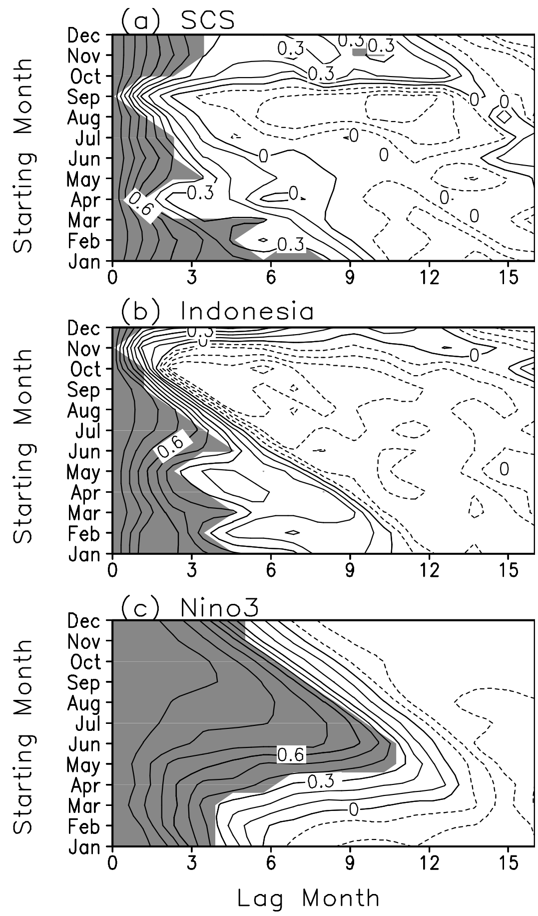

Fig. 4. Lag correlation of SSTA in (a) the SCS region, (b) the Indonesia region, and (c) the Niño-3 region as a function of the starting month (ordinate) and lag month (abscissa) from the 7-year high-pass filtered data. Correlation values greater than the 95% confidence level are shaded, and the effective degrees of freedom are used here.

persistence does not exhibit obvious seasonal differences. This indicates that the influence of interdecadal variability on the occurrence of the ENSO SPB is not significant, since the SPB still occurs even when interdecadal variability is not considered. In contrast, the interannual variability of SSTA in the SCS and the Indonesia region cannot induce persistence barriers alone, and interdecadal variability may be closely associated with the occurrence of the persistence barriers in these two regions. However, this does not mean that the interannual variability of SSTA is not important for the occurrence of the persistence barrier in these two regions. Comparing the left panels of Fig. 2 with Fig. 4, it can be seen that the interannual-interdecadal variability of SSTA has different impacts on SSTA persistence in the SCS and the Indonesia region for every season. The SSTA persistence for winter and spring is long, and is mainly influenced by interdecadal variability, while for the summer and fall it is short and mainly influenced by interannual variability. Thus, the combined effect of the interannual and interdecadal variability is to induce significant seasonal differences in SSTA persistence, and persistence barriers in the SCS and the Indonesia region. In summary, the interdecadal as well as the interannual variability of SSTA are both important for the occurrence of persistence barriers in the SCS and the Indonesia region, which is different from the case of the ENSO SPB.

As mentioned above, in addition to the interannual variability, the persistence barriers in the SCS and the Indonesia region are also associated with the interdecadal variability of SSTA. What are the factors influencing the interdecadal variability and persistence characteristics of SSTA in these two regions? The leading mode with interdecadal time scale in the Pacific is usually called the PDO (Mantua et al., 1997). Are the persistence barriers of SSTA in the SCS and the Indonesia region associated with the PDO? In order to investigate the influence of the PDO on persistence barriers, linear regression is used. The SSTA associated with the PDO is obtained by regressing the SCS (the Indonesia region) SSTA upon the PDO index; the "residual SSTA", the variability associated with the PDO has been removed, is obtained by subtracting the regression value from the original SSTA in the SCS and the Indonesia region. Figure 5 gives the lag correlation for the "residual SSTA". The persistence characteristic of the "residual SSTA", which is linearly independent of the PDO, is similar to the original SSTA and displays a persistence barrier. This indicates that the occurrence of the SSTA persistence barrier in the SCS and the Indonesia region are linearly independent of the PDO. The PDO might therefore not be closely associated with the occurrence of

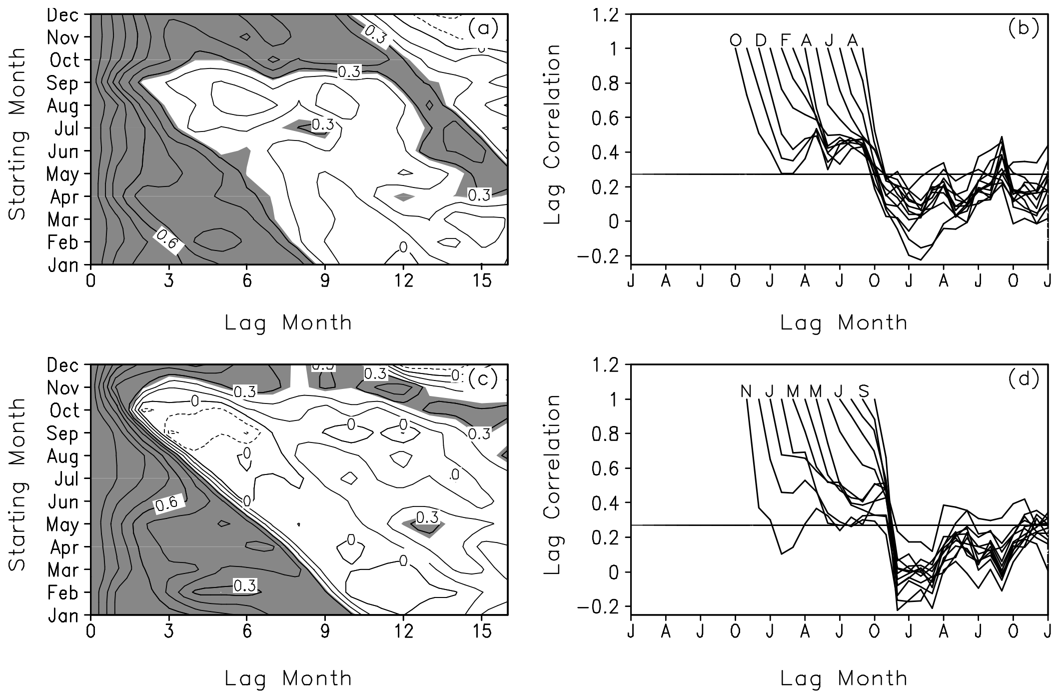

Fig. 5. Same as Figs. 2a–d, but for the "residual SSTA" in the SCS (upper panels) and the Indonesia region (bottom panels) obtained by subtracting the "PDO-related SSTA" from the original SSTA in the SCS and the Indonesia region. The "PDO-related SSTA" is formed by regressing SSTA in the SCS and the Indonesia region upon the PDO index.

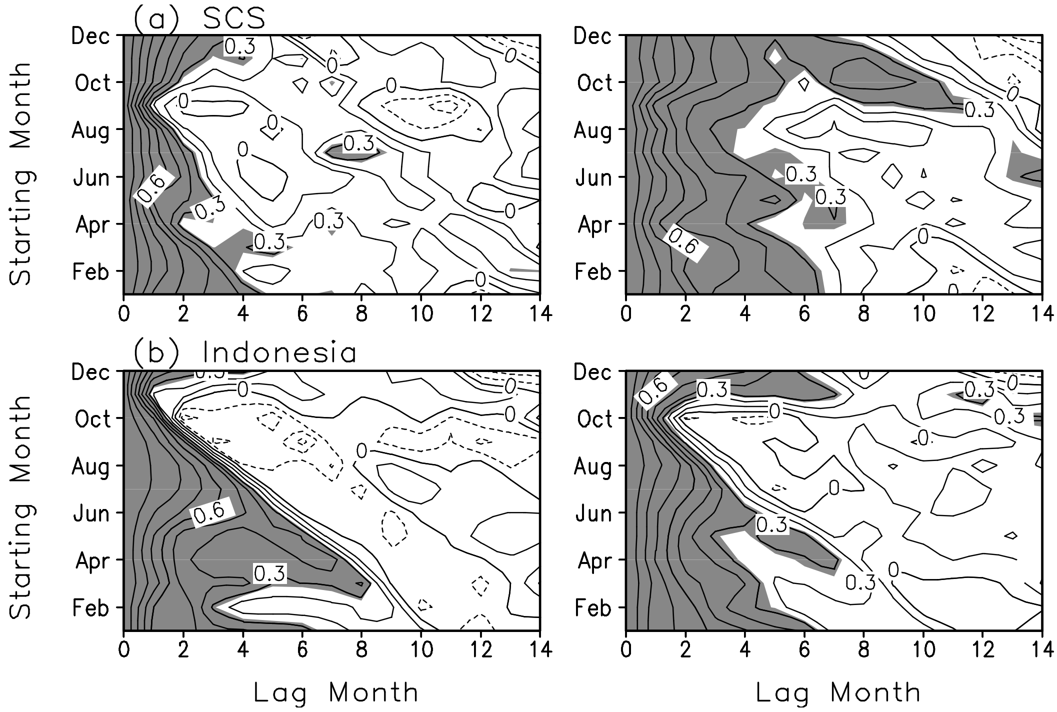

Fig. 6. Lag correlation of SSTA in (a) the SCS region and (b) the Indonesia region. Left panels are for the "residual SSTA" in the SCS and the Indonesia region obtained by subtracting the SSTA associated with the Indian Ocean SSTA from the original SSTA in the SCS and the Indonesia region. Right panels are the same as the left panels, but the SSTA associated with the western Pacific SSTA has been removed using linear regression.

persistence barriers in these two regions.

In addition, the SCS and the Indonesia region are located between the Indian Ocean and the western Pacific, and SSTA in the western Pacific and Indian Ocean also show significant interdecadal variability (e.g. Zhout et al., 2001). Next, the relationships between SSTA in the western Pacific (10°S–30°N, 120°–150°E) and Indian Ocean (20°S–20°N, 50°–100°E) and SSTA persistence barriers in the SCS and the Indonesia region are investigated. The SSTA associated with the Indian Ocean and western Pacific have been removed through linear regression. Figure 6 gives the lag correlation for the "residual SSTA". For the SCS (Fig. 6a), the SSTA in the Indian Ocean might have a close relationship with the SCS persistence barrier, since SSTA in the SCS has a short memory of less than 4 months for all starting months and does not display a persistence barrier when removing the variability associated with the Indian Ocean SSTA (left panel of Fig. 6a). Although there are some changes in the SCS SSTA persistence when the variability associated with the western Pacific SSTA is removed (right panel of Fig. 6a), the changes are not greater than those when the variability associated with the Indian Ocean SSTA is removed. For the Indonesia region (Fig. 6b), it seems that SSTA in the western Pacific is closely related to the persistence of SSTA in the Indonesia region, since the Indonesia SSTA persistence for those starting months from January to June becomes significantly shorter when the SSTA associated with the western Pacific are removed (right panel of Fig. 6b). The changes are not greater than those in the right panels, in which the variability associated with the Indian Ocean SSTA is removed (left panel of Fig. 6b). This indicates that the influence of the interdecadal variability of SSTA on the persistence barrier of SSTA in the SCS and the Indonesia region may be associated with SSTA in the Indian Ocean and western Pacific. However, the dynamic process is not clear, and more in-depth investigation is required in the future.

3.3 *The relationship of the persistence barrier in the SCS and the vicinity of Indonesia with ENSO*

Chen et al. (2007) have already examined the relationship between the SCS FPB and ENSO, and they pointed out that the SCS FPB is well-recognized in the developing phase of strong ENSO cases, but becomes vague in weak ENSO and non-ENSO cases. We perform similar computations for the SCS and the Indonesia region. The ENSO cases are classified into three categories according to the intensity of the win-

Table 1. Member years of strong ENSO, weak ENSO, and non-ENSO cases.

Strong ENSO	El Niño	1957/58, 1965/66, 1972/73, 1982/83, 1986/87, 1991/92, 1997/98
	La Niña	1955/56, 1967/68, 1970/71, 1973/74, 1975/76, 1988/89, 1998/99, 1999/2000
Weak ENSO	El Niño	1968/69, 1969/70, 1976/77, 1987/88, 1994/95, 2002/03, 2003/04
	La Niña	1950/51, 1954/55, 1956/57, 1962/63, 1964/65, 1966/67, 1971/72, 1974/75, 1984/85, 1995/96, 1996/97
Non-ENSO	Positive	1951/52, 1952/53, 1953/54, 1958/59, 1963/64, 1977/78, 1979/80, 1981/82, 1990/91, 1992/93, 1993/94
	Negative	1959/60, 1960/61, 1961/62, 1978/79, 1980/81, 1983/84, 1985/86, 1989/90, 2000/01, 2001/02

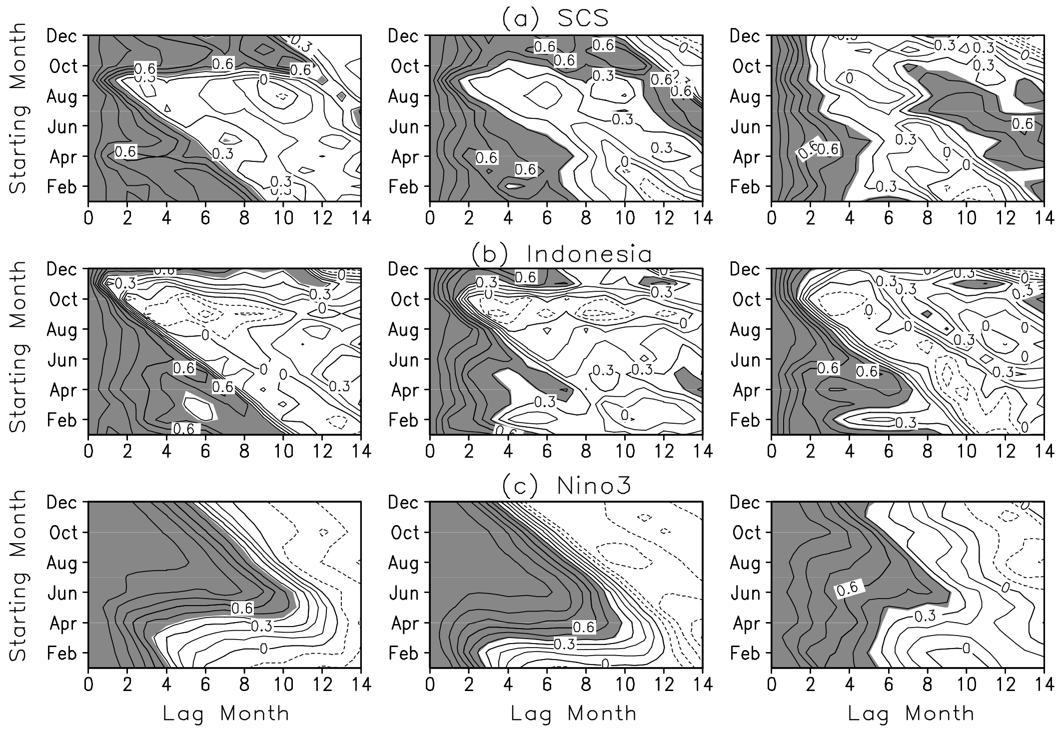

Fig. 7. Lag correlation of SSTA in (a) the SCS region, (b) the Indonesia region, and (c) the Niño-3 region as a function of the starting month (ordinate) and lag month (abscissa) for strong ENSO cases (left panels), weak ENSO cases (middle panels), and non-ENSO cases (right panels). The counter interval is 0.1 and correlation values greater than the 95% confidence level are shaded.

ter (December–February) Niño-3 region SST. A strong ENSO (weak ENSO, non-ENSO) case is defined as a year in which the winter Niño-3 SST has an intensity larger than 1.0 (0.5–1.0, smaller than 0.5) standard deviation (see Table 1). Figure 7 shows the characteristics of SSTA persistence in the SCS and the Indonesia region for these three cases. For ease of comparison, we also give the result of the Niño-3 region. It can be seen that, similar to the SCS and Niño-3 region, the persistence barrier in the Indonesia region is quite obvious for strong ENSO cases. However, the persistence characteristics of SSTA in the Indonesia region have some differences for weak ENSO and non-ENSO cases. For weak ENSO cases, there is no persistence barrier in the Indonesia region, while SSTA in the SCS shows a weak persistence barrier. For non-ENSO cases, SSTA in the Indonesia region shows a weak persistence barrier, while there are no persistence barriers in the SCS and Niño-3 region. It seems that, in addition to ENSO, there may be other factors influencing the persistence barrier in the Indonesia region.

To further investigate the influence of ENSO on the persistence characteristics of SSTA in the SCS and the Indonesia region, linear regression is performed. The variability associated with ENSO is removed by subtracting the regression value from the original SSTA for the SCS and the Indonesia region. Figures 8 and 9 give the persistence characteristics of SSTA in the SCS and the Indonesia region for all years and three ENSO cases, respectively; these are the same as Figs. 2a–d

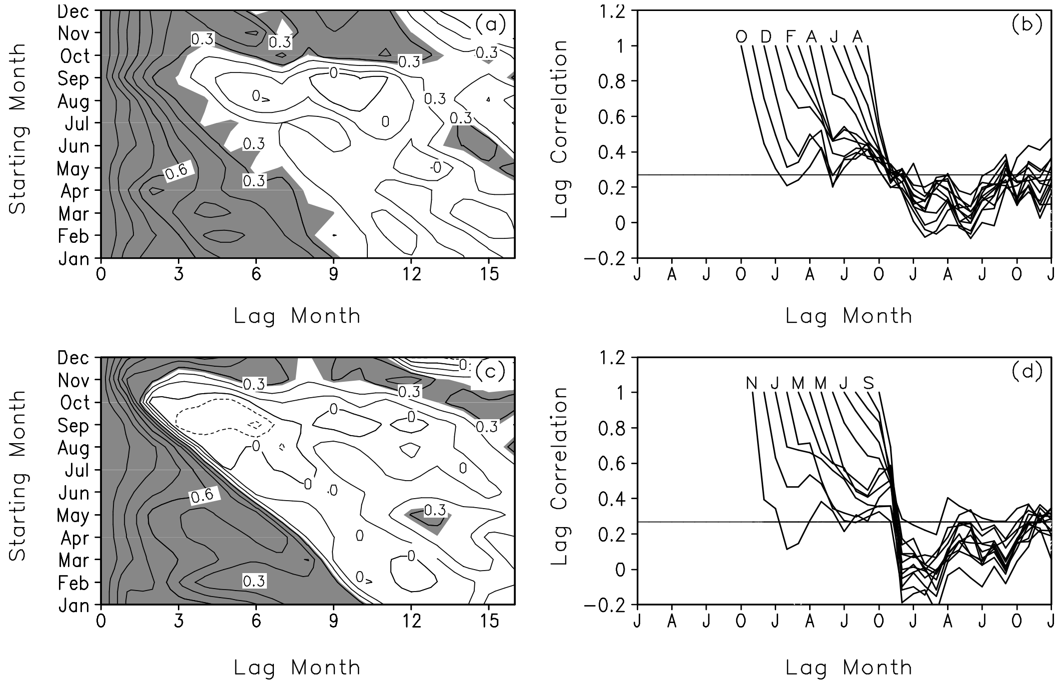

Fig. 8. Same as Figs. 2a–d, but for the "residual SSTA" in the SCS (upper panels) and the Indonesia region (bottom panels) obtained by subtracting the "ENSO-related SSTA" from the original SSTA in the SCS and the Indonesia region. The "ENSO-related SSTA" is formed by regressing the SCS and Indonesia SSTA upon the Niño-3 SSTA.

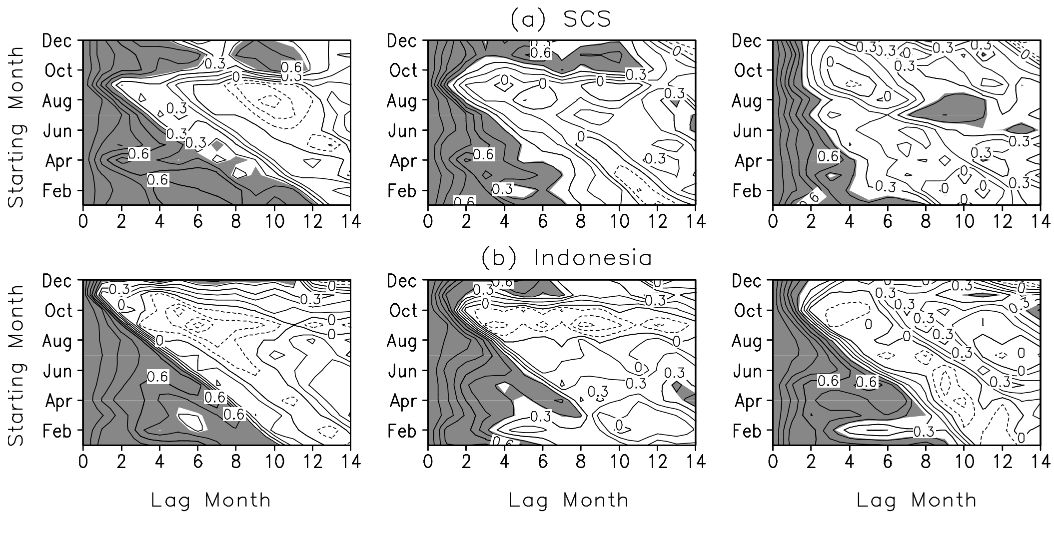

Fig. 9. Same as Figs. 7a and 7b, but subtracting the "ENSO-related SSTA" from the original SSTA in the SCS and the Indonesia region.

and Figs. 7a–b, but with the "ENSO-related SSTA" subtracted from the original SCS and the Indonesia SSTA. It can be seen that there are some changes when the ENSO signal is removed, but the changes are not obvious in either Fig. 8 or Fig. 9, especially for SSTA in the Indonesia region. Moreover, it is known that from variance analysis, the ratio of the ENSO-related variance to the total variance of SSTA in the SCS region is about 13%, while the ratio is about 1% in the Indonesia region. This indicates that, in addition to ENSO, there may be other factors influencing the persistence barrier of SSTA in the SCS and the Indonesia region.

As shown in the previous section, the occurrence of the persistence barriers in the SCS and the Indonesia region are closely connected with both the interdecadal and interannual variability of SSTA. Although the years are classified into three categories according to the intensity of the winter Niño-3 region SST, this does not mean that the interdecadal variability of SSTA in the SCS (the Indonesia region) is filtered out. The combined effect of the interannual and interdecadal variability of SSTA in the SCS (the Indonesia region) may be the reason why the FPB is obvious in strong ENSO case. Thus, it is necessary to further analyze the role of the interannual-interdecadal variability of SSTA in the relationship between persistence barriers and ENSO. We first apply the 7-year high-pass filter to the original data. Subsequently, lag correlation analysis is performed for the three ENSO cases (Table 1), which are the same as those in Fig. 7. Taking into account the effect of the filtering on the degree of freedom and significant test, the effective degrees of freedom are evaluated. Figure 10 shows the characteristics of SSTA persistence in the SCS, the Indonesia region, and the Niño-3 region for the three ENSO cases. It can be seen that, for strong ENSO cases, there are no persistence barriers of SSTA in the SCS and the Indonesia region when low frequency variability (7 years and longer) is removed, because their SSTA have a short memory of less than 4 months for all starting months (Figs. 10a and 10b). This suggests that, owing to the participation of the interdecadal variability of SSTA, the persistence barriers in the SCS and the Indonesia region are quite obvious for strong ENSO cases. Therefore, interdecadal variability of SSTA plays a non-negligible role in the relationship between the persistence barrier in the SCS (the Indonesia region) and the strong ENSO cases. In contrast, the ENSO SPB is not influenced by interdecadal variability, since the persistence barriers in the Niño-3 region are still obvious for strong ENSO cases when low frequency variability is filtered out (Fig. 10c).

4. Summary and discussion

In the present study, the possible causes for the persistence barrier of SSTA in the SCS and its adjacent regions are investigated from a new perspective. Our analyses focus on examining the relationship between the persistence barrier and the interannual-interdecadal variability of SSTA in the SCS and its adjacent regions, and comparing the results with those of the ENSO SPB. The results may be helpful for bet-

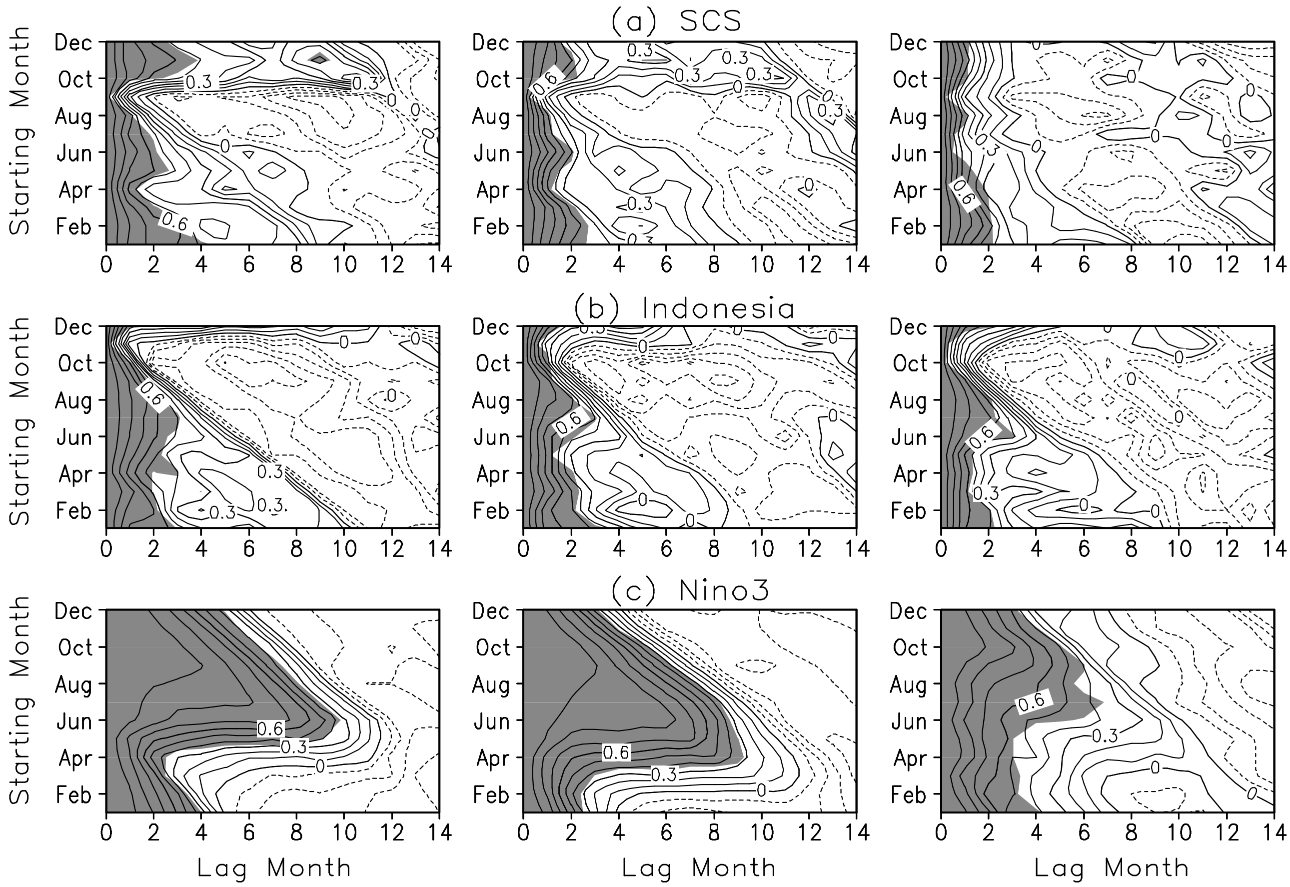

Fig. 10. Same as in Fig. 7, but for the 7-year high-pass filtered data. The effective degrees of freedom are used here.

ter understanding the causes and physical processes of the persistence barrier in the SCS, and for detecting regional differences in the persistence barrier of the SCS and ENSO.

The results indicate that the persistence barrier of SSTA also exists in the vicinity of Indonesia south of the equator as well as the SCS. The SSTA persistence in these two regions shows a rapid decline during October–December, regardless of the starting month. The occurrence of the barrier in the Indonesia region is about one month later than that in the SCS: the SCS barrier occurs around October–November, while around November–December in the Indonesia region.

Variance analysis shows that the ratio of interdecadal variance to the total variance of SSTA in the SCS and the Indonesia region is about 25%, while that in the Niño-3 region is about 10%. The former is obviously larger than the latter. Furthermore, for the SCS and the Indonesia region, the persistence barriers do not exist alone if interdecadal variability is not considered, because SSTA have a short memory of less than 4 months for all starting months. The combined interannual and interdecadal SSTA variability may induce the persistence barriers in the SCS and the Indonesia region. The persistence of SSTA for winter and spring is long, and is mainly influenced by interdecadal variability, while for summer and fall it is short and mainly influenced by interannual variability. Thus, the SSTA persistence shows obvious seasonal differences and persistence barriers. The occurrence of persistence barriers in the SCS and the Indonesia region is therefore closely associated with the interdecadal as well as the interannual variability of the SSTA. However, compared with the ENSO SPB, the close relationship of the persistence barrier and the interdecadal variability of SSTA in the SCS and the Indonesia region is unique, since the ENSO SPB still occurs when the interdecadal variability of SSTA is filtered out. Interdecadal variability of SSTA may not be a necessary factor for the occurrence of the ENSO SPB. These results indicate that there are regional differences between the ENSO SPB and the persistence barrier in the SCS and the Indonesia region.

Although the persistence barriers in the SCS and the Indonesia region are quite obvious for strong ENSO cases, the interdecadal variability of SSTA plays a non-negligible role in this relationship, since the persistence barriers do not occur in strong ENSO cases if the interdecadal variability of SSTA is not considered.

From the above analysis, we can see that in addition to the interannual variability of SSTA, the interdecadal variability is also important for the persistence barrier in the SCS and the Indonesia region. Further investigation shows that the influence of the interdecadal variability of SSTA on the persistence barrier of SSTA in the SCS (the Indonesia region) may be associated with SSTA in the Indian Ocean and western Pacific, but is not closely associated with the PDO. However, the dynamic process is not clear, and more in-depth investigation is required in the future.

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