State Key Laboratory of Numerical Modelling for Atmosph
and Geophysical Fluid Dynamics (LASG)
Institute of Atmospheric Physics, Chinese Academy of Sci

# Influences of ENSO teleconnection on the persistence of sea surface temperature in the tropical Indian and Atlantic oceans

Ruiqiang Ding and Jianping Li

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# Outlines

- Introduction.
- I. Persistence characteristics of the TIO SSTA associated with ENSO.
- II. Persistence characteristics of the NTA SSTA associated with ENSO.
- Summary and discussion.

# Background: ENSO teleconnection

- By shifting tropical convection, El Niño forces a delayed spring warming of the tropical Indian Ocean (TIO) (Klein et al. 1999) and of the northern tropical Atlantic (NTA) (Enfield and Mayer 1997) via atmospheric teleconnection.
- The El Niño-forced warming of the TIO and NTA can persist from spring to summer, strongly influencing the spring and summer regional climate.
  - ✓ The NTA warming forces a northward displacement of the Atlantic ITCZ (Nobre and Shukla 1996).
  - ✓ The TIO warming, following El Niño, has a strong influence on the summer climate over the Indo–western Pacific and East Asia (Xie et al. 2009).

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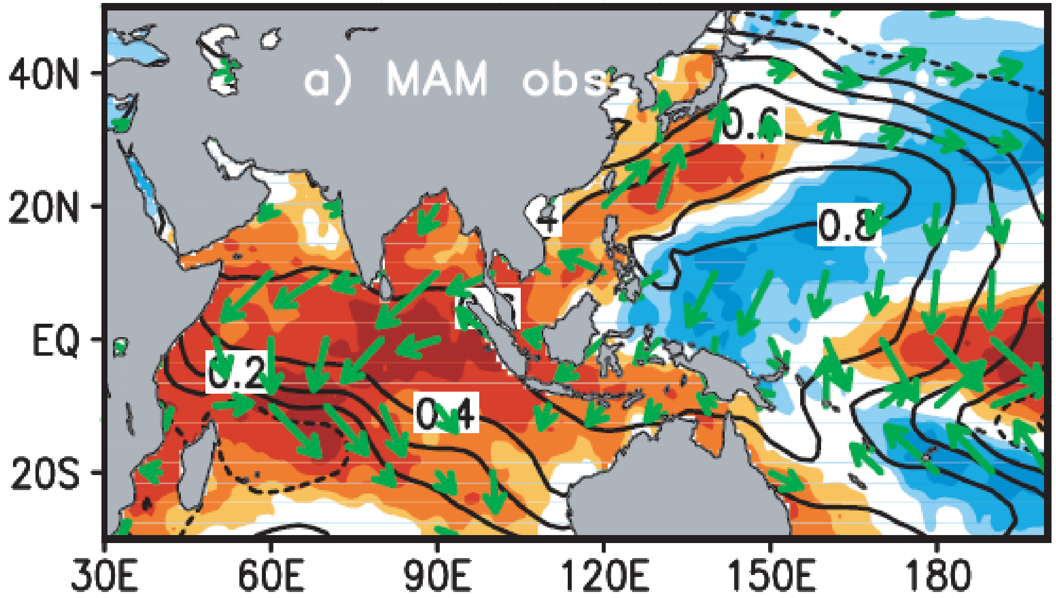
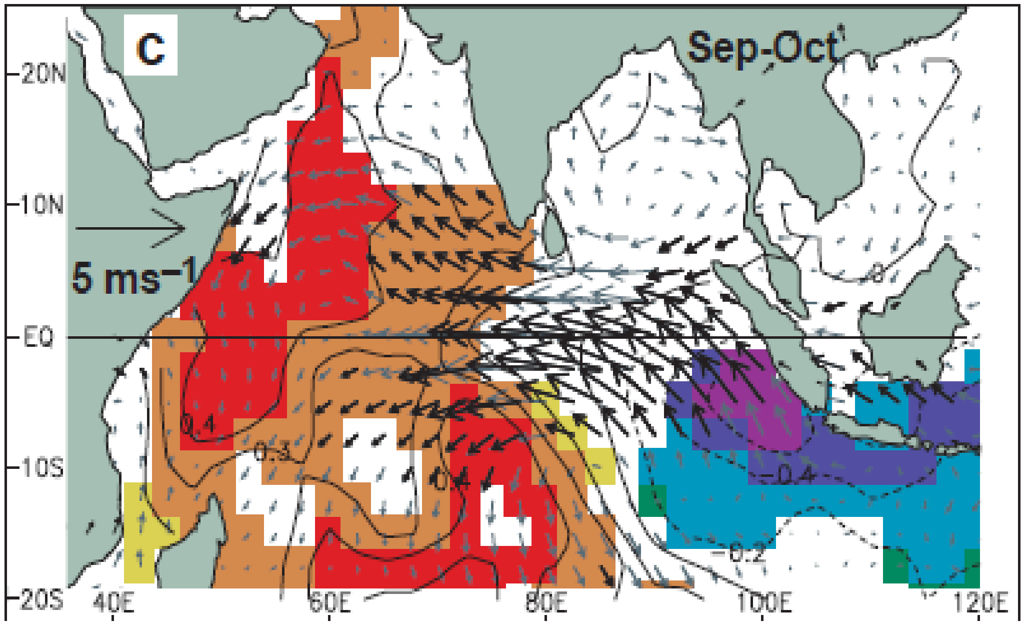
- Introduction.
- I. Persistence characteristics of the TIO SSTA associated with ENSO.
- Persistence characteristics of the NTA SSTA associated with ENSO.
- Summary and discussion.

# Variability of Tropical Indian Ocean




(from Zheng et al. 2011)




(from Saji et al. 1999)

# Purpose of this study

**The previous studies have shown a close linkage between ENSO and the TIO SSTA. However, a detailed analysis of how ENSO influences the persistence of the TIO SSTA is still lacking.**

- **How does the remote influence of ENSO affect the persistence of TIO SSTA?**
- **What are possible mechanisms responsible for these influences?**
- **What are the relative contributions of ENSO and IOD to the persistence of the TIO SSTA?**

# Data and Methodology

## Data

- ✓ HadISST (1900-2007).
- ✓ ERSST V2 (Smith and Reynolds 2004; 1900-2007).
- ✓ NCEP/NCAR reanalysis(1950-2007).
- ✓ Annual cycle are removed, then a 7 year high-pass Gaussian filter.

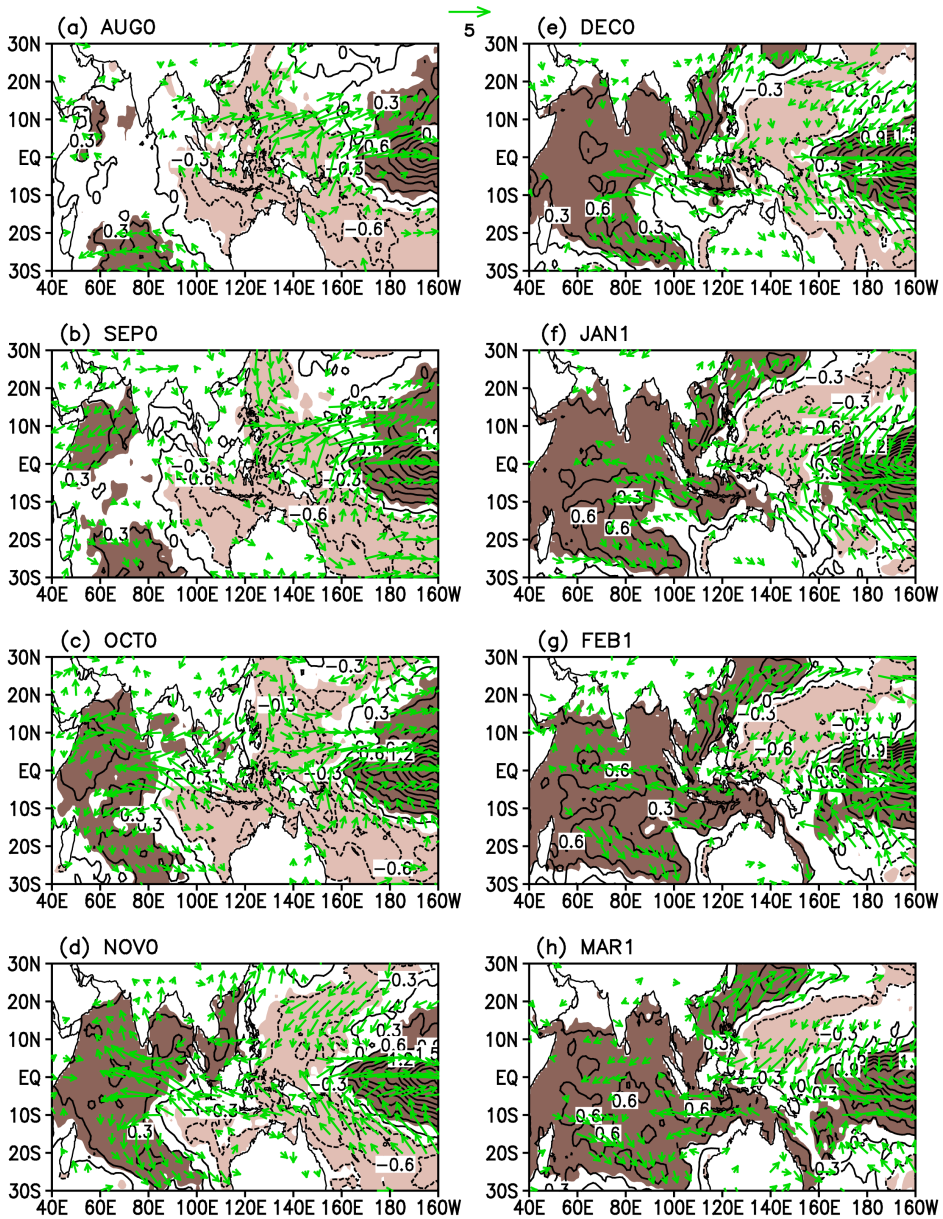
## Methodology

- ✓ Autocorrelation analysis was used to measure the persistence of the SSTA.
  - The correlation between the time series of the starting calendar month (January–December) and the time series of a succeeding lag month in a period of given duration.
- ✓ Persistence barrier is referred as the phenomenon that autocorrelations showing a rapid and significant decrease (autocorrelation reduces to half its value) from one month to the next, regardless of the starting month (Webster and Yang 1992).

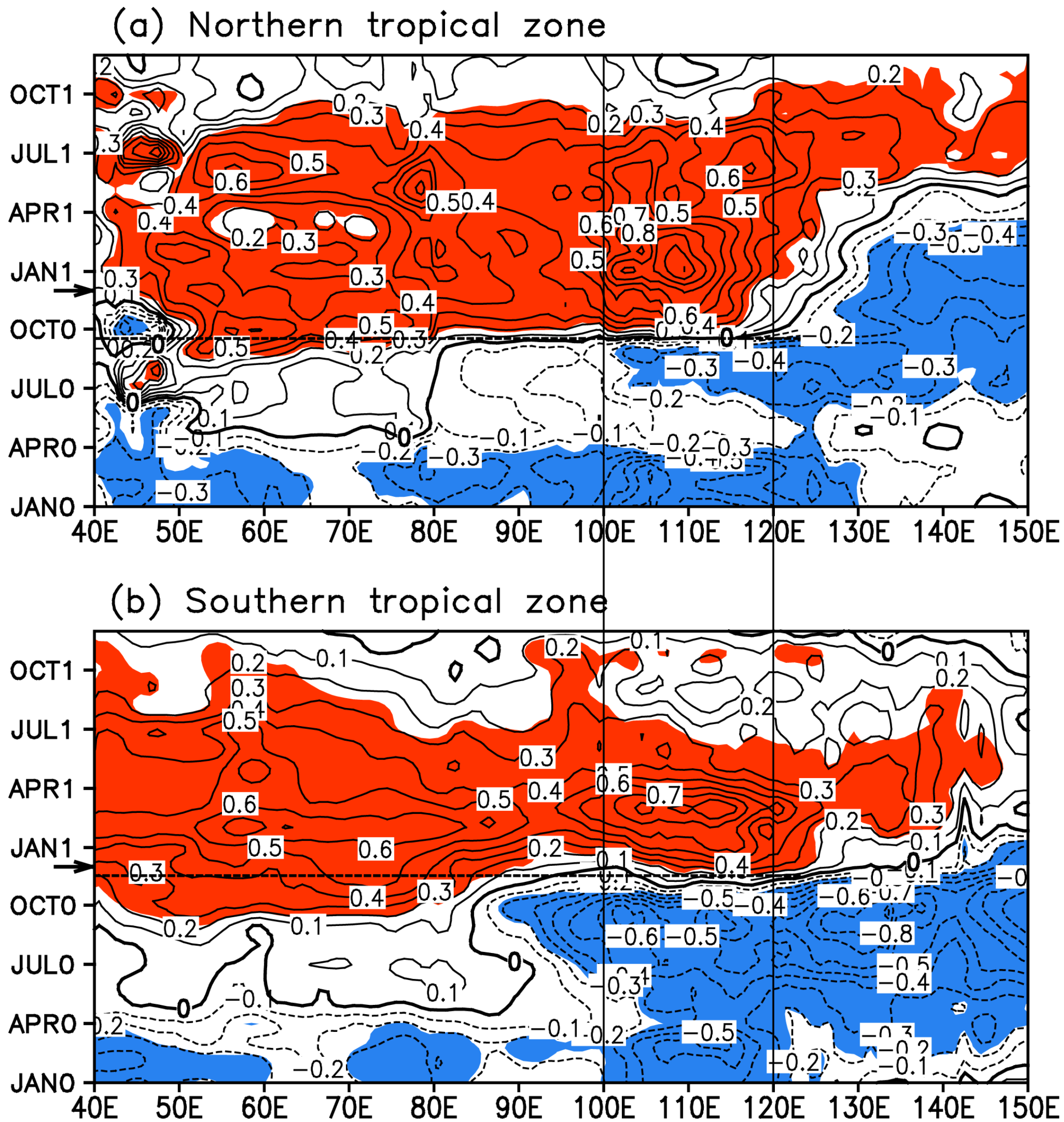
**Table. Member years of strong ENSO, weak ENSO, and normal (non-ENSO) cases for the period 1950–2007.**

| | | |
|---|---|---|
| Strong ENSO | El Niño | 1957, 1965, 1972, 1982, 1986, 1987, 1991, 1994, 1997, 2002 |
| | La Niña | 1954, 1955, 1964, 1970, 1973, 1975, 1988, 1998, 1999, 2007 |
| Weak ENSO | El Niño | 1951, 1963, 1968, 1969, 1976, 1977, 2004, 2006 |
| | La Niña | 1950, 1956, 1962, 1967, 1971, 1974, 1984, 1995, 2000 |
| Normal | Positive | 1952, 1953, 1958, 1979, 1990, 1992, 1993, 2003 |
| | Negative | 1959, 1960, 1961, 1966, 1978, 1980, 1981, 1983, 1985, 1989, 1996, 2001, 2005 |

# Evolution of the TIO SSTA associated with ENSO



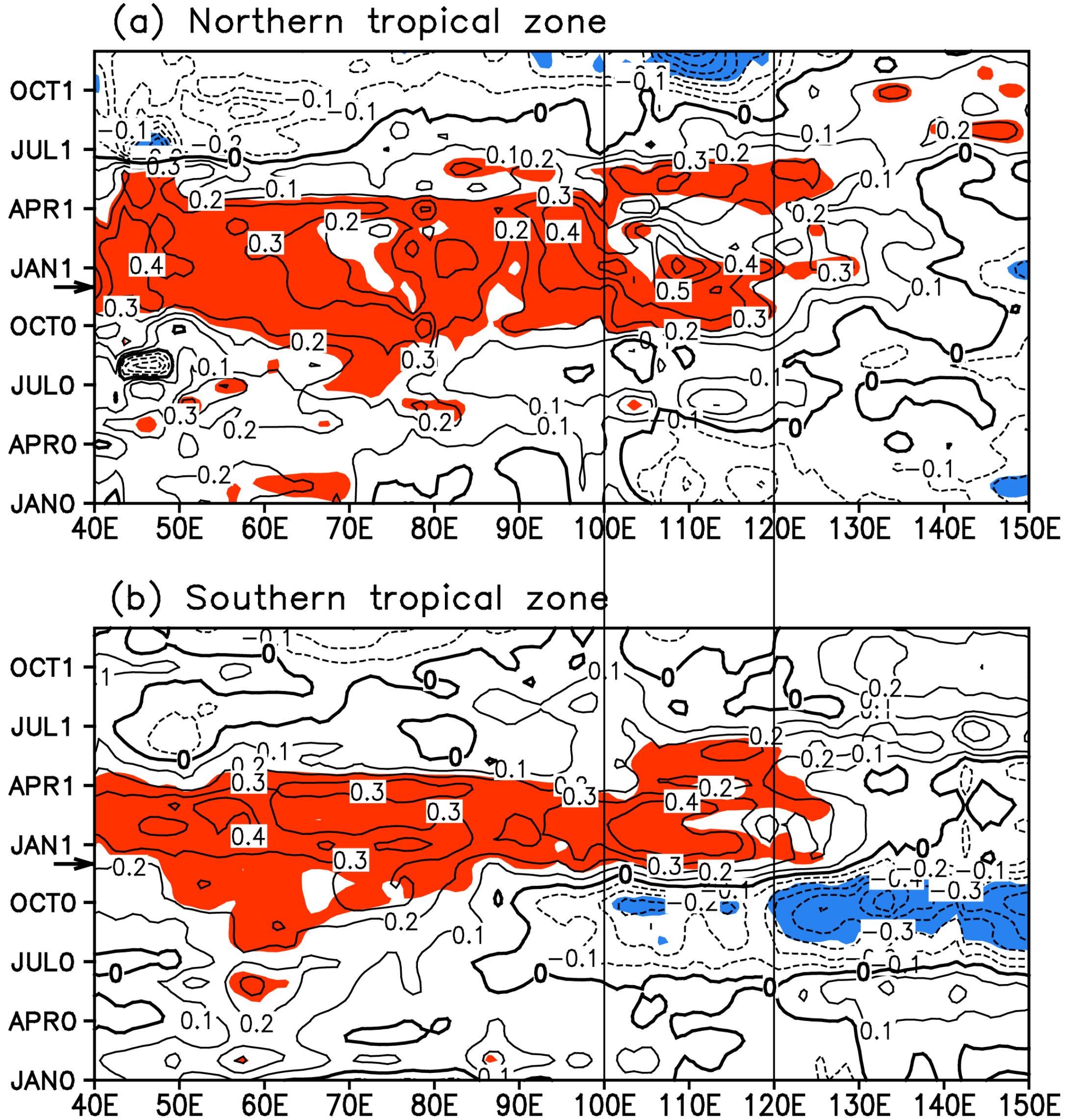

**Composite difference of the SSTA and surface wind velocity for strong ENSO cases during their developing and mature phases.**




(averaged over the 5N to 20N zone)

(averaged over the 15S to 0 zone)

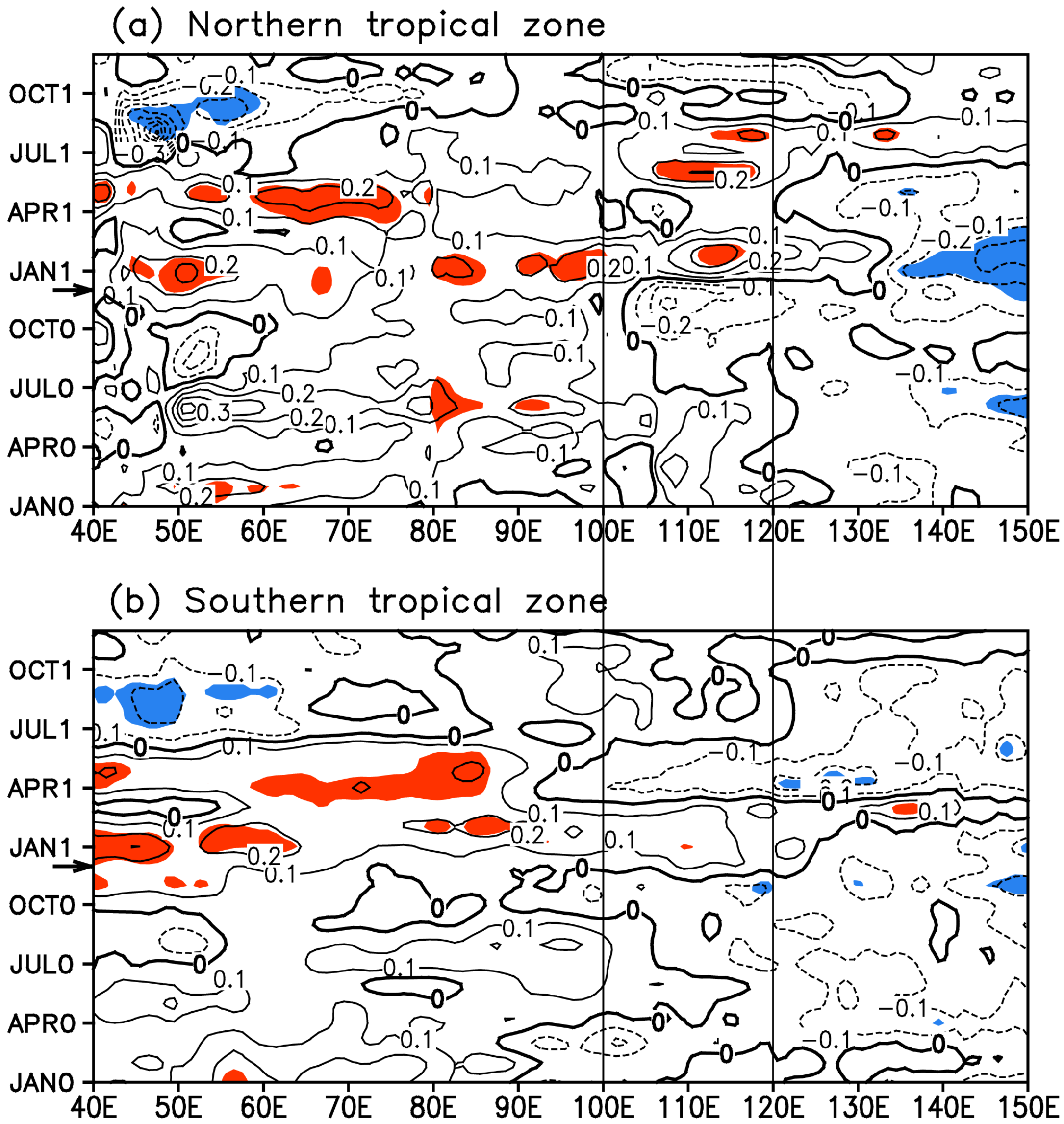
**Longitude–time diagrams of the composite difference of the SSTA averaged over the northern and southern zones**




(averaged over the 5N to 20N zone)

(averaged over the 15S to 0 zone)

**Longitude–time diagrams of the composite difference of the SSTA averaged over the northern and southern zones for weak ENSO cases**




(averaged over the 5N to 20N zone)

(averaged over the 15S to 0 zone)

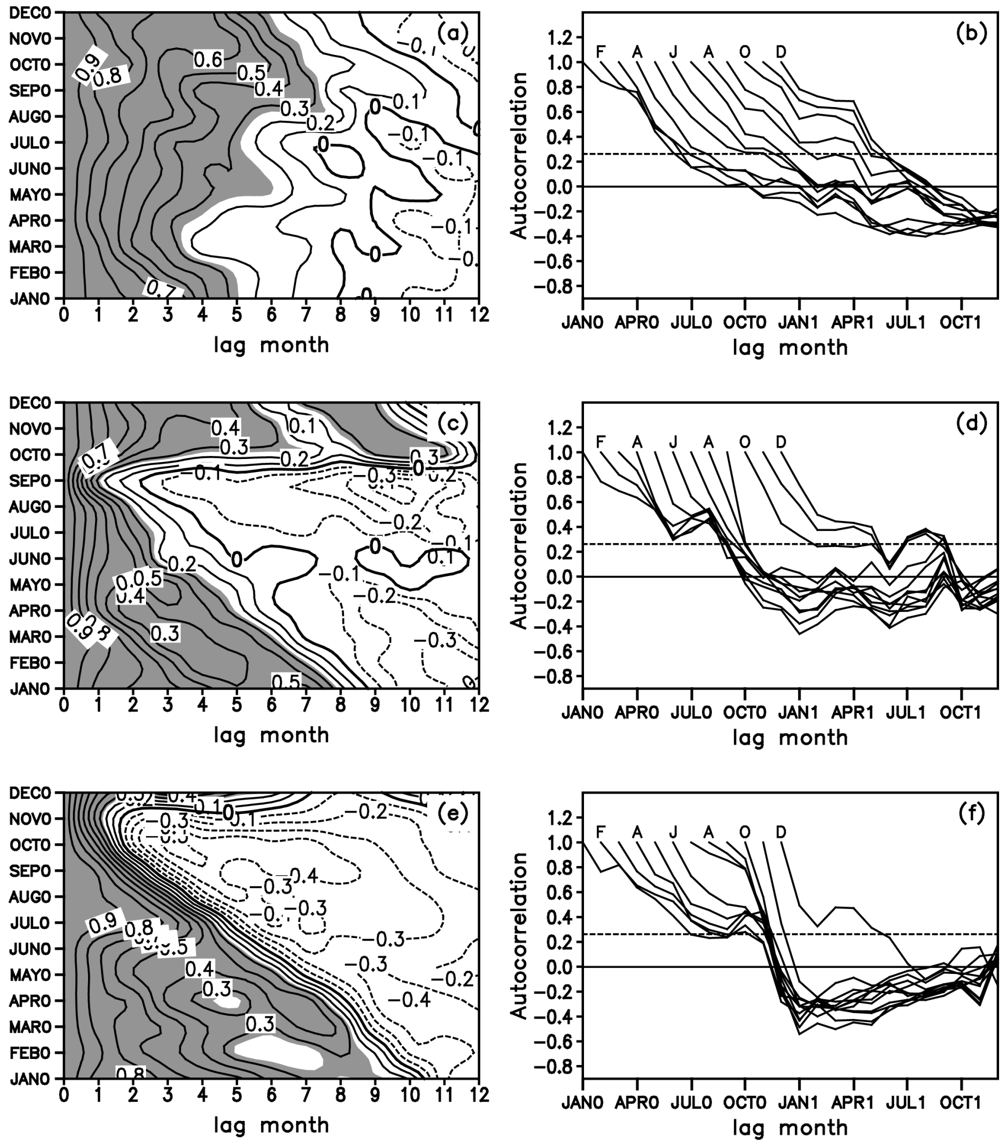
**Longitude–time diagrams of the composite difference of the SSTA averaged over the northern and southern zones for no-ENSO cases**

# Persistence characteristics of the TIO SSTA

**WIO**
**(50-70E, 10S-10N)**

**SCS**
**(100-120E, 5-20N)**

**SEIO**
**(100-120E, 15S-0)**

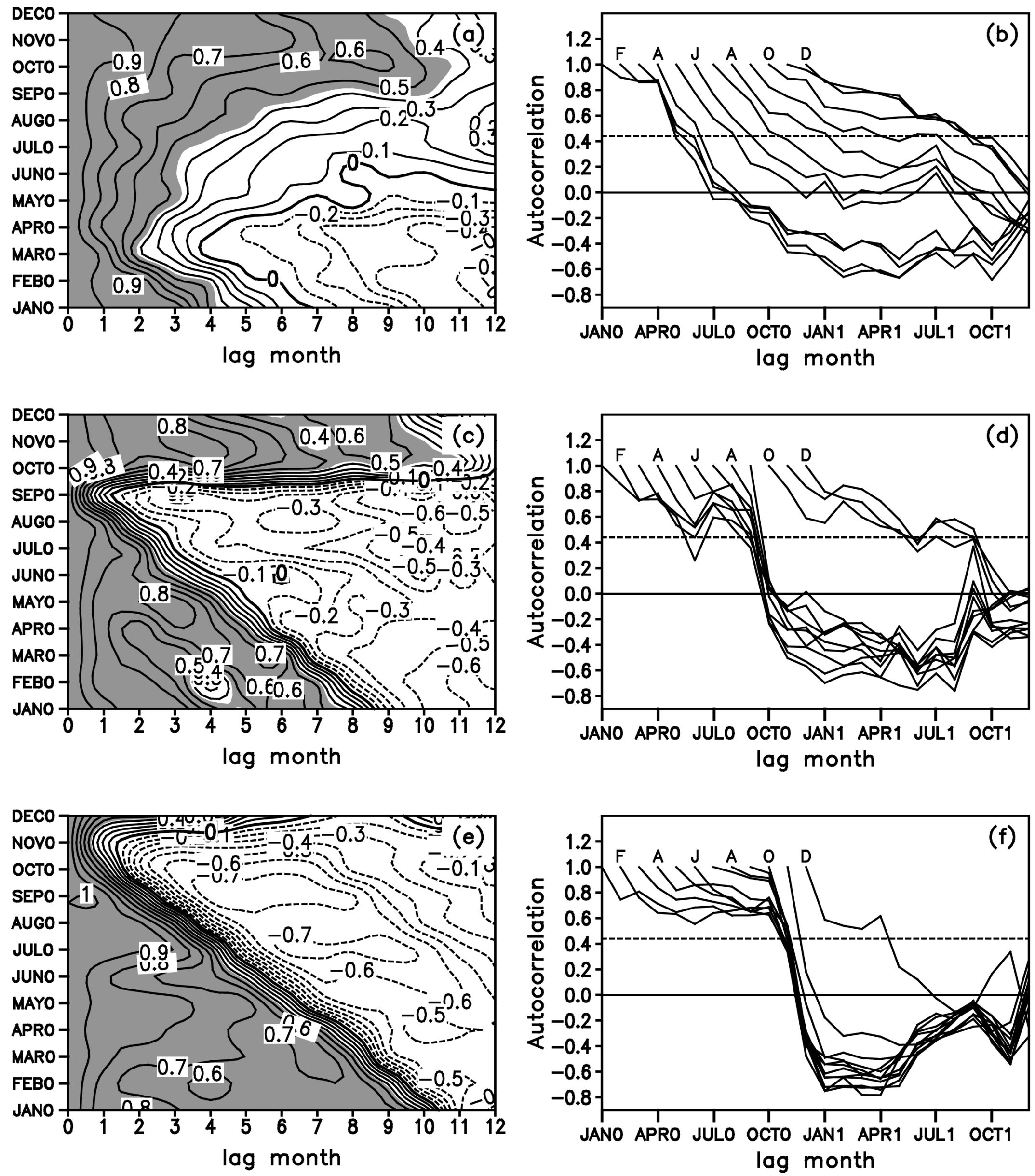



**Autocorrelations of the area-averaged SSTA for the period 1950-2007**

**WIO**
**(50-70E, 10S-10N)**

**SCS**
**(100-120E, 5-20N)**

**SEIO**
**(100-120E, 15S-0)**

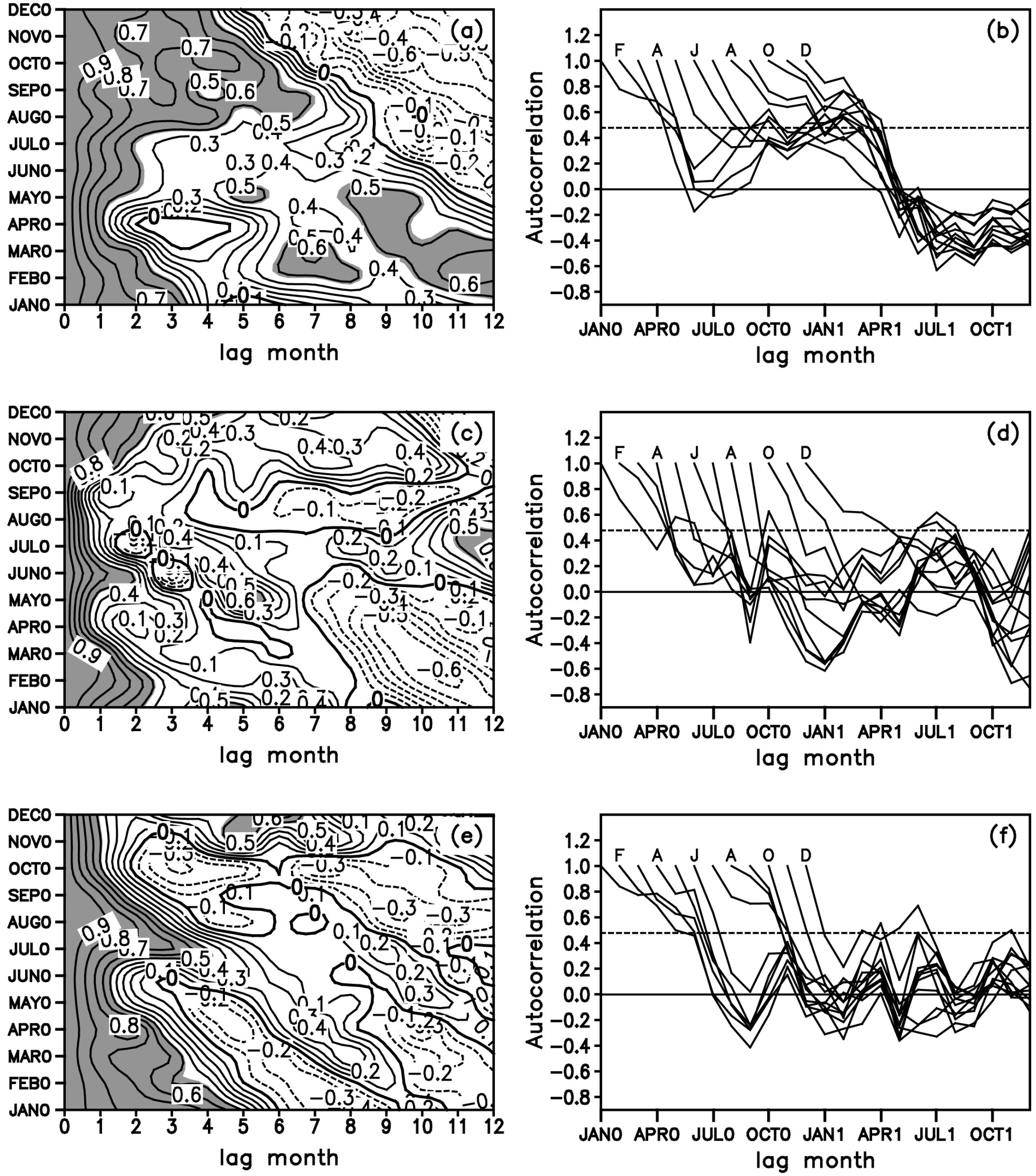



**Autocorrelations of the area-averaged SSTA for strong ENSO cases**

**WIO**
**(50-70E, 10S-10N)**

**SCS**
**(100-120E, 5-20N)**

**SEIO**
**(100-120E, 15S-0)**

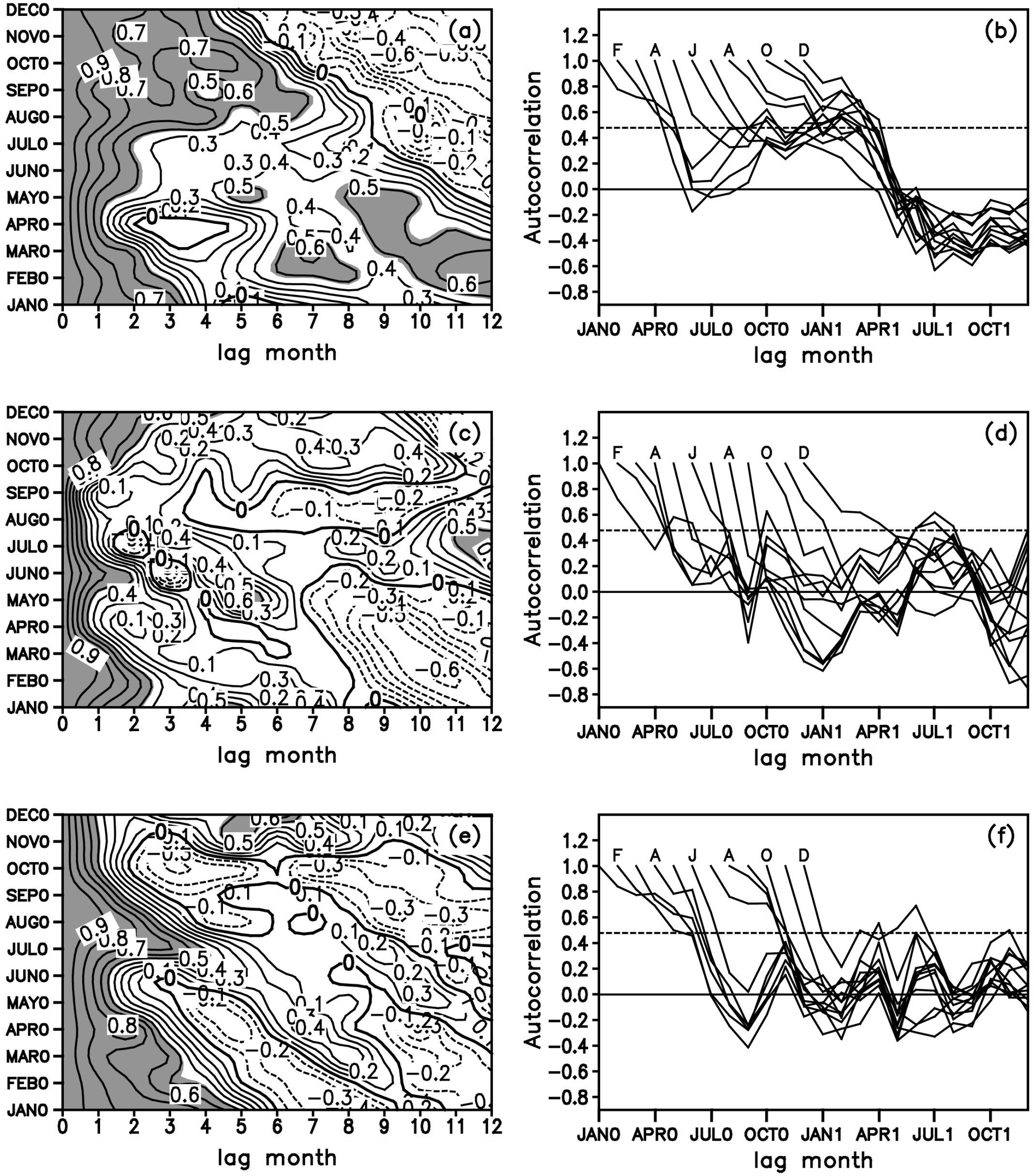



**Autocorrelations of the area-averaged SSTA for weak ENSO cases**

**WIO**
**(50-70E, 10S-10N)**

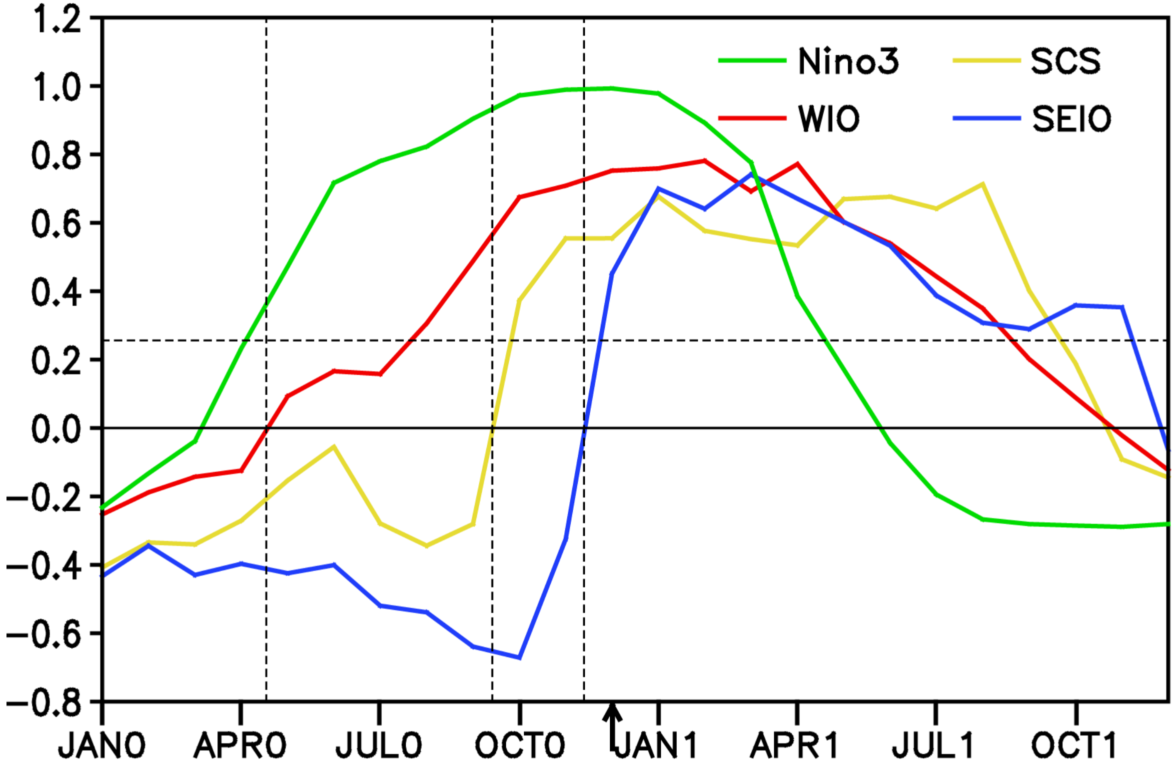
**SCS**
**(100-120E, 5-20N)**

**SEIO**
**(100-120E, 15S-0)**




**Autocorrelations of the area-averaged SSTA for Non-ENSO cases**

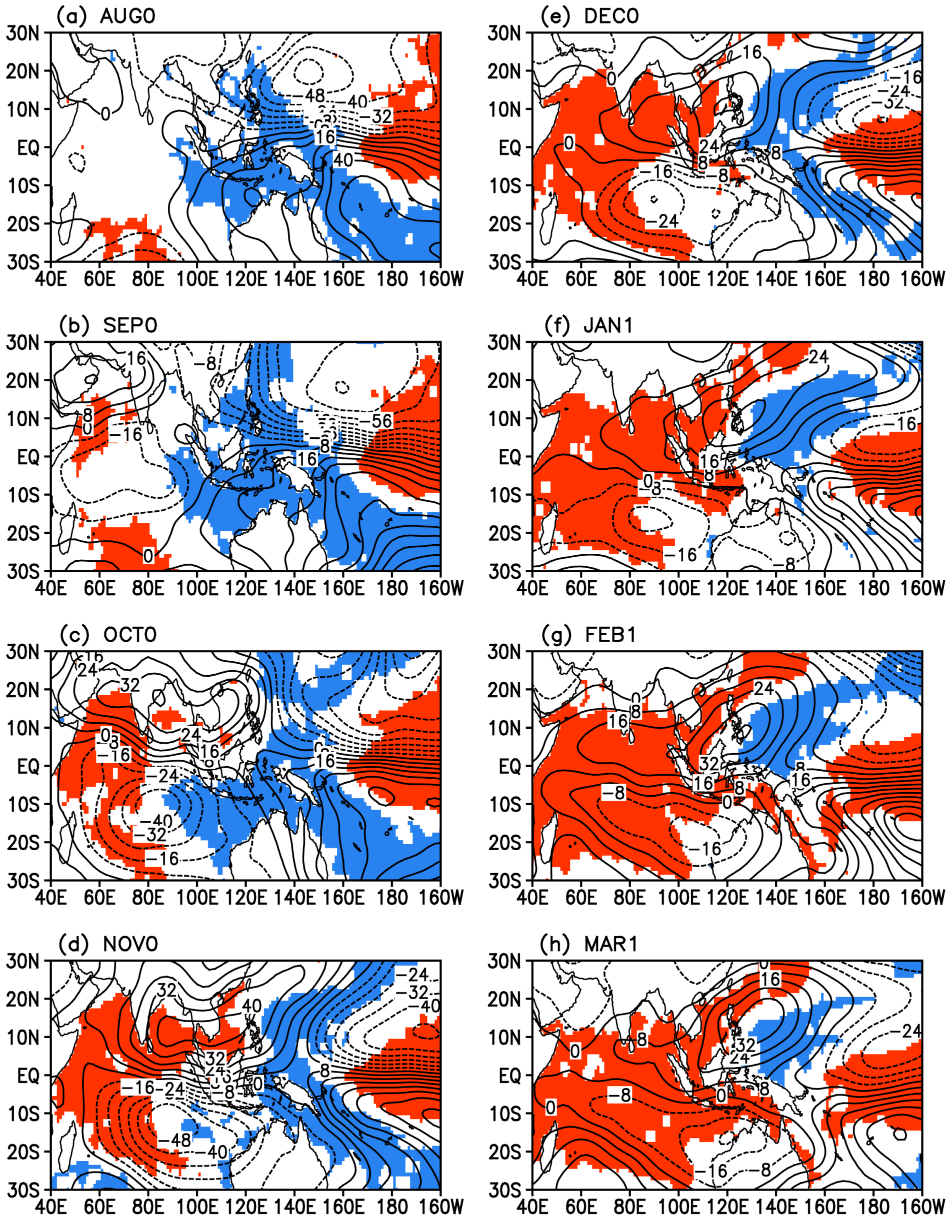
# Mechanisms of barrier development



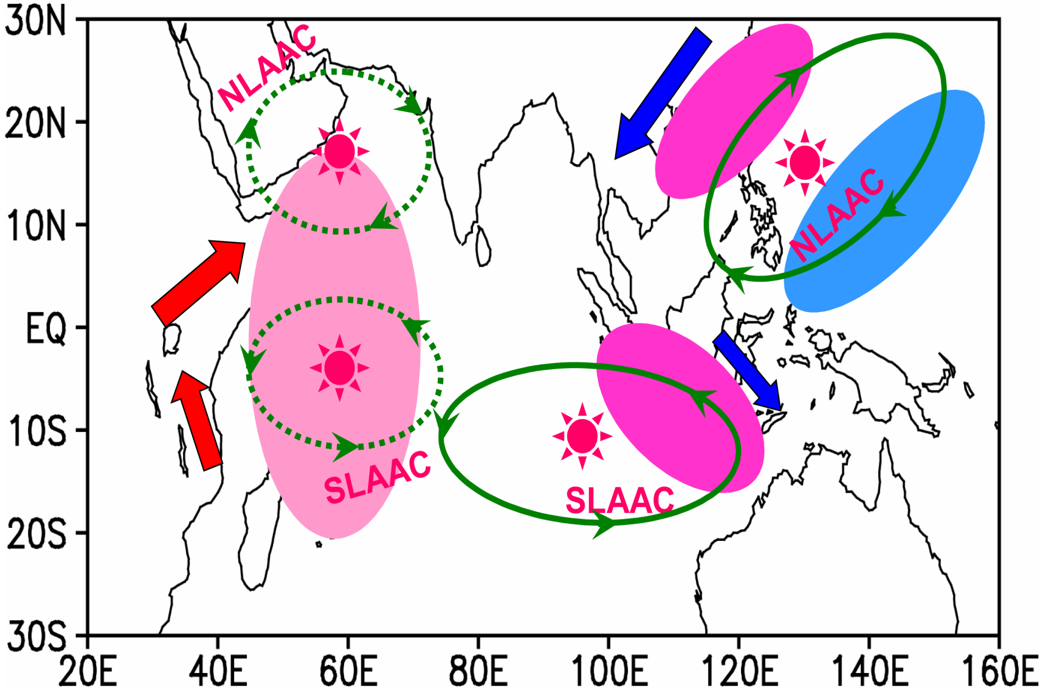

weak strong strongest

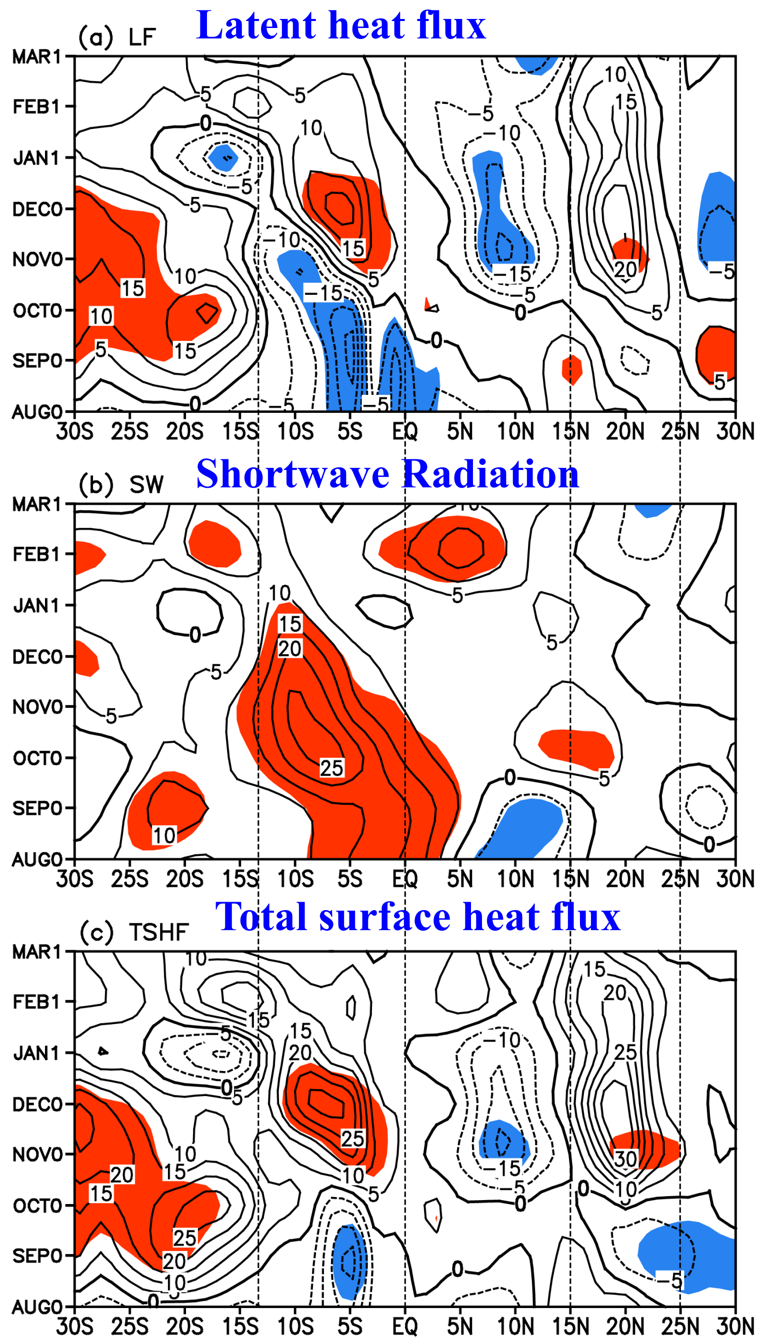
**The occurrence seasons and strengths of the persistence barriers are consistent with those of the SSTA sign reversal, indicating a close connection between the two phenomena. The sign reversal of SSTA implies a rapid decrease in the SSTA persistence, which is favorable for the occurrence of a persistence barrier.**

# Mechanisms by which ENSO affects the TIO SSTA




**Composite difference of the 850 mb level stream function and the SSTA for strong ENSO cases**




**Schematic diagram summarizing the processes that may explain how ENSO causes successive sign reversals in the WIO, SCS, and SEIO SSTA.**

# Why are persistence barriers phase-locked to different seasons?

**The seasonal cycle of the prevailing surface winds has an important influence on the timing of the persistence barriers in the TIO.**

**The WIO SPB occurs in spring ⟷ wintermonsoon to summermonsoon flows.**

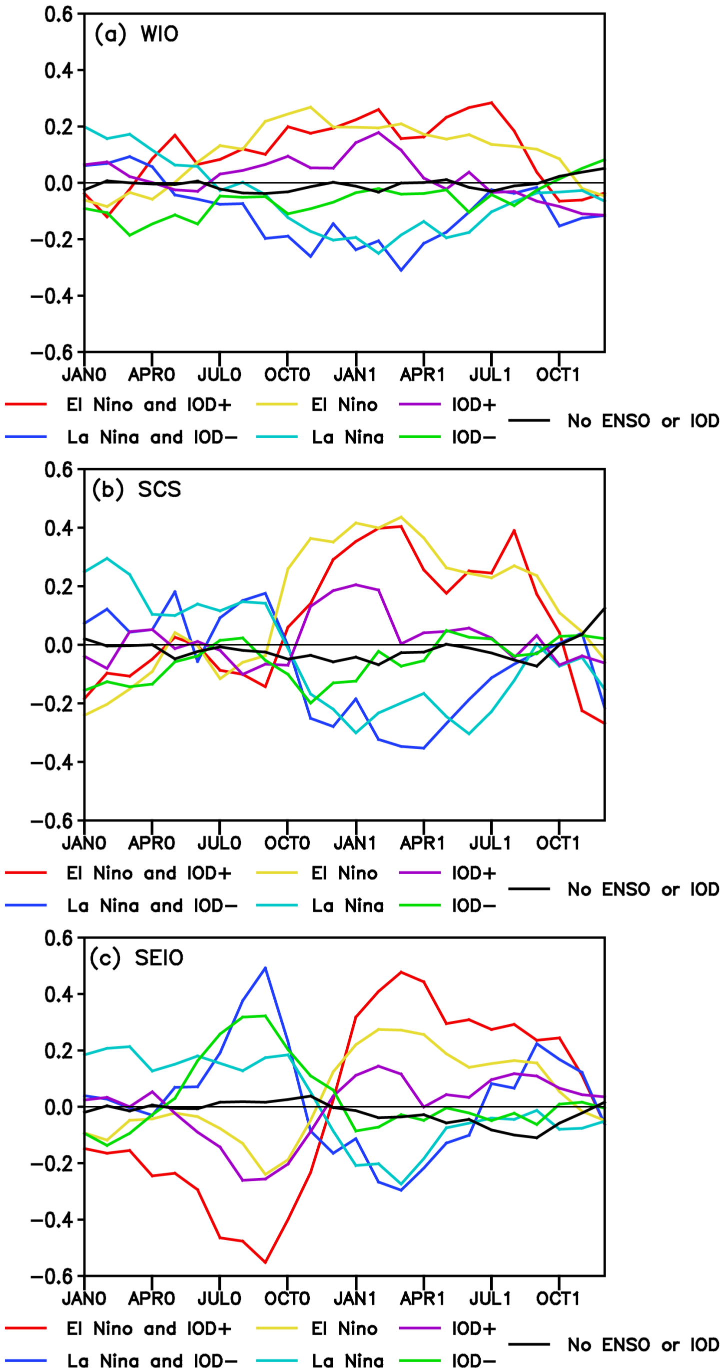
**The SCS FPB occurs in fall ⟷ southwest summermonsoon to the northeast winter monsoon.**

**The SEIO WPB occurs in winter ⟷ prevailing southeasterly flows to cross-equatorial northwesterly flows**

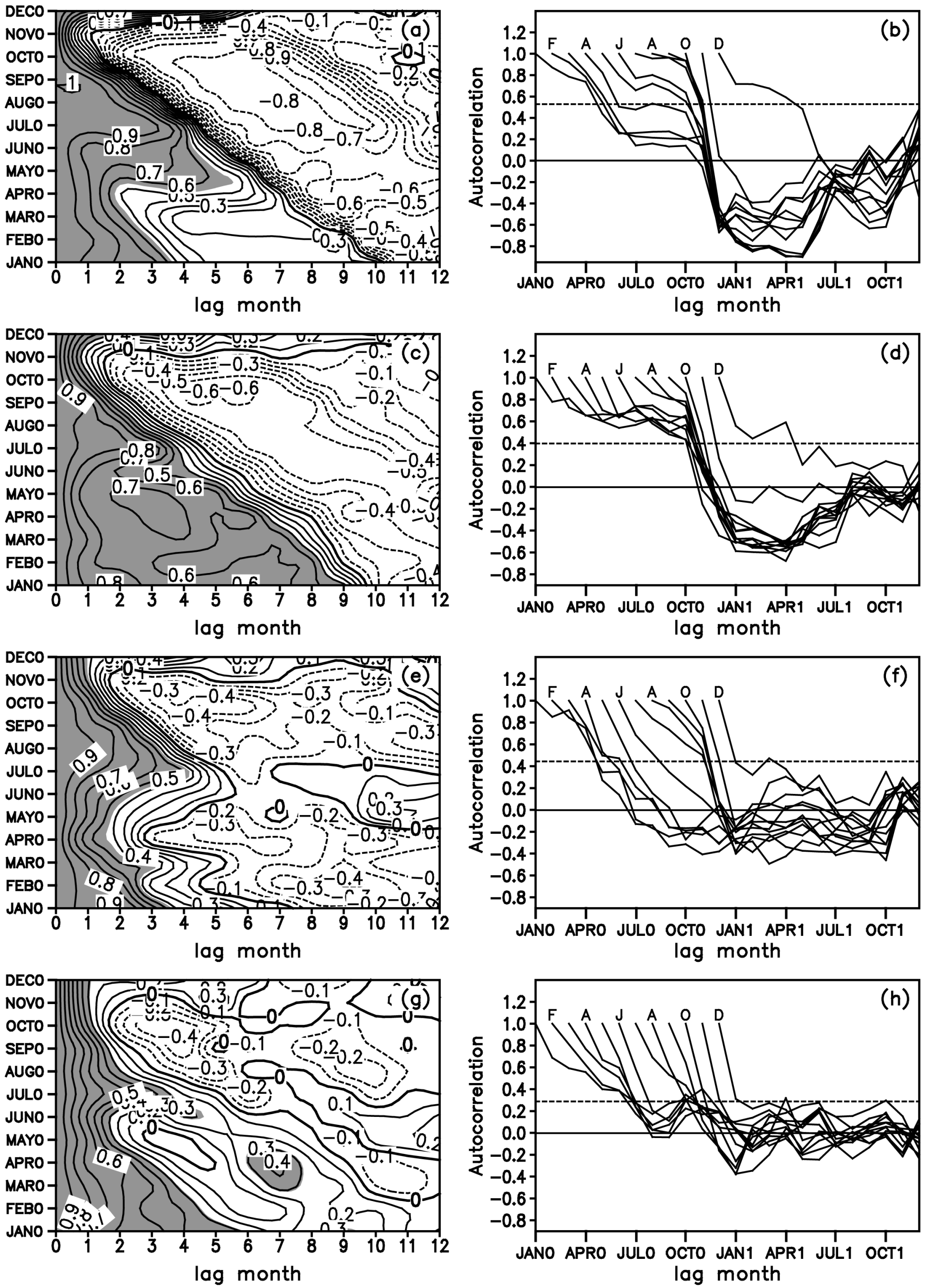
# Influences of IOD on the TIO persistence

**Table. Classification of years in which El Niño or La Niña and/or positive or negative IOD occurred during the period 1900–2007.**

| | Negative IOD | No event | Positive IOD |
|---|---|---|---|
| El Niño | 1930 | 1905, 1911, 1914, 1918, 1925, 1940, 1941, 1965, 1986, 1987, 2002 | 1902, 1957, 1972, 1982, 1991, 1994, 1997 |
| No event | 1917, 1928, 1958, 1968, 1974, 1980, 1985, 1989, 1992, 1996, 2005 | 1900, 1901, 1904, 1907, 1908, 1910, 1912, 1915, 1920, 1921, 1927, 1929, 1931, 1932, 1934, 1936, 1937, 1939, 1943, 1945, 1947, 1948, 1950, 1951, 1952, 1953, 1956, 1959, 1960, 1962, 1966, 1969, 1971, 1976, 1977, 1979, 1981, 1983, 1984, 1990, 1993, 1995, 2000, 2001, 2003 | 1913, 1919, 1923, 1926, 1935, 1944, 1946, 1961, 1963, 1967, 1978, 2004, 2006 |
| La Niña | 1906, 1909, 1916, 1933, 1942, 1975, 1988 | 1903, 1922, 1924, 1938, 1949, 1954, 1955, 1964, 1970, 1973, 1998, 1999, 2007 | |




**Composite difference of the area-averaged SSTA over the (a) WIO, (b) SCS, and (c) SEIO for categories of the ENSO–IOD relationship**




El Niño with positive IOD &
La Niña with negative IOD

pure El Niño & La Niña

pure positive IOD & negative IOD

no-ENSO or IOD

# Summary I

- This study confirms a weak SPB of SSTA in the WIO, a strong FPB in the SCS, and the strongest WPB in the SEIO.
- During El Niño events, a less abrupt sign reversal of SSTA occurs in the WIO during spring, an abrupt reversal occurs in the SCS during fall, and the most abrupt reversal occurs in the SEIO during winter. The present results indicate that a more abrupt reversal of SSTA sign generally corresponds to a more prominent persistence barrier.
- El Niño-induced changes in atmospheric circulation result in reduced evaporation and suppressed convection. This in turn leads to the warming over much of the TIO Basin, which is an important mechanism for the abrupt switch in SSTA in the northern SCS and SEIO. The seasonal cycle of the prevailing surface winds has a strong influence on the timing of the persistence barriers in the TIO.

# Summary I

- **The Indian Ocean Dipole (IOD) alone can cause a weak WPB in the SEIO. El Niño events co-occurring with positive IOD further strengthen the SEIO WPB. The SEIO WPB appears to be more strongly influenced by ENSO than by the IOD. In contrast, the WIO SPB and the SCS FPB are relatively independent of the IOD.**

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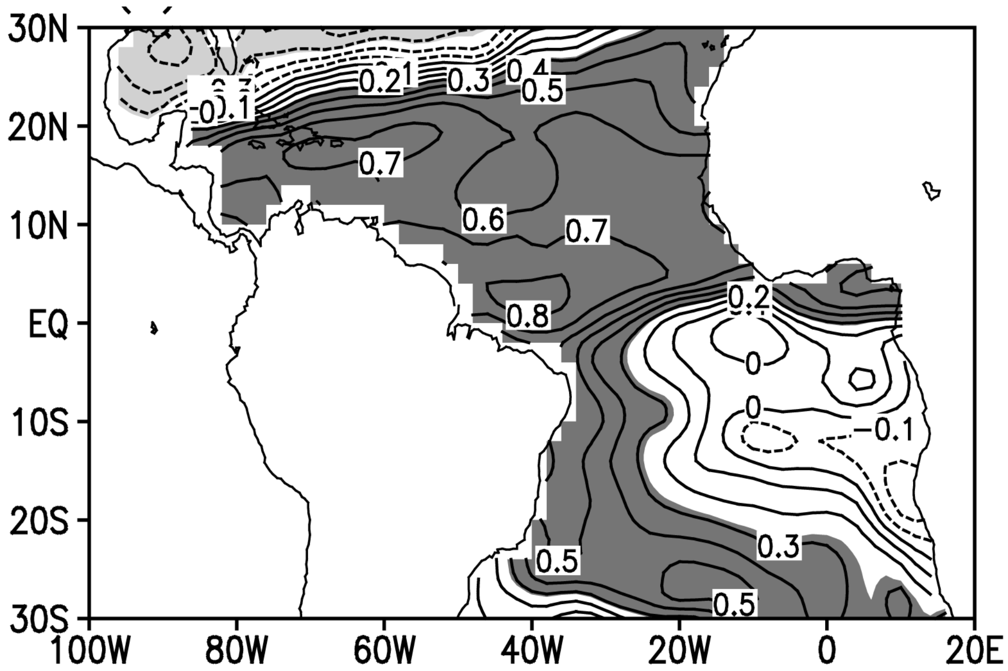
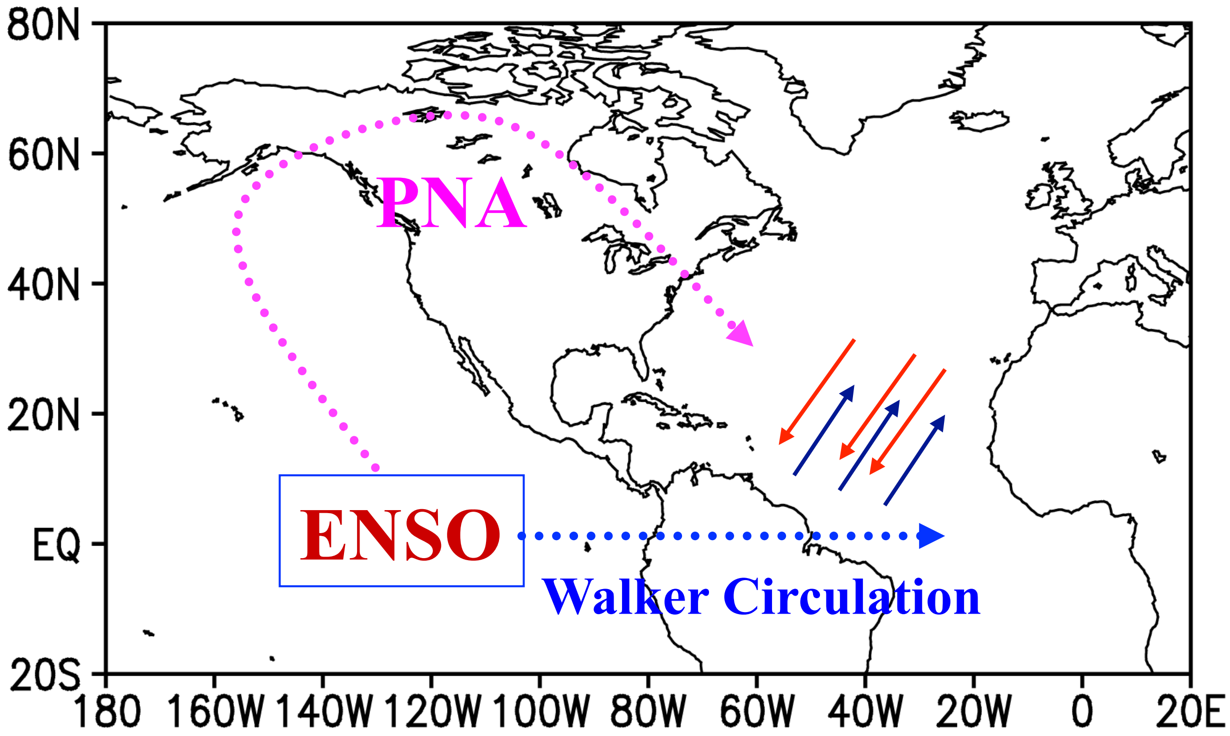
# NTA: the major region affected by ENSO




**Correlations of the winter (DJF) Niño-3 index with the TA SSTA in the following spring (MAM)** **(e.g., Enfield and Mayer 1997; Penland and Matrosova 1998; Latif and Grötzner 2000; Saravanan and Chang 2000; Chang et al. 2003; Huang 2004)**

**The significant warming in the NTA occurs approximately 4–5 months after the mature phase of Pacific warm events.**

# Two mechanisms that ENSO affects the NTA




**Two mechanisms via which ENSO may influence the NTA region: (1) the PNA pattern and (2) the Walker and Hadley circulations (e.g., Nobre and Shukla 1996; Saravanan and Chang 2000; Sutton et al. 2000; Wang 2002, 2004; Handoh et al. 2006)**

# Tropical Atlantic Variability

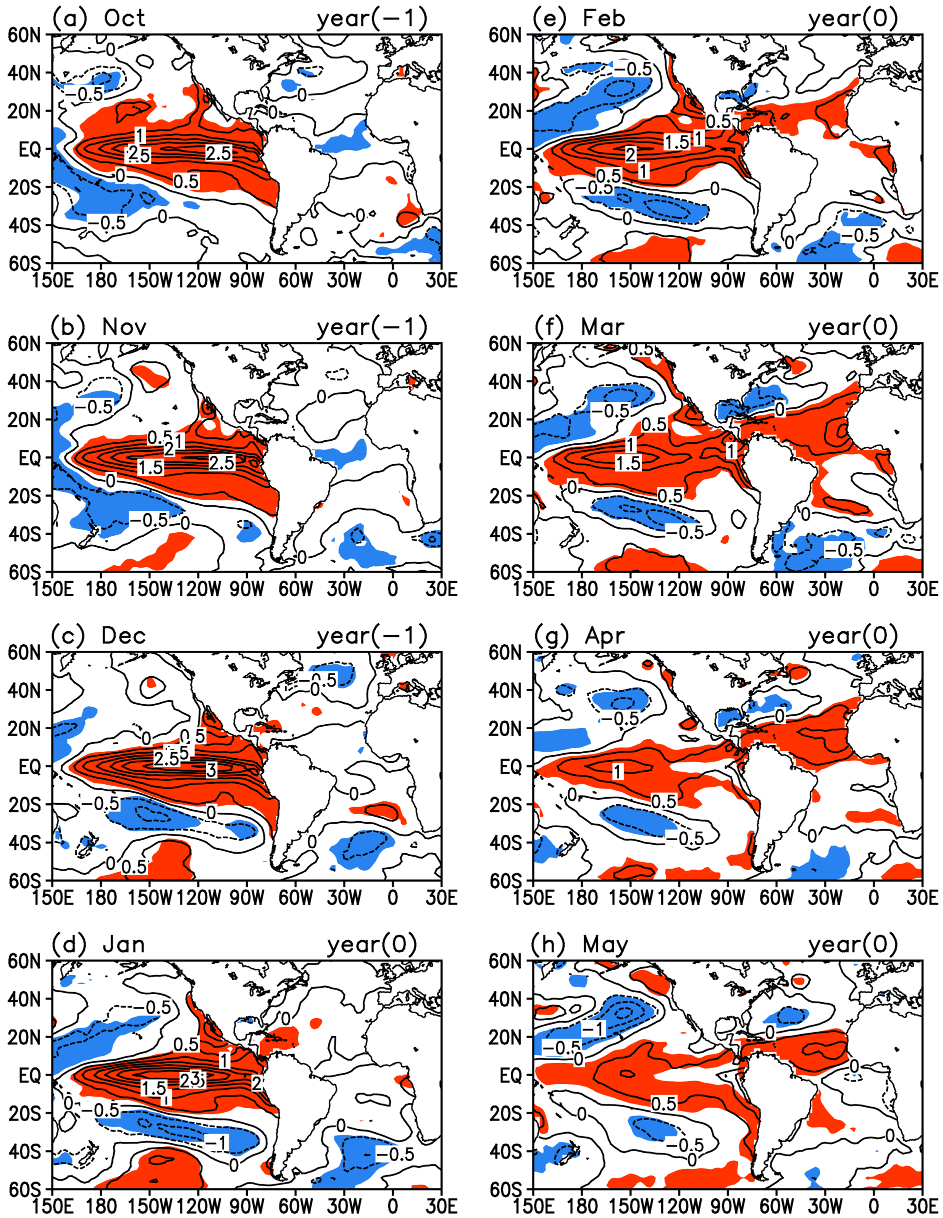
- **TAV influences: rainfall over northeast Brazil and sub-Saharan drought (Folland et al. 1986; Taschetto and Wainer 2008).**
- **Impact factors on the TAV**
  - ✓ **ENSO (Enfield and Mayer 1997; Chang et al. 2003; Huang 2004).**
  - ✓ **NAO (Deser and Timlin 1997; Marshall et al. 2001).**
  - ✓ **Regional ocean-atmosphere interactions (Huang et al. 2002; Huang and Shukla 2005).**

# Purpose of this study

**The dynamic relationships that exist between the NTA SSTA and ENSO give rise to two questions:**

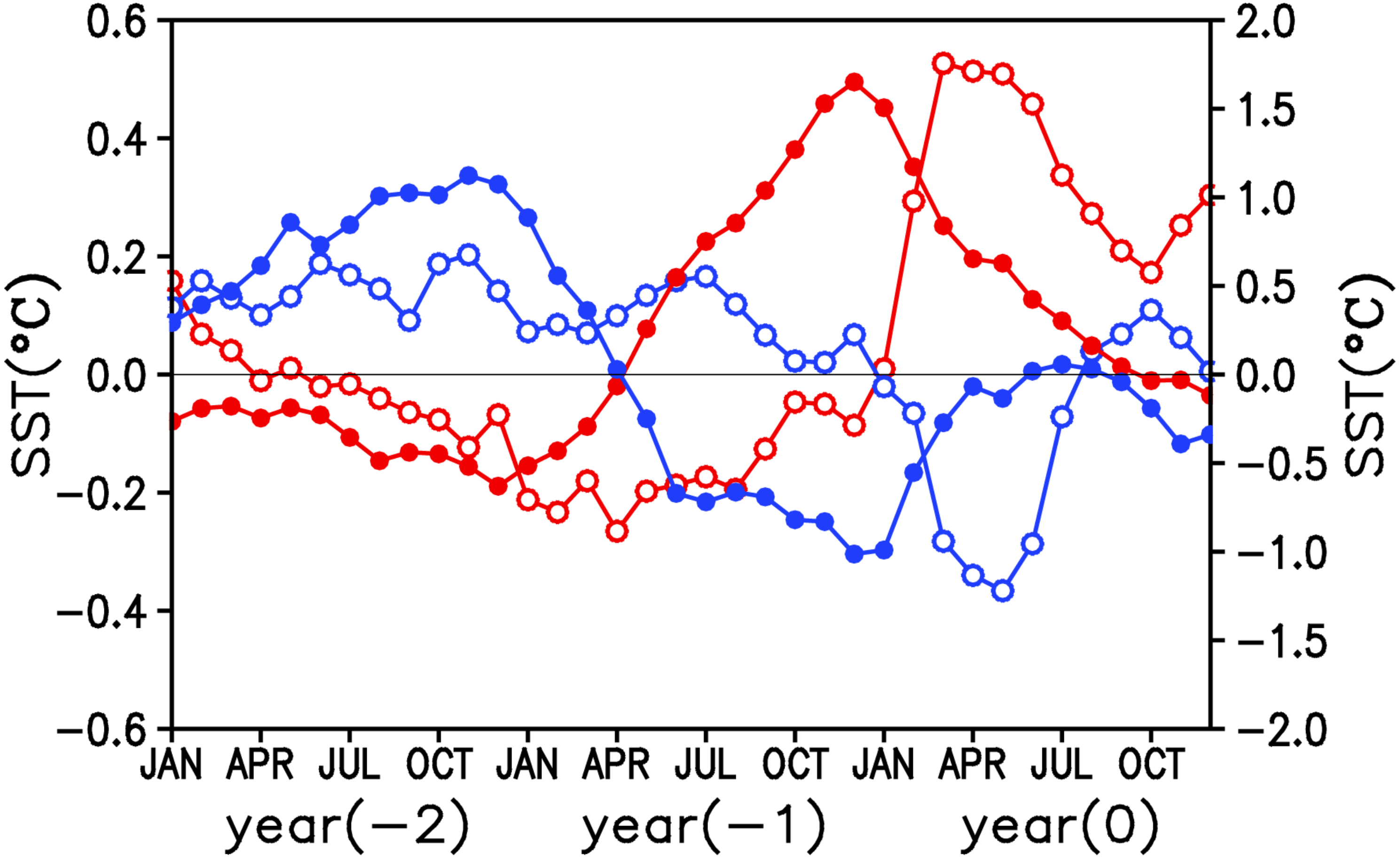
- **Does the ENSO remote influence lead to a persistence barrier in the NTA SSTA?**
- **Influences of the NAO on the NTA persistence?**

# Evolution of the NTA SSTA associated with ENSO




**Composite SSTA difference for strong ENSO cases (El Niño minus La Niña)**

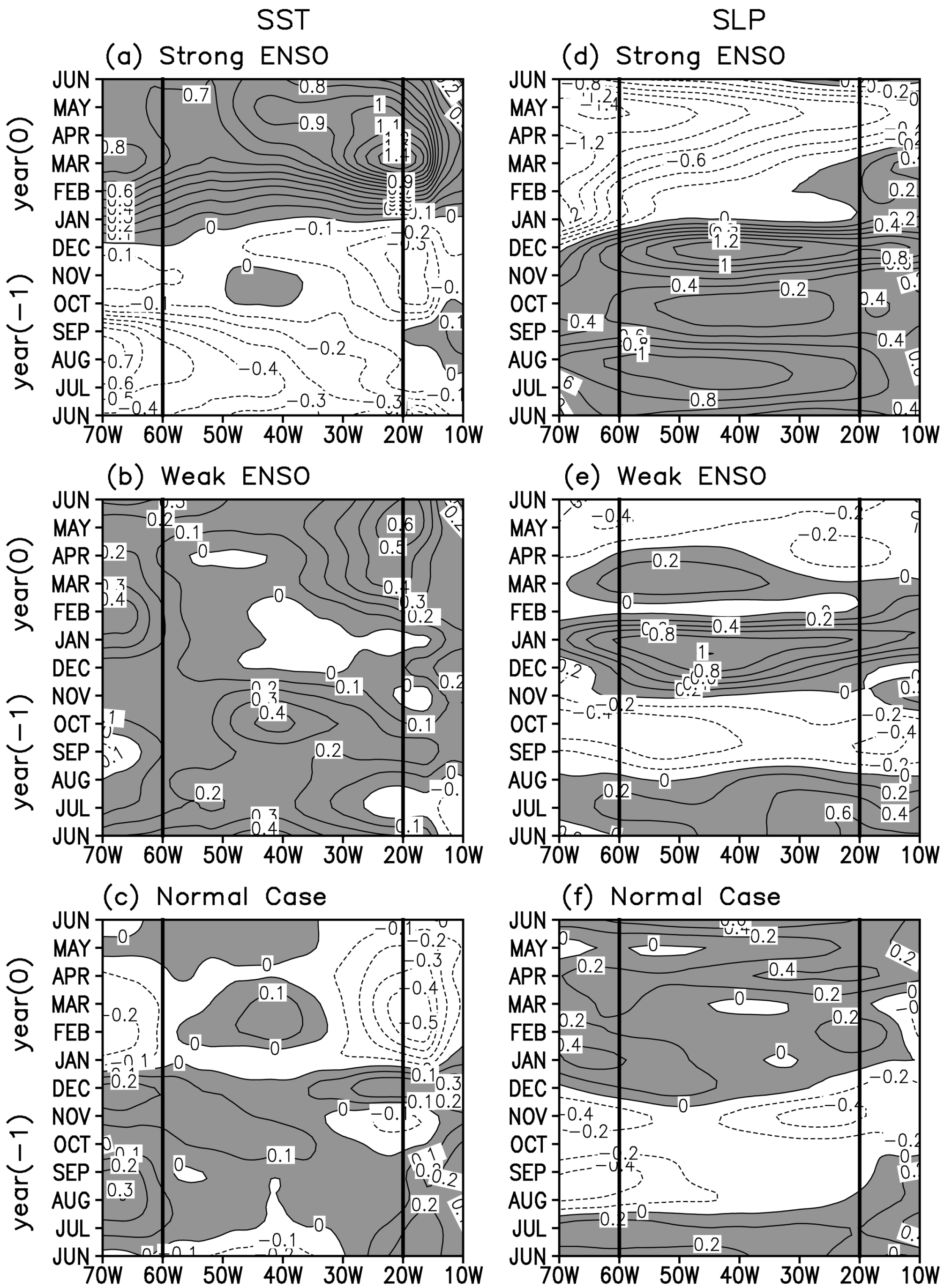
**Anomalies significant at the 0.05 level are shaded**




**Composite difference of the area-averaged SSTA over the NTA (open circles) and Niño-3 region (closed circles)**

**Left y axis: the NTA SSTA for strong El Niño and La Niña events**

**Right y axis: the Niño-3 SSTA for strong El Niño and La Niña events**

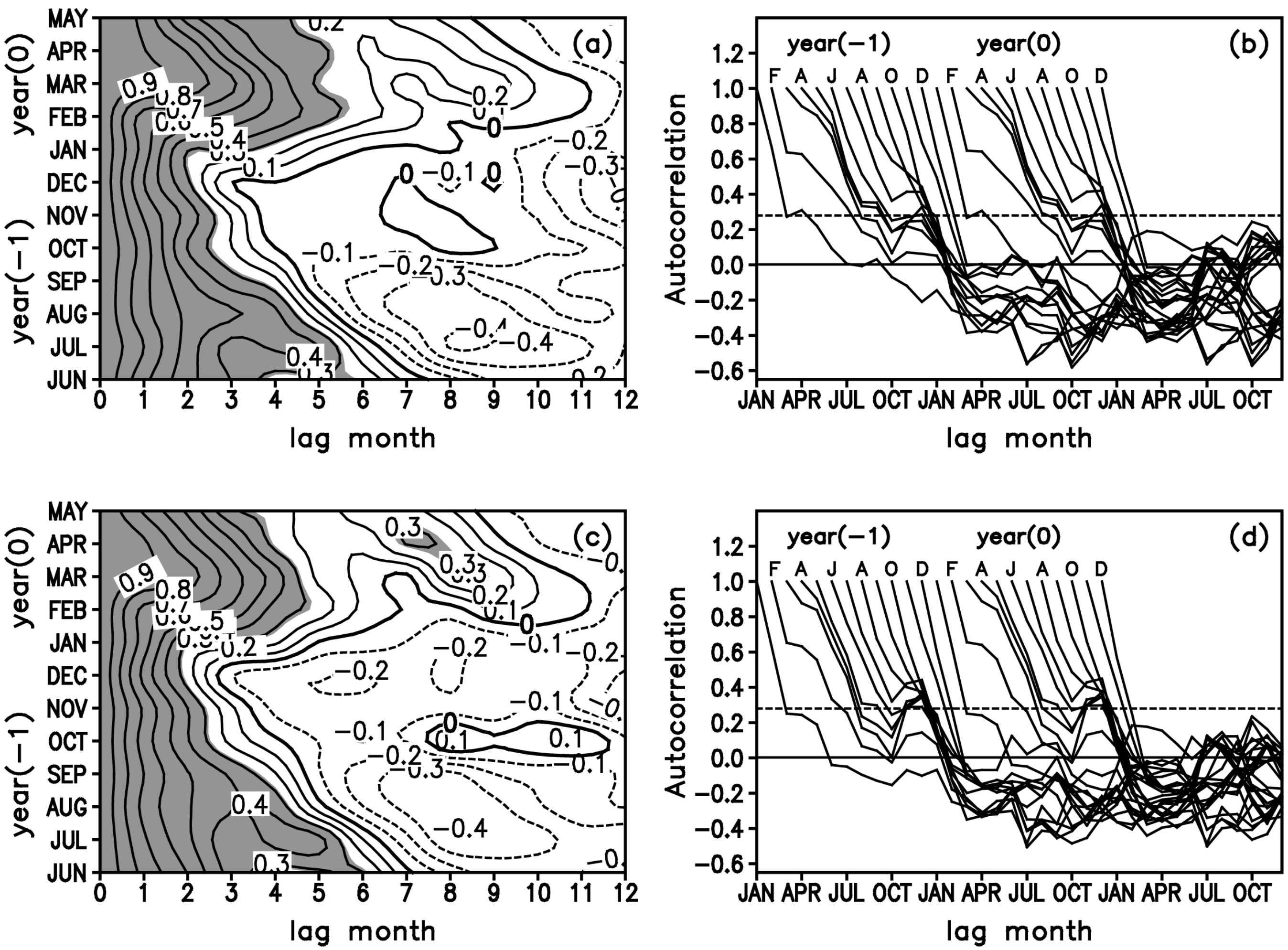



**Composite longitude–time patterns of SST–SLP difference averaged over 5–15N**

# WPB phenomenon in the NTA

ERSST

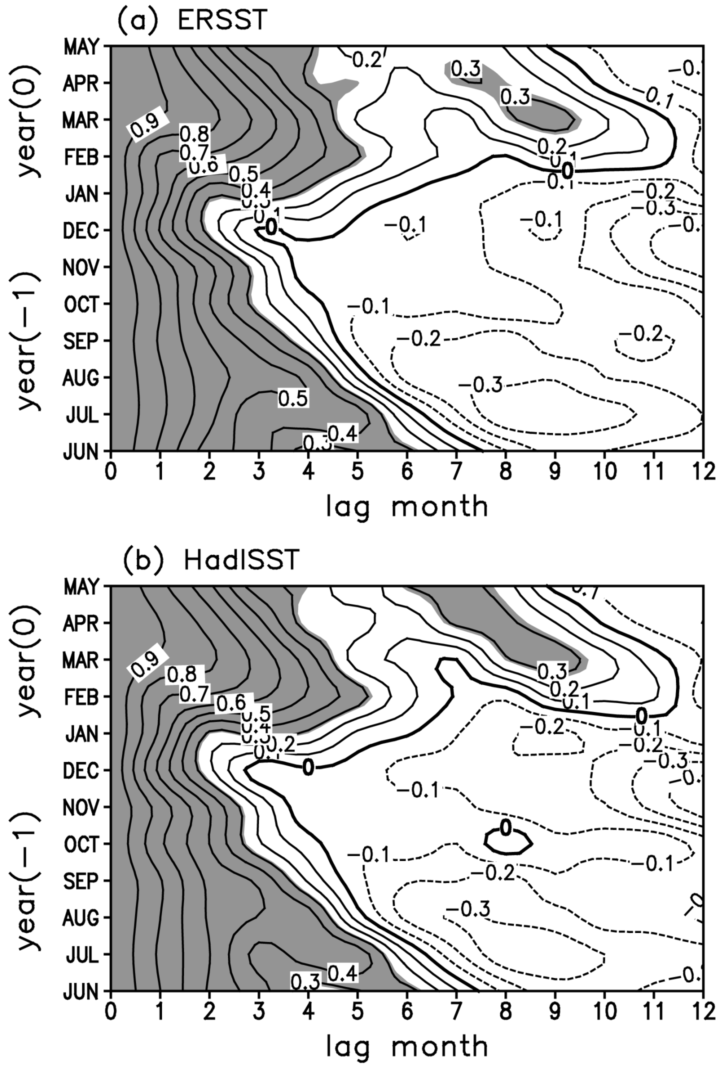
HadISST




**Autocorrelations of the area-averaged NTA (20–60W, 5–15N) SSTA**

**Autocorrelations significant at the 95% level (≥0.27) are shaded.**

# Robustness of the WPB in the NTA

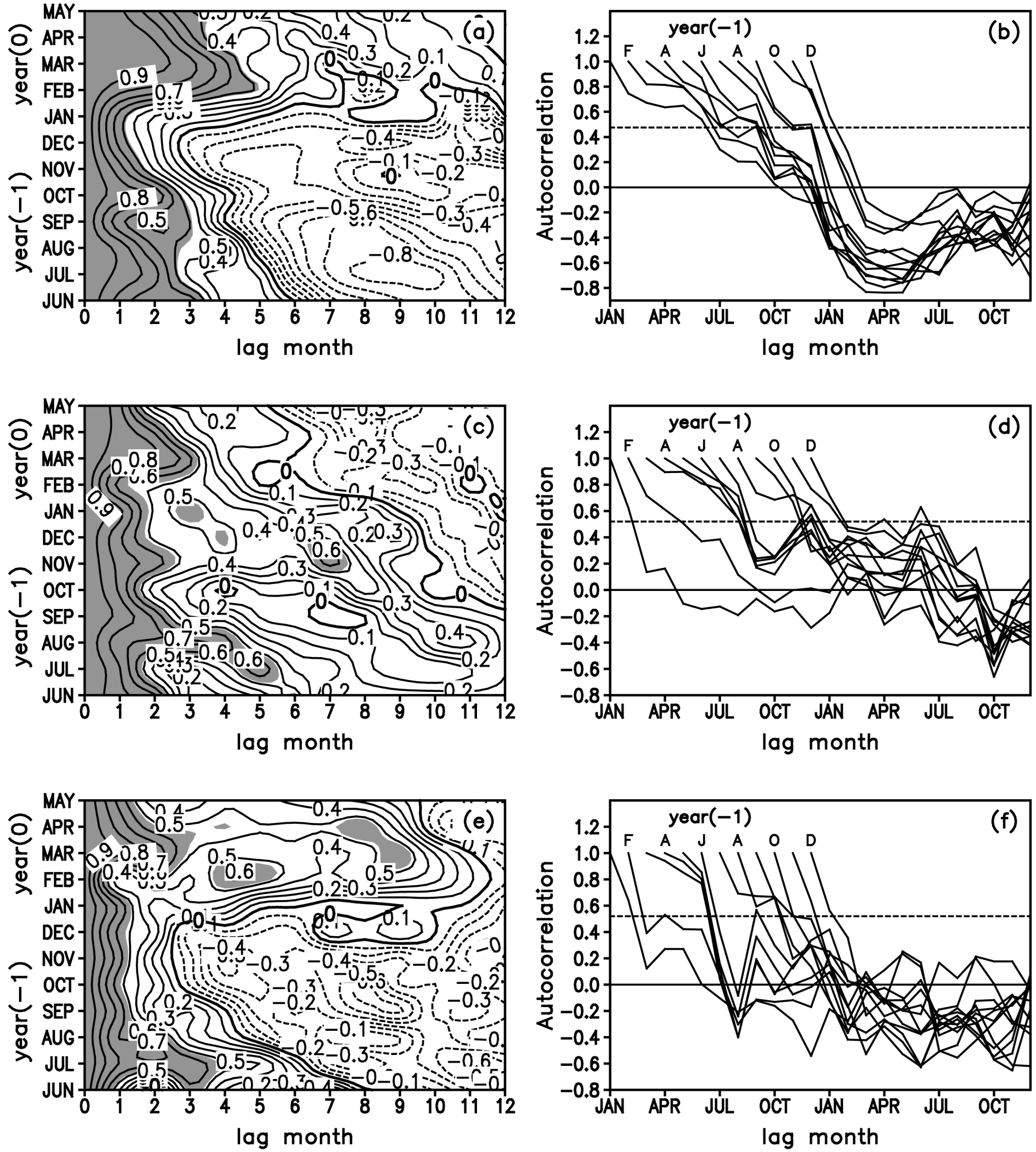



**Autocorrelations of the area-averaged SST over a larger region of the NTA (10–70W, 5–20N, including the coast of northwest Africa and the eastern part of the Caribbean Sea)**

Strong ENSO

Weak ENSO

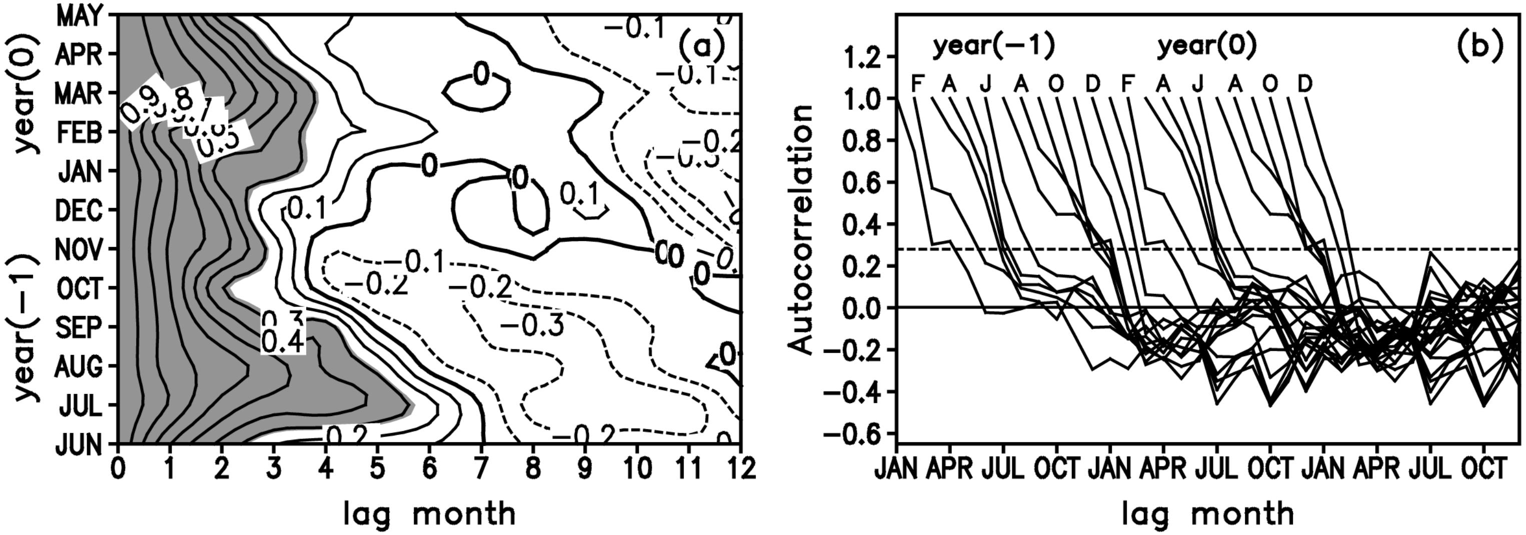
Normal ENSO

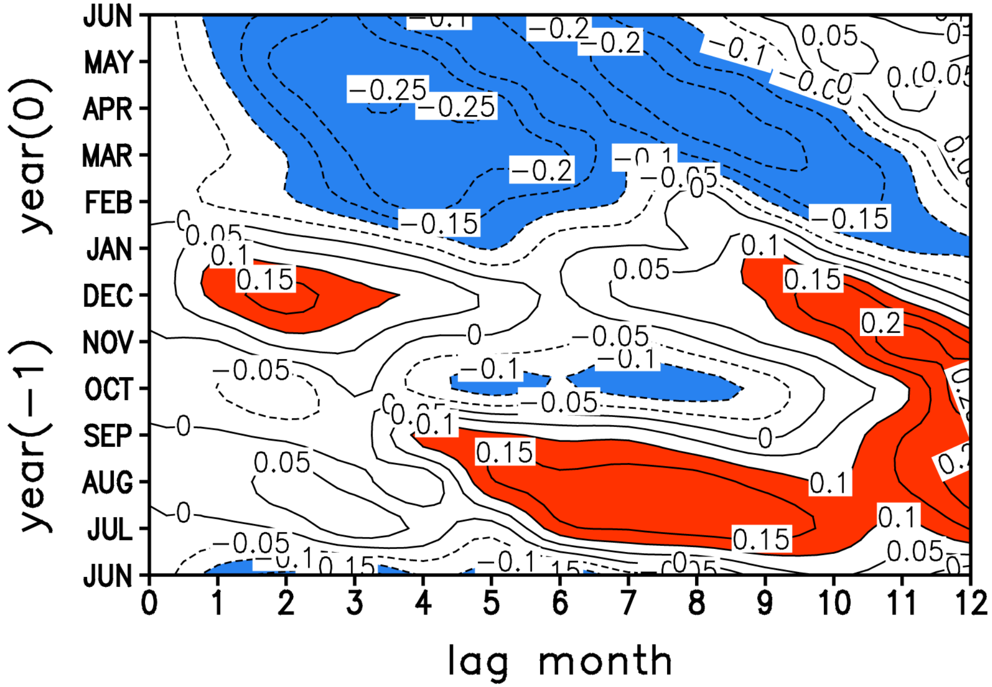



# Relationship between ENSO and the NTA WPB

# The WPB exists after removing the ENSO signal?

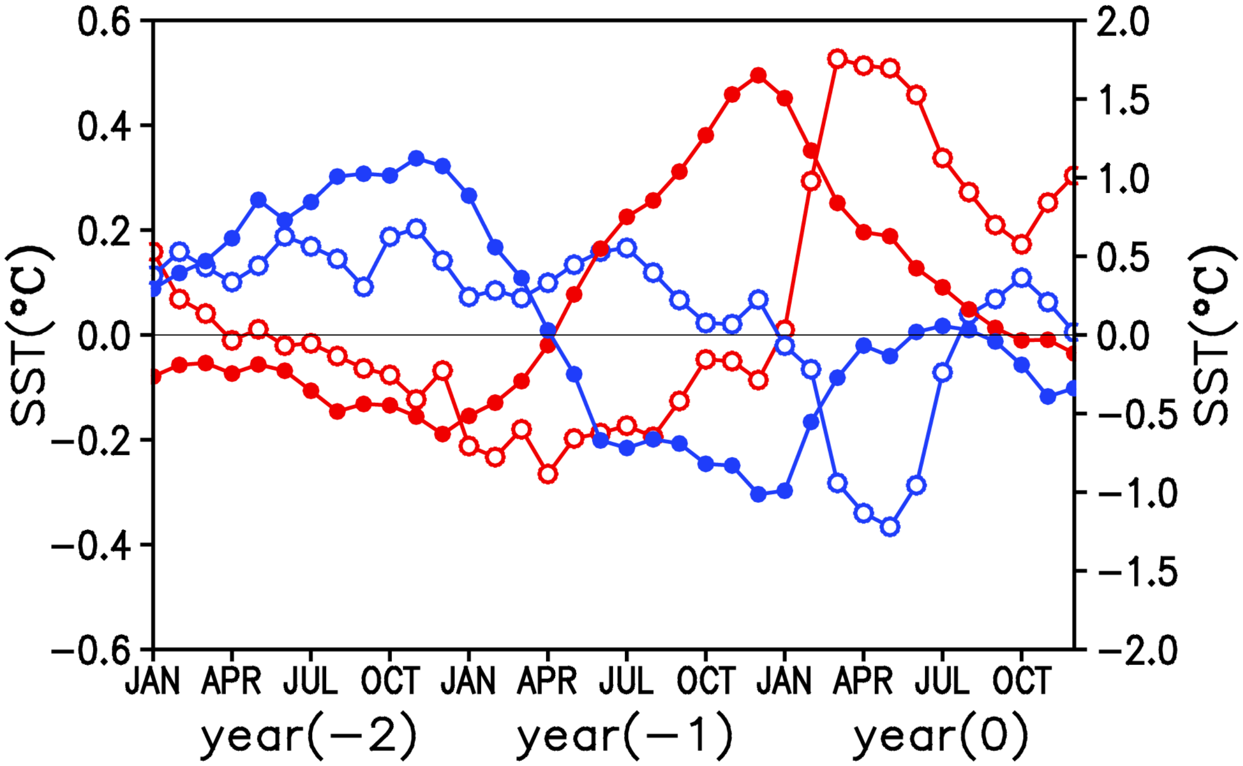
**Residual SSTA**



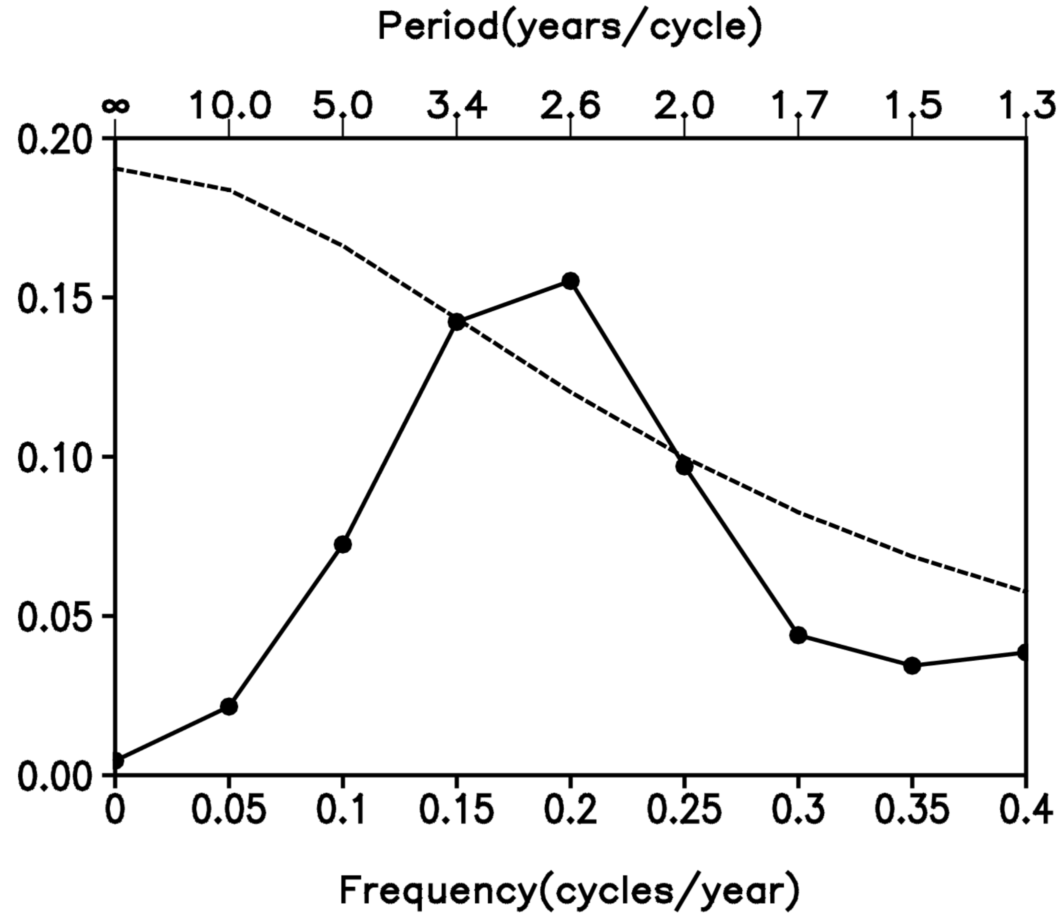




**Difference between autocorrelations from the residual SSTA and those from the original SSTA.**

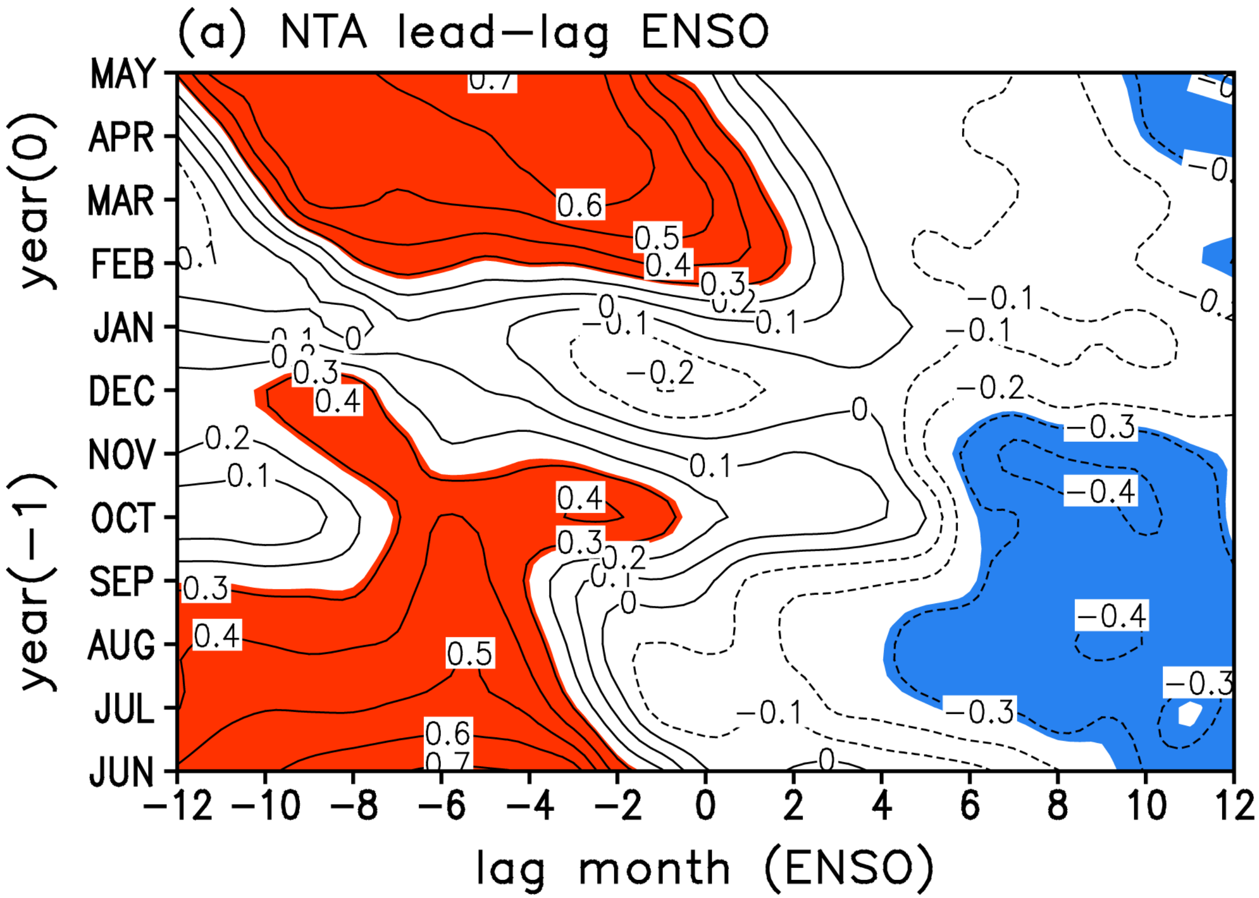
# Why the negative NTA SSTA occurs before the occurrence of the WPB?




**El Niño events are often preceded or followed by La Niña events (Quasi-biennial variability of ENSO; Rasmusson et al. 1990).**




**Power spectrum (dotted solid line) of the monthly NTA SSTA time series**




**Lead–lag correlations between the area-averaged SSTAs over the NTA and the Niño-3 region**

## Dynamic relationship among the Pacific ENSO, the NTA SSTA, and the NTA WPB on the quasi-biennial time scale

**A strong El Niño event is preceded by a strong La Niña event**

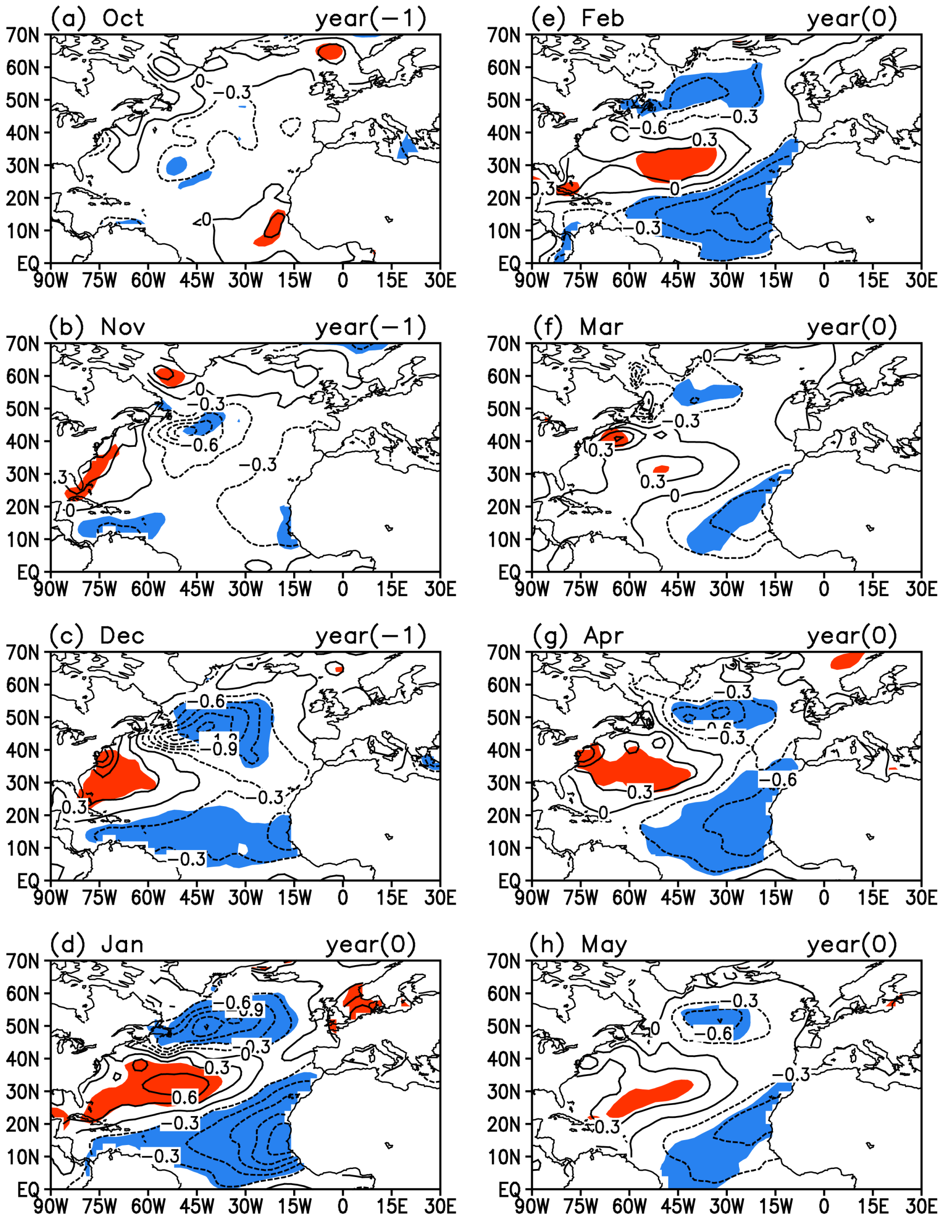
↓

**A sign reversal of the NTA SSTA in winter**

↓

**The NTA WPB**

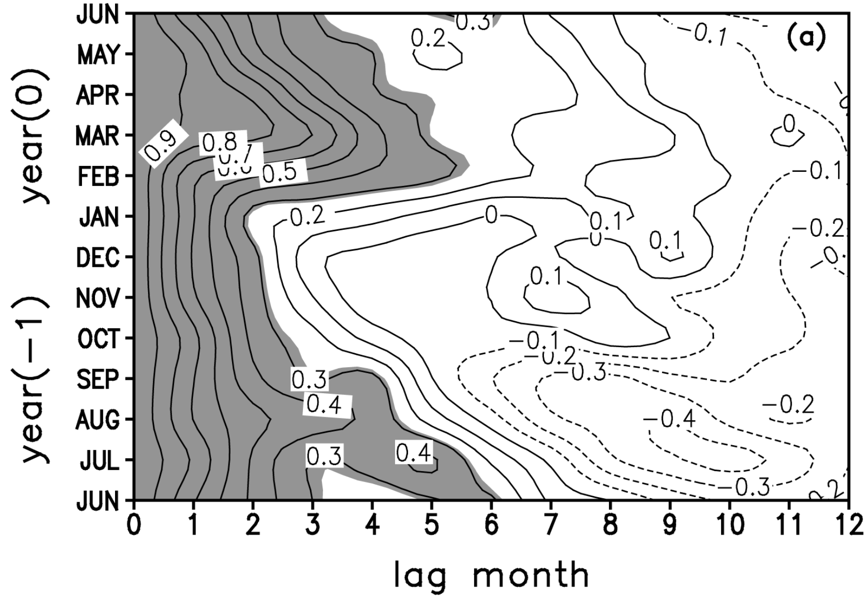
# Influences of NAO on the NTA persistence



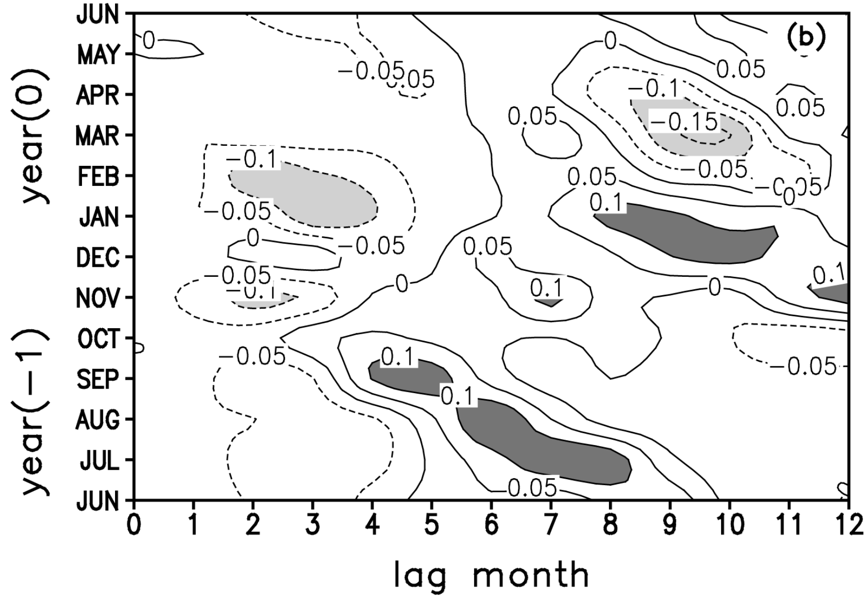

**Composite SSTA difference for strong NAO cases (positive minus negative)**

**Anomalies significant at the 0.05 level are shaded**

**Residual NTA SSTA obtained by removing the NAO signal from the original NTA SSTA**

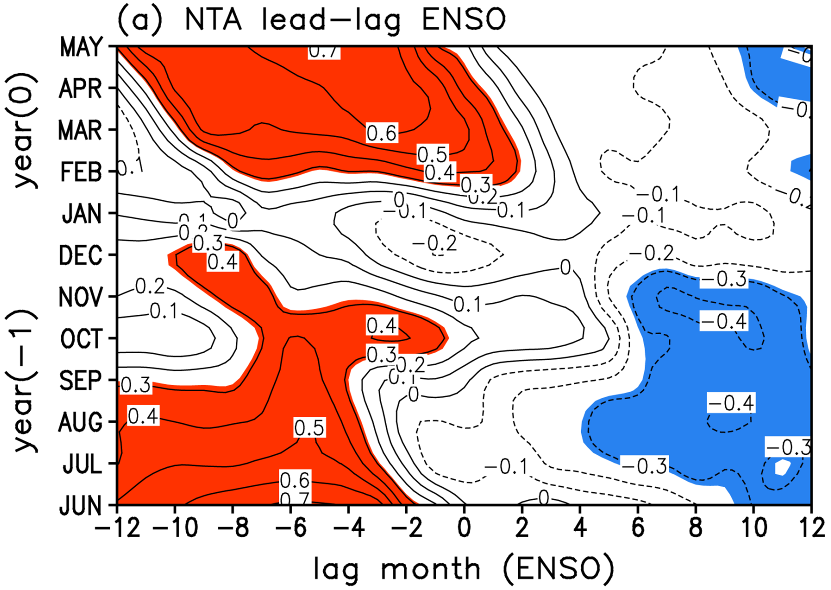


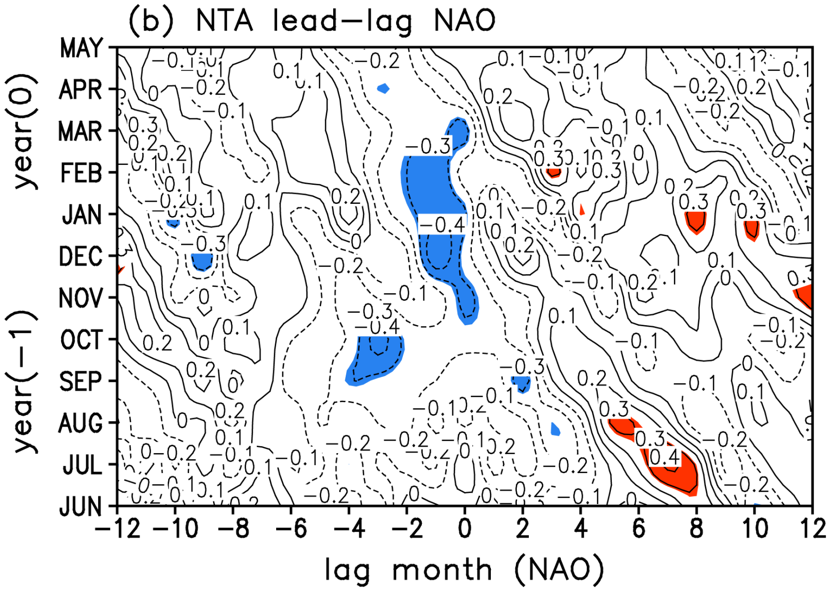

**Difference between autocorrelations obtained from the residual NTA SSTA and those obtained from the original NTA SSTA**



# Why does not NAO produce a WPB in the NTA?

- The NTA SSTA responds more quickly to NAO than to ENSO (1-2 months).
- The NTA SSTA has an evident QBO relationship with ENSO and not NAO.



# Summary II

- Autocorrelations of the NTA SSTA show a weakest persistence in December and January, revealing the existence of a WPB in the NTA SST.
- The NTA WPB is prominent during the mature phase of strong ENSO cases, but becomes indistinct in the weak ENSO and normal (i.e., non-ENSO) cases.
- During strong El Niño cases, the NTA SSTA experiences a reversal in sign and rapid warming during winter. This SSTA sign reversal may reduce the persistence, creating favorable conditions for the occurrence of the NTA WPB.
- There may be a dynamic relationship among the Pacific ENSO, the TNA SSTA, and the TNA WPB on the quasi-biennial time scale.

# Summary II

- The NTA WPB is affected by the North Atlantic Oscillation (NAO). **The NAO enhances the persistence of the TNA SSTA during winter and spring, tending to weaken the TNA WPB.**

# General summary

- ENSO induced persistence barriers in the tropical Indian and Atlantic oceans, respectively, by inducing a reversal of SST anomalies in particular seasons.

- Tropical Indian Ocean: SEIO WPB > SCS FPB > WIO SPB;
- Northern tropical Atlantic: WPB

- Other major modes modulate the persistence barriers;

- IOD tends to strengthen the SEIO WPB;
- NAO tends to weaken the NTA WPB.

# Future work

- The spring persistence barrier (SPB) of ENSO results in a decrease in forecast skill for most ENSO forecast models during the boreal spring (March–May).
- The influences of the persistence barriers on predictions of the TIO and NTA SSTA?

# *Thanks for your attention!*


- **Ding, R. Q., and J. P. Li, 2012: Influences of ENSO teleconnection on the persistence of sea surface temperature in the tropical Indian Ocean. *J. Climate*, doi: 10.1175/JCLI-D-11-00739.1.**
- **Ding, R. Q., and J. P. Li, 2011: Winter persistence barrier of sea surface temperature in the northern tropical Atlantic associated with ENSO. *J. Climate*, 24, 2285-2299.**