On South China Sea Monsoon Onset: A Possible Scenario

by

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One of the most prominent features during the so-called eastern Asia monsoon (EAM) onset (or the first transition period of Asia summer monsoon) is a dramatic change in the lower-level large-scale circulation over South China Sea (SCS) area. Prior to the onset (in May or June), this area is primarily dominated by an anti-cyclonic circulation (or termed as the SCS High). The region is then mainly occupied by a cyclonic circulation after the onset.

As an example, the year of 1987 was first chosen to illustrate the evolving sequence of the circulational transition over the SCS area. It was the TAMEX (Taiwan Area Mesoscales Experiment) year, and most local experts seemed to agree that the EAM onset would come late in June. From the OLR data, we noted that a persistent heating over the Bay of Bengal and Indochina Penisula areas had existed since 24 May. On 3 June, deep convection systems had continually started to move into (or to develop locally over) the regions near south of Philippines. Further, there was a mid-latitude frontal systems moving its way into the northern SCS region on 7 June, and later most of the area was covered by deep convection systems since 9 June till 20 June.

From the results of Gill's model (1980), we hypothesize that the existence of SCS High before the EAM onset might be partly enhanced by the persistent heating near the Bay of Bengal and Indochina subcontinent areas. By the same token, the SCS monsoon onset could have been triggered by the weakening of deep convection systems over those areas and the emergence of continual deep convections near south of Philippines, in associate with the intrusion of frontal systems from mid-latitudes. The former provides a necessary offset to weaken (or even reverse) the existed SCS High by inducing a cyclonic circulation, and the latter introduces a necessary dynamical forcing to help the explosion of deep convections over this already thermally unstable SCS region (for its relatively high sea-surface temperatures). In other words, the existence and demise of SCS High around the onset period is very likely a passive response to the surrounding thermal forcing over lands.

By randomly selecting other years, say 1983, 1988 and 1990, our preliminary results showed that similar evolving sequences could be identified in each of these years. It, however, remains to see if the proposed scenario can be applied to other available years. Nevertheless, if confirmed, it would suggest an alternative way to properly define the SCS monsoon onset.

Key words: the South China Sea monsoon onset, thermally-induced circulations

ON SOUTH CHINA SEA SUMMER MONSOON ONSET: A POSSIBLE SCENARIO

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1. Introduction

One of the prominent features in East Asian Summer Monsoon (EASM) system is a dramatic change in low-level circulation over the South China Sea (SCS) area in April–June (e.g., 滕 1996, and references therein). Prior to this transition, the SCS area is primarily dominated by an anticyclonic flow generally associated with the North Pacific High system. It is then mainly occupied by a cyclonic circulation, after the transition, usually regarded as an extension of the Tibetan Thermal Low system and the South Asian Summer Monsoon flow. For convenience, it is termed as *the SCS circulational reversal* in this study.

Accompanied with this circulational change is a sharp difference in deep-convection activities over the SCS area. Before, there is virtually nowhere to find any deep convective action over this area. In contrast, after the transition, most of the area are often covered by organized, long-lasting deep convections associated with a frontal cloud-band extended northeastward to the open oceanic areas south of Japan. It generally signifies the arriving of Mei-Yu season in Taiwan area as well.

The time in which an abrupt change in either (low-level) flows or deep-convection activities (or both) were observed, over the SCS region, is often referred to as the SCS summer monsoon onset. Many (e.g., Murakami and Takahashi 1993, Chang and Chen 1995, Chen and Chen 1995, 林 and 林 1996) had proposed to dynamically explain the occurrence of such a circulational reversal, and therefore the onset, but none of them is satisfactory. It is thus our incentive to explore more on this issue.

Preliminary analyses revealed that the SCS circulational reversals around those defined onset period (date or pentad) of previous studies (e.g., Hsu 1996; 胡 et al. 1996; 盧 1998; and references aforementioned) could be quick and complete, lingering, or even incomplete. This suggests that we were perhaps either looking at not-quite-the-same objects, or similar things as it appears yet with different triggering mechanisms. Consequently, we want to be more specific on what we are trying to investigate.

To serve our purpose, the manners that each circulational transition demonstrated are of particular interest. Specifically, we want to know if a "complete" circulational reversal can be observed in April-June of each available year? Is there any similarity (or dissimilarity) among them? Is there a major type of them?

2. Circulational Reversal

A "complete" circulation reversal in this study is subjectively defined as the fact that the low-level anti-cyclonic circulation (mainly easterlies), associated with the North Pacific High, is fully pushed out of the SCS area box, (10–20°N, 110–120°E), and replaced by the cyclonic flow primarily from the Bay of Bengal (as seen from the 850 hPa streamlines). In addition, the circulation patterns must be steady (i.e., sustained for at least 5 days) both before and after the reversal. For convenience, the time it takes to evolve from (the last day of) one regime to (the first day of) another is referred to as the circulational transition period. More specifically, it must be the first episode that appears in April-June of each year, and after which no occurrence of winter-like circulations is allowed. Also, to be as specific as possible, the transitions considered should come before the first appearence of a monsoon-trough-like pattern.

It is surprising to note that not all the available years (1979–95) in which a "complete" reversal can be identified (Table 1). They are 1982, 1991, 1984, 1992 and 1993, among which one can still notice a fully circulational reversal in the 3 latter years that sustains for only 3 days before the first occurrence of a monsoon-trough-like pattern. On the other hand, not only did a complete circulational reversal occur in 9 out of the 17 years, but the associated transitions also took place within a very short period (≤ 5 days). These years are 1979–81, 1986–89, and 1994–95, respectively. The rest are with a circulational transition period longer than 3 pentads, except for 1990 (9 days).

In summary, there does exist a major group of circulational transition that evolves in a very dramatic manner. It is hereafter referred to as *the SCS circulational reversal of the first kind* for convenience. The next question is: what causes such a rapid circulational reversal?

3. OLR Analyses

a. Conjecture

It is well recognized that circulations in tropical atmosphere are very likely driven by thermal forcing, after the study by Gill (1980). Geographically speaking, the SCS area and its surrounding are well belong to the subtropical-to-tropical regions. Therefore, it is presumed that the SCS circulational reversal would be largely related to the tropical deep convections around this area, although mid-latitude frontal systems can often be seen nearby before the transition. In light of this, our question may be rephrased as: what happens in local thermal distributions before, during and after the circulational reversal?

According to Gill (1980), a smaller but stronger cyclonic circulation (associated with the Rossby wave) will be generated to the northwest sector of a given deep convective thermal forcing away from equator, while a larger but weaker anti-cyclonic flow (associated with the Kelvin wave) to its northeast. Therefore, ideally the most possible way to induce a cyclonic westerly circulation over the SCS area is to deploy a heat source to its east flank. It is thus inferred that we might observe an emergence of deep convection activity over the Philippines and/or nearby areas prior to the low-level circulational transition. To verify this conjecture, the daily OLR data were examined.

b. Result

It is exciting, though expected, to note that the deep convections (OLR values ≤ 180 W/m^2) over the Philippines sector (mainly referring to the area box of 5–15°N, 120-140°E) do appear (usually suddenly) prior to the ongoing of SCS circulational reversal in all the 9 particular years aforementioned. These deep convections usually last until the completion of the circulational transition. In addition, we also noted that a large-area, organized, deep convective system had already existed over the Bay of Bengal regions (primarily the area box of 5–25°N, 80-100°E) before the emergence of Philippine deep convections. (The only exception is probably the year of 1980.) During the circulational overturning, it is astonished to learn that the large-area, organized, deep convective system over Bay of Bengal were quickly dissipating (sometimes may even totally disappear), instead of simply moving eastwards. Moreover, the occurrence of deep convections over Philippines sector was found to coincide with the time when the large-are, organized, deep convection system of Bay of Bengal turning from its intensifying to decaying stage. As an example, we only show the daily evolutions of area-mean OLR indices around the circulational reversal in 1987 (Fig. 1).

It is noted that the deep convective cloud-band associated with mid-latitude frontal systems started to migrate into the SCS area in the meantime when the low-level flows came towards the completion of regime transition (not shown). After that, or a lag of few days in some years, the organized deep convection systems exploded over most of the open ocean of SCS and its vicinity.

In summary, we had noticed a general occurring sequence of deep-convection activities in those 9 years classified as with a SCS circulational reversal of the first kind. It is:

(1) a large-area, organized, deep convective system first appeared over the Bay of Bengal and the Indochina areas, which reached its mature stage within 4 days prior to the beginning of circulational transition;

(2) a generally smaller-scale deep convection system over the Philippines sector then emerged around the time when (1) turning to its decaying phase;

(3) as (2) developing and/or moving closer to (or eventually into) the SCS area, accompanied by a fast decay in (1), the circulational overturning began and quickly transited into a regime mainly prevailed by westerlies from Bay of Bengal areas;

(4) upon the circulational reversal coming into its finishing stage, the cloud-band associated with mid-latitude fronts started to move into the SCS area;

(5) the large-area, organized, deep-convective activity finally exploded, covering most of the SCS area, and last for at least 5 days.

The only exception among those 9 specific years is 1995, in which the circulational reversal came after the deep-convective cloud-band associated with a mid-latitude front had already moved into the northern SCS area.

4. Discussion

a. Triggering Mechanism

Apparently, the emergence of deep convections over Philippines sector, together with the weakening of large-area, organized, deep-convective systems over Bay of Bengal regions would be the key factors in triggering the SCS circulational reversal of the first type. Seldom did we see the circulational transition had evolved at the same pace with a moving frontal system into the SCS area, nor did the eastward propagating of large-area, organized deep convections from Bay of Bengal areas.

Dynamically speaking, the planetary-scale subsidence sustained from winter time is no longer able to effectively suppress the developing of deep convections around this subtropical-to-tropical latitudinal belt upon the appearance of a large-area, organized deep convection system over the Bay of Bengal regions (Fig. 1). This may also signify that the low-level anti-cyclonic circulation over the SCS area is now largely controlled by the deep convection systems over the Bay of Bengal region. Thus, as the latter grows (decays), the SCS anti-cyclonic flow is enhanced(weakened).

Obviously, the large-scale land-sea contrast over the Bay of Bengal and surrounding areas, at this time of season, plays an important role in helping the development of deep convections. By the same token, the easterlies and the land-sea contrast over the Philippines sector certainly will help the developing of convective activity, though the corresponding spatial scale is smaller. On the other hand, the weakening of anti-cyclonic flow associated with the dissipating of deep convections over Bay of Bengal regions will also provide a dynamically more favorable condition to the developing of convective activity over the Philippines areas.

Suppose that now a deep convection system develops over the Philippines sector, whether or not it is related to the weakening of large-area, organized deep convective system over Bay of Bengal regions, it will induce a cyclonic circulation to its west which not only starts to weaken the existed easterlies over the SCS area, but also to bring in the warm sea-surface water-vapor resources of that area. Both effects would result in a reduction of intensity to the system over Bay of Bengal, if the energy resources over the SCS area were crucial to its maintenance. This will weaken the SCS low-level anticyclonic flow and help the developing of deep convections over Philippines sector, which in turns further reduces the intensity of the deep convection system over Bay of Bengal.

In other words, assuming that the water-vapor resources over SCS area are important to the system over Bay of Bengal regions, the occurrence of organized deep convections over Philippines sector would inevitably trigger a positive-feedback loop which then results in a quick, complete circulational reversal over the SCS area (Fig. 2).

b. Conceptual Model

We therefore propose that a "normal" East Asian summer monsoon onset, as demonstrated over the SCS, area should exhibit a standard evolving sequence that includes at least 3 thermal entities, one thermal/dynamical entity and one dynamical illustration (Fig. 3).

Firstly, a large-area, organized, deep-convection system develops over the Bay of Bengal areas. Secondly, when it reaches its prime and begins to decline, the deep convections over Philippines sector emerge. In the meantime, mid-latitude frontal systems are active over the east coast of Asian continent and may extend to areas close to the northern SCS. Thirdly, a dramatic circulational reversal undergoes over the SCS area as deep convections over Philippines sector continued to exist, associated with a fast decay for those over Bay of Bengal regions. Also accompanied with the circulational change is the intrusion of mid-latitude frontal system into the SCS area, which can extend to the open ocean south of Japan. Finally, the deep convection systems explode and cover most of the SCS area. For reference purpose, let us term it as *the SCS summer monsoon onset of the first type* (SCS-SMOFT).

In this conceptual framework, we want to point out the follows:

1. Although the warm SST over the SCS area made it a thermally potentially unstable region, the explosion of SCS deep convections cannot be achieved without other external lifting mechanisms but only the low-level circulational reversal. Therefore, a lower boundary lifting forcing (such as land-sea contrast, tropical cyclone, or in this case, the mid-latitude frontal system) must be provided. It is however only a necessary condition since sometimes the explosion may delay for a few days after the frontal system has moved into this SCS area. Apparently, something(s) is (are) still missing.
2. The frontal cloud band, as depicted from the OLR data, tends to move into the SCS area after the low-level circulational reversal, not before nor synchronously. Therefore, the disappearing of SCS anticyclonic cap is probably not mainly pushed out by the intrusion of mid-latitude fronts, except in 1995.
3. The explosive development of SCS deep convections associated with fronts generally occurs after the circulational overturning and later links with the deep convections reappearing over Bay of Bengal regions. From a low-frequency point of view, it may look like the deep convections have expanded (propagated) from over the Bay of Bengal regions before the onset to cover the SCS area after that, and the circulational reversal happened at the same time associated with the expansion.
4. A "complete" circulational reversal cannot be accomplished without the existence of deep convections over Philippines sector. However, the quick ones can only be induced with an additional help from the weakening of deep convections over Bay of Bengal region by getting into a plausible positive-feedback mechanism well attributed to, again, the emergence of Philippine deep convections. As such, it is regarded as a necessary critical factor in triggering the SCS-SMOFT, but not sufficient.

So far, we had only pointed out the importance of the emergence of Philippine deep convections in possibly triggering the SCS summer monsoon onset of the first type, but did not have any words on why it might occur. Further analysis suggests that it is associated with the deepening of upper-level westerly trough near the Philippines sector, which in turns is very likely related to the developing of the large-area, organized deep convection system over Bay of Bengal regions. Theoretically, the SCS-SMOFT thus might well be a phenomenon triggered by heat-induced tropical Rossby waves interacting with mid-latitude systems.

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Table 1. List of circulational transition periods in 1979–95. Also included are the duration times of low-level circulational pattern after the reversal (column 3: * indicates < 5 days), explosive deep convections associated with fronts (column 4), and monsoon-trough-like pattern of selected years (column 5).

Year	Transition Period	Duration	SCS Deep Convection	Monsoon Trough
1979	5/11–16 (5)	5/16–6/1	5/16–25	
1980	5/13–18 (5)	5/18–22	5/17–23	
1981	5/29–6/2 (4)	6/2–16	6/5–13	
1982	5/27–?		5/28–30	6/10–20
1983	5/19–6/4 (16)	6/4–8	6/4–8	
1984	5/18–24 (6)	5/24–26*	5/23–26	6/7–11
1985	5/23–6/7 (15)	6/7–20	6/8–11	
1986	5/9–13 (4)	5/13–26	5/15–22	
1987	6/5–9 (5)	6/9–20	6/10–19	
1988	5/20–22 (2)	5/22–6/6	5/24–6/6	
1989	5/15–18 (3)	5/18–25	5/18–26	
1990	5/15–24 (9)	5/24–6/3	5/28–6/3	
1991	6/5–?		6/8–11	6/13–19
1992	5/16–6/1 (16)	6/1–3*	6/11–15	6/16–26
1993	5/24–6/11 (18)	6/11–13*	5/24–26	6/19–27
1994	5/23–27 (4)	5/27–6/6	5/30–6/6	
1995	5/9–13 (4)	5/13–21	5/9–14	

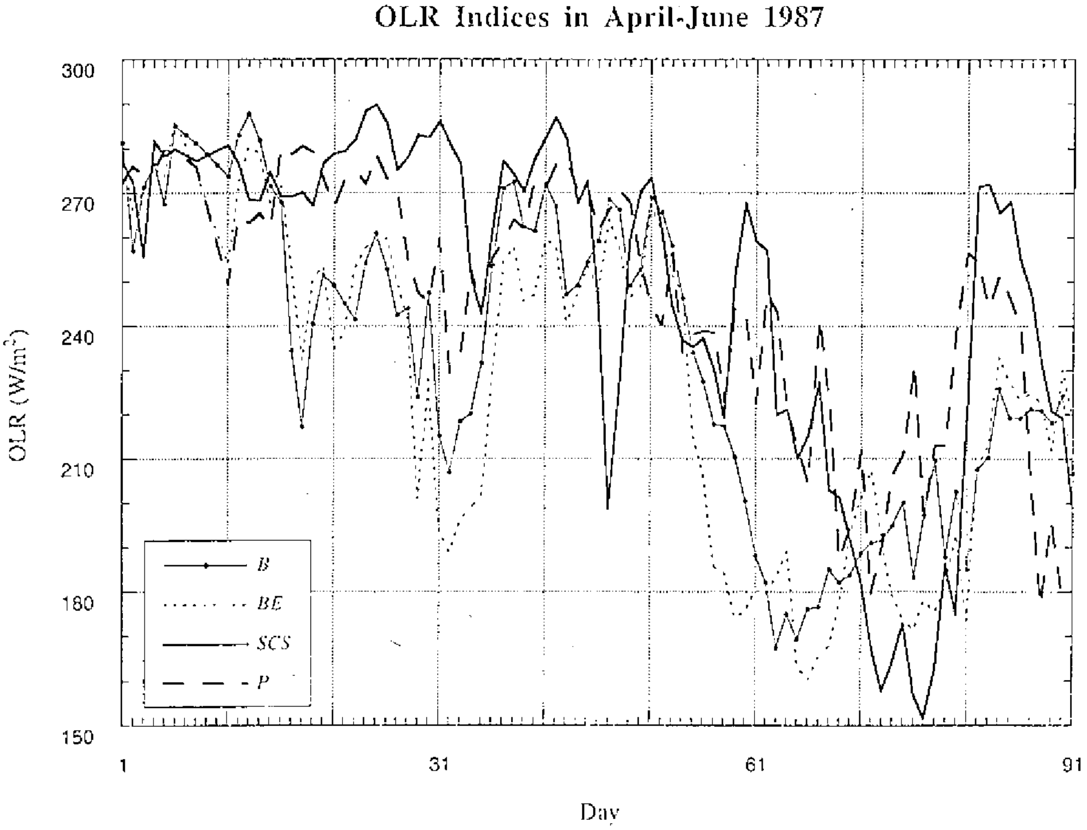

Fig 1. Area-mean OLR indices in April–June of 1987. ("B" stands for the Bay of Bengal regions defined by the area box of 5–20°N, 80–100°E; "BE" indicates the eastern portion of "B," i.e., east of 90°E; "SCS" represents the South China Sea area given by the area box of 10–20°N, 110–120°E, and "P" the Philippines sector of 5–15°N, 120–140°E.)

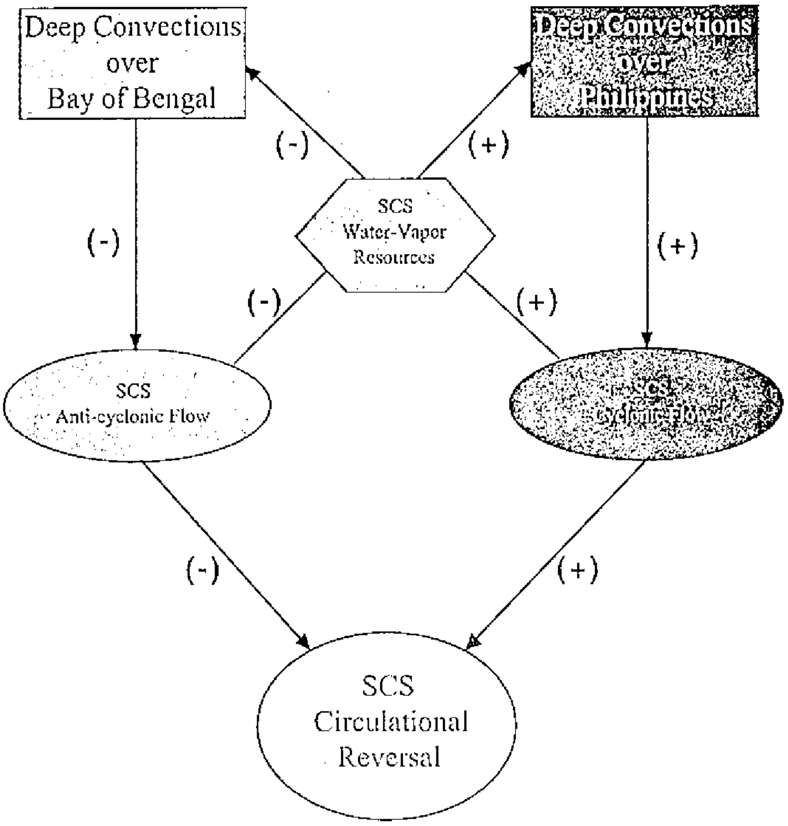

Fig 2: Schematic diagram of a possible mechanism in triggering the SCS sirculational reversal of the first kind.

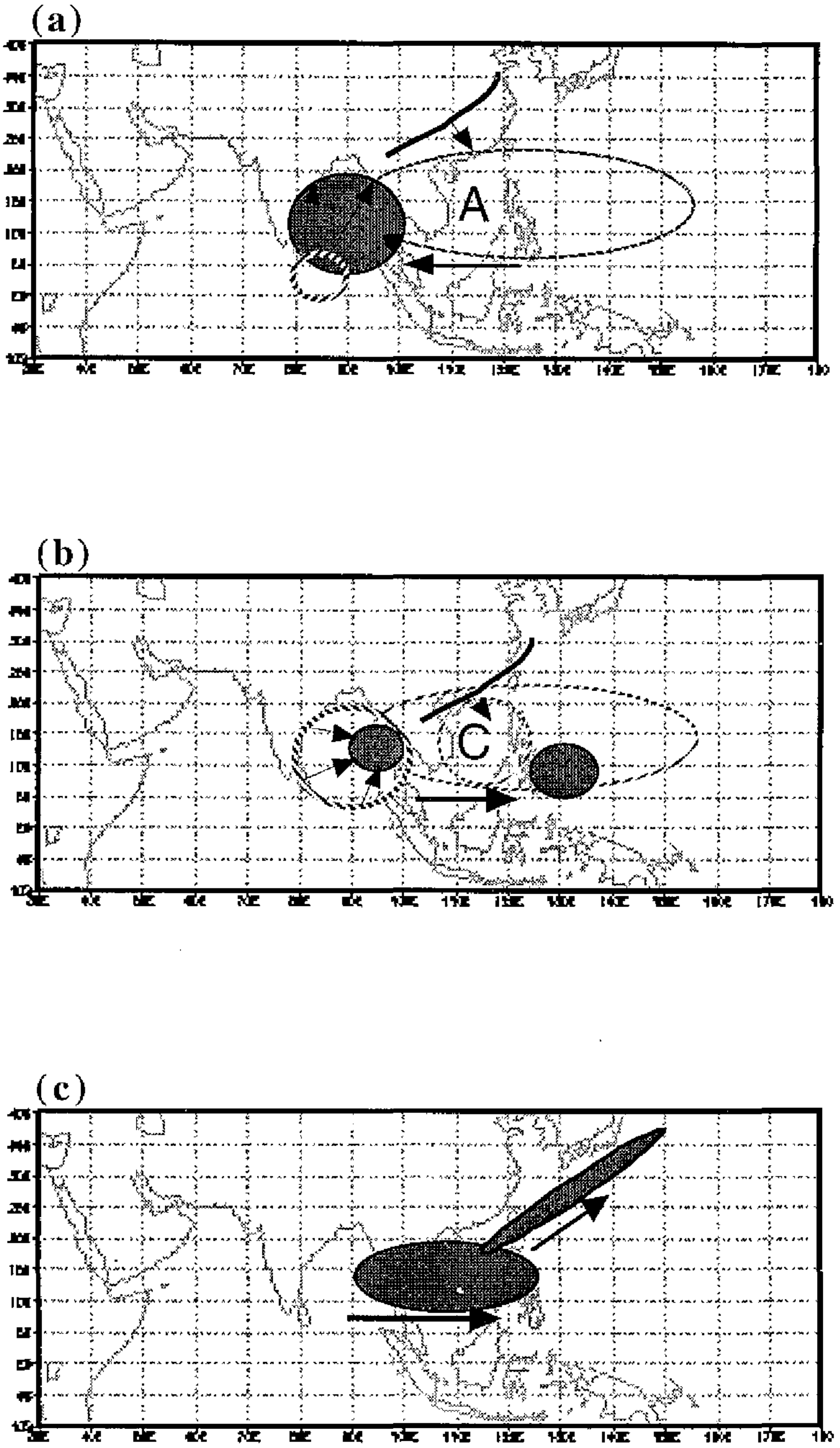

Fig 3. Schematic diagram of a conceptual model on the SCS summer monsoon onset of the first type: (a) before, (b) during, and (c) after the circulational reversal. (See the text for details.)