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# Response of sea state to the monsoon onset

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**सार** – इस शोध पत्र में आरमेक्स के आरंभिक चरण के दौरान एकत्रित किए गए अरब सागर के प्लव मौसम विज्ञान के आँकड़ों का उपयोग करते हुए धरातलीय प्राचलों पर मानसून 2003 के आरंभ के प्रभाव की जाँच करने का प्रयास किया गया है। मानसून 2003 के आरंभ के दौरान उष्ण जल कुँड की चरम अवस्था और समाप्ति की तुलना सामान्य चरम अवस्था और इसकी समाप्ति की स्थितियों के साथ की गई है और इससे यह पता चलता है कि 2003 के मानसून के आरंभ होने के दौरान उष्ण जल कुँड की धीरे–धीरे समाप्ति हुई। वस्तुतः 2003 के मानसून के आरंभ होने के दौरान उष्ण जल कुँड क्षेत्र में वाष्पण का शीतलन अत्यंत धीमा था जिससे यह पता चला है कि भ्रमिल के आरंभ होने पर ही उष्ण जल कुँड के अचानक समाप्त होने की आशंका रहती है जबकि यह स्थिति 2003 के दौरान नहीं थी। मानसून के आरंभ होने से लगभग 2–3 दिन पहले दक्षिण पूर्वी अरब सागर में समुद्र की प्रचंडता (तरंग की ऊँचाई) में वृद्धि हुई है जिससे यह पता चलता है कि महातरंगें मानसून के आरंभ होने की विश्वसनीय पूर्वसूचक हैं। 8 जून को केरल में मानसून के आंरभ से लगभग एक सप्ताह पहले समुचे पूर्वी अरब सागर (8°–20° उ.) में एस. एल. पी. में भारी कमी दिखी। डी. एस. 7 से एस. डब्ल्यू. 1 तक के सभी प्लवों में इसी प्रकार के एस. एल. पी. परिवर्तन रिकार्ड किए गए हैं। 1 जून को आई अचानक कमी के पश्चात 8 जून को मानसून के आरंभ होने अथवा इसके पश्चिमी तट के साथ–साथ लगातार आगे बढ़ने से पूर्वी अरब सागर पर एस. एल. पी. अधिकांशतः स्थिर और सुनिश्चित बने रहे।

**ABSTRACT.** Utilizing the buoy meteorological data of Arabian Sea collected during the onset phase of ARMEX an attempt has been made to examine the influence of monsoon onset 2003 on the surface parameters. The peaking and collapse of warm pool during monsoon onset 2003 has been compared with the normal peaking and collapse conditions and it has been found that the collapse of warm pool during the onset of 2003 monsoon was very gradual. As a matter of fact the evaporative cooling in the warm pool region was quite subdued during 2003 monsoon onset which shows that the sudden collapse of warm pool should be expected to occur only when onset vortex is formed which did not happen during 2003.The roughness of sea (wave height) increased over the southeastern Arabian Sea about 2-3 days before the monsoon onset showing that the swells are reliable precursors of monsoon onset. There was a steep fall in SLP throughout the eastern Arabian Sea (8° - 20° N) about a week before the monsoon onset over Kerala on 8 June. All buoys from DS7 to SW1 registered this type of SLP change. After the sudden fall on 1 June the SLPs over the eastern Arabian Sea remained almost steady and unimpacted by the monsoon onset on 8 June or subsequent advance along the west coast.

**Key words** – ARMEX, Warm pool, Sea surface temperature (SST), Sea level pressure (SLP), Meteorological buoy, Sea state, Onset vortex.

## 1. Introduction

One of the main objectives of ARMEX-2003 was to study the changes in the warm pool region in the Lakshadweep Sea during the onset phase of summer monsoon 2003. For this purpose continuous monitoring of surface parameters like SST, SLP etc. was made in the eastern Arabian Sea during the onset period of 2003 monsoon through two deep water buoys, DS7 and DS2 deployed in that area. Three shallow water buoys, SW4, SW3 and SW1 recorded the surface data to facilitate the study of impact of monsoon advance along the west coast of India. The Lakshadweep Sea warm pool is associated with local SST maximum and reaches its peak intensity just before the onset of summer monsoon over the southeastern Arabian Sea and collapses with the monsoon onset. There are large interannual variations in the intensity and extent of the warm pool. Though there have been many studies on the genesis of warm pool (Joseph, 1990; Vinayachandran and Shetye, 1991; Shankar, 1998; Shenoi *et al*., 1999; Rao and Sivakumar, 1999) there was a need to collect intensive observations from the warm pool region during the onset phase of monsoon to establish the association of warm pool with the monsoon onset. The surface data of buoys deployed in the Arabian Sea during ARMEX was extremely useful in the study of day-to-day changes that occurred over the eastern Arabian Sea especially in the warm pool region with the advance of summer monsoon over that area.

## 2. Data and methodology

The study utilizes the surface data of 5 meteorological buoys deployed in the Arabian Sea namely

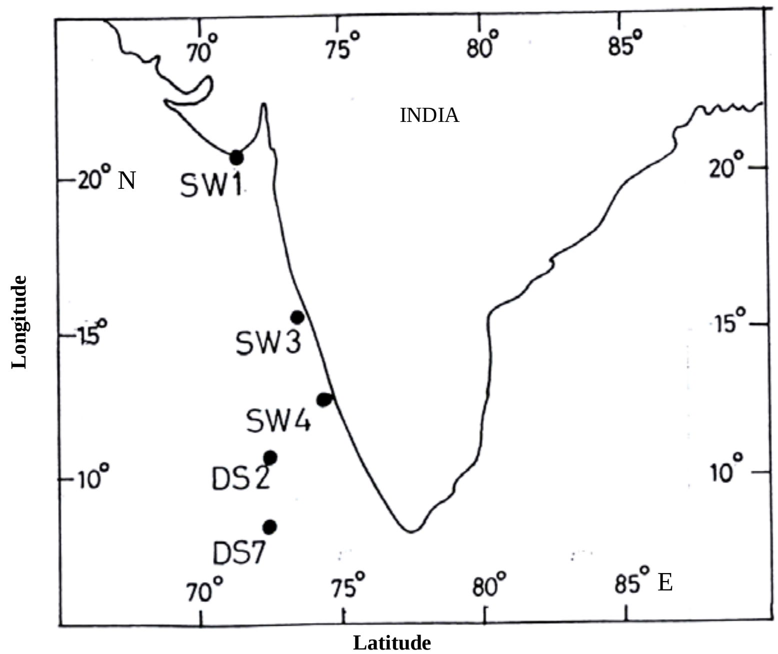


**Fig. 1.** Locations of Meteorological buoys in the Arabian Sea during ARMEX-2003

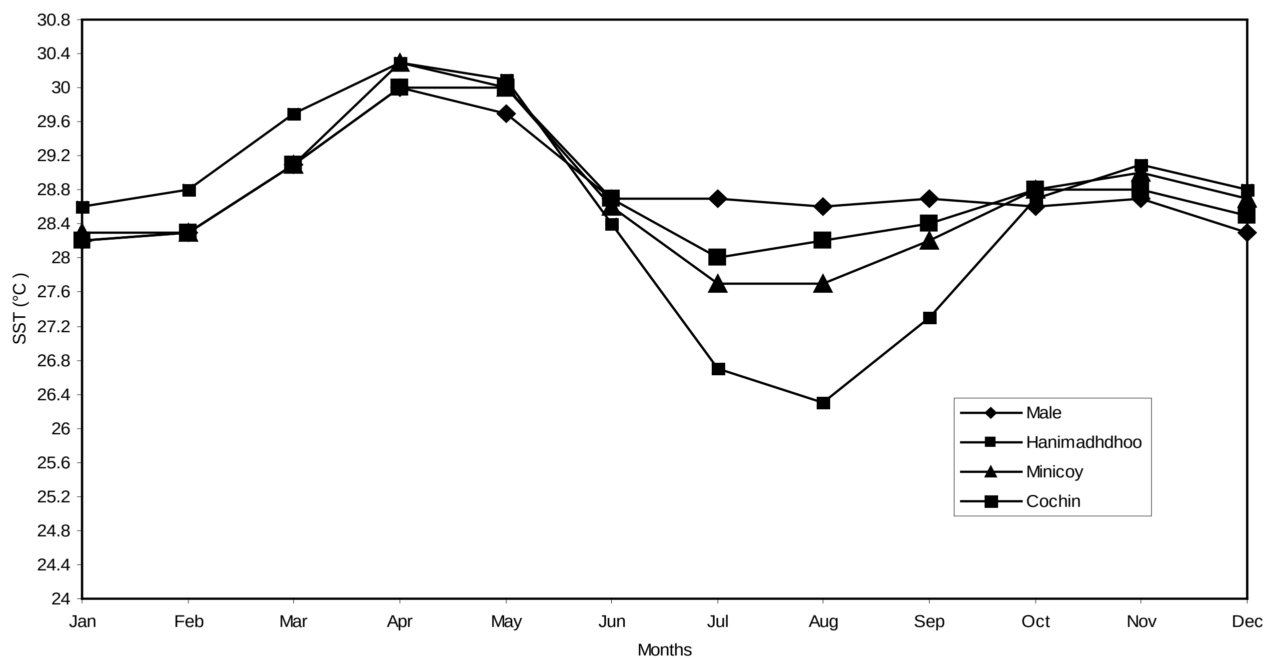


**Fig. 2.** Annual variation of SST near selected stations in southeastern Arabian Sea (Based on satellite derived SSTs for 1985-98)

DS7, DS2, SW4, SW3 and SW1 during the onset phase of summer monsoon 2003 (26 May to 14 June). The locations of buoys have been shown in Fig. 1. The daily means of surface parameters *i.e.*, SST, SLP, wave height and wind speed were computed utilizing all the observations available on a particular day. Thus, the day-

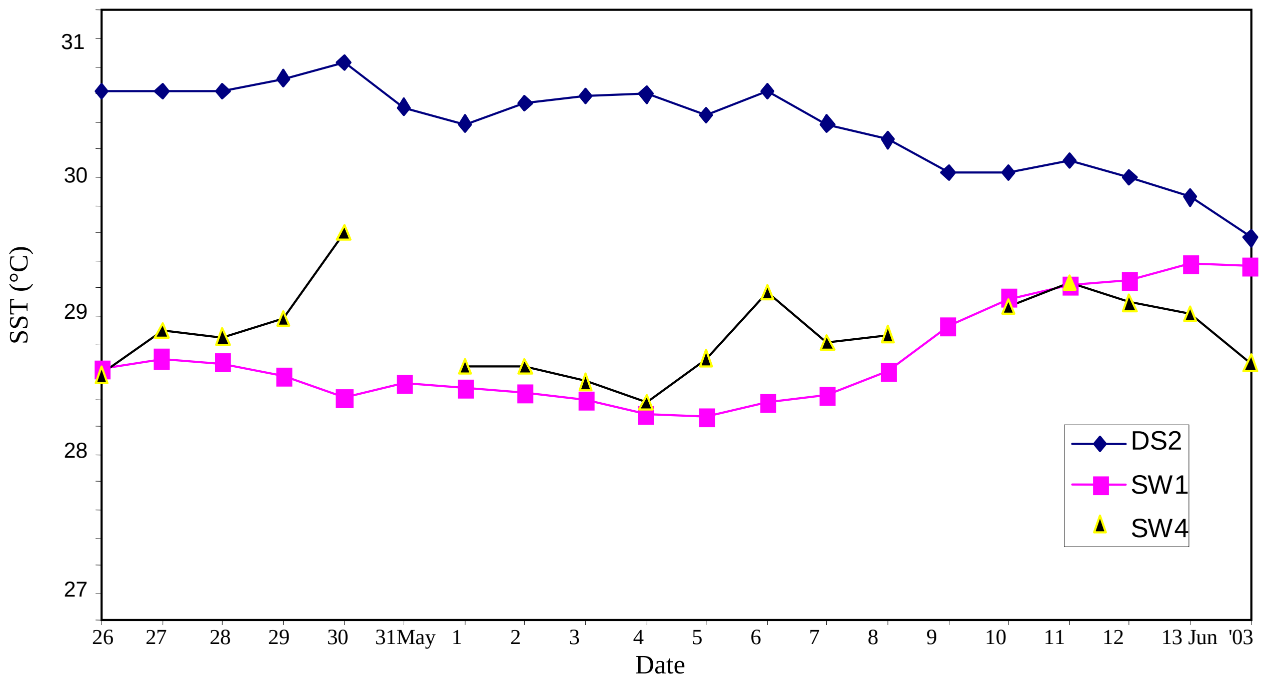


**Fig. 3.** Daily variation of SST at different buoy locations in the southeastern Arabian Sea during 26 May - 14 June, 2003

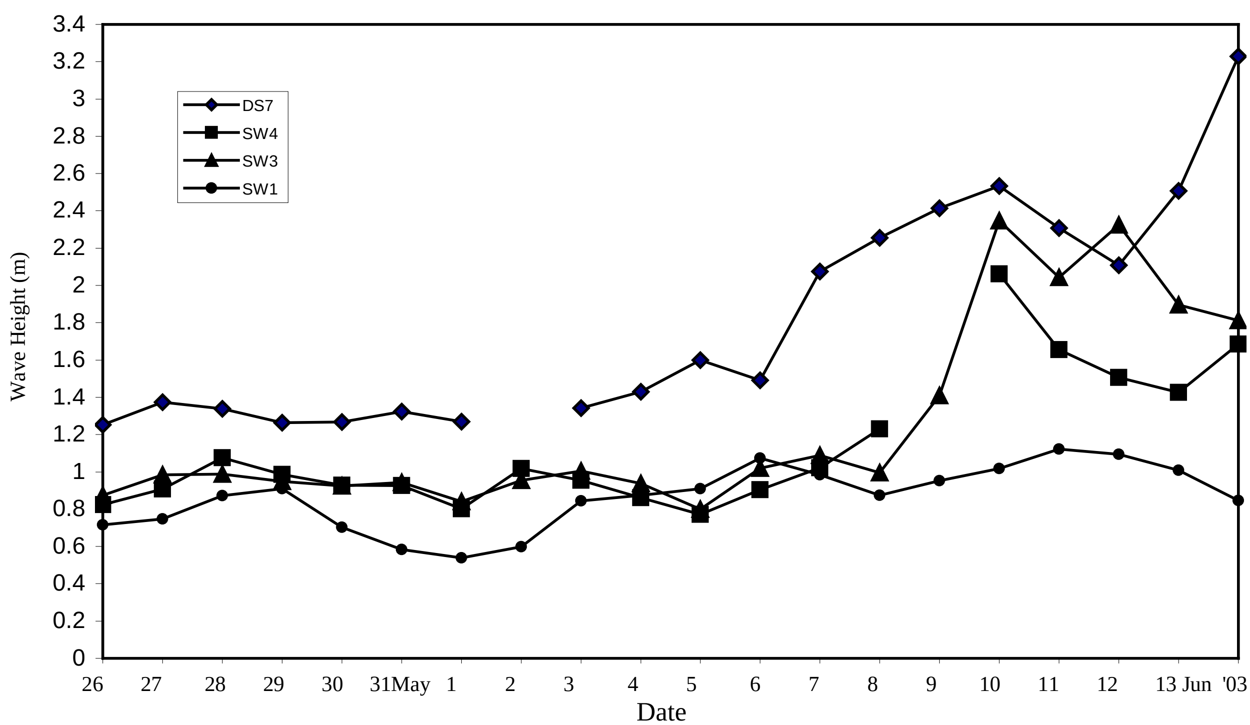


**Fig. 4.** Daily variation of wave height at different buoy locations in the southeastern Arabian Sea during 26 May - 14 June, 2003

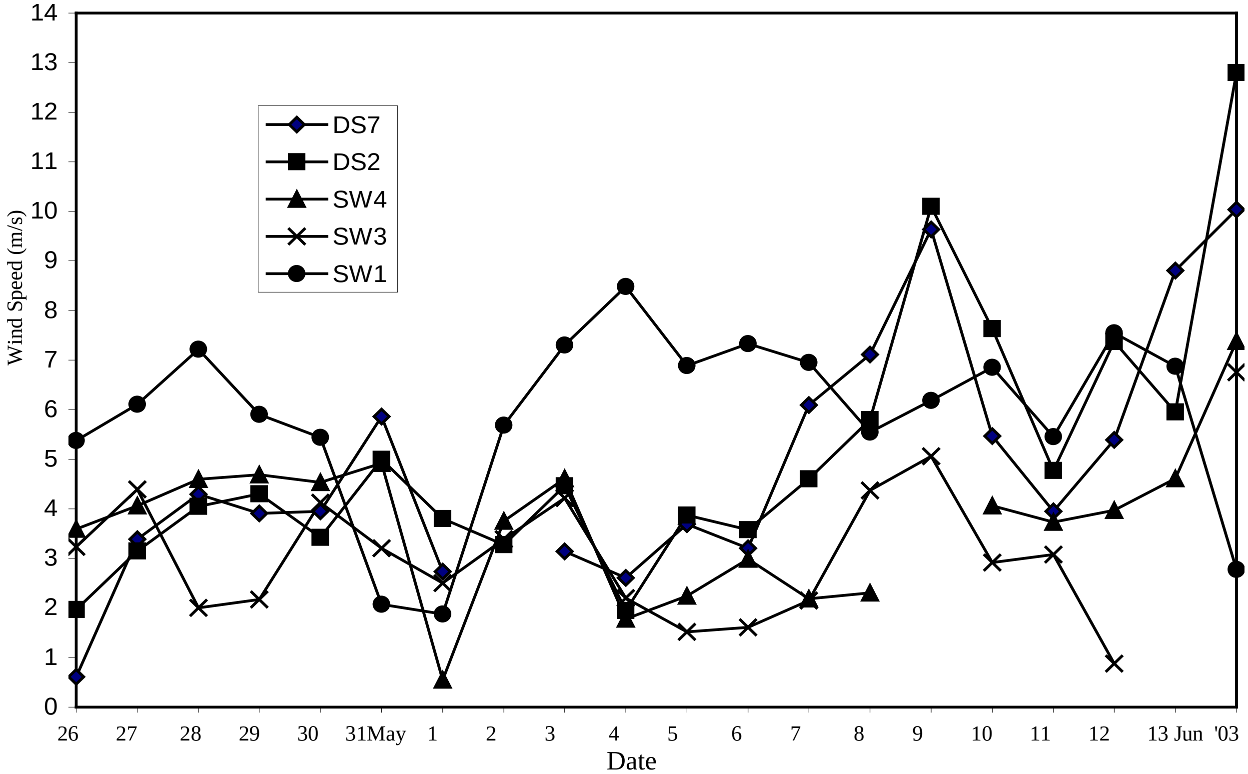


**Fig. 5.** Daily variation of wind speed at different buoy locations in the southeastern Arabian Sea during 26 May-14 June, 2003

to-day changes reported here are reliable as the sporadic diurnal fluctuations have been smoothed out. The temporal variations of the above- mentioned parameters have been analysed at the fixed buoy locations in order to bring out the changes taking place with the advance of monsoon. In order to prepare a normal SST profile in the Lakshadweep Sea area, we have utilized the gridded NOAA-AVHRR SST data for the period 1985-98 obtained from the NASA, Physical Oceanography Distributed Active Archive Centre, California, U.S.A. The gridded data have been used to prepare the SST climatology in the coastal waters near Cochin, Minicoy, Hanimadhdhoo and Male (Maldives).

## 3. Results and discussion

### 3.1. *Onset of 2003 summer monsoon*

The progress of monsoon 2003 has been shown in the paper by Hatwar *et al*. in this volume [(Fig. 5) at page 14]. The summer monsoon 2003 set in over Kerala on 8 June a week after the normal onset (1 June). After the initial delay the rate of progress along the west coast was normal and the monsoon reached the Gujarat coast almost on time. Therefore, 2003 monsoon progressed well along the west coast. However, there was very slow progress in the Gangetic plains region (as given in the paper by Hatwar *et al*. in this volume [(Fig. 5) at page 14]. The observations of deep water buoys DS7 and DS2 in the southeastern Arabian Sea were instrumental in the study of influence of monsoon onset over Lakshadweep Sea region. However, in absence of onset vortex the 2003 onset was less dramatic and changes that took place over the sea areas seemed to be gradual.

### 3.2. *Normal intensity of warm pool and its collapse with the summer monsoon onset*

The satellite derived SSTs have been very useful in the study of the warm pool region in the Lakshadweep Sea. It has been possible to prepare SST climatologies for smaller sea regions using the high resolution grid point SST data. We have prepared the SST climatologies for the south Asian coast using NOAA-AVHRR SST data for the period 1985-98. Here we present the annual variations of SST in the coastal waters near Male and Hanimadhdhoo (Maldives) and Minicoy and Cochin in the warm pool region. Fig. 2 presents the annual variations of SST at the above-mentioned four locations. A close examination of

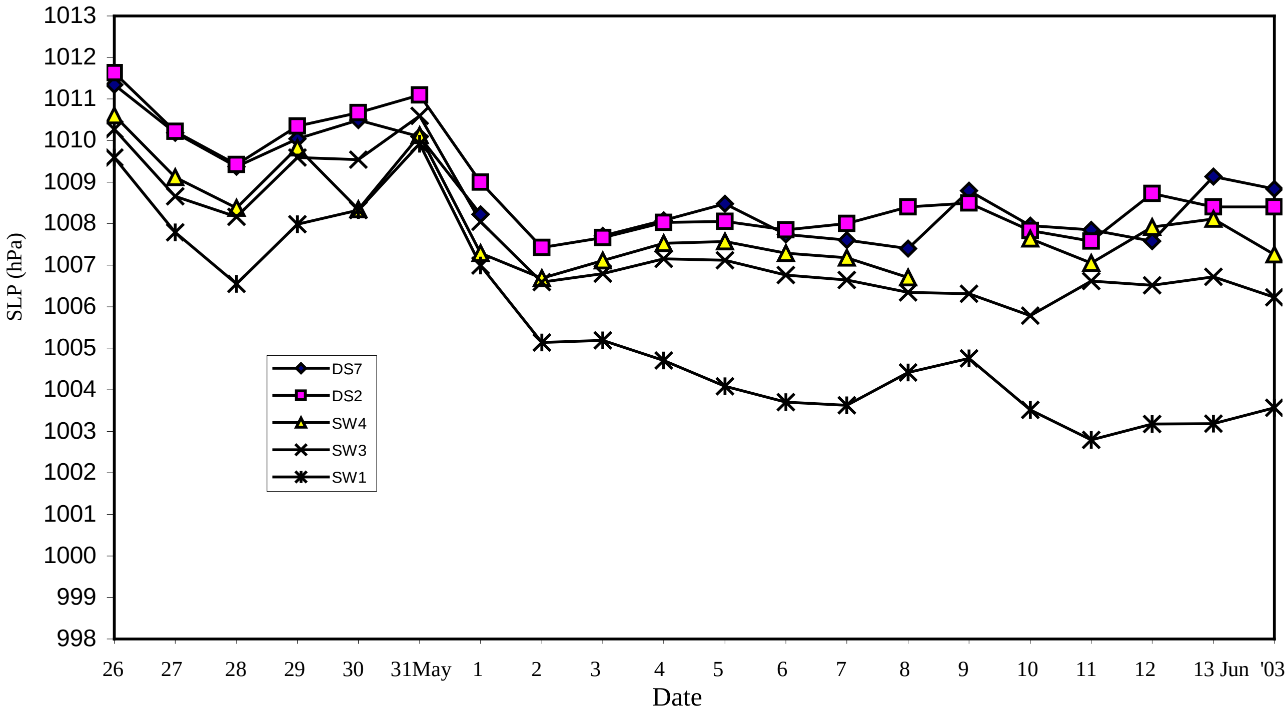


**Fig. 6.** Daily variation of SLP at different buoy locations in the southeastern Arabian Sea during 26 May - 14 June, 2003

Fig. 2 reveals several salient features of evolution of warm pool in the Lakshadweep Sea area.

The intensity of warm pool reaches its peak during April-May and the lowest SSTs are observed during July-August at the peak of the summer monsoon. From September onwards there is a steep rise in the SST near Cochin till November. It is very interesting that the abrupt rise in SSTs during post-monsoon period is almost comparable with the abrupt fall with the monsoon onset in June. Fig. 2 also reveals the important aspects of spatial variation of warm pool intensity. Undoubtedly, the maximum intensity of warm SST is more pronounced near Cochin and least pronounced near Male. Generally, the intensity of warm pool increases northward towards the southwestern coast of India. The mean intensity of warm SST near Cochin during April is 30.3° C and during May it is 30.1° C. A mean fall of about 2° C is observed in the warm pool area near Cochin from May to June with the advance of summer monsoon. Large Interannual variations in the intensity and extent of warm pool have been observed during the period 1985-98. The maximum SST of 31.2° C was observed during April 1998 near Cochin whereas the minimum value of 29.5° C was recorded during April, 1990. The amplitude of interannual variation is maximum during June. In some years the mean SSTs continued to remain in excess of 30° C in the warm pool during June whereas there have been years when the June SSTs fell to as low as 26° C (during 1989). The analysis of entire SST data set for the 14-year period from 1985-98 reveals that every year the intensity of warmest SST occurs near Cochin.

### 3.3. *SST variation in the warm pool region during the onset phase of summer monsoon 2003*

The daily variations of SSTs during onset phase of 2003 monsoon at the fixed buoy locations in the warm pool region have been presented in Fig. 3. DS2 reported a fall of about 0.5° - 0.6° C in SST from 6-9 June, 2003. The gradual evaporative cooling in the warm pool region commenced about 48 hours before the monsoon onset on 8 June in that area. After the establishment of monsoon current the SST fell by about 1° C - 1.2° C within a week. The SSTs reported by SW4 showed a gradual fall after 11 June onwards after the arrival of monsoon current over that area on 10 June. However, a temporary fall was observed in SSTs at SW4 location between 6 to 7 June also.

Evidently along the Gujarat coast at SW1 location SST continued to increase upto 14 June (data available only upto 14 June) as monsoon advanced over that area much later (*i.e.*, on 17 June). Thus in general the evaporative cooling over the eastern Arabian Sea was subdued during the onset phase of 2003 monsoon. The SSTs fell by about 1° - 1.2° C over the period of one week in the warm pool region in the Lakshadweep Sea area after the establishment of monsoon current. Therefore, 2003 monsoon onset was marked by the absence of dramatic SST fall in the warm pool region probably due to the fact that onset vortex did not form during the onset phase of 2003 monsoon.

### 3.4. *Impact of monsoon onset on the wave height*

The roughness of sea increases considerably with the advance of monsoon due to the strengthening of winds. It can be seen from Fig. 4 that height of swells registered an increase of 2 metres at DS7 location between 6-14 June. The marked increase in the swell height commenced over the east central Arabian Sea (SW3) from 8 June onwards. Thus, the wave height showed a marked increase of about 2-3 m before the monsoon onset over southeastern and east central Arabian Sea, which is a well known feature.

### 3.5. *Daily variation of wind speed*

Fig. 5 shows the daily variations of wind speed at the buoy locations. The wind speed variability is marked by large day-to-day fluctuations. After the onset of monsoon over southeastern Arabian Sea on 8 June, though the winds strengthened over that area the daily mean wind speeds did not go beyond 10 $ms^{-1}$. Thus, the onset current seemed to be feeble. After a lull of about 2-3 days the surface winds strengthened again from 12 June onwards. This shows the pulsatory nature of monsoon current. It is due to the feeble monsoon current that the evaporative cooling in the warm pool region was subdued during 2003 monsoon onset.

### 3.6. *Daily variation of SLP*

The SLP variations are presented in Fig. 6. The SLPs registered a sharp fall after 31 May throughout eastern Arabian Sea. It is interesting to note that the sea level pressure fell almost concurrently from southeastern to northeastern Arabian Sea about one week prior to the summer monsoon onset over Kerala on 8 June. The onset of monsoon seems to have little influence on the SLP fields as there was very little change in SLPs at the time of monsoon advance. It may be due to the absence of onset vortex during 2003 onset. However, the sudden fall of SLPs over the Arabian Sea about a week before the monsoon onset may serve as a good precursor of ensuing monsoon onset.

## 4. Conclusions

The study has brought out the following results:

(*i*) The collapse of warm pool in the Lakshadweep Sea area was very gradual during the onset phase of summer monsoon, 2003. The evaporative cooling was subdued due to absence of onset vortex.

(*ii*) The height of swells increased about 2-3 days before the monsoon advance over the eastern Arabian Sea showing that the swells are useful precursors of monsoon onset.

(*iii*) There was large fluctuation in the wind speed during the onset phase of the monsoon implying the pulsatory nature of monsoon.

(*iv*) The sea level pressure fell sharply over the eastern Arabian Sea about a week before the monsoon onset over Kerala.

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