CHAPTER

34

EL NIÑO AND ITS IMPACT ON CORAL REEF ECOSYSTEM IN THE EASTERN INDIAN OCEAN

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Introduction

The coral reef bleaching associated with the elevated Ocean temperature has been widely reported in the last three decades from different regions of the world. The rising temperature and acidification of Oceans makes a big challenge for the survival of reefs in the world. The other important stresses for the reefs include increased UV radiation, sea level variations, suspended sediments and increased turbidity of water. There are different studies which relate bleaching events with global warming and climate change. However, the increased frequency of mass bleaching events could not be sufficiently explained with current warming rates of the Ocean. Stone *et al.,* (1999) put forward a new theory that recent increases in mass bleaching events were in response to the relative increase in El Niño experienced over the last two decades. The bleaching threshold temperature is site dependent and it may vary from one reef region to other. The threshold temperature for the Indian reefs is approximately 31°C (Vivekanandan *et al.,* 2008). In the Indian Ocean, the coral reefs around the Andaman Islands suffered bleaching events during 1998, 2002, 2005, 2010 and 2016. In the Andaman Sea, the rise in temperature was abnormal during 1998 and 2010 and hence mass bleaching events were happened during that period (Krishnan *et al.,* 2011; Vivekanandan *et al.,* 2008). The coral reef bleaching associated with warm water anomalies in the Pacific Ocean during an El Niño period is well studied and documented. However, the link between the massive bleaching events in the Indian Ocean and El Niño is not straightforward as in the Pacific. For example, the massive bleaching event of 1998 in the Indian Ocean was happened in May and that was a transition period from a strong El Niño to a strong La Niña in the Pacific. Hence, in the Indian Ocean, the role of El Niño in the mass coral reef bleaching event of 1997-98 was not clear (Wilkinson, 1999). Moreover, the ocean temperature variability in the Indian Ocean can be significantly modulated by the different regional processes in the Indian Ocean itself such as Indian Ocean Dipole, formation of cyclone, early arrival of monsoon *etc*. However, a recent study shows that massive bleaching events in the Andaman reefs of the Indian Ocean is directly linked with the strong El Niño events in the Pacific Ocean (Lix *et al.,* 2016). The atmospheric teleconnections between the two Ocean basins is the primary reason for this link.

Hot spot Method

By using long term satellite data sets, Goreau and Hayes (1994) developed a 'hot spot' method to predict the possibility of bleaching events in the reef region. A hot spot is the area of the ocean with sea surface temperature anomalies over 1°C above long-term averages of monthly maximum. AVHRR Pathfinder SST with 4x4 km resolution that available from 1982 onwards can be used to estimate the hot spot area.

Hot Spot = Weekly average SST – Monthly Mean Maximum Climatology

Hot spot products based on satellite data sets is also directly available from NOAA coral reef watch program. The details of the NOAA products such as hot spot, degree heating week, bleaching alert area, SST anomaly are available in the NOAA website https://coralreefwatch.noaa.gov/satellite/index.php. If the hot spot anomaly greater than 1°C exists for greater than or equal to 4 weeks, there is a strong chance for severe bleaching. Hot spot region around the Andaman reefs for a mass bleaching event (2010) and non bleaching event (2011) is shown in figure 1 and figure 2.

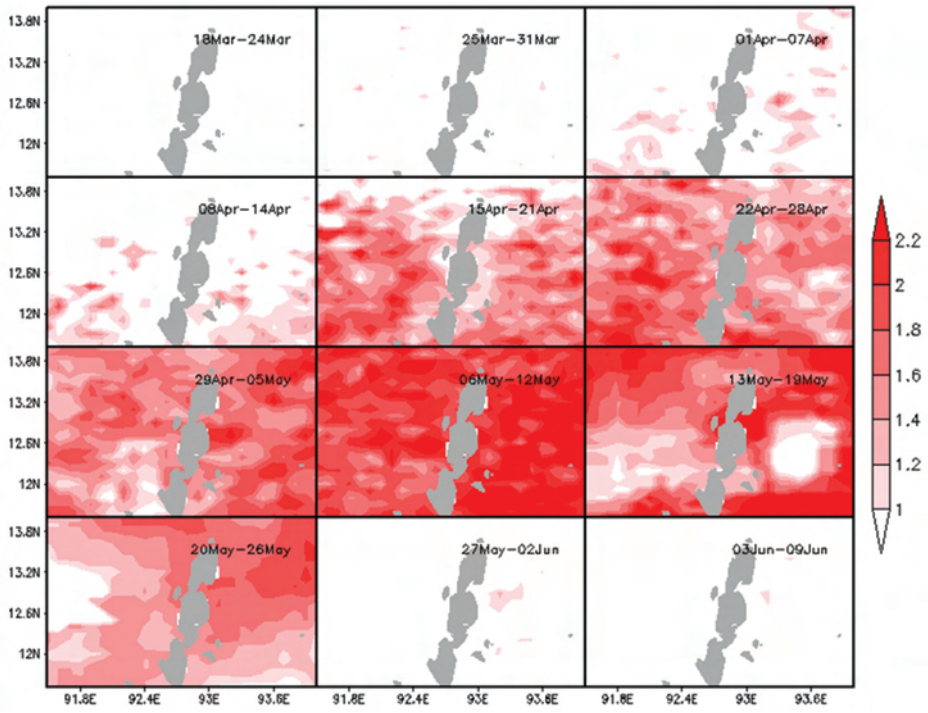

Figure 1. The spatial distribution of the weekly hot spot images from March 18 to June 9, 2010 around the Andaman Islands (Lix, Venkatesan, Grinson et al., 2016)

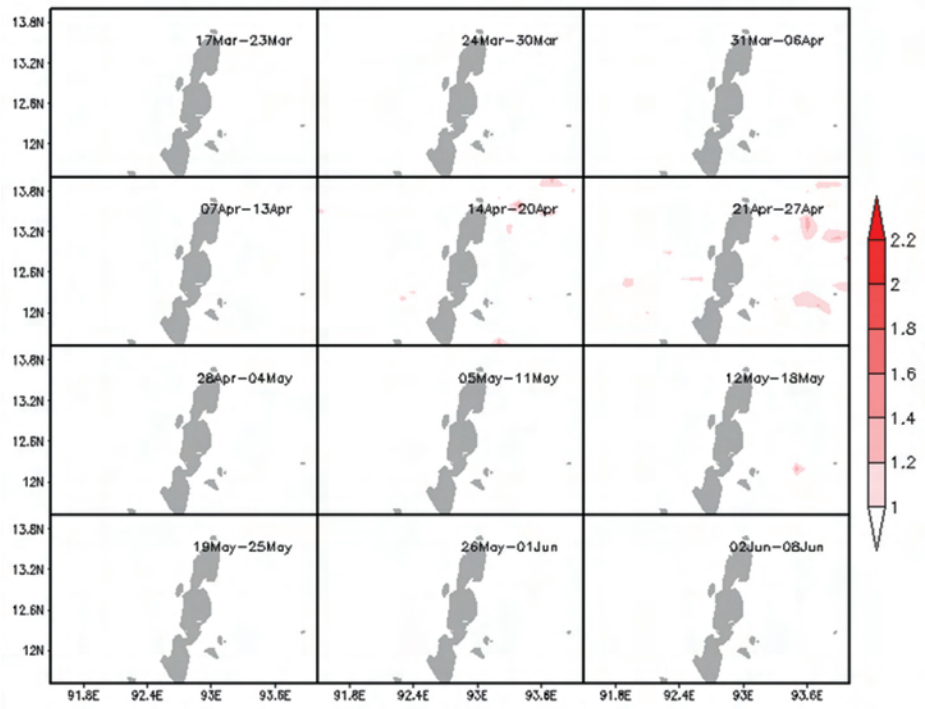

Figure 2. The spatial distribution of the weekly hot spot images from March 17 to June 8, 2011 around the Andaman Islands

El Niño and its impact on Andaman Sea temperature and coral reefs

El Niño is a warming of the tropical Pacific that occurs roughly every three to seven years and lasts for 12 to 18 months (McPhaden, 2002). During El Niño, trade winds weaken along the equator and that causes for the reduction in the upwelling and subsequent warming in the central and eastern Pacific. For more detail of El Niño physics see McPhaden (2002). A strong El Niño in the Pacific causes a similar warming in the Andaman Sea and Eastern Indian Ocean and that warming may lag the peak of El Niño by 4 to 6 months. The delayed response of Indian Ocean to an El Niño event leads to the formation of unusual warm anomalies during the pre monsoon months of an El Niño followed year. Niño 3 index and Niño 3.4 index are the most commonly used indices to define El Niño events which are based on SST anomalies averaged across a specific region. The Niño 3 Region is bounded by 90°W-150°W and 5°S- 5°N. The Niño 3.4 Region is bounded by 120°W-170°W and 5°S-5°N. The change in cloud cover can significantly modulate the incoming solar radiation that reaches the Ocean surface. The net incoming shortwave radiation is the primary factor that determines the heat budget of a shallow reef region. Hence the change in cloud cover due

to the change in the large scale atmospheric circulation can significantly alter the net heat gain and hence the sea surface temperature of a reef environment. A schematic diagram for an altered Walker circulation and its role on the warming of Eastern Indian Ocean is given in figure 3. The altered Walker circulation and the resultant atmospheric forcing on the Ocean surface has a significant role on the warming of the Indian Ocean during an El Niño followed year (Klein *et al.,* 1999).

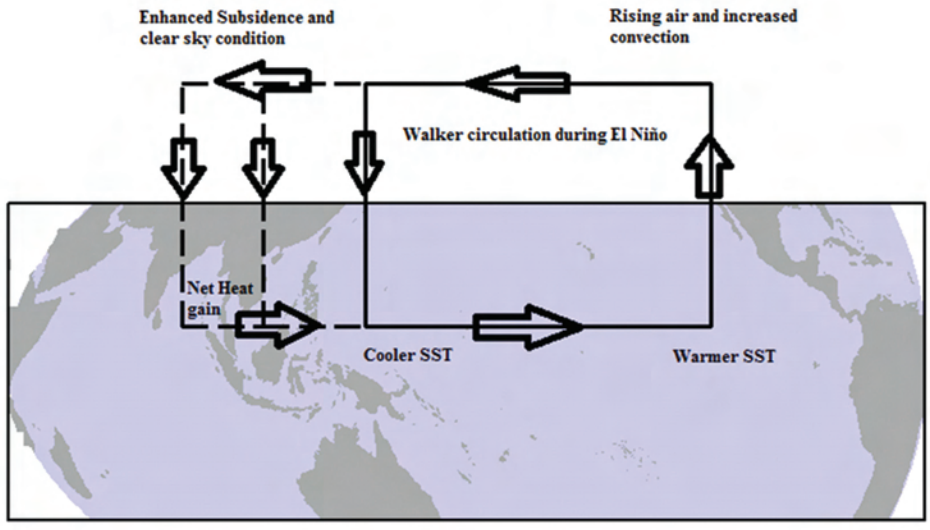

Figure 3. The altered Walker circulation for a typical El Niño event

Summary

The formation of hotspot pattern and its existence for a prolonged duration can induce bleaching in Indian reef region. A strong El Niño as in 1997-98, 2009-10 and 2015-16 can cause for the abnormal warming and resultant massive bleaching events in the Indian reefs. However, the thermal environment of Indian reefs can significantly affected by the regional atmospheric and oceanic processes. The regional processes can enhance or reduce the El Niño related warming in the Indian Ocean and hence regulate the intensity of bleaching. There is a considerable increase in the intensity and frequency of El Niño in the last four decades. At present, the impact of global warming on El Niño frequency and intensity is unknown. However, recent modeling studies indicate that frequency of El Niño may increase in the future. Hence, Indian reef may experience more mass bleaching events in future. Among all the reef regions of India, the effect of El Niño is more severe on Andaman reef because the perturbation associated with El Niño arrives at the climatological maxima in the seasonal heating cycle of the Andaman Sea.

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