*International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081 (Online)*
*An Open Access, Online International Journal Available at http://www.cibtech.org/jgee.htm*
*2014 Vol. 4 (3) September-December, pp. 101-108/Pramanik*
***Research Article***

# CLIMATE CHANGE AND SEA SURFACE TEMPERATURE: MODELLING THE EFFECTS ON CORAL BLEACHING

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## ABSTRACT
Presently climate change is a serious Problem on corals and their associated ecosystems that also affects the national and international income. The Present study emphasizes the impact of sea surface temperature on coral living, coral bleaching, coral growth and modeling for influential high temperature on corals as a significant biodiversity of tropical regions. Coral bleaching information, data of Sea Surface Temperature (SST), and coast watch utility software collected from the National Oceanic and Atmospheric Administration (NOAA) is an important way of monitoring and modeling of coral responses to SST. These data represent that the higher range of sea surface temperature and anomaly is responsible for the greater change of the coral bleaching area and hotspot. Within the narrow sea surface temperature change coral can respond significantly. This model finds southern pacific is most vulnerable and attractive sites for coral bleaching. Eastern tropical Pacific and Caribbean coral has been affected by El Nino and the anomaly of sea surface temperature. We need to continue to develop the models for protecting the coral reefs to present natural and anthropogenic climate change induced sea surface temperature causing the coral bleaching events.

***Keywords:*** *Coral Bleaching, Hotspot, Climate Change, Biodiversity, Coral Reef Crisis*

## INTRODUCTION
The coral reef is a rich and predominant oceanic ecosystem of the tropics of Cancer and Capricorn where one third of total marine fish species, also thousands of other species present. These ecosystems also provide 6 million tons of fish in a year and have a greater significance for the generation of national and international income (James and Crabbe, 2008). This is not only significant but also helps for the income of local community and their nutritional sustenance (Crabbe, 2008). But now, these significant biodiversity is threatened due to increasing present climate change related events (Hughes *et al.,* 2003). So these impacts now become one of the most serious problems with the Oceanic ecosystem as well as coral reefs. These corals are significantly bleached due to Climate change related increasing mean and anomaly of sea surface temperatures (SSTs). Here, Coral bleaching indicates the general whitening of coral colonies that generalized the responses to climate related unfavorable global environmental conditions such as high sea surface temperature (Glynn, 1993; Brown, 1997; Hoegh-Guldberg, 1999), anthropogenic influences (Nystrom *et al.,* 2000), such as pollution, industrial waste, overfishing and mining (Mumby *et al.,* 2007), salinity disturbances (Goreau, 1964) and other conditions also (Glynn, 1993; 1996). Climate induced ENSO events also resulted to mass coral bleaching that approximately destructed 16% of the total world's coral community (Wilkinson, 2000). Since 1979, the intensity, number, and scale of coral bleaching incidents have grown in a devastating way and the trend also has been interconnected with present climate change related events (e.g. Hoegh-Guldberg, 1999). These coral bleaching or coral mortality arrives a significant deterioration for cumulative burdening of water temperature (Wilkinson, 2008). In 1998, coral mortality occurred across most of the western part of Indian Ocean at an unprecedented scale (Graham *et al.,* 2006) that altered significantly, the services and goods of this region (Pratchett *et al.,* 2008) as well as all over the Indian ocean (Obura, 2005). These phenomena also occurred in a localized way for major storm events, tidal exposure, sedimentation and thermal shock (Glynn, 1993).

The sea surface temperature increases with the predicted global air temperature arrived since 1.8°-4.0°c (IPCC, 2007). The normal growth of coral depends on 29°-31°c usual summer temperature in the tropics if coral can endure short term temperature raises up to 34° c but when these warming occur in a long term warming of SSTs is about 32°-33° c cause to start to expel their zooxanthellae that means coral lose their tissue due to thermal stress (Szmant and Gassman, 1990). So the communities of coral reef are passing very smartly from healthy condition to marginal status, at last dead. But recent coral bleaching occurred due to human induced sea level rise (Phongsuwan and Chansang, 2012). Coral bleaching is arrived potential condition widely when inshore monthly sea surface temperature exceeds 30°- 34° c (Phongsuwan and Chansang, 2012).

In present view about "Coral reef crisis" (Wilkinson, 2000), we emphasize potential sea surface temperature in the last 10 years that contributed by present significant human impacts (Sheppard, 1995; Pandolfi *et al.,* 2003). The present study explores the relationship between temporal change of climate induced elevated sea surface temperature and global coral bleaching events.

## MATERIALS AND METHODS

### *Database and Methodology*

#### *Data Used*

The present study, primarily based on the collecting data of SST, anomaly of SST, coral bleaching alerted area and Coral bleaching hotspot. All the data has been collected from National Oceanic and Atmospheric Administration (NOAA)-14 from 2001 to 2014. NOAA-14 primarily used AVHRR sensor for the collection of all ocean data. After collecting these data were processed by using coast watch data analysis tool and software. Editing and formatting of the data of mean sea surface temperature and coral bleaching is usually based on the data layer of NOAA. Coral Reef Early Warning System software also used for producing the coral bleaching alert area and coral bleaching hotspot.

#### *Analytical Tool*

For the representation of their relationship, gridded files of sea surface temperature and coral bleaching area were imported in Environmental systems research Institute's (ESRI) Arc Info software. Guinotte (1999) explains in more detail the methods of spatial analysis, mapping, and visual techniques in global marine environments.

#### *Threshold Identification*

The effects of present increasing sea surface temperature on coral reefs were identified on the basis temporal change. The increasing hotspot area determined by the increasing sea surface temperature because of the coral's higher response abilities. Kinsman (1964) describes the critical limits of coral growth are signing up to 39.5°c but significant departures of temperature (sea surface temperature anomaly) are most significant. This sea surface temperature and anomaly of oceanic temperature is the main factor to identify the coral threshold.

#### *The Role of SST on Coral Growth*

Several studies analyze the importance of air temperature and growth of Coral colonies, but present studies examined the relation between sea surface temperature and growth of coral reefs. The relation undertakes the period from 2001 to 2014 which shows the negative relation between them. The calcification rate and growth rate also related to these factors and also extend the incoming solar radiation and temperature (Lough and Barnes, 2000; Nie *et al.,* 1997). However, in the case of juvenile corals, a cooler year represents algometric growth and warmer years promote the isometric growth of corals (Edmunds, 2006; Edmunds, 2008). The skeletal density also declined in a small scale due to sea surface temperature and other environmental parameter (Cooper *et al.,* 2008). The fluctuations of sea surface temperature (figure 3) make them for the persistence of increasing hostile environment (McClanahan *et al.,* 2007).

Coral growth rates also depend on the mean seasonal temperature. Inter decadal and inter seasonal changes in the coral growth rate interlinked with the minimum air temperature in the winter season. These temperatures affects the convenient changes of sea surface temperature, but here also responsible some

other meteorological and oceanographic variables (Slowey and Crowley, 1995) also. Cold, dry air may be responsible for stressing corals and reducing their winter growth rate. This effect has been found in the flower gardens that is the cause of declining coral growth.

## RESULTS AND DISCUSSION

### *Results*

### *Modeling the Effects of High Sea Surface Temperature on Corals*

The frequency of coral bleaching depends upon the present sea mean sea surface temperature and anomaly of SST and maximum SST (figure 1 and 2). This Mean sea surface temperature gradually increases due to present greenhouse emissions. The future coral bleaching may be estimated by the projecting sea surface temperature from four different general Circulation models of IPCC (Intergovernmental panel for climate change) the sea surface temperature projections were used to find out the thermal thresholds of corals by using the Integrated Global Ocean Services System (IGOSS). All the datasets collected from the Joint world and Scientific Meteorological Organization (WMO), United Nations Educational, Scientific and Cultural Organization (UNESCO), Joint Intergovernmental Oceanographic commissions (JCOMM), Marine Meteorology and Technical Commission for Oceanography, also from Internet reports and literature. Available these data indicate that frequency of bleaching events rises rapidly where the higher rate has been found in the Caribbean, Southeast Asia, and Australian Great Barrier Reef and the lowest rate found in the only Central Pacific (figure 4). Bleaching events occurred due to the changes of sea surface temperature rather than by El Nino events (Jones, 2008) Coral mortality of the Indian Ocean has been found in a repeated way (Sheppard, 2003). Increasing SST at 33 sites was blended into previous SST of the Indian Ocean. The satellite oriented coral bleaching and alerts (NOAA CRW) area significantly predicted by using the anomaly of sea surface temperature (figure 3) (Liu *et al.*, 2006). The products mainly collected by Advanced Very High Resolution Radiometer (AVHRR) and the NOAA polar orbiting satellites (primarily SST) on nighttime.

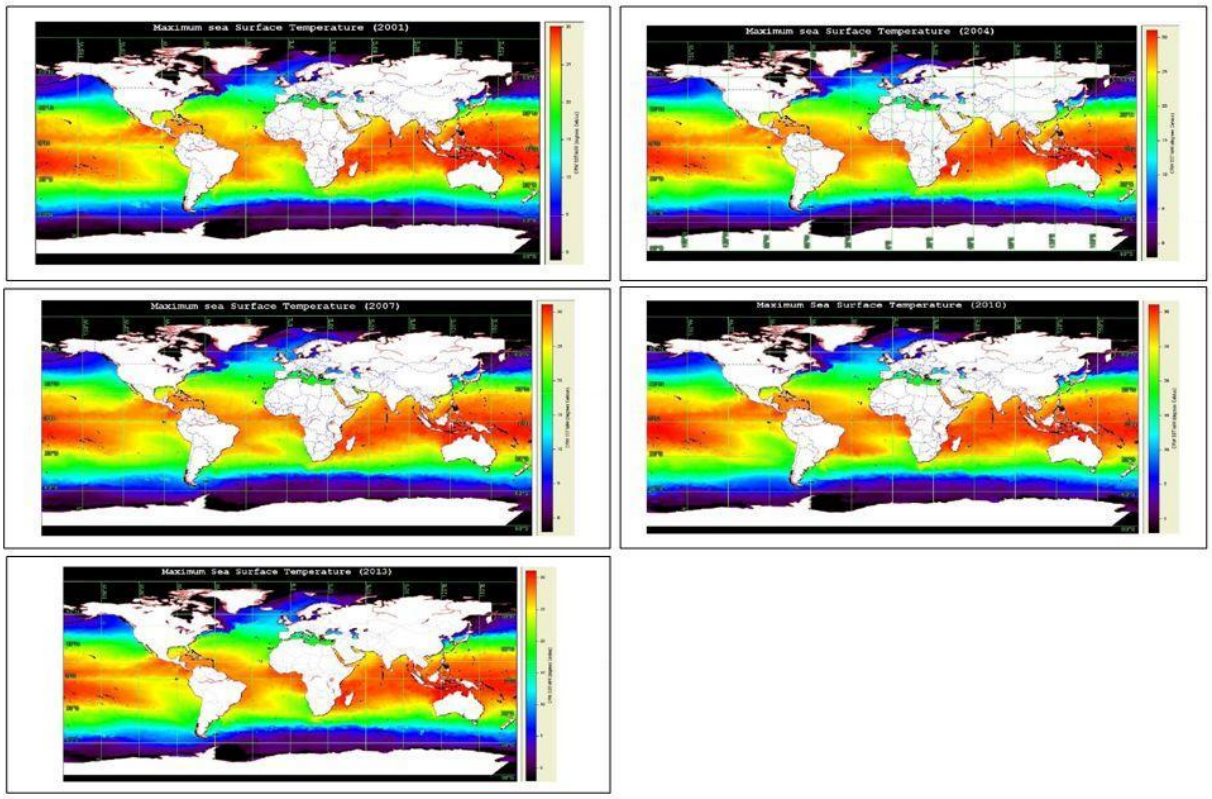


**Figure1: sea surface temperature of 2001, 2004, 2007, 2010, and 2013 respectively.**

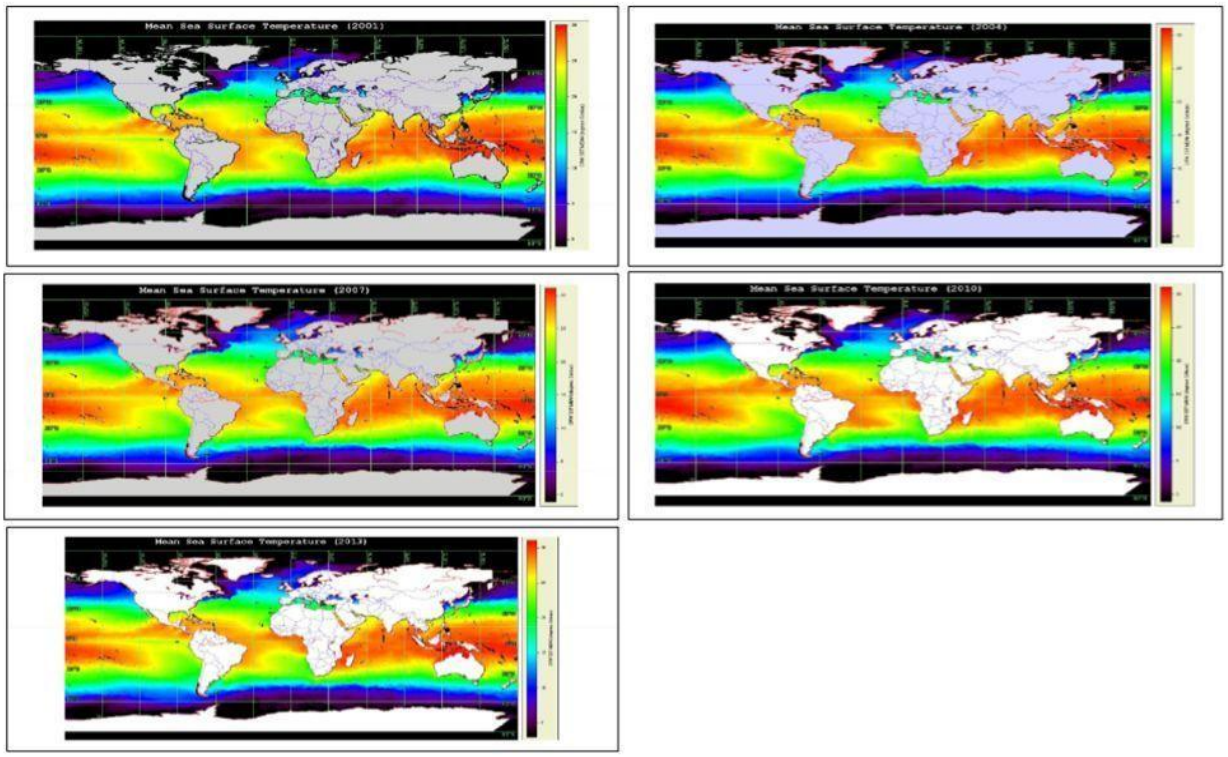


**Figure 2: Maximum Sea surface temperature in 2001, 2004, 2007, 2010, 2013 successively**

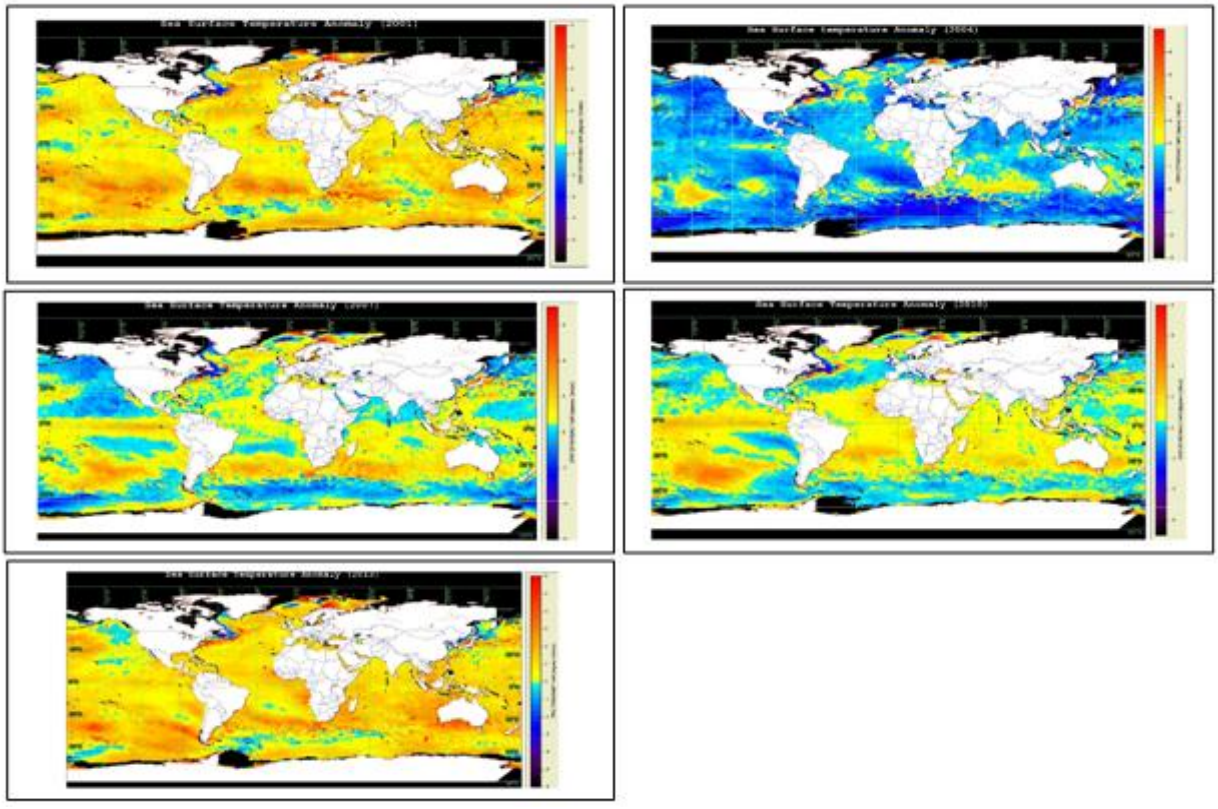

**Figure 3: Sea surface temperature anomaly of 2001, 2004, 2007, 2010, 2013 respectively**

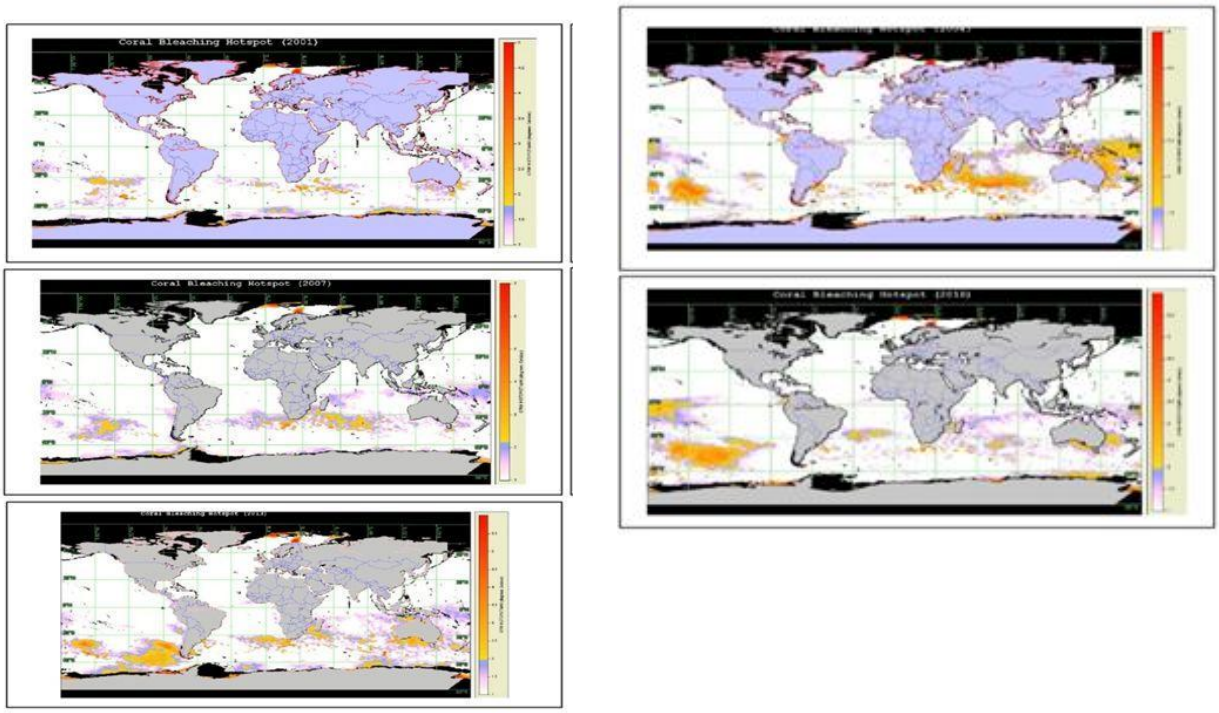


**Figure 4: Coral Bleaching Hotspot in 2001, 2004, 2007, 2010, 2013 respectively**

Average (30 days) maximum daily temperature might be explaining the variability of the time dependent coral growth (Crabbe *et al.*, 2008). High temperature water has been suggested that the increasing rate of locally unrespectable mass bleaching events (Goreau, 1992). The modeling of James and Crabbe (2008) suggests that coral, mostly responded by the rate of temperature change as well as anomaly of temperature also. The present study analyzes that coral lives close to their maximum temperature threshold at the time of warmest summer months that may stress to coral bleaching. The study has been found most of the bleaching events occur in the tropical Indian Ocean and tropical Pacific and but not significantly in the Atlantic oceans. The coral bleaching events also affected to Acropora elizabethensis (Middleton reef) and Acropora tortuosa (Elizabeth reef) in south eastern Australia, Rawaki Island, Cook Island and Phoenix Islands (Protected Area), Orona atoll, Manihiki Atoll in the south western Pacific region. Alberta atoll and Glorioso islands in South Western Indian ocean Coral bleaching is mostly varies during the last decade. In the Present view of coral bleaching southern pacific is most vulnerable site and most attractive bleaching events occur in Southern Pacific as well as Tropical Pacific region. Most of eastern tropical Pacific and Caribbean coral has been affected by El Nino (Goreau and Hayes, 1994) and the anomaly of sea surface temperature. This Unprecedented nature of coral bleaching events in the last decade has led some to cause of Global Warming (Gleeson and Strong, 1995).

***Discussion***

Sea surface temperature increases due to natural and man-made (indirect and direct) disturbances at various scales. Storm, typhoon is also responsible for these changing patterns that conveniently occur in Tropical Pacific Ocean, Indian Ocean as well as Andaman Sea (Phongsuwan, 1991). South western part of the Pacific Ocean is the only place where most of Coral bleaching area increases due to Tsunami (2004, 26$^{th}$ December). Such results prove that the Tsunami activity also affects the Coral bleaching as well as coral mortality. But in Present time coral bleaching occurred at different time period due to increasing SST (Chansang and Phongsuwan 2012), that must be linked with present climate change. In last several year's coral bleaching also affected by nutrients, Turbidity and high sedimentation loads (Reopanichkul *et al.*, 2010).

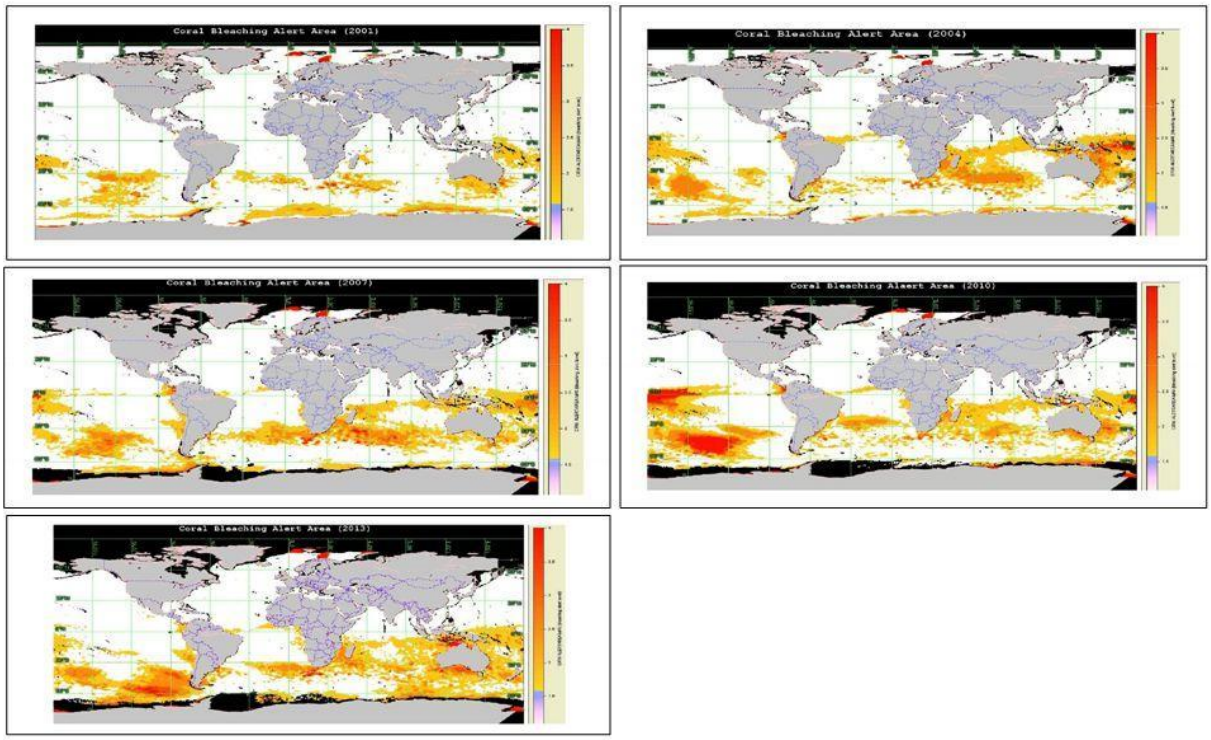


**Figure 5: Coral bleaching alert area in 2001, 2004, 2007, 2010, 2013 respectively**

These sedimentation rate responsible for the increase ocean temperature and temperature anomaly also. On a large spatial scale, live coral area gradually decreases in the southern Indian Ocean, Eastern Pacific Ocean & western Pacific Ocean. That's why these regions have a lot of alert area (figure 5) of coral bleaching. In addition, internal wave action and offshore current play the fluctuation of sea surface temperature. The amount of coral bleaching also depends upon Species diversity, bleaching susceptibility and relative fluctuation of ocean water. However, the live corals bleached in higher rate due to the affection of all factors all over the world's oceans.

***Conclusion***

Climate processes and extreme weather events can influence the growth of reef colonies. The Coral growth highly influential and sensitive to narrow range of temperature, water PH, radiation, salinity, intensity, ocean currents, turbidity and sedimentation rate. Present day all empirical models signify that the growth of coral influenced by the small changes in temperature and the rates of temperature change. We need to continue developing various models for knowing non steady-states (such as, climate change &global warming) effects on the morphology of coral reef. With respect to, ecosystem based management option (Bouma *et al.*, 2008; Crabbe, 2009), it might be essential to emphasize over fishing, coastal pollution, destructive fishing and sedimentation rate.

**ACKNOWLEDGEMENT**

The authors wish the first and foremost; thanks to my research supervisor Dr. Krishnendra Meena and my first year course work professors, including Prof. Rajesh Rajagopalan, Dr. Madhan Mohan, Dr. Manish Dabhade, Dr. Shivaji Kumar, Dr. Dipendra Nath Das and Prof. Milap Chand Sharma and at Jawaharlal Nehru University (JNU). I also thankful to National Oceanic and atmospheric administration (NOAA) for providing the significant software and data. Also extend huge and warm thanks to some of my friends Biswajit Mondal, Sumantra Sarathi Biswas and Raghunath Pal and seniors Prasenjit Acharya and Avijit Mistri at JNU who always support different kinds of technical and supportive assistance for the research work.

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