A PILOT STUDY ON PREDICTION OF HEAT WAVE EVENTS OVER THE COASTAL AREA OF INDIA USING SEA SURFACE TEMPERATURE

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ABSTRACT: India has witnessed several extreme heat wave events during the summer season. The frequency and the severity of heat wave events have caused the death of over 22562 people since 1992 to 2015 in India. These statistics demand a proper study of heat wave events and its root causes. Previous studies on heat waves show a significant correlation between air temperature over land and sea surface temperature (SST).This study examines the heat wave events and its predictability based on SST reading during previous heatwave period, thus attempts to establish a relationship between the temperature changes happened over land and the changes in the sea surface. The approach to this study is purely observational in nature. The heat wave period from 1985 and 2015 over the coastal parts of India were identified based on the measures set by India Meteorological Department (IMD).Most of the heat wave events over coastal areas were falling between April and June months. Analysis of sea surface temperature retrieved using satellite data over the sea surface at the time of heat wave events shows an increase in the minimum and maximum SST during identified heat wave periods at land. It is found that the maximum sea surface temperature gets intensified near the coastal areas that are identified as heat wave affected zones by IMD. Hence the study shows the significant influence of SST on heat waves over the land and the marginal predictability of heat waves based on these patterns. This study calls for further investigation of the physical parameters which affect heat wave, and this can even lead to the possibility of a potential tool for long lead predictability of heat waves.

1. INTRODUCTION

Heatwave events are one among the dangerous natural hazards which often lack the characteristic of sudden violence of other hazards such as tropical cyclones or floods. The world has witnessed several extreme heat wave events which even lead to the loss of life. Heatwave events can have a heavy toll on human systems, affecting health, livelihoods, and infrastructure. The severe impacts of heat wave events on the natural system are beyond the duration of heat wave events.

As there is no universal definition of heat waves(Perkins and Alexander, 2013; Robinson, 2001),they are understood to be periods of unusually hot and dry or hot and humid weather that have a subtle onset and cessation, a duration of at least two to three days and a discernible impact on human activities. Not only the daytime temperature but also the nocturnal temperatures and humidity levels may also rise beyond their long-term mean during such hot weather periods. The characteristics of heat waves were found that they are relative to a particular locations climate; it is not necessary that particular meteorological conditions in one location which constitute a heat wave need not constitute heat wave in other location. Also, all heat wave events are not same as their spatial extent, and the intensity may vary considerably across a region (Stefanon et al., 2012).

In India, the period of high temperatures, more than normal maximum temperature, happens amid the pre-monsoon (April to June) summer season. Heat - waves normally happen between March to June, and in some uncommon cases even extend until July. On a normal, 5-6 heat wave events happen each year over the northern parts of India. Figures show that heat wave caused the death of 22562 since 1992 to 2015 in various states of India (National Disaster Management Authority, 2016).

From a physical meteorology point of view, two types of heat wave occasions may be identified. Dry heat waves are frequently connected with stable periods of climate that bring clear skies and substantial contributions of solar radiation. Hot and dry conditions may likewise be joined by windy conditions, which can increase heat stress. Dry heat waves, as a rule, happen in areas with a mainland or Mediterranean atmosphere or where the air is heated adiabatically.

Moist heat waves are described by warm, oppressive conditions throughout day and night, sometimes with night time cloud cover, a component that prevents loss of heat accumulated throughout the day and hence little night time

relief. Such heat waves are sometimes a feature of mid-latitude temperature and oceanic atmospheres and might be endemic to few areas (Hunt, 2007).Based on these attributes, heat waves will probable to happen in areas that have an exceptionally variable summer climate or a clear hot season and, accordingly, may result from a range of large-scale meteorological situations and climate-related mechanistic processes (Chang and Wallace, 1987; Choi and Meentemeyer, 2002; Grumm, 2011; Hunt, 2007; Kunkel et al., 1996; Palecki et al., 2001; Pezza et al., 2012; Zaitchik et al., 2006). Areas without an exceptionally variable summer climate or clear hot season are not immune from heatwaves, in any case. On events, an unusual combination of sea, land and atmospheric conditions may give the climatological circumstances for sudden climate surprises and occurrence of extreme temperature and humidity events. The duration of heat wave events may likewise be halfway identified with the general climate setting.

There is a need to understand the proper definition of a heat wave as one of the objectives of the study is dealing with the identification of heat wave events.According to World Meteorological Organization's Meteoterm vocabulary," a heat wave is an extreme weather event with the marked warming of the air, or the invasion of very warm air, over a large area; it usually lasts from a few days to a few weeks". In the Intergovernmental panel on climate change (IPCC) glossary, "the heat wave is a period of abnormally and uncomfortably hot weather". This definition of heat wave by WMO and IPCC broadly describes the event, but are not precise and sufficient to develop tools and methodologies for heat wave monitoring and comparison of the event across the globe.

The WMO TT-DEWCE (Task Team on Definitions of Extreme Weather and Climate Event) defined heat wave as "A marked unusual hot weather (Max, Min, and daily average) over a region persisting at least two consecutive days during the hot period of the year based on local climatological conditions, with thermal conditions recorded above-given thresholds."The definition suggests looking into the local climatological conditions. As this study is in the Indian context the criterion on heat wave by India Meteorological Department (IMD) is used for identifying heat wave events.

The factors that favour severe heat wave events over the land include (Sinha Ray et al., 1999) (1) Warm dry air and its suitable flow pattern for transporting hot air (2) Lack of moisture content in the upper air (3) Cloudless sky to permit maximum insolation (4) Dry adiabatic lapse rate (5) Large amplitude anti-cyclonic flow or the thickness values should be considerably above normal in all layers.

The increase in temperature over a region can be because of the displacement of heat being carried by the mass of air. In some cases, this increase in temperature leads to extreme hot days by creating variations from the locations average climatic conditions.The continuous interactions of oceans with the atmosphere have strong effect on global climate. The increases in the SST have led to the change in atmospheric water vapour over the oceans. The relationship of the water vapour content with the weather systems influences the precipitation and increasing risk of heavy rain and snow. Changes in SST are capable in changing the storm tracks which can even lead to droughts in some areas (IPCC, 2013)

This study aims to look into the possibility of prediction of heat wave events over coastal districts of India using sea surface temperature variation by finding a relation between sea surface temperature and air temperature.

2. METHODOLOGY

For this study, the coastal districts of India is considered for the analysis with the assumption that the changes in the sea should first reflect on the coastal area associated with it. The coastal districts were selected based on Centre for Coastal Zone Management and Coastal Shelter Belt's database.

The daily air temperature data and sea surface temperature data is used.Daily air temperature data were obtained from National Climatic Data Center (NCDC), National Oceanic and Atmospheric Administration. The dataset includes observations from World Meteorological Organization, Cooperative, and CoCoRaHS networks. Some of the data are based on data exchanged under the World Meteorological Organization (WMO) World Weather Watch Program according to WMO Resolution 40 (Cg-XII). The dataset includes station name, geographic location, and maximum, minimum, average daily temperature field with the quality flags.The air temperature from April to June of 1985 and 2015 are considered for this study.

NOAA OI SST V2 High-Resolution Sea surface temperature dataset is used for SST measurement.NOAA's Optimum Interpolation Sea Surface Temperature (OISST, also known as Reynolds' SST) is a series of global analysis products, including the weekly OISST on a 1° grid to the more recent daily on a ¼° grid. In this analysis, the daily sea surface temperature of ¼° resolution is used.This data is a spatially gridded product created by interpolating and extrapolating data, resulting in a smoothed complete field. OISST provides global fields that are based on a combination of ocean temperature observations from satellite and in situ platforms (i.e., ships and buoys). Statistical methods (optimum interpolation, OI) are applied to fill in the data where there are missing

values. The methodology includes a bias adjustment step of the satellite data to in situ data prior to interpolation. (Reynolds et al. 2002).The SST data from April to June of 1985 and 2015 are obtained for the process.

Identification of heat wave events is done by considering the criteria by IMD.

The criteria for heat wave is given as

(1). Heat wave need not be considered till the maximum temperature of the stations reached at least 40^{o}C for plains and 30^{o}C for hilly regions.
(2). When the normal maximum temperature of a station is less than or equal to 40^{o}C: A departure of 5^{o}C to 6^{o}C from normal is to be considered a heat wave.
(3). When the normal maximum temperature of a station is more than 40^{o}C: A departure of 4^{o}C to 5^{o}C from normal is to be considered a heat wave.
(4). When actual maximum temperature remains 45^{o}C or more irrespective of normal maximum temperature heat wave should be declared.
(5). For coastal stations, if the maximum temperature of 40^{O}C is reached, heat wave may be declared.

The criterion for coastal stations is considered and is applied on the Daily temperature data set. The heat wave events were identified by considering those stations whose daily maximum temperature is greater than or equal to 40^{O}C continuously for three or more days (IMD).

3. RESULTS AND DISCUSSION

Heat wave events that occurred in the coastal districts of India in the summer (from April to June) of 1985 and 2015 were identified and studied. The variation in the air temperature over land and SST were found to have some common trend in some region.

3.1. Analysis of the year 1985

The heat wave events in the year 1985 were identified based on the criteria by IMD. During this period, 10 major heat wave events occurred. Maximum air temperature during the heat wave was recorded as 45^{o}C at Bhuj rudramata IN. The duration of heat wave event was observed to be from 3 to 9 days.

Sea surface temperature change: Before and during heat wave event

The changes in sea surface temperature before and during the heat wave events were analyzed. The observed minimum SST and maximum SST over the study area were recorded from the OISST dataset. The trend over time of these SST readings shows that either the minimum or the maximum SST is showing a similar trend with the air temperature over land, especially during heat wave events.

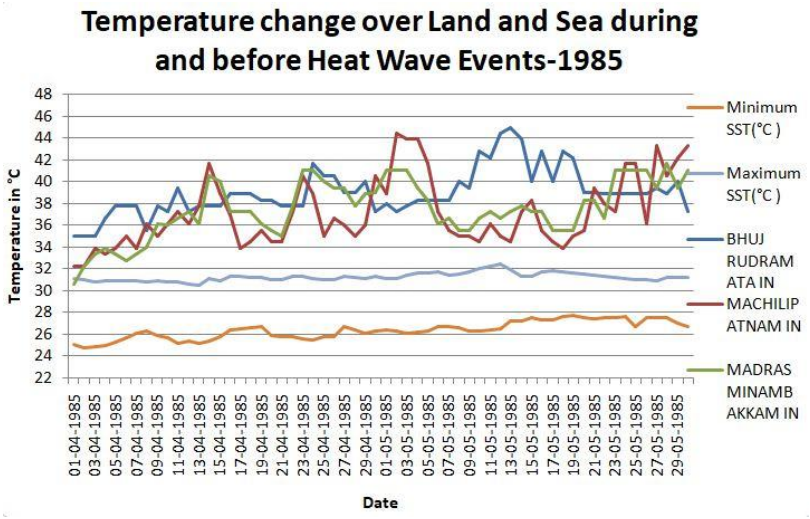


Figure 1: Temperature change over Land and Sea during and before Heat Wave Events-1985

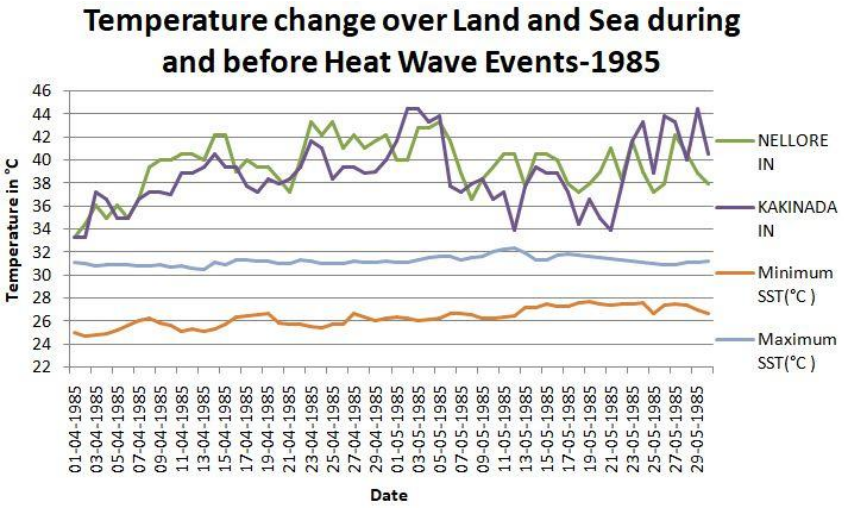


Figure 2: Temperature change over Land and Sea during and before Heat Wave Events-1985

The graphical analysis of SST variation over the period and the air temperature change shows that the changes in sea surface temperature were reflected in air temperature of land /heat wave events to some extent. To check whether any such relationship exists between the SST change and the air temperature over land, one coastal station is considered and the temperature variation is examined.

3.2. Analysis of the year 2015

The heat wave events in the year 2015 were identified based on the criteria by IMD. During this period, 8 major heat wave events occurred. Maximum air temperature during the heat wave was recorded around 47^{o}C at Vijayawada gannava IN.

Sea surface temperature change: Before and during heat wave event

The changes in sea surface temperature before and during the heat wave events were analyzed. The observed minimum SST and maximum SST over the study area were recorded from the OISST dataset. The trend over time of these SST readings shows that either the minimum or the maximum SST is showing a similar trend with the air temperature over land, especially during heat wave events.

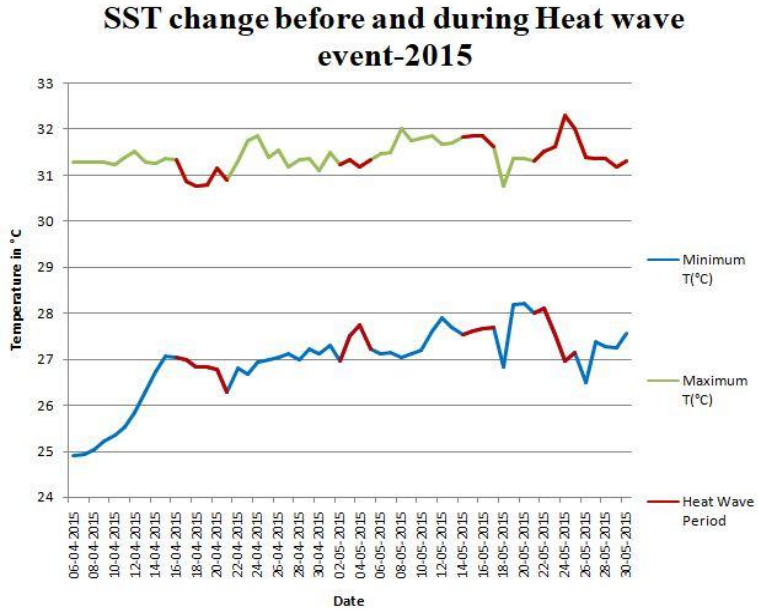


Figure 3: SST change before and during Heat wave event-2015

An effort was made in looking at an observable pattern in the SST change before and during heat wave event over the land. Map depicting daily sea surface temperature over the study area was created and compared it with the successive days SST. In some cases, it is found that the maximum sea surface temperature gets intensified near the coastal areas that are later identified as heat wave affected zones by IMD.Visual examination of SST patterns near the heat wave event(event starting from 21st May) reported stations (which Include Bhubaneswar IN,Vijayawada Gannava IN,Machilipatnam IN And Kakinada IN) shows that SST is getting intensified in the Bay of Bengal region before the heat wave period.

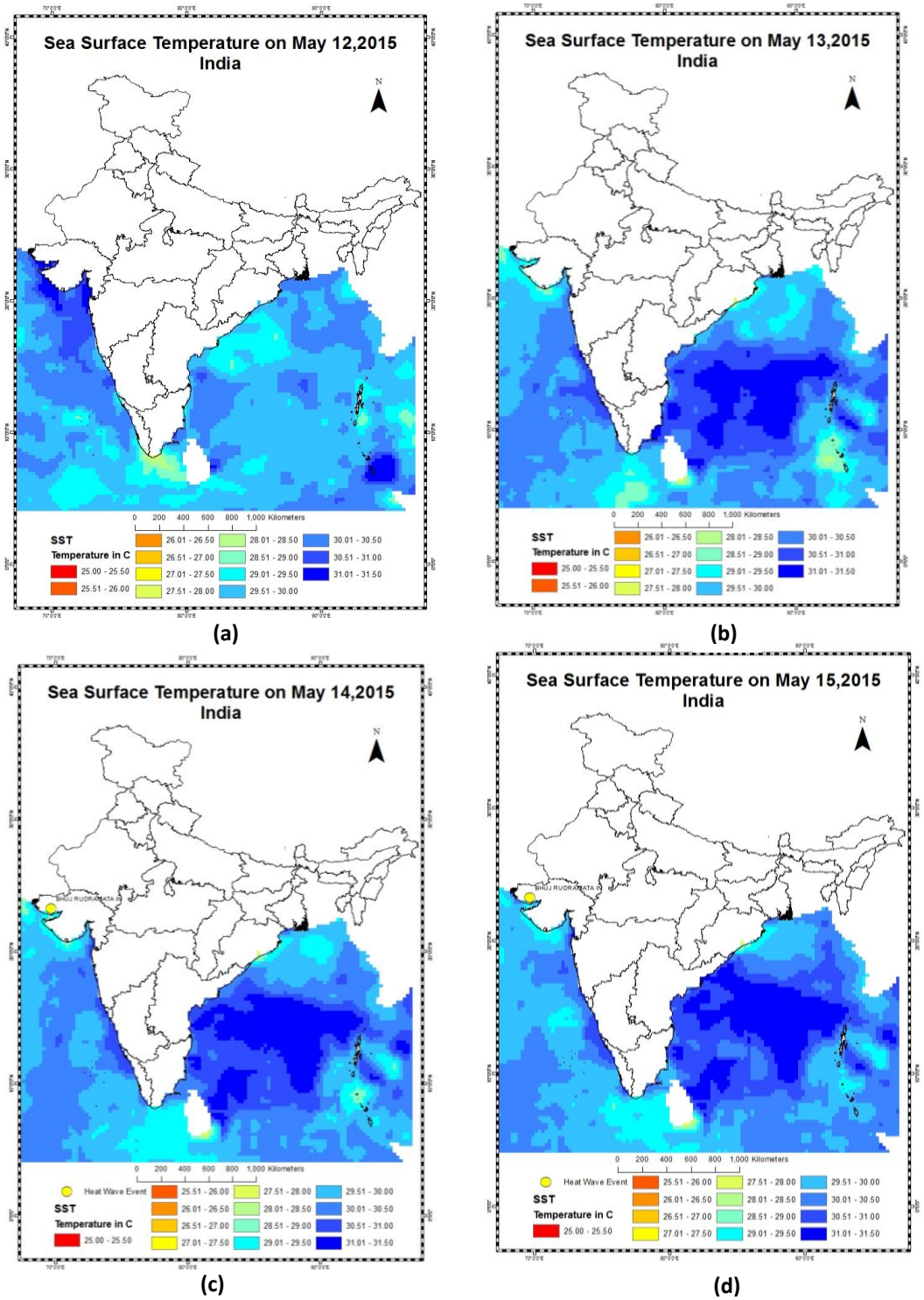


Figure 4: Daily Sea surface temperature ;(a) May 14, 2015. (b)May 15, 2015

(c) May 16, 2015. (d)May 15, 2015.

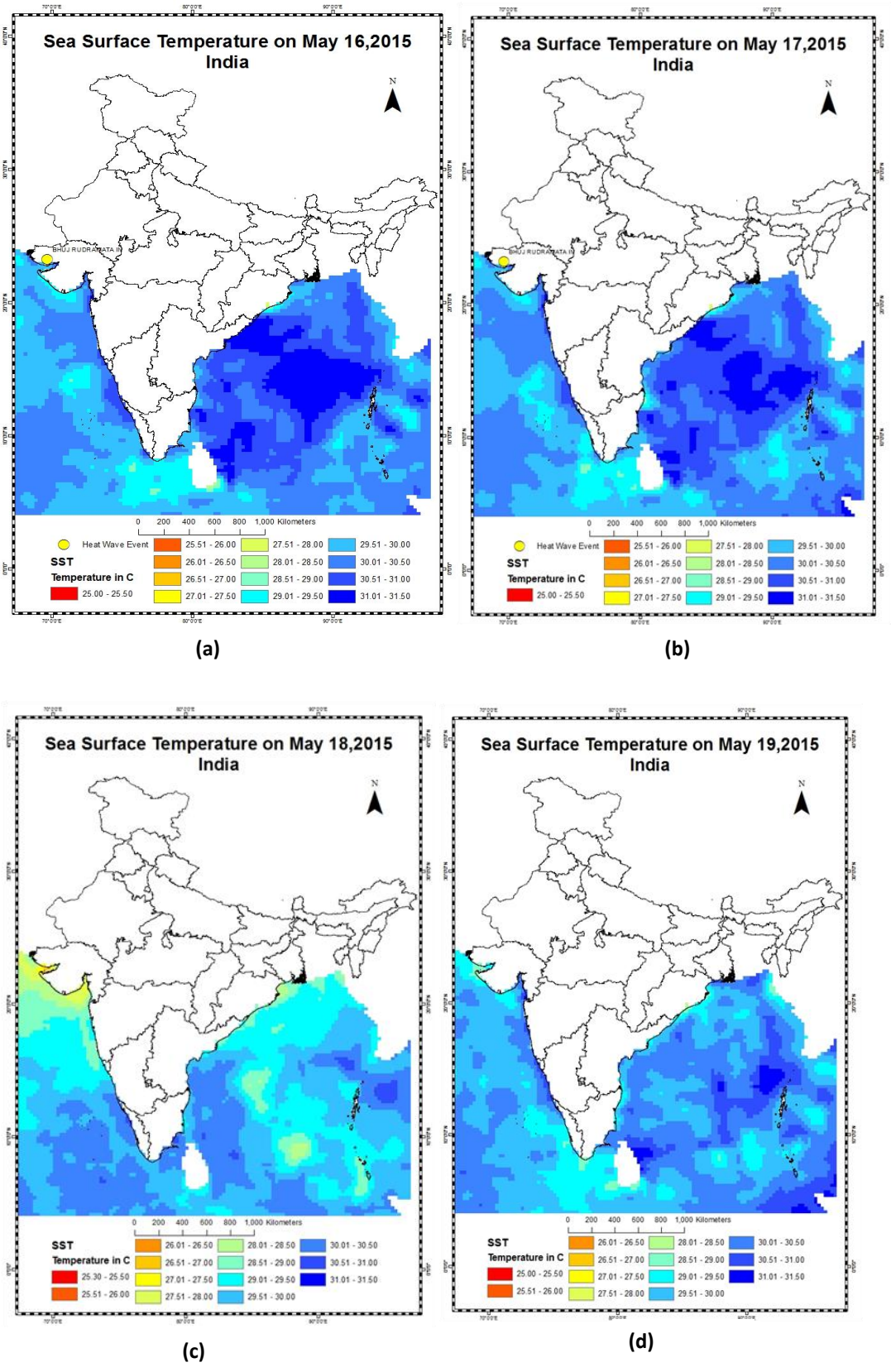


Figure 5: Daily Sea surface temperature ;(a) May 16, 2015. (b)May 17, 2015. (c)May 18, 2015. (d)May 19, 2015.

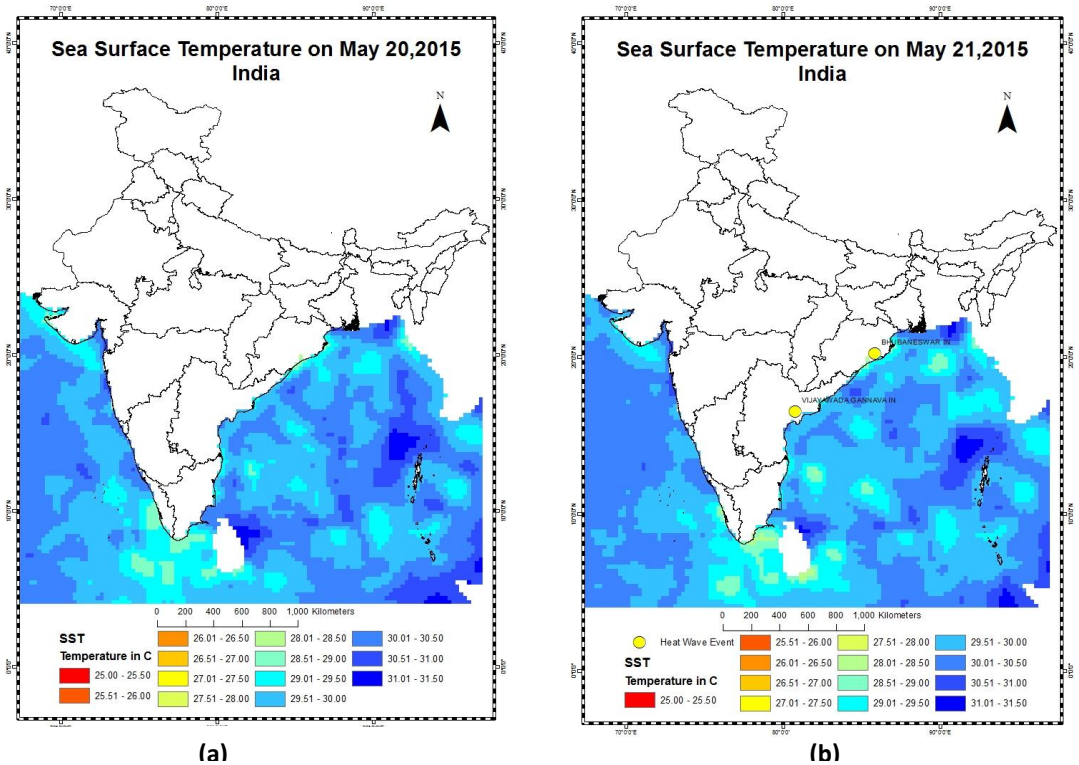


Figure 6: Daily Sea surface temperature ;(a) May 20, 2015. (b)May 21, 2015.

As we can see from the maps, there is a visible pattern of high sea surface temperature in the Bay of Bengal region from 12th May to 17th May. Later on 18th May the high region of SST got shifted. On 19th and 20thMay, SST patterns were visible but were not that intense as of the one which observed from 12th May to 17thMay.

The wind vector from 12th May to 23rd May 2015 is examined. The direction of wind was towards the coast of Bay of Bengal region where the heat wave events were identified. Each day the speed of the wind was found to be increasing. In the initial period, the speed was near 5 m/s whereas in the later period it reached about 20 m/s.

The intensity of wind gets increased towards the heat wave event period.

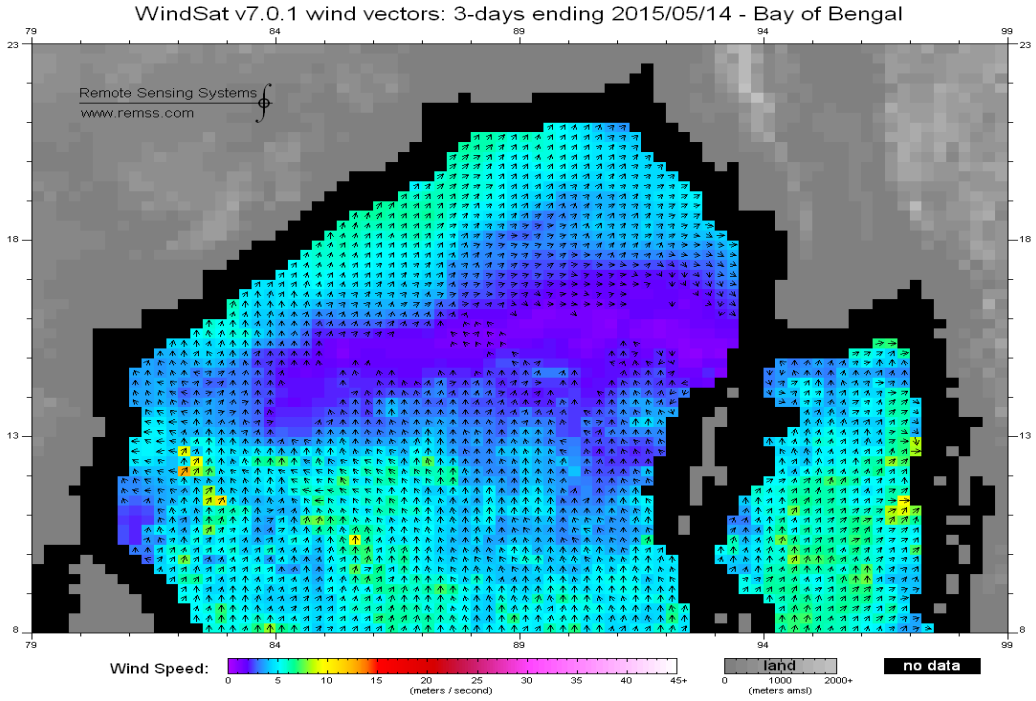
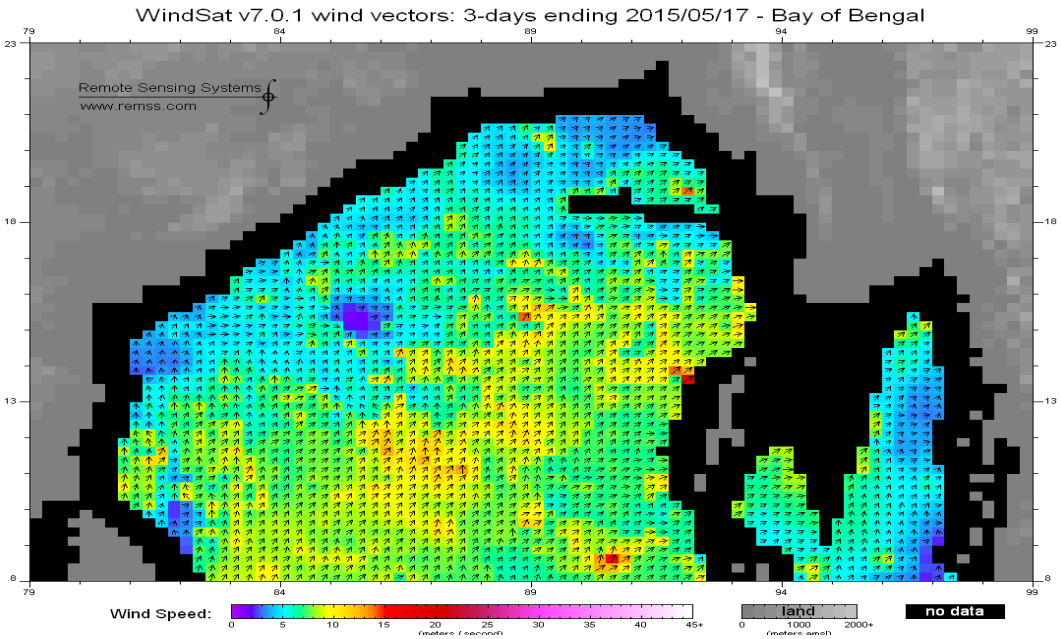


Figure 7: Wind vector; May 12 to 14, 2015.


WindSat v7.0.1 wind vectors: 3-days ending 2015/05/17 - Bay of Bengal
Remote Sensing Systems
www.remss.com
Wind Speed:
0 5 10 15 20 25 30 35 40 45+
(meters / second)
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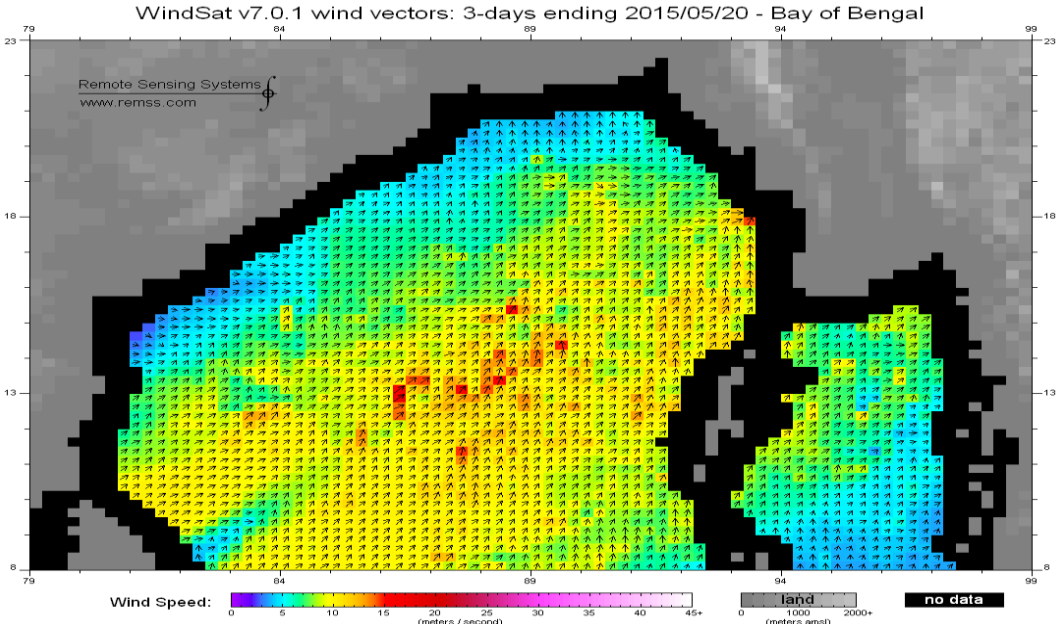
(meters amsl)

(a)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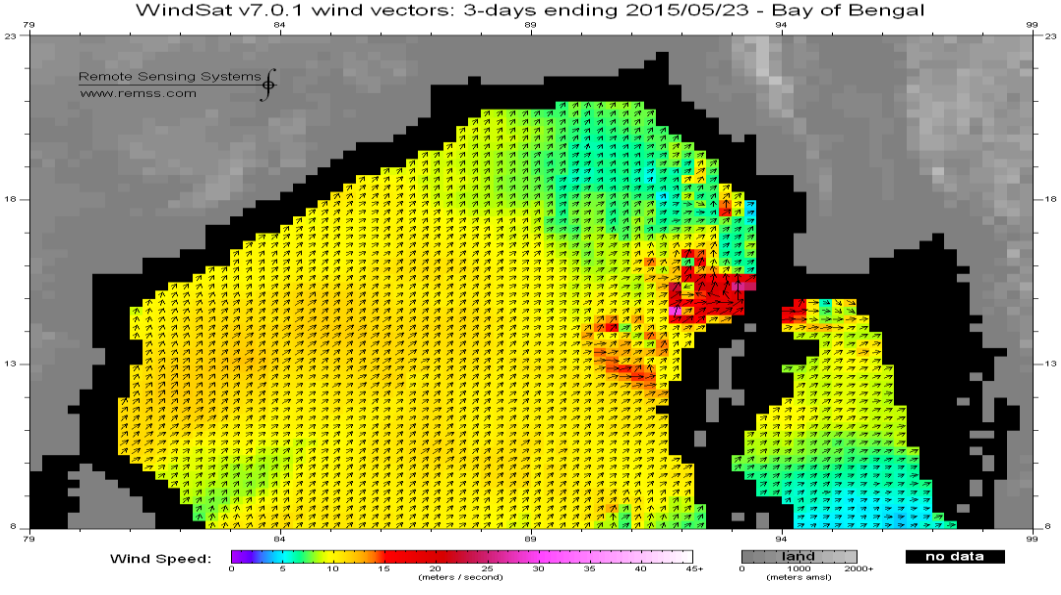
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0 5 10 15 20 25 30 35 40 45+
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(c)

Figure 8: Wind vector ;(a) May 15 to 17, 2015 (b) May 18 to 20, 2015. (c)May 21 to 23, 2015.

From these interpretations of the sea surface temperature pattern and wind vector, one can say that there is a possibility in reflectance of the variations in the SST over the region over the heat wave events. But the exact relation between SST change and air temperature variation over land is not yet revealed from these limited observations.Other factors which affect the sea surface temperature and air temperature over land needed to be studied for deriving exact relationship among themThe Correlation between air temperature over land and sea surface temperature are found to have a positive correlation coefficient in the year 1985 and 2015 during the heat wave period.

4. CONCLUSION

The study showed that there is a relation between sea surface temperature change and the air temperature variation over coastal region of India. This relation helps in the predictability of heat wave events that happens in the land based on the changes in the sea surface temperature. It is found that the maximum sea surface temperature gets intensified near the coastal areas before the heat wave event. The intensified patterns of high SST can be used for the marginal predictability of heat wave events. The wind vectors before and during the heat wave event shows their directions towards the coastal region, where the heat wave events were identified, carrying the heat from the sea with the increase in speed. The positive correlation coefficient shows the relation between air temperature over land and the sea surface temperature.

This study calls for further investigation of the physical parameters which affect heat wave, and this can even lead to the possibility of a potential tool for long lead predictability of heat waves.

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