

**PERSISTENT VOLCANIC SIGNATURE OBSERVED AROUND BARREN ISLAND,  
ANDAMAN SEA, INDIA**

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**Abstract**

This study delineates the formation of a warm pool ( $> 33^{\circ}\text{C}$ ) of air to the west (downwind) of the active volcano of the Barren Island during October-November 2005. Barren Island is located in the Sumatra-Andaman region, about 135 km east of Port Blair, and lies within the Burma microplate, the southern tip of which experienced a submarine earthquake ( $M_w$  9.3) causing a tsunami in December 2004. Barren Island is the only volcano, which has shown sustained eruptive activity since shortly after the Great Sumatran Earthquake of December 2004. Our observations require further corroboration to relate how submarine earthquakes activate volcanoes and how far these thermal emissions influence climate changes. Because it links global warming and climate changes to the frequent emissions from a volcano activated by submarine earthquakes, this case study is of special interest to the earth-ocean-atmosphere sciences community.

**Key words:** Andaman Sea, Barren Island, volcano, warm air pool, global warming.

## **Introduction**

The causes of the global surface air temperature warming in the previous century remain a topic of debate (Shiogama et al. 2006). Although it is known that increase in greenhouse gases and solar irradiance changes are responsible for the rise in the surface air temperature (Stott et al. 2003), recent studies suggest that natural forcing such as volcanic activity, along with solar irradiance changes may be the most important factors influencing global warming (Hegerl et al. 2003; K-I Model Developers 2004; Nozawa et al. 2005). Understanding the forcing functions of the past climate change is much needed to improve the global circulation model and to predict future climate changes precisely. In this study, we present observational evidence of a warm air pool supporting the relative importance of volcanic emissions on surface air heating in the Bay of Bengal, a region of tropical cyclones (Shenoi et al. 2002; Pankajakshan et al. 2002). On 24<sup>th</sup> December 2004, this region experienced a devastating tsunami caused by a submarine earthquake, the deadliest disasters in modern history (Javed and Murty 2005; Waltham 2005; Bandopadhyay et al. 2006; <http://www.volcano.si.edu/reports/usgs/index>). The very fact that a warm air pool was observed in the Andaman Sea where the Stratovolcano (Barren Island) erupted soon after the Great Sumatran Earthquake, makes this study important to models linking climate and solid Earth tectonic and magmatic activity.

## **Material and methods**

Hydrographic observations were made during an oceanographic expedition (FORV Sagar Sampada, cruise No.SS 239) in the Andaman Sea during October-November 2005 (Figure 1). On noticing the volcano in the Barren Island emitting fumes (Figure 2, photograph taken from the ship when it was west of the island on 30/10/2005), we made site-specific observations around the island to evaluate the atmospheric and oceanographic disturbances in the vicinity of an active volcano. Atmospheric temperature was recorded using the ship-mounted automatic weather station (AWS, model YSI 44202, accuracy,  $\pm 0.15^{\circ}\text{C}$ ; 10 minute interval), as was weekly wind velocity (R.M. Young wind monitor 05103, range 0-60 m/s) and sea surface temperature using the Conductivity-Temperature-Depth profiler (CTD, Seabird Electronics, accuracy  $\pm 0.001^{\circ}\text{C}$ ) available onboard the research vessel. In order to avoid diurnal variability in the air temperature, only data recorded during 10.00-14:00 hr was used in the present study. Similarly, in order to describe the meteorological features of the region, wind velocity (monthly average) were retrieved from the available satellite-derived source (<ftp://ftp.ssmi.com>; QuickSCAT, USA, resolution 25 x 25 km). In

order to put our findings into context, we use the oceanographic and meteorological data of the region collected on two occasions for comparison; one observation taken prior to the volcanic eruption (cr. SS 220, December-January 2004) and the second represents a recent observation (cr. SS 243, March-April 2006).

## **Results and discussion**

The QuickSCAT diagrams over the Bay of Bengal indicate that in general, winds shifts from a southeasterly to a northeasterly direction as the season changes from October to November (Figure 3 a and b). Distribution of air temperature indicated a thermally elevated region ( $> 33^{\circ}\text{C}$ ) surrounding Barren Island (Figure 4c). This warm air pool is unusual because corresponding plots for the same region during the previous winter season (cruise No. SS 220, December-January 2004, Figure 5) did not show such an anomaly. The heat wave emanating from this region is seen as a plume oriented in the north-northwest direction as well as in the north-northeasterly direction. The spread of the warm pool in the north-northwest direction matched the monthly averaged wind velocities (Figure 3a and b), but could not explain the drift towards the north-northeast. In order to illustrate this, we averaged the wind velocity in the Andaman Sea during the period 25 to 30<sup>th</sup> October 2005. It is evident that during this period, the local winds were weak and northerly (Figure 3c), consistent with the orientation of the warm air pool. The heat source feeding the warm air mass may be above the sea level, as the slightly warmer surface waters ( $>29.4^{\circ}\text{C}$ ) may be an artifact of this warm air (Figure 4d). The vertical distribution of temperature measured at different locations around Barren Island using the Conductivity-Temperature-Depth Profiler (CTD) also indicated a steady decrease with depth below sea level. From the distribution pattern of air temperature and the sea surface temperature, we suggest that the source of this warm air is the Barren Island volcano, probably the volcanic emission. The following facts regarding Barren Island are also provided to support and substantiate our findings.

Barren Island (area  $10 \text{ km}^2$ , summit elevation 335 m) has experienced several phases of volcanic activity in the past; i.e. during 2000, 1994-95, 1991, 1852, 1803-04, 1795, 1789 and 1787 (<http://www.geos.iitb.ac.in/dchandra/biexp/>; Raina 1987; Haldar 1989; Haldar et al. 1992, 1995; Ravi et al. 2001; Haldar and Luhr 2003). The recent eruption of this volcano on 28<sup>th</sup> December 2004 was followed by a series of eruptions in January, May and October 2005 with greater intensities (Bandopadhyay et al. 2006; <http://globalrumblings.blogspot.com/2005>

[01\\_01globalrumblings\\_archive.html](#)). Generally, volcanic eruptions are followed by very high thermal evolution ( $>1000^{\circ}\text{C}$ ), which extruded large volumes of rocks, emitting tephra and other trace gases that must have heated the air (Cadle et al. 1976). The intensity and movement of this hot air mass depends on the strength and endurance of eruption and the winds (Mass and Portman, 1989). Persistence of a warm air pool in the Andaman Sea, especially in the winter season is significant because of its closeness in space and time to the Great Sumatran Earthquake of December 2004. It would be worthwhile to know whether the sustained eruption of this volcano since January 2005 was a manifestation of this earthquake, indicating seismic-magmatic connectivity. Processes-related studies on earthquakes have pointed out the existence of a close relationship between seismic and volcanic activities (Thomas and Steven 1984; William et al. 1991; Hill et al. 2002; Bandopadhyay et al. 2006). In the Sumatra Island, there is a fault zone extending towards Barren Island, indicating the volcano overlying a seismically active zone (Javed and Murty 2005; Waltham 2005).

Volcanic emissions are found to influence surface warming and climate change (both heating and cooling) on different timescales (Rampino and Self, 1992; Zielinski, 2000; Nozawa et al. 2005; Shiogama et al. 2006). The climate response to large eruptions lasts for several years. The aerosol clouds produce cooling at the surface but heating in the stratosphere (Robok 2000). Volcanic eruptions that inject large quantities of sulfur-rich gases into the stratosphere have the capability of cooling global climate by  $0.2\text{-}0.3^{\circ}\text{C}$  for several years after the eruption (Zielinski, 2000). Equatorial eruptions will impact global climate whereas mid-latitude eruptions can cool climate in the hemisphere of origin (Rampino and Self, 1992). Magnitude of cooling varies by latitude and it is possible for warming to occur in certain regions, primarily during the winter (Shiogama et al. 2006). Furthermore, the role of sea surface temperature in the genesis and intensification of tropical cyclones has been well demonstrated (Emanuel 1999; Trenberth et al. 2003; Webster et al. 2005; Trenberth 2005). Sea surface temperatures of  $> 28^{\circ}\text{C}$  are generally considered favourable for the development of tropical cyclones (Whitney and Hobgood 1997; Saunders and Harris 1997; Shapiro and Goldenberg 1998) and in the Bay of Bengal; the surface temperature remained higher than  $28^{\circ}\text{C}$  (Anwar, 1999; Lal 2001). At present, there is no evidence to suggest that these volcanic activities influence atmospheric warming in the Bay of Bengal but this remains to be elucidated. However, it has been observed that there was an increase in the number of cyclonic systems developed in the Bay of Bengal during the northeast monsoon of 2005

(Five cyclonic depressions compared to an average 3.5 cyclonic depressions for the same period during 1971–2004 (Ramakrishnan, 2006; [http://en.wikipedia.org/wiki/2005\\_North\\_Indian\\_cyclone\\_season](http://en.wikipedia.org/wiki/2005_North_Indian_cyclone_season)). An important point to be mentioned here is that, Barren Island volcano continues to be active even in May 2006 (<http://www.volcano.si.edu/reports/usgs/archive.cfm?volcano=barren#mar2006>). We have an evidence in support of this volcanic activity, as our recent observations in the Andaman Sea (cruise No. SS 243, March-April 2006) still show a feeble, but persistent warm pool in this region (Figure 5).

The Bay of Bengal has some climatic features including high precipitation, sea surface temperature and low surface salinity that cause density stratification, all of which lead to frequent cyclonic depressions (Murthy et al. 2000; Shenoi et al. 2002; Pankajakshan et al. 2002; Vijayachandran et al., 2002; Jayu and Prasannakumar, 2006). These are generally illustrative of a basin in which, a complex interplay of diverse processes takes place. The frequent atmospheric perturbations in this region are to be investigated carefully in relation to the occurrence of seismic-volcanic activities and their influence on cyclonic depressions. With a possession of 36 medium and large size volcanoes in the Sumatra-Myanmar subduction zone, their emissions are expected to influence the surface air temperature substantially. Because volcanic eruptions and their subsequent climatic change represent a large perturbation to the climate system over a relatively short period, volcanic emissions should be considered in global circulation models to predict the regional climatic responses, as suggested by Shiogama et al. (2006).

### **Acknowledgements**

We thank Sh. Rasik Ravindra, Director, National Centre for Antarctic and Ocean Research, Goa and Dr. S.R. Shetye, Director, National Institute of Oceanography, Goa for the encouragement and Dr. C.T. Achuthankutty, Scientist-in-Charge, NIO, Kochi for critical comments. This study was funded by Centre for Marine Living Resources and Ecology of the Ministry of Earth Sciences under the project “Biodiversity of phytoplankton and zooplankton in the island ecosystem: Andaman Sea”. Critical comments from Dr. Peter Clift, Dr. Amy E. Draut and an anonymous reviewer helped improve the manuscript considerably. We gratefully acknowledge all staff of FORV Sagar Sampada for the facilities, the Fishing Master and his team of MoES as well as the engineers of NORENCO for assisting in the additional data collection. This is NIO contribution number

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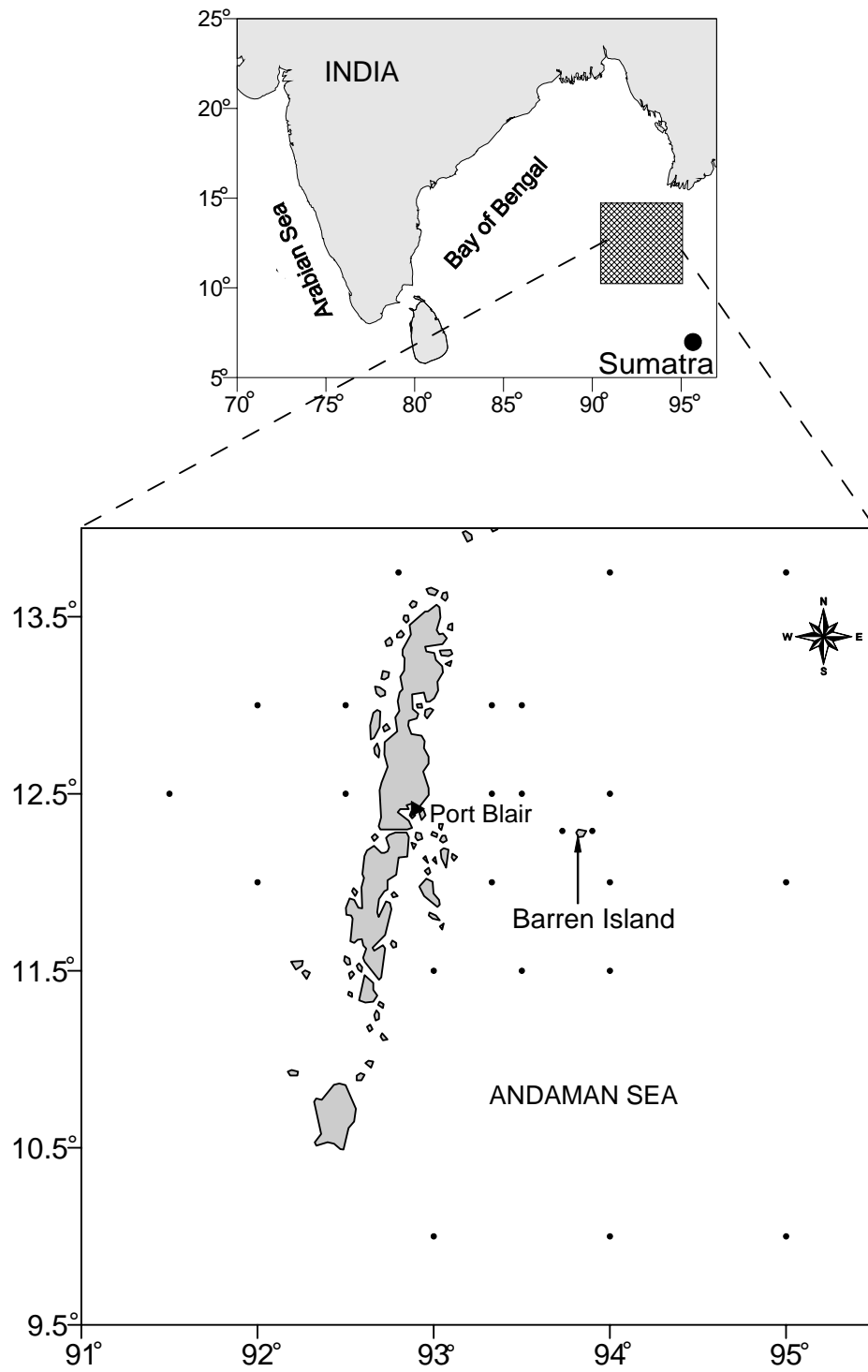


Figure 1. Study region in the Bay of Bengal, showing Andaman Sea, Port Blair (▶), Barren Island (pointed by arrow) and the Sumatra Island. (Station locations are given as solid dots).



Figure 2. Barren Island and its active volcanic vent (Photograph taken from FORV Sagar Sampada on 30/10/2005). The view of the volcano is seen from the western side. Inset shows the Barren Island in Andaman Sea.

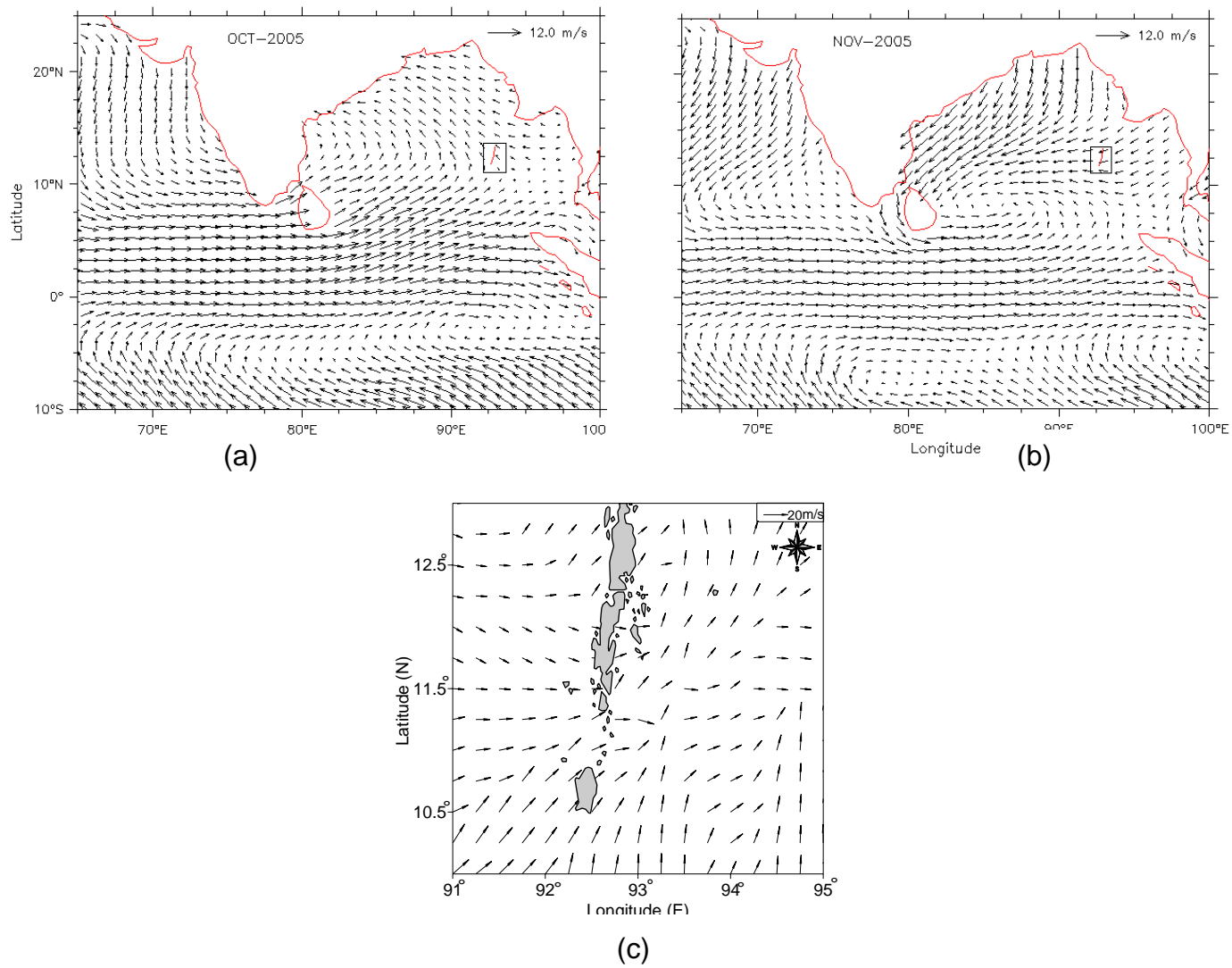


Figure 3. Average wind velocity (m/s) in the Bay of Bengal during (a) October, (b) November (c) Average wind velocity (m/s) in the Andaman Sea during 25-30<sup>th</sup> October 2005.

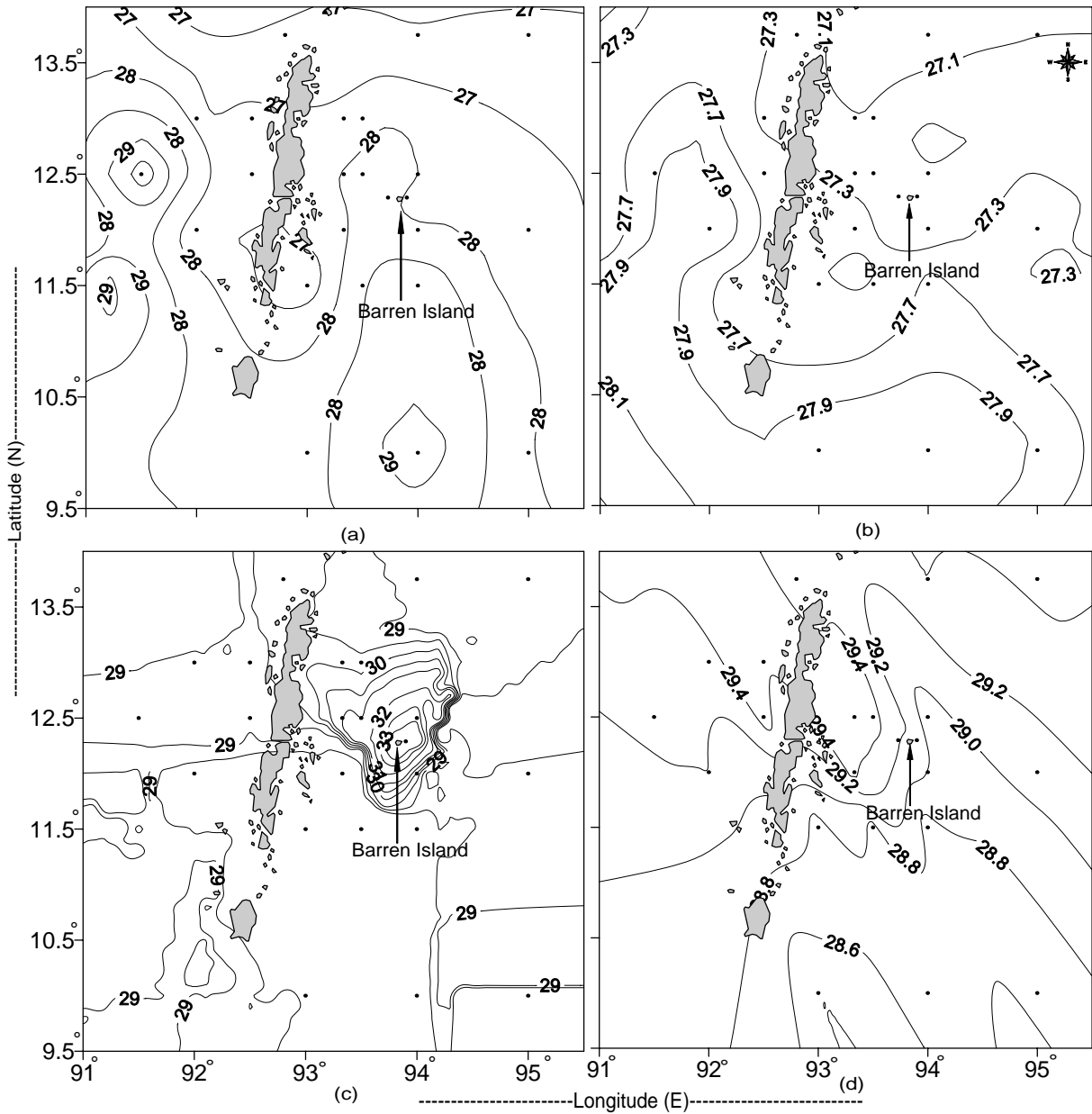


Figure 4. Distribution of (a) air temperature and (b) sea surface temperature during December- January 2003-2004, prior to volcanic eruption and (c) air temperature and (d) sea surface temperature during October- November 2005, during the volcanic eruption in the Andaman Sea. All the units are given in degree Celsius ( $^{\circ}\text{C}$ ). Stations are shown as solid dots.

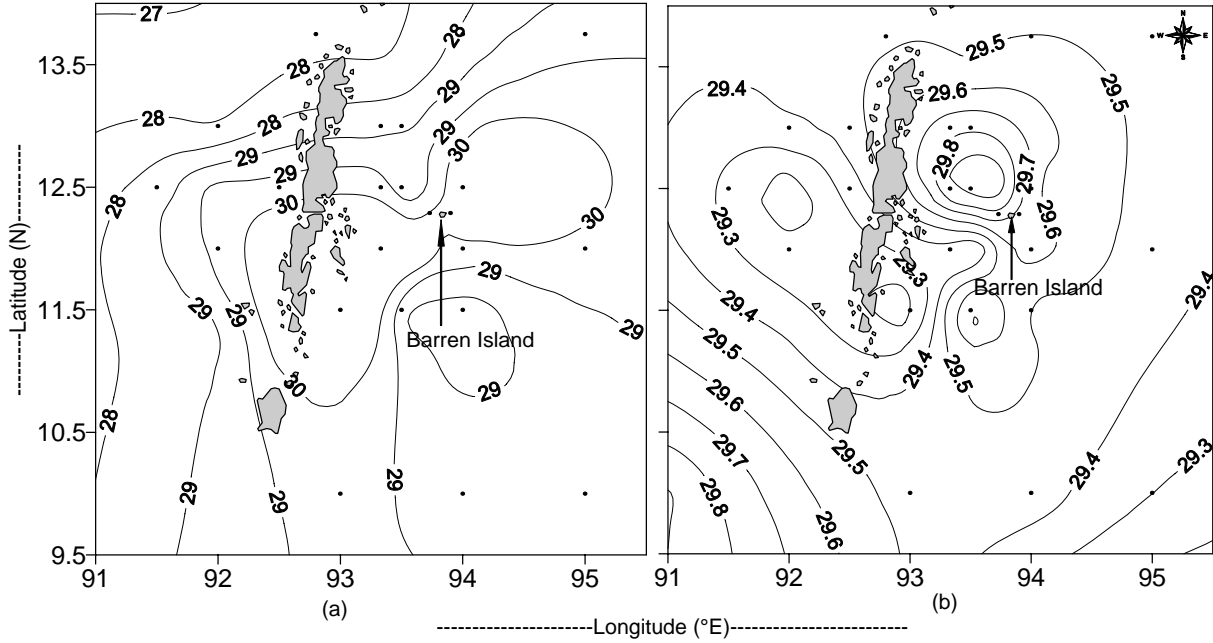


Figure 5. Distribution of (a) air temperature and (b) sea surface temperature in the Andaman Sea during March-April 2006. There is a feeble, but persistent warm air pool around the Barren Island ( $>30^{\circ}\text{C}$ ). All the units are given in degree Celsius ( $^{\circ}\text{C}$ ). Stations are shown as solid dots.