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Oil spill detection using SSM/I satellite data over Bombay High location in Arabian Sea

O P N Calla[$,*], Harendra Kumar Dadhich[#] & Shruti Singhal[+]

International Centre for Radio Science, Ranoji Ka Baag, Khokariya Bera Nayapura Mandore, Jodhpur 342 304 (Raj), India
E-mails: [$]opnc06@gmail.com, [#]dadhichharendra@gmail.com, [+]shrutisinghal21@gmail.com

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Oil spill pollution is a severe environmental problem, which persists in marine environment or in inland water across the world. It has grown to an alarming magnitude with increased levels of oil production and transport. Thus, it is important to study and analyze this environmental pollution. The study and detection of oil spills can only be accomplished by satellite microwave remote sensing techniques. As microwaves have unique all weather penetration capability and can be used both in day and night, it does not require illumination of target from the sun. Two types of microwave sensors [Ulaby F T *et al*. *Microwave remote sensing – Active and passive,* Vol 1 and 3, 1981] exist: one is passive sensor and other active sensor. Passive microwave sensor is radiometer that operates in the microwave region and detects microwave radiation emitted by the earth surface in addition to passively sensing emissions coming from objects on Earth. Active microwave sensor emits microwaves toward the earth's surface. These microwaves are reflected back from earth's surface and return back to the sensor. In this paper, for the detection of oil spills, data of passive microwave sensors onboard Special Sensor Microwave/Imager (SSM/I) [Hollinger J *et al*. *Special Sensor Microwave/Imager user's guide*, 1987, 120] satellite at 19.3 GHz frequency is used and analyzed. The analyses shows sudden decrease of brightness temperature values in both horizontal and vertical polarization over the oil spill area (Bombay High Area, Arabian Sea) when compared to the brightness temperature values over oil free area in the Arabian sea.

Keywords: Brightness temperature, Environmental pollution, Microwave/Imager sensor, Oil spill detection

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1 Introduction

Now a days, reducing the risk of oil spill disasters has become essential for protecting the environment and reducing economic losses. Oil spill inspections constitute an important component of oil spill disaster management. Advances in remote sensing technologies[3] have helped to identify parties potentially responsible for pollution and to identify minor spills before they cause widespread damage.

Basically, oil spill is the release of liquid petroleum hydrocarbon into the environment, especially over marine areas due to human activity, and is a form of pollution. It is a major environmental threat for many countries in the world and its detection at sea surface is very difficult. Oil spill have a wide impact and long term consequences on wildlife, fisheries, coastal and marine habitats, human health and livelihood.

At global level, mapping of oil spill[4] distributions is not feasible manually, as it is a time consuming process. Therefore, this task can be accomplished by satellite remote sensing techniques. In the present paper, the study area is Bombay High (Fig. 1) in Arabian Sea having longitude 71.33333°E and latitude 19.416667°N as it is the India's largest offshore oil field situated 161 km north of the Mumbai coast that produces 14 per cent of India's oil requirements and accounts for 38 per cent of all domestic production. The whole of Bombay High rigs have the production capacity of approximately 260,000 barrels of oil every day and tons of oil spills into the sea. There are many issues related to Bombay High oil field production claiming leakage of oil in Arabian Sea near Bombay High location. Hence, it has become an important location to be monitored. For the detection of oil spills over Bombay High location, the SSM/I satellite brightness temperature data[5] for both horizontal and vertical polarizations at 19.3 GHz is analyzed over the oil spill area, depicted by block 1 in Fig. 2 located in Arabian Sea and these data are compared with the oil free area in Arabian Sea depicted by block 2 in Fig. 2. The study has been carried out with passive microwave sensors, which has been rarely done so far.

Fig. 1—Bombay High oil field location (●)

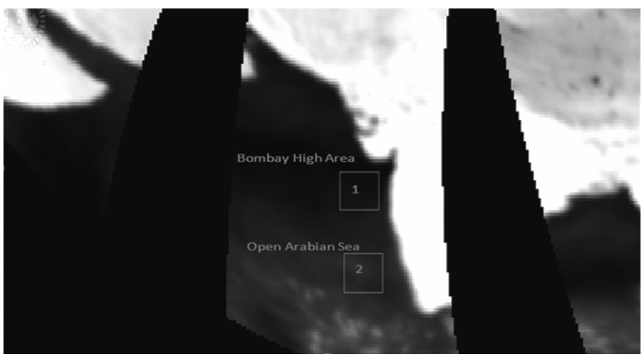

Fig. 2—Snapshot of SSM/I satellite pass over Arabian Sea

Table 1 — SSM/I satellite specifications

Type	Polar Orbiter (~102 min per orbit)
Areal coverage	Twice daily (one ascending and one descending orbit)
Sensor	Passive microwave
Receptors	7 Microwave channels
Measurement	Brightness temperature
Frequency bands	19(H,V), 22(V), 37(H,V), 85(H,V) GHz, where, H is horizontal polarisation; and V, vertical polarisation
Swath, km	1392
Number of data cells	64
Cell footprint, km	40
Wind height, m	20
Range of wind speeds, m s^{-1}	3 – 25
Speed accuracy	2 m s^{-1} up to 20 m s^{-1} and 10% above 20 m s^{-1}
Direction accuracy	Not applicable
Algorithm used	GWSP and OMBNN3

2 SSM/I satellite data procurement

The Special Sensor Microwave/Imager (SSM/I) is a seven channels, four frequencies, linearly polarized, passive microwave radiometric system. Data products are produced as part of NASA's Pathfinder Program (http://www.oso.noaa.gov/dmsp/ & http://www.ssmi.com/ssmi/ssmi_description.html). Defense Meteorological Satellite Program (DMSP) satellites carry the SSMIS instrument which provides the brightness temperature data. The instrument specifications are shown in Table 1. The SSM/I is said to be a very successful instrument, with radiometric sensitivity and receiver gain stability exceeding the prelaunch performance expect for the 85.5 GHz vertically polarized channel.

3 Methodology

In the present paper, the analysis has been done over India's one of the major oil production platform that is Bombay High Area. The SSM/I brightness temperature data at 19.3 GHz for10 days has been procured and analyzed. The data was taken for the duration 1-10 April 2012 over Bombay High location in Arabian Sea as well as for oil free area in Arabian Sea. The brightness temperature data near the Bombay High location was found to be full of anomalies as compared to the oil free area in Arabian Sea. The snapshot of SSM/I satellite pass over Arabian sea (Fig. 2) is having two blocks in which the block 1 shows location near the Bombay High area and block 2 shows location of open Arabian Sea.

After analysis and comparison of the data over these two blocks, dip in brightness temperature values over block 1 data was found which could be due to the presence of some substance (oil) on the surface of the sea. An oil spill may be due to a number of reasons, including oil production platforms, transportation accidents and controlled release of oil by shipping operators and all these activities mostly takes place in some or the other way at Bombay High. Once oil is spilled, it quickly spreads to form a thin layer on the water surface, known as an oil slick[6]. As time passes, the oil slick becomes thinner, forming a layer known as a sheen which has a rainbow like appearance. Light oils are highly toxic but evaporate quickly, whereas, heavy oils are less toxic but persist in the environment for a long time.

After data procurement, it was compared for both the locations and graphs were plotted accordingly. The graphs depict clearly the presence of oil over the block 1 area as compared to the block 2. The graphs show the variation of brightness temperature values with respect to latitude and longitude. The methodology used is shown in the flow diagram (Fig. 3).

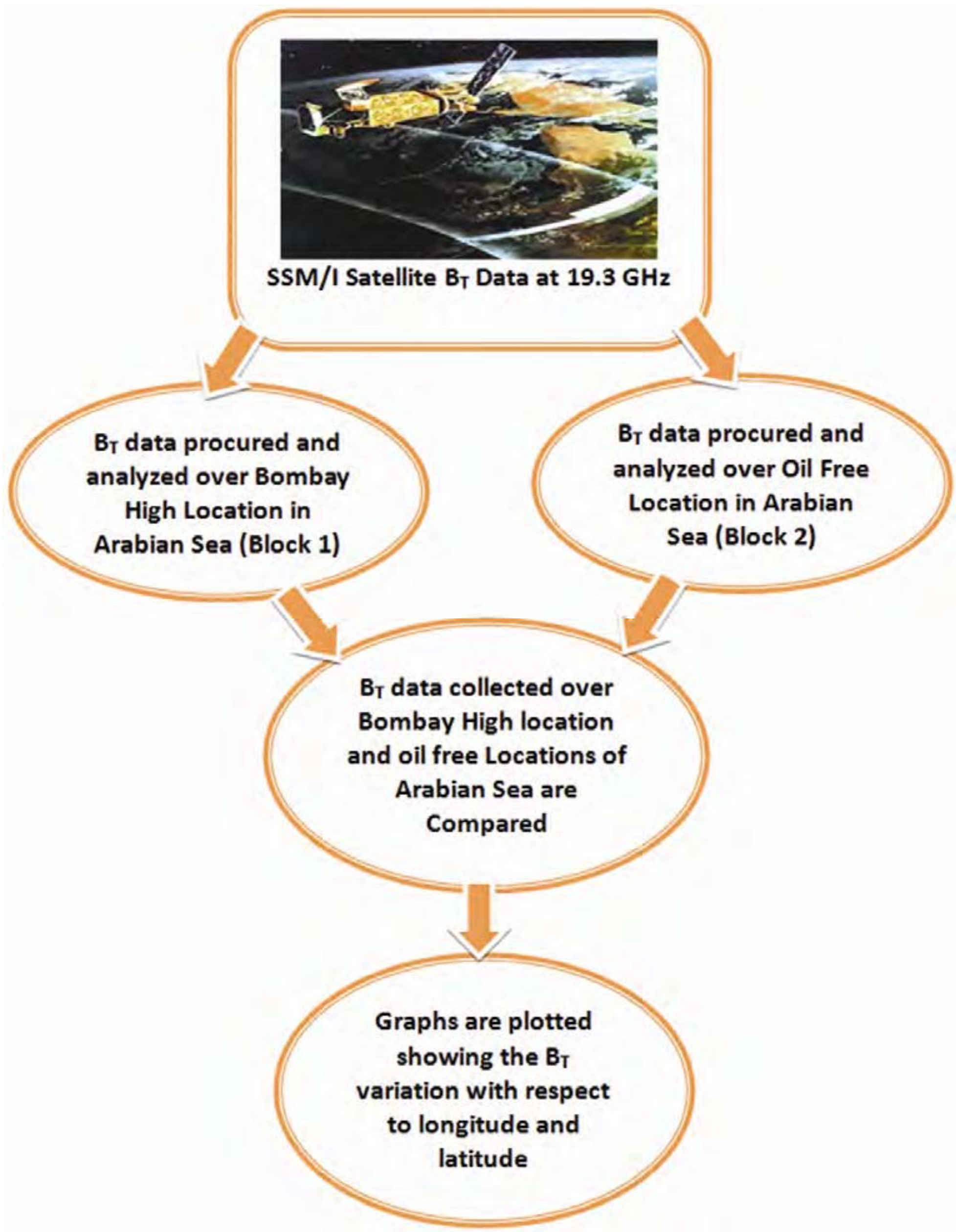

Fig. 3—Flow diagram for methodology

4 Results and Discussion

After analysis of brightness temperature values in both horizontal and vertical polarization at 19.3 GHz of SSM/I satellite during 1 - 10 April 2012, it has been observed that the brightness temperature of sea surface over Bombay High area (block 1) shows sudden decrease in brightness temperature values of both horizontal and vertical polarization as compared to the block 2 data for open Arabian sea. This depression can be observed from the Table 2 and graphs.

From Table 2, it is observed that a large variability of around 10 - 30 K in brightness temperature values for different days and for both horizontal and vertical polarization over both the blocks. This dip in the values of brightness temperature indicates the likelihood of oil spill at Bombay High area. It has also been reported by Blume *et al.*[7] that the expected brightness temperature increase at 1.43 GHz for a multilayered oil-sea water model and an unexpected brightness temperature depression is observed over a monomolecular oil film layer. The dip in brightness temperature over Bombay High area - block 1 (Fig. 2) may be due to formation of monomolecular oil film layer over sea surface which causes an unexpected brightness temperature depression[8,9]. The graphs shown in Figs [4(a)-9(b) illustrate the depression in

Table 2 — Brightness temperature values of SSM/I at 19.3 GHz

Date	Bombay High oil spill area		Oil free area of Arabian Sea	
	Horizontal B_T, K	Vertical B_T, K	Horizontal B_T, K	Vertical B_T, K
01.04.2012	120.6 – 130.1	193.0 – 199.1	138.0 – 146.3	205.2 – 210.7
05.04.2012	118.5 – 132.5	191.4 – 199.2	141.1 – 151.0	207.0 – 211.1
06.04.2012	117.5 – 127.2	191.5 – 196.1	146.4 – 157.7	208.3 – 214.5
07.04.2012	118.7 – 127.7	192.1 – 197.0	149.8 – 126.2	211.0 – 215
08.04.2012	115.9 – 122.6	191.1 – 194.0	143.3 – 155.3	208.6 – 215
09.04.2012	118.9 – 128.9	192.3 – 198.3	148.1 – 156.4	211.1 – 215.4

*****during 2-4 April 2012, pass of SSM/I not found over Bombay High location

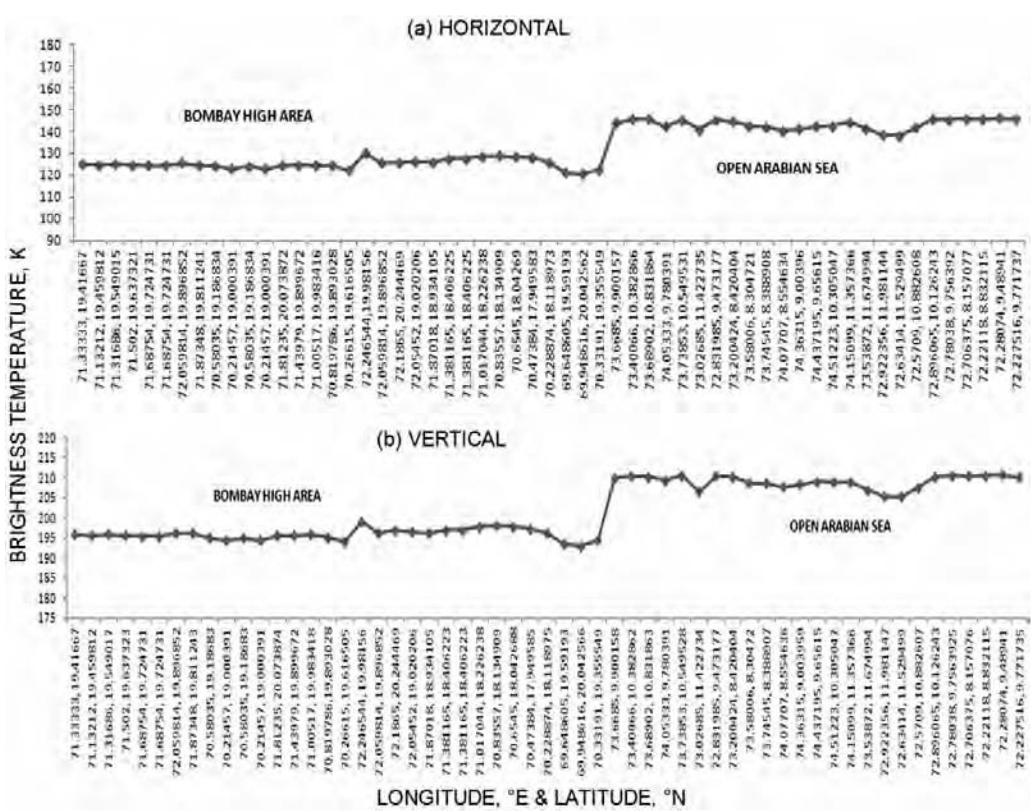

Fig. 4—Variation of brightness temperature with respect to longitude and latitude on 1 April 2012: (a) Horizontal; (b) Vertical

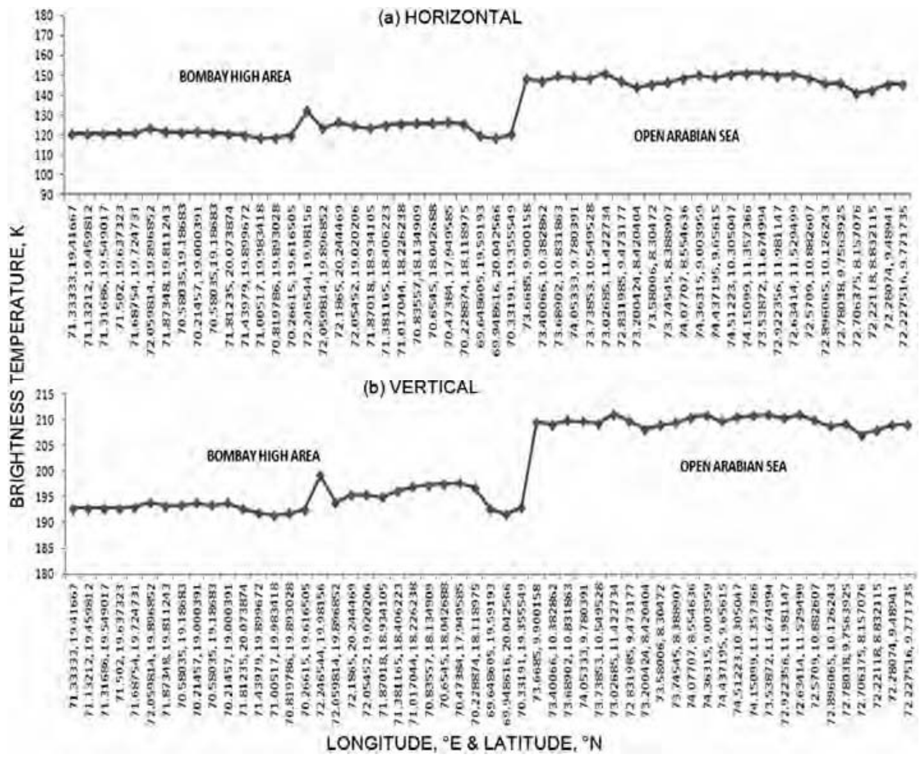

Fig. 5—Variation of brightness temperature with respect to longitude and latitude on 5 April 2012: (a) Horizontal; (b) Vertical

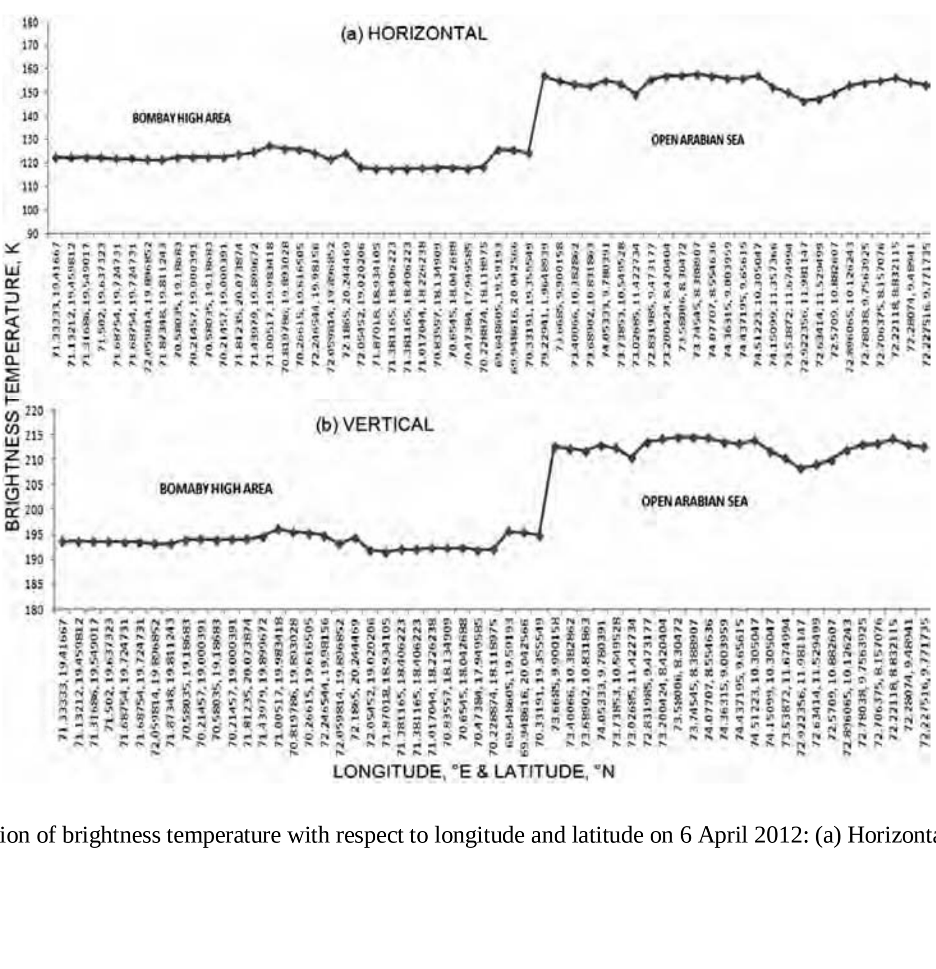

Fig. 6—Variation of brightness temperature with respect to longitude and latitude on 6 April 2012: (a) Horizontal; (b) Vertical

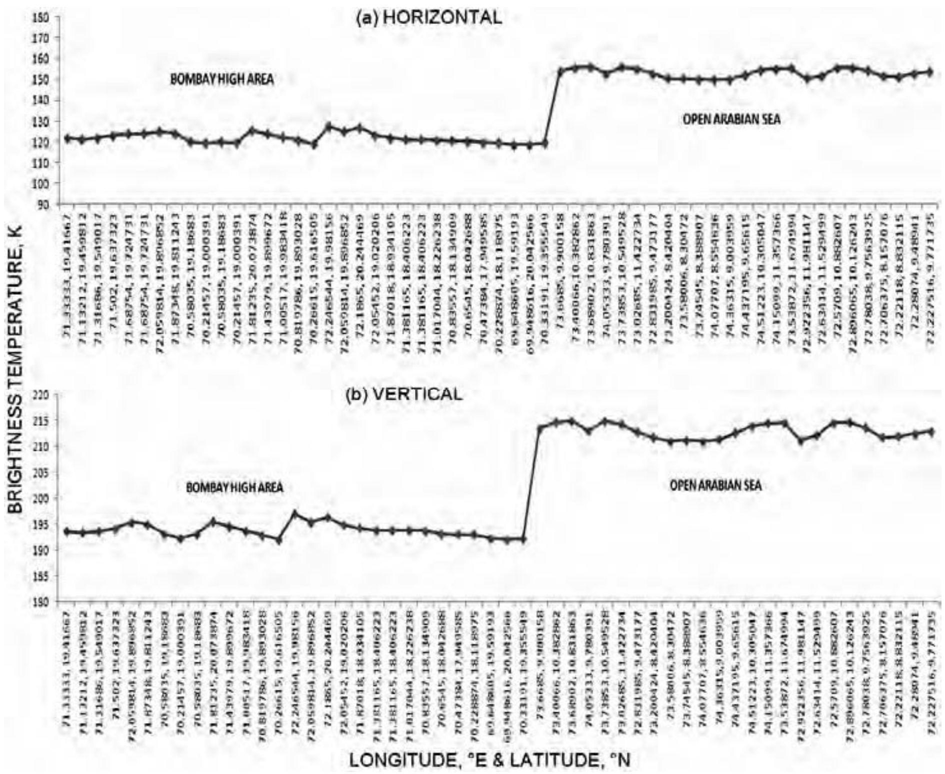

Fig. 7—Variation of brightness temperature with respect to longitude and latitude on 7 April 2012: (a) Horizontal; (b) Vertical

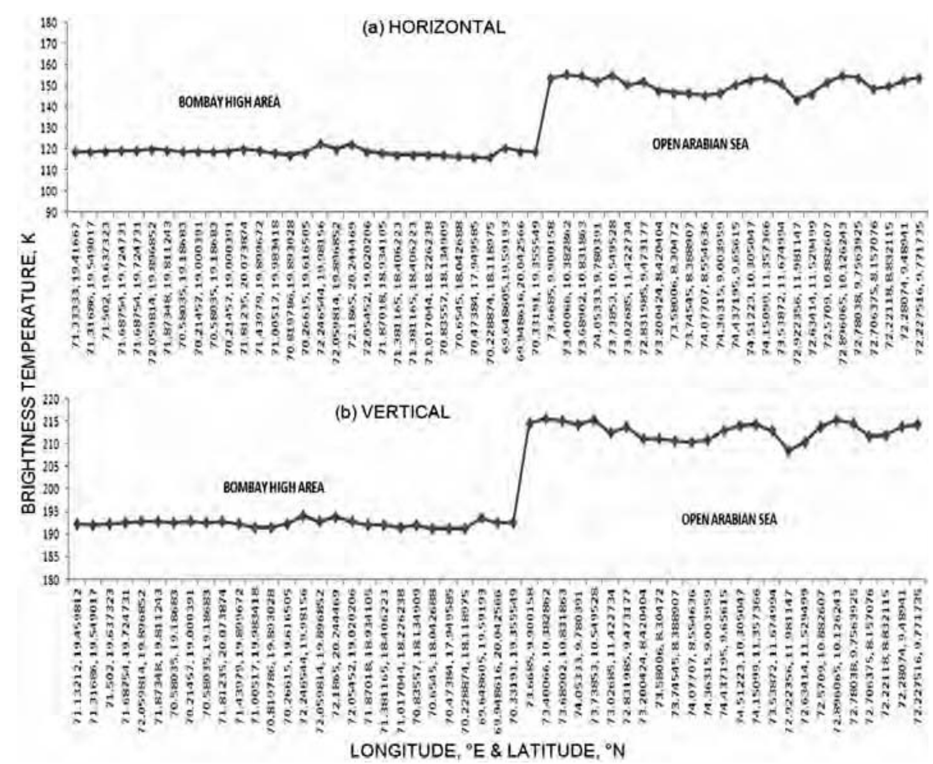

Fig. 8—Variation of brightness temperature with respect to longitude and latitude on 8 April 2012: (a) Horizontal; (b) Vertical

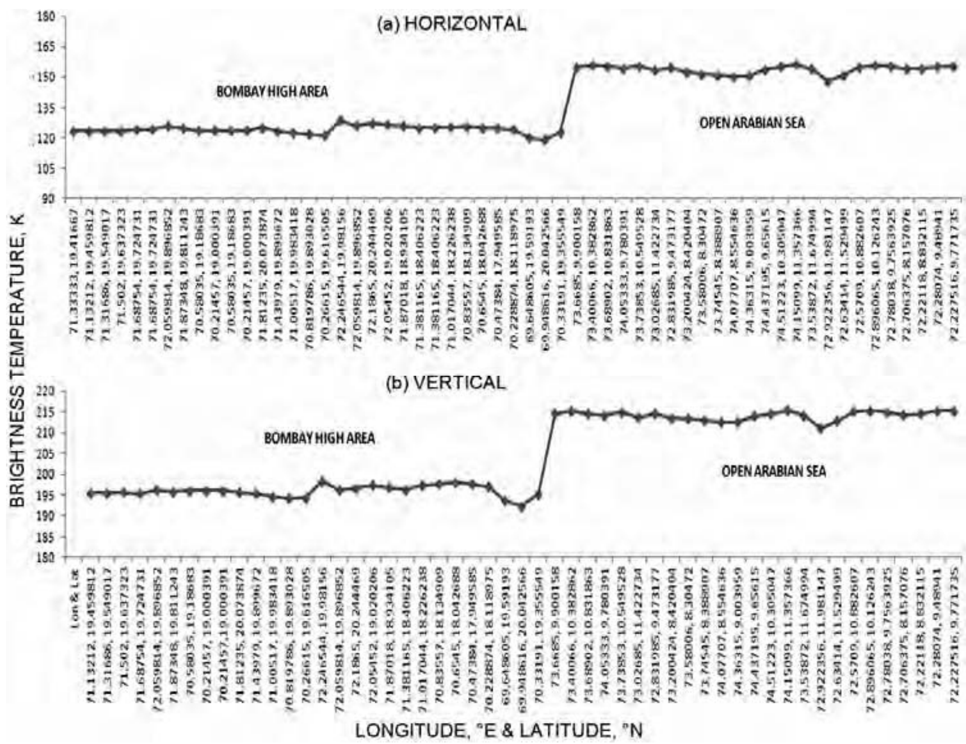

Fig. 9—Variation of brightness temperature with respect to longitude and latitude on 9 April 2013: (a) Horizontal; (b) Vertical

the brightness temperature values over sea surface at Bombay High area when compared to brightness temperature values over open Arabian Sea. The variation of both horizontal and vertical brightness temperature at 19.3 GHz with respect to longitude and latitude are shown in these graphs.

It can be seen from the graphs that the brightness temperature of sea surface obtained from SSM/I data, when plotted with respect to the location, show a large difference. The brightness temperature values over sea surface values at the Bombay High location were found to be low as compared to the brightness temperature values over open or oil free Arabian Sea. The lower values of brightness temperature of sea surface at the Bombay High location clearly indicate the presence of oil over the surface.

5 Conclusions

This paper focuses on the importance of microwave remote sensing in detection and monitoring of oil spill pollution. By monitoring the brightness temperature data of SSM/I satellite at 19.3 GHz, one can predict the presence of oil spills. In the present paper, depression in the brightness temperature value was found over oil spills area as compared to oil free sea surface. This depression in the brightness temperature was due to the presence of oil, as about 260,000 barrels of oil is daily produced at the oil field. For better prediction of discharge of oil, one can continuously monitor the Bombay High area and other oil spill prone areas and even measure the dielectric constant.

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