As early as 1959, it was suggested by Conney *et al.*[21] that multiple forms of drug-metabolizing enzymes catalysing the same reaction exist in the liver of a given species. The criteria adopted for the presence of multiple forms have been mobility on SDS–PAGE, spectral and catalytic properties, immunological relatedness, peptide mapping and finally the protein sequence. In this study, based on the mobility of the protein on SDS–PAGE, it appears that different forms of cytochrome P-450 are present in drug-sensitive, isoniazid-resistant and isoniazid and rifampicin-resistant *M. tuberculosis* and also the same isoform patterns of the protein are present in the resistant and phenobarbital-induced *M. tuberculosis*. Further studies at the molecular level would confirm these findings and give a better understanding of the significance of this study.

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Estimation of monthly rain rate over Indian Ocean region using MSMR data

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India is surrounded by ocean in three directions. The land and ocean interaction controls the climatic conditions over the Indian subcontinent. The study of meteorological parameters over ocean has paramount importance in understanding the interaction between ocean and land. In the present study, efforts have been made to deduce the monthly variations of the rain rate over the oceanic region adjacent to India from July 1999 to June 2000 using brightness temperature data observed by the Multi-channel Scanning Microwave Radiometer (MSMR) sensor on-board IRS-P4 (OCEANSAT). Using brightness temperature measured at 10 and 18 GHz frequencies in horizontal and vertical polarizations, rainfall rate has been compared. The rain rate deduced from MSMR brightness temperature data shows a high value over the ocean during June and July. The rain rate shows moderate to low values during October–November and increases in January, followed by a decrease in March and April, again it increases from May. Variation of rain rate is mainly controlled by summer and winter monsoon. The southwest summer monsoon hits India in May/June; as a result high rain rate, which is responsible for higher rainfall, has been observed over the ocean. Due to the northeast winter monsoon, rain rate increases over the ocean during January–February. The rain rate retrieved from MSMR data is compared with NCEP monthly averaged rain rate.

THE passive microwave remote sensing technique has proved to be a powerful tool in monitoring spatial and temporal behaviour of the earth surface. Numerous studies have been carried out to explore the use of microwave remote sensing technique to retrieve information regarding the physical state of ocean and land surfaces. All-time and all-weather operational advantage of microwave remote sensing allows monitoring of the earth with better temporal resolution compared to the sensors in the visible portion of the electromagnetic spectrum. A number of space-borne sensors have shown sensitivity to rain rate or to other features associated with rain[1]. The retrieval and monitoring of the rain rate over ocean surrounding India has made significant progress after the launching of OCEANSAT-I (IRS-P4). Multi-channel Scanning Microwave Radiometer (MSMR), one of the sensors of IRS-P4, has the ability to penetrate through clouds and is also highly sensitive to rain[2]. IRS-P4 is a polar orbiting satel-

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lite with very high temporal resolution[2] of two days (global coverage). In the present communication, efforts have been made to study the variability of rain rate over ocean surrounding India.

The brightness temperature over a raining ocean is higher than that over a clear ocean. The rain rate is extracted from the difference (excess) between the brightness temperature values of the raining and clear ocean. Passive microwave remote sensing relies on a scattering-based technique to measure rain rate over land, whereas it relies on an emission-based technique to measure rain rate over ocean[3]. The emission signal is related to the total amount of liquid water in the atmospheric column. In order to estimate the surface rain rate, it is necessary to estimate the height of the column. This technique works over the ocean, where a uniform background of microwave emission allows rainfall to be detected by the absorption of low microwave energy by raindrops. The vertical (V) and horizontal (H) polarizations of brightness temperature are analysed as a function of rain rate over the Indian oceanic conditions. At frequencies 10 and 18 GHz, rain affects predominantly through the emission/absorption process, whereas the scattering contributions are negligible. This lower frequency channel penetrates easily to near the cloud base and the high oceanic reflectivity allows us to take advantage of rainfall detection.

India launched its first ocean remote sensing satellite IRS-P4 (OCEANSAT-1) on 26 May 1999, on-board an MSMR and an ocean colour monitor (OCM) sensor. OCEANSAT-1 is a sun-synchronous satellite with a global coverage period of two days. The MSMR provides global microwave brightness temperature data at 6.6, 10.65, 18 and 21 GHz frequencies, with dual polarizations having spatial resolutions of 150, 75, 50 and 50 km respectively. The operational algorithms for deriving various parameters from MSMR brightness temperature data in different grid schemes have been developed[4].

A combination of brightness temperatures at 10 and 18 GHz frequencies for both H and V polarizations has been used in the following algorithm for retrieval of rain rate over ocean[5]. This algorithm is validated from some of the observations made from the ship, and it is found that the rain rate estimated using this algorithm is accurate and reliable. Large volume of rain rate data from the ship over the ocean is required for detailed analysis, but at present such observation is very limited.

$$\text{RR (mm/h)} = 241.1 - 17.57 \ln [280 - T_{\text{B10V}}] - 40.65 \ln [280 - T_{\text{B10H}}] + 5.478 \ln [280 - T_{\text{B18V}}] + 5.621 \ln 280 - T_{\text{B18H}}], \quad (1)$$

where RR is the rain rate in mm/h, suffix V and H are

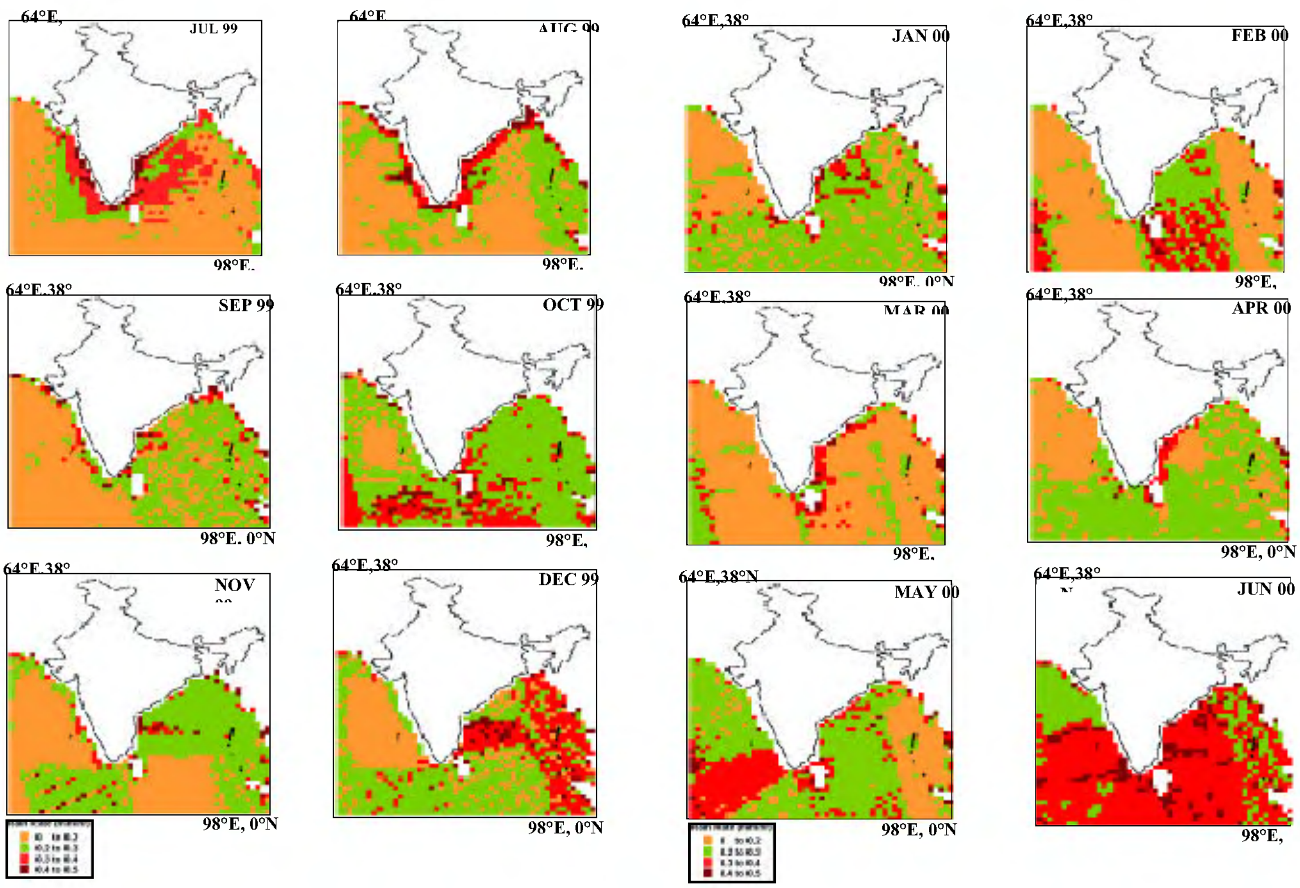

Figure 1. Monthly variations of rain rate over oceanic region around India.

rate over the Bay of Bengal, Arabian Sea and Indian Ocean is found to be higher during May and June due to the onset of SW monsoon compared to other months. It gradually decreases in the succeeding months, again followed by increase during winter due to winter (NE) monsoon. Low rainfall is found over ocean during March and April due to hot and dry weather. Satellite-derived rain rate is found to be similar to the NCEP/NCAR-derived climate reanalysis data. The MSMR data show the potential in deducing rain rate over the ocean, which will be useful in understanding the complex climatological phenomena over the Indian subcontinent and in the numerical forecast modelling.

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Laser-induced chlorophyll fluorescence spectra of mung plants growing under nickel stress

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The *in vivo* laser-induced chlorophyll fluorescence (LICF) spectra of mung (*Vigna radiata* Linn.) for the control, and nickel (a heavy metal)-treated plants were recorded in the region 600–800 nm with two characteristic bands lying at 680 nm and 730 nm using 488 nm argon ion laser line for excitation. The chlorophyll fluorescence intensity ratio (FIR) F680/F730, and peak positions were calculated by evaluating curve-fitted parameters using Gaussian spectral function. It was found that the FIR decreases with increasing chlorophyll content in case of 0.1 mM nickel-treated plants. When the nickel concentration was raised to 1.0 mM, the FIR showed increasing trends, although it was much less than the control, with decreasing chlorophyll content. Our study demonstrates the use of LICF spectra in the early detection of heavy metal stress impact on crops, particularly mung.

LASER-induced fluorescence (LIF) for remote detection of vegetation stress had been initially proposed by Chappelle *et al.*[1]. Later, LIF studies of vegetation were used to explore the possibility of using laser as a remote means of measuring vegetation characteristics such as plant vigour, as affected by various stress factors such as drought, natural nutrient deficiency, etc. plant type identification and forest biomass estimation. LIF signal can be used to make an inference regarding health and identity of the plants[2,3]. Saito *et al.*[4] have reported fluorescence lidar as a potential new technique for remote terrestrial vegetation monitoring.

The chlorophyll fluorescence spectrum of a green leaf has the maxima near 690 nm and 730 nm. The fluorescence intensity ratio (FIR) of the two maxima red/far-red (F690/F730) is strongly influenced by variation in photosynthetic activity. The intensity of the red and far-red chlorophyll fluorescence is inversely related to the photosynthetic activity. When photosynthesis decreases owing to various stress conditions, the FIR increases. The increase in chlorophyll content in plants results in a decrease in the value of the FIR. The FIR has also been established as an indicator of the *in vivo* chlorophyll content in plants[3]. This stress indicator has been utilized in active remote sensing of the plant in fluorescence lidar system by Valentini *et al.*[5]. Subhash and his associates have studied the effect of different stresses on various plants[6–11], collecting LIF radiation using optical fibre. Buschmann *et al.*[12] have recorded fluorescence imaging of leaf, which provides ample information about as many as ten thousand pixels over the whole leaf area. This allows detection of local disturbances and the gradients in the fluorescence emission. Single-point or spot-data fluorescence measurements, which are still widely used, usually have the advantage of low cost and possibility of relatively high spectral resolution, but a disadvantage that fluorescence information of one leaf spot seldom represents the whole leaf.

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