EMISSIVITY OF VARIOUS GEOLOGICAL TERRAINS USING IRS P4 MSMR DATA

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Detailed analysis of the Multi-frequency Scanning Microwave Radiometer (MSMR) data obtained from IRS P4 Oceansat over different geological terrains of Indian region has been carried out. From the MSMR data, seasonal variations of emissivity over major geological terrains has been studied. The emissivity at 6 GHz frequency shows almost similar behaviour over geological terrains but contrast variations in the emissivity are seen during rainy season compared to the winter and summer seasons, especially in the Indo-Gangetic basin.

Introduction

Optical remote sensing data have been used extensively for mapping and monitoring earth, ocean and snow surfaces. Optical sensors have their limitations during the night time and when cloud cover is present. Under such circumstances, the microwave sensors are considered as potential tool in mapping surface features and with deeper penetration capability providing information about the soil moisture. In the present paper, efforts have been made to deduce emissivity of various geological terrains of the Indian subcontinent. The emissivity of the surface materials is related to the brightness temperature data and scattering coefficient data, respectively available from the passive microwave radiometers and active microwave sensors. In order to analyze these data, knowledge of the emissivity of different geological terrains and effect of the season is important in understanding the radiative and reflective characteristics of the earth, ocean and atmosphere. Using brightness temperature data, efforts have been made to study the characteristics of the land, ocean, snow covered and atmospheric parameters of Indian region (Pandey, 1980; Pandey and Sharma, 1980; Pandey et al. 1981; Rao et al. 1986; Rao et al. 1993; Kumar et al. 1999; Singh et al. 1999; Mishra et al. 2000). In the present short communication, we present the variations of emissivity over the different geological terrains and the seasonal effect there upon.

Methodology

All the objects above absolute temperature (0 K or -273°C) emit electromagnetic radiation. The energy emitted by the object is related by the Stefan-Boltzmann law which states:

$$M = \sigma T^4 \qquad (1)$$

where M is total radiant existence from the surface of a material in watts, σ is Stefan-Boltzmann constant, 5.6697×10^{-8} $Wm^{-2}K^{-4}$, T = absolute temperature (K) of the emitting material.

The emitting ability of an object compared to that of a black body is referred to as emissivity (e).

$$e(1) = \frac{\textit{radiant exitance from an object at a given temperature}}{\textit{radiant exitance from a blackbody at the same temperature}}$$

The emissivity of the surface material is a measure of the energy emitted when a surface is directly viewed. The surface emissivity is related as e = 1 - reflectivity, where reflectivity is given as:

$$r = \frac{\sqrt{\varepsilon_r - 1}}{\sqrt{\varepsilon_r + 1}}, \quad \varepsilon_r{}^* = \varepsilon_r' - i\varepsilon_r'' \qquad (2)$$

where ε_r' is the real part and ε_r'' is the imaginary part of dielectric constant. Emissivity ranges from values between 0 to 1. The emissivity (e) is related to brightness temperature (T_B) by the equation (Rees, 1990):

$$T_B = e_g . T_g + T_{b(up)} + (1 - e_g) . T_g + (1 - e_g) . T_{b(down)} \qquad (3)$$

where e_g is the emissivity of ground, T_g is the temperature of ground, $T_{b(up)}$ is the self emission of the atmosphere (observed at the top of the atmosphere), the third term is the attenuated atmospheric radiation reflected at the earth's surface towards the sensor and the fourth term is the cosmic background radiation, attenuated twice by its propagation through the atmosphere via the earth's surface. The first term gives the contribution of the brightness temperature of the ground and the last three terms together give the atmospheric contribution to the measured brightness temperature by a microwave sensor. The contribution of brightness temperature from the ground and from the atmosphere is dependent on the frequency of the sensor.

To determine the emissivities of various geological terrains, 6 GHz frequency data of IRS P4 MSMR have been used. At this low frequency, the atmospheric contribution is minimal and can be neglected due to higher wavelength and deeper penetration power of the signal (Ball, 1986). Ignoring atmospheric contribution, equation (3) reduces to

$$T_B = e_g \cdot T_g \Rightarrow e_g = T_B/T_g \qquad (4)$$

Emissivity depends on following factors:

- Type of target and its physical properties,
- Dielectric properties,
- Surface Temperature and brightness temperature,
- Thermal conductivity (the rate at which heat will pass through a specific thickness of a substance),
- Heat capacity (the ability of a material to store heat), and
- Thermal inertia (the resistance of a material to temperature change).

India has launched its first ocean remote sensing satellite IRS-P4 (Oceansat-1) on May 26, 1999, carrying a multi-frequency scanning microwave radiometer (MSMR) and ocean colour monitor (OCM). Oceansat-1 is a sun-synchronous satellite with a global coverage period of two days (Kanwar and Narayan, 2002). The MSMR provides global microwave brightness temperature measurements at 6.6, 10.65, 18 and 21 GHz frequencies with dual polarization having spatial resolutions of 150, 75, 50 km, respectively. The operational algorithms for deriving various parameters from MSMR brightness temperature data in different grid schemes have been developed (Kanwar and Narayan, 2002). The brightness temperature accuracy for eight MSMR channels have been evaluated based on simulation of brightness temperatures and minimizing the difference from MSMR data over Indian oceanic region between 30° latitude belt around the equator.

Results and Discussion

Detailed mapping of seasonal variations of emissivity over India have been carried out in four different zones: Indo-Gangetic Basin, Deccan Traps, Shield region and Desert region using the IRS P4 MSMR brightness temperature data in the 6 GHz frequency and horizontal polarization and NCEP/NCAR (National Centers for Environmental Prediction and National Center for Atmospheric Research) surface temperature data. The NCEP/NCAR data are generated from the model, based on the nature of the region. These data are found to be accurate and reliable (Kalnay et al. 1996). The emissivity for various regions are shown in Figs. 1-4. The emissivity shows more or less same seasonal trend in all geological terrains having highest emissivity (0.85 to 0.95) during summer and decreasing gradually in winter and very less in rainy season. Figure 1 shows the seasonal variations of emissivity in the Deccan Trap region. In general, the emissivity shows higher values and varies in the range of 0.75 to 0.95 due to several factors. Deccan Trap region usually consists of dark coloured basaltic formations, which generally have a high radiant temperature and therefore high brightness temperature, which is a major factor for higher values of emissivity of Deccan Trap regions. Figure 2 shows seasonal variations of emissivity in the shield region, which is found to vary in the range from 0.45 to 0.95. This is due to the variations in the rock composition from igneous metamorphic (granitic) rocks to sedimentary rocks, which produces broad variations in thermal conductivity, heat capacity, and also in brightness temperature. Figure 3 shows seasonal variations of emissivity of the desert region, which varies in the range 0.65 to 0.95. Desert region is generally covered by sandy soil and the observed brightness temperature values in the desert regions are comparatively higher than other regions with the seasonal emissivity values being quite high. In some places, sands depending on their colour, texture and other physical properties act as a good reflectors, which reduces the emissivity of the region. Figure 4 shows seasonal variations of emissivity in the range 0.65-0.95 for the Indo-Gangetic Basin. This region is generally covered with alluvial soil, where brightness temperature value in summer is very high compared to rainy season, due to which emissivity reduces from 0.95 during summer to 0.65 during the rainy season.

Emissivity is largely dependent on dielectric properties of the materials varying with the moisture content of the soil and rocks. For example, because of the high dielectric constant of the water, emissivity decreases from about 0.95 to 0.60, which is related to the increase of moisture content of the soil from dry to saturated state. During summer season very little moisture is present in the soil and rock, the dielectric constant is very less which is responsible for the increase of the emissivity. During winter, some moisture is present in the soil due to dew, which gives a medium emissivity (0.75 to 0.85) values and during rainy season moisture content is very high resulting in very high values of dielectric constant, which drastically reduces the emissivity values of over all geological terrains.

Conclusions

The variations of emissivity in different geological

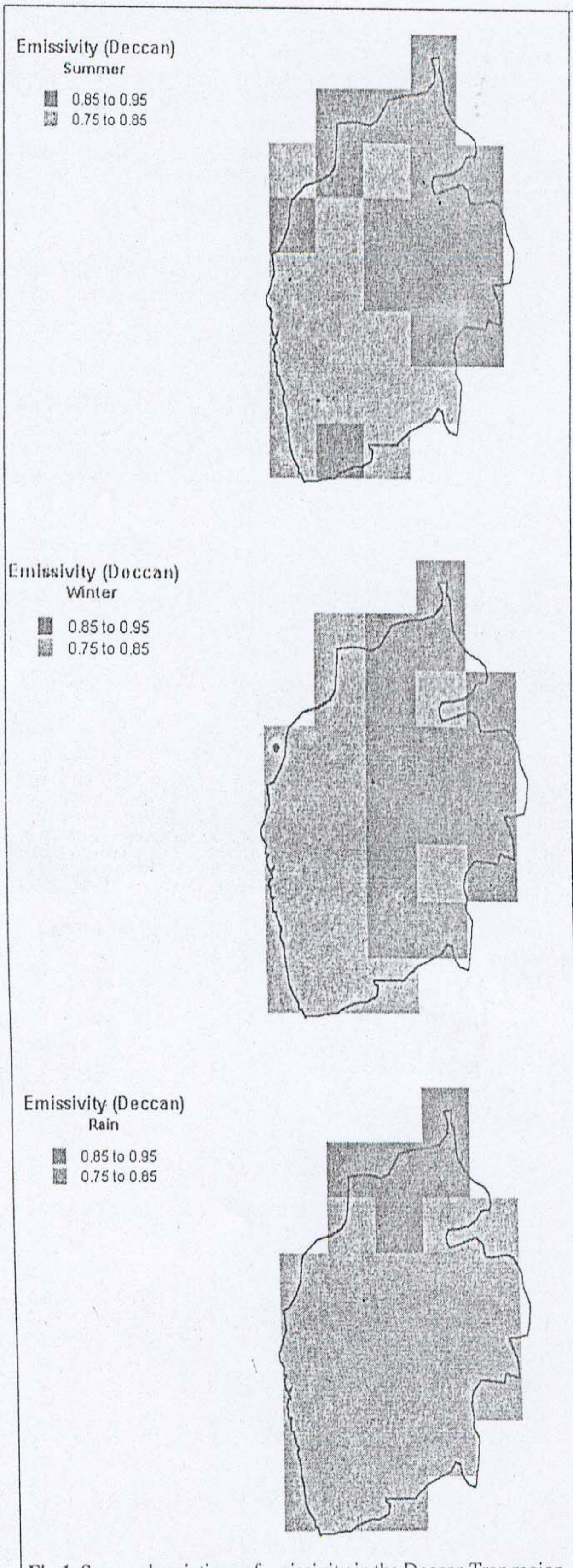

Fig.1. Seasonal variations of emissivity in the Deccan Trap region.

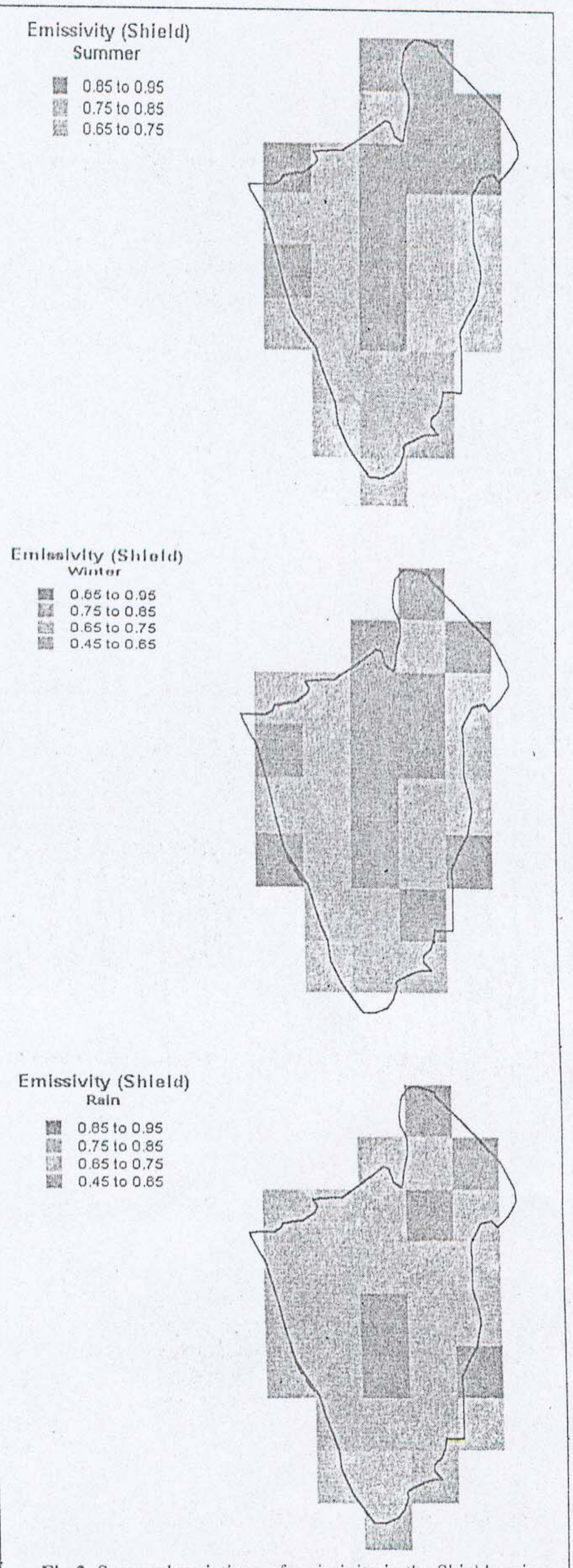

Fig.2. Seasonal variations of emissivity in the Shield region.

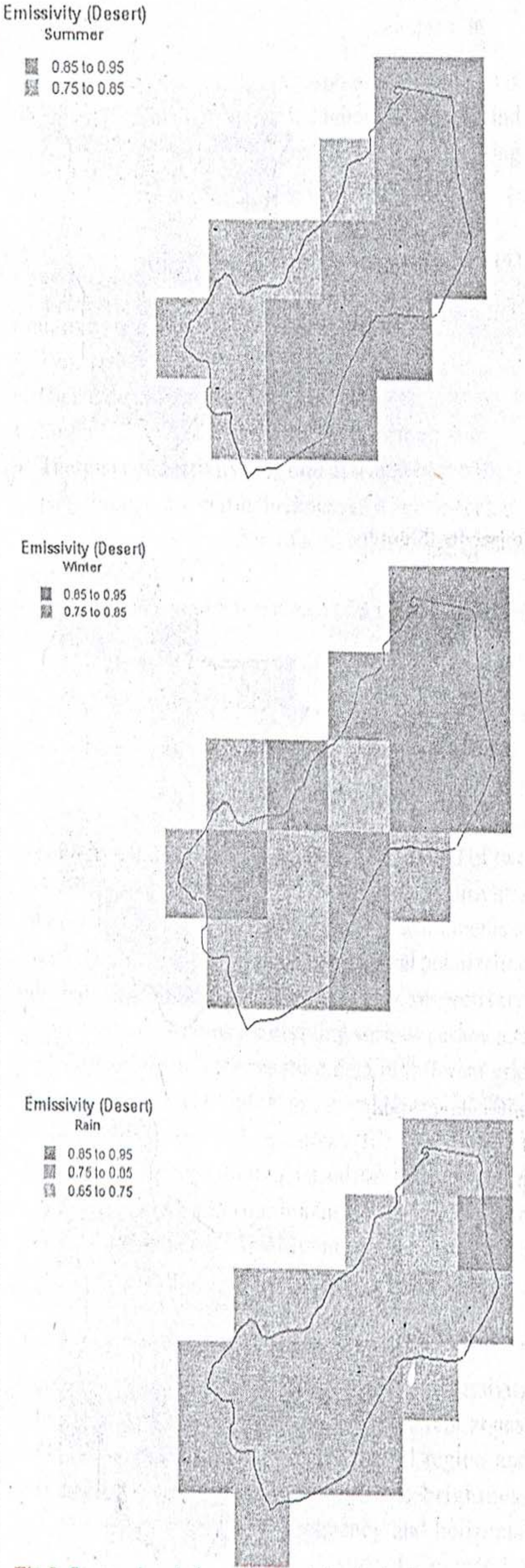

Fig.3. Seasonal variations of emissivity in the Desert region.

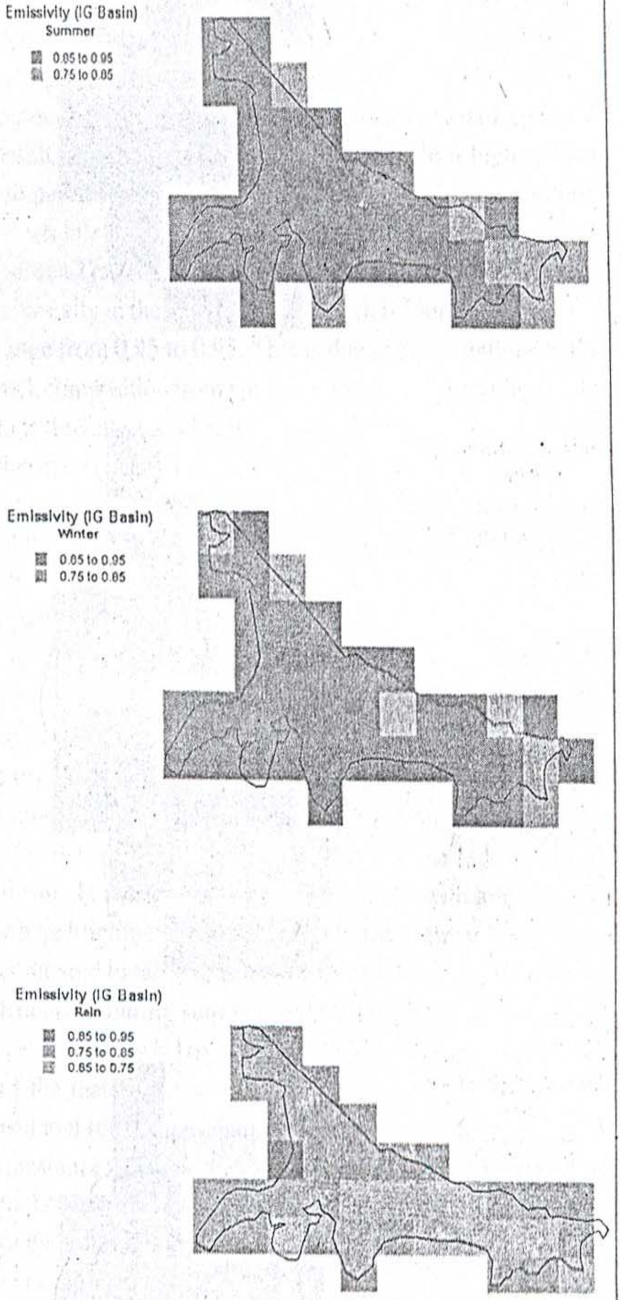

Fig.4. Seasonal variations of emissivity in the Indo-Gangetic basin.

terrains of India shows similar seasonal trend, having maximum in summer, moderate in winter and minimum during rainy season. It provides us information about the variation of soil moisture in these regions, as emissivity decreases as moisture content in the soil increases. The present results show qualitative variations of emissivity over different geological terrains. The validation of the results discussed in the present communication is difficult since direct measurements of emissivity are difficult and have not been done in India. However, the brightness temperature measured through IRS P4 MSMR data at 18 and 21 GHz frequencies are found to be comparable with the brightness temperature measured by the SSM/I (Special Sensor Microwave Imager) sensors at 19 and 22 GHz frequencies. The poor resolution of MSMR sensors provide emissivity data over larger grids which may not provide realistic values of emissivity specially along the coastal region due to mixed land and ocean pixels. In a broad sense, the present results show that the emissivity of Indian region varies in the range of 0.65 to 0.95 and shows strong seasonal effect. The results present in this paper will be useful in the analysis of microwave remote sensing data and in the development of emissivity models of the Indian terrains.

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