

Application of MSMR brightness temperature for retrieval of land surface parameters

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Abstract

ISRO, India launched Indian Remote Sensing satellite IRS-P4 on 26th may 1999, onboard Multi-channel Scanning Microwave Radiometer (MSMR) and an Ocean Colour Monitor (OCM). MSMR provides measurements of brightness temperatures at 6.6, 10.65, 18 and 21 GHz frequencies in both horizontal and vertical polarizations at three different resolutions 50 Km, 75 Km and 150 Km. Our idea is to estimate the soil moisture, vegetation water content and surface roughness in different parts of India with different soil type using MSMR Brightness Temperature data. The soil moisture and vegetation water content are some of the significant parameters for hydrologists, agriculturists and meteorologists. Large area soil moisture information is useful for modeling weather forecasting. Brightness temperature of the soil is dependent on physical parameters like dielectric constant, surface roughness, soil type, vegetation cover etc. Study is done on the retrieval of land surface parameters using Brightness Temperature (TB) and the results for Nimbus 7 SMMR data is compared with the results of MSMR TB data of IRS P4 satellite.

A case study is done for a particular area of 50 Km by 50 Km at Bikaner in Rajasthan, India. The results obtained are compared with ground values from the agricultural department [1].

Introduction

Multi Scanning Microwave Radiometer (MSMR) provides data for Brightness Temperature (TB) at four different frequencies 6.6 GHz, 10.65 GHz, 18 GHz and 21 GHz, at Vertical and Horizontal Polarizations. From the previous studies there are various models provided for estimating soil moisture, vegetation water content, surface roughness, etc. Due to the complexity of equations used, it is a tedious task to obtain these parameters with better accuracy. In the present work, 50 by 50 Km area at Bikaner Rajasthan, India is considered and the TB data of MSMR of IRS P4, SMMR of Nimbus 7 and theoretical calculations are compared. Plots of TB v/s frequency shows an unexpected fall in TB values at 18 GHz frequency of IRS P4 indicating some problem at 18 GHz of IRS P4. thus the measurements at 6.6 GHz, 10.65 GHz and 21 GHz are considered. Referring to data from "Benchmarks of India" [1], the TB is calculated for range of soil

moisture, vegetation water content, surface roughness values etc., for 50 by 50 Km area of Bikaner. These results are compared with TB data of Nimbus 7 and IRS P4 satellites for the retrieval of land surface parameters with better accuracy.

Theory

Brightness Temperature as a function of soil moisture, vegetation water content, and surface roughness is given as [2]

$$TB_p = T \{ (1-R_{sp}) \exp(-\tau c) + (1-w_p) [1 + R_{sp} \exp(-\tau c)] \} \dots\dots\dots(1)$$

Where

TB_p is the polarization at vertical or horizontal brightness temperature.

R_{sp} is rough surface reflectivity.

τc is the vegetation opacity.

w_p is the single scattering albedo.

Relation for R_{sp} and τc are same as given in [3].

$$R_{sp}(\theta) = R_p(\theta) \exp(-h \cos^2 \theta) \dots\dots\dots(2)$$

where R_r is the rough surface reflectivity at look angle θ , and h is

$$h = 4\sigma^2 \left(\frac{2\pi}{\lambda} \right)^2$$

R_p is the refractivity of smooth surface and is given by

$$R_h(\theta) = \left| \frac{\cos\theta - (\epsilon - \sin^2\theta)^{1/2}}{\cos\theta + (\epsilon - \sin^2\theta)^{1/2}} \right|^2 \dots\dots\dots(3)$$

and

$$R_v(\theta) = \left| \frac{\epsilon \cos\theta - (\epsilon - \sin^2\theta)^{1/2}}{\epsilon \cos\theta + (\epsilon - \sin^2\theta)^{1/2}} \right|^2 \dots\dots\dots(4)$$

and the dielectric constant 'C' is given by

$$\epsilon^\alpha = 1 + \rho_b/\rho_s (\epsilon_s^\alpha - 1) + m_v^\beta \epsilon_{fw}^\alpha - m_v \dots\dots\dots(5)$$

And that of free water ϵ_{fw} is

$$\epsilon_{fw} = \epsilon_{w\infty} + \frac{\epsilon_{w0} - \epsilon_{w\infty}}{1 + j2\pi f \tau_w} - j \times \frac{\sigma_{eff} \times (\rho_s - \rho_b)}{2\pi f \epsilon_0 \rho_s m_v} \dots\dots\dots(6)$$

where $\sigma_{eff} = -1.645 + 1.939 \rho_b - 0.02256 S + 0.01594 C$

S is the % of sand

C is the % of clay

$\epsilon_{w\infty}$ is the high frequency limit of ϵ_w

ϵ_{w0} is the static dielectric constant of water

- f is the frequency in hertz
- τ_w is the relaxation time of water
- ρ_s is the specific soil density
- ρ_b is the bulk soil density
- ϵ_0 is the permittivity of the free space equal to $8.854 \times 10^{-12} \text{ F.m}^{-1}$

Thus for the ranges of soil moisture, vegetation water content and if required surface roughness, for the area under study, the simulations can be made and the results can be compared with satellite data sets for estimation of Land surface parameters.

Results and Discussion

On comparison the plots of TB v/s frequency of IRS P4, Nimbus 7 and Theoretical calculations it is seen that there is a decrease in the value of TB for IRS P4 at 18 GHz.

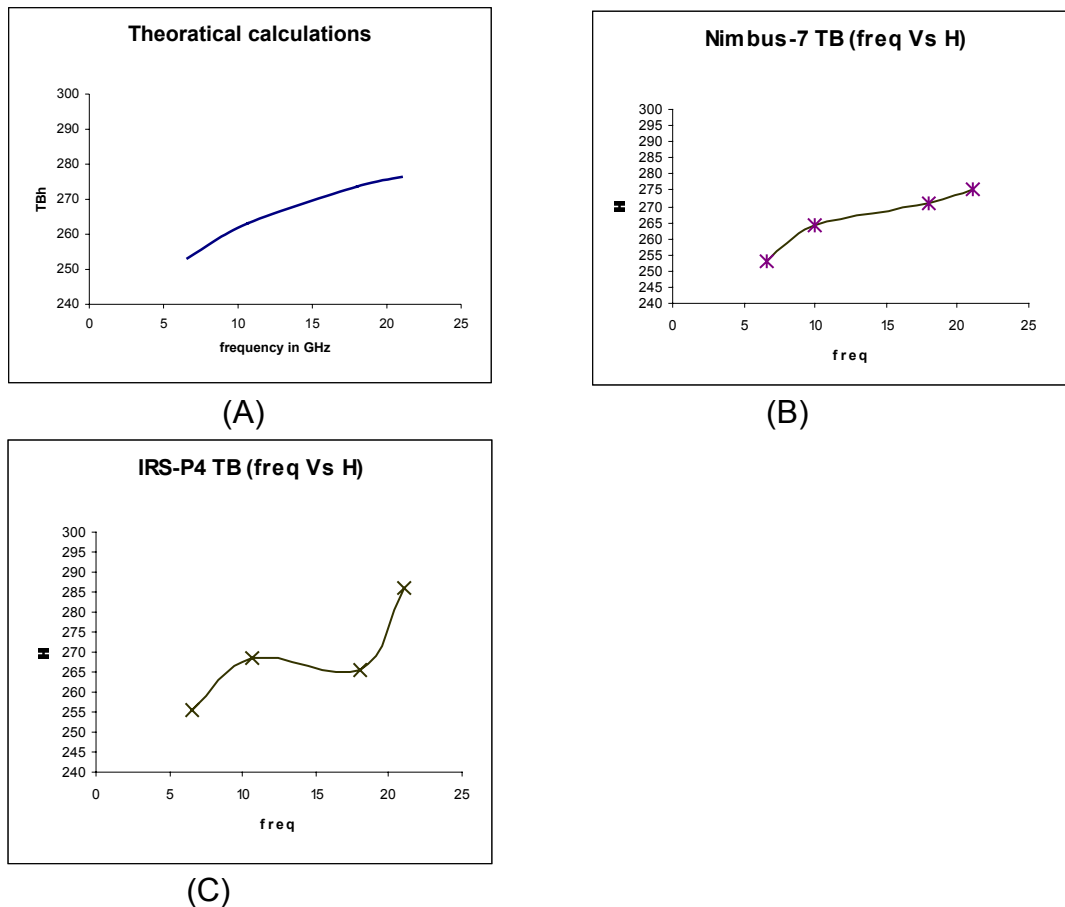
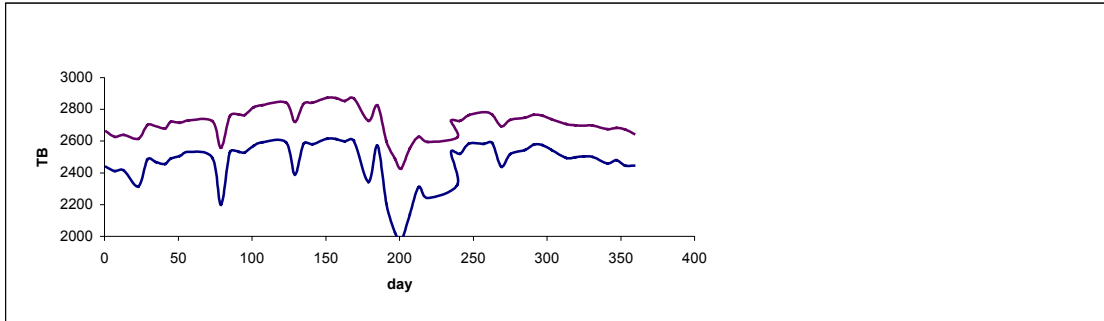


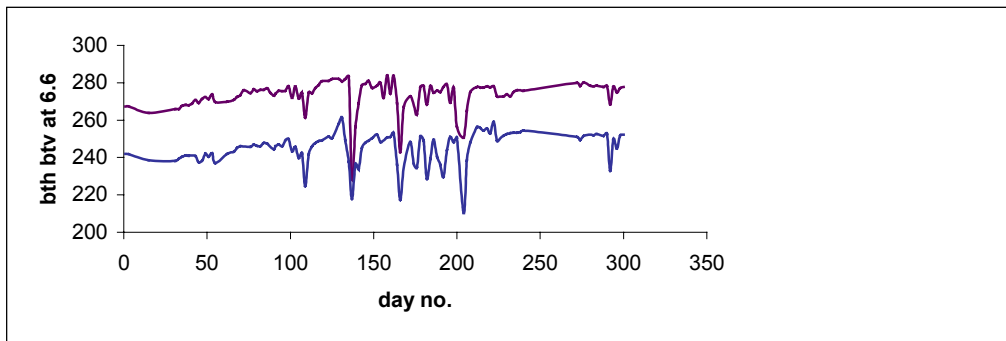
Figure 1: shows plots for TB at horizontal polarizations with frequency for (A) Theoretical calculations, (B) for Nimbus 7 and (C) for IRS P4.

Plot (C) shows after 10.65 GHz the value of TB decreases for 18 GHz and then again increases for 21 GHz. While in other two cases (A) and (B), value of 18 GHz is more than the 10.65 GHz. Thus calculation are done at other three frequencies i.e. 6.6 GHz, 10.65 GHz and 21 GHz for the month of September.

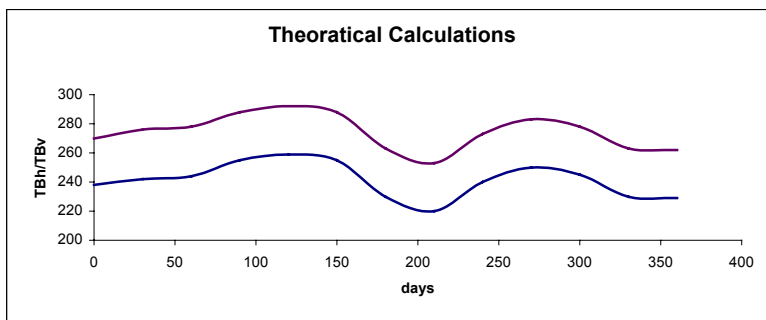
The graphs of TB v/s Days are plotted for Nimbus 7 for 1978, IRS P4 for 2001 and Theoretical calculations are made for the values from Benchmark soil of India [1].



(a) plots for Nimbus 7



(b) plots for IRS P4



(c)

Figure 2: plots shows the variation of brightness temperature. Curve at higher TB is for vertical polarization and one with lower TB is for horizontal polarizations at 6.6 GHz frequency for Nimbus 7(a), IRS P4(b) and Theoretical calculations (c).

These plots are compared to see the variations of TB throughout the year for the Area of interest. Theoretical curve is drawn taking average of TB over a month. It is seen that around month of May there is a decrease in the TB because of soil moisture present and due to the effect of vegetation water content. In the similar way the simulations are made for all the ranges temperatures, soil moisture, and vegetation water content. These simulations can be compared with the actual values of TB from satellite so that to get perfect match with satellite data.

Conclusion

The results obtained using above technique closer resemblance with the actual ground values of surface parameters. Thus using satellite data it is possible to get idea of the nature of the surface and vegetation presence, which can be used effectively weather forecasting, hydrologists, agriculturist, etc. It has been seen that, microwave polarization difference gives more accurate estimation of vegetation water content and soil moisture. Thus it has been tried to use this difference in inversion technique to get better results in future.

References

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- [3]. Myron C. Dobson, et al, Microwave Dielectric Behavior of Wet Soil-Part II: Dielectric Mixing Model, Member IEEE.