SURFACE REFERENCE NORMALIZED RADAR CROSS SECTION OVER LAND FOR THE IMPROVEMENT OF THE TRMM PR ALGORITHM

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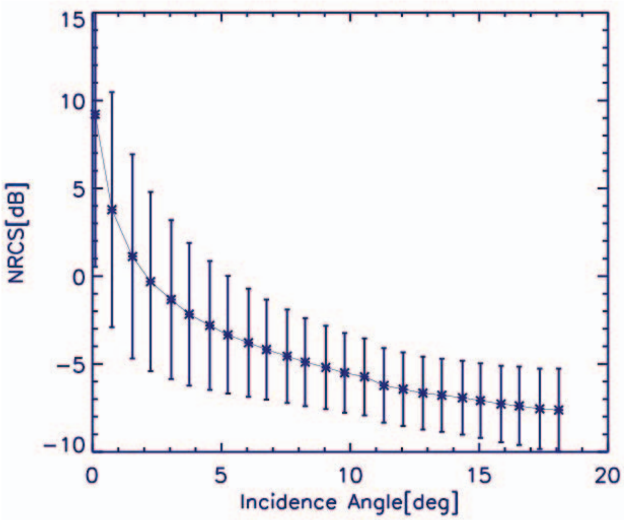
1. INTRODUCTION

The TRMM precipitation radar (PR) is the single frequency (13.8 GHz) radar and its rain retrieval algorithm utilizes the path integrated attenuation (PIA) values of the surface normalized radar cross section (NRCS) in the surface reference technique (SRT) to perform the rain attenuation correction (Iguchi and Meneghini [1], Iguchi et al. [2], Meneghini et al.[3, 4]). The SRT rests on the assumption that the difference between the measurements of the NRCS within and outside the raining area provides a measure of the PIA. An estimate of the NRCS under no rain condition is used as a reference value for computing PIA. Although the SRT works fairly well over the ocean, it does not work well over the land because the land surface is not so much uniform as the ocean surface and NRCS varies widely as the land surface condition varies. NRCS is treated as a function of incidence angle only over land in the present TRMM standard algorithm. In this study, for estimating reference NRCS , we try to introduce not only incidence angle but also new physical parameters over land (the normalized differential vegetation index (NDVI), surface roughness, and soil moisture) in order to increase the accuracy of the estimated reference NRCS.

2. LAND SURFACE NRCS VERSUS INCIDENCE ANGLE RELATION

Fig. 1 shows NRCS versus incidence angle relation over global land by TRMM PR within the latitude of +/- 35 degs. in January 2000. This relation over land is quite different from the relation over ocean. The NRCS over land decreases sharply with increase of the incidence angle from 0 degs. to around 10 degs., and decreases gradually for incidence angles of more than 10 degs. As NRCS values vary widely over land, standard deviations shown by error bar in Fig. 1 take very large values. This variability of NRCS is due to the large variances of NDVI, surface roughness, soil moisture and other physical parameters over land. Therefore it is not a good approximation to determine reference NRCS values over land which is used for the Surface Reference Technique only from the incidence angles. The present TRMM PR standard algorithm applies only along track SRT to compensate rain attenuation effect over land. Fig. 2 shows NRCS versus incidence angle relation in January 2000 for Sahara(longitude: 0-30E, latitude: 15N-30N), Amazon(longitude: 60W-50W, latitude: 10S-0) and global



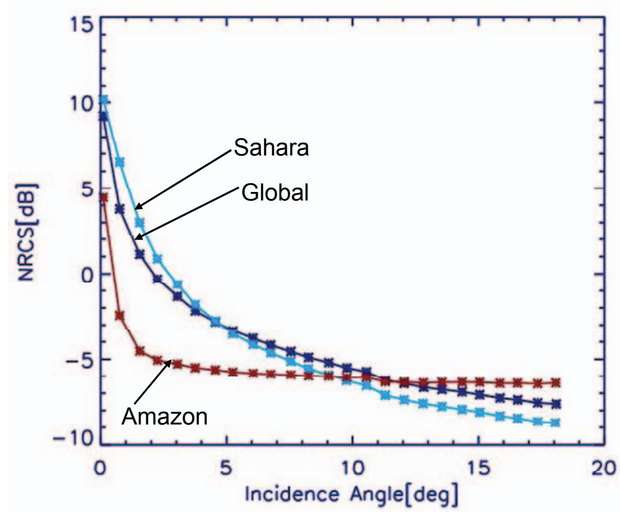


Fig. 1 NRCS vs. incidence angle over the land in January 2000.

Fig. 2 NRCS vs. incidence angle of various surfaces (global, Sahara and Amazon) in January 2000.

regions. As the Amazon region is covered by vegetation canopy, the volume scattering effect by vegetation is noticeable. Therefore, the NRCS nearly takes constant value of about -5 dB for the incidence angle of more than 3 degs. On the other hand, as the Sahara desert region is devoid of vegetation, the surface scattering by the desert soil is noticeable. Therefore, the NRCS decreases gradually with increase in the incidence angle.

3. THE EFECTS OF NDVI

In order to study the effects of physical parameters(NDVI, surface roughness, soil moisture, and so on) on the NRCS over land, the correlations between monthly averaged NRCS and NDVI, surface roughness, and soil moisture for each 1 deg. by 1 deg. grid box within the latitude of +/-35 degs. are studied for various incidence angles. Fig. 3 shows scatter plots of NRCS versus NDVI at incidence angles of 0, 3, 12, and 18 degs in January 2000. NDVI values are observed by the NOAA AVHRR(Advanced Very High Resolution Radiometer). NDVI takes values between 1.0 and -1.0. NDVI takes large values(more than 0.25) in the vegetation area and takes small positive values in the soil area. NDVI takes negative value in the water area. The NRCS and NDVI take negative correlation coefficient of -0.6 at the incidence angle of 3 degs. and take positive correlation coefficient of 0.4 at the incidence angle of 18 degs. The NRCS values take almost same values at incidence angle of 12 degs. in spite of the NDVI variations, and no correlation is observed. At the incidence angle of 0 deg., both NRCS and NDVI values scatter and it is difficult to find any correlations between them. The correlations between the NRCS and surface roughness, and soil moisture are studied in the same way. The NRCS and logarithm of surface roughness take negative correlation coefficient of -0.4 at the incidence angle of 0 degs. and take positive correlation coefficient of 0.3 at the incidence angle of 18 degs. The NRCS and soil moisture do not show the noticeable correlation.

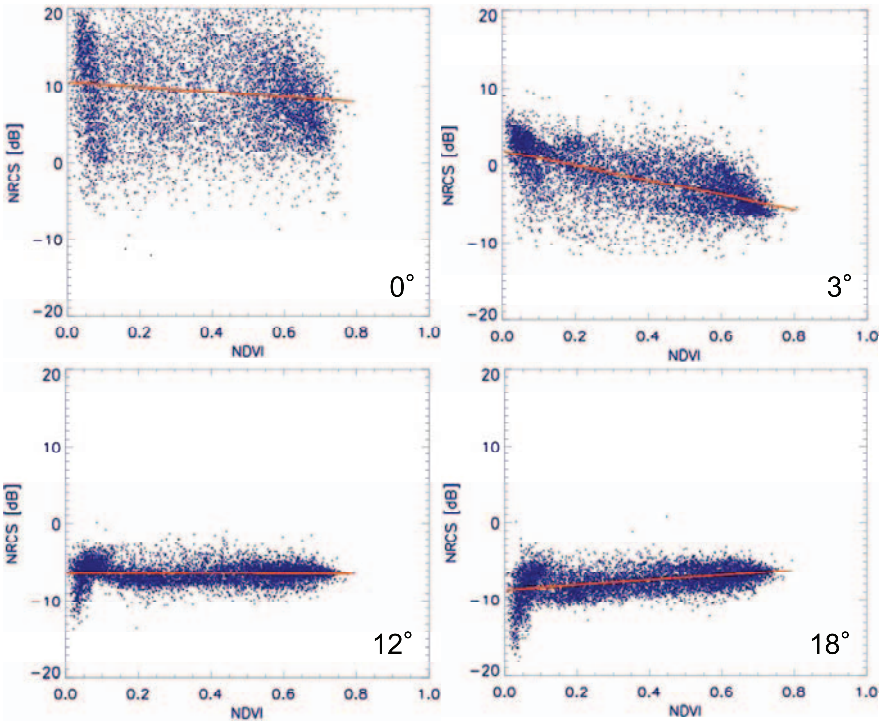


Fig. 3 Scatterplots of NRCS vs. NDVI at incidence angles of 0 degs., 3 degs., 12 degs., and 18 degs. in January 2000.

4. MULTIPLE REGRESSION ANALYSIS OF NRCS

We try to introduce an approximate expression of the reference NRCS of every incidence angle by applying the multiple regression analysis method, considering effects of NDVI, logarithm of surface roughness, and soil moisture at a time. We use monthly averaged NRCS of every incidence angle and physical parameters(NDVI, logarithm of surface roughness, and soil moisture) for each 1 deg. by 1 deg. grid box within the latitude of +/-35 degs. We apply both the simple linear multiple regression analysis shown by the equation (1) and polynomial multiple regression analysis including interaction term shown by the equation (2) as the approximation of the reference NRCS of every incidence angle.

$$NRCS[dB] = a_0 + a_1 \times NDVI + a_2 \times \log(roughness) + a_3 \times moisture \quad \text{.................(1)}$$

$$NRCS[dB] = \sum_{p=0}^{l}\sum_{q=0}^{m}\sum_{r=0}^{n} C_{pqr} \times (NDVI)^p \times (\log(roughness))^q \times (moisture)^r \quad \text{........(2)}$$

In the equation (2), we set restriction conditions $p \le 2,\ q \le 2,\ r \le 2,\ p+q+r \le 3$ for the simplicity of the calculation. We determine the best suited coefficients and power indexes in the equations (1) and (2) by the least square method. Then, we calculate differences between the monthly averaged NRCS and approximated NRCS values by the equations (1) and (2) for each 1 deg. by 1 deg. grid box and finally calculate the root mean square

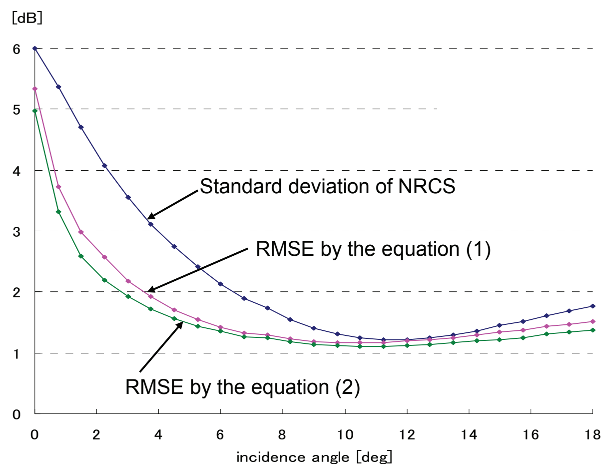


Fig. 4 Comparisons of rmse of the multiple regression analysis of NRCS by the equations (1) and (2) with the standard deviations of NRCS as a function of incidence angle in January 1998.

error(RMSE) of all grid boxes within the latitude of +/-35 degs. for every incidence angles. These RMSE values are compared with the standard deviations of averaged NRCS of all 1 deg. by 1 deg. grid box within the latitude of +/-35 degs. for every incidence angles in January 1998 and are shown in the Fig. 4. The estimated RMSE values become about the half of the standard deviation of NRCS for the incidence angles smaller than 5 degs. The estimated RMSE values are slightly smaller than the standard deviation of NRCS for the incidence angles larger than 5 degs.

The approximate expressions of the NRCS by applying the multiple regression analysis method will be the better approximation for the reference NRCS than the averages of the monthly averaged NRCS of all 1 deg. by 1 deg. grid boxes within the latitude of +/-35 degs.

5. CONCLUSION

We study the correlation between the monthly averaged NRCS and physical parameters(NDVI, surface roughness, soil moisture, and so on) over land for each 1 deg. by 1 deg. grid box. The approximate expressions of the reference NRCS as functions of physical parameters are obtained by applying the multiple regression analysis method. The approximate expressions of the NRCS gives smaller RMSE than the standard deviations of NRCS, and will be the better approximation for the reference NRCS. It will be necessary to compare NRCS and physical parameters of the instantaneous field of view size in order to propose the approximation of the reference NRCS which can be used in the standard TRMM PR algorithm in the future.

6. REFERENCES

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