Evaluation of Soil Moisture Data of Advanced Microwave Scanning Radiometer (AMSR) 2 for Azara area of Assam, India

Bikramjit Goswami[1*], Banira Thapa[2], Nitumoni Deka[3], Ripranchi Ch. Marak[4] and Manoranjan Kalita[5]

Assam Don Bosco University, Guwahati, Assam, India
E-mail: bikramjitg@gmail.com

Abstract—*Advanced Microwave Scanning Radiometer 2 was launched on the Global Change Observation Mission (GCOM) Satellite by Japan Aerospace Exploration Agency (JAXA), to observe microwaves naturally emitted from the atmosphere, land surface, sea surface and cryosphere. In this paper, we have presented the evaluative study about the usefulness of the soil moisture product of AMSR 2 for places having mixed land cover characteristics. While performing our experiments, we observed that AMSR 2 gives inaccurate values of soil moisture for places having large areas of open water bodies. The results are also validated by measurement of dielectric constant variation of the soil samples collected.*

Keywords*: AMSR 2, microwave remote sensors, soil moisture, capacitance, dielectric constant.*

1. INTRODUCTION

The sensors used for Microwave remote sensing may be classified into Active sensors and Passive sensors. The active sensors retrieve the spectrum of incident energy return from the surface of the earth that is imaged by providing its own illumination whereas the Passive sensors receive energy that is naturally reflected by the surface of the earth [1].

Japan Aerospace Exploration Agency (JAXA) has launched a satellite under Global Change Observation Mission (GCOM). GCOM- Water and GCOM- Climate are the two different observing systems of GCOM. The Advanced Microwave Scanning Radiometer 2 (AMSR 2) launched in GCOM observes soil moisture content, water vapor, precipitation, snow depth and sea surface wind. Soil moisture impacts on weather forecasting and soil moisture content data help in improving the flood and drought monitoring [2].

Low frequency passive microwave sensors on board of satellites are sensitive to dielectric properties of the surface. The dielectric property of the soil is strongly related to soil moisture [3].

More specifically, the soil moisture content is directly related to dielectric constant. Experiments can be done in order to study the relation between capacitance and plate separation based on the principle of parallel plate capacitance as,

$$C = \varepsilon_0 \varepsilon_r A/d \qquad (1)$$

where, C is the capacitance, A is the area of the plate, d is the distance between the plates, while ε_o is the permittivity of free space and ε_r is the permittivity of the medium.

If A and d are kept same throughout a capacitance measurement exercise, then the variations in the capacitance of a medium would be directly proportional to the dielectric constant (ε_r) only.

The microwave remote sensing of soil moisture depends on the dielectric constant of water as well as soil. At lower microwave frequencies, the large dielectric constant causes a large change in the emissivity of soil as they become wet [0.95 (for dry) and 0.6 (for wet)]. However, the vertical and horizontal scale of roughness affects the sensitivity of microwave emission to soil moisture [4].

Soil moisture is the amount of moisture contained in soil and is expressed in percentage. Forecasting of climatic changes aids in resource management and also in disaster management and this can be done by studying the soil moisture variations for different places. Hence the usefulness of the soil moisture product of AMSR 2 for places having mixed land cover characteristics, in the state of Assam in India, is studied and presented in this paper. For the study, the Azara area in the western fringe of Guwahati, the capital city of Assam is selected, as the pixel falling on the area consists of varied land cover types such as vegetation, water bodies, urban settlements and paddy fields.

2. AREA OF STUDY

The area of study includes the Azara area in the state of Assam in India including Azara, Rani, VIP, Kahikuchi, Dharapur, Majir Gaon etc., The AMSR 2 derived soil moisture data is collected for the pixel covering all these areas within its 10 km x 10 km boundary. The pixel ranges from 26.0^{o}N to 26.14^{o}N latitude and 91.5^{o}E to 91.65^{o}E longitude. Fig. 1 shows the google earth image of the area under study, where the pixel boundary is shown by the yellow pin marks.

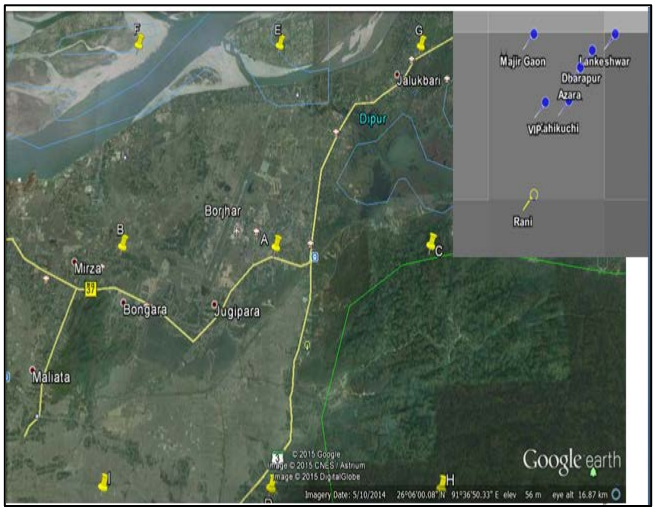

Fig. 1: Google earth image of the area under study (Azara)

3. METHODOLOGY

Soil samples are taken from various places within the study area, including the boundary regions and the values of capacitance and dielectric constant are determined by using the experimental setup described in the following paragraph.

The experimental setup consists of a parallel plate capacitor box, an LCR Q meter, weighing balance, electric oven and measuring probes. A parallel plate capacitor is made by inserting two aluminum sheets inside a wooden box which has dimensions of 10 cm x 5 cm x 5 cm, so that the setup acts as a capacitor (Fig. 2). Two terminals from the two aluminium electrodes are taken out of the box for connecting to the LCR meter. This capacitor box when connected to the LCR meter gives the capacitance corresponding to the dielectric medium separating the aluminium plates. Soil samples can be put inside the box to act as dielectric and dielectric constant of the sample can be found out from the capacitance measured as shown in equation (1). From equation (1) we can see that for soil sample inside the capacitance box, equation (2) will give the capacitance value.

$$C_{soil} = \varepsilon_0 \varepsilon_{r1} A/d \quad (2)$$

where, ε_{r1} is the relative permittivity of the dielectric medium, i.e., soil.

Similarly for air filling up the space between the two aluminium electrodes inside the capacitor box equation (1) can be written as shown in equation (3).

$$C_{air} = \varepsilon_0 \varepsilon_{r2} A/d \quad (3)$$

where, ε_{r1} is the relative permittivity of the dielectric medium, i.e., air. ε_{r2} for dry air ~ 1

Dividing (2) by (3) equation (4) is obtained.

$$C_{soil}/C_{air} = \varepsilon_{r1} \quad (4)$$

From equation (4) it is seen that the dielectric constant of soil with different soil moisture content can be determined experimentally by measuring the capacitance values. This way the measurements of dielectric constants for various soil samples are done in the study.

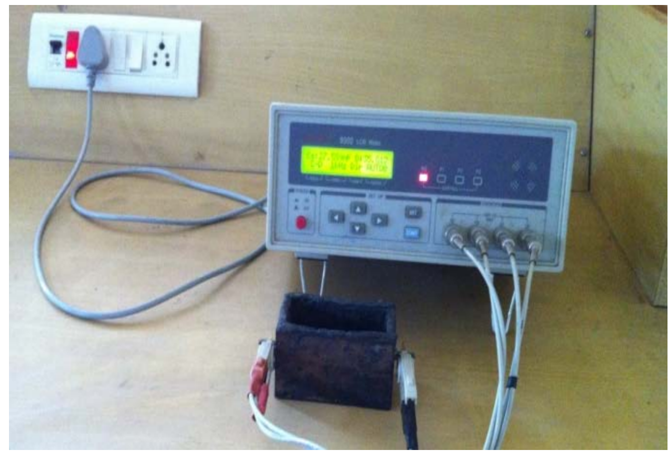

Fig. 2: Experimental set-up with the capacitor box

The soil moisture values for the soil samples are measured by using volumetric analysis in terms of percentage. Those soil moisture values obtained from the analyses are plotted against the dielectric constant values. The variation of soil moisture and dielectric constant is analyzed for evaluating the AMSR2 derived soil moisture data. Since AMSR2 gives the soil moisture content value in volumetric percentage, it is convenient to compare the data with the physical volumetric soil moisture measurement results.

4. RESULTS AND DISCUSSION

Soil samples were collected from different places in Azara in order to do experiments and verify the dependence of soil moisture on dielectric constant of the soil. Soil was dug using an auger and was collected in zip lock bags to retain the moisture. The weight of the soil samples collected were taken and then the soil samples were put in a container and kept for drying in the oven at 105^0 C for 24 hours. After 24 hours, the soil was removed from the oven and its weight was measured again as all moisture contained in the soil was removed due to complete drying.

The capacitance of the soil, having soil moisture content of 10.95% is found to be 4 nF. On adding 10 ml of water the capacitance value increased to 7.7 nF. On adding 20 ml of water capacitance value increased to 78 nF. On adding 30 ml of water the capacitance value increased to 360 nF and on adding 40 ml of water the capacitance value increased to 540 nF. The empty box capacitance value was found to be 85 nF. Using equation (4), the dielectric constant values were found as shown in Table 1.

Thus the dielectric constant variations show direct relationship to the soil moisture variations. The passive microwave sensing depends on the variations which are dependent on the dielectric constant of the emitting surface. Hence, the soil moisture measurement by satellite radiometers actually depends on the dielectric constant variations of the soil due to moisture content. Therefore, both volumetric soil moisture measurement and dielectric constant measurements are done for different places within the pixel of Azara area and satellite measured soil moisture values are also compared as shown in Table 2.

Table 1: Capacitance and dielectric constant variation with soil moisture

Soil moisture (%)	Capacitance(nF)	Dielectric Constant
10.95	4	0.047
15	7.7	0.09
19	78	0.917
23	360	4.235
27	540	6.353

From Table 2 it is seen that the soil moisture values shown by AMSR 2 data are not correct. Also the variations of the values shown by the satellite data are not uniform as compared to the dielectric constant variations. However, for some other places of India such as Umrangsho and Kalimpong, the measured soil moisture values and satellite derived soil moisture values are very close as seen from Table 3. It is seen that the same procedure followed in all the measurements led to significantly different results as seen in Table 2 and Table 3. Soil moisture variations are also analyzed for the same location in Azara and dielectric constant measurement is done, as shown in Table 4. The AMSR 2 soil moisture data for the area on the same dates are also shown in the table. In this table also it is seen that the AMSR 2 data show irregular variations in the soil moisture percentage value.

5. CONCLUSION

From the experiments it is observed that AMSR 2 derived soil moisture data is not useful for places like Azara, where there is a diversity of the land cover types including large open water bodies. From the experiments done it is understood that the dielectric constant of soil varies with the change in moisture content. However, the satellite measured soil moisture is not showing correct values for Azara area and the data is also not showing any uniformity of variations with the dielectric constant values. Hence, it is concluded that the AMSR 2 soil moisture data need to be verified, especially for the areas having large open water bodies, apart from other land cover types.

Table 2: Comparison of soil moisture and dielectric constant values with AMSR 2 soil moisture data

Places	Date	Latitude	Longitude	Measured volumetric soil moisture	Measured dielectric constant values	AMSR 2 derived soil moisture value
Azara	28.8.14	26.13	91.62	19.07%	0.22	596 %
Azara	31.1.15	26.12	91.62	19.92 %	0.23	108 %
Dharapur	31.1.15	26.13	91.63	10.66 %	0.12	71 %
Kahikuchi	31.1.15	26.10	91.61	13.68 %	0.16	83 %
Lankeshwar	31.1.15	26.14	91.65	19.99 %	0.24	71 %
VIP	31.1.15	26.10	91.59	11.99 %	0.14	83 %
Lankeshwar	15.2.15	26.14	91.65	6 %	0.07	84 %
Dharapur	15.2.15	26.13	91.63	6 %	0.06	84 %
Kahikuchi	15.2.15	26.10	91.61	15.54%	0.18	109 %
Majir Gaon	15.2.15	26.14	91.58	11.99 %	0.14	90 %
Azara	15.2.15	26.12	91.62	19.8 %	0.23	83 %
Rani	15.2.15	26.044	91.58	35.2 %	0.41	109 %
VIP	15.2.15	26.099	91.59	7.99 %	0.09	109 %
Azara	1.3.15	26.12	91.62	15.38%	0.18	118%
Dharapur	1.3.15	26.13	91.63	17.49%	0.2	127%
Majir gaon	1.3.15	26.14	91.58	17.19%	0.26	127%
Kahikuchi	1.3.15	26.10	91.61	16.05%	0.19	127%
VIP	1.3.15	26.099	91.59	17.56%	0.21	127%

Table 3: Comparison of measured volumetric soil moisture values with and AMSR 2 soil data for two other place

Places	Date	Latitude	Longitude	Measured volumetric soil moisture	AMSR 2 derived soil moisture value
Umrangsho	23.9.14	25.51	92.73	18.86%	16%
Kalimpong	6.10.14	27.057	88.44	35.36%	35%

Table 4: Comparison of measured and satellite derived soil moisture values for Azara on different dates

Sl. No.	Date	Measured volumetric soil moisture	AMSR 2 soil moisture data	Dielectric constant
1	27.03.15	10.955%	208%	0.2
2	07.04.15	28.53%	191%	2.55
3	21.04.15	53.54%	369%	7
4	26.04.15	41.328%	100%	5.29

6. ACKNOWLEDGEMENT

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