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# Seasonal and Diurnal Variability of Albedo and Soil Moisture over Ranchi

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*Keywords: surface albedo, solar elevation angle, soil moisture.*

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# Seasonal and Diurnal Variability of Albedo and Soil Moisture over Ranchi

Roshan Kumar [α] & Smita Dey [σ]

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## I. Introduction

Over recent years an increase amount of attention has been paid by the atmospheric climate research community to the role of land-atmospheric interactions in influencing, and being influenced by, the atmospheric structure on large scale. On these issues there are a number of national and international programs devoted. One topic which has been incorporated into these activities is the desire to come to a more comprehensive understanding of the role of surface albedo ,soil moisture ,soil thermal parameters, and there relationship in climate. It is an aspect of this general question to which this paper has been directed for Ranchi, Jharkhand, which lies at the extreme eastern end along the monsoon trough. The influence of anomalous soil moisture conditions on the atmosphere has been the subject of research for some time. Namias (1958, 1963) was among the first to address the issue, noting that the seasonal anomalies of soil wetness could have impact on seasonal cycle of the atmosphere. Recently, a number of modeling studies have explicitly examined the influence of anomalies of soil moisture on the atmosphere. Shukla and Mintz(1982) examined the impact on the atmosphere of prescribed constant anomalies of soil wetness. They demonstrated that negative anomalies of soil moisture decreases evaporation rates and increase the surface temperature. In order to regional climatic variation, soil moisture plays an very important role (Elfatih 1998; Douville and Chauvin 2000; Timbal et al 2002; Koster et al 2004; Lakshmi et al 2004; Shi 2009). The soil moisture can greatly affect albedo and evaporation phenomenon. Rao et al.,[2008] found new algorithm, which gives a realistic estimation of soil temperature,which is helpful as the tools for interpretation of the role of heterogeneity in observed diurnal temperature variation. Soil moisture formulate the partition the available energy near land surface into sensible and latent heat exchanges with atmosphere(Wei,1995). low pass-filter soil moisture has long memory (Pielke et al 1999; Wu et al 2002),which result in persistence of climatic anomalies. surface albedo is the fraction of incoming solar radiation reflected back to the atmosphere and space. It's a basic property of land surface and is a required component of climate and weather forecasting model [e.g,Knorr et al.,2001; Viterbo and Betts, 1999 ]. By influencing the absorption of solar energy, albedo helps to determine the soil heat fluxes, latent, sensible and consequently thermal and moisture stratification of the atmospheric boundary layer. So it is imperative that the observed spatial and temporal variability in surface albedo be adequately represented in land-atmosphere models. Climate models commonly specify separate albedos for soil. Earlier research, conducted over a limited geographic area, suggested that observed spatial variability in surface albedo can be related to soil types [Tsvetsinskaya et al., 2002a; Zhou et al., 2003a]. The climate response to change in surface albedo has also been a topic of considerable study (e.g., Charney et al. 1977; Dickinson and Henderson-Sellers 1988; Xue and Shukla 1993), McCumber and pielke(1981) performed sesitivity tests(24-h simulations) in which soil albedo was free to vary as a function of surface moisture according to Idso's formation.The numerical experiments of Clark and Arritt [1995], who found that the albedo effect is lower the effect of soil moisture availibility for the simulation of an atmospheric convection event. Idso et al. [1975] showed in a pioneering field that bare soil is a linear function of the water content in top layer (0.2-cm to 10-cm). Such a linear relationship has been implemented in land surface model (LSMs) [ Pitman et al., 1991; Arc and Hantel, 1998; Nai et al., 2001; Lawrence and Slingo, 2004; Matsui et al., 2009]. But Idso's work has been challenged by more recent

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studied which indicated that, for many soil types, a non-linear exponential relationship is more appropriate to depict the dependence of bare soil albedo on water content [ Duke and Guerif, 1998; Liu et al., 2002; Lobell and Asner ,2002;wang et al.,2005; Gascoin et al., 2009a]. Guan et al (2009) studied the seasonal variability in land surface albedo and soil thermal conductivity, diffusivity, soil heat capacity and their relationship with soil moisture. The result shows a typical exponential relationship as surface albedo decreases with increase of soil moisture. In dry season the thermal diffusivity is increases as the power function of soil moisture.Charney (1975) discussed the effect of surface albedo's variation on the Sahara desert by the use of general circulation model. According to him change of albedo is an important factor for the formation of deserts and may be pertinent to drought conditions in Sahel. He postulates biogeophhysical feedback mechanism in which lack of rainfall leading to a lack of vegetation results in a higher surface albedo. The atmosphere due to high surface albedo and positive feedback between land result in the negative effect of moisture flux convergence and rainfall, and desertification(generally in droughts). From Charney's hypothesis for the maintenance of desert,the use of more realistic albedos tends to regions of lower albedo(Cunnington and Rowntree 1986).

In the present study, A time series of continuous measurements (from Jan 2009 to Dec 2009) from the data on soil moisture, soil temperature at different depths, soil heat fluxes (at 2.56 & 5cm), air temperatures, wind speed & directions (at 1,2,4,8,16 & 32 m heights), albedo at 32 m height and all four components of radiations at 2 m height were taken from the Land Surface Atmosphere and Micrometeorological Observational System (LATAMOS) established in the Institute at Ranchi (India), which lies along extreme eastern end of monsoon trough line is used to investigate the diurnal, monthly and seasonal variations of changes in surface albedo , solar elevation angle and soil thermal parameters, and their relationship with soil moisture.

## II. Study Site and Available Data

Our study site is Ranchi, Jharkhand (85° 30'E, 23° 45'N,elev 652.272 AMSL), which falls under Chhotanagpur plateau region of eastern (figure1a and 1b). This plateau is not only important for the evolution of monsoon trough extending from Jharkhand region along its extreme eastern end to the Rajasthan region at the western end, but also vulnerable for the thunderstorm activity during pre-monsoon summer season associated with lightning and also influence rainfall associated with lightning and cyclone during the SW monsoon period.

In Ranchi annual soil temperature varies from minimum 1.0°C at surface in winter to maximum 45.0°C during summer season and soil colour varies from grey in summer to radish grey during winter with small green grass cover during monsoon period.

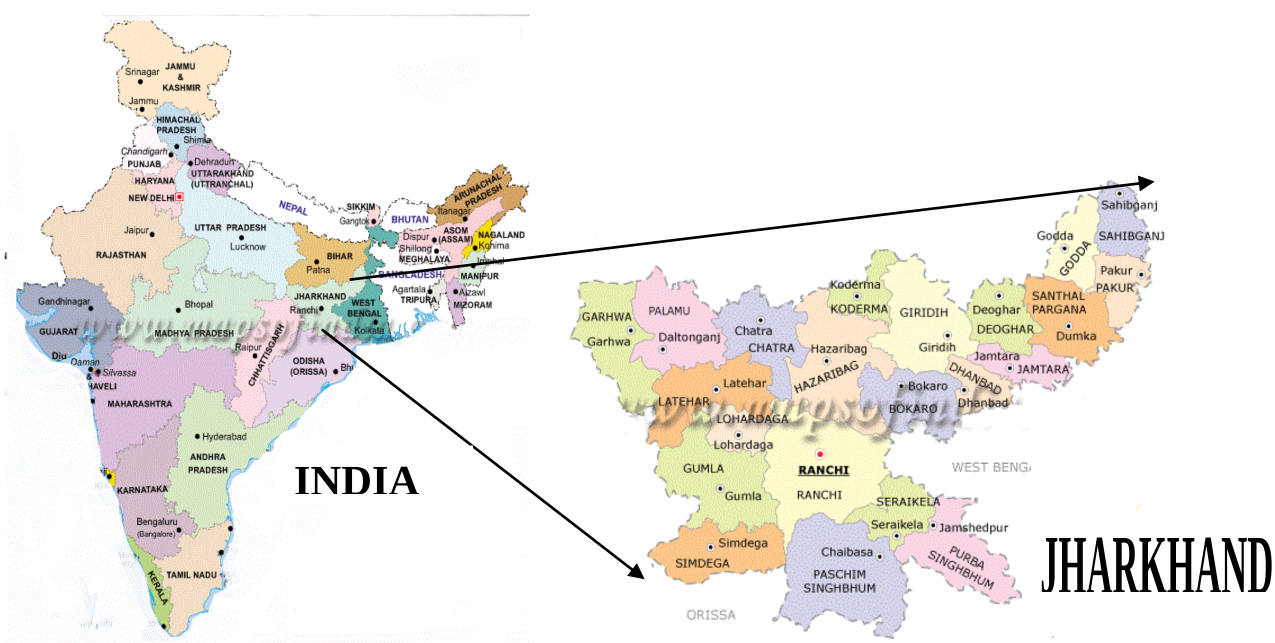


*Figure 1 :* An overall view of location of the experimental site (85° 30'E, 23° 45'N, elev 652.272m)

*a) Relationship of soil moisture and albedo*

Land surface albedo (α) can be calculated from the measurements of the shortwave radiation components as follows:

$$\alpha = \frac{\Sigma(S_{out})}{\Sigma(S_{in})} \qquad (1)$$

Where the summation of incoming radiation or outgoing radiation was carried out over a specified time period. The parameters which influence surface albedo are based on the soil moisture, soil colour, solar elevation angle, roughness and so on. Solar altitude angle and soil moisture are the two main factors which influence the albedo (Li, 2009). In order to study the influence of soil moisture on the albedo, it is necessary to first examine the influence of Solar elevation angle on the surface albedo. For this, the surface albedo is calculated with Eq. (1) .The Solar elevation angle can be calculated from the longitude and latitude of the site, Julian day, and mean measurement time. In addition sharp peaks in surface albedo are removed. We have taken the soil moisture data corresponding to the albedo data. For a 12 hour observation figure(2), shows that during summer Solar elevation angle is maximum and minimum for winter.

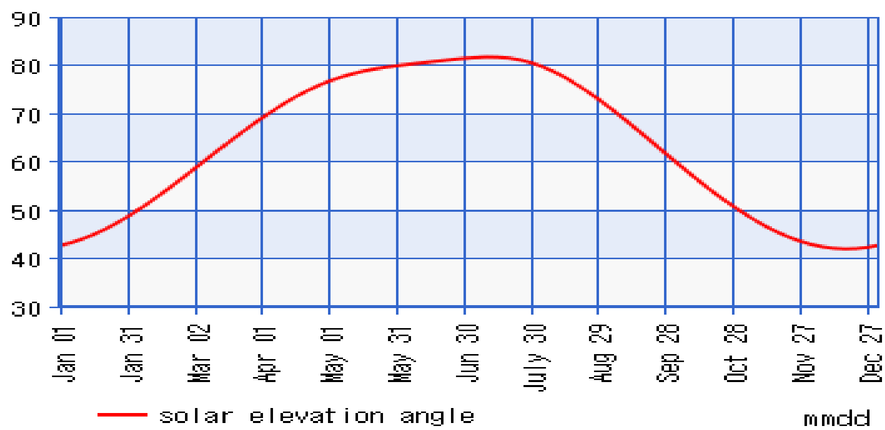


*Figure 2 :* Variation solar elevation angle with month's (for 12 hour observation)

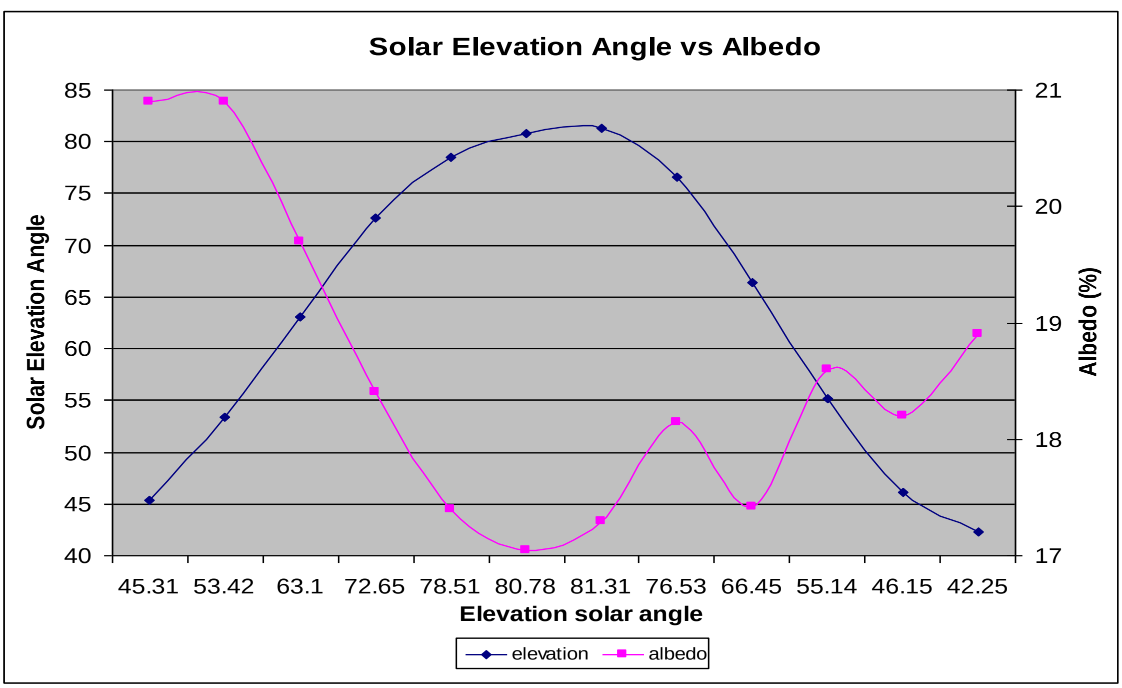


*Figure 3 :* Influence of Solar elevation angle (12 hour observation) on surface albedo.

From figure (3) We can see that in solar elevation influence of Solar elevation angle on surface albedo is small enough to be omitted when the solar elevation varies from 400 to 810. When solar elevation angle greater than 450, then surface albedo tends to be a constant.. In this experiment daily surface albedo calculated from solar elevation angle greater than 450 can be used to study its variation with soil moisture. The soil moisture data can also be used to calculated the surface albedo. Daily average surface albedo (α) is given by the Eq (2)

$$\alpha = 0.2106 + 0.1762\, e^{\left(-\frac{ASM_d}{9.321}\right)} \qquad (2)$$

Where is the daily average soil moisture at 15 cm. from Eq(2)decreases with increase of

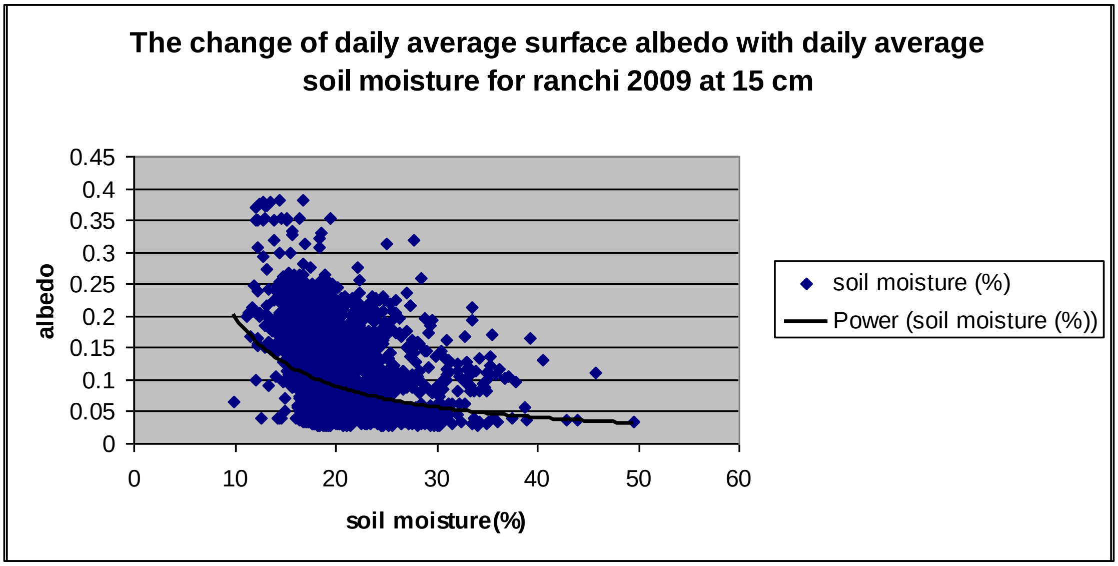


*Figure 4 :* The change of daily average surface albedo with daily average soil moisture at 15 cm depths

The value is 0.3213 for the regression. Similar exponential relation have also been derived by Guan et al.,(2009), Liu et al., (2008), Wang et al., (2005), Liu et al., (2002), Lobell and Asner (2002), Hoffer and Johannsen (1969). Figure 8 shows the time series of the daily average albedo and daily average soil moisture content at depth of 5 cm from january 2009 to December 2009.From figure 5 ,it is clear that surface albedo decreases (increases) with increase (decrease) in soil moisture.

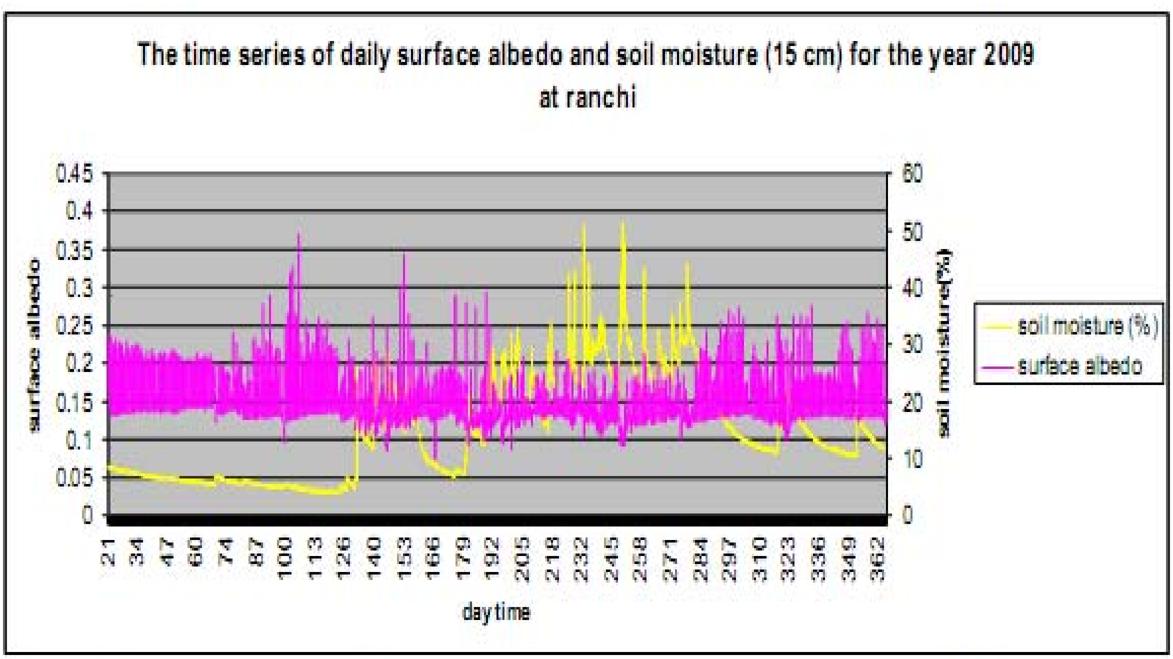


*Figure 5 :* The time series of daily surface albedo and soil moisture for the year 2009

Remote sensing of surface properties and estimation of clear-sky and surface albedo generally assumed that the albedo variation is symmetrical about local noon, which is shown in figure 6. As the typical diurnal variation of the surface albedo on clear-day looks like U-shaped curve, in this study, the seasonal and diurnal cycle of soil moisture is observed at Ranchi, which is shown in figure(7a-d).We can see the variation of soil moisture for the four seasons.

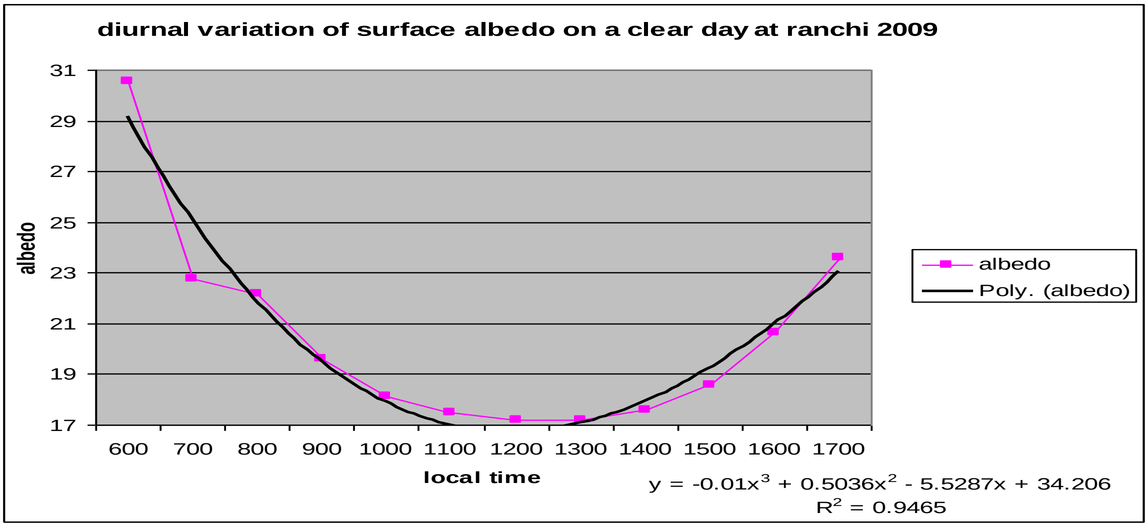


*Figure 6 :* Diurnal variation of surface albedo on a clear day seasonal and diurnal cycle of soil moisture

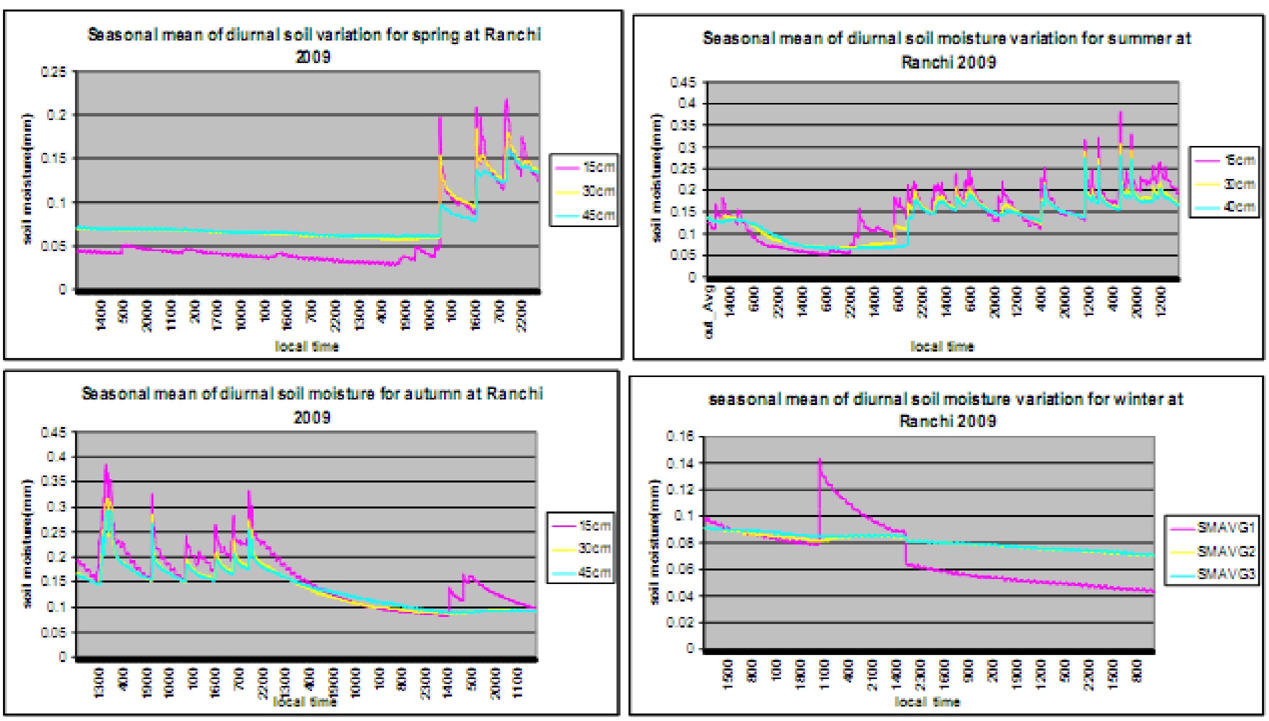


*Figure 7:* Seasonal mean of diurnal soil moisture variation for different seasons

At the depth of 15 cm,30 cm, and 45 cm Soil moisture content value is observed to be more during monsoon period when the surface is completely wet due to SW monsoon rainfall and soil sub-surface is at saturation level. The soil water content in rainy season is predominant as compare to dry season. The soil moisture at the depth of 15 cm in not maximum of all the depths. The similar variation in soil is also observed by Guan et al., (2009).the diurnal variation reaches its minimum around 0800 LST and maximum around 1600 LST. The climatic variations of different months affect the soil moisture content. Figure (8) shows the seasonal variation of soil moisture at the depth of 5 cm, 10 cm, 20 cm, 30 cm and 50 cm for the period from January 2009 to December 2009.

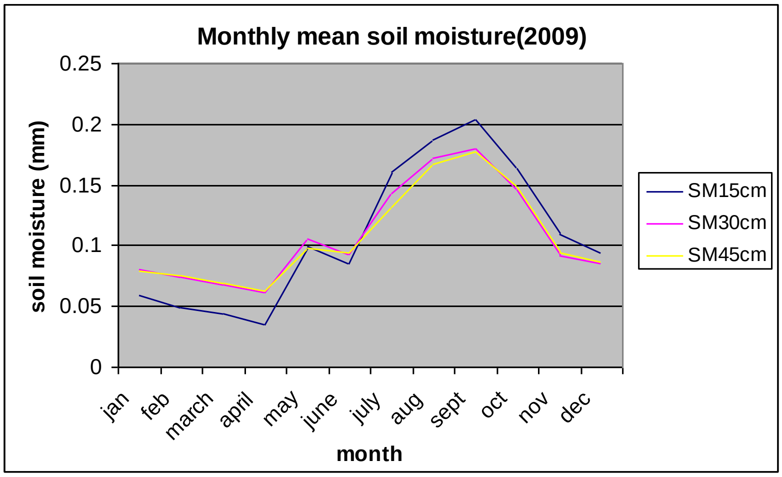


*Figure 8 :* Monthly mean soil moisture

The moisture content is low during the dry season and it increases as the rainy season begins. The monthly average soil moisture is higher for deeper layer than the surface layer. This is may be due to the rapid evaporation of soil moisture from the surface layer.

## III. Conclusions

- The seasonal and diurnal variation of soil moisture is analyzed for the year 2009.
- It is found that the soil moisture is low during the dry season and high during the rainy season.
- The diurnal variation of surface albedo is not symmetrical about mid day.
- During sunny day, the diurnal variation of surface albedo appears as a U-shaped curve.
- The surface albedo decreases with increase of moisture content.
- When the solar elevation angle is greater than 45° then it tends to be a constant.

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