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Studies in albedo measurements at Pune

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सार — पुणे में पड़ती मृदा पर परावर्तित सौर विकिरण माप नियमित रूप से लिए जा रहे हैं। विशिष्ट अवधि से संबंधित एल्बिडो में विभिन्नताओं की चर्चा की गई है। एल्बिडो का मान प्रबल रूप से मृदा की नमी पर निर्भर होता है। यह परिवर्तन लगभग 30 प्रतिशत होता है। एल्बिडो में विसरित विकिरण के कारण होने वाले परिवर्तन और मेघीय स्थितियों के विभिन्न प्रकारों की भी चर्चा की गई है। ऊपर कपासी मेघों की उपस्थिति, एल्बिडो को वृद्धि की ओर प्रवृत्त करती है, जबकि स्तरी कपासी मेघ इसे नीचे की ओर प्रवृत्त करती है। जलभरित सतह निम्नतम एल्बिडो मानों को दर्शाती है।

ABSTRACT. Reflected solar radiation measurements are being made regularly at Pune over bare soil. The variations in albedo for a selected period are discussed. The value of albedo is strongly dependent on the wetness of soil, the change being of the order of 30 per cent. The changes in albedo due to diffuse radiation and for different types of cloudy conditions are also discussed. The presence of cumulus clouds above tend to increase the albedo whereas that of stratocumulus clouds tend to lower it. Waterlogged surfaces show the lowest albedo values.

1. Introduction

Albedo of a surface is the ratio of the solar radiation reflected by the surface to the global solar radiation incident on it. The determination of albedo values is extremely important in study of energy balances of underlying surfaces because this indirectly enables determination of the quantity of heat absorbed by the underlying surface. The study of albedo can be over the entire spectrum 300-3000 nm and in small spectral bands. The spectral albedo is of more interest for bioclimatology, biophysiology, aerosurvey etc. The study of integral albedo over the entire spectrum is principally used in meteorological studies. The present paper discusses only the variations of albedo over the entire spectrum. The albedo is dependent on the characteristics of the underlying surface besides on the angle of incidence of solar radiation.

Reflected solar radiation measurements have been made at Pune using an inverted thermoelectric pyranometer. Global solar radiation is measured using another pyranometer. The values of albedo over the entire spectral range 300-3000 nm have been woked out for 1978 and 1979 and are discussed here. Mani *et al.* (1975, 1978) have discussed the variations in albedo from measurements made with instruments mounted on board aircraft and Mani *et al.* (1977) have also made measurements over different surfaces. These studies, however, were made for a specific purpose and do not cover the effects of wetness of soil and of cloud cover on the values of surface albedo.

2. Measurements

The global and reflected solar radiation measurements are regularly made at the Agricultural College farm by the India Meteorological Department using two independent Kipp thermoelectric pyranometers. The global pyranometer is mounted on the terrace of a single storey building of 3 m in height using a Kipp pyranometer. The inverted pyranometer is mounted on a stand at a height of 1.2 m above the ground. The mounting of the pyranometer is well ventillated and shades the pyranometer from direct irradiation. The soil is generally maintained bare of all vegetations to minimise the number of controlling factors and up to a solid angle of 70° subtended at the sensor. The instruments have a very good exposure on all sides, being located in the farm, except for a small hill in the west. The outputs of the instruments are fed individually to two recorders and the data extracted later. The instruments are calibrated annually with the standards maintained at the National Radiation Centre, Pune.

3. Discussion of results

3.1. *General*

1978 was an year with normal rainfall, while 1979 was an year of large rainfall deficit. Fig. 1 gives the albedo in the form of isopleths for years 1978 and 1979. While June and July 1978 show the low values of the order of 10-12 per cent, the month of August 1978 with scanty rain shows a sudden increase (albedo is 16 per cent) of more than 30 per cent. August 1979, with similar rainfall deficit, also has the same albedo of

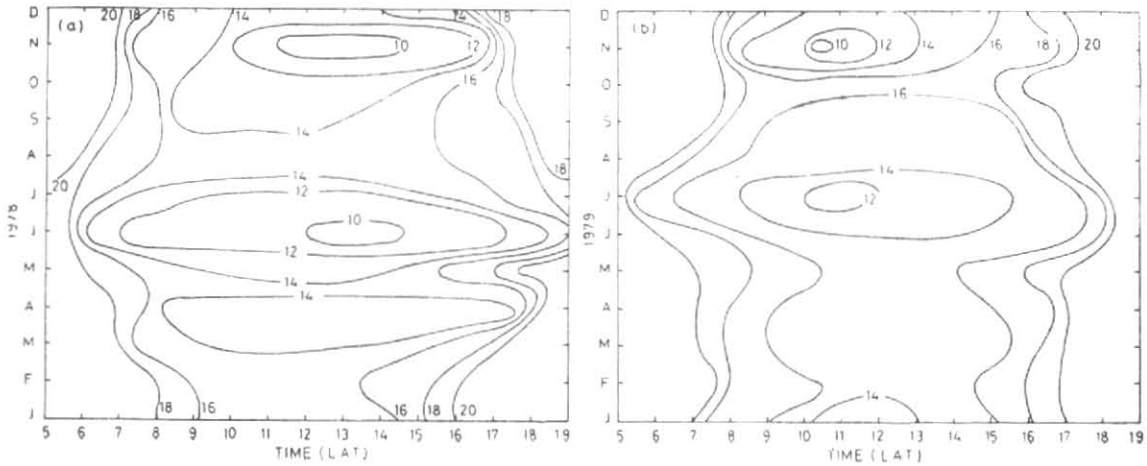

Fig. 1. Isopleths of albedo over bare soil at Pune (%)

16 per cent. The absence of normal rainfall in June 1979 has clearly affected the albedo of the surface, 14 per cent as against 10-11 per cent of June 1978. In addition to lack of moisture in the soil, the looseness of the soil leads to increased reflection of the solar radiation. These changes in albedo are clearly seen in October-November 1979 as compared to the same period in 1978, the albedo value increasing from 13 to 17 per cent and from 9 to 14 per cent in October and November respectively.

3.2. *Effect of moisture*

The surface at Pune below the pyranometer is black cotton clay soil and is generally kept bare, devoid of vegetation. The mean hourly value of albedo for lower angles of incidence is around 13 per cent. Albedo shows a strong diurnal variaton, being 13-15 per cent for higher solar elevations between 08 and 16 hr LAT, and showing a marked increase as solar elevations decrease towards sunrise and sunset, to as high as 60 per cent. As can be expected, the albedo is lower during the monsoon months due to the more incident radiation being more vertical and the increased wetness in the soil. The winter values have opposite characteristics.

3.3. *Effect of clouds on albedo*

An attempt was made to study the effect of clouds on the albedo. For convenience, the data are grouped into seasons based on the angle of incidence of the solar beam, rather than on the meteorological factors. Those cases where only a particular type of cloud was present without the vitiating effects of other types of clouds were isolated and the effects of such conditions on the albedo were studied and are presented. For example, when the data discussed refer to *As* clouds, no other types of clouds were present. The angle of incidence of solar irradiance was kept in view while studying the effect of clouds.

3.4. *Cloudless skies*

3.4.1. *March-May*

This period is warmest at Pune and also the solar radiation is incident more vertically. The albedo is 13 per cent around noon time compared to the mean of the whole period, 14 per cent.

3.4.2. *November-February*

The solar radiation is incident at more slanting angles resulting in increased reflection. Since Pune gets more cloudless skies in December-February than in November (which gets occasional rains as well), the values of albedo are of the order of 15 per cent compared to the mean seasonal value of 13 per cent.

3.5. *Cloudy skies*

The changes in albedo due to the presence of cirrus and medium clouds are not clearly discernible. However, there are some changes in albedo due to low clouds. The clouding over Pune during the winter months is insignificant and the low clouds that are formed are not very thick. The sky covered is also small and consequently the changes in the value of albedo are not clearly discernible (Fig. 2). The pre-monsoon months, March to May show a slight increase in the values of albedo, an increase of the order of 8-9 per cent due to *Sc* and *Cu* clouds (Fig. 3). As stated earlier, medium and high clouds do not seem to have a significant effect on the aldedo of the soil.

The monsoon months, however, show larger variations due to *Sc* and *Cu*, the increase being of the order of 4-15 per cent almost throughout the day (Fig. 4), presumably due to these clouds being thicker. The presence of *St* along with *As* above has an opposite effect, the albedo being lower by about 10 per cent. The presence of *St* in combination with *Sc* balances the two effects and albedo then corresponds to the mean value of the month. The combination of all types of clouds with *Sc* and *Cu*

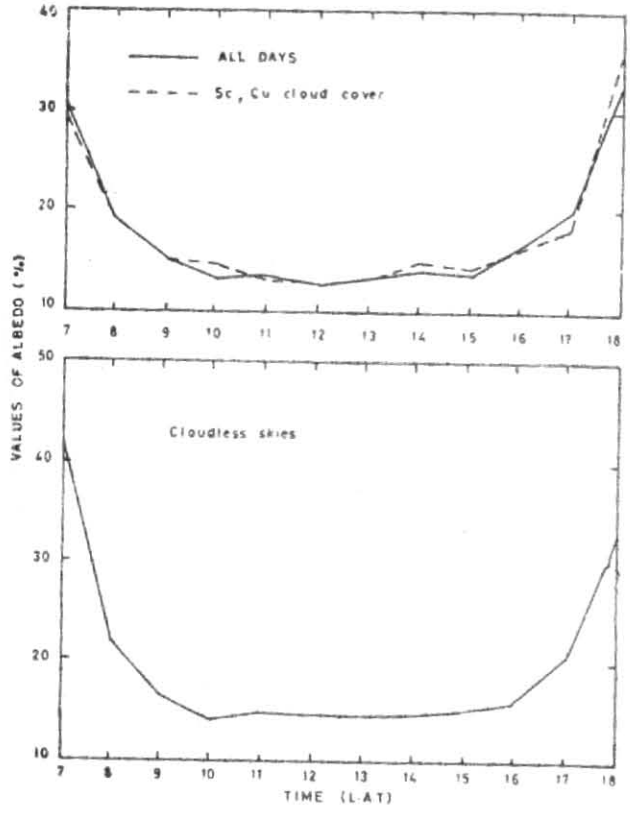

Fig. 2. Variation of albedo during November-February

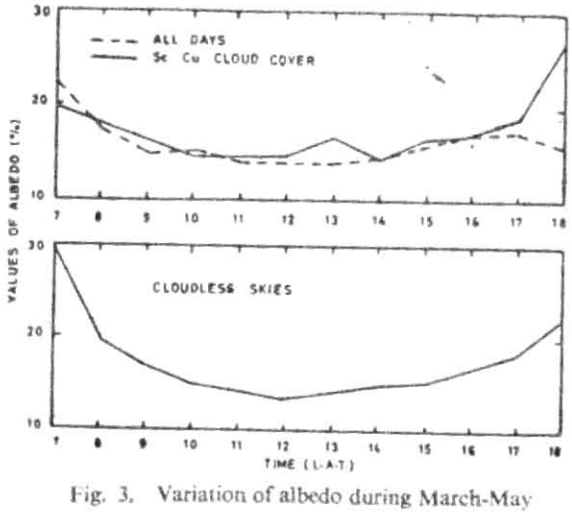

Fig. 3. Variation of albedo during March-May

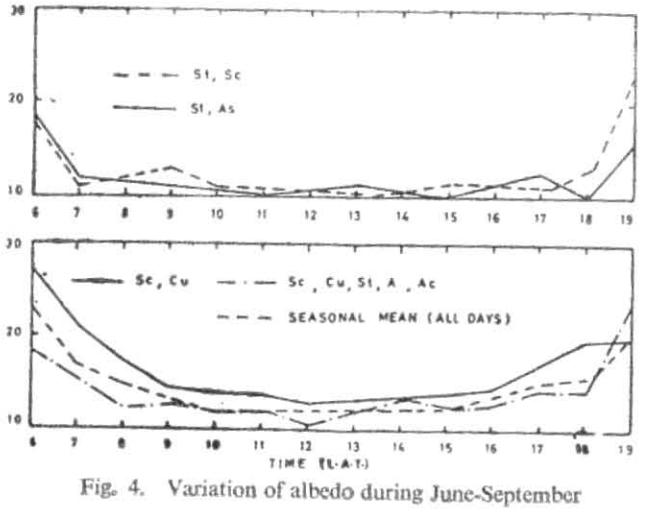

Fig. 4. Variation of albedo during June-September

again increases the albedo though only slightly (6 - 8 per cent) above the seasonal mean.

3.6. *Overcast skies*

Albedo with overcast skies represents only the effect of diffuse solar radiation, though the diffuse radiation is highly variable, depending on the type and the thickness of the various cloud layers. Fig. 5 gives the albedo for June, July and August as means for whole months and means for days with overcast skies. Albedo due to diffuse radiation alone is quite low decreasing by about 50 per cent in June and 10 per cent in July and August, as compared to the mean values of the whole months. The noon values also decreased by 51 per cent during June and 13 per cent in July and August. The large differences in June are to be attributed to heavier rainfall and consequent wetness of the soil. All days in 1978 and 1979 with overcast skies in June recorded rain. The diurnal variation due to diffuse radiation alone is, however,

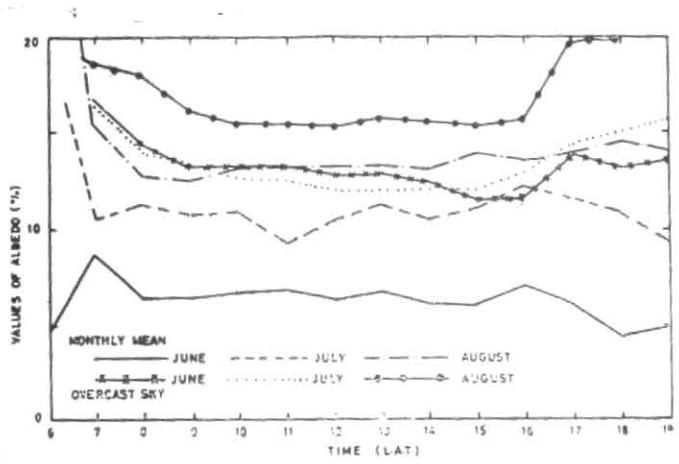

Fig. 5. Diurnal variations of albedo — Means for the month and for overcast sky conditions

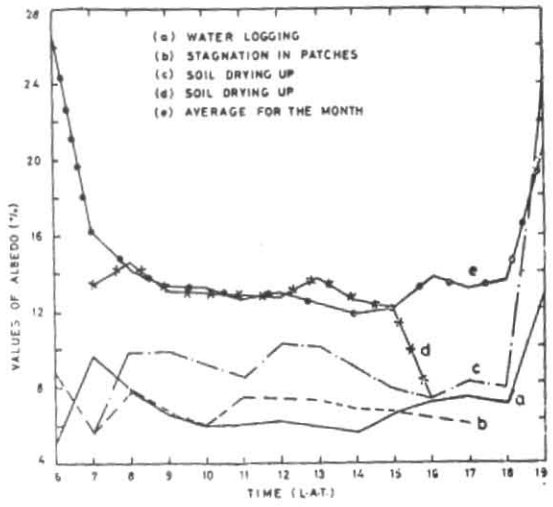

Fig. 6. Variation of albedo due to changes in wetness of soil

within 22-28 per cent on completely and continuously overcast days (Kondratyev 1969).

3.7. The effect of individual cloud mass was studied. The variations in albedo were very much scattered, obviously due to the different controlling factors, chief among them being (*i*) the proximity of the cloud to the sun, (*ii*) the angle of incidence of radiation on the cloud mass, (*iii*) the vertical extent of the cloud mass and (*iv*) the structure of the cloud itself, ice crystals or warm or cold water droplets. The variations have been found to be extremely high when the sun was about to be clouded or just coming out of a cloud patch. For shallow low clouds, the variation was within 10-20 per cent, while for a towering *Cu* cloud which was about to cover the sun, the aldedo variation was larger.

Attempts were also made to study the changes that take place when cloud masses are in very close proximity to the sun. The strong reflections from the sides of the clouds increase the global and reflected radiation and hence affect the albedo. The changes depend upon the type and thickness of the clouds. In specific cases, when only fair weather cumulus with stratocumulus clouds was near the sun, the increase in radiation though was of the order of 8 per cent due to the nearness of cloud, did not register any change in the albedo values. When the *Cu* clouds were larger, the increase in global radiation was of the order of 9-11 per cent and the albedo also increased but only by 2-4 per cent. Further intensive studies are needed to identify the degree of proximity and the estimate of thickness of clouds and also the angle of incidence of radiation and then decide on the effect of increase in albedo due to proximity to the sun of various clouds.

3.8. *Effect of moist soil*

Fig. 6 gives the variations in albedo under different wetness conditions of the soil, curve (a) shows the albedo values in June when there was water logging underneath the instrument. The values were centred around 6-7 per cent for the whole day. Curve (b) shows the water stagnating in patches. Curves (c) and (d) indicate the rapid changes as the soil started drying up. Curve (e) shows the mean values for the month as a whole. The value of albedo is between 4 and 6 per cent for large water surfaces and the values shown by (a) are more than this as the effect of the underlying soil on the albedo of water is considerable and has to be taken into account.

4. Conclusion

The albedo of any given surface is normally a function of both wavelength and zenith angle and these functions are in turn dependent on surface character. Soil moisture and clouds thus play an important role in the albedo of the surface. While *Sc* clouds generally lower the albedo, *Cu* clouds increase it slightly. Albedo on days with both *Sc* and *Cu* is slightly more than those with *Sc* clouds alone. The normal albedo of 10 to 14 per cent of bare black soil drops to 6 to 7 per cent when water logging takes place, with higher value for wet soil. The diurnal variation due to changes when only diffuse radiation is present is only 20-28 per cent.

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