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SEASONAL CLOUD COVER VARIATION OF LANDSAT DATA IN FLORIDA

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ABSTRACT

Cloud cover condition is an important factor affecting Landsat data utilization. About 1300 Landsat computer-compatible tapes, available in the University of Florida, are used to study the seasonal cloud cover variation. The rainfall distributed in the Summer is about 40% of the annual rainfall, and about 70% in the wet season (May through October). If the Landsat data is expected to have a cloud cover condition less than 20% then the chance of getting data in the Summer is about 25% less than in the Spring, and in the wet season is about 15% less than in the dry season. Thus, a research program which intends to cooperate with the Landsat data should be conducted during the period which has less rainfall and a higher percentage of duration of sunshine.

I. INTRODUCTION

Landsats 1, 2, 3, and 4 were launched by the National Aeronautics and Space Administration (NASA) on July 23, 1972; January 22, 1975; March 5, 1978; and July 16, 1982, respectively; to gather about the earth's surface and telemeter those data to ground receiving stations. The operation of Landsat 1 was ended on January 6, 1978. In terms of orbital passes, Landsat 3 follows Landsat 2 by 9 days in an 18-day cycle, and Landsat 4 has a 16-day cycle. The local passing time is around 9:30 a.m. The Landsat data have been used to study the problems associated with the agricultural production, hydrology, land use, environmental conservation and management, etc. Based on experience, an important fact has been realized by most users, i.e. a successful utilization of Landsat system depends heavily not only on the Landsat sensed data itself but also on the ground-truth information. Unfortunately, due to some inherent limitations involved in the Landsat system, the utilization of Landsat data in many civil applications is not fully realized. For instance, the Landsat remote sensing system currently in use is not able to penetrate through cloud cover except for the infrared band which can penetrate light cloud cover. Due to this problem of cloud cover, the user wonders whether he should risk not only paying $650 per tape (the price listed at the time of this writing, 1984) for the purchase of a computer-compatible tape (CCT), but also whether an expensive experiment to gather the ground-truth information should be conducted. In other words, if the cloud cover can be predicted to some extent, the utilization of Landsat remote sensing system can be improved considerably.

The question remains as to how to predict the cloud cover during the periodically passing time of Landsat. Fortunately, a fact has been realized that both rainfall and incoming solar radiation are somewhat related to the cloud cover condition. In other words, the seasonal variation of solar radiation and rainfall may possibly be used to study the seasonal cloud cover variation of Landsat data. Therefore, the objectives of this study were: (1) to analyze the seasonal variation of rainfall and solar radiation; (2) to study the cloud cover condition of the historical Landsat data; and (3) to investigate whether the cloud cover of Landsat data is also varied with the seasonal patterns as shown in rainfall and solar radiation.

II. MATERIAL AND METHODS

A. LANDSAT TAPE AVAILABILITY

The General Electric Image 100 located at the NASA, Kennedy Space Center, was relocated to the Institute of Food and Agricultural Science (IFAS) Remote Sensing and Image Analysis Laboratory, University of Florida, in January, 1982. This Image 100 System is one of the most advanced photo-analyzers. About 1300 Landsat computer-compatible tapes came with the Image 100 facility. The dates of tapes varied from August 1, 1972 to January 2, 1978. Eleven categories which were used to classify the cloud cover conditions are 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 99%. Each tape covered an area of 100 nautical miles by 25 nautical miles, and 4 tapes comprised a set. In other

words, each set of tapes covered a 100 x 100 nautical mile area. The 1300 tapes covered almost the entire state of Florida except the northwest region.

B. RAINFALL DATA

The rainfall pattern in Florida consists of two types of yearly cycle. The first is the cycle of Winter, Spring, Summer, and Autumn. The other is the dry (November through April) and wet (May through October) seasonal cycle. The rainfall data were reported by the National Oceanic and Atmospheric Administration (NOAA, 1972-78). Since the northwest region of the state of Florida was not covered by the current IFAS Landsat tape availability, the rainfall data in the nortwest region was not included in this study. In order to observe whether the rainfall pattern in the study period (8/72-1/78) was any different from the normal conditions, the normal rainfall pattern was also analyzed in this study.

C. SOLAR RADIATION

Since the percent of cloud cover condition is not available in most weather stations, the percentage of the duration of sunshine is used as an alternative to indicate the percent of cloud cover. The percentage of possible sunshine can be estimated from the solar radiation measurement in accordance with the method given by Penman (1948), i.e.

$$R_s = (0.18 + 0.55S)R_a \qquad [1]$$

or the Equation [1] can be rewritten as

$$S = 1.818\ (R_s/R_a) - 0.327 \qquad [2]$$

where R_s = measured solar radiation;

R_a = extraterrestrial radiation; and

S = estimated ratio of actual duration of bright sunshine to maximum possible duration of bright sunshine.

The solar radiation data, as measured from the weather station located at the University of Florida, Agricultural Research and Education Center (AREC) at Belle Glade, were used to exemplify the percentage of the duration of sunshine estimation. Since the solar radiation data in the AREC were begun to record from January, 1971, the long term average (i.e. considered as normal condition) was computed from the 12 years data (1971-82). In the meantime, the solar radiations during the study period (8/72-1/78) were also computed. The data of extraterrestrial radiation, R_a, as defined in Equation [2], at 26°40' latitude (same as AREC Weather Station) were computed from the report given by Van Bavel (1956).

In order to investigate the seasonally measured solar radiation varied with the years, a percentage of solar radiation deviation is introduced as follows:

$$\%\ \text{solar radiation deviation} = 100\ \frac{s}{\bar{x}} \qquad [3]$$

where s = standard deivation of the measured solar radiation; and

$\bar{x}$ = mean value of the measured solar radiation.

The lower percentage of solar radiation deviation implies that the data constitute less variation between the years.

D. COMPARISON OF TWO POPULATION PROPORTIONS

As mentioned earlier, the rainfall pattern in Florida consists of two types of yearly cycles. It is important to know whether the cloud cover conditions of Landsat data are also following the pattern of two types of yearly cycles. If the answer is positive, the climatic conditions could be used as a potential tool to predict the possible cloud cover condition of Landsat data. To answer this question, the following test is introduced.

To compare the percent of cloud cover of the Landsat data difference between seasons, let P_1 and P_2 be the sample proportions obtained in large samples of size N_1 and N_2 drawn from respective seasons having proporitions p_1 and p_2. Consider the null hypothesis that there is no difference between the seasons, i.e. $p_1 = p_2$, and thus the samples are really drawn from the same population. The sampling distribution of differences in proportions is approximately normally distributed with mean and standard deviation given by:

$$\mu_{p_1-p_2} = 0 \qquad [4]$$

$$\sigma_{p_1-p_2} = \sqrt{pq\ (1/N_1 + 1/N_2)} \qquad [5]$$

where $p = (N_1P_1 + N_2P_2)/(N_1 + N_2)$ [6]

$q = 1-p$

the p is used as an estimate of the population proportion. By using the testing statistic, Z is

$$Z = \frac{P_1-P_2}{\sigma_{p_1-p_2}} \qquad [8]$$

This Z-test can be used to observe the seasonal differences of the cloud cover conditions of the Landsat data at an appropriate level of significance and thereby test the null hypothesis.

III. RESULTS AND DISCUSSION

A. SEASONAL RAINFALL VARIATION

The rainfall distribution of Winter, Spring, Summer, Autumn, dry and wet seasons are shown in Table 1. The total rainfall during the study period was about 10% less than the normal condition. The most deviation came in Autumn which was about 25% less than the normal condition. The rainfall in Summer was about 80 to 200% higher than that in the other seasons. Summer had the most rainfall and Winter had the least rainfall. The rainfall in Autumn ranked as second, and in Spring as third. About 70% of rainfall was in the wet season as compared to the dry season.

B. SEASONAL SOLAR RADIATION VARIATION

The extraterrestrial radiation as reported by Van Bavel (1956) at 26°40' latitude for January through December are 537, 718, 766, 891, 923, 971, 923, 875, 820, 681, 593, and 507 $cal/cm^2/day$. The average daily extraterrestrial and measured solar radiations of Winter, Spring, Summer, Autumn, dry and wet seasons are also listed in Table 1. The measured solar radiation during the study period is close to the normal condition except that the Summer season is about 4% lower than the normal condition.

The seasonal percentage of solar radiation deviation during the study period and during normal conditions are computed based on Equation [3], and the results are listed in Table 1. The variations of solar radiation among the years in the Summer and Autumn are much greater than that in other seasons, and in the wet season is also higher than that in the dry season. The percentages of the duration of sunshine for different seasons are computed based on the method given in Equation [2] and the results are listed in Table 1. The predicted percentage of sunshine for the study period is similar to the normal condition except that the Summer has about 6% less than the normal condition. The Spring has about 70% of the duration of sunshine and about 15% more than other seasons. The dry season also has more duration of sunshine condition. In other words, the ground-truth conducted at either Spring or dry season has a better chance to meet a less cloud cover condition of Landsat data.

C. SEASONAL CLOUD COVER VARIATION OF LANDSAT DATA

The percentage of cloud cover of Landsat data as related to the chance of occurrence for dry and wet seasons, and annual condition are plotted on Figure 1, and for Winter, Spring, Summer, and Autumn are plotted on Figure 2. In some practical applications, the Landsat data within 20 or 30% of cloud cover conditions are considered to be quite useful data. As Figure 1 shows, about 50% of the Landsat data in Florida have the cloud cover conditions within (i.e. less than and equal to) 30%. Some cloud cover variations between the seasons are clearly shown in Figures 1 and 2. For instance, the Landsat data available within 30% cloud cover condition in dry season are about 10% more than that in wet season, and in the Spring are about 15% more than that in Summer. If the Landsat data is expected to have a cloud cover condition less than 20%, then the chance of getting the data in the dry season is about 15% more than that in the wet season, and in the Spring is about 25% more than that in the Summer.

D. COMPARISON OF THE SEASONAL CLOUD COVER DIFFERENCES OF LANDSAT DATA

The testing statistic, Z, as defined in Equation [8] is used to examine the cloud cover differences between seasons. The results are shown in Table 2. Several observations are made from Table 2.

There is no cloud cover differences between the Winter and Spring, Winter and Autumn, Spring and Autumn, and between Summer and Autumn except that there are some differences between the Winter and Spring when the cloud cover condition is greater than 80%.

Within 30% cloud cover condition, the availability of Landsat data in the Winter and Spring are significantly more than that in the Summer. Furthermore, within 40 to 80% cloud cover condition, the availability of the data in the Spring also are significantly more than that in the Summer. These results are similar to the climatic condition as shown in Table 1, where there is a higher rainfall and lower percentage of the duration of the sunshine in the summer than that in the other seasons.

Within 40% cloud cover condition, the availability of Landsat data in dry season is significantly more than that in the wet seasons. This result also is similar to the climatic condition as shown in Table 1, where there is a higher rainfall and lower percentage of the duration of sunshine in the wet season than that in the dry season.

In sum, although the Landsat data are gathered periodically, the cloud cover condition of the data varied with seasons are quite similar to the seasonal variation of climatic condition. Especially, both rainfall and percentage of the duration of the sunshine are important parameters related to the seasonal cloud cover variation of the Landsat data.

The conclusions drawn in this study can be implemented to some practical applications. First, if the objective of study does not concentrate on the seasonal variation, the Landsat data should be purchased in the dry season instead of in the wet seasons. The Summer season is the worst period for purchasing the Landsat data. Second, if the objective of study has not only interest in the seasonal variation but also requires a significant effort for gathering the ground-truth information, then the ground-truth experiment should be conducted during the dry season if possible. In other words, the heavy rainfall or relatively low

percentage of the duration of sunshine period is not an optimum season for conducting a research program which is related to use of the Landsat data.

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BIOGRAPHICAL DATA

S. F. "Tony" Shih is Professor of hydrology, Agricultural Engineering Department, University of Florida. He received a BS in Agricultural Engineering from the National Taiwan University and an MS and PhD in Biological and Agricultural Engineering from North Carolina State University. Dr. Shih participated in a variety of hydrological investigations at North Carolina State University and South Florida Water Management District before joining the University of Florida in 1976. His current interests include water flow under saturated and unsaturated soil conditions, management of watersheds and irrigation and drainage systems, surface runoff modeling and applications of remote sensing technique to study the water resources system.

Table 1. Seasonal solar radiation, predicted % sunshine, and rainfall during the study period (Aug. 1972-Jan. 1978) and normal conditions.

Season	Solar radiation			% Solar radiation deviation		Predicted % sunshine		Rainfall	
	Extra-terrestrial	Study period	Normal	Study period	Normal	Study period	Normal	Study period	Normal
	-------cal/cm^2/day---------			------%-------		-------%-------		-------mm--------	
Winter	587	296	301	4.4	5.8	58.97	60.52	180	175
Spring	860	480	482	2.8	4.4	68.77	69.19	228	247
Summer	923	451	470	7.9	8.0	56.13	59.87	526	538
Autumn	698	359	359	6.4	6.7	60.80	60.80	285	382
Dry Season	669	356	358	4.0	5.2	64.04	64.59	360	376
Wet Season	866	437	448	6.8	7.2	59.04	61.38	857	967
Annual	759	398	403	3.0	5.0	62.63	63.83	1217	1343

Table 2. Comparison of the cloud cover difference between the seasons by using the testing statistic (Z) value.

Comparison	Z - value								
	Less than and equal to % of cloud cover								
	10	20	30	40	50	60	70	80	90
Winter-Spring	0.657	0.415	1.176	0.587	1.058	1.250	1.191	1.869*	1.689*
Winter-Summer	2.294*	2.706**	1.880*	1.362	0.353	0.606	0.375	0.264	0.208
Winter-Autumn	1.232	1.151	0.163	0.702	0.054	0.347	0.098	0.292	0.140
Spring-Summer	1.792*	3.378**	1.753*	2.079*	1.691*	1.942*	1.652*	2.187*	1.507
Spring-Autumn	0.778	1.568	0.464	1.224	0.949	0.677	1.125	1.317	1.555
Summer-Autumn	0.656	1.153	0.921	0.436	0.245	0.850	0.217	0.519	0.029
Dry-Wet Seasons	2.339*	2.720**	1.667*	1.816*	1.436	1.038	1.405	0.586	0.439

*Significant at 0.05% level by one-tailed test.
**Highly significant at 0.01% level by one-tailed test.

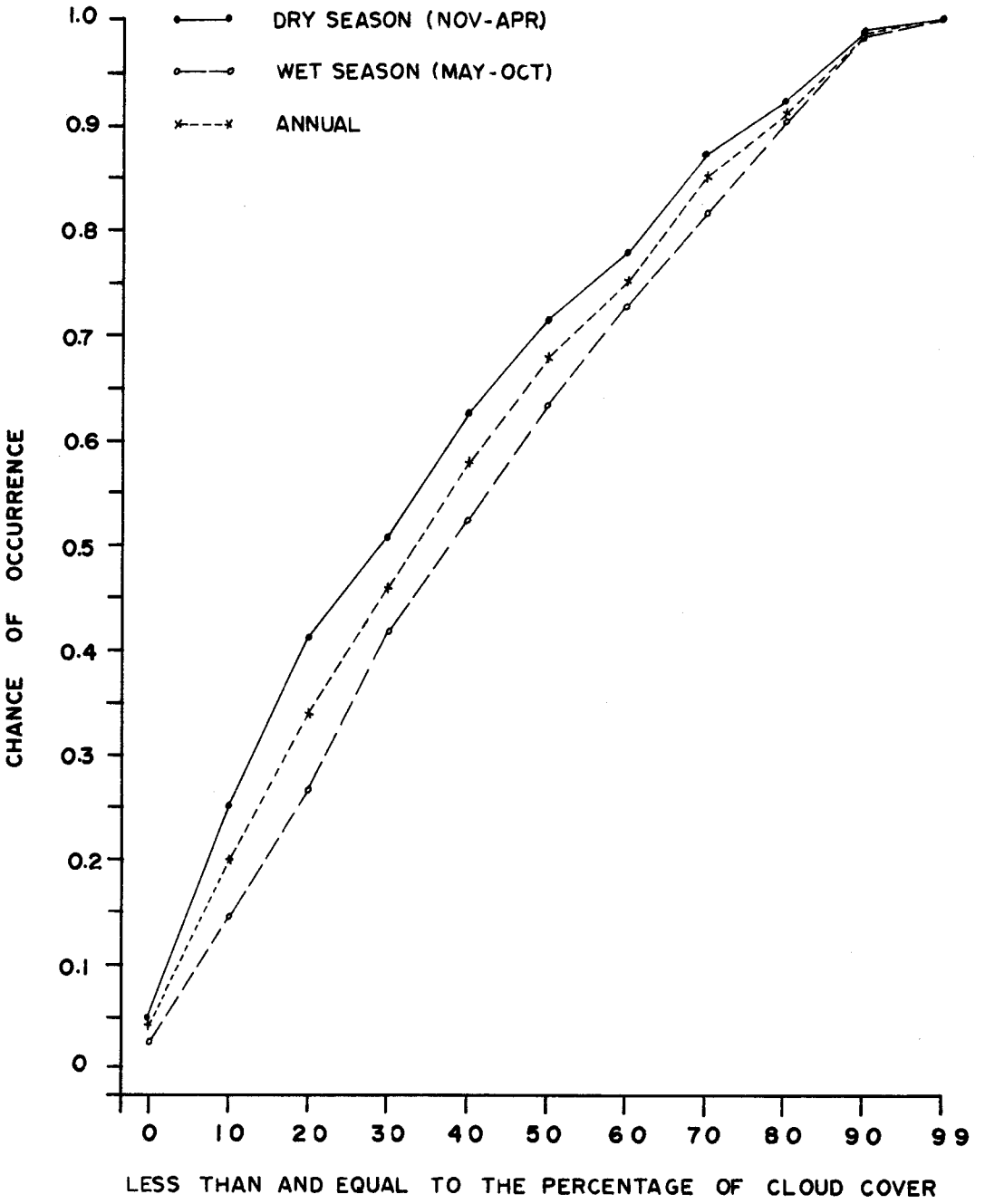

Figure 1. The Percentage of Cloud Cover Related to the Chance of Occurrence for Annual, and Dry and Wet Seasons.

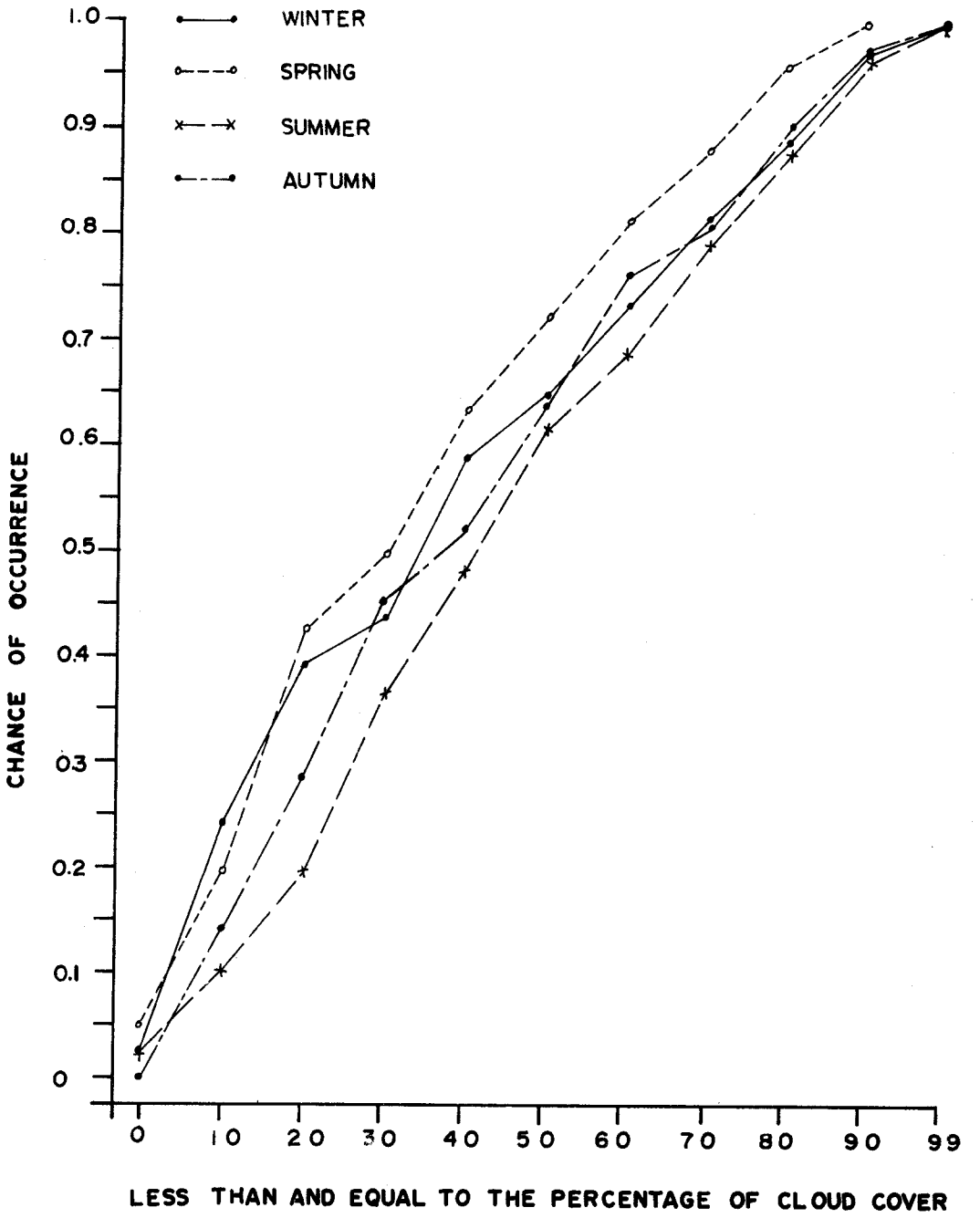

Figure 2. The Precentage of Cloud Cover Related to the Change of Occurrence for Winter, Spring, Summer, and Autumn.