ANGULAR LIMITS ON SCANNER IMAGERY FOR VEGETATIVE ASSESSMENT

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ABSTRACT

Tracking the condition of field crops by remote observation requires frequent (about weekly or more often) repetition of coverage. Landsat data alone does not provide this frequency of coverage and must be supplemented by other sources of information such as soil moisture models and alarm models driven by meteorological inputs. Satellite systems with a wider scanning capability than that of Landsat or with a pointing capability can provide frequent acquisition. This frequency increase is provided at the expense of spatial resolution and/or consistency in viewing geometry, thereby confounding interpretation of the observed data. As the viewing angle departs from nadir the path length of the signal increases, amplifying atmospheric effects; and the scene content (fraction of soil, vegetation and shadow in the scene) varies. The effects of these phenomena are apparent even over the relatively narrow scan angle of Landsat.

Using NOAA-6 and -7 Advanced Very High Resolution Radiometer (AVHRR) data the magnitude of these effects for wider angles have been considered. The degree to which several existing models can correct for these effects have are being considered along with the sensitivity of various vegetative indices. Practical limits to scan angle for vegetative assessment using current technology are being established.

INTRODUCTION

Tracking the condition of field crops as they respond to their environment requires frequent updates. During critical stages of growth this update may be required as frequently as each week. The Landsat system with an 18 day repeat cycle (assuming no clouds) was not designed specifically for this purpose. It has been used, however, in conjunction with land based information and weather observations, in this manner. The NOAA 6 & 7 AVHRR channels 1 and 2 when ratioed or differenced provide indices related to vegetation cover and/or vigor very much like the indices developed using the Landsat MSS channels. Significant differences in the capability of the two systems exist, however. The AVHRR (designed for cloud monitoring) can provide multiple views daily at a maximum spatial resolution of 1 Km^2 while Landsat with a spatial resolution of 1 acre views once each 18 days. The frequency of AVHRR data comes with a cost. Not only is the resolution less than that of Landsat (This is something that can be accommodated for wide area crop condition monitoring), but the wide scan angles required to obtain frequent observations complicate considerably the analysis problem due to the non-Lambertian nature of the surface effects and, due to atmospheric effects, both of which increase with scan angle. (Fig. 1) The frequency with which scene information can be acquired in the absence of clouds as a function of ability to use off nadir data is:

Full scan width AVHRR ($\pm 56^{\circ}$) provides multiple views daily;
Half scan width AVHRR ($\pm 28^{\circ}$) provides coverage every other day;
Quarter scan width AVHRR ($\pm 14^{\circ}$) provides coverage every 5th day;
Landsat scan width ($\pm 5^{\circ}$) provides coverage every 18 days;

To make full use of the wider scan angle of the AVHRR, procedures must be provided so that comparison can be made between scenes viewed from different illumination and viewing angles.

When techniques to apply AVHRR data to crop condition assessment first became available (Gray, 1961) a decision was made by the principle operational user of the data at the time, USDA-Foreign Agriculture Service, to use quarter scan width, uncorrected, until improvements could be made. This provides 5 day repetitions which could be adequate for their need except for clouds. However, clouds are found to be a significant problem during critical growth periods of many crops and there is a definite need to have the capability to analyze data at intermediate times. The Early Warning Crop Condition Assessment Project in AgRISTARS has, as one of its objectives, the development of procedures that will permit extension of the swath width used.

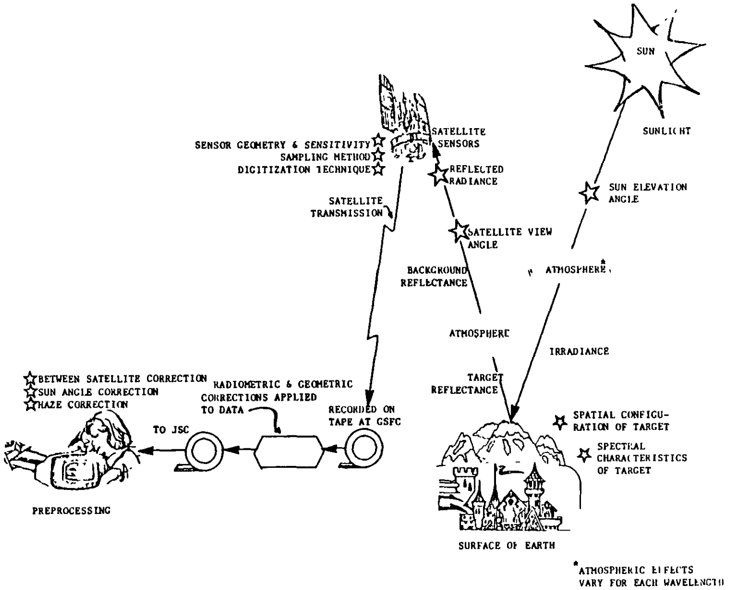


Fig. 1. The Problem

APPROACH

We have chosen to address the problem with a combined simulation modeling and empirical approach. Both canopy reflectance models and atmospheric models are employed. Surface data to support model test and the empirical approach are taken from the LARS archives at Purdue University and from scattered other sources as may be found. Satellite data used is the AVHRR data available to the AgRISTARS Early Warning Project.

The canopy models considered for use to date is that of Suits (1972) and a simpler model developed by Jackson, et al (1979). Atmospheric transfer models selected for consideration are those of Herman (1975) and from Dave (1978).

In the empirical part of the study we have selected full swaths over the U.S. east of the Rockies and averaged 50 scan lines; the resulting "average" scans will be subject to statistical analysis from which seasonal and location specific patterns are expected to emerge. In addition, selected typical sites are selected and the change which occur in signature as a function of viewing geometry, illumination geometry and season, are determined. The empirical portion of the study is intended to provide a family of primitive correction procedures, and guidance in selection of existing models; and should, with time, lead to improved comprehensive models designed specifically for this application.

DISCUSSION OF FINDINGS

Experimental results were obtained from digital data analysis in the following manner. Fifty sequential lines on the Julian dates 187 and 192 in 1981 were selected from the Global Area Coverage (GAC) format of AVHRR, in which four pixels were averaged out of each sequence of five along every third scan line each give a compressed scene value. These GAC values were averaged over the 50 scan lines. Before anlaysis, the data were first screened using bands 1, 2, and 4 (400-700 nanometers, 700-1100 nanometers, and 10-12 microns). These three bands were presented in a false color rendition in order to examine the location of cloud. Particular attention was accorded the presence of popcorn cloud, so that as far as was possible sub pixel sized cloud was avoided. Figures 2 shows that not only do the raw digital radiance values obtained in each of the first 2 AVHRR bands demonstrate an angle dependence, but so does the vegetation index.

$$\text{VIN2} = \frac{\text{AVHRR2}-\text{AVHRR1}}{\text{AVHRR2}+\text{AVHRR1}}$$

This form of analysis does suffer from the disadvantage that the target probably varies across the area whose image is analyzed. However, the area was selected for uniformity to minimize this problem and consists of farmland, with a small proportion of forest. In order to further substantiate the angle-dependence of the data shown, like areas were examined from different view angles on sequential days (Fig. 3). The count values are shown plotted against view angle for a mixed forest.

In a somewhat different analysis assorted uniform scenes were selected over a period from Julian day 189 to 194 in 1981. (Fig. 4) In this analysis, counts were normalized to solar zenith so that the pattern of counts as a function of viewing angle is proportioned to the pattern of bi-directional reflectánce. In some cases two views of the same area were acquired. The bi-directional reflectance pattern tends to be similar to that acquired from ground base observation, i.e. reflectance strongest with sun to the back of the observer. For this time of year (mid Oct) the agriculture scenes have little green vegetation remaining and the effects of the non-Lambertian effects of the canopy is suppressed over that taken prior to harvest (Fig. 2). Fig 5 shows the pattern of another form of vegetation index for this collection of views. Again general enhancement of the index occurs near nadir.

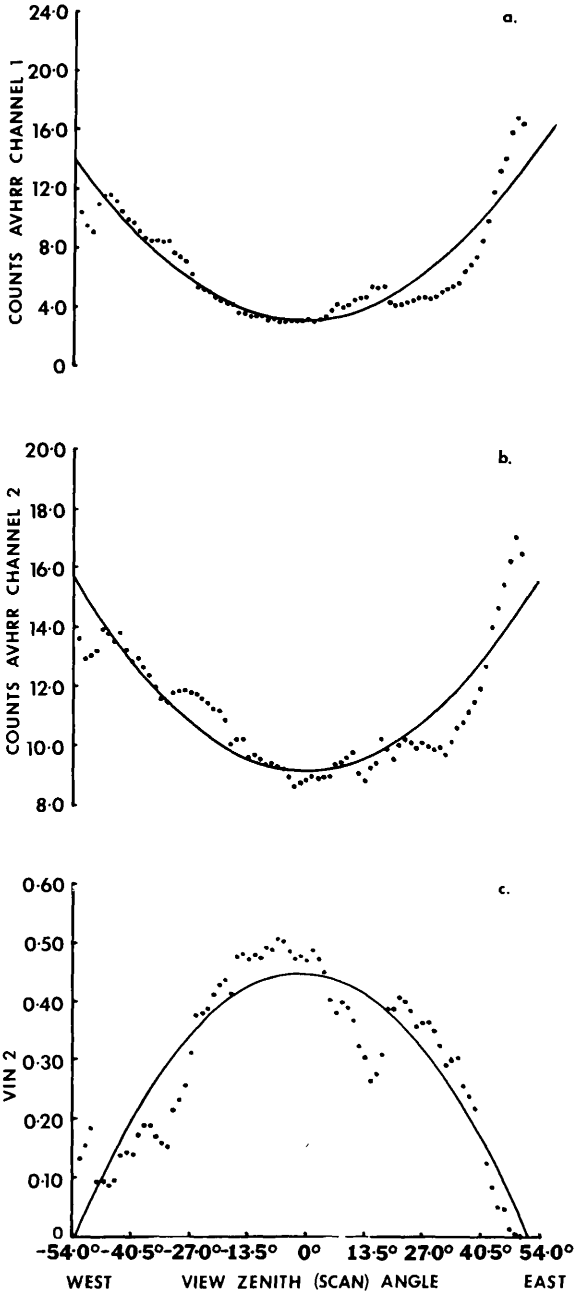


Fig. 2. Average Value over 50 Scan Lines of Channel 1, Channel 2, and Vin 2.

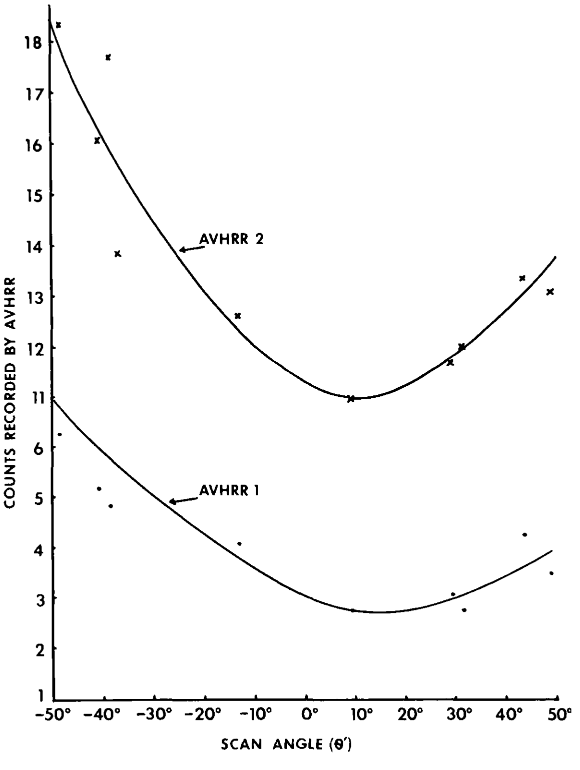


Fig. 3. Areas of Mixed Forest Viewed from Several Angles.

Fig 4. BI-DIRECTIONAL REFLECTANCE FACTOR FOR ASSORTED SCENES.

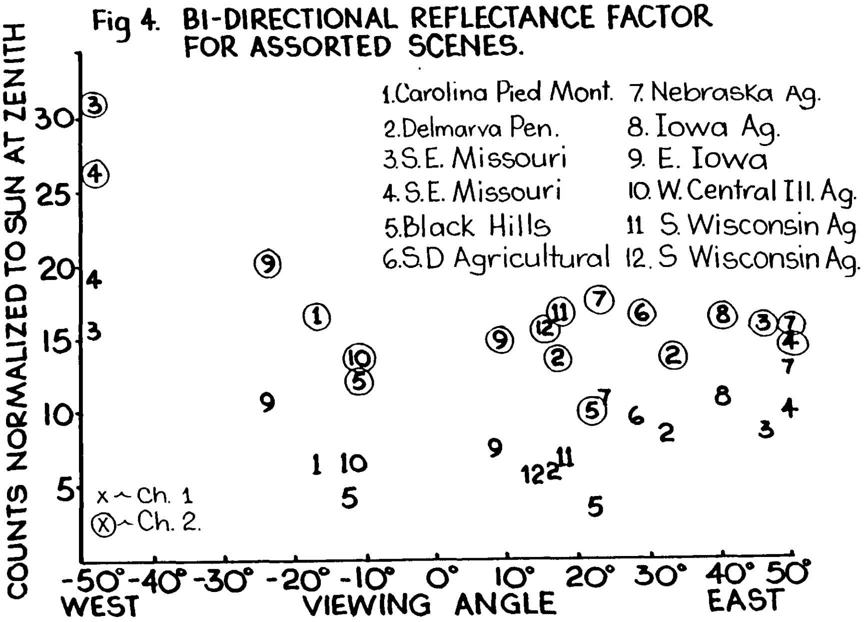
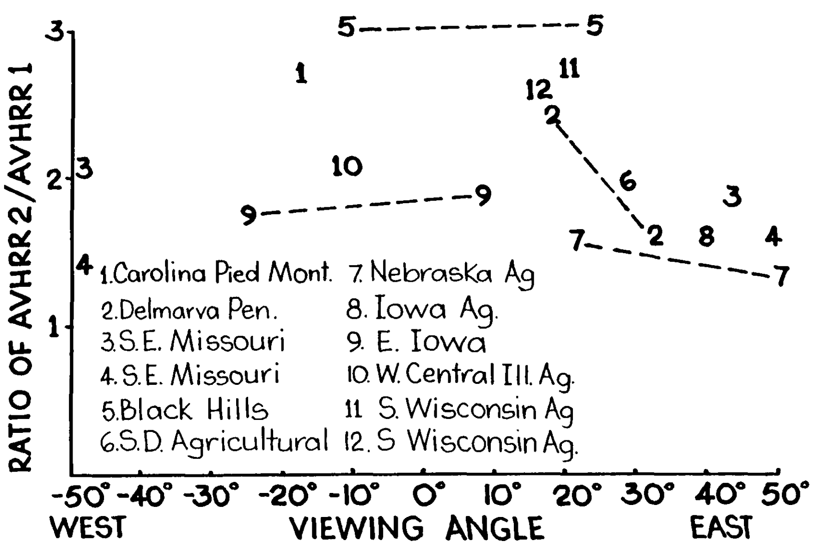


Fig 5. RATIO OF AVHRR (CHANNEL 2/CHANNEL 1) AS A FUNCTION OF VIEWING ANGLE FOR SELECTED UNIFORM SCENES.



An example of atmospheric modelling is shown in Figures 6 and 7. In this (preliminary) analysis, the ground is assumed to have a goniometrically isotropic (Lambertian) reflectance at those wavelengths considered; the reflectance factors are considered to be 0.15 and 0.30. The atmospheric optical depth is taken to be 0.45 in this simulation. The sun-target-sensor geometries considered approximate to those of NOAA-6 and of NOAA-7. This work, based on Dave's models of the atmosphere will be extended to include goniometrically anisotropic ground reflectance. In order to achieve this goal, we will include calibrated ground reflectance models into such simulation studies, so that the fictitious Lambertian assumption will not be made.

CONCLUSION

The approach chosen (the combined modeling and empirical analysis) appears to be the proper one for this problem. While existing models provide an initial estimate of effect of non-Lambertian reflectance and atmosphere, the combining of these into a single comprehensive estimator is a necessary but complex task. The available NOAA AVHRR data appears to be ideal, for providing an initial corrector, for test data for existing models and as a basis from which more comprehensive descriptors can be developed. Software in development that will simplify registration of areas of study viewed and illuminated from a variety of configurations will expedite the follow up to the early work described here.

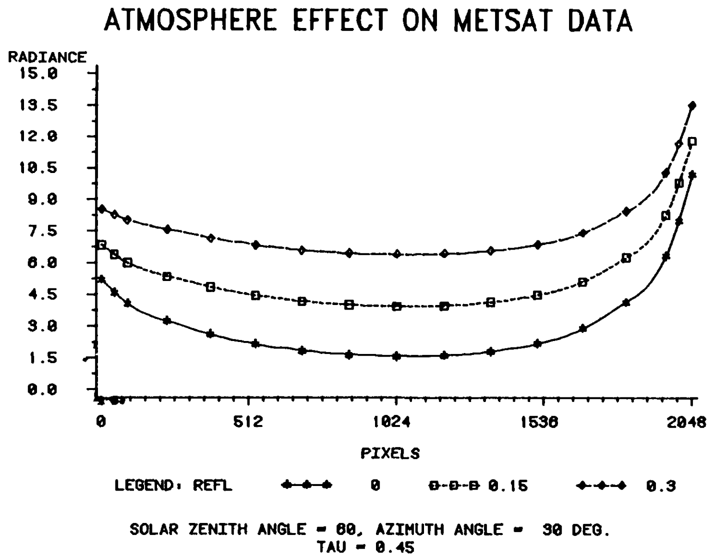


Fig. 6. Atmosphere Effect on Metsat Data (NOAA 6).

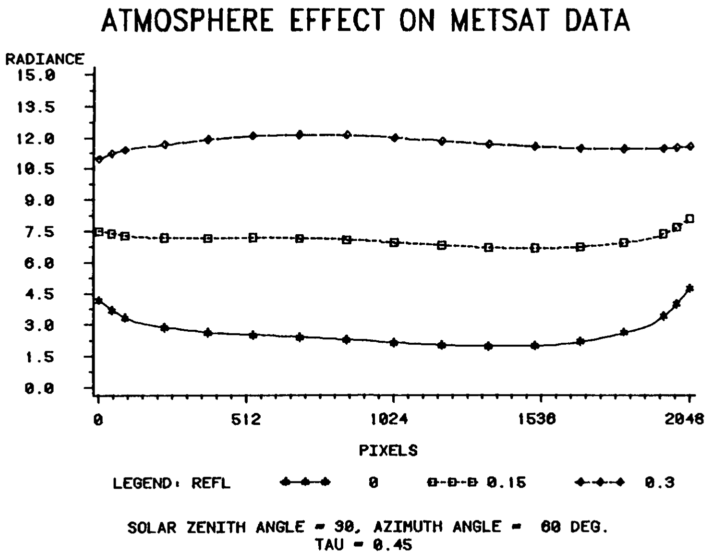


Fig. 7. Atmosphere Effect on Metsat Data (NOAA 7).

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