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URBAN AND REGIONAL LAND USE ANALYSIS: CARETS AND CENSUS CITIES EXPERIMENT PACKAGE

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SKYLAB/EREP INVESTIGATION NO. 469
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MONTHLY PROGRESS REPORT

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a.1. CARETS--Land use analysis: No change.

a.2. CARETS--Land use climatology: Our first S-192 computer tapes arrived during the period of this report. We have made considerable progress in the reading and manipulation of the S-192 type data, with the assistance and advice of Mr. Robert McNelly of the USGS Computer Center. We first ran print-out maps from channel 21 (thermal band, low sampling rate) of the Baltimore-Washington area where our prime test site for the climatology project is located. The first few print-outs were block smoothed through a 10 x 10 filter. This facilitated the printing of the entire scan width on a single print-out sheet. More recently we have received an unsmoothed print-out of the first one-hundred scan-line pixels along a track form Liberty Reservoir on the west to the Chesapeake Bay on the east. No analysis of this scene, however, has taken place.

A preliminary list of data manipulation and output requirements for S-192 tapes has been compiled. The primary constituents are:

1) The computation of range, mean standard deviation and coefficient of skewness for all pixels within a single spectral band and specific area of interest.

2) Histogram plots of pixel values in PCM count intervals versus number of occurences in each interval, within a single spectral band, within a specific area of interest.

3) Application of calibration factor, according to a specified function, to each data element pixel within a specific area of interest.

4) Production of digital map print-outs with and without block smoothing. In the case of smoothed versions a variety of matrix operator sizes, e.g. 4 x 4, 5 x 5, 10 x 10, etc., would be desirable.

In the analysis thus far, we have assumed that the internal scanner calibration has already been performed (by NASA) and that each pixel value that we are reading on the tape has already been corrected as a result of that calibration. We also assume that no corrections have been made for atmospheric water vapor.

a.3. Census cities: No change.

b. Recommendations concerning decision and/or actions required to ensure attainment of the experiment's scientific objectives: With respect to the S055-4 data PCM count interval change requested in the last report the new intervals, as recommended, may not be as precise as desired. During the coming weeks a more exact determination of these intervals should be made and subsequently forwarded in the February monthly report.

c. Expected accomplishments during the next report periods: Conversion of raw PCM counts to radiance values and then to temperature in °C should be completed by the end of January. When this is accomplished these temperature values will then be compared to the results of the Outcalt urban climate simulator, probably here on the USGS computer.

d. Significant results and their relationship to practical applications or operational problems:

1. Maps originally created under USGS Contract 14-08-0001-11914 at U.C. Riverside have been refined and a paper has been prepared which describes their making for presentation at the forthcoming ASP annual convention in Washington, D.C. These maps, which merge electro-optical scanner technology with automated cartography, are isarithmic displays showing for Baltimore the distribution of such complex phenomena as surface albedos, energy absorbed and emitted by the surface and the distribution of net radiation, often considered the injection of energy in a terrestrial thermal system. The project comprises an advance in extraction of data from calibrated electro-optical scanners as well as providing synoptic displays of the diversity of energy - related phenomena which can be used as analytic tools for investigating surface energy states.

2. Early in January, 1975, the Geography Program received tapes of thermal Skylab data made over the CARETS test site on August 5, 1973. The problem was presented to (1) format and interpret the values for pixels of the satellite thermal scan and to (2) correct the values recorded for the gray-window effects of the atmosphere and thus achieve true surface values. The gray-window in effect damps the signal so that a 27°C target records in this case only as about 2° to 4°C.

   Formatting and deciphering of the hexadecimal tape code was accomplished by Robert McNelly of the computer center. His results were made according to NASA/SKYLAB directions and were verified by the fact that rational energy values were achieved which could be calibrated to known surface values by the following procedures.

   The gray window physical model, upon which surface to sensor calibration was finally accomplished, was originally created as a part of USGS/U.C. Riverside participation in the Barbados (BOMEX) experiment. In it, a surface signal is modified in two ways by air through which it is transmitted; (1) the air, by its water vapor and aerosol content, alternates or weakens the signal, but (2) this loss is to an extent compensated by tha addition of upward atmospheric longwave emission. Only the attenuated surface signals can produce a thermal image, the air addition acts as unwanted, contrast-reducing noise. In its original form, the model was handled as a single equation.

   For purposes of calibrating Skylab thermal pixel data, the gray-window model was broken into its two parts which were considered separately. This arises from the fact that the satellite is in space and the air emission is actually simply atmospheric longwave radiation leaking into space. On the other hand, the signal attenuation is taking place in the lowest atmospheric layers. Of course, both factors are eventually brought together.

It was the original intention to estimate the upward longwave atmospheric radiation ($R\uparrow a$) from the amount of water vapor in the air column, as measured in precipitable centimeters as derived from a radiosonde sounding made at Baltimore Washington Internation Airport. The air column was to be examined in its stratification using the following equation for each layer:

$$P_v = \bar{m}\ (P_1 - P_2)\ /\ g$$

Where P_v = Water Vapor in precipitable centimeters, $\bar{m}$ the mean mixing ratio of each layer, $(P_1 - P_2)$ the mean air pressure of the layer in dynes (1 millibar = 1000 dynes), and g the acceleration of gravity = 980 cm/sec^2. Some problem still exists as to how to translate the precipitable water value into $R\uparrow a$ since values must be for radiance in the spectral sensing window only. Determination of water vapor transmissivity by Beers Law (e^{-ku}) may be best.

Since the atmospheric soundings were not yet available, an alternate method was devised to determine both precipitable water and atmospheric energy emission to space. First, synoptic weather conditions for the overflight time were determined from appropriate weather maps which with the imagery defined the depth of the humid layer and its dew point. By the above equation, the water vapor in this layer was given close estimate. Second, a numerical iteration was performed in which various values for $R\uparrow a$ were inserted into appropriate equations (see attachment 1) and by means of the Beer's Law relationship (e^{-ku}), water vapor contents were determined to match each value of atmospheric upward emission. The value that matched the estimated water vapor content was deemed to be close to correct. Thus, values derived by two different approaches must agree.

To enable this iteration process to work, a new refinement was added to the gray-window model. Beer's Law as used applies only to water vapor in the air. A method was therefore devised to measure a complementary turbidity transmissivity (T_t). The overall transmissivity (T) thus became:

$$T = T_t\ (T_{wv})\ \text{Where } T_{wv} = \text{water vapor transmissivity}$$

This constitutes a worthwhile addition to the model which should make it better fit reality.

It is possible that the numerical solution is an improvement on original plans for a calibration lacking calibration targets. Since the original ground truth target was omitted, data was obtained that enabled Chesapeake Bay to act as a substitute. This one target made it possible to tie calibration equations to the surface. An analytic solution for use when one calibration target is available is included as attachment 2. The basic equation for the sensor to surface correction is:

$$R_o = \frac{R_z - R\uparrow a}{T}$$ where R_o = spectral radiance at surface

R_z = spectral radiance measured aloft, $R\uparrow a$ =

Longwave atmospheric emission as a spectral radiance in the sensing window.

A successful tentative calibration was achieved by the procedures described. These permit computer programs to be written to convert Skylab thermal tapes into line-printed graymaps showing actual surface radiation temperature distributions at the time of imaging. The calibrations will be further checked when the atmospheric soundings for August 5, 1973 are available from Asheville. A procedure was provided to guide the programmer.

Black/white transparencies for the thermal band of the tape plus three bands made with reflected solar energy have been received. These can be made into a sequence of energy - related maps as was done for Baltimore if desired. Such a set of maps, with the broad geographic perspective of a satellite field of view would indeed be a first and should be very useful in the analysis of CARETS land-use climatology. The map sequence can also be made directly from the original tapes with proper programming.

Success of Skylab calibration suggests that satellites are feasible platforms for thermal scanning and provide a much broader geographical field of view than is possible with airborne platforms.

e. Summary outlook for the remaining effort to be performed: No change.

f. Travel summary and plans: Robert Pease visited the USGS National Center from January 15-17 to analyze the tape data as described in section d.

Approved:

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ATTACHMENT 1

Equations Used to Numerically Iterate for Emission to Space and Precipitable Water

R_z = spectral radiance measured at satellite in $w/cm^2/ster/\mu m$

R_o = spectral radiance at surface in $w/cm^2/ster/\mu m$

1. $$\frac{R_z - R\uparrow a}{R_o} = T$$ where

$R\uparrow a$ = spectral radiance of atmosphere into space in $w/cm^2/ster/\mu m$

T = overall transmissivity of air column

T_t = turbidity transmissivity

2. $T = T_t(T_{wv})$ where

T_{wv} = water vapor transmissivity

3. $T_{wv} = e^{-ku}$

= Beer's law exponential expression of water vapor transmissivity

k = kondrateyev mass absorption coefficient for 10-12 μm spectral sensing window = .10

u = water vapor in precipitable centimeters

4. $$T_t = \frac{\text{Silicon cell measured solar input}}{\text{Theoretical solar input (with sun angle and water vapor correction)}}$$

ATTACHMENT 2

An Analytical Method for Determining R↑a When One Target is Known

1. Determine precipitable water in air column by equation:

P_v = water vapor in precipitable centimeters

$\overline{m}$ = mean mixing ratio

$(P_1 - P_2)$ = mean pressure of air layers in dynes

$$P_v = \frac{\overline{m}(P_1 - P_2)}{g}$$ where g = accelleration of gravity = 980 cm/sec^2

2. Use $P_v = u$ in Beer's Law (e^{-ku}) exponential expression for water vapor transmissivity (T_{wv}). K = mass absorption coefficient (kondrateyev)= .10 for 10-12 μm. Resolve the exponential to determine the T_{wv} for μ amount of precipitable water.

3. Find overall transmissivity $T = T_t \times T_{nv}$. Determine T_t (turbidity transmissivity) as described.

4. Multiply known target R_o by T and subtract product from R_z to find R↑a.

$$R_z - R_oT = R{\uparrow}a$$

This becomes a constant for the image.

5. To solve for other image elements:

$$R_o = \frac{R_z - R{\uparrow}a}{T}$$