Practical Paper

A Technique for Processing NOAA-AVHRR Data into a Geographically Referenced Image Map

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ABSTRACT: A method for proceeding from raw National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) digital numbers to a georeferenced dataset for a region of interest is presented. This is an important prerequisite for both multitemporal analyses and other scientific evaluation of the information in AVHRR spectral datasets. The method should hold interest for anyone conducting regional- or global-scale research.

INTRODUCTION

OVER THE PAST SEVERAL YEARS, the use of coarse-resolution satellite data for land-resource investigations has become commonplace (Justice, 1986). This trend seems to be related not only to the increased cost of using high resolution satellite systems such as Landsat or SPOT, but also to increased scientific emphasis on quantifying global resources (Gutman, 1990). The National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) sensor has emerged as the preeminent tool for addressing large-area environmental issues. The characteristics of these polar orbiting satellites include their twice-daily coverage, low cost, high radiometric resolution, and synoptic view.

The purpose of this paper is to demonstrate the use of a commercially available image-processing software package to allow a user to proceed from an AVHRR computer compatible tape (CCT) to a georeferenced dataset that facilitates precise delineation of an area of interest (Figure 1). The specific example discussed in the paper results in the preparation of an image map similar to those appearing on the cover of the January 1991 issue of *Photogrammetric Engineering & Remote Sensing*. An additional benefit that can be achieved through implementation of these procedures is the creation of AVHRR datasets in a format suitable for further analysis. The specific research accomplished by implementing these methods involved an investigation of drought effects on vegetation over a two year period in the state of Nebraska, utilizing 22 AVHRR datasets (Peters *et al.*, 1991, in press).

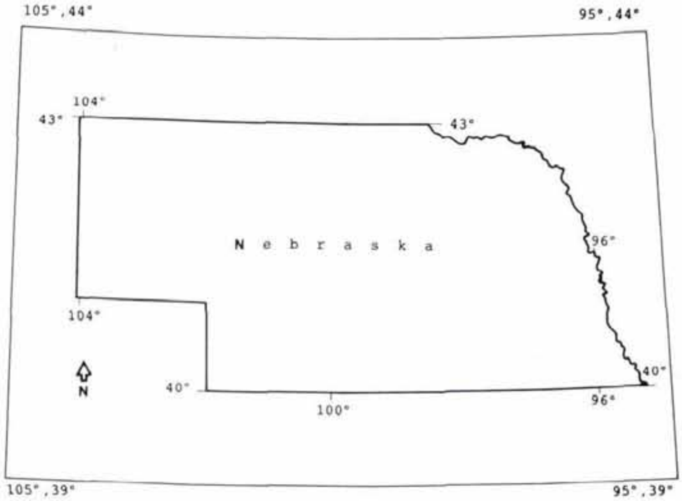

FIG. 1. Example study area of Nebraska.

PROCEDURE

Our technique makes use of the Earth Resources Data Analysis System (ERDAS)[1] image-processing software (ERDAS, 1990). The procedures are discussed in a generic fashion, however, so that the reader can implement other commonly available image-processing software.

The first step in our procedure involves reading a standard NOAA level 1b CCT (NOAA, 1988) containing AVHRR ten-bit data (1024 grey levels). Subsequent processing (Figure 2) involves cloud masking and image transformations; in this case the computation of a Normalized Difference Vegetation Index. These steps should be performed prior to image georeferencing so that maximum accuracy can be maintained in the digital value of each pixel in the matrix.

CCT READING

A standard level 1b CCT containing an AVHRR scene consists of a header file and a data file. The header file contains information on the date the scene was taken, the satellite in use, the geographic coverage, and the number of scan lines in the scene. On even numbered NOAA satellites (e.g., NOAA-10) the data file contains four bands of data while odd numbered satellites contain an additional thermal band of data (NOAA, 1988). A standard (full set) level 1b AVHRR scene contains 2048 columns of data and a variable number of scan lines.

Depending on the type of software being utilized to read the tape, a subset of the image and a subset of the data bands may

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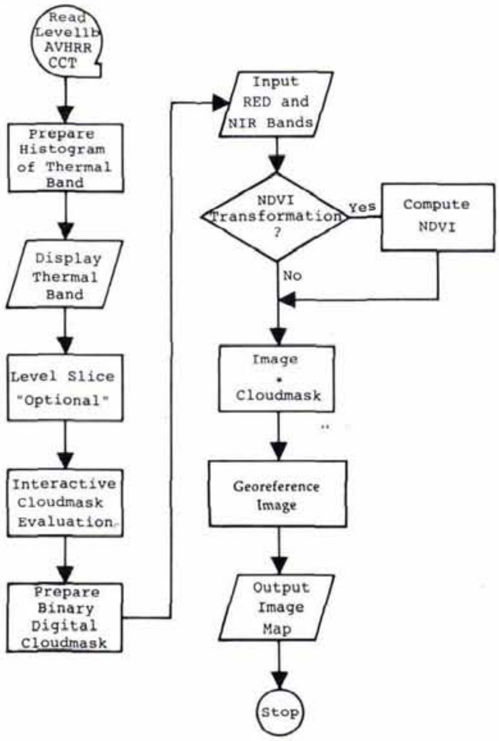

FIG. 2. Image processing flow chart.

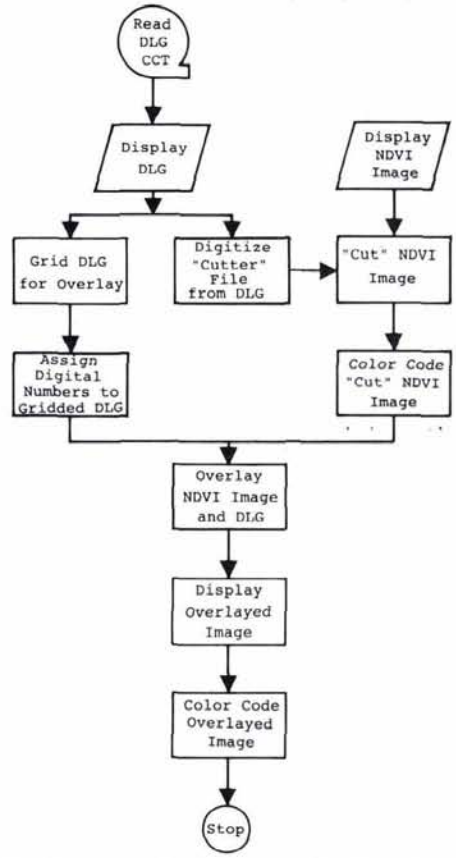

FIG. 3. Image subsetting and political boundary overlay flow chart.

be extracted. In this example we utilized bands 1, 2, and 4, and a subset of the original image that is somewhat larger than the state of Nebraska (Figure 1).

Cloud Masking

At this point in the process, we recommend that the user utilize the thermal band (AVHRR channel 4) to facilitate a simple interactive cloud-masking procedure (Figure 2). Interactive cloud-identification procedures are recommended because of uncertainties with regard to the digital thermal threshold; i.e., a particular "temperature" may not be appropriate for all geographic locations and atmospheric situations. We suggest that the user analyze a histogram of the thermal dataset to facilitate decision making concerning the necessary digital cloud threshold. Users of AVHRR thermal data must also be aware that the radiometer slope/intercept has been inverted by NOAA so that cooler objects such as clouds have higher digital numbers and appear white on an image; therefore, all clouds and other cool portions of the scene, such as rivers and lakes, have high brightness values and are located on the "high side" of the histogram.

Next, we suggest displaying and level slicing the thermal band to visually assist in the cloud discrimination procedure. The user may wish to color all brightness values above the determined cloud threshold in an effort to highlight those features and alter the previously determined cloud threshold. This procedure is not "foolproof," and features such as high, thin clouds or ground fog may not be detected without specific atmospheric information gathered on the date an image is recorded. However, it is an effective method of minimizing cloud "contamination" of the data. When the user is interactively involved in this process, clouds can usually be distinguished from water bodies on the monitor, and this threshold can be used to identify a proper stopping point for cloud identification.

Once the locations of cloud-contaminated pixels have been firmly established, the final step in cloud masking is to prepare a binary digital cloudmask by changing all land features on the thermal image to a value of 1, and all cloud-contaminated pixels to a value of 0. Eventually, this dataset will be multiplied by a processed image, for example, a vegetation index, to isolate those pixels contaminated by clouds.

Computing a Transformation

While a number of analyses can be conducted on AVHRR data, for purposes of our discussion we will assume that the user has chosen to construct an image map of a state or region where the Normalized Difference Vegetation Index (NDVI) is to be shown. The NDVI is a common transformation of AVHRR data that is frequently used for vegetation monitoring (e.g., Justice *et al.*, 1986; Prince and Tucker, 1986; Tucker and Gatlin, 1984; Tucker *et al.*, 1985). The calculation of NDVI is readily accomplished using a formula of the form

$$[(X2 - X1)/(X2 + X1)] \quad (1)$$

where X1 is the "red" band 1 and X2 the "near-infrared" band 2. Clouds can be eliminated from the resulting NDVI image by multiplying the image transformation by the previously prepared cloud mask.

Georeferencing

Georeferencing of the dataset is necessary at this point in the processing procedure because the sensor system scan angle must be accounted for to make the geometry of the scene planimetric (Jensen, 1986). Geographic coordinates (e.g., latitude/longitude or UTM) are required for segmenting the desired area from the full scene and performing other image processing functions which cannot be accomplished while the data are not spatially referenced. For purposes of this discussion, we have decided to utilize latitude/longitude coordinates. For an area the size of Nebraska, it is recommended that 10 to 12 evenly spaced ground control points (GCPs) be utilized. The greatest success can be obtained if the AVHRR near-infrared band (band 2) is used and the ground control points consist of permanent water bodies. The next step is to calculate the transformation equations which relate GCP coordinates (the latitude/longitude of the water bodies) to the corresponding AVHRR image (row/column) coordinates.

One important issue in preparing an image map for a state is the areal ground coverage of each pixel. In the case of Nebraska, we use a cell size of 0.0135 degree for longitude and 0.0100 degree for latitude. The pixel dimensions are based on the number of AVHRR 1.1-km pixels per degree of latitude and longitude at 43 degrees North. This gives each degree of latitude and longitude the correct dimension for the northern boundary of the state, and yields a state image with a shape as depicted, for example, on a typical conic projection. Cell dimensions are usually specified by the analyst during the georeferencing procedure. Nearest-neighbor resampling is recommended for georeferencing because it preserves individual pixel values as closely as possible.

The example dataset, at this point, has been transformed to an NDVI image, masked for clouds, and georeferenced to latitude/longitude coordinates. Final processing steps include subsetting the geographic area of interest from the larger, original dataset (see Figure 1).

Subsetting and Political Boundary Overlay

A 1:2,000,000-scale Digital Line Graph (DLG), referenced to latitude and longitude coordinates, of political boundaries (e.g., state and county boundaries) can be acquired from the United States Geological Survey (USGS) at a cost of about $80. The DLG can be displayed on the video monitor, and a vector "cutter file" can be created by screen digitizing the boundary of interest (in this case the Nebraska state boundary) from the displayed boundary file (Figure 3). Using the cutter file, an image area representing a state can be "cut" from the NDVI image. This is accomplished within the image processing software by cutting the NDVI image at the precise latitude and longitude coordinates of each pixel corresponding to the location described by the boundary cutter file.

If state and county boundaries are to be a part of the final image map, the original DLG should be gridded to the same cell size as the AVHRR data (0.0135, 0.0100, in our example). Then the NDVI matrix can be overlaid with the gridded DLG, resulting in an image map of the state which can be displayed on a monitor. Cartographic enhancements such as color coding or classifications can be created by assigning colors to NDVI data-value ranges (e.g., as determined from an NDVI image histogram). Of course, if the cut NDVI image is to be used for further analysis, the state and county boundaries should not be added to the dataset in order to avoid including their pixel values in the analysis.

SUMMARY

This paper describes a method of producing georeferenced NOAA AVHRR digital files to facilitate analysis of multiple scenes or to produce an image map for a selected geographic area. The method involves use of specific commercial software for cloud masking, image transformation, and cartographic enhancements. Even though the techniques represent only one possible use of the AVHRR imagery, it is intended to demonstrate a procedure that could be easily modified to facilitate other scientific applications of these data for natural resource investigations.

REFERENCES

ERDAS, 1990. *Earth Resources Data Analysis System User's Manual*, ERDAS, Inc., Atlanta, Georgia.

Gutman, G. G., 1990. Towards Monitoring Droughts from Space. *Journal of Climate*, Vol. 3, No. 2, pp. 282-295.

Jensen, J. R., 1986. *Introductory Digital Image Processing*. Prentice-Hall, New Jersey, 379 p.

Justice, C. O., 1986. Editorial. *International Journal of Remote Sensing*, Vol. 7, No. 11, pp. 1391-1393.

Justice, C. O., B. N. Holben, and M. D. Gwynne, 1986. Monitoring East African Vegetation Using AVHRR Data, *International Journal of Remote Sensing*, Vol. 7, No. 11, pp. 1453-1474.

NOAA, 1988. *NOAA Polar Orbiter Data User's Guide*. U.S. Department of Commerce, NOAA, NESDIS, NCDC, and the Satellite Data Services Division, Washington, D.C.

Peters, A. J., D. C. Rundquist, and D. A. Whilhite, 1991. Satellite Detection of the Geographic Core of the 1988 Nebraska Drought, *Agricultural and Forest Meteorology*, In Press.

Prince, S. D., and C. J. Tucker, 1986. Satellite Remote Sensing of Rangelands in Botswana. II. NOAA AVHRR and Herbaceous Vegetation, *International Journal of Remote Sensing*, Vol. 7, No. 11, pp. 1555-1570.

Tucker, C. J., and J. A. Gatlin, 1984. Monitoring Vegetation in the Nile Delta with NOAA-6 and NOAA-7 AVHRR Imagery, *Photogrammetric Engineering & Remote Sensing*, Vol. 50, No. 1, pp. 53-61.

Tucker, C. J., J. R. G. Townshend, and T. E. Goff, 1985. African Land-Cover Classification Using Satellite Data. *Science*, Vol. 227, No. 4685, pp. 369-375.

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