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SHORT COMMUNICATION

Geographic Location of Individual Pixels

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A major problem in processing thermal infrared digital data from very high resolution radiometers aboard NOAA Polar Orbiting Satellites is the geographic placement of digital data fields. Geographic placement is especially difficult over oceanic areas because of the lack of landmarks. Using a series of geometric constructions, an analytical approach can be developed for geographic location of individual data pixels. The errors associated with this method are generally less than 0.1° latitude and longitude.

Introduction

Kirkham and Stevenson (1976) presented a method for applying a given geographical grid-coordinate matrix (Bonner, 1969) to a computer-generated digital image. Accurate placement of the grid-coordinate matrix relative to the satellite data field is a critical part of this method. Previously, this required lining up a geographic grid overlay with a scanline/pixel overlay on the photographic image to identify an individual pixel. With NOAA-5 Very High Resolution Radiometer (VHRR) data, errors of up to 0.6° in latitude and longitude were found when using this procedure for the placement of the grid-coordinate matrix. This communication describes a method for analytically determining the geographic location of an individual data pixel to an accuracy of less than 0.1° in latitude and longitude.

Geometric Relationships

The geographic placement of the center pixel of a given scanline on the photographic image can be derived using an algorithm for the satellite orbit path subpoint location developed by Eber (1973). Since the spacecraft is in earth orbit and the satellite sensor scans perpendicular to the orbit path, the individual scanlines approximate great circle arcs over the earth's surface. The scanning rate of the instrument is sufficiently fast so that skewing of individual scanlines due to earth rotation is negligible and can be ignored (Legeckis and Pritchard, 1976).

The distance between the scanline subpoint and an individual pixel on that line is the great circle distance, d, and can be computed given the satellite sensor angle α (see Fig. 1). The angular range for the NOAA-5 VHRR is 66° from sync-line to sync-line and corresponds to 2912 pixels. The center pixel of each scanline is number 2666. Thus for a given pixel P the sensor angle α, in degrees, can be expressed by

$$\alpha = \frac{|P-2666|\times 66°}{2912}. \qquad (1)$$

The great circle distance in degrees of

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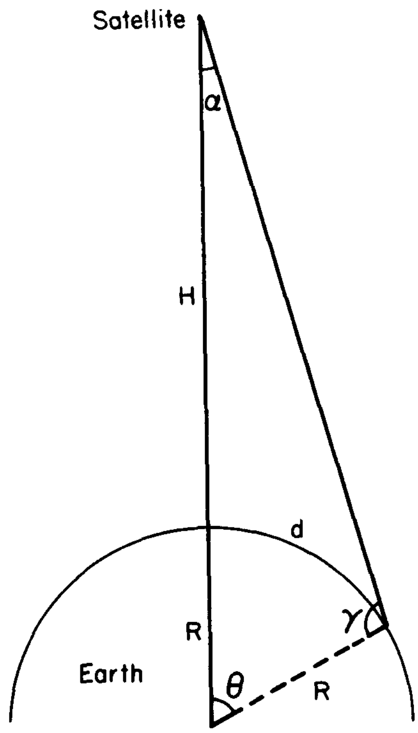

FIGURE 1. Relevant geometry for defining the great circle distance d.

latitude, d, can be computed as follows:

$$d = \frac{\pi R \theta}{180° \times 1.852 \times 60}, \quad (2)$$

where

$\theta = \gamma - \alpha$,

$\sin\gamma = [(H+R)\sin\alpha]/R$,

H is the height of the satellite orbit (1511.4 km for NOAA-5),

R is the radius of the earth (an average of 6371.0 km),

α is the sensor angle as expressed in Eq. (1),

γ is the angle between the satellite and the earth's center at the individual pixel,

θ is the angle between the satellite and the individual pixel at the earth's center.

The scanline azimuth (Z_n) or angle relative to true north (see Fig. 2) is computed using the following equation (Legeckis and Pritchard, 1976):

$$\cos\varepsilon = \cos I / \cos L_1, \quad (3)$$

where

I is the inclination angle at the equator,

L_1 is the latitude at the scanline subpoint.

If $P < 2666$ then $Z_n = \varepsilon + 180$. If $P > 2666$ then $Z_n = \varepsilon$.

Given the great circle distance, α, and the azimuth, Z_n (as shown in Fig. 3), we can solve the spherical triangle for the geographic latitude and longitude using the following formulas (Dunlap and Shufeldt, 1969):

$$\sin R = \sin Z_n \times \sin d, \quad (4)$$

$$\cos|K - L_1| = \frac{\cos d}{\cos R}, \quad (5)$$

$$\sin L_2 = \sin K \times \cos R, \quad (6)$$

$$\sin t = \frac{\sin R}{R \cos L_2}, \quad (7)$$

where R and K are intermediate points used for computational purposes only.

The result t is the difference in longitude between the scanline subpoint and the desired pixel. Thus the geographic coordinates of P are L_2 and $(\lambda_1 + t)$ if $Z_n > 180°$ or L_2 and $(\lambda_1 - t)$ if $Z_n < 180°$.

Results

Table 1 compares the location of individual pixels with known landmarks using both the analytical approach pre-

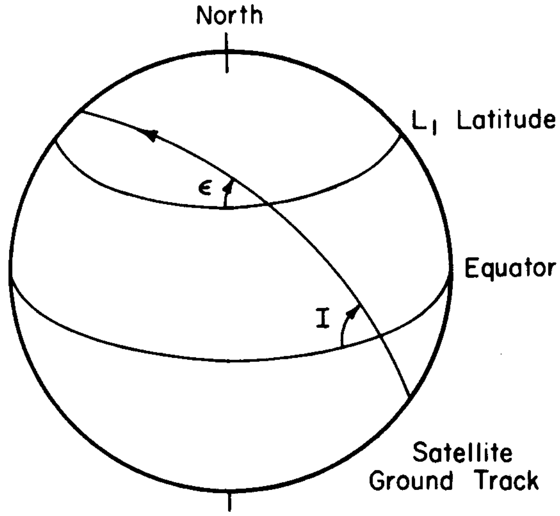

FIGURE 2. Geometry used to derive the scanline azimuth (Z_n).

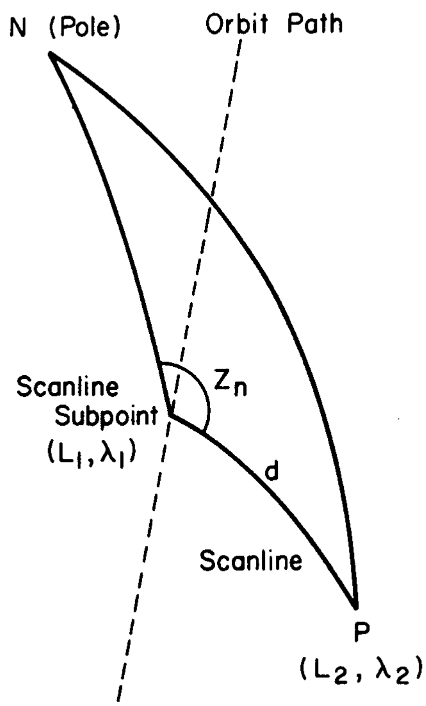

FIGURE 3. The spherical triangle used to compute the latitude and longitude at pixel *P*.

sented in this communication and the approach described by Kirkham and Stevenson (1976). A significant reduction in error of geographic placement is apparent using the analytical approach, which appears generally to be accurate to less than 0.1° latitude and longitude.

The grid-coordinate matrix generated by Bonner's program may be accurate over small areas such as a high resolution digital field, but for satellite photographic images where large distances are involved, location errors become significant. It is advisable to use an analytical approach to geographically identify a local area on a satellite photographic image before applying a grid-coordinate matrix to a digital field.

References

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TABLE 1 Comparisons for Pixel Location Using Both the Analytical Approach and The Grid Overlay Approach.

NOAA-5 orbit	Scan line	Pixel	Charted Latitude	Charted Longitude	Computed Latitude	Computed Longitude	Differences Latitude	Differences Longitude
3268	4128	3232	34.03	120.35	34.05	120.37	−.02	−.02
3268	4198	3390	33.28	119.55	33.25	119.54	.03	.01
8120	4327	2347	36.63	121.93	36.56	121.83	.07	.10
8120	4677	3041	33.03	118.57	32.97	118.46	.06	.11
8145	4300	3341	36.63	121.93	36.56	121.97	.07	−.04

NOAA-5 orbit	Scan line	Pixel	Charted Latitude	Charted Longitude	Grid Overlay Latitude	Grid Overlay Longitude	Differences Latitude	Differences Longitude
3268	4128	3232	34.03	120.35	34.25	120.50	.22	.15
3268	4198	3390	33.28	119.55	33.45	119.75	.17	.20
8120	4327	2347	36.63	121.93	36.90	121.95	.27	.02
8120	4677	3041	33.03	118.57	33.45	118.20	.42	−.37
8145	4300	3341	36.63	121.93	37.25	121.35	−.62	.58

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