The Simplified Mapping Equation of VISSR Image Data from the Geostationary Meteorological Satellite (GMS)

Abstract

This paper aims to develop a simplified mapping equation based on the limited information like a set of longitude-latitude values, VISSR display format and specific values of space-craft, which are easily obtained from the satellite data producer.

The popular transformation is a linear interpolation equation for mapping the image data, but it is difficult to maintain a sufficient accuracy. The present mapping equation is defined as a transformation matrix to perform a mapping with reasonable accuracy. An error analysis is also investigated using actual data set.

Introduction

There exists a considerable potential for more sophisticated image products that use mapped image data as the basic data source. The display media of principal concern for computer-processed image products are the VISSR data displays (so called, High Resolution Facsimile, Low Resolution Facsimile) rebroadcast via GMS and recorded on either photo-facsimile (FAX) or other facsimile recorder.

Coastlines, latitude-longitude lines and other physiographic features are implanted in the FAX's. These are helpful for positioning the targets. In most cases there is an advantage in dealing with linear interpolation scheme, but in some applications, such as in time-compositing mapped image data, planimetered measure of brightness contours, displacement measurement of clouds, the precision of mapping is critically important.

In these applications, the transformation from projection plane (for examples, FAX or VISSR frame) to geocentric coordinate system is essential. In general, it may turn out to be an impracticable procedure to map data without any information on orbital elements and specifications of space craft. The present model is reduced to simplest forms on the condition of limited information which the user can be known. Chan (1978) investigated the transformation procedure in detail, and calculated this problem exactly based on satellite dynamics and its specifications.

1. Input Data

Inputs to mapping technique include the line and pixel coordinates (I, J) of the FAX elements plus information needed to transform these coordinates into geocentric coordinates (φ, λ).

The information on transformation derived from the FAX are;

1) a pair of scan line number, pixel number which are corresponded to the sub-

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Table 1 Parameters for mapping model.

	SSP Position		Stepping Angle	Sampling Angle
	Line No.	Pixel No.	rad.	rad.
VISSR Original Image Data	——	——	34.98618	23.9748
High-Resolution FAX				
Full Disc	2177	4945	69.9081	39.05299
Partial Disc				
(19°S, 140°E)	−318	4945	69.55504	39.05299
(35°S, 140°E)	−910	4945	69.55504	39.05299

Average Earth Radius: 0.637028949×10^7 m.
Distance between Space-Craft and Earth Center: 0.422702899×10^8 m.

satellite point (SSP).

2) data set of intersection points of the latitude-longitude lines which are melded with the FAX, and their (I, J) coordinates values.

In addition, some constants are needed for solving the mapping equation. These are defined as specific values which depend on the characteristics of the GMS spacecraft, and on the FAX formats.

These are;

3) stepping angle (radians per line).

4) sampling angle (radians per pixel).

5) average earth radius.

6) nominal distance between earth and satellite.

The actual data related to the GMS are summarized in Table. 1 except for 2). Line, pixel number associated with SSP are fixed, depending on a type of FAX (gray scale, scale mark, annotation and back porch data which are inserted to the FAX data format are not considered).

2. Mapping Model

2. 1 Definition of Coordinate System

The present picture-taking process of the VISSR takes about 25 minutes. This is equivalent to about 5° or 0.1 radians of orbital motion. In view of this, it is permissible to consider that the change of orbital elements are ignored. The nominal values may then be used to represent the orbital elements with justifiable accuracy.

The coordinate systems related to the subsequent discussion are defined.

1) Satellite Coordinate System (X, Y, Z)

This system is defined such that the X-axis is in the direction of the earth center-space craft center, the Y-axis is perpendicular to the X-axis and lies in the plane obtained from rotating X-axis with spacecraft, and the Z-axis given by $\hat{Z} = \hat{X} \times \hat{Y}$. This system is illustrated in Fig. 1 (left side).

2) Earth Coordinate System (x, y, z)

This is defined such that the minus x-axis is in the direction of 140°E (nominal position of the GMS) and lies in the equatorial plane, the z-axis is perpendicular to this plane (in the direction of the north pole), and the y-axis is given by $\hat{y} = \hat{z} \times \hat{x}$. This is well-known as the inertial coordinate system when the direction of x-axis is in the vernal equinox, as illustrated in Fig. 1 (right side).

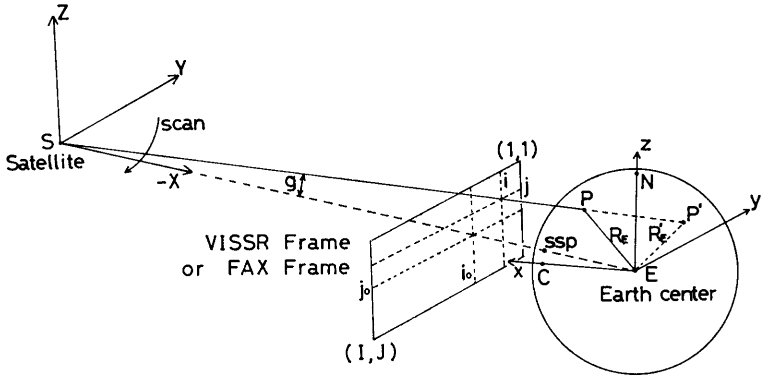

Fig. 1 Illustration of various coordinate system.

2) VISSR Frame Coordinate System (I, J)

This is defined such that the origin of this system is in the center of VISSR frame, the I-axis is in the direction of scanning and the J-axis is in the VISSR stepping direction, as shown in Fig. 1. The I-axis is perpendicular to the J-axis. The values of I and J are generally called a line number and a pixel number respectively when the origin is positioned at the upper left corner of the VISSR frame.

2. 2 Mapping Equation

Throughout this report, the abbreviation s, e, p are used to denote space-craft, earth, position of the point of interest which is located on the earth, as illustrated in Fig. 1.

The following assumptions are made in the present model.

1) The attitude of space-craft is nearly constant during VISSR observation period, and may then be assinged a nominal attitude to an actual attitude.

2) The spin rate is constant during VISSR observation period.

3) The difference between scan line, pixel number defined from the VISSR coordinate system and those expressed in the satellite coordinate system is negligible.

4) The shape of earth is a perfect sphere.

Following vectors, Vse, Vsp, Vep are defined.

$$Vse = \begin{pmatrix} Xs \\ Ys \\ Zs \end{pmatrix} = Rse \cdot \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \tag{1}$$

$$Vsp = \begin{pmatrix} Xp \\ Yp \\ Zp \end{pmatrix} = R \cdot \begin{pmatrix} \cos q(J_0 - Jp) \cdot \cos p(I_0 - Ip) \\ \cos q(J_0 - Jp) \cdot \sin p(I_0 - Ip) \\ \sin q(J_0 - Jp) \end{pmatrix} \tag{2}$$

$$Vep = \begin{pmatrix} xe \\ ye \\ ze \end{pmatrix} = Re \cdot \begin{pmatrix} -\cos\varphi \cdot \cos(\lambda_0 - \lambda) \\ \cos\varphi \cdot \cos(\lambda_0 - \lambda) \\ \sin\varphi \end{pmatrix} \tag{3}$$

where,

Rse: distance between space-craft and earth.

Re: averaged earth radius.

R: distance between space-craft and interest point on the earth.

q: stepping angle.

p: sampling angle.

J_0: line number associated to the SSP.

I_0: pixel number associated to the SSP.

λ_0: direction of the minus X-axis (140°E).

Jp: line number associated to the point of interest.

Ip: pixel number associated to the point of interest.
φ: latitude of the point interest.
λ: longitude of the point of interest.

The transformation matrix $[M]$ from earth coordinate system to satellite coordinate system is defined by the following equation

$$[M]\times Vep=Vsp-Vse \tag{4}$$

The transformation matrix $[M]$ is a function of orbital elements, space-craft specifications etc. Instead of estimating $[M]$ from these factors exactly, it is possible that, for simplifications, $[M]$ may then be derived from limitted input data described in Section 1. Such simplifications will lead to increased efficiency of the mapping process without affecting the accuracy.

Consider a small quadrangle to be mapped which is surrounded by four points P_1, P_2, P_3, P_4, they can be designated arbitrarily on the earth. The vectors related to these points are given by

$$Vep_i=\begin{pmatrix} xe_i \\ ye_i \\ ze_i \end{pmatrix}=\begin{pmatrix} -Re\cdot\cos\varphi_i\cdot\cos(\lambda_0-\lambda_i) \\ Re\cdot\cos\varphi_i\cdot\sin(\lambda_0-\lambda_i) \\ Re\cdot\sin\varphi_i \end{pmatrix} \tag{5}$$

$$(i=1,\ 2,\ 3,\ 4)$$

$$Vsp_i-Vse=\begin{pmatrix} X'p_i \\ Y'p_i \\ Z'p_i \end{pmatrix}$$

$$=\begin{pmatrix} R\cdot\cos q(J_0-Jp_i)\cdot\cos p(I_0-Ip_i)-Rs \\ R\cdot\cos q(J_0-Jp_i)\cdot\sin p(I_0-Ip_i) \\ R\cdot\sin q(J_0-Jp_i) \end{pmatrix} \tag{6}$$

$$(i=1,\ 2,\ 3,\ 4)$$

Consequently, it may be shown that the above equations (4), (5) and (6) yield the following result.

$$[M]\times\begin{pmatrix} xe_1 & xe_2 & xe_3 & xe_4 \\ ye_1 & ye_2 & ye_3 & ye_4 \\ ze_1 & ze_2 & ze_3 & ze_4 \end{pmatrix}$$

$$=\begin{pmatrix} X'p_1 & X'p_2 & X'p_3 & X'p_4 \\ Y'p_1 & Y'p_2 & Y'p_3 & Y'p_4 \\ Z'p_1 & Y'p_2 & Z'p_3 & Z'p_4 \end{pmatrix} \tag{7}$$

For convenience, above equation is symbollically written as

$$[M]\times[Ve]=[Vs] \tag{8}$$

The transformation matrix $[M]$ can be derived following equation, from equation (8).

$$[M]=[Vs]\times[Ve]^t\times([Ve]\times[Ve]^t) \tag{9}$$

where, t denotes the inverse matrix.

Finally, it remains to obtain R which appears in the equation (2), (6). R can be expressed simply by the trigonometry formula, applying to the triangle SEP as illustrated in Fig. 1.

$$Re^2=Rs^2+R^2-2Rs\cdot R\cdot\cos g \tag{10}$$

where,

$$\cos g=(Vse,\ Vsp)/|Vse|\cdot|Vsp|$$
$$=\cos q(J_0-Jp)\cdot\cos p(I_0-Ip) \tag{11}$$

Then, it is obvious that

$$R=Rs\cdot\cos g\pm\sqrt{Rs^2\cdot\cos^2 g-(Rs^2-Re^2)} \tag{12}$$

The equation (12) yields two solutions, it follows that the desired solution is

$$R=Rs\cdot\cos g-\sqrt{R_s^2\cdot\cos^2 g-(Rs^2-Re^2)} \tag{13}$$

2. 3 Mapping Procedure

The transformation from earth coordinate system to VISSR frame coordinate system, and its inverse transformation are described. Both transformation are frequently occured to the user who plans to handle the image data using the VISSR image data displays or the raw digital image data.

Let considers the small quadrangle previously defined in Section 2.2. The transformation matrix [M] can be estimated from equation (9) based on the locations of four corners related to small quadrangle.

1) Transformation from Earth Coordinate System to VISSR Coordinate System

The point of interest located on the earth is expressed by a pair of longitude-latitude values (λ, φ). Those points within the small quadrangle are transformed to the VISSR frame coordinate system. The computations for accomplishing this are given by equation (4), it is obvious that

$$\begin{pmatrix} X'p \\ Y'p \\ Z'p \end{pmatrix} = [M] \times \begin{pmatrix} -Re\cdot\cos\varphi\cdot\cos(\lambda_0-\lambda) \\ Re\cdot\cos\varphi\cdot\sin(\lambda_0-\lambda) \\ Re\cdot\sin\varphi \end{pmatrix} \quad (14)$$

Knowing Xp', Yp', Zp', the pair of line number (Ip)/pixel number (Jp) corresponding to (λ, φ) are derived from following equation

$$Ip = I_0-(Yp'/(R\cdot\cos(\sin^{-1}Zp'/R'))/p \quad (15)$$

$$Jp = I_0-(\sin^{-1}(Zp'/R'))/q \quad (16)$$

where,

$$R'=\sqrt{(Xp'+Rs)^2+Yp'^2+Zp'^2} \quad (17)$$

2) Transformation from VISSR Frame Coordinate System to Earth Coordinate System

It may be preferable to apply the transformation to selected data set of fairly well-known points which are expressed by the VISSR frame coordinate system (I, J). Knowing the values of line-pixel number corresponding to four points, the following equations are derived

$$\begin{pmatrix} xe \\ ye \\ ze \end{pmatrix} = [M]^{-1} \times$$

$$\begin{pmatrix} R\cdot\cos q(J_0-Jp)\cdot\cos p(I_0-Ip)-Rs \\ R\cdot\cos q(J_0-Jp)\cdot\sin p(I_0-Ip) \\ R\cdot\sin q(J_0-Jp) \end{pmatrix} \quad (18)$$

where,

$$R=Rs\cdot\cos g-\sqrt{Rs^2\cdot\cos g-(Rs^2-Re^2)} \quad (19)$$

$$\cos g=\cos q(J_0-Jp)\cdot\cos p(I_0-Ip) \quad (20)$$

Finally, the longitude-latitude values corresponding to I and J are given by

$$\varphi=\sin^{-1}(ze/Re') \quad (21)$$

$$\lambda=\lambda_0-ye/Re'\cdot\cos(\sin^{-1}(ze/Re')) \quad (22)$$

where,

$$Re'=\sqrt{xe^2+ye^2+ze^2} \quad (23)$$

3. Verification

The exact mapping model concerned with a general derivation of (φ, λ)$-$(I, J) relation has been developed for operational purposes at the Meteorological Satellite Center(MSC). An effective way to validate the present model is to calculate a difference between estimates derived from the exact mapping model and those from the present model.

The differences expressed in visible channel pixel are shown in Tables 2, 3 and 4. Throughout in these Tables, VISSR observation time and previously defined constants I_0, J_0, Re, Rs, q, p are summarized at the top of tables. The location of designated four points for calculating the transformation matrix [M] is also shown in the middle of table. The figures appearing in upper portion of table indicate the

Table 2 Differences between the present model and the exact mapping model. The quadrangle for estimating the transformation matrix is located at a high latitude region (northern hemisphere).

VISSR TIME = 1978 : 04 : 06 : 23 : 33 :

USED CONSTANT PARAMETERS

```
JO   =        5092(LINE)          IO   =        6571(PIXEL)
RE   = .637028949E+07(M)          RS   = .422702899E+08(M)
Q    = .350000000E-04(RAD.)       P    = .239748001E-04(RAD.)
```

PHAI / LAMBDA	100.0	101.0	102.0	103.0	104.0	105.0	106.0	107.0	108.0	109.0	110.0
40.0	0.3-0.0	0.3-0.1	0.3-0.1	0.3-0.2	0.3-0.2	0.3-0.3	0.3-0.3	0.3-0.3	0.3-0.3	0.4-0.2	0.4-0.2
39.0	0.2 0.0	0.2-0.1	0.2-0.1	0.3-0.2	0.3-0.2	0.3-0.2	0.3-0.3	0.3-0.3	0.3-0.3	0.4-0.3	0.4-0.2
38.0	0.2 0.0	0.2-0.0	0.2-0.1	0.2-0.2	0.2-0.2	0.3-0.2	0.3-0.3	0.3-0.3	0.3-0.3	0.3-0.3	0.4-0.2
37.0	0.1 0.1	0.1-0.0	0.2-0.1	0.2-0.2	0.2-0.2	0.2-0.2	0.3-0.3	0.3-0.3	0.3-0.3	0.3-0.3	0.4-0.3
36.0	0.0 0.1	0.1 0.0	0.1-0.1	0.1-0.1	0.2-0.2	0.2-0.2	0.2-0.3	0.3-0.3	0.3-0.3	0.3-0.3	0.4-0.3
35.0	-0.0 0.1	0.0 0.0	0.1-0.1	0.1-0.1	0.1-0.2	0.2-0.3	0.2-0.3	0.2-0.3	0.3-0.3	0.3-0.3	0.3-0.3
34.0	-0.1 0.1	-0.1 0.0	-0.0-0.1	0.0-0.1	0.1-0.2	0.1-0.3	0.2-0.3	0.2-0.3	0.3-0.3	0.3-0.3	0.3-0.3
33.0	-0.2 0.1	-0.1 0.0	-0.1-0.1	-0.0-0.2	0.0-0.2	0.1-0.3	0.1-0.3	0.2-0.4	0.2-0.4	0.3-0.4	0.3-0.4
32.0	-0.3 0.1	-0.2 0.0	-0.1-0.1	-0.1-0.2	-0.0-0.2	0.0-0.3	0.1-0.3	0.1-0.4	0.2-0.4	0.3-0.4	0.3-0.4
31.0	-0.3 0.1	-0.3 0.0	-0.2-0.1	-0.1-0.2	-0.1-0.3	-0.0-0.3	0.0-0.4	0.1-0.4	0.2-0.4	0.2-0.4	0.3-0.4
30.0	-0.4 0.1	-0.3 0.0	-0.3-0.1	-0.2-0.2	-0.1-0.3	-0.1-0.3	-0.0-0.4	0.1-0.4	0.1-0.5	0.2-0.5	0.3-0.5

(UNIT ; LINE AND PIXEL FOR VIS.)

FOUR SELECTED POINTS (PHAI LAMBDA)---(LINE PIXEL)

```
( 40.0   100.0)---(  2099   3270)      ( 40.0   110.0)---(  2061   3988)
( 30.0   100.0)---(  2745   2748)      ( 30.0   110.0)---(  2711   3562)
```

LINE / PIXEL	2748	2873	2998	3123	3248	3373	3498	3623	3748	3873	3998
2061	99.999.9	99.999.9	99.999.9	4.9-9.3	3.1-5.3	1.8-2.4	0.8-0.5	-0.0 0.8	-0.6 1.6	-1.0 2.1	-1.3 2.2
2130	99.999.9	99.999.9	4.7-9.8	3.1-5.7	1.8-2.8	0.9-0.9	0.2 0.4	-0.3 1.1	-0.6 1.6	-0.8 1.7	-0.9 1.7
2199	99.999.9	99.999.9	3.0-6.0	1.8-3.2	0.9-1.2	0.3 0.0	-0.1 0.8	-0.3 1.2	-0.5 1.3	-0.5 1.3	-0.4 1.1
2268	99.999.9	2.8-6.4	1.7-3.4	0.9-1.4	0.3-0.2	-0.0 0.6	-0.2 1.0	-0.2 1.1	-0.2 1.0	-0.0 0.7	0.2 0.4
2337	2.5-6.6	1.5-3.6	0.7-1.5	0.2-0.3	-0.1 0.5	-0.2 0.8	-0.2 0.9	-0.0 0.8	0.2 0.5	0.5 0.1	0.9-0.3
2406	1.2-3.6	0.5-1.5	0.0-0.2	-0.2 0.5	-0.3 0.8	-0.2 0.9	-0.0 0.7	0.3 0.4	0.6 0.0	1.0-0.5	1.5-1.0
2475	0.2-1.5	-0.2-0.1	-0.4 0.6	-0.5 1.0	-0.4 1.0	-0.1 0.8	0.2 0.4	0.6-0.0	1.1-0.6	1.6-1.1	2.2-1.7
2544	-0.6 0.1	-0.8 0.9	-0.7 1.2	-0.6 1.2	-0.3 0.9	0.0 0.5	0.5 0.0	1.0-0.5	1.6-1.1	2.2-1.8	2.8-2.4
2613	-1.1 1.3	-1.1 1.6	-0.9 1.5	-0.6 1.2	-0.2 0.8	0.3 0.2	0.8-0.4	1.4-1.1	2.1-1.7	2.8-2.4	3.5-3.1
2682	-1.5 2.0	-1.3 2.0	-1.0 1.7	-0.6 1.2	-0.1 0.6	0.5-0.1	1.2-0.9	1.9-1.6	2.6-2.4	3.4-3.1	4.1-3.8
2751	-1.8 2.6	-1.4 2.2	-1.0 1.7	-0.5 1.0	0.2 0.3	0.8-0.5	1.6-1.4	2.3-2.2	3.1-3.0	3.9-3.7	4.8-4.4

(UNIT ; 1/100 DEGREE PHAI LAMBDA)

Table 3 Same as Table 1, except for the quadrangle is located at a low latitude region.

VISSR TIME = 1979 : 04 : 09 : 11 : 33 :

USED CONSTANT PARAMETERS

```
JO   =        5158(LINE)          IO   =        6634(PIXEL)
RE   = .637028949E+07(M)          RS   = .422702899E+08(M)
Q    = .349861829E-04(RAD.)       P    = .239748001E-04(RAD.)
```

PHAI / LAMBDA	140.0	141.0	142.0	143.0	144.0	145.0	146.0	147.0	148.0	149.0	150.0
10.0	-0.1-0.0	-0.1-0.0	-0.1 0.0	-0.1 0.0	-0.1 0.0	-0.1 0.1	-0.1 0.1	-0.1 0.1	-0.1 0.1	-0.1 0.2	-0.0 0.2
9.0	-0.1-0.1	-0.1-0.0	-0.1-0.0	-0.1 0.0	-0.1 0.0	-0.1 0.0	-0.1 0.1	-0.1 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1
8.0	-0.1-0.1	-0.1-0.1	-0.1-0.0	-0.1-0.0	-0.1-0.0	-0.1 0.0	-0.0 0.0	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1
7.0	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.0	-0.1-0.0	-0.0-0.0	-0.0 0.0	-0.0 0.0	-0.0 0.0	-0.0 0.1	0.0 0.1
6.0	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.0-0.1	-0.0-0.0	-0.0-0.0	-0.0-0.0	-0.0 0.0	-0.0 0.0	0.0 0.0
5.0	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.0	-0.0-0.0	0.0-0.0	0.0-0.0
4.0	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	0.0-0.0	0.0-0.0
3.0	-0.1-0.2	-0.1-0.2	-0.1-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	0.0-0.1	0.0-0.1
2.0	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.0-0.2	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1	0.0-0.1	0.0-0.1
1.0	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.0-0.2	-0.0-0.2	-0.0-0.2	-0.0-0.1	-0.0-0.1	-0.0-0.1	0.0-0.1	0.0-0.1
0.0	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.0-0.2	-0.0-0.2	-0.0-0.2	-0.0-0.2	-0.0-0.1	-0.0-0.1	0.0-0.1

(UNIT ; LINE AND PIXEL FOR VIS.)

FOUR SELECTED POINTS (PHAI LAMBDA)---(LINE PIXEL)

```
( 10.0   140.0)---(  4284   6610)      ( 10.0   150.0)---(  4288   7874)
(  0.0   140.0)---(  5160   6607)      (  0.0   150.0)---(  5162   7895)
```

LINE / PIXEL	6607	6736	6865	6994	7123	7252	7381	7510	7639	7768	7897
4284	-0.2 0.0	-0.1 0.0	-0.1 0.0	-0.1-0.0	-0.1-0.0	-0.1-0.0	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.2
4372	-0.1 0.0	-0.1 0.0	-0.1 0.0	-0.1 0.0	-0.1-0.0	-0.1-0.0	-0.0-0.0	-0.0-0.1	-0.0-0.1	-0.0-0.1	-0.0-0.1
4460	-0.1 0.1	-0.1 0.0	-0.1 0.0	-0.1 0.0	-0.1 0.0	-0.0-0.0	-0.0-0.0	-0.0-0.0	-0.0-0.0	-0.0-0.1	-0.0-0.1
4548	-0.1 0.1	-0.1 0.1	-0.1 0.0	-0.1 0.0	-0.0 0.0	-0.0 0.0	-0.0 0.0	-0.0-0.0	-0.0-0.0	-0.0-0.0	-0.0-0.1
4636	-0.1 0.1	-0.1 0.1	-0.1 0.1	-0.1 0.1	-0.0 0.0	-0.0 0.0	-0.0 0.0	-0.0 0.0	-0.0 0.0	-0.0-0.0	0.0-0.0
4724	-0.1 0.1	-0.1 0.1	-0.1 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.0	0.0 0.0	0.0 0.0	0.0-0.0
4812	-0.1 0.1	-0.1 0.1	-0.1 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	0.0 0.1	0.0 0.0	0.0 0.0
4900	-0.1 0.1	-0.1 0.1	-0.1 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	0.0 0.1	0.0 0.1	0.0 0.0
4988	-0.1 0.1	-0.1 0.1	-0.1 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	0.0 0.1	0.0 0.1
5076	-0.1 0.2	-0.1 0.1	-0.1 0.1	-0.1 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	-0.0 0.1	0.0 0.1	0.0 0.1
5164	-0.1 0.2	-0.1 0.2	-0.1 0.2	-0.1 0.2	-0.1 0.2	-0.0-0.2	-0.0 0.2	-0.0 0.1	-0.0 0.1	-0.0 0.1	0.0 0.1

(UNIT ; 1/100 DEGREE PHAI LAMBDA)

Table 4 Same as Table 1, except for the quadrangle is located at a high latitude region (southern hemisphere).

VISSR TIME = 1979 : 04 : 09 : 11 : 33 :

USED CONSTANT PARAMETERS

JO =	5158(LINE)	IO =	6634(PIXEL)
RE =	.637028949E+07(M)	RS =	.422702899E+08(M)
Ω =	.349861829E-04(RAD.)	P =	.239748001E-04(RAD.)

PHAI / LAMBDA	100.0	101.0	102.0	103.0	104.0	105.0	106.0	107.0	108.0	109.0	110.0
-30.0	0.2-0.3	0.2-0.3	0.2-0.4	0.3-0.4	0.3-0.4	0.3-0.5	0.3-0.5	0.3-0.5	0.3-0.5	0.3-0.6	0.4-0.6
-31.0	0.1-0.3	0.1-0.3	0.2-0.3	0.2-0.4	0.2-0.4	0.2-0.4	0.2-0.5	0.2-0.5	0.3-0.5	0.3-0.5	0.3-0.6
-32.0	0.0-0.3	0.1-0.3	0.1-0.3	0.1-0.3	0.1-0.4	0.1-0.4	0.2-0.4	0.2-0.4	0.2-0.5	0.2-0.5	0.2-0.5
-33.0	-0.0-0.3	-0.0-0.3	0.0-0.3	0.0-0.3	0.1-0.3	0.1-0.4	0.1-0.4	0.1-0.4	0.1-0.4	0.1-0.4	0.1-0.5
-34.0	-0.1-0.2	-0.1-0.3	-0.0-0.3	-0.0-0.3	0.0-0.3	0.0-0.3	0.0-0.3	0.1-0.3	0.1-0.3	0.1-0.3	0.1-0.3
-35.0	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.0-0.2	-0.0-0.2	-0.0-0.2	0.0-0.3	0.0-0.3	0.0-0.3	0.0-0.3
-36.0	-0.2-0.1	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.0-0.2	-0.0-0.2	-0.0-0.2	-0.0-0.2	-0.0-0.2
-37.0	-0.2-0.1	-0.2-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.1-0.2	-0.1-0.2
-38.0	-0.2-0.1	-0.2-0.1	-0.2-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1
-39.0	-0.2-0.1	-0.2-0.1	-0.2-0.1	-0.2-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.1	-0.1-0.0
-40.0	-0.2-0.0	-0.2-0.0	-0.2-0.0	-0.2-0.0	-0.2-0.0	-0.1-0.0	-0.1-0.0	-0.1-0.0	-0.1 0.0	-0.1 0.0	-0.1 0.0

(UNIT ; LINE AND PIXEL FOR VIS.)

FOUR SELECTED POINTS (PHAI LAMBDA)---(LINE PIXEL)

(-30.0 100.0)---(7526 2718) (-30.0 110.0)---(7566 3532)
(-40.0 100.0)---(8166 3207) (-40.0 110.0)---(8210 3925)

LINE / PIXEL	2718	2839	2960	3081	3202	3323	3444	3565	3686	3807	3928
7526	0.3 0.5	0.2 0.4	0.3 0.4	0.3 0.5	0.4 0.6	0.5 0.7	0.6 0.9	0.7 1.1	0.9 1.3	1.1 1.5	1.2 1.7
7595	0.2 0.5	0.1 0.4	0.1 0.3	0.2 0.4	0.2 0.5	0.3 0.6	0.4 0.8	0.6 0.9	0.7 1.1	0.9 1.3	1.0 1.5
7664	0.1 0.5	0.0 0.3	0.0 0.3	0.0 0.3	0.1 0.3	0.2 0.4	0.3 0.6	0.4 0.8	0.5 1.0	0.7 1.2	0.9 1.4
7733	0.1 0.6	-0.0 0.3	-0.1 0.2	-0.1 0.2	-0.1 0.2	0.0 0.3	0.1 0.4	0.2 0.6	0.4 0.8	0.5 1.0	0.7 1.2
7802	0.1 0.7	-0.1 0.4	-0.2 0.2	-0.2 0.1	-0.2 0.1	-0.1 0.1	-0.0 0.3	0.1 0.4	0.2 0.6	0.3 0.8	0.5 1.0
7871	0.1 0.8	-0.1 0.3	-0.2 0.1	-0.3-0.1	-0.3-0.1	-0.2-0.1	-0.2 0.0	-0.1 0.2	0.0 0.3	0.2 0.5	0.4 0.7
7940	0.2 1.1	-0.1 0.5	-0.2 0.1	-0.3-0.1	-0.3-0.2	-0.3-0.2	-0.3-0.1	-0.2 0.0	-0.1 0.2	0.0 0.3	0.2 0.5
8009	0.3 1.6	0.0 0.7	-0.2 0.2	-0.3-0.1	-0.4-0.2	-0.4-0.3	-0.4-0.2	-0.3-0.1	-0.2-0.0	-0.1 0.2	0.0 0.3
8078	0.6 2.2	0.2 1.1	-0.1 0.4	-0.3-0.3	-0.4-0.3	-0.5-0.4	-0.5-0.4	-0.4-0.3	-0.3-0.2	-0.2-0.0	-0.1 0.1
8147	0.9 3.2	0.4 1.7	0.1 0.8	-0.2 0.2	-0.4-0.2	-0.5-0.4	-0.5-0.5	-0.5-0.4	-0.4-0.4	-0.3-0.2	-0.2-0.1
8216	1.5 4.7	0.8 2.6	0.3 1.3	-0.0 0.5	-0.3-0.1	-0.4-0.4	-0.5-0.5	-0.5-0.6	-0.5-0.5	-0.4-0.4	-0.3-0.3

(UNIT ; 1/100 DEGREE PHAI LAMBDA)

difference of estimates obtained from both models, applying the conversion from (I, J) into (φ, λ). Those in lower portion are the difference of estimates in the case of conversion (φ, λ) into (I, J). The differences ranging 9.9 from -9.8 are replaced to 99.9. -9.9 is set where the point of interest is located at the deep space area. The frame appearing in lower portion illustrates the area to be converted.

The result shows that the difference is less than 0.6 pixel (or line) unit within the area of interest and its vicinity. 0.6 pixel is equivalent to 0.2 infrared pixel.

4. Conclusion and Remarks

The mapping equations are optimized as much as possible and reduced to simplest forms. Such simplifications will lead to increased efficiency of the mapping process.

From the foregoing discussion, it is seen that the present model approximates the exact mapping model with justifiable accuracy. If the satellite data producer provides previously defined six constants and a table involving $(\varphi, \lambda)-(I, J)$ relation every 10 deg. longitude/latitude intervals, the model allows the user to perform the coordinate transformation without detailed information on orbital elements, misalignments, etc.

References

F.K. Chan (1978): Distortion-Free Mapping of VISSR Imagery Data from Geosynchronous Satellites. National Environmental Satellite Service, Under Contract No. 01-3-M01-1864.