

A QUADRILATERALIZED SPHERICAL  
CUBE EARTH DATA BASE

F. K. Chan  
Systems and Applied Sciences Corporation  
6811 Kenilworth Avenue Suite 500  
Riverdale, Maryland 20840

ABSTRACT

A Quadrilateralized Spherical Cube has been constructed to form the basis for the rapid storage and retrieval of high resolution data obtained of the earth's surface. The structure of this data base is derived from a spherical cube, which is obtained by radially projecting a cube onto its circumscribing sphere. An appropriate set of curvilinear coordinates is chosen such that the resolution calls on the spherical cube are of equal area and are also of essentially the same shape.

The main properties of the earth data base are that the indexing scheme is binary and telescopic in nature, the resolution cells are strung together in a two-dimensional manner, the cell addresses are easily computed, and the conversion from geographic to data base coordinates is comparatively simple.

Based on numerical results obtained, it is concluded that this data base structure is perhaps the most viable one for handling remotely-sensed data obtained by satellites. It can be used either as a data base for individual satellites or as a composite one for multiple satellites.

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## SECTION 1 - INTRODUCTION

In the numerous satellites presently orbiting the Earth, enormous amounts of data are continuously taken of the Earth's surface and atmosphere. These data are of a varied nature: topography, crop distribution, sea surface temperature, cloud coverage, etc. The measurements are used by research and applications personnel of diverse scientific disciplines. These users usually employ an Earth-oriented coordinate system, such as the traditional geographic frame of reference. Thus, it is not surprising that almost all existing Earth data bases have been constructed with latitudes and longitudes as grid-lines, either in a patched-up partial fashion or in the entire outlay.

However, what is convenient to the user is not necessarily also efficient from the standpoint of data management and data processing by the computer. Efficiency is especially important because of the large amounts of data rapidly acquired in global coverage, the necessity to update data continually for operational use, and the desire to access directly relatively small amounts of data corresponding to selected geographic regions at appropriate times.

The high computer overhead encountered in processing can therefore be minimized by designing an Earth data base structure with constant (but selectable) geometric resolution cells, which are also locally invariant in shape along a translation in any direction. This would eliminate the necessity to account for nonequal-area resolution cells, and also the need to compute the location of every resolution cell in the data base. Moreover, the design should also utilize a fairly simple transformation between the user-preferred geographic coordinates and the internal data base coordinates. This would greatly facilitate arithmetic and transfer operations desired by the user in mathematical computations or in graphic display.

The Quadrilateralized Spherical Cube<sup>(1)</sup> or the Chan Projection was especially constructed to form the basis for an earth data base of remotely-sensed satellite data. In this model, the sphere is visualized as a spherical cube, as illustrated in Figure 1-1. This spherical cube is obtained by radially projecting the edges of an inscribed cube, as shown in Figure 1-2.

From Figure 1-2, it is obvious that equal-area elements on the plane square do not radially project as equal-area elements on the spherical square. For example, those elements near the center of the plane square have larger projections than those elements near the edges of the plane square. Hence, if a rectangular grid of equal-area elements is first constructed on the plane square, it is then necessary to distort this grid into a curvilinear network so that the elements near the center are smaller than those near the edges. The distortion is such that when the curvilinear elements are projected radially, equal-area elements are again obtained on the spherical square. The desired sequence of transformations is illustrated in Figure 1-3 through 1-5. The mathematical details of deriving these transformations are discussed in Section 2.

For the present, it suffices to say that it is possible to obtain a world map such as Figure 1-6. This map illustrates the continental outlines as they would appear on the cube with the original undistorted rectangular coordinates. This is accomplished by reversing the sequence of transformations previously illustrated by Figures 1-3 through 1-5. Thus, in Figure 1-6, equal-area regions correspond to equal-area regions on the spherical Earth. An examination of this planar equal-area world map shows that the distortion of the continental outlines is not as great as might be expected.

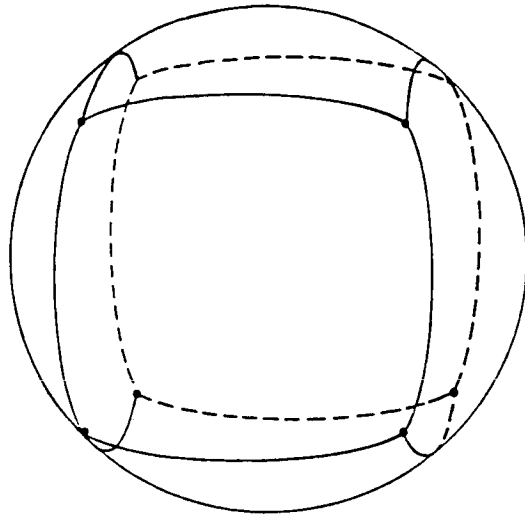


Figure 1-1. Spherical Cube

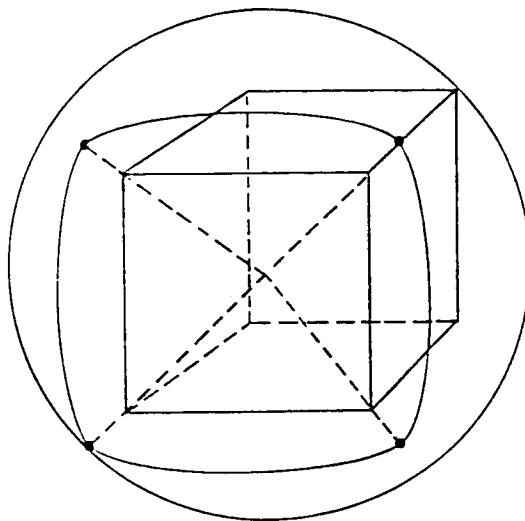


Figure 1-2. Construction of the Spherical Cube

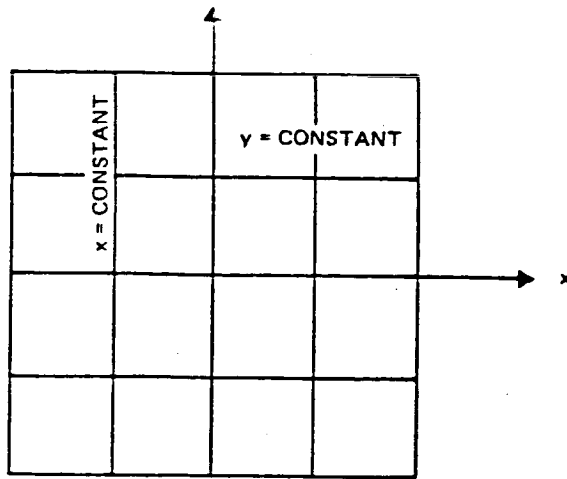


Figure 1-3. Plane Square With Cartesian Coordinates

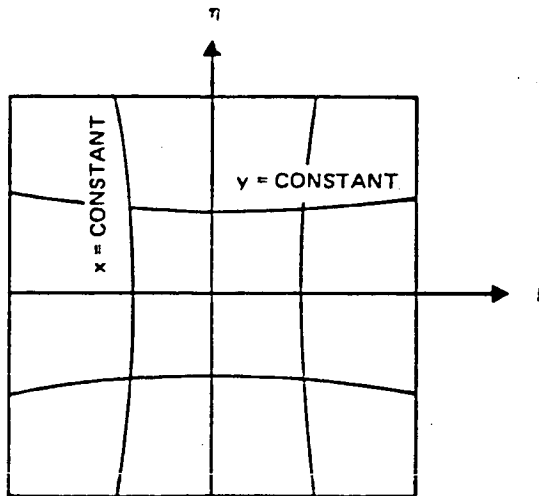


Figure 1-4. Plane Square With Curvilinear Coordinates

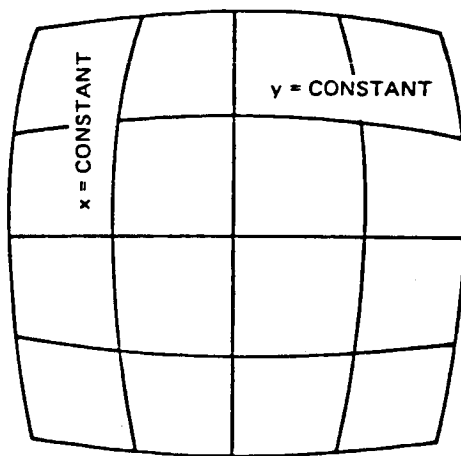


Figure 1-5. Spherical Square With Curvilinear Coordinates

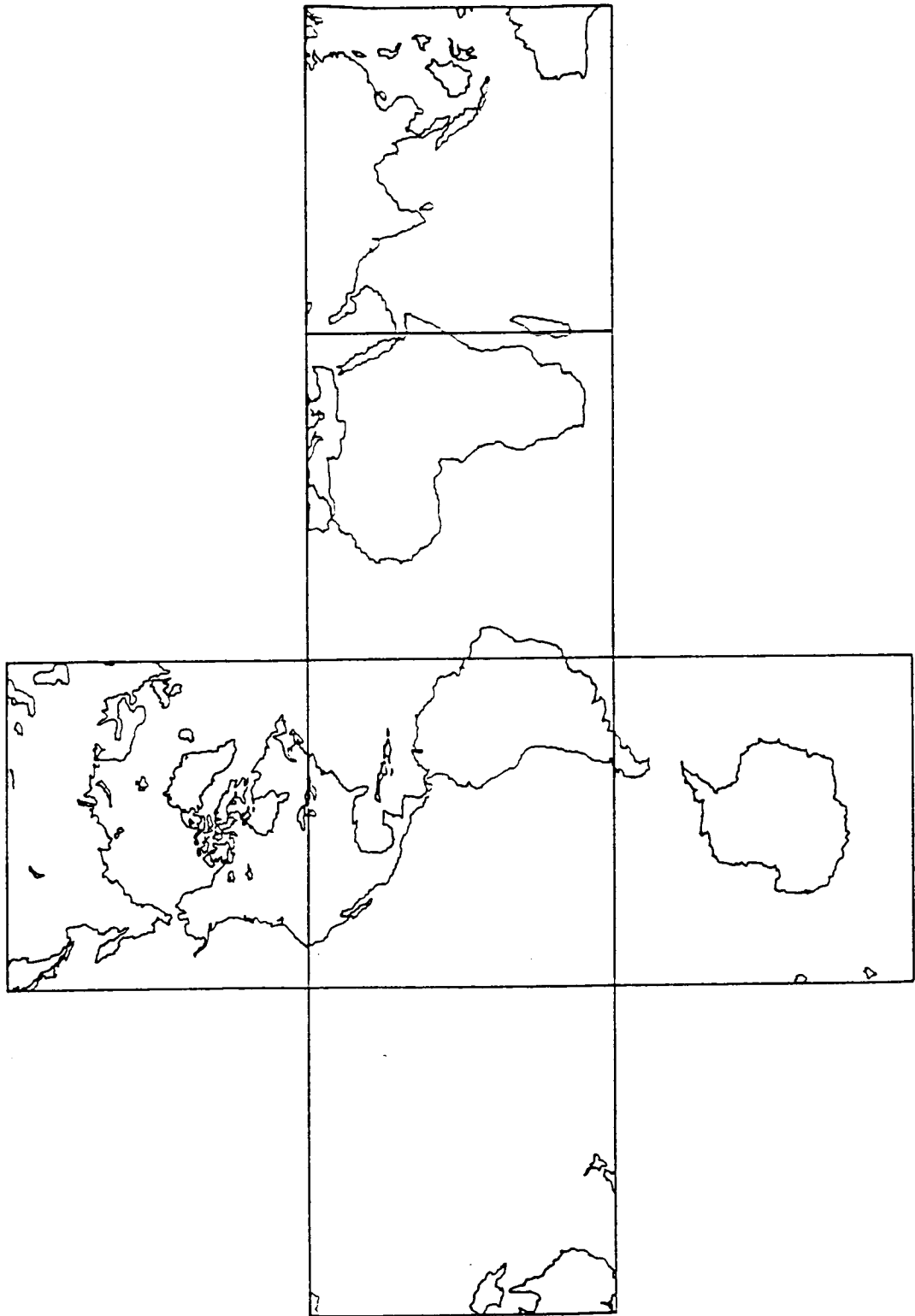


Figure 1-6. World Map on Equal-Area Cube

SECTION 2 - MATHEMATICAL FORMULATION OF  
DATA BASE STRUCTURE

DERIVATION OF DIRECT MAPPING FUNCTION

First, consider a plane surface subtended by a spherical surface with radius  $R$ . Let  $\vec{r}_0$  be the vector from the center of the sphere to the given plane. As shown in Figure 2-1, let  $dA_p$  be an area element on this plane, and let  $\vec{r}$  be the vector from the center of the sphere to the area element  $dA_p$ .

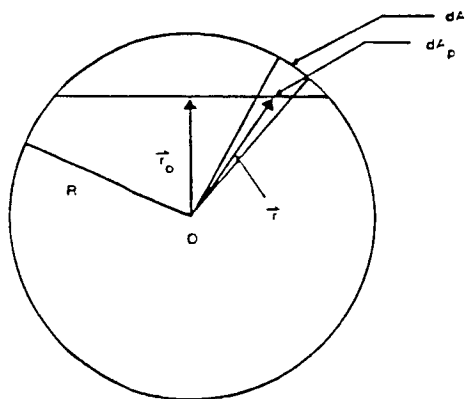


Figure 2-1. Relation Between Plane and Spherical Area Elements

Let  $dA_s$  be the spherical area element obtained by projecting  $dA_p$  radially onto the sphere. Then, it can be readily shown that the following relation between  $dA_p$  and  $dA_s$  holds:

$$dA_s = \frac{R^2 \cos^3 (\vec{r}, \vec{r}_0)}{r_o^2} dA_p \quad (2-1)$$

where  $(\vec{r}, \vec{r}_0)$  denotes the angle between  $\vec{r}$  and  $\vec{r}_0$ .

Let  $(\xi, \eta, r_0)$  denote the components of the vector  $\vec{r}$ . Then, it follows that

$$\cos(\vec{r}, \vec{r}_0) = \frac{r_0}{r} = \frac{r_0}{(r_0^2 + \xi^2 + \eta^2)^{1/2}} \quad (2-2)$$

Moreover, for convenience, let the unit of length be chosen such that the radius,  $R$ , of the sphere is equal to unity. Then, Equations (2-1) and (2-2) yield

$$dA_s = \frac{r_0}{(r_0^2 + \xi^2 + \eta^2)^{3/2}} dA_p \quad (2-3)$$

Next, consider a cube together with a circumscribing spherical surface. On each of the six plane faces of the cube, a rectangular coordinate system  $(x, y)$  may be defined, the domain of definition being  $-r_0 \leq x, y \leq r_0$ . It may be easily verified that

$$r_0 = \frac{1}{\sqrt{3}} \quad (2-4)$$

Let a new coordinate system  $(\xi, \eta)$  be defined by

$$\begin{aligned} \xi &= \xi(x, y) \\ \eta &= \eta(x, y) \end{aligned} \quad (2-5)$$

where  $\xi(x, y)$  and  $\eta(x, y)$  are independent arbitrary functions.



The new area element  $d\xi d\eta$  is related to the original area element  $dx dy$  by

$$d\xi d\eta = J\left(\frac{\xi, \eta}{x, y}\right) dx dy \quad (2-6)$$

where  $J\left(\frac{\xi, \eta}{x, y}\right)$  is the Jacobian of transformation

$$J\left(\frac{\xi, \eta}{x, y}\right) = \begin{vmatrix} \frac{\partial \xi}{\partial x} & \frac{\partial \xi}{\partial y} \\ \frac{\partial \eta}{\partial x} & \frac{\partial \eta}{\partial y} \end{vmatrix} \quad (2-7)$$

If this new area element is projected radially onto the surface of the sphere, Equations (2-3) and (2-6) yield

$$dA_s = \frac{r_o}{\left(r_o^2 + \xi^2 + \eta^2\right)^{3/2}} J\left(\frac{\xi, \eta}{x, y}\right) dx dy \quad (2-8)$$

which relates the spherical area element  $dA_s$  to the original area element  $dx dy$ . For original equal-area plane elements  $dx dy$  to transform into equal-area spherical elements  $dA_s$ , it follows that

$$\frac{r_o}{\left(r_o^2 + \xi^2 + \eta^2\right)^{3/2}} J\left(\frac{\xi, \eta}{x, y}\right) = \lambda^2 \quad (2-9)$$

or

$$\frac{r_o}{(r_o^2 + \xi^2 + \eta^2)^{3/2}} \left( \frac{\partial \xi}{\partial x} \frac{\partial \eta}{\partial y} - \frac{\partial \xi}{\partial y} \frac{\partial \eta}{\partial x} \right) = \lambda^2 \quad (2-10)$$

where  $\lambda^2$  is a constant.

It is easy to verify that the value of  $\lambda^2$  is equal to the ratio of the area of the spherical square to the area of the plane square, i. e.,

$$\lambda^2 = \frac{2\pi/3}{4 r_o^2} = \frac{\pi}{2} \quad (2-11)$$

An alternative form of Equation (2-10) is

$$\frac{\partial \xi}{\partial x} \frac{\partial \eta}{\partial y} - \frac{\partial \xi}{\partial y} \frac{\partial \eta}{\partial x} = \gamma^2 \left( 1 + \frac{\xi^2}{r_o^2} + \frac{\eta^2}{r_o^2} \right)^{3/2} \quad (2-12)$$

where

$$\gamma^2 = r_o^2 \lambda^2 = \frac{\pi}{6} \quad (2-13)$$

From Equations (2-7) and (2-12), it is seen that  $\gamma^2$  may be interpreted as the area-scale of transformation at the point  $(\xi = 0, \eta = 0)$ .

Equation (2-12) in itself is quite general. It is now desirable to specify the following general properties for the transformation from  $(x, y)$  to  $(\xi, \eta)$ .

1. To preserve symmetry in the transformation Equation (2-5), it is required that

$$\begin{aligned}\xi &= f(x, y) \\ \eta &= f(y, x)\end{aligned}\tag{2-14}$$

Equation (2-14) states that  $\xi$  and  $\eta$  have exactly the same form of dependence on  $x$  and  $y$ , except that the roles of  $x$  and  $y$  are interchanged. Moreover, symmetry preservation also requires that the function  $f(x, y)$  be odd in  $x$  and even in  $y$ , i.e.,

$$\begin{aligned}f(-x, y) &= -f(x, y) \\ f(x, -y) &= f(x, y)\end{aligned}\tag{2-15}$$

As a consequence of Equations (2-14) and (2-15), it is seen that the origin maps back into itself, i.e.,

$$f(0, y) = 0\tag{2-16}$$

2. To map points on the sides of the square back into points on the same sides, it is necessary that

$$f(r_0, y) = r_0\tag{2-17}$$

As a consequence of all the above requirements, it may be shown that  $\frac{\partial \xi}{\partial y}$  and  $\frac{\partial \eta}{\partial x}$  are zero at the points  $(0, 0)$  and  $(r_0, r_0)$ . Therefore, from Equation (2-12), it follows that

$$\left. \frac{\partial \xi}{\partial x} \right|_{\substack{x=0 \\ y=0}} = \left. \frac{\partial \eta}{\partial y} \right|_{\substack{x=0 \\ y=0}} = \gamma = \sqrt{\frac{\pi}{6}} = 0.72360 \ 12545 \ 582 \quad (2-18)$$

$$\left. \frac{\partial \xi}{\partial x} \right|_{\substack{x=r_0 \\ y=r_0}} = \left. \frac{\partial \eta}{\partial y} \right|_{\substack{x=r_0 \\ y=r_0}} = \mu = \sqrt{\frac{\sqrt{3}\pi}{2}} = 1.6494 \ 54166 \ 187 \quad (2-19)$$

If  $f(x, y)$  can be expanded in a power series in  $x$  and  $y$ , then Equation (2-16) requires that

$$f(x, y) = x \sum_{i=0}^{\infty} \sum_{j=0}^{\infty} a_{ij} x^{2i} y^{2j} \quad (2-20)$$

The condition in Equation (2-18) yields

$$a_{00} = \gamma \quad (2-21)$$

The condition in Equation (2-17) may be incorporated into  $f(x, y)$  by writing it in the form

$$f(x, y) = \gamma x + \frac{(1-\gamma)}{r_0} x^3 + (r_0^2 - x^2) x \sum_{(i+j) \geq 1} b_{ij} x^{2i} y^{2j} \quad (2-22)$$

It may be shown that Equation (2-12), together with the conditions given by Equations (2-16) through (2-18), are not sufficient to determine uniquely the transformation in Equation (2-14). This nonuniqueness is manifested by the fact that there are more unknowns ( $b_{ij}$ ) than equations when Equation (2-22) is substituted into Equation (2-12) and terms of the same degree are equated. Finally, to incorporate the condition in Equation (2-19), it is most efficient to express  $f(x, y)$  in the following form. The details for arriving at this form are given in Reference 1.

$$\begin{aligned}
 f(x, y) = & \gamma x + \frac{(1-\gamma)}{r_o^2} x^3 \\
 & + xy^2 \left( r_o^2 - x^2 \right) \left[ \delta + \left( r_o^2 - y^2 \right) \sum_{\substack{i \geq 0 \\ j \geq 0}} c_{ij} x^{2i} y^{2j} \right] \\
 & + x^3 \left( r_o^2 - x^2 \right) \left[ \omega + \left( r_o^2 - x^2 \right) \sum_{i \geq 0} d_i x^{2i} \right]
 \end{aligned} \tag{2-23}$$

where

$$\delta = \frac{1}{4r_o^4} \left[ -(\mu + 2\gamma) + \sqrt{(\mu^2 - 4\mu\gamma + 4\gamma^2 + 16\sqrt{2}\gamma^2)} \right] \tag{2-24}$$

$$= 0.79048 \ 64491 \ 208$$

$$\omega = \frac{1}{2r_o^4} \left( 3 - 2\gamma - \mu - 2r_o^4 \delta \right) \tag{2-25}$$

$$= - 1.2254 \ 41487 \ 984$$

An approximate mapping function may be obtained by truncating the series expansion in Equation (2-23) at some degree, and then obtaining the coefficients  $c_{ij}$  and  $d_i$  which minimize the following residual function:

$$\phi(c_{ij}, d_i) \equiv \int_{-r_0}^{r_0} \int_{-r_0}^{r_0} \left[ r_0^{-2} \left( 1 + \frac{\xi^2}{r_0^2} + \frac{\eta^2}{r_0^2} \right)^{-3/2} \times \left( \frac{\partial \xi}{\partial x} \frac{\partial \eta}{\partial y} - \frac{\partial \xi}{\partial y} \frac{\partial \eta}{\partial x} \right) - \lambda^2 \right]^2 dx dy \quad (2-26)$$

This residual function is obtained by considering Equation (2-10) or (2-12). Then,  $\phi(c_{ij}, d_i)$  is evidently equal to zero for the exact transformation function  $f(x, y)$ . For computational purposes, Equation (2-26) is replaced by

$$\phi(c_{ij}, d_i) = \sum_{x_k} \sum_{y_l} \left[ r_0^{-2} \left( 1 + \frac{\xi^2}{r_0^2} + \frac{\eta^2}{r_0^2} \right)^{-3/2} \times \left( \frac{\partial \xi}{\partial x} \frac{\partial \eta}{\partial y} - \frac{\partial \xi}{\partial y} \frac{\partial \eta}{\partial x} \right) - \lambda^2 \right]^2 \quad (2-27)$$

where the points  $(x_k, y_l)$  are chosen to form a regular grid over the plane square. A computer software program for performing this minimization problem is given in Reference 1. For a second-degree approximation of the series in Equation (2-23), the following values of  $c_{ij}$  and  $d_i$  are obtained:

$$c_{00} = -2.7217 \quad 05366 \quad 1814$$

$$c_{10} = -5.5842 \quad 16830 \quad 5430$$

$$\begin{aligned}
c_{01} &= 2.1711 \ 17480 \ 9423 \\
c_{20} &= -3.4578 \ 62747 \ 3390 \\
c_{11} &= -6.4160 \ 15152 \ 6783 \\
c_{02} &= 1.9736 \ 26575 \ 8872 \\
d_0 &= 1.4833 \ 12929 \ 4187 \\
d_1 &= 1.1199 \ 72606 \ 9742 \\
d_2 &= 6.0515 \ 38216 \ 1464
\end{aligned}$$

The corresponding mapping function  $f(x, y)$  is accurate to about five significant figures.

#### DERIVATION OF INVERSE MAPPING FUNCTION

Corresponding to the symmetrical direct mapping function expressed in Equation (2-14), it may be verified that the inverse mapping function is also symmetrical, i.e.,

$$\begin{aligned}
x &= f^*(\xi, \eta) \\
y &= f^*(\eta, \xi)
\end{aligned} \tag{2-28}$$

As discussed in Reference 1,  $f^*(\xi, \eta)$  must be expressed in the form

$$\begin{aligned}
f^*(\xi, \eta) &= \gamma^* \xi + \frac{(1 - \gamma^*)}{r_0^2} \xi^3 \\
&+ \xi \eta^2 \left( r_0^2 - \xi^2 \right) \left[ \delta^* + \delta_1^* \left( r_0^2 - \xi^2 \right) + \left( r_0^2 - \eta^2 \right) \sum_{\substack{i \geq 0 \\ j \geq 0}} c_{ij}^* \xi^{2i} \eta^{2j} \right] \\
&+ \xi^3 \left( r_0^2 - \xi^2 \right) \left[ \omega^* + \left( r_0^2 - \xi^2 \right) \sum_{i \geq 0} d_i^* \xi^{2i} \right]
\end{aligned} \tag{2-29}$$

where

$$\gamma^* = \frac{1}{\gamma}$$

$$\mu^* = \frac{1}{\mu}$$

$$\gamma_1^* = \frac{1}{\gamma + r_0^4 \delta}$$

$$\mu_1^* = \frac{1}{\mu + 2r_0^4 \delta}$$

(2-30)

$$\delta^* = \frac{(\mu_1^* - \mu^*)}{2r_0^4}$$

$$\omega^* = \frac{1}{2r_0^4} (3 - 2\gamma^* - \mu^* - 2r_0^4 \delta^*)$$

$$\delta_1^* = \frac{1}{r_0^2} \left[ \frac{(\gamma_1^* - \gamma^*)}{r_0^4} - \delta^* \right]$$

An approximate inverse mapping function may be obtained by truncating the series expansion in Equation (2-29) at some degree, and then obtaining the coefficients  $c_{ij}^*$  and  $d_i^*$  which minimize the following residual function:

$$\phi^*(c_{ij}^*, d_i^*) \equiv \int_{-r_0}^{r_0} \int_{-r_0}^{r_0} \left\{ \left[ x - f^*(f(x, y), f(y, x)) \right]^2 \right.$$

(2-31)

$$\left. + \left[ y - f^*(f(y, x), f(x, y)) \right]^2 \right\}^{1/2} dx dy$$



In obtaining this residual function, the direct mapping function  $f(x, y)$  is considered, as given by Equation (2-23). Then,  $\phi^*(c_{ij}^*, d_i^*)$  is evidently equal to zero for the exact inverse mapping function  $f^*(\xi, \eta)$ . Again, for computational purposes, Equation (2-31) is replaced by

$$\begin{aligned} \phi^*(c_{ij}^*, d_i^*) = \sum_{x_k} \sum_{y_\ell} \left\{ \left[ x - f^*(f(x, y), f(y, x)) \right]^2 \right. \\ \left. + \left[ y - f^*(f(y, x), f(x, y)) \right]^2 \right\}^{1/2} \end{aligned} \quad (2-32)$$

A computer software program for performing this minimization problem is also given in Reference 1. For a second-degree approximation of the series in Equation (2-29), the following values of  $c_{ij}^*$  and  $d_i^*$  were obtained:

$$c_{00}^* = 3.973 \quad 89249$$

$$c_{10}^* = 6.591 \quad 19476$$

$$c_{01}^* = -25.368 \quad 92536$$

$$c_{20}^* = -73.064 \quad 97000$$

$$c_{11}^* = 77.381 \quad 61133$$

$$c_{02}^* = 21.685 \quad 89623$$

$$d_0^* = 1.811 \quad 28250$$

$$d_1^* = 37.635 \quad 47857$$

$$d_2^* = 63.000 \quad 23655$$

The corresponding mapping function  $f^*(\xi, \eta)$  is accurate to about five significant figures.

### SECTION 3 - ORGANIZATION OF DATA BASE

The underlying principle in organizing the data base is specifically related to the binary division and the stringing pattern discussed below. In this scheme, the process starts at the level of the faces in the spherical cube, numbering these faces 1 through 6 as in Figure 3-1.

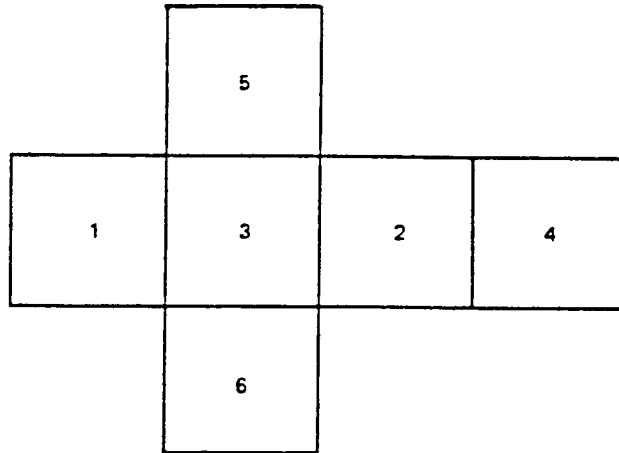


Figure 3-1. Face Numbering Scheme

Each face is divided, to the requisite resolution level, by a two dimensional binary grid, as shown in Figure 3-2. On each level of division, the areas are divided into quadrants, which are labeled by a 2-bit binary number. Each level of division,  $k$ , is indicated by the addition of two binary bits to the least significant end of a  $2^k$  bit binary number. Figure 3-3 illustrates the indexing scheme corresponding to the third level of division. Suppose there are  $n$  levels of division altogether. Then, the binary index defines the serial location of a point in the  $2^n$  array.

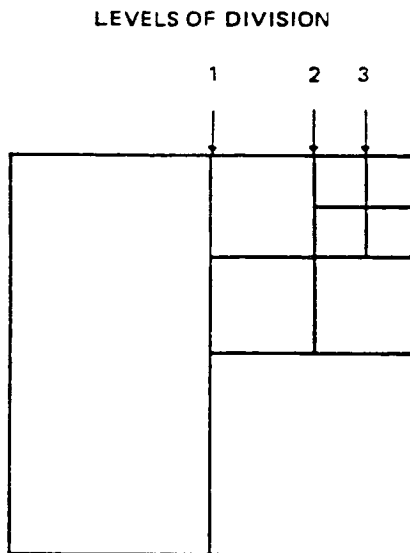


Figure 3-2. Binary Division Scheme

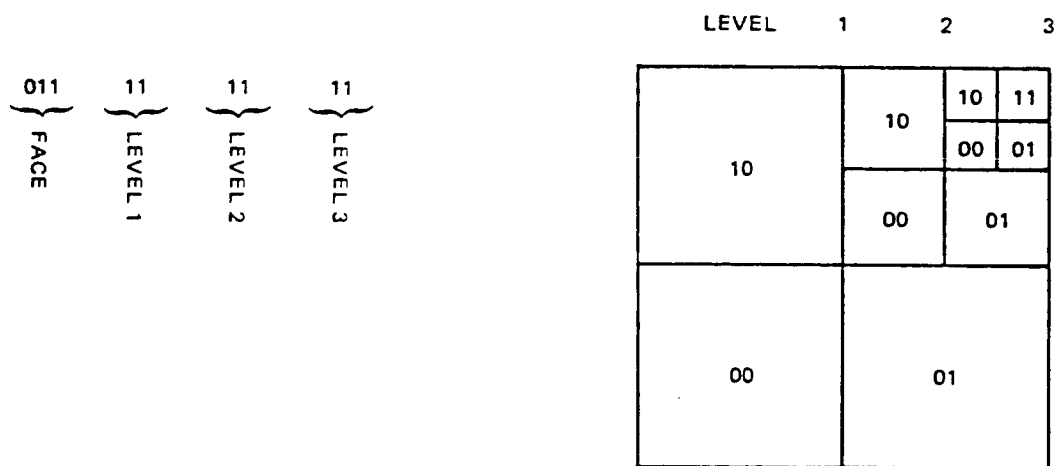


Figure 3-3. Illustrative Labeling by Binary Bits

In comparison to the normal row and column addressing scheme, the present one has the following advantages:

1. Reduction in I/O time through maintenance of near-neighbor relationships
2. Compactness of arrays containing addresses
3. Maintenance of a consistent addressing scheme regardless of resolution level

The serial addressing scheme reduces I/O time for disk type storage devices because more near neighbors of a point are within the range which requires no arm motion for accessing. The expression of addresses as a single bit string allows storage of addresses as single machine words, whereas a two-dimensional addressing scheme would require two or three words, including one for the face number. Finally, the expandibility and generality of the serial string permit the use at any resolution level without regard to physical storage considerations, such as record size. Any reasonable matrix type storage scheme would require a dual (or multiple) level of addresses for record and item within record location in the serial scheme. This is accomplished simply by considering the high order  $m$  bits as the record number, and the low order  $n-m$  bits as the address within record.

Implicit in the manner of binary labeling at each level, it is obvious that one obtains an ordering pattern whose basic nature is that of an upside-down Z. Figures 3-4 and 3-5 illustrate the binary indexing and the stringing sequence for the first two levels of division.

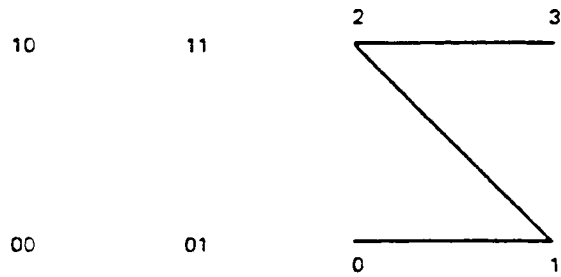


Figure 3-4. First Level of Division

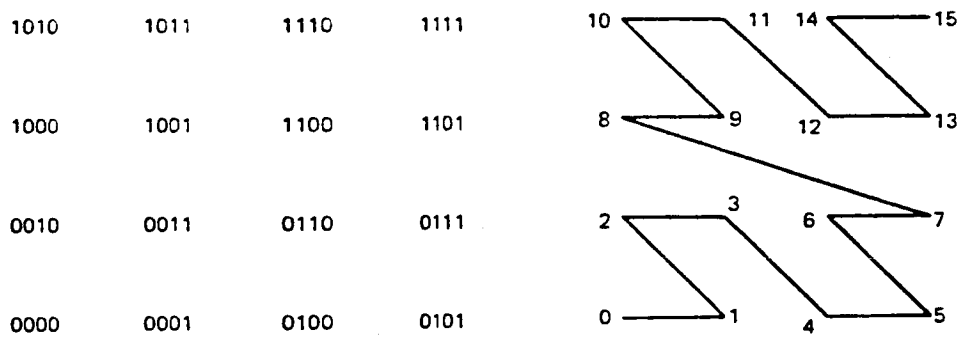


Figure 3-5. Second Level of Division

Next, suppose that a point (or cell) is represented by its rectangular coordinates (x,y). A little consideration of Figure 3-4 which illustrates the basic nature of each level of division reveals that, in general, the x and y coordinates respectively can only be associated with the odd and even bits in the binary index (or serial address) s of the cell, no matter how many levels of division there are. Furthermore, a more important property is that the x and y coordinates respectively can be directly obtained by merely masking out the even and odd bits in the serial address. Conversely, this important property means that if the x and y coordinates are given, then the serial address s may be obtained by

1. Representing x and y in binary form of n bits.
2. Expanding the n-bit format to 2n-bit format by appropriately inserting 0 in the even bits for x and in the odd bits for y, as illustrated in Table 3-1.
3. Adding the modified forms for x and y to obtain s.

Table 3-1. Binary Representation of Coordinates

DECIMAL VALUE	BINARY	X-COORDINATE (ODD)	Y-COORDINATE (EVEN)
1	1	01	10
2	10	100	1000
3	11	101	1010
4	100	10000	100000
5	101	10001	100010
6	110	10100	101000
7	111	10101	101010

As an example, consider the cell (2,3). Thus, from Table 3-1, we obtain

$$x = 10 \implies 100$$

$$y = 11 \implies 1010$$

$$s = 100 + 1010 = 1110$$

which checks with Figure 3-5.

The calculation of the serial string index may also be accomplished by the construction of a very simple hardware device. This device would consist of three registers: an x register, a y register, and a s register.

Two register-to-register instructions would provide packing from x, y to s and unpacking s to x, y. These instructions would initiate parallel transfer from the two n-bit coordinate registers to the 2n-bit serial register and vice versa. The interconnection is shown in Figure 3-6.

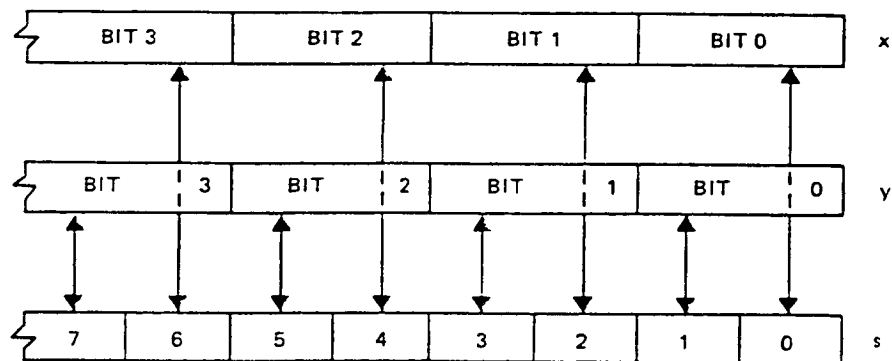


Figure 3-6. Transfer Between Registers

## SECTION 4 - CONCLUSION

The main properties of the Quadrilateralized Spherical Cube Earth Data Base are:

1. The indexing scheme is binary in nature, and telescopic in the sense that each additional level of resolution is addressed by appending additional binary bits. Thus, minimal work is needed for indexing cells of higher resolution.
2. The resolution cells are strung together in a two-dimensional manner, so as to accomplish area coverage with a serial bit string. Consequently, a higher degree of proximity is achieved for near-neighbors in this stringing pattern than in the usual one-dimensional array of stringing by rows and columns.
3. The cell addresses are readily computed because of the indexing scheme which is the same regardless of the resolution level, and because of the stringing pattern which permits the decomposition of the cell address into two independent binary indices.
4. The conversion from geographic coordinates to data base coordinates is comparatively simple because of the simplicity of the data base structure.
5. Incoming data can be stored rapidly by interpolation, using benchmarks only occasionally. This method of fast-filling is made possible by the equal-area nature and translational shape invariance of the data base resolution cells.
6. Input/output operations with this data base are also simplified because of the rectangularized nature of the data base records and the rhombic nature of the interpolation blocks.



7. The user can rapidly and directly access data corresponding to specified geographic regions of arbitrary shape and size. This data-accessing is accomplished by retrieving the relatively few bit-strings which lie within the associated data base records. The rapidity and directness of data access are the result of equal-area resolution, translational invariance, indexing scheme, stringing pattern, and relatively simple coordinate transformation.
8. The primary contemplated uses of the retrieved data are mathematical computations and visual display. For the former, the equal-area resolution property eliminates the need to distinguish between density measurements and integrated measurements. For the latter, the quadrilateralized nature of the resolution cells on the spherical cube and the comparative simplicity of coordinate transformation both simplify and minimize the internal operations.

#### REFERENCES

1. Chan, F. K., and O'Neill, E. M., "Feasibility Study of Quadrilateralized Spherical Cube Earth Data Base," Computer Sciences Corporation, Silver Spring, Maryland. EPRF Technical Report 2-75 (CSC), (1975).