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GEOGRAPHIC DISPLAY OF CIRCULATION MODEL DATA

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NESIDS 6 The Advantages of Sounding with the Smaller Detectors of the VISSR Atmospheric Sounder. W. Paul Menzel, Thomas H. Achtor, Christopher M. Hayden and William L. Smith, July 1984. (PB851518/AS)

NESDIS 7 Surface Soil Moisture Measurements of the White Sands, New Mexico. G.R. Smith, September 1984. (PB85 135754)

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Table of Contents

Page

1. INTRODUCTION 1

2. THE GEOGRAPHIC INFORMATION SYSTEM 3

2.1. Hardware 3
2.2. GIS Images 3
2.3. Images of Model Data 5

3. THE NUMERICAL CIRCULATION MODEL 7

3.1. Model Variables 7
3.2. The Grid 8
3.3. Simulation of Astronomical Tides 11
3.4. Data Formats 11

4. CONVERSION OF MODEL DATA TO PIXEL FORMAT 13

4.1. The Raster Coordinate System 13
4.2. Augmenting the Model Grid. 14
4.3. Filling Values at Pixels 15
4.4. The Color Look-up Table for Model Data Display . . 16

5. THE COMPUTER PROGRAM 19

5.1. Introduction 19
5.2. Input and Output Files 19
5.3. Program Flow Chart 19

6. CHESAPEAKE BAY APPLICATIONS 21

7. REFERENCES 25

Appendix A. Horizontal Interpolation of Water Levels 27

Appendix B. Computer Program OVERLAY Listing 31

GEOGRAPHIC DISPLAY OF CIRCULATION MODEL DATA

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1. INTRODUCTION

The Marine Applications Branch (MAB) presently has the capability to display and manipulate satellite imagery (Everdale, 1986; Stumpf, 1987). In addition, MAB is running numerical circulation models of coastal areas and thus generating a large amount of information (Hess, 1985, 1986); although not generated by measurement, this model information will also be referred to as data. These data can potentially be integrated with geographic locations, satellite data, and other types of information and used for analysis, prediction, and verification. The goal of this project, therefore, is to put circulation model data into a geographic mode for display in combination with other data fields. The satellite image display software allows for overlaying several planes of different types of data on top of a gridded field in geographic format, so the software is essentially a geographic information system (GIS).

The VAX-based satellite image processing system has been used to analyze the NOAA polar orbitor's Advanced Very High Resolution Radiometer (AVHRR) data, including sea surface temperature, chlorophyll, and sediment concentration. The data are displayed with a geographic orientation using a matrix having dimensions of 512 x 512 to hold data for a selected area of the earth's surface. Compound images showing several data types result from overlaying the AVHRR field with other fields such as coastline geography, land masks, and scale bars.

Numerical circulation models produce gridded data fields of such variables as bathymetry, tidal elevations, and water currents. These fields can be further processed to produce tide range, maximum current speed, and tidal mixing energy. Because these model data are voluminous, graphic display offers a convenient mode of representing information synoptically. In addition, because the model data are gridded, they can be

easily transformed into a geographic image format with functions converting latitude into scanline and longitude into pixel column number. Individual pixel values are filled using interpolation of pointwise model data. Finally, model field data are converted into a dimensionless count number in the range 1 - 240 and saved in a 512 x 512 array on the VAX.

The image display format for the Chesapeake Bay region is a square domain bounded by the latitudes 34.5^{o} to 40° north, and 72° to 78.91^{o} west. For display, VAX-based files are transferred to PC image processing system and loaded. There they can be displayed with other fields including coastline and latitude-longitude ticks. A look-up color table can be employed to emphasize features of interest. Several examples have been processed for various effects.

2. THE GEOGRAPHIC INFORMATION SYSTEM

The present GIS system consists of an EASI/PACE software system installed on an IBM PC/AT and on a COMTAL and VAX 11/780 configuration. Its display capabilities are apparent in an image showing the distribution of water depths that was produced on this system (Figure 1).

2.1. Hardware

The PC and the COMTAL-VAX systems both have high resolution color monitors with 512 x 512 picture elements (pixels). The monitor colors are generated with the red, blue, and green color guns each of which is set to an appropriate intensity for a given color. The PC/AT system has a mouse and keypad which allows for locating and manipulating image features easily. The pen and keypad on the COMTAL system are less sophisticated and most mouse type functions are done on the COMTAL keyboard. The PC/AT system is equipped with a Dunn color camera for making 8 x 10 Polaroid pictures and transparencies or 35 mm pictures or slides. The COMTAL system is equipped with a smaller Dunn camera used for making slides of the displayed image.

2.2. GIS Images

Each GIS image is a combination of image planes and superimposed graphic planes that are displayed on a high-resolution CRT monitor. The PC/AT system displays three image planes and eight graphics planes and the COMTAL system displays four image planes and four graphics planes. Typical image planes consist of the processed model data for water level, current, salinity, or other fields. Overlays are typically coastlines, land masks, color bar legends, and other display items which do not change from image to image. The color bar itself is part of the image plane. Colors are controlled by applying a look-up table to the image.

Each GIS image is generated from a ASCII data file that consists of header information followed by a 512 x 512 array of byte data with count values ranging from 0 to 255. The header contains information that allows the software to display the image. A different color can be displayed at each image picture element (pixel) location, depending upon the count value. Additionally, a gray scale can be used to display the data field.

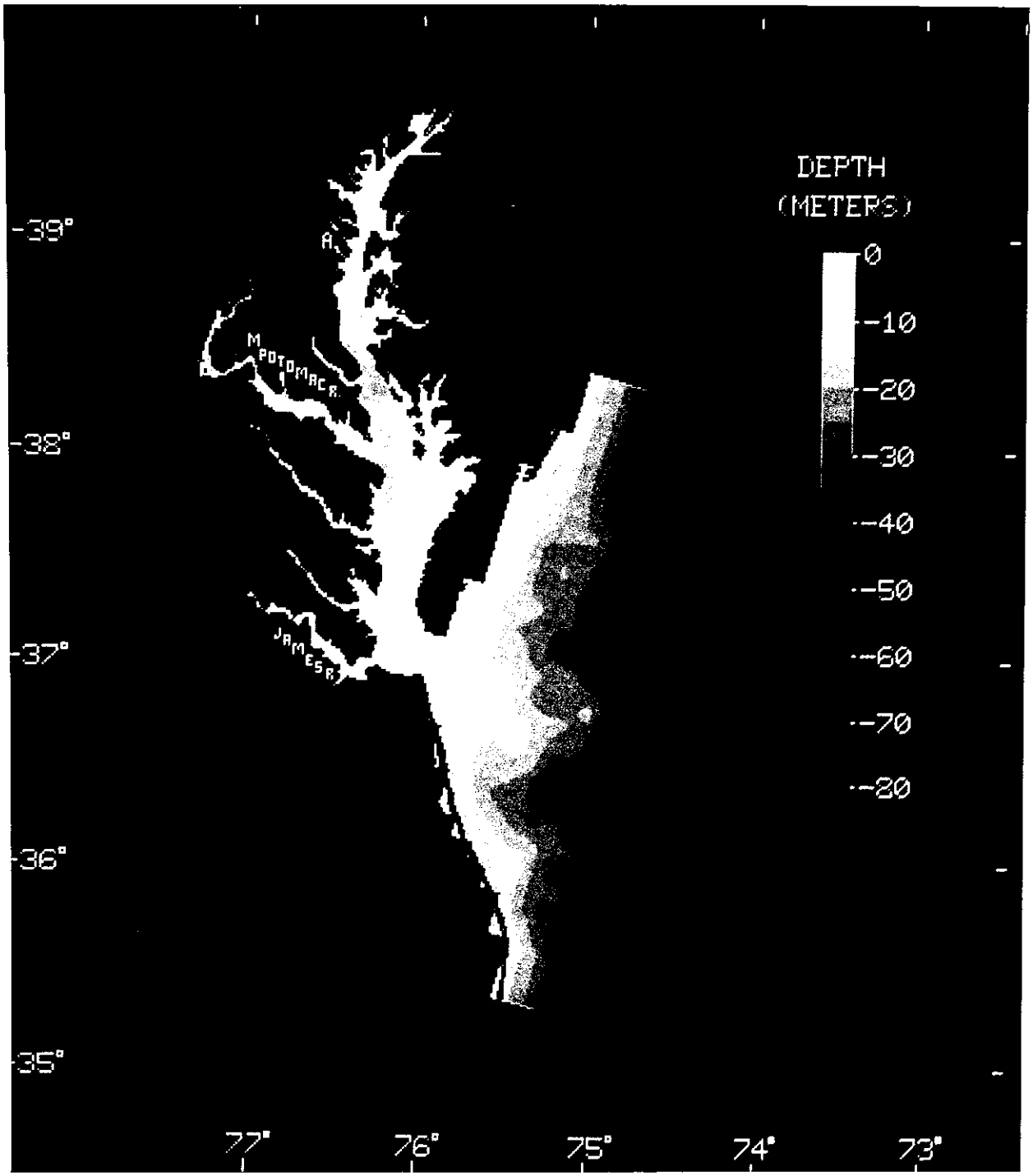

Figure 1. A sample image showing the distribution of water depths in the modeled Chesapeake Bay and adjacent continental shelf. Depths are depicted by a light to dark gray scale. The black area to the left is the land mask and the dark gray area to the right is outside the modeled region.

Color is determined by the intensity settings of the red, blue, and green guns. The range of intensity of each gun is from 0 to 255, where 0 represents the total absence of the color, and 255 the highest setting. For each pixel count value, the color is therefore determined by a set of three intensity values. A color look-up table is used to assign intensity values to each count value.

The color specification consists of the five values

I_1, I_2, R, G, B

where I_1 to I_2 is the range of count values for which the red intensity, R, the green intensity, G, and the blue intensity, B, apply.

2.3. Images of Model Data

Circulation model data are displayed using overlays developed previously for Chesapeake Bay satellite data. The latitude-longitude window that produces a square domain in a Mercator projection is bounded by 34.5° to 40° north, and 72° to 78.91° west.

At present, image data generated from circulation model runs are stored on the VAX in files with the suffix .PIC. Several PIC files have been generated and stored in directory [LFMPJP]; these are listed below:

File Name	Contents
PETE34.PIC	Model Grid
PETE35.PIC	Bathymetry
PETE31.PIC	S_2 tide at hour 0
PETE32.PIC	S_2 tide at hour 1
PETE33.PIC	S_2 tide at hour 2

PIC files contain an array with count values of zero everywhere except in the regions covered by the circulation model grid and the scale bar; counts that are non-zero represent some particular scaled model variable such as water level.

The scale bar was created by a separate procedure and added to the image. A scale bar with the desired number of intervals was first generated and stored in the file SCALE2.PIX. The bar was then inserted into the image file using EASI/PACE commands.

Several overlays are available for generating the final, compound image. These include the coastline, the latitude-longitude ticks, the scale bar header and ticks, and the land

mask. The overlays are stored in the segmented files OVERLAYS.PIX and SCALE2.PIX. These are:

File	Segment	Contents
OVERLAYS.PIX	1	Land Mask
SCALE2.PIX	13	Coastline
SCALE2.PIX	11	Lat-Lon Ticks
SCALE2.PIX	12	Scale Bar Legend

3. THE NUMERICAL CIRCULATION MODEL

NESDIS has developed and tested a three-dimensional, time-dependent numerical model of coastal circulation called MECCA (Model for Estuarine and Coastal Circulation Assessment) (Hess, 1985). The model was designed to simulate tidal, wind-driven, and density-driven currents in bays and on the shallow continental shelf. MECCA has been applied to study the salinity and temperature distribution in Chesapeake Bay and the Chesapeake Bay/Shelf area (Hess, 1986).

3.1. Model Variables

The MECCA model equations consist of two horizontal velocity equations, an equation of continuity, an equation of state, the hydrostatic approximation, and conservation equations for salinity and temperature.

The input data are:	bathymetry or depths	(d)
	cell status indices	(I)
	land-water boundary indices	(M,N)
	initial and boundary values	
The output data are:	water levels, or tides	(h)
	water currents	(u,v,w)
	salinities	(S)
	temperatures	(T)

Cell status indices are as follows: 0-9=land cells; 10-19=cells that are half water and half land; 20-29=water cells; 50-59=ocean boundary cells; 60-69=river boundary cells. The land-water boundaries are denoted by the condition of zero flow across a cell side; this information is found in the flux parameters M and N as follows:

M = 0	no flow in the x direction	(3.1a)
1	flow in the x direction	(3.1b)
N = 0	no flow in the y direction	(3.2a)
1	flow in the y direction	(3.2b)

Model variables are not continuous in space, but are represented only at specific points on a three-dimensional grid. The grid is described in the next section.

3.2. The Grid

The circulation model data are represented in space on a grid and can be easily displayed on a GIS for interpretation. Each model variable is represented as a two- or three-dimensional array, with the location of each element known. For example, the variable F(x,y,z) can be approximated at specific points in space by the array

$$F(z,y,x) \simeq F_{l,n,m} \tag{3.3}$$

where

$$x = m\Delta L,\ y = n\Delta L,\ z = l\Delta z, \tag{3.4}$$

ΔL is the horizontal grid cell size (meters), and Δz is the vertical grid cell size (meters). Also, $0 \leq m \leq mmax$, $0 \leq n \leq nmax$, $0 \leq l \leq lmax$.

The locations of the variables within a single cell are shown in Figure 2. Water level is at the center of the cell, and velocity components are given at the sides of the cell.

```
+-------------+ ---> y
|             |
|             |
|             |
|     1       3
|             |
|             |
|             |
+------2------+
|
V
x
```

Locations of variables

at 1: h,d,S,T,I

at 2: u,M

at 3: v,N

Figure 2. The placement of variables on an individual grid cell.

The grid is oriented to the earth's surface by choosing a reference cell, designated (m_C, n_C), close to the center of the grid. This cell has a latitude, λ_α, and a longitude, λ_o; the latitude is used to compute the Coriolis parameter for the whole grid. The model's internal coordinate system is as shown in Figure 3, with the x axis downward (south) and the y axis rightward (east). A rotation angle, ϑ, indicates how much clockwise rotation of the grid is needed to align it with the geographic coast.

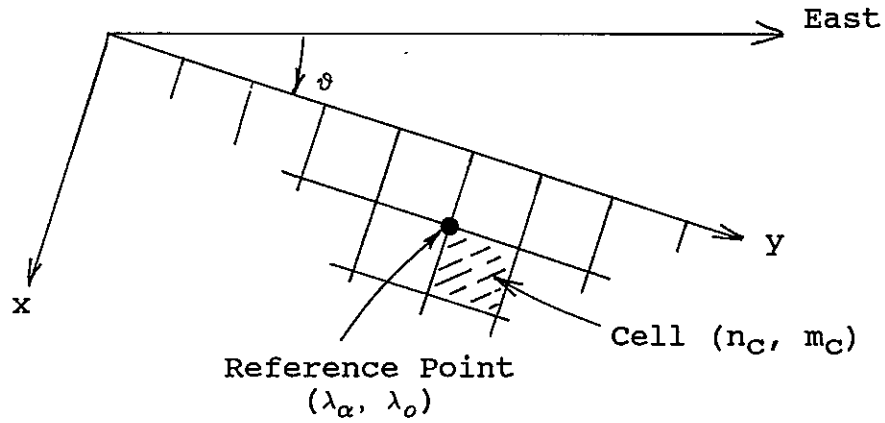

Figure 3. Representation of the model grid, its orientation with respect to the earth's surface (ϑ), and the latitude-longitude (λ_α, λ_o) of the Coriolis reference point (n_c, m_c).

Any grid position (x, y) in the horizontal plane can be converted to a geographic latitude and longitude (L_a, L_o) by applying the equations

$$L_a = \lambda_\alpha + D_h(x_c - x) + D_v(y_c - y) \tag{3.5}$$

$$L_o = \lambda_o + a[D_h(y_c - y) - D_v(x_c - x)] \tag{3.6}$$

where

L_a = north latitude (degrees) of point (x,y)

L_o = west longitude (degrees) of point (x,y)

λ_α = basin reference north latitude (degrees)

λ_o = basin reference west longitude (degrees)

x,y = position on the MECCA grid (meters)

D_h = conversion factor = $\Delta L \cdot \sin(\vartheta)/(60 \cdot 1852)$ (degrees/m)

D_v = conversion factor = $\Delta L \cdot \cos(\vartheta)/(60 \cdot 1852)$ (degrees/m)

$a = 1/\cos(\pi\lambda_\alpha/180)$

x_c, y_c = Coriolis reference positions (meters):
$x_c = (m_c - 1)\Delta L$ and $y_c = (n_c - 1)\Delta L$

The model grid for the Chesapeake Bay is shown in Figure 4.

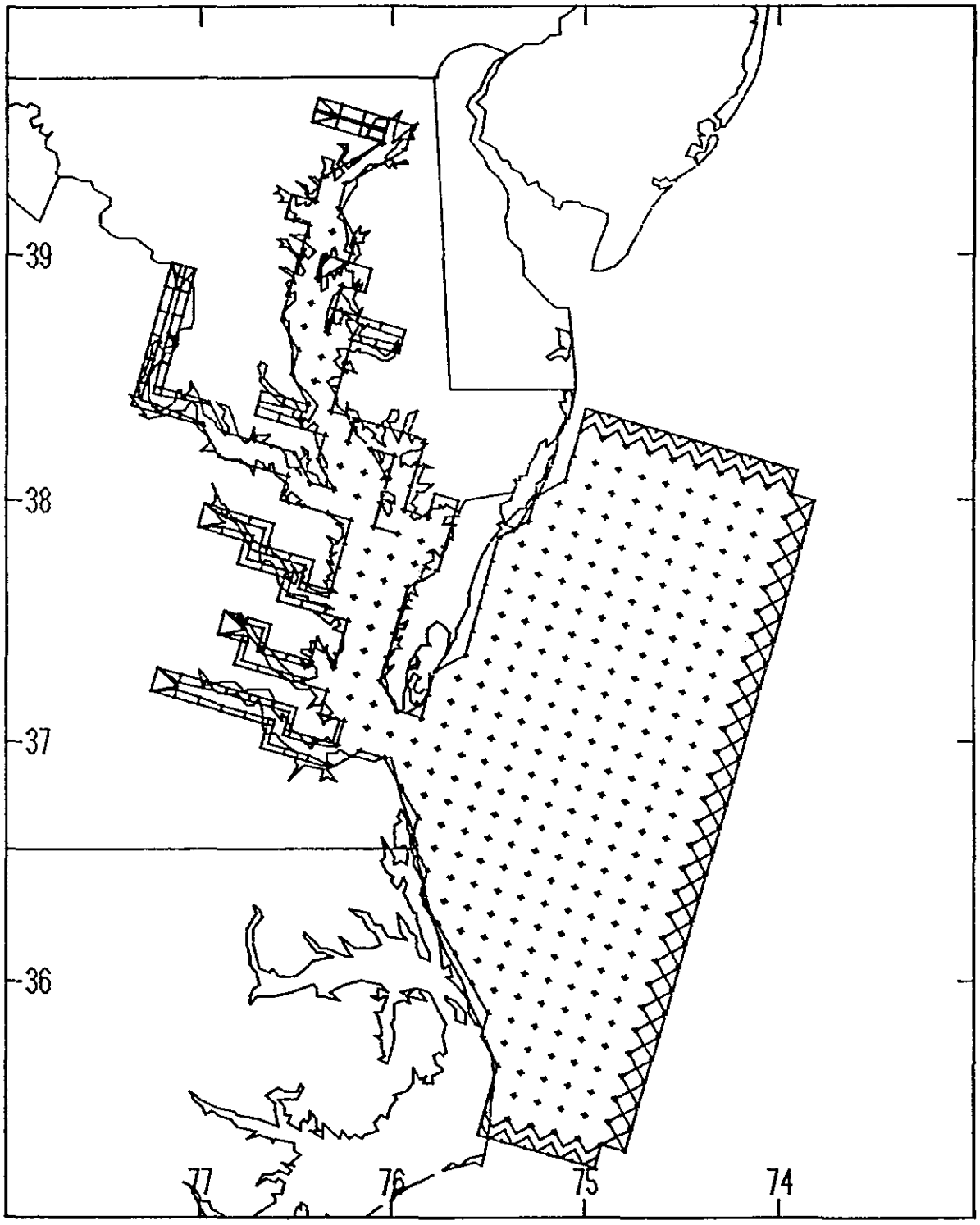

Figure 4. Model grid for the Chesapeake Bay and adjacent shelf.

3.3. Simulation of Astronomical Tides

One of the fields used in the GIS application was a water level, the S_2 component of the astronomical tide. This constituent has a period of exactly 12 hours. The tide was driven by imposing a sinusoidal tide with an amplitude of 0.20 meters at the oceanic boundary.

A linearized configuration of the model was used: the non-linear advective acceleration terms were neglected, constant horizontal and vertical viscosity were used, and a linear bottom friction term was incorporated. The circulation model was run for 10 days, with the first 9.5 days used for the spin-up period. Hourly water level fields from the last 12-hour tidal cycle were saved for plotting.

3.4. Data Formats

Output fields from the circulation model, representing any of the desired display variables, are written to an output file in a fixed format for later use as input to the GIS program, OVERLAY (Chapter 5). Output variables must be scaled to fit into a two-digit integer (positive or negative). For example, water level values (h) at any time period are converted to integer arrays (J) by the scaling equation

$$J_{n,m} = f \cdot h_{n,m} \tag{3.7}$$

where f is the scaling factor (taken here to be 100).

The data file can have instantaneous scaled water level arrays for one or more times. The overall organization of the file is as follows:

Record Numbers			Contents
1			Header Record
2	to	L+1	Data for the first time period
L+2	to	2L+1	Data for the second time period
2L+2	to	3L+1	Data for the third time period
:			:
:			:

where L = mmax+1.

The header record of the MECCA data file contains the values

f,K,TITLE

where f is the scaling factor (c.f. eq. 3.7), K is the format code (set equal to 2 for this application), and TITLE is a character description of the file.

The data records for each time period following the initial time period are organized as follows:

Record	Contents
1	Column Numbers
2	1, (J(n,1), n = 1,nmax)
3	2, (J(n,2), n = 1,nmax)
4	3, (J(n,3), n = 1,nmax)
:	:
:	:
mmax+1	mmax, (J(n,mmax),n=1,nmax)

The format for each record after the first is (1X,41I3).

4. CONVERSION OF MODEL DATA TO PIXEL FORMAT

Processing the model data involves converting grid cell values on the MECCA grid to picture element (pixel) values within a 512 x 512 display array. A geography file is read to retrieve depth (d) and cell index (I) values, then the computational file is read to retrieve the desired modeled field (J). The conversion process consists augmenting the grid, looping through the MECCA grid, generating count values, and filling in all pixels. This conversion is performed by the computer program OVERLAY (see Section 5); the basic procedure is described here.

4.1. The Raster Coordinate System

The image plane raster is a two-dimensional Cartesian coordinate system as shown in Figure 5. The origin is at the upper-left corner, with the horizontal axis (pixel number p) directed rightward and the vertical axis (scanline number s) directed downward. The range of each coordinate is

$$0 \leq p \leq p_{max} \qquad \text{and} \qquad 0 \leq s \leq s_{max}$$

where $p_{max} = s_{max} = 512$. The image consists of count values in the range 0 to 255 at all pixel locations (p,s).

```
Origin +-------------- > p
       |
       |
       |
       ↓
       s
```

Figure 5. The raster coordinate system. The origin is at the upper-left corner, with the horizontal axis, or pixel number p, is directed rightward, and the vertical axis, or scanline number s, is directed downward.

The scanline and pixel number are related to latitude and longitude (L_a, L_o) and are

$$s = 512 - \ln\{\tan(45 + L_a/2)\}(R/S) + SCLOFF + 0.5 \qquad (4.1)$$

and

$$p = (180 - L_o)(R/S) - PXLOFF + 0.5 \quad (4.2)$$

where s is the scanline computed from the latitude, p is the pixel number computed from the longitude, L_a is latitude (north) in degrees, L_o is longitude (west) in degrees, R is the Earth's radius (6371.2 km), S is a scale term (1.5 km), SCLOFF is the scanline offset, and PXLOFF is the pixel offset.

First the upper right corner of the scene for Chesapeake Bay was chosen to be at 40°N, 72°W. The lower latitude should be approximately 35°N to include the whole Bay and model grid (Figure 4). The precise values of the lower latitude and western longitude must then be determined so that the Mercator projection of the scene (in pixel-scanline space) is a square.

The scale term, S, was then chosen for this application for the Chesapeake Bay region so that the Mercator pixel size, P, at a latitude near the middle of the scene would be approximately equal to, but slightly greater than, the satellite pixel size at nadir, 1.1 km. The Mercator pixel size at any latitude is

$$P = 111.12\{2\tan^{-1}[\exp(S/R)\tan(45+L_a/2)]-90-L_a\} \quad (4.3)$$

where P is Mercator pixel size (km) and 111.12 is the number of km/deg. At a latitude of 38°N, P is 1.16 km when S is 1.5 km.

The scanline offset (SCLOFF) and pixel offset (PXLOFF) were chosen next. These terms are translational values that ensure that the pixel and scanline numbers are within the range 0 to 512 for data within the Chesapeake Bay study region. The scanline offset is determined by substituting the upper latitude, 40°N, into (4.1) and setting s to zero, to give SCLOFF=2727.8. Then lower latitude was determined to be 34.50°N, the latitude that yields 512 for s in (4.1). The pixel offset is determined by substituting 72°W into (4.2) and setting p to 512 to yield PXLOFF=7494.0. Finally, the western boundary was determined by setting p to zero in (4.2) and solving for L_o to yield 78.91°W.

4.2. Augmenting the Model Grid

Originally, there was no provision for assigning model values to those areas in the image where the land mask indicates the presence of water, but which are not water cells in the MECCA grid. However, these void areas are now filled in by augmenting the MECCA grid with additional water cells (Figure 6). The augmentation changes all land cells adjacent to the Bay in the original grid into fictitious water cells.

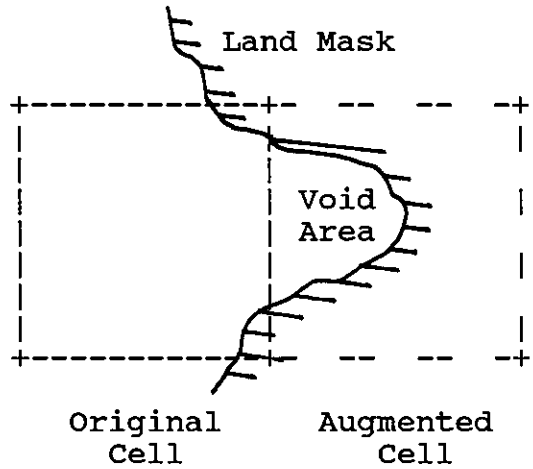

Figure 6. Filling in void areas by augmenting the model grid.

The augmented grid cell is assigned a field value equal to the model field value in the nearest MECCA cell along the appropriate coordinate direction, and a flag is set in the cell status index array, I, which effectively includes augmented cells in the water area of the grid beyond the coastal boundaries originally specified.

The averaging method then is used to derive values at pixel locations using the augmenting grid cells and original water cells in the same way. The averaging scheme apportions the weights applied to the four surrounding MECCA cells of each pixel according to the flag values identifying each as either an open water cell or a boundary cell.

4.3. Filling Values at Pixels

The model data are read in and converted to a general field array in model coordinates, F, by the scaling equation

$$F_{n,m} = J_{n,m}/f \tag{4.4}$$

which restores the original values of the circulation model field data (c.f. eq. 3.7) at each MECCA cell (n,m). At the same time, the maximum value and minimum value of $F_{n,m}$ are determined.

Since the MECCA cell size, ΔL, is 11.2 kilometers and the pixel size, δ, is 1.2 kilometers, there will be numerous pixels within each cell of the MECCA grid. These are filled by

defining model values at subcells corresponding to pixels. Given the model grid rotation angle ϑ, the number of raster lines per cell will be approximately

$$r = (\Delta L/\delta)(\sin\vartheta + \cos\vartheta) \tag{4.5}$$

If (x,y) are the MECCA cell coordinates and the corner nearest the origin of a MECCA cell is denoted as (x_o, y_o), then the location of subcells in a single MECCA cell is found by

$$x_i = x_o + i(\Delta L/r) \quad , i = 1, .. r \tag{4.6a}$$

$$y_j = y_o + j(\Delta L/r) \quad , j = 1, .. r \tag{4.6b}$$

The relative location of each subcell (x_i, y_j) is used in deriving a weighted average field value, $\hat{F}$, from the values in the four surrounding model cells. Mass flux indices across the cell boundaries are used to determine the weights, so that the method is equivalent to a bilinear interpolation for the case of four open water cells. Details of the interpolation scheme are given in Appendix A.

The subcell values, $\hat{F}$, are converted into dimensionless count values in the range 1 to 240 by specifying the minimum and maximum unscaled values for the field. This method allows a different scaling for each model variable displayed. The scaling equation is

$$C = \mathrm{Max}[1, 240(\hat{F} - F_{min})/(F_{max} - F_{min})], \tag{4.7}$$

where C is the count value, Max[a,b] is a function giving the maximum of a and b, $\hat{F}$ is the field value, F_{min} is the minimum specified value for the field, and F_{max} is the maximum specified value for the field.

The dimensionless count value is inserted into the image array at the pixel number and scanline determined by converting the subcell location (x_i, y_j) first into a latitude-longitude pair by (3.5, 3.6) and then into (p,s) by (4.1, 4.2).

4.4. The Color Look-up Table for Model Data Display

For the GIS image to be displayed in color, a look-up table must be created to assign a color to each of the 240 scaled integer values of the model data. The GIS provides a default table that assigns a unique color to each integer in a continuous span of the spectrum, but this table is of limited use. We instead chose to develop our own color tables for this model application: a two-color table to represent tides and a pair of single-color tables to represent bathymetry.

The modeled tides are represented by a two-color table with red hues for water levels above mean sea level (msl) and blue hues for water levels below msl. For levels above msl, we assigned the maximum intensity value of 255 to the red gun and varied intensity of the green and blue guns in equal measure from high to low so that the highest water level would contain the lowest green and blue intensities. For levels below msl, we assigned 255 to the blue gun and varied the red and green guns in equal measure from high to low so that the lowest water level would contain the lowest red and green intensities.

An added criterion was that the contrast about the zero level represented by gray should be heightened by allowing the dropoff in the intensities of the alternate two color guns to red and blue to be much more steep about zero than at the ends of the scale. The color table used for the tides is given in Figure 7a.

Since the bathymetry consists of depth values which are either zero or positive, a single hue can be used to represent depth. The first generated table was designed to apply to the bathymetry of the entire modeled region, and assigns a hue of near-white to the smallest depths, and a hue of dark blue to the greatest. Sixteen hues each represent 5-meter increments to span an 80-meter range. The table is given in Figure 7b, and the result is shown in Figure 1.

Chesapeake Bay averages only 10 meters in depth, so its bathymetry is represented by only a few 5-meter hues in Figure 1. A second table was generated with nine hues to span the lowest 30 meters of depth, and a single hue to represent the remainder of the range. This table is given in Figure 7c.

I1	I2	R	G	B
0,	0,	0,	80,	120
1,	14,	15,	15,	255
15,	29,	35,	35,	255
30,	44,	60,	60,	255
45,	59,	85,	85,	255
60,	74,	115,	115,	255
75,	89,	135,	135,	255
90,	104,	165,	165,	255
105,	119,	200,	200,	255
120,	120,	127,	127,	127
121,	135,	255,	200,	200
136,	150,	255,	165,	165
151,	165,	255,	135,	135
166,	180,	255,	115,	115
181,	195,	255,	85,	85
196,	210,	255,	60,	60
211,	225,	255,	35,	35
226,	240,	255,	15,	15
241,	255,	0,	80,	120

(a)

I1	I2	R	G	B
0,	1,	0,	0,	0
2,	15,	15,	15,	15
16,	30,	30,	30,	30
31,	45,	45,	45,	45
46,	60,	60,	60,	60
61,	75,	75,	75,	75
76,	90,	90,	90,	90
91,	105,	105,	105,	105
106,	120,	120,	120,	120
121,	135,	135,	135,	135
136,	150,	150,	150,	150
151,	165,	165,	165,	165
166,	180,	180,	180,	180
181,	195,	195,	185,	195
196,	210,	210,	210,	210
211,	225,	225,	225,	225
226,	240,	240,	240,	240
241,	255,	255,	255,	255

(b)

I1	I2	R	G	B
0,	151,	0,	0,	0
152,	156,	15,	15,	15
157,	162,	30,	30,	30
163,	168,	45,	45,	45
169,	174,	60,	60,	60
175,	180,	75,	75,	75
181,	186,	90,	90,	90
187,	192,	105,	105,	105
193,	198,	120,	120,	120
199,	204,	135,	135,	135
205,	210,	150,	150,	150
211,	216,	165,	165,	165
127,	222,	180,	180,	180
223,	226,	195,	185,	195
227,	234,	210,	210,	210
235,	240,	225,	225,	225
241,	246,	240,	240,	240
247,	255,	255,	255,	255

(c)

Figure 7. Color look-up table for (a) tides, (b) regional bathymetry, and (c) Chesapeake Bay bathymetry. In each column of five numbers, the first two numbers identify the first and last scaled count values of the color interval and the remaining three values assign intensity levels to the red, green, and blue color guns, respectively.

5. THE COMPUTER PROGRAM

5.1. Introduction

A Fortran computer program, OVERLAY, has been written to analyze the data in three steps. The program (1) reads in the circulation model data, (2) processes the data to generate a 512 x 512 array of interpolated values, then (3) writes a file readable by the GIS system. The model data consists of the geography files (grid data, bathymetry) and the field data (water levels, current speeds, salinity, or temperature). The processing step consists of navigating the grid data and filling in pixel values.

5.2. Input and Output Files

The program OVERLAY requires two MECCA input files to run, i.e., a geography file and a file with the circulation variables. For the VAX, these are [HESS]BSE1.GEO and [HESS]TIDES1.DAT. The output files have the designator .PIC, and are shown in Section 2.3.

5.3. Program Flow Chart

The program consists of three basic parts: the read step, the processing step, and the write step. A flow chart for the program appears in Figure 8.

```
                        MAIN
                         |
Read Step                |----MGRID-----RDGEO
                         |
                         |
Processing Step          |----MECFLD
                         |----RDMEC
                         |----AUGRID
                         |----MNFLUX
                         |----GRIDDER---FILL------PXLSCL
                         |               LINE      CENAVG
                         |                         ISCALE
Write Step               |----MGPLOT
                         |
                       (end)
```

Figure 8. Flow chart for the program OVERLAY. Subroutines (uppercase) are called by MAIN from top to bottom and from left to right. Multiple calls are shown only once.

The Read Step

The first two subroutines (Figure 8) read the data files. Subroutine MGRID sets up the plotting options and RDGEO reads in the geography file, .GEO. This file contains the bathymetry, grid attributes, and channel locations.

The Processing Step

The second group of subroutines (Figure 8) processes the input data. Subroutine MECFLD, if called, sets the plot field to the depth

$$F_{n,m} = -d_{n,m} \tag{5.1}$$

Subroutine RDMEC, if called, reads the circulation model input file and selects the appropriate data as follows

$$F_{n,m} = (h,\ u,\ v,\ S,\ T)_{n,m} \tag{5.2}$$

The subroutine AUGRID produces an augmented grid that has an extra row of fictitious water cells around the original water cells. Subroutine MNFLUX generates the barrier index fields, M and N, that define the location of land-water boundaries.

Subroutine GRIDDER controls the creation of the 512 x 512 array. The subroutine loops through all cells in the grid and computes the latitude and longitude of the cell center. There are then three options: plot the MECCA variable with or without the grid, or plot only the grid. If the MECCA variable is to be plotted, all values within the cell are generated by subroutine FILL, which computes the latitude-longitude locations of the subset of all 512 x 512 array elements that fall within the cell, interpolates a MECCA value for each location, and finds the pixel-scanline location of that point. The interpolation takes place in a call to subroutine CENAVG and uses the method described in Appendix A. The pixel-scanline location of the point is determined in subroutine PXLSCL. The interpolated value is rescaled to an integer by (3.7) and stored in the 512 x 512 array named IMAGE. If the grid is to be plotted, the center of the cell is marked, and lines are drawn by subroutine LINE to indicate the cell sides.

The Write Step

After the MECCA data are processed, a GIS file is created. First a formatted header line, containing all EASI/PACE GIS protocols, is written, followed by the 512 x 512 unformatted array, one byte per pixel.

6. CHESAPEAKE BAY APPLICATIONS

The first application is the display of the MECCA grid (Figure 4) on the GIS system. The grid array is represented in the geography file, BSE1.GEO, as an array of cell indices. A GIS file is generated by running the program OVERLAY and entering the plot-grid option. The program then calculates the latitude and longitude of each cell corner and joins these points with straight lines. The pixel nearest the cell center is also highlighted. The result is shown in Figure 9.

The depth data are also contained in BSE1.GEO. A plot of the bathymetry of the entire modeled region has been shown in Figure 1. The depth is depicted by a 16-band color scale, with white representing the shallowest water (0 meters), and dark gray the deepest water (80 meters), in 5-meter bands. Since in the model the Bay's maximum depth is about 20 meters, its bathymetry is depicted in only four bands. To gain higher resolution in the Bay, its bathymetry was depicted with a different scaling: fifteen 2.0-meter bands that cover depths from 0 to 30 meters, and one band for all remaining depths (Figure 10).

The astronomical tide can also be depicted. The scaling chosen was a two-color scale, with a number of bands (sixteen) centered around zero to show water levels above (red) and below (blue) mean sea level. The highest water level that can be depicted is F_{max} and the lowest is $-F_{max}$, where for this application $F_{max} = 0.40$ meters. Each of the 16 color bands corresponds to tides within a 0.05-meter increment. Water levels between 0.00 and 0.0033 meters are colored gray.

The circulation model was run in a linearized mode to simulate the S_2 (solar diurnal) tidal constituent because its period of exactly 12 hours makes the interpretation of hourly values relatively easy. The forcing amplitude at the deep water boundary was 0.20 meters.

The tidal elevations at model hour 0, which are zero at the offshore boundary and correspond in phase to 2.2 hours after low water at Hampton Roads, Virginia (at 36.95^{o}N, 76.4^{o}W, near the mouth of the James River), are shown in Figure 11. The depiction shows that tides within the mid-Bay are still below mean sea level when the ocean tide has risen above mean sea level. Tides in the upper Bay are still above mean sea level from the previous tidal cycle.

Preliminary work was initiated to display GIS tide images on a video monitor. Further work and additional hardware are necessary to reach the goal of producing a motion picture of tidal change.

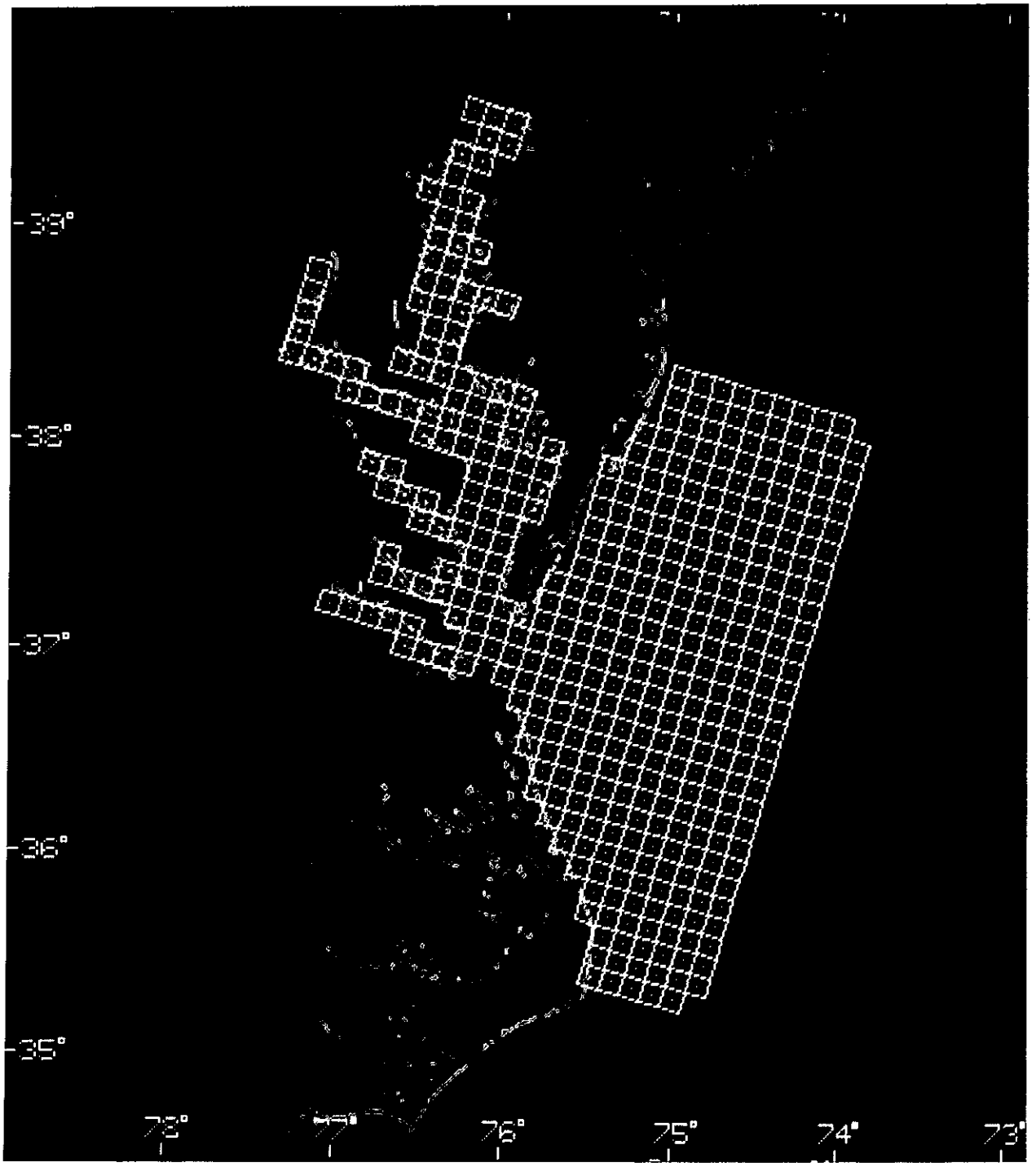

Figure 9. The grid array is represented in the geography file, BSE1.GEO, as an array of cell indices. The pixel nearest the cell center is also highlighted.

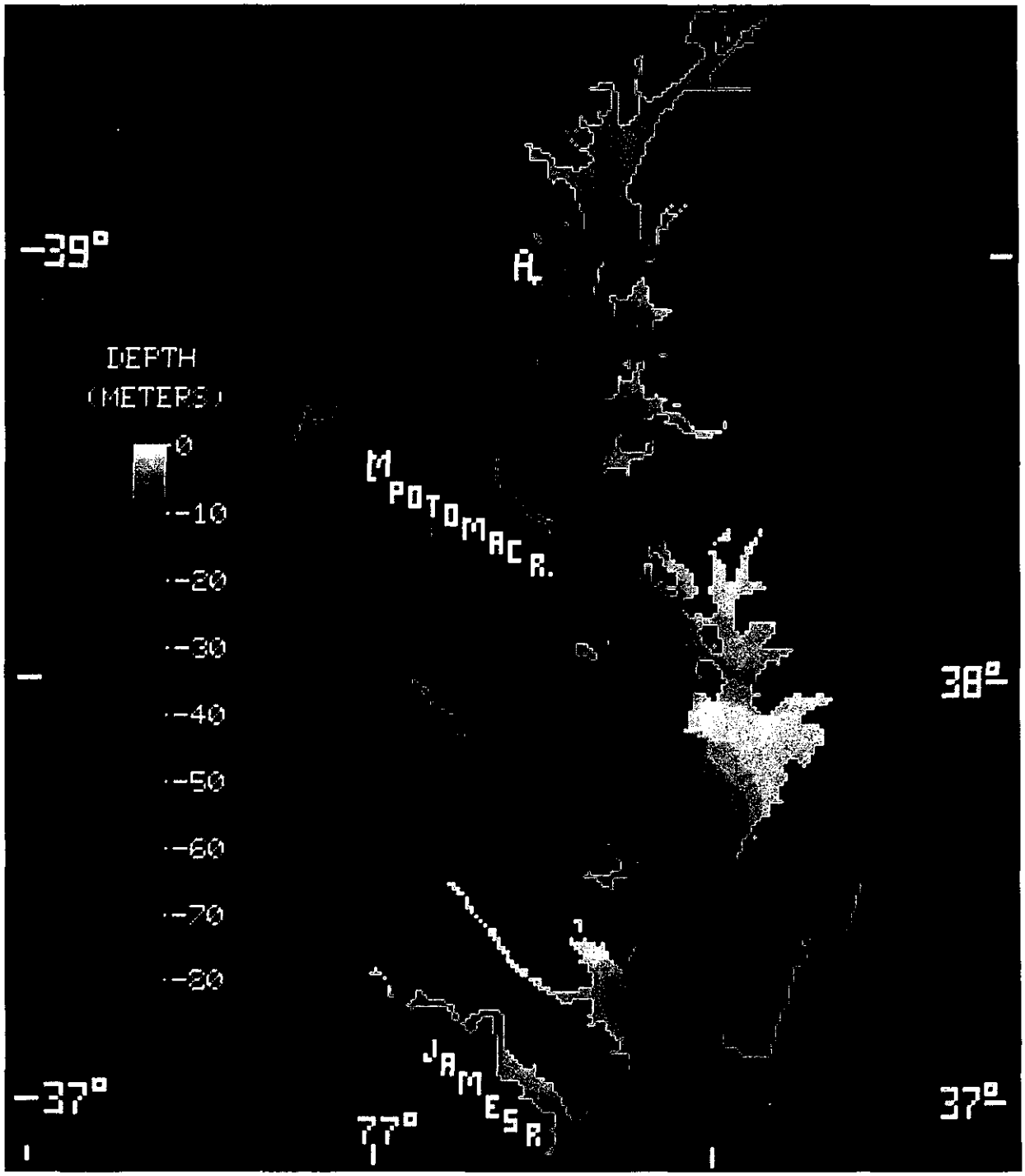

Figure 10. To gain higher resolution, the Bay's bathymetry was depicted with a different scaling: fifteen 2.0-meter bands cover depths from 0 to 30 meters, and one band for all remaining depths.

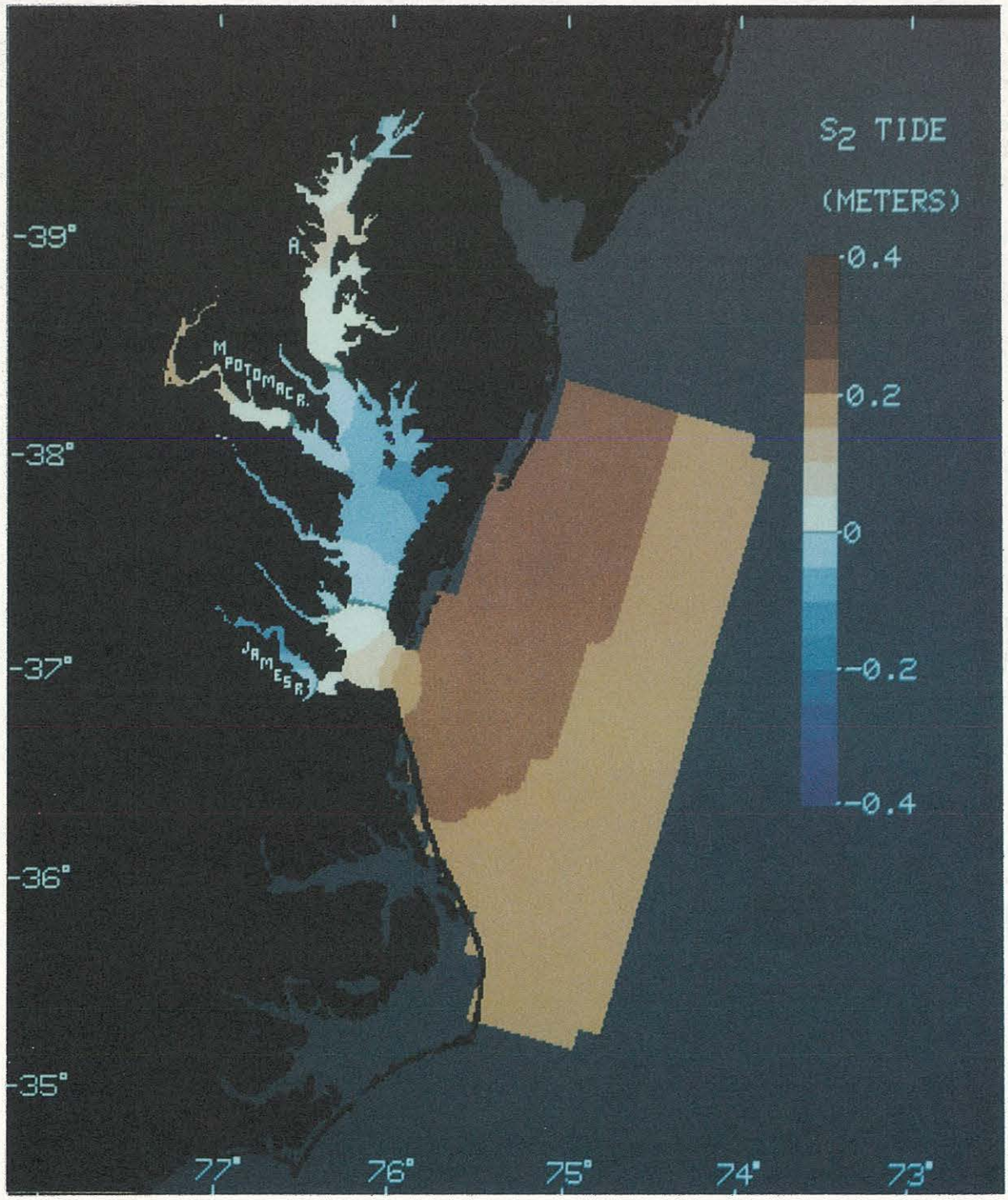

Figure 11. The S_2 tides at model hour 2, corresponding to 4.2 hours after low water at Hampton Roads, Virginia.

7. REFERENCES

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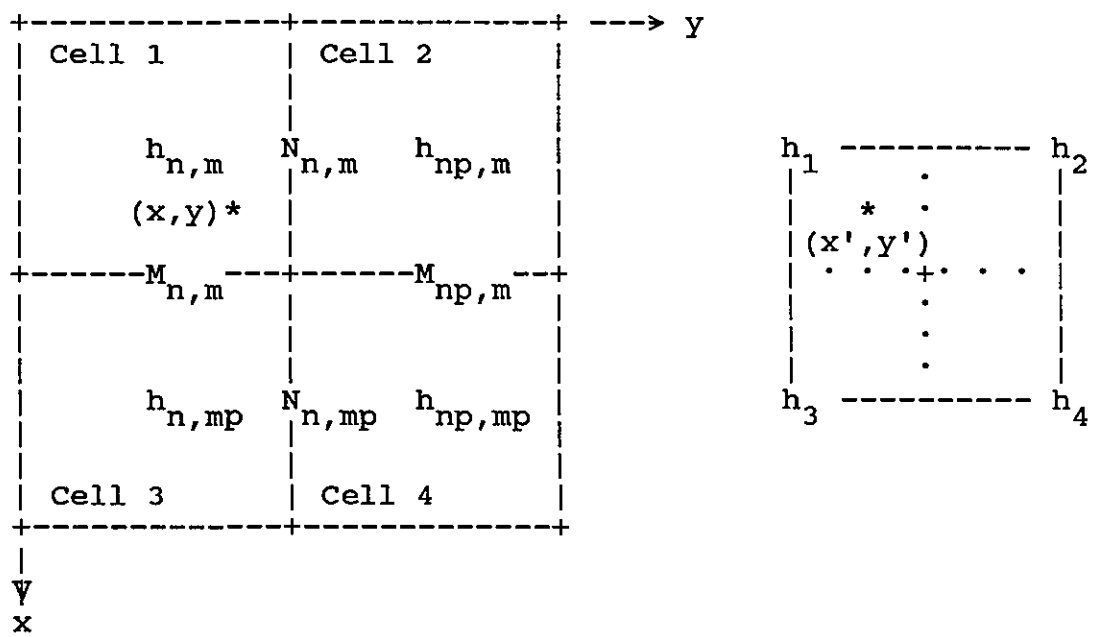
APPENDIX A. Horizontal Interpolation of Water Levels

Interpolation of values in horizontal space can be accomplished knowing the position of the point in a square whose corners are the locations of the modeled values. Since the water levels (h) are located at the center of MECCA cells, a sub-cell with the water levels at the corners must be defined. An example is shown in Figure A.



a. Water levels in four adjacent MECCA cells.

b. Sub-cell based on water levels at corners

Figure A. Plan view of grid cells showing (a) the location of the interpolation point (*) and the four surrounding cells with their water levels (h), x direction land-water boundary indices (M), and y direction land-water boundary indices (N); and (b) the sub-cell. Note that mp = m+1 and np = n+1.

The Sub-Cell

In order for the interpolation to be carried out, the sub-cell with water level values at the four corners must be identified. Consider an arbitrary point in the cell (n_o,m_o) with coordinates x,y $(0 \leq x,y \leq 1)$, denoted by an asterisk in Figure A.1. Cell 1 (n,m) and the coordinates within the sub-cell (x',y') are determined as follows:

$$\text{if } x \leq 0.5, \text{ then } m = m_o - 1 \text{ and } x' = x + 0.5$$

$$\text{otherwise } m = m_o \text{ and } x' = x - 0.5$$

$$\text{and if } y \leq 0.5, \text{ then } n = n_o - 1 \text{ and } y' = y + 0.5 \qquad (A.1)$$

$$\text{otherwise } n = n_o \text{ and } y' = y - 0.5$$

where x' and y' are the fractional distances:

$$0 \leq x' \leq 1 \quad \text{and} \quad 0 \leq y' \leq 1. \qquad (A.2)$$

<u>The Interpolation Function</u>

The bilinearly interpolated value at the point is found by

$$\underline{h} = (1 - x')(1 - y')h_1 + (1 - x')(y')h_2 + (x')(1 - y')h_3 + (x')(y')h_4$$

$$= f_1h_1 + f_2h_2 + fh_3 + f_4h_4 = \sum_{i=1}^{4} f_ih_i \qquad (A.3)$$

where i is the number of the corner and f is the weighting factor.

<u>Interpolation with Land-Water Barriers</u>

When one of the four cells defining the sub-cell is a land cell, it is not appropriate to use the water level in that cell when computing the spatial average. Also, it is not appropriate whenever there is a barrier separating the point of interpolation from a corner of the sub-cell. In these cases, we use the equivalent, but more general, expression

$$\underline{h} = \sum_{i=1}^{4} B_if_ih_i \Big/ \sum_{i=1}^{4} B_if_i, \qquad (A.4)$$

where B_i is a barrier factor determined as follows: B_i is equal to 1 if cell i is water and no barrier is present between the interpolation point and cell i; otherwise B_i is equal to 0.

For example, suppose that Cell 3 in Figure A was a land cell or there was a barrier between Cells 1 and 3; then $M_{n,m} = 0$. For this case, $\underline{h}$ at (x',y') should not be a function of h_3; therefore the term $B_3f_3h_3$ in the numerator and the term

$B_3 f_3$ in the denominator of (A.4) should be dropped. This is accomplished by setting

$$B_3 = 0. \tag{A.5}$$

Suppose that $N_{n,m}=0$. The correct interpolation function is obtained if

$$B_2 = 0. \tag{A.6}$$

Suppose that either $M_{np,m}$ or $N_{n,mp}$ (but not both) is zero. For this case, the values of B_i are unaltered because there is free connection to the water level value, h_4.

Suppose that both $M_{np,m}$ and $N_{n,mp}$ are zero, or that both $M_{n,m}$ and $N_{n,m}$ are zero. For this case,

$$B_4 = 0, \tag{A.7}$$

because there is no connection to the water level value h_4.

Appendix B. Computer Program OVERLAY Listing

```
      PROGRAM OVERLAY
C        APRIL 1988   K. W. HESS   MEAD   VAX11/780
C        PURPOSE - PROGRAM TO
C                  (1) READ GEOGRAPHY FILE
C                  (2) SELECT GRID LOCATION (CENTER) AND CORNERS
C                  (3) CREATE STRING OF LAT-LONS
C                  (4) CONNECT GRID CORNERS WITH LINE SEGMENTS
C                  (5) CREATE EASI/PACE PLOT FILE FOR GRIDMESH AND CENTERS
C                  (6) CREATE PLOT FILE FOR MECCA FIELD DATA
C
C          MAIN
C           :
C           :-----MGRID--------RDGEO
C           :                  OPEN
C           :
C           :-----MECFLD
C           :-----RDMEC
C           :-----AUGRID
C           :-----MNFLUX
C           :-----GRIDDER------FILL------PXLSCL
C           :                  LINE      CENAVG
C           :                            ISCALE
C           :
C           :-----MGPLOT
C          (END)
      COMMON/GCEN/GLAT(1000),GLON(1000)
      COMMON/IMAGE/IMAGE(512,512)
      COMMON/DATA1/FIELD(40,60),FAC
      COMMON/PARM1/IO,ISCR,NST,NSTMAX,NSTO,NMAX,MMAX,NCELL,DMAX,NEGS
      COMMON/GEOG1/IFIELD(40,60),ICOL(5,200),IROW(5,200),NCOL,NROW
      COMMON/SCALE/FMIN,FMAX
      COMMON/OPT1/GRDMSH,PRMTR,TIDES,DEPTHS,AUG
      LOGICAL GRDMSH,PRMTR,TIDES,DEPTHS,AUG
      DIMENSION JFIELD(40,60)
C---     GET FIELD DATA AND OPTIONS INFORMATION
      OPEN(UNIT=6,STATUS='NEW',DISPOSE='PRINT/DELETE',NAME='IFIELD.LIS')
      CALL MGRID
C---     STORE ORIGINAL IFIELD FOR AUGMENTED GRIDMESH AND MULTIPLE ARRAYS
      DO N=1,NMAX
      DO M=1,MMAX
      JFIELD(N,M)=IFIELD(N,M)
      END DO
      END DO
      WRITE(5,1007)
 1007 FORMAT('$ENTER NUMBER OF ARRAYS TO READ: > ')
      READ(5,*) IMG
      DO 5 I=1,IMG
C---     RESTORE ORIGINAL IFIELD FOR AUGMENTED GRIDMESH AND MULTIPLE ARRAYS
      DO N=1,NMAX
      DO M=1,MMAX
      IFIELD(N,M)=JFIELD(N,M)
      END DO
      END DO
        IF(TIDES) THEN
C---        GET SCALED FIELD DATA
C         CALL MECTID(JMAX)
          CALL RDMEC(JMAX)
        ELSE IF(DEPTHS) THEN
          CALL MECFLD
        END IF
```

```
      PMIN=1.E6
      PMAX=-1.E6
      DO 10 N=1,NMAX
      DO 10 M=1,MMAX
      IF(IFIELD(N,M).LE.9) GO TO 10
C---    RESET HEAD OF RIVER WITH FALLS CONDITION CASE TO A LAND INDEX VALUE
      IF(IFIELD(N,M).GT.59.AND.IFIELD(N,M).LT.71) IFIELD(N,M)=0
      PMIN=AMIN1(PMIN,FIELD(N,M))
      PMAX=AMAX1(PMAX,FIELD(N,M))
   10 CONTINUE
      WRITE(5,1006) I,PMIN,PMAX
      WRITE(5,1005)
 1005 FORMAT('$ENTER SCALING FACTORS FOR PARAMETER: FMIN,FMAX: > ')
 1006 FORMAT(1X,'ARRAY',I5,' MINIMUM,MAXIMUM PARAMETER VALUES = ',2F9.4)
      READ(5,*) FMIN,FMAX
C---    AUGMENT MECCA CELLS TO FILL WATER AREAS IN BAY PROPER IN GIS IMAGE
      IF(AUG) CALL AUGRID
C---     COMPUTE FLUX INDICES
      IF(PRMTR) CALL MNFLUX
C---     FILL PIXELS AND SCANLINES
C---    BUILD IMAGE FILE FOR MECCA GRIDMESH AND CENTERS
C---    AND/OR FOR MECCA OUTPUT PARAMETER(S) [FIELD DATA]
C       LOOP THRU GRID
      CALL GRIDDER
C
C
C---     SET UNIT FOR OUTPUT FILE AND WRITE HEADER AND ARRAY TO DISK
      NFLE = 2
      CALL MGPLOT(NFLE)
    5 CONTINUE
      LU=4
      CLOSE(UNIT=LU)
      CLOSE(UNIT=NFLE)
      STOP
      END
C
C-----------------------------------------------------------------
C
      SUBROUTINE MGRID
C
      CHARACTER*20 FGEO
      CHARACTER*1 Q
      LOGICAL GRDMSH,PRMTR,TIDES,DEPTHS,AUG
CC    DIMENSION GLAT(1000),GLON(1000)
      COMMON/PARM1/IO,ISCR,NST,NSTMAX,NSTO,NMAX,MMAX,NCELL,DMAX,NEGS
      COMMON/GCEN/GLAT(1000),GLON(1000)
      COMMON/IMAGE/IMAGE(512,512)
      COMMON/DATA1/FIELD(40,60),FAC
      COMMON/OPT1/GRDMSH,PRMTR,TIDES,DEPTHS,AUG
C       SET DATA
      IO=5
      ISCR=5
      RAD=57.29578
C        GET GEOGRAPHY FILE NAME
  100 TYPE 110
  110 FORMAT('$ENTER .GEO FILE NAME : ')
      ACCEPT 120,FGEO
  120 FORMAT(A20)
      LUG=10
      OPEN(UNIT=LUG,NAME=FGEO,STATUS='OLD',FORM='FORMATTED',
     1 ACCESS='SEQUENTIAL',READONLY,ERR=100)
C       READ THE FILE
      CALL RDGEO(LUG)
      CLOSE(UNIT=LUG)
      GRDMSH = .TRUE.
```

```
      PRMTR = .FALSE.
      TIDES = .FALSE.
      DEPTHS = .FALSE.
C---     USER TO SPECIFY IF MECCA GRIDMESH TO BE DRAWN (DEFAULT[CR] = NO)
      WRITE(5,1001)
 1001 FORMAT(/,1X,'WANT MECCA GRIDMESH PLOTTED?(Y/N)[N]: > ',$)
      READ(5,1002) Q
 1002 FORMAT(A)
      IF(Q.NE.'Y'.AND.Q.NE.'y') GRDMSH = .FALSE.
C---    USER TO SPECIFY IF MECCA PARAMETER TO BE PLOTTED (DEFAULT[CR] = YES)
      WRITE(5,1003)
 1003 FORMAT(/,1X,'WANT MECCA PARAMETER PLOTTED?(Y/N)[Y]: > ',$)
      READ(5,1002) Q
      IF(Q.NE.'N'.AND.Q.NE.'n') PRMTR = .TRUE.
C---    USER TO SPECIFY IF MECCA GRIDMESH IS TO BE AUGMENTED (DEFAULT[CR] = YES)
      WRITE(5,1006)
 1006 FORMAT(/,1X,'WANT MECCA GRIDMESH AUGMENTED?(Y/N)[Y]: > ',$)
      READ(5,1002) Q
      IF(Q.NE.'N'.AND.Q.NE.'n') AUG = .TRUE.

C---
      IF(PRMTR) THEN
      WRITE(5,1004)
 1004 FORMAT(/,1X,'SELECT MECCA FIELD DATA PARAMETER: >',/,
     25X,'T = TIDES',/,
     35X,'D = DEPTHS',/,
     41X,': > ',$)
      READ(5,1002) Q
      IF(Q.EQ.'T'.OR.Q.EQ.'t') TIDES = .TRUE.
      IF(Q.EQ.'D'.OR.Q.EQ.'d') DEPTHS = .TRUE.
      IF(TIDES.NE..TRUE..AND.DEPTHS.NE..TRUE.) GO TO 5
        IF(TIDES) THEN
          LU=4
          CALL OPEN(LU)
        END IF
      END IF
      RETURN
      END
C
C-----------------------------------------------------------------
C
      SUBROUTINE GRIDDER
C
C        GRID    1----2----Y
C                |    |
C                3----4
C                |
C                X
C
CC
      COMMON/FLAG2/BSNLON,CON2M,HMSL,NUMBC,NUMRIV,NCOL1,NRDAYS
      COMMON/CONS2/IEXTRN,COR,NCOR,MCOR,DFDN,DFDM,BSNLAT,BSNANG,NONLIN
      COMMON/CONS3/DT,DL,CDRGWB,AHORIZ,C1,C2,C3,C4,C5,C6,C7,C8,C9,C10
      COMMON/GEOG1/IFIELD(40,60),ICOL(5,200),IROW(5,200),NCOL,NROW
      COMMON/GRAF1/ISTART,INTVEL,NGPMAX,XG(36,300),IGRALL,IO1,IO2
      COMMON/GRAF2/IGPH,LGPH(36),MGPH(36),NGPH(36),ITYP(36)
      COMMON/GRID1/AREA(40,60),BX(40,60),BY(40,60),AH(40,60),AHC(40,60)
      COMMON/GRID2/THETA1(40,60),THETA2(40,60),THETA3(40,60)
      COMMON/GRID3/DELSE(40,60),NUMBXY,IEXSUB,IHVISC,AH00,AH0,CAH
      COMMON/GRID4/XE(122),YE(122),MZONS(2),NZONS(2),
     1 LENX(15,2),LENY(15,2),ASTX(15,2),BSTX(15,2),CSTX(15,2),
     2 ASTY(15,2),BSTY(15,2),CSTY(15,2),DXC(122),DXS(122),DYC(122),
     3 DYS(122),DX(122),DY(122),NSCTOR,MSCTOR
      COMMON/PARM1/IO,ISCR,NST,NSTMAX,NST0,NMAX,MMAX,NCELL,DMAX,NEGS
      COMMON/GCEN/GLAT(1000),GLON(1000)
```

```
      COMMON/IMAGE/IMAGE(512,512)
C---     MECCA OUTPUT OF TIDE LEVELS OR OTHER PARAMETER
      COMMON/MECCA/K(1000)
      COMMON/DATA1/FIELD(40,60),FAC
      COMMON/DATA2/DVERT,DHOR,FCOS,XC,YC
      COMMON/OPT1/GRDMSH,PRMTR,TIDES,DEPTHS,AUG
      DIMENSION X(122),Y(122)
      LOGICAL GRDMSH,PRMTR,TIDES,DEPTHS,AUG
      DATA JCOLOR/253/
C        SET THE INCREMENTS
      RAD=57.29578
      DVERT=DL/1852./60.*SIN(BSNANG/RAD)
      DHOR= DL/1852./60.*COS(BSNANG/RAD)
      FCOS=1./COS(BSNLAT/RAD)
      WRITE(5,80)DL,BSNLAT,BSNLON,BSNANG
 80   FORMAT(1X,'DL=',F8.2,' BSNLAT,BSNLON,BSNANG=',3F8.2)
      WRITE(5,85)
 85   FORMAT(1X,'PROCESSING IMAGE DATA...',/)
C        INITIALIZE
      DO 90 I=1,122
      X(I)=FLOAT(I-1)
 90   Y(I)=FLOAT(I-1)
      XC=X(MCOR)
      YC=Y(NCOR)
C      IF(NCOR.GE.NSCTOR)XC=X(MCOR+MMAX+1)
C      IF(MCOR.GE.MSCTOR)YC=Y(NCOR+NMAX+1)
C        LOOP THRU THE GRID MESH
      I=0
      DO 310 M=1,MMAX
      MP=M+1
      DO 300 N=1,NMAX
      NP=N+1
C       CALCULATE SHIFT FOR SECTORS
      MR=0
      NR=0
C     IF(N.GE.NSCTOR)MR=MMAX+1
C     IF(M.GE.MSCTOR)NR=NMAX+1
      II=IFIELD(N,M)/10
      IF(IFIELD(N,M).LT.10)GOTO 300
C           ANGLES: EAST
      RAD=1.
C        UPPER LEFT (X=DOWN, Y=RIGHT
      ALAT1= (BSNLAT+ DHOR*(XC-X( M+MR))+DVERT*(YC-Y( N+NR)))/RAD
      ALON1=-(BSNLON+(DHOR*(YC-Y( N+NR))-DVERT*(XC-X( M+MR)))*FCOS)/RAD
C        UPPER RIGHT
      ALAT2= (BSNLAT+ DHOR*(XC-X( M+MR))+DVERT*(YC-Y(NP+NR)))/RAD
      ALON2=-(BSNLON+(DHOR*(YC-Y(NP+NR))-DVERT*(XC-X( M+MR)))*FCOS)/RAD
C        LOWER LEFT
      ALAT3= (BSNLAT+ DHOR*(XC-X(MP+MR))+DVERT*(YC-Y( N+NR)))/RAD
      ALON3=-(BSNLON+(DHOR*(YC-Y(N+NR ))-DVERT*(XC-X(MP+MR)))*FCOS)/RAD
C        LOWER RIGHT
      ALAT4= (BSNLAT+ DHOR*(XC-X(MP+MR))+DVERT*(YC-Y(NP+NR)))/RAD
      ALON4=-(BSNLON+(DHOR*(YC-Y(NP+NR))-DVERT*(XC-X(MP+MR)))*FCOS)/RAD
C        CENTER OF CELL
      I=I+1
      GLAT(I)=.5*(ALAT1+ALAT4)
      GLON(I)=-.5*(ALON1+ALON4)
C         FILL IN DATA FOR ALL PIXELS IN EACH CELL
      FXO=X(M+MR)
      FYO=Y(N+NR)
      IF(PRMTR) CALL FILL(FXO,FYO,N,M)
C---      CONVERT LAT,LON OF EACH CELL CENTER TO PIXEL AND SCANLINE
      CALL PXLSCL(GLAT(I),GLON(I),IPXL,ISCL)
      IF(GRDMSH) THEN
C---     DRAW LINES BETWEEN EACH PAIR OF END POINTS OF CELL
```

```
      CALL LINE(ALAT1,ALAT2,-ALON1,-ALON2)
      CALL LINE(ALAT1,ALAT3,-ALON1,-ALON3)
      CALL LINE(ALAT2,ALAT4,-ALON2,-ALON4)
      CALL LINE(ALAT4,ALAT3,-ALON4,-ALON3)
C---      FILL IMAGE ARRAY WITH VALUE FOR EACH CELL CENTER
        IMAGE(IPXL,ISCL) = JCOLOR
      END IF
CUT   WRITE(5,110)I,N,M,GLAT(I),GLON(I),IPXL,ISCL
 110  FORMAT(1X,'I=',I4,'  N,M=',2I3,'  ALAT,ALON=',2F7.2,'  IPXL,ISCL=
     2 ',2I4)
 300  CONTINUE
 310  CONTINUE
      RETURN
      END
C
C-----------------------------------------------------------------------
C
      SUBROUTINE RDGEO(IGEO)
C        OCTOBER 1984   K. W. HESS   ASIC/MEAD    VAX 11/750
C        PURPOSE - TO READ IN PARAMETERS, PLUS IFIELD, DEPTH, AND
C                  FLAG DATA.
C        VARIABLES -
C                 IAH = INDEX TO READ HORIZ. EDDY VISCOSITY: 0=NO
C               IGRID = INDEX TO READ STRETCHED GRIDS:0=NO, 1=READ XE,YE,
C                       2=READ NSEGX, ETC.
C              NUMBXY = NUMBER OF CHANNEL GRIDS
C               NO,NR = NUMBER OF OCEAN, RIVER BOUNDARY CELLS AS
C                       DETERMINED BY IFIELD
C            NO1,NRV1 = NUMBER OF OCEAN, RIVER BOUNDARY CELLS AS
C                       DETERMINED BY NUMBC, NUMRIV
C               XC(,) = DISTANCE FROM ORIGIN TO GRID CENTER
C               XE(,) = DISTANCE TO LOWER SIDE OF GRID M
C        COMMON BLOCK FOR PROGRAM MECCA
      COMMON/CONS1/AG,OMEGA,PI,RAD,VISMOL,E,VONKAR,CRICH0,CRICH1,CRICH2
      COMMON/CONS2/IEXTRN,COR,NCOR,MCOR,DFDN,DFDM,BSNLAT,BSNANG,NONLIN
      COMMON/CONS3/DT,DL,CDRGWB,AHORIZ,C1,C2,C3,C4,C5,C6,C7,C8,C9,C10
      COMMON/FLAG1/MB1(6),MB2(6),NB1(6),NB2(6),ITP(6),ISET1(6),ISET2(6)
      COMMON/FLAG2/BSNLON,CON2M,HMSL,NUMBC,NUMRIV,NCOL1,NRDAYS
      COMMON/GEOG1/IFIELD(40,60),ICOL(5,200),IROW(5,200),NCOL,NROW
      COMMON/GEOG2/NAB(200),KOCNBC,KRIVBC
      COMMON/GRID1/AREA(40,60),BX(40,60),BY(40,60),AH(40,60),AHC(40,60)
      COMMON/GRID3/DELSE(40,60),NUMBXY,IEXSUB,IHVISC,AH00,AH0,CAH
      COMMON/GRID4/XE(122),YE(122),MZONS(2),NZONS(2),
     1 LENX(15,2),LENY(15,2),ASTX(15,2),BSTX(15,2),CSTX(15,2),
     2 ASTY(15,2),BSTY(15,2),CSTY(15,2),DXC(122),DXS(122),DYC(122),
     3 DYS(122),DX(122),DY(122),NSCTOR,MSCTOR
      COMMON/PARM1/IO,ISCR,NST,NSTMAX,NSTO,NMAX,MMAX,NCELL,DMAX,NEGS
      COMMON/RIVR1/MR1(10),MR2(10),NR1(10),NR2(10),ITRP(10),JTRP(10)
      COMMON/VELS2/D(40,60),SE(40,60),SEP(40,60),SEPP(40,60),FAREA(5)
C        ADDITIONAL COMMON STATEMENTS FOR MECCA
      COMMON/BNDS1/IMACH,KKIND,NUMOBC,NRIV
      CHARACTER*4 CTITLE,GTITLE(15)
      DIMENSION NUM(101),XC(101),YC(101)
      CHARACTER*10 FORM
C      TYPE 100,IGEO
 100  FORMAT(1X,'IGEO=',I3)
C        READ IN MECCA FILE HEADER BLOCK
 200  READ(IGEO,210,ERR=130)(GTITLE(N),N=1,15)
 210  FORMAT(1X,15A4)
      GOTO 218
 130  WRITE(IO,135)
 135  FORMAT(1X,'**** RDGEO. PROBLEM READING LINE GTITLE ***')
 218  READ(IGEO,220)NMAX,MMAX,NCOL1,NCOL2,NCOL3,NCOR,MCOR,ISIDE
 220  FORMAT(1X,8I4)
      READ(IGEO,230,ERR=232)FORM,DL,CON2M,CDRGWB,CDRGWS
```

```
 230  FORMAT(1X,A10,F10.2,F8.4,2F6.4)
      GOTO 234
 232  WRITE(IO,233)
 233  FORMAT(1X,'**** RDGEO. PROBLEM READING LINE FORM,DL, ETC ***')
 234  READ(IGEO,235)HMSL,BSNLAT,BSNLON,BSNANG
 235  FORMAT(1X,4F7.3)
C        READ IN BOUNDARY CONDITIONS
      READ(IGEO,220)NUMBC,NUMRIV,KOCNBC,NUMBXY,IAH,IGRID
      IF(NUMBC.NE.NUMOBC)WRITE(ISCR,236)NUMBC,NUMOBC
 236  FORMAT(5X,'*** READGEO:NUMBC = ',I2,' IS NOT EQUAL TO READCON:',
     1 'NUMOBC = ',I2)
      IF(NUMRIV.NE.NRIV)WRITE(ISCR,237)NUMRIV,NRIV
 237  FORMAT(5X,'*** READGEO:NUMRIV = ',I2,' IS NOT EQUAL TO READCON:',
     1 'NRIV = ',I2)
      IF(NUMBC.LE.0)GOTO 245
      DO 240 I=1,NUMBC
      READ(IGEO,242)MB1(I),MB2(I),NB1(I),NB2(I),ITP(I),ISET1(I),ISET2(I)
 242  FORMAT(1X,I4,6I2)
      IF(MB1(I).GT.MB2(I).OR.NB1(I).GT.NB2(I))GOTO 239
      GOTO 240
 239  WRITE(IO,238)I,MB1(I),MB2(I),NB1(I),NB2(I)
 238  FORMAT(/,1X,'*** ERROR *** AT OCEAN BOUNDARY # ',I2,' MB1=',I2,
     1 ' IS GT MB2=',I2,/,'  OR NB1=',I2,' IS GT NB2=',I2)
      STOP
 240  CONTINUE
C        READ IN RIVER BOUNDARIES
 245  IF(NUMRIV.LE.0)GOTO 248
      DO 246 I=1,NUMRIV
      IF(I.LE.10)READ(IGEO,242)MR1(I),MR2(I),NR1(I),NR2(I),ITRP(I),
     1 JTRP(I)
      JTRP(I)=MAX0(1,MIN0(2,JTRP(I)))
      IF(MR1(I).GT.MR2(I).OR.NR1(I).GT.NR2(I))GOTO 1239
      GOTO 246
 1239  WRITE(IO,1238)I,MR1(I),MR2(I),NR1(I),NR2(I)
 1238  FORMAT(/,1X,'*** ERROR *** AT RIVER BOUNDARY # ',I2,' MB1=',I2,
     1 ' IS GT MB2=',I2,/,'  OR NB1=',I2,' IS GT NB2=',I2)
      STOP
 246  IF(I.GT.10)READ(IGEO,242)
C        READ THE IFIELD
 248  DO 250 M=1,MMAX
      NX=MIN0(NMAX,NCOL1)
      NXP=NX+1
      READ(IGEO,252)(IFIELD(N,M),N=1,NX)
      IF(NCOL1.LT.NMAX)READ(IGEO,252)(IFIELD(N,M),N=NXP,NMAX)
 250  CONTINUE
 252  FORMAT(40I2)
CC
      DO 260 M=1,MMAX
 260  XE(M)=FLOAT(M-1)
      XE(MMAX+1)=FLOAT(MMAX)
      DO 262 N=1,NMAX
 262  YE(N)=FLOAT(N-1)
      YE(NMAX+1)=FLOAT(NMAX)
C
C        READ THE DEPTHS
      NCELL=0
      NBAD=0
      NSWEEP=1+(NMAX-1)/NCOL2
      DO 280 M=1,MMAX
      DO 270 NN=1,NSWEEP
      N1=1+NCOL2*(NN-1)
      N2=MIN0(NMAX,N1+NCOL2-1)
 270  READ(IGEO,FORM)(NUM(N),N=N1,N2)
C        CHECK FOR NO DEPTH AND CONVERT DEPTHS TO METERS
      DO 275 NN=1,NMAX
```

```
387          IF(IFIELD(NN,M).GE.10)NCELL=NCELL+1
388          IF(IFIELD(NN,M).GE.10.AND.NUM(NN).GT.0)GOTO 275
389          IF(IFIELD(NN,M).LT.10)GOTO 275
390          NBAD=NBAD+1
391          WRITE(ISCR,272)M,NN
392     272  FORMAT(1X,'NO DEPTH VALUE AT M=',I2,'  N=',I2)
393     275  D(NN,M)=FLOAT(NUM(NN))*CON2M+HMSL
394     280  CONTINUE
395     C
396     C       SET GRID WIDTHS AND AREA
397          DO 285 M=1,MMAX
398          DO 285 N=1,NMAX
399          BX(N,M)=1.0
400          BY(N,M)=1.0
401          AREA(N,M)=(XE(M+1)-XE(M))*(YE(N+1)-YE(N))
402     285  IF(IFIELD(N,M)/10.EQ.1)AREA(N,M)=0.5*AREA(N,M)
403          IF(NUMBXY.LE.0)GOTO 291
404          DO 290 J=1,NUMBXY
405          READ(IGEO,*)M,N,BX(N,M),BY(N,M),F1
406          AREA(N,M)=AREA(N,M)*F1
407     290  CONTINUE
408     C
409     C       SET HORIZONTAL EDDY VISCOSITY
410     291  CONTINUE
411     400  RETURN
412          END
413     C
414     C-----------------------------------------------------------------------
415     C
416            SUBROUTINE MGPLOT(MFLE)
417     C---      [SUBROUTINE MGPLOT: 9 MAY 1988]
418     C---        PURPOSE: TO CREATE EASI/PACE PLOT FILE
419     C---                 FROM 512 x 512 INTEGER IMAGE ARRAY
420            CHARACTER*103 FILNME
421            CHARACTER*48 TEXT
422            CHARACTER*1 SCLINE(512),DUM412(412),TXT(48),DUM4(4),BLNK,ANS
423            INTEGER*4 IFLSO
424            COMMON/GCEN/GLAT(1000),GLON(1000)
425            COMMON/IMAGE/IMAGE(512,512)
426            EQUIVALENCE (TEXT,TXT(1))
427            DATA DUM412/412*' '/,DUM4/4*' '/,BLNK/' '/
428            DATA TEXT/'AVERAGED TIDES FOR LOOP(NEW GRIDMESH, NEW SCALE)'/
429            WRITE(5,1006) TEXT
430     1006   FORMAT(1X,'DEFAULT TEXT TITLE FOR IMAGE ARRAY IS: ',/,1X,A)
431            WRITE(5,1003)
432     1003   FORMAT(/,'$SPECIFY "NEW" TEXT TITLE FOR ARRAY? (Y/N) : > ')
433            READ(5,1004) ANS
434     1004   FORMAT(A)
435            IF(ANS.NE.'Y'.AND.ANS.NE.'y') GO TO 1
436            DO I=1,48
437            TXT(I)=BLNK
438            END DO
439            WRITE(5,1005)
440     1005   FORMAT('$ENTER TITLE (UP TO 48 CHARACTERS) FOR ARRAY: >',/)
441            READ(5,1004) TEXT
442        1   CONTINUE
443     C---     USER IS TO SPECIFY OUTPUT FILENAME
444            WRITE(5,1001)
445            READ(5,1002) FILNME
446     1001   FORMAT(1X,'SPECIFY OUTPUT FILENAME: >',/)
447     1002   FORMAT(A)
448            OPEN(UNIT=MFLE,NAME=FILNME,TYPE='NEW',ACCESS='SEQUENTIAL',
449        2   FORM='UNFORMATTED',RECORDSIZE=128,RECORDTYPE='FIXED')
450     C---     DEFINE VARIABLES FOR HEADER BLOCK OF OUTPUT FILE
451            NUMPIX = 512
```

```
452             NUMLIN = 512
453             NUMPLN = 1
454             XSIZE = 1500.
455             YSIZE = 1500.
456             IBITS = 8
457             IFLSO = 1
458             UTMX = 0.
459             UTMY = 0.
460             NUMRPS = 1
461       C---    WRITE OUT HEADER BLOCK
462             WRITE(MFLE) NUMLIN,NUMPIX,NUMPLN,XSIZE,YSIZE,DUM4,DUM4,DUM4,
463           2 NUMRPS,TEXT,UTMX,UTMY,IBITS,DUM412,IFLSO
464       C---    CONVERT INTEGERS TO CHARACTER*1 VALUES FOR 512 PIXELS IN SCANLINE
465             DO I=1,512
466             DO J=1,512
467             SCLINE(J) = CHAR(IMAGE(J,I))
468             END DO
469       C---    WRITE DATA FOR SCANLINE TO DISK FILE
470             WRITE(MFLE,ERR=100) SCLINE
471             END DO
472             GO TO 200
473         100 CONTINUE
474             WRITE(5,8000) I,J
475        8000 FORMAT(2X,'ERROR IN WRITING VALUE IN SCANLINE,PIXEL = ',2I4)
476         200 CONTINUE
477             RETURN
478             END
479       C
480       C-----------------------------------------------------------------------
481       C
482             SUBROUTINE PXLSCL(SLAT,PLON,IPXL,ISCL)
483       C---      PURPOSE: TO COMPUTE INTEGER IMAGE PIXELS AND SCANLINES
484       C---               (1-512) FROM DECIMAL LATITUDES AND LONGITUDES.
485       C---      CONSTANTS:
486       C---                D2R = RADIANS/DEGREE
487       C---                EARTHR = EARTH RADIUS (KM)
488       C---                SCALE = PIXEL SIZE AT EQUATOR (KM)
489       C---      VARIABLES:
490       C---                PXLOFF = PIXEL OFFSET FOR LEFT COLUMN
491       C---                SCLOFF = SCANLINE OFFSET FOR BOTTOM ROW
492       C---                SLAT = DECIMAL LATITUDE IN DEGREES
493       C---                PLON = DECIMAL LONGITUDE IN DEGREES
494       C---                (WEST LONGITUDE IS POSITIVE)
495       C---                IPXL = INTEGER VALUE OF PIXEL
496       C---                ISCL = INTEGER VALUE OF SCANLINE
497             DATA D2R,PI,EARTHR,SCALE/.0174533,3.14159265,6371.2,1.5/
498       C---      VALUES OF PXLOFF AND SCLOFF ARE FOR CHESAPEAKE BAY
499       C---      PXLOFF FOR 78.91 DEGREES WEST
500             PXLOFF = 7494.
501       C---      SCLOFF FOR 34.5 DEGREES NORTH (40.0 DEGREES N = 3240.4)
502             SCLOFF = 2727.8
503       C---      CALCULATE INTEGER PIXEL (IPXL) FROM DECIMAL LONGITUDE
504             IPXL=(180.-PLON)*D2R*EARTHR/SCALE -PXLOFF+0.5
505       C         CALCULATE SCANLINE
506             ISCL=512.-ALOG(TAN((45.+.5*SLAT)*D2R)*EARTHR/SCALE+SCLOFF+.5
507             RETURN
508             END
509       C
510       C-----------------------------------------------------------------------
511       C
512             SUBROUTINE LINE(SLAT1,SLAT2,SLON1,SLON2)
513       C---    [ SUBROUTINE LINE - 12 MAY 1988 ]
514       C---      PURPOSE: TO DRAW LINE BETWEEN TWO IMAGE POINTS
515       C---               BY INTERPOLATING PIXELS AND SCANLINES BETWEEN THEM
516             COMMON/IMAGE/IMAGE(512,512)
```

```
517        C---    SET COLOR VALUE FOR GRIDMESH PIXELS AND SCANLINES TO 252
518                DATA ICOLOR/252/
519        C---      CONVERT END POINT LATS AND LONS TO PIXELS AND SCANLINES
520                CALL PXLSCL(SLAT1,SLON1,IPXL1,ISCL1)
521                CALL PXLSCL(SLAT2,SLON2,IPXL2,ISCL2)
522        C---      COMPUTE PIXEL AND SCANLINE DIFFERENCES
523                IDELP = IPXL2 - IPXL1
524                IDELS = ISCL2 - ISCL1
525        C---      TEST FOR CASE OF DEGENERATE LINE (SINGLE POINT)
526                IF(IDELP.EQ.0.AND.IDELS.EQ.0) THEN
527                  IMAGE(IPXL1,ISCL1) = ICOLOR
528                  GO TO 1
529                END IF
530        C---      CONVERT PIXEL AND SCANLINE DIFFERENCES TO REAL NUMBERS
531                DELP = IDELP
532                DELS = IDELS
533        C---      LOOP EITHER ON PIXELS OR SCANLINES FOR A CONTINUOUS
534        C---      APPEARING LINE SEGMENT
535                IF(ABS(DELP).GT.ABS(DELS)) THEN
536                  INCR = JISIGN(1,IDELP)
537                  DO IPXL=IPXL1,IPXL2,INCR
538                    ISCL = ISCL1 + ((IPXL-IPXL1)/DELP)*DELS + 0.5
539                    IF(ISCL.LT.1) ISCL = 1
540                    IF(ISCL.GT.512) ISCL = 512
541                    IMAGE(IPXL,ISCL) = ICOLOR
542                  END DO
543                ELSE
544                  INCR = JISIGN(1,IDELS)
545                  DO ISCL=ISCL1,ISCL2,INCR
546                    IPXL = IPXL1 + ((ISCL-ISCL1)/DELS)*DELP + 0.5
547                    IF(IPXL.LT.1) IPXL = 1
548                    IF(IPXL.GT.512) IPXL = 512
549                    IMAGE(IPXL,ISCL) = ICOLOR
550                  END DO
551                END IF
552         1      CONTINUE
553                RETURN
554                END
555        C
556        C-----------------------------------------------------------------------
557        C
558              SUBROUTINE MECTID(JMAX)
559        C---     [ SUBROUTINE MECTID - 18 MAY 1988 ]
560        C---        PURPOSE - TO READ IN A TIDE AMPLITUDE FIELD FROM A MECCA RUN
561        C---                  VALUES SCALED (1 TO 255) FOR GRID CELL CENTERS
562              DIMENSION IX(40,60)
563              COMMON/MECCA/K(1000)
564              COMMON/DATA1/FIELD(40,60),FAC
565              DATA MMAX,NMAX/29,40/
566              LU=4
567              CALL OPEN(LU)
568              DO 90 I=1,3
569           90 READ(LU,100)
570          100 FORMAT(1X)
571        C
572              IMAX=0
573              IMIN=999999
574              DO 200 NN=1,NMAX
575              N=NMAX+1-NN
576              READ(LU,*)I,(IX(N,M),M=1,MMAX)
577        CUT   WRITE(5,120)N,(IX(N,J),J=1,10)
578          120 FORMAT(1X,30I4)
579              DO 130 M=1,MMAX
580              FIELD(N,M)=IX(N,M)
581              IF(IX(N,M).EQ.0)GOTO 130
```

```
582          IMAX=MAX0(IMAX,IX(N,M))
583          IMIN=MIN0(IMIN,IX(N,M))
584   130    CONTINUE
585          READ(LU,100)
586   200    CONTINUE
587          TYPE 220,IMAX,IMIN
588   220    FORMAT(/,5X,'IMAX=',I3,'  IMIN=',I3)
589    C
590          J=0
591          KMAX=0
592          DO 300 M=1,MMAX
593          DO 300 N=1,NMAX
594          IF(IX(N,M).EQ.0)GOTO 300
595          J=J+1
596    C---     SCALE THE TIDAL AMPLITUDES AND STORE IN ARRAY K
597          K(J)=255.*FLOAT(IX(N,M))/FLOAT(IMAX)+.5
598          KMAX=MAX0(KMAX,K(J))
599   300    CONTINUE
600          TYPE 320,KMAX
601   320    FORMAT(/,5X,'KMAX=',I3)
602          JMAX=J
603    C---     CLOSE MECCA FILE
604          CLOSE(UNIT=LU)
605          RETURN
606          END
607    C
608    C-----------------------------------------------------------------
609    C
610          SUBROUTINE OPEN(LU)
611    C---     [ SUBROUTINE OPEN - 18 MAY 1988 ]
612    C---         PURPOSE - TO OPEN MECCA PARAMETER FILE
613          CHARACTER*40 FNAME
614          ISCR=5
615    C        GET NAME OF FILE
616   100    TYPE 110
617   110    FORMAT('$ENTER DATA FIELD FILE NAME : ')
618          READ(ISCR,120)FNAME
619   120    FORMAT(A)
620          OPEN(UNIT=LU,NAME=FNAME,ACCESS='SEQUENTIAL',FORM='FORMATTED',
621         1 STATUS='UNKNOWN',READONLY,ERR=100)
622          RETURN
623          END
624    C
625    C-----------------------------------------------------------------
626    C
627          SUBROUTINE FILL(FX0,FY0,N,M)
628    C         PURPOSE - TO FILL IN ALL PIXELS AND SCANLINES IN EACH
629    C                   MECCA GRID CELL WITH A VALUE
630    C
631    C          +-----> IPIX
632    C          !
633    C          !
634    C          v
635    C         ISCL
636    C
637          COMMON/DATA1/FIELD(40,60),FAC
638          COMMON/DATA2/DVERT,DHOR,FCOS,XC,YC
639    C
640          COMMON/FLAG2/BSNLON,CON2M,HMSL,NUMBC,NUMRIV,NCOL1,NRDAYS
641          COMMON/CONS2/IEXTRN,COR,NCOR,MCOR,DFDN,DFDM,BSNLAT,BSNANG,NONLIN
642          COMMON/CONS3/DT,DL,CDRGWB,AHORIZ,C1,C2,C3,C4,C5,C6,C7,C8,C9,C10
643          COMMON/GEOG1/IFIELD(40,60),ICOL(5,200),IROW(5,200),NCOL,NROW
644          COMMON/GRID1/AREA(40,60),BX(40,60),BY(40,60),AH(40,60),AHC(40,60)
645          COMMON/GRID4/XE(122),YE(122),MZONS(2),NZONS(2),
646         1 LENX(15,2),LENY(15,2),ASTX(15,2),BSTX(15,2),CSTX(15,2),
```

```
     2 ASTY(15,2),BSTY(15,2),CSTY(15,2),DXC(122),DXS(122),DYC(122),
     3 DYS(122),DX(122),DY(122),NSCTOR,MSCTOR
      COMMON/PARM1/IO,ISCR,NST,NSTMAX,NSTO,NMAX,MMAX,NCELL,DMAX,NEGS
      COMMON/IMAGE/IMAGE(512,512)
      DIMENSION ISL(20,20)
      CHARACTER*2 AA(20),CH1,CH2
      DATA CH1,CH2/' .',' 1'/
C        INITIALIZE
      JMAX=12
      JMAXP=JMAX+1
      DF=1./FLOAT(JMAX)
      IPMIN=99999
      ISMIN=99999
C        SET TO ZERO:  ISL(LINE, KOLUMN)
      DO 120 KL=1,20
      DO 120 LN=1,20
 120  ISL(LN,KL)=0
C        TEST LOOP: KMAX=1, NO TEST P/O; KMAX=2, TEST P/O
      KMAX=1
      DO 225 KK=1,KMAX
C        LOOP THRU TO GET PIXEL & SCANLINE      J=X, I=Y
      DO 200 J=1,JMAXP
      DDX=FLOAT(J-1)*DF
      FX=FXO+DDX
      DO 200 I=1,JMAXP
      DDY=FLOAT(I-1)*DF
      FY=FYO+DDY
      ALATX= (BSNLAT+ DHOR*(XC-FX)+DVERT*(YC-FY))
      ALONX= (BSNLON+(DHOR*(YC-FY)-DVERT*(XC-FX))*FCOS)
      CALL PXLSCL(ALATX,ALONX,IPXL,ISCL)
C         WE NOW HAVE PIXEL AND SCANLINE; GET VALUE OF FIELD
      IVAL=FIELD(N,M)
C---      COMPUTE SPATIAL AVERAGE FOR CELL
      CALL CENAVG(N,M,DDX,DDY,FC)
C---      ROUND TO NEAREST INTEGER
      ROUND=SIGN(0.5,FC)
      IVAL=FC+ROUND
C---      SCALE VALUES TO RANGE FROM 1 TO 240
      JVAL=ISCALE(FC)
C---      FILL PIXEL AND SCANLINE OF INTERIOR OF MECCA CELL WITH
C---      SPATIALLY AVERAGED FIELD DATA IF GRIDMESH NOT PRESENT
      IF(IMAGE(IPXL,ISCL).NE.252) THEN
        IMAGE(IPXL,ISCL) = JVAL
      END IF
C      WRITE(5,190)J,I,IPXL,ISCL,IVAL,JVAL
 190  FORMAT(1X,'J,I=',2I3,'  IPXL,ISCL=',2I5,' IVAL,JVAL=',2I5)
C        GET MINIMUM PIXEL AND SCANLINE FOR TEST P/O
      IF(KK.EQ.2)GOTO 195
      IPMIN=MINO(IPMIN,IPXL)
      ISMIN=MINO(ISMIN,ISCL)
      GOTO 200
C        RESCALE FOR P/O
 195  ISL(ISCL-ISMIN+1,IPXL-IPMIN+1)=IVAL
 200  CONTINUE
CUT   IF(KK.EQ.1)WRITE(5,220)M,N,IPMIN,ISMIN
 220  FORMAT(5X,'M,N=',2I3,'  IPMIN=',I3,'   ISMIN=',I3)
 225  CONTINUE
C        P/O AS TEST FOR COMPLETE FILL
      IF(KMAX.EQ.1)GOTO 300
      DO 240 LN=1,20
      DO 230 KL=1,20
      AA(KL)=CH1
      IF(ISL(LN,KL).EQ.1)AA(KL)=CH2
 230  CONTINUE
CUT   WRITE(5,265)LN,(ISL(LN,KL),KL=1,15)
```

```
 265  FORMAT(1X,I2,1X,15I4)
 240  CONTINUE
 300  CONTINUE
      RETURN
      END
C
C-----------------------------------------------------------------
C
      FUNCTION ISCALE(FVAL)
C        MAY 1988   HESS   VAX
C        PURPOSE - TO CONVERT AN INTEGER VALUE TO A
C                  SCALED REFLECTANCE LEVEL (1 - 240)
      COMMON/SCALE/FMIN,FMAX
      ISCALE=240.*((FVAL-FMIN)/(FMAX-FMIN))+.5
      IF(ISCALE.GT.240) ISCALE = 254
      IF(ISCALE.LT.1) ISCALE = 251
      RETURN
      END
C
C-----------------------------------------------------------------
C
      SUBROUTINE MNFLUX
C        VARIABLES -
C            MFLUX(,) = INDEX FOR MASS FLUX IN X-DIRECTION (0=NO, 1=YES)
C            NFLUX(,) = INDEX FOR MASS FLUX IN Y-DIRECTION (0=NO, 1=YES)
      COMMON/GEOG1/IFIELD(40,60),ICOL(5,200),IROW(5,200),NCOL,NROW
      COMMON/DATA3/MFLUX(40,60),NFLUX(40,60)
      COMMON/PARM1/IO,ISCR,NST,NSTMAX,NSTO,NMAX,MMAX,NCELL,DMAX,NEGS
C        LOOP DOWN THE LINES
      DO 100 M=1,MMAX
      MP=MINO(MMAX,M+1)
      DO 100 N=1,NMAX
      NP=MINO(NMAX,N+1)
      I=MOD(IFIELD(N,M),10)
      IX=1
      IF(IFIELD(N,M).LT.10.OR.IFIELD(N,MP).LT.10)IX=0
      IF(I.EQ.1.OR.I.EQ.3)IX=0
      IF(M.EQ.MMAX)IX=0
      MFLUX(N,M)=IX
      IY=1
      IF(IFIELD(N,M).LT.10.OR.IFIELD(NP,M).LT.10)IY=0
      IF(I.EQ.2.OR.I.EQ.3)IY=0
      IF(N.EQ.NMAX)IY=0
      NFLUX(N,M)=IY
 100  CONTINUE
      RETURN
      END
C
C-----------------------------------------------------------------
C
      SUBROUTINE CENAVG(N,M,DX,DY,FC)
C        MAY 1988   HESS   MEAD   VAX/780
C        PURPOSE - TO COMPUTE THE SPATIAL AVERAGE FOR FIELD DATA
C                  AT GRID CELL CENTER
C        VARIABLES -
C               DX,DY = DISTANCE IN CELL FROM LOWER SIDE TO POINT
C                       AT WHICH AVERAGE IS TAKEN
C                  FC = SPATIAL AVERAGE
C                 M,N = CELL INDICES
C
C
C          NA          NB
C        MA 1-----------2   Y
C           :  GX       :
C           :GY *       :
```

```
C          :          :
C          :          :
C       MB 3----------4
C          X
C
C
      COMMON/GEOG1/IFIELD(40,60),ICOL(5,200),IROW(5,200),NCOL,NROW
      COMMON/PARM1/IO,ISCR,NST,NSTMAX,NSTO,NMAX,MMAX,NCELL,DMAX,NEGS
      COMMON/DATA3/MFLUX(40,60),NFLUX(40,60)
      COMMON/DATA1/FIELD(40,60),FAC
C        X DIRECTION
      I=1.5-DX
      GX=DX-.5+FLOAT(I)
      MA=M-I
      MB=MA+1
C---    LOOK FOR NON-POSITIVE (ZERO-TH) ROW AND COLUMN SUBSCRIPTS AND SET MASS
C---    FLUX INDEX VALUES TO ZERO IN THAT CASE
C     IF(MA.LT.1)MA=MMAX
      LM=1
      IF(MA.LT.1)LM=0
C        Y DIRECTION:   NA-- J=0 --+-- J=1 --NB
      J=1.5-DY
      GY=DY-.5+FLOAT(J)
      NA=N-J
      NB=NA+1
C---    LOOK FOR NON-POSITIVE (ZERO-TH) ROW AND COLUMN SUBSCRIPTS AND SET MASS
C---    FLUX INDEX VALUES TO ZERO IN THAT CASE
C     IF(NA.LT.1)NA=NMAX
      LN=1
      IF(NA.LT.1)LN=0
C        LOOK FOR ZERO-TH ROW OR COLUMN
      NFAA=NFLUX(NA,MA)*LN*LM
      NFAB=NFLUX(NA,MB)*LN
      MFAA=MFLUX(NA,MA)*LN*LM
      MFBA=MFLUX(NB,MA)*LM
C        SET WEIGHTS BASED ON FLUXES ACROSS SIDES
      IF(I.EQ.0.AND.J.EQ.0)THEN
       A1=1.
       A2=NFAA
       A3=MFAA
       A4=1.
       IF(A2+A3.EQ.0..OR.(MFBA.EQ.0.AND.NFAB.EQ.0))A4=0.
      ELSE IF(I.EQ.0.AND.J.EQ.1)THEN
       A2=1.
       A1=NFAA
       A4=MFBA
       A3=1.0
       IF(A1+A4.EQ.0..OR.(MFAA.EQ.0.AND.NFAB.EQ.0))A3=0.
      ELSE IF(I.EQ.1.AND.J.EQ.0)THEN
       A3=1.
       A4=NFAB
       A1=MFAA
       A2=1.
       IF(A1+A4.EQ.0..OR.(MFBA.EQ.0.AND.NFAA.EQ.0))A2=0.
      ELSE IF(I.EQ.1.AND.J.EQ.1)THEN
       A4=1.
       A3=NFAB
       A2=MFBA
       A1=1.
       IF(A2+A3.EQ.0..OR.(MFAA.EQ.0.AND.NFAA.EQ.0))A1=0.
      END IF
C
C        COMPUTE SPATIAL AVERAGE
      G=GX*GY
      FC=((1.-GX-GY+G)*A1*FIELD(NA,MA)+(GY-G)*A2*FIELD(NB,MA)+
```

```
     1 (GX-G)*A3*FIELD(NA,MB)+G*A4*FIELD(NB,MB))/((1.-GX-GY+G)*A1+
     2 (GY-G)*A2+(GX-G)*A3+G*A4)
C
CUT   IF(M.EQ.1.AND.N.LE.25)WRITE(5,1000)M,N,FC,DX,DY,A1,A2,A3,A4
 1000 FORMAT(1X,'CENAVG PRINT',2I4,7F8.3)
      RETURN
      END
C
C-----------------------------------------------------------------
C
      SUBROUTINE MECFLD
      COMMON/DATA1/FIELD(40,60),FAC
      COMMON/VELS2/D(40,60),SE(40,60),SEP(40,60),SEPP(40,60),FAREA(5)
      COMMON/PARM1/IO,ISCR,NST,NSTMAX,NSTO,NMAX,MMAX,NCELL,DMAX,NEGS
      COMMON/GEOG1/IFIELD(40,60),ICOL(5,200),IROW(5,200),NCOL,NROW
      DO 1 N=1,NMAX
      DO 1 M=1,MMAX
      IF(IFIELD(N,M).LE.9) GO TO 1
      FIELD(N,M)=-D(N,M)
    1 CONTINUE
      RETURN
      END
C
C-----------------------------------------------------------------
C
      SUBROUTINE RDMEC(JMAX)
C        MAY 1988   HESS   VAX   MEAD
C        PURPOSE - TO READ IN A TIDE AMPLITUDE FIELD FROM A MECCA RUN
      COMMON/PARM1/IO,ISCR,NST,NSTMAX,NSTO,NMAX,MMAX,NCELL,DMAX,NEGS
      COMMON/DATA1/FIELD(40,60),FAC
      COMMON/DATA2/LNE(40)
      DIMENSION IX(40,60),K(1000)
CCC   CHARACTER*12 TITLE
      CHARACTER*17 TITLE
      LU=4
      READ(LU,101)FAC,IFOR,TITLE
 100  FORMAT(A12)
 101  FORMAT(F7.1,I3,3X,A17)
      WRITE(5,111)TITLE
 110  FORMAT(1X,A12)
 111  FORMAT(1X,A17)
CCC   READ(LU,*)FAC
      READ(LU,112)LNE
 112  FORMAT(4X,40I3)
      WRITE(5,120)FAC,MMAX,NMAX
 120  FORMAT(1X,'FAC=',F6.1,'  MMAX,NMAX=',2I3)
C
      IMAX=0
      IMIN=999999
      JMAX=0
      WRITE(6,112)LNE
      DO 200 M=1,MMAX
      READ(LU,141)I,(IX(N,M),N=1,NMAX)
CUT   WRITE(5,141)M,(IX(J,M),J=1,10)
      WRITE(6,141)M,(IX(J,M),J=1,NMAX)
 140  FORMAT(41I3)
 141  FORMAT(1X,41I3)
      DO 180 N=1,NMAX
CC    FIELD(N,M)=IX(N,M)
      FIELD(N,M)=IX(N,M)/FAC
      IF(IX(N,M).EQ.0)GOTO 180
      IMAX=MAX0(IMAX,IX(N,M))
      IMIN=MIN0(IMIN,IX(N,M))
      JMAX=JMAX+1
 180  CONTINUE
```

```
 200  CONTINUE
      RETURN
      END
C
C-----------------------------------------------------------------
C
      SUBROUTINE AUGRID
C---     SEPTEMBER 1988
C---     PURPOSE - TO AUGMENT MECCA GRID WITHIN CHES. BAY BY ADDING
C---               LAYER(S) AROUND ORIGINAL GRIDMESH FOR FILLING
C---               WATER AREAS WITH DATA IN GIS IMAGERY
      COMMON/DATA1/FIELD(40,60),FAC
      COMMON/DATA2/LNE(40)
      COMMON/PARM1/IO,ISCR,NST,NSTMAX,NSTO,NMAX,MMAX,NCELL,DMAX,NEGS
      COMMON/GEOG1/IFIELD(40,60),ICOL(5,200),IROW(5,200),NCOL,NROW
      INTEGER*2 IX(40,60)
      DO 1 N=1,NMAX
      DO 2 M=1,15
        IF(M.EQ.15.AND.N.LT.22) GO TO 2
        IF(IFIELD(N,M).EQ.98.OR.IFIELD(N,M+1).EQ.98) GO TO 2
        IF(IFIELD(N,M).LT.10.AND.IFIELD(N,M+1).GE.10) THEN
          IFIELD(N,M)=98
          FIELD(N,M)=FIELD(N,M+1)
        ELSE IF (IFIELD(N,M).GE.10.AND.IFIELD(N,M+1).LT.10) THEN
          IFIELD(N,M+1)=98
          FIELD(N,M+1)=FIELD(N,M)
        END IF
    2 CONTINUE
    1 CONTINUE
      DO 3 M=1,16
      DO 4 N=1,NMAX-1
        IF(M.EQ.16.AND.N.LT.22) GO TO 4
        IF(IFIELD(N,M).EQ.99.OR.IFIELD(N+1,M).EQ.99) GO TO 4
        IF(IFIELD(N,M).LT.10.AND.IFIELD(N+1,M).GE.10) THEN
          IFIELD(N,M)=99
          FIELD(N,M)=FIELD(N+1,M)
        ELSE IF (IFIELD(N,M).GE.10.AND.IFIELD(N+1,M).LT.10) THEN
          IFIELD(N+1,M)=99
          FIELD(N+1,M)=FIELD(N,M)
        END IF
    4 CONTINUE
    3 CONTINUE
      DO 5 M=1,MMAX
      DO 5 N=1,NMAX
      F=FAC*FIELD(N,M)
      ROUND=SIGN(0.5,F)
      IX(N,M)=F+ROUND
    5 CONTINUE
      WRITE(6,1002)
      WRITE(6,1003)LNE
      DO 6 M=1,MMAX
      WRITE(6,1004)M,(IFIELD(J,M),J=1,NMAX)
    6 CONTINUE
CCC   WRITE(6,1001) IFIELD
      WRITE(6,1002)
      WRITE(6,1003)LNE
      DO 7 M=1,MMAX
      WRITE(6,1004)M,(IX(J,M),J=1,NMAX)
    7 CONTINUE
 1001 FORMAT(1X,40I3)
 1002 FORMAT(//)
 1003 FORMAT(4X,40I3)
 1004 FORMAT(1X,41I3)
      RETURN
      END
```

(Continued from inside front cover)

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