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THE GLOBALL COMPUTER PROGRAM AND GLOBEMAP - A SPECIAL PURPOSE THREE-DIMENSIONAL PLOTTER SUBROUTINE

CENTER FOR NAVAL ANALYSES
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Naval Warfare Analysis Group

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GLOBALL manipulates several smaller computer programs to calculate global ranges and surface areas. GLOBEMAP provides a three-dimensional map background upon which the ranges and areas may be presented. This paper is not intended to be a user's manual but to describe characteristics of these models and possible applications of them.

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INTRODUCTION

GLOBALL was developed to give the desk-bound navigator computer-aided solutions to his global range and surface area problems. The program can accomplish tasks that are tedious and time consuming, if not virtually impossible, to perform by hand. To verify inputs and visualize results, a three-dimensional, computer-drawn plot of the earth's surface is furnished. The plot can also be used for graphic presentation of work in a document.

Three basic calculations can be performed: determining great-circle distances, generating range circles about points, and computing surface areas from inputted point coordinates describing the perimeters of the areas. These operations can be combined to solve a variety of problems.

GLOBALL was designed to be used as a library routine to call various subroutines which use inputs that are read in and stored, or values that are calculated during a run.

This paper presents a general description of the basic computer program and its accompanying plotter subroutine, a detailed description of the inputs required in the subroutines, and several examples of possible applications. Each example is accompanied by a program listing, computer printouts, and illustrative plots.

PART I: GENERAL DESCRIPTION

The GLOBALL Computer Program, which is a package of Fortran IV subroutines, was developed at the Center for Naval Analyses to compute global distances and areas anywhere on the surface of the earth. It evolved from three computerized algorithms that were used for calculating great-circle distances, range circles, and surface areas. The algorithms were combined with a specially adapted three-dimensional plotting subroutine, forming the three main subroutines: GCLINE, SURFAREA, and GLOBEMAP.

Great-Circle Distances

SUBROUTINE GCLINE calculates great-circle distances between points on the earth's surface in one degree segments (60 n.mi.) and plots them. The coordinates at the junction of each segment are computed and printed out.

Range Circles

A range circle may be generated about any point on the earth's surface and is formed by revolving its great-circle radius about its center. The track of the range circle is divided into one degree arcs beginning at true north clockwise through 360 degrees. A number of range circles may be calculated and drawn on the same plot. If the circles intersect, the intercept points and the areas of intersection are computed.

Surface Areas

SUBROUTINE SURFAREA will compute a surface area of the portion of the earth's surface enclosed within a given perimeter. A perimeter described by a set of points may represent an area up to a hemisphere in size. An area enclosure may take on any shape and cover both land and water.

Projection Map

GLOBALL provides an accurate and easy-to-use analytical tool for use in a wide variety of applications. To get a better "feel" for the numerous possible range and area configurations, a two-dimensional, global representation or map is plotted by the SUBROUTINE GLOBEMAP.

GLOBEMAP PLOTTER SUBROUTINE

GLOBEMAP was developed from another three-dimensional plotting subroutine that was used to plot quadric surfaces, and draws azimuthal orthographic projections of the earth's curved surface. Either a full hemisphere or an enlarged projection may be selected. The physical size of the plots may be varied. The projection plots, showing the coastlines of the earth land masses, make excellent document maps with titles along three of the four sides.

Inheriting the characteristics of an azimuthal projection, every point is shown at its true direction from the center of the projection. Similarly, a great-circle distance from the center point to any other point projects as a straight line.

The user has complete freedom to specify any point on the surface of the earth as the center of the projection. Each view is obtained after rotating the globe about fixed spatial axes.

Spherical coordinates (ρ, θ, ϕ) are used to pinpoint the positions of points lying on the projected sphere. The radius of the sphere, ρ, is assumed to be one unit in length to simplify calculations. To compute surface areas, ρ is set equal to the earth's radius, 3440.07 nautical miles. θ and ϕ are the co-latitude and longitude of a point, respectively.

Types of Plots

The user has the option to draw either a globe projection, showing a hemisphere at a time, or an enlarged view of a smaller part of the earth's surface. Examples of both are illustrated in part III of this paper.

The hemisphere projection is drawn by plotting only the visible half of the earth. Plotting only the points that are within 5, 400 nautical miles of the center of the plot, the back side is suppressed. A circular border or horizon is drawn with a radius of 5, 400 n.mi.; SUBROUTINE GLOBEMAP is called for the hemisphere plot.

A separate subroutine, BLOWUP, is called for enlarged projections. An input parameter, BRANGE, which will be referred to as the blow-up range, enables the user to vary the magnification of the projection. The blow-up range is the maximum distance from the center of the projection outside of which points are not plotted. This distance is internally set equal to 5, 400 n.mi. for a hemisphere plot. The reduced field of view is then enlarged to completely fill a circular or rectangular border. The dimensions of the border are preset by other inputs and unchangeable during the enlarging.

The ability to vary the magnification and the physical size of a projection enables the user to "zoom" in on a particular region.

Shorelines

The earth's land masses and inland bodies of water are drawn by connecting shoreline points. The mean distance between the points is approximately 8 nautical miles. All islands, lakes and inland seas greater than $\approx$ 250 square nautical miles are represented.

The coordinates of the points are stored on tape and read in for each plot. Each point of every shoreline is tested to determine whether it is within the dimensions of the plot. A shoreline is drawn from point to point until either all its points have been read in or until it extends past the border. A shoreline may enter and exit a plot several times.

Meridians and parallels, spaced every ten or twenty degrees, may be added.

CONCLUDING REMARKS

The ability to rotate the projections of the earth's surface and draw a sequence of plots adds a fourth dimension -- time. Production of time-variable plots enables the researcher to pictorially analyze campaign results at various stages.

A future version of GLOBALL is currently under development to improve the conceptual quality of the projection maps by including the political boundaries of the countries. Two additional subroutines, RADARC and FIRANGE, will be added to compute and draw radar azimuthal coverages and missile firing ranges, respectively.

GLOBALL can provide a valuable graphic tool to visualize and study satellite ground track patterns. The satellite's path across the surface of the earth can be plotted by SUBROUTINE GCLINE and coverage areas computed by SUBROUTINE SURFAREA. Additional modifications to GLOBALL's coordinate transformation routine would be required to actually plot the satellite's orbit and any other space trajectories.

PART II: INPUT PARAMETERS AND SUBROUTINES

INPUTS

The principal inputs are coordinates of points, (σ, λ) and ranges (n.mi.). The coordinates identify the positions of points for which an indicated operation is to be performed. The latitudinal position of a point measured in degrees is the angular distance north or south of the equator. As an input parameter, the latitude, σ, of a point is considered positive north of the equator and negative, south. Similarly, longitude, λ, is measured positive, east, of the prime meridian.

GLOBALL's subroutines and input parameters are listed as follows:

GLOBEMAP (XLAT, XLON, PRANGE, NOPTS, XTITLE, NX, YTITLE, NY, TITLE, NT, NTYPE, XSIZE, YSIZE)

BLOWUP (XLAT, XLON, PRANGE, BRANGE, NOPTS, XTITLE, NX, YTITLE, NY, TTITLE, NT, NTYPE, XSIZE, YSIZE)

SECRANGE (XLAT, XLON, SRANGE, NOPTS)

GCLINE (XLATS, XLONS, NPTS, NOPTS)

SURFAREA (XLATS, XLONS, NPTS, CX, CY, NOPTS)[1]

The list of inputs consists mostly of the usual plotting parameters. XTITLE, YTITLE, and TTITLE are used for placing titles containing NX, NY and NT number of characters along three of the four sides of a plot. NTYPE orients the plot for viewing from either side of the plot page. For NTYPE = 0, the plot is viewed from the 11" dimension; for NTYPE = 1 from the 8-$\frac{1}{2}$" dimension. XSIZE and YSIZE are the plot's dimensions expressed in inches.

NOPTS is an array of inhouse options built into GLOBALL to display internal computations, alter or suppress printouts, and control various aspects of the projection maps. None of the options were employed for the examples in this paper.

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[1] SURFAREA's inputs are listed and described on page 31.

Other inputs are:

- GLOBEMAP

  XLAT, XLON = latitude and longitude of center point of plot and center of a primary range circle.

  PRANGE = radius of a primary range circle in nautical miles

- BLOWUP

  XLAT, XLON = same as above.

  PRANGE = same as above.

  BRANGE = blow-up range (discussed later in the paper).

- SECRANGE

  XLAT, XLON = center coordinates of secondary range circle.

  SRANGE = radius of secondary range circle in nautical miles.

- GCLINE

  XLATS = array of latitudes of NPTS number of points

  XLONS = array of longitudes of NPTS number of points

  NPTS = number of points

AUXILIARY FUNCTION SUBROUTINES

All spherical distances and angles used by the previous mentioned subroutines are computed by the function subprograms CALCSIDE, CALCANGL and OPPOSIDE. FUNCTIONS CALCSIDE and CALCANGL are used together to determine great-circle distances and range circles. FUNCTION OPPOSIDE is the spherical trigonometric identity required for computing intercept points of intersecting ranges.

Given two sides and an included angle of a spherical triangle, FUNCTION CALCSIDE calculates the third side.

$$\text{CALCSIDE} = \text{COS}^{-1}\left[(\text{COS(X1)} \cdot \text{COS(X2)} + \text{SIN(X1)} \cdot \text{SIN(X2)} \cdot \text{COS(X3)}\right],$$

where X1 and X2 are the two sides and X3 is the included angle.

Given three sides of a spherical triangle, FUNCTION CALCANGL calculates an angle opposite one of the sides.

$$\text{CALCANGL} = \text{COS}^{-1}\left[\frac{\text{COS(X3)} - \text{COS(X1)} \cdot \text{COS(X2)}}{\text{SIN(X1)} \cdot \text{SIN(X2)}}\right],$$

where X1, X2, and X3 are the three sides and the computed angle is opposite side X3 .

Given two sides and an opposite angle of a spherical triangle, FUNCTION OPPOSIDE calculates the third side.

$$\text{OPPOSIDE} = \text{SIN}^{-1}\left[\text{SIN}(\text{TAN}^{-1}(\text{TAN(X3)} \cdot \text{COS (X1)})) \cdot \text{TAN(X1)} \cdot \text{COT(X2)}\right] - \text{TAN}^{-1}\left[\text{TAN(X3)} \cdot \text{COS(X1)}\right],$$

where X1 and X2 equal the two sides and X3 is the opposite angle.

MAP CHARACTERISTICS

To draw a two-dimensional representation of the earth's curved surface, all points defined in spherical coordinates (ρ, θ, ϕ) must be transformed to two-dimensional cartesian coordinates (X, Y). The two coordinates systems are related through the equations

$$X = \rho \cdot \text{SIN}(\theta) \cdot \text{SIN}(\phi)$$

$$Y = \rho \cdot \left[\text{COS}(\alpha) \cdot \text{COS}(\theta) - \text{SIN}(\alpha) \cdot \text{COS}(\phi) \cdot \text{SIN}(\theta)\right],$$

where α = latitude of the center point of the projection.

The power of magnification, X_p, of an enlarged projection is inversely proportional to the sine of the degree equivalent of the blow-up range.

$$X_p = \frac{1.0}{\text{SIN}(\beta)}$$

where β = BLOW-UP range/60.0 (n.mi. per degree).

Whether a circular border or a rectangular border is drawn around a map is determined by the blow-up range. For the rectangular border, this range is measured along the longer dimension. The range must be small enough to insure that the diagonal distance is less than or equal to 4, 800 nautical miles. The horizon, which is 5, 400 n.mi. from the center of the plot, is not allowed to appear in the corners of the plot. A 600 n.mi.

margin is observed for interpolation to determine intercept points with the border. If the user is in doubt, the following hand calculation should be made before submitting a run.

$$DIA = \frac{\sqrt{DL^2 + DS^2}}{DL} ,$$

where

DL = longer dimension,

DS = shorter dimension.

Then,

$$\text{BLOW-UP range} \leq SIN^{-1}(DIA \cdot SIN(80^{o})) \cdot 60.0 \text{ (n.mi. per degree)}.$$

Example: For an 8" x 6" border, the blow-up range must be less than or equal to 3,119 nautical miles.

PART III: APPLICATIONS AND EXAMPLES

GREAT CIRCLE DISTANCES

Great-circle distances can be computed by calling the SUBROUTINE GCLINE. The original version of GCLINE was used to compute a great-circle distance in nautical miles between two points on the earth's surface. Before inclusion as a subroutine of GLOBALL, GCLINE was given the additional capability to be called with two or more points. For N number of points, N-1 great-circle distances are calculated between the points in the order that they are inputted. Summing the computed distances, the cumulative total distance to the ith point (for $1 < i \leq n$) is printed out.

Since straight lines are drawn between points by a computer's plotter, two end points are insufficient to represent a great-circle distance. Therefore, each distance is broken down into shorter line segments, 60 nautical miles (1^{o}) in length. If the distance is not evenly divisible by 60, the last or end segment will be less than 60 n.mi. The coordinates of the points at each division are computed and then plotted with the original end points.

SUBROUTINE GCLINE is most commonly used to determine a great-circle distance between two cities. Inputting the coordinates of the cities, the distance is computed in nautical miles and plotted. From the projection plot, the direction of the shortest distance between the cities can be visualized. Any number of great-circle distances may be illustrated on the same plot.

GCLINE may also be used to calculate great-circle distances for consecutive points. If the points are the successive positions of a ship sailing between the first and last points, the total distance traveled would equal the sum of great-circle distances.

The following two examples are possible applications of GCLINE. Accompanying each example is a listing of the program, illustrating the sequence of the call statements, computer printouts, and appropriate plot.

EXAMPLE 1

Great-circle distances have been computed and plotted between the cities below. A hemisphere plot was required to illustrate these long distances. Centered at 55.0^{o} north and 145.0^{o} west, the plot was drawn without the customary meridians and parallels.

- Washington, D.C. to Moscow, USSR
- Los Angeles, California, to Peking, China

```
      PROGRAM EXAMPLE1
      DIMENSION NOPTS(25),XLAT(2),XLON(2)


C   A CALL IS FIRST MAOE TO THE SUBROUTINE GLOBEMAP TO GENERATE A FULL
C   GLOBE PROJECTION. TO SHOW BOTH GREAT-CIRCLE OISTANCES , THE PLOT
C   IS CENTERED AT THE POINT (55.0 NORTH , 145.0 WEST).


      CALL GLOBEMAP (55.0,-145.0,0.0,NOPTS,
     *               41HWASH. O.C. TO MOSCOW  ANO  L.A. TO PEKING,41,
     *               31HCENTERED TO SHOW BOTH OISTANCES,31,
     *               18HPLOT FOR EXAMPLE 1,18,1,6.0,6.0)


C   STORE THE COOROINATES OF WASHINGTON , O.C. (38.55 NORTH , 77.0 WEST)
C   ANO MOSCOW , USSR (55.45 NORTH , 37.42 EAST). THEN CALL GCLINE TO
C   COMPUTE THE GREAT-CIRCLE OISTANCE.


      XLAT(1)=38.55
      XLON(1)=-77.00
      XLAT(2)=55.45
      XLON(2)=37.42

      CALL GCLINE (XLAT,XLON,2,NOPTS)


C   REPEAT CALCULATION FOR LOS ANGELES (34.06 NORTH , 118.25 WEST) TO
C   PEKING , CHINA (39.55 NORTH , 116.25 EAST).


      XLAT(1)=34.06
      XLON(1)=-118.25
      XLAT(2)=39.55
      XLON(2)=116.25

      CALL GCLINE (XLAT,XLON,2,NOPTS)


      STOP
      ENO
```

FIG. 1: GREAT CIRCLE DISTANCES

****

GREAT - CIRCLE DISTANCE EQUALS 4,244.16 (N.M.)

38.55 NORTH 77.00 WEST TO 55.45 NORTH 37.42 EAST

****

LATITUDES AND LONGITUDES
OF DISTANCE IN ONE-DEGREE INCREMENTS

NO.	LAT.	LONG.	NO.	LAT.	LONG.	NO.	LAT.	LONG.
1-	38.6 N,	77.0 W	2-	39.4 N,	76.3 W	3-	40.2 N,	75.6 W
4-	41.0 N,	74.8 W	5-	41.9 N,	74.1 W	6-	42.7 N,	73.3 W
7-	43.5 N,	72.5 W	8-	44.3 N,	71.7 W	9-	45.1 N,	70.8 W
10-	45.9 N,	69.9 W	11-	46.7 N,	69.0 W	12-	47.4 N,	68.1 W
13-	48.2 N,	67.2 W	14-	49.0 N,	66.2 W	15-	49.7 N,	65.2 W
16-	50.5 N,	64.1 W	17-	51.2 N,	63.1 W	18-	51.9 N,	62.0 W
19-	52.7 N,	60.8 W	20-	53.4 N,	59.6 W	21-	54.0 N,	58.4 W
22-	54.7 N,	57.2 W	23-	55.4 N,	55.9 W	24-	56.0 N,	54.5 W
25-	56.7 N,	53.1 W	26-	57.3 N,	51.7 W	27-	57.9 N,	50.2 W
28-	58.5 N,	48.6 W	29-	59.0 N,	47.0 W	30-	59.6 N,	45.4 W
31-	60.1 N,	43.7 W	32-	60.6 N,	42.0 W	33-	61.1 N,	40.1 W
34-	61.5 N,	38.3 W	35-	62.0 N,	36.4 W	36-	62.4 N,	34.4 W
37-	62.7 N,	32.4 W	38-	63.1 N,	30.3 W	39-	63.4 N,	28.2 W
40-	63.7 N,	26.1 W	41-	63.9 N,	23.9 W	42-	64.1 N,	21.6 W
43-	64.3 N,	19.4 W	44-	64.5 N,	17.1 W	45-	64.6 N,	14.8 W
46-	64.6 N,	12.5 W	47-	64.7 N,	10.1 W	48-	64.7 N,	7.8 W
49-	64.6 N,	5.4 W	50-	64.5 N,	3.1 W	51-	64.4 N,	0.8 W
52-	64.3 N,	1.5 E	53-	64.1 N,	3.7 E	54-	63.9 N,	6.0 E
55-	63.6 N,	8.1 E	56-	63.3 N,	10.3 E	57-	63.0 N,	12.4 E
58-	62.7 N,	14.4 E	59-	62.3 N,	16.5 E	60-	61.9 N,	18.4 E
61-	61.5 N,	20.3 E	62-	61.0 N,	22.2 E	63-	60.5 N,	24.0 E
64-	60.0 N,	25.7 E	65-	59.5 N,	27.4 E	66-	59.0 N,	29.0 E
67-	58.4 N,	30.6 E	68-	57.8 N,	32.1 E	69-	57.2 N,	33.6 E
70-	56.6 N,	35.0 E	71-	55.9 N,	36.4 E	72-	55.5 N,	37.4 E

****

****

GREAT - CIRCLE DISTANCE EQUALS 5,449.26 (N.M.)

34.06 NORTH 118.25 WEST TO 39.55 NORTH 116.25 EAST

****

LATITUDES AND LONGITUDES
OF DISTANCE IN ONE-DEGREE INCREMENTS

NO.	LAT.	LONG.	NO.	LAT.	LONG.	NO.	LAT.	LONG.
1-	34.1 N,	118.2 W	2-	34.8 N,	119.0 W	3-	35.6 N,	119.8 W
4-	36.4 N,	120.6 W	5-	37.1 N,	121.4 W	6-	37.9 N,	122.2 W
7-	38.6 N,	123.1 W	8-	39.4 N,	123.9 W	9-	40.1 N,	124.8 W
10-	40.8 N,	125.7 W	11-	41.6 N,	126.6 W	12-	42.3 N,	127.6 W
13-	43.0 N,	128.5 W	14-	43.7 N,	129.5 W	15-	44.4 N,	130.5 W
16-	45.1 N,	131.5 W	17-	45.7 N,	132.6 W	18-	46.4 N,	133.7 W
19-	47.0 N,	134.8 W	20-	47.7 N,	135.9 W	21-	48.3 N,	137.1 W
22-	48.9 N,	138.3 W	23-	49.5 N,	139.5 W	24-	50.1 N,	140.7 W
25-	50.7 N,	142.0 W	26-	51.3 N,	143.3 W	27-	51.8 N,	144.7 W
28-	52.4 N,	146.1 W	29-	52.9 N,	147.5 W	30-	53.4 N,	148.9 W
31-	53.8 N,	150.4 W	32-	54.3 N,	151.9 W	33-	54.8 N,	153.5 W
34-	55.2 N,	155.0 W	35-	55.6 N,	156.6 W	36-	56.0 N,	158.3 W
37-	56.3 N,	160.0 W	38-	56.7 N,	161.7 W	39-	57.0 N,	163.4 W
40-	57.3 N,	165.2 W	41-	57.5 N,	167.0 W	42-	57.8 N,	168.8 W
43-	58.0 N,	170.6 W	44-	58.1 N,	172.5 W	45-	58.3 N,	174.3 W
46-	58.4 N,	176.2 W	47-	58.5 N,	178.1 W	48-	58.6 N,	179.9 E
49-	58.6 N,	178.0 E	50-	58.7 N,	176.1 E	51-	58.6 N,	174.2 E
52-	58.6 N,	172.3 E	53-	58.5 N,	170.4 E	54-	58.4 N,	168.4 E
55-	58.3 N,	166.5 E	56-	58.2 N,	164.7 E	57-	58.0 N,	162.8 E
58-	57.8 N,	161.0 E	59-	57.5 N,	159.2 E	60-	57.3 N,	157.4 E
61-	57.0 N,	155.6 E	62-	56.7 N,	153.9 E	63-	56.3 N,	152.2 E
64-	56.0 N,	150.5 E	65-	55.6 N,	148.8 E	66-	55.2 N,	147.2 E
67-	54.8 N,	145.7 E	68-	54.3 N,	144.1 E	69-	53.9 N,	142.6 E
70-	53.4 N,	141.1 E	71-	52.9 N,	139.7 E	72-	52.4 N,	138.3 E
73-	51.8 N,	136.9 E	74-	51.3 N,	135.5 E	75-	50.7 N,	134.2 E
76-	50.2 N,	132.9 E	77-	49.6 N,	131.7 E	78-	49.0 N,	130.5 E
79-	48.3 N,	129.3 E	80-	47.7 N,	128.1 E	81-	47.1 N,	127.0 E
82-	46.4 N,	125.9 E	83-	45.8 N,	124.8 E	84-	45.1 N,	123.7 E
85-	44.4 N,	122.7 E	86-	43.7 N,	121.7 E	87-	43.0 N,	120.7 E
88-	42.3 N,	119.7 E	89-	41.6 N,	118.8 E	90-	40.9 N,	117.9 E
91-	40.2 N,	117.0 E	92-	39.6 N,	116.3 E			

****

EXAMPLE 2

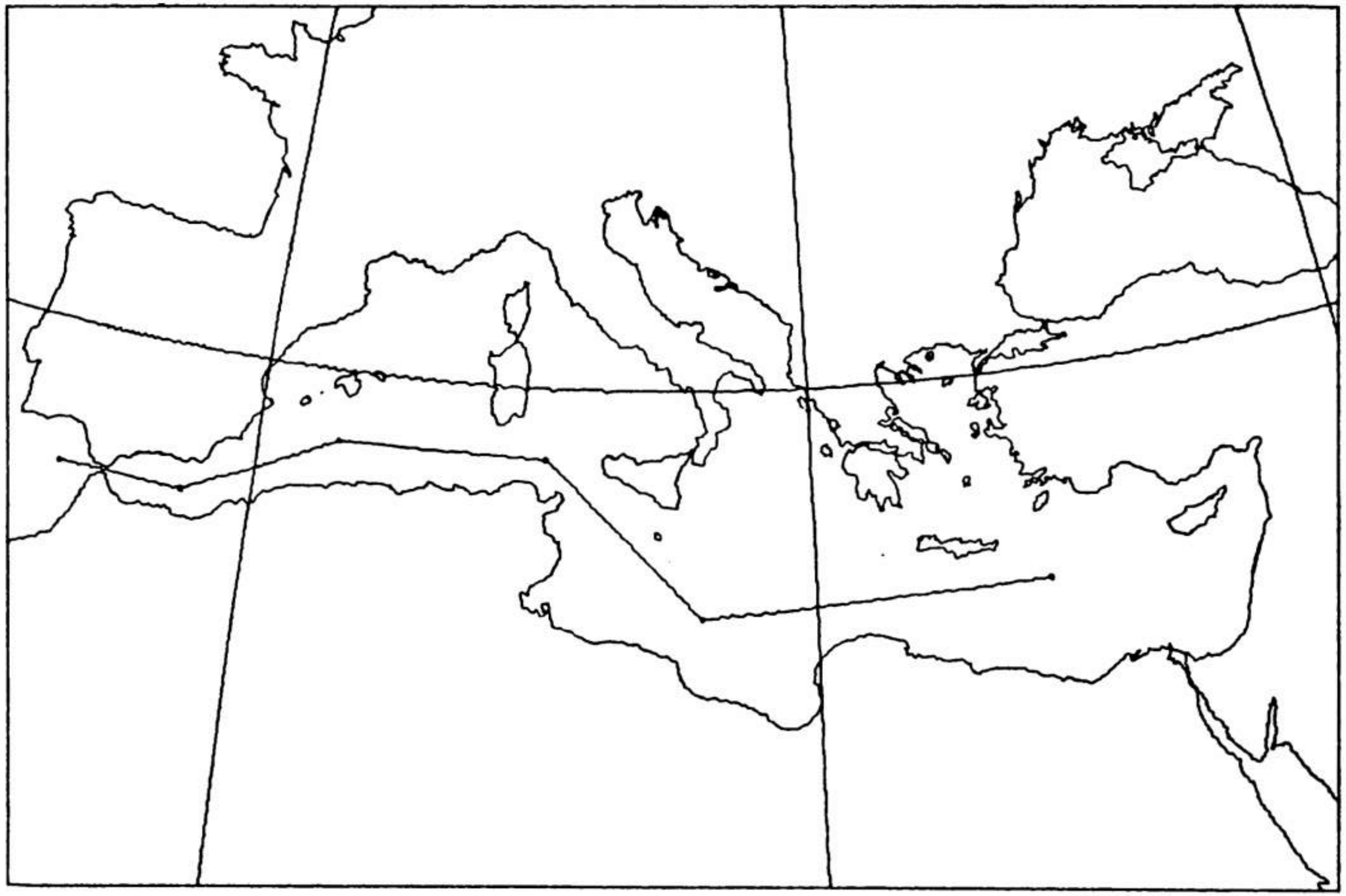
Listed below are the coordinates of the positions of a ship's course through the Mediterranean Sea:

1. 36.0 north, 7.0 west -- commence transit
2. 35.9 north, 2.5 west -- 1st course change
3. 38.0 north, 3.0 east -- 2nd course change
4. 38.0 north, 10.5 east -- 3rd course change
5. 33.5 north, 16.0 east -- 4th course change
6. 34.0 north, 28.0 east -- transit complete.

The total distance traveled is determined by calling SUBROUTINE GCLINE with the six positions.

```
      PROGRAM EXAMPLE2
      DIMENSION NOPTS(25),XLAT(6),XLON(6)


C    STORE THE SIX POSITIONS OF SHIP....


      DATA (XLAT=36.0,35.9,38.0,38.0,33.5,34.0)
      DATA (XLON=-7.0,-2.5, 3.0,10.5,16.0,28.0)


C    CALL BLOWUP FOR ENLARGED PROJECTION OF MEDITERRANEAN SEA , CENTERED
C    AT 38.5N , 15.0E.  THE BLOW-UP RANGE , MEASURED HORIZONALLY FROM
C    THE CENTER OF THE PLOT , EQUALS 1150 NAUTICAL MILES....


      CALL BLOWUP (38.5,15.0,0.0,1150.0,NOPTS,
     *             44HENLARGED PROJECTION OF THE MEDITERRANEAN SEA,44,
     *             20HSHOWS COURSE OF SHIP,20,
     *             18HPLOT FOR EXAMPLE 2,18.0, 9.0,6.0)


C    CALL GCLINE TO DETERMINE THE TOTAL DISTANCE TRAVELED BY THE SHIP....


      CALL GCLINE (XLAT,XLON,6,NOPTS)

      STOP
      END
```

PLOT FOR EXAMPLE 2



ENLARGED PROJECTION OF THE MEDITERRANEAN SEA

(9" x 6" plot, reduced for this document)

FIG. 2: PLOT OF SHIP'S COURSE

* GREAT - CIRCLE DISTANCES *

OISTANCE FROM POINT 1 TO POINT 2 EQUALS 218.64 (N.M.)

NO.	LAT.	LONG.	NO.	LAT.	LONG.	NO.	LAT.	LONG.
1-	36.0 N,	7.0 W	2-	36.0 N,	5.8 W	3-	36.0 N,	4.5 W
4-	35.9 N,	3.3 W	5-	35.9 N,	2.5 W			

CUMULATIVE DISTANCE TO POINT 3 EQUALS 510.84 (N.M.)

NO.	LAT.	LONG.	NO.	LAT.	LONG.	NO.	LAT.	LONG.
1-	35.9 N,	2.5 W	2-	36.4 N,	1.4 W	3-	36.8 N,	0.3 W
4-	37.2 N,	0.9 E	5-	37.6 N,	2.0 E	6-	38.0 N,	3.0 E

CUMULATIVE DISTANCE TO POINT 4 EQUALS 865.35 (N.M.)

NO.	LAT.	LONG.	NO.	LAT.	LONG.	NO.	LAT.	LONG.
1-	38.0 N,	3.0 E	2-	38.0 N,	4.3 E	3-	38.1 N,	5.5 E
4-	38.1 N,	6.8 E	5-	38.1 N,	8.1 E	6-	38.0 N,	9.3 E
7-	38.0 N,	10.5 E						

CUMULATIVE DISTANCE TO POINT 5 EQUALS 1,245.50 (N.M.)

NO.	LAT.	LONG.	NO.	LAT.	LONG.	NO.	LAT.	LONG.
1-	38.0 N,	10.5 E	2-	37.3 N,	11.4 E	3-	36.6 N,	12.3 E
4-	35.9 N,	13.2 E	5-	35.2 N,	14.0 E	6-	34.5 N,	14.9 E
7-	33.7 N,	15.7 E	8-	33.5 N,	16.0 E			

CUMULATIVE DISTANCE TO POINT 6 EQUALS 1,844.57 (N.M.)

NO.	LAT.	LONG.	NO.	LAT.	LONG.	NO.	LAT.	LONG.
1-	33.5 N,	16.0 E	2-	33.6 N,	17.2 E	3-	33.7 N,	18.4 E
4-	33.8 N,	19.6 E	5-	33.8 N,	20.8 E	6-	33.9 N,	22.0 E
7-	33.9 N,	23.2 E	8-	34.0 N,	24.4 E	9-	34.0 N,	25.6 E
10-	34.0 N,	26.8 E	11-	34.0 N,	28.0 E			

RANGE CIRCLES

A range circle is computed and drawn by inputting the coordinates of its center and its radius. The circle is divided into 360 one-degree arcs, and the coordinates at each division are computed beginning at true north clockwise through 360 degrees. The coordinates, which are used to draw the circle on a projection map, are also printed out in one-degree or five-degree increments. The computer printouts in this section display the coordinates every five degrees. The surface area of the range circle is also computed and displayed.

A range circle is referred to as a primary or secondary range. Executing a call to either of the subroutines, GLOBEMAP or BLOWUP, a primary range is generated about the center point of the projection. Limited to one per plot, a primary range is used in surface area calculations with the subroutines, SECRANGE and SURFAREA.

SUBROUTINE SECRANGE is called for additional secondary ranges radiating from any point on the earth's surface. A secondary range is tested to determine whether it intersects the primary range. If so, the following are computed:

- intercept points;
- the area of intersection;
- complement surface areas;
- total surface area covered by both ranges.

The primary and secondary ranges have upper limits of 5, 400 and 10, 800 nautical miles, respectively. A primary range is set equal to zero if not desired when calling the subroutines, GLOBEMAP and BLOWUP.

The following two examples illustrate possible applications of intersecting range circles. The first, example 3, is a simple two-range intersection, describing an area of operation in the North Atlantic. Example 4 introduces the technique for determining the surface area of multiple range intersections.

EXAMPLE 3

The surface area of the area of operation that is everywhere less than or equal to 2,000 n.mi. from New York City, New York and 1,200 n.mi. of London, England, is equal to the area of intersection of the range circles radiating from the cities. The points of the resulting area's perimeter have been outlined on the following computer printouts.

```
      PROGRAM EXAMPLE3
      DIMENSION NOPTS(25)


C    CALL SUBROUTINE BLOWUP TO DRAW AN ENLARGED PROJECTION CENTERED AT
C    NEW YORK (40.71N , 74.0W) AND A RANGE CIRCLE EQUAL TO 2000 N. MILES.


      CALL BLOWUP (40.71,-74.0,2000.0,2400.0,NOPTS,
     *            37HCENTERED AT NEW YORK CITY , NEW YORK   ,37,
     *            41HRANGES EQUAL 1200 AND 2000 NAUTICAL MILES,41,
     *            18HPLOT FOR EXAMPLE 3,18,
     *            1,6.0,6.0)


C    DRAW A RANGE CIRCLE EQUAL TO 1200 N. MILES ABOUT LONDON , ENGLAND
C    (51.49N , 1.00W).


      CALL SECRANGE (51.49,-1.0,1200.0,NOPTS)

      STOP
      END
```

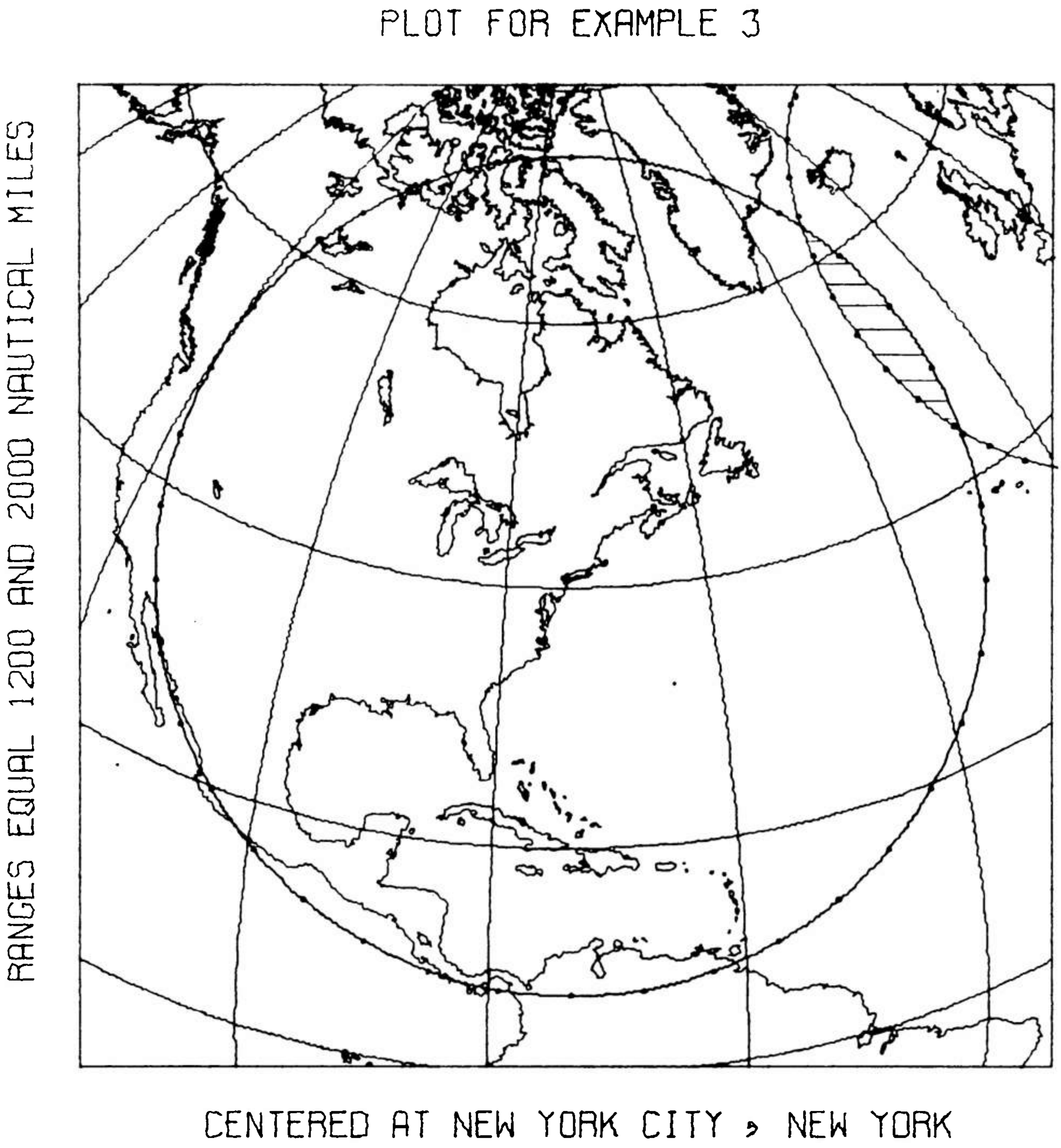


FIG. 3: TWO INTERSECTING RANGE CIRCLES

****

PRIMARY RANGE EQUALS 2,000.00 NAUTICAL MILES
CENTERED AT 40.71 NORTH, 74.00 WEST

****

SURFACE AREA OF ZONE EQUALS 12,232,423.49 SQ. NAUTICAL MILES

****

LATITUDES AND LONGITUDES
DESCRIBING TRACK OF RANGE IN INCREMENTS OF FIVE DEGREES
(BEGINNING AT TRUE NORTH AND ROTATED CLOCKWISE THROUGH 360 DEGREES)

DEGREE	LATITUDE	LONGITUDE	DEGREE	LATITUDE	LONGITUDE
0-	74.04 NORTH	74.00 WEST			
5-	73.72 NORTH	64.17 WEST	185-	7.47 NORTH	76.77 WEST
10-	72.77 NORTH	55.20 WEST	190-	7.74 NORTH	79.53 WEST
15-	71.31 NORTH	47.65 WEST	195-	8.20 NORTH	82.26 WEST
20-	69.45 NORTH	41.63 WEST	200-	8.83 NORTH	84.96 WEST
25-	67.29 NORTH	37.03 WEST	205-	9.64 NORTH	87.62 WEST
30-	64.91 NORTH	33.61 WEST	210-	10.61 NORTH	90.23 WEST
35-	62.39 NORTH	31.15 WEST	215-	11.75 NORTH	92.78 WEST
40-	59.77 NORTH	29.45 WEST	220-	13.05 NORTH	95.26 WEST
45-	57.08 NORTH	28.35 WEST	225-	14.50 NORTH	97.66 WEST
50-	54.36 NORTH	27.75 WEST	230-	16.09 NORTH	99.98 WEST
55-	51.61 NORTH	27.54 WEST	235-	17.82 NORTH	102.22 WEST
60-	48.87 NORTH	27.66 WEST	240-	19.67 NORTH	104.35 WEST
65-	46.13 NORTH	28.05 WEST	245-	21.65 NORTH	106.40 WEST
70-	43.42 NORTH	28.69 WEST	250-	23.73 NORTH	108.34 WEST
75-	40.75 NORTH	29.52 WEST	255-	25.92 NORTH	110.17 WEST
80-	38.12 NORTH	30.54 WEST	260-	23.20 NORTH	111.88 WEST
85-	35.54 NORTH	31.72 WEST	265-	30.57 NORTH	113.48 WEST
90-	33.02 NORTH	33.05 WEST	270-	33.02 NORTH	114.95 WEST
95-	30.57 NORTH	34.52 WEST	275-	35.54 NORTH	116.28 WEST
100-	28.20 NORTH	36.12 WEST	280-	38.12 NORTH	117.46 WEST
105-	25.92 NORTH	37.83 WEST	285-	40.75 NORTH	118.48 WEST
110-	23.73 NORTH	39.66 WEST	290-	43.42 NORTH	119.31 WEST
115-	21.65 NORTH	41.60 WEST	295-	46.13 NORTH	119.95 WEST
120-	19.67 NORTH	43.64 WEST	300-	48.87 NORTH	120.34 WEST
125-	17.82 NORTH	45.78 WEST	305-	51.61 NORTH	120.46 WEST
130-	16.09 NORTH	48.02 WEST	310-	54.36 NORTH	120.25 WEST
135-	14.50 NORTH	50.34 WEST	315-	57.08 NORTH	119.65 WEST
140-	13.05 NORTH	52.74 WEST	320-	59.77 NORTH	118.55 WEST
145-	11.75 NORTH	55.22 WEST	325-	62.39 NORTH	116.85 WEST
150-	10.61 NORTH	57.77 WEST	330-	64.91 NORTH	114.39 WEST
155-	9.64 NORTH	60.38 WEST	335-	67.29 NORTH	110.97 WEST
160-	8.83 NORTH	63.04 WEST	340-	69.45 NORTH	106.37 WEST
165-	8.20 NORTH	65.74 WEST	345-	71.31 NORTH	100.35 WEST
170-	7.74 NORTH	68.47 WEST	350-	72.77 NORTH	92.80 WEST
175-	7.47 NORTH	71.23 WEST	355-	73.72 NORTH	83.83 WEST
180-	7.38 NORTH	74.00 WEST	360-	74.04 NORTH	74.00 WEST

****

****

SECONDARY RANGE EQUALS 1,200.00 NAUTICAL MILES
CENTERED AT 51.49 NORTH, 1.00 WEST

****

SURFACE AREA OF ZONE EQUALS 4,484,199.06 SQ. NAUTICAL MILES

****

LATITUDES AND LONGITUDES
DESCRIBING TRACK OF RANGE IN INCREMENTS OF FIVE DEGREES
(BEGINNING AT TRUE NORTH AND ROTATED CLOCKWISE THROUGH 360 DEGREES)

DEGREE	LATITUDE	LONGITUDE	DEGREE	LATITUDE	LONGITUDE
0-	71.49 NORTH	1.00 WEST			
5-	71.34 NORTH	4.35 EAST	185-	31.54 NORTH	3.00 WEST
10-	70.91 NORTH	9.47 EAST	190-	31.71 NORTH	5.00 WEST
15-	70.22 NORTH	14.17 EAST	195-	31.98 NORTH	6.99 WEST
20-	69.30 NORTH	18.32 EAST	200-	32.36 NORTH	8.96 WEST
25-	68.17 NORTH	21.88 EAST	205-	32.84 NORTH	10.91 WEST
30-	66.89 NORTH	24.83 EAST	210-	33.43 NORTH	12.82 WEST
35-	65.47 NORTH	27.20 EAST	215-	34.12 NORTH	14.71 WEST
40-	63.95 NORTH	29.05 EAST	220-	34.90 NORTH	16.55 WEST
45-	62.36 NORTH	30.42 EAST	225-	35.78 NORTH	18.34 WEST
50-	60.71 NORTH	31.39 EAST	230-	36.76 NORTH	20.09 WEST
55-	59.03 NORTH	31.99 EAST	235-	37.82 NORTH	21.77 WEST
60-	57.33 NORTH	32.28 EAST	240-	38.96 NORTH	23.39 WEST
65-	55.62 NORTH	32.29 EAST	245-	40.19 NORTH	24.94 WEST
70-	53.92 NORTH	32.07 EAST	250-	41.49 NORTH	26.41 WEST
75-	52.23 NORTH	31.64 EAST	255-	42.86 NORTH	27.79 WEST
80-	50.56 NORTH	31.02 EAST	260-	44.29 NORTH	29.07 WEST
85-	48.93 NORTH	30.24 EAST	265-	45.79 NORTH	30.25 WEST
90-	47.33 NORTH	29.31 EAST	270-	47.33 NORTH	31.31 WEST
95-	45.79 NORTH	28.25 EAST	275-	48.93 NORTH	32.24 WEST
100-	44.29 NORTH	27.07 EAST	280-	50.56 NORTH	33.02 WEST
105-	42.86 NORTH	25.79 EAST	285-	52.23 NORTH	33.64 WEST
110-	41.49 NORTH	24.41 EAST	290-	53.92 NORTH	34.07 WEST
115-	40.19 NORTH	22.94 EAST	295-	55.62 NORTH	34.29 WEST
120-	38.96 NORTH	21.39 EAST	300-	57.33 NORTH	34.28 WEST
125-	37.82 NORTH	19.77 EAST	305-	59.03 NORTH	33.99 WEST
130-	36.76 NORTH	18.09 EAST	310-	60.71 NORTH	33.39 WEST
135-	35.78 NORTH	16.34 EAST	315-	62.36 NORTH	32.42 WEST
140-	34.90 NORTH	14.55 EAST	320-	63.95 NORTH	31.05 WEST
145-	34.12 NORTH	12.71 EAST	325-	65.47 NORTH	29.20 WEST
150-	33.43 NORTH	10.82 EAST	330-	66.89 NORTH	26.83 WEST
155-	32.84 NORTH	8.91 EAST	335-	68.17 NORTH	23.88 WEST
160-	32.36 NORTH	6.96 EAST	340-	69.30 NORTH	20.32 WEST
165-	31.98 NORTH	4.99 EAST	345-	70.22 NORTH	16.17 WEST
170-	31.71 NORTH	3.00 EAST	350-	70.91 NORTH	11.47 WEST
175-	31.54 NORTH	1.00 EAST	355-	71.34 NORTH	6.35 WEST
180-	31.49 NORTH	1.00 WEST	360-	71.49 NORTH	1.00 WEST

****

SECONDARY RANGE INTERSECTS PRIMARY RANGE AT
63.15 NORTH, 31.79 WEST AND 43.75 NORTH, 28.60 WEST

****

SURFACE AREA OF INTERSECTION EQUALS 177,381.74 SQ. NAUTICAL MILES

****

SURFACE AREA OF REMAINING PRIMARY ZONE EQUALS 12,055,041.75 SQ. NAUTICAL MILES

****

SURFACE AREA OF REMAINING SECONDARY ZONE EQUALS 4,306,817.33 SQ. NAUTICAL MILES

****

TOTAL COVERAGE AREA OF BOTH RANGES EQUALS 16,539,240.82 SQ. NAUTICAL MILES

****

EXAMPLE 4

For three range circles centered at Canton, Peking, and Tokyo, and having radii equal to 750, 800 and 900 nautical miles, respectively, find the surface areas of double and triple coverages.

From the computer printouts the three areas of intersection equal 453, 293; 25, 881; and 492, 861 n.mi.[1] Subtracting the area of triple coverage,[2] which equals 17, 995 n.mi., from each of the above areas, the surface area of exactly double coverage equals 918, 050 n.mi. The perimeter points of the triple intersection have been outlined on the printouts.

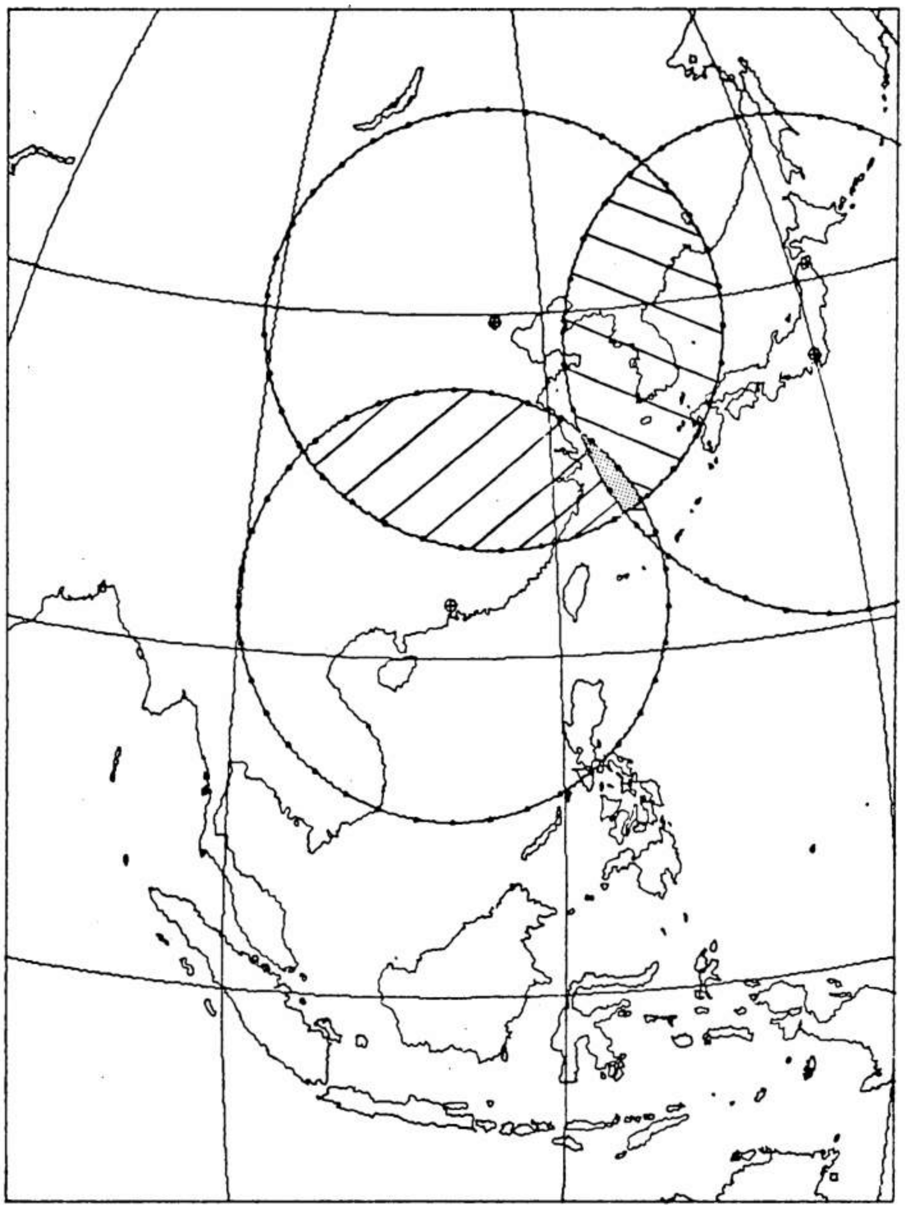
---

[1] This problem required an additional plot to determine the area of intersection between Peking and Tokyo circles. Only the plot centered at Canton is presented.

[2] See example 6, page 37, for the surface area solution of the triple coverage.

```
      PROGRAM EXAMPLE4
      DIMENSION NOPTS(25)


C    CALL SUBROUTINE BLOWUP TO DRAW AN ENLARGED PROJECTION CENTERED AT
C    CANTON , CHINA (23.08N , 113.20E). PRIMARY RANGE EQUALS 750 NAUTICAL
C    MILES.....


      CALL BLOWUP (23.08,113.20,750.0,2200.0,NOPTS,
     *            39HRANGES EQUAL 750 , 800 AND 900 N. MILES,39,
     *            45HFROM CANTON , PEKING AND TOKYO , RESPECTIVELY,45,
     *            18HPLOT FOR EXAMPLE 4,18,
     *            1,6.0,8.0)


C    DRAW RANGE CIRCLE OF 800 N.MILES FROM PEKING , CHINA....


      CALL SECRANGE (39.55,116.25,800.0,NOPTS)


C    DRAW RANGE CIRCLE OF 900 N.MILES FROM TOKYO , JAPAN....


      CALL SECRANGE (35.67,139.75,900.0,NOPTS)

      STOP
      END
```

PLOT FOR EXAMPLE 4



FROM CANTON , PEKING AND TOKYO , RESPECTIVELY

RANGES EQUAL 750 , 800 AND 900 N. MILES

FIG. 4: THREE INTERSECTING RANGE CIRCLES

****

.PRIMARY RANGE EQUALS 750.00 NAUTICAL MILES
. CENTERED AT 23.08 NORTH, 113.20 EAST

****

SURFACE AREA OF ZONE EQUALS 1,762,527.64 SQ. NAUTICAL MILES

****

LATITUDES AND LONGITUDES
DESCRIBING TRACK OF RANGE IN INCREMENTS OF FIVE DEGREES
(BEGINNING AT TRUE NORTH AND ROTATED CLOCKWISE THROUGH 360 DEGREES)

DEGREE	LATITUDE	LONGITUDE	DEGREE	LATITUDE	LONGITUDE
0-	35.58 NORTH	113.20 EAST			
5-	35.53 NORTH	114.53 EAST	185-	10.62 NORTH	112.10 EAST
10-	35.37 NORTH	115.84 EAST	190-	10.76 NORTH	111.01 EAST
15-	35.10 NORTH	117.13 EAST	195-	10.98 NORTH	109.93 EAST
20-	34.74 NORTH	118.37 EAST	200-	11.28 NORTH	108.87 EAST
25-	34.28 NORTH	119.56 EAST	205-	11.67 NORTH	107.84 EAST
30-	33.72 NORTH	120.68 EAST	210-	12.14 NORTH	106.84 EAST
35-	33.08 NORTH	121.72 EAST	215-	12.69 NORTH	105.89 EAST
40-	32.36 NORTH	122.68 EAST	220-	13.31 NORTH	104.98 EAST
45-	31.57 NORTH	123.55 EAST	225-	14.00 NORTH	104.12 EAST
50-	30.71 NORTH	124.32 EAST	230-	14.76 NORTH	103.33 EAST
55-	29.80 NORTH	124.99 EAST	235-	15.58 NORTH	102.59 EAST
60-	28.83 NORTH	125.56 EAST	240-	16.45 NORTH	101.93 EAST
65-	27.83 NORTH	126.02 EAST	245-	17.37 NORTH	101.34 EAST
70-	26.80 NORTH	126.37 EAST	250-	18.34 NORTH	100.83 EAST
75-	25.74 NORTH	126.62 EAST	255-	19.34 NORTH	100.40 EAST
80-	24.66 NORTH	126.77 EAST	260-	20.37 NORTH	100.06 EAST
85-	23.58 NORTH	126.81 EAST	265-	21.43 NORTH	99.81 EAST
90-	22.50 NORTH	126.75 EAST	270-	22.50 NORTH	99.65 EAST
95-	21.43 NORTH	126.59 EAST	275-	23.58 NORTH	99.59 EAST
100-	20.37 NORTH	126.34 EAST	280-	24.66 NORTH	99.63 EAST
105-	19.34 NORTH	126.00 EAST	285-	25.74 NORTH	99.78 EAST
110-	18.34 NORTH	125.57 EAST	290-	26.80 NORTH	100.03 EAST
115-	17.37 NORTH	125.06 EAST	295-	27.83 NORTH	100.38 EAST
120-	16.45 NORTH	124.47 EAST	300-	28.83 NORTH	100.84 EAST
125-	15.58 NORTH	123.81 EAST	305-	29.80 NORTH	101.41 EAST
130-	14.76 NORTH	123.07 EAST	310-	30.71 NORTH	102.08 EAST
135-	14.00 NORTH	122.28 EAST	315-	31.57 NORTH	102.85 EAST
140-	13.31 NORTH	121.42 EAST	320-	32.36 NORTH	103.72 EAST
145-	12.69 NORTH	120.51 EAST	325-	33.08 NORTH	104.68 EAST
150-	12.14 NORTH	119.56 EAST	330-	33.72 NORTH	105.72 EAST
155-	11.67 NORTH	118.56 EAST	335-	34.28 NORTH	106.84 EAST
160-	11.28 NORTH	117.53 EAST	340-	34.74 NORTH	108.03 EAST
165-	10.98 NORTH	116.47 EAST	345-	35.10 NORTH	109.27 EAST
170-	10.76 NORTH	115.39 EAST	350-	35.37 NORTH	110.56 EAST
175-	10.62 NORTH	114.30 EAST	355-	35.53 NORTH	111.97 EAST
180-	10.58 NORTH	113.20 EAST	360-	35.58 NORTH	113.20 EAST

****

****

SECONDARY RANGE EQUALS 800.00 NAUTICAL MILES
CENTERED AT 39.55 NORTH, 116.25 EAST

****

SURFACE AREA OF ZONE EQUALS 2,004,268.26 SQ. NAUTICAL MILES

****

LATITUDES AND LONGITUDES
DESCRIBING TRACK OF RANGE IN INCREMENTS OF FIVE DEGREES
(BEGINNING AT TRUE NORTH AND ROTATED CLOCKWISE THROUGH 360 DEGREES)

DEGREE	LATITUDE	LONGITUDE	DEGREE	LATITUDE	LONGITUDE
0-	52.88 NORTH	116.25 EAST			
5-	52.82 NORTH	118.16 EAST	185-	26.26 NORTH	114.37 EAST
10-	52.63 NORTH	120.03 EAST	190-	26.39 NORTH	113.69 EAST
15-	52.31 NORTH	121.85 EAST	195-	26.60 NORTH	112.42 EAST
20-	51.88 NORTH	123.59 EAST	200-	26.90 NORTH	111.18 EAST
25-	51.33 NORTH	125.22 EAST	205-	27.29 NORTH	109.95 EAST
30-	50.68 NORTH	126.73 EAST	210-	27.75 NORTH	108.76 EAST
35-	49.93 NORTH	128.11 EAST	215-	28.29 NORTH	107.61 EAST
40-	49.10 NORTH	129.33 EAST	220-	28.91 NORTH	106.50 EAST
45-	48.19 NORTH	130.41 EAST	225-	29.59 NORTH	105.44 EAST
50-	47.21 NORTH	131.32 EAST	230-	30.35 NORTH	104.44 EAST
55-	46.19 NORTH	132.08 EAST	235-	31.17 NORTH	103.49 EAST
60-	45.11 NORTH	132.69 EAST	240-	32.05 NORTH	102.62 EAST
65-	44.01 NORTH	133.14 EAST	245-	32.99 NORTH	101.82 EAST
70-	42.88 NORTH	133.45 EAST	250-	33.97 NORTH	101.10 EAST
75-	41.73 NORTH	133.62 EAST	255-	35.00 NORTH	100.47 EAST
80-	40.58 NORTH	133.65 EAST	260-	36.07 NORTH	99.93 EAST
85-	39.43 NORTH	133.55 EAST	265-	37.16 NORTH	99.49 EAST
90-	38.29 NORTH	133.34 EAST	270-	38.29 NORTH	99.16 EAST
95-	37.16 NORTH	133.01 EAST	275-	39.43 NORTH	98.95 EAST
100-	36.07 NORTH	132.57 EAST	280-	40.58 NORTH	98.85 EAST
105-	35.00 NORTH	132.03 EAST	285-	41.73 NORTH	98.88 EAST
110-	33.97 NORTH	131.40 EAST	290-	42.88 NORTH	99.05 EAST
115-	32.99 NORTH	130.68 EAST	295-	44.01 NORTH	99.36 EAST
120-	32.05 NORTH	129.88 EAST	300-	45.11 NORTH	99.81 EAST
125-	31.17 NORTH	129.01 EAST	305-	46.19 NORTH	100.42 EAST
130-	30.35 NORTH	128.06 EAST	310-	47.21 NORTH	101.18 EAST
135-	29.59 NORTH	127.06 EAST	315-	48.19 NORTH	102.09 EAST
140-	28.91 NORTH	126.00 EAST	320-	49.10 NORTH	103.17 EAST
145-	28.29 NORTH	124.89 EAST	325-	49.93 NORTH	104.39 EAST
150-	27.75 NORTH	123.74 EAST	330-	50.68 NORTH	105.77 EAST
155-	27.29 NORTH	122.55 EAST	335-	51.33 NORTH	107.28 EAST
160-	26.90 NORTH	121.32 EAST	340-	51.88 NORTH	108.91 EAST
165-	26.60 NORTH	120.08 EAST	345-	52.31 NORTH	110.65 EAST
170-	26.39 NORTH	118.81 EAST	350-	52.63 NORTH	112.47 EAST
175-	26.26 NORTH	117.53 EAST	355-	52.82 NORTH	114.34 EAST
180-	26.22 NORTH	116.25 EAST	360-	52.88 NORTH	116.25 EAST

****

SECONDARY RANGE INTERSECTS PRIMARY RANGE AT
31.69 NORTH, 102.97 EAST AND 28.69 NORTH, 125.63 EAST

****

SURFACE AREA OF INTERSECTION EQUALS 453,292.83 SQ. NAUTICAL MILES

****

SURFACE AREA OF REMAINING PRIMARY ZONE EQUALS 1,309,234.81 SQ. NAUTICAL MILE

****

SURFACE AREA OF REMAINING SECONDARY ZONE EQUALS 1,550,975.43 SQ. NAUTICAL MILE

****

TOTAL COVERAGE AREA OF BOTH RANGES EQUALS 3,313,503.07 SQ. NAUTICAL MILE

****

****

SECONDARY RANGE EQUALS 900.00 NAUTICAL MILES
CENTERED AT 35.67 NORTH, 139.75 EAST

****

SURFACE AREA OF ZONE EQUALS 2,533,609.98 SQ. NAUTICAL MILES

****

LATITUDES AND LONGITUDES
DESCRIBING TRACK OF RANGE IN INCREMENTS OF FIVE DEGREES
(BEGINNING AT TRUE NORTH AND ROTATED CLOCKWISE THROUGH 360 DEGREES)

DEGREE	LATITUDE	LONGITUDE	DEGREE	LATITUDE	LONGITUDE
0-	50.67 NORTH	139.75 EAST			
5-	50.60 NORTH	141.79 EAST	185-	20.72 NORTH	138.37 EAST
10-	50.38 NORTH	143.79 EAST	190-	20.87 NORTH	136.99 EAST
15-	50.03 NORTH	145.74 EAST	195-	21.11 NORTH	135.63 EAST
20-	49.54 NORTH	147.59 EAST	200-	21.45 NORTH	134.29 EAST
25-	48.92 NORTH	149.33 EAST	205-	21.88 NORTH	132.98 EAST
30-	48.19 NORTH	150.94 EAST	210-	22.41 NORTH	131.70 EAST
35-	47.35 NORTH	152.41 EAST	215-	23.02 NORTH	130.47 EAST
40-	46.41 NORTH	153.71 EAST	220-	23.71 NORTH	129.28 EAST
45-	45.39 NORTH	154.86 EAST	225-	24.49 NORTH	128.15 EAST
50-	44.30 NORTH	155.83 EAST	230-	25.35 NORTH	127.08 EAST
55-	43.15 NORTH	156.64 EAST	235-	26.27 NORTH	126.07 EAST
60-	41.94 NORTH	157.29 EAST	240-	27.27 NORTH	125.14 EAST
65-	40.70 NORTH	157.77 EAST	245-	28.32 NORTH	124.30 EAST
70-	39.43 NORTH	158.10 EAST	250-	29.43 NORTH	123.54 EAST
75-	38.15 NORTH	158.29 EAST	255-	30.59 NORTH	122.87 EAST
80-	36.85 NORTH	158.32 EAST	260-	31.79 NORTH	122.30 EAST
85-	35.56 NORTH	158.23 EAST	265-	33.02 NORTH	121.84 EAST
90-	34.28 NORTH	158.00 EAST	270-	34.28 NORTH	121.50 EAST
95-	33.02 NORTH	157.66 EAST	275-	35.56 NORTH	121.27 EAST
100-	31.79 NORTH	157.20 EAST	280-	36.85 NORTH	121.18 EAST
105-	30.59 NORTH	156.63 EAST	285-	38.15 NORTH	121.21 EAST
110-	29.43 NORTH	155.96 EAST	290-	39.43 NORTH	121.40 EAST
115-	28.32 NORTH	155.20 EAST	295-	40.70 NORTH	121.73 EAST
120-	27.27 NORTH	154.36 EAST	300-	41.94 NORTH	122.21 EAST
125-	26.27 NORTH	153.43 EAST	305-	43.15 NORTH	122.86 EAST
130-	25.35 NORTH	152.42 EAST	310-	44.30 NORTH	123.67 EAST
135-	24.49 NORTH	151.35 EAST	315-	45.39 NORTH	124.64 EAST
140-	23.71 NORTH	150.22 EAST	320-	46.41 NORTH	125.79 EAST
145-	23.02 NORTH	149.03 EAST	325-	47.35 NORTH	127.09 EAST
150-	22.41 NORTH	147.80 EAST	330-	48.19 NORTH	128.56 EAST
155-	21.88 NORTH	146.52 EAST	335-	48.92 NORTH	130.17 EAST
160-	21.45 NORTH	145.21 EAST	340-	49.54 NORTH	131.91 EAST
165-	21.11 NORTH	143.97 EAST	345-	50.03 NORTH	133.76 EAST
170-	20.87 NORTH	142.51 EAST	350-	50.38 NORTH	135.71 EAST
175-	20.72 NORTH	141.13 EAST	355-	50.60 NORTH	137.71 EAST
180-	20.67 NORTH	139.75 EAST	360-	50.67 NORTH	139.75 EAST

****

SECONDARY RANGE INTERSECTS PRIMARY RANGE AT
32.99 NORTH, 121.35 EAST AND 25.76 NORTH, 126.62 EAST

****

SURFACE AREA OF INTERSECTION EQUALS 25,881.13 SQ. NAUTICAL MILES

****

SURFACE AREA OF REMAINING PRIMARY ZONE EQUALS 1,736,646.51 SQ. NAUTICAL MILE

****

SURFACE AREA OF REMAINING SECONDARY ZONE EQUALS 2,507,728.85 SQ. NAUTICAL MILE

****

TOTAL COVERAGE AREA OF BOTH RANGES EQUALS 4,270,256.49 SQ. NAUTICAL MILE

****

SURFACE AREAS

SUBROUTINE SURFAREA will compute the surface area of the portion of the earth's surface enclosed by a set of points describing its perimeter. An area is assumed to have great-circle sides and is computed in square nautical miles. The length of its perimeter is also computed.

Surface Area Within a Range

SURFAREA has the additional capability to determine how much of an area is within a particular distance of a specified point. The procedure is to intersect the area with a range circle and calculate the surface area lying within the circle. Since a range circle's circumference isn't a great-circle arc, the part that intersects the area is broken down into one degree great-circle line segments. If an area has an irregular shape, two or more intersections may occur with the range circle, as illustrated in example 5. The various computed areas must be added or subtracted to determine the total surface area within the circle.

Inputs

SURFAREA's input parameters to the Fortran statement,

CALL SURFAREA (XLAT, XLON, NP, CLAT, CLON, NOPTS),

are described as follows:

XLAT, XLON = arrays of latitudes and longitudes of NP number of points.

NP = number of points.

CLAT, CLON = coordinates locating the position of alphanumeric character, identifying the area.

NOPTS = inhouse options.

Rules and Limitations

- The accuracy in calculating a surface area is dependent upon the selection of the points outlining the area. A fraction of a degree difference in one of the points can vary the total area by several thousand square nautical miles.

- The coordinates of the first and last points must be equal to close the area.

- The exception to the above occur when intersecting an area with a range circle. The first and last points can be selected to lie just outside the circle and need not be equal. When working with a large area, only the perimeter points inside and just outside the range circle have to be inputted.

- The routine that controls the plotting of all points also checks the points of an area's perimeter to determine whether they fall outside the plot border. If they do, these points are omitted from the calculation. The resulting surface area is erroneous and usually negative.

- The size of an area has an upper limit equal to a hemisphere of 74, 355, 728 square nautical miles.

- The perimeter of an area must be represented by at least four points.

EXAMPLE 5

The objective of this example is to illustrate four different surface area calculations. Given the perimeter coordinates of the four areas, the surface areas within 2,000 nautical miles of Washington, D.C. are calculated. The coordinates of the perimeters can be found in the program listing.

The following results were observed:

- AREA A was entirely enclosed within the 2,000 n.mi. range circle. Its surface area and perimeter were 290,288.0 square n.mi. and 4,171.7 n.mi., respectively.

- AREA B was intersected by the range circle yielding a surface area equal to 361,348.4 square n.mi. The perimeter which includes the part of the range circle intersecting the area equals 4,617.8 n.mi.

- AREA C, due to its irregular shape, was intersected in three places. The total surface area within the circle equals 676,045 square n.mi. [C(1) + C(2) - C(3)] .

- Since AREA D was outside the range, it was not plotted and no surface area was calculated.

Since SURFAREA will not plot pass the primary range, the perimeters lying outside have been drawn by hand. SUBROUTINE GCLINE could have been called to plot the entire areas.

```
      PROGRAM EXAMPLE5
      DIMENSION NOPTS(25),ALAT(30),ALON(30),BLAT(30),BLON(30),
     *          CLAT(30),CLON(30),DLAT(30),DLON(30)

C     STORE COORDINATES OF PERIMETER POINTS OUTLINING THE FOUR AREAS....


      DATA (ALAT=44.0,42.5,39.5,38.0,35.0,30.0,27.0,22.0,21.0,21.0,23.0,
     *           25.5,29.0,31.0,36.0,40.0,43.0,44.0,44.0)
      DATA (ALON=-62.0,-67.5,-69.0,-73.0,-74.0,-79.0,-75.0,-70.0,-69.0,
     *           -65.0,-65.0,-70.0,-74.0,-75.0,-70.0,-65.0,-61.0,-61.0,
     *           -62.0)

      DATA (BLAT=22.5,22.0,22.0,20.0,18.0,16.5,14.0,15.0,12.0,12.0,8.0,
     *           6.5,7.5,5.0)
      DATA (BLON=-113.0,-111.0,-108.0,-107.0,-104.0,-100.0,-97.0,-95.0,
     *           -91.0,-88.0,-85.0,-81.0,-79.0,-78.5)

      DATA (CLAT=58.0,58.0,58.0,58.0,55.0,55.0,55.0,55.0,51.0,51.0,51.0.
     *           51.0,51.0.50.0,49.0,47.0,44.0,40.0,33.0,32.0,35.0,37.0,
     *           39.0,40.0.41.5,43.0,45.5,50.0,53.0)
      DATA (CLON=-21.0,-30.0,-40.0,-46.0,-46.0,-40.0,-30.0,-29.0,-29.0.
     *           -30.0,-40.0,-50.0,-52.0,-51.0,-50.5,-51.0,-50.0,-45.0,
     *           -40.0,-34.0,-31.0,-32.0,-37.0,-37.5,-37.0,-30.0,-21.0,
     *           -21.0,-21.0)

      DATA (DLAT=16.0,14.0,10.0,8.0,6.0,5.0,4.0,0.0,-2.0,0.0,3.0,6.0,
     *           10.0,15.0,16.0)
      DATA (DLON=-110.0,-106.0,-105.0,-104.0,-102.0,-98.0,-98.0,-103.0.
     *           -107.0,-109.0,-110.0,-113.0,-112.0,-111.0,-110.0)


C     CALL FOR ENLARGED PROJECTION CENTERED AT WASHINGTON , D.C. AND
C     A PRIMARY RANGE EQUAL TO 2000 N. MILES....


      CALL BLOWUP (38.55,-77.00,2000.0,2500.0,NOPTS,
     *             29HCENTERED AT WASHINGTON , D.C.,29,
     *             30HPRIMARY RANGE EQUALS 2000 N.M.,30,
     *             18HPLOT FOR EXAMPLE 5,18,
     *             1,6.0,5.0)


C     COMPUTE THE SURFACE AREAS WITHIN THE 2000 N.M. RANGE CIRCLE....


      CALL SURFAREA (ALAT,ALON,19,30.0,-77.0,NOPTS)
      CALL SURFAREA (BLAT,BLON,14,12.0,-95.0,NOPTS)
      CALL SURFAREA (CLAT,CLON,29,43.0,-42.0,NOPTS)
      CALL SURFAREA (DLAT,DLON,15,6.0,-118.0,NOPTS)

      STOP
      END
```

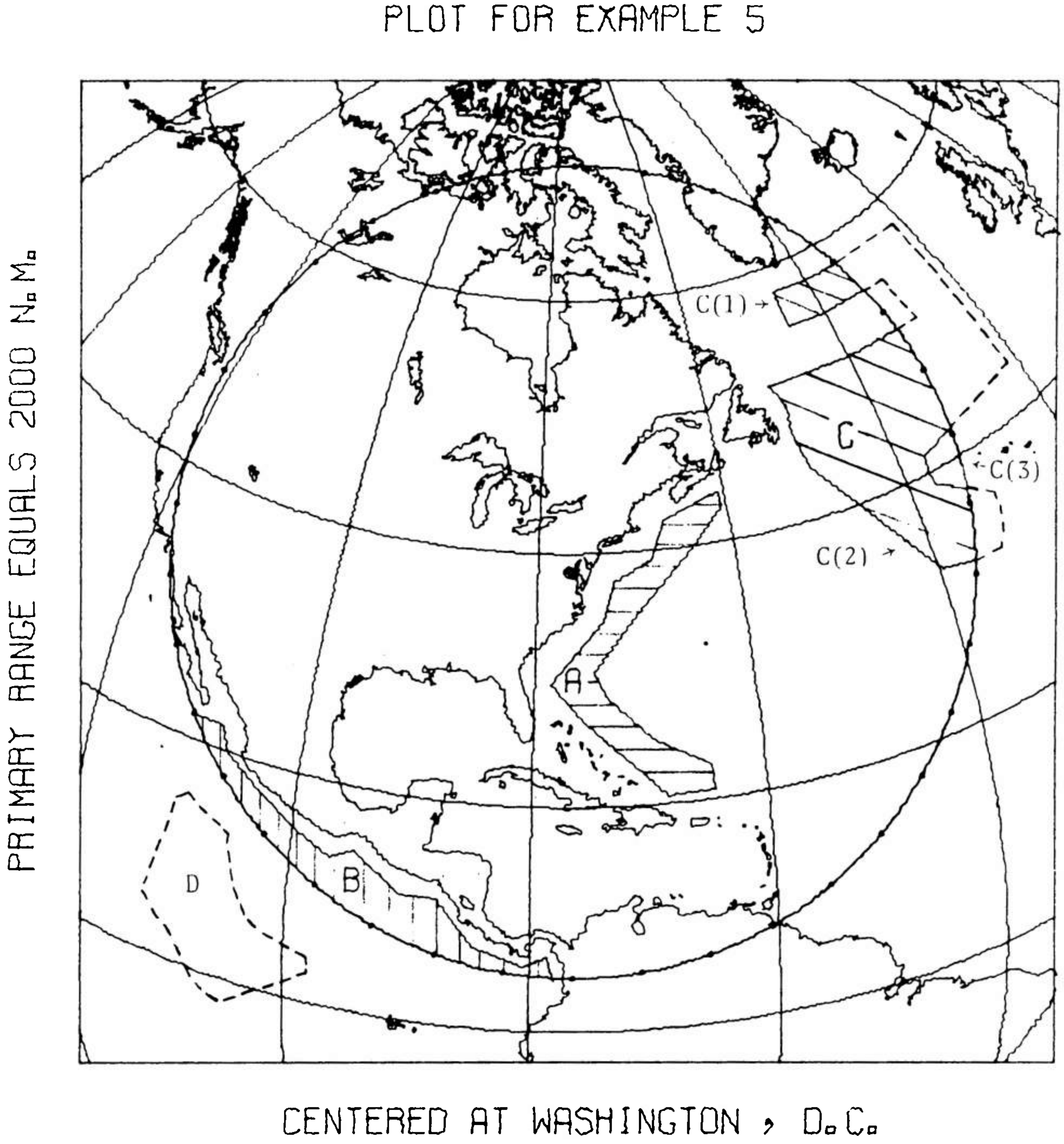


FIG. 5: FOUR SURFACE AREA CALCULATIONS WITHIN
2,000 N.MI. OF WASHINGTON, D.C.

```
             *************

           -----------------
           ---  AREA  A  ---
           -----------------

SURFACE  AREA  OF  A  EQUALS 290,288.0  SQ.  NAUTICAL  MILES
                          *** * ***
    PERIMETER  OF  A  EQUALS    4,171.7  NAUTICAL MILES

             *************

             *************

           -----------------
           ---  AREA  B  ---
           -----------------

SURFACE  AREA  OF  B  EQUALS 361,348.4  SQ.  NAUTICAL  MILES
                          *** * ***
    PERIMETER  OF  B  EQUALS    4,617.8  NAUTICAL MILES

             *************

             *************

           -----------------
           ---  AREA  C  ---
           -----------------
SURFACE AREA OF C(1)  EQUALS  70,946.4  SQ.  NAUTICAL  MILES
                          *** * ***
   PERIMETER OF C(1)  EQUALS   1,151.7  NAUTICAL MILES

             *************
SURFACE AREA OF C(2)  EQUALS 640,652.6  SQ.  NAUTICAL  MILES
                          *** * ***
   PERIMETER OF C(2)  EQUALS   3,312.9  NAUTICAL MILES

             *************
SURFACE AREA OF C(3)  EQUALS  35,571.8  SQ.  NAUTICAL  MILES
                          *** * ***
   PERIMETER OF C(3)  EQUALS 769.7  NAUTICAL MILES

             *************
```

EXAMPLE 6

The triple range intersection of example 4 is computed here. Since the area of interest is small, the field-of-view was enlarged for better observation of the intersection. A primary range was not required and was set equal to 0.0.

Triple coverage equals 17,995 square n.mi.

```
      PROGRAM EXAMPLE6
      DIMENSION NOPTS(25),XLAT(15),XLON(15)


C    STORE COORDINATES OF INTERSECTION....


      DATA (XLAT=32.99,32.36,31.57,30.71,29.80,28.83,28.69,28.29,28.08,
     *          28.32,29.43,30.59,31.79,32.99)
      DATA (XLON=121.85,122.68,123.55,124.32,124.99,125.56,125.63,
     *          124.89,124.47,124.30,123.54,122.87,122.30,121.85)


C    CALL FOR ENLARGED PLOT WITH BLOW-UP RANGE EQUAL TO 500 N.M. ....


      CALL BLOWUP (29.00,123.50,0.0,500.0,NOPTS,
     *             27HSHOWING TRIPLE INTERSECTION,27,
     *             1H ,1,
     *             18HPLOT FOR EXAMPLE 6,18,
     *             1,6.0,6.0)


C    COMPUTE SURFACE AREA OF INTERSECTION....


      CALL SURFAREA (XLAT,XLON,14,29.00,124.2,NOPTS)


      STOP
      END
```

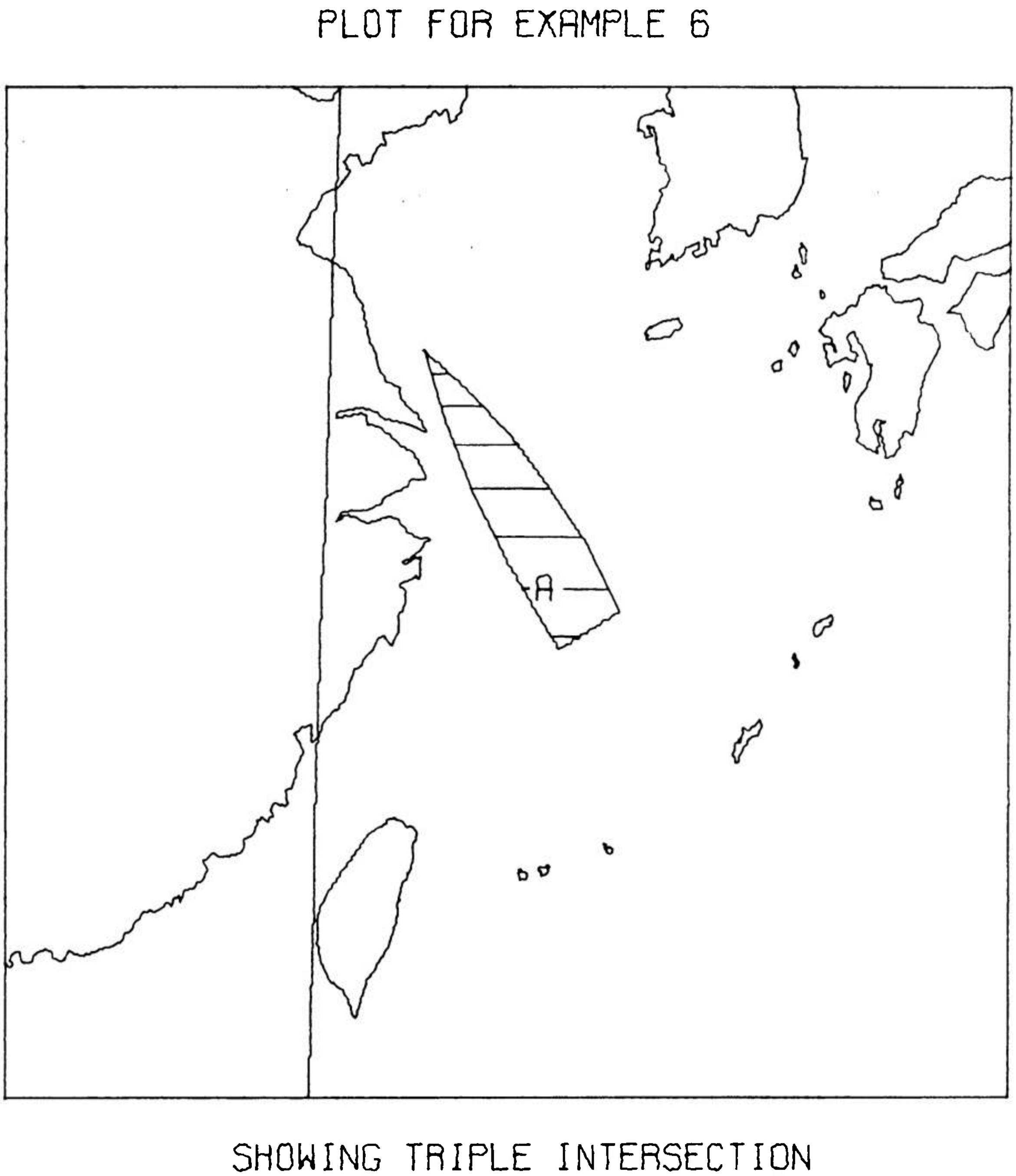


FIG. 6: ENLARGED TRIPLE INTERSECTION SHOWN IN EXAMPLE (4)

```
              *************

            -----------------
            ---  AREA  A  ---
            -----------------

SURFACE  AREA  OF  A  EQUALS  17,994.8  SQ.  NAUTICAL  MILES
                         *** * ***
   PERIMETER  OF  A  EQUALS 722.6  NAUTICAL MILES

              *************
```