

LEVEL II

12

AD A092424

A COMPARISON STUDY
AND SOFTWARE IMPLEMENTATION
OF NORDA OCEAN MODELS

JAYCOR

THIS DOCUMENT IS BEST QUALITY PRACTICABLE.
THE COPY FURNISHED HEREIN CONTAINED A
SIGNIFICANT NUMBER OF PAGES WHICH DO NOT
REPRODUCE CORRECTLY.

DEC 4 1980
C

DOC FILE COPY

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

300 Unicorn Park Drive
Woburn, Massachusetts 01801

80 10 15 010

12

A COMPARISON STUDY
AND SOFTWARE IMPLEMENTATION
OF NORDA OCEAN MODELS

JAYCOR Project #6181

Final Report on NORDA

Contract No. N00014-79-C-0874

PSD-200-80-008FR

October 8, 1980

DEC 4 1980
C

Submitted to:

Office of Naval Research
Arlington, Virginia

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution unlimited

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER PSD-200-80-008FR	2. GOVT ACCESSION NO. AD-A092 424	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Comparison Study and Software Implementation of NORDA Ocean Models.	5. TYPE OF REPORT & PERIOD COVERED Final Report 8/6/79 - 5/5/80	6. PERFORMING ORG. REPORT NUMBER PSD-200-80-008FR
7. AUTHOR(s) Liang-Bee Lin	8. CONTRACT OR GRANT NUMBER(s) N00014-79-C-0874	9. PERFORMING ORGANIZATION NAME AND ADDRESS JAYCOR 300 Unicorn Park Drive Woburn, Massachusetts 01801
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Department of the Navy 800 No. Quincy St., Arlington, VA 22217	12. REPORT DATE October 8, 1980
13. NUMBER OF PAGES 41	14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) DCASMA, San Diego Bldg 4 AF Plant 19 4297 Pacific Hwy. San Diego, CA 92110	15. SECURITY CLASS. (of this report) Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	16. DISTRIBUTION STATEMENT (of this Report) DODAAD Code N68462 N62887 S0514A N00173 S47031	17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
18. SUPPLEMENTARY NOTES	19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Ocean Circulation Seamounts Eddy-meanflow Energetics Hydrodynamic Models Ocean Basins Flow Fields	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Work on modeling ocean circulation is described. Specifically addressed are eddy-meanflow energetics, extension of existing modeling capabilities to include basins of irregular geometry and modelling flow fields near seamounts.		

6
10

14 JAYCOR 15

9 Final Rept. 6 Aug 79 - 5 May 80

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

411751

66

TABLE OF CONTENTS

	<u>Page</u>
I. SUMMARY	1
II. EDDY-MEANFLOW ENERGETICS.	2
A. One-layer Energetics (g' -model)	3
B. Two-layer Energetics (small core version)	7
III. IRREGULAR GEOMETRY CAPABILITY	14
A. Quasi-Geostrophic One-layer Model	16
B. Rigid-lid One-layer Model	21
C. Quasi-Geostrophic Two-layer Model	24
D. Rigid-lid Two-layer Model	27
IV. SEAMOUNT.	30
Figures	32

Accession No.

NTIS Code

DTIC No.

User Name

file

file

Distribution

Availability Codes

Date

A 23

CP

I. SUMMARY

During the course of this research, three technical areas have been addressed:

- (i) eddy-meanflow energetics
- (ii) model extension to irregular geometries, and
- (iii) flows around seamounts.

In the first area, three models have been developed to study eddy-mean-flow energetics in ocean circulation. The formulation of these models is unique and it is felt that they are the first truly applicable to regional energetics.

Similarly, NORDA modeling capabilities have been considerably extended by permitting the modelling of irregular ocean basins. This extension from simple rectangular geometries has greatly improved the realism of the model and its behavior.

The seamount studies are specifically directed at an examination of measured circulation perturbations near a seamount topography and a comparison with predicted patterns. These comparisons provide data on model ability to predict flow fields and also on the accuracy of predictions.

Each of these areas is discussed in the remainder of this report.

II. EDDY-MEANFLOW ENERGETICS

Three software packages are developed and tested for the study of eddy-meanflow energetics in ocean circulation. They are:

- (i) one-layer g' -model energetics
 - (ii) two-layer free-surface energetics (large core version)
 - (iii) two-layer free-surface energetics (small core version)
- (ii) and (iii) can also be used for rigid-lid model, a separate preprocessor is provided for this purpose.

The ocean models when subjected to steady forcing functions usually reach a steady or statistically steady state, provided some dissipation mechanism is present and integration is carried out long enough. For statistically steady cases, a meanflow can be defined as the average of the flow field over a period of time in the final trendless state. The eddy field is defined as the difference between the instantaneous flow and the meanflow. Energy equations are then derived for the meanflow and the eddy field; they relate the time-rate-of-change of various energy measures (K_m, P_m, K_e, P_e) to the energy transfers between them. A schematic energy diagram is often constructed to quantitatively show the flow of energy between the different variables.

Several energetics studies have been done in the research of mesoscale eddies and general circulation. Most of them, however, are concerned only with the global energy balance, or integral properties for the entire basin. Our formulation, we believe, is the first for layered ocean models that has correct Reynold's stress terms and the capability of regional energetics. Detailed derivations of the energetics equations

have been delivered to Drs. J. D. Thompson and H. G. Hurlburt of NORDA. Because of the length and the onerous mathematical formulae, the derivations are not presented in this report. Rather, we concentrate on the usage of these energy packages.

A. One-layer Energetics (g'-model)

(i) Run Preprocessor

```
/ JOB LIN.GGM.EMILPREP,17X049X,LEVEL1,CPT=(C,O,R),CAT=34
/ LIMIT BAND=450,MIN=2.
/ PD MY,USERCAT/077/050/LE13L1
/ FD FT09F001,BAND=20/35/5,FORG=PS,BK SZ=4000,LREC=3996,RCFN=YES
/ FD FT09F002,BAND=20/35/5,FORG=PS,BK SZ=4000,LREC=3996,RCFN=YES
/ FD FT09F003,BAND=20/35/5,FORG=PS,BK SZ=4000,LREC=3996,RCFN=YES
/ MFR FILEIN,EFID=006834,LABEL3
/ FIT FT09F001
/ FIT FT09F002
/ FIT FT09F003
/ MFR=
/ FD FT10F001,BAND=150/250/20,FORG=PS,BK SZ=4000,LREC=3996,RCFN=YES
/ ASG Q1,MY/ENG1LYK0,USE=SLR
/ LNK LNKOPT=(N,Y,A,S,E,Q,K)
LIBRARY 01
INCLUDE PREPRO
/ FXGT OPT=(Y,Z),CPTIME=9.000
&INPT
  RH0=1000.,RC=-1,SPVAL=1.0E+10,"=3,N36=36,
&END
/ CATV MY/EM6834Y3,ACOM=FT10F001
/ E0J
```

The history tape is #006834, the output is a long file containing three years of data and resides on disk "EM6834Y3".

See program listing for the meanings of the input parameters.

(ii) Run Energetics Program

```
/ JOB LIN.0774.EMEILR04,17X045XC,LT,3L1,7PT=(C,D,R),CAT=6
/ LIMIT BAND=50,MIN=3
/ PD MY,USERCAT/077/050/LIN041
/ ASG 01,MY/ENG1LYR3,USE=SHIP
/ ASG 0BJ,MY/NORDATEK,USE=SHIP
/ ASG FT10F001,MY/EM6834Y3,USE=SHIP
/ LNK LNKOPT=(N,Y,A,S,F,J,K),LSPACE=20000
LIBRARY 01
INCLUDE ENG1LR
LIBRARY 0BJ
/ FD FT11F001,BAND=4/10/1
/ FXQT 3PT=(Y,Z),OPTIME=90000
&INPUT
  ISTDH=1,INDH=90,JSTDH=4,JSDH=48,
  IFLAG=1,IDAY=340,ISKIP=11,MAXREC=97,
&END
/ CATV MY/ERAS5,ACOM=FT11F001
/ E0J
```

The output from preprocessor ("EM6834Y3") is used as the input for this program. The user should examine the printout of the preprocessor and determine the time domains of the averaging process (i.e. ISKIP, MAXREC, and IDAY). See listing for meanings of input parameters.

(iii) Switching Storage Device for Data File

```
/ JOB LIN.COM.TAPE2DSK,17X045X0,LIN#L1,UNIT=(C,D,R),CAT=10  
/ LIMIT BAND=280,MIN=1  
/ PD MY,USERCAT/077/050/LIN#L1  
/ FD F,BAND=150/250/20  
/ ASG F,MY/EM6834Y3,USE=SHR  
/ CATV MY/EM6834Y3,ACNM=F  
/ END
```

```
-----//-----  
/ JOB LIN.COM.DSK2TAPE,17X045X0,LIN#L1,UNIT=(C,D,R),CAT=1  
/ LIMIT BAND=50,MIN=1  
/ PD MY,USERCAT/077/050/LIN#L1  
/ ASG F,MY/EM6834Y3,USE=SHR  
/ CATV MY/EM6834Y3,ACNM=F,DTYP=TAPE  
/ END
```

The preprocessor creates data file "EM6834Y3" on disk, ready for use by the energetics program. However, disk changes for such a long file are quite high. It is advisable that the user move the file to tape after each use. The above two short jobs switching the storage device.

(iv) Program Modification

```
/ JOB LIN$GOM$ENERGY,17X045X0,LIN$L1,TRT=(C,D,R),CAT=1
/ LIMIT BAND=50,MIN=5
/ PD MY,USERCAT/077/350/LIN$L1
/ ASG S1,MY/ENG1LYRS,USF=SR
/ ASG 01,MY/ENG1LYRS,USF=SR
/ CIFER CADDMEM=30K,SEC=240
<< COPY S1,S2
<< COPY 01,02
<< MERGE S1,TEMP,UPDATE
< SELECT MASK
-10,10
      1  INDP2,JSTP,I MAX 1,J JDP,J JDP2,I MAXP2
-43
      I MAXP2=I MAX+2
< SELECT PREPR3
-152,152
      888  FORMAT(1X,"REC=",I3,5X,"NE=",1PE12.3,"
/ FTN FTVERS=NX,FTNOPT=(U,K,I,Y,V,D),IN=TEMP
/ FD FT06EQ01,BAND=4/10/2
/ CIFER CADDMEM=30K,SEC=240
<< SPLIT TEMP,S2
<< SPLIT SYS.0000,00
<< PRINT S2
/ CATV MY/ENG1LYRS,ACNH=50
/ CATV MY/ENG1LYRS,ACNH=70
/ E0J
```



In the event that the user wants to make permanent changes to the energetics package, the above program provides the CIFER updating procedure. Changes should be bracketed between << MERGE and /FTN.

B. Two-layer Energetics (small core version)

(i) Run Preprocessor

```
/ JOB LIN.03".SCORP:R:R,17A045X,LI,3,1,"PT=(C,7,8),CAT=10
/ LIMIT BAND=300,MIN=31
/ PD MY,USERCAT/177/350/LIN,3,1
/ ASG 01,MY/SCORCLR3,USF=S,LR
/ LNK LNKOPT=(Y,A,S,F,1,K)
LIBRARY *1
INCLUDE PREPR*
/ FD FT09FC01,BAND=80/110/11,FORS=PS,PKSZ=4001,RCF=7-S
/ FIT FT09FC01,EFID=002022,LA=1
/ FD FT41FC01,BAND=40/7/5,FORS=PS,PKSZ=4001,RCF=7-S
/ FD FT42FC01,BAND=40/7/5,FORS=PS,PKSZ=4001,RCF=7-S
/ FXQT OPT=(Y,Z),OPTIME=9000
  INPUT
  RH9=1000.,BC=-1.,M=1,N6=35,
  IFL=1,LAST=3,
  END
/ CATV MY/U02022FC5,ACN=FT41FC01
/ CATV MY/L02022FC5,ACN=FT42FC01
/ CRY
/ FIT FT09FC01,EFID=000243,LA=1
/ FXQT OPT=(Y,Z),OPTIME=9000
  INPUT
  RH9=1000.,BC=-1.,M=1,N6=35,
  IFL=2,LAST=3,
  END
/ CATV MY/U0243FC1,ACN=FT41FC01
/ CATV MY/L0243FC1,ACN=FT42FC01
/ CRY
/ FIT FT09FC01,EFID=000243,LA=1
/ FXQT OPT=(Y,Z),OPTIME=9000
  INPUT
  RH9=1000.,BC=-1.,M=1,N6=35,
  IFL=3,LAST=3,
  END
/ CATV MY/U0243FC2,ACN=FT41FC01
/ CATV MY/L0243FC2,ACN=FT42FC01
/ CATV MY/FT30FC01,ACN=FT30FC01
/ END
```

In this particular case year 5-7 are input to the preprocessor. Year 5 resides as the fifth file on #002022, year 6 and 7 reside as the first two files on #000243.

Note that a total of 7 files are created by the preprocessor program. Each year has 2 files (U and L) and FT30F001 contains bottom topography and other information.

See program listing for interpretation of input parameters.

(ii) Create Load Modules

```
/ JOB LINBGM$LM001,17X 45X1,LIN$LL1,PT=(C,D,2)
/ LIMIT BAND=50,MIN=1
/ PD MY,USERCAT/D77/351/LIN$LL1
/ ASG 01,MY/SCOR2LR0,USE=SHR
/ LNK LNKOPT=(N,Y,A,S,F,.,K),LSPACE=2000
LIBRARY 01
INCLUDE MODUL1
/ CATV MY/LM001,ACN=SYS.LM00
/ E0J
```

```
/ JOB LINBGM$LM002,17X 45X1,LIN$LL1,PT=(C,D,2)
/ LIMIT BAND=50,MIN=1
/ PD MY,USERCAT/D77/350/LIN$LL1
/ ASG 01,MY/SCOR2LR0,USE=SHR
/ ASG 02J,MY/NBRDATEK,USE=SHR
/ LNK LNKOPT=(N,Y,A,S,F,.,K),LSPACE=2000
LIBRARY 01
INCLUDE MODUL2
LIBRARY 02J
/ CATV MY/LM002,ACN=SYS.LM00
/ E0J
```

The small-core version of the 2-layer energetics program has two driving programs (PROGRAM MODUL1 and PROGRAM MODUL2). These two programs should be executed in series. The above two jobs create load modules from the object library and store the modules on disk, ready for execution with appropriate input data.

(iii) Execution of the Load Modules

```
/ JOB LIN.GM4.EG2LFXQT,17X045X1,LIV6L1,OPT=(C,D,R),CAT=4
/ LIMIT BAND=50,MIN=3
/ PD MY,USERCAT/077/050/LI16L1
/ FD FT61F001,BAND=5/15/1,RCFM=VDS
/ FD FT70F001,BAND=1/8/1,RCFM=VDS
/ FD FT71F001,BAND=1/8/1,RCFM=VDS
/ FD FT72F001,BAND=1/8/1,RCFM=VDS
/ ASG FT41F001,MY/U2022F05,USE=SHR
/ ASG FT42F001,MY/L2022F05,USE=SHR
/ ASG FT30F001,MY/FT30F001,USE=SHR
/ ASG LM001,MY/LM001,USE=SHR
/ FXQT OPT=(Y,Z),OPTIME=90000,GM=LM001
&INPUT1
IYC=1,ISKIP=5,LMAX=31,NBS=0,LAST=J,MAXREC=100,
ISTH=1,INDH=75,JSTH=3,INDH=48,IDAY=1500,
&END
/ REL FT41F001
/ REL FT42F001
/ ASG FT41F001,MY/U0243F01,USE=SHR
/ ASG FT42F001,MY/L0243F01,USE=SHR
/ FXQT OPT=(Y,Z),OPTIME=90000,GM=LM001
&INPUT1
IYC=2,ISKIP=0,LMAX=36,NBS=31,LAST=3,MAXREC=100,
ISTH=1,INDH=75,JSTH=3,INDH=46,IDAY=1500,
&END
/ REL FT41F001
/ REL FT42F001
/ ASG FT41F001,MY/U0243F02,USE=SHR
/ ASG FT42F001,MY/L0243F02,USE=SHR
/ FXQT OPT=(Y,Z),OPTIME=90000,GM=LM001
&INPUT1
IYC=3,ISKIP=0,LMAX=33,NBS=67,LAST=3,MAXREC=100,
ISTH=1,INDH=75,JSTH=3,INDH=46,IDAY=1500,
&END
/ REL FT41F001
/ REL FT42F001
/ REL LM001
/ ASG LM002,MY/LM002,USE=SHR
/ ASG FT41F001,MY/U2022F05,USE=SHR
/ ASG FT42F001,MY/L2022F05,USE=SHR
/ FXQT OPT=(Y,Z),OPTIME=90000,GM=LM002
&INPUT2
IYC=1,ISKIP=5,LMAX=31,MAXREC=100,LAST=3,IPH=25*1,
ISTH=1,INDH=75,JSTH=3,INDH=46,
IDAY=1500,
&END
```

```

/ REL FT41F001
/ REL FT42F001
/ ASG FT41F001,MY/U0243F01,USE=SIH
/ ASG FT42F001,MY/L0243F01,USE=SIH
/ FXQT OPT=(Y,Z),CPTIME=90000,GO=L1002
&INPUT2
IYC=2,ISKIP=0,LMAX=56,MAXREC=100,LAST=3,IPF=25=0,
ISTH=1,INDH=75,JSTH=3,JNDH=48,
IDAY=1500,
&END
/ REL FT41F001
/ REL FT42F001
/ ASG FT41F001,MY/U0243F02,USE=SIH
/ ASG FT42F001,MY/L0243F02,USE=SIH
/ FD FT11F001,BAND=4/20/2
/ FXQT OPT=(Y,Z),CPTIME=90000,GO=L1002,ADDMEM=24K
&INPUT2
IYC=3,ISKIP=0,LMAX=33,MAXREC=100,LAST=3,IPF=25=0,
ISTH=1,INDH=75,JSTH=3,JNDH=48,
IDAY=1500,
&END
/ REL FT41F001
/ REL FT42F001
/ CAT MY/ERASS,ACNN=FT11F001
/ END

```

This is the main program of the two-layer energetics package. The output of the preprocessor should be examined by the user to determine the time interval for the averaging process. For this case the first five records on the first file are skipped and the averaging period covers 100 records. See program listing for meanings of input parameters.

(iv) Switching of Storage Device for Data Files

```
/ JOB LIN.GMM.USK2TAPE,17X145X,LINBL1,PT=(C,D,R),CAT=1
/ LIMIT BAND=50,MIN=1
/ PD MY,USERCAT/077/050/LINBL1
/ ASG F1,MY/U0222F05,USI=SI1
/ ASG F2,MY/L0222F05,USI=SI1
/ ASG F3,MY/U0243F01,USI=SI1
/ ASG F4,MY/L0243F01,USI=SI1
/ ASG F5,MY/U0243F02,USI=SI1
/ ASG F6,MY/L0243F02,USI=SI1
/ MFR FILE
/ CATV MY/U0222F05,ACNM=F1,DTYP=TAPF
/ CATV MY/L0222F05,ACNM=F2,DTYP=TAPF
/ CATV MY/U0243F01,ACNM=F3,DTYP=TAPF
/ CATV MY/L0243F01,ACNM=F4,DTYP=TAPF
/ CATV MY/U0243F02,ACNM=F5,DTYP=TAPF
/ CATV MY/L0243F02,ACNM=F6,DTYP=TAPF
/ MFR
/ E0J
```

```
/ JOB LIN.GMM.TAPE29SC,17X145X,LINBL1,PT=(C,D,R),CAT=36
/ LIMIT BAND=420,MIN=1
/ PD MY,USERCAT/077/050/LINBL1
/ FD F1,BAND=40/70/5,FORG=PS,BKSZ=4000,RCFM=Y1S
/ FD F2,BAND=40/70/5,FORG=PS,BKSZ=4000,RCFM=Y1S
/ FD F3,BAND=40/70/5,FORG=PS,BKSZ=4000,RCFM=Y1S
/ FD F4,BAND=40/70/5,FORG=PS,BKSZ=4000,RCFM=Y1S
/ FD F5,BAND=40/70/5,FORG=PS,BKSZ=4000,RCFM=Y1S
/ FD F6,BAND=40/70/5,FORG=PS,BKSZ=4000,RCFM=Y1S
/ MFR FILEOUT
/ ASG F1,MY/U0222F05,USI=SI1
/ ASG F2,MY/L0222F05,USI=SI1
/ ASG F3,MY/U0243F01,USI=SI1
/ ASG F4,MY/L0243F01,USI=SI1
/ ASG F5,MY/U0243F02,USI=SI1
/ ASG F6,MY/L0243F02,USI=SI1
/ MFR
/ CATV MY/U0222F05,ACNM=F1
/ CATV MY/L0222F05,ACNM=F2
/ CATV MY/U0243F01,ACNM=F3
/ CATV MY/L0243F01,ACNM=F4
/ CATV MY/U0243F02,ACNM=F5
/ CATV MY/L0243F02,ACNM=F6
/ E0J
```

These two programs switch the storage device for the data files. To avoid high disk changes, it is advisable to move data from disk to tape, and then before another execution of the energetics program, move them back to disk. Note that the outputs of the preprocessor reside on disk, they should not be left on the disk overnight.

(v) Program Modification

```
/ JOB LIN.G04,SCUPDATE,177.45A ,LIMEL1,MP1=(C,D,R),CAT=1
/ LIMIT SAND=51,MIN=1
/ PD MY,USERCAT/077/750/L1.BL1
/ ASG S3,MY/SCOR2LRS,US =S31
/ ASG T3,MY/SCOR2LR7,US =S32
/ CIFER
<< COPY S3,S2
<< COPY T3,T2
<< MERGE S2,TEMP,UPDATE
< SELECT SURC
-257,265
-286
  READ(70) M1
  IF(IPFC(3).EQ.0) CALL PLTFC(1,"(K14,S: P-432) ",17)
  READ(70) M2
  IF(IPFC(7).EQ.0) CALL PLTFC(1,"(K10,S: P-432) ",17)
  READ(70) M3
  IF(IPFC(12).EQ.0) CALL PLTFC(1,"(K27,S: P-432) ",17)
  READ(70) M4
  IF(IPFC(17).EQ.0) CALL PLTFC(1,"(K28,S: P-432) ",17)
  READ(70) M5
  IF(IPFC(21).EQ.0) CALL PLTFC(1,"(CPM,PT )",17)
/ FTN FIVEES=NK,MP1=(U,K,T,V,D),L1=TEMP
/ FD FT06F001,SAND=2/10/78
/ CIFER CADDHEN=30K,SEQ=14
<< SPLIT TEMP,S2
<< SPLIT SYS.0440,M2
<< PRINT S2
/ CATV MY/SCOR2LRS,ACNHE5
/ CATV MY/SCOR2LR7,ACNHE7
/ END
```

User may make permanent changes to the package by executing this program. The changes should be bracketed by << MERGE and /FTN.

III. IRREGULAR GEOMETRY CAPABILITY

The hydrodynamical ocean models developed at NORDA were originally designed for rectangular basins, because of the ease in applying the fast Helmholtz solver for regular geometries and the simplicity in coding the computer programs. Most dynamic features of ocean circulation can be investigated with these "square oceans" and, indeed, the computation cost is relatively low because of the fast solver and the high degree of vectorization. However, as ocean modeling outgrows its infant state, a realistic coastline necessarily becomes a major factor in defining the domain of the flow field.

Historically, the successive over relaxation method (SOR) is used to solve the Poisson (or Helmholtz) equation in a basin of realistic shape. This technique is time consuming (especially when a large number of grid points is concerned) its accuracy is not quite desirable, and the procedure is usually difficult to vectorize. In order to extend the modeling capability at NORDA, JAYCOR proposed to implement the vectorized irregular geometry Helmholtz solver to NORDA's existing hydro-models. The technique, the so-called capacity matrix method, was developed by Dr. D. R. Moore of Cambridge University. It has been successfully used in Dr. H. E. Hurlburt's free surface ocean models in the study of the Gulf of Mexico.

The implementation is done in the following way. For each model we have two packages of routines instead of just one as in the square basin version. The first package is almost the same as its predecessor except one parameter NREG is added to the input NAMELIST; it controls

the basin geometry. If NREG equals zero, the model is run just as it would with the regular geometry version. If NREG is not zero, it stands for the number of land blocks added to an otherwise rectangular basin, e.g. NREG=3 means 3 land blocks are present in the basin. When NREG is not equal to zero, a number of subroutines are called by the model program to activate the irregular geometry solver. These routines reside in the second package, usually named with abbreviations of Land and Sea such as "QGLNDSGS".

The present irregular Helmholtz solver can handle land blocks of arbitrary size (rectangular though), at arbitrary location as long as they don't share a common boundary with each other. Once the basin geometry is decided, one can modify the subroutine "IRGBDY" in the second package to define the basin shape and change the parameter IBP (for number of interior boundary points) in other routines of the same package. The first package need not be changed except for parameters which determine the number of grid points (i.e. ISF and JSF). Following is a detailed description of the usage of four hydro models.

A. Quasi-Geostrophic One-Layer Model

(i) Run Main Program

```
/ JOB LIN.MDL, QGL1TRGM, 17X145X, LPT=LL1, OPT=(C, D, E), CNT=1
/ LIMIT (A, I)=50, NI,=5
/ PD (NY, USERCAT/077/151/ZL1BL1
/ ASG (LI1, USERCAT/077/151/ZL1BL1, USE=SI1
/ ASG (I1, NY/ZGL1TRGM, USE=SI1
/ ASG (I2, NY/DANSLVR0, USE=SI1
/ ASG (I3, NY/QGLNDSE0, USE=SI1
/ LNK LNK OPT=(C, Y, A, S, D, E, K)
LIBRARY (I1
INCLUDE MAIN
LIBRARY (I3
LIBRARY (I2
LIBRARY (LI1
/ EXOT OPT=(Y, 2), OPTIME=9999
&INPJ
XL=1000., YL=1000., DT=14400., A=300., IZIT=500., FZ=7.43E-05, U=1.83E-11,
TYIT=0.5E-04, S=0.02, I3=0, IOUT=5., PRINT=0., IQULE=480, TMAX=360.,
MAXFJL=2, ALA1=0.5, ISTART=-1.,
G=0.02, GP=0.02,
NREG=0,
NREG=1,
&END
/ E7J
```

"QGL1TEMO" is the updated version of Lin's QG one-layer model.

A parameter NREG is added to the input namelist; it controls the basin geometry. "QGLNDSE0" contains routines bridging the irregular geometry capability to the Helmholtz solver for regular geometry ("DANSLVR0").

See listing for meanings of input parameters.

(ii) Update Irregular Geometry Subroutines

```
/ JOB LIM.NOL.06IRREGU,17X.45X.,L1#L1,MP1=(0,0,2),CAT=1
/ LIMIT BAND=50,MIN=5
/ PD MY,USERCAT/077/050/L1#L1
/ ASG S1,MY/06LANDSIS,US:=SIR
/ ASG 01,MY/06LANDSES,US:=SIR
/ CIFER
<< COPY S1,S2
<< COPY 01,02
<< MERGE S2,TERM,UPDATE
< SELECT EVKLN0
-13,13
COMMON/PERI/ IBOX,JBDY,PER,AREA
-50,73
-74,74
ENTRY INTGRA (X,I ,J1,CST,ZDUM,IC94)
REAL*8 ZDUM
-82,85
60 ZDUM=ZDUM+M1(I,J)
ZDUM=ZDUM+ PER=CST
IF(IC94 .EQ. 0) RETURN
SIGMA=-ZDUM/AREA
DO 70 J=1,J1
DO 70 I=1,I1
70 X(I,J)=X(I,J)+SIGMA
ZERO=0.
CALL LANDC1 (X,IA,IA,J1,ZERO)
< SELECT IRGBDY
-1
PARAMETER ISF=51,JSF=4)
-4
COMMON/PERI/ IBOX,JBDY,PER,AREA
-10,10
DATA IBB/0,1,1,0/
-11,11
PER=((JMI(1)-2)+(JSF-2)+(ISF-2)+(ISF-IMA(1)-1)+
1 (IMA(1)-2)+(JSF-JMI(1)-1))*0.5+2.
AREA=(JMI(1)-2)*(JSF-2)+(ISF-IMA(1)-1)*(JSF-JMI(1))+PER
C PICK A POINT ON THE TRUE LAND-SEA BOUNDARY
IBOX=ISF-1
JBDY=JSF
< SELECT LANDC
-4
1 ,IBB(4,NREG)
-14
C
```

```

ENTRY LANDC1 (C, NPA, K, Y, VALUE)
DO 20 K=1, NREG
IMIN=IMI(K)
IF(IBM(4,K) .NE. 0) IMIN=IMI(K)+1
IMAX=IMA(K)
IF(IBM(2,K) .NE. 0) IMAX=IMA(K)-1
JMIN=JMI(K)
IF(IBM(3,K) .NE. 0) JMIN=JMI(K)+1
JMAX=JMA(K)
IF(IBM(1,K) .NE. 0) JMAX=JMA(K)-1
DO 20 J=JMIN, JMAX
DO 20 I=IMIN, IMAX
20  W(I,J)=VALUE
RETURN
/ FTN FIVERS=NX, FTNBPT=(J,K,N,Y,V,D), IN=TEMP
/ CIFEP
<< SPLIT TEMP, S2
<< SPLIT SYS.0400, S2
<< PRINT S2
/ CATV MY/QGLNDSGS, ACN=51
/ CATV MY/QGLNDSGN, ACN=51
/ EQU

```

The file "QGLNDSGS" (QG-LAND-SEA-SOURCE) contains the irregular geometry routines. User should modify this file to suit his basin geometry. Subroutine "IRGBDY" is the one describing the basin shape. The above is for permanent changes of the file. All changes should be bracketed by << MERGE and /FTN.

(iii) Update QG One-layer Model

```
/ J93 LIN,17X045X0,LIN411,TEMP=(C,D,F),DATE=1
/ LIMIT BAND=50, IIN=3
/ PD MY,USERCAT/077/050/L11,SL1
/ ASG S1,MY/QGLITEMS,US1=S11
/ ASG 01,MY/QGLITEM0,US1=S11
/ CIPHER
<< COPY S1,S2
<< COPY 01,02
<< MERGE S1,TEMP,UPDATE
< SELECT CALC0
-13,13
COMMON/PER1/ IBDX,JBDY
-85
ZDUM=0.000
IF(NREG.GT.0) GO TO 421
DO 421 J=2,JSFN
DO 421 I=2,ISFN
421 ZDUM=ZDUM+S(I,J,N1)
IPER=(ISF-2)+(JSF-2)+1
ZDUM=ZDUM+IPER*S(1,10,N1)
SIGMA=-ZDUM/((ISF-2)+(JSF-2)+IPER)
DO 422 J=1,JSF
DO 422 I=1,ISF
422 S(I,J,N1)=S(I,J,N1)+SIGMA
GO TO 424
423 IONE=1
CALL INTGRA (S(1,1,N1),ISF,JSF,S(IIDX,JBDY,N1),ZDUM,IONE)
424 CONTINUE
< SELECT MAIN
-98,98
REAL=8 ZDUM
COMMON/PER1/ IBDX,JBDY
-188
IBDX=1
JBDY=10
-237,237
ZDUM=0.000
-241,242
16 ZDUM=ZDUM+PSJ(1,J)
ZDUM=ZDUM+(ISF-2)+(JSF-2)+1
-245,246
IZERO=0
CALL INTGRA (PSJ,ISF,JSF,ONE,ZDUM,IZERO)
-248,249
RSJ=1./ZDUM
```

```

-330,331
  ZDUM=0.001
-334,335
  689  ZDUM1=ZDUM+SC1,J,K)
      ZDUM1=ZDUM1+((ISF-2)+(JSF-2)+1)*SC1D(X,J,DY,1)
-337,338
  21  CALL INTGRA (SC1,J,K),ISF,JSF,SC1D(X,J,DY,1),ZDUM1,ZERR)
-340,341
      ZDUM=ZDUM1*FTRJ
      PRINT 690,ZDUM
-343,343
/ FTN FIVERS=NX,FINOPT=(J,K,M,Y,V,1),I4=TOP
/ CIFER
<< SPLIT TEMP,S2
<< SPLIT SYS.OMD,JD
<< PRINT S...
/ CATV MY/UGLITERIS,ACN=ES
/ CATV MY/UGLITERM,ACN=EL
/ ESJ

```

This job is for permanent update of the QG one-layer model. All changes should be bracketed between << MERGE and /FTN.

B. Rigid-lid One-layer Model

(i) Run Main Program

```
/ JOB LIN,IRI,RGLINEWS,17X045X0,LIN,LI1,OPT=(C,D,X),CAT=1
/ LIMIT BA=0=50,MIN=10
/ PD MY,USERCAT/077/050/LIN,LI1
/ ASG NLI3,USERCAT/077/050/LI3,USE=SI
/ ASG 01,MY/RGLINEWS,USE=SI
/ ASG 02,MY/DANSLVRO,USE=SI
/ ASG 03,MY/LANDSEAS,USE=SI
/ LNK LNKOPT=(C,Y,A,S,R,Z,K)
LIBRARY 01
INCLUDE MAIN
LIBRARY 03
LIBRARY 02
LIBRARY NLI3
/ FXQT OPT=(Y,Z),OPTIME=0.001
&INPUT
XL=1000.,YL=1000.,DT=1200.,H0Z=30.,X=100.,DP=0.02,HTST=400.,
FZ=1.0E-04,B=2.0E-11,THI=1.0E-14,G=9.8,IX=1,MOIT=3.,PRCMT=5.,IEULER=36,
TMAX=1.,MAXEUL=2,ALAN=1.5,TSTART=-1.,
DT=14400.,TMAX=360.,PRCMT=50.,IEULER=36,
HTST=500.,
NREG=1,
NREG=0,
&END
/ END
```

"RGLINEWS" is the updated version of Lin's Rigid-lid one-layer model. A parameter NREG is added to the input NAMELIST; it controls the basin geometry. "LANDSEAS" contains routines bridging the irregular geometry capability to the Helmholtz solver for regular geometry ("DANSLVRO"). See program listing for meanings of input parameters.

(ii) Update Rigid-lid One-layer Model

```
. JOB LIN,17X045X0,LIN$LI,OPT=(C,D,R),GAT=D
/ LIMIT BALD=50,MIN=5
/ PD MY,USERCAT/077/050/LIN$LI
/ ASG S1,MY/RGLINEWS,USF=SHO
/ ASG S1,MY/RGLINEWS,USF=SR
/ CIPHER
<< COPY S1,S2
<< COPY O1,O2
<< MERGE S2,TEMP,UPDATE
< SELECT CALCU
-5,7
-11,12
COMMON/NREG/NREG
-15,15
1 DX2,IB,TRDX2,TRDY2
-43
W1=0.
-70,70
-76,83
450 CALL SOLVND(N1)
-94,95
-126,126
503 CALL LANDBC (IB,N1,RDX2,RDY2)
< SELECT MAIN
-94,97
-101,101
-106
COMMON/ABC/AA,BB,CC
-123,123
1 DX2,IB,TRDX2,TRDY2
-177
TRDX2=2.*RDX2
TRDY2=2.*RDY2
-225,229
IF(NREG .GT. 0) CALL EVKLN()
/ FTN FTVER$=MX,FTN,OPT=(U,K,1,Y,Y,0),I1=TEMP
/ CIPHER
<< SPLIT TEMP,S2
<< SPLIT SYS.0430,02
<< PRINT S2
/ CATV MY/RGLINEWS,ACNN=S2
/ CATV MY/RGLINEWS,ACNN=1
/ END
```

This job is for permanent update of the rigid-lid one-layer model. All changes should be bracketed between <<MERGE and /FTN.

(iii) Update Irregular Geometry Subroutines

```
/ JOB LIN,17X045X0,LINBL1,OPT=(C,D,R),CAT=1
/ LIMIT BAND=50,MIN=5
/ PD MY,USERCAT/077/350/LINBL1
/ ASG S1,MY/LANDSEAS,US =S.1
/ ASG O1,MY/LANDSEAS,US =S.1
/ CIPHER
<< COPY S1,S2
<< COPY O1,O2
<< MERGE S1,TEMP,UPDATE
< SELECT IRGBDY
-10,10
      DATA IBB/0,1,1,0/
/ FTN FIVEBS=NX,FTNOPT=(J,K,M,Y,V,D),IN=TEMP
/ CIPHER
<< SPLIT TEMP,S2
<< SPLIT SYS.0M90,02
<< PRINT S2
/ CATV MY/LANDSEAS,ACM=S2
/ CATV MY/LANDSEAS,ACM=O.
/ END
```

The file "LANDSEAS" contains the irregular geometry subroutines. User should update this file to suit his basin geometry. Subroutine "IRGBDY" is the one describing the basin shape. The above job is for permanent changes of the file, all changes should be bracketed between <<MERGE and /FTN.

C. Quasi-Geostrophic Two-Layer Model

(i) Run Main Program

```
/ JOB LIN.MDL.QGL2NEW0,17X145X,LIT11,OPT=(C,D,R),CAT=1
/ LIMIT DAND=50,MIN=5
/ PD MY,USERCAT/D77/350/LIN4L1
/ ASG 01,MY/QGL2NEW0,USE=SHR
/ ASG 02,MY/Q2LNDSGS,USE=SHR
/ ASG 03,MY/DAYSLEVR0,USE=SHR
/ ASG NLIN,USERCAT/D77/L50/LIN,USE=SHR
/ LNK LNKOPT=(C,Y,A,S,F,I,K)
LIBRARY 01
INCLUDE MAIN
LIBRARY 02
LIBRARY 03
LIBRARY NLIN
/ EXQT OPT=(Y,Z),CPTIME=30000
&INPUT
XL=1000.,YL=1000.,DT=1440.,HJZ=500.,N=300.,GP=0.02,HTHT=4000.,
FZ=7.43E-05,B=1.80E-11,TINT=0.5E-14,C=0.5,I=0,HOUT=5.,PROUT=90.,ISULCR=400,
TMAX=360.,MAXCUL=2,ALFA=1.0,N36=72,TSTART=1.,
TINT=1.0E-04,HJZ=800.,GP=0.035,
TSTART=-1.,TMAX=60.,NREG=0,
PROUT=30.,
NREG=1,
&END
/ END
```

"QGL2NEW0" is the updated version of Lin's QG two-layer model. A parameter NREG is added to the input namelist; it controls the basins geometry. "Q2LNDSGS" contains routines bridging the irregular geometry to the Helmholtz solver for regular geometry. See listing for meanings of input parameters.

(ii) Update Model Program

```
/ JOB LIN.MDL.QGL2NEWS,17X.45X ,L1,V1L1,NPT=(0,0,0),CAT=1
/ LIMIT BATT=57,MIG=
/ PD MY,USERCAT/D77/250/LINBL1
/ CIFER
/ ASG S1,MY/QGL2NEWS,US1=S11
/ ASG S1,MY/QGL2NEWS,US1=S11
/ CIFER
<< COPY S1,S2
<< COPY S1,S2
<< MERGE S1,TEMP,UPDATE
.
.
.
.
/ FTN FIVERS=MX,FTNPT=(0,0,1,Y,V,0),LN=TEMP
/ CIFER
<< SPLIT TEMP,S2
<< SPLIT SYS.0100,02
<< PRINT S2
/ CATV MY/QGL2NEWS,ACN=S2
/ CATV MY/QGL2NEWS,ACN=S2
/ END
```

This job is for permanent update of the QG two-layer program.
All changes should be bracketed by <<MERGE and /FTN.

(iii) Update Irregular Geometry Subroutines

```
/ JOB LIN,MDL,UGL2LDSF,17X,45X,LTNELL1,PT=(C,D,R),CAT=1
/ LIMIT BAND=50,MIN=4
/ PD MY,USERCAT/D77/550/LI,ELL1
/ ASG S1,MY/UGLNDSES,UST=SM
/ ASG O1,MY/UGLNDSEN,UST=SM
/ CIFER
<< COPY S1,S2
<< COPY O1,O2
<< MERGE S1,TEMP,UPDATE
.
.
.
.
/ FTN FIVERS=NA,FTNPT=(C,K,M,Y,V,D),IN=TEMP
/ CIFER
<< SPLIT TEMP,S2
<< SPLIT SYS.0000,S2
<< PRINT S2
/ CAT MY/UGLNDSES,ACAT=SE
/ CAT MY/UGLNDSEN,ACAT=SE
/ EQU
```

This job updates permanently the land sea package for a particular basin shape. Replace dots with your changes.

D. Rigid-lid Two-Layer Model

(i) Run Main Program

```
/ JOB LIN.MDL.RGL2NEW0,17X045X,LI=LI1,OPT=(C,D,R),CAT=5
/ LIMIT BAND=50,MIN=10
/ PD MY,USERCAT/D77/850/LI=LI1
/ ASG 01,MY/RGL2NEW0,US1=S1
/ ASG 02,MY/R2LNDESE0,US1=SHR
/ ASG 03,MY/DANSLVR3,US1=S1P
/ ASG NLI0,USERCAT/D77/L50/LI1,US1=SHR
/ ASG S1,MY/R2LNDESE5,US1=SHR
/ CIFER
<< MERGE S1,TEMP,UPDAT
< SELECT IRBODY
-7,8
    DATA JMI/1/
    DATA JMA/15/
-10,10
    DATA IBS/1,1,0,0/
/ FIN FIVERS=FX,FINOPT=(C,Y,A,S,E,.,K),FI=TEMP
/ LNK LNKOPT=(C,Y,A,S,E,.,K)
LIBRARY 01
INCLUDE MAIN
LIBRARY 02
LIBRARY 03
LIBRARY NLI0
/ FXQT OPT=(Y,Z),OPTIME=9.00
&INPUT
XL=1000.,YL=1000.,DT=1800.,HIZ=500.,A=300.,GP=0.02,HTOT=4000.,
FZ=7.43E-05,B=1.88E-11,TBOT=0.5E-04,B=9.8,LD=0,HOUT=5.,PROUT=90.,IEULER=430,
TMAX=36.,MAXEUL=2,AL4=1.0,TSTART=0.,
DT=1200.,HIZ=300.,GP=0.035,TBOT=1.0E-04,
TMAX=30.,TSTART=-1.,NRIG=1,PROUT=15.,
TMAX=60.,PROUT=30.,
A=1000.,
&END
/ END
```

This job run is a rigid-lid, two-layer model with a flat bottom and closed basin. "RGL2NEW0" contains the main calculation. "R2LNDESE0" contains land-sea information.

(ii) Update Irregular Geometry Subroutines

```
/ JOB LIN.MOL.RGL2UPDT,17X045X',LINBL1,OPT=(C,D,R),DAT=1
/ LIMIT BAND=50,MIN=5
/ PD MY,USERCAT/D77/B50/LINBL1
/ ASG S1,MY/R2LNDSSES,USE=SHR
/ ASG 01,MY/R2LNDSSES,USE=SHR
/ CIFER
<< COPY S1,S2
<< COPY 01,02
<< MERGE S2,TEMP,UPDATE
.
.
.
.
/ FTN FTVERS=NX,FTNOPT=(U,K,M,Y,V,J),IT=TEMP
/ CIFER
<< SPLIT TEMP,S2
<< SPLIT SYS.0470,02
<< PRINT S2
/ CATV MY/R2LNDSSES,ACT=SE
/ CATV MY/R2LNDSSES,ACT=SE
/ EQU
```

This job is for permanent update of the land sea package.

Changes are inserted at the dots.

(iii) Update Model Program

```
/ J93 LIN.MDL.RGL2UPDT,177045X ,217811,791=(0,0,0),CAT=1
/ LIMIT BAND=50,MIN=
/ PD MY,USERCAT/077/650/LIN.BLI
/ ASG S1,MY/RGL2NEWS,USP=SHD
/ ASG 01,MY/RGL2NEWS,USP=SHD
/ CIPHER CADDLEN=30K,SEC=12
<< COPY S1,S2
<< COPY M1,M2
<< MERGE S2,TEMP,UPDATE
.
.
.
.
/ FTN FTVERS=NX,FTNPT=(0,K,1,Y,V,0),IN=TEMP
/ CIPHER CADDLEN=30K,SEC=12
<< SPLIT TEMP,S2
<< SPLIT SYS.0000,00
<< PRINT S2
/ CATV MY/RGL2NEWS,ACN=52
/ CATV MY/RGL2NEWS,ACN=52
/ E9J
```

This is for permanent update of the main calculation program.

The changes should replace the dots.

IV. SEAMOUNT

A joint study is presently being conducted with Dr. Andrew Vastano of Texas A&M University on flow effects near a seamount. Dr. Vastano has gathered data from drogues released in the western North Pacific Ocean. The drogues passed through the Emperor Seamount chain located at approximately 40°N , 170°E . The path of the drogues was dramatically altered in the vicinity of the seamounts (see Fig. 1). Using models presently available at Code 322, NORDA, the dynamic effects of flow around a seamount are being investigated.

The first model chosen for use in this study was the barotropic model. This model demonstrates the effect of the external mode. The model is designed to have a steady prescribed inflow along the entire western boundary and an open eastern boundary with conservation of mass transport strictly enforced. Numerous experiments were made using 10 km grid spacing in x and y , a coefficient of eddy viscosity of 3×10^5 dynes/cm² and an inflow velocity of 10 cm/sec. When the model was run with no topography, solutions were steady out to 90 days. However, when a small magnitude seamount was introduced, a disturbance appeared on the upstream side of the seamount. Tests showed that the steepness of the seamount was not the cause of the instability. The disturbance disappeared when a westward flow was used or when beta was set equal to zero. The western boundary condition does not allow the "Rossby Wave" out of that boundary and the solutions degenerate (Fig. 2).

A number of methods were tried to alleviate this problem at the western boundary. It was finally decided to use viscous damping at the

boundary of the form $C_D V$ where C_D is a drag coefficient of 5×10^{-2} . This boundary damping was also used at the outflow boundary to avoid any instability on outflow. Figure 3 shows that the solution using the boundary damping ran to at least 200 days without the instabilities of the previous cases.

After testing the effects of the location of the seamount in a basin the size of that in Fig. 3, and a test with a topography like that of the Emperor Seamount, a two-layer model will be used and drifter tracks will be made from those solutions to compare with the real data.

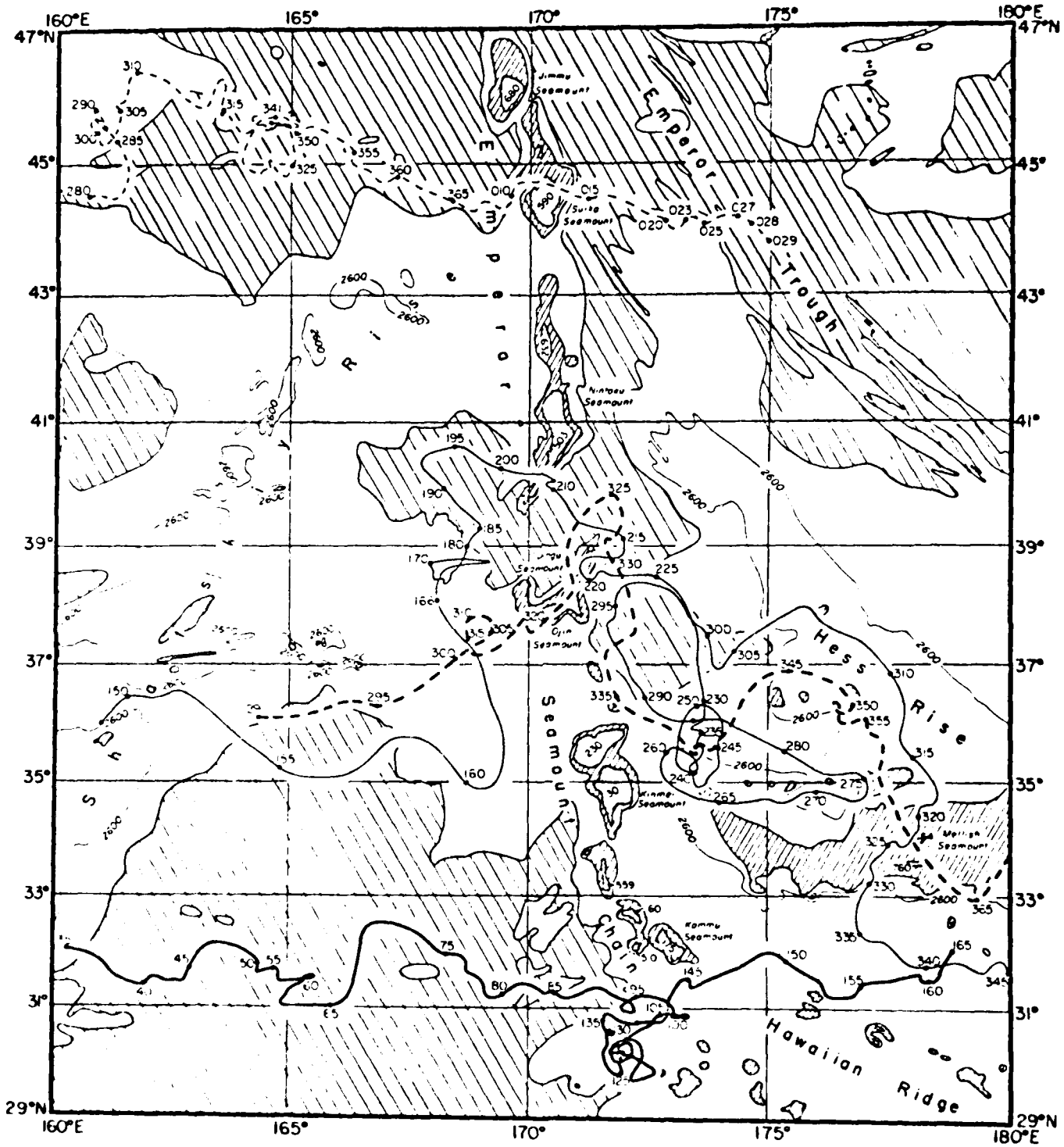


FIGURE 1

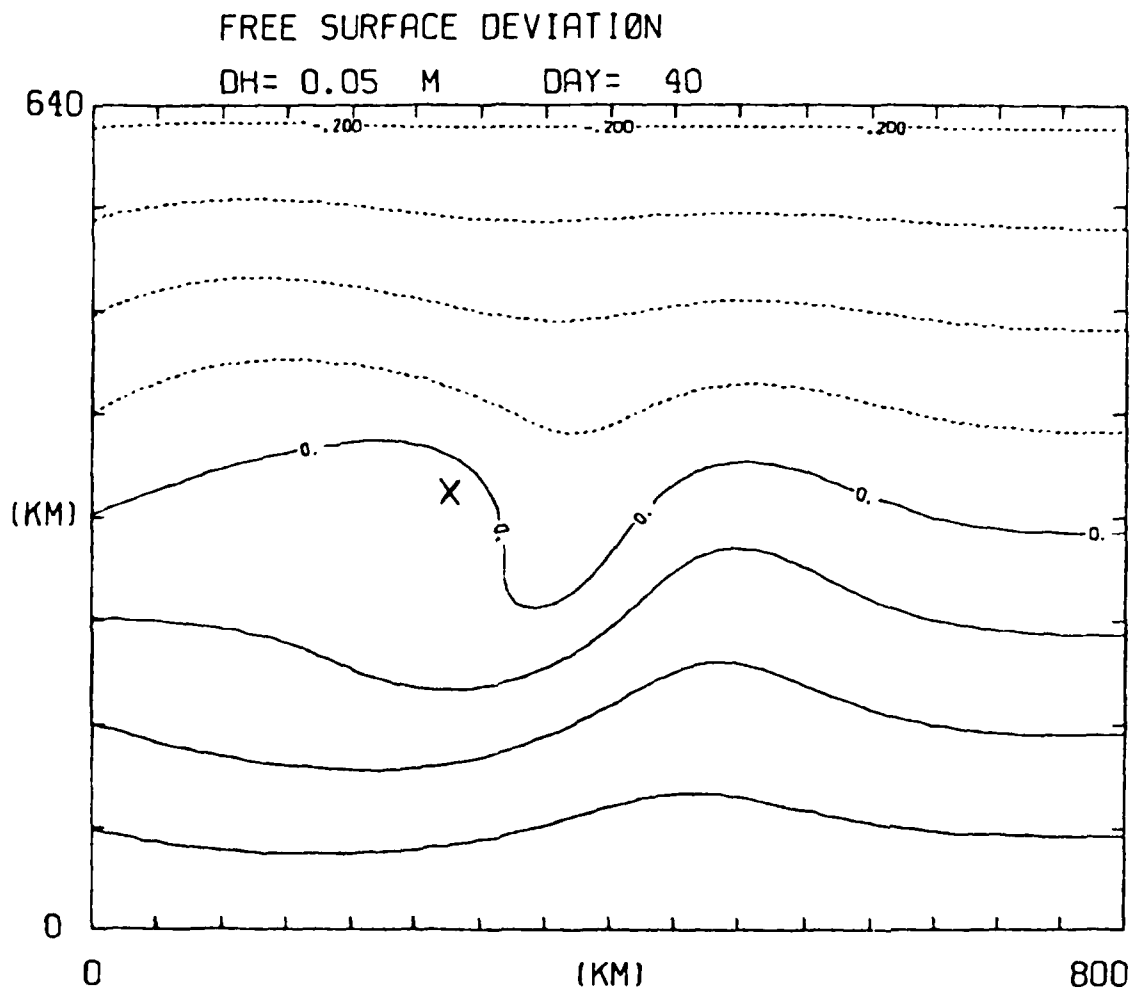


FIGURE 2a

"X" Marks the Center of the Seamount in all 4 Figures

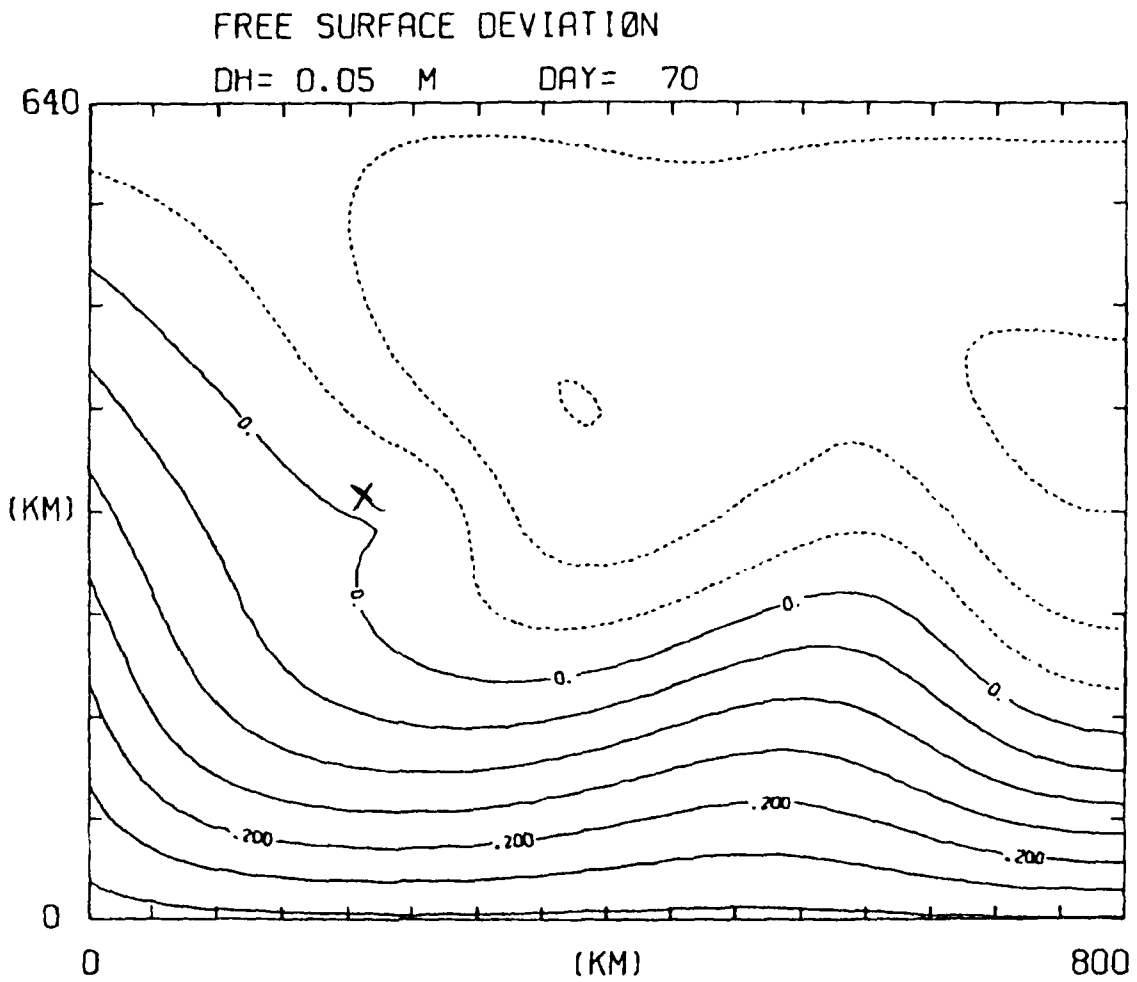


FIGURE 2d

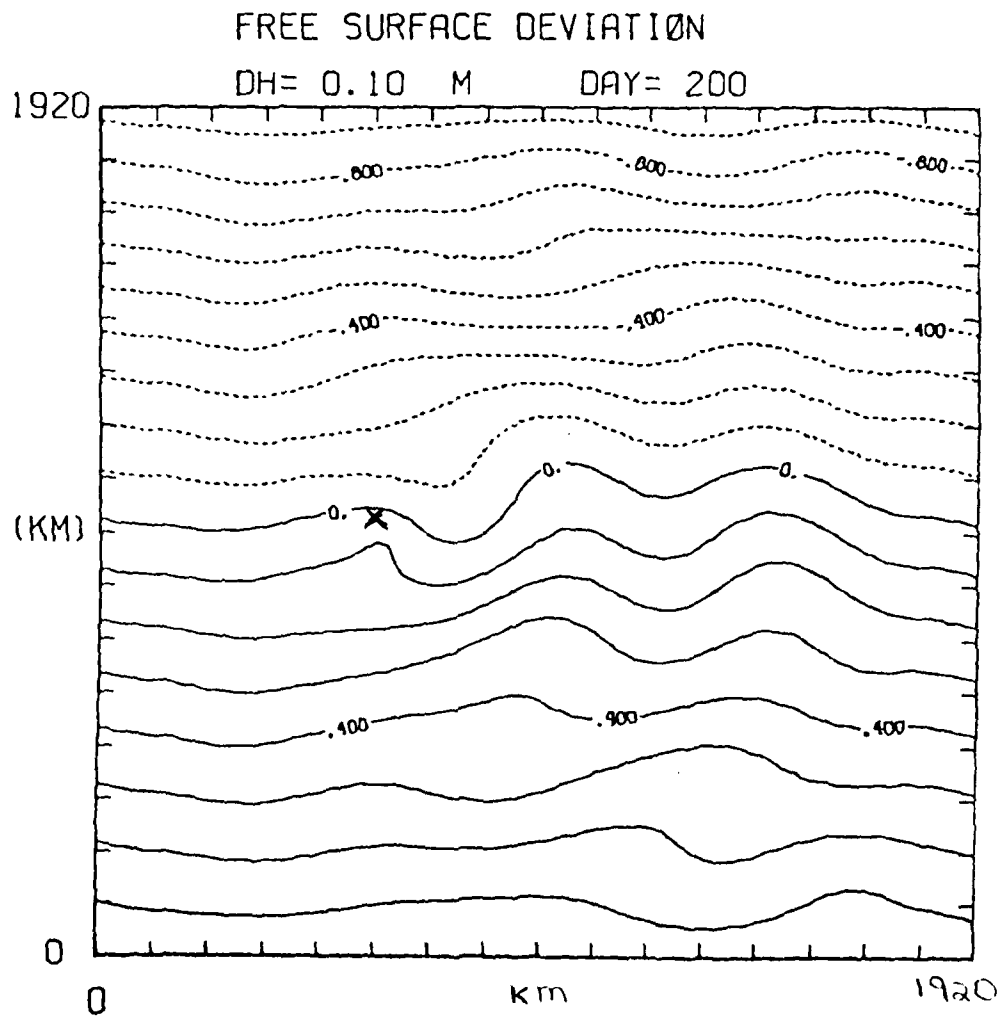


FIGURE 3b

"X" Marks the Center of the Seamount